Phasing, flanging, echo, reverb & vibrato

Versatile effects unit for creative musicians

What would you say to a versatile "Effects Unit" that can create phasing, flanging, echo, reverb and vibrato effects for around $75? This unit does all that and is easy to build.

by COLIN DAWSON

At the heart of our new Effects Unit is a bucket brigade device (BBD) which functions as an analog delay line. Each of the various sound effects can be selected individually or in combination for some really offbeat effects. Whether you're a professional musician or an aspiring amateur, this unit will add a whole new dimension to your music.

Three input sockets, each corresponding to a different input signal level, are featured on the new design. These might, for example, be set up to accommodate an electret microphone, an electric guitar and a line input. You don't have to use the exact set-up that we used, however – there is plenty of scope for customising the Effects Unit.

Sound effects

For those readers not familiar with the subtleties of modern music, the advantages of an effects unit might not be immediately apparent. If you find yourself scratching your head in bewilderment at the mention of "phasers" and "flangers", the following description of the most popular effects will be of assistance.

Let's begin with the echo effects. An echo is a well known naturally occurring phenomenon and, in electronic form, is fundamental to most of the effects in this project. Our circuit has two categories of echo effect which we have labelled "single" (phaser) and "reverb" (flanger). These effects are selected by a three-position slide switch (off, single, reverb).

Single echo: When single echo is selected, the original signal is presented to the output of the unit together with a delayed version of this signal. The amount of delay will be somewhere between 1ms and 25ms and is adjustable by means of a delay control. It's worth pointing out, however, that a single echo is not a very powerful effect. It is only at the maximum delay setting that the echo becomes really apparent as a separate event.

Phasing: Phasing is achieved by mixing the original signal with an echo of relatively short delay. The amount of phase shift which occurs through the delay line will depend on the frequency of the signal. For some frequencies, this will be 180°. In this case, mixing the delayed signal with the original will cause almost total cancellation. At other frequencies, where little phase shift has occurred, additive mixing will result.

The response curve for this effect will consist of a series of peaks and troughs. Thus, the circuit behaves as a "comb filter". The result is a metallic sound that can be made stronger by slowly sweeping the notches of the comb filter up and down the audio band (in our design, by applying a small amount of vibrato).

Reverb: If a certain amount of delayed signal is fed back to the input of the delay stage, it is possible to achieve multiple, decaying echos. This is known as reverberation and, by virtue of an adjustable depth control, can produce some varied and extraordinary sounds.

With a short echo delay and maximum

Each of the various effects can be selected individually or in combination.

reverb depth, *flanging* is achieved. This is a more profound version of phasing and makes the music sound as though it is travelling down a long piece of drainpipe. Increasing the echo delay produces the classical "reverb" sound until finally the original sound is virtually unrecognisable amidst the mass of echoes.

At slightly less than maximum reverberation depth, a human voice will sound very much like a Cylon voice, losing all its individual tonal quality and becoming very metallic.

When the echo switch (S1) is set to "off", only the delayed signal appears at the output. In other words, the signal is still routed through the delay line. The reason for this is that it is necessary to be able to vary the signal delay to achieve the vibrato effect.

Vibrato: If the amount of delay applied to a signal is varied continuously, the frequency of the output signal will appear to vary proportionately. In fact, we can achieve a frequency modulated output. This effect is known as vibrato and is commonly used by vocalists (without any electronic assistance!).

Vibrato is usually set at between 2 and 7Hz (ie, the tone is modulated at this frequency). For this reason, our effects unit can be switched (S2) to either 2Hz or 7Hz vibrato. The amount of vibrato is adjustable by means of a depth control which determines the amount by which the signal frequency is shifted either side of normal!

Only a small depth setting is necessary to simulate natural vibrato. At moderate depth settings, a guitar will sound quite "Hawaiian" while at maximum depth both guitar and voice will become virtually unrecognisable.

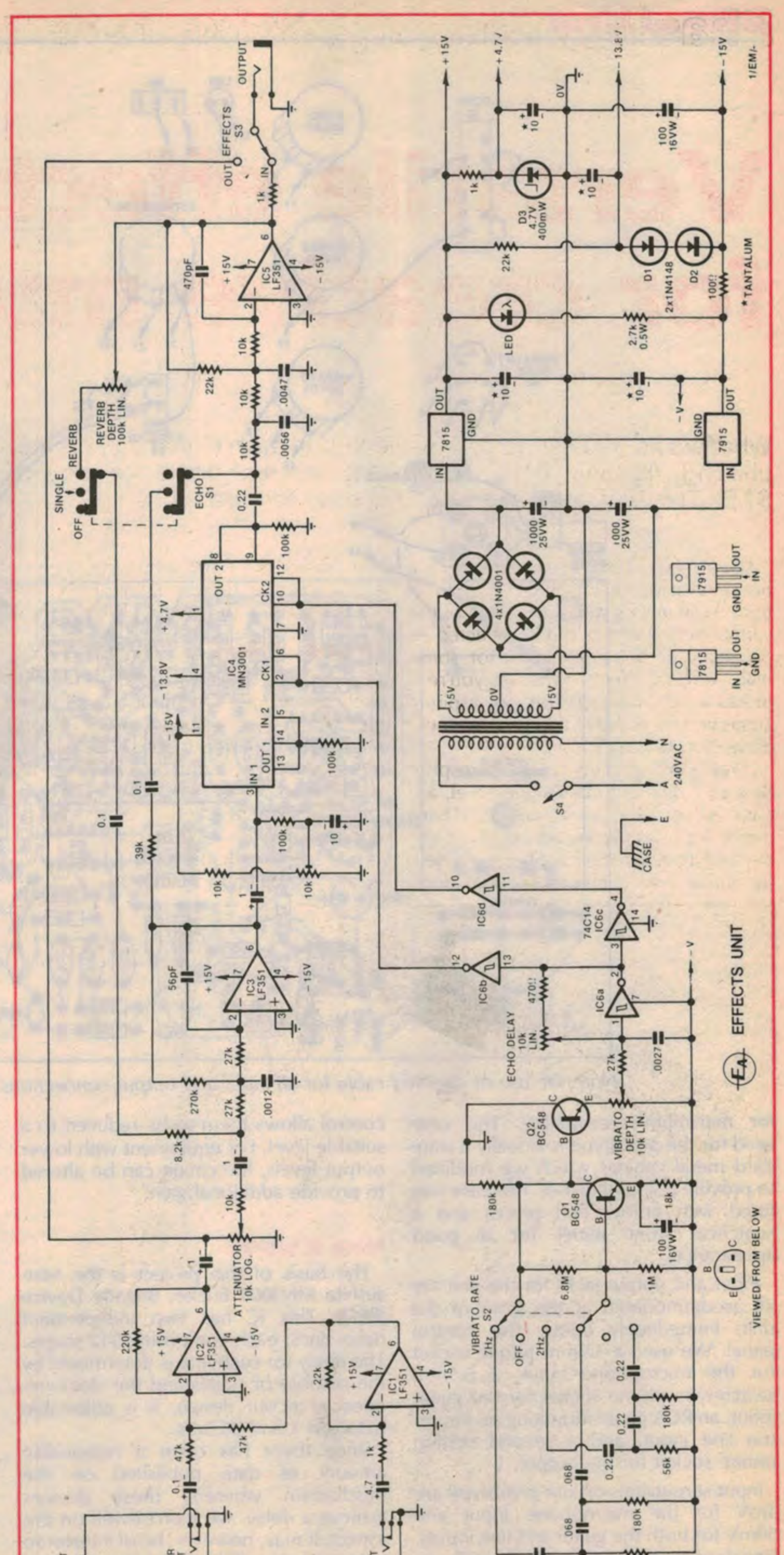
The only other controls on the front panel are an input attenuation control, an effects on/off switch (S3), and a power on/off switch (S4). As its name implies, the effects switch simply switches the Effects Unit in and out of circuit. In the off position, the input signal bypasses the delay line and is fed directly to the output.

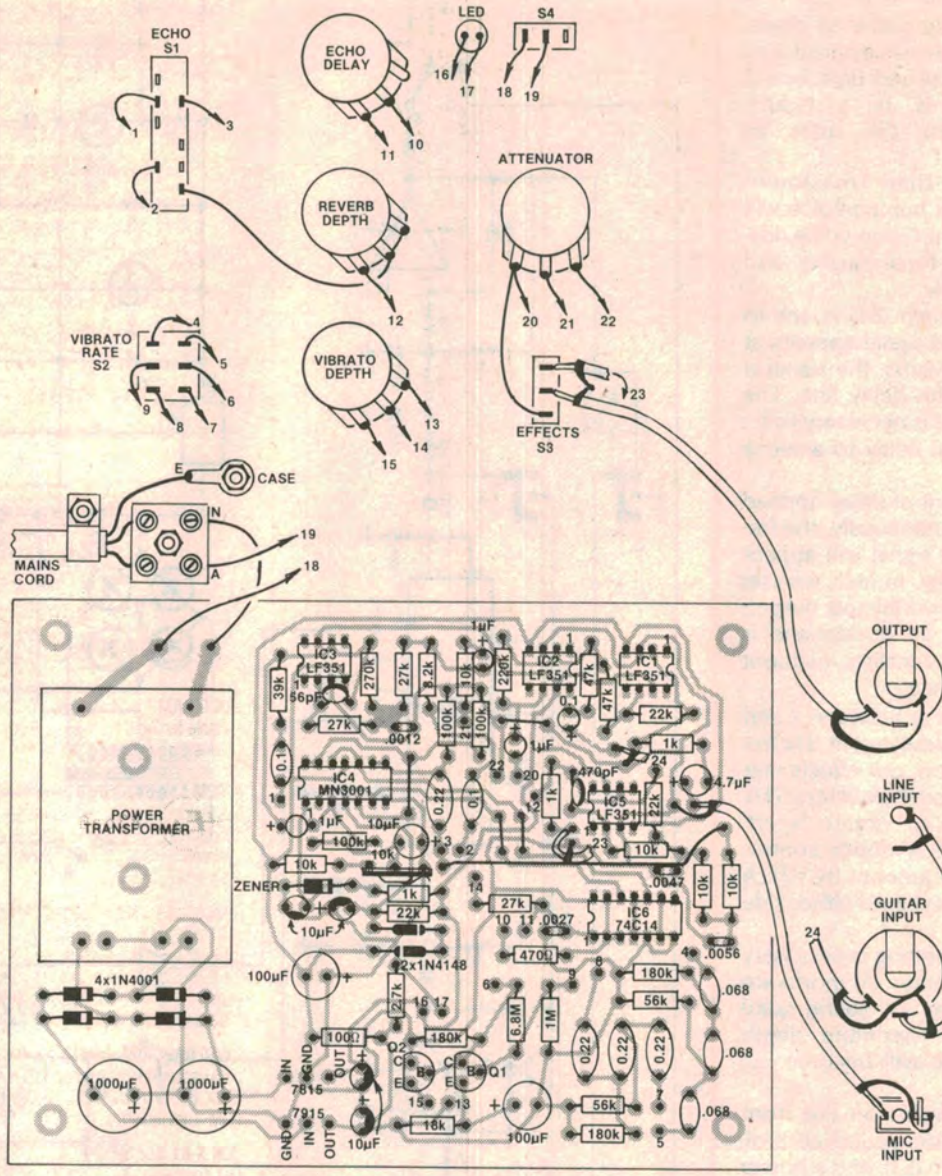
Although we chose to mount the effects on/off switch on the front panel, this function could be easily operated by remote control. A foot-operated switch would be ideal for this purpose.

That outlines the basic features of the Effects Unit. However, by combining effects, it is possible to produce many additional sounds to those described above. Obviously any attempt to give an accurate description of these sounds is bordering on the futile – the only way to get a worthwhile appreciation is to build the Effects Unit and have a listen!

Presentation

All control facilities for our new Effects Unit are laid out on a sloping front panel





Note the use of shielded cable for all input and output connections.

for maximum accessibility. The case used for the prototype is actually a standard metal cabinet which we modified to provide a sloping panel. This case was fitted with timber end pieces and a Scotchcal front panel for a good appearance.

Input and output jacks for the unit are all accommodated at the front of the unit, immediately below the control panel. We used a 3.5mm phone socket for the microphone input, a 6.5mm switch-type phone socket for the guitar input, an RCA panel-mounting socket for the line input, and a second 6.5mm phone socket for the output.

Input sensitivities on our prototype are 1mV for the microphone input and 50mV for both the guitar and line inputs. Signals of greater amplitude are easily accommodated, however – the attenuator control allows them to be reduced to a suitable level. For equipment with lower output levels, the circuit can be altered to provide additional gain.

How it works

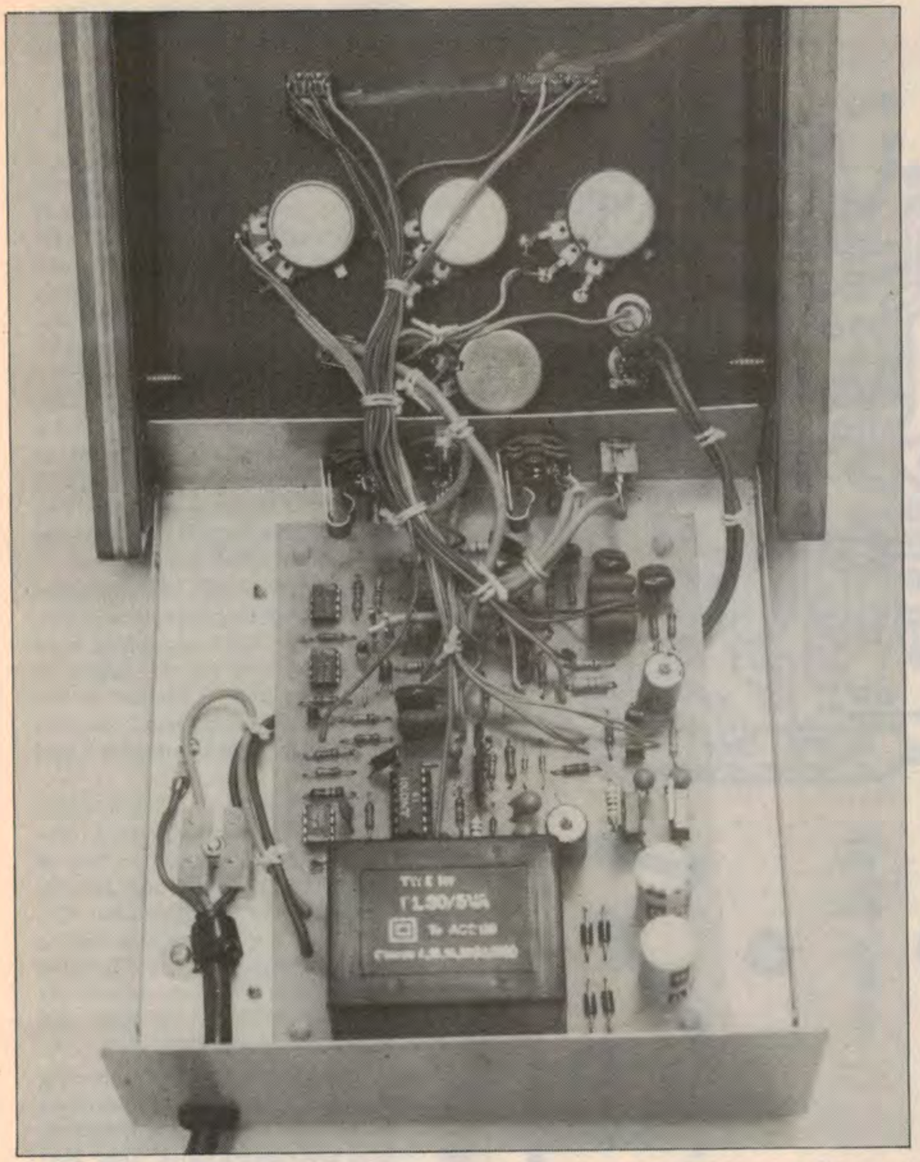
The basis of this project is the Matsushita MN3001 Bucket Brigade Device (BBD). This IC has two independent delay lines, each comprising 512 stages. The delay for each line is determined by the number of stages and the clock frequency. In our design, it is adjustable between 1 and 25.6ms.

Since there has been a reasonable amount of data published on the mechanism whereby these devices achieve a delay, we won't dwell on this aspect. It may, however, be of interest to examine some of the difficulties involved in using the MN3001.

In order to pass an analog signal from input to output, each delay line requires two clock signals. These signals must be in antiphase (ie, one high while the other is low and vice versa). The output of each delay line is the analog signal plus a significant amount of clock noise!

This characteristic dictates that the clock must operate at a supersonic frequency – ie, higher than 20kHz. Because the delay for each line is 512 divided by twice the clock frequency, this immediately limits the maximum delay to 12.8ms per delay line.

The clock frequency determines not only the delay but also the frequency response of the BBD. The highest frequency which can be passed through the delay line is generally regarded as being one-third that of the clock frequency or, for a higher level of distortion, one half



View inside the completed prototype. Keep all mains wiring neat and tidy, and sleeve the connections to the power switch (S4) to avoid electric shock.

of the clock frequency. Therefore, the clock frequency selected, is a compromise between delay period and frequency response. In the interests of low distortion, we opted for a maximum frequency which is one-third of the clock (ie, about 7kHz).

One further limitation of an analog delay line is the loss of signal through it. This is in the vicinity of 8.5dB per line. In our design, with the two lines connected in series, this amounts to 17dB. This loss must be made good with gain elsewhere in the circuit.

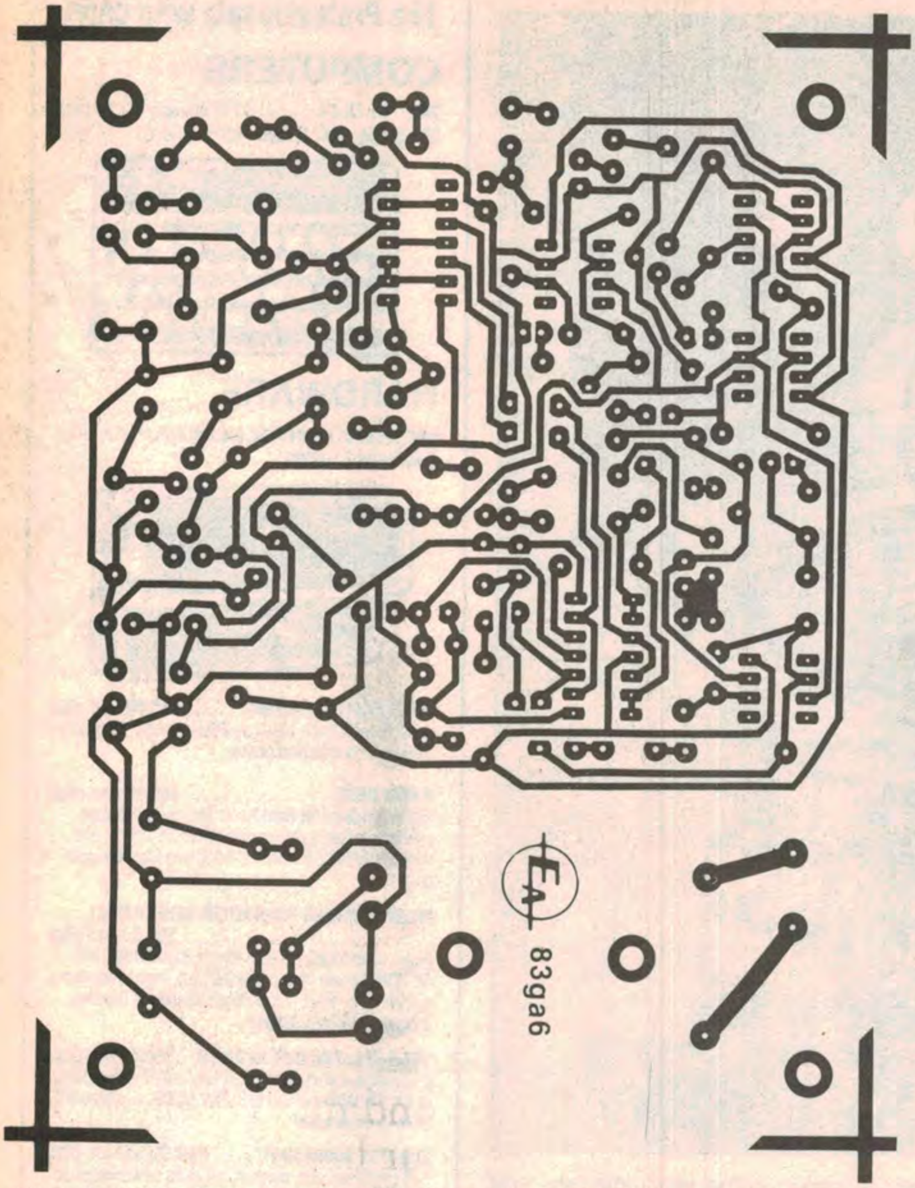
The three inputs on the Effects Unit are arranged such that the microphone input will be mixed with either the guitar or line level inputs. The guitar input, however, has priority over the line level input so that when both are connected, only the guitar signal will be used.

The most sensitive of the three inputs is the microphone input which is connected to IC1. This is a FET input op amp such as the TL071 or LF351. ICs 2, 3 and 5 are also of this type.

IC1 is configured as an inverting amplifier with an input impedance of 1kΩ and a gain of 22. This will suit electret microphones as typically supplied with portable cassette recorders. The 22kΩ feedback resistor determines the gain and altering its value will have a proportional effect on gain.

Assuming that the microphone has an output of almost 1mV, this will correspond to 20mV at the output of IC1. A 47kΩ resistor feeds this signal to the inverting input (pin 2) of IC2.

Pin 2 of IC2 is also connected to the guitar input socket (via a series 47kΩ resistor and 0.1μF capacitor). This



Above is an actual-size reproduction of the PCB artwork. Ready-etched boards (and front panels) are available from the usual retailers.

particular socket must be a switching type so that signal is supplied from the RCA line level input socket unless a guitar jack is inserted. IC2 has a gain of five so that its output will typically be in the vicinity of 100-200mV for microphone and guitar signals and 500mV for line input signals.

The output of IC2 is subsequently fed via the attenuator control and then to active filter IC3. This is a low pass filter with a −3dB point at 7kHz (one-third of the minimum clock frequency). The roll off above 7kHz is 12dB per octave.

The active filter has a gain of 10 which gives us a nominal signal level of up to 2V RMS for the microphone and guitar signals and 5V RMS for line signals. The MN3001 (IC4) can accept input signals at a maximum of 2V RMS – higher levels will cause a substantial increase in distortion, with clipping occurring at 2.5V!

Since the level of clock noise present at the output of the MN3001 is fairly constant, it is desirable to maintain the 2V input signal level in order to achieve the optimum signal to (clock) noise ratio. The purpose of the attenuator control now becomes apparent – it enables the optimum signal level to be achieved with different input sources. It is not a volume control.

The delay line

The output of IC3 is coupled via a 1μF capacitor to the input of delay line 1 (pin 3 of IC4). A 10kΩ resistor and a 10kΩ trimpot connected in series across the −15V rail set the bias on pin 3 to around −3.7V. In practice, the exact bias level is determined by listening to the output and adjusting the trimpot for the cleanest signal.

The two clock signals for delay line 1 are connected to pins 2 and 12 respectively. These are derived from IC6, a 74C14 CMOS hex Schmitt trigger. One of the Schmitt trigers (IC6a) is connected as an oscillator while IC6c inverts the clock output to provide the antiphase clock signal. IC6b and IC6d are simply employed as buffers. The clock frequency is adjustable by means of the 10kΩ echo delay potentiometer.

Due to the internal circuitry of the MN3001, the output of each delay line is presented in complementary form at two pins. For delay line 1, these two pins are 13 and 14. For our purposes these two pins need only be tied together and to ground with a 100kΩ load resistor.

The output of delay line 1 is connected directly to the input of delay line 2 (pin 5). Because there is DC coupling from output to input, it is not necessary to provide separate biasing for pin 5. The two clock inputs for delay line 2 are pins 6 and 10, and the outputs are pins 8 and 9.

Note that the output of delay line 2 is coupled via an 0.22μF capacitor to the echo switch, S1. Ignore the function of the switch for the moment and assume that the signal is fed to active filter IC5. This filter is also a low pass type with a −3dB point at 7kHz and a roll off above this frequency of 18dB per octave. Its purpose is to eliminate clock noise and harmonics higher than 7kHz.

That outlines the method of obtaining the delayed signal or echo. However, in order for the echo to have any meaning, the original undelayed signal must also be present. This is obtained from the output of IC3 and is fed via the echo switch for mixing with the output of delay line 2.

Reverberation

For reverberation to occur, it is necessary to have a system of multiple echoes. This brings us to the second function of the echo switch – to provide a feedback path. When reverb is selected, the output of IC5 is coupled back to the input of IC3 where it is mixed with the incoming signal. In this way, it is possible to provide continuing echoes even after the original sound has ceased.

Due to losses through the delay line, the echoes will be decaying, although the time taken for them to vanish will depend on the amount of signal coupled back to IC3. The reverb depth control is provided for this purpose – it can adjust the reverb depth from negligible to the point where sounds take about one se-

PARTS LIST

1 printed circuit board, code 83ga6, 144 x 107mm
1 metal case, 160mm(W) × 70mm(H) × 184mm(D)
1 Scotchcal label, 122 x 155mm
1 30V centre-tapped PC mounting transformer, Ferguson PL30/5VA or Arlec AL7VA/30
1 3-pin mains plug and cord
1 mains cord clamp
1 rubber grommet
1 2-way insulated terminal block
1 solder lug
4 6mm plastic PCB supports
4 knobs
1 2-pole, 3-position slide switch
1 2-pole, 3-position miniature toggle switch
2 SPDT miniature toggle switches
1 6.5mm jack socket (switching type)
1 6.5mm jack socket
1 3.5mm jack socket (shorting type)
1 panel-mounting RCA socket
1 14-pin IC socket
2 timber side pieces to suit

SEMICONDUCTORS
2 1N4148 diodes
4 1N4001 diodes
1 LED (red)
1 4.7V/400mW zener diode
1 7815 (3-terminal) +15V regulator
1 7915 (3-terminal) −15V regulator
2 BC548 NPN transistors
1 74C14 CMOS hex Schmitt trigger
1 MN3001 dual BBD
4 LF351 or TL071 FET-input op amps

CAPACITORS
2 1000μF/25V electrolytics
2 100μF/16V electrolytics
4 10μF/25V tantalum
1 10μF/16V tantalum or low-leakage (LL) electrolytic
1 4.7μF/16V tantalum or LL electrolytic
3 1μF/16V tantalum or LL electrolytics
4 0.22μF metallised polyester (greencap)
1 0.1μF/16V tantalum or LL electrolytic
2 0.1μF greencap
3 .068μF greencaps
1 .0056μF greencap
1 .0047μF greencap
1 .0027μF greencap
1 .0012μF greencap
1 470pF ceramic or polystyrene
1 56pF ceramic

RESISTORS (¼W, 5%)
1 × 6.8MΩ, 1 × 1MΩ, 1 × 270kΩ, 1 × 220kΩ, 3 × 180kΩ, 3 × 100kΩ, 2 × 56kΩ, 2 x 47kΩ, 1 x 39kΩ, 3 x 27kΩ, 3 x 22kΩ, 1 x 18kΩ, 5 x 10kΩ, 1 x 8.2kΩ, 1 x 2.7kΩ (½W), 3 x 1kΩ, 1 x 470Ω, 1 x 100Ω, 1 x 100kΩ linear potentiometer, 2 x 10kΩ linear potentiometers, 1 x 10kΩ log potentiometer, 1 x 10kΩ vertical trimpot (10mm).

MISCELLANEOUS
Hook-up wire, rainbow cable, shielded cable, machine screws and nuts, solder, etc.

cond to decay (if the depth were any greater than this, instability would result and the echos would not decay at all).

Vibrato

When vibrato is selected, a sine wave is applied to the input of IC6a. This modulates the clock frequency, causing the amount of delay to be correspondingly modulated. The frequency of any signal passing through the delay line will thus be phase modulated – hence the vibrato effect.

It is important that this modulation be imposed in the form of a sine wave to achieve a natural sounding vibrato. In this circuit, sine waves are derived from a simple phase shift oscillator consisting of transistor Q1. By switching in different RC feedback networks, sine waves at two different frequencies (2Hz and 7Hz) are obtained.

Emitter follower Q2 buffers the output from Q1 and feeds the signal to pin 1 of IC6a via a 10kΩ potentiometer and a 27kΩ series resistor. The 10kΩ potentiometer is used to adjust the vibrato depth.

To use vibrato without any other effects, the echo switch should be set to off. This will allow only the delayed signal to be passed to the output – ie, there will be no original signal present and hence no phase induced effects.

The power supply is conventional and consists of a 30V centre-tapped transformer driving a bridge rectifier, with filtering provided by two 1000μF 25VW electrolytic capacitors. Regulated ±15V supplies are derived using positive and negative 3-terminal regulators, while zener diode D3 provides the +4.7V rail. The remaining −13.8V rail is derived using diodes D1 and D2.

Decoupling of the regulator outputs is provided by two 10μF tantalum capacitors, while a LED connected in series with a 2.7kΩ resistor across the ±15V rails provides power on/off indication.

Construction

The printed circuit board (PCB) used for this project is coded 83ga6 and measures 144 x 107mm. Before soldering any components on it, check that the larger devices will actually fit into their intended mounting holes. If any holes need to be re-drilled, now is the time to do it.

The only components which are not polarised (ie, can be fitted to the PCB either way round) are the resistors, metallised polyester capacitors (greencaps), and ceramic capacitors. All other components must be inserted with the correct polarity. Take the usual precautions when soldering the CMOS 74C14 (ie, earth the soldering iron barrel and solder the supply connections first.) We suggest that you use a socket for the MN3001 device – at $16 each they're far too expensive to risk.

We recommend the use of PC stakes to facilitate external wiring connections, but not for connections to the transformer primary.

With assembly of the PCB finished, attention can be turned to the metalwork. It is essential to use a metal case for this project to provide correct earthing for the mains power supply. The shielding afforded by a metal case will also make the project far less susceptible to interference from spurious RF signals.

Our "non-sloping" front-panel case was modified to a sloping-panel design with the assistance of a pair of tin-snips and a hacksaw. This is admittedly a tedious task, but it is worth the effort of doing a neat job.

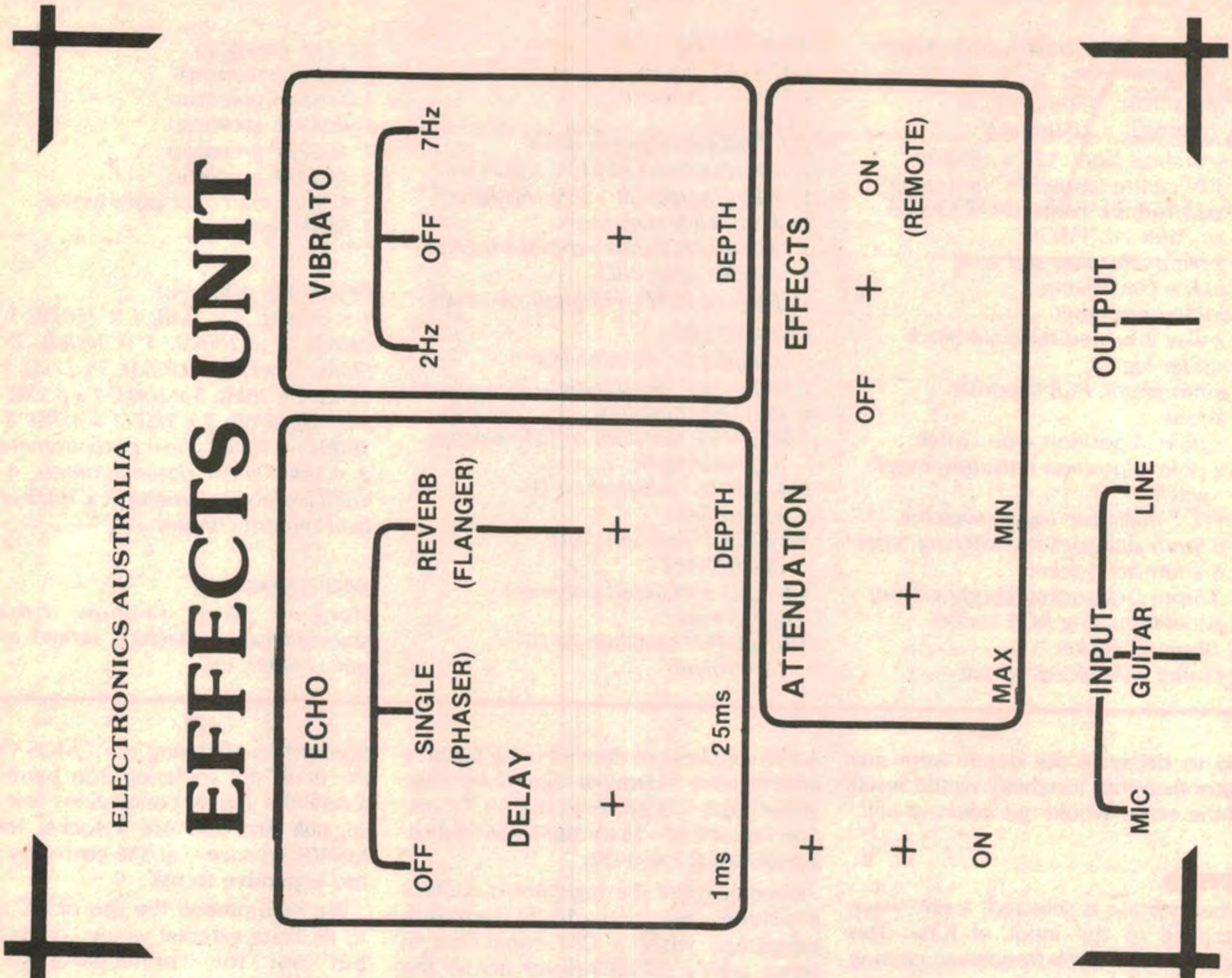
The job of modifying the case involves trimming the height of the front of the base to 38mm. The lid of the case, which also forms the two sides, is then modified to suit the base. This is done by measuring down 38mm from the top/front corner of the lid on each side, and scribing a line from this point to the bottom rear corner. The two side pieces beneath the scribed lines are then cut away using a hacksaw.

Once this is done, you will also find it necessary to trim the rear edges of the two sides so that they line up with the back of the case. In addition, new moun-

We estimate that the current cost of components for this project is approximately

$75

This includes sales tax.



Here is an actual-size reproduction of the front panel artwork.

ting holes have to be drilled in the sides for the case mounting screws.

If you are fitting the timber end pieces, use the box sides as a template for marking them out. Don't forget that each piece will need two holes for the mounting screws. The timber is now ready for any stain or varnish that you may wish to apply.

Before affixing the Scotchcal label, it is a good idea to spray it with a clear lacquer (eg, Estapol) to prevent scratches. When dry, it can be applied to the front panel and used as a drilling template. You can now install the various front panel controls, the LED, and other items of hardware into the case. The PCB is mounted on the base using four 6mm plastic stand-offs.

The internal wiring can now be completed according to the wiring diagram. Rainbow cable is suitable for most of the wiring connections, but be sure to use shielded cable where indicated. The mains wiring to on/off switch S4 and to the transformer primary must be run using 250VAC-rated hook-up wire.

Take care with the mains wiring. The mains cable enters through a grommeted hole on the rear panel and must be anchored securely with a cord clamp. The active (brown) and neutral (blue) leads are connected to an insulated terminal block, while the earth lead (green/yelow) goes to a solder lug bolted to the chassis. It is a good idea to sleeve the connections to switch S4 to avoid the possibility of electric shock.

With construction now completed, go back over your work and carefully check for possible wiring errors. In particular, check that the ICs and transistors are correctly oriented and that the mains wiring is correct.

Testing, testing!

Before plugging in the MN3001, it is a good idea to check supply voltages first. Assuming that everything is correct, you can proceed with the test procedure.

To test the Effects Unit, plug in a guitar or a microphone and connect the unit to an amplifier and loudspeaker. Set the amplifier volume to a low level, select "Effects Off" and check that the guitar is amplified as normal.

Next, set all controls to "Off" or minimum depth and set the attenuation control to maximum. Select "Effects On" and gradually reduce the attentuation until the signal becomes audible. Provided this occurs without an excessive amount of noise being present, the delay line circuitry is functioning normally.

The next step is to set the bias voltage on pin 3 of the MN3001 for the cleanest signal. This is accomplished with the 10kΩ trimpot on the PCB. Make only small adjustments and wait a few seconds before deciding on the result – the 10μF tantalum capacitor connected to the wiper of the trimpot will delay any changes. The "Echo" and "Vibrato" switches should be set to "Off" and the "Delay" control set to minimum during this adjustment procedure.

Finally, you can check that each of the various effects function correctly, simply by trying the Effects Unit out. That's it – ditch the soldering iron, don the guitar and go for it!