Experiment
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The Analog Communication Board (ACB)

Hardware Experimentation

Objectives

The objective of this lab is to give the students a first introduction to the Analog Communication Board (ACB), which will be extensively used in subsequent experiments.

- The Lab will enable the students to identify the different circuits of the ACB, and understand their respective functions.
- The configuration of the different circuit blocks to implement analog communication systems is introduced.
- Some testing and experimentation with the ACB, Function Generator and Oscilloscope equipment is also included.

Pre-Lab Work

In preparation for this lab, do the following tasks:

1) Consider a linear time-invariant (LTI) system such as a filter, etc. Explain how to characterize the input-output relationship for such a system. Give the results both in time-domain and in frequency-domain (using convolution, frequency response, etc).

2) The function generator that you will be using in the lab generates many special functions such as sine waves, rectangular pulses, triangular signals, etc. How do you classify these signals: as “energy” signals or “power” signals? Explain why.

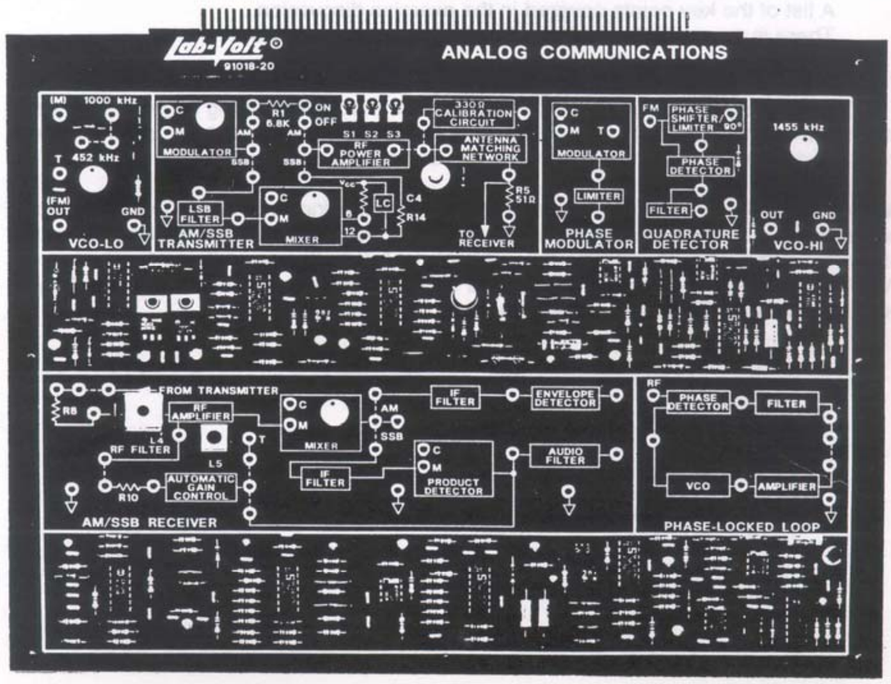
3) Assume now for simplicity that these signals are truly periodic, with a given period T_o. Give the Fourier series for each type of the basic waveforms: sinusoidal, rectangular and triangular.

Overview

The ACB is made of several building blocks, including the following:

1. Voltage-Controlled Oscillators: VCO-LO (low frequency), and VCO-HI (high frequency)
2. AM/SSB Transmitter
3. AM/SSB Receiver
4. Phase Modulator
5. Phase Locked Loop (PLL)
6. Quadrature Detector

The architecture of the ACB is illustrated in the following block diagram:



Analog Communications circuit board

The basic operation of the different ACB blocks is briefly summarized below. Throughout many of the subsequent experiments, you will become more familiar with their different functions.

1. VCO-LO & VCO-HI:

These voltage-controlled oscillators generate sinusoidal signals, with VCO-LO providing frequencies in the range of 452 KHz or 1000 KHz, and VCO-HI a single frequency in the range of 1455 KHz. These signals are typically used in the modulation & demodulation operations. The basic operation of the VCOs is described as follows:

- Choosing either frequency for VCO-LO is done by switching a two-post connector in the corresponding position.
- The potentiometer knob adjusts the oscillator amplitude.
- The negative supply knob on the upper left side of the unit allows the user to do small adjustments of the frequency of VCO-LO, while the positive supply knob adjusts the frequency of VCO-HI.
- VCO-LO can also be used for frequency modulation (FM).

2. AM/SSB Transmitter:

This block can be configured to generate an AM signal (including a carrier component), a Double-Sideband Suppressed-Carrier (DSB-SC) signal or a Single Sideband (SSB) signal. The AM/SSB block can be further divided into the following circuits:

Modulator:

This component is a balanced modulator used for the generation of AM or DSB-SC signals. It basically combines the message signal m(t) with the carrier signal c(t) to produce a modulated signal of the form [A + m(t)] c(t). (DSB-SC modulation is obtained when A = 0).

RF Filter:

This block filters the signal to the desired transmission band and it also provides a power amplifier to boost the signal power so that it can be radiated over a long distance.

Mixer:

This is a three-port system that works as a signal multiplier. It multiplies two signals (one is the message signal, and the other is the carrier signal). Notice that this essentially to the modulator functionality. However, a mixer can also be used in other applications (including frequency translation, demodulation, etc).

S1-S2-S3 Switches:

When these switches are in the ON positions, they function as follows:

S1: produces a DSB signal at the Modulator output (disables the modulator potentiometer).

S2: produces a DSB signal at the Mixer output (disables the mixer potentiometer).

S3: automatically matches the antenna impedance.

Note: R5 is a 51Ω resistor that emulates the antenna impedance.

3. AM/SSB Receiver:

This block can be configured to receive and demodulate an AM, DSB-SC or SSB signal. It consists of the following:

R8:

This is 1 M Ω resistor that emulates transmission losses.

RF Filter:

This is a tunable band-pass filter (BPF). It should be tuned to pass the desired transmission band and reject other noise and out-of-band interference.

RF Amplifier:

This amplifier is used to boost the level of the weak received signal so that can be processed and demodulated.

Mixer:

This is used to translate the signal from its RF band to an intermediate frequency (IF) set at 455 KHz.

IF Filter:

This is a good quality (high Q) band-pass filter (BPF) that is factory-tuned at a fixed IF frequency (455 KHz). This filter can be tuned to provide the desired selectivity to select the AM band for a given transmitting station.

Envelope Detector:

This is used for non-coherent envelope detection of AM-modulated signals.

Product Demodulator:

This is used for coherent demodulation of DSB and SSB signals.

Audio Filter:

This is a LPF that passes the audio band and rejects higher frequencies.

4. Phase Modulator:

This block is used for Phase Modulation (PM). It consists of a phase modulator and an amplitude limiter, and is used to demonstrate PM operation with a message signal of 5 KHz sinusoidal tone and a carrier frequency of 452 KHz.

5. PLL:

The PLL block is a very useful component in communication systems. It has three main components: a phase comparator, a LPF and VCO. The PLL is used for many applications in communication, including: carrier acquisition and tracking, FM demodulation, etc. A subsequent lab will provide more details on the PLL.

6. Quadrature Detector:

This block is used for FM detection, and consists of three main components: a phase shifter & limiter, a phase detector and a LPF.

Lab Work

1. Use the oscilloscope to measure the range of amplitudes and frequencies that are available for VCO-LO and VCO-HI.

2. Use the Signal Generator to apply a sinusoidal signal with frequency 1000 KHz to the input of the input of the RF amplifier of the transmitter circuit. Use the appropriate equipment to measure the voltage gain and phase shift of the resulting output signal.

   Note: You should set the signal amplitude at low level (for example V_{pp} = 50mV), because the RF amplifier gain is very high.

3. In this part, you are expected to measure the amplitude transfer function H(f) = V_{out}/V_{in} of the IF filter. The procedure is as follows. First apply a sinusoidal signal from the external function generator to the input port of the IF filter. Vary the frequency of this signal in the range of 435KHz to 465KHz, in steps of 5KHz, and measure V_{out} at each frequency (you can set the input amplitude to a fixed value in order to simplify the computation of H(f)). You should also reduce the frequency step size around the frequency of 455 KHz (use, for example, 1 or 2 KHz).

4. From the measured transfer function H(f), determine the center frequency of the IF filter and its 3-dB bandwidth. Recall that the 3dB cutoff frequency is defined as the frequency for which the output amplitude gain drops to 1/sqrt(2) of its maximum value.

   Note: Recall that the signal power is proportional to the squared amplitude. Hence, a 1/sqrt(2)-factor in signal amplitude corresponds to a 1/2-factor in signal power, which in terms of dB units corresponds to 3dB. This explains why we use the term 3dB bandwidth in the above part.

5. Now, change the input signal shape to apply a rectangular pulse stream from the external signal generator. Set the frequency of this signal in the range of the central frequency (around 455 KHz) with V_{pp}= 1V, and observe the output signal. Record your observations and explain your results. What happens if you change the rectangular signal frequency?

(Hint: refer to the pre-lab exercise related to the Fourier series expansion of the rectangular signal).

Homework Questions

Q1. If a message signal $\cos(2{,}000\,\pi\, t)$ and a carrier signal $\cos(20{,}000\pi\, t)$ are fed to a mixer, what is the resulting output signal? Assume that the mixer passes the higher frequency term and suppresses the lower one.

Q2. Consider Part 5 above and imagine the case where the input rectangular pulse train had double the central IF frequency (i.e., around 2x455KHz). Explain, in a simple and precise way, the kind of output you expect to get from this filter.