# ENG 100    Lab #1
# Laboratory Equipment

**Objectives:** To learn the operation of the laboratory equipment: oscilloscope ("scope"), digital multimeter (DMM), DC power supplies, and function generator.

**General Instructions**
Follow instructions and fill in the blanks. Ask the TA for help if you encounter difficulties.

**HAND IN THESE SHEETS AT THE END OF THE LAB PERIOD.**
**THEY WILL BE GRADED AND THEN GIVEN BACK TO YOU TO USE AS A REFERENCE.**

## Laboratory Procedures

**l. Scope Control Settings:**
**General Info:**
The oscilloscope reticule is the line grid on the scope display. The vertical axis of the display represents signal amplitude, while the horizontal axis represents time.

(a) Turn the power/line switch **ON** if it is not already on.
(b) In the TRIGGER section of the control panel under **MODE,** select the **AutoLevel** display soft key.
(c) In the HORIZONTAL section, adjust the **Time/Div** knob so the middle top of the display reads **200 μs (0.2 ms).**
(d) Press **1** in the "Vertical" section to view **Channel 1**; move the trace **up** and **down** with Ch 1's **Position knob**, then turn Channel 1 **off** (Press **1** again, then press leftmost softkey. (Softkeys are the buttons below the screen).
(e) Press **2** in the "Vertical" section to view Channel 2; move the **trace up and down** with Ch 2's **Position knob**, then turn Channel 2 off (Press **2** again, then press leftmost softkey).
(f) Select Channel **1** again and turn it on with the leftmost softkey; you will use Channel **1** for the rest of the lab.
(g) In order to measure voltage, press the **Voltage** button. Press the Source **1** softkey and then press the **Vp-p** softkey. You should see Vp-p(1) on the bottom of the screen.
(h) In order to measure frequency, press the **Time** button. Press the Source **1** softkey and then press the **Freq** softkey. You should see Freq(1) on the bottom of the screen.
(i)You should **NOT** trust the function generator's display and instead use the scope or a DMM to ensure you have the correct voltage output.

**2. Function Generator Control**
The frequency and amplitude values on the function generator can be set either by rotating the control knob on the right or by entering the values using the **Enter Number** and **Enter** keys (for digital function generator).

(a) **Turn on** the power if not already on.

(b) Select the sine wave key (~).

(c) Set the amplitude to 1000 mVpp: Press: **Ampl , Enter Number ,1000, ^** (up). OR: **Ampl** and **turn the knob** OR: Locate **Output level** and **turn the knob.** (If the output level isn't low enough, push the **–20 dB button in.**)
Note: l000mV = 1.0V

(d) Set the offset to **0 V DC** : **Offset, Enter Number, 0, Shift, v** (down**).** OR: **Offset**, and **turn the knob** OR: Press the **Offset button** so it's sticking out.

(e) Set the frequency to **1**kHz: **Freq, Enter Number, 1, v** (down**).** OR: **Freq**, and **turn the knob** OR: Turn the **Coarse knob** until you're around **1**kHz and then fine-tune by turning the **Fine knob**.

(f) Connect the function generator **OUTPUT** to the scope's Channel **1** input using a single BNC-to-BNC cable (These have circular ends). [**OUTPUT** may be labeled **Vp-p** on some function generators.]

**3. AC Voltage Measurement Using the Scope**

(a) Adjust the Channel l **Volts/Div** knob on the scope so the waveform is as large as possible, but within the top and bottom horizontal reticule lines.

(b) Adjust the **Time/Div** control to see **two cycles** of the waveform on the screen.

(c) Adjust Channel **l Position knob** so the bottom of the waveform is on **the bottom** reticule line.

(d) Adjust the HORIZONTAL position/**Delay knob** so a top peak of the waveform is on the center vertical reticule line.

(e) Record the sensitivity of the scope (the Volts/Div reading on the top left of the display): _______ V/Div

(f) Estimate the peak-to-peak height of the waveform to the nearest tenth of a division (note whether each subdivision tick down the center vertical line is 1/4 or 1/5 division). For accuracy, take the waveform trace (line) thickness into account: _______ Div

(g) The peak-to-peak value of the waveform in volts is the difference between the peak and the valley in divisions times the scope's sensitivity in Volts/Div. Calculate the peak-to-peak voltage. _______ Vpp

(h) The standard specification of a waveform's amplitude is its zero-to-peak (or simply peak) voltage. For a sinusoid, this is one-half the peak-to-peak voltage. Convert the peak-to-peak voltage amplitude Vpp in part (g) to peak voltage, Vp: ________ Vp

**4. Period and Frequency Measurement Using the Scope**

**General lnfo:**
A scope can be used to measure **a signal's period** (the duration of one cycle of the signal) and the frequency (number of cycles per second). These are both measured with the horizontal (time) scale of the scope display. The space between the bigger vertical lines on the scope graticule (the display grid) is considered to be one "division". This space corresponds to the time-base setting (how fast the signal is drawn across one division). The time between two points on the signal can be found by multiplying the horizontal distance between the points (in divisions) and by the time-base setting (in seconds/division).

(a) Set the amplitude (**Ampl**) of the function generator to **1000 mVpp.**

(b) Select **Autoscale** on the scope to center the waveform, and confirm the scope's time-base setting is still 200 µs (0.2 ms).

(c) If the generator's frequency is still 1 kHz, then there should be two cycles on the screen. Record the time base setting (top middle of display): ________ s/Div

(d) Note two consecutive places where the rising waveform is crossing the center horizontal graticule line (these are "positive-slope zero crossings"); the time between these two crossings is one period of the waveform. Estimate the distance, in divisions, between these zero-crossings: ________ Div

(e) Calculate the period T in seconds, by multiplying the time-base by the period in divisions: T = ______ s

(f) The frequency is the reciprocal of the period: f = l/T
(This frequency should be close to the setting on the function generator.) f = ______ Hz

**5. DC Voltage Measurement Using the Scope**

**General Info**:
Signal $v(t) = A \cdot \cos(\omega t)$ oscillates as far above **0 V** as below, and has 0V DC offset. A signal $v2(t) = 0.3\cos(\omega t)$ + 1V oscillates around +1V; it has a DC offset of +1 VDC and an amplitude (AC component) of 0.3 V peak (or 0.3 Vp), or 0.6 V peak-to-peak = 0.6 Vpp.
More generally: ***A signal $v(t) = A\cos(\omega t) + B$ has a DC component of B Volts DC and an AC component of A Volts peak (Vp) or 2A Volts*** **peak-to-peak (*Vpp*).**

(a) Confirm the function generator output is connected to the Channel 1 input of the scope and confirm the generator's output has an offset of 0 V.

(b) Center the generator output on the scope display by pressing the scope's **Autoscale** key.

(c) If not already there, set the function generator frequency (**Freq**) to 1 kHz and amplitude (**Ampl**) to **1000 mVpp**.

(d) Set the generator **Offset** to +**500 mV DC**.

(e) The waveform should be a sine wave raised up from the center of the vertical scale; it is **DC offset** from the zero level of the display. **Estimate the DC offset** (the distance from the display zero level to the middle level of the sine wave) **by using the divisions on the scope**: ________ mVDC
Now estimate the amplitude (peak) of the signal's AC component: ________ mVp

(f) Set the function generator offset as high as it will go and record the offset: ________ mVDC

Now set the function generator offset as negative as it will go and record the offset: ________ mVDC

Now use the control knob to vary the **DC offset**; play with it a bit to see what happens as the DC offset changes.

(g) Another way of measuring DC offset is using **Cursors.** Press **Cursors** at the top of the scope's panel, then press the Source **1** softkey. If there's an option, press the **V1V2** softkey. Then press the **V1** softkey. Turn the knob that's next to the **Cursors** button on the panel. You will see the line that represent the cursor move up and down. To measure offset, set the offset to **0V** and then move the cursor so it touches the wave on the very bottom.

(h) Press the **V2** softkey. Turn the knob again and you can see the line that represents the cursor move up and down. Set the offset back to either **+500 mV** or **–500 mV** and then move the cursor so it touches the wave on the very bottom.

(i) The offset is given on the bottom of the screen and is shown under **ΔV(1)**. This function displays the difference between the **V1** and **V2** cursors (V2 – V1).

**6. AC Voltage Measurement with the Digital Multimeter (DMM)**

**General Info**:
RMS amplitude (**rms = root-mean-square**) is a way of describing a signal's amplitude. If we square a signal, take its mean over one time period (see your text), and then take the **square root** of that, we get the rms value of the signal. If a sinusoid has a <u>peak amplitude</u> of A Vp (which is 2A Vpp), it has an rms amplitude of $0.7071 \cdot A$ Vrms. Note that this is a relation for sinusoids only; the ratio of peak to rms is different for different wave shapes.

(a) With the function generator still connected to the scope (use a BNC-BNC cable), set the generator for a 1-kHz sine wave with 0 V offset. Then set the amplitude *as high as* the function generator will allow.

(b) Measure the (peak) amplitude of the sine wave with the scope: _______ Vp

(c) Disconnect the function generator output from the scope and connect the generator to the input of the DMM (**red**

**to red, black to black – be careful to connect to the red DMM input that can measure Voltage – look for a 'V'**).

(d) Set the DMM to measure V AC and choose an appropriate voltage range. You might see an "over-range" display, indicating the DMM cannot display the result on its current setting.

(e) Increase the DMM range, one range at a time, until the correct voltage is displayed with the most significant figures. Record the displayed (rms) voltage: _______ Vrms

Recalling that the rms amplitude is 0.7071 times the peak amplitude, convert the rms voltage just measured to peak voltage: _______ Vp

If this value is not the same as in (b), then there is some error. Estimate the error using the peak voltage derived from the DMM reading as the "assumed correct" value:
% Error= ([Vp_from_DMM_reading – scope_reading] / Vp_from_DMM_reading) x 100%: _______ % Error

Note that the DMM is more accurate than the scope, but the DMM only measures rms voltage correctly for pure sine waves in a limited frequency band. Due to internal limits of the DMM, there is a maximum frequency, above which the DMM gives inaccurate rms values.

(f) Set the function generator, with frequency still at 1 kHz, to an amplitude of exactly 1.00 Vrms amplitude as **measured with the DMM:**
Do this by setting the function generator to **1.00 Vrms** with the function generator front panel, then turn the generator's knob to fine-adjust the reading on the DMM.

Now change the generator frequency upwards (do it in big steps: 10 kHz, then 100 kHz, then 1 MHz) until the DMM reading falls by at least 10%; now search downwards in frequency until you find the frequency (above 1 kHz) where the DMM reads exactly 0.9 Vrms (10% decrease): _________kHz

Now adjust the frequency below **1 kHz** to find where the DMM reading falls by 10% and record that frequency, too: _________ Hz

Since the function generator amplitude varies little over the whole frequency range, the roll-off is due to the DMM's frequency response. So you can only use the DMM reliably between the above frequencies for AC measurements.

**7. DC Voltage Measurement with the DMM**

**General Info:** A DC power supply that is described as being a "positive +20 VDC" supply may, in fact, go a bit higher than.+20 V and may go a little bit negative; a similar situation exists for a "−20 VDC" supply. Here, you will measure the true voltage range of your DC power supplies using the DMM.

Set the DMM to measure V DC (DC volts), not VAC (AC volts).
For each measurement, set the DMM scale to the range that gives you the most significant figures.

(a) Connect the +20V DC voltage supply to the DMM with two banana-plug-to-banana-plug cables. (Make sure there is a wire connecting COMMON and the GROUND symbol on a Triple Output Supply [OR for a Dual Output Supply: a wire connecting from the GROUND symbol to the **–** terminal on the left half of the supply, where you will generate a Positive DC Voltage, and a wire connecting from the GROUND symbol to the **+** terminal on the right half of the supply, where you will generate a Negative DC Voltage. ]

> For a Triple Output Supply:
> (1) Connect COM/**ground/black banana terminal** of <u>the power supply</u> to the COM/**ground/black input** of the <u>DMM</u>
> (2) Connect +20V power supply (**red**) banana terminal to the **red V input** of the DMM

For a Dual Output Supply:
(1) Connect COM/**ground/black banana terminal** on the left half of the power supply to the COM/**ground/black input** of the DMM
(2) Connect +20V power supply (**red**) banana terminal on the left half of the power supply to the **red V input** of the DMM

(b) Turn the 20V voltage amplitude knob to its **maximum**, measure the voltage: _________ VDC

(c) Turn the 20V voltage amplitude knob to its **minimum**, measure this (usually slightly negative) voltage: _________ mVDC

(e) On the Triple Output Supply: Remove the **red connector** from the +20 V supply and connect it to the –20V supply output terminal, instead.
On the Dual Output Supply: Move **the red connector** from the left half of the supply and connect it to the black banana terminal on the right half of the supply. (The right-side output voltage is generated between the + and – terminals on the right half of this supply. However, due to the GROUND wires, the black output on the left half of the power supply is connected to the red output on the on the right half of the power supply.)
Turn the amplitude knob to its **maximum**, measure the voltage (negative): _________V DC

Turn the amplitude knob to its **minimum**, measure the voltage (may be slightly positive) _________ mV DC