Lab 5 Amplitude Modulation and Demodulation

Prelab 5. Amplitude modulation and Demodulation.

In this experiment, the properties and characteristics of amplitude modulated (AM) signals and their frequency spectra are examined. An AM modulator is constructed using the Analog Devices AD534 four quadrant multiplier, and the properties of the resulting signal are examined using LabVIEW. The data sheet for the AD534 can be viewed or downloaded from

http://www.analog.com/products/sheets/AD534.html

You will need a copy of the data sheet to perform the AM lab.

Although AM is a continuous wave (CW) modulation, you will deal with it as a digital signal (discrete data points) when you perform the MatLab simulations. Because of the way MatLab simulates an AM signal, the outputs will look somewhat different from the results you will see when you create an AM signal in the Communications Lab. The MatLab m-files for the prelab are available on the CommLab web site, located at

http://www.utdallas.edu/~gibbs/commlab.

In amplitude modulation, the modulated carrier is represented by

$$\phi(t) = f(t)\cos(\omega_c t) + A\cos(\omega_m t) \tag{5.1}$$

$$= A(t)\cos(w_c t) \tag{5.2}$$

Depending on the nature of the spectral relationship between *f(t)* and *A (t)*, the following types of amplitude modulation schemes can be created: double-sideband (DSB) modulation, ordinary amplitude modulation (AM), single-sideband (SSB) modulation, and vestigial-sideband (VSB) modulation. In this experiment, you will examine DSB and AM.

Prelab 5.1 (Double Sideband Suppressed Carrier) AM signal

1. The modulating signal of DSB-SC AM signal is represented by

$$A(t) = A\,f(t)\,. \tag{5.3}$$

Using MatLab, generate a DSB-SC AM signal. The parameters for the simulation of DSB-SC are

Carrier	Modulating Signal
Sine wave	Sine wave
1 V_{pp}	1 V_{pp}
f_c = 55 kHz	f_m = 5 kHz

For this simulation set the time increment (t) to [0:1000-1] / f_s where f_s is the sampling frequency. *What time span does this time increment represent?*

Use a gain of one (unity gain) for the amplitude multiplier of the signal.

2. Create FFT plots of the modulated and carrier signals (2 plots). Compare the FFT plots of modulated signal and the carrier signal. *How many peaks are there in the FFT plot of the modulated signal?* Carefully observe the peaks. Measure the distance between the peaks in the frequency domain. Scale the plot to display greater detail around the significant peaks[1].

3. Demodulate this AM signal using a local oscillator with a LPF (Low-pass Filter).

   The demodulation technique which uses a local oscillator is defined as synchronous or coherent demodulation. Observe the outputs of demodulated signal in the time and frequency domains. You will need to add a gain component to view the filtered signal at the same amplitude as the original modulating signal. Observe the sinusoidal curve for the LPF output.

   There are two methods to generate SSB-SC signals. One is the frequency discrimination method and the other is the phase-shift method. In the MatLab simulation you will use the phase shift method. The frequency discrimination method generates a DSB signal and then suppress one of the sideband by filtering. In practice this method is not easy because the filter must have extremely sharp cut-off characteristics. The phase-shift method uses a $-\pi/2$ phase shifter which delays the phase of every frequency component by 90°. An ideal phase shifter is almost impossible to implement practically. For this simulation the Hilbert transform is used to provide the 90° phase shift. The MatLab function *hilbert.m* will generate the 90° phase shift.

Prelab 5.2 DSB-LC (Double Sideband Large Carrier) AM signal

1. The DSB-LC AM signal corresponding to $f(t) = a \cos(\omega_m t)$ is represented by

$$\phi(t) = A\,[\,1 + m \cos(\omega_m t)\,]\cos(\omega_c t) \qquad (5.4)$$

where m is modulation index for DSB-LC signal. Using the same settings as in Prelab 5.1, generate a DSB-LC AM signal.

2. Use a sine wave for the modulating and carrier waveforms. Generate four plots, one each at modulation indices of 10%, 50%, 90%, and 150%. In your report, describe the effects of the modulation index on the output signals.

3. Compare the FFT plots of the modulated signal and the carrier signal. How many significant peaks can you find in the FFT plot of the modulated signal? Carefully observe the peaks. Measure the distance of the peaks in the frequency domain. Scale the plot to more closely examine the significant peaks.

---

[1] Scaling can be done in one of three ways. First, you can modify the time base of the signal you create in MatLab. Second, you an use the *axis* function to narrow the time displayed in the plot. Finally, you can use *zoom* to accomplish the same purpose.

4. Next, demodulate this AM signal using a *envelope detector* and a *local oscillator* with LPF (Low-pass Filter). You learned how to filter the signal in time domain during the prelab of the last experiment. For this lab use the MatLab function *hilbert.m* to perform envelope detection. Observe the outputs of demodulated signal in the time and frequency domains. You will need to amplify the filtered signal appropriately. Observe the detail of sinusoidal curve for the LPF output by using *zoom.m*. This observation is to be done in the LPF that uses the system function of time domain.

Prelab 5.3 SSB-SC (Single sideband Suppressed Carrier) AM signal

If we let $\hat{f}(t)$ be the output of the $-\pi/2$ phase shifter due to the input $f(t)$, then a single sideband signal is represented by

$$\phi_{SSB\pm}(t) = f(t)\cos\omega_c t \mp \hat{f}(t)\sin\omega_c t \qquad (5.5)$$

The difference represents the upper-sideband SSB signal, and the sum represents the lower-sideband SSB signal.

1. Generate an upper-sideband SSB signal and then a lower-sideband SSB signal. Use the same frequency and amplitude configuration as you used to create DSB-LC and DSB-SC. Compare the FFT plots of the upper-sideband SSB signal and the lower-sideband SSB signal. Determine the frequencies of the significant peaks.
2. Demodulate the SSB signals using a local oscillator. Plot the output of the receiver in both the time and frequency domains.

Prelab 5.4 DSB-LC AM modulated by a triangular wave

For this procedure a Triangular wave is the modulating signal input for DSB-LC AM. Use the same frequency and amplitude configuration used for DSB-LC. Observe the harmonic distortion of the FFT in the output.

Keep in mind that the frequency axis of the FFT plot in MatLab cannot exceed the sampling frequency. Using these settings you will not be able to observe the harmonic distortion caused by using a triangular signal for the modulating input. To properly display the distortion requires increasing the resolution of FFT by increasing the number of samples. Within the limits of the student edition of MatLab, increase the number of data points to the maximum possible, and create a plot showing the harmonic distortion.

Prelab 5.5 PSpice modeling

Carefully study the data sheet for an AD534 and determine the necessary components for constructing an AM modulator using this multiplier. A PSpice model of the AD734, which functions similarly to the AD534, is available on the Analog Devices web site at

http://www.analog.com.

You may want to use PSpice to simulate the circuits external to the AD534.

Lab Experiment 5 Amplitude modulation and demodulation

Part List for Lab 5

Resistors:
 Determined by circuit
Capacitors:
 Determined by circuit
Integrated circuits:
 2 – Op-amp uA741
 2 – AD534 Multiplier
Semiconductors:
 1 – 1N4148 diode

Lab 5.1 Create a DSB-SC signal

1. Build the linear AM modulator shown in Figure 1. For more information, see Figure 10 of the data sheet.

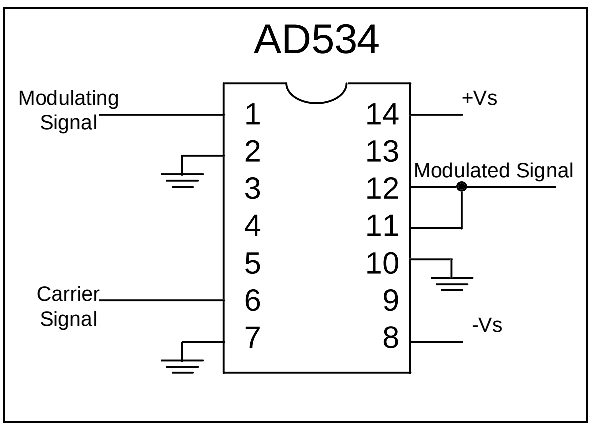

Figure 1. AM Suppressed Carrier Modulator

2. The function generators will be used to generate both carrier and modulating signals. To set up the function generators, use the following parameters:

Carrier	Modulating Signal
Sine wave	Sine wave
5 V_{pp}	10 V_{pp}
f_c = 55 kHz	f_m = 5 kHz

3. Generate a double side band suppressed carrier (DSB-SC) signal by connecting pin 10 to ground.

4. Plot the resulting DSB-SC AM signal in the time and frequency domains.

Lab 5.2 Create a DSB-LC signal

1. Connect pin 10 to pin 6, generating a double side band large carrier (DSB-LC) AM signal.

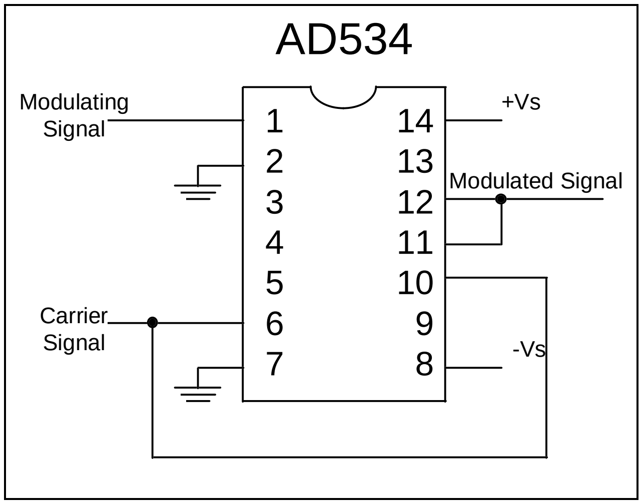

Figure 2. AM Large Carrier Modulator

2. Measure the modulation index.
3. Plot the resulting DSB-LC AM signal using the oscilloscope in the time and frequency domains.
4. Adjust the amplitude of the modulating signal to create modulating indices of m = 0.5 and m = 0.9 and repeat (3) for each.

Lab 5.3 Demodulate the DSB signal using Envelope Detection

1. Use the circuit shown in Figure 3 to demodulate the AM LC signal. Set the carrier frequency, f_c, to 140 kHz. Use component values for the Low Pass Filter, R_2 and C_1, which are appropriate for the modulation frequency, i.e., RC >> $1/\omega_c$.

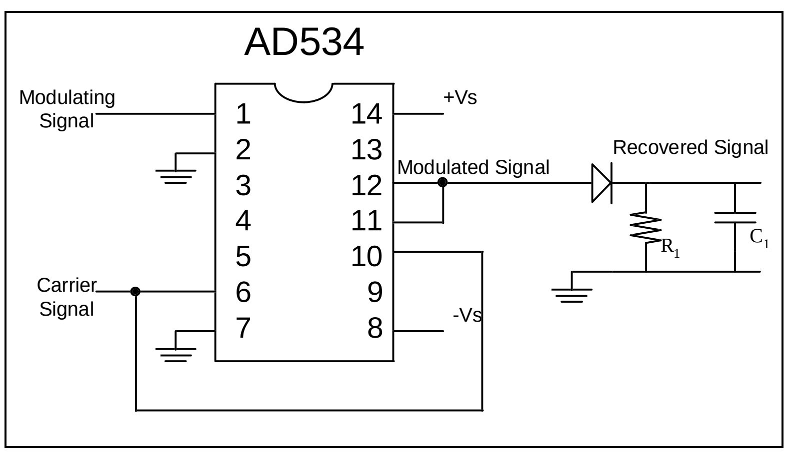

Figure 3. Modulator and Envelope Detector for AM DSB

1. Plot the recovered signal in the time and frequency domains.
2. Repeat steps (1) and (2) when the modulating signal is a triangle wave.

Lab 5.4 Demodulate the DSB signal using Coherent Detection

1. Set up the demodulation circuit with using the second AD534 as shown in Figure 4. This demodulator, which performs coherent demodulation, can demodulate both DSB-LC and DSB-SC.

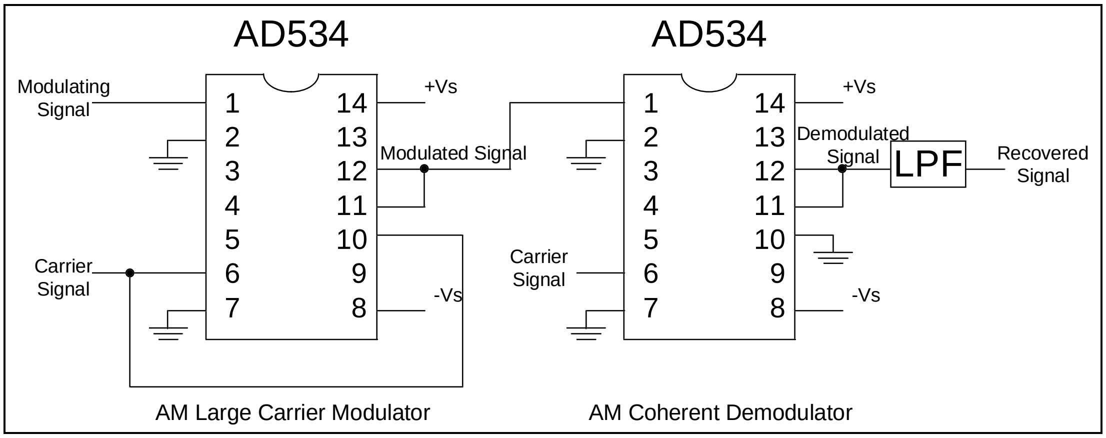

Figure 4. AM Modulator and Demodulator

2. Observe the output of the demodulator and plot the demodulated signal in the time and frequency domains.
3. In order to recover the original modulating signal, connect a low pass filter to the output of the demodulator. You may use a circuit based on the band pass filter you designed in Lab 4, or implement the circuit shown in Figure 5.

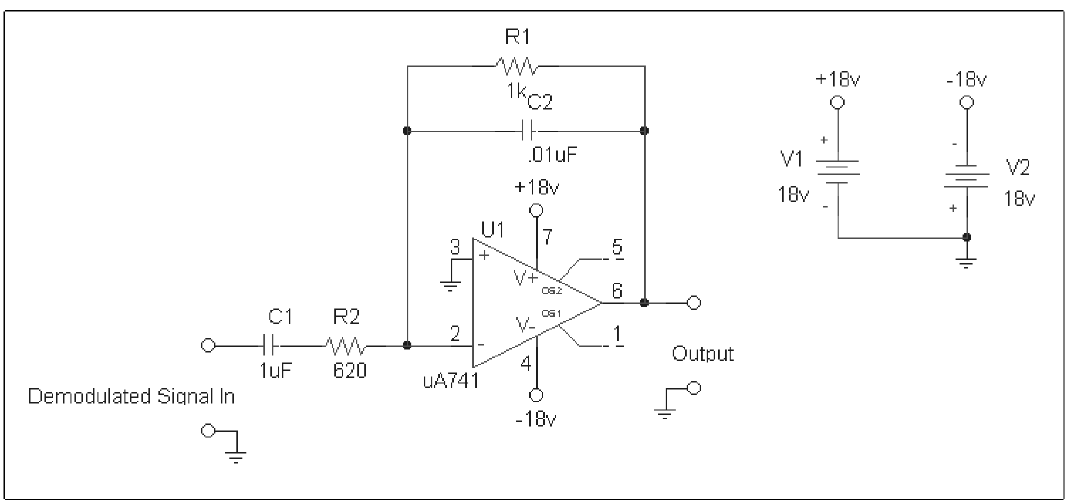

Figure 5. Low Pass Filter

4. Observe the output of the LPF and plot it in the time and frequency domains.
5. Repeat steps (1) through (4) when the input is a triangle wave.

Report

In your report compare the different modulation schemes.

Describe the differences you noticed between the MatLab simulation and the actual circuit design.

What design criteria did you use to design the LPF to recover the original modulating signal? How well did it work for the different modulation schemes?

Describe difficulties you encountered demodulating the triangle wave.

Explain any areas where you departed from the procedure in order to complete the experiment.

Answer any questions raised in the Prelab procedure.