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CLASS A POWER AMPLIFIERS

INTRODUCTION

As its name notes, the emphasis of the power amplifier is power gain. It is most often found in the final stages of multistage amplifiers. Some important features of the class A amplifier are the current drain, maximum power dissipation by the transistor, the stage efficiency and full power output (maximum unclipped signal the amplifier can deliver).

In this experiment you will calculate and measure power output and efficiency of a class A Power amplifier.

The troubleshooting section of this experiment will simulate two amplifier faults and you will, through measurements made, be able to relate failures to circuit measured values.

REFERENCE

Principles of Electronic Devices and Circuits - Chapter 6, Section 6.3

OBJECTIVES

In this experiment you will:

✓ Determine by measurement the efficiency of a class A power amplifier

✓ Understand the effect of a swamping resistor on the signal linearity of a large signal amplifier

✓ Simulate faults and be able to determine their effect on amplifier parameters

EQUIPMENT AND MATERIALS

DC power supply
Digital multimeter
Dual-trace oscilloscope
Function generator
NPN transistor, 2N3904 or equivalent
Resistors: 220 Ω, 820 Ω, 1 kΩ, 3.3 kΩ [2], 6.8 kΩ, 33 kΩ
Capacitors: 1 μF [2], 470 μF

SECTION I FUNCTIONAL EXPERIMENT

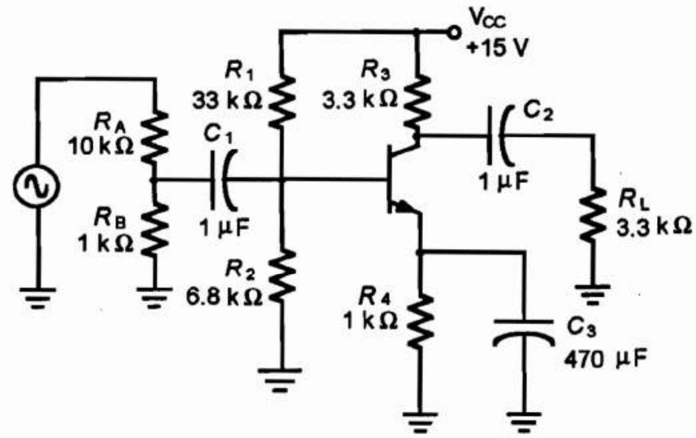

Figure 22.1

1. Construct the circuit in Figure 22.1
2. Apply DC power and with no signal applied, measure and record in Table 22.1 the values of I_{CQ}, V_{CEQ}, and the total current drawn by the amplifier (I_{CC}).
3. Connect the function generator and adjust for a signal of 20 $mV_{p\text{-}p}$ at 1 kHz at the base of the transistor.

   Using the oscilloscope, observe the load voltage while increasing the AC input signal. Continue to increase the input signal until clipping is observed. Take note of the nonlinear distortion of the signal, in fact the signal begins to squash and elongate before clipping in reached. This is due to the changes in r'_e.

NOTE: Although, at the power levels of your circuit you won't do any damage, it is usually not desirable to operate an amplifier in saturation clipping for long intervals.

4. Reduce the input signal until the output signal is at its maximum value without clipping.
5. Measure and record in Table 22.1 the peak-to-peak output voltage ($V_{p\text{-}p}$).
6. Calculate and record in Table 22.1 the DC power supplied to the amplifier (P_{DC}).
7. Calculate and record in Table 22.1 the total power delivered to the load (P_L).
8. Calculate and record in Table 22.1 the efficiency of the amplifier.

Equation for step 6:

$$P_{DC} = V_{CC} \cdot I_{CC}$$

Equations for step 7:

$$V_{Lp} = \frac{V_{Lp\text{-}p}}{2}$$

$$V_{LRMS} = 0.707 V_{Lp}$$

$$P_L = \frac{{V_{LRMS}}^2}{R_L}$$

Equation for step 8:

$$\text{Efficiency} = \frac{P_L}{P_{DC}} \times 100\%$$

I_{CQ} =
V_{CEQ} =
$V_{p\text{-}p}$ =
I_{sat} =
P_{DQ} =
P_L =
P_{DC} =
Eff =

Table 22.1

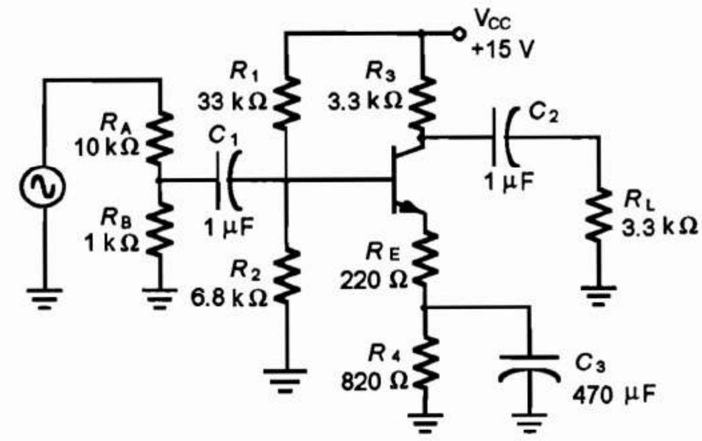

Figure 22.2

9. Turn off the circuit power. Change the emitter circuit to add a swamping resistor as shown in Figure 22.2. Reapply circuit power and the AC signal input.

10. Connect the oscilloscope to monitor the amplifier output. Adjust the input signal amplitude until the output just starts to clip. Compare the signal waveshape to that observed in step 3. Does it appear to be less distorted?

This completes the measurements of this section.

SECTION II TROUBLESHOOTING

Fault 1 - Output capacitor C_2 is shorted

1. Starting with the circuit of Figure 22.1, place a jumper wire to short the output capacitor, C_2.

   Apply circuit power, measure and record the following DC voltages:

   V_C = __________ V_{CE} = __________ V_{RL} = __________

   Apply an AC input signal of 20 $mV_{p\text{-}p}$ at 1 kHz. Measure and record the peak-to-peak voltages.

   V_C = ______________ V_{RL} = ______________

2. Turn off circuit power. Remove the jumper shorting capacitor C_2.

Fault 2 - Emitter bypass capacitor C_3 is shorted

1. With circuit power off, connect a jumper wire to short C_3 Apply DC power, measure and record the following DC voltages:

   V_B = __________ V_C = __________ V_E= __________

2. Apply an input signal of 20 $mv_{p\text{-}p}$ at 1 kHz. Measure the record the following peak-to-peak AC voltages:

   V_C = ______________ V_{RL} = ______________

Observe the waveshape of the output signal at the collector and load. Does this waveshape imply anything about the state of the transistor?

3. Turn off the power and disconnect your circuit.

DISCUSSION

Section I

1. What effect did including a swamping resistor have on your measurements. Explain the effect.

2. The amplifier efficiency you calculated in step 8 should have been much less than the ideal class A efficiency of 25 percent. With reference to your text, can you identify measured circuit parameters that contributed to the low efficiency?

Section II

1. What happens to the signal at the load when the bypass capacitor shorts. Why does this occur?

2. What does nonlinear distortion look like and explain why it occurs in a class A amplifier

3. What one measurement could you make to be certain to identify a shorted output capacitor? Explain why this measurement would be certain.

Quick Check

1. The class A amplifier is highly efficient.

   True   False

2. The maximum, theoretical, efficiency of a class A amplifier is _____.

   (a) 50%   (b) 25%
   (c) 75%   (d) 33.3%

3. Overdriving an amplifier is a good idea.

   True   False

4. Distortion is caused by changes in _____.

   (a) r'_e (b) R_E
   (c) R_L (d) r_c

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CLASS B PUSH-PULL AMPLIFIERS

INTRODUCTION

In this experiment you will construct a voltage divider biased and a diode (current mirror) biased class B push-pull amplifier. This will allow you to observe crossover distortion and its elimination by the diode biased amplifier. You will also demonstrate that changing class B bias to class AB eliminates crossover distortion. You will also determine the efficiency of your class B amplifier.

Simulated fault measurements will be made in Section II of the experiment. You will fault a portion of the circuit and make measurements to see the effects of the fault.

REFERENCE

Principles of Electronic Devices and Circuits - Chapter 6, Sections 6.4 and 6.5

OBJECTIVES

In this experiment you will:

✓ Observe crossover distortion

✓ Demonstrate the AC and DC operating characteristics of the class B complementary symmetry amplifier

✓ Demonstrate class B amplifier faults

EQUIPMENT AND MATERIALS

DC power supply	Diode [2], 1N914 or equivalent
Oscilloscope	NPN transistor, 2N3904
Digital multimeter	PNP transistor, 2N3906
Function generator	Resistors: 220 Ω, 1 kΩ [2], 1.8 kΩ [2]
Circuit protoboard	Potentiometer: 1-kΩ ten-turn trimpot
	Capacitors: 1 μF [2], 100 μF

SECTION I FUNCTIONAL EXPERIMENT

Crossover Distortion

1. Construct the circuit in Figure 23.1.
2. Adjust the potentiometer (R_2) for a total resistance of 50 Ω or less between the bases of Q_1 and Q_2.
3. Connect a milliamp meter to measure the collector current of Q_1.
4. Connect the DC power supply to your circuit and set it for 12 V.

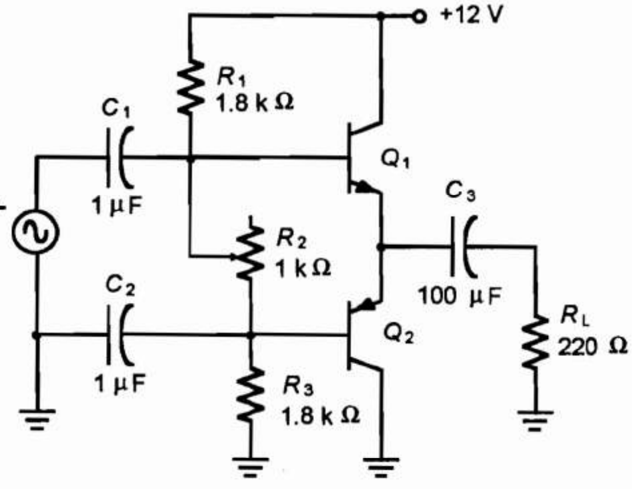


Figure 23.1

CAUTION

Step 5 below must be performed carefully to avoid exceeding the current limit of Q_1 and Q_2.

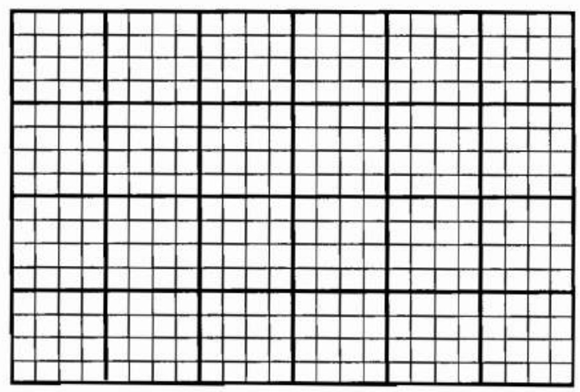
5. Slowly adjust the potentiometer (R_2) while observing the milliammeter. Adjust R_2 to obtain a current value of 0.25 mA. The exact value is not critical and can be in the range of 0.1 to 0.25 mA. Following the adjustment of R_2, record your current meter reading.

   I_{CEQ} = ___________ (0.1 to 0.25 mA)

6. Turn the DC power supply off and disconnect the current meter.
7. Reapply 12 VDC. Use your digital voltmeter; measure and record the V_{CEQ} of each transistor.

   Q_1 V_{CEQ} = ___________

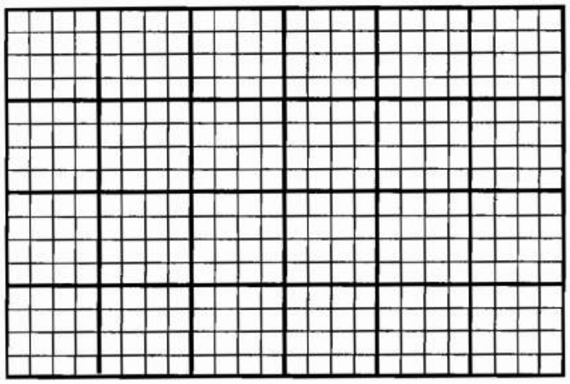
   Q_2 V_{CEQ} = ___________



Graph 23.1

8. Connect the function generator to your circuit and set the generator to provide a 1-kHz sine wave at 2 V_{p-p}.
9. Using the oscilloscope, observe the signal across the load resistor. The signal you observe should have crossover distortion.
10. Draw the signal in Graph 23.1.

The following procedure step allows you to provide Class AB biasing of your voltage divider biased circuit and observe the elimination of crossover distortion.



Graph 23.1

11. Repeat Procedure steps 3 through 10, except in step 5 adjust the collector current to 5 mA, and plot your signal in Graph 23.2. Do the adjustment carefully; follow the procedure exactly. You will be increasing the transistor forward bias, and too big an increase can put the transistor into full conduction with no limit on the collector current.

This completes the first part of the experiment. Disconnect all power and disassemble the circuit.

> Crossover distortion is caused by need for the input signal to increase to the point where the Class B biased transistor will turn on and start conduction. Increasing the bias to a point where the transistor is barely in conduction (Class AB) allows the transistor to follow the input signal without the delay that appears as crossover distortion. This is not easily accomplished with voltage divider biased transistors because of the difficulty in selecting resistor sizes and the danger of thermal runaway.

The Diode Biased Amplifier

1. Connect the circuit in Figure 23.2.
2. Calculate and measure the DC level at the emitter junction of Q_1 and Q_2 (point A). Record your data in Table 23.1.
3. Calculate the remaining parameters shown in Table 23.1 and enter the results in the *Calculated* column.

Reminder: I_{CC} is equal to the sum of the current mirror bias network (I_D) plus the amplifier transistor collector current (I_{CEQ}):

$$I_{CC} = I_D + I_{CEQ}$$

Since your circuit may not be operating at maximum power to the load, use an estimated load voltage value of 9 $V_{p\text{-}p}$ to calculate load power.

4. When your calculations are complete, make the I_{CC} measurement before connecting the function generator to your circuit.
5. Connect the function generator to your circuit and set the generator to provide a 1-kHz signal at 2 $V_{p\text{-}p}$.

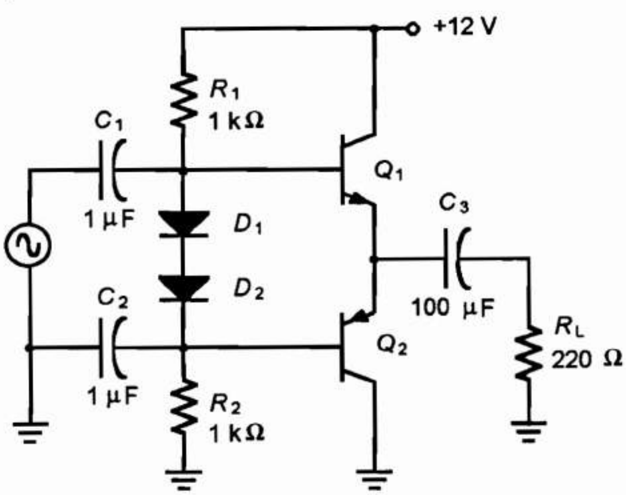


Figure 23.2

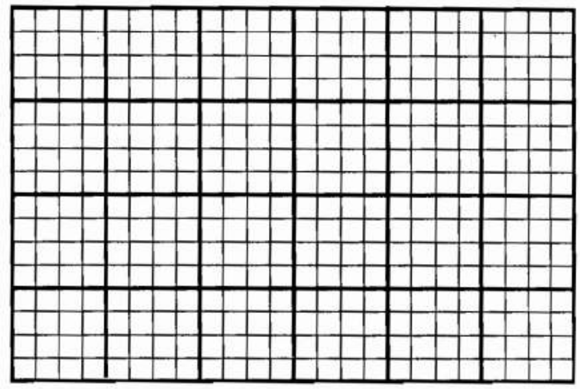
	Calculated	Measured
Q_1 V_{CEQ}		
Q_2 V_{CEQ}		
I_{CEQ}		
P_L		
I_{CC}		
P_{DC}		
Eff		

Table 23.1

6. Connect the oscilloscope to measure the output voltage across the load. While observing the scope display, adjust the function generator output amplitude to obtain the maximum undistorted (no clipping) load voltage.

7. Measure the output voltage across the load and sketch the load signal waveform in Graph 23.3.

8. Turn off the generator and power supply. Complete the power calculations for the output load power, the circuit DC power, and the amplifier efficiency from your measured values. Enter the results in Table 23.1.



Graph 23.2

You may leave the circuit connected if you are proceeding to the troubleshooting section.

SECTION II TROUBLESHOOTING

Fault 1 - D_1 shorted

Place a jumper wire across D_1. Measure the DC levels and signals at the base of Q_1 and Q_2, and the output junction before the coupling capacitor. Are the DC levels normal?

Fault 2 - Injected fault

Have your instructor or lab partner inject a problem into the circuit. Try covering the fault with a piece of tape to hide the fault, and make your conclusions based on your measurements only.

DISCUSSION

Section I

1. Explain the term *push-pull*. How does this term describe the class B amplifier?

2. Describe crossover distortion. What does it look like and how can it be eliminated?

3. Considering the measured efficiency of your amplifier versus the theoretical maximum value, what things would you suggest to increase your amplifier efficiency?

Section II

1. Describe the procedure you used to troubleshoot the fault that your instructor or partner injected into the circuit.

2. If the base to emitter junction of Q_1 opened, what signal would you expect to observe at the output?

Quick Check

1. The maximum efficiency of a class B amplifier is approximately _____.

   (a) 50% (b) 63.3%
   (c) 25% (d) 78.5%

2. A class B amplifier is normally biased above cutoff to eliminate crossover distortion.

   True False

3. The class B amplifier consists of two transistors each conducting for 270 degrees of the input signal.

   True False

4. Provided the transistors are biased equally, the DC level at the collector emitter junction of a class B amplifier is _____.

   (a) half the value of V_{CC} (b) 10% of V_{EE}
   (c) 0.7 V above ground (d) 10% below V_{CC}

5. An abnormal voltage reading at the emitter junctions (point A) indicates _____.

   (a) an open biasing resistor (b) an open coupling capacitor
   (c) a shorted or saturated transistor (d) an excessive load