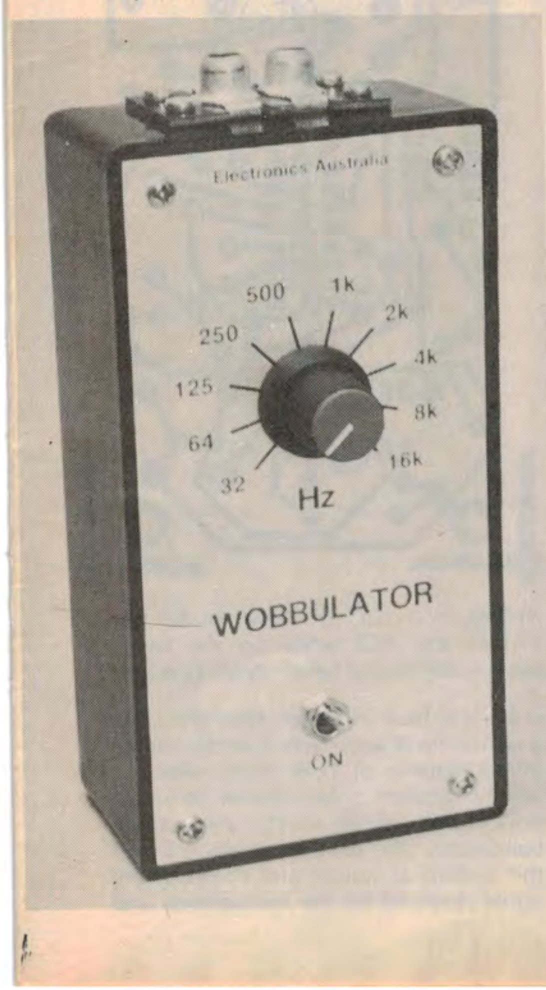
Tune up your hifi system with a

Wobbulator and Sound Level Meter

Many people own a graphic equaliser as part of their hifi system. With this simple project, you can analyse your room acoustics and correctly adjust the equaliser to get rid of those nasty peaks and troughs in the frequency response.

By JOHN CLARKE & GREG SWAIN

With the trend towards the purchase of complete hifi systems these days, many enthusiasts now regard a graphic equaliser as standard equipment. Certainly a graphic equaliser can look impressive, with a row of 20 or more vertical slider controls – just the thing to impress the uninitiated.



In many cases, though, they serve as little more than a "knob-twiddler's" delight. The inveterate fiddler can play to his heart's content, pushing the knobs up and down to obtain all sorts of weird and wonderful sounds. You can accentuate the highs, boost the lows, fiddle the middles and so on. But once the novelty has worn off, the equaliser is likely to be switched out of circuit altogether or used simply as a glorified tone control.

That's a shame (and a waste of money), since a graphic equaliser is a useful tool that can give real improvements to the sound quality of your hifi system. But there is a catch: an equaliser is not easy to use unless you have another instrument called an analyser. The two instruments go together and allow you to adjust the response of your hifi system to cancel out the peaks and dips in the frequency response of typical loudspeakers and in the response of the listening room itself.

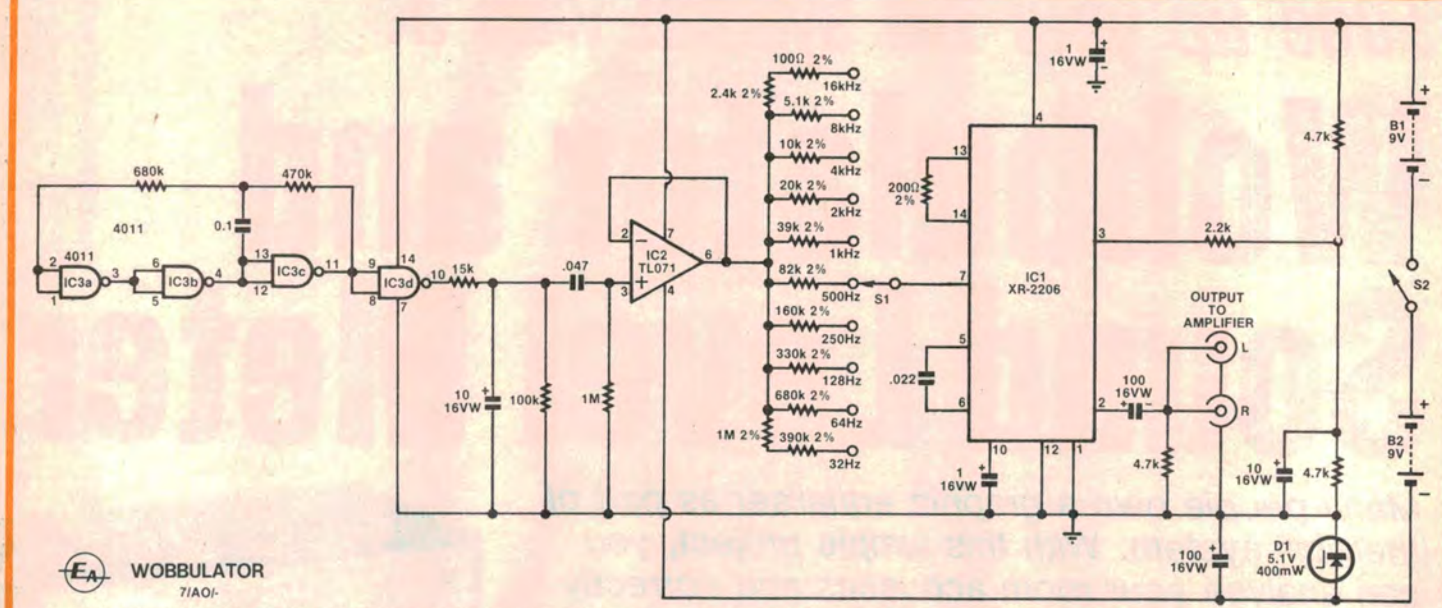
By way of explanation, loudspeakers are definitely the weak link in the hifi chain and even good quality units have peaks and dips in their frequency response. On a larger scale, interaction between the loudspeakers and the listening room can also significantly modify the response of the signal reaching our ears. It is these effects that the graphic equaliser is designed to correct.

In practice, it is not possible to eliminate the peaks and dips completely although, properly used, a graphic equaliser can effect a considerable improvement.

Equalisers explained

Before we explain how an equaliser and an analyser are used together, let's take a closer look at the equaliser itself. Most stereo graphic equalisers divide the audible spectrum into octaves and are thus often called octave equalisers. An octave is a band of frequencies in which the highest frequency is twice that of the lowest. For example, an octave may cover the range from 750Hz to 1.5kHz or from 3kHz to 6kHz.

Each slider control is used to provide around 15dB cut or boost over a



The Wobbulator consists of an XR-2206 function generator which is modulated by a CMOS oscillator.

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particular octave and the equaliser will have enough sliders to cover the whole audible frequency range from 20Hz to 20kHz. This means that there are usually 10 sliders for each channel, each labelled with the respective centre frequency for its octave as follows: 32Hz, 64Hz, 125Hz, 250Hz, 500Hz, 1kHz, 2kHz, 4kHz, 8kHz and 16kHz.

Note that the interval between any two centre frequencies is also an octave (or very close to it). As an economy measure, some octave equalisers cut out one or two sliders and stretch the range of each octave a bit, but the principle remains the same. By suitably adjusting each slider, we can impose a correction "curve" on the input signal to produce an "equalised" system that corrects for the peaks and dips in the loudspeaker and room response.

The trouble with using a graphic equaliser is that nobody has sufficiently well calibrated ears to tell what is wrong with the system and the listening room. After those first few tentative alterations, even the most acute listener is bound to become totally confused, a fact that every enthusiast is usually blissfully unaware of at the time of purchase. No wonder that many people simply press the bypass button to switch the equaliser out of circuit!

Octave analyser

To avoid this confusion you must use an octave analyser. This is an instrument which consists of an in-built noise source, a microphone pick-up, and a level meter or bar graph display. Not surprisingly, the analyser breaks the audio spectrum into the same octave bands as the equaliser, although there are different ways of doing this.

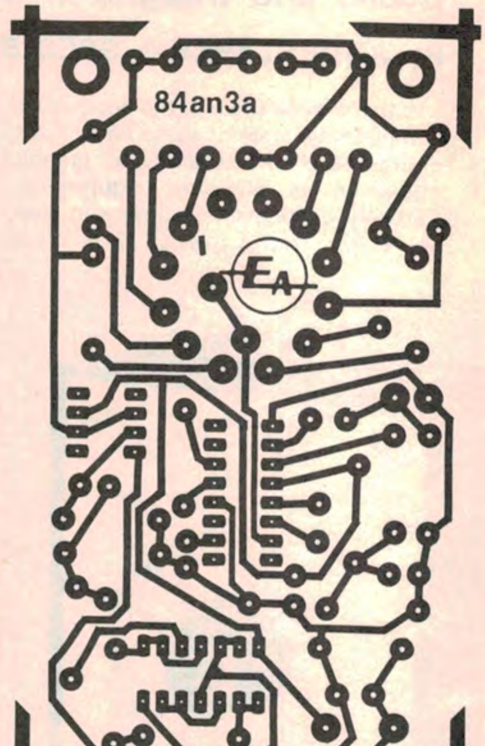
What happens is that the noise source is fed through the equaliser, amplifier, and loudspeakers of the hifi system. The resulting signal is then monitored by the microphone, suitably processed, and fed to the display which shows the signal level. Because each octave is displayed separately, the user is now able to manipulate the equaliser controls to bring each band to the same level.

It really is as simple as that. You display and adjust each octave in turn until the worst deficiencies have been eliminated. There's no more guesswork, no more confusion and no more frustration. At last you can use your graphic equaliser in the role for which it was originally designed.

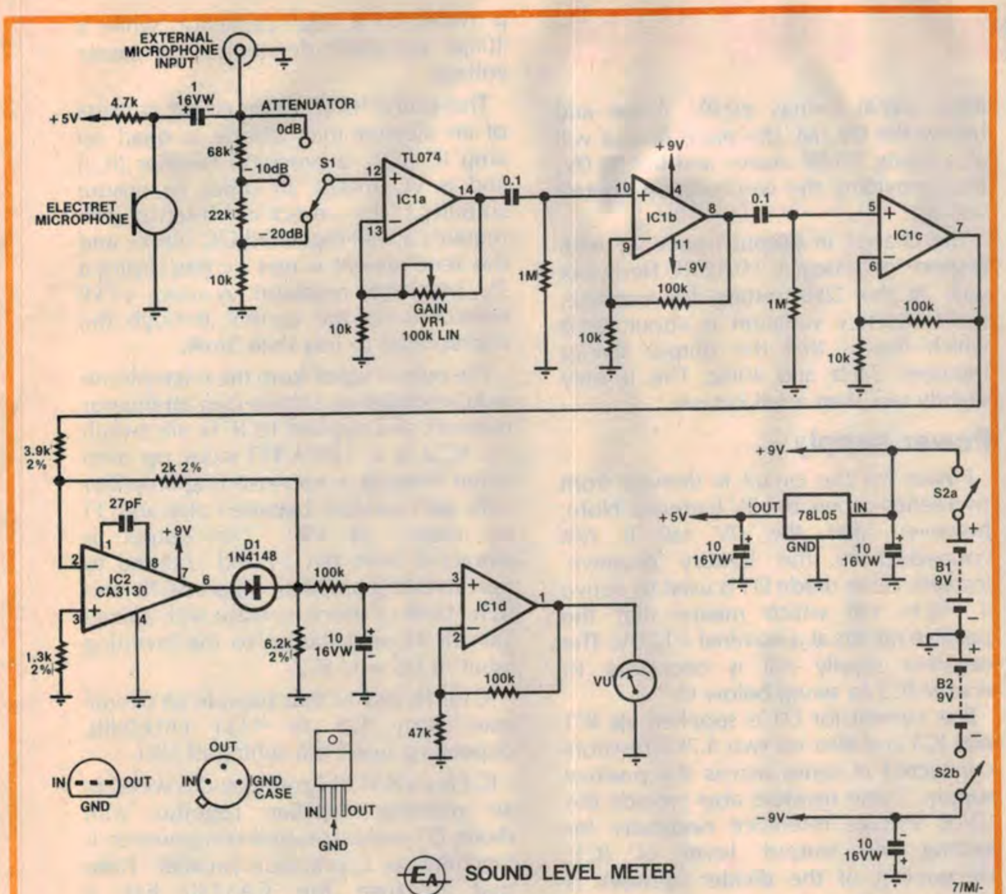
The whole process takes about two minutes and can produce quite startling improvements in sound quality. As with all things though, you don't get something for nothing. An equaliser/analyser cannot turn a poor loudspeaker into a good one. You have to start with good quality equipment.

Once properly set up, the equaliser should not be altered unless there is a major change in the system. Further adjustments to the program quality are best made using the normal tone controls to emphasise or cut the highs and lows as required.

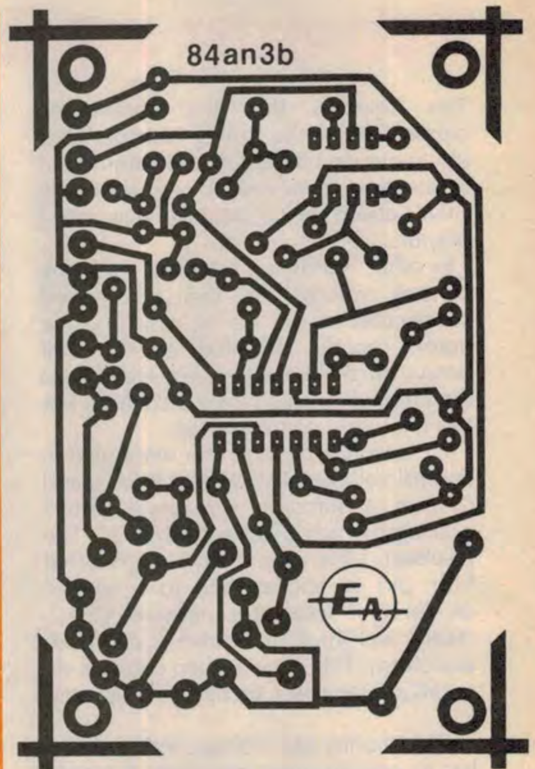
Several approaches can be employed in implementing a practical analyser system. Our last graphic analyser was published back in March 1981 and used a rather novel approach. It employed an inbuilt source of pink noise which is simply random noise (similar to white noise) with equal energy per octave bandwidth. The pink noise was fed into the system as above and the resulting signal detected by the microphone and



Above is actual size artwork for the Wobbulator PCB while on the facing page is the Sound Level Meter PCB.



The Sound Level Meter. Signals from the microphone are amplified, fed to a precision rectifier (IC2), and applied to a VU meter.



Cost Estimate

We estimate that parts will cost approximately $27 for the Wobbulator and $37 for the Sound Level Meter. These figures include sales tax.

fed to ten octave band filters.

Up to that point, the circuitry was perfectly conventional. It was the method of display that we thought rather clever. The outputs of the ten octave filters were processed and fed to a colour TV receiver to produce a histogram bar-graph display, the height of each bar corresponding to the signal level for a particular octave. All the user had to do was adjust the equaliser controls until the bar graphs were all of equal height.

We were rather proud of the instrument, the more so since the on-screen display concept was a world first as a magazine construction article.

By comparison, our latest design employs far simpler circuitry and should set you back no more than about $65 all up.

The approach used here is quite different. Instead of a pink noise source, the new design employs a wobbulator signal source (or frequency modulated oscillator) and a sound level meter. The wobbulator and sound level meter circuits are housed in separate cases, the two units together forming a complete low-cost equalisation analyser system.

In greater detail, the wobbulator is a switched sinewave oscillator with ten nominal output frequencies centred on the various octave bands; viz 32Hz, 64Hz, 128Hz etc. As well as being switchable, the oscillator frequency is continuously swept over the selected octave band using a 10Hz modulation waveform. The output level is around 100mV RMS, making it suitable for direct connection to the auxiliary inputs of a stereo amplifier (the equaliser is in the tape loop).

The sound level meter is used to measure the resulting response at the listening position. It uses an electret microphone pickup, the output of which is amplified and fed to a precision rectifier, and thence to a VU meter. Thus by switching the wobbulator to each octave band in turn and checking the response on the sound level meter, the user can quickly adjust the equaliser controls to give the requisite flat frequency response.

Wobbulator circuit

The wobbulator circuit can be divided into three sections: an XR-2206 function generator IC (IC1), a buffer stage (IC2), and a CMOS oscillator (IC3) which provides the wobbulation control signal.

Heart of the circuit is the XR-2206 IC. This is a monolithic function generator capable of producing high quality sine, triangle, ramp and pulse waveforms over the range .01Hz to more than 1MHz. It comes as a 16-pin DIL package which contains a voltage controlled oscillator (VCO), a multiplier and sine shaper circuit, and current switches which control the VCO frequency.

The VCO produces a triangle waveform and this can be converted to a sinewave by connecting an external pulse shaping resistor between pins 13 and 14. Our circuit uses a fixed 200Ω pulse shaping resistor which gives a sinewave output with sufficiently low distortion (about 2.5%) for the job. The output level is set to around 100mV by the 2.2kΩ resistor between pin 3 and ½Vcc (half supply).

The frequency of oscillation, fo, is generally determined by the external timing capacitor C across pins 5 and 6, and by the external timing resistor R connected to pin 7. For our purposes, the requisite frequency range can be achieved using a fixed .022μF timing capacitor. Switch S1 selects one of ten timing resistor positions to give the required octave centre frequency.

For those interested in the maths, the output frequency is simply fo = 1/RC.

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This assumes that the commoned connection of the timing resistors is at 0V. In our circuit though, the commoned connection is moved up and down by ±0.8V about the 0V point to give an FM output.

In other words, by applying a varying control voltage to the commoned connection of the timing resistors, the output can be "wobbled" over the full octave range. In practice, just slightly less than the full octave range is covered but this is of little consequence.

IC2 and IC3 provide the wobbulation control voltage. NAND gates IC3a, b and c form a standard three-gate CMOS oscillator which is buffered by IC3d. The resultant 10Hz squarewave is extracted from pin 10 and applied to a voltage divider and integrator network (15kΩ, 100kΩ and 10μF) to derive a sawtooth waveform. This signal is then coupled via a .047μF capacitor to pin 3 of op amp IC2.

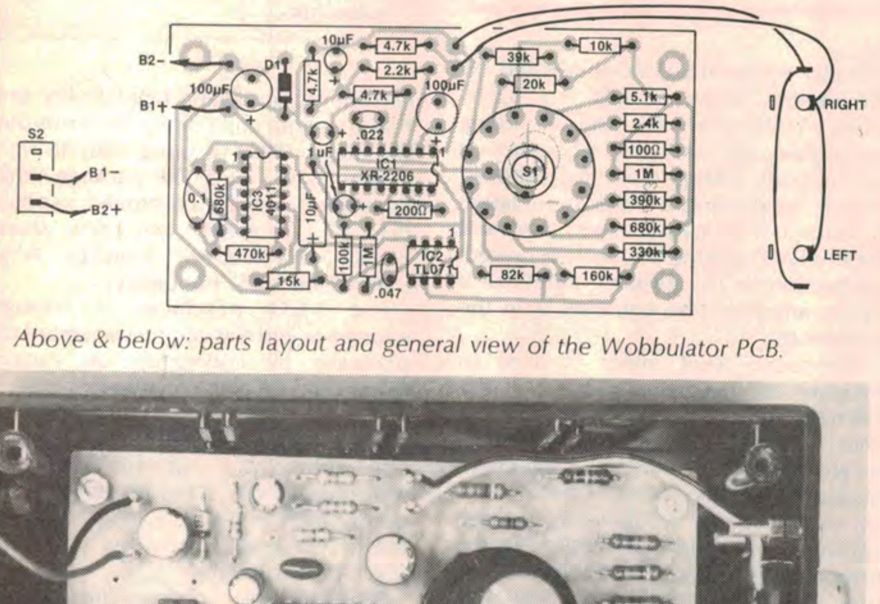
IC2 is a unity gain voltage follower and has its non-inverting input (pin 3) biased to 0V via a 1MΩ resistor. In this configuration it has a high input impedance, thus minimising loading on the sawtooth input waveform. Since the input signal swings ±0.8V above and below the 0V rail, the pin 6 output will also swing ±0.8V above and below 0V, thus providing the wobbulation control voltage.

The change in output frequency with respect to voltage is −0.32/RC Hertz per volt. At the 32Hz setting, for example, the frequency variation is about 16Hz which means that the output swings between 24Hz and 40Hz. This is only slightly less than a full octave.

Power supply

Power for the circuit is derived from two series-connected 9V batteries. Note, however, that the 0V rail is not connected to the battery negative. Instead, zener diode D1 is used to derive a −5.1v rail which means that the positive rail sits at a nominal +12.9V. The negative supply rail is necessary to enable IC2 to swing below 0V.

Bias current for D1 is supplied via IC1 and IC3 and also via two 4.7kΩ resistors connected in series across the positive supply. These resistors also provide the ½Vcc voltage reference necessary for setting the output level of IC1. Decoupling of the divider network is provided by a 10μF capacitor, while a 100μF capacitor decouples the zener voltage.



Above & below: parts layout and general view of the Wobbulator PCB.

The sound level meter circuit consists of an electret microphone, a quad op amp IC (IC1), a precision rectifier (IC2) and a VU meter. In order to ensure stability, the electret microphone requires a well-regulated DC supply and this requirement is met by employing a 5V 3-terminal regulator. A series 4.7kΩ resistor limits the current through the microphone to less than 1mA.

The output signal from the microphone is AC-coupled to a three-step attenuator network and applied to IC1a via switch S1. IC1a is a TL074 FET-input op amp wired here as a non-inverting amplifier with gain variable between one and 11 by means of VR1. The output is extracted from pin 14 and coupled to non-inverting amplifier stages IC1b and IC1c, both of which operate with a fixed gain of 11, and thence to the inverting input of op amp IC2.

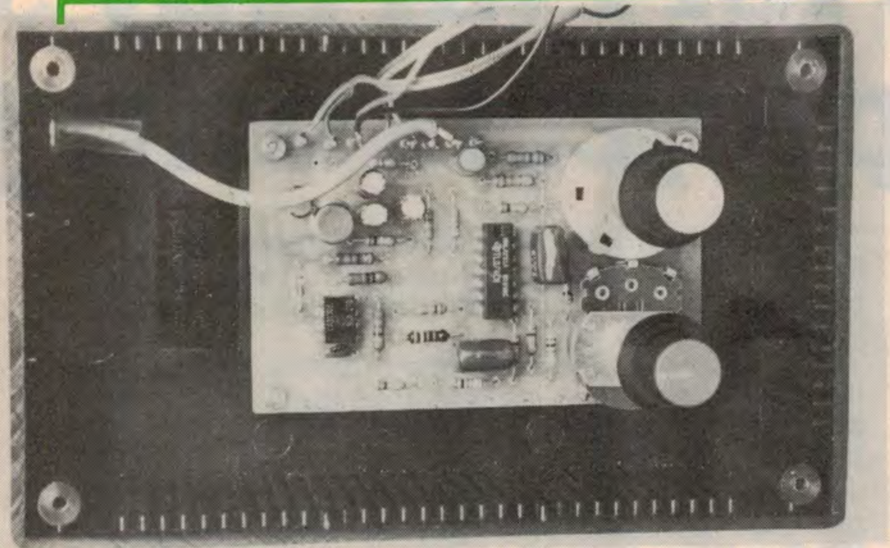
IC1a, 1b and 1c thus provide an overall gain from 121 to 1331 (40-60dB), depending upon the setting of VR1.

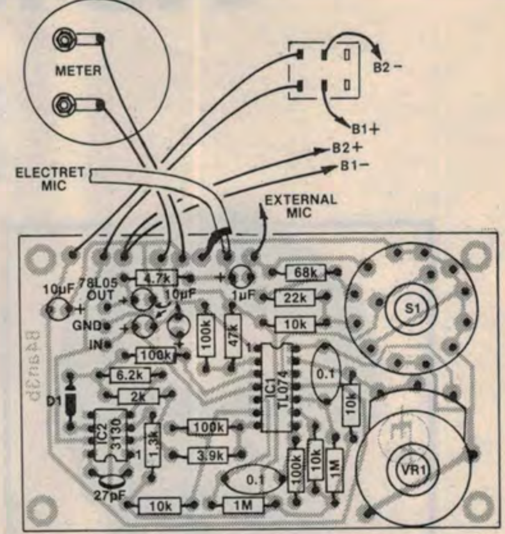
IC2 is a CA3130 op amp and is wired as an inverting amplifier. Together with diode D1 and associated components, it functions as a precision rectifier. Note that because the CA3130 has a maximum supply rating of 16V, IC2 is operated from half supply. This has no effect on circuit operation.

The precision rectifier works like this: when the input swings negative, pin 6 of IC2 swings positive and forward biases D1. The output signal thus appears at D1's cathode and, because the diode is in the feedback loop of the op amp, diode non-linearities are considerably reduced. The gain of the stage is determined by the ratio of the 2kΩ and 3.9kΩ resistors; thus gain = 2kΩ/3.9kΩ = 0.5128.

When the input subsequently swings positive, pin 6 of IC2 swings to 0V and diode D1 is reverse biased. This means that the output of op amp is effectively disconnected from the signal output. The circuit now behaves as a simple potential divider which reduces the input signal by 6.2kΩ/(6.2kΩ + 2kΩ + 3.9kΩ) or 0.5124.

So IC2 operates as a full-wave rectifier that attenuates both positive and negative swings of the input signal by about 0.5, and produces a positive output signal. This signal is filtered to provide a steady DC level and applied to non-inverting amplifier IC1d. IC1d operates with a gain of three and directly drives the VU meter which displays the relative signal level. Note that the circuit does not depend on, or provide for, the ballistics or other specified parameters of the VU meter. We have specified a





Switch S1 and gain control pot VR1 are mounted directly on the Sound Level Meter PCB (see text).

VU meter merely to provide the dB scale.

Power for the circuit is derived from two 9V batteries, with on/off switching provided by double-pole switch S2. Two 10μF capacitors decouple the resulting ±9v supply rails, while a third 10μF capacitor decouples the output of the 78L05 3-terminal regulator.

Finally, the circuit diagram shows an external microphone input. Generally speaking, an electret microphone has quite adequate specifications for the job although the response of the circuit can be improved by substituting a high quality microphone. If an external microphone is to be used, the electret microphone and 5V regulator circuit should be deleted.

Construction

Construction is straightforward with both circuits built on PCBs and housed in plastic zippy cases. The Wobbulator PCB is coded 84an3a and measures 55 x 103mm, while the Sound Level Meter PCB is coded 84an3b and measures 58 x 94mm.

Begin construction by assembling the two PCBs, taking care to ensure that all polarised parts are correctly oriented. It's not necessary to follow any strict sequence, although it's best to mount the resistors first, followed by the capacitors and the semiconductors. Note that the 4011 IC is a CMOS device, so solder its supply pins (7 and 14) first to enable the internal static protection diodes.

The use of PC stakes at all external wiring points is recommended as they greatly simplify the job of wiring. You will need 14 PC stakes in all, four for the Wobbulator and 10 for the Sound Level Meter.

PARTS LIST

Wobbulator

1 PCB, code 84an3a, 36 x 103mm
1 Scotchcal front panel, 63 x 121
1 plastic utility case, 130 x 68 x 41mm
2 9V batteries (Eveready 216)
2 battery clips to suit
1 single pole, 10-position rotary switch
1 knob to suit
1 SPDT toggle switch
1 2-way RCA socket panel
4 6mm spacers

SEMICONDUCTORS
1 XR-2206 monolithic function generator IC
1 TL071, LF351, CA3140, op amp
1 4011 quad 2-input NAND gate
1 5.1V 400mW zener diode

CAPACITORS
2 100μF/16VW PC electrolytic
1 10μF/16VW PC electrolytic
1 10μF/16VW pigtail electrolytic
2 1μF/16VW PC electrolytic
1 0.1μF metallised polyester
1 .047μF metallised polyester
1 .022μF metallised polyester

RESISTORS (¼W, 5%)
1 x 1MΩ, 1 x 680kΩ, 1 x 470kΩ, 1 x 100kΩ, 1 x 15kΩ, 3 x 4.7kΩ, 1 x 2.2kΩ

RESISTORS (¼W, 2%)
1 x 1MΩ, 1 x 680kΩ, 1 x 390kΩ, 1 x 330kΩ, 1 x 160kΩ, 1 x 82kΩ, 1 x 39kΩ, 1 x 20kΩ, 1 x 10kΩ, 1 x 5.1kΩ, 1 x 2.4kΩ, 1 x 200Ω, 1 x 100Ω

Sound Level Meter

1 PCB, code 84an3b, 58 x 94mm
1 Scotchcal front panel, 92 x 155mm
1 plastic utility case, 158 x 95 x 51mm
2 9V batteries (Eveready 216)
2 battery clips to suit
1 University TD-48 VU meter
1 single pole, 3-position rotary switch
1 DPDT toggle switch
1 100kΩ linear potentiometer
1 electret microphone
2 knobs to suit
4 6mm standoffs
1 rubber grommet (9mm bore)
10 PC stakes
1 120mm length of 9mm dia. aluminium tubing
1 140mm length of 10mm inside dia. heatshrink tubing
1 200mm length of shielded cable

SEMICONDUCTORS
1 TL074, LF347 quad op amp
1 CA3130 op amp
1 78L05, 7805 5V 3-terminal regulator
1 1N4148 diode

CAPACITORS
4 10μF/16VW PC electrolytic
1 1μF/16VW PC electrolytic
2 0.1μF metallised polyester
1 27pF ceramic

RESISTORS (¼W, 5%)
2 x 1MΩ, 4 x 100kΩ, 1 x 68kΩ, 1 x 47kΩ, 1 x 22kΩ, 4 x 10kΩ, 1 x 4.7kΩ

RESISTORS (¼W, 2%)
1 x 6.2kΩ, 1 x 3.9kΩ, 1 x 2kΩ, 1 x 1.3kΩ

MISCELLANEOUS
Machine screws and nuts, rainbow cable, solder etc.

Wobbulator and Sound Level Meter

The two rotary switches are soldered directly to the PCBs while the gain control potentiometer is mounted flat against the Sound Level Meter PCB and supported by two PC stakes soldered to the pot body. It will be necessary to clean the solder points on the pot before soldering in order to avoid dry joints. Connections between the pot terminals and the PCB are run using short lengths of tinned copper wire.

With the PCB assemblies completed, the Scotchcal labels can be affixed to the lids of the cases and used as drilling templates for the front panel hardware. You will also have to mark out and drill mounting holes for the VU meter, the PCBs, and the RCA socket panel. This done, the PCBs can be mounted on 6mm spacers and the internal wiring completed.

The electret microphone is mounted on the end of a 120mm x 9mm dia. aluminium tube so that it will be clear of any surfaces that may cause unwanted reflections. To make up the assembly, solder the microphone to a 200mm length of shielded cable, then butt the microphone and the tube together with the cable running down the centre of the tube. The microphone is now secured by fitting a 140mm length of plastic heatshrink sleeving over the microphone body and the full length of the tube.

This assembly can now be attached to the Sound Level Meter by pushing the tube into a mains cord grommet fitted to the top of the case.

The pot and switch shafts can now be trimmed to suitable lengths, the batteries connected, and the cases assembled. The batteries are isolated from the PCBs using foam insulation which also serves to secure the batteries when the lids are screwed down.

Using the analyser

Let's conclude by taking a look at how the two instruments are used together to analyse the response of your hifi system.

To begin with, it should be pointed out that each channel of the hifi system is analysed in turn. First, set the Wobbulator to 1kHz and connect it to the auxiliary inputs of the stereo amplifier using a stereo cable fitted at both ends with RCA plugs. Switch on and adjust the volume control for a comfortable level, then cut out one channel by rotating the balance control fully in one direction.

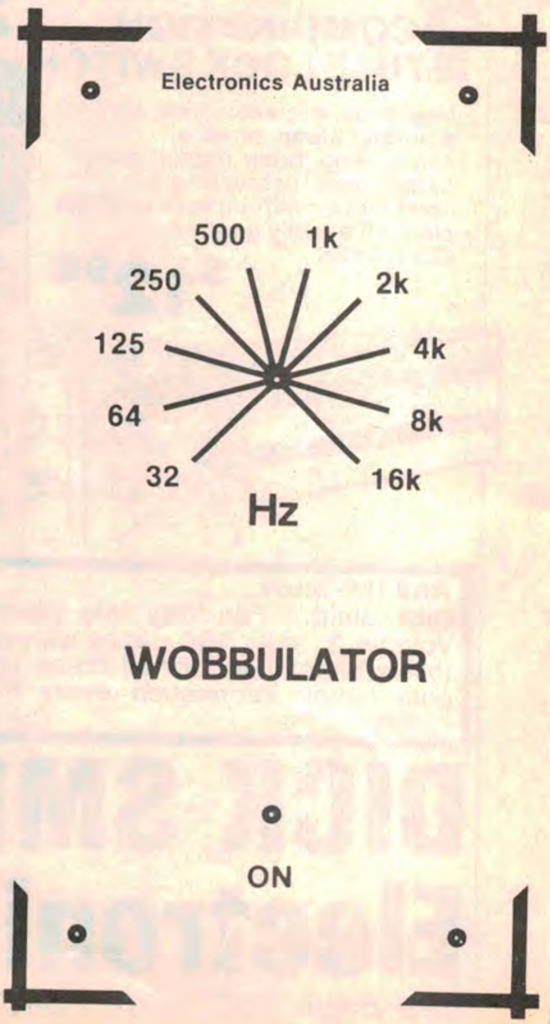
The slider controls on the equaliser should all be set initially to 0dB (ie, to the centre position) while the amplifier tone controls should be set flat or, where the facility exits, switched out of circuit.

Readings on the Sound Level Meter are made at the central listening position. Support the meter on a solid object at about head height and check that there are no obstructions between the microphone and the loudspeaker. The microphone should point to a spot about midway between the two loudspeakers.

The next step is to set the 0dB reference level. This is done simply by adjusting the gain and attenuator controls as appropriate until the meter reads 0dB. Having done that, you must not move the meter or adjust either control for the remainder of the equalisation procedure, otherwise you will have to start all over again.

You are now ready to commence equalisation. It's really quite easy. You simply switch the Wobbulator to each of the octave frequencies in turn and adjust the corresponding equaliser slider control until the meter reads 0dB (or as close to 0dB as possible). Since there is a degree of interaction between each control, it is a good idea to repeat the procedure a couple of times.

Once you are satisfied with the result, the balance control can be fully rotated



in the opposite direction and equalisation carried out on the other channel. Don't expect to achieve perfect equalisation, though. In practice, you will be doing well if you can equalise to better than ±6dB.

In some cases, it will be found that the equaliser does not have sufficient range to cope with the large peaks and dips that can occur at bass frequencies. In particular, placing a loudspeaker too close to a wall or in a corner position can lead to heavy emphasis in the 100Hz region.

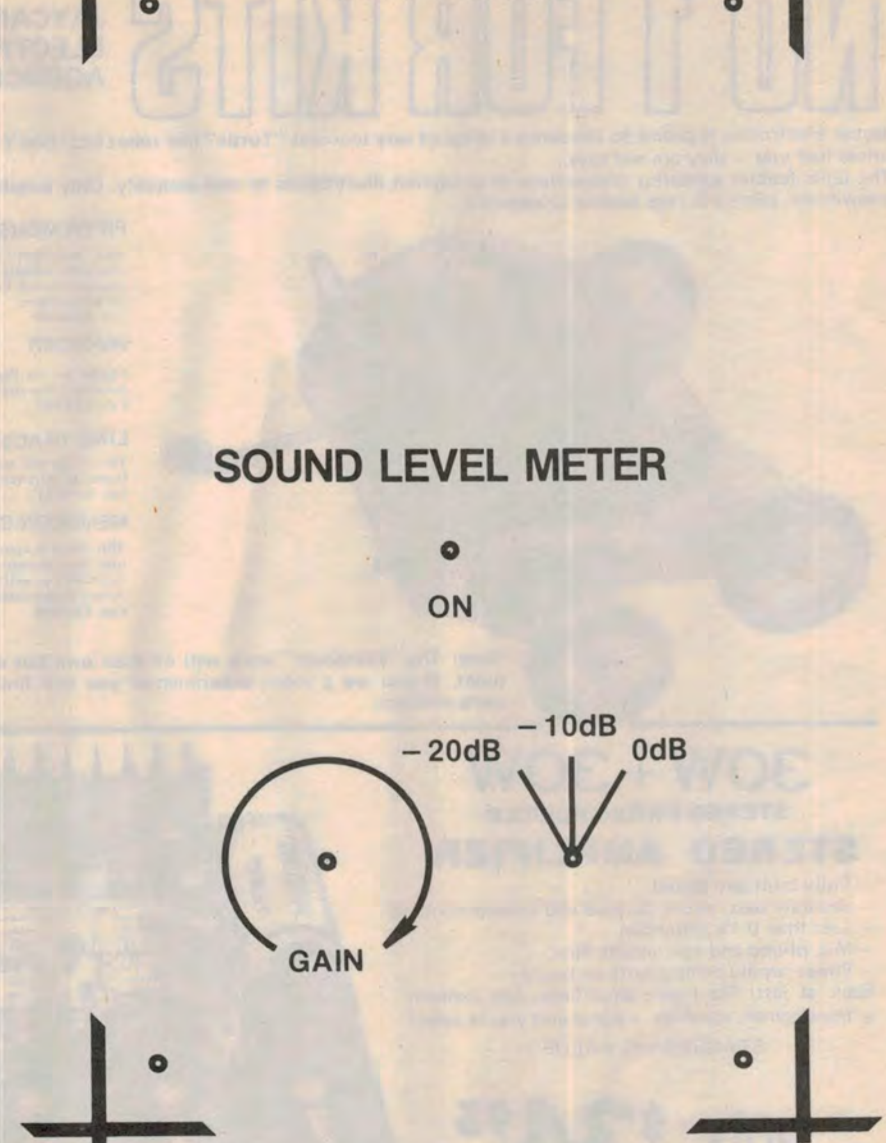
If this occurs, the correct thing to do is to try moving the loudspeaker away from the wall, or corner position, to reduce the worst peaks in the frequency response. Raising the loudspeaker can also help smooth the response by reducing floor reflections or absorption due to thick carpeting. Of course, if you do move the loudspeakers you will have to start the equalisation process all over again.

In fact, the trick is to use the equaliser as little as possible, since too much boost can rapidly push an amplifier or loudspeaker into overload. It is also important to avoid having all the controls either above or below the centre. If this occurs, alter the volume control on the amplifier and repeat the equalisation process for each channel.

One point that should be kept in mind is that an equaliser cannot be used to augment the designed-in frequency response of a loudspeaker by very much. Many small loudspeaker systems, for example, have a rapid rolloff below 100Hz. Applying large amounts of bass boost in these circumstances would only succeed in driving the loudspeaker into overload.

Finally, once you have finished equalisation, it's possible that you will find the sound too bright. That's because in a typical concert hall the treble frequencies are naturally attenuated by absorption by the walls, seating, audience, etc. Thus, it's common practice to equalise a system to approximate a typical auditorium by adjusting for a 3dB/octave rolloff above 2kHz.

This slight treble rolloff will result in a response that is about 6dB down at 10kHz and is the response that you've learned to recognise as flat. However, the degree of high end rolloff is your own decision and may even be influenced by the type of music you wish to hear.



Above is the front panel artwork for the Sound Level Meter while the Wobbulator front panel artwork is shown on the facing page.