

Uncle Sparky's Guide to Voltage, Current, and Resistance Measurements

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The most important quantities in a circuit system are voltage and current. These include both AC and DC voltages and currents. In addition, resistance measurement provides an easy and important check during construction and debugging stage.

Voltage Measurement

Voltage measurement is most commonly conducted because the measurement equipment is connected in parallel with the interested nodes and requires minimum rearrangement. To minimize disturbance or loading to the circuit under test, the voltage measurement equipment should provide very large input impedance.

For DC voltage, a multimeter (Elenco) provides the quickest measurement. Elenco has 10M Ω input impedance.



Fig.1 Elenco DMM

- Set the proper probe location for voltage measurement
- Set at DC measurement
- Set the proper scale under voltage setting
- Polarity of the probe affects the sign of the voltage (use color coding for probe, for example red for high potential or active voltage, and black for low potential or GND reference)

For AC voltage measurement, a multimeter (Elenco) provides RMS reading assuming a sinusoidal signal. Similar to DC measurement on using the right scale and probe setting, and

- Set at AC measurement

- Note the RMS reading only works for sinusoidal signal, not for other waveforms. The Elenco actually measure the average of the rectified voltage signal and numerically converts to RMS reading assuming it's a sinusoid. Therefore, it simply tells a lie if you input waveform other than sinusoids, and should not be trusted in such cases.
- “True-rms” reading instruments instead of “average” reading also exist such as Agilent/HP34401A-6.5digit-DMM, but they are much more expensive. HP34401A is a bench-top DMM (located in VLSI lab) that provides true-rms reading.



Fig.2 HP34401A (Located in E80 lab and VLSI lab)

The best way for AC voltage measurement is using an oscilloscope. It always tells truth of the signal without assumption of the waveform.



Fig.3 Tektronix 2212 Oscilloscope



Fig.4 10x probe

- For minimum loading between the scope and the circuit under test, 10x scope probe (provides 10MΩ impedance) should always be used by default. As a result, the signal reading on the scope will be 1/10 of the signal at the probe tip. A 1x probe provides lower impedance (1MΩ scope impedance), so only use it when measuring a lower impedance circuits or when the signal sensitivity is not sufficient using 10x probe.
- Make sure 10x probe is calibrated properly, which can be conducted using “1kHz probe” from the scope. The observed 1kHz square wave should be perfect square wave as shown in Fig.5 if the adjustable capacitor in the front of 10x probe is tuned (use a screw driver) and compensated properly.

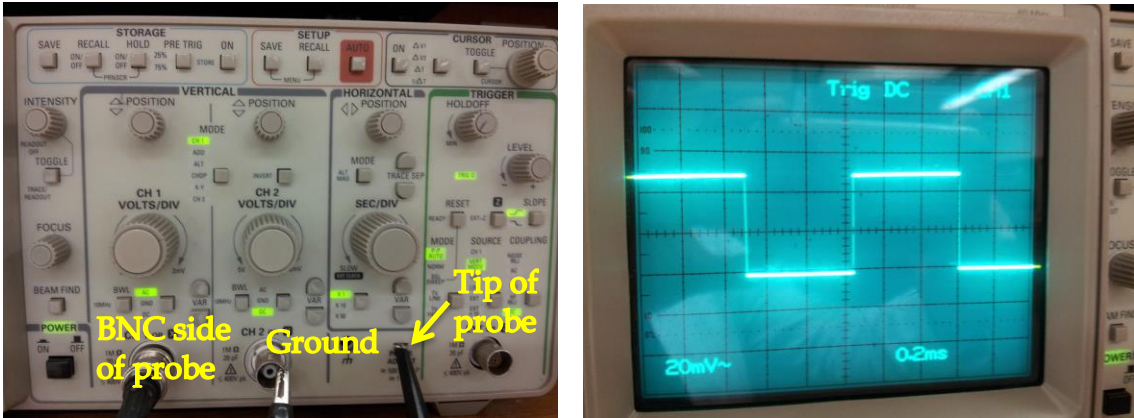


Fig.5 Setup of probe during tuning and properly tuned square wave

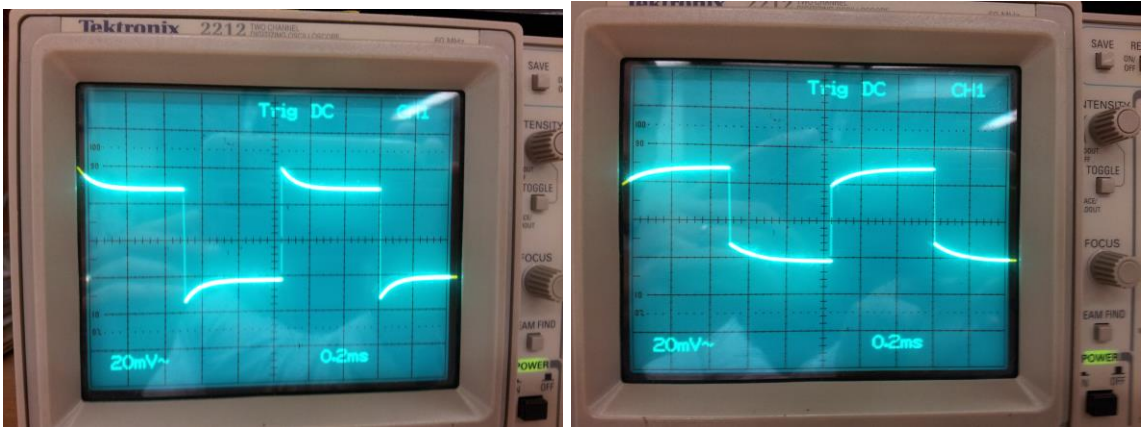


Fig.6 Distorted square wave when 10x probe that's not properly tuned

- For easier and stable probing, add wire at the testing point on breadboard for good gripping. If you only need to touch or contact with small pin such as IC pins, remove the probe hook as shown in Fig.7.

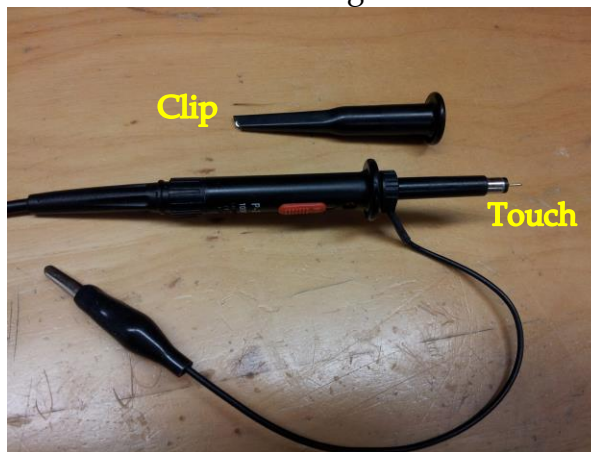


Fig.7 10x probe with tips to touch or clip

- Both AC and DC can be measured using scope. Select AC for AC voltage measurement (with internal DC blocking capacitor), or select DC for the total signal. GND selection is used to adjust the DC line for easy reference.
- Cursor option can be used to read voltage difference and time difference more precisely. The toggle option is used to move different cursors.
- Adjust the scale properly in x-axis (sec/div) and y-axis (volt/div) to visualize the signal clearly. Only use the Auto button as a last resort.

Current measurement

For current measurement, the Elenco multimeter used as current meter should be placed in series with the circuit under test.

- Set the correct probe position
- Set the proper scale
- Set at DC for DC current measurement
- Set at AC for AC RMS current measurement. Similar to voltage measurement using multimeter, this assumes a sinusoidal waveform unless a true-rms DMM is used.
- Sometimes for convenience, current measurement can be deduced/calculated from voltage measurement across a small known resistor instead.
- The polarity of the probes dictates the direction of the current flow.

Resistance measurement

Resistance measurement using Elenco multimeter should be conducted when the resistors are singled out. If a resistor is connected with other components within a circuit, other components could skew the measurement because the power supply from the meter could potentially run current through those components too.

- Set the correct probe position
- Set the proper scale
- Short probes to check the battery of the meter, it should read zero.
- Resistance measurement can be used for testing conductivity of nodes, and provides a quick check for open circuit or short circuit.

Digital vs. analog multimeter



Fig.8 Simpson 260 - analog multimeter

Elenco multimeter or digital multimeter is often used because of its simplicity and better precision. In theory, an analog meter or Simpson 260 can carry out the same measurement in voltage, current and resistance. Analog meters use needle reading instead of digital display, so there is always additional human (reading) error involved. Because a digital meter has high input impedance of $10\text{M}\Omega$, which is often at least 50 times higher than that of an analog meter (for example $20\text{k}\Omega/\text{volt}$ in DC, $5\text{k}\Omega/\text{volt}$ in AC), it provides much less loading effect and much better precision. The benefit of analog multimeter is sometimes it provides easier visualization. For applications where precision is less important, such as debugging an open or closed circuit, an analog meter provides more direct telling of such operation. On the other hand, improper use of digital meter may tell a lie instead. Analog meters with higher precision also do exist, but are usually much more expensive and hard to come by. That's one of the main reasons that digital multimeters are far more widely used than analog multimeters.

DMM (digital multimeter) and scope using myDAQ

Nowadays, Data Acquisition (DAQ) is widely used in circuit measurement and data collection procedures. In E80, myDAQ is accessible for students in the lab and field experiments. Either myDAQ DMM (digital multimeter) or myDAQ scope can be used to measure voltage, current and resistances, which is similar to a stand-alone multimeter and oscilloscope. In addition, myDAQ bode can provide frequency-domain measurement as a spectrum analyzer. LabView can be used to program the user interface and provide more flexible combinations of measurements and data storage options for post processing. These features make myDAQ-based measurement very attractive, and especially useful for E80 field experiments.

Please refer to myDAQ references for the setup procedures. Make sure to check the following before the measurement:

- Proper grounding
- Single probe is only for RSE signal

- Differential signal requires 2 probes

Reference:

1. True rms reading vs. average reading: www.newark.com/pdfs/techarticles/fluke/whyTrueRMS.pdf
2. Analog and digital multimeter: www.autoshop101.com/forms/h4.pdf
3. Using myDAQ measuring voltage: <http://www.ni.com/example/31436/en/>
4. Using myDAQ scope: www.ni.com/pdf/manuals/373060e.pdf