CHORUS UNIT

Designed to complement the Noise Gate described in our July issue, Ian Coughlan's Chorus unit offers the maximum of versatility in the minimum of space.

Two of the most popular effects available to musicians are double-tracking and auto double-tracking, better known simply as echo and chorus respectively. The design to be described offers both of these effects in a simple, compact, battery-operated unit.

Double-tracking can be produced by placing a large, heavy, metal plate close to the vocalist or musician, to reflect sound back to the microphone. The result is a much richer, fuller sound. Strictly speaking, this ought not to be called echo since the time-delays involved are too short for the ear to interpret them as such. The subtle phase-differences produced will be interpreted quite correctly as a 'a large, heavy ojbect close to the sound-source'! Plates are still popular in the studio and many electronic delay units seek to reproduce their sound or perhaps offer several types of 'plate sound'.

Chorus is an attempt to emulate the sound of another instrument or voice playing or singing along in perfect harmony with the first. To understand what is involved in producing this effect, consider for a moment what an extra instrument or voice would sound like — exactly the same as the original. Either heard singly would be indistinguishable from the other, but heard together they will interact, producing subtle phase shifts which our ears then interpret as a second instrument or voice.

The chorus effect can be produced by delaying a portion of the audio signal, slowly varying this

HOW IT WORKS

IC2a is connected as a high-impedance input buffer, and R7 and C5 provide high frequency pre-emphasis, or boost, to the input signal. Part of this signal goes to Mix control RV1, and part goes through IC2b which has a gain of about 0.3 and then through a low-pass filter built around IC3a. This filter prevents high-frequency components from reaching the BBD line, IC4. IC4 requires two DC bias voltages, and these are provided by the divider chain R12, R13 and R14. The delay-line also requires two anti-phase clock signals, and these are supplied by IC5 which is a phase-locked loop IC, but is used in this design as a simple voltage controlled oscillator. IC4, a TDA1097, is specified for a supply voltage of no less than 12 volts. Because this is a compact battery-operated unit and the supply must be regulated, 5V is all it gets. It will work, but the performance suffers. In particular the attenuation from input to output, typically 0dB at 12V, is very much higher at the reduced supply voltage.

IC3b is configured as another low-pass filter, and gets rid of most of the clock-frequency from the output of the delay-line. Q1, a field-effect transistor, functions as a simple switch to gate the signal through to the next stage depending on whether or not the Effect is selected. The next stage is an amplifier with sufficient gain to compensate for the attenuation of the delay-line. The output from this stage goes to the Mix control. It can be seen that at one end of the Mix potentiometer is the un-delayed signal and at the other is the delayed signal. The position of the Mix control determines the proportion of each that appears at the output.

The 1n0 capacitor (C21) across the feedback resistor of IC2c will reduce the high-frequency response of this stage but remember that high-frequencies were boosted at the input stage, so the overall response is fairly flat.

IC6 is the sweep-generator. IC6a is an integrator, and IC6b is connected as a Schmitt. If the voltage on IC6 pin 7 is of a sufficiently high level, pin 1 will also be high. This will cause pin 7 to ramp downwards at a rate determined by R32, C23, C24 and the Rate control. When the voltage is low enough, it will cause IC6b to switch, sending its output low. This will cause IC6 pin 7 to ramp upwards, and the cycle repeats itself.

Unfortunately, the linear ramp which IC6 produces is of little use in a chorus. The sweep-generator is used to vary the clock-frequency of the BBD line, and hence the delay-time. There's no problem when the delay-time changes from, say, 7 to 10 milliseconds, but if the delay-time changes from 17 to 20ms in the same time, the ear hears a not-very-musical "whoop". What is needed is some way of slowing down the rate-of-change of the delay-time as it approaches the 20ms end of the range.

The solution relies on the fact that bipolar transistors have a very non-linear switch-on characteristic at low levels of base current. This characteristic is used to turn the linear output of the ramp generator into something approaching that shown in Fig. 3. At the 7ms end of the delay-time range, the rate-of-change is high but inaudible; at the other end, the rate-of-change is much slower. RV3 and RV4 are used to adjust the shape of the waveform.

When the width control is fully clockwise, it can be seen that the signal present at IC3d will appear at the input of the VCO, and therefore the delay-time will sweep over the entire range. As the width control is turned counterclockwise, the input to the VCO is derived more and more from IC2d, whose output is set by the Manual control, RV5. Thus the Width control provides the option of a fully swept delay-time, a fully manual delay-time, or anything in between.

All of the op-amps are supplied with +9V except IC6, which is supplied with +5V. The delay-line and its clock generator are also supplied with +5V. A 78L05 provides the +5V supply. Some parts of the circuit require half the battery voltage and others require +2.5V. These voltages are provided by potential dividers.

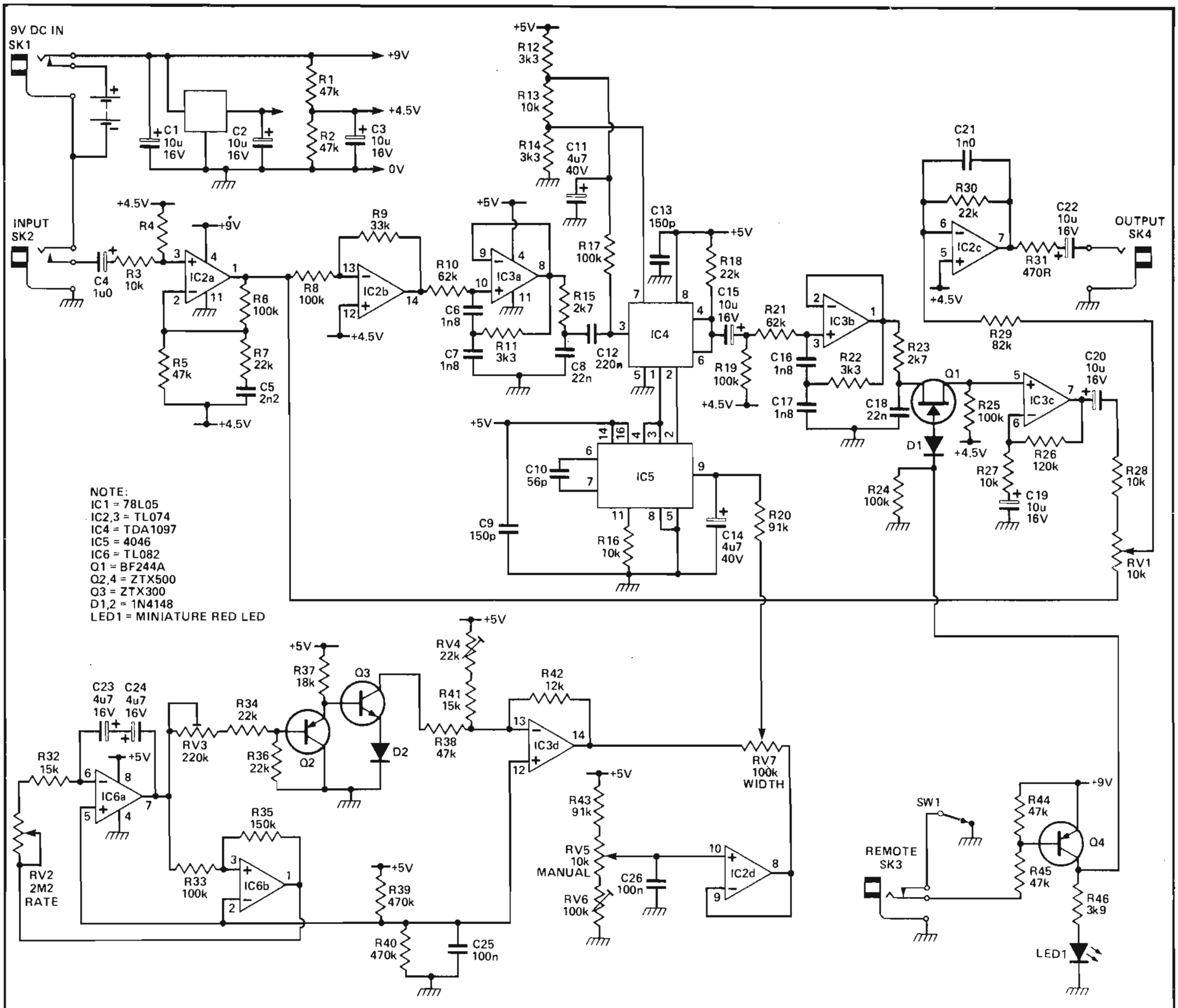

Fig. 1 Complete circuit diagram of the chorus unit.

delay, and mixing the delayed signal with the undelayed signal.

The two signals are identical, but mixed together they will interact, sometimes adding together and sometimes cancelling out. Our ears are fooled into thinking that what they are hearing is a second instrument or voice.

The Circuit

The heart of the Chorus is a Bucket Brigade device (BBD), in this case a TDA1097 which has 1536 stages or 'buckets'. To get an idea of how a BBD device works, imagine a line of people trying to put out a fire by handing buckets of water along the line, then imagine that they don't pass the buckets but each pour the water from their bucket into the next person's bucket. If we ignore spillage, then it's clear that the contents of the first bucket will eventually find their way into the last bucket, delayed by the time taken to pass along the line.

In an electronic 'bucket-brigade' the buckets are capacitors, the men are transistors and the water is a voltage level. The voltage level on the input to the BBD line will eventually appear at the output, delayed by the time taken to pass through all the 'buckets'. The delay time is dependant on the clock frequency applied to the BBD line.

The TDA1097 requires a two-phase clock and this is supplied by the voltage controlled oscillator section of a 4046 phase-locked loop chip. Two clock cycles are required to shift the input signal through each stage, so the delay time can be expressed as:

$$t_{(d)} = \frac{N}{2f}$$

where N is the number of stages and f is the clock frequency. For chorus, a delay range of seven to 20 milliseconds is about right, and this gives a minimum clock frequency of 38.4kHz and a maximum of 109.7kHz. The TDA1097 is only specified to 100kHz, but no problems were encountered with the prototype.

A BBD line is essentially a sampling device, and as such introduces the problem of the clock-signal interfering with the audio-signal. The clock signal will

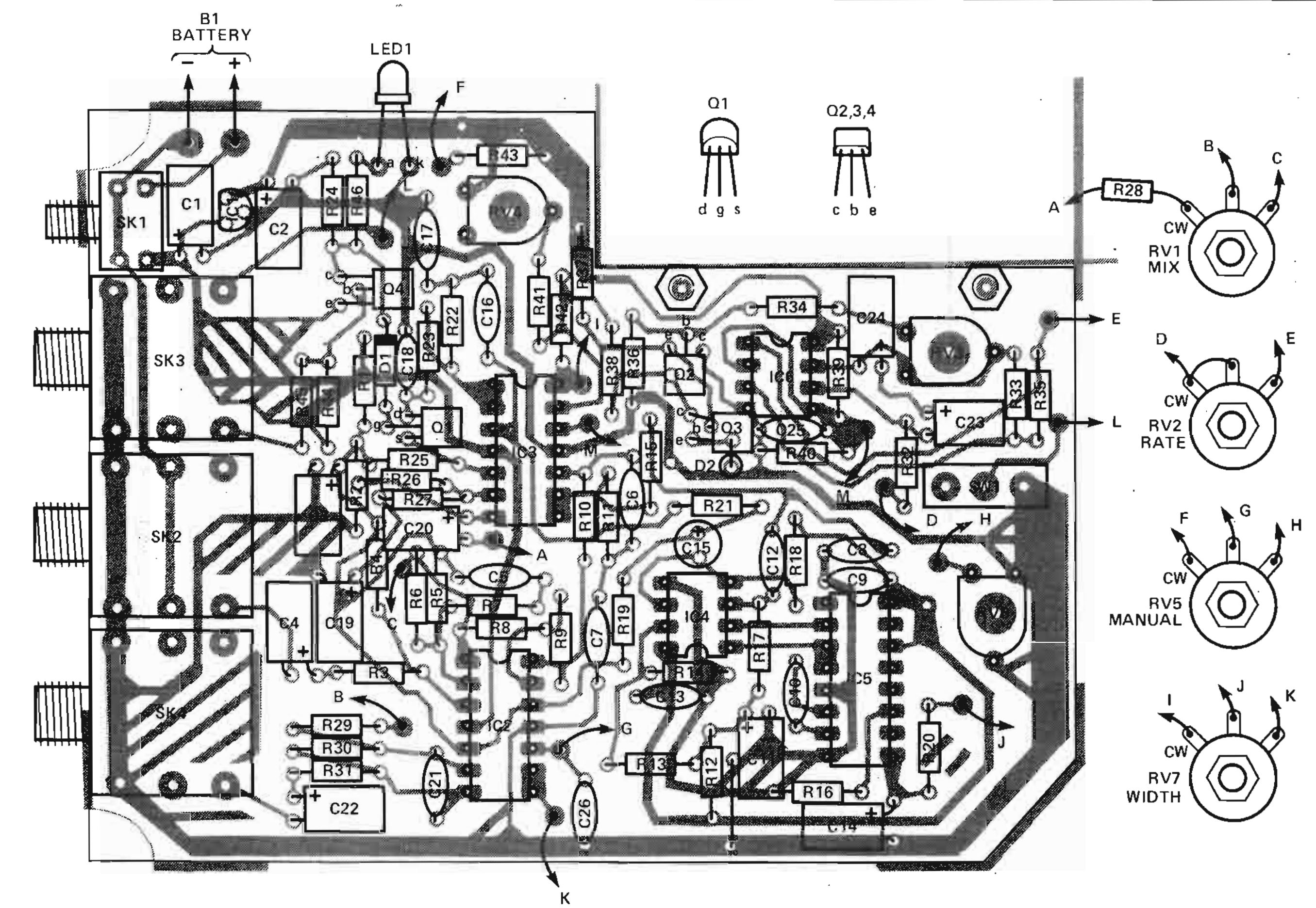

Fig. 2 Component overlay for the chorus unit PCB.

inevitably find its way to the output, albeit at a much lower amplitude than the audio signal. The clock frequency never falls below 38.4kHz so it will not be audible. The problem is that as the harmonic or noise frequency components of the input signal approach half the clock frequency, the lower sideband of the clock frequency will become audible. For example, if noise components in the range 10kHz to 40kHz are present at the input to the BBD line, they will mix with the clock signal to produce sum and difference signals. The difference signals will be in the range 1.6kHz to 28.4kHz. Trying to filter out these difference signals is obviously impractical, since doing so would also get rid of most of the audio signal.

The solution is to put a low-pass filter immediately before the input to the BBD line, with a cut-off frequency of around 6kHz. In this way, difference signals can only be produced above 32kHz, and a similar low-pass filter on the output of the BBD line effectively gets rid of those.

A cut-off frequency of 6kHz may seem a bit brutal, but the chorus effect ceases to be audible above this, and in any event, only the delayed portion is so affected: the undelayed signal is not filtered. The filters in this design have an actual cut-off of 6.2kHz and a slope of −20db/octave. In addition, pre-emphasis on the input and de-emphasis on the output endow this unit with a good noise performance.

In order to achieve adequate chorus effects, the delay time must vary steadily rather than being constant. This is made

BUYLINES

The ¼" jack sockets used in the prototype are made by Cliff and are designed for PCB mounting. They are not reaidly available in small quantities but their pin spacing is the same as that of Cliff's panel mounting ¼" jack sockets which are available from Electrovalue. The panel mounting type have solder tags with eyelets rather than pins, but it is a simple matter to cut away one side of the eyelet so as to leave a pin narrow enough to suit the holes in the PCB. Other makes of jacket socket available from other suppliers may also be suitable if so modified but we have not tried this.

The potentiometers used are also supplied by Electrovalue and are from their P20 range. RS Components stock a suitable switch (catalogue number 339-241) and a 15mm button for it (catalogue number 339-279 for a pack of three) but they do not stock a shroud as used on the prototype. A switch with a shroud is available from Electromatch for £4.15 including post and packing. The part numbers are MPA106D for the switch, C23 for the button and G13 for the shroud and you can contact them on 0403 - 814111 to obtain up-to-date ordering information. The box is made by STC and is type number 73399B. It costs £1.97 plus VAT but inclusive of post and packing from STC Electronic Services Ltd, Edinburgh Way, Harlow, Essex CM20 2DF. All of the other components are available from our regular advertisers except the TDA1097 which you can obtain from Cricklewood (It's listed in their catalogue even if it isn't in their advertisement). The PCB will be available from our PCB Service.

PARTS LIST

RESISTORS	
R1, 2, 5, 38, 44, 45	47k
R3, 13, 16, 27, 28	10k
R4, 39, 40	470k
R6, 8, 17, 19, 24, 25, 33	100k
R7, 18, 30, 34, 36	22k
R9	33k
R10, 21	62k
R11, 12, 14, 22	3k3
R15, 23	2k7
R20, 43	91k
R26	120k
R29	82k
R31	470R
R32, 41	15k
R35	150k
R37	18k
R42	12k
R46	3k9
RV1, 5	10k linear potentiometer
RV2	2M2 linear potentiometer
RV3	220k horizontal skeleton preset
RV4	22k horizontal skeleton preset
RV6	100k horizontal skeleton preset
RV7	100k linear pontentiometer

CAPACITORS	
C1, 2, 3, 15, 19, 20, 22	10u 16V radial electrolytic
C4	1u0 63V radial electrolytic
C5	2n2 polyester
C6, 7, 16, 17	1n8 polyester
C8, 18	22n polyester
C9, 13	150p polystyrene
C10	56p polystyrene
C11, 14	4u7 40V radial electrolytic
C12	220n polyester
C21	1n0 polystyrene
C23, 24	4u7 16v tantalum
C25, 26	100n polyester

SEMICONDUCTORS	
IC1	78LO5
IC2, 3	TLO74
IC4	TDA1097
IC5	4046
IC6	TLO82
W1	BF244A
Q2, 4	ZTZ500
Q3	ZTX300
D1, 2	1N4148
LED1	miniature red LED with mounting bezel

MISCELLANEOUS	
SK1	3.5mm miniature jack socket, PC mounting, with switch
SK2	¼" stereo jacket socket, PC mounting
SK3	¼" mono jack socket, PC mounting, with switch
SK4	¼" mono jack socket, PC mounting
SW1	SPDT alternate action push switch, panel mounting

PCB; case; knobs, 4 off; battery connector; ¾" (20mm) high pillars, 2 off and screws or bolts to fit; IC sockets if desired, 2 off 8 pin and one off 16 pin DIL; thin foam rubber; 9V battery, PP3 or similar.

possible by a sweep facility which repeatedly swings the delay period from its maximum to its minimum and back again. The sweep rate can be varied from once every ten seconds to ten times a second, and the width of the sweep is continuously variable from full sweeps between the limits of 7ms and 20ms delay and no sweep at all (ie, a constant delay period). In the latter condition, the delay period can be manually set to permit the 'plate' effects described earlier. Further versatility is provided by a Mix control which allows the delayed and undelayed signals to be mixed in any proportions. This makes it possible, for example, to use the full amount of sweep but still achieve a very subtle effect.

Power to the unit is provided by a PP3 size battery (preferably alkaline), and a socket allows connection to an external supply. The unit is switched on by inserting a mono jack plug into the input socket, and Effect or Bypass mode is selected by the built-in footswitch or by a remote switch connected to the REM socket. An LED indicates when the unit is in Effect mode.

Construction

Commence assembly by installing the wire link, the four jack sockets, and if desired, sockets for ICs 4, 5 and 6. Sockets cannot be used for ICs 2 and 3 or they will interfere with the potentiometers when the unit is assembled. The jack sockets must be of the recommended type if they are to fit correctly into the prepared holes in the PCB.

Continue assembly by soldering into place the resistors, capacitors, and presets, taking care that the capacitors near the connector end of the board are mounted flat so as to clear the potentiometers. Next fit the diodes, transistors, and ICs 1, 2 and 3. Cut to length three pieces of ordinary insulated connecting wire, and solder them between the points shown on the PCB overlay, then fit the two battery-guide pillars and the battery connector. Connect the four potentiometers, R28 and the LED to the PCB using insulated wire. Lastly, fit ICs 4, 5 and 6. The board can now be tested.

An oscilloscope is essential if the chorus unit is to be accurately set up, so if you don't own one you will have to borrow or otherwise acquire one before proceeding further.

Connect the oscilloscope input to IC5 pin 2 and check that a square wave signal is present with an amplitude of about 5V peak-to-peak. Turn the Width and Manual controls fully anti-clockwise and adjust RV6 until the frequency of the square wave is about 38.4 kHz. Turn the Manual control fully clockwise and check that the frequency rises to about 109 kHz. If either of these frequencies are outside the range of adjustment of RV6, try altering the value of R43.

Connect the oscilloscope input to IC6 pin 7 and check that a triangular waveform is present with an amplitude of about 2V peak-to-peak. Rotate the Rate control (RV2) and check that the frequency varies from about 0.1Hz when it is fully anti-clockwise to 10Hz when it is fully clockwise. Move the oscilloscope probes to IC3 pin 14 and check that the waveform present is similar to that shown in Fig. 3. Make any

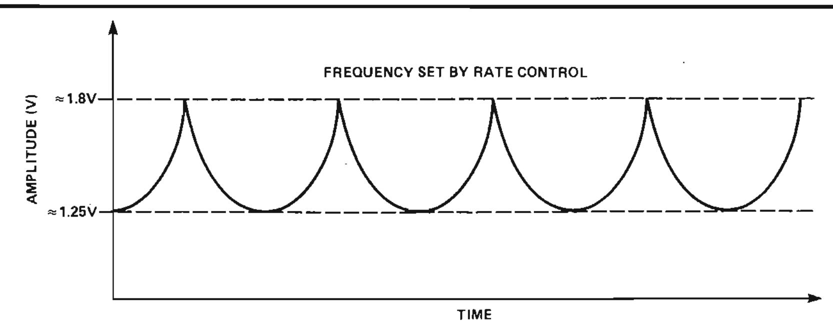

Fig. 3 The sweep generator ouput waveform, as measured at IC3 pin 14.

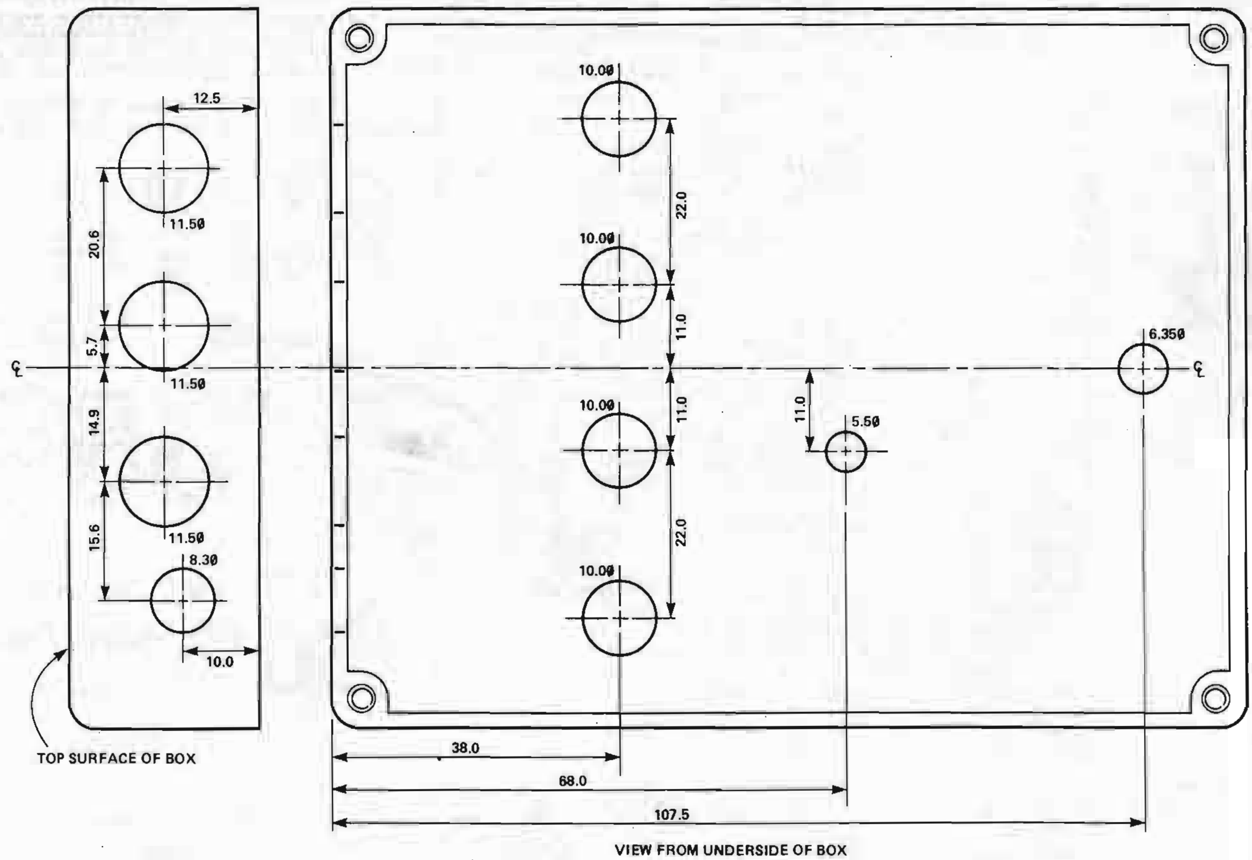

Fig. 4 Drilling details for the case, shown here at its actual size.

necessary adjustments, using RV3 to set the amplitude and RV4 to alter the offset.

Return the oscilloscope connections to IC5 pin 2 and set the Width control fully clockwise and the Rate control fully anti-clockwise. The frequency of the signal should be slowly changing between the previously-set limits of 38.4 kHz and 109 kHz. Carry out any fine tuning required using RV3 and RV4 and the setting up is complete.

If you want a particularly compact unit it is best to use the recommended box, but if you are unable to find the correct type or for any other reason wish to use a different box, choose one that is slightly larger than our prototype so as to avoid cramping the components.

Refer to Fig. 4 and drill the necessary holes as accurately as possible. Take particular care with the holes for the switch and the sockets since these must line up with the components on the PCB. If you have any doubts about your skills in this direction, try drilling the holes a little smaller than is required in the first instance, then offer up the PCB to check that they coincide and make any necessary adjustments with a small file before enlarging the holes to their final diameter.

When drilling is complete, rub down the outside of the box with glass paper to deburr the holes and prepare the surface. Clean the box thoroughly and then prime and paint it allowing suitable drying times. Loosely assemble the potentiometers and knobs as a guide and use rub-down lettering to apply the legends. Remove the fittings, lightly buff the surface to remove any fingerprints, etc, then apply a coat of clear varnish and leave to dry.

Glue a piece of foam rubber inside the box to prevent the battery rattling around. Mount the switch in position through the appropriate hole in the case but do not tighten the fixing nut. Mount the potentiometers through the top panel of the case. Place fibre washers onto each of the sockets on the PCB, then offer the board up to the case, socket end first. Loosely assemble the socket securing nuts from the outside to stop the board slipping back through. Jiggle the switch and the PCB until the switch pins appear through the holes in the board, then solder them to the pads and tighten the switch into position. Complete the construction by adding the switch cap, the knobs and the base plate and tightening the securing nuts on the sockets. Don't forget to install a battery!

Apply an input signal of about 1 kHz at a few hundred millivolts to SK2. Inserting the jack plug should turn the unit on. Connect up an oscilloscope so that you can alternatively observe the input signal and the output signal from SK4. Better still, if you have a dual-beam oscilloscope use it to monitor both at once. Press the footswitch if necessary until the Effect LED is off and check that the output waveform closely resembles the input waveform. Press the switch again and the output waveform should start to subtly alter in shape. Operating the various controls should influence the nature and extent of the alteration.

Having got the pretend stuff out of the way, you can now plug in a real instrument, hook the unit up to an amplifier and get chorused away!

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