ECE Tools & Breadboards

ECE 403 Senior Design II

Week #4

Please visit Bison Academy for corresponding lecture notes,
homework sets, and videos
www.BisonAcademy.com

Introduction

In Homework #8, you are to demonstrate your proficiency with two ECE tools.

- In reality, you probably did that already in homework sets #4 to #7.
- Any time you are collecting data to validate your design, you're probably using some ECE tool.
- There are tons of tools you can use - as long as you use two or more you get full credit for homework set #8.

ECE Tools

ECE 403 Homework #8

When completing your tasks, use two or more ECE tools. ECE tools are typically used to take measurements to validate your design. These tools include
- Oscilloscopes
- Multimeters
- Digital Signal Analyzers
- Power Quality Meters
- etc

Update your OneNote document to point out
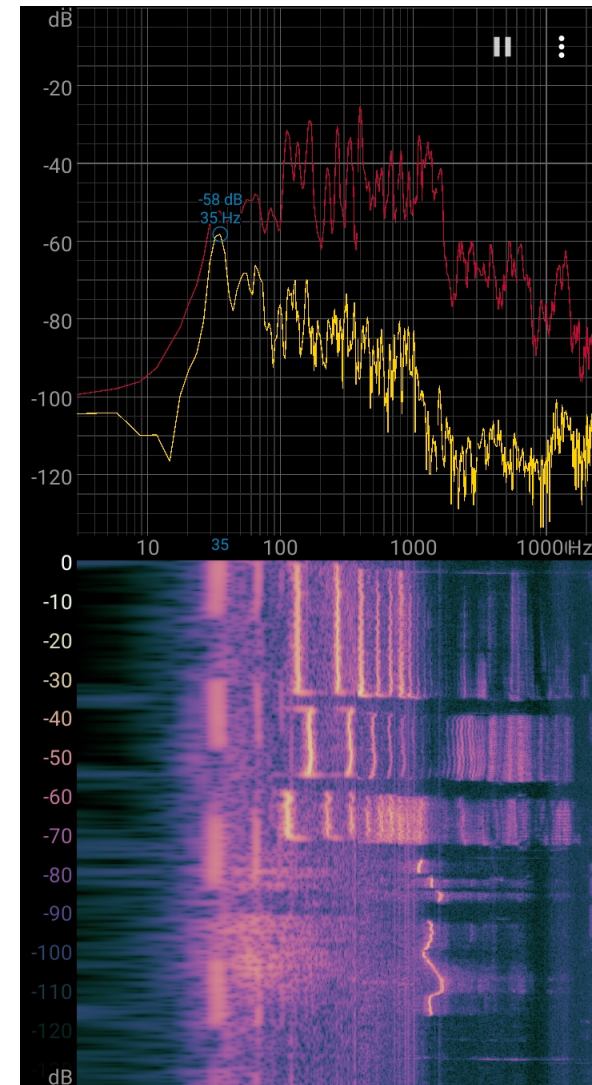- Which tools you used, and
- Where you used these tools

Senior Design - Week #4

This lecture covers a few ECE tools and some of the things you can do with them, including

- Multimeters,
- Frequency Counters
- Oscilloscopes

Other tools can be used in Senior Design as well:

- Spectrum Analyzer
- Power Quality Meter
- Watt Meter
- etc.

Multimeters

Multimeters give you a single number.

- Usually this works best when dealing with DC signals
- They can give you amplitude information for AC signals.

They often measure

- Voltage (DC)
- Voltage (AC rms)
- Resistance (Ohms)
- Current (usually the fuse is blown)

Some measure

- Temperature
- Frequency (Hz)
- Transistor gain (hfe)

Multimeters and RLC

If you remove the component from the circuit (motor, resistor, inductor, etc.) you can measure the DC resistance, inductance, or capacitance.

Example: two 47mH inductors reads as

Inductor	R	L
#1	98.3 Ohms	45.3mH
#2	96.9 Ohms	46.6mH

Two DC servo motors read as

Motor	R	L
#1	120.6 Ohms	13.12mH
#2	103.3 Ohms	13.03mH

Using statistics, you can find

- The mean
- The standard deviation,
- The 90% confidence interval
  - 2-sided t-test
- The probability that R > 100 Ohms
  - 1-sided t-test
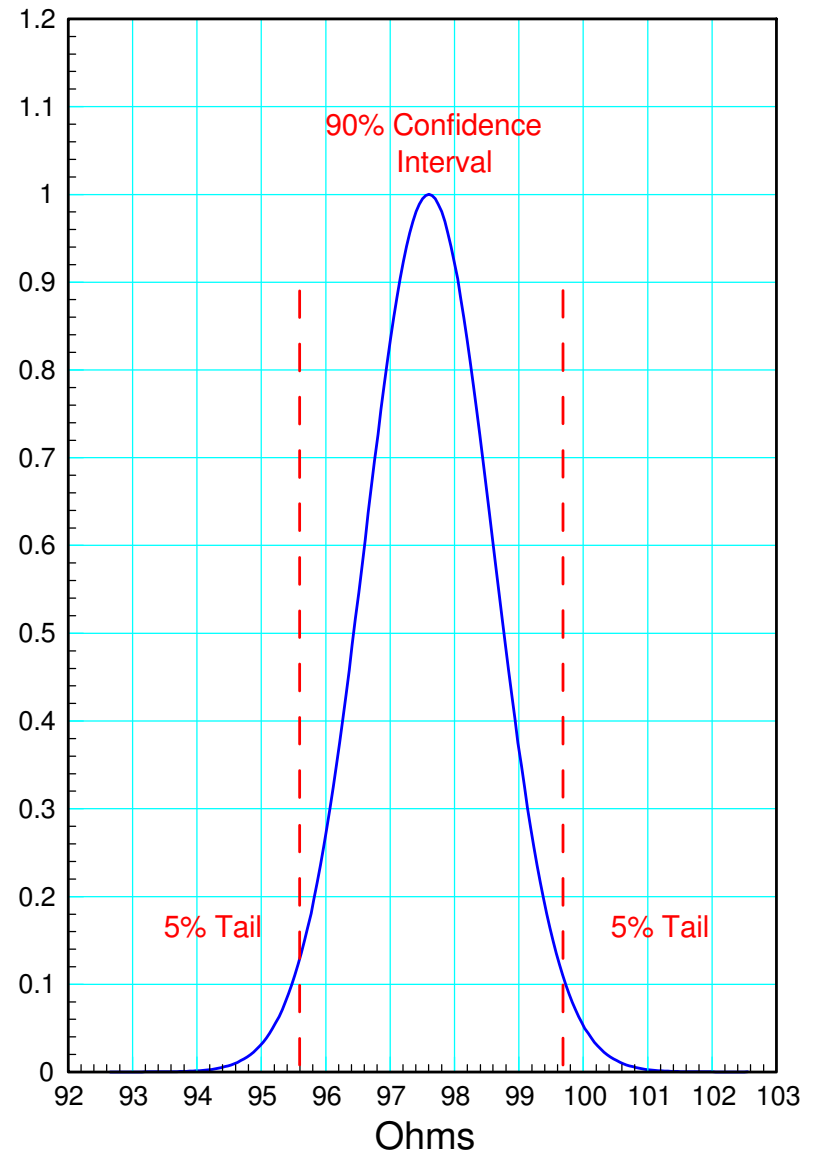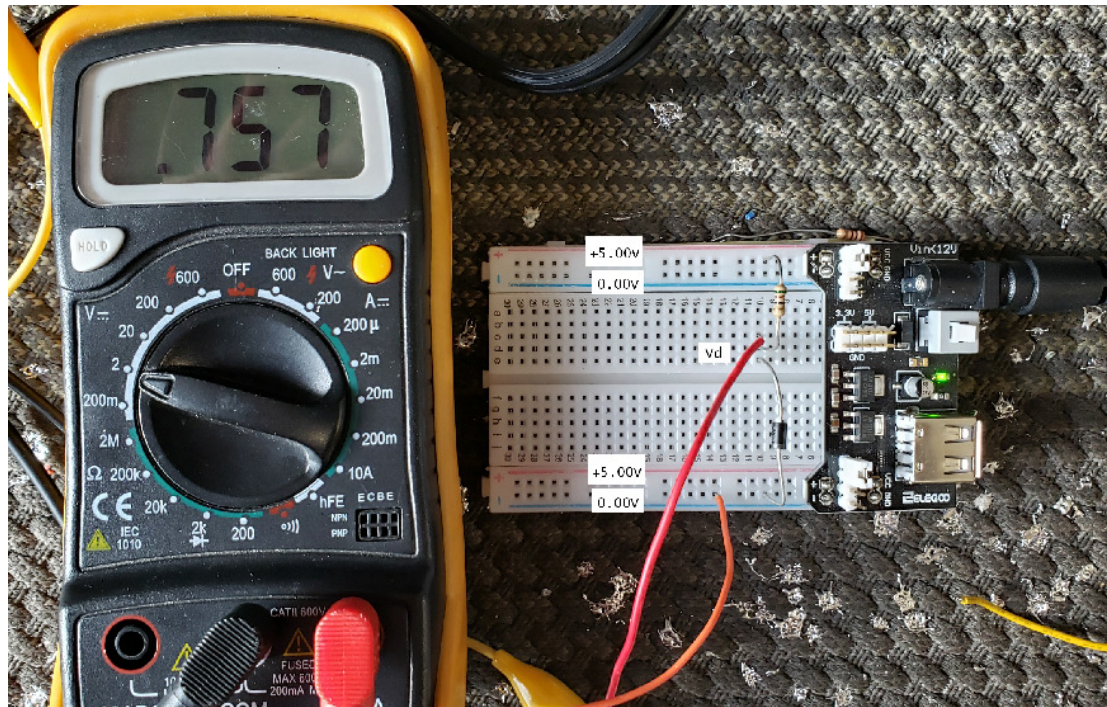
Multimeters & Voltages:

Voltages tell you a lot.

- Power Supply: what the actual power to the circuit is
- Vce: is the transistor off, active, or saturated?
- V(resistor): The current through the resistor (I = V/R)
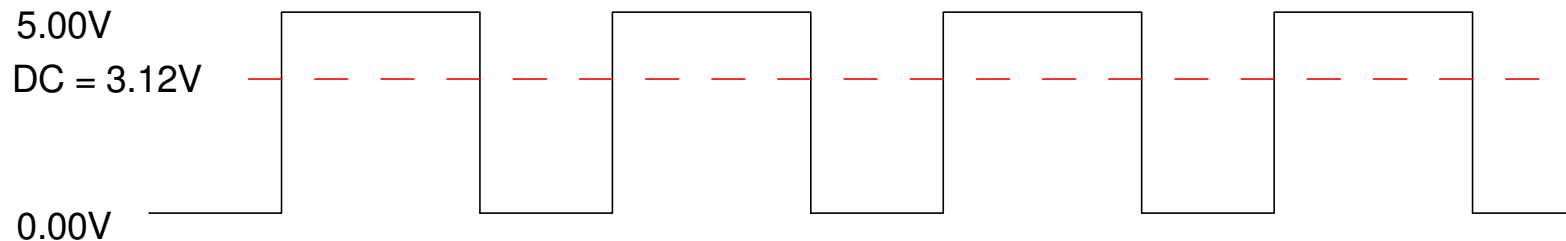- PWM Signal: The duty cycle

Voltage & PWM

PWM signal has

- A peak of 5.00V and
- A DC reading of 3.12V

The duty cycle is

$$Duty = \left(\frac{3.12V}{5.00V}\right) = 0.624 = 62.4\%$$

5.00V

DC = 3.12V

0.00V

# Voltage & Transistors:

Measure the voltages of a transistor switch

What this tells you is:

- $I_b = \left(\frac{4.89V - 0.68V}{1000\Omega} \right) = 4.21mA$

- $I_c = \left(\frac{8.63V - 2.02V}{100\Omega} \right) = 66.1mA$

- The transistor is saturated
  - Vce is about 0.2V
- The LED has a 1.86V drop across it
  - it's probably a red LED with Vf = 1.9V
- The gain of the transistor is at least 15.7
  - the ratio of Ic / Ib
  - Since the transistor is saturated, you don't know what the gain actually is - just its lower limit.
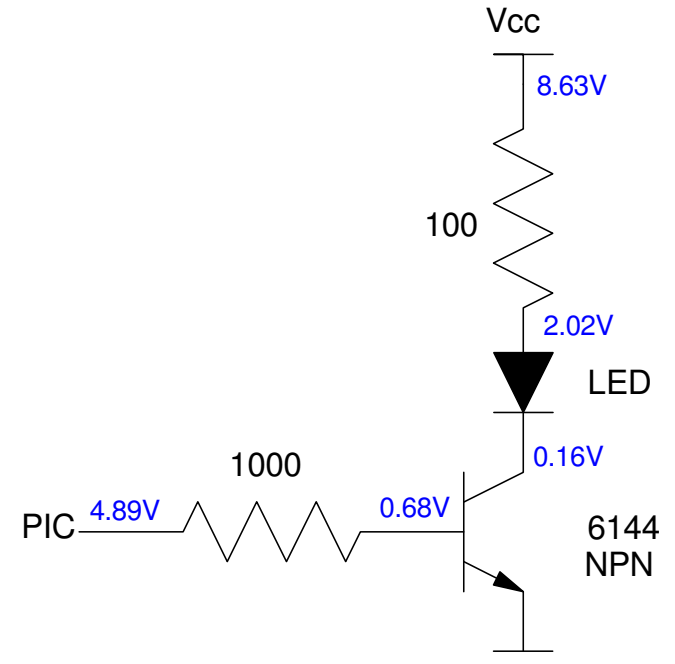
You actually can tell quite a bit about this circuit with just voltage measurements.

Multimeters with AC Voltages:
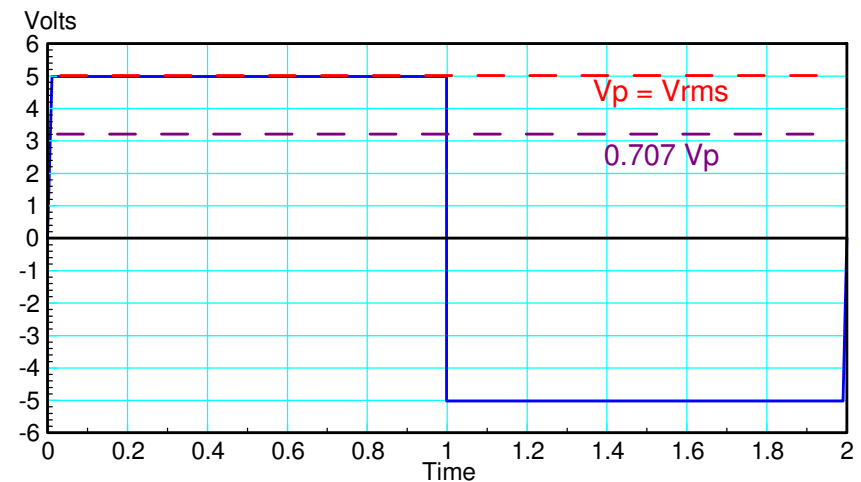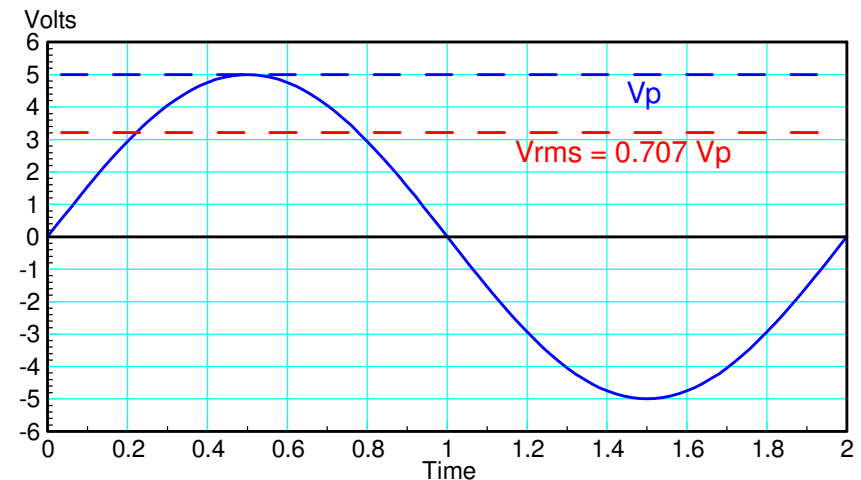
DC Voltage = Average Voltage

AC voltage = RMS Voltage
- Could be true RMS, or
- Could be $Vp / 2\sqrt{2}$.

For sine waves, the two are the same.

For other waveforms, they're different.
- Example, a +/- 5V square wave has
  - 5.000Vrms true RMS, or
  - 3.535Vrms if computed as $Vpp / 2\sqrt{2}$

Multimeters with AC Voltages (cont'd)

With AC readings and sinusoidal inputs, you can

- Measure the input and output of a filter at a given frequency
- Calculate the gain of a filter at a given frequency (gain = output / input)
- Measure the ripple in an AC/DC converter
- Measure the noise on the power supply
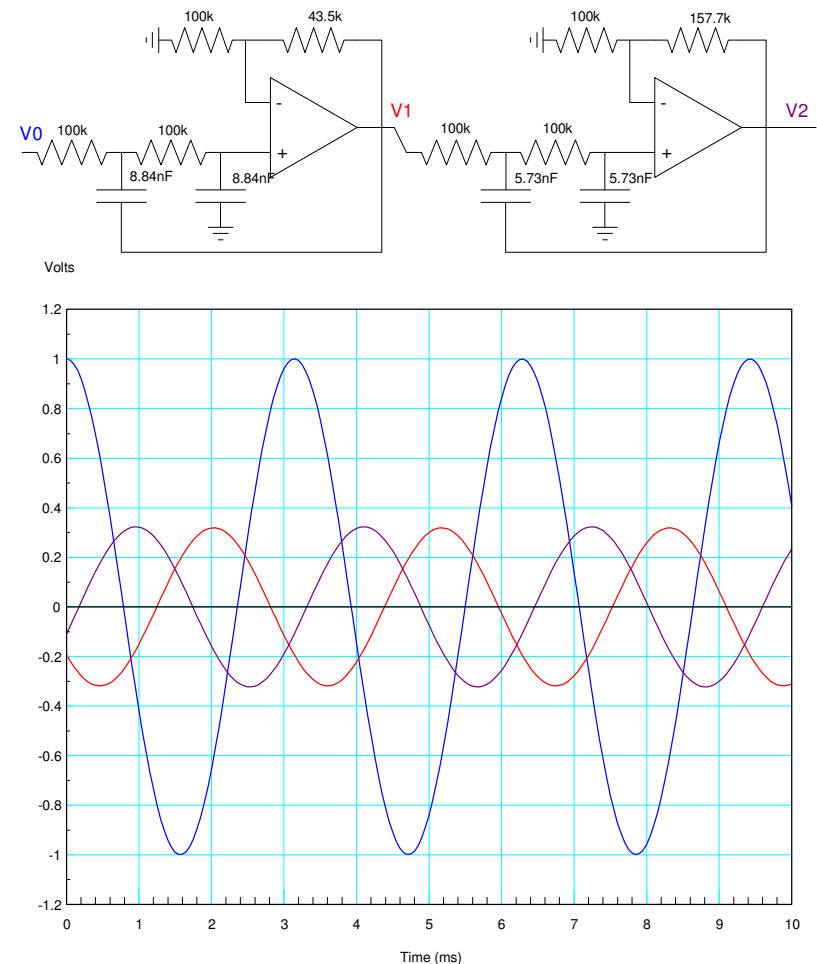
Voltages & AC to DC Converter

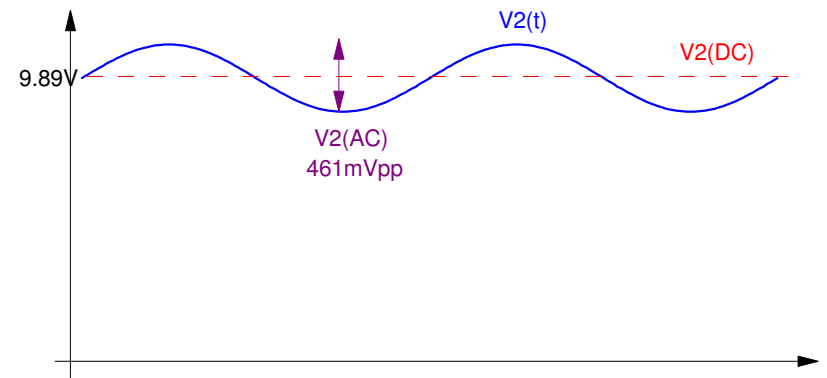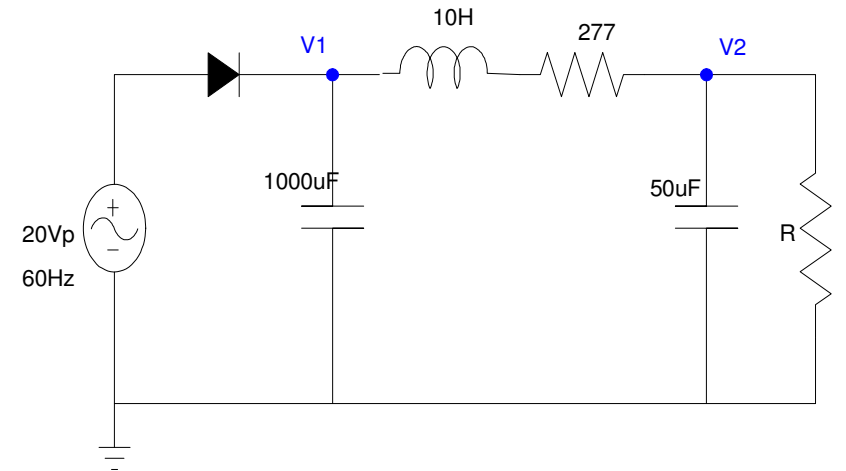If V2's readings are:

- 9.89V   DC Voltage
- 163.2mV   AC Voltage (rms)

Tells you

- The average of V2 is 9.89V
- The ripple on V2 is
  - 163.2mVrms
  - 230.8mVp
  - 461.6mVpp

Note that with AC signals, you *need* to specify the units.

- Vrms, Vp, and Vpp are all different numbers.
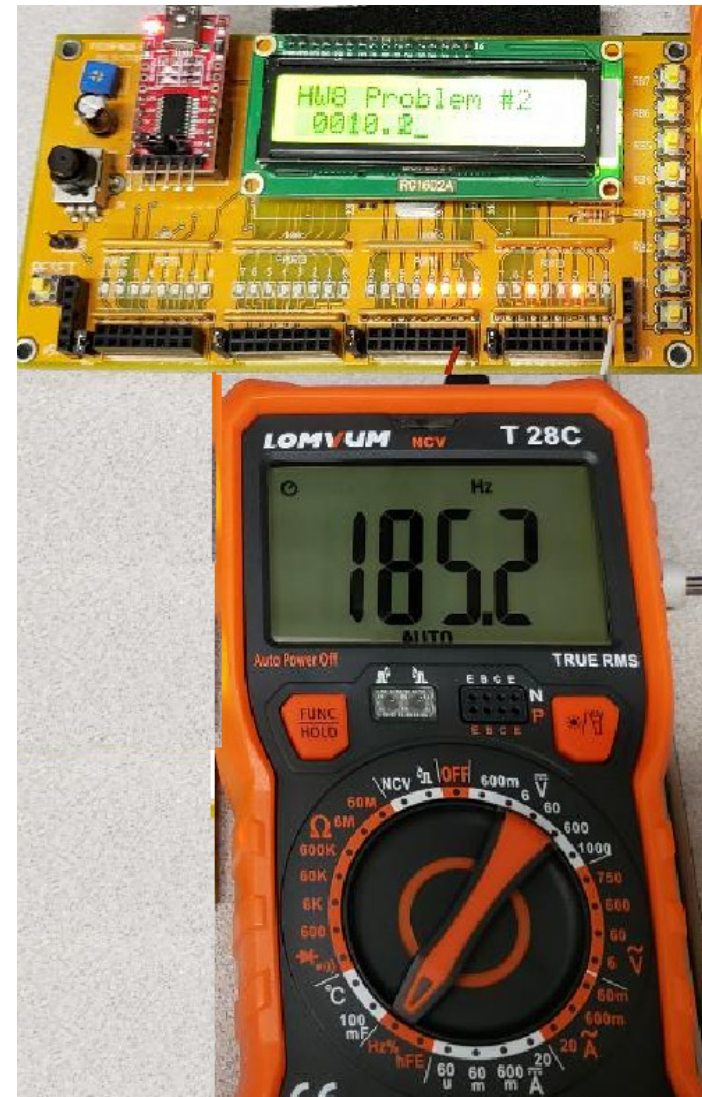
Frequency Counter:

Some multimeters include frequency counters

- Usually they work best with TTL signals

These allow you to measure execution time

- Example: Measure the frequency on RC0
- f = 185.2Hz
- Execution time $= \left(\frac{1}{2 \cdot Hz}\right) = 2.70ms$

```
while(1) {
    RC0 = !RC0;
    TIME = TIME + 1;
    LCD_Move(0,0);
    LCD_Out(TIME, 7, 1);
    }
```

Multimeters & Transistor Gain:

Many multimeters also tell you the gain of a BJT transistor
- NPN or PNP

This is also useful if you don't know what the correct polarity is:
- The connection with the higher gain is usually the correct way to connect the transistor

For example, measuring the gain of several 3906 PNP transistors results in

NPN	Correct (hfe)	Incorrect (hfe)
#1	293	3
#2	291	9

Oscilloscopes

- Electroboom - What is an oscilloscope?
- https://youtu.be/DgYGRtkd9Vs?feature=shared

Multimeters just give you a number

- OK for steady-state circuits
- Information is limited

Oscilloscopes give you an image

- *Lots* more information

Oscilloscopes are just darned useful. They can tell you

- DC and AC Voltage
- Clipping
- Phase Delay
- Time Delay (digital signals)
- Rise Time (digital signals)
- Spectral Content

Triggering:

Tells the oscilloscope when to start recording a signal.
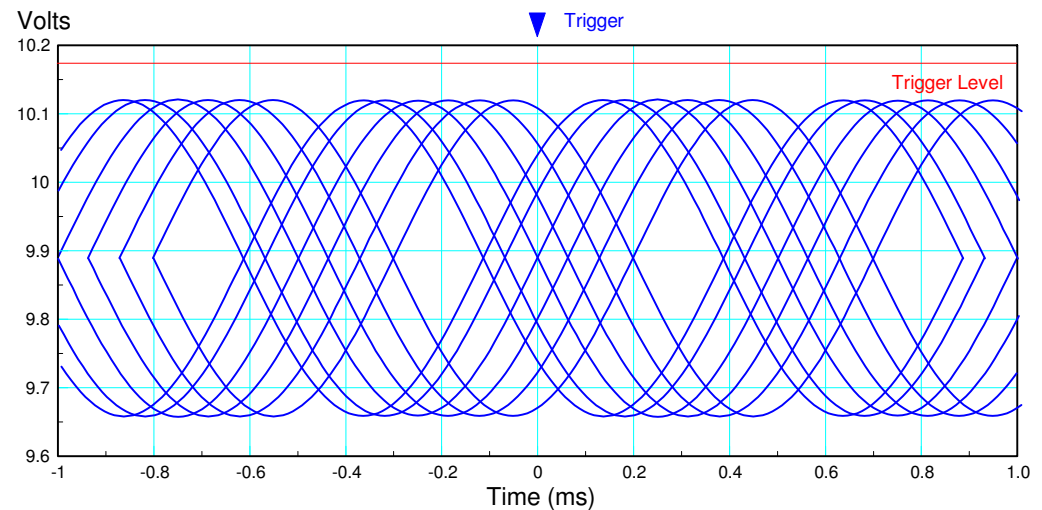
Normal: You specify

- The voltage and
- The rising / falling edge
- A knob lets you adjust the trigger level

Auto:

- The scope picks the trigger level
- If no trigger, it sweeps anyway
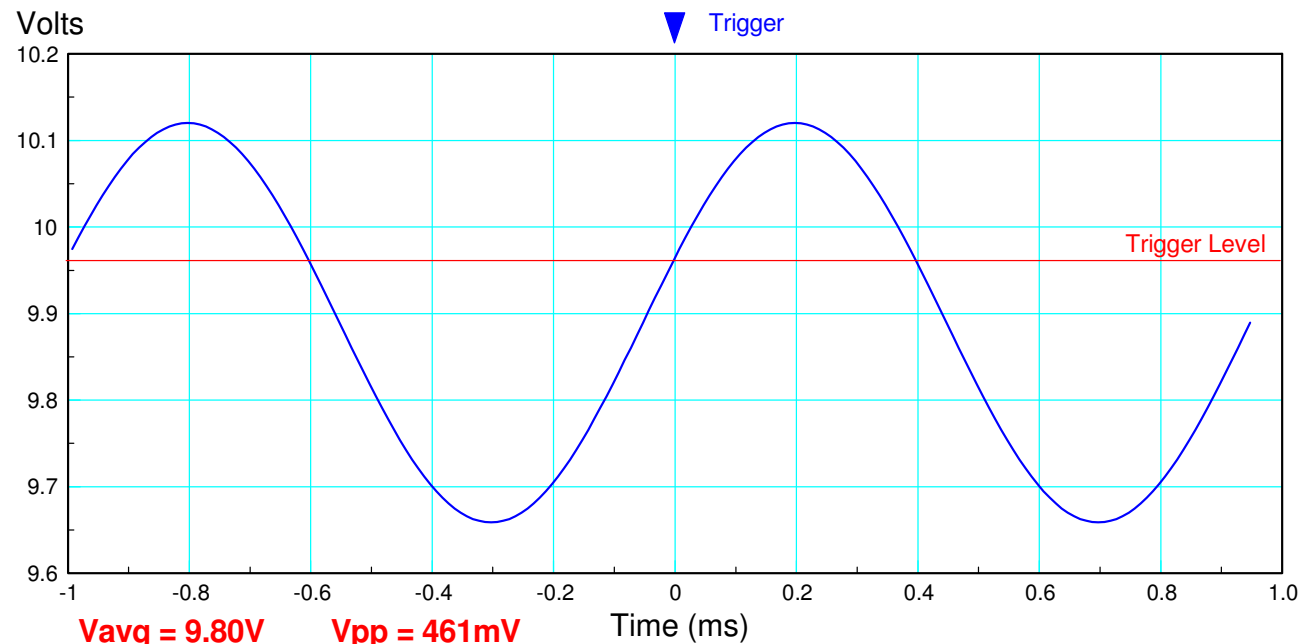
Single:

- Normal but
- Stops after one trigger
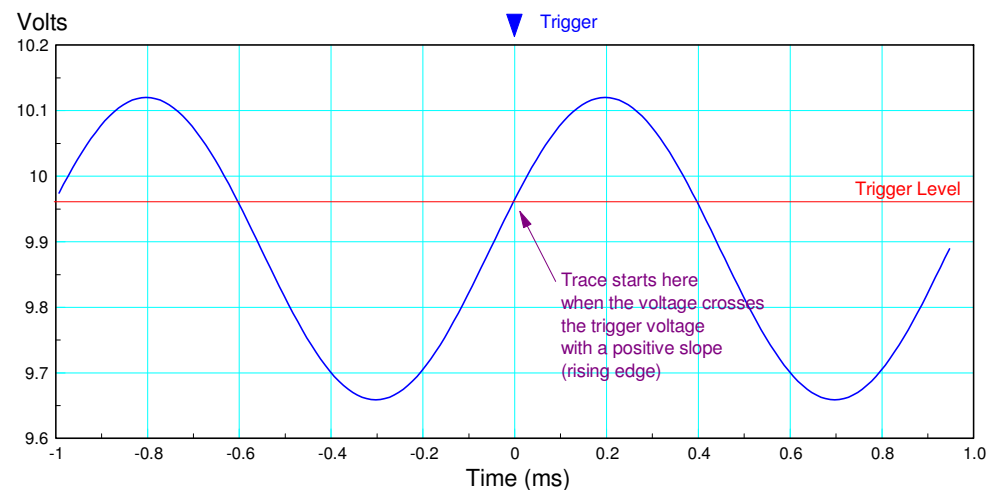
Oscilloscopes & DC / AC Voltages

Oscilloscopes can be used as an expensive multimeter

- They'll tell you the DC voltage (average)
- They'll tell you the AC voltage (Vpp, Vp, Vrms)

Personally, I prefer Vpp for AC readings

- It avoids confusion as to what you are reading.
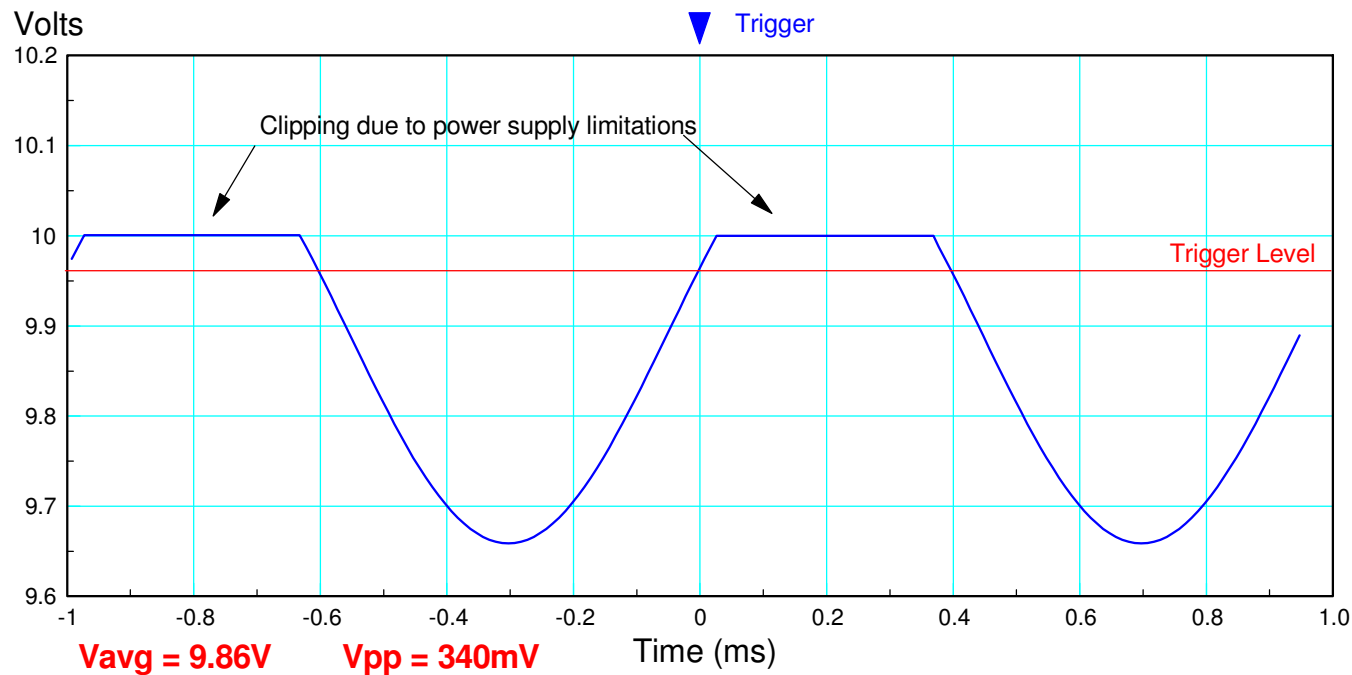

Vavg = 9.80V   Vpp = 461mV

Clipping:

Oscilloscopes can detect clipping

- The power supply limits affect the waveform
- Easy to see with an oscilloscope

Clipping means you need to reduce the input
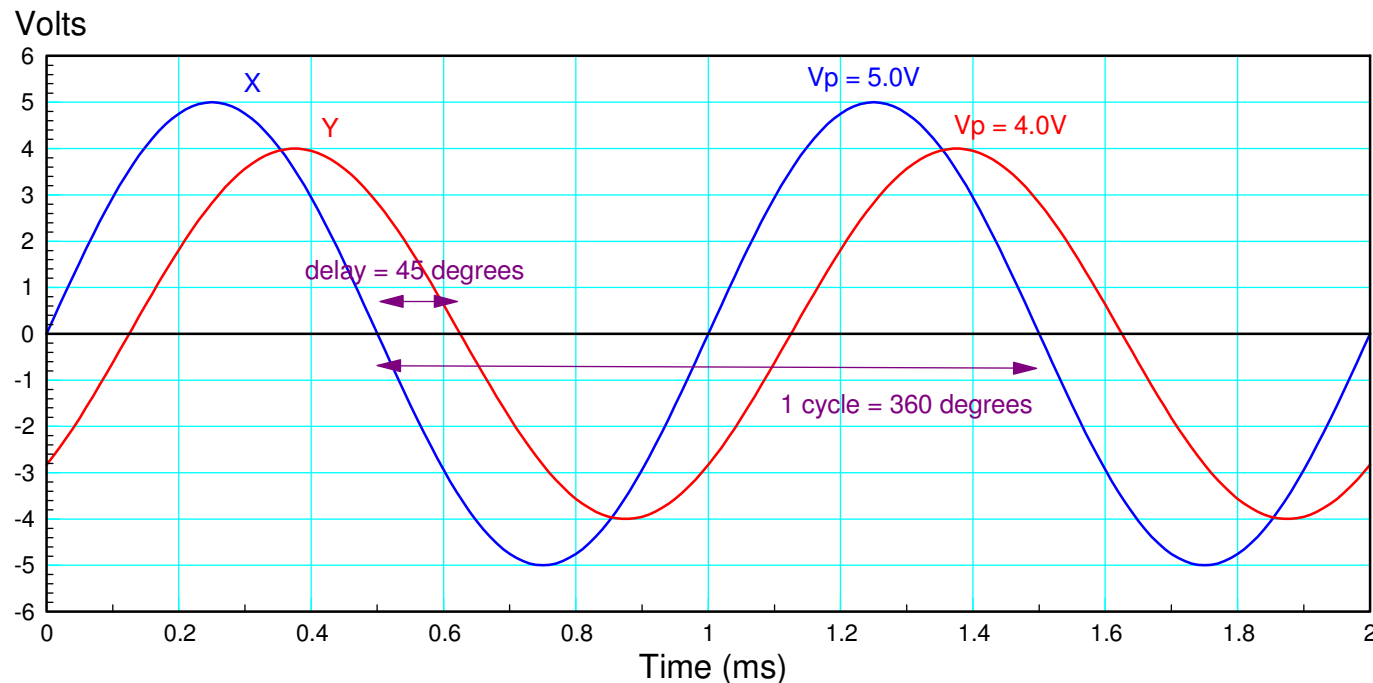
- Gain readings will be of otherwise

Phase Delay:

Filters provide both gain and phase shift

A delay is a negative phase shift

$$\theta = -\left(\frac{delay}{period}\right) \cdot 360^0$$

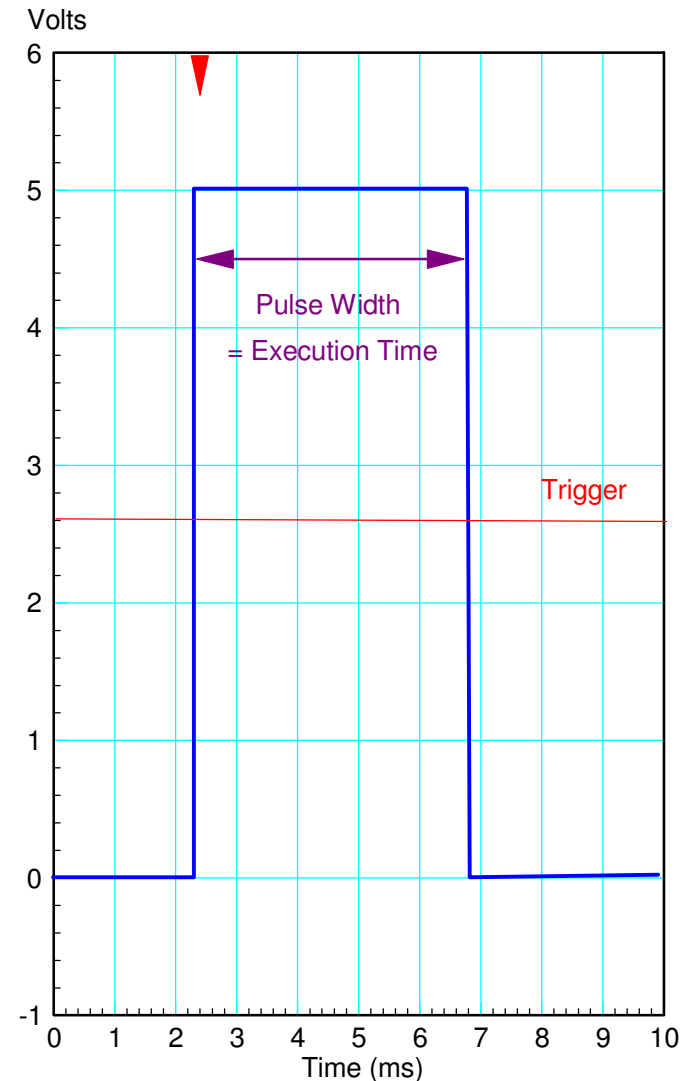Example: This shows a gain of $0.8\angle - 45^0$

Pulse Width

One trick to measure a program's execution time is to

- Set a pin before the routine
- Clear the pin afterwards

The pulse width is the execution time

```
while(1) {
    TIME = TIME + 1;
    RC0 = 1;
    LCD_Out(TIME, 7, 3);
    RC0 = 0;
    Wait_ms(10);
    }
```
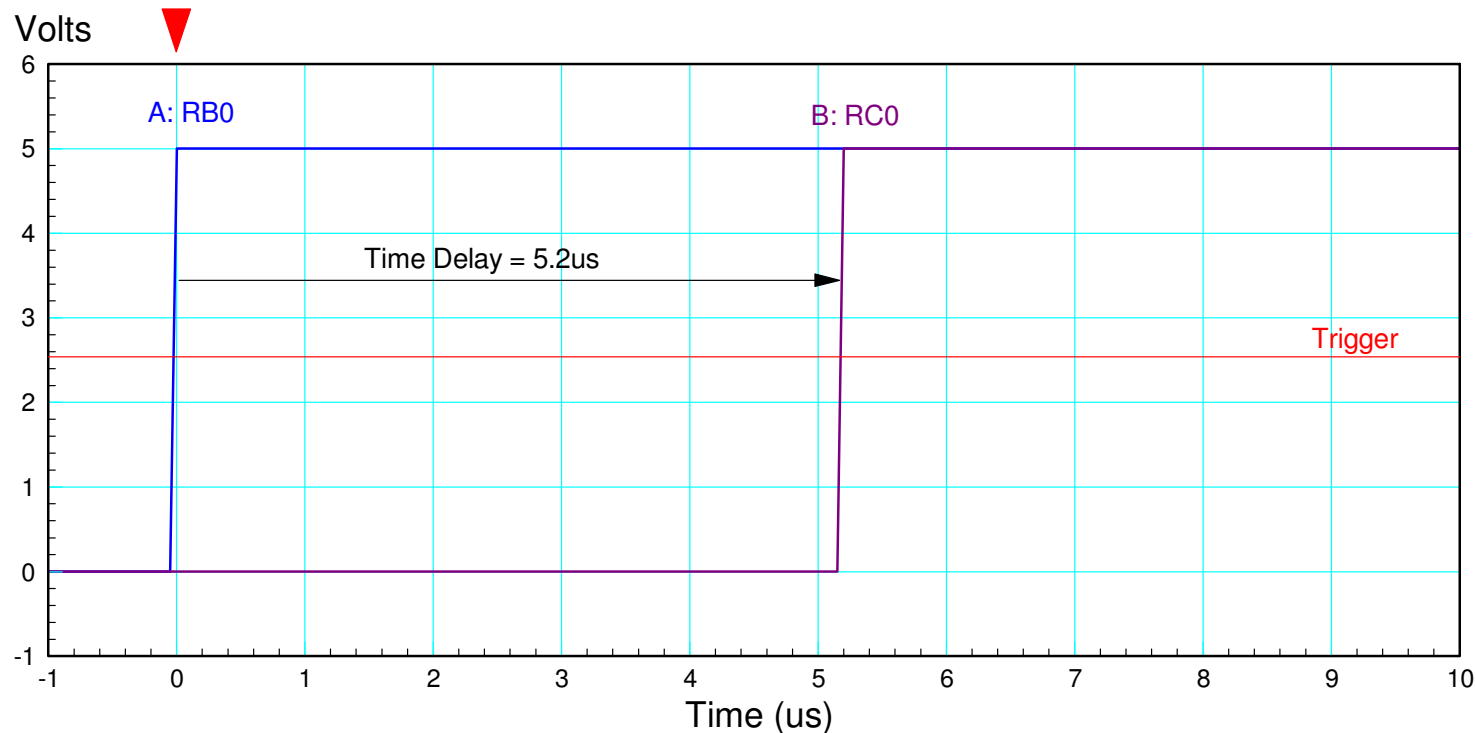
Time Delay (digital signals):

With digital signals, you can measure the delay between two signals.

Example: Find the delay between
- When I press a button (RB0) and
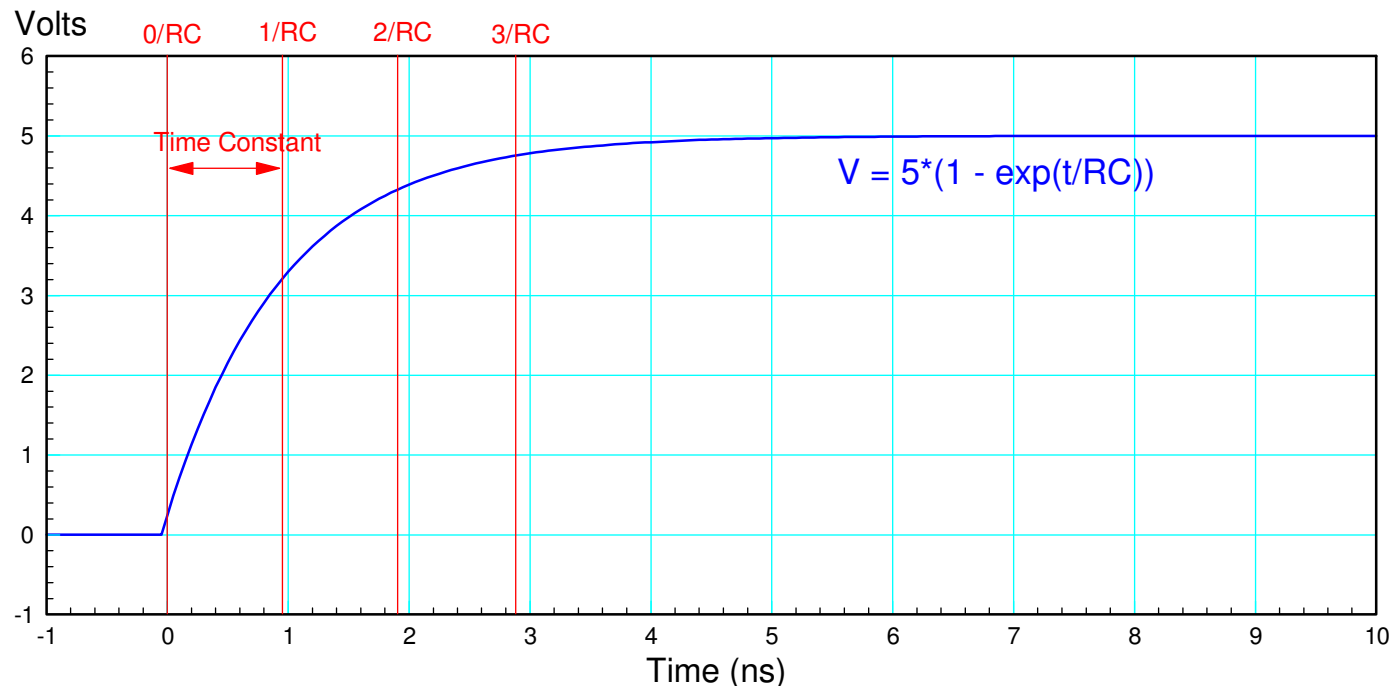- A signal goes high (RC0)

Rise Time (digital signals):

All traces have some capacitance and resistance.

This causes the voltages to rise and fall with an RC time constant.

If you zoom in on the time scale, you can usually see this

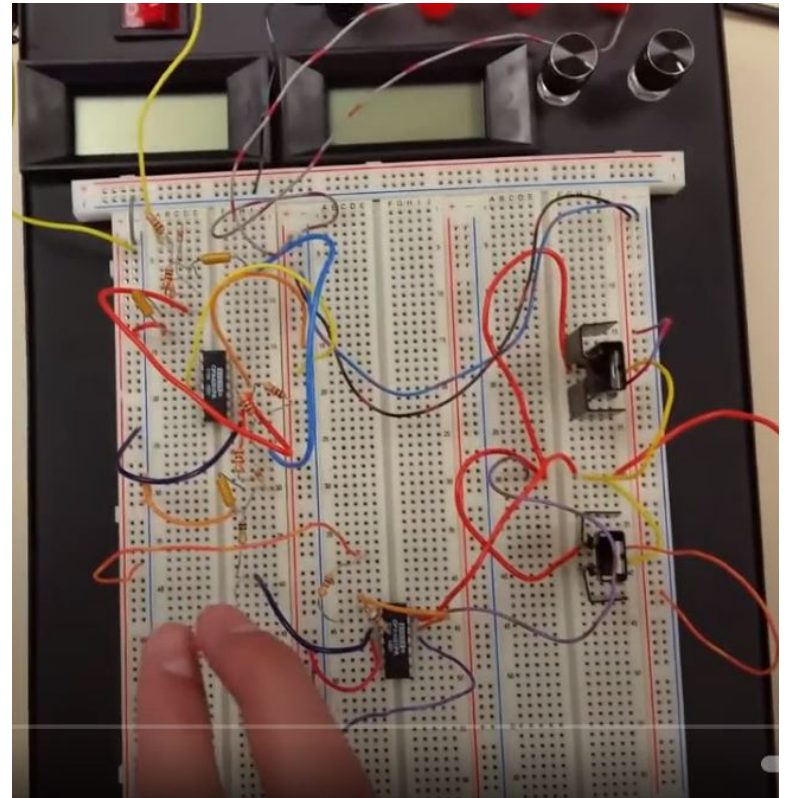- It might be really small (a couple of nano-seconds)

Breadboards - Do's and Don'ts

Many of your tasks will include a breadboard circuit

- Not always needed
- Example: apply knowledge in software engineering

Some do's and don'ts when building your breadboard circuit

1) Keep Your Circuit Neat

- Use short wires
- Use short component leads
- Organize your breadboard into sections

Keeping your wires short

- Reduces the noise picked up by your wires
- Reduces the chance of a wire falling out
- Helps you see the wiring in your board
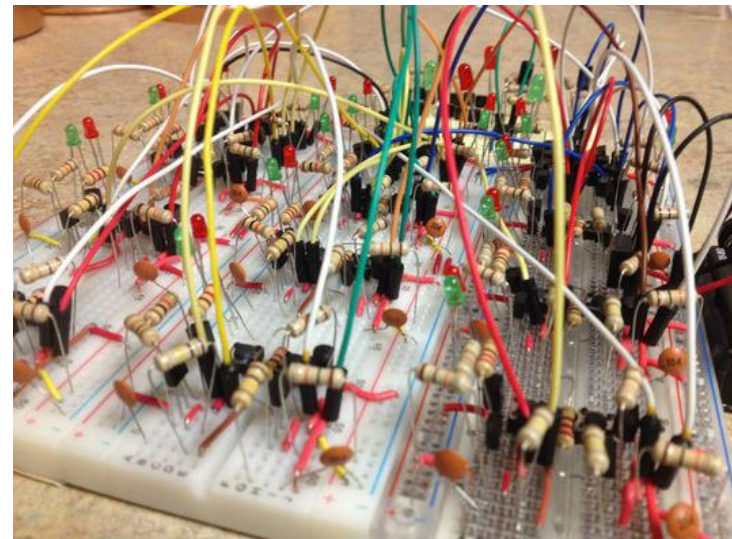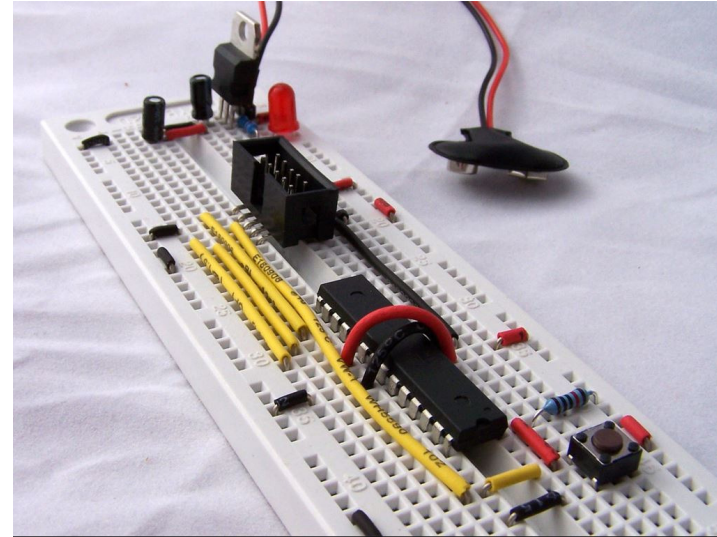- Helps when you need to modify your breadboard circuit.
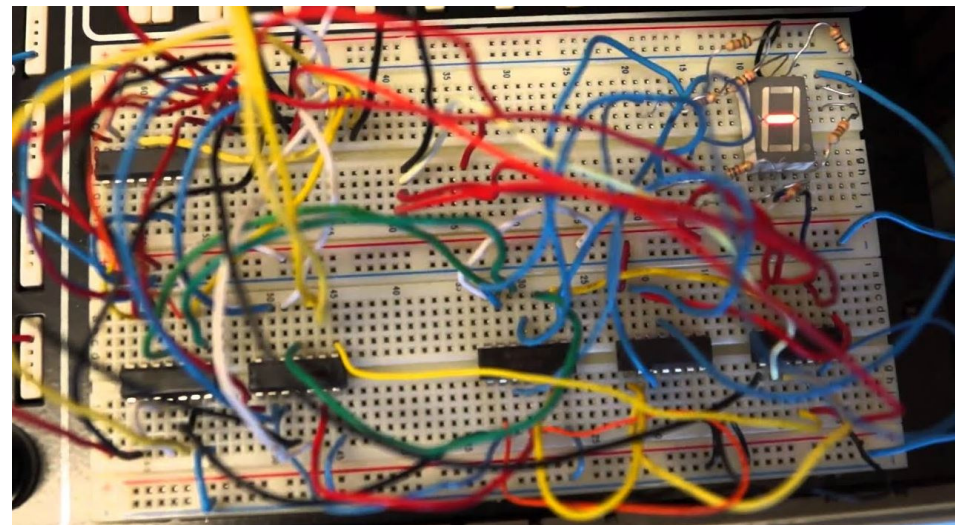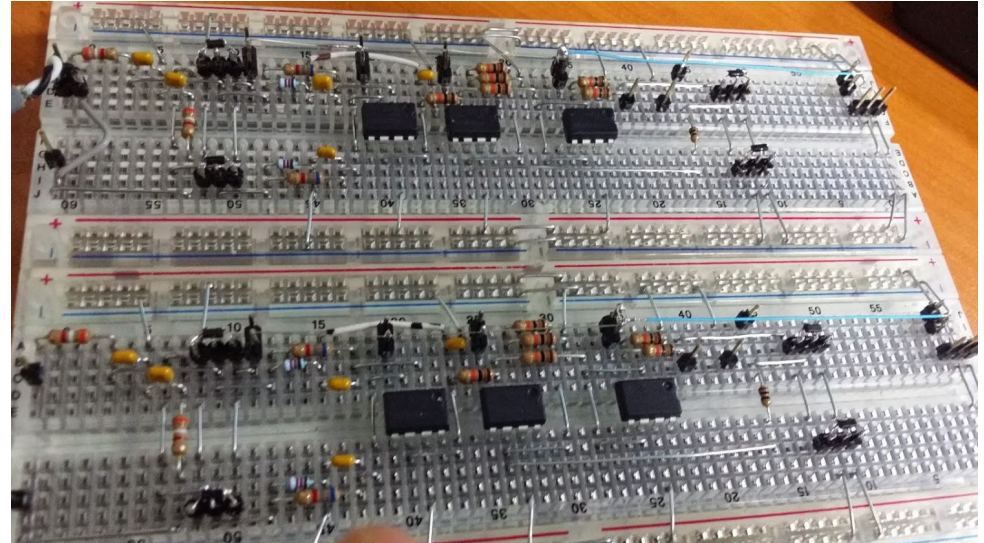
2. Color Code your Wires

- Use red wires for +5V
- Use black wires for ground
- Use different colors for different types of signals.
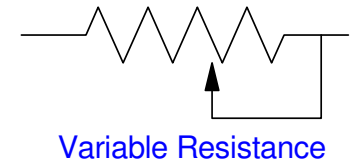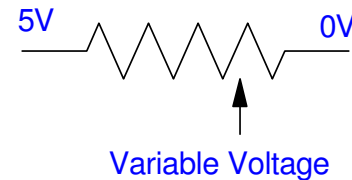
By color coding your wires,

- You can quickly spot if a chip is missing power and/or ground.
- You can quickly see if a signal wire is missing between two ICs

3. Use Potentiometers

Potentiometers allow you to

- Adjust voltages (0..5V)
- Adjust resistors (0% to 100%)
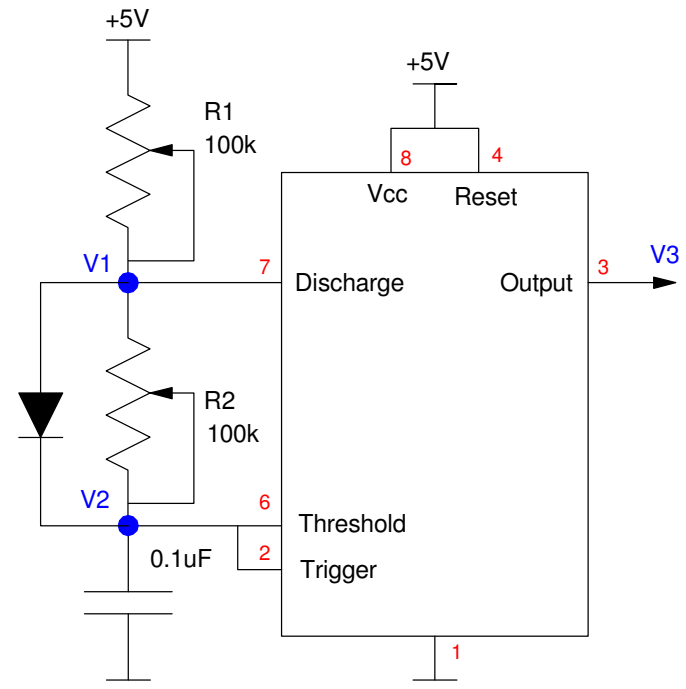
5V 0V

Variable Voltage

Variable Resistance

Replacing a resistor with a potentiometer allows you to tune your circuit without having to replace components

- Really useful when you get to PCB's

But...

- A resistor costs $0.02
- Potentiometers cost $1.55
- Be reasonable...

+5V

R1
100k

+5V

8   4

Vcc   Reset

V1   7   Discharge   Output   3   V3

R2
100k

V2   6   Threshold

0.1uF   2   Trigger

1

4. Use Evaluation Boards

- PIC, Arduino, Raspberry Pi, etc.

In Senior Design II

- Using EVB's is encouraged
- They make it easy to connect hardware to a microcontroller
- They make it easy to test your code as you write it
- It's what evaluation boards are for
  - We have spares if you need a PIC EVB
  - We also have Pi-Pico breadboards (several types)

In Senior Design III

- Replace the EVB with a custom PCB
- Strip out everything you don't need
- Reduce the package size
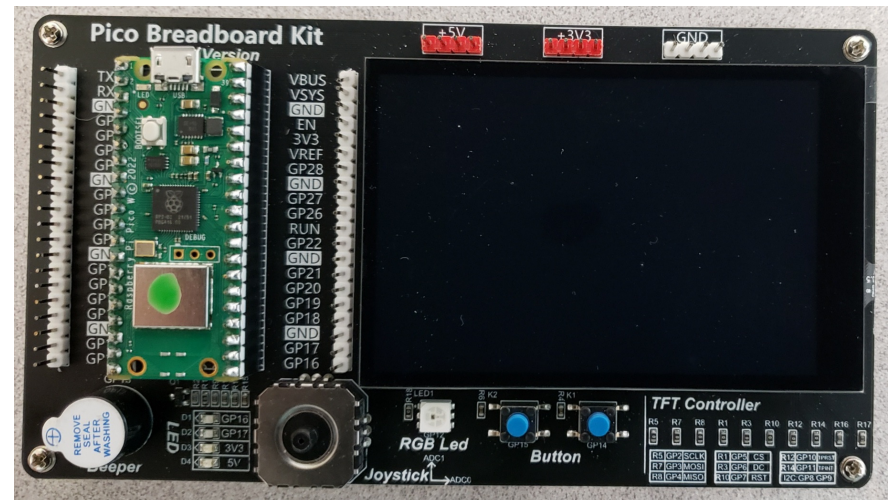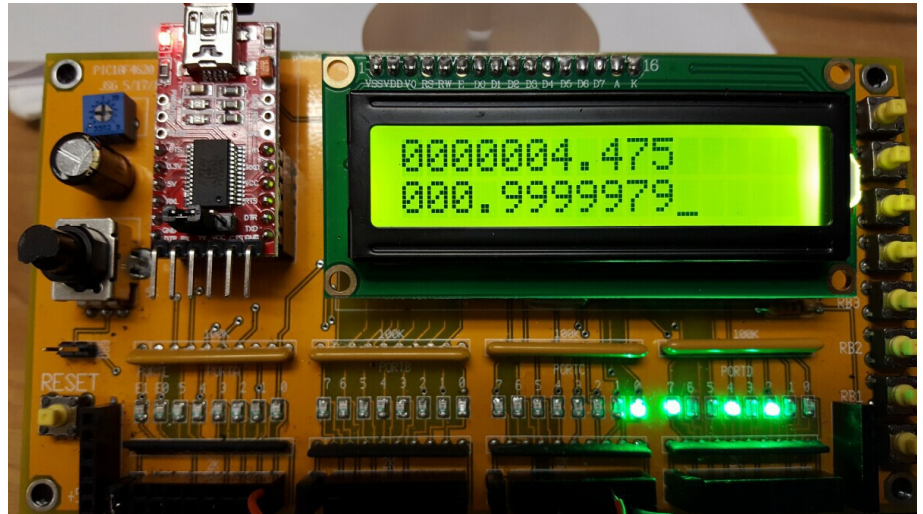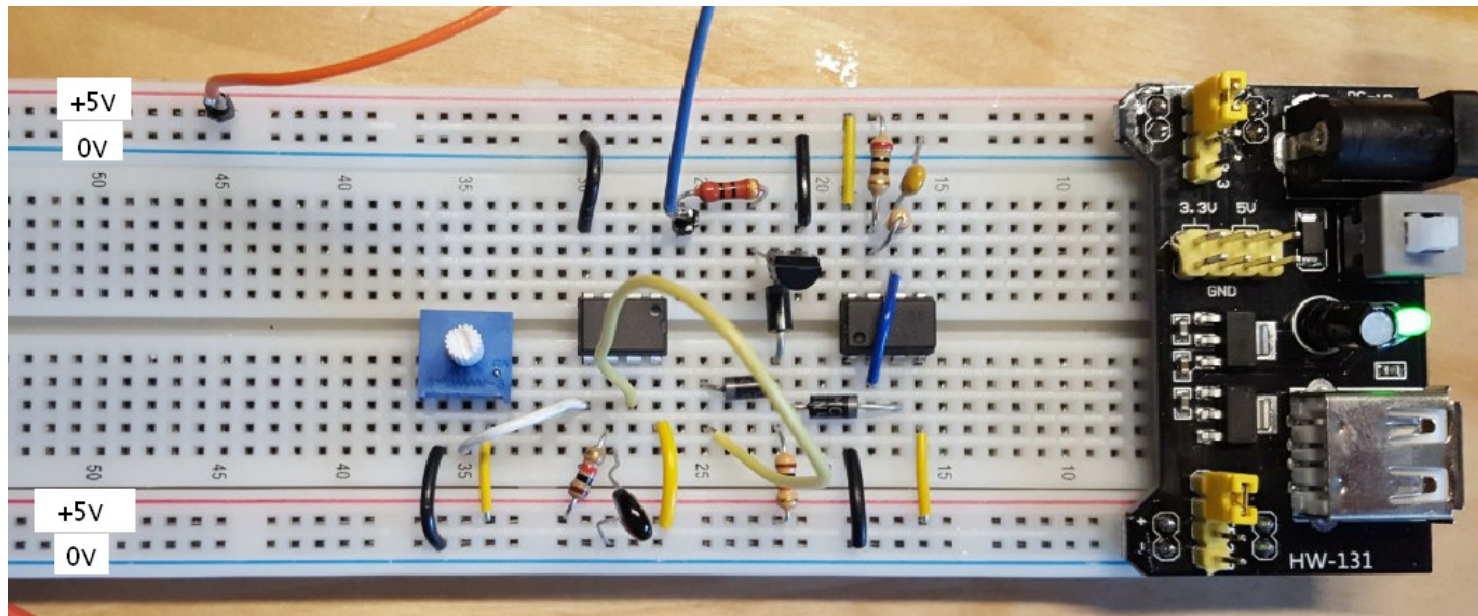
5. Keep Your Breadboard

- Don't tear it down and cannibalize it for parts

It'll be useful when you get to Design III

- Reminder of what worked
- Useful when combining sections into a single working device

If you need more breadboards, just ask

- We buy them by the hundred

Homework #8: ECE Tools

While collecting data as you work on your tasks...

- Use multimeters, frequency counters, oscilloscopes
- To tell you what's happening with your circuit, and
- What's its limitations are

You will almost invariably be using ECE tools when you validate your tasks

- Many tools are available
- Many tools count
- Nothing wrong with using more than two
- Just be sure to use at least two different tools to get full credit