RET
Lab 1. Introduction to Laboratory Instruments

Objectives:

1. Study the safety procedures of the electrical lab
2. Study the basic functions of digital multi-meter (DMM)
3. Study common electronics laboratory instruments
4. Principles of measuring voltage, current and resistance
5. Build and analyze a simple electrical circuit
6. Intro to Ohms Law

Equipment:

1. Digital Multi-meter
2. Function Generator
3. Oscilloscope
4. Proto-board
5. Assorted resistors and diodes

Procedure:

1. Please read carefully the general safety procedures in the lab

2. Voltage, Current and Resistance measurement

   All multi-meters measure *voltage*, *current* and *resistance*. Some multi-meters measure additional electrical parameters.

   1. Voltage is measured in volts (V). You always measure a *voltage change*: i.e., the voltage difference between two points in a circuit.

   2. Current, measured in Amperes (A), is the net amount of electrical charge flowing past a point per second.

   3. Resistance, measured in Ohms (Ω), limits the flow of current.

   Measure Voltage in parallel

Notes:
• Notice that some of the current flowing in the circuit actually flows through the voltmeter. This current must be very small in relation to the total circuit current I. Thus, the internal resistance of a voltmeter is very high.

• A voltmeter measures a voltage change, which may be positive or negative. All voltmeters are designed to give a positive reading whenever the red probe is placed on the side of the circuit element that is closest to the positive pole of the battery. Red to positive.

• Because the voltmeter is placed in parallel with the circuit element, you do not need to physically alter your circuit in order to measure voltage.

Measure Current in Series

To measure current through a particular loop of your circuit, connect the ammeter in series with the other elements in the circuit loop. This means you must physically modify your circuit in the following way:

1. Create a gap in the segment where you want to measure the current.

2. Reconnect the gap using your ammeter as a jumper wire
Notes:

- You must be VERY careful to make sure that your multi-meter is configured correctly before placing it in parallel across a circuit element. Ammeters have very LOW internal resistance, and can be damaged when placed in parallel across circuit elements.

- You can use the ammeter to measure the direction of current flow, provided to follow the convention of red to positive.

- Because the ammeter is placed in series with the other circuit elements, you must physically alter your circuit in order to measure current with an ammeter.

Measure Resistance

To measure resistance, select the ohms mode, remove the resistor to be measured from your circuit, and place the ohmmeter leads across the resistor leads. It is not OK to use your fingers to do this.
Notes:

- The Ohmmeter works by placing a small voltage across the circuit element. The current that flows through the element in response to that voltage determines the ohmmeter reading.

- You cannot measure the resistance of a resistor while it is in a circuit - there may be many other current paths available, or the battery may force current backwards through the ohmmeter.

A Simple Electrical Circuit

**Caution!!** A Common Mistake

Study the diagram below very carefully. This is a very common mistake and it is very easy to do. A multi-meter configured as a current meter is placed in parallel across a source capable of supplying a significant amount of current - in this case the power supply. Because the ammeter has a very small internal resistance,
full current capability of the supply is delivered to the ammeter. This can easily
destroy the meter, although most all meters have a fuse to protect the meter.

Ohms Law (general form):

\[ E = I \times R \]

where:
\[ E = \text{Energy or Voltage (Volts, V)} \]
\[ I = \text{Current (Amps, A)} \]
\[ R = \text{Resistance (Ohms, } \Omega \text{)} \]
Lab 1

Data Sheet

Name(s):

Measure Resistors

<table>
<thead>
<tr>
<th>Nominal Value</th>
<th>DMM Reading</th>
<th>% Error Calculated</th>
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</thead>
<tbody>
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</table>

In-circuit readings

<table>
<thead>
<tr>
<th>Voltage (V)</th>
<th>Current (I)</th>
<th>Calculated Resistance (R)</th>
</tr>
</thead>
<tbody>
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</table>

Compare Resistance Readings

<table>
<thead>
<tr>
<th>DMM</th>
<th>In-Circuit</th>
<th>% Error calculated</th>
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</thead>
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Lab 2. Series and Parallel Circuits

Objectives:

1. To study series and parallel circuits
2. To further study Ohm’s Law

Equipment:

1. Digital multi-meter
2. Light bulbs
3. Proto-Board

Procedure:

1. Series circuit

   Connect the following circuit. Use different types of bulbs if possible.

   ![Series Circuit Diagram]

   Figure 1. Series Circuit

   Complete the attached table (round all numbers to be within two decimal places).

   a. Before turning the power on, measure the resistance of each bulb ($R_{c1}$, $R_{c2}$, and $R_{c3}$). Note that these are the resistance of the cold filaments.
   b. Set supply voltage to 15V and note in both tables.
   c. After turning on the power, measure the voltage across each of the bulbs ($V_1$, $V_2$, and $V_3$).
   d. Measure the current flowing through the bulbs (I).
   e. Calculate the resistance of each of the bulbs ($R_{h1}$, $R_{h2}$, and $R_{h3}$) using your measured voltages and current. Again, note that these are the resistance of hot filaments.
   f. Calculate the power dissipated on each bulb ($P_1$, $P_2$, and $P_3$).

   Answer the following questions on the attached sheet:

   i) What should be the total resistance of the bulbs with hot filaments?
   ii) What should be the current flowing through the battery or power supply?
   iii) What should be the total power dissipated on all three bulbs?
   iv) Is the resistance of a hot filament higher or lower than that of a cold filament?...why?

2. Parallel circuit
Connect the following circuit.

![Parallel Circuit Diagram]

Figure 2. Parallel Circuit

Complete the attached table (round all numbers to be with two decimal places).

a. When the power is on, measure the voltage across each bulb ($V_1$, $V_2$ and $V_3$)
b. Measure the current flowing through each bulb ($I_1$, $I_2$ and $I_3$).
c. Calculate the resistance of each of the bulbs ($R_{h1}$, $R_{h2}$, and $R_{h3}$) using your measured voltages and current. Again, note that these are the resistance of hot filaments.
d. Calculate the power dissipated on each bulb ($P_1$, $P_2$, and $P_3$).

Answer the following questions on the attached sheet:

i) What should be the total resistance of the bulbs with hot filaments?
ii) What should be the current flowing through the battery or power supply?
iii) What should be the total power dissipated on all three bulbs?
Series Circuits

PRESSURE DROP = VOLTAGE DROP

Tire acts as resistance

TOOL SHED

1 PSI

40 PSI

NO FLOW NO VOLTAGE DROP

Electricity → Water
Voltage → Pressure
Amperage → Flow
Resistance → Resistance

NOZZLE CLOSED

40 PSI

Tire

TOOL SHED

40 PSI

VOLTAGE DROP

NOZZLE OPEN

20 PSI

TOOL SHED

40 PSI

The hose causes resistance and the pressure at nozzle is less than at the source.
Lab 2 Ohm’s Law and Simple Circuits
Assignment Page

Series Circuit Chart
Supply voltage: _________________

Show your work below for the questions in Procedure # 1

Parallel Circuit Chart
Supply voltage: _________________

Show your work below for the questions in Procedure # 2

<table>
<thead>
<tr>
<th></th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
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<tbody>
<tr>
<td>R, (R)</td>
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<td>Voltage (E)</td>
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<td>Amps (I)</td>
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<td>R, (R)</td>
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<td>P (W)</td>
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<td>$R_c$ (R)</td>
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<td>Voltage (E)</td>
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<td>Amps (I)</td>
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<tr>
<td>$R_b$ (R)</td>
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<td>P (W)</td>
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Lab 3. Thermistor

Objectives:

1. To build a temperature sensor using a thermistor
2. To study the procedures of thermistor calibration
3. To study data analysis techniques

Equipment:

1. Thermistor
2. Lego brick
3. Soldering equipment
4. Thermometer
5. Ice
6. Heater box

Procedure:

A. Build the temperature sensor using the procedure on the handouts

B. Calibration of Thermistor

   a. Take RAW readings from the thermistor using the RCX at various temperatures
   b. Simultaneously measure the actual temperature
   c. Either use the following equation for thermistor calibration or use a spreadsheet such as Microsoft Excel to graph your data using a log-log scale and a regression equation. The following equation relates the logarithm of electrical resistance $R$ to the Kelvin temperature $T$.

   Steinhart-equation:

   $$\frac{1}{T} = A + B \ln R + C (\ln R)^3$$

   $R$ = resistance of thermistor ($\Omega$)
   $T$ = ambient temperature in $^\circ$K
   $A$, $B$ & $C$ = curve fitting constants

   A, B and C are found by selecting three data points on the published data curve and solving the three simultaneous equations.

C. Common thermistor curve
Thermistor calibration chart:

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>RCX reading</th>
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Lab 4. Relay temperature control circuit

Objectives:
1. To study the function of relays, transistors, and diodes
2. To design a relay circuit to control a heater device

Equipment:
1. RCX
2. Digital multi-meter
3. Breadboard or proto-board
4. Relays
5. Transistors
6. Resistors
7. Diodes

Procedure:
1. Construct the following circuit on proto-board:

   ![Transistor Relay Driver Circuit Diagram]

   An input of 4 V or greater will drive this relay circuit.
Lab 5. Rectification circuit using diode and capacitor

Objectives:

1. To study the rectification function of diodes
2. To study the filtering function of capacitors
3. Become familiar with laboratory instruments

Equipment:

1. Digital oscilloscope, Agilent 54621-A
2. Function generator
3. Digital multi-meter
4. Proto-board
5. Resistors 1kΩ, 100Ω
6. Capacitors, 1000μF
7. Diodes 1N4001

Procedure:

1. Function generator and oscilloscope

   The instructor has connected channel 1 of the oscilloscope to the output of the function generator. After turning the power on, you should, on the oscilloscope, see a sinusoidal wave with frequency of 60hz, and amplitude of 10v, and zero DC offset generated by the function generator. This signal will be used as the input signal for both circuits you will test in this lab.

   Follow the instructions of the instructor, adjust the oscilloscope and the function generator in order to study the functions.

2. Rectification

   Connect the following full-wave rectification circuit. Use the sinusoidal signal generated at step 1 as the input signal. Use a 1kΩ resistor as the load resistor.
Monitor the input and output signals using the channel 1 of the oscilloscope. Due to the fact that these two signals do not have a common ground, you can only observe one signal at a time. What is the major difference between these two signals?

With the help of the instructor, connect the input and output signals to the digital oscilloscope. What is the major difference between the two signals?

3. Filtering

Add an RC-filter to the rectification circuit as shown below. Monitor the input and output signals using the oscilloscope.

What is the major difference between the two signals? Based on the plots, comment on the effects of rectification and filtering.
1. What does signal “A” represent? In 3-4 sentences, describe the “A” signal and what is going on with it?

2. What does signal “B” represent? In 3-4 sentences, describe the “B” signal and what is going on with it?

3. What does signal “C” represent? In 3-4 sentences, describe the “C” signal and what is going on with it?

4. Describe the differences and similarities between the 3 graphs.
Sig A

Sig B

Sig C
Objectives:

1. Build the distance sensor circuit
2. Calibrate the distance sensor

Equipment:

1. Voltage regulator LM78L05
2. Distance sensor GP2D12
3. 9V battery
4. 9V battery connectors
5. Toggle switch
6. Capacitors 0.1μF
7. Resistors 1kΩ and 47kΩ
8. Diodes 1N4148
9. NTE 234 transistor
10. RCX connector wire
11. Proto-board
12. Punchboard
13. Soldering iron and solder

Procedure:

1. Build the circuit

Build the following circuit on the breadboards by using the components and then solder on a punchboard:

![Distance Sensor Circuit](image)

**Figure 1: Distance Sensor Circuit**
2. Test the Circuit by taking RAW readings using the RCX.

3. Calibrate the sensor by recording RAW readings at various distances and graphing those readings in a spreadsheet such as Microsoft Excel. Then find a regression relationship between the RAW readings and the actual distance to find a formula to be used in your distance sensor program.

Example chart of readings:

![Figure 2: Chart of distance versus RCX readings](image)

Distance sensor calibration chart:
<table>
<thead>
<tr>
<th>Distance (   )</th>
<th>RCX reading</th>
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Lab 7. Color Sensor

Objectives:

1. Build the color sensor circuit
2. Calibrate the color sensor

Equipment:

1. Color sensor components
2. Breadboards
3. Soldering iron and solder

Procedure:

1. Build the circuit

   Build the following circuit on the breadboards by using the components then solder on punchboards:

   ![Color sensor circuit diagram](image)

   **Figure1: Color sensor circuit**

2. Test the Circuit by taking RAW readings using the RCX.

3. Calibrate the sensor by recording RAW readings for different known colors and relating those readings to a particular color in your program.
Lab 8. Digital counter

Objectives:
1. Study a J-K flip-flop-based digital counter.
2. Study BCD seven segment display decoder and 7-segment display.
3. Study logic gates.

Equipment:
1. Proto-board
2. Digital multi-meter (DMM)
3. Logic probe
4. Common-anode 7-segment LED display, LR1737R
5. BCD-to-seven-segment decoder/driver 7447
6. Dual J-K negative-edge-triggered flip-flop 74112 (2)
7. TTL logic gates, assorted
8. Resistors, assorted

Procedure:
1. 7-segment display and its driver.

Connect a common-anode 7-segment LED display to a 7447 decoder/driver as shown in the following circuit schematic. Please note that the area contained in the dashed-lined box is the “DIP switch” section of the proto-board and you do not need to reconstruct it. To provide the A, B, C, and D pins of the 7447 decoder with binary-coded-decimal (BCD) inputs of 0000 to 1001 (0-9 decimal), you may set the slide switch to the +5V position, and set the DIP switches to upper or lower positions accordingly.

Make the right decimal point of the seven-segment display always lit. To do this, you need to connect pin 9 of the 7-segment display to ground through a 330Ω resistor.

Do not disassemble this circuit because you will need to use it at step 2.

A. Use the DIP switch to provide BCD inputs of 0000 through 1001 (0-9 decimal). Verify that correct numbers are displayed.

B. What are displayed when A, B, C, and D are set for hexadecimal values A through F (i.e. binary 1010 through 1111)?
Four-bit counter

Construct the following counter circuit using four JK flip-flops (two 74112). Connect this circuit to the BCD driver-display circuit you have constructed during step 1, with the A, B, C, and D outputs replacing the DIP switches.

A. Connect all four CLEAR inputs to a normally-high pushbutton. Connect the CLK input of the first JK flip-flop to another normally-high pushbutton. These pushbuttons will provide high-to-low transitions for the CLEAR and the CLK pins of 74112, which are needed to clear the output and to toggle the output, respectively.

There are two pushbuttons on the protoboard and you can use them for this purpose. Make sure you understand the functions of the pushbuttons before connecting them into your circuit. The easiest way to check the functions is to use a multimeter to check the connectivity at each position of the pushbutton. Your normally-high pushbuttons may be built using the following diagram.
B. Clear the counter by pushing the CLEAR pushbutton.

C. Push the CLK pushbutton. Observe the display changes each time the button is pushed. Note that the pushbutton sometimes does not provide a clear-cut high-to-low transition due to switch rebounce. As a result, you may observe sluggish responses or multiple jumps of the display.

D. Draw a timing diagram, including at least 10 clock cycles, to show the states of the CLK input and the A, B, C, and D outputs.

E. Use a function generator on the proto-board to generate a TTL signal with a period of 0.5 sec. Use this signal as the clock input to the counter. Your digital display should show sequential increment from 0 to 9, followed by unrecognizable displays of hex numbers A through F. The display should then go back to 0 and repeat the above sequence. Demonstrate the function of your circuit to the instructor.

F. Design a logic circuit to make the counter display automatically return to 0 after displaying decimal 9. Try to make your logic design simple. Find the logic gates you need in the storage area of Room 134B. Insert this circuit into the counter circuit you have built. Test your circuit and demonstrate the results to your instructor.

G. Increase the frequency of the clock signal and observe the display change. How fast can you update the display?

Keys to success for this lab: **Patience** and **Neatness**.