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

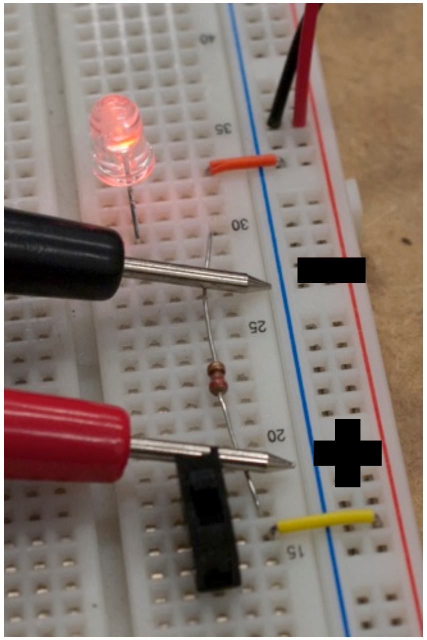
Multimeter

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

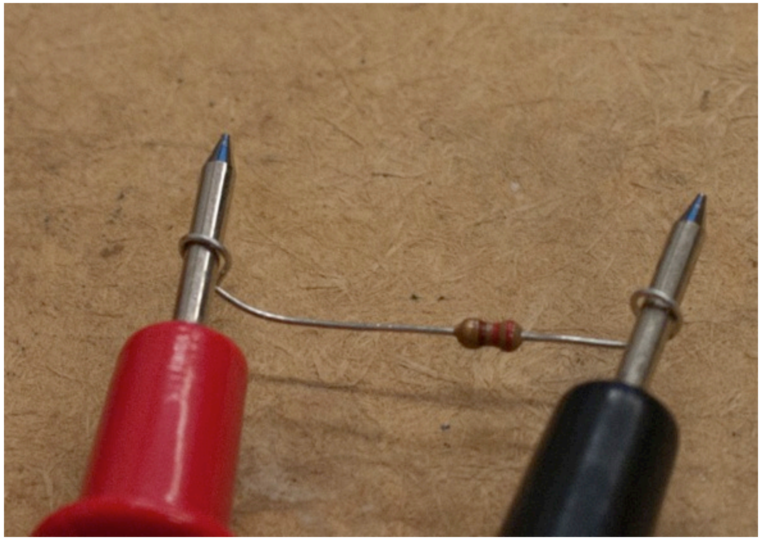
Choosing a measurement

Try it on last week's project

- Measure voltage across resistor

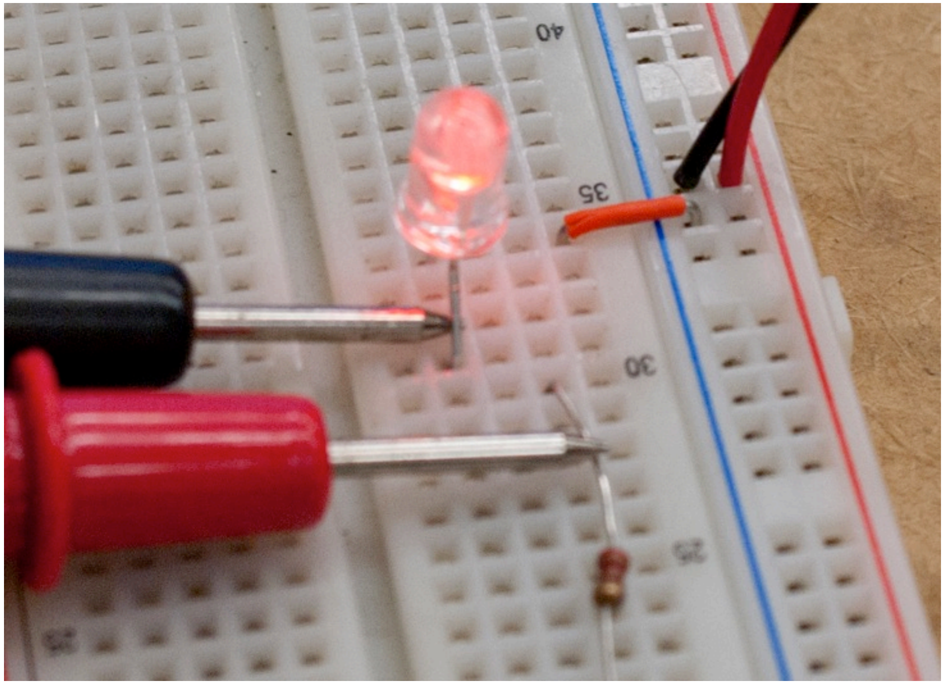


- Measure resistance of resistor



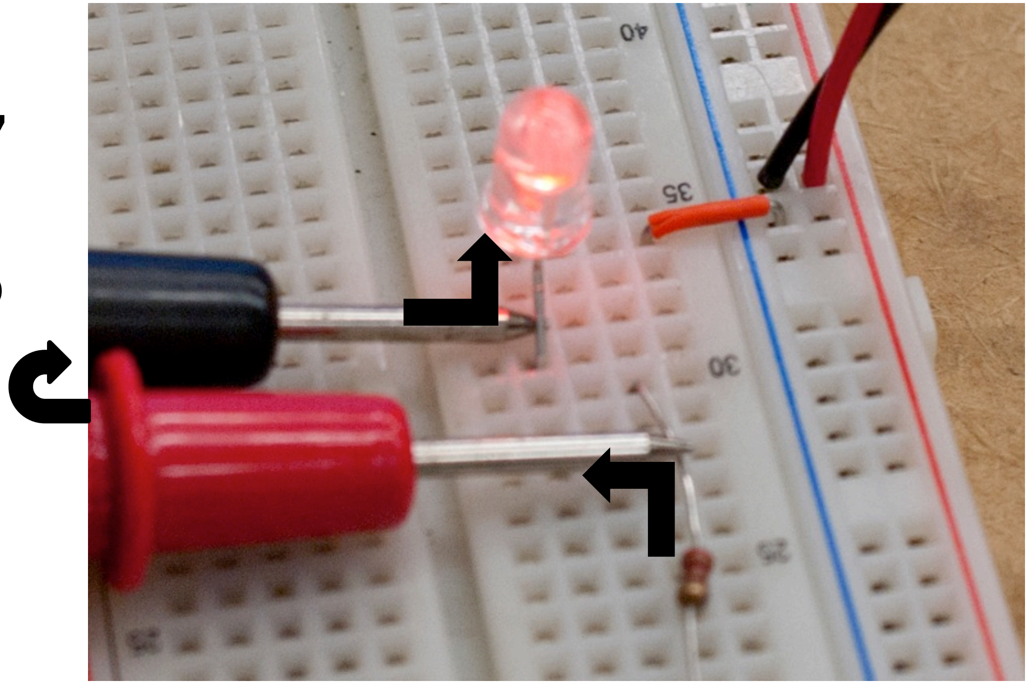
Try it on last week's project

- 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

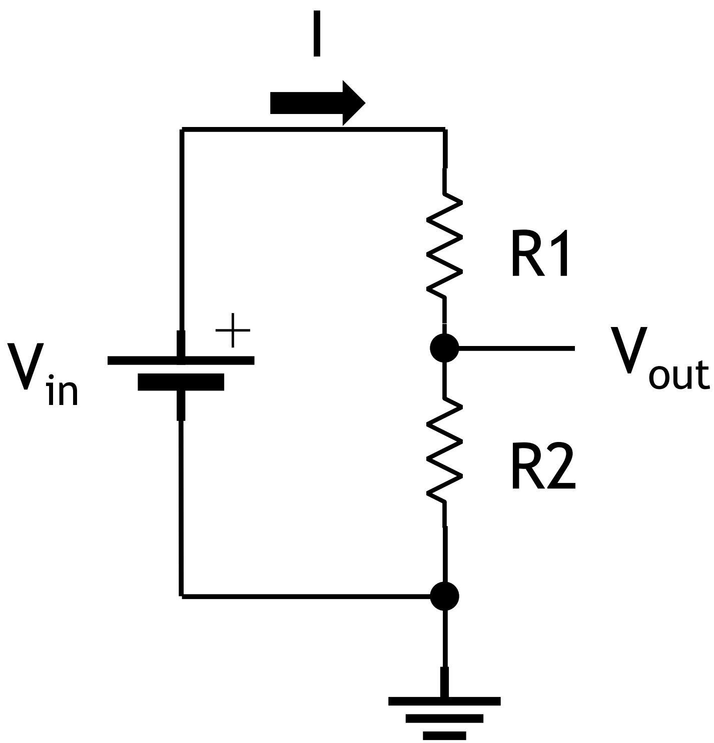
The problem

- 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

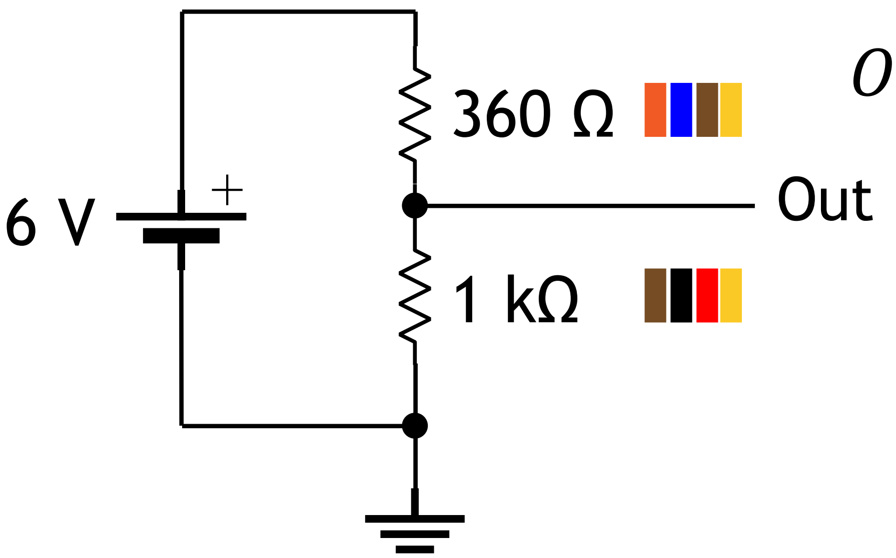


$$I = \frac{V_{in}}{R1 + R2}$$

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

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

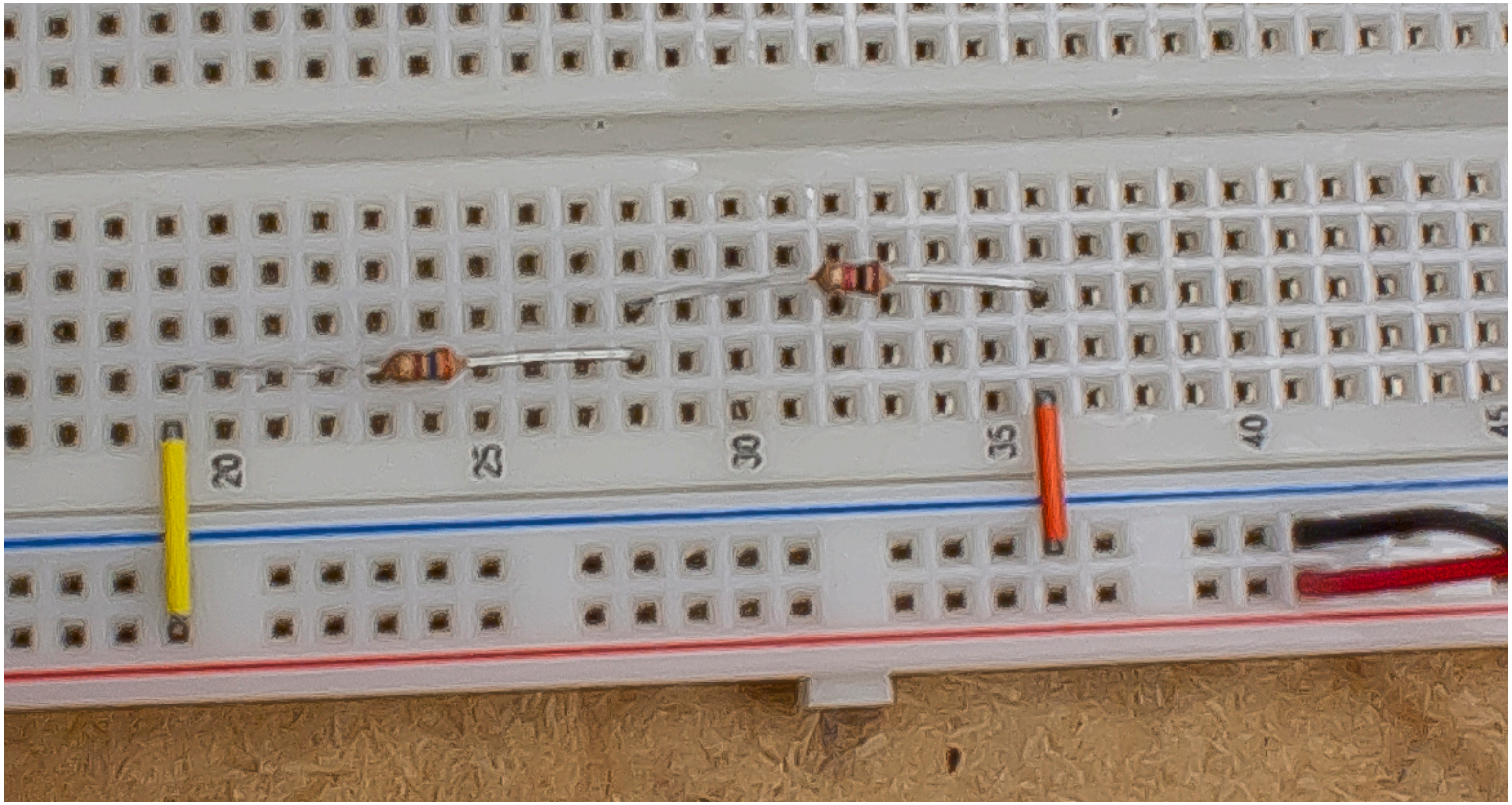
Try it



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

$$Out = 4.4\,V$$

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

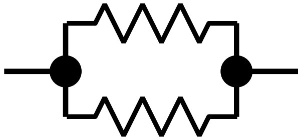
- Remember how batteries could be connected in series or in parallel?
- Remember how they added up differently in each case?

Combining resistances

- Series

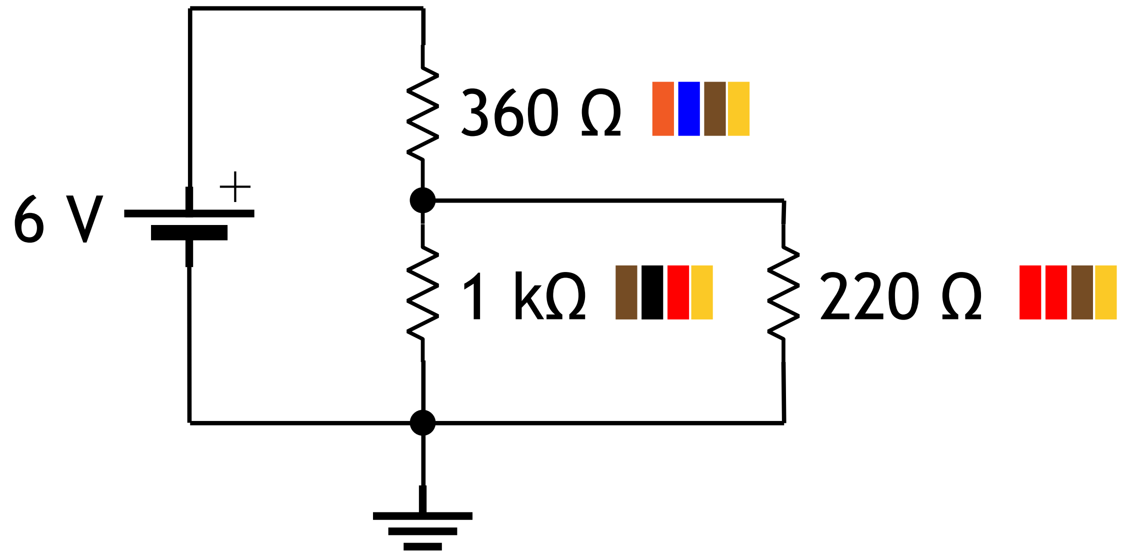
$$R_{total} = R_1 + R_2$$

- Parallel



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

What happens here?

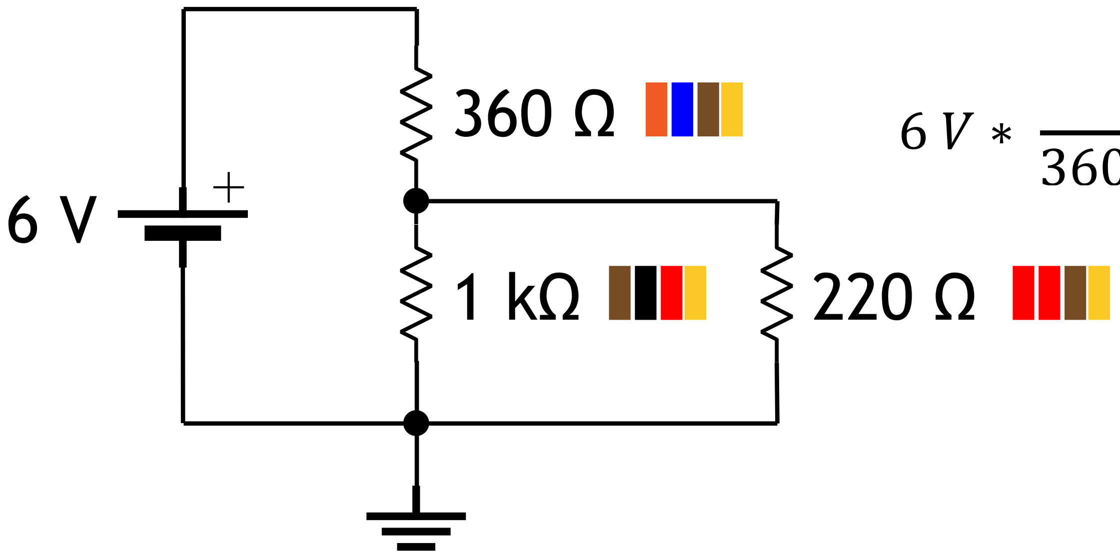


What happens here?

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

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

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



What else can we do?

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

What else can we do?

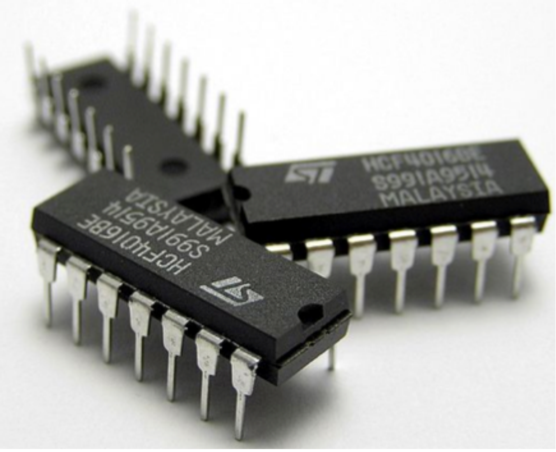
- Use a voltage regulator
  - Some are more complicated than others
  - Some let you set the output voltage you want
  - Some just lower voltage; others raise it

How do they work?

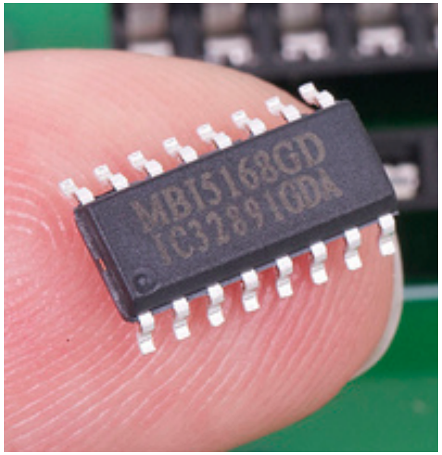
- Details? Outside the scope of this class
- But let's find out how to use one!

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



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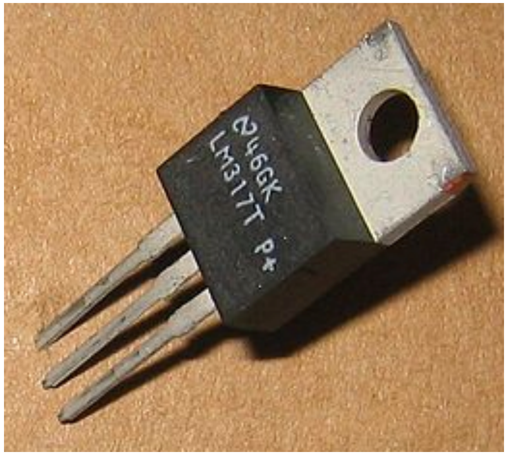
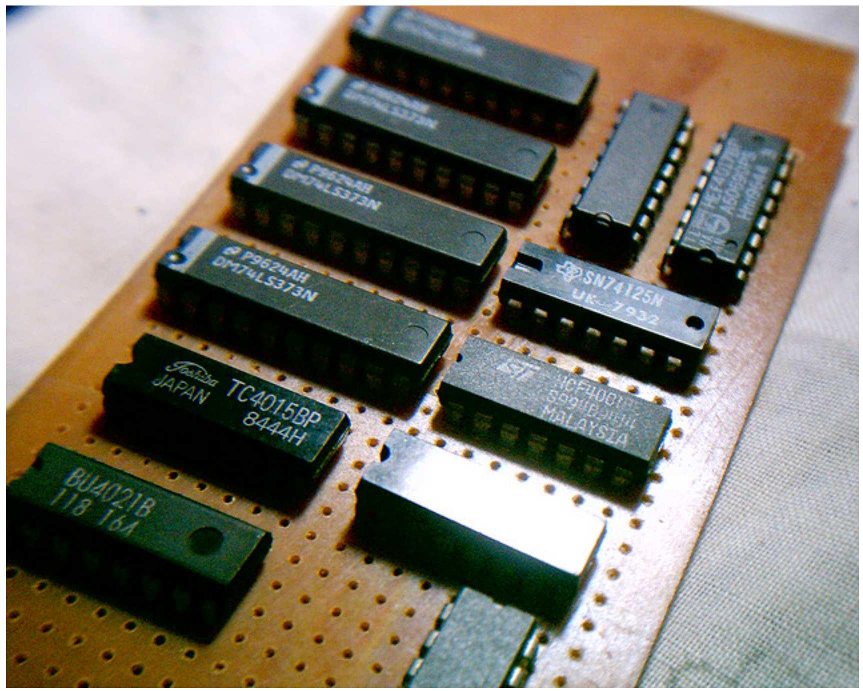


http://en.wikipedia.org/wiki/File:TO-220_Package_Four_Different_Projections.jpg

Problem

- They can sort of look the same

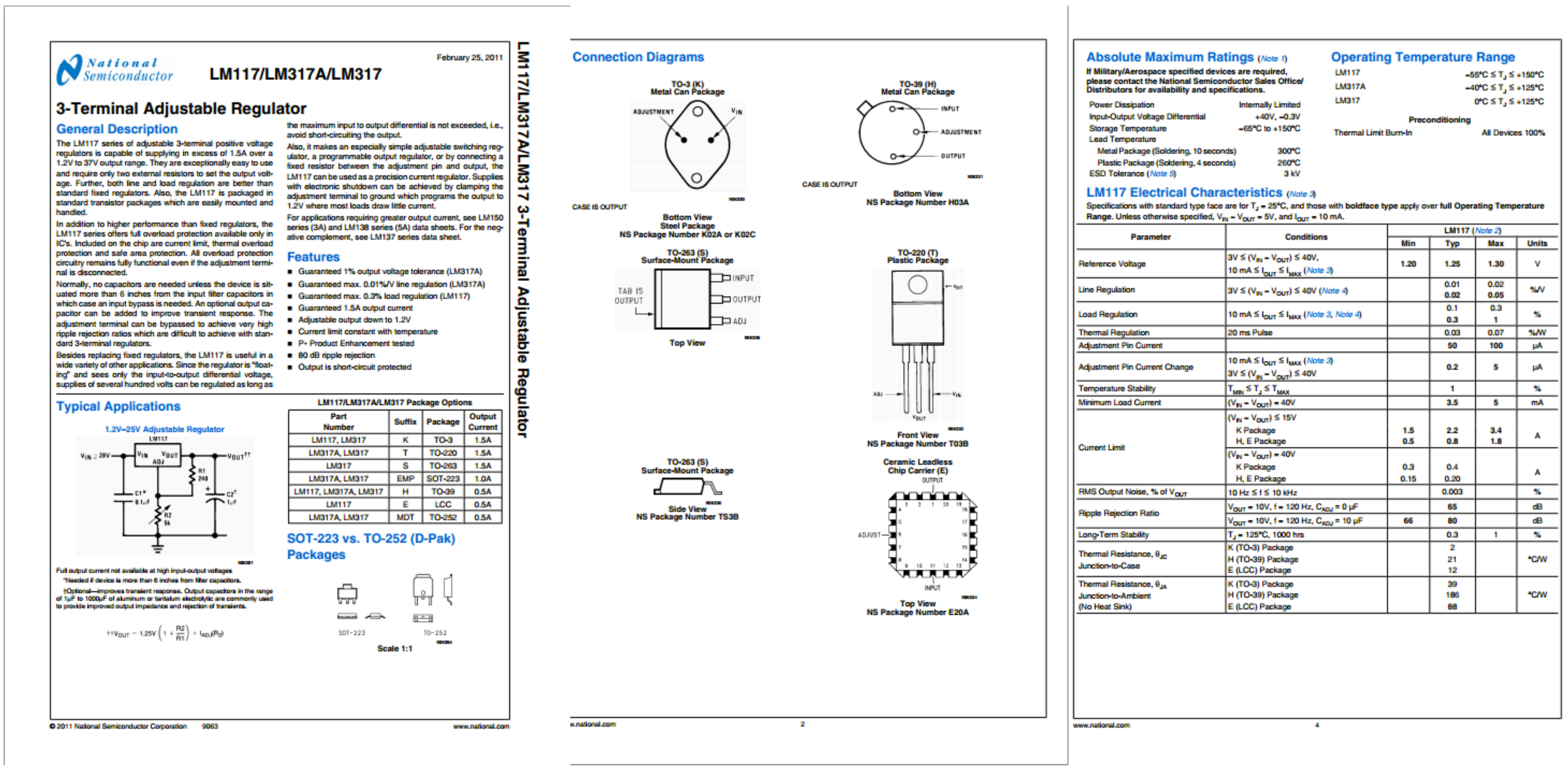


http://www.flickr.com/photos/ronybc/1713396200/

Datasheet

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

Example


National Semiconductor
LM117/LM317A/LM317
3-Terminal Adjustable Regulator
General Description
Features
Typical Applications
SOT-223 vs. TO-252 (D-Pak) Packages
LM117/LM317A/LM317 3-Terminal Adjustable Regulator
Connection Diagrams
Absolute Maximum Ratings
Operating Temperature Range
LM117 Electrical Characteristics

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

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

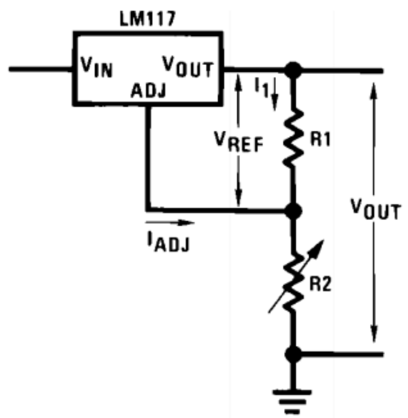


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FIGURE 1.

Since the 100μA 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...

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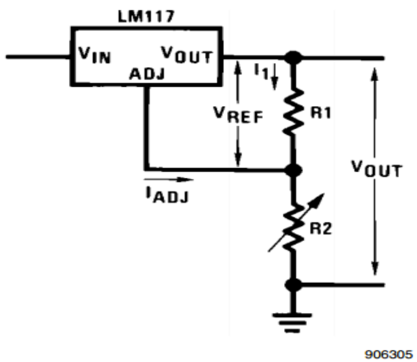
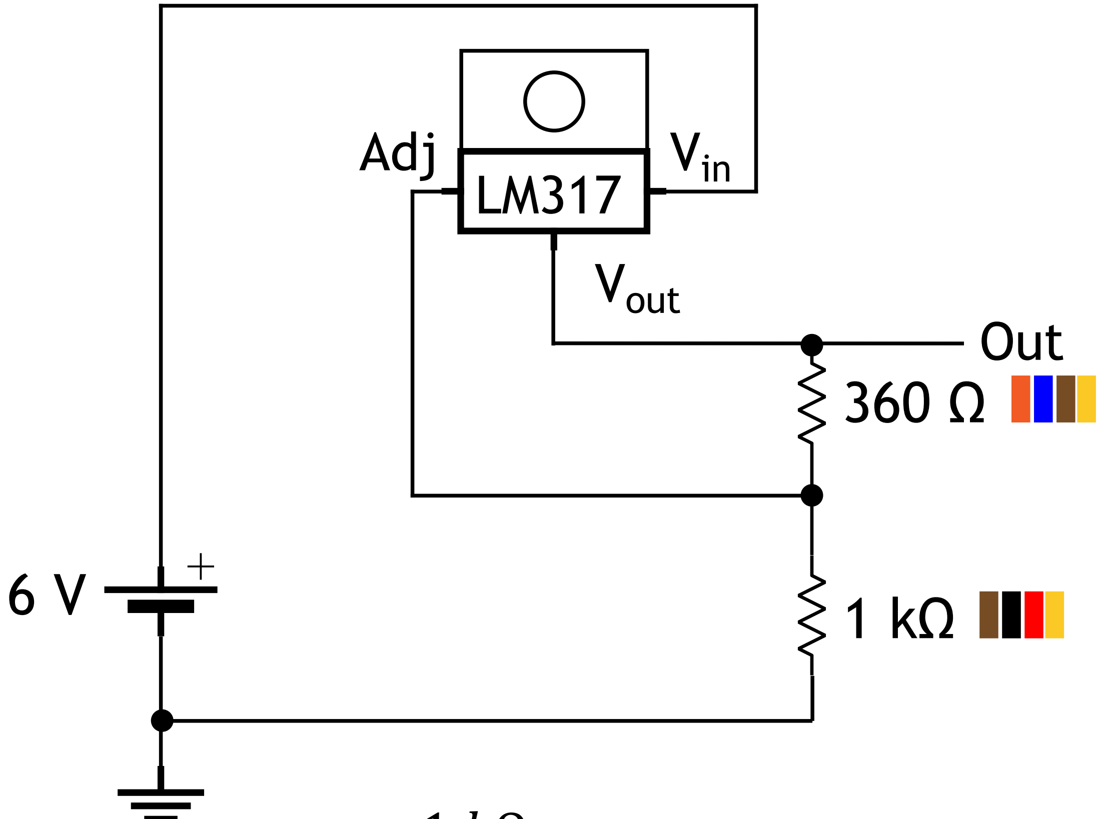


FIGURE 1.

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

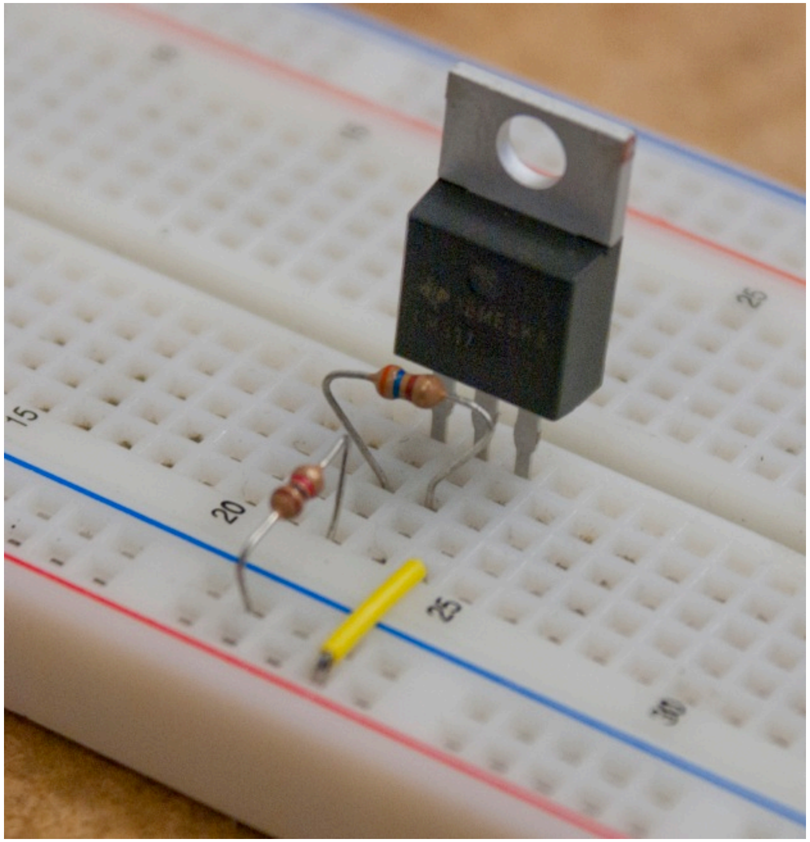
- V_{out} doesn't depend on V_{in}!

Try it



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

Try it



Capacitors

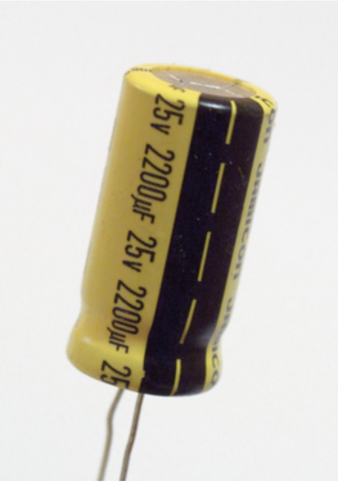
- Store energy in an electric field
- Can be used to smooth out noisy signals
- Also useful for:
  - Filters for audio and RF
  - Reaching high voltages

Capacitors

- Some can be used in either direction
  - These generally look like discs

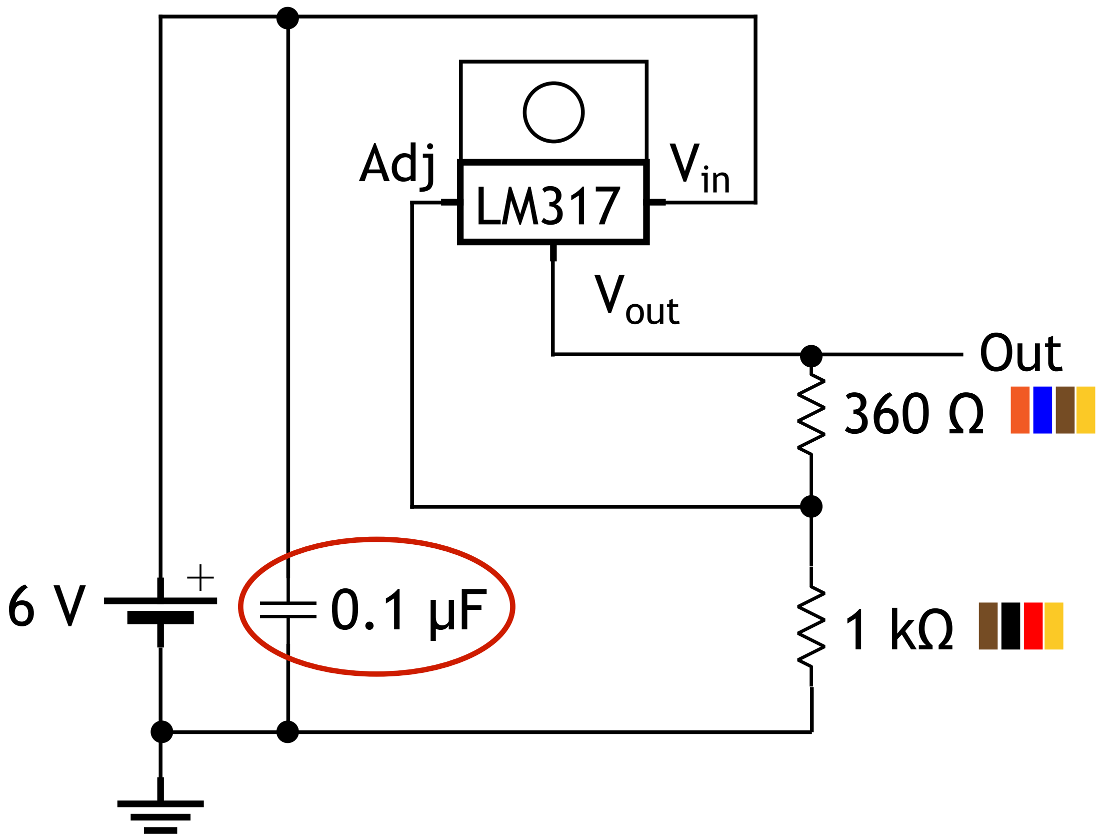
http://www.flickr.com/photos/zero-waste/4117130831/

- Others blow up if you put them in backward
  - These generally look like cans



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

Let's add one

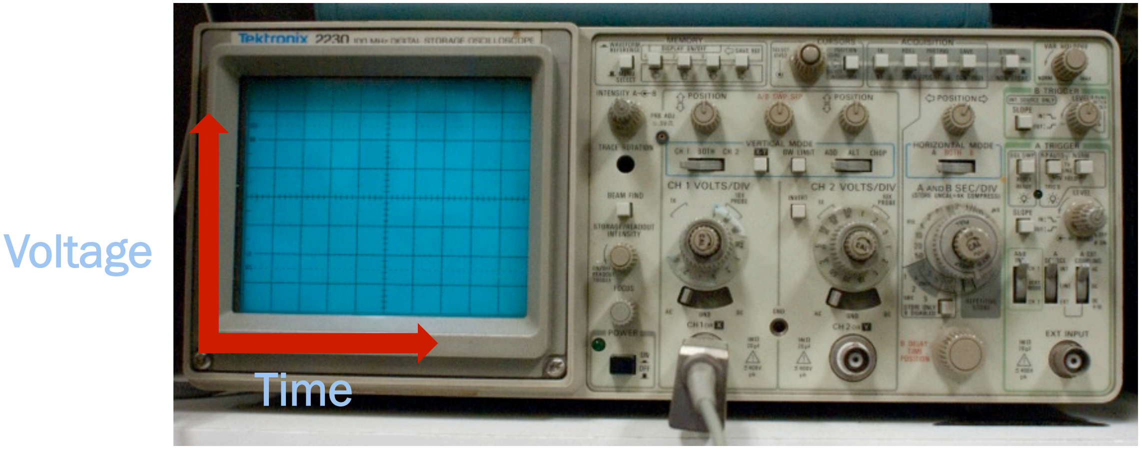


The difference

- 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