## A. Use of current limited power supply (Topward TPS-4000)

A current limited power supply (PS) allows the user to set the maximum output current. If a circuit tries to draw too much current the output voltage will drop keeping the current below the limit. The dual supplies can be connected in series for more voltage, parallel for more current, or used individually if a single supply meets the current and voltage needs. Note: The outputs are floating so any one of the terminals can be tied to ground. You can get Pos, Neg, or Pos & Neg voltages.

Parallel
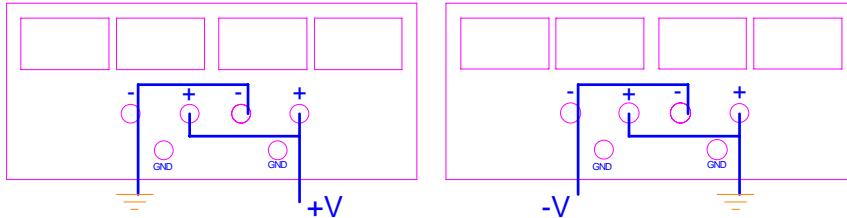
Series
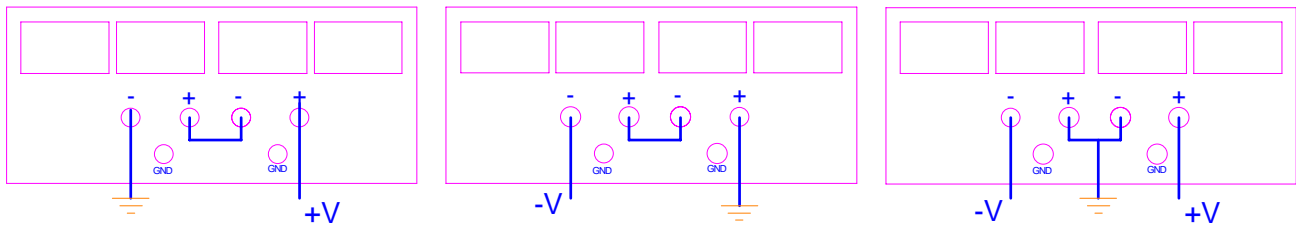
Example: You have the PS set to deliver 10V and the current limit set to 100mA.

If you connect a 150Ω resistor across the 10V output you will draw $10V/150Ω = 67mA$ (OK)

If instead you use a 75Ω resistor the output voltage would drop to 7.5V to limit the current to 100mA.

To set the output current and voltage:

With the power supply off, turn the current limit and voltage knobs (Pos & Neg) all the way down (CCW).

Short the outputs with a wire (Pos to GND and Neg to GND) and turn on the PS.

Turn up the voltage knobs slowly until the current limit lights comes on for the Pos and Neg supplies.

Adjust the Pos & Neg current limits until the desired maximum current is reached.

      Note: You can have different maximum currents for the positive and negative outputs.

Remove the wires shorting out the power supply (current limit lights should go out).

Adjust the Pos & Neg voltages to the desired level (if in tracking mode the voltages will be the same).

Turn off the power supply and connect your circuit.
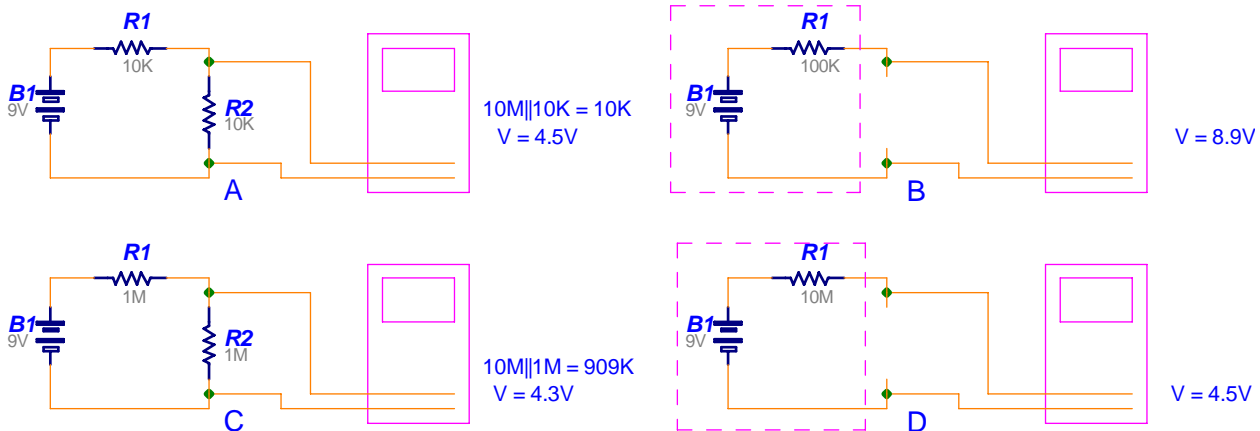
Experiment:

Set the PS for +10V@100mA and -5V@200mA. Connect 150Ω & 75Ω resistors (one at a time) to the 10V side and record the output voltage and current. Connect 75Ω and 20Ω resistors (one at a time) to the -5V side and record the output voltage and current. Note: Use 2W power resistors in this experiment. The resistors will get hot so turn off the PS between measurements. Connect the supply in series for a 40V@1A supply and show me. Connect the supply in parallel for a 8V@3A supply and show me.

Warning: Never short the outputs of a power supply that isn't current limited!

B. Use of autoranging multimeter (Fluke 77)

Error due to non-infinite input impedance (DC voltage measurement):

The multimeters input impedance is around 10MΩ so the meter should have little effect on most measurements (unless the impedance is comparable to that of the meter). In the examples below, A is accurate because the meter impedance is very large compared to the resistance of the circuit, B is off by 1% because the meters input impedance is 100 times the source impedance, C is off by 9%, and D is off by a factor of two.

R1
10K
B1
9V
R2
10K
10M||10K = 10K
V = 4.5V
A

R1
100K
B1
9V
V = 8.9V
B

R1
1M
B1
9V
R2
1M
10M||1M = 909K
V = 4.3V
C

R1
10M
B1
9V
V = 4.5V
D

Experiment: Use a circuit similar to example D above to measure the input impedance of the multimeter. Adjust R1 until the measured voltage is half of the supply voltage. If the voltage drop is the same then they have to have the same impedance (i.e. the meter input impedance is the same as R1).

**Error due to high or low frequency (AC voltage measuremnt):**

The meter responds differently to different voltage levels, frequencies, and wave shapes. This meter is not a true RMS meter (i.e. it assumes the input is a sine wave). If you are measuring the amplitude of a ramp or square wave the reading will be off. Depending on the amplitude of the input signal the frequency response can change. If the input is large (say above 3VRMS) no amplification is needed inside the multimeter and it responds faster. If the input is small (say below 1VRMS) the meter automatically amplifies the signal before measuring it. This will slow the response. For example: a 10KHz, 7VRMS, sine wave will read about 6VRMS on the meter. A 10KHz, 1VRMS sine wave will read about 350mVRMS. It's assumed the meter will be used at or near 60Hz (the power line frequency). If you are operating below 20Hz or above 1KHz don't trust the multimeter to give you the correct voltage (use a scope).

Experiment: Use the function generator to provide an AC signal to the multimeter as shown in figure A below. Test the frequency response with a 0.5VRMS and 5VRMS inputs. Using 60Hz as the base line for the correct reading, what is the maximum frequency the multimeter can respond to before being off by more than 5% (for both amplitudes)? Next, add a 10MΩ resistor as shown in figure B and set the FG to 60Hz and 50mV. What happens to the reading if you touch one or both of the multimter leads? Will you get the same effect if you replace the 10MΩ resistor with a10KΩ resistor? Explain your results.

VAC
Function Generator
A

R1
10M
VAC
Function Generator
B
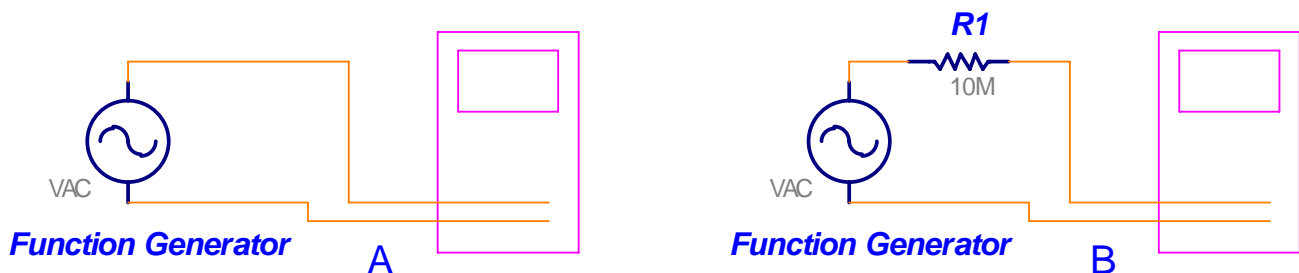
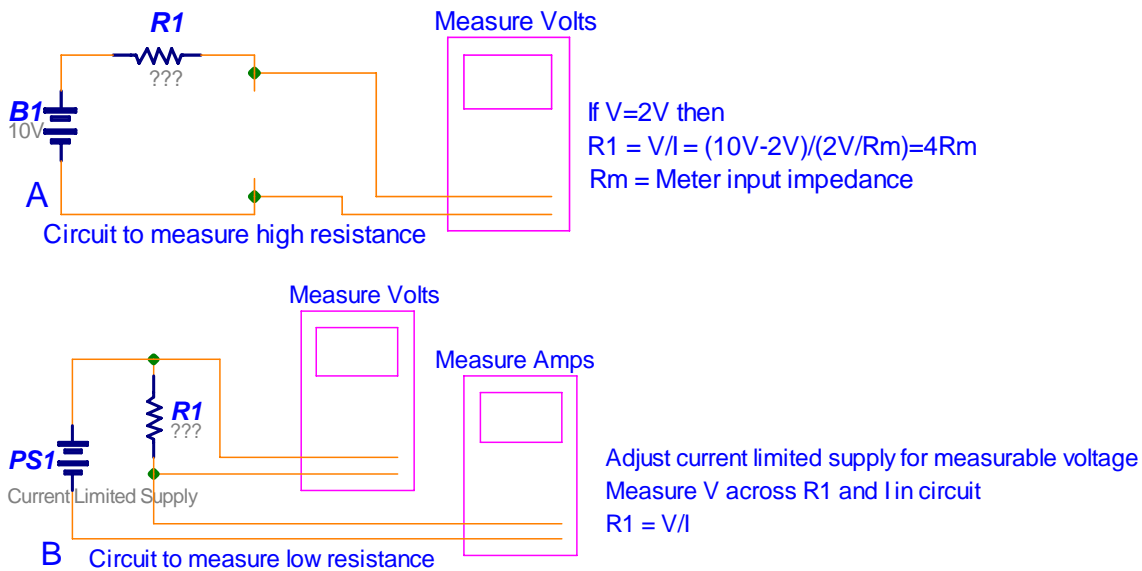**Error due to internal shunt resistance (current measurement)**:

The multimeter measures current by placing a small sense resistor across the input and measuring the voltage drop across it due to current through the resistor. For currents less than 300mA there is an internal fuse to protect the sense resistor from damage due to over current. For currents up to 10A there is no protection for the smaller sense resistor. If more than 10A is put through the meter the resistor won't be able to dissipate the heat and damage will occur. The following two diagrams are roughly equivalent. In A the current is measured with a voltmeter and external sense resistor. In B the current is measured directly using the multimeter. In both cases the addition of the sense resistor will decrease the current in the circuit. As long as the voltage dropped across the sense resistor is small compared to the voltage dropped across the load the error will be small. Note: The current being measured is the actual current (at that time the sense resistor is in the circuit) but the current may be noticeably less than the current drawn by the load without the sense resistor.
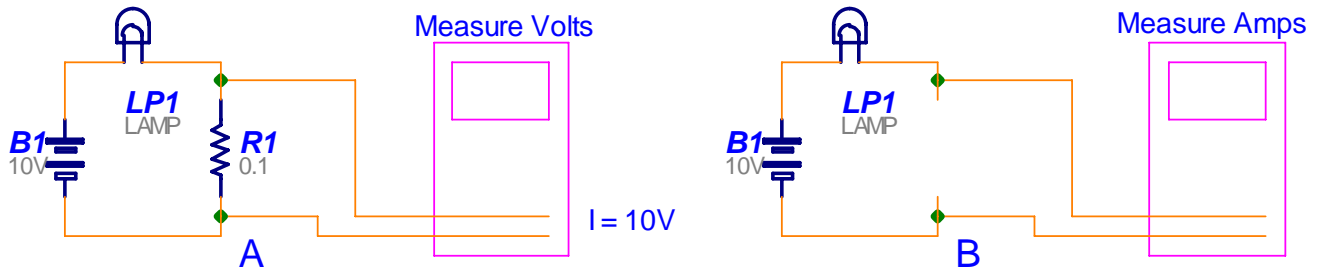
Experiment: Using a circuit similar to B above, determine the size of the sense resistor in the multimeter for both the <300mA and <10A settings. You may use a second voltmeter.

How to measure very small and very large resistances:

The multimeter sends a known current through the load and measures the voltage produced. If the voltage measured is below a certain value the meter (being autoranging) will increase the current to a higher value until the voltage is above some minimum level or the meter is on its most sensitive setting. Low resistance readings (below 10Ω) may be inaccurate because the meter can't produce enough current to get the measured voltage into the desired range. High resistance readings (above 1MΩ) may be inaccurate because the input impedance of the meter is around 10MΩ. Figure A below shows one way to measure extremely high resistances. Note: One could also put a resistor in parallel with the voltmeter input to lower the resistance (or for a known value). Figure B below shows one way to measure extremely low resistances. Note: Make sure the I^2R heating of the resistor isn't enough to significantly change the resistance.

If V=2V then
$R1 = V/I = (10V-2V)/(2V/Rm)=4Rm$
Rm = Meter input impedance

A   Circuit to measure high resistance

Adjust current limited supply for measurable voltage
Measure V across R1 and I in circuit
$R1 = V/I$

B   Circuit to measure low resistance

Experiment: Measure the resistance of the two items given to you (one is << 1Ω the other is >> 1MΩ).

C. Use of oscilloscope

Probes:
Usually 1X or 10X amplification, 1MΩ or 10MΩ input impedance and 20-33pF input capacitance.
Description at:http://zone.ni.com/devzone/cda/ph/p/id/17   Note: The description has Watts (W) not ohms
Note: The scope ground lead is tied to earth ground. If you connect the scope ground to your circuit the circuit must be floating (i.e. not referenced to ground) or the ground contact point must be at ground potential.

Coupling:
AC: An internal capacitor blocks the DC part and passes all AC frequencies above about 10Hz.
GND: Used to position the trace on the screen (i.e. move ground to a particular horizontal line).
DC: Doesn't alter the signal.

Triggering (get the picture you want on the scope):
The level and edge settings determine when the picture is drawn on the screen. For example, if you were triggering on the rising edge of channel 1 with the level set at 2V, every time channel 1 went from 1.99V to 2.01V the scope would begin drawing the picture on the screen. It would continue drawing the picture until the beam worked its way across the screen (depends on the time per division). What you see on the screen is a plot of the voltage vs. time for channel 1 starting at the time the voltage rose through 2V. The time until the next picture is drawn (replacing the current picture) depends on the following trigger settings.

Auto: When triggering in Auto mode the scope will trigger as described above but if after some time there is no trigger, meaning the voltage never rises through 2V, the scope will trigger anyway. This is useful when initially connecting the probe to an unknown voltage because it will display something even if the level is set incorrectly. Auto mode also works well with simple repetitive signals because when the level is set properly the scope always triggers at the proper time and never has to trigger it self.

Norm: when triggering in Normal mode the scope will begin drawing the picture when triggered. For example, if triggering on channel 1 with the level set to 3V and channel 1 has a 1V sine wave nothing will ever be displayed on the scope because the input never crossed the trigger threshold. Normal mode is good for looking at things that happen less often. For example, if a glitch is a few volts higher that the rest of the signal and only comes by ever few seconds you can display only the trace with the glitch rather than redrawing (and confusing) the picture with all the good traces in between by setting the level above the normal signal level and using normal mode.

Holdoff: the holdoff controls the minimum amount of time between triggers. If a second trigger comes in before the holdoff time has elapsed the second trigger is ignored and nothing is displayed. The holdoff usually needs to be adjusted to view complex signals such as a serial stream from a computer but any holdoff value will display a sine wave correctly.

Triggering sources:
ch1:   triggers off of channel 1
ch2:   triggers off of channel 2
line: triggers off the 60Hz wall power (useful when dealing with power supplies or 60Hz noise)
ext: external trigger source (useful when there is a common trigger or clock)