LABORATORY REPORT - CHAPTER 7

Lastname, Firstname	Sait Sarper Özaslan
Student ID	22002861
Date	07.12.2022
Total Grade	/100

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

Preliminary Work

1. Envelope detector

1. The envelope detector circuit of TRC-11 is given in Fig. 1. It serves to recover the AM modulation signal present on the RF signal. It does so by rectifying the positive side of the AM modulated signal. A low-pass circuit composed of C65 and R65 gets rid of the RF signal frequency.

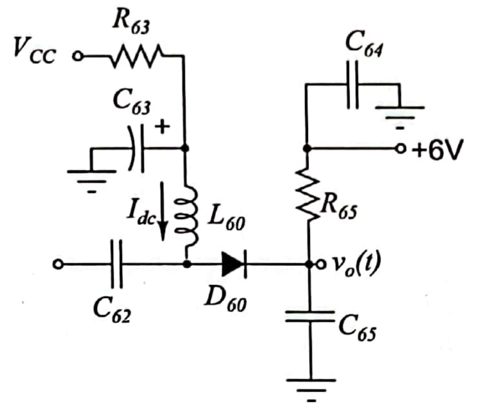


Figure 1: TRC-11 envelope detector circuit.

Calculate the dc bias current, I_{dc}, through the detector diode 1N4148, from V_{CC}=12 V to +6 V, assuming C62, C63, C64, C65 are open-circuit and L60 is short-circuit. For this calculation, first assume that V_o of the diode is approximately 0.6 V. Then, find the actual voltage V_o of 1N4148 for this bias current. You can do this by examining the datasheet of 1N4148 on page 396. The graph "V_F -Forward Voltage" versus "I_F -Forward Current" reveals this information. Record this voltage.

2. From the same datasheet, find the capacitance, C_D, of 1N4148 when it is zero-biased.

3. L60 is a 6.8 μH fixed inductor with a color code just like resistors, and the value is specified in μH. It resonates at 15 MHz with the parallel combination of C62 and capacitance, C_D,

Designator	Comment	Description
C62	TBD	Capacitor, 50V
C63	100u	Electrolytic Capacitor, 16V
C64	100n	Capacitor, 50V
C65	1n	Capacitor, 50V
D60	1N4148	Silicon Signal Diode
L60	6.8u	Inductor
R63	56K	Resistor
R65	10K	Resistor

Figure 2: Bill of materials for the envelope detector circuit

of the 1N4148 diode. The signal magnitude increases by the quality factor of the resonator. Find the value of C62 and pick the closest standard value.

4. The cutoff frequency of the low-pass network formed by C65 and R65 is set sufficiently high so that the envelope detector output can follow the variation at the high-frequency end of the modulation frequency. Find the corner frequency, f_c,

I_{dc}= 81.8 µA	V_{dc}= 480mV	
C_D=4pF	C_{62}=12pF	f_s= 100kHz

1.4. GRADE:

2. Automatic gain control (AGC)

1. A PIN diode acts like an RF resistance whose value is determined by the DC current flowing through it. It is inserted between the first and second IF amplifiers when the jumper JP70 is shorted. If the DC current through it increases, its resistance reduces and hence attenuates the signal going to the second IF amplifier as shown in Fig. 1. Refer to the datasheet of the PIN diode on page 399. Find the reverse breakdown voltage, V_R, and the series RF resistance, R_S, and the forward voltage, V_F of the PIN diode when 1 mA DC flows through it.

V_R=20V	R_S= 0.7Ω	V_F= 0.65V

2.1. GRADE:

2. The automatic gain control (AGC) circuit of TRC-11 is given in Fig. 4.

It is intended to reduce the gain of the IF amplifier to prevent the saturation of the second stage. The AGC circuit observes the average value of the detector output and adjusts the IF gain by using a PIN diode placed in shunt in between the first and second IF stages. The average value of the detector output at the positive input of the OPAMP is compared

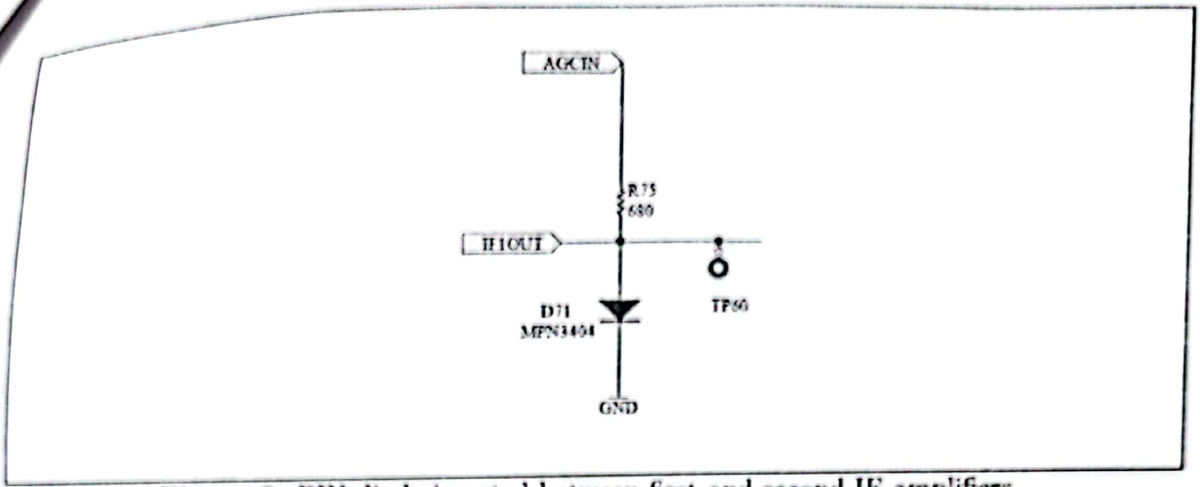


Figure 3: PIN diode inserted between first and second IF amplifiers.

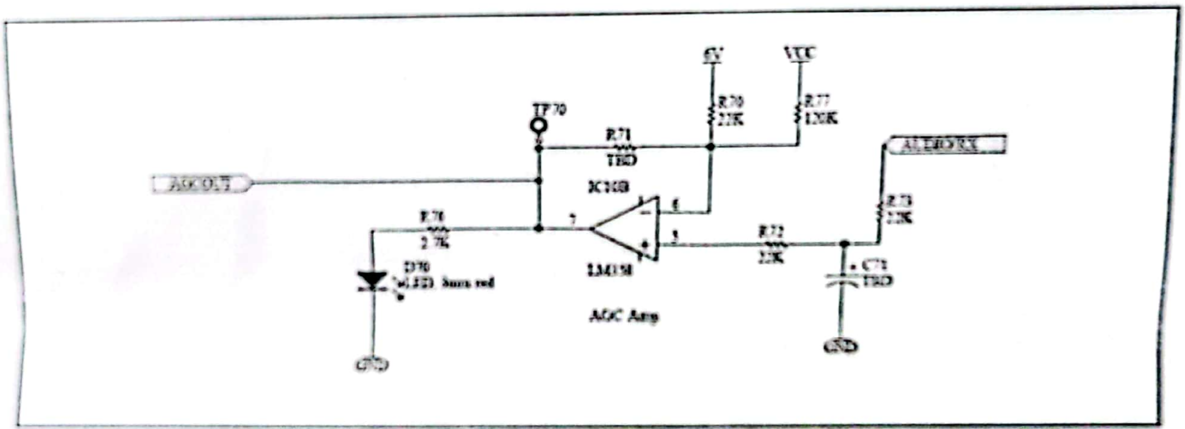


Figure 4: Automatic gain control circuit.

with a set point, V_s, at the negative input of the OPAMP. If the average value is higher than the set point, the output of the OPAMP increases to a higher voltage. That increases the DC current through the PIN diode, reducing the RF resistance of the PIN diode and hence reducing the IF gain.

On the other hand, if the average detector output is less than the set point, the OPAMP output voltage decreases, decreasing the DC current through the PIN diode. This, in turn, increases the RF resistance of the PIN diode, causing an increase in the IF gain. Overall, the AGC circuit keeps the detector output at the same average level once the signal is sufficiently high. If the input signal is below the threshold, the OPAMP output is set to zero, making the DC current through the PIN diode also zero. Under that condition, the PIN diode is open-circuit for RF signals, maximizing the IF gain.

AGC circuit uses the OPAMP in the feedback path. The voltage gain of the OPAMP in the non-inverting amplifier configuration is determined in terms of R71 and the parallel combination of R70 and R77. Since the value of R70 and R77 is given, find the value of R71 to set the gain to 100. Choose the closest standard value.

R_{71} = 1.5MΩ

Designator	Comment	Description
C71	TBD	Electrolytic Capacitor, 50V
D70	LED, 3mm red	Light-Emitting-Diode
D72	BZX55C5V1	Zener Diode, 5.1V
R70, R72, R73	22K	Resistor
R71	TBD	Resistor
R76	2.7K	Resistor
R77	120K	Resistor

Figure 5: Bill of Materials of the automatic gain control circuit.

2.2. GRADE:

3. The set point, V_S, at the negative input of OPAMP is determined by R70 and R77 and by the voltages they are connected to. We may neglect the current through R71 since it is a large value. Find V_S.

V_S= 6.92V

2.3. GRADE:

4. The detector output is averaged using a low-pass-filter with a very small cutoff frequency. The cutoff frequency is determined by R73 and C71. Determine the value of C71 to make the corner frequency 0.1 Hz. Choose a polarized capacitor with the next largest standard value.

C_{71}= 100µF

2.4. GRADE:

5. We have a visual indication of the AGC feedback circuit using a green LED, D70. It is connected to the OPAMP output through a resistor, R76. We would like the LED to turn on as soon as the AGC circuit begins to work. Find the current, I_{LED}, flowing in the green LED when the AGC circuit works and OPAMP output reaches its maximum value of 10 V. For this purpose, you may assume an LED forward voltage drop of 2 V. Refer to the LED datasheet on page 402 to find the maximum allowable LED current, I_F.

I_{LED}= 3mA. I_F= 20mA

2.5. GRADE:

6. The OPAMP output that generates the DC current for the PIN diode can become as high as 10 V. Find the maximum DC current, I_{FMax}, through D72, R75, and D71 assuming the forward voltage drop of the PIN diode is 0.7 V. Find the RF resistance, R_{SMin}, of the PIN diode when this current is flowing through it using its datasheet.

I_{FMax}= 13,7 mA R_{SMin}= 0.69 Ω

2.6. GRADE:

Experimental Work

1. Envelope Detector

1. Install the components L60, R63, R65, D60, C63, C64, C65 (watch the polarity of C63) and solder them. For C62, use the value of the capacitor you calculated in the Preliminary Work.

2. Solder a loop of wire to TP62.

3. Apply the power. Using your multimeter, measure the voltage V_F, across the D60 diode. Does it agree with V_F that you have found from the datasheet of 1N4148?

Measured V_F= 0,498 V

1.3. GRADE:

4. Set to signal generator to AM signal with 5 V_{pp} amplitude and 50% modulation to obtain

$$2.5[1 + 0.5\cos(2\pi f_m t)]\cos(2\pi f_{IF} t)$$

where f_m is 1 KHz, and f_{IF} is 15 MHz. Press [RATE] to adjust the modulation frequency, f_m, to 1 KHz. Press [DEPTH] to adjust the modulation index to 50%. Connect the oscilloscope probe to the output of the generator. On the oscilloscope, set ACQUIRE to PEAK DETECT. This setting allows good visualization of an AM signal. The PEAK DETECT setting should be used when the sampling rate of the oscilloscope is too low compared to the carrier signal. Set the time setting to 5 ms/div. Connect the "Modulation" output of the signal generator (on the back of the signal generator) to EXT trigger input of the oscilloscope using a coaxial BNC cable. Set the Trigger source of the oscilloscope to Ext, coupling AC. Make sure that the oscilloscope is triggered. Observe the AM waveform. Plot the waveform below. Observe the signal's envelope as you change modulating function to Square, Triangle, and Ramp.

AM Waveform for sinusoidal modulation

1.4. GRADE:

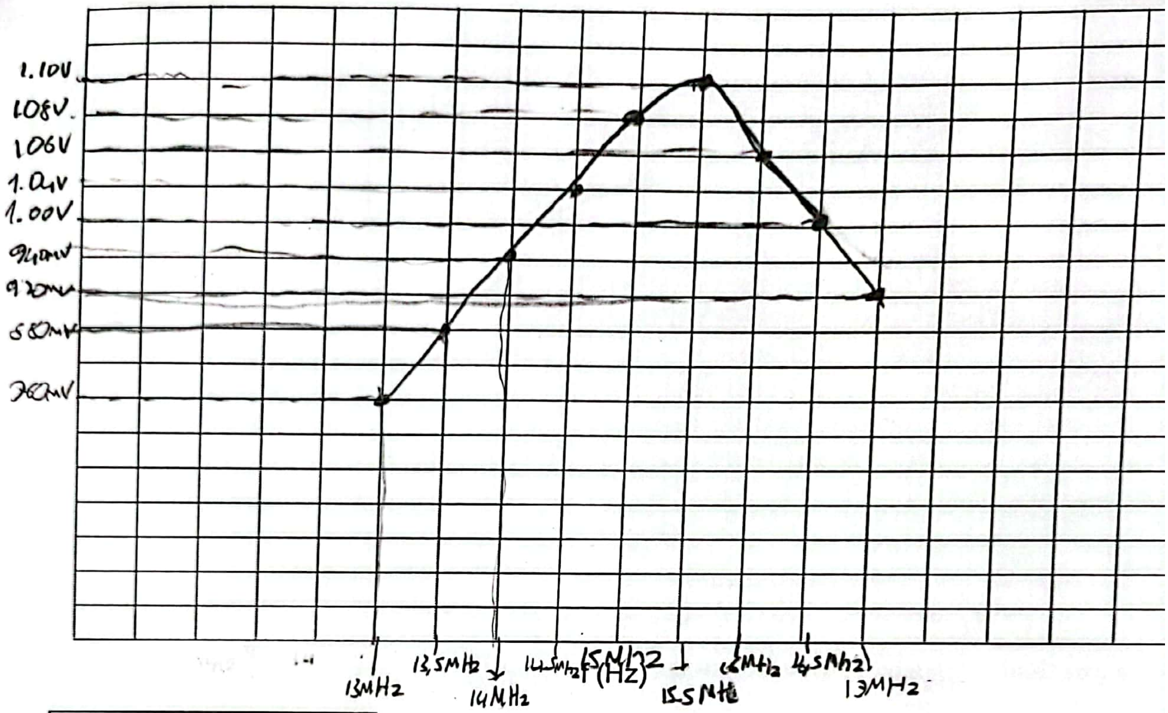
5. Set the modulating function to Sine. Set ACQUIRE button of the oscilloscope to the usual setting of SAMPLE. To be able to freeze the screen. Press RUN/STOP button of the oscilloscope. What do you observe? The high-frequency signal is *aliased* because the sampling rate is not sufficient to capture it.

Explain what you see: Oscillope couldn't give a accurate, proper signal as dotes were too fast to observe. Also the signal was cut off and the display was aliased

1.5. GRADE:

6. Set the signal generator output voltage to 20 mV peak-to-peak. Connect the signal generator between TP60 and the ground. Connect the Ch 1 probe to the envelope detector output, TP62. On the oscilloscope, set ACQUIRE to PEAK DETECT. Apply the power to TRC-11. Record the peak-to-peak voltage, V_{pp}, as f_{IF} is varied between 13 to 17 MHz in 0.5 MHz steps. Since C62 value is adjusted to resonate with L60, you should see the maximum variation at 15 MHz. If the resonance occurs at frequencies greater than 17 MHz or lower than 13 MHz, you may change the value of C62 to the next higher or the next lower standard value.

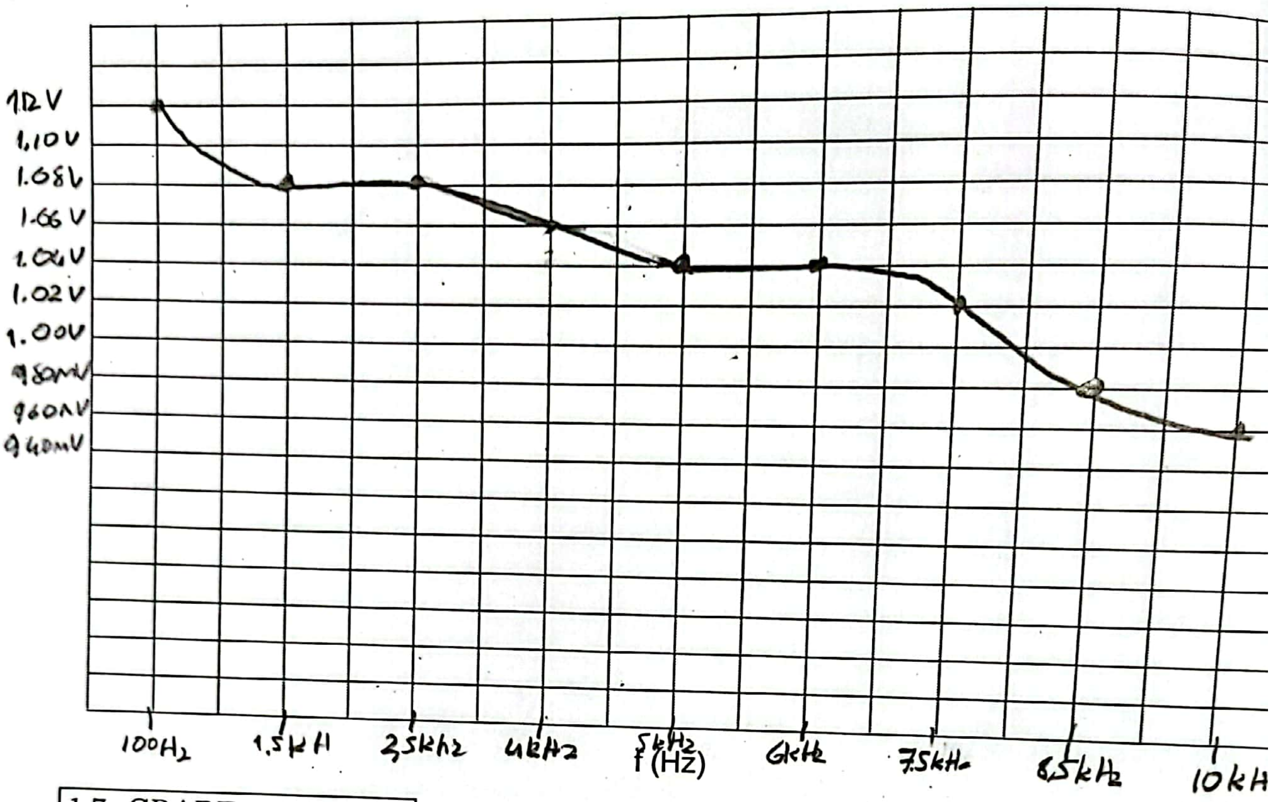
f_{IF} (Hz)	V_{pp}(V)	f_{IF} (Hz)	V_{pp}(V)	f_{IF} (Hz)	V_{pp}(V)
13 MHz	960mV	14.5 Mhz	1.04V	16 Mhz	1.06V
13.5 MHz	980mV	15 Mhz	1.08V	16.5 Mh	1.00V
14 MHz	940mV	15.5 Mhz	1.02V	17 MHz	920mV



1.6. GRADE:

7. Set f_{IF} to 15 MHz and vary the modulation frequency f_m between 100Hz and 10 kHz after pressing [RATE]. Modulation [DEPT] should be at 50%. Measure the envelope detector output at TP62. Choose the number of measurements and measurement frequencies adequately. Plot the peak-to-peak output voltage as a function of f_m.

f_m (Hz)	V_{pp}(V)	f_m (Hz)	V_{pp}(V)	f_m (Hz)	V_{pp}(V)
100Hz	1.12V	4kHz	1.06V	7.5kHz	1.02V
1.5 kHz	1.08V	5k Hz	1.04V	8.5kHz	980mV
2.5kHz	1.08	6k Hz	1.04V	10k Hz	960mV



1.7. GRADE:

8. Adjust the volume pot all the way counter-clockwise to reduce the volume. Plug in the earphones. Increase the volume until you hear a sound. This sound is the detected modulation signal.

9. Connect the signal generator between TP40 and GND. Set the amplitude of the signal generator to the smallest amplitude (10mV). Set the frequency to the center frequency of your IF filter. This should be very close to 15.00 MHz. Set the AM modulation frequency f_m to 1 kHz. Set the modulation index to 50%. Apply the power. Now, you should hear the demodulated 1 kHz signal from the earphones. Observe 1 kHz signal at TP62 using the scope. Change the frequency of the carrier, f_{IF}, around 15 MHz in 1 KHz steps to find the maximum signal position. 15.000900 Hz

10. Increase the input signal amplitude. At some point, IF amplifiers saturate. The demodulated signal gets distorted. As the input amplitude increases further, the demodulated signal gets smaller. Record the input peak-to-peak signal level where the saturation begins and the signal observed on the scope begins to distort.

Input signal level for saturation= 600mV I only started hearing a silent signal

200mV

1.10. GRADE:

2. Automatic gain control (AGC) circuit

1. Now, we are ready to incorporate the automatic gain control (AGC) circuitry to prevent saturation of the IF amplifiers. Refer to Fig. 4. Place R70, R72, R73, R75, R77, and D71.

Watch the direction of the PIN diode. Solder them. Cut the leads on the back side.

2. For R71 and C71, place the values you calculated earlier. Solder them.

3. Place the red LED, D70. Note that the longer lead is the positive terminal. Solder it. Place and solder R76.

4. Solder a loop of wire to TP70.

5. Connect the signal generator between TP40 and GND. Set the signal generator frequency to the center frequency of your IF filter (15 MHz). Set the amplitude to 10 mVpp. Set the AM modulation frequency to 1 kHz and modulation index to 50%. Using the oscilloscope, observe the demodulated signal at TP62. Increase the amplitude of the signal generator beyond the point where saturation took place. Observe that saturation is now avoided and a demodulation takes place without distortion at larger signal levels.

6. Observe that the LED turns on. You may need to increase the generator voltage or change the center frequency in small steps if the LED does not turn on. With a well-tuned receiver, the LED should turn on with about 10 mVpp at 15.000 MHz. Record the center frequency, f_0, and the smallest input amplitude which turns on the LED.

7. While at the smallest signal level, change the frequency in both directions with small steps to find out where the LED turns off.

300

f_0= 15001300Hz LED turns on with V_{inpp}= 0.040 V (40mV)

LED turns off at f_1=14999600Hz and at f_2= 15001700Hz

2.7. GRADE:

8. Since the testing of IF amplifier is finished, remove the resistor R41. You may just cut its ungrounded lead.

CHECK POINT: