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COMMON EMITTER AMPLIFIER

INTRODUCTION

One of the most commonly used small-signal amplifiers is the common emitter configuration. In this experiment you will be testing a single-stage common emitter amplifier. You will be measuring voltage gain for both an unswamped and a swamped configuration, measuring amplifier phase shift, and observing the amplifier response to loading.

In the troubleshooting section, you will insert amplifier faults and observe the failed amplifier AC and DC circuit values.

REFERENCE

Principles of Electronic Devices and Circuits - Chapter 5, Sections 5.3 and 5.4

OBJECTIVES

In this experiment you will:

✓ Learn how to determine voltage through circuit measurements

✓ Gain understanding of the effects of loading on amplifier gain

✓ Be able to relate amplifier AC and DC voltages to component failures

EQUIPMENT AND MATERIALS

DC power supply
Digital multimeter
Dual-trace oscilloscope
Function generator
NPN transistor, 2N3904 or equivalent
Circuit protoboard
Resistors: 1 kΩ, 2.2 kΩ, 3.9 kΩ [2], 10 kΩ, 47 kΩ
Capacitors: 1 μF [2], 470 μF

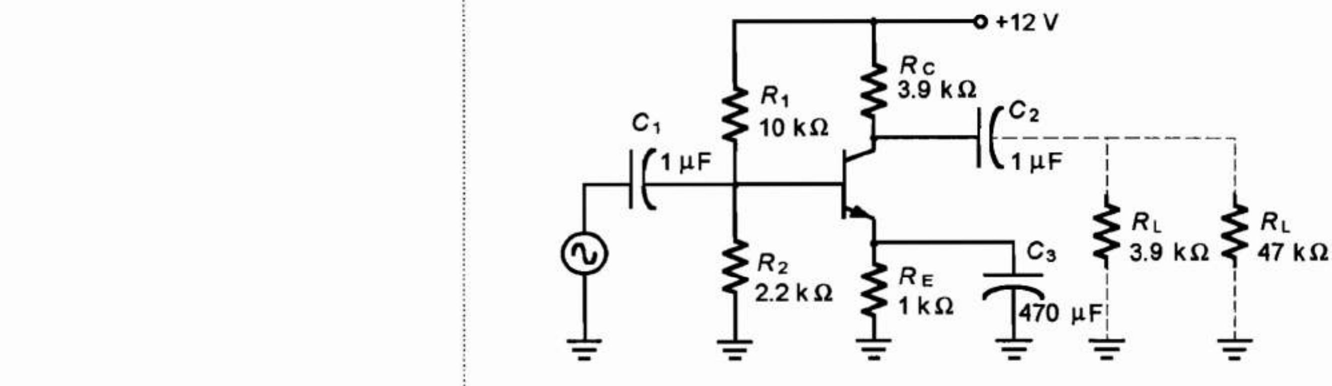


Figure 17.1

1. Build the circuit of Figure 17.1, without connecting a load resistance at this time.

2. Connect the DC power supply set to 12 V. *Do not connect the audio function generator* at this time. Measure and record the following DC voltages:

   V_B = ______________ V_E = ______________

   V_C = ______________ V_{CE} = ______________

   Is the amplifier operating at or close to the load line midpoint?

   ____

3. Connect the function generator, and set it to provide a signal of 20 $mV_{p\text{-}p}$ at the base of the transistor.

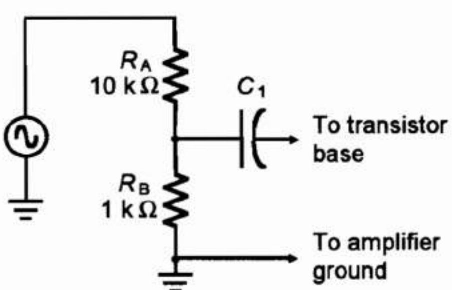


Figure 17.2

If you have difficulty obtaining a low enough output from your function generator in step 3, add the voltage divider network of Figure 17.2 to your circuit.

Do not rely on the divider value to determine the amplifier input signal. Measure the signal at the base of the transistor and adjust the function generator to obtain the required value.

4. Set the oscilloscope coupling to AC and connect the scope to the transistor collector. Adjust the function generator to obtain the maximum output signal possible without clipping. Observe the shape of this output waveform. Reduce the input signal to obtain an output signal of approximately 4 $V_{p\text{-}p}$. (The exact value is not critical.)

5. Set the oscilloscope coupling to DC. Measure and sketch the combined AC and DC signals at the base (V_B), emitter (V_E), and collector (V_C) in Graph 17.1. Record the positive and negative peak values obtained at the collector in the waveform sketch.

6. Using your dual trace oscilloscope, connect channel 1 to the transistor base and channel 2 to the collector. Set the scope coupling to AC. Set the scope to trigger from channel 2. What is the phase angle between the input and output of the amplifier?

   Phase angle = __________

7. Adjust the function generator to provide a 20 m$V_{p\text{-}p}$ input signal to the
   transistor base. Using your oscilloscope, measure and record V_{in} and V_{out} of the amplifier. Calculate and record the value of unloaded voltage gain.

   V_{in} = __________ V_{out} = __________ A_V = __________

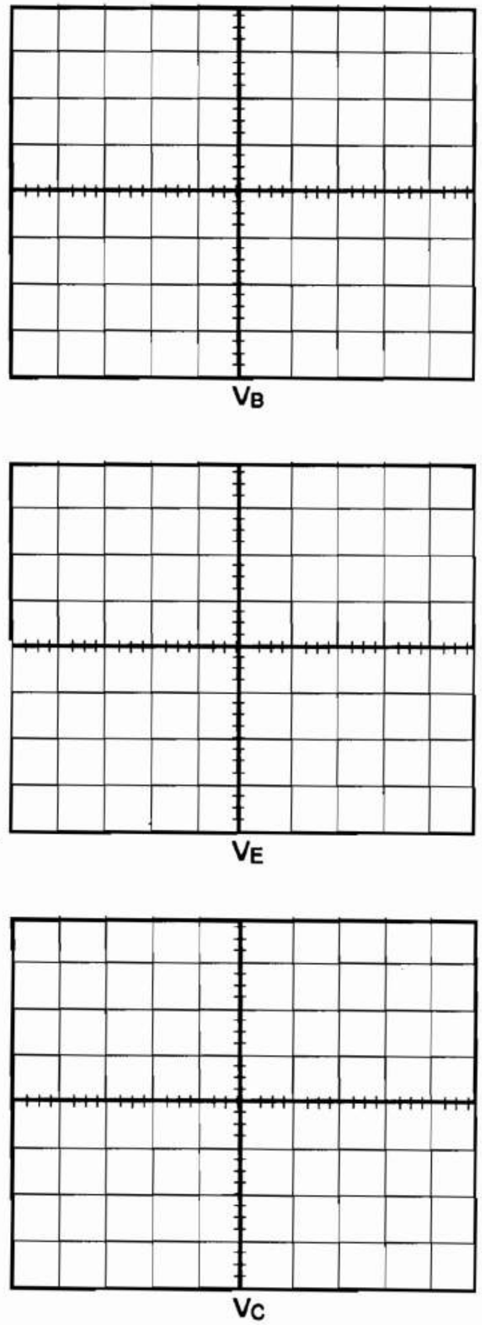
8. Turn off the circuit power and connect the 3.9-kΩ load. Measure the input signal and output across the load. Record these values. Calculate the amplifier loaded voltage gain.

   V_{in} = __________ V_{out} = __________ A_{VL} = __________

9. Turn off the circuit and replace the 3.9-kΩ load with 47-kΩ measurements of step 8 to determine the loaded voltage gain.

   A_{VL} = __________

10. Turn off the circuit power. Modify your circuit to the swamped amplifier of Figure 17.3. Apply the circuit power. Set the function generator to apply a 20 m$V_{p\text{-}p}$, 1 kHz input signal, using your oscilloscope. Measure and record the amplifier input and output signal values. Then calculate the amplifier loaded voltage gain.



Graph 17.1

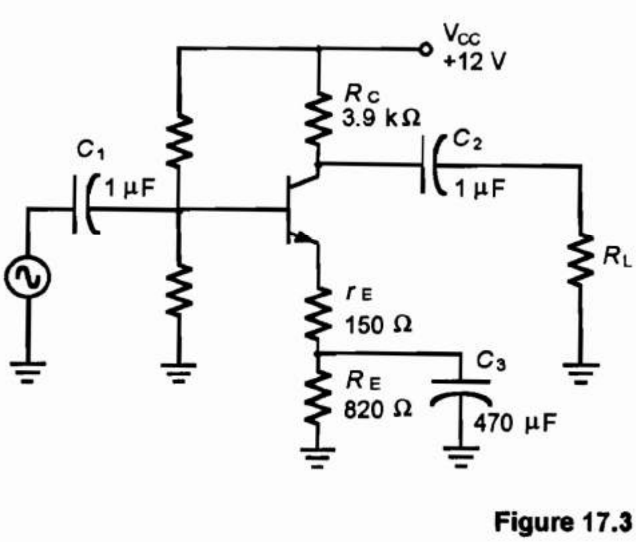


Figure 17.3

V_{in} = __________

V_{out} = __________

A_{VL} = __________

11. While monitoring the output signal at the load, increase the input signal to the point just short of clipping. Observe this waveform. You should observe a clean and undistorted waveform. Contrast this waveform to that obtained in step 4.

Step 11 completes your measurements. You may disconnect your circuit.

SECTION II TROUBLESHOOTING

Fault 1 - Emitter bypass capacitor open

1. Capacitors have three failure modes: They can open, short, or leak. You will now explore what happens to the V_{out} when the Emitter bypass capacitor opens.

2. Apply 12 VDC and the AC signal of 1 kHz at 20 mV_{p-p} to the amplifier circuit. While monitoring the V_{out} carefully, remove one end of the emitter bypass capacitor and record the V_{out} below. Also observe and record gain differences.

   With emitter bypass capacitor:

   V_{out} = ______________ A_V = ______________

   Without emitter bypass capacitor:

   V_{out} = ______________ A_V = ______________

Fault 2 - Transistor shorted

1. The transistor in the CE amplifier has two main failure modes: The transistor can open or short from emitter to collector. You will explore the shorted failure mode here.

2. Turn off the circuit power. Place a shorting wire from the emitter to the collector of the transistor. Apply circuit power. Monitor the output signal and record the voltages below.

   V_{out} ______________ V_E ______________

   V_C ______________ V_{RC} ______________

DISCUSSION

Section I

1. In Procedure step 6, you measured the phase shift between the signal input on the base to the signal output on the collector. Describe, using the functional operation of the transistor, the reason for the phase shift you measured.

2. In Procedure step 4, using the oscilloscope with AC coupling, the average value of the amplifier signal was 0 V. That is because the positive peak value was equal in magnitude and opposite in polarity to the negative peak value.

   A. In Procedure step 5, the average value of the output signal was not zero. Calculate the average value from the data of Figure 17.3.

      V_{avg} = __________

   B. What is the circuit parameter value represented by the average value V_{avg} of part A? Explain why you obtained the collector waveform values recorded in Figure 17.3.

3. In Procedure step 5, you measured the AC signal on the emitter of the transistor, which should have been essentially 0 VAC. Explain why this value should have been obtained.

Section II

1. In Fault 1 you discovered that the emitter bypass capacitor can greatly affect the gain of the amplifier. What operational measurement would you make to determine if the capacitor was open? Why?

2. In Fault 2 you found that sometimes the AC signal may disappear completely. You must then rely on DC voltage measurements for trouleshooting. Which of the DC voltages checked do you think was the most obvious for showing a shorted transistor? Why?

Quick Check

1. What would be the gain of the amplifier in Figure 17.1 if the value of R_C were changed to 5 kΩ? (Assume no change in quiescent operating point.)

2. What should be the normal AC voltage read at the emitter of the transistor amplifier of Figure 17.1?

3. If the amplifier of Figure 17.1 were exactly midpoint biased (V_{CZ} = 6 V), what would be the maximum undistorted peak output voltage swing?

   (a) 4 V (b) 5 V
   (c) 6 V (d) 10 V

4. If capacitor C_3 in Figure 17.1 shorted, the transistor would likely be _____.

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MULTISTAGE AMPLIFIERS

INTRODUCTION

Many times the gain required from an amplifier cannot be obtained by only one amplifier stage. Therefore, several amplifier stages are cascaded together so that the individual gain of each amplifier is multiplied to get an overall gain.

In this experiment you will build a two-stage cascaded amplifier, make measurements, and draw conclusions based on those measurements.

The troubleshooting section will examine the effects of capacitor failures on the multistage amplifier. You will install faults and make circuit measurements to be able to relate measured values to component failures.

REFERENCE

Principles of Electronic Devices and Circuits - Chapter 5, Section 5.9

OBJECTIVES

In this experiment, you will:

✓ Add to your knowledge of multistage amplifiers

✓ Be able to relate measured values to circuit failures

EQUIPMENT AND MATERIALS

DC power supply
Digital multimeter
Dual-trace oscilloscope
Function generator
Circuit protoboard
NPN transistor [2], 2N3904 or equivalent
Resistors: 82 Ω, 180 Ω, 330 Ω, 1 kΩ, 3.3 kΩ, 3.9 kΩ, 4.7 kΩ, 5.6 kΩ, 33 kΩ, 56 kΩ
Capacitors: 1μF [3], 47 μF [2]

SECTION I FUNCTIONAL EXPERIMENT

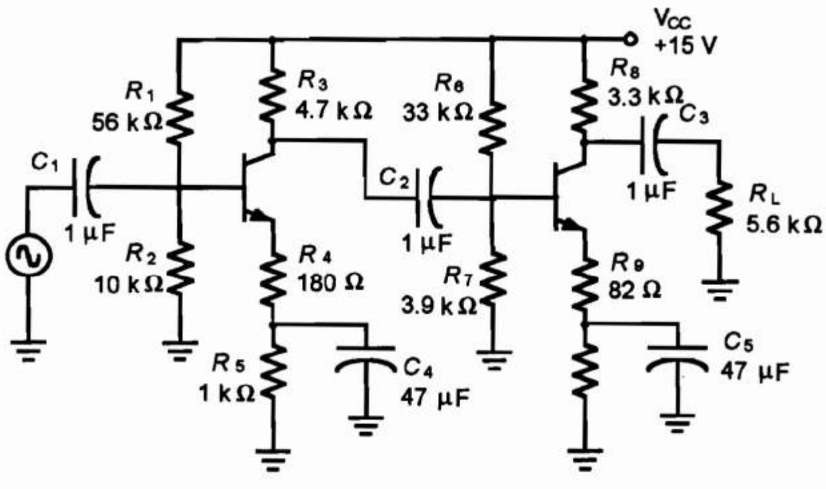

Figure 21.1

1. Construct the two-stage amplifier of Figure 21.1.
2. Apply DC power. Do not connect the function generator at this time.

   Measure the DC voltages at the base, collector, and emitter of the first and second stages of the amplifier. Record your values in Table 21.1.

	DC Values			AC Values			
	V_B	V_E	V_C	V_b	V_c	V_e	V_{out}
Stage 1							
Stage 2							

Table 21.1

3. Connect the function generator to provide an input to your amplifier at C_1. Set the generator to 20 $mV_{p\text{-}p}$ at 1 kHz.

   Note: If your function generator will not adjust to a sufficiently low signal, connect the input voltage divider network of Figure 21.2 to your circuit.

4. Using the oscilloscope, measure the peak-to-peak AC signal at the base, emitter and collector of each amplifier stage, and measure the amplifier output across the load resistor. Record your measured values in Table 21.1.
5. From your measured data, calculate the loaded voltage gain of each stage and record below.

   A_{VL} (Stage 1) = __________ A_{VL} (Stage 2) = __________

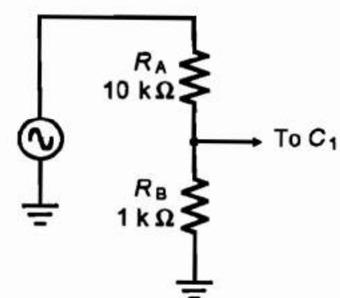

Figure 21.2

6. Calculate the overall voltage gain of the amplifier by taking the product of the individual stage gains from step 5.

7. From the data of Table 21.1, calculate the overall gain of the amplifier.

   A_{VT} = ___________

This result should be the same as the value calculated in step 6. The total gain of a multistage amplifier is the product of the individual stage gains.

For stable 'scope triggering in step 8, set the 'scope to trigger on the channel connected to the amplifier output.

8. Connect your oscilloscope to measure the phase shift from input to output of the amplifier. Connect one channel of the scope to the input signal at C_1, and the other channel to the output at the load resistor. Measure and record the amplifier phase shift.

   Phase shift = ___________

This completes the first section measurements. If you are proceeding to the troubleshooting, leave your circuit connected.

SECTION II TROUBLESHOOTING

Troubleshooting amplifiers is very similar to troubleshooting the single stage amplifier. There are some differences, however. One major difference is the coupling capacitors. Like a leaky or shorted bypass capacitor, coupling capacitors alter the signal characteristics. Also, since they isolate the V_c of the first stage from the V_b of the second stage, network bias is affected. Another difference of the amplifier from the single-stage is that the subsequent stages act as the load for the previous stage. Therefore, any problem in later stages affects the operation of the previous stages. This experiment, then, focuses on these two major differences by examining failures of the coupling capacitors.

Fault 1 - C_2 open

1. Turn off circuit power. Open C_2 by disconnecting one end from the capacitor at Q_1. Reapply circuit power and the AC signal of 20 m$V_{p\text{-}p}$ at 1 kHz. Measure and record in Table 21.2 the AC and DC voltages at the collector of Q_1 and the base of Q_2.

2. Reconnect C_2 and measure V_c of Q_1 and V_b of Q_2. Do you observe any differences in the signal?

Fault 2 - C_2 shorted

Turn off circuit power. Remove capacitor C_2 and replace it with a jumper wire (connecting the collector of Q_1 to the base of Q_2). Reapply circuit power and the input signal. This simulates a leaky or shorted capacitor. Measure and record the appropriate data in Table 21.2. Also record the DC levels.

	DC Values			AC Values		
Fault	V_B	V_E	V_C	V_b	V_c	V_e
C_2 open						
C_2 shorted						

Table 21.2

DISCUSSION

Section I

1. Calculate the unloaded voltage gain of the amplifier first stage. How does it compare to your measured value?

2. The overall gain you measured for your multistage amplifier could be approximated by a single-stage unswamped amplifier. What reasons would you give for using the multistage amplifier? What reasons would you give for using the multistage amplifier as a better choice?

Section II

1. What effect did an open coupling capacitor have on the circuit? Also, explain how and why the signal changed when C_2 was reinserted into the network.

2. Explain what effect a leaky coupling capacitor would have on the operation of the multistage amplifier.

3. Explain the measurements you observed when C_2 was shorted. What, for example, happened to the gain of the amplifier, or to the output signal waveshape?

Quick Check

1. The term h_{fe} refers to _____.

   (a) Av (b) beta
   (c) impedance (d) slew rate

2. C_2 is used to couple the first stage to the second stage.

   True False

3. An open emitter bypass capacitor _____ the gain of an amplifier?

   (a) increases (b) decreases
   (c) has no effect on

4. A multistage amplifier increases signal strength in small steps.

   True False

5. In a multistage amplifier, faults in one stage can affect the operation of other stages.

   True False