normal use this control should be adjusted so that the LED just begins to glow, which occurs at a nominal level of 2.5 V p-p with one VCO input signal, less if more than one VCO is connected. If the LED glows brightly, then the VCA is being overmodulated and distortion may occur. This is not to say that this should never be allowed to happen, since the deliberate introduction of distortion can be used to produce 'fuzz' effects. If the LED does not glow, then this indicates undermodulation and the possibility of a poor signal-to-noise ratio.

**Tremolo**

To produce tremolo effects a low-frequency oscillator signal (LFO) can be fed into the AM input socket. The Formant LFOs, described later in the series, have an output voltage swing of ± 2.5 V, and if the GAIN potentiometer P3 is set in its mid-position this will give a modulation depth of 100%. Reducing the LFO input signal by means of the AM potentiometer P4 allows the modulation depth to be varied down to 0%.

**Expression Pedal**

An expression pedal may also be connected to the AM input. This can be a pedal fitted with a logarithmic potentiometer and battery, whose output can be varied from zero to about +5 V with the pedal fully depressed.

**Tuning**

The ENV/OFF switch S1 is particularly useful when tuning the synthesiser, since it allows signals to pass continuously through the VCA, unaffected by the envelope shaper when in the OFF position.

**Outputs**

The external output of the VCA has an impedance of about 500 Ω, and this output may be fed to other equipment such as tape decks and external amplifiers, or to high impedance headphones for monitoring.

The internal output signal (IOS) is taken to the Formant amplifier module, which will be described later. This is fitted with tone and volume controls and a small power amplifier for monitoring purposes. It will drive low impedance headphones and loudspeakers, and can also be used to drive spring line reverberation units or other external equipment.

chapter 11

# LFOs and noise module

**The low frequency oscillators and noise generator are invaluable components in a synthesiser system. The LFOs allow amplitude and frequency modulation of the VCO outputs to provide tremolo, vibrato and other effects. The noise sources can be used for random modulation of the VCO signals, and in addition can be used as signal sources themselves.**

Mention has already been made of the fact that conventional instruments exhibit more 'life' and variation in tonal character than electronic instruments due to the way in which they are played. For example, string instruments and woodwind instruments can exhibit marked tremolo and/or vibrato due to variations in the bowing or blowing. The keyboard of a synthesiser provides a relatively inflexible and expressionless means of playing that does not allow these nuances to be introduced into the sound, and in order to make the sound more 'lively' amplitude and frequency modulation must be introduced using the LFOs and noise source.

The noise source also provides the basic material to produce a whole spectrum of sounds that do not have a defined pitch. White noise can be used to produce sounds such as wind, rain and surf. 'Coloured' noise, which is white noise with the low frequency components boosted, is used for sounds having a strong bass content, such as the rumbling of thunder.

In addition to modulating the VCO signals, noise can also be added to these signals to simulate wind noise in organ pipes and woodwind instruments.

## The LFO module

The Formant LFOs are basically low-frequency function generators that produce three different waveforms. Each LFO module contains three LFOs, two of which are identical and produce square, triangle and sawtooth waveforms. The third LFO produces a triangular waveform and two sawtooth waveforms in antiphase with each other, i.e. one with a positive-going ramp and the other with a negative-going ramp.

The circuit of LFO1 is shown in figure 1a; LFO2 is identical. The basic oscillator circuit consists of two op-amps IC1 and A3 connected respectively as an integrator and a Schmitt trigger. When the output of A3 is positive a potential of about +2.5 V (depending on the position of the wiper of P3) is applied to R9. The full positive output voltage of A3 is applied to P1, so a current (dependent on the wiper position of P1) flows into the integrator through R1. The output of IC1 ramps negative until it reaches about −2.5 V, when the voltage on the non-inverting input of A3 will fall below the voltage on the inverting input (zero volts) and the output of A3 will swing negative. The voltage applied to R9 is now −2.5 V, and the full negative output voltage of A3 is applied to P1. Current will flow out of the integrator through R1, and the integrator output will ramp positive until it reaches about +2.5 V, when the voltage on the non-inverting input of A3 will rise above zero and the output of A3 will swing positive. The whole cycle then repeats.

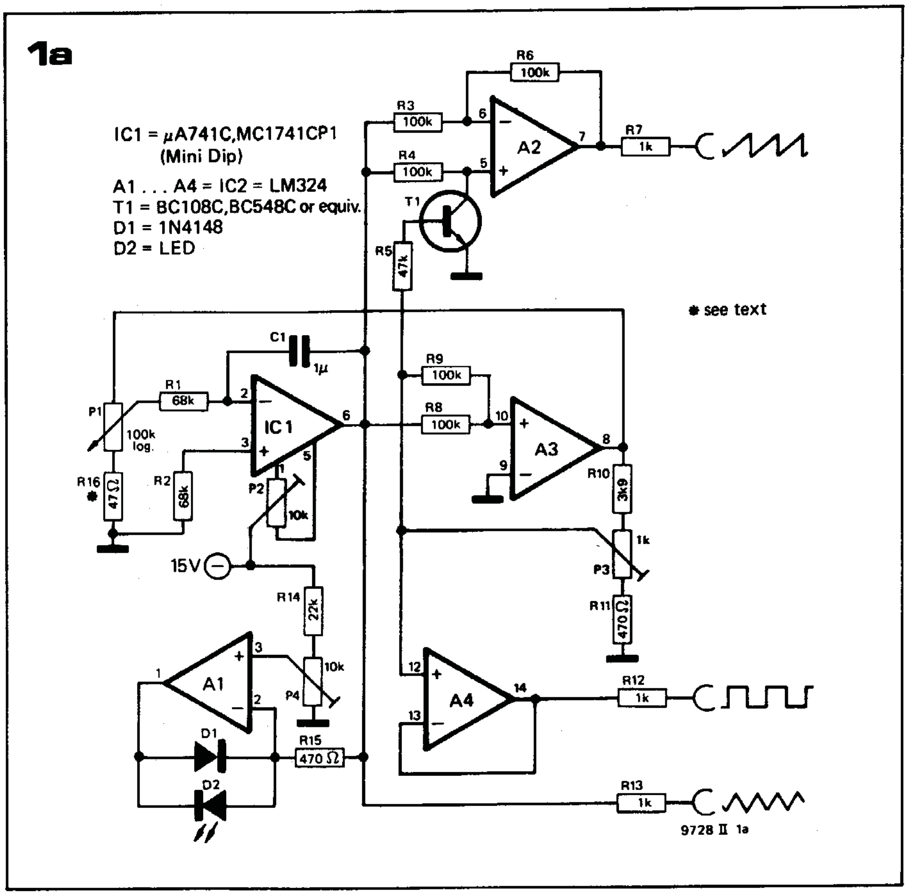
The output from IC1 is thus a triangular waveform with a peak-to-peak voltage of about 5 V, while at the wiper of P3 a squarewave of the same amplitude and frequency is available. P3 presets the trigger threshold of A3 and hence the signal amplitude. P1 is used to adjust the frequency of the LFO by varying the voltage applied to the integrator input, which alters the integrator input current and hence the rate at which the integrator ramps positive or negative.

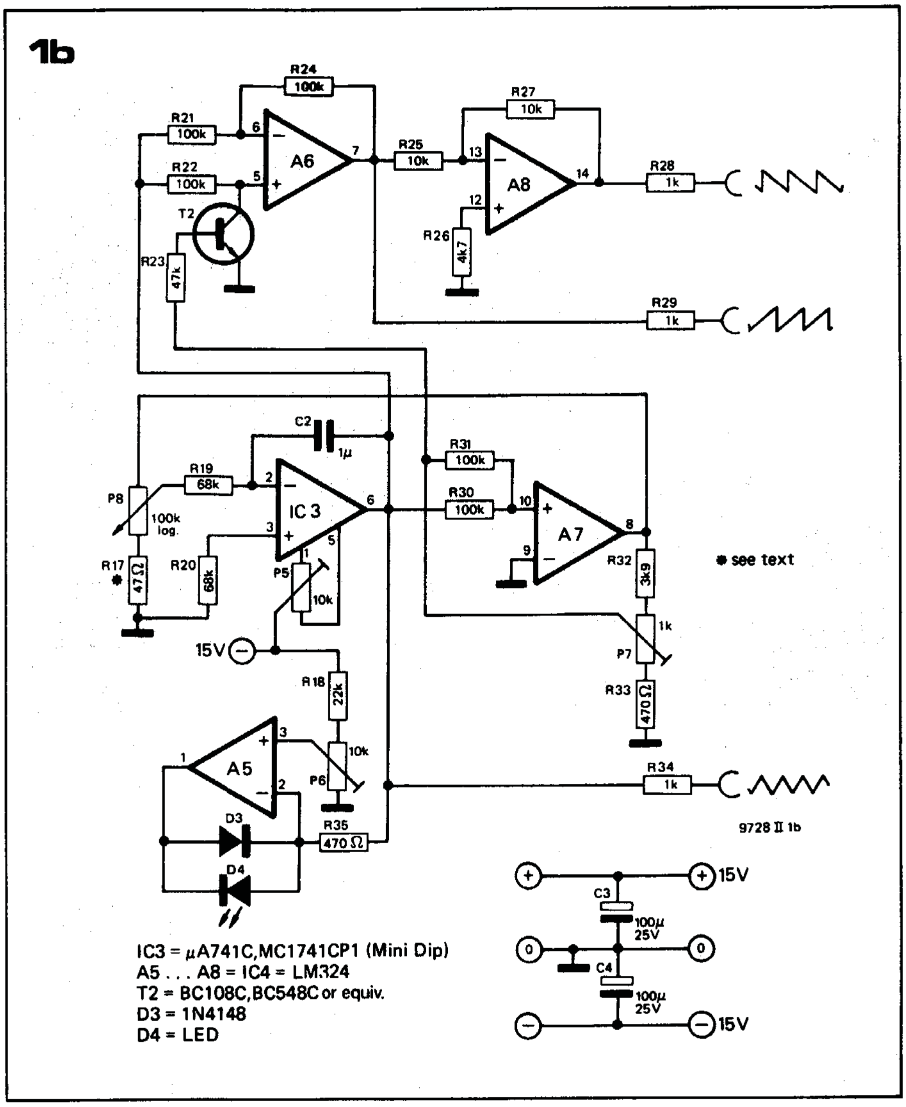
The triangular wave output is taken direct from IC1 via R13, whilst the squarewave output is buffered by voltage follower A4. The sawtooth waveform is derived from the triangle by A2. When the output of A3 is positive and the triangle output is on its negative-going slope, T1 is turned on, grounding the non-inverting input of A2. A2 thus functions as a unity-gain inverting amplifier, producing a positive-going ramp. When the output of A3 is negative and the output of IC1 is positive going, T1 is turned off and A2 functions as a unity-gain non-inverting amplifier (voltage follower), again producing a positive-going ramp. The positive- and negative-going ramps of the triangular waveform are thus converted into a series of positive-going ramps. Since every half-cycle of the triangle is converted into a full cycle of the sawtooth, the frequency of the sawtooth is twice that of the triangle and square waveforms, as illustrated in figure 2.

To indicate that the LFO is functioning a LED indicator, constructed around A1, is connected to the triangle output.

**Figure 1a. Circuit of LFO 1, which is identical to LFO 2 and produces triangle, sawtooth and square waveforms.**

**Figure 1b. LFO 3 also produces three waveforms, but instead of a squarewave output a negative-going sawtooth is provided.**




The third LFO circuit, shown in figure 1b, is similar to the first circuit, with two exceptions. Firstly, no squarewave output is provided; secondly, a sawtooth with negative-going slope is provided by A8, which inverts the positive-going sawtooth from A6.

## Construction of the LFO module

Figure 3 shows the printed circuit board and component layout of the LFO module, which of course contains three LFOs. The components for LFO2 are identical to those for LFO1, being distinguished on the board and in the components list by an apostrophe (').
The board layout is fairly cramped, and care should be taken when soldering components to avoid solder bridges. A front panel layout is given in figure 4.

## Adjustment of the LFOs

Each LFO requires four adjustments:
- P3, P3' and P7 set the signal amplitude.
- P2, P2' and P5 null the offset of the integrators.
- R16, R16' and R17 must be selected to set the lowest frequency of the LFO.
- P4, P4' and P6 adjust the LED indicators.

The adjustment procedure, which is identical for all three LFOs, will be described for LFO1.

#### Amplitude adjustment

1. Monitor the triangle output on an oscilloscope; set P2 to its mid-position and P1 for maximum frequency.
2. Adjust P3 to give a peak-to-peak output of 5 V.
3. Check the amplitude and waveform of the other outputs.

#### Offset adjustment

1. Disconnect R1 from the wiper of P1 and ground it.
2. Monitor the output voltage of IC1 with a multimeter. It will probably exhibit a tendency to drift positive or negative, and the voltage will settle at +15 V or −15 V. Reset the

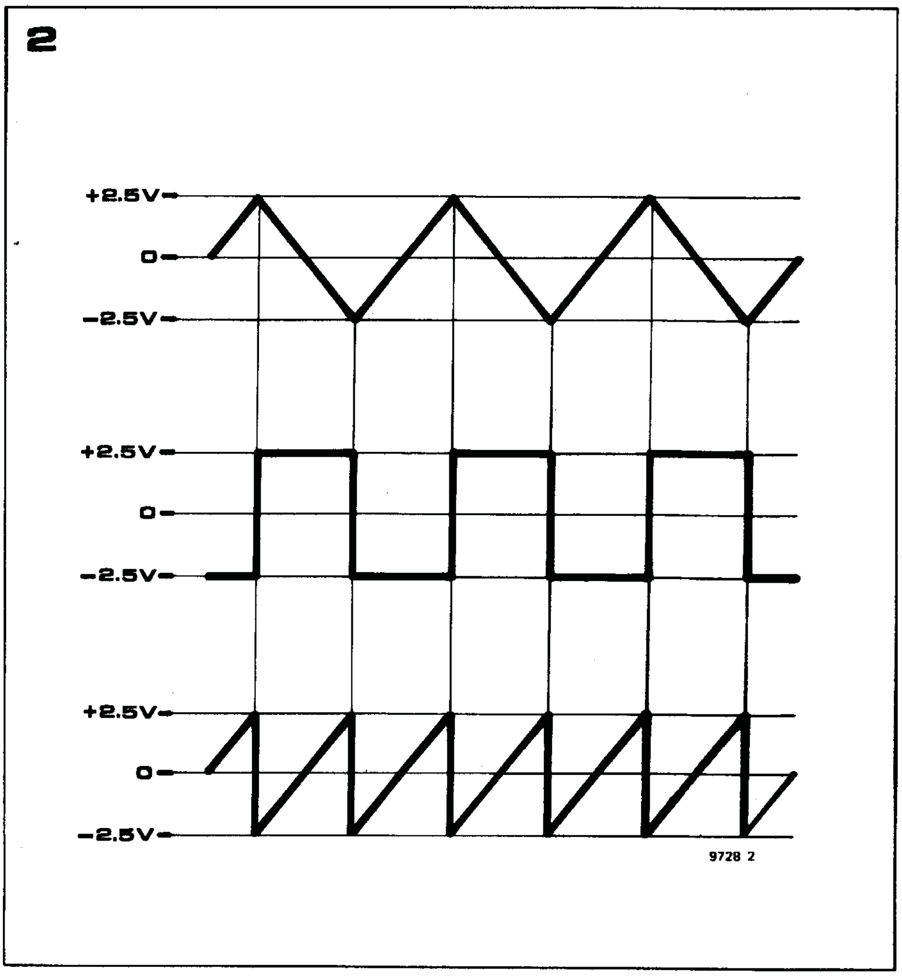
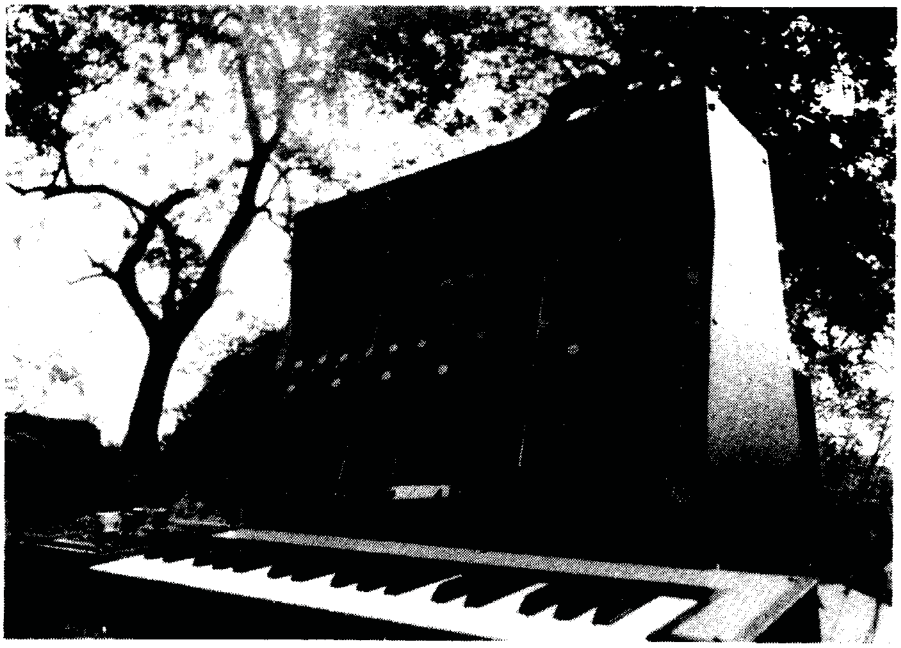



**Figure 2. Showing the phase relationship of the triangle, square and sawtooth waveforms. Since the sawtooth is derived by inverting alternate half-cycles of the triangle waveform, its frequency is twice that of the other waveforms.**

**Figure 3. Printed circuit board and component layout for the LFO module (EPS 9727-1).**



output voltage to zero by discharging C1 through a 1 k resistor. Adjust P2 until the voltage remains stable at zero volts for a period of several seconds (without the discharge resistor in circuit). Repeat this adjustment, progressively switching the multimeter to more sensitive ranges until the drift is only a few hundred millivolts in several seconds.

Careful adjustment of the offset is vital, as it determines the minimum frequency at which the LFO will operate reliably and the symmetry of the waveforms at low frequencies.

#### Selection of R16

The value of R16 determines the minimum integrator input voltage that can be set by P1, and hence the minimum frequency of the LFO. The value of R16 must not be chosen too high or the minimum LFO frequency will be too great. On the other hand it should not be chosen too low, or the integrator input current at the minimum setting of P1 will be comparable with the input currents of IC1. This will result in unreliable operation of the oscillator at low frequencies.

R16 should be chosen so that the minimum frequency of the LFO is about one cycle every three minutes, but the value of R16 should not be less than 10 Ω. If it is not possible to obtain this low frequency then the input currents of IC1 may be too high, or C1 may be leaky.

The maximum LFO frequency is about 20 Hz.

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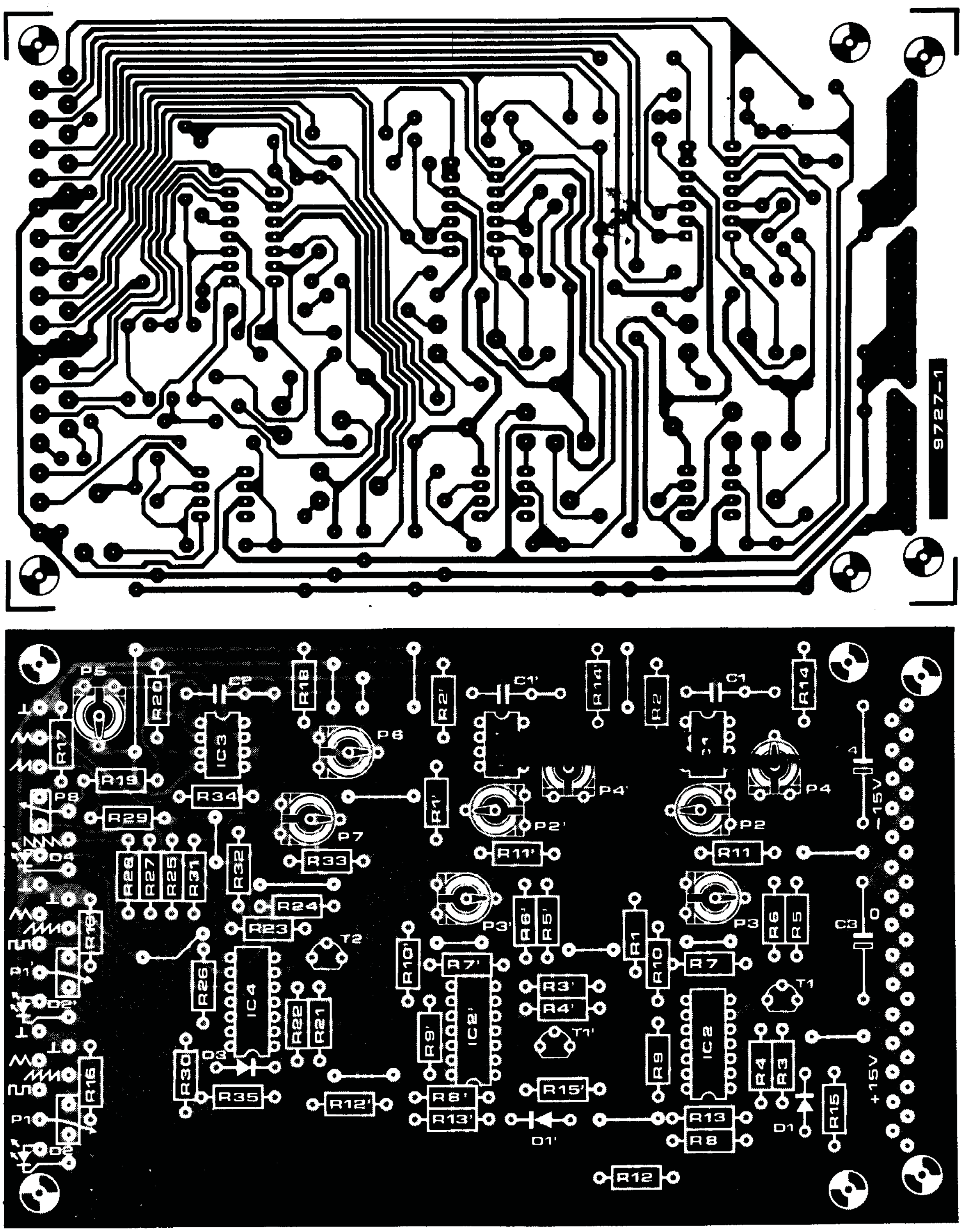


**Parts list for LFO module**

Resistors:
R1,R1',R2,R2',R19,R20 = 68 k
R3,R3',R4,R4',R6,R6',R8,R8',
R9,R9',R21,R22,R24,R30,
R31 = 100 k
R5,R5',R23 = 47 k
R7,R7',R12,R12',R13,R13',R28,
R29,R34 = 1 k
R10,R10',R32 = 3k9
R11,R11',R15,R15',R33,
R35 = 470 Ω
R14,R14',R18 = 22 k
R16,R16',R17 = 47 Ω (see text)
R26 = 4k7

Potentiometers:
P1,P1',P8 = 100 k log
P2,P2',P4,P4',P5,P6 = 10 k preset
P3,P3',P7 = 1 k preset

Semiconductors:
IC1,IC1',IC3 = μA 741C,
MC 1741CP1 (Mini DIP)
IC2,IC2',IC4 = LM 324 (DIP)
T1,T1',T2 = BC 108C, BC 548C or
equivalent
D1,D1',D3 = 1N4148, 1N914
D2,D2',D4 = LED (e.g. TIL209)

Capacitors:
C1,C1',C2 = 1 μ (polyester or
polycarbonate)
C3,C4 = 100 μ/25 V

Miscellaneous:
31-way connector (DIN 41617)
9 x 3.5 mm jack
3 x 13 . . . 15 mm knobs

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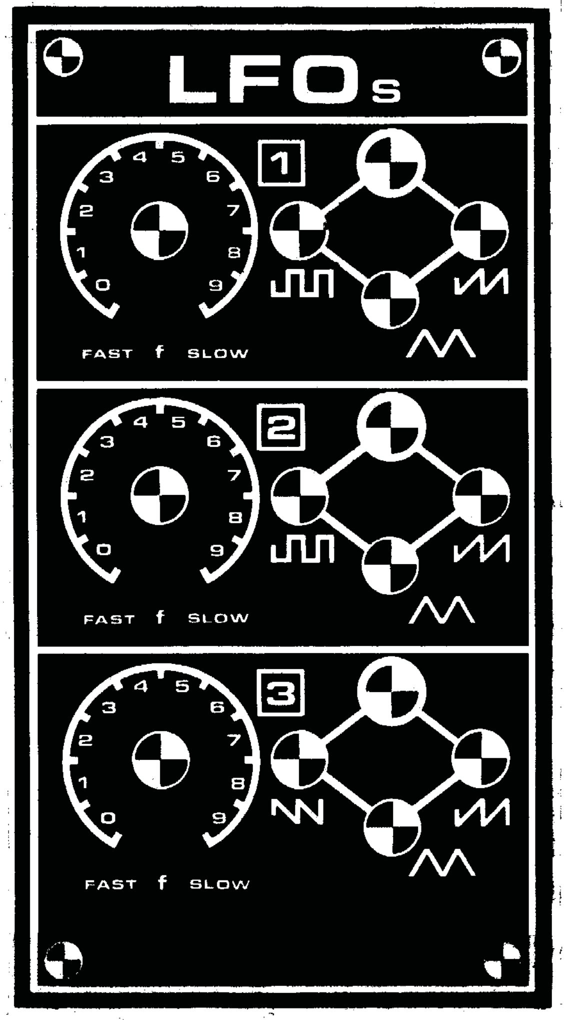


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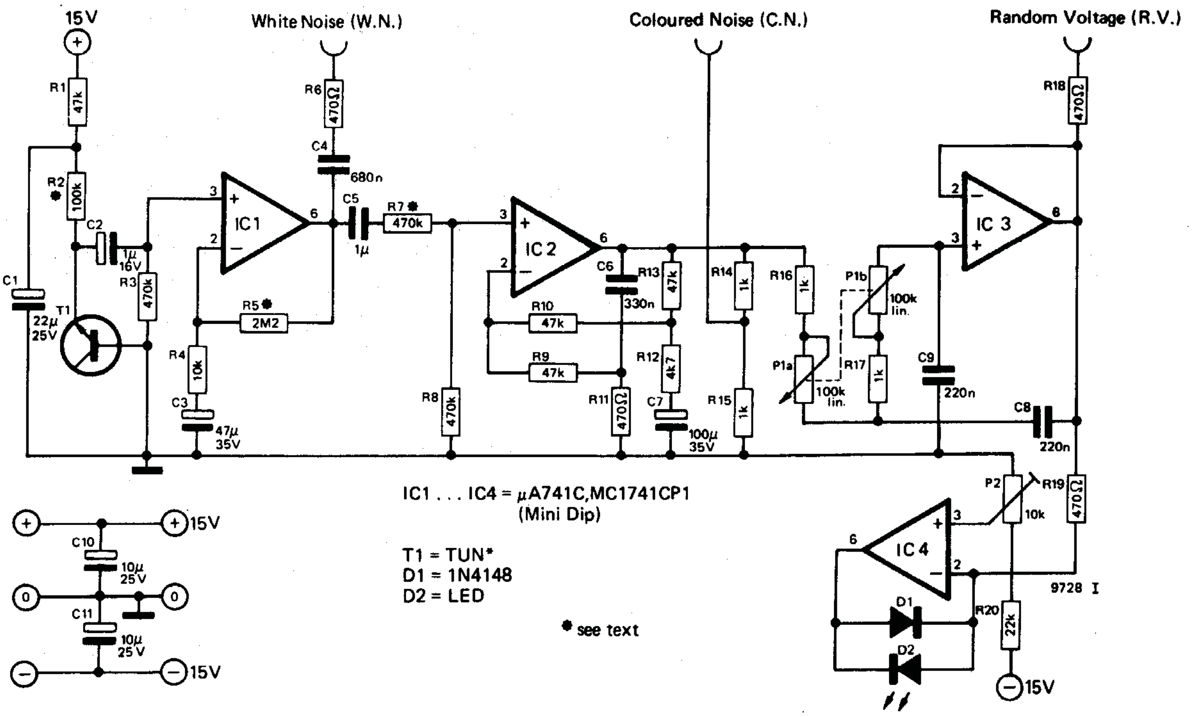


**Figure 4. Front panel layout of the LFO module.**

**Figure 5. Circuit of the noise module.**

**Figure 6. Printed circuit board and component layout for the noise module (EPS 9728-1).**