

MODULE 80-6

VOLTAGE CONTROLLED FILTERS

1. INTRODUCTION

Four types of filter are available in the DIGISOUND 80-6 series, namely, low pass, high pass, band pass and allpass (phase shift). They are all four pole filters with one volt per octave control of their cut-off, or centre, frequency. The latter frequency may be set anywhere in the audio range. Voltage control of signal regeneration (resonance or Q factor) is also included.

Filters are normally used in three modes. Firstly, timbre modulation which allows more complex waveforms to be developed by continuously altering

the partials present during the course of a note. The latter may be accomplished using a low frequency oscillator to vary the cut-off frequency of the filter. A widely employed variation of the latter technique is the use of an envelope generator, triggered by the keyboard, to control the cut-off frequency. In this way a tone may be produced, assuming a low pass filter, which begins at the fundamental followed by an increasing number of partials. Next, subtractive synthesis, in which partials are subtracted from complex waveforms to effect changes in tone quality. The third technique is resonant synthesis in which the regeneration of the signal is increased to a level which will cause the filter to oscillate on receiving a sharp impulse, e.g., from an envelope generator set to near minimum time constants or from a pulse waveform. This technique is widely used to produce percussive sounds. For additional information please consult the DIGISOUND 80 user's manual.

A brief description of the four types of filters is given below.-

LOW PASS FILTER. This will pass all frequencies up to the cut-off point and thereafter the frequencies are sharply attenuated at a rate of 24dB/octave. By increasing the resonance control, manually or using an external control voltage, a band of frequencies around the cut-off point are emphasised and the more regeneration used the more 'electronic' the sound becomes. Low pass filtering is useful in simulating the tonal characteristics of several conventional instruments.

HIGH PASS FILTER. This passes all frequencies above the cut-off point and the roll-off below this point is again 24db/octave. The effect of high pass filtering is therefore to remove the fundamental and lowest partials and leave only the weak upper partials. It does not, therefore, find widespread use in subtractive synthesis of waveforms although high pass filtering of a sawtooth waveform can produce bright sounds. The filter

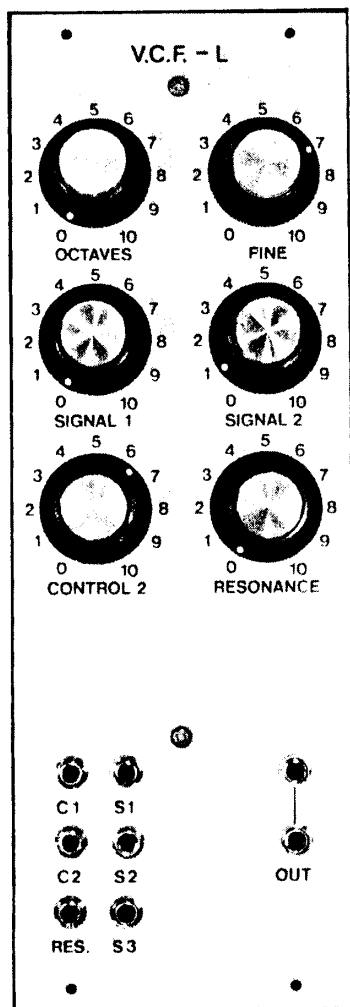


FIGURE 1. 80-6L PANEL

is also of use in filtering white noise. It is not normal to include resonance control with this type of filter, due to the limited application of the effect, but it has been included in the 80-6 design since it can be implemented for a low cost. Its effect is the same as with the low pass filter, namely, to emphasise a band of frequencies at the cut-off point.

BAND PASS FILTER. This will pass a band of frequencies centred on the pole frequency of the filter. The filter is derived from two poles of high pass followed by two stages of low pass filtering thus giving a 12dB/octave roll-off on either side of the centre frequency. The effect of the resonance control, or Q control, in this mode is to emphasise the cut-off frequency and so increase the rate of roll-off. This filter is used in imitative synthesis but more commonly a number of band pass filters need to be employed in order to achieve effective results.

PHASE SHIFT FILTER. This is an allpass filter with mixing of the original signal to create two deep notches. The effect of regeneration (resonance) is to sharpen the corners of the notches thereby increasing their depth. The 'phasing' effect is well known and most of the low cost phasers only have two notches and usually not as sharp as the 80-6P. A particular advantage of the design described below is its low noise but even so we believe that six notches are a minimum for a rich phasing effect.

2. DESIGN

The 80-6 filters utilise the CEM 3320 voltage controlled filter (VCF) IC from Curtis Electromusic Specialties. The functional block diagram and pin out of this device is shown in Figure 2. It will be seen that the CEM 3320 contains four independent filter stages which may be interconnected to provide a wide variety of filter responses. The pole frequency of the four stages is controlled by a single exponential generator which has a minimum range of ten octaves. The IC also includes a separate transconductance amplifier (pins 8 and 9) whose output is connected to the first

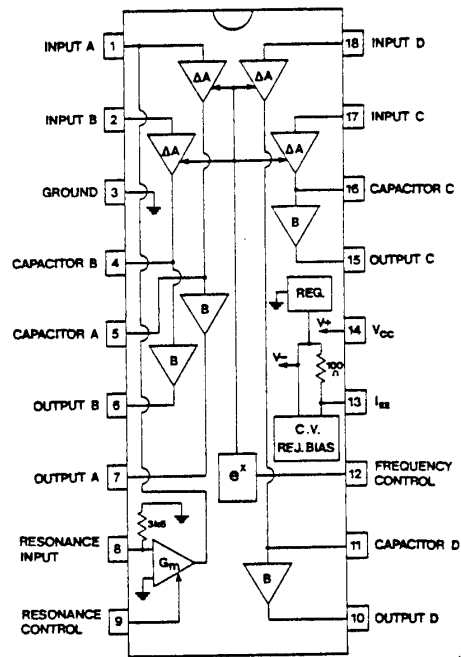


FIGURE 2. CEM 3320

filter stage. In the present design this amplifier is used to provide manual or external voltage control of regeneration (resonance). A major advantage gained by using the CEM 3320 is the low signal to noise ratio coupled with low distortion.

Figure 3 shows the complete circuit diagram for the 80-6L low pass filter. Note the letters A to E since within the area bounded by these points the components around the CEM 3320 vary in order to achieve the required filter response. Conversely, the components outside of these points, except for the value of R5, remains constant irrespective of filter type. Thus the modifications required for the 80-6H high pass filter, the 80-6B band pass filter and the 80-6P phase shift filter are shown in Figures 4, 5 and 6 respectively. The configuration of the filters follows the design principles given in the CEM 3320 data sheet and reference should be made to the latter if a full understanding of the design is required. Note, however, that the component values are based on using the filters with a $\pm 15V$ supply. Each filter is designed to accept 10V P-P signals and up to three signals may be mixed via the Signal 1 to 3 inputs which are summed by ICl. Since the Signal 3 input does not have a potentiometer its gain has been reduced. Thus three 10V P-P

signals may be mixed in equal proportions by setting RV1 and RV2 at 33% rotation. Similarly two 10V P-P signals may be mixed in any proportions via the Signal 1 and Signal 2 inputs so long as the combined percentage rotation of RV1 and RV2 does not exceed 100%. The overall gain of the filters is nominally one but allowance has been made for peak voltages that occur at maximum resonance. The signal level within the CEM 3320 is determined by R5 which varies according to the type of filter and has been chosen such that no clipping will occur with a 10V P-P signal. The input signal is inverted by IC1 but re-inverted by the output stage configured around IC2b. Note that the CEM 3320 is a current-in current-out device and for proper operation with a +15V supply there will be a quiescent DC voltage of about 6V5 on each output buffer. This DC voltage is trimmed out by RV8 prior to amplification of the filtered AC signal by IC2b.

Regeneration (resonance) is obtained by feeding the filtered signal to the transconductance amplifier via C12 and R32. The amount of signal fed back to the input stage is controlled by a positive DC voltage applied to pin 9 of the CEM 3320. By using a jack socket this voltage may be applied manually or it may be obtained from an external control voltage source. In the manual mode, R6 connected to the +15V supply forms an attenuating network with RV3 such that there will be approximately +10V at the input of

RV3. If a jack plug is now inserted into the jack socket, J3, then R6 is disabled and RV3 may be used to attenuate the external control voltage. The value of R32 varies with different filter types and its value has been chosen such that +10V applied to R7 will cause the filter to oscillate.

A current limiting resistor, R32, is always required on the negative supply to pin 13 of the CEM 3320 and its value must be selected according to the supply voltage used - refer to data sheet for further information. By adjustment of the current limiting resistor an improvement in control voltage feedthrough is obtained, and this is the purpose of RV9.

The control scale for the CEM 3320 is 18mV/octave and this is applied to pin 12. The control inputs are summed by IC2a. The scaling components are R13, RV7, R14 and R15 and are such that after calibration a one volt control voltage applied to R10 or R11 will shift the cut-off frequency by one octave. The best control range is achieved with a voltage at pin 12 varying from -25mV to +155mV. Also an increasing positive voltage at this pin decreases pole frequency. The ranging is achieved with R12 connected to the negative supply and in order to obtain the usual convention of increasing positive voltage to increase frequency the voltages are inverted by IC2a. Normally Control Input 1 would be connected to the keyboard control voltage so that the

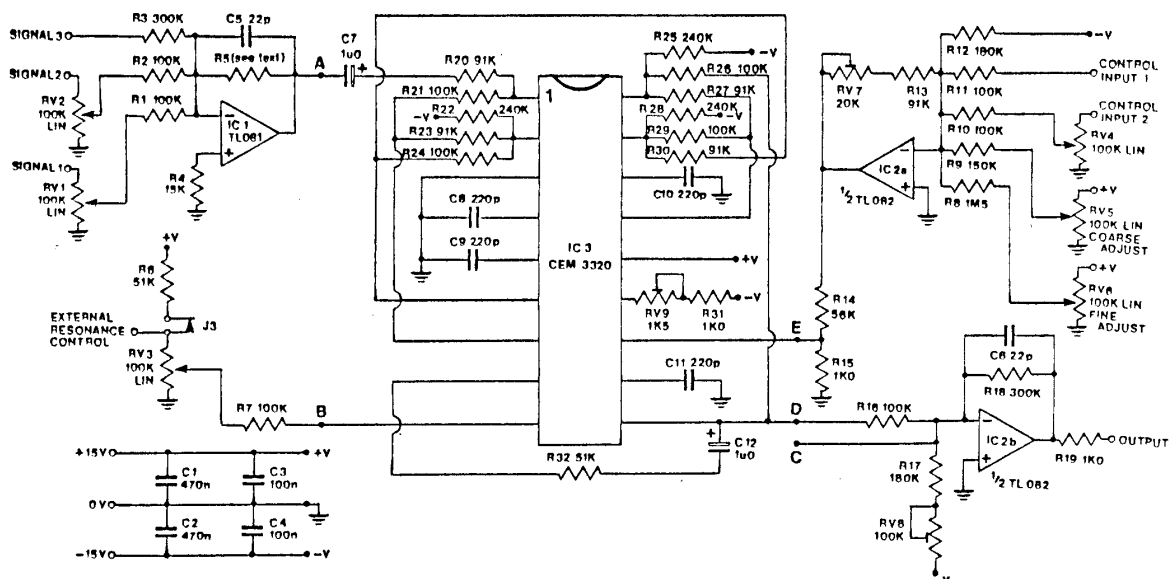


FIGURE 3. CIRCUIT FOR LOW PASS FILTER

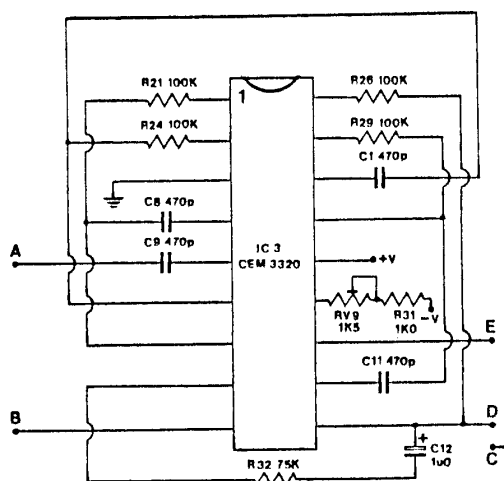


FIGURE 4. HIGH PASS FILTER

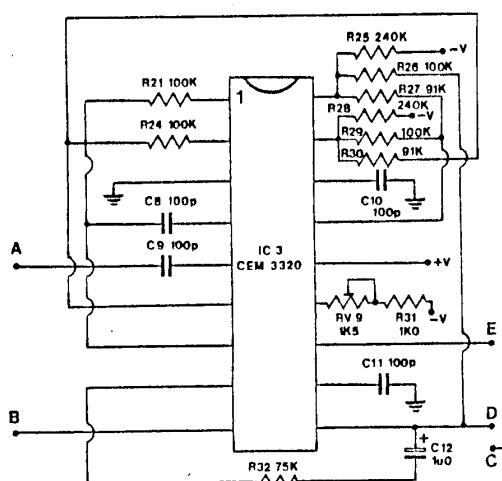


FIGURE 5. BAND PASS FILTER

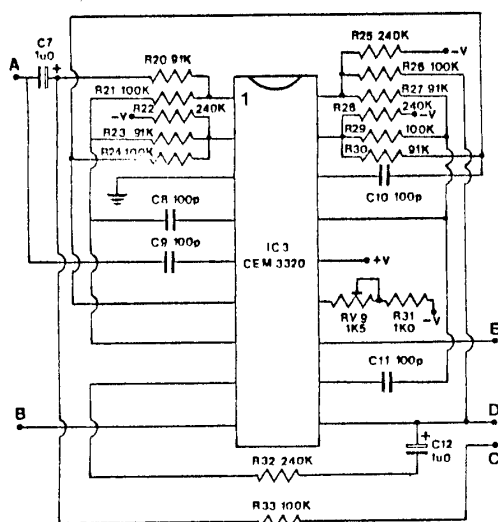


FIGURE 6. PHASE SHIFT FILTER

filter tracks the voltage controlled oscillator (VCO). Control Input 2 has an attenuator and the normal use for this input would be connection of an envelope generator to vary the cut-off frequency during the course of a note. This latter input is also suited to modulation from an external oscillator. The initial cut-off frequency is determined by the Coarse Control, RV5, and the Fine Control, RV6. Accurate adjustment of initial frequency is not usually available on synthesiser filters but it will be found useful for polyphonic applications, e.g., when used in conjunction with the ALPHADAC 16 microprocessor control system. RV5 allows adjustment over a range of ten octaves while the Fine Control, RV6, has a one octave span. The filter capacitors, C8 to C11, are chosen such that the filter covers a 1000:1 frequency range with the lowest frequency being typically in the range of 20 to 25Hz.

3. CONSTRUCTION

The 80-6 PCB has the component placement printed on which simplifies construction. This component overlay is reproduced in Figure 7. It should be noted, however, that not all of the component locations are used, as will be evident from examination of the circuit diagrams shown in Figures 3 to 6. Components used should therefore be checked against the components list. A more important point is that there are alternative locations for the polystyrene capacitors C8, C9, C10 and C11. The locations are either identified by the capacitor number or the number followed by the suffix 'H', e.g., C8H. The locations are listed below for the four filter types.-

- i) For the 80-6L low pass filter the four capacitors, C8 to C11, are located in the positions where the capacitor number is NOT followed by the 'H' suffix.
- ii) For the 80-6H high pass filter and the 80-6P phase shift filter then C8 to C11 ARE installed in the positions denoted by the 'H' suffix.
- iii) In the case of the 80-6B band pass filter C8 and C9 are installed at the positions marked C8H and C9H while C10 and C11 are installed at the positions marked C10 and C11.

The usual care must be taken over the orientation of the electrolytic capacitors and the IC'S. Even when the latter are installed in their DIL sockets the number '1', denoting pin 1, should still be visible on the PCB. In any event compare the completed PCB against Figure 7 prior to applying power.

Wiring of potentiometers and other panel connections to the PCB are shown in Figure 8. This diagram illustrates the components when viewed from the rear of the panel. The arrows and associated letters indicate that a wire connection must be made from the position shown to the PCB. The latter has a connecting point on its front edge with letters corresponding to those shown in Figure 8.

The jack sockets in the diagram are of the type supplied by Digisound Limited. The top connection, as illustrated, is the connection which is made with the jack when the latter is inserted. The lower connection is disabled by insertion of a jack plug. Finally, the tab under the socket is the ground connection. It is recommended that all of these ground connections are wired to the 0V line since this facilitates connection of the filters to other equipment which may be using a separate power supply. The ground tabs may be joined together using tinned copper wire but other panel wiring should be made with insulated wire. 1/0.6mm insulated wire is ideal for panel wiring since it retains any shaping and thus allows a neat appearance to be obtained.

On completion of the construction stage carefully examine the underside of the PCB to ensure that all connections are properly soldered and that no solder bridges have been formed. Also check polarity of power supply before powering up.

4. CALIBRATION

A simple check may be made of the frequency control input and also that the wiring of RV5 and RV6 are correct. With IC3 removed, the power on and the coarse and fine controls fully anti-clockwise measure the voltage at the junction of R14 and R15 and adjust RV7 to obtain +155mV. Now turn RV5, coarse, or 'octaves', control fully clockwise and the voltage should be about -25mV. If you are able to make these measurements with a reliable voltmeter but do not obtain values which are close to those given then check the control input components and double check that there are no solder bridges on the foil side of the PCB.

Turn off power and insert IC3, power up, turn RV3 (resonance control) fully anti-clockwise and RV5 to about mid position. Measure the voltage at the output of the filter module and adjust RV8 until a zero reading is obtained. This cancels the DC voltage at the output from pin 10 of IC3.

The next step is to trim the control voltage feedthrough using RV9. Power up the filter and connect the +/-5V sine or triangle wave from the 80-2

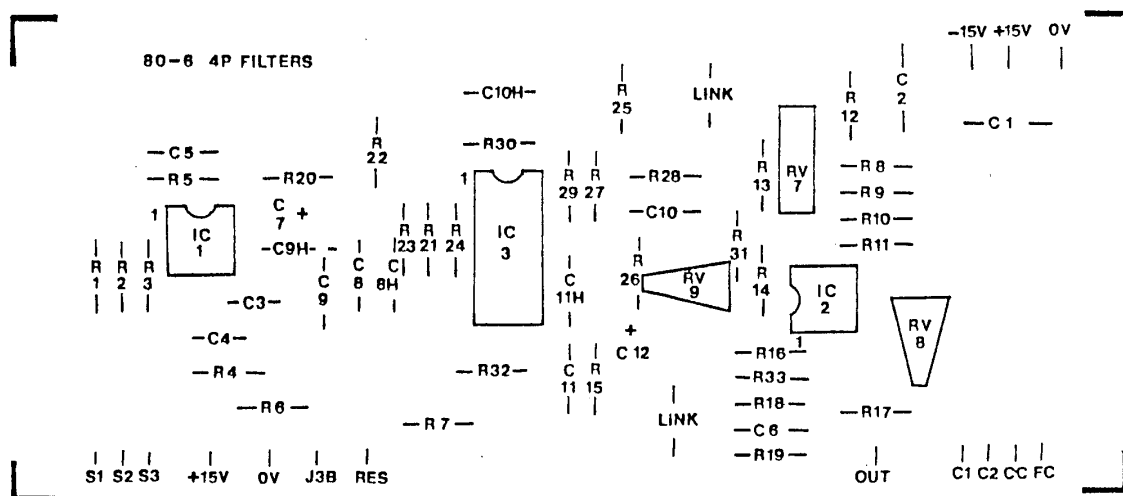


FIGURE 7. 80-6 COMPONENT OVERLAY

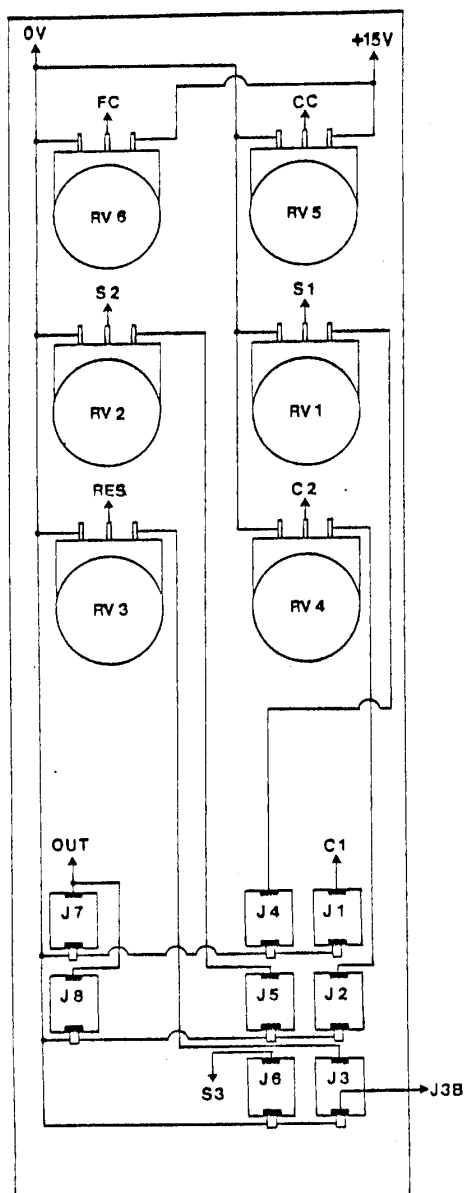


FIGURE 8. PANEL WIRING

VCO, or other oscillator with a similar output, to the Control Input 2. The oscillator should be at a frequency of about 50 to 100Hz. RV4 and RV5 should be set midway and all other potentiometers fully anti-clockwise. Connect the output of the filter to an amplifier and adjust RV9 for minimum output. Some adjustment to RV4 or the amplifier 'volume' may have to be made in order to obtain the optimum position for RV9. The value of RV9 or R31 must not be altered. If a suitable oscillator is not available then this step may be omitted and RV9 set to its mid position.

The last step is to calibrate the filter so that it will track 1V/octave

oscillators, such as the DIGISOUND 80-2. The resonance control feedback resistor, R32, has been selected such that the filter will oscillate when some frequency control input is present, thus turning the filter into a low distortion sine wave oscillator. A calibrated VCO will normally be available at this stage in the construction of a synthesiser and this will simplify calibration. Any of the following techniques may be used in addition to treating the filter as an oscillator and using the methods described for the VCO.

i). **Beat frequency technique.** Apply about 3V5 to Control Input 1, which will be the normal input for the keyboard, and adjust PR7 to give a frequency of about 250 to 300Hz when RV3 is rotated to the point where oscillation is sustained - as heard through one channel of an amplifier. Connect a calibrated VCO to the other channel of the stereo amplifier and apply an external control voltage to the VCO until there is no beat frequency. Increase voltage to both VCO and VCF frequency control inputs by exactly one volt and the adjust RV7 until no beat frequency is heard.

ii). **Lissajous figures.** Same procedure as (i) but outputs from VCO and VCF are coupled to the X and Y inputs of an oscilloscope to generate Lissajous figures. This method will probably be described in the handbook accompanying the oscilloscope. As an example, if both inputs are sine waves of equal amplitude then a stable circle will be generated when their frequencies are matched.

iii). **Maximum signal amplitude.** Another approach with an oscilloscope is to apply a signal of about 250Hz from a calibrated VCO to Signal Input 1 of the filter and observe the output from the filter on the oscilloscope. Apply a voltage to Control Input 1 of the filter until the point where the output reaches its maximum amplitude is observed. A small amount of resonance will help. Increase voltage to both VCO and VCF by exactly one volt and adjust RV7 until maximum amplitude is restored.

5. COMPONENTS

COMPONENTS COMMON TO ALL FILTERS.

RESISTORS, 5%, 1/4w carbon film
R1,2,7,16,21,24,26,29 100k
R3,18 300k
R4 15k
R6 51k
R8 1M5
R9 150k
R17 180k
R19,31 1k0

RESISTORS, 1%, 1/4w metal film, 100ppm
R10,11 100k
R12 180k
R13 91k
R14 56k
R15 1k0

POTENTIOMETERS, PRESETS
RV1,2,3,4,5,6 100k lin.
RV7 20k cermet multiturn
RV8 100k carbon
RV9 1k5 carbon

CAPACITORS
C1,2 470n polyester
C3,4 100n polyester
C5,6 22p polystyrene
C12 1u0 PCB electrolytic

SEMICONDUCTORS
IC1 TL 081
IC2 TL 082
IC3 CEM 3320

ADDITIONAL COMPONENTS FOR LOW PASS FILTER, 80-6L.

RESISTORS, 5%, 1/4w carbon film
R5 36k
R20,23,27,30 91k
R22,25,28 240k
R32 51k

CAPACITORS
C8,9,10,11 220p polystyrene
C7 1u0 PCB electrolytic

ADDITIONAL COMPONENTS FOR HIGH PASS FILTER, 80-6H

RESISTORS, 5%, 1/4w carbon film
R5 24k
R32 75k

CAPACITORS
C8,9,10,11 470p polystyrene

ADDITIONAL COMPONENTS FOR BAND PASS FILTER, 80-6B

RESISTORS, 5%, 1/4w carbon film
R5 33k
R25,28 240k
R27,30 91k
R32 75k

CAPACITORS
C8,9,10,11 100p polystyrene

ADDITIONAL COMPONENTS FOR PHASE SHIFT FILTER, 80-6P

RESISTORS, 5%, 1/4w carbon film
R5 12k
R20,23,27,30 91k
R22,25,28,32 240k
R33 100k

CAPACITORS
C8,9,10,11 100p polystyrene
C7 1u0 PCB electrolytic