Introduction to Using LEDs in Model Kits

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Agenda

- Overview
- Notes on Safety, Liability and Author's Background
- Definitions
- Introduction to Electricity in Model Kits
- How electricity works – a very basic introduction
- Ohm's Law and Why You Need to Know It
- What are LEDs?
- How to Use LEDs in Basic Circuits
- Placing LEDs in Models
- Designing Your Circuit
- Some Soldering Basics
- Useful Tools
- Resources for Shopping and Research

Overview

- My intention is to provide a very basic introduction to how to use LEDs in model kits.
- It does not provide a general introduction to all applications of LEDs.
- It also does not provide a general introduction to electronics.
- If the response to this presentation is positive, then presentations on more complex topics, such as using microcontrollers for complex functions will be forthcoming.

Liability and Safety Notes

- Neither the author nor IPMS San Diego accept any responsibility or liability for any of the circuits or any derivatives thereof in this presentation or for any other information contained in this presentation. Anyone who builds them does so entirely at their own risk. Anyone who solders or performs any other action related to this presentation does so entirely at their own risk.
- Safety –
  - Never solder a wire directly to a battery for any reason. Use a battery connector.
  - Never disassemble a battery.
  - For the purposes of these circuits, do not use a wall-socket or any power source other than small alkaline batteries (1.5V-9V each). Do not use a car battery, laptop battery, cellphone battery, etc.
  - If something starts to heat up or smoke, immediately disconnect it from its power source.
  - If in doubt – wear eye and skin protection.

Author's Background

- I graduated from CSU Sacramento in 2004 with a Second Bachelor's Degree in Computer Engineering.
- I am also a past member of the Institute for Electrical and Electronics Engineers and the Association for Computer Machinery.
- I am a lifetime member of Tau Beta Pi, the national engineering honors society.
- I interned at Intel in 2002.
- I have worked for Qualcomm since 2004.

Definitions

- Voltage – The force used to push a current through some resistance.
- Current – The flow of electric charge. The convention is that current flows from the positive to negative terminals of a power source.
- Resistance – A measure of the difficulty of moving current through an electrical conductor.
- Diode – An electronics component, usually a semiconductor, which offers very low resistance in one direction and very high resistance in the other direction.
- LED – A Light Emitting Diode.

Using Electricity In Model Kits

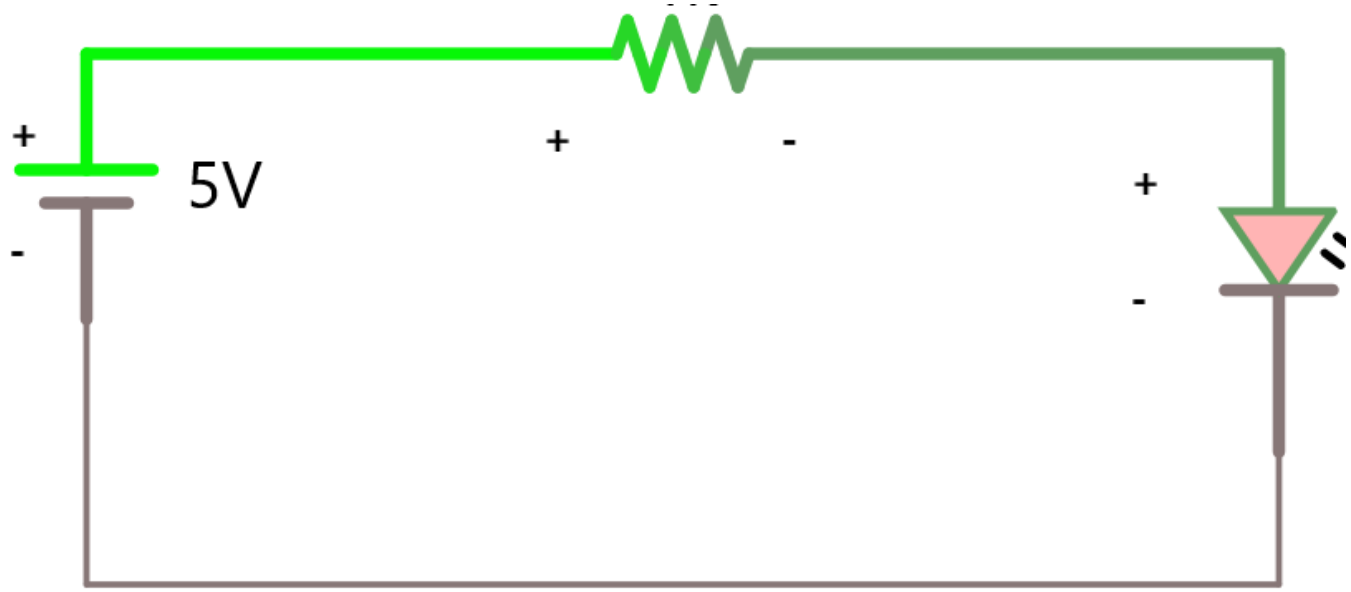
- Most model kits have very modest electrical needs that can be provided by alkaline batteries.
- Electronic components use what is called “direct current”, in which the voltage level remains relatively stable while the circuit is on. Batteries can provide direct current without any transformation.
- LEDs are the most common and easiest application of electronics in model kits.
  - Sound effects and motors are other applications, but are outside of the scope of this presentation.

How Electricity Works

- Electricity works such that current flows from the positive terminal of the power source, through the circuit and to the negative terminal of the power source.
- Some electronic components can be connected to a circuit in any direction. Resistors are such components.
- Some components have positive and negative connectors or leads. LEDs are such components. Connect them such that the positive lead is connected towards the positive terminal of the power supply, and the negative lead is towards the rest of the circuit.

Connecting Components - Example

- This shows a battery, a resistor and an LED (left to right).
- Note the + and - in the circuit. These indicate the voltage. The current will flow from the positive terminal of the battery through the resistor and the LED to the negative terminal of the battery
- Note that the resistor symbol is symmetrical but the battery and LED are not. They must be connected in a certain way or the circuit will not work.

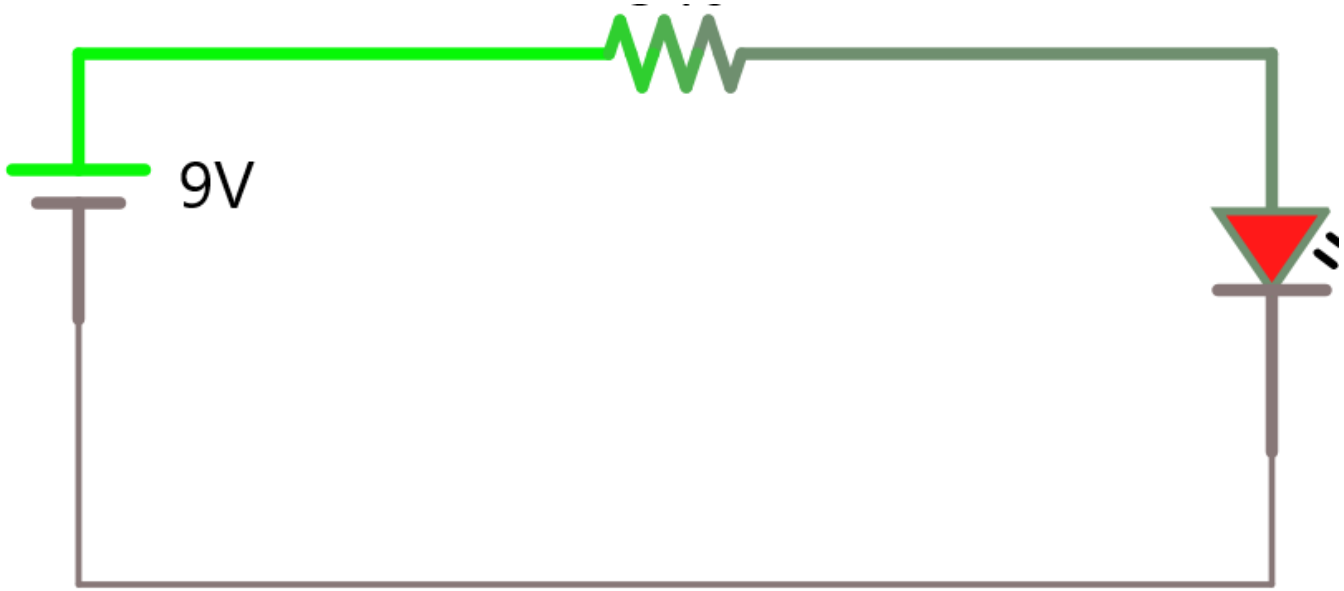


Ohm's Law – and Why You Need to Know It

- Ohm's Law states that the voltage in a circuit is a direct function of the resistance and the current.
  - Voltage = Resistance x Current ($V = I \times R$)
  - Voltage is in volts (V), Resistance is in ohms (Ω) and Current is in amperes, or amps (A).
- Also – the voltage into a circuit must match the total voltage drop of a circuit.
- This is important to remember because LEDs have several values in their specification sheets – including voltage drop and maximum current.
- In order to connect LEDs to a battery you need to make sure that the current does not exceed its maximum rating. This means you need to add a resistor of the correct resistance value.

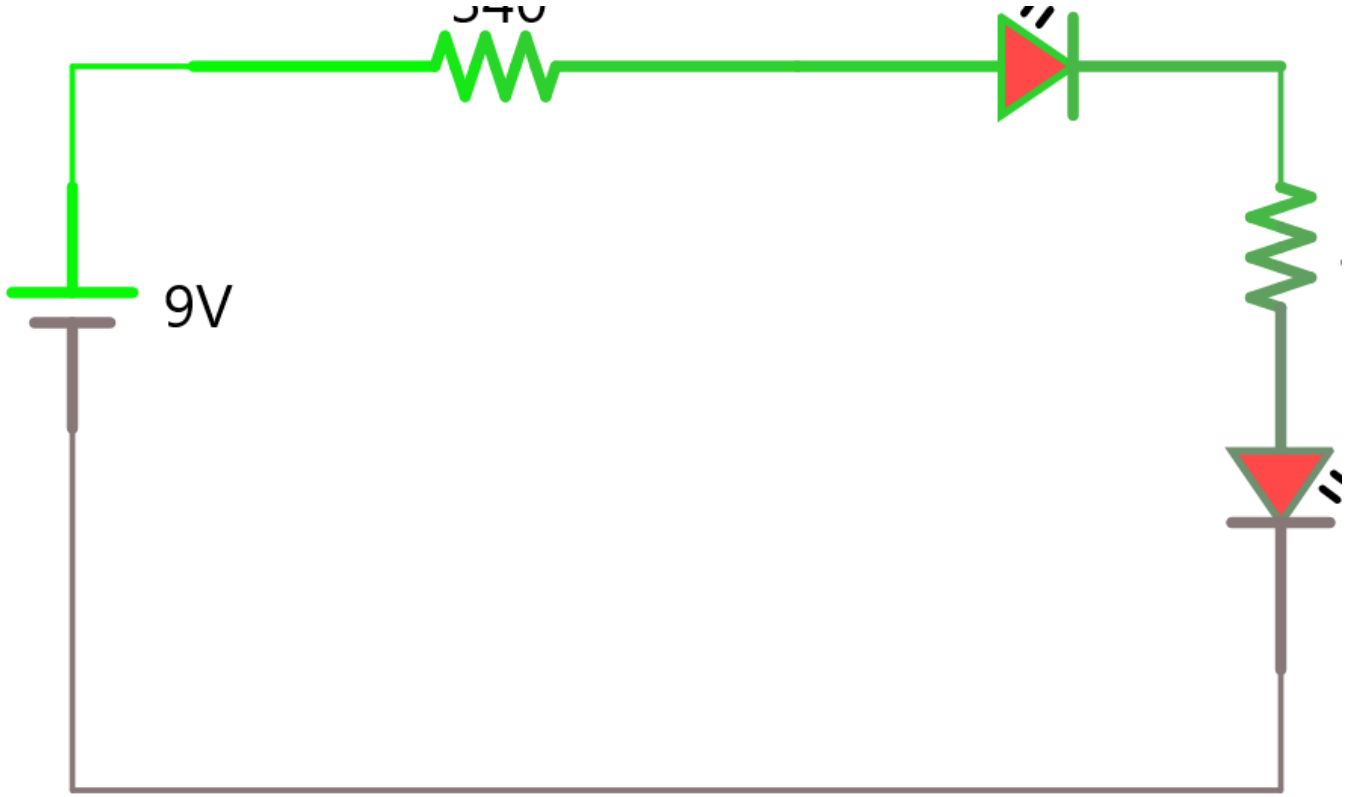
Ohm's Law Example

- I have a battery that is 9V.
- I want to connect a single LED to it. That LED has a voltage drop of 2.2V.
- The LED also has a maximum current allowance of 20 mA, or 0.020 A.
- So, from Ohm's Law, the LED takes away 2.2V, leaving me with 6.8V to deal with.
- 6.8V = R * 0.020 A
- R = 6.8V / 0.020 A = 340 Ω
- R = 340 Ω (the voltage drop across the resistor will be 6.8V).



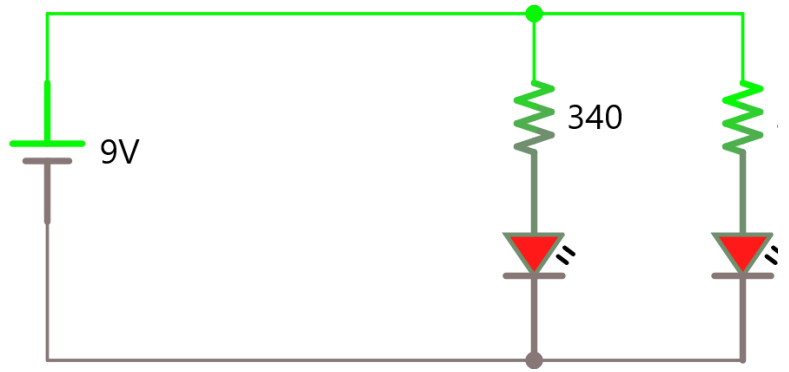
Some More Things to Know – Series Circuits

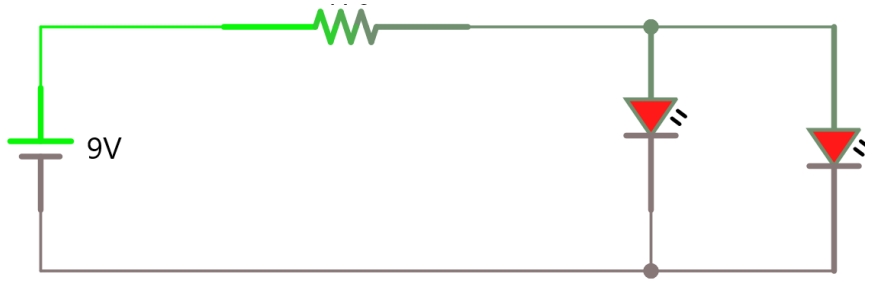
- Voltage drops linked in series add.
- Resistance in series also adds.
- So, in this case, I have two LEDs, 2.2 V each. So, that means my resistors have to deal with 9V – 4.4V = 4.6V (instead of 6.8V in the previous circuit). This means 4.6 V = 0.02 A * (R1 + R2).
- R1+R2 = 4.6/0.02 = 230 Ω total.
- My resistors in this case add, so I can have 2 resistors of 115 Ω each, or one of 230 Ω.



Some More Things to Know – Parallel Circuits

- Voltages in parallel from the same power source will be the same.
- The current, however will split according to the resistance.
- Resistors in parallel do not add directly – the total resistance of this circuit is
- 1/R = 1/R1 + 1/R2.
- 1/R = 1/340 + 1/340 = 2/340.
- R = 340 / 2 = 170 Ω.
- This means that the two resistors in the circuit that are in parallel could be replaced with one 170 Ω resistor placed just after the positive terminal of the battery.





Switches

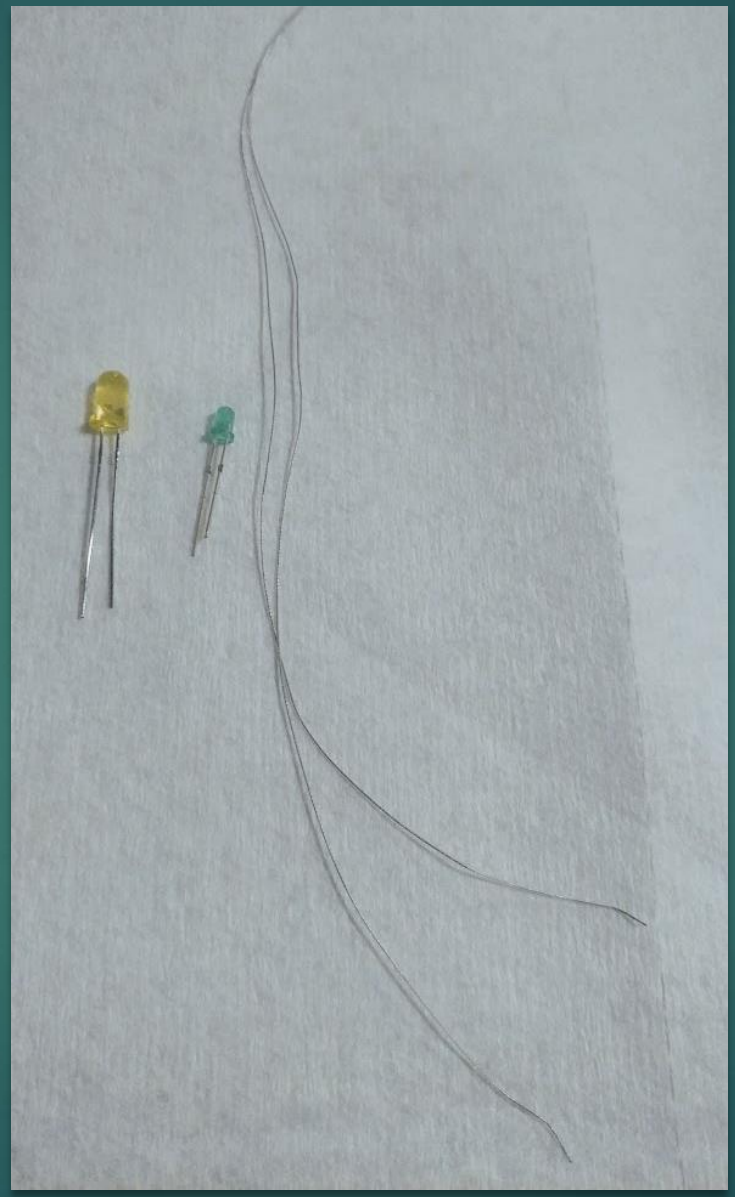
- In order to turn a circuit on and off, you need a switch.
- For simplicity, it is best to use a switch that will hold its position mechanically – eg, once it is on, it stays on until it is turned off.
  - Rocker switches and paddle switches are good examples.
  - Slide switches can also be used.
  - Pushbutton switches can be used if they are marked as “latching”.
- Stay away from tactile or momentary switches at least at the beginning.
  - These are switches that are on so long as you press the button, but spring back to off when you let go.

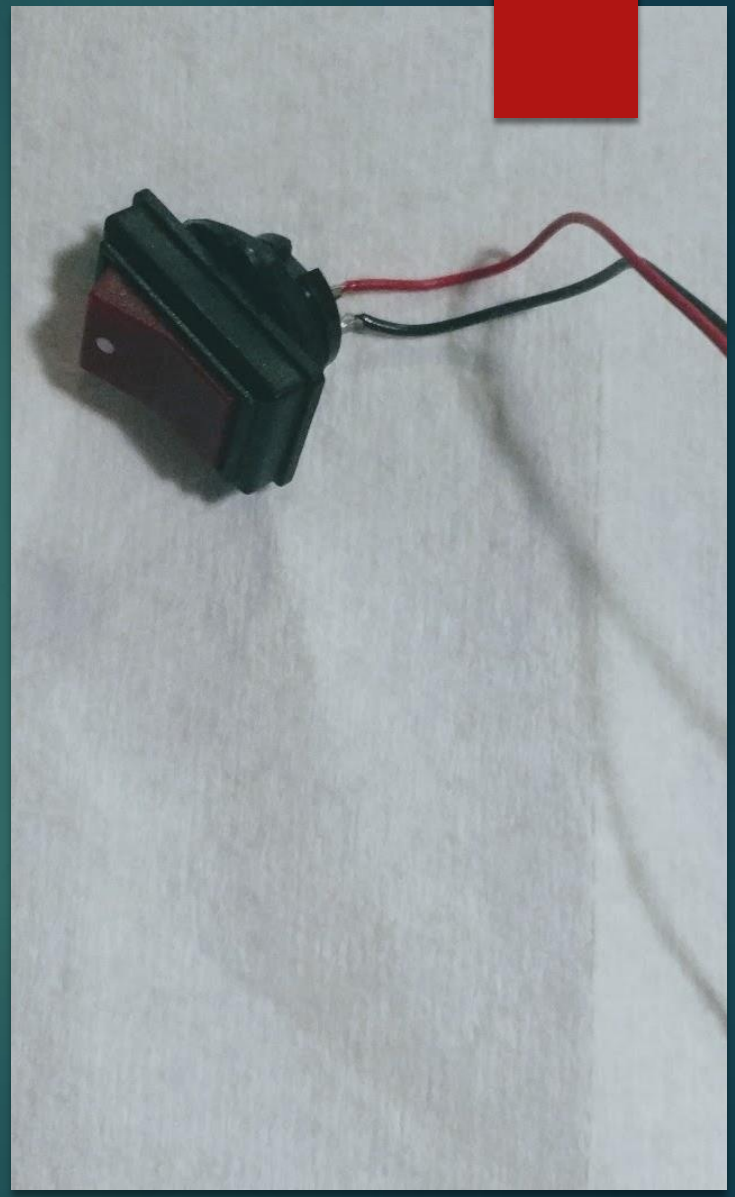
More on LEDs

- LEDs come in different shapes and sizes.
- The most common are round and are about 5mm in diameter.
- Some are 3mm in diameter.
- Others are very tiny and rectangular in shape. If you buy these, make sure they have the wires pre-soldered on.
- LEDs have two sides, a positive and negative side. The positive side must be connected to the positive terminal of the power source. The negative side must be connected to the negative terminal of the power source.
  - The shorter lead on an LED is the negative side.
  - On round LEDs, there is also a flat side over the negative lead.

LEDs and Switches

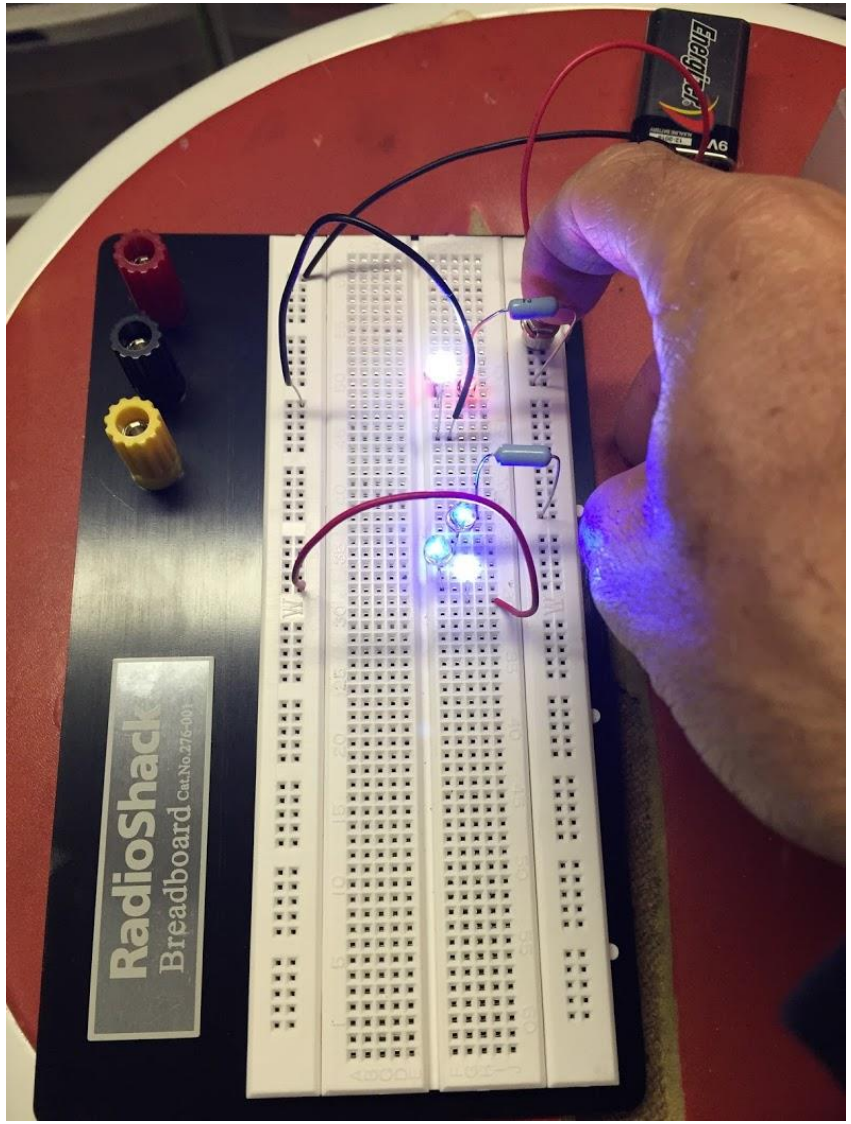
- To the left are three LEDs – 5mm, 3mm and a micro square LED with pre-soldered leads.
- To the right is a rocker switch – probably the easiest to use.





Designing Your Circuit

- Design and test your circuit before it goes into the model.
- Use a solderless breadboard to prototype what you want to do.
- Use Ohm's law to determine how many and what kind of resistors you will need as well as how many and what kind of batteries to use.
- Once the design of the circuit is finished and the prototype works, you can begin placing LEDs in the model itself. LEDs can be placed using LED sockets if desired or solderless jumper wires, etc.
- As you build the model, before you seal up the LEDs, test them to make sure the wired connections work.



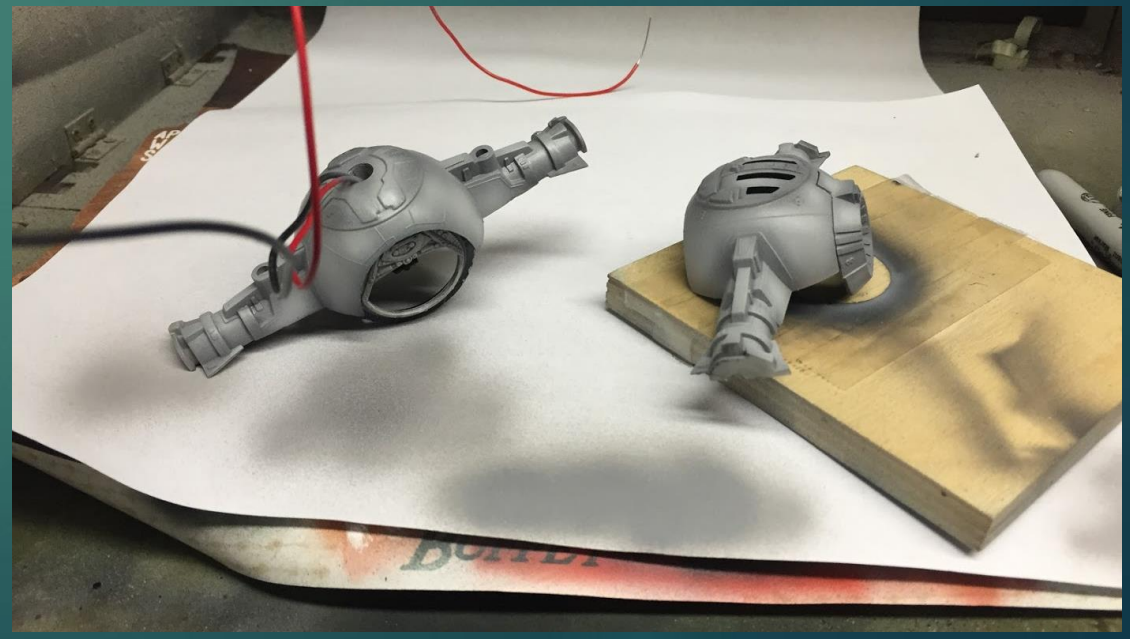
TEST IT FIRST!

Placing LEDs in Your Model

- Determine where to place LEDs at the very beginning of the build process.
- Decide how much space you have, what kind and how many LEDs you can place.
- Decide also what the LEDs will illuminate, and decide whether or not you want them to be visible themselves.
  - They may be somewhat maskable using a matte-coated translucent plate.
- Decide also where the wires will go and where the battery compartment and switch will be.
  - I have found it usually better to place the switches and battery compartment in the stand for the model rather than in the model itself.
  - You may need to replace the kit stand, if provided, with something more suitable for housing the wires, switch and battery.

Placing LEDs in Your Model

- When I built the Tie Interceptor, I decided to have all LEDs in the rear of the cockpit, connected in series, to a 9V battery.
- The battery and switch would be in the base of the model, with wires connecting through the stand opening.
- I replaced the kit stand with a brass tube.



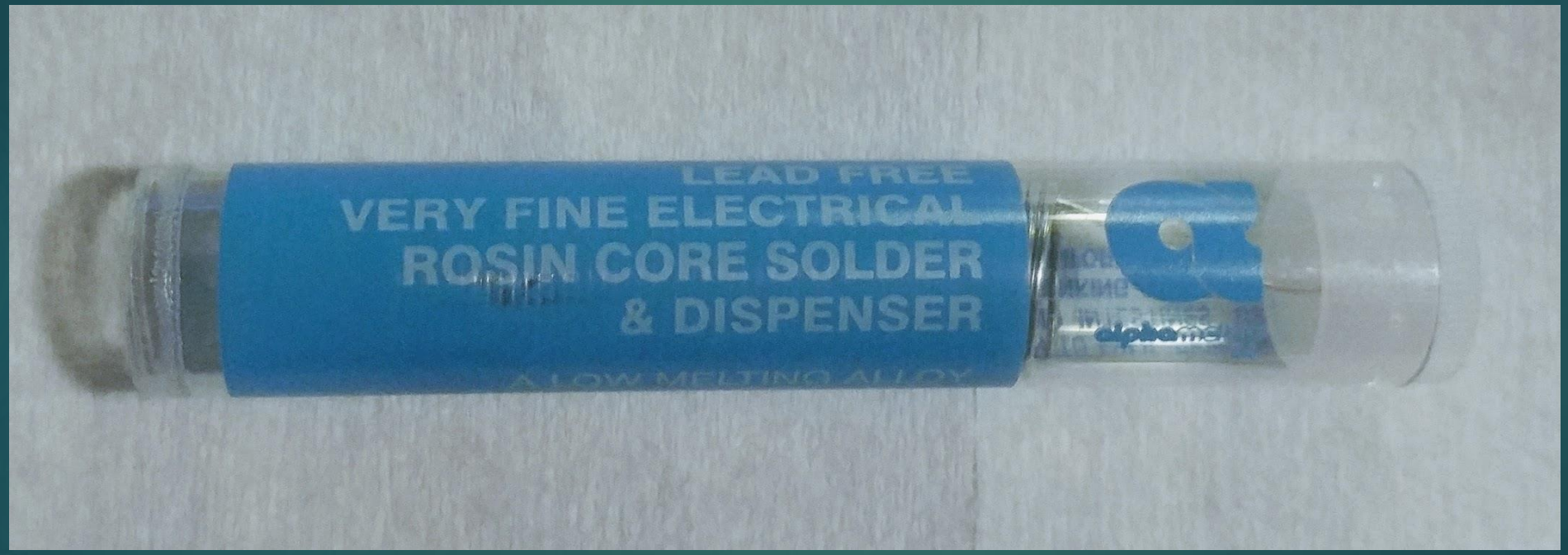
Placing LEDs in Your Model

- The LEDs in the cockpit are visible. If I were to redo this, I would place them in the front, shining back towards the pilot.
- The third LED mimics the Tie's engines. A matte-coated translucent plate masks some of the LED, but not all.

Soldering – Some Basics

- Use a soldering iron with an adjustable heat range.
- If possible, clean the connectors to be soldered thoroughly before soldering. Otherwise the solder may not stick.
- Use an aluminum clamp as a heat-sink to protect the LEDs if they are being soldered directly.
- Use electronics rosin-core solder. Do not use plumbing or other solder. Electronics solder should not require flux.
- **NEVER SOLDER A WIRE DIRECTLY TO A BATTERY.**
- Heat up the connection and melt the solder into the connection. Do not heat up the solder directly with the iron.
- Practice, read the instructions that came with your soldering iron and look up instructional videos online if you are new to soldering.
- **BE CAREFUL** – soldering irons are very hot (up to 800 ° F).
- Bare wires can be covered with liquid electrical tape for insulation once they are cool.

Choose the Right Solder

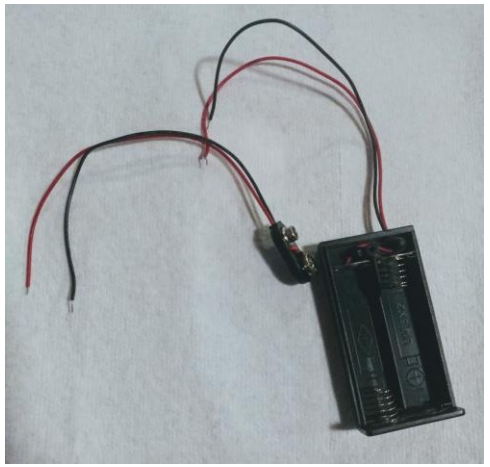


Useful Tools

- Some 22 gauge wire in different colors. You can also get 22 gauge jumper wires which have solderless connectors already attached.
- Wire stripper
- Resistors of varying values.
- LEDs.
- Battery connectors – it is useful to have some for AA, AAA and 9V batteries.
- A solderless breadboard – this is a prototyping board used for testing circuit designs without having to solder them.
- A multimeter can be a useful tool when things do not work.
- A circuit simulator, such as iCircuit, is useful for the layout. (iCircuit is $4.99 from the Microsoft Store).
- A soldering iron, rosin core solder specifically for electronics, a heatsink clamp and some liquid electrical tape.

Useful Tools

- The top left picture has two examples of solderless breadboards.
- The lower-left picture has two examples of battery connectors
- To the right are examples of 22 gauge wire, jumper wires with female connectors and jumper wires with male connectors.



Resources For Shopping and Learning

- One great online resource for both is Sparkfun Electronics - https://www.sparkfun.com/
  - They sell all kinds of electronic components, kits and tools.
  - They also provide educational videos (eg – "How to Solder").
- Lots of components can be purchased from eBay (but you have to know what to look for). The prices on eBay, however, are often lower than on Sparkfun.
- You can still purchase electronic components locally from Fry's.
  - Unfortunately, Radio Shack is pretty much gone.
- For a basic reference, I use volume IV of the Engineer's Mini Notebook by Forrest M. Mims III
  - Available from http://www.masterpublishing.com

Any Questions?