Experiment 7: Design of a Communication System

This experiment deals with the design and implementation of a communication system based on one of the modulation schemes that were examined in previous experiments (Exp. 3, 4, 5, and 6). The message (modulating) signal is bandlimited by using a passive second-order lowpass filter (Exp. 2) and the high frequency components are removed from the demodulated signal by using an active LPF (Exp. 2).

1 Introduction

There are two motivations for this experiment. First, among the requisites imposed by the Accreditation Board for Engineering and Technology (ABET) to laboratory courses in engineering schools is to have the students involved in the design of the experiments. Second, since this experiment requires the application of several of the important concepts learned in previous experiments, it is an excellent opportunity to review and summarize these concepts and to test not only your knowledge about the theoretical aspects of the lab but also your ability to design, assemble and test electronic circuits.

The complete experiment must be performed individually. You may consider this experiment as a final exam for the course. The grade you will obtain, however, accounts for the final grade just like any other experiment. A communication system with different parameters will be assigned to each student. You will have **one** lab period to complete the experiment working individually. You will not be able to perform this experiment without the prelab. Since this is a final exam, the help from the TA will be limited only to provide integrated circuits and to solve equipment problems. Since you already know what the signals and spectra should look like, the TA will not tell you if your results are correct or not.

The experiment will be graded based only on the plots *printed* during the lab and **no** lab report will be required. The criteria for grading will be the agreement between the experimental results and the given system specifications, as well as the proper selection of the time and frequency spans for each plot. In each spectral plot *all* the significant components belonging to the signal must be shown. Clipping, distortion and excessive noise in the signals will be penalized.

A block diagram of the communication system is shown in Fig. 1. Notice that two low pass filters are required, the first one in the transmitter end, limits the frequency range of the input signal. The second one, in the receiver stage, removes high frequency components that are contained in the demodulated signal. These filters will be designed by you according to some given specifications. The modulator and demodulator will correspond to the modulation scheme assigned to you.

2 Prelab instructions

1. Download the Matlab script *exp7.m*. Execute this script in order to obtain the specifications for your communication system. A file named *myproject.txt* will be generated by the script. Include a hard copy of this file in your prelab. [1].

2. Consider the circuit of the passive lowpass filter shown in Fig. 2:

   (a) Determine the components values to set the cut-off frequency f_c specified in *myproject.txt* (refer to Exp. 2). Avoid small input impedances and choose $R \geq 500\,\Omega$. The capacitor values available in the lab are: 100 pF, 470 pF, 1 nF, 10 nF, 22 nF and 100 nF. [Hint: You may need to get your own set of capacitors of different values to meet the requirement of $R \geq 500\,\Omega$]. Also, in the lab there is a vast selection of resistor values that you can use.

(b) Include a PSPICE simulation of the **magnitude response** of the circuit (refer to Exp. 2) [4].

3. Consider the circuit of the active lowpass filter shown in Fig. 3:

   (a) Determine the components values to set the cut-off frequency f_c and gain K specified in *myproject.txt* (refer to Exp. 2).

   (b) Include a PSPICE simulation of the **magnitude response** of the circuit [4].

4. From the schematics of Exp. 3, 4, 5, and 6, copy the modulator and demodulator schematics corresponding to the modulation scheme assigned in *myproject.txt* and modify, if necessary, any component values to create a schematic of the entire communication system described in Fig. 1 (consider the notes below). This schematic will be your guide to assemble the system. [4].

   Notes:

   - The output passive lowpass filter used in coherent detection of DSB signals (Exp. 3) must be replaced by the active filter of part 3.
   - To provide buffering of the output signal, the voltage follower of Fig. 4 must be placed between the output of the envelope detector (Exp. 4) or the output of the FM demodulator (Exp. 5) and the input of the active filter of part 3.

5. Review the lab procedure of the experiment corresponding to the modulation scheme you will use for your system. Pay special attention to the parameters of the input (modulating) and carrier (or sampling for PCM) signals that were used to test these circuits. Report the following parameters: [3]

   - Modulating signal.
     - Amplitude=
     - Offset=
     - Waveform=
   - Carrier (or sampling) signal.
     - Amplitude=
     - Offset=
     - Waveform=

   These parameters will be used to test your communication system. The values of the input and carrier signal frequencies are assigned in *myproject.txt*.

3 Lab procedure

GENERAL INSTRUCTIONS:

- Print each of the required plots. In Labview press `Ctrl-P` to print the window of the virtual instrument.
- Make sure to label (by hand) all the plots with a meaningful title.

3.1 Lowpass filters

In this section the lowpass filters will be tested prior to their incorporation to the communication system. The motivation for doing this is to facilitate the troubleshooting of the system.

1. Assemble the passive LPF shown in Fig. 2 with the component values you computed in Prelab part 2.
2. Obtain the frequency response of this filter by using RESPONSE.vi. Remember that this VI (virtual instrument) requires connecting Channel 1 of the oscilloscope to the output of the filter and Channel 2 to the input. Use the top function generator (FG1) to provide the input signal. The parameters for the VI are: *Lowfreq*=100, *Upperfreq*=100E3, *Amplitude*=10 V, *points/decade*=10, *Save data*=OFF.

3. Verify that the resulting frequency response is in agreement with the results of Prelab part 2. Print the plot by pressing `Ctrl-P`. Label the plot with a meaningful title. This is plot 1 (P1) [5].

4. Assemble the active LPF shown in Fig. 3 with the component values you computed in Prelab part 3.

5. Obtain the frequency response of this filter. The parameters for RESPONSE.vi are: *Lowfreq*=100, *Upperfreq*=100E3, *Amplitude*=8 V, *points/decade*=10. Verify that the resulting frequency response is in agreement with the results of Prelab part 3. Print and label the plot. This is plot 2 (P2) [5].

3.2 Modulator and Demodulator

In this section you will implement and test the modulator and demodulator for the communication system. *No plots will be printed in this section.*

1. Assemble the modulator and demodulator (without involving the filters yet) from the schematics of Prelab part 4.

2. Test the modulator and demodulator by applying a modulating sine wave signal (from FG1) with a frequency of f_x and a carrier (or sampling) signal (from FG2) with a frequency of f_s (both assigned in *myproject.txt*). Use the amplitude and offset voltages you reported in Prelab part 5. From previous experiments you should be able to determine if your circuit is producing the correct modulated and demodulated signals.

3.3 The Communication System

In this section you will build the communication system as described in Fig. 1. *Select a time span for each plot such that **2 to 4** periods of the signal are shown.*

1. Connect all the previous stages as shown in the schematic you created in Prelab part 4.

2. Apply the modulating (at node A, shown in Fig. 1) and carrier (or sampling) signal using the parameters of the previous section.

3. Using TIMEFREQ.vi take and print plots of the following signals: (when selecting the time and frequency span, use only values from a 1, 2, 4, 5 step sequence, i.e. 1, 2, 4, 5, 10, 20, 40, 50, 100, 200, 400, 500, etc).

   (a) Input signal to the system. Connect Channel 1 of the oscilloscope to the node A shown in Fig. 1. Choose a proper time (TS) and frequency span (FS) for your particular input frequency f_x. (P3) [2].

   (b) Input signal to the modulator. Connect Channel 1 of the oscilloscope to the node B shown in Fig. 1. Use the same TS and FS as in the previous plot. (P4) [3].

   (c) Modulated signal (**DSB and AM only**). Connect Channel 1 of the oscilloscope to the node C shown in Fig. 1. Choose a proper TS and a FS. Make sure *all* the components of the modulated signal are displayed in the spectrum. (P4a) [5].

   (d) Demodulated signal. Connect Channel 1 of the oscilloscope to the node D shown in Fig. 1. Again, make sure the spectrum shows all the significant components of the demodulated signal (for PCM at least the repetition of the message spectrum at f_s) (P5) [5].

   (e) Recovered signal. Connect Channel 1 of the oscilloscope to the node E shown in Fig. 1. Use the same TS and a FS as in the previous plot (P6) [5].

4. Make sure all the plots are labeled with a *meaningful* title, and turn them in to the TA. Please replace the wires box and the breadboard to the corresponding places but leave all the components in the workbench.

A lab report is not required for this experiment.

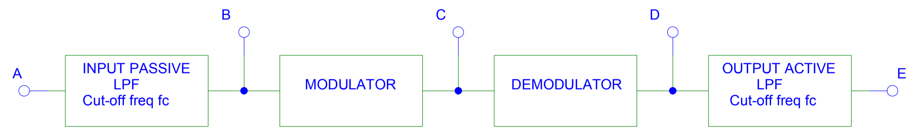

Fig. 1 Block diagram of a communication system.

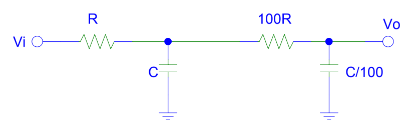

Fig. 2 Passive LPF.

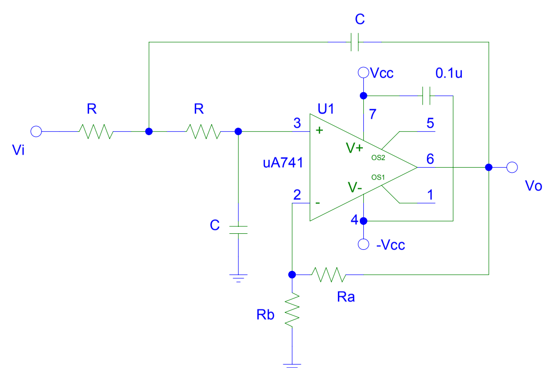

Fig. 3 Active LPF.

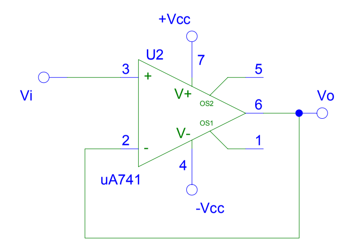

Fig. 4 Voltage follower

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