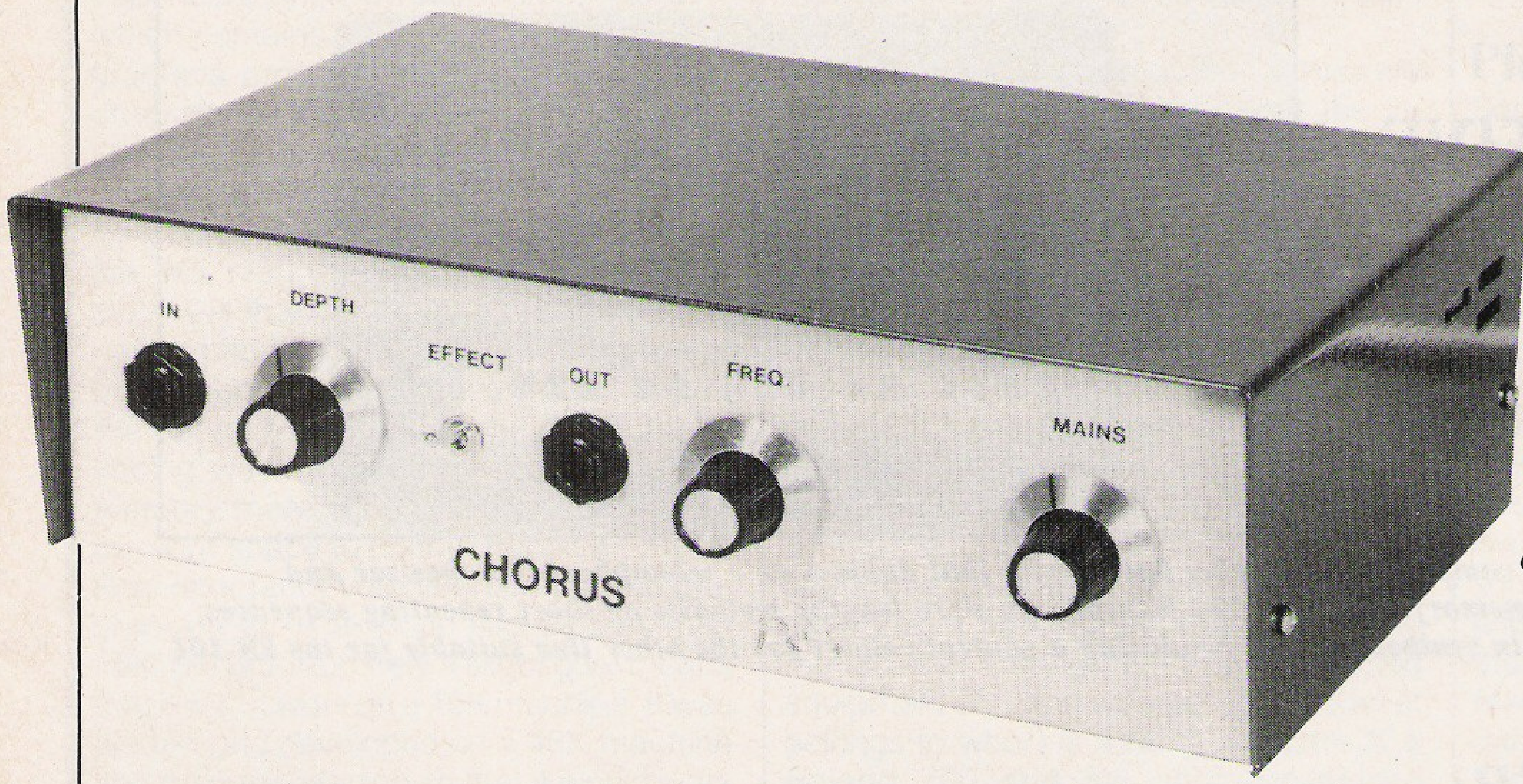
Chorus Effects Unit



A high quality, low noise design by Peter Rodgers, based on the latest analogue signal delay techniques.

Chorus units can be used effectively with virtually any instrument to produce a range of multiple tracking effects — a 'chorus' as opposed to a single voice. Commercial units vary greatly in terms of complexity, but they all use one or more delay lines to generate the effect. Basic units have a single delaying circuit which gives a period that is automatically varied from around 10 to 25 milliseconds (10 to 25 thousandths of a second), and then the delayed signal is mixed with a non-delayed signal. Strictly speaking this does not give a true chorus effect, since the two signals at the output appear to have different origins, or double up on the input signal. Thus a single voice input gives an output that sounds like a duet rather than a choir. Units of this type are often called 'mini-chorus'.

More sophisticated units use basically the same technique, but have three or more delay lines with their periods varied independently so that the mixed output signal gives a much richer effect. This type of circuit, however, is quite complex and expensive and in our design a compromise between 'mini-chorus' and full chorus effect has been adopted. A single delay line is used, but this has a long period which gives a series of shorter delays in addition to the full delay. The three longest delays available are used, and although independent modulation of the delay times is not possible, an excellent and useful effect is nevertheless obtained.

Circuit Blocks

The chorus unit's operating system is shown in the block diagram of *Fig 1*. The amplifier at the input is called a buffer and ensures that no loading is placed on the equipment that supplies the input signal and that there is a suitably low drive impedance for the subsequent stage. This is a low-pass filter which reduces the amount of high frequencies above 7kHz. This filtering is necessary since any high frequency (HF) components in the input signal could react with HF signals generated within the circuit to produce whistles at the output. Many electronic instruments are capable of producing strong harmonics at frequencies outside the audio range, and there is also a slight possibility of radio signals being picked-up by the input cable.

The next stage in the chorus unit is the delay line; a clock oscillator is used to control the period of delay. A low frequency oscillator varies the operating frequency of the clock and thus the delay time as well. Depth and frequency controls give a useful degree of control over the effect produced. The three (used) outputs of the delay line are mixed together and then fed to a second low-pass filter circuit. This is primarily needed to remove the clock signal, which breaks through quite strongly at the output and would otherwise adversely effect whatever equipment was being fed. A secondary function of this filtering is to limit the bandwidth of the circuit to prevent an excessive amount of output noise. A mixer at the output combines the delayed and non-delayed signals, and since the latter is not subjected to any filtering, the frequency response of the circuit as a whole is not limited.

Buffer And Filter

The buffer uses an operational amplifier in the configuration shown in *Fig 2a*. It is possible to 'program' the voltage gain of an operational amplifier using two resistors, but if the output is coupled straight back to the inverting (−) input, as here, there is unity voltage gain — no amplification of voltages — from the non-inverting (+) input to the output. This may seem a little pointless, but the circuit does give *current* amplification, and it is current rather than voltage amplification that we need here. Another operational amplifier (op-amp) is used as the basis of the input filter, and the configuration used is shown in *Fig 2b*.

Resistors, R_a and R_b provide an easy path for the input signal, since the op-amp requires an extremely small input current. At low frequencies, C_a and C_b represent a very difficult path for the input signal and have no significant effect. The circuit therefore acts as a straightforward buffer stage.

At high audio frequencies, C_b represents a relatively easy path for the input signal so that a large part of this signal is leaked away to earth and there are substantial losses through R_a and R_b. This gives low-pass filtering, though the level of performance is quite poor. With the roll-off in the response being introduced only quite gradually, the ultimate rate of the filter is only 6dB per octave (ie, doubling the input frequency halves the gain of the circuit).

The inclusion of C_a helps to overcome this problem by feeding some of the output signal back to the input at frequencies where the gain of the circuit would otherwise have fallen slightly. However, at frequencies where C_b produces severe attenuation, this feedback effect no longer helps to maintain the gain of the circuit — just the opposite, since the signal at the junction of R_a-R_b-C_a is far higher than that at the output of the circuit and some of the input signal is tapped off through C_a, and the output stage of the op-amp to earth. This has a two-fold effect: giving a more abrupt introduction of the filtering, and giving a doubling of the ultimate attenuation rate. The filters used in this circuit have an additional RC filter stage at the input and this boosts the maximum roll-off rate to 18dB per octave (doubling the signal frequency causes the gain of the circuit to fall by a factor of eight).

Delay Line

The delay line is a very complex device. *Fig 2c* shows the arangement used in the delay line (greatly simplified). With the switches in the position shown, C_a is connected to the input and will charge up to the input voltage. If all the switches are changed to the opposite setting, C_a will be connected to C_b and will pass its charge on to this component. Setting the switches back to their original position reconnects C_a to the input so that it takes a new input sample, while C_b passes its charge onto C_c. In other words, by repeatedly changing the switches from one position to another the input is sampled and the sampled voltage is passed down the circuit until it eventually appears on C_f at the output.

Obviously the signal at the output is not the same as the input signal — the input varies continuously whereas the output changes in a series of steps — however, provided the switches are operated at a frequency which is at least double (and preferably treble) the highest input frequency, the output will consist of the input signal plus some higher frequencies, which can be filtered out to leave just the wanted signal. In practice the switches are a form of electronic switch and are controlled by an oscillator. The time taken for the signal to pass through the delay line

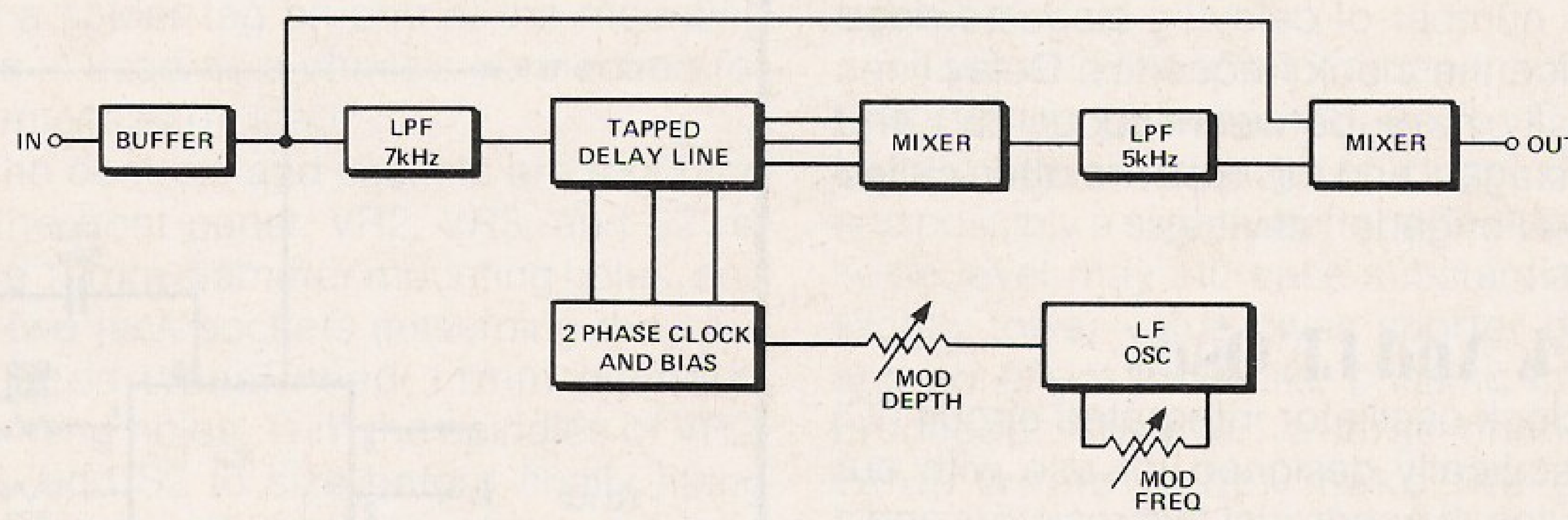


Figure 1. Effects Unit block diagram

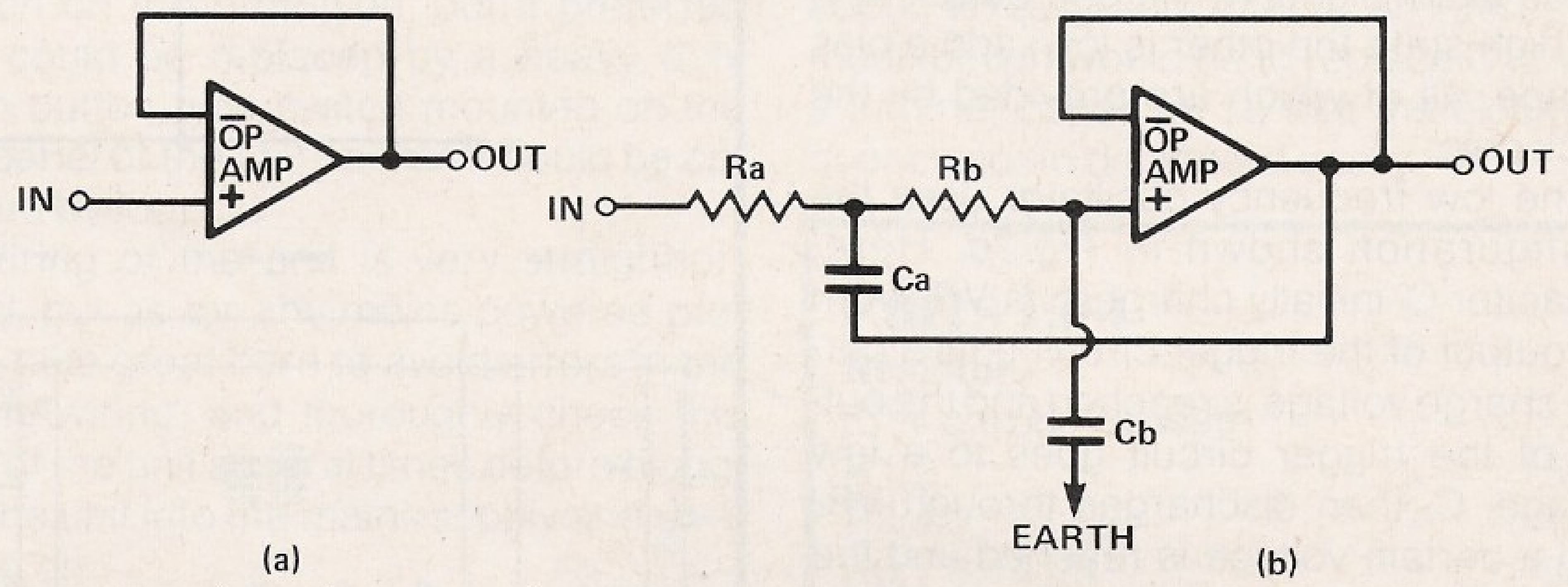


Figure 2. Op-amp connections — basic circuit (a) and using input resistors (b)

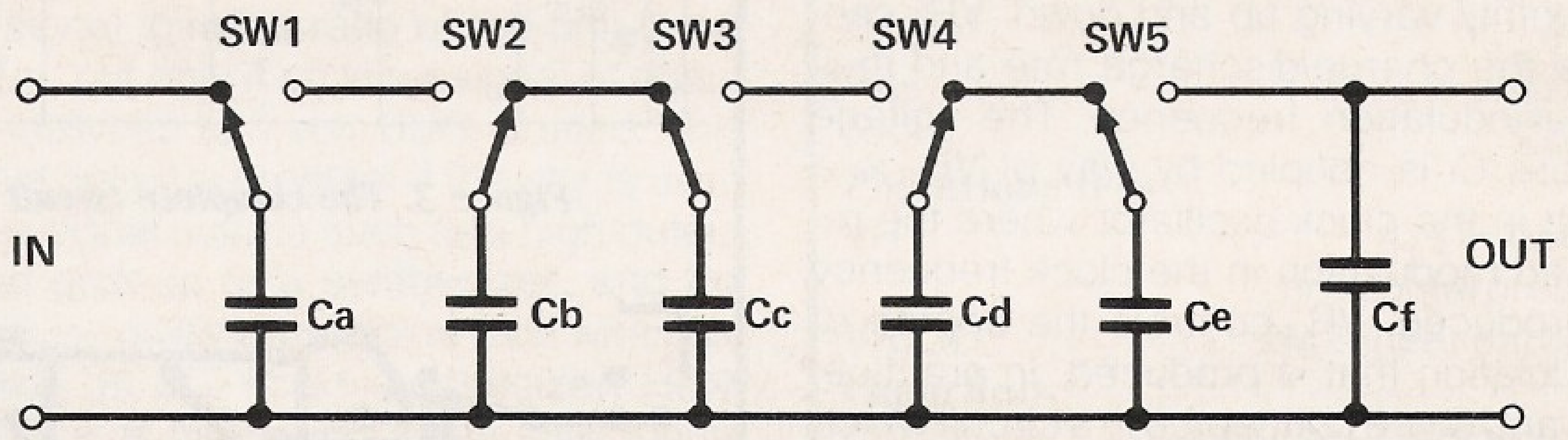


Figure 2c. The switching line.

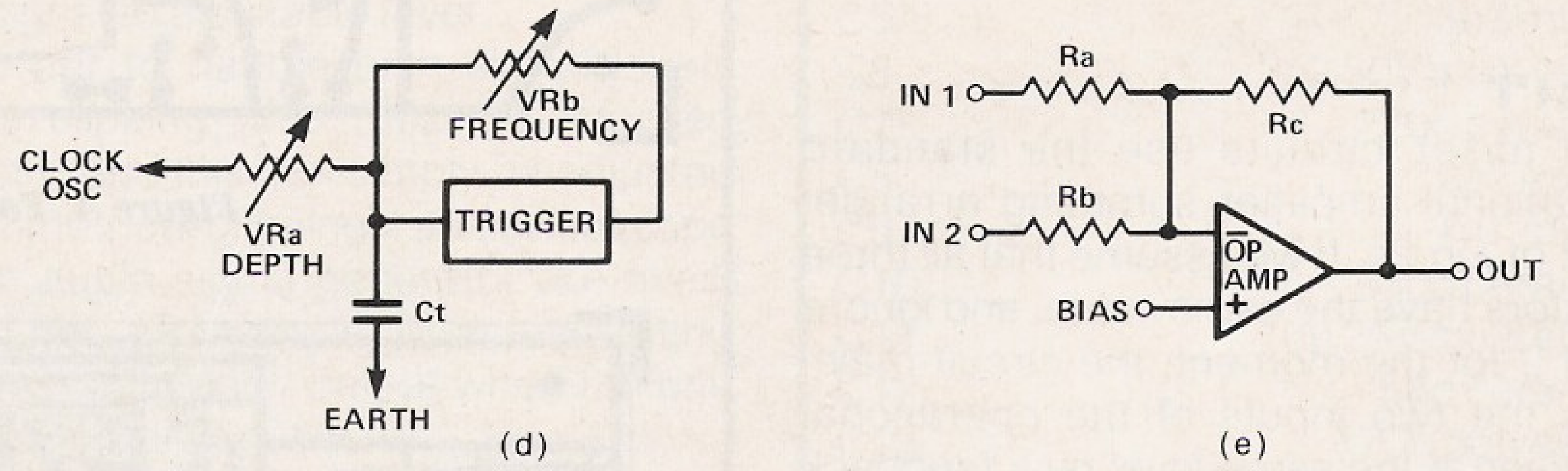
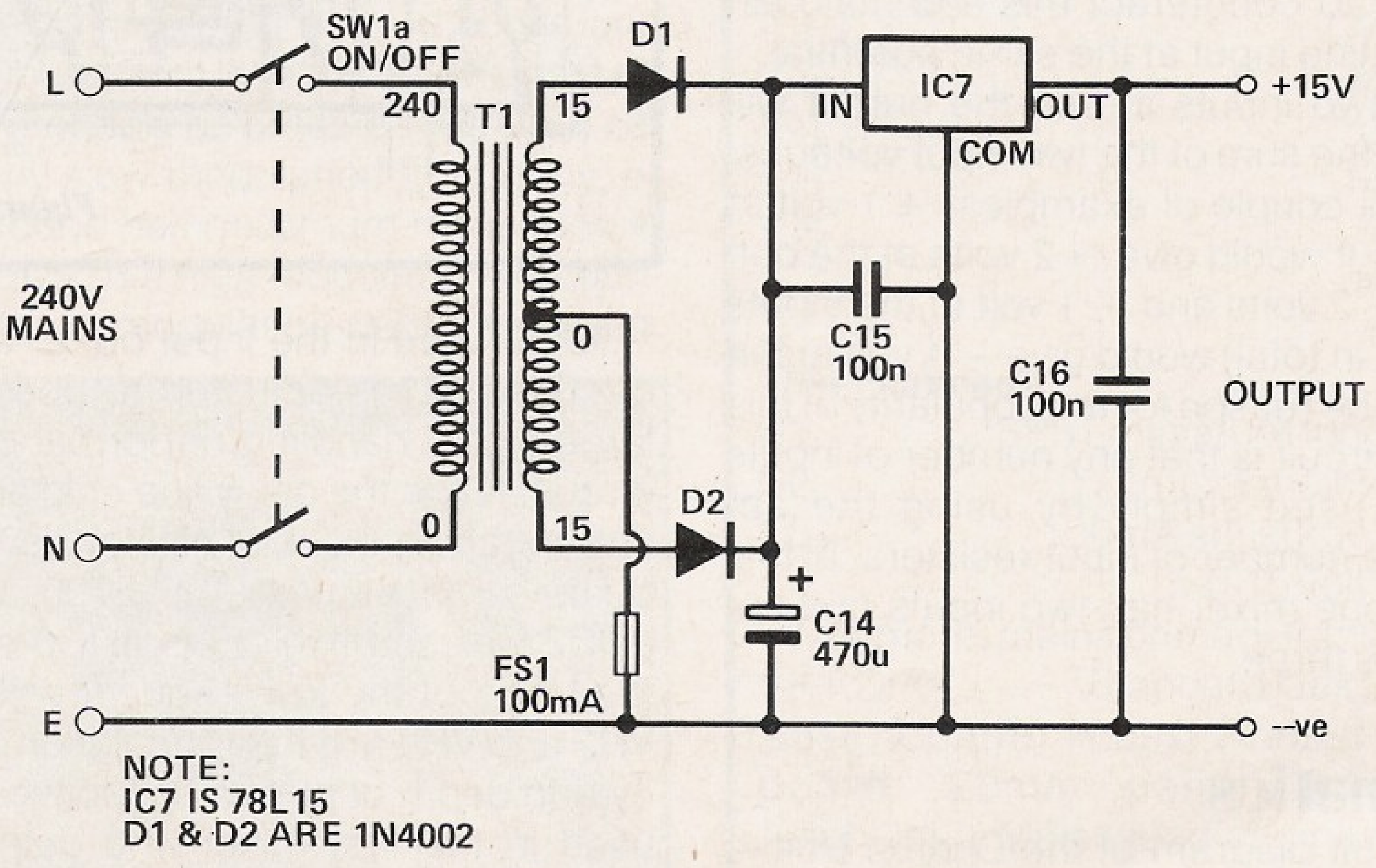


Figure 2b. Circuits for the trigger (d) and buffer (e).



The Chorus PSU

depends on the number of stages and the frequency of the clock oscillator. It is equal to the number of delaying stages divided by twice the clock frequency. Delay lines normally have between about 250 and 4000 stages, and *this* type are often called "bucket brigade" devices.

Clock And LF Oscs

The clock oscillator integrated circuit (IC) is specifically designed for use with our delay line. It needs just two resistors and a capacitor to set the desired operating frequency. The delay line requires a two-phase clock signal (while one output is in the high state the other is low) and a bias voltage, all of which are provided by the clock chip.

The low frequency oscillator uses the configuration shown in *Fig 2d*. Here, capacitor C_t initially charges via VR_b from the output of the trigger circuit until a certain charge voltage is reached and the output of the trigger circuit goes to a low voltage. C_t then discharges through VR_b until a certain voltage is reached and the output of the trigger then reverts to its original (high) state. This process continues indefinitely with the potential on C_t smoothly varying up and down. VR_b controls the charge/discharge rate and thus the modulation frequency. The voltage across C_t is coupled by way of VR_a to a point in the clock oscillator where the required modulation in the clock frequency is produced. VR_a controls the degree of modulation that is produced. In practice, VR_b and C_t are connected in a circuit which gives a linear charge/discharge rate and a triangular output waveform to provide a good effect.

Mixer

Both mixer circuits use the standard operational amplifier summing arrangement of *Fig 2e*. If we assume that all three resistors have the same value, and ignore input 2 for the moment, the circuit maintains the two inputs of the operational amplifier at the same level by a feedback action. If, for example, input one is taken one volt positive, the output goes one volt negative to counteract this and maintain the inverting input at the same potential.

With two inputs in use the output will balance the sum of the two input voltages, and, as a couple of examples, + 1 volt at each input would give − 2 volts at the output, or + 2 volts and − 1 volt at the inputs (+ 1 volt in total) would give − 1 volt at the output. The reason for the popularity of this type of circuit is that any number of inputs can be used simply by using the appropriate number of input resistors. In this project one mixer has two inputs and the other has three.

Schematics

The circuit diagram of the Chorus Unit is shown in *Fig 3*, and *Fig. 1* shows the circuit of the mains power supply unit.

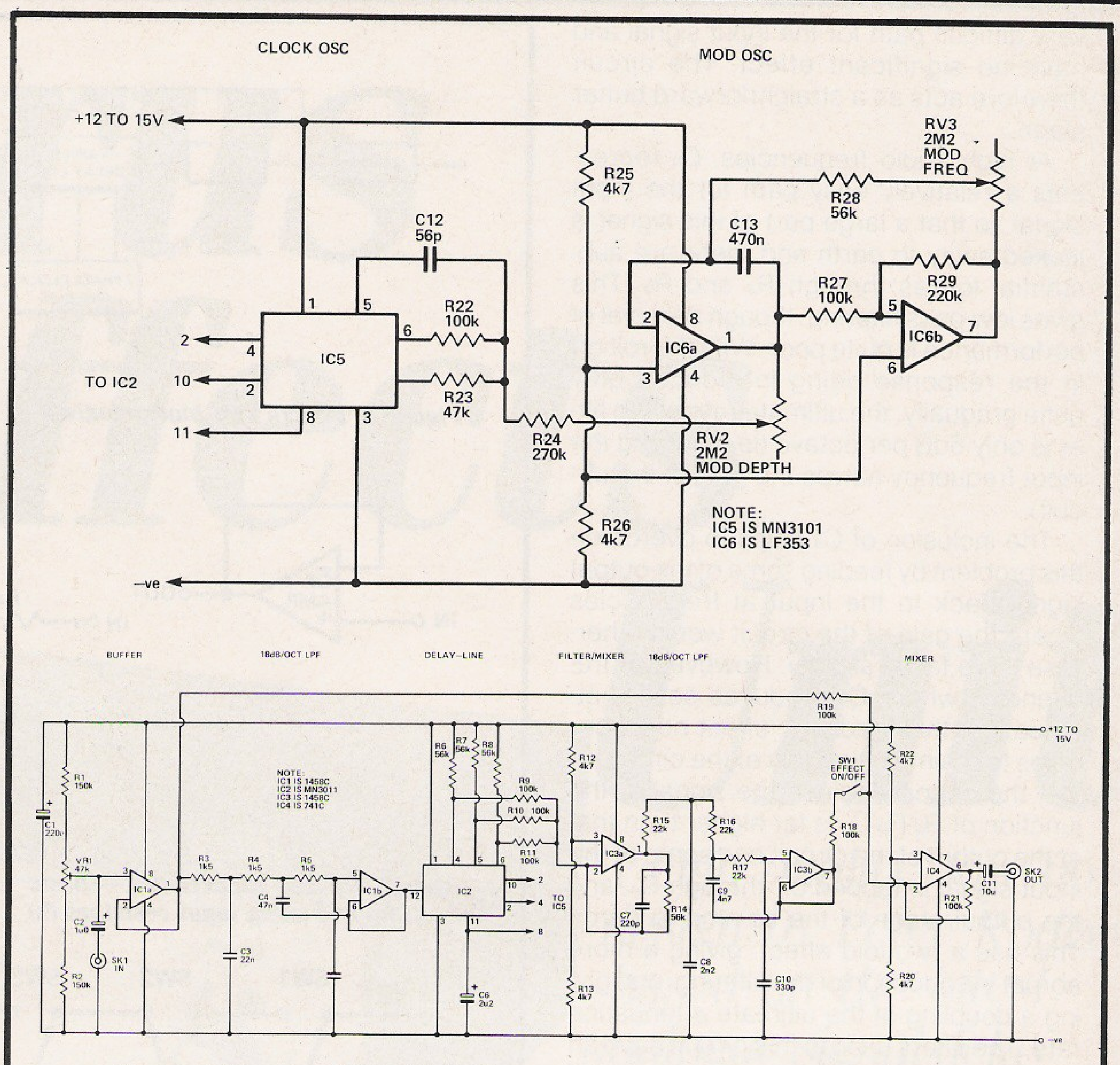


Figure 3. The complete circuit diagram of the Chorus Effects Unit

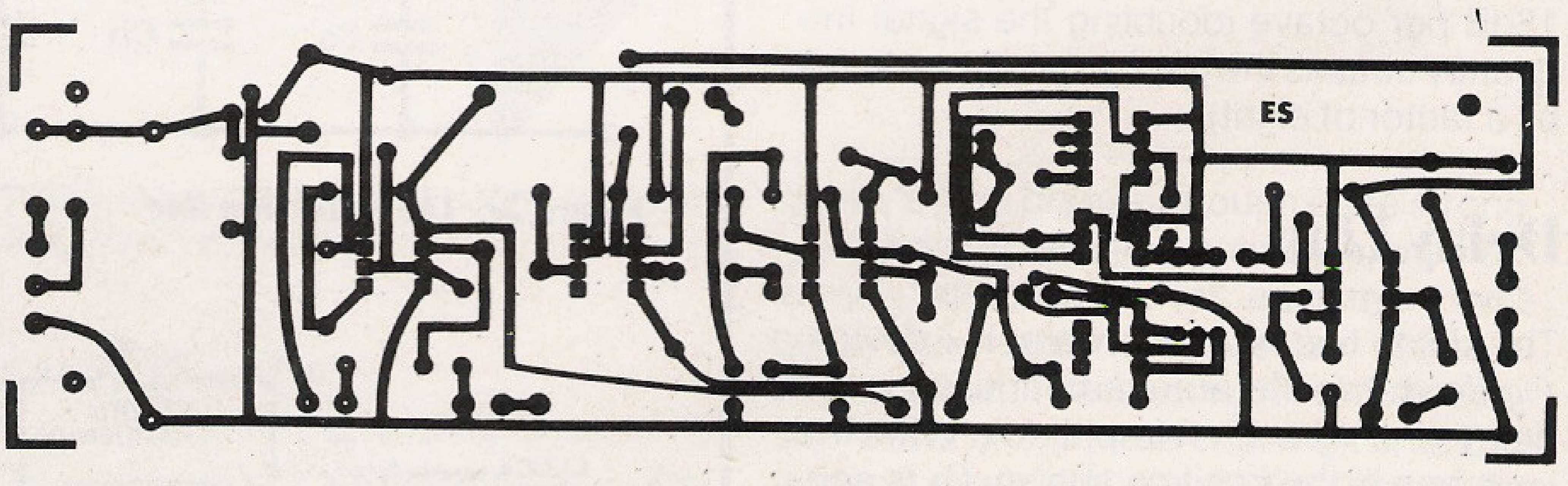


Figure 4. Foilside pattern of the PCB

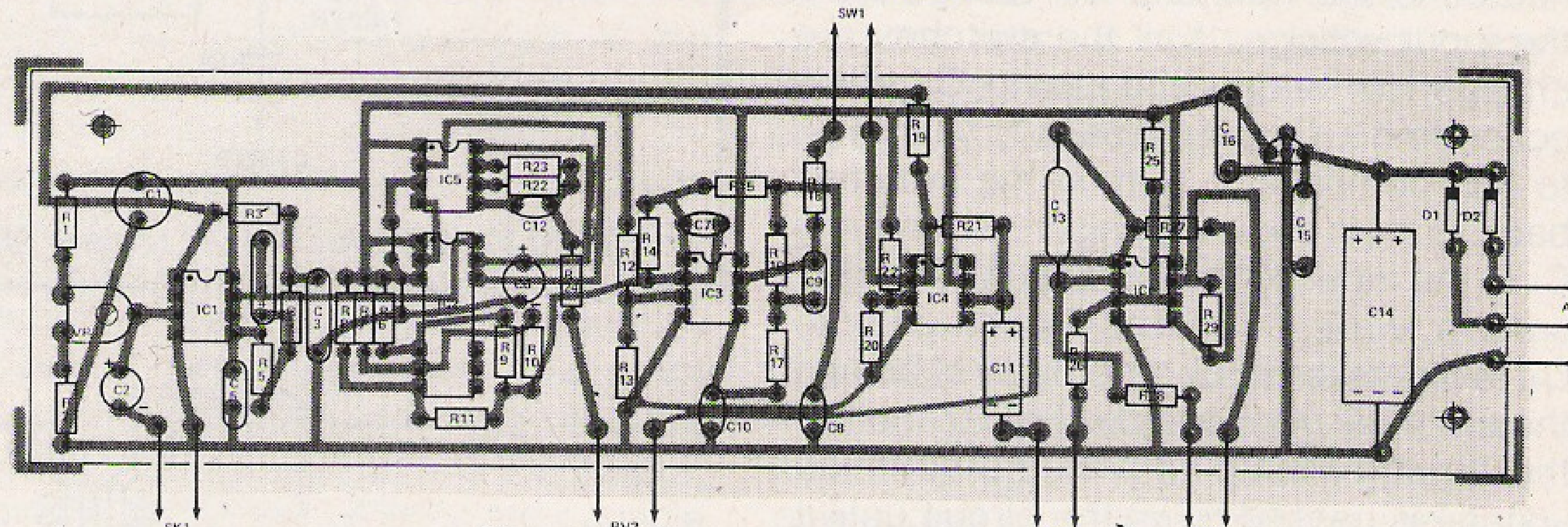


Figure 5. Component overlay

ICl is used in the input buffer and filter circuits. VR1 is adjusted to optimise the large signal handling performance of the circuit. IC2 is the delay line chip and IC5 is the matching clock oscillator device. The outputs from stages 1726, 2790, and 3328 of IC2 are used in this circuit. IC6 is used as the basic of the low frequency oscillator. VR2 and VR3 are the modulation frequency and depth controls respectively. IC3 is used in the first mixer and output filter, while the output mixer is based on IC4. S1 can be used to disconnect the delayed signals from the output mixer so that the effect is switched out.

The power supply gives a well smoothed and stabilised 15 volt output, and uses a conventional arrangement.

Construction

Construction of the unit is made reasonably straightforward by the use of a printed circuit board which takes most of the components, the only exceptions being the controls, mains transformer, sockets, and fuseholder. Details of the printed circuit board are shown in *Fig 5*.

Start construction of the board by wiring in the two link wires just to the left of the position for IC2. Then add in the resistors, capacitors, and finally the semiconductor devices. An important point to note is that IC2 and IC5 are MOS devices, and these are susceptible to damage by high static voltages. These components should be supplied with some form of protective packaging (usually a plastic tube or a conductive foam block), and they should be left in this until they are to be fitted onto the board. To avoid soldering these components in place they should be fitted in IC sockets. IC2 requires an 18 pin DIL type, while IC5 needs an 8-pin DIL socket. IC2 is rather unusual in that it only has 12 pins, the middle three of each row being absent. As the printed circuit board only has 12 mounting holes for IC2, the six unused pins of IC2's socket should either be trimmed down or removed using pliers. Do not fit IC2 and IC5 into place until all the other components have been soldered in place, and handle them as little as possible when they are being fitted into their holders.

Single sided Veropins are fitted to the board at the 13 places where connections to off-board components will be made.

If you are new to electronics construction it would be advisable to practice soldering a few odd bits of wire together, or perhaps soldering them to a piece of stripboard, before building the printed circuit board.

A metal instrument case measuring about 250 by 150 by 75mm is a suitable housing for this project, but it would not be difficult to fit the unit into a somewhat smaller case if desired. The use of a metal case (earthed to the mains earth lead) is strongly recommended. The general layout can be seen from the photographs, and the wiring is perfectly straightforward provided you adhere to this layout. There should be reasonable separation between the mains wiring and transformer and the rest of the unit in order to avoid problems with stray pick-up of mains hum.

The printed circuit board is mounted on the base panel of the case using 6BA fixings, and spacers about 6 to 12mm long are used on the fixing screws to hold the underside (the track side) of the board clear of the base panel. The fuseholder is a panel mounting type which is fitted on the rear of the unit, and a hole for the mains lead is made alongside this. This hole should be fitted with a grommet to protect the mains lead. The mains transformer is bolted to the base panel using 4BA fixings, and a solder tag on one of the mounting bolts is used as a chassis connection for the mains earth lead.

The controls and sockets are mounted on the front panel. VR2, VR3, and S2 require 10mm diameter mounting holes, and the two jack sockets (assuming they are insulated types) need 11mm diameter mounting holes. Trim the spindles of VR2, VR3, and S2 to size before finally fitting them on the panel. Use a hacksaw, and grip the spindles in a vice (not the bodies of the components). S1 is a miniature toggle switch on the prototype, but if preferred this could be replaced by a heavy duty push button type switch mounted on the top panel of the unit so that it could be operated by foot.

Wiring of the unit is very straightforward, but as for any mains powered project, take great care to avoid errors in the mains wiring, and thoroughly check this part of the unit several times before plugging the unit into the mains supply and switching on.

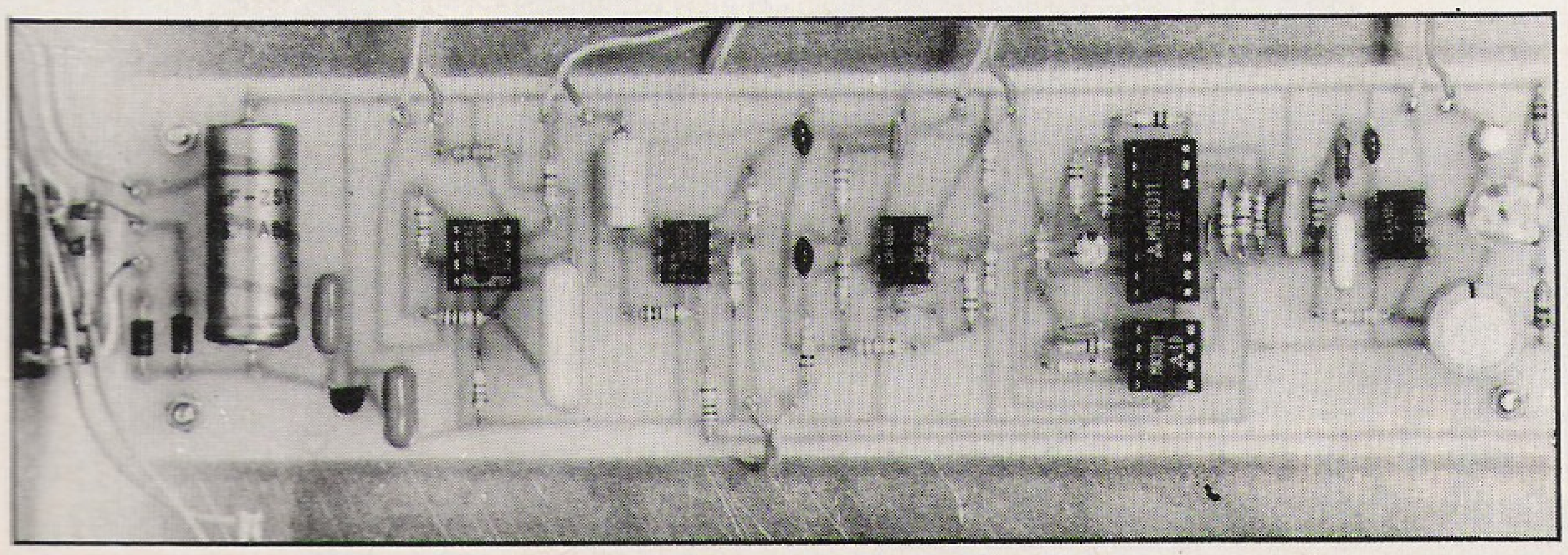
In Use

The signal-to-noise ratio of the unit is excellent, but only if an input signal of about 300 millivolts to 1 volt RMS is used. This should not be a problem if the unit is used with a signal source such as a high-output guitar pick-up or a synthesizer, and the prototype gives excellent results when used with an SCI Pro 1 synthesizer. However, if it is used with a low level signal source such as a low output guitar pick-up or a microphone it will be necessary to use a preamplifier ahead of the unit to raise the input signal to a suitable level.

In order to handle high signal levels without clipping, VR1 must be adjusted correctly, and this can simply be adjusted for symmetrical clipping if an oscilloscope and an audio signal generator are available. If not, VR1 can be given any setting that gives a "clean" output when the unit is handling signal peaks.

In normal use VR2 will need to be set at or near maximum modulation so that a good strong chorus effect is produced, but it can be backed off if a more subtle and less obvious effect is required. The best effect will probably be obtained with VR3 set for a fairly slow modulation frequency, or set at around half maximum resistance in other words. If a high modulation frequency and large modulation depth are used, quite a strong effect is obtained due to the large amount of vibrato which the delayed signals pick up.

Those who like to experiment might like to try using different values for C12. A slightly higher value gives longer delays and possibly a slightly better effect, but the noise level may increase substantially. A slightly lower value gives shorter delays and an effect more like phasing can be produced. However, a large change in value would either make the clock frequency audible at the output or would result in the delay line failing to operate, and it is advisable to keep changes within about +100% and −50%. An interesting modification would be to replace C12 with a trimmer capacitor so that the clock frequency could be altered easily. ■



Parts List

Resistors

(5% carbon ¼ watt)

R1,2	150k
R3,4,5,	1k5
R6,7,8,14,28	56k
R9,10,11,18,21,22,27	100k
R12,13,19,20,25,26	4k7
R15,16,17	22k
R23	47k
R24	270k
R29	220k

Potentiometers

VR1	47k 0.1 watt horizontal preset
VR2,3	2M2 linear carbon

Capacitors

C1	220u 25V radial elect
C2	1u 50V axial elect
C3	22n polyester
C4	47n polyester
C5	3n3 mylar
C6	2u2 50V axial elect
C7	220p ceramic
C8	2n2 mylar
C9	4n7 mylar
C10	330p ceramic
C11	10u 25V axial elect
C12	56p ceramic
C13	470n polyester
C14	470u 25V axial elect
C15,16	100n polyester

Semiconductors

ICI,3	LM1458C
IC2	MN3011
IC4	uA741C
IC5	MN3101
IC6	LF353
IC7	uA78L15
D1,2	1N4002

Miscellaneous

S1	SPST miniature toggle type
S2	rotary mains switch
FS1	100mA antisurge, 20mm
T1	15-0-15 volt 100mA or more, mains primary transformer
SK1,2	Standard jack sockets

Case, Control knobs, Printed circuit board, 20mm panel mounting, fuseholder, Mains lead and plug, wire, etc.