ECE 146A: Analog Communication Theory and Techniques
Lab 3: Amplitude Modulation and Demodulation – Hardware

Lab Report Due: 5:00 p.m., Tuesday, February 12, 2008
(Place in the ECE 146A Homework Box on the 3rd Floor of Harold Frank Hall or Bring to Class)

1 Objective

The goal of this lab is to implement and verify various techniques for performing amplitude modulation (AM) and demodulation, such as a balanced modulator and a synchronous detector. You will utilize integrated circuit chips and simple nonlinear circuits.

2 Laboratory Room

Engineering I, Room 5162. Note that you will work in groups of two students, but each student must submit a separate lab report.

3 Equipment

Along with an oscilloscope, a digital multimeter (DMM), a function generator, and a power supply, you will need the following equipment:

1. MC1496 balanced modulator/demodulator.
2. LF353 wideband dual JFET operational amplifier.
3. Various resistors, capacitors, and diodes.
4. Breadboard.
5. Cables: BNC to IC clips (3 each), banana cable for DC power supply (3 each), DMM test leads (1 each).
6. Needle nose pliers and wire cutters.
7. Wire.
8. Card key for room 5162.

Most of these items can be purchased as a lab kit from the Electronics Shop on the first floor of Engineering I.

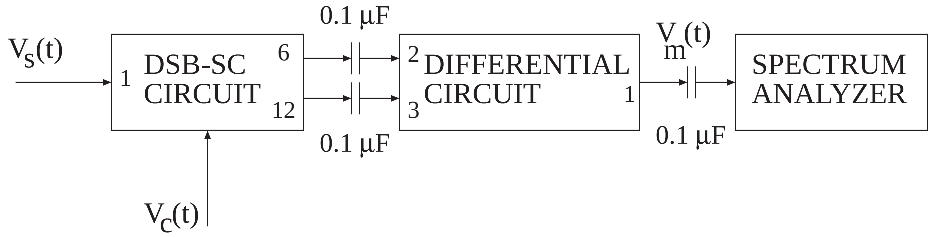

Figure 1: DSB-SC modulator using the MC1496.

4 Background

4.1 MC1496 Balanced Modulator/Demodulator

The MC1496 is a monolithic transistor array integrated circuit (IC) arranged as a balanced modulator/demodulator. It was designed for use where the output voltage is a product of an input voltage (the message) and a switching function (the carrier). Typical applications include double-sideband suppressed-carrier (DSB-SC) modulation, conventional amplitude modulation (AM), synchronous detection, frequency modulation (FM) detection, phase detection, and chopper applications. Refer to the MC1496 data sheet located at the ECE 146A web site. In particular, observe the pin connection diagram and the signal waveforms for the various modulation formats.

4.2 DSB-SC Modulation

Recall from Lab 2 that waveform modulation is a process by which a certain parameter of a signal (the carrier) is varied in proportion to a second signal (the message). In conventional AM and DSB-SC modulation, the amplitude of a sinusoidal signal, whose frequency and phase are kept constant, is varied in proportion to the message signal. This alters the message signal by translating its frequency components to a higher frequency range. In general, we will use the following notation: A_c = the carrier amplitude, A_m = the message amplitude, $m(t)$ = the original message signal, $s(t)$ = the modulated signal, and f_c = the carrier frequency.

Figure 5 of the MC1496 data sheet shows a typical circuit for implementing a DSB-SC modulator. Note that this chip provides a balanced output where the modulated signal $s(t)$ is the difference between $+V_0$ and $-V_0$. Thus, a difference circuit based on the LF353 must be used to generate a single output V_0 with respect to ground. A block diagram of the overall DSB-SC modulator using the ICs is shown in Figure 1.

4.3 LF353 Dual Operational Amplifier

The LF353 is a JFET operational amplifier with an internally compensated input offset voltage. The JFET device provides a wideband signal, with low input bias currents and offset currents. Refer to the LF353 data sheet located at the ECE 146A web site. In particular, observe the pin connection diagram and the table of electrical characteristics.

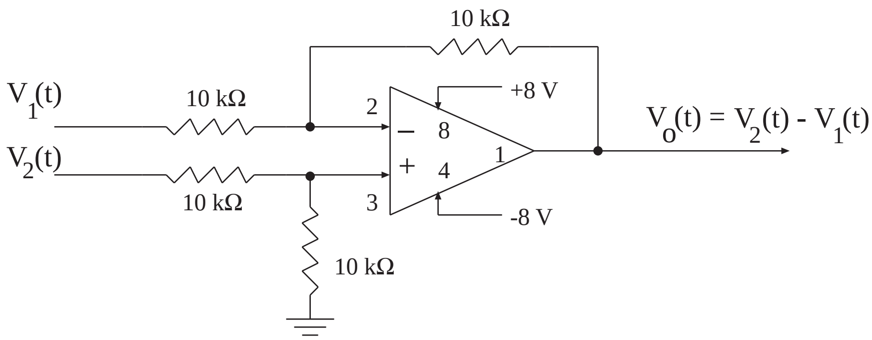

Figure 2: Difference circuit based on the LF353.

4.4 Synchronous Demodulation

In order to recover the message signal $m(t)$ from the modulated signal $s(t)$, the receiver modulates the received signal using the same carrier signal and subsequently filters out the undesired high-frequency components. Refer to a discussion of this in your course textbook.

5 Preparation

- Review the discussions of AM and read the data sheets for the two ICs used in this lab.
- Review how to design a first-order lowpass filter (LPF).
- Review the discussion of envelope detection in your textbook.
- Answer the following questions:
  1. Draw a schematic diagram for a first-order LPF, and write the formula for its cutoff frequency f_{cutoff}. What should f_{cutoff} be for a 1 kHz sine wave and a 1 kHz square wave?
  2. Explain why we do not choose a carrier frequency higher than 100 kHz in this lab.
  3. What mathematical operation does the MC1496 perform?
  4. You will perform DSB-SC modulation and synchronous demodulation using a sinusoidal carrier. Assuming that the message signal is $m(t)$: (a) Provide equations for the modulated signal $s(t)$ and the demodulated signal $v(t)$. (b) Plot the spectra of $s(t)$ and $v(t)$. (c) What mathematical operation should be applied to $v(t)$ in order to obtain the message $m(t)$? (d) What is f_{cutoff} for the LPF used in this demodulator?
  5. Implement a difference circuit using the LF353 with inputs $V_1(t)$ and $V_2(t)$ and output $V_0(t) = V_2(t) - V_1(t)$, based on Figure 2.

6 Procedure

Let $V_s(t)$ be sinusoidal with 0.5 V rms and a 1 kHz frequency. Let $V_c(t)$ be sinusoidal with 50 mV rms and a 100 kHz frequency. After you have completed the following experiments, use a square wave as the source signal and repeat each step to generate the plots and response data. Then qualitatively compare the two sets of results, i.e., that of the sinusoidal wave with that of the square wave. Check that your circuit is working properly before taking any measurements.

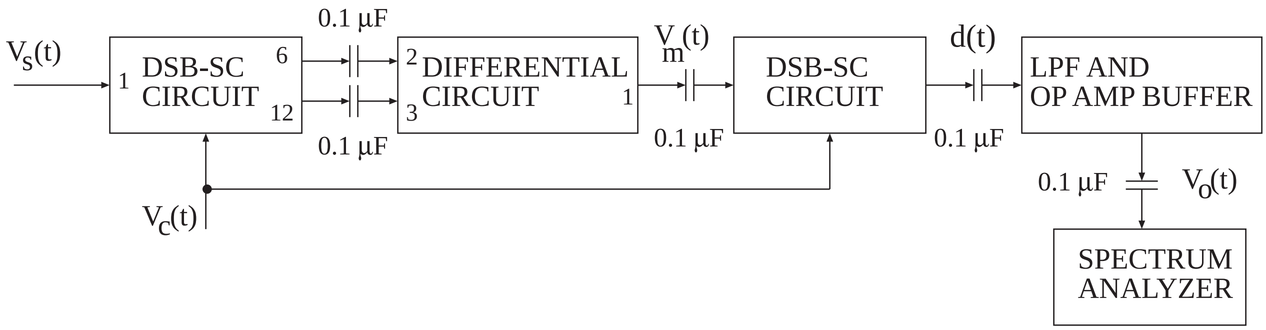

Figure 3: Synchronous DSB-SC demodulator.

6.1 DSB-SC Modulation

(a) Using the function generator to generate the sinusoidal waveforms, implement the circuit in Figure 1. Verify that the circuit works properly by observing and recording $V_s(t)$, $V_c(t)$, and $V_m(t)$. It is recommended that $V_s(t)$ be used as the trigger voltage to view $V_m(t)$.

6.2 DSB-SC Demodulation

(b) Design a DSB-SC demodulator based on the circuit in Figure 3 to retrieve the message from the DSB-SC modulator.

(c) View and print the spectrum of the modulated signal $V_m(t)$ centered at the carrier frequency $f_c = 100$ kHz.

(d) Observe the spectrum of the resulting signal $d(t)$. Determine the cutoff frequency value f_{cutoff} of the LPF so that the filter extracts the original signal from $d(t)$. What is the frequency of the unwanted signal component?

(e) Process $d(t)$ by the LPF with f_{cutoff} and observe the resulting signal in both the time domain and the frequency domain.

(f) Repeat the previous steps a couple of times using different frequency ratios of the message signal and its carrier. What are your observations and interpretations?

(g) Repeat the previous steps for a square-wave message signal. The LPF should be carefully designed to eliminate the sum frequency of the two demodulator inputs. Explain how a square-wave message changes your results in parts (c), (d), and (e).

6.3 Conventional AM and Envelope Detection

Modify your circuit to create a conventional AM signal (DSB with carrier) as described in the MC1496 data sheet, and design an envelope detector for the AM modulator based on the circuit in Figure 4.

(h) Verify the circuit functionality (modulated and demodulated signals) using the oscilloscope for the sinusoidal and square-wave message signals. Which demodulation technique performs better: DSB-SC with synchronous demodulation or conventional AM with envelope detection? Explain why.

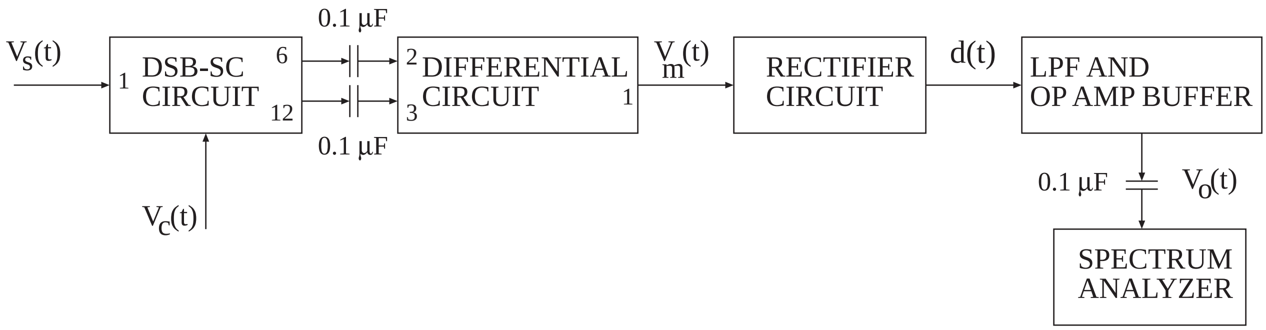

Figure 4: Envelope detector for demodulating conventional AM.

(i) In which situations would you use DSB-SC with synchronous detection over conventional AM? Why would you use the envelope detector, if at all?

(j) What input signal level causes overmodulation of the modulated signal? Verify your results at the output of the rectifier detector.

7 Lab Report

Use the standard lab report format and include the following items.

- Printouts from the oscilloscope showing the modulated signal.
- Answers to all questions in this handout.
- Circuit designs, schematic drawings, and a parts list.
- Testing results: circuit debugging, spectrum plots, and time-domain waveforms.
- Write a paragraph about any questions or confusions that you may have experienced with this lab.