Ammeter

Introduction

The purpose of this lab is to design and build our own analog ammeter.

The D'Arsonval movement is the key component that allows us to build an analog voltmeter and ammeter. This movement contains a coil and magnet that sense current flowing through the movement. When current flows through the movement, the indicator needle moves. The amount of current required to make the needle move to 100% varies per movement. Movements are typically 100μA, 1mA, or 10mA full scale movements. The movements in our lab are 100μA. Section 3.5 of the Nilsson textbook explains in more detail how these movements work.

To complete our design we need to know how much current makes the needle deflect to full scale and what the load resistance of the movement is. When placed into a circuit the movement will represent a resistor and inductor in that circuit. For our purposes we only care about the resistance of the movement and not the inductance. When analyzing circuits involving this movement, the movement is simply replaced by this load resistance in the schematic. This makes analysis of the circuit much simpler. The movements in lab are nominal 100μA movements and have a nominal load resistance of about 2.2kΩ.

The analog movements will be used in conjunction with resistors to create an ammeter that has a 0-10mA range. The meter (Volt or Amp) consists of the analog movement and additional resistors. Think of placing your complete circuit in a box. The user will be able to see the meter and terminals of your meter. The ammeter will have 2 terminals: common, current input. A block diagram of the meter is shown in Figure 1. The resistor network and proper connections are what you must design.

![Figure 1: Block diagram of Ammeter](image)

Our lab setup only contains voltage source and not current sources. In order to test your ammeter we must find a way to convert voltage to current. The resistor does this naturally. We are going to use a variable resistor or potentiometer to convert the voltage of the power supply into a current that we can control.

The schematic symbol for the pot is shown in Schematic 1-a. Terminals 1 and 3 are in fixed positions, while terminal 2, the wiper, is variable. Turning the knob or screw on the pot causes the location of
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terminal 2, the wiper, to move relative to terminal 1 and 3. Schematic 1-b shows a simple resistor model of a pot. The total resistance of the pot is always measured between terminals 1 and 3, R13. R13=R12+R23. As the knob is turned and the wiper moves, R12 and R23 change values. However R13 doesn't change. For a 100Ω pot, R13 is100Ω. R12 and R23 range from 0Ω to 100Ω. Pin 2 is usually offset or indicated in some way. Pins 1 and 3 are interchangeable on linear potentiometers.

Potentiometers come in a variety of sizes (physical and resistor value) and shapes. Some pots have a slider for adjusting, some use a knob, and some require a screw driver. Pots come in single turn or multi-turn options as well. Single turn means that R12 will go from min to max in one turn of the knob. Multi-turn, typically 10-turn, pots require multiple turns of the knob for the full range of R12 values.

Potentiometer values are stamped on the potentiometer. They don't use color codes like normal resistors but the do use a 3 digit code: abc. The potentiometer value is a.b x 10^c. So a 473 potentiometer would be a 4.7KOhm potentiometer.

When used in audio applications the potentiometer will usually have log taper. This means that the resistance doesn't change linearly as the wiper moves from terminal 1 to 3. This is to accommodate how we hear sound, which is usually on a log scale. Don't worry, all of our pots are linear taper.

Objectives

- Use parallel resistance and current division to control current.
- Improve circuit design techniques on a practical circuit
- Understand how a potentiometer works
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Procedure

Design an ammeter using the same analog D'Arsonval movement used in part 1 of this assignment. The ammeter should be able to measure current in the range of 0-10mA.

You must use more than 1 resistor in conjunction with the movement. The resistors used in building your design should be within 1% of ideal or design values, which you should be able to achieve by using combinations of resistors.

Make sure you understand parallax reading errors associated with analog movements before you proceed with this lab.

Your ammeter will be tested using the test circuit shown in Schematic 2. Because pins 1 and 2 of the potentiometer are shorted together, current only flows through the potentiometer between terminals 2 and 3. This means that as the wiper is moved the resistance between pins 2 and 3 changes and the potentiometer acts as a variable resistor.

Prelab:

• Design your circuit and draw your schematic using nominal resistance values. The resistors used in building your design should be within 1% of ideal or design values, which you should be able to achieve by using combinations of resistors. Your completed schematic must show resistor values that are readily available in 5% tolerance, see Appendix H on page 763 of your text.

• What is the input resistance of an ideal ammeter? What is the input resistance of your ammeter using ideal components? This is the resistance that the user will see if they use an Ohmmeter across the terminals of your ammeter.

• Create a data table to record the actual value of all resistors used. You should also include an actual value of the meter movement's resistance and the ammeter's input resistance.

• Draw Schematic 2 in your lab notebook.

• Calculate what values of resistance between pins 2 and 3 of the potentiometer are needed to produce: 2, 5, and 8 mA. Record these ideal resistance values in a table. Create a column in the table for the actual resistance value and %error of resistance.

Lab:

1. Use the same analog movement as the previous lab. Record the actual movement resistance from that lab.

2. Measure and record the actual values for all resistors that you will use in your ammeter design. How do the actual values change the input resistance of your meter? How will this affect the accuracy or range of your meter, be specific? Draw the schematic for your “as built” design showing the nominal resistor values used to construct your meter. Each resistor shown in the schematic must have a reference designator as well as a nominal value. Include a table of actual
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resistor values.

3. Build your meter.

   A. Use a DMM to make sure the power supply is at 1V. Record the actual voltage setting.
   B. Adjust the potentiometer until your ammeter reads 2mA.
   C. Remove the potentiometer and measure the resistance between pins 2 and 3. Record this value in your table. **Note: It is important that you do not attempt to measure the resistance of the potentiometer while it is still connected to a complete circuit. If you do this you will see the potentiometer in parallel with the voltage source and ammeter. The result is often close but not accurate.**
   D. Repeat steps B and C for 5mA and 8mA. (As the current setting goes up the resistance error should increase)

5. Repeat step #4 using the DMM to measure current instead of your ammeter.

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**Schematic 2: Ammeter test circuit. Circle with A inside of it represents your ammeter**

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**Analysis**

1. What is the ideal input resistance of your meter? What is the actual input resistance? What is the input resistance of the DMM? (you will have to look this up on the web or in the user manual)
2. Calculate the error between the nominal pot setting and actual pot setting. Perform this calculation for both the DMM and your analog meter.
   A. Explain why this error is so large and gets bigger for larger current readings.
   B. Explain why the DMM is more accurate than your meter. Be able to prove your theory.