A Simple Audio Notch Filter

Dr Paul Stewart, G7EAH, shows how to use the LMF90 chip as a simple high performance audio filter for about £10 including a 2W amplifier.

AUDIO FILTERS ARE USED in radio communications in a variety of ways depending on the nature of the wanted and interfering signals. If the wanted signal is broadband (eg SSB) and there is a narrow interfering signal within the audio band (eg CW), then a filter with a narrow band of attenuation can be tuned to the unwanted signal without any appreciable loss of information in the wanted signal - the 'notch' mode. If, on the other hand, the required signal is narrowband and the interfering signal is broadband, then a narrow passband filter tuned to the wanted signal is more appropriate - the 'bandpass' mode. If both signals are narrow band but both audible then either a passband or a notch filter can be used.

In order to understand the advantages of the switched capacitor filter over other types, it is useful to outline some of the practical difficulties encountered in realizing filters. One of the earliest types of audio filter consisted of combinations of inductors, capacitors and resistors. Of the three components, it was the inductor which was the biggest problem for the designer. This was because of its poor Q (goodness) factor, large size (due to inductance) and weight.

The development of cheap operational amplifiers, like the 741, and the development of active filters, meant that inductors could be eliminated from audio filter design. A filter could be produced with the addition of only resistors and capacitors - both cheap and small.

Such designs suffered from the obvious disadvantage that they required a power supply, but there was yet another serious practical problem caused by external component tolerances and temperature sensitivity. This is particularly serious in the design of high selectivity filters. Indeed, whether resistors and capacitors are implemented internally or externally to an integrated circuit, the temperature and/or voltage tracking between them has proved a difficult and expensive problem to solve to date. The constraints facing the designer, namely (1) the reduction of the external component count by larger scale integration and (2) the reduction of the temperature sensitivity of the complete filter, were to be met following a clever idea due, among others, to Poschenrieder (1966) and Freid (1972) relating to the AC behaviour of rapidly switched components. One aspect of their analyses particularly apposite to Metal Oxide Semiconductor (MOS) technology was the behaviour of various configurations of switched capacitors and amplifiers.

In essence, it became evident that a capacitor which is switched between nodes of a circuit at a frequency which is much greater than that of an alternating signal passing between the same nodes appears to the signal like a steady resistor across the nodes. The particular advantage of this fact is that, while the absolute value of a capacitor cannot be fabricated on a chip to better than about 10%, the ratio of two capacitors on the same integrated circuit can be made to an accuracy of about 1%. This has profound implications for the production of high selectivity filters with good temperature stability because the temperature tracking of two capacitors is excellent. As the basis of the switched capacitor filter is the switched capacitor integrator whose performance is directly dependent on the ratio of pairs of capacitors, all of the ingredients were now available for a new type of filter.

In addition to the above features, this type of filter can be continuously tuned simply by changing the applied clock frequency and the frequency response is scaled in direct proportion. For example, a bandpass filter designed to have a bandwidth of 100Hz and a central frequency of 100Hz, using a clock frequency of 100kHz, would have a bandwidth of 200Hz centred on 2000Hz if the clock frequency were doubled.

THE CIRCUIT

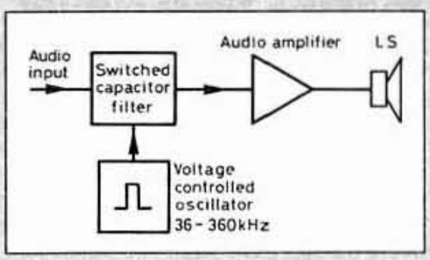
FIGURE 1 SHOWS A BLOCK diagram of the filter circuit which comprises essentially three elements: (a) switched capacitor filter, (b) voltage controlled oscillator (VCO) and (c) 2W audio amplifier. The filter's centre frequency is tuned by the application of a 5V square wave from the voltage controlled oscillator running at a frequency 100 times that of the centre audio frequency. The output of the filter is fed into a 2W amplifier feeding an 8 ohm loudspeaker.

The LMF90 is the latest in a generation of switched capacitor filters exploiting MOS technology. By using a 74LS629M VCO chip, whose frequency lies in the range of 36 to 360kHz, the LMF90 can be made to operate in the audio range 360 to 3600Hz.

While National Semiconductors designed the LMF90 as a notch filter, it can also be configured as a bandpass filter and this feature has been incorporated into this design. There are two advantages in practice in having a bandpass capability: (a) it is often easier to tune the filter to peak the unwanted signal and then switch to the notch mode for a final adjustment to reduce the unwanted signal further and (b) the bandpass mode can be used to receive a signal over a narrow band - setting 1 of switch S2 is particularly useful for narrow band reception of CW.

The bandwidth of the notch response, expressed as a percentage of the centre frequency (Fc) is independent of Fc, regardless of its value.

Figure 2 shows the measured notch attenuation of the design for the three bandwidth settings; here 1.0 on the horizontal scale corresponds to the centre frequency.



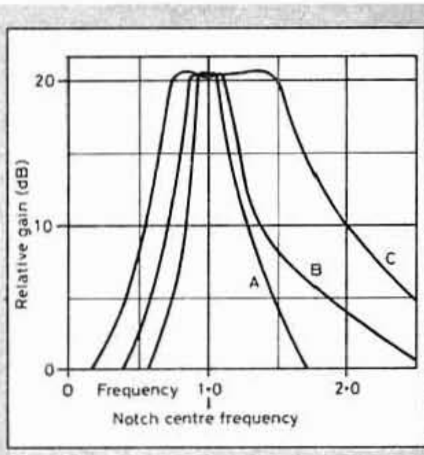
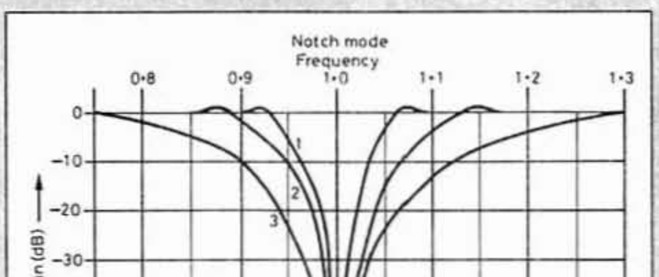


Fig 1: Block Diagram for the Switched Capacitor Filter.

Fig 2: Filter Frequency Response in the Notch Mode

Fig 3: Filter Frequency Response in the Passband Mode



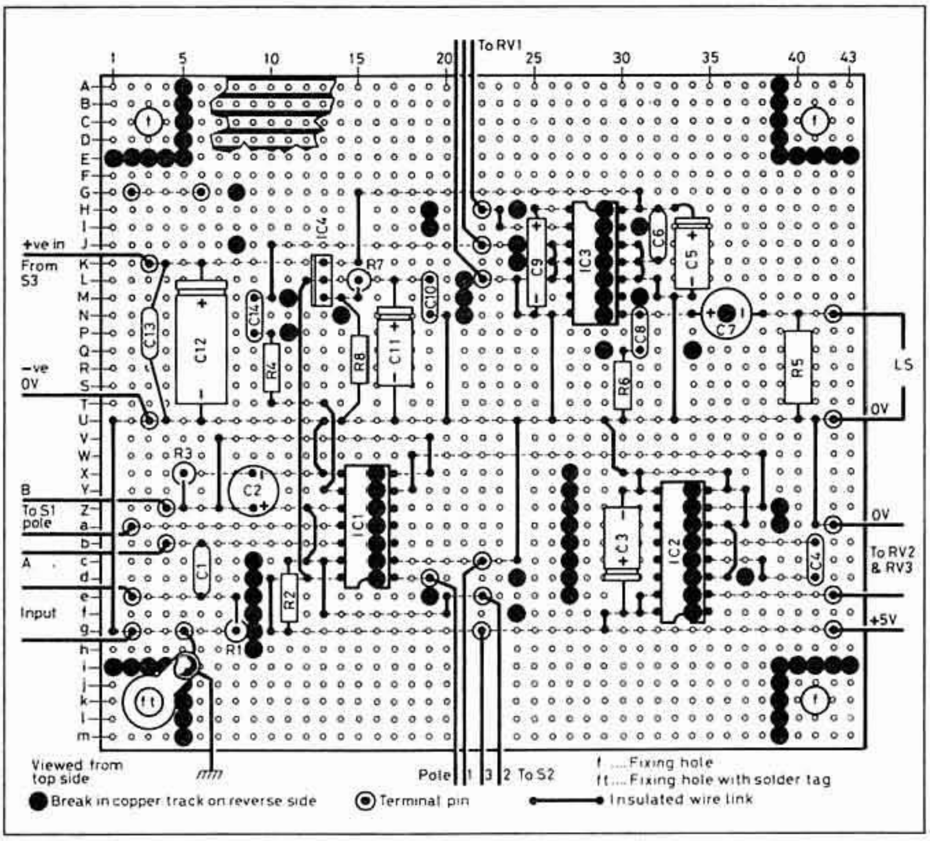


Fig 4: Veroboard Layout

The graphs marked 1, 2 & 3 in the figure area are the filter responses corresponding to the settings 1, 2 & 3 respectively, of S2. The values of 1%, 2.5% & 5% associated with these settings are the bandwidths expressed as percentages of Fc within which the attenuation is more than 35, 40 and 40 dB, respectively. The corresponding figures for the maximum attenuation at the notch frequency for these different settings are 40, 52 and 48dB. These responses are within the manufacturer's specification.

The bandpass performance of the present design is shown in **Figure 3**. It is clear that the bandpass response is wider than that in the notch mode, and this lower discrimination facilitates initial tuning. For the narrowest bandwidth setting, the bandwidth between 10dB points is 35% of Fc.

The notching of an unwanted sharply keyed CW signal, ie one with a relatively wide bandwidth, can be best achieved by increasing the bandwidth of the filter to its maximum setting to minimize key clicks.

Figure 5 shows the circuit which is designed to operate from a single voltage supply in the range 8 to 20V. The AF signal into the filter may be taken directly from the loudspeaker jack of the receiver, and the loudspeaker connected to the output of the filter.

The LM317MP was chosen to provide a high degree of regulation of the 5V supply required by the VCO chip. Its frequency is then so stable that the centre frequency of the notch filter is maintained to an accuracy of 1Hz in 3600Hz for a variation of the external supply voltage from 8 to 20V. The load and line regulation figures of the LM317MP are, respectively, two and six times as good as the cheaper regulator, the 7805.

The VCO chip provides the 50% duty cycle which the LMF90 requires. The audio signal to be filtered is fed to pin 12 of the LMF90; the output appears on pin 9 which is connected to the input of the LM380 audio amplifier which in turn feeds an 8Ω loudspeaker.

R1 is chosen to match the audio output impedance of the receiver and may be 4, 8, or up to 10kΩ (eg high impedance headphone o/p), depending on the receiver in use. This value is not critical from the notch filter's viewpoint but is inserted to provide the proper termination for the receiver. What is important, however, is that the input audio voltage to IC1 should not exceed 1.8V RMS. An input voltage as low as 80mV RMS will give maximum undistorted output from the LM380 with the 10k log volume control turned to max.

A value of 6000pF for C4 gives an Fc range of 360 to 3600Hz. Some transceivers have a top audio response of 2500Hz and by changing C4 to 9000pF the notch will tune from 250 and 2500Hz.

CONSTRUCTION AND TESTING

VEROBOARD CONSTRUCTION IS quite adequate at these frequencies; **Fig 4** gives the layout to scale. Several simple precautions should be observed. Sockets should be used for the ICs, particularly the LMF90 which, because of its MOS technology, should not be inserted until all of the soldering is completed. The decoupling capacitor leads to the IC supply pins should be as short as possible. Further, a solid earth rail is advisable as the VCO produces a square wave with fast rise and fall times. Finally, the filter should be housed in a metal box and the audio lead from the receiver to the input of the filter should have a screen connected to the filter circuit. The LM317MP regulator should have a heat sink about 2" (4cm) long attached to the bolt hole plane, and should be insulated from earth. The 0.1 and 1μF capacitors (C10 and C11) should be wired directly onto the chip.

To test the unit, connect a signal of about 1000Hz from the receiver's AF output to the filter input. The receiver's audio should now

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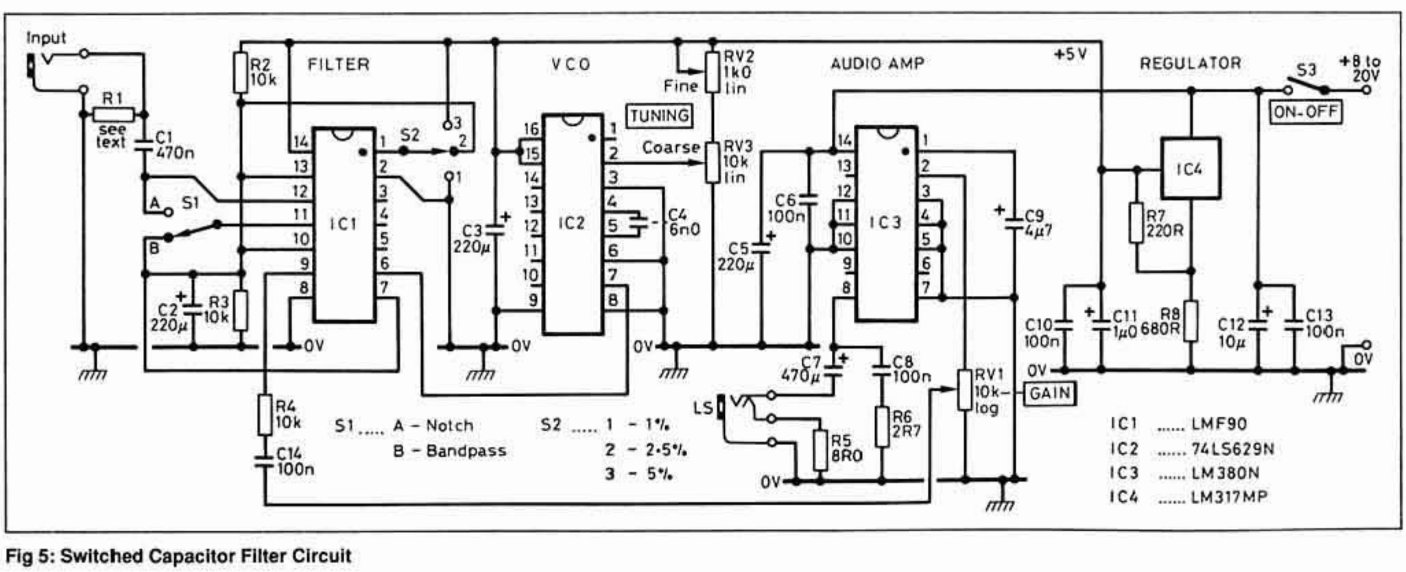

Fig 5: Switched Capacitor Filter Circuit

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One such product is the wideband DF Model F6, the latest in a range of DF products achieving world recognition and sales, and which begun with the amateur DF1 as long ago as 1981.

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It is good to see yet another pioneering British manufacturer succeeding in the face of stiff international competition and to know that, as a matter of policy, the amateur side continues to retain a high priority in company thinking.

Datong Electronics Ltd: Clayton Wood Close, West Park, Leeds. Tel 0532 744822.

Professional DF receiver manufactured by Datong founded by innovative radio amateur David Tong, G4MGQ.

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be heard. Set the volume to a comfortable level and switch S1 to the notch mode, turning the coarse tuning potentiometer to give minimum signal, the fine control can then be used to obtain a final null. The three bandwidth settings of S2 should change the sharpness of the notch. Now switch S1 to the bandpass mode without changing the audio input frequency and you should find that the signal reappears at a volume which is close to its maximum. Moving the coarse or fine tuning potentiometers either side will reveal a slight rise in the volume level which will drop fairly sharply if swung beyond these settings.

One final word regarding the installation of this filter in a receiver: the whole circuit should be screened from the RF stages by enclosing it in a metal box.

ACKNOWLEDGEMENTS

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Further Reading

LMF90 4th Order Elliptic Notch Filter, National Semiconductor Data Sheet TL/H/10354, Feb 1989.

Analog MOS Integrated Circuits for Signal Processing R Gregorian & G C Temes; John Wiley & Sons 1986. This describes the Switched Capacitor Filter in depth.

Supplier

All of the chips may be obtained from The Chip Shop (Semicons) Ltd., 6 Beanleach Drive, Stockport, Cheshire.

COMPONENTS LIST

RESISTORS - 0.25W Rating unless otherwise stated Tolerance 10%

R1 see text
R2,3,4, - 10K
R5 - 8R0, 2W
R6 - 2R7
R7 - 220R
R8 - 680R

RV1 - 10K log
RV2 - 1K0 lin
RV3 - 10K lin

CAPACITORS:

C1 - 470k
C2,3,5, - 220µ
C4 - 6k0+/-10%
C6,8,10,13,14 - 100k
C9 - 4µ7
C11 - 1µ0
C12 - 10µ
Wkg voltages - 30V

SWITCHES:

S1 - 1-pole, 2-way
S2 - 1-pole, 3-way
S3 - 1-pole, 1-way

ICs:

IC1 - LMF90
IC2 - 74LS629N
IC3 - LM380N
IC4 - LM317MP