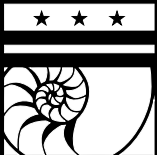


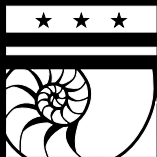
Intro to Electronics

Week 2

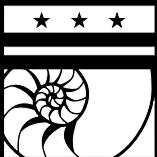


Build a simple power supply

TODAY'S PROJECT

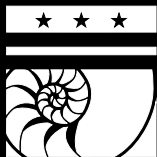


BUT FIRST:



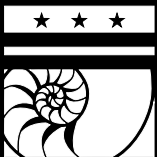
How to measure what your circuit's doing

TEST EQUIPMENT

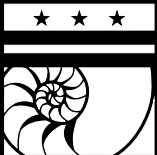


Multimeter

- Measures all kinds of things
 - Voltage
 - Current
 - Resistance
 - Other fancy things
 - Tests continuity
 - Some can give diode and transistor properties
 - etc.

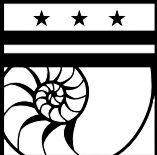
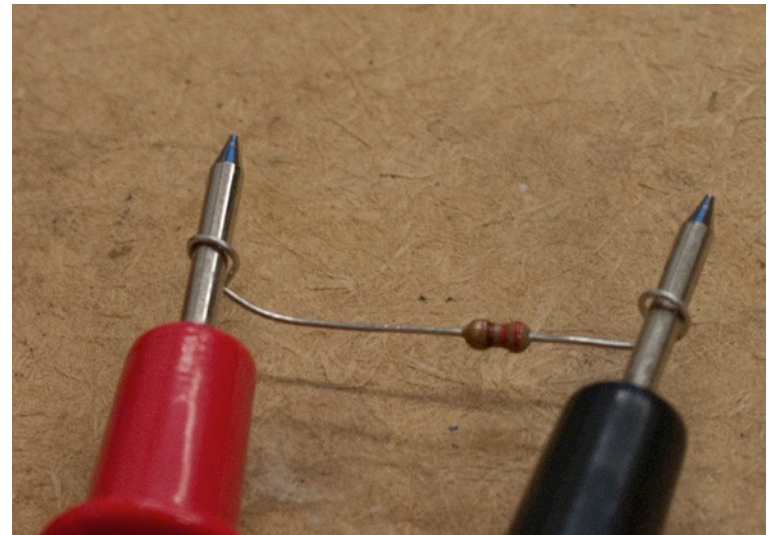
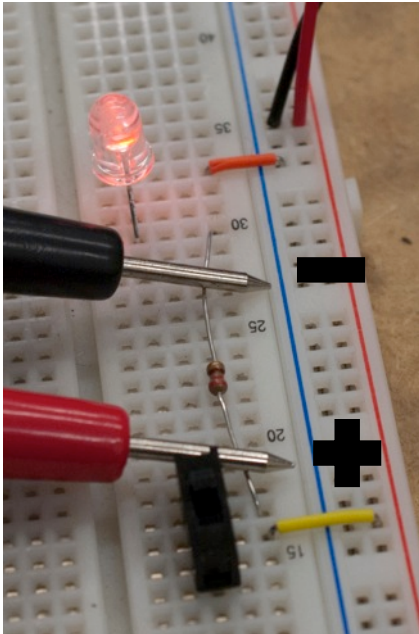


Choosing a measurement



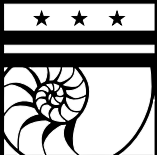
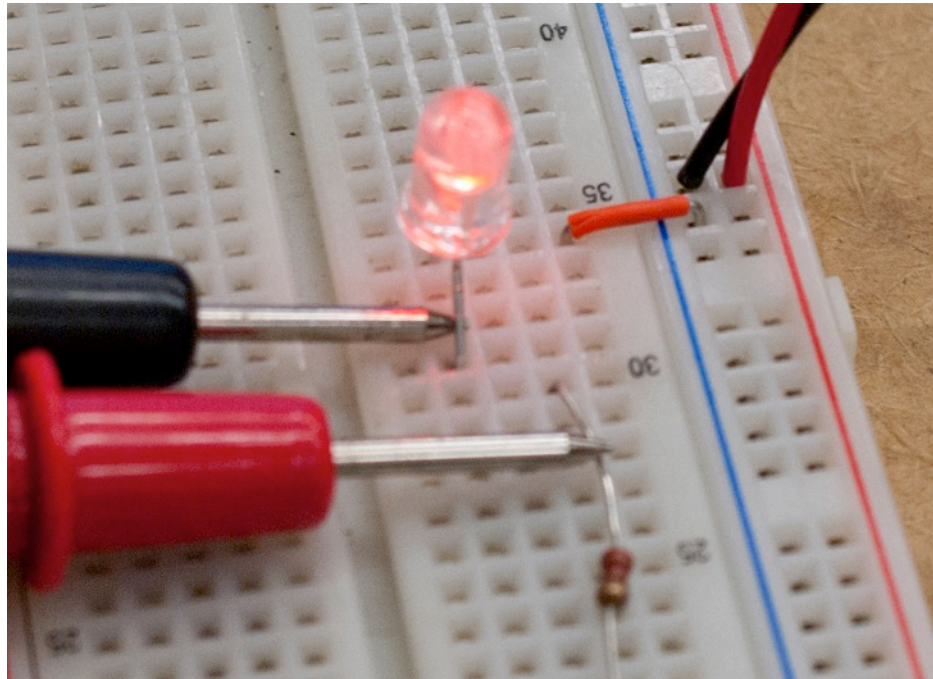
Try it on last week's project

- Measure voltage across resistor
- Measure resistance of resistor



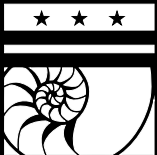
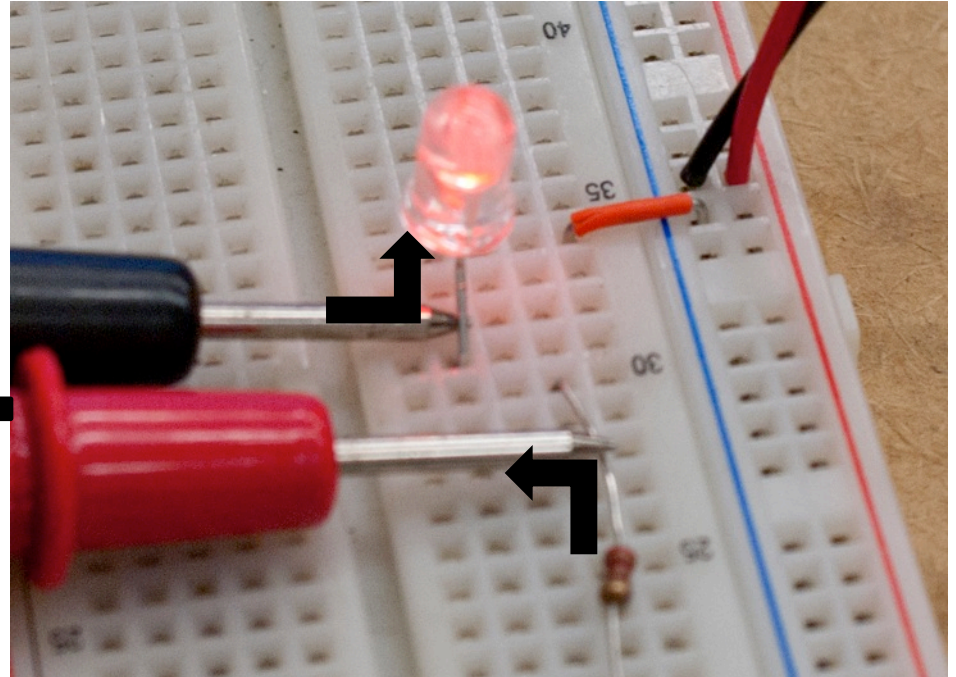
Try it on last week's project

- Measure current going into LED



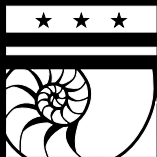
Try it on last week's project

- When getting ready to measure current, look on the meter
 - Leads often have to be connected to different jacks than for voltage or resistance measurements



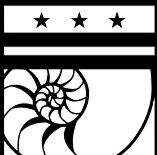
On to building new stuff

POWER SUPPLIES



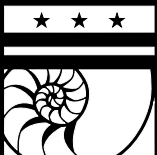
The problem

- Some circuits need specific voltages to work
- Exact voltage we need isn't always available
- Solution: Convert what we have into what we need

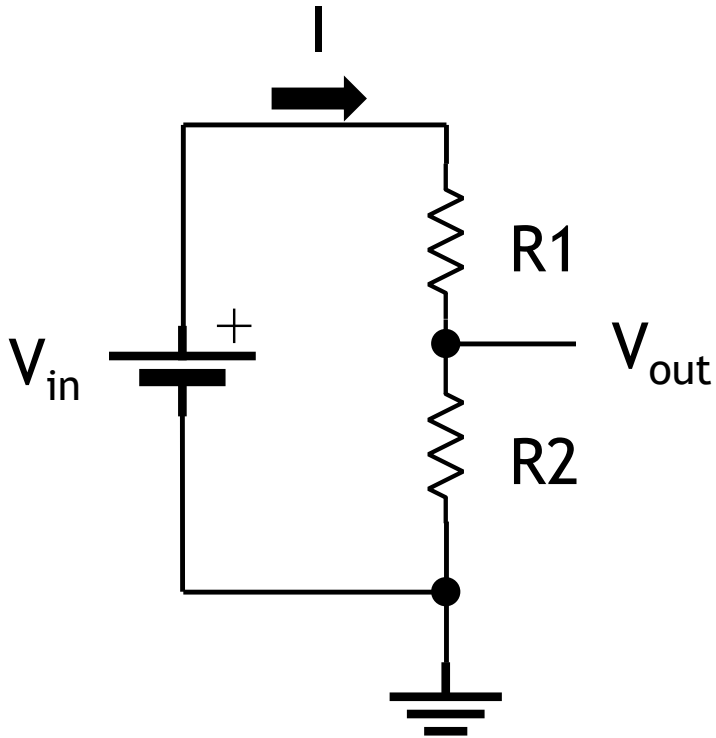


Voltage divider

- Easy way to get from one voltage to a lower voltage
- Quick and dirty
 - Not too stable
 - Need to be able to predict your input voltage *and* output resistance
- But it's cheap!



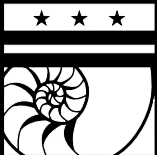
The idea



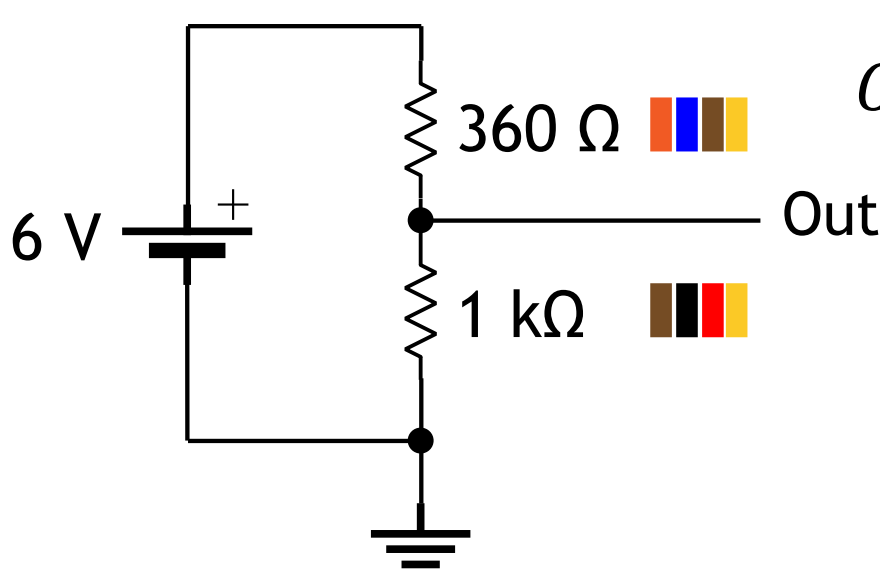
$$I = \frac{V_{in}}{R1 + R2}$$

$$V_{out} = I * R2$$

$$V_{out} = V_{in} * \frac{R2}{R1 + R2}$$

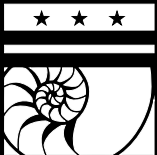


Try it

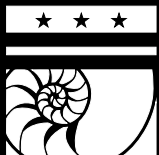
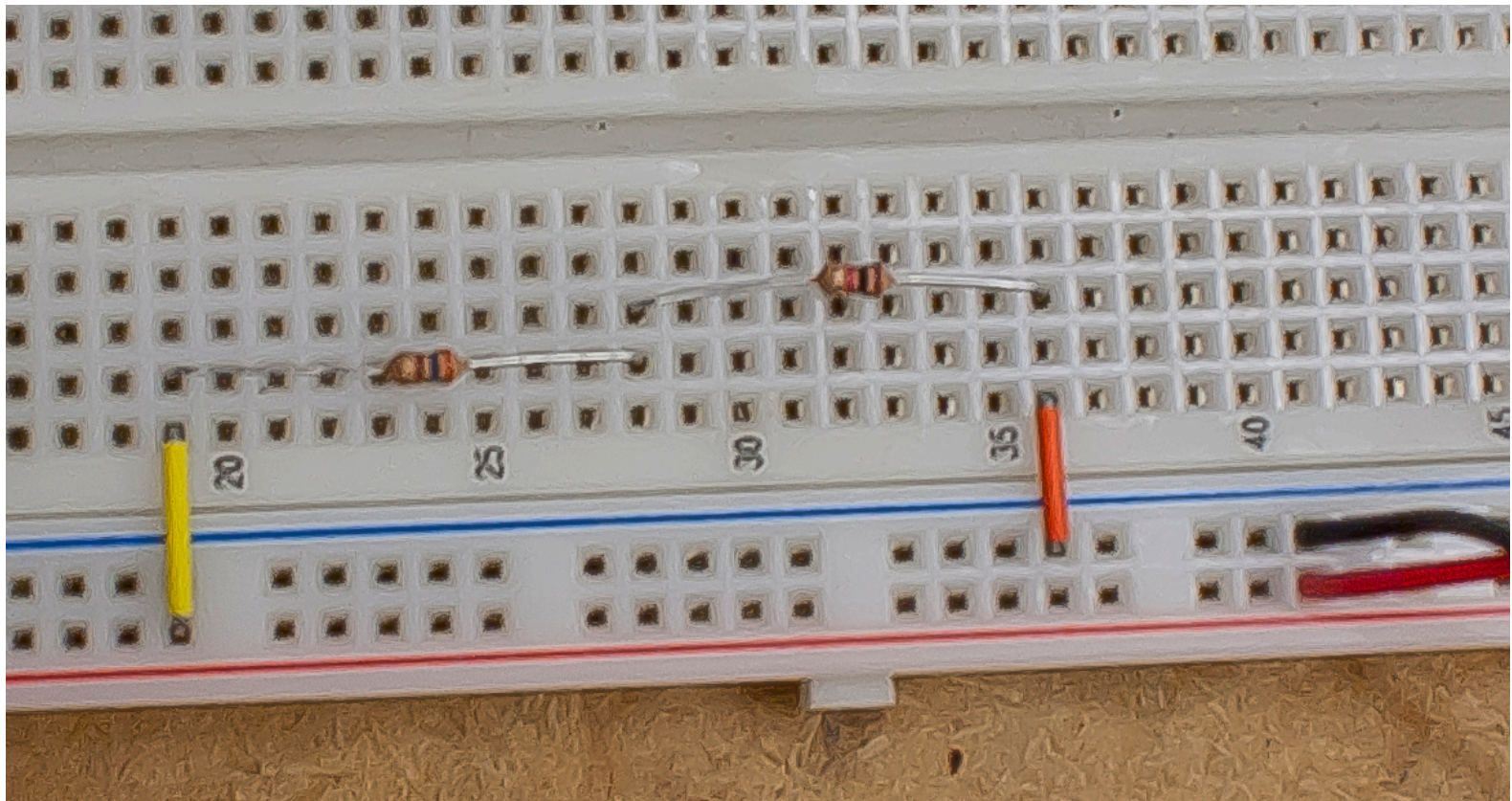


$$Out = 6V * \frac{1k\Omega}{360\Omega + 1k\Omega}$$

$$Out = 4.4V$$

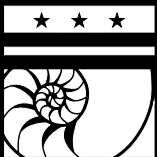


Try it



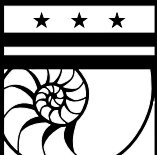
Two problems

- V_{out} directly depends on V_{in}
 - Unstable input = unstable output
- If V_{out} is connected to anything, it could change!
 - Why is this?



Combining resistances

- Remember how batteries could be connected in series or in parallel?
- Remember how they added up differently in each case?



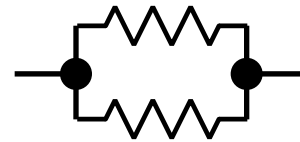
Combining resistances

- Series

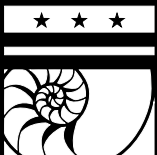


$$R_{total} = R_1 + R_2$$

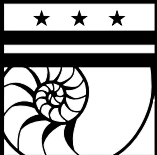
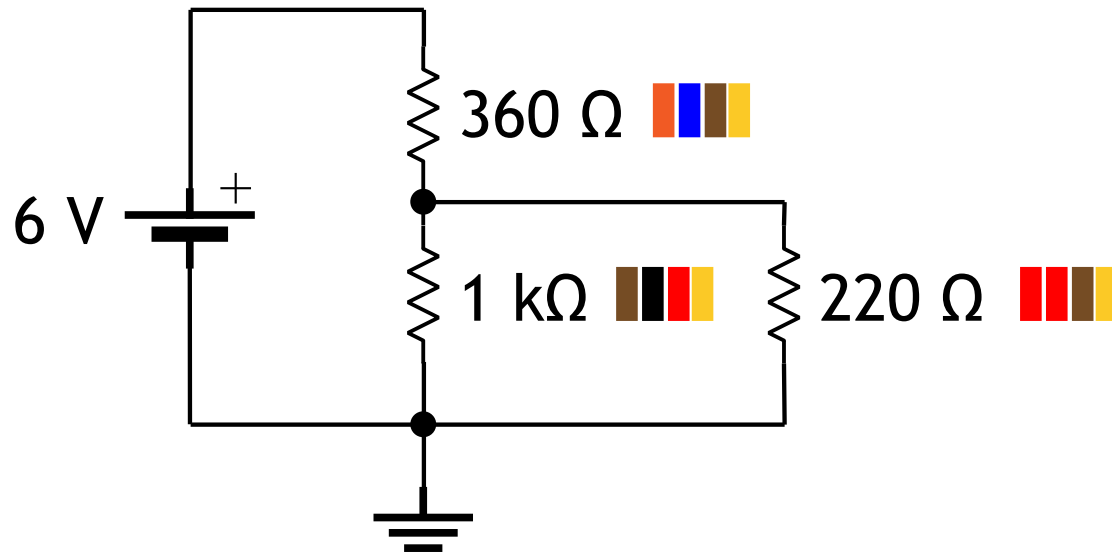
- Parallel



$$R_{total} = R_1 \parallel R_2 = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$



What happens here?

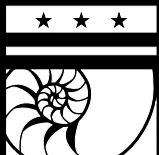
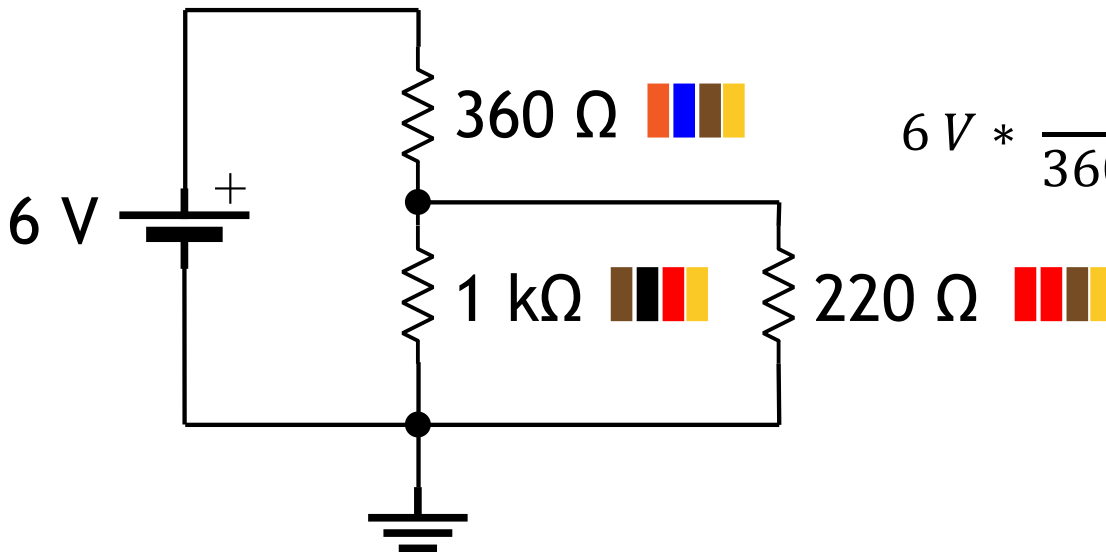


What happens here?

$$V_{out} = 6 V * \frac{1 k\Omega \parallel 220 \Omega}{360 \Omega + (1 k\Omega \parallel 220 \Omega)}$$

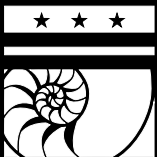
$$1 k\Omega \parallel 220 \Omega = \frac{1 k\Omega * 220 \Omega}{1 k\Omega + 220 \Omega} = 180.3 \Omega$$

$$6 V * \frac{180.3 \Omega}{360 \Omega + 180.3 \Omega} = 2 V$$



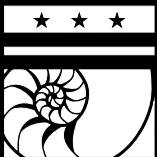
What else can we do?

- Use a voltage regulator
 - Inexpensive (usually) chip
 - Handles all of this stuff for you



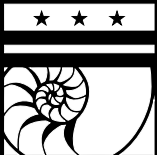
What else can we do?

- Use a voltage regulator
 - Some are more complicated than others
 - Some let you set the output voltage you want
 - Some just lower voltage; others raise it



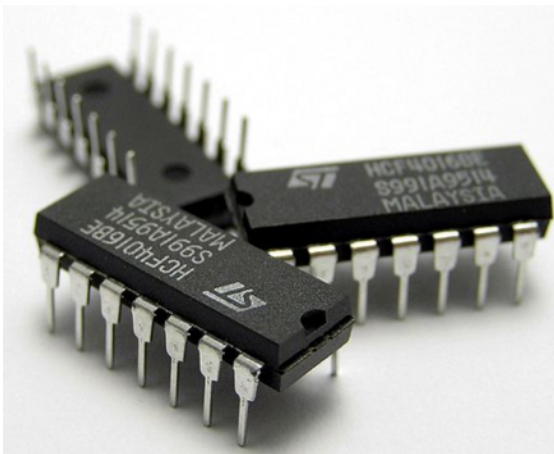
How do they work?

- Details? Outside the scope of this class
- But let's find out how to use one!

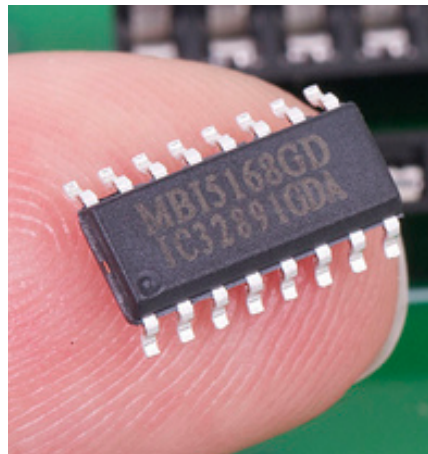


Integrated circuits (ICs)

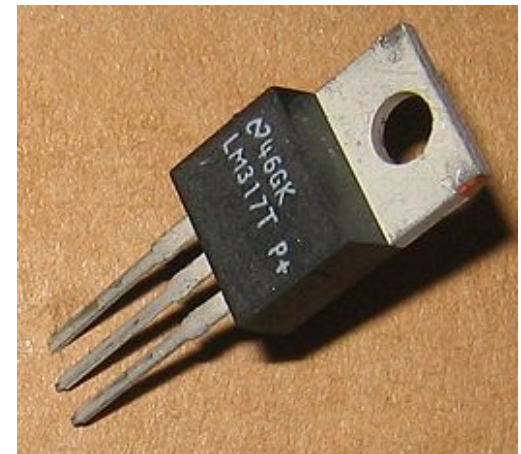
- What people generally mean by “chip”
- Usually black plastic with some metal pins



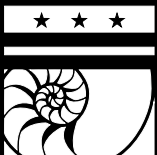
http://en.wikipedia.org/wiki/File:Three_IC_circuit_chips.JPG



<http://www.flickr.com/photos/oskay/6328929468/>

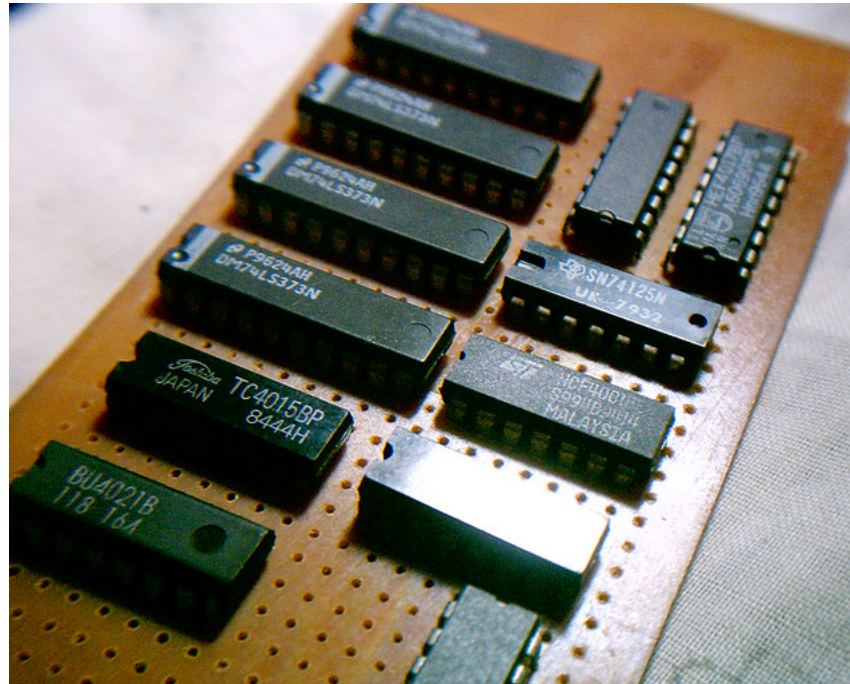


http://en.wikipedia.org/wiki/File:T0-220_Package_Four_Different_Projections.jpg

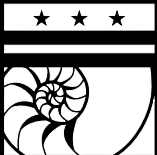


Problem

- They can sort of look the same

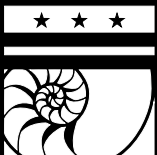


<http://www.flickr.com/photos/ronybc/1713396200/>



Datasheet

- Manufacturer's instructions on how to use it
- Can be a page or hundreds



Example



LM117/LM317A/LM317

February 25, 2011

3-Terminal Adjustable Regulator

General Description

The LM117 series of adjustable 3-terminal positive voltage regulators is capable of supplying in excess of 1.5A over a 1.2V to 37V output range. They are exceptionally easy to use and require only two external resistors to set the output voltage. Further, both line and load regulation are better than standard fixed regulators. Also, the LM117 is packaged in standard transistor packages which are easily mounted and handled.

In addition to higher performance than fixed regulators, the LM117 series offers full overload protection available only in ICs, included on the chip are current limit, thermal overload protection and safe area protection. All overload protection circuitry remains fully functional even if the adjustment terminal is disconnected.

Normally, no capacitors are needed unless the device is situated more than 6 inches from the input filter capacitors in which case an input bypass is needed. An optional output capacitor can be added to improve transient response. The adjustment terminal can be bypassed to achieve very high ripple rejection ratios which are difficult to achieve with standard 3-terminal regulators.

Besides replacing fixed regulators, the LM117 is useful in a wide variety of other applications. Since the regulator is "floating" and sees only the input-to-output differential voltage, supplies of several hundred volts can be regulated as long as

the maximum input to output differential is not exceeded, i.e., avoid short-circuiting the output.

Also, it makes an especially simple adjustable switching regulator, a programmable output regulator, or by connecting a fixed resistor between the adjustment pin and output, the LM117 can be used as a precision current regulator. Supplies with electronic shutdown can be achieved by clamping the adjustment terminal to ground which programs the output to 1.2V where most loads draw little current.

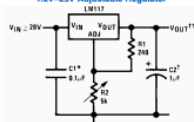
For applications requiring greater output current, see LM150 series (SA) and LM138 series (SA) data sheets. For the negative complement, see LM137 series data sheet.

Features

- Guaranteed 1% output voltage tolerance (LM317A)
- Guaranteed max. 0.01%/V line regulation (LM317A)
- Guaranteed max. 0.3% load regulation (LM117)
- Guaranteed 1.5A output current
- Adjustable output down to 1.2V
- Current limit constant with temperature
- P-Product Enhancement tested
- 80 dB ripple rejection
- Output is short-circuit protected

Typical Applications

1.2V-25V Adjustable Regulator



Full output current not available at high input-output voltages.

*Required if device is more than 6 inches from filter capacitors.

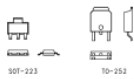
†Optional—improves transient response. Output capacitors in the range of 1µF to 100µF of aluminum electrolytic are commonly used to provide improved output impedance and rejection of transients.

$$1V_{OUT} = 1.25V \left(1 + \frac{R1}{R2} \right) + I_{ADJ}R2$$

LM117/LM317A/LM317 Package Options

Part Number	Suffix	Package	Output Current
LM117, LM317	K	TO-3	1.5A
LM317A, LM317	T	TO-220	1.5A
LM317	S	TO-263	1.5A
LM317A, LM317	EMP	SOT-223	1.0A
LM117, LM317A, LM317	H	TO-39	0.5A
LM117	E	LCC	0.5A
LM317A, LM317	MDT	TO-252	0.5A

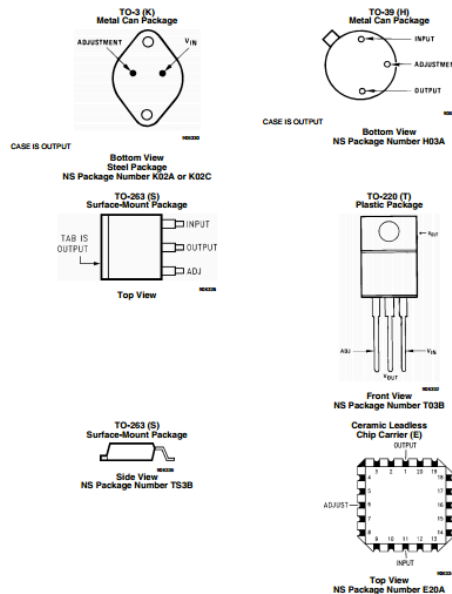
SOT-223 vs. TO-252 (D-Pak) Packages



Scale 1:1

LM117/LM317A/LM317 3-Terminal Adjustable Regulator

Connection Diagrams



Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Power Dissipation	Internally Limited
Input-Output Voltage Differential	+40V, -0.3V
Storage Temperature	-65°C to +150°C
Lead Temperature	
Metal Package (Soldering, 10 seconds)	300°C
Plastic Package (Soldering, 4 seconds)	260°C
ESD Tolerance (Note 5)	3 kV

Operating Temperature Range

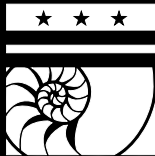
LM117	-55°C ≤ T _J ≤ +150°C
LM317A	-40°C ≤ T _J ≤ +125°C
LM317	0°C ≤ T _J ≤ +125°C

Preconditioning All Devices 100%
Thermal Limit Burn-In

LM117 Electrical Characteristics (Note 3)

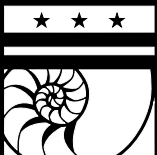
Specifications with standard type face are for T_J = 25°C, and those with boldface type apply over full Operating Temperature Range. Unless otherwise specified, V_{IN} = V_{OUT} = 5V, and I_{OUT} = 10 mA.

Parameter	Conditions	LM117 (Note 3)			Units
		Min	Typ	Max	
Reference Voltage	3V ≤ (V _{IN} - V _{OUT}) ≤ 40V, 10 mA ≤ I _{OUT} ≤ I _{MAX} (Note 3)	1.20	1.25	1.30	V
Line Regulation	3V ≤ (V _{IN} - V _{OUT}) ≤ 40V (Note 4)	0.01	0.02	0.05	%/V
Load Regulation	10 mA ≤ I _{OUT} ≤ I _{MAX} (Note 3, Note 4)	0.1	0.3	1	%/V
Thermal Regulation	20 ms Pulse	0.03	0.07		%/W
Adjustment Pin Current		50	100		µA
Adjustment Pin Current Change	10 mA ≤ I _{OUT} ≤ I _{MAX} (Note 3) 3V ≤ (V _{IN} - V _{OUT}) ≤ 40V	0.2	5		µA
Temperature Stability	T _{MIN} ≤ T _J ≤ T _{MAX} (V _{IN} = V _{OUT}) = 40V	1			mA
Minimum Load Current	(V _{IN} = V _{OUT}) = 15V	3.5	5		mA
Current Limit	(V _{IN} = V _{OUT}) = 40V K Package H, E Package	1.5	2.2	3.4	A
		0.5	0.8	1.8	A
		0.3	0.4		A
RMS Output Noise, % of V _{OUT}	10 Hz ≤ f ≤ 10 kHz	0.003			%
Ripple Rejection Ratio	V _{OUT} = 10V, f = 120 Hz, C _{OUT} = 0 µF	55			dB
	V _{OUT} = 10V, f = 120 Hz, C _{OUT} = 10 µF	66	80		dB
Long-Term Stability	T _J = 125°C, 1000 hrs	0.3	1		%
Thermal Resistance, θ _{JC}	K (TO-3) Package	2			°C/W
	H (TO-39) Package	21			°C/W
	E (LCC) Package	12			°C/W
Thermal Resistance, θ _{JA}	K (TO-3) Package	39			°C/W
	H (TO-39) Package	186			°C/W
	E (LCC) Package	88			°C/W



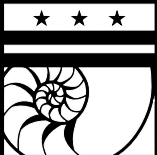
LM317 adjustable regulator

- Adjustable
 - Easy to set — just add two resistors
- Cheap (maybe \$0.50)
- Can regulate either voltage *or* current
- Can take anywhere from 1.2 V to 37 V



LM317 adjustable regulator

- Not very efficient
 - Good chance you'll need a heatsink
(We won't in this class)



In the datasheet...

Application Hints

In operation, the LM117 develops a nominal 1.25V reference voltage, V_{REF} , between the output and adjustment terminal. The reference voltage is impressed across program resistor $R1$ and, since the voltage is constant, a constant current I_1 then flows through the output set resistor $R2$, giving an output voltage of

$$V_{OUT} = V_{REF} \left(1 + \frac{R2}{R1} \right) + I_{ADJ}R2 \quad (1)$$

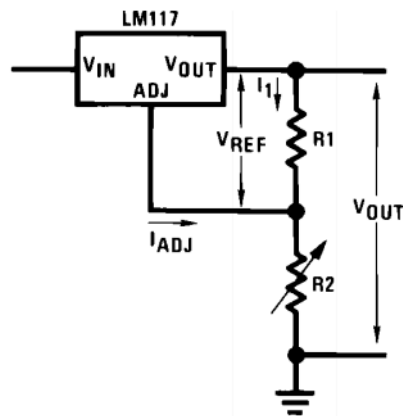
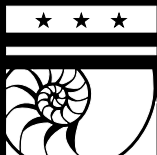


FIGURE 1.

Since the $100\mu\text{A}$ current from the adjustment terminal represents an error term, the LM117 was designed to minimize I_{ADJ} and make it very constant with line and load changes. To do this, all quiescent operating current is returned to the output establishing a minimum load current requirement. If there is insufficient load on the output, the output will rise.

<http://www.ti.com/lit/ds/symlink/lm117.pdf>



In other words...

Application Hints

In operation, the LM117 develops a nominal 1.25V reference voltage, V_{REF} , between the output and adjustment terminal. The reference voltage is impressed across program resistor $R1$ and, since the voltage is constant, a constant current I_1 then flows through the output set resistor $R2$, giving an output voltage of

$$V_{OUT} = V_{REF} \left(1 + \frac{R2}{R1} \right) + I_{ADJ} R2 \quad (1)$$

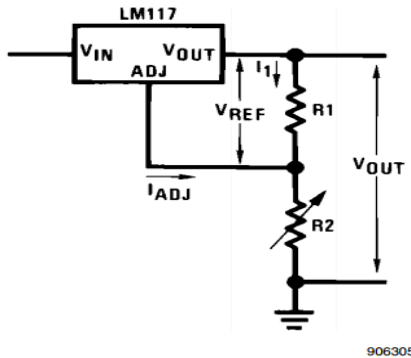
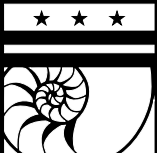


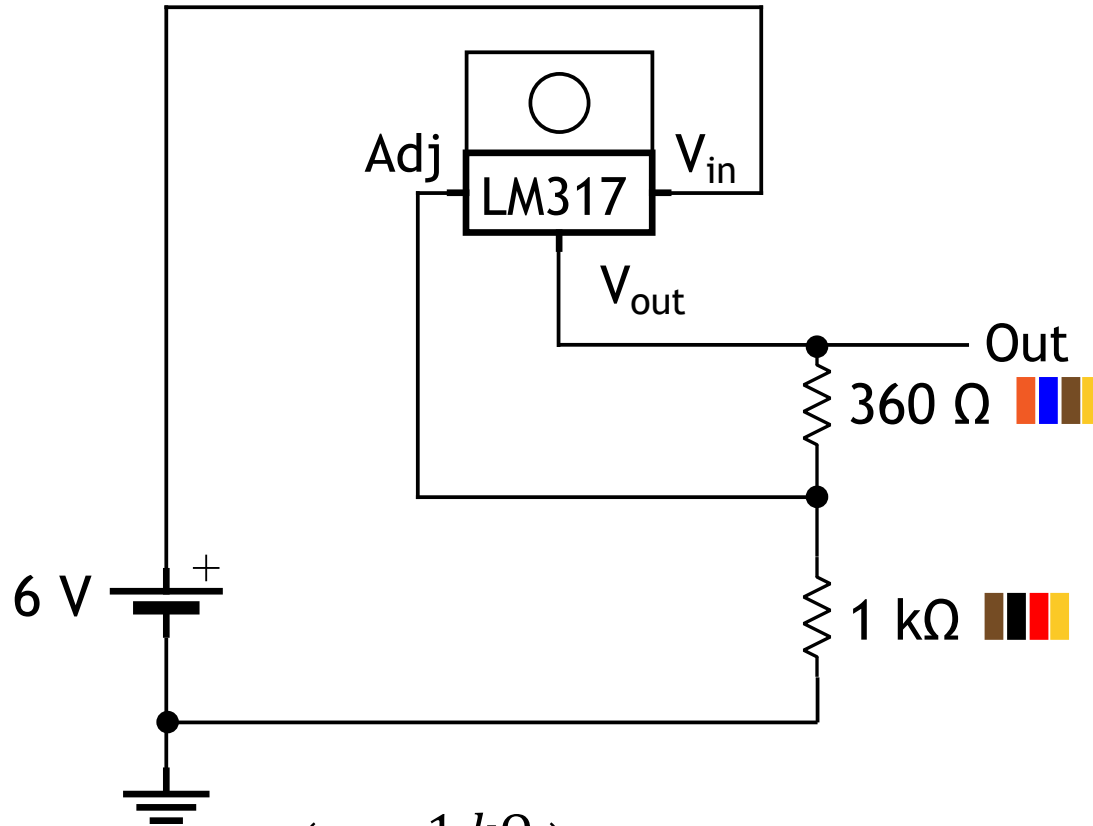
FIGURE 1.

$$V_{out} = 1.25 V * \left(1 + \frac{R2}{R1} \right) + 0.0001 A * R2$$

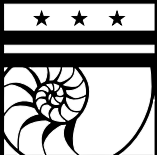
- V_{out} doesn't depend on V_{in} !



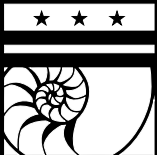
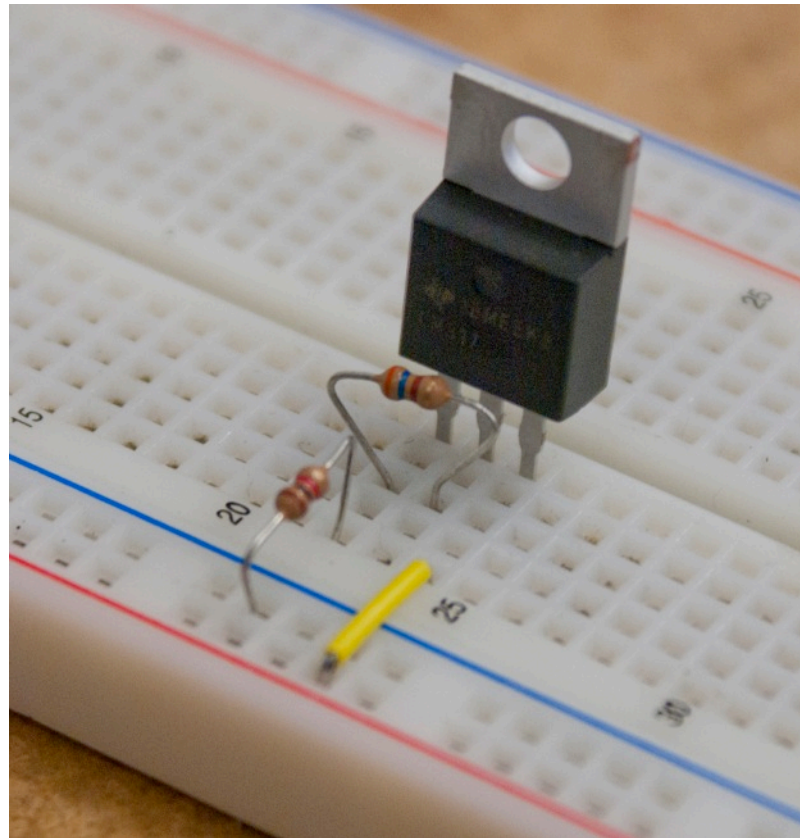
Try it



$$V_{out} = 1.25 V * \left(1 + \frac{1 k\Omega}{360 \Omega}\right) + 0.0001 A * 1 k\Omega = 4.82 V$$

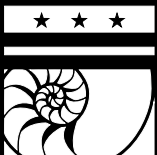


Try it



Capacitors

- Store energy in an electric field
- Can be used to smooth out noisy signals
- Also useful for:
 - Filters for audio and RF
 - Reaching high voltages



Capacitors

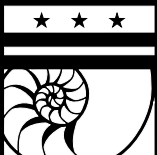
- Some can be used in either direction
 - These generally look like discs
- Others blow up if you put them in backward
 - These generally look like cans



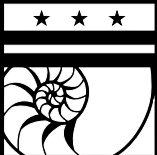
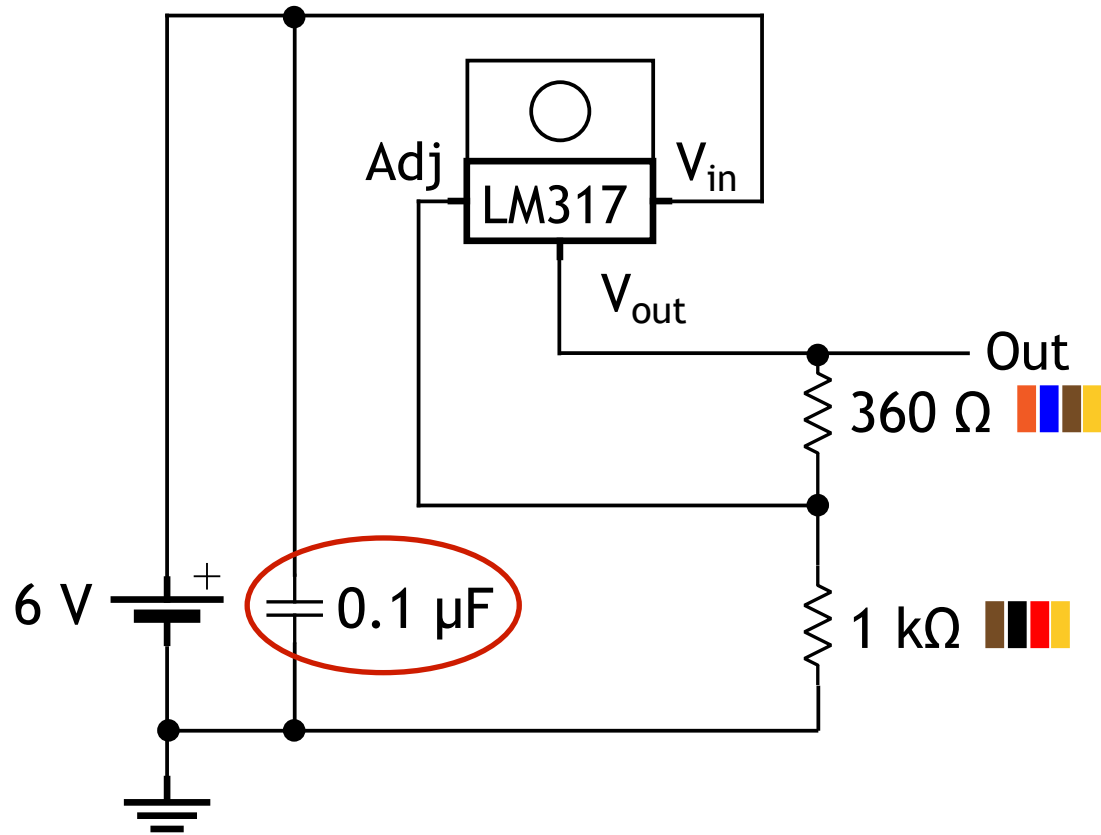
<http://www.flickr.com/photos/zero-waste/4117130831/>



<http://www.flickr.com/photos/dj-dwayne/5584102517/>

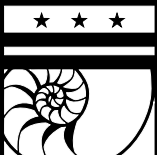


Let's add one



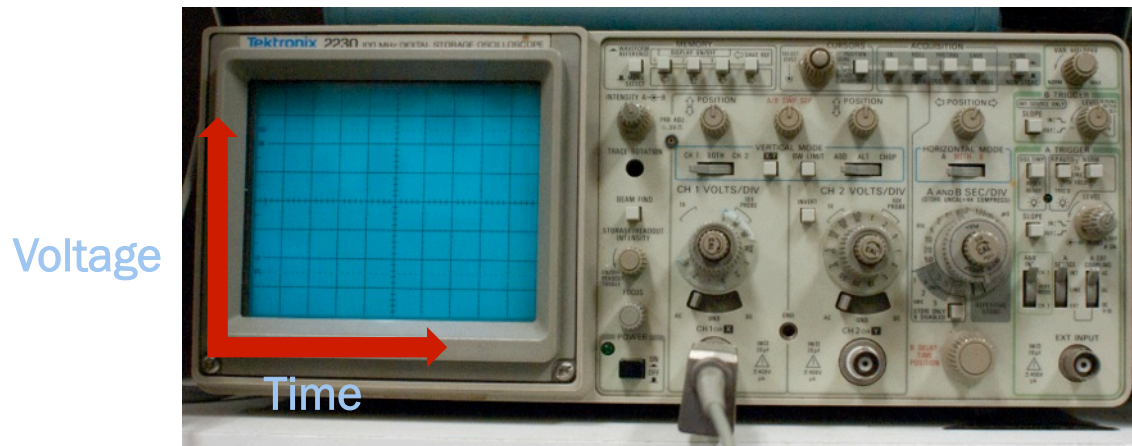
The difference

- Probably won't notice one here
 - Battery powered, no load
- Generally good practice
 - Helps keep things a bit more predictable
 - Datasheets can help provide guidance
 - LM317 said it's useful on the input but unnecessary on the output



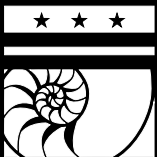
Oscilloscope

- What if we want to look at the difference?
- Oscilloscope shows voltage waveforms over time



Oscilloscope

- Sort of expensive
 - Hundreds of dollars to tens of thousands
- Really handy, though



That's it for tonight

- Next week
 - Lights (both making and detecting)
 - Transistors
 - Maybe some digital logic

