Laboratory Project 2 - AM & DSB-SC Modulation and Detection

Objectives

This lab project consists of 2 parts. In Part 1, you will investigate the performance of the simple envelope detector. In Part 2, you will generate and detect AM and DSB-SC bandpass signals using the LM1596/LM1496 Balanced Modulator-Demodulator.

This lab introduces the Rowan University Modular Backplane system. This system will be outlined below.

In both parts, you will test the system with single-tone AM (with and without added Gaussian noise) and multi-tone AM signals (without added noise).

Equipment and Software

* Function Generator/Arbitrary Waveform Generator
* Oscilloscope
* Modular Backplane
* Envelope Detector Module
* Audio Preamplifier Module
* AM Modulator Module
* Standard AM Demodulator Module
* DSB-SC AM Demodulator Module
* Assorted Resistors and Capacitors (based on design of filter).
* PC speakers
* Breakout Board
* 3.5mm Stereo Cable
* Audio Player Software on PC
* CD/mp3 with your favorite music!
* MATLAB (with Instrument Control Toolbox)
* MATLAB Connectivity Functions

Modular System Overview

Lab 2 introduces the new, fully modular backplane system (MBS), Figure 1, which you will use for the remaining labs in Ecomms. This system saves you the tedious process of prototyping all of the circuits required to complete the labs.

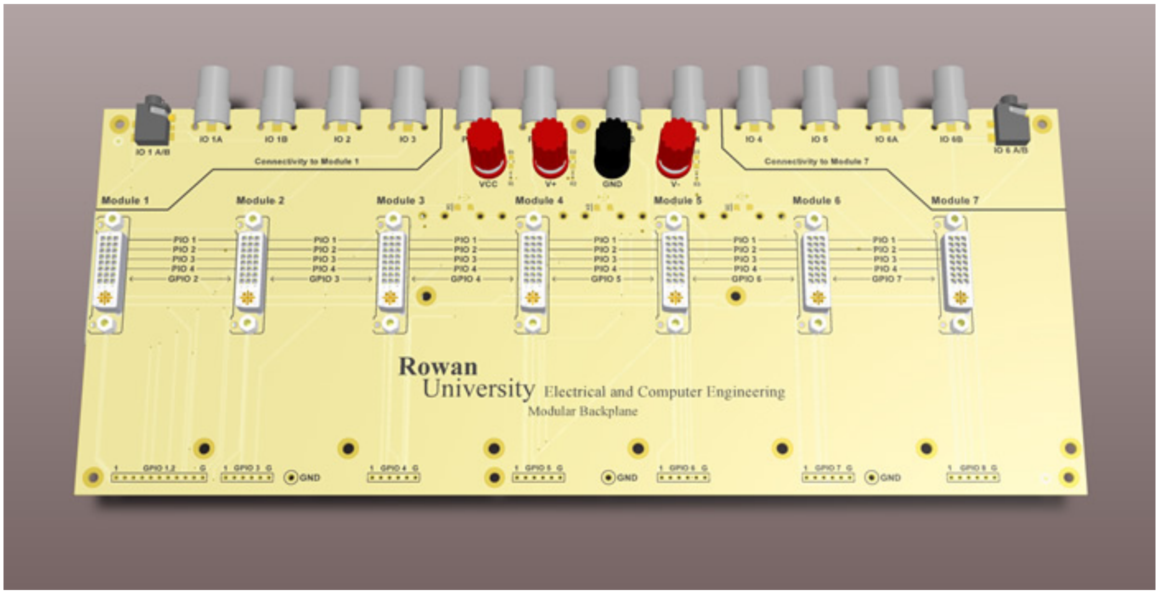

Figure 1. Modular Backplane.

This system is comprised of a modular backplane, which supplies power, baseband and RF connectivity, and GPIO to the inserted modules. The backplane has locations for up to 7 modules, which are installed in the DVI connectors on the board. The first (module location 1) and last (module location 7) modules are important and have special connectivity to the screened off sections (IO1, 2, 3 and IO 4, 5, 6). Generally, you should always put your first (input) and last (output) modules in the Module 1 and Module 7 positions, respectively.

It is important to note that the backplane is designed with both parallel and serial connectivity between the modules. This means that some IO are connected to ALL modules and some are only transferred into a module. Parallel IO (PIO Ports 1 thru 4) are selected by the layout of the specific modules so you must use the appropriate PIO specified by the module you are using (connections are marked on the module PCBs). The serial connectivity is utilized for inputs that are fed to a processing block on a module, processed, then output to another pin. Serial IO is only user-accessible via. the GPIO headers.

The GPIO headers at the bottom of the backplane tap into all tranferred IO between each module slot. This allows direct access of any signal, if needed.

The modules for this kit will vary depending on the application. It is up to you to decide the proper locations and signal path for your application. The backplane has no physical lockout for placing certain modules in certain locations to retain full functionality, so you must be very careful in laying out your system. Some modules include: Audio Preamplifier, Envelope Detector, AM Mod/Demod, FM Tx/Rx, etc...

If you need to get from one end of the board to the other and your application calls for less modules than slots, then you can use a jumper. This jumper simply transfers any serial connectivity between slots to the next, adjacent slot. You are supplied with 4 jumpers in your kit.

Most modules have test points located at the bottom edge of the PCB. These points are to be used with the hook of a scope probe. Grounds are convieniently located on the backplane. Test point maps will be specified in the lab pages.

The kit is also supplied with a breakout board, which can be used as a general purpose adapter to convert, for example, a BNC type connection to 3.5mm stereo.

All components of the MSB are housed in a custom case. When finished, mount the backplane with (AT LEAST!) 2 modules installed, place on its stand, and close the lid. This applies the correct amount of pressure to the plane and keeps it secure during transport. Ensure all modules are placed in their appropriate cutouts and any cables are coiled and placed neatly in the circular cutout. Do not leave any components loose!

Part 1

* The circuit for the passive envelope detector is shown in Figure 2. The design equation for the first-order low-pass filter made up by C1 and R1 is:

$$f_{co} = \frac{1}{2\pi R_1 C_1} \text{ where } f_{co} \text{ is the cut-off frequency of the LPF network: } R_1 C_1$$

* C2 is a coupling capacitor, chosen such that C2 >> C1. Note that this capacitor also forms a filter with the load impedance so you may wish to discover what rolloff is created here. As initial design parameters, choose a cut-off frequency of 5 kHz. (As part of the theory section in your report, you are expected to derive this design equation).

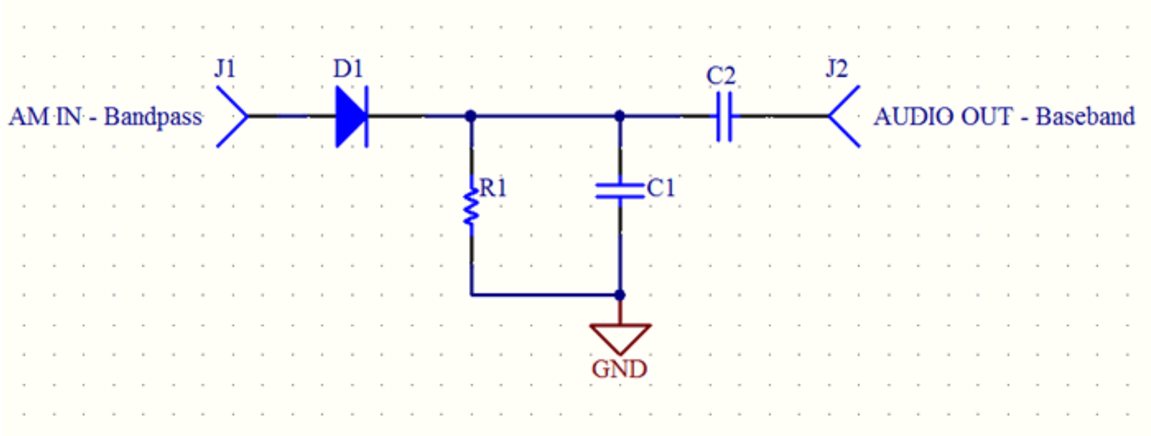

Figure 2. Passive Envelope Detector Circuit

* The envelope detector has been fabricated as a module, which is to be plugged-in to the modular backplane. This module has provisions for inserting the selected C1 and R1 components. Locations of these components are shown in Figure 3 below. **NOTE:** There is a RefDes on the board 'C1' in black silkscreen. This is NOT the C1 as above. The actual RefDes is C5 on the board. You will plug in the resistor and capacitor leads into the sockets in these positions.

Click here for the full schematic of the envelope detector module (includes circuit locations of test points).

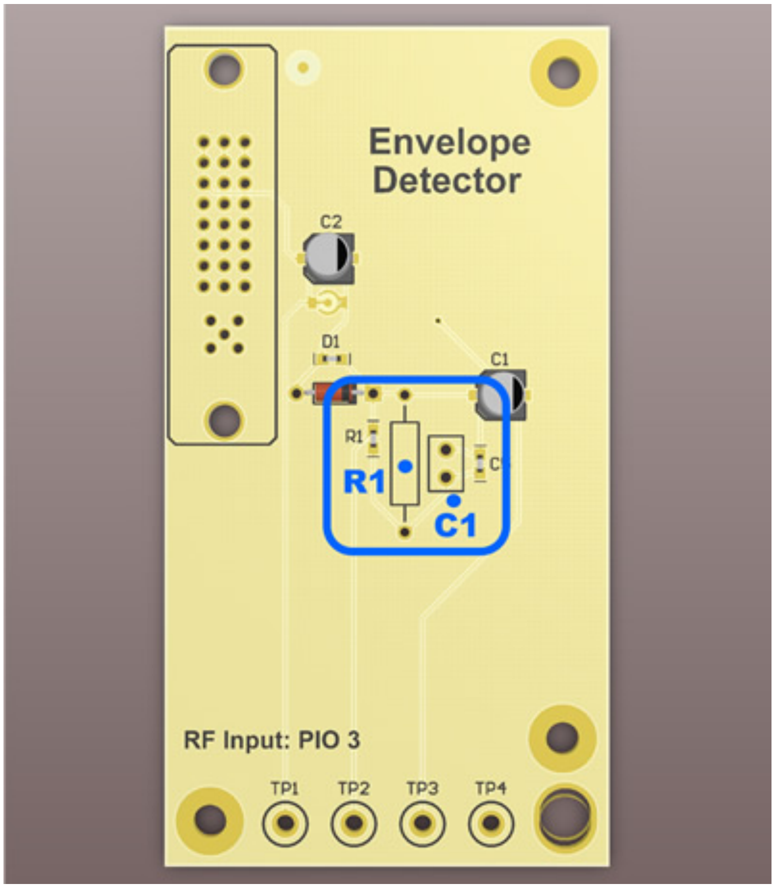

Figure 3. PCB locations for C1 and R1 on the Envelope Detector Module.

Single-Tone AM Detection: No added Gaussian Noise

* Using the HP/Agilent Arb. Function Generator, generate an AM wave with carrier frequency of 600 kHz (in the AM band) and modulation frequency 1 kHz (single tone). Feed this signal to the input of the envelope detector.

- Vary the modulation depth from 10% to 120%.

- For each modulation depth, observe and digitally capture the input and output waveforms using the scopedat.m MATLAB function.

- Perform a spectral analysis of the input and output waveforms. Observe the spectral components due to ripple and harmonic distortion. You may want to view the signal's spectrum using the oscilloscope FFT-Magnitude function before pulling data to MATLAB. To use the scope's FFT properly, you will likely need to manually set the frequency span and center. As with any spectrum analysis, you should have some idea what frequencies you are looking for (choose these settings accordingly).

- Listen to the output signal using the PC speakers. Note that the PC speakers and audio output of most consumer electronics is in stereo. This means each right/left channel has a distinct audio signal. In this lab, using only one detector, you will only be able to listen to one channel of audio and will effectively be 'mono.'

- Compare the signal with the pure tone of the same frequency.

* Set the modulation index to an optimal value (max value for minimum distortion) and vary the modulating signal frequency to determine the 3-dB bandwidth of the detector (value at which the output signal falls to 0.707 of its maximum value).

* Experiment by varying the carrier frequency and/or cut-off frequency of the LPF.

Multi-Tone AM Detection: No added Gaussian Noise

Figure 4 shows the overall block diagram for this part of the lab project.

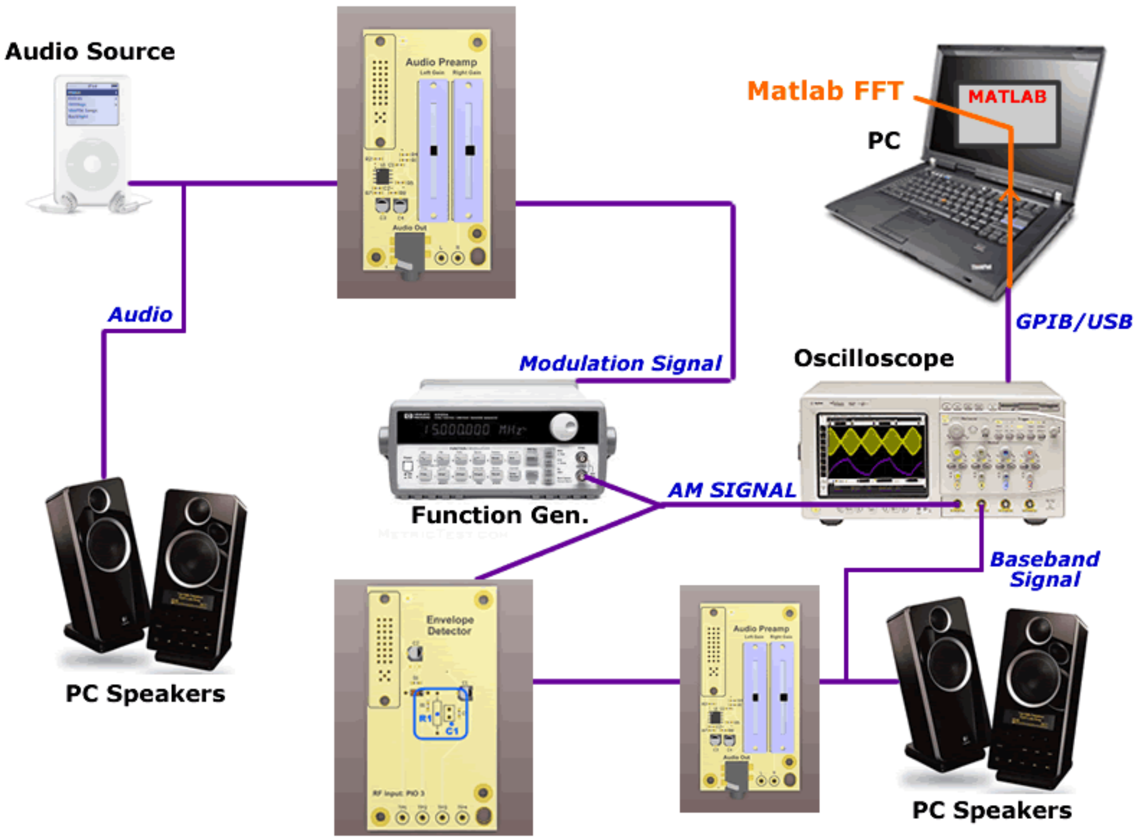

Figure 4: Multi-tone AM generation and detection.

* Obtain a multi-tone baseband signal by playing a CD on your PC, an mp3 on your favorite portable audio device, or mp3 on your PC and tapping into D/A converter output of the sound card (i.e. the headphone jack).

* Feed this baseband signal into the external AM modulating source input located on the back of the HP/Agilent 33120A Function Generator.

* Set the function generator to AM with EXTERNAL source. There should be an 'EXT' string displayed on the front panel indicating the AM modulator of the function generator will use the external port as the modulation source.

* Choose a suitable carrier frequency in the AM broadcast band ('medium wave' AM is most common for broadcast AM radio) and generate an AM signal.

* Observe the modulated signal on the oscilloscope. Vary the modulation depth by varying the gain of the operational amplifier.

* Apply the multi-tone AM signal to the input of the envelope detector. For each modulation depth:

- Observe, calculate the modulation depth and digitally capture the input and output waveforms.
- Perform a spectral analysis of the input and output waveforms.

Single-Tone AM Detection: With added Gaussian Noise (Optional)

* Repeat the single-tone AM detection experiment by digitally synthesizing single-tone AM signals with varying SNR in MATLAB as you did in Lab 1. As always, pay special attention to sampling and duration of your synthesized waveform and the frequency and amplitude settings of the function generator. Figure 5 shows the overall block diagram for this part of the lab project.

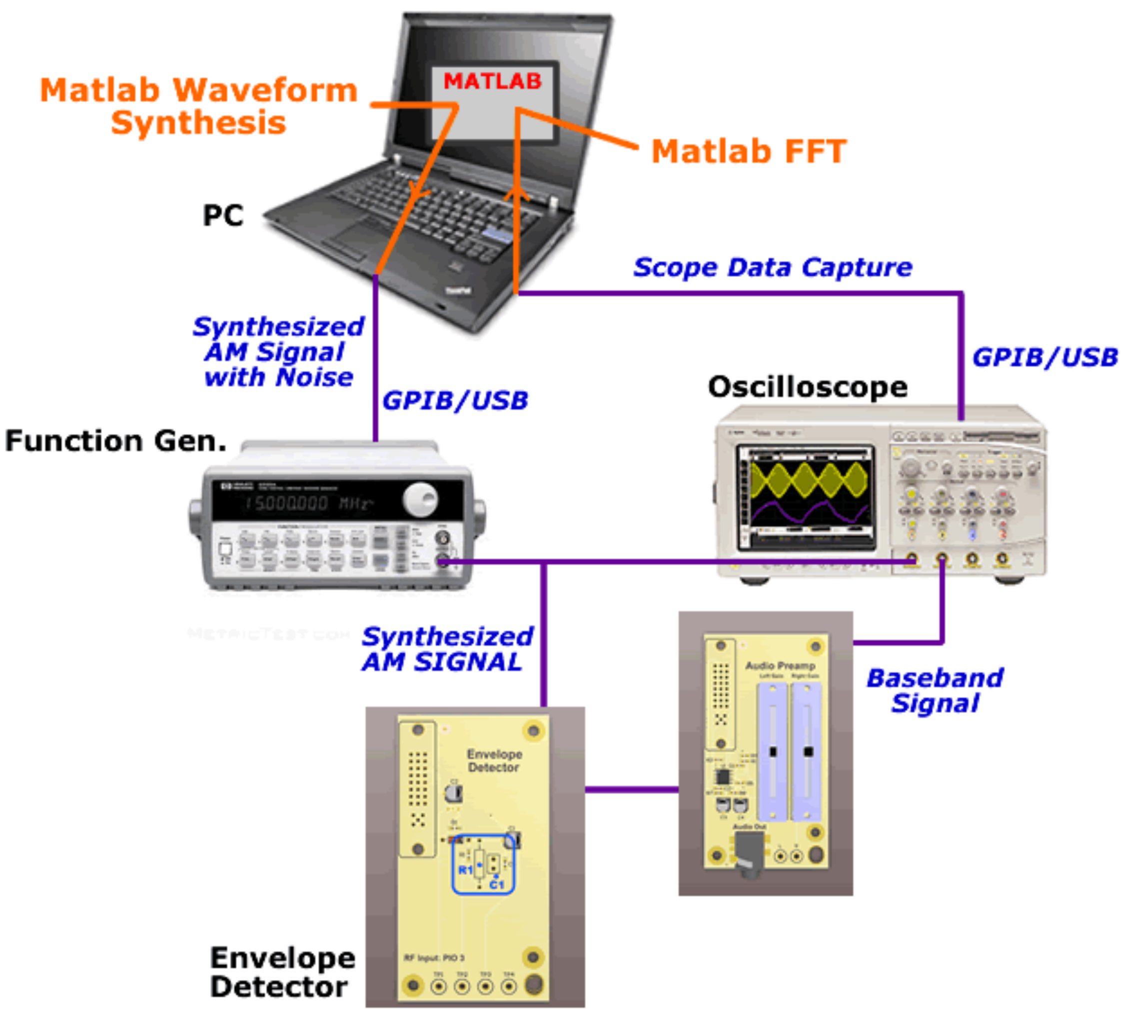

Figure 5: Block diagram of the approach for single-tone AM detection with added Gaussian noise.

* At each stage, note your observations and conclusions.

Part 2

The objective for part 2 is to observe (in both the time and spectral domains) & listen as audio progresses along a modulation-demodulation system, both in the presence and absence of added Gaussian noise.

* Configure the system for standard AM as shown in Figure 6 below. As an initial test, determine the system response by feeding two audio-frequency (<20kHz) tones to the input pins. The carrier signal amplitude should be 300mVRMS or about 1Vpp. Observe the waveforms on the oscilloscope and listen to the output using the speakers. **NOTE:** if you want to hear the 'volume' swell of the AM signal (which audibly demonstrates 'Amplitude Modulation') be sure you choose an appropriate message frequency (i.e. below ~10Hz). If it is too fast, it will simply sound like another tone.

Full schematics for each module are provided below (this includes circuit access for each test point):

AM Modulator
AM DSB-SC Modulator
AM Demodulator

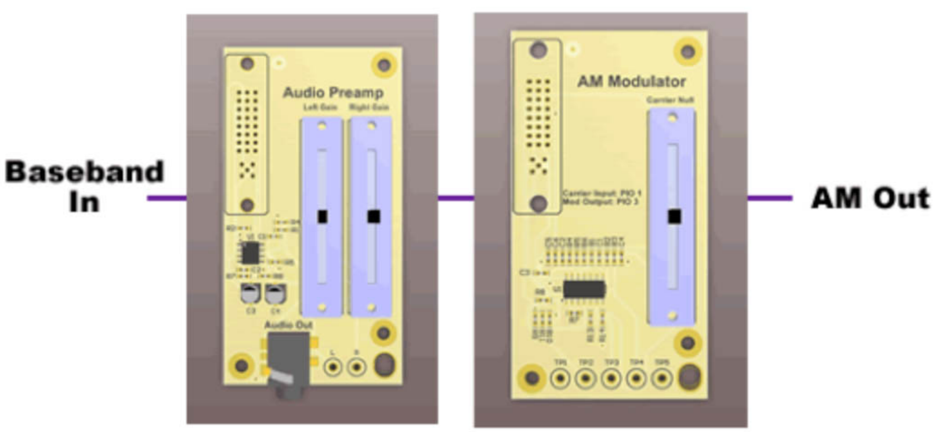

Figure 6: System configuration for standard AM modulation.

* Now increase the carrier signal frequency to the RF range and observe the output waveforms.

* Now connect the AM DSB-SC modulator module in place of the standard AM module. Vary the carrier null potentiometer to trim the DSB-SC modulation. Observe the system response both in the time and spectral domains (you need to perform a signal capture followed by an FFT operation to do this). Confirm the carrier null by viewing it in the frequency domain (use the scope's FFT-Magnitude function).

* Experiment with various carrier and modulation frequency settings.

* Vary the modulation signal amplitude - calculate the corresponding changes in modulation index. Determine the spectral response.

* Repeat the experiment by mixing in a multi-tone modulating signal (generated as in Part 1).

* Now configure the system for AM demodulation as shown in figure 7. Test the circuit by feeding in an external modulation multi-tone AM signal from the arb. Observe and listen to the audio output.

Figure 7: System configuration for AM demodulation.

* Test the product detector by feeding in digitally synthesized single-tone AM and DSB-SC signals with varying SNR. When does the modulator fail to detect the message signal? **NOTE:** The MC1496 AM demodulator performs best when the carrier frequency is above 100kHz.

* Link the modulator-demodulator circuits and observe signal progression from input to output. Be sure to capture screenshots to confirm the proper progression of the signal from baseband-to-baseband.

Required Reading

* Sections 4.11 - 4.13, 5.1 - 5.4 of textbook.

These labs originally created by Dr. Shreekanth Mandayam & Dr. John Schmalzel.

References:

* Appendix B (p. 650) in textbook
* Zsolt Papay, Technical University of Budapest (TUB),"Experiments in Gaussian White-noise Generation," HP Test and Measurements Educator's Corner,**http://www.home.agilent.com/upload/cmc_upload/All/Exp65.pdf**
* Chapter 4, 5 in the texbook.