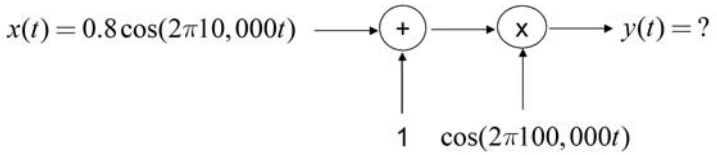
Name:_____

EE322: Lab 10-Filters & Amplitude Modulation

This lab has two parts: (1) to have you create and analyze some amplitude modulated (AM) signals; and (2) to see the effects of low pass filtering in hardware.

PART I: Amplitude Modulation

1. Given the double-sideband transmitted-carrier modulation system below, answer the questions that follow:



What is the equation for the output signal? y(t) = _____

What is the modulation index? _____

What is the frequency of the carrier? _____

What is the frequency of the lower sideband? _____

What is the frequency of the upper sideband? _____

Sketch the magnitude of the frequency spectrum for this AM signal:

2. Using the 33220A function generator, create a 100 kHz sine wave with a peak-to-peak voltage of 1V. Make sure the output is set to 50 Ω impedance (*Utility→Load*). Don't forget to push the "**Output**" button to get the output.

   Pass this signal using a T-coax connector to the Infiniium oscilloscope (left most BNC connector). Turn on the Oscope (if not already on). Ensure the impedance is set to **50Ω** to match the function generator.

   a. Push the Oscope's **"Default Setup"** and "**Autoscale**" buttons. To get a good display, you could also adjust the oscilloscope's horizontal knob (which controls the time axis, in seconds/div) and vertical knob (which controls the amplitude axis, in volts/div) until you get a satisfactory display of the sinusoid. Use the markers (**"Marker A"** and **"Marker B"**) to verify the period, frequency and amplitude of the signal the function generator is creating.

      Period: _____ Frequency: _____ Amplitude:_____

b. Connect the other end of the T-coax connector to the input of the spectrum analyzer. The spectrum analyzer will display a 1.8 GHz range of frequencies, which is too large to view the 100 kHz sinusoid. Using the "FREQUENCY" button, adjust the *Start Frequency* to 50 kHz. This can be done by depressing the following sequence of buttons:

"FREQUENCY", "Start Frequency", "5", "0", "kHz".
Similarly, adjust the *Stop Frequency* to 150 kHz.

c. Change the spectrum analyzer from a log (decibel) scale to a linear scale using the following sequence of buttons:

"AMPLITUDE", "Scale Log/Lin" (until the word "LIN" is underlined).

d. If needed, to make the peaks more prominent on the spectrum analyzer or just to fit the peak on the display, adjust the reference voltage level as follows:

Push the **"AMPLITUDE"** then **"REF LVL"** buttons, and turn the nearby dial to adjust the reference level value.

e. Using the marker (press "**MKR**", then turn the round white knob, measure the frequency and amplitude of the peak…the frequency and amplitude will be displayed when using the marker.

Frequency: _____ Amplitude: _____

The frequency at the peak should be approximately the same as in part (a). However, the amplitude in the frequency domain should be less than the amplitude in the time domain. This is due to the fact that the spectrum analyzer is displaying the *rms* voltage vice the peak voltage. Note also that the spectrum analyzer is only displaying positive frequencies.

2. Now use the function generator to create a full amplitude modulated signal. The message signal (modulating signal) will be a 10 kHz sinusoid, and the carrier is still the $1V_{pp}$, 100 kHz sinusoid.

a. On the function generator, push the "**Mod**" button, then set the following values:
Type: AM
Shape: Sine
AM Depth: 80% … also referred to as the % Modulation
AM Frequency: 10kHz … the frequency of the modulating signal (the message)

b. Using the spectrum analyzer, record the frequencies and magnitudes of the lower sideband (LSB), the carrier, and the upper sideband (USB):

LSB freq: _____ Carrier freq: _____ USB freq: _____

V_{LSB}: _____ V_C: _____ V_{USB}: _____

How do the frequencies and magnitudes of the carrier and sidebands compare to your theoretical answers in question 1 (keep in mind that the spectrum analyzer shows the rms value)?

c. Fill in the following table, where V_{LSB}, V_C and V_{USB} are the amplitudes of the lower sideband, carrier and upper sideband as measured on the spectrum analyzer. Vary the % modulation by adjusting the **AM Depth**. View the results on the spectrum analyzer and on the oscilloscope, and complete the table below.

	V_{LSB}	V_C	V_{USB}
50% Modulation			
80% Modulation			
100% Modulation			

The relationship between % modulation and the amplitudes of these components will become clearer when you cover amplitude modulation in EE354 next semester.

d. Describe the changes you see on the oscilloscope *and* the spectrum analyzer as the AM Depth is <u>reduced</u> (part c above).

_____

_____

_____

_____

<u>PART 2: Low Pass Filtering</u>

3. Recall that in Lab 6, you determined the Fourier series for a square wave that had a 50% duty cycle. You found that only odd multiples of the fundamental frequency of the square wave were present. If the frequency of the square wave is f_0 Hz, then the square wave is composed of frequency components of: f_0, $3f_0$, $5f_0$, etc. components. If you pass a square wave through a low pass filter, then some of the higher frequency components are removed and you no longer have a square wave. The goal here is to see how the shape of the square wave changes as the square wave is passed through the low pass filter.

   a. Obtain one of the five active low pass filter boards available in the lab. Read over the spec sheets on the filter board. The board has two channels (two low pass filters); we will only use one. The filters themselves are on the board and are labeled LTC 1569-7 (they are the small blue boxes).

   b. Connect the function generator output to the input of the low pass filter AND to the

Oscope channel 1 (break the connection to the spectrum analyzer, which we won't be using right now). Connect the output of the low pass filter ONLY to channel 2 of the Oscope (make sure Oscope channel 2 is set to 50 Ω input). Note that if you use the red connector on the input to the filter, that you should also use the red output connector (this connects the input and output to the same filter on the board). The same is true if you use the white connector in—use the white connector out.

c. Set up the function generator to produce a 1 kHz square wave. Its amplitude is not important. Push the Autoscale on the Infinuum Oscope to be able to see both the input and output of the filter displayed. The input is the yellow signal (channel 1), the output is the green signal (channel 2). Ensure that the low pass filter is turned on (switch on the upper right side—the filter is on if the red LED is bright.

d. The black switch in the center of the LPF board has three positions that control its cutoff frequency. Left corresponds to f_c = 8 kHz, middle corresponds to f_c = 32 kHz and right corresponds to f_c = 128 kHz. Adjust the switch to the three positions. Describe the effect on the output signal as the cutoff frequency is increased…does the filtered square wave get better or worse as f_c increases? Why is this?

e. Reset the cutoff frequency to 8 kHz, then increase the frequency of the square wave and describe what happens. At what frequency of the square wave does the output of the filter look like a sinusoid? Does that make sense considering the cutoff frequency?

f. Now connect the output of the filter to a T-coax connector, and pass the filter output to BOTH the Oscope channel 2 AND the spectrum analyzer. Set the frequency of the square wave to 15 kHz (high enough so it can be viewed on the spectrum analyzer). Adjust the start/stop frequencies on the spectrum analyzer to 10 kHz and 250 kHz, using a <u>linear</u> amplitude scale. Adjust the reference level on the spectrum analyzer as needed so the largest peak occupies the full window. You should see several of the frequency components of the square wave coming out of the filter.

g. Adjust the cutoff frequency of the filter from 128 kHz to 32 kHz to 8 kHz. Does the display on the Oscope and spectrum analyzer make sense as the cutoff freq. changes? Why?

h. Set the cutoff frequency of the filter to 128 kHz. Increase the frequency of the square wave as you observe the displays on the Oscope and spectrum analyzer…as you increase the frequency, what happens to the square wave? Why?