1. Test and Measurement

<u>Chapter 1 Goals</u>

- Become familiar with lab test equipment
- Generate and measure sine waves
- Become familiar with amplitude modulation
- Generate and measure an AM signal

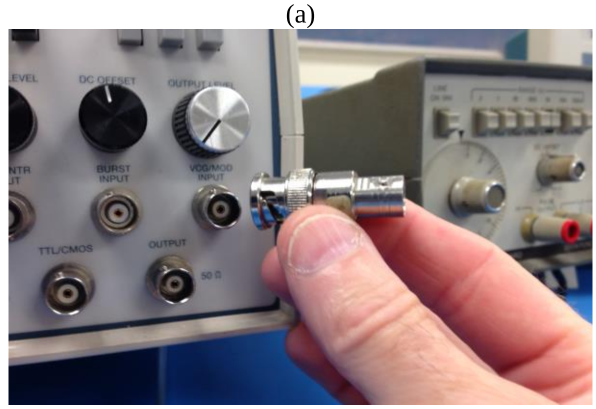
Your lab station should have 1 each of the following:

Hewlett-Packard 3311A function generator
BNC-to-banana adapter (see Fig 1.1a)
Pomona 20 dB attenuator (see Fig 1.1b)
BK Precision 4040 function generator
Tektronix TDS2022 oscilloscope
Tenma DC power supply
Omega HHM90 digital multimeter (DMM)

The following tasks are designed to familiarize you with the equipment. Some helpful pointers are included, and your teaching assistant should be able to help you as well. Before you begin, spend a few minutes examining the buttons on the instruments. Remember that the goal is to get familiar with the equipment, so feel free to deviate from the procedure and do a little experimenting.

See the Course Canvas page for some excerpts from the operating manuals of the BK Precision generator and the Tektronix oscilloscope.

(a)



(b)

Figure 1.1: (a) the BNC-to-banana adapter close to the appropriate sockets of the Hewlett-Packard 3311A function generator. Note the gnd ("ground") tab on the adapter which tells you which plug is tied to the outer BNC conductor. (b) The Pomona 20 dB attenuator close to the appropriate BNC connector of the BK Precision 4040 function generator.

1.1 Simple Sine Waves

1. The following bullets will show you how to use the 3311A function generator to produce a 1 V amplitude 10 kHz sine wave and view it on the TDS2022 scope. See Figure 1.2.

- Turn on power to the 3311A and the TDS2022.
- On the 3311A, turn the amplitude fully counterclockwise, press the "10k" range button, select the sine wave function, and rotate the dial to 1.
- Use a BNC-to-banana adapter plugged into the rightmost pair of outputs on the 3311A. Attach a coaxial cable to the adapter and run the other end of the cable to "Ch 1" of the scope. Note that ground side of the banana plugs is indicated with a small tab.
- On the 2022, press "AutoSet".
- Averaging the data will sharpen the signal. Press the "Acquire" button at the top of the scope, and select "Average" from the screen menu (default is "Sample"). Set "Averages" to 16 (button toggles through 4, 16, 64, and 128).
- Adjust the 3311A amplitude to achieve a 1 V amplitude; you may also need to adjust the 3311A's "zero offset" to center the wave.
- Now press the "cursor" button at the top of the scope, and choose "Type" Voltage and "Source" as CH1. This brings up a pair of cursor lines that are adjusted with the channel 1 and channel 2 vertical position knobs. Adjust these to the top and bottom of the wave. Note the "Delta" should be about 2 V.
- The signal frequency is displayed at the lower right of the scope. Adjust the knob on the 3311A to get as close to 10 kHz as you can.
- If at any point you experience difficulty with the signal, press "AutoSet" again.

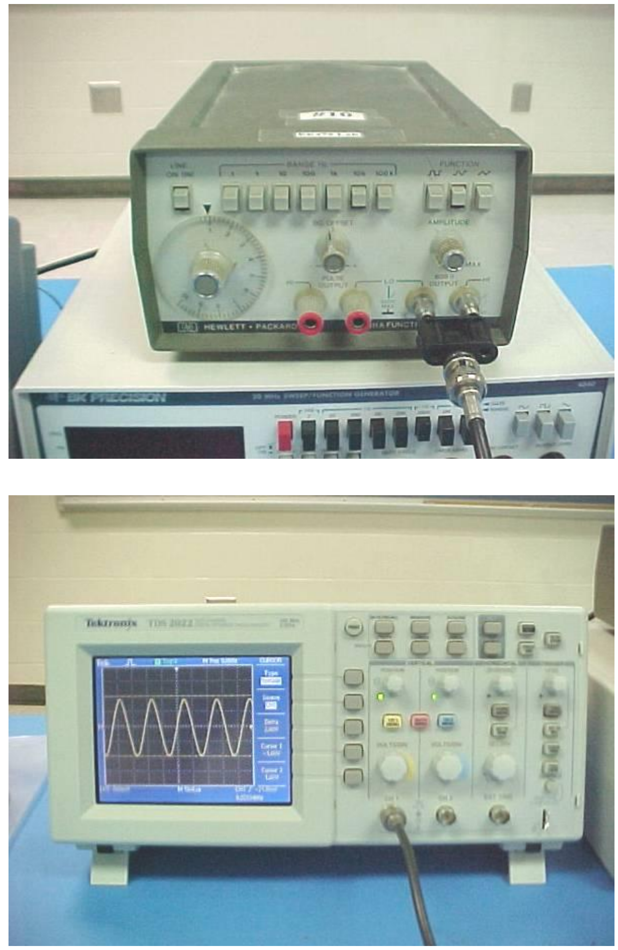


Figure 1.2: A 10 kHz sine wave generated by the 3311A is displayed on the TDS2022.

2. View the Sine wave on the Omega DMM.

- Disconnect the frequency generator from the scope. Set the DMM to read 20V AC and probe the output of the function generator:

DMM Voltage: _________

Is the voltage what you expect? Do you think the DMM is measuring amplitude or RMS?

3. Repeat exercises 1 & 2 using the BK Precision 4040 function generator.

- Make sure modulation is off and output level is minimum.
- In setting the frequency, note you have both a course and a fine adjustment knob.
- Adjusting the output level to achieve a 1 V amplitude may require activating the '-20 dB' button, which changes the output amplitude range.

1.2 Amplitude Modulation

Signals received by an AM radio are amplitude-modulated, meaning that the intelligence signal (usually an audio signal of voice or music) is carried along via a carrier wave. The intelligence is said to modulate the amplitude of the carrier. This is observed in Figure 1.3, where a 10 kHz carrier is modulated by a 1 kHz sine wave intelligence signal. While a typical amplitude modulation scheme would feature a carrier frequency much larger than the intelligence, here a relatively small carrier frequency is chosen for better visualization of the AM signal. The amount of modulation is given by the modulation index, *m*, which is the ratio of the intelligence amplitude to the carrier amplitude. In the figure, a 0.5 modulation index is shown. This is sometimes referred to as "50% modulation." Care is taken in the modulation scheme not to overmodulate.

It is instructive to observe the *spectrum* of an AM signal. The AM signal of Figure 1.3 has the spectrum shown in Figure 1.4 featuring 3 frequency components: the carrier frequency f_c, the lower side frequency f_c-f_i, and the upper side frequency f_c+f_i. Notice that the intelligence frequency, f_i, does not itself appear in the spectrum. Now, if this AM signal is fed through a detector, the intelligence is extracted and only the f_i is observed in the output spectrum (Figure 1.5).

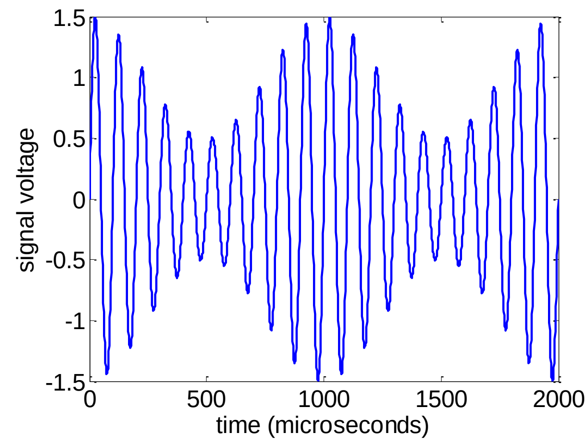


Figure 1.3: AM signal with f_i = 1 kHz and f_c = 10 kHz, with 0.5 modulation index

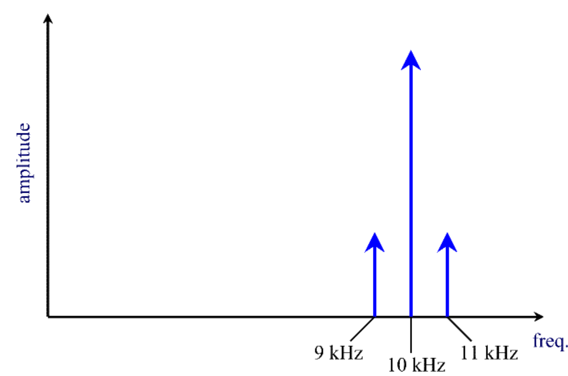


Figure 1.4: the spectrum of the AM signal of Figure 1.3.

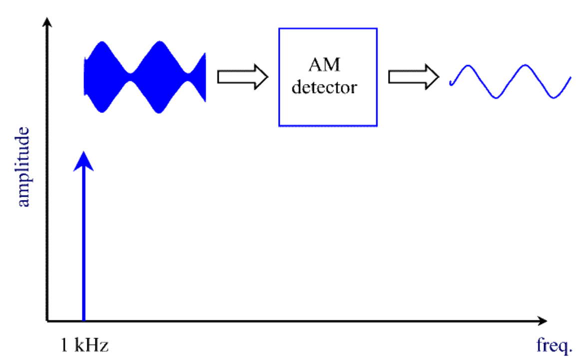


Figure 1.5: intelligence extracted by an AM detector has the spectrum shown.

1.2a A Simple AM Signal

1. Here we will use the BK Precision 4040 function generator to create an amplitude modulated signal, which you will view on the scope (see Figs. 1.6 and 1.7)

- Change the generator frequency to something big, like 1 MHz, with the amplitude dial set to yield roughly 4 volts pk-pk.
- Employ internal amplitude modulation (a 1 kHz signal).
- Rotate the '% modulation' knob about 1/3 of a revolution from full counterclockwise.
- Press "AutoSet" on the scope. **Note that autoset will zoom in on the carrier frequency.** In order to see the amplitude modulated signal, adjust the "Sec/Div" knob to 250 μs (this time scale is visible at the bottom of the scope display). This is a step you will repeatedly perform as you measure AM signals this semester.
- Adjust the scope's Trigger Level knob until you get an amplitude modulated signal similar to the one in Figure 1.6.

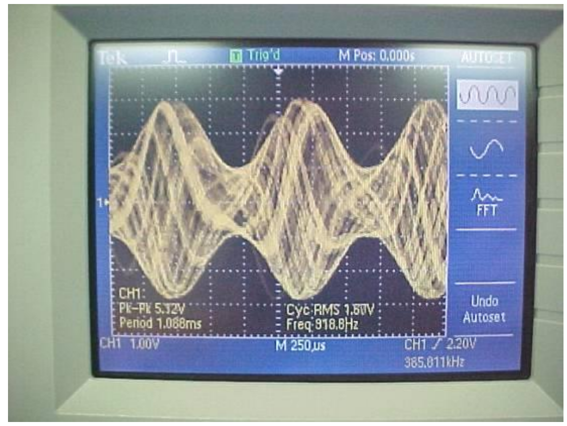


Figure 1.6: An amplitude modulated wave with approximately 50% modulation

2. With internal modulation, you are limited to a 1 kHz signal. To get around this limitation, we can use the 3311A function generator as an external modulation source.

- Use the scope to obtain a 2 kHz, 2 V amplitude signal from the 3311A.
- Now feed this signal into the VCG/Mod Input connection (near the bottom right of the front of the BK4040 generator). The 4040 should be connected to the scope. (See Figure 1.7).
- Change the modulation Ext/Int button to be in the "Ext" state.
- Adjust the Sec/Div knob to about 100 μs, and adjust the Trigger level knob to look for an AM signal.
- Slowly adjust the amplitude knob on the 3311A until you get about 50% modulation.

1.2b AM Signal Frequency Spectrum

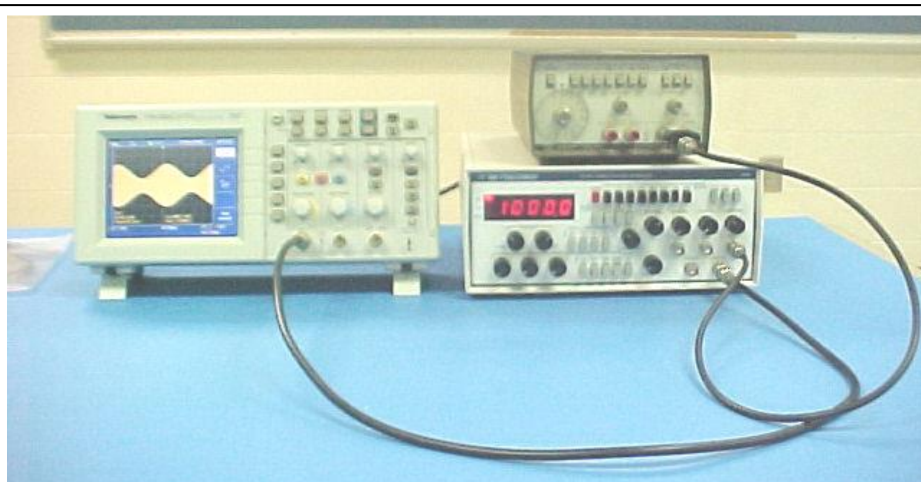


Figure 1.7: Using external modulation to generate an AM signal

Here we will look at the AM signal in more detail, including use of the oscilloscope's built-in fast Fourier transform (FFT) feature that allows viewing the spectrum of the signal.

1. Connect the 4040 generator output to the scope input (channel 1). Now adjust the generator to a 50 kHz sine wave, minimum amplitude. Press "autoset" on the scope. Note that the time base setting at the bottom of the screen should be "M 10 μs".

2. Turn on internal AM modulation (modulates at 1 kHz), and rotate the % Modulation knob to about the 10 o'clock position. Adjust the time base (the "sec/div" knob) to achieve 'M 500 μs'. Now adjust the trigger to see the AM wave.

3. Use the cursors to measure the maximum and minimum amplitudes. Adjust the generator output and the % modulation to achieve 100 mV maximum amplitude and 50 mV minimum amplitude. This corresponds to 50% modulation.

4. Press the "Math Menu" button and select operation "FFT". Adjust the time base knob (it should be at f = 25 kHz) to 12.5 kHz. Now adjust the horizontal position to center the main peak (at 50 kHz), and change the "FFT Zoom" to "X 10".

5. Press the "cursor" button, choose source "math" and type "frequency". Locate the frequency location of the carrier and the two AM sidebands. Record these frequencies in Table 1.1.

6. Change the cursor type to 'magnitude' and determine the level in dB of the carrier and two sidebands. Record these dB levels in Table 1.1.

7. Convert the recorded dB levels to voltage amplitudes using the following information: According to the scope manual, the dB value is referenced to 0 dB at 1 V_{RMS}. This means our dB value is related to the RMS value by

$$dB = 20\log\left(\frac{V_{rms}}{1}\right),$$

or

$$V_{rms} = 10^{dB/20},$$

and finally,

$$V_{amplitude} = \sqrt{2}\ V_{rms}.$$

Record the voltage amplitudes in Table 1.1.

8. Repeat step 3, but adjust for ~100% modulation (keep maximum amplitude at 100 mV, minimum should be about zero). Now repeat steps 4 through 7 and fill in Table 1.2.

Table 1.1: Spectrum information (~50% modulation)

	Frequency	dB level	Voltage amplitude
Lower sideband			
Carrier			
Upper sideband			

Table 1.2: Spectrum information (~100% modulation)

	Frequency	dB level	Voltage amplitude
Lower sideband			
Carrier			
Upper sideband			