A SUPER SIMPLE THREE-MODE SIMULTANEOUS INPUT, VARIABLE RESONANCE, VOLTAGE CONTROLLED FILTER FOR SIGNAL PROCESSING

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Unlike the well known State Variable Voltage Controlled Filter with one input and three separate outputs, this V.C.F. has three separate inputs and only one output. This allows simultaneous Low Pass, High Pass or Band Pass operation on separate input signals with all filtered signals appearing at the one output.

The Steiner filter described here is of second order capable of three mode operation, realized through slight modification of the well known Sallen and Key low pass filter circuit. (Fig. 1)

The Steiner circuit is very much different from the very popular state variable filter and is shown in basic form in Figure 2. The technique of making it voltage controllable will be shown later.

The basic Sallen and Key circuit (Fig. 1) operates only in the low pass mode because the signal is fed into V1. What happens however, if we feed the signal in at different points of the circuit?

We can place op amp buffers at various points of the circuit to allow the insertion of the signal at any desired point without disturbing the circuit characteristics.

If no signal is present at a particular buffer input the buffer will act as a ground because of its zero output impedance. From the viewpoint of each input buffer the filter circuit appears as a different circuit configuration.

By examining the circuit of Figure 2 we can see by redrawing the circuit that a signal fed in at V1 sees a basic lowpass circuit of Figure 3A. A signal fed in at V2 will see a basic band pass circuit which is simply a high pass R.C. network followed by a low pass R.C. network with feedback. (Fig. 3B) Similarly a signal fed in at V3 will see a basic high pass R.C. network. What we now see are three different simple R.C. frequency selective networks with an added amplifier to form three different kinds of active filters.

The behavior of the circuit in Figure 2 for the special case of $R_1=R_2$ and $C_1=C_2$, can be described by the following transfer function:

$$V_4 = \frac{V_1 + V_2 \tau S + V_3 \tau S (2 + \tau S)}{\alpha + (3\alpha - 1) \tau S + \alpha \tau^2 S^2}$$

$$\text{where } \tau = R_1 C_1 \quad \text{and} \quad \alpha = \frac{R_3}{R_3 + R_4}$$

The noninverting amplifier is used to enable the Q to be adjustable.

Voltage Controlled Circuit

The actual voltage controlled filter is a very similar circuit to that of Figure 2 except that silicon diodes are used as resistors R_1 and R_2. By varying the amount of DC voltage across these diodes we can change their effective resistance over a very wide range.

Two problems are introduced with this technique:
1. The bias voltage across the diodes is an unwanted parasite in the presence of the signal which is also across the diode. 2. The diodes being nonlinear devices can cause nonlinear distortion as the signal itself acts as a changing bias voltage across the diodes.

The above two problems can be corrected by actually making two R_1, R_2, C_1, C_2 networks and connecting them in parallel (basic circuit of two networks in parallel is shown in Figure 4) such that the bias control voltage pulls one set negative and the other set positive leaving zero control (bias) voltage at their output. The signal voltage, however, is fed in both sides in phase and therefore passes through and appears at their output. Signal distortion from the nonlinearity of the diodes cancells itself since the bias effect of the signal on the diode is opposite for each set of diodes and capacitors. The signal distortion can be kept very low if the signal amplitude does not exceed approximately 35 mv.

The situation described above is achieved very simply by placing a string of six diodes and three capacitors between the two collectors of a simple two transistor differential amplifier. (Fig. 6)

The input buffers for v1, v2, and v3 can be substituted with low value resistors if their value is negligible in comparison to the impedance values of the R.C. filter network. (Fig. 5) The effects that these input resistors have on the filter's operation tend to cancel themselves since a resistance at one input will have an opposite effect from a resistor on another input.

We have now eliminated three op amps which can be extra sources of noise, expense and used up p.c. board space.

By using these low value resistors we have also formed low impedance signal summing points for each signal input almost like the input summing point of an op amp. By running each signal through a high value resistor we can sum many signals from different sources into each input. This setup is also advantageous in that convenient signal levels such as zero DBM (2.2 v pp) are automatically attenuated down to optimum levels for proper filter operation.

The noninverting amplifier for the VCF can be almost any noninverting amplifier with a high input impedance and an adjustable gain of about two. This requirement in an amplifier is trivial and can be accomplished with any standard op amp. A simple Darlington emitter follower with gain does an excellent job.
The condition set up in our theoretical discussion calls for an amplification of three in order to achieve infinite Q or oscillation, however, the actual voltage controlled circuit requires even a substantially less gain.

Uses

A typical VCF as used in an electronic music synthesizer might appear as in Figure 7 with a set of inputs, an output, a center Frequency control, a Q control, a mode control and a V.C. input. Either the Steiner circuit described here or the well known state variable filter could be used to build a V.C.F. section as shown in Figure 7 and the sound and operation would be basically identical. A person operating a V.C.F. such as the one in Figure 7 would probably not be able to tell whether it was built using a state variable filter or the circuit described here except for the expense and trouble of building the VC state variable circuit.

Figure 8 shows a filter module that could be built using a state variable filter having one set of inputs and three simultaneous outputs. This can be useful for a number of things, but these will not be covered in this paper since the subject is well covered in other literature. It can be seen that one set of inputs and three sets of outputs does not allow two separate simultaneous signals to pass through the filter, one in the low pass mode and the other one in the high pass mode for example. No matter what mode is chosen, both signals must be acted upon simultaneously by the same mode.

Figure 9 shows a filter module using the Steiner V.C.F. that can be built for a synthesizer that does allow two or three signals to simultaneously pass through to the filter output yet each one being filtered in a different mode, namely low pass, band pass or high pass.

COMPARISON OF V.C.F. COVERED IN PAPER TO STATE VARIABLE V.C.F.

Steiner V.C.F.	Most Present Designs of State Variable V.C.F.
Super simple, uses very few low cost general purpose components.	More complex, requiring sophisticated op amps.
No parts need to be sorted or matched.	Most designs require special transconductance op amps that need to be sorted with rejection rates of up to 90%.
Low cost.	Op amps and exponential converters, etc., are more expensive.
Circuit has inherent exponential voltage to freq relationship.	Requires separate exponential converter.
Three mode operation.	Three mode operation.
Can operate in different modes simultaneously on separate input signals.	Cannot use different modes on separate input signals. All signals must be acted upon by the same mode at one time.
Very little signal distortion.	Signal distortion can arise from non-linearities of most transconductance op amps.
Variable resonance.	Variable resonance.
Reasonably accurate exponential voltage to frequency relationship.	Can be as accurate as exponential circuit used.
All inputs are convenient summing points.	Single input is convenient summing point.
Adjustment necessary for operation is always easy.	Adjustment depends upon how carefully specialiaze op amps are sorted.
Wide range - <20 Hz to >20 kHz.	Wide range- <20 Hz to >20 kHz.
Amplification necessary in amplifier stage: low.	High gain necessary in all op amps.
Excellent control voltage rejection. Only one adjustment necessary.	Excellent control voltage rejection if components are carefully selected. Two adjustments necessary.
Can be built using one center tapped variable resistance device to form both poles.	Requires separately isolated resistance devices to form the two poles.
Low pass 12 DB/oct Band pass 6 DB/oct each side Hi pass 6 DB/oct	Low pass 12 DB/oct Band pass 6 DB/oct each side Hi pass 12 DB/oct
Has both non-inverting and inverting control voltage inputs.	Inverting control voltage depends upon the fact that the exponential current source being used has provisions for it.

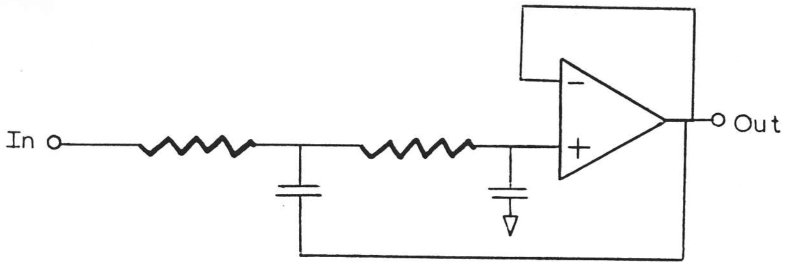

Figure 1. Sallen and Key Low-pass Filter

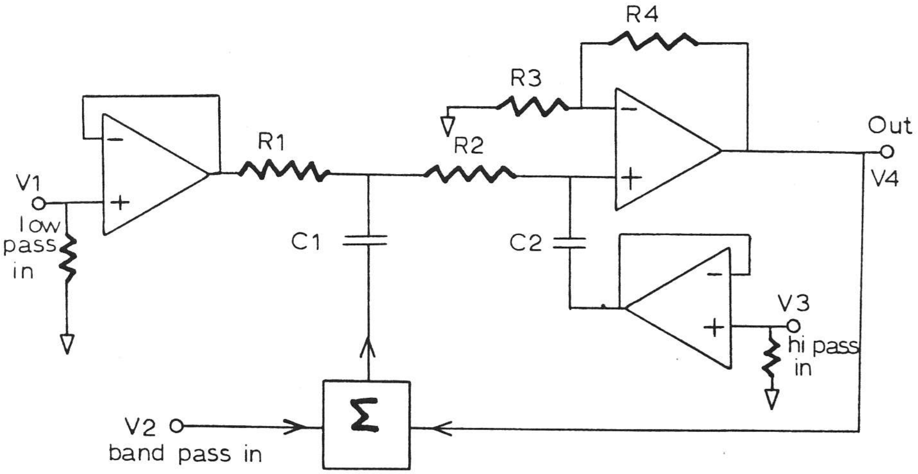

Figure 2. Basic Steiner Three Mode Filter

Signal's eye view as seen from different inputs of Steiner filter

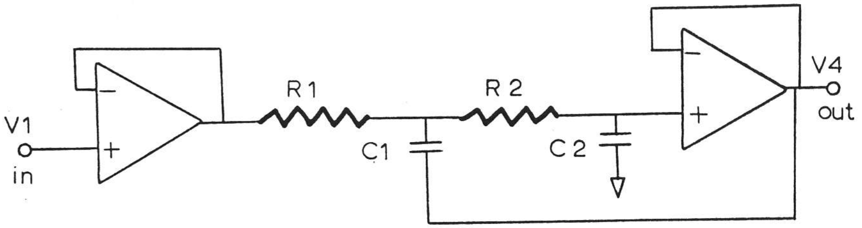

Figure 3A. Low-pass

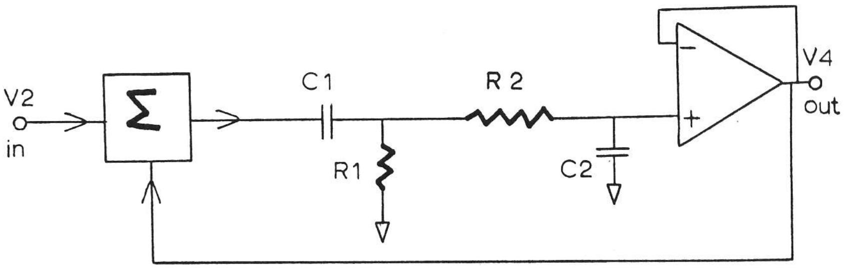

Figure 3B. Band-pass

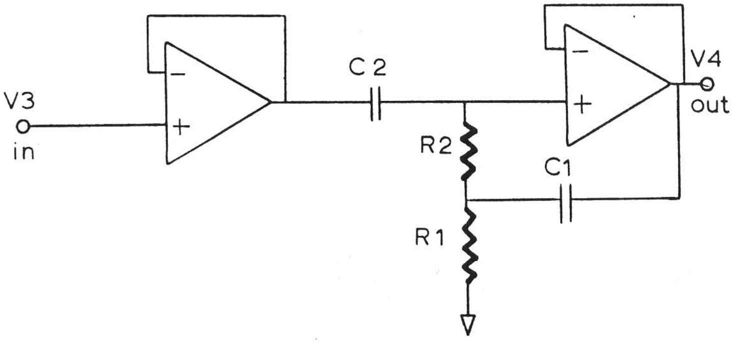

Figure 3C. High-pass

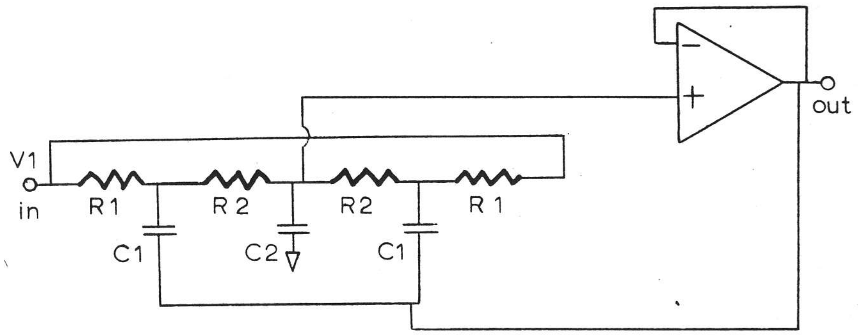

Figure 4.
Basic circuit configuration of connecting two RC networks in parallel

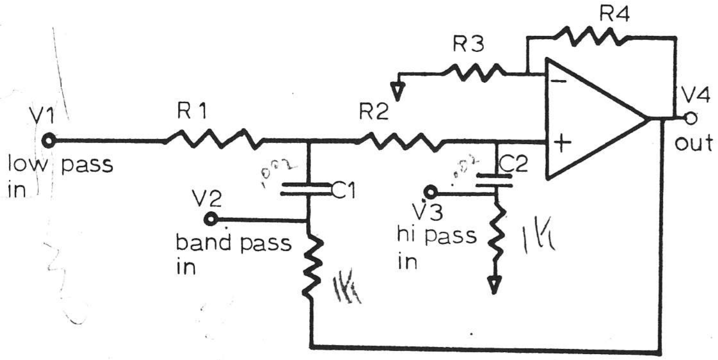

Figure 5.
Basic Steiner filter using low value resistors to replace input buffers

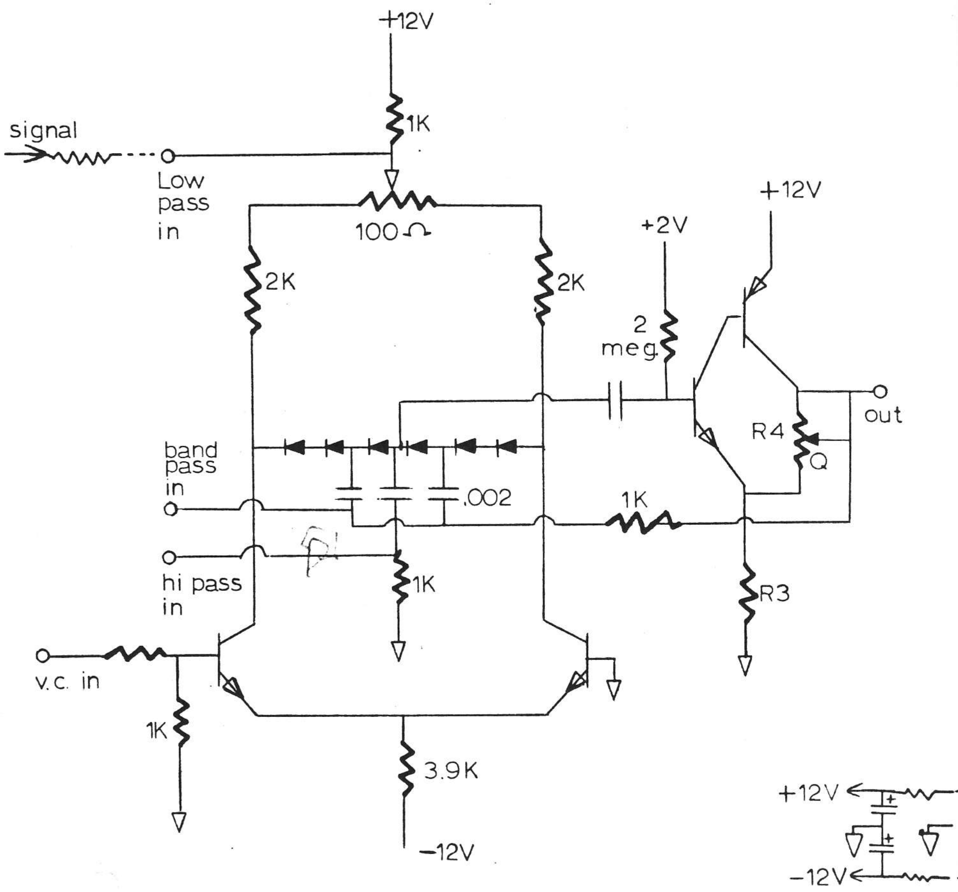

Figure 6. Voltage Controlled Steiner Filter

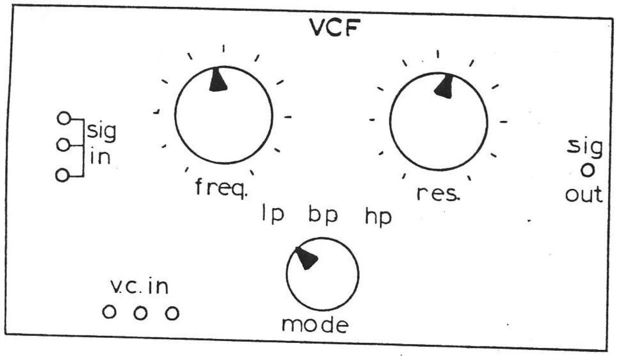

Figure 7. Typical Synthesizer Three Mode VCF

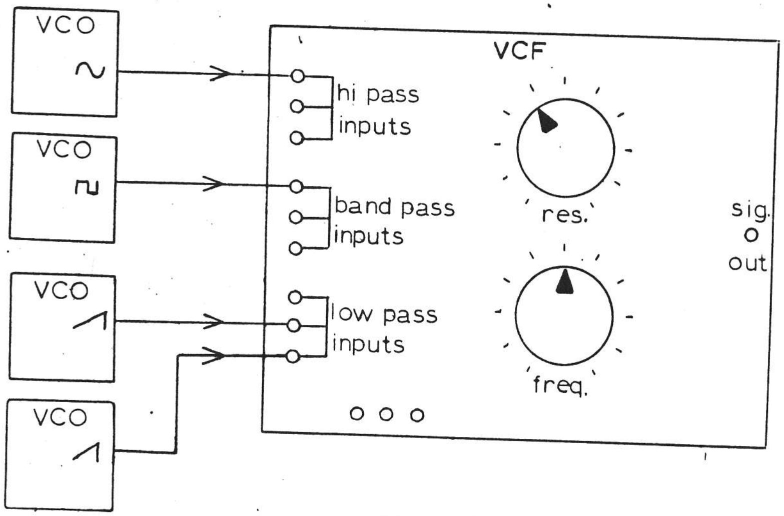

Figure 9.
Three Mode Simultaneous Input Synthesizer VCF Module Using Steiner Circuit

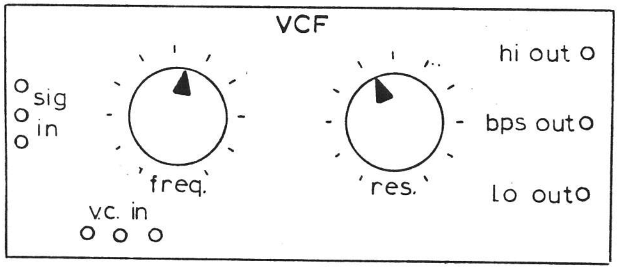

Figure 8. Three Mode Simultaneous Output State Variable VCF