

# ECE 404L: RF ELECTRONICS LABORATORY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

MICHIGAN STATE UNIVERSITY

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**I. TITLE:** Lab IV - AM/FM Radio - FM Radio

**II. PURPOSE:**

This lab will focus on soldering and testing of the FM portion of the radio.

The concepts covered are:

1. frequency modulation (FM);
2. superhetrodyne receiver;
3. FM ratio detector and automatic frequency control (AFC);
4. Intermediate Frequency (IF) transformers;
5. IF amplifiers;
6. FM oscillator and mixer.

The laboratory techniques covered are:

1. using the FM feature on the function generator;
2. troubleshooting by doing static measurements with a digital multimeter;
3. measuring gain, bandwidth and quality factor with a scope;
4. tuning.

**III. BACKGROUND MATERIAL:**

See Lab Lecture Notes.

**IV. EQUIPMENT REQUIRED:**

- 1 Agilent 54833A Infiniium Oscilloscope
- 2 Agilent 1161A 10:1 Miniature Passive Probes
- 1 Agilent 33250A Function / Arbitrary Waveform Generator
- 1 Fluke 8840A Digital Multimeter
- 1 HP 6216C DC Power Supply
- 1 Soldering Station

## V. PARTS REQUIRED:

- 1 Elenco Model AM/FM-108TK kit
- 1 9-Volt adapter plug
- 1 Sub-miniature phono plug
- 2 BNC-to-Banana adapters
- 1 .001 $\mu$ F capacitor

## VI. LABORATORY PROCEDURE:

### A) FM Ratio Detector

1. This is a two week lab. When time runs out for the first week, go to section N) which describes clean-up. Pick up where you left off the following week.
2. Get your Elenco AM/FM-108TK kit from the storage cabinet.
3. Find and remove the parts listed on page 34 of the Assembly and Instruction Manual. These are in your FM RADIO PARTS bag.

We have found that some of the IF Cans (transformers) are defective. One quick way to test them is to take a resistance measurement. Because these Cans are used in the 10 MHz range, there is fewer turns of wire and the resistor ratio is very different from the turns ratio in this case. So we will just measure the resistance to look for defects.

We will still need to do a 4-wire measurement. Locate the green dot FM IF Coil (T3). The primary side has three terminals. Measure and record in the Lab Report the resistance of the outer two terminals of the primary side. This should be around 290 m $\Omega$ . Then measure the resistance of the secondary windings which has two terminals. Record. This should be around 63 m $\Omega$ . If these resistances are way off ask your instructor for another green dot transformer.

Locate the blue dot FM Detector Coil (T5). Measure and record in the Lab Report the resistance of the outer two terminals of the primary side. This should be around 250 m $\Omega$ . Then measure the resistance of the secondary windings which has two terminals. Record. This should be around 40 m $\Omega$ . If these resistances are way off ask your instructor for another blue dot transformer.

The pink dot FM detector coil (T4) is connected very differently from all of our other Cans. The bottom view is shown in Fig. 1. Measure and record the resistance between pins 1 and 6 in the Lab Report. This should be around 360 m $\Omega$ . Then measure the resistance between pins 3 and 5. Record. This should be around 110 m $\Omega$ . If these resistances are

way off ask your instructor for another pink dot transformer.

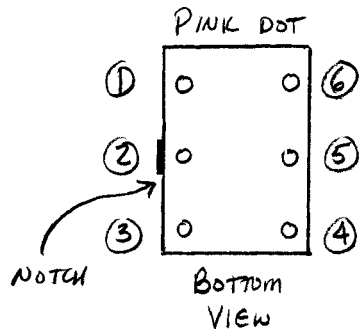


Figure 1. Bottom view of the pink dot Can

4. Prepare your soldering iron for use. Do all soldering on the soldering tray. Please take turns soldering in the parts.

Because you are handling solder which contains lead, please make sure you wash your hands with hot soapy water when you finish lab.

If you are unsure about any instructions, please ask your instructor for help and/or view one of the assembled radios.

5. Complete the assembly instructions on page 34 of the Assembly and Instruction Manual.

#### B) Static Measurements of the FM Ratio Detector

1. We will use the HP6216C power supply in place of the 9 volt battery. The HP6216C power supply is adjustable from a magnitude of 0 to 30V.

Set the magnitude of the supply to approximately 9 volts and set the current limiter to approximately 25mA. Leave the meter in the current reading position. If you have forgotten how to do this, see Lab II.

2. Obtain a 9 volt battery adapter from your Parts' Box. Do not connect this to the radio until instructed to do so.
3. Connect the **BLACK** wire of the battery adapter to the **positive terminal** of the power supply and the **RED** wire of the battery adapter to the **negative terminal**.

Using a black banana wire, short the minus terminal to the ground terminal.

4. Turn **OFF** the power supply. Obtain a sub-miniature plug from the wall racks and connect the banana ends to a 10  $\Omega$  load mounted on a gray block. Plug the other end into the earphone jack on the printed circuit

(pc) board. (This will make the following measurements less painful!)

5. Set the volume control on the radio to the OFF position (turned fully counter-clockwise). Connect the 9 volt adapter to the battery holder on the radio. Turn **ON** the power supply. The current meter should read zero. If not ask your instructor for help.
6. While watching the current meter on the power supply, turn the volume control of the radio to the **ON** position (rotate clockwise until a click is heard). The meter should read under 20 mA. If so, go to step 7. If this is not the case, turn off the power supply. Check for shorts or poor solder connections.

<p>Note: If your radio tries to draw more than 25mA of current then the voltage will collapse, that is, it will drop to a much lower value in voltage than what is set by the voltage control. <b><i>Do not try to increase the current control setting because something is seriously wrong.</i></b> Increasing the current control may melt some of the components in your radio. Please ask your instructor for help.</p>
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7. Connect the **LO** input of the Fluke 8840A DMM to the ground of the power supply. Using a grabber-to-banana wire on the positive **HI** input of the DMM, measure the power supply voltage at the emitter of Q13 and adjust if necessary to 9.0 volts.

Make sure that the AM/FM switch is in the FM position.

Measure the DC voltage as shown in Fig. 29 on page 35 of the Assembly and Instruction Manual. This should be between 7 and 9 Volts.

If so, proceed to step 8. If this reading is off, turn off the power supply and check that R25 and C25 are installed correctly or ask your instructor for help.

8. Measure the DC voltage at the emitter of Q6 as shown in Fig. 30. This should be approximately 0.8 volts. Record in the Lab Report.

If so, proceed to step 9. If not, turn off the power supply and check that R20, R21, R22, R24 and Q6 are installed correctly or ask your instructor for help.

9. Turn the volume control to the **OFF** position.

C) Dynamic Measurements of the FM Ratio Detector

1. To connect the function generator to the radio, we need to convert the BNC connector on the function generator to a banana connector. Place the BNC-to-Banana adaptor, found in the blue box on your lab bench, on the function generator output. Connect a black banana wire from the black terminal on the function generator to the black ground terminal on the power supply.

Connect a grabber wire from the red terminal of the function generator to a  $0.001\mu\text{F}$  capacitor from your Parts' Box.

Connect the banana plug of another grabber wire into an alligator clip from your blue box. Connect the alligator clip to the other side of the  $0.001\mu\text{F}$  capacitor. Connect the remaining grabber end to the base of Q6 as shown in Fig. 31 on page 36 of the Assembly and Instruction Manual.

2. Turn **ON** the volume control and monitor the current of the power supply. It should still be less than 20 mA. Turn **ON** the function generator and using the keypad set the frequency to 10.7 MHz with an amplitude of  $200\text{ mV}_{\text{p,p}}$  (High Z).
3. Turn **ON** the oscilloscope. If not already present, connect two 10:1 probes to your scope, one for channel **1** and one for channel **2**. Press the **Default Setup** button to clear the settings of the last user.

We would like to display the base of Q6 on channel **1** and TP8 on channel **2**. Connect the ground clips to any grounded point on the pc board.

4. Using a small screw driver, adjust T4 for peak at TP8. Adjust the amplitude of the function generator until the output is about  $700\text{ mV}_{\text{p,p}}$  or an undistorted sinewave. Use AC coupling and averaging.

If you are having trouble doing this, adjust T3 until TP8 peaks.

Measure the peak-to-peak voltage at TP8 (which is the collector of Q6) and at the base of Q6. Record and calculate the gain of the FM Ratio Detector Amplifier. It may be around 5 to 40.

5. Print these waveform for each member of your group. Mark which waveform is which. Mark this section letter and number on the top right side of your plot and attach it as indicated in the Lab Report.
6. Leave the function generator set to 10.7 MHz. Turn on the frequency modulation option of the function generator by pressing the **MOD** button on the lower left side. Press **Type** and select **FM**. Set the frequency

deviation ( **Freq Dev** ) to 22.5 kHz. Set the **FM Freq** to 2 kHz.

7. Remove the 10 $\Omega$  load. Adjust the volume control until you hear the 2 kHz tone in the small speaker. Set the volume control to a comfortable sound level.
8. We want to display this 2 kHz tone. Place the channel ② probe at the collector of Q10. Again to block the DC level, check that the coupling of channel ② to AC. Adjust the scope to display only the 2 kHz tone. Adjust the volume control if necessary to get an undistorted sinewave.

If the waveform is erratic you may want to use High Frequency Reject on the triggering but don't forget to turn this off when finished.

You can also replace the speaker with the 10  $\Omega$  resistor again if the sound is too irritating.

9. Adjust T4 until the 2 kHz tone is maximum. Adjust T5 for a maximum. Repeat as necessary to maximize the tone.
10. Print this waveform for each member of your group. Mark the waveform as the collector of Q10. Mark this section letter and number on the top right side of your plot and attach it as indicated in the Lab Report.
11. Turn **OFF** and disconnect the power supply.
12. Turn the Output of the function generator **OFF** and disconnect it from the radio.

#### D) Second FM IF Amplifier

1. Find and remove the parts listed on page 38 of the Assembly and Instruction Manual. These are in your FM RADIO PARTS bag.

Locate the green dot FM IF Coil (T2). Measure and record in the Lab Report the resistance of the outer two terminals of the primary side. This should be around 290 m $\Omega$ . Then measure the resistance of the secondary windings which has two terminals. Record. This should be around 63 m $\Omega$ . If these resistances are way off ask your instructor for another green dot transformer.

Complete the assembly instructions on page 38.

2. Reconnect the power supply and turn **ON** the power supply. Again monitor the current for problems.
3. Measure the DC voltage at TP10 which is the base of Q5. This should be

approximately 1.45 volts. Record the value in the Lab Report.

If so, proceed to step 4. If you don't get this reading, turn off the power supply and check that R16, R17, R18, T2 and Q5 are installed correctly or ask your instructor for help.

4. Connect the function generator to TP10 through a 0.001 $\mu$ F capacitor as shown in Fig. 36 on page 39 of the Assembly and Instruction Manual. Use banana-to-grabber wires and alligator clips to make this connection like that done in section VI-C.
5. Connect one channel of the scope to TP9 and the other to TP10.
6. Turn **ON** the function generator output and set the frequency to 10.7 MHz and 100 mV<sub>P,P</sub> (High Z). Turn **OFF** the FM modulation by pressing the **MOD** button.

Increase the amplitude of the function generator until the voltage at TP9 is 4 V<sub>P,P</sub>.

7. What we need to do next is make the amplifier resonate at 10.7 MHz. We will do this by varying the inductance of the coil.

Using a small screwdriver, adjust T3 so that the gain from TP10 to TP9 is maximized. Re-adjust the function generator's amplitude to maintain an approximate 4 V<sub>P,P</sub> signal at TP9. Re-adjust T3 slightly to verify that the gain is maximum. Repeat if necessary.

8. Once T3 is aligned, measure the peak-to-peak voltage at TP9 (which is the collector of Q5) and at TP10 (which is the base of Q5). Record and calculate the gain of the 2nd IF Amplifier. It may be around 10 to 30.
9. Print these waveform for each member of your group. Mark which waveform is which. Mark this section letter and number on the top right side of your plot and attach it as indicated in the Lab Report.
10. Vary the frequency of the function generator and measure the upper and lower 3 dB frequencies, that is, where the voltage at TP9 drops to 0.707 of its center frequency value or approximately 2.82 V<sub>P,P</sub>. Record.

As a check, calculate  $f_0$  as indicated in the Lab Report. It should be very close to 10.7 MHz. If not, repeat the bandwidth measurements.

Calculate the bandwidth and  $Q_0$  as indicated in the Lab Report which may be around 300 to 600 kHz and 36 to 18, respectively.

11. Turn **OFF** and disconnect the power supply.

12. Turn the Output of the function generator **OFF** and disconnect it from the radio.

E) First FM IF Amplifier

1. Find and remove the parts listed on page 40 of the Assembly and Instruction Manual. These are in your FM RADIO PARTS bag.

Locate the orange dot FM Mixer Coil (T1). Measure and record in the Lab Report the resistance of the outer two terminals of the primary side. This should be around 175 m $\Omega$ . Then measure the resistance of the secondary windings which has two terminals. Record. This should be around 40 m $\Omega$ . If these resistances are way off ask your instructor for another orange dot transformer.

Complete the assembly instructions on page 40.

2. Reconnect the power supply and turn **ON** the power supply. Again monitor the current for problems.
3. Measure the DC voltage at the base of Q4. This should be approximately 1.45 volts. Record the value in the Lab Report.

If so, proceed to step 4. If you don't get this reading, turn off the power supply and check that R12, R13, R15, T1 and Q4 are installed correctly or ask your instructor for help.

4. Connect the function generator to the base of Q4 through a 0.001 $\mu$ F capacitor as shown in Fig. 38 on page 41 of the Assembly and Instruction Manual. Use banana-to-grabber wires and alligator clips to make this connection like that done in section VI-D.
5. Connect one channel of the scope to TP11 and the other to the base of Q4.
6. Turn **ON** the function generator output and set the frequency to 10.7 MHz and 100 mV<sub>P-P</sub> (High Z).

Increase the amplitude of the function generator until the voltage at TP11 is 4 V<sub>P-P</sub>.

7. What we need to do next is make the amplifier resonate at 10.7 MHz. We will do this again by varying the inductance of the coil.

Using a small screwdriver, adjust T2 so that the gain from the base of Q4 to TP11 is maximized. Re-adjust the function generator's amplitude to maintain an approximate 4 V<sub>P-P</sub> signal at TP11. Re-adjust T2 slightly to verify that the gain is maximum. Repeat if necessary.

8. Once T2 is aligned, measure the peak-to-peak voltage at TP11 (which is the collector of Q4) and at the base of Q4. Record and calculate the gain of the 1st IF Amplifier. It may be around 3 to 10.
9. Print these waveform for each member of your group. Mark which waveform is which. Mark this section letter and number on the top right side of your plot and attach it as indicated in the Lab Report.
10. Vary the frequency of the function generator and measure the upper and lower 3 dB frequencies, that is, where the voltage at TP11 drops to 0.707 of its center frequency value or approximately  $2.82 V_{P.P.}$ . Record.

As a check, calculate  $f_o$  as indicated in the Lab Report. It should be very close to 10.7 MHz. If not, repeat the bandwidth measurements.

Calculate the bandwidth and  $Q_o$  as indicated in the Lab Report which may be around 300 to 600 kHz and 36 to 18, respectively.

11. Turn **OFF** and disconnect the power supply.
12. Turn the Output of the function generator **OFF** and disconnect it from the radio.

#### F) FM Mixer

1. Find and remove the parts listed on page 42 of the Assembly and Instruction Manual. These are in your FM RADIO PARTS bag. Complete the assembly instructions on page 42.
2. Reconnect the power supply and turn **ON** the power supply. Again monitor the current for problems.
3. Measure the DC voltage at TP13. This may be approximately 1.8 volts. Record the value in the Lab Report.

If your measured voltage differs by more than 2 volts, turn off the power supply and check that R7, R8, R11 and Q3 are installed correctly or ask your instructor for help.

4. Connect the function generator to TP13 through a  $0.001\mu\text{F}$  capacitor as shown in Fig. 40 on page 44 of the Assembly and Instruction Manual. Use banana-to-grabber wires and alligator clips to make this connection like that done in section VI-E.
5. Connect one channel of the scope to TP12 and the other to TP13
6. Turn **ON** the function generator output and set the frequency to 10.7

MHz and  $100 \text{ mV}_{\text{p-p}}$  (High Z).

Increase the amplitude of the function generator until the voltage at TP12 is  $4 \text{ V}_{\text{p-p}}$ .

7. Using a small screwdriver, tune T1 so that the gain from TP13 to TP12 is maximized at 10.7 MHz while re-adjusting the generator's amplitude to maintain a  $4 \text{ V}_{\text{p-p}}$  signal at TP12.
8. Once T1 is aligned, measure the peak-to-peak voltage at TP12 (which is the collector of Q3) and at TP13 (which is the base of Q3). Record and calculate the gain of the Mixer Amplifier. It maybe as low as 2.5. (*The gain is lower here because the emitter resistor is not bypassed to ground.*)
9. Print these waveform for each member of your group. Mark which waveform is which. Mark this section letter and number on the top right side of your plot and attach it as indicated in the Lab Report.
10. Vary the frequency of the function generator and measure the upper and lower 3 dB frequencies, that is, where the voltage at TP12 drops to 0.707 of its center frequency value or approximately  $2.82 \text{ V}_{\text{p-p}}$ . Record.

As a check, calculate  $f_0$  as indicated in the Lab Report. It should be very close to 10.7 MHz. If not, repeat the bandwidth measurements.

Calculate the bandwidth and  $Q_0$  as indicated in the Lab Report which may be around 300 to 600 kHz and 36 to 18, respectively.

11. Turn **OFF** and disconnect the power supply.
12. Turn the Output of the function generator **OFF** and disconnect it from the radio.

#### G) FM Oscillator

1. Find and remove the parts listed on page 44 of the Assembly and Instruction Manual. These are in your FM RADIO PARTS bag. Complete the assembly instructions on page 44.
2. Reconnect the power supply and turn **ON** the power supply. Again monitor the current for problems.
3. Measure the DC voltage at the base of Q2. This may be approximately 3.5 volts. Record the value in the Lab Report.

If so, proceed to step 4. If you don't get this reading, turn off the power supply and check that R4, R5 and Q2 are installed correctly or ask your

instructor for help.

4. Turn **OFF** and disconnect the power supply.
- H) Automatic Frequency Control (AFC)
1. Find and remove the parts listed on page 45 of the Assembly and Instruction Manual. These are in your FM RADIO PARTS bag. Complete the assembly instructions on page 45.
  2. Reconnect the power supply and turn **ON** the power supply. Again monitor the current for problems.
  3. Connect the function generator again to TP13 through a  $0.001\mu\text{F}$  capacitor as shown in Fig. 42 on page 46 of the Assembly and Instruction Manual. Use banana-to-grabber wires and alligator clips to make this connection like that done in section VI-F.
  4. Connect the DMM to measure the DC voltage at the AFC node as shown in Fig. 42 on page 46 of the Assembly and Instruction Manual.
  5. Turn **ON** the function generator output and set the frequency to 10.7 MHz and  $100\text{ mV}_{\text{p,p}}$  (High Z). Record the DC voltage in the Lab Report.
  6. Decrease the frequency of the generator to 10.6 MHz. You should see an increase in the DC voltage. Record the value in the Lab Report.
- If so, proceed to step 7. If you don't get this response, turn off the power supply and check that R29, R30, C26, C27 and D1 are installed correctly or ask your instructor for help.
7. Increase the frequency of the generator to 10.8 MHz. You should see a decrease in the DC voltage from that in VI-H-5. Record the value in the Lab Report.
- This correction voltage is what keeps the oscillator from drifting.
8. Turn **OFF** and disconnect the power supply.
  9. Turn the Output of the function generator **OFF** and disconnect it from the radio.
- D) RF Amplifier
1. Find and remove the parts listed on page 46 of the Assembly and Instruction Manual. These are in your FM RADIO PARTS bag. Complete the assembly instructions on page 46.

2. Reconnect the power supply and turn **ON** the power supply. Again monitor the current for problems.
3. Measure the DC voltage at the base of Q1. This should be approximately 1.6 volts. Record the value in the Lab Report.

If so, proceed to step 4. If you don't get this reading, turn off the power supply and check that R1, R2, R3 and Q1 are installed correctly or ask your instructor for help.

4. Turn **OFF** and disconnect the power supply.

#### J) FM Antenna

1. Find and remove the parts listed on page 47 of the Assembly and Instruction Manual. Complete the assembly instructions in Fig. O on page 47.

#### K) IF Alignment

1. Connect the function generator to TP14 through a 0.001 $\mu$ F capacitor as shown in Fig. 47 on page 49 of the Assembly and Instruction Manual. Use banana-to-grabber wires and alligator clips to make this connection like that done in section VI-H.

Connect one channel of the scope to the collector of Q10.

2. Set the function generator to 10.7 MHz with 100 mV<sub>P-P</sub> (High Z) . Turn on the frequency modulation option of the function generator by pressing the **MOD** button on the lower left side. Press **Type** and select **FM**. Set the frequency deviation ( **Freq Dev** ) to 22.5 kHz. Set the **FM Freq** to 1 kHz.
3. Using a banana-to-grabber wire with an alligator clip, short the base and emitter of Q2 as shown in Fig. 47 on page 49 of the Assembly and Instruction Manual. This will "kill" the local oscillator.

Be careful on how you position the alligator clip so that you don't short other points on the radio. Monitor the supply current as an indicator of problems.

4. Reconnect the power supply and turn **ON** the power supply. Again monitor the current for problems.
5. Vary the volume control until a 1 V<sub>P-P</sub>, 1 kHz signal is seen on the scope. Use the toolbar to display the peak-to-peak voltage. (If the sound is irritating you can use the 10  $\Omega$  load.)

6. Using a screwdriver, adjust T1 for a peak on the scope by watching the toolbar's displayed value. Likewise, adjust T2 for a peak, then T3 and then T4. If the waveform is distorted slightly adjust T5.

7. You now have aligned the FM IF amplifiers to 10.7 MHz.

Print this waveform for each member of your group. Mark what waveform this is. Mark this section letter and number on the top right side of your plot and attach it as indicated in the Lab Report.

8. Play the 1k Hz sound through the JBL speaker. Remove the grabber connector from TP14 and leave it near the radio. Does the sound in the speaker go away? If not, why?

9. Remove the short circuit from the base-emitter of Q2. Disconnect the scope and function generator from the radio.

#### L) Oscillator Alignment

1. Locate the wooden spacer shown in Fig. 46 on page 49 of the Assembly and Instruction Manual. Use this to spread the winding of coil L3 to about a spacing of 1/16th of an inch.

2. Tune your radio to a station on the low end of the dial. If you cannot discern what station this is, ask the lab instructor for an FM radio and find the station.

3. If the actual frequency of the radio station is below where the white pointer is roughly pointing then go to step 4. If not then L3 is too small. Press together the coil and then find the station by rotating the dial.

Press together or pull apart the windings until the white pointer setting is correct. Go to step 5.

4. If the actual frequency of the radio station is below where the white pointer is roughly pointing then L3 is too large. Spread the coil wider and then find the station by rotating the dial.

Press together or pull apart the windings until the white pointer setting is correct. Go to step 5.

5. Tune your radio to a station on the high end of the dial. If you cannot discern what station this is, ask the lab instructor for an FM radio and find the station.

6. Set the white pointer to the correct frequency. Locate the FM oscillator trimmer capacitor found in Fig. L on page 24 of the Assembly and

Instruction Manual and adjust until the station is found.

7. Repeat steps 2 - 6 until the dial settings are correct.

You have now set the FM oscillator range at 98.7 MHz to 118.7 MHz.

M) RF Alignment

1. Press together L1 and L2.
2. Spread coil L1 apart so that it looks like Fig. 46 on page 49 of the Assembly and Instruction Manual.
3. Tune the radio of a weak station and adjust the FM antenna trimmer capacitor (see Fig. L on page 24) so that the received station is stronger.

This process of adjusting L1 and C of the trimmer optimizes the gain of the RF amplifier.

4. Check the radio again for other stations. If no further alignment is needed, use the sub-miniature plug to connect the JBL speaker on your lab bench and test your radio reception.
5. Demonstrate the operation of your FM radio to your lab instructor. Have the instructor sign off on this in the Lab Report.

N) Clean up

Please return all wires to the racks from which they were taken. Put the 9 volt adaptor back into the Parts' Box. Turn off all equipment and brush off your bench. Put all of your radio parts back into the box, make sure your name is on the box. Place the box back in your storage cabinet.

O) Lab Report

1. Finish your Lab Report at home. Use the information that you have gathered to write a qualitative description of how the FM radio works.

This due at the next lab meeting after completion of step VI-M-5.

# Lab Report

## Lab IV - AM/FM Radio - FM Radio

Name: .....

Partner: .....

Date: .....

Lab Section Number .....

Lab Station Number .....

### Code of Ethics Declaration

All of the attached work was performed by our lab group as listed above. We did not obtain any information or data from any other group in this lab or any other lab section.

Signature .....

VI-A-3

Primary resistance (green dot) =  $R_p$  = \_\_\_\_\_

Secondary resistance (green dot) =  $R_s$  = \_\_\_\_\_

Primary resistance (blue dot) =  $R_p$  = \_\_\_\_\_

Secondary resistance (blue dot) =  $R_s$  = \_\_\_\_\_

Resistance Pins 1 to 6 (pink dot) =  $R_{1-6}$  = \_\_\_\_\_

Resistance Pins 3 to 5 (pink dot) =  $R_{3-5}$  = \_\_\_\_\_

VI-B-8

$V_{EQ6}$  = \_\_\_\_\_

VI-C-4

$V_{TP8}$  = \_\_\_\_\_  $V_{p-p}$

$V_{BQ6}$  = \_\_\_\_\_  $V_{p-p}$

|Gain| = \_\_\_\_\_

VI-C-5

Mark VI-C-5 on the top right side of your plot and attach as the next page.

VI-C-10

Mark VI-C-10 on the top right side of your plot and attach behind VI-C-5.

VI-D-1

Primary resistance (green dot) =  $R_p$  = \_\_\_\_\_

Secondary resistance (green dot) =  $R_s$  = \_\_\_\_\_

VI-D-3

$V_{TP10}$  = \_\_\_\_\_

VI-D-8

$V_{TP9}$  = \_\_\_\_\_  $V_{p-p}$

$V_{TP10}$  = \_\_\_\_\_  $V_{p-p}$

|Gain| = \_\_\_\_\_

VI-D-9

Mark VI-D-9 on the top right side of your plot and attach as the next page.

VI-D-10

Upper -3dB frequency ( $f_{UPPER}$ ) = \_\_\_\_\_

Lower -3dB frequency ( $f_{LOWER}$ ) = \_\_\_\_\_

$f_o = [f_{UPPER} \cdot f_{LOWER}]^{0.5} =$  \_\_\_\_\_

$BW = f_{UPPER} - f_{LOWER} =$  \_\_\_\_\_

$Q_o = f_o / (f_{UPPER} - f_{LOWER}) =$  \_\_\_\_\_

VI-E-1

Primary resistance (orange dot) =  $R_p$  = \_\_\_\_\_

Secondary resistance (orange dot) =  $R_s$  = \_\_\_\_\_

VI-E-3

$$V_{BQ4} = \underline{\hspace{2cm}}$$

VI-E-8

$$V_{TP11} = \underline{\hspace{2cm}} V_{p-p}$$

$$V_{BQ4} = \underline{\hspace{2cm}} V_{p-p}$$

$$|\text{Gain}| = \underline{\hspace{2cm}}$$

VI-E-9

Mark VI-E-9 on the top right side of your plot and attach as the next page.

VI-E-10

$$\text{Upper -3dB frequency ( } f_{\text{UPPER}} \text{ )} = \underline{\hspace{2cm}}$$

$$\text{Lower -3dB frequency ( } f_{\text{LOWER}} \text{ )} = \underline{\hspace{2cm}}$$

$$f_o = [ f_{\text{UPPER}} \cdot f_{\text{LOWER}} ]^{0.5} = \underline{\hspace{2cm}}$$

$$\text{BW} = f_{\text{UPPER}} - f_{\text{LOWER}} = \underline{\hspace{2cm}}$$

$$Q_o = f_o / ( f_{\text{UPPER}} - f_{\text{LOWER}} ) = \underline{\hspace{2cm}}$$

VI-F-3

$$V_{TP13} = \underline{\hspace{2cm}}$$

VI-F-8

$$V_{TP12} = \underline{\hspace{2cm}} V_{p-p}$$

$$V_{TP13} = \underline{\hspace{2cm}} V_{p-p}$$

$$|\text{Gain}| = \underline{\hspace{2cm}}$$

VI-F-9

Mark VI-F-9 on the top right side of your plot and attach as the next page.

VI-F-10

$$\text{Upper -3dB frequency ( } f_{\text{UPPER}} \text{ )} = \underline{\hspace{2cm}}$$

$$\text{Lower -3dB frequency ( } f_{\text{LOWER}} \text{ )} = \underline{\hspace{2cm}}$$

$$f_o = [ f_{\text{UPPER}} \cdot f_{\text{LOWER}} ]^{0.5} = \underline{\hspace{2cm}}$$

$$\text{BW} = f_{\text{UPPER}} - f_{\text{LOWER}} = \underline{\hspace{2cm}}$$

$$Q_o = f_o / ( f_{\text{UPPER}} - f_{\text{LOWER}} ) = \underline{\hspace{2cm}}$$

VI-G-3

$$V_{\text{BQ2}} = \underline{\hspace{2cm}}$$

VI-H-5

$$V_{\text{AFC}} = \underline{\hspace{2cm}} @ 10.7 \text{ MHz}$$

VI-H-6

$$V_{\text{AFC}} = \underline{\hspace{2cm}} @ 10.6 \text{ MHz}$$

VI-H-7

$$V_{\text{AFC}} = \underline{\hspace{2cm}} @ 10.8 \text{ MHz}$$

VI-I-3

$$V_{\text{BQ1}} = \underline{\hspace{2cm}}$$

VI-K-7

Mark VI-K-7 on the top right side of your plot and attach as the next page.

VI-K-8

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VI-M-5

I observed the proper operation of the FM radio \_\_\_\_\_