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Date: September 9, 2019
Professor Steven Gillette

Trainer # 11

Abstract

Using 3 capacitors, an LED, and the trainer, I built circuits to facilitate measuring voltage, resistance, current, frequency and capacitance. I tested a LED using the diode setting of the multimeter. Lastly, I observed the differences in the significance of the measurements using the various range settings of the multimeter. This lab provided a foundational understanding of how to properly use the multimeter to obtain relevant readings.

Introduction

Learning Objectives

- Use a digital multimeter (DMM) to take voltage, resistance, current, frequency and capacitance readings.
- Select the proper measurement ranges to provide the highest measurement resolution.
- Build a simple circuit using the Global Specialties Proto-Board.
- Test the circuit with the multimeter and record the results.

Materials

Quantity	Description
1	Global Specialties Trainer
1	Digital multimeter
3	Capacitors of different values $\leq 0.4\mu F$ I used a 0.1 µF, 0.1 µF, and .33 µF.
1	Light emitting diode (LED)
	Multiple jumper wires

Setup

1. Checked out a Proto-Board PB-503 trainer and a digital multimeter from the laboratory tool crib.
2. Plugged in and powered up the PB-503 trainer. Noted the red LED indicator on the on-off rocker switch which indicated a successful power up.
3. Removed the BK Precision, Test Bench 388B DMM and test leads from the case and insert the black lead into the COM plug and the red lead into the V Ω plug.

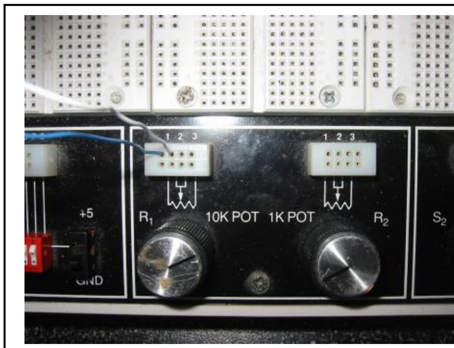


Figure 1 – 10k POT

Activities – Resistance Measurement

1. Inserted two jumper wires into terminals 1 and 2 of the 10K POT as shown in ***Figure 1***. Set the potentiometer knob to the middle of its travel.
2. Set the DMM center dial to the **Ω 40M** range as per ***Figure 2*** and attached the DMM test leads to the other ends of the wires.
3. Recorded the "as found" resistance reading exactly as indicated on the DMM dial for each range setting in the table below.

Figure 2 – Resistance Setting

DMM Setting	As Found Value (Ω)
40M	0MΩ
4M	.004 MΩ
400k	4.0 kΩ
40k	4.10 kΩ
4k	.0L kΩ
400	0L. kΩ

4. After recording the "as found" resistance, I turned the potentiometer knob and noted the effect on the DMM readings.

The potentiometer varied resistance from 0-10 kΩ.

Activities – DC Voltage Measurement

5. Attached one each jumper wires to the **+ 5-15V** buss and the ground buss as shown in Figure 3. Set the adjustment dial to mid-scale.
6. Set the DMM center dial to **1000 VDC**.
7. Recorded the "as found" voltage reading exactly as indicated on the DMM dial for each range setting in the table below.

DMM Setting	As Found Value (Volts DC)
1000 VDC	12VDC
400 VDC	11.9VDC
40 VDC	11.89VDC
4 VDC	.0LVDC
400m VDC	0L.VDC

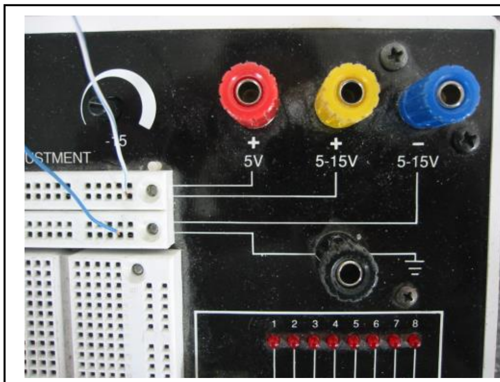


Figure 3 +5, ±15V and ground buss connections

8. After recording the “as found” voltage, turned the **+15**-potentiometer knob and noticed the effect on the DMM readings.

The voltage varied from 1.3VDC to 20.2VDC. This appeared odd as the labeling indicated that the trainer should only be from 5-15VDC.

9. Pressed the AC button on the meter and noted the response by the DMM.

The meter dropped and varied the voltage display. I set the trainer to maximum voltage and meter at the 400mV range. The display showed more significant digits and varied between 120mV and 4mV.

Activities – AC Voltage Measurement

Figure 4 - Function generator

10. Attached two jumper wires to the **Function Generator** center tap and -28 dB pins as shown here.
11. Set the function generator to **kHz x 10, sine wave form**, and placed both sliders to ½ of full scale.
12. Set the DMM center dial to **V 400m,** and pressed the AC/DC button until the meter displays **AC**.
13. Recorded the "as found" voltage reading exactly as indicated on the DMM dial for each range setting in the table below.

DMM Setting	As Found Value (Volts AC)
750 VAC	0VAC
400 VAC	1.6VAC
40 VAC	3.20VAC
4 VAC	3.27VAC
400m VAC	0L.VAC

14. After recording the "as found" voltage, adjusted the frequency, amplitude, and waveform independently and noticed the effect on the DMM reading. Each of these parameters (frequency, amplitude, and waveform) affected the voltage output.

At low amplitude and mid frequency, the meter at 400mV range, measured .3mV. Frequency change had no effect. Amplitude and frequency set to max, meter at 40mV range, measured 6.81mV. Sawtooth had 5.43mV, and square wave had 17.94mV.

Activities – AC Current Measurement

15. Set the DMM center dial to measure amperage (**A**) on the **2000m** setting as per Figure 5.
16. Pulled the red DMM test lead plug and inserted it into the **µA mA** plug on the DMM. I also reset to 10kHz, and mid levels on the trainer as depicted in Figure 4.
17. Recorded the "as found" current reading exactly as indicated on the DMM dial for each range setting in the table below.

DMM Setting	As Found Value (Milli-Amperes)
20A	tone
2000m	0mA
400m	1.9mA
40m	4.71mA
4m	.0LmA
400µ	0L.mA

18. Selected sine wave, saw tooth and square waveforms, and recorded the voltage, current and frequency readings for each waveform.

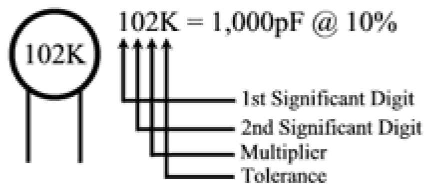
	Sine Wave Form	Saw Tooth Wave Form	Square Wave Form
Current (mA)	4.71mA	3.81mA	14.53mA
Voltage (V)	3.43mV	2.76mV	10.69mV
Frequency (kHz)	5.35kHz	5.35kHz	5.35kHz

Activities – Capacitance Measurement

19. Choose three capacitors with different values (≤ 400ηF) printed on the body. Record the printed values in the charts below.
20. Discharge the capacitor by shorting the leads together.
21. Insert the capacitor leads into the Cx slots of the DMM.
22. Record the "as found" capacitance reading exactly as indicated on the DMM dial for each range setting in the table below.

Capacitor 1-Printed Value________BC104______		Capacitor 2-Printed Value______334k5C_____		Capacitor 3-Printed Value_______104K.B.______	
DMM Setting	**DMM Capacitance (Farads)**	**DMM Setting**	**DMM Capacitance (Farads)**	**DMM Setting**	**DMM Capacitance (Farads)**
40µ	.09 µF	**40µ**	.30 µF	**40µ**	.11 µF
4µ	.086 µF	**4µ**	.291 µF	**4µ**	.101 µF
400n	86.3nF	**400n**	291.8nf	**400n**	100.9nF
40n	0.L	**40n**	0.L	**40n**	0.L
4n	.0L	**4n**	.0L	**4n**	.0L

Reading Capacitor Printed Values



Tolerance Table

Code	Tolerance
C	±0.25pF
J	±5%
K	±10%
M	±20%
D	±0.5pF
Z	+80% / -20%

Multiplier Table

Number	Multiply By .. (Additional no. of Zeros)
0	None (0)
1	10 (1)
2	100 (2)
3	1,000 (3)
4	10,000 (4)
5	100,000 (5)
6	1,000,000 (6)

Activities – Diode Test

23. Inserted the red DMM lead into the V Ω socket and the black lead into the COM socket.
24. Set the DMM center dial to the diode test position.
25. Using alligator clips on the test leads, connected across a light emitting diode.
    Does the LED dimly light up? Yes
    Recorded the voltage value displayed on the meter. 1.673V
26. Reverse the test leads across the diode.
    Does the LED dimly light up? No
    Record the voltage value displayed on the meter. 3.048V

Activities – Audible Continuity Test

27. Inserted the red DMM lead into the V Ω socket and the black lead into the COM socket.
28. Set the DMM center dial to the audible continuity test position.
29. Inserted two jumper wires into the single pole double throw (SPDT) switch and connected the DMM leads to the wires.
30. Operated the switch and observe the DMM response.

The multimeter beeped when the switch was closed and was silent when the switch was open.

Conclusions

Resistance

1. Which range setting provides the highest resolution (most accurate) reading of the potentiometer resistance?

I found the 40kΩ setting to give the best resolution of the potentiometer resistance.

2. What does OL mean. Why did the meter show OL for some of the readings?

A number of sources have indicated that OL means "open loop." Other sources have indicated that it means "over load." The Fluke article here: https://support.fluke.com/find-sales/Download/Asset/1260898_6116_ENG_M_W.PDF describes "OL" as being beyond the range that the meter can display.

DC Voltage Measurement

3. Which range setting provides the highest resolution reading of the voltage?

I found that the 40VDC setting gave the best resolution for voltage readings.

4. What happens when you push the DC/AC button on the DMM? Why did the display change?

When the AC/DC button was pressed, the meter began reading the signal present, but the reading did not settle. I believe this is because it was reading not receiving a signal that it was expecting through the internal circuitry.

AC Voltage Measurement

5. Which range setting provides the highest resolution reading of the AC voltage?

I found the 4AC setting provided the best resolution for AC voltage readings.

6. What is RMS voltage and current?

RMS stands for Root Mean Square. According to https://www.fluke.com/en-us/learn/blog/electrical/what-is-true-rms, a non RMS meter will measure the signal and calculate an average reading on either a sinusoidal or non-sinusoidal waveform. When presented with a non-sinusoidal waveform, a non-RMS meter will display an inaccurate reading. A true RMS meter will display a more accurate reading due to additional capabilities in measuring the "dc heating value" of the signal.

7. Describe the advantages of a true RMS digital multimeter. Note; our lab DMM's are ***not*** true RMS meters![1]

[1] A true RMS multimeter measures the DC effective voltage and current, regardless of the frequency or waveform. A non-true RMS multimeter assumes that all measurements are taken on 60Hz sine waves.

If measuring any ac waveform, a true RMS meter would be the correct tool for the job as it will accurately read the waveform that could be distorted by a number of factors and not a pure sinewave. Our lab meters are “averaging” and would not be the correct tool for the job. The BK Precision datasheet for the 388B meter used in the lab confirms that our meters are not true RMS meters. They are a great value though!

AC Current Measurement

8. Which range setting provides the highest resolution reading of the AC current?

I found that the 40mA setting gave the best resolution for measuring AC current.

9. What happens to the voltage readings when you change the function generator waveforms between sine, saw tooth and square?

The meter displays a higher reading for sine and square waveforms and lower for sawtooth waveforms. I believe this is due to the averaging of the meter. Sine and square waveforms spend more time at the max amplitude of the waveform than the sawtooth and thus result in higher readings.

10. Are square waves and saw tooth voltages measured accurately with a multimeter that is not true RMS?

Square and sawtooth voltages are not measured accurately with a multimeter that is not true RMS.

Diode Test

11. Why does the diode light up with the leads attached in one polarity but not the other?

A multimeter in diode mode delivers a small current to the probes that pass across the component. When the polarity is matched, the LED passes the current and lights up. If the diode is functioning correctly, when reversed, the diode will not pass the current leaving the LED unlit.

Audible Continuity Test

12. Is this feature used with the circuit energized or de-energized?

Audible continuity tests should be performed with the circuit de-energized.

13. Describe how this test can help with troubleshooting electrical circuits.

Continuity is necessary for electrons to pass along a circuit. If no continuity, a circuit path is disconnected and there is nowhere for electrons to flow.

Additional Conclusions
This lab was a great way to become familiar with testing AC and DC voltage, resistance, current, continuity, and diodes. Additionally, it was a great method for becoming familiar with one of the most important tools in the technician's toolbox, the multimeter.

Appendix A – Lab Notes

SIERRA COLLEGE	MECH 04&10 - Lab 03 Basic Multi-Meter Functions	Mechatronics *Real Skills Real Jobs*
Name	Cayce Beames	
Trainer #	11	

Learning Objectives

- Use a digital multimeter (DMM) to take voltage, resistance, current, frequency and capacitance readings.
- Select the proper measurement ranges to provide the highest measurement resolution.
- Build a simple circuit using the Global Specialties Proto-Board.
- Test the circuit with the multimeter and record the results.

Materials

Quantity	Description
1	Global Specialties Trainer
1	Digital multimeter
3	Capacitors of different values $\leq 0.4\mu F$
1	Light emitting diode (LED)

Setup

1. Check out a Proto-Board PB-503 trainer and a digital multimeter from the laboratory tool crib.
2. Plug in and power up the PB-503 trainer. Note the red LED indicator on the on-off rocker switch indicates a successful power up.
3. Remove the BK Precision, Test Bench 388B DMM and test leads from the case and insert the black lead into the COM plug and the red lead into the V Ω plug.

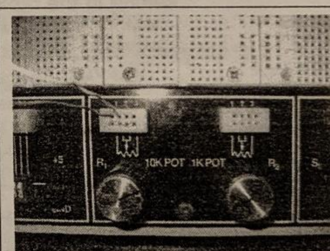


Figure 1 – 10k POT

Activities – Resistance Measurement

1. Strip the ends of two small gauge wires and insert them into terminals 1 and 2 of the 10K POT as shown in ***Figure 1***. Set the potentiometer knob to the middle of its travel.
2. Set the DMM center dial to the **Ω 40M** range as per ***Figure 2*** and attach the DMM test leads to the other ends of the wires.
3. Record the "as found" resistance reading exactly as indicated on the DMM dial for each range setting in the table below. Note that 40M stands for 40 meg-ohms (40 million ohms), 400k stands for 400 thousand ohms…

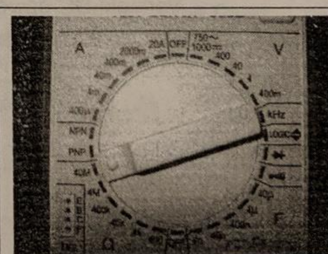


Figure 2 – Resistance Setting

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DMM Setting	As Found Value (Ω)
40M	0MΩ
4M	.004MΩ
400k	4.0KΩ
40k	4.10KΩ
4k	.0L KΩ
400	0L. Ω

4. After recording the "as found" resistance, turn the potentiometer knob and note the effect on the DMM readings. A potentiometer is a variable resistor that allows the user to set specific values of resistance.

Activities – DC Voltage Measurement

5. Attach the two small gauge wires to the **+ 5-15V** buss and the ground buss as shown in Figure 3. Set the adjustment dial to mid scale.
6. Set the DMM center dial to **1000 VDC**.
7. Record the "as found" voltage reading exactly as indicated on the DMM dial for each range setting in the table below.

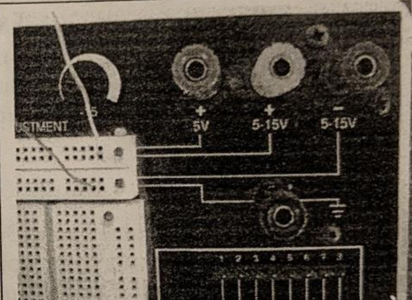

Figure 3 +5, ±15V and ground buss connections

DMM Setting	As Found Value (Volts DC)
1000 VDC	12 VDC
400 VDC	11.9 VDC
40 VDC	11.89 VDC
4 VDC	.0L VDC
400m VDC	0L. VDC

8. After recording the "as found" voltage, turn the **+15**-potentiometer knob and notice the effect on the DMM readings. The Global Specialties trainer has a variable DC power supply that ranges from -15VDC to +15VDC. The +5 volt buss is typically used for logic level circuits.
9. Press the AC button on the meter and note the response by the DMM.

Meter drops + varies voltage display. Set to max voltage dmeter at 400 mV.
The display is more interesting varying between 120 + 4 mVolts with

Activities – AC Voltage Measurement

10. Attach the two small gauge wires to the **Function Generator** center tap and -28 dB pins as shown here.
11. Set the function generator to **kHz x 10, sine wave form**, and place both sliders to ½ of full scale.
12. Set the DMM center dial to **V 400m,** and press the AC/DC button until the meter displays **AC**.
13. Record the "as found" voltage reading exactly as indicated on the DMM dial for each range setting in the table below. *Note, check for proper function generator operation. You should see voltages greater than 2 volts AC with the DMM set to the proper range.*

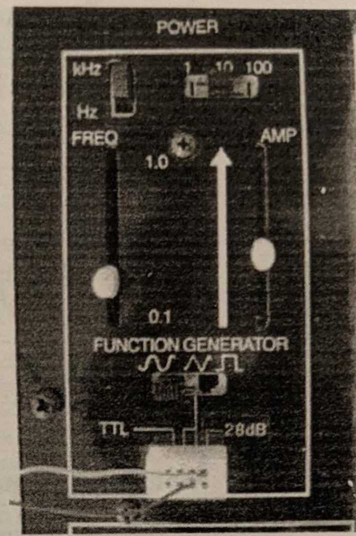

Figure 4 - Function generator

DMM Setting	As Found Value (Volts AC)
750 VAC	0VAc
400 VAC	1.6VAc
40 VAC	3.20VAc
4 VAC	3.274VAc
400m VAC	OL.

14. After recording the "as found" voltage, try adjusting the frequency, amplitude, and waveform independently and the notice the effect on the DMM reading. Each of these parameters (frequency, amplitude, and waveform) will affect the voltage output. You will see this graphically later in MECH 10 using an oscilloscope to visualize voltage and frequency.

at low amp + mid freq, meter at 400mV, .3mV
frequency change no effect.
amplitude + freq max, meter at 40
6.81. & both to 5.43.
Square to 17.94

Activities – AC Current Measurement

15. Set the DMM center dial to measure amperage (**A**) on the **2000m** setting as per Figure 5.
16. Pull the red DMM test lead plug and insert it into the **µA mA** plug on the DMM.
17. Record the "as found" current reading exactly as indicated on the DMM dial for each range setting in the table below.

reset to 10kHz & mid levels as depicted

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DMM Setting	As Found Value (Milli-Amperes)
20A	fore
2000m	0
400m	1.9 mA
40m	4.71 mA
4m	.OL
400μ	OL.

18. Select sine wave, saw tooth and square waveforms, and record the voltage, current and frequency readings for each waveform. Be sure to select the best measurement range for each reading recorded.

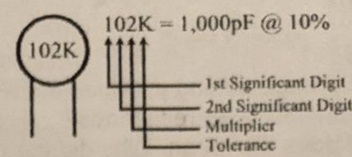
	Sine Wave Form	Saw Tooth Wave Form	Square Wave Form
Current (mA)	4.71 mA	3.81 mA	14.53 mA
Voltage (V)	3.43 V	2.76 V	10.69 V
Frequency (kHz)	5.35 KHz	5.35 KHz	5.35 KHz

Activities – Capacitance Measurement

19. Choose three capacitors with different values (≤ 400ηF) printed on the body. Record the printed values in the charts below.
20. Discharge the capacitor by shorting the leads together.
21. Insert the capacitor leads into the Cx slots of the DMM.
22. Record the "as found" capacitance reading exactly as indicated on the DMM dial for each range setting in the table below.

Capacitor 1-Printed Value BC 104		Capacitor 2-Printed Value 334 K5C		Capacitor 3-Printed Value 104 K.B.	
DMM Setting	DMM Capacitance (Farads)	DMM Setting	DMM Capacitance (Farads)	DMM Setting	DMM Capacitance (Farads)
40μ	.09 μF	40μ	.30 μF	40μ	.11 μF
4μ	.086 μF	4μ	.291 μF	4μ	.101 μF
400n	86.3 nF	400n	291.8 nF	400n	100.9 nF
40n	O.L	40n	O.L	40n	O.L
4n	.OL	4n	.OL	4n	.OL

Reading Capacitor Printed Values



Tolerance Table

Code	Tolerance
C	±0.25pF
J	±5%
K	±10%
M	±20%
D	±0.5pF
Z	+80% / -20%

Multiplier Table

Number	Multiply By (Additional no. of Zeros)
0	None (0)
1	10 (1)
2	100 (2)
3	1,000 (3)
4	10,000 (4)
5	100,000 (5)
6	1,000,000 (6)

Activities – Diode Test

23. Insert the red DMM lead into the V Ω socket and the black lead into the COM socket.
24. Set the DMM center dial to the diode test position.
25. Using alligator clips on the test leads, connect across a light emitting diode.
y. Does the LED dimly light up? Record the voltage value displayed on the meter. 1.673
26. Reverse the test leads across the diode. Does the LED dimly light up? Record
n. the voltage value displayed on the meter. 3.048V

Activities – Audible Continuity Test

27. Insert the red DMM lead into the V Ω socket and the black lead into the COM socket.
28. Set the DMM center dial to the audible continuity test position.
29. Insert two wires into the single pole double throw (SPDT) switch and connect the DMM leads to the wires.
30. Operate the switch and observe the DMM response.

DMM Beeps

Conclusions

Resistance

1. Which range setting provides the highest resolution (most accurate) reading of the potentiometer resistance? 40k
2. What does OL mean. Why did the meter show OL for some of the readings?

   Open loop. Meter could not display meaningful value. i.e. too much resistance (AIR)

DC Voltage Measurement

3. Which range setting provides the highest resolution reading of the voltage? 40 VDC
4. What happens when you push the DC/AC button on the DMM? Why did the display change? Began reading expecting AC signal which wasn't present, meter isn't seeing what expecting.

AC Voltage Measurement

5. Which range setting provides the highest resolution reading of the AC voltage? 4 VAC
6. What is RMS voltage and current? Root mean square
7. Describe the advantages of a true RMS digital multimeter. Note; our lab DMM's are ***not*** true RMS meters![1]

AC Current Measurement

8. Which range setting provides the highest resolution reading of the AC current? 40 mA
9. What happens to the voltage readings when you change the function generator waveforms between sine, saw tooth and square? Average measurement. Sign more than sawtooth, square most
10. Are square waves and saw tooth voltages measured accurately with a multimeter that is not true RMS? no due to averaging

Diode Test

11. Why does the diode light up with the leads attached in one polarity but not the other? because the meter applies a voltage and diode shouldn't pass current if reversed

Audible Continuity Test

12. Is this feature used with the circuit energized or de-energized? de-energized
13. Describe how this test can help with troubleshooting electrical circuits.

    Continuity is the most critical factor of a circuit functioning

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[1] A true RMS multimeter measures the DC effective voltage and current, regardless of the frequency or waveform. A non-true RMS multimeter assumes that all measurements are taken on 60Hz sine waves.

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Grading Criteria

		Points Possible	Points Earned
Documentation	Abstract, introduction, experiment, data results, conclusions, attachments, clarity, spelling, grammar	**10**	
	Resistance measurements accurate and complete	**5**	
	DC voltage measurements accurate and complete	**5**	
	AC voltage measurements accurate and complete, frequency recorded	**5**	
	AC current measurements accurate and complete	**5**	
	Capacitor measured and recorded accurately	**5**	
	Diode & audible continuity test completed	**5**	
Conclusions	Questions answered completely & accurately. State conclusions drawn and lessons learned from the lab	**10**	
On-time submittal	Lab report is submitted in accordance with the assignment due date as posted on Canvas	**5**	
	Total	**55**	

Lab Report Format

Abstract - a summary and high-level overview of the lab and its results
Introduction - State the objectives of the laboratory and list the equipment required
Experiment - Describe the procedure used to carry out the lab
Data Results - list data taken in table or graphical format where appropriate
Conclusion - State the conclusions drawn and lessons learned from the laboratory activities. Answer any questions found within the lab procedure.
Attachments – grading criteria, verification signatures, circuit diagrams, lab procedures & notes