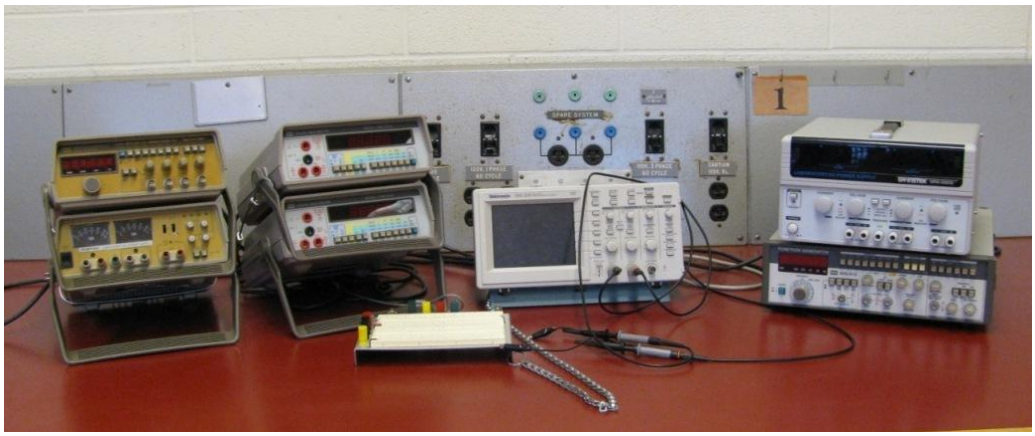
University of Toronto
Department of Electrical and Computer Engineering
Instrumentation Laboratory GB341

Laboratory Equipment Instruction Manual – 2011

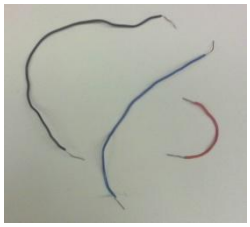


Explanations are kept to a minimum; only basic instructions relevant to the first-year laboratory experiments are covered. Complete instruction manuals are available in the laboratory and you may refer to them for more detailed explanations.

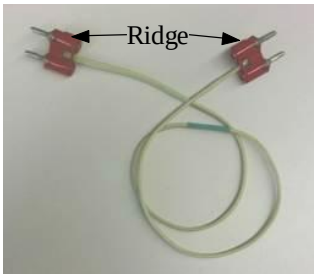
Although the descriptions that follow are specific to instruments of certain manufacturers and models, the operating instructions apply generally to any equipment of the same category.

1. Wires and Cables

i) **Hook-up Wire**
single insulated conductor used to interconnect components on the protoboard.



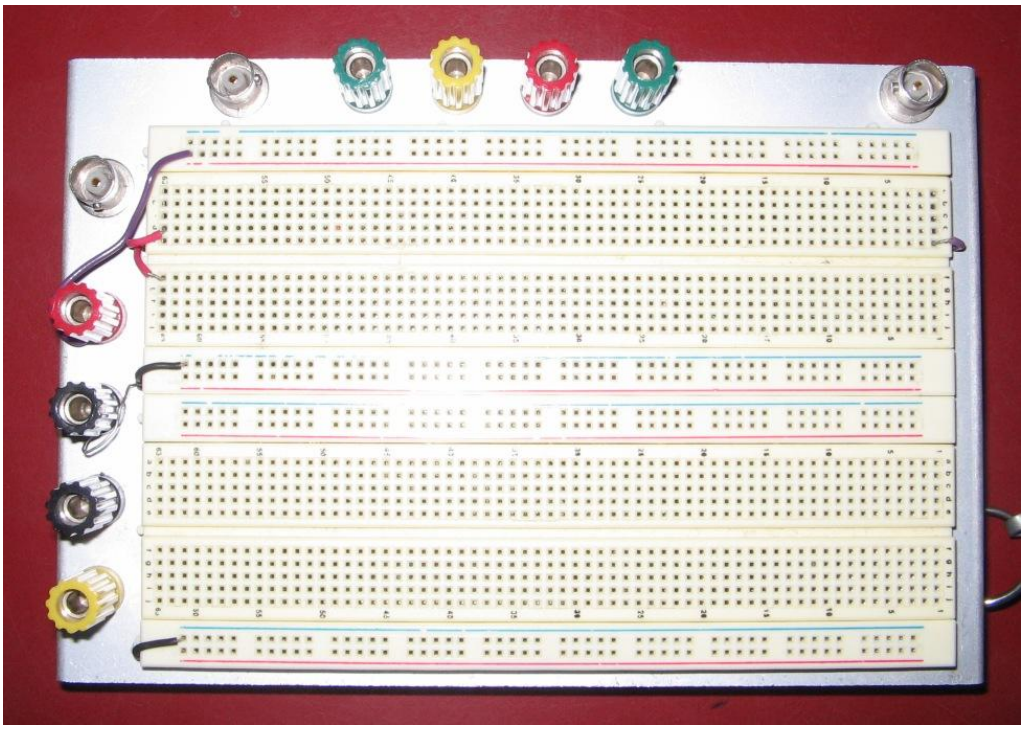
ii) **Two-Wire Lead**
with "*double-banana*" plugs (left) or separate plugs (right) on each end. By convention the "ridge" side of the plug is used for the ground or reference line.



iii) **Coaxial Cable**
with a BNC connector on each end, used for connecting AC signals. The shield of this cable is connected to the outer rings of the BNC connectors.

iv) **Coaxial Cable**
with a BNC connector on one end and a "*double-banana*" plug on the other end. The shield is connected to the outer ring of the BNC connector and the "ridge" side of the double-banana plug, which has to be connected to the ground or reference line.

2. Protoboard



The protoboard may be viewed as a neatly arranged set of interconnecting wires, as indicated by thick lines in the drawing shown in Fig. A-1. Signals are brought to and from the protoboard via terminals (sockets) and BNC connectors. Internal connections between sockets and some of the protoboard "wires" are shown by dotted lines.

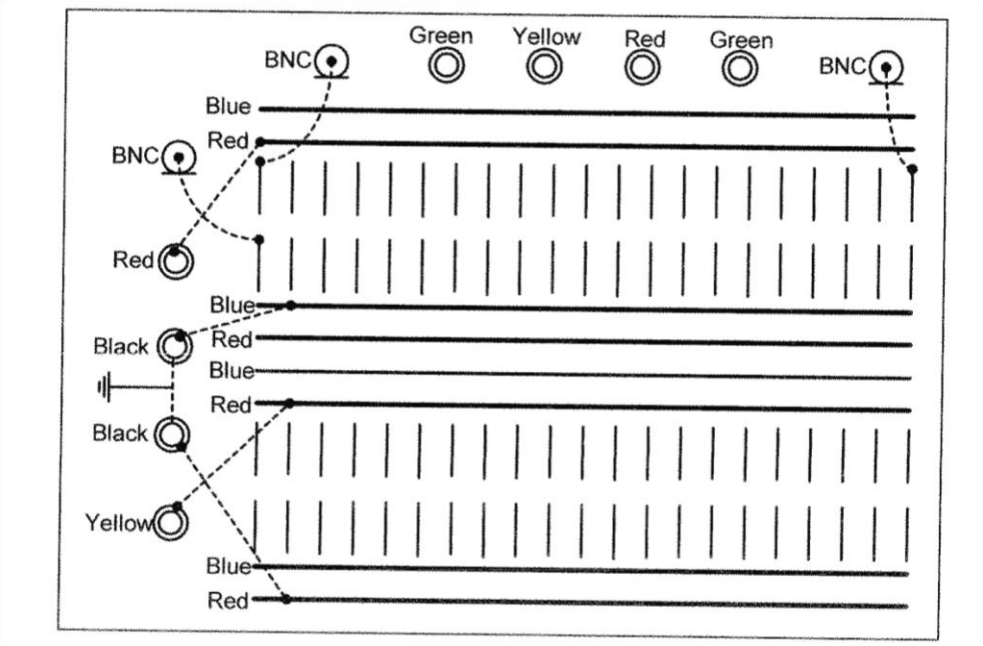


Fig. A-1

- By convention the **black** sockets, and the associated "ground" rail, are reserved for the ground (common or reference) line. For detailed ground wiring refer to the drawing of Fig. A-1 (thick lines).
- Never use the aluminum base as a reference point or the ground, always use the designated ground rail!
- Note that all **BNC** shield wires are soldered to the ground (common) line.
- The **red** socket and the associated rail are reserved for positive DC voltage.
- The **yellow** socket and the associated rail are to be used for a negative DC voltage.
- The **BNC** sockets are reserved for AC signals, i.e. AC inputs and outputs.
- The "floating" pairs of sockets (**green-yellow** and **red-green**) can be used for DC current and voltage measurement. Hookup-wires are needed to connect them to the circuit under test on the protobard.
- **Caution**: there is a fine conducting foil web (under a white plastic board) that gets easily damaged when interconnecting ("hook-up") wires are pushed in too deeply, 3 to 5 mm long conductor ensures sufficient contact!

Before each experiment carefully check the connections between the sockets and associated rails against Fig. A-1. Fix connections to the black, red, and yellow sockets if needed. Report broken BNC connections to a TA immediately.

3. DC Power Supplies

There are four models of DC power supplies in the laboratory. Mostly used in the first year laboratory are the "*Laboratory DC Power Supply*", Models GPS-3303 and GPC-3030, both manufactured by the GW-Instek Company. The other two are the *"Laboratory DC Power Supply"* Model PC 2405, manufactured by the Instek Company, and the "*Regulated DC Power Supply*", Model 6218A, manufactured by the Hewlett-Packard Company.

- **Functions**

  DC power supplies are variable *DC voltage sources*, which means that the voltage they supply can be adjusted to any level within the operational limits of the instrument; and, once set, that the voltage remains constant with time regardless of variations in the current supplied within the operational limits of the instrument, as indicated graphically in Fig. A-2.a and Fig. A-2.b.

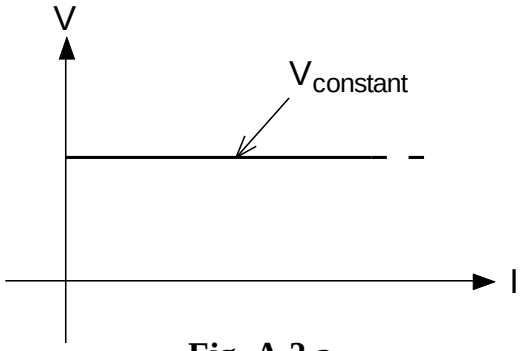


Fig. A-2.a

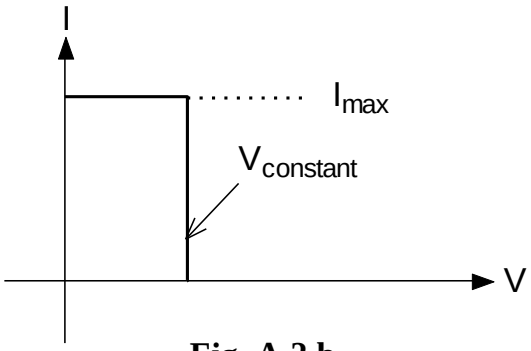


Fig. A-2.b

- **Symbolic Representation**

The symbolic representation of a DC voltage source that will be used in the subsequent drawings is shown in Fig. A-3.

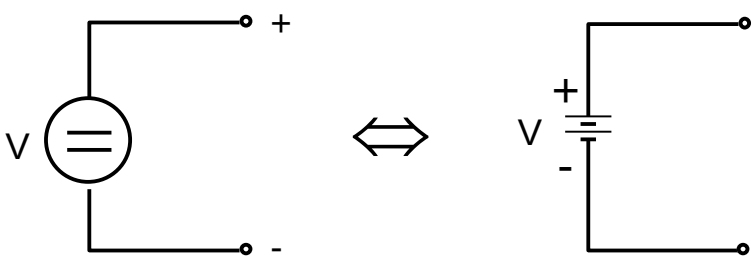


Fig. A-3

- DC power supplies have one or more sets of two terminals labeled (+) and (-), between which the output voltage will appear. Another terminal is labeled (GND), as indicated schematically in Fig. A-4, and is isolated from the (+) and (-) terminals. The GND terminal is internally connected to the ground pin on the power plug.

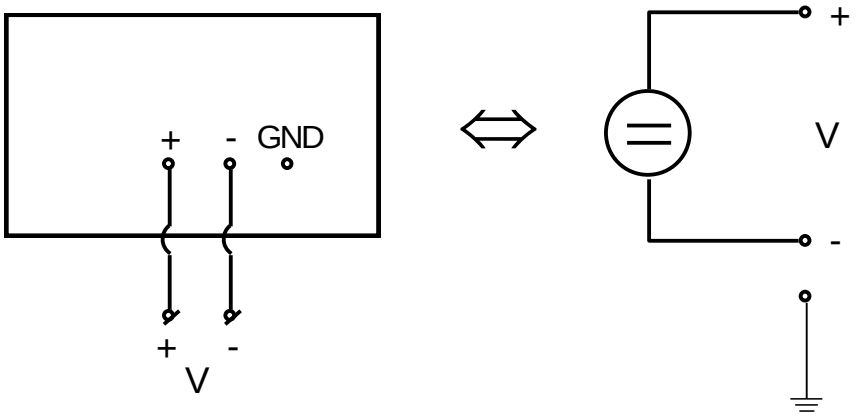


Fig. A-4

If a grounded voltage source is required, either the (+) or (-) terminal has to be connected to the ground terminal as shown in Fig. A-5a and A-5b.

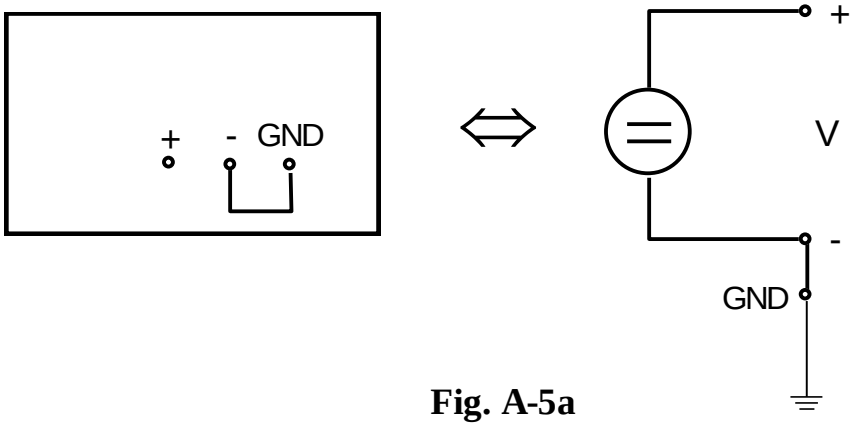


Fig. A-5a

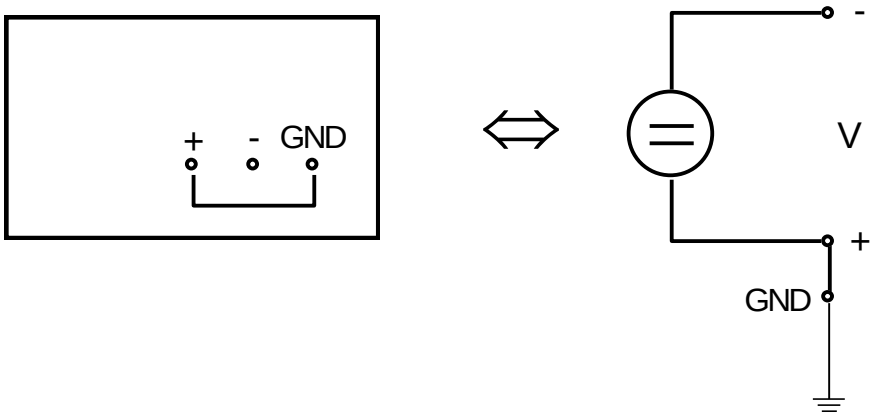


Fig. A-5b

3.1 GW-Instek Laboratory DC Power Supply Model GPS-3303

The GW-Instek Model GPS-3303 has three sets of output terminals, the "Master" or CH1 output, the "Slave" or CH2 output and the 5V fixed output (CH3) and can run in three "modes". In the independent mode CH1 and CH2 are independent from one another and can be used as two separate power supplies. This is the mode in which this instrument will mostly be used in the first-year laboratory. The other two modes are the series and parallel tracking modes and will not be described here. The instrument's front panel, showing the most important controls, displays, and terminals is displayed in Fig. A-6.

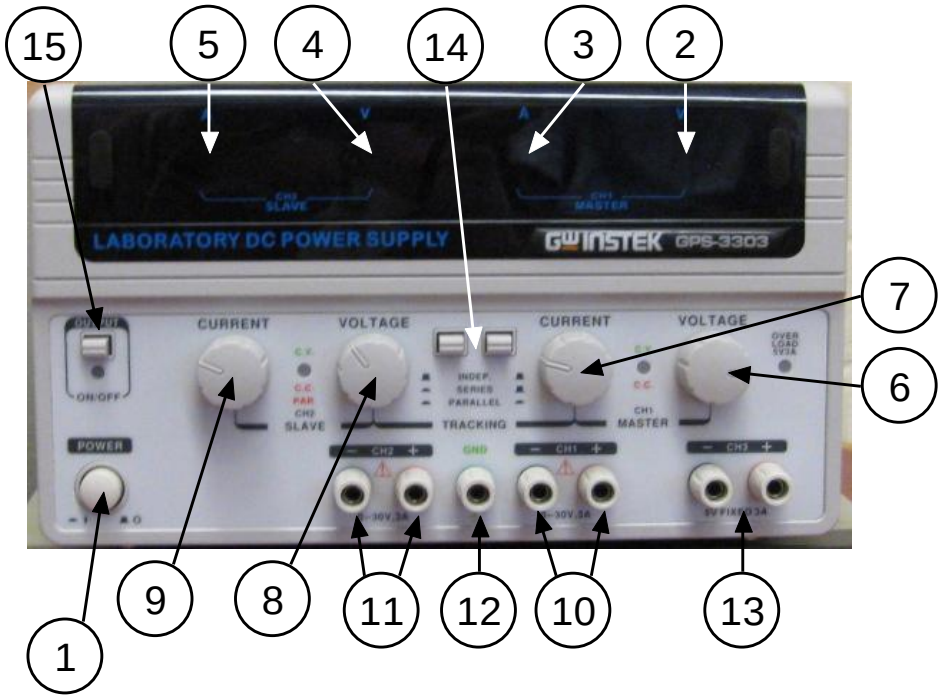


Fig. A-6

(1) **Power** switch.
(2) **Meter V** – indicates the CH1 voltage (green).
(3) **Meter A** – indicates the CH1 current (red).
(4) **Meter V** – indicates the CH2 voltage (green).
(5) **Meter A** – indicates the CH2 current (red).
(6) **Voltage Control Knob** – to adjust the voltage for the CH1 supply.
(7) **Current Control Knob** – to adjust the maximum output current for the CH1 supply.
(8) **Voltage Control Knob** – to adjust the voltage for the CH2 supply.
(9) **Current Control Knob** – to adjust the maximum output current for the CH2 supply.
(10) **Output terminals** ((+) and (-)) for the CH1 supply.
(11) **Output terminals** ((+) and (-)) for the CH2 supply.
(12) **GND** terminal – earth and Chassis ground.
(13) **Output terminals** ((+) and (-)) for the 5V fixed output (CH3).
(14) **Tracking Mode Switches** – for the independent mode both switches have to be disengaged (out).
(15) **Output Switch** – switches the output on or off.

Operating Instructions (Setup Procedure)

- Push the **Power** button (1).
- Ensure that both **Tracking Mode Switches** (14) are disengaged (out).
- Turn the **Current Control Knob** (7) and/or (9) fully clockwise for maximum output current.
- Adjust the voltages for CH1 and/or CH2 by turning the **Voltage Control Knob** (6) and/or (8) until the required values are reached while watching the **Meter V** displays (2) and/or (4).
- Connect a two-wire lead with double-banana plugs to the output terminals of CH1 (10) and/or CH2 (11) to connect the output voltage to your circuit. (See below).
- Push the Output Switch (15) in. The voltages shown on the Meter V displays now appear between the (+) and (-) terminals of CH1 (10) and CH2 (11). The output indicator light below the output switch should be on.

  Below the GPS-3303 is set up in independent mode for a 10 V voltage in CH2.

3.2 GW DC Power Supply Model GPC-3030

The GW Model GPC-3030 is very similar to the Model GPS-330 – it also has three sets of output terminals, the "Master" or CH1 output, the "Slave" or CH2 output and the 5V fixed output (CH3) and can run in the same three "modes". In the independent mode CH1 and CH2 are independent from one another and can be used as two separate power supplies. This is the mode in which this instrument will mostly be used in the first-year laboratory. The other two modes are the series and parallel tracking modes and will not be described here. The instrument's front panel, showing the most important controls, displays, and terminals is displayed in Fig. A-7.

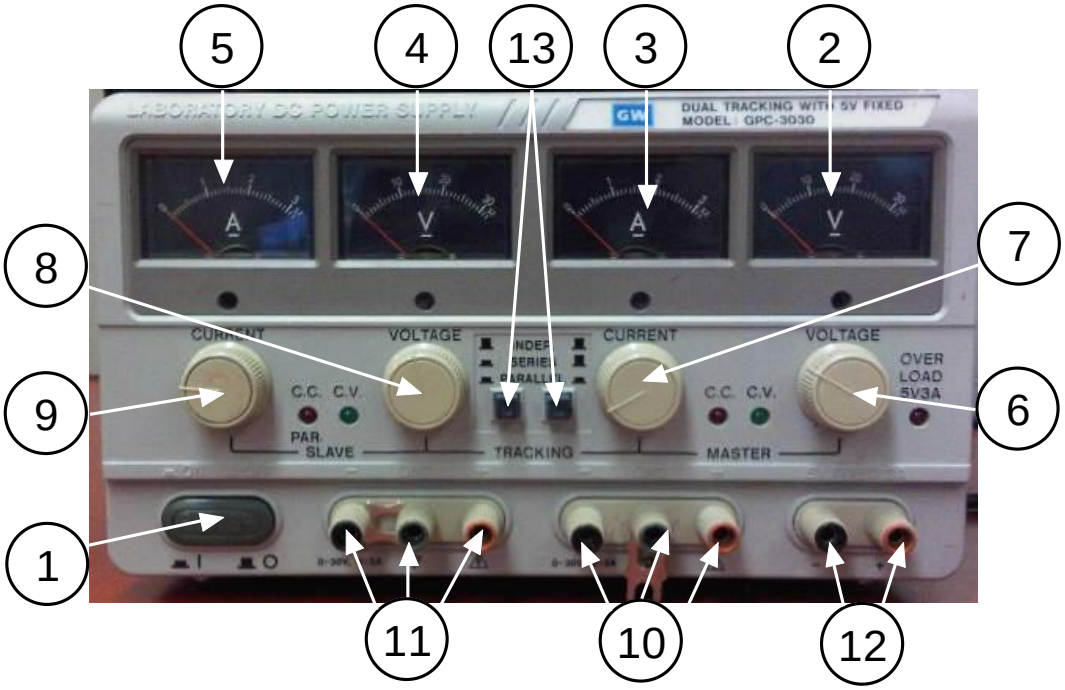


Fig. A-7

(1) **Power** switch.
(2) **Meter V** – indicates the CH1 voltage.
(3) **Meter A** – indicates the CH1 current.
(4) **Meter V** – indicates the CH2 voltage.
(5) **Meter A** – indicates the CH2 current.
(6) **Voltage Control Knob** – to adjust the voltage for the CH1 supply.
(7) **Current Control Knob** – to adjust the maximum output current for the CH1 supply.
(8) **Voltage Control Knob** – to adjust the voltage for the CH2 supply.
(9) **Current Control Knob** – to adjust the maximum output current for the CH2 supply.
(10) **Output terminals** ((+), (grnd), and (-)) for the CH1 supply.
(11) **Output terminals** ((+), (grnd), and (-)) for the CH2 supply.
(12) **Output terminals** ((+) and (-)) for the 5V fixed output (CH3).
(13) **Tracking Mode Switches** – for the independent mode both switches have to be disengaged (out).

One difference between the Models GPS-3303 and GPC-3030 is in the layout of the CH1 and CH2 outputs in that GND (ground) connection is placed between the (+) and (-) terminals.

The output voltage appears between the right and left terminals and the voltage source is not grounded. For a grounded voltage source as in Figs. A-5a and A-5b, electrically connect either the (-) or the (+) terminal to the ground terminal as shown below.

As in Fig. A-5a

As in Fig. A-5b

The polarity of a grounded voltage source can NOT be reversed by reversing the connections of the two-wire lead connected to its terminals. Instead, to change from a positive grounded voltage to a negative one, the ground connection has to be changed from the (-) terminal to the (+) terminal, and vice versa to change from a negative to a positive grounded voltage.

Operating Instructions (Setup Procedure)

- Push the **Power** button (1).
- Ensure that both **Tracking Mode Switches** (14) are disengaged (out).
- If a grounded voltage is required connect either the (+) or the (-) terminal(s) to ground accordingly.
- Turn the **Current Control Knob** (7) and/or (9) fully clockwise for maximum output current.

- Adjust the voltages for CH1 and/or CH2 by turning the **Voltage Control Knob** (6) and/or (8) until the required values are reached while watching the **Meter V** displays (2) and/or (4).

- Connect a two-wire lead the output terminals of CH1 (10) and/or CH2 (11) to connect the output voltage to your circuit. (see previous page)

Below the CH1 and CH2 of the GPC-303 are set up as two independent voltage sources, where one is not grounded (left), while the other one is grounded (right).

3.2 Instek Laboratory DC Power Supply Model PC 2405

Another DC power supply found in the laboratory is the Instek Laboratory Model PC 2405. Like the GPS-3303 it has three output terminals - the "Master", "Slave", and 5V outputs - and it also can be run in series tracking mode, parallel tracking mode, or in independent mode. Only the independent mode is described here. In the independent mode the "Master" and "Slave" outputs are independent from one another and can be used like two separate power supplies. The front panel of the instrument is shown in Fig. A-8.

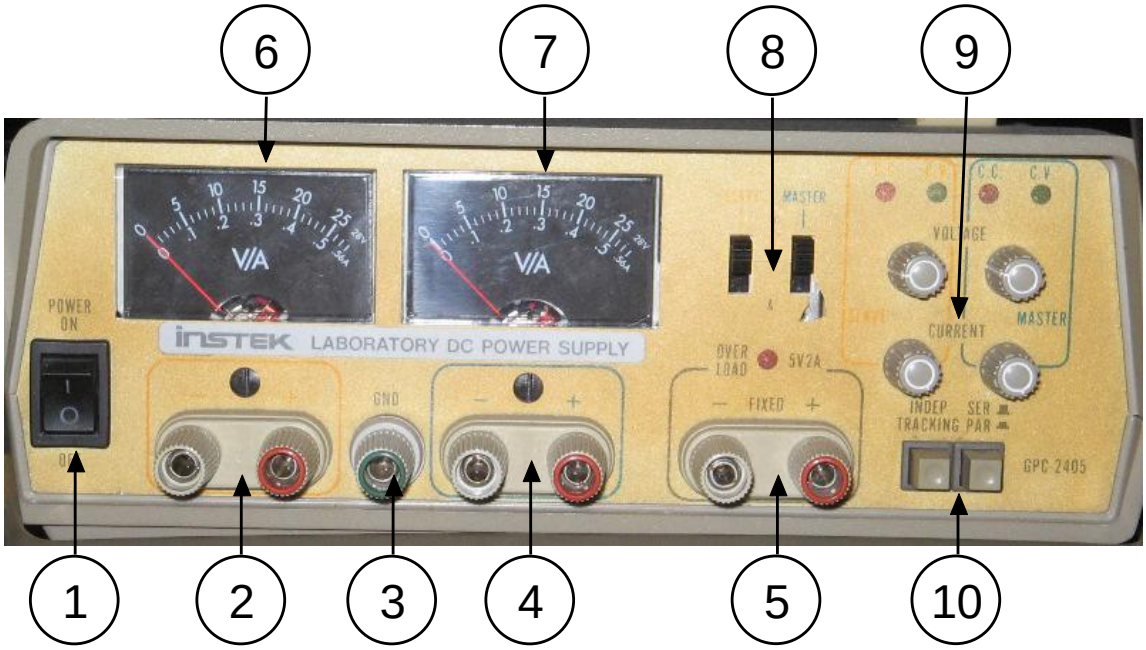


Fig. A-8

(1) **Power** switch.
(2) **Output** for the "Slave" supply. Left: negative polarity, right: positive polarity.
(3) **GND** terminal, Earth and Chassis ground.
(4) **Output** for the "Master" supply. Left: negative polarity, right: positive polarity.
(5) **Output** for the 5 V supply.
(6) **Meter** for the "Slave" output.
(7) **Meter** for the "Master" output.
(8) **A/V selection switches.** Select if the meters indicate voltage or current. For voltage reading set both to "V".
(9) **Voltage and current controls** for the "Master" and "Slave" outputs. Adjust the voltages by turning the two top knobs.
(10) **Tracking mode switches**. Push both switches **out** for the independent mode.

3.3 Hewlett-Packard Regulated DC Power Supply Model 6218A

Instead of the GW-Instek *Laboratory DC Power Supply*, Model GPS-3303 or GPC-3030, some workstations are equipped with two *Hewlett-Packard Regulated DC Power Supplies*.

- **Front panel**

Locations of controls, terminals, and the light indicator are shown in Fig. A-9.

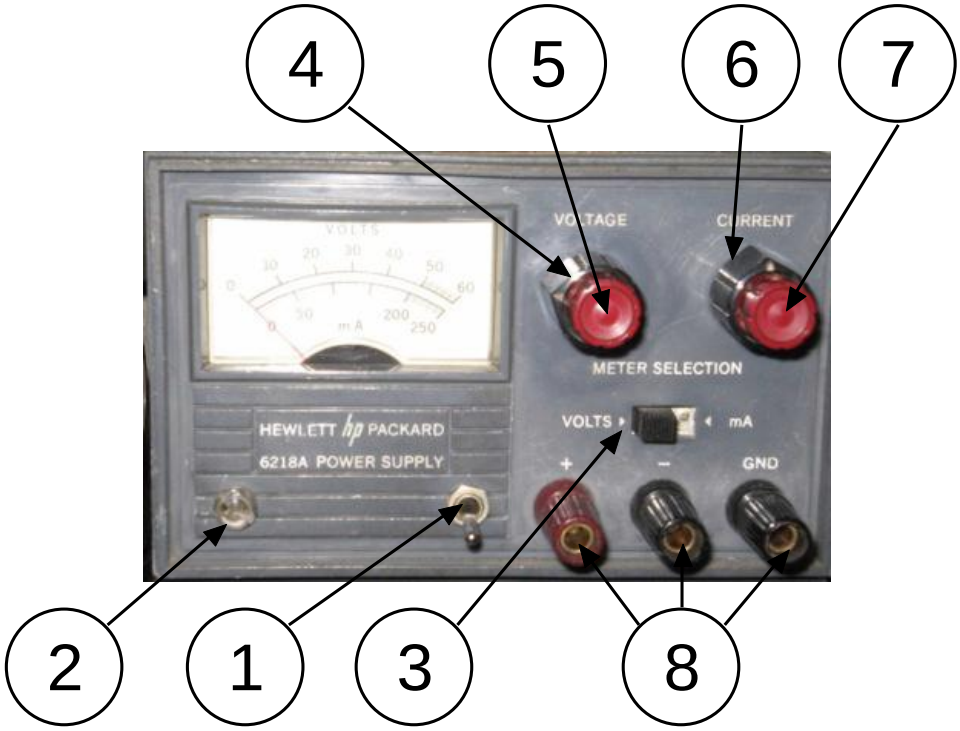


Fig. A-9

- **Operating Instructions (set-up procedure)**

  - Turn on the power supply switch (1). Indicator (2) will light up.
  - Set the meter selection switch (3) to the "V" position (read the voltage scale).
  - Turn the "CURRENT" controls (6) and (7) fully clockwise to allow for the maximum current to be drawn.
  - Adjust the output voltage using the "VOLTAGE" coarse (4) and fine (5) controls.

4. Digital Multimeter

The digital multimeter (DMM) is a multipurpose measuring instrument that can be used, depending on the selected mode of operation, as a *DC or AC voltmeter* (DVM), *as a DC or AC milliammeter*, or as an *ohmmeter*.

The instructions that follow apply to the DMM model GDM-8145, manufactured by the Good Will Instrument Company.

- Front Panel

  Locations of the DMM controls, input terminals ("jacks") and the display are shown in Fig. A-10.

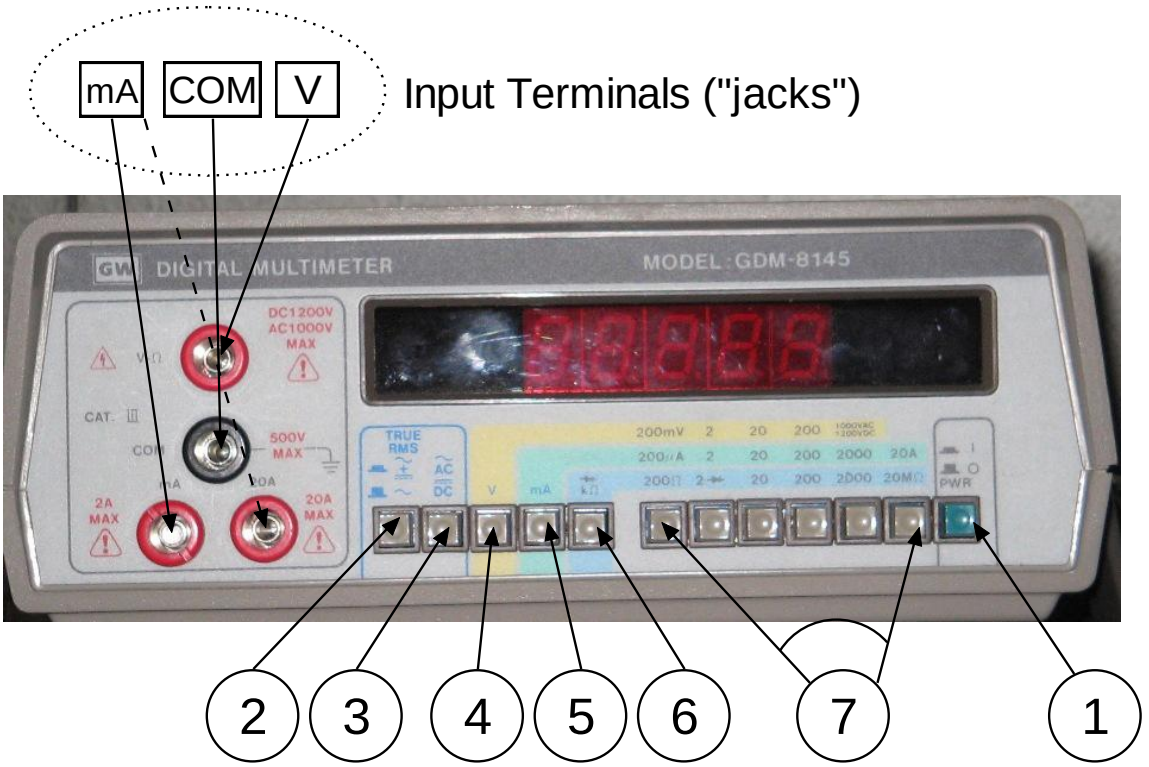
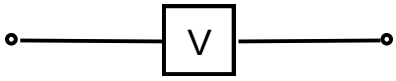


Fig. A-10

The use of a DMM as a DC voltmeter, DC milliammeter, and an Ohmmeter are described in the following.

4.1 DC Voltmeter

Symbolic representation of a voltmeter, as used in circuit drawings:



Operating instructions (set-up procedure, i.e. to set up the DMM as a *DC voltmeter*), proceed as follows:

- Turn on the DMM, push the power switch (1) to the "on" position.
- Select the "DC voltage" mode of operation by depressing the V (4) switch and and making sure that the "TRUE RMS" (2) and "AC/DC" (3) switches are NOT depressed.
- Select the desired range by depressing one of the range switches (7). For the most precise results, the range selected should be the lowest that can handle the voltage expected to be measured.

The controls and terminals used for *DC voltage measurement* are highlighted in Fig. A-11. DO NOT use the (mA) input terminal when measuring voltage!

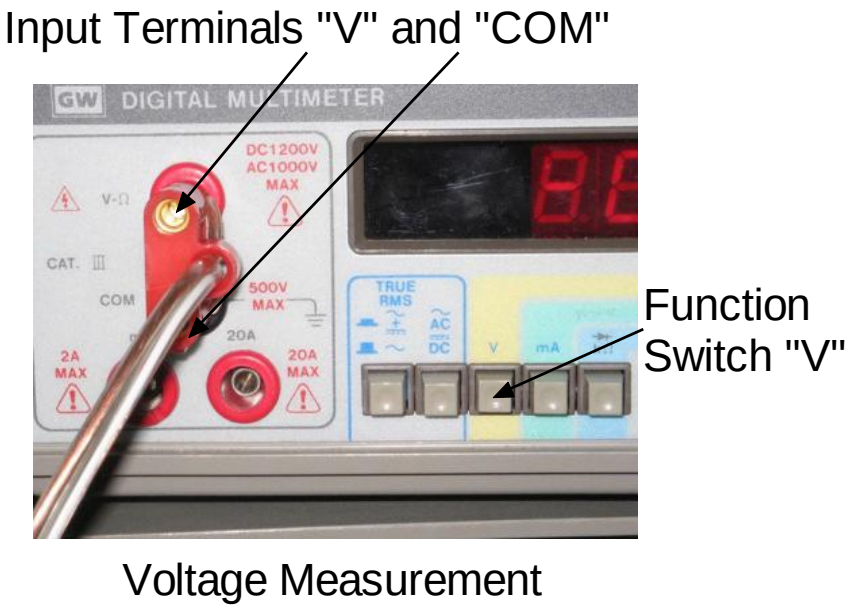


Fig. A-11

- Connect the input terminals (COM) and (V) *across* the voltage to be measured. Both the (COM) and (V) terminals are isolated from the power ground.

a) Voltage measurement across a floating resistor (R_1) is shown in Fig. A-12. The polarity sign in the display indicates the polarity of the (V) terminal with respect to the (COM) terminal.

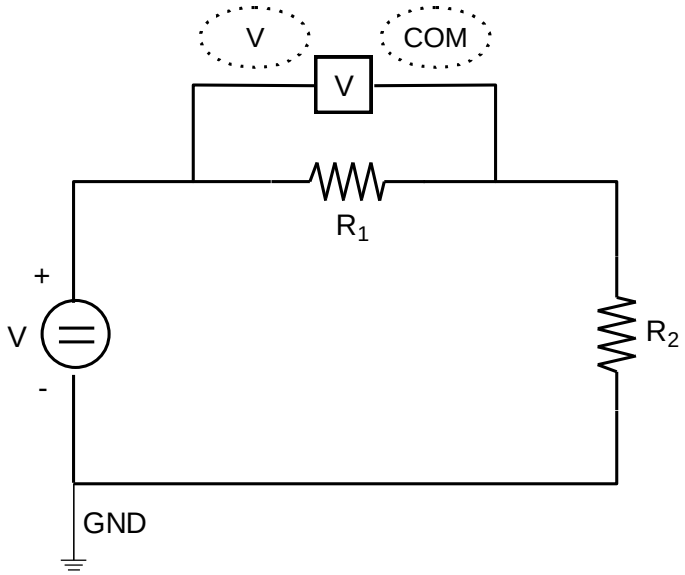


Fig. A-12

b) When measuring voltage across a grounded resistor (R_2) the (COM) terminal should be connected to the ground line, as indicated in Fig. A-13.

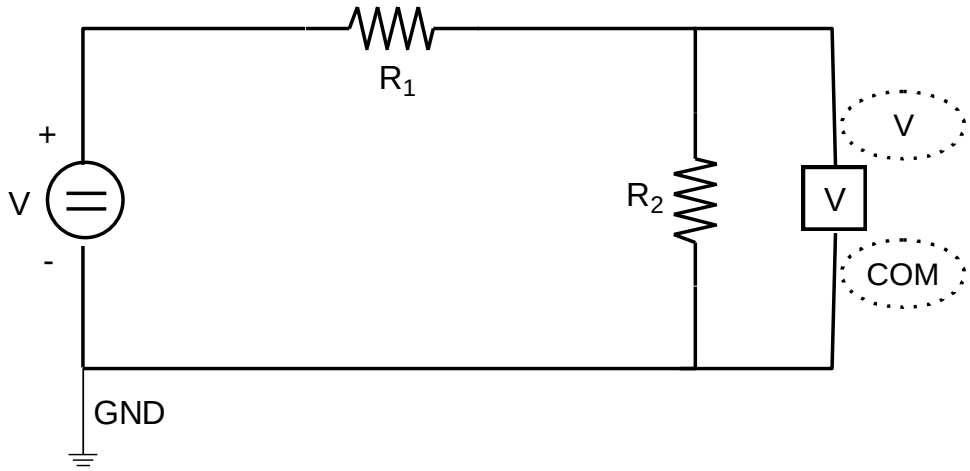
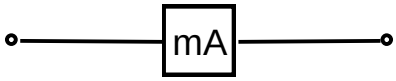


Fig. A-13

4.2 DC Milliammeter

Symbolic representation of a milliammeter, as used in circuit drawings is shown below:



Operating instructions (set-up procedure): to set up the DMM as a *DC milliammeter*, proceed as follows:

- Turn on the DMM, push the power switch (1) to the "on" position.
- Select "DC current" mode of operation by depressing the mA (5) switch and and making sure that the "TRUE RMS" (2) and "AC/DC" (3) switches are NOT depressed..
- Select the desired range by depressing one of the range switches (7).

The controls and terminals used for *DC current measurement* are highlighted in Fig. A-14. DO NOT use the (V) input terminal when measuring current.

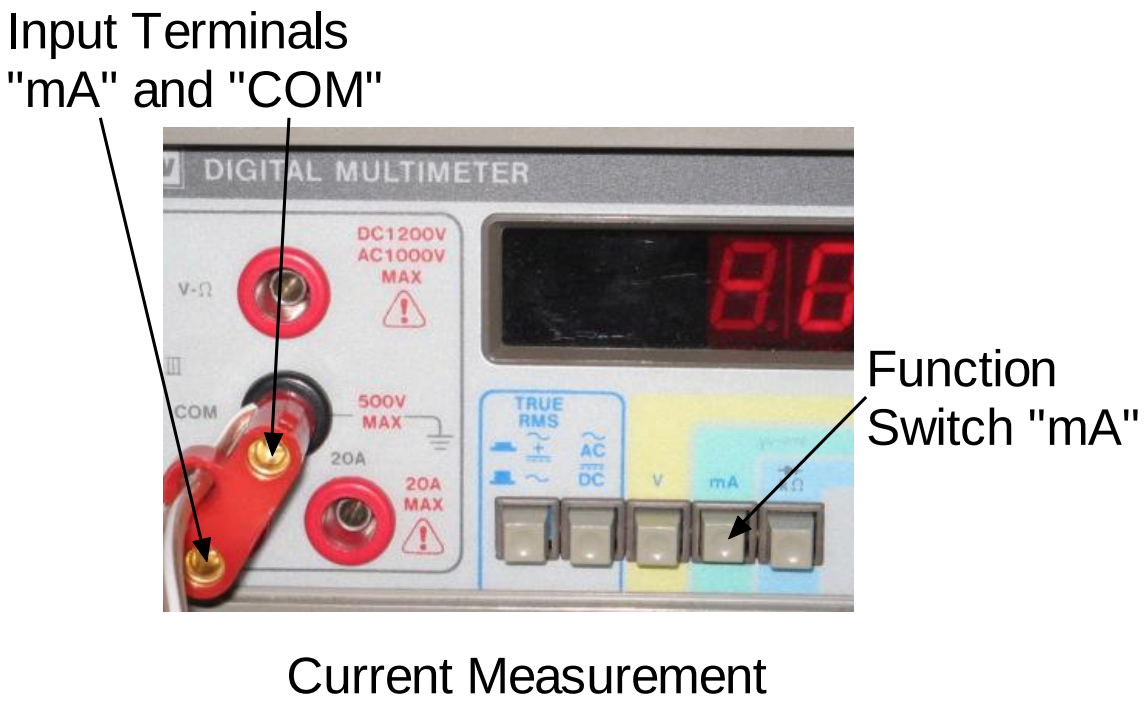


Fig. A-14

- Connect the milliammeter into the current loop as shown in Fig. A-15. Use the "mA' terminal labeled "2A". **Always** have a resistor (R) in series with the milliammeter to limit the current (I) supplied by the voltage source.

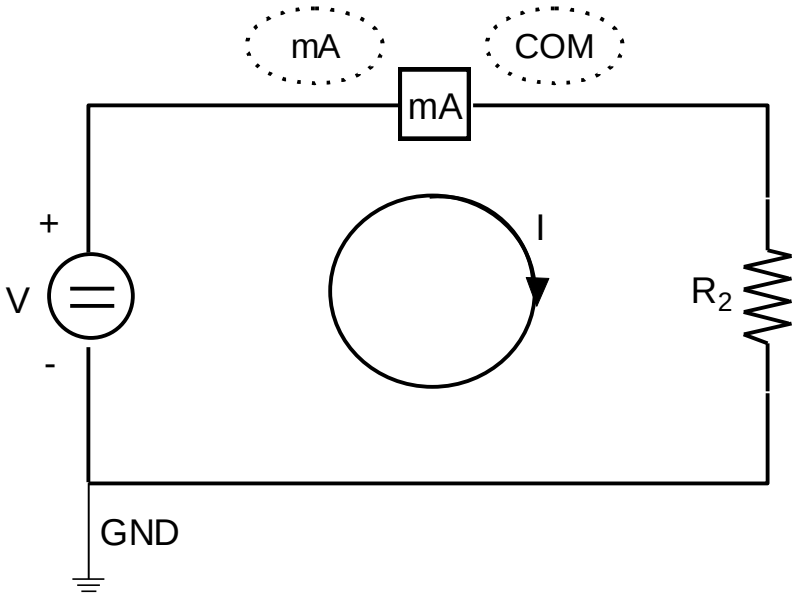
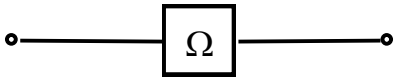


Fig. A-15

4.3 Ohmmeter

Symbolic representation of a milliammeter, as used in circuit drawings is shown below:



Operating instructions (set-up procedure): to set up the DMM as an *ohmmeter*, proceed as follows:

- Turn on the DMM, push the power switch (1) to the "on" position.
- Select the mode of operation by depressing the kΩ (6) function switch.
- Select the desired range by depressing one of the range switches (7).

The controls and terminals used for *resistance measurement* are highlighted in Fig. A-16.

- Connect the input terminals (COM) and (V) across the resistor as shown in Fig. A-15.

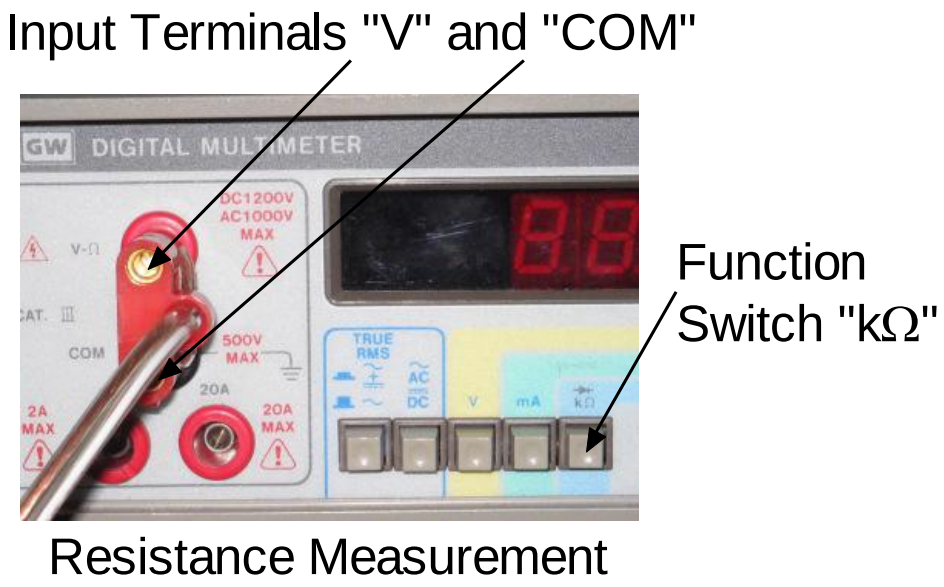


Fig. A-16

NOTE: When measuring resistance, the resistor (R) ***has to be disconnected*** from the signal source as shown in Fig. A-17, because the ohmmeter has its built-in voltage source which causes a current to flow through the unknown resistor.

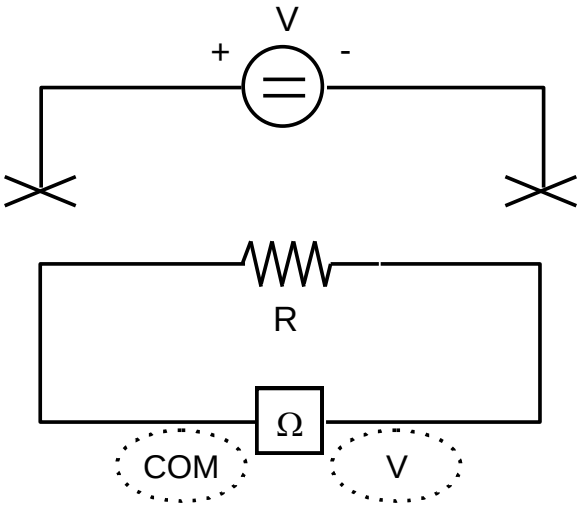
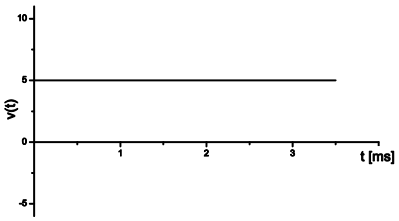


Fig. A-17

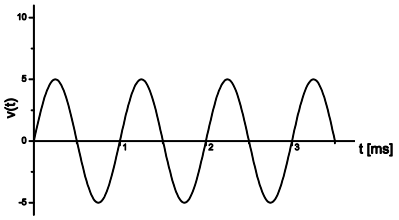
5. Function Generator

A function generator is a *grounded voltage source* that supplies voltages of different amplitude, shape (sine, triangle, square wave) and frequency (typically 0.1 Hz to several MHz). The typical maximum current that can be supplied by a function generator is 100 mA. The typical output resistance is 50Ω.

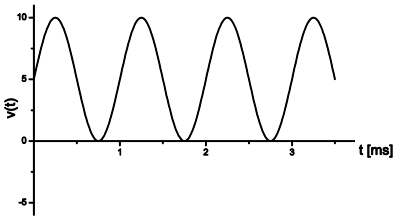
Examples of some waveforms supplied by a function generator are shown below.

i) 

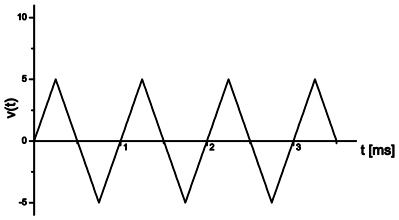
A DC voltage of 5V.

ii) 

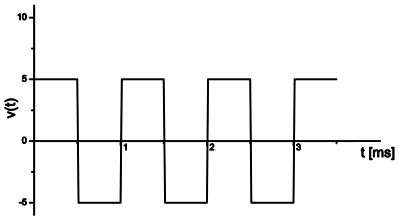
A sinusoidal voltage with a 10-V peak-to-peak value and a frequency of 1 kHz.

iii) 

A sinusoidal voltage with a 10-V peak-to-peak value and a frequency of 1 kHz, with a DC offset of +5V.

iv) 

A triangular voltage with a peak-to-peak value of 10 V_{p-p} and a frequency of 1 kHz.

v) 

A square wave voltage with a peak-to-peak value of 10 V and a frequency of 1 kHz.

Symbolic Representation

One of the two output terminal of the function generator, i.e the outer ring of the BNC connector, is internally connected to the power ground. Hence, its symbolic representation should be that of a grounded voltage source as shown in Fig. A-18.

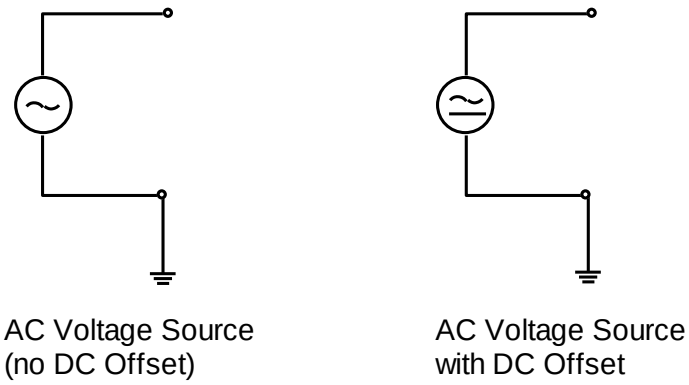


Fig. A-18

5.1 Good Will Instrument Company Model GFG8016G

The front panel controls and connectors are shown in Fig. A-19. Only the controls required to set four basic parameters, *waveform*, *frequency*, *amplitude*, and *DC offset* will be described. For more details refer to the Instruction Manual available in the laboratory.

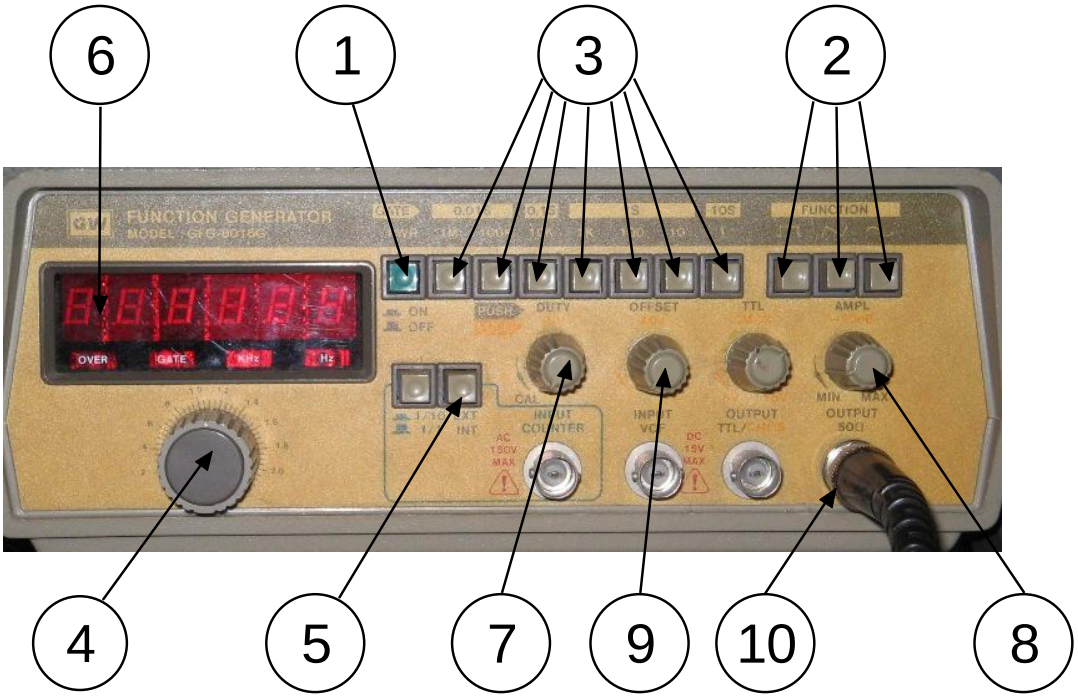


Fig. A-19

(1) **Power Switch:** When pushed in, the LED indicator (5) will light up.
(2) **Function Switches:** Select one of three signal shapes, sine, triangle, and square wave.
(3) **Frequency Multiplier Switch:** Frequency and period are labeled for each setting.
(4) **Frequency Dial:**
The setting under the dial index mark, when multiplied by the setting of (3), determines the output signal frequency.
(5) **EXT/INT Selector Switch:** Selects the signal source for the frequency display (6). Leave this button in the INT (out) position.
(6) **Frequency Display:** Displays the frequency of the signal selected by (5).
(7) **Duty Control:** When this control is set to the CAL position, the output waveforms will have 50% duty cycle.
(8) **Amplitude Control:** Attenuates the output signal by up to a factor of 10. The signal is attenuated by another factor of 10 when the switch is pulled to the out position.
(9) **DC OFFSET With Level Control:** A DC OFFSET control is provided to allow the DC level of the OUTPUT waveform to be set as desired.
(10) **Function Out BNC Connector:** The output signal of the function generator is available at this connector. It is labeled "**50Ω**".

Operating Instructions (set-up procedure)

A typical setting for the function generator is shown in Table A-1. In this case the output signal is specified as a sinusoidal voltage with a frequency of 1 kHz and an amplitude of 6 $V_{p\text{-}p}$ and no DC offset.

Table A-1

Control	Control No.	Position
Power	1	push in
Function	2	~
Frequency Multiplier	3	1 k
Frequency Dial	4	1.0. It should read 1.0 kHz on the LED display.
ET/INT Selector	5	push out
DUTY	7	push in, CAL position
AMPLITUDE	8	push in, adjust using the oscilloscope.
DC OFFSET	9	push in, 12 o'clock position

For the waveform output, connect a BNC-BNC cable to the BNC connector labeled "50Ω" as in Fig. A-19.

5.2 Good Will Instrument Company Model GFG-813

The front panel controls and connectors are shown in Fig. A-20. Only the controls required to set four basic parameters, *waveform*, *frequency*, *amplitude*, *attenuation*, and *DC offset* will be described. For more details refer to the Instruction Manual available in the laboratory.

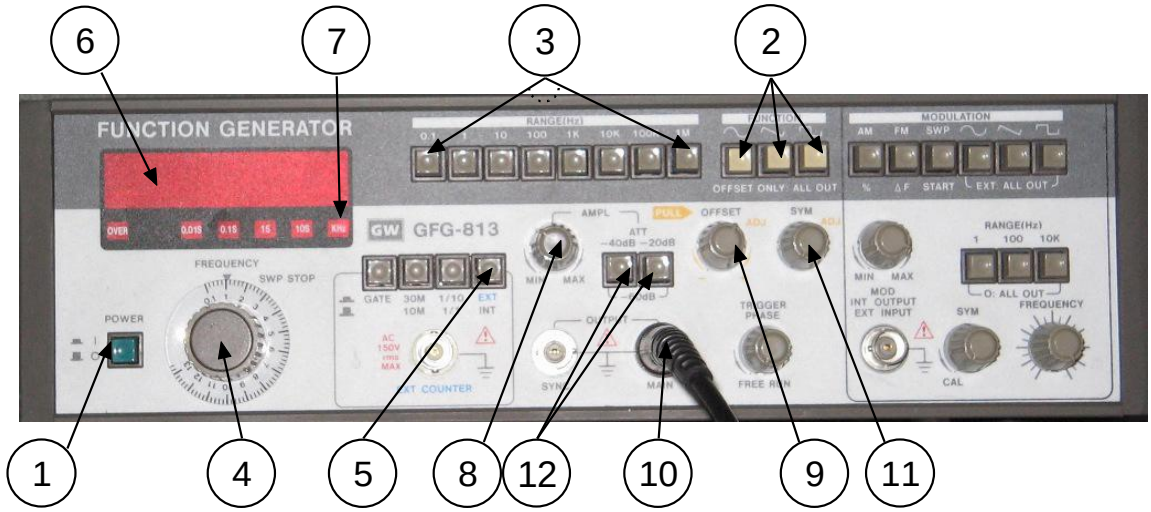


Fig. A-20

(1) **POWER** switch
(2) **Function Switches** – Selects one of three waveforms: sinusoidal, square, or triangular.
(3) **Frequency Multiplier Switches** – selects the frequency range
(4) **Frequency Dial** – Sets the frequency within the range selected by (3)
(5) **INT. EXT.** – Selected counting frequency for internal and external input frequency
(6) **Frequency Display**
(7) **kHz indicator** – indicates if the frequency displayed in (6) is in kHz
(8) **Amplitude Control** – adjusts the amplitude of the waveform selected by (6).
(9) **OFFSET** – adjusts DC offset when pulled out.
(10) **Function Out** – Output terminal for waveforms, labeled **MAIN**.
(11) **Symmetry** – Varies the symmetry of the output waveforms.
(12) **Attenuation Switches** – attenuations of 20 db (push in ONLY the 20 dB switch), 40 dB (push in ONLY the 40 dB switch), or 60 dB (push in BOTH the 20 dB and the 40 dB switch).*

* 60 dB attenuation leads to a very low signal. Always make sure that no more than one attenuation switch is pushed in.

Operating Instructions (set-up procedure)

To set up the GFG-813 function generator for a sinusoidal output voltage with a frequency of 1 kHz and an amplitude of 6 V peak-to-peak and no DC offset, use the settings in Table A-2.

Table A-2

Control	Control No.	Position
Power	1	push in
Function Switches	2	~
Frequency Multiplier	3	1 k
Frequency Dial	4	1.0. It should read 1 kHz on the LED display.
ET/INT Selector	5	push out
Amplitude Control	8	adjust using the oscilloscope
Attenuation Switches	12	push out both
OFFSET	9	push in.

For the waveform output, connect a BNC-BNC cable to the BNC connector labeled "MAIN" as in Fig. A-20.

6. Oscilloscope

Oscilloscopes are used for the measurement of time-dependent voltages with reference to ground, for example the waveforms generated by the function generators described in the previous section. Voltage waveforms can be displayed on the screen and measurements of amplitude, frequency, etc can be easily carried out. The oscilloscopes in the laboratory are TEKTRONIX TDS 210 digital oscilloscopes, their front panel is shown in Fig. A-21. The following is a brief introduction to oscilloscope measurement, for more details please see the oscilloscope manual.

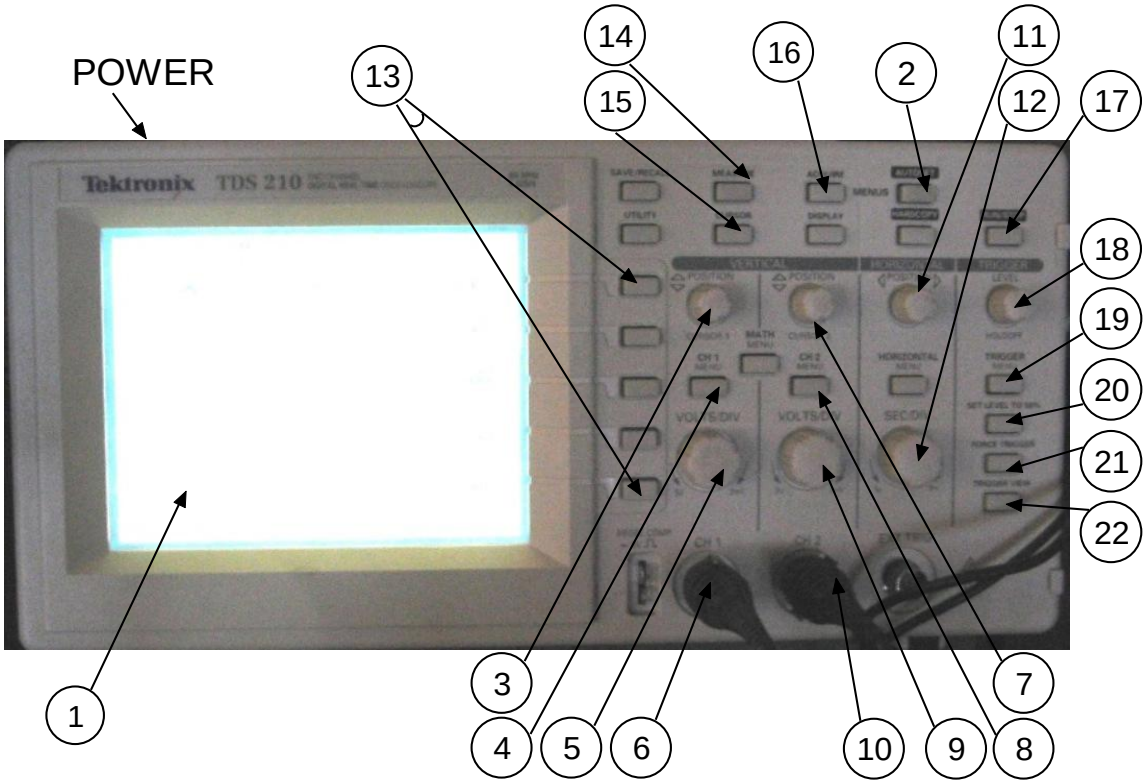


Fig. A-21

Front Panel Overview

The **POWER** button is on top, on the left hand side (not visible in Fig. A-20).

(1) **Display Screen**
(2) **Autoset Button -** Automatically adjusts the vertical and horizontal scaling as well as other settings.
(3) **CH 1 Position -** Positions the Channel 1 waveform vertically
(4) **CH 1 Menu -** Displays Channel 1 input menu selections on the right hand side of the display screen (1) and repeated pushing of this button turns the channel display on and off.
(5) **CH 1 VOLTS/DIV -** Adjusts scaling for the vertical (voltage) axis for Channel 1. Its setting is displayed at the bottom of the display screen (1).
(6) **BNC Connector for CH 1 -** Here the Channel 1 probe is connected.
(7) **CH 2 Position -** Positions the Channel 2 waveform vertically
(8) **CH 2 Menu -** Displays Channel 2 input menu selections on the right hand side of the display screen (1) and repeated pushing of this button turns the channel display on and off.
(9) **CH 2 VOLTS/DIV -** Adjusts scaling for the vertical (voltage) axis for Channel 2. Its setting is displayed at the bottom of the display screen (1).
(10) **BNC Connector for CH 2 -** Here the Channel 2 probe is connected.
(11) **Horizontal Position -** Positions all waveforms horizontally.
(12) **SEC/DIV -** Adjusts scaling of the horizontal (time) axis. Its setting is displayed at the bottom of the display screen (1).
(13) **Softkeys -** Their function depends on the menu button pushed
(14) **MEASURE -** Displays the automated measurements menu for automatic measurement.
(15) **CURSOR -** Displays cursor menu. When activated, two vertical (time) or horizontal (voltage) cursors can be displayed and adjusted by the vertical positions controls fro CH 1 and CH 2. Menu options appear once the CURSOR button is pushed. When activated, the positions of the cursors as well as the difference between cursor positions are displayed on the right hand side of the display.
(16) **ACQUIRE -** Displays acquisition menu
(17) **RUN/STOP -** Starts and stops waveform acquisition
(18) **TRIGGER LEVEL/HOLDOFF -** Dual purpose – as edge trigger level control it sets the amplitude level a signal must cross to cause an acquisition, as holdoff control is sets the amount of time before another trigger event can be accepted.
(19) **TRIGGER MENU -** Displays the trigger menu.
(20) **SET LEVEL TO 50% -** Sets trigger level to the vertical midpoint between the peaks of the trigger signal.
(21) **FORCE TRIGGER -** Starts an acquisition regardless of adequate trigger signal
(22) **TRIGGER VIEW -** While held down it displays the trigger waveform instead of the channel waveform

Oscilloscope Probes

- The oscilloscopes used in the laboratory have been designed to measure node voltages, thus one end of the oscilloscope probe (long lead) has to be connected to the ground terminal.
- As for the "hot" terminal of the probe always use a "hook-up" wire to measure a voltage (refer to a drawing in Fig. A-22). Do not attach the "hot" terminal directly to a circuit component and never take a plastic sleeve off the probe.
- **Always** use the oscilloscope probes when measuring waveforms, never use a BNC cable to connect the function generator to the oscilloscope!

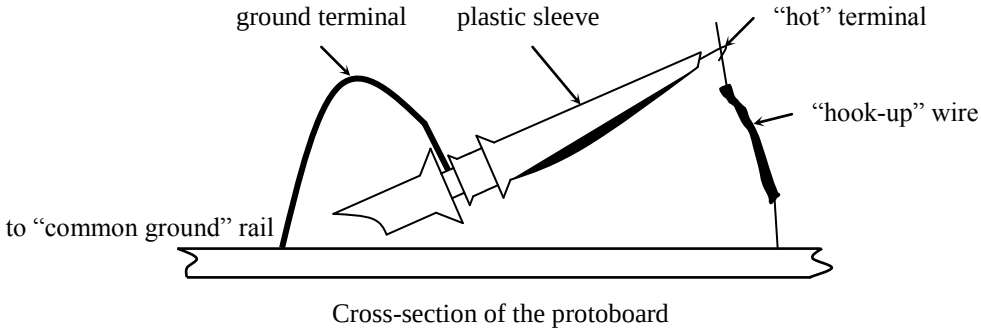


Fig. A-22

Taking Automatic Measurements

The MEASURE function (14) lets you automatically measure peak-to-peak voltage, frequency, and period of a signal by following these steps to perform these measurements for the signal in CH 1:

- Push **MEASURE** (14), the MEASURE menu will be displayed.
- Push the top softkey (13) to select **Source**
- Select **CH1**
- Push the top softkey (13) again to select **Type**
- Push the second softkey (13) to select **Freq** for frequency measurement
- Push the third softkey (13) to select **Period**
- Push the fourth softkey (13) to select **Pk-Pk** for peak-to-peak voltage measurement.

Frequency, period and peak-to-peak voltage are displayed now and will be updated periodically.

When using the MEASURE function ALWAYS double check the displayed results with the VOLTS/DIV and SEC/DIV settings (on the bottom of the display (1)).

Setup Procedure:

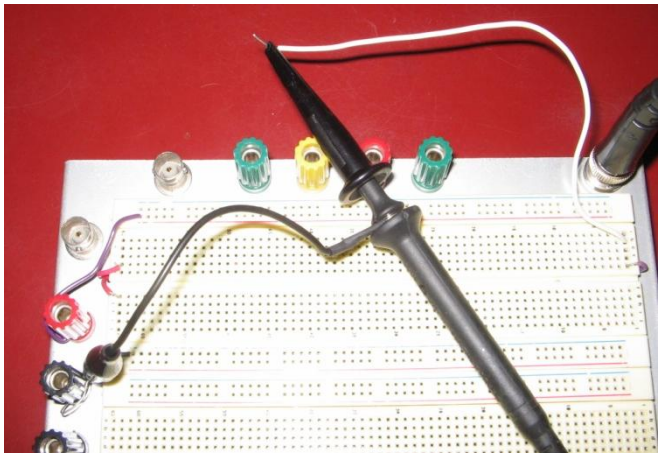
- Turn on the power by pushing the **Power** button.
- Press **AUTOSET**. You should see two traces, i.e. horizontal lines, on the display.
- Push the **CH 1 MENU** button once. Check the right hand side of the display for the probe attenuation (PROBE). It should read 10X.
- If PROBE does not read 10X push the **softkey** next to PROBE on the display repeatedly until it reads 10X.
- Use the **Position** dial for CH 1 to vertically align the trace with the center graticule line.
- Push the **CH 2 MENU** button once. Check the right hand side of the display for the probe attenuation (PROBE). It should read 10X.
- If PROBE does not read 10X push the **softkey** next to PROBE on the display repeatedly until it reads 10X.
- Use the **Position** dial for CH 2 to vertically align the trace with the center graticule line.
- Check the oscilloscope probes if one or both have an **attenuation switch**. If so, make sure they are set to 10X as well.

If you want to display only one waveform in CH 1:

- At any time, you can push the CH 2 MENU button repeatedly until one of the two traces disappears. CH 2 is now turned off and the visible trace is that of CH 1.
- CH 2 can be turned back on at a later time by pushing the CH 2 button. The second trace will reappear.

To connect the probes to the signal:

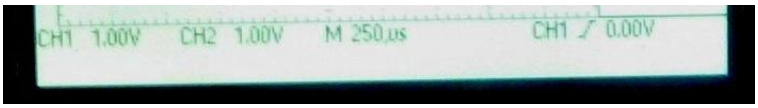
- Always use the probes!
- Connect a BNC-BNC cable from the function generator output to one of the BNC connectors on the protoboard.
- Use a hook-up wire in connection with the oscilloscope probe as explained under "Oscilloscope Probes" and Figure A-22 on the previous page.



Example:

Display a 6 V peak-to-peak sinusoidal waveform of frequency 1 kHz, generated by one of the function generators.

- Set up the oscilloscope to display only one waveform in CH 1 as outlined on the previous page.
- Set up the function generator by following the instructions in either Table A-1 for the GFG8016C or Table A-2 for the GFG-813, depending on which function generator you are using.
- Set the VOLTS/DIV dial (vertical scale) for CH 1 (5) to 1V and the SEC/DIV dial (12) (horizontal scale) to 250 μs. These settings are displayed at the bottom of the display.



- Connect the output signal of the function generator to the protoboard and connect the CH 1 probe to the protoboard as shown on the previous page.
- Adjust the amplitude of the waveform on the function generator. Once adjusted it should look like the waveform in Fig. A-23.

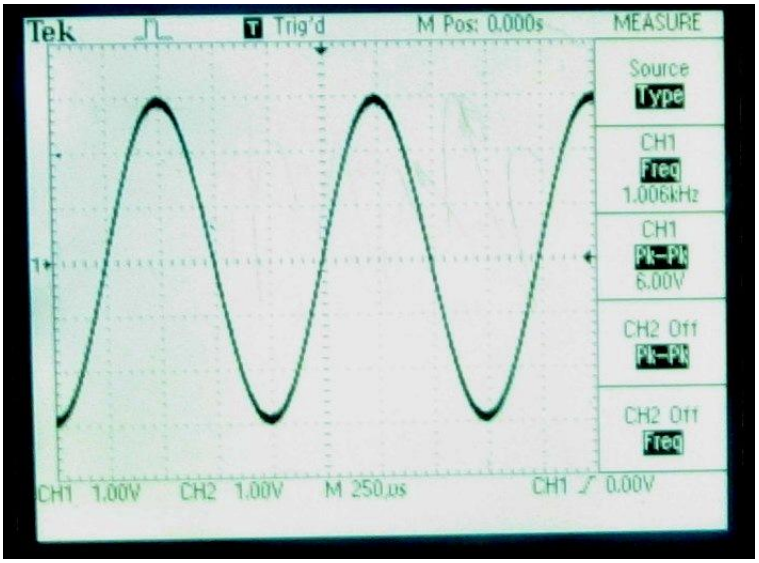
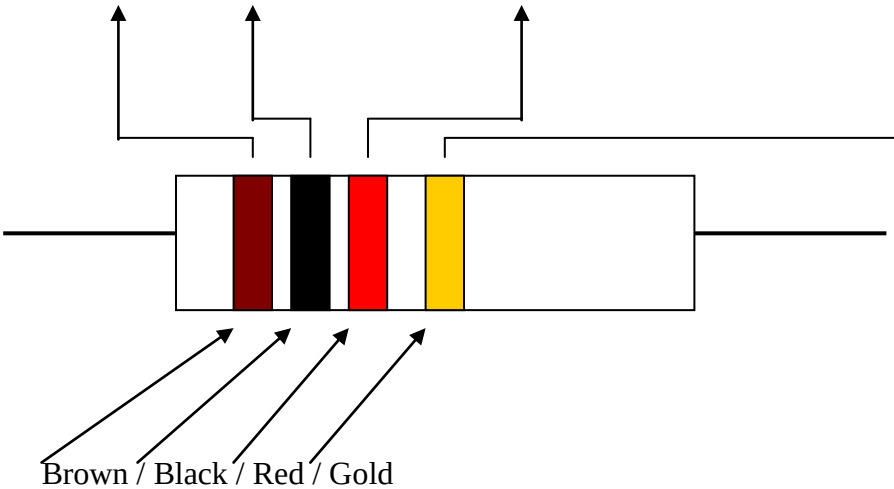


Fig. A-23

7. Color Code and Standard Values of Low Power Resistors

The table below shows the color code for the resistance values and tolerances of low power resistors, which you will be using in the laboratory experiments. The arrangement of the color bands is shown in the drawing below the table.

COLOR	VALUE OF RESISTANCE			COLOR	TOLERANCE
Black		0	$10^0 = 1$	Red	2 %
Brown	1	1	$10^1 = 10$	Gold	5 %
Red	2	2	$10^2 = 100$	Silver	10 %
Orange	3	3	$10^3 = 1{,}000$	None	20 %
Yellow	4	4	$10^4 = 10{,}000$		
Green	5	5	$10^5 = 100{,}000$		
Blue	6	6	$10^6 = 1{,}000{,}000$		
Violet	7	7	$10^7 = 10{,}000{,}000$		
Gray	8	8	$10^8 = 100{,}000{,}000$		
White	9	9	$10^9 = 1{,}000{,}000{,}000$		
	1st band	2nd band	3rd band	4th band	



Example: Brown / Black / Red / Gold

1 0 10^2 5 % => 10 x 10^2 Ω = 1 kΩ (5 % tolerance)

The **Standard Values** of the 10 % resistors (the first two digits are shown) are as follows:

10 12 15 18 22 27 33 39 47 56 68 82

8. Troubleshooting – Common Problems

Often problems occur when during an experiment the measurements do not turn out as expected. If one is fairly sure that the circuit has been set up correctly it is time to check on the laboratory equipment. Below is a list of what you should check, mostly to verify the correct setup of the equipment. If you have followed through all applicable steps and the problem still persists, alert your TA. Do not attempt to fix any of the hardware yourself!

When checking the settings of any instrument, first make sure the power is on!

8.1 Protoboard

- Make sure the protoboard at your workstation is wired as shown in Fig. A-1.
- You can and should fix missing connections to the red, black, and yellow sockets with hook-up wires.
- Check the BNC connectors. If one of them is broken off report it to a TA so it can be fixed. There are three in total and you can use the other ones for the time being.

8.2 DC Power Supplies

- For a positive grounded voltage make sure that the GND terminal on the power supply is connected to the (-) terminal.
- For a negative grounded voltage make sure that the GND terminal on the power supply is connected to the (+) terminal.
- For either grounded voltage source make sure that GND on the voltage source is connected to ground on the protoboard (black sockets). To avoid confusion one should connect the ‘ridge’ side to ground.
- Make sure the current delimiter dial is set to maximum.
- If using the GPS-3303 DC power supply make sure the output is on.

8.3 Digital Multimeters (DMMs)

- Make sure the measurement mode is set appropriately:
    - The V function switch has to be pushed for voltage measurement (Fig. A-11)

  - The mA function switch has to be pushed for current measurement (Fig. A-14)
  - The kΩ function switch has to be pushed for resistance measurement (Fig. A-16)

- Make sure the two-wire lead is connected correctly:

  - To terminals COM and V-Ω for voltage (Fig. A-11) and resistance (Fig. A-16) measurement.
  - To terminals COM and mA for current measurement (Fig. A-14)

- Verify the AC/DC settings by referring to Fig. A-10. For DC measurement the TRUE RMS" (2) and "AC/DC" (3) switches are NOT depressed.

- If a problem with current measurement persists and you have already checked all the previous points it is possible that the fuse of the DMM has blown and needs replacement. Alert a TA or the lab manager. Do not attempt to remove the fuse yourself!

8.4 Function Generators

The following refers to Fig. A-19 for the GFG8016G model and to Fig. A-20 for the GFG-813 model.

- Make sure the BNC cable is connected to the function output (10).

  - For the GFG8016G it is labeled 50Ω.
  - For the GFG-813 it is labeled MAIN.

- Make sure the ET/INT selector (5) is pushed out

- If no DC offset is required, make sure that the DC offset control is pushed in.

- For the GFG8016G model make sure the DUTY control is in the CAL position and pushed in.

- Make sure the correct Frequency Multiplier Switch (3) is selected. What does it read on the Frequency Display (6)?

- For the amplitude control start with a setting without attenuation.

  - For the GFG8016G this means that the amplitude control (8) is pushed in.
  - For the GFG-813 this means that both attenuator switches (12) are not pushed in.

- If you have followed through these steps and the problem persists, check the oscilloscope.

8.5 Oscilloscope

The following refers to Fig. A-21.

- Never trust an automatic measurement alone! ALWAYS check the VOLTS/DIV and SEC/DIV settings on the bottom of the display (1).

- If your oscilloscope probes have attenuation switches, make sure they are set to 10X.

- Push the CH1 switch (4) to make the CH1 menu appear on the right-hand side of the display (1). Make sure probe is set to 10X, if not push the appropriate softkey repeatedly until it is at 10X.

- Push the CH2 switch (8) to make the CH2 menu appear on the right-hand side of the display (1). Make sure probe is set to 10X, if not push the appropriate softkey repeatedly until it is at 10X.

- Press AUTOSET (2). Check if your waveform looks the way it is expected to.

- If the problem persists, check the function generator if you have not done so yet.

- Check the probes by connecting them to the reference terminal on the oscilloscope as shown below. If the probe is functioning you should see a 5V peak-to-peak square wave.

8.6 Cables

Every once in a while a cable becomes defective and needs to be fixed or replaced. This does not happen very frequently though.

- Check for visible damage. Look for broken or frayed connections between wiring and plugs. A visibly damaged cable should be given to a TA or the lab manager so it can be fixed or replaced.

- If there is no visible damage but you still suspect the cable is damaged replace it by another one of the same type. If this fixes the problem, give the damaged cable to a TA or to the lab manager.