Lighting Basics for Modeling Applications
by Jim Osborn, MMR®

Lighting Basics for Modeling Applications

Today's Topics

- Bulbs vs. Light Emitting Diodes (LEDs)
- Properties of Components
- How to Wire various LED Circuits
- Selecting LEDs
- Interior Lighting Installation Example
- Tools & Components Glossary
- Commercially available Hobby Lighting
- Photo Gallery of Examples
- Reference information

Filament Bulb Properties

Filament Bulbs – AKA Grain of wheat bulbs

- Desirable shape for certain applications – Pole lights, shed lights, under a light shade, etc.
- Bulbs have a nice warm incandescent color temperature.
- Bulbs are voltage controlled. More voltage yields a brighter light output – but lowers its life.
- Bulbs **will** require replacement.
- Cold filament inrush current kills the bulbs. A slow voltage ramp-up circuit will extend their life.
  (See ref. notes)

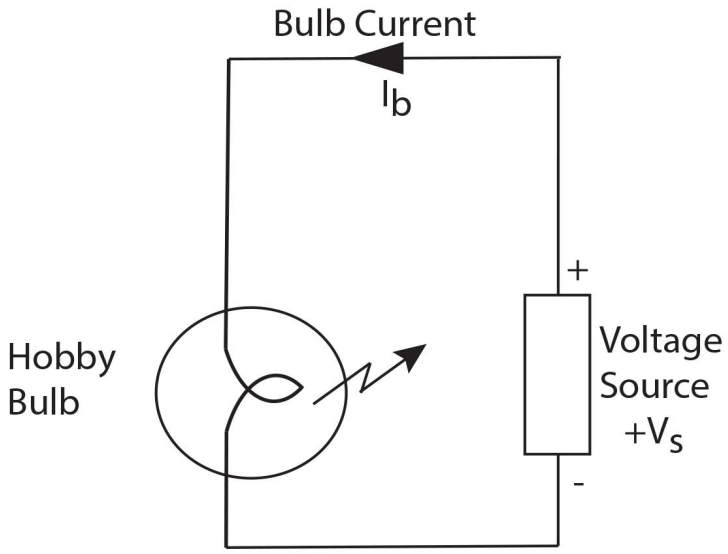
Filament Bulb Properties

Filament Bulb Application

Filament Bulb Properties

Wiring Basics

- A filament bulb is a voltage-controlled device.
- Do not exceed the bulb voltage rating
- Higher voltage > Brighter light > shorter life.
- Bulbs can be run off ac or dc power.
- Bulbs come in a variety of size, voltage and current ratings.



Model 18-001-20
Incandescent Lamps
1.5 Volt 15mA 1.2mm Dia.
Pre Tested Av. Life 500 Hours
(20 pcs.)
Miniatronics Corp.
"electronics for the hobbyist"

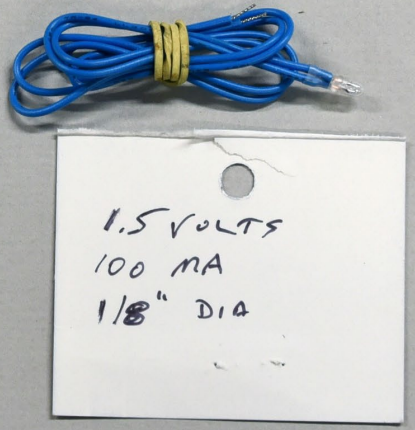
Model 18-701-10
Incandescent Lamps
1.5 Volt 40mA 1.7mm Dia.
Pre Tested Av. Life 5,000 Hours
(10 pcs.)
Miniatronics Corp.
"electronics for the hobbyist"

Model 18-024-20
Incandescent Lamps
12 Volt 50mA 5.5mm Dia.
Pre Tested, Av. Life 10,000 Hours
(20 pcs.)
Miniatronics Corp.
"electronics for the hobbyist"

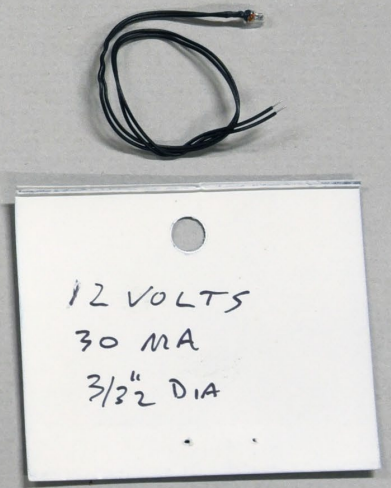
5 VOLTS
50 MA
3/16" DIA

Mo 563 1803
DREAMERS TRAINS
$ 9.95
Incandescent Lamps-Clear
1.5 Volt 30mA 1.2mm Dia.
Pre Tested, Av. Life 500 Hours
(10 pcs.)
.050"
Miniatronics Corp.
"electronics for the hobbyist"

16 Volt 30mA 2.4mm Dia.
Pre Tested Av. Life 10,000 Hours
(10 pcs.)
Miniatronics Corp.
"electronics for the hobbyist"



1.5 VOLTS
100 MA
1/8" DIA

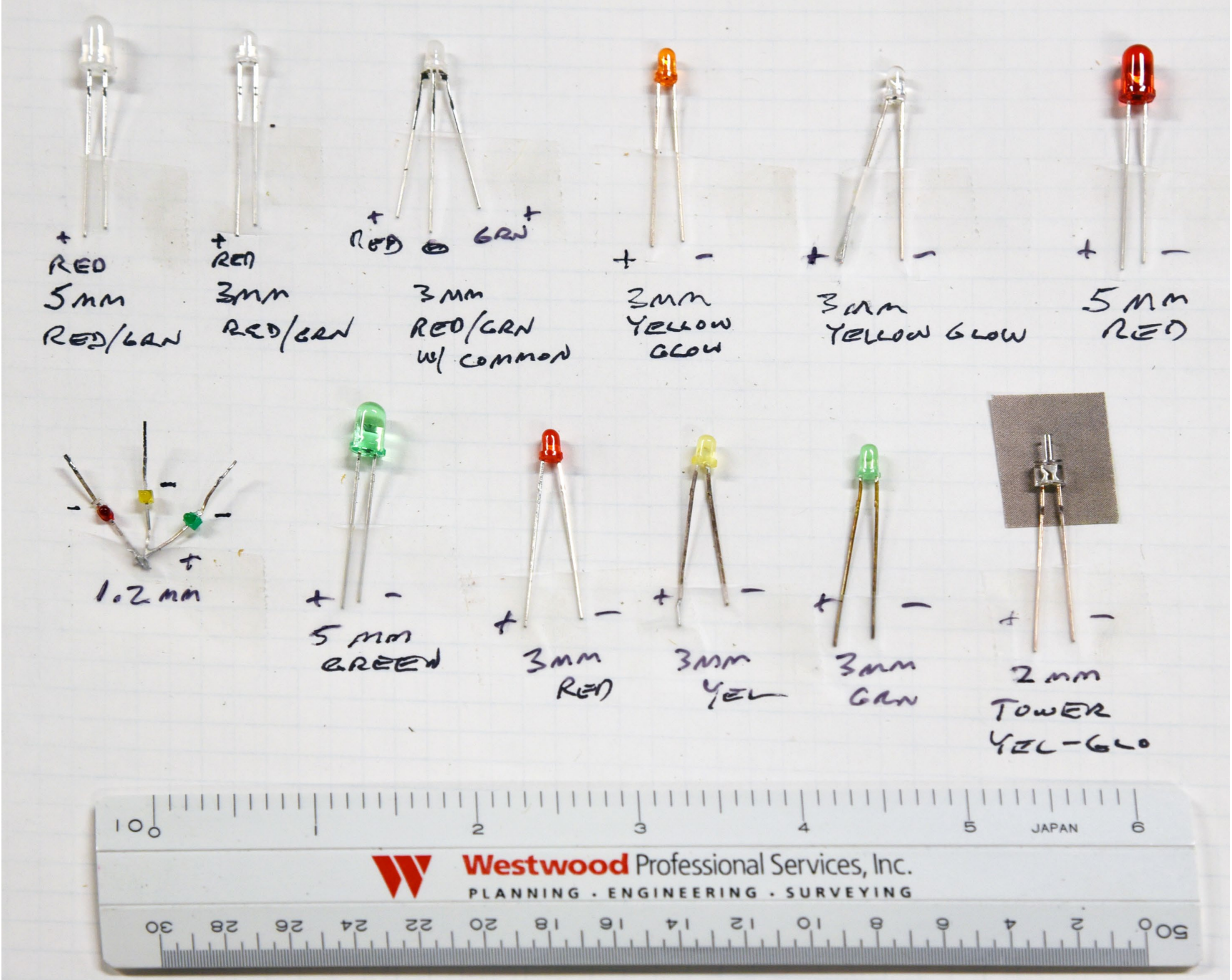


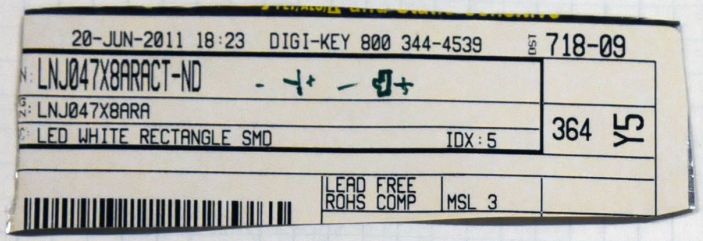
12 VOLTS
30 MA
3/32" DIA

LED Properties

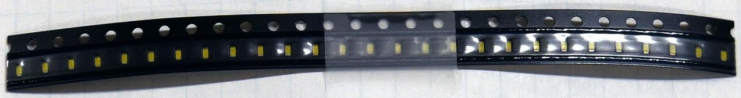
The Versatile LED

- **Very** long life-time.
- Cooler and often use less power than bulbs.
- Available in a variety of colors.
- Can be tinted with glaze paints.
- Great for many applications like streetlights, over door fixtures, ceiling lights, and other space restricted locations.
- Some have multiple colors built in.
- Many shapes & sizes.

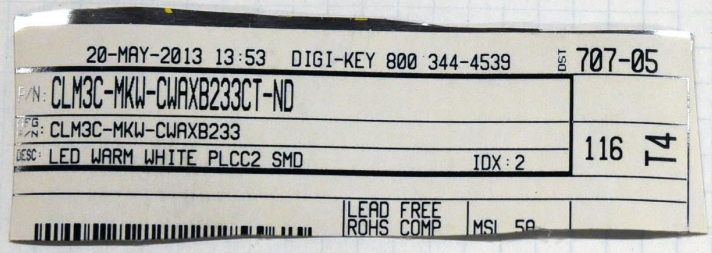

RED
5MM
RED/GRN
RED
3MM
RED/GRN
RED
GRN
3MM
RED/GRN
W/ COMMON
3MM
YELLOW
GLOW
3MM
YELLOW GLOW
5MM
RED
1.2MM
5 MM
GREEN
3MM
RED
3MM
YEL
3MM
GRN
2MM
TOWER
YEL-GLO
Westwood Professional Services, Inc.
PLANNING · ENGINEERING · SURVEYING
JAPAN

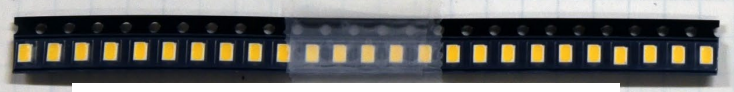


1.5 mm white
10 ma.



2.0 mm white
20 ma.

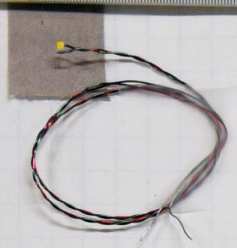




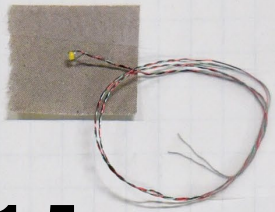
3.0 mm soft white
20 ma.

Surface Mounted LEDs (SMD)

Pre-wired SMDs

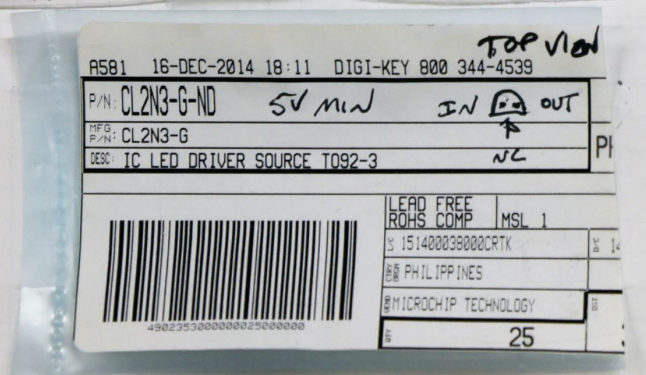


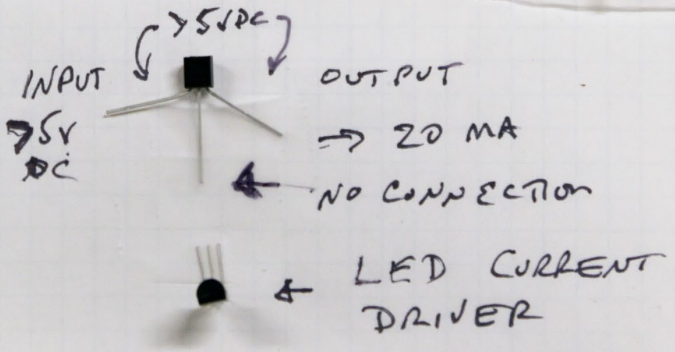
RED = +
GRN = −



2.0 mm

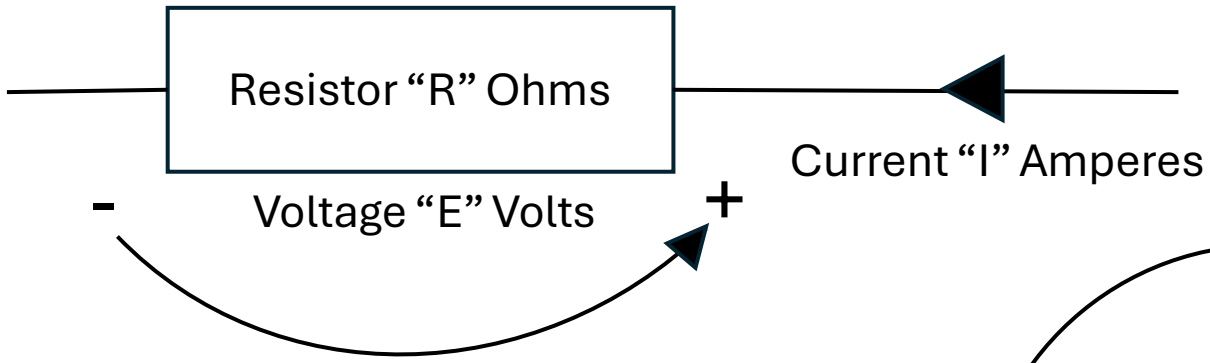
1.5 mm



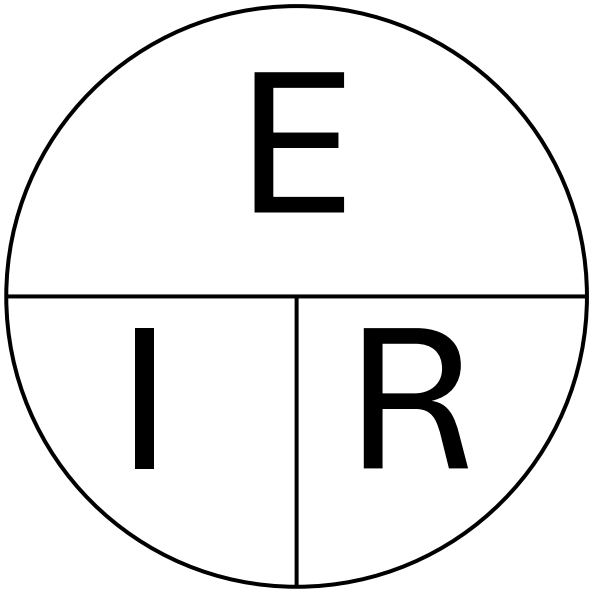


E. E. 101

Electronics Basics – Ohm's Law



- Ohm's Law E = I x R
- Remember this simple Icon
- Cover the element you're solving for
- The remaining symbols define the ratio



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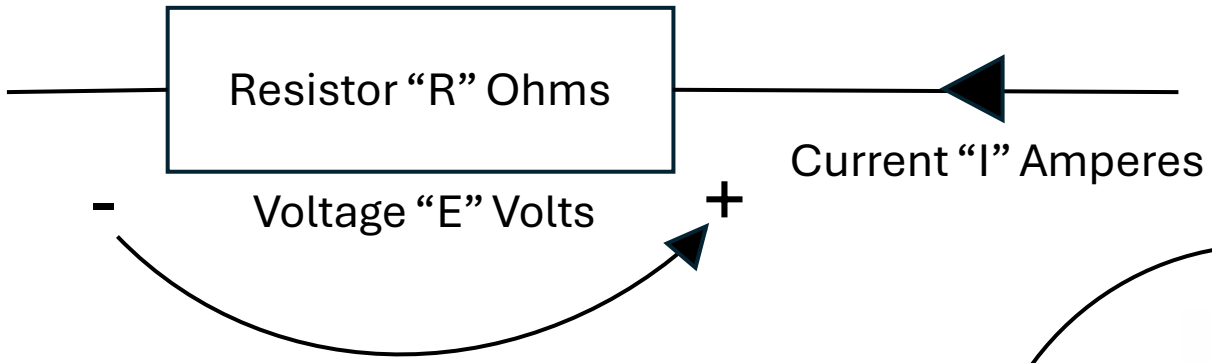

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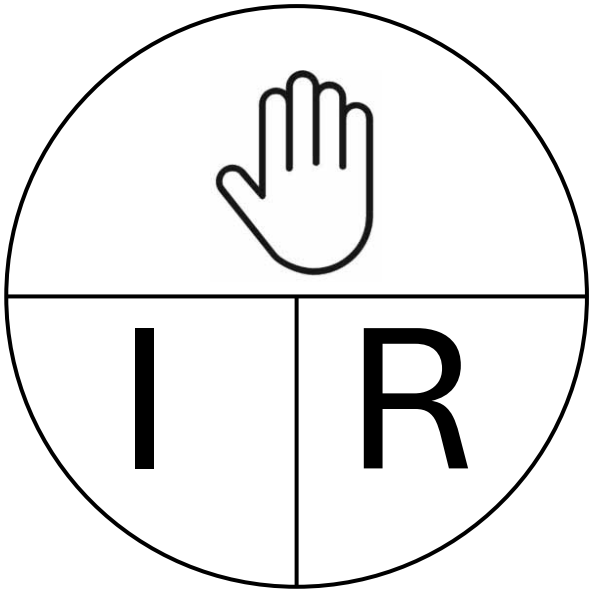

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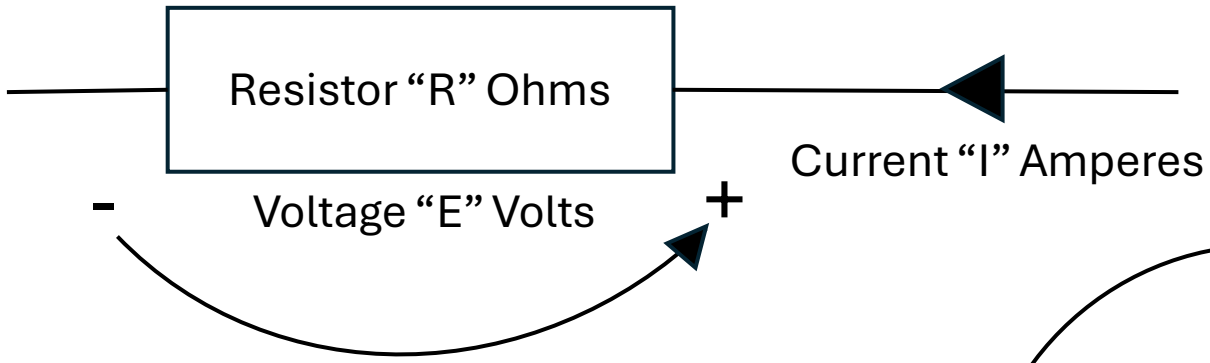
Electronics Basics – Ohm's Law



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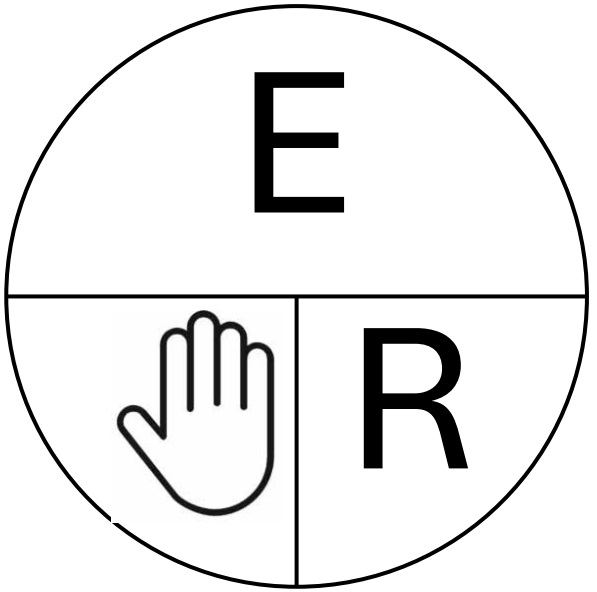

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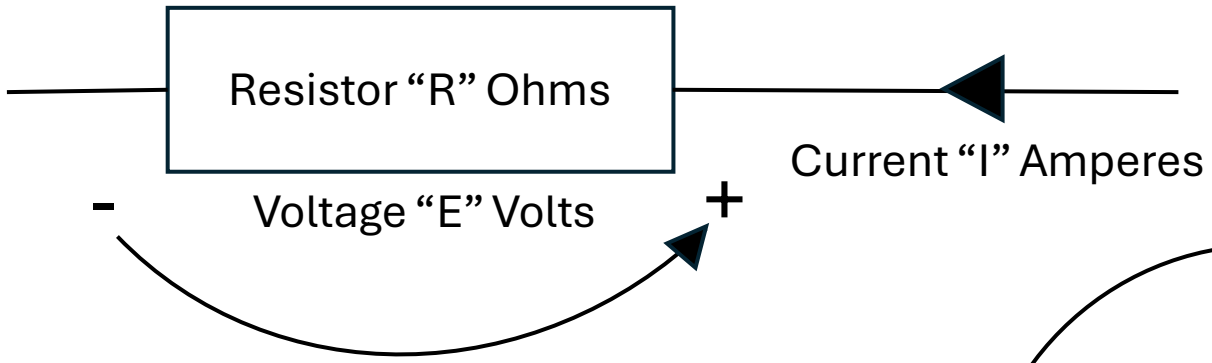
Electronics Basics – Ohm's Law



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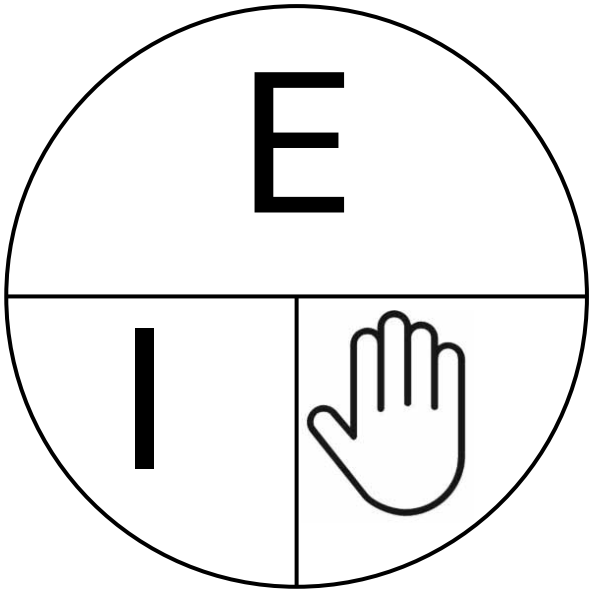


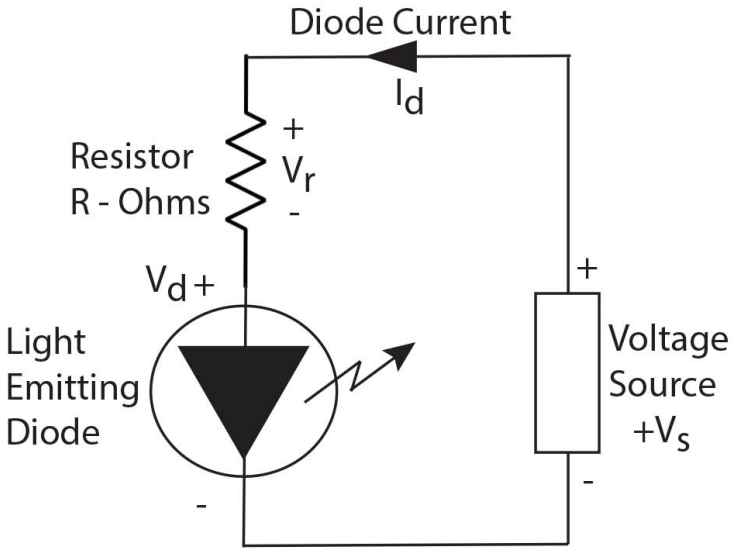
LED Properties

LED Applications

LED Properties

LED Wiring Basics

- Current controlled device not voltage controlled like a bulb.
- Brightness is a function of the current flowing through it.
- More current yields a brighter light output.
- Most will usefully illuminate with 5 to 20 milliamps (ma) current flow.
- White LEDs have a max continuous current rating of 20 ma and a voltage drop of approximately 3 volts.
- DO NOT apply a voltage source directly across the LED. You will likely kill it!
- The wattage rating of the series resistor needs to be calculated.



Governing Equations

$Vs = Vr + Vd$

or

$Vr = Vs - Vd$

Need to calculate R

$Vr = Ir \times R$ (Ohm's law)

or

$R = Vr/Id$

Power dissipated in R

$Pr = Id \times Id \times R$ (watts)

LED Properties

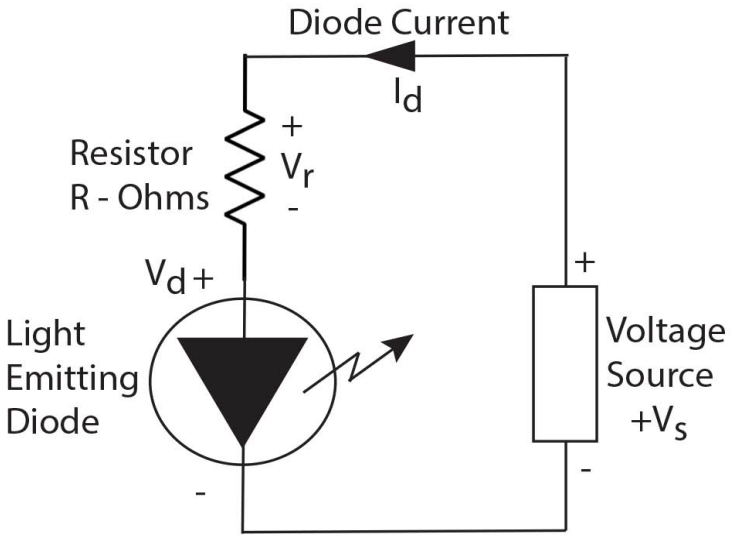
LED Wiring Basics Example 1

The value of resistor R sets the current through the LED.

If Vs = **12 volts** and Vd = 3 Volts, then Vr will = 9 volts

If we want Id to = **.02 amps (20 ma)** then **R = 450 ohms**
(470 ohms is a standard value)

Resistor wattage = 0.18 watts (Use a ½-watt resistor. Design practice is to keep resistor dissipation to half its rated value.)



Governing Equations

Vs = Vr + Vd
or
Vr = Vs - Vd

Need to calculate R
Vr = Ir x R (Ohm's law)
or
R = Vr/Id

Power dissipated in R
Pr = Id x Id x R (watts)

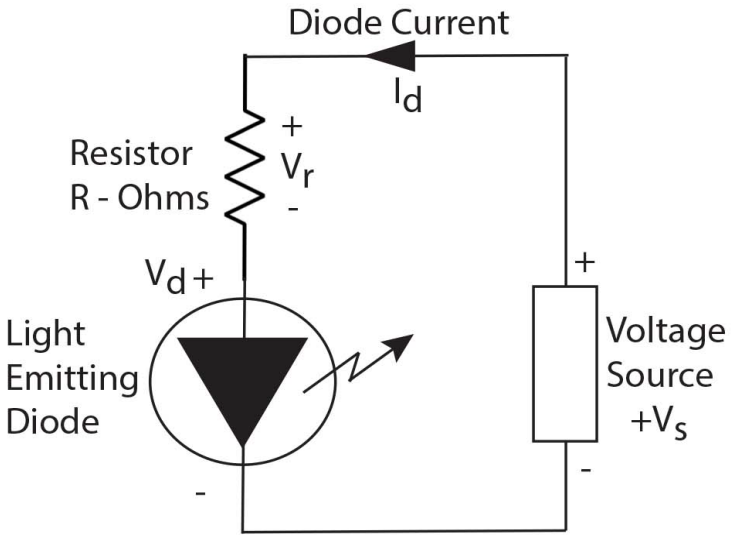
LED Properties

LED Wiring Basics Example 2

If Vs = **12 volts** and Vd = 3 Volts, then Vr will = 9 volts

If we want Id to = **.01 amps (10 ma)** then **R = 900 ohms**
(1000 ohms is a standard value)

Resistor wattage = 0.09 watts
(1/4-watt resistor will do)



Governing Equations

$Vs = Vr + Vd$
or
$Vr = Vs - Vd$

Need to calculate R
$Vr = Ir \times R$ (Ohm's law)
or
$R = Vr/Id$

Power dissipated in R
$Pr = Id \times Id \times R$ (watts)

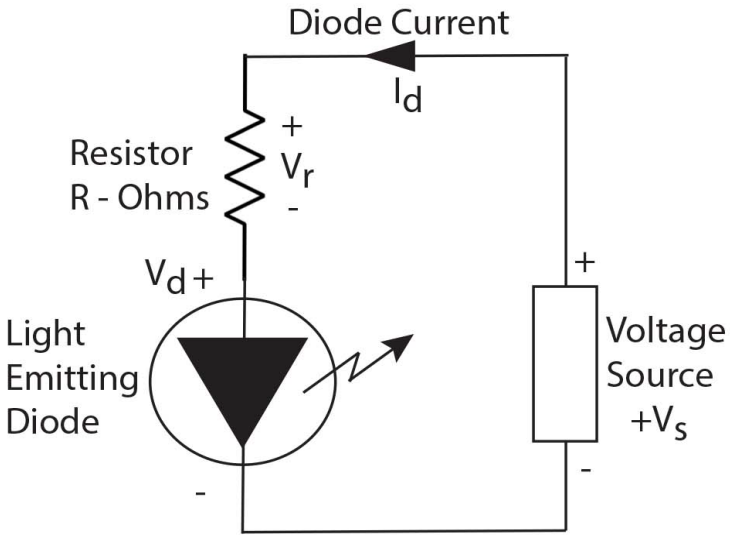
LED Properties

LED Wiring Basics Example 3

If Vs = **5 volts** and Vd = 3 Volts, then Vr will = 2 volts

If we want Id to = **.02 amps (20 ma)** then **R = 100 ohms**.

Resistor wattage = 0.04 watts
(1/8 or 1/4-watt resistor)



Governing Equations

$Vs = Vr + Vd$
or
$Vr = Vs - Vd$

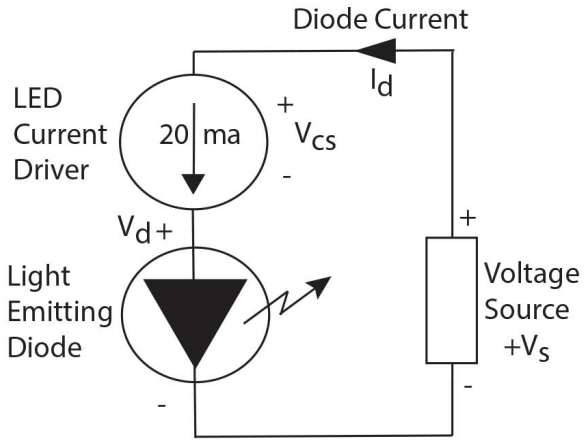
Need to calculate R
$Vr = Ir \times R$ (Ohm's law)
or
$R = Vr/Id$

Power dissipated in R
$Pr = Id \times Id \times R$ (watts)

LED Properties

LED Wiring LED Driver - Example 4

- An **LED Driver** replaces the resister in the LED circuit
- An **LED Driver** supplies a constant current if its minimum voltage is maintained.
- Small LED drivers require at least 5 volts across them.
- In this example the driver supplies 20 ma to what ever is connected to it.
- A quick and easy LED circuit.



Current Source Governing Equations

$Vs = Vcs + Vd$

Voltage across the current source must be > 5.0 volts, so --

Vs must be > 5.0 + Vd

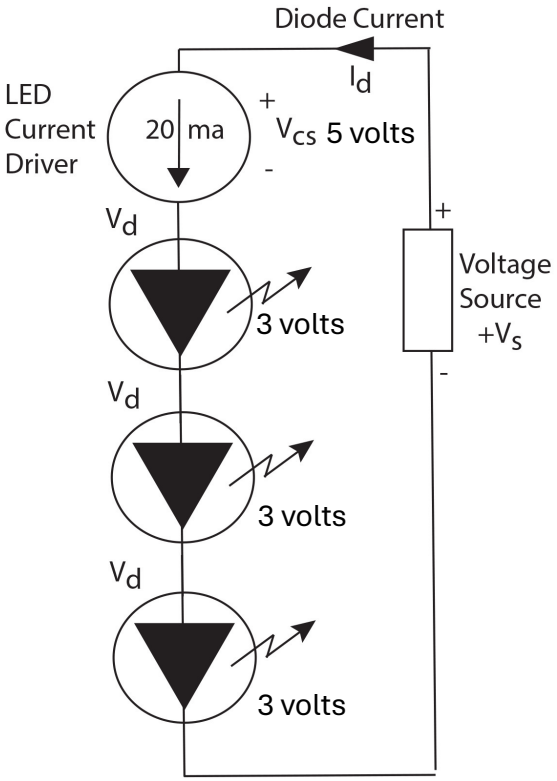
Assume Vd = 3.0 volts therefore Vs must be greater than 8 volts

LED Properties

LED Wiring LED Driver - Example 5

- In this example the driver supplies 20 ma to what ever is connected to it.
- A quick and easy LED circuit.
- There is no limitation on the number of LEDs added as long as the minimum driver voltage is maintained at greater than 5 volts.
- In this case Vs = 3 x Vd+5 or

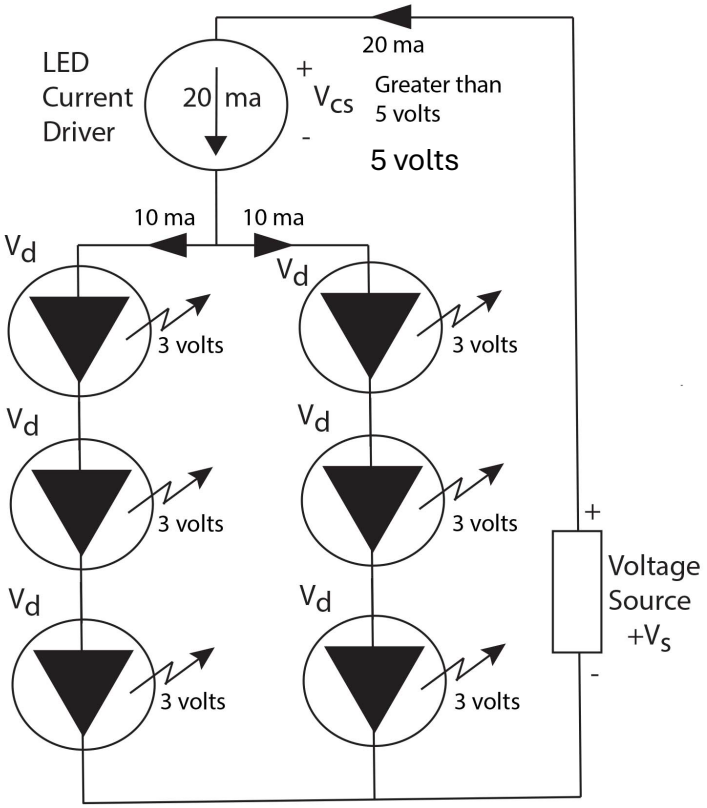
  3 x 3 + 5 = 14v or greater



LED Properties

LED Wiring LED Driver - Example 6

- An **LED Driver** replaces the resister in the LED circuit
- In this example the driver supplies 20 ma to what ever is connected to it.
- In this example the 20 ma source current is split down the two LED legs.
- The LEDs should be same to balance the current paths.
- There is no limitation on the number of LEDs added as long as the minimum driver voltage is maintained. (5 volts)
- In this case Vs = 3 x Vd + 5 or
  greater than 3 x 3 + 5= 14v.



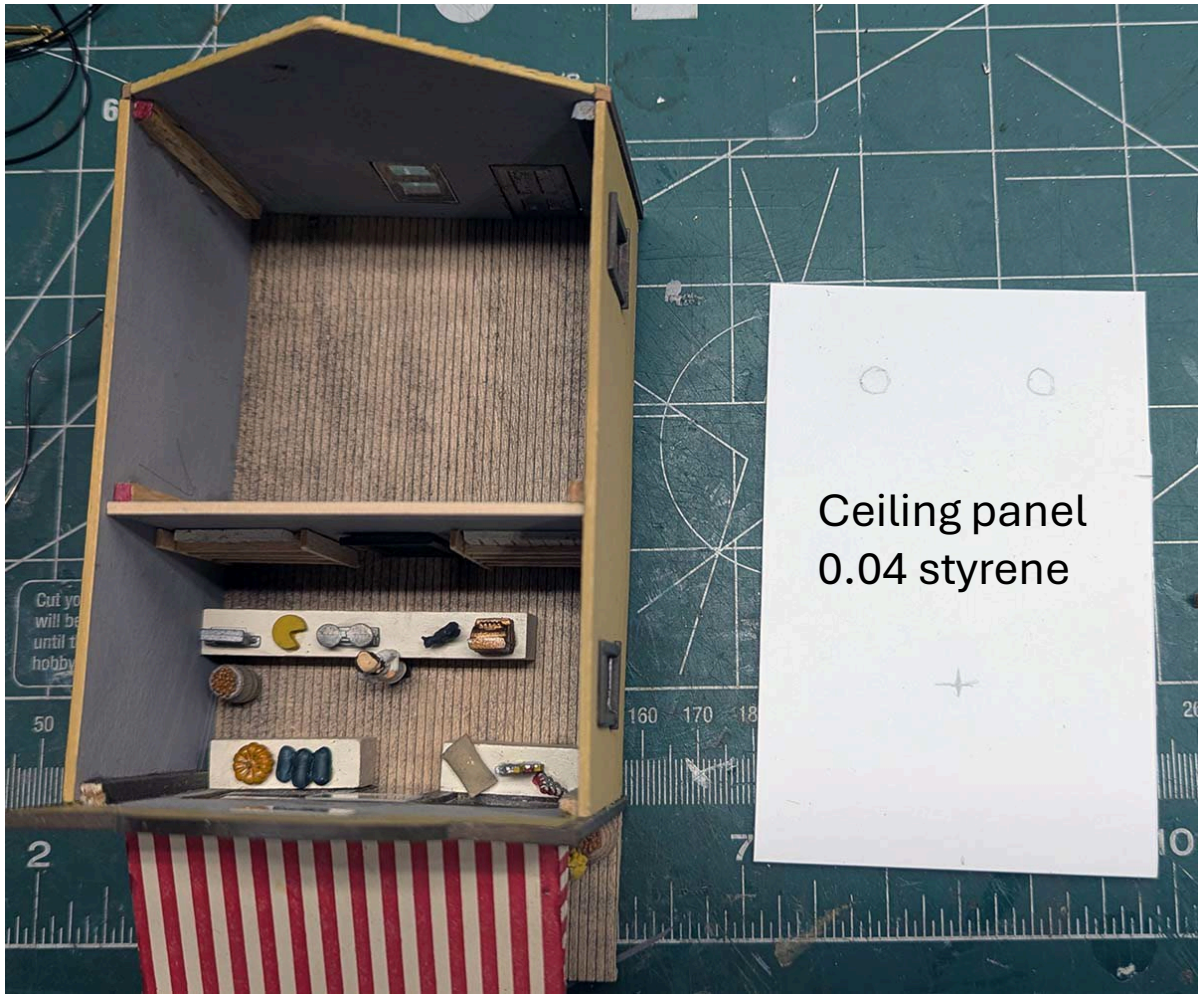
Selecting LEDs

Many choices – Here's a couple suggestions

- For the 1.5 and 2 mm LED sizes I buy pre-wired LEDs
  -- they come with or without 9-12v sized resistors
- In most cases use "cool white" LEDs for general lighting
- Over door goose neck lights – 2.0 mm SMD @ 10 ma current flow
- Modern street lights – 2.0 mm SMD @ 20 ma current flow
- Modern In building ceiling lights – 3 mm SMD @ 10 to 20 ma
- Old building lighting – 3 mm SMD @ 10 to 20 ma & orange glaze
- Target signals – 1.5 to 3 mm leaded two color two or three leaded.
  -- two leaded bi-color leds require a special driver circuit for yellow.
- 3 light vertical signals – R, Y & G in an appropriate size for the target.
- Panel lights - 5 mm single or bi-color depending on need.
- Turnout indicators – 3 or 5 mm bi-color.

Interior Lighting Installation Example

Let’s light up this small shop.

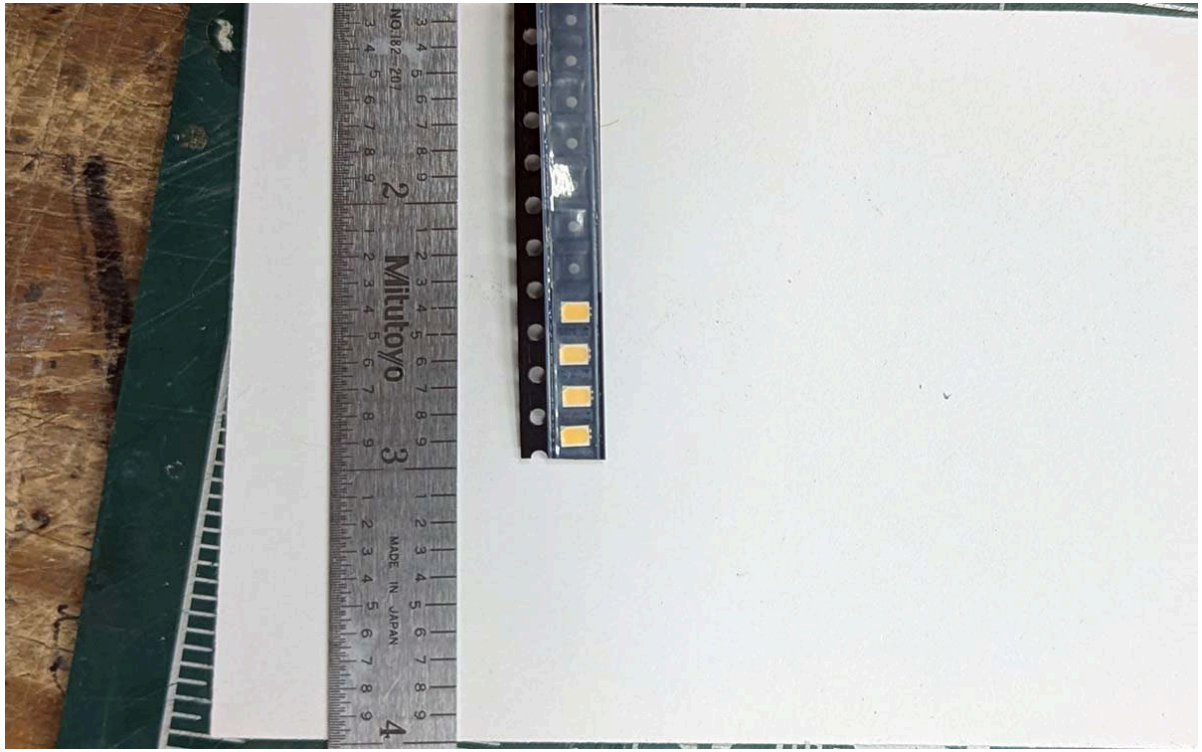


Interior Lighting Installation Example

Copper foil adhesive tape will be used to connect the LEDs

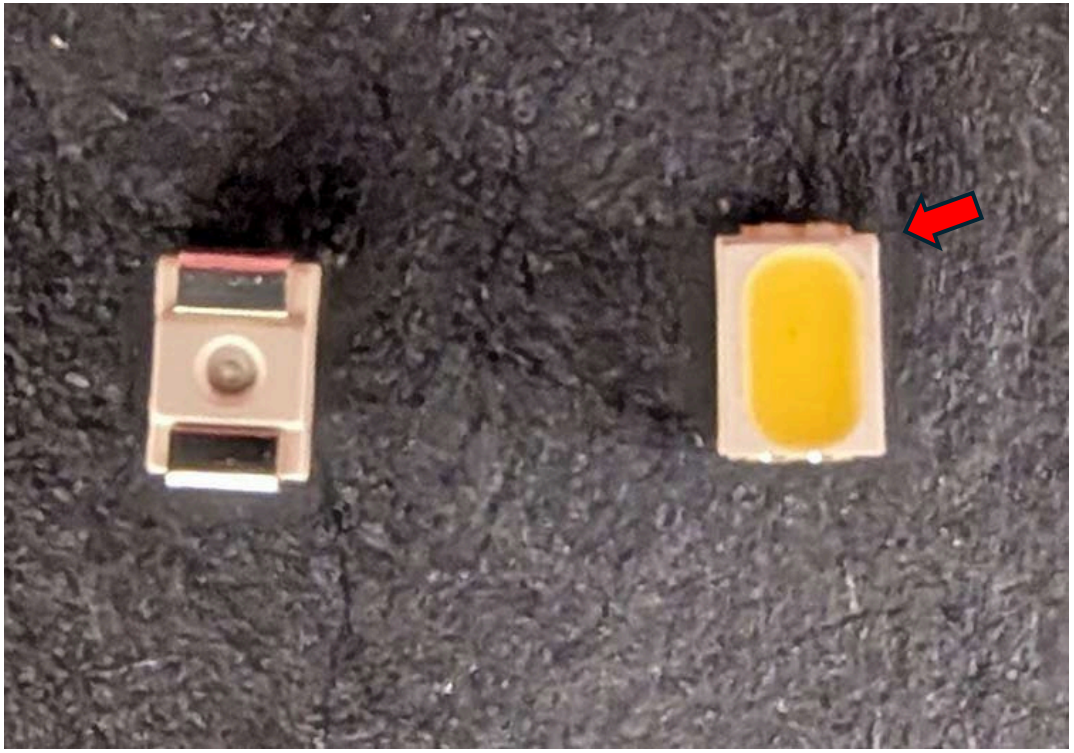
Interior Lighting Installation Example

3 mm SMD LEDs for the ceiling lights



Interior Lighting Installation Example

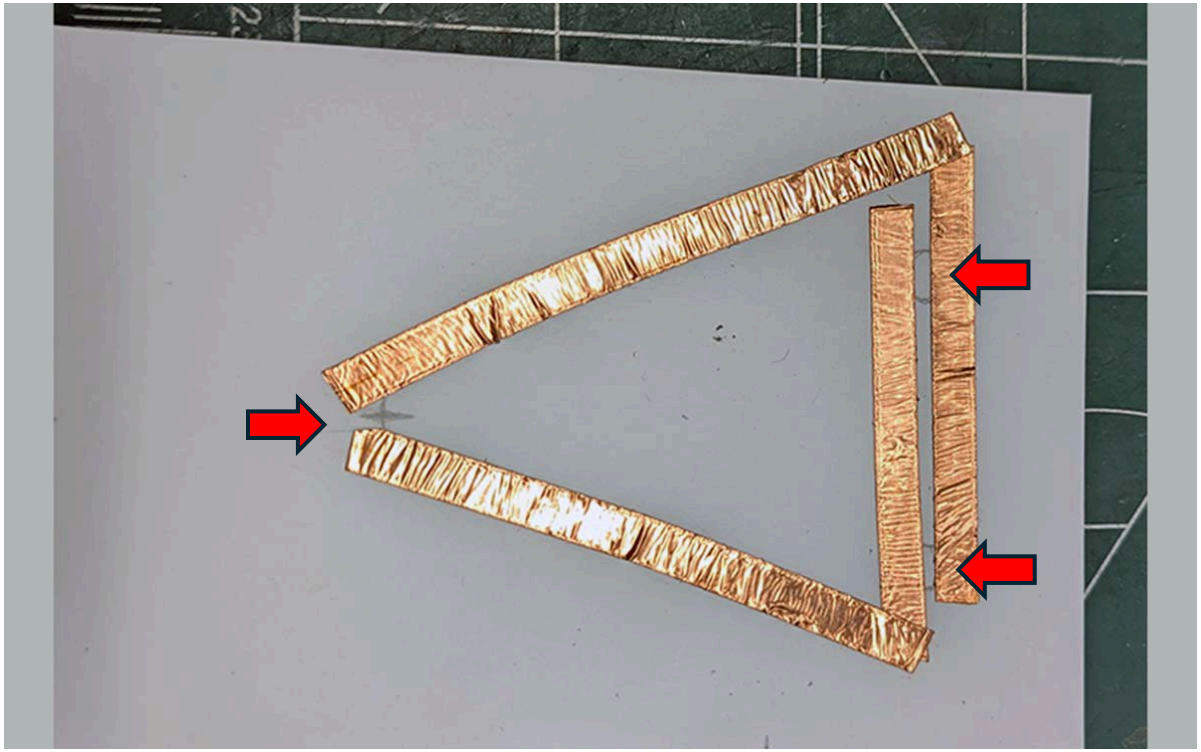
Front and back of an SMD LED. Note the notch on the upper right corner that denotes the Anode or + connection.



Interior Lighting Installation Example

The LED positions are marked and the tape applied.

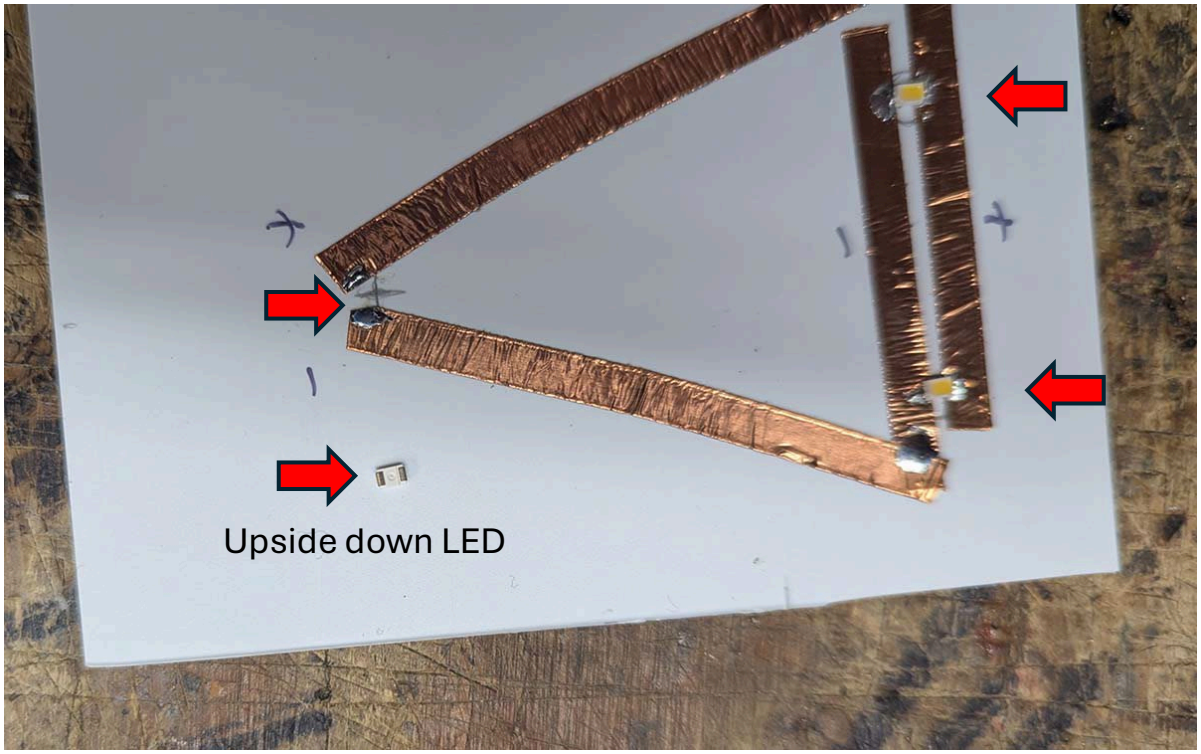
The LEDs will bridge the + and – tape runs.



Interior Lighting Installation Example

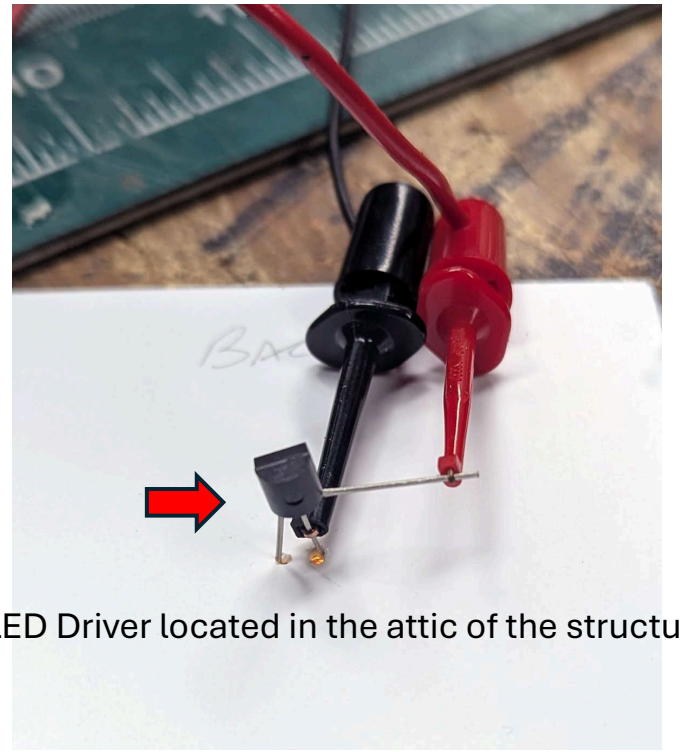
The LEDs will bridge the + and – tape runs.

Solder the tape joints and pre tin the LED contact locations. Mark the + and – tape runs.



Interior Lighting Installation Example

Attach a LED driver or resistor on the opposite side of the ceiling panel. Connect the output lead to the + foil tape on the opposite side

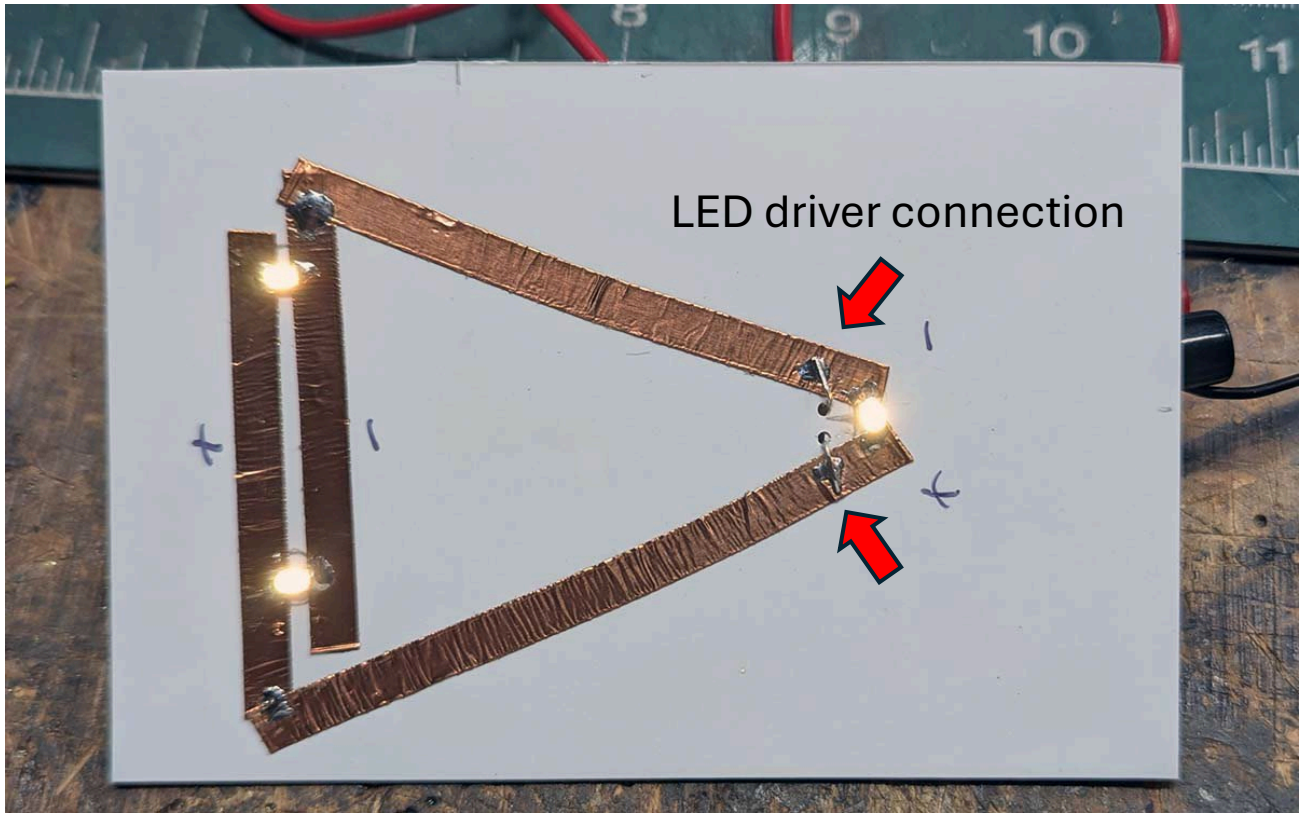


LED Driver located in the attic of the structure

Interior Lighting Installation Example

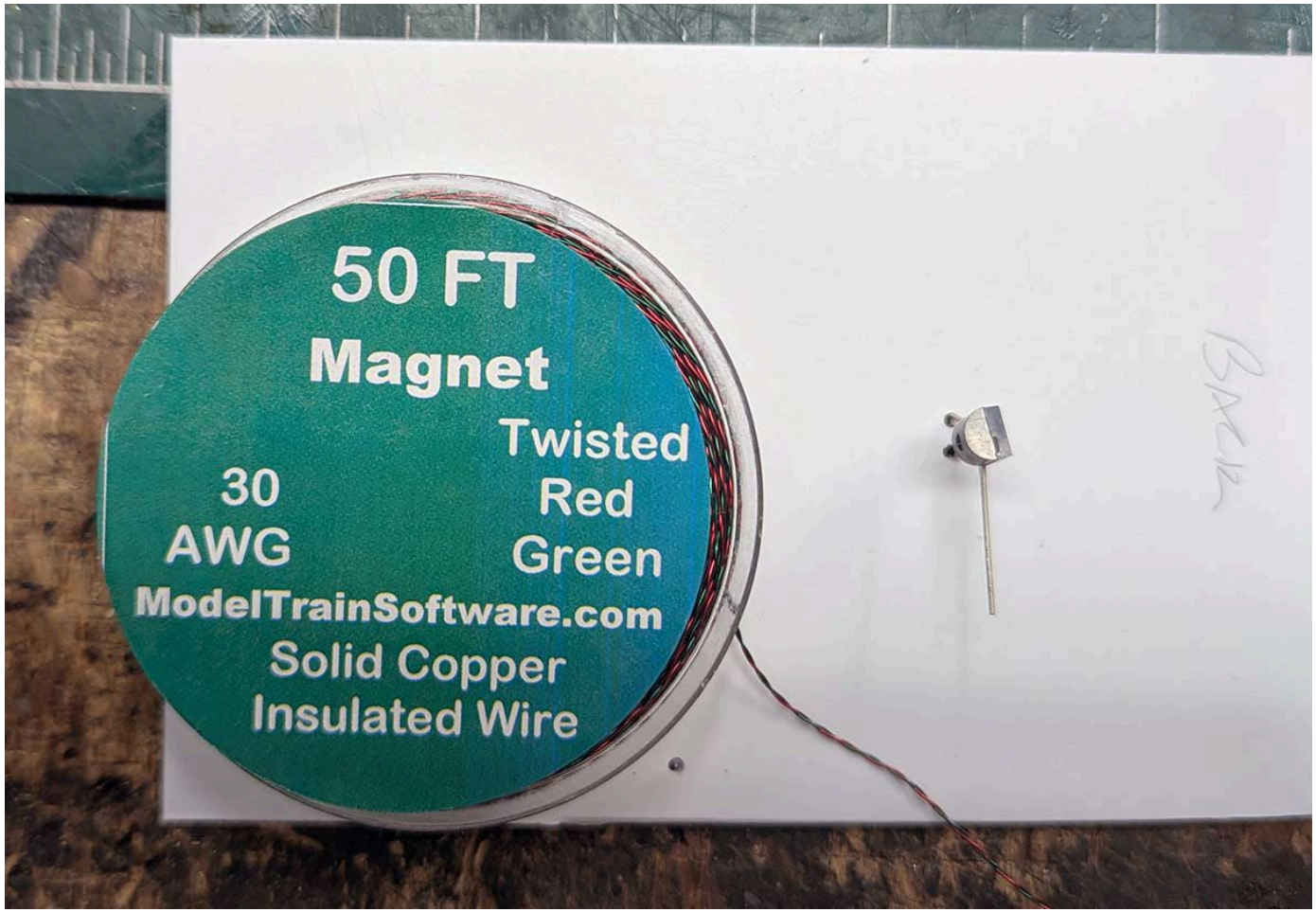
Always test the lights before proceeding.

The LED driver is on the opposite side.



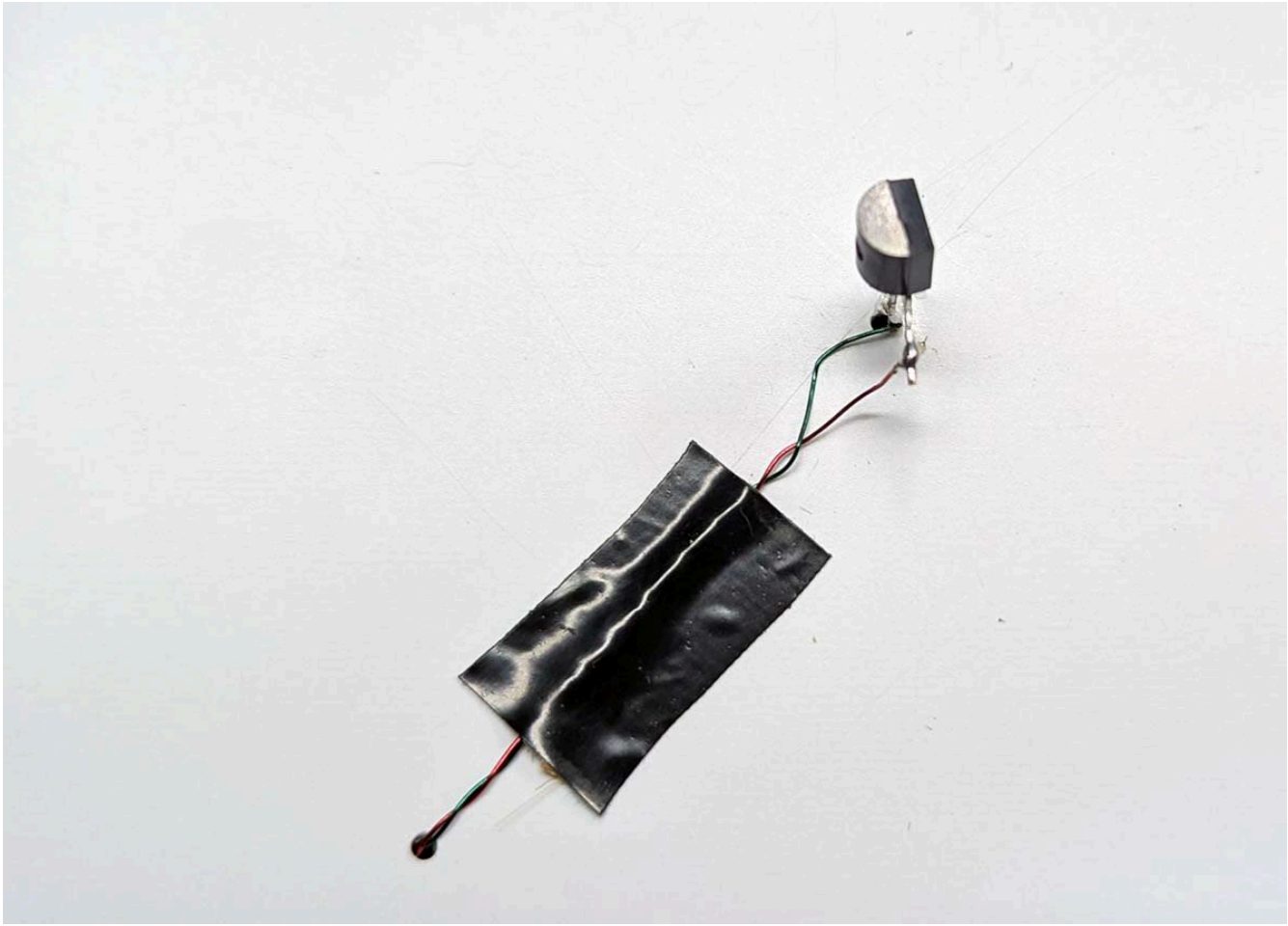
Interior Lighting Installation Example

Prepare the wiring connection for the structure.



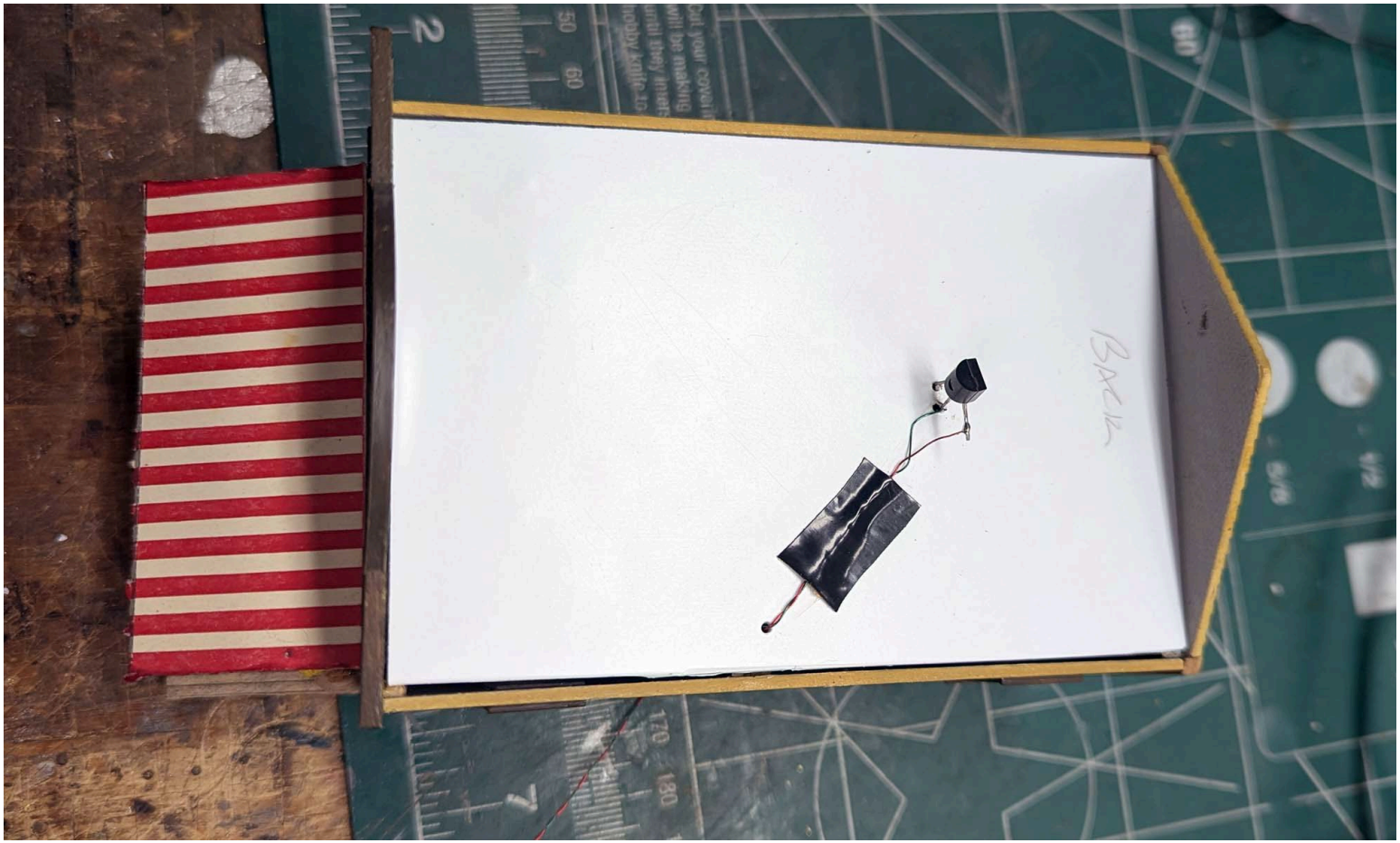
Interior Lighting Installation Example

Prepare the wiring connection for the structure.



Interior Lighting Installation Example

Fit the lighting panel in the structure and add the roof.



Interior Lighting Installation Example

Open for business!

Tools & Components Glossary

Tools

-40 watt adjustable heat soldering iron
-Small wet sponge to clean the iron tip
-0.031 diameter thin rosin core solder
-Fine tipped tweezers & an Xacto knife
-Volt-ohm-ammeter – nothing fancy
-Hemostat clamp - dental pick
-Small drills and pin vises

Soldering

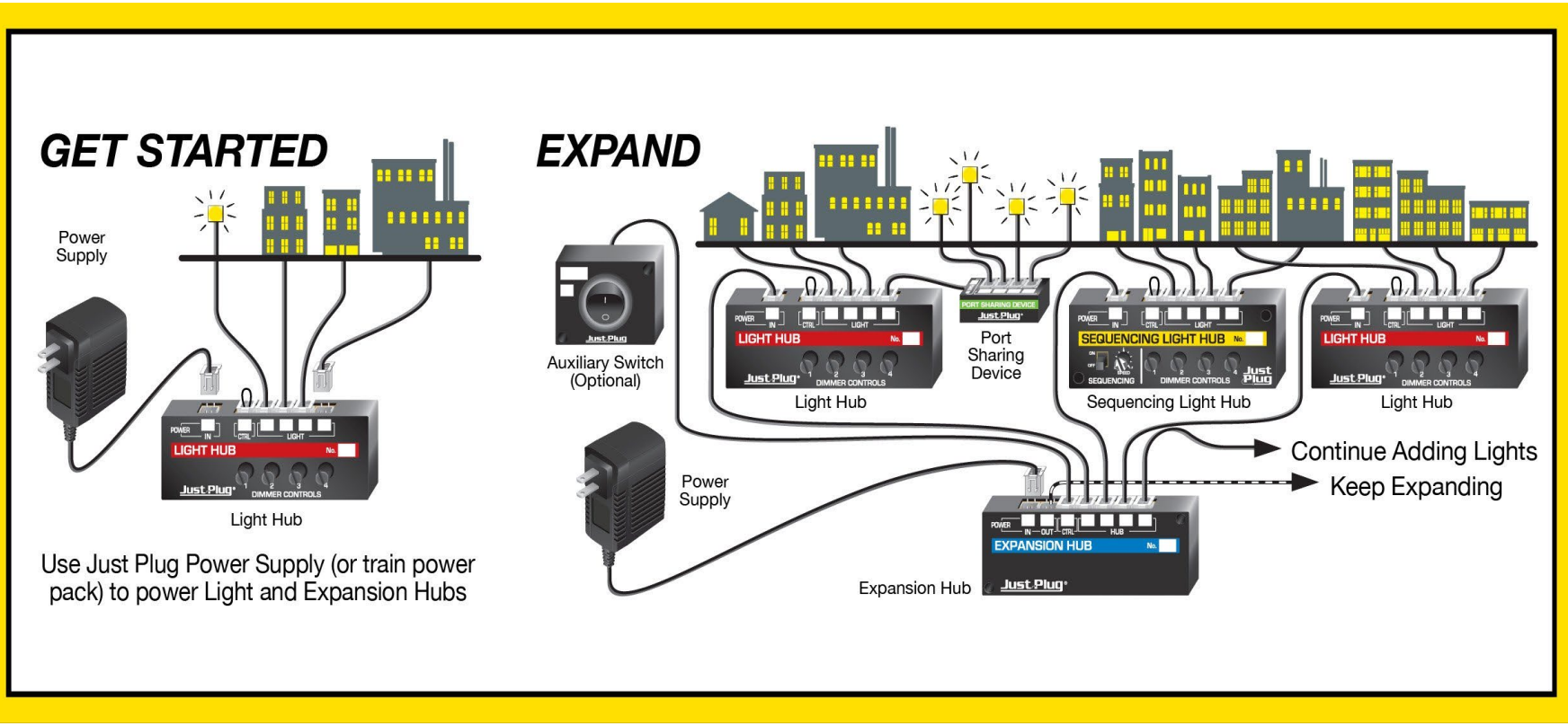
-Keep the iron tip clean – essential!
-Pre-tin the copper tape connections.
-Do not dilly-dally on the copper tape – use a hot iron but be quick.
-Hold down the SMDs with a dental pick, heat the copper for the 1st joint – be quick.
- The second LED connection is easy

Components

-Long life bulbs, lamp shade, other Miniatronics
-Various LEDs , resistors & other DigiKey, Jemco, Mouser
-TO-92 package LED Drivers DigiKey, Jemco, Mouser
-Copper tape – Hobby Lobby ¼ inch
-30 AWG R/G twisted magnet wire
-Pre-wired LEDs – Evan Designs
-Other LEDs – Evan Designs – D., J., or M.
-Thin tubing, lamp shades, wire & all kinds of lighting stuff www.ngineering.com
-Tamiya Clear Glazes Red, Orange and Green. Orange makes a nice incandescent lamp.

Commercially available Hobby Lighting

Woodland Scenics has a very broad selection on pre-configured lighting accessories – and it's Plug n Play!



Commercially available Hobby Lighting – to Name a Few.

Woodland Scenics Just Plug Lighting System

- Traffic Lights
- Vehicles
- Street Lights
- Train Yard Lights
- Wall Mount Lights
- Pre-lit Buildings
- LED Lights
- Bill Boards

Walthers Lighting Categories

- Street Lights
- Signals
- Passenger car interiors
- Buildings
- Wall mount
- Grade Crossing Signals

Commercial Street Lighting in Use

Photo Gallery – Team Track

Photo Gallery – Sterling Station

Photo Gallery – Auction House

Photo Gallery – Patrone Ready-Mix

Photo Gallery – Icing Ramp

Photo Gallery – Gravel City

Photo Gallery – Lumber Yard Workshop

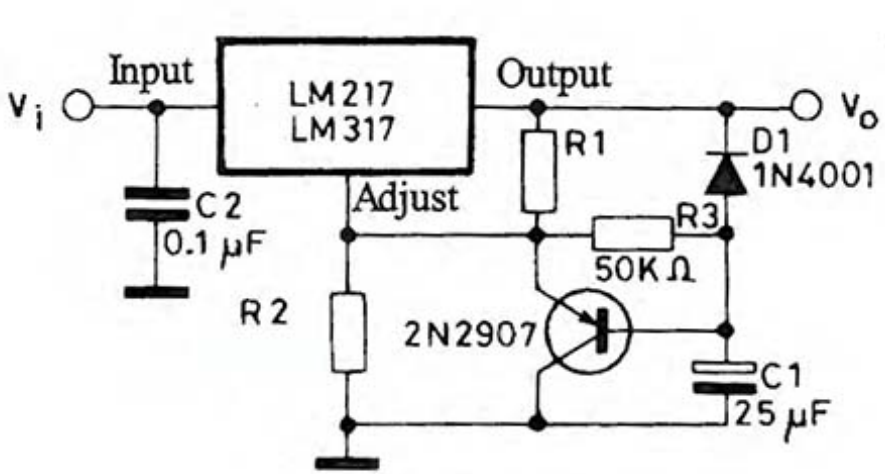
Photo Gallery – Flower Shop

Photo Gallery – Row Houses
Jerry Marci's Pennsylvania Horseshoe Curve RR

Photo Gallery – Fire Station

Photo Gallery – Wheel Works

Reference Sheet – Slow turn-on Power Supply



Slow Turn-on Regulator

For 1.5v output

R1=2700 Ohms

R2 = 540 Ohms

(Adjustable)

For 12v output: R2=2200 Ohms (adjustable) & R1= 270 Ohms

For 10v output: R2=2000 Ohms (adjustable) & R1= 270 Ohms

Reference Sheet – LED Resistor Calculator

LED Dropping resistor calculator

Series resistor values given LED forward voltage drop as entered in the brown box below.

LED forward voltage drop = **3.0** volts

DC Supply Voltage	LED Current in milliamps						
	5	7.5	10	12.5	15	17.5	20
5	400	267	200	160	133	114	100
6	600	400	300	240	200	171	150
7	800	533	400	320	267	229	200
8	1000	667	500	400	333	286	250
9	1200	800	600	480	400	343	300
10	1400	933	700	560	467	400	350
11	1600	1067	800	640	533	457	400
12	1800	1200	900	720	600	514	450
13	2000	1333	1000	800	667	571	500
14	2200	1467	1100	880	733	629	550
15	2400	1600	1200	960	800	686	600
16	2600	1733	1300	1040	867	743	650
17	2800	1867	1400	1120	933	800	700
18	3000	2000	1500	1200	1000	857	750
19	3200	2133	1600	1280	1067	914	800
20	3400	2267	1700	1360	1133	971	850

Note: Use the next largest standard resistor value from the calculated chart value.
It is not necessary to be 100% accurate unless you are targeting currents near the 20ma range.

Cell color shows minimum resistor wattage required >> 1/8 watt | 1/4 watt | 1/2 watt

Ranges of Forward voltage drops for various LED colors			
Color	Vf - Min	Vf - Max	Vf - Avg
Infrared	1.6	1.6	1.6
Red	1.6	2.0	1.8
Orange	2.0	2.1	2.1
Yellow	2.1	2.2	2.1
Green	1.9	4.0	3.0
Blue	2.5	3.7	3.1
Violet	2.8	4.0	3.4
Purple	2.5	3.7	3.1
Ultraviolet	3.1	4.4	3.8
Pink	3.3	3.3	3.3
White	2.8	3.5	3.2

Voltages vary by specific LED. These values are from Wikipedia and my own tests. Best to try a value, measure Vf and then recalculate to get the correct value. This is important if you are targeting currents near the 20ma limit value.

Note that most common LEDs have a maximum forward current of 20ma. Some of the micro surface mount LEDs have a continuous rating of 5 ma. Consult a spec sheet for exact operating limits.

Use this link to download your own copy of the calculator

https://www.foxvalleydivision.org/fvd2016/imagesfvd2016/clinicdata/led-resistor-selection.xlsx

A Green Board Ahead to light up your Pike!
Any Questions?