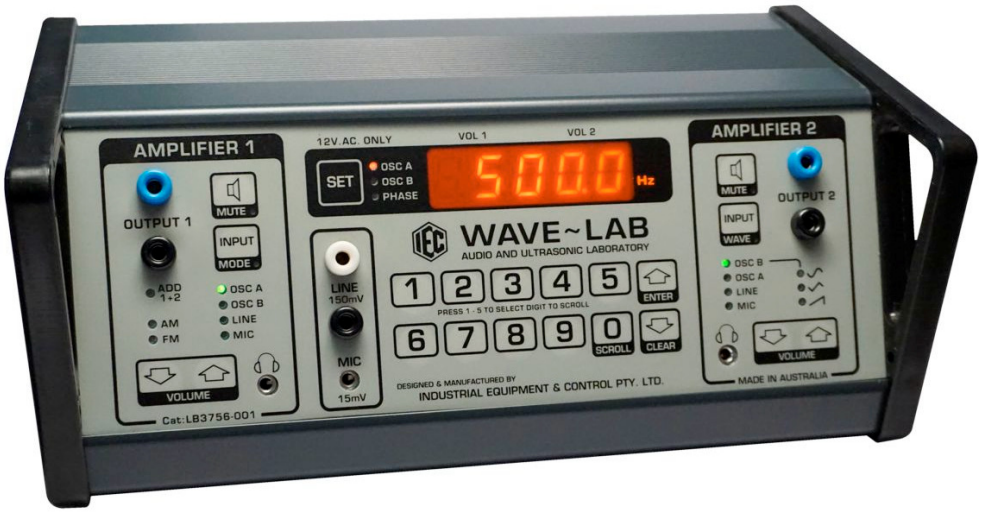
WAVE~LAB

Dual Wave Signal Generator



LB3756-101

Description:

The 'Wave~Lab' provides two sources of oscillating waves that are sourced from the one microprocessor. They can be perfectly in phase or can be shifted in frequency and phase relative to one another over the range of 0.1Hz to 40kHz.

The waveform can be sine, triangle or sawtooth and waveforms can be added or one wave modulated by the other. The two outputs are very high power and can drive large speakers. Sockets are provided for headphones for private study.

A full entry keyboard permits the entry of any frequency or a shift of phase in degrees between the two signals.

This equipment is for the production and manipulation of waves for the study of the principles of wave propagation, wave inter-relationships and sound.

LB3756-001 compact speakers are a low cost, broad range design with a power, size and fidelity suitable for the 'Wave~Lab'. They are internally protected against power overload.

The Standard 240V.AC Wave~Lab Kit Contains:

- Wave~Lab instrument.
- Set of mini headphones, with cable and plug.
- Microphone, dynamic type (moving coil), with cable, switch and plug.
- Instruction sheets

Length: 270mm	Width: 140mm	Height: 105mm	Weight: 2.2kg

Features of the IEC 'Wave~Lab' include:

- Digital design for absolute accuracy and stability of frequencies.
- Australian design and manufacture for ongoing service and backup.
- Construction is very robust to take normal classroom abuse.
- Front panel uses 'touch buttons' for reliability and the whole panel is 'wipe clean'.
- There are no knobs or switches to accumulate dirt and dust.
- Output gain (volume) settings are digital so they can be set precisely and viewed on the display.
- A full keyboard is provided for setting volumes, frequencies and phase angle.
- The frequency, the amplifier volume levels and the phase relationship is displayed on a large LED display.
- A keypad permits precise entry of frequency and phase relationship.
- A special 'scroll' feature permits more rapid input keying of digital values.
- Compact design for ease of operation and storage.
- Incorrect settings are avoided because of the logic behind the instrument buttons.
- To avoid confusion, functions are monitored by mini LED indicators.
- Very broad range of frequency from 0.1 Hz to 40 kHz.
- High output power for operating mechanical devices.
- Supplied with microphone and headphones.
- A brief set of instructions is provided in the form of a durable label on the rear of the instrument to assist the user.
- Either output can be separately 'Muted' to control various effects.
- The outputs can be connected to large or small speakers, to mechanical devices for vibrating strings or to two channels of an oscilloscope for viewing.
- For individual student use and for private listening to wave interference, beating or other phenomena, provision is made for connecting standard mini headphones.
- Inputs are provided for both Microphone (15mV) and 'Line' (150mV).
- Any external input signal can be mixed with any internally generated wave
- Operation is simple and intuitive.

General Description:

This microprocessor controlled instrument has been specially developed to provide two digitally generated and very accurate oscillating signals to teach the concepts of wave theory.

Two sine wave oscillators feed high power amplifiers and the outputs can be set independently for both frequency and amplitude. The two outputs can be used independently or they can be precisely added or subtracted (mixed) and one output can be modulated by the other output.

This instrument runs from 240V.AC mains power to provide an enormous output power of 7V RMS into 4 ohm load. This is equivalent to 1.75 amps AC. RMS per output which is sufficient to operate mechanical devices like Recording Timers or String Vibrators or the largest of loud speakers.

Front Panel Layout and Controls:

The centre section of the panel is the digital display and select section. The SET button selects and permits the frequency setting of the two independent oscillators Osc A and Osc B and also selects and permits the setting of the PHASE ANGLE in degrees between the two oscillator waveforms.

The lower centre section of the panel is the KEYPAD that permits the keying of the oscillator frequencies in Hz or phase angle shift in degrees between the two waves as required for an experiment. The input sockets for microphone and external signal are grouped also into this section.

Output AMPLIFIER 1 and AMPLIFIER 2 are positioned at each end of the front panel.

These areas include both muting and selection buttons, volume controls and output sockets for headphones, speakers or other devices.

The Display and Select Section:

The SET button selects either oscillator A or oscillator B and the Phase Angle between the two waves of Osc A and Osc B. When selected, the value is then keyed into the keypad and ENTER is pressed. The unit of the selection (Hz or DEG) can be seen on the right end of the display. Pressing the SET button at any time permits the values to be checked of any of the three settings.

The Keypad and Signal Inputs Section:

Note that for values up to 9999.9 Hz, the display resolution is 0.1 Hz. Above 10,000 Hz the display resolution is 1 Hz.

DATA ENTRY: There are three ways to enter data:

1) Press CLEAR to clear the display, then enter the digits one by one to build the number you need. Then press ENTER.

2) When some data is entered, press the ARROW buttons to adjust up or down from the displayed value. Hold the arrow button down to permit continuous incrementing or decrementing. This is dynamic and pressing ENTER is not required.

3) Press SCROLL and right hand digit will flash. Using buttons 1 to 5, select the digit you need to alter. When selected, it will flash alone. Use arrow buttons to scroll to the number wanted. Then use 1-5 buttons to select another digit to change. When all digits are correct, press SCROLL again to enter the final value.

Signal Inputs:

Two 4mm sockets are provided for input signals from tape recorder or signal generator. This input is called ‘LINE’ input and signal level of about 150mV is required.

A 3.5mm phone socket is provided for the input from a moving coil or ‘dynamic’ microphone. Signal level of about 15mV is required.

NOTES on INPUTS: These are both sensitive inputs. If the input connection is exposed and touched with the finger, a severe hum or squeal might result from the speakers.

FEEDBACK: If a microphone picks up sound from the speakers, it will feed the sound back into the Wave~Lab and it will amplify and feed the speakers louder, which the microphone will pick up etc.etc.. Therefore a very loud squeal will result and this is called “FEEDBACK”. Try to avoid feedback by always pointing the microphone away from the speakers and keeping the volume to minimum required for the experiment.

The Amplifier 1 and Amplifier 2 Sections:

The arrow VOLUME buttons increase and decrease the amplification on each amplifier from zero up to 100%. First press on the button displays current settings digitally and further presses change the setting. Zero volume shows two low bars on the display. 100% volume shows two high bars on the display. All other volumes are digital from 1 to 99.

NOTE: The increase in 'volume' is actually an increase in voltage at the output terminals. If the frequency is set to zero, the output voltage will be DC and will rise and fall with volume setting. If a centre zero voltmeter is connected to the output terminals when the frequency is set to about 0.3 Hz, the output voltage swings can easily be measured and understood.

The 4mm OUTPUT sockets can be connected to voltmeters, loud speakers or mechanical devices or to an oscilloscope for viewing the waveforms. Maximum voltage available at the outputs is 7V.RMS or 20V peak to peak.

The MUTE button closes down the output and a red LED warns that the mute has been selected. A second press on the button will release the mute function.

The INPUT button selects the various types of inputs that can be fed to the Amplifier. Both Amplifier 1 and 2 can choose either oscillator or microphone or line (an external signal) as the signal source. The input button selects more options when MODE function is selected.

If the INPUT button of Amplifier 1 is held depressed until 2 beeps are heard, the small MODE LED will illuminate and further normal presses of this button will select the ADD 1&2 mode of operation where the outputs of the two Amplifiers are added. The Input button now selects which signal to add to the selection of Amplifier 2.

When in ADD 1&2 mode, if this button is pressed until 2 beeps are heard, a second MODE is entered for modulation. When this is done, Amplifier 2 automatically changes to WAVE mode and can select the different waveforms for modulating Amplifier 1. The input button for Amplifier 1 now selects either Amplitude Modulation (AM) or Frequency Modulation (FM).

If the INPUT button of Amplifier 2 is held depressed until 2 beeps are heard, the small WAVE LED will illuminate and further presses of this button will select the desired waveform of oscillator B to be fed into Amplifier 2. These different waveforms can be added to the signal selection of Amplifier 1.

Press INPUT buttons again until 2 beeps are heard to exit the MODE functions.

The Wave Relationships:

- Frequency of either Osc A or Osc B can be set from 0.1Hz to 40kHz in steps of 0.1Hz up to 9,999.9 and in steps of 1Hz from 10,000Hz to 40,000Hz (ultrasound).
- The waves from the two oscillators can be added together in real time.
- The waves from the two oscillators can be shifted in phase relationship from zero to 360 degrees in one degree steps. 0^o = in phase, 180^o = out of phase, 360^o = in phase.
- One wave can be modulated by the other wave in either Amplitude Modulation (AM) or in Frequency Modulation (FM) modes. These functions and the resulting wave 'envelopes' are easily studied on an oscilloscope.
- The modulating wave can be set to be either sine, sawtooth or triangular.

Output Power, Distortion and Protection:

Note:

On all outputs, automatic current regulation and overheat shutdown prevents damage on overload or short circuit.

Distortion:

If the power supply inside the instrument fails and therefore is insufficient to supply the requirements of the load (loud speakers etc.), voltages inside the instrument will begin to fall too far and there will be distortion on the output. The distortion will be evident as a 50Hz sine wave present in the output waveform and a 'HUM' heard through the speakers

Full Power:

Both outputs can normally provide sine wave voltage of 20V peak to peak (7V.RMS) and current up to 1.75A. This is approx. 12 Watts per output and this is the full power rating of the instrument.

Operating Instructions:

Power In:

240V.AC. 50/60Hz. Mains cable is provided with the instrument.

Output Sockets:

The high power Amplifier 1 and Amplifier 2 outputs for external speakers or mechanical devices is provided from 4mm banana sockets. The same outputs are suitable for an oscilloscope to view the waveforms and an oscilloscope may be connected to the sockets in parallel with the load.

The black output sockets are connected to 'earth' or 'ground'.

CAUTION: Oscilloscopes normally have one side of their input cables connected to earth, therefore connecting an oscilloscope to the output sockets of the Wave~Lab forces one of the output sockets to be earth. ALWAYS CONNECT THE EARTH SIDE OF THE OSCILLOSCOPE TO THE BLACK SOCKETS OR SHORT CIRCUIT ON THE OUTPUT OR UNPREDICTABLE BEHAVIOUR MAY OCCUR.

Headphone Socket:

A 3.5mm stereo socket is provided on Amplifier 1 and Amplifier 2 for mini headphones. The

output is configured as MONO with the amplifier output signal present in both sides of the headphones. To hear both Amplifier 1 and Amplifier 2 together, select MODE 'ADD 1&2' on Amplifier 1 and use the Amplifier 1 headphone output socket.

Input Signal Sockets:

Input signal for LINE: Any external signal from a music source or oscillator or similar can be applied to these sockets using 4mm banana plugs. Either amplifier can select this input.

To avoid distortion, the signal strength should not exceed 150mV.

Input signal for MICROPHONE: A dynamic (moving coil) microphone can be used in this 3.5mm socket. Either amplifier can select this input. Voice patterns or other sounds can be viewed on an oscilloscope or can be added to any other selection. To avoid distortion, the signal strength should not exceed 15mV. If a crystal microphone is the signal source, it is suggested that the LINE input be used for this higher level signal.

The Main Display:

Set Button:

This SET button selects Osc. A, Osc. B or Phase. The selection chosen and the relevant units are visible at the ends of the display panel.

If Osc. A is selected, the value entered by the keyboard sets the exact frequency in Hz. of Oscillator A.

If Osc. B is selected, the value entered by the keyboard sets the exact frequency in Hz. of Oscillator B.

If PHASE is selected, the value keyed by the keyboard sets the phase difference between Osc. A and Osc. B is in degrees from 0 to 360. 0^{o} means 'in phase', 180^{o} phase', 360^{o} means 'in phase'.

The Keyboard:

Digit Buttons:

After selecting either Osc. A or Osc. B, the desired frequency can be displayed by pressing the digits to build the desired value on the display. Up to 9999.9Hz, the decimal point permits resolution of 0.1Hz. Above 10,000Hz, the decimal point disappears and the resolution becomes 1Hz up to a maximum frequency of 40,000Hz.

Enter Button:

When the digital value is displayed, press the ENTER button to enter the value into the selected Oscillator.

Clear Button:

While entering a digital selection, if a mistake is made, the clear button will clear the display to zero.

Arrow Up / Down Buttons:

The frequency can be incremented or decremented by using the arrow UP/DOWN buttons. If the arrow buttons are held depressed, the frequency value in the display will scroll quickly on the lowest digits.

Scroll Function Button:

To enter a large number directly, press the SCROLL button and right hand digit will flash. Use the 1-5 buttons to select your digit and press arrow buttons to scroll that digit up or down. Press 1-5 to select another digit to scroll etc.. When all digits are set correctly, press the SCROLL button again to enter the selection. The display will cease flashing to indicate that the selection has been entered. After a digital value is entered, the arrow buttons can be used at any time to adjust the values up or down in small increments.

Phase:

To set a PHASE difference, first set Osc. A and Osc. B to the same or a low multiple frequency (perhaps 1200/1200 or 400/800 or 1000/2000 or 500/1500 and so on).

Then press the SET button to select PHASE. The display will show bars to indicate that the waves have no definite phase relationship. A phase relationship between two waves occurs only when a specific phase angle is set into the display. Use the digits or the arrow buttons to increment the phase difference between the two waves from 0 to 360o . Setting 0o makes the waves 'in phase'. If the two waves are viewed on a dual channel oscilloscope, the phase difference can clearly be seen.

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If two waves are to be ADDED by Amplifier 1 MODE selection of ‘ADD 1&2’, always remember to set their phase relationship first. The resultant added waveform can be seen from the output of Amplifier 1 on an oscilloscope.

Note 1:

Remember that when two waves differ in frequency by a large amount, the phase relationship between them is constantly and rapidly changing. A PHASE DIFFERENCE between two waves can be easily seen or heard only if the two waves are of similar frequencies or if they are a low multiple of one another, perhaps 2:1 or 3:1.

Note 2:

The 1-5 SCROLL function used for setting larger numbers as described above cannot be used when in PHASE setting. Digits can be entered directly or the up/down arrow buttons can be used.

Note 3:

If either Osc. A or Osc. B is altered in frequency, any preset PHASE difference between them is lost and will require resetting. If PHASE is selected again, two bars will be visible indicating that there is no definite phase relationship set at that time between the two waves.

Amplifier 1:

Mute Button:

Pressing this button toggles MUTE ON / MUTE OFF. When output is muted, the small red LED in the button is ON and the sound from Amplifier 1 is stopped. Amplifier 2 is unaffected.

Input / Mode Button:

Input Function:

For Amplifier 1, this button normally selects amplifier inputs of:

- Osc. A. The signal of oscillator A is applied to the amplifier.
- Osc. B The signal of oscillator B is applied to the amplifier.
- Line input. This external signal should not exceed 150mV.
- Microphone input. This external signal should not exceed 15mV.

Mode Function:

If the button is held depressed until a double beep is heard, the MODE function permits:

ADD 1-2

Adds the outputs of Amplifier 1 and Amplifier 2 together to provide the resultant waveform at the output terminals of Amplifier 1.

When in this mode, further normal presses on the INPUT button select the Osc. A, Osc. B, Line or Microphone to be added to the selection at Amplifier 2.

If the INPUT button is held depressed again until a double beep is heard, the next MODE function permits selection of:

AM

Selects Amplitude Modulation where the waveform of Osc. B modulates the Amplitude of the waveform of Osc. A.

FM

Selects Frequency Modulation where the waveform of Osc. B modulates the Frequency of the waveform of Osc. A.

When this AM/FM mode is selected, the Amplifier 2 WAVE MODE is automatically turned on and the waveform shape for Osc. B (the modulating wave) can be selected.

Volume Up/Down Buttons:

The first press of either UP or DOWN arrow buttons will display the volume settings of both of the amplifiers on the LED display panel. The left side display is for Amplifier 1 and the right side display is for Amplifier 2.

The volume setting begins at 2 low bars, representing zero volume, then through digits up to 99%. Maximum of 100% is represented by 2 high bars. Individual presses of the buttons adjusts the volume in steps of 1%. If the button is held depressed, the volume scrolls up or down quickly.

Amplifier 2:

Mute Button:

Pressing this button toggles MUTE ON / MUTE OFF. When output is muted, the small red LED in the button is ON and the sound from Amplifier 2 is stopped. Amplifier 1 is unaffected.

Input / Wave Button:

Input Function:

For Amplifier 2, this button normally selects amplifier inputs of:

- Osc. B. The signal of oscillator B is applied to the amplifier.
- Osc. A The signal of oscillator A is applied to the amplifier
- Line input. This external signal should not exceed 150mV.
- Microphone input. This external signal should not exceed 15mV.

Wave Function:

This function can be selected when Amplifier 1 is selecting ADD 1&2 mode. WAVE function is selected by pressing the INPUT button until double beep is heard. The WAVE function is automatically selected when Amplifier 1 is selecting AM or FM. When active, pressing the WAVE button selects:

- Sine waveform of Osc. B to ADD TO or to modulate signal of Osc. A
- Triangular wave of Osc. B to ADD TO or to modulate signal of Osc. A.
- Sawtooth wave of Osc. B to ADD TO or to modulate signal of Osc. A.

Volume Up/Down Buttons:

The first press of either UP or DOWN arrow buttons will display the volume settings of both of the amplifiers on the LED display panel. The left side display is for Amplifier 1 and the right side display is for Amplifier 2.

The volume setting begins at 2 low bars, representing zero volume, then through digits up to 99%. Maximum of 100% is represented by 2 high bars. Individual presses of the buttons adjusts the volume in steps of 1%. If the button is held depressed, the volume scrolls up or down quickly.

Examples for Practise in Using the Wave~Lab:

Adding Sine Waves To Create Beat Frequencies:

The term 'beating' means two separate sounds of almost identical frequencies, repetitively adding to become louder and then subtracting to become softer.

- Turn on the Wave~Lab. Automatically the frequncies of both oscillators default to 500 Hz and the output volumes default to 5% so that sound is heard immediately.
- Press the SET button to select Oscillator A.
- Using the keyboard, key in the following numbers 5,0,0,0 and press the Enter key. Notice that frequency has a decimal point up to 9,999.9 Hz. The frequency will be 500.0 Hz.
- Press the SET button to select Oscillator B.
- Using the keyboard, key in the following numbers 5,0,0,0 and press the Enter key.

Notice that frequency has a decimal point up to 9,999.9 Hz. The frequency will be 500.0 Hz.

At this time we have identical frequencies on both oscillators and both sine waves are in phase (rising and falling at exactly the same time). To check this, connect the 2 beams of an oscilloscope to Output 1 and Output 2. Press the Volume button of Amplifier 1 and see the display increase from zero to 99% of maximum output power. See the same on Amplifier 2.

Set both amplifiers to say level 20 on the digital display.

Plug the Headphones into the Amplifier 1 socket. Press Input button to select Oscillator A or Oscillator B. 'Line' and 'Mic' should have no sound. Notice that both Oscillators sound exactly the same. Try the same thing plugging into the socket of Amplifier 2. Press the Input button of Amplifier 2 and notice that Oscillators A and B sound the same.

Plug headphones back into Amplifier 1. Hold Input button pressed for few seconds until Mode function illuminates. Notice that the first Mode is 'ADD A+B'. This is the addition of the sine waveforms of Oscillator A and Oscillator B coming from the output of Amplifier 1.

The sound in the headphones may be louder than before because both waves are adding.

Notice the waveform on the oscilloscope for Amplifier 1. It should be different (both waves added) from waveform on Amplifier 2 (one wave only). Remember that at this time the Phase of the two waves is unknown.

To make the waves 'beat', we must slightly change the frequency of one of the waves. When this is done, the two waves will move relevant to one another so that they will move in and out of phase. When in phase, the wave height will be double and when out of phase they will cancel.

- Press Set button to select say Osc A.
- Use the keyboard to enter the following numbers: 5,0,1,0. This is frequency of 501.0 Hz. This means that as the faster wave moves past the slower one (see on the oscilloscope) they will repetitively add then subtract. Listen to the 'beating' of the two waves in your headphones.
- Take one good quality loud speaker and connect it to the Amplifier 1 output. The 'beating' can easily be heard by the whole class.

Press the Input button of Amplifier 1 and hold depressed until double beep (this is 'modulation' mode), then press and wait for double beep again to escape from Mode functions.

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Connect a speaker to Output 1 and Output 2.

Try different frequencies for Osc A and notice that the 'beating frequency' gets faster as the separation between Osc A and Osc B gets larger. If frequencies and the difference become much higher, the 'beat frequency' can be so fast that it can be heard as a tone. If say 10,000 Hz is used for Osc A and say 10,100 is used for Osc B, when the two frequencies are of the same power and are added (Mode A+B), the beat frequency of 100Hz can be heard as a tone.

Alter the output Volume of say Amplifier #1 to say 40%. Then one wave will be 20% volume and the other will be 40% volume. Connect the oscilloscope to Output #1 to see A+B which is the adding and subtraction of the two waves of different size.

Listen to the result and notice that beating is present but there is also a steady undertone of the frequency of the larger power oscillator.

Adding and Subtracting Sine Waves by Changing Their Phase:

Press Set button and key in the value to set Osc A and Osc B to the same frequency.

Press Set button to select Phase. Display will show bars which means the waves are not in any particular phase relationship. Enter zero phase difference to make the the two waves exactly in phase.

Connect Oscilloscope to Output #1 and select Mode to be A+B. See a single sine wave.

Press Mute on Amplifier #2 to close down that output. Notice the oscilloscope wave is now half height. When Mute is pressed again to activate that output, the two waves add to become a double height sine wave.

Select Set Phase and key in 180 and press enter key. This sets the Osc B to be 180 degrees out of phase with Osc A. The resulting waveform should be zero. This should be almost a straight line on the oscilloscope and almost no sound in the headphones or speaker.

Select Phase again and key in 90 degrees and press enter key. Firstly predict, then observe result of adding two sine waves displaced 90 degrees in phase. The result is a still a pure sine

wave but of lesser amplitude than either of the two being added.

Now change the frequency of say Osc A to be double the frequency of Osc B. Note that as soon as frequency is changed, the phase relationship is lost and the display will show bars until a new phase angle is keyed.

Observe the addition of two sine waves where one frequency is double the other. Explore other possibilities.

Modulating One Sine Wave With Another Sine Wave:

Amplitude Modulation (known as 'AM'):

This means changing the amplitude or size of one waveform by another waveform.

Low Frequency: If a wave frequency of 1000 Hz is modulated by a sine wave of 5 Hz the 1,000 Hz tone will increase and decrease its loudness 5 times per second. Try it and see.

Set Osc A to 1000.0 Hz and Osc B to 5.0 Hz. On Amplifier 1, press and hold the Input button until Mode LED is on. The mode A+B will be selected first. Then press button again until mode shifts to AM/FM. Select Mode to 'AM' modulation.

Notice on the Amplifier 2, the Mode is automatically set to Osc B sine wave. At this time, 1,000 Hz is being modulated at 5 Hz. The result can be seen or heard from Output 1.

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Medium Frequency: If a wave of 5,000 Hz is modulated by a sine wave of say 200 Hz, the 200 Hz tone can be heard behind the 5,000 Hz tone. Set Osc A to 5,000 Hz and Osc B to 200 Hz. The result can be seen or heard from Output 1.

Higher Frequency: If a wave of 25,000 Hz is modulated by a wave of say 1,000 Hz, nothing can be heard. The high frequency is being increased and decreased in amplitude at an audible frequency but the fundamental frequency cannot be heard at any amplitude.

The modulation of a high 'Carrier Frequency' by a low frequency 'Amplitude Modulating Signal' is the principle of AM Radio transmission. The principle cannot be fully simulated here because the modulated carrier signal is processed to extract the modulating signal so it can be heard.

Frequency Modulation (known as 'FM'):

Select Mode to 'FM' modulation.

Set various frequencies as in the previous section, but notice that now the frequency of Osc A is being modulated by the signal of Osc B.

Use the different wave shapes available for Osc B. The best audible effects are when The Osc A is set to about 2000 Hz and Osc B is set to about 2 or 3 Hz.

Siren sounds and other alarms can be simulated by choosing the correct frequencies and the correct modulating waveform to use.

Optional Equipment Available to Be Used With the Wave~Lab:

Pair of good quality loud speakers (4 ohm impedance). Cat: LB2065-001 (pair). Note that these speakers are protected internally against overload.

The IEC speakers used for the Wave~Lab are specially protected internally against burn-out, but other speakers will not be protected against overload.

The IEC Wave~Lab is a high power instrument for running large speakers and mechanical devices. It can supply enough power to destroy low impedance loud speakers.

4 ohm impedance speakers will draw heavy currents but 8 ohm speakers will draw half the current of the 4 ohm type and will be less likely to burn out their coil.

Remember that a constant and steady tone is much more destructive to a loud speaker coil than the variable frequency and variable loudness tonal patterns of music or voice.

When using speakers other than the IEC Wave~Lab speakers, to protect them from burning out or loosening their speaker coils, it is not recommended to exceed 50% of the Wave~Lab output power.

As the frequency is reduced, the current through the speaker coil increases. Be especially careful not to run the speakers at high powers when the frequency is lower than 100 Hz.

Remember that at very low frequencies (from 0 Hz to 40 Hz), the impedance of the speaker is lowest and the current is highest and at these frequencies the sound may not be heard, so the speaker can burn out silently.

There is no warranty on burned out or loose speaker coils.

Designed and manufactured in Australia