INTRODUCTION TO ELECTRONIC TEST EQUIPMENT AND
BASIC ELECTRONICS MEASUREMENTS

The purpose of this lab is to guide students through a few simple activities to increase your familiarity with basic electronics laboratory equipment.

Electronic Components: Components: Resistors, Capacitors, and Inductors:

**Resistors:** Resistors have three important parameters, the resistance value, the precision of that value, and the maximum power it can dissipate.

**Resistance Value:** The resistance that a particular resistor presents to the flow of current is shown on the device in color-coded bands. To read the code, hold the resistor so that the first band (closest to one end, or not gold or silver,) is on the left. Then the first 3 bands give the value of the resistance as follows:

The first 2 bands give the first two significant digits of the resistance value, without any decimal points:

<table>
<thead>
<tr>
<th>Color</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0</td>
</tr>
<tr>
<td>Brown</td>
<td>1</td>
</tr>
<tr>
<td>Red</td>
<td>2</td>
</tr>
<tr>
<td>Orange</td>
<td>3</td>
</tr>
<tr>
<td>Yellow</td>
<td>4</td>
</tr>
<tr>
<td>Green</td>
<td>5</td>
</tr>
<tr>
<td>Blue</td>
<td>6</td>
</tr>
<tr>
<td>Violet</td>
<td>7</td>
</tr>
<tr>
<td>Grey</td>
<td>8</td>
</tr>
<tr>
<td>White</td>
<td>9</td>
</tr>
</tbody>
</table>

The third band gives the power of ten by which you multiply the first two digits:

<table>
<thead>
<tr>
<th>Color</th>
<th>Power of Ten</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>$10^0$</td>
</tr>
<tr>
<td>Brown</td>
<td>$10^1$</td>
</tr>
<tr>
<td>Red</td>
<td>$10^2$</td>
</tr>
<tr>
<td>Orange</td>
<td>$10^3$</td>
</tr>
<tr>
<td>Yellow</td>
<td>$10^4$</td>
</tr>
<tr>
<td>Green</td>
<td>$10^5$</td>
</tr>
<tr>
<td>Blue</td>
<td>$10^6$</td>
</tr>
<tr>
<td>Violet</td>
<td>$10^7$</td>
</tr>
<tr>
<td>Grey</td>
<td>$10^8$</td>
</tr>
<tr>
<td>White</td>
<td>$10^9$</td>
</tr>
</tbody>
</table>
So a resistor with bands "green-red-blue" would have the value $52 \times 10^6 \, \Omega$ (NOTE: This is 52, NOT 5.2)

*Precision of value:* The precision of the resistor is specified by the fourth color band.

<table>
<thead>
<tr>
<th>Color</th>
<th>Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>No band</td>
<td>20%</td>
</tr>
<tr>
<td>Silver</td>
<td>10%</td>
</tr>
<tr>
<td>Gold</td>
<td>5%</td>
</tr>
<tr>
<td>Red</td>
<td>2%</td>
</tr>
</tbody>
</table>

*Maximum power dissipation:* The maximum power that a resistor can dissipate is not marked on the device, but can be told from the physical size of the resistor; the smaller the resistor, the lower the power dissipation rating. Standard values are 1/8 Watt, 1/4 Watt, 1/2 Watt, and 1 Watt, and on up in 1 Watt steps. There is danger in selecting a resistor with too small a power dissipation capability in a circuit, as they will melt and burn up if too much power is dissipated in them (too much current), but the only reason not to use a larger resistor is the additional size and expense of higher power resistors.

**Capacitors:** Capacitors store electric charge and are the second most common element in electronic circuits. They are described by their capacitance, safe working voltage, and type of insulator.

*Capacitance:* Values are given in micro ($10^{-6}$) or pico ($10^{-12}$) Farads. The value is often printed on the device, or sometimes there is a manufacturer's code. Unfortunately there is no uniform coding as there is for resistors.

*Working voltage:* The working voltage of a capacitor is determined by the breakdown potential of the dielectric material and typical values are 50 Volts DC, 100 V-DC, and 250 V-DC. As with resistors, using too high a value doesn't hurt except for the added size and weight and expense.

*Dielectric:* Capacitors consist of conductive plates (metal) separated by an insulator (dielectric), and are made with many different materials as dielectrics, such as mica, polystyrene, mylar, teflon, ceramic or others. For noncritical uses the cheapest and most popular type of capacitor is the disk ceramic. Ceramic capacitors are not suitable for very high frequency use however and mica capacitors are usually used in such applications. Each type of dielectric has its own merits and the choice of capacitor depends on the intended application.

**Inductors:** Inductors store magnetic fields and are the least common passive elements in modern circuits, appearing mostly in filters and in high frequency applications. Also, inductors are often the least ideal in their behavior. Inductors are described by their value of inductance, the quality factor (Q), and the maximum current they can carry.
Inductance: Values are usually in the micro ($10^{-6}$) to milli ($10^{-3}$) Henry range. Again, the value may be printed on the component, or there may be a manufacturer's code, but there are no standard symbols.

Quality factor: The quality factor is a dimensionless parameter that is a measure of how ideal the inductor is, i.e. the ratio of inductance to its internal resistance. Q will be discussed in lectures. Typical Q values for inductors are in the range of 40 or 50, that is the resistance is just a few percent of the inductive impedance in the intended frequency range.

Maximum current rating: As usual, the higher the current the larger the size and the higher the price. Many inductors are designed for high frequency, low current use, so these ratings are typically in the milliAmpere range.

Bread Boards: In the lab we use what are known as breadboards, which have many small holes in their surface big enough for the leads of components and which have spring-loaded connectors behind them. These connectors are complete electrical circuits in one direction and are separated electrically in the other direction (see the Figure below.)

![Breadboard Image](image_url)

Figure 1 - A typical breadboard is shown. The green boxes indicate the connections of sockets. The sockets in the top and bottom two rows are connected across and the vertical rows of 5 sockets are connected. Each row (or column) of connected sockets is independent of every other row or column.
The advantage of the breadboard is that it is reusable. To use the breadboard, simply push the leads of the component into the desired holes, being careful not to force in a wire that's too large for the hole, as this destroys the spring connectors.

**Power Supplies:** On the lab benches we have power supplies that provide direct current at +12V and -12V, along with a reference (ground). There are three terminals on the supply: red (+12V), black (-12V) and green (ground). Use the banana plug connectors provided to connect the power supply to the breadboard. Each side is protected against overload by a 1 A fuse that will burn out if you short the supply to ground through a resistance of less than about 12 Ω. If you have any problems with a circuit, the first thing to check is whether the supplies are still at ±12V. If your fuse blows, try to find the problem that caused it to blow in the first place, then ask a TA for another fuse.

If you need to disconnect a circuit from the bench ±12 V power supply, do so by unplugging the leads from the supply, not from the circuit board so you do not have energized leads hanging from the banana plugs.

**Signal Generators:** The signal generators on the benches can provide sine, square, and triangle wave signals at frequencies from a few cycles per second (Hertz, abbreviated Hz) up to millions of cycles per second (megaHertz, MHz). The amplitude is also adjustable over a range of voltages, typically 0 to 5 V. The offset, or DC level, of the waveform also is adjustable, often you have to turn on this feature. We will always leave the DC offset off unless explicitly directed to do otherwise.

**Digital Multimeters (DMM):** These devices are capable of measuring several quantities and are of great use in the electronics lab. The specifications are usually noted on the front or back of the DMM. The most important functions are described below.

**Volt Meter:** Connect one probe (usually the black one) to the "common" terminal on the face of the multimeter, and the other (usually a red one) to the "V-Ω" terminal. Set the dial or pushbuttons to "VDC" and the appropriate range expected (if in doubt about the range, always start with a high one.) The meter will now measure the voltage difference between the two points to which the leads are attached. We always measure the voltage across a component or group of components by placing the meter in parallel with the component(s). The ideal voltmeter has an infinite resistance so that no current flows through it, thereby bypassing the component across which you are measuring the voltage. The DMM's are almost, but not completely, ideal, having resistances of about 10 MΩ.

**Ammeter:** Connect one probe (usually the black one) to the "common" terminal on the face of the multimeter, and the other (usually a red one) to the "A" terminal. Set the dial or pushbuttons to "A" and the appropriate range expected (if in doubt about the range, always start with a higher one.) The meter will now measure the current through the circuit into which the meter is inserted. We always measure the current through a component or group of components by placing the ammeter in series with the
component(s). The ideal ammeter has zero resistance, in order to not affect the flow of current through the device under test. The meters provided are very low in resistance.

**Ohmmeter:** Connect one probe (usually the black one) to the "common" terminal on the face of the multimeter, and the other (usually a red one) to the "V-Ω" terminal. Set the dial or pushbuttons to "Ω" and the appropriate range expected. The meter will now measure the resistance of any component or group of components that are placed across the leads by applying a voltage to it and measuring the current that flows. A component must be removed from the rest of a larger circuit before measuring its resistance. In particular, if any voltage or current sources are connected to the ohmmeter they will cause erroneous readings.

**Oscilloscope:** The oscilloscope is the workhorse of the electronics laboratory. It is therefore extremely important to be able to use one.

**Practice Exercises:** By following the prescribed list of activities below you will learn the basics of using an oscilloscope. Pay particular attention to the underlined questions. You should have at your station the following items:

1. Oscilloscope
2. Signal Generator
3. Digital Multimeter
4. circuit breadboard
5. 2 BNC-to-clip leads for the oscilloscope
6. 3 Banana to banana leads (1 ea. red, black, green)
7. 2 Probe leads for the DMM (1 ea. red, black)

**Digital Multimeters (DMM)**

**Ohmmeter:** Select a few resistors of different values from the parts bin in the lab, noting the value for each given on the front of the drawer. Use the color code given above to verify the nominal values of the resistors. Connect the DMM to measure resistance as described above and measure the actual resistance of each of the resistors that you selected. Note if they are within the tolerance shown by the fourth band.

**Voltmeter:** Use the DMM as a voltmeter to measure the voltages on the power supplies. Familiarize yourself with the polarity of the power supply, how you would connect it to get +10 Volts, -10 Volts etc.

**Ammeter:** We will defer the use of the ammeter function to below.

**Breadboards:** Insert the ends of one of the resistors that you selected into two different vertical columns on the breadboard. (The resistor should be greater than 10kΩ.) Connect the +12 V power supply across it and using the multimeter, verify that the voltage drop is still 12 V. Then change the DMM configuration to ammeter and measure...
the current flowing through the resistor. Compare the measured current to that expected from Ohm’s Law?

**Signal Generators:** Signal generators are best demonstrated in conjunction with an oscilloscope, so we defer the use of these until we use the scope a bit.

**Oscilloscope:**

*Inputs and Time Base:* Connect the output of the signal generator to the Channel 1 input of the oscilloscope. Adjust the generator to provide a sine wave with maximum amplitude and set the vertical deflection sensitivity of the scope appropriately. Vary the frequency of the generator over its complete range and adjust the scope sweep speed to maintain a usable display. Vary the offset voltage of the generator and observe its effect. Make sure that there is no offset present? Note how the amplitude and frequency of the mathematical description of the sine wave relate to the display on the oscilloscope?

*Trigger Level:* Set triggering to NORM (NOT AUTO) and adjust the trigger level and slope controls and observe the effects. Also, vary the signal input amplitude to verify that the trigger is activated at a determined voltage threshold. What happens when the input upon which you are triggering falls below the threshold?

LEARN TO RECOGNIZE WHAT HAPPENS WHEN THE SCOPE IS NOT TRIGGERED! THIS IS THE MOST COMMON SOURCE OF ERROR IN USING THE OSCILLOSCOPE.

Now set the triggering to AUTO and repeat the above. ONCE AGAIN, LEARN TO RECOGNIZE A ’SCOPE THAT IS IN AUTO-TRIGGER MODE AND NOT SYNCHRONIZING PROPERLY! YOU SHOULD BE ABLE TO RECOGNIZE THIS FROM ACROSS THE ROOM AND KNOW WHAT TO DO ABOUT IT. If your scope has a slope (positive or negative) button press it and try to figure out its effect on the triggering of the scope.

*More on Time and Frequency:* Measure the peak-to-peak (p-p) amplitude of the signal when the generator is set for maximum output. Measure the frequency of the signal when the generator dial is set for 1 kHz, 10 kHz, and 100 kHz. Which setting is more accurate, the ’scope or the generator settings?

*Rise and Fall Time:* Set the generator to produce square waves with a frequency of 1 kHz. Ideally, a square wave changes from maximum negative to maximum positive values instantaneously. The real signal cannot, for physical reasons, go from the maximum negative level to the maximum positive level, or vice-versa, instantly. The rise- and fall-times of signals are conventionally defined as the time it takes the signal to go from 10% to 90% of the full voltage change (either increase or decrease.) Try to measure the rise time of the 1 kHz square wave using the oscilloscope.

**Use of External Trigger:** Connect the TTL OUTPUT of the signal generator to Channel 1, and the signal output to Channel 2 of the scope. Then set up a dual-trace display,
making sure that Channel 1 is selected as the trigger source, and inspect the time relationship between the TTL OUTPUT (or SYNC) and signal waveforms for all types of outputs. Verify that you can alter the signal amplitude without affecting the triggering of the scope. Now move the line from channel 1 to the EXT SYNC input of the 'scope and set the trigger source switch to external. Note that Channel 2 remains the same as when triggering internally on Channel 1. Vary the trigger level and slope and observe the effects on the display of Channel 2. Verify again that you can alter the signal amplitude without affecting the triggering of the scope.

Summary: By following activities outlined above hopefully you will have gained some confidence in the use of the electronics test equipment. There is no written lab report but these simple skills will be indispensible for building and testing audio electronic circuits.