The Voltage Controlled Filter module has a 100:1 control range.

ETI 3600/4600

THIS month we describe the operation and construction of the Voltage Controlled Filters (VCF). These filters have more than a two decade range and provide switchable lowpass, highpass and bandpass modes of operation, all with a 12 dB per octave slope.

The operation of this filter is covered by Provisional Patent (Aust) 3651.

CONSTRUCTION

The method of assembly is similar to that used for most of the other modules. A small aluminium bracket is used to hold the printed circuit board and associated switches and potentiometers.

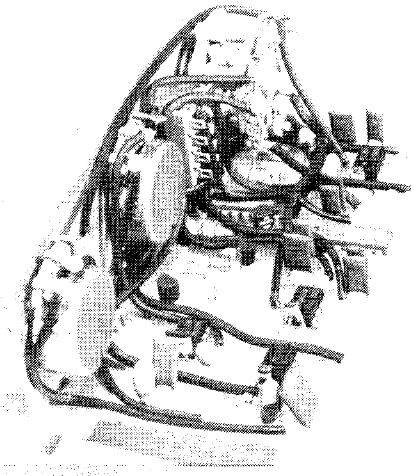
When assembling the components to the printed circuit board the usual care must be taken with the orientation of

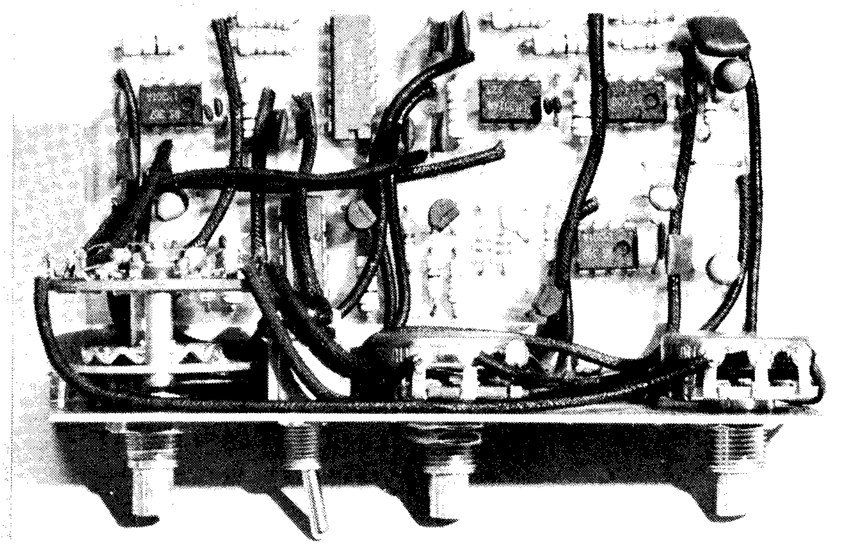
PARTS LIST V.C.F.

R1	Resistor	220 k	¼W	5%
R2	"	22k	"	"
R3	"	680Ω	"	"
R4	"	6.8 k	"	"
R5	"	39Ω	"	"
R6	"	330Ω	"	"
R7,8,14	"	1.2 k		
R17,	"	1.2 k		
R9	"	200 k	"	"
R10	"	150 k	"	"
R11	"	100 k	"	"
R7,8,14	"	10 k		
R15,18,19	"	10 k		
R20	"	3.3 k	"	"
RV1	Potentiometer	100 k log rotary		
RV2	"	25 k lin rotary		
C1,5,10,15	Capacitor	33pF ceramic		
C2	"	470pF "		
C3	"	47pF "		
C4	"	0.082µF polyester		
C6,8,11,13	"	0.022µF polyester		
C7,9,12,14	"	0.0047µF polyester		
C16,17,18,20	"	10µF 20V tag tantalum or pc electrolytic		
C19	"	0.01µF polyester		
Q1,3	Transistor	PN3638 or similar		
Q2	"	PN3643 "		

IC1,3,4,5 Integrated circuit LM301A
IC2 Integrated circuit SCL4001AL **
IC6 Integrated circuit SCL4016AL *

** MUST be Solid State Scientific.
* Prefix and suffix varies from manufacturer to manufacturer.
D1-D3 diode IN914
SW1 3 pole 3-position rotary switch
SW2 4-pole 2-position toggle switch C & K type 7401 or similar
PC Board ETI 601 h
metal bracket to Fig. 3.





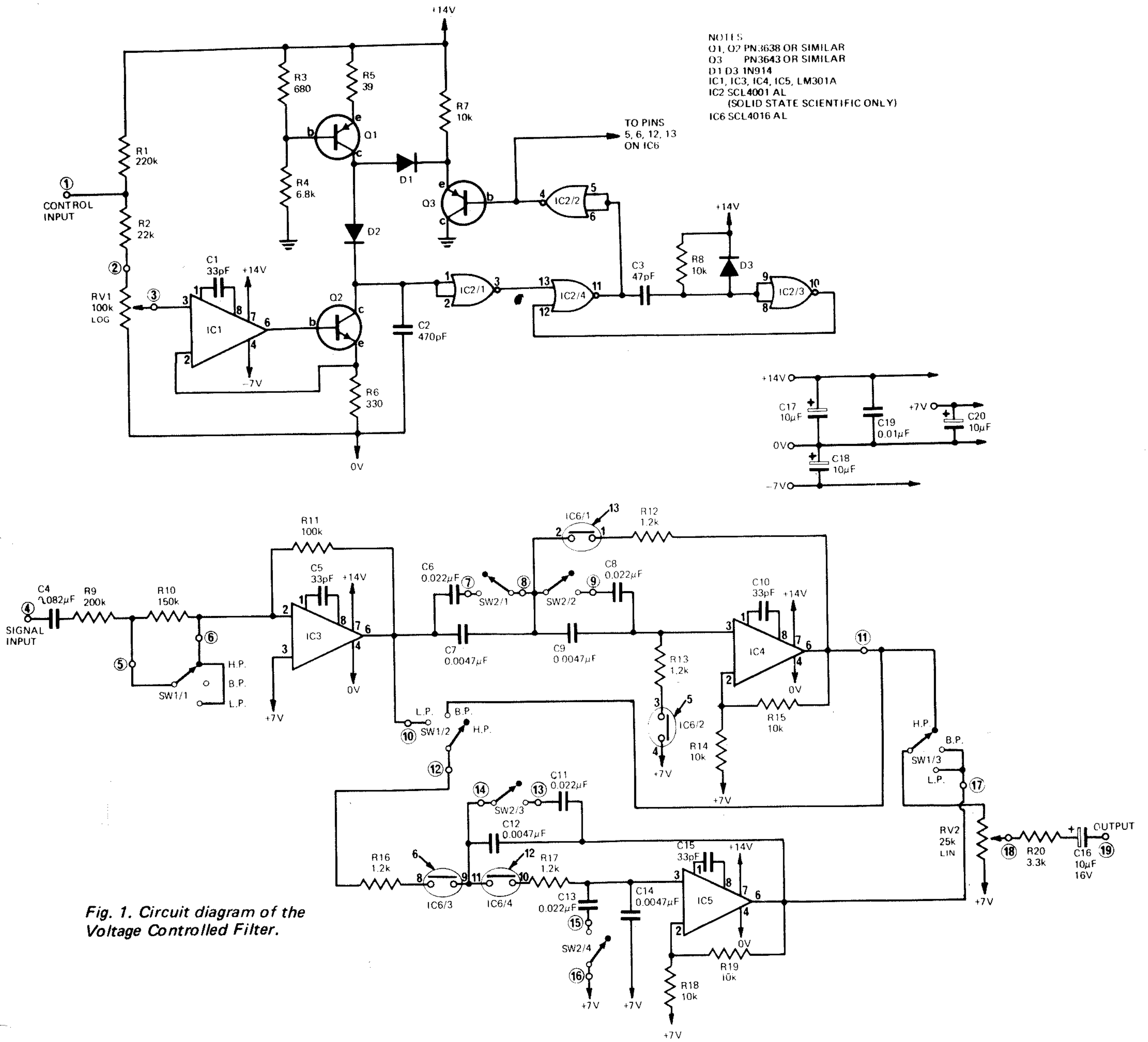
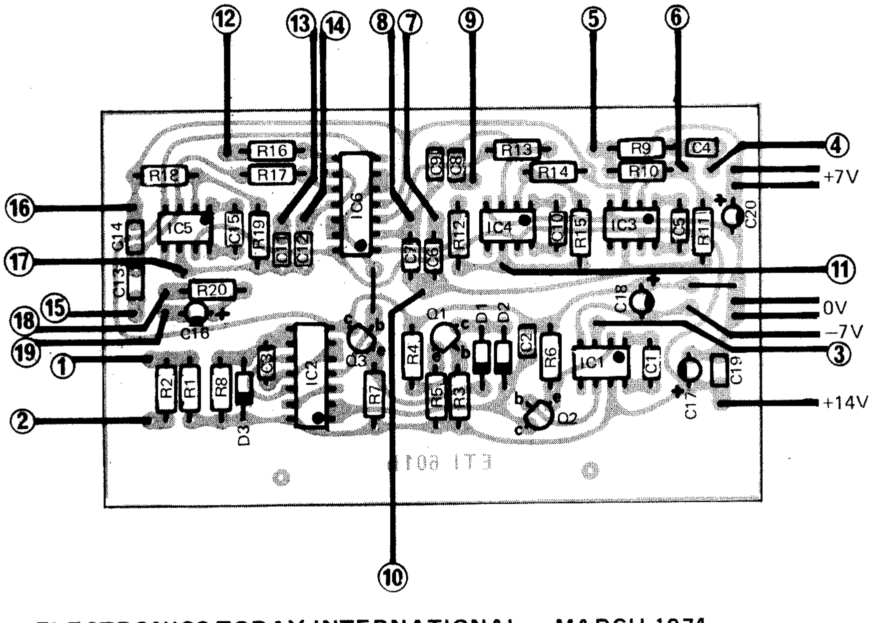


Fig. 1. Circuit diagram of the Voltage Controlled Filter.



◀ *Fig. 2. Component overlay of VCF.*

SPECIFICATION

MODES	low pass high pass band pass
SLOPES	12 dB/octave
Q	bandpass 1.5
CONTROL RANGE	> 100 : 1
FREQUENCY RANGE (Nominal)	
Low range	20 Hz – 2 kHz
High range	100 Hz – 10 kHz
INPUT VOLTAGE RANGE	
Time control at maximum.	30 mV – 5 V

NOTE: Low end of range is limited by the chopping frequency dropping below 20 kHz thus becoming audible. High end of range is limited by the maximum obtainable oscillator frequency. (> 2MHz).

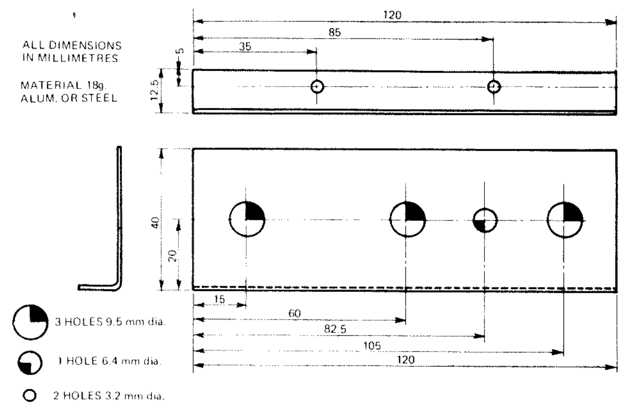


Fig. 3. VCF mounting bracket.

polarized components. Assemble the components to the board in accordance with the overlay Fig. 2, using sockets for the CMOS ICs at least. Note that IC2 MUST be a SCL4001AL as made by Solid State Scientific. Although this component is made under the same number by other companies, the Solid State Scientific version is much faster and has a much narrower linear region. If another brand is substituted the oscillator may work over a restricted range, or worse still may not work at all.

Wiring from the printed circuit board to switches and potentiometers is as shown in Fig. 4.

See also Errata column – page 79. ●

HOW IT WORKS

The voltage Controlled Filter consists of four main sections:

1. The Buffer Amplifier.
2. A High Pass Filter.
3. A Low Pass Filter.
4. A Voltage/Frequency Converter.

The buffer amplifier, IC3, is used to provide a high input impedance (greater than 200 k) and a level shift. In the low pass and high pass modes the gain is approximately –6 dB and in the bandpass mode –11 dB. The reason for this will become obvious as we proceed. Note, that although we have called this circuit an amplifier, the output is in fact less than the input.

If, for the moment, the CMOS ICs (which are analogue switches) are considered to be ON (IC6, 4016), it may be seen that the highpass (IC4) and lowpass (IC5) filters are normal 2-pole active types. They have a gain of 6 dB (which accounts for the 6 dB loss in the buffer) and have a 1 dB rise just before cutoff frequency is reached.

In the bandpass mode the two filters are connected in series and the resultant overall gain is 11 dB, hence the 11 dB cut in the buffer-amp in this mode.

Thus it can be seen that by selecting buffer gains the overall gain is held at unity in all modes.

Note that the supply rails are +14 volts and zero. Thus the 'common' line, as used internally in the unit, is +7 volts.

To vary cutoff frequency, either the resistive or capacitive arms of the filter must be altered. To select the HIGH or LOW range (10 kHz or 2 kHz nominal upper limit) we change the capacitive arms. For voltage control we use special circuitry to change the resistive arms as follows:

If a resistor is switched in and out of circuit at a variable rate, and for a fixed duration, the effective resistance will be equal to Rx TOTAL TIME/ON TIME. A voltage-controlled oscillator is used to switch the resistive arms of the filter on for a period of 200 nanoseconds and off for a time which is made variable. Take for example R12 (1.2 k) which is switched by IC6/1 (CMOS IC has a resistance of about 300Ω when on). If IC6/1 is switched at 1 MHz the effective resistance will be

$$\frac{(1200 + 300) \times 10^{-6}}{200 \times 10^{-9}} = 7500\Omega$$

If the oscillator frequency is reduced to 100 kHz the effective resistance will be 75 k, since the cutoff frequency of the filter is proportional to resistance, and the resistance is proportional to chopping frequency. If now the chopping frequency is made proportional to input voltage, it can be seen that cutoff frequency will be proportional to input voltage.

The voltage-to-frequency converter used does in fact have a linear relationship from about 10 kHz to 3.5 MHz. Frequencies below 20 kHz however should not be used, as the chopping frequency will become audible.

A variable constant-current source is provided by IC1 and Q2, where the base-emitter voltage of Q2 is compensated by taking feedback from the emitter of Q2 to IC1. A further constant current source is provided by Q1. The current from Q1 can flow either via Q3 to ground (output of IC2/2), or through Q2 as well as into C2. The current provided by Q1 is higher than the maximum available through Q2 and thus C2 will be charged by a constant current (when IC2/2 is high) the value of which is determined by the input voltage.

The voltage on C2 is passed to the input of IC2/1 such that if this voltage is above approximately 7 volts the output of IC2/1 will be low (0V) whereas if the input voltage is less than 7 volts the output will be high (+14V).

A monostable having a pulse duration of 200 nanoseconds is formed by IC2/3 and IC2/4. If the input at pin 13 of IC2/4 goes high a negative going 200 nanoseconds wide, pulse occurs at pin 11 and is inverted by IC2/2. This positive pulse will turn off Q3 allowing the current from Q1 to charge C2. The voltage across C2 will rise about 3V in the 200 nanoseconds, and will go above the 7V level causing IC2/1 output to go low. Capacitor C2 will now be discharged by the current through Q2 until C2 voltage falls below the 7V level, retriggering the monostable, thus generating another 200 nanosecond pulse.

The repetition rate of the pulse is determined by the current through Q2 and hence is proportional to the input voltage. The 200 nanosecond pulse thus derived is used to turn on the CMOS switches in the active filters.

The input voltage to IC1 is variable by means of RV1 which thus acts as a 'tune' control. Resistor R1 provides a static voltage across RV1 which allows the filter to be tuned to a fixed frequency in the absence of a control input.

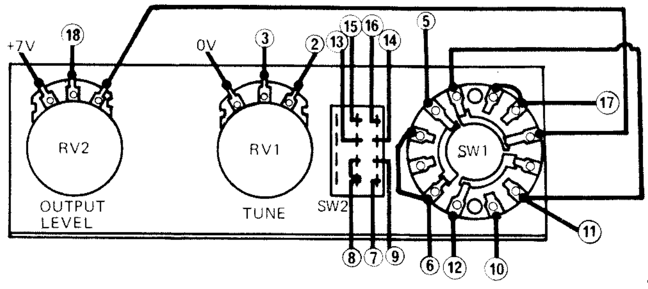


Fig. 4. Wiring diagram for switches potentiometres.