Wave Fundamentals and Modulation Demonstration Board

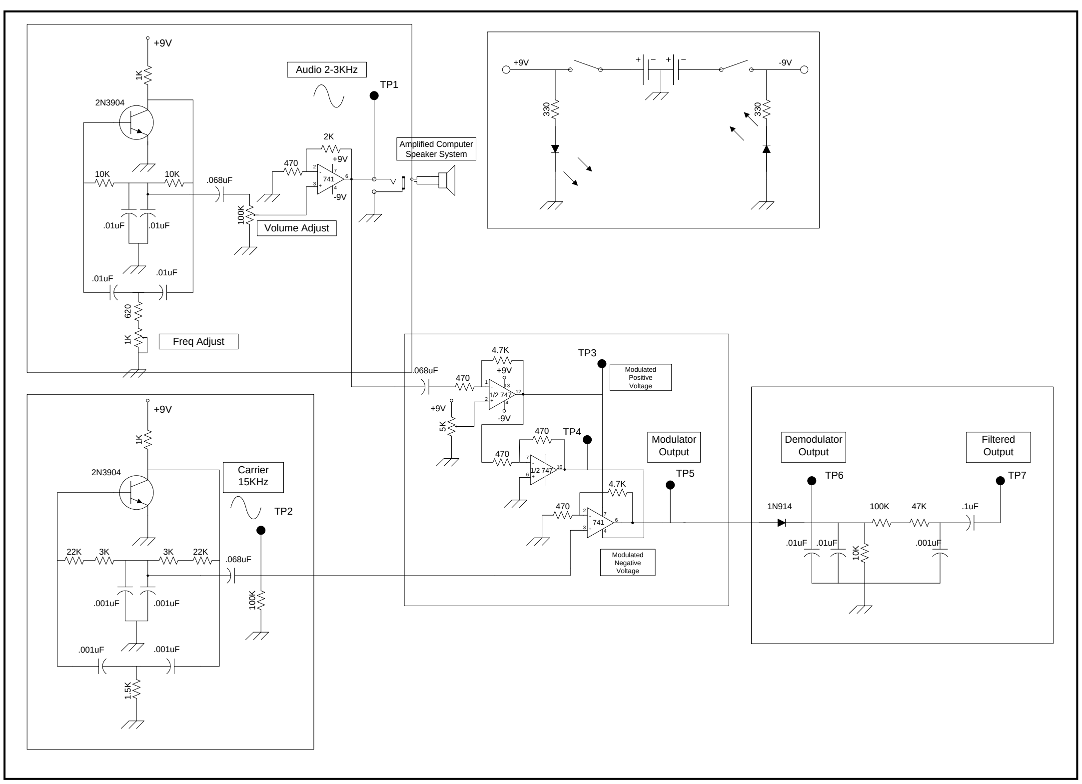
Purpose: The purpose of this board is to give the instructor a ready instructional resource to support lesson presentations in wave fundamentals and modulation. The board would be used in conjunction with a projection capable oscilloscope and an external audio amplifier during platform instruction of the concepts.

During the wave fundamentals lesson, the board produced audio waveform frequency and amplitude are manipulated to reinforce the relationship between frequency, wavelength, and pitch and to reinforce the independence of amplitude and frequency. The audio is fed into the external amplifier to provide audio presentation while the waveform is visually displayed on the oscilloscope.

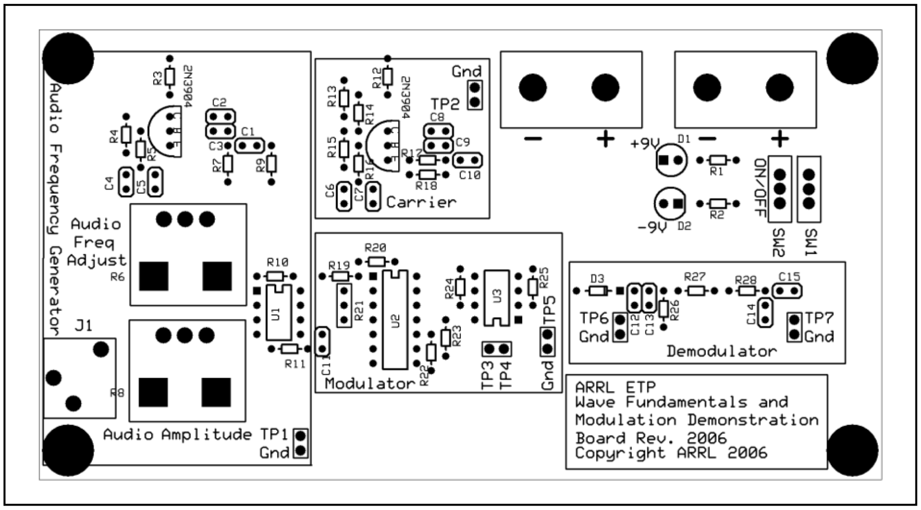
During the modulation lesson, a simulated carrier wave is modulated by the audio wave using amplitude modulation. The input and output waveforms are displayed by the oscilloscope so that comparisons can be made as the waveforms are manipulated. The audio wave’s frequency and amplitude are manipulated to show the effects of varying modulation percentages and over modulation.

During the demodulation lesson, the modulated carrier is fed into a demodulator circuit. The input modulated waveform, original audio waveform, demodulator output, and filtered output waveforms are displayed sequentially on the oscilloscope to allow the instructor to walk the students through the demodulation process.

Circuit Diagram: This the circuit diagram of the board:

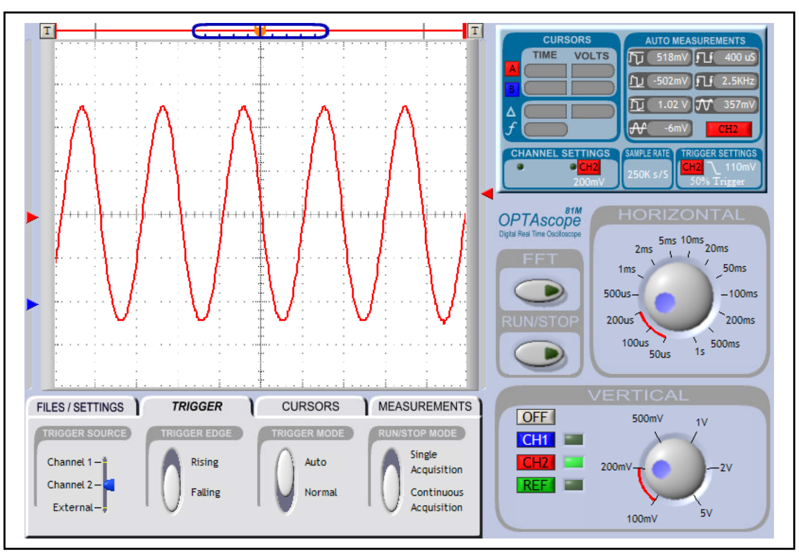


Circuit Board: This is what the board looks like:



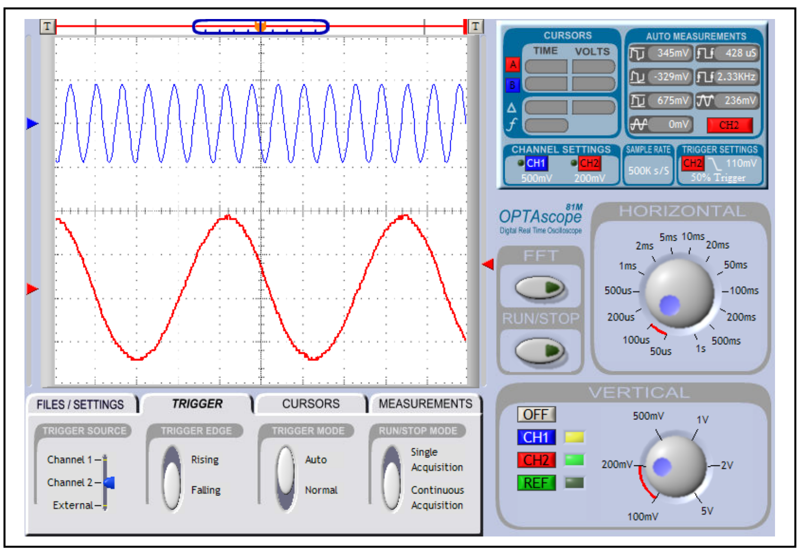
Lesson examples:

<u>Wave Fundamentals:</u> The instructor would begin the lessons by presentation the vocabulary of waveforms so that students will be able to understand the subsequent lessons on modulation where that vocabulary is used. The instructor would connect the oscilloscope to TP1 to display the audio waveform and connect a computer speaker amplifier to J1 to provide sufficient audio levels to be heard by the students. The projected display would look like this:

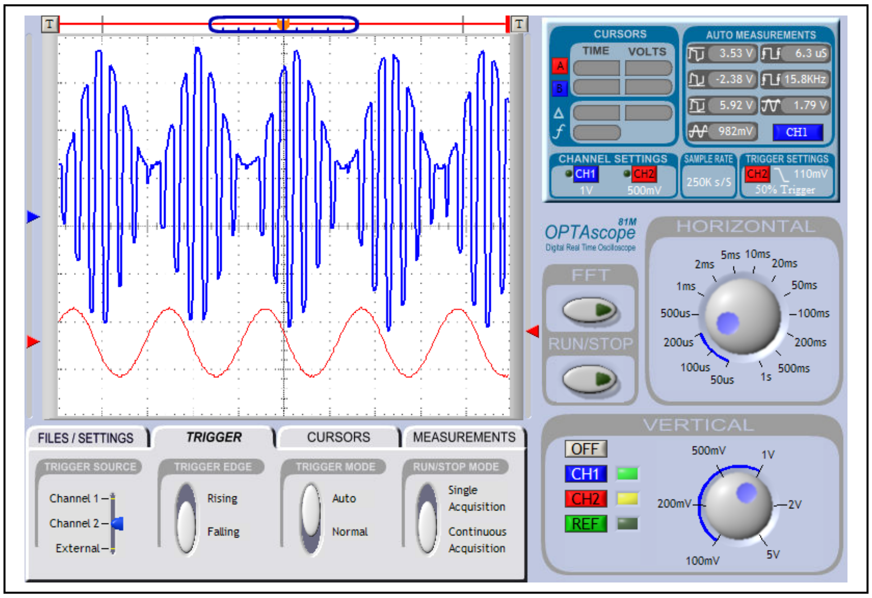


The instructor would use this screen to illustrate the vocabulary used to describe a waveform (crest, trough, wavelength, frequency, period, amplitude). Then the frequency is changed through the range by adjusting R6. The frequency range is between approximately 2 and 3 Kilo Hertz. During this portion of the demonstration, the instructor would emphise the relationship between frequency and pitch. Next, the instructor would emphasize the inverse relationship between frequency and wavelength. Finally, the instructor would vary the amplitude of the wave using R8. During this portion of the demonstration, the instructor would emphasize the relationship between amplitude and loudness (strength) of the wave while pointing out the independence of amplitude and frequency.

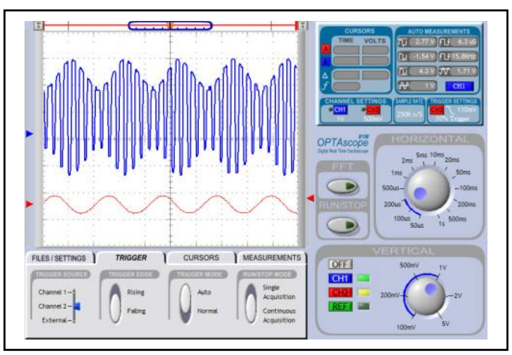
Modulation: The instructor would begin the modulation demonstration by providing some background material on the concept of modulation. The board and oscilloscope would be set up by connecting one channel of the scope to TP1 and the other channel to TP2. The scope display would be as depicted below. The red trace simulated a radio frequency carrier wave; the blue trace represents the audio to be imbedded on the carrier wave during modulation.

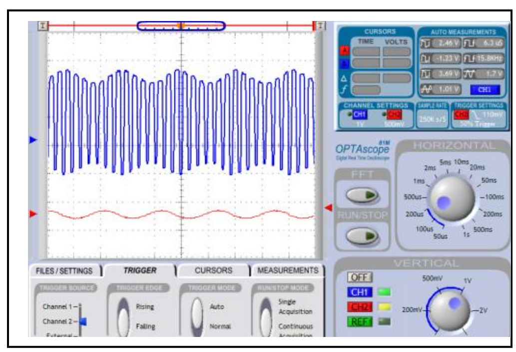


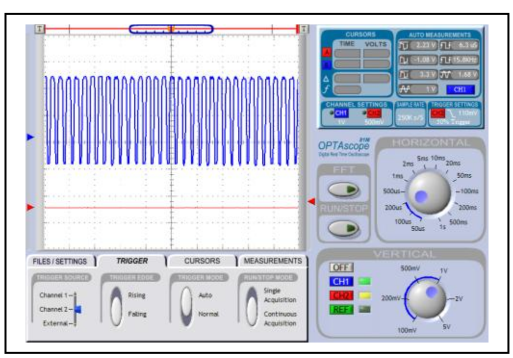
Next, one channel of the scope is moved from the carrier on TP2 to the demodulator output on TP5. The demodulator output is display in this example in blue. The instructor uses this waveform to illustrate the concept of amplitude modulation…the amplitude of the carrier wave is varied in step with the amplitude of the audio wave being imprinted on the carrier.



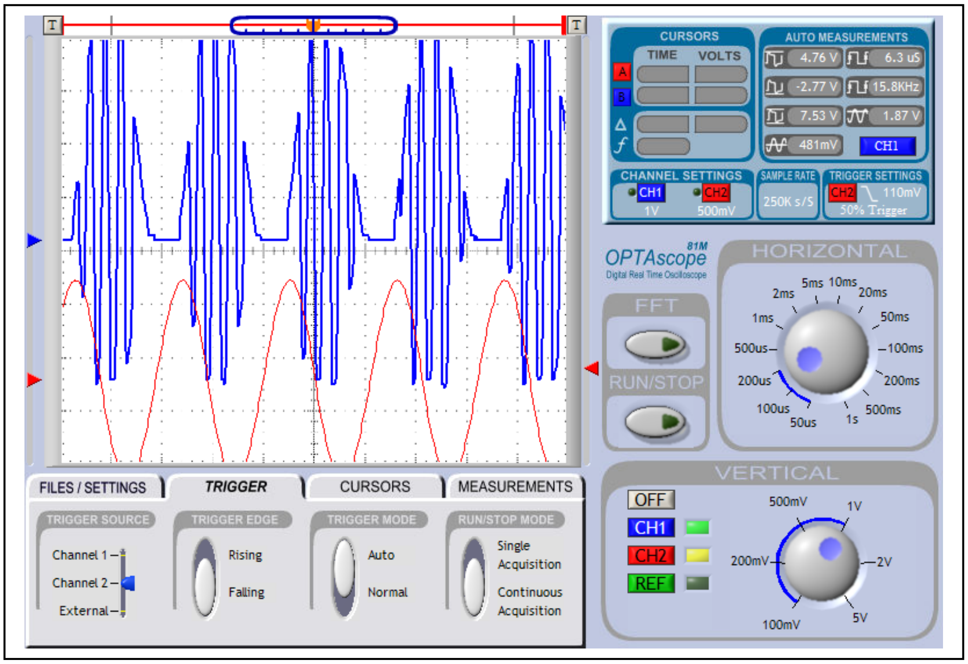
The concept of amplitude modulation is further reinforced by varying the amplitude of the audio wave using the R8 control. The following panels show approximate levels of 50%, 25%, and 0% modulation:





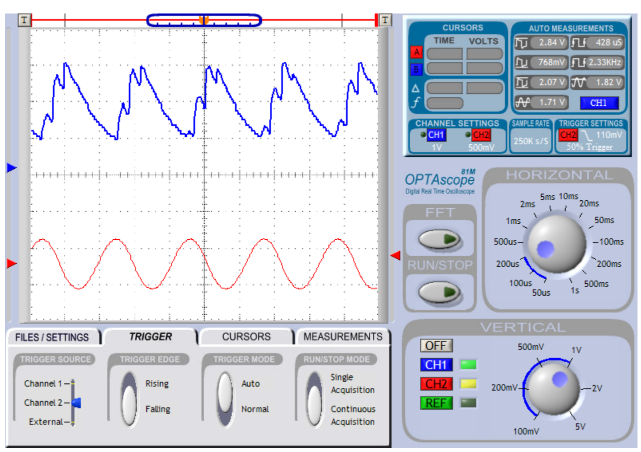


The instructor can next demonstrate the concept of over modulation by increasing the audio wave amplitude beyond the 100% modulation level. Varying amounts of distortion become evident as the modulation level goes beyond 100%.



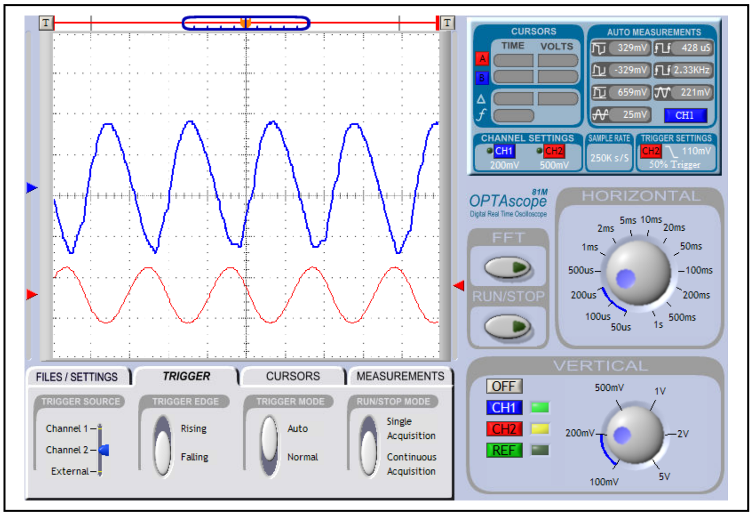
Here the student can see the amplitude of the audio wave increase and at beyond a certain point (100% modulation), the carrier waveform becomes distorted (flat topping) and no longer faithfully follows the audio waveform.

<u>Demodulation:</u> The instructor would begin the demodulation demonstration by providing some background material on the concept of demodulation. The demodulation demonstration is set up by configuring the board for 100% modulation and connecting one channel of the scope to the audio waveform at TP1 and the other channel the output of the demodulator at TP6. TP6 is connected to a simple diode rectifier that is used to demodulate the AM waveform. The display will look like this:



The instructor can use this display to illustrate that the carrier waveform has been modified by the demodulator (the AC component has been eliminated and a DC wave is the result). The instructor can also point out that there are still some remnants of the carrier wave still present that corrupts the desired audio waveform.

The board is next configured with one scope channel connected to the filter output at TP7. The display would look like this:



Using this display the instructor would point out that filter has removed virtually all of the remnants of the carrier that remained after demodulation and that the audio output is a fair duplication of the original audio waveform. This is a good opportunity for the instructor to point out that the modulation/demodulation process is not perfect and that there is always going to be some distortion of the audio waveform during the process due to the imperfections of electronic circuitry.

Modulation Demonstration Board Setup

Learning Objectives

After completing this lesson you will be able to adjust the modulation demonstration board to ready the board for use in the classroom

Study Materials

Modulation Demonstration Board circuit diagram

Equipment and Materials

Modulation Demonstration Board
OptaScope or similar two channel oscilloscope

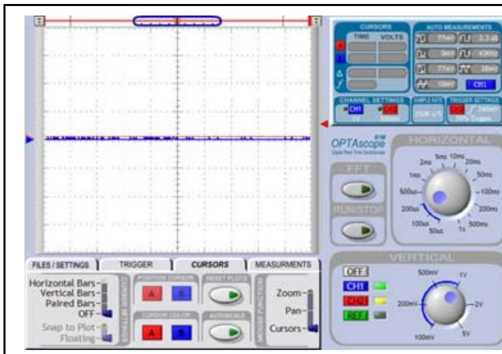
Recommended Strategy

The only adjustment need to ready the modulation demonstration board for use in classroom demonstrations is to properly set the balance control of the modulator power supply IC U2. This adjustment depends on the battery voltages, the setting of the audio amplitude control, and the setting of R18. R18 is the main control that will compensate for variations in the other two parameters.

Remember, the purpose of this board is to demonstrate the concept of modulation, consequently the circuit is designed to reliably produce a modulated waveform for display in the classroom. This waveform is formed by feeding the carrier wave into one channel of an OpAmp circuit and varying the +/- voltage to the OpAmp in step with the audio wave producing amplitude modulation.

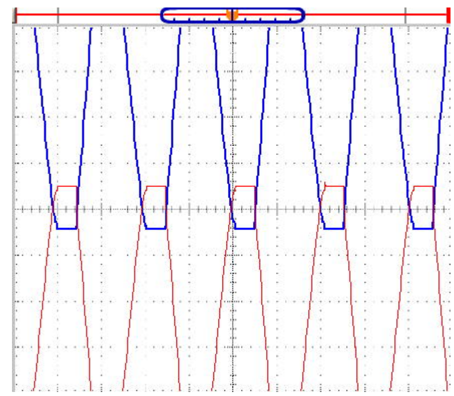
To set the balance control R18 before use:

1. Set the scope vertical scale to 1 volt and the horizontal scale to 200 uS.
Set both scope channels so that zero is in the center of the display.



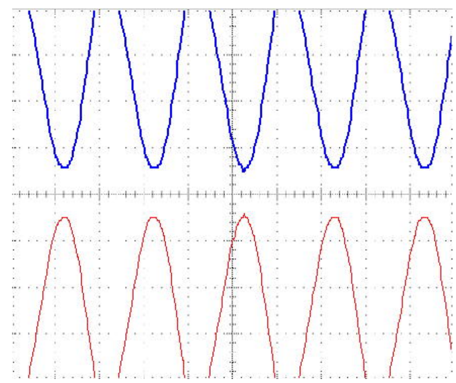
Scope Setup

2. Connect one channel to TP3 and the other channel to TP4, connect the scope to a Gnd post on the board.
3. Apply power to the board and increase the audio amplitude control until you just see flat-topping of the peak/troughs.



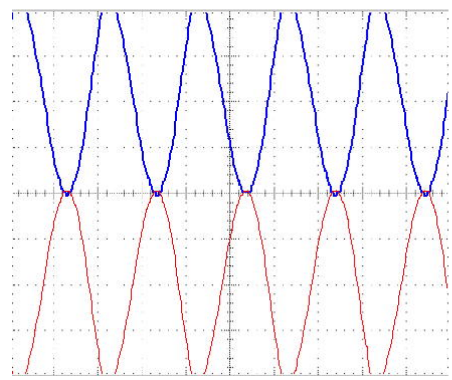
Adjust amplitude control until waveforms flat-top.

4. Then backing down the amplitude until you get a nice smooth sine wave.



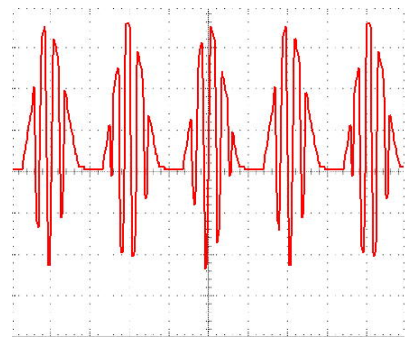
Back off amplitude control until waveforms are smooth sine waves.

5. Adjust R18 until the peaks just touch the troughs.



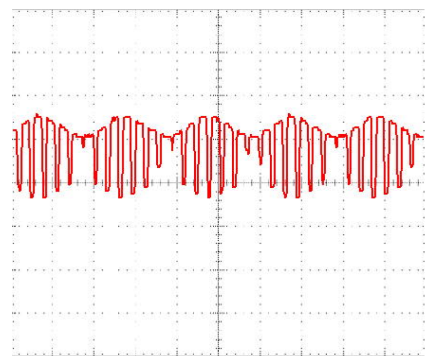
Adjust R18 until peaks/troughs touch.

6. Connect one of the channels to TP5, the output of the modulator. You should see a 100% modulated waveform.



TP5 waveform, 100% modulation.

7. Now if you adjust the audio amplitude control up and down, you will see varying amounts of modulation.



Approximately 50% modulation.

Suggested Activities

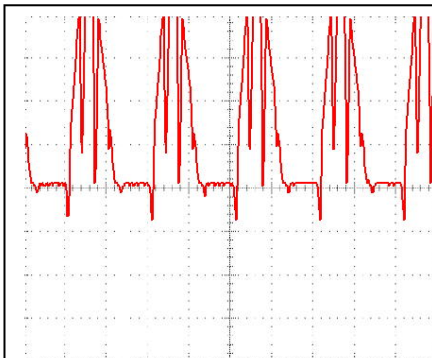
None

Reading Assignment for next class

None

Homework suggestions to reinforce lesson materials

None



Over modulation and distortion.

WAVE BASICS

Learning Objectives

In this lesson you will learn:

- The definition of the components of a wave: frequency, wavelength, amplitude, (and pitch for audio waves).
- To label a diagram of a wave.
- That the frequency of a wave is directly proportional to the pitch of a wave.
- That the amplitude, or strength, or volume, of a wave is independent of the wave's frequency, wavelength, or pitch.
- That the relationship between a wave's frequency and wavelength is described mathematically by the formula $frequency = \frac{speed\_of\_the\_wave}{wavelength}$.
- How to find the frequency of a radio wave when given the wavelength using the formula $f_{MHz} = \frac{300}{\lambda_{meters}}$.
- How to find the wavelength of a radio wave when given the frequency (in MHz) using the formula $\lambda_{meters} = \frac{300}{f_{MHz}}$.

Study Materials

- Understanding Basic Electronics pages 16-1 through 16-14.
- Relevant ARRL License Manual chapter and pages

Equipment and Materials

- Modulation Demonstration Board
- Two channel oscilloscope or OptaScope
- Computer with audio sound card or audio amplifier

Recommended Strategy

1. Review the difference between direct current and alternating current.
2. Review the difference between longitudinal waves and transverse waves. Emphasize that waves in radio and electronics are transverse waves and that sound waves are longitudinal waves (though you will be using sound waves in the demonstration, they will be depicted and used to demonstrate transverse waves)
3. Review the vocabulary associate with waves; frequency, wavelength, amplitude, pitch, period, cycles per second, Hertz.
4. Draw various waveforms and illustrate the labeling of the wave components.
5. Perform the live demonstration using the modulation demonstration board.
6. Discuss that there is a relationship between a wave's frequency and wavelength and that relationship is proportional to the speed of the wave. This is true of all waves; the only variable is the speed of the wave. Use the formula during the discussion.

7. Discuss that it is generally accepted that radio waves and other electronic waves travel at the speed to light (in a vacuum) which is 300,000,000 meters per second, or 186,000 miles per hour. A side bar discussion of the real speed of radio waves and the factors that affect that speed may be useful for some audiences to set the stage for more advanced theory.
8. Insert the speed of radio waves into the formula and discuss with the students how to reconcile different time and distance units in the formula.
9. Model the solution of a few common frequency and wavelength problems using ham radio frequencies and bands. Doing actual computations using technician exam problems will be helpful.

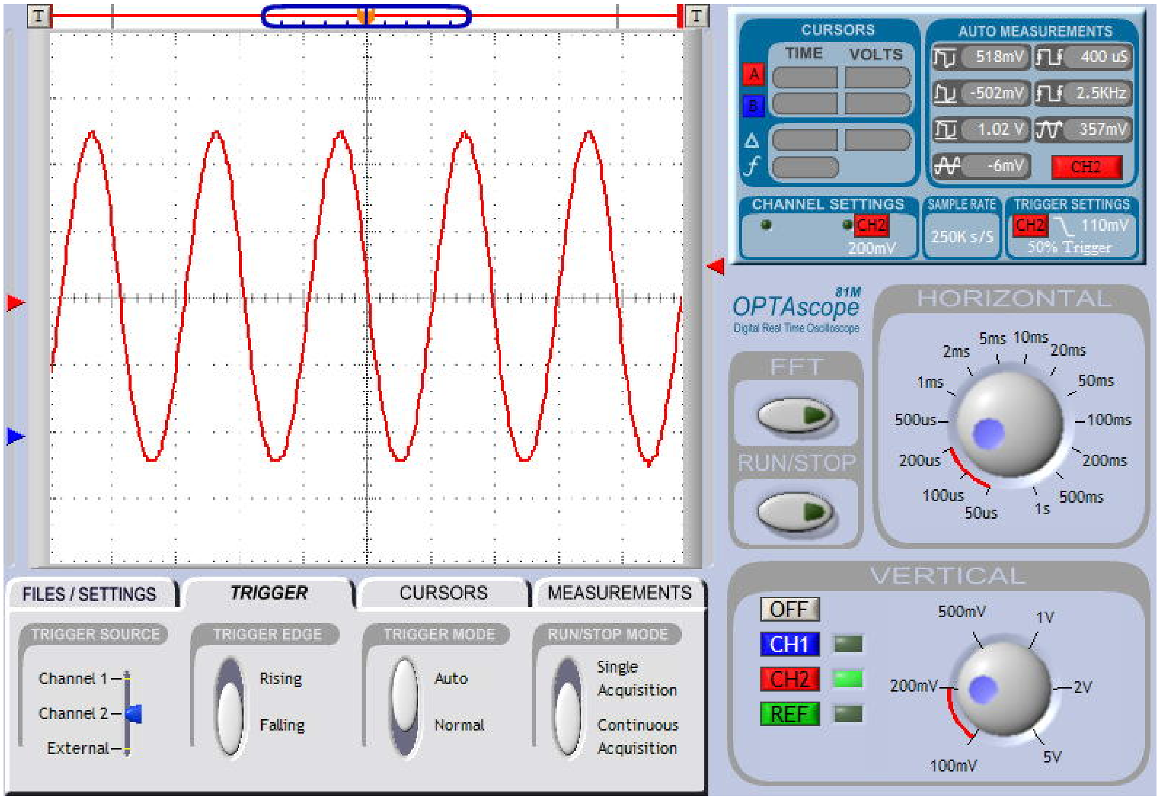
Suggested Activities

1. Connect the oscilloscope to TP1, the audio output of the variable frequency oscillator.
2. Connect J1 to the sound card or audio amplifier. Turn on the power to the board and adjust the volume so the classes can here the signal.
3. While the waveform is displayed, point out the various portions of the wave as you discussed.
4. Vary the frequency of the wave, and task the students to take note of the change in wavelength and the change in pitch. Ask students to explain what they are observing and make inferences as to the relationship between frequency, wavelength, and pitch.
5. Point out the numerical display of the OptaScope and show the students how to interpret the information.
6. With the board set at a specific frequency, vary the amplitude of the wave. Task the students to take note of the change in amplitude and the change in volume of the audio. Ask students to explain what they are observing and make inferences as to the relationship between amplitude and the strength of the wave. Emphasize that the frequency of the wave is independent of the amplitude of the wave.

Reading Assignment for next class

Homework suggestions to reinforce lesson materials

- Assign an appropriate number and difficulty of problems to convert between frequency and wavelength and visa versa. Use different units of meters, feet and inches.
- For challenge problems, assign problems involving different fractions of wavelengths.


CURSORS
TIME
VOLTS
AUTO MEASUREMENTS
518mV
400 uS
-502mV
2.5KHz
1.02 V
357mV
-6mV
CH2
CHANNEL SETTINGS
CH2
200mV
SAMPLE RATE
250K s/S
TRIGGER SETTINGS
CH2
110mV
50% Trigger
OPTAscope
81M
Digital Real Time Oscilloscope
FFT
RUN/STOP
HORIZONTAL
VERTICAL
OFF
CH1
CH2
REF
FILES / SETTINGS
TRIGGER
CURSORS
MEASUREMENTS
TRIGGER SOURCE
Channel 1
Channel 2
External
TRIGGER EDGE
Rising
Falling
TRIGGER MODE
Auto
Normal
RUN/STOP MODE
Single Acquisition
Continuous Acquisition

Modulation

Learning Objectives

- In this lesson you will learn:
- That modulation is the process of combining some form of intelligence with a radio carrier wave so that the intelligence can be transmitted to a distant location.
- That the efficiency of modulation can vary and depends on how much the modulating intelligence varies the carrier wave's characteristics.
- That there is inherently some level of distortion of the intelligence during the modulation process.
- That severe distortion can result from over modulation.

Study Materials

- Handbook For Radio Communications, 2005 pages 9.2-9.4, 11.1-11.7
- ARRL License Manual chapter and pages

Equipment and Materials

- Modulation Demonstration Board
- Two channel oscilloscope or OptaScope

Recommended Strategy

1. Review the vocabulary associated with AC waveforms in particular frequency and amplitude.
2. Discuss with the students the concept of modulation and how modulation is used in radio to convey information. A block diagram of a simple radio transmitter will help to illustrate the point.
3. Cover with the students the basic types of modulation and in very basic terms, the advantages and disadvantages of each type of modulation technique. Stress amplitude modulation during the discussion because that is the modulation technique that you will be using in the demonstration.
4. Perform the modulation demonstration detailed in the suggested activities section. Note that for demonstration purposes you will be demonstrating modulation using amplitude modulation.
5. Discuss with the students the concept of bandwidth and the relationship between intelligence throughput and modulation level and bandwidth.
6. Discuss with the students the concept of percent modulation, that the efficiency of modulation is dependent of the percent modulation, 100% being ideal. Note that 100% may not always be the desirable modulation level because of the dynamic range of the modulating signal may result in over modulation, distortion, and interference.
7. Perform the percent modulation demonstration as detailed in the suggested activities section.

Suggested Activities

1. Perform the modulation board calibration procedure before class.

Modulation demonstration.

1. Connect one channel of the OptaScope to TP1 (the audio input) and the other channel to TP2 (the simulated carrier). Power up the board.
2. Discuss with the students that the audio wave simulates the modulating intelligence, perhaps your voice. Discuss with the students that the carrier wave in an actual radio would be much higher in frequency and the waveform would appear to be just a blur instead of showing the individual peaks and troughs of the waves. The frequencies used here are for demonstration only and it really isn't a practical carrier wave.
3. Draw a representation of the audio and carrier waves on the board.
4. Move the OptaScope channel from TP2 to TP5 which is the output of the modulator. Point out to the students that the amplitude of the carrier wave is changed in step with the peaks and troughs of the audio input wave…this is modulation.

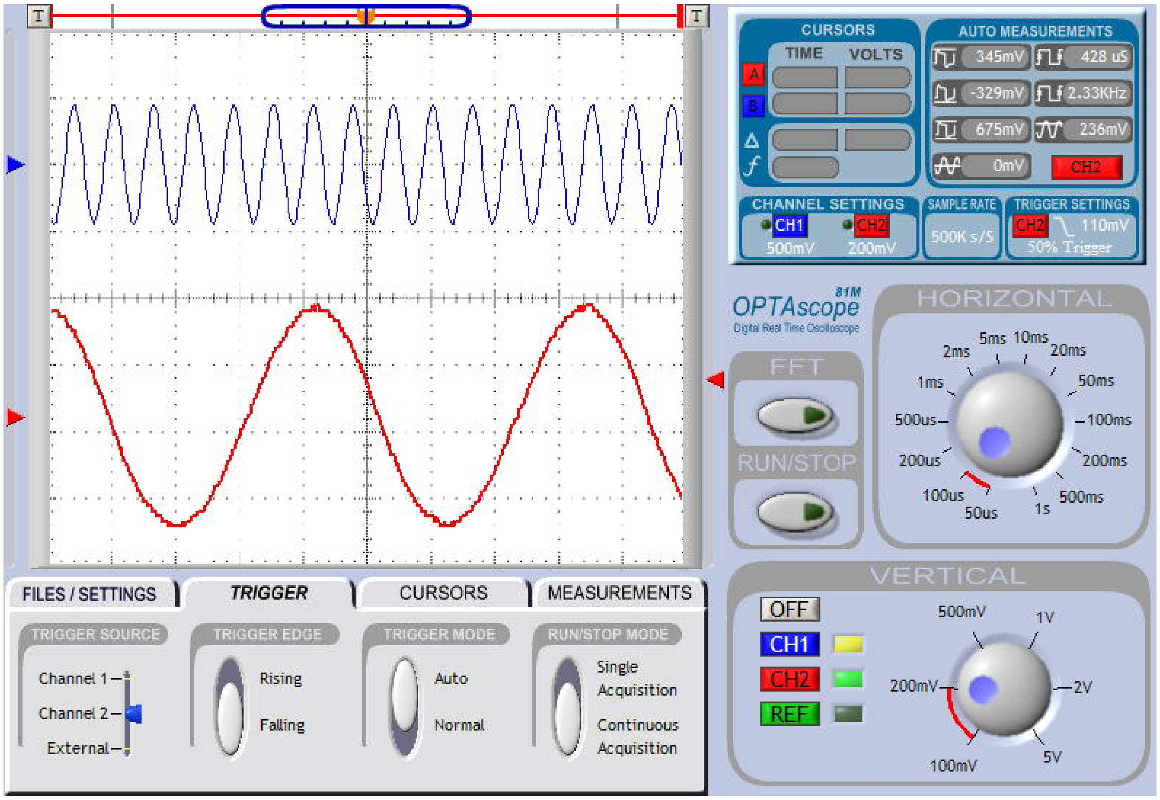
Modulation percentage demonstration.

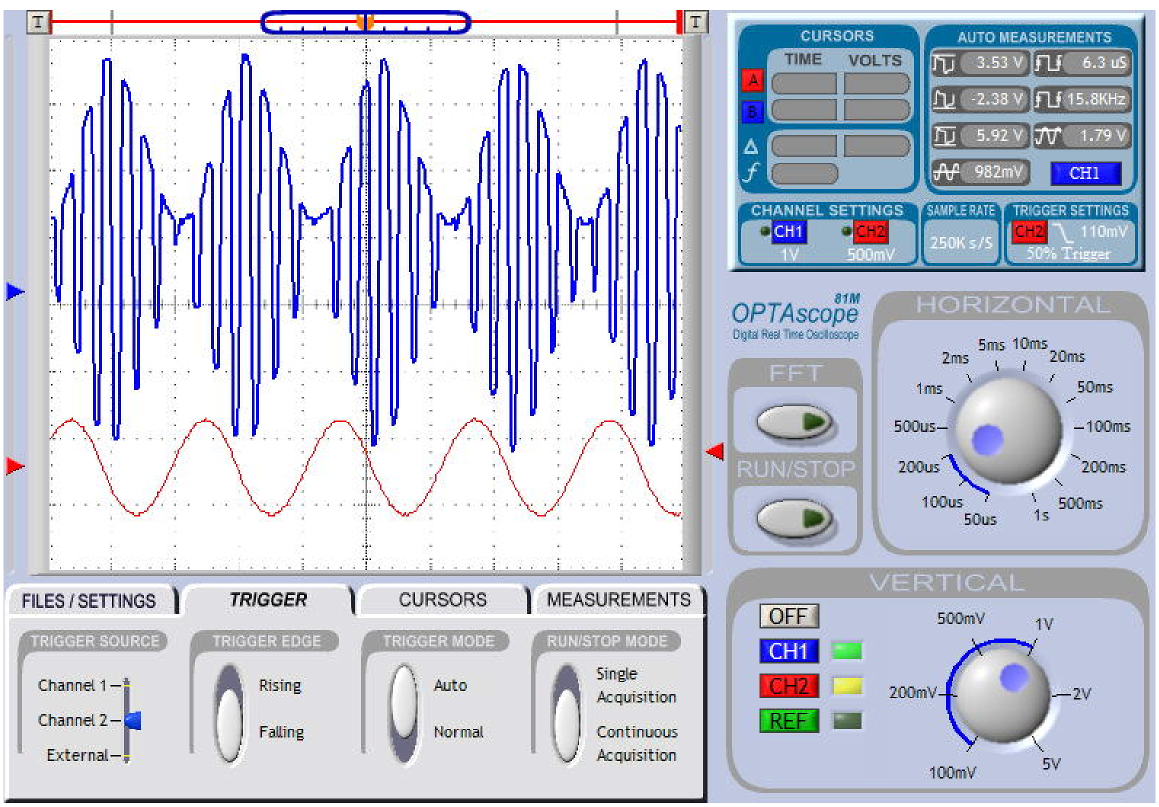
1. Vary the amplitude of the audio input wave and note the variation of the percent of modulation, apply some relative percentage values with each step.
2. Increase the amplitude of the audio input wave until there is significant distortion in the modulated wave. Discuss with the students the symptoms of over modulation and the consequences of over modulation.
3. Discuss with the students how to avoid over modulation and corrective actions they can take to correct over modulation.

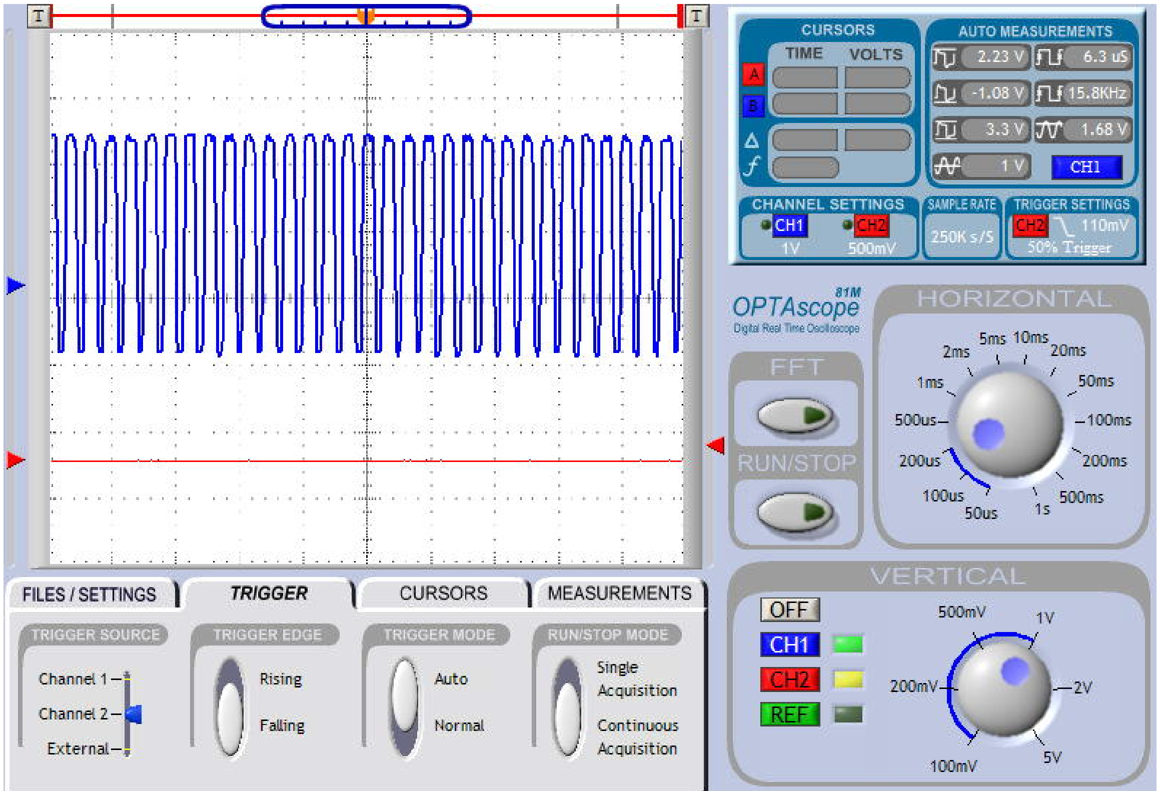
Reading Assignment for next class

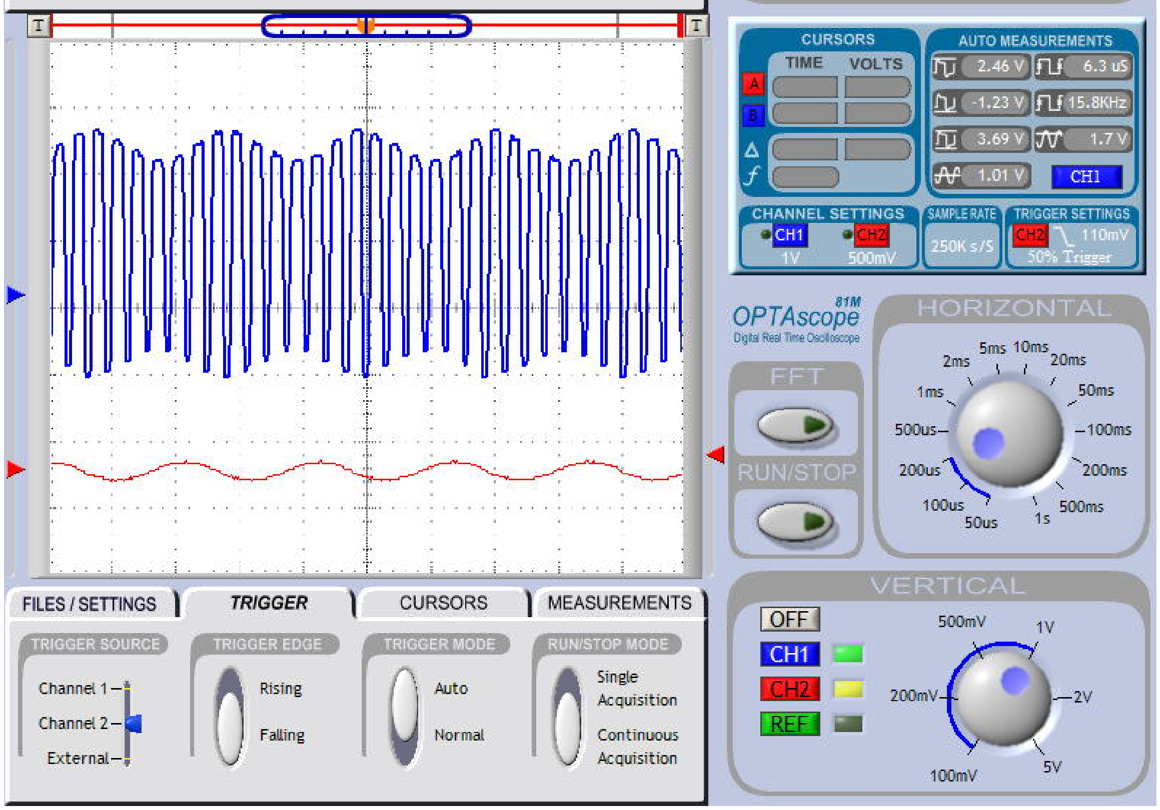
Homework suggestions to reinforce lesson materials

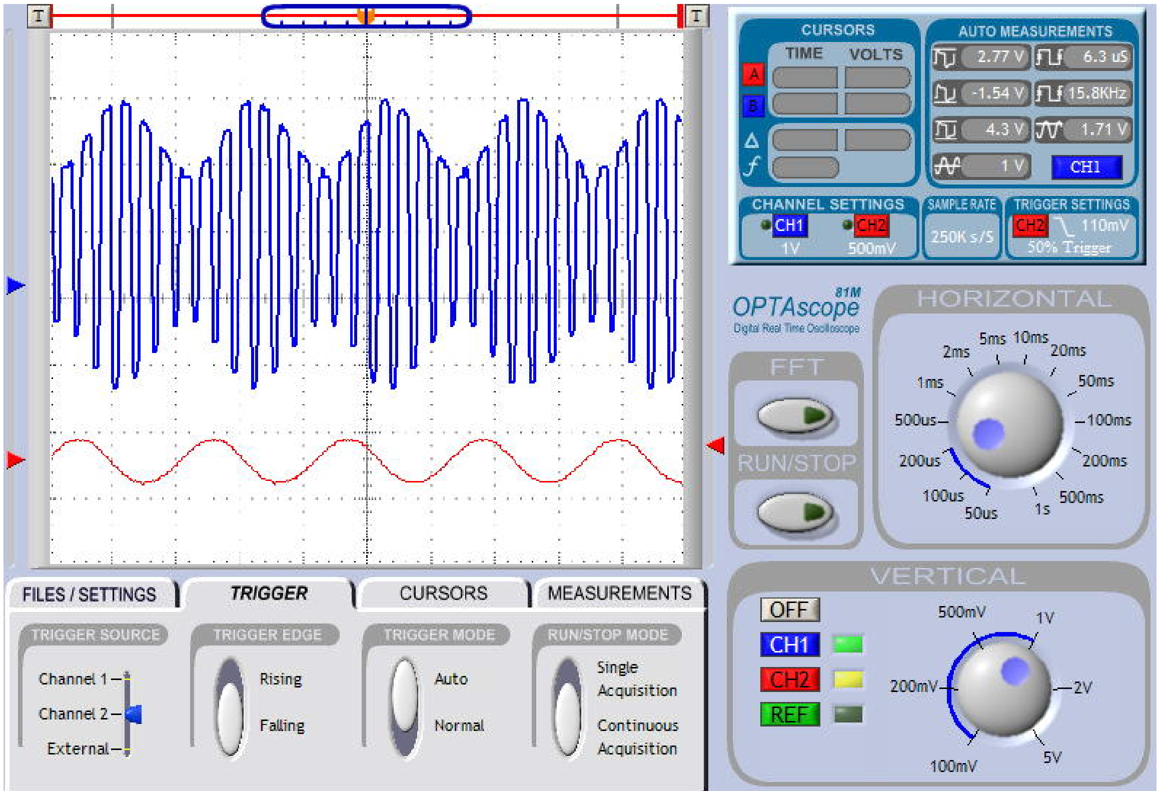
- Tasked the students to go home and turn up the volume of their home entertainment system until they hear distortion and then turn down the volume until the distortion disappears. Ask them to make the correlation between what was covered during the lesson and what they observed with their home entertainment system.
- Ask them, "is louder volume always better?"

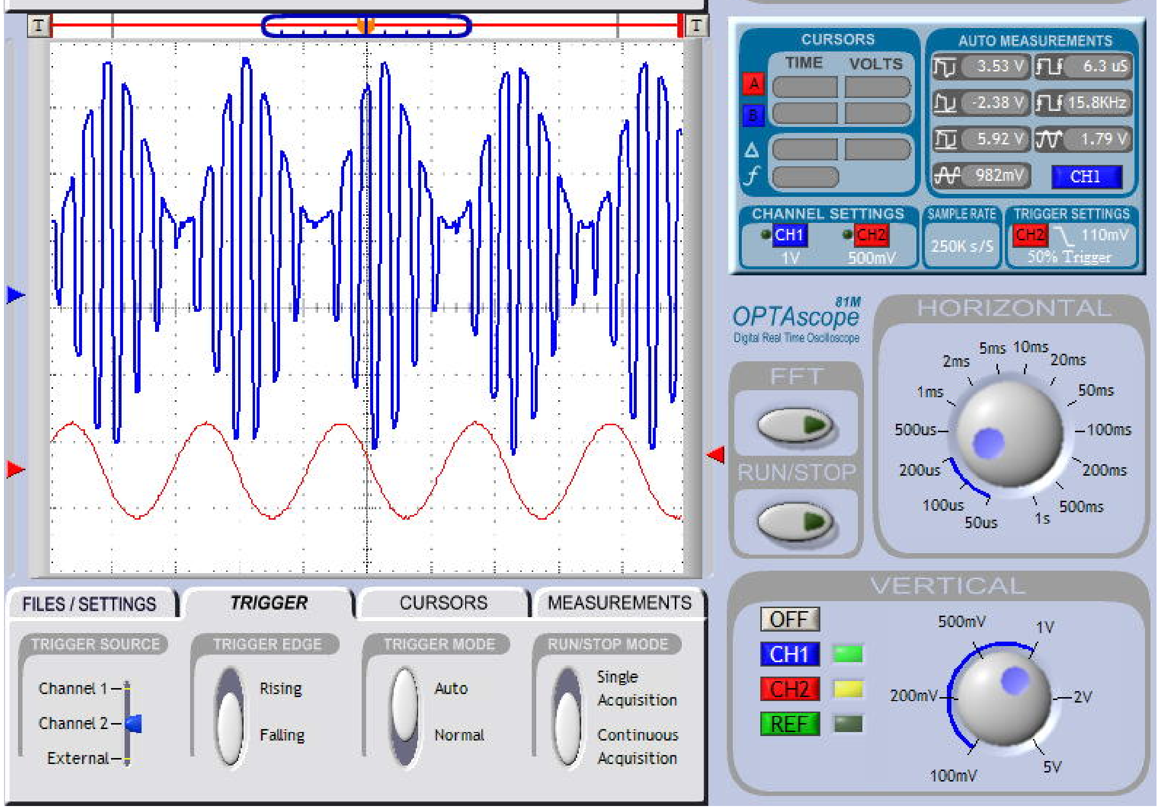

CURSORS
TIME
VOLTS
AUTO MEASUREMENTS
345mV
428 uS
-329mV
2.33KHz
675mV
236mV
0mV
CH2
CHANNEL SETTINGS
CH1
CH2
500mV
200mV
SAMPLE RATE
500K s/S
TRIGGER SETTINGS
CH2
110mV
50% Trigger
OPTAscope
81M
Digital Real Time Oscilloscope
HORIZONTAL
FFT
RUN/STOP
VERTICAL
OFF
CH1
CH2
REF
FILES / SETTINGS
TRIGGER
CURSORS
MEASUREMENTS
TRIGGER SOURCE
Channel 1
Channel 2
External
TRIGGER EDGE
Rising
Falling
TRIGGER MODE
Auto
Normal
RUN/STOP MODE
Single Acquisition
Continuous Acquisition

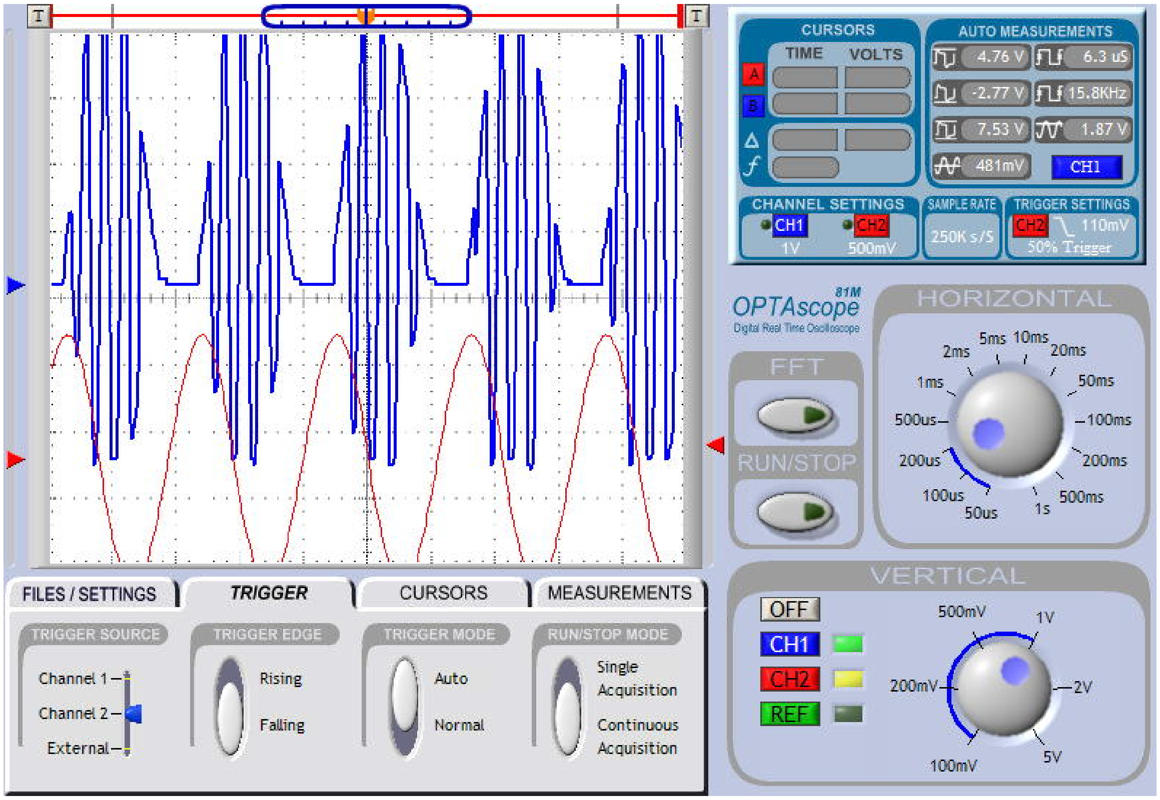

CURSORS
TIME
VOLTS
AUTO MEASUREMENTS
3.53 V
6.3 uS
-2.38 V
15.8KHz
5.92 V
1.79 V
982mV
CH1
CHANNEL SETTINGS
CH1
CH2
1V
500mV
SAMPLE RATE
250K s/S
TRIGGER SETTINGS
CH2
110mV
50% Trigger
OPTAscope
81M
Digital Real Time Oscilloscope
HORIZONTAL
FFT
RUN/STOP
VERTICAL
OFF
CH1
CH2
REF
FILES / SETTINGS
TRIGGER
CURSORS
MEASUREMENTS
TRIGGER SOURCE
Channel 1
Channel 2
External
TRIGGER EDGE
Rising
Falling
TRIGGER MODE
Auto
Normal
RUN/STOP MODE
Single Acquisition
Continuous Acquisition


CURSORS
TIME VOLTS
AUTO MEASUREMENTS
2.23 V
6.3 uS
-1.08 V
15.8KHz
3.3 V
1.68 V
1 V
CH1
CHANNEL SETTINGS
CH1 1V
CH2 500mV
SAMPLE RATE
250K s/S
TRIGGER SETTINGS
CH2 110mV
50% Trigger
OPTAscope 81M
Digital Real Time Oscilloscope
FFT
RUN/STOP
HORIZONTAL
VERTICAL
OFF
CH1
CH2
REF
FILES / SETTINGS
TRIGGER
CURSORS
MEASUREMENTS
TRIGGER SOURCE
Channel 1
Channel 2
External
TRIGGER EDGE
Rising
Falling
TRIGGER MODE
Auto
Normal
RUN/STOP MODE
Single Acquisition
Continuous Acquisition


CURSORS
TIME VOLTS
AUTO MEASUREMENTS
2.46 V
6.3 uS
-1.23 V
15.8KHz
3.69 V
1.7 V
1.01 V
CH1
CHANNEL SETTINGS
CH1 1V
CH2 500mV
SAMPLE RATE
250K s/S
TRIGGER SETTINGS
CH2 110mV
50% Trigger
OPTAscope 81M
Digital Real Time Oscilloscope
FFT
RUN/STOP
HORIZONTAL
VERTICAL
OFF
CH1
CH2
REF
FILES / SETTINGS
TRIGGER
CURSORS
MEASUREMENTS
TRIGGER SOURCE
Channel 1
Channel 2
External
TRIGGER EDGE
Rising
Falling
TRIGGER MODE
Auto
Normal
RUN/STOP MODE
Single Acquisition
Continuous Acquisition


CURSORS
TIME
VOLTS
AUTO MEASUREMENTS
2.77 V
6.3 uS
-1.54 V
15.8KHz
4.3 V
1.71 V
1 V
CH1
CHANNEL SETTINGS
CH1 1V
CH2 500mV
SAMPLE RATE
250K s/S
TRIGGER SETTINGS
CH2 110mV
50% Trigger
OPTAscope 81M
Digital Real Time Oscilloscope
FFT
RUN/STOP
HORIZONTAL
5ms 10ms 2ms 20ms 1ms 50ms 500us 100ms 200us 200ms 100us 500ms 50us 1s
VERTICAL
OFF
CH1
CH2
REF
500mV 1V 200mV 2V 100mV 5V
FILES / SETTINGS
TRIGGER
CURSORS
MEASUREMENTS
TRIGGER SOURCE
Channel 1
Channel 2
External
TRIGGER EDGE
Rising
Falling
TRIGGER MODE
Auto
Normal
RUN/STOP MODE
Single Acquisition
Continuous Acquisition


CURSORS
TIME
VOLTS
AUTO MEASUREMENTS
3.53 V
6.3 uS
-2.38 V
15.8KHz
5.92 V
1.79 V
982mV
CH1
CHANNEL SETTINGS
CH1 1V
CH2 500mV
SAMPLE RATE
250K s/S
TRIGGER SETTINGS
CH2 110mV
50% Trigger
OPTAscope 81M
Digital Real Time Oscilloscope
FFT
RUN/STOP
HORIZONTAL
5ms 10ms 2ms 20ms 1ms 50ms 500us 100ms 200us 200ms 100us 500ms 50us 1s
VERTICAL
OFF
CH1
CH2
REF
500mV 1V 200mV 2V 100mV 5V
FILES / SETTINGS
TRIGGER
CURSORS
MEASUREMENTS
TRIGGER SOURCE
Channel 1
Channel 2
External
TRIGGER EDGE
Rising
Falling
TRIGGER MODE
Auto
Normal
RUN/STOP MODE
Single Acquisition
Continuous Acquisition


CURSORS
TIME
VOLTS
A
B
AUTO MEASUREMENTS
4.76 V
6.3 uS
-2.77 V
15.8KHz
7.53 V
1.87 V
481mV
CH1
CHANNEL SETTINGS
CH1
1V
CH2
500mV
SAMPLE RATE
250K s/S
TRIGGER SETTINGS
CH2
110mV
50% Trigger
OPTAscope
81M
Digital Real Time Oscilloscope
HORIZONTAL
2ms
5ms
10ms
20ms
1ms
50ms
500us
100ms
200us
200ms
100us
50us
1s
500ms
FFT
RUN/STOP
VERTICAL
OFF
CH1
CH2
REF
500mV
1V
200mV
2V
100mV
5V
FILES / SETTINGS
TRIGGER
CURSORS
MEASUREMENTS
TRIGGER SOURCE
Channel 1
Channel 2
External
TRIGGER EDGE
Rising
Falling
TRIGGER MODE
Auto
Normal
RUN/STOP MODE
Single Acquisition
Continuous Acquisition

Demodulation

Learning Objectives

In this lesson you will learn:

- That demodulation is the process of extracting the intelligence from a modulated carrier wave.
- That there is some inherent level of distortion of the intelligence during the process of demodulation.
- That filtering can help to alleviate some of the inherent distortion.

Study Materials

- Handbook For Radio Communications, 2005 pages 11.8-11.9
- ARRL License Manual chapter and pages

Equipment and Materials

- Modulation Demonstration Board
- Two channel oscilloscope or OptaScope

Recommended Strategy

1. Review the concept of modulation with the student.
2. Discuss with the students the process of demodulation and that it is used to extract the intelligence that modulated the carrier wave from the carrier wave. The extracted intelligence is applied to circuits within a radio to interface with the user (speakers, video screens, computers, etc.)
3. Draw a block diagram of a simple receiver to illustrate the process.
4. Perform the demodulation demonstrated detailed in the suggested activities section.
5. Note with the students that any time a wave form is manipulated by electronic circuits, the imperfections in those circuits inject some distortion or corruption of the wave forms. Properly designed circuits are required to minimize that distortion.
6. Discuss with the students that filters are often used in radio circuits to help eliminate or reduce some of the distortion caused by manipulating wave forms. Though filters are far from perfect, the improvement in the quality of the wave form after filtering is dramatic.
7. Perform the filtering demonstration detailed in the suggested activities section.

Suggested Activities

1. Perform the modulation board calibration procedure before class.

Demodulation demonstration

2. Connect one channel of the OptaScope to TP5, the output of the modulator. Connect the other channel of the scope to TP6, the output of the demodulator.
3. Draw on the board a diode symbol and review with the students the electrical properties of the diode. This demodulator circuit uses a single diode.

4. Turn on power to the board and discuss with the students the wave forms being displayed. Make the connection between the properties of a diode and the concept of demodulation.
5. Make specific note that the demodulated wave form is only a rough approximation of the modulating audio wave form, spend some time to make sure that each student can see the connection.
6. Make specific note that the carrier wave from has been essentially removed by the demodulator, but not quite all of the carrier is removed.

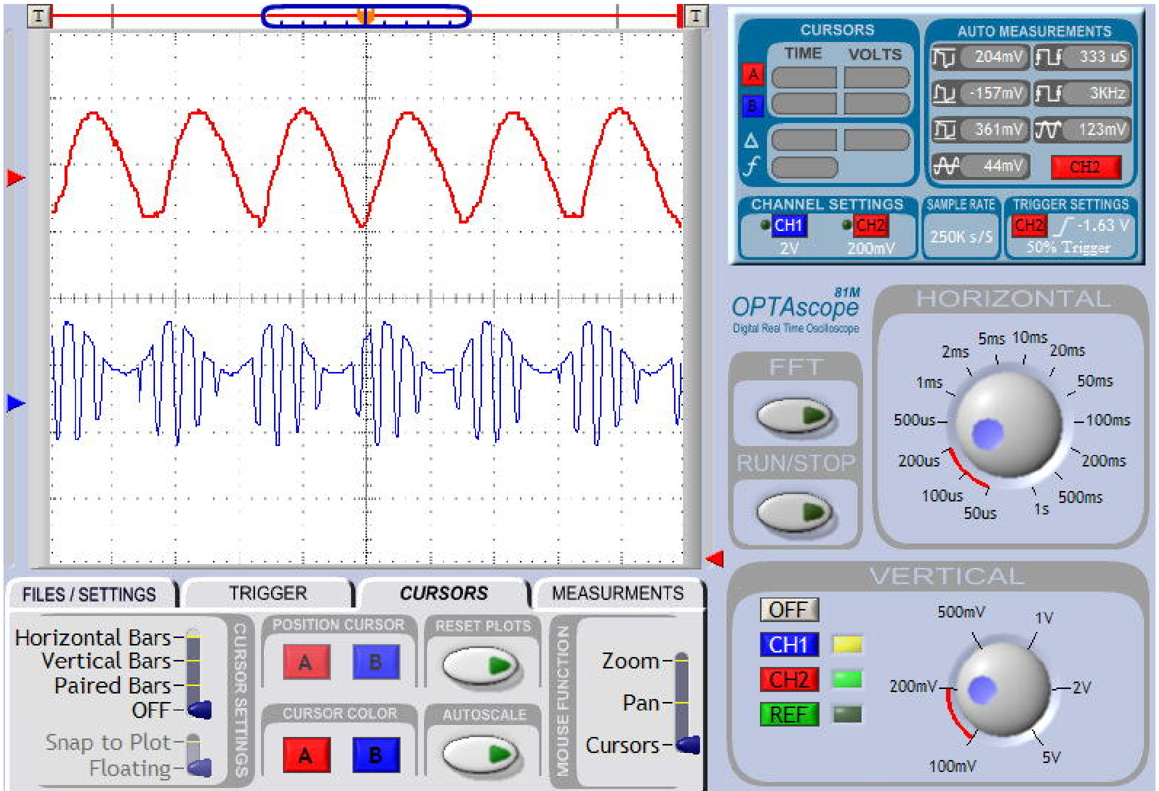
Filtering demonstration

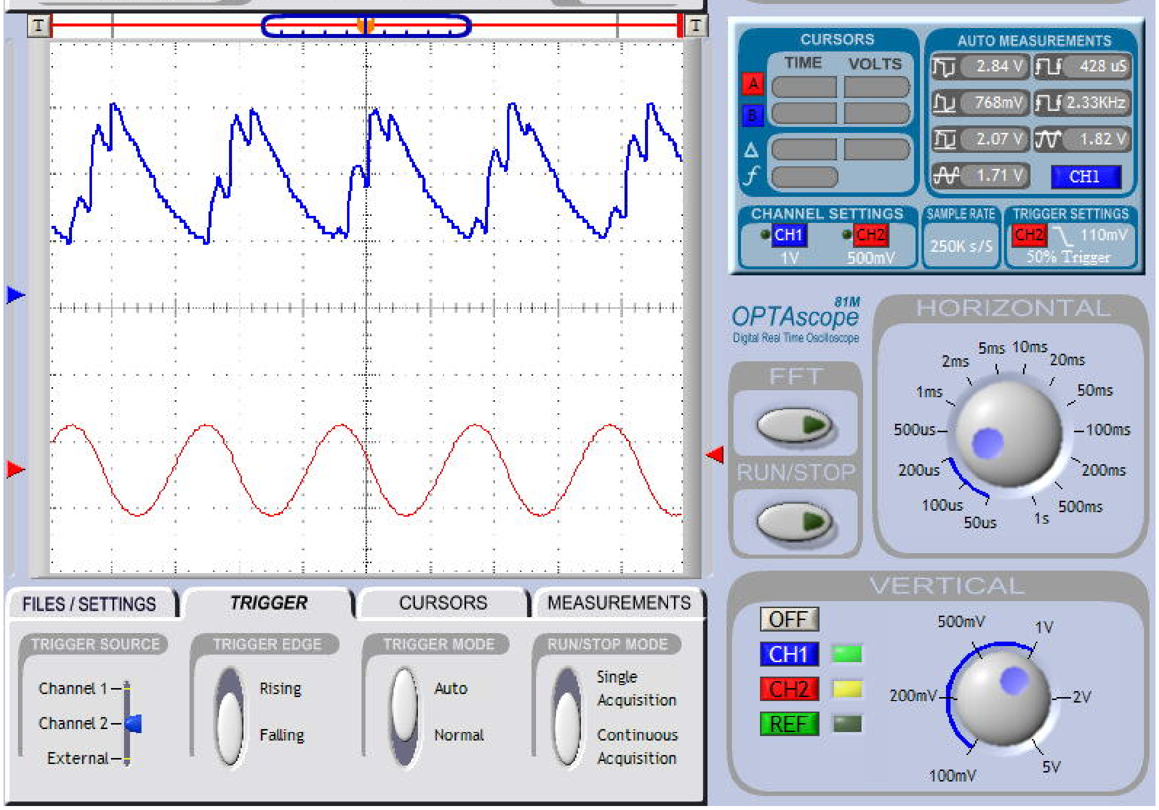
7. Move the scope connection from TP5 to TP7 (the filter output).
8. Draw on the board the circuit diagram of the filter. Take a moment to simply explain how a filter works.
9. Turn on the power to the board and emphasize the difference between the demodulator output before filtering and after filtering. Make specific note that there is still some distortion of the wave form even after filtering.
10. Move the scope connection from TP6 to TP1 (audio input) and make necessary scaling adjustments.
11. Task the students to compare the audio input wave form to the filtered demodulator output wave form.
12. Draw a block diagram of a separated transmitter and receiver on the board. Use this diagram to review the concept of modulation, transmission, reception, and demodulation to bring it all together.

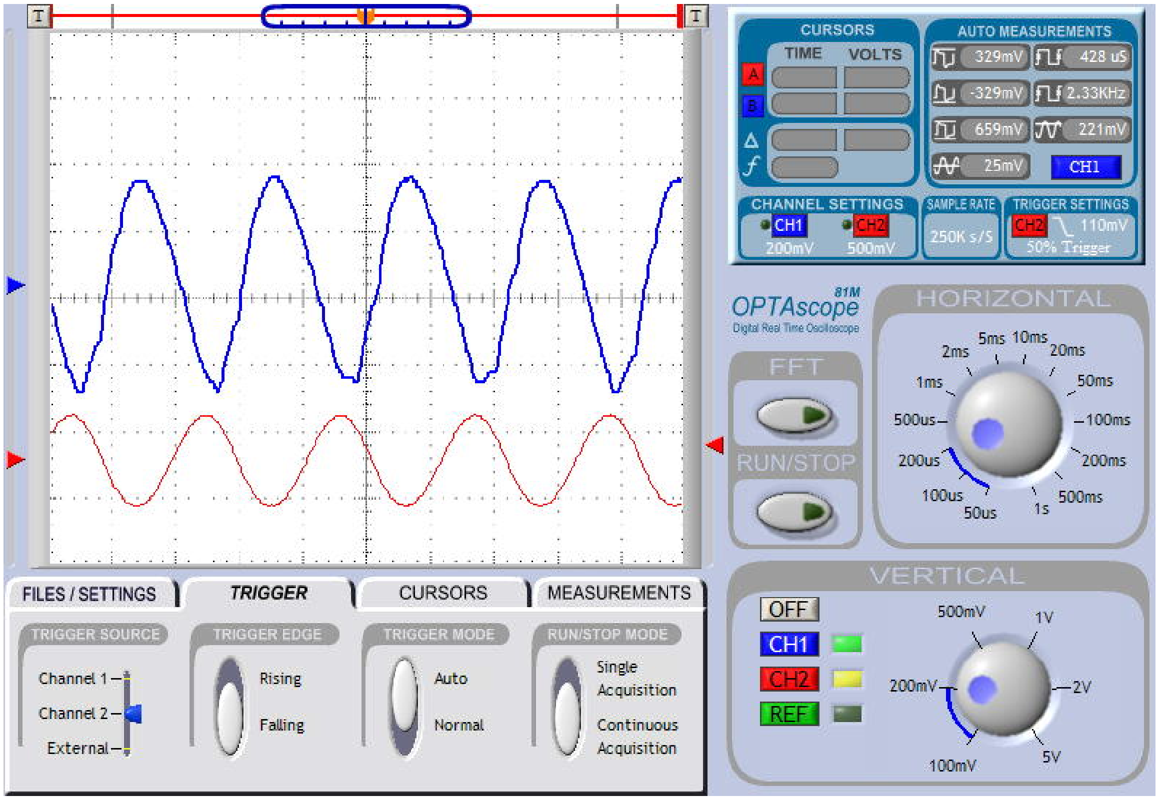
Reading Assignment for next class

Homework suggestions to reinforce lesson materials

- Task the students to draw a block diagram of a radio transmitter, the radio waves traveling to the receiver, and a radio receiver. Ask them to draw simulated wave forms of modulating intelligence at various locations along the way from transmitter to receiver.
- At the next class meeting ask selected students to use their drawings to explain the process of modulation and demodulation.


CURSORS
TIME
VOLTS
AUTO MEASUREMENTS
204mV
333 uS
-157mV
3KHz
361mV
123mV
44mV
CH2
CHANNEL SETTINGS
CH1
CH2
2V
200mV
SAMPLE RATE
250K s/S
TRIGGER SETTINGS
CH2
-1.63 V
50% Trigger
OPTAscope 81M
Digital Real Time Oscilloscope
FFT
RUN/STOP
HORIZONTAL
5ms 10ms 2ms 20ms 1ms 50ms 500us 100ms 200us 200ms 100us 50us 1s 500ms
VERTICAL
OFF
CH1
CH2
REF
500mV 1V 200mV 2V 100mV 5V
FILES / SETTINGS
TRIGGER
CURSORS
MEASURMENTS
Horizontal Bars
Vertical Bars
Paired Bars
OFF
Snap to Plot
Floating
CURSOR SETTINGS
POSITION CURSOR
A
B
RESET PLOTS
CURSOR COLOR
A
B
AUTOSCALE
MOUSE FUNCTION
Zoom
Pan
Cursors


CURSORS
TIME
VOLTS
AUTO MEASUREMENTS
2.84 V
428 uS
768mV
2.33KHz
2.07 V
1.82 V
1.71 V
CH1
CHANNEL SETTINGS
CH1
CH2
1V
500mV
SAMPLE RATE
250K s/S
TRIGGER SETTINGS
CH2
110mV
50% Trigger
OPTAscope 81M
Digital Real Time Oscilloscope
FFT
RUN/STOP
HORIZONTAL
5ms 10ms 2ms 20ms 1ms 50ms 500us 100ms 200us 200ms 100us 50us 1s 500ms
VERTICAL
OFF
CH1
CH2
REF
500mV 1V 200mV 2V 100mV 5V
FILES / SETTINGS
TRIGGER
CURSORS
MEASURMENTS
TRIGGER SOURCE
Channel 1
Channel 2
External
TRIGGER EDGE
Rising
Falling
TRIGGER MODE
Auto
Normal
RUN/STOP MODE
Single Acquisition
Continuous Acquisition



CURSORS
TIME
VOLTS
A
B
AUTO MEASUREMENTS
329mV
428 uS
-329mV
2.33KHz
659mV
221mV
25mV
CH1
CHANNEL SETTINGS
CH1
CH2
200mV
500mV
SAMPLE RATE
250K s/S
TRIGGER SETTINGS
CH2
110mV
50% Trigger
OPTAscope 81M
Digital Real Time Oscilloscope
HORIZONTAL
FFT
RUN/STOP
5ms
10ms
2ms
20ms
1ms
50ms
500us
100ms
200us
200ms
100us
500ms
50us
1s
VERTICAL
OFF
CH1
CH2
REF
500mV
1V
200mV
2V
100mV
5V
FILES / SETTINGS
TRIGGER
CURSORS
MEASUREMENTS
TRIGGER SOURCE
Channel 1
Channel 2
External
TRIGGER EDGE
Rising
Falling
TRIGGER MODE
Auto
Normal
RUN/STOP MODE
Single Acquisition
Continuous Acquisition