EE 230
Experiment 4
Fall 2006

Amplifiers, Dependent Sources, Two-Port Circuits and Transducer Interfaces

Objective: The objective of this lab is to introduce the student to practical amplifiers.

Equipment:
Computer with SPICE, Signal Express, GP-IB capability, and appropriate IVI drivers
HP E3631A or equivalent power supply (GP-IB Capable)
HP 33120A or equivalent signal generator (GP-IB Capable)
HP 34401A or equivalent multimeter (GP-IB Capable)
HP 54602B or equivalent oscilloscope

Parts:
Assortment of Resistors and Capacitors
Potentiometer
741 op amp
Amplified speaker
2 Photoresistors
TH-103 thermistor
T Thermocouple
Heat source
Thermometer

Practical Details: The dependent source has been used repeatedly in your introductory circuits course but there are no primitive circuit components that serve as dependent sources. As such it was difficult to conduct laboratory experiments with circuits that incorporate dependent sources. Although electronic devices can be used to build dependent sources, the concept of dependent sources and the implementation of dependent sources is generally viewed in a different context in the electronics community. The term "amplifier" is generally used in stead of the term "dependent source" and the four basic types of amplifiers, the voltage amplifier, the current amplifier, the transresistance amplifier, and the transconductance amplifier actually represent the four basic types of dependent sources. In all cases, the input variable to the amplifier that is sensed is either a voltage or a current and the output variable is a voltage or current. The input variable is sensed with reference to two terminals, often designated as a port, and the output variable is provided between two terminals, also designated as a port. Thus an amplifier has 4 terminals and is often termed a two-port network. One of the terminals is often common between the input and output of the amplifier so in this case it may appear that there are only three terminals associated with the amplifier but it can be still viewed as a two-port. The two-port designation in the two cases is shown in Fig. 1.

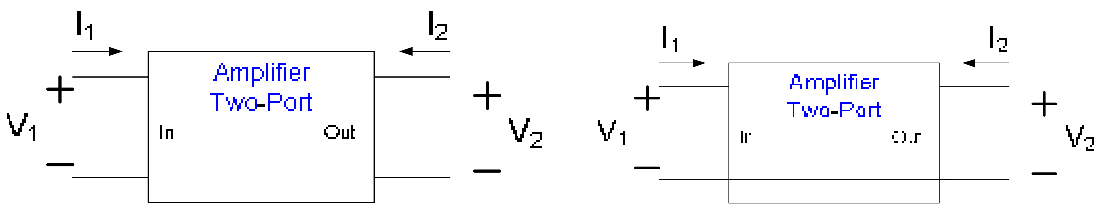

Fig. 1 Amplifiers Depicted as Two-Port Networks

In this network, performance characteristics of amplifiers will be investigated. In the next experiment, emphasis will be placed on the design of the amplifiers themselves.

Although the four basic types of amplifiers ideally differ significantly, when operating linearly, all can be modeled by the equivalent circuit shown in Fig. 2 where R_{IN} denotes the input impedance and R_{OUT} denotes the output impedance. The gain A_V may vary with frequency and this frequency dependence could better be emphasized by showing specifically the s-domain frequency dependent $A_V(s)$.

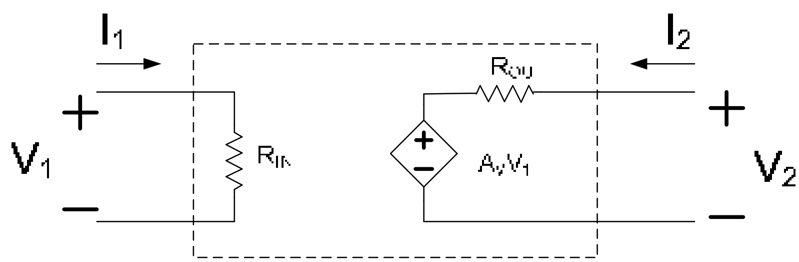

Fig. 2 Model of an Amplifier

In this experiment we will use electronic components to build a voltage amplifier or, using the circuit theory technology, to build a voltage dependent voltage source. A circuit that shows a voltage amplifier using an operational amplifier internal to the dependent source is shown in Fig. 3. Although we have not yet discussed modeling or use of an operational amplifier, we will consider the amplifier shown in Fig. 3 as a basic voltage amplifier where the gain can be programmed or set with the resistor R_2. In this figure, an implementation is shown with a specific commercial operational amplifier, the uA 741. (with the uA 741, the pin 2 corresponds to the "-" in the schematic, pin 3 corresponds to the "+" in the schematic, and node that goes to the positive V_2 output is pin 6. The 15V and -15V supplies must be connected to properly provide power and biasing to the op amp. These are connected to pins 7 and 4 respectively. All remaining pins should remain unconnected.)

The low-frequency gain of this amplifier is given by the expression

$$A_V = 1 + \frac{R_2}{1K}$$

and the frequency-dependent gain is given by the expression

$$A_V(s) = \frac{pA_V}{s+p}$$

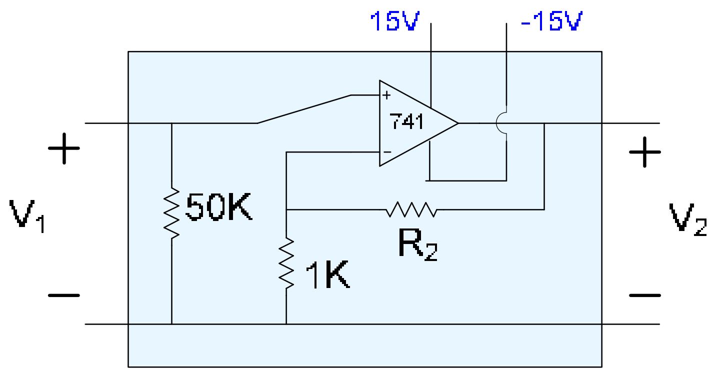

Fig. 3 Two-Port Voltage Amplifier

Part 1 Measure Amplifier Parameters

Select the resistor R_2 in the Voltage Amplifier so that the voltage gain is 25.

a) Measure the voltage gain of this amplifier with both sinusoidal excitations and with square-wave excitations when the frequency of the excitation is 1KHz. Keep the amplitude of the input small enough so that the peak to peak swing at the output is less than 10V.

b) Determine the maximum input that can be applied without excessive distortion and determine what output voltage corresponds to this input.

c) Increase the input by 10% and by 50% and observe the output. Listen to the effects of the distortion on the amplified speaker that is available in the lab. With a sinusoidal excitation, can the distortion be observed first on the waveform displayed on the oscilloscope or by hearing the distortion through the speaker?

d) Measure the input impedance of this amplifier.

e) Measure the 3-dB bandwidth of this amplifier.

f) Determine the pole location of this amplifier.

g) From the previous measurements, analytically determine the step response and compare with measurements

h) Can you relate the rise time of the step response to the pole location of the amplifier?

Part 2 Light-controlled amplifier

A photo-resistor is a device that behaves as a resistor but with the added property that the resistance value changes with light intensity.

a) Obtain a photo-resistor from your TA and characterize the resistance versus light intensity. Since we do not have a meter for measuring the light intensity, you might do this characterization in terms of light environments you can control in the laboratory. For example, completely dark, a little light shining in, and maybe full ambient light levels.

b) With the values you have measured in part a), determine the gain of the amplifier if the photo-resistor is used to replace the resistor R_2 in the amplifier you have worked with I the previous part of the experiment. Compare your predicted gain with the measured gain.

Part 3 Temperature Controlled Amplifier

A thermister is a device that behaves as a resistor but with the added property that the resistance value changes with temperature. A thermocouple is a one-port device that has an output voltage that is proportional to the temperature difference between the two ends of the thermocouples.

a) Characterize the TH-103 thermister over the temperature range from room temperature to approximately 100C. Use the heat gun and the thermometer to help with this characterization.

b) Can you select a dc voltage at the input to your amplifier so that the output voltage will change by 1V when the thermister temperature changes from room temperature to 100C if the thermister is used for R_2 in the amplifier. Explain why you can or can not select such a dc voltage.

c) Obtain a thermocouple from your laboratory instructor. The output of the thermocouple is given by the expression

$$V_{TC} = K_{TC}\left(T_2 - T_1\right)$$

where K_{TC} is a constant that characterizes the thermocouple. Measure the K_{TC} for your thermocouple. If the output of the thermocouple serves directly as the input to the amplifier, determine the value of R2 needed for a 5V change in the output voltage if the temperature changes from ambient to 100C. Verify this change experimentally.