Worcester Polytechnic Institute
Department of Electrical and Computer Engineering
ECE3311 Principles of Communication Systems B05
Exercise#7 (extra exercise)

Envelope detector setup (a very preliminary draft)

Monday	5-6pm in AK317a
Tuesday	5-6pm in AK317a
Wednesday	5-6pm in AK317a

(or any other time before Thursday 6 pm).

I. Parts
II. Construction
III. Low-frequency amplifier
IV. Test
V. Friis transmission formula
VI. A simple audio amplifier

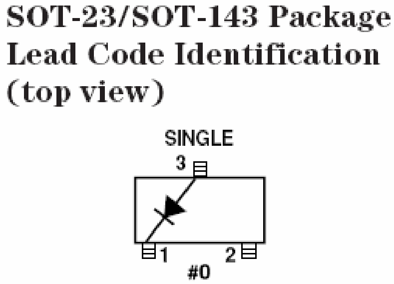
The present project will modify exercise #6 by soldering the corresponding circuit and testing it in AK227. This room now has a signal generator that creates a DSB amplitude-modulated signal with a carrier (see lecture #3). The goal of this experiment is to evaluate the demodulation performance of the envelope detector.

I. Parts

Part list includes:

1. Board – was designed according to exercise #6.
2. Patch antenna – was designed according to exercise #2 but with the microstrip feed instead of the probe feed for assembly simplicity. The feed inset was optimized using Ansoft parametric sweep. The corresponding Ansoft project is available for consideration.
3. Two Female SMA connectors – should solder one to the board and one to the antenna.
4. Female-to-Female SMA adaptor – is used to connect the antenna connector to the board connector.

5. Agilent Schottky Diode HSMS-2850-TR1/ SOT-23. The top view is shown in the figure to the right.
6. Chip capacitor 100 pF.
7. Chip inductor 39 nH.
8. Chip resistor 12.7 kΩ.
9. Connecting pins (3).



II. Construction

The board layout with the parts to be soldered is shown in Fig. 1. One major difficulty is dealing with the proper biasing of the diode.

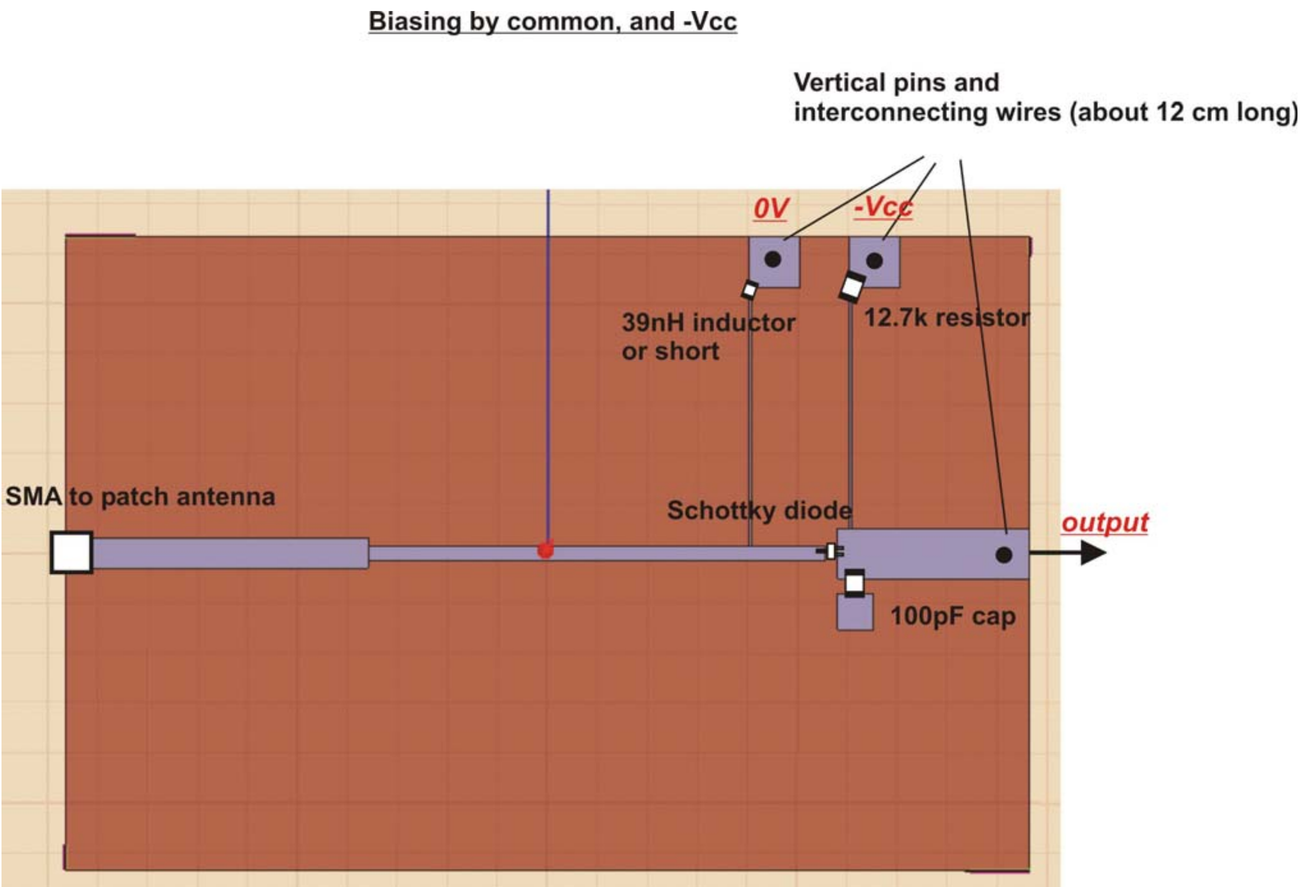


Fig. 1: Board layout with surface-mount components.

The biasing implies that

1. The diode current should be about 0.3-0.4 mA.
2. The output to the board needs to be kept at approximately zero volts versus common of a dual-rail low-frequency (modulation) amplifier (amplifier for the demodulated signal).
3. The RF chokes should isolate not only the carrier but also the AC modulation signal from the power supply!

The initial scheme with two inductors and the external envelope detector resistor did not satisfy condition #3. Therefore, it was modified in the following ways:

1. The envelope detector resistor is made internal – the second inductor is replaced by that resistor.

2. Also, the resistor value is reduced to 12.7 kΩ, in order to enable 0.3-0.4mA of current at reasonably small voltages (on the order of 10 V rail to rail).

Note that the RF signal is present ONLY on the board. There is no RF signal at the output to the board: it is shorted by the capacitor. Only a demodulated baseband signal is present there. Therefore, we can further process this baseband signal on a protoboard.

III. Low-frequency amplifier

A simple low frequency inverting amplifier for the baseband signal is shown in Fig. 2. The amplifier has a large absolute gain – about 2000. The 2.2 μF capacitor at the input to the amplifier removes a small DC bias that always occurs at the output to the envelope detector, due to DC bias current applied to it.

Thus, only the AC modulation component is present at input. The 0.5 kΩ resistor to ground is intended for better impedance matching.

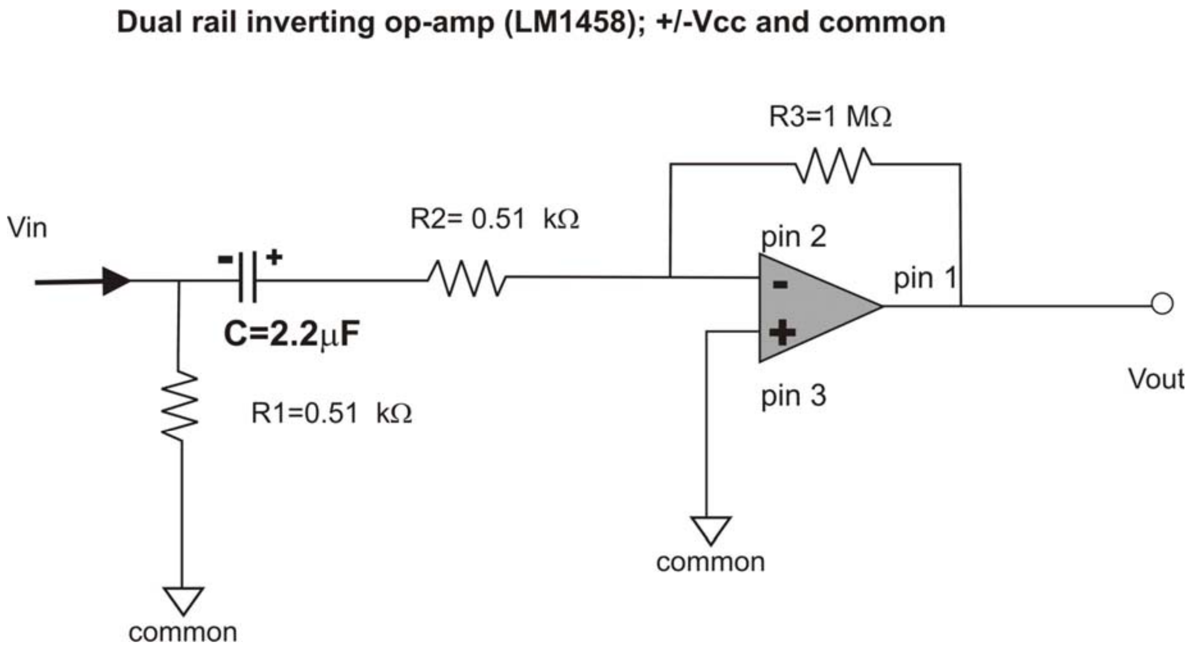


Fig. 2: A low frequency part of the circuit – to be assembled on the protoboard.

The reason for the large gain is that the entire RF system does not have a front-end RF amplifier (or the so-called low-noise amplifier). The demodulation is done solely by the envelope detector just after the antenna, without the low-noise RF amplifier. It is also interesting to note that the antenna simultaneously plays the role of the RF filter.

IV Test

Assemble the antenna, board, and the protoboard, and connect the dual power supply to it. Most difficult is to solder the inductor – replace it by a short circuit if you are not able to do so. The performance of the envelope detector will degrade, but not very significantly.

With the oscilloscope connected to the amplifier output you should be able to see the modulation on the screen – the AM modulation frequency will be either 400 Hz or 1 kHz.

Note that the present circuit **does not** have an automatic gain controller. Therefore, the amplitude of the received signal will strongly depend on many ambient factors including, mostly, your relative position in AK 317a plus the relative position of your partner.

Keeping your position nearly the same, measure the amplitude of the received signal at different values of Vcc. Find the value of Vcc at which the amplitude becomes maximum. Now, based on Fig. 1, estimate the corresponding bias current assuming that the diode resistance is approximately 100Ω. Does this value agree with the theoretical prediction obtained in exercise #5?

V. Friis transmission formula

It is interesting to estimate the power that is received by the board from the signal generator. This is done using the so-called Friis transmission equation that has the following form:

$$P_R = P_T \frac{G_T G_R}{(4\pi R)^2} \lambda^2 \qquad (1)$$

Here,

P_R is the power delivered to a conjugate-matched load attached to the receiving antenna.
P_T is the transmit power (power delivered to the transmitting antenna)
R is the distance between two antennas in meters
G_T, G_R is the linear antenna gain of the transmit/receive antenna:
$G_{\log} = 10\log_{10} G_{lin}$
λ is the wavelength at the working carrier frequency in meters.

The Friis equation is widely used in wireless networking where it is often the only part that is left from the physical layer.

Using Eq. (1) and the fact that the logarithmic antenna gain for the patch antenna is about 1 dB (taking into account losses in FR4) you can estimate the received power (in mW) if the transmit power P_T is 16 dBm.

VI. A simple audio amplifier

The audio amplifier setup is shown in Fig. 3. It is based on LM384 chip, with the internally fixed gain of 50. The audio amplifier has a single-rail, with the supply voltage of 22 V. Therefore, it should be assembled on a separate board and powered by a separate power supply.

The setup should be tested either with the signal generator or with the PC audio output after assembly but prior to connecting it to the rest of the circuit.

After the test is done, connect the amplifier input to the output of the low-frequency amplifier, put a CD of your choice into the base PC (or ask for an audio clip) and estimate the performance of this simplest receiving system. Note that it operates at about 1 GHz, which implies 100 times higher carrier frequency than AM radio.

Which changes could be made to convert the present circuit to an FM receiver?

No report is required for this exercise. This is an extra exercise and, when accomplished in full, it will give 5 points to the final grade.

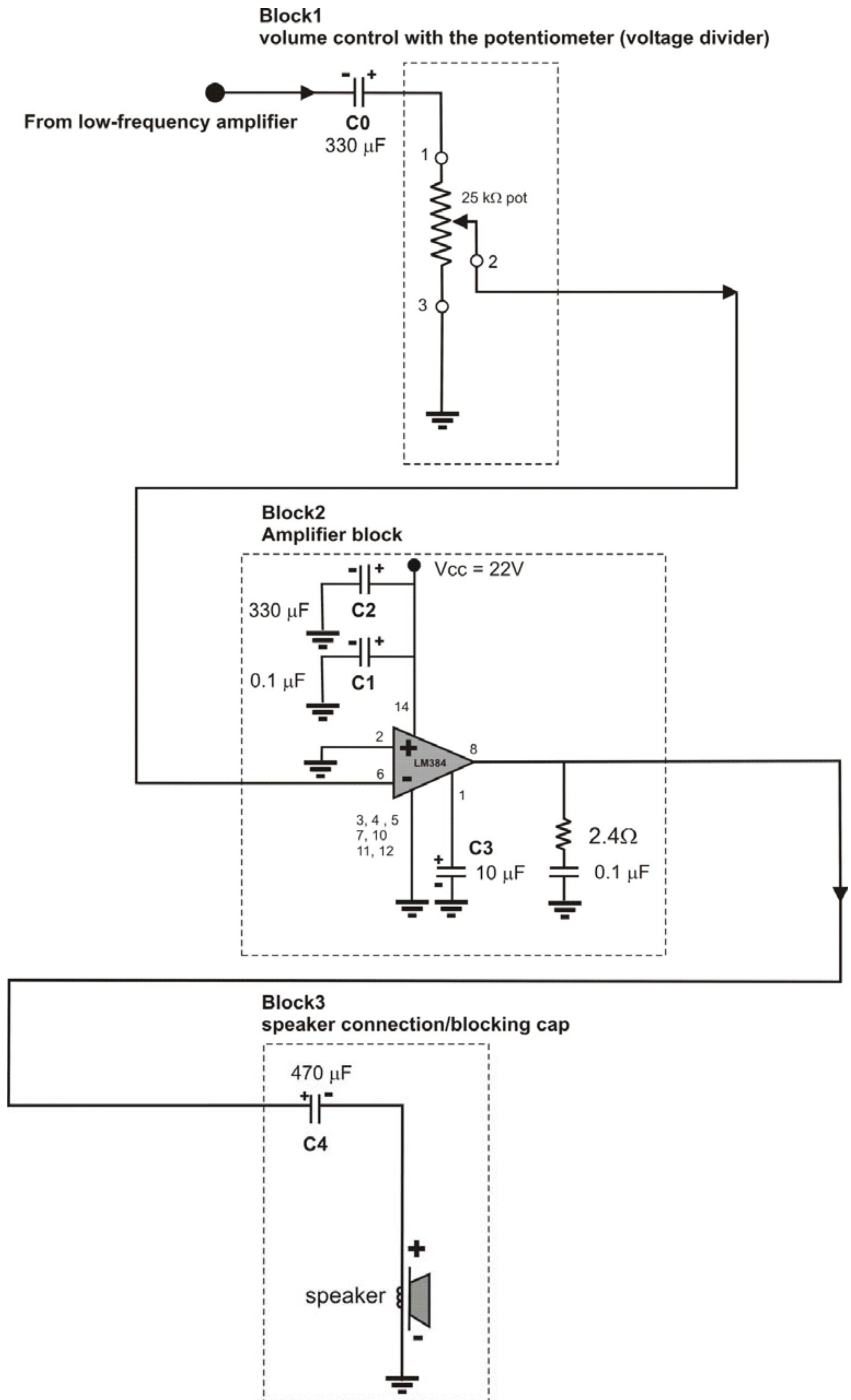


Fig. 3: Audio amplifier setup.