Lab 9: System Integration and Testing

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1. Purpose

The purpose of this exercise is to design the amplifier stage of the receiver and to test the transmitter and receiver circuits with the servo controller. The purpose and operation of the GFCI will also be explored.

1.1 Equipment

- Agilent 34401A Digital Multimeter
- Agilent 33120A Function Generator
- Agilent 54600B Oscilloscope or Agilent 54622A Deep Memory Oscilloscope
- Agilent E3631A DC Power Supply

2. GFCI Demonstration

At the beginning of this lab your instructor will demonstrate for you a Ground Fault Circuit Interrupt (GFCI). This circuit can be found in the wall outlet of most bathrooms and garages. Its purpose is to prevent electrocution. Recall that (metal) plumbing is electrically connected to earth ground in a house. A dangerous situation that often occurs is when a person accidentally makes contact with the line voltage. For example, a hair dryer may have a loose wire and a person could touch it by accident. If the person is electrically isolated there is usually no problem. However, if that person were to touch a (metal) plumbing fixture, the person would be connected to earth ground, causing the completion of a circuit through the person's body. Electric current causes muscle contractions in human beings when as little as 6 mA for women and 9 mA for men goes through the body. This may cause a person to be unable to release anything he or she is holding. Such a small current is usually not enough to kill a person. However, once you make contact with electricity, you begin to sweat and the skin beneath the point of contact is destroyed which reduces the body's surface resistance so that more current flows through you. Once this current reaches 50- 100 mA through the heart, it will likely cause it to stop beating (called fibrillation). The GFCI is a circuit breaker that produces an open circuit in the power line if the difference between the currents in the hot and neutral wires (see the residential power system diagram in the EE61 Coursepak) in the GFCI is greater than 5 mA. This occurence would indicate that 5 mA or more had found an alternate route to ground, possibly through a person. The GFCI senses the difference in current between the hot and neutral wires by mutual inductance. Three coils are utilized in the sensor. One coil is wrapped around the hot wire and the other is wrapped around the neutral wire. The current flowing in the wires induces a voltage across each of the two coils. These two coils are wrapped so that if the currents are approximately equal, the net flux will be zero. However, if the currents are not equal, the net flux will not be zero. This non-zero flux will induce a voltage across a third coil wrapped around the other two. This voltage is then used to open the circuit breaker, cutting off the current flow.

3. Integrating the Amplifier

In the previous laboratory exercise, you determined the gain required by your receiver in order to drive the servo controller. In this portion of the lab you will be using that result in order to modify the design of the non-inverting op-amp circuit you built in Lab 5.

1. Build the split power supply shown in Figure 1. **The center tap (common) will be used as ground for the entire receiver circuit.**

2. Design a non-inverting amplifier which has the required amplification, using resistors greater than 1kΩ and less than 50 kΩ. Modify the non-inverting amplifier circuit on your project board as needed.

4. Connecting the Circuits

1. Obtain a 1 kΩ potentiometer and connect it in the transmitter circuit.

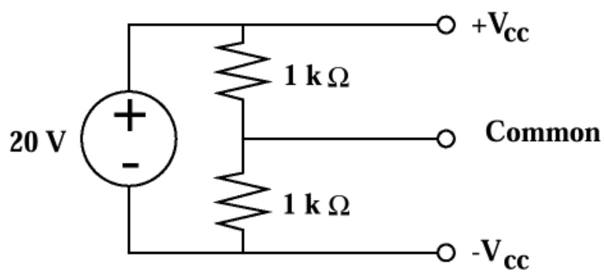

Figure 1: Split Power Supply

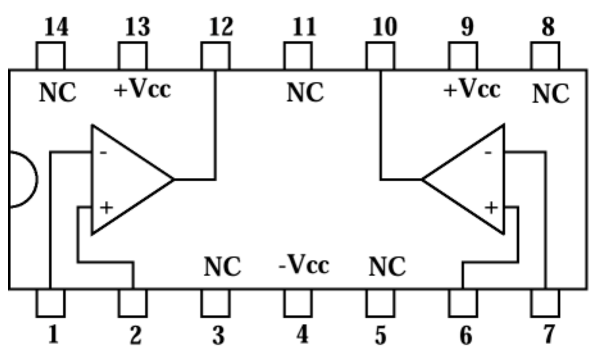

Figure 2: 747 Dual Op-Amp Integrated Circuit

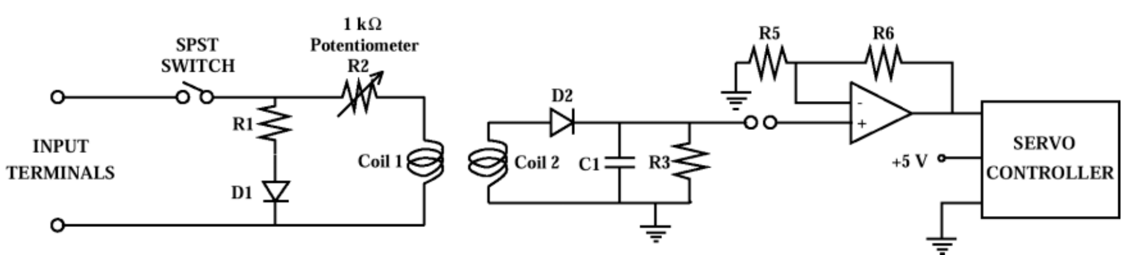

Figure 3: Transmitter and Receiver Circuit

2. Set the function generator to 10 $V_{p\text{-}p}$ (as shown on its front panel display) with a frequency of 200 kHz.

3. Connect the function generator across the input terminals.

4. Set the DC power supply to 20 V and connect it across your voltage splitting power supply.

5. Connect the common of the split power supply to the ground on both the receiver and the servo controller.

6. Connect the Agilent 3631A 6V output to the 5 volt input of the servo controller and set the output voltage to 5 volts. Connect the ground terminal of the power supply to ground (common) of the receiver.

5. Measuring the Output of the Amplifier

Before connecting your receiver output to the servo controller, you ***must*** test the other portions of your circuit to make sure they are operating as designed.

1. Turn on your circuit.

2. Set the multimeter to read DC voltage.

3. Test the amplifier you designed by applying a small DC voltage ($\approx 250mV$) at the non-inverting input and determine if the output voltage is what you would expect it to be.

4. Connect the non-inverting input to R_3.

5. Connect the multimeter across the output of the amplifier.

6. Vary the potentiometer from one extreme to the other, to find the range of values you can obtain at the output of the amplifier. Record this range.

7. Is the range great enough to drive the servo controller? If not, try adjusting the frequency of the function generator. You may have to redesign your amplifier to increase or reduce the amplification. Do not go on to the next step until you have demonstrated the ability to produce a 0-10V output capability for your system.

6. Interfacing the Receiver and Servo Controller

Once you have demonstrated to your lab TA the ability of your system to produce a 0-10V output capability:

1. Set your transmitter switch to the off position.

2. Connect the output of the amplifier to the signal input of the servomotor controller.

3. Turn on the switch in your transmitter.

4. Vary the potentiometer in the transmitter and observe the servo position. Is the servo being driven as expected?

5. Make measurements as appropriate using any of the test instruments. Be sure to explain each measurement made along with a discussion of its meaning in your lab report. Hint: Measure voltages and/or currents for several different positions of the potentiometer and

observe the position of the servo. Provide tables of measured data, graphs of servo position as a function of voltage and/or current measured. Discuss the relationship between servo position and the measured quantities. Are the relationships linear?

7. Disassembly of the Transmitter and Receiver Circuitry

1. Desolder your switch using the desoldering pump. Try to remove as much solder as possible. Place the desoldered switch in the correct drawer in the parts bin.
2. Unwind your coils. Place the used magnet wire in the "magnet wire" box and your PVC tube in the "PVC tube" box.
3. Return all parts to the proper drawers in the part bin. Do NOT just drop them in a pile on the table!

8. Questions

1. Can a person be electrocuted by a wall socket equipped with a GFCI? Justify your answer.