Lab 7

Sampling

7.1 Pre-Lab

1. According to the sampling theorem, if the input of a sampling circuit is an analog sine wave whose frequency is f_0, what is the minimum sampling frequency? If the implemented sampling frequency is lower than this, what will happen?
2. In Pulse Amplitude Modulation, there are two ways to realize the sampling: natural and flat-top sampling. According to the circuit diagram in Figure 7.1a, which kind of sampling are we going to use? Explain your answer.

7.2 Overview

In this lab we will investigate the sampling theorem and the concept of aliasing.

The sampling theorem states that to recover a signal from a collection of samples, those samples must be taken at a rate greater than or equal to double the signal's bandwidth. The reasoning behind this is that we can represent the action of sampling as a summed train of impulses multiplied by the signal.

$$\bar{g}(t) = \sum_n g(nT_s)\delta(t - nT_s)$$

where T_s is the sampling interval.

This action in the time domain corresponds to copying, scaling, and shifting by $f_s = 1/T_s$ in the frequency domain. Thus, to avoid frequency-domain overlap, we require that the shift to be such that

$$f_s \geq 2B \tag{7.1}$$

where B is the bandwidth of the original signal.

Thus, the original signal can, theoretically, be recovered with a low-pass filter and an inverse Fourier transform.

7.3 Procedure

1. Build the balanced modulator circuit shown in Fig. 7.1a. Adjust the pulse generator to generate a sequence of very narrow pulses of width 300 ns at a frequency of 30 kHz. Adjust the output of the pulse generator to be 1 V High and 0 V Low. This will be the *carrier input* to the balanced modulator.

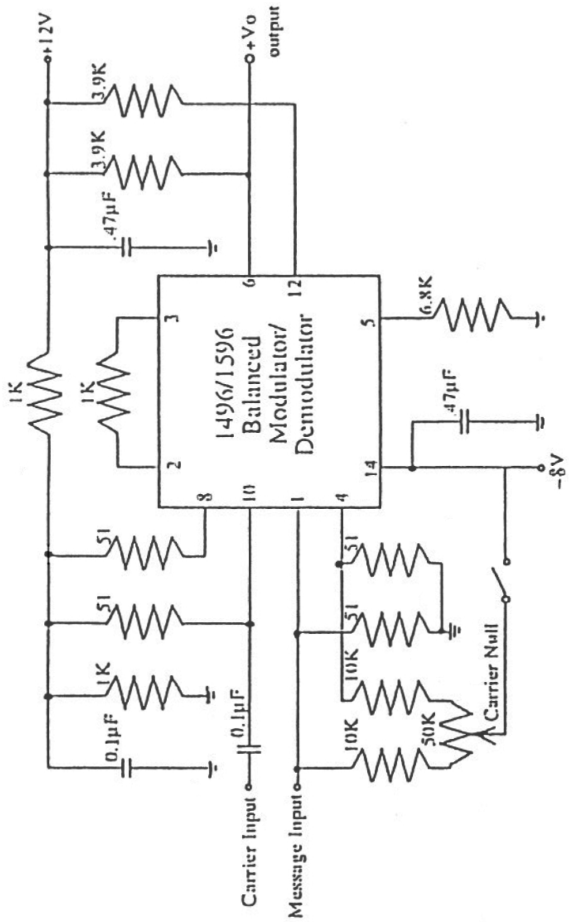
2. Let the *message input* be a sinusoid signal at a low frequency (approximately 1 kHz) of peak amplitude 1 V and observe the output waveform on the oscilloscope. What do you expect to see? Sketch the resulting waveform. Refer to Figure 7.1b for the block diagram of a balanced modulator.

3. Buffer the output signal according to Figure 7.2 to view it on the spectrum analyzer (attenuate as needed). Sketch the waveform observed on the spectrum analyzer.
   Use a simple voltage divider to ensure that the op-amp receives a supply voltage of ± 8 V.

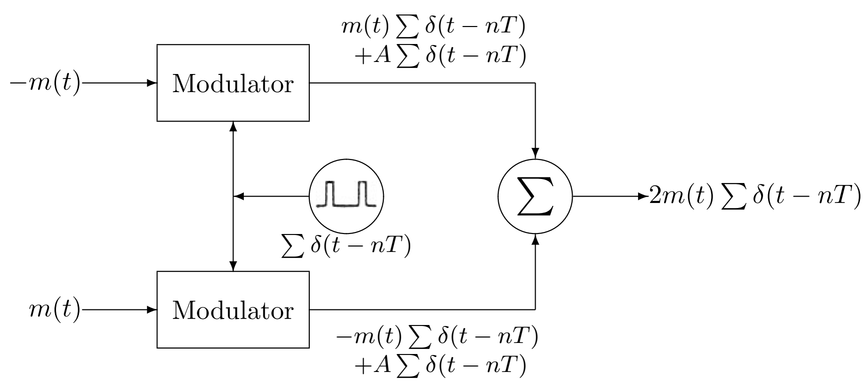
4. Pass this signal thrugh a low-pass filter (refer to Figure 3.2) to recover the message signal. Design the values of R and C for a cutoff frequency of 10 kHz.

5. Adjust the carrier frequency until you observe aliasing. Record this frequency. Sketch the signal in time and frequency domains. Do these results match with theory?

6. Change the message input to a triangular wave, and repeat Steps 2 through 5.

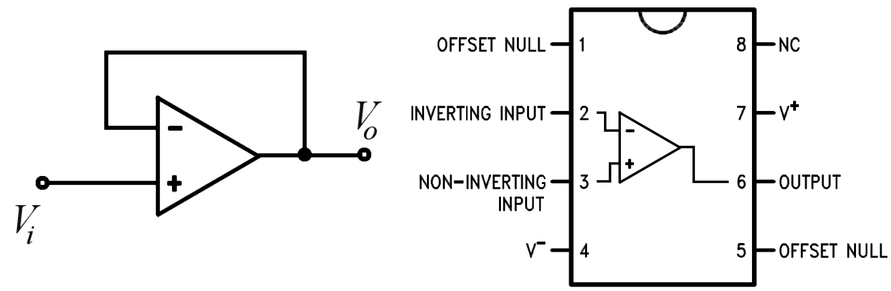


(a) Balanced modulator circuit diagram



(b) Balanced modulator block diagram

Figure 7.1: Balanced Modulator



(a) Common buffer amplifier (also known as a voltage follower)

(b) Single op-amp IC 741 pinout diagram. Courtesy [1].

Figure 7.2: Buffer construction for viewing on the spectrum analyzer

7.4 Discussion

If a triangular wave with fundamental frequency f_0 will be sampled, and we require that at least the fifth spectral harmonic of the wave be preserved while the higher harmonics must be removed, what is the minimum sampling frequency? In order to prevent aliasing, what must be done before sampling this signal?

Bibliography

[1] National Semiconductor LM741 Operational Amplifier datasheet. `http://www.national.com/ds/LM/LM741.pdf`