Many thanks to Prof. Lee for her excellent work on the lecture figures
Why are We Talking?

**GIVEN:** Schematics

**DESIRE:** Experiments
The Three Parts of a Schematic

**Input:**
- Signal Generator
- Power Supply

**Circuit Under Test (CUT):**
- Breadboard, PCB

**Output:**
- Multimeter
- Oscilloscope
A Circuit Under Test

Stuff to notice:

• Breadboard Routing

• Layout Sins

• Parasitic Elements

• Color Coding

http://makezine.com/2010/03/22/improving-breadboard-layout-through/
Multimeter

Don’t forget this
Two Tricky Things

• What the heck does AC RMS Mean?
  • To the board!
  • It is one number that describes the amplitude of a sine wave*
  • Specifically, it is the DC voltage which dissipates the same power in a resistor as a sine wave of amplitude $V_{ZeroPeak}$
  • $V_{RMS} = V_{ZeroPeak}/\sqrt{2}$ in a sinusoidal wave

• Why are there so many plug holes?
  • Next few slides
Let’s Do a Current Measurement

- Put multimeter in series
- Current flows through it
- Multimeter must look like a wire to be non-invasive
The Multimeter has Impedance

• $R_{ma}$ is needed to take a measurement.

• Most of the time, this won’t matter. It could for small $R$.

• Do analysis with equivalent circuit model if necessary.
Let’s do a Voltage Measurement

Schematic

R1

R2

Schematic w/ Eq. Ckt Model

R1

R_mv

R2

M

V
Let’s do a Resistance Measurement

• Current source will do weird stuff if it interacts with chips
Oscilloscopes

- Leave wires in your board, don’t wrap around probes
- Don’t lose probe hats!

Ground, not like multimeter

Voltage

Time

10x probe

1x / 10x switch

Signal
Power Supplies Make DC Voltage

Use this to make negative voltage:
\[ -1 \times \frac{V_{-20}}{V_{+20}} \]
Old Signal Generators

Bad Habit to use these for oscilloscopes
New Signal Generators
Model of Signal Generators and 50 Ohm/Hi Z

- Output term has NO PHYSICAL EFFECT
- This confuses _lots_ of people. Use Hi-Z.
- I hate the 50 Ohm setting, but it has some historical significance related to high speed measurements.