communication project phase 2

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1 Introduction

In the previous phase of this project (Phase 1) we have designed an AM modulator and an AM demodulator circuit using Matlab. In this phase, we have implement this design on a breadboard to test the reliability of our design and see how it would translate into a real-world circuit. Unfortunately, due to the ongoing war in Gaza, we were not able to attend the university to build the circuit on an actual breadboard. However, we were successfully able to simulate the circuit using a circuit simulator named *TinkerCad* which could be used to build breadboard application using realistic pieces and see actual results.

We concluded from the results of our simulation that, with very minor tweaks to our design largely due to the assumption that the parts used are ideal, the circuit we have designed on Matlab is very accurate and gives great results on breadboard. So let's dive in!

2 Comparison between Matlab Circuit and Breadboard Circuit

2.1 The Matlab Circuit

In **Figure 1**, you can see the circuit that we have designed using Matlab. The diodes were ideal, the operational amplifiers used where elementary and everything work as calculated.

As you can see, the design consisted of five main components; a switching modulator to modulate the signal, a band-pass filter to choose the desired frequency, a buffer to separate the modulator and the demodulator, an envelope detector with a low-pass filter to purify the received signal, and finally a difference amplifier to offset the signal and amplify it to have similar attributes as the message signal.

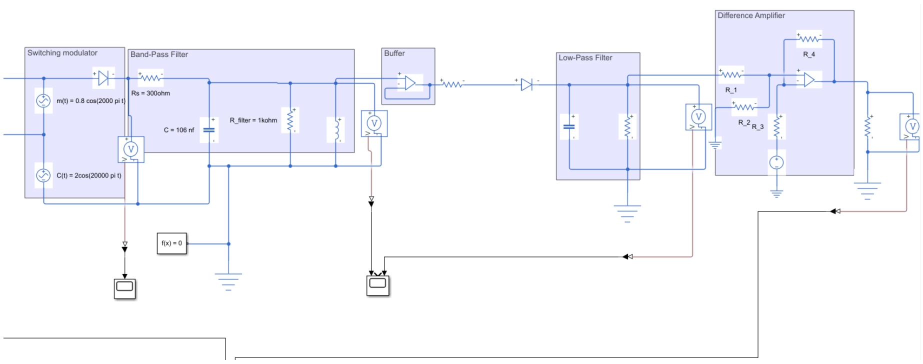

Figure 1: Matlab Circuit Design

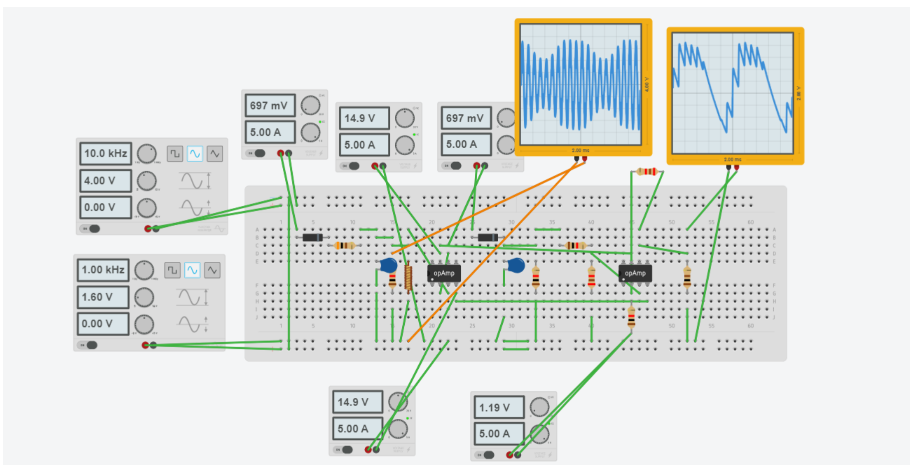

Figure 2: Full Breaboard Circuit

You can notice that the design is neat and clean due to the fact that we he had no constraint on the footprint of the desing. This will look different on the breadboard!

2.1.1 The Breadboard Circuit

In **Figure 2**, you can see the design of the breadboard signal. We have used a standard breadboard to build the circuit with very basic elements. When first looking at the breadboard circuit, you may feel a little confused due to the many wires and the wired configuration of the elements. But that's okay! This is what a real circuit looks like. To help you better navigate the elements used in the circuit, we have provided below a table containing all the elements used in the circuit.

Table 1: Elements Used in the Design of the Circuit

Name	Quantity	Component
m(t)	1	1000 Hz, 1.6 V, 0 V, Sine Function Generator
c(t)	1	10000 Hz, 4 V, 0 V, Sine Function Generator
P1, P4	2	0.7 , 5 Power Supply
D1, D2	2	Diode
R1	1	300 Ω Resistor
R2, R3, RR_1, RR_3	4	1 kΩ Resistor
L1	1	2.4 mH Inductor
C1	1	106 nF Capacitor
U1, U3	2	741 Operational Amplifier
P2, P3	2	15 , 5 Power Supply
U2	1	0.2 ms Oscilloscope
C2	1	1 μF Capacitor
R_2, R_4	2	2.12 kΩ Resistor
P5	1	1.2 , 5 Power Supply
R4	1	100 Ω Resistor

Despite the look of the circuit, it is actually almost identical to the one designed using Matlab in function and topology. The differences between both circuits are :

1. We have assumed in the Matlab circuit that the diodes we are using are ideal. However, no such diodes exist. Therefore, we used a conventional silicon diode which has a forward bias voltage of about $0.7V$. While this voltage may seem small, it is considerably large to the voltages in our circuit. Thus, before each diode, we have added DC voltage of $0.7V$ via DC power supply. This way, we cancel out the side effect of the silicon diode.

2. In the Matlab circuit, we used an operational amplifier that worked ideally and did not need a power. However, in breadboard implementation we are using a classic 741 Op-Amp, which needs to be powered by a $15V$ voltage, one negative and the other is positive. Therefore, we have used two $15V$ power supplies.

These were the only differences between the designed circuit and the actual implementation.

3 Results

After comparing both designs, what about the final results? Well, no surprises here, they are actually very similar!

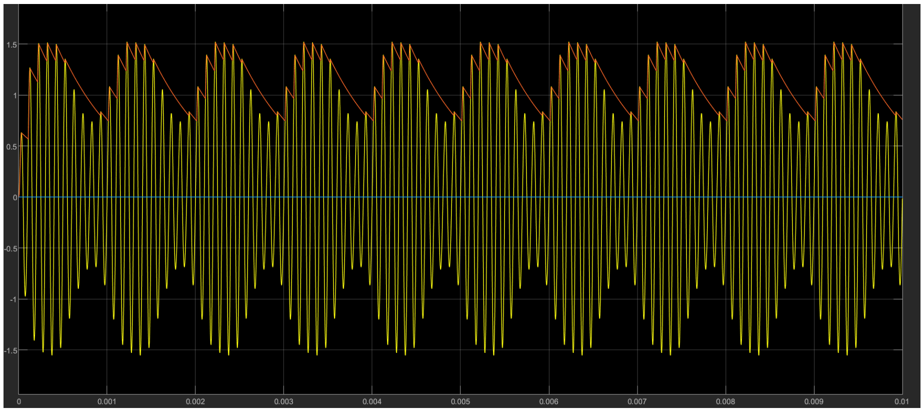

Figure 3: Matlab modulated signal waveform (yellow) with the result of the envelope detector (red)

In **Figure 3**, you will see the modulated signal as simulated on Matlab. you can see that the maximum value is somewhere around $1.5V$ which is very close to the result calculated using pen and paper.

compare the result in **Figure 3** to that in **Figure 4**, which shows the modulated signal as output of the modulator built using the breadboard.

To explain the result shown in the oscilloscope in **Figure 4**, the scale of the oscilloscope goes from 2 to -2 (hence it shows $4V$ peak-to-peak), and each step is about $0.4V$. The waveform in the oscilloscope of our breadboard is almost identical to that simulated on Matlab, having a maximum a little short of $1.6V$ which is a fantastic result!!

Now, let us compare the demodulated (recovered) signals from both the Matlab simulation and oscilloscope of the breadboard implementation.

Beginning with the Matlab circuit's demodulated signal in **Figure 5**, we can see that its peak-to-peak voltage is very close to that of the message signal (almost $1.6V$) and has the same frequency. We can see that there's a ripple in the circuit which can be smoothen out later.

Now compare the result of the Matlab simulation in **Figure 5** to that in **Figure 6**, which contains the waveform of the demodulated signal in the breadboard implementation. You can notice that both waveforms are almost identical and therefore the breadboard implementation of the demodulator resembles perfectly the one designed on Matlab, they even have the same ripples!

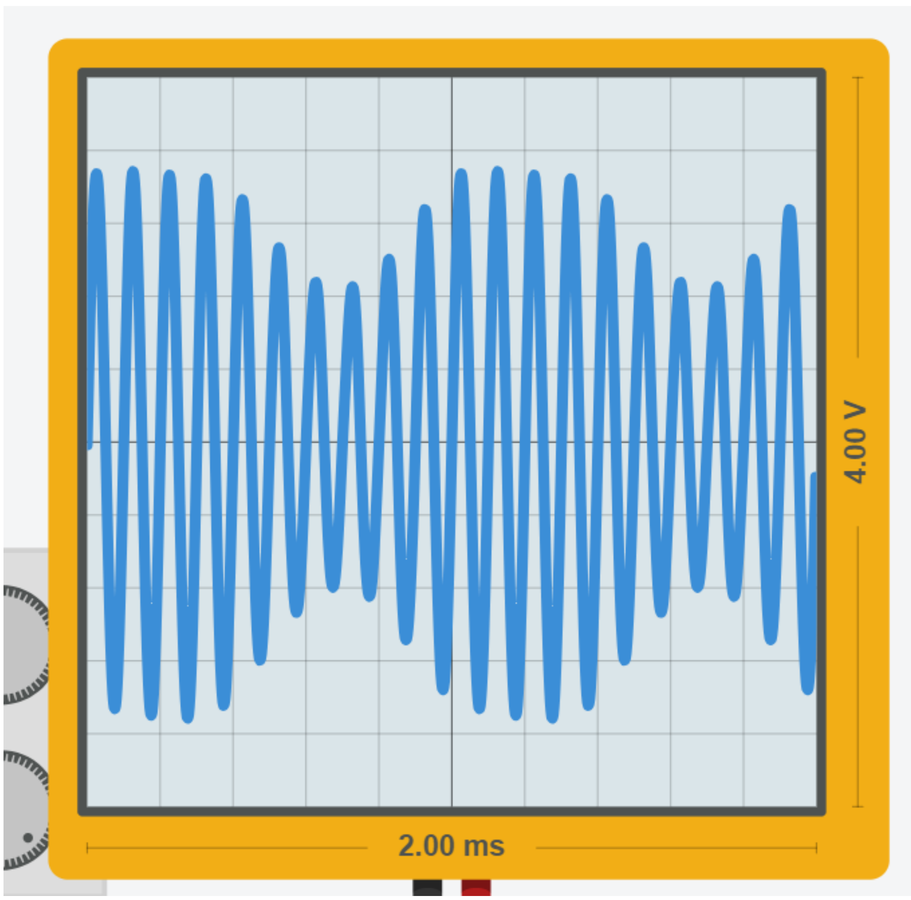

Figure 4: Breadboard modulated signal waveform

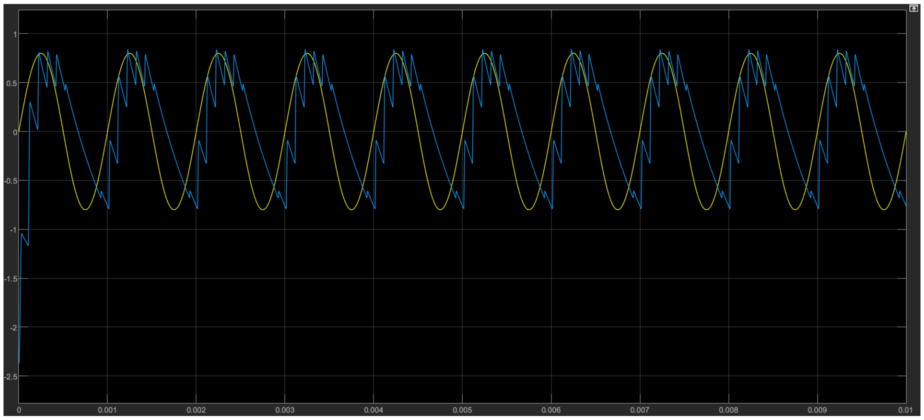

Figure 5: The Matlab demodulated signal (blue) compared to the message signal (yellow)

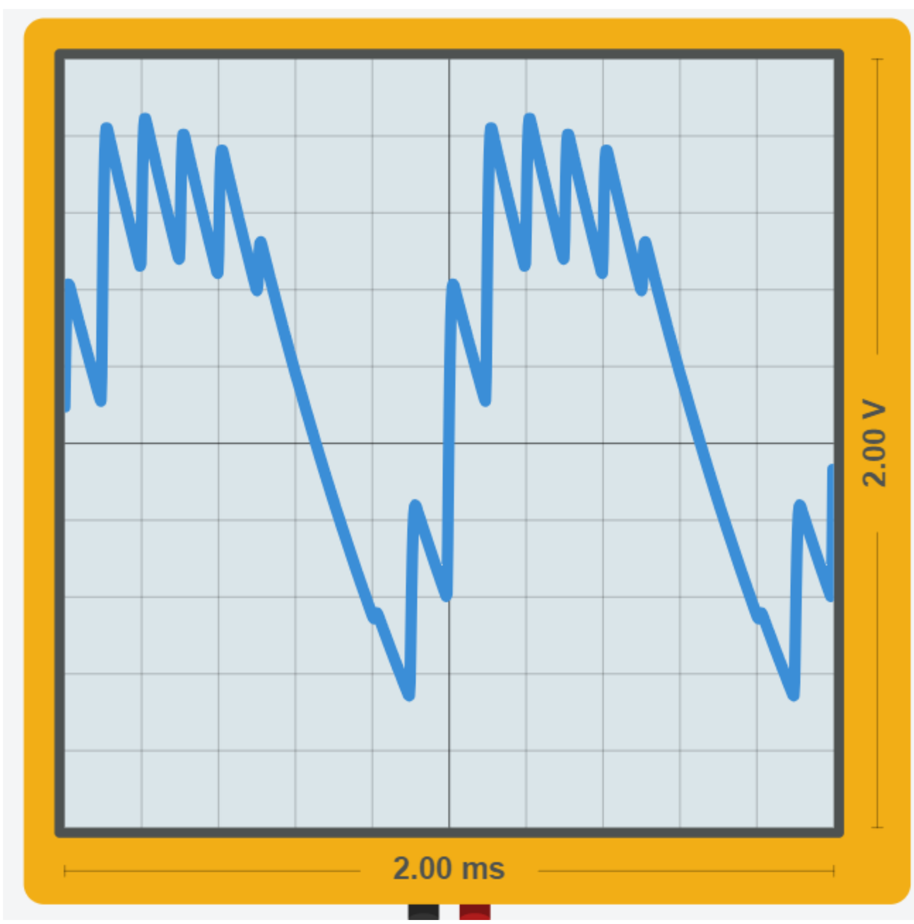

Figure 6: The Breadboard demodulated signal

4 Conclusion

In this phase of the project, we were able to implement the circuit that we have designed in the first phase with great success. By comparing the outputs and measurements of both circuits, we can conclude that our design is accurate and our breadboard implementation is sturdy and works as expected.