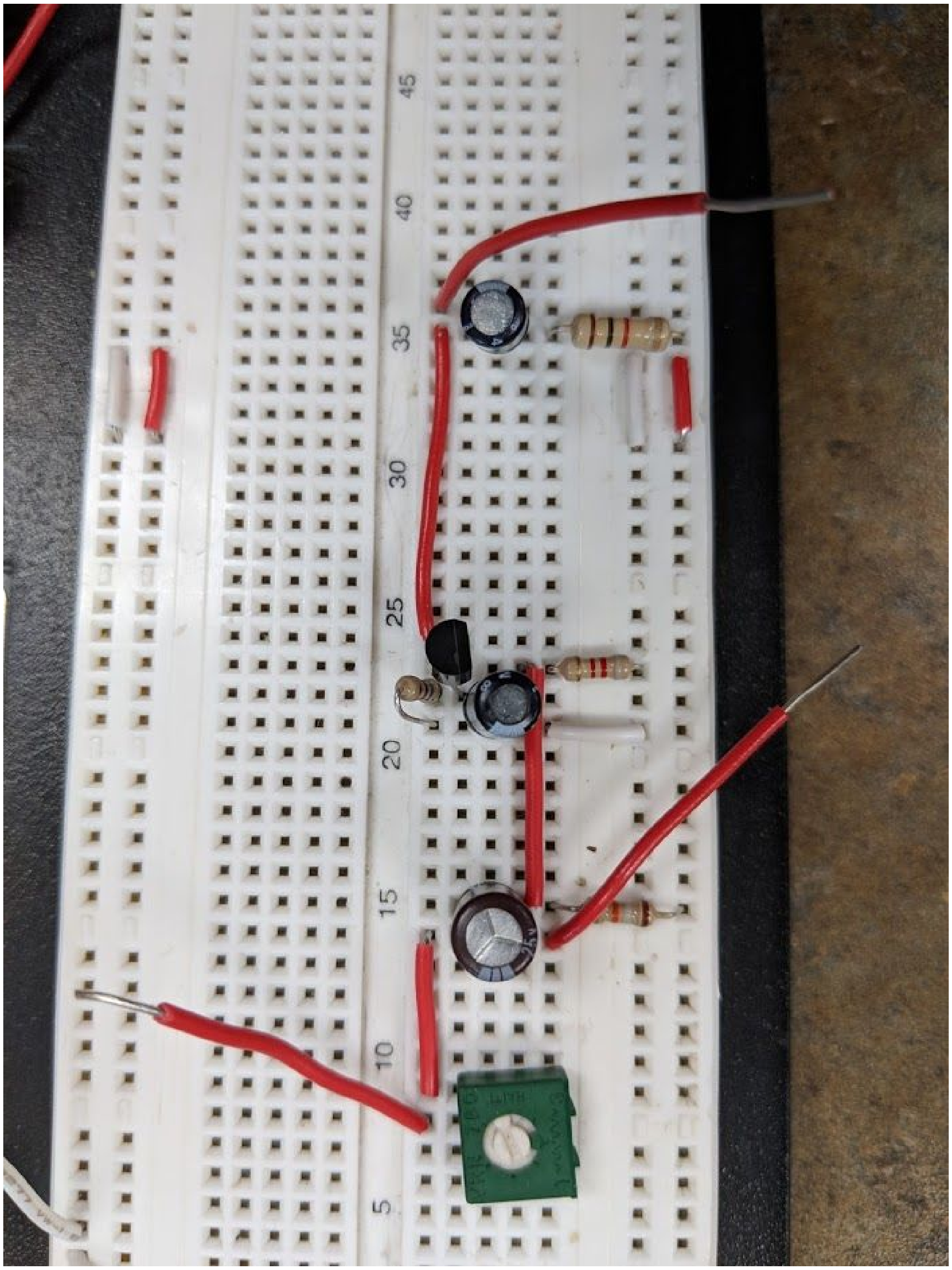
Experiment 16

Troubleshooting a CE Amplifier



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Objectives:

1. Make a dynamic test which will determine whether an AC amplifier is working properly
2. Use DC voltage and resistance measurements in a correctly functioning amplifier to troubleshoot a defective amplifier.
3. Troubleshoot a defective amplifier

Materials:

- **0-30 V variable power source**
- **A Digital Multimeter**
- **An Oscilloscope**
- **An AF sine-wave generator**
- **560 Ω, 1000 Ω, 8200 Ω, 18000 Ω resistors**
- **A 100 µf-50 V and two 25 µf-50 V electrolytic capacitors**
- **A 2N3904 NPN Transistor**
- **A SPST switch**
- **Computer with Multisim**
- **Breadboard and Wires**

Procedure:

1. The circuits in figures 16-5 and 16-9 should be constructed with an input amplitude of 30 mV peak to peak and the voltage of the output of the amplifier, base, and collector then record in tables 16-2 and 16-6.
2. Open C_1, then measure the voltage of the input, base, collector, and output.
3. C_1 should be placed back into the circuit and then C3 should be opened and the voltage of the input, base, collector, and output should be recorded in tables 16-2 and 16-6. When opened the AC gain should decrease heavily and the dc bias should also decrease.
4. Remove the signal generator from the input and record in tables 16-3 and 16-7 in the normal voltage column estimates of the dc voltages of the base, emitter, and collector with a assumed current of 4.0 mA using the estimation equations below then measure the voltages of the emitter, base, and collector with respect to ground and record in tables 16-2 and 16-6.

Estimation Equations:

$V_{R1} = V_{CC}\left(\frac{R1}{R1+R2}\right)$ $= (9)\left(\frac{18000}{18000+8200}\right)$ $= 6.18$ V

$V_B = V_{CC} - V_{R1}$ $= (9) - (6.18)$ $= 2.81$ V

$V_E = V_B - 0.7$ $= (2.81) - 0.7$ $= 2.11$ V

$I_C = \frac{Ve}{Re}$ $= \frac{(2.11)}{(560)}$ $= 3.77$ mA

$V_{RC} = (I_C)(R_C)$ $= (0.00377)(1000)$ $= 3.77$ V

$V_C = V_{CC} - V_{RC}$ $= (9) - (3.77)$ $= 5.22$ V

5. Open S_1 , then remove R_3 and in the emitter open column estimate the dc voltages of the base, emitter, and collector using the estimation equations and record them in tables 16-3 and 16-7.
6. Close S_1 then physically measure and record the DC voltages of the base, emitter, and collector.
7. Open S_1 and place R_3 back into the circuit, then disconnect the resistor lead of R_1 that is connected to the base and estimate the voltages of the base, emitter, and collector using the estimation equations and record them in tables 16-3 and 16-7.
8. $S_{1,}$ is closed again to measure and record the DC voltages of the base, emitter, and collector.
9. S_1 is opened to reconnect the base to R_1 and remove R_4 from the circuit.
10. The DC voltage values for the base, collector, and emitter were estimated with the estimation equations before S_1 was closed and the values were measured and recorded in tables 16-3 and 16-7.
11. S_1 is opened and resistor R_4 is placed back into the circuit.
12. The resistance to ground values were estimated and recorded in tables 16-4 and 16-8
13. The resistance from the base to ground, emitter to ground, and collector to ground should be measured and recorded in tables 16-4 and 16-8.

14. A fault was inserted into the circuit and a troubleshooting guide should be created as shown below in Table 16-1.

1. The first step that was taken was a dynamic check with an oscilloscope on the input, base, collector, and output. While the amplifier was operation, both the input and the output wave were highly distorted

2. A DC voltage test was done, the voltages of all three elements were around 3V.

3. A resistance test was done and both the base and collector elements had a resistance value that was far higher than it should have been, as it looks like an open

4. During this step it was found that a resistor with a value of 9.1 MΩ was placed on the base of the transistor where a R3. a resistor with a value of 560Ω was supposed to be placed.

Table 16-1

Step	Condition	V p-p (V)				Amplifier Operation	Gain
		Input	Base	Collector	Output		
1	Normal	0.03	0.05	3.24	3.24	Yes	108.33
		Voltage (V)					
		Emitter	Base	Collector			
2	Measured	3.13	3.76	3.56			
		Resistance to Ground k(Ω)					
		Emitter	Base	Collector			
3	Measured	0.55	OL	OL			
		Resistance to Ground M(Ω)					
		Emitter	Base	Collector			
4	Measured	0.00	9.18	9.18			

Table 16-2 Real World Data

Step	Condition	V p-p (V)				Amplifier Operation	Gain
		Input	Base	Collector	Output		
1	Normal	0.03	0.02	2.28	2.28	Yes	76.00
2	C_1 open	0.03	0.00	0.00	0.00	No	0.00
3	C_3 open	0.03	0.11	0.19	0.19	Yes	6.33

Table 16-3

Element	Voltage (Normal) (V)		Voltage (Emitter Open) (V)		Voltage (Base Open) (V)		Voltage (Collector Open) (V)	
	Estimated	Measured	Estimated	Measured	Estimated	Measured	Estimated	Measured
Emitter	2.11	1.87	0.00	0.00	0.00	0.00	0.70	0.19
Base	2.81	2.60	2.81	2.77	2.81	2.72	2.81	0.87
Collector	5.23	5.61	9.00	9.00	9.00	9.02	9.00	9.00

Table 16-4

Element	Resistance to Ground k(Ω)	
	Estimated	Measured
Emitter	0.56	0.56
Base	8.20	8.030
Collector	27.20	26.90

Figure 16-5

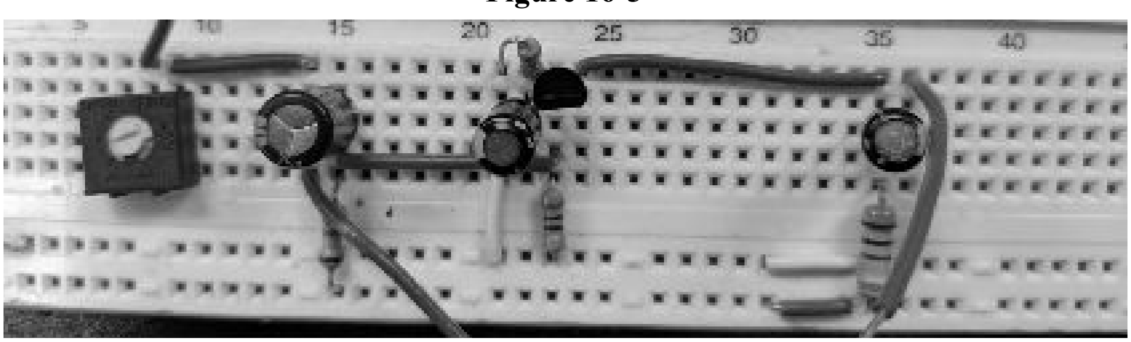


Table 16-6 Multisim Data

Step	Condition	V p-p (V)				Amplifier Operation	Gain
		Input	Base	Collector	Output		
1	Normal	0.03	0.03	3.57	3.57	Yes	119.00
2	C_1 open	0.03	0.00	0.00	0.00	No	0.00
3	C_3 open	0.03	0.03	0.08	0.08	Yes	2.66

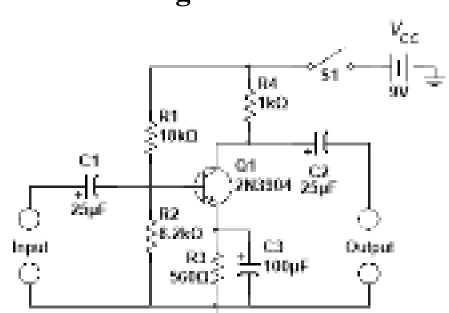
Table 16-7

Element	Voltage (Normal) (V)		Voltage (Emitter Open) (V)		Voltage (Base Open) (V)		Voltage (Collector Open) (V)	
	Estimated	Measured	Estimated	Measured	Estimated	Measured	Estimated	Measured
Emitter	2.11	1.99	0.00	0.00	0.00	0.00	0.70	0.19
Base	2.81	2.69	2.81	2.82	2.81	2.82	2.81	0.84
Collector	5.23	3.71	9.00	6.18	9.00	6.18	9.00	8.15

Table 16-8

Element	Resistance to Ground (kΩ)	
	Estimated	Measured
Emitter	0.56	0.56
Base	8.20	8.20
Collector	27.20	27.20

Figure 16-9



Questions:

1. Why is a dynamic test of an amplifier's operation more meaningful than static dc voltage and resistance checks?

A dynamic test of an amplifier will directly show if an amplifier is working correctly as you can quickly compare the input and output signals. If the output wave is undistorted, has an amplitude that is larger and a phase shift that is 180° to the input, then the amplifier is operating correctly. The reason why a dynamic test is more meaningful than a static dc voltage and resistance check is because these types of checks can only provide information about the amplitude. While on the other hand, dynamic tests can provide information about distortion, phase shift, as well as amplitude.

2. The technique of signal tracing can be used to isolate trouble in a two-(or more) transistor (stage) amplifier to a specific transistor stage. Explain how this technique may be used to determine which transistor stage is defective in a three-stage amplifier. The transistors are connected so that the output of the first is capacitively coupled to the input of the second, and the output of the second is capacitively coupled to the input of the third.

When using the technique of signal tracing to troubleshoot an amplifier you start from the end of an amplifier circuit and work your way back, checking for a signal after stage. If you have no output signal at the end of all three stages, check for a signal until there is a stage where on one side there is a signal and none on the other side, this stage is causing the circuit to fail.

3. Compare the estimated and measured voltages in
Table 16-2 for an amplifier operating normally. Explain any discrepancies.

The values that we had estimated in Tables 16-2 through 16-4 and Tables 16-6 through 16-8 had different from the measured values. As the measured values that were in the Tables 16-2 through 16-4 were quite different from the estimated ones. On the other hand the measured values that were in the Tables 16-6 through 16-8 were much closer to the estimated values. The reason for these values being much similar is due to the fact that Multisim does not have any tolerances, being therefore very accurate while the real world data has tolerances.

4. Interpret and explain the voltages at the elements of the transistor with the emitter open (Table 16-7).

Collector - 9.00 V
Base - 2.81 V
Emitter - 0.00 V

Since there is no current flowing in the collector element, it has the full Vcc at the element causing the collector voltage to be 9.00V. As R1 and R2 are not affected by an open transistor it would continue to be 2.81 V. With the emitter element being open, Vcc can not reach the element, this causes no current to flow and because it is only connected to ground the voltage is 0.00V

5. Interpret and explain the voltages at the elements of the transistor with the collector resistor open (Table 16-7).

Collector - 9.00 V
Base - 0.85 V
Emitter - 0.19 V

Since there is no current flowing in the collector element, it has the full Vcc at the element causing the collector voltage to be 9.00V. With the collector element open there is no current flowing to the output of the circuit, because of this the transistor can turn on but can't do much else. Therefore the base element will only have enough voltage to turn on the transistor and for the R_e voltage drop, the voltage required for this was 0.85 V. The emitter element voltage is the voltage drop of R_e , this value is 0.19 V

6. Is an understanding of the operation of a transistor amplifier helpful in troubleshooting it? Why?

Yes, the understanding of the operation of a transistor amplifier very important in troubleshooting an amplifier circuit. With the understanding of an amplifier circuit you would be able to properly perform dynamic tests, dc voltage and resistance checks. With the ability to do these tests, you could be able to use the data that you would gather during these tests the determine if an amplifier circuit is functioning properly. If the circuit is not functioning properly you would be able to use the data in order to point out components or stages of an amplifier circuit that is damaged.

7. Why is it preferable to use a low-power ohms function of a digital multimeter rather than the conventional ohms function of a VOM in measuring resistance in the external circuit of the transistor amplifier.

Unlike a VOM, a DMM does not apply enough power to affect the circuit that is being measured. A VOM can apply a large amount of power to the circuit that it is measuring, this can skew the data that you get when measuring the circuit or damage a transistor inside of the circuit.

8. Assume a short-circuited base to emitter voltage in figure 16-3. determine the voltages with respect to common which you would measure at the elements of the transistor. Show your computations.

Collector - 8.75 V
Base - 0.25 V
Emitter - 0.25 V

Because there is no current flowing in the collector element as the base - emitter junction is shorted, it has the full Vcc at the element causing the collector voltage to be closer to 9.00V, and in this case it is 8.75 V. Since the voltage of the emitter element is the voltage drop of R_e at around 0.25 V, this is also the voltage of the base element as the two elements are shorted together.

Discussion:

When performing the lab we had no major problems.

Conclusion:

1. A dynamic test is used as an initial test to determine the performance of a CE amplifier. The test is to measure each stage of the amplifier for a sine wave in order to determine if the components in each stage is functioning. For example, an inputted 50 mV sine wave should have an outputted 2.5V undistorted sine wave if its voltage gain is 50. If the amplifier is not functioning as the output signal is faulty when measured in the aforementioned manner, further dynamic signal-tracing can be used to determine the exact fault. For example, if there is no signal at the base when measured with an oscilloscope, this could mean that C1 is open or that the base terminal is short-circuited to ground. After the oscilloscope is used to find the fault, other test equipment such as VOMs can be used to pinpoint the issue.

2. To troubleshoot a defective amplifier it is helpful to have data about the normal voltage and resistance measurements so it would be possible to compare the defective amplifiers measurements to the normal measurements. With this comparison of data, it would be possible to locate discrepancies that may occur. Faults that may require a DC voltage or resistance test can include opened, shorted, or defective component.

3. In order to troubleshoot an CE amplifier, a dynamic test is to be done first. It is performed stage by stage in the amplifier to determine if there are issues with the capacitors, the transistors, and the input signal or output signal. If the amplifier circuit does not pass the dynamic test, a DC voltage and resistance test is to be performed in order to pinpoint a fault in the circuit. In order to find a fault it is recommended to compare the measurements from the DC voltage and resistance tests to the values of a known good working circuit in order to find the faulty part of the circuit. A dynamic test is performed first as it can quickly determine if a circuit is working by showing the output signal amplitude, distortion, and phase shift. As DC voltage and resistance tests can only determine the amplitude of the signal.