Lab 7: Assembly of the Transmitter and Receiver Circuits

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1. Purpose

The purpose of this exercise is to build the transmitter and receiver circuits. In the process you will learn to solder. There is no report required for Laboratory 7.

1.1 Equipment

- Agilent 33120A Function Generator
- Agilent 34401A Digital Multimeter

2. Soldering

There are five soldering stations in the lab each composed of a soldering iron and soldering stand. Soldering is an art that some of you may have already experienced. In preparation for making a solder joint, plug in the soldering iron and allow approximately 3 minutes for heating. Wet the sponge located in the soldering stand with water. Touch some solder to the tip of the iron letting a small amount drip on the tip. Then swipe the tip of the iron on the wet sponge. This process is called *tinning* and helps the transfer of heat from the iron tip. To make a solder joint, heat the contact point by touching the connection with the tip of the iron while touching the solder to the other side of the contact point. It is important that the solder melts on the joint itself due to the heated joint, not from contact with the tip of the iron. There are several important facts to keep in mind when soldering:

1. Some circuit elements can only tolerate the heat produced by the soldering iron for short periods of time. It is good practice to minimize the amount of time the soldering iron is in contact with the connection.

2. Tinning the tip of the iron helps heat transfer. If you have trouble heating the connection to be soldered, consider tinning the iron. Make sure you have a wet sponge.

3. Do not breathe the smoke produced from the solder. Solder is approximately 1/2 tin and 1/2 lead.

4. When you are finished soldering, unplug the iron.

3. Construction of the Transmitter Circuit

Observe the schematic of the transmitter and receiver circuits shown in Figure 1. In this section, you will build the transmitter and receiver circuitry.
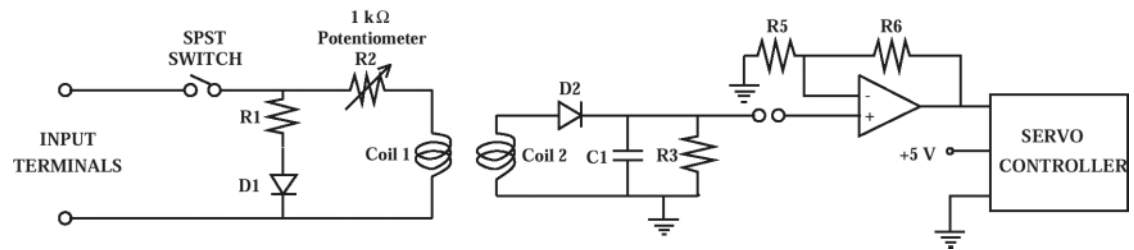
Figure 1: Transmitter and Receiver Circuit

The circuit contains:

1. a single pole single throw (SPST) switch

2. a light emitting diode (LED-D1) with current limiting resistor

3. a 1 kΩ potentiometer (variable resistor)

4. a transmitting coil

5. a receiving coil

6. a germanium rectifying diode (D2) with smoothing capacitor (C1).

3.1 Soldering leads to the switch

1. Obtain two 4" (approximate length) pieces of 22 AWG **solid conductor** wire.

2. Strip 1/2" of insulation off both ends of each wire. There is a wire gauge adjustment you can make on the handle of the wire cutters/strippers that will close the cutters to the diameter of the conductor for ease of stripping.

3. Solder one end of each wire to the terminals of the switch. Be sure to tin the iron tip. Avoid excessive time of contact of the iron tip with the switch terminals. In addition, be very careful about what you touch with the hot iron tip. It is very easy to accidentally touch a meltable or flammable item.

3.2 LED Current Limiter Design

Assuming:

1. a voltage of 5V across the series combination of the LED and resistor and

2. a 1.6V drop across the LED

Find the design value of the current limiting resistor such that the current through the LED will be approximately 7 mA. Select a resistor from the parts bin that is as close as possible to your design value. Assemble the portion of the transmitter prior to the potentiometer (R2) noting that the longer terminal of the LED is the anode (See Figure 2).

3.3 Winding the Transmit and Receive Coils

1. Obtain two segments of PVC (polyvinyl chloride) pipe.

2. Obtain two pieces of 26 AWG magnet wire, each long enough to result in 25-30 turns on the outside of the PVC segment as well as approximately 4" at the beginning and end of the coil. You may find useful the fact that the tiles on the floor are 12" square.

3. Every student must wind a coil. Observe the notch on one end of the PVC segment. Begin winding the coil from the notch. Take your time winding, making sure that the coil turns are on the surface of the PVC and snug against the previous coil turn. Try to wind the coil near the notched end rather than in the middle of the PVC segment. Leave approximately 4" of length of magnet wire at the beginning and end of the coil for connection. When you have completed the winding, place a piece of scotch tape along the length of the coil to hold the windings in place. Count (and record) the number of windings on each coil.

4. Obtain a match and burn 1/2" of enamel off both ends of the coil to expose the copper conductor. The flame only needs to contact the magnet wire for one second. There are stick matches in the lab. Use a small piece of 400 grain paper to scrape off the burned enamel from the ends of the coils.

5. Obtain a piece of masking tape, place it on the PVC tube, and write your initials on the tape.

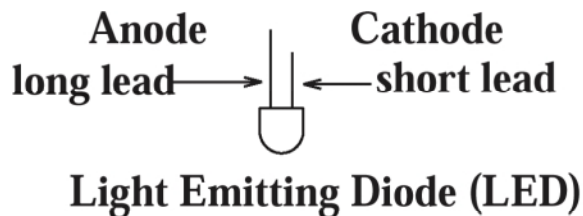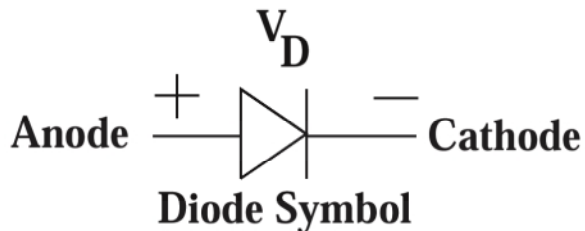6. Use the multimeter to measure the DC resistance of your coil.

Figure 2: Diode Types with Polarity Indication

7. The inductance of your coil will be in the vicinity of 10-30 μH. Think about how you might measure the inductance. Hint: Suppose the inductance is 10 μH and you placed the coil in series with a 100 Ω resistor. Then, you applied a 300 kHz square-wave to the series combination. What would the voltage across the 100 Ω resistor look like? Each student is required to measure the inductance of their coil. To measure the inductance of your coil, obtain a 50Ω resistor, measure its value, and connect it in series with your coil on either your project board or the bench-top board. Connect the function generator across the series combination. The equivalent circuit of this measurement scheme is shown in Figure 3.
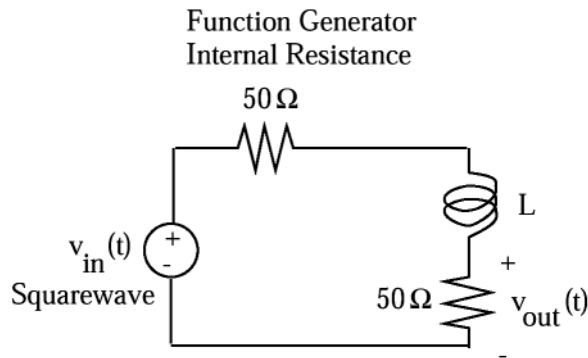
Function Generator
Internal Resistance

$50\,\Omega$

$v_{in}(t)$ (+/-)
Squarewave

L

$50\,\Omega$

+
$v_{out}(t)$
-

Figure 3: Circuit for Measuring Coil Inductance

Note that the 50Ω internal resistance of the function generator has to be included in the analysis. Measure the inductance of your coil by considering the **time constant** of the RL circuit.

Let R be the total series resistance (100 Ω in this case). A KVL around the loop produces the following first order differential equation in the current i(t):

$$L\,\frac{di((t))}{dt} + Ri\,(t) = v_{in}(t)$$

The complementary (transient) solution to this differential equation is

$$i_{comp}(t) = Be^{-\frac{R}{L}t}$$

which has a time constant $\tau = \dfrac{L}{R}$. The time constant is the amount of time required for the exponential to drop to $e^{-1} = 0.368$ times its initial value.

The function generator defaults to an amplitude of 100 mV PP. Set the amplitude to a value large enough to produce a distinct exponential voltage across the 50Ω resistor.

3.4 Rectifier and Smoothing Circuit

A rectifier is a circuit that performs AC to DC conversion. AC, an acronym for Alternating Current, means sinusoidal variation with time. DC, an acronym for Direct Current, means constant. Hence, a rectifier converts a sinusoidal voltage to a constant voltage. Most rectifiers utilize one or more semiconductor **diodes**. The theory behind diode operation will be investigated in the next lab exercise. For now, think of a diode as a one-way valve. While re-examining Figure 1, consider what happens in the receiver circuitry. The two coils are linked via mutual inductance. Since the transmitter input will be connected to the function generator and driven with an AC (sinusoidal) voltage, the current through the transmitting coil will be sinusoidal. Therefore, the induced voltage across the receiving coil will be sinusoidal as well. In order to drive the servo controller, we need a DC voltage. Hence, we will use a rectifier circuit to perform this conversion. The rectifier (and smoothing circuit) is composed of D_2, C_1, and R_3 in Figure 1. The induced sinusoidal voltage across the receiving coil will cause a current to flow to the right through Diode 2, but only during the positive half-cycle of the induced voltage. During the negative half-cycle, the induced voltage across the receiving coil attempts to force current to the left through Diode 2. However, due to the **unidirectional** one-way valve nature of the diode, no current flows through it. The capacitor C_1 charges during the positive half-cycle and discharges through resistor R_3 during the negative half-cycle. However, since the **time constant** τ is $R_3C_1 = 0.047s$ (see item 1 below) which is large compared to the period of the sinusoidally induced voltage, the next positive half-cycle occurs before the capacitor discharges at all. The result is a nearly constant (DC) voltage across C_1 and R_3. As

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will be seen in the next lab, the DC voltage across C_1 and R_3 will depend on the amplitude of the current through the transmitting coil.

1. Obtain a germanium diode (labeled "Germanium Diodes" in one of the EE-61 parts bins), a 4.7 nF **mylar** capacitor C_1, and a 10 MΩ resistor R_3.

2. Assemble the transmitter and receiver circuits. Recall that the banded end of the diode is the cathode. The orientation of the anode and cathode of D_2 is very important. Do not

    a) make the connection between the rectifier and the non-inverting amplifier.

    b) connect the potentiometer. There are not enough potentiometers for every pair of lab partners. Therefore, when you test your circuits next week, you will use a potentiometer and then return it to the parts bin.

Return any unused parts to the correct drawer in the parts bin. In the next lab you will perform test measurements of the transmitter and receiver circuits.

There is no report required for Laboratory 7.