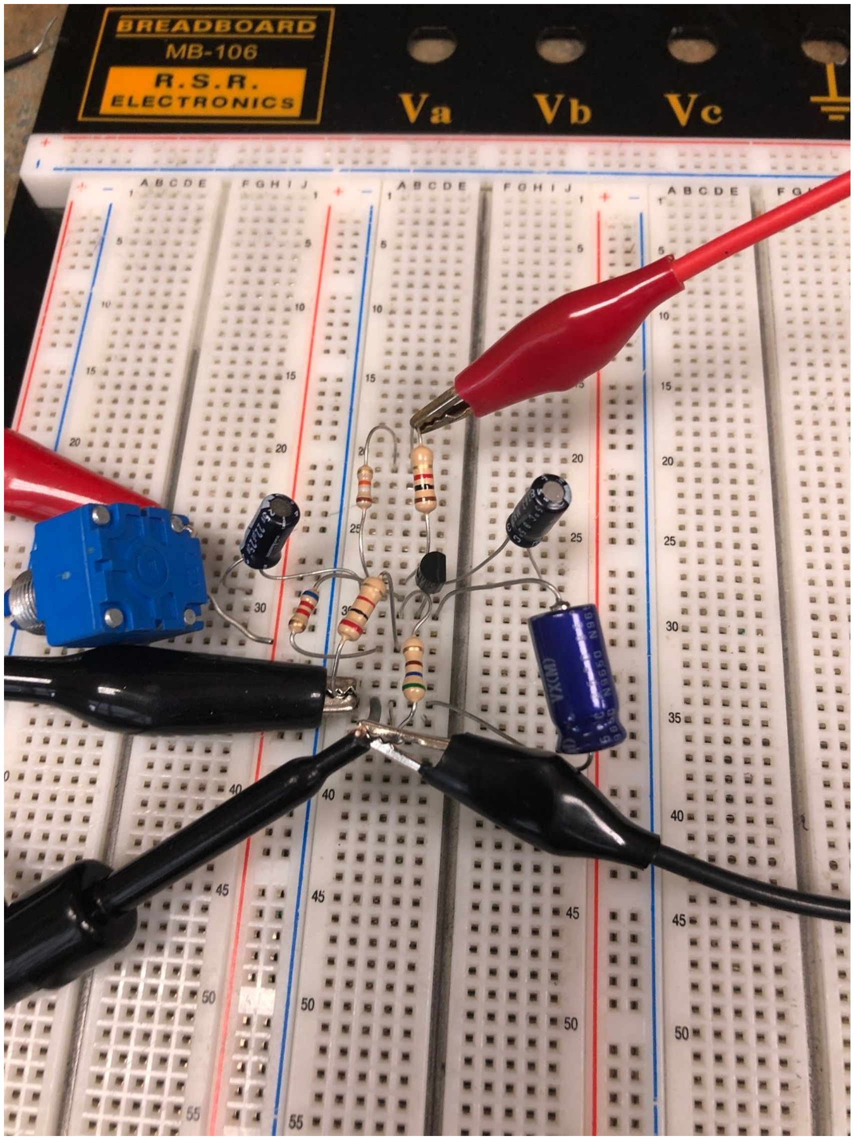
Experiment 16: Troubleshooting a CE Amplifier



Kevin Downing
Tyler Doyle
Ryan Shaw
January 27-31, 2020

Objectives:

During this lab, you will be able to:

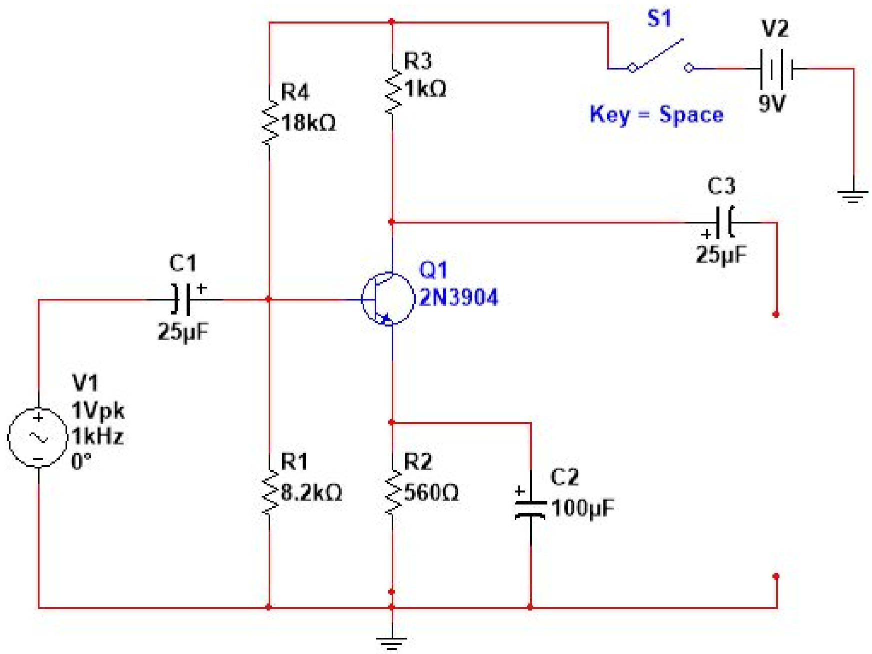
- Test to see if an ac amplifier is operating properly with a dynamic test
- Consider dc voltages and resistance norms in an amplifier to infer the troubles in a defective amplifier
- Troubleshoot a defective amplifier

Procedure:

During this lab, you will need the following items:

- DC power supply
- Oscilloscope
- Multimeter
- Function generator
- 560Ω resistor
- 1kΩ resistor
- 8.2kΩ resistor
- 18kΩ resistor
- 2N3904 transistor
- Defective components

1. First, connect the circuit shown in circuit 16-1 and figure 16-1. Set the function generator for a 30 mV peak-to-peak sine wave into the input (15 mV peak). Then, close S1 and measure the peak-to-peak voltage of the output and record it in table 16-1.



Circuit 16-1

Step	Condition	V_{in} (mV)	V_{base} (mV)	$V_{collector}$ (V)	V_{out} (V)	Amplifier Operation
1,2	Normal	30.00	29.86	3.53	3.53	Undistorted
3	C1 Open	0.00	0.00	0.00	0.00	Nonexistent
4	C2 Open	30.00	29.86	0.05	0.05	Undistorted

Table 16-1 (Multisim)

Step	Condition	V_{in} (mV)	V_{base} (mV)	$V_{collector}$ (V)	V_{out} (V)	Amplifier Operation
1,2	Normal	30.00	30.00	3.00	3.10	Undistorted
3	C1 Open	30.00	0.00	0.00	0.00	Nonexistent
4	C2 Open	30.00	30.00	0.07	0.07	Undistorted

Table 16-2 (Breadboard)

2. Then, measure and record, in table 16-1, the peak-to-peak voltage of the base and the collector.
3. After this, remove C1 and measure and record the voltages at the input, base, collector, and output of the amplifier. Record these values also in table 16-1.
4. Then, put C1 back into the circuit and remove C2 instead. Measure and record the voltages at the input, base, collector, and output, also recording these into table 16-1.
5. Remove the function generator from the circuit. Estimate and record the dc voltages at the emitter, base, and collector of the transistor with an estimated 4mA of current in table 16-3.

Element	V_n (V) (Estimated)	V_n (V) (Measured)	V_{EO} (Estimated)	V_{EO} (Measured)	V_{BO} (Estimated)	V_{BO} (Measured)	V_{CO} (Estimated)	V_{CO} (Measured)
Emitter	2.10	1.99	0.00	0.00	0.00	0.00	0.25	0.19
Base	2.80	2.69	2.82	2.82	2.82	2.82	0.95	0.85
Collector	5.20	5.47	9.00	9.00	9.00	9.00	0.00	0.00

Table 16-3 (Multisim)

Element	V_n (Estimated)	V_n (Measured)	V_{EO} (Estimated)	V_{EO} (Measured)	V_{BO} (Estimated)	V_{BO} (Measured)	V_{CO} (Estimated)	V_{CO} (Measured)
Emitter	2.12	2.00	0.00	0.00	0.00	0.00	0.25	0.20
Base	2.82	2.80	2.82	3.00	2.82	3.00	0.95	1.00
Collector	5.22	5.60	9.00	9.00	9.00	9.00	0.00	0.00

Table 16-4 (Breadboard)

6. Then, measure these voltages and record the measured results in table 16-3.
7. After this, open the switch and remove the resistor in the emitter branch. Again, estimate and record the predicted voltage values in table 16-3.
8. Then, close the switch and measure the voltage values, putting them again in table 16-3.
9. After this, open the switch and replace the resistor into the emitter branch. Then, disconnect the lead from the base of the transistor to the voltage divider, thus leaving the base open. Estimate and record again the voltages required in table 16-3.
10. Then, close the switch and measure the voltages at the elements of the transistor, putting them again into table 16-3.
11. Open the switch again and reconnect the base of the transistor to the voltage divider. Remove the 1kΩ resistor, opening the collector branch. Then, estimate the voltages at each part of the transistor and record the values in table 16-3.
12. Then, close the switch and measure and record the voltage values and put these in the table as well.
13. Open the switch and replace the resistor into the collector branch.
14. After this, estimate the resistances at the emitter, base, and collector of the amplifier (in reference to ground) and record these values in table 16-5.

Element	Estimated (kΩ)	Measured (kΩ)
Emitter	0.560	0.560
Base	8.2	8.222
Collector	27.2	27.301

Table 16-5 (Multisim)

Element	Estimated (kΩ)	Measured (kΩ)
Emitter	0.560	0.560
Base	8.20	8.20
Collector	27.2	27.00

Table 16-6 (Breadboard)

15. Next, open the switch and measure, with a multimeter, the actual resistances at the three leads of the transistor (also in reference to ground). Then, put these values in table 16-5 as well.
16. Once all of this is done, have another group member add any fault into the circuit and have a different group member find what that fault is using the data that has been previously found.
    - When we did this Ryan opened the bypass capacitor in the emitter and Tyler was given the task of finding the fault. In order for Tyler to find the fault, he first started with dynamic checks. By doing so, he found that the voltage at the base and at the input were the same but the voltage at the collector and the output were reading close to 0.075V. Through this, Tyler found that, in fact, the capacitor on the emitter branch was open, for these were values that were found earlier in the lab when this capacitor was taken out.

Discussion:

During this lab, there seemed to be a lot of problems, but once these were solved, the lab itself did not take very long. Our first problem was with our actual protoboard. The board itself had very large holes, making the connections loose. This made it so that sometimes our parts weren't connected when they should've been. To fix this, we replaced our board with a new board that had tighter holes, allowing our connections to stay intact. Another problem we had was with our oscilloscope. When measuring voltages, the oscilloscope would sometimes give a form of distortion. It was found that this was due to the fact that the probes weren't fully into the oscilloscope and pressure needed to be applied to them to keep them in. We replaced our oscilloscope to fix this problem, and when we tested again, that distortion was no longer there. A third problem that we had during this was with our power supply. As we were trying to find what was causing our input voltage to skyrocket as we removed our bypass capacitor, we tested to see if there was a problem with our power supply. We hooked up the power supply to the oscilloscope to measure the ripple to see if that would have an effect on the circuit and we saw that the power supply had a .15V ripple, which is much too high. To fix this, we replaced the dc power supply with another new one. Our fourth problem was with our transistor. We had noticed that our transistor was not amplifying nearly enough as it should. We took out the transistor from the circuit and measured its beta, seeing that it was only 88, when it should be 200. We replaced this component as well with a transistor that was tested to have a beta of 200. Our fifth problem was with our wire lengths. We noticed on our oscilloscope that there was noise affecting the circuit, leading us to determine that our wires were too long. The thing was that, we had not used any wires besides ground, probes for the oscilloscope, alligator clips for the power supply, and a wire to connect the function generator to the circuit. This led us to narrow it down to the ground wire, for we had used two different wires, connected to each other, as ground. We changed it so that there was only one wire connecting ground to the circuit, and when we remembered, we saw that practically all of the noise had disappeared. Our sixth problem was with our bypass capacitor itself. This one wasn't a large problem, but the fact of the matter is that the wires on it were also fairly long. We replaced it with a capacitor with axial leads, decreasing the length of the wire. Our seventh (and final) problem was with the function generator. This was a problem that had bugged us since the beginning of the lab, for as we tried to fix it, we only found more and more problems that have been stated previously. The main problem was that as we affected the circuit, the input voltage adjusted, even though it shouldn't. This eventually led us to see if this problem was occurring with any other group, where it was, but not nearly as much. We then used another group's function generator, seeing that when we used theirs, it resulted in both my group and their group getting roughly the same values. We learned that because our old function generator was operating at its lowest amplitude, it did not always work to the best of its ability and its amplitude could fluctuate. When we changed the function generator, we made it so that the amplitude (on the function generator) was more than the minimum. In doing so, we also had to change our attenuator to a higher resistance.

Observations:

1. A dynamic test provides information of the signal as a whole and overall operation, providing the signal from the output which can indicate dc and voltage along with the frequency of the wave which can point out distortion. This information can pinpoint whether there is a short or open in any of the components because all of these factors directly affect the signal.
2. Signal tracing allows for the voltages across each stage of the collector to be measured. Measuring the output of each collector provides information of whether the signal is being amplified without distortiation across each stage. If the output signal is normal and properly amplified then the stage is functional, if the output signal across the collector of a stage is distortion then that stage contains a defection.
3. The estimated and measured values in Table 16-6 have little variance between them.
4. With the emitter open the voltage measured at the emitter read 0V because it was simply read across the resistor to ground with no positive side connected. The voltage across the

collector was 9V because with the open, just the voltage potential difference between the positive and negative side of the battery are being measured. The voltage across the base was 2.82V which is completely normal and this is because the voltage dividers and base voltage aren't affected by an open across the emitter.

5. When the collector is open, the voltage across the collector is 9V because it's just the potential voltage across the positive and negative side of the battery. When the collector is open, the base and emitter act as branches parallel with each other which decreases their overall resistance leading to a smaller voltage drop across them. The base is 0.7V more than the base because of the voltage dropped across the base to emitter junction.
6. Understanding how to troubleshoot a transistor amplifier makes it easier for technicians to fix audio equipment which commonly contain CE, class A, amplifiers. This would not just money but time for the technician as they don't have to order all new parts.
7. The ohmmeter sends a voltage to the circuit which can lead to current flow in the transistor which can result in a parallel path through the transistor which would impact resistance readings.
8. Diodes drop 0.7V across the base to emitter junction so measuring the voltage drop across them and finding a value close to 0V would indicate that there is a short across the emitter to base junction.

Conclusion:

Dynamic testing is a method of troubleshooting that is used to see if an amplifier is actually amplifying. To set up for a dynamic test, both the function generator and the dc power supply need to be on, doing so will allow for the oscilloscope to measure the peak-to-peak voltages in the circuit. During this lab, the input, base, collector, and output voltages were measured to normally be 30 mV, 30 mV, 3 V, and 3.1 V respectively. These values should be the values found at each of these points in the circuit, but if this amplification is not found, that shows that there is a fault in the circuit. This is shown in table 16-2 when the bypass capacitor is taken out, giving an output voltage and a collector voltage of .075 V.

A DC check is a test that is used after performing a dynamic test. To perform a DC check, one should have a sense of what values should be at certain points. In this lab it was found during the breadboards what the measured values should be at certain points. In this lab when the circuit is constructed correctly with no faults the measured values should be 2 volts at the emitter, 2.8 volts at the base, and 5.6 volts at the collector, as shown in table 16-4. Through dynamic checks one must disconnect the function generator, and either have a multimeter or a oscilloscope in order to check the DC voltage at the emitter, base, and collector. Another option for checking your circuit is to do resistance checks. When doing resistance checks, your readings at the emitter should be 560Ω, the base should be 8.2kΩ, and the collector should be 27kΩ.

When troubleshooting a defective amplifier, there are multiple processes that can be taken to find the defect. The first of these is a dynamic test, which can be tested with an oscilloscope when both the function generator and the dc power supply are on. With the oscilloscope, the input and output waveforms should be measured, seeing if amplification is actually happening. If amplification is happening, which would result in the values shown in table 16-1 and 16-2 of an input voltage of 30 mV_{p-p} and an output voltage of roughly 3.1 V, the next thing to test is the transistor itself with dc checks. For dc checks, the function generator needs to be turned off and either an oscilloscope or a multimeter can be used to check the voltages at each leg of the transistor. If these too are seen to be normal (normal meaning the voltage values found in table 16-3 or table 16-4 for V_n), the final thing to check is resistance. To do resistance checks, disconnect all power from the circuit and measure, with an ohmmeter, the resistance located in each branch of the transistor, which was found to be 560Ω in the emitter, 8.2kΩ on the base, and 27.2kΩ on the collector. If any of these checks are found to be different, the defect can easily be found. For example, if the voltage is amplifying to .075 V instead of 3.1 V, the defect is that the capacitor in the emitter is open, which is shown in table 16-2.