

Rid your hifi system of hiss with this

Stereo Dynamic Noise Filter

by LEO SIMPSON

For many people, cassette decks have one big problem. During quiet passages hiss becomes obtrusive. The stereo dynamic noise filter presented provides a marked reduction in hiss while not affecting the bandwidth of high level signals.

The dynamic filter unit described here is interposed in the signal line between a cassette deck playback terminals and the tape monitor inputs of typical stereo amplifiers.

Basically, it monitors the signal level in both channels and when the signal rises above a predetermined level, it progressively switches out two single-pole filters which otherwise roll off the response above 7kHz. Maximum rate of attenuation of high frequencies is 12dB/octave.

probably also do not have a problem as far as tape hiss is concerned.

For the few acute-eared readers, cats and dogs still interested in this article, let me state that I did not really want to alienate all those other readers. But at least they will not needlessly build this device!

Even for those of us with acute hearing (notice how the author has subtly included himself amongst the fortunate few) tape hiss really only becomes

on some records in our reviews it is very rare that this is obtrusive and certainly not to the same degree as present with cassette recorders. Nor is this unit really suitable for eliminating the residual hiss of Dolby cassette recordings.

Now have a look at the circuit. It is based on the same principle which was first featured in the December 1975 issue, in the article on a dynamic noise filter for movie projectors by Jamieson Rowe. However, I have not merely produced a duplication of Mr Rowe's circuit for the stereo version. While the principle is the same the circuit is quite different.

Tr1 (and Tr3) is an emitter-follower which feeds a cascaded pair of single-section low-pass filters each with a roll-off above 7kHz. When both filters are switched in, they give a maximum rate of attenuation of high frequencies of 12dB/octave. The first filter consists of a 10k resistor and .0022uF capacitor which results in a filter impedance of roughly five times less than the second filter (47k and 470pF) to avoid loading effects. Output signal of the second filter is buffered by a second emitter-follower, Tr2 (Tr4), to give a low output impedance.

So Tr1, 2, 3 and 4 provide the actual signal path for both channels, with an overall gain of slightly less than unity. Since four filter sections are involved, two per channel, then four switches are needed to place them in and out of circuit. The switches are provided by the CMOS quad bilateral switch IC, type 4016.

This CMOS IC provides four SPST switches which closely approach the ideal for our purpose. The signal path of each switch can handle signals of up to 15V peak-to-peak (i.e., equal to the supply voltage) with very low distortion and low cross-talk between other switches. The switches have very high OFF resistance and low ON resistance (typically 200 ohms), and all switches are closely matched. Isolation between control and controlled signals is extremely high, with resistance values in the region of 1 Tera-ohm being quoted. 1 Tera-ohm is 1 million megohms.

Finally, the feedthrough signal can be as high as 40MHz while toggle rates can be up to 10MHz. These figures add up to impressive performance.

There are two points about the circuit



High level signals switch the filter circuits out and extinguish the two LED indicators.

A CMOS quad bilateral switch is used to switch the filter sections in and out of circuit in both channels.

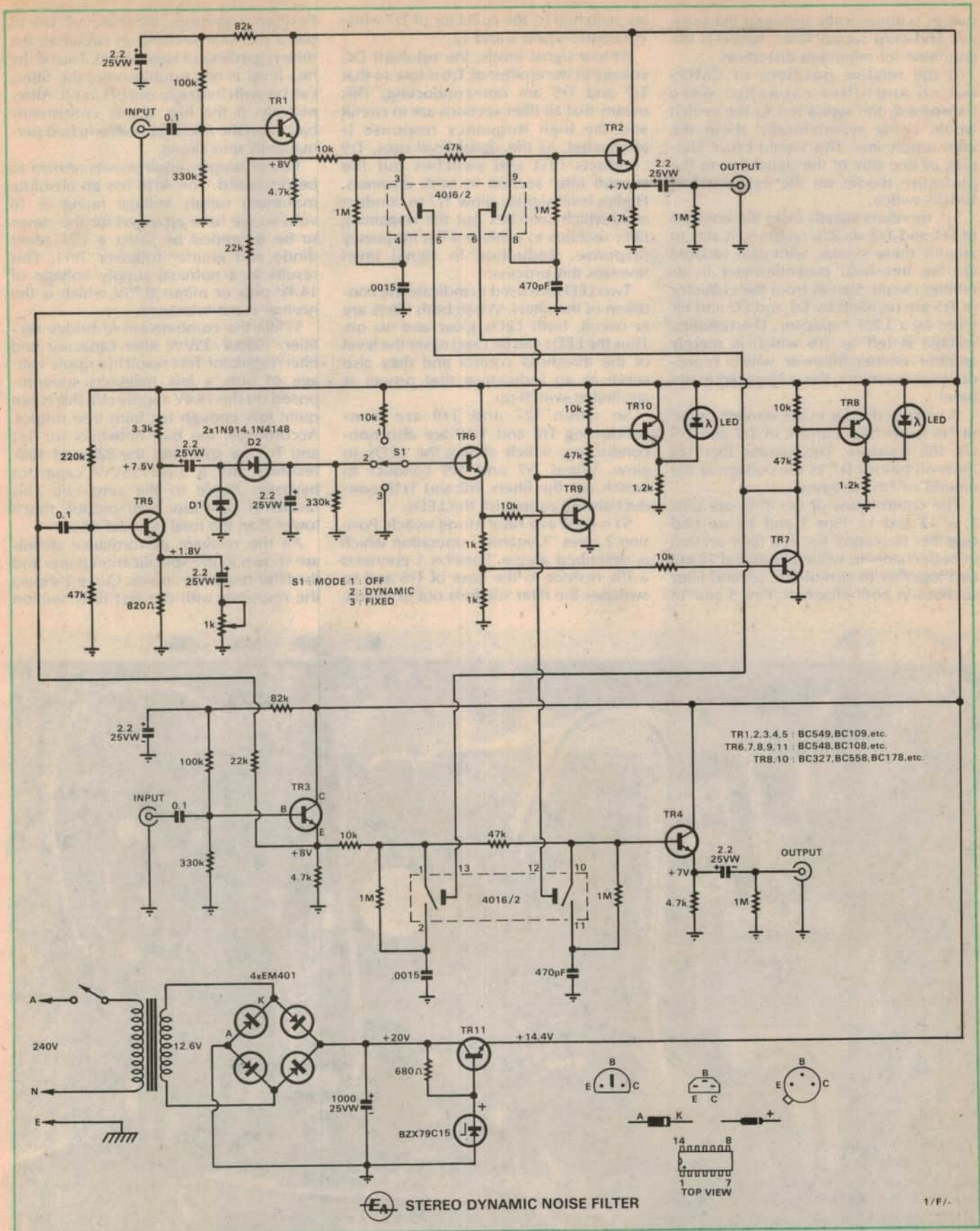
Let us state at the beginning that in our opinion most users of cassette decks do not need this unit. For a start, a major part of the population just are not aware of tape hiss as being a problem. If you are over 30 and/or cannot hear the normal 15,625Hz whistle of television flyback circuitry, or the somewhat more intense whistle of the switching regulator used in many colour television receivers, then you probably fall into this group.

Taking the comparison a little further, if you can hear no appreciable difference in quality between the average disc and a cassette copy of that disc, then you

obtrusive when the volume control is well advanced to give an appreciable sound level and particularly while playing softly recorded passages. At other times you can largely "tune out" the hiss using the brain/ear combination's remarkable capability to resolve a noisy signal.

Of course if you are one of those fussy listeners who tends to "tune in" the hiss, i.e., you always listen for faults rather than enjoy the music, then you really do need a dynamic noise filter of this kind. There is a subtle catch, though and we will talk more about that later.

We should also state, at this point, that this filter is of no use in reducing noise or hiss on some discs. While we occasionally note that tape hiss is present



which should be noted at this stage of our discussion. First, Tr2 is biased via the 10k and 47k signal path resistors from the emitter of Tr2 (similarly with Tr4 and Tr3)

so that the signal swings symmetrically between the supply lines (ie, with reference of approximately half the supply voltage). Second, each CMOS bilat-

eral switch is interposed between the signal path and the rolloff capacitors which are .0022uF and 470pF. Thus the signal applied to the CMOS switches

swings symmetrically between the positive and zero supply lines, which is the condition for minimum distortion.

If the relative positions of CMOS switch and filter capacitor were transposed, the signal fed to the switch would swing symmetrically about the zero supply line. This would cause clipping of one side of the signal due to the protective diodes on the inputs of the CMOS switch.

Tr5 monitors signals from the emitters of Tr1 and Tr2 via 22k resistors. It acts to amplify these signals, with gain variable via the threshold potentiometer in its emitter circuit. Signals from the collector of Tr5 are rectified by D1 and D2 and filtered by a 2.2uF capacitor. The resulting voltage is fed to Tr6 which is merely another emitter-follower which reproduces at its emitter, the voltage fed to the base.

A voltage-divider in the emitter circuit of Tr6 feeds base current to Tr7 and Tr9 via 10k resistors. This means that Tr9 turns on before Tr7 as the voltage at the emitter of Tr6 increases.

The control pins of the 4016 are pins 5, 6, 12 and 13. Pins 5 and 13 are tied together to control the first filter section in both channels, while pins 6 and 12 are tied together to control the second filter sections in both channels. Pins 5 and 13

are switched by the collector of Tr7 while Tr9 controls pins 6 and 12.

At low signal levels, the resultant DC voltage at the emitter of Tr6 is low so that Tr7 and Tr9 are non-conducting. This means that all filter sections are in circuit and the high frequency response is attenuated. As the signal level rises, Tr9 conducts first and switches out the second filter section in both channels. Higher level signals allow Tr7 to conduct also, which switches out the remaining filter sections to achieve a flat frequency response. Reduction in signal level reverses this process.

Two LEDs are used to indicate the condition of the filters. When both filters are in circuit, both LEDs glow and so on. Thus the LEDs can be used to set the level of the threshold control and they also serve as an indication that power is applied at switch on.

So when Tr7 and Tr9 are non-conducting Tr8 and Tr10 are also non-conducting, which allows the LEDs to glow. When Tr7 and Tr9 conduct to switch out the filters Tr8 and Tr10 conduct also to extinguish the LEDs.

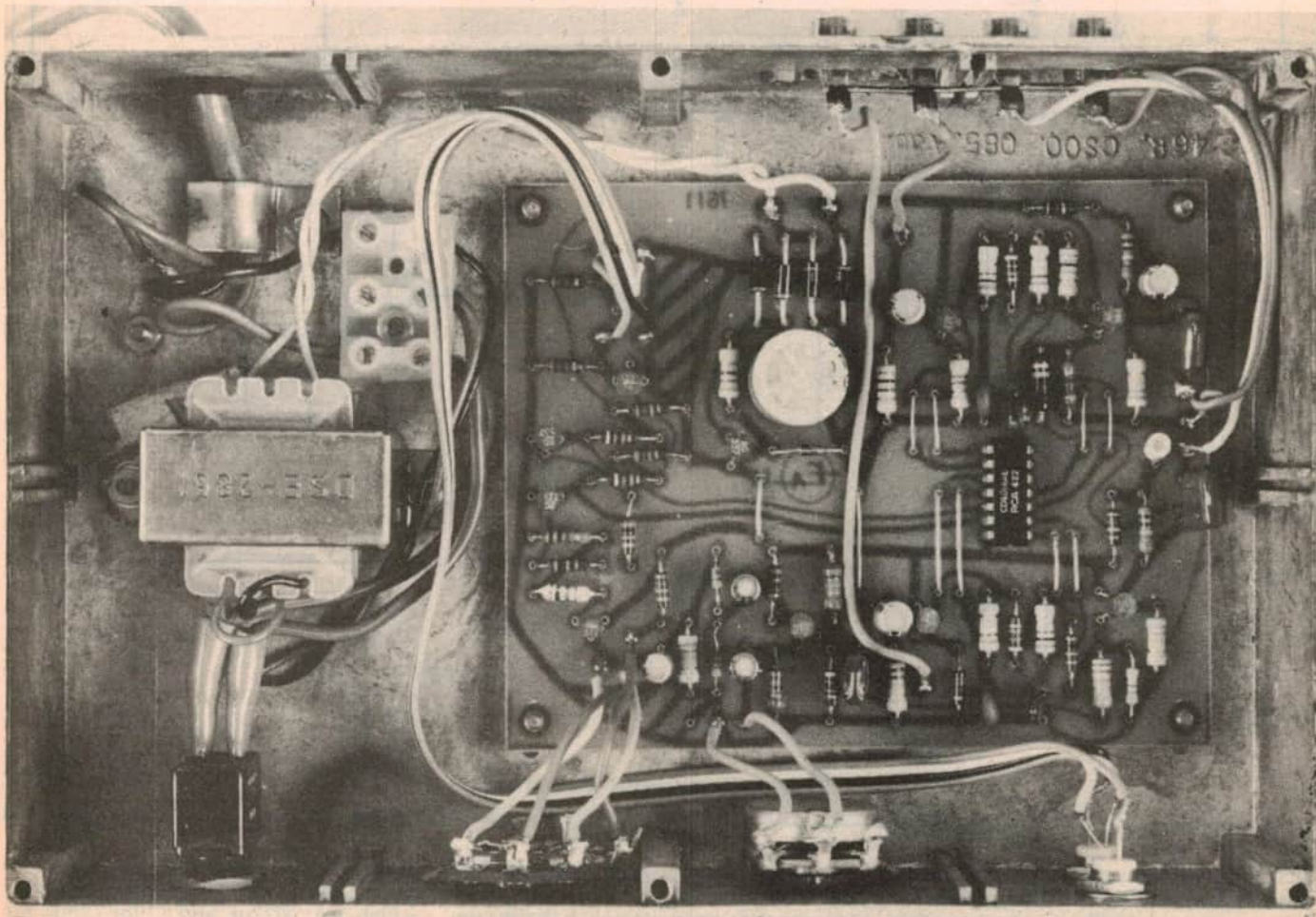
S1 is used as a Filter Mode switch. Position 2 gives "Dynamic" operation which is described above. Position 1 connects a 10k resistor to the base of Tr6 and so switches the filter sections out of circuit.

Position 3 grounds the base of Tr6 to place the filter sections in circuit all the time regardless of signal level. Thus if the hiss level is not troublesome, the filters can be switched right out of circuit. Alternatively, if the hiss seems consistently bad, then the filters can be switched permanently into circuit.

Power supply requirements remain to be discussed. The 4016 has an absolute maximum supply voltage rating of 16 volts so we have arranged for this never to be exceeded by using a 15V zener diode and emitter follower Tr11. This results in a nominal supply voltage of 14.4V plus or minus 0.75V which is the normal zener tolerance.

While the combination of bridge rectifier, 1000uF/25VW filter capacitor and filter/regulator Tr11 result in a ripple voltage of only a few millivolts superimposed on the 14.4V supply rail, this is not quite low enough for hum free output. Accordingly, the bias networks for Tr1 and Tr2 are split with the 82k and 100k resistors and a 2.2uF/25VW capacitor bypasses ripple to the zero rail. This results in very low hum output, much lower than the total residual noise.

All the relevant performance details are shown in the specification panel and the filter response curves. Curve 1 shows the response with the first filter section



Readily available and economical components are used throughout. The 4016 integrated circuit sells for about \$1.00.

THRESHOLD

FILTER MODE

POWER

OFF ●

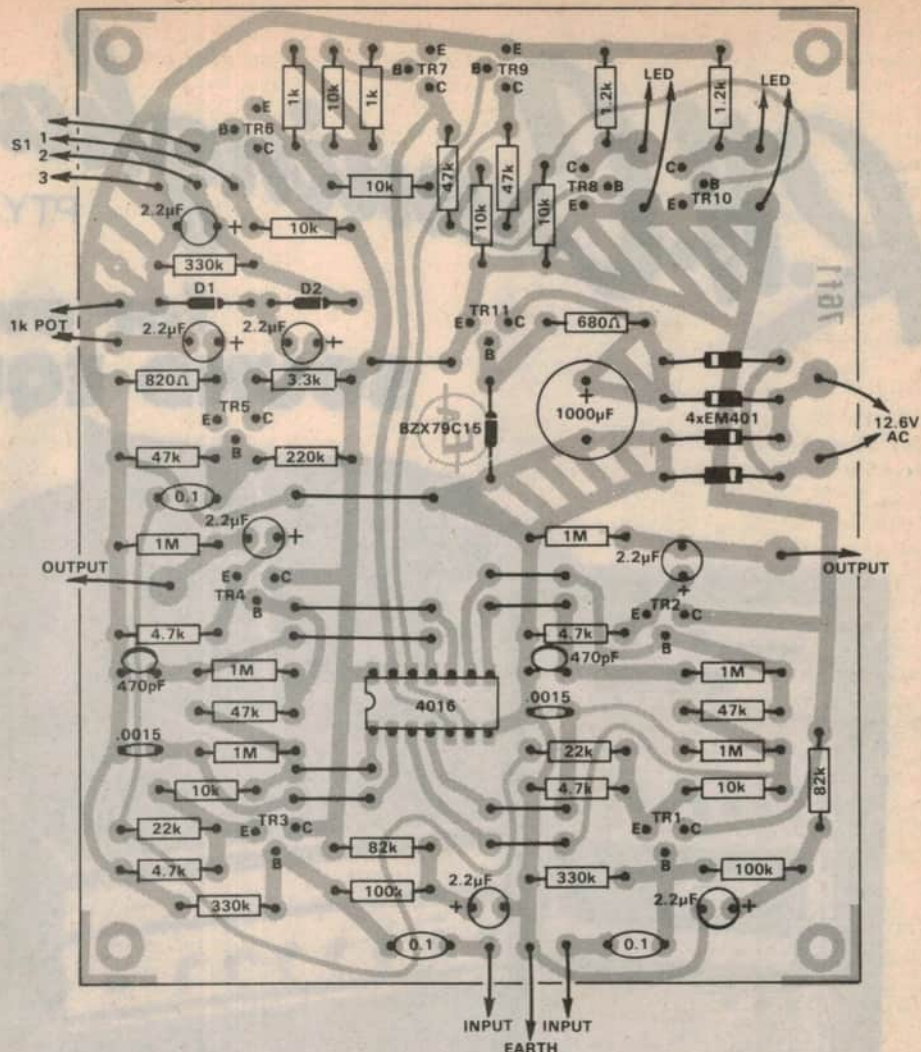
DYNAMIC ●

FIXED ●

STEREO DYNAMIC NOISE FILTER



Above is the artwork for the control panel.



When all the small components are soldered in, insert and carefully solder the 4016.

PARTS LIST

- 1 diecast case and lid
- 1 front panel to suit (see text)
- 1 PC board, 127 x 102mm, code 76f1
- 1 three-pin mains plug
- 1 power transformer, 12.6V secondary, Ferguson PF2851, DSE 2851, A & R 6474.
- 1 SPST toggle switch, McMurdo 475 series or similar
- 1 four-way RCA phono connector strip
- 2 decorative knobs

SEMICONDUCTORS

- 1 SCL4016A, CD4016 or equivalent CMOS quad bilateral switch
- 5 BC549 or equivalent low noise silicon NPN transistors
- 4 BC548 or equivalent general purpose silicon NPN transistors
- 2 BC327, BC558 or equivalent general purpose silicon PNP transistors
- 1 BZX79/C15 15 volt 400mW zener diode
- 4 EM401 silicon rectifier diodes
- 2 1N914, 1N4148 silicon signal diodes
- 2 LEDs with chrome bezel, McMurdo 3240-01-02 (see text)

CAPACITORS

- 1 x 1000µF/25VW PC electrolytic
- 7 x 2.2µF/25VW PC electrolytic
- 3 x 0.1µF metallised polyester
- 2 x .0022µF metallised polyester
- 2 x 470pF polystyrene or low voltage ceramic

RESISTORS

- (¼W or ½W, 5% tolerance)
- 6 x 1M, 3 x 330k, 1 x 220k, 2 x 100k, 2 x 82k, 5 x 47k, 2 x 22k, 7 x 10k, 4 x 4.7k, 1 x 3.3k, 2 x 1.2k, 2 x 1k, 1 x 680 ohms
- 1 x 1k potentiometer (log or lin.)

MISCELLANEOUS

- 17 PC stakes, length of three-core mains flex, 30cm of 1 flat rainbow cable, solder lug, grommet, rubber feet (if required), screws, nuts, lock-washers, solder, three-way insulated terminal block, cable clamp.

NOTE: Components with higher ratings may be used provided they are physically compatible. Lower rated components may also be used in some cases, provided their ratings are not exceeded.

switched in while curve 2 shows the resultant response with both filters switched in. The maximum rate of attenuation as shown in curve 2 is closer to 10dB/octave than the 12dB/octave that simple theory would suggest. This can be explained by loading effects on each filter section.

Frequency response with both filter

SPECIFICATIONS

Frequency Response: 30Hz to 100kHz between -1dB points with filters switched out.

Insertion loss: 1dB (0.9).

Input impedance: 70k.

Output impedance: less than 1k. Output load should be more than 10k for low distortion.

Distortion: Less than 0.1% up to 3V RMS input.

Separation between channels: Better than 40dB.

Input overload: 4V RMS.

Signal-to-noise Ratio: Better than 63dB with respect to 100mV out; Hum output: less than 74dB with respect to 100mV.

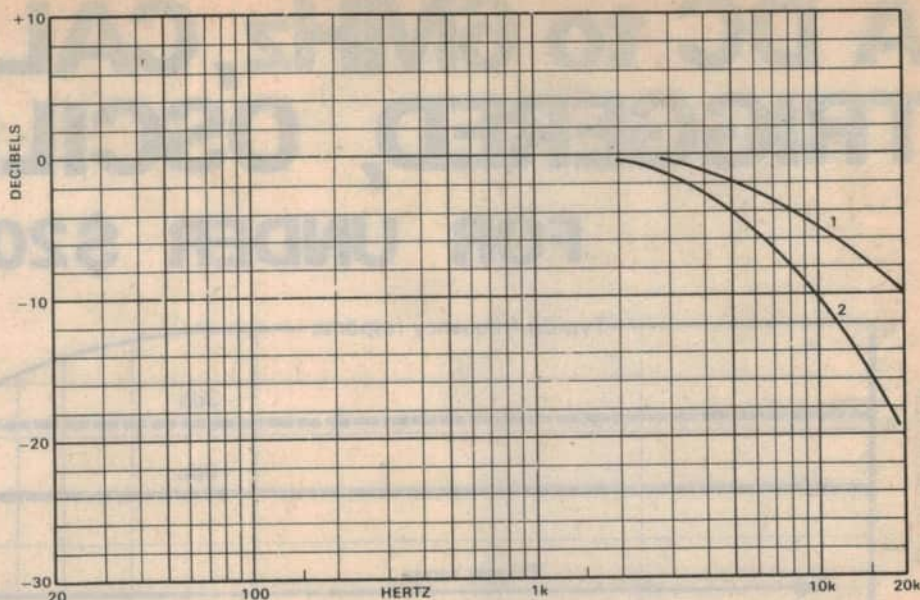
sections switched out is very flat, with -1dB points at 30Hz and 100kHz. Gain or insertion loss is minus 1dB, which is negligible.

Harmonic distortion is very low under all conditions and in fact we were merely measuring the distortion of our oscillator at most times. Accordingly, for signal levels below 3V RMS and for all frequencies in the normal audio bandwidth, we have quoted distortion at less than 0.1%. Actual distortion will be very much lower than this.

Maximum input signal before clipping is 4V RMS. Separation between channels is better than 40dB for all frequencies of interest. This is measured with the unused input unloaded so actual results would be better again. Similarly, signal-to-noise ratio is quoted at -63dB with respect to 100mV RMS with open-circuit inputs and with a noise bandwidth of 25kHz. Loading the inputs with a low impedance source improves the figure to 65dB. In practice, the unit causes no discernible degradation of an amplifier's S/N ratio and is considerably better than the average or even above-average cassette deck in this respect.

Threshold settings to actuate the filter control circuitry are variable between 50mV and 300mV RMS. Attack time is about 7 milliseconds while decay time is about 200 milliseconds (mainly determined by the beta of Tr6).

Now to explain the compromise or "catch" we mentioned earlier in the article. Notice that each filter section begins its rolloff (-3dB point) at about 7kHz and the total rolloff begins at about 4kHz. While this sounds drastic, this compromise was necessary in order to obtain a useful reduction in hiss. Now the catch is that people with acute ears may



Response curves for the filters. Curve 2 is the resultant curve with both filters.

be able to hear the hiss being "gated" on and off by the arrival of high level signals. This can be more disturbing to some people than a constant background hiss. To reduce this effect, the rolloff frequency should be raised by reducing the filter section capacitors. However this means a consequent lesser reduction in hiss.

For those who wish to experiment with the rolloff frequencies, the .0022uF and 470pF capacitors are varied directly in proportion to the proposed rolloff frequency.

Whichever rolloff frequency you do decide upon, we think you will agree that this circuit is very attractive because it has no internal setting up adjustments and literally no distortion.

Our prototype was housed in a diecast metal box measuring 222 x 146 x 57mm, with the control panel on one side and the input and output sockets on the opposite side. The front panel was made using Scotchcal photosensitive aluminium. The artwork for the panel is included in these pages. For a final touch to the finish, install the diecast case in a veneered timber sleeve or finish to match the other components in your system.

A PC board coded 76f1 and measuring 127 x 102mm accommodates the circuitry. Assembly of the PC board can begin by installing all the small components, leaving the CMOS integrated circuit till last.

General-purpose small-signal silicon transistors can be used in this circuit. Ideally, Tr1, 2, 3, 4 and 5 should be BC549 or equivalent low-noise silicon NPN types to ensure the best signal-to-noise ratio and high beta requirements set by the high resistance base bias networks. However, the performance we quote in the specification panel was obtained using BC548's which were selected for beta of 250 or more. So if you have means

for measuring beta and have BC548's or other general-purpose silicon transistors to spare, they may be pressed into service here.

Tr6, 7, 9 and 11 can also be BC548 or any equivalent type. Tr8 and 10 are BC327, BC558 or equivalent general purpose silicon PNP types. D1 and D2 can be any small signal diodes, germanium or silicon or small rectifier diodes such as EM401.

Resistors can be 1/4W or 1/2W types with 5% tolerance. Use low noise types such as cracked carbon or metal glaze for the high value resistors, particularly those used in the bias networks for Tr1 and Tr3. The smaller 1/4W resistors are preferable since they are easier to insert.

All the electrolytic capacitors are end-mounting PC types and we have standardised on 2.2uF (for all but the main reservoir capacitor) in the interest of the economy and simplicity. Capacitors used in the single-section filters, .0022uF and 470pF, should have 10% tolerance or better. If low voltage ceramic capacitors are used for the 470pF, they should be checked to ensure they are within 10% of value specified.

Use PC stakes or pins to make interconnections to the PC board. Seventeen will be required.

When all the small components have been inserted and soldered, you can deal with the CMOS integrated circuit. It will be supplied with its pins inserted into black conductive foam or wrapped in aluminium foil. Refer to the PC layout to determine the correct orientation for the IC and then insert and solder it, still with foil or foam shorting the pins. When soldering is complete, remove the foam or foil. Actually, if you have a low-voltage soldering iron with a grounded tip you can remove the foam or foil before soldering. This latter procedure is relatively safe for this particular CMOS IC since it has diode protection on all inputs.

DYNAMIC NOISE FILTER

This does not mean you can use your old 240VAC 100W soldering iron that your father used to solder galvanised guttering! That is asking for trouble. Care is still required.

Having completed assembly of the PC board, attention can be turned to the diecast case. Drill all the required holes and countersink where necessary. Now the hardware can be installed.

A four-way connector strip was used for the RCA phono input and output connectors. These require more filing and cutting of the case than if four individual sockets were used, but the final result is neater. Alternatively, if your system uses DIN sockets, then these are equally appropriate. The earth connections of the sockets are all connected together and then finally connected to the PC board earth but the signal earth does not connect to the case. This is earthed back via the three-core mains cord.

The transformer we used was a small unit with a 12.6V secondary. We used a DSE 2851 kindly supplied by Dick Smith Electronics, but a Ferguson PF 2851 or A&R 6474 are equally suitable and slightly smaller, which might be an advantage if a smaller case is used.

These transformers normally have a centre tap connection to the secondary winding but this is not used here. It should be coiled up and taped to avoid shorting to the case.

The three-core mains cord should be passed through a grommetted hole in the rear of the case and anchored with a cord clamp. Terminate the earth conductor to a solder lug on the chassis and the active and neutral conductors to a three-way insulated terminal block. Connections to the power switch and transformer are then made via the terminal block.

We used a McMurdo series 475 toggle for the mains switch. After wires are soldered to the switch, the connections should be covered with plastic sleeving to avoid contact with incautious fingers. The mode switch requires a single-pole, three-position rotary type but the one we actually used was a two-pole, three-position wafer. Both the rotary switch and potentiometer shafts should be cut to a length to suit the knobs before being installed. The potentiometer can be a logarithmic or linear type with value 1k.

Several choices are available as far as the LED indicators. We used LEDs with chrome bezels, as distributed by McMurdo. A cheaper approach would be to use LEDs with plastic clip-lock bezels or simply glue the LEDs into holes in the front panel with a suitable adhesive such as Araldite.

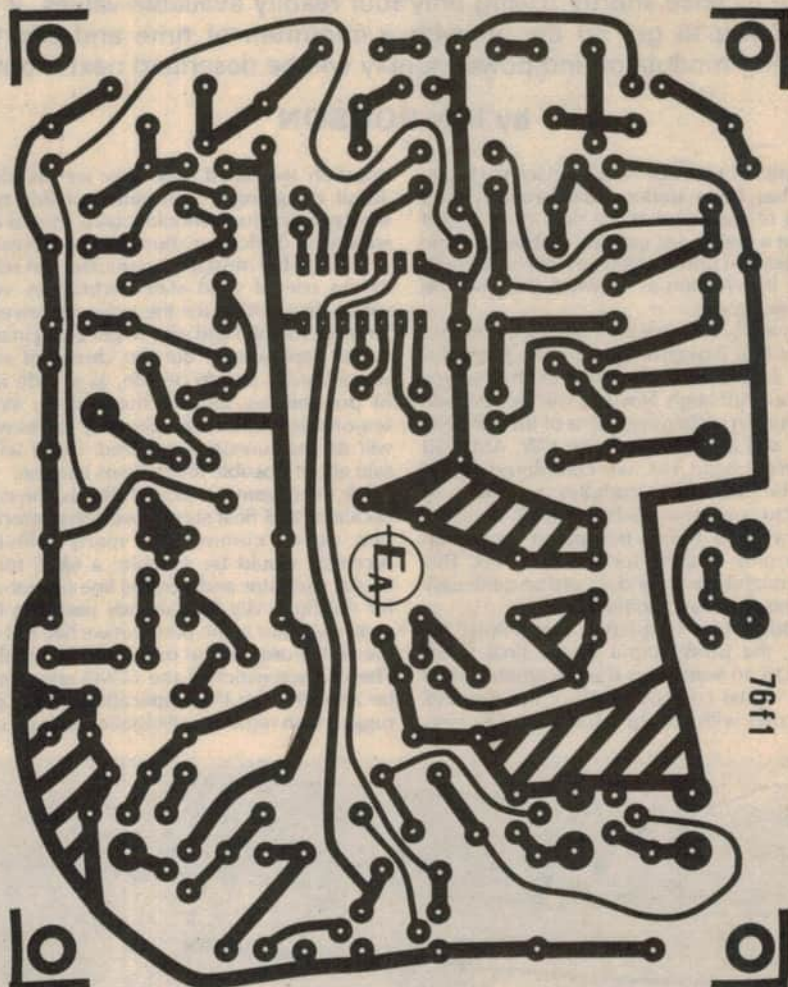
When all the hardware is installed in the case drop the PC board into place and make all the connections. There is no need to use shielded cable for the

inputs and outputs nor would there be any noticeable improvement gained by doing so. A short length of multi-coloured "rainbow" cable will provide all the necessary hook-up wire. It results in a neat job without the need for cable lacing. About 30cm of rainbow cable will be adequate.

Double-check your wiring and then apply power. Check voltages. These

control so that the LEDs are extinguished when the playback signal exceeds about -15dB as indicated on the VU meters of the cassette deck. This adjustment will give you optimum results for most tapes but it can be varied to suit particular conditions.

It is important that the threshold control is not advanced to the point where the LEDs are flashing on and off with low



Actual size artwork for the PC board.

should be within 0.5V of those on the circuit. The main supply rail should be slightly less than 15V. If it exceeds 15V there is danger of "blowing" the CMOS IC. If all checks are OK you are ready to test the filter with a cassette deck and stereo amplifier.

First connect the output of the filter to the tape monitor inputs or high level inputs of the amplifier and listen for any hum or noise. Unless the amplifier has an exceptional signal-to-noise ratio, there should be no degradation, i.e., the amplifier should be no noisier than it normally is at a given volume control setting.

Now connect the line outputs from the cassette deck to the input of the filter and play a cassette. Adjust the threshold con-

level signals. In this condition the listener is more likely to be conscious that the signal is "gating" the noise on and off. As noted above, this effect could be more objectionable than continuous hiss.

In conclusion we note that this unit could be incorporated into a stereo amplifier with consequent savings on the case and power supply. If built as a free-standing unit like our prototype it would be possible to fit the PC board into a smaller case although more care would be required with layout and transformer location and orientation to ensure hum-free performance. It is also possible to replace the threshold control with a preset potentiometer soldered directly into the PC board, should you wish.