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JPL engineer Jose Guzman : Picture curtesy of NASA

Mechatronic Applications

Featuring the fischertechnik Construction System

Written by Tom White & Associates

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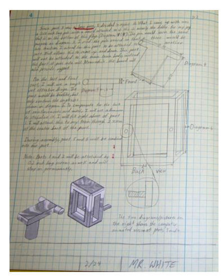
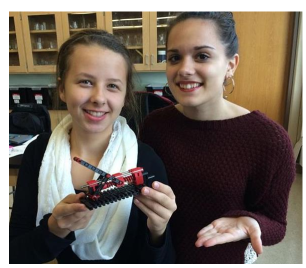
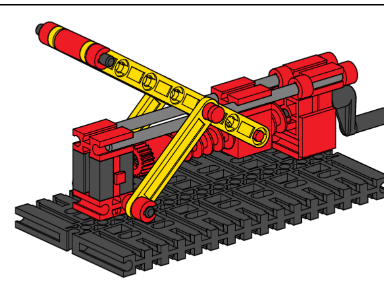
Sketching and Documentation	
Simple Machines	
Mechanical Systems	

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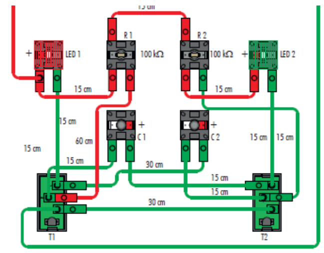
<tr><td>Basic Electricity Energy</td><td>
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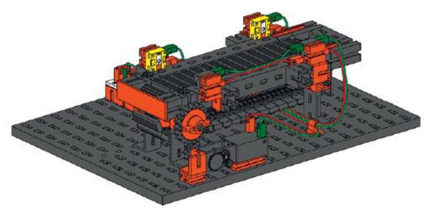
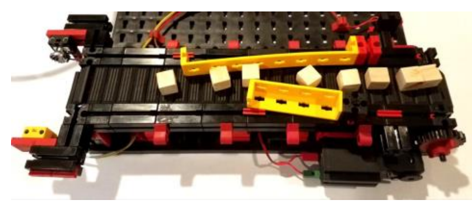
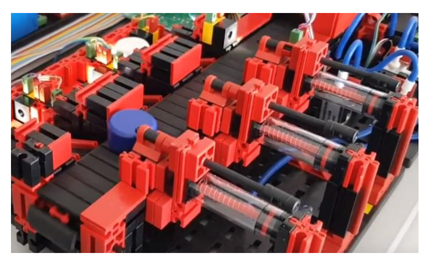
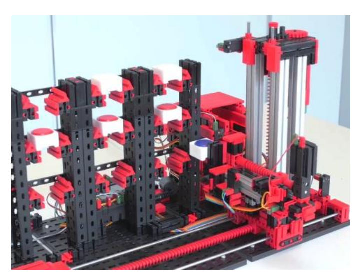
<tr><td>Programming Basic Control Systems</td><td></td></tr>
<tr><td>Conveyor with Counter</td><td></td></tr>
<tr><td>Pneumatic Clamping System</td><td></td></tr>
<tr><td>Pneumatic Feeder System</td><td></td></tr>
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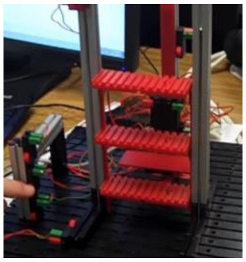
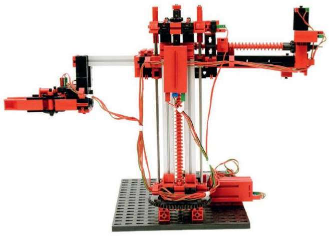
Elevator	
Robot Control	
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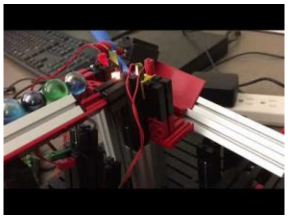
Color Glass Sorter	
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Mechatronics: Project Based STEM Education

Mechatronics has been called the science of intelligent machines. It is a study that focuses on electrical, control and mechanical systems, robotics, the internet of things and computer science. In today's society technicians and engineers with mechatronic backgrounds are in high demand.

One of the many benefits of STEM education is the integration and application of cross curricular content. This allows students to understand the relationship of the subjects they study. To be effective a STEM program needs to be fully integrated. The easiest and best way demonstrated so far is with a comprehensive project based curriculum. This helps students answer the questions "Why do I need to know this" and "Where will I ever use this".

According to the National Association of Colleges and Employers (NACE) skills that are in high demand include leadership, ability to work in teams, communication, analytical and quantitative, flexibility, adaptability and problem solving. To develop these skills it is imperative that students work in teams to solve problems.

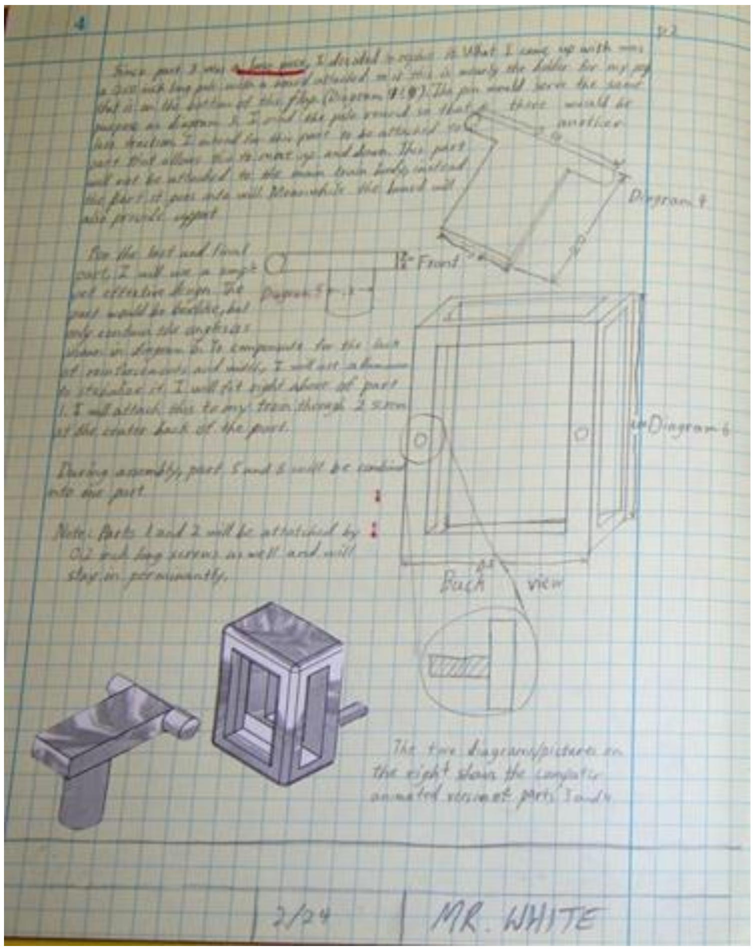
Project based curriculum allows for deep exploration of a problem. The project should be designed to allow different student groups to develop several and distinct solutions to the same problem. The problem presents the student with an opportunity to plan, organize and conduct research. Enabling activities can provide students with needed skills and knowledge "just in time". Students utilize their research in the design, prototyping, testing, evaluation, and redesign of a solution. According to the National Association of Colleges and Employers these skills are in high demand by prospective employers.

The term engineering implies a mathematical evaluation of a design. This analysis allows students to create mathematical models that can inform decisions and increase the speed at which a solution can be put forth. Once the initial analysis is done a prototype can be created and evaluated. The data is gathered and organized. Flaws are further analyzed and the design improved.

Once an acceptable design solution is reached student create final documentation. This documentation includes sketches, drawings, notes, research reports, data analysis and anything else utilized in the creation of the final design. Students craft explanatory or argumentative writing to explain the merits of their solutions. The writing is glue for the integration of the learning. Having to explain the solution takes the learning to higher levels.

True project based curriculum needs to be standards based, utilizing several standard sets. College and career readiness science standards will be in place this year as a companion to the existing College and career readiness Math Standards. There is a temptation to ignore the literacy standards as they do not appear in the STEM designation. They are as important as the College and career readiness Math standards. Reading and Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects prepare students for further education and entering into employment.

One of the biggest impediments to successful preparation for careers in STEM fields is the need for remediation before true college work can begin. Project based STEM education provides students with the preparation necessary for successful entry into college programs. Several colleges are conducting studies of their students who have participated in STEM programs in high school. They find higher GPA, better retention and better preparation for the rigors of college study.



Sketching and Documentation

Purpose of the Project:

The purpose of this project unit is to introduce students to basic sketching and documentation techniques utilized as the primary mode of communication in the initial stages of the design process. This project focuses on some of the fundamental skills used in freehand sketching. Students will become familiar with type of lines and what they represent. They will explore the design process and sketching's role in that process. During this course students will frequently use sketching techniques in their engineering notebooks to convey their ideas.

The research and learning activities are designed to help students:

- Explain the of sketching in the design process
- Create sketches utilizing basic shapes such as lines circles and ellipses
- Communicate ideas to a group through the use of sketches and other documentation
- Understand the difference between isometric and orthographic sketches
- Utilize sketching techniques to aid in the design process

Concepts:

- Sketches are used to aid in creative thinking and to communicate ideas
- Sketching is frequently used to document original thought for future reference
- Design is an iterative process and there are many methods used to create and document ideas
- Lines form shape, value, color texture and space are all utilized to communicate and collaborate

Outline:

Documentation
- Engineering Notebook
- Documenting computer programs
- Documenting research

Sketching
- Line types
- Isometric
- Orthographic
- Dimensioning

Standards:

College and career readiness Math Standards

Geometric Measurement and Dimension G-GMD

Explain volume formulas and use them to solve problems

1. Give an informal argument for the formulas for the circumference of a circle, area of a circle, volume of a cylinder, pyramid, and cone. *Use dissection arguments, Cavalieri's principle, and informal limit arguments.*
3. Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems.

Modeling with Geometry G-MG

Apply geometric concepts in modeling situations

1. Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).
2. Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).
3. Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

Create equations that describe numbers or relationships CED

A.4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.

Reading Standards for Literacy in History/Social Studies 9-10

Key Ideas and Details

1. Cite specific textual evidence to support analysis of primary and secondary sources, attending to such features as the date and origin of the information.
3. Analyze in detail a series of events described in a text; determine whether earlier events caused later ones or simply preceded them.

Integration of Knowledge and Ideas

7. Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text.
9. Compare and contrast treatments of the same topic in several primary and secondary sources.

Range of Reading and Level of Text Complexity

10. By the end of grade 10, read and comprehend science/technical texts in the grades 9–10 text complexity band independently and proficiently.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 9-10

Text Types and Purposes

1. Write arguments focused on *discipline-specific content.*
2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

Production and Distribution of Writing

4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Research to Build and Present Knowledge

7. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

8. Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

Range of Writing

10. Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Science

The projects engage students in the scientific and engineering practices taken from the National Research Council's Framework for K-12 Science Education, Practices, Crosscutting Concepts, and Core Ideas. This is the document upon which the NGSS are based.

These practices are used for two reasons: 1) they parallel the design process utilized in each project, and 2) they serve as the foundation of the NGSS.

The eight science and engineering practices are:

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Standards for Technological Literacy

STL Standard 2:

Students will develop an understanding of the core concepts of technology.

STL Standard 8:

Students will develop an understanding of the attributes of design.

STL Standard 9:

Students will develop an understanding of engineering design.

STL Standard 10:

Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

STL Standard 11:

Students will develop the abilities to apply the design process.

STL Standard 19:

Students will develop an understanding of and be able to select and use manufacturing technologies.

Assessment:

Assessment comes in both formative and summative. It is an integral part of quality instruction. During the course of the projects one of the teacher's main functions is to work with student groups, keeping track of progress and providing formative assessment in the form of feedback and promoting reflection on the part of students. The focus should be on lifetime and 21st century skills. The goal of instruction is to promote abilities in research, problem solving, design, experimentation, testing and collecting data.

Rubrics are used in the assessment process to communicate expectations of quality of a task. Rubrics should be shared with students at the beginning of a project so they can clarify any misconceptions before beginning work. They can then build the skills and gather knowledge to solve the problem presented to the expectations of excellence described.

> General Rubrics for Literacy tasks:
> Argumentative_Pursuasive
> Informational_Explanatory
>
> Individual Project Rubric:
> Sketching and Documentation Rubric

Essential Question:

How do I document an original idea so I can communicate with others easily?

Student Scenario:

You are a designer working for the Fischertechnik Company. The company has asked you to work with a client who needs some specialty parts created. Your supervisor would like to see ideas for a proposed design for a new building block. Your supervisor has asked you to sketch out some possible designs and present them to the design team for comment.

After conducting research on sketching techniques and participating in enabling activities you will select a part that does not exist and sketch out several variations. You will need to identify how it will connect with the rest of the building system, identify the material and select the proposed color of the proposed part. You will be responsible for giving a short presentation about the part using your sketch to highlight the points you wish to make.

Daily Plan:

Day 1

Key Question: What are the expectations for this project?

> Introduce students to the main problem by providing them with the Essential question and the project description.

Cover with your students the design process, engineering notebook and design documentation requirements. Discuss the problem statement design brief, testing protocol and management plan. Review the elements of a good engineering report.

Have the students form teams of two. Allow the students five minutes to discuss the problem. Students begin brainstorming ideas in their engineering notebooks. The teacher will provide a list of vocabulary terms that students will need to research. Student teams can break the lists up and determine how to define the terms.

Day 2
Key Question: Is there only one design process?

The teacher leads a discussion of how an object that the students are familiar with might be designed. Students break into groups and spend 10 minutes in discussion and then create a quick diagram of their process.
The teacher has the students view the webpage:
https://www.discoverdesign.org/handbook
Once the students have viewed the page they return to their groups and compare their results with what the webpage designed.
If there is time students can search out other design processes.

Day 3-4
Key Question: How do we properly communicate with sketching?

The teacher reviews the design process from Day 2 with the idea of generating ideas through sketching.
The teacher demonstrates how isometric sketches are created. The Teacher can use resources found by searching for isometric sketching.
The teacher will review drawing in isometric views. The teacher can use isometric graph paper to help student visualize what the sketch should look like.
The template for Isometric graph paper can be downloaded from http://www.printfreegraphpaper.com/.
The teacher gives each group of students a die from a set of dice.
The teacher has the students draw an isometric sketch of the die including the dots on each face. Students save the sketch in their engineering notebooks.

Day 5-7
Key Question: How can I show detail on a surface?

The teacher reviews what the students had drawn.
The teacher introduces the orthographic sketching concepts. The teacher can use resources found by searching for orthographic sketching.

The teacher will introduce the sketching activity have each student sketch a fischertechnik 30 mm building block in their engineering notebook. The sketches should have notes and any other necessary descriptors. Students should show instructor when completed and insert into their engineering notebook.

Day 8-9
Key Question: How much information is really necessary to include in a sketch.

The teacher begins by reviewing various sketching techniques the students have learned. Students discuss other information that should be included in sketches.

The teacher introduces the sketching activity. The teacher should have prepared several objects made from different fischertechnik pieces before the students arrive. (an alternative is to have each student team build a model of miscellaneous parts that will be given to a second team to sketch, and reconstructed by a third team.) All the objects should be different. An object created from several different fischertechnik pieces is hidden behind a screen so that only the team working on the sketch will be able to see it. Teams will have 20 minutes to view the object and sketch out as much information as they can without removing the object. Partners must each create their own sketch.

Student teams are then forbidden to look at the object again. The student teams utilize the drawings they each created to create one sketch that will be given to another team who will then have to recreate the object without asking questions or seeing the original model. The new models are compared to the original to see how accurate the process was.

The students should comment in their engineering notebooks about the information that they needed in their sketch to solve the issue. Students should also comment on what they wish had been included on the sketch they used.

Day 10-11
Key Question: How do we organize our thoughts on paper?

The teacher will discuss a student scenario where a team of students will sketch out their design to submit to Fischertechnik pertaining to a new building block that does not exist yet.
Students will examine some fischertechnik blocks and see how they interconnect.
The teams of students will brainstorm their new designs. The teacher should encourage different sketching techniques and annotations. Students may also wish to sketch how their new block might link to existing blocks.

Day 12
Key Question: How do we convey our ideas?

The teacher outlines the options students have for their presentations. Teams decide how to best present their material.
Students present their solutions to the class one at a time. At the end students reflect on their work and how they would have improve their designs

Vocabulary:

Annotated sketch
Brainstorming
Center Line
Design process
Engineering notebook
Hidden Line
Isometric sketch
Isometric Graph Paper
Multi-view sketch
Object Line
Orthographic

Resources:

Websites:

Engineering Notebook:

- http://www.wisegeek.com/what-is-an-engineering-notebook.htm
- https://www.firstinspires.org/sites/default/files/uploads/resource_library/ftc/engineering-notebook-guidelines.pdf
- https://www.asme.org/career-education/articles/early-career-engineers/my-engineers-notebook-jenn-t-dandrea

Engineering Reports

- http://web.mit.edu/me-ugoffice/communication/technical-writing.pdf
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/writing_engineering_reports.html
- https://www.youtube.com/playlist?list=PLDAAF7A8FD5CD582C&feature=plcp
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/mechanical_engineering_writing_enhancement_program/report_writing.html
- https://owl.purdue.edu/owl/subject_specific_writing/professional_technical_writing/technical_reports_and_report_abstracts/reports_proposals_and_technical_papers.html

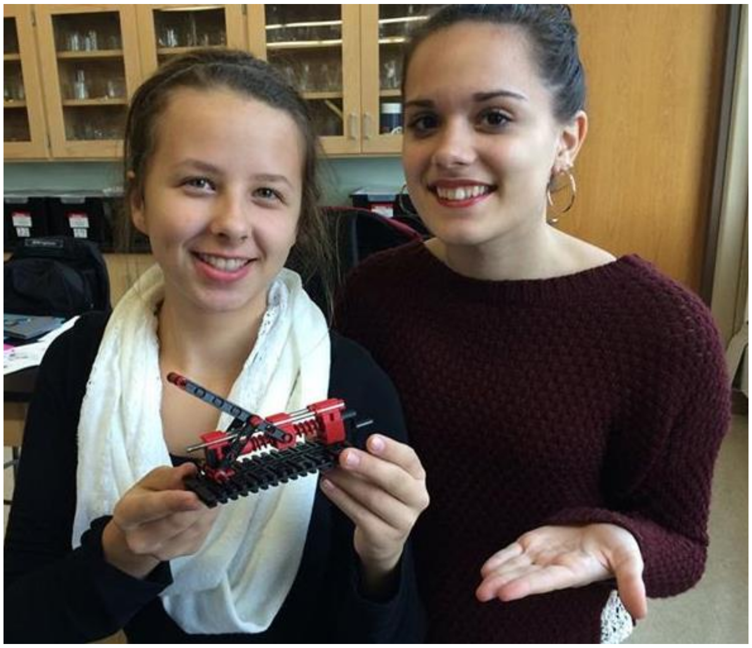
Engineering sketching:

http://www.me.umn.edu/courses/me2011/handouts/drawing/blanco-tutorial.html#isodrawing
http://www.youtube.com/watch?v=KN7281MUp_U
http://www.youtube.com/watch?v=ZBuhGaGPYfQ

http://www.technologystudent.com/designpro/isocube1.htm
https://www.sciencebuddies.org/science-fair-projects/engineering-design-process/engineering-design-process-steps

Department of Labor:
http://www.bls.gov/bls/topicsaz.htm
http://www.mynextmove.org/

Simple Machines



Introduction:

The purpose of this project is to introduce students to the six types of simple machines and how they are used every day. Simple machines are basic devices used to make work easier. A force is said to do work when there is a displacement of the point of application in the direction of the force. Simple machines make this process easier, although the same work will be done. In this activity the students will research the different types of simple machines and then build a model of one or several machines. They will demonstrate their application of the simple machine to the instructor and to the class.

The research and learning activities are designed to help students:

- Utilize mathematical analysis, scientific inquiry and engineering design to develop solutions to open ended problems.
- Access, generate, process, and transfer information using appropriate technologies
- Apply the design process in the design of a mechanical system.

- Read and analyze detailed descriptions of machinery and provide a concise summary for documentation purposes.
- Assign mathematical relationships to analyze mechanical advantage.
- Apply problem solving methodology in the creation of unique solutions to mechanical motion problems.

These authentic learning experiences will provide the students with awareness and skills valuable for a multitude of careers in the programming, robotics, automation, manufacturing and related industries.

Concepts:

Simple machines have been around since ancient times and have helped humans in many ways.

Simple machines can work alone or as a combination known as a compound machine to make work easier

All simple machines have a mechanical advantage.

Work is done when a force causes motion in the direction of the force.

The mechanical advantage can be mathematically calculated and used in the design of products.

A machine can reduce the force required to perform a task but cannot reduce the work required.

If the force required is reduced the distance through which the force acts must be increased if the work is to be the same.

Outline:

- Simple Machines
  - Wedge
  - Inclined plane
  - Lever
    - First class
    - Second class
    - Third class
  - Screw
  - Pulley
  - Wheel and Axle
- Mechanical Advantage
- Work
- Force
- Energy
- Efficiency

Standards:

College and career readiness Math- MS

Ratios and Proportional Relationships

Analyze proportional relationships and use them to solve real-world and mathematical problems.

1. Compute unit rates associated with ratios of fractions, including ratios of lengths, areas and other quantities measured in like or different units.
2. Recognize and represent proportional relationships between quantities.
3. Use proportional relationships to solve multistep ratio and percent problems.

Expressions and Equations

Use properties of operations to generate equivalent expressions.

1. Apply properties of operations as strategies to add, subtract, factor, and expand linear expressions with rational coefficients.

Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

3. Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.
4. Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.

Geometry

Draw, construct, and describe geometrical figures and describe the relationships between them.

1. Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale
2. Draw (freehand, with ruler and protractor, and with technology) geometric shapes with given conditions. Focus on constructing triangles from three measures of angles or sides, noticing when the conditions determine a unique triangle, more than one triangle, or no triangle.

Solve real-life and mathematical problems involving angle measure, area, surface area, and volume.

4. Know the formulas for the area and circumference of a circle and use them to solve problems; give an informal derivation of the relationship between the circumference and area of a circle.

Expressions and Equations

Understand the connections between proportional relationships, lines, and linear equations.

5. Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways.

Use functions to model relationships between quantities.

4. Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function

from a description of a relationship or from two (x, y) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models, and in terms of its graph or a table of values.

5. Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). Sketch a graph that exhibits the qualitative features of a function that has been described verbally.

Geometry

Understand and apply the Pythagorean Theorem.

7. Apply the Pythagorean Theorem to determine unknown side lengths in right triangles in real-world and mathematical problems in two and three dimensions.

8. Apply the Pythagorean Theorem to find the distance between two points in a coordinate system.

Reading Standards for Literacy in Science and Technical Subjects 6–12

Key Ideas and Details

1. Cite specific textual evidence to support analysis of science and technical texts.

3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

Craft and Structure

4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6–8 texts and topics.*

Integration of Knowledge and Ideas

7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

8. Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

9. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6–12

Text Types and Purposes

1. Write arguments focused on *discipline-specific content*.

2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

Production and Distribution of Writing

4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
6. Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas clearly and efficiently.

Research to Build and Present Knowledge

7. Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.
8. Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.
9. Draw evidence from informational texts to support analysis reflection, and research.

Range of Writing

10. Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Science

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3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Standards for Technological Literacy

STL Standard 2:

Students will develop an understanding of the core concepts of technology.

STL Standard 7:
Students will develop an understanding of the influence of technology on history.

STL Standard 8:
Students will develop an understanding of the attributes of design.

STL Standard 9:
Students will develop an understanding of engineering design.

STL Standard 17:
Students will develop an understanding of and be able to select and use information and communication technologies.

STL Standard 20:
Students will develop an understanding of and be able to select and use construction technologies.

Assessment:

Assessment comes in both formative and summative. It is an integral part of quality instruction. During the course of the projects one of the teacher's main functions is to work with student groups, keeping track of progress and providing formative assessment in the form of feedback and promoting reflection on the part of students. The focus should be on lifetime and 21st century skills. The goal of instruction is to promote abilities in research, problem solving, design, experimentation, testing and collecting data.

Rubrics are used in the assessment process to communicate expectations of quality of a task. Rubrics should be shared with students at the beginning of a project so they can clarify any misconceptions before beginning work. They can then build the skills and gather knowledge to solve the problem presented to the expectations of excellence described.

General Rubrics for Literacy tasks:
Argumentative_Pursuasive
Informational_Explanatory

Individual Project Rubric:
Simple machines Rubric

Essential Question

How do simple machines make our lives easier?

Student Scenario:

You have recently joined a team of exhibit designers for an event management company. Your company builds displays for trade shows, conferences, television and museums. Your team has been assigned the responsibility of creating an exhibit of simple machines for a children's museum. The museum curator has asked for an interactive display that clearly demonstrates the advantage of the simple machine. They need a display of the mathematical formula showing how the mechanical advantage is found. You should have a picture collage showing a number of uses for the specific simple machine.

After researching online resources on simple machines and mechanical advantage and participating in enabling activities you will design, build and test your model to be sure it functions. You will create the display that will go with the model you will present your simple machine to the class for approval for use in the children's museum.

Daily Plan:

Day 1-2

Key question: What is mechanical advantage and what has it ever done for me?

> Introduce students to the main problem by providing them with the Essential question and the project description.
>
> Cover with your students the design process, engineering notebook and design documentation requirements. Discuss the problem statement design brief, testing protocol and management plan. Review the elements of a good engineering report.
>
> The Teacher provides the Student Scenario to the students. Have the students form teams of two. Allow the students five minutes to discuss the problem. Students begin brainstorming ideas in their engineering notebooks.
>
> The teacher will provide a list of vocabulary terms that students will need to research. Student teams can break the lists up and determine how to define the terms.
>
> Students will begin research simple machine concepts and mechanical advantage. Students should begin at https://www.thoughtco.com/six-kinds-of-simple-machines-2699235 or https://www.ck12.org/physics/simple-machines-1501903848.65/lesson/Simple-Machines-PHYS/. Students should sketch each simple machine and make notes about mechanical advantage in the students engineering notebook.

Day 3

Key question: How come it took so long to invent the wheel?

> The teacher reviews simple machines with the students checking for understanding of mechanical advantage offered by each simple machine and how it might be calculated. Have students construct the Crank Gear. Have students sketch the model in their engineering notebook. Have them determine

the gear ratio of the model and explain what effect the gear ratio has on the speed of the output gear.

Days 4-7

Key question: What is a gear train?

The teacher reviews the concept of a gear train with the students and how the Crank gear 2 the students constructed the previous day changed the speed. Students should know that the purpose of a gear train is to change speed or direction of the power. Students should build one version of the Vehicle. The teacher can assign different ones to each group.

Students should document their construction of the vehicle and how the gears change the output speed depending on their settings. Students should record their observations in their engineering notebook.

Day 8-11

Key question: How can I tell in advance what the mechanical advantage of a design will be?

Student groups will be assigned a simple machine to be included in a model to be built. Students will work in teams and construct a working model of a simple machine. The design and building process should be captured in the engineering notebook.

The teacher checks on the progress the students are making to be sure there are no major issues. Students will watch a video on mechanical advantage. Some suggestions for videos can be found in the resources section below, making notes in their engineering journal. This should help them measure and calculate mechanical advantage of their simple machine model.

Students will finish construction. Students will make entries in their engineering notebook about their observations and challenges during the construction of the project. Students can photograph their project to include in their engineering notebook. Students begin preparation for their display.

Day 12-13

Key question: How can I communicate about my design?

Students finish the creation of their display and print out necessary materials. Students will present their prototyped simple machine design project display to the teacher and the class. There should be time allowed for each team of students to handle and observe every simple machine model.

Vocabulary:

1st class lever
2nd class lever
3rd class lever
Distance
Energy
Force
Fulcrum
Inclined plane
Lever
Mechanical advantage
Pulley
Screw
Simple machine
Wedge
Wheel and axle
Work

Resources:

Websites:

Engineering Notebook:

- http://www.wisegeek.com/what-is-an-engineering-notebook.htm
- https://www.firstinspires.org/sites/default/files/uploads/resource_library/ftc/engineering-notebook-guidelines.pdf
- https://www.asme.org/career-education/articles/early-career-engineers/my-engineers-notebook-jenn-t-dandrea

Engineering Reports

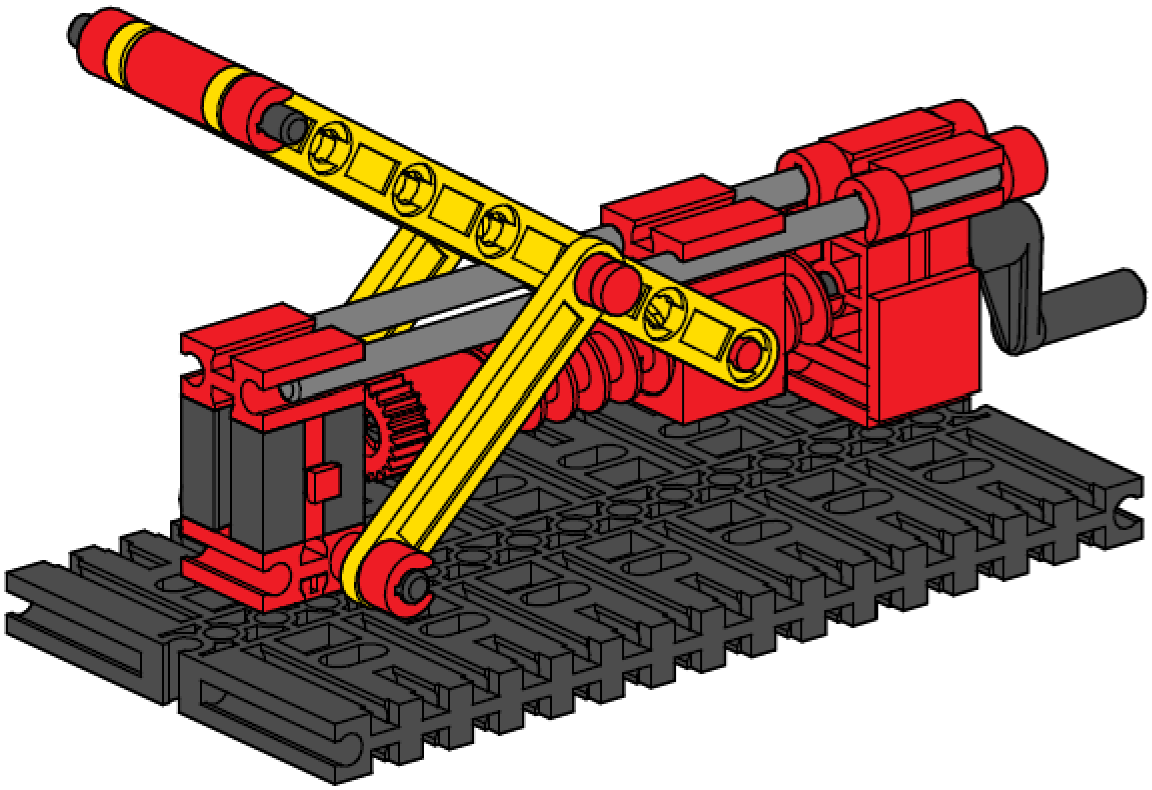
- http://web.mit.edu/me-ugoffice/communication/technical-writing.pdf
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/writing_engineering_reports.html
- https://www.youtube.com/playlist?list=PLDAAF7A8FD5CD582C&feature=plcp
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/mechanical_engineering_writing_enhancement_program/report_writing.html
- https://owl.purdue.edu/owl/subject_specific_writing/professional_technical_writing/technical_reports_and_report_abstracts/reports_proposals_and_technical_papers.html

Simple machines:

- https://www.thoughtco.com/six-kinds-of-simple-machines-2699235
  https://www.ck12.org/physics/simple-machines-1501903848.65/lesson/Simple-Machines-PHYS/
- http://www.msichicago.org/play/simplemachines/

Mechanical advantage:

- http://www.edinformatics.com/math_science/simple_machines/mechanical_advantage.htm
- http://www.school-for-champions.com/machines/mechanical_advantage.htm#.Vj0FZLerTBQ
- https://www.youtube.com/watch?v=yhzMYHiuEC4
- https://www.khanacademy.org/science/physics/work-and-energy/mechanical-advantage/v/introduction-to-mechanical-advantage
- http://www.schooltube.com/video/e8419c70e9bdf67d3d85/
- http://www.sciencekids.co.nz/videos/physics/pulleys.html



Mechanical Systems

Introduction:

Mechanisms were first recognized during the renaissance and made from simple machines. A mechanism is an arrangement of parts in a mechanical device or machine that is capable of defined movement. It is usually accepted that mechanisms produce a change in motion from the input to the output. Mechanisms change the movements speed, direction or type of motion. The elements in a mechanism are referred to as links. Linkages can be represented by schematic sketches. In this unit students will be introduces to some forms of mechanisms and how they behave and how to represent the linkages as schematics.. During the course of this project, students will design and implement a mechanism to solve a problem. They must apply concepts related to mechanisms and practice proper documentation techniques. They will become familiar with several types of mechanisms and how they are controlled.

The research and learning activities are designed to help students:

- Utilize mathematical analysis, scientific inquiry and engineering design to develop solutions to open ended problems.
- Access, generate, process, and transfer information using appropriate technologies
- Apply the design process in the design of a mechanical system.
- Read and analyze detailed descriptions of machinery and provide a concise summary for documentation purposes.
- Assign mathematical relationships to schematics to apply forces.
- Apply problem solving methodology in the creation of unique solutions to mechanical motion problems.

These authentic learning experiences will provide the students with awareness and skills valuable for a multitude of careers in the programming, robotics, automation, manufacturing and related industries.

Concepts:

- Mechanisms utilize a combination of simple machines to change the speed, direction or type of motion.
- A mechanism can be modeled as an assembly of links and the motion and forces can be mathematically predicted.
- Linkages are a series of links connected by joints represented in schematic drawings which show fixed and movable pins (joints) and links.
- Understand practical uses of mechanisms

Outline:

- Mechanisms
  - Gears and Gear Ratios
  - Crank and slider
  - Cams
- Motions
  - Rotary
  - Inline
  - Reciprocating
- Forces
  - Tension
  - Compression
  - Torque
  - Efficiency

Standards:

College and career readiness Math Standards

Vector and Matrix Quantities N -VM

Represent and model with vector quantities.
Perform operations on vectors.

Seeing Structure in Expressions A-SSE

Interpret the structure of expressions

1. Interpret expressions that represent a quantity in terms of its context.

Write expressions in equivalent forms to solve problems

3. Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.

Creating Equations A -CED

Create equations that describe numbers or relationships

1. Create equations and inequalities in one variable and use them to solve problems.
2. Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

Represent and solve equations and inequalities graphically

10. Understand that the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line).

Similarity, Right Triangles, and Trigonometry G-SRT

Define trigonometric ratios and solve problems involving right triangles

6. Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles.
7. Explain and use the relationship between the sine and cosine of complementary angles.
8. Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems.

Geometric Measurement and Dimension G-GMD

Explain volume formulas and use them to solve problems

1. Give an informal argument for the formulas for the circumference of a circle, area of a circle, volume of a cylinder, pyramid, and cone. *Use dissection arguments, Cavalieri's principle, and informal limit arguments.*
3. Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems.

Modeling with Geometry G-MG

Apply geometric concepts in modeling situations

1. Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).
2. Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).

3. Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

Reading Standards for Literacy in History/Social Studies 9-10

Key Ideas and Details

1. Cite specific textual evidence to support analysis of primary and secondary sources, attending to such features as the date and origin of the information.
3. Analyze in detail a series of events described in a text; determine whether earlier events caused later ones or simply preceded them.

Integration of Knowledge and Ideas

7. Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text.
9. Compare and contrast treatments of the same topic in several primary and secondary sources.

Range of Reading and Level of Text Complexity

10. By the end of grade 10, read and comprehend science/technical texts in the grades 9–10 text complexity band independently and proficiently.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 9-10

Text Types and Purposes

1. Write arguments focused on *discipline-specific content.*
2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

Production and Distribution of Writing

4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Research to Build and Present Knowledge

7. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

8. Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

Range of Writing

10. Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Science

The projects engage students in the scientific and engineering practices taken from the National Research Council's Framework for K-12 Science Education, Practices, Crosscutting Concepts, and Core Ideas. This is the document upon which the NGSS are based.

These practices are used for two reasons: 1) they parallel the design process utilized in each project, and 2) they serve as the foundation of the NGSS.

The eight science and engineering practices are:

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Standards for Technological Literacy

STL Standard 8:

Students will develop an understanding of the attributes of design.

STL Standard 9:

Students will develop an understanding of engineering design.

STL Standard 10:

Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

STL Standard 11:

Students will develop the abilities to apply the design process.

STL Standard 12:

Students will develop the abilities to use and maintain technological products and systems.

STL Standard 13:

Students will develop the abilities to assess the impact of products and systems.

STL Standard 18:
Students will develop an understanding of and be able to select and use transportation technologies.

Assessment:

Assessment comes in both formative and summative. It is an integral part of quality instruction. During the course of the projects one of the teacher's main functions is to work with student groups, keeping track of progress and providing formative assessment in the form of feedback and promoting reflection on the part of students. The focus should be on lifetime and 21st century skills. The goal of instruction is to promote abilities in research, problem solving, design, experimentation, testing and collecting data.

Rubrics are used in the assessment process to communicate expectations of quality of a task. Rubrics should be shared with students at the beginning of a project so they can clarify any misconceptions before beginning work. They can then build the skills and gather knowledge to solve the problem presented to the expectations of excellence described.

General Rubrics for Literacy tasks:
Argumentative_Pursuasive
Informational_Explanatory

Individual Project Rubric:
Mechanical Systems Rubric

Essential Question

How can I design a mechanism to do what I want it to?

Student Scenario:

You are a mechanical designer. You have been given the task of designing a vehicle that can carry one pound up an inclined slope. Your team should research hill climbing vehicles and decide on the best method of designing a vehicle that is capable of transporting the weight to the top of the ramp.

Once the prototype is constructed and working, the students should record a brief movie. Their final presentation should document the design process and then describe the features of your hill climbing system that makes it unique.

Daily Plan:

Day 1
Key Question: What are the expectations for this project?

Introduce students to the main problem by providing them with the Essential question and the project description.

Cover with your students the design process, engineering notebook and design documentation requirements. Discuss the problem statement design brief, testing protocol and management plan. Review the elements of a good engineering report.

The Teacher provides the Student Scenario to the students. Have the students form teams of two. Allow the students five minutes to discuss the problem. Students begin brainstorming ideas in their engineering notebooks.

The teacher will provide a list of vocabulary terms that students will need to research. Student teams can break the lists up and determine how to define the terms.

Students should begin by researching simple mechanisms. Good sites for mechanisms are found below.

Day 2
Key Question: How do we begin designing a mechanism?

The teacher reviews the simple mechanisms and how they work with the students. The teacher should provide the students with the document on Linkage Diagrams to aid them in organizing their thoughts. Students work through the activity and create sketches in their engineering notebooks.

Day 3
Key question: If I see an idea for a mechanism someplace how can I record it for later use?

Students begin to brainstorm how they will create a vehicle to travel up the teacher provided ramp. They should create a linkage diagram of the proposed model. Students record their observations in their engineering notebook.

Day 4-7
Key Question: How can I construct a mechanism to do what I want it to?

Students will research types of systems used to transport freight on hills and begin the design of their transportation system. Students will brainstorm ideas and complete a mechanism diagram before beginning the build. Student should use digital photographs and sketches to record the progress in their engineering notebooks. The students should record their vehicle in motion and save the video for use in their presentation video.

Day 8-9
Key Question: What information does my presentation need?

Students will finish their mechanisms. They should record a brief movie to be presented to the teacher and the class. They should point out their best concepts and mechanisms used and record a short presentation about the design process used to create their vehicle.

Students should save their video to a shared folder and watch other groups videos.

Vocabulary:

Bell Crank
Cam
Compression
Crank and slider
Efficiency
Follower
Force
Gear
Lever
Linear motion
Linkage
Linkage diagram
Links
Reciprocating motion
Rotary motion
Tension
Torque
Work

Resources:

Engineering Notebook:

- http://www.wisegeek.com/what-is-an-engineering-notebook.htm
- https://www.firstinspires.org/sites/default/files/uploads/resource_library/ftc/engineering-notebook-guidelines.pdf
- https://www.asme.org/career-education/articles/early-career-engineers/my-engineers-notebook-jenn-t-dandrea

Engineering Reports

- http://web.mit.edu/me-ugoffice/communication/technical-writing.pdf
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/writing_engineering_reports.html
- https://www.youtube.com/playlist?list=PLDAAF7A8FD5CD582C&feature=plcp
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/mechanical_engineering_writing_enhancement_program/report_writing.html

- https://owl.purdue.edu/owl/subject_specific_writing/professional_technical_writing/technical_reports_and_report_abstracts/reports_proposals_and_technical_papers.html

Mechanisms:

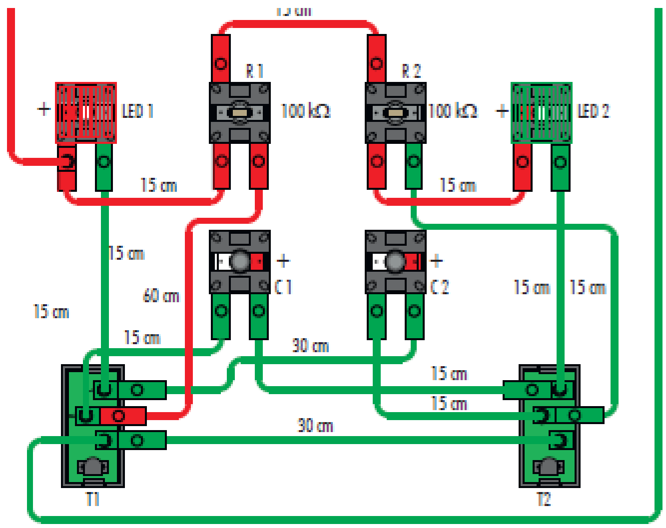
- http://www.technologystudent.com/cams/camdex.htm
- http://www.technologystudent.com/cams/link1.htm
- http://www.technologystudent.com/gears1/geardex1.htm
- http://www.technologystudent.com/cams/crkslid1.htm
- https://phet.colorado.edu/en/simulation/legacy/ramp-forces-and-motion
- http://www.physicsgames.net/game/Mechanism.html

Animated mechanisms:

- http://www.mekanizmalar.com/

Gear ratio:

- https://www.youtube.com/watch?v=D_i3PJIYtuY



Basic Electricity

Introduction:

Where does electricity come from? Electricity makes everything from your lights in your classroom work all the way down to your cell phone. In this unit we will explore the terms of electricity and the theory behind it. Students will build several models that will allow them to measure and calculate basic electrical terms like volts, amps and watts. This process will introduce several basic electricity concepts that they will be able to apply in upcoming units. They will give a small presentation at the end of this unit to the teacher.

The research and learning activities are designed to help students:

- Identify and apply appropriate methodology when designing electrical circuits.
- Utilize mathematical analysis, scientific inquiry and engineering design to develop solutions to open ended problems.
- Access, generate, process, and transfer information using appropriate technologies.
- Use proper electrical design to process sensor information and control output.
- Read and analyze schematics and provide a concise summary for documentation purposes.
- Express graphically an electrical circuit.

- Apply problem solving methodology in the creation of unique solutions to robotic problems.

These authentic learning experiences will provide the students with awareness and skills valuable for a multitude of careers in the programming, robotics, electronics, machine maintenance automation, manufacturing and related industries.

Concepts:

- Current is the flow of electrons and measured in amperage
- Current, voltage and resistance are all related in basic electricity
- A circuit can be series, parallel or a combination of the two.
- Current only flows when there is a complete electrical path
- Current is the same anyplace in a series circuit
- Voltage is the same across branches of a parallel circuit.
- Electrical circuits can be represented by schematics

Outline:

Circuits
  Open circuit
  Closed Circuit
  Short Circuit
  Series Circuit
  Parallel Circuit
  Schematics
Ohm’s Law
  Voltage
  Current
  Resistance
Power

Standards:

College and Career Readiness Standards Math

Ratios and Proportional Relationships

Analyze proportional relationships and use them to solve real-world and mathematical problems.

1. Compute unit rates associated with ratios of fractions, including ratios of lengths, areas and other quantities measured in like or different units.
2. Recognize and represent proportional relationships between quantities.
3. Use proportional relationships to solve multistep ratio and percent problems.

The Number System

Apply and extend previous understandings of operations with fractions to add, subtract, multiply, and divide rational numbers.

1. Apply and extend previous understandings of addition and subtraction to add and subtract rational numbers; represent addition and subtraction on a horizontal or vertical number line diagram.

Expressions and Equations

Use properties of operations to generate equivalent expressions.

1. Apply properties of operations as strategies to add, subtract, factor, and expand linear expressions with rational coefficients.

Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

3. Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.
4. Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.

The Number System

Know that there are numbers that are not rational, and approximate them by rational numbers.

1. Know that numbers that are not rational are called irrational. Understand informally that every number has a decimal expansion; for rational numbers show that the decimal expansion repeats eventually, and convert a decimal expansion which repeats eventually into a rational number.

Expressions and Equations

Work with radicals and integer exponents.

4. Perform operations with numbers expressed in scientific notation, including problems where both decimal and scientific notation are used. Use scientific notation and choose units of appropriate size for measurements of very large or very small quantities

Understand the connections between proportional relationships, lines, and linear equations.

5. Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways.

Use functions to model relationships between quantities.

4. Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x, y) values, including reading these from a table or from a graph. Interpret the rate of change

and initial value of a linear function in terms of the situation it models, and in terms of its graph or a table of values.

5. Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). Sketch a graph that exhibits the qualitative features of a function that has been described verbally.

Reading Standards for Literacy in Science and Technical Subjects 6–12

Key Ideas and Details

1. Cite specific textual evidence to support analysis of science and technical texts.

3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

Craft and Structure

4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6–8 texts and topics.*

Integration of Knowledge and Ideas

7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

8. Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

9. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6–12

Text Types and Purposes

1. Write arguments focused on *discipline-specific content*.

2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

Production and Distribution of Writing

4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

6. Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas clearly and efficiently.

Research to Build and Present Knowledge

7. Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

8. Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.
9. Draw evidence from informational texts to support analysis reflection, and research.

Range of Writing

10. Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Science

The projects engage students in the scientific and engineering practices taken from the National Research Council's Framework for K-12 Science Education, Practices, Crosscutting Concepts, and Core Ideas. This is the document upon which the NGSS are based.

These practices are used for two reasons: 1) they parallel the design process utilized in each project, and 2) they serve as the foundation of the NGSS.

The eight science and engineering practices are:
1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Standards for Technological Literacy

STL Standard 2:
Students will develop an understanding of the core concepts of technology.

STL Standard 3:
Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

STL Standard 10:
Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

STL Standard 11:
Students will develop the abilities to apply the design process.

STL Standard 12:
Students will develop the abilities to use and maintain technological products and systems.

STL Standard 13:
Students will develop the abilities to assess the impact of products and systems.

Assessment:

Assessment comes in both formative and summative. It is an integral part of quality instruction. During the course of the projects one of the teacher's main functions is to work with student groups, keeping track of progress and providing formative assessment in the form of feedback and promoting reflection on the part of students. The focus should be on lifetime and 21st century skills. The goal of instruction is to promote abilities in research, problem solving, design, experimentation, testing and collecting data.

Rubrics are used in the assessment process to communicate expectations of quality of a task. Rubrics should be shared with students at the beginning of a project so they can clarify any misconceptions before beginning work. They can then build the skills and gather knowledge to solve the problem presented to the expectations of excellence described.

General Rubrics for Literacy tasks:
Argumentative_Pursuasive
Informational_Explanatory

Individual Project Rubric:
Basic Electricity Rubric

Essential Question

How do I document and communicate the electrical circuit design?

Student Scenario:

You are in head engineer in charge of wiring a new factory that is being built. It is very important to the workers that will be there that they have plenty of bright lights in the ceiling so they can see their work. There will be large manufacturing equipment on the factory floor running all day long. We do not want the lights and the machines interfering with each other. If wired incorrectly, the lights could become too dim or the machines might slow down. This situation could cause accidents to workers or damage to machines. It is your job to make sure the building is wired correctly.
You will conduct internet research to discover electrical theory. Then we will test this theory by building prototype circuits. All work should be documented in the engineering notebook. Students will create a schematic to wire three lights to maximize the lights and to connect one motor so it will not slow down. Students will create a prototype

wiring of the schematic. A small presentation on PowerPoint including the schematic and digital photo will be submitted at the conclusion to the teacher.

Daily Plan:

Day 1

Key Question: What are the expectations for this project?

Introduce students to the main problem by providing them with the Essential question and the project description.

Cover with your students the design process, engineering notebook and design documentation requirements. Discuss the problem statement design brief, testing protocol and management plan. Review the elements of a good engineering report.

The Teacher provides the Student Scenario to the students. Have the students form teams of two. Allow the students five minutes to discuss the problem. Students begin brainstorming ideas in their engineering notebooks.

The teacher will provide a list of vocabulary terms that students will need to research. Student teams can break the lists up and determine how to define the terms.The teacher can assign a few words for the students to research each day so they have an understanding of the discussions as they occur. The teacher should also help the students outline the research they will need to do to be ready to work independently on the project at the end of the unit.

Day 2

Key Question: How does electricity work?

Students divide into groups. Each group will be responsible for assuring all members of the group understand the basics of electricity. Students will research the basics of electricity using sites listed in the resource area to get started. As a wrap up activity the teacher should call on each team to explain one aspect of the basics of electricity. The team will select a spokesperson to provide the basic explanation of the assigned aspect. Other groups can add comments as needed. Each group explains a different aspect or term.

Day 3-4

Key Question: What is the difference between series circuits and parallel circuits?

The teacher will take some time to review the basics of electricity to be sure they understand. Working in their teams the students should research series circuits, open circuits and short circuits and parallel circuits. Have the students work with https://phet.colorado.edu/en/simulation/circuit-construction-kit-dc-virtual-lab. Once the teams finish they should work through the activity on circuits and schematics.

Day 5
Key question: How can I figure out the relationship between Voltage, Current, and Resistance?

The teacher reviews with the students the concepts of the basics of electricity. The teacher explains the concept of direct and inverse relationships checking for understanding. The teacher should show how X=Y is a direct relationship. When X increases, Y increases. The teacher should also show that X=1/Y is an inverse relationship where X increases as Y decreases and X decreases as Y increases. Students should then break into teams to research Ohms Law. Students should begin with https://phet.colorado.edu/en/simulation/ohms-law. When finished students should work on the Ohms Law and Power activity.

Day 6-7
Key Question: What needs to be in my presentation?

Students will finish up any readings and calculations on the different types of circuits. Students will prepare their schematics and assemble a test circuit to demonstrate their schematic. Students will prepare their findings in a brief PowerPoint and submit to the teacher.

Vocabulary:

Alternating Current
Amperage
Branches
Circuit breaker
Current
Direct Current
Multimeter
Ohms Law
Open circuit
Parallel
Power
Resistance
Series
Short circuit
Voltage
Watts

Resources:

Engineering Notebook:

- http://www.wisegeek.com/what-is-an-engineering-notebook.htm
- https://www.firstinspires.org/sites/default/files/uploads/resource_library/ftc/engineering-notebook-guidelines.pdf
- https://www.asme.org/career-education/articles/early-career-engineers/my-engineers-notebook-jenn-t-dandrea

Engineering Reports

- http://web.mit.edu/me-ugoffice/communication/technical-writing.pdf
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/writing_engineering_reports.html
- https://www.youtube.com/playlist?list=PLDAAF7A8FD5CD582C&feature=plcp
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/mechanical_engineering_writing_enhancement_program/report_writing.html
- https://owl.purdue.edu/owl/subject_specific_writing/professional_technical_writing/technical_reports_and_report_abstracts/reports_proposals_and_technical_papers.html

Basics of Electricity

- http://www.allaboutcircuits.com/vol_1/index.html
- http://www.physics4kids.com/files/elec_intro.html
- http://www.eia.gov/kids/energy.cfm?page=electricity_home-basics-k.cfm
- http://science.howstuffworks.com/electricity.htm

Schematic symbols

- http://www.rapidtables.com/electric/electrical_symbols.htm

Series Circuit:

- http://technologystudent.com/elec1/srcirc1.htm

Parallel circuit:

- http://technologystudent.com/elec1/prcir1.htm

How to use a multi-meter:

- http://technologystudent.com/elec1/metre1.htm

Ohms law

- http://www.allaboutcircuits.com/vol_1/chpt_2/1.html

Voltage dividers

- http://www.youtube.com/watch?v=XxLKfAZrhbM

Garage Door

Introduction to Control Systems:

Automated doors are everywhere in our lives today. This automation technology allows for the safe entry and exit from buildings. Automated doors use a sensor to determine when movement is occurring near the door. The automated door computer program decides when the door should open and after a set amount of time, when the door closes automatically saving heat or air conditioning.

Introduction:

Most garage doors have a sensor that detects objects crossing their plane. They are digital sensors that provide a Boolean signal when something obstructs a beam. Automating a door is a convenient way to address the need to enter a home or building. However, some important factors must be included in the design. For example, the door should not open or close when conditions are not right. The door should not close on people, animals, or anything else that might be crushed by the action of the door. Modern garage doors have a sensor that prevents the door from closing when there is a person, child, animal, or object in the door's path.

The research and learning activities are designed to help students:

- Identify and apply appropriate methodology associated with logic.
- Utilize mathematical analysis, scientific inquiry and engineering design to develop solutions to open ended problems.
- Access, generate, process, and transfer information using appropriate technologies.

- Design control algorithms for the processing of sensor information and controlling output.
- Read and analyze detailed descriptions of programming situations and provide a concise summary for documentation purposes.
- Connect the relationship between the outputs and the inputs and expressed them in a flow chart.
- Apply problem solving methodology in the creation of unique solutions to programming problems.

These authentic learning experiences will provide the students with awareness and skills valuable for a multitude of careers in the programming, robotics, automation, manufacturing and related industries.

Concepts:

- Computer programs are collections of instructions that tell a computer how to interact with the user, interact with the computer hardware and process data.
- Control statements can be Sequential, Conditional (decision making) and/or Iterative.
- A flowchart is a diagram that represents a process.
- Some control systems utilize feedback while others do not.
- Control systems can be either digital or analog or both.
- Design is an iterative process.
- Automated systems perform with minimal human intervention.

Outline:

Methods of writing programs
- Flow charts
- Word problems

Program characteristics
- Open Loop System
- Closed Loop System
- Flow Chart
- PLC – Programmable Logic Control

Documenting Programs
- Adding Comments to programs
- Writing software documentation

Object Blocks
- Inputs
- Outputs

Loops
- Types
- exiting

Branching
- Digital
- Analog

Standards:

Career and Technical Standards

Engineering Design Process

- Maintain an Engineering Notebook for research, prototype creation, documentation and daily reflections.
- Apply engineering design and problem solving as an iterative process incorporating science, mathematics, and engineering to optimally convert resources to meet a design solution.
- Communicate design solutions utilizing effective technical writing skills including correct spelling, proper grammar, and accurate technical vocabulary.
- Prepare a quantitative plan for the successful completion of a project.
- Assume leadership responsibility for collaborative team actions and decisions related to the successful completion of a project.
- Evaluate the needs and costs of resources necessary for the completion of a project.
- Prepare and communicate model documentation to include such details as product analysis, size, materials, assembly details, installation and service requirements.

Automation with Programmable Logic Controllers (PLCs)

- Design and analyze an electrical system to efficiently convert, transform, and transmit electricity to where it is needed.
- Research and specify electrical devices necessary to provide needed power.
- Apply machine control systems, sensory feedback, and information processing to increase productivity in manufacturing.
- Use flow charts and diagrams to apply logic in the design of control programs.

Applying Logic Software RoboPro to Create Problem Solutions

- Design a system of elements that manages power to accomplish a task involving defined movement.
- Design a control system to vary the speed and performance of a motor by utilizing feedback from the system to gain the most efficiency possible.
- Formulate a system to utilize data collection and analysis to maintain and improve product quality and provide adequate confidence that the product will satisfy design requirements.
- Design and analyze the application of machine control systems, sensory feedback, and information processing to increase productivity in manufacturing.

Common Core Math- MS

Expressions and Equations 7.EE

Use properties of operations to generate equivalent expressions.

1. Apply properties of operations as strategies to add, subtract, factor, and expand linear expressions with rational coefficients.

Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

3. Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.

4. Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.

Geometry 7.G

Draw, construct, and describe geometrical figures and describe the relationships between them.

1. Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale

2. Draw (freehand, with ruler and protractor, and with technology) geometric shapes with given conditions. Focus on constructing triangles from three measures of angles or sides, noticing when the conditions determine a unique triangle, more than one triangle, or no triangle.

Solve real-life and mathematical problems involving angle measure, area, surface area, and volume.

4. Know the formulas for the area and circumference of a circle and use them to solve problems; give an informal derivation of the relationship between the circumference and area of a circle.

Geometry 8.G

Understand congruence and similarity using physical models, transparencies, or geometry software.

1. Verify experimentally the properties of rotations, reflections, and translations

2. Understand that a two-dimensional figure is congruent to another if the second can be obtained from the first by a sequence of rotations, reflections, and translations; given two congruent figures, describe a sequence that exhibits the congruence between them.

Understand and apply the Pythagorean Theorem.

7. Apply the Pythagorean Theorem to determine unknown side lengths in right triangles in real-world and mathematical problems in two and three dimensions.

8. Apply the Pythagorean Theorem to find the distance between two points in a coordinate system.

Reading Standards for Literacy in Science and Technical Subjects 6–12

Key Ideas and Details

1. Cite specific textual evidence to support analysis of science and technical texts.

3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

Craft and Structure

4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6–8 texts and topics.*

Integration of Knowledge and Ideas

7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

8. Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

9. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 6–12

Text Types and Purposes

1. Write arguments focused on *discipline-specific content*.

2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

Production and Distribution of Writing

4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

6. Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas clearly and efficiently.

Research to Build and Present Knowledge

7. Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.
8. Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.
9. Draw evidence from informational texts to support analysis reflection, and research.

Range of Writing

10. Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Science

The projects engage students in the scientific and engineering practices taken from the National Research Council's Framework for K-12 Science Education, Practices, Crosscutting Concepts, and Core Ideas. This is the document upon which the NGSS are based.

These practices are used for two reasons: 1) they parallel the design process utilized in each project, and 2) they serve as the foundation of the NGSS.

The eight science and engineering practices are:

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Standards for Technological Literacy

STL Standard 1:
Students will develop an understanding of the characteristics and scope of technology.

STL Standard 2:
Students will develop an understanding of the core concepts of technology.

STL Standard 3:
Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

STL Standard 4:
Students will develop an understanding of the cultural, social, economic, and political effects of technology.

STL Standard 5:
Students will develop an understanding of the effects of technology on the environment.

STL Standard 6:
Students will develop an understanding of the role of society in the development and use of technology.

STL Standard 7:
Students will develop an understanding of the influence of technology on history.

STL Standard 8:
Students will develop an understanding of the attributes of design.

STL Standard 9:
Students will develop an understanding of engineering design.

STL Standard 10:
Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

STL Standard 11:
Students will develop the abilities to apply the design process.

STL Standard 12:
Students will develop the abilities to use and maintain technological products and systems.

STL Standard 13:
Students will develop the abilities to assess the impact of products and systems.

STL Standard 14:
Students will develop an understanding of and be able to select and use medical technologies.

STL Standard 16:
Students will develop an understanding of and be able to select and use energy and power technologies.

STL Standard 17:
Students will develop an understanding of and be able to select and use information and communication technologies.

STL Standard 19:
Students will develop an understanding of and be able to select and use manufacturing technologies.

STL Standard 20:
Students will develop an understanding of and be able to select and use construction technologies.

Assessment:
Assessment comes in both formative and summative. It is an integral part of quality instruction. During the course of the projects one of the teacher's main functions is to work with student groups, keeping track of progress and providing formative assessment in the form of feedback and promoting reflection on the part of students. The focus should be on lifetime and 21st century skills. The goal of instruction is to promote abilities in research, problem solving, design, experimentation, testing and collecting data.

Rubrics are used in the assessment process to communicate expectations of quality of a task. Rubrics should be shared with students at the beginning of a project so they can clarify any misconceptions before beginning work. They can then build the skills and gather knowledge to solve the problem presented to the expectations of excellence described.

General Rubrics for Literacy tasks:
Argumentative_Pursuasive
Informational_Explanatory

Individual Project Rubric:
Garage Door Rubric

Essential Question:
How can I create a program for my prototype so it will behave the way I envision?

Student Scenario:
You are a member of the design team of a firm that manufactures Garage door openers. You have been assigned to design the control system for the new door line that is coming out. The manufacturer has stated that the door should open and close smoothly using limit switches so the door can be adjusted to the frame in the home it will be installed in. There are also codes that outline a needed safety system that will sense when anything is in the way and not let the door close until the path is clear and the switch pressed again. There is also an expressed desire to have a light that will come on for a minute to allow people to see until they can get to the house. This light should automatically turn off to be energy efficient.

After researching online information on garage door opener regulations and programming as well as participating in enabling activities you will design a control system to meet the requirements. You will design a prototype garage door to demonstrate your program on. Your program should be completely documented to allow anyone to understand how the program functions.

The research and learning activities are designed to help students:

- Learn the basic principles of PLC control
- Apply digital logic to determine the door operation
- Utilize a closed loop system to identify the door operating parameters.

Deliverables:

- Engineering Notebook with reflections, research notes, bibliography, and other processes used in the design.
- Sketches of the device and planning for programming
- Descriptions of the sensors utilized and where they should be positioned
- Working prototype
- Engineering report of the design process
- Presentation for the authentic audience

Daily Plan:

Day 1

Key Question: What are the expectations for this project?

Introduce students to the main problem by providing them with the Essential question and the project description.

Cover with your students the design process, engineering notebook and design documentation requirements. Discuss the problem statement , design brief, testing protocol and management plan. Review the elements of a good engineering report.

The Teacher provides the Student Scenario to the students. Have the students form teams of two. Allow the students five minutes to discuss the problem. Students begin brainstorming ideas in their engineering notebooks.

The teacher will provide a list of vocabulary terms that students will need to research. Student teams can break the lists up and determine how to define the terms.

The teacher should also help the students outline the research they will need to do to be ready to work independently on the project at the end of the unit.

The teacher should be sure that the RoboPro software and drivers are installed on all the computers.

Students will conduct internet research on different types of control systems and their functions. They will enter their findings in their engineer's notebook.

Day 2
Key Question: How does the computer know what I want it to do?

The teacher begins by discussing various types of interfaces with students. Students should understand that the controls of a car are an example of an interface. The teacher then provides an overview of the RoboPro Graphical User Interface. Teachers make sure students can launch the software.

Teacher provides the Introduction to RoboPro Software activity. Students work through identifying various sections and recording the information. Students should have the teacher mark off their completion of the activity and store it in their engineering notebook.

Day 3-4
Key Question: How do computers interact with the outside world?

The Teacher reviews the vocabulary with the students checking for any difficulty in defining the terms. Other teams should offer their definitions, if a group has any difficulty. Teacher checks specifically about understanding of controllers.

The teacher leads a discussion of the TX controller and software interface and their purpose. The teacher will demonstrate hooking up the interface to the computers stressing safety.

The teacher distributes the document Introduction to the TX Controller. Each student group will be given a controller to study while completing the assignment. Students should have the teacher mark off their completion of the activity and store it in their engineering notebook.

Students are introduced to different input and output devices in the RoboPro software by the teacher. Students research analog and digital sensors to determine what each type does and electrical signal provided.

Day 5-6
Key Question: How can I organize my thoughts about what I want the controller to do?

The teacher begins by checking for questions about how the controller functions with the software.

Teacher provides the activity on Flow Charts. Students practice creating flow charts.
Students should have the teacher mark off their completion of the activity and store it in their engineering notebook.

Day 7
Key Question: How does my dishwasher know when the dishes are clean?

The teacher leads a discussion of student thoughts on flow charts. Student groups should take a few minutes to discuss the most difficult part of the process and report to the main group. The teacher has the students write their own definition of what a loop is.

The teacher will provide the activity Open Loop Programming. Students begin the activity. The teacher answers questions from the groups about open loop programming and timers. Students should have the teacher mark off their completion of the activity and store it in their engineering notebook.

Day 8-10
Key Question: How does a computer sense the world around it?

Students begin by listing as many things as they can think of in 5 minutes that use open loop programming.

Groups report to the class about all the things they have thought of. After the first group, each group adds only the new items that didn't appear on the first list. A student can be selected to act as a recorder.

The teacher will provide the activities Sensors: Digital Switch, Digital Phototransistor and Introduction to Closed Loop Programming. Review the requirements with students. Students begin the activity, demonstrating finished work to the teacher. Students should have the teacher mark off their completion of the activity and store it in their engineering notebook.

Day 11-12
Key Question: How do programs make decisions on the information they gather?

The teacher begins by having the students discuss Closed Loop programs. The teacher needs to focus the students on what happens when a loop is not flexible enough to accomplish what we want and a decision needs to be made in a program. Students should write an example in their engineering notebook. The students should break into their groups. The question they should ponder is the difference between analog and digital information. They should list examples of each in their engineering notebooks.

The teacher will provide activity Digital Branching to the students. Students begin the activity, demonstrating finished work to the teacher. Students should have the teacher mark off their completion of the activity and store it in their engineering notebook.

Day 13-18
Key Question: How do we design a control system to operate safely?

The class begins with a review of the project scenario. Students divide into teams to research garage door openers. Good information on the requirements can be found at http://www.dasma.com/PDF/Publications/TechDataSheets/OperatorElectronics/TDS351.pdf. Students should brainstorm a list of things the garage door opener should do and the order they should be done in. Students should then develop a flow chart for their program. Students should sketch a design for their garage door. All design documents should be kept in the engineering notebook.

Information about the sensors and programming can be found in the Activities Section. Student groups share their flow charts and programs with each other.

On the final day students should demonstrate the working of their opener plan. They should have a completely documented program to demonstrate.

Vocabulary:

Closed loop programming
Closed loop system
Counter
CPU
Cylinder
Digital
Feedback
Flow charts
Flowchart
Input
Input device
Load
Network
Nor gates
Normally Closed
Normally Open
Open Loop programming
Output
Output device
Phototransistor
Power Supply
Power Terminals
Schematic
Sensors
State diagrams
Switch
Timers
Wiring

Resources:

Engineering Notebook:

- http://www.wisegeek.com/what-is-an-engineering-notebook.htm
- https://www.firstinspires.org/sites/default/files/uploads/resource_library/ftc/engineering-notebook-guidelines.pdf
- https://www.asme.org/career-education/articles/early-career-engineers/my-engineers-notebook-jenn-t-dandrea

Engineering Reports

- http://web.mit.edu/me-ugoffice/communication/technical-writing.pdf
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/writing_engineering_reports.html
- https://www.youtube.com/playlist?list=PLDAAF7A8FD5CD582C&feature=plcp
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/mechanical_engineering_writing_enhancement_program/report_writing.html
- https://owl.purdue.edu/owl/subject_specific_writing/professional_technical_writing/technical_reports_and_report_abstracts/reports_proposals_and_technical_papers.html

Open vs closed loop:

- https://www.servocity.com/open-loop-vs-closed-loop/
- https://circuitglobe.com/difference-between-open-loop-and-closed-loop-system.html
- https://www.youtube.com/watch?v=FurC2unHeXI

Garage door opener requirements

- http://www.dasma.com/PDF/Publications/TechDataSheets/OperatorElectronics/TDS351.pdf

Drawing flowcharts with Word and Excel

- https://www.youtube.com/watch?v=xX8H6jCWOOo
- https://www.smartdraw.com/flowchart/how-to-make-a-flowchart-in-word.htm
- https://www.breezetree.com/articles/how-to-flowchart-in-word

Flowchart Examples

- http://www.rff.com/flowchart_samples.htm

Project: Elevator Control

Introduction:

Elevators have been in use for millennia. Applying power to raise and lower loads made mines more productive, buildings easier to construct and multistory warehouses possible. Electricity replaced steam as the power source of choice about 130 years ago. The first electric elevator was the brainchild of Werner von Siemens.

Purpose of the Project:

The purpose of the elevator control project is the introduction to digital logic and how this is used in decision making. The switches involve allow students to apply the design process to solve the problem of how an elevator control system allows motion to the correct location dictated by the user.

Concepts:

- Creating technical solutions requires the use of mathematical analysis, scientific inquiry, and engineering design.
- Science and engineering professionals use data and graphical analysis in making decisions
- Modern design requires the ability to generate, process, and transfer information digitally using appropriate technologies.

- The Engineering Design Process is sometimes referred to as the sequential actions of research, design, build, evaluate; then redesign, and communicate.
- Engineering professionals design solutions and communicate the solutions through graphics and pictures.
- Engineers use integrity and ethics when communicating ideas, including citing sources of information.
- In all systems, there is a tradeoff between performance and complexity. Higher complexity is generally associated with higher cost; hence the shortened form of the syllogism is performance versus cost.
- Designing mechanical systems requires the knowledge and application of simple machines to manage and transform power and forces into required motion.
- Electricity is a form of energy caused by the movement of charged particles. It is often used to transfer energy from one place to another.
- The first law of thermodynamics (conservation of energy and matter) states that output power of a system is always less than the power supplied to the system.
- The design of mechanisms requires the use of dimension tolerances to assure that component parts work together effectively with minimum power losses.
- “Green Principles” of design are used for eventual disassembly and resource recovery and is referred as Product Lifecycle Management (PLM)
- A Programmable Logic Controller (PLC) is a hardened computer used for industrial automation. PLCs can automate a process, machine function, or even an entire production line.
- The term “Logic” is based upon the mathematical system called Boolean Algebra named after George Boole (Born November 2, 1815-Died December 8, 1864) who was a self-taught English mathematician and philosopher who invented this form of algebra where values are either True or False where rules are created to consistently arrive at desired values.
- The ability to collect data, transform them into information, and use that information to improve an existing process is an enabling skill for Lean manufacturing.
- Applying automated control systems to existing manual processes can dramatically improve quality and reduce the amount of human (manual) time required.
- Electronic sensors detect and transform real-world phenomena into information that is used by computers to control valves, pumps, and other industrial equipment.
- Timers allow programmers to design and control specialized clocks to turn machinery on or off for specific amounts of time.
- Keeping track of events as they occur can be accomplished using logic programs called counters.
- Analog inputs for such things as temperature, pressure, speed, etc., are voltage values that can be converted into a digital value to be stored and used by a computer.

Outline:

- Documentation
  - Engineering Notebook
  - Documentation object to be designed
- Programmable Logic Controllers (PLC)
  - Basic electricity-Multimeter schematics/ Ohms law
  - Setup
  - Inputs
  - Outputs
  - Logic
  - Timers
  - Counters
- Evaluation
  - Testing of the ability sort products by color
- Communication
  - Presentation of design solutions

Standards:

Career and Technical Standards

Engineering Design Process

- Maintain an Engineering Notebook for research, prototype creation, documentation and daily reflections.
- Apply engineering design and problem solving as an iterative process incorporating science, mathematics, and engineering to optimally convert resources to meet a design solution.
- Communicate design solutions utilizing effective technical writing skills including correct spelling, proper grammar, and accurate technical vocabulary.
- Prepare a quantitative plan for the successful completion of a project.
- Assume leadership responsibility for collaborative team actions and decisions related to the successful completion of a project.
- Evaluate the needs and costs of resources necessary for the completion of a project.
- Prepare and communicate model documentation to include such details as product analysis, size, materials, assembly details, installation and service requirements.

Design for Assembly

- Create a management plan that includes quality planning, quality control, quality assurance, and quality improvement for an advanced manufacturing environment.

Automation with Programmable Logic Controllers (PLCs)

- Design and analyze an electrical system to efficiently convert, transform, and transmit electricity to where it is needed.
- Research and specify electrical devices necessary to provide needed power.

- Apply machine control systems, sensory feedback, and information processing to increase productivity in manufacturing.
- Use flow charts and diagrams to apply logic in the design of control programs.

- **Applying Logic Software RoboPro to Create Problem Solutions**
- Design a system of elements that manages power to accomplish a task involving defined movement.
- Design a control system to vary the speed and performance of a motor by utilizing feedback from the system to gain the most efficiency possible.
- Formulate a system to utilize data collection and analysis to maintain and improve product quality and provide adequate confidence that the product will satisfy design requirements.
- Design and analyze the application of machine control systems, sensory feedback, and information processing to increase productivity in manufacturing.

Business of Manufacturing

- Research and evaluate the new approaches of rapid development and deployment of products that saves time and is more efficient.
- Create a management plan including quality planning, quality control, quality assurance and quality improvement for an advance manufacturing environment.

College and Career Readiness Math Standards

Creating Equations

CED.A1 Create equations and inequalities in one variable and use them to solve problems.

CED.A.2 Create equations in two or more variables to represent relationships between quantities

CED.A.3 Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or nonviable options in a modeling context

CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations

Create equations that describe numbers or relationships CED

A.4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations

Quantities

Q.A.1Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays

Making Inferences & Justifying Conclusions

IC.A.1 Understand statistics as a process for making inferences about population parameters based on a random sample from that population.

IC.B.3 Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.

Reading Standards for Literacy in History/Social Studies 9-10

Key Ideas and Details

1. Cite specific textual evidence to support analysis of primary and secondary sources, attending to such features as the date and origin of the information.
3. Analyze in detail a series of events described in a text; determine whether earlier events caused later ones or simply preceded them.

Integration of Knowledge and Ideas

7. Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text.
9. Compare and contrast treatments of the same topic in several primary and secondary sources.

Range of Reading and Level of Text Complexity

10. By the end of grade 10, read and comprehend science/technical texts in the grades 9–10 text complexity band independently and proficiently.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 9-10

Text Types and Purposes

1. Write arguments focused on *discipline-specific content.*
2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

Production and Distribution of Writing

4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Research to Build and Present Knowledge

7. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

8. Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

Range of Writing

10. Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Next Generation Science Standards

The projects engage students in the scientific and engineering practices taken from the National Research Council's Framework for K-12 Science Education, Practices, Crosscutting Concepts, and Core Ideas. This is the document upon which the NGSS are based.

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2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

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STL Standard 5:
Students will develop an understanding of the effects of technology on the environment.

STL Standard 7:
Students will develop an understanding of the influence of technology on history.

STL Standard 8:
Students will develop an understanding of the attributes of design.

STL Standard 9:
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Students will develop the abilities to use and maintain technological products and systems.

STL Standard 13:
Students will develop the abilities to assess the impact of products and systems.

STL Standard 14:
Students will develop an understanding of and be able to select and use medical technologies.

STL Standard 16:
Students will develop an understanding of and be able to select and use energy and power technologies.

STL Standard 17:
Students will develop an understanding of and be able to select and use information and communication technologies.

STL Standard 18:
Students will develop an understanding of and be able to select and use transportation technologies.

STL Standard 19:
Students will develop an understanding of and be able to select and use manufacturing technologies.

STL Standard 20:
Students will develop an understanding of and be able to select and use construction technologies.

Assessment:

Assessment is both formative and summative. It is an integral part of high quality instruction. During the course of a project one of the instructor's main functions is to work with student groups, keeping track of progress and providing formative assessment using feedback and promoting reflection about the design process. The focus should be on lifetime learning and 21st century skills. The goal of instruction is to promote abilities in research, problem solving, design, experimentation, testing, and collecting data.

Rubrics are used in the assessment process to communicate expectations of quality. Rubrics should be shared with students at the beginning of a project to clarify any misconceptions before beginning their work. Students can then build the skills and gather knowledge to solve the problem presented to the expectations of excellence described.

General Rubrics for Literacy tasks:
Argumentative_Pursuasive
Informational_Explanatory

Individual Project Rubric:
Elevator Control

Essential Question:

How is a control program designed to allow for the proper control of an elevator?

Student Scenario:

You are working with a team of technicians and programmers at UpLifts Inc. Your team is tasked with coming up with a new program to control the elevator at the Syracuse Supply Warehouse, a company that specializes in appliance sales. The elevator will be used to transport inventory from floor to floor and will carry employees.

Your team will have to create a model of the section of the warehouse with access to three floors. Each floor will need a call button and you will have to create a panel for the inside of the elevator to select the desired floor.

The design requirements are as follows:

- The program must read the call buttons.
- The elevator should know what floor it is on.
- The elevator must move in the correct direction.
- It must have a safety switch to stop the elevator in emergencies.
- The elevator needs a door that opens only at the correct floor.

Your team's design will be presented by use of a working model of the elevator system. This will lead to an elevator that responds to the employees and moves their appliances from floor to floor safely.

The research and learning activities are designed to help students:

- Learn the basic principles of programming and digital signals
- Apply digital logic to determine the calling floor and current elevator position
- Utilize a closed loop system to identify positions

Deliverables:

- Engineering Notebook with reflections, research notes, bibliography, and other processes used in the design.
- Sketches of the device and planning for programming
- Descriptions of the sensors utilized and where they should be positioned
- Working prototype
- Engineering report of the design process
- Presentation for the authentic audience

Daily Plan:

Day 1
Key Question: What are the expectations of the project?

Introduce students to the main problem by providing them with the Essential question and the project description.

Cover with your students the design process, engineering notebook and design documentation requirements. Discuss the problem statement , design brief, testing protocol and management plan. Review the elements of a good engineering report.

The teacher will provide a list of vocabulary terms that students will need to research. Student teams can break the lists up and determine how to define the terms.

The teacher should also help the students outline the research they will need to do to be ready to work independently on the project at the end of the unit.

Have the students form teams of two. Allow the students sufficient time to discuss the problem. Students begin by brainstorming ideas in their Engineering Notebooks. The teacher will provide a list of vocabulary terms that students will need to research on their own. The teams can divide the list of terms among team members and share their definitions. All team members are responsible to know all definitions.

Day 2
Key Question: How do we get started in the design process?

The teams will be responsible for researching types of digital sensors, controllers and logic. Teams need to research creating branch statements and where they are used to control the logic of a program. They should research combinational logic and how those results affect their programs.

The student teams discuss possible elevator control systems including:

- What kinds of sensors might we need to use?
- Where might sensors be located where they will be effective?
- Will the model meet the stated design requirements?
- How will our logic work?
- Are there safety switches in place?
- What are the basic electrical safety issues?

Students can enter terms and view a tutorial for creating certain features. Students can reference specific terms from the vocabulary list for specific commands to be used in the design of the elevator control system.
Remind students to record research notes and sources as well as reflections on the day in the Engineering Notebook.

Day 3-7
Key Question: How do we get started on our individual designs?

Student teams brainstorm needed components of their design and then create their written description of what they want the program to accomplish to add to their design brief to be include with their sketches of the location of sensors. They include operating requirements along with expected logic signals. They then meet with their clients who will need to sign off on the design proposal before programming and model building begins. The client can be the teacher or an authentic advisor.

Students should work through the tutorials on Logic Gates, Combinational Logic and Edge Triggered vs Level Triggered signals. This will take several days to work through these necessary basics.

Teams discuss how their elevator control systems should be tested. The groups decide what components will be tested and how the team will know when their design achieves the test requirements.

Day 9-11
Key Question: How can we begin to design our elevator control system model?

Teams discuss their proposed elevator control systems and how to achieve the design given the approved design brief they presented. They work together to brainstorm ideas and begin to narrow their vision of their solution. Next the team divides the work of creating the elevator device and programming scheme. They must also decide on sensors, wiring and programing. They utilize the division of work in the creation of the project management plan.

Students record sketches and reflections in the Engineering Notebook. Once the students have a solution to the elevator control system design, they need to determine how the design will meet the requirements. This means students must consider how the design will be tested before building.

Teams discuss how the various designs and placement of sensors work and that the designs created will meet the elevator control system requirements and the performance will be within the specifications they established

Information about the sensors and programming can be found in the Activities Section. Student groups share their flow charts and programs with each other.

Day 12-14
Key Question: How can we put our new designs together?

Student teams conduct meetings to review all designs elements created so far. They look at the criteria and testing protocols created. They discuss which design they wish to use as the team final design. It could be a single design or contain elements of several designs. Once the decision is made the students develop a plan for creating the team prototype. They need to create a design that incorporates their ideas. Once the final plan is completed they will create prototype program. The teams discuss the final testing of their prototypes and how that will be achieved.

Students create the final plans and begin programming and testing to see how they are communicating with the various sensors they selected. Students record any changes in their designs and enter reflections in their Engineering Notebooks.

Day 15-16
Key Question: How do we build and test our designs?

Students assemble their prototype elevator control system. When students encounter problems assembling their prototype they must discuss how they will resolve the issue and change the design.

Students record any changes in their designs and enter reflections in their Engineering Notebooks.

Once the working prototype is assembled testing can begin to see if the model meets the stated design requirements. Students begin runs to check the accuracy of their systems. They gather data on tests and to show how accurate the system is and how the various functions are performing. Students discuss results of their initial testing and propose improvements to the system.

Day 17-18

Key Question: How do we organize our thoughts in a presentation to the class?

The student teams discuss and finish any changes that are needed.
The teacher will discuss with the teams how to optimally present their ideas.

Students discuss the outline of the presentation to their clients. The deliverables will include the prototype, program design and information about the design process and how they solved many of the issues they encountered. The students should be required to write the introduction, provide results including graphics, and form a conclusion including an acknowledgement section reporting the source of information. Students decide how to divide the work to create a team report.

Day 19
Key Question: How do we convey our ideas?

Students can present their solutions to the class one at a time. Students display the completed elevator control system model and demonstrate how it functions. Students discuss changes they would consider if they had time to create another iteration of their design.

In the end, all students can reflect on their work by giving and receiving feedback on how they could possibly improve their designs

Vocabulary:

And Gates
Boolean Logic
Closed Loop Programming
Combinational Logic
Counter
CPU
Cylinder
Digital
Dual axis
Exclusive Or gates
Feeders
Flow charts
Input
Load
Logic
Nand gates
Network
Nor gates
Normally Closed
Normally Open
Open Loop programming

Or Gates
Output
Phototransistor
Power Supply
Power Terminals
Schematic
Single Axis
Solenoid
State diagrams
Switch
Timers
Wiring

Resources:

Engineering Notebook:

- http://www.wisegeek.com/what-is-an-engineering-notebook.htm
- https://www.firstinspires.org/sites/default/files/uploads/resource_library/ftc/engineering-notebook-guidelines.pdf
- https://www.asme.org/career-education/articles/early-career-engineers/my-engineers-notebook-jenn-t-dandrea

Engineering Reports

- http://web.mit.edu/me-ugoffice/communication/technical-writing.pdf
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/writing_engineering_reports.html
- https://www.youtube.com/playlist?list=PLDAAF7A8FD5CD582C&feature=plcp
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/mechanical_engineering_writing_enhancement_program/report_writing.html
- https://owl.purdue.edu/owl/subject_specific_writing/professional_technical_writing/technical_reports_and_report_abstracts/reports_proposals_and_technical_papers.html

Electricity

- https://www.allaboutcircuits.com/textbook/direct-current/
- https://learn.sparkfun.com/tutorials/alternating-current-ac-vs-direct-current-dc
- https://engineering.mit.edu/engage/ask-an-engineer/whats-the-difference-between-ac-and-dc/
- https://www.school-for-champions.com/science/dc.htm#.W372zehKguU
- http://sinovoltaics.com/learning-center/basics/direct-current-dc-power-definition-and-applications/
- https://whatis.techtarget.com/definition/DC-direct-current
- http://macao.communications.museum/eng/exhibition/secondfloor/MoreInfo/2_3_1_DCCircuit.html
- https://www.khanacademy.org/science/ap-physics-1/ap-circuits-topic/introduction-to-dc-circuits-ap/a/circuit-introduction

- https://www.allaboutcircuits.com/textbook/direct-current/chpt-5/what-are-series-and-parallel-circuits/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-1/static-electricity/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-2/voltage-current-resistance-relate/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-3/importance-electrical-safety/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-5/what-are-series-and-parallel-circuits/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-9/analog-and-digital-signals/

Elevators

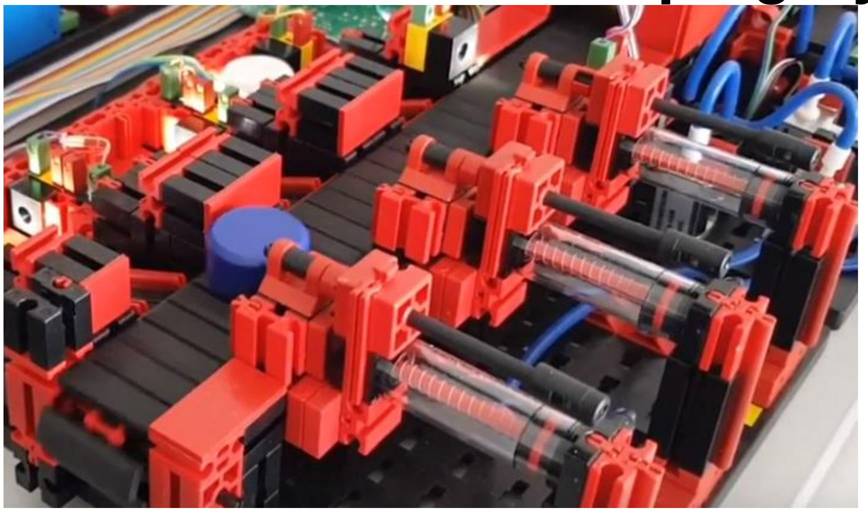
- https://www.siemens.com/history/en/news/1051_werner_von_siemens.htm
- https://www.siemens.com/history/en/news/1043_elevator.htm
- https://www.youtube.com/watch?v=088IRtGAWbg
- https://www.youtube.com/watch?v=8T5PlDdItmo

Logic

- http://www.plcdev.com/book/export/html/9
- https://www.allaboutcircuits.com/textbook/digital/chpt-6/digital-logic-functions/
- https://www.i-programmer.info/babbages-bag/235-logic-logic-everything-is-logic.html
- https://academo.org/demos/logic-gate-simulator/
- https://sciencedemos.org.uk/logic_gates.php
- http://www.cburch.com/logisim/

Studica

Automated Pneumatic Clamping System



Introduction:

Workholding is a term used to describe the devices we use to keep stock from moving around while work is performed. An example would be a vise or clamps. Automating the clamping process allows for greater accuracy in the machining process creating fewer errors and faster part creation. Frequently pneumatics is used to accomplish this task. By utilizing air pressure to operate clamps, vises or vacuum tables allows for automation of the process. Objects can be placed and the movement of vise jaws or clamps locates and secures the parts.

Purpose of the Project:

The purpose of the automated pneumatic clamping system project is the introduction of logic and decision making. Students will apply decision making elements such as State Diagrams and Flow Charts to design the logic flow in a program. These skills will allow students to define the logic required to have events occur.

Concepts:

- Creating technical solutions requires the use of mathematical analysis, scientific inquiry, and engineering design.
- Science and engineering professionals use data and graphical analysis in making decisions

- Modern design requires the ability to generate, process, and transfer information digitally using appropriate technologies.
- The Engineering Design Process is sometimes referred to as the sequential actions of research, design, build, evaluate; then redesign, and communicate.
- Engineering professionals design solutions and communicate the solutions through graphics and pictures.
- Engineers use integrity and ethics when communicating ideas, including citing sources of information.
- In all systems, there is a tradeoff between performance and complexity. Higher complexity is generally associated with higher cost; hence the shortened form of the syllogism is performance versus cost.
- Designing mechanical systems requires the knowledge and application of simple machines to manage and transform power and forces into required motion.
- Electricity is a form of energy caused by the movement of charged particles. It is often used to transfer energy from one place to another.
- The first law of thermodynamics (conservation of energy and matter) states that output power of a system is always less than the power supplied to the system.
- The design of mechanisms requires the use of dimension tolerances to assure that component parts work together effectively with minimum power losses.
- “Green Principles” of design are used for eventual disassembly and resource recovery and is referred as Product Lifecycle Management (PLM)
- A Programmable Logic Controller (PLC) is a hardened computer used for industrial automation. PLCs can automate a process, machine function, or even an entire production line.
- The term “Logic” is based upon the mathematical system called Boolean Algebra named after George Boole (Born November 2, 1815-Died December 8, 1864) who was a self-taught English mathematician and philosopher who invented this form of algebra where values are either True or False where rules are created to consistently arrive at desired values.
- The ability to collect data, transform them into information, and use that information to improve an existing process is an enabling skill for Lean manufacturing.
- Applying automated control systems to existing manual processes can dramatically improve quality and reduce the amount of human (manual) time required.
- Electronic sensors detect and transform real-world phenomena into information that is used by computers to control valves, pumps, and other industrial equipment.
- Timers allow programmers to design and control specialized clocks to turn machinery on or off for specific amounts of time.
- Keeping track of events as they occur can be accomplished using logic programs called counters.
- Analog inputs for such things as temperature, pressure, speed, etc., are voltage values that can be converted into a digital value to be stored and used by a computer.

- Computer controlled automated systems often use a solenoid valve to open and close a valve to control the flow of a medium such as pressurized gas. A solenoid valve is an electromechanical device where electrical current is used to cause movement.

Outline:

- Documentation
  - Engineering Notebook
  - Documentation object to be designed
- Programmable Logic Controllers (PLC)
  - Basic electricity-Multimeter schematics/ Ohms law
  - Setup
  - Inputs
  - Outputs
  - Logic
  - Timers
  - Counters
- Workcell Creation
  - Pneumatics
  - Solenoids
  - Schematics
  - Electricity
  - Hand shaking
- Evaluation
  - Testing of the ability to open with the correct combination of inputs
- Communication
  - Presentation of design solutions

Standards:

Career and Technical Standards

Engineering Design Process

- Maintain an Engineering Notebook for research, prototype creation, documentation and daily reflections.
- Apply engineering design and problem solving as an iterative process incorporating science, mathematics, and engineering to optimally convert resources to meet a design solution.
- Communicate design solutions utilizing effective technical writing skills including correct spelling, proper grammar, and accurate technical vocabulary.
- Prepare a quantitative plan for the successful completion of a project.
- Assume leadership responsibility for collaborative team actions and decisions related to the successful completion of a project.
- Evaluate the needs and costs of resources necessary for the completion of a project.

- Prepare and communicate model documentation to include such details as product analysis, size, materials, assembly details, installation and service requirements.

Design for Manufacturing
- Understand and apply Statistical Process Control (SPC) to acquire quality control.

Design for Assembly
- Create a management plan that includes quality planning, quality control, quality assurance, and quality improvement for an advanced manufacturing environment.

Automation with Programmable Logic Controllers (PLCs)
- Design and analyze an electrical system to efficiently convert, transform, and transmit electricity to where it is needed.
- Research and specify electrical devices necessary to provide needed power.
- Apply machine control systems, sensory feedback, and information processing to increase productivity in manufacturing.
- Use flow charts and diagrams to apply logic in the design of control programs.

- **Applying Logic Software RoboPro to Create Problem Solutions**
- Design a system of elements that manages power to accomplish a task involving defined movement.
- Design a control system to vary the speed and performance of a motor by utilizing feedback from the system to gain the most efficiency possible.
- Formulate a system to utilize data collection and analysis to maintain and improve product quality and provide adequate confidence that the product will satisfy design requirements.
- Design and analyze the application of machine control systems, sensory feedback, and information processing to increase productivity in manufacturing.

Pneumatics Design and Control
- Construct systems that efficiently utilize a fluid (liquid or gas) under pressure to generate, transmit, and control power.
- Design an integrated system of machines, machine tools, jigs, fixtures, instruments, and control programs to produce needed parts.
- Utilize jigs, fixtures, drill guides, gauges, and other manufacturing and assembly tools.
- Research, construct and evaluate a plan for an assembly line or work cell.
- Identify systems, sub-systems and typical components of an automated manufacturing operation.
- Apply the necessary safety precautions associated with a fully automated system.

Business of Manufacturing

- Research and evaluate the new approaches of rapid development and deployment of products that saves time and is more efficient.
- Create a management plan including quality planning, quality control, quality assurance and quality improvement for an advance manufacturing environment. Review and evaluate the benefits of a plan for an assembly line or work cell.
- Create a strategy to increase efficiency and decrease waste by receiving inventory just in time for the production process to reduce costs and reduce use of natural resources.
- Evaluate the use of production organization, planning, and resources, both human and capital, as well as regulatory requirements, to successfully and efficiently bring a product to market.
- Create a management plan including quality planning, quality control, quality assurance, and quality improvement for an advance manufacturing environment.
- Create a plan for protecting the health and safety of the people engaged in a manufacturing environment.

College and Career Readiness Math Standards

Creating Equations

CED.A1 Create equations and inequalities in one variable and use them to solve problems.

CED.A.2 Create equations in two or more variables to represent relationships between quantities

CED.A.3 Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or nonviable options in a modeling context

CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations

Create equations that describe numbers or relationships CED

A.4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations

Quantities

Q.A.1Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays

Making Inferences & Justifying Conclusions

IC.A.1 Understand statistics as a process for making inferences about population parameters based on a random sample from that population.

IC.B.3 Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.

Reading Standards for Literacy in History/Social Studies 9-10

Key Ideas and Details

1. Cite specific textual evidence to support analysis of primary and secondary sources, attending to such features as the date and origin of the information.

3. Analyze in detail a series of events described in a text; determine whether earlier events caused later ones or simply preceded them.

Integration of Knowledge and Ideas

7. Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text.

9. Compare and contrast treatments of the same topic in several primary and secondary sources.

Range of Reading and Level of Text Complexity

10. By the end of grade 10, read and comprehend science/technical texts in the grades 9–10 text complexity band independently and proficiently.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 9-10

Text Types and Purposes

1. Write arguments focused on *discipline-specific content.*

2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

Production and Distribution of Writing

4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Research to Build and Present Knowledge

7. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

8. Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

Range of Writing

10. Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Next Generation Science Standards
The projects engage students in the scientific and engineering practices taken from the National Research Council's Framework for K-12 Science Education, Practices, Crosscutting Concepts, and Core Ideas. This is the document upon which the NGSS are based.

These practices are used for two reasons: 1) they parallel the design process utilized in each project, and 2) they serve as the foundation of the NGSS.

The eight science and engineering practices are:
1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Standards for Technological Literacy

STL Standard 1:
Students will develop an understanding of the characteristics and scope of technology.

STL Standard 2:
Students will develop an understanding of the core concepts of technology.

STL Standard 3:
Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

STL Standard 4:
Students will develop an understanding of the cultural, social, economic, and political effects of technology.

STL Standard 5:
Students will develop an understanding of the effects of technology on the environment.

STL Standard 7:
Students will develop an understanding of the influence of technology on history.

STL Standard 8:
Students will develop an understanding of the attributes of design.

STL Standard 9:
Students will develop an understanding of engineering design.

STL Standard 10:
Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

STL Standard 11:
Students will develop the abilities to apply the design process.

STL Standard 12:
Students will develop the abilities to use and maintain technological products and systems.

STL Standard 13:
Students will develop the abilities to assess the impact of products and systems.

STL Standard 14:
Students will develop an understanding of and be able to select and use medical technologies.

STL Standard 16:
Students will develop an understanding of and be able to select and use energy and power technologies.

STL Standard 17:
Students will develop an understanding of and be able to select and use information and communication technologies.

STL Standard 19:
Students will develop an understanding of and be able to select and use manufacturing technologies.

STL Standard 20:
Students will develop an understanding of and be able to select and use construction technologies.

Assessment:

Assessment is both formative and summative. It is an integral part of high quality instruction. During the course of a project one of the instructor’s main functions is to work with student groups, keeping track of progress and providing formative assessment using feedback and promoting reflection about the design process. The focus should be on lifetime learning and 21st century skills. The goal of instruction is to promote abilities in research, problem solving, design, experimentation, testing, and collecting data.

Rubrics are used in the assessment process to communicate expectations of quality. Rubrics should be shared with students at the beginning of a project to clarify any misconceptions before beginning their work. Students can then build the skills and gather knowledge to solve the problem presented to the expectations of excellence described.

General Rubrics for Literacy tasks:
Argumentative_Pursuasive
Informational_Explanatory

Individual Project Rubric:
Automated Pneumatic Clamping System Rubric

Essential Question:

How to we design and automate a pneumatic clamping system for an automated line?

Student Scenario:

You are a member of a design team for Workholding Associates. Your company has a client that is currently having their employees mount work blanks on their machines manually for every operation. The company feels the addition of an automated clamping system will save a lot of operator setup time. They would like a proposal for designing the system, setup and training.

Your team will build a prototype clamping system that will automatically locate and hold down the work blank. You can use existing parts or design and print new components to utilize. You will design, document and create a program to control the system. You will perform a test to time how long a manual setup takes to determine the time savings. This is important as the company is implementing a lean manufacturing program and this will help them justify the costs.

The design requirements are as follows:

- The prototype must locate the blank accurately and securely hold it for machining.
- The program must wait for a signal before applying pneumatic pressure.
- Once clamped there must be a pause to simulate the running of the machine operation.
- When the machine is done and a signal received the clamps must release and the part must be easily removed.
- A sensor to identify the component is clamped tightly in place.

Your team's design will be presented by use of a working model of the automated pneumatic clamping system. This demonstrates the speed and accuracy of the clamping system.

The research and learning activities are designed to help students:

- Learn the basics of pneumatics.
- Learn the basic principles of logic control
- Apply digital logic to determine the order and sequences of switches
- Utilize Boolean logic to simplify the parameters.

Deliverables:

- Engineering Notebook with reflections, research notes, bibliography, and other processes used in the design.
- Sketches of the device and planning for programming
- Descriptions of the sensors utilized and where they should be positioned
- Working prototype
- Engineering report of the design process
- Presentation for the authentic audience

Daily Plan:

Day 1
Key Question: What are the expectations of the project?

Introduce students to the main problem by providing them with the Essential question and the project description.

Cover with your students the design process, engineering notebook and design documentation requirements. Discuss the problem statement , design brief, testing protocol and management plan. Review the elements of a good engineering report.

The teacher will provide a list of vocabulary terms that students will need to research. Student teams can break the lists up and determine how to define the terms.

The teacher should also help the students outline the research they will need to do to be ready to work independently on the project at the end of the unit.

Have the students form teams of two. Allow the students sufficient time to discuss the problem. Students begin by brainstorming ideas in their Engineering Notebooks. The teacher will provide a list of vocabulary terms that students will need to research on their own. The teams can divide the list of terms among team members and share their definitions. All team members are responsible to know all definitions.

Day 2
Key Question: How do we get started in the design process?

The teams will be responsible for researching pneumatics, cylinders, solenoids Boolean Logic, flow charts and state diagrams as they apply to planning the programming necessary to control their device.

The student teams discuss possible pneumatic clamping control systems including:

- What kinds of logic might we need to use?
- How will we know when it is safe to clamp the part
- Will the model meet the stated design requirements?
- How will our logic work?
- Does the pneumatic clamping system open when through?
- What are the basic electrical and pneumatic safety issues?

Students can reference specific terms from the vocabulary list for specific commands to be used in the design of the color sorting control system.

Remind students to record research notes and sources as well as reflections on the day in the Engineering Notebook.

Day 3-7
Key Question: How do we get started on our individual designs?

Student teams brainstorm needed components of their design and then create their written description of what they want the program to accomplish to add to their design brief to be include with their sketches of the location of sensors. They include operating requirements along with expected logic signals. They then meet with their clients who will need to sign off on the design proposal before programming and model building begins. The client can be the teacher or an authentic advisor.

Students should work through the tutorials on Pneumatics and Control.
This will take two days to work through these necessary basics.

Teams discuss how their automated pneumatic clamping control systems should be tested. The groups decide what components will be tested and how the team will know when their design achieves the test requirements.

Information about the sensors and programming can be found in the Activities Section. Student groups share their flow charts and programs with each other.

Day 9-10
Key Question: How can we begin to design our automated pneumatic clamping system model?

Teams discuss their proposed automated pneumatic clamping control systems and how to achieve the design given the approved design brief they presented. They work together to brainstorm ideas and begin to narrow their vision of their solution. Next the team divides the work of creating the pneumatic clamping device and programming scheme. They must also decide on sensors, wiring and programing. They utilize the division of work in the creation of the project management plan.

Students record sketches and reflections in the Engineering Notebook. Once the students have a solution to the automated pneumatic clamping control system design, they need to determine how the design will meet the requirements. This means students must consider how the design will be tested before building.

Teams discuss how the various designs and placement of sensors work and that the designs created will meet the automated pneumatic clamping control system requirements and the performance will be within the specifications they established

Day 11-13
Key Question: How can we put our new designs together?

Student teams conduct meetings to review all designs elements created so far. They look at the criteria and testing protocols created. They discuss which design they wish to use as the team final design. It could be a single design or contain elements of several designs. Once the decision is made the students develop a plan for creating the team prototype. They need to create a design that incorporates their ideas. Once the final plan is completed they will create prototype program. The teams discuss the final testing of their prototypes and how that will be achieved.

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Day 14-16
Key Question: How do we build and test our designs?

Students assemble their prototype automated pneumatic clamping control system. When students encounter problems assembling their prototype they must discuss how they will resolve the issue and change the design.

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Once the working prototype is assembled testing can begin to see if the model meets the stated design requirements. Students begin runs to check the accuracy of their systems. They gather data on tests and to show how accurate the system is and how the various functions are performing. Students discuss results of their initial testing and propose improvements to the system.

Day 17-18
Key Question: How do we organize our thoughts in a presentation to the class?

The student teams discuss and finish any changes that are needed.
The teacher will discuss with the teams how to optimally present their ideas.

Students discuss the outline of the presentation to their clients. The deliverables will include the prototype, program design and information about the design process and how they solved many of the issues they encountered. The students should be required to write the introduction, provide results including graphics, and form a conclusion including an acknowledgement section reporting the source of information. Students decide how to divide the work to create a team report.

Day 19
Key Question: How do we convey our ideas?

Students can present their solutions to the class one at a time. Students display the completed automated pneumatic clamping control system model and demonstrate how it functions. Students discuss changes they would consider if they had time to create another iteration of their design.

In the end, all students can reflect on their work by giving and receiving feedback on how they could possibly improve their designs

Vocabulary:

And Gates
Boolean Logic
Closed loop programming
Counter
CPU
Cylinder
Digital
Dual axis
Exclusive Or gates
Feeders
Flow charts

Input
Load
Logic
Nand gates
Network
Nor gates
Normally Closed
Normally Open
Open Loop programming
Or Gates
Output
Phototransistor
Power Supply
Power Terminals
Schematic
Single Axis
Solenoid
State diagrams
Switch
Timers
Wiring

Resources:

Engineering Notebook:

- http://www.wisegeek.com/what-is-an-engineering-notebook.htm
- https://www.firstinspires.org/sites/default/files/uploads/resource_library/ftc/engineering-notebook-guidelines.pdf
- https://www.asme.org/career-education/articles/early-career-engineers/my-engineers-notebook-jenn-t-dandrea

Engineering Reports

- http://web.mit.edu/me-ugoffice/communication/technical-writing.pdf
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/writing_engineering_reports.html
- https://www.youtube.com/playlist?list=PLDAAF7A8FD5CD582C&feature=plcp
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/mechanical_engineering_writing_enhancement_program/report_writing.html
- https://owl.purdue.edu/owl/subject_specific_writing/professional_technical_writing/technical_reports_and_report_abstracts/reports_proposals_and_technical_papers.html

Electricity

- https://www.allaboutcircuits.com/textbook/direct-current/
- https://learn.sparkfun.com/tutorials/alternating-current-ac-vs-direct-current-dc

- https://engineering.mit.edu/engage/ask-an-engineer/whats-the-difference-between-ac-and-dc/
- https://www.school-for-champions.com/science/dc.htm#.W372zehKguU
- http://sinovoltaics.com/learning-center/basics/direct-current-dc-power-definition-and-applications/
- https://whatis.techtarget.com/definition/DC-direct-current
- http://macao.communications.museum/eng/exhibition/secondfloor/MoreInfo/2_3_1_DCCircuit.html
- https://www.khanacademy.org/science/ap-physics-1/ap-circuits-topic/introduction-to-dc-circuits-ap/a/circuit-introduction
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-5/what-are-series-and-parallel-circuits/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-1/static-electricity/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-2/voltage-current-resistance-relate/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-3/importance-electrical-safety/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-5/what-are-series-and-parallel-circuits/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-9/analog-and-digital-signals/

Logic

- http://www.plcdev.com/book/export/html/9
- https://www.allaboutcircuits.com/textbook/digital/chpt-6/digital-logic-functions/
- https://www.i-programmer.info/babbages-bag/235-logic-logic-everything-is-logic.html
- https://academo.org/demos/logic-gate-simulator/
- https://sciencedemos.org.uk/logic_gates.php
- http://www.cburch.com/logisim/

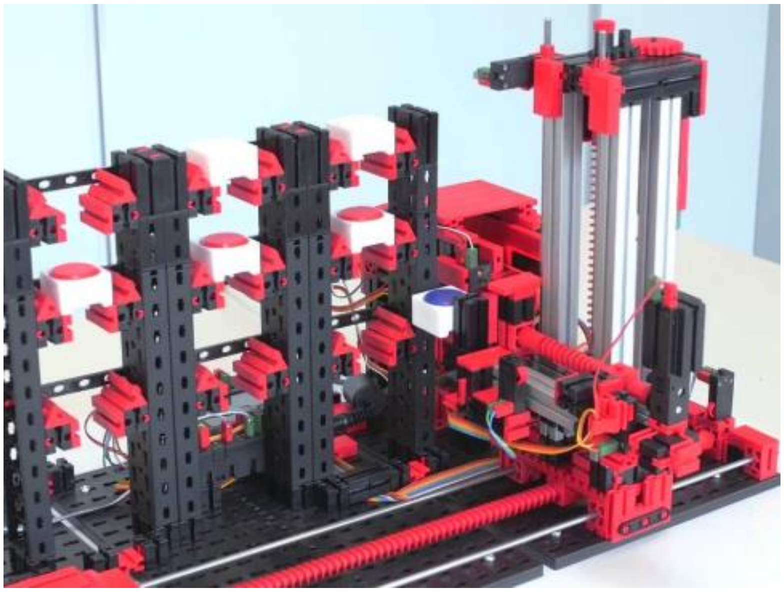
Pneumatic Clamping

- https://www.youtube.com/watch?v=eY5cAYudchw
- https://www.youtube.com/watch?v=5P2pk54wPlo
- https://www.youtube.com/watch?v=snlR6C1ZCo0
- https://www.youtube.com/watch?v=8NKKit18cX8
- https://youtu.be/5P2pk54wPlo
- https://youtu.be/9FGJQ6WRzPY
- https://www.youtube.com/watch?v=Cs0vy42gUkQ
- https://www.youtube.com/watch?v=40WUbK2gCxI
- https://www.datron.com/blog/cnc-workholding-for-milling-machines/

State Diagrams and Flow Charts

- https://www.lucidchart.com/pages/uml-state-machine-diagram
- https://www.geeksforgeeks.org/unified-modeling-language-uml-state-diagrams/
- http://www.agilemodeling.com/artifacts/stateMachineDiagram.htm
- http://www.cs.unc.edu/~stotts/145/CRC/state.html
- https://www.visual-paradigm.com/guide/uml-unified-modeling-language/what-is-state-machine-diagram/
- https://www.youtube.com/watch?v=L9UCsQxuWmw
- https://www.lucidchart.com/pages/what-is-a-flowchart-tutorial
- http://www.breezetree.com/articles/how-to-flow-chart-in-excel.htm
- https://www.gliffy.com/blog/the-comprehensive-guide-to-flowcharts

Project: Automatic Pneumatic Feeder System



Introduction:

Feeders are an important component of automated production. A steady stream of parts allows machinery to run continuously. Feeders assure the components are in the correct position to be used. Repetition is handled by the machines and people keep track of the machines using statistical process control and other sampling and testing methods and use those results to assure the machine is in control and delivering parts within spec.

Purpose of the Project:

The purpose of the automatic pneumatic feeder system project is the introduction of logic and decision making. Students will apply decision making elements such as State Diagrams and Flow Charts to design the logic flow in a program. These skills will allow students to define the logic required to have events occur.

Concepts:

- Creating technical solutions requires the use of mathematical analysis, scientific inquiry, and engineering design.

- Science and engineering professionals use data and graphical analysis in making decisions
- Modern design requires the ability to generate, process, and transfer information digitally using appropriate technologies.
- The Engineering Design Process is sometimes referred to as the sequential actions of research, design, build, evaluate; then redesign, and communicate.
- Engineering professionals design solutions and communicate the solutions through graphics and pictures.
- Engineers use integrity and ethics when communicating ideas, including citing sources of information.
- In all systems, there is a tradeoff between performance and complexity. Higher complexity is generally associated with higher cost; hence the shortened form of the syllogism is performance versus cost.
- Designing mechanical systems requires the knowledge and application of simple machines to manage and transform power and forces into required motion.
- Electricity is a form of energy caused by the movement of charged particles. It is often used to transfer energy from one place to another.
- The first law of thermodynamics (conservation of energy and matter) states that output power of a system is always less than the power supplied to the system.
- The design of mechanisms requires the use of dimension tolerances to assure that component parts work together effectively with minimum power losses.
- “Green Principles” of design are used for eventual disassembly and resource recovery and is referred as Product Lifecycle Management (PLM)
- A Programmable Logic Controller (PLC) is a hardened computer used for industrial automation. PLCs can automate a process, machine function, or even an entire production line.
- The term “Logic” is based upon the mathematical system called Boolean Algebra named after George Boole (Born November 2, 1815-Died December 8, 1864) who was a self-taught English mathematician and philosopher who invented this form of algebra where values are either True or False where rules are created to consistently arrive at desired values.
- The ability to collect data, transform them into information, and use that information to improve an existing process is an enabling skill for Lean manufacturing.
- Applying automated control systems to existing manual processes can dramatically improve quality and reduce the amount of human (manual) time required.
- Electronic sensors detect and transform real-world phenomena into information that is used by computers to control valves, pumps, and other industrial equipment.
- Timers allow programmers to design and control specialized clocks to turn machinery on or off for specific amounts of time.
- Keeping track of events as they occur can be accomplished using logic programs called counters.

- Analog inputs for such things as temperature, pressure, speed, etc., are voltage values that can be converted into a digital value to be stored and used by a computer.
- Computer controlled automated systems often use a solenoid valve to open and close a valve to control the flow of a medium such as pressurized gas. A solenoid valve is an electromechanical device where electrical current is used to cause movement.

Outline:

- Documentation
  - Engineering Notebook
  - Documentation object to be designed
- Programmable Logic Controllers (PLC)
  - Basic electricity-Multimeter schematics/ Ohms law
  - Setup
  - Inputs
  - Outputs
  - Logic
  - Timers
  - Counters
- Workcell Creation
  - Pneumatics
  - Solenoids
  - Schematics
  - Electricity
  - Hand shaking
- Evaluation
  - Testing of the ability to open with the correct combination of inputs
- Communication
  - Presentation of design solutions

Standards:

Career and Technical Standards

Engineering Design Process

- Maintain an Engineering Notebook for research, prototype creation, documentation and daily reflections.
- Apply engineering design and problem solving as an iterative process incorporating science, mathematics, and engineering to optimally convert resources to meet a design solution.
- Communicate design solutions utilizing effective technical writing skills including correct spelling, proper grammar, and accurate technical vocabulary.
- Prepare a quantitative plan for the successful completion of a project.
- Assume leadership responsibility for collaborative team actions and decisions related to the successful completion of a project.

- Evaluate the needs and costs of resources necessary for the completion of a project.
- Prepare and communicate model documentation to include such details as product analysis, size, materials, assembly details, installation and service requirements.

Automation with Programmable Logic Controllers (PLCs)
- Design and analyze an electrical system to efficiently convert, transform, and transmit electricity to where it is needed.
- Research and specify electrical devices necessary to provide needed power.
- Apply machine control systems, sensory feedback, and information processing to increase productivity in manufacturing.
- Use flow charts and diagrams to apply logic in the design of control programs.

Applying Logic Software RoboPro to Create Problem Solutions
- Design a system of elements that manages power to accomplish a task involving defined movement.
- Design a control system to vary the speed and performance of a motor by utilizing feedback from the system to gain the most efficiency possible.
- Formulate a system to utilize data collection and analysis to maintain and improve product quality and provide adequate confidence that the product will satisfy design requirements.
- Design and analyze the application of machine control systems, sensory feedback, and information processing to increase productivity in manufacturing.

Pneumatics Design and Control
- Construct systems that efficiently utilize a fluid (liquid or gas) under pressure to generate, transmit, and control power.
- Design an integrated system of machines, machine tools, jigs, fixtures, instruments, and control programs to produce needed parts.
- Utilize jigs, fixtures, drill guides, gauges, and other manufacturing and assembly tools.
- Research, construct and evaluate a plan for an assembly line or work cell.
- Identify systems, sub-systems and typical components of an automated manufacturing operation.
- Apply the necessary safety precautions associated with a fully automated system.

Business of Manufacturing
- Research and evaluate the new approaches of rapid development and deployment of products that saves time and is more efficient.
- Create a management plan including quality planning, quality control, quality assurance and quality improvement for an advance manufacturing

environment. Review and evaluate the benefits of a plan for an assembly line or work cell.
- Create a strategy to increase efficiency and decrease waste by receiving inventory just in time for the production process to reduce costs and reduce use of natural resources.
- Evaluate the use of production organization, planning, and resources, both human and capital, as well as regulatory requirements, to successfully and efficiently bring a product to market.
- Create a management plan including quality planning, quality control, quality assurance, and quality improvement for an advance manufacturing environment.
- Create a plan for protecting the health and safety of the people engaged in a manufacturing environment.

College and Career Readiness Math Standards

Creating Equations

CED.A1 Create equations and inequalities in one variable and use them to solve problems.

CED.A.2 Create equations in two or more variables to represent relationships between quantities

CED.A.3 Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or nonviable options in a modeling context

CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations

Create equations that describe numbers or relationships CED

A.4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations

Quantities

Q.A.1Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays

Making Inferences & Justifying Conclusions

IC.A.1 Understand statistics as a process for making inferences about population parameters based on a random sample from that population.

IC.B.3 Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.

Reading Standards for Literacy in History/Social Studies 9-10

Key Ideas and Details

1. Cite specific textual evidence to support analysis of primary and secondary sources, attending to such features as the date and origin of the information.
3. Analyze in detail a series of events described in a text; determine whether earlier events caused later ones or simply preceded them.

Integration of Knowledge and Ideas

7. Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text.
9. Compare and contrast treatments of the same topic in several primary and secondary sources.

Range of Reading and Level of Text Complexity

10. By the end of grade 10, read and comprehend science/technical texts in the grades 9–10 text complexity band independently and proficiently.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 9-10

Text Types and Purposes

1. Write arguments focused on *discipline-specific content.*
2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

Production and Distribution of Writing

4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Research to Build and Present Knowledge

7. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

8. Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

Range of Writing

10. Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Next Generation Science Standards

The projects engage students in the scientific and engineering practices taken from the National Research Council's Framework for K-12 Science Education, Practices, Crosscutting Concepts, and Core Ideas. This is the document upon which the NGSS are based.

These practices are used for two reasons: 1) they parallel the design process utilized in each project, and 2) they serve as the foundation of the NGSS.

The eight science and engineering practices are:
1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Standards for Technological Literacy

STL Standard 1:
Students will develop an understanding of the characteristics and scope of technology.

STL Standard 2:
Students will develop an understanding of the core concepts of technology.

STL Standard 3:
Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

STL Standard 4:
Students will develop an understanding of the cultural, social, economic, and political effects of technology.

STL Standard 5:
Students will develop an understanding of the effects of technology on the environment.

STL Standard 7:
Students will develop an understanding of the influence of technology on history.

STL Standard 8:
Students will develop an understanding of the attributes of design.

STL Standard 9:
Students will develop an understanding of engineering design.

STL Standard 10:
Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

STL Standard 11:
Students will develop the abilities to apply the design process.

STL Standard 12:
Students will develop the abilities to use and maintain technological products and systems.

STL Standard 13:
Students will develop the abilities to assess the impact of products and systems.

STL Standard 14:
Students will develop an understanding of and be able to select and use medical technologies.

STL Standard 16:
Students will develop an understanding of and be able to select and use energy and power technologies.

STL Standard 17:
Students will develop an understanding of and be able to select and use information and communication technologies.

STL Standard 19:
Students will develop an understanding of and be able to select and use manufacturing technologies.

STL Standard 20:
Students will develop an understanding of and be able to select and use construction technologies.

Assessment:

Assessment is both formative and summative. It is an integral part of high quality instruction. During the course of a project one of the instructor's main functions is to work with student groups, keeping track of progress and providing formative assessment using feedback and promoting reflection about the design process. The focus should be on lifetime learning and 21st century skills. The goal of instruction is to promote abilities in research, problem solving, design, experimentation, testing, and collecting data.

Rubrics are used in the assessment process to communicate expectations of quality. Rubrics should be shared with students at the beginning of a project to clarify any misconceptions before beginning their work. Students can then build the skills and gather knowledge to solve the problem presented to the expectations of excellence described.

General Rubrics for Literacy tasks:
Argumentative_Pursuasive
Informational_Explanatory

Individual Project Rubric:
Automatic Pneumatic Feeder System Rubric

Essential Question:

How can we design a system to automatically provide a part on demand using pneumatic and other components?

Student Scenario:

You are a member of a design team for Automated Feeders. Your company has a client, Workholding Associates, who are designing a system for their clients that is currently having their employees mount work blanks on their machines manually for every operation. They wish to subcontract the feeder design to Automated Feeders.

Your team will build a prototype feeder system that will automatically deliver the work blank properly so an arm can select the part for delivery to the clamping site. You can use existing parts to prototype a feeder system. You will design, document and create a program to control the system

The design requirements are as follows:

- The prototype must feed the blank in the correct position.
- The program must wait for a signal before feeding the next part.
- Once the feeder delivers the part it should retract and pause while sending a signal to the system.
- When the operation is done the feeder should wait for the next signal.
- A sensor to identify the presence of parts in the feeder.

Your team's design will be presented by use of a working model of the automated pneumatic feeder system. This demonstrates the ability to automatically deliver a part to the correct pickup location.

The research and learning activities are designed to help students:

- Learn the basics of pneumatics.
- Learn the basic principles of PLC control
- Apply digital logic to determine the order and sequences of switches
- Utilize Boolean logic to simplify the parameters.

Deliverables:

- Engineering Notebook with reflections, research notes, bibliography, and other processes used in the design.
- Sketches of the device and planning for programming
- Descriptions of the sensors utilized and where they should be positioned
- Working prototype
- Engineering report of the design process
- Presentation for the authentic audience

Daily Plan:

Day 1
Key Question: What are the expectations of the project?

Introduce students to the main problem by providing them with the Essential question and the project description.

Cover with your students the design process, engineering notebook and design documentation requirements. Discuss the problem statement , design brief, testing protocol and management plan. Review the elements of a good engineering report.

The teacher will provide a list of vocabulary terms that students will need to research. Student teams can break the lists up and determine how to define the terms.

The teacher should also help the students outline the research they will need to do to be ready to work independently on the project at the end of the unit.

Have the students form teams of two. Allow the students sufficient time to discuss the problem. Students begin by brainstorming ideas in their Engineering Notebooks. The teacher will provide a list of vocabulary terms that students will need to research on their own. The teams can divide the list of terms among team members and share their definitions. All team members are responsible to know all definitions.

Day 2
Key Question: How do we get started in the design process?

The teams will be responsible for researching pneumatics, cylinders, solenoids Boolean Logic, flow charts and state diagrams as they apply to planning programming to be used with their feeder. Teams should research types of feeder systems.

The student teams discuss possible pneumatic feeder control systems including:

- What kinds of logic might we need to use?
- How will we know when it is safe to deliver the part

- Will the model meet the stated design requirements?
- How will our logic work?
- Does the pneumatic feeder system return to its home position when through?
- What are the basic electrical and pneumatic safety issues?

Students can reference specific terms from the vocabulary list for specific commands to be used in the design of the color sorting control system.

Remind students to record research notes and sources as well as reflections on the day in the Engineering Notebook.

Day 3-7
Key Question: How do we get started on our individual designs?

Student teams brainstorm needed components of their design and then create their written description of what they want the program to accomplish to add to their design brief to be include with their sketches of the location of sensors. They include operating requirements along with expected logic signals. They then meet with their clients who will need to sign off on the design proposal before programming and model building begins. The client can be the teacher or an authentic advisor.

Students should work through the tutorials on Pneumatics and Control if they have any confusion.

Teams discuss how their automatic pneumatic feeder control systems should be tested. The groups decide what components will be tested and how the team will know when their design achieves the test requirements.

Information about the sensors and programming can be found in the Activities Section. Student groups share their flow charts and programs with each other.

Day 9-10
Key Question: How can we begin to design our automatic pneumatic feeder system model?

Teams discuss their proposed automatic pneumatic feeder control systems and how to achieve the design given the approved design brief they presented. They work together to brainstorm ideas and begin to narrow their vision of their solution. Next the team divides the work of creating the pneumatic feeder device and programming scheme. Students can see an example set of instructions for a block feeder if needed. They must also decide on sensors, wiring and programing. They utilize the division of work in the creation of the project management plan.

Students record sketches and reflections in the Engineering Notebook. Once the students have a solution to the automatic pneumatic feeder control system design, they need to determine how the design will meet the requirements. This means students must consider how the design will be tested before building.

Teams discuss how the various designs and placement of sensors work and that the designs created will meet the automatic pneumatic feeder control system requirements and the performance will be within the specifications they established

Day 11-13
Key Question: How can we put our new designs together?

Student teams conduct meetings to review all designs elements created so far. They look at the criteria and testing protocols created. They discuss which design they wish to use as the team final design. It could be a single design or contain elements of several designs. Once the decision is made the students develop a plan for creating the team prototype. Information about the sensors and programming can be found in the Activities Section. They need to create a design that incorporates their ideas. Once the final plan is completed they will create prototype program. The teams discuss the final testing of their prototypes and how that will be achieved.

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Students can present their solutions to the class one at a time. Students display the completed automatic pneumatic feeder control system model and demonstrate how it functions. Students discuss changes they would consider if they had time to create another iteration of their design.

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Exclusive Or gates
Feeders
Flow charts
Input
Load
Logic
Nand gates
Network
Nor gates
Normally Closed
Normally Open
Open Loop programming

Or Gates
Output
Phototransistor
Power Supply
Power Terminals
Schematic
Single Axis
Solenoid
State diagrams
Switch
Timers
Wiring

Resources:

Engineering Notebook:

- http://www.wisegeek.com/what-is-an-engineering-notebook.htm
- https://www.firstinspires.org/sites/default/files/uploads/resource_library/ftc/engineering-notebook-guidelines.pdf
- https://www.asme.org/career-education/articles/early-career-engineers/my-engineers-notebook-jenn-t-dandrea

Engineering Reports

- http://web.mit.edu/me-ugoffice/communication/technical-writing.pdf
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/writing_engineering_reports.html
- https://www.youtube.com/playlist?list=PLDAAF7A8FD5CD582C&feature=plcp
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/mechanical_engineering_writing_enhancement_program/report_writing.html
- https://owl.purdue.edu/owl/subject_specific_writing/professional_technical_writing/technical_reports_and_report_abstracts/reports_proposals_and_technical_papers.html

Electricity

- https://www.allaboutcircuits.com/textbook/direct-current/
- https://learn.sparkfun.com/tutorials/alternating-current-ac-vs-direct-current-dc
- https://engineering.mit.edu/engage/ask-an-engineer/whats-the-difference-between-ac-and-dc/
- https://www.school-for-champions.com/science/dc.htm#.W372zehKguU
- http://sinovoltaics.com/learning-center/basics/direct-current-dc-power-definition-and-applications/
- https://whatis.techtarget.com/definition/DC-direct-current
- http://macao.communications.museum/eng/exhibition/secondfloor/MoreInfo/2_3_1_DCCircuit.html
- https://www.khanacademy.org/science/ap-physics-1/ap-circuits-topic/introduction-to-dc-circuits-ap/a/circuit-introduction

- https://www.allaboutcircuits.com/textbook/direct-current/chpt-5/what-are-series-and-parallel-circuits/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-1/static-electricity/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-2/voltage-current-resistance-relate/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-3/importance-electrical-safety/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-5/what-are-series-and-parallel-circuits/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-9/analog-and-digital-signals/

Logic

- http://www.plcdev.com/book/export/html/9
- https://www.allaboutcircuits.com/textbook/digital/chpt-6/digital-logic-functions/
- https://www.i-programmer.info/babbages-bag/235-logic-logic-everything-is-logic.html
- https://academo.org/demos/logic-gate-simulator/
- https://sciencedemos.org.uk/logic_gates.php
- http://www.cburch.com/logisim/

Pneumatic Clamping

- https://www.youtube.com/watch?v=eY5cAYudchw
- https://www.youtube.com/watch?v=5P2pk54wPlo
- https://www.youtube.com/watch?v=snlR6C1ZCo0
- https://www.youtube.com/watch?v=8NKKit18cX8
- https://youtu.be/5P2pk54wPlo
- https://youtu.be/9FGJQ6WRzPY
- https://www.youtube.com/watch?v=Cs0vy42gUkQ
- https://www.youtube.com/watch?v=40WUbK2gCxI
- https://www.datron.com/blog/cnc-workholding-for-milling-machines/

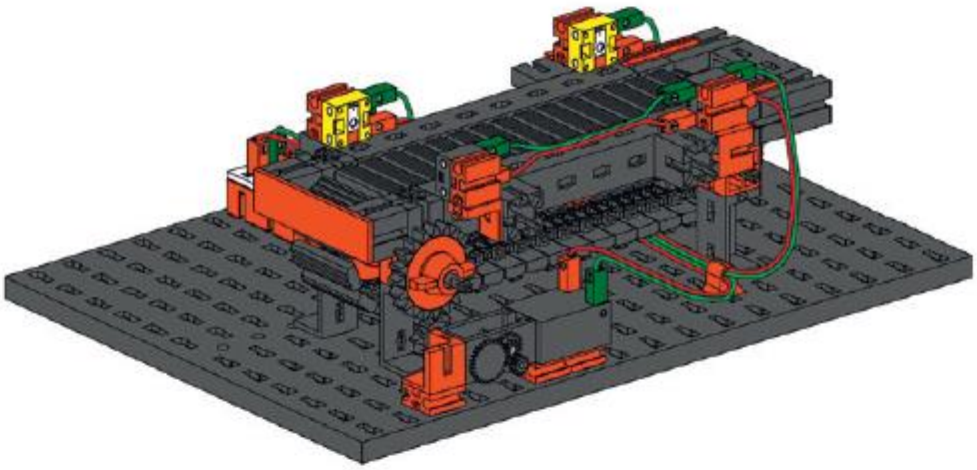
State Diagrams and Flow Charts

- https://www.lucidchart.com/pages/uml-state-machine-diagram
- https://www.geeksforgeeks.org/unified-modeling-language-uml-state-diagrams/
- http://www.agilemodeling.com/artifacts/stateMachineDiagram.htm
- http://www.cs.unc.edu/~stotts/145/CRC/state.html
- https://www.visual-paradigm.com/guide/uml-unified-modeling-language/what-is-state-machine-diagram/
- https://www.youtube.com/watch?v=L9UCsQxuWmw
- https://www.lucidchart.com/pages/what-is-a-flowchart-tutorial
- http://www.breezetree.com/articles/how-to-flow-chart-in-excel.htm
- https://www.gliffy.com/blog/the-comprehensive-guide-to-flowcharts

Part Feeders

- https://www.youtube.com/watch?v=1-oNjN-TvgI
- https://www.youtube.com/watch?v=KpkC4GmBsW8
- https://www.youtube.com/watch?v=UkdEN30762E
- https://www.youtube.com/watch?v=pQQSk3Ujc0I
- https://www.youtube.com/watch?v=xD5ifTDFtRQ
- https://youtu.be/B13ffPEv1q4
- https://www.youtube.com/watch?v=c4jgr8xz25Q
- https://www.feedall.com/feeders-conveyors/billet-feeders/manual-load-billet-feeder/
- https://www.youtube.com/watch?v=pjEN88IMFvc
- https://www.youtube.com/watch?v=LCN2LSjeRBM
- https://www.wrabacon.com/automated-systems/tray-stackers.html
- https://youtu.be/wa_fMM5N1rw
- https://youtu.be/3UPVjuvRDcM
- https://youtu.be/Xy7tGAF8UmU
- https://www.youtube.com/watch?v=B3Q3Wtx7STY
- https://www.youtube.com/watch?v=Vm_Tfnwq3MQ
- http://www.autoindtech.com/up210-upstacker.html

Project: Conveyor with Counter



Did you ever wonder how the bags or boxes of screws, washers, or other items are created? When a kit or piece of ready to assemble furniture is purchased how do they assure the correct number of small parts are included. To have people counting those parts into bags all day long would pose all kinds of problems which might include inaccurate counts, boredom and missed time at work which would all impact quality and deliveries. Automation allows for the accurate count of materials

Introduction:

Conveyors are devices for moving material from one place to another. Essentially they consist of a continuous belt. They come in all shapes and sizes. If you have ever ridden on an escalator then you have ridden on a type of conveyor designed for people. Conveyors are found in all kinds of locations. Airports, assembly lines and conveyors for hay bales are common. The post office, FedEx and UPS all have conveyors to move products. Warehouses, manufacturing, and mining industries all utilize conveyors. The longest conveyor is 61 miles long and is used to transport phosphate from mines to shipping terminals.

Conveyors are used in many different ways. By adding sensors timers and controls the conveyors become a component of smart systems which can make decisions and follow complex programming. Central to controlling the conveyor is the Programmable Logic

Controller (PLC) which is a hardened computer that is tasked with running the programming associated with automated systems. They are used anyplace where repetition, reliability and repeatability are needed.

Purpose of the Project:

The purpose of the Conveyor with Counter project is to introduce some basis concepts of automation, programming and sensors. Students will apply the design process to solve the problem of how to place the correct number of parts in a container.

Concepts:

- Creating technical solutions requires the use of mathematical analysis, scientific inquiry, and engineering design.
- Science and engineering professionals use data and graphical analysis in making decisions
- Modern design requires the ability to generate, process, and transfer information digitally using appropriate technologies.
- The Engineering Design Process is sometimes referred to as the sequential actions of research, design, build, evaluate; then redesign, and communicate.
- Engineering professionals design solutions and communicate the solutions through graphics and pictures.
- Engineers use integrity and ethics when communicating ideas, including citing sources of information.
- In all systems, there is a tradeoff between performance and complexity. Higher complexity is generally associated with higher cost; hence the shortened form of the syllogism is performance versus cost.
- Designing mechanical systems requires the knowledge and application of simple machines to manage and transform power and forces into required motion.
- Electricity is a form of energy caused by the movement of charged particles. It is often used to transfer energy from one place to another.
- The first law of thermodynamics (conservation of energy and matter) states that output power of a system is always less than the power supplied to the system.
- The design of mechanisms requires the use of dimension tolerances to assure that component parts work together effectively with minimum power losses.
- “Green Principles” of design are used for eventual disassembly and resource recovery and is referred as Product Lifecycle Management (PLM)
- A Programmable Logic Controller (PLC) is a hardened computer used for industrial automation. PLCs can automate a process, machine function, or even an entire production line.
- The term “Logic” is based upon the mathematical system called Boolean Algebra named after George Boole (Born November 2, 1815-Died December 8, 1864) who was a self-taught English mathematician and philosopher who invented this form of algebra where values are either True or False where rules are created to consistently arrive at desired values.

- The ability to collect data, transform them into information, and use that information to improve an existing process is an enabling skill for Lean manufacturing.
- Applying automated control systems to existing manual processes can dramatically improve quality and reduce the amount of human (manual) time required.
- Electronic sensors detect and transform real-world phenomena into information that is used by computers to control valves, pumps, and other industrial equipment.
- Timers allow programmers to design and control specialized clocks to turn machinery on or off for specific amounts of time.
- Keeping track of events as they occur can be accomplished using logic programs called counters.

Outline:

Documentation
- Engineering Notebook
- Documentation object to be designed

Programmable Logic Controllers (PLC)
- Basic electricity-Multimeter schematics/ Ohms law
- Setup
- Inputs
- Outputs
- Logic
- Timers
- Counters

Evaluation
- Testing of the ability to control a conveyor and count items

Communication
- Presentation of design solutions

Standards:

Career and Technical Standards

Engineering Design Process

- Maintain an Engineering Notebook for research, prototype creation, documentation and daily reflections.
- Apply engineering design and problem solving as an iterative process incorporating science, mathematics, and engineering to optimally convert resources to meet a design solution.
- Communicate design solutions utilizing effective technical writing skills including correct spelling, proper grammar, and accurate technical vocabulary.
- Prepare a quantitative plan for the successful completion of a project.
- Assume leadership responsibility for collaborative team actions and decisions related to the successful completion of a project.

- Evaluate the needs and costs of resources necessary for the completion of a project.
- Prepare and communicate model documentation to include such details as product analysis, size, materials, assembly details, installation and service requirements.

Design for Manufacturing

- Understand and apply Statistical Process Control (SPC) to acquire quality control.

Design for Assembly

- Create a management plan that includes quality planning, quality control, quality assurance, and quality improvement for an advanced manufacturing environment.

Automation with Programmable Logic Controllers (PLCs)

- Design and analyze an electrical system to efficiently convert, transform, and transmit electricity to where it is needed.
- Research and specify electrical devices necessary to provide needed power.
- Apply machine control systems, sensory feedback, and information processing to increase productivity in manufacturing.
- Use flow charts and diagrams to apply logic in the design of control programs.

- **Applying Logic Software RoboPro to Create Problem Solutions**
  - Design a system of elements that manages power to accomplish a task involving defined movement.
  - Design a control system to vary the speed and performance of a motor by utilizing feedback from the system to gain the most efficiency possible.
  - Formulate a system to utilize data collection and analysis to maintain and improve product quality and provide adequate confidence that the product will satisfy design requirements.
  - Design and analyze the application of machine control systems, sensory feedback, and information processing to increase productivity in manufacturing.

  Business of Manufacturing

  - Research and evaluate the new approaches of rapid development and deployment of products that saves time and is more efficient.
  - Create a management plan including quality planning, quality control, quality assurance and quality improvement for an advance manufacturing environment.

College and Career Readiness Math Standards

Creating Equations

CED.A1 Create equations and inequalities in one variable and use them to solve problems.

CED.A.2 Create equations in two or more variables to represent relationships between quantities

CED.A.3 Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or nonviable options in a modeling context
CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations

Create equations that describe numbers or relationships CED

A.4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations

Quantities

Q.A.1Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays

Making Inferences & Justifying Conclusions

IC.A.1 Understand statistics as a process for making inferences about population parameters based on a random sample from that population.
IC.B.3 Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.

Reading Standards for Literacy in History/Social Studies 9-10

Key Ideas and Details

1. Cite specific textual evidence to support analysis of primary and secondary sources, attending to such features as the date and origin of the information.
3. Analyze in detail a series of events described in a text; determine whether earlier events caused later ones or simply preceded them.

Integration of Knowledge and Ideas

7. Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text.
9. Compare and contrast treatments of the same topic in several primary and secondary sources.

Range of Reading and Level of Text Complexity

10. By the end of grade 10, read and comprehend science/technical texts in the grades 9–10 text complexity band independently and proficiently.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 9-10

Text Types and Purposes

1. Write arguments focused on *discipline-specific content.*
2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

Production and Distribution of Writing

4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Research to Build and Present Knowledge

7. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

8. Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

Range of Writing

10. Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Next Generation Science Standards

The projects engage students in the scientific and engineering practices taken from the National Research Council's Framework for K-12 Science Education, Practices, Crosscutting Concepts, and Core Ideas. This is the document upon which the NGSS are based.

These practices are used for two reasons: 1) they parallel the design process utilized in each project, and 2) they serve as the foundation of the NGSS.

The eight science and engineering practices are:

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Standards for Technological Literacy

STL Standard 1:

Students will develop an understanding of the characteristics and scope of technology.

STL Standard 2:
Students will develop an understanding of the core concepts of technology.

STL Standard 3:
Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

STL Standard 4:
Students will develop an understanding of the cultural, social, economic, and political effects of technology.

STL Standard 5:
Students will develop an understanding of the effects of technology on the environment.

STL Standard 7:
Students will develop an understanding of the influence of technology on history.

STL Standard 8:
Students will develop an understanding of the attributes of design.

STL Standard 9:
Students will develop an understanding of engineering design.

STL Standard 10:
Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

STL Standard 11:
Students will develop the abilities to apply the design process.

STL Standard 12:
Students will develop the abilities to use and maintain technological products and systems.

STL Standard 13:
Students will develop the abilities to assess the impact of products and systems.

STL Standard 14:
Students will develop an understanding of and be able to select and use medical technologies.

STL Standard 16:
Students will develop an understanding of and be able to select and use energy and power technologies.

STL Standard 17:
Students will develop an understanding of and be able to select and use information and communication technologies.

STL Standard 18:
Students will develop an understanding of and be able to select and use transportation technologies.

STL Standard 19:
Students will develop an understanding of and be able to select and use manufacturing technologies.

STL Standard 20:
Students will develop an understanding of and be able to select and use construction technologies.

Assessment:

Assessment is both formative and summative. It is an integral part of high quality instruction. During the course of a project one of the instructor's main functions is to work with student groups, keeping track of progress and providing formative assessment using feedback and promoting reflection about the design process. The focus should be on lifetime learning and 21st century skills. The goal of instruction is to promote abilities in research, problem solving, design, experimentation, testing, and collecting data.

Rubrics are used in the assessment process to communicate expectations of quality. Rubrics should be shared with students at the beginning of a project to clarify any misconceptions before beginning their work. Students can then build the skills and gather knowledge to solve the problem presented to the expectations of excellence described.

General Rubrics for Literacy tasks:
Argumentative_Pursuasive
Informational_Explanatory

Individual Project Rubric:
Conveyor with Counter

Essential Question:

How can we automatically count the number of components processed?

Student Scenario:

You work for Conveyor Systems Inc. As a member of the new automation team that was created to streamline many of the processes of a customer. The customer is automating their manufacturing process. They have ordered a feeding system to provide parts on an as needed basis. They have ordered a pneumatic clamping system to secure the components for machining. They need a conveyor to carry the parts from the feeder to a position where an arm can pick up the piece and deliver it to the clamping system. Once the system has processed the part it will be place on the conveyor for removal and the conveyor must count the parts as they reach the removal place.

The design requirements are as follows:

- The program must run the conveyor until the desired position is reach.
- The conveyor must have a switch or signal to begin operation
- The conveyor must have an emergency stop.
- The program must stop the conveyor in the proper place.
- The program must report the count number.

Your team's design will be presented by use of a working model of the automated conveyor position and counter system.

The research and learning activities are designed to help students:

- Learn the basic principles of logic control
- Apply counters to control motion
- Understand the role of statistics plays in automation requirements

Deliverables:

- Engineering Notebook with reflections, research notes, bibliography, and other processes used in the design.
- Sketches and planning for programming
- Descriptions of the sensors utilized
- Working prototype
- Engineering report of the design process
- Presentation for the authentic audience

Daily Plan:

Day 1

Key Question: What are the expectations of the project?

Introduce students to the main problem by providing them with the Essential question and the project description.

Cover with your students the design process, engineering notebook and design documentation requirements. Discuss the problem statement , design brief, testing protocol and management plan. Review the elements of a good engineering report.

The teacher will provide a list of vocabulary terms that students will need to research. Student teams can break the lists up and determine how to define the terms.

The teacher should also help the students outline the research they will need to do to be ready to work independently on the project at the end of the unit.

Have the students form teams of two. Allow the students sufficient time to discuss the problem. Students begin by brainstorming ideas in their Engineering Notebooks. The teacher will provide a list of vocabulary terms that students will need to research on their own. The teams can divide the list of terms among team members and share their definitions. All team members are responsible to know all definitions.

Day 2
Key Question: How do we get started in the design process?

The teams will be responsible for researching conveyors, sensors and programming. Teams are also responsible for research into program design and basic statistics

The student teams discuss possible conveyor counting and control systems including:

- How does a counter work?
- What kinds of sensors might be used?
- Where might sensors be located where they will be effective?
- Does the model meet the stated design requirements?
- Are there safety switches in place?
- What are the basic electrical safety issues?

Students can reference specific terms from the vocabulary list for specific commands to be used in the design of the split mold systems.

Remind students to record research notes and sources as well as reflections on the day in the Engineering Notebook.

Day 3-8
Key Question: How do we get started on our individual designs?

Student teams brainstorm needed components of their design and then create their written description of what they want the program to accomplish to add to their design brief to be include with their sketches of the location of sensors. They include operating requirements along with expected voltage readings. The design plan also includes the plan for gathering statistical data about performance. They then meet with their clients who will need to sign off on the design proposal before programming and model building begins. The client can be the teacher or an authentic advisor.

Teams discuss how their counting systems should be tested. The groups decide what components will be tested and how the team will know when their design achieves the test requirements.

The teacher should introduce counters and have students complete the activity on Variables.

Information about the sensors and programming can be found in the Activities Section. Student groups share their flow charts and programs with each other.

Day 9-10
Key Question: How can we begin to design our conveyor counter system model?

Teams discuss their proposed counting systems and how to achieve the design given the approved design brief they presented. They work together to brainstorm ideas and begin to narrow their vision of their solution. Next the team divides the work of creating the conveyor, sensors, wiring and program They utilize the division of work in the creation of the project management plan.

Students record sketches and reflections in the Engineering Notebook. Once the students have a solution to the conveyor counting system design, they need to determine how the design will meet the requirements. This means students must consider how the design will be tested before building.

Teams discuss how the various designs and placement of sensors work and that the designs created will meet the counter system requirements and the performance will be within the specifications they established

Day 11-13
Key Question: How can we put our new designs together?

Student teams conduct meetings to review all designs elements created so far. They look at the criteria and testing protocols created. They discuss which design they wish to use as the team final design. It could be a single design or contain elements of several designs. Once the decision is made the students develop a plan for creating the team prototype. They need to create a design that incorporates their ideas. Once the final plan is completed they will create prototype program. The teams discuss the final testing of their prototypes and how that will be achieved.

Students create the final plans and begin programming and testing to see how they are communicating with the various sensors they selected. Students record any changes in their designs and enter reflections in their Engineering Notebooks.

Day 14-16
Key Question: How do we build and test our designs?

Students assemble their prototype counting system. When students encounter problems assembling their prototype they must discuss how they will resolve the issue and change the design.

Students record any changes in their designs and enter reflections in their Engineering Notebooks.

Once the working prototype is assembled testing can begin to see if the model meets the stated design requirements. Students begin runs to check the accuracy of their systems. They gather data on tests and build histograms to show how accurate the system is. Students discuss results of their initial testing and propose improvements to the system.

Day 17-18
Key Question: How do we organize our thoughts in a presentation to the class?

The student teams discuss and finish any changes that are needed.
The teacher will discuss with the teams how to optimally present their ideas.

Students discuss the outline of the presentation to their clients. The deliverables will include the prototype, program design and information about the design process and how they solved many of the issues they encountered. The students should be required to write the introduction, provide results including graphics, and form a conclusion including an acknowledgement section reporting the source of information. Students decide how to divide the work to create a team report.

Day 19
Key Question: How do we convey our ideas?

Students can present their solutions to the class one at a time. Students display the completed conveyor counting system model and demonstrate how it functions. Students discuss changes they would consider if they had time to create another iteration of their design.

In the end, all students can reflect on their work by giving and receiving feedback on how they could possibly improve their designs

Vocabulary:

Connection Terminals
Counter
CPU
Digital

Input
Load
Logic
Network
Normally Closed
Normally Open
Output
Phototransistor
Power Supply
Power Terminals
Schematic
Switch
Wiring

Resources:

Engineering Notebook:

- http://www.wisegeek.com/what-is-an-engineering-notebook.htm
- https://www.firstinspires.org/sites/default/files/uploads/resource_library/ftc/engineering-notebook-guidelines.pdf
- https://www.asme.org/career-education/articles/early-career-engineers/my-engineers-notebook-jenn-t-dandrea

Engineering Reports

- http://web.mit.edu/me-ugoffice/communication/technical-writing.pdf
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/writing_engineering_reports.html
- https://www.youtube.com/playlist?list=PLDAAF7A8FD5CD582C&feature=plcp
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/mechanical_engineering_writing_enhancement_program/report_writing.html
- https://owl.purdue.edu/owl/subject_specific_writing/professional_technical_writing/technical_reports_and_report_abstracts/reports_proposals_and_technical_papers.html

Electricity

- https://www.allaboutcircuits.com/textbook/direct-current/
- https://learn.sparkfun.com/tutorials/alternating-current-ac-vs-direct-current-dc
- https://engineering.mit.edu/engage/ask-an-engineer/whats-the-difference-between-ac-and-dc/
- https://www.school-for-champions.com/science/dc.htm#.W372zehKguU
- http://sinovoltaics.com/learning-center/basics/direct-current-dc-power-definition-and-applications/
- https://whatis.techtarget.com/definition/DC-direct-current
- http://macao.communications.museum/eng/exhibition/secondfloor/MoreInfo/2_3_1_DCCircuit.html

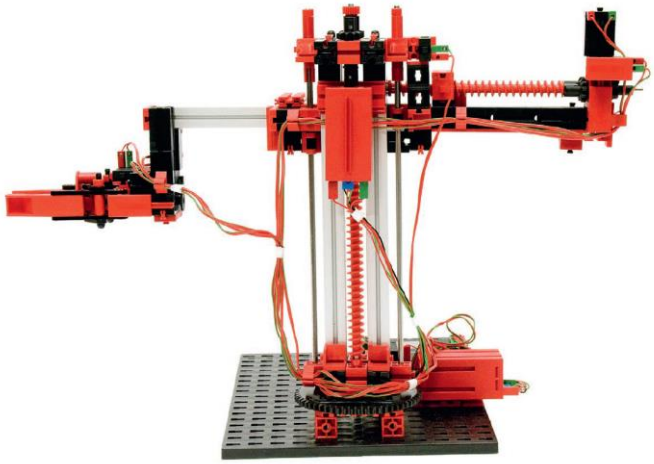
- https://www.khanacademy.org/science/ap-physics-1/ap-circuits-topic/introduction-to-dc-circuits-ap/a/circuit-introduction
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-5/what-are-series-and-parallel-circuits/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-1/static-electricity/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-2/voltage-current-resistance-relate/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-3/importance-electrical-safety/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-5/what-are-series-and-parallel-circuits/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-9/analog-and-digital-signals/

Logic

- http://www.plcdev.com/book/export/html/9
- https://www.allaboutcircuits.com/textbook/digital/chpt-6/digital-logic-functions/
- https://www.i-programmer.info/babbages-bag/235-logic-logic-everything-is-logic.html
- https://academo.org/demos/logic-gate-simulator/
- https://sciencedemos.org.uk/logic_gates.php
- http://www.cburch.com/logisim/

Studica

Project: Robot Control



Introduction:

Industries are using robots for a variety of reasons. There are shortages of people for manufacturing positions so businesses are moving to implement robotics as a way to overcome the shortages. The robots can be more accurate, faster and work on tight tolerances. They can work under conditions that humans cannot and can provide consistent results.

Purpose of the Project:

The purpose of the robotic control project is the introduction to the design, assembly and programming the arm. Digital logic is applied in decision making. The project introduces concepts such as positions, recording and reading positions in Excel, and the design of human machine interfaces.

Concepts:

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- Science and engineering professionals use data and graphical analysis in making decisions
- Modern design requires the ability to generate, process, and transfer information digitally using appropriate technologies.
- The Engineering Design Process is sometimes referred to as the sequential actions of research, design, build, evaluate; then redesign, and communicate.

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- Keeping track of events as they occur can be accomplished using logic programs called counters.
- Analog inputs for such things as temperature, pressure, speed, etc., are voltage values that can be converted into a digital value to be stored and used by a computer.

Outline:

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  Engineering Notebook

  Documentation object to be designed

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- Basic electricity-Multimeter schematics/ Ohms law
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- Outputs
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- Counters

Evaluation
- Testing of the ability of the arm to make movements that can be precise and repeatable

Communication
- Presentation of design solutions

Standards:

Career and Technical Standards

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- Prepare a quantitative plan for the successful completion of a project.
- Assume leadership responsibility for collaborative team actions and decisions related to the successful completion of a project.
- Evaluate the needs and costs of resources necessary for the completion of a project.
- Prepare and communicate model documentation to include such details as product analysis, size, materials, assembly details, installation and service requirements.

Design for Assembly

- Create a management plan that includes quality planning, quality control, quality assurance, and quality improvement for an advanced manufacturing environment.

Automation with Programmable Logic Controllers (PLCs)

- Design and analyze an electrical system to efficiently convert, transform, and transmit electricity to where it is needed.
- Research and specify electrical devices necessary to provide needed power.
- Apply machine control systems, sensory feedback, and information processing to increase productivity in manufacturing.
- Use flow charts and diagrams to apply logic in the design of control programs.

Applying Logic Software RoboPro to Create Problem Solutions

- Design a system of elements that manages power to accomplish a task involving defined movement.
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College and Career Readiness Math Standards

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CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations

Create equations that describe numbers or relationships CED

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Reading Standards for Literacy in History/Social Studies 9-10

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2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Standards for Technological Literacy

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General Rubrics for Literacy tasks:
Argumentative_Pursuasive
Informational_Explanatory

Individual Project Rubric:
Robot Control System

Essential Question:
How is a control program designed to allow for the precise control of robot to deliver a part to the correct location?

Student Scenario:
You are working with a team of technicians and programmers at Automated Arms Inc. Your team is tasked with coming up creating an arm prototype to move a part from a conveyor to an automated clamping device. After processing the arm will retrieve the part and return it to the conveyor for removal.

Your team must design the program to automatically move the part to the correct location at the correct time and then move out of the way. The arm must signal the system that it is out of the way and is ready for other activities.

The design requirements are as follows:
- The program must wait for the operating signal.
- The arm must remove the part from the conveyor and place it in the clamping device.
- The arm must move out of the way and then signal the clamping device.
- The arm must wait for a signal then retrieve the part.
- It must have a safety switch to stop the arm in case of emergencies.
- The arm must return the component to the conveyor, move out of the way then signal the conveyor .

Your team's design will be presented by use of a working model of the arm system controlled by the PLC.

The research and learning activities are designed to help students:

- Learn the basic principles of PLC control
- Apply digital logic to create the digital communication system
- Utilize a closed loop system to identify positions

Deliverables:

- Engineering Notebook with reflections, research notes, bibliography, and other processes used in the design.
- Sketches of the device and planning for programming
- Descriptions of the sensors utilized and where they should be positioned
- Working prototype
- Engineering report of the design process
- Presentation for the authentic audience

Daily Plan:

Day 1
Key Question: What are the expectations of the project?

Introduce students to the main problem by providing them with the Essential question and the project description.

Cover with your students the design process, engineering notebook and design documentation requirements. Discuss the problem statement , design brief, testing protocol and management plan. Review the elements of a good engineering report.

The teacher will provide a list of vocabulary terms that students will need to research. Student teams can break the lists up and determine how to define the terms.

The teacher should also help the students outline the research they will need to do to be ready to work independently on the project at the end of the unit.

Have the students form teams of two. Allow the students sufficient time to discuss the problem. Students begin by brainstorming ideas in their Engineering Notebooks. The teacher will provide a list of vocabulary terms that students will need to research on their own. The teams can divide the list of terms among team members and share their definitions. All team members are responsible to know all definitions.

Day 2
Key Question: How do we get started in the design process?

The teams will be responsible for researching types of robotic arms, drive mechanisms and inputs and outputs.

The student teams discuss possible robot control systems including:

- What kinds of sensors might we need to use?
- Where might sensors be located where they will be effective?
- Will the model meet the stated design requirements?
- How will our logic work?
- Are there safety switches in place?
- What are the basic electrical safety issues?

Students can reference specific terms from the vocabulary list for specific commands to be used in the design of the color sorting control system.

Remind students to record research notes and sources as well as reflections on the day in the Engineering Notebook.

Day 3-7
Key Question: How do we get started on our individual designs?

Student teams brainstorm needed components of their design and then create their written description of what they want the program to accomplish to add to their design brief to be include with their sketches of the location of sensors. They include operating requirements along with expected logic signals. They then meet with their clients who will need to sign off on the design proposal before programming and model building begins. The client can be the teacher or an authentic advisor.

Students should work through the tutorials on Positions, Recording Positions and Creating a Graphical User Interface.
This will take several days to work through these necessary basics.

Teams discuss how their robot control systems should be tested. The groups decide what components will be tested and how the team will know when their design achieves the test requirements.

Information about the sensors and programming can be found in the Activities Section. Student groups share their flow charts and programs with each other.

Day 9-12
Key Question: How can we begin to design our robot control system model?

Teams discuss their proposed robot control systems and how to achieve the design given the approved design brief they presented. They work together to brainstorm ideas and begin to narrow their vision of their solution. Next the team divides the work of creating the robotic device and programming scheme. They must also decide on sensors, wiring and programing. They utilize the division of work in the creation of the project management plan.

Students record sketches and reflections in the Engineering Notebook. Once the students have a solution to the elevator control system design, they need to determine how the design will meet the requirements. This means students must consider how the design will be tested before building.

Teams discuss how the various designs and placement of sensors work and that the designs created will meet the robotic control system requirements and the performance will be within the specifications they established

Day 13-15
Key Question: How can we put our new designs together?

Student teams conduct meetings to review all designs elements created so far. They look at the criteria and testing protocols created. They discuss which design they wish to use as the team final design. It could be a single design or contain elements of several designs. Once the decision is made the students develop a plan for creating the team prototype. They need to create a design that incorporates their ideas. Once the final plan is completed they will create prototype program. The teams discuss the final testing of their prototypes and how that will be achieved.

Students create the final plans and begin programming and testing to see how they are communicating with the various sensors they selected. Students record any changes in their designs and enter reflections in their Engineering Notebooks.

Day 16-18
Key Question: How do we build and test our designs?

Students assemble their prototype robot control system. When students encounter problems assembling their prototype they must discuss how they will resolve the issue and change the design.

Students record any changes in their designs and enter reflections in their Engineering Notebooks.

Once the working prototype is assembled testing can begin to see if the model meets the stated design requirements. Students begin runs to check the accuracy of their systems. They gather data on tests and to show how accurate the system is and how the various functions are performing. Students discuss results of their initial testing and propose improvements to the system.

Day 19-20
Key Question: How do we organize our thoughts in a presentation to the class?

The student teams discuss and finish any changes that are needed.
The teacher will discuss with the teams how to optimally present their ideas.

Students discuss the outline of the presentation to their clients. The deliverables will include the prototype, program design and information about the design process and how they solved many of the issues they encountered. The students should be required to write the introduction, provide results including graphics, and form a conclusion including an acknowledgement section reporting the source of information. Students decide how to divide the work to create a team report.

Day 21
Key Question: How do we convey our ideas?

Students can present their solutions to the class one at a time. Students display the completed elevator control system model and demonstrate how it functions. Students discuss changes they would consider if they had time to create another iteration of their design.

In the end, all students can reflect on their work by giving and receiving feedback on how they could possibly improve their designs

Vocabulary:

Closed loop programming
Connection Terminals
Counter
CPU
Digital
Input
Load
Logic
Network
Normally Closed
Normally Open
Open Loop programming
Output
Phototransistor
Power Supply
Schematic
Switch
Timers
Wiring

Resources:

Engineering Notebook:

- http://www.wisegeek.com/what-is-an-engineering-notebook.htm
- https://www.firstinspires.org/sites/default/files/uploads/resource_library/ftc/engineering-notebook-guidelines.pdf
- https://www.asme.org/career-education/articles/early-career-engineers/my-engineers-notebook-jenn-t-dandrea

Engineering Reports

- http://web.mit.edu/me-ugoffice/communication/technical-writing.pdf
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/writing_engineering_reports.html
- https://www.youtube.com/playlist?list=PLDAAF7A8FD5CD582C&feature=plcp
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/mechanical_engineering_writing_enhancement_program/report_writing.html
- https://owl.purdue.edu/owl/subject_specific_writing/professional_technical_writing/technical_reports_and_report_abstracts/reports_proposals_and_technical_papers.html

Electricity

- https://www.allaboutcircuits.com/textbook/direct-current/
- https://learn.sparkfun.com/tutorials/alternating-current-ac-vs-direct-current-dc
- https://engineering.mit.edu/engage/ask-an-engineer/whats-the-difference-between-ac-and-dc/
- https://www.school-for-champions.com/science/dc.htm#.W372zehKguU
- http://sinovoltaics.com/learning-center/basics/direct-current-dc-power-definition-and-applications/
- https://whatis.techtarget.com/definition/DC-direct-current
- http://macao.communications.museum/eng/exhibition/secondfloor/MoreInfo/2_3_1_DCCircuit.html
- https://www.khanacademy.org/science/ap-physics-1/ap-circuits-topic/introduction-to-dc-circuits-ap/a/circuit-introduction
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-5/what-are-series-and-parallel-circuits/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-1/static-electricity/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-2/voltage-current-resistance-relate/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-3/importance-electrical-safety/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-5/what-are-series-and-parallel-circuits/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-9/analog-and-digital-signals/

Robotic Arms

- http://www.robots.com/education/industrial-history
- http://www.ehow.com/about_5566887_robotic-arm-information.html
- http://www.ehow.com/about_4793878_use-robots-industry.html
- http://en.wikipedia.org/wiki/George_Devol
- http://en.wikipedia.org/wiki/Industrial_robot
- http://www.ehow.com/about_4678910_robots-car-manufacturing.html
- http://en.wikipedia.org/wiki/Robotic_arm
- http://en.wikipedia.org/wiki/Ultimate
- http://science.howstuffworks.com/robot2.htm
- http://www.theatlantic.com/technology/archive/2011/08/unimate-the-story-of-george-devol-and-the-first-robotic-arm/243716
- http://helix.gatech.edu/Students/SiouxWill/I2)21)us.htm

Logic

- http://www.plcdev.com/book/export/html/9
- https://www.allaboutcircuits.com/textbook/digital/chpt-6/digital-logic-functions/
- https://www.i-programmer.info/babbages-bag/235-logic-logic-everything-is-logic.html
- https://academo.org/demos/logic-gate-simulator/
- https://sciencedemos.org.uk/logic_gates.php
- http://www.cburch.com/logisim/

Project: Sun Tracking Solar Panel

Solar panels generate electricity when photons (a light particle) knock electrons free from the specially developed materials generating a flow of electrons. The majority of solar panels are on a fixed base or what is known as ground mounted. This is a less expensive way to setup the initial systems but at the expense of only being pointed directly at the sun for a few moments each day. It might be cloudy at that point or the energy might be needed at other times.

Introduction:

Solar cells or photo voltaic cells, the individual components that make up solar panels are semiconductor devices. The amount of energy produced is based upon many factors including the color of the light, the amount of photons that strike at the correct angle and even climate conditions. The demand for electricity varies but is greatest through the day times. Solar panels have become more efficient in recent years meaning each square foot of panel is generating more electricity.

Since electrical output is tied to the angle the light strikes the panel many installations are now installing tracking devices that are designed to rotate in several dimensions so they are always pointed at the sun, maximizing the amount of energy production. The costs of these systems are now being offset by gains in the amount of energy generated. These are especially important in off grid installations, where maximizing the output is critical.

Purpose of the Project:

The purpose of the Sun Tracking Solar Panel project is the introduction to analog sensors and how they might be used to provide input signals. This project will also introduce students to comparison decision making. Students will apply the design process to solve the problem of how automate a solar panel tracker system to keep the panel always pointed at the sun.

Concepts:

- Creating technical solutions requires the use of mathematical analysis, scientific inquiry, and engineering design.
- Science and engineering professionals use data and graphical analysis in making decisions
- Modern design requires the ability to generate, process, and transfer information digitally using appropriate technologies.
- The Engineering Design Process is sometimes referred to as the sequential actions of research, design, build, evaluate; then redesign, and communicate.
- Engineering professionals design solutions and communicate the solutions through graphics and pictures.
- Engineers use integrity and ethics when communicating ideas, including citing sources of information.
- In all systems, there is a tradeoff between performance and complexity. Higher complexity is generally associated with higher cost; hence the shortened form of the syllogism is performance versus cost.
- Designing mechanical systems requires the knowledge and application of simple machines to manage and transform power and forces into required motion.
- Electricity is a form of energy caused by the movement of charged particles. It is often used to transfer energy from one place to another.
- The first law of thermodynamics (conservation of energy and matter) states that output power of a system is always less than the power supplied to the system.
- The design of mechanisms requires the use of dimension tolerances to assure that component parts work together effectively with minimum power losses.
- “Green Principles” of design are used for eventual disassembly and resource recovery and is referred as Product Lifecycle Management (PLM)
- A Programmable Logic Controller (PLC) is a hardened computer used for industrial automation. PLCs can automate a process, machine function, or even an entire production line.
- The term “Logic” is based upon the mathematical system called Boolean Algebra named after George Boole (Born November 2, 1815-Died December 8, 1864) who was a self-taught English mathematician and philosopher who invented this form of algebra where values are either True or False where rules are created to consistently arrive at desired values.
- The ability to collect data, transform them into information, and use that information to improve an existing process is an enabling skill for Lean manufacturing.
- Applying automated control systems to existing manual processes can dramatically improve quality and reduce the amount of human (manual) time required.

- Electronic sensors detect and transform real-world phenomena into information that is used by computers to control valves, pumps, and other industrial equipment.
- Timers allow programmers to design and control specialized clocks to turn machinery on or off for specific amounts of time.
- Keeping track of events as they occur can be accomplished using logic programs called counters.
- Analog inputs for such things as temperature, pressure, speed, etc., are voltage values that can be converted into a digital value to be stored and used by a computer.

Outline:

Documentation
- Engineering Notebook
- Documentation object to be designed

Programmable Logic Controllers (PLC)
- Basic electricity-Multimeter schematics/ Ohms law
- Setup
- Inputs
- Outputs
- Logic
- Timers
- Counters

Evaluation
- Testing of the ability to control a solar panel so it tracks the sun

Communication
- Presentation of design solutions

Standards:

Career and Technical Standards

Engineering Design Process

- Maintain an Engineering Notebook for research, prototype creation, documentation and daily reflections.
- Apply engineering design and problem solving as an iterative process incorporating science, mathematics, and engineering to optimally convert resources to meet a design solution.
- Communicate design solutions utilizing effective technical writing skills including correct spelling, proper grammar, and accurate technical vocabulary.
- Prepare a quantitative plan for the successful completion of a project.
- Assume leadership responsibility for collaborative team actions and decisions related to the successful completion of a project.
- Evaluate the needs and costs of resources necessary for the completion of a project.

- Prepare and communicate model documentation to include such details as product analysis, size, materials, assembly details, installation and service requirements.

Design for Manufacturing

- Understand and apply Statistical Process Control (SPC) to acquire quality control.

Design for Assembly

- Create a management plan that includes quality planning, quality control, quality assurance, and quality improvement for an advanced manufacturing environment.

Automation with Programmable Logic Controllers (PLCs)

- Design and analyze an electrical system to efficiently convert, transform, and transmit electricity to where it is needed.
- Research and specify electrical devices necessary to provide needed power.
- Apply machine control systems, sensory feedback, and information processing to increase productivity in manufacturing.
- Use flow charts and diagrams to apply logic in the design of control programs.

Applying Logic Software RoboPro to Create Problem Solutions

- Design a system of elements that manages power to accomplish a task involving defined movement.
- Design a control system to vary the speed and performance of a motor by utilizing feedback from the system to gain the most efficiency possible.
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General Rubrics for Literacy tasks:
Argumentative_Pursuasive
Informational_Explanatory

Individual Project Rubric:
Sun Tracking Solar Panel Rubric

Essential Question:

How can a design team create a control system to maximize the energy collected by a solar panel?

Student Scenario:

You are working with a design team at Sun Trackers LLC a firm that supplies solar panel installations to remote areas. This allows areas far from the grid to have reliable power. In the past these installations were done with fuel powered generators adding noise and pollution to sensitive areas. The cost of trucking and storing of fuel is also growing. The costs of solar panel systems are falling it is now more cost effective to use solar installations for power. Since much of the costs are in storage and conversion to AC electricity clients want to maximize the power being collected.

Your team has been charged with the design of a two axis solar mount that will track the sun and keep the panels at the ideal angle for the greatest collection. The team will have to conduct research on the sensors to be used and study how those sensors can be used in controlling motion.

The design requirements are as follows:

- The program must control the panel in two axes.
- The program must point the panel at the best angle to track the sun.
- It must have a safety switch to send the panel to the morning position
- The program must have a dark setting where the panel rotation control is turned off to wait for the sun rise

Your team's design will be presented by use of a working model of the Sun Tracking system controlled by the PLC. This system is proposed to increase the production of solar energy by 40%. It will reduce the area requirement for panels and provide for energy on days when weather would affect a stationary fixed solar installation.

The research and learning activities are designed to help students:

- Learn the basic principles of logic control
- Apply analog sensors to monitor environmental conditions
- Apply ranges to the control so motion is incremental not continuous

Deliverables:

- Engineering Notebook with reflections, research notes, bibliography, and other processes used in the design.
- Sketches of the device and planning for programming
- Descriptions of the sensors utilized and where they should be positioned
- Working prototype
- Engineering report of the design process
- Presentation for the authentic audience

Daily Plan:

Day 1

Key Question: What are the expectations of the project?

Introduce students to the main problem by providing them with the Essential question and the project description.

Cover with your students the design process, engineering notebook and design documentation requirements. Discuss the problem statement , design brief, testing protocol and management plan. Review the elements of a good engineering report.

The teacher will provide a list of vocabulary terms that students will need to research. Student teams can break the lists up and determine how to define the terms.

The teacher should also help the students outline the research they will need to do to be ready to work independently on the project at the end of the unit.

Have the students form teams of two. Allow the students sufficient time to discuss the problem. Students begin by brainstorming ideas in their Engineering Notebooks. The teacher will provide a list of vocabulary terms that students will need to research on their own. The teams can divide the list of terms among team members and share their definitions. All team members are responsible to know all definitions.

Day 2

Key Question: How do we get started in the design process?

The teams will be responsible for researching types of analog sensors, analog decision making and programming. Teams need to research creating comparison statements and where they are used to control the logic of a program.

The student teams discuss possible sun tracking solar control systems including:

- How does an analog sensor work?
- What kinds of sensors might we need to use?
- Where might sensors be located where they will be effective?
- Will the model meet the stated design requirements?
- Are there safety switches in place?
- What are the basic electrical safety issues?

Students can reference specific terms from the vocabulary list for specific commands to be used in the design of the solar tracking control system.

Remind students to record research notes and sources as well as reflections on the day in the Engineering Notebook.

Day 3-7
Key Question: How do we get started on our individual designs?

Student teams brainstorm needed components of their design and then create their written description of what they want the program to accomplish to add to their design brief to be include with their sketches of the location of sensors. They include operating requirements along with expected voltage readings. The design plan also includes the plan for gathering statistical data about performance. They then meet with their clients who will need to sign off on the design proposal before programming and model building begins. The client can be the teacher or an authentic advisor.

Students should work through the tutorials on Photocell, Analog Branching, NTC Resistor, Potentiometer and Data. This will take several days to work through these necessary basics.

Teams discuss how their sun tracking systems should be tested. The groups decide what components will be tested and how the team will know when their design achieves the test requirements.

Information about the sensors and programming can be found in the Activities Section. Student groups share their flow charts and programs with each other.

Day 8-9
Key Question: Why do I need a flow chart to solve this problem?

Students are given the instructions for assembling the HVAC Model. Students are asked to devise a program to turn the light on and warm the sensor. They should turn the light off at a certain temperature they determine and turn the fan on to cool the sensor. When if falls below a set temperature they determine they turn the fan off and turn the light on to repeat the cycle.

Day 10-11
Key Question: How can we begin to design our Sun tracking control system model?

Teams discuss their proposed sun tracking systems and how to achieve the design given the approved design brief they presented. They work together to brainstorm ideas and begin to narrow their vision of their solution. Next the team divides the work of creating the sun tracking device. They must also decide on sensors, wiring and programing. They utilize the division of work in the creation of the project management plan.

Students record sketches and reflections in the Engineering Notebook. Once the students have a solution to the sun tracking system design, they need to determine how the design will meet the requirements. This means students must consider how the design will be tested before building.

Teams discuss how the various designs and placement of sensors work and that the designs created will meet the automatic door system requirements and the performance will be within the specifications they established

Day 12-14
Key Question: How can we put our new designs together?

Student teams conduct meetings to review all designs elements created so far. They look at the criteria and testing protocols created. They discuss which design they wish to use as the team final design. It could be a single design or contain elements of several designs. Once the decision is made the students develop a plan for creating the team prototype. They need to create a design that incorporates their ideas. Once the final plan is completed they will create prototype program. The teams discuss the final testing of their prototypes and how that will be achieved.

Students create the final plans and begin programming and testing to see how they are communicating with the various sensors they selected. Students record any changes in their designs and enter reflections in their Engineering Notebooks.

Day 15-16
Key Question: How do we build and test our designs?

Students assemble their prototype sun tracking system. When students encounter problems assembling their prototype they must discuss how they will resolve the issue and change the design.

Students record any changes in their designs and enter reflections in their Engineering Notebooks.

Once the working prototype is assembled testing can begin to see if the model meets the stated design requirements. Students begin runs to check the accuracy of their systems. They gather data on tests and to show how accurate the system is and how the various functions are performing. Students discuss results of their initial testing and propose improvements to the system.

Day 17-18
Key Question: How do we organize our thoughts in a presentation to the class?

The student teams discuss and finish any changes that are needed.
The teacher will discuss with the teams how to optimally present their ideas.

Students discuss the outline of the presentation to their clients. The deliverables will include the prototype, program design and information about the design process and how they solved many of the issues they encountered. The students should be required to write the introduction, provide results including graphics, and form a conclusion including an acknowledgement section reporting the source of information. Students decide how to divide the work to create a team report.

Day 19
Key Question: How do we convey our ideas?

Students can present their solutions to the class one at a time. Students display the completed automatic door system model and demonstrate how it functions. Students discuss changes they would consider if they had time to create another iteration of their design.

In the end, all students can reflect on their work by giving and receiving feedback on how they could possibly improve their designs

Vocabulary:

Analog
Azimuth
Counter
CPU
Digital
Input
Load
Logic
Network
Normally Closed
Normally Open
Output
Phototransistor
Photovoltaic
Power Supply
Schematic
Switch
Tilt angle
Timers
Wiring

Resources:

Engineering Notebook:

- http://www.wisegeek.com/what-is-an-engineering-notebook.htm
- https://www.firstinspires.org/sites/default/files/uploads/resource_library/ftc/engineering-notebook-guidelines.pdf
- https://www.asme.org/career-education/articles/early-career-engineers/my-engineers-notebook-jenn-t-dandrea

Engineering Reports

- http://web.mit.edu/me-ugoffice/communication/technical-writing.pdf
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/writing_engineering_reports.html
- https://www.youtube.com/playlist?list=PLDAAF7A8FD5CD582C&feature=plcp
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/mechanical_engineering_writing_enhancement_program/report_writing.html
- https://owl.purdue.edu/owl/subject_specific_writing/professional_technical_writing/technical_reports_and_report_abstracts/reports_proposals_and_technical_papers.html

Electricity

- https://www.allaboutcircuits.com/textbook/direct-current/
- https://learn.sparkfun.com/tutorials/alternating-current-ac-vs-direct-current-dc
- https://engineering.mit.edu/engage/ask-an-engineer/whats-the-difference-between-ac-and-dc/
- https://www.school-for-champions.com/science/dc.htm#.W372zehKguU
- http://sinovoltaics.com/learning-center/basics/direct-current-dc-power-definition-and-applications/
- https://whatis.techtarget.com/definition/DC-direct-current
- http://macao.communications.museum/eng/exhibition/secondfloor/MoreInfo/2_3_1_DCCircuit.html
- https://www.khanacademy.org/science/ap-physics-1/ap-circuits-topic/introduction-to-dc-circuits-ap/a/circuit-introduction
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-5/what-are-series-and-parallel-circuits/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-1/static-electricity/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-2/voltage-current-resistance-relate/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-3/importance-electrical-safety/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-5/what-are-series-and-parallel-circuits/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-9/analog-and-digital-signals/

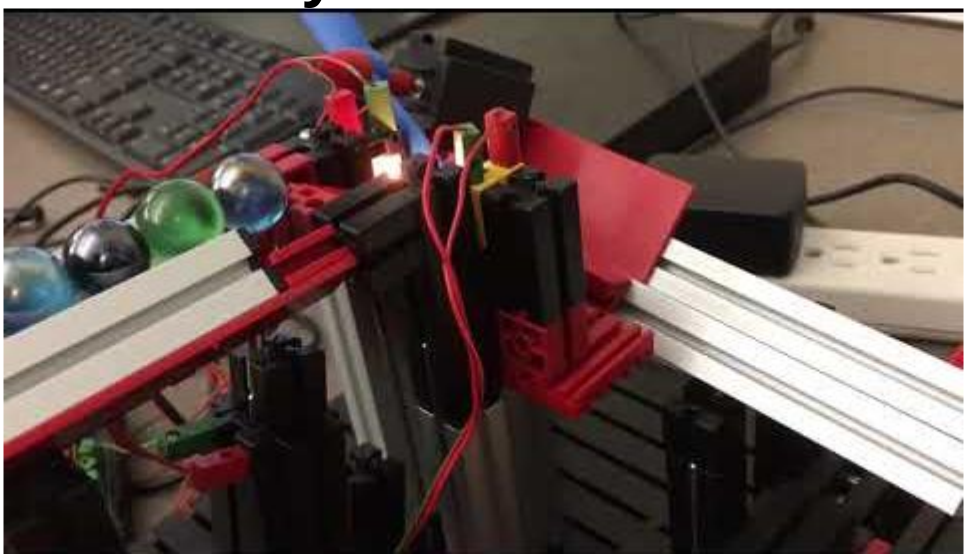
Logic

- http://www.plcdev.com/book/export/html/9
- https://www.allaboutcircuits.com/textbook/digital/chpt-6/digital-logic-functions/
- https://www.i-programmer.info/babbages-bag/235-logic-logic-everything-is-logic.html
- https://academo.org/demos/logic-gate-simulator/
- https://sciencedemos.org.uk/logic_gates.php
- http://www.cburch.com/logisim/

Solar Panels and Control

- https://w3.siemens.com/verticals/mea/en/solar-industry/field-supply/tracking-control/Documents/e20001-a100-t112-x-7600.pdf

Project: Sort by Color



Cadmium Sulfide cells (CdS Cell) are more commonly known as Photo-resistors or Photocells. They form a category of analog sensors that measure the amount of light striking the surface. The less light that strikes the surface the greater the resistance the photo-resistor has. This allows a Photo-resistor to be used in a voltage divider circuit and the level of the voltage measured can tell us how much light is striking the surface.

Introduction:

Light striking a mirror is reflected and the color appears as it did before striking the mirror. When our eye sees color we are really seeing the light reflecting of the surface of the object. Most objects reflect or absorb the light striking them differently. The darker the object the less light is reflected and the more is absorbed. If no light is reflected the object appears black to our eye.

We take advantage of this concept in basic ways. We can create paint in colors that people find pleasing. We control light used to illuminate stages for theaters, concerts and movies. In automation we use reflective light to select colors.

Calibrating sensors allows the programmer to know from the voltage created what color the sensor is “seeing”. The programmer can then select what they want to happen in the presence of a certain color. This works whenever there is a condition where there are different colors. This might be an inspection system to allow only completely finished products through and block the others. The product with one area not finished will cause a different voltage to be produced by the sensor.

Purpose of the Project:

The purpose of the Sort by Color project is the introduction to analog sensors and how they might be used to provide input signals. This project will also introduce students to comparison decision making. Students will apply the design process to solve the problem of how automate a color sorting system to only allow the correct color through the system.

Concepts:

- Creating technical solutions requires the use of mathematical analysis, scientific inquiry, and engineering design.
- Science and engineering professionals use data and graphical analysis in making decisions
- Modern design requires the ability to generate, process, and transfer information digitally using appropriate technologies.
- The Engineering Design Process is sometimes referred to as the sequential actions of research, design, build, evaluate; then redesign, and communicate.
- Engineering professionals design solutions and communicate the solutions through graphics and pictures.
- Engineers use integrity and ethics when communicating ideas, including citing sources of information.
- In all systems, there is a tradeoff between performance and complexity. Higher complexity is generally associated with higher cost; hence the shortened form of the syllogism is performance versus cost.
- Designing mechanical systems requires the knowledge and application of simple machines to manage and transform power and forces into required motion.
- Electricity is a form of energy caused by the movement of charged particles. It is often used to transfer energy from one place to another.
- The first law of thermodynamics (conservation of energy and matter) states that output power of a system is always less than the power supplied to the system.
- The design of mechanisms requires the use of dimension tolerances to assure that component parts work together effectively with minimum power losses.
- “Green Principles” of design are used for eventual disassembly and resource recovery and is referred as Product Lifecycle Management (PLM)
- A Programmable Logic Controller (PLC) is a hardened computer used for industrial automation. PLCs can automate a process, machine function, or even an entire production line.
- The term “Logic” is based upon the mathematical system called Boolean Algebra named after George Boole (Born November 2, 1815-Died December 8, 1864) who was a self-taught English mathematician and philosopher who invented this form of algebra where values are either True or False where rules are created to consistently arrive at desired values.

- The ability to collect data, transform them into information, and use that information to improve an existing process is an enabling skill for Lean manufacturing.
- Applying automated control systems to existing manual processes can dramatically improve quality and reduce the amount of human (manual) time required.
- Electronic sensors detect and transform real-world phenomena into information that is used by computers to control valves, pumps, and other industrial equipment.
- Timers allow programmers to design and control specialized clocks to turn machinery on or off for specific amounts of time.
- Keeping track of events as they occur can be accomplished using logic programs called counters.
- Analog inputs for such things as temperature, pressure, speed, etc., are voltage values that can be converted into a digital value to be stored and used by a computer.

Outline:

Documentation
- Engineering Notebook
- Documentation object to be designed

Programmable Logic Controllers (PLC)
- Basic electricity-Multimeter schematics/ Ohms law
- Setup
- Inputs
- Outputs
- Logic
- Timers
- Counters

Evaluation
- Testing of the ability sort products by color

Communication
- Presentation of design solutions

Standards:

Career and Technical Standards

Engineering Design Process

- Maintain an Engineering Notebook for research, prototype creation, documentation and daily reflections.
- Apply engineering design and problem solving as an iterative process incorporating science, mathematics, and engineering to optimally convert resources to meet a design solution.
- Communicate design solutions utilizing effective technical writing skills including correct spelling, proper grammar, and accurate technical vocabulary.

- Prepare a quantitative plan for the successful completion of a project.
- Assume leadership responsibility for collaborative team actions and decisions related to the successful completion of a project.
- Evaluate the needs and costs of resources necessary for the completion of a project.
- Prepare and communicate model documentation to include such details as product analysis, size, materials, assembly details, installation and service requirements.

Design for Manufacturing

- Understand and apply Statistical Process Control (SPC) to acquire quality control.

Design for Assembly

- Create a management plan that includes quality planning, quality control, quality assurance, and quality improvement for an advanced manufacturing environment.

Automation with Programmable Logic Controllers (PLCs)

- Design and analyze an electrical system to efficiently convert, transform, and transmit electricity to where it is needed.
- Research and specify electrical devices necessary to provide needed power.
- Apply machine control systems, sensory feedback, and information processing to increase productivity in manufacturing.
- Use flow charts and diagrams to apply logic in the design of control programs.

Applying Logic Software RoboPro to Create Problem Solutions

- Design a system of elements that manages power to accomplish a task involving defined movement.
- Design a control system to vary the speed and performance of a motor by utilizing feedback from the system to gain the most efficiency possible.
- Formulate a system to utilize data collection and analysis to maintain and improve product quality and provide adequate confidence that the product will satisfy design requirements.
- Design and analyze the application of machine control systems, sensory feedback, and information processing to increase productivity in manufacturing.

Business of Manufacturing

- Research and evaluate the new approaches of rapid development and deployment of products that saves time and is more efficient.
- Create a management plan including quality planning, quality control, quality assurance and quality improvement for an advance manufacturing environment.

College and Career Readiness Math Standards

Creating Equations

CED.A1 Create equations and inequalities in one variable and use them to solve problems.
CED.A.2 Create equations in two or more variables to represent relationships between quantities
CED.A.3 Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or nonviable options in a modeling context
CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations

Create equations that describe numbers or relationships CED

A.4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations

Quantities

Q.A.1Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays

Making Inferences & Justifying Conclusions

IC.A.1 Understand statistics as a process for making inferences about population parameters based on a random sample from that population.
IC.B.3 Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.

Reading Standards for Literacy in History/Social Studies 9-10

Key Ideas and Details

1. Cite specific textual evidence to support analysis of primary and secondary sources, attending to such features as the date and origin of the information.
3. Analyze in detail a series of events described in a text; determine whether earlier events caused later ones or simply preceded them.

Integration of Knowledge and Ideas

7. Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text.
9. Compare and contrast treatments of the same topic in several primary and secondary sources.

Range of Reading and Level of Text Complexity

10. By the end of grade 10, read and comprehend science/technical texts in the grades 9–10 text complexity band independently and proficiently.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects 9-10

Text Types and Purposes

1. Write arguments focused on *discipline-specific content.*
2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

Production and Distribution of Writing

4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Research to Build and Present Knowledge

7. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

8. Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

Range of Writing

10. Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Next Generation Science Standards

The projects engage students in the scientific and engineering practices taken from the National Research Council's Framework for K-12 Science Education, Practices, Crosscutting Concepts, and Core Ideas. This is the document upon which the NGSS are based.

These practices are used for two reasons: 1) they parallel the design process utilized in each project, and 2) they serve as the foundation of the NGSS.

The eight science and engineering practices are:

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Standards for Technological Literacy

STL Standard 1:
Students will develop an understanding of the characteristics and scope of technology.

STL Standard 2:
Students will develop an understanding of the core concepts of technology.

STL Standard 3:
Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

STL Standard 4:
Students will develop an understanding of the cultural, social, economic, and political effects of technology.

STL Standard 5:
Students will develop an understanding of the effects of technology on the environment.

STL Standard 7:
Students will develop an understanding of the influence of technology on history.

STL Standard 8:
Students will develop an understanding of the attributes of design.

STL Standard 9:
Students will develop an understanding of engineering design.

STL Standard 10:
Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

STL Standard 11:
Students will develop the abilities to apply the design process.

STL Standard 12:
Students will develop the abilities to use and maintain technological products and systems.

STL Standard 13:
Students will develop the abilities to assess the impact of products and systems.

STL Standard 14:
Students will develop an understanding of and be able to select and use medical technologies.

STL Standard 16:
Students will develop an understanding of and be able to select and use energy and power technologies.

STL Standard 17:
Students will develop an understanding of and be able to select and use information and communication technologies.

STL Standard 18:
Students will develop an understanding of and be able to select and use transportation technologies.

STL Standard 19:
Students will develop an understanding of and be able to select and use manufacturing technologies.

STL Standard 20:
Students will develop an understanding of and be able to select and use construction technologies.

Assessment:

Assessment is both formative and summative. It is an integral part of high quality instruction. During the course of a project one of the instructor's main functions is to work with student groups, keeping track of progress and providing formative assessment using feedback and promoting reflection about the design process. The focus should be on lifetime learning and 21st century skills. The goal of instruction is to promote abilities in research, problem solving, design, experimentation, testing, and collecting data.

Rubrics are used in the assessment process to communicate expectations of quality. Rubrics should be shared with students at the beginning of a project to clarify any misconceptions before beginning their work. Students can then build the skills and gather knowledge to solve the problem presented to the expectations of excellence described.

General Rubrics for Literacy tasks:
Argumentative_Pursuasive
Informational_Explanatory

Individual Project Rubric:
Color Sorting Control

Essential Question:
How do we create a program to sort different colors into bins?

Student Scenario:
You are working for Sorters Inc. Your company is working on a design for a single stream recycling company. The company wants to sort the colors of glass they are receiving by color.

Your team has been charged with coming up with an automated inspection system to look at the glass and determine the color You will have to research a method of determining what constitutes correct color and what should be rejected. Your team will have to apply this to design and implement a control program on a conveyor or ramp system.

The design requirements are as follows:

- The program must sort the glass into acceptable and non-acceptable categories.
- The program scans the parts as they pass.
- It must have a safety switch to stop the flow of products
- The program must be able to sort objects so there is a continuous flow.
- The program must separate the glass into different colors and reject any outside of the set parameters

Your team's design will be presented by use of a working model of the color sorting system controlled by the PLC. For the prototype glass marbles or similar product can be utilized to demonstrate the concept of the sorter.

The research and learning activities are designed to help students:

- Learn the basic principles of PLC control
- Apply analog sensors to monitor environmental conditions
- Apply timers or counters to control the functioning of the conveyor

Deliverables:

- Engineering Notebook with reflections, research notes, bibliography, and other processes used in the design.
- Sketches of the device and planning for programming
- Descriptions of the sensors utilized and where they should be positioned
- Working prototype
- Engineering report of the design process
- Presentation for the authentic audience

Daily Plan:
Day 1
Key Question: What are the expectations of the project?

Introduce students to the main problem by providing them with the Essential question and the project description.

Cover with your students the design process, engineering notebook and design documentation requirements. Discuss the problem statement , design brief, testing protocol and management plan. Review the elements of a good engineering report.

The teacher should also help the students outline the research they will need to do to be ready to work independently on the project at the end of the unit.

Have the students form teams of two. Allow the students sufficient time to discuss the problem. Students begin by brainstorming ideas in their Engineering Notebooks. The teacher will provide a list of vocabulary terms that students will need to research on their own. The teams can divide the list of terms among team members and share their definitions. All team members are responsible to know all definitions.

Day 2
Key Question: How do we get started in the design process?

The teams will be responsible for researching types of analog sensors, analog decision making and logic control. Teams need to research creating comparison statements and where they are used to control the logic of a program.

The student teams discuss possible color sorting control systems including:

- How does an analog sensor work?
- What kinds of sensors might we need to use?
- Where might sensors be located where they will be effective?
- Will the model meet the stated design requirements?
- Are there safety switches in place?
- What are the basic electrical safety issues?

Students can reference specific terms from the vocabulary list for specific commands to be used in the design of the color sorting control system. Other tutorials in the Resources section are available for student use.

Remind students to record research notes and sources as well as reflections on the day in the Engineering Notebook.

Day 3-7
Key Question: How do we get started on our individual designs?

Student teams brainstorm needed components of their design and then create their written description of what they want the program to accomplish to add to their design brief to be include with their sketches of the location of sensors.

They include operating requirements along with expected voltage readings. The design plan also includes the plan for gathering statistical data about performance. They then meet with their clients who will need to sign off on the design proposal before programming and model building begins. The client can be the teacher or an authentic advisor.

If students need review about analog sensors and decision making have them review the tutorials on Photocell, Analog Branching, NTC Resistor, Potentiometer and Data. This will take several days to work through these necessary basics.

Teams discuss how their color sorting systems should be tested. The groups decide what components will be tested and how the team will know when their design achieves the test requirements.

Information about the sensors and programming can be found in the Activities Section. Student groups share their flow charts and programs with each other.

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Key Question: How can we begin to design our Color Sorting control system model?

Teams discuss their proposed color sorting systems and how to achieve the design given the approved design brief they presented. They work together to brainstorm ideas and begin to narrow their vision of their solution. Next the team divides the work of creating the color sorting device. They must also decide on sensors, wiring and programing. They utilize the division of work in the creation of the project management plan.

Students record sketches and reflections in the Engineering Notebook. Once the students have a solution to the color sorting system design, they need to determine how the design will meet the requirements. This means students must consider how the design will be tested before building.

Teams discuss how the various designs and placement of sensors work and that the designs created will meet the color sorting system requirements and the performance will be within the specifications they established

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Key Question: How can we put our new designs together?

Student teams conduct meetings to review all designs elements created so far. They look at the criteria and testing protocols created. They discuss which design they wish to use as the team final design. It could be a single design or contain elements of several designs. Once the decision is made the students develop a plan for creating the team prototype. They need to create a design that incorporates their ideas. Once the final plan is completed they will create prototype program. The teams discuss the final testing of their prototypes and how that will be achieved.

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Day 14-16
Key Question: How do we build and test our designs?

Students assemble their prototype color sorting system. When students encounter problems assembling their prototype they must discuss how they will resolve the issue and change the design.

Students record any changes in their designs and enter reflections in their Engineering Notebooks.

Once the working prototype is assembled testing can begin to see if the model meets the stated design requirements. Students begin runs to check the accuracy of their systems. They gather data on tests and to show how accurate the system is and how the various functions are performing. Students discuss results of their initial testing and propose improvements to the system.

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Key Question: How do we organize our thoughts in a presentation to the class?

The student teams discuss and finish any changes that are needed.
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Students discuss the outline of the presentation to their clients. The deliverables will include the prototype, program design and information about the design process and how they solved many of the issues they encountered. The students should be required to write the introduction, provide results including graphics, and form a conclusion including an acknowledgement section reporting the source of information. Students decide how to divide the work to create a team report.

Day 19
Key Question: How do we convey our ideas?

Students can present their solutions to the class one at a time. Students display the completed color sorting system model and demonstrate how it functions. Students discuss changes they would consider if they had time to create another iteration of their design.

In the end, all students can reflect on their work by giving and receiving feedback on how they could possibly improve their designs

Vocabulary:

Analog
Connection Terminals
Counter
CPU
Digital
Input
Load
Logic
Network
Normally Closed
Normally Open
Output
Phototransistor
Photovoltaic
Power Supply
Power Terminals
Schematic
Switch
Tilt angle
Timers
Wiring

Resources:

Engineering Notebook:

- http://www.wisegeek.com/what-is-an-engineering-notebook.htm
- https://www.firstinspires.org/sites/default/files/uploads/resource_library/ftc/engineering-notebook-guidelines.pdf
- https://www.asme.org/career-education/articles/early-career-engineers/my-engineers-notebook-jenn-t-dandrea

Engineering Reports

- http://web.mit.edu/me-ugoffice/communication/technical-writing.pdf
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/writing_engineering_reports.html
- https://www.youtube.com/playlist?list=PLDAAF7A8FD5CD582C&feature=plcp
- https://owl.purdue.edu/owl/subject_specific_writing/writing_in_engineering/mechanical_engineering_writing_enhancement_program/report_writing.html
- https://owl.purdue.edu/owl/subject_specific_writing/professional_technical_writing/technical_reports_and_report_abstracts/reports_proposals_and_technical_papers.html

Electricity

- https://www.allaboutcircuits.com/textbook/direct-current/
- https://learn.sparkfun.com/tutorials/alternating-current-ac-vs-direct-current-dc
- https://engineering.mit.edu/engage/ask-an-engineer/whats-the-difference-between-ac-and-dc/
- https://www.school-for-champions.com/science/dc.htm#.W372zehKguU
- http://sinovoltaics.com/learning-center/basics/direct-current-dc-power-definition-and-applications/
- https://whatis.techtarget.com/definition/DC-direct-current
- http://macao.communications.museum/eng/exhibition/secondfloor/MoreInfo/2_3_1_DCCircuit.html
- https://www.khanacademy.org/science/ap-physics-1/ap-circuits-topic/introduction-to-dc-circuits-ap/a/circuit-introduction
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-5/what-are-series-and-parallel-circuits/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-1/static-electricity/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-2/voltage-current-resistance-relate/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-3/importance-electrical-safety/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-5/what-are-series-and-parallel-circuits/
- https://www.allaboutcircuits.com/textbook/direct-current/chpt-9/analog-and-digital-signals/

Logic

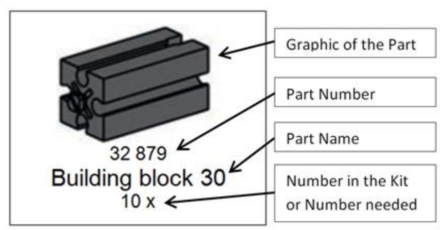
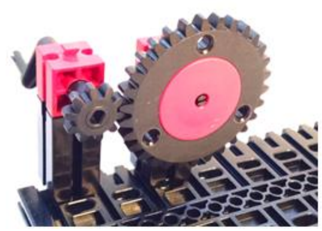
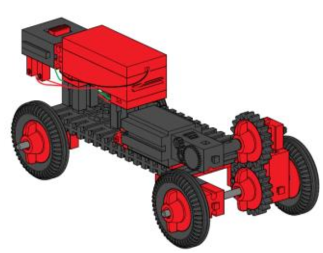
- http://www.plcdev.com/book/export/html/9
- https://www.allaboutcircuits.com/textbook/digital/chpt-6/digital-logic-functions/
- https://www.i-programmer.info/babbages-bag/235-logic-logic-everything-is-logic.html
- https://academo.org/demos/logic-gate-simulator/
- https://sciencedemos.org.uk/logic_gates.php
- http://www.cburch.com/logisim/

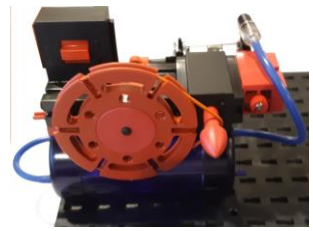
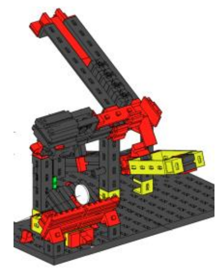
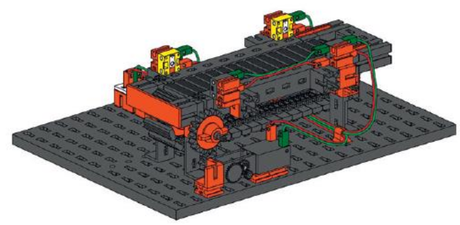
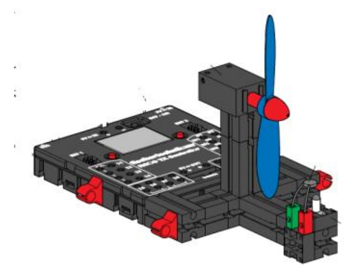
CdSCells

- http://www.bristolwatch.com/ele/pd.html
- https://learn.adafruit.com/photocells/overview
- https://acroname.com/examples/reading-photoresistor-using-reflex
- https://www.radio-electronics.com/info/data/resistor/ldr/light_dependent_resistor.php
- https://www.youtube.com/watch?v=QMLjeZ81d_s
- https://www.youtube.com/watch?v=mU3tHvMCGi0

Studica

fischertechnik section

How Components Go Together	
Part Identification	
Building a Simple Model	
Vehicles	

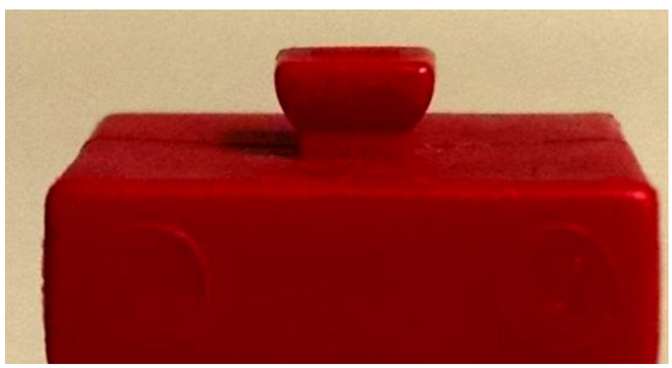
Compressor	
Block Feeder	
Conveyor	
HVAC	

How Components Go Together

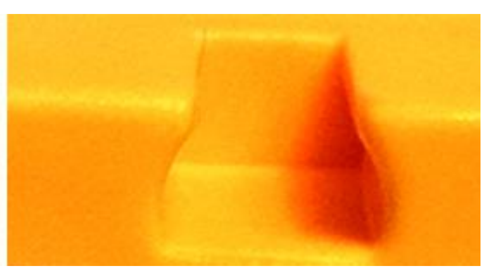
The fischertechnik modeling system is a modularized system. This means that a reference dimension is used and then all the components are based upon the same dimension. With this building system 15mm is the base measurement. This makes them easier to assemble. The components fit together in a variety of ways depending on the design and what we want the parts to do when they are actually assembled.

Pin and Groove

The basic assembly is done with what is known as pin and groove. The pin (shown in the close-up below is wider at the end with a narrow neck.

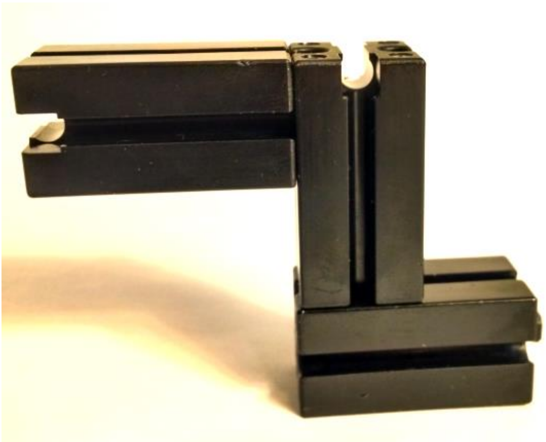


The Groove is shaped to accommodate the pin. It might appear as a circular path (left) or on some parts it might resemble a dovetail shape (right.

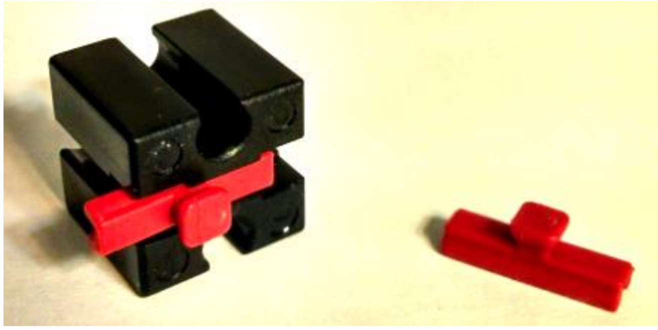
These fit snuggly together. The pins are designed to enter at a 90 degree angle and not allow the part to rotate.

The parts need to slide in from the end and then down the groove until the desired position is reached.

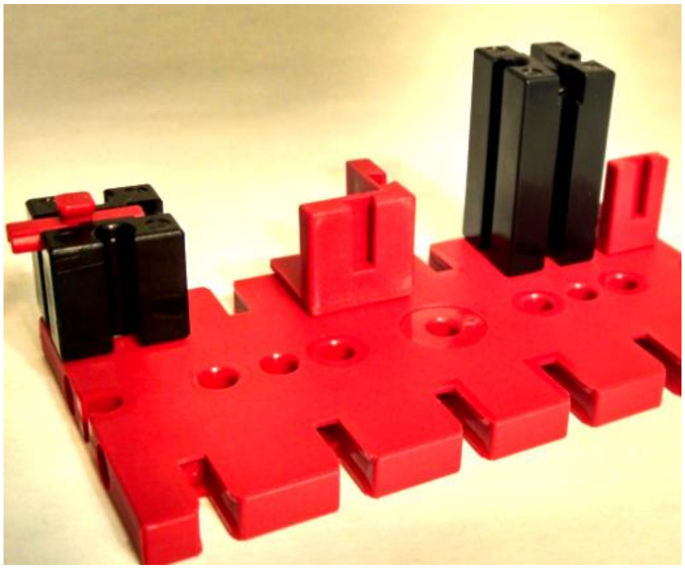


To remove the components they must be slid apart in the same manner they were put together with the part sliding to the end where the pin releases from the groove. Pulling straight out will damage the pin.

When a pin is needed on a component a part known as a spring cam is used. The spring cam is red and shown in the photo below. It is slid into the selected groove and positioned where needed. This allows you to place a pin anywhere in a groove.

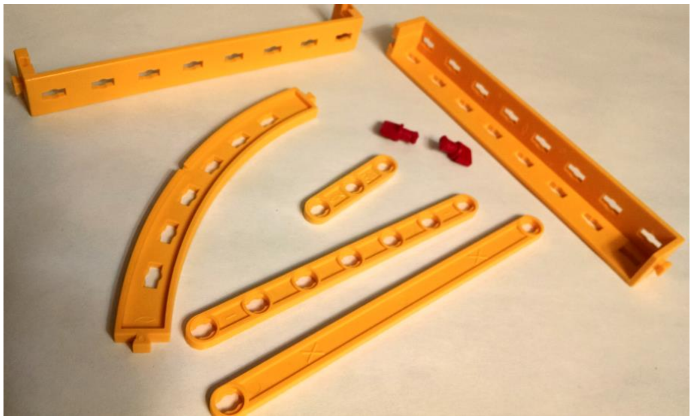


The picture below shows several different types of components that have been slid into the grooves of the baseplate.

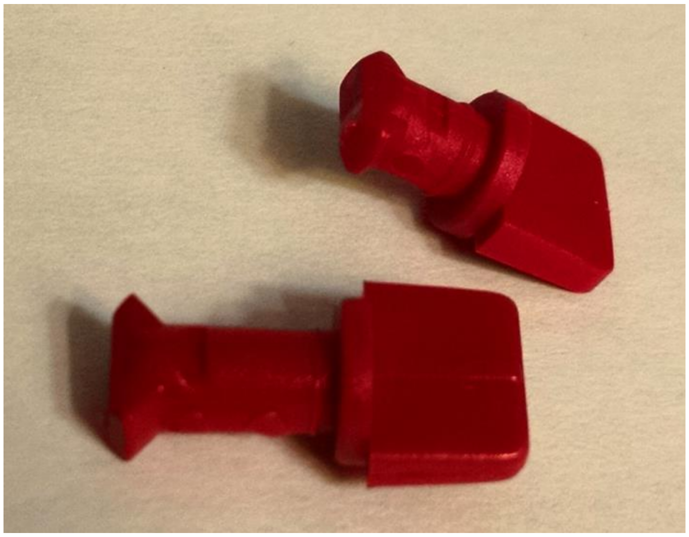


Girders and Rivets

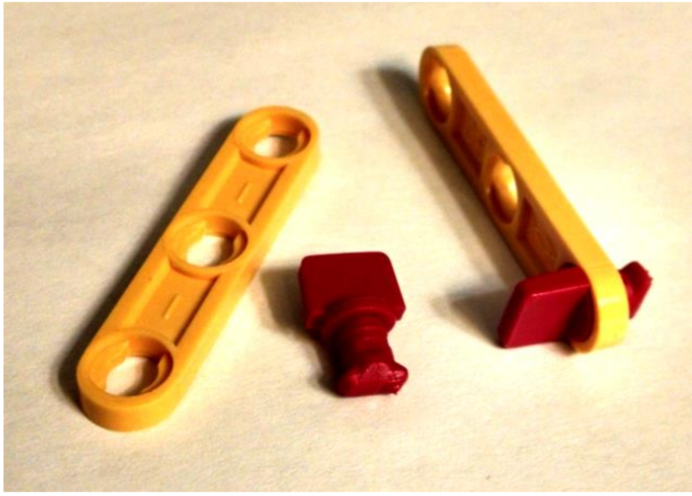
When building larger structure; girders, beams and struts are utilized to create the structure and add support to resist tension and compression forces. Rivets are used join the struts to the girders and to align the components. The ends of the girders and beams have the pin and groove system and the centers have a different type of shape.



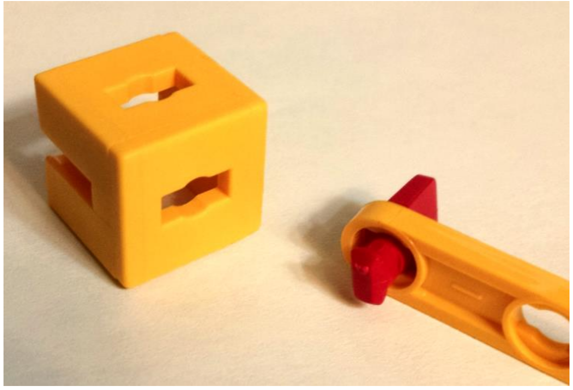
There are two sizes of rivets. The most common is the 4 mm rivet that is shown in the upper position. The 6mm rivet is used to join three components all together.



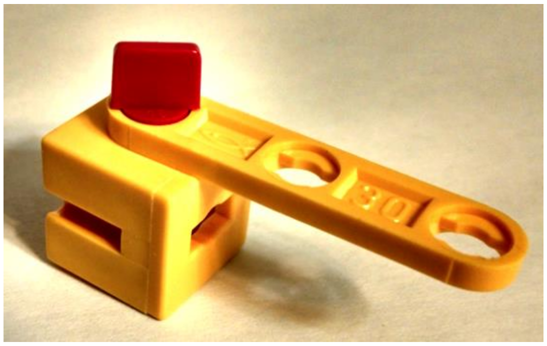
The rivets are shaped so they only pass through the shape in one position and then are rotated to make removing the rivet difficult.



The rivet passes through a bore in a strut and then into the desired location on a girder of beam.

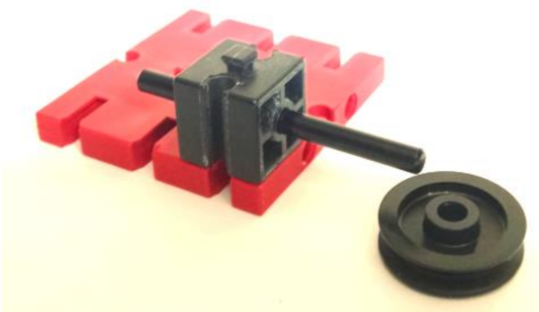


Once they are in the desired position the rivet is rotated 90 degrees to tighten the joint and to hold it in position.



Axles

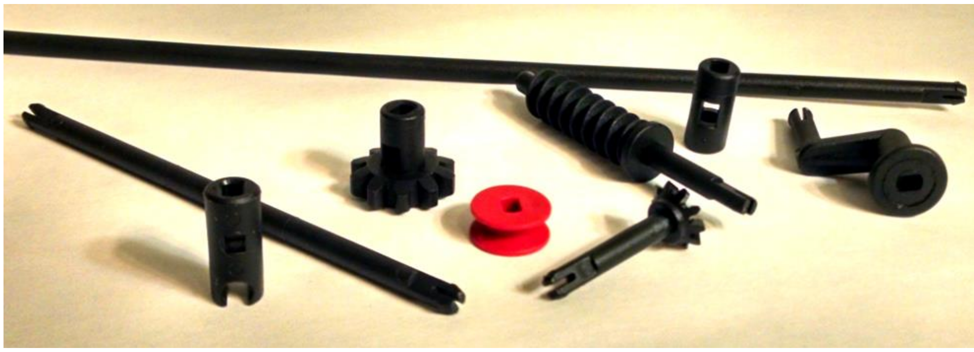
When parts need to rotate axles are used. The axles need to be supported so special blocks are used. In the picture below the axle is passing through a 15mm building block with two pins and bore.



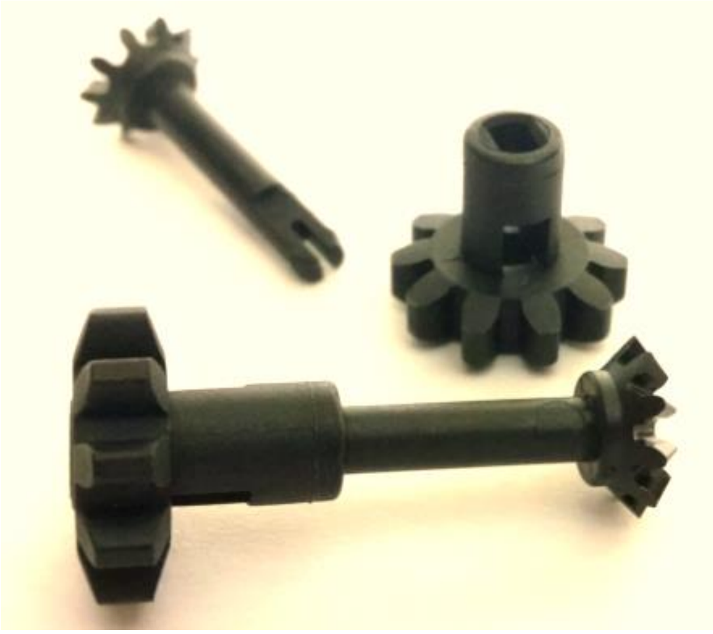
There are also times when we want to use objects besides a pulley on an axle. Hubs are used to allow soft objects such as tires to be utilized with the specially sized axles. The hubs are designed to push into the center of the tire and the friction fit keeps them aligned.

Clip Axles

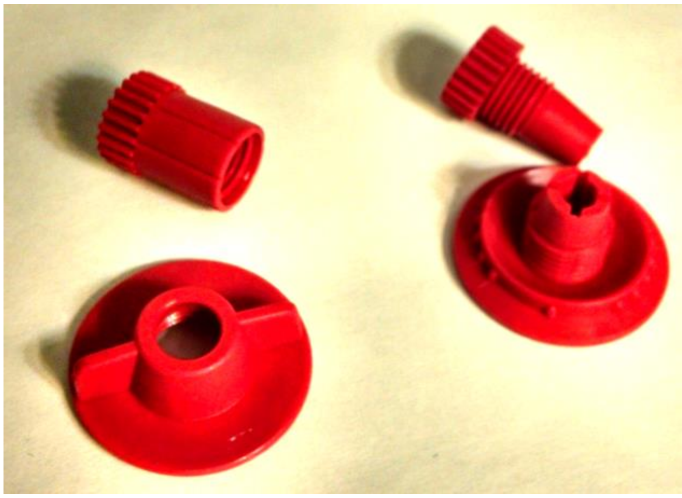
There are two major types of axles in use with the system. The smooth axle is shown in use above. Below is a picture of many of the clip axle components. These axles have a specially shaped end that makes joining components together much easier.



The special shape on the end allows the part to compress when entering the other component and then expand holding it firmly in place. The picture below shows the clip axle end on the bevel gear and the clip axle receptor on the cog wheel. The bevel gear is aligned and then slowly inserted into the cog wheel until a small click is heard. The remove the parts the force is directly reversed with a smooth pulling action to separate the components.

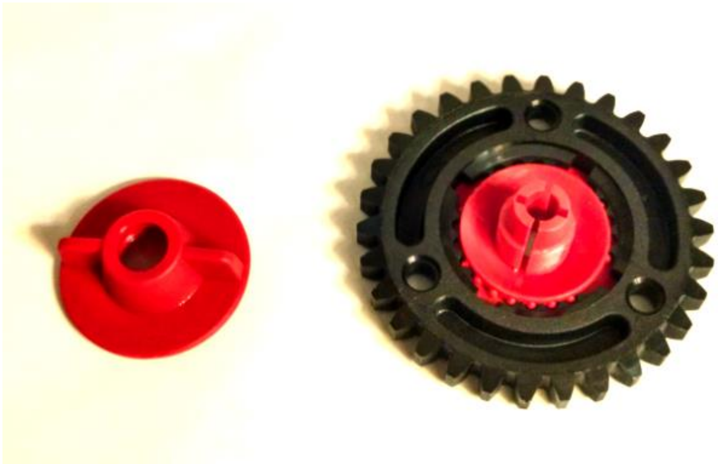


If we need to attach a component to an axle or make the system adjustable we utilize a component known as a collet. A collet is a type of chuck or clamp that forms a collar around the shaft. Pictured below are two different collet systems.



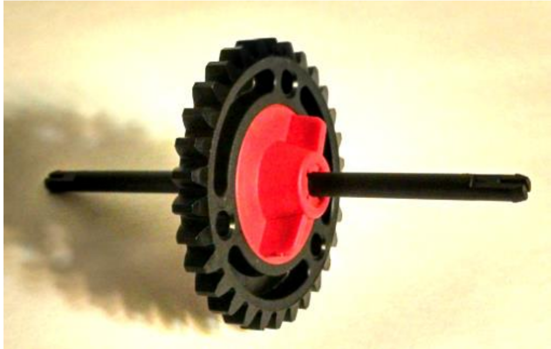
They consist of a threaded part that has separations in it. As the tapered cap is threaded onto the collet the sections of the collet squeeze together and clamp onto the shaft passing through the center. When the collet is lose the shaft is free to pass in and out. When the cap is tightened the movement ends and the shaft is caught in position. In the example below a collet is used to hold a gear in position on a shaft.

The gear is place upon the collet.



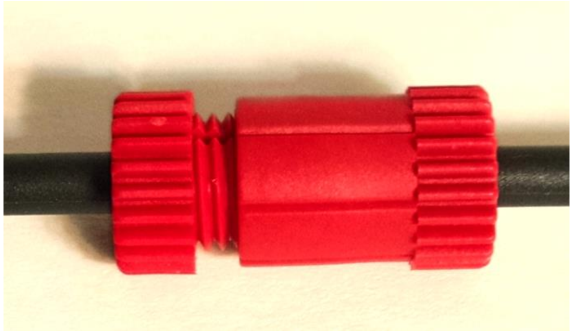
Notice the collet has notches on the outside to help the gear connect with the collet.

The cap is lightly placed on the axle and the entire assemble is slid into position and tightened. To adjust you will need to loosen the nut and then retighten the cap when it is exactly where you want it.



There are a number of gears, cams, pulleys, tires and other components that can be placed upon shafts in this way.

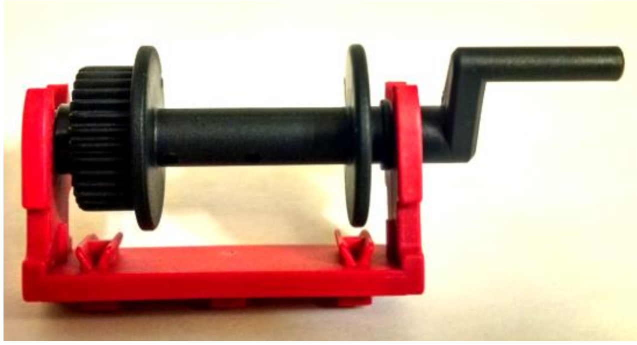
Below is pictured a different type of collet that is attached to a shaft.



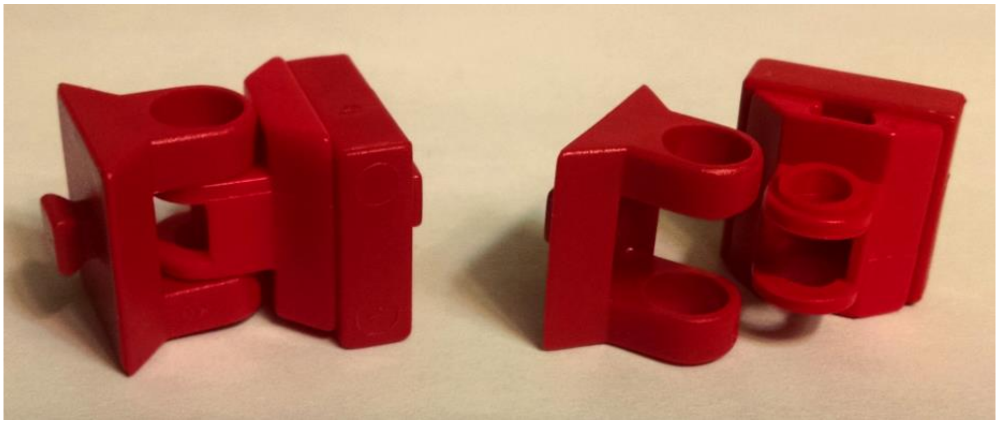
Snap Fit Parts

There are some components that are just snapped together. The shape of the parts allows them to be pushed together and the once together remain in position. If they are not needed separately anywhere else you might consider leaving them together.

Below is the cable winch drum and cable winch frame.



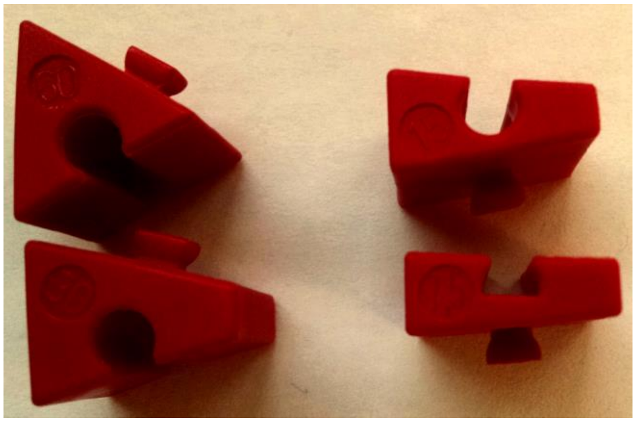
Hinge block and claw are commonly used together to allow movement in assemblies. Generally they are only used together.



Another component that is joined in this way is the chain link. The links are set up so they are in the same position and then the long link is snapped into the shorter link. The chain is then used with gears for making drive trains. It is also commonly used with track links to make conveyor belts or caterpillar tracks.

Angle Pieces:

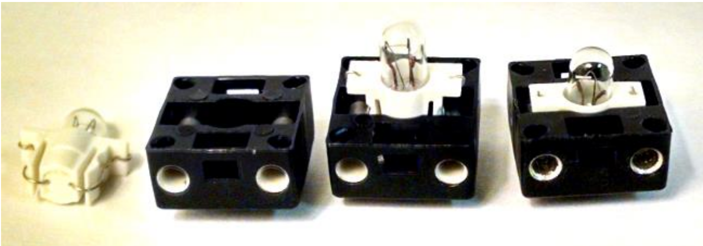
In addition to square blocks the kit comes with angle blocks. There are four sizes 7.5, 15, 30 and 60 degree blocks. There is a number on one side of the block. This way you can visually check to see the angle of the block.



Assembling the lights

The kit comes with two different kinds of lamps. They look very similar. The lens tip bulb has a heavy lens in the front and is in a grey socket shown in the left of the picture below. The regular bulb is in a white socket and has an even glass all the way around. The lens tip bulb can be used anywhere but when you are using the phototransistor you should use the lens tip bulb as it focuses the light.

Before using the lamps they must be inserted into a socket. In the picture below you can see the lamp and the socket. The lamp must be lined us so the wires on the sides of the bulb will contact the metal bars in the socket. The correct alignment is shown in the picture in the middle. Be sure the lamp if fully seated in the socket before using. See the picture on the right.



Motor and Transmission

The motor has two long pins on the end with the worm gear. The transmission has two grooves on the end. These are shown in the left hand side of the picture below. The pins are slid into the long grooves as shown in the middle picture. The picture on the right shows the motor fully seated in the transmission. You can tell it is fully seated when the gears on the side no longer turn.

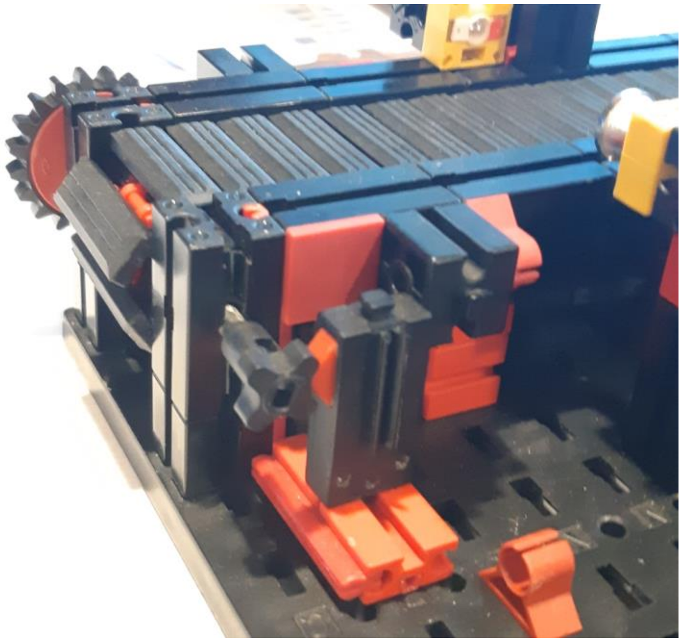
Sometimes the motor and transmission are used by themselves. Other times an additional clip axle with gear wheel is added. The clip axle can then connect to any clip axle coupling or device. The axle is inserted through the hole in the side of the transmission. The clip axle will click into place and the gears should be fully meshed.

Using the Motor with the Propeller

Sometimes the motor is used without the transmission. This is the case when you are using the propeller. The propeller is assembled with the pointed adaptor for the propeller. The pointed adaptor slides over the worm gear on the end of the motor. Care should be taken that you slide the pointed adaptor evenly over the gear to keep it aligned.

Using the Pulse Wheel with a Switch for Counting

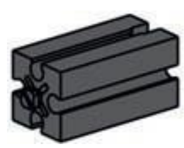
There are times when positions can be found by counting a series of pulses. The pulse wheel has four lobes which will push on the switch as the shaft rotates. Each pulse can be counted and added or subtracted from a total count so positions can be set.



Part Identification

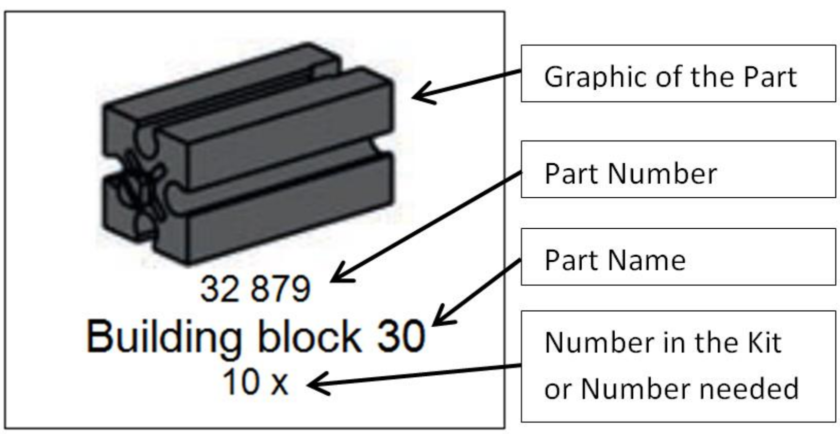
For each kit and project there is a list of necessary components. Each list is graphical and contains a wealth of information. This section will help you read and interpret the data presented. Every list contains a lot of parts and we have attempted to provide you with a lot of information about the parts and how they are used.

In the picture below you see a typical part.



32 879
Building block 30
10 x

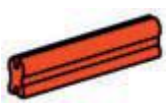
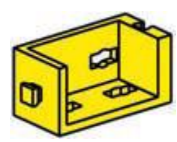
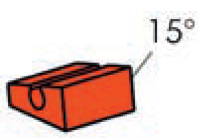
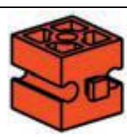
When you look at the part you will see four basic pieces of information shown in the graphic below.

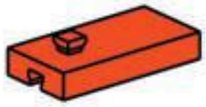


The graphic representation of the part is usually color accurate. Parts can be physically the same but a color change will give them a separate part number. The part numbers can be used to order spare parts and be sure you are getting exactly what you need. An exercise will have a parts list of what is needed for that specific section of the curriculum. Generally with young students the breath of parts can be intimidating and many experienced teachers will use the list to build small kits of just what is needed.

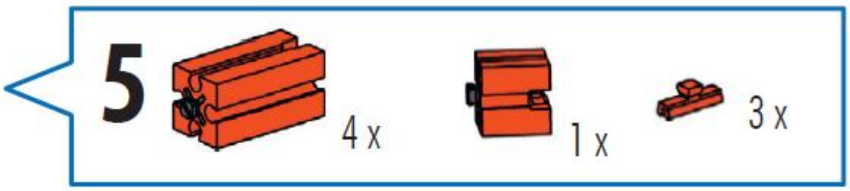
This helps with getting all the parts back. Many people take the parts list and use those as labels for the various part bins for storage. The number of parts in the kit is the same, but the number needed for each exercise will change.

The part name contains a lot of information about the part. It is important to note that these components are modular in nature so you will see many of the dimensions follow patterns. In the pictures below you will see several examples of the naming conventions and what they mean.

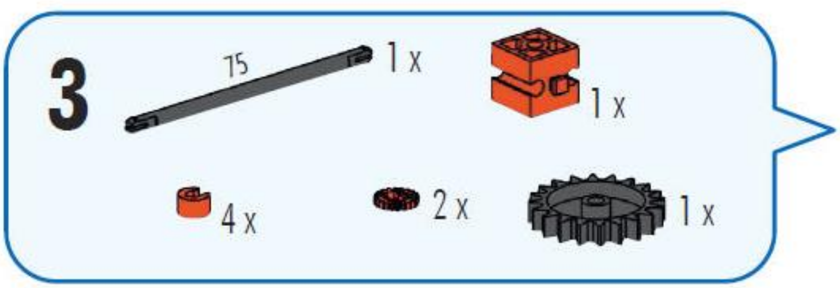
 31 019 Large pulley 60 1 x	This large pulley is also 60 mm in diameter. The number after the name generally points to a size description	 36 336 X-Strut yellow 169,6 2 x	Struts are mechanical components used to resist compression forces. This one is 169.6 mm in length. In many parts of the world the comma is used to represent decimals.
 31 021 Gear wheel T20 1 x	This Gear Wheel has 20 teeth around the circumference. This knowledge comes in handy when combining with other gears to help calculate the gear ratio and mechanical advantage	 35 063 Clip axle 30 2 x	There are many parts such as this clip axle that come in various lengths. The length becomes important to models. This one is 30 mm.
 31 061 Link 30 2 x	This part known as a link can slide into the grooves between parts for a good fit. This one is 30 MM long.	 36 299 Angle girder 30 8 x	Girders are structural components. Each part has the length listed. This one is 30 MM
 31 981 Angular block 15° 2 x	The angle blocks are each identified by the number of degrees between the surface with the pin (bottom of the part) and the surface with the groove (top of the part)	 37 238 Building block 5 with 2 pins 4 x	When a part is not in the traditional pattern it is noted in the name. For example this one is 5mm thick but has a pin on both faces
 32 064 Building block 15 with bore 7 x	This is a 15 mm by 15 mm block. The term “with bore” is used to let you know that an axle will slide through the bore and have freedom to rotate.	 37 468 Building block 7,5 6 x	This building block is half the thickness of the modular thickness

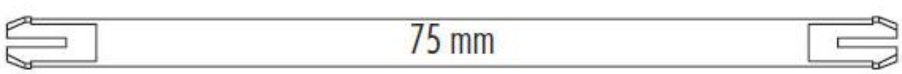
 35 049 Building block 15x30x5 with groove and pin 2 x	This building block is 15 mm wide, 30 mm long and 5 mm thick. It has a pin on one end and a groove the length of the other. It is handy for making adjustments to mechanisms	 38 258 Rope pulley 12 2 x	This pulley is 12 mm in diameter

When your students are following the instructions in the manuals you will see groups of parts listed with the step number. In the example pictured below you see there are three different kinds of parts needed for the step. The first part needed is the 30mm block and the students will use four of that part. Then three of spring cams and one of the of 15mm blocks will be used.



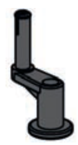
In the case where there could be confusion there is usually a graphic to assist you. In the example below you will see that a clip axle 75 is needed. The picture of the clip axle below the call out is actual size so student can get visual feedback they have the correct device.





Building a Simple Model

This exercise will help you understand how to build a simple model with the fischertechnik modeling system. The first step in building a model is to be sure you have the correct parts. This model will use the following parts.

 35 129 Base plate 120x60 1 x	 35 063 Clip axle 30 2 x	 35 088 Crank shaft 1 x	 32 879 Building block 30 2 x
 32 064 Building block 15 with bore 2 x	 36 264 Gear wheel T30 1 x	 35 945 Cog wheel T10 1 x	 35 031 Flat hub collet 1 x
 31 058 Hub nut 1 x			

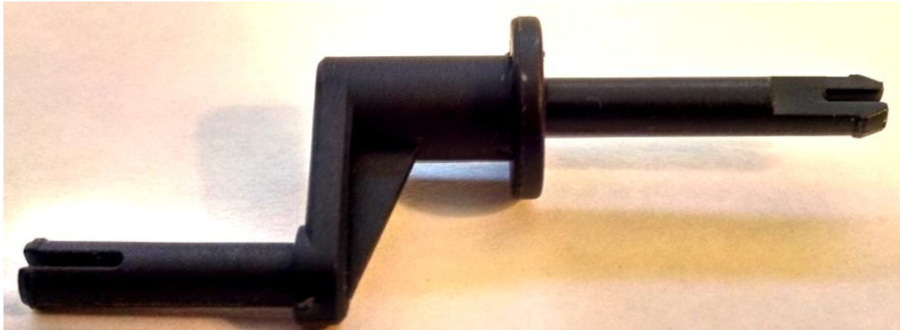
Once you have the twelve parts lay them out on the organizer above. There are three parts that you will need a quantity of two.

The first step is to take a building block 15 with bore and join this to a building block 30 by sliding the pin of the building block 15 with bore into the groove on the building block 30. A bore is a term we use for a really round hole.

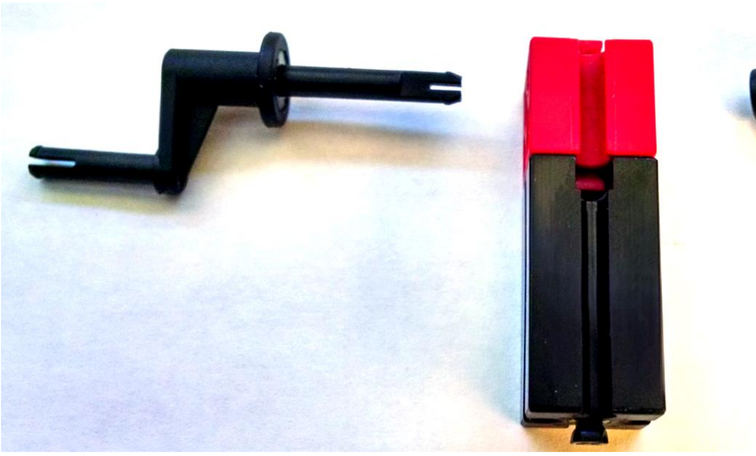
Do that step a second time so you have two sets.

Set those aside and find the crank shaft and one of the clip axles. Set them next to each other on your table.

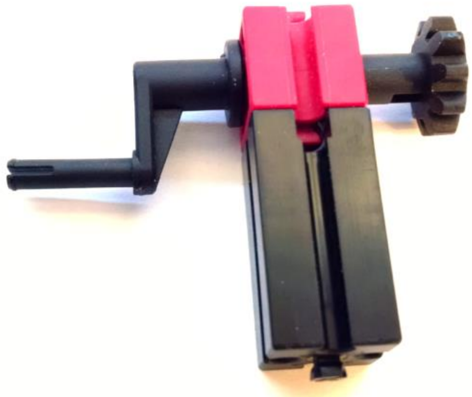
Line up the clip end of the axle with the opening in the crank shaft. Insert the shaft into the crank shaft. It will look like the picture below.



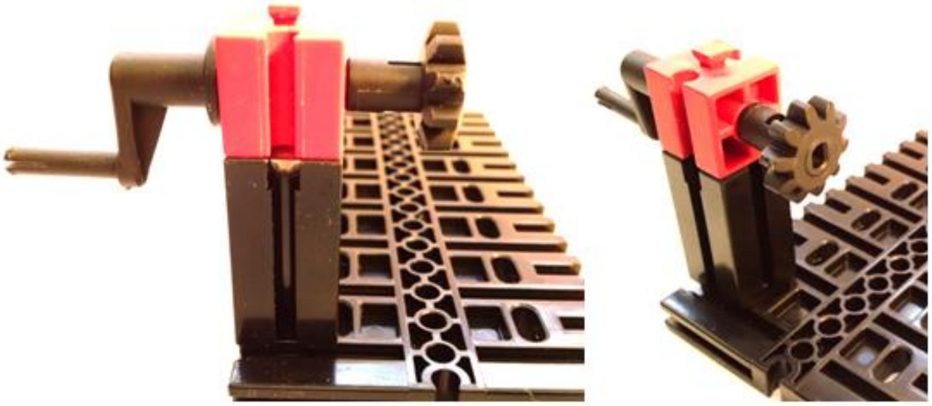
Take one of the sets of building blocks you created in the first step and a cog wheel. Place them on your table like the picture below.



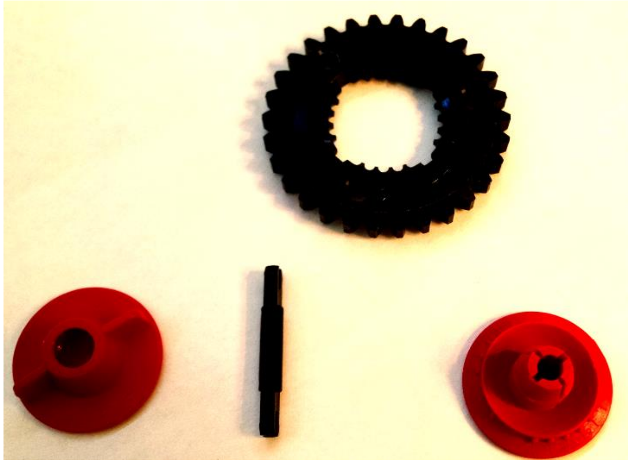
Slide the clip axle through the bore in the block. Insert the cog wheel on the other end of the clip axle. It should look like the picture below.



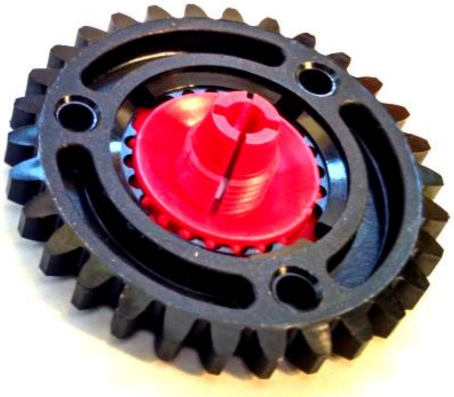
Find the base plate and place that on your table. Slide the end of the block 30 into the first short groove on the plate. Below are two views of the assembly so far.



Now take the other clip axle, the gear wheel 30, the flat hub collet and the hub nut and place them on the table in front of you.



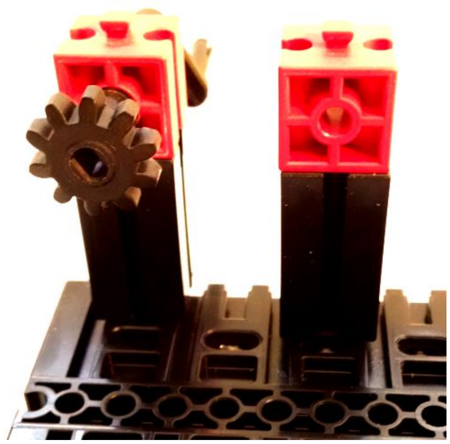
Place the gear wheel 30 on the flat hub collet. It should look like the picture below.



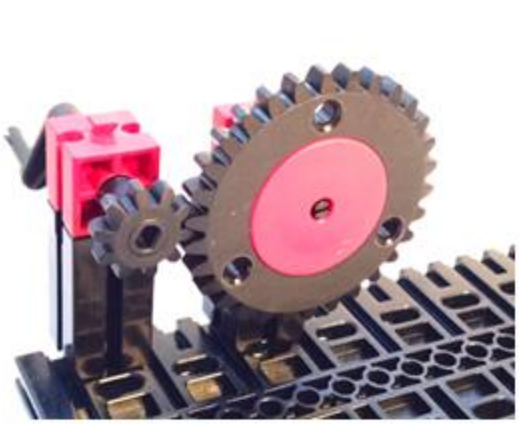
Now insert the clip axle in the center of the flat hub collet. The table will keep the axle from going all the way through the collet.

Place the hub nut over the axle and tighten the nut so it is tight and the axle will not move. Tighten it only with your fingers to prevent damage. Engineers call this finger tight.

Now take the other block 30 and block 15 with bore that you put together before and add that to the base plate. Place this assembly in the third short slot on the base plate, leaving one short groove between the two block towers. Be sure the bore is facing in the same direction as the first assembly.



Insert the clip axle into the empty bore and line up the gears.




Your assembly is now complete. Turn the crank and observe what happens.

Activities

The activities are arranged in the order of the curriculum. They can be accessed from this page to make it easier for students to have them on their computers.

Sketching Activity

Purpose:

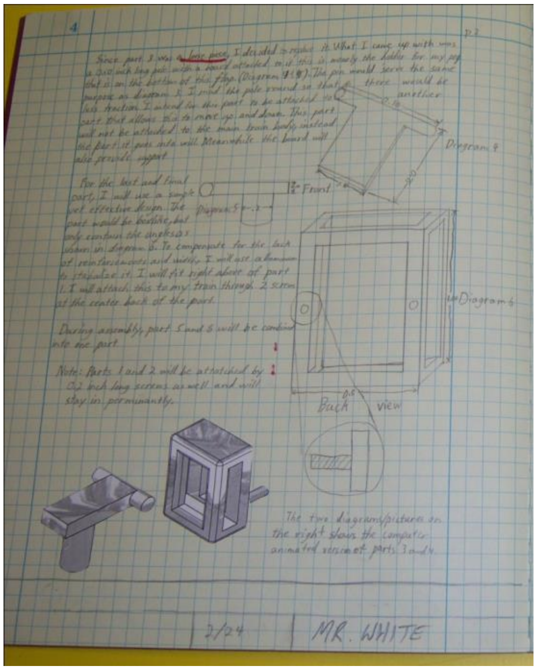
The primary objective of the sketch is effective communication. One of the most difficult things is to evaluate your work through someone else's eyes. Put yourself in the position of the person who must interpret your sketch. If you have trouble finding the right piece of information someone else will not be able to either. Sketches are used for planning and design and to help visualization. Frequently several people work on the same sketch sharing ideas. Sketches are frequently used to create field drawings to record important information.

Equipment:

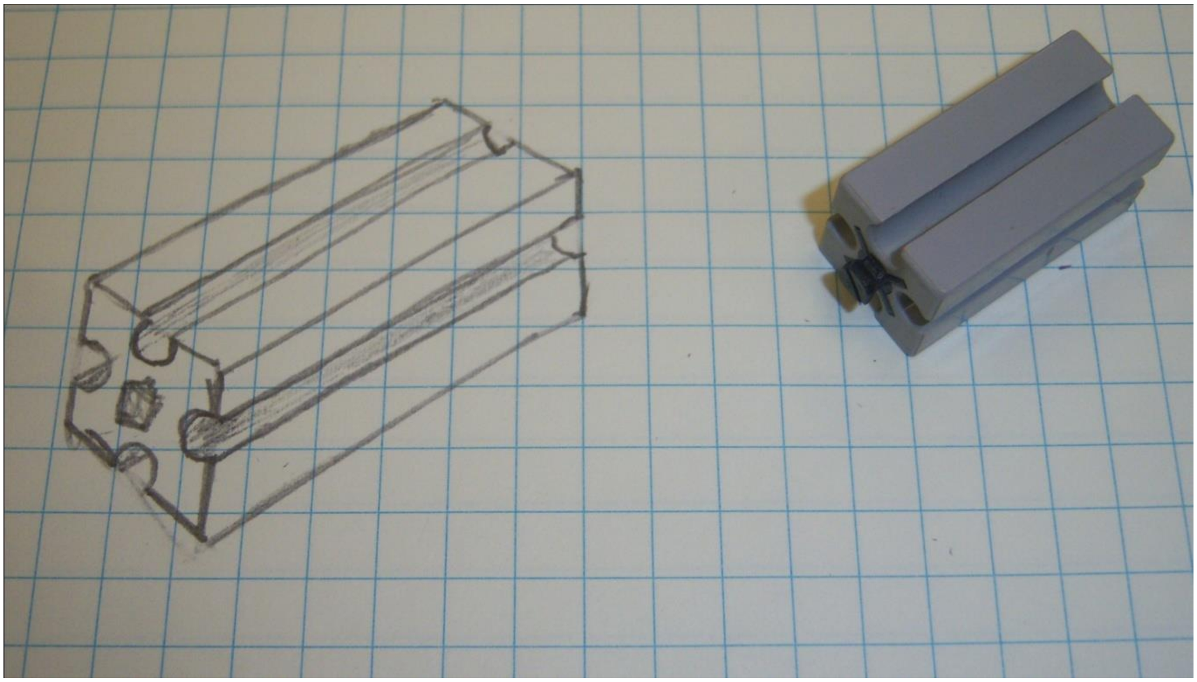
Pencil
Engineering notebook

Procedure:

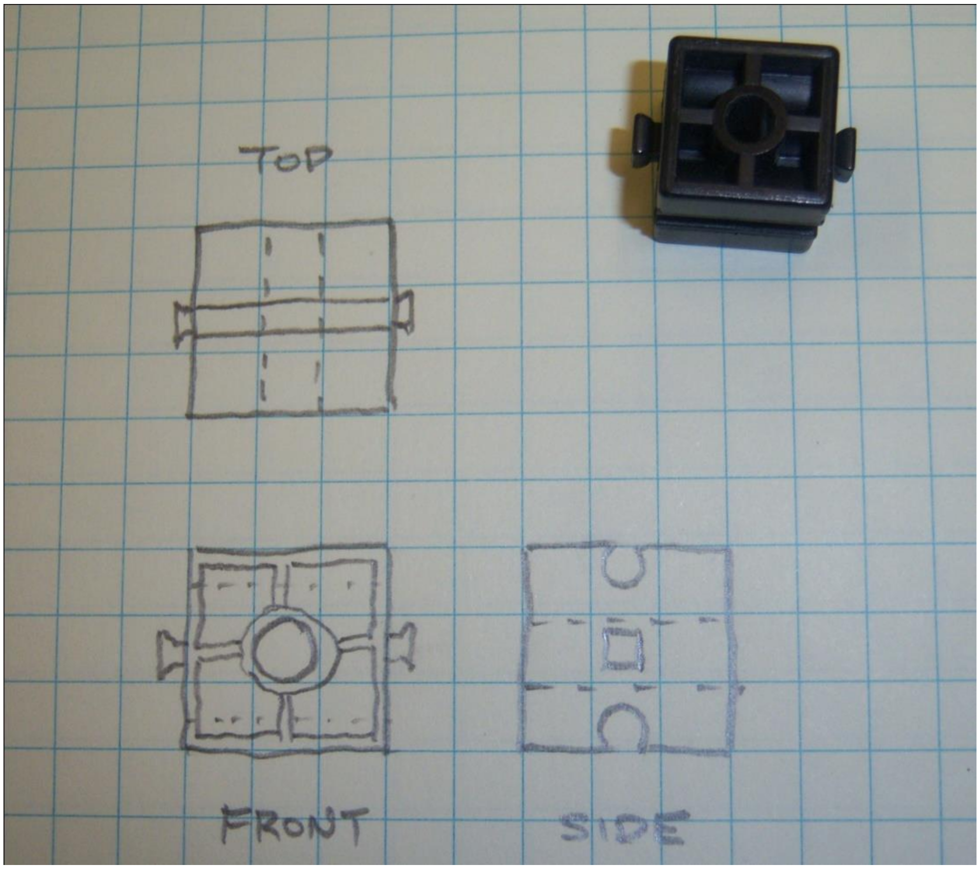
All sketching should be done in the engineer's notebook with a pencil. No other tools are needed. Sketches that contain notes on them are considered annotated sketches. Below is an example of an annotated sketch in an engineer's notebook.



There are many different ways to sketch objects in your notebook. We always use pencil and we want to make the object or design look as real as possible. The first object we will practice sketching on is a 30mm building block. This following representation is called isometric, and it shows 3 sides at once. Each side is drawn approximately 30 degrees up from the horizon. Please be careful to pay attention to size and proportion. Now let's try sketching a 30 mm building block in an isometric view on our own. Students can also sketch a 15mm or other block of their choice in an isometric view.



The next common way to sketch objects in our notebook is called mutiview or orthographic.. This is where we look at each side of the block straight on and sketch it as we see it. The lower left view is called a front view and this should be the most descriptive. The view on top is indeed the top view and the view on the right is the right side view. The short dashed lines are called hidden lines and indicate something is there but cannot be seen in that view. Now let's try sketching a multiview of a 30mm building block. Please keep all the views placed properly paying attention to size and proportion. Students can also sketch a 15mm block or another block of their choice. Final sketches should be shown to the instructor for approval.



Conclusion:

Try sketching other objects using both graph paper and isometric graph paper. Once you have the sketch done on the graph paper try to create the same sketch without the graph paper.

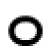
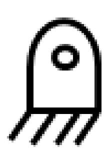
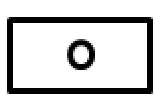
Linkage Diagrams

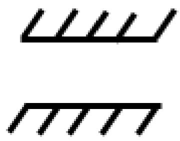
Purpose:
When sketching linkages it is standard practice to utilize schematic symbols to represent the parts. This allows a fast representation where the details can be filled in at a later time. It allows for the quick notation of existing systems and for quickly representing new ideas. In this activity you will be looking at mechanisms and creating a schematic representation of it.

Equipment:
Pencil
Engineering notebook

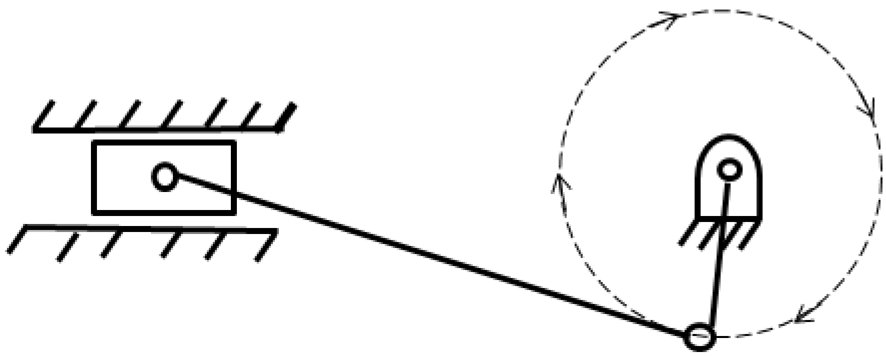
Procedure:
Since all the components of a mechanism are considered links the non-movable parts have a grounding symbol under them. See the fixed pivot point and housing symbols in the chart below. Everything else can move. The pins are placed where these components come together. The pin is a movable joint tying the two points together.

The chart below shows the most common symbols for you to use in your schematics.

	Pin Joint
	Fixed Pivot Joint
	Slider

	Housing
	Linkage

Browse to view the crank and slider at
http://www.technologystudent.com/cams/crkslid1.htm.
Watch the action. Compare the action to the schematic below.



Label the parts on the schematic.

Conclusion:

Now browse to http://www.technologystudent.com/cams/link1.htm

You will see four linkages on that page. Sketch the four linkage schematics in your engineering notebook. Check with your partner to be sure you agree on what you have drawn.

Schematics

Purpose:

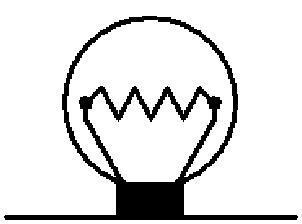
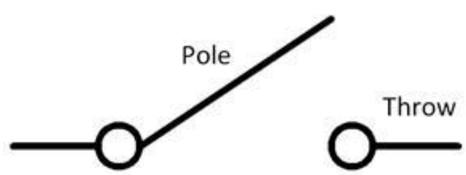
Schematic diagrams are used to show an element by element relationship of all the elements in a system. Schematics are drawings using a set of standardized symbols to show the arrangement and interconnections of the conductors and components of your electrical devise or system. They are used to quickly convey the how a circuit should be set up using an organized two dimensional representation of the wiring. By using standardized symbols anyone who understands the symbols can read and interpret the drawing. You should know that different countries use slight variations in symbols. This activity will show you the basics of how to create a schematic and use it to communicate your designs.

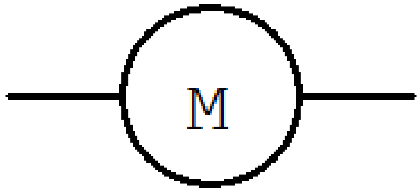
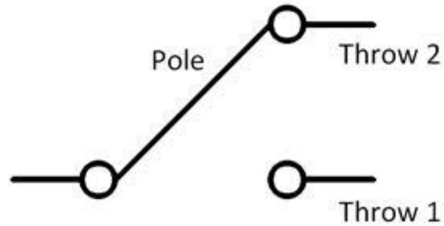
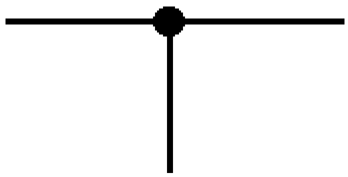
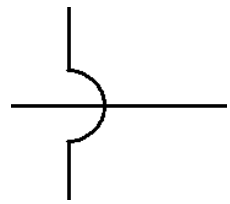
Equipment:

Motors (2)
Lamps (2)
Switches (2)
Wires
Controller

Procedure:

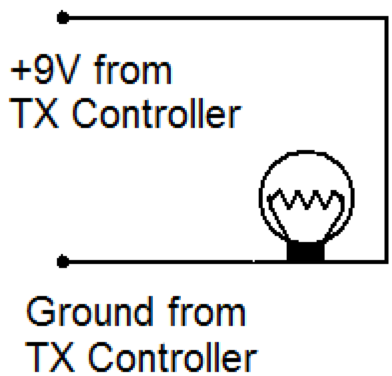
The following table has the schematic symbols that will be used in this activity. You can find additional symbols at http://www.rapidtables.com/electric/electrical_symbols.htm.

 Lamp	 Single pole Switch

 Motor	 Single pole Double throw switch
 Wire connection used when wires joined	 Two wires that do not connect use the curved bridge to avoid confusion

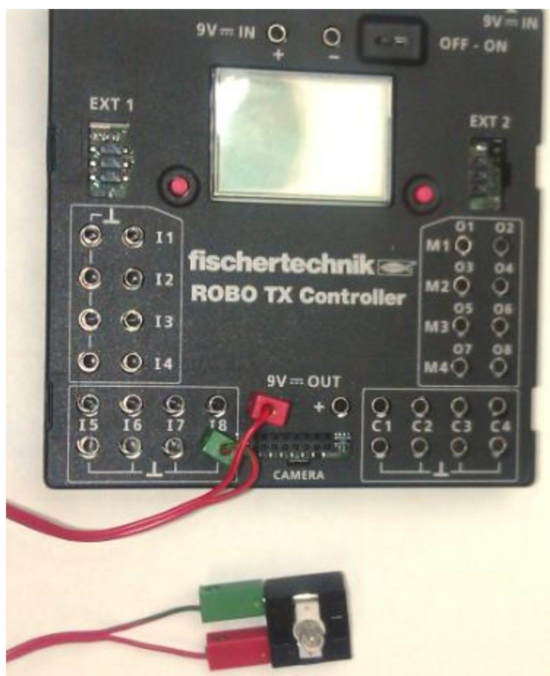
Simple Circuit

The following is a simple schematic of a closed circuit.



Using a wire, the lamp and the TX controller wire the circuit. Use the +9V and Ground highlighted in red in the picture below.

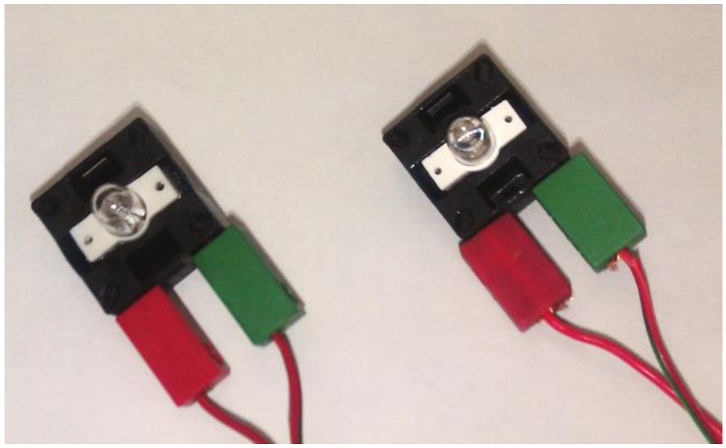
Set up the following circuit. Get your teachers permission before plugging in the Controller.



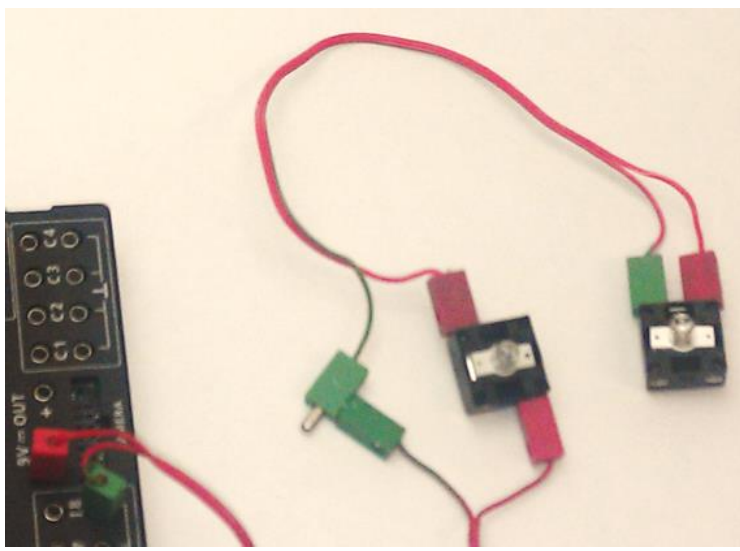
Conclusion:

This next section you will set up a Series circuit with two lamps. In a series circuit there is only one pathway for the electrons to travel.

Begin by connecting each lamp to different set of wires.



Plug one lamp into the TX controller as you did in the simple closed circuit above. Disconnect the green wire from the lamp you connected to the TX Controller and connect the red wire from the other lamp in the place of the green wire. Then connect the green wire from the second lamp to the first green wire. You now have a series circuit utilizing two bulbs. This circuit has only one path for electrons.

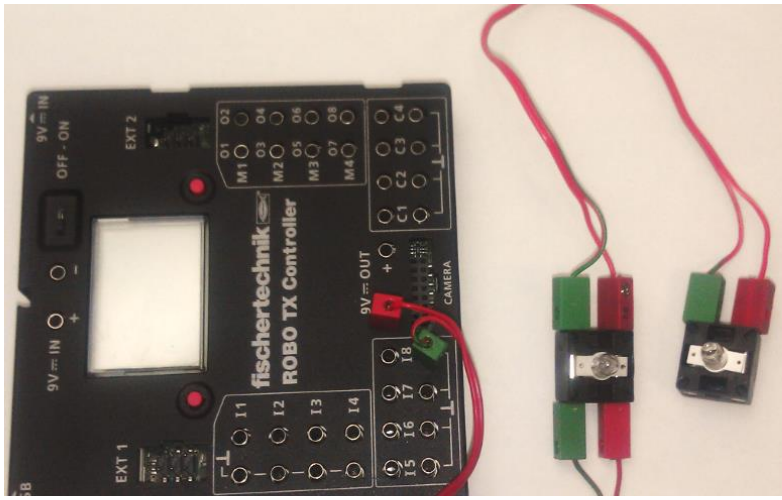


Draw a schematic of the circuit in your engineering notebook. Show the circuit and schematic drawing to your teacher and get permission to plug in the controller. When you have connected the power comment on what you see in your engineering notebook.

Disconnect the power form the circuit.

Parallel Circuit

Wire the circuit so the two bulbs are in parallel. It should look like the circuit below. Draw a schematic of the parallel circuit in your engineering notebook.

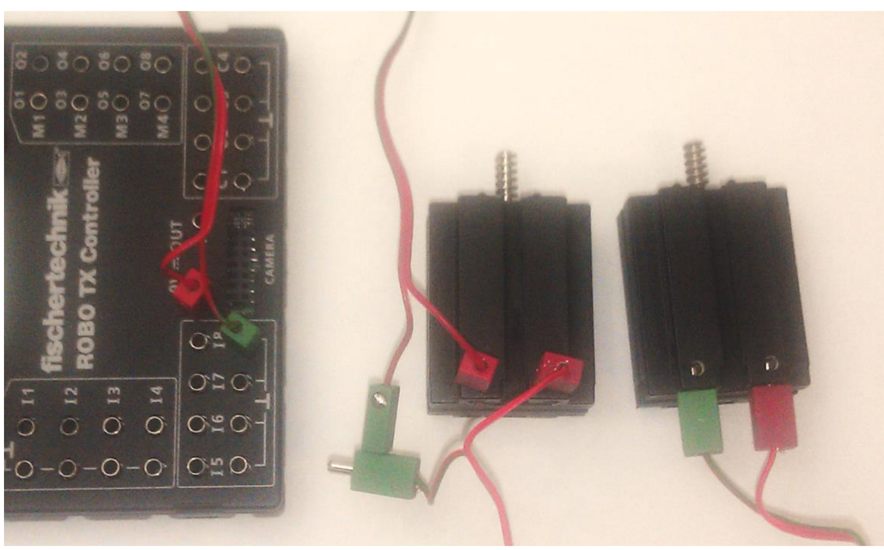


Obtain your teachers permission and turn on the circuit. How does the brightness of the bulbs differ from the series circuit? Are the outlets in your house hooked up in series or parallel?

Motors in Series and Parallel

Draw a schematic for a closed circuit using a motor a set of wires and the TX controller in your engineering notebook. Once you have wired the motor to the controller and shown the schematic to your teacher, turn on the power to the controller. The motor should turn. Listen to the sound it makes.

Turn off the power. Wire a second motor in series with the first. The power will have to go through the first motor and then the second motor to return to the controller.



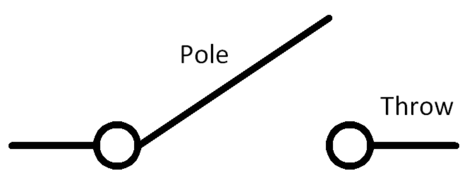
Draw the schematic in your engineering notebook. Once you have shown the schematic to your teacher turn the power on to the controller. Write an observation in your engineering notebook. Do you think the motors are moving as fast as the single one did? Why or why not?

Disconnect the power and wire the two motors in parallel. Draw the schematic in your engineering notebook. Once you have your instructors permission turn on the power. Explain the difference in speed between the series and parallel connections to the motors.

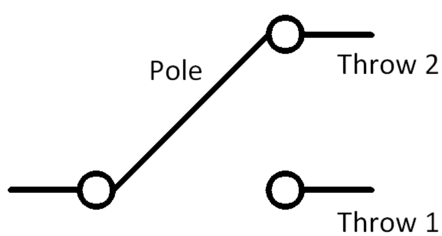
Switches

Switches are installed in circuits to control the flow of electrons through the circuit. They are categorized by the way they are actuated, by the number of poles and throws they have and their normal position. The actuator is the mechanical method that causes the switch to open and close. Common types include momentary, toggle, slide, rocker etc. A normally open switch is one where the circuit is open in its normal position and the actuator has to triggered in order to close the circuit and allow current to flow. A normally closed switch is one where the current can flow unless the actuator causes the switch to open blocking the current flow.

Poles provide the path for electrons. Throws control the circuits. The schematic below represents a single pole single throw switch (SPST). It provides a single path for electrons and controls one circuit.



The basic fischertechnik switch is a Single pole double throw switch. It has a single path for electrons but two different paths. The schematic is shown below.

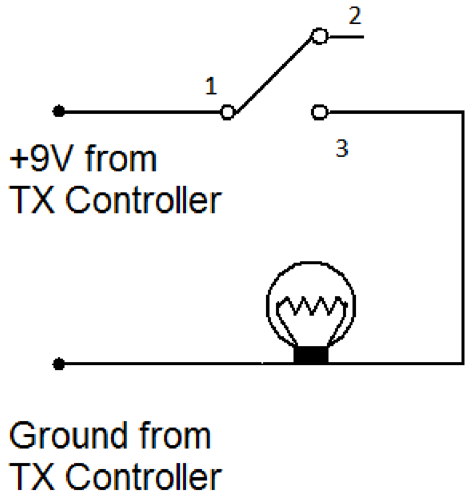


The picture below shows the actual switch. It is a momentary switch which means depressing the actuator causes a temporary changing of the path. As soon as you let go it reverts to its original position.

With the cover removed the internal components are visible. The number 1 connection is the middle contact. You can see that it is in contact with the contact with the number 2 connection making the 1 & 2 normally closed and the 1 &3 normally open. When the button is pushed the connection between 1 and 2 is opened and the connection between 1 and 3 is closed. This is a temporary connection as the spring will return the switch to its normal position as soon as the pressure is released.

Using switches

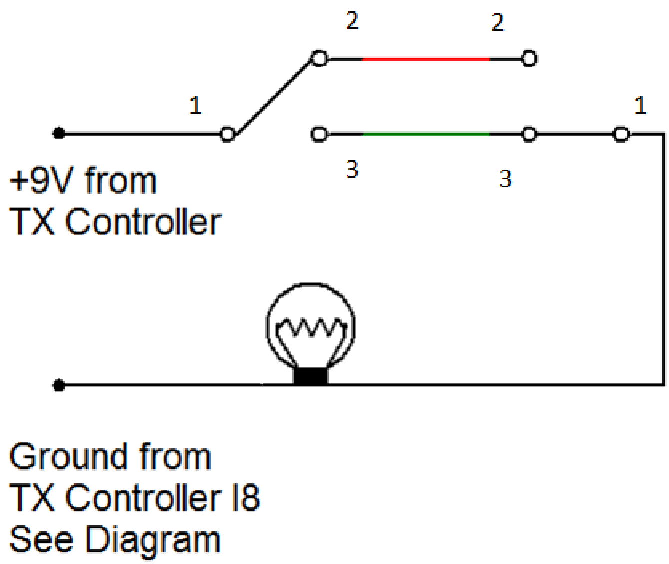
Wire the following circuit: Get permission from your teacher before connecting to the power for any circuit.



What happens when you connect the power to the circuit?

Describe what happens when you depress the switch.

Now wire the following circuit. This is similar to switches at the top and bottom of the stairs.



Using two SPDT switches allows you to create two pathways for electrons to take. Depress one switch and describe what happens to the lamp.

Keeping the first switch depressed push the second switch and record what happens.

Ohms Law and Power

Purpose:

Ohms law expresses the relationship between voltage, current and resistance. We use Ohms law to help us predict behavior of our components. We say the current is proportional to voltage and inversely proportional to resistance. If we take a motor or lamp of known resistance and increase the voltage, the lamp will glow brighter and the motor turn faster. Similarly if we reduce the voltage applied the lamp will grow dimmer and the motor slow. This relationship is known as Ohms law.

Electrical power is measured in watts in Direct Current situations. A Watt is equal to the work done in one second by one volt of potential difference moving one amp. Simply stated P=V X I or the total power is equal to the voltage times the current used. We can use the wattage to compare things. The light bulb in your lamp might be rated at 60 Watts. Another light bulb giving off the same light might be rated at 13 Watts. This is why many people are switching older style incandescent bulbs for LED or Compact Fluorescent ones as they cut the energy usage to accomplish the same work.

Procedure:

Open the webpage describing the Ohm's Law Wheel. This is found at http://www.ohmslawcalculator.com/ohms_law_wheel.php. This wheel is a handy device for showing the relationship between all the devices.

Use the wheel to assist you in solving some of the following problems. Show all work in your engineering notebook.

A fischertechnik lamp is measured at 9 ohms of resistance when cold. 9V is placed across the lamp. Calculate the startup current for the bulb. Show your formula and work in your engineering notebook.

Because of the way a lamp behaves it draws the most current when it is warming up. As the lamp gets brighter the voltage has to work harder to excite the filament. The hot resistance of the bulb is 85 ohms. If 9V is place across the bulb, how much power is the lamp consuming if the lamp is at full brightness?

If the limit on each motor channel is ¼ amp at 9V how many bulbs can you connect to each motor output of the TX controller?

The startup resistance of a fischertechnik motor is measured at 10.6 ohms. You can find this by measuring the resistance between the terminals with the motor stopped and no current applied. If we apply 9V to the motor, calculate the starting current of the motor. Show all your work in the engineering notebook.

The design of the motor allows it to reuse most of the collapsing magnetic field to offset the current required. This is why a motor when running with no load draws .059 amps in the example. What is the running resistance of the motor in this situation?

When the motor in the above situation is fully loaded driving a mechanism it is drawing .225 amps. What is the power consumed by the motor in driving the mechanism if the voltage is at 9V? Show your work in your engineering notebook.

Conclusion:

We use Ohm’s law and Watt’s laws to help us understand what is happening in circuits and keep us from overloading any one circuit. If a circuit is overloaded a lot of heat will be generated and a fire can result. To help us prevent that we use a special type of switch called a circuit breaker. Talk with your partner and see if you can figure out how a circuit breaker prevents circuits from overloading.

Flow Charts

Purpose:

Flowcharts are a graphic representation of an algorithm, often used in the design phase of programming to work out the logical flow of a program. Flowcharts use simple geometric symbols and arrows to define relationships between elements. This activity will introduce you to flowchart symbols. Since Robo Pro is software based on flow charts this will help you understand the logical flow of a Robo Pro program.

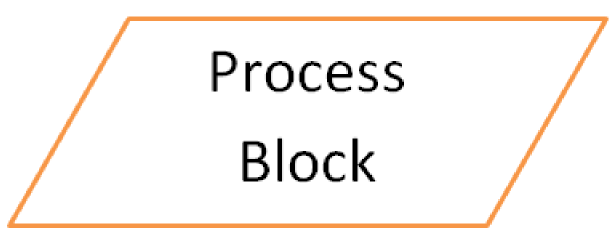
Equipment:

Paper
Pencil

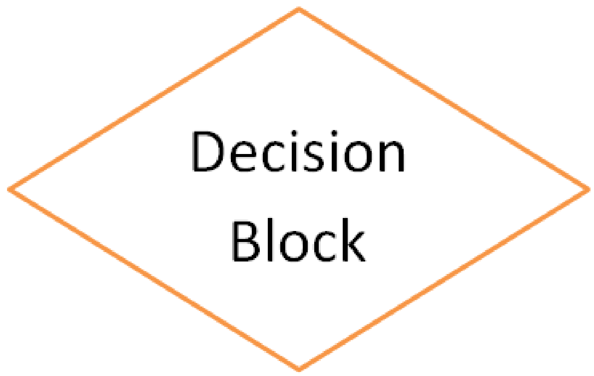
Procedure:

While there are numerous symbols used by professional programmers we will concentrate on the ones used most often. You should familiarize yourself with the basic shapes and what they represent.

The Terminator block is used to indicate the Start or End of a program.



The process block represents a Process that occurs. This might be turning a motor or lamp on, getting the value of a variable, or setting input or output pins.

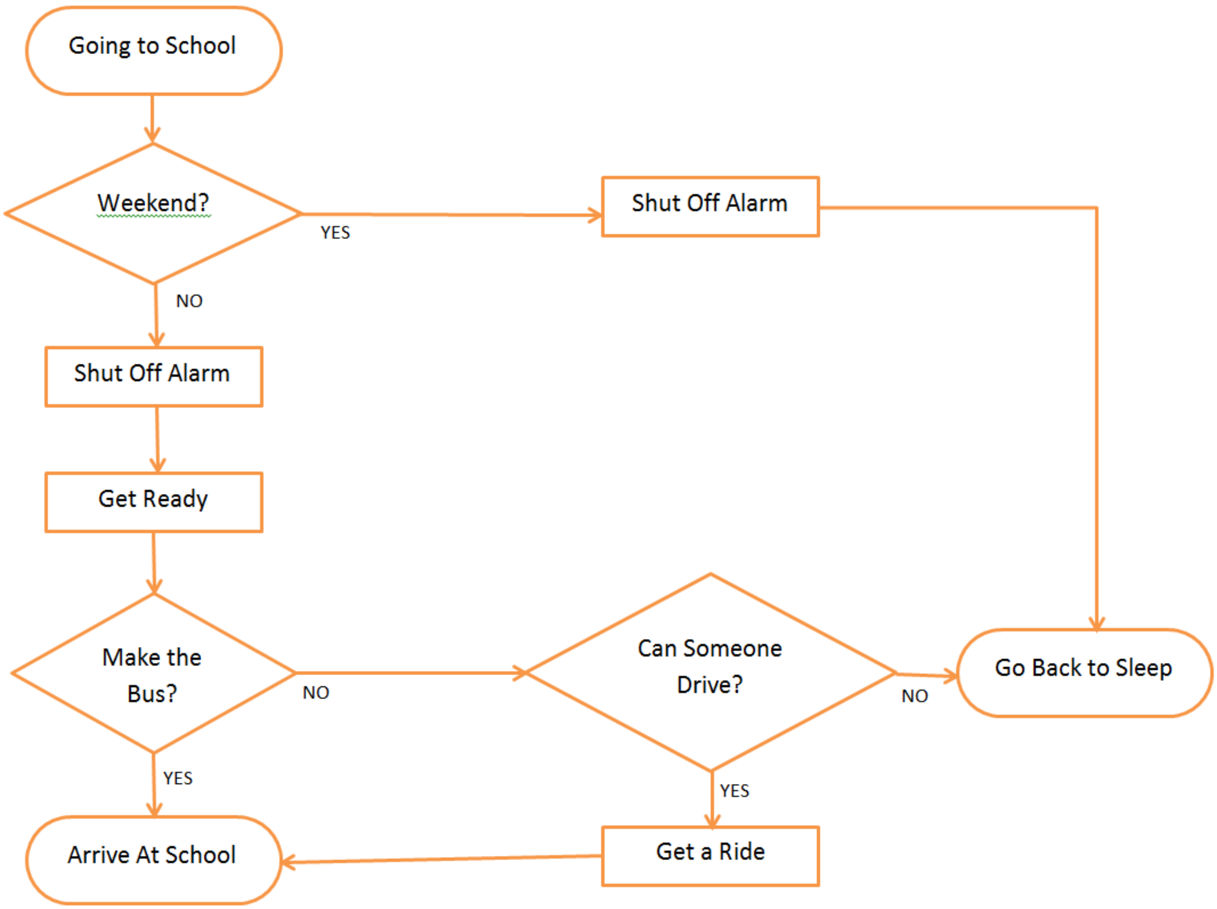


The Decision block is used to branch the program after comparing variables or checking the position of switches.

Data blocks are used to assign variables and allow us to set parameters. This shape is also used for assigning inputs and outputs to variables as well as defining delays.

Blocks are connected by arrows called Flow Lines which show how the blocks connect together.

Review the flow chart that follows. Step through it to follow the logic it is mapping out.



What is the eventual course of action if it is the weekend?

If it is not the weekend and you missed the bus what is your next action.

Conclusion:

Using the information from the flowchart section above prepare a flow chart for each of the following problems and attach them to this sheet.

1. Create a flow chart for placing toothpaste on a toothbrush and then brushing your teeth for 45 seconds.
2. Create a flowchart for creating a peanut butter and jelly sandwich.
3. Create a flowchart for helping a three-year-old child put on their jacket.

Introduction to RoboPro Software

Purpose:

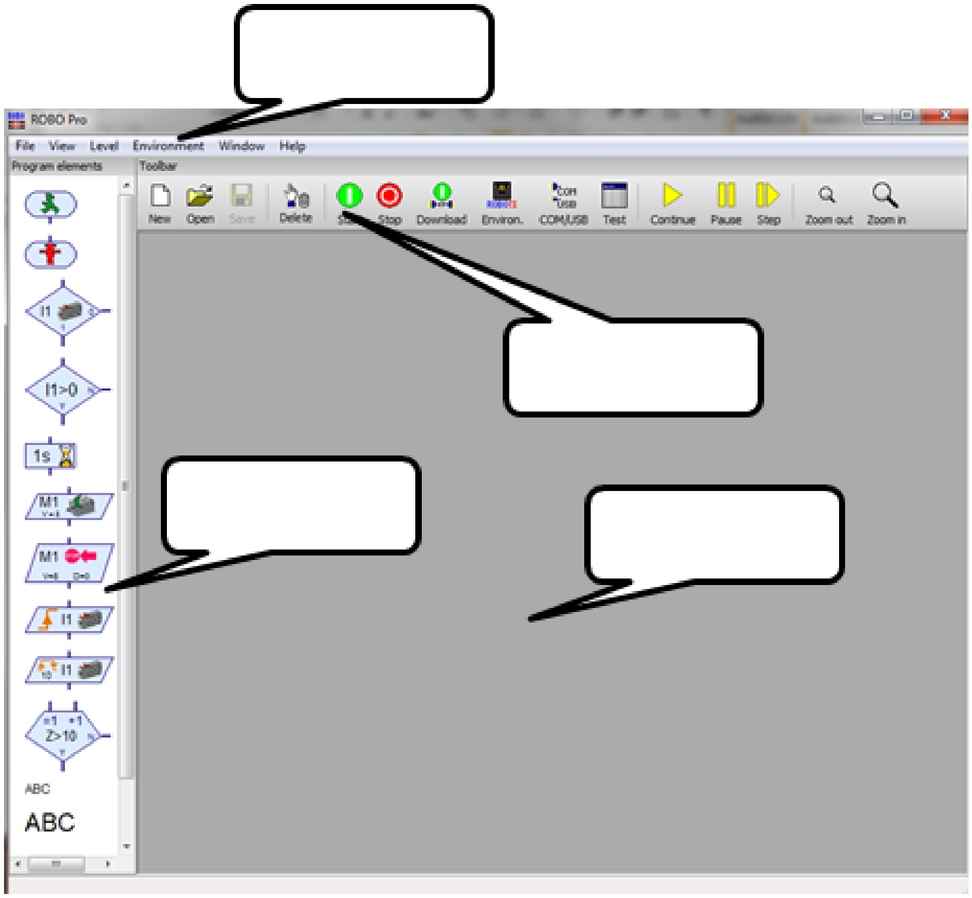
Most software titles utilize a Graphical User Interface (GUI, pronounced gooey). Becoming familiar with the GUI will make your learning of the software easier by helping you locate the tools you need. A lot of time and effort goes into the design of the human computer interface to make the software easy to use. This activity is designed to help you interact with the software environment.

Equipment:

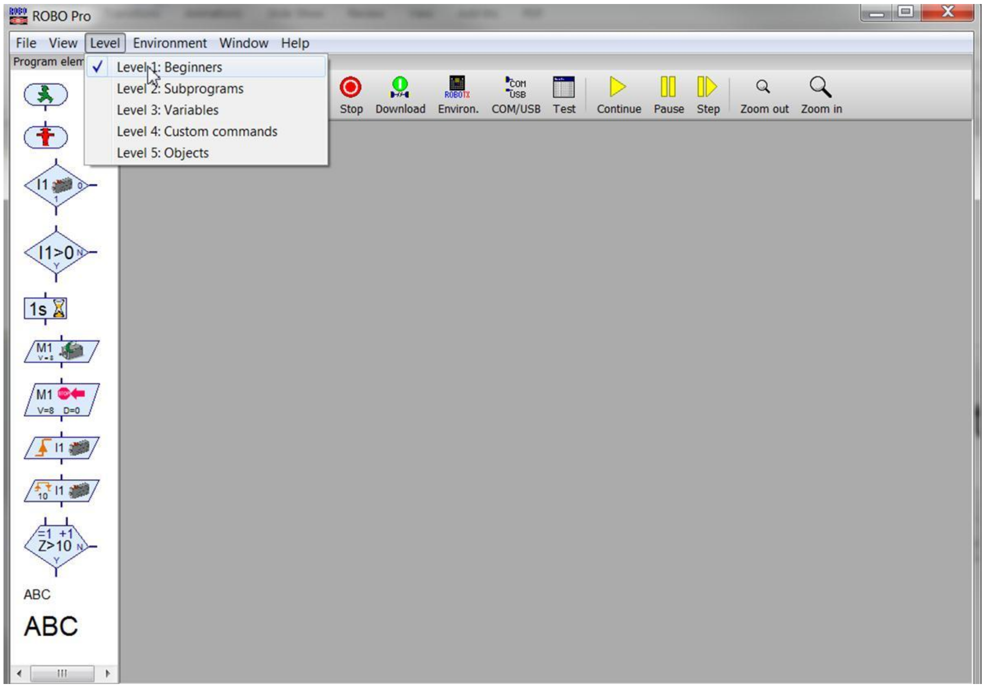
RoboPro

Procedure:

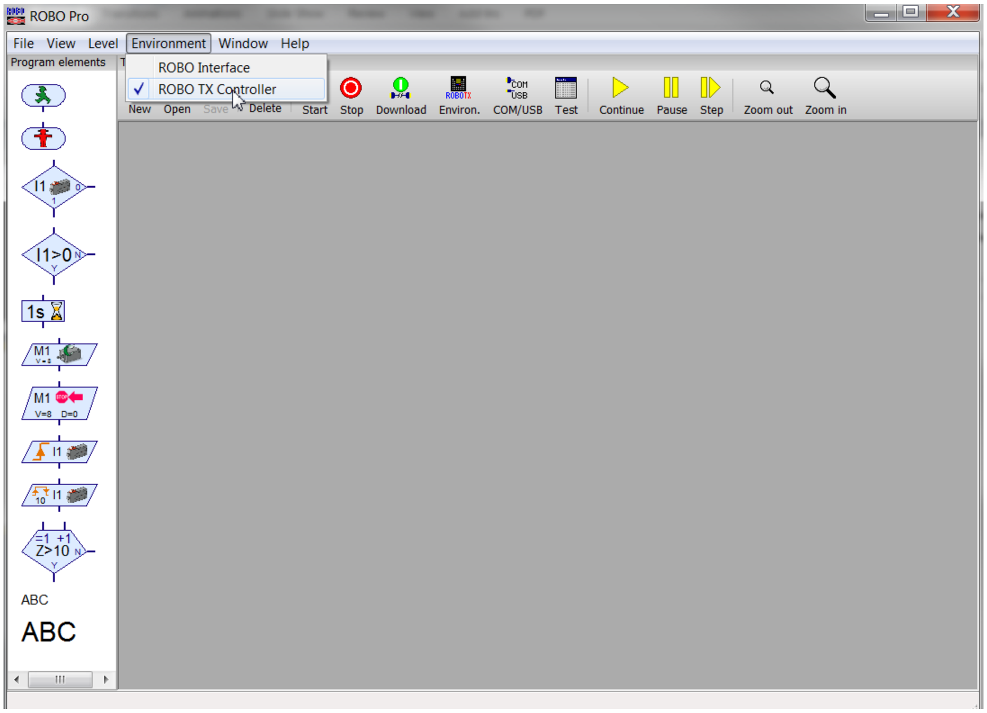
Be sure the RoboPro software is installed on your computer. Open the software and maximize the screen. Your screen should look like the one here. Identify the following areas on the screen: Menu Bar, Toolbar Program Elements Window, and Program Window.



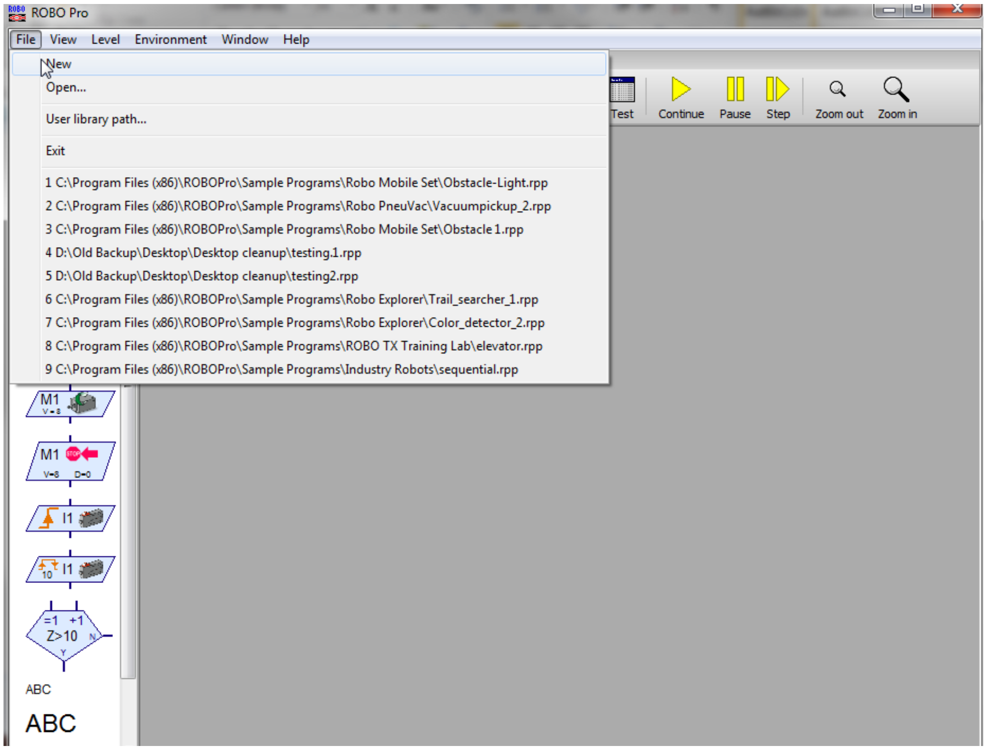
Before you begin to write programs you must establish the environment for your work. From the Menu Bar select the Level pull down menu. Set the option to Level 1: Beginners.



Next select the Environment pull down menu and select the option for ROBO TX Controller.

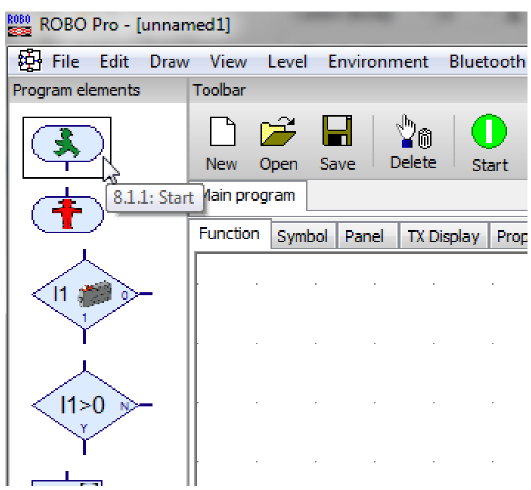


Once that is set go to the File pull down menu and select New.

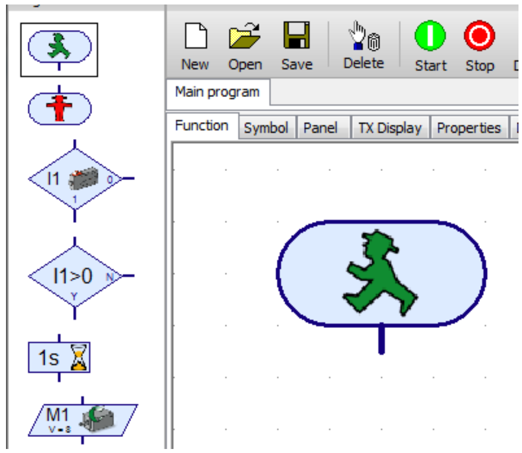


This will open the Program Window and you are ready to write your first program.

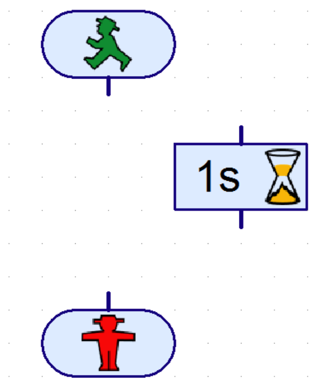
Left click and hold on the Start Element and drag it to the program window and let go of the left button. This will drop the start icon into the program window.



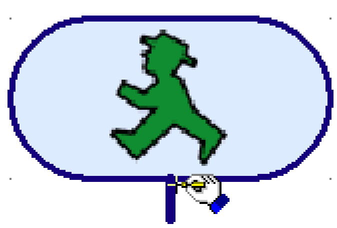
You should see the start element on the screen.



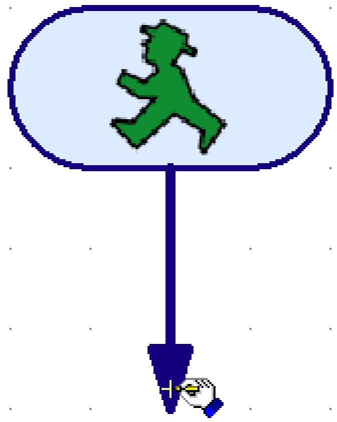
Use the same process to place the Stop and Wait elements on the screen.



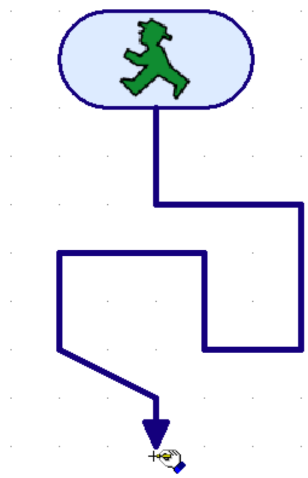
In order for your program to function the elements need to be connected. We connect them with lines called program flow lines. They have an arrowhead on the end to indicate the direction of flow through the program. Notice the Start element only has an exit flow line, and the stop element only has an entrance flow line. Nothing can come before a start element or after a stop element. To draw flow lines hover over the exit flow line where it meets the element and you should see the hand with a pencil appear.



Left click and release. Drag your mouse away and the flow line with the arrowhead will follow out of the element.

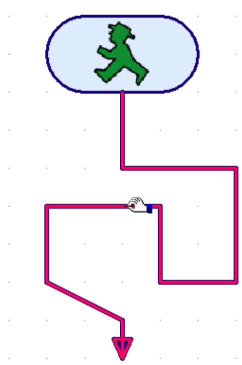


You can left click and the arrow can then take a turn. Practice making some turns.

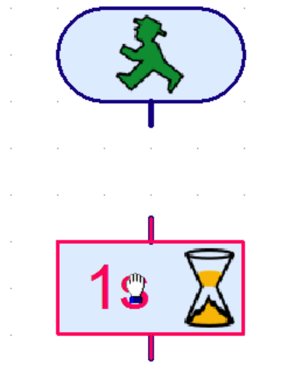


Hit the escape button on your keyboard twice and the line will stay on your screen.

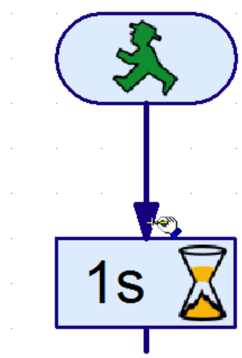
Now hover over the line and left click. The line will turn red. Once it is red you can hit your delete key and the flow line will disappear.



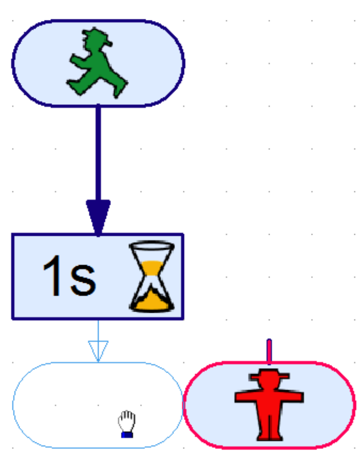
Click on the Wait element and it will turn red. Left click and hold the button down and you will be able to drag the element anywhere on the screen. Position it below the start element.



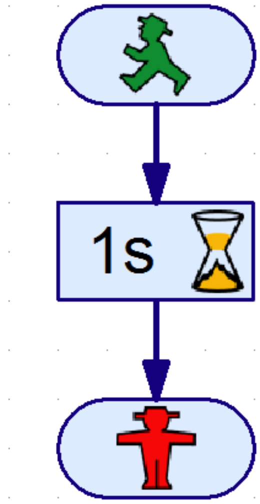
Draw a flow line from the start element to the wait element. Click on the exit flow line of the start element and let go. Move your mouse over the flow line of the wait element and left click again and the flow line will connect and stay.



Now click on the stop element. Drag it very near to the exit flow line of the wait element. You should see a flow line automatically appear.

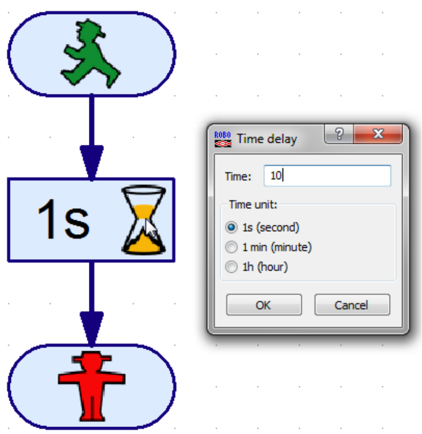


Let go of the element and it should now look like the following picture.

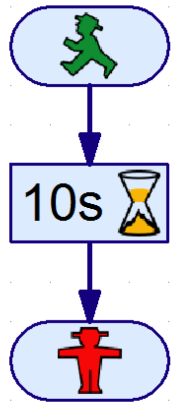


Now click on any element and move them around on the screen until you are comfortable with elements and flow lines.

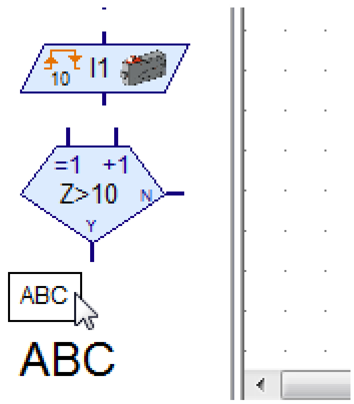
We will edit the wait element next to change how long it waits before moving on. Right click on the wait element and release. You will see the dialog box appear. Enter 10 in the time slot.



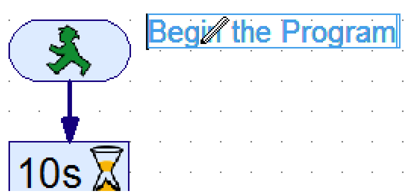
When you are done, select OK. The wait element should change to represent that it will wait 10 seconds.



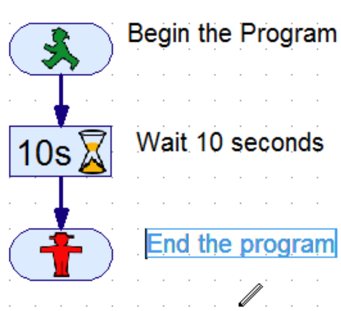
It is good practice to document your program. Although this program is simple it is never too early to begin good habits. From the program elements window select the text tool.



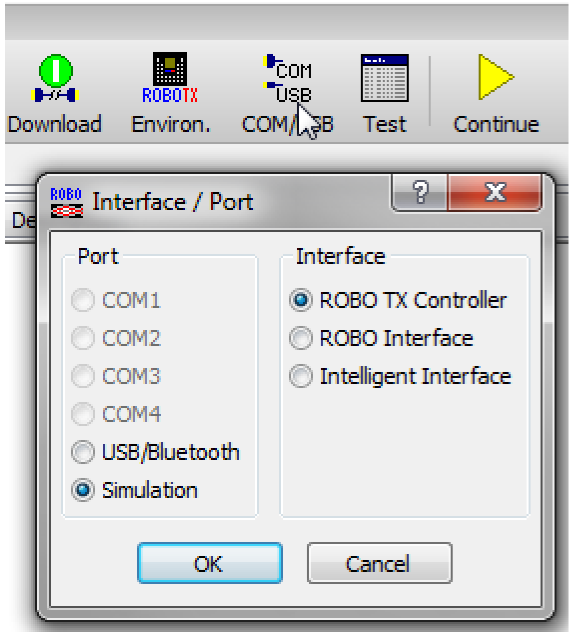
Now click to the right of the start element. You should see a small square appear. Begin typing.



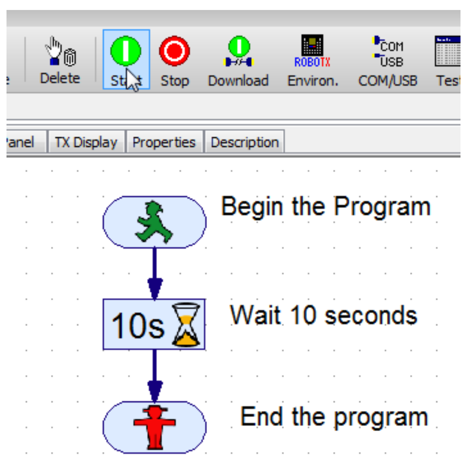
Continue placing comments on your program.



Now it is time to test the first program. Select the COM/USB icon on the toolbar. This will open the Interface/Port dialog box. Select the Simulation radio button for the port setting. Select OK



Find the start button on the toolbar.



What happens when you press start?

Conclusion:

Edit your program so that it only waits 5 seconds.

Introduction to the TX Controller

Purpose:
In order for you to use a computer to control your models, you need control software and a TX Controller, which is the link between your computer and the Fischertechnik model. The controller converts the software commands so that the computer can control motors and signals from sensors can be processed.

Equipment:
TX controller
Power Supply
USB cable
Switch
Lamp

Procedure:

Label the various sections of the controller on the diagram below.

The various parts of the controller are:

9V—IN
Connection to supply 9V from the Accu-Set battery

DC Socket
Optional connection to supply the 9V from a wall transformer

Port
Connection to your computer is made via the USB port.

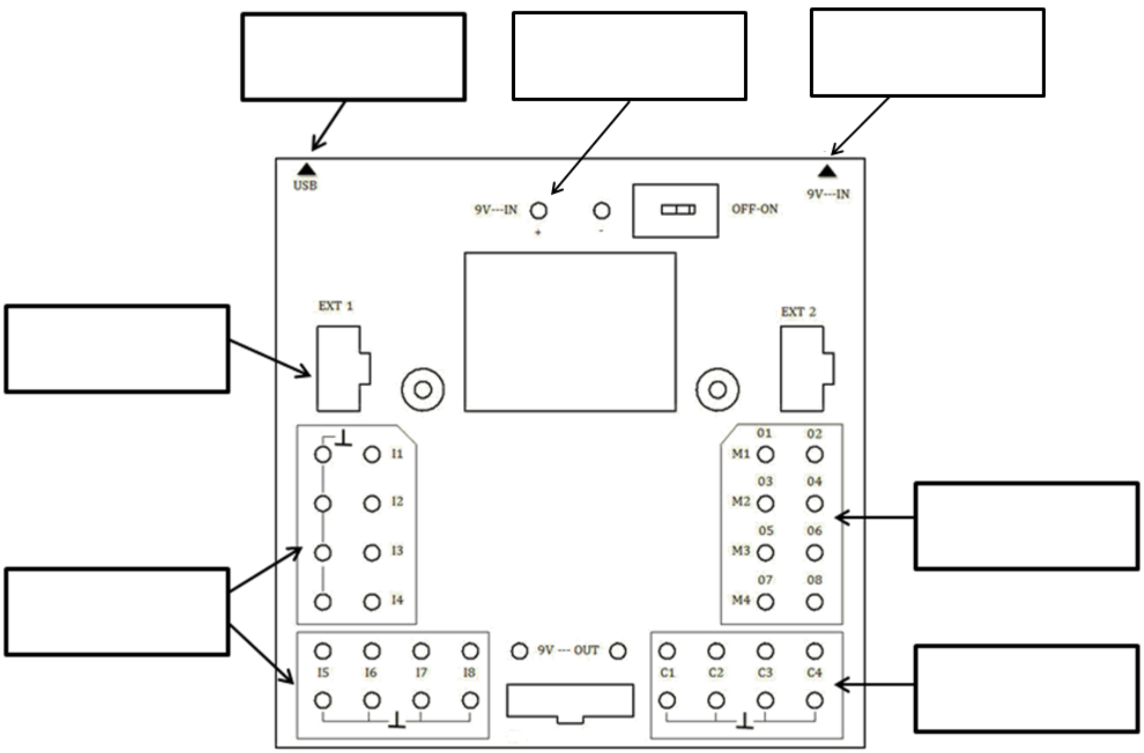
Outputs (M1 – M4) (01-08)
These are power outputs, which supply 9V of electricity to whatever component is connected to them. The only components that should be connected to these outputs are; motors, lamps, buzzers, or an electromagnet. Connections M1-M4 are Differential outputs (when one connection is high the other is low) allowing motors to be run in either direction. 01-08 can be used with the ground and can run 8 different outputs.

Universal Inputs (I1-I8)

These connections are for input devices. They can be described as digital, sensing a digital condition of a 1 or 0. They can be used as analog inputs reading either voltage and/or current

Inputs (C1-C4)
These are components that sense a digital condition of a 1 or 0. Typical components of this type are switches, or a phototransistor.
These are digital inputs. They can be used with encoders on motors or as a general purpose digital input.

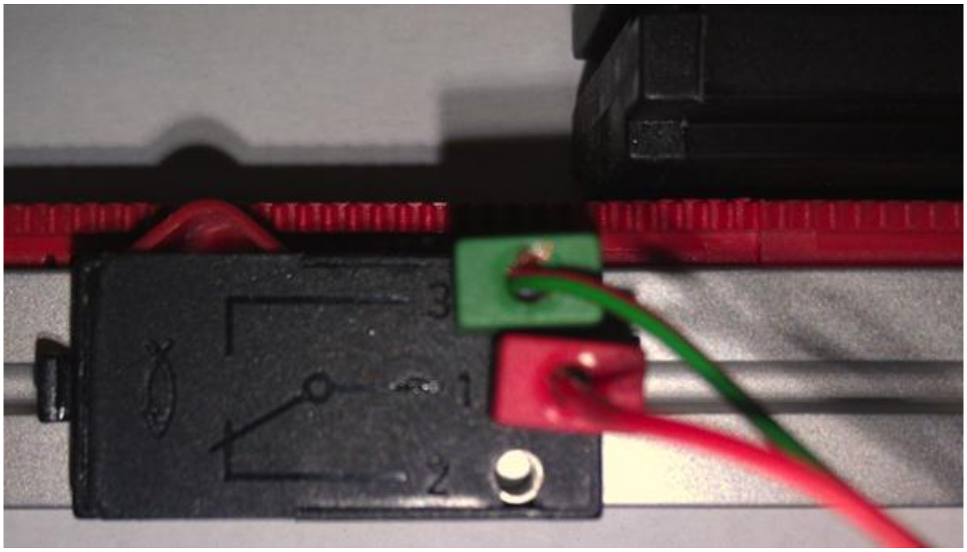
EXT 1 (EXT2)
Ports for connecting controllers together to add more inputs and outputs.



Connecting the Controller

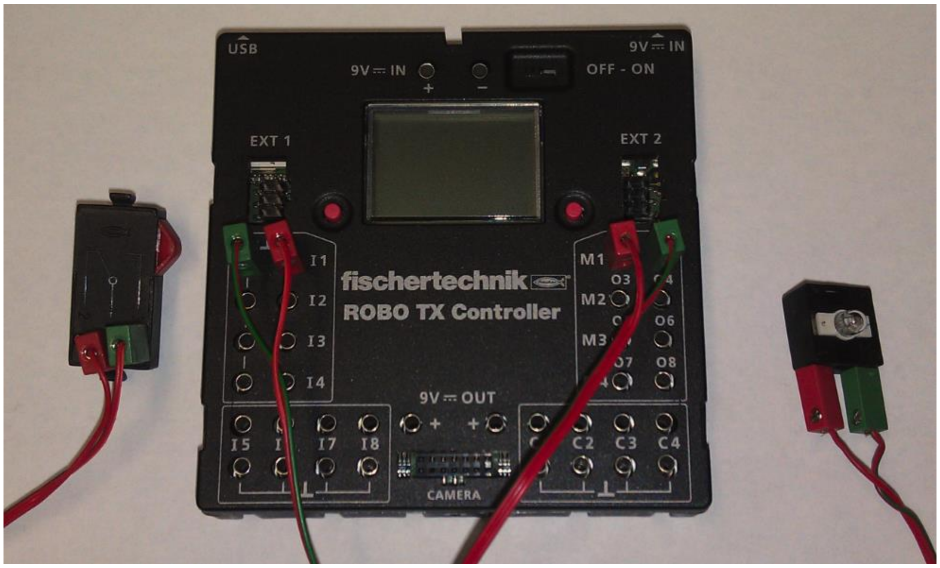
Connect the USB cable between the computer and the controller. Do not connect the power supply until your teacher approves the rest of the electrical connections.

Connect a switch in normally open mode to the I1 input on the controller using plug wires. The switch is wired Normally Open using terminals 1 and 3.



Connect the other end of the wires to the two terminals marked I1 on the controller.

Connect the Lamp to the M1 inputs shown above. Your completed wiring should look similar to the photo below.



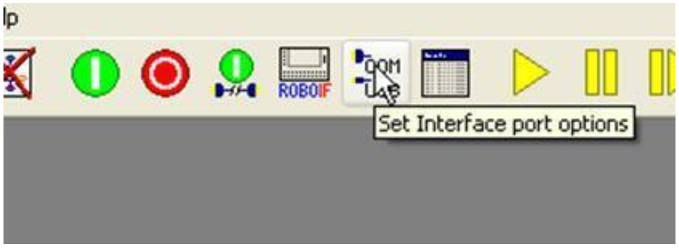
Once your teacher has approved your connections you can connect the controller to the computer with the USB cable and connect the power supply to the back of the controller. Turn the controller on.

We are now ready to test the connections to the controller. Open RoboPro.

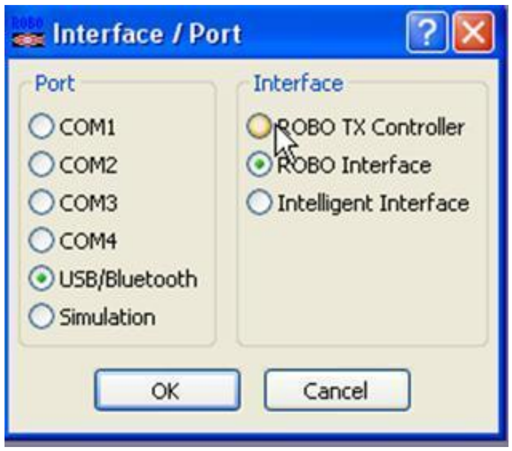
RoboPro Software has a choice of controllers and programming environments. We are using the TX Interface. You need to set the environment and select the controller. Select the TX Interface from the Environment pull down menu at the top of the user interface.

You might see a warning that you are only changing the environment not the actual interface connections.

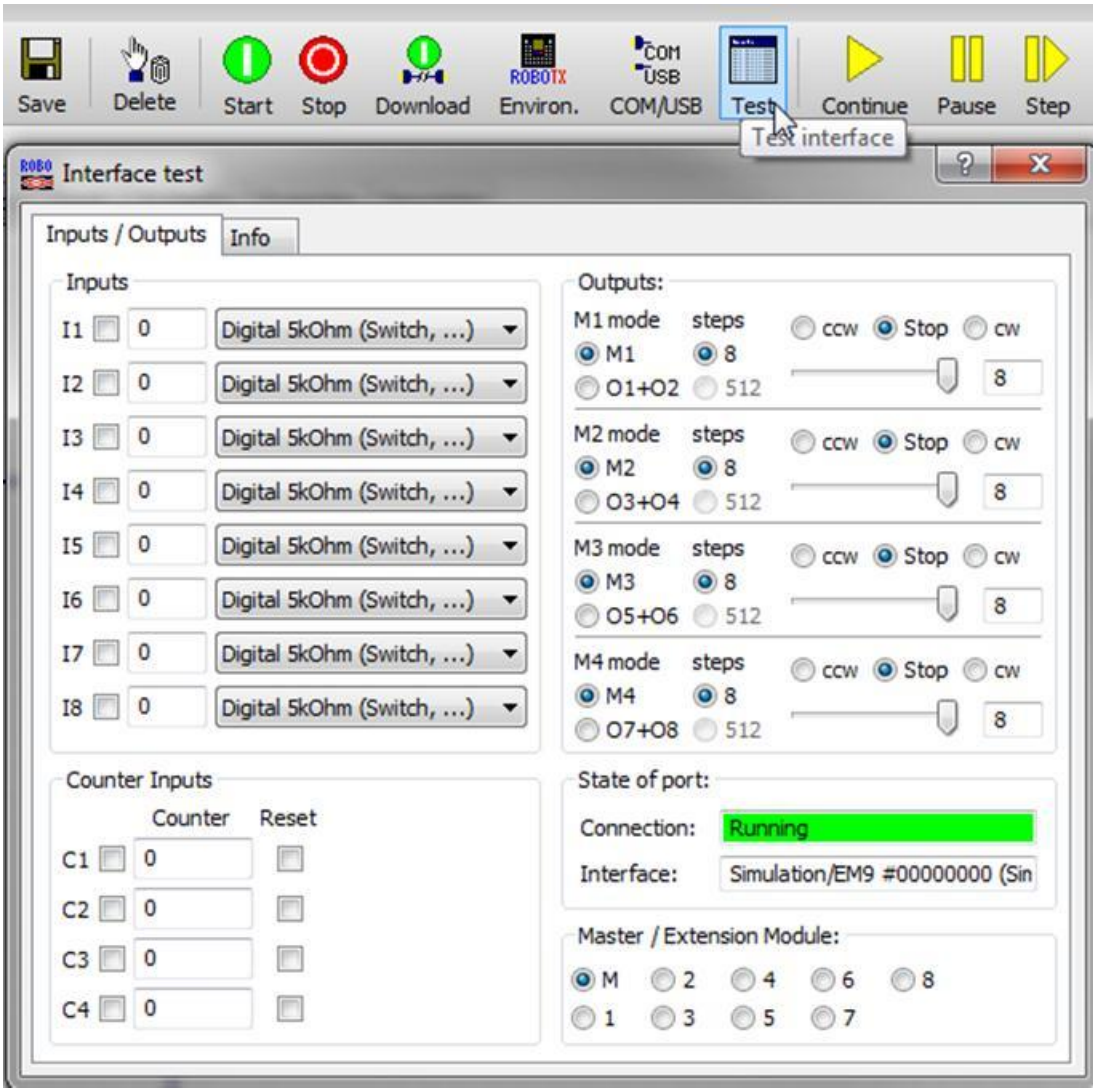
Once you select OK you need to set the actual controller setting. Select the COM/USB icon on the main toolbar.



In the dialog box select the push buttons for the TX Interface and the USB/Bluetooth, select the OK button.



Test the controller by selecting the Test Interface icon on the main toolbar. This will open the Interface test dialog box shown below.



Depress the switch we connected to the controller. What happens in the Interface test dialog box?

Now click on the cw button in the M1. Explain what happens when you do that. Move the M1 slider underneath the cw button. Observe the lamp and explain what happens when you do. What setting is the highest? Click the stop button on M1. Turn the controller off and return all your equipment to its storage location.

Conclusion:

Explain the function of a PLC (Programmable Logic Controller).

Why is the controller necessary?

Open Loop Programming

Purpose:

A loop in programming allows for code to be repeated. An open-loop system is one in which a control system receives no feedback as the system is running. There is an input, a process and then an output. For example when you put your dishes in the dishwasher and turn it on, the dishwasher runs through its cycle. The dishwasher doesn't know it the dishes are clean at the end or not. A human made a decision on how long the dishwasher will run and a timer turns off the machine when it is done. In this activity you will be learning about ways to control machines with no feedback.

Equipment:

TX Controller
RoboPro
Light
Motor
Wires

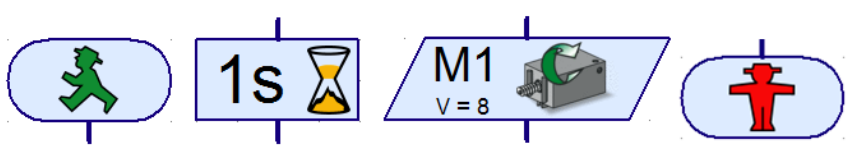
Procedure:

Open loop programs run a machine or robot with no other input once they are turned on. The most common type of open loop control involves a timer to control action.

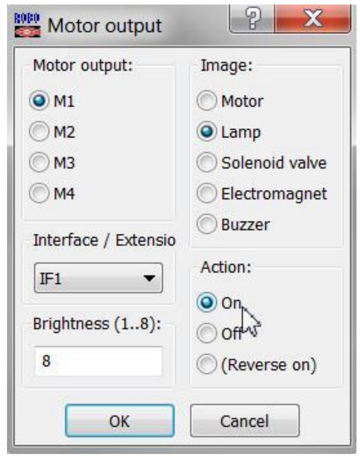
Setting up the program:

Open RoboPro. Start a new file. Set the Level to Basic.

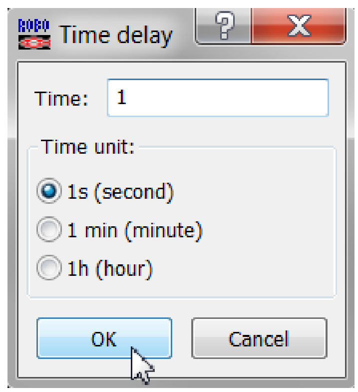
You will be using the following programming blocks:



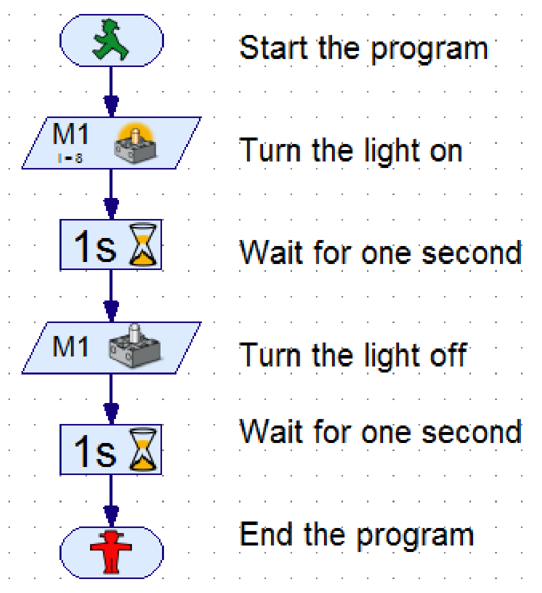
By right clicking on the motor you will get a dialog box that will allow you to turn the motor into a lamp icon and set it to turn on or off.



By right clicking on the Time Delay icon you will be able to change the duration of the wait.



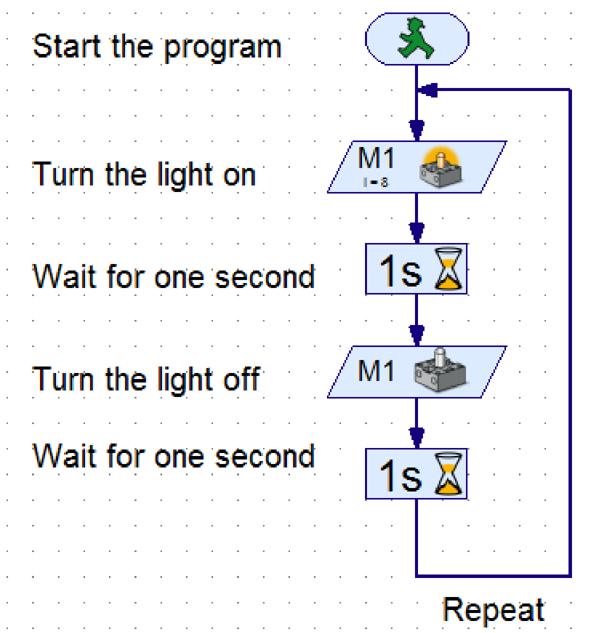
Create the following program.



Setting up the hardware:

Connect the lamp to the M1 connections shown below.

Run the program. The light should come on for a second and then turn off and the program ends. To be an official loop the program must be changed to remove the end of program and return to another place. Modify your program to look like the following.



What should happen when you run the program? Run the program and see if you are correct. Since this program does not have an end you will have to cancel the program to stop it.

Conclusion:

Write a program to turn the light on for three seconds and off for 2.

Write a program to turn the light on for 5 seconds, off for 2 then on for 3.

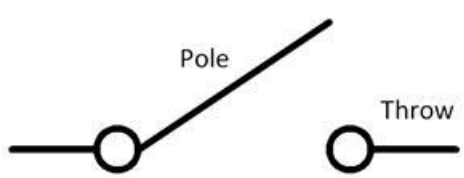
Sensors: Digital Switch

Purpose:
Digital inputs are those transducers that provide an output that is one of two states: high or low, open or closed, Logic 1 or Logic 0. Digital inputs are the easiest to deal with in programming. Switches work by closing or opening a set of contacts. Generally we say a switch is closed when we see a digital high and current is flowing and open when we see a low.

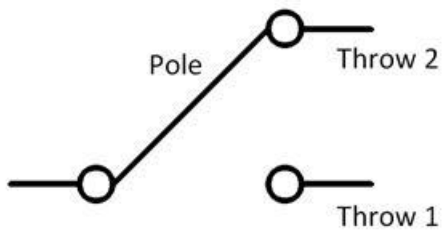
Equipment:
TX Controller
Wires
Switch
Lamp

Procedure:
Switches are installed in circuits to control the flow of electrons through the circuit. They are categorized by the way they are actuated, by the number of poles and throws they have and their normal position. The actuator is the mechanical method that causes the switch to open and close. Common types include momentary, toggle, slide, rocker etc. A normally open switch is one where the circuit is open in its normal position and the actuator has to be triggered in order to close the circuit and allow current to flow. A normally closed switch is one where the current can flow unless the actuator causes the switch to open blocking the current flow.

Poles provide the path for electrons. Throws control the circuits. The schematic below represents a single pole single throw switch (SPST). It provides a single path for electrons and controls one circuit.

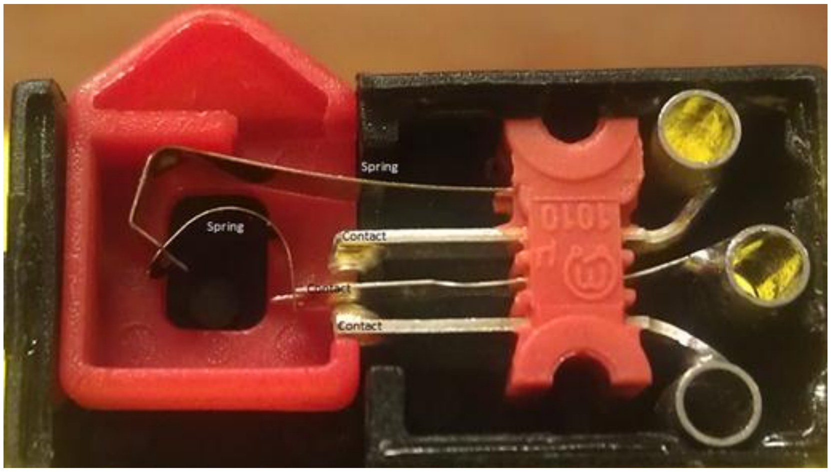


The basic fischertechnik switch is a Single pole double throw switch. It has a single pole for electrons but two different paths. The schematic is shown below.



The picture below shows the actual switch. It is a momentary switch which means depressing the actuator causes a temporary changing of the path. As soon as you let go it reverts to its original position.

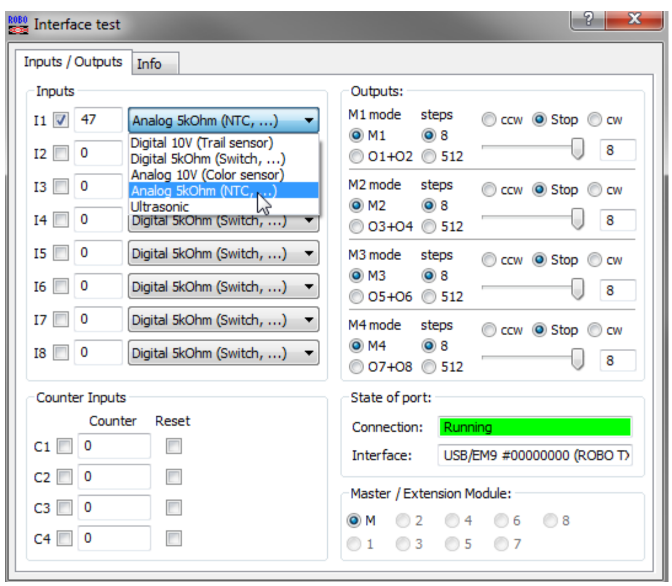
With the cover removed the internal components are visible. The number 1 connection is the middle contact. You can see that it is in contact with the contact with the number 2 connection making the 1 & 2 normally closed and the 1 &3 normally open. When the button is pushed the connection between 1 and 2 is opened and the connection between 1 and 3 is closed. This is a temporary connection as the spring will return the switch to its normal position as soon as the pressure is released.



Using the switch

Connect Pins 1 and 3 to the I1 connection on the TX Controller

Whenever you hook up a variable sensor to the TX Controller it is a good idea to open the Interface Test application in the RoboPro software to check to be sure the sensor is giving you the correct input for your selected type. It will also assist in programming if you can see what the reading is at selected values. Select the Test Interface icon on the main toolbar. When the application opens you will need to set the type to match your sensor before it will give you correct information. In this case you will be selecting Analog 5k Ohm(NTC…).



Once you click on your selection it will stay in the window. Turn on the interface. Rotate the shaft of the potentiometer and observe the readings.

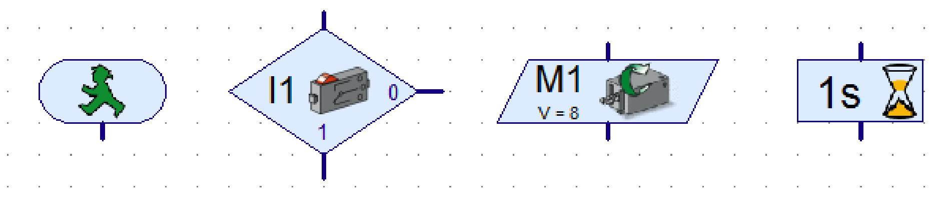
Conclusion:

Include a sketch of your setup in your Engineering notebook. Explain what happens when you rotate the shaft. What is the lowest reading you see? What is the highest?

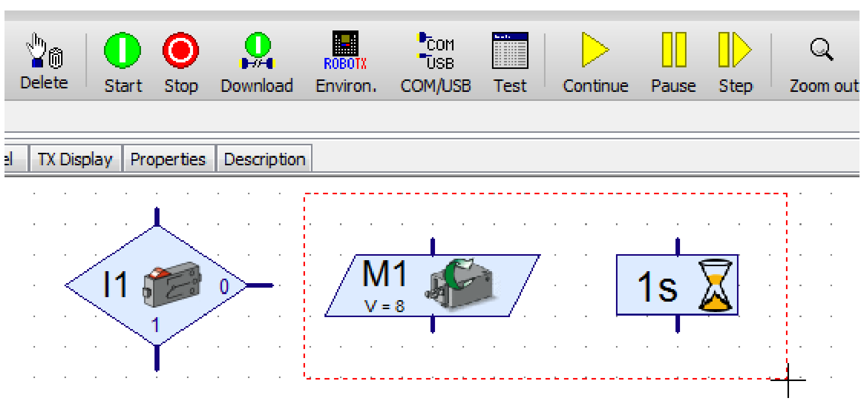
Reverse the wires on the TX controller. Does reversing the wires have any effect on the operation of the sensor?

Begin by creating a new file in RoboPro. Set the environment to the TX controller and the Level to Beginners. Use the COM/USB to set the Interface type to the Robo TX Controller.

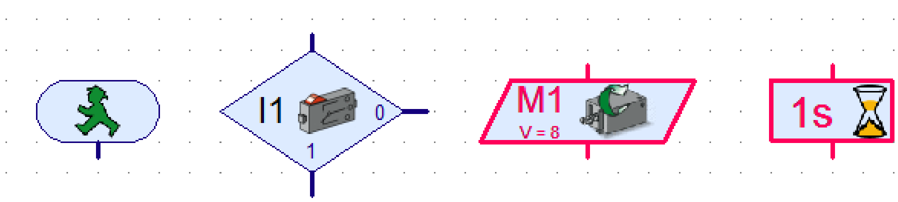
Drag one of each of the following elements to the screen.



Drag a window around the motor and the timer elements.

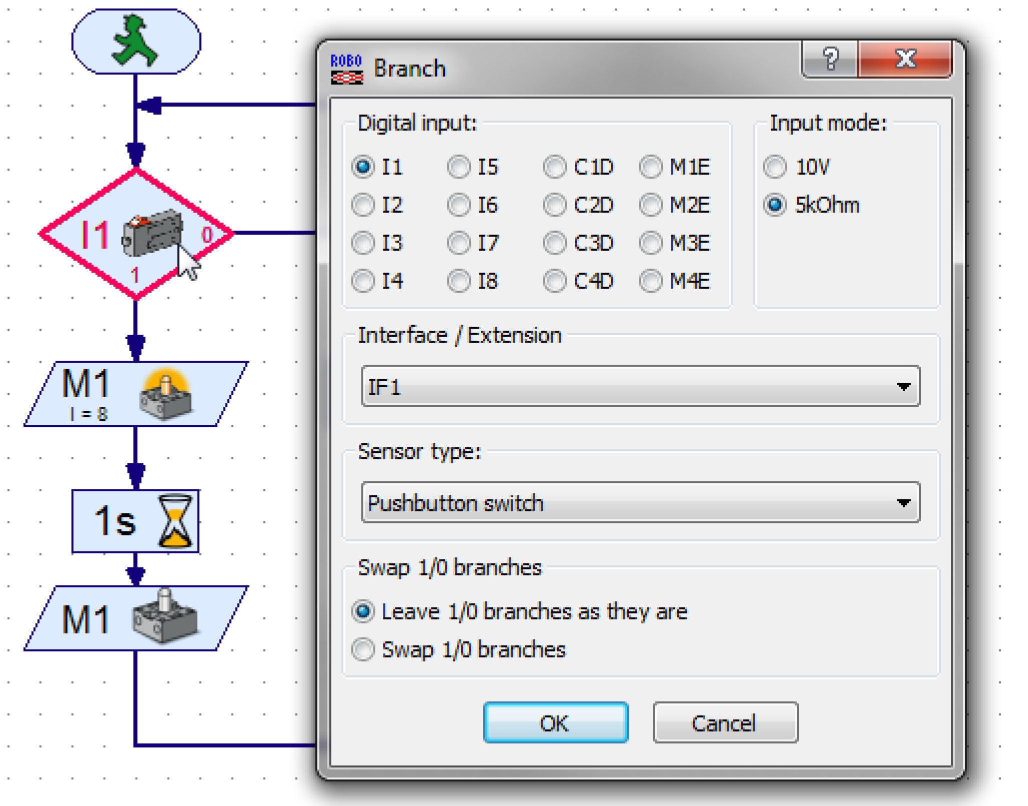


Once you click again both will be highlighted.

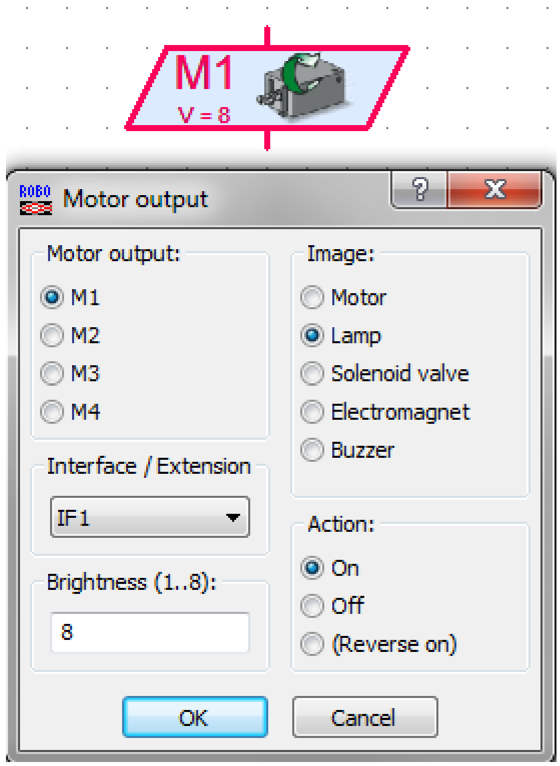


Hold your control key down while you left click on one of the highlighted elements and drag off them. When you let go you will have a copy of the blocks.

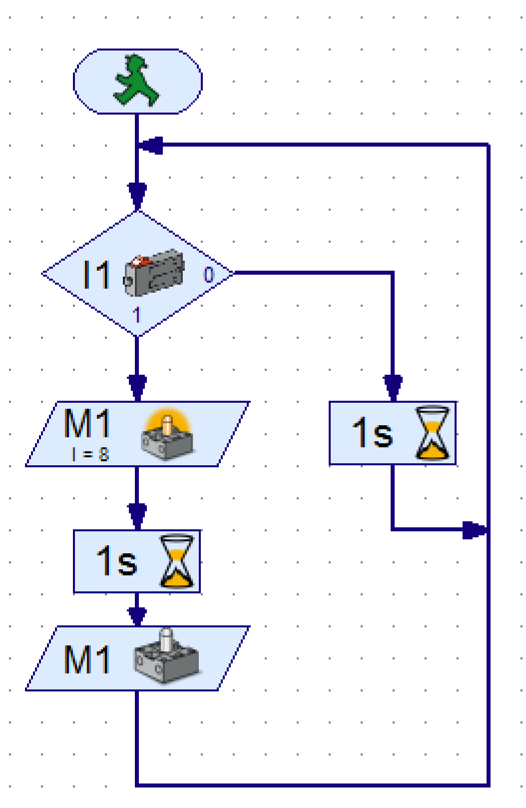
Right click on the Digital Branch icon. Set the Digital input to I1 and the Sensor type to Pushbutton Switch.



Right click on the motor blocks one at a time and set them to show a lamp. Set one to On and one to Off.



Setup the following simple circuit to test out your sensor:



Wire the light to the M1 connection on the Controller and the Switch to the I1 connection.

Obtain your instructors permission and then connect the controller to the computer. Turn on the power to the controller and run the program.

Print a copy of the program for your engineering notebook. Write an observation about what the effect of pushing the switch has. Describe the operation of the circuit.

End the program by using the stop icon from the main toolbar. Turn the controller off.

Sensors: Digital Phototransistor

Purpose:

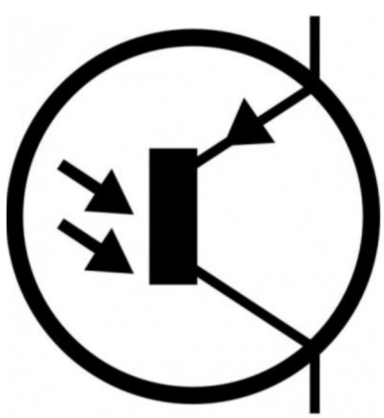
Digital inputs are those transducers that provide an output that is one of two states: high or low, open or closed, Logic 1 or Logic 0. Digital inputs are the easiest to deal with in programming. A phototransistor is a bipolar transistor in a transparent case. Light can enter the case and when it strikes the base-collector junction it causes electrons to be generated by the photons in the light. This will cause the phototransistor to conduct. Think of the phototransistor as a fast acting semiconductor switch. If strong light strikes the device it conducts. If the light is interrupted the device will not conduct.

Equipment:

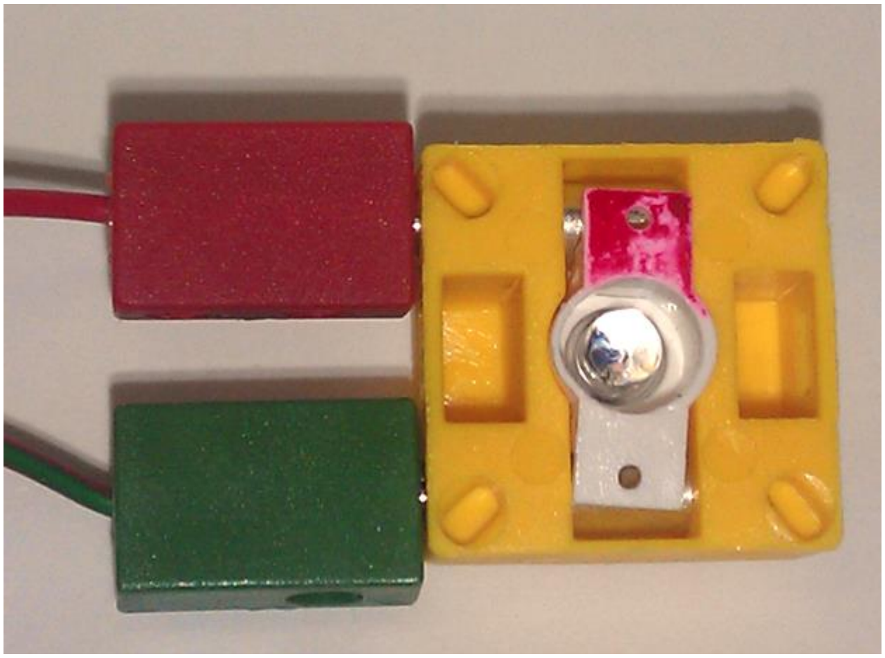
TX Controller
Wires
Phototransistor
Lamps (2)

Procedure:

Switches are installed in circuits to control the flow of electrons through the circuit. The phototransistor is setup as a fast acting semiconductor switch. Without light it is a normally open switch. When light strikes the device it begins to conduct and will continue to conduct until light is no longer there. The schematic for a phototransistor is shown below.



Because it is a semiconductor device polarity is critical. There is a red spot on the transistor.

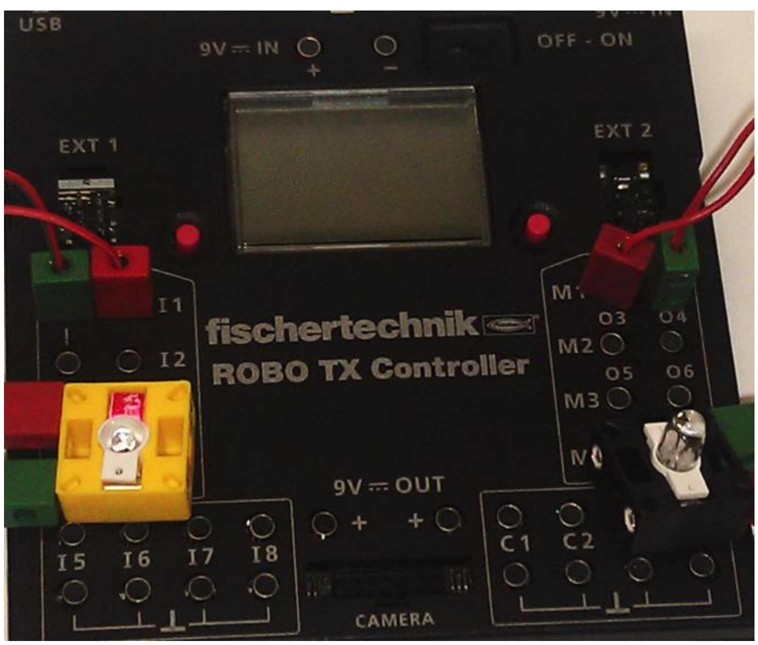


The red spot represents the collector of this transistor. This should be connected by a red wire to the positive input side of the connections on TX controller shown circled in red below.

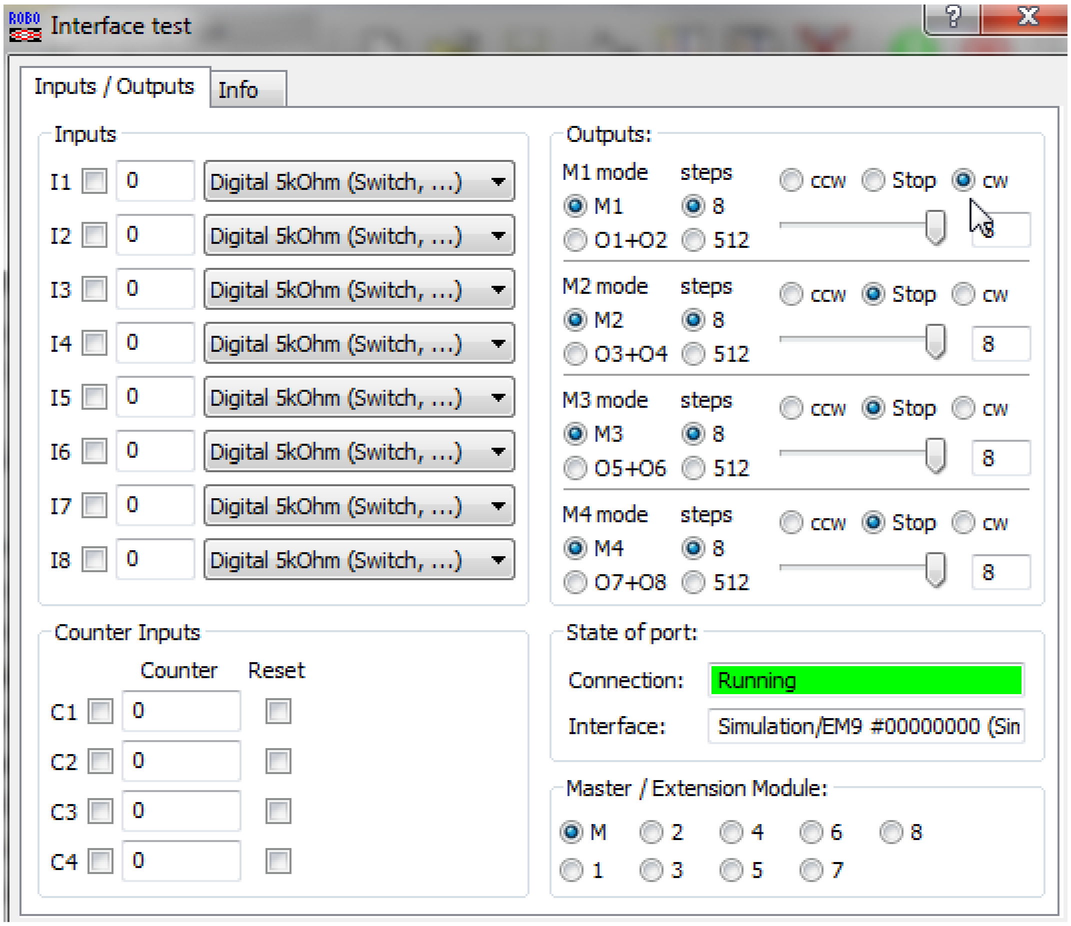
The connections associated with the other terminal are at ground potential. The ground symbol is circled below.

Using the Phototransistor

Connect the wires to the I1 connection from the phototransistor using the correct polarity on the TX Controller. Connect the lamp to M1.



Whenever you hook up a sensor to the TX Controller it is a good idea to open the Interface Test application in the RoboPro software to check to be sure the sensor is giving you the correct input for your selected type. Select the Test Interface icon on the main toolbar. When the application opens you will need to set the type to match your sensor before it will give you correct information. In this case you will be selecting Digital 5KOhm(Switch…)



Once you click on your selection it will stay in the window. Turn the power on for the interface. Click the CW on M1. This will turn the light on.

Move the light so it shines directly on the phototransistor.

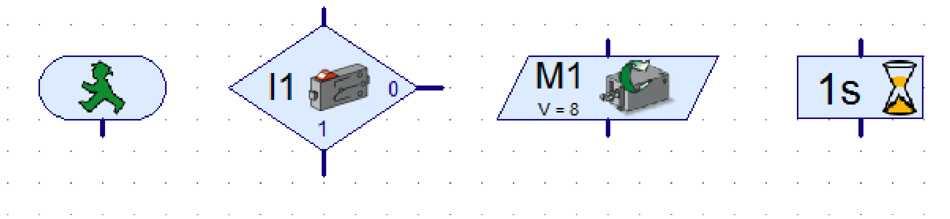
Conclusion:

Include a sketch of your setup in your Engineering notebook. Explain what happens when you shine the light on the phototransistor.

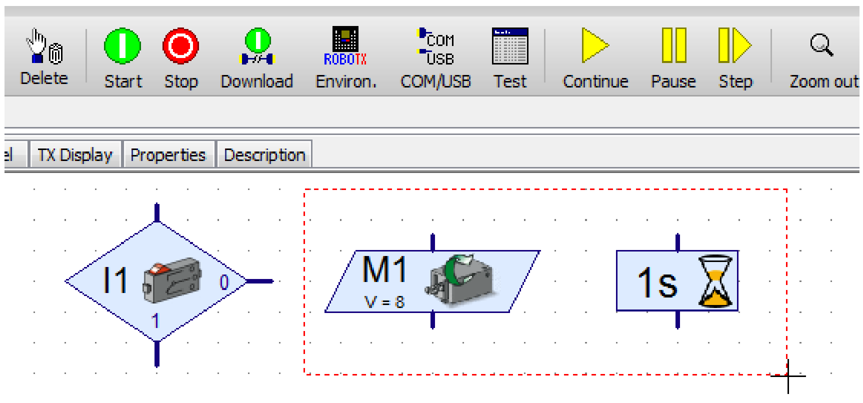
Reverse the wires on the TX controller. Does reversing the wires have any effect on the operation of the sensor?

Begin by creating a new file in RoboPro. Set the environment to the TX controller and the Level to Beginners. Use the COM/USB to set the Interface type to the Robo TX Controller.

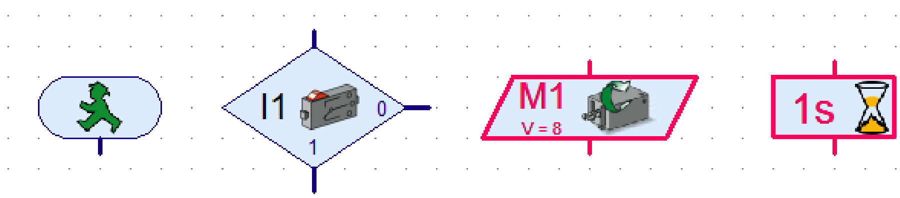
Drag one of each of the following elements to the screen.



Drag a window around the motor and the timer elements.

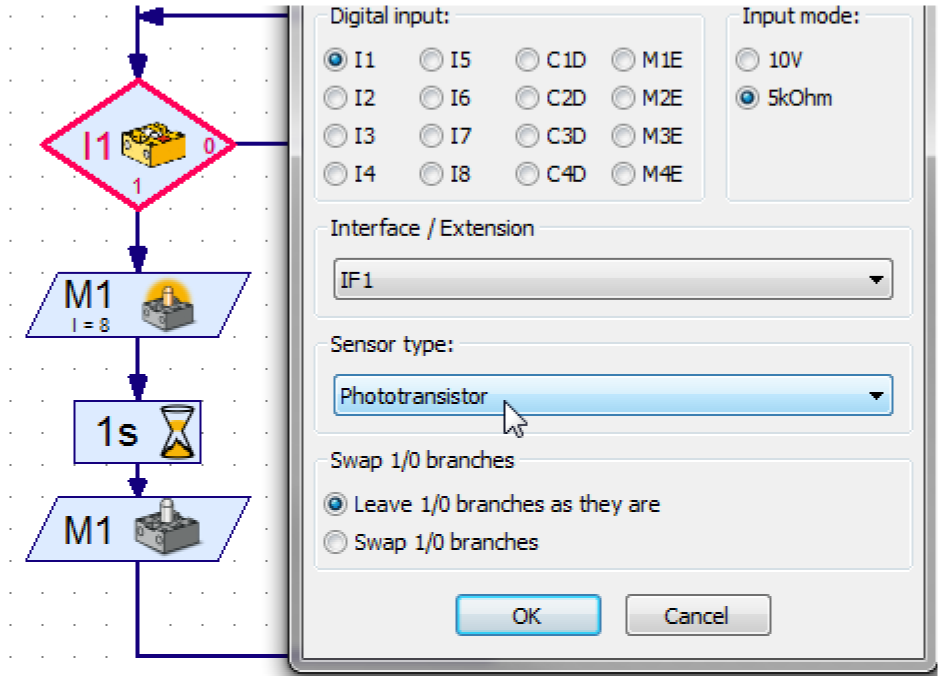


Once you click again both will be highlighted.

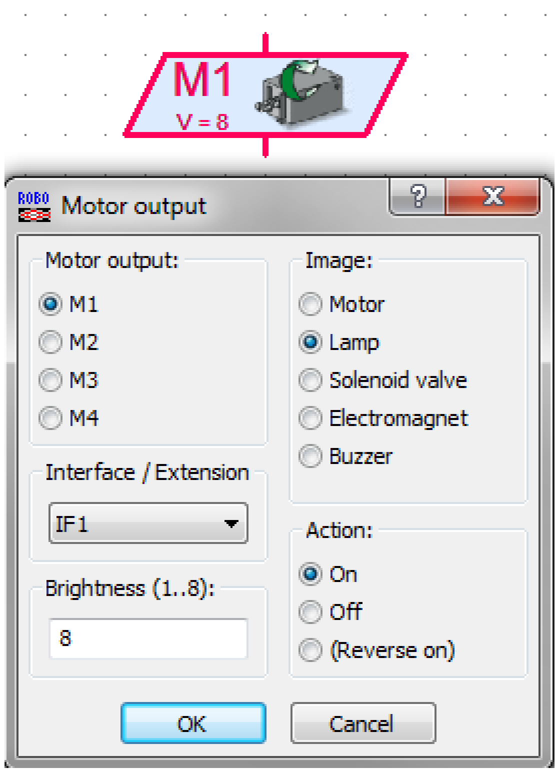


Hold your control key down while you left click on one of the highlighted elements and drag off them. When you let go you will have a copy of the blocks.

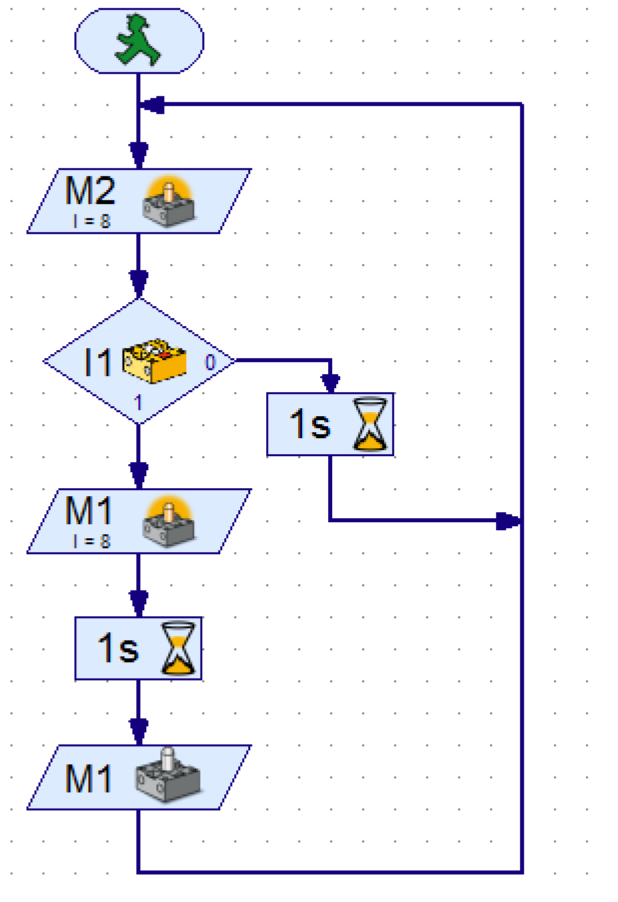
Right click on the Digital Branch icon. Set the Digital input to I1 and the Sensor type to Phototransistor.



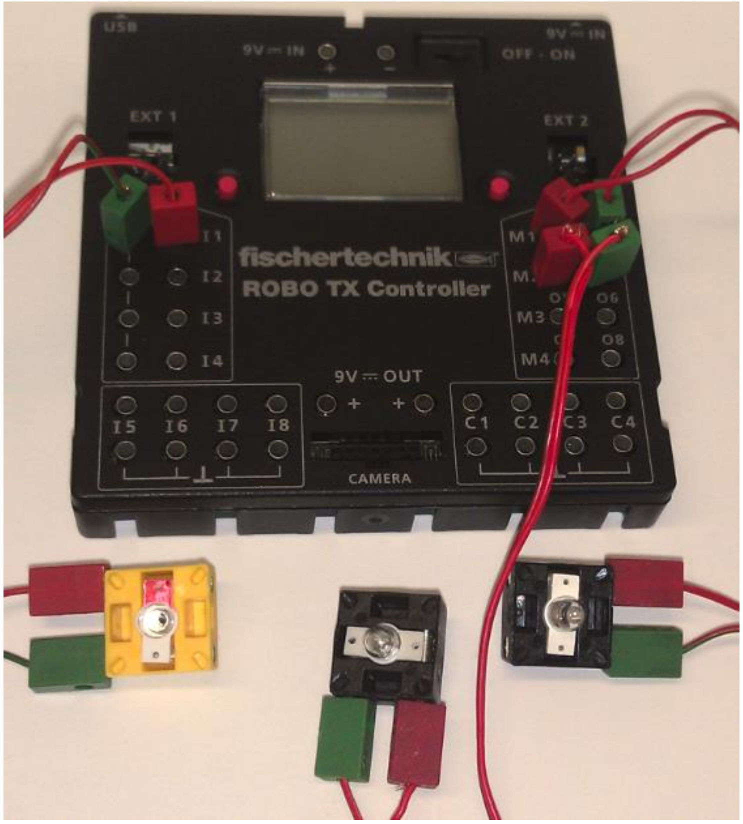
Right click on the motor blocks one at a time and set them to show a lamp. Set one to On and one to Off.



Setup the following simple circuit to test out your sensor:



Wire a light to each of the connections M1 and M2 on the Controller and the Phototransistor to the I1 connection.



Obtain your instructors permission and then connect the controller to the computer. Turn on the power to the controller and run the program. Move the light connected to M2 over the phototransistor.

Print a copy of the program for your engineering notebook. Write an observation about what the effect of bringing the light over the phototransistor. Describe the operation of the circuit.

End the program by using the stop icon from the main toolbar. Turn the controller off.

Introduction to Closed Loop Programming

Purpose:

Basic systems consist of an input, a process and an output. These simple systems are called open loop systems because the system cannot interact with the world. They perform a function and end. For most of our needs simple systems are not enough or are energy wasters. Closed loop systems add feedback to the system from sensors to continuously monitor and regulate the system. Street lights have a sensor to turn themselves on when it gets dark and off again when it becomes light. In programming we design loops to monitor the sensors and control what happens.

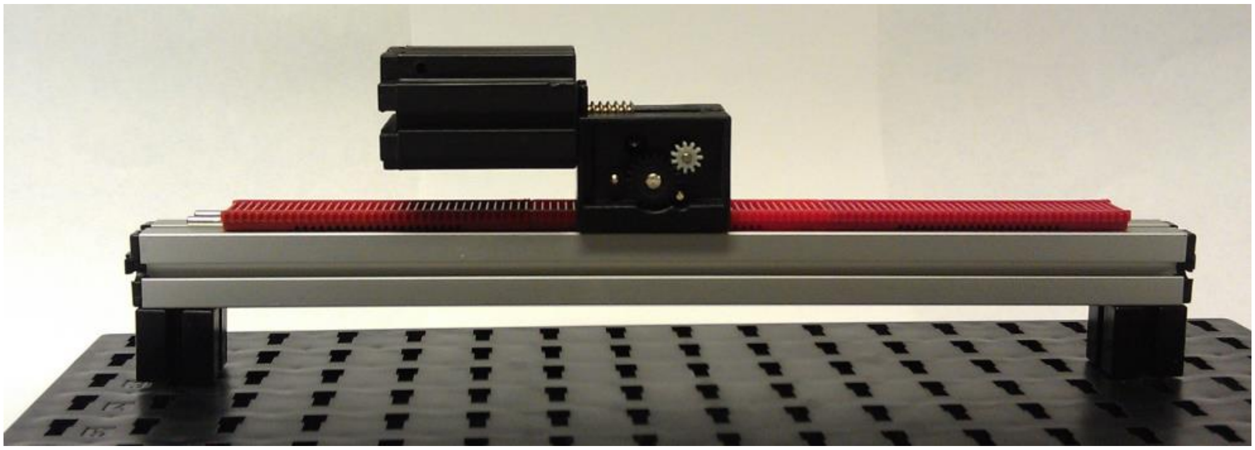
Equipment:

TX Controller
RoboPro
Wires

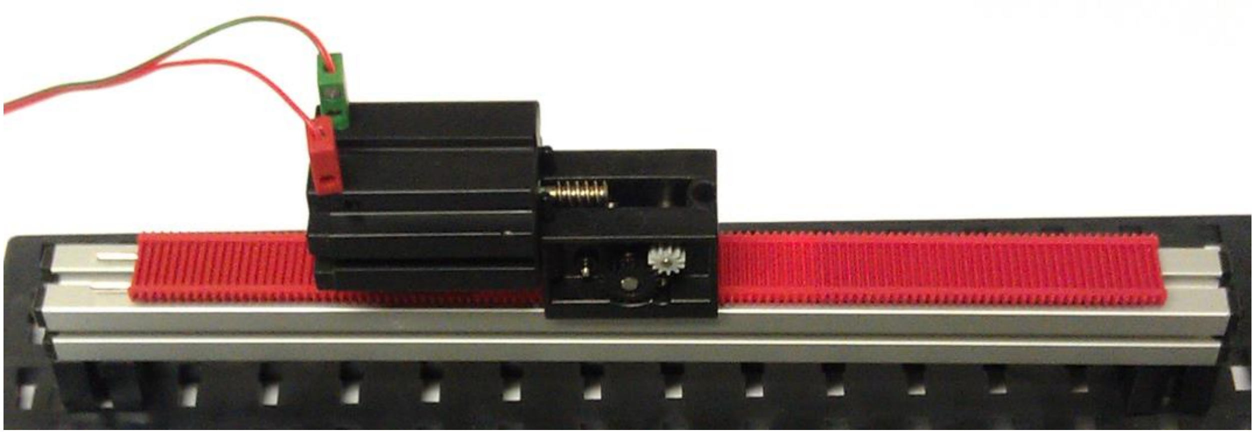
 37351 Rack and Pinion 60 3	 37272 Motor Rack Gearbox 1	 32882 Building block 15 with 2 pins 2	 31226 Aluminum Strut 210 mm 1
 37783 Mini-Switch 2	 32985 Base Plate 1	 32293 S-Motor 1	 31060 Link 15 2

Procedure:

Set up the parts so your setup resembles the one below. Leave the motor raised up from the gearbox so it will slide back and forth freely.



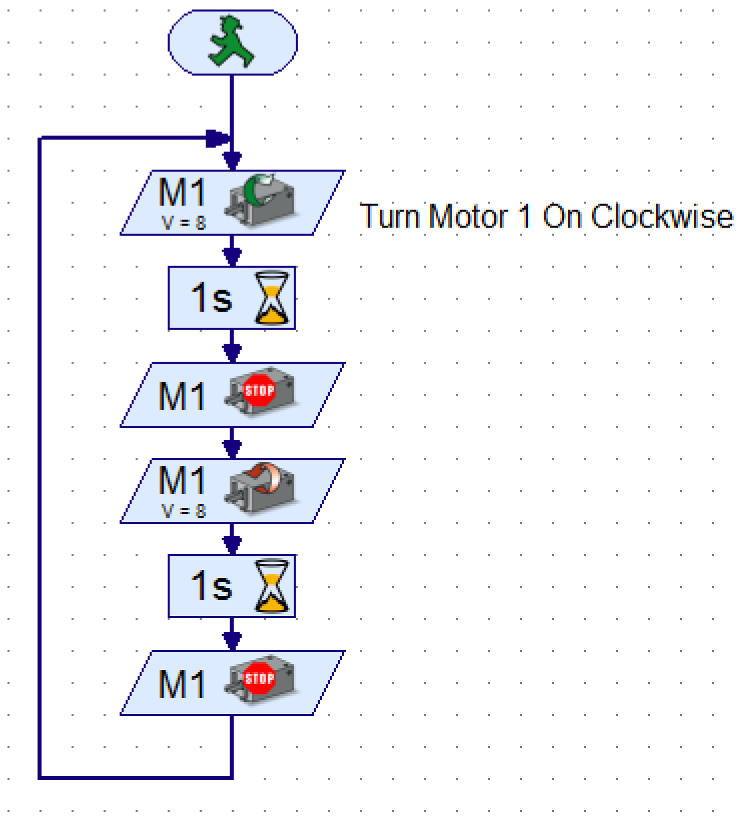
Wire the motor and connect it to the interface connections M1.



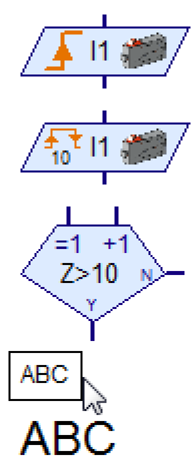
The M1 connections are shown below.

Center the motor and gearbox in the middle of the rack gear and push the motor down until it engages with the gear box. You should not be able to move the motor and gearbox now.

Write the following program that will allow the motor to move back and forth on the rack gear. Place a label next to each step to explain what should happen.



To place a label you will select the Text function from the Program Elements window. Then select the area on the screen you wish to type on.

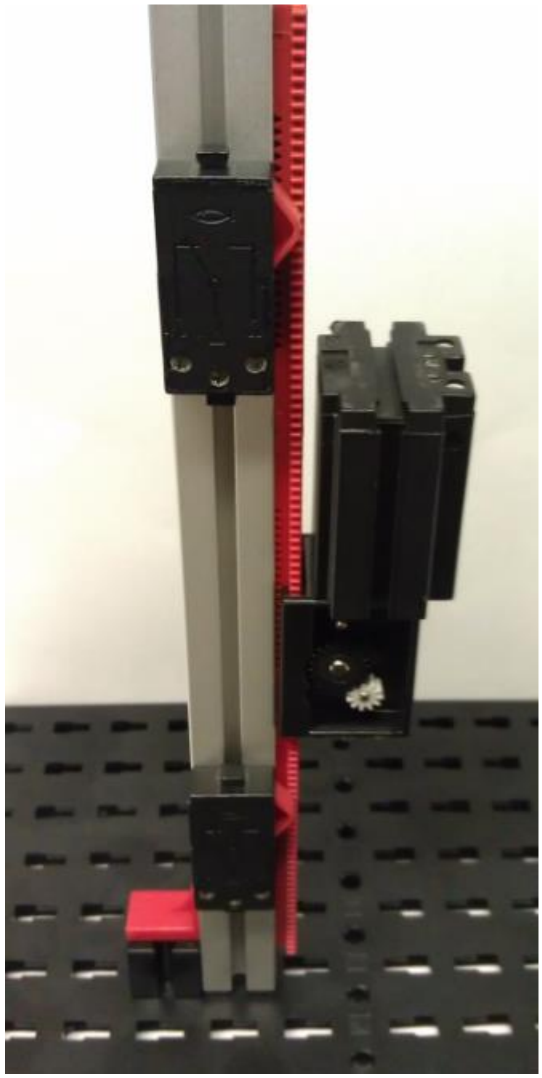


Get your instructors permission and run the program. You will see the motor travel back and forth on the rack.

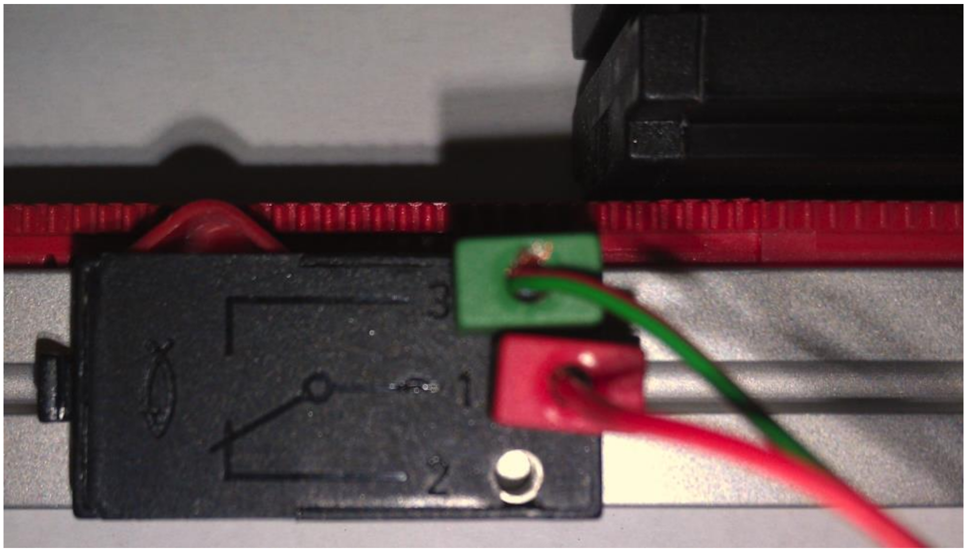
Print a copy of your program for your engineering notebook. Explain the motion of the motor on the rack. Comment about the position. Mark the extreme left and right side of the edge of the gearbox as it moves back and forth. Let the motor run for a few seconds. What do you notice about the distances traveled? Is it the same in both directions?

Closed Loop

In the program above you used time to control how far the motor went. The program didn’t really know where the motor was. Reconfigure your setup to resemble the picture below. This time the motor and gear box are between two switches.



Connect the motor to the M1 connections we used earlier. Wire both switches so they are Normally Open using terminals 1 and 3.

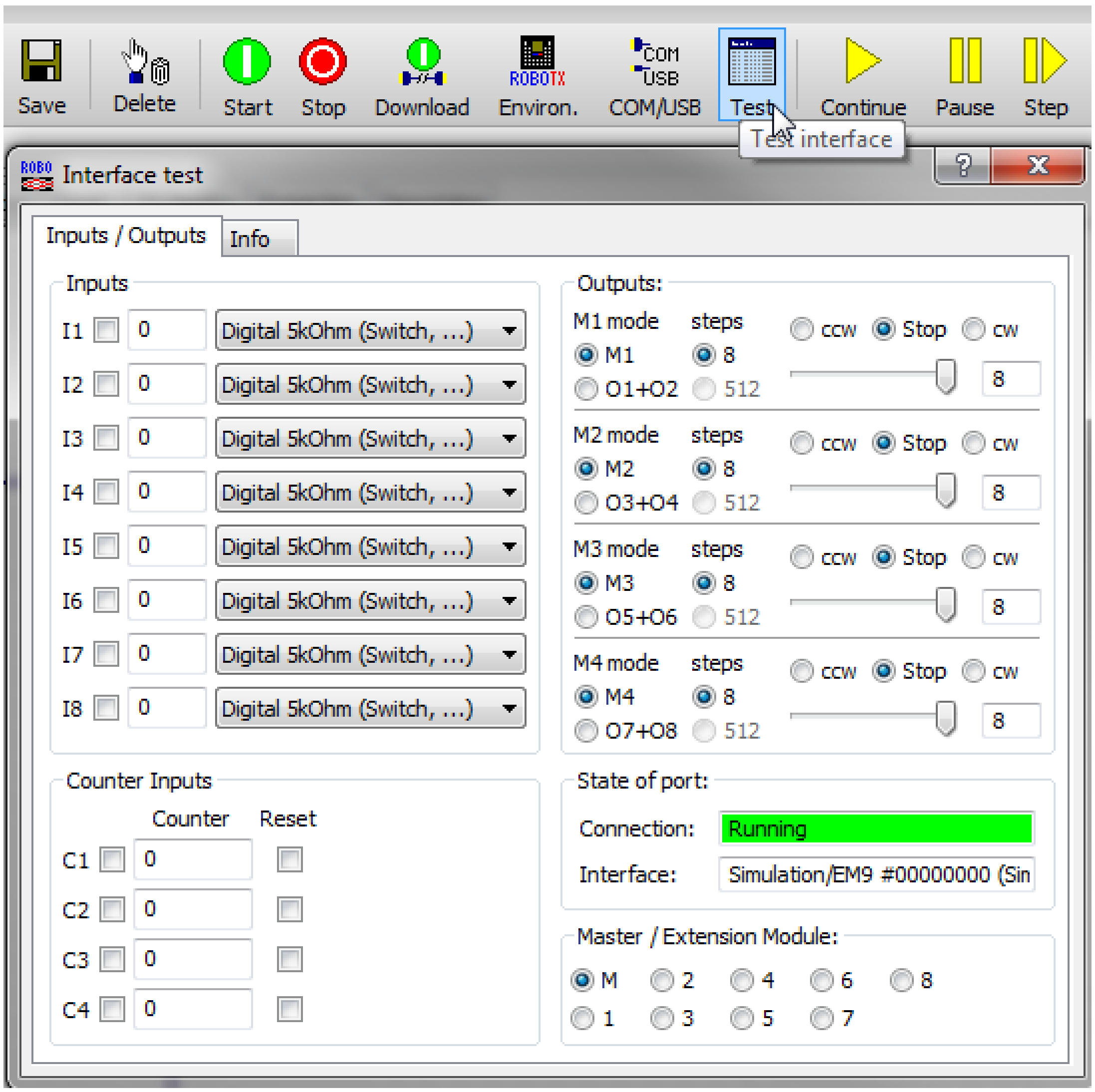


Connect the upper switch to the I1 connections on the controller and the lower switch to the I2 connections.

Program Control:

In order to control the motor moving along the rack, we need to write a program. Before writing this program, we need to find which direction (up or down) running the motor clockwise will create, and therefore be able to plan which switch will be contacted in that direction.

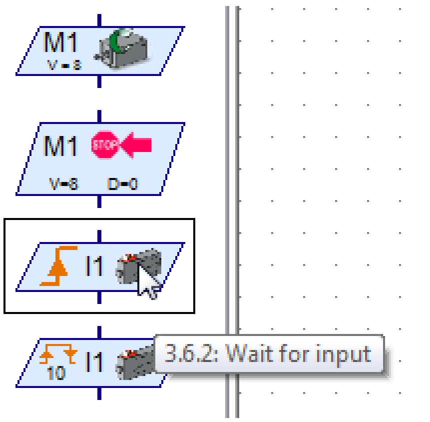
RoboPro gives us a tool to diagnose these issues. It is called the Interface Test and can be found in the main toolbar. Open that dialog box now.



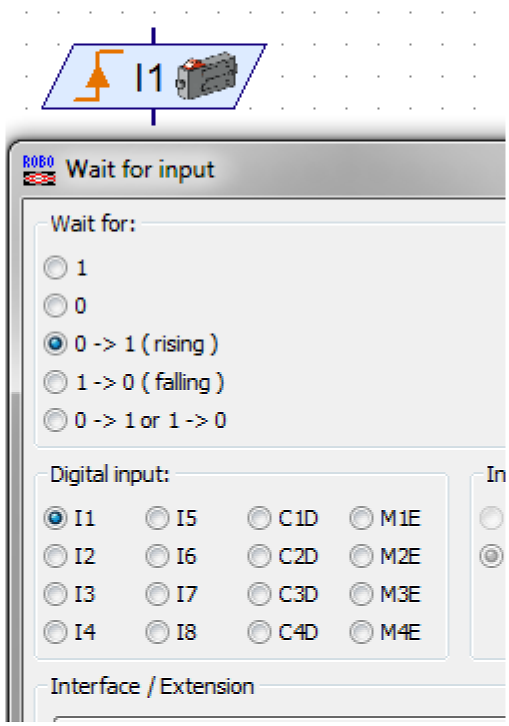
First, depress the switch connected to I2. Notice that the box next to it will have a checkmark appear. Do the same to the switch connected to I1. Push both switches at the same time. Be sure that the signals change from low to a high. If either one doesn't, check your wiring and your connections. Sometimes the plugs come loose, or the connections aren't tight.

Next, click on the CCW for M1. Let the motor move a little bit and then press the stop button. Make sure that you have reengaged the gearbox and the motor, after moving it earlier. This represents the counterclockwise direction. Which way does the motor move? Up or Down? It should move down. If it doesn't, interchange the wiring plugs on the motor. (This will change the motor's polarity, making it move in the opposite direction.) Check the motor one more time before leaving this step. By selecting CCW for Motor 1, the "train" should move down. CW for Motor 1 should move the "train" up. Once everything is connected correctly, and works properly, "x" out of the box.

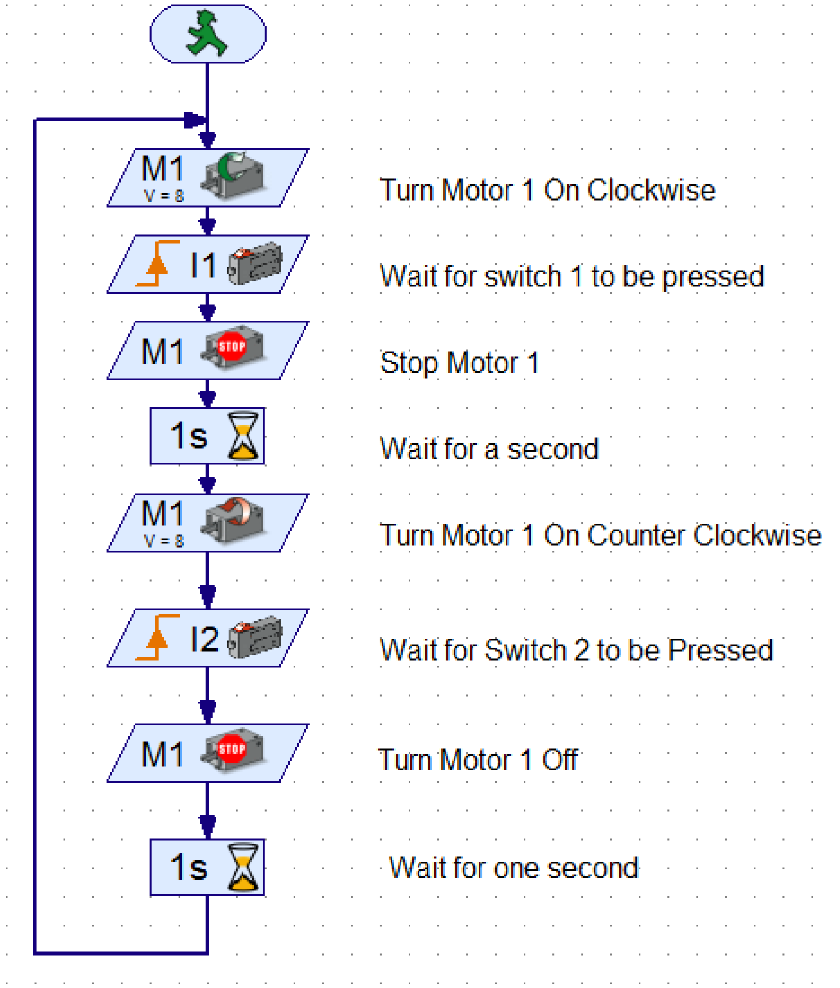
We need to turn the motor on; run it until it connects with a switch. Once it connects with a switch, the motor should change direction and move to the other end until it comes into contact with the other switch. Again, once it connects to that switch, the motor should change directions and keep going back and forth forever.
This program utilizes a special type of wait function called a Wait for Input. It is found in the Program Elements.



Right clicking on the icon after it has been placed in your program will bring up the context menu. You can select the switch you want the program to wait for.



The program shown here is one way to accomplish the task. Text notes have been entered so that you understand what is happening at each step.



Save your program as Closed Loop.
From the Main toolbar, select Run.
The program will compile, checking for errors. The program will then start the motor as instructed by the flowchart steps.
It is always a good idea to leave your cursor over the Stop button on the main toolbar just in case the program doesn't behave the way it was designed.

Conclusion:

Is a closed-loop system a great way to control the distance traveled? Can it remain unattended for an infinite period of time without your having to change the inputs?

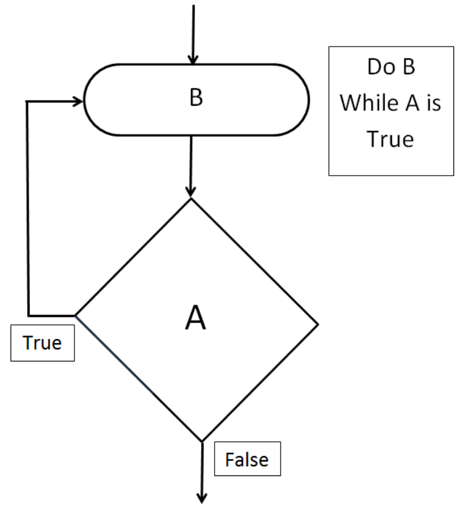
Rewrite the program so that, on startup, the "train" moves down first and then up.

Digital Branching

Purpose:

In computer programming a loop is a sequence of instructions that is repeated until a condition is reached. Once the condition is reached then the program Branches sequentially to the next path of instructions.

This activity is designed to introduce you to two types of loops. The first is called a Do/While loop. It is also called a Do loop or a While loop depending on the language you are using. In the example below operation B is repeated while condition A is true. When A is false then the program moves on to the next sequential step. True and false are markers for a digital signal.



The second type of loop is called a For/Next loop. This type of loop repeats a set of instructions until the loop counter reaches a preset number. It is like the previous loop with the condition being a set number for the counter. Once the counter is reached control is passed to the next sequential instruction. If you think about the question “is the counter equal to or greater than” it should be answered with either a Yes or a NO. Yes and No are also markers for a digital signal.

Equipment:

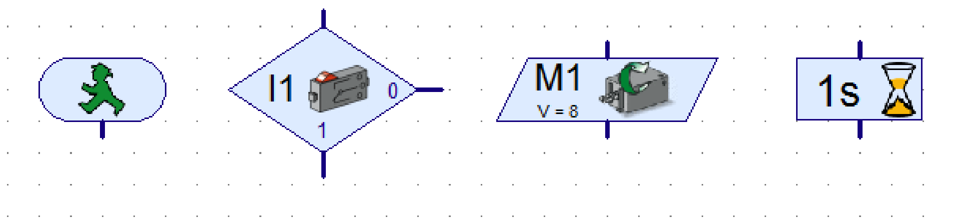
Lamp

Switch
TX controller
Power Supply
Wires

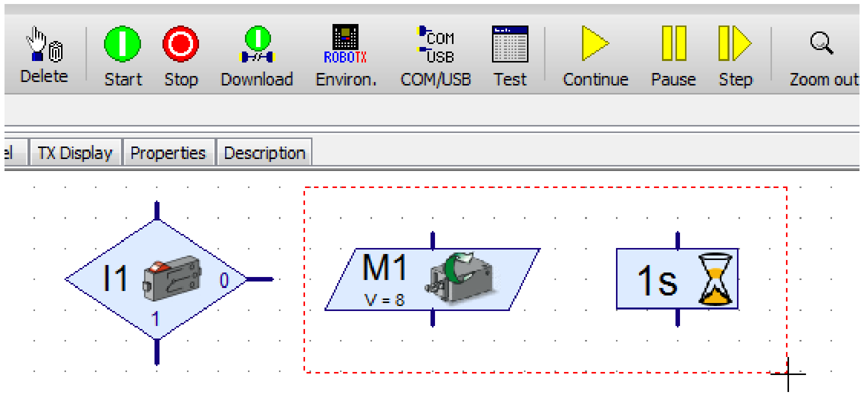
Procedure:

Begin by creating a new file in RoboPro. Set the environment to the TX controller and the Level to Beginners. Use the COM/USB to set the Interface type to the Robo TX Controller.

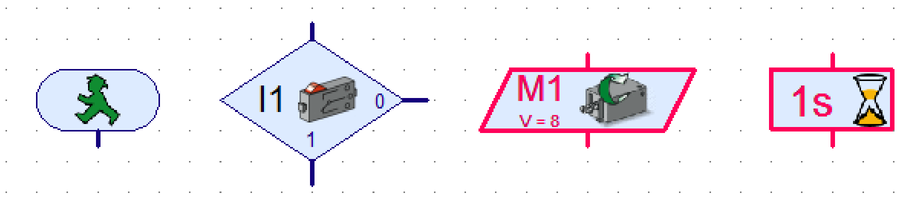
Drag one of each of the following elements to the screen.



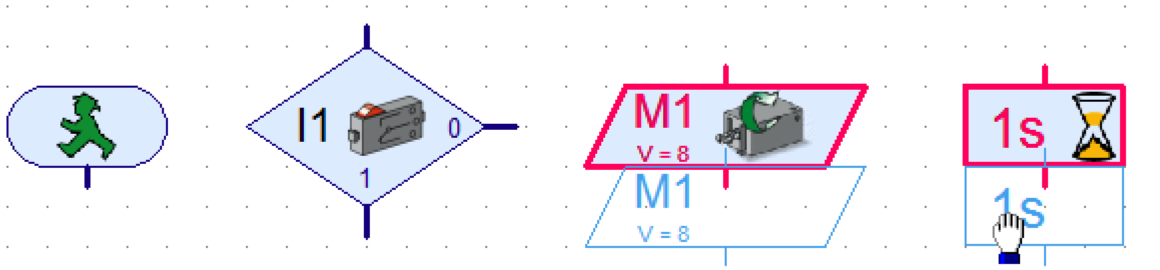
Drag a window around the motor and the timer elements.



Once you click again both will be highlighted.

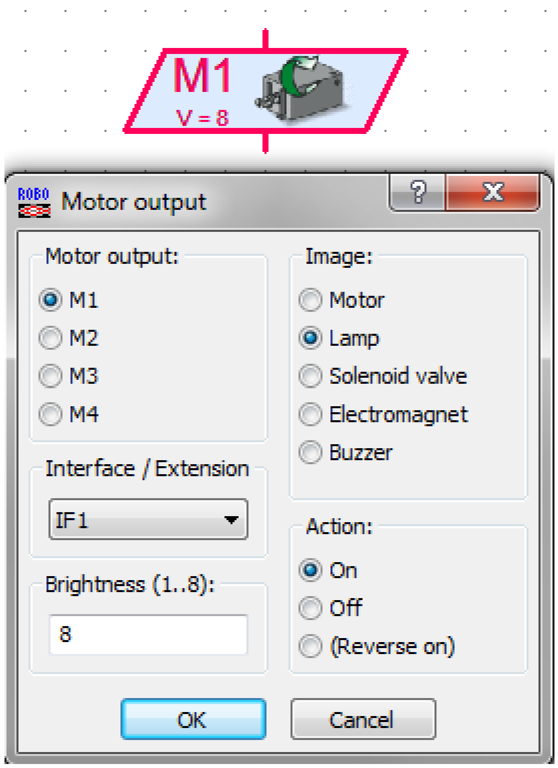


Hold your control key down while you left click on one of the highlighted elements and drag off them. When you let go you will have a copy of the blocks.

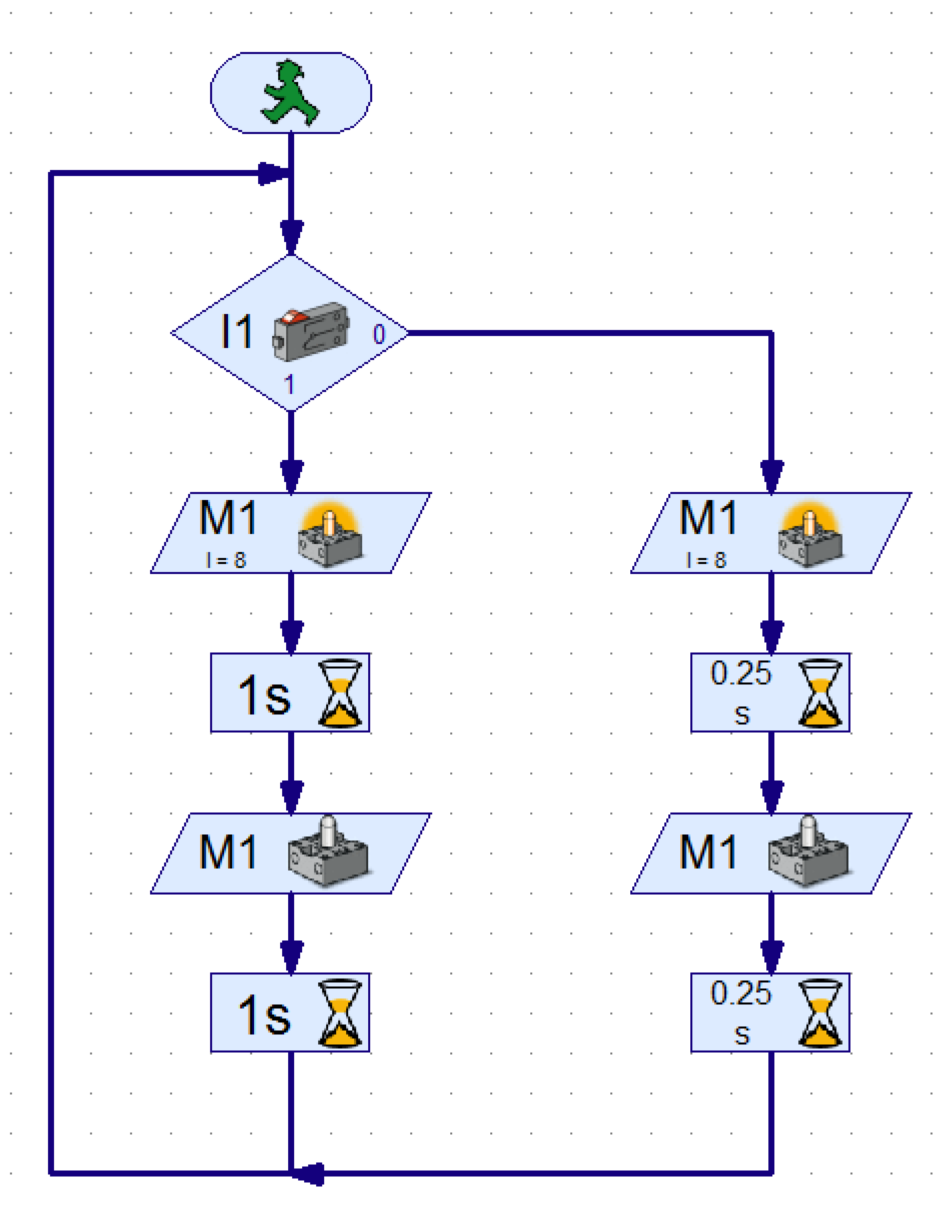


Repeat the process again and you will have four of each control block.

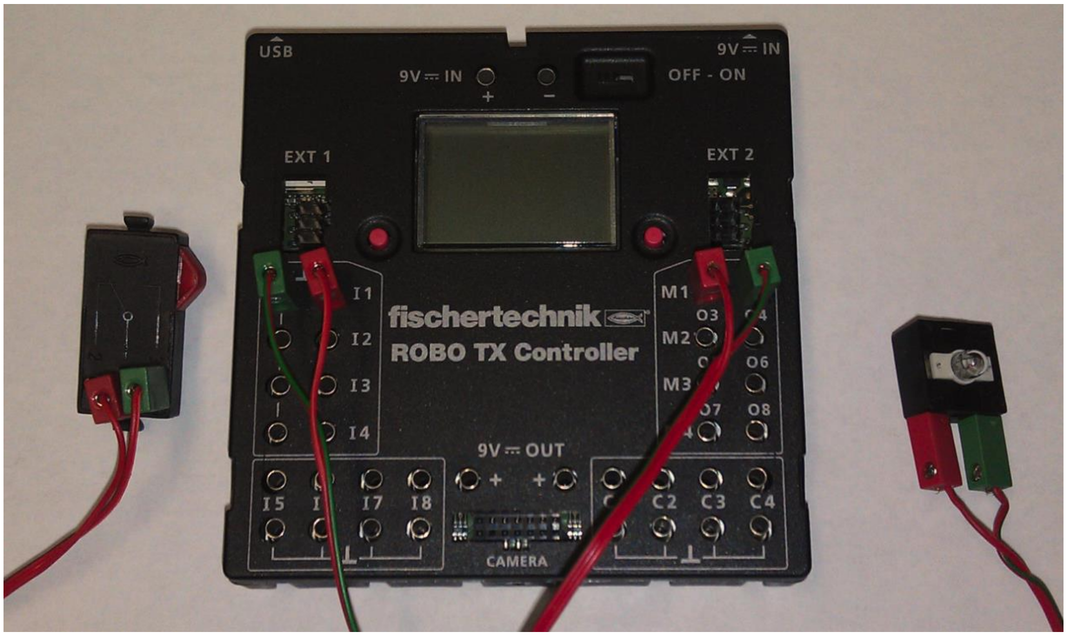
Right click on the motor blocks one at a time and set them to show a lamp. Set two to On and two to Off.



Arrange the elements in a program similar to the one below.



Wire the light to the M1 connection on the Controller and the Switch to the I1 connection.

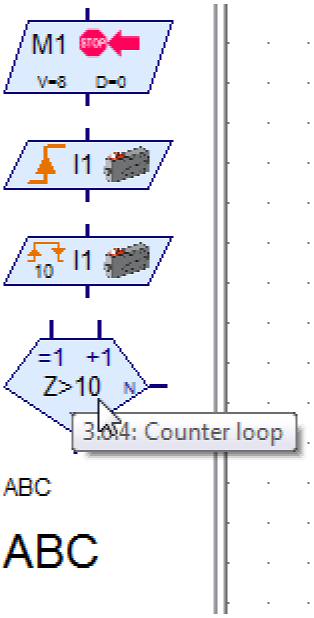


Obtain your instructors permission and then connect the controller to the computer. Turn on the power to the controller and run the program.

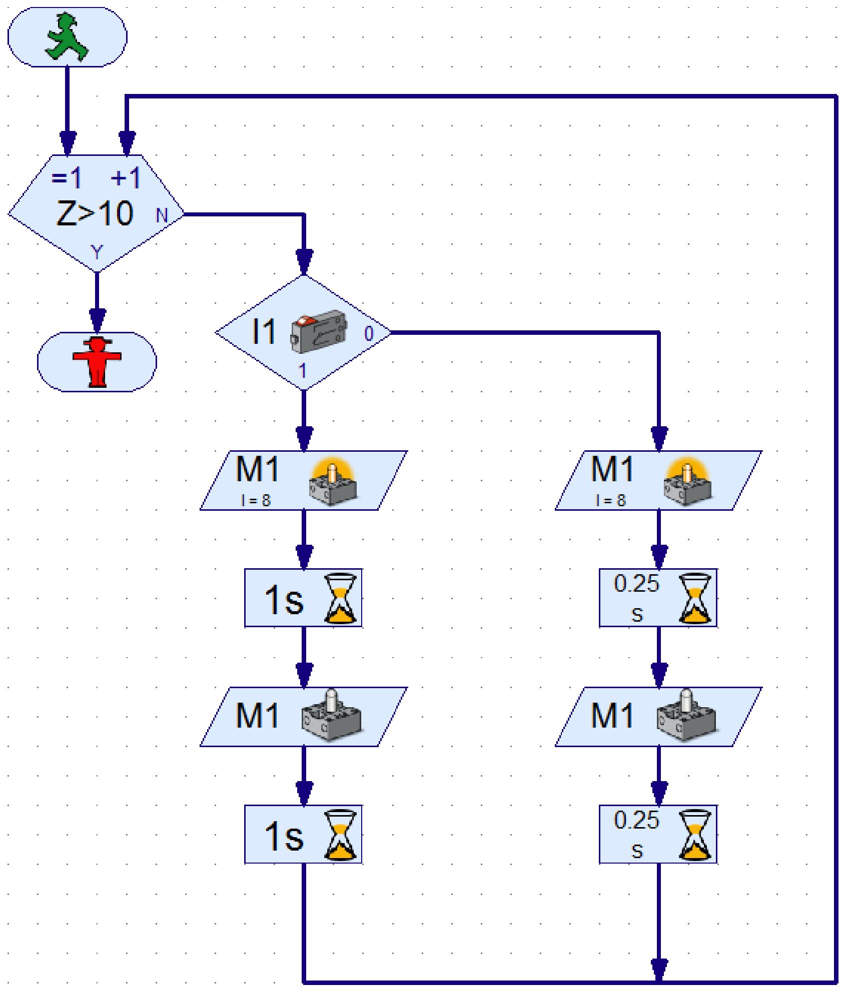
Print a copy of the program for your engineering notebook. Write an observation about what the effect of pushing the switch has. Describe the operation of the circuit.

End the program by using the stop icon from the main toolbar. Turn the controller off.

To create a loop that counts we will need to use the Counter Loop element from the element window.



Drag this one out to the program window and rewire your program to match the one below.



Obtain the instructor permission before turning on the controller to test this circuit.

Run the program.

Print a copy of the program for your engineering notebook. Write an observation about what the effect of pushing the switch has. Describe the operation of the circuit. Explain the differences between the two circuits.

Conclusion:

Write a program that will begin with the light on. Allow the light to stay on until you push the switch. This should turn the light off and end the program.

Write a program that blink the light 15 times and end or end when the switch is pushed.

Print a copy of these program for your engineering notebook. Write an observation about what the effect of pushing the switch has. Describe the operation of the circuit.

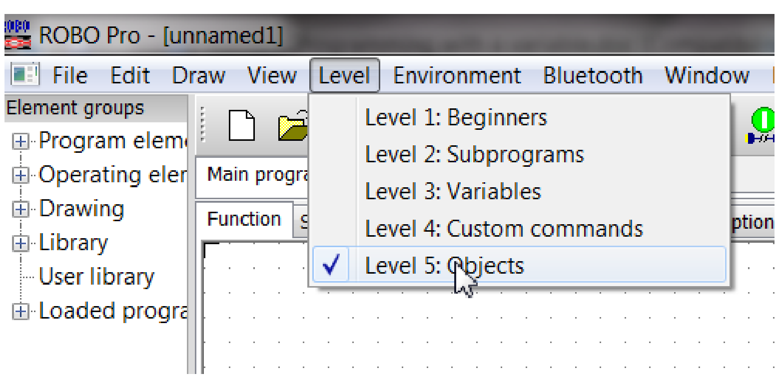
Logic Gates

Purpose:
In order to solve more complicated problems electronically, logic must be used. Logic investigates, formulates and establishes principles of valid reasoning. The process involves applying truth tables and formulas to create the solution to the problem at hand. Logic utilizes two basic states. People use different terms for the two states; Yes and No, High and Low, 1 and 0, On and Off.

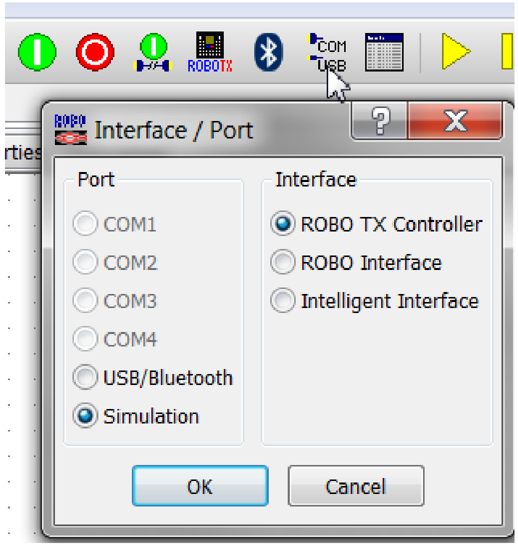
There are several systems for documenting the logic of problem solving and you will find some more suited to your individual styles than others. It is important to be able to move from one system to another. The basic building block in a digital circuit is labeled a logic gate. There are several types of gates and each gate has a mathematical relationship between the inputs and the output that can be written as a Boolean expression, a truth table or a circuit. As you work through the activity you will be translating from a gate to a table to a formula to a gate to learn the relationship and how it is represented. Once you master the basics, solving a complex problem is much easier.

Equipment:
RoboPro

Procedure:
Open RoboPro and start a new project. Set the level to Level 5:Objects

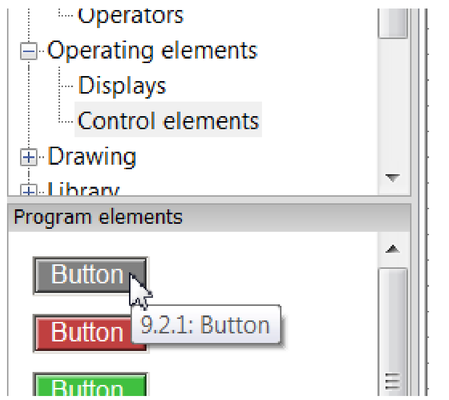


From the COM/USB button select Simulation and select OK

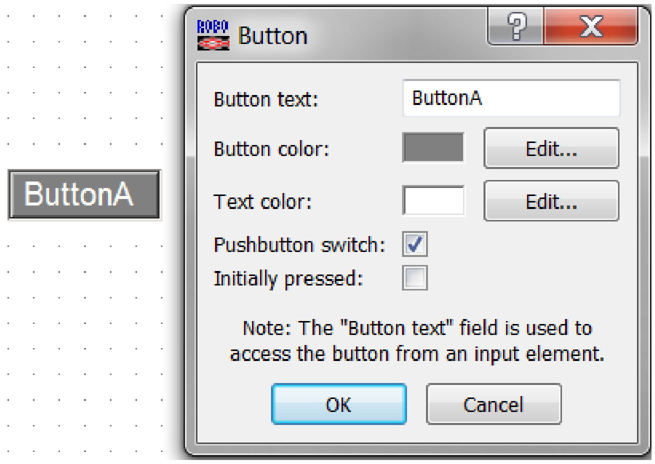


The NOT Gate

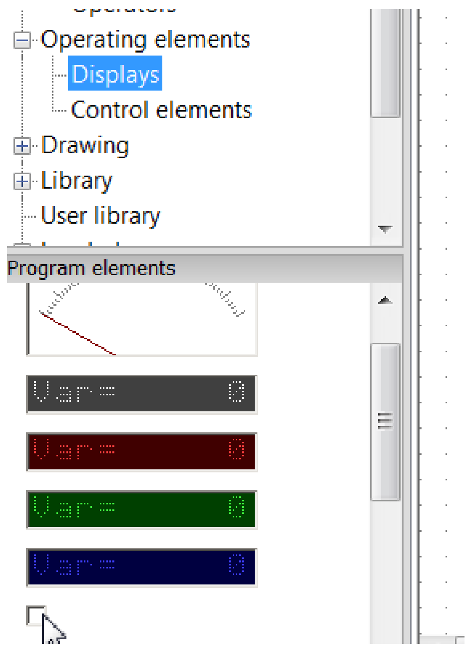
The not gate is the simplest of gates with only one input and one output. Sometimes these gates are called inverters. Start by placing a button. You will find the buttons in the Control elements found in the Operating elements section.



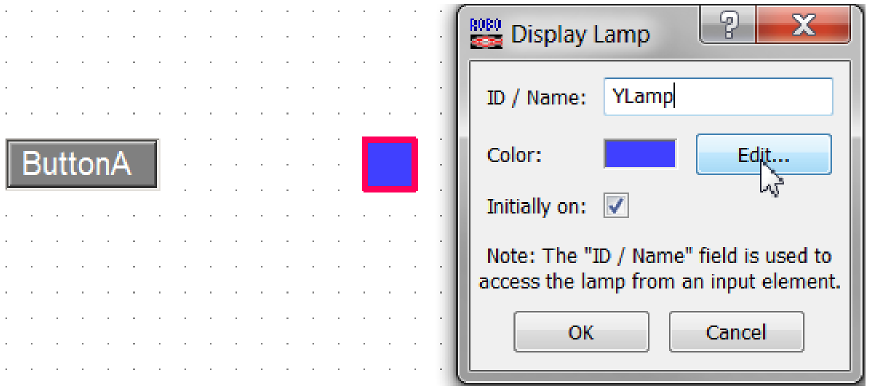
Drag a button out onto the main function area of the program. Right click on it and Name the Button ButtonA. A is a common name for Logic inputs. At this point you can adjust the color if you wish by selecting Edit and selecting a new color. Be sure you check the box for Pushbutton switch:.



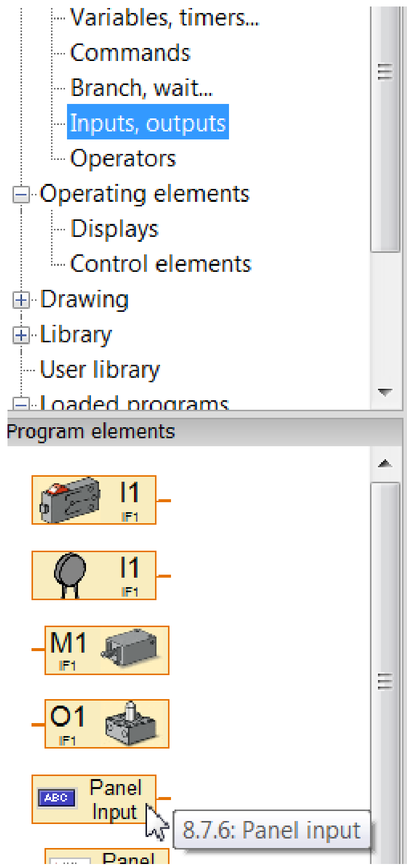
You will now need a lamp to indicate the output state. Drag out a Display lamp found in the Displays section of the Operating elements.



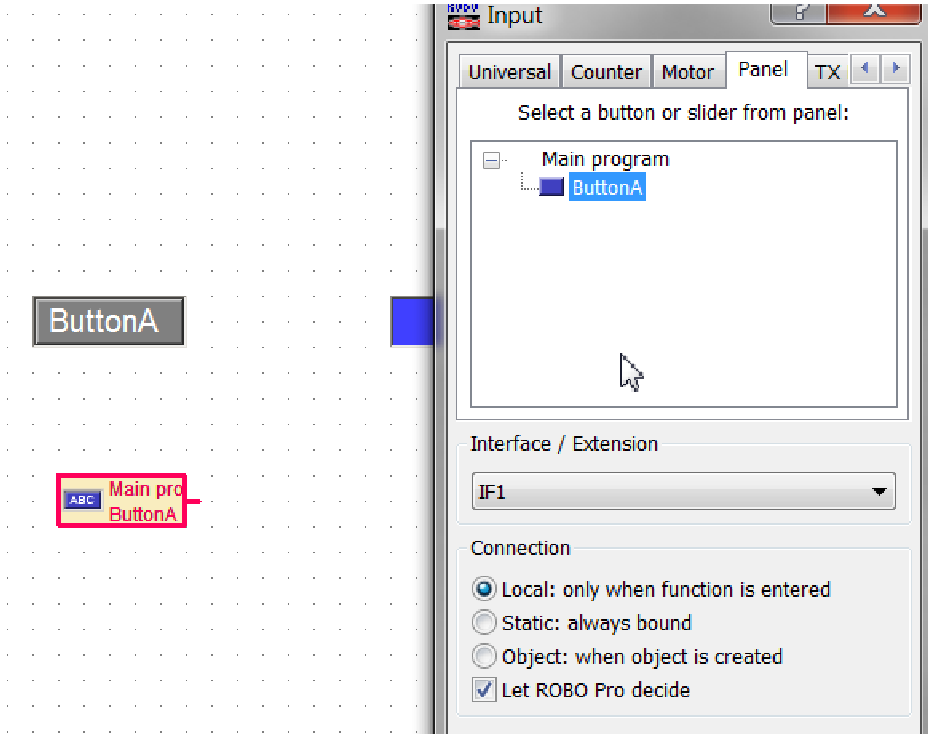
Right click on the lamp and rename the lamp to YLamp. Y is a common letter to define the output of a logic gate. You can change the color by selecting edit.



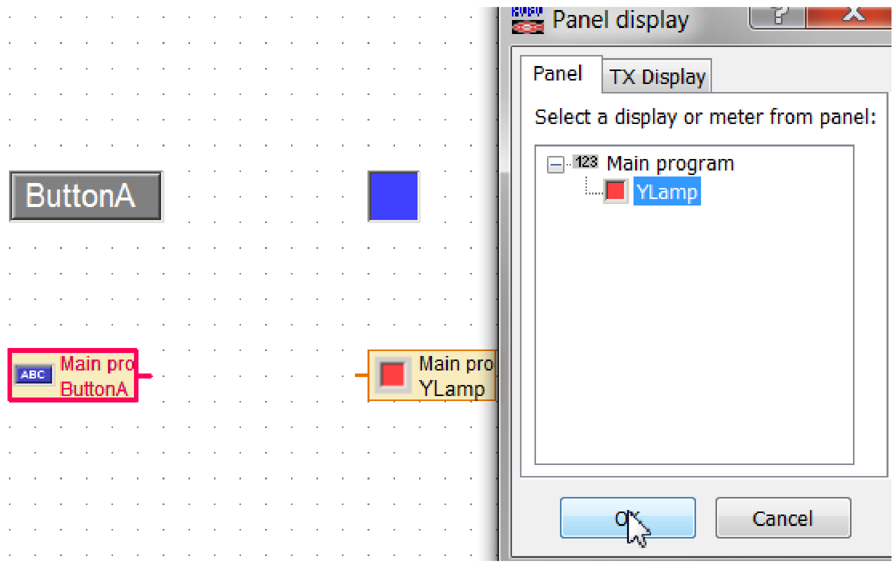
Now that we have the operating elements we need to build the logic. From the Inputs, outputs section of the Program Elements, select the Panel Input.



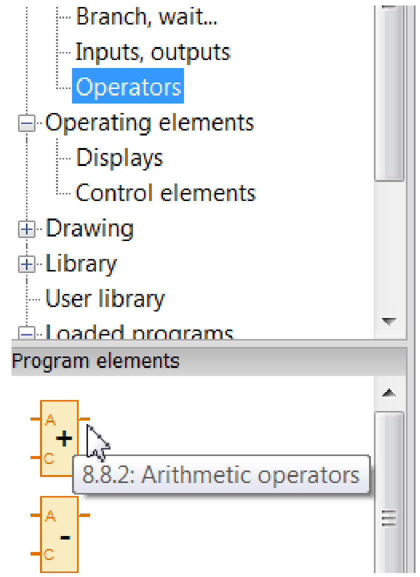
Right click on the Panel Input and Highlight Button A in the list to assign it to the input.



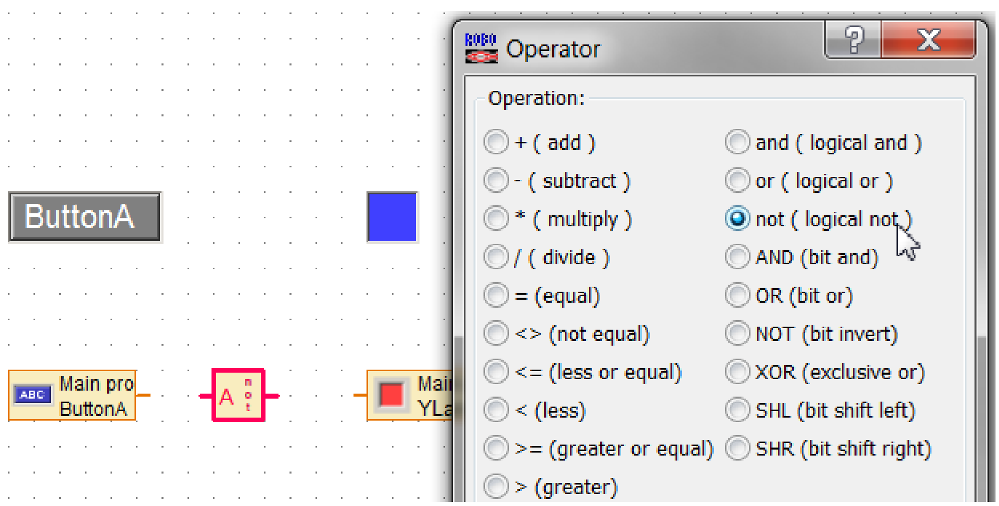
Place a Panel Display from the Inputs, outputs section. Right click on the Display and Highlight the YLamp and select OK.



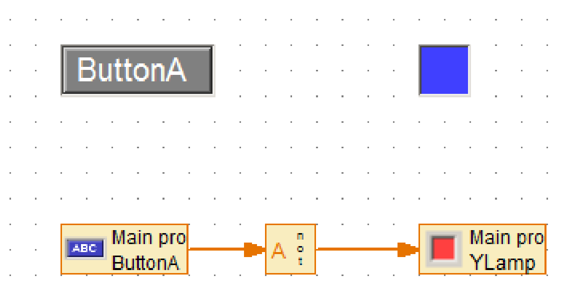
At this point we have to add the logic to your program. From the Operators section of the Program elements section place a logical operator on the screen. Since these blocks are defined later you can take the first one on the list.



Right click on the block and select not (logical not) from the choices. When you select OK you will see the shape change and the label not will appear.



Wire the circuit.



Truth Table:

Start the program. When the program is running record what you see in the chart below. Click on the Button to toggle it from a 0 to a 1. If you see a 0 in the chart that means the button should be off. Observe the Logic lamp. If the light is off place a 0 in the logic column. If the light is on place a 1 in the logic column.

NOT	
A	Y
0	
1	

Boolean Expression:

A Boolean Expression is a mathematical expression detailing the relationship between the inputs and the outputs. It is written in the form of the Output equals the Input that caused the output. The Input in our example is called A. Since A has two states we call it A when the input is High and NOT A when the input is Low. We write NOT A by placing a bar over the letter. $(\bar{A})$

In our example the Output is called Y. From your Truth Table above you must determine the formula. Circle the correct one below and cross the other out. Ask yourself was the Y Lamp lit when A was pressed or not pressed.

$Y = A$

$Y = \bar{A}$

AND and OR Gates:

The first step here is to place two buttons. You will find them in the Control elements found in the Operating elements section. Drag two buttons out to the Main program area. Right click on each button and name them and adjust the color if you wish by selecting Edit. This example uses Button A and Button B for names. Be sure to place a check in the box for Pushbutton switch on each one.

Drag out a Display lamp found in the Displays section of the Operating elements.

Right click on the display lamp. Rename it, the example here uses the name Y Lamp and the color was changed by selecting edit.

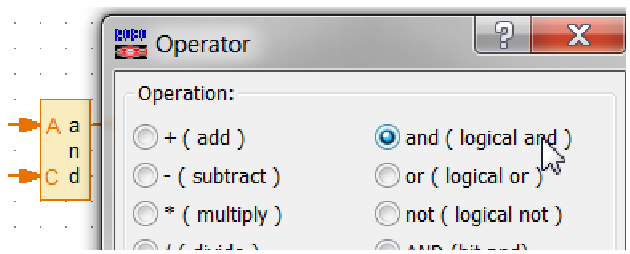
Now that we have the operating elements we need to build the logic. From the Inputs, outputs section, select the Panel Input. Place two on your sheet. Right click on each button in turn and apply the Button A and Button B to the Panel Inputs.

Place a Panel Display from the Inputs, outputs section.

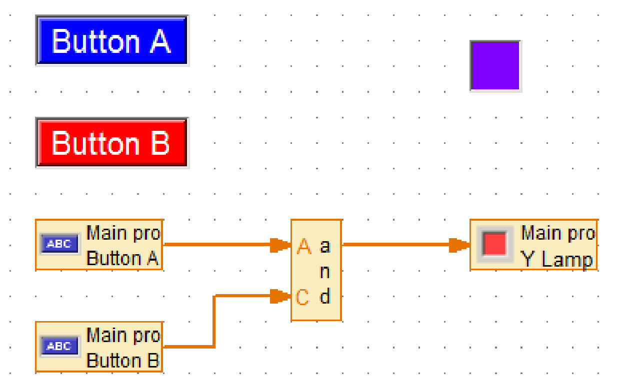
Right click on the Panel display and select the Y Lamp we created earlier and select OK.

From the Operators section of the Program elements section place a logical operator on the screen.

Right click on the Operator and be sure you have and (logical and) selected.



Wire the circuit together.



AND Gate Truth Table:

Start the program. When the program is running record what you see in the chart below. Click on the Button to toggle it from a 0 to a 1. If you see a 0 in the chart that means the button should be off. Observe the Logic lamp. If the light is off place a 0 in the logic column. If the light is on place a 1 in the logic column.

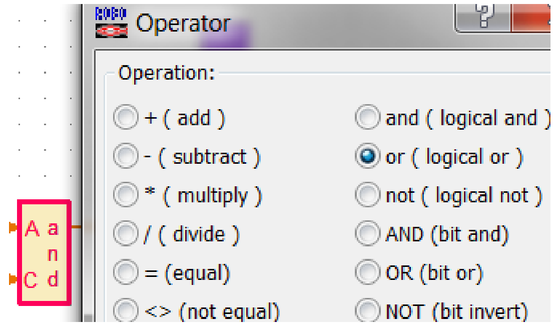
AND		
A	B	Y
0	0	
1	0	
0	1	
1	1	

Boolean Expression:

Since there are two inputs there are more possibilities for the Boolean expression. From your earlier research you found out that we are interested only in the value of the Inputs when the Output is High. Write the Boolean expression for the AND gate below.

OR Gate

Stop the program and then right click on the AND change it to an OR



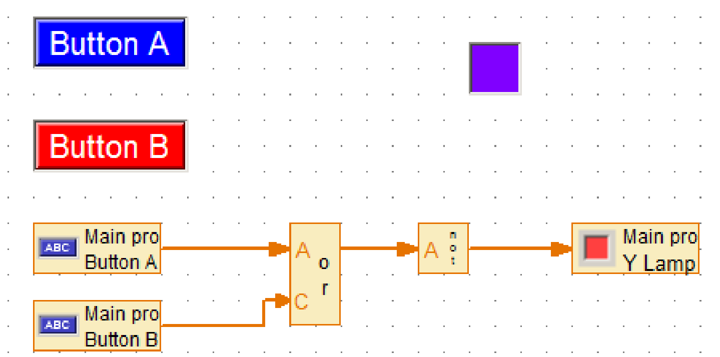
Repeat the process with the buttons and fill in the OR truth table and write the Boolean Expression for the OR Gate.

OR		
A	B	Y
0	0	
1	0	
0	1	
1	1	

Boolean Expression:

NOR Gate

Now Delete the wire from the gate to the Logic output and place a NOT on the page. Remember the NOT changes a 0 to a 1 and a 1 to a 0.



Wire the circuit. This logic is called a NOT OR or NOR for short. Repeat the test to discover the truth table. Record it below. Write the Boolean expression next to the Truth Table.

NOR		
A	B	Y
0	0	
1	0	
0	1	
1	1	

NAND Gate

Change the OR gate to an AND gate. Now we have a NOT AND gate, a NAND for short. Develop the truth table for this one and write the Boolean expression for the gate next to the truth table.

NAND		
A	B	Y
0	0	
1	0	
0	1	
1	1	

Conclusion

1. Describe in words each gate and what inputs are required to get an output.

2. How does the truth table of an and gate differ from an or gate?

3. Describe the difference between the AND and NAND truth tables?

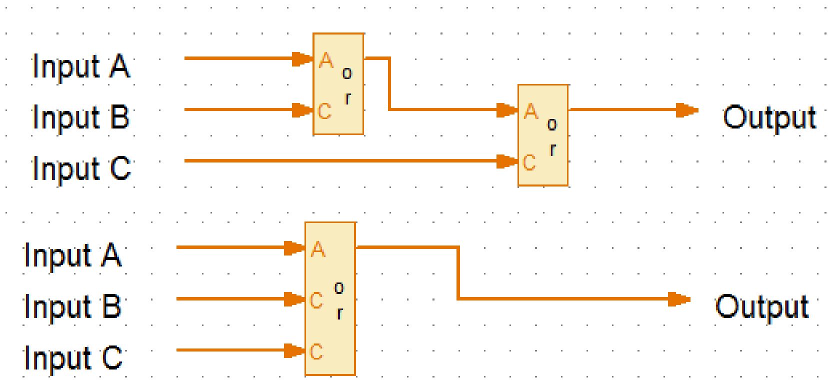
4. Could you use a truth table to figure out which gates to use to solve a problem?

Combinational Logic

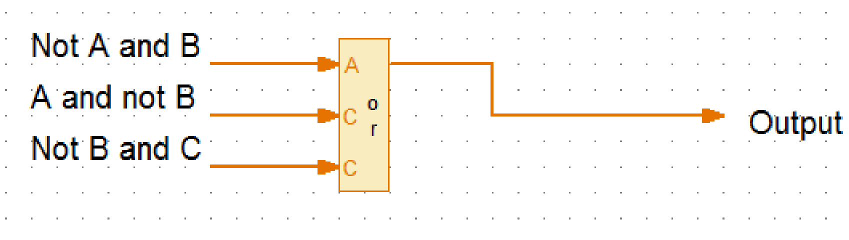
Purpose:
When asked to design a control system you will probably be presented with a description of the problem or a statement of desired outcomes for the inputs. In order to begin designing the control system you will have to translate the word problem into a digital logic circuit. The first step is to identify the various inputs and what the outputs will be. Most people begin by translating the design specifications into truth tables. This truth table will show what the output of the control system should be for each combination of inputs. Combinational logic describes what happens when you have several inputs to a system. The program will need a way to define what the system behavior should be when presented with the different combinations of inputs. Once the truth table is designed they can then be translated into Boolean equations, which make the process of creating the logic circuits easier. This activity will help you learn to translate specifications to truth tables to expressions to the logic those expressions represent. In a previous exercise you were introduced to truth tables and simple Boolean expressions.

Equipment:
RoboPro
TX Interface
Lamp
Wires

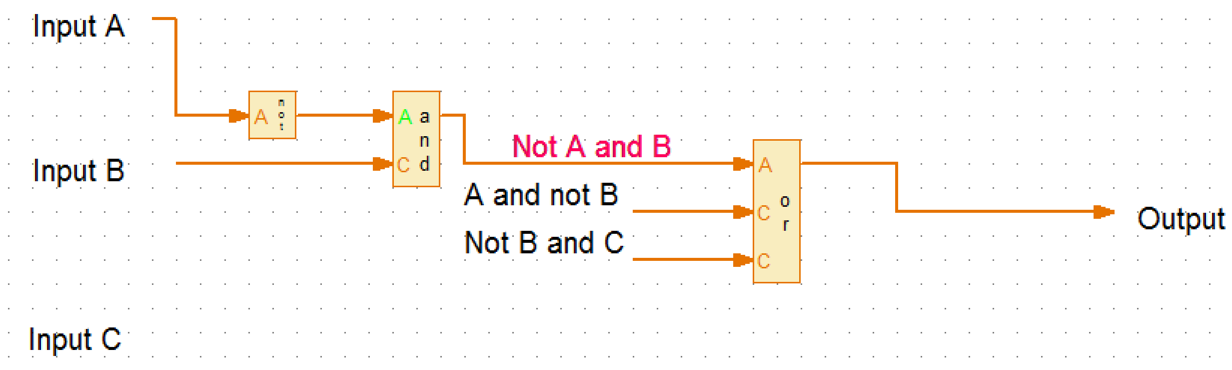
Procedure:
Learning to translate the design specifications to logic requires you to master a few intermediate steps. To begin we will look at how a Boolean expression is translated into a logic circuit. The design spec for this problem defines three separate inputs and one output. The specification requires an output when any of the inputs is high. That expression would be represented as A+B+C=Y. This would be read as A or B or C=Y. In the activity on basic gates you learned about the 2 input OR gate. It produced an output if either of the inputs was high. Below are two different representations of possibilities.



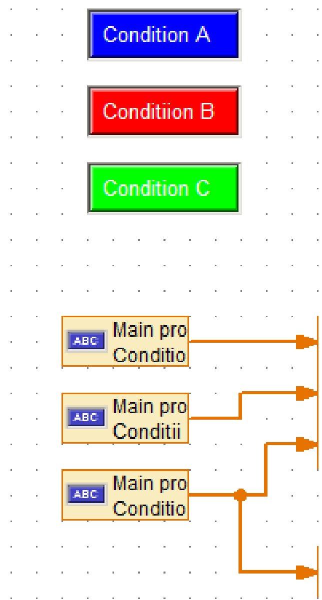
You will notice that the second option is a three input OR gate. Now if you are given an equation such as $\overline{A}B + A\overline{B} + \overline{B}C = Y$. (Not A and B or A and not B or not B and C) Using the example above you would then have a three input OR gate to combine the logic.



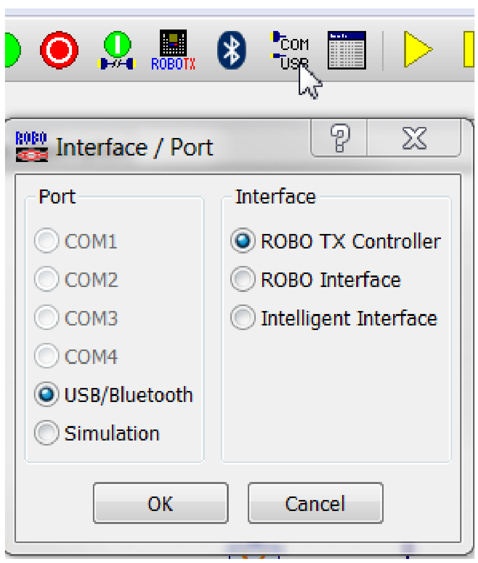
We now create the three inputs. Beginning with the Not A and B we see that it should look like the picture below. You can see to create Not A we take input A and insert a not gate. When A is low the not gate will invert the signal and you will have the AND gate output a high when input B is high and input A is low. Create the circuits for the A and not B and the not B and C and add them to the circuit. Make a screen shot of your completed program and have your teacher approve it.



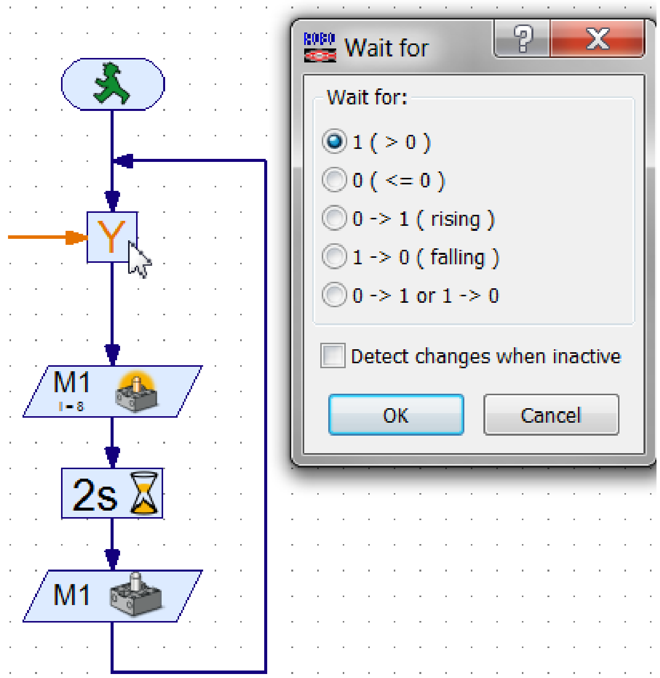
Combinational logic allowed you to create the logic circuit from the Boolean expression using only AND, OR, and NOT gates. We can take the combination and connect to an output. Take the circuit you designed above and use buttons on your screen to supply logic pulses to your design.



We will display the results of your logic using a lamp connected to the M1 connection on the TX controller. To do this you must select the COM/USB icon and set the Port to USB/Bluetooth.



In the program below you can see the output of the logic coming into a Wait For block which is found in the Branch, wait…. Section of the program elements. We set it to wait for the condition when the input is high (greater than 0). As long as the logic is putting out a low it will wait. When your switches meet the conditions a logic high ends the wait and the program advances to turn the light on.



Test your programs and demonstrate for your teacher.

Truth Table to Boolean Expressions

The next thing you will need to be able to do is to convert a Truth Table to a Boolean Expression.

Looking at the Truth Table below, begin by observing any place a 1 appears in the output column. You can then write the expression for each place a one appears in the output.

Inputs			Output
A	B	C	Y
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	1

$Y = \bar{A}B\bar{C}$

The first expression would be $Y = \bar{A}B\bar{C}$
Write the other two expressions here.

Y=

Y=

Since there are three output possibilities you can now write the entire equation using OR between the three expressions from the above truth table. Write the equation below.

Y=

Write a program and test by using buttons and a lamp connected to the TX Controller

Converting a problem to a truth table

The first thing to do is to read and reread the problem. Once you are familiar with what is being asked make a list of all mentioned inputs and the output. Read the following description of a circuit:

In order to save energy the Cozy Bed and Breakfast hotel would like to install automatic hallway lights. They would like the lights to come on automatically when there are people in the hall and it is dark. They will have a master switch to turn the lights on or set them to the Automatic mode if they wish. In the automatic mode they would like the light to stay on for until the sensor does not see any activity then turn off automatically. For this example we will assume the motion sensor will give us a high or low condition.

What are the three inputs and the conditions that should be met for the automatic section to work described in the problem? Use words to describe each condition.

Condition 1:

Condition 2:

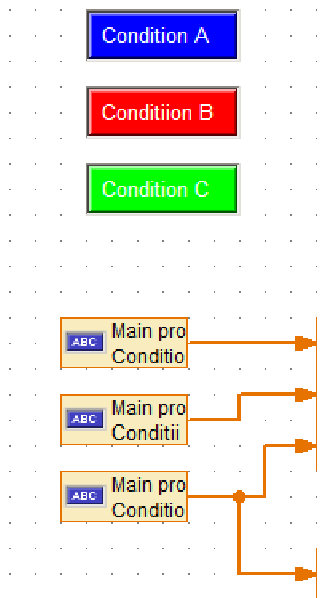
Condition 3:

Now construct a truth table from your three conditions.

Condition 1	Condition 2	Condition 3	Output
A	B	C	Y

From the table above develop the Boolean expression for your circuit. Write the Boolean expression below.

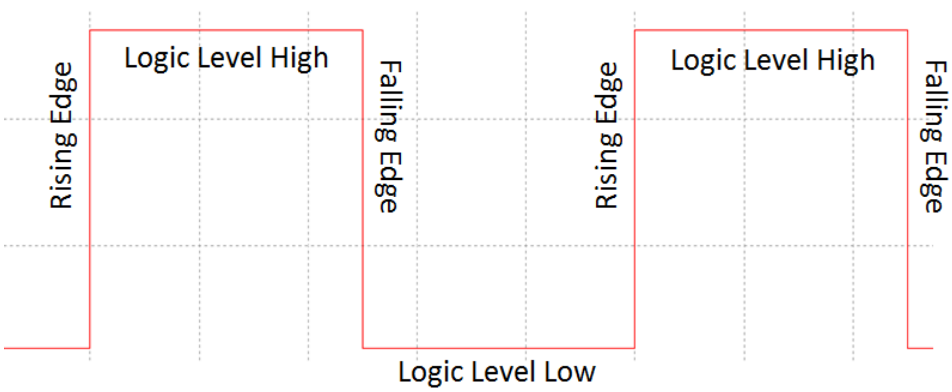
Now design your circuit using logic. This time use buttons for the input to represent your three conditions.



Wire the circuit and try it out with the TX Controller. Demonstrate the control system to your teacher.

Edge Triggered vs. Level Triggered

Purpose:
Triggering is the process of making a branch of the program active when it receives the expected digital input. This means the program will perform a function once the trigger is activated. There are important differences in the effects of the triggering process. The first is level triggering. In level triggering the branch occurs when the desired level of input is present. This can be a logic high or low. Edge triggering the circuit becomes active when the triggering input goes from low to high or from high to low.

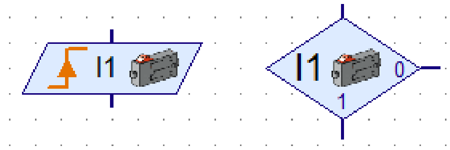


The picture above depicts the logic waveform from a switch as it changes states. The logic levels are Low (0) and High (1). The transitions between the levels are the edges of the waveform. The rising edge is going from Logic Level Low toward Logic Level High. The Falling Edge occurs when the logic transitions from High to Low. To demonstrate the difference between the edge triggering and level triggering you will be building several simple circuits to see the effects of the triggering.

Equipment:
RoboPro
TX Controller
Lamp

Procedure:

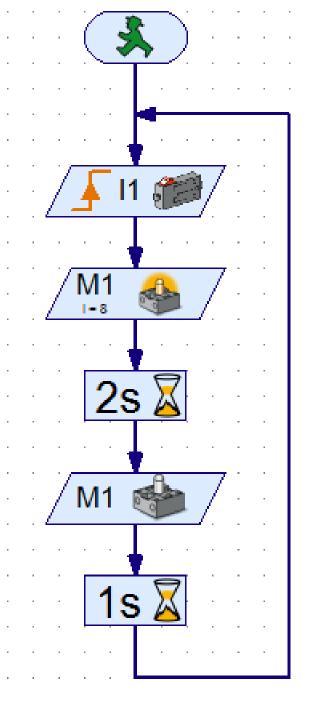
There are two blocks that determine how your program will process the inputs. On the left is the Wait for block. In this case it is set to wait for a rising edge. The block on the right is a Digital Branch block. Depending on the level of the switch it selects the appropriate way out of the block.



Set up the controller. Wire a switch to the I1 input and ground as normally open (connections 1 & 3). Connect the lamp to the M1 connections on the controller.

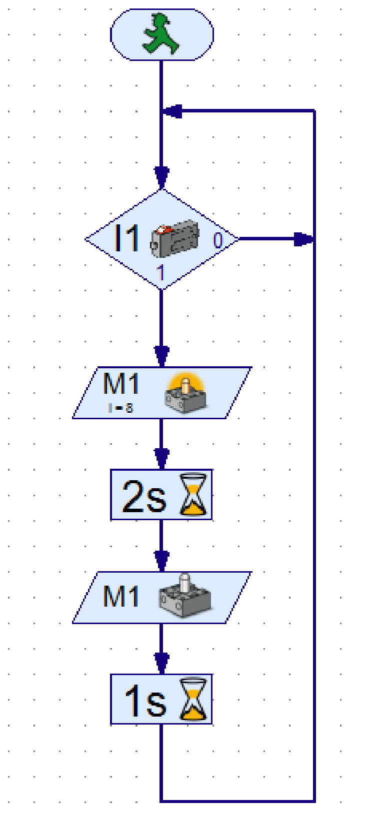
The setup on the controller will not change, but the programs will be slightly different. Observing what happens will help you make programming decisions when it is time to solve problems and troubleshoot programs.

We begin with the Edge triggered program. You will find the Wait for block in the Basic elements section of the Program elements. Begin a new program and set it up similar to the program below.



Run the program and hold the switch down for 15 seconds. Describe the behavior of the lamp when you do.

Edit your program and change the Wait for block to the Digital Branch.

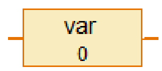


Run the program again and hold the switch down for 15 seconds and observe what happens. Describe the behavior of the lamp and note the difference in behavior from the Wait for block.

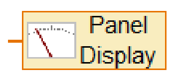
Now we will use a classic counter to truly show how edge triggering differs.

Begin a new program. Be sure you are in Level 3 or above.

From the variables, timers…. section of the Program elements, place a var block.

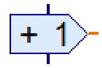


From the Inputs, outputs… section of the Program elements place a Panel Display.

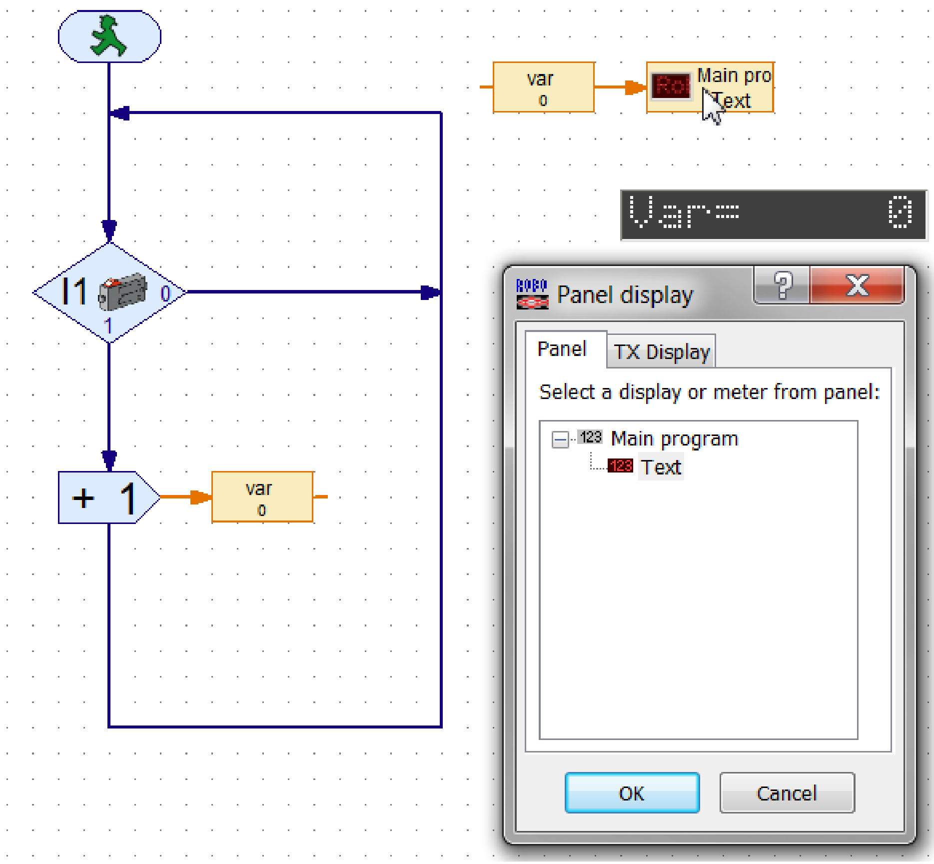


From the Displays section of the Operating elements, place a Text Display

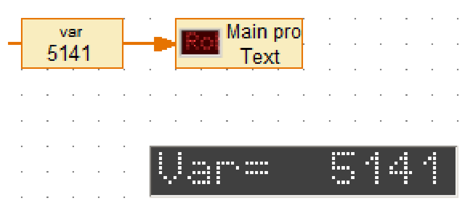
From the Commands section of the Program elements, place a Plus Block.



Wire the circuit similar to the picture below. Be sure to right click on the Panel Display block and assign the display to the Text Display.

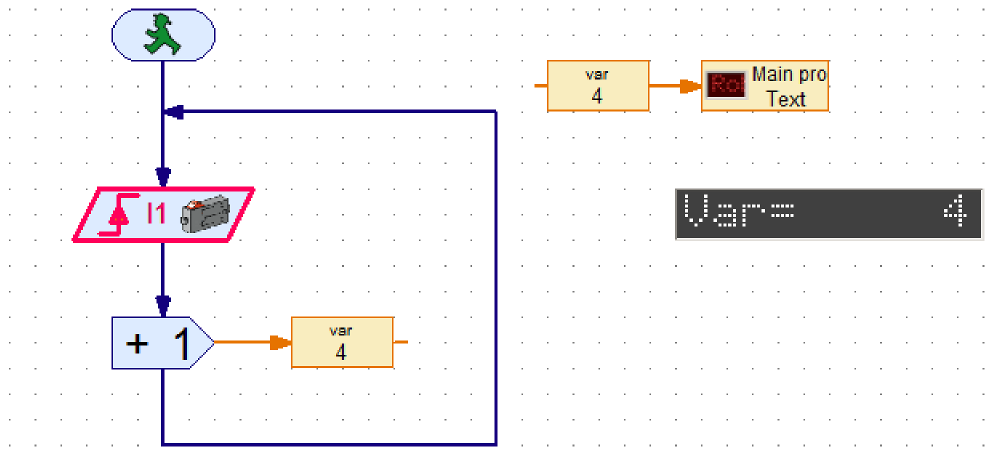


Start the program and press and release the switch as fast as you can. Do you see a number? If you were too slow you would only see question marks.



Add a Wait block after the Plus block and see if that helps you get a number. How many milliseconds do you need to be able to have the counter advance one place every time you click the switch?

Replace the Digital Branch block with the Wait for block. Run the program again and click the switch.



Describe what happens when you click the switch once. Explain why it did what you observed.

Conclusion:

Describe two situations where using the Wait for block would be the better choice in programming.

Describe two situations where using the Digital Branch block would the better choice.

Pneumatics

Pneumatics is the branch of science and engineering that deals with compressed gas. This is allows transfer of power to machinery by means of pressurize air in a piping system. It can be adjusted at point of use making it a desirable power source for many automation installations.

Pneumatics is a component of fluid power. Fluid power employs fluids under pressure to transmit power. Hydraulics deals with liquids under pressure. Liquids such as water and oil are not compressible. Air is an example of a compressible fluid. The laws listed below layout how a compressible fluid behaves in relation to pressure volume and temperature.

Pascal's law: Pressure exerted by a confined fluid will transmit the power equally in all directions.

The formula $\rho = \frac{F}{A}$ expresses the relationship of pressure to force and area. This applies to pressure acting on a cylinder. Since there is only one direction the piston in a cylinder can move the air pressure is transferred in that direction. The input force will equal the output force. In a pneumatic system we know the air pressure being used. We can calculate the amount of force we can deliver.

Boyle's law: The volume of a gas at constant temperature varies inversely with the pressure exerted on it. In pneumatics we are interested in the relationship between pressure and volume.

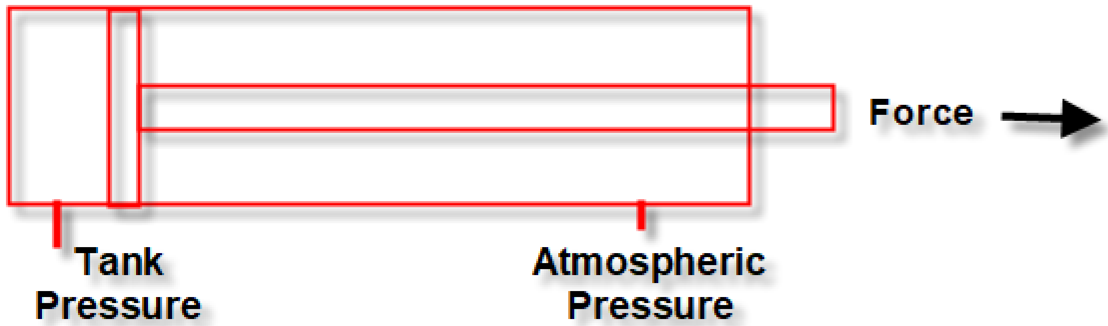
The formula $\rho V = k$ explains that for a given mass at constant temperature the pressure times the volume is constant. As the gas expands the temperature changes and this is why the air used in pneumatic systems feels cool or cold when it exits. It is also why we are concerned with moisture in the system. As the air cools the water vapor condenses and in a larger system a few gallons on a hot muggy day might be found in the tank.

Charles law: The volume of gas increases or decreases as the temperature increases or decreases provided the amount of gas and pressure remain constant. The same number of gas molecules will occupy different volumes at different temperatures. If the temperature rises the gas will expand. If we pressurize a tank when it is cold and the tank heats up what happens?

Force exerted by a piston is calculated by the formula $F = \rho\pi({d_1}^2 - {d_2}^2)/4$

Where F is the force exerted
p is the pressure
d_1 is the diameter of the piston
d_2 is the diameter of the piston rod

In the example below we will apply 80 pounds of air pressure to a two inch cylinder with a ¼" diameter piston rod.



$$F = \rho\pi({d_1}^2 - {d_2}^2)/4$$

$$F = 80 \times 3.14(2^2 - .25^2)/4$$

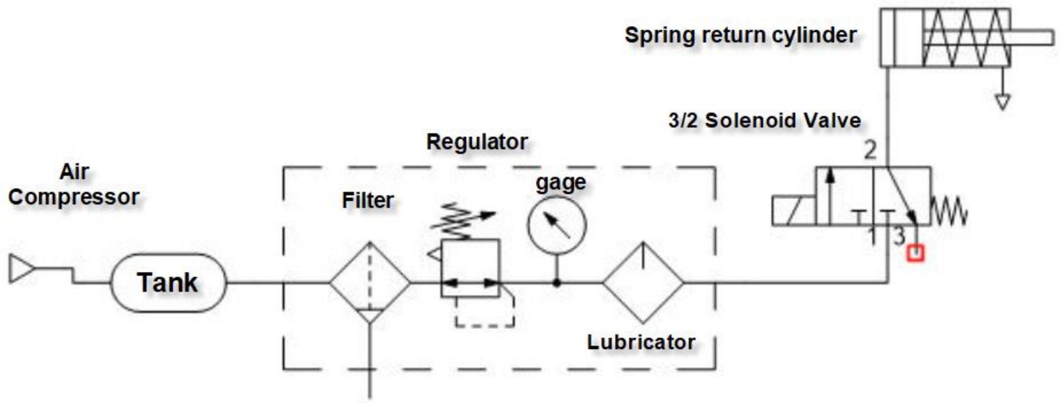
$$F = 989.601/4$$

F=247.400 of force delivered by the piston.

Air systems

Air systems can be quite complicated. We use schematics to indicate components in a system. Having a schematic for a complicated system allows the viewer to quickly figure out what is happening and if there is a problem how to narrow the search for an issue.

Below the schematic is an explanation of the components and a picture so they can be identified in a laboratory setting.



Air Compressor
This example displays the electric motor (right) that drives the compressor on the left.

A compressor is a type of pump. It uses pistons similar to a car to compress air so that it takes less space. This compression creates heat. If you look closely at a compressor you will see slots about the cylinders to allow for cooling. A one way valve allows the compressed air to flow into the tank. As more is added the pressure rises. Most compressors have a switch which will turn off the compressor or divert the air flow when a set pressure is reached. Pressure is measured in pounds per square inch or the Bar (SE) system. 1 Bar is roughly equivalent to atmospheric pressure at sea level. 1 Bar equals approximately 14.7 psi or 100 kPa (kilopascals)

Tank
The tank is frequently the largest component of a system. The picture below shows the tank under the compressor. They frequently come preassembled.

The tank receives the compressed air from the compressor. The tank volume helps keep the pressure constant in the system absorbing spikes in demand. The compressor can be reduced in size due to this averaging. The compressor is cycled on and off to maintain a constant range of pressure in the tank.

Regulators and Gauges

The schematic above shows several components together within a dashed line. When you see this on a schematic it indicates close proximity to the other components in the system. In the schematic you see air entering from the tank. In the picture below you see a ball valve with a blue handle. This allows the system to be drained and locked out for repairs and maintenance. When the electricity is turned off the tank is filled with compressed air and could power devices for a long time so the need for a manual cutoff switch.

After the ball valve there are filters and dryers to remove any water left in the compressed air. When air leave the tank it expands and following the gas laws drops in temperature. Without filters and dryers water would be sent through the system contaminating and corroding components that connect to the air. Sometime an oiler is connected here to provide a fine mist of oil to protect the equipment at the point of use. Regulators are used to adjust the output pressure for the system. They have a knob to increase or decrease pressure and often have a pressure gage attached to see what the pressure is.

Pipes hoses and fittings

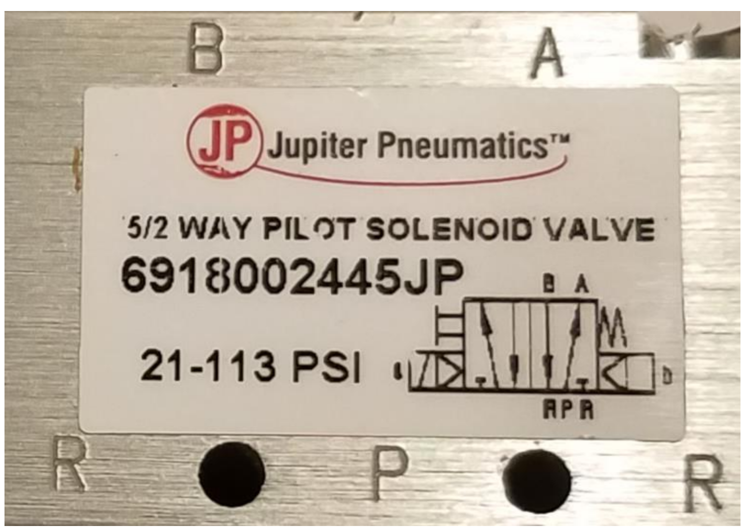
Every pneumatic system needs to supply the air to point of use. In many plants the air compressor is located in a central location with a system of pipes to deliver the air where needed. Where ever a piece of equipment will be disconnected from the system a quick connect air coupling is used. When the male end of the hose is disconnected the fitting seals the connection so there is no loss of air pressure. The picture below shows an air hose with the male end on the top and the quick connect coupling on the bottom. The manifold next to the coil has the coupling on the left. This allows the manifold to be plugged into the system and the push to connect fittings on the top can run to individual components of the system. In this example the hose that connects to the push to connect fittings is ¼ inch. The hose is cut to length and inserted into the fitting. To release the gray sleve is pushed down whil the hose is pulled out.

The larger the lines, hoses and fittings are the more pressure can be delivered. There are many styles of fittings so it is important that the fittings are compatible.

Directional Valves

Air is controlled to individual circuits by valves. Valves can be manual in nature such as levers, pedals or hand switches. The can also be controlled by powered valves similar to the ones in the photo below. These are based upon solenoid valves and described by the number of ports and positions among other factors.

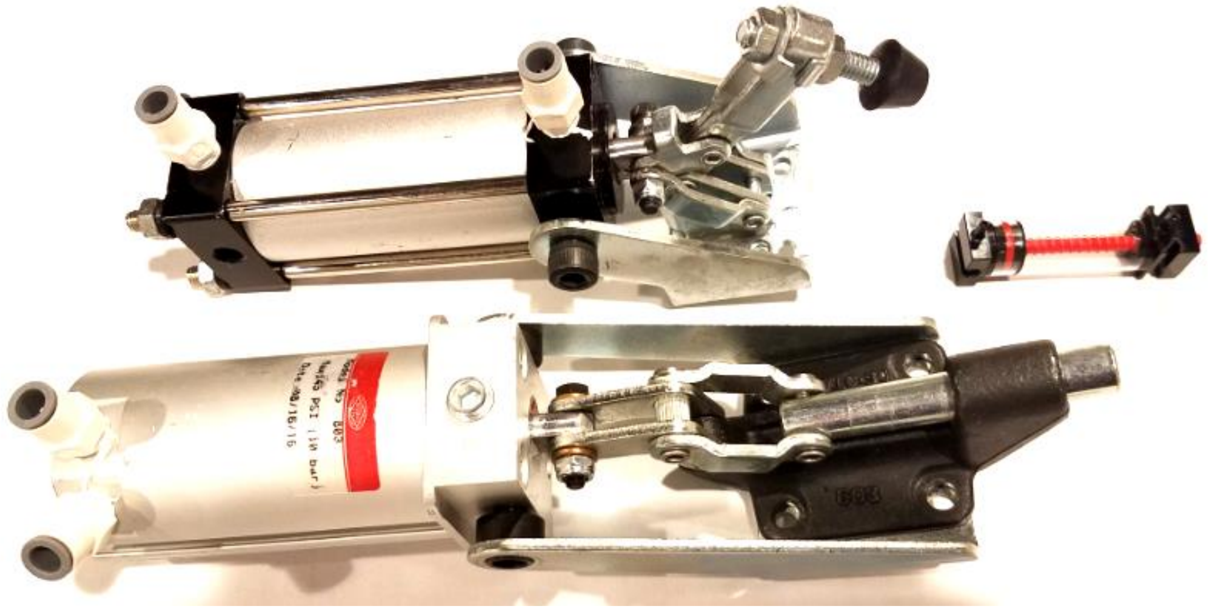
The small solenoid valve in the upper right hand corner of the picture and the valve on the bottom left are both 3/2 solenoid valves. The difference is one of size. The three stands for three ports which are the openings into the valve. (the solenoid on the top left is a 5/2 valve). Air pressure is supplied to the appropriate port. In the example below the air is supplied to the P (pressure) terminal. In its initial position pressure flows to port A and anything connected to B will vent out the R on the left side. When the solenoid is engaged the pressure is attached to B and A vents out the R on the right.



This solenoid valve might be used on a cylinder where there is no return spring. Position A holds the cylinder in one position and when the solenoid is triggered the air pressure is released and the cylinder moves to the other position. The 3/2 solenoids are more like an on off switch. Power in the solenoid allows air through the valve. When the power is removed the air is vented from the other port on the valve.

Actuators

An actuator in a pneumatic system is the component that converts the pressure into work. The picture below shows several different kinds of actuators though there are thousands of different types depending on the motion or force needed.



Helpful Sites
https://www.boschrexroth.com/en/xc/products/engineering/econfigurators-and-tools/d-c-scheme-editor/forms/registration-33#
http://www.logiclab.hu/index.php

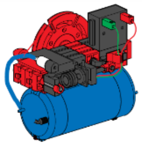
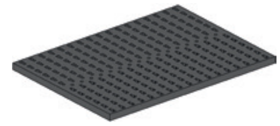
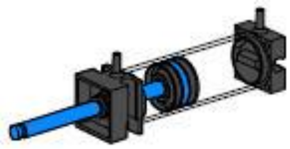
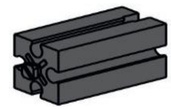
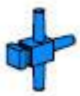
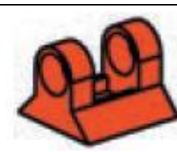
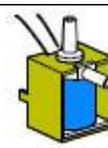
Build a system

Purpose:

This activity is designed to introduce you to some of the components used in Pneumatic systems. Pneumatics involves transferring energy to create and control motion through the use of pressurized gasses. Pneumatic devices include paint spray equipment, jack hammers, breaks for trucks and other large equipment, rock drills, construction nailing equipment, food processing equipment, soda fountains, pipe organs and industrial equipment of all types. Pneumatic devices are popular because of their simple design, reliability and safety. They are ideal for clamping systems, grippers and for a safe power source in explosive environments. You should build the compressor before completing these experiments.

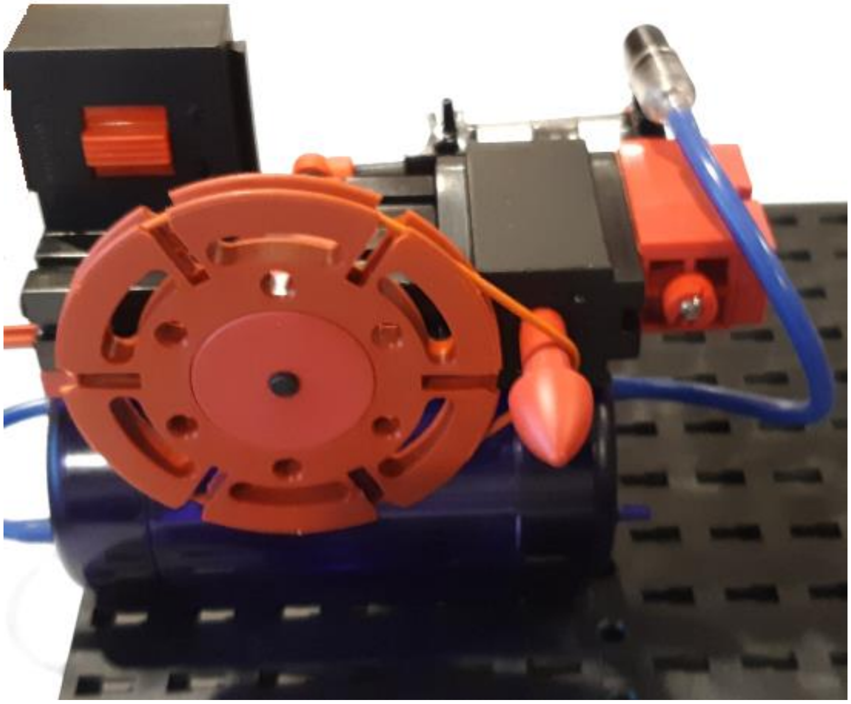
Equipment:

TX controller
Switch
Wires

 Compressor from Instructions	 37003 Hose	 Base plate 258x186 32985 1
 36938 Cylinder 60 1	 36934 Pneumatic hand valve 1	 Building block 30 32879 2
 31642 T-Piece	 35328 Hose connection solenoid	 36915 Hose connection Compressor
 31426 Hinged block Tab	 31436 Hinged Block Claw	 35327 3/2 Solenoid Valve

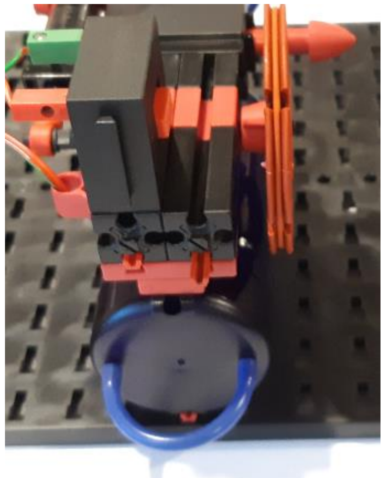
Procedure:

Begin by placing the compressor on one half of the base plate. This will allow you to use the compressed air from the tank to run experiments.

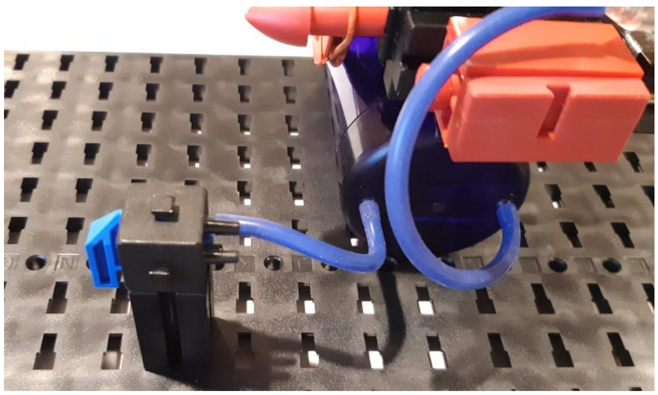


Be sure the valve handle is pointed straight up. Connect the power to the compressor. Use the 9V out to give the 9V to the compressor. Use the Ground from I8 for the other connection.

The tank has four outlets and only one is connected to the compressor. Take a short piece of blue hose and connect the two outputs together.

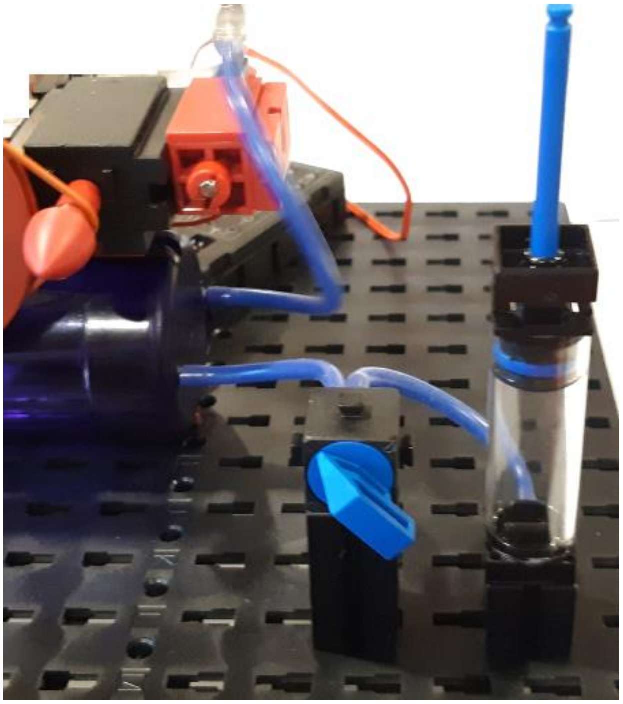


At the other end of the tank you should have one port open. This is used with another short piece of hose to connect the tank to the right hand port of the valve.



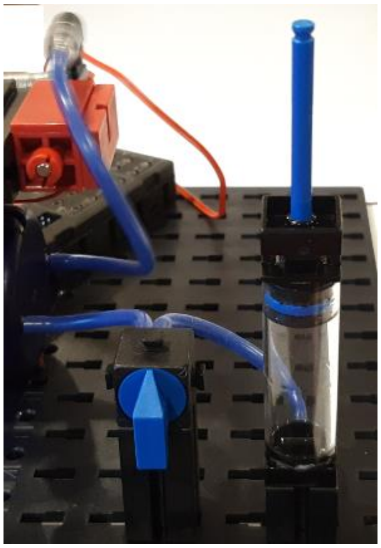
Connect the middle port of the valve to the cylinder as shown in the picture below.

Connect the interface to power and turn it on. Turn the compressor on by sliding the switch to the top position. Let the compressor run for a few seconds to build up pressure in the tank. Move the valve to the left. You now have a path for the air from the compressor through the valve and to the cylinder.

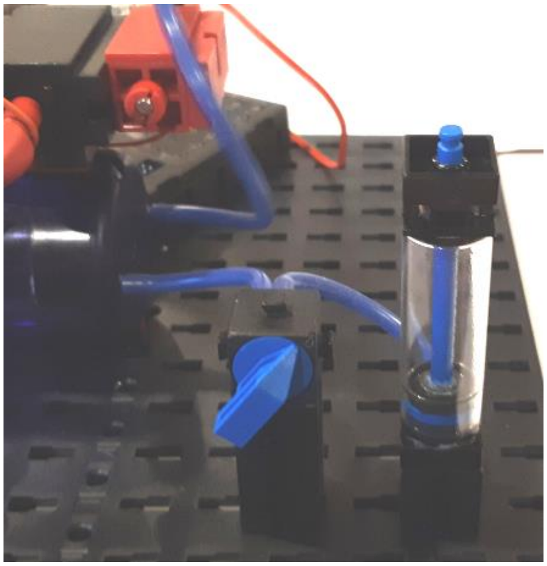


If you hooked everything up right the cylinder should extend. If you push gently on it what happens? Sketch the setup in your engineering notebook. Explain what happens when you turn the valve toward the tank.

Return the valve to the upright position. If you gently push down on the cylinder explain what happens.



Now position the valve so it is pointing to the unconnected side. Gently push down on the cylinder. Explain what happens.



Conclusion:

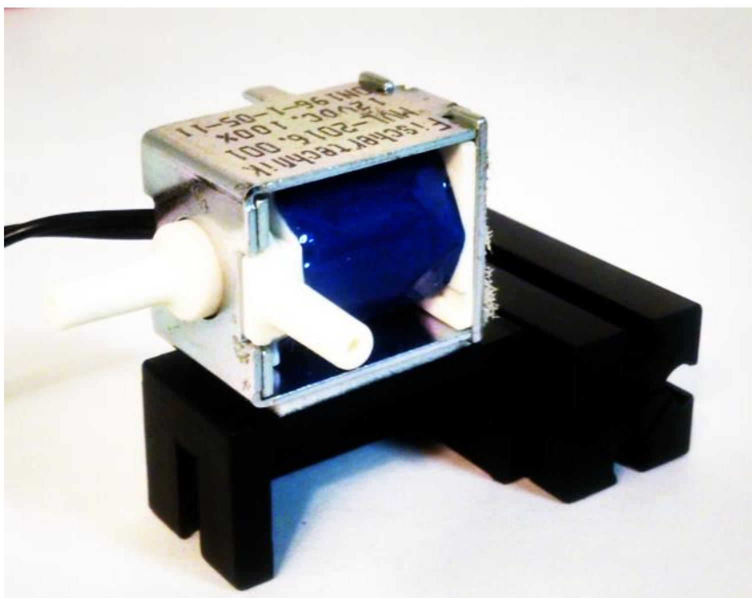
Remove the hoses from the valve. Connect the hose from the tank to the center pin of the valve. Connect a hose from one side of the valve to the top of the cylinder. Connect the other port on the valve to the bottom of the cylinder.

Adding the Solenoid

In the previous section you used a hand valve. It had three connections or ports. In this section you will replace the hand valve with the solenoid. The solenoid has two connections, but it also has an exhaust port under the white foam on the end. Connect the air compressor to the top of the solenoid.

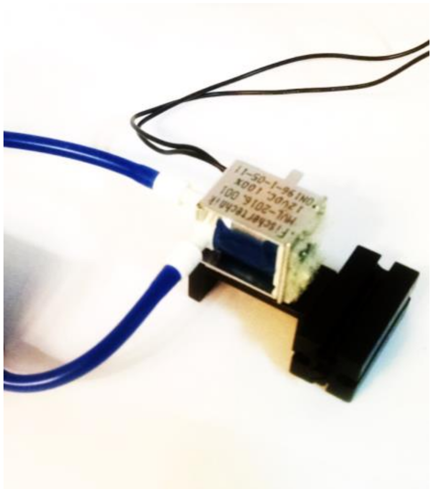
The solenoid valve is an electromechanically operated valve. When an electric current passes through the solenoid valve the solenoid switches states. In the case of a 3 port valve the outflow is switched to either run the cylinder or exhaust through the end of the valve. This solenoid will connect to the controller the same way a motor does. It will connect to one of the outputs.

The solenoid valve is attached to a 30mm girder with double sided tape. This allows you to attach the solenoid valve to the structure to keep it stable.

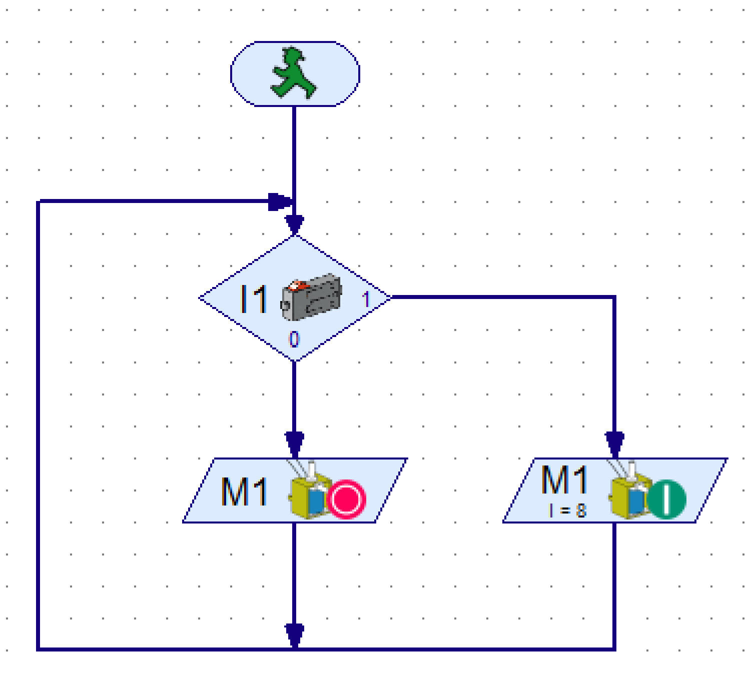


This solenoid valve is a 3/2-way solenoid valve. The simplest directional control valve is the 2-way valve. A 2-way valve stops flow or allows flow. A water faucet is a good example of a 2-way valve. A water faucet allows flow or stops flow by manual control. A single-acting cylinder needs supply to and exhaust from its port to operate. This requires a 3-way valve. A 3-way valve allows fluid flow to an actuator in one position and exhausts the fluid from it in the other position. The 3 in the name stands for 3 ports. You can see two of the ports in the picture above. The third port is hidden behind the covering at the other end. This covering acts as a muffler and diffuser when the air is released from the cylinder.

Because air is released from the cylinder when the solenoid valve closes it is important to know which port is the supply and which port feeds the cylinder. When the valve closes the spring in the cylinder returns the piston rod to its initial position. This forces the air back down the hose and out the open port of the 3/2-way valve. If the valve is connected in reverse the cylinder will never return.



A switch will be used for our program to recognize it is time to allow air to flow to the cylinder. A sample program is below.

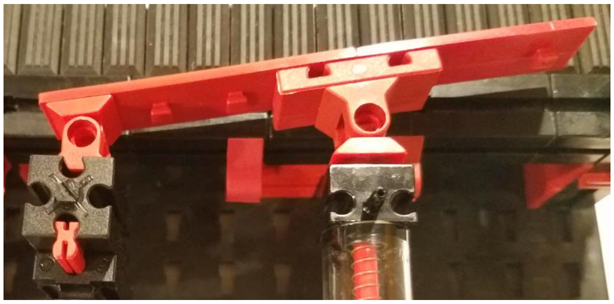


If your connection to the solenoid valve has the air pressure going to the incorrect port the cylinder piston will not retract. If that is the case turn off the power to the circuit so the air compressor stops. Drain the air from the system then swap the hose connections to the valve and try it again.

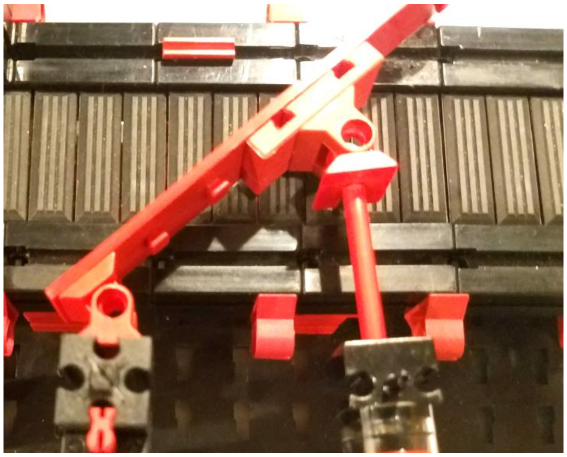
Sorting connection
The power delivered by the piston rod can be harnessed in many different ways.

In the picture below is a directional arm. The conveyor will be running continuously and the program will decide when to remove a part.

The arm is attached at two pivot points. Each pivot is made from a hinge block tab and a hinge block claw.



When the solenoid is energized the cylinder forces the gate across the conveyor changing the direction of the components to another conveyor or storage bin.



Variables

Purpose:

There are numerous ways to create a program to accomplish a given task. Programs can very quickly grow to unmanageable size. One of the learning tasks in programming to help limit the length is to develop an understanding of loops and variables. Loops allow programs to repeat a set of functions for a specified number of times. Variables allow the ability to assign values and monitor their value. Their use allows for complex control of a system.

Equipment:

Computer interface
Power supply
Serial cable
Motor
Wire

Procedure:

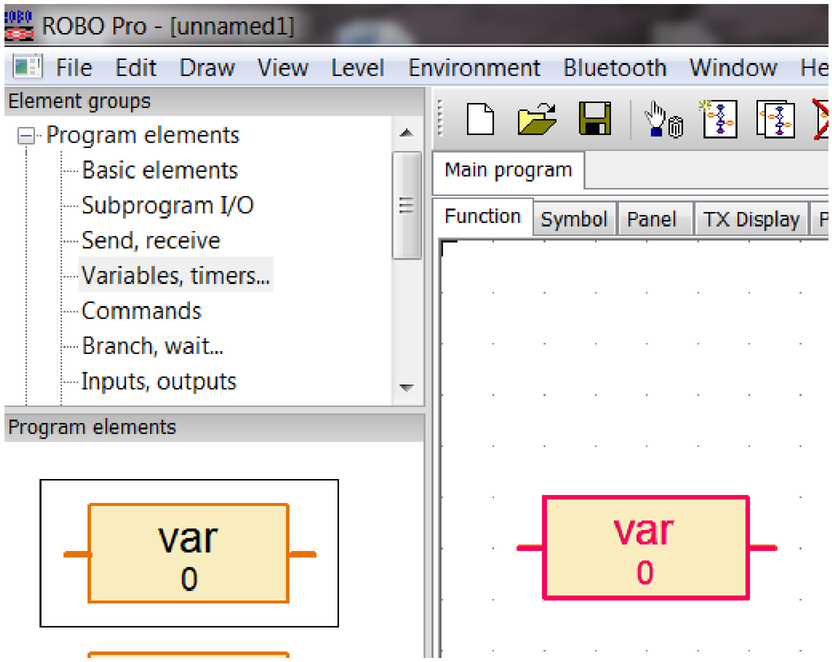
The ability to use variables in your program is a very powerful feature. Variables are intermediate storage spots for specific information. At specific spots in your program you can query the variable and have the program act on that information. This information can be whether a particular switch has been pressed or if a predetermined number has been reached, or how often a specific event has occurred.

A variable has two parts, a fixed name that we can use to access the variable and an expression or value, which is changeable.

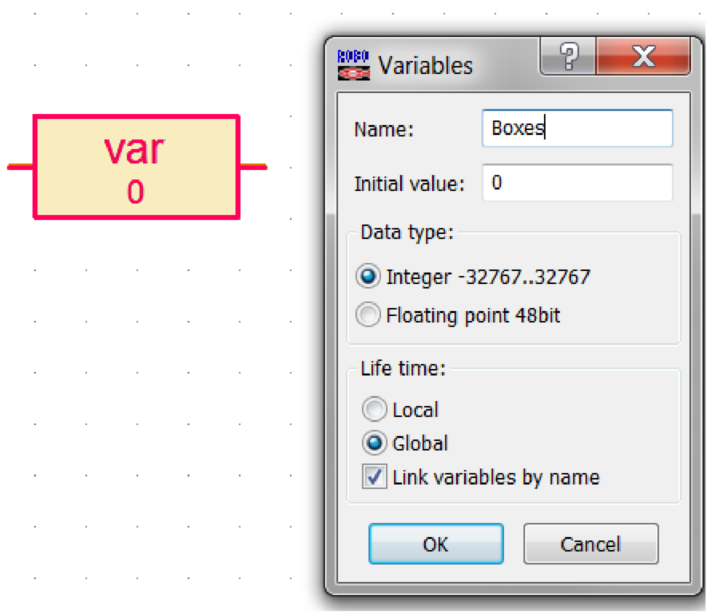
The variable expression can be several types. The variable can equal another variable, an analog input, or a number. We can manipulate the variables to produce the output we desire.

Variable

The first step in adding a variable to your program is to place a variable from the Element Window. You should be in either Level 3 or Higher to access the Variable menu.



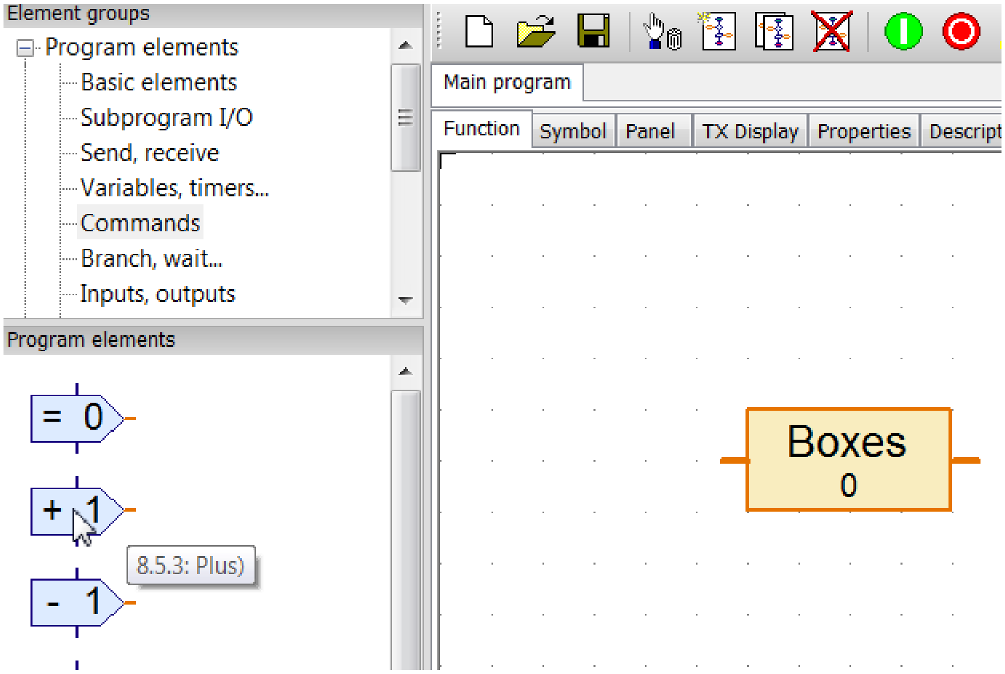
After dragging this icon out into your program area right click on the icon and the following dialog box opens.



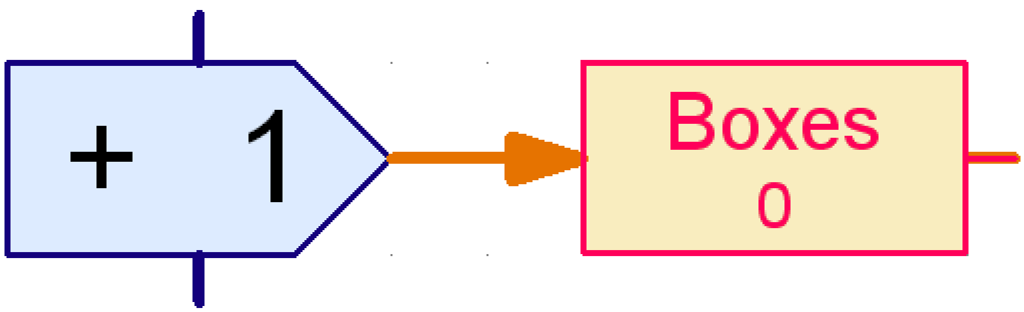
Within this box you will assign the specific information to the variable. Notice the color of the input and output sections of the variable block are a different color.

Variable +/- Programming Block
At times it may become necessary in your program to increase or decrease the value of a variable by a set amount. This is particularly true in a counting sequence. Each time your program performs a certain routine that you are keeping track of you

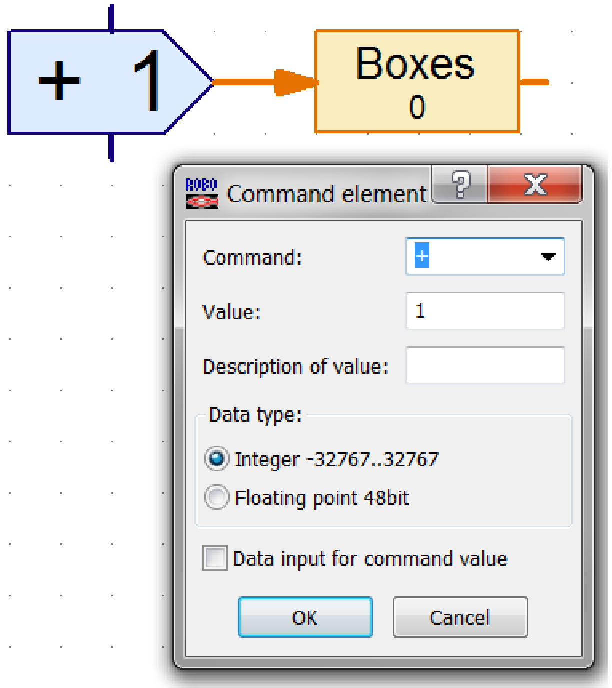
would increase a variable by 1. Then after the predetermined number of sequences had been performed you program would then move on to the next operation. The elements for performing changes to a variable are found in the Command section.



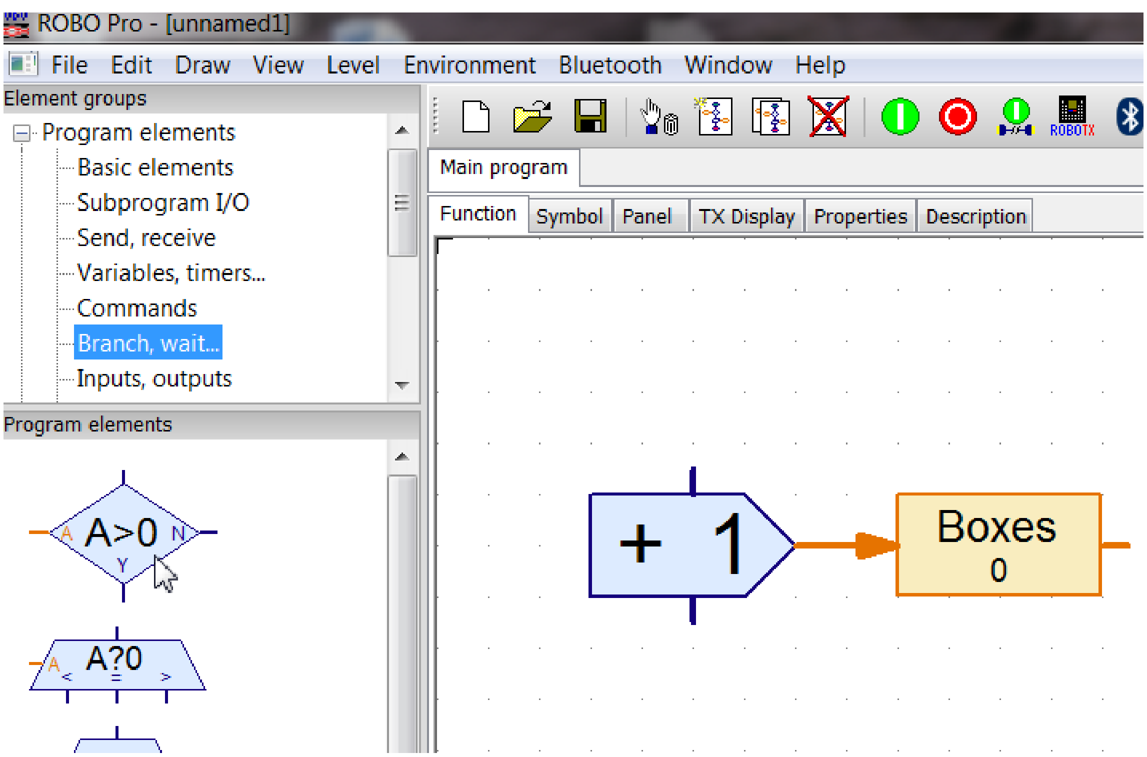
The element shown here will increase the value of Boxes by 1 each time the program goes through the loop.



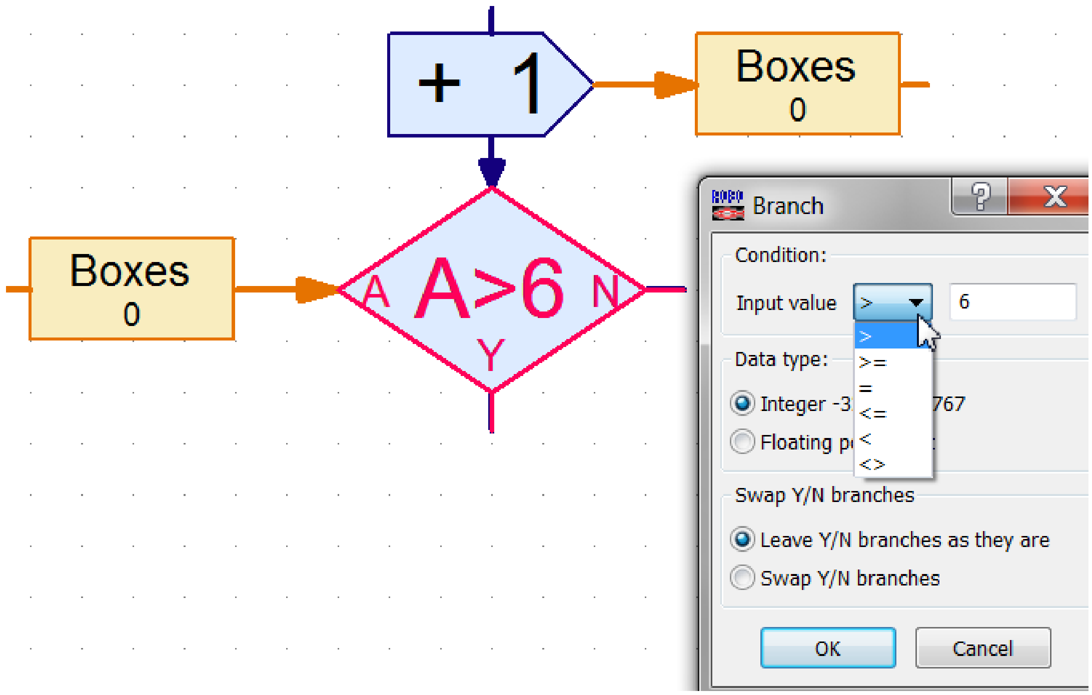
After dragging this icon out into your program area the following dialog box opens. In the Command section the selection is made for what process should occur and what value the Command Element should use.



Creating Program Branches
Usually when working with variable you will compare the variable with a condition in your program. Based on this condition your program might perform a particular operation. To do this you use the Branch function block. These are found in the Branch, wait… section.



The Branch function block is used to create a program-processing branch based on the value of a variable. Depending on the results of the comparison, processing continues either with the function block at the lower output or the one at the output on the right.



Right clicking on the Branch will display the dialog box where you set the conditions of the branch. To modify the branch direction, select the radio button for the desired setup.

Programming Practice:
Write **<u>one</u>** program to do the following;

- Turn a motor on for 8 seconds.
- Turn a motor off for 4 seconds.
- Repeat this sequence 3 times.
- Save as Program2

Demonstrate the operation of this program to your instruction and obtain their initials to indicate completion.

Instructor's Initials:______________________

Create a printout of the program and attach it to this sheet.

Conclusion

1. What is the purpose of the **VARIABLE** function block?

2. In your last program (Program1) you repeated a sequence of commands 2 times. In this program (Program 2) you also repeat a series of commands. Explain the difference between these two programs with respect to the methods used for repeating a command sequence.

3. What is the function of the **BRANCH** function block?

Positions

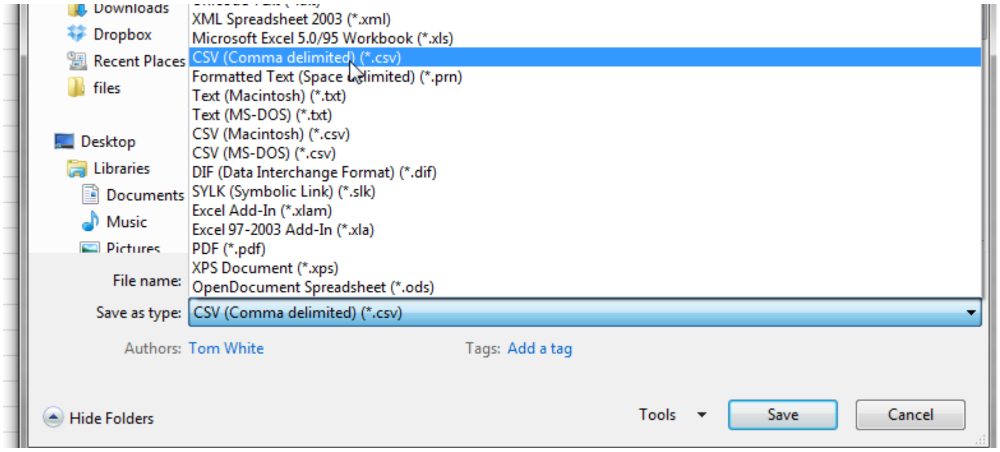
Purpose:
In automated machinery it is common to have a series of prepositions that can be fed to the equipment. In programming it is easier to read a spread sheet file for the data than to write a separate program element for each position. You will need to construct the conveyor belt from [the instructions for building the conveyor.]

Equipment:
Conveyor Belt

Procedure:
Open Excel. Enter the data seen below.

	A	B
1	Values	Direction
2	6	0
3	12	0
4	6	0
5	12	1
6	12	1
7		

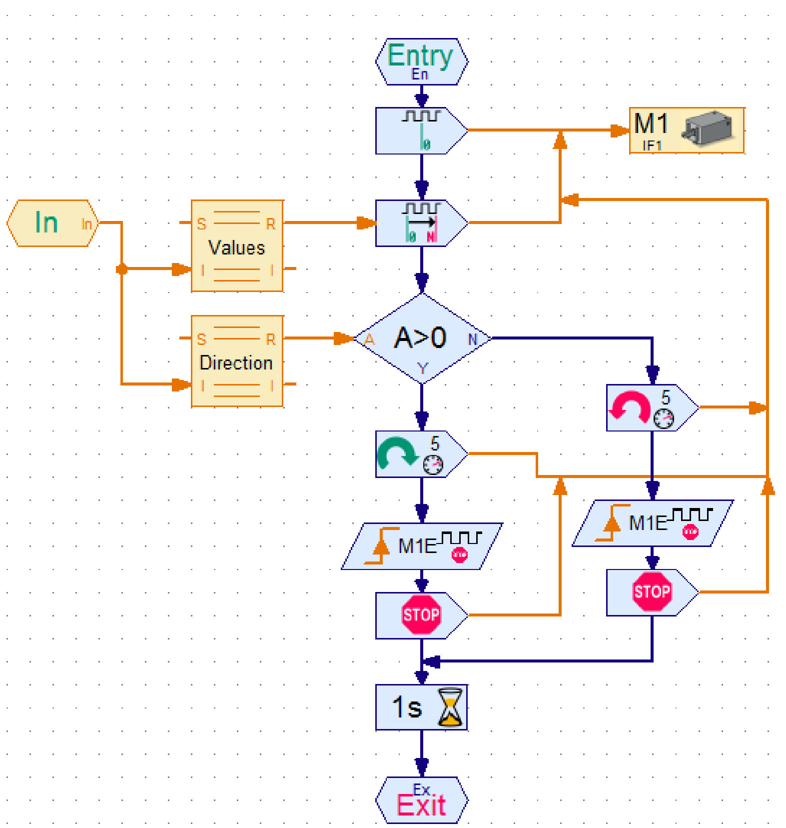
Save as a comma separated values file. (.csv). Give the file a name you will remember and save to a location you have access to.



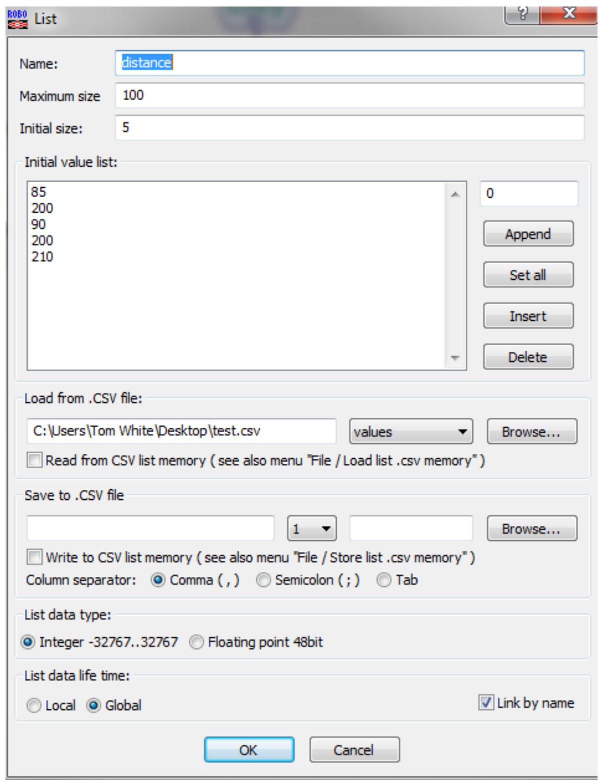
We will create a program to control the conveyor belt. This would be used in an automated work cell when the line would take a part from machine to machine and then remove the part to a bin and be ready to do the same thing all over again. Rather than use multiple sensors to stop the belt we will use encoder counts to move from place to place. This is how robotic equipment is programmed to go to the same place time after time.

Create a new program in RoboPro and use the Level 5 objects.

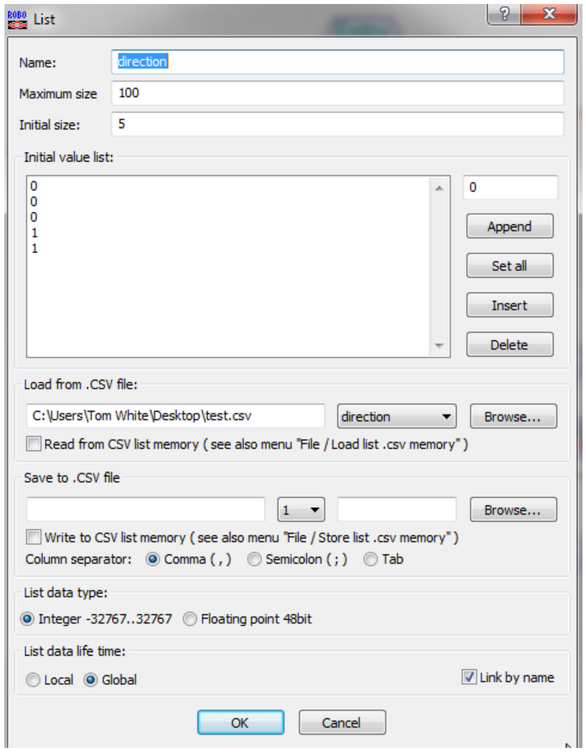
Create a subprogram. Give it a name.



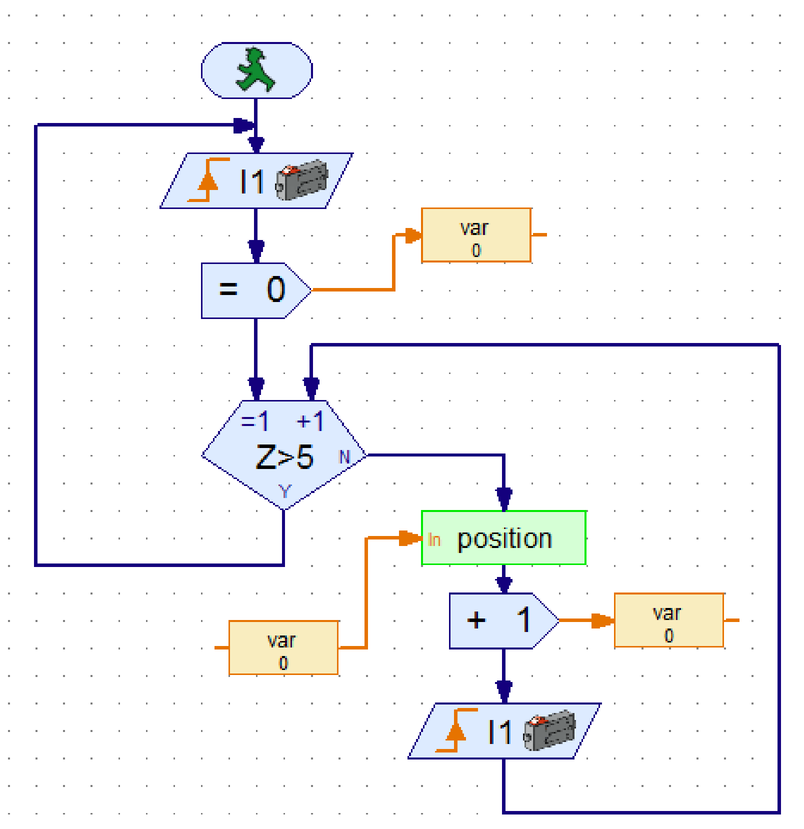
In this subprogram are two lists right click on the first list and name it Distance. In the Load from .CSV file, browse to the file you created. Once you select the file you will see a drop down menu. Select the Values option and you will see the information you entered. Select OK.



Now right click on the second list and name it Direction. In the Load from .CSV file, browse to the file you created. Once you select the file you will see a drop down menu. Select the Direction option and you will see the information you entered. Select OK.



Write the main program so it looks like the following.



Be sure the variables are global. Right click on the variable and check the global option in the life time section.

Conclusion:

Troubleshoot and then run the program. Print a copy of the program for your engineering notebook. Describe what the program does and how it looks up the information. Explain how the variable cycles the program.

Recording Positions

Purpose:

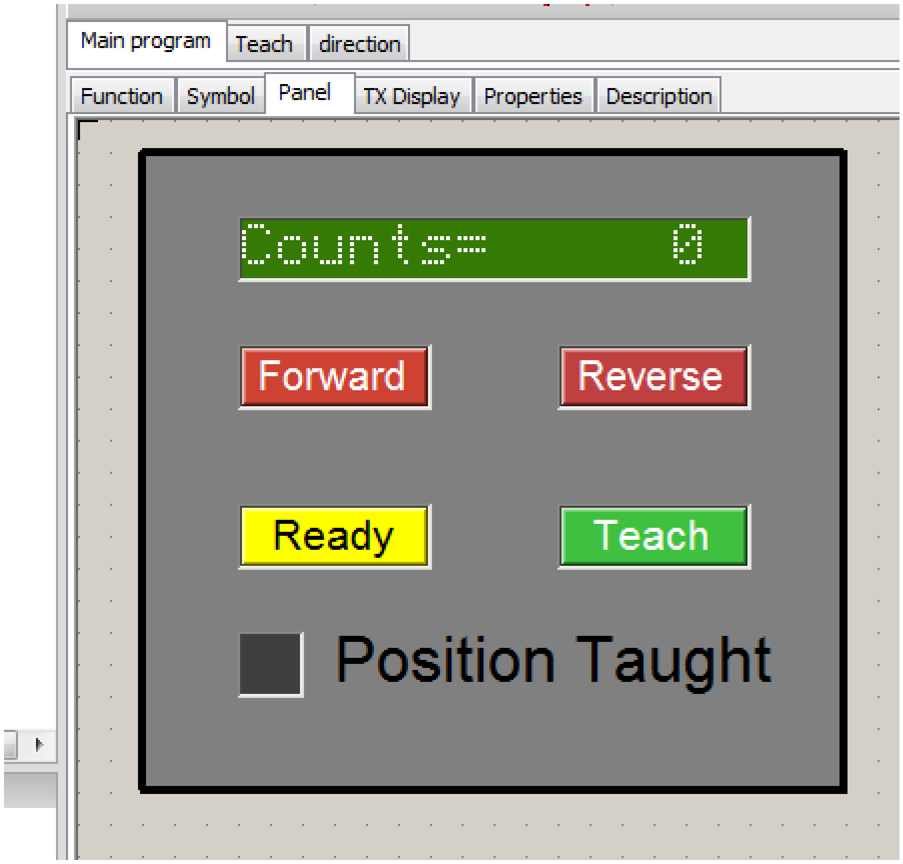
When building automated machinery programmers create a teach program so the positions can be recorded for later use. This activity will help you learn how to design a program that will allow you to position the conveyor to a location of your choice and save them to the CSV file for future use. We will build a front panel that can be used by people who are not familiar with programming. It is important to note that there are many different ways to accomplish this task. Every programmer develops a signature style and they utilize what works for them. That is why documentation of your program is critical. Another programmer can spend a lot of time deciphering how a program was designed to work.

Equipment:

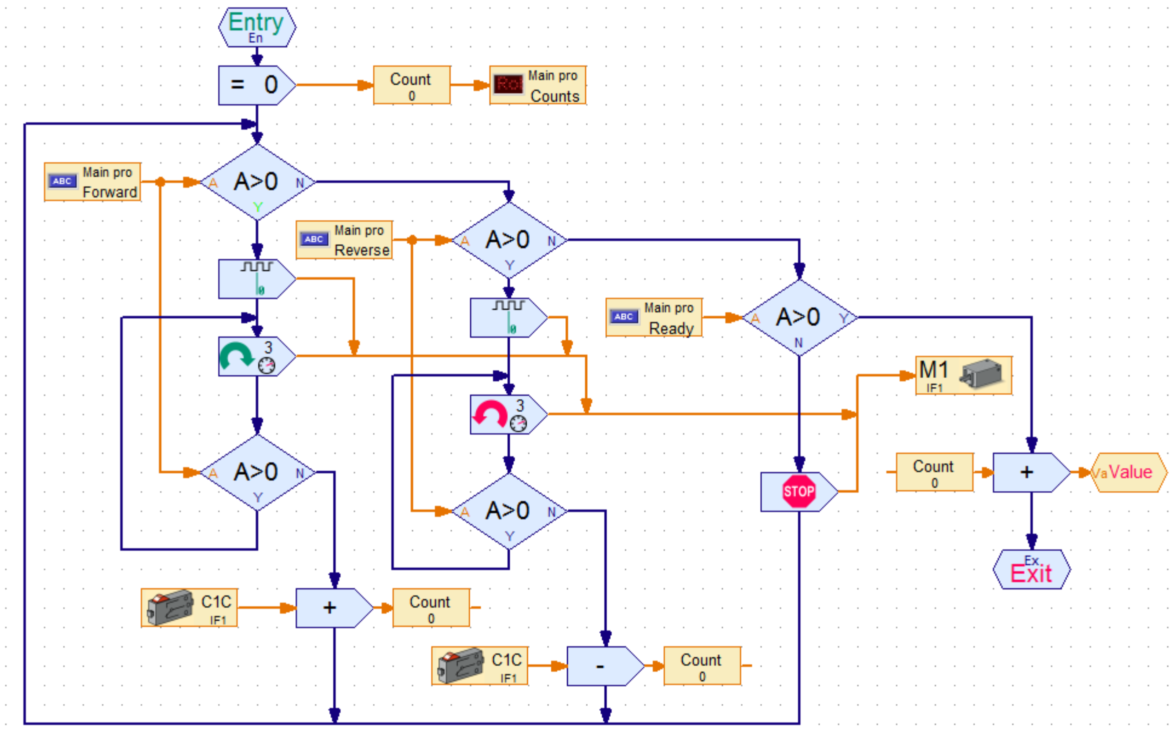
Conveyor belt

Procedure:

Begin a new program. Set it to Level three: Variables. This program started with the desired simplicity for the user in mind. Since this is a one dimensional control system the user needs a button for each direction. When the desired position is arrived at a button to lock in the settings enables the teach button which causes the program to record the position. It was also desired that there be a visual sign that the position was taught so a lamp was placed on the panel.

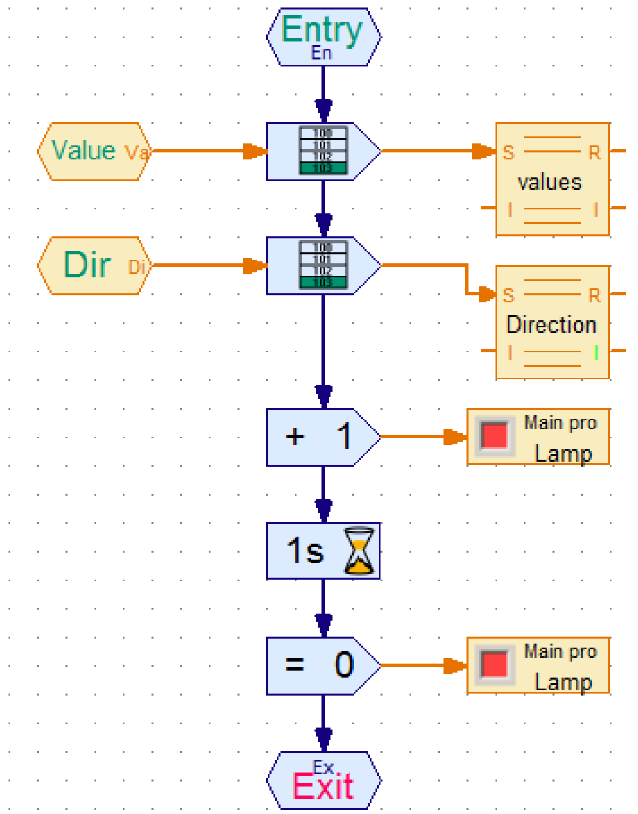


The next step was creating the logic behind moving the conveyor belt and counting up the encoder counts. In the positioning of the belt the user might adjust back and forth until the exact position was achieved. Moving in one direction it was necessary to add counts to the total. Moving in the opposite direction meant subtracting counts from the total. Once the correct position was reached it was important to know how many encoder counts it was from the last position. In this example a subprogram named Direction is used to move and keep track of the encoder counts. A variable named Count is used to keep track of the encoder counts. When the user pushes a direction button for the first time the variable Count is set to 0. The program then looks to see which of the buttons is pushed if it is forward or reverse the first step is to use a command to reset the encoder count on the motor to 0. The motor drives the belt in the appropriate direction. The loop counts as long as the button is pushed. When you let go of the button the encoder count is added or subtracted from the variable Count. When you push another direction button the process is repeated adding and subtracting from the total count as needed. When you push the ready button the Count is passed out of the subprogram for use.

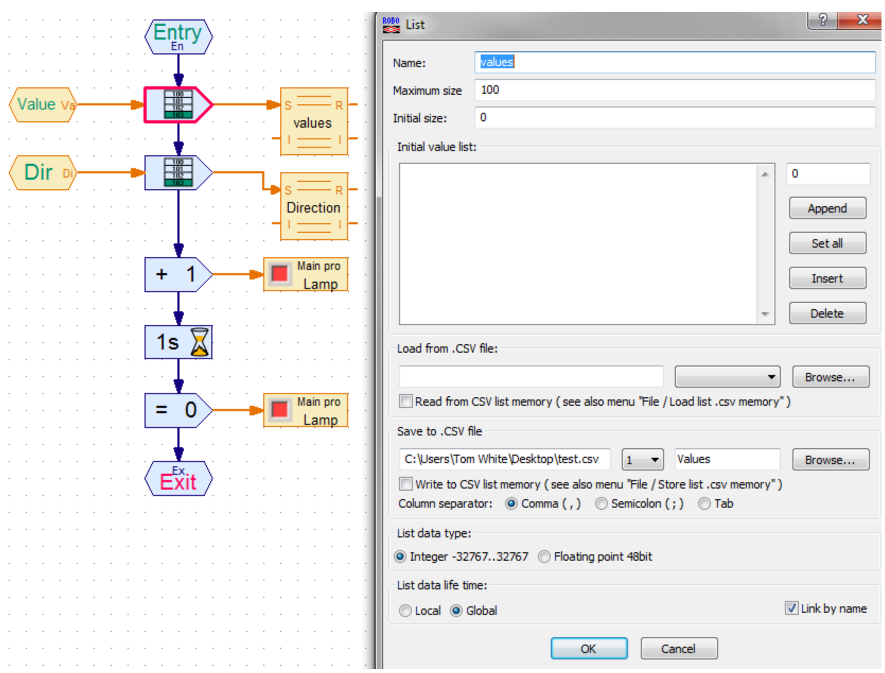


The next thing this program has to do is to record the positions and the direction it needs to travel to get there. A subprogram named Teach was used to do this.

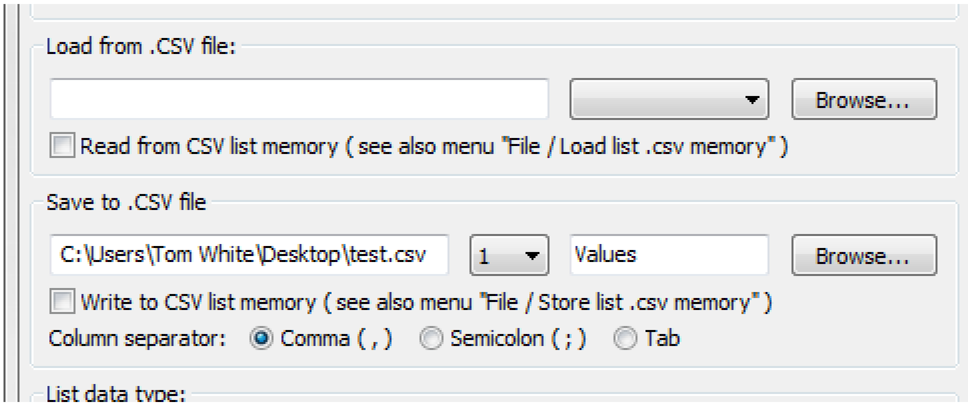
The programs use the command element called Append. This takes the encoder counts and direction passed to it and records in in a file using the lists. When it is finished it lights a lamp on the user interface.



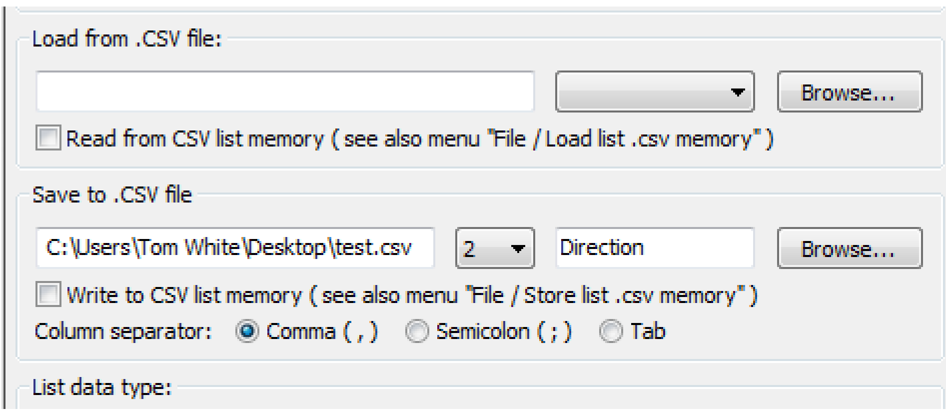
By right clicking on the list element you can name it and set the path to the .CVS file.



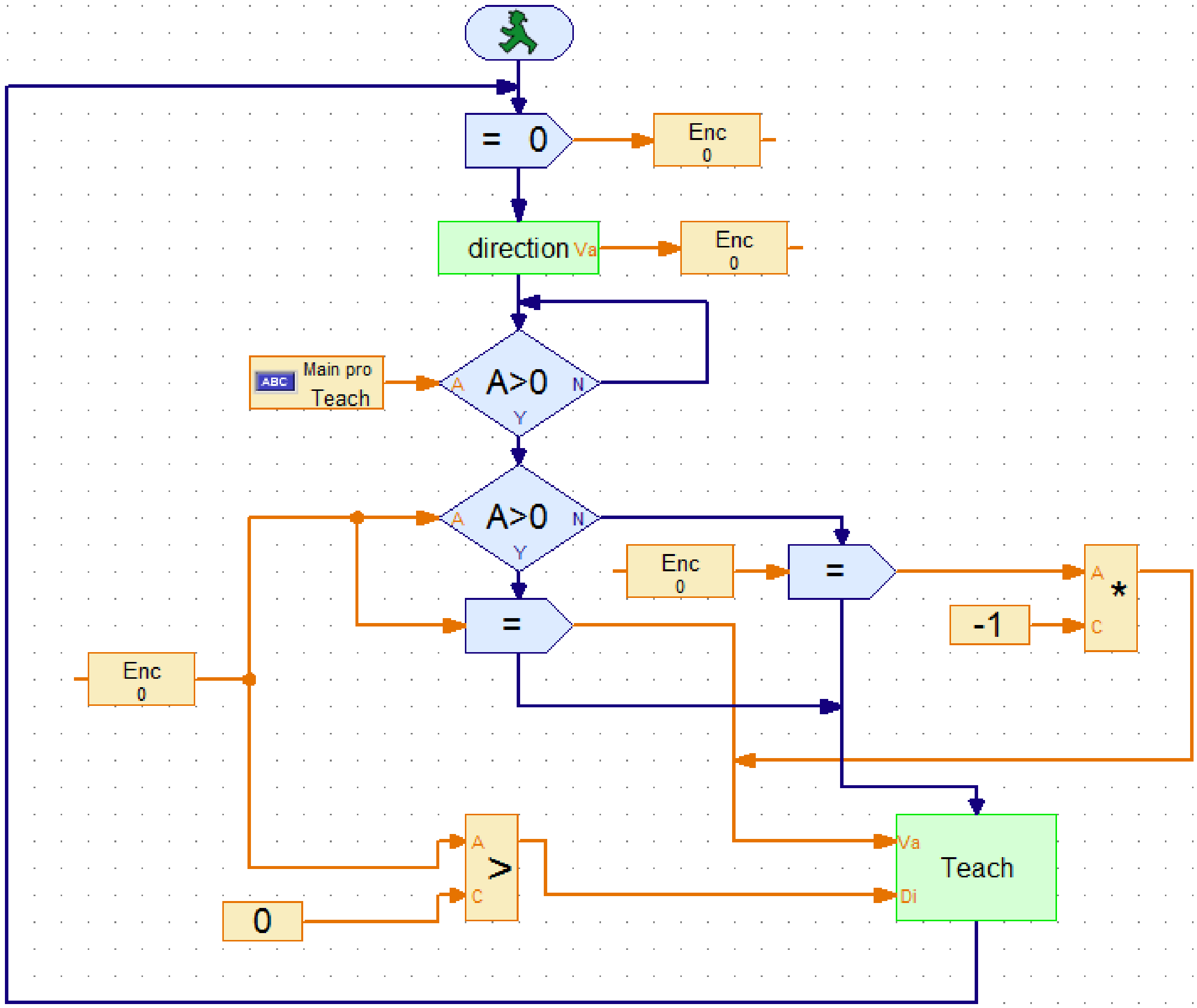
This one was named Values. It was targeted at a .CVS file named test on the desktop. The column was called Values.



The Direction list element was targeted to the same file but the column number was changed to 2 and the title Direction was assigned.



The last thing to build is the main control program. When the program begins it sets the variable Enc equal to 0 so the count can begin. It then passes control to the subprogram direction which keeps track of the movement and encoder counts. When the ready button in the subprogram is pressed the encoder count is passed out to the variable Enc. The program waits for you to push the teach button. When the teach button is pushed the program has to decide if the count is positive or negative as this will determine the direction the belt must travel. If the count is positive it is passed directly to the Teach subprogram. If it is negative the count has to be changed to a positive number before being passed to the Teach subprogram. The multiply element was selected from the operators submenu of the program elements. By multiplying by -1 the sign is changed to make the encoder count positive. To handle the direction the value of Enc is passed through a Greater than operator element. Being compared to the value 0, if the value is greater than 0 an output of 1 is produced. If it is less than 0 the output will be a 0. This value is then transferred to the Teach subprogram. Once the Teach subprogram is finished the control is rerouted to the beginning and the Enc value is reset to 0 and control passes to the direction subprogram again so a new position can be achieved.



Conclusion:

Create a program to control the conveyor and record positions. Print out a copy of your program for your engineering notebook and document how it works.

Creating a Graphical User Interface (GUI)

Purpose:

When people need to control machines they normally create a graphical interface for the user to make it easy to operate. Complex programs quickly become unwieldy. Imagine if Windows were a single program. It would be so large that a computer would struggle to launch it. Windows is broken down to a series of smaller sections and then linked together. Windows calls these dynamically linked libraries and these files can be identified by their .dll extension. In RoboPro we can take a loop of code and make it into its own element with a single name. The main program calls up these sub-programs for use. The user can see the logic in the main program and then open the sub-programs to see them as needed. This activity introduces you to the creation of subprograms.

Equipment:

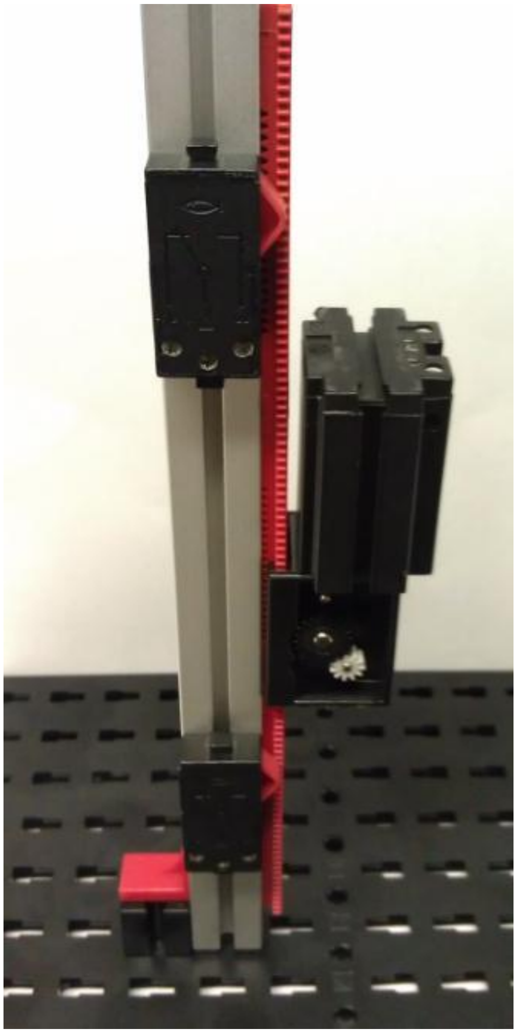
TX Controller
Power Supply
Wires

 37351 Rack and Pinion 60 3	 37272 Motor Rack Gearbox 1	 32882 Building block 15 with 2 pins 2	 31226 Aluminum Strut 210 mm 1
 37783 Mini-Switch 2	 32985 Base Plate 1	 32293 S-Motor 1	 31060 Link 15 2
			

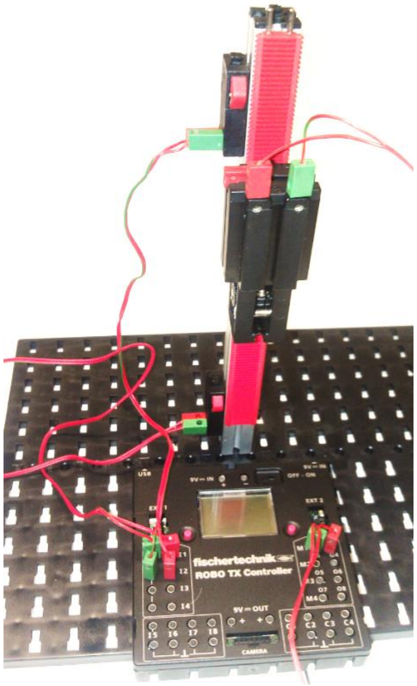
Angle block 10x15x15

Procedure:

Assemble the parts so they are in the configuration below.



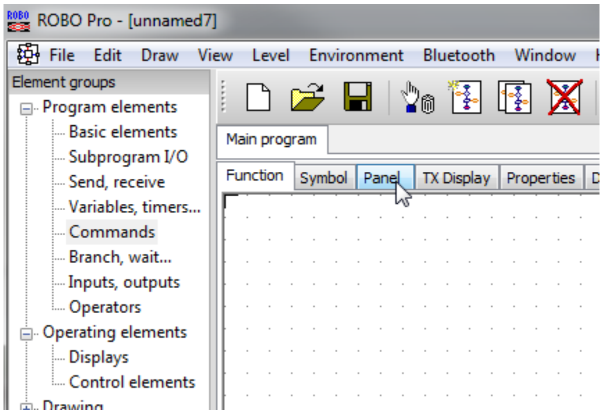
Wire them to the controller using the I1 and I2 inputs for the switches and M1 for the motor. See picture below



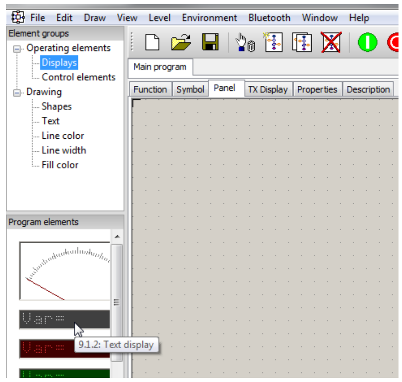
Begin a new RoboPro program. Set the level to Level 3: Variables

Creating the Interactive Panel:

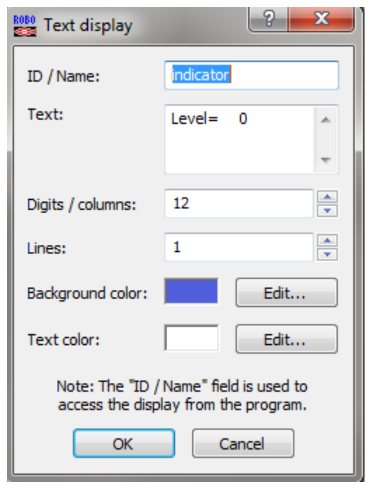
In the program window select the tab for Panel.



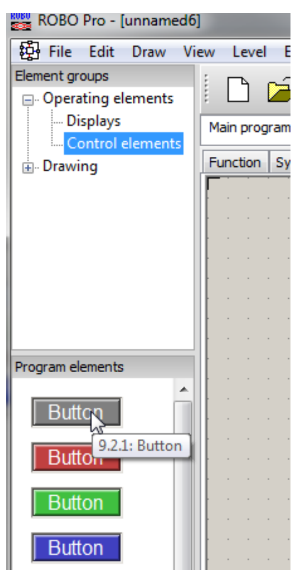
In the element group window expand the Operating elements and select Displays. Drag a text display element to the program window.



After placing the text display element right click on it and configure it as follows.

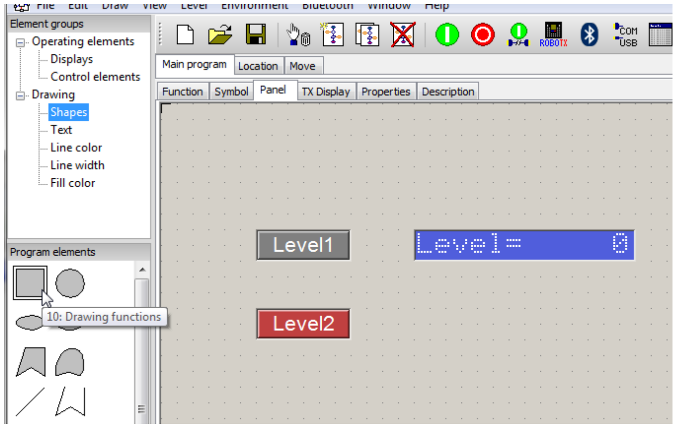


From the Operating elements section select Control elements. Drag two buttons to the program area.

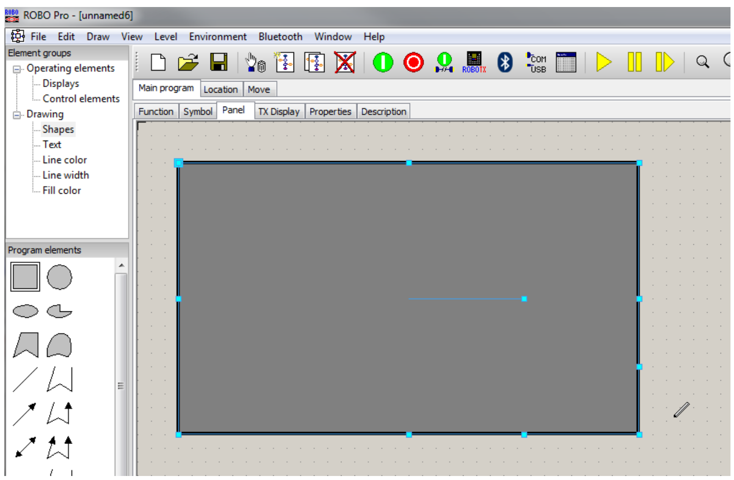


Right click on each button, naming one Level1 and the other level2.

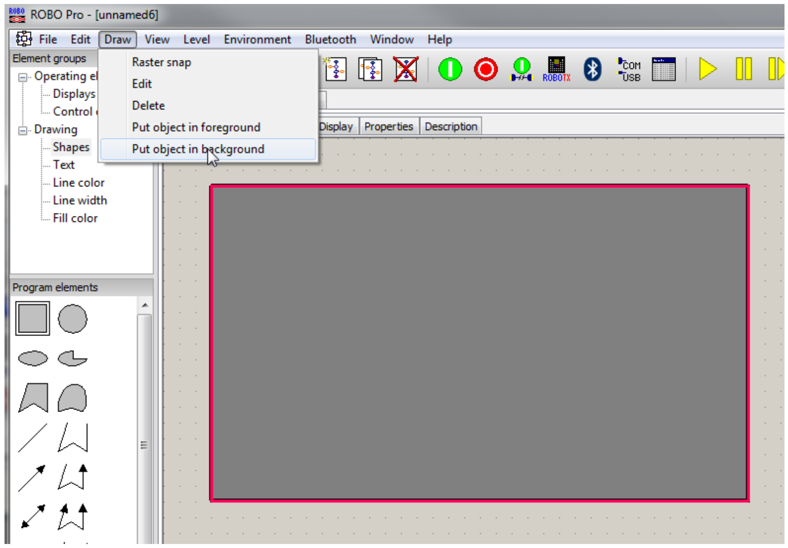
From the Drawing element group select Shapes.



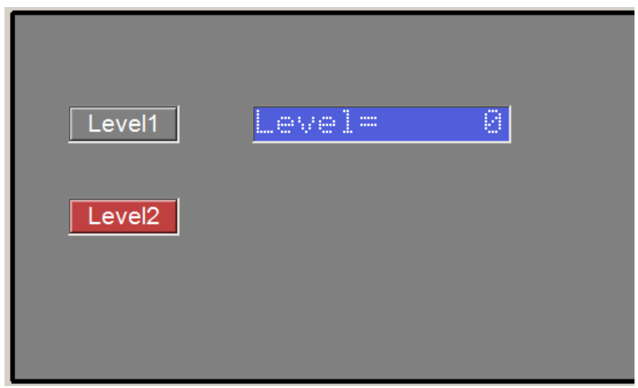
Select the rectangle by clicking on it. Move to your screen and draw a rectangle.



Hit escape to exit the command. Click on the edge of the rectangle and it will highlight. Move to the Draw pull down menu and select “Put object in background”.



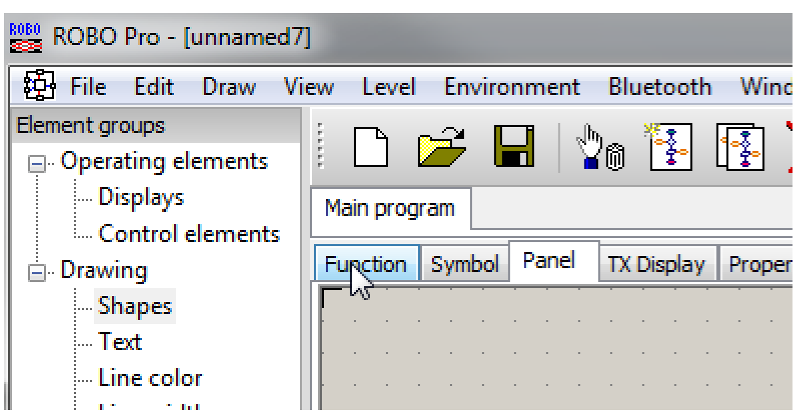
Your displays and controls will now be visible.



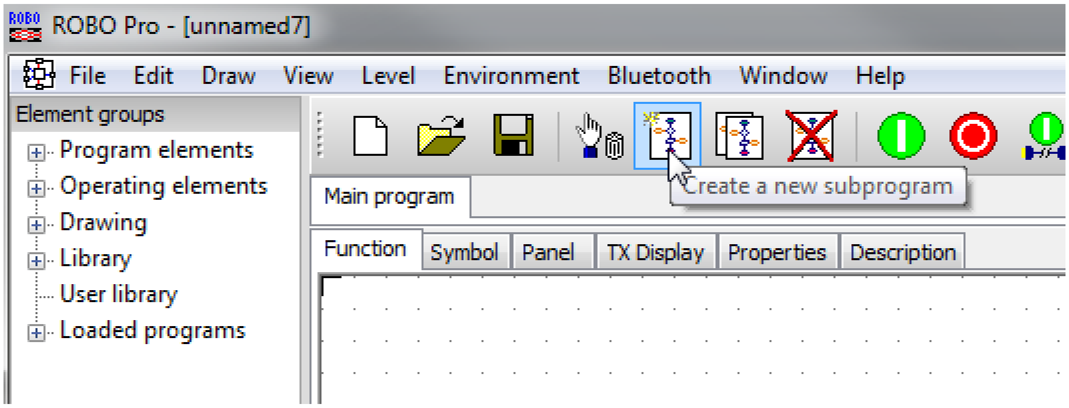
Arrange your displays and buttons to your satisfaction. Edit colors if you want.

Creating the Subprograms:

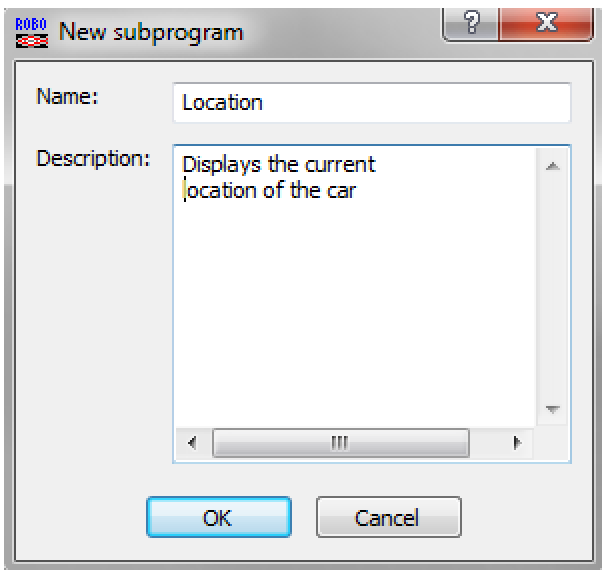
Select the Function tab of the main program.



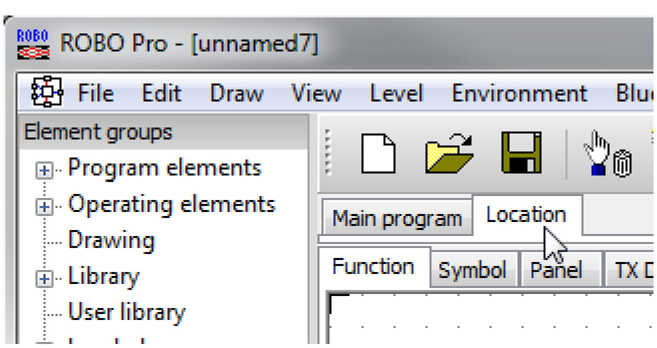
From the main toolbar select Create a new subprogram icon from the toolbar.



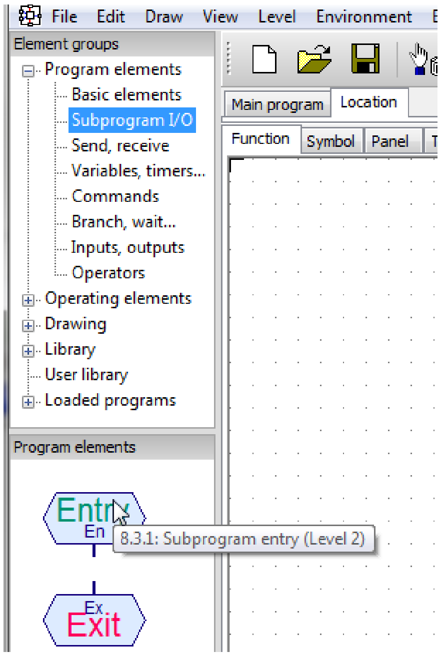
A dialog box appears to prompt you to name the new subprogram. This example uses the name Location. You can enter a description of the subprogram if you wish.



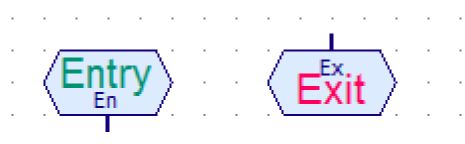
Once you select OK you will see a new tab next to the Main Program tab. It should have the name of your new subprogram. Click on the Location tab.



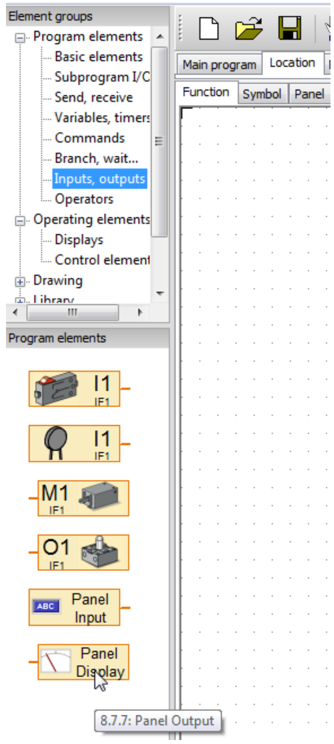
The first step it to create the program entry. This is similar to the Start program element. In the element groups window expand the program elements and highlight the Subprogram I/O menu. Select the Entry element from the choices.



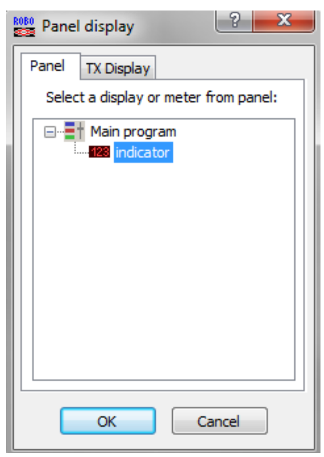
Drag an entry element and an exit element to the program window.



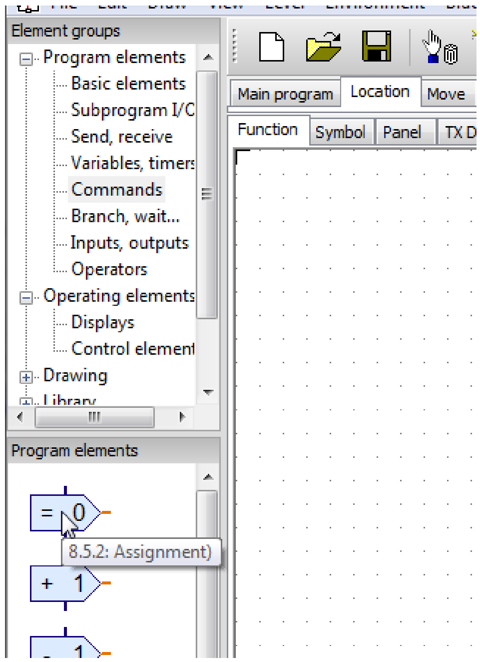
The purpose of this subprogram is to display the car location. Depending on which switch is pressed we would like a display to indicate where the car is. In order to display information we select the Inputs, outputs… section of the element groups window and drag a panel display element to the program window.



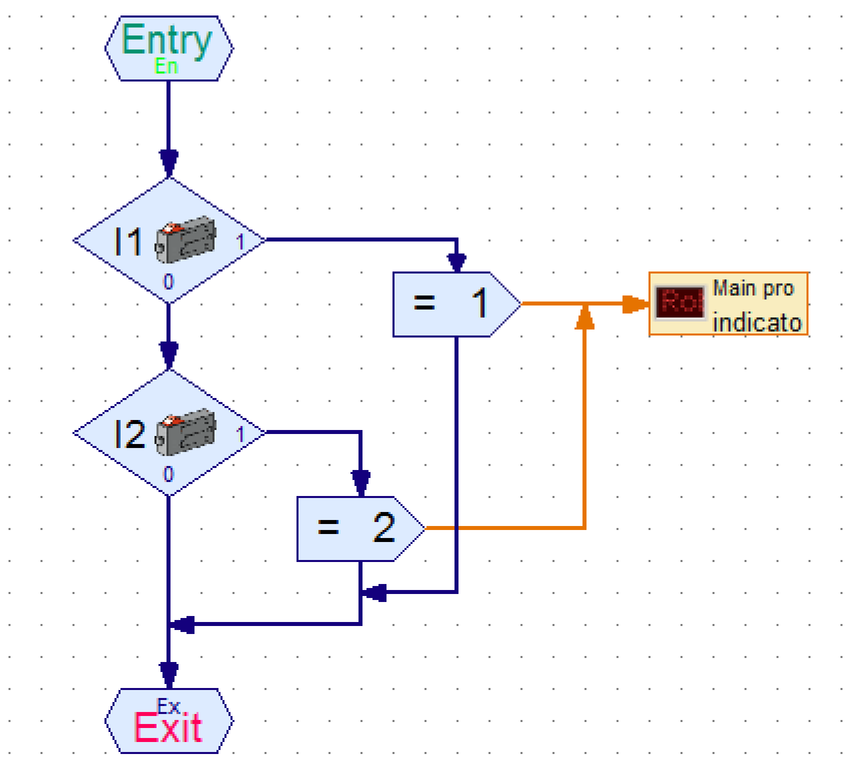
After dragging it to the program area right click on the Panel display and assign it to the Indicator.



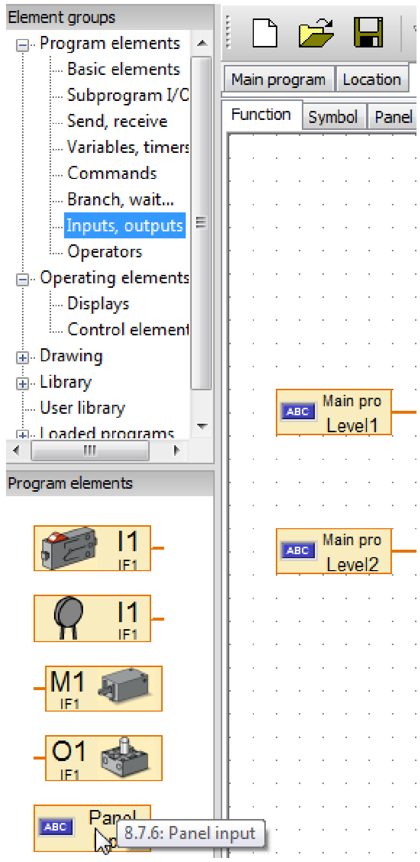
In addition we need to poll the switches to see which is pressed so we need to place two digital branch elements. To provide information to export we use the Assignment element from the Commands elements. After placing them right click and assign a value of one to the first and two to the second.



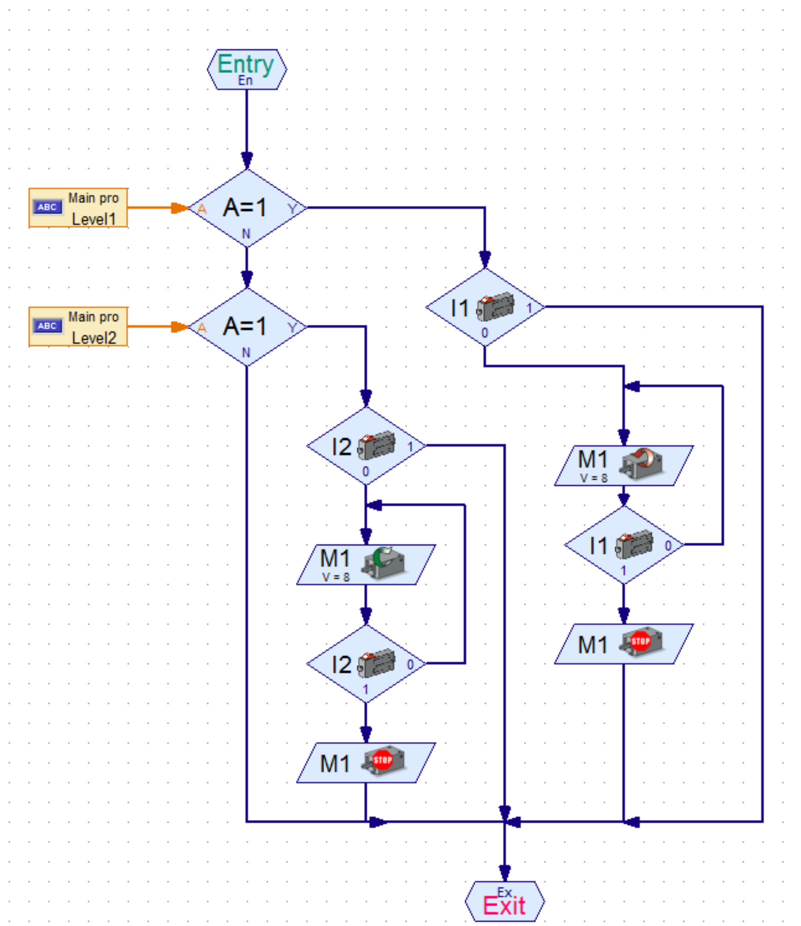
Assemble the program you see below. Use the text tool to explain what is happening at each step.



It is a good idea to save your work periodically to be sure it is not lost. Some people report that saving to a network can cause loss of the subprograms. Save either locally or to a thumb drive. Once saved you can then copy it to your network share and you will not lose the information. Return to the main menu. Select the create a new sub program again. Call this subprogram Move. This one will control the movement of the car. You will need to provide input from your panel to this subprogram. You will do this by placing panel inputs from the Inputs, outputs section of the Program elements. Once you drag them to the program area, right click on them and assign one to each level available.

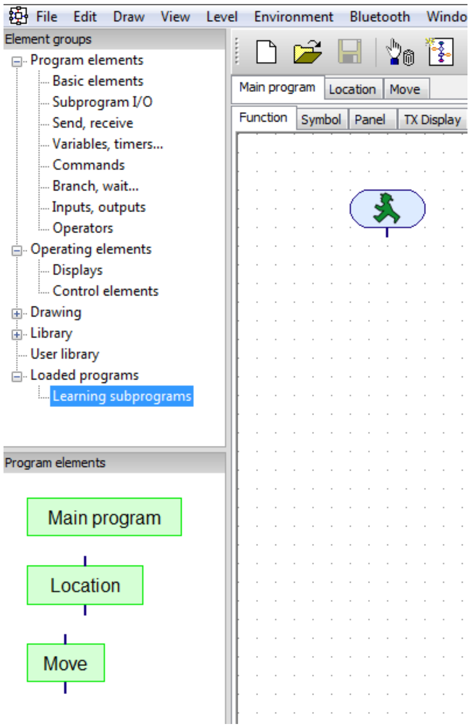


Construct your circuit as follows.

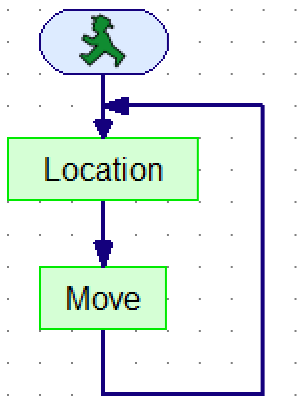


It is a good idea to save your work periodically to be sure it is not lost. Some people report that saving to a network can cause loss of the subprograms. Save either locally or to a thumb drive. Once saved you can then copy it to your network share and you will not lose the information. Use the text tool to document the function of each branch.

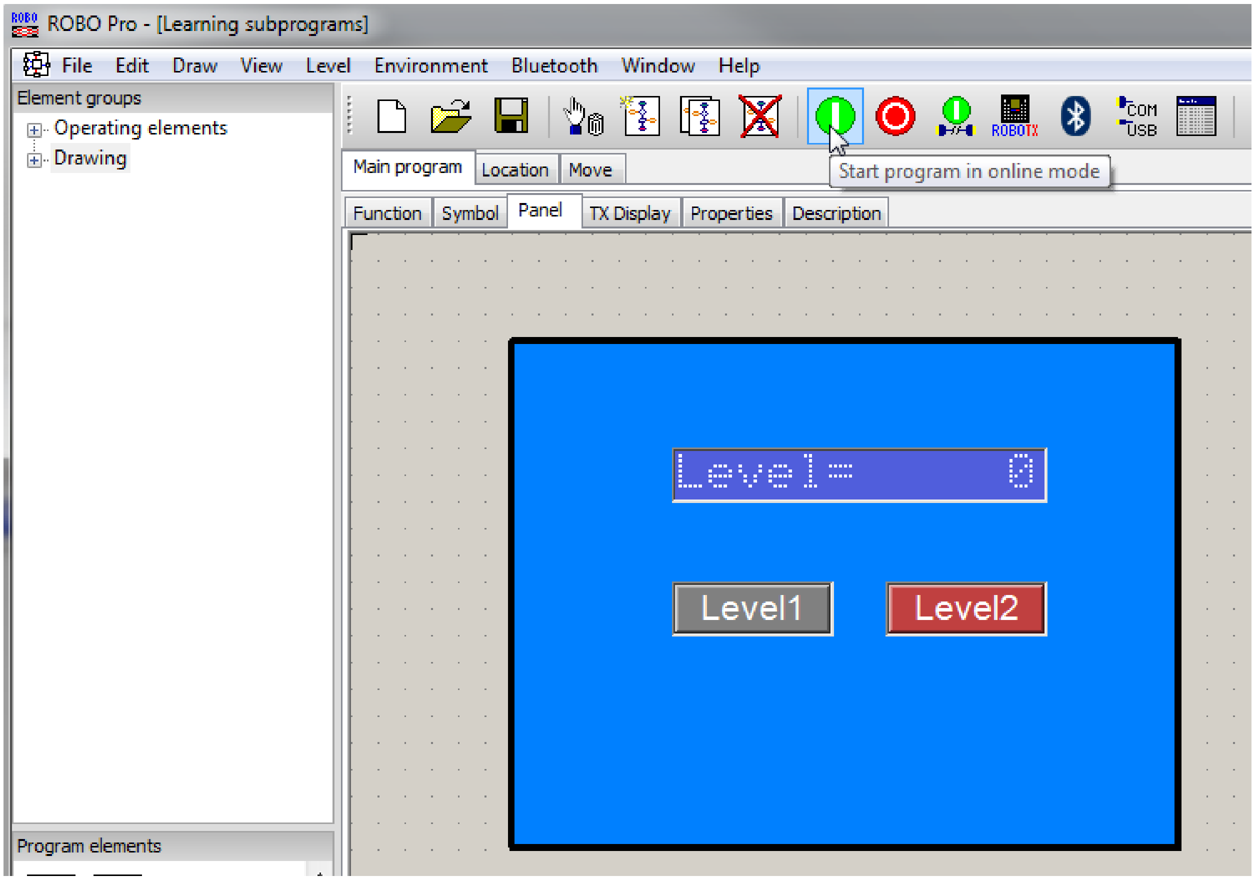
When you are finished return to the main program tab. Place a start element. Then look under loaded programs in the Elements group. When you expand that you will see the name of the program you are working on. If you didn't name it yet it will appear as Unnamed. Highlight the name of your program and you will see the subprograms in the program elements window.



Drag Location and Move under your start element and use flow lines to connect them.



Obtain your instructors permission to proceed. Locate the motor in the middle of the rack and turn the controller on. Be sure you are on the main program tab and then select the Panel tab to display your panel. Start the program. Nothing should happen until you push a level1 or level2 button. If you hit Level1 and the car begins to go up, select Stop and reverse the wires on your motor.



Print copies of each page for your engineering notebook.

Conclusion:

How does the program know which button is pushed on the panel.

Analog Sensors: Photocell LDR

Purpose:

Analog sensors produce a change in an electrical property to indicate a change in its host environment. Most things that we need to measure have a range of possibilities. Sensors are designed so they have a measurement section that is fairly linear but frequently the low and upper ranges of the device are not. It is important to select a sensor of the appropriate range to allow fairly good response to the property being measured. The price will vary on sensors depending on the precision and accuracy requirements of the measurement being performed. There are differences between two sensors made at the same time in the same factory. Because of this difference calibration of sensors is sometimes necessary if exact results are required. The fuel level in the gas tank of a car is important to know so a refueling trip can be scheduled before the automobile stops running. However you might not need to know how many milliliters are left in the tank. Analog sensors are divided into two basic categories; active and passive. Passive sensors react to the world around them and produce a change in a passive electrical quantity, such as resistance, capacitance, or inductance which can be measured. Active sensors actively probe the environment and will require energy from a power source to function.

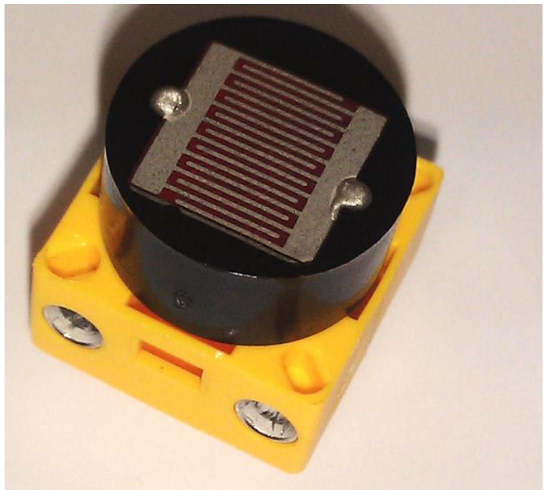
Equipment:

TX Controller
Power Supply
Wires
Photocell LDR 03

Lamp

Procedure:

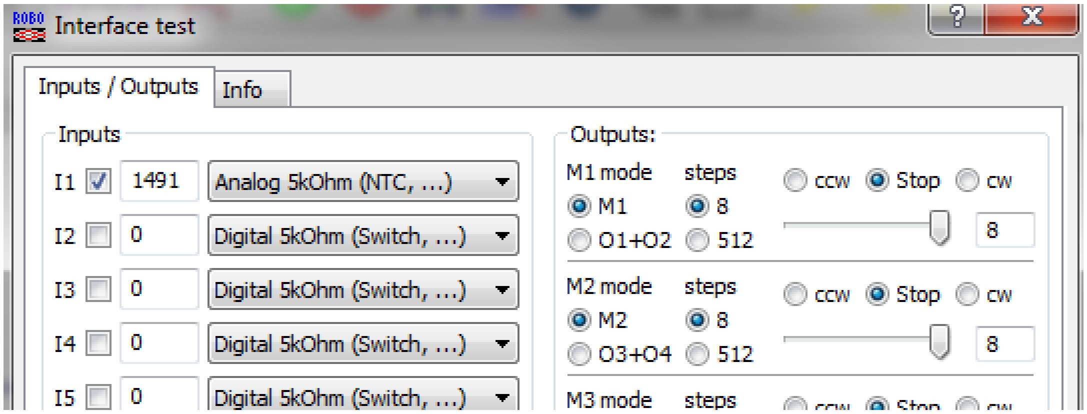
The LDR (Light Dependent Resistor) is a device made from Cadmium Sulfide (CdS) . These devices have multiple names such as photo resistor, photocell, CdS cell or light dependent resistor. This device changes resistance with the exposure to light. The stronger the light source the greater the change.



The schematic symbol for the Photocell is shown below.

The photocell is a passive device and is connected to any of the inputs I1-I8. They will not work in the C1-C4 connections.

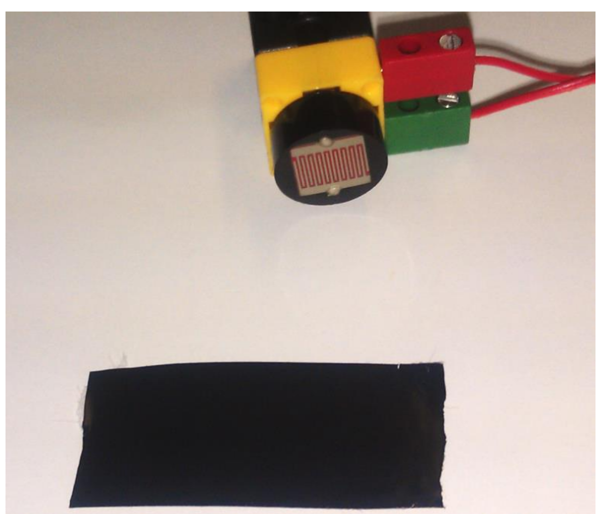
Whenever you hook up a sensor to the TX Controller it is a good idea to open the Interface Test application in the RoboPro software to check to be sure the sensor is giving you the correct input for your selected type. Select the Test Interface icon on the main toolbar. When the application opens you will need to set the type to match your sensor before it will give you correct information. In this case you will be selecting Analog 5KOhm(NTC,…)



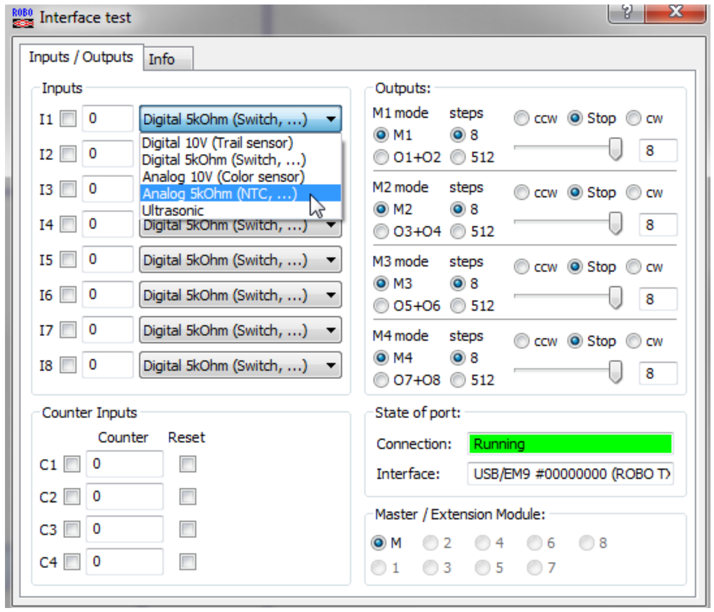
Once you click on your selection it will stay in the window.

Conclusion:

Wire the Photoresistor to the I1 input of the controller. Wire the lamp to the M1 input of the controller.
Begin by preparing the test setup. Take a piece of plain white paper and apply a small piece of electrical tape to the surface.

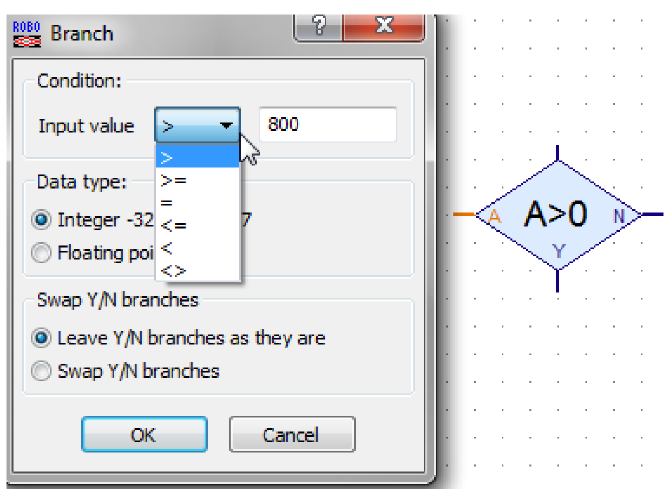


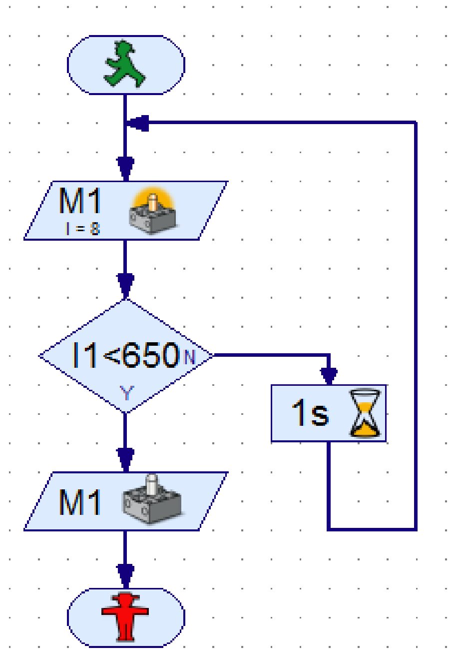
Turn on the power to the interface. From the toolbar select the Interface Test button to bring up the dialog box. Change the setting of input of I1 to Analog 5kOhm by selecting the down arrow next to the entry and selecting the appropriate setting.



Once this is done you will see a check appear in the I1 inputs column and a value appear next to the check. As you move or shade the sensor you should see the value change. Hold the sensor pointing downward at your paper with the tape at an approximate distance of 1 inch. Hold it over a white section of the paper and record down the value. Next move the sensor over the black tape and record the value. Record these values in your engineering notebook. Comment on why the readings are different.

Create the following program using the Analog branch found in the elements window. You can change the value of the branch by right clicking on the element and setting the value. Set your value to be half way between the dark and light settings you recorded previously as a place to start.

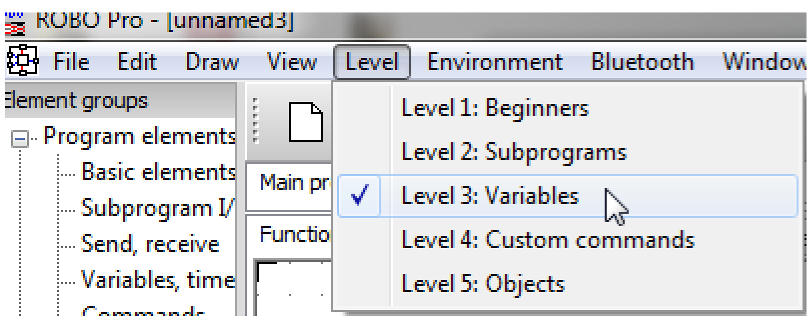




Run the program. Begin with the sensor over the tape. Slowly move the sensor toward the white section of the paper.

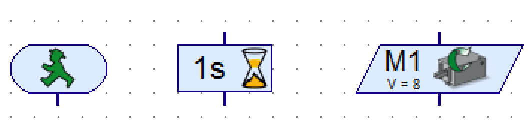
Print a copy of this program and include it in your engineering notebook. Explain what happened while running the program and moving the sensor. List several common items that utilize a sensor such as this one.

Begin a new program. Set the level to Level 3: Variables.

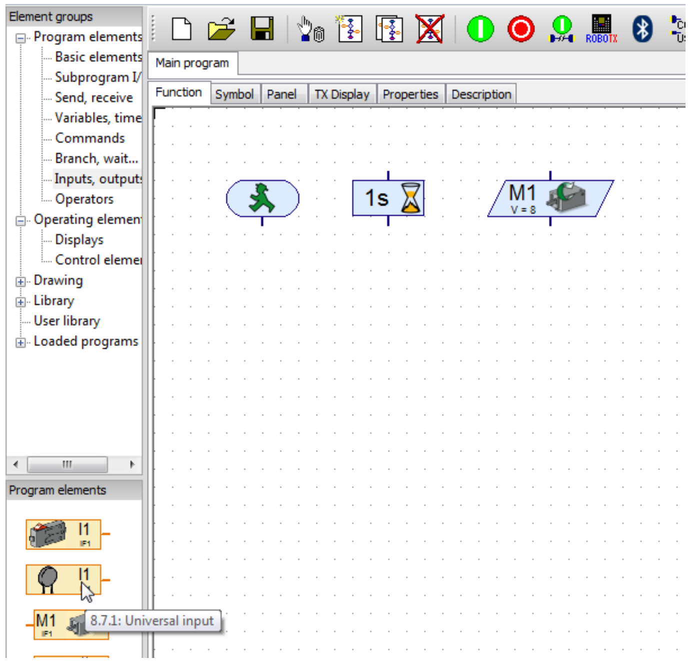


This will make some new commands available.

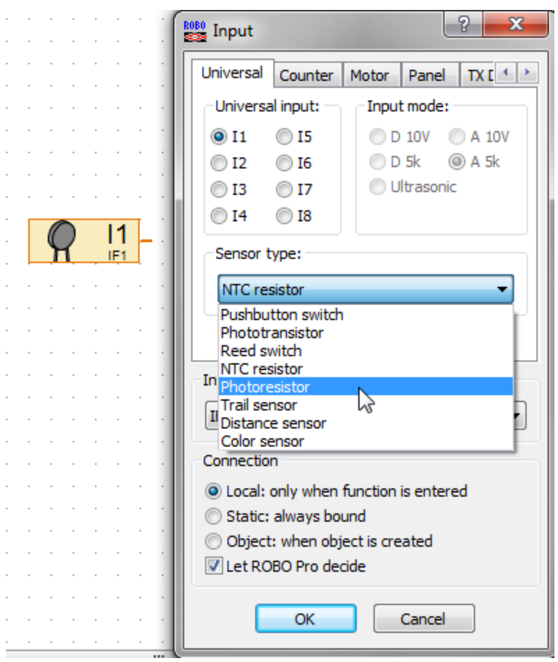
Begin by placing the following elements from the Basic Elements window.



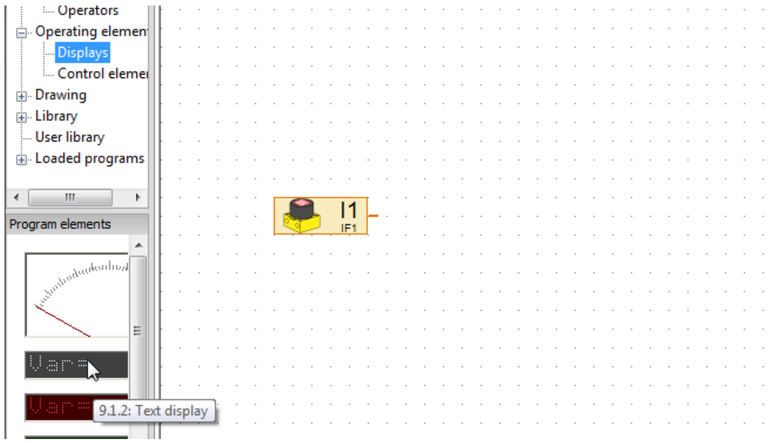
Next highlight the Inputs, outputs menu selection and select the Universal Input from the Program elements window.



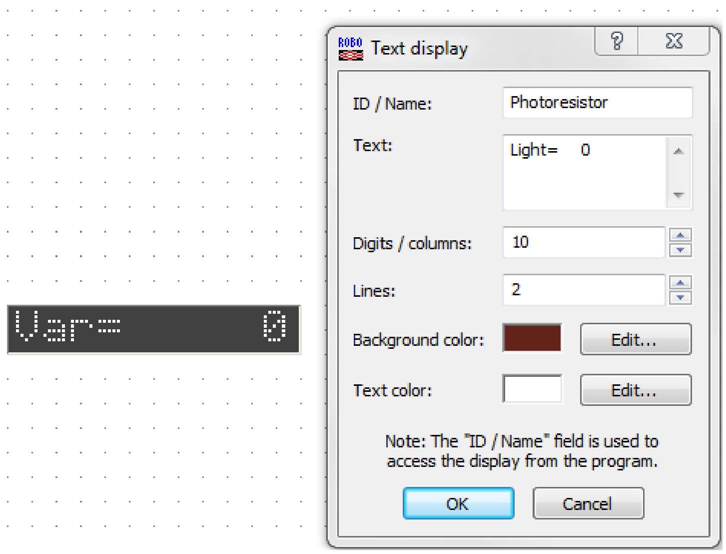
Right click on the universal input element and select Photoresistor as the Sensor type. Be sure that the I1 radio button is pushed. Once you select OK you will see the image on the surface change.



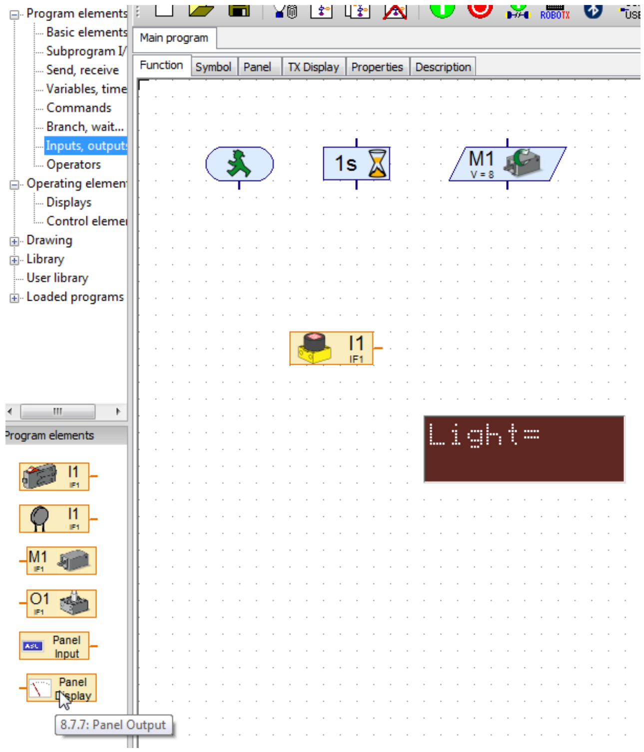
Next expand the Operating elements section of the menu in the elements group window and select the displays group. Displays allow us to see a value on the screen. Drag out a text display onto the program window.



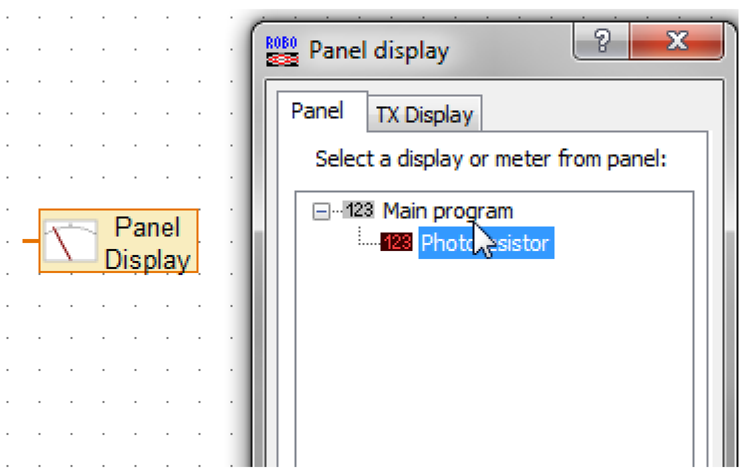
Right click on the text display element. Make changes to the display properties similar to the ones seen below.



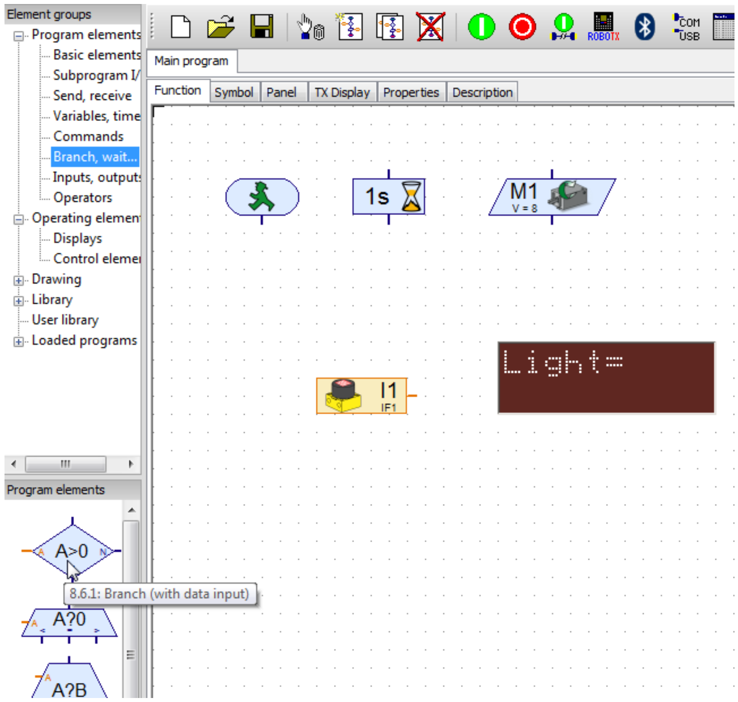
Return to the Inputs, outputs section of the Program elements group. Select a Panel Display and drag it to the program window.



Right click on the Panel display element to open the dialog box. Highlight the Photoresistor. If we had more than one display they would all appear and we would have more to select from. Select OK and you will see the name change

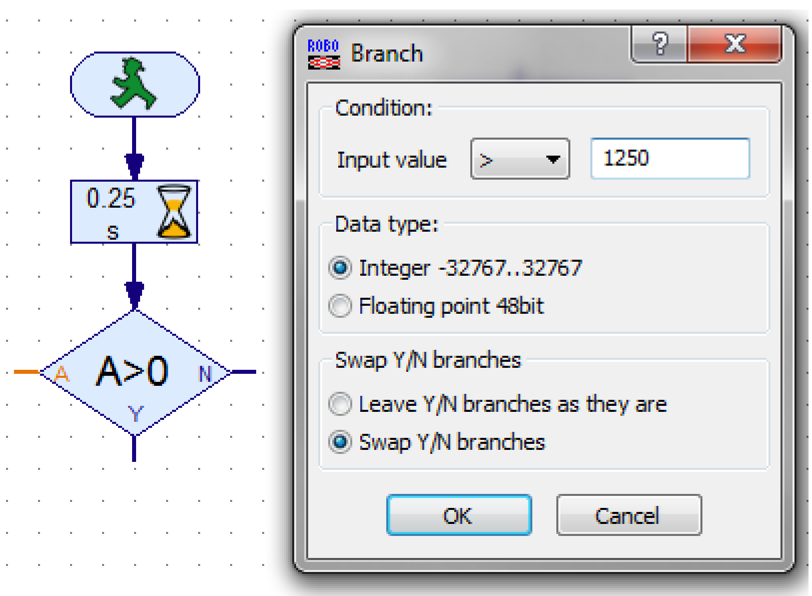


From the Branch, wait… section of the Program elements group select the Branch with data input.

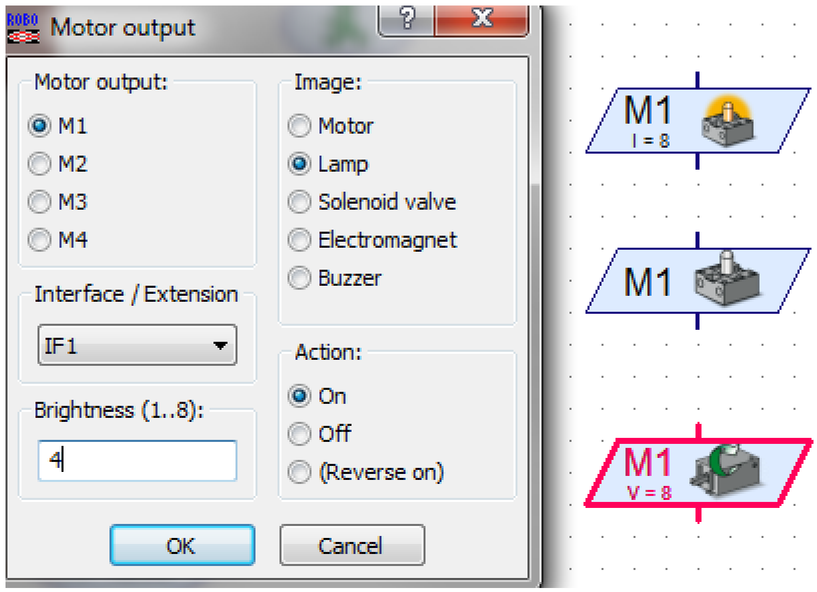


Place the icon on your program window.

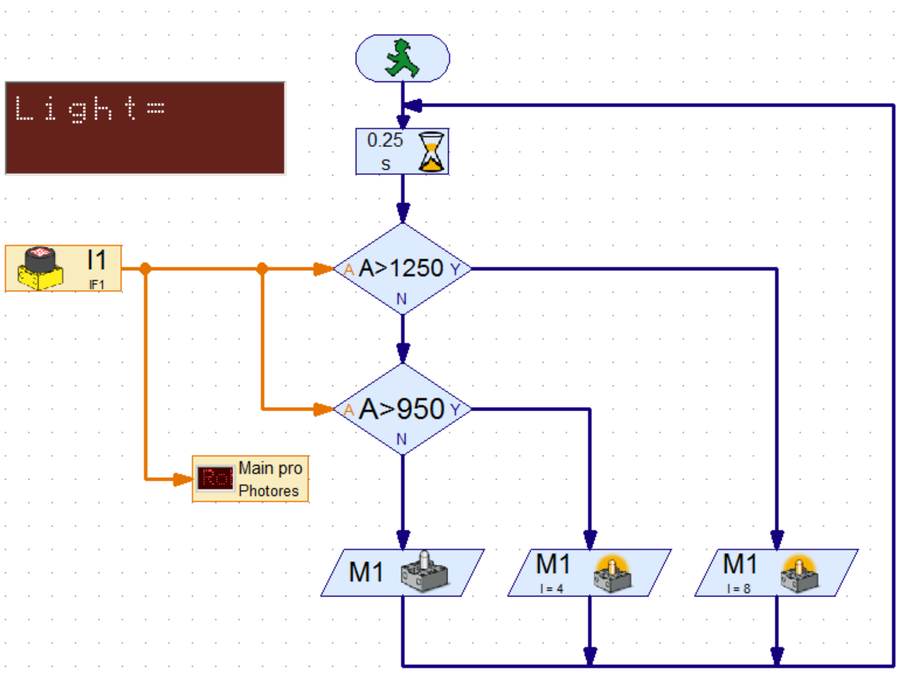
Right click on the branch element. Set the input value just below your dark setting. There is a radio button toward the bottom of the dialog box to Swap Y/N branches. Select that option and when you say OK the pathways will switch.



Duplicate the motor element so you have three for M1. Right click on them one at a time. Set the image to Lamp. Set one to Off, one to On with a brightness of 8 and one to On with a brightness of 4.



Place a second Branch and set it to the value of half on the tape and half off. Finish designing the program similar to the one below. When you are ready run the program and move the sensor over the tape and off.
When you are ready run the program and move the sensor over the tape and off.



When you are ready run the program and move the sensor over the tape and off. Observe what happens. Adjust the values of the branching to change the output to be more responsive to changing light conditions.

Print the program and put it in your engineering notebook. Explain how you adjusted your circuit to obtain the performance you wanted. Comment on the value of the display in your ability to adjust the circuit.

Analog Branching

Purpose:

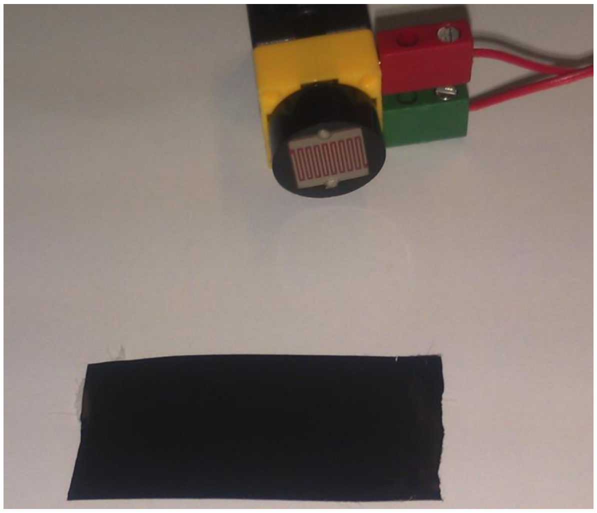
Most of life is not yes or no. It is an infinite variety or shades of grey. When an automated device senses the world around it the majority of information is in analog form. Temperatures, light, sound, and distances all vary. When measured they cannot be used in a program directly. Programmers have devised ways to convert analog signals to digital ones. This activity will help you import analog values and make decisions with them.

Equipment:

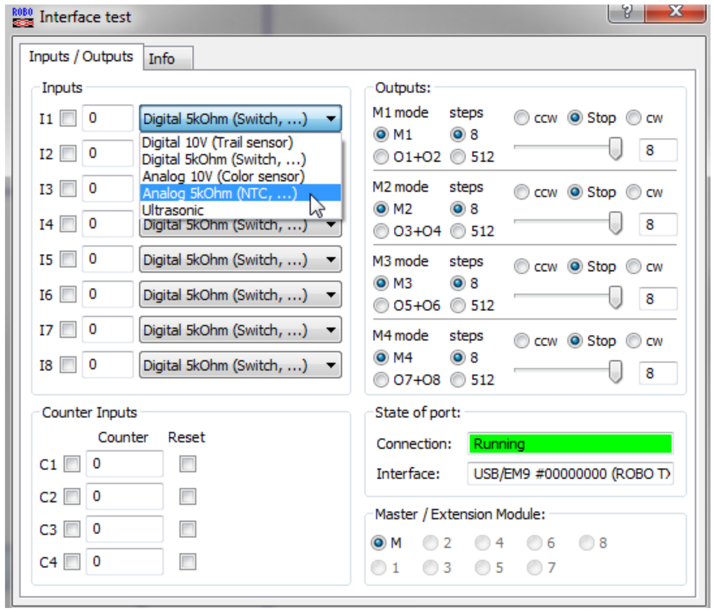
Photocell
Lamp
TX Controller
Power Supply
Paper
Small piece of electrical tape

Procedure:

Wire the Photoresistor to the I1 input of the controller. Wire the lamp to the M1 input of the controller.
Begin by preparing the test setup. Take a piece of plain white paper and apply a small piece of electrical tape to the surface.

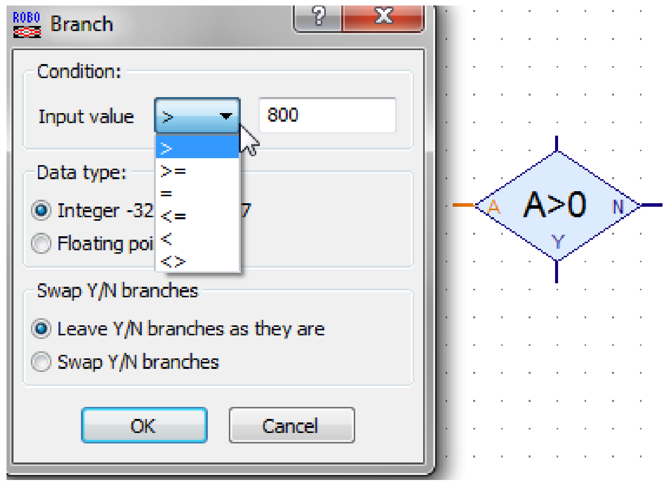


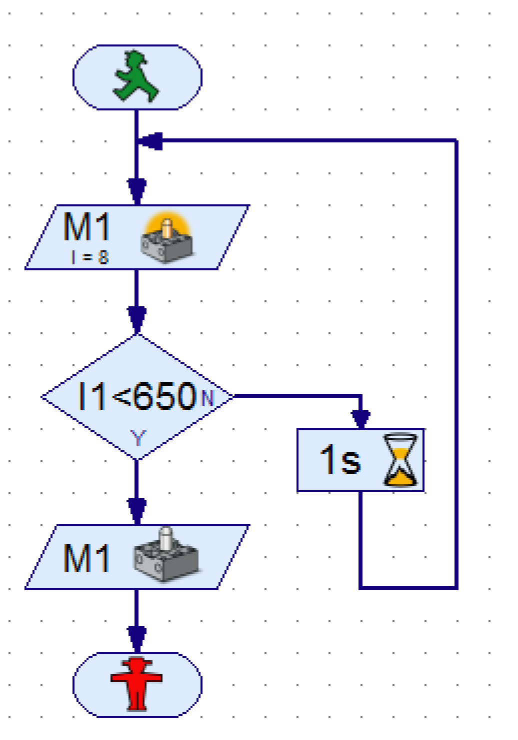
Turn on the power to the interface. From the toolbar select the Interface Test button to bring up the dialog box. Change the setting of input of I1 to Analog 5kOhm by selecting the down arrow next to the entry and selecting the appropriate setting.



Once this is done you will see a check appear in the I1 inputs column and a value appear next to the check. As you move or shade the sensor you should see the value change. Hold the sensor pointing downward at your paper with the tape at an approximate distance of 1 inch. Hold it over a white section of the paper and record down the value. Next move the sensor over the black tape and record the value. Record these values in your engineering notebook. Comment on why the readings are different.

Create the following program using the Analog branch found in the elements window. You can change the value of the branch by right clicking on the element and setting the value. Set your value to be half way between the dark and light settings you recorded previously as a place to start.

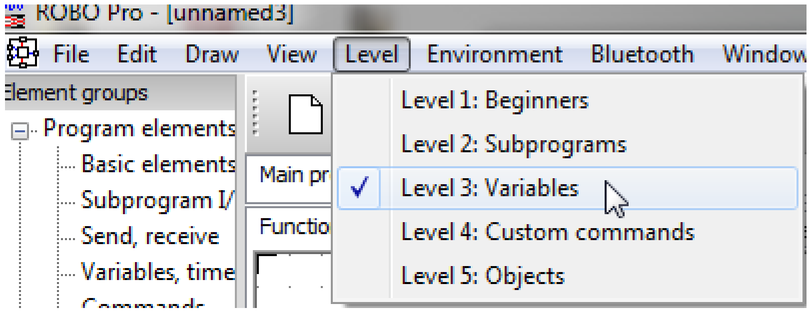




Run the program. Begin with the sensor over the tape. Slowly move the sensor toward the white section of the paper.

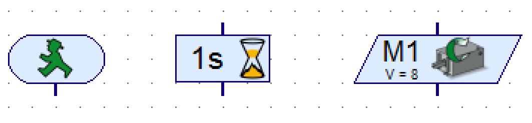
Print a copy of this program and include it in your engineering notebook. Explain what happened while running the program and moving the sensor. List several common items that utilize a sensor such as this one.

Begin a new program. Set the level to Level 3: Variables.

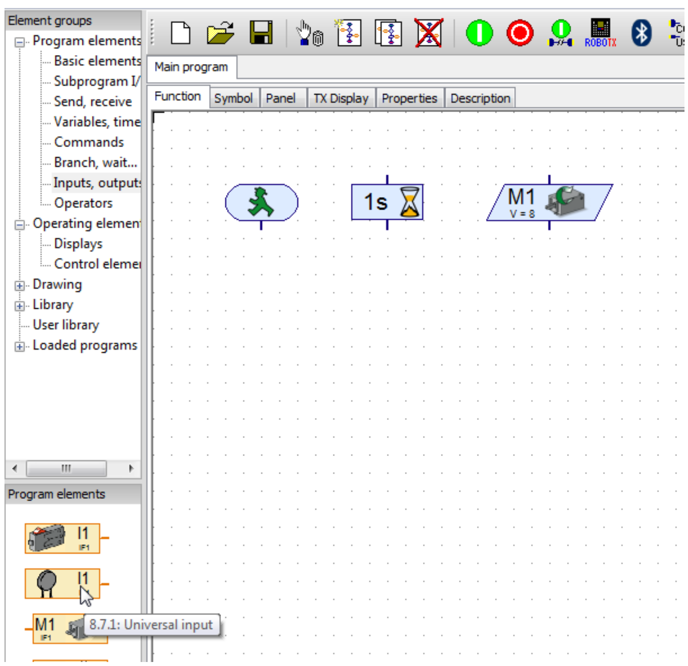


This will make some new commands available.

Begin by placing the following elements from the Basic Elements window.



Next highlight the Inputs, outputs menu selection and select the Universal Input from the Program elements window.



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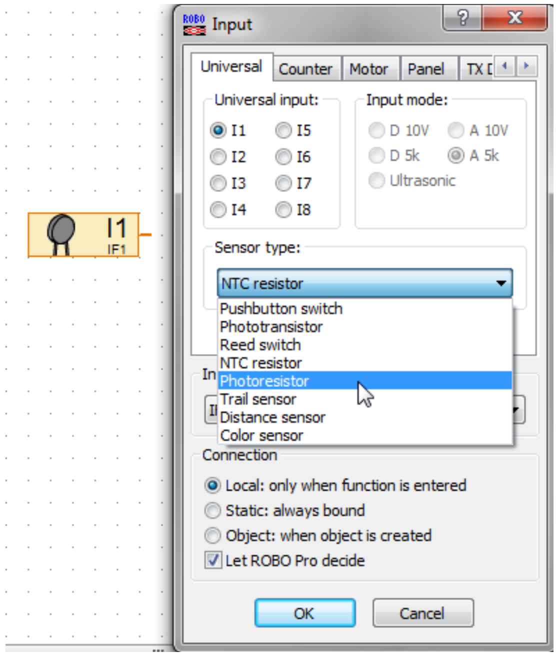

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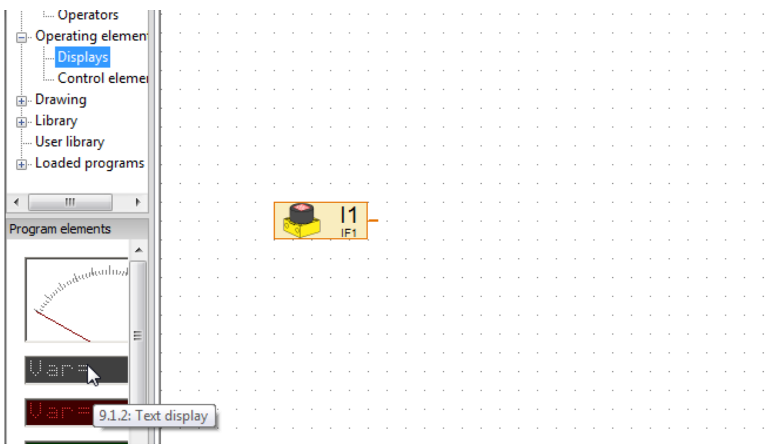
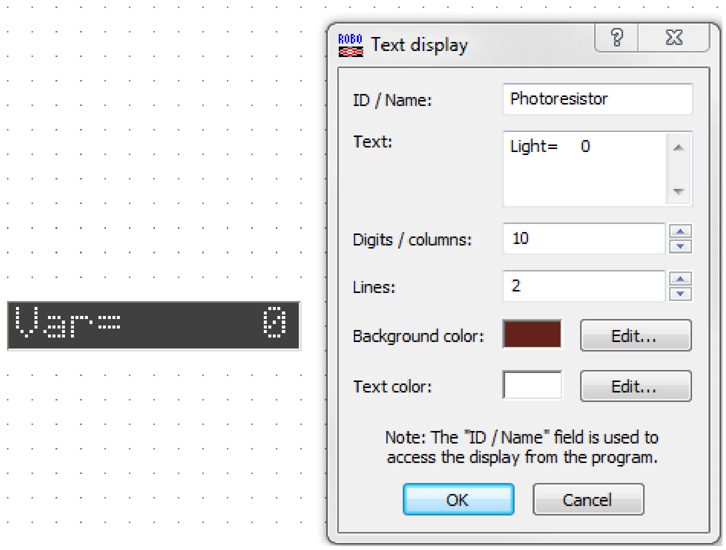
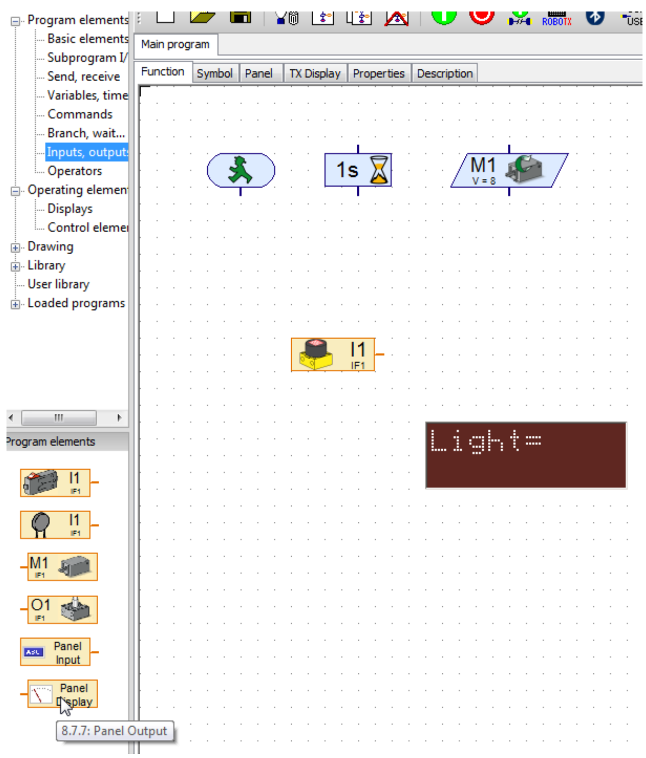


Right click on the text display element. Make changes to the display properties similar to the ones seen below.



Return to the Inputs, outputs section of the Program elements group. Select a Panel Display and drag it to the program window.



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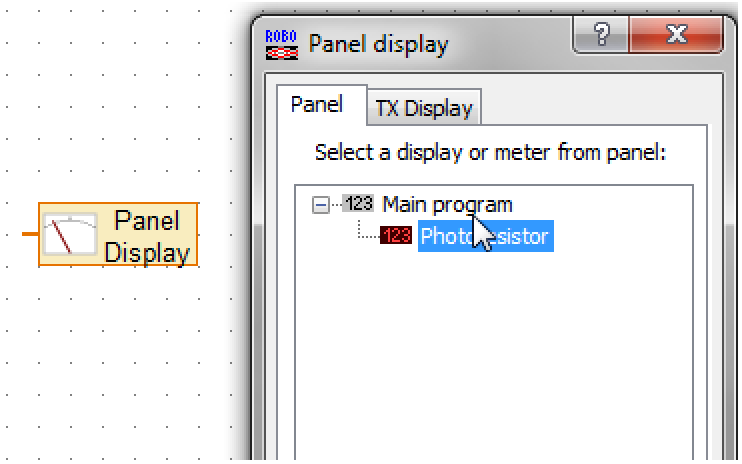
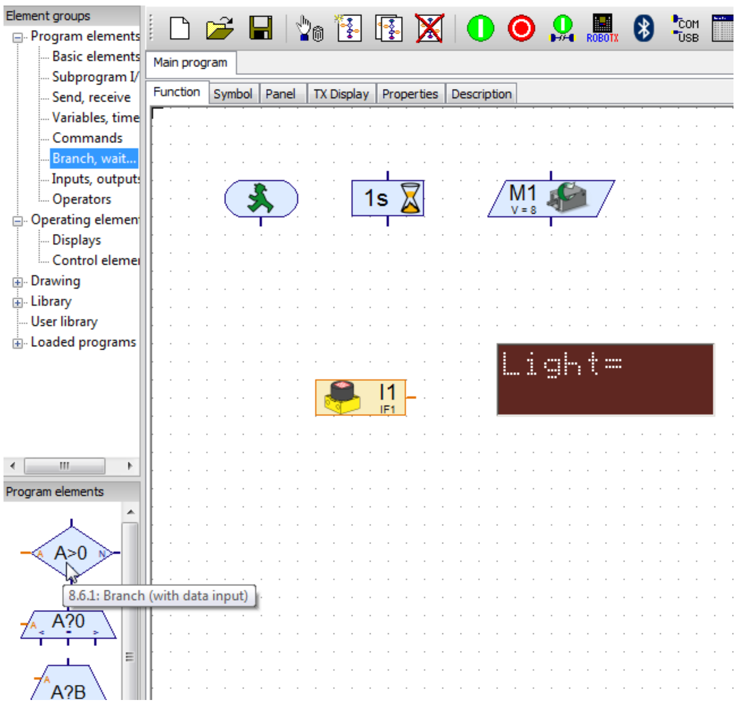


From the Branch, wait… section of the Program elements group select the Branch with data input.



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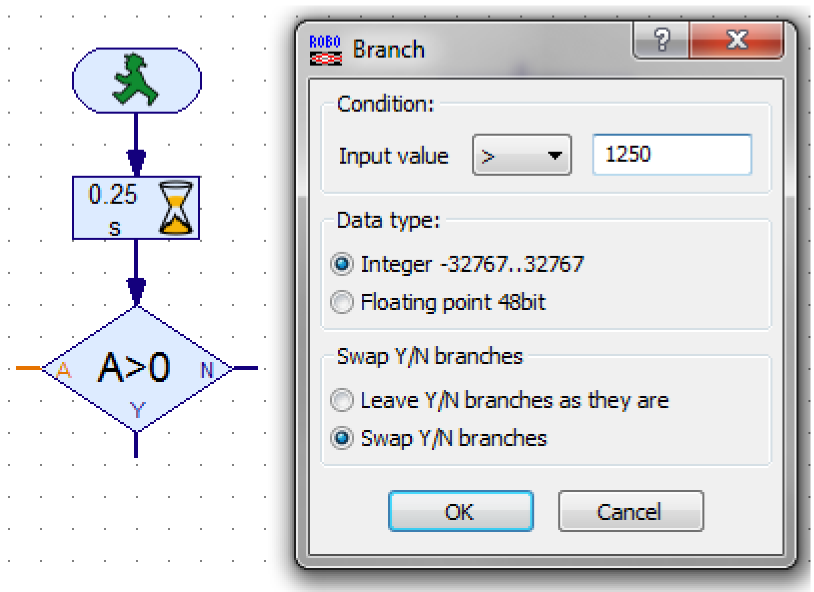
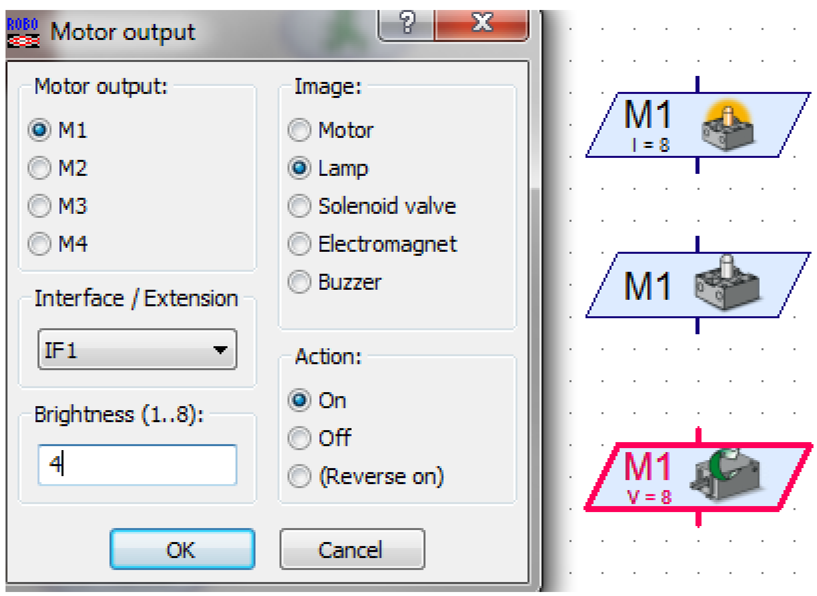
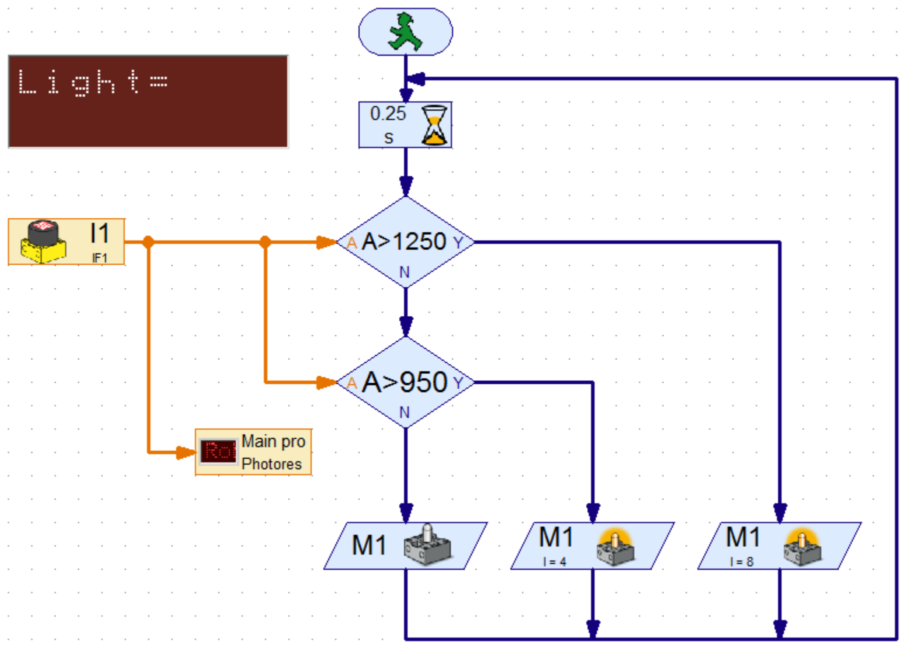


Duplicate the motor element so you have three for M1. Right click on them one at a time. Set the image to Lamp. Set one to Off, one to On with a brightness of 8 and one to On with a brightness of 4.



Place a second Branch and set it to the value of half on the tape and half off. Finish designing the program similar to the one below. When you are ready run the program and move the sensor over the tape and off.
When you are ready run the program and move the sensor over the tape and off.



When you are ready run the program and move the sensor over the tape and off. Observe what happens. Adjust the values of the branching to change the output to be more responsive to changing light conditions.

Print the program and put it in your engineering notebook. Explain how you adjusted your circuit to obtain the performance you wanted. Comment on the value of the display in your ability to adjust the circuit.

Conclusion:

How does creating an analog branch in a circuit differ from a digital branch?

How are they similar?

What applications would be based on a varying level of input?

Analog Sensors: NTC Resistor

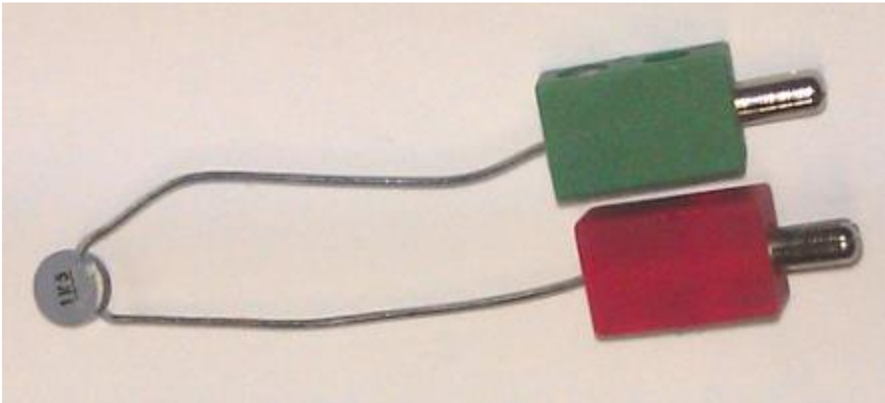
Purpose:
Analog sensors produce a change in an electrical property to indicate a change in its host environment. Most things that we need to measure have a range of possibilities. Sensors are designed so they have a measurement section that is fairly linear but frequently the low and upper ranges of the device are not. It is important to select a sensor of the appropriate range to allow fairly good response to the property being measured. The price will vary on sensors depending on the precision and accuracy requirements of the measurement being performed. There are differences between two sensors made at the same time in the same factory. Because of this difference calibration of sensors is sometimes necessary if exact results are required. The fuel level in the gas tank of a car is important to know so a refueling trip can be scheduled before the automobile stops running. However you might not need to know how many milliliters are left in the tank. Analog sensors are divided into two basic categories; active and passive. Passive sensors react to the world around them and produce a change in a passive electrical quantity, such as resistance, capacitance, or inductance which can be measured. Active sensors actively probe the environment and will require energy from a power source to function.

Equipment:
TX Controller
Power Supply
Wires
NTC resistor

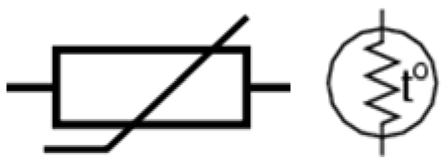
Lamp

Procedure:
The NTC resistor is in the class of semi-conductors known as thermistors. A thermistor is a resistor whose resistance varies widely depending on the temperature. Thermistors are used in all kinds of household appliances including; thermostats, coffee pots, toasters, refrigerators, hair dryers, ceiling lights, transformers and any other place where protection for over current is needed. There are two basic types of thermistors known as PTC and NTC. PTC (Positive Temperature Coefficient) thermistors are used to help limit the over current conditions as their resistance increases with heat. NTC

(Negative Temperature Coefficient) thermistors are used to measure temperature and in power supplies to prevent inrush of current during start up. Once started it heats up and poses less resistance to the flow of current. The picture below shows the NTC thermistor connected to fischertechnik plugs.

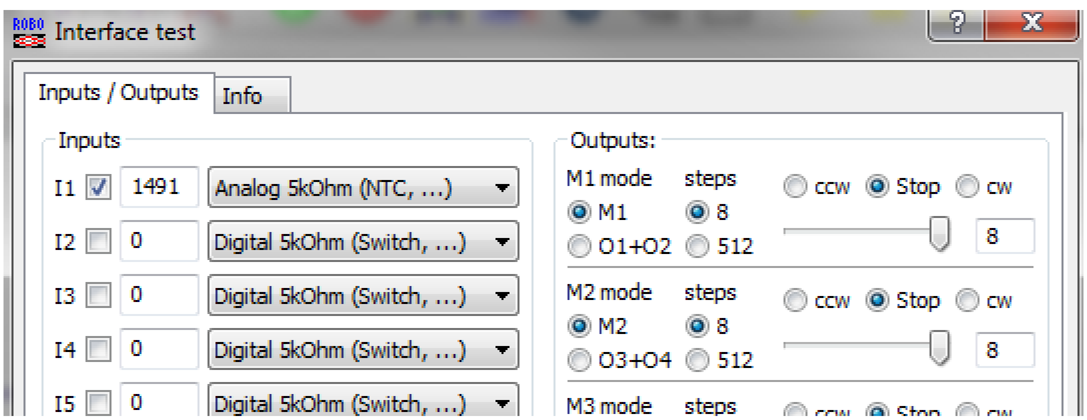


The schematic symbols for the thermistor are shown below.



The NTC resistor is a passive device and is connected to any of the inputs I1-I8. They will not work in the C1-C4 connections.

Whenever you hook up a sensor to the TX Controller it is a good idea to open the Interface Test application in the RoboPro software to check to be sure the sensor is giving you the correct input for your selected type. Select the Test Interface icon on the main toolbar. When the application opens you will need to set the type to match your sensor before it will give you correct information. In this case you will be selecting Analog 5KOhm(NTC,…)



Once you click on your selection it will stay in the window.

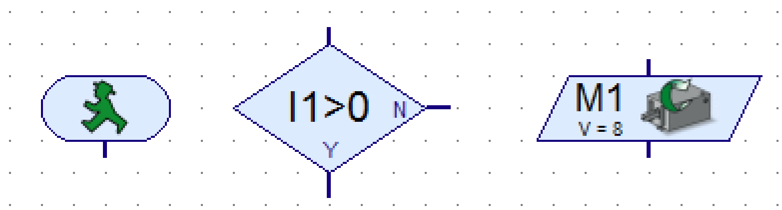
Conclusion:

Include a sketch of your setup in your Engineering notebook. Record the reading when you first plug in the thermistor. Pinch the head of the thermistor between your fingers. As your body heat warms the thermistor what happens to the reading? Hold the thermistor for 30 seconds. Let go of the thermistor. How long does it take to return to its original reading? Does it return to the original value? Look up the term Hysteresis and explain how it explains what happened to your reading.

Reverse the wires on the TX controller. Does reversing the wires have any effect on the operation of the sensor?

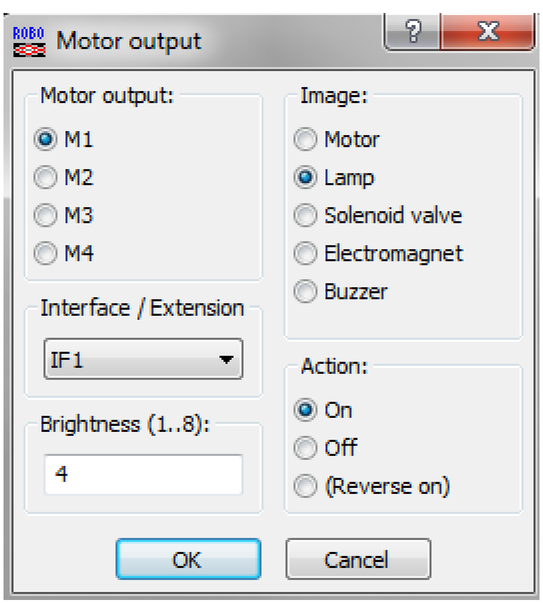
Begin by creating a new file in RoboPro. Set the environment to the TX controller and the Level to Beginners. Use the COM/USB to set the Interface type to the Robo TX Controller.

If you saved a copy of the program below open that. If not create the following program. Place a Start, Analog branch and Motor element on your program window.

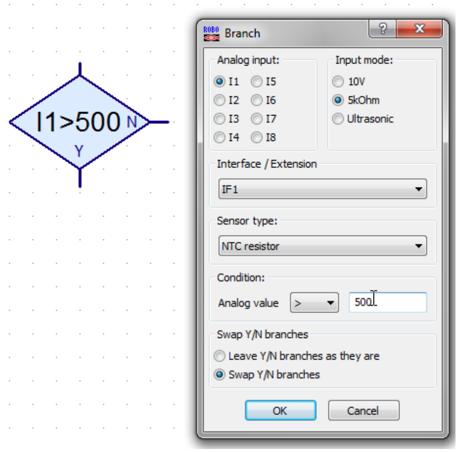


You will need four digital branch elements and 5 motor elements.

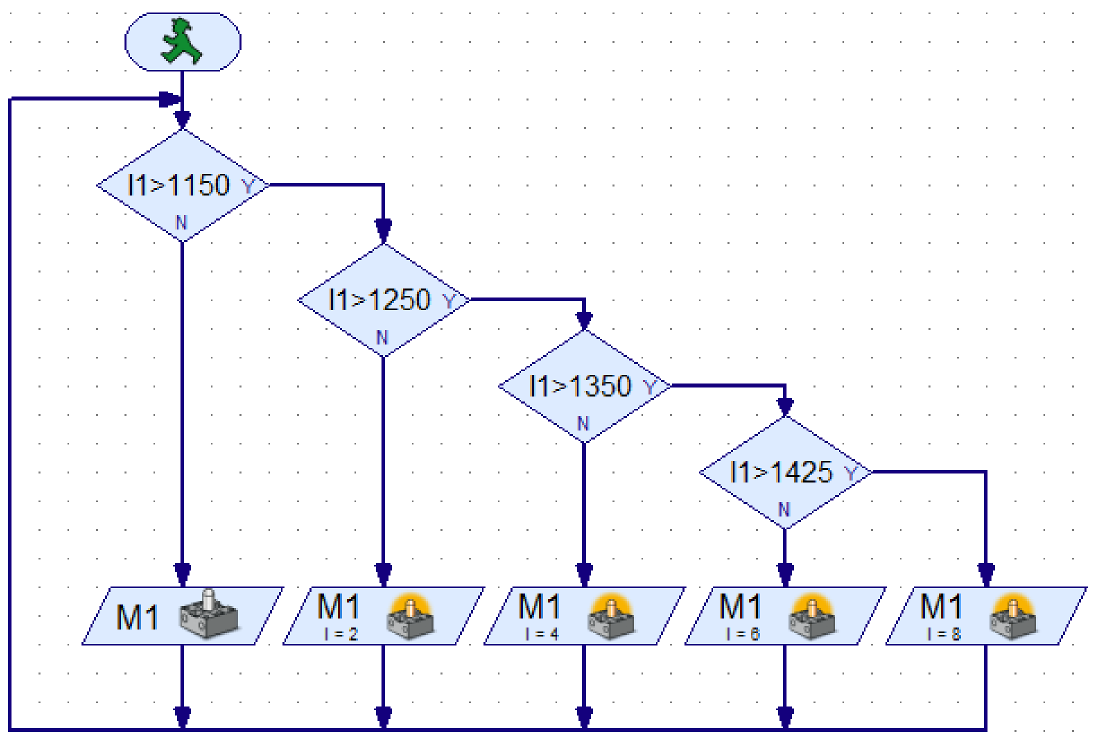
The motor element should be changed so that one is set to Off for an action and the others set to On. Of the four that are set to on set the Brightness to 2, 4, 6 and 8 respectively.



Adjust the four analog branch elements to values of 25 below the room temperature recording for the last one. Set it to 25 above the lowest value you recorded. Set the other two to midpoints between the two values. Swap the Y/N branches



Your program should be similar to the one below.



Obtain your instructors permission and then connect the controller to the computer. Turn on the power to the controller and run the program. Pinch the thermistor and hold it for 30 seconds.

Print a copy of the program for your engineering notebook. Write an observation about what the effect of warming the thermistor has. Describe the operation of the circuit.

End the program by using the stop icon from the main toolbar. Turn the controller off. Save the program for testing other sensors.

Analog Sensors: Potentiometer

Purpose:
Analog sensors produce a change in an electrical property to indicate a change in its host environment. Most things that we need to measure have a range of possibilities. Sensors are designed so they have a measurement section that is fairly linear but frequently the low and upper ranges of the device are not. It is important to select a sensor of the appropriate range to allow fairly good response to the property being measured. The price will vary on sensors depending on the precision and accuracy requirements of the measurement being performed. There are differences between two sensors made at the same time in the same factory. Because of this difference calibration of sensors is sometimes necessary if exact results are required. The fuel level in the gas tank of a car is important to know so a refueling trip can be scheduled before the automobile stops running. However you might not need to know how many milliliters are left in the tank. Analog sensors are divided into two basic categories; active and passive. Passive sensors react to the world around them and produce a change in a passive electrical quantity, such as resistance, capacitance, or inductance which can be measured. Active sensors actively probe the environment and will require energy from a power source to function.

Equipment:
TX Controller
Power Supply
Wires

Potentiometer
Lamp

Procedure:
The potentiometer is a variable resistor with three terminals. The two end terminals are fastened to opposite ends of a fixed resistor ring. The middle terminal is connected to a brass brush that can be moved so the resistance between the middle terminal and the end is variable.

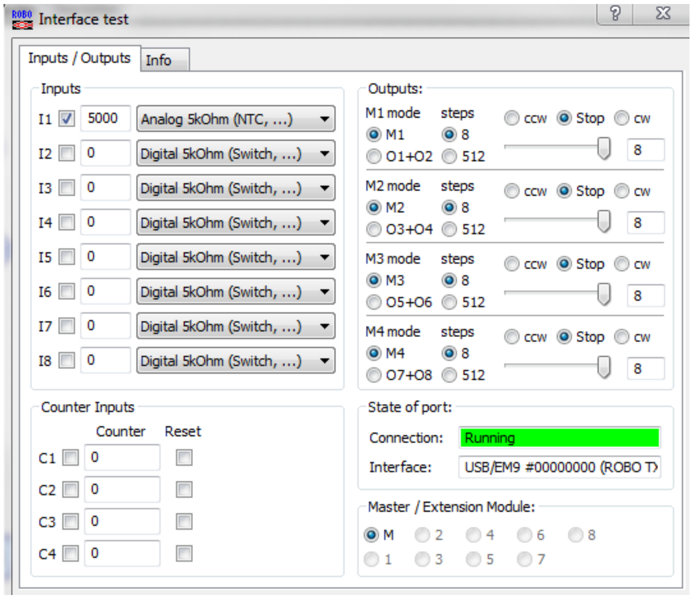
The schematic symbols for the potentiometer are below. Depending on where you live you will see it drawn differently.

Usually you only need a connection on one end and one on the middle terminal. Because of the mechanical connection these devices are noisy and prone to failure but are useful for some applications

.

Connect Pins 1 and 2 to the I1 connection on the TX Controller

Whenever you hook up a sensor to the TX Controller it is a good idea to open the Interface Test application in the RoboPro software to check to be sure the sensor is giving you the correct input for your selected type. Select the Test Interface icon on the main toolbar. When the application opens you will need to set the type to match your sensor before it will give you correct information. In this case you will be selecting Analog 5KOhm(NTC,…)



Once you click on your selection it will stay in the window. Rotate the shaft of the potentiometer connected to the TX Controller.

Conclusion:

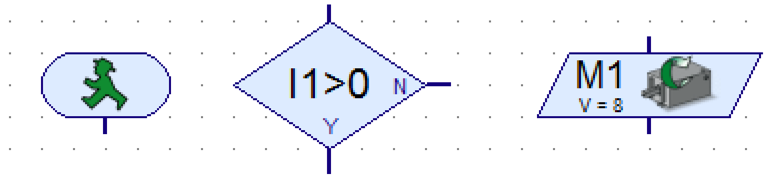
Include a sketch of your setup in your Engineering notebook. Explain what happens when you rotate the shaft.

Reverse the wires on the TX controller. Does reversing the wires have any effect on the operation of the sensor?

Record the changes in your engineering notebook.

Begin by creating a new file in RoboPro. Set the environment to the TX controller and the Level to Beginners. Use the COM/USB to set the Interface type to the Robo TX Controller.

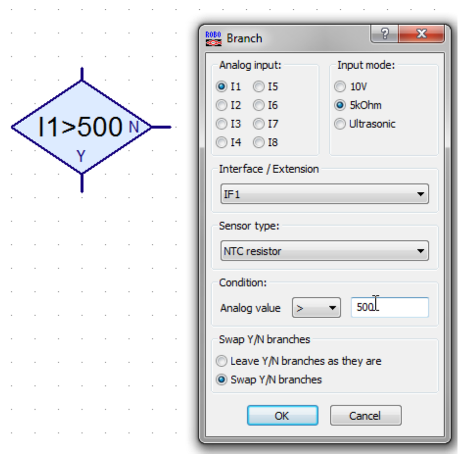
Place a Start, Analog branch and Motor element on your program window.



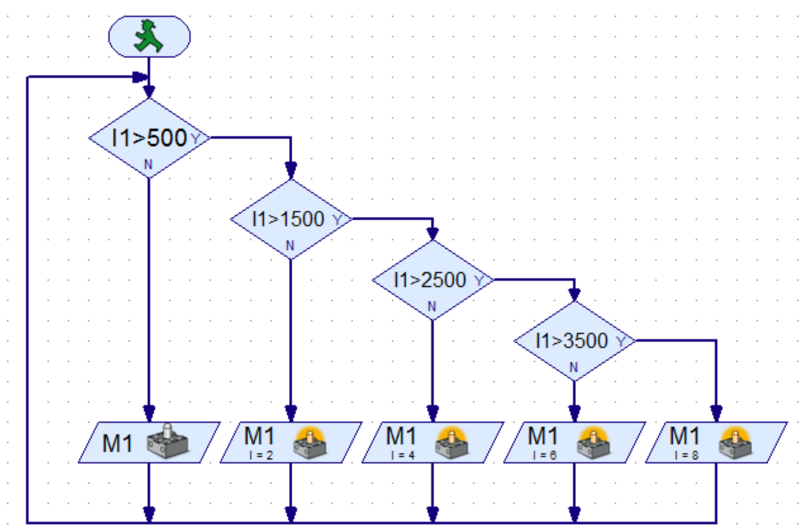
You will need four digital branch elements and 5 motor elements.

The motor element should be changed so that one is set to Off for an action and the others set to On. Of the four that are set to on set the Brightness to 2, 4, 6 and 8 respectively.

Adjust the four analog branch elements to values of 500, 1500, 2500, and 3500. Swap the Y/N branches



Your program should be similar to the one below.



Obtain your instructors permission and then connect the controller to the computer. Turn on the power to the controller and run the program.

Print a copy of the program for your engineering notebook. Write an observation about what the effect of turning the shaft of the potentiometer has. Describe the operation of the circuit.

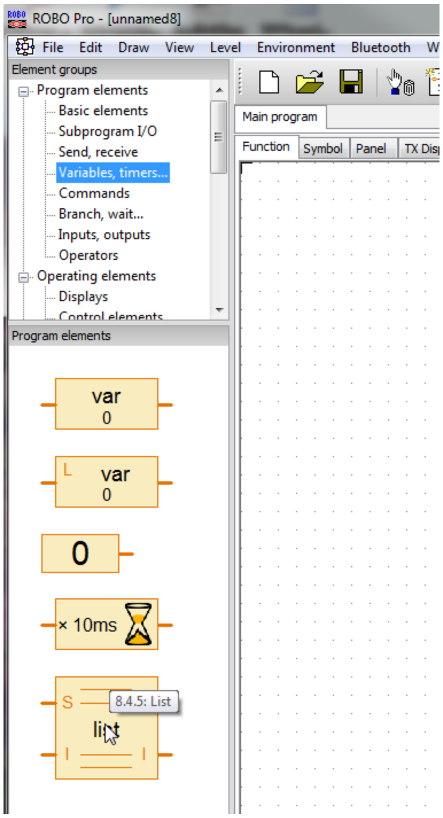
End the program by using the stop icon from the main toolbar. Turn the controller off. Save the program for testing other sensors.

Data

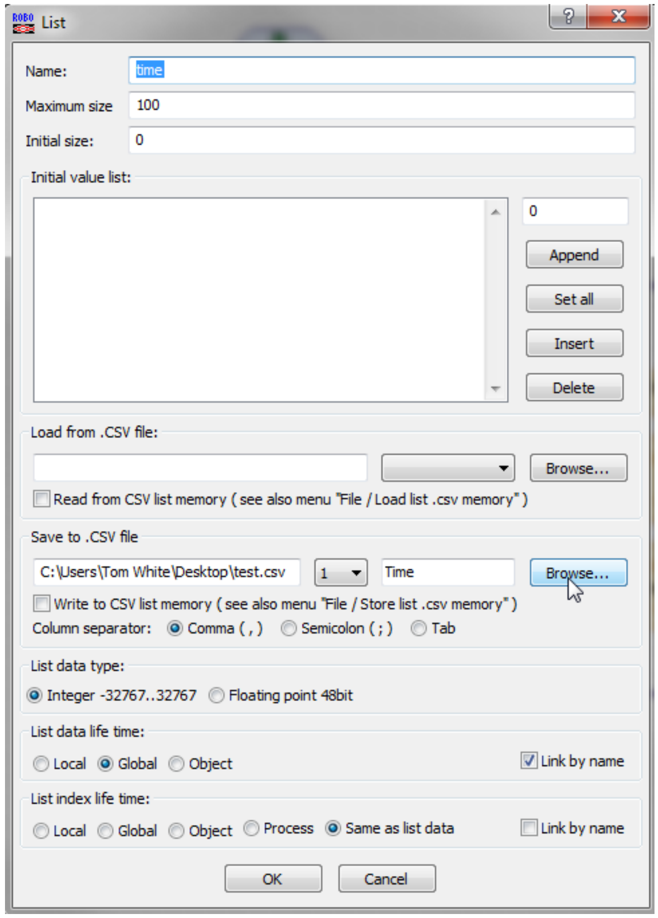
Purpose:
The ability to collect and process data is critical to advanced programming. You could automate a greenhouse to turn fans and heaters on and off during the course of a day, but without some reporting you would never know what had really happened while you were not there. Data is collected over a period of time that makes sense to the application. A temperature measurement in a greenhouse every 15 minutes might be enough. Your speedometer in the car might need to be updated more often. This activity is designed to introduce you to data collection and reporting. Evaluating the success of a design is frequently dependent on information collected and analyzed. Data are only as accurate as the collection process.

Equipment:
TX Controller
Power supply
Thermistor
Excel

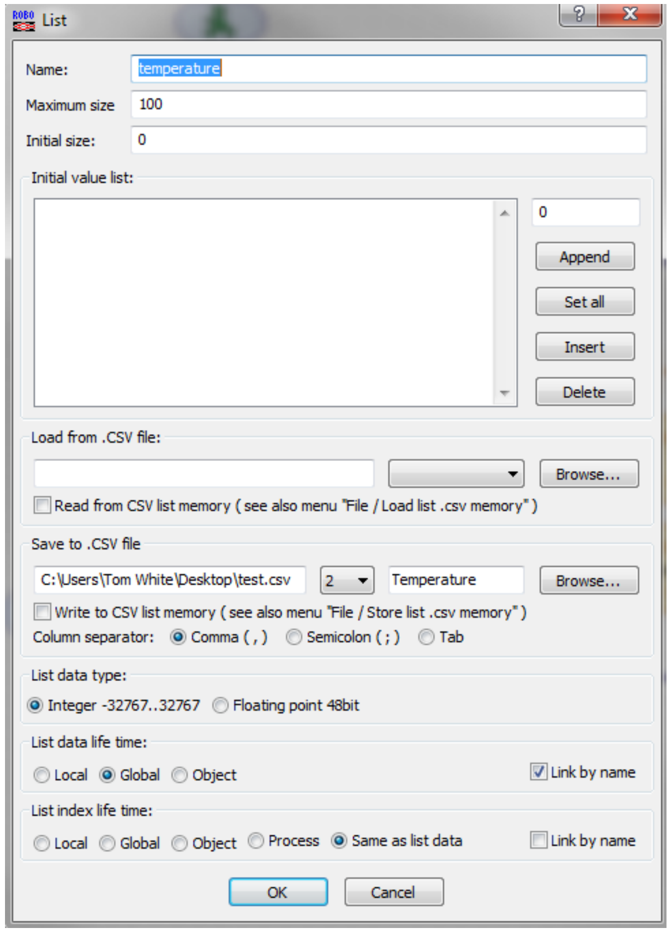
Procedure:
In this activity you will specify what information to collect and how it is to be reported. Begin a new RoboPro file. There are two new elements used to create the program. The first is the List. It is found in the Variables, timers section. Drag one out to the program window.



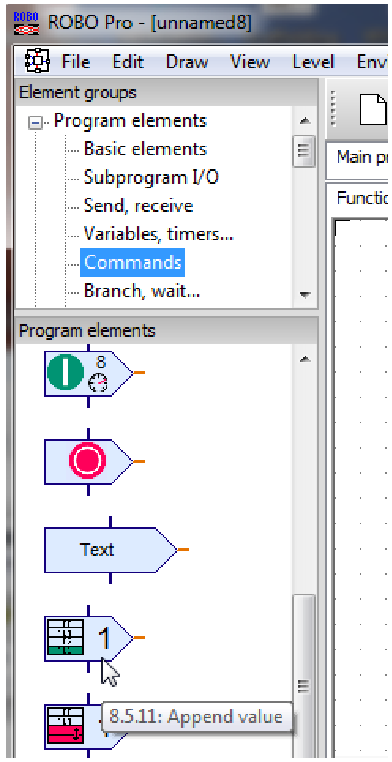
Right click on the list. This will bring up the list dialog box. Change the name to time. This will become the name of this element. About ½ way down the dialog box you will see the section to “Save to .CVS file” Click on the browse button on the right hand side. This will allow you to select a location to save this file. Some people have reported issues saving to a network location so select a location for the file on the local computer or thumb drive. Next to the file name there is a drop down menu with numbers. This represents the number of the column to be created. The number 1 is the left hand most column in the spread sheet. The window next to the number is the location for the column header. In this case we are calling it Time. This is the column we will track the time of the experiment.



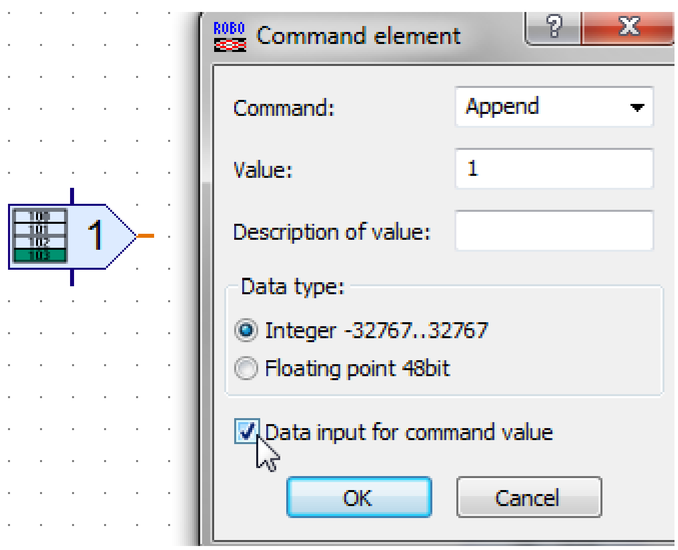
Select OK and drag a second List element to the screen. Right click on this one and name it temperature. Use the same file as “Time” so the results will all be on the same spreadsheet. This time the Column number will be 2 and we will name it Temperature.



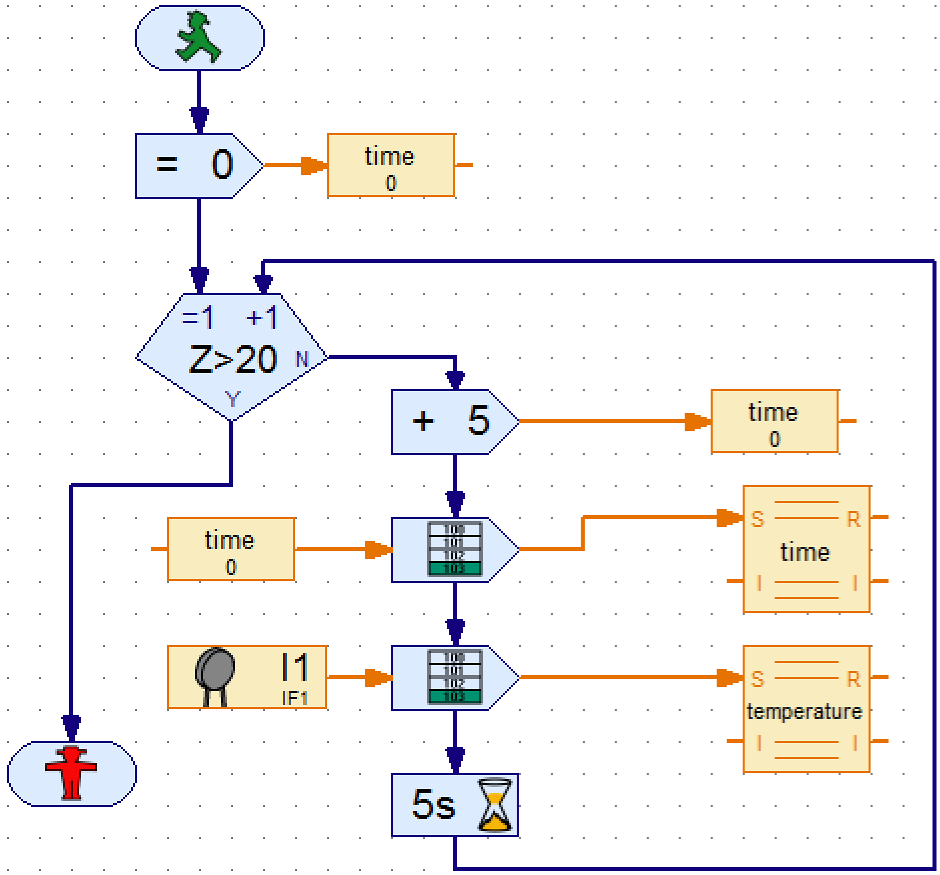
Select OK.
The other new element is called the Append value element. You will find this in the Commands section of the Program elements.



Drag two of them out to your program window. Right click on the Append value element and place a check in the “Data input for command value” check box. This will provide an extra data input on the left of the element.



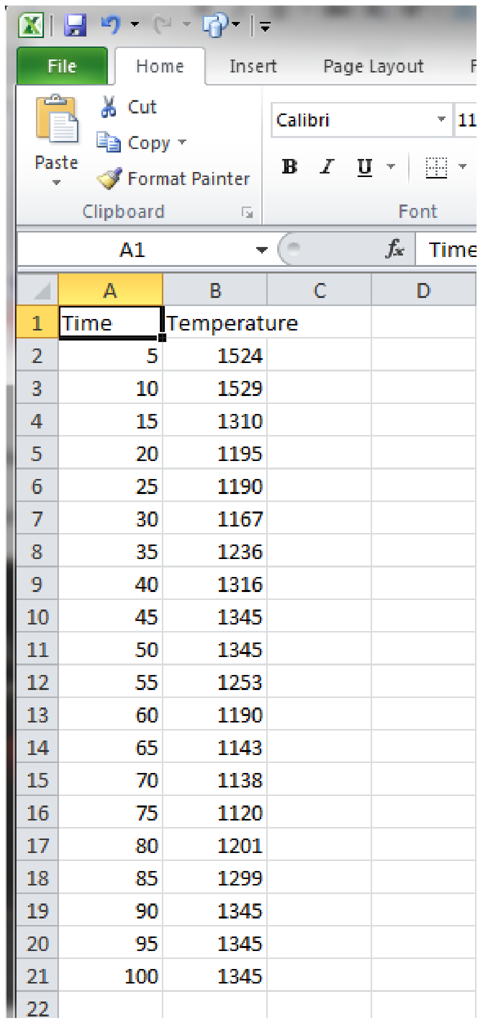
Create the program shown below. Use a variable named time to transfer all the data to the time collection.



Use the text tool to label the program to explain what is happening.

Connect the thermistor to the I1 input.

Turn the power on to the Controller. Run your program. Pinch the grey end of the thermistor between your fingers for at least 15 seconds. Let go of the thermistor and wait 20 seconds. Repeat.
When your program ends locate the file you created. You should see the data in the proper columns that you set up.

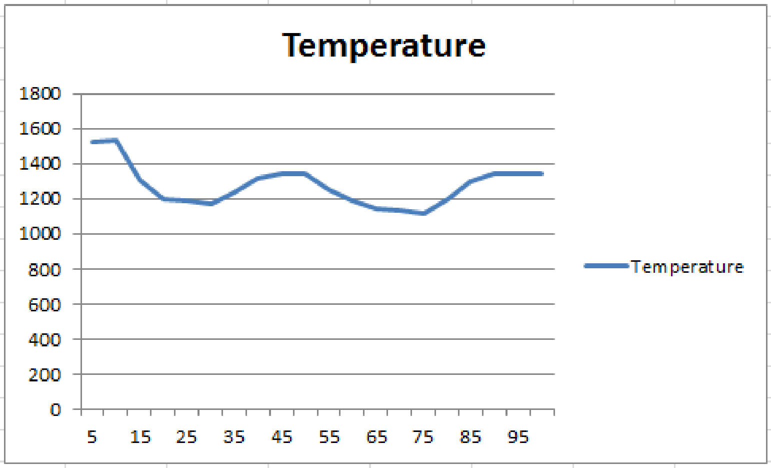


Time	Temperature
5	1524
10	1529
15	1310
20	1195
25	1190
30	1167
35	1236
40	1316
45	1345
50	1345
55	1253
60	1190
65	1143
70	1138
75	1120
80	1201
85	1299
90	1345
95	1345
100	1345

Take this data and graph it. If you have never created a graph in Excel you can find a good set of instructions at:
http://office.microsoft.com/en-us/excel-help/create-a-chart-from-start-to-finish-HP010342356.aspx?CTT=1
http://office.microsoft.com/en-us/excel-help/present-your-data-in-a-scatter-chart-or-a-line-chart-HA010227478.aspx?CTT=1

Since the thermistor is a NTC (negative temperature coefficient) the warmer the thermistor gets the less resistance it has. Looking at the graph below can you tell where we pinched the thermistor and where we let it go?

Time	Temperature
5	1524
10	1529
15	1310
20	1195
25	1190
30	1167
35	1236
40	1316
45	1345
50	1345
55	1253
60	1190
65	1143
70	1138
75	1120
80	1201
85	1299
90	1345
95	1345
100	1345



Print a copy of your program and your data with graph for your engineering notebook.

Conclusion:

Describe how you could use this method to create a true thermometer for values between room temperature and freezing.

Engineering Documents

This section contains documentation to help students manage their projects. This allows students to take control and embeds technical literacy into the projects.

Design Process

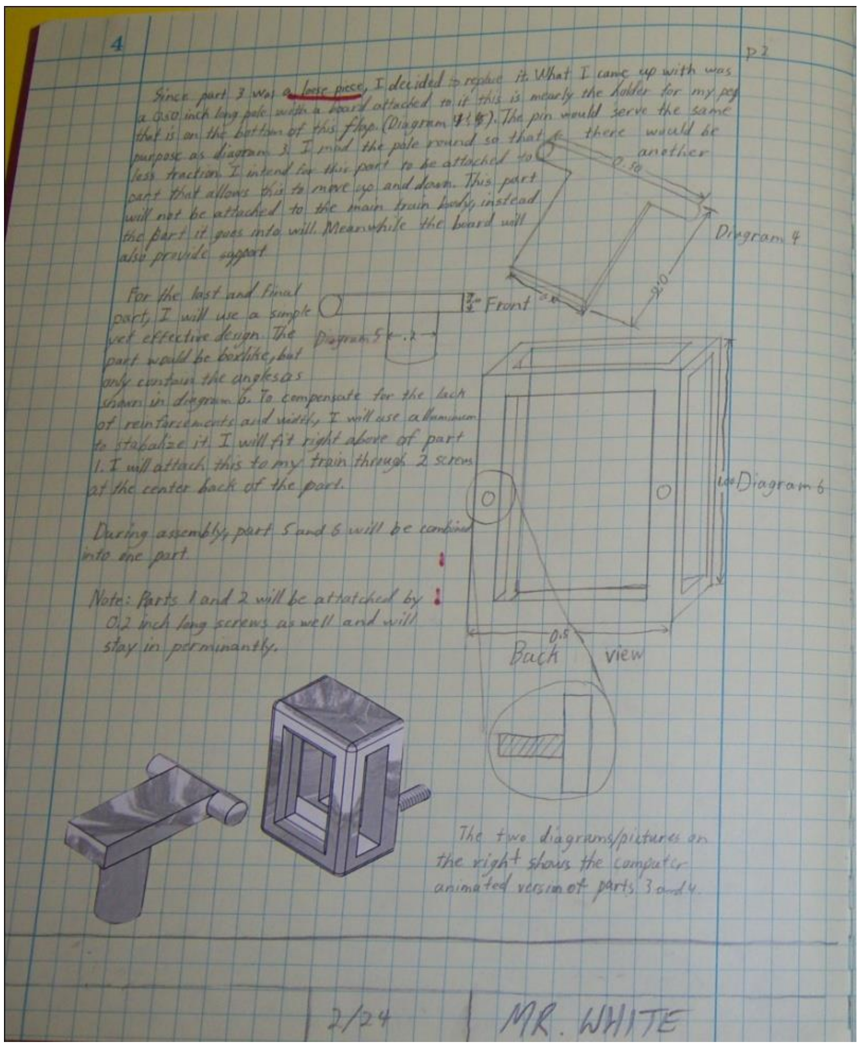
The engineering design process is a series of steps that engineers follow when solving problems. There are many variations of the design process in use and every situation or problem will have different elements that you should investigate. The steps listed below as well as the bullets included should inform the process but not dictate the process for every situation.

Design Process
Conduct Preliminary Research • Research Background Information and Identify Vocabulary. • Identify Criteria and Constraints for the Problem • Define Limits of the Problem to be Solved • Refine the Problem Statement in the Context of Criteria and Constraints • Define Areas of Research Needed to Solve the Problem • Independent Research • Enabling Activities • Lab Activities
Create the Project Management Plan • Overview • Scope • Schedule • Budget • Communication • Closure
Create a Design Brief • Objectives and Goals of the Design • Client and Context • Scope of the Project • Problem Statement or Description • Resources and Budget • Constraints • Time Needed

Brainstorm Possible Solutions • Generation of Ideas • Preliminary Sketches
Design Testing Methods and Protocol for Critical Assumptions • Introduction • Test Strategy • Data Collection Plan; Sampling Plan • Definition of a Successful Test, Pass / Fail Criteria • Test Conditions, Setup Instructions • Logistics and Documentation: • Analysis of Data • Conclusion
Create Optimization Matrix for Decision Making and Select Solution • Design Matrix • Identify Key Criteria • Assign Value to Each • Rate Possible Solutions
Develop, Refine and Document Selected Solution • Creation of Design Documentation • Identify New Issues
Create a Prototype • Turning the Plans into a Prototype
Test and Acquire Data • Design Testing to Evaluate the Prototype • Acquire Testing Data
Analyze Test Data • Creation of Graphs and Charts • Statistical Examination of Data
Refine and Iterate the Design • Apply the Changes Suggested by the Analysis of the Test Data
Finalize Documentation of Design • Application of the Results of the Test Data • Propose Design Changes • Retesting of the Prototype • Repeat

Prepare Communication Plan for Authentic Audience • Research Audience • Plan for Explanations and Graphics • Plan for Feedback
Prepare Communication Documents • Reports • Design Documentation • Design Proposals • Presentations for the Authentic Audience
Present/Defend to an Authentic Audience with Feedback

The Engineering Notebook



An Engineering Notebook is known by several names depending on the person and industry it is being used in. It is a bound book that contains the time-sequential written documentation of the development of the ideas of its author, along with all notes, data, observations, calculations, and other information relevant to the discovery or experiment being conducted. It provides an important record of the progress of an engineer, scientist’s or inventor's work. When properly maintained, it may be submitted as a legal document for patent purposes or legal records.

It is the equivalent of a technical diary and has multiple uses. It presents the authors thought process and work in an easy to access manner, allowing an author to confirm conclusions, details, or dates.

Engineering research and development organizations usually require their engineers to keep a running record of their activities. In the event that a project is shelved or the person leaves employment it can provide others working on a project the paths of inquiry that have been investigated, and can offer justification for decisions or courses of action taken.

Use a bound notebook with a stitched binding. Do not use a loose leaf or Spiral bound notebook.

All entries should be in ink not pencil.

The title, project number, and book number should be accurately recorded when starting a new Page.

All data is to be recorded directly into the notebook. Elaboration of details is preferable. Notes and calculations should be recorded in the notebook. In the case of an error, draw a single line through the incorrect data. Do not erase or use correction fluid. All corrections should be initialed and dated. When making a correction, make a notation of the page number where the correct information is found.

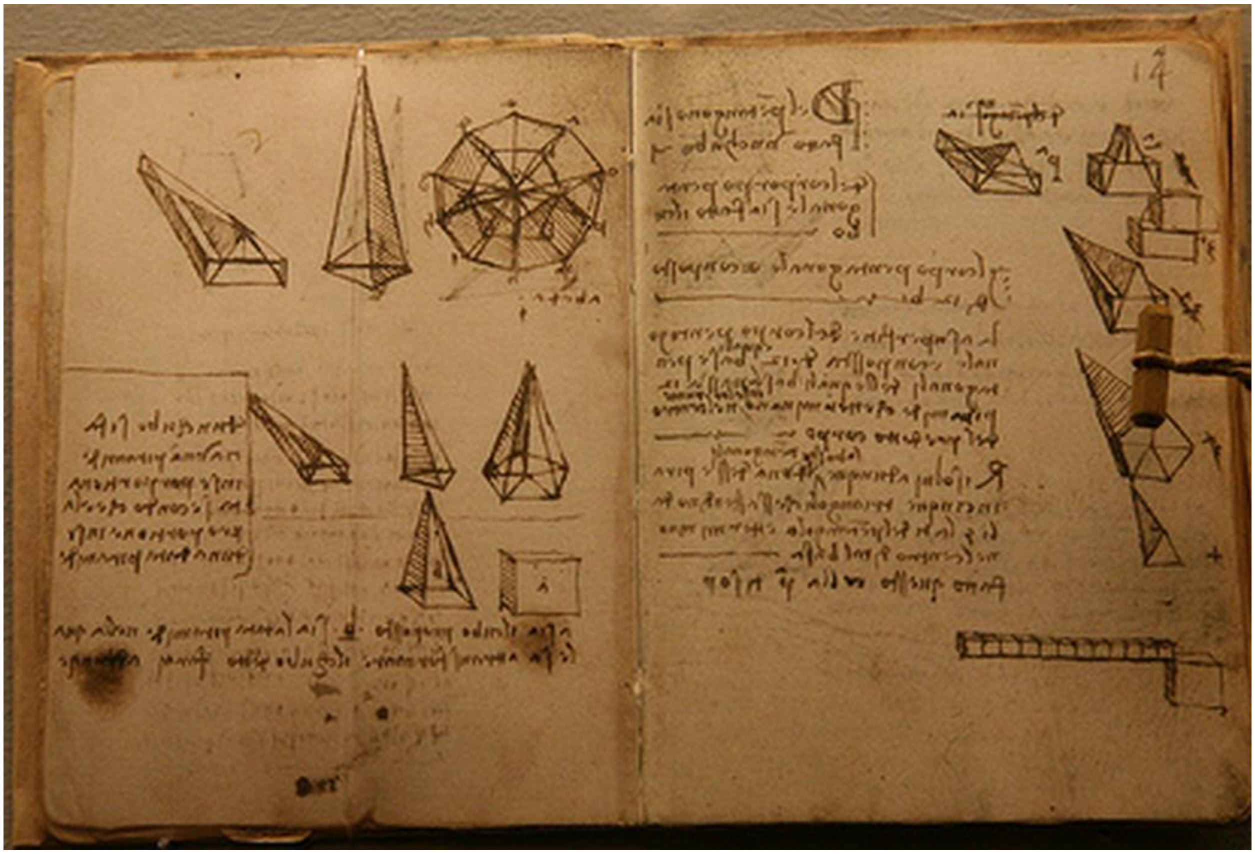
After entering your data, sign and date all entries. Witness or witnesses should sign and date each entry. The witness must observe the work that is done, and have sufficient knowledge to understand what they have read. Names of all who were present during any demonstration, phone conversation or discussion should also be recorded.

Never leave any White Space: "X" out or Crosshatch all unused space, and don't forget to initial and date the entry. Use both sides of the page.

When the notebook is full, begin a new notebook with the title, project number, and book number. Also make a notation of the preceding notebook number. Archive the full notebook in a safe location.

If necessary, items may be taped into the notebook with a handwritten date and title. Permanently attach inserted items (glue is preferred). Sign across the edge of the inserted sheet with half of the signature on the page.

Following this procedure can help students. It will foster improved documentation, research and sketching skills. It can help with time management skills and provide a convenient method for class closure. Early adoption by students of the use of the Engineering Notebook will help with project reports they will be expected to complete.



The pages above come from an Engineering Notebook kept by Leonardo da Vinci. It is a bound notebook containing sketches and explanations.

An example can be found at:
http://web.mit.edu/me-ugoffice/communication/labnotebooks.pdf

Design Documentation

- A design isn't "read" it is "used".
- The design process goes from least specific to most specific.
- Never write a paragraph when a sentence will do.
- Never write a sentence when a bullet point will do.
- Use Diagrams.
- A good table replaces long narratives.
- Never use adjectives. That is the function of sales people and project managers. (Examples: great, beautiful, wonderful, etc.)
- Use appendixes for supportive information that you think is relevant.

Design documentation is the collection of details about the final design requirements and specifications that illustrate and thoroughly describe a designed product. Writing effective design documentation (like design itself) is really all about making sure you serve the needs of your audience.

Items might include:

- 3D CAD Design
- Analysis
  - Finite Element Analysis (FEA)
  - Stress
  - Load Distribution
  - Fluid Flow
  - Heat Transfer
- Conceptual Designs
- Flowcharts
- Instructions
- Linkage Diagrams
- Reference Guides
- Sketches
- Specifications
- Tutorials
- Working Drawings
- Prototypes
  - Black Box Prototype: An existing enclosure or box with mechanical, electrical, optical and or software internals fully functioning.

- Concept Model: formally describing some aspects of the physical and social world around us for the purposes of understanding and communication
- Evolutionary Prototyping (also known as breadboard prototyping) a very robust prototype in a structured manner with the ability to constantly refine it.
- Feasibility Prototype: Determine feasibility of various solutions
- Functional Storyboarding: Determine useable sequences for presenting information
- Horizontal Prototype: Demonstrates outer layer of human interface only, such as windows, menus, and screens
- Mathematical Prototype: algorithm development for analysis operations
- Mock up: A rough construction using crude materials such as cardboard, foam, paper or wood typically done to show the idea in 3D form.
- Model: A form built and painted for aesthetic appearance only
- Presentation Prototype: representation of the product as it will be manufactured. Often used for promotional purposes.
- Proof of Concept: The use of existing materials, parts and components to prove the new Idea works or not.
- Rapid Prototype: A group of techniques used to quickly fabricate a scale model of a part or assembly using three dimensional CAD data. Frequently associated with 3D printing.
- Usability prototypes used to define, refine, and demonstrate user interface design usability, accessibility, look and feel.
- Vertical Prototype: Refine database design, test key components early
- Virtual Prototype: 3D Computer Aided Design (CAD) rendering
- Working Prototype: A fully functioning item yet may not be fully designed & engineered for manufacturability, nor it may not be appearance like.

Problem Statement

The problem statement is the statement that the students write from their preliminary research and is their definition, or redefinition, of the problem as they understand it. It is a clear and concise description of the issues that need to be addressed by the team.

The problem statement becomes part of the Design Brief and consists of several parts in a few sentences. It includes:

- The **Vision Statement**: This statement describes the goals, values or the desired results that solving the issue will have.
- The **Issue Statement**: This statement is a sentence or two that describes the problem or what is preventing the vision from being accomplished using specific issues. This would consist of the “Who, What, When, Where, and Why” of what is getting in the way of solving the issue.
- The **Method Statement**: This describes the approach the team will take to solve the problem.

Example:

Bicycles are an efficient and low pollution method of transportation in overcrowded urban areas that frequently move faster than motorized transportation. Secure storage, passenger safety and inclement weather all impact the desirability of adopting this mode of transportation. We are proposing to design an enclosed hybrid pedal powered vehicle that will allow use in all weather, provide greater passenger safety and have the same ability to be secured as a car while taking up a fraction of the space.

Design Brief

A design brief communicates a summary of how a team will approach a problem. This is a document that presents to the customer the exact problem your team will be solving for them and a projection of the resources needed. This is usually a one to two page document meant to quickly communicate the scope and goals of a specific design project. The document is focuses on the desired results of design. It is frequently done in conjunction with the client. This assures the client understands the proposed work and is agreeing to the process.

Design briefs should have most of the following sections.

- Client and context of the problem
- Problem statement or description (developed early in the design process)
- Criteria and constraints of the problem
- Objectives and goals of the design
- Scope of the project (what will be solved and what is not included)
- Resources needed to solve the problem
- Time needed to create a solution

Design Brief Example

Client and Context of the Problem
Reflective Gear, manufacturer of safety gear for cyclists is designing a new line of gear for people who cycle or run in periods of low light. Accidents are four times more probable at night.

Problem Statement:
Ideally the clothing should be lightweight, comfortable to wear, durable and washable. Existing clothing is either uncomfortable or not reflective enough for safety in dark environments. The company has contacted us to design new reflective designs, either passive such as reflective tape or active LED based systems.

Criteria and Constraints:
The design proposed needs to provide a reflected light with minimum loss so it is plainly visible at 100 feet. If we select an LED system it must be visible at 100 feet and have a minimum battery life of 50 hours. The design must survive repeated washings and not lose reflectivity. The total weight allowed is 6.5 ounces in addition to the base clothing.

Objectives and Goals:
We will experiment and report back on various ways to achieve the necessary visibility within the weight and comfort limits.

Scope of the Project:
We will test various methods of utilizing reflective strips. We will develop a method of attaching the reflective strips with the goal of less than 1% failure after 10 washings. We will experiment with various methods of using LEDs in clothing. We will not design the clothing, only using clothing provided by Reflective Gear. We will not test for clothing survival over a period of years.

Resources Needed:
Our team will need access to the latest clothes designs from Reflective Gear. We will need access to reflective materials and plastic strip sealer/heaters to experiment with easy methods used to incorporate the reflective material. LED strips and power sources will also be needed. We will need resources for three members of the team for a month along with necessary computer and measuring resources.

Time needed:
It is our estimate that testing and reporting can be done in one month's time from the date of the agreement. We will provide our report and examples of our visibility solution with the report.

TESTING PROTOCOL

Sections to be included

Introduction: what is the project about and what are the critical parts that need testing?

Test Strategy: How are you going to test the part or component and under what conditions?

Data Collection Plan; Sampling Plan: How are you going to collect the information? Will this be a random sample of a run? One time testing of a craft build prototype?

Measurement Capability, Equipment: What are we measuring and how accurate do we have to be? What kind of testing equipment will we need?

Definition of a Successful Test, Pass / Fail Criteria: This is a description of what constitutes success. For example, not breaking after 100 repetitions or being within measurement tolerances etc.

Test Conditions, Setup Instructions: How will you set up the test? If someone else has to duplicate your testing are there instructions they have to follow?

Logistics and Documentation: This is a description of what was tested and how.

Analysis of Data – Design Summary: What happened during testing?

Conclusion or Design Summary: what did the testing tell you?

Testing Protocol Example

Introduction:

This project involved the creation of a method to alert drivers to the presence of a person in the dark near the highway. The system to be tested must be visible from 100 feet away in dim light situations. To assure the design meets the criteria a testing method must demonstrate the ability of the product to communicate the bicycles presence to a driver more than 100 feet in advance.

Test Strategy:
Various designs will be tested for reflective light at 100 feet. All tests will require the equivalent of a car head light pointing at the reflective gear from 100 feet away. We will photograph results of each test of the reflective gear and/or LED display. The photographs will be compared and analyzed to determine the best selection or combination of strategies to incorporate. In addition to cameras we will also use light meters to measure lumens. Our last test will involve a survey of drivers who will provide feedback on the easiest system to see when driving down the road.

Data Collection Plan
Photos will be labeled and the data tagged upon the picture. The pictures will include data upon the brightness of the reflected light as well as the contrast. Surveys will ask four questions relating to the easiest design to see as well as the drivers comfort level when seeing the test reflected object. Surveys will be given to test subjects about the comfort of the item and ease of use.

Measurement Capability
We will need a standard digital camera and software to allow the pictures to be analyzed to show which combination of reflectors/LEDs are the brightest at 100 feet. Lumens will be measured utilizing a lux meter and the results added to the database of pictures and driver responses. A stationary headlight, 12V battery and a camera will be used to simulate cars at 100 feet. Real drivers will drive by the test subject and record their impressions. Visibility distance will need to be measured.

Definition of a Successful Test:
The selected solution will provide a combination of the greatest reflected light, driver responses and distance measurements. The solution will need to below the preset weight limit and be comfortable to test subjects. The solution must survive the laundry test and be comfortable to wear as judged by the survey of users.

Test Conditions:
The tests will be conducted at dawn, dusk and fully dark. Fog or mist would be beneficial to have when tests are conducted but not necessary.

The laundry test will be conducted after the first night light test. Items will be washed 10 times and then the tests with cameras, lights, and drivers will be repeated.

Two surveys will be given to people wearing the device. The first before the washing test and the second after it has been washed 10 times.

Logistics and Documentation:
Surveys for the test drivers will be combined with the measurement data for each proposed solution. Graphs of visibility will be created along with a chart with all solutions so they can be compared.

Analysis of data:
Pictures will be measured to determine which provide the greatest reflected light. The driver responses will be added to the data to account for "human factor" and perception. The optimum solution will provide the best combination of results. The picture analysis will count for 50% of the score, light detection at 100 feet will account for 25% of the final result and the driver reactions to what they observed while driving will count for other 25%.

Conclusion:
We hope that the combination of test results will provide us with the best possible solution to recommend. A major component of the engineering report will be based upon the results of the testing and anecdotal reporting on surveys.

Project Management Plan

A project management plan is a formal written document establishing the process and procedures to guide a project from inception to conclusion. The larger the project the greater the detail needed. It communicates to the team and their clients, information about the management of the necessary details and who will be responsible for each component. Every project will be different but the following sections give you an idea what to include.

- Customer: A description of the person or company that needs the project
- Project Team: Who is on the team and what roles do they play
- Project Summary: (includes purpose, goals, assumptions/guess, and constraints) What we know or need to know about the project.
- Scope: lists work to be included and excluded. For example "We will design a working rocket and all software needed to control the launch. We will not be responsible for the design of the rocket engine.
- Budget: A breakdown of costs to complete the job.
- Team Communication Plan: What type of communication will our team be responsible for?
- Time Schedule: This includes milestones to be met along the way and who will be responsible.

Project Management Plan Example

Customer:
Our client is the company Reflective Gear. They specialize in athletic clothing designed for people who work out in the dark, at dusk or dawn when accidents are more likely to occur. They would like us to design a way for their clothing line to show up better to keep their customers safer.

Project Team:
Our team consists of four people.

Wendy: Team Leader

Joe: Secretary and Editor
Linda: Time Keeper and Communications Director
Jose: Technical Lead and Researcher

Summary:
Our goal is to conduct research and experiments to determine which types of reflective devices should be incorporated to meet the customer needs. We believe that we must test several different combinations of materials and LED lighting. We will design testing to assure our final recommendation meets the needs of our client.

Scope:
Our goal is to research reflectivity and light generation to provide the most durable combination of elements with the greatest visibility to drivers. We will be testing reflective materials and various combinations of LEDs. We will make recommendations for how these materials will attach to existing clothing designs. We will not be creating new clothing designs or suggesting manufacturing options.

Budget:
Our team will need four weeks to complete our testing and report generation. We will need testing equipment such as cameras as well as computer equipment for recording the process. In addition to salaries and benefits our standard overhead of 40% applies to provide electricity, data connection, heat, phone service and printing costs.

Communication Plan:
At the conclusion of our work we will provide an overview of the work, samples of our selection and a printed copy of our report including data gathered for your use.

Time Schedule:

<table>
<tr><th>Week 1</th><th>Week 2</th><th>Week 3</th><th colspan="2">Week 4</th></tr>
<tr><td>Team Formation</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Basic research</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Budget</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Management plan</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Research into reflective materials</td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Preliminary Testing</td><td></td><td></td></tr>
<tr><td></td><td>Survey Designs</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Testing Protocol</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Prototype creation</td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Testing of prototype</td><td></td></tr>
<tr><td></td><td></td><td>Testing setup</td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Evaluate and Improve</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Report generation</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Presentation preparation</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Presentation</td></tr>
<tr><td></td><td></td><td></td><td></td><td>End of project life</td></tr>
</table>

Engineering Report

Good report organization should promote readability and reflect the scientific method of attack, which proceeds with objective, method, results, and conclusions. It is logical to report a project in the sequence in which it is done, and many engineering reports are organized on this basis. Two improvements to the logical sequence are the addition of an abstract or executive summary and the insertion of headlines. These two features facilitate "scanning" of the report. Thus, a busy executive or engineer may quickly assess the major findings and conclusions of the report, and then easily find further details as required.

Sections that should be included:

- Title Page. Identify the group members, project, dates and timeframe.
- Summary or Abstract (Executive Summary)
- Nomenclature. Students need to list and define all science and engineering terms and measurements used in the report.
- Introduction. This should include the entire project description.
- Theory and Analysis
- Experimental Procedures
- Results and Discussion
- Conclusions and Recommendations
- Acknowledgments
- Literature Cited
- Appendix

Assessment Rubrics

Assessment comes in both formative and summative. It is an integral part of quality instruction. During the course of the projects one of the teacher's main functions is to work with student groups, keeping track of progress and providing formative assessment in the form of feedback and promoting reflection on the part of students. The focus should be on lifetime and 21st century skills. The goal of instruction is to promote abilities in research, problem solving, design, experimenting, testing and collecting data.

Rubrics are used in the assessment process to communicate expectations of quality of a task. Rubrics should be shared with students at the beginning of a project so they can clarify any misconceptions before beginning work. They can then build the skills and gather knowledge to solve the problem presented to the expectations of excellence described.

General Rubrics for Literacy tasks

Individual Project Rubrics

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Literacy Rubric for Argumentative or Persuasive Project				
	Not Yet	**Getting There**	**Meets Expectations**	**Exceeds Expectations**
	1	**2**	**3**	**4**
Focus	An attempt to answer the problem, but the response lacks focus.	Answers the problem and states a position but the focus is varying or weak.	Fully answers the problem keeping a clear focus. Argument is generally convincing.	Fully answers the problem keeping a very clear focus and strong, convincing argument.
Main Idea	Attempts to create a main idea but lacks focus and clarity. No mention of argument other than their own.	Creates an argument and makes note of claims of other than their own.	Creates a convincing argument; develops and presents argument and counter argument fairly.	Creates a convincing and meaningful argument; develops and presents argument and counter arguments fairly and fully.
Reading & Research	Tries to present information but does not connect it to the problem.	Presents information from research that addresses the problem with only small errors.	Presents accurate and relevant information from research that helps develop their argument	Effectively presents accurate and relevant information from research that develops a strong argument.
Development	Tries to give details but they are poorly written or do not apply to the problem. They make no claim, or make an irrelevant claim	Gives details to support their main idea with only minor weaknesses in reasoning. Makes a weak claim.	Gives details that fully support the main idea and answer the problem. Gives an example that helps clarify the claim.	Gives thorough details that fully support the main idea and strongly answer the problem. Makes strong connections to their argument that clarifies and helps the reader understand the claim.

Organization	Tries to organize ideas but lacks structure.	Organizes ideas to fulfill requirements, with some gaps in structure.	Organizes response to meet all requirements of the problem. Organization reveals the reasoning behind the claim.	Organizes response in a way that enhances the information given in response to the problem. Organization reveals the reasoning behind the argument and creates more support for it.
Conventions of English	Writes response with many errors in grammar, usage and writing mechanics. Sources of research are not cited.	Is inconsistent with grammar, usage, and mechanics; uses tone and language inappropriate to audience or topic. Only some sources are cited.	Work has very few errors in grammar, usage, and mechanics; tone and language are appropriate to the project and audience. Few errors in citation formatting.	Demonstrates a full command of the conventions of English; tone and language enhance the response. Consistently and correctly cites sources.
Understanding of Content	Tries to show understanding of content but knowledge is weak or incorrect.	Connects basic knowledge of content to problem, shows minor errors in understanding.	Presents full factual understanding of content as it applies to the project.	Presents in-depth understanding of content that applies to, and enhances, the response to the project.

Informational Explanatory Rubric				
	Not Yet	**Getting There**	**Meets Expectations**	**Exceeds Expectations**
	1	**2**	**3**	**4**
Focus	An attempt to answer the problem, but response lacks focus.	Answers the problem but the focus is varied or distracted.	Fully answers the problem keeping a clear focus.	Fully answers the problem keeping a very well developed and clear focus.
Main Idea	Attempts to create a main idea but lacks focus and clarity.	Creates a basic main idea with general purpose.	Creates a main idea with a clear purpose that is carried though the piece.	Creates a strong main idea with a clear purpose that guides the response throughout the piece.
Reading & Research	Tries to present information but does not connect it to the problem. Does not evaluate the integrity of sources.	Presents information from research that addresses the problem with only small errors Starts to evaluate the integrity of sources.	Presents detailed information from research that helps answer the problem. Evaluates the integrity of sources.	Selectively presents detailed information that helps answer all parts of the problem. Evaluates the integrity of sources and identifies credible sources.
Development	Tries to give details but they are poorly written or do not apply to the problem. Does not address implication of project, or it is irrelevant. Does not address unanswered questions.	Gives details to support the main idea and answer the problem. Mentions implications of project or an unanswered question.	Gives details that fully support the main idea and answer the problem. Explains the implications of project and an unanswered question.	Gives thorough details that fully support the main idea and strongly answer the problem. Entirely explains the implications of project and one or more unanswered questions.

Organization	Tries to organize ideas but lacks structure.	Organizes ideas to fulfill requirements, with some gaps in structure.	Organizes response to meet all requirements of the problem.	Organizes response in a way that enhances the information given in response to the problem.
Conventions of English	Writes response with many errors in grammar, usage and writing mechanics. Sources of research are not cited.	Is inconsistent with grammar, usage, and mechanics; uses tone and language inappropriate to audience or topic. Only some sources are cited.	Work has very few errors in grammar, usage, and mechanics; tone and language are appropriate to the project and audience. Few errors in citation formatting.	Demonstrates a full command of the conventions of English; tone and language enhance the response. Consistently and correctly cites sources.
Understanding of Content	Tries to show understanding of content but knowledge is weak or incorrect.	Connects basic knowledge of content to problem, shows minor errors in understanding.	Presents full factual understanding of content as it applies to the project.	Presents in-depth understanding of content that applies to, and enhances, the response to the project.

Comments: **Total---->**

Sketching and Documentation Rubric

Criteria	Novice-1	Apprentice-2	Proficient-3	Expert-4	
Engineering Notebook	No evidence of notes, sketches or research	Shows some evidence of notes, sketches and research	Evidence of most notes, sketches and research	Clear notes and sketches with all research documented and signed	
Cooperative Group Work	One student did all or most of the work in the group	Most team members did some work but workload varied	All team members did some work but workload varied	Workload is divided and shared equally by all group members	
Project Design	The sketches are incomplete or poorly drawn. They are hard to read	The sketches are complete , but design is poor and will not link to other blocks	The project is complete, well constructed and will link to other blocks	The project is complete, well planned, always works and is easily adaptable to the set.	
Presentation	Some difficulty communicating ideas. 1 member presents to class	Good communication. 1 member presents to class	Group communicates well and all members present to class.	Entire group communicates with enthusiasm. All members contribute and know their responsibilities	
Completeness of requirements	Less than 60% of the requirements are met	Between 60 and 80% of the requirements are met	Between 81 and 99% of the requirements are met	Total inclusion of all tasks. 100% of requirements are met	
				Total---->	

Comments:

Simple Machines Rubric

Criteria	Novice-1	Apprentice-2	Proficient-3	Expert-4	
Engineering Notebook	No evidence of notes, sketches or research	Shows some evidence of notes, sketches and research	Evidence of most notes, sketches and research	Clear notes and sketches with all research documented and signed	
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Comments:

Mechanical Systems Rubric

Criteria	Novice-1	Apprentice-2	Proficient-3	Expert-4	
Engineering Notebook	No evidence of notes, sketches or research	Shows some evidence of notes, sketches and research	Evidence of most notes, sketches and research	Clear notes and sketches with all research documented and signed	
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				Total---->	

Comments:

Conversion of Energy Rubric

Criteria	Novice-1	Apprentice-2	Proficient-3	Expert-4	
Engineering Notebook	No evidence of notes, sketches or research	Shows some evidence of notes, sketches and research	Evidence of most notes, sketches and research	Clear notes and sketches with all research documented and signed	
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				Total---->	

Comments:

Basic Electricity Rubric

Criteria	Novice-1	Apprentice-2	Proficient-3	Expert-4	
Engineering Notebook	No evidence of notes, sketches or research	Shows some evidence of notes, sketches and research	Evidence of most notes, sketches and research	Clear notes and sketches with all research documented and signed	
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Completeness of requirements	Less than 60% of the requirements are met	Between 60 and 80% of the requirements are met	Between 81 and 99% of the requirements are met	Total inclusion of all tasks. 100% of requirements are met	
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Comments:

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Garage Door Rubric

Criteria	Novice-1	Apprentice-2	Proficient-3	Expert-4	
Engineering Notebook	No evidence of notes, sketches or research	Shows some evidence of notes, sketches and research	Evidence of most notes, sketches and research	Clear notes and sketches with all research documented and signed	
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Comments:

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Automatic Feeder Rubric

Criteria	Novice-1	Apprentice-2	Proficient-3	Expert-4	
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Comments:

Automated Clamping Rubric

Criteria	Novice-1	Apprentice-2	Proficient-3	Expert-4	
Engineering Notebook	No evidence of notes, sketches or research	Shows some evidence of notes, sketches and research	Evidence of most notes, sketches and research	Clear notes and sketches with all research documented and signed	
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				Total---->	

Comments:

Conveyor with Counter Rubric

Criteria	Novice-1	Apprentice-2	Proficient-3	Expert-4	
Engineering Notebook	No evidence of notes, sketches or research	Shows some evidence of notes, sketches and research	Evidence of most notes, sketches and research	Clear notes and sketches with all research documented and signed	
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Comments:

Studica

Elevator Control Rubric

Criteria	Novice-1	Apprentice-2	Proficient-3	Expert-4	
Engineering Notebook	No evidence of notes, sketches or research	Shows some evidence of notes, sketches and research	Evidence of most notes, sketches and research	Clear notes and sketches with all research documented and signed	
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Comments:

Robot Control Rubric

Criteria	Novice-1	Apprentice-2	Proficient-3	Expert-4	
Engineering Notebook	No evidence of notes, sketches or research	Shows some evidence of notes, sketches and research	Evidence of most notes, sketches and research	Clear notes and sketches with all research documented and signed	
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Comments:

Studica

Sun Tracking Solar Cell Rubric

Criteria	Novice-1	Apprentice-2	Proficient-3	Expert-4	
Engineering Notebook	No evidence of notes, sketches or research	Shows some evidence of notes, sketches and research	Evidence of most notes, sketches and research	Clear notes and sketches with all research documented and signed	
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Comments:

Color Sorting Rubric

Criteria	Novice-1	Apprentice-2	Proficient-3	Expert-4	
Engineering Notebook	No evidence of notes, sketches or research	Shows some evidence of notes, sketches and research	Evidence of most notes, sketches and research	Clear notes and sketches with all research documented and signed	
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				Total---->	

Comments:

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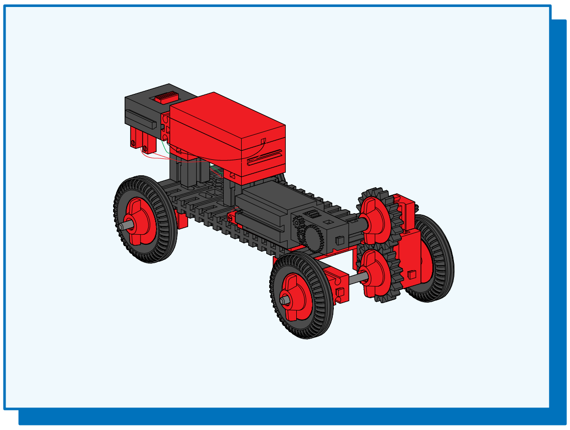
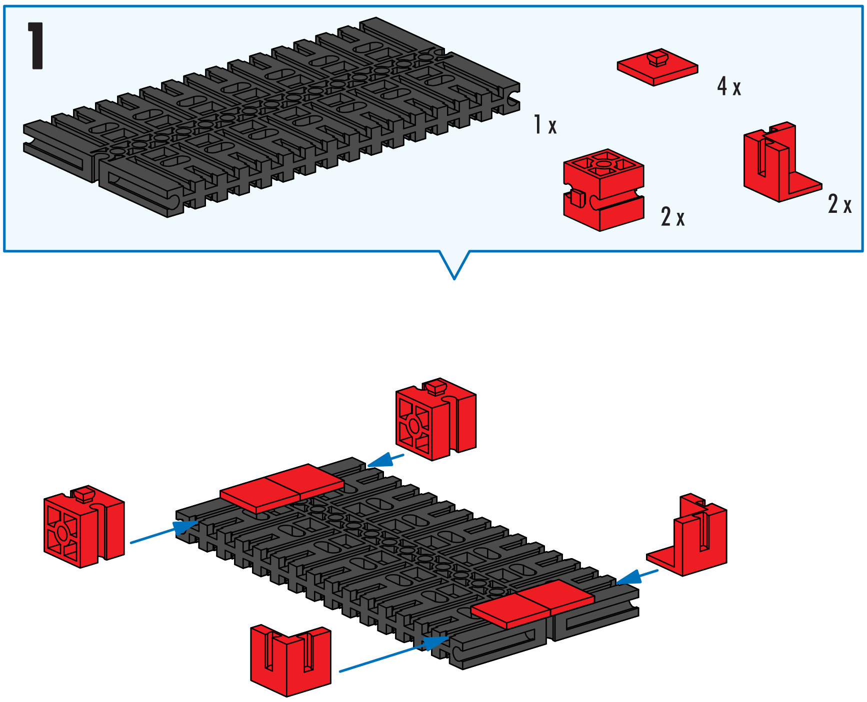
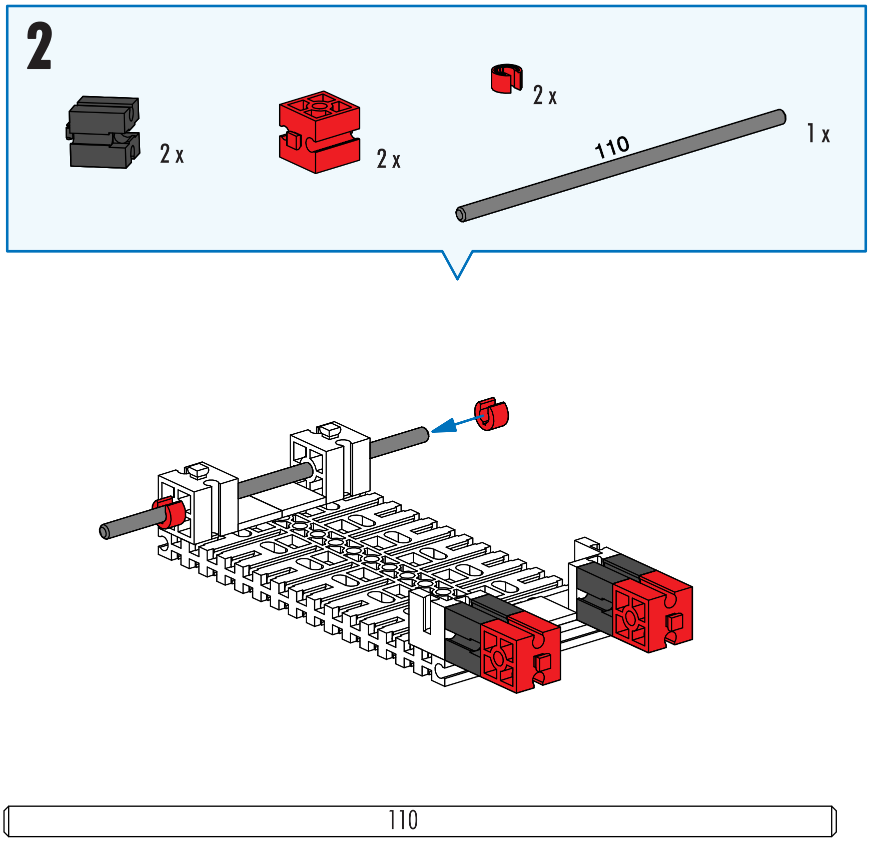
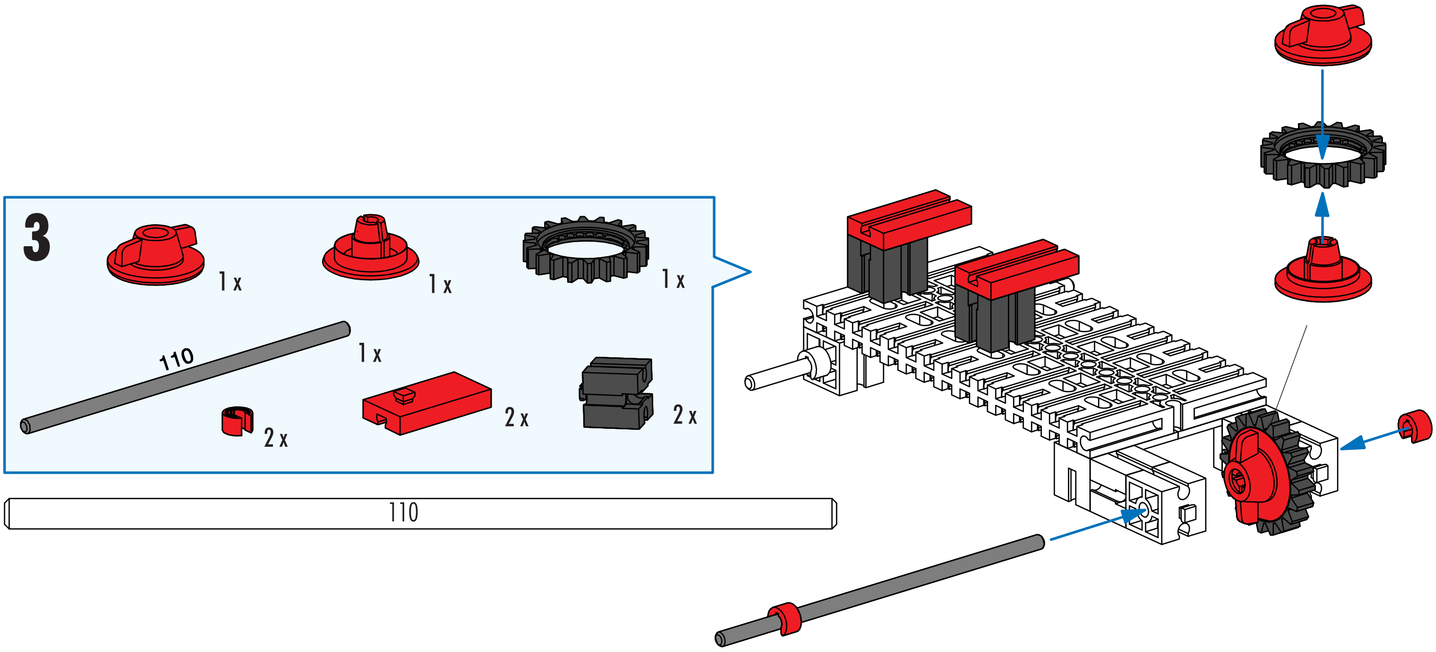


Fahrzeug 1
Vehicle 1
Véhicule 1
Voertuig 1
Vehículo 1
Veículo 1
Veicolo 1
Автомобиль 1
1号汽车



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2 x
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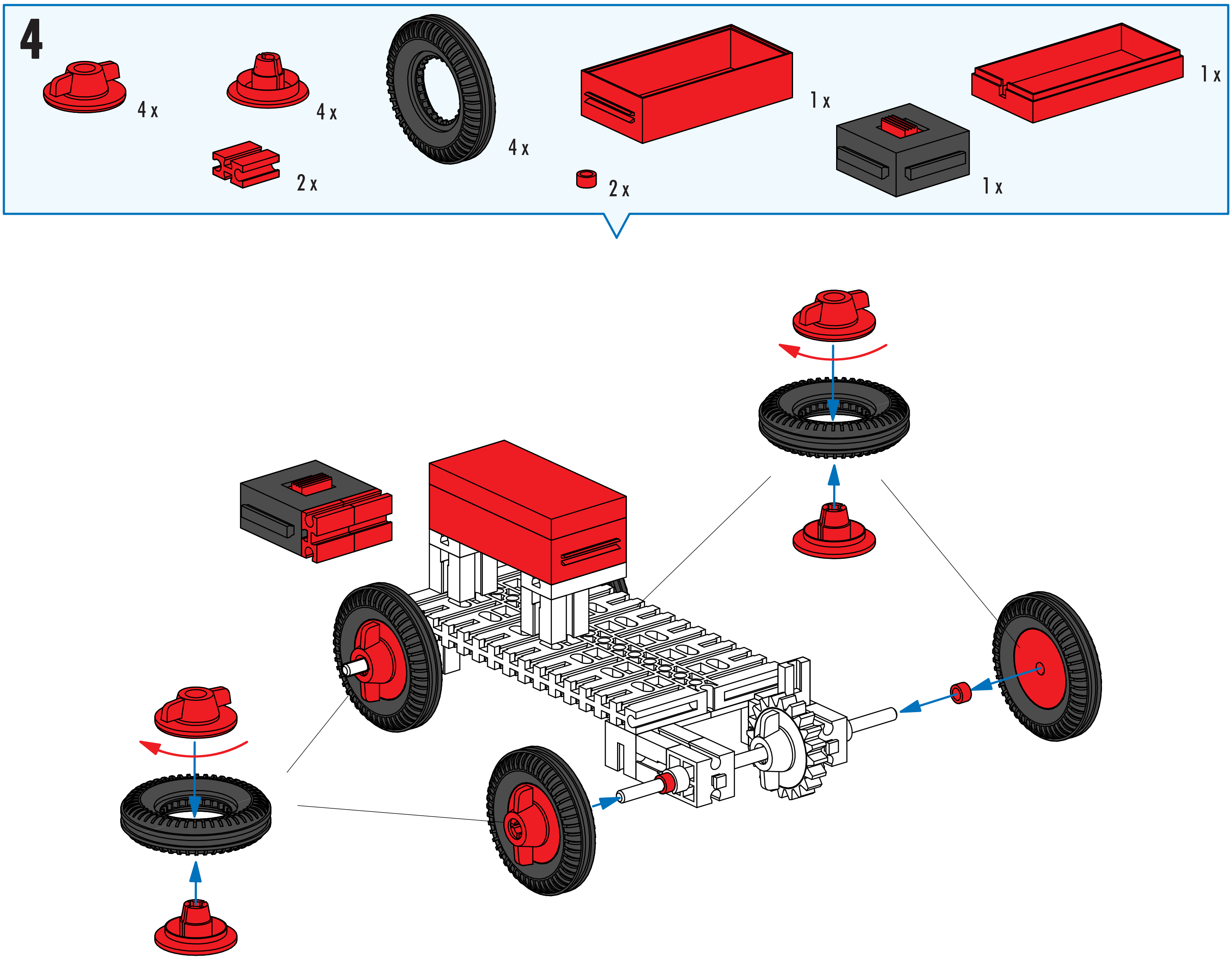
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2 x
2 x
1 x

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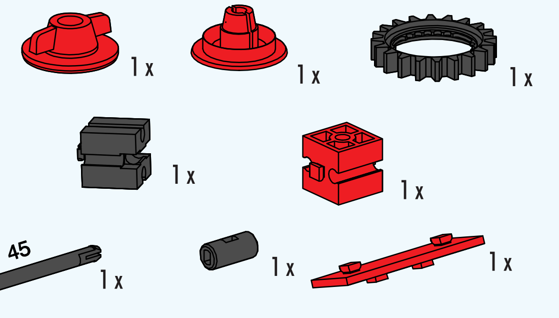

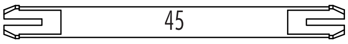

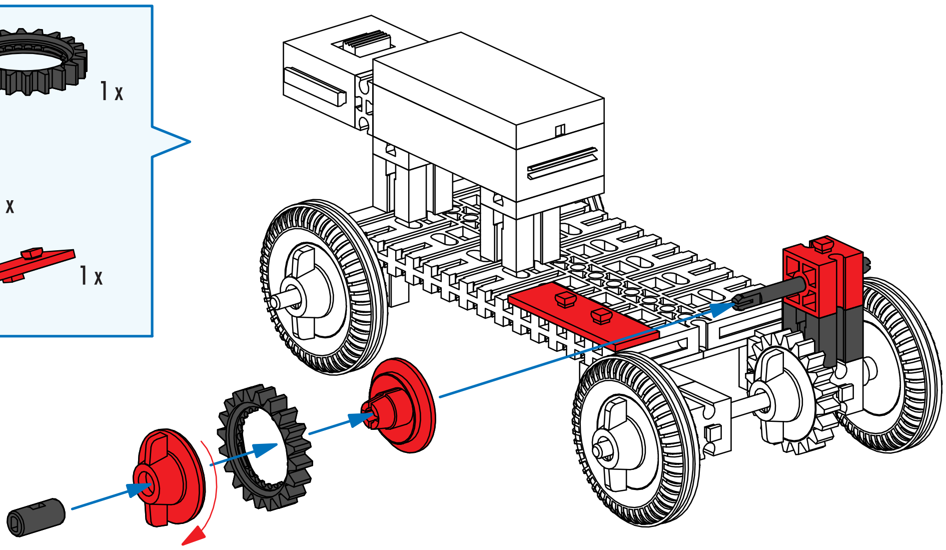

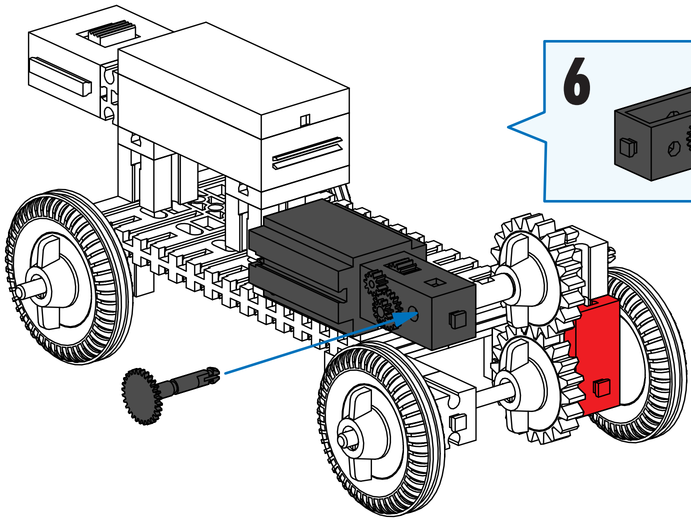

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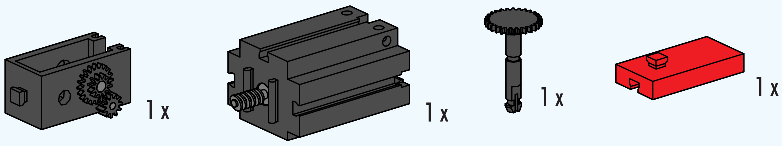
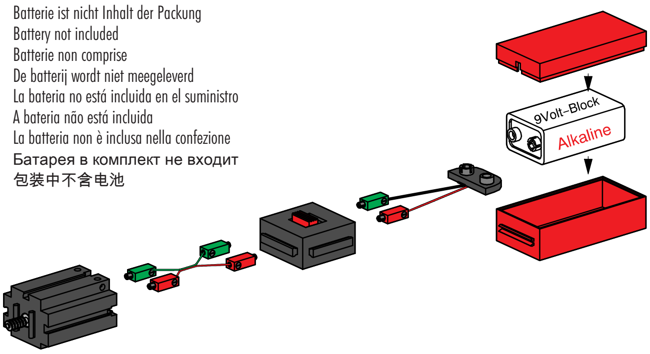
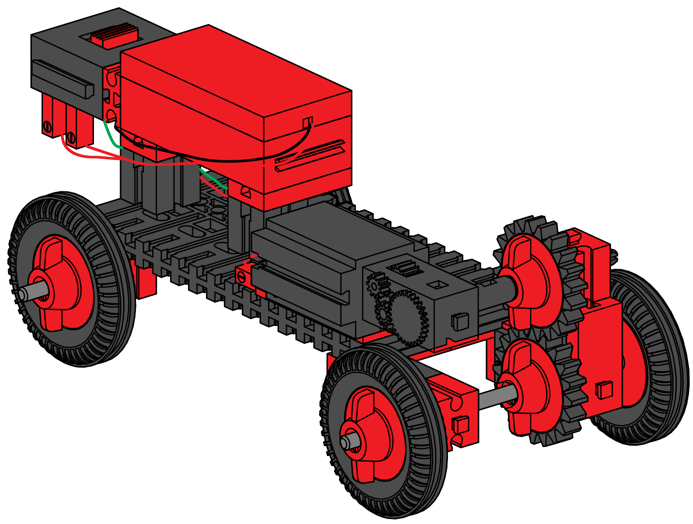
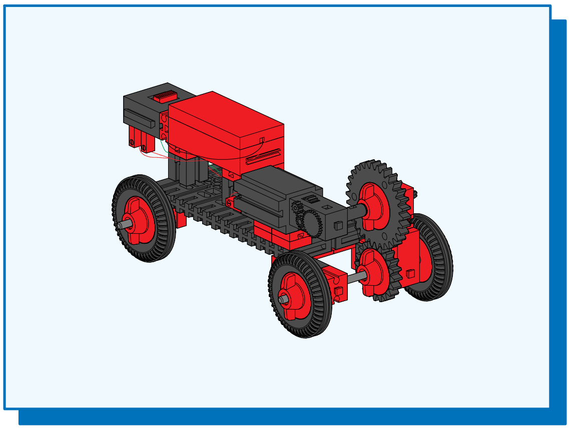


Batterie ist nicht Inhalt der Packung
Battery not included
Batterie non comprise
De batterij wordt niet meegeleverd
La bateria no está incluida en el suministro
A bateria não está incluida
La batteria non è inclusa nella confezione
Батарея в комплект не входит
包装中不含电池







Fahrzeug 2
Vehicle 2
Véhicule 2
Voertuig 2
Vehículo 2
Veículo 2
Veicolo 2
Автомобиль 2
2号汽车

1-4

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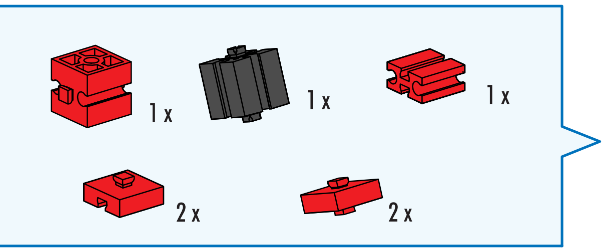
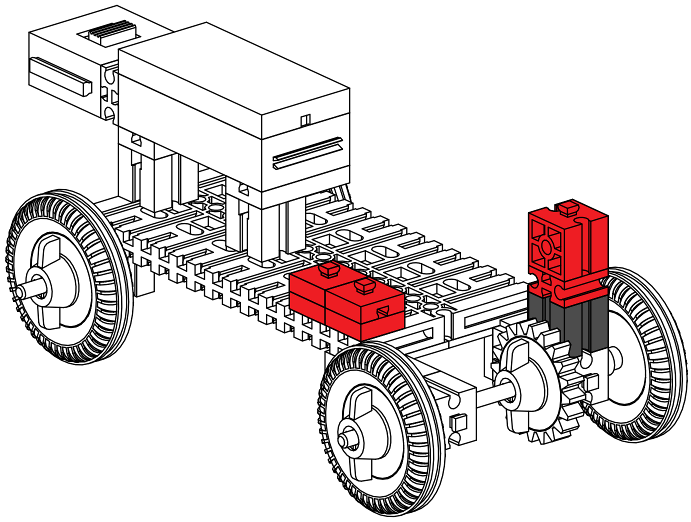
5





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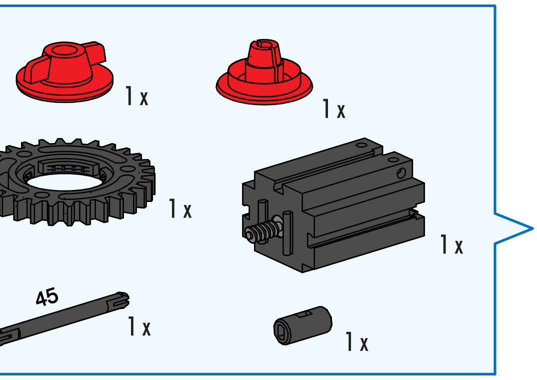

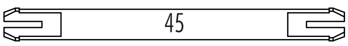

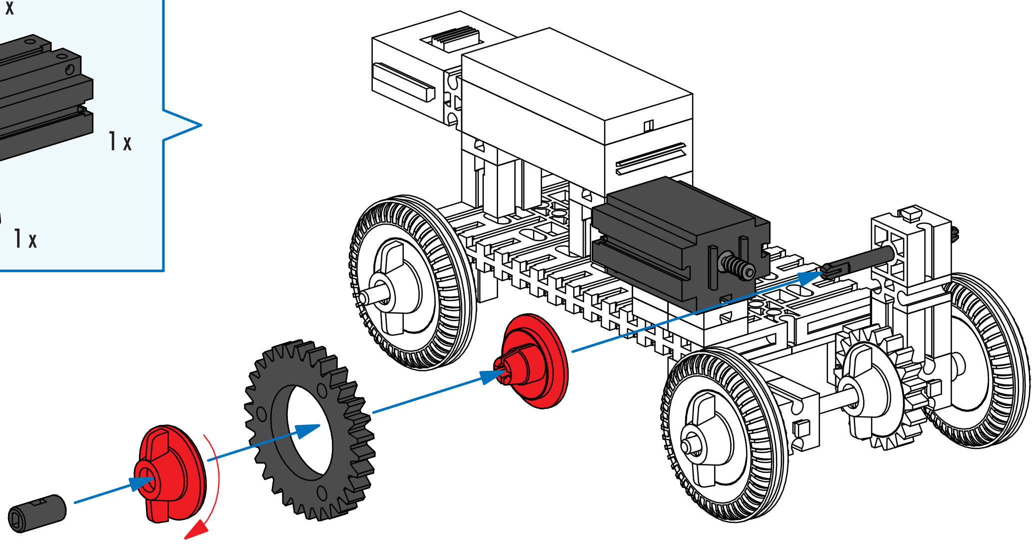

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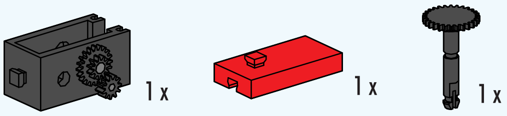

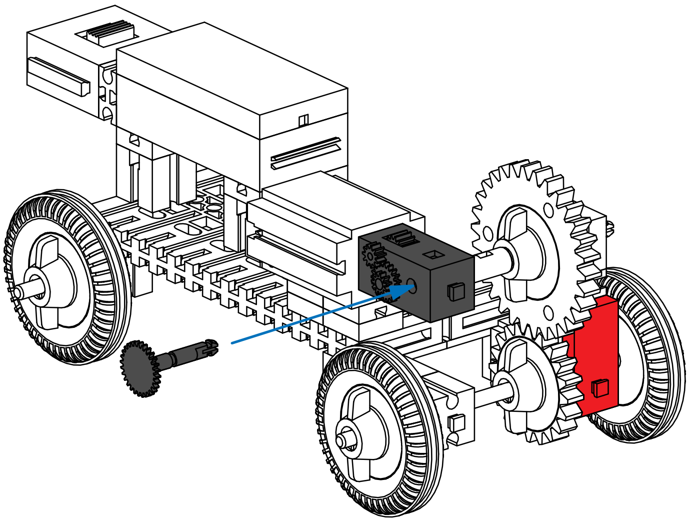

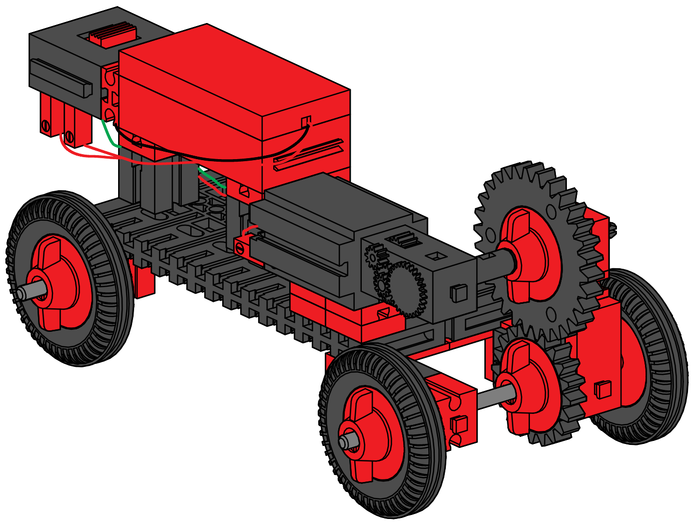

Batterie ist nicht Inhalt der Packung
Battery not included
Batterie non comprise
De batterij wordt niet meegeleverd
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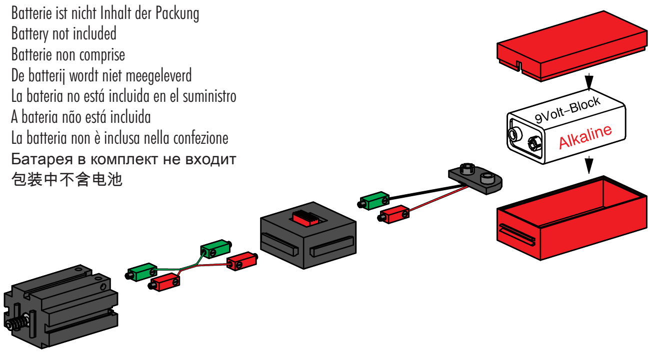

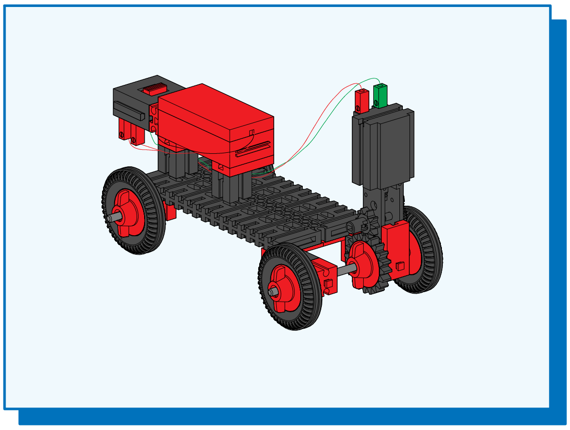

Fahrzeug 3
Vehicle 3
Véhicule 3
Voertuig 3
Vehículo 3
Veículo 3
Veicolo 3
Автомобиль 3
3号汽车

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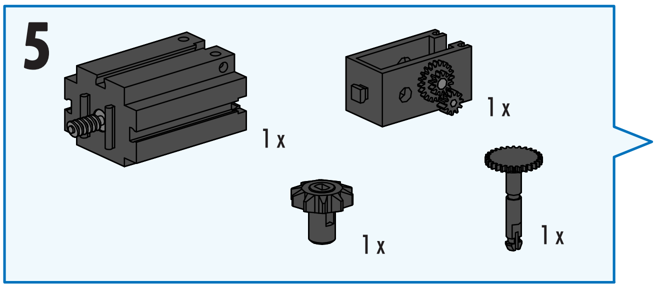

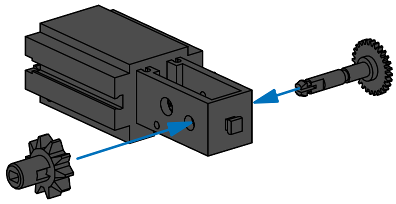

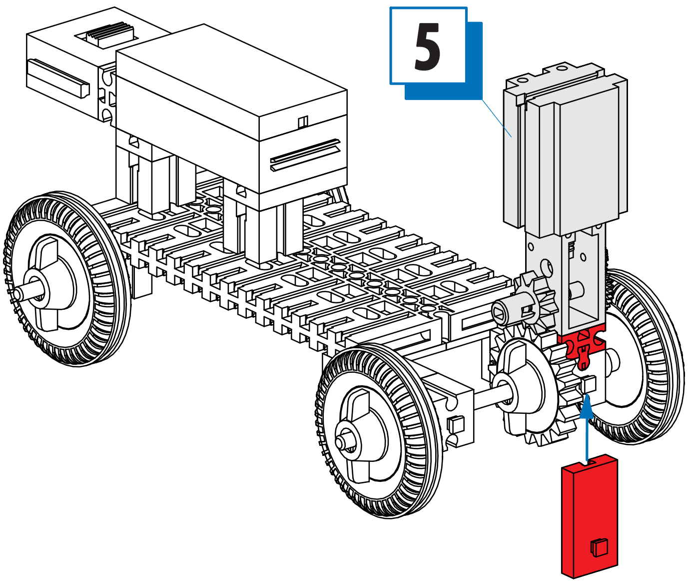

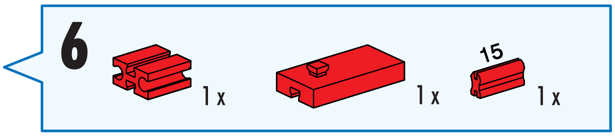

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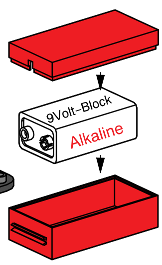
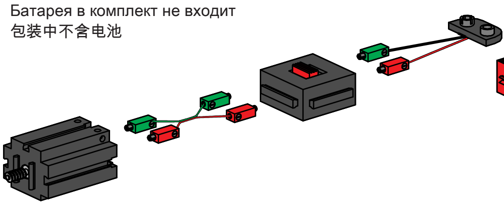
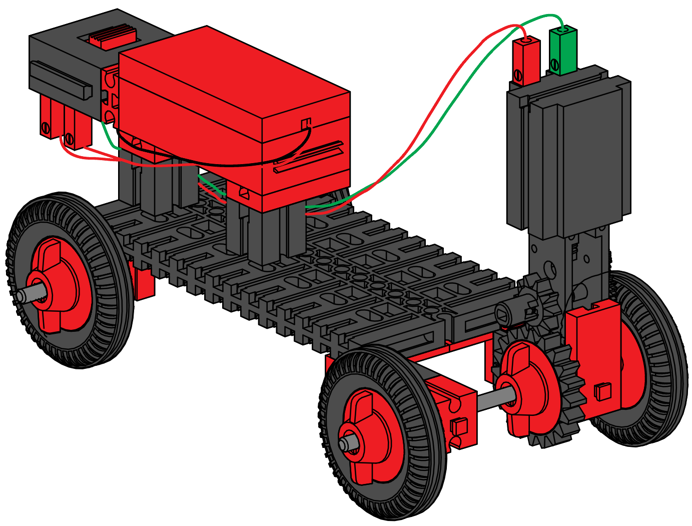
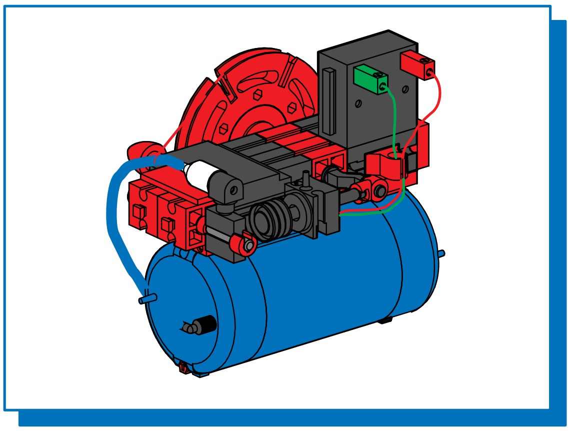


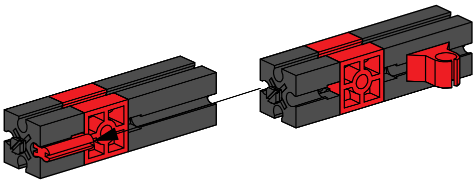


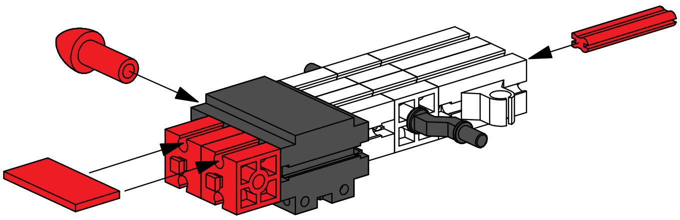




Kompressor / Compressor / Compresseur / Compressor / Compresor / Compressor / Compressore / Компрессор / 压缩机

1





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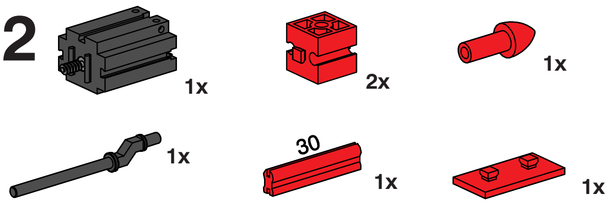

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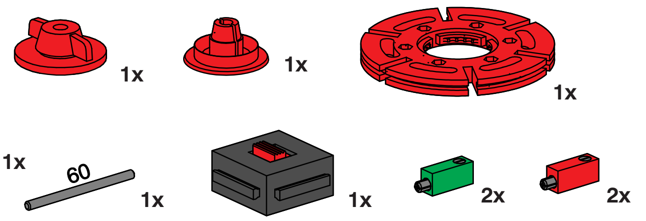
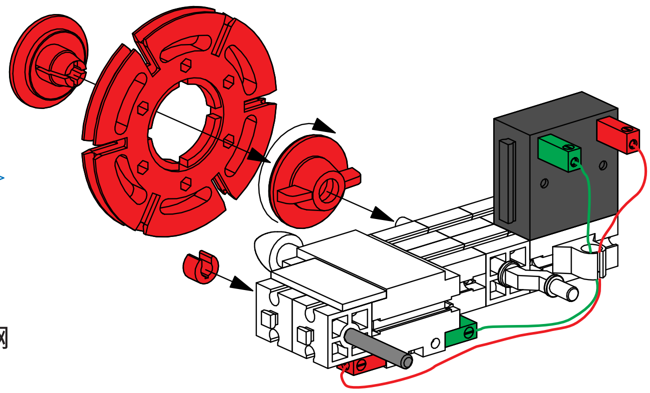
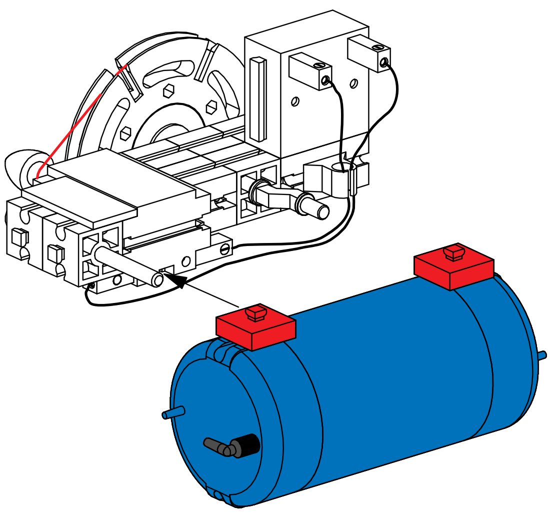


Stahl / Steel / Сталь / 钢





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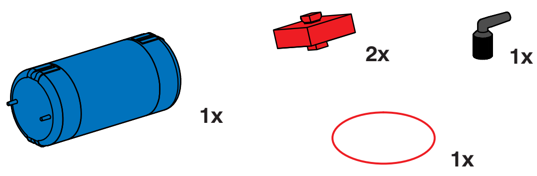
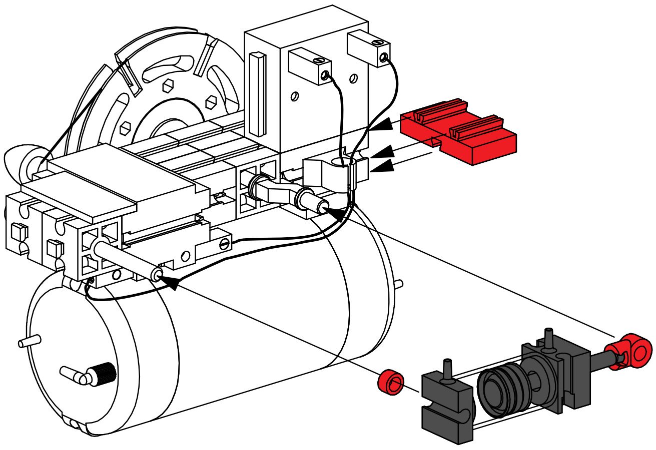
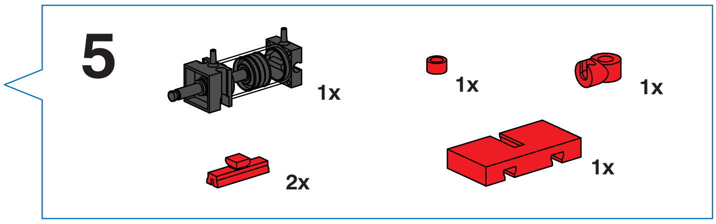
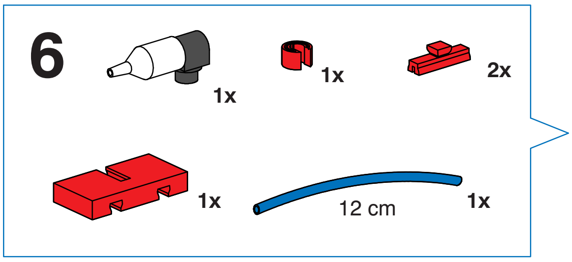
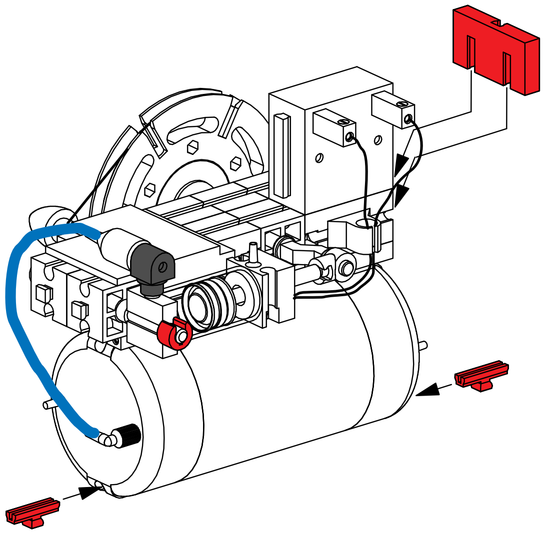
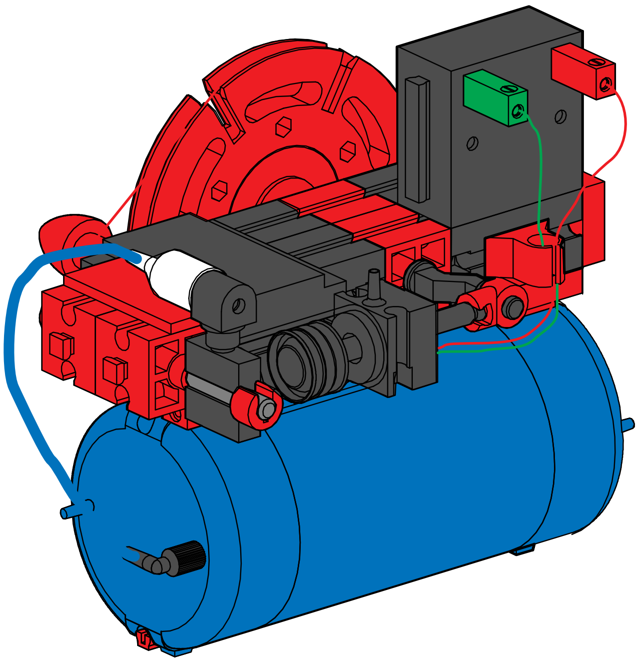




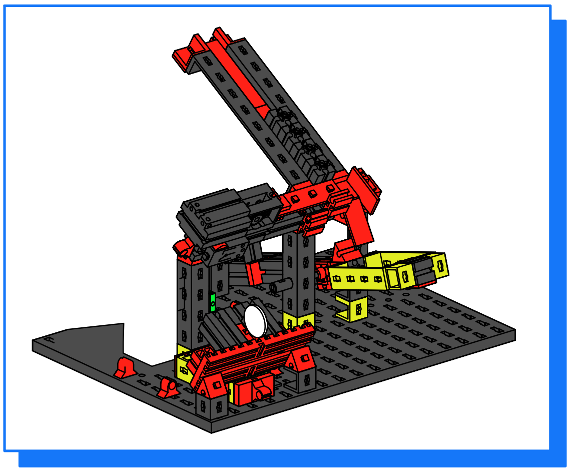

5
1x
1x
1x
2x
1x

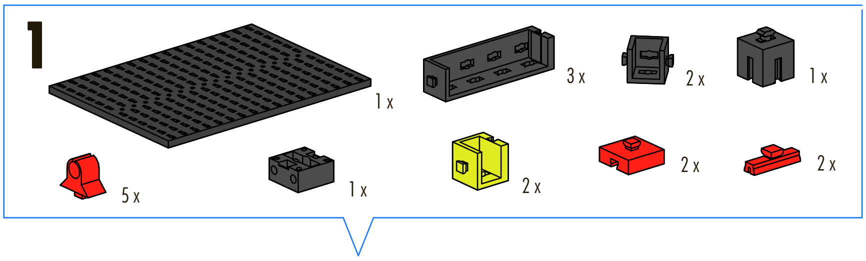

6
1x
1x
2x
1x
12 cm
1x

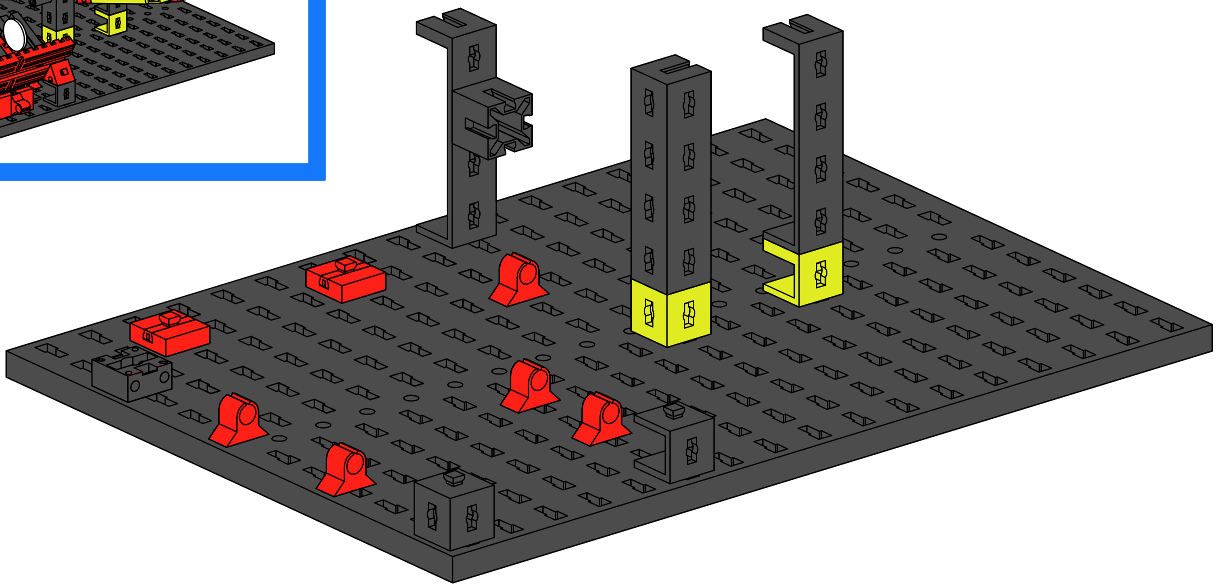


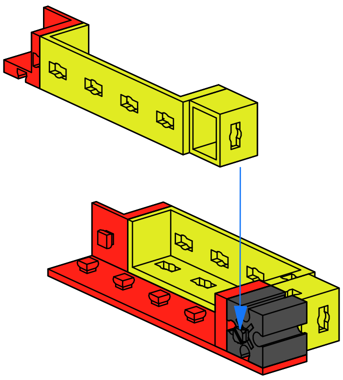


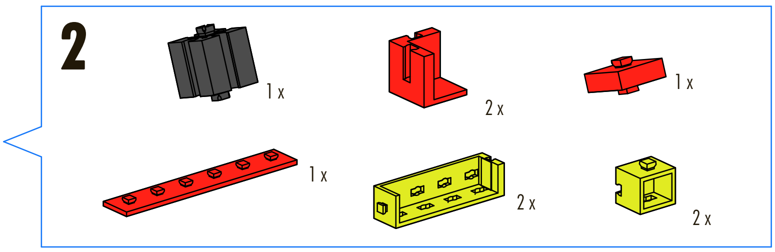
Bausteinspender
Brick dispenser
Distributeur d'éléments de construction
Bouwsteenautomaat
Dispensador de elementos
Distribuidor do componente
Distributore di elementi
Подаватель кирпичей
砖块分送机

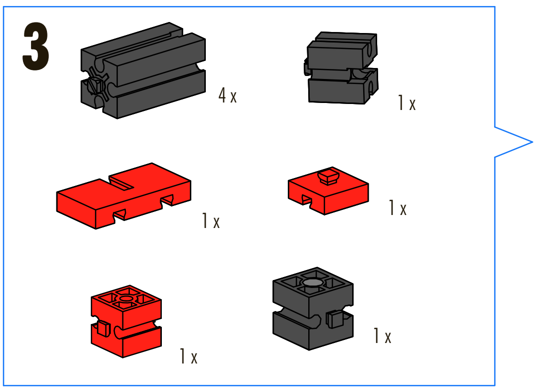


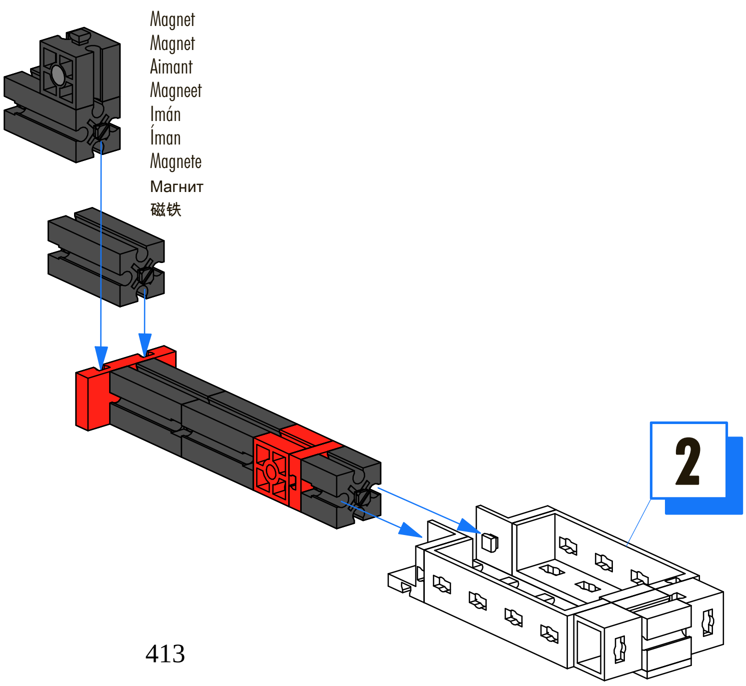


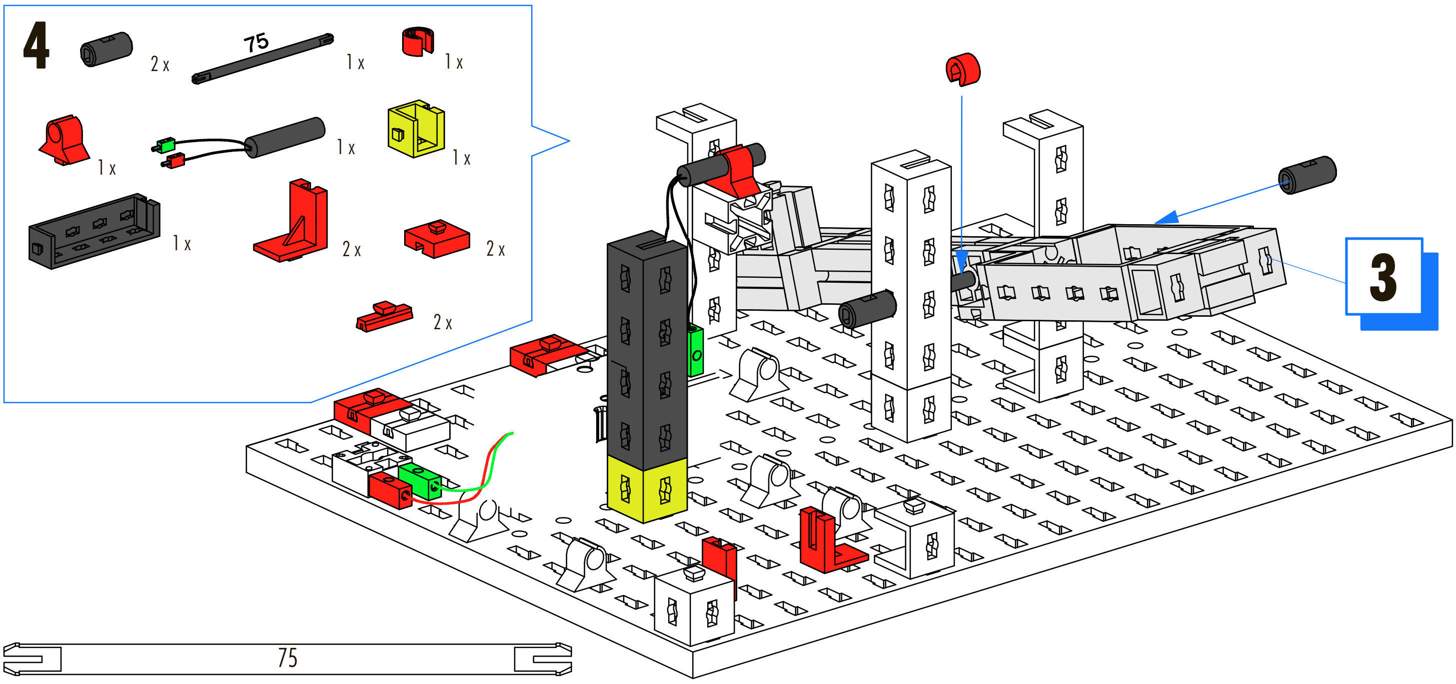








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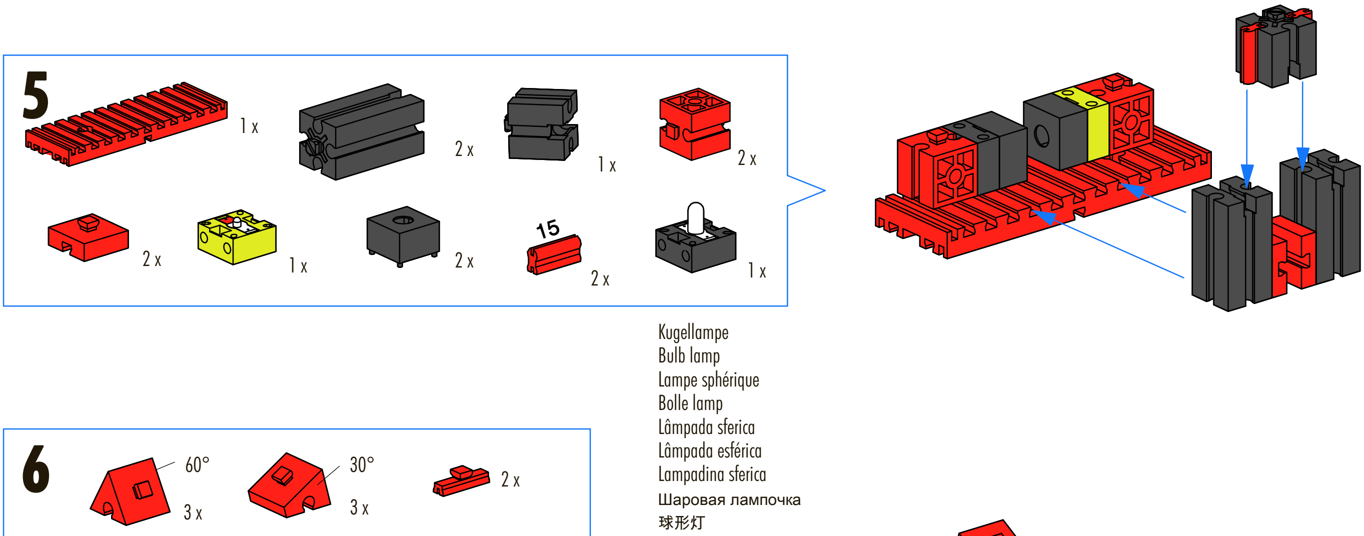
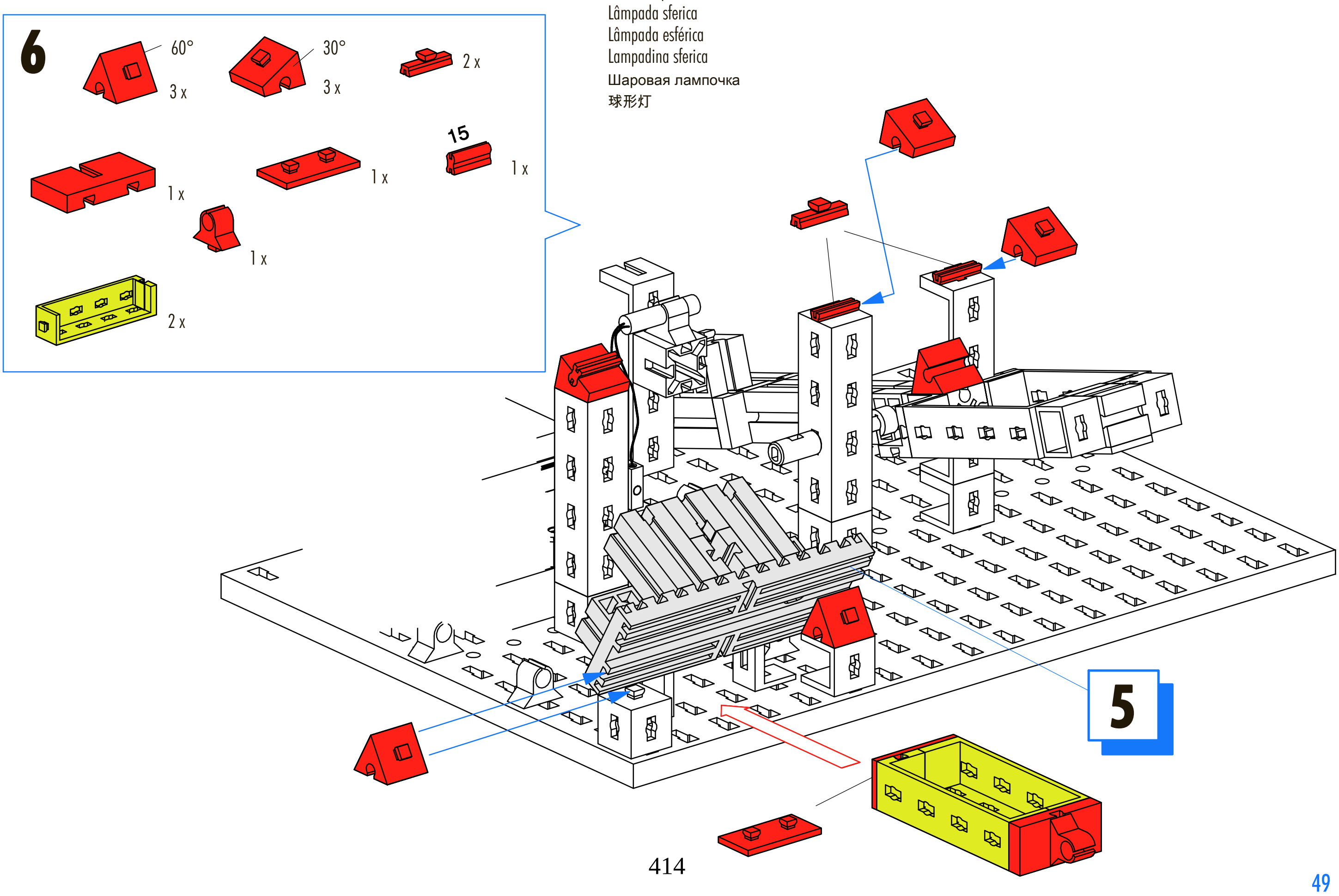
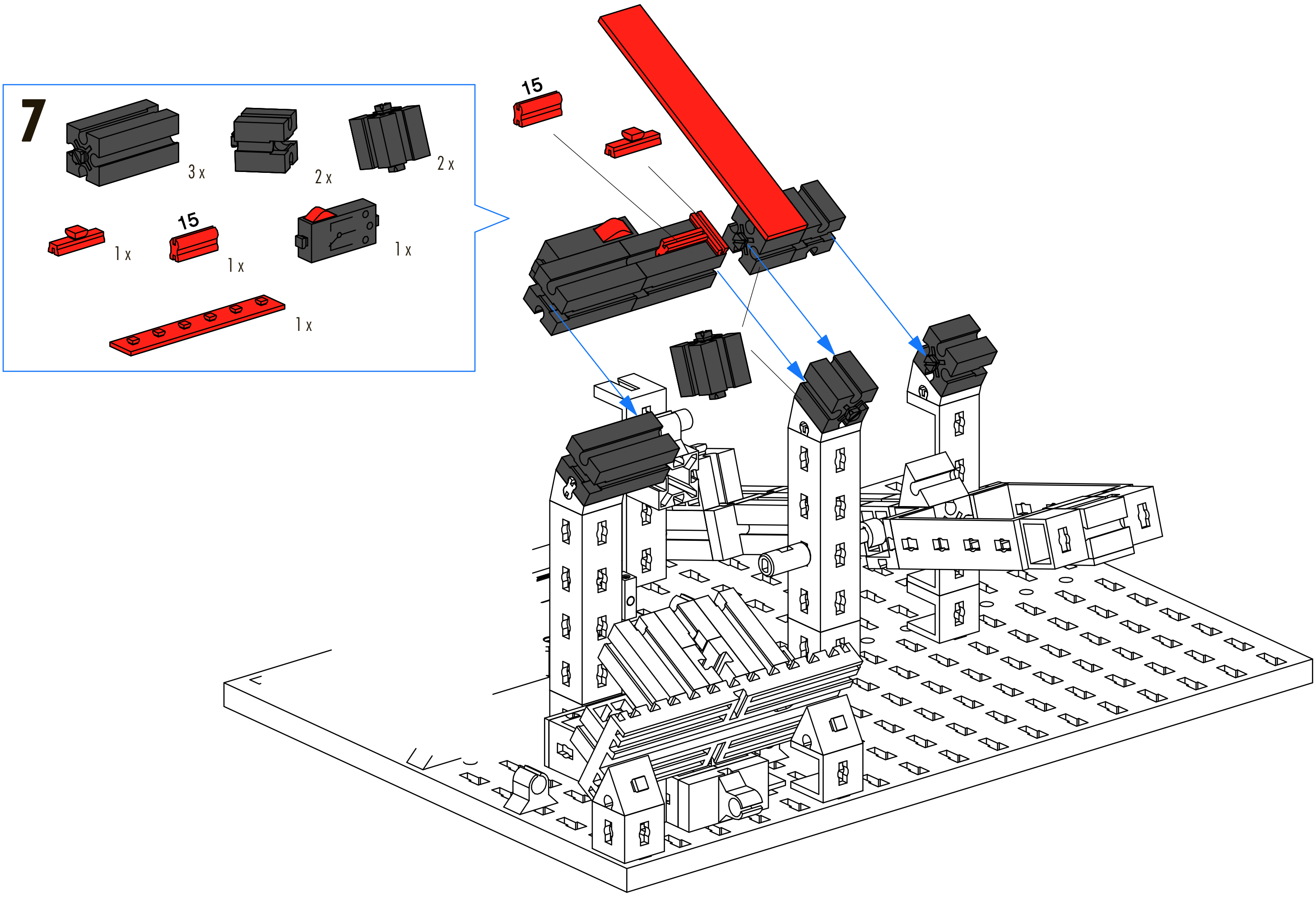
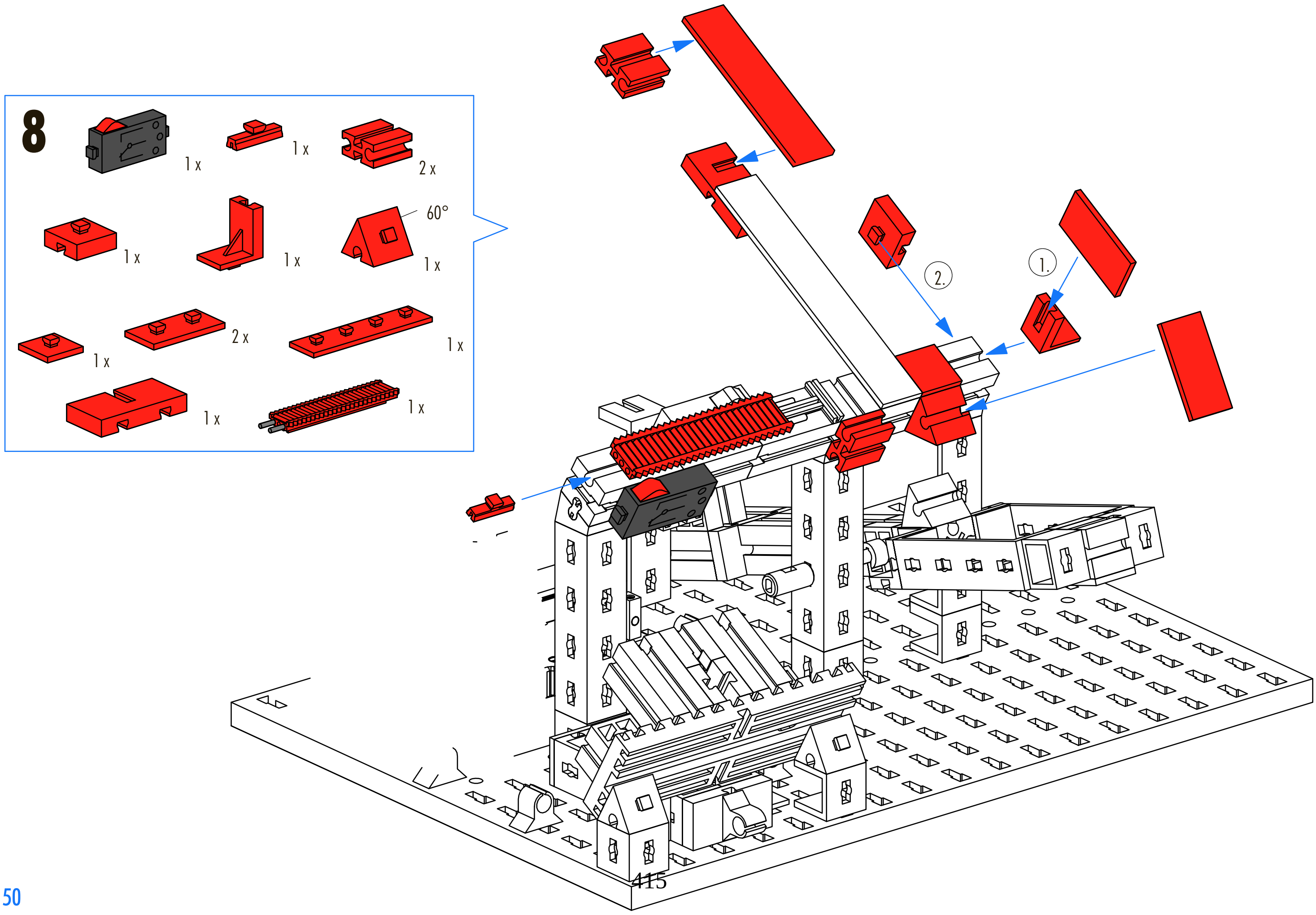
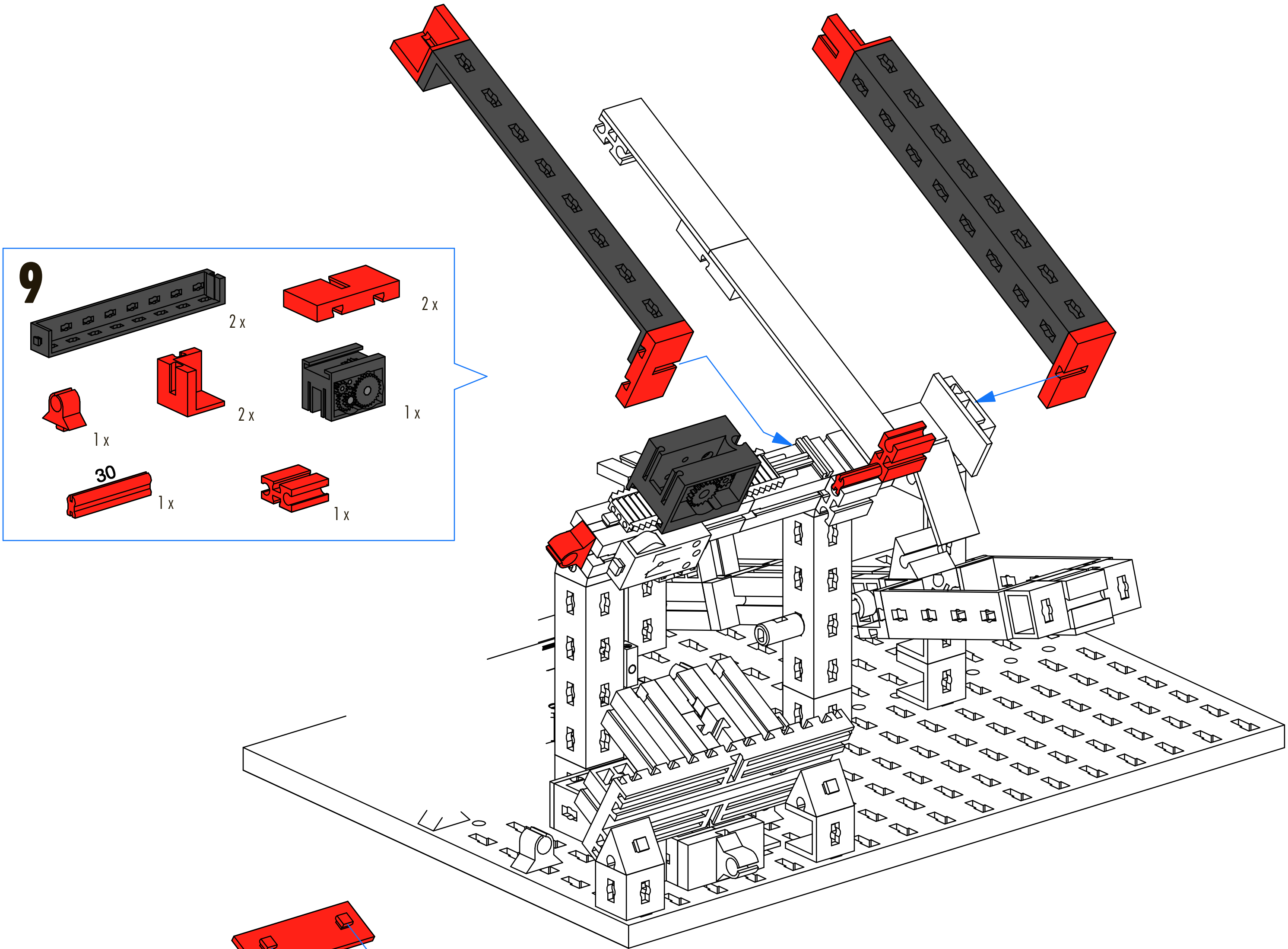
2 x
75
1 x
1 x
1 x
1 x
1 x
1 x
2 x
2 x
2 x
3
75

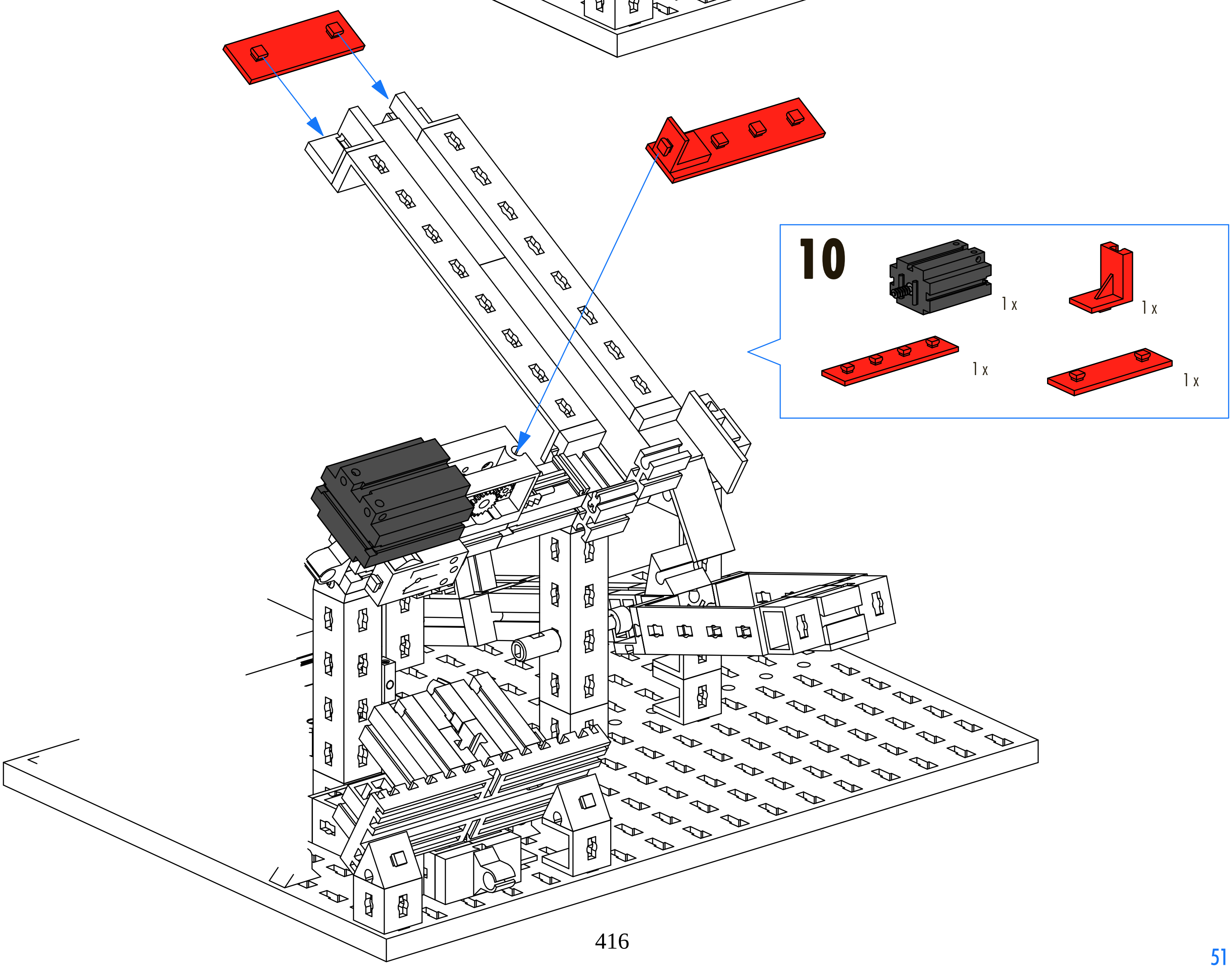

5
1 x
2 x
1 x
2 x
2 x
1 x
2 x
15
2 x
1 x
Kugellampe
Bulb lamp
Lampe sphérique
Bolle lamp
Lâmpada sferica
Lâmpada esférica
Lampadina sferica
Шаровая лампочка
球形灯

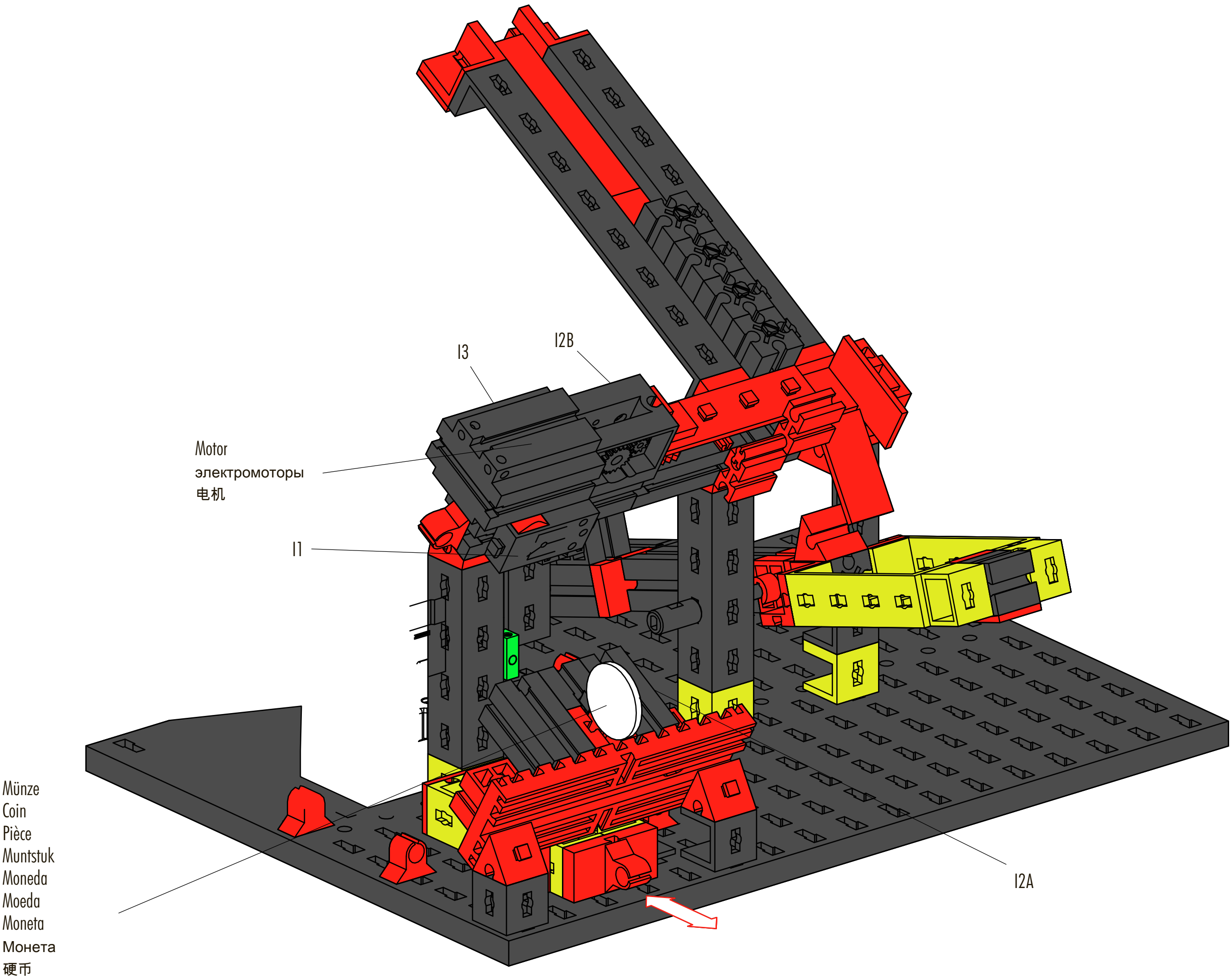

6
60°
3 x
30°
3 x
2 x
1 x
1 x
15
1 x
1 x
2 x
5


7
3 x
2 x
2 x
1 x
15
1 x
1 x
1 x
15


8
1 x
1 x
2 x
1 x
1 x
60°
1 x
1 x
2 x
1 x
1 x
1 x
2.
1.


9
2 x
2 x
1 x
2 x
1 x
30
1 x
1 x

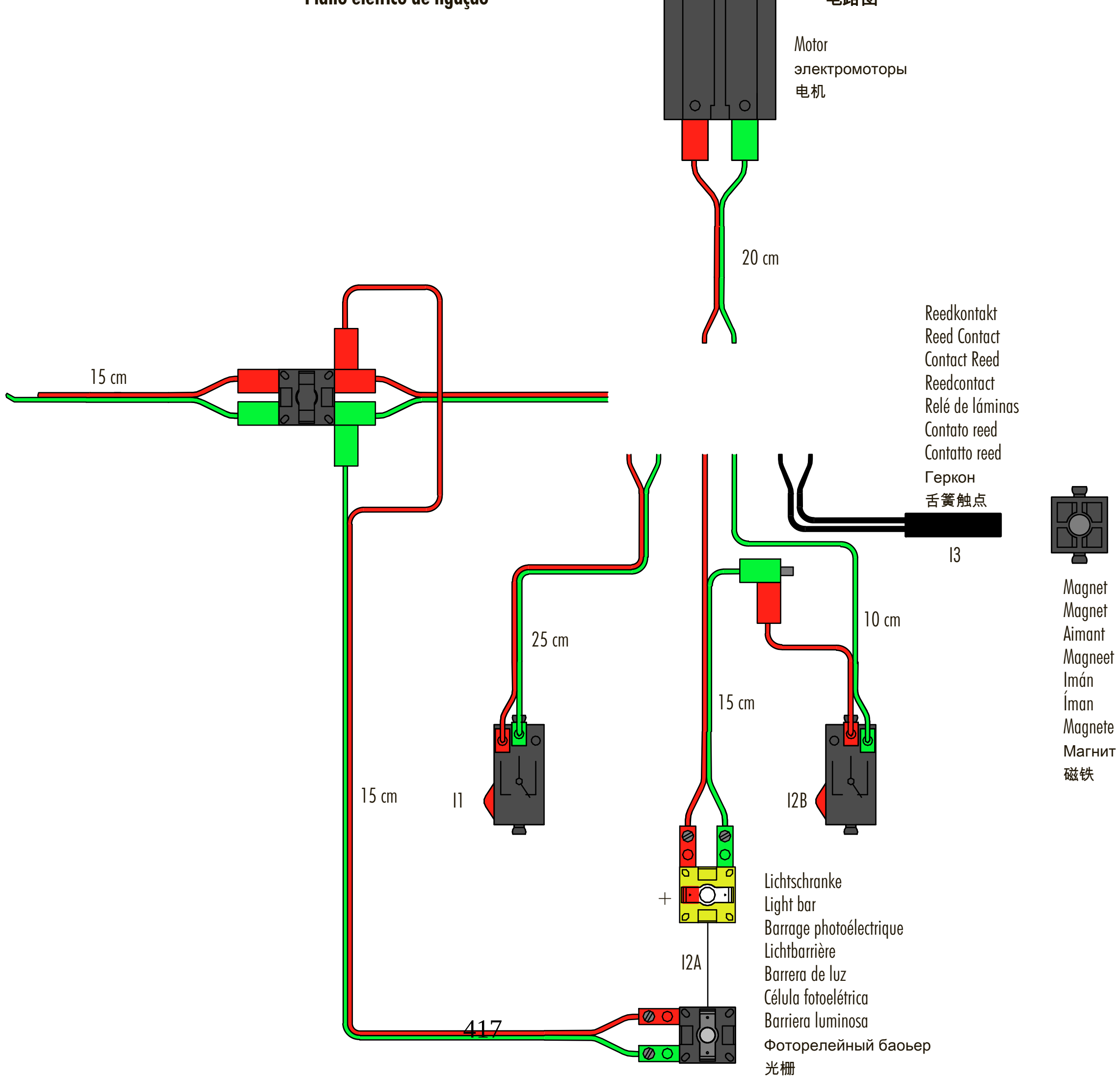

10
1 x
1 x
1 x
1 x



Schaltplan
Circuit diagram
Plan électrique

Schakelschema
Diagrama de circuitos
Plano elétrico de ligação

Schema elettrico
Схема подключения
电路图



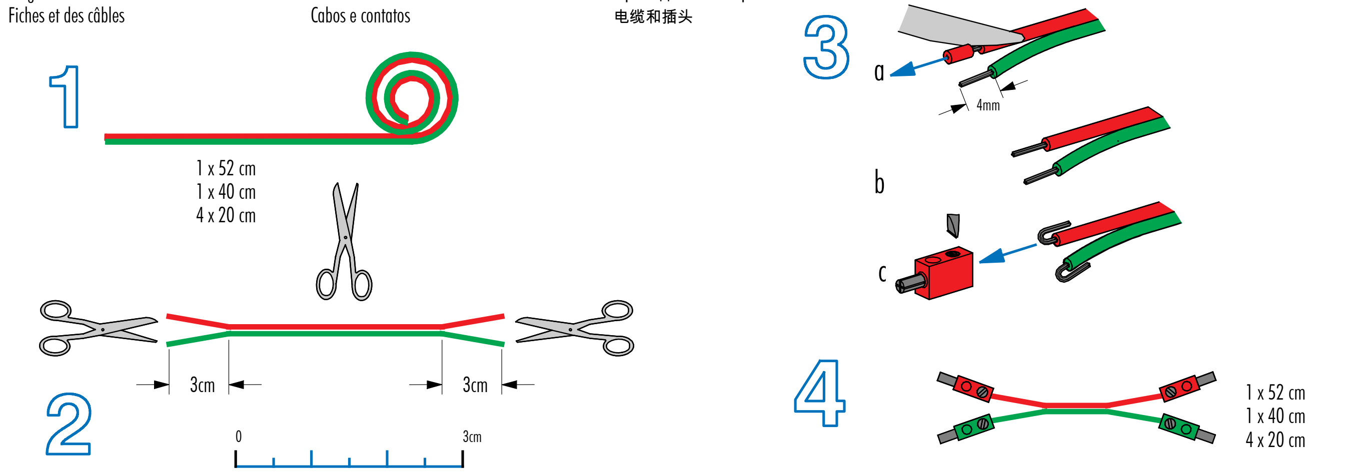
Einzelteilübersicht
Spare parts list
Liste des pièces détachées
Onderdelenoverzicht
Lista da piezas
Resumo de peça individual
Singoli componenti
Отдельные детали
零件概览

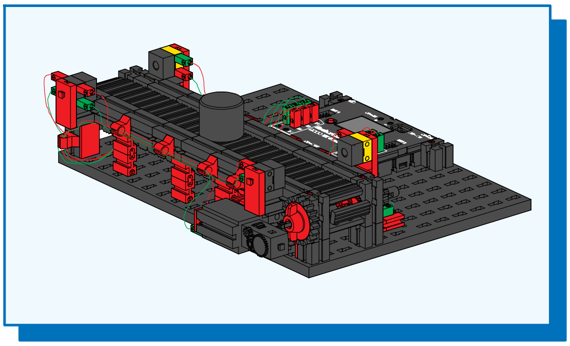
31 021	1 x	31 982	16 x	35 064	3 x	37 679	4 x
31 058	1 x	32 293	1 x	35 945	3 x	37 783	1 x
31 060	16 x	32 321	2 x	35 969	10 x	37 875	2 x
31 061	3 x	32 879	14 x	36 134	2 x	38 216	2 x
31 078	1 x	32 880	4 x	36 248	110 x	38 241	5 x
31 082	1 x	32 881	12 x	36 334	4 x	38 242	1 x
31 330	8 x	32 882	4 x	36 532	4 x	38 246	1 x
31 336	12 x	32 985	1 x	36 819	2 x	38 317	1 x
31 337	12 x	35 031	1 x	37 157	1 x	103 463	1 x
31 360	1 x	35 049	4 x	37 238	2 x	107 355	2 x
31 762	55 x	35 063	1 x	37 468	15 x		

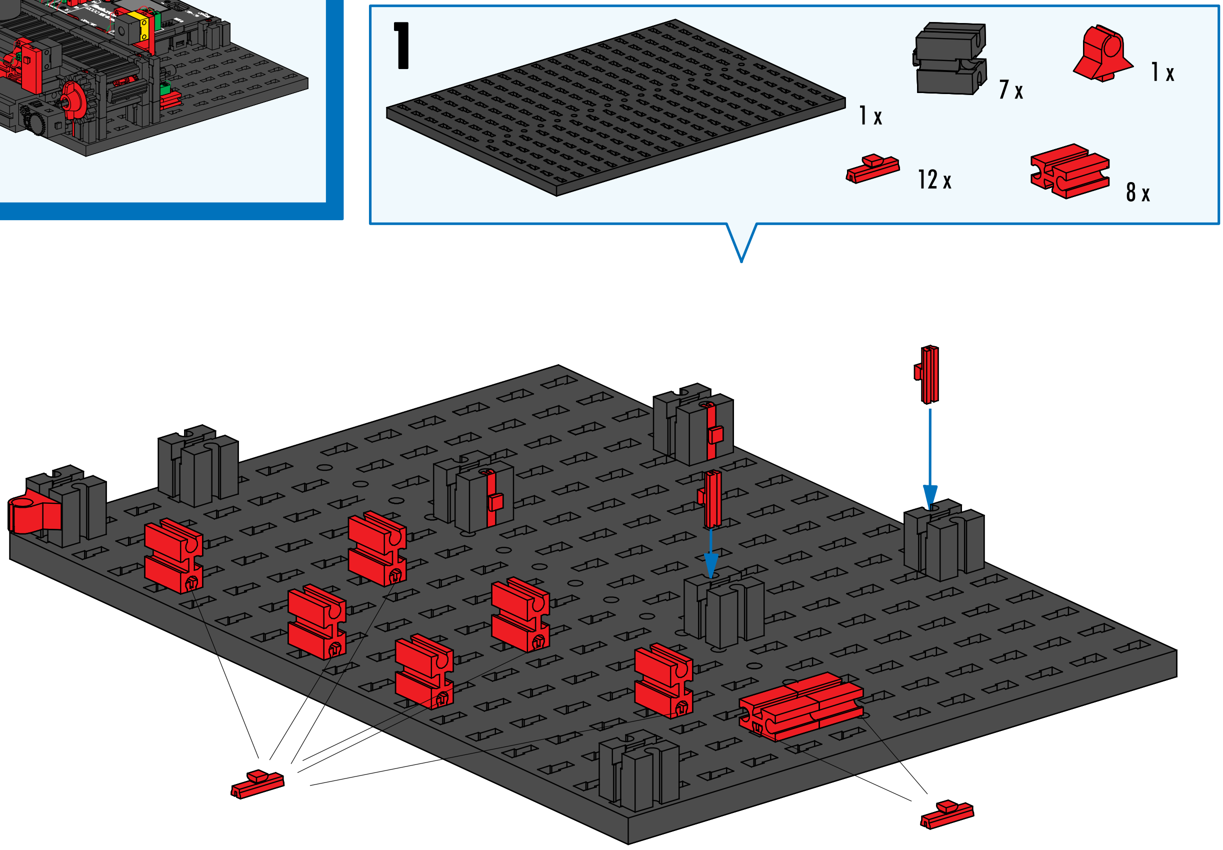
Kabel und Stecker
Plugs and cables
Fiches et des câbles

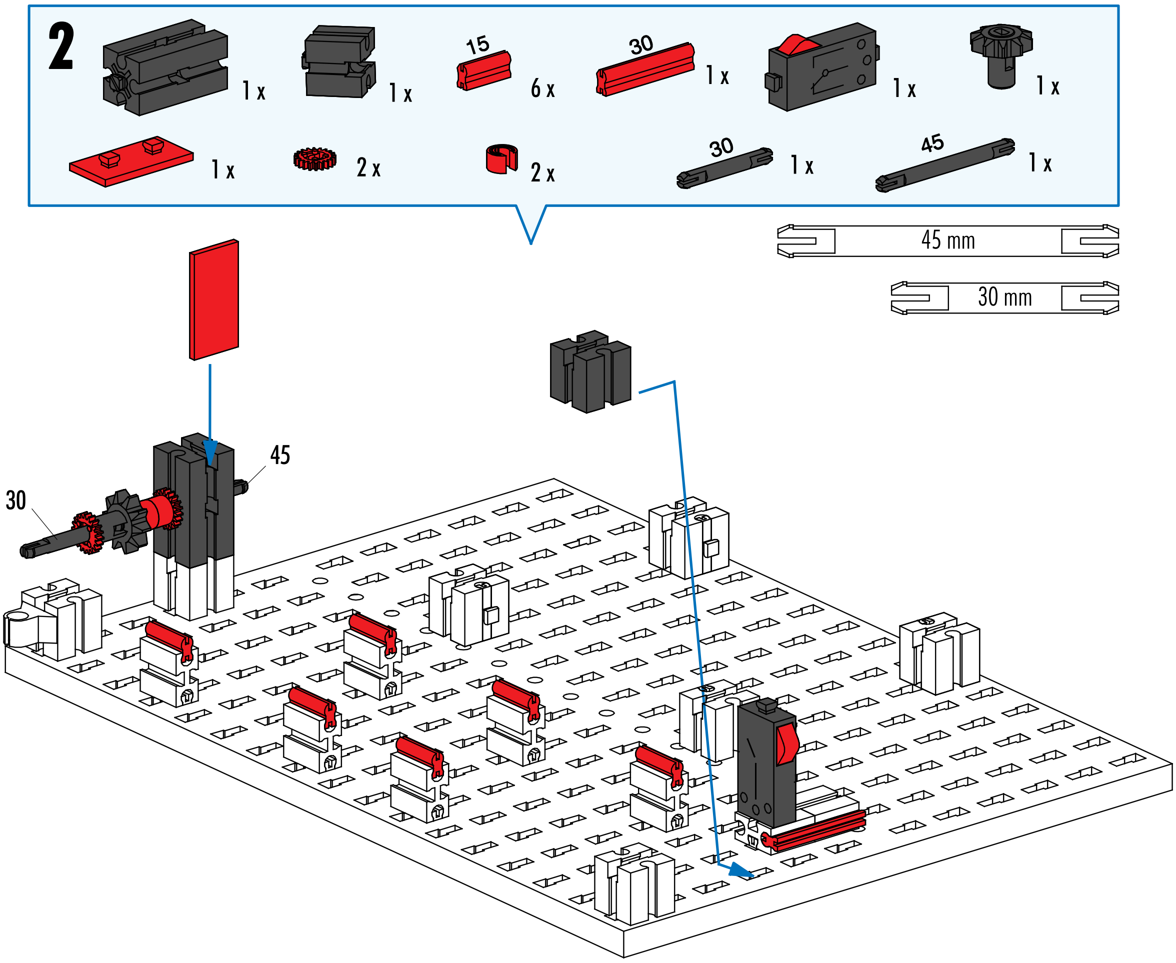
Stekkers en cables
Enchufes en cables
Cabos e contatos

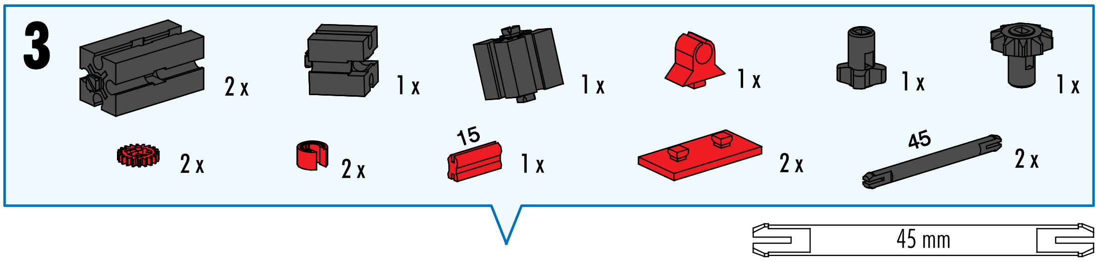
Cavi e connettori
Провода и штекеры
电缆和插头

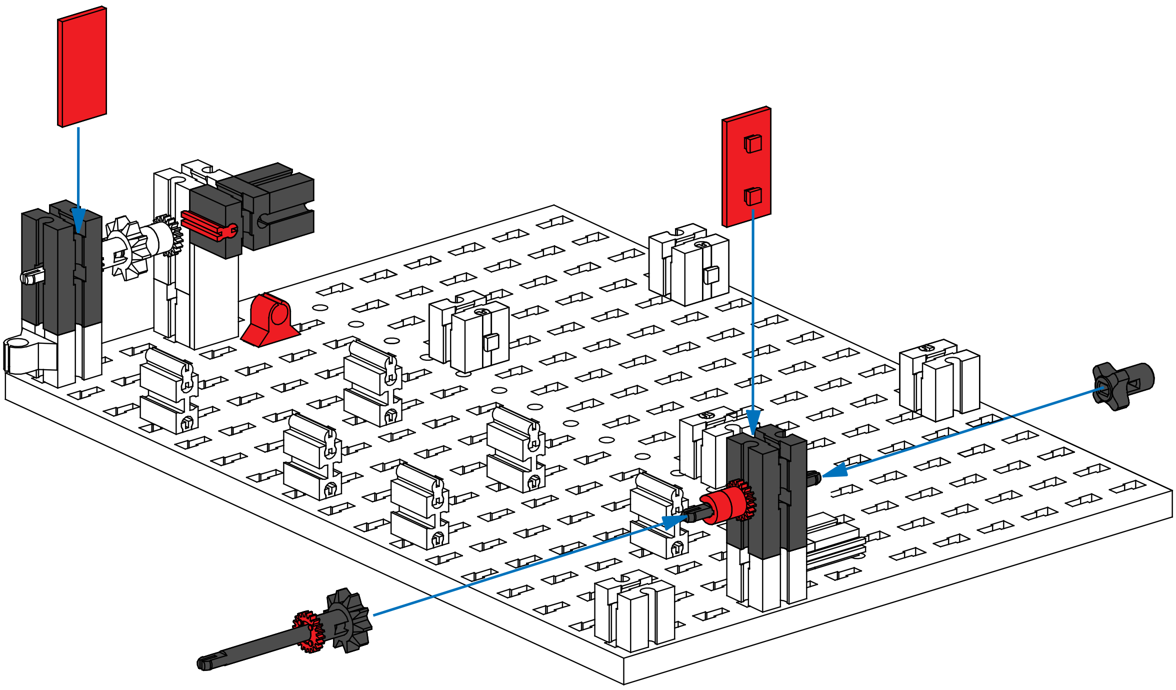


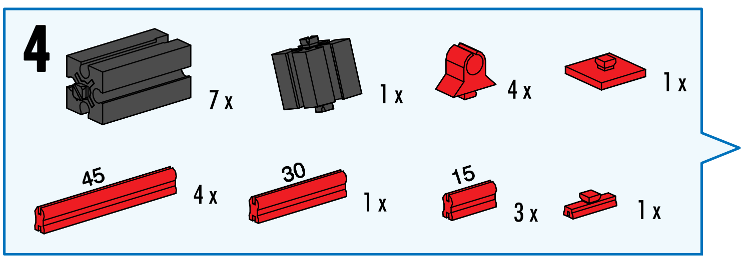


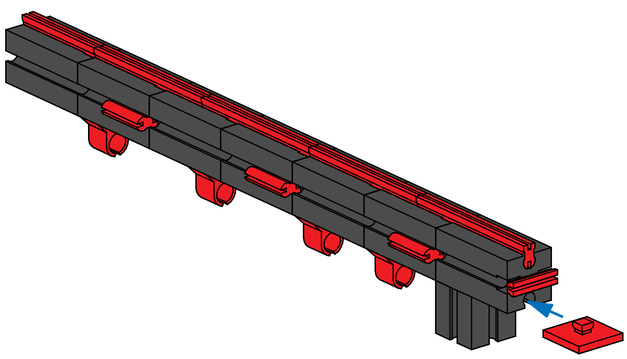

1
1 x
7 x
1 x
12 x
8 x

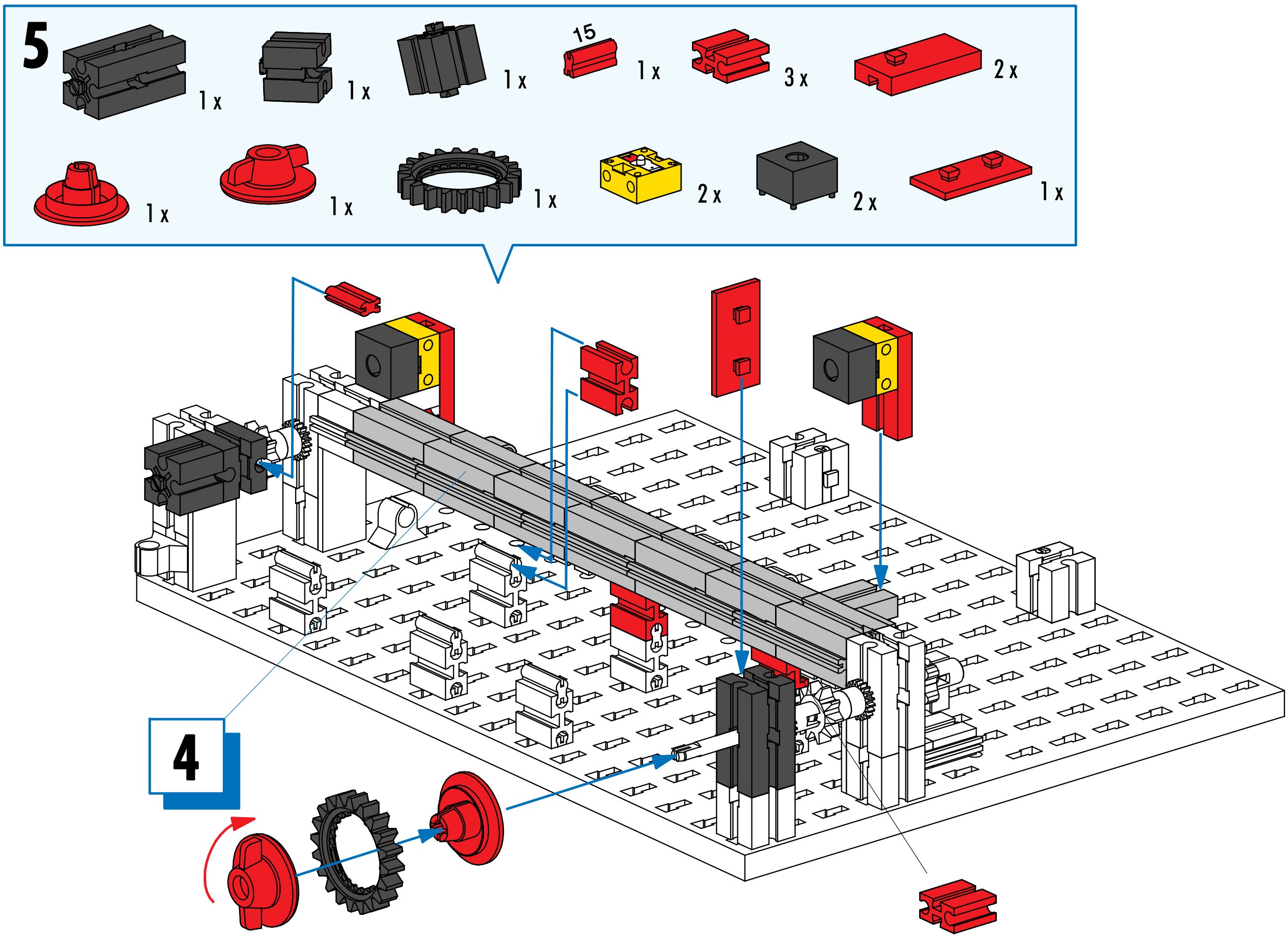

2
1 x
1 x
15
6 x
30
1 x
1 x
1 x
1 x
2 x
2 x
30
1 x
45
1 x
45 mm
30 mm
30
45

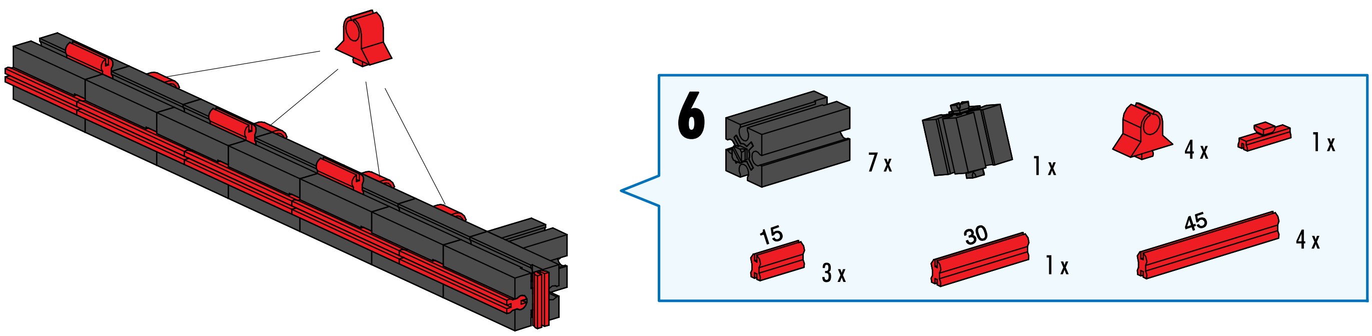

3
2 x
1 x
1 x
1 x
1 x
1 x
2 x
2 x
15
1 x
2 x
45
2 x
45 mm

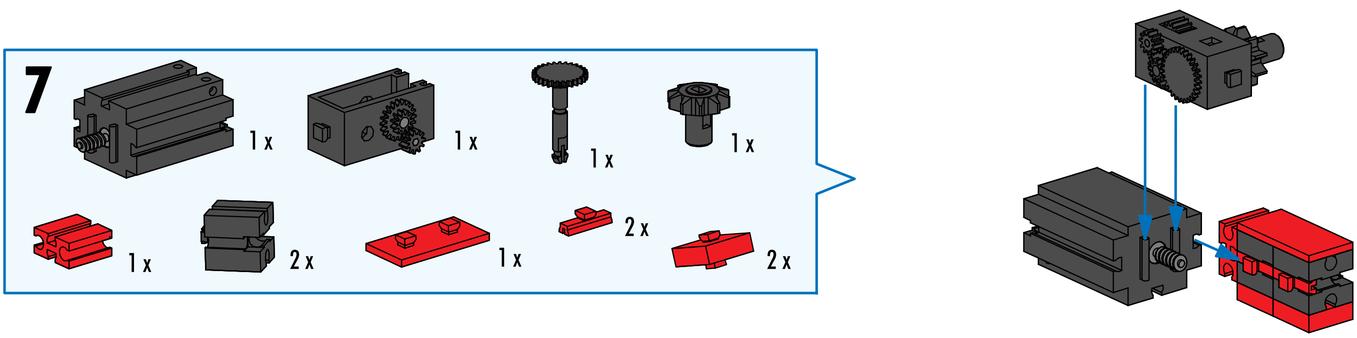


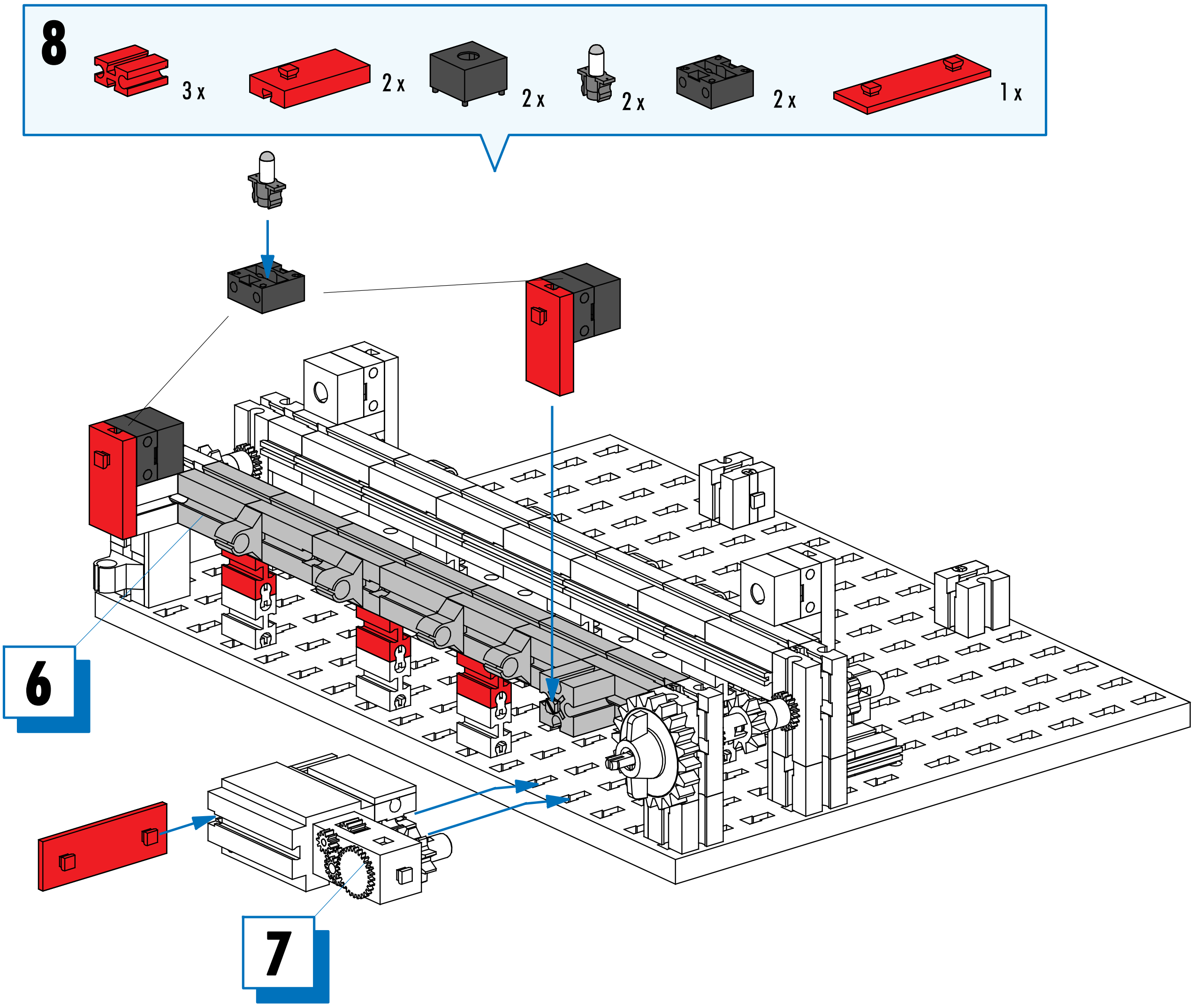

4
7 x
1 x
4 x
1 x
45
4 x
30
1 x
15
3 x
1 x

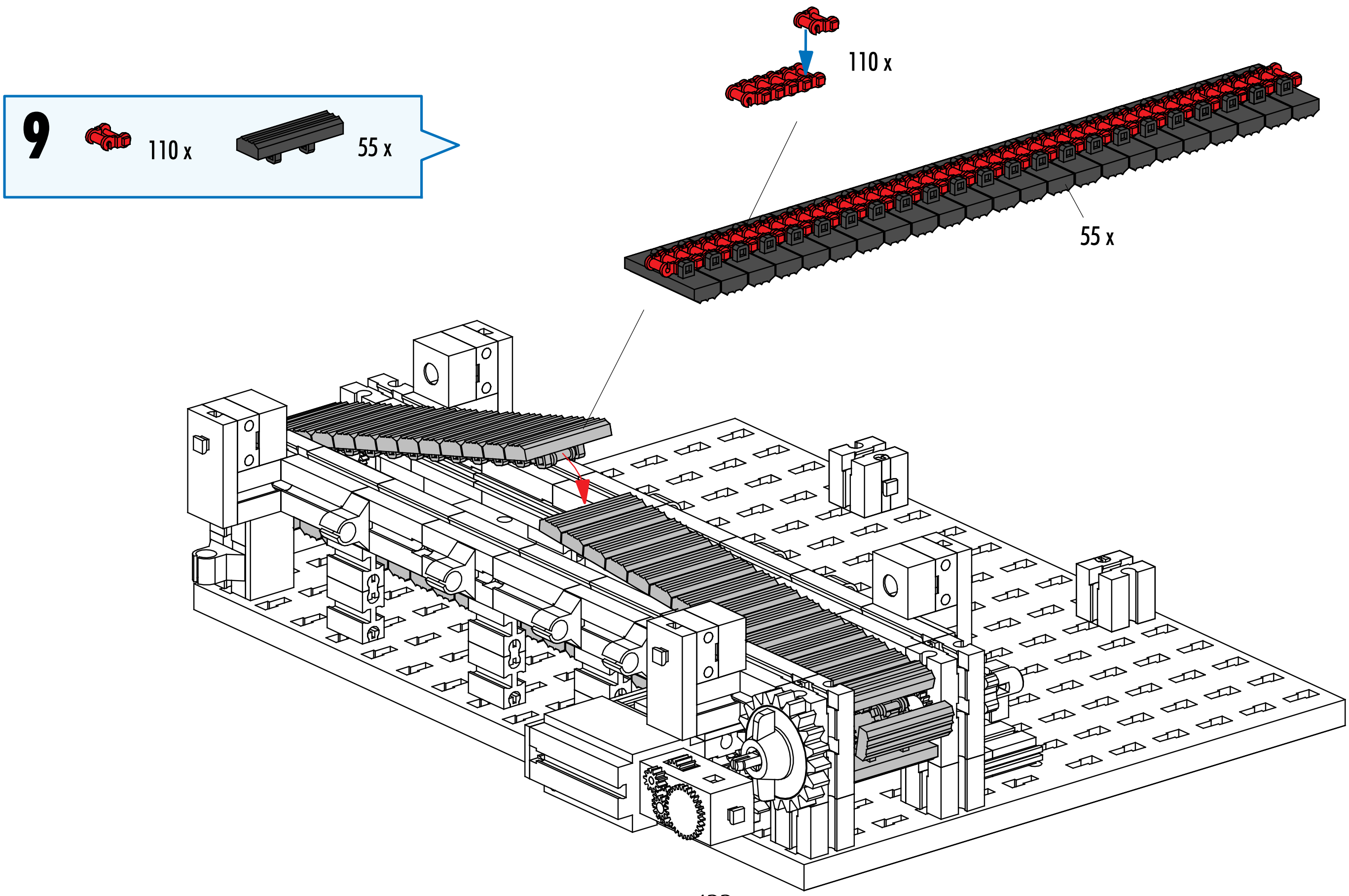



5
1 x
1 x
1 x
15
1 x
3 x
2 x
1 x
1 x
1 x
2 x
2 x
1 x
4

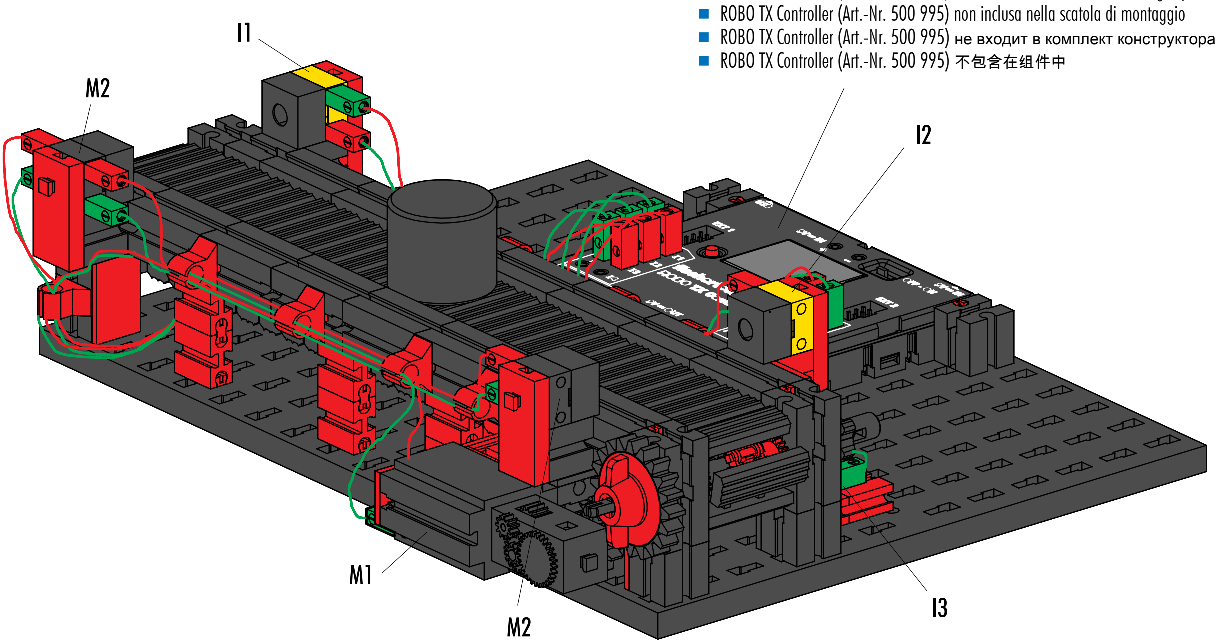

6
7 x
1 x
4 x
1 x
15
3 x
30
1 x
45
4 x


7
1 x
1 x
1 x
1 x
1 x
2 x
1 x
2 x
2 x

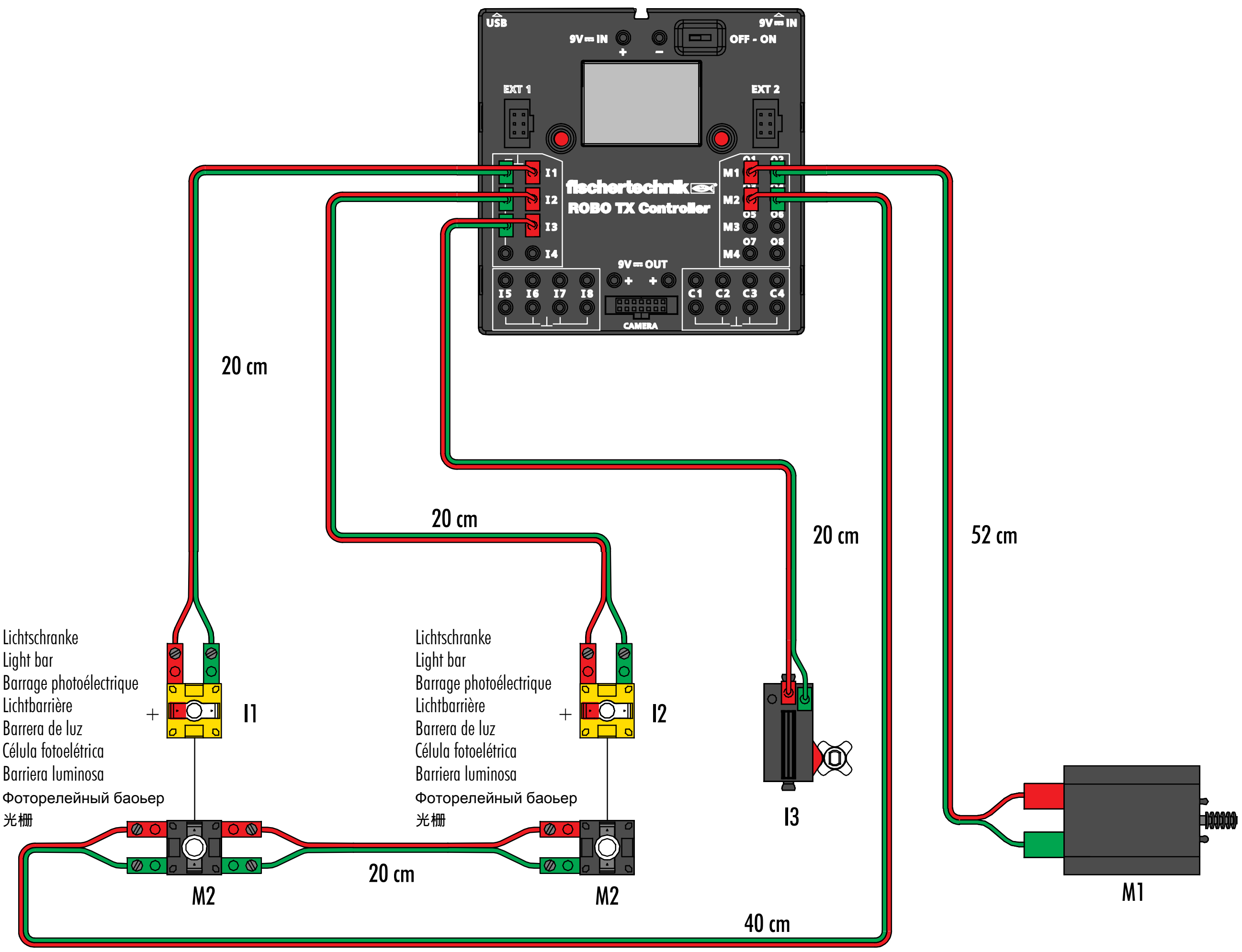

8
3 x
2 x
2 x
2 x
2 x
1 x
6
7

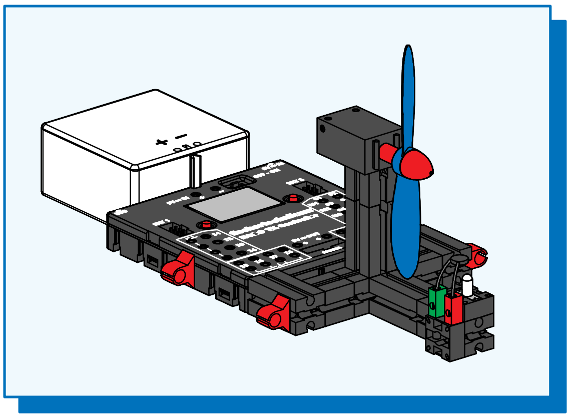

9
110 x
55 x
110 x
55 x

- ROBO TX Controller (Art.-Nr. 500 995) nicht im Baukasten enthalten
- ROBO TX Controller (Art.-Nr. 500 995) not included in the modular kit
- ROBO TX Controller (Art.-Nr. 500 995) n'est pas contenue dans le kit
- ROBO TX Controller (Art.-Nr. 500 995) niet in de bouwdoos opgenomen
- ROBO TX Controller (Art.-Nr. 500 995) no está incluido en el conjunto
- ROBO TX Controller (Art.-Nr. 500 995) não contido no sistema de construção por blocos
- ROBO TX Controller (Art.-Nr. 500 995) non inclusa nella scatola di montaggio
- ROBO TX Controller (Art.-Nr. 500 995) не входит в комплект конструктора
- ROBO TX Controller (Art.-Nr. 500 995) 不包含在组件中

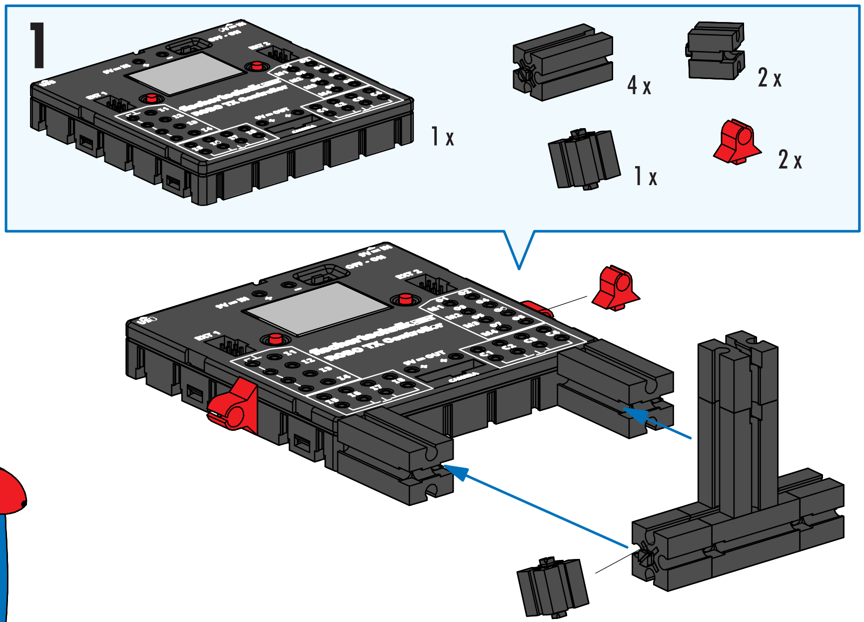


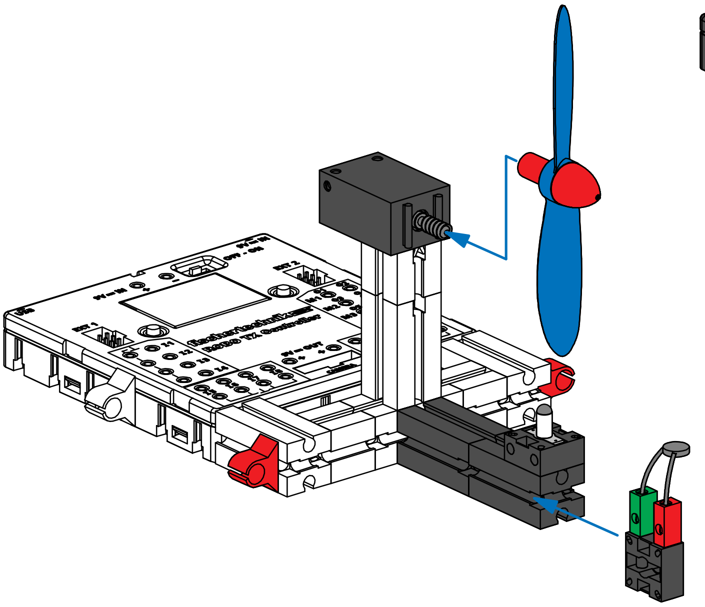
Schaltplan
Circuit diagram
Plan électrique
Schakelschema
Diagrama de circuitos
Plano elétrico de ligação
Schema elettrico
Электросхема
电路图

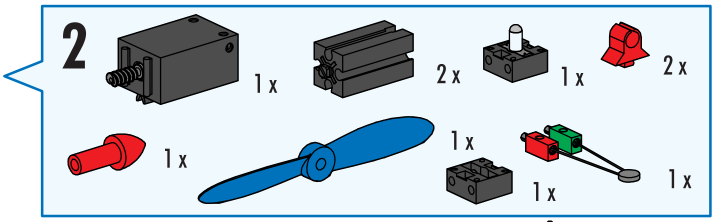




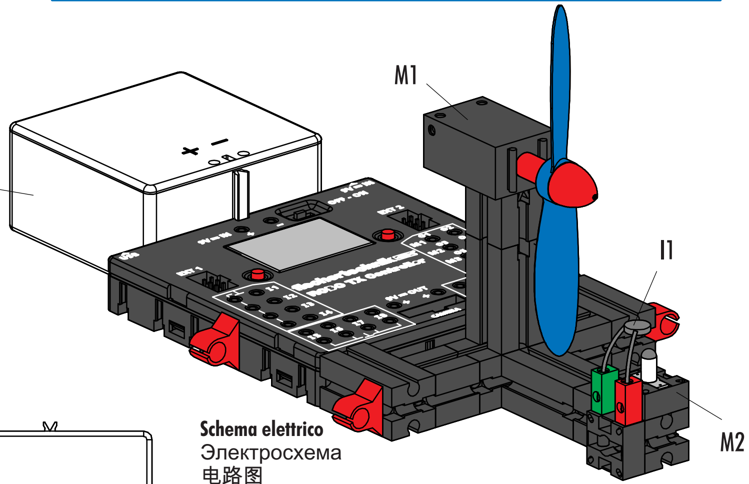
Temperaturregelung
Temperature control
Régulation de la température
Temperatuurregeling
Regulador de temperatura
Regulagem de temperatura
Regolazione temperatura
Регулирование температуры
温度调节器







- Accu Set (Art.-Nr. 34 969) nicht im Baukasten enthalten
- Accu Set (Art. No. 34 969) not included in the modular kit
- Accu Set (réf. 34 969) n'est pas contenue dans le kit
- Accu Set (art.-nr. 34 969) niet in de bouwdoos opgenomen
- Accu Set (art. n° 34 969 no está incluido en el conjunto
- Accu Set (Nº de prod. 34 969) não contido no sistema de construção por blocos
- Accu Set (cod. prod. 34 969) non incluso nella scatola di montaggio
- Аккумулятор Accu Set (арт.№ 34 969) не входит в комплект конструктора
- 电池套件(产品号 34 969)不包含在组件中



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