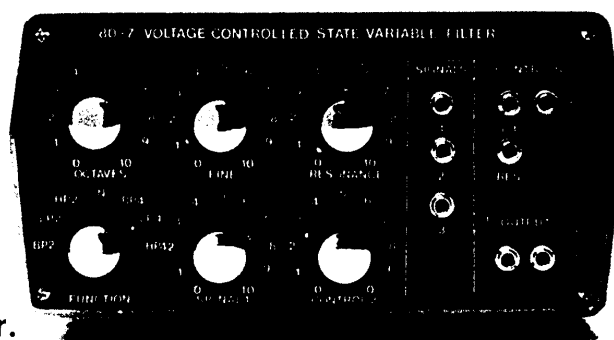


STATE VARIABLE FILTER

Choose one of seven filter responses with this voltage controlled state variable filter design by R.C. Blakey for your Project 80 modular synthesiser.



The Voltage Controlled State Variable Filter has low pass, high pass, band pass and notch filtering capabilities. The first three responses are available as both two pole (12 dB/octave) and four pole (24 dB/octave) filters. Manual and external control of resonance is included.

Design Features

The state variable filter using three operational amplifiers, as shown in Fig 1, is probably familiar to most readers.

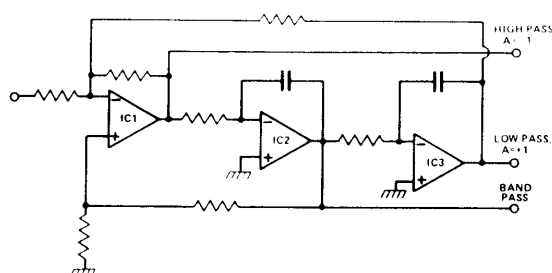


Fig. 1. Circuit diagram of a state variable filter using three op amps.

A simple way to convert this into a voltage controlled filter is to interpose operational transconductance amplifiers (eg CA3080) prior to the two integrators around IC2 and IC3. Voltage control of Q (or resonance) can also be obtained by using an OTA in the feedback to the non-inverting input of IC1. This is the basis of the present design. Such a filter gives 12 dB/octave low and high pass responses and second order band pass response. By placing two such filters in series it is possible to increase the roll-off characteristics by a factor of two. In practice, however, this is often difficult due to component mismatching which results in uneven roll-off characteristics. The problem has been minimised in this design by using a customised integrated circuit from

Solid State Micro Technology for Music, namely, the SSM2040. This device contains four closely matched transconductance amplifiers and an exponential generator which is common to the four cells. For resonance control the relatively new LM13600, dual transconductance amplifier, is used in the feedback of the two stages of state variable filters. Both manual and external voltage control of resonance is provided and while these controls are additive the maximum useful range is our standard 0 to 10 volts into 100k.

Seven filter responses are available, one at a time, via a selector switch — low pass (12 and 24 dB/octave); high pass (12 and 24 dB/octave); band pass (2nd and 4th orders); and notch. The low pass and high pass outputs are 180° out of phase and so combining these outputs results in a notch. A notch filter is of limited use in synthesis since the ear only responds to frequencies present and not to frequencies which are absent. The latter may sound rather obvious but since the notch filter allows most frequencies to pass the ear cannot detect the difference between the original and filtered signals, except in some exceptional circumstances or unless the notch is fairly wide.

The filter has three signal inputs and the combined signal should not exceed 10 volts peak to peak. An attenuating potentiometer has been provided on one of the inputs and if mixing of signals is required then external attenuating controls can be used. The filter has approximately unity gain at maximum resonance feedback.

Frequency response control is obtained using the exponential converter within the SSM2040 and an attenuating network, with adjustment, allows the 1 V/octave characteristic to be obtained. Initial frequency (zero control voltage) is set to approximately 20 Hz and the filter has a 1,000:1 control range. Control Input 1 is used for keyboard input. Control Input 2 has an attenuating potentiometer for use in conjunction with an envelope shaper, etc. A coarse control provides manual sweep over 10 octaves and a fine control is included for more accurate initial setting and has an adjustment range of one octave. Temperature stability should not be

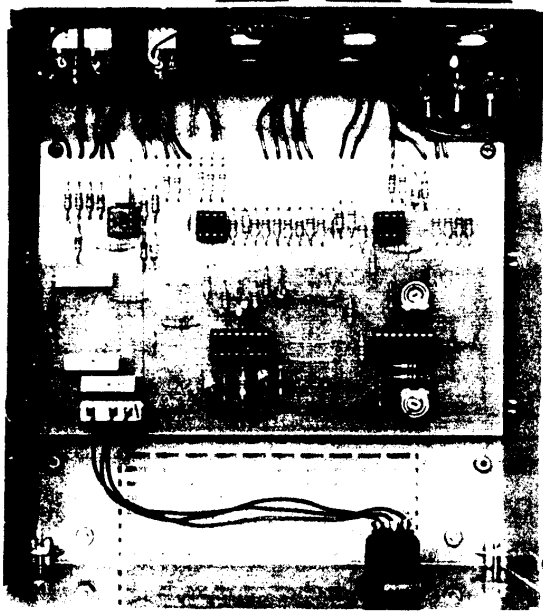


Fig.2. The voltage controlled state variable filter can be built into this Teko Alba case (see Buylines) as a 'stand alone' project.

a problem under normal circumstances. If required, however, R47 may be replaced by a Q81 1k Ω , 1% temperature compensating resistor.

Construction

The first point to note is that the SSM2040 outputs (OUT, CAPACITOR and IN) are not short circuit protected and shorting any of these to either supply will generally blow the circuit, although connections to ground can be tolerated for several seconds. Some additional resistors have been used to provide additional safeguard in the latter circumstances. Take particular care on both the orientation of this IC and when any probes are connected to components on the PCB, for whatever reason.

Identify and solder the seven wire links before installing components. The capacitors around the SSM2040 will accept both preformed (as illustrated) and normal polystyrene capacitors. When all components have been installed, the two holes remaining around IC1 are for installing a Q81 temperature compensating resistor, when required. The manual resonance control (RV2) may be wired via the jack socket used for the external resonance control such that the former is disabled when external control is in use. The manual and external controls may also be wired up independently but no increase in gain will be achieved when their combined voltages exceeds the equivalent of about 10 volts into 100k, eg manual control half way and five volts external input. In fact the resonance will begin to decrease somewhere above 10 volts.

The most complicated task is wiring up the switch

but this should not pose any problems if reference is made to both the circuit diagram and the PCB layout.

Setting Up And Calibration

First adjust the module to achieve the seven filter responses. These can be readily observed on an oscilloscope by using the VCLFO and VCO as a sweep frequency generator, as described for the 80-6 filters. There are, however, only two adjustments to make in order to ensure that the seven responses are present (assuming no wiring errors) and these can be made by ear with the aid of an amplifier, as shown below.

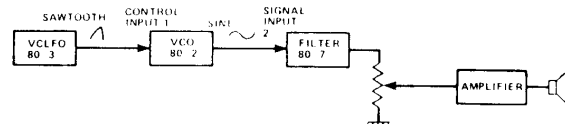
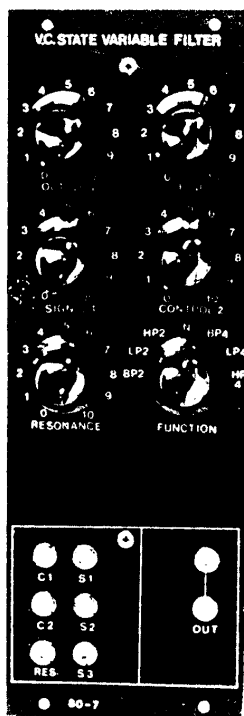


Fig.2. The seven filter responses can be inspected with the circuit shown above.

Set Coarse frequency controls on VCLFO and filter 80-7 to mid position and to zero on the VCO. With the edge connections of the filter facing you and the components uppermost set the wipers of both PR1 and PR2 to about the 9 o'clock position. Put selector switch on BP2 output and slowly turn PR1 anti-clockwise. Initially there may be no output but then a low pass output will be heard. Further rotation of PR1 will result in a fairly abrupt change from low pass to band pass and this is audibly obvious. PR1 should be left at this setting. Now switch to LP4 output and turn PR2 slowly clockwise. Initially nothing will be heard and then a low pass response. PR2



If you wish to build all of the Project 80 modules and install them in a single case with keyboard, mount the PCB on this front panel. At the end of the series you'll have a matching set.



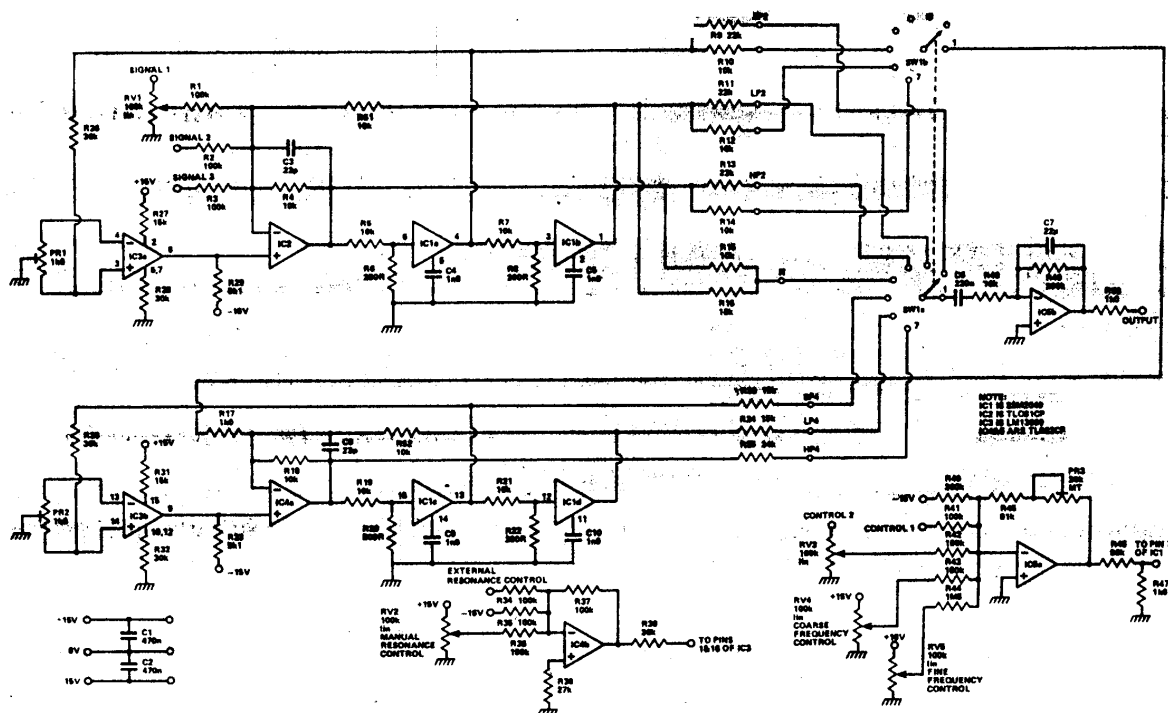


Fig.2. Circuit diagram of the state variable filter.

HOW IT WORKS

The SSM2040, VCF produced by Solid State Micro Technology for Music, contains four independent filter sections which may be interconnected to provide a wide variety of filter responses. Each section contains a transconductance amplifier followed by a buffer and by using two of these sections with an external op amp a state variable filter may be realised as shown below.

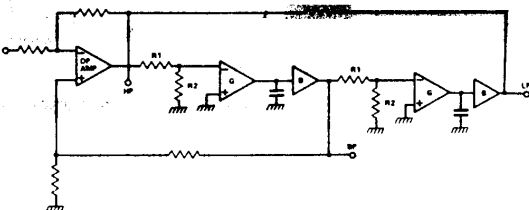


Fig.3. Using the sections of the SSM 2040 and an op amp to form a state variable filter.

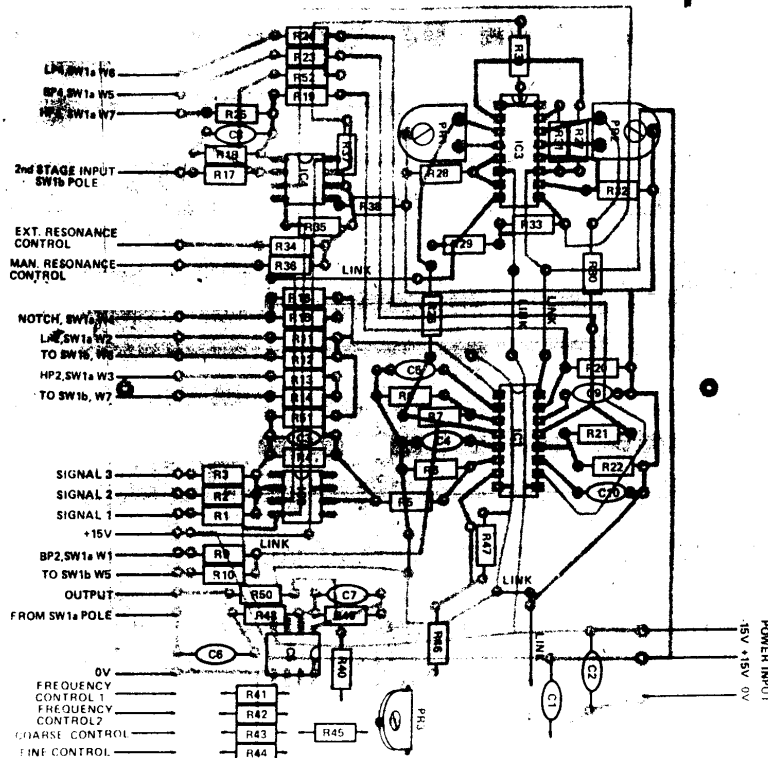
The signal levels into the gain cells should be limited to 2mV RMS and since R2 should be 200 R for optimum control rejection then R1 is 10k with a 1 V signal at the op amp output. The equivalent input noise for the SSM2040 is 0.5 uV RMS at 20 Hz to 20 kHz so a signal to noise ratio of about 90 dB is achieved. In the first state variable filter section around IC3a, IC2, IC1a and IC1b a 10 V signal into R1, 2 or 3 is reduced by IC2 and R4 to produce the 1 V into attenuating resistor network R5, 6. The two pole low pass, high pass and band pass filter responses are derived and a notch produced by combining the low and high

pass outputs which are 180° out of phase. These four outputs are connected to the rotary switch, SW1a and the signal restored to its original level by R49, R50 and IC5b. The signals are AC coupled into IC5b to remove any DC offsets.

The low pass, high pass and band pass outputs from the first stage are also separately connected to rotary switch, SW1b and fed into the second stage formed around IC3b, IC4a, IC1c and IC1d. The four pole outputs derived in this section return to switch SW1a and are available via IC5b, as before.

Resonance control is provided by an LM13600 (IC3), dual transconductance amplifier, interposed between the band pass output and the non-inverting input of the filters external op amps (IC2 and IC4a). The amount of feedback is controlled by the current developed across R39 and this has been commoned for both halves of the LM13600. Manual control is obtained via RV2 and R36 into IC4b and external voltage control via R34 into the same input summing node. The control voltage should be limited to an equivalent of 10 V into 100k.

Frequency control is common to all four amplifiers in the SSM2040 and best results for a 1,000 to 1 sweep in the range 20 Hz to 20 kHz is obtained with +90 V at pin 7. Resistor R40 connected to -15 V provides approximately +90 mV and a lower frequency limit of about 20 Hz. A 0 to +10 V control voltage into Control Inputs 1 or 2 will then allow frequency adjustment over a range of ten octaves. Manual adjustment over a ten octave range is provided by the Coarse Control (RV4 into R43) and Fine Control over a range of one octave by RV5 into R44. Precise adjustment of the 1 V per octave response is achieved by adjusting the gain of IC5a using PR3.



PARTS LIST

Resistors 1/4W, 5% carbon film except where stated

R1,2,3,34,35,37	100k
R4,5,7,10,12,14,15,16,18,19,21,48,51,52	10k
R6,8,20,22	200R
R9,11,13	22k
R17,50	1k0
R23,24,27,31	15k
R25	24k
R26,28,30,32,39	30k
R29,33	5k1
R36	150k
R38	27k
R40	300k, 1% metal film
R41,42	100k, 1% metal film
R43	150k, 1% metal film
R44	1M5
R45	91k, 1% metal film
R46	56k, 1% metal film
R47	1k0, 1% metal film
R49	200k

Potentiometers

RV1,2,3,4,5	100k linear
PR1,2	1k0 carbon
PR3	20k cermet multiturn

Capacitors

C1,2	470n polyester
C3,7,8	22p polystyrene
C4,5,9,10	1n0 polystyrene
C6	220n polyester

Semiconductors

IC1	SSM2040
IC2	TL081CP, or equivalent
IC3	LM13600
IC4,5	TL082CP, or equivalent

Miscellaneous

SW1	2 Pole 7 (or more) Way Rotary Switch
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should be left at the setting where the low pass output commences. The selector switch can then be turned through its seven outputs to check that the appropriate response is present and these can be clearly identified by ear. If an oscilloscope is available then switching to BP2, LP4 and HP4 outputs and making minor adjustments to both PR1 and PR2 may result in some improvement to the filter responses.

The final step is to calibrate the filter for 1 V/octave frequency control. The 80-7 filter will not oscillate at maximum resonance feedback and so the best approach is to observe the maximum signal amplitude using an oscilloscope. Connect the sinewave output from a VCO to Signal Input 2. Connect the LP4 output to an oscilloscope, set VCO frequency to about 250 Hz and adjust RV4 (Coarse Control) and RV5 (Fine Control) to obtain maximum signal amplitude. Increase voltage on Control Inputs 1 of both VCO and VCF by exactly 1 V and adjust PR3 until maximum amplitude is restored. Repeat the above steps until calibration is achieved. If an oscilloscope is not available then an alternative ap-

proach is to set all VCF controls to zero and apply about 4 V to Control Input 1 and measure the voltage at the junction of R46 and R47, using a high input impedance voltmeter. Increase the control voltage by exactly 1 V and then adjust PR3 to obtain an 18.0 mV change at the junction of R46 and R47. Again repeat the procedure until an 18.0 mV change is obtained for a 1.000 V change in control voltage.

