ECE Tools

ECE 403 Senior Design II

Week #4

Please visit Bison Academy for corresponding lecture notes,
homework sets, and videos
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Introduction

In Homework #9, you are to demonstrate your proficiency with two ECE tools.

- In reality, you probably did that already in homework sets #5 to #8.
- Any time you are collecting data to validate your design, you're probably using some ECE tool.

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

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

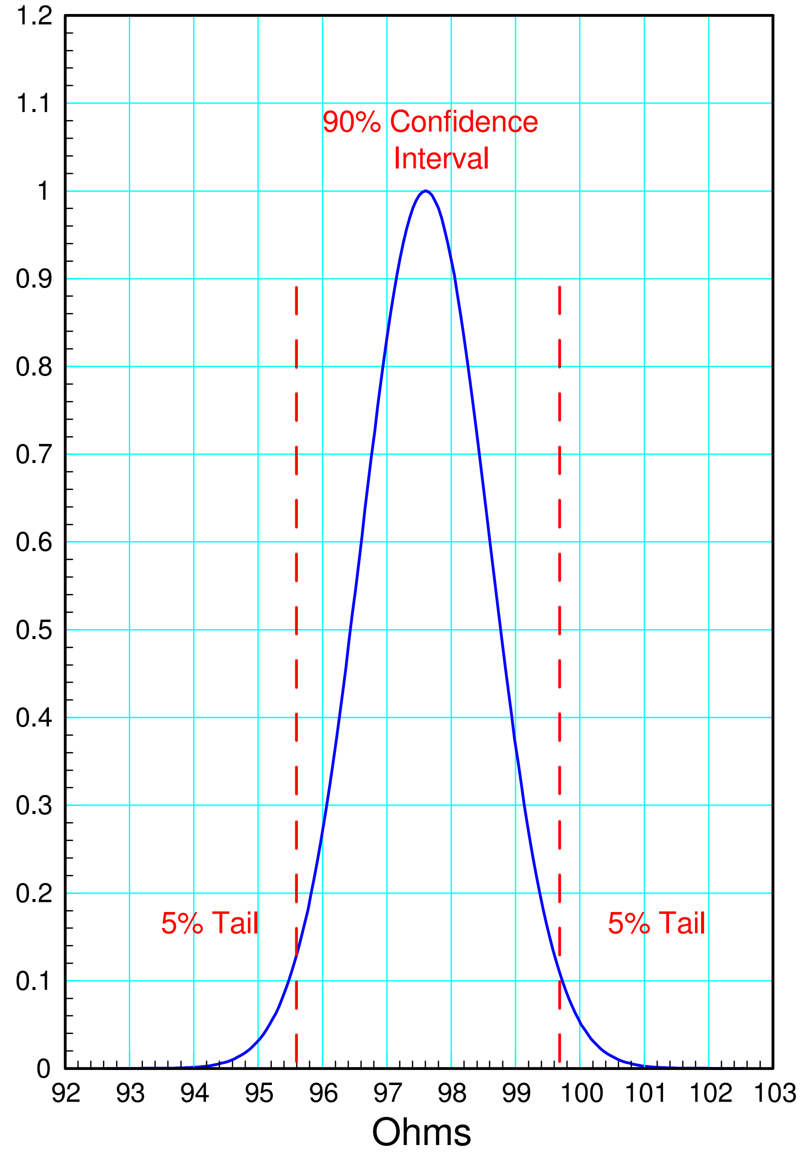
Inductor	R	L
#1	98.3 Ohms	45.3mH
#2	96.9 Ohms	46.6mH

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

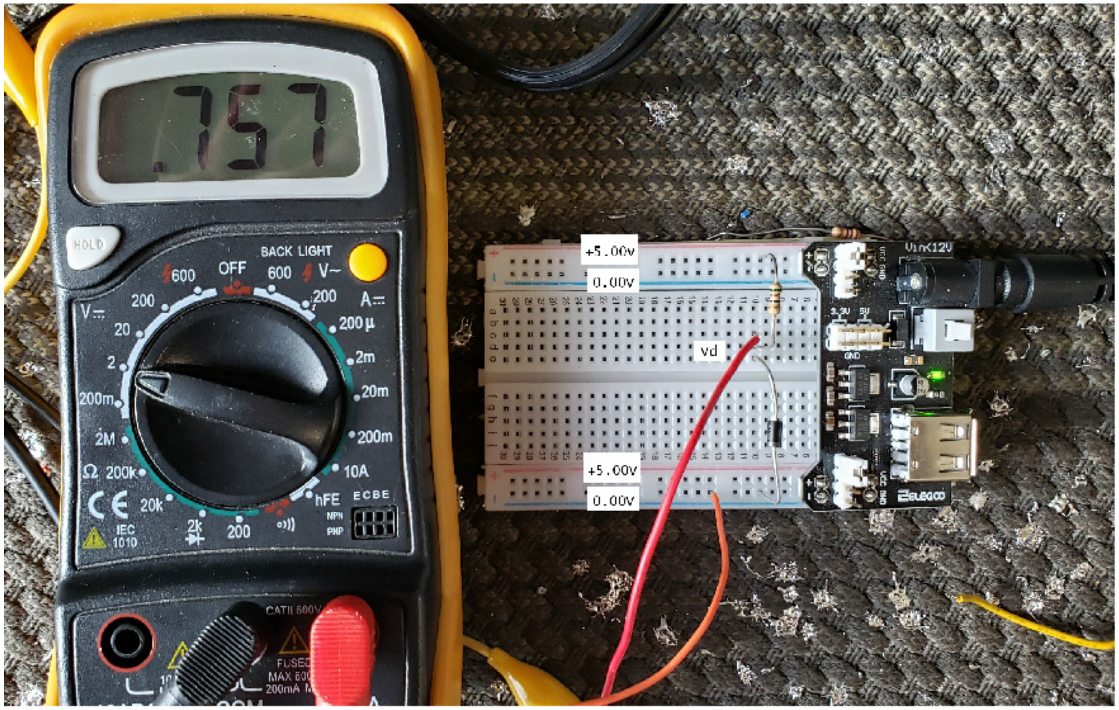
- The mean
- The standard deviation,
- The 90% confidence interval
  - 2-sided t-test
- The probability that R > 100 Ohms
  - 1-sided t-test



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



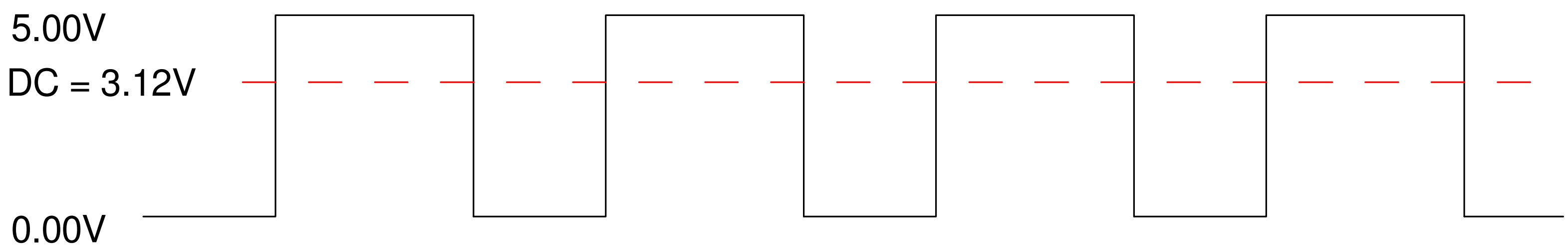
Voltage & PWM

PWM signal has

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

The duty cycle is

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

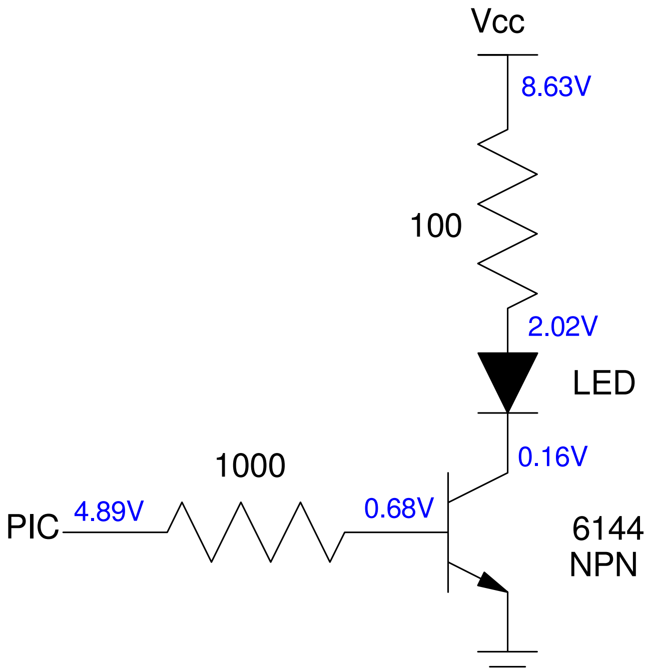


Voltage & Transistors:

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

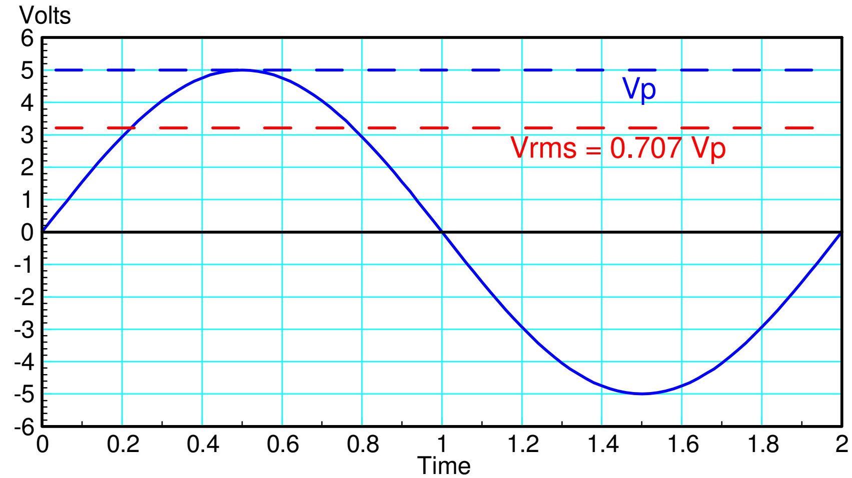
AC voltage = RMS Voltage

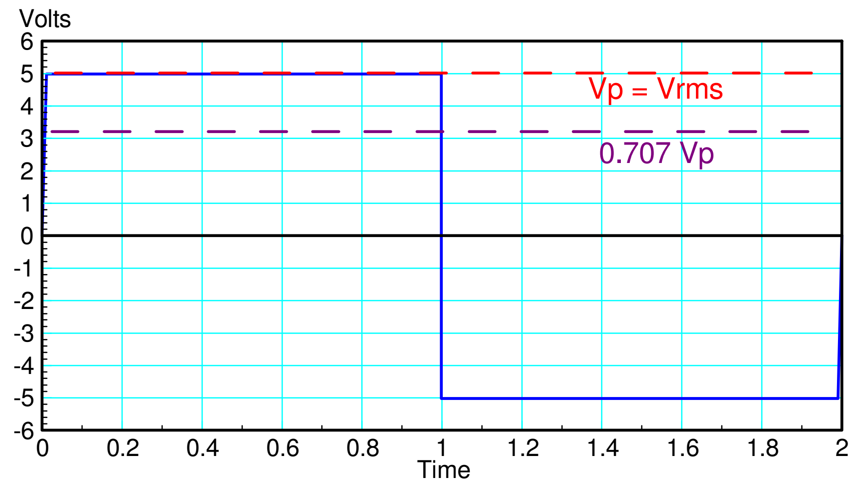
- Could be true RMS, or
- Could be Vp / $2\sqrt{2}$.

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 / $2\sqrt{2}$





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:

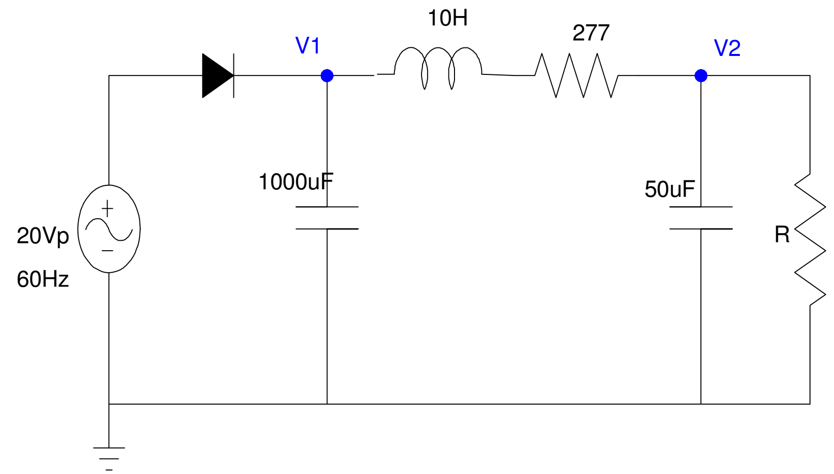
- 9.89V DC Voltage
- 163.2mV AC Voltage (rms)

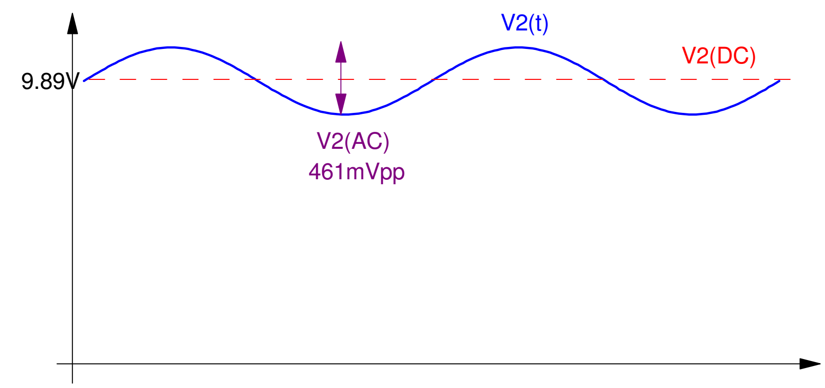
Tells you

- 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

Multimeters are really designed to measure DC signals (although you can measure the rms voltage of an AC signal). While this does provide you with some information, it's somewhat limited. Oscilloscopes, in contrast, present the voltages vs. time as a picture. This tells you a *lot* more about what's happening.

Oscilloscopes are just darned useful. They can tell you a lot about a signal.

- 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

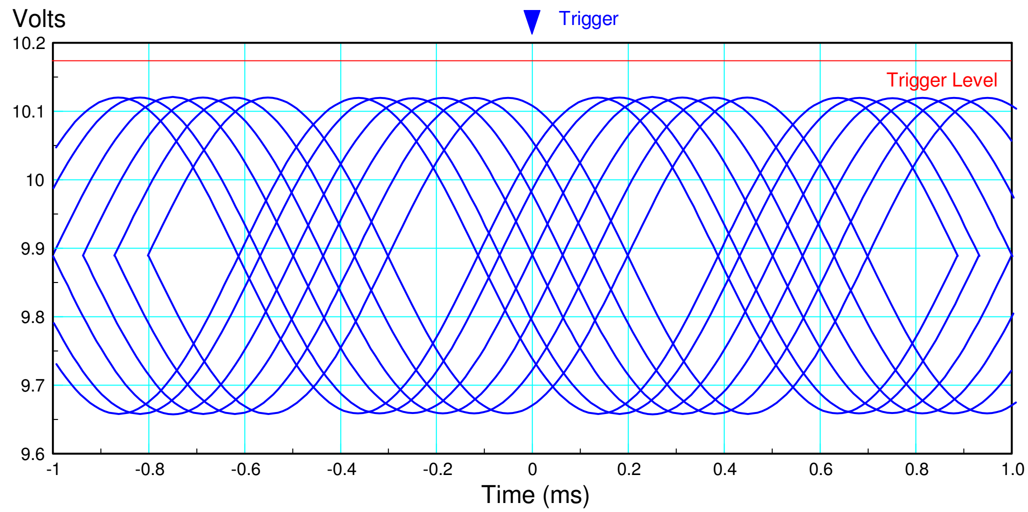
- The voltage and
- The rising / falling edge
- A knob lets you adjust the trigger level

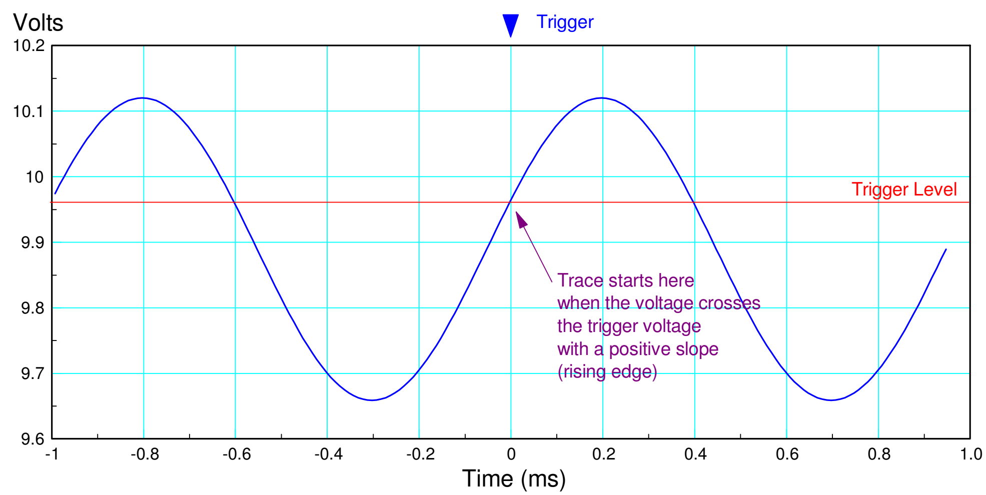
Auto:

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

Single:

- Normal but
- Stops after one trigger





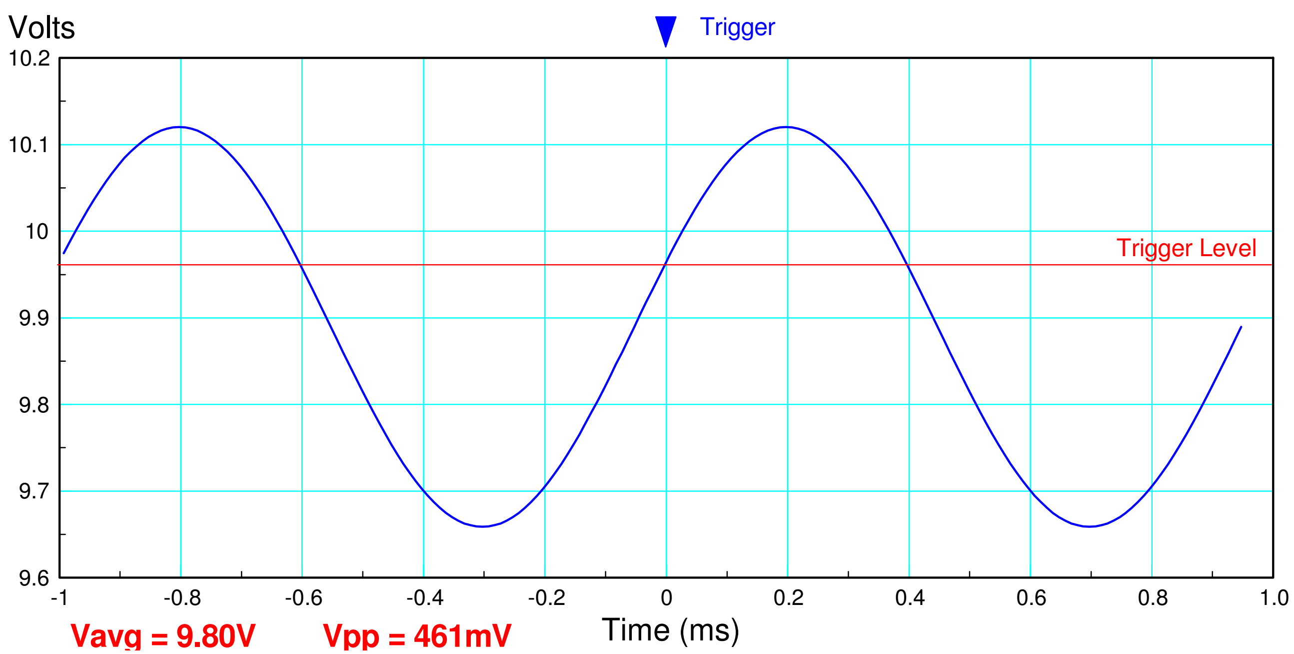
Oscilloscopes & DC / AC Voltages

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.



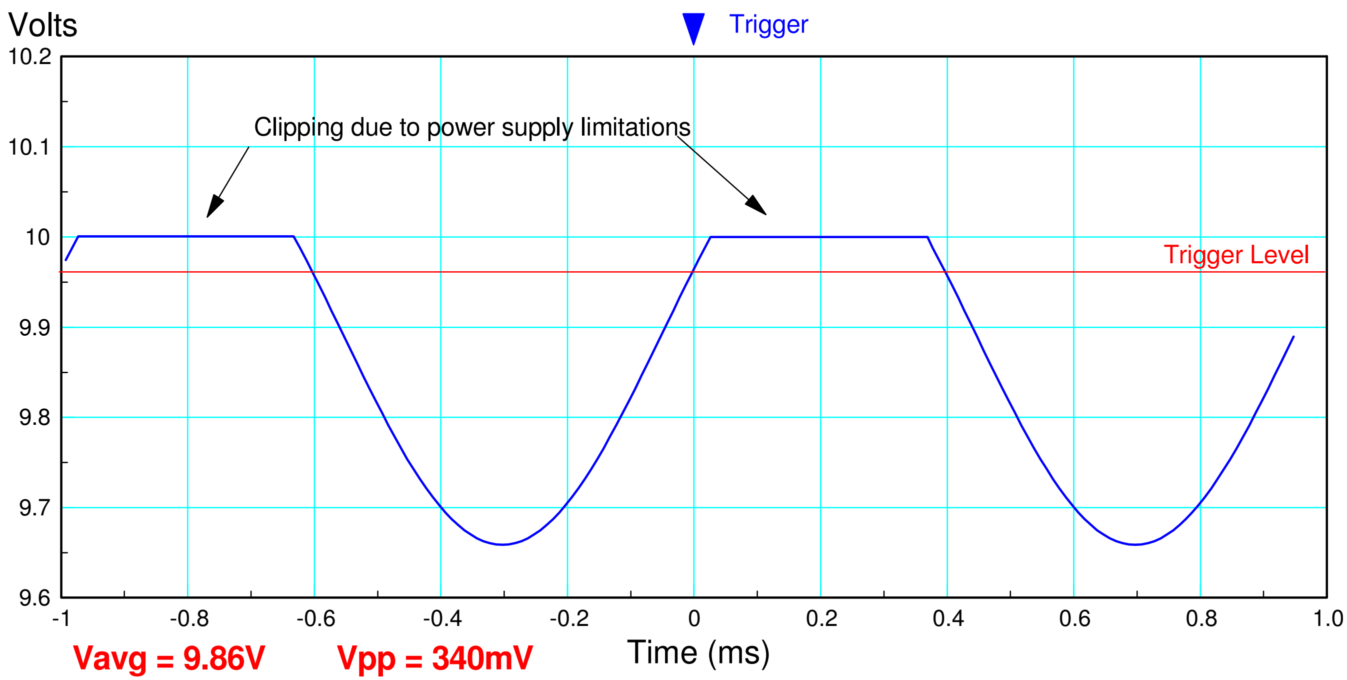
Clipping:

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



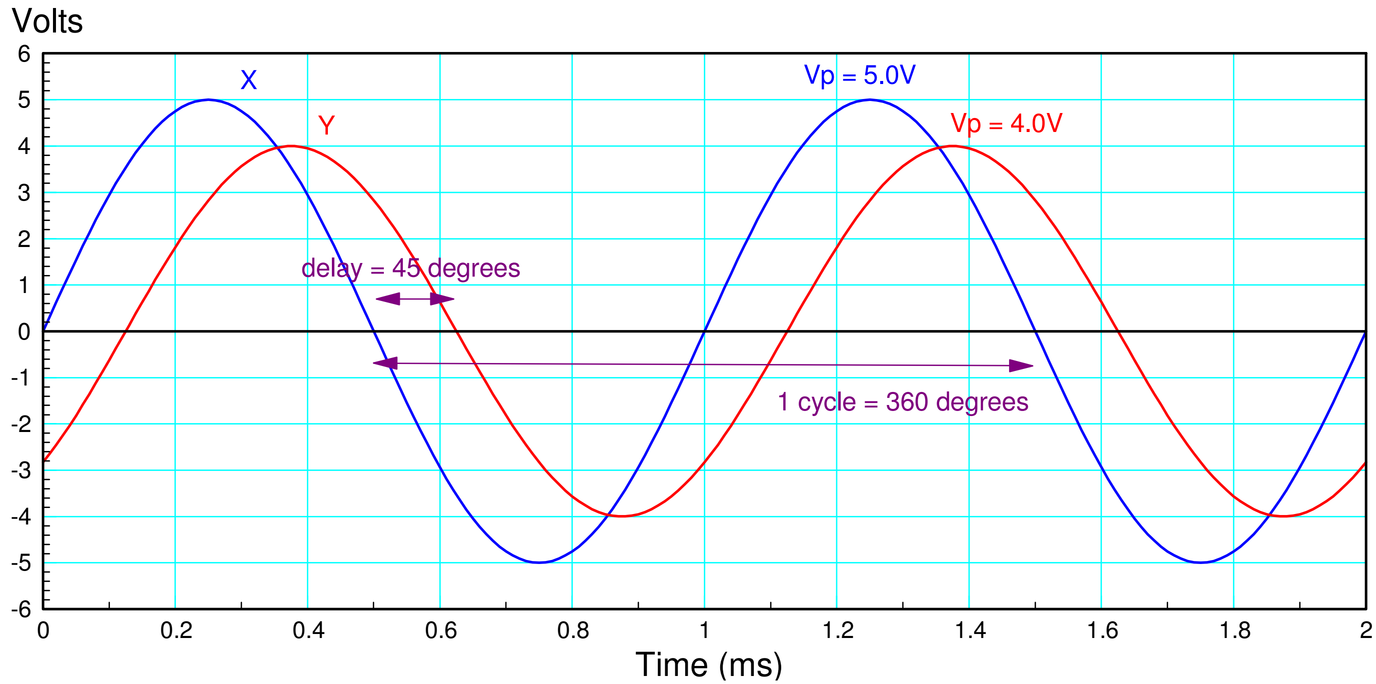
Phase Delay:

Filters provide both gain and phase shift

A delay is a negative phase shift

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

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



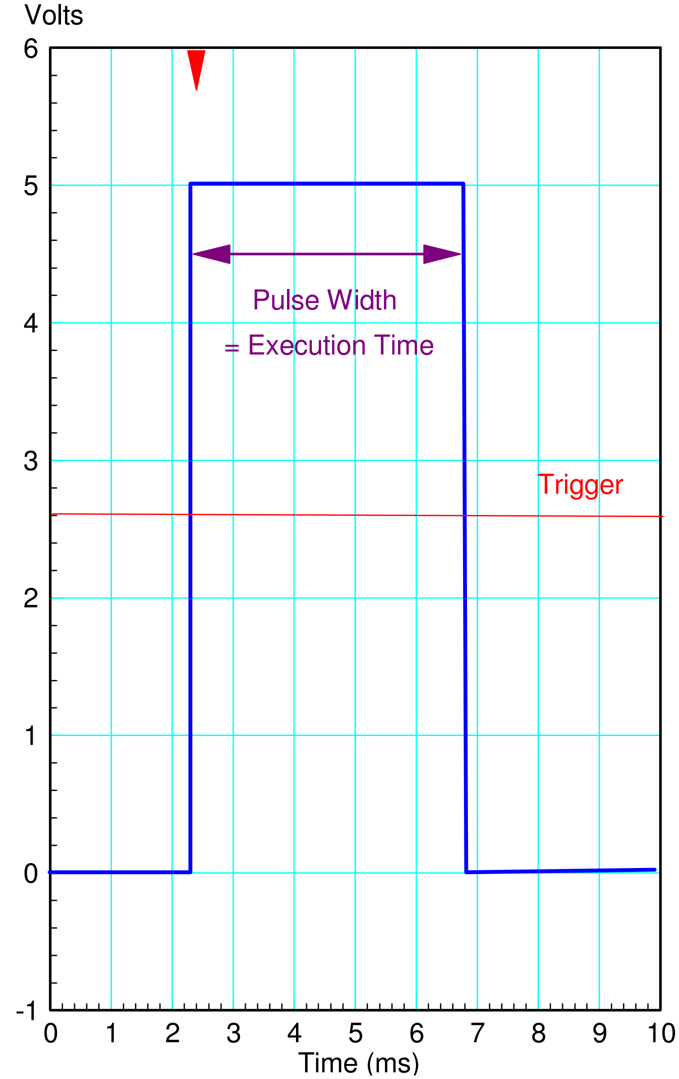
Pulse Width

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);
    }
```

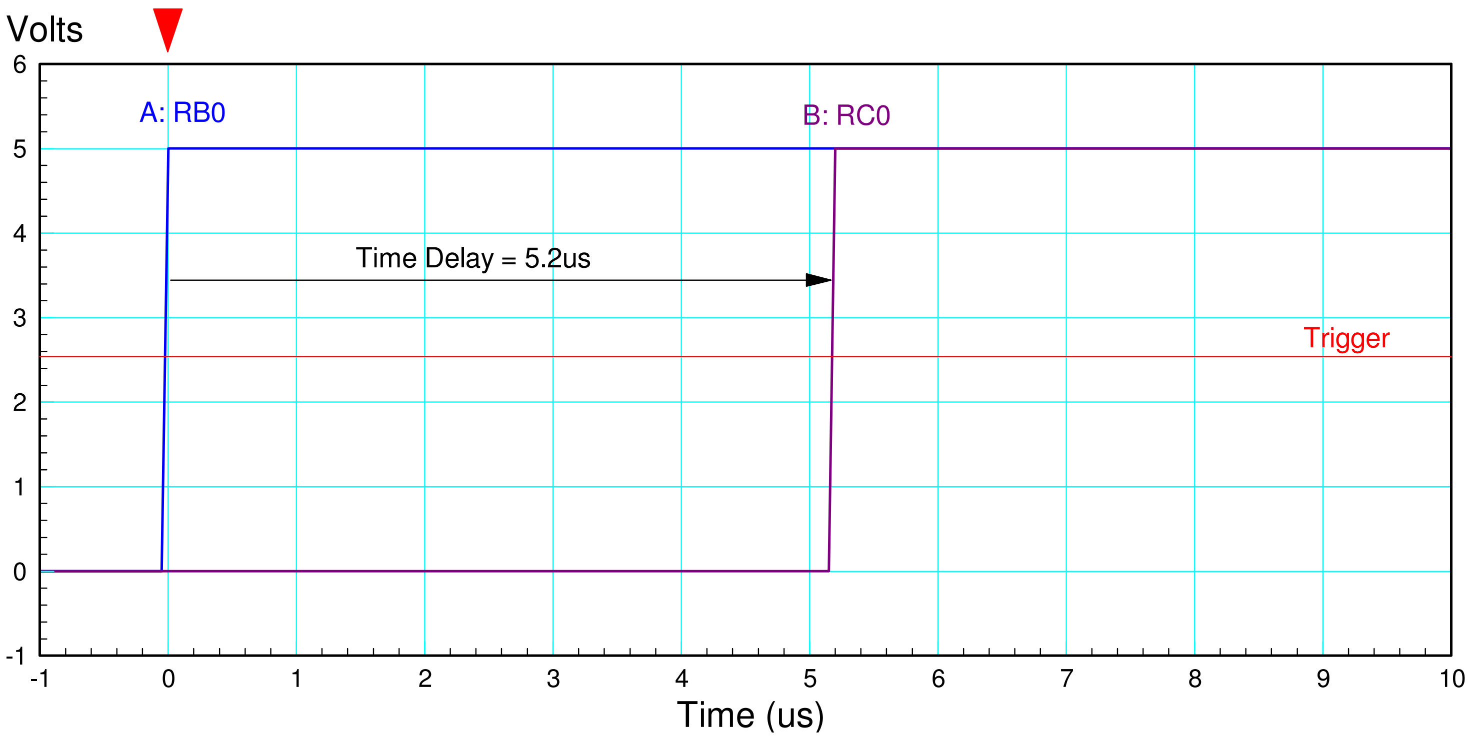


Time Delay (digital signals):

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)



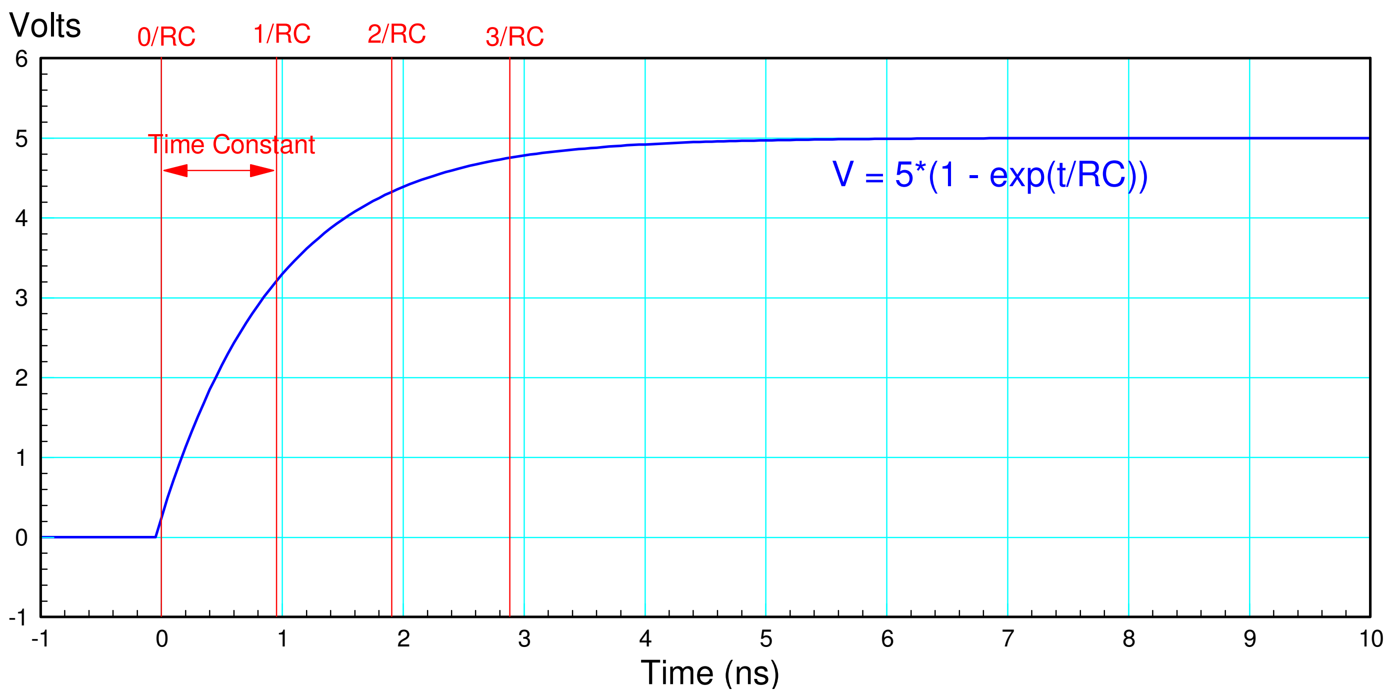
Rise Time (digital signals):

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)



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 invariable be using ECE tools to validate your design works in hardware

- Just be sure to use at least two different tools