LABORATORY REPORT - CHAPTER 8

V7.3

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Total Grade	/100

Remarks: Record all your measurements and write all your answers in the boxes provided.

Preliminary Work

1. Transmitter Oscillator

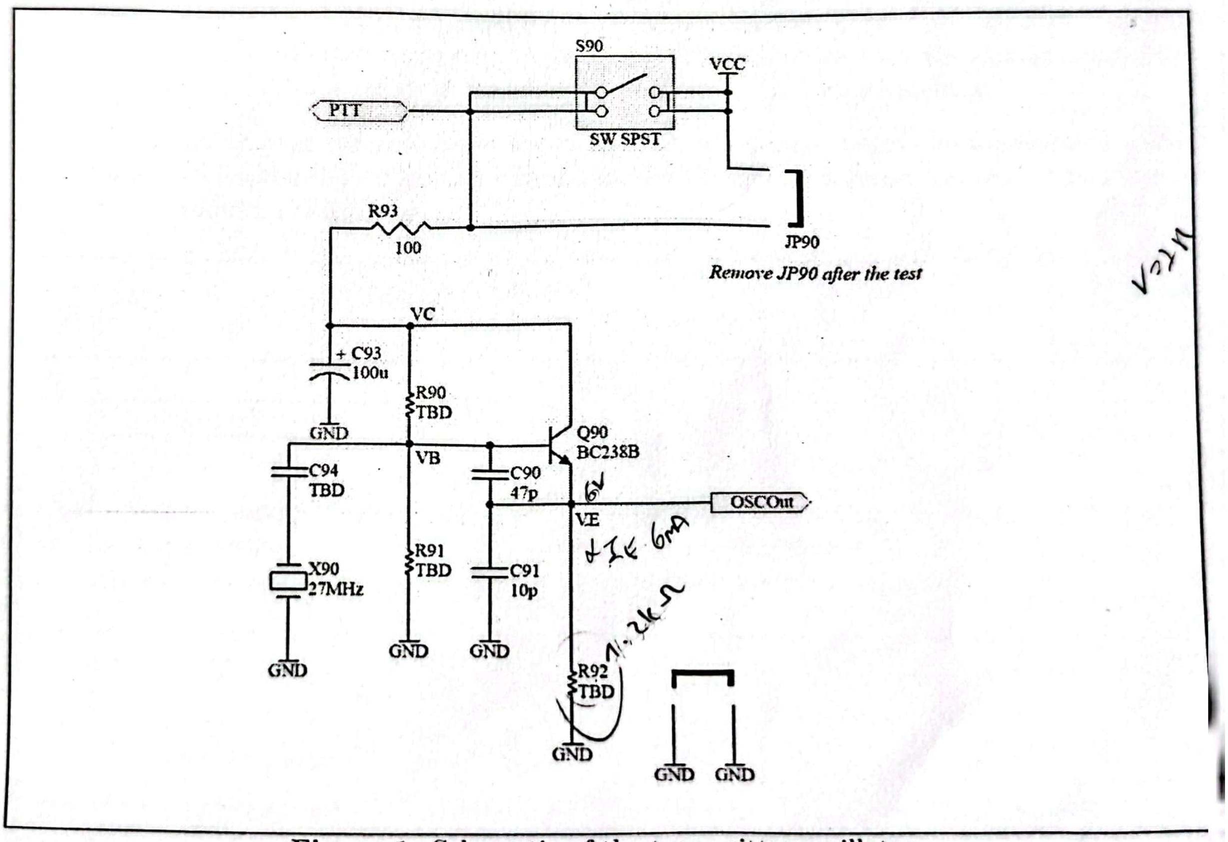


Figure 1: Schematic of the transmitter oscillator

Designator	Comment	Description
C90	47p	Capacitor, ceramic disk, 50V
C91	10p	Capacitor, ceramic disk, 50V
C93	100 μ	Electrolytic capacitor, 16V
Q90	BC238B	NPN Bipolar transistor
R93	100	Resistor, carbon film, axial leaded, 1/4W
S90	SW SPST	Push-button switch, PCB mount
X90	27MHz	Crystal

Figure 2: Bill of materials for the transmitter oscillator

1. The transmitter oscillator is built using a 27 MHz quartz crystal in a Colpitts oscillator configuration. The active device of the Colpitts oscillator is an NPN transistor, BC238B, as shown in Fig. 8.5 in page 8.5. The resistors R90, R91, and R92 form a conventional biasing circuit of the transistor. The capacitors C90 and C91 are placed for Colpitts oscillator configuration. As discussed on page 306, this circuit results in a negative resistance between the base of the transistor and the ground. When a resonant circuit, like a quartz crystal, X90, is placed between the base and the ground, an oscillation starts at the crystal resonant frequency. A capacitor, C94, in series with the quartz crystal is present to adjust the resonant frequency of the crystal by a small amount.

2. Choose an emitter current, I_E, in the range 4 mA to 6 mA. Determine the emitter resistance R92 for the chosen emitter current and for an emitter voltage, V_E=6 V. Choose the closest standard resistor value.

I_E= 5mA   R92 = 1.2k Ω

1.2. GRADE:

3. Inspect the data sheet of the BC238B on page 386. Noting that the transistor BC238B has the B suffix, what is the β=(h_{FE}) range of the transistor? For design purposes, set the β to the midpoint in this range. Calculate the corresponding base current, I_B.

β_{min}=180 β_{max}= 460

β= 320 I_B = 0.0156

1.3. GRADE:

Ic=100mA

Ic= βIB

320×IB = 100mA

100mA / 320

460
-180
280 / 2 = 140

4. R_{90} and R_{91} form a voltage divider network to supply the base current of the transistor. To find the values of R_{90} and R_{91}, set the Thevenin equivalent resistance of R90 and R91 to 20 times R92. (The factor 20 is somewhat arbitrary, you can choose any number in the range 10 to 30).

$$R_T = \frac{R_{90}R_{91}}{R_{90}+R_{91}} = 20R_{92} \tag{1}$$

Since the base current drop over this small resistance is small, we can assume that the Thevenin equivalent voltage (formed by R_{90}, R_{91} and V_{CC}) is equal to the emitter voltage plus V_{BE}=0.7V:

$$V_T = \frac{R_{91}}{R_{90}+R_{91}}V_{CC} \approx V_E + 0.7 \tag{2}$$

We can combine these equations to get

$$R_{90} \approx \frac{20R_{92}V_{CC}}{V_E+0.7} \quad = 35.8K \tag{3}$$

Choose closest standard value for R_{90}. If the standard value is too far, modify the arbitrary factor 20 to make R_{90} found from the equation above equal to the closest standard value. Then use the same factor in the following equation

$$R_{91} = \frac{20R_{90}R_{92}}{R_{90}-20R_{92}} \quad 1000 \quad 45k \tag{4}$$

to find R_{91}. Choose the closest standard value for R_{91}.

R_{90}= 47KΩ	R_{91}= 56kΩ

1.4. GRADE:

2. Receiver Mixer

1. TRC-11 uses a mixer for the receiver as the down-converter. SA602A integrated circuit is used for this purpose. It is an analog multiplier. Refer to the data sheet on page 394.

   The block diagram and pin configuration of SA602A is given in Fig. 3. SA602A has an internal amplifier between pins 6 and 7 to build an oscillator. A local oscillator can be directly implemented within this integrated circuit. The oscillator output is fed to the internal mixer. The RF input pins 1 and 2 of the mixer are differential. The difference between these two pins are applied to the mixer. The input pins have an internal bias voltage of about 1.4 V, they should not be biased externally. The differential input impedance is about 3 kΩ in parallel with 1.5 pF. L80 and C84 form an impedance transformation network to transform the low impedance of the antenna to a higher impedance of the mixer. The output pins 4 and 5 are also differential. The differential output impedance is also about 3 kΩ. The conversion gain of the mixer is 17 dB. The conversion gain means that there is gain in addition to frequency conversion.

   The local oscillator is a Colpitts crystal oscillator, made from a transimpedance amplifier between the pins OSC_B and OSC_E, the quartz crystal X80, and the capacitors C82 and C83.

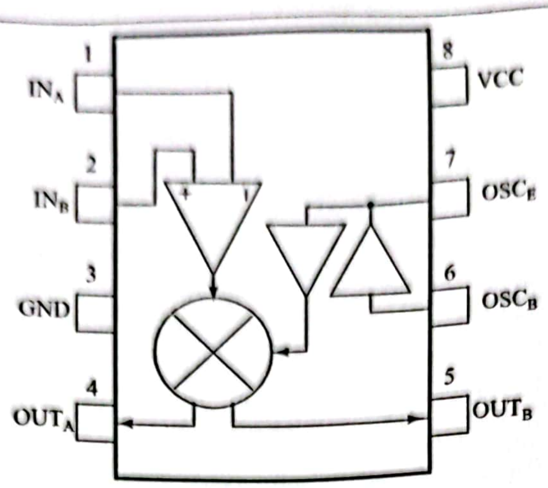


Figure 3: SA602A block diagram.

Experimental Work

1. Transmitter Oscillator

1. Mount and solder the resistors, R90, R91, and R92 using the values you calculated.
2. Mount and solder R93.
3. Mount and solder the capacitors, C90 and C91.
4. The power supply circuit of the oscillator is connected to VCC through a PTT (push-to-talk) switch and R93. A shunt capacitor (C93) to ground is added as a power supply *bypass* capacitor. Solder C93.
5. Mount and solder the push-button switch, S90.
6. We want this oscillator to operate only when we are transmitting. Therefore, we switch its power off during reception. But, for testing we will bypass the switch. A piece of wire was already soldered in the jumper position JP90. This jumper will be removed later, when testing is finished.
7. Solder a piece of wire in the GND jumper for a convenient ground connection.
8. Mount the transistor, Q90. Watch the orientation of the transistor. Solder it.
9. Apply the power to TRC-11. Measure the emitter voltage, V_E, at TP30. It should be close to 6 V. Turn off the power.

V_E= 5.31 V

1.9. GRADE:

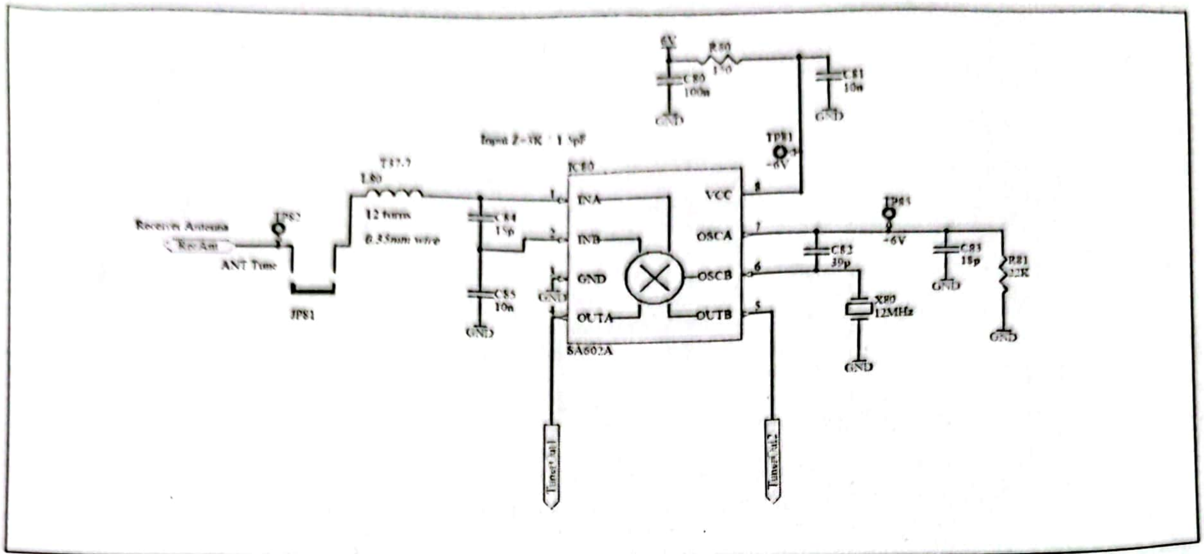


Figure 4: Receiver mixer schematic diagram.

10. Mount and solder the 27.000 MHz quartz crystal, X90. We need a series capacitor, C94, to set the oscillation frequency at 27.000 MHz. Mount a 47 pF capacitor, but do not solder it yet. Make sure that capacitor leads touch the mounting holes. Without the capacitor connection the oscillator does not work.

11. Apply the power to TRC-11. Connect the oscilloscope probe to TP90. You should have an oscillation around 27.000 MHz. If the frequency is lower than 26.999 MHz, remove 47 pF and insert the next smaller standard capacitance. If it is higher than 27.001 MHz, insert the next larger standard capacitance. Solder the capacitor when the frequency is right. If the oscillation frequency is higher than 27.002 MHz ask for a different crystal from the lab technician.

    Measure the frequency and the peak-to-peak voltage at TP90. Make sure that bandwidth limit of the oscilloscope is turned off. The peak-to-peak voltage should be should be larger than 1.5 V.

C94= 39pf	Oscillation frequency= 29.9997 MHz	Peak-to-peak voltage= 1.40

1.11. GRADE:

2. Amplitude Modulator

1. Most of the amplitude modulator is already built as given in Fig. 7. It uses a PNP transistor (Q31) to modulate the supply voltage of the transmitter amplifier (Q30). The only missing components are R34 and C32. Watch for the direction of C32 while mounting. Solder them. They connect the input of the modulation amplifier to the microphone amplifier output.

2. Cut the jumper wire of JP12 in the microphone amplifier section. This action will disconnect the microphone.

Designator	Comment	Description
C80	100n	Capacitor, ceramic disk, 50V
C81	10n	Capacitor, ceramic disk, 50V
C82	39p	Capacitor, ceramic disk, 50V
C83	18p	Capacitor, ceramic disk, 50V
C84	15p	Capacitor, ceramic disk, 50V
C85	10n	Capacitor, ceramic disk, 50V
IC80	SA602A	Oscillator/mixer
L80	T37-7	Toroidal core
R80	150	Resistor, carbon film, axial leaded, 1/4W
R81	22 K	Resistor, carbon film, axial leaded, 1/4W
X80	12MHz	Crystal

Figure 5: Bill of materials for receiver mixer

Designator	Comment	Description
C32	2.2μ	Electrolytic capacitor, 16V
R34	1K	Resistor, carbon film, axial leaded, 1/4W

Figure 6: Bill of materials for amplitude modulator (missing components)

3. Connect the signal generator cable between TP11 and GND. Set its magnitude to 10 mV and its frequency to 1 KHz.

4. Apply the power. Observe the signal between TP12 and GND. You should see an undistorted sine wave.

5. Observe the signal between JP30 and GND. You should see an amplitude modulated (AM) 27.000 MHz signal as shown in Fig 8. Set your oscilloscope time scale to 500 μs/div. Set the ACQUIRE mode to Peak-detect. This setting allows the oscilloscope to capture the peak of the RF signal even though the sampling rate of the oscilloscope is not enough the capture the RF signal itself. Increase the signal amplitude until AM signal gets distorted. At this point, determine the modulation index, m, of the AM signal using the following equation

$$m = \frac{1}{2}\frac{V_{max} - V_{min}}{V_{max} + V_{min}}$$

where V_{max} is the maximum peak-to-peak voltage, V_{min} is the minimum peak-to-peak voltage of the amplitude modulated signal.

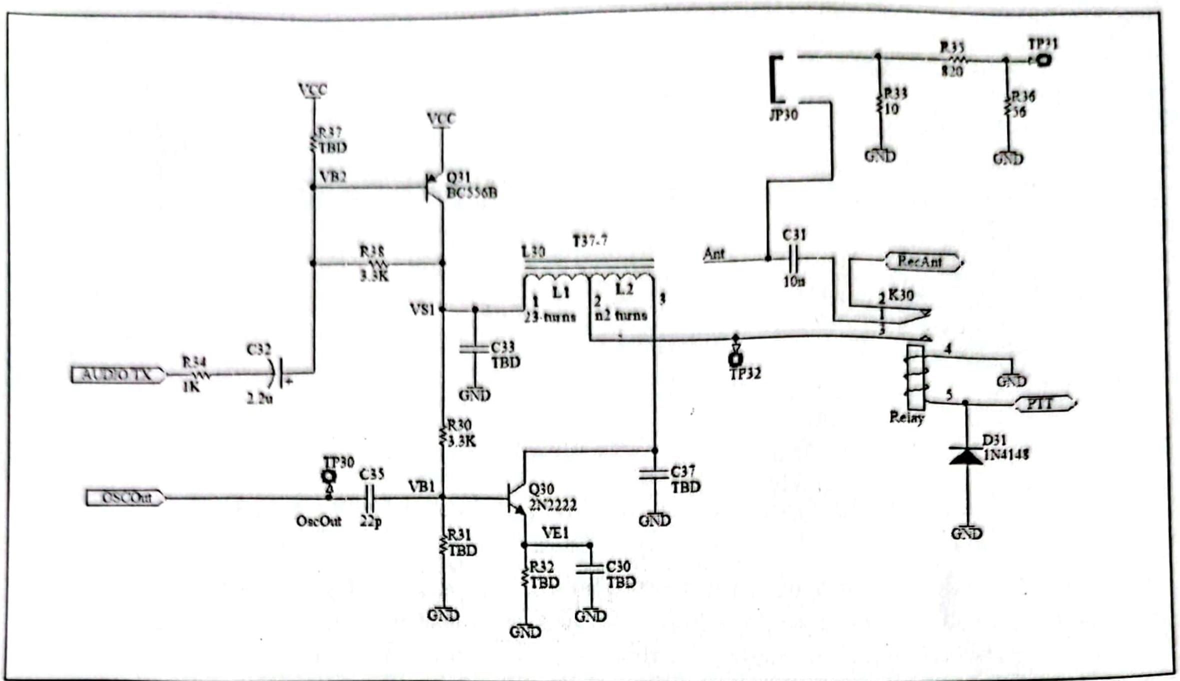


Figure 7: Schematic of the Amplitude modulator of TRC-11.

V_{max}=2.74V V_{min}= 1.12V m= 0.26

2.5. GRADE:

3. Receiver Mixer

1. Install and solder IC80, the receiver mixer. Make sure that pin 1 gets installed into the rectangular shaped pad on the PCB. Note that all other pads are oval shaped. This mixer converts 27.000 MHz signal to 15.000 MHz. The pin OSC_B of the mixer chip has a negative input resistance at high frequencies, if small capacitors (C82 and C83) are connected at pins OSC_B and OSC_E. When a quartz crystal resonator at 12.000 MHz is connected to this pin as shown in Fig. 4, an oscillator at 12.000 MHz is obtained.

2. Install and solder X80, C80, C81, C83, R80, and R81.

3. Mount and solder C82 such that it can be removed easily.

4. Solder looped pieces of wires to TP81 and TP85.

5. Solder C84 and C85.

6. Use 0.35 mm wire to wind 12 turns on T37-7 core to make L80. Install and solder L80.

7. Install and solder the jumper wire JP81.

75.65

8. Switch the power on. Measure and record the DC supply voltage at pin 8 (TP81). It should be slightly less than 6 V due to the voltage drop on R80. Measure the DC voltages

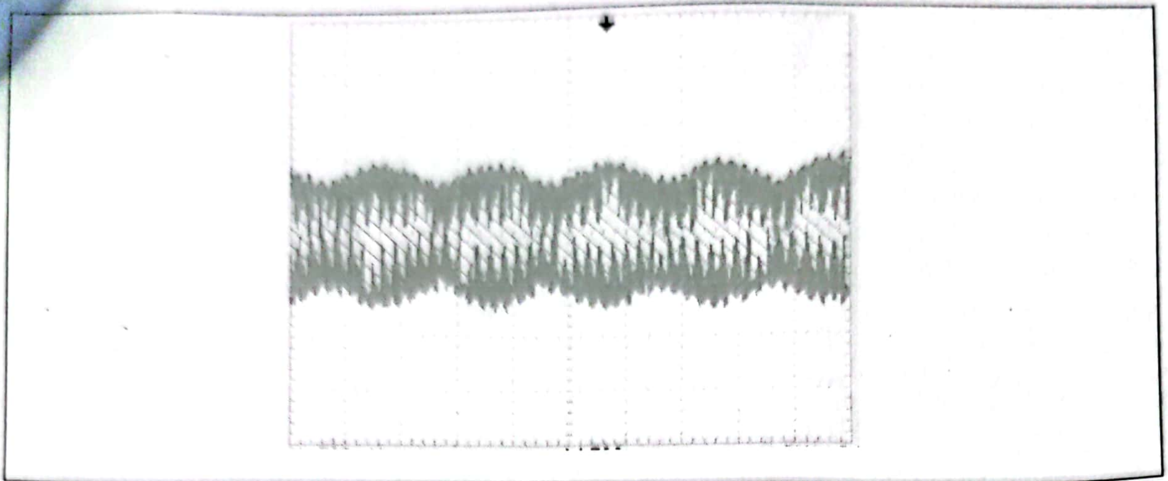


Figure 8: Oscilloscope photo of an AM modulated signal.

at two input pins, 1 and 2. They should be equal and between 1.0 V to 1.7 V. Measure the DC voltages at the two output pins, 4 and 5. The voltages should be equal and between 2 V to 5.5 V. If you cannot measure these voltages, there is something wrong with your circuit.

IC80 pin 8= 5.65	pin 1= 1.27	pin 2= 1.29
IC80 pin 4= 4.11	pin 5= 4.11	

3.8. GRADE:

9. Connect the oscilloscope probe (in 10× setting) to TP85. You should be able to see an oscillation around 12.000 MHz. Measure the frequency of the oscillation with a 1 KHz accuracy. If the frequency is lower than 11.999 MHz, change the capacitor C82 to the next smaller standard value. If the frequency is higher than 12.001 MHz, change C82 to the next larger value. Record the capacitor value and the oscillation frequency

10. Measure the amplitude of the oscillation.

C82= 39 pF	Frequency= 11.9996 MHz	p-p amplitude= 1.26 V

3.10. GRADE:

11. Make sure that the jumper JP90 is cut.

12. Since your receiver is now ready, you can test it. Apply the power to TRC-11. Watch the red signal presence indicator LED. It should be off, indicating that there is no 27.000 MHz transmitter signal nearby.

    We need a very very small signal to test the receiver. Set the signal generator to frequency to 27.000 MHz with an amplitude of V_g=100 mVpp. Set the AM modulation at 1KHz.

Connect the signal generator between TP31 and GND. Turn on the generator. The signal presence indictor LED should turn on. Note that if there are other transmitters nearby, your LED may be turned on even without applying the input voltage. If the signal presence indictor LED does not turn on even with 100 mVpp signal generator, you have something wrong in the receiver or it is not adjusted well.

13. Turn the volume down all the way counter-clockwise. Connect an earphone to the earphone jack. Increase the volume gradually while listening to the earphone. You should be able to hear the 1KHz demodulated tone of the signal generator through the earphones.

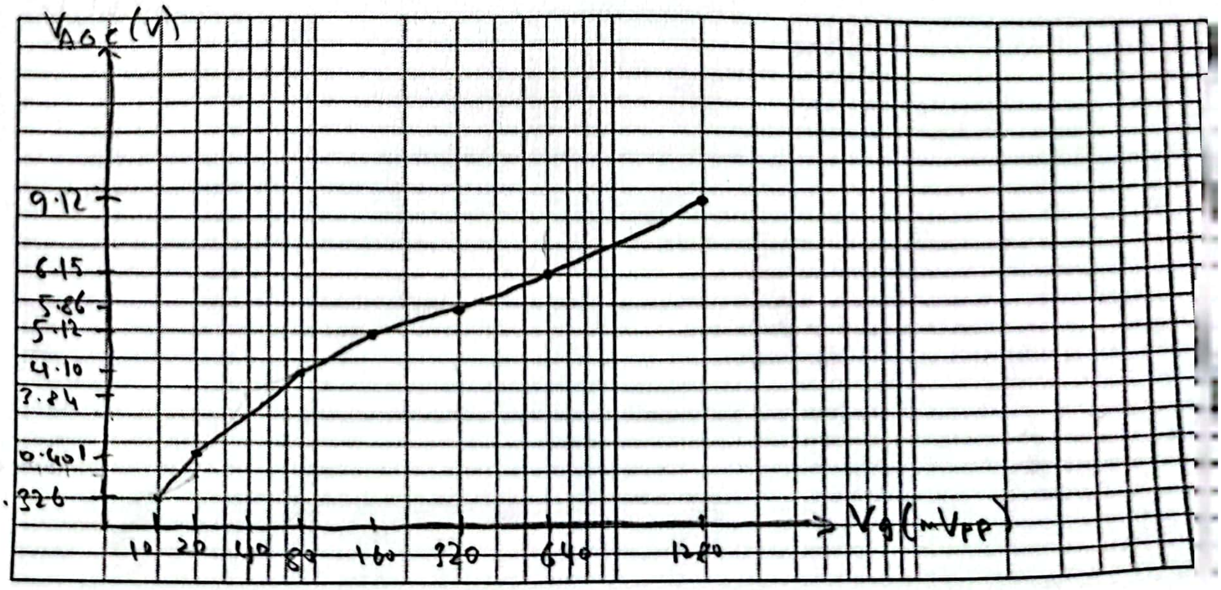
14. Connect Ch-1 probe between TP70 and GND. This is the test point showing the AGC detector output. Change the frequency in 1 KHz steps to find the center frequency, f_{center}, of the receiver. When the voltage at TP70 is maximum, record that frequency.

f_{center}= 27.00 2000 MHz

15. Record the DC voltage amplitude at TP70, V_{AGC}, as a function of signal amplitude, V_g, at this frequency. Note that you can use MEASURE button of the oscilloscope in Ch1 Mean position to read the AGC output voltage. Change the signal generator output from 10 mV_{pp} to 1280 mV_{pp}. Change the amplitude in 6-dB steps (20mV, 40mV, 80mV, 160mV, etc.) The AGC output voltage should be more and more positive as the signal generator output voltage is increased.

Plot V_{AGC} as a function of V_g on a semilog paper.

V_g (mV_{pp})	V_{AGC}(V)	V_g (mV_{pp})	V_{AGC}(V)
10	0.326	160	5.12
20	0.401	320	5.86
40	3.84	640	6.15
80	4.10	1280	9.12



3.15. GRADE:

16. Recall that the mixer adds or subtracts the two frequencies. Since the local oscillator frequency is 12 MHz, an image frequency of 3 MHz will create a sum frequency of 3+12=15 MHz, which will go through the quartz crystal IF filter. However, the receiver's input RF tuner is tuned to 27 MHz, and it hopefully rejects 3 MHz and reduce the gain at that frequency.

    Let us find the image rejection ratio of your receiver at the image frequency of 3 MHz. Set the signal generator to 3 MHz and amplitude at 2 V_{pp}. Connect the signal generator cable between TP31 and GND. Connect the oscilloscope probe to TP70, the AGC output voltage. Change the frequency in 1 KHz steps to maximize the AGC output voltage. Record that frequency as f_{image}. If the AGC output voltage is zero, increase the signal generator voltage until you see a voltage. Adjust the amplitude such that you have the same AGC output voltage as the 0.02=20 mV_{pp} signal at 27 MHz (which is recorded in the previous step). Record that amplitude, $V_{g,image}$. Find the image rejection ratio of your receiver in dB using

$$IR_{dB} = 20\log_{10}\frac{V_{g,image}}{\cancel{0.02}} \quad 150 \quad 0.08$$

f_{image}= ~~3.000~~ 3.000 MHz

IR_{dB}= 5.46 dB

3.16. GRADE:

If you have trouble with your receiver, refer to Appendix J at page 457 for TRC-11 troubleshooting.

17. If your transmitter and receiver is OK, cut the jumper wire at JP30. TRC-11 is ready to go on the air!

    CHECK POINT: