EXPERIMENT #3
BUFFER AMPLIFIER

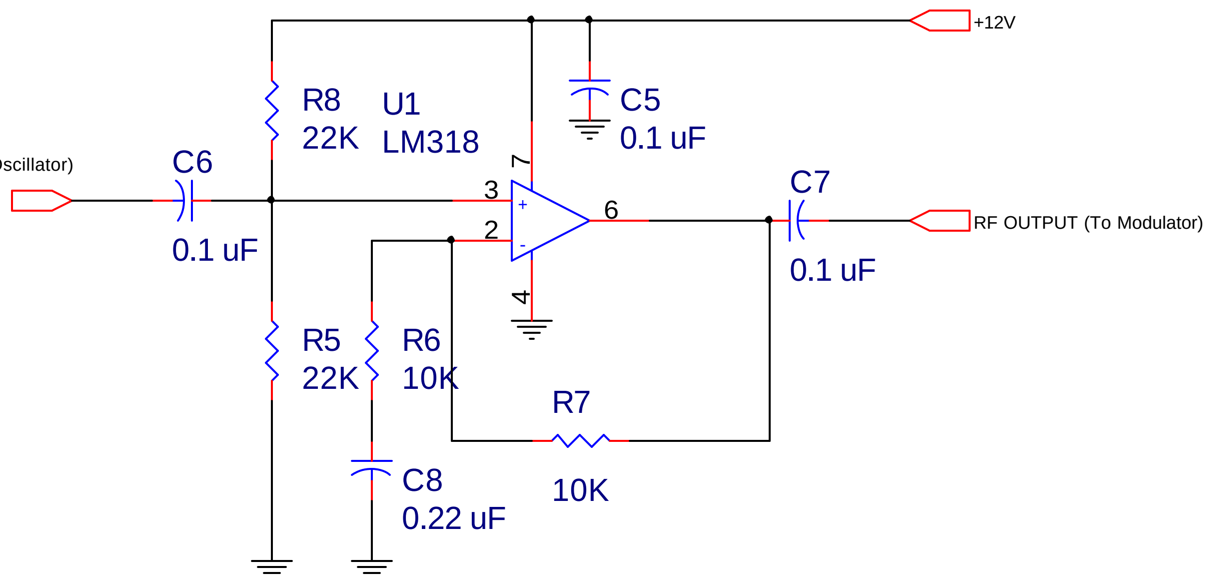
INTRODUCTION:

Oscillator circuits in radio transmitters are required to stay very close to their intended frequency--in other words, they are required to be *frequency stable*. If the master oscillator in a radio transmitter drifts too far off its intended frequency, the transmitter will be sending on the wrong frequency--and this might cause interference with other stations.

One of the things that can cause an oscillator to "drift" off frequency is a change in the load resistance it provides signal to. In a practical transmitter, the oscillator always drives a special amplifier stage with a constant input resistance; this stage is called the *buffer amplifier*.

Normally, a buffer amplifier provides very little power gain. Stages later on in the transmitter will do that. Instead, the buffer amplifier provides a light, but constant load for the oscillator, regardless of the load on the output terminals. Thus, the oscillator cannot drift off frequency due to output load changes.

Normally, a transmitter will use a buffer amplifier constructed using a class-A transistor amplifier with tuned circuits. The circuit you'll build here is the op-amp equivalent.

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IMPORTANT: C5 must be placed directly onto pin 7 of U1
           to prevent oscillation.
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Figure 1: Buffer Amplifier

CIRCUIT ANALYSIS:

The unit is designed around an op-amp wired as a non-inverting amplifier. Which resistors set the gain? Right, R7, and R6.

You might remember the old "standby" formula for the voltage gain of the non-inverting operational amplifier; that is:

$$Av = \frac{Rf}{Ri} + 1$$

Of course, R6 is in the *"Ri"* position, and *"Rf"* is R7.

The RF OUTPUT from the oscillator is AC coupled into the amplifier by C6, while R5 and R8 form a *voltage divider* to bias the non-inverting input of the op-amp at half *Vcc*, or approximately 6 volts. When the circuit is operating correctly, the DC voltage readings on pins 2,3, and 6 of the op-amp will all be close to 6 volts. Capacitor C8 is an DC block that provides an AC ground at the bottom of R6, while preventing DC current from flowing there, which would disrupt the mid-point bias of the op-amp.

The output of the buffer amplifier is coupled to the next stage by C7, a 0.1 µF capacitor. At radio frequencies, large coupling capacitors are no longer needed. Why do you think this is so? Right, it's because Xc (capacitive reactance) goes down as frequency goes up. At very high frequencies, a relatively small capacitor will have only a few ohms of reactance--in other words, it will be a good coupling capacitor. *At radio frequencies, coupling capacitors will almost always tend to be smaller than 1 mF.*

C5 is an important capacitor. It serves as an *RF Bypass* for the power supply buss. It is possible for a little bit (well, sometimes a lot!) of radio frequency energy to "leak" into the power supply busses. The RF energy on the power supply will travel right back to the most sensitive stages in the unit; this is unwanted feedback, and usually it results in unwanted oscillation. C5 shorts any RF voltage present on the power supply busses to ground, before it can reach other stages. Well-built equipment always has plenty of strategically-placed RF bypass capacitors. In fact, capacitors are generally the most numerous components in any radio equipment.

LABORATORY PROCEDURE:

Name _______________ Sign-off _________

Some op-amps are better suited for RF amplification than others. In the first part of the experiment, you will compare the performance of a standard 741 op-amp with the 318 op-amp. (The pin-outs of both units are identical.)

Part I: 741, 318 Comparative Frequency Response

0. Use 10:1 probes for all oscilloscope measurements.

1. Build the circuit of figure 1 using a 741 op-amp. It is OK to build on the same breadboard as the oscillator.

   <u>Don't connect the RF INPUT of this circuit to the oscillator stage yet!</u>

2. Now, tell me, what should the voltage gain of this circuit be? **Show your calculation**.

   Voltage gain (calculated):__________

> Important: Even though the units "cancel out" in this calculation, voltage gain should be reported in units of *volts per volt*, or *V/V*.

3. Connect the signal generator sine wave output to the *RF INPUT* of the circuit.

4. Connect channel #1 of the scope to the *RF INPUT* of the circuit.

5. Connect channel #2 of the scope to the *RF OUTPUT* of the circuit.

6. Set the signal generator for 1 KHz, 1 volt peak-to-peak output. Use channel #1 of the scope to verify the settings.

7. The output should be visible on channel #2. What is the peak-to-peak value?

   Vout p-p @ 1KHz:____________

8. What is the *measured* voltage gain, in V/V, for the circuit? (Use the information from steps 6 and 7 to calculate.) **Show your work**.

   Voltage gain (measured): ____________

9. Record the results from step 8 in the table below; then go back and repeat steps 7 and 8 for each frequency shown in the table.

> *NOTE: Make sure that the output of the signal generator is still 1 Volt p-p after each frequency change!*

Frequency	Vin (p-p)	Vout (p-p)	Gain A_v, V/V	Gain, dB
1 KHz				
10 KHz				
20 KHz				
50 KHz				
100 KHz				
200 KHz				
500 KHz				
1 MHz				
2 MHz				

Table 1: Frequency Response using the 741

10. Fill in the rest of the missing information in the table. Remember the formula for dB gain, given two voltages? It is:

$dB = 20 \log Av$ Where *Av* is the voltage gain in V/V.

11. At what frequency did the gain of the 741 start to decrease?

Frequency @ 741 gain decrease : ______________

12. Now replace the LM741 with the LM318, and repeat steps 6-10 above, using table 2. From here on out, the LM318 will be left in the circuit.

Frequency	Vin (p-p)	Vout (p-p)	Gain A_v, V/V	Gain, dB
1 KHz				
10 KHz				
20 KHz				
50 KHz				
100 KHz				
200 KHz				
500 KHz				
1 MHz				
2 MHz				

Table 2: Frequency Response using the 318

13. At what frequency did the gain of the 318 start to decrease? (If a gain decrease occurred.)

Frequency @ 318 gain decrease : ______________

14. Comparing the frequency response information from tables 1 and 2, which op-amp would be best suited as an RF amplifier, the 741 or the 318? Why?

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Part II: Oscillator and Buffer Amplifier

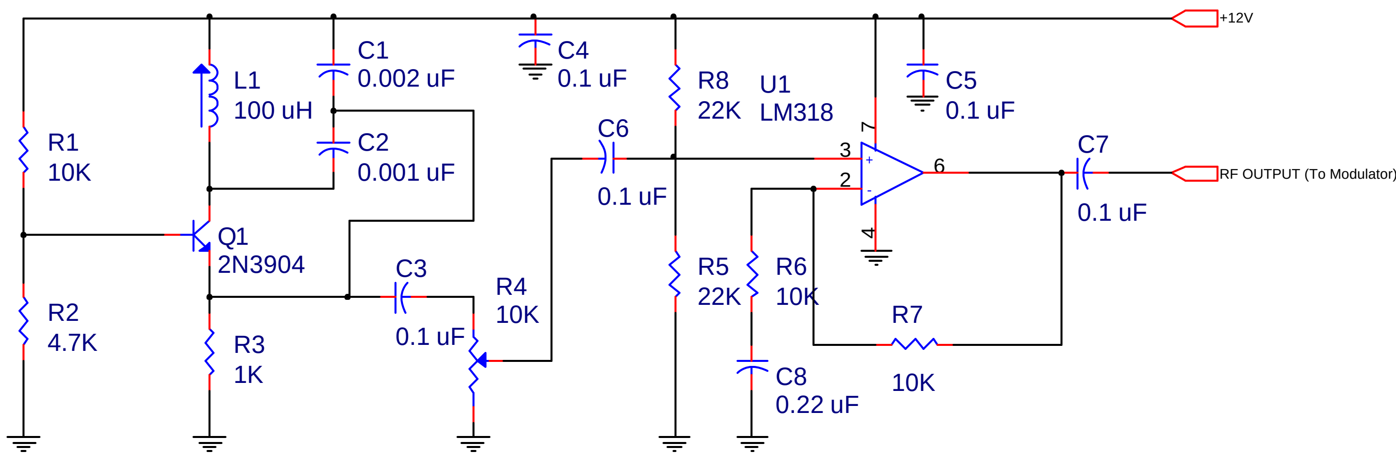

Figure 2: Oscillator and Buffer Amplifier

15. Before connecting the oscillator to the buffer amplifier, very carefully measure the following:

Oscillator *RF OUTPUT* voltage peak-to-peak:___________

Oscillator *RF OUTPUT* frequency :___________

Right! These are the "unloaded" values for the oscillator.

16. Now connect or "couple" the oscillator to the buffer amplifier. Figure 2 shows the complete circuit you've built to this point.

17. Re-measure the oscillator output voltage amplitude and frequency. These are the values when "loaded" by the buffer amplifier.

Oscillator *RF OUTPUT* voltage peak-to-peak (loaded):___________

Oscillator *RF OUTPUT* frequency (loaded):___________

18. How much difference is there between the measurements in steps 15 and 17?

Output voltage difference ? _________________

Output frequency difference ? _______________

19. From the comparisons in step 18, would you say that connection of the buffer amplifier had a great effect on the output of the oscillator? Why or why not?

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20. What is the maximum undistorted *RF OUTPUT* voltage you can get from the buffer amplifier output by adjusting R4?

Maximum undistorted *RF OUTPUT* output voltage:______________

Troubleshooting Hints

Most troubles with the *buffer amplifier* circuit can be traced to wiring errors or power supply troubles. In case of trouble, try the following:

1. Perform a careful visual inspection of the circuit, comparing it to the schematic diagram. Make sure each component value matches what is called for on the schematic diagram.

2. Check the DC voltage at the following locations:

Circuit Location	DC voltage reading and tolerance	Comments
U1 pin 7	12 V +/- 0.5 V	*Vcc* power supply for the operational amplifier IC
U1 pins 2,3,6	6 V +/- 0.25 V	The potential of 6V represents a centered DC operating point for the amplifier circuit. Resistors R8 and R5 set up this operating point as a voltage divider. Pins 2 and 6 should "follow" the voltage provided to pin 3 by this divider.

3. Check the AC voltages <u>in the order listed</u> at the following locations, using an oscilloscope and a 10:1 probe. The test points are listed in order of signal flow, from input to output.

Circuit Location	AC signal reading	Comments
Junction of C3 and R4	5 Vpp +/- 3 Vpp @ 480 - 680 KHz.	Oscillator output signal voltage. Frequency determined by L1 adjustment.
U1 pin 3	0 - 5 Vpp @ 480 - 680 KHz.	Input signal to amplifier circuit. The amplitude of this voltage is controlled by potentiometer R4.
U1 pin 6	0 - 10 Vpp @ 480 - 680 KHz	Output signal of amplifier circuit.

QUESTIONS

1. Why is a buffer amplifier used after an oscillator stage? (What is the benefit?)

2. Are large electrolytic capacitors necessary for coupling RF amplifier stages? Why or why not?

3. What is the function of an RF bypass capacitor?

4. What is a possible symptom of an OPEN RF bypass capacitor?

5. What have you learned from this experiment?