disc preamp

A preamplifier-equaliser for magnetic pickup cartridges has to meet quite exacting requirements. Values for gain, noise level and maximum input voltage which will guarantee trouble-free operation under all conditions are not so easy to achieve. The well-known two-transistor configuration, operating from a 12 . . . 18 V supply, invariably falls short on gain and overdrive-margin - unless it is designed for a low nominal output voltage (about 30 mV). An alternative approach is to make use of a good integrated amplifier. The design about to be described, which meets all the requirements, employs a SN 76131. An almost identical I.C. is the μA 739.

To make optimum use of the possibilities for groove-modulation, gramophone records are cut with low audio frequencies attenuated and high audio frequencies boosted (with respect to 1 kHz). To simplify playback equalisation, a single weighting curve has been standardised throughout the world - the IEC disc-cutting characteristic. (This curve originated as the RIAA standard: Record Industry Association of America).

The disc-cutting engineer arranges for a '0 dB standard (reference)level' in the taped programme to produce a stylus tip-velocity about 14 dB below the 'safe' drive-level, to provide headroom for instantaneous signal peaks. 0 dB standard level (corresponding roughly to the average level in loud passages) is typically 39 mm/sec tip peak velocity at 1 kHz. Standard level on carrier-channel discs (CD4 and UD4) is lower, about 22 mm/s.

Experience indicates that wide-band cartridges suitable for carrier discs deliver 70 . . . 140 μV for each mm/sec of tip velocity. The usual 'hifi' cartridges deliver about 6 dB more. (Note that sensitivity specifications are usually given in RMS millivolts per peak centimetre per second). So the input to the preamplifier at standard level 1 KHz will be about 1 . . . 10 mV peak.

What are the consequences of all this for the preamplifier?

Suppose it is the intention that the output voltage at standard level be about 100 mV RMS with the lowest-output cartridge. The closed-loop gain must therefore be 100 at 1 KHz. Now allow 20 dB of extra gain for IEC equalisation at the lowest frequencies, not including 20 dB of negative feedback (which should reasonably be maintained at the 'low end'). This tots up to an open-loop gain of at least 80 dB! Ten thousand times. That seems to eliminate the two-transistor configuration.

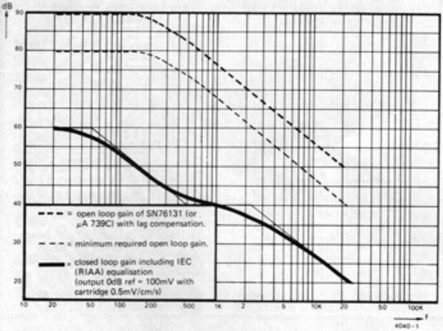
The SN 76131 integrated circuit, with the chosen lag compensation, has a typical open-loop response according to the upper dashed curve in figure 1. The

Figure 1. The desired closed-loop gain curve follows the IEC (RIAA) disc equalisation characteristic, with a mid-band gain (1 KHz) of 40 dB (heavy line). The open-loop gain must be at least 20 dB greater; the SN 76131, with the chosen lag compensation, provides this with a margin of about 10 dB (upper dashed curve).

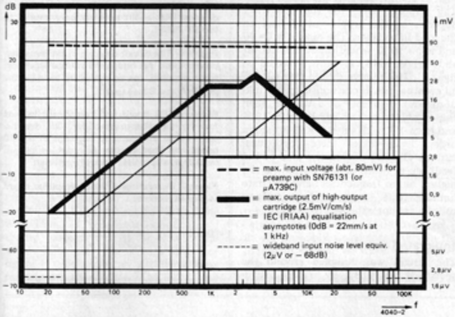
Figure 2. The heavy line is an estimated contour for the highest voltage delivered to the preamplifier by a high-output dynamic cartridge. The preamplifier cannot be overdriven by the highest input voltage; the upper dashed line is the overdrive threshold for the disc-preamplifier with SN 76131. This clears the maximum-input contour by approximately 10 dB.

Figure 3. The maximum RMS output level produced by the preamp when used with a high-output cartridge follows the thick contour. The dashed line indicates the maximum output capability. The safety margin is here once again about 10 dB.

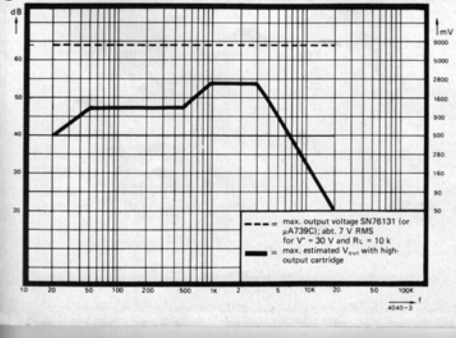
1



2



3

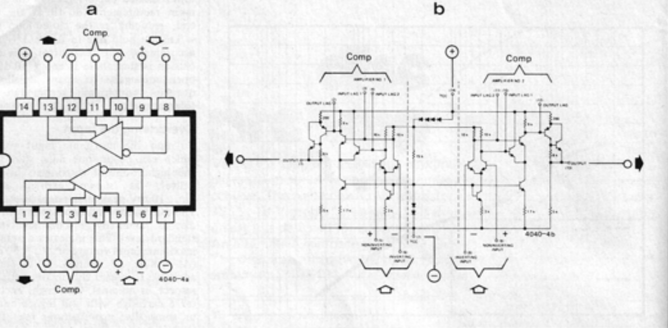


lower dashed curve indicates the minimum requirement (80 dB at the low end, reducing as the closed-loop gain – i.e. the bold line in figure 1 – falls according to the IEC curve). The conclusion is that there is about 10 dB of open-loop gain to spare at all frequencies, which will accomodate IC-tolerances etc.

Overdriving the input

To find the maximum input voltage which can occur, one must start with the highest-output cartridge. This will deliver, as shown earlier, about 5 . . . 10 mV peak at standard level.
The maximum level encountered on the disc is nominally +14 dB relative to standard level. This indicates a nominal maximum input voltage of 25 . . . 50 mV. (At 1 KHz of course). It is clearly advisable to regard this figure, with due respect, as nominal. One might encounter a cartridge with still higher output or some disc manufacturer may fully exploit tracing-compensation, to cut a clean signal at more than +14 dB . . . The absolute limit (set by 'slope-overload' at the inner radius of LP discs) is presently about 350 mm/s (+18 dB) – but a 33 disc also has outer grooves and they can be cut at a level 6 dB higher. This means that in theory the maximum output level for the highest output cartridge is about 200 mV! With the circuit arrangement given, the SN 76131 will accept 80 mV at the input (thick dashed line in figure 2).
The same figure can be used to estimate the effect of amplifier noise. The wideband noise level, referred to the SN 76131 input, is 2 μV (RMS). This is −68 dB in the figure (0 dB = 5 mV RMS). For the least sensitive cartridge, this noise level is −54 dB relative to standard level for CD-4 or UD-4 discs. Assuming maximum signal level to be +14 dB the overall S/N ratio is (for this worst case) 68 dB. Manufacturers estimate that the S/N ratio possible with a first-rate LP pressing is about 70 dB. Conclusion: pass.
Figure 2 can be used once more to determine the hum-level requirements. The IEC bass-lift now aggravates matters: to achieve a hum level 60 dB below standard level, with a fairly high-output cartridge (5 mV RMS at 1 KHz), it becomes necessary to keep the hum voltage at the input below 1 μV! This can be achieved, in general, by providing good screening for the input circuit and for the preamplifier itself (signal-return inside the cable-screen, the latter bonded to signal-earth at the amplifier end only), and by properly smoothing (preferably regulating) the DC supply.
The sensitivity of the SN 76131 to interference on the DC supply rail is quoted – under operating conditions rather different to the above – as 50 μV/V. (i.e. 50 μV apparent input for each volt of supply disturbance). To achieve the 1 μV hum level just mentioned means keeping supply ripple below 20 mV. A simple active circuit will readily meet this requirement;

4



simple smoothing of a 'raw' DC supply would probably be inadequate or too expensive (or both!).

Clipping at the output

The requirement that the input circuit is not overdriven will not by itself guarantee that the amplifier as a whole operates within limits. The output circuit can still 'run out of' voltage or current swing.

Taking the combination of a sensitive cartridge and the maximum disc modulation likely to be encountered, one can estimate the highest level of output signal that the preamplifier will have to deliver. This can be done by combining the closed-loop gain characteristic (figure 1, thick line) with the maximum cartridge output contour (thick line in figure 2). The result is shown in figure 3 (thick line). The conclusion is that the voltage swing at the output can be as high as 2.5 V RMS (7 V p-p).

The clipping level for the SN 76131 depends on the supply voltage and on the load impedance. The case of $V^+ = 30$ and $R_L = 10$ K, where the IC can deliver about 7 V RMS, is shown dashed in figure 3. This reserve should take care of all eventualities. If one considers a brink-of-disaster capability of 3 V RMS, then the combinations 18 V/5 K, 14 V/10 K and even $V^+ = 12$ (at $R_L = 50$ K) are in order. Even under these conditions, current clipping due to the load of the feedback network on the output (at the highest audio frequencies) and slew-rate limiting (due to the early open-loop rolloff) are not expected to occur.

Integrated circuit

The circuit was designed around the specified SN 76131 by Texas Instru-

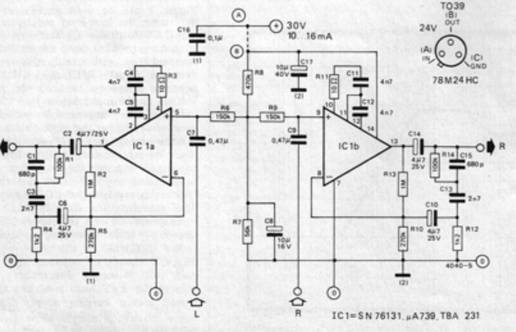
Figure 4. The pinning of the IC's SN 76131, TBA 231, TCA 590C, μA 739C and LM 1303 (figure 4a) is identical. The internal circuit diagram (figure 4b) however only applies to the SN 76131.

Figure 5. The circuit diagram of the equaliser-preamplifier. An integrated voltage regulator, when required, can be connected between the points A and B (see text).

Figure 6. PC board and component layouts for the equaliser-preamplifier. All external connections are made to one edge of the PC board, so that it can be used as plug-in module in a complete control amplifier.

Figure 7. Illustration of the preamplifier board as plug-in module.

5



Parts list to figure 5.

Resistors:
R_1, R_{14} = 100 k
R_2, R_{13} = 1 M
R_3, R_{11} = 10 Ω
R_4, R_{12} = 1k2
R_5, R_{10} = 270 k
R_6, R_9 = 150 k
R_7 = 56 k
R_8 = 470 k

Capacitors:
C_1, C_{15} = 680 p
C_2, C_6, C_{10}, C_{14} = 4μ7, 25 V
C_3, C_{13} = 2n7
C_4, C_5, C_{11}, C_{12} = 4n7
C_7, C_9 = 0.47 μ
C_{16} = 0.1 μ

Semiconductors:
IC_1 = SN 76131, μA 739C, TBA 231

6

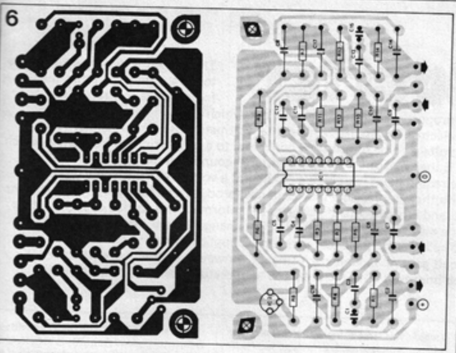


Table 1. The most important specifications of the SN 76131 and μA 739C.

V^+ max.	36 V
V_{in} max.	± 5 V
P_{tot} max.	500 mW
V_{out} swing	1 . . . 26 V*
Open loop gain typ	18000*
Open loop gain min	6500*
Z_{in} typ.	150 KΩ*
Z_{in} min.	37 KΩ*
Z_{out} (1 KHz)	5 KΩ*
Crosstalk (10 KHz)	−140 dB*

* These values apply for V^+ = 30 V; R_L = 50 KΩ

ments. According to the maker's data sheets, the Fairchild μA 739C and the SGS TBA 231 are almost identical and should perform well in the circuit. The three IC's are pin compatible (see figure 4a). Two other IC's with the same pinning are the Philips TCA 590 C and

Table 2. Main specifications of the disc preamplifier described here.

Voltage gain, 1 KHz	40 dB
Equalisation IEC	± 1 dB
Max. input (RMS)	80 mV
Max. output (RMS)	7 V
Input noise level	2 μV
S/N ratio	55 . . . 70 dB*
Crosstalk (1 KHz)	−80 dB
T.H.D.	⩽0.1%

* see text

the LM 1303 by National Semiconductors. This last device has lower specifications for gain, noise and drive level – it will probably work acceptably in the preamplifier, but we have not checked this.

The internal circuit of the SN 76131 (and the TBA 231) is given in figure 4b. Except for the output transistor, the μA 739C is identical. Table 1 lists the most important characteristics of the device. The TCA 590C has an additional class B output stage, while the LM 1303 circuit dispenses with the stabilising diodes and with the current sinks for the second long-tail pairs.

The external circuit

Figure 5 gives the complete circuit diagram of the equaliser-preamplifier. The open-loop response is set up by $C_4/C_5/R_3$ and $C_{11}/C_{12}/R_{11}$; it follows the appropriate dashed curve in figure 1. The IEC correction networks are $R_1/R_2/R_4/C_1/C_3$ and $R_{12}/R_{13}/R_{14}/C_{13}/C_{15}$. R_5 and R_{10} take care of the DC biassing. With the values given, the correction obtained using 5% components is within 1 dB of the IEC (RIAA) standard.

The input blocking capacitors C_7 and C_9 should not be replaced by larger values or by electrolytics. This could lead to undesirable switch-on phenomena ('plop' or even momentary oscillation). The values given will not affect the bass response (which is 1 dB down at 20 Hz).

It has already been pointed out that the supply ripple must be well filtered. A typical regulated supply will meet the requirements, but a 'raw' supply followed by resistor-electrolytic filter will usually cause too much hum. In this case one can use an IC voltage regulator which will deliver 24 . . . 30 V at 15 mA (or more), e.g. the Fairchild μA 78M24HC. The printed circuit board (figure 6) has a position for this regulator. If such a device is not to be used, the points A and B should be bridged.

To simplify assembly, all external connections have been placed at one edge of the PC board, using standard grid-spacing. A control amplifier which will be published at a later date has a PC board designed to accomodate the disc preamplifier as a plug-in module (figure 7).

Table 2, in conclusion, summarises the most important specifications of the equaliser-preamplifier for disc records.

Lit.: Texas Instruments data sheets for SN 76131.

7