

INTRODUCTION

PREREQUISITES: MODULE 01: BASICS.

OUTLINE OF MODULE 02:

What you will learn about in this Module:

Tools: soldering, desoldering, solderless bread boards, wire types, etc.

Standard Laboratory Bench Instrumentation

VOM

Oscilloscope and Probes

Power Supplies

Signal Generators

Electrical Safety

What you will build in the lab:

You will use a pre-built signal generator to give you the opportunity to learn to use the oscilloscope and the volt meter. The signal generator schematic is shown in the laboratory exercises, so if you are not taking this as a laboratory class at U of Michigan, you can build one readily. You will also get some practice soldering in the lab.

INTRODUCTION:

In many ways this will be the most difficult module for beginners. This is because the first thing you encounter in any real electronics lab is an oscilloscope. Keep in mind, the objective of this course is to help you to learn how to figure out electronics by yourself. This course is, by design, *self-paced*. Once you get into the laboratory you will undoubtedly run into frustrations. This is particularly true the first time you try to use sophisticated laboratory bench equipment, such as an oscilloscope.

READINGS FROM HOROWITZ AND HILL (H&H): *ART OF ELECTRONICS*

Appendix A (pg 1045): The O-Scope. Read this chapter several times!

Pay special attention to Chapter 3, section 3.15 (ESD Precautions)

ADDITIONAL READINGS & INTERNET RESEARCH:

Find Allegro Microsystems on the Web, and locate the application note: "Electrostatic Protection for Semiconductor Products". This brief (2-page) Applications Note will tell you a bit about how to handle electronic circuit components. Some ICs are extremely susceptible to damage by electrostatic discharge; you can easily destroy them just by touching them. The soldering iron that we will use (Weller) is "ESD Safe": it connects you to ground to prevent electrostatic discharge to the electronic parts you are working with.

If you want to understand how the signal generator (the one you will use for this lab) works, get on the web and locate the datasheet for the integrated circuit: MC14106B (try Motorola or Texas Instruments). This is an inverting Hex Schmidt Trigger (we will use them in Module 07 also). These are incredibly useful chips: you can use them as digital buffers (to “clean-up” a digital signal), pulse generators (this is how the world’s first cardiac pace maker was made), to make switch debouncers (see Module 14), digital pulse edge detectors, and lots of other things. Best of all, they come six to a package: thus the single IC chip that holds them all is called a “Hex Inverter”. The “Schmidt Trigger” part of the designation means that the inputs of each logic gate have a *hysteresis*. Study the datasheet for the IC to find out what this means. For this lab, the circuit is already built for you and is installed in the “Black Box Power Supply and Signal Generator” in the laboratory (schematic diagram appears later in this module).

SELF QUIZ

1: What does ESD stand for?:

2: What is the source of ESD?:

3: In general, how do you protect circuits from damage due to ESD?:

4: Every oscilloscope has a screen on which it displays waveforms. In general (there are some exceptions to this) the oscilloscope screen will display the following on each axis:

Y-axis = (what is measured along the Y-axis)

X-axis = (what is measured along the X-axis)

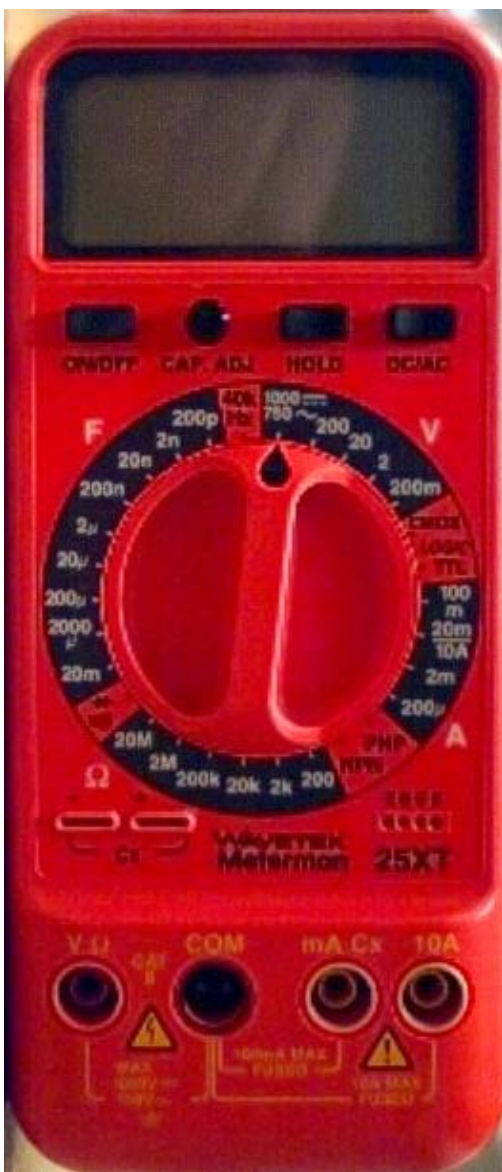
5: Modern oscilloscopes come in many varieties with a huge range of capabilities, but the simplest and least expensive modern oscilloscopes are usually “dual trace”. What does this mean?

PLEASE ANSWER THE ABOVE QUESTIONS AND E-MAIL TO THE INSTRUCTOR
“I have neither given nor received aid on this examination, nor have I concealed any violation of the Honor Code”

X_____

LABORATORY PROJECTS

1- The first piece of test equipment that we will use is a digital multi meter (DMM). This is sometimes also called a digital volt meter (DVM), but modern ones measure much more than just voltage. In fact, we will be using a WaveTek model 25XT (see next page for photo) which is really a “component tester”. Have a look at the photograph. This device can be used to do all of the normal functions of a DMM (measure AC or DC voltage, current, and electrical resistance), and it can also measure capacitance, frequency of a signal up to 40 kHz, detect logic level signals, and it can test the function of diodes and transistors (NPN and PNP). So, if you are new to electronics, most of this will not mean much to you...yet. Note that this



device is not “auto-ranging”, that is, you need to rotate the knob to the correct position to get an accurate reading. Some DMMs are very sophisticated...you just hook them up and they will figure out what you are trying to measure, and set the range appropriately. For this meter, you will need to select both the correct function *and* range by setting the dial appropriately. On the dial, “F” designates capacitance (measured in *Farads*), V is *Volts*, “A” is current (*Amps*), and Ω is resistance (*Ohms*).

Also, take note of the fact that there are two electrical test leads with the meter (one red, the other black). The meter has 4 places to plug in test leads, so you need to think about what you are trying to do, then decide where to plug the test leads. By convention, we use the black lead as ground or “common”; it is always plugged into the port labeled “COM”. For testing high levels of current (up to 10 Amps), plug the red lead into the port on the right labeled “10A”. For lower currents or for measuring capacitance, plug the red lead into the port labeled “mA Cx”. For all other measurements, plug the red lead into the leftmost port labeled “V Ω”. If you hear the meter buzzing when you do something (like plugging in a test lead, or rotating the knob) that means you have the test leads configured improperly for the meter knob setting. Look closely and be sure to plug the test lead in the correct port. If you make a mistake here, you’ll probably burn out a fuse (no big deal actually,

but you have to disassemble the meter to replace it). Also note, for capacitors, you can plug the wires directly into the meter; no need to use test leads (use the two tiny

horizontal slots on the lower left face of the meter). Some capacitors are “polarized”, one lead will be marked either “+” or “-”. Connect the meter accordingly. On this meter, you can also zero the capacitance by turning the little knob on the top row of buttons.

In the cabinet in the laboratory we have a standard set of resistors and capacitors for you to build your circuits. The meters are also stored there. You will test the values of several components just to get some practice with the meter. We will also use the meter later when testing the signal generator. If you are not registered for this course at U of Michigan, you will need to scrounge up a DMM from somewhere. The one we are using costs about \$90 and is readily available.

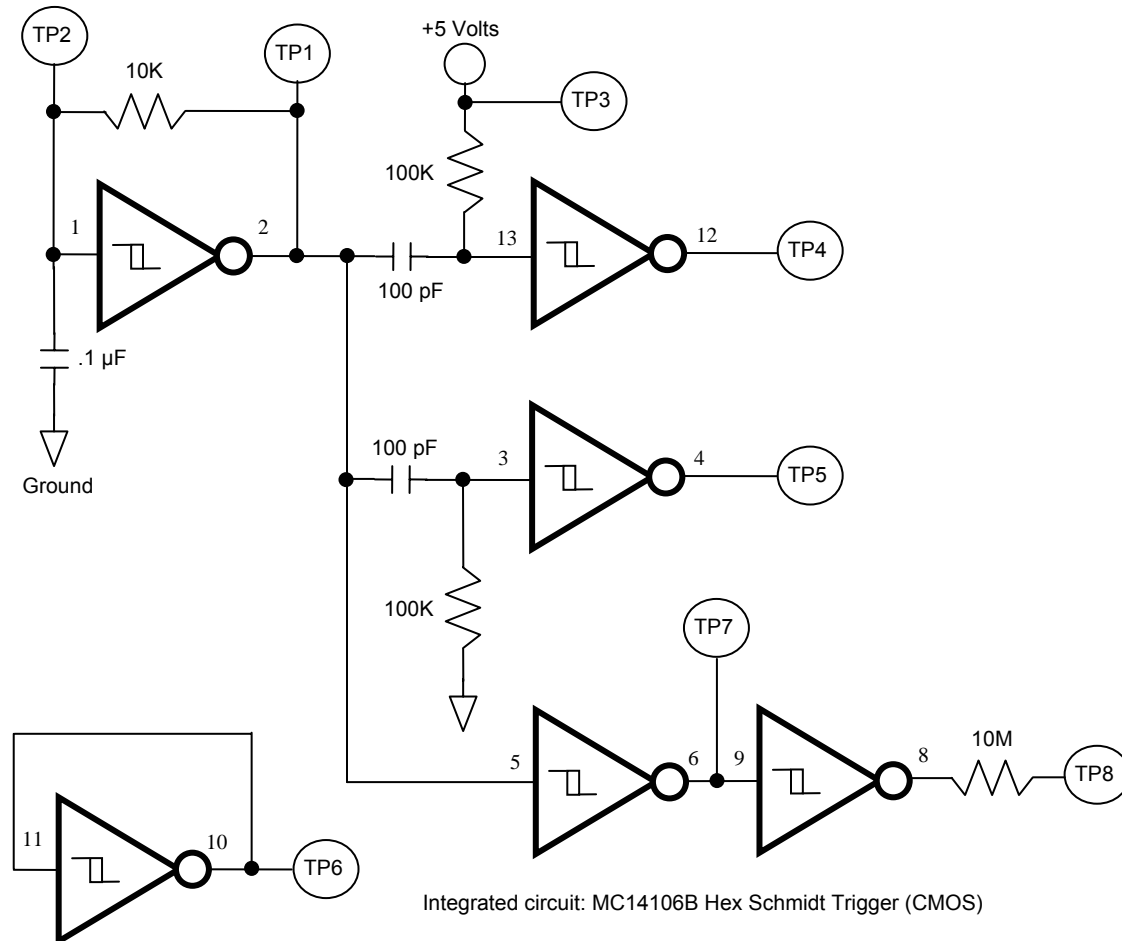
TIP: when removing electrical components from the parts bins, take them out one at a time, test them, and then replace them immediately when done (if you are not going to solder them into a circuit). Leave the plastic drawer open while testing, this way you will not inadvertently put the component back in the wrong drawer. This can cause problems later when you pull out a misplaced component and solder it into a circuit. I have seen people waste hours of time debugging a circuit that had a single 10 k Ω resistor where a 1 k Ω resistor belonged, just because it was placed in the wrong drawer. The best practice is to test every component before you solder it into place. I do this and in the end it actually saves a huge amount of debugging time because you avoid using faulty, mislabeled or mislocated components. Use the meter to measure and verify the values of each of the components on the list on the next page.

Component	Markings (colors or numbers)	Measured value
56 pF capacitor	_____	_____
330 pF capacitor	_____	_____
1000 pF capacitor	_____	_____
.01 μ F capacitor	_____	_____
.1 μ F capacitor	_____	_____
10 μ F capacitor	_____	_____
470 μ F capacitor	_____	_____
1 Ω resistor	_____	_____
6.8 Ω resistor	_____	_____
180 Ω resistor	_____	_____
560 Ω resistor	_____	_____
2.7 k Ω resistor	_____	_____
33 k Ω resistor	_____	_____
130 k Ω resistor	_____	_____
220 k Ω resistor	_____	_____
1.3 M Ω resistor	_____	_____
9.1 M Ω resistor	_____	_____
No Resistance (just clip the test leads together)	_____	_____

What do you notice about the allowable tolerance of the capacitors compared with the resistors?

Try the following: with your fingers touch both lead wires on a large resistance component (such as the 9.1 M Ω resistor) when taking a reading. Does this influence your measurement? Try it with a smaller resistor, and then a large and a small value capacitor. Rule of thumb: be careful when measuring large resistances and small capacitances, they are easy to screw up just by touching the component.

2- We will use a signal generator (see schematic below) to learn about the some of the other functions of the DMM (also known as a *component tester*), as well as to get acquainted with the oscilloscope.



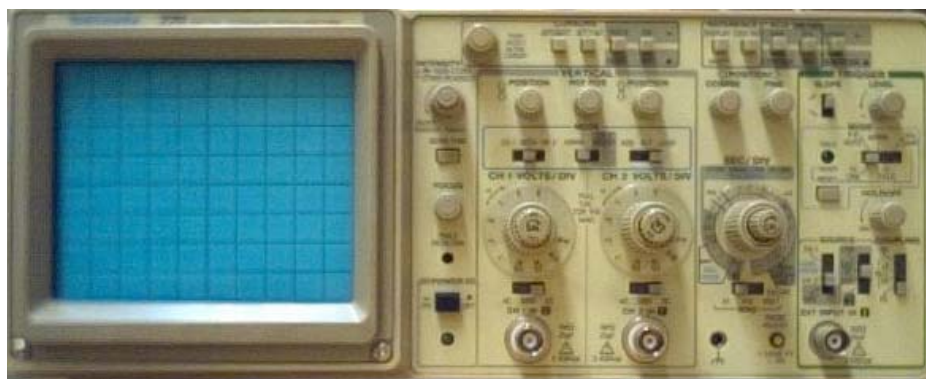
Notes on this schematic: If you build this circuit, you should use a CMOS logic chip, not a different type, such as TTL or HS (more on this in Module 07: Digital Circuits). Standard CMOS chips will allow a wider range of supply voltages (3 to 18 Volts DC) than most other types of digital logic, which are sometimes limited to a supply voltage of 4.5 to 5.5 VDC. Also, CMOS ICs consume far less power, and have many other favorable characteristics. They are, however, susceptible to damage from electrostatic discharge (ESD).

TPx = a “test point”. These are the points in the circuit you will test with the o-scope. The little numbers on each side of each logic gate correspond to the pin numbers on the IC. All six of the logic gates are packaged in one tiny 14-pin IC chip (the MC14106B).

Oscilloscope:

We will also be using an oscilloscope (a.k.a. o-scope or just “scope”) in almost every module for the remainder of the course. After the DVM, the oscilloscope is by far the most common and most useful piece of electronics bench testing equipment. Once you have developed a bit of skill with an oscilloscope, you can built and test almost any electronic circuit. Oscilloscopes are very complex devices because they are such a powerful tool, but with some practice, you’ll become very comfortable with them. You will probably find this to be the most frustrating part of electronics: getting comfortable with using an oscilloscope.

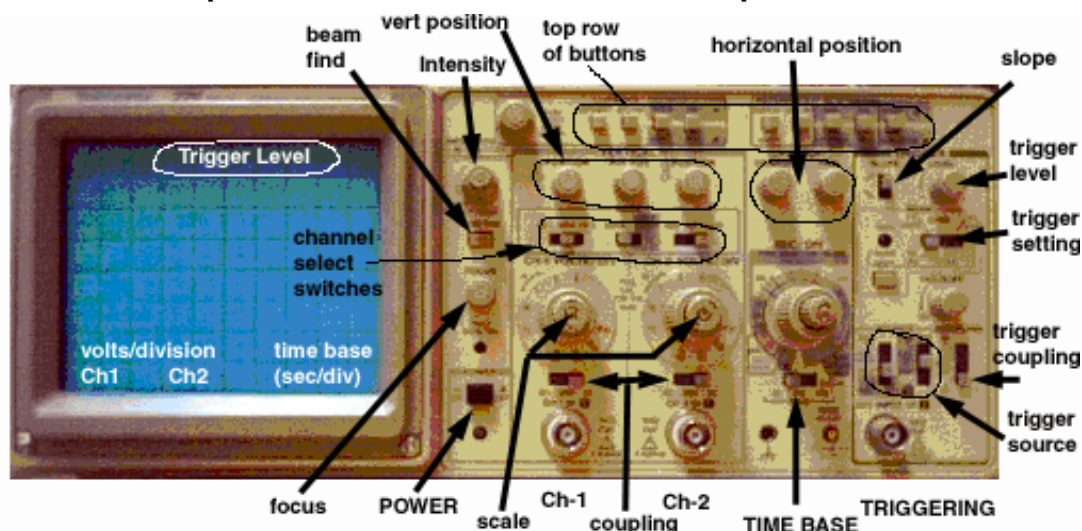
We will use the Tektronix Model 2211 (see image below) for this class, but once you have used one o-scope, you’ve pretty much used them all. They all have the same basic features, some just have extra stuff added on, or the buttons and knobs are in different places.



On the next page you will learn how to set up the o-scope so that you can take your first measurements. Eventually this will all become second nature to you, but for now you should carefully check to be sure every button and switch is properly set so that you can get the oscilloscope to work properly. This takes some time, so be prepared to get a bit frustrated at first.

For the remainder of this module keep in mind that learning to solder properly and learning to use an oscilloscope are perhaps the two most difficult things in building electronic circuits. Once you can do both of those, the rest is fairly easy.

How to setup and use the Tektronix 2211 o-scope:



Overview: Take a look at the front of the o-scope. The buttons and switches are actually grouped together on the basis of their function. This is a 2-channel o-scope, so you can see two waveforms simultaneously on the screen. This is the most common type of o-scope. Signal 1 is plugged into the BNC connector labeled “Ch-1”, signal 2 goes to “Ch-2”. The scale settings for Ch-1 & 2 are located directly above the BNC connectors for those channels. To the right of this is the knob that controls the speed (time base). Using this, you can look at electrical events that take minutes to complete, or ones that occur in less than a microsecond. To the right of this is the “Triggering” control. You can set the trigger to start a trace on the screen when a certain event occurs, such as when the voltage Ch-1 goes above 1 Volt, for example.

Setup:

- 1- Press the **POWER** switch in (a green LED should come ON, indicating that the device has power)
- 2- Make sure that none of the buttons in the **top row of buttons** is pressed in.
- 3- Set the **trigger setting** (or *trigger mode*, on the extreme right of panel) to “Auto”. This will allow the scope to sweep continuously, no matter what the input signal is.
- 4- For now this will not matter, but it will be important later, so set the **trigger coupling** to “DC”, and the two **trigger source** switches to “Ch-1” and “Line”, and then set the **slope** to detect a rising slope (slide the switch to the top position). Directly above these switches you will see a knob labeled “Hold off”, set this to “min” (turn the knob fully counter-clockwise).
- 5- There are three **channel select switches**. From left to right, set them as: “Both”, “Norm”, “Chop”
- 6- Set the **TIME BASE** knob to 1 ms, and set the little slide switch below it to “x1”.
- 7- Set the **coupling** for **Ch-1** and **Ch-2** to “DC”.
- 8- Set the **scale** for both channels to “2 V/div”. Be sure to check that the little knob in the center of both scale knobs is pushed IN. It is labeled “10X”, and if you leave it pulled out, then your readings will be off by a factor of 10.
- 9- Look closely at the screen. At the top you will see some text that tells you the **trigger level** (a voltage) and which channel you are using for the trigger (should be Ch-1 at this time). On the bottom of the screen you will see the scale setting for each active channel, and the time base. The signals you measure will always sweep from left-to-right on the screen. The voltage is measured vertically (V/division), and time is measured horizontally (seconds/division). Note that the screen has 8 divisions vertically, and 10 divisions horizontally. The screen should now tell you that your trigger source is Ch-1, that both Ch-1 and Ch-2 are set for 2V/div, and that the time base is set for 1 ms/div.
- 10- Because the o-scope is “auto-triggering”, and because you are not putting in any signals, you should see two horizontal green lines on the screen. Twiddle the **vertical position** knobs for Ch-1 and Ch-2. When you turn the knob for Ch-1, you should see one of the two green lines move up and down. Adjust Ch-1 so that the green line is about 4 divisions from the top of the

screen (i.e., in the middle of the screen). Adjust Ch-2 so that the trace is one division from the bottom of the screen.

- 11- Find the **intensity** knob (near the screen). This knob is actually two knobs stacked one on top of the other. The outer one adjusts the intensity of the signal traces; the inner one adjusts the intensity of the alpha-numeric screen display. Adjust them both so that you can see both the alpha-numeric display and the trace lines clearly, but do not set them so high that you see a phosphorescent glow around the traces or text.
- 12- Connect a BNC cable to the Ch-1 & Ch-2 connectors (use two separate cables). There are several cables to choose from: some have test clips on one end, some have BNC connectors on both ends. For now, use cables with BNC connectors on both ends (you will connect these to the signal generator box later).
- 13- Look just below the TIME BASE knob: you should see a little gold pin sticking out. This pin provides a calibration signal you can look at on the scope. Now, take the BNC cable that is connected to Ch-1, and look at the loose end. You should see a little pin sticking out of the center of the cable. Touch the pin in the BNC connector to the little gold pin on the o-scope, and look at the trace for Ch-1. What do you see? You should see a small square wave. Repeat this once or twice just so you can see the trace change on the screen.
- 14- Now repeat this for Ch-2. Do you see the same thing?
- 15- Now, look in the cabinet and find the black box labeled "Signal Generator". The schematic for this signal generator is shown several pages above in this Module. Plug the Signal Generator in, and push the rocker switch to turn it ON. There are 8 BNC lugs on the Signal Generator box (the box is called an "enclosure"). They are labeled TP-1 through TP-8. TP stands for "Test Point", these numbers correspond to the test points indicated on the schematic given above. Connect the BNC cable from Ch-1 to TP-1. What do you see? You should see a square wave signal on the trace for Ch-1. You can use the vertical divisions on the screen to measure the voltage of the signal, and the horizontal divisions to measure the time period of the square wave. Go ahead and do this: Volts: _____; Period for 1 square wave: _____
- 16- Leave the Ch-1 BNC cable connected to TP-1. Now connect the BNC cable from Ch-2 to TP-2. What do you see? You should see a saw-tooth wave. This saw-tooth wave is the feedback signal that is driving the oscillator in the Signal Generator, shown in the schematic. It is OK if you do not yet understand how this works yet. This is just for practice using the o-scope.
- 17- Now, leave everything connected, and switch the **trigger setting** to "norm". The traces may or may not disappear...this is OK. You have now set the o-scope to trigger off of the signal in Ch-1. Find the **trigger level** knob and slowly turn it over its full range, from left to right and back again. What you will see is that all of a sudden the square wave in Ch-1 will appear, then all of a sudden it will disappear. The reason for this is that you are adjusting the trigger level (you can see the level on the screen, top right). When the trigger threshold is in the range of the signal on Ch-1 (in this case, between 0 and +5 Volts), AND when the o-scope detects a rising slope at this threshold, the o-scope trace will trigger, and you will see the waveform. Note that the o-scope will only trigger when you have set the trigger level so that the square wave crosses over it (between 0 and +5 Volts). This is very useful: it lets you capture a pre-defined event on one of your signals, so that you can see it only when it happens!
- 18- Set the trigger level so that you can continuously see the square wave on Ch-1. Now, flip the **slope** switch, and watch what happens. Since the o-scope is now detecting a falling slope (rather than a rising slope), it will appear that the square wave trace has "flipped over". Do this several times and watch the trace carefully. Actually, the trace is not "flipping", you are just triggering on the falling edge now, instead of the rising edge of the square wave.
- 19- Now, disconnect Ch-2 from TP-2, and reconnect the cable to TP-4. You just might be able to see very little pulses on the trace for Ch-2. These are very narrow pulses. Change the **TIME BASE** setting to faster and faster values, and watch the little pulses widen. NOTE: You may need to **switch** the slope of the trigger to keep the little pulse from being pushed off the screen. Also, you should see the square waves on Ch-1 widen with each click of the **TIME BASE** knob. When you have the **TIME BASE** set to about 1 μ s, you should be able to see the pulse very clearly. Using TIME BASE setting (visible both on the knob and on the screen), estimate the width of this very narrow pulse. Study the narrow pulse closely: does it go from ground to +5V,

or from +5V to ground? When does it happen with respect to the signal in Ch-1 (on the rising or falling edge?).

20- How soon after the rising edge on Ch-1 does the narrow pulse start? _____ You may need to turn the speed way up to see this. Note, as you turn the speed up, the traces get darker, so you may need to turn up the **intensity** knob to see them.

21- Using the BNC cable connected to Ch-2, go ahead and explore the other signals from the Signal Generator. At this point you should mostly be adjusting the time base, the triggering slope, and maybe even the voltage scale on Ch-2 so that you can see the signals clearly. Describe what you see at each test point:

TP-1:

TP-2:

TP-3:

TP-4:

TP-5:

TP-6:

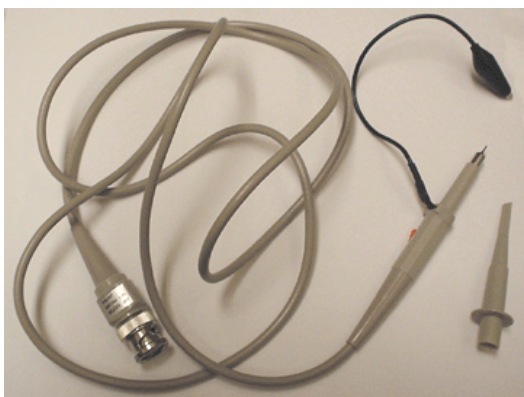
TP-7:

TP-8:

Oscilloscope Probes: Now, locate the 10X Oscilloscope Probe and connect it to Ch-2 on the oscilloscope, instead of using the BNC cables as you have up until this point. Every oscilloscope comes with special probes like this, though you often have to search around to find them. Two different 10X probes are shown on this page: Hewlett-Packard (Top) and Gould (bottom). Both will work with the oscilloscope in the laboratory. Opposite the BNC connector, each 10X probe will have a fine-tipped probe end and a black alligator clip. The fine tip goes to the signal you want to measure, and the black alligator clip connects to ground.

Use the probe to repeat the above measurements for TP-1 through TP-8, and compare the results to your first set of measurements. For each signal that you measure use the fine-tipped probe to touch the center of the BNC output connector on the Signal Generator Black Box and be sure that the ground clip on the Probe is connected to the outer metal part of the BNC lug on the Signal Generator Black Box.

NOTE: To get the correct reading when using the 10X probes, you will need to set the oscilloscope properly. To do this on the Tektronix scope, just pull out the little knob labeled “10X” (see step # 8 from the last exercise above, where it tells you how to adjust the “scale”).



What is the difference when you use the oscilloscope probes, and why? Hint: The biggest difference will be at TP-8. Check the “input impedance” on the front panel of the oscilloscope, and then the input impedance of the oscilloscope probe. The input impedance of the oscilloscope is printed next to the BNC lug on the front panel of the scope. The input impedance of the probes is described in the little pamphlet in the plastic bag that the probe comes in (sometimes called “series resistance”). **IMPORTANT POINT:** every time you connect test equipment to a circuit, it has an effect on that circuit. If you connect the oscilloscope directly to a circuit without a 10x probe, it is just like connecting a 1M Ω resistor at between your test point in the circuit and ground. The 10X probe is more like a 10M Ω resistor. Sometimes this doesn’t matter, but sometimes this can make a huge difference in the measurement you get.

The importance of input and output impedance will be discussed further in subsequent modules.

When finished, be sure to put both the probe and the pamphlet back in the plastic bag, put both back in the cabinet, and push in the “10X” knob on the o-scope scale.

Soldering:

Soldering is also a surprisingly difficult thing to do. All that is involved really is the melting of a metal (mostly a lead-tin alloy) so that it flows between and connects two or more electrical components. Most people do not know how to solder very well, so they find building a circuit to be frustrating, since nothing goes together well. Also, the circuits are prone to failure, since most of the solder joints are crummy. This is such a problem that I actually caught one graduate student trying to build a circuit using crazy glue instead of solder (no joke...he eventually got his Ph.D., which scares me). He was unable to use a soldering iron, so he tried to “fake it”. Of course, his circuit never worked, and he wasted many months on it. It is definitely worth your time to learn the Art of Soldering. At least you will be able to make jewelry if you decide to never build a circuit after this course is over. If you follow a few basic rules, soldering is easy. Here they are:

- 1- Use the correct solder. There are several types of solder. You need to use electrical solder (as opposed to plumbing solder, used on copper pipes, or silver solder, used on stainless steel cooking utensils). Electrical solder is a low melting temperature lead-tin alloy which contains *soldering flux*. The flux is an amber colored material that is inside the core of the solder (like jelly in a jelly donut). When you melt the solder, the flux is released as a molten fluid that helps to clear oxides from the surfaces of the parts you are trying to solder together. The best electrical solder is called “multicore”, which means that the solder has about 6 little cores of flux arranged near the surface of the solder, so that the flux gets out faster as soon as the solder begins to melt.
- 2- If you have an adjustable-temperature soldering iron, for general electronics assembly set your soldering iron to about 650 °F (this is “65” on the dial). If the iron is not adjustable, just learn to live with it.
- 3- NEVER use the soldering iron forcefully (as a chisel or pry bar). If you need to do this, something is wrong with your technique.
- 4- ALWAYS keep the very tip of the iron clean. This means that, when it is hot, it should look shiny, as if a drop of mercury were on the very tip. This is the hardest thing to do, and it is also the most important thing to do. A good solder joint requires good heat transfer from the iron to the metal you are trying to solder. Why do tips get black and crusty so fast? Because they are hot and have a molten metal surface, so they oxidize very rapidly. Why is a dirty tip a bad thing? Because a dirty tip has an oxide coating, so it is a lousy conductor of heat, so it will do a poor job of soldering. Here is how you keep the tip clean: As soon as the iron heats up, put a bead of solder on the tip and leave it there. That way, the oxide forms on the surface of the *liquid solder*, which you can easily wipe off and replace. Never leave a dry hot soldering iron tip exposed for very long or it will oxidize and you will have to clean it. What to do if the tip gets dirty (oxidized): Heat it up. Try mechanically wiping it off with a piece of double-folded paper towel (careful), then try adding flux-core solder until a bead forms on the tip. Repeat wiping and adding solder if necessary. Once a bead sticks on the tip, leave the molten solder bead in place and carefully set the soldering iron in the stand to cook for a while (this

- will tend to remove traces of the oxide on the tip). If the tip is in extremely bad shape, you can try using solder flux (usually in a little tin can): plunge the hot tip into the flux, wipe clean with folded paper towel, repeat. Eventually the tip will be clean enough that you can add a drop of solder, as described above. Only do this as a last resort. I keep my tip clean, so I only need to do this about once every 5 years or so, or after I loan my soldering iron out to someone.
- 5- To use the iron, first be sure your electrical components are in place and ready to be soldered. Then, simply take a piece of folded paper towel (I fold it twice, since the iron is HOT) and wipe the tip clean. Immediately add a very small amount of solder to the tip and begin soldering your components together.
 - 6- Place the soldering iron tip so that it is in good mechanical contact with the metal surfaces to be soldered. A very small amount of molten solder on the tip is helpful here, because it will wick between the tip of the iron and the metal to be soldered, increasing the surface contact and speeding up the heating process. NOTE: when soldering, use a *very small* amount of molten solder on the tip of the iron; when storing the iron, place a *large drop* of solder on the tip of the iron.
 - 7- Touch some fresh solder to the metal surfaces to be soldered. The solder should flow instantly and wick between the metal surfaces (usually a wire and a copper pad on a printed circuit board (PCB).
 - 8- USE AS LITTLE SOLDER AS YOU CAN! Less is better. The surface of the solder joint should be concave, not bulged out and convex.
 - 9- Whenever you go to set the iron down, add a drop of solder to the tip and *carefully* place the iron in the holder, being sure not to knock the drop of molten solder off. Then, each time you use the iron, wipe the tip clean, add a small amount of fresh solder, and carry on!
 - 10-Don't use the sponge that comes along with most soldering irons. It is for losers. The wrong-minded Idea is that you wet the sponge and then repeatedly plunge the tip into it to "clean" it. This makes a satisfying hiss as water is flash evaporated, but it simply does not keep the iron clean...it actually keeps it oxidized!!! If you see someone using one some time, discretely check out how *their* tip looks compared to *your* tip. Theirs will be a dull gray, and will not work well. Yours will be a shiny mercury color, and will melt solder instantly.
 - 11-To store the soldering iron, add enough solder to form a large drop on the tip, then turn off the iron so that the drop hardens while still on the tip.
 - 12-When you are all done soldering you should remove the residual flux from the board. I simply use 190 proof laboratory-grade ethanol and a clean tooth brush. Because some people have "issues" with ethanol, it is a controlled substance and you may not be able to get your hands on any (this is good if you happen to be 12 years old). There are commercial flux removers that work well, but they taste nasty and can have an unpleasant chemical vapor (assuming you have no problems with ethanol vapor). Just moisten the

toothbrush with the fluid of choice, scrub the solder joints thoroughly, and wipe dry with paper towel.

13-Weird soldering facts and tricks: The less solder you use, the better. A great solder joint will almost look as if there were not enough solder on it! To solder stainless steel wire or sheet (commonly used in corrosive environments or for biological electrodes) you will need to use zinc-chloride flux. This is nasty stuff; essentially zinc dissolved in hydrochloric acid. You can buy this flux specially prepared, but in a pinch you can make it by dissolving the zinc plating off of galvanized sheet metal in a small amount of hydrochloric acid (I did this once when stranded at a laboratory in the middle of nowhere on a Sunday without a car...long story). The trick is to put a bead of the flux on the stainless steel that you want to solder, then melt a bead of solder onto the tip of the iron. Simply touch the molten solder to the metal under the bead of flux. The instant the flux evaporates, the solder will wet (i.e., it will adhere) to the stainless steel underneath. This is all necessary because stainless steel is "stainless" (corrosion resistant) because it forms a tough oxide layer on it's surface. The zinc chloride flux removes the oxide layer for an instant, so the soldering takes place at the instant the flux evaporates. NOTE: You MUST thoroughly clean both the solder joint and the soldering iron thoroughly after using zinc chloride flux. Clean the solder joint by brushing and scrubbing with a commercial detergent or surface cleaner, and clean the soldering tip by repeatedly adding fresh solder and wiping the tip clean with paper towel.

Soldering Practice:

Each of you was given a starter kit for this course, which contains a generic printed circuit board (PCB) for making prototypes and a wire harness. For the remainder of this course you will build your circuits on this PCB. The wire harness connects to the wire sticking out of the Signal Generator box. The wires are color coded, and we will use the same color convention throughout this course:

GREEN = Ground

YELLOW = +5V

RED = +15V

BLACK = -15V

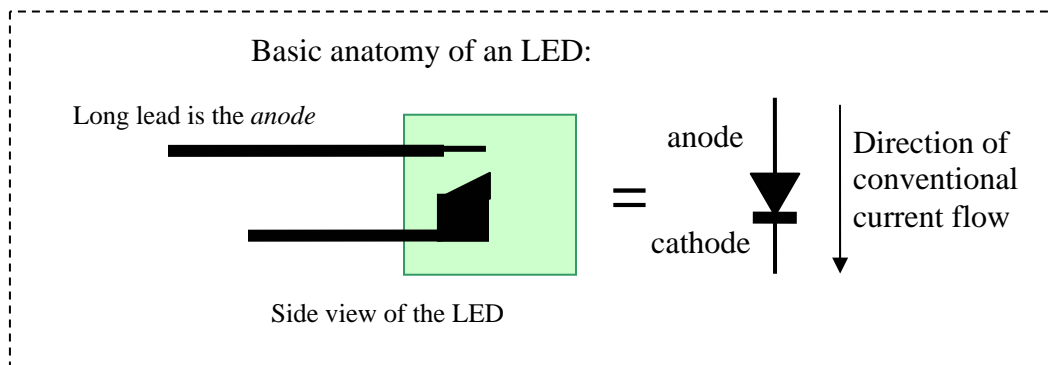
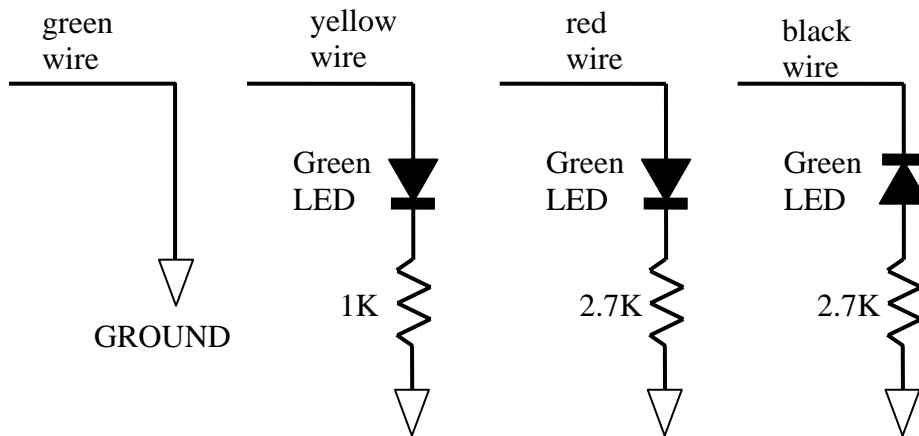
The color convention is not the same everywhere, for example, on both the o-scope and on the DMM, the red wire or the red clip is the signal you are measuring, and black is common (ground). Nonetheless, if you always build your instruments using the same color convention, you will find that after many years you can pick up one of your circuits and quickly trace all the wires again to remember what you did. Also, this makes it easier for me to debug your circuits for you in this class. Eventually, you will hear me ask a question like: Why do you have a red wire going to ground?

I have wired up an example board for you to look at in the supply cabinet.

The wire harness is soldered in place such that power will be available on your circuit board for the circuits you will build in the future. We will be using three LEDs

(light-emitting diodes), so you may want to quickly review page 44: section 1.25 “Diodes” in H&H before starting.

Note that the LED that is connected to the BLACK wire is put in in the opposite direction (polarity) than the other two LEDs. This is because the direction of conventional current flow will be from Ground to -15V. By convention, current always flows from the more positive voltage to the less positive (or more negative) voltage. The green LEDs and the resistors are available in the supply cabinet. Build your board exactly as I have done with the example board. You may want to ask to have the instructor present during this first circuit practice, to show you all of the minute details about how to strip wire properly, etc.



Once you have connected the resistors and LEDs as shown, you should turn ON the Signal Generator box, and plug in the wire harness. All three green LEDs should glow. This means that all of your power is available, and that you wired the circuit correctly.

First, disconnect the wire harness from the Signal Generator (never work on a circuit board with electrical power applied). Next, you will want to connect wires from the wire harness to other traces on the PCB. These will serve as “power rails” for you to hook up other circuits later in the course. Look at the example board, and place

your wires exactly the same way. Finally, you should use a permanent marker to label your power traces, so that you don't make mistakes later when wiring up other circuits.

Finally, you will want to add capacitors to the board. These will reduce the "noise" on the power lines, resulting in better operation of your circuits. Use three 100 μF aluminum electrolytic capacitors (look at the example board), and place them as shown on the example board. This type of capacitor is "polarized", so it does matter which wire is connected where. Either the positive terminal will be marked with a "+", or the negative terminal will be marked with a "-" along the side of the capacitor. Make sure that the capacitor is aligned such that it is not in backwards: the "-" terminal must go to the most *negative* connection. For example, when connecting between +15V and ground, the "-" terminal connects to GROUND. When connecting -15V to ground, the "-" terminal goes to -15V.

FINAL EXERCISE:

Use ExpressSCH to duplicate the signal generator schematic shown at the beginning of this module. You can use any "Hex Inverter with Schmidt trigger Inputs" that you can find in the component library of ExpressSCH, or you can draw your own custom component (it's easy to do) within ExpressSCH, and save it for later use. To learn how to draw custom components, read the User Manual in the HELP pulldown menu in ExpressSCH.

Then, on a new sheet use ExpressSCH to draw the power cable and LED power indicators that you built on your prototyping PBC. Save this, as you will add to it in later modules.

FEEDBACK

Was this Module useful and informative?

Is there a topic that should get more or better coverage?

In what way can this Module be improved:

Content: _____

Depth of Coverage: _____

Style: _____

Any additional comments that will help us to improve this course:

If you prefer, you may e-mail comments directly to Bob Dennis: yoda@umich.edu