

# Lab Handout

E 250L – Electric Circuits Lab  
Santa Ana College

Welcome to the Electric Circuits Laboratory course (Engineering 250L) at Santa Ana College. This laboratory course is intended to familiarize the student about the fundamentals of practical circuit construction and analysis. These topics form the basis for more advanced courses covering semi-conductors, motor control, data acquisition, and microprocessors.

It is important to learn the basics of the equipment used in an electric circuits lab, and it is important to follow instructions to enhance learning and to ensure your safety.

## 1 ELECTRICAL COMPONENTS

### I. Wire

#### A. Intro

1. Wire is designed to conduct electric current with very little resistance.
2. Wires come in a variety of sizes, styles, and insulator colors.
3. Styles – solid or stranded. Stranded wire is more flexible & is selected if the wire is going to be repeatedly bent.
4. Size – a common standard for wire size is AWG (American Wire Gauge). Increasing gauge numbers correspond to decreasing wire diameters.
5. Insulator – wire is usually coated with an insulative plastic or rubber material that prevents short circuits.
6. Resistance – wire is presumed to have no resistance, but it actually has a little (e.g., 20 AWG copper has ~ 10 m $\Omega$ / ft)



#### B. Wire gauge (selected sizes in table below)

1. Wire sizes are often rated using AWG (American Wire Gauge) standards.
2. Note – the AWG # goes down as wire diameter goes up.

AWG	Wire Diameter (in)
1	.289
2	.258
3	.229
10	.102
12	.0808
14	.0641
16	.0508
17	.0453
18	.0403

AWG	Wire Diameter (in)
19	.0359
20	.0320
21	.0285
22	.0253
23	.0226
24	.0201
25	.0179
26	.0159
27	.0142

## II. Resistors

### A. Intro

1. R's "resist" electric current, dissipate power, & produce heat (like friction)
2. Resistor values are in "Ohms" ( $\Omega$ )
3. Key parameters the "value" (indicated by color bands) and the "power rating".
4. Power rating indicates the amount of power (energy/time) that the resistor can dissipate without "blowing up."
5. Usually, resistors that are physically small have lower power ratings.
6. We will be using low-power resistors (1/4 Watt, sometimes 1/2 Watt).

### B. Resistor values (4-band code)

1. The first 3 color bands specify the R value. The 4<sup>th</sup> band specifies tolerance.

#### Value bands

No.	Color
0	Black
1	Brown
2	Red
3	Orange
4	Yellow

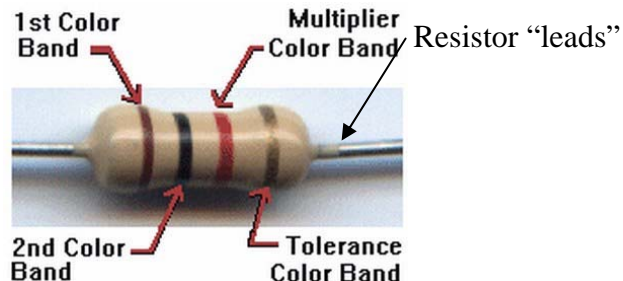
No.	Color
5	Green
6	Blue
7	Violet
8	Gray
9	White

#### Tolerance bands

Tol.	Color
$\pm 10\%$	Silver

Tol.	Color
$\pm 5\%$	Gold

2. Example – Brown/ Black/ Red/ Gold



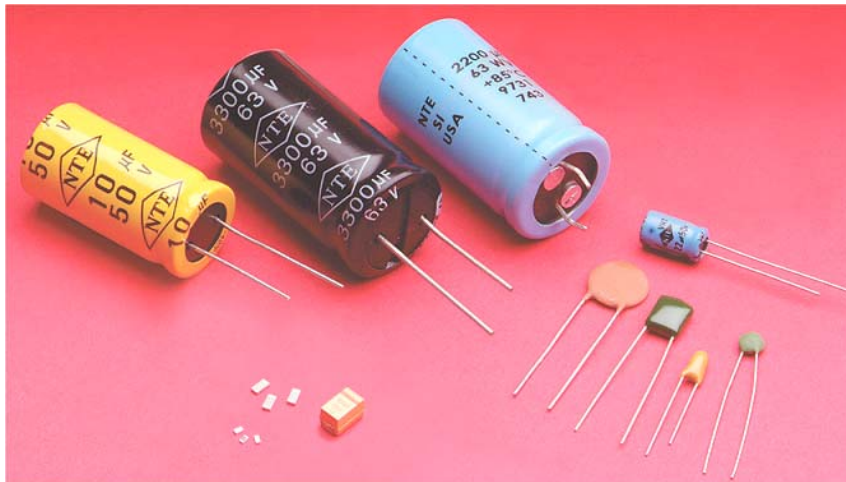
$$\begin{array}{cccc}
 1 & 0 & 2 & \pm 5\% \\
 \downarrow & \downarrow & \downarrow & \downarrow \\
 10 & \times & 10^2 & \pm 5\%
 \end{array}$$

$$1000 \pm 5\% \quad \text{or} \quad 1\text{k}\Omega \pm 5\%$$

### III. Capacitors

#### A. Intro

1. Capacitors store electric charge (like a battery, but with very different characteristics).
2. The key characteristic of capacitors is to resist **CHANGES** in voltage.
3. There are many types of capacitors.
4. Key parameters are the capacitance (in units of “Farads”), power rating, voltage rating (maximum amount of voltage that can be applied across the C), and whether or not the capacitor is “polar”.
5. A polarized capacitor may only have voltage applied across it in 1 polarity direction. If the voltage polarity is applied in the opposite direction, the capacitor will blow up.
6. Electrolytic capacitors are often used when higher capacitance is needed, but these capacitors are polarized.



### IV. Inductors

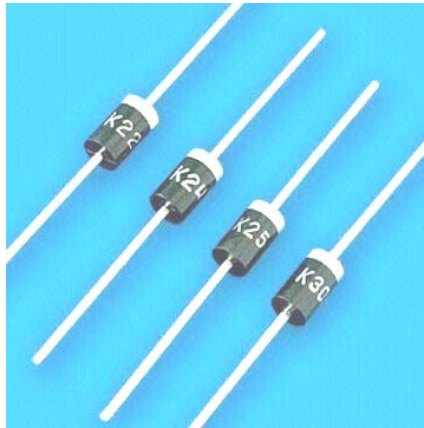
#### A. Intro

1. They are coils of wire that produce a magnetic field when electricity passes through them.
2. The key characteristic of inductors is to resist **CHANGES** in current.
3. Key parameters are inductance (in “Henrys”), voltage, and current.
4. Often, inductors look like coils of wire, but there are also inductors whose coils are encased in a cover and look like capacitors.



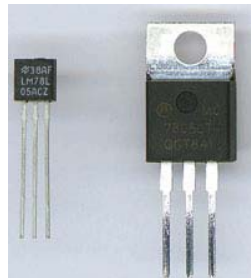
## V. Diodes

- A. Diodes are like one-way valves for circuits. They allow current to flow in one direction but not the other. Diodes form the basis for transistors.

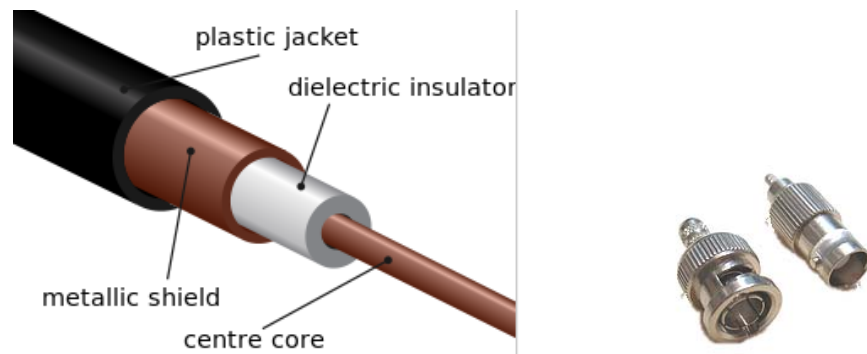


## VI. Transistors

- A. Transistors are like on/off switches for electric current. They form the basis for modern electronics in our TVs, cell phones, radios, mp3 players, and computers. A transistor has 3 “legs” and the body can be shaped as a box or a cut-off cylinder.



## VII. BNC Connectors



- A. Most of our cables are coaxial, meaning that there is an inner conductor surrounded by an insulating layer and then a tubular conducting shield. Normally the shield is kept at ground and the center conductor carries the signal.
- B. It is common to see BNC (Bayonet Neill-Concelman) connectors on the ends of these cables. These are commonly-used connectors on radio-frequency electronic equipment for frequencies below 3 GHz and below 500V.
- C. Engaging the connectors involves slipping the male connector over the female connector. The female connector has a protruding portion that must line up with a slot on the sleeve of the male connector. After slipping it over, you must rotate the sleeve until it is secure.
- D. In our lab, BNC connectors are used for the output of the function generator and the oscilloscope.

## 2 EQUIPMENT

### I. Digital multimeter (DMM)

#### A. Intro

The DMM is an electronic instrument used to measure several types of electrical signals, including voltage, current, & resistance (“digital” = display is digital instead of a needle, “multi” = many, “meter” = to measure). Many DMM’s can also measure frequency, capacitance, and inductance; test transistors; or test “continuity” (to see if there is a “break” in a wire). DMM’s can vary quite a bit in price. Usually more expensive DMMs have more functions, but there are some very reasonable DMMs that can do plenty!

#### B. Use

1. First select the desired setting (e.g., “~ V” for AC volts, “ $\Omega$ ” for resistance). See below.

$\overline{\overline{V}}$  DC Voltage       $\overline{\overline{A}}$  DC Current

$\widetilde{V}$  AC Voltage       $\widetilde{A}$  AC Current

$\Omega$  Resistance      **F** Capacitance (in Farads)

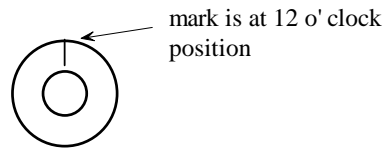
2. Insert the DMM “test leads” (insulated wires) into the appropriate terminal. The black lead goes into the black “COM” terminal. The red lead goes into one of 3 possible “red” terminals, depending on the variable to be measured. Generally the red lead stays in the terminal marked “Hz V  $\Omega$ ” unless you are measuring current.
3. Set the range within the setting type. The set range value must be GREATER THAN the measured signal (e.g., to measure a 100 k $\Omega$  resistor, set the range to 200K, 2M, or 20M). The best range setting is the smallest one that is still greater than signal’s magnitude.

4. If the measured signal exceeds the range setting, the DMM may display an “OL”, meaning “overload”. “Auto-ranging” DMMs do not require the range to be selected.
- C. BK Precision, BK 2704C Digital multi-meter



## II. Trainers (Elenco XK 700)

- A. Our labs use the Elenco XK 700 “trainer” kits, which are used to build and test digital or analog circuits. The trainers include 5 independent power supplies, an analog trainer, a digital trainer, and a solderless breadboard. The XK 700 is housed in a sturdy briefcase and includes a variety of tools.
- B. Power supplies
  1. Positive variable power supply (0 – 15V at .5A, 15 – 20V at 1A).
  2. Negative variable power supply ( same specs as above)
  3. 3 fixed voltage (DC) power supplies (+12VDC, –12 VDC, +5VDC, at 1A each)
  4. AC voltage power (15 or 30 VAC)
  5. Note – supplies are regulated to within 150 mV, and are short-circuit-protected using integrated circuit regulator devices.
- C. Function generator: The quality is not as good as a dedicated function generator.
  1. Waveforms: sine (the symbol looks a bit like a triangle), triangle, square;
  2. Frequency: 1 Hz – 100 kHz, in 5 steps)
  3. Amplitude: 0 – 15 Vpp
  4. DC offset adjustment (no indexing at 0 V. Must verify zero offset using ensuring Vavg on the oscilloscope is = 0)
  5. Output impedance: ~ 330 Ω
  6. Function generator output is at the “FREQ” terminals
  7. Positive (+) voltage output of the function generator is thru the “FREQ” terminals. Negative (–) voltage is “GND”.
  8. Good initial settings for frequency are: sine wave output (most CW setting... the sine wave symbol looks a bit like a triangle). Set the COARSE FREQ knob to “1k”. Set the FINE ADJ, AMPLITUDE, & DC OFFSET knobs to the “12-o’ clock” position (see figure below).



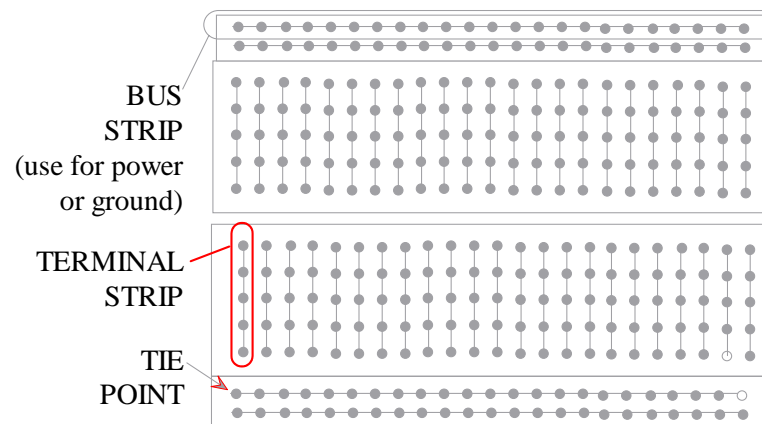
#### D. Potentiometers (1 kΩ and 10 kΩ)

#### E. Digital trainer “section” (not used in Engr 250L)

1. Clock generator, 2 no-bounce logic switches, 8 LED indicators with data switches
2. CLK, LOGIC INDICATORS, LOGIC SW, DATA SWITCHES

#### F. Breadboard (protoboard or solderless breadboard, or “plug board”)

1. There are different types of breadboards (or protoboards). Some breadboards require solder to secure wires and components. We will use the other kind (“solderless”). These breadboards may be used to create “prototype” circuits that can be easily changed.
2. The breadboard is made up of a grid of holes which have specific “connectivity” beneath (where you can’t see). Each of the holes is called a “tie point”. Our protoboards are designed for 22 gauge wire or smaller (bigger AWG number). If you “jam” overly-large wire into the board, it damages them.
3. The layout of interconnections fall under 2 categories: “terminal strips” and “bus strips”.



### III. Analog devices (we probably won’t use these older measurement tools)

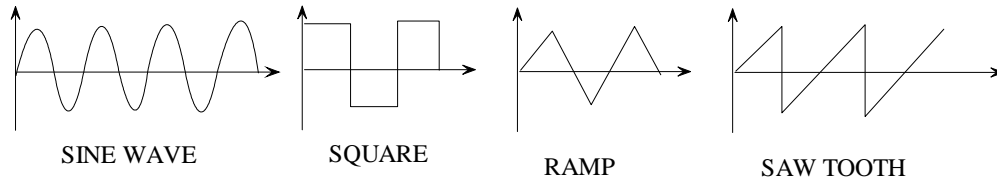
- A. Voltmeter – older analog voltmeters measure voltage, but the display uses a needle-type gauge. This type of display requires you to “interpolate” or “extrapolate” to figure out the voltage value. Many expert technicians like to use the analog meters when they are measuring irregular signals. The movement of the needle may help them assess problems in an electrical circuit. Irregular signals can be more difficult to see on a digital meter
- B. Ammeter – measure current (amps).
- C. Ohmmeter – measure resistance (ohms).

### IV. Function Generator

#### A. Intro

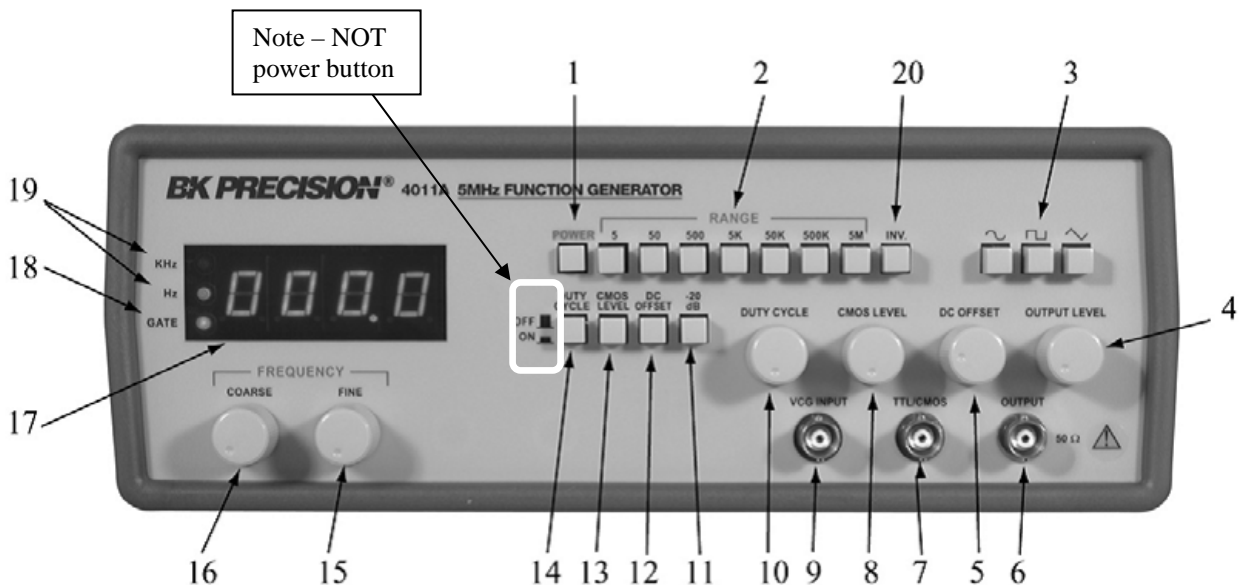
1. Function generators produce voltage signals of different “waveform” patterns.
2. Examples of waveforms include: sine, square, saw tooth, and ramp.
3. Function generators can alter the magnitude and frequency of these signals as well.

- The signal of these function generators is typically output to an oscilloscope, a DMM, and/or to an electric circuit.



## B. BK Precision 4011A – 5 MHz Function Generators

- These FG's have a digital display for the frequency of the output signal.
- Front panel
  - Button 1 – Power button (NOT button 14)
  - Button 3 – selects waveform (sine, square, or triangle)
  - Button 2 – set of buttons to select coarse frequency range.
  - Knob 16 – coarse adjustment of frequency (use this after selecting button 2)
  - Knob 15 – fine adjustment of frequency (use this after using knob 16)
  - Knob 4 – adjusts output amplitude
  - Button 11 – “-20 dB” reduces the amplitude of the output signal.
  - Connector 6 – output jack accepts BNC-style connectors
  - Knob 5 – adjusts the DC offset of the waveform
  - Button 20 – inverts the signal (e.g., a  $V_{out} = -A\sin\omega t$  instead of  $+A\sin\omega t$ ).
- Connection to output jack (connector 6)
  - Only connect the alligator clip “breakout” connector (see pic below), BNC cable, or BNC-T connector. NEVER connect a scope probe to this output jack



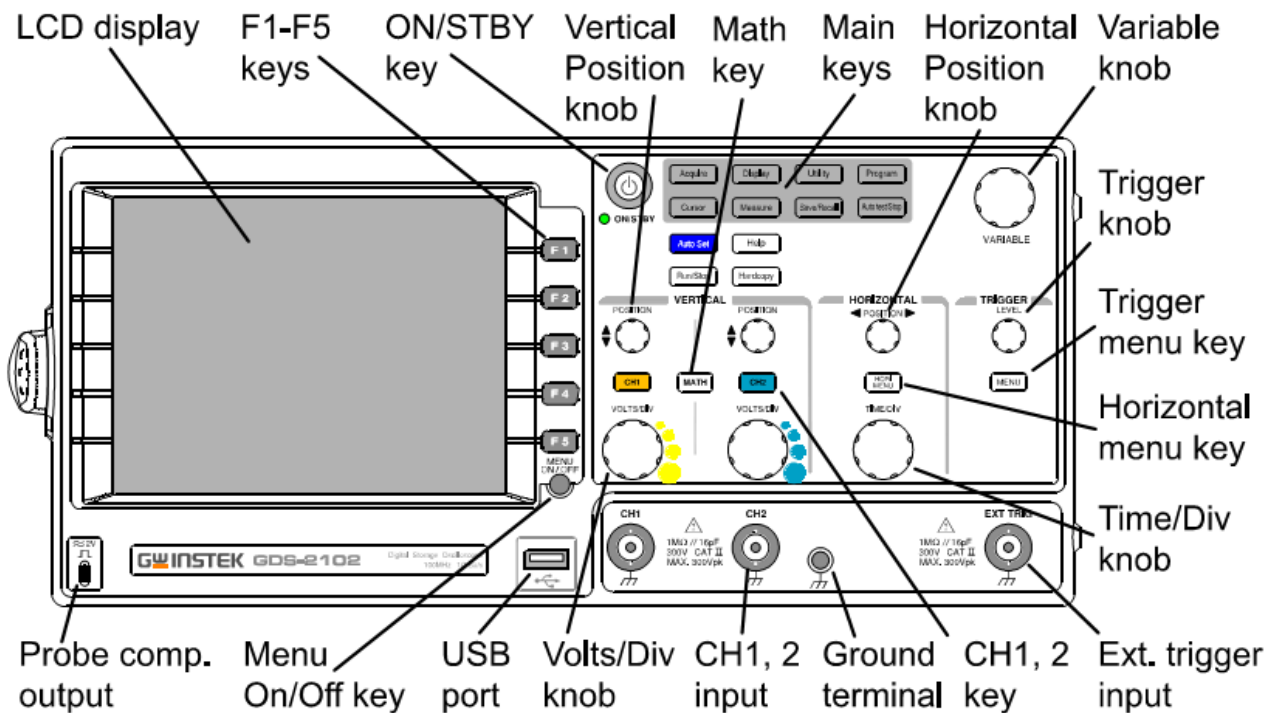
## V. Oscilloscope

### A. Introduction

- The oscilloscope (or “scope” for short) is an electronic device that displays voltage values as a function of time, just as you might draw them on an XY plot on a piece of paper (e.g., displaying a sine wave voltage).

2. There are digital and analog scopes. Modern scopes tend to be digital, and they are generally easier to use. Older scopes are typically analog. However, students may benefit from using an analog scope. The analog scope forces the student to better understand how the scope works & what its controls do. Analog scopes are often preferred by experienced electronics technicians because they are able to display some “irregular” signals that may provide clues to what is wrong in a circuit.
3. How an oscilloscope works – an analog scope with a CRT display “sprays” a stream of electrons against a phosphor-coated screen (just like a tube TV). When the electron strikes the screen, the phosphor glows so we can see it. Newer scopes use LCD displays.
4. Sweep and triggering: In order to make a repeating signal appear non-moving and stable on a display, the scope must synchronize the electron stream with the frequency of the signal. The scope uses “triggering” and “sweeping” in order to repeatedly display the same portion of the input signal.
  - a. Horizontal sweep refers to movement of the glowing dot across the screen.
  - b. Triggering is what starts (or triggers) the horizontal sweep. The trigger ensures that the sweep begins at the same relative point of a repeating signal.
  - c. Together, synchronized horizontal sweeping and the vertical deflection (caused by voltage) trace a graph on the screen.
5. Basics of scope use – the basic idea is to connect the scope to some point on the circuit to measure the voltage there. After connecting the scope to the circuit, you must adjust the scope’s controls in order to get a “nice” looking trace on the scope display.
  - a. Time and voltage scale – these controls control how the scope directs this electron beam so that we get a proper display of the voltage signal.

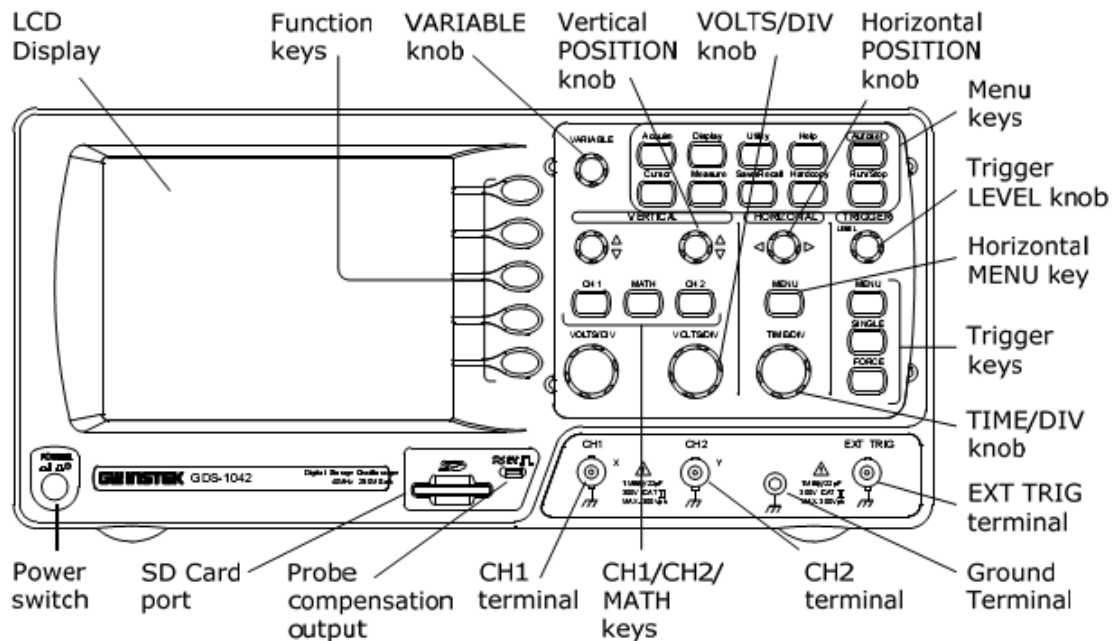
B. Instek GDS-2062 (60MHz, 1 GSa/s)



- C.
- D. Instek GDS-1022 25 MHz digital storage oscilloscopes.

1. These scopes are low-end 2-channel DSO's. The "25 MHz" means that the device can measure signals of up to 25 MHz frequency. "2-Channel" means the scope can measure 2 different voltage signals at a time. Other scopes may have more channels.
2. Front panel controls (Instek GDS-1022)

## Front Panel



- a. LCD Display – TFT color, 320 x 234 resolution, wide angle view display
- b. Function keys – activates the functions that appear on left of LCD display
- c. Variable knob – increase/decrease value or move to next/previous parameter
- d. Vertical position knob – sets vertical position of waveforms
- e. VOLTS/DIV knob – selects vertical scale; fine (clockwise), coarse(counter cw)
- f. Horizontal position knob – sets horizontal position of waveforms
- g. Menu keys
  - i. Acquire key – configures acquisition mode
  - ii. Display key – configures display settings
  - iii. Utility key – configures Hardcopy, system info, menu language, calibration, & probe compensation
  - iv. Help key – shows Help contents
  - v. Autoset key – finds signals & sets proper horizontal & vertical trigger settings
  - vi. Cursor key – runs cursor measurements
  - vii. Measure key – configures & runs automatic measurements
  - viii. Save/Recall key – saves & recalls image, waveform, panel setup
  - ix. Hardcopy key – transfers data to SD card
  - x. Run/stop key –
- h. Trigger level knob – sets trigger level (THIS IS IMPORTANT)
- i. Horizontal menu key – configures horizontal view
- j. Trigger keys
  - i. Trigger menu key – configures trigger settings
  - ii. Single trigger key – selects single trigger mode

- iii. Trigger force key – forces trigger level to 50% of signal amplitude
  - k. TIME/ DIV knob – sets horizontal scale
  - l. EXT TRIGGER terminal –
  - m. Ground terminal – accepts GUT
  - n. CH 2 terminal – accepts input signals,  $1M\Omega \pm 2\%$  input imped, BNC terminal
- 3. CH 1/ CH 2 math keys –
    - a. CH 1
    - b. Math
    - c. CH 2
  - 4. CH 1 terminal – accepts input signals,  $1M\Omega \pm 2\%$  input imped, BNC terminal
  - 5. Probe compensation output – outputs 2Vp-p, 1kHz signal for probe compens.
  - 6. SD card port – facilitates transferring waveform data & display image
  - 7. Power switch – power ON/OFF
- E. Front panel controls for “OLD” scopes (BK Precision, 40 MHz, 1540) (eh – we probably won't use these old scopes)