Optimised MC circuit is 4dB quieter

Universal preamplifier for MC cartridges

The Universal Phono pre-amplifier described in May 1982 was one of our best to date, particularly as regards signal-to-noise ratio. Nevertheless, the S/N ratio was a compromise between the needs of both the moving magnet and moving coil cartridges it was designed to serve. This article explains how to optimise it for moving coil cartridges, for those who have an exclusive need.

Before delving into the actual modification, it may be helpful to look at the whole subject of signal-to-noise (S/N) ratio in pre-amplifiers, some of the factors effecting it, how it is measured, and some of the limitations of current measuring standards.

The IHF-A-202 "Standard Methods of Measurement for Audio Amplifiers, 1978" specifies a standard input (source) termination of 100Ω and a standard input reference level of 500μV at 1000Hz for moving coil (MC) amplifier inputs. These specifications can produce results which are quite misleading. For example, many pre-amplifiers quote basically similar S/N figures (around 75dB) for both MC and MM (moving magnet) modes, yet even the untrained ear can detect that the noise is noticeably increased when the pre-amplifier is in the MC mode.

To illustrate why these figures are so unrealistic, let us consider the figures specified for the MM type pickup. These call for a source of termination of 1000Ω and an input of 5mV at 1000Hz. These figures are quite realistic and are based on the assumption that most MM cartridges generate 1mV/cm/s, and that the reference level for disc recordings lies between 3.5 and 5cm/s.

By comparison, typical MC cartridges produce only 20 to 30μV/cm/s, or about 100 to 150μV from the same 3.5 to 5cm/s disc reference level. On this basis the IHF figure of 500μV is between four to five times (12 to 14dB) higher than practical output figures. On this basis we suggest that a more practical reference level would be between 100 and 150μV; the lower figure for preference.

A second important factor in assessing signal-to-noise ratio is the source, or cartridge, resistance. Ideally, the S/N ratio of an amplifier should improve by 10dB for every decade that this resistance is reduced, ie, a 10Ω source resistance should produce a 10dB improvement over a 100Ω value. And, while the IHF standard specifies 100Ω as the test value for MC cartridges, typical cartridges have values considerably less than this, many lying in the region two to 10Ω.

Thus an amplifier designer who tests an MC amplifier on the basis of the IHF standard, with a 100Ω source resistance, may be inadvertently underrating his amplifier's capability, when used with a typical (say) 10Ω cartridge. Alternatively, two different amplifiers, with identical MC S/N ratios, according to the IHF standard, can produce quite different results when tested with a practical cartridge of only 10Ω.

More realistically, S/N ratios for an MC input should be quoted for source resistances of not only 100Ω, but also for 10Ω and short circuit. This would give a far clearer picture of the performance of the preamplifier and also give some indication of the noise versus resistance trend.

All of which is simply by way of leading up to some practical changes to our Universal Phono Preamplifier, and the

Moving Coil Mode

Noise below 500μV input level at 1kHz

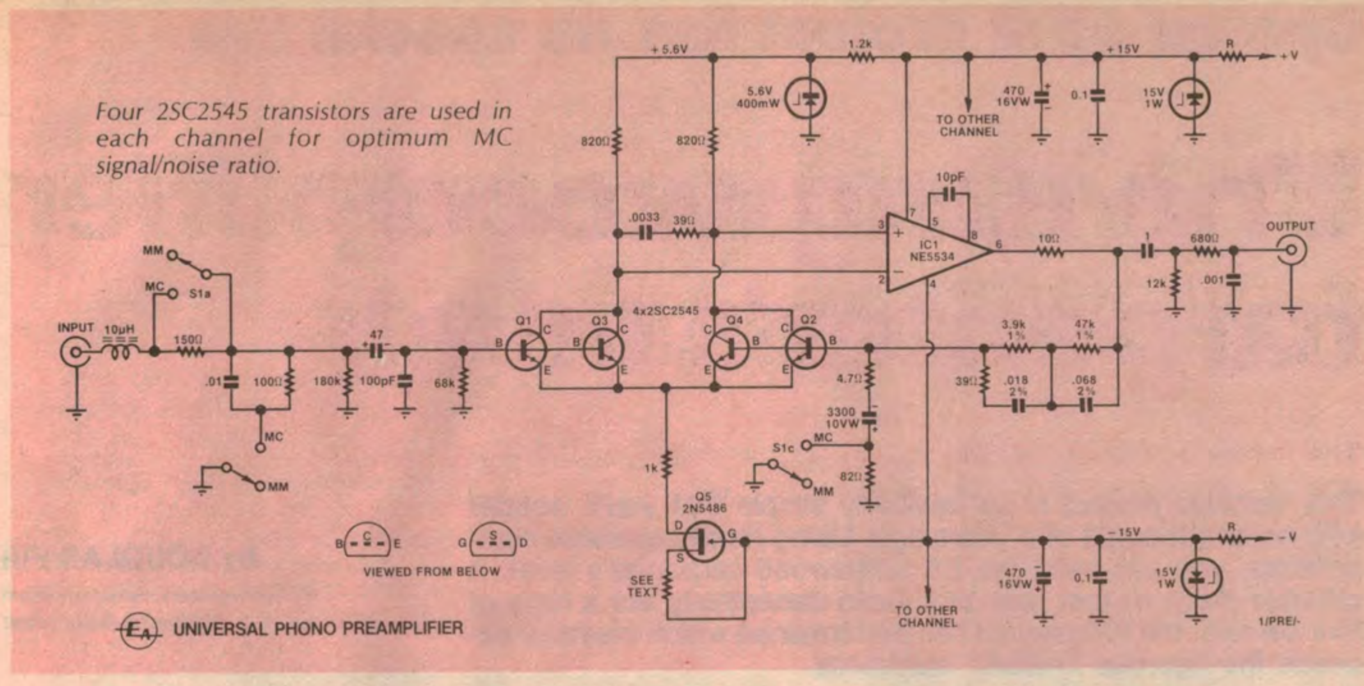
Input Termination	May 1982 version (LM394s)	New version (2SC2545)
Open circuit	75dB	77dB
100Ω	77dB	78dB
10Ω	78dB	82.5dB
Short circuit	79dB	84dB

Moving Magnet Mode

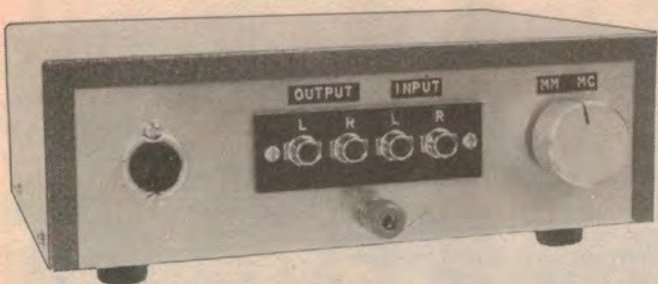
Noise below 5mV input level at 1kHz

Input Termination	May 1982 version	New version
Open circuit	66dB	64dB
22kΩ	74dB	72.5dB
18kΩ	75dB	73.5dB
*10kΩ	77.5dB	76.5dB
1kΩ	86dB	85.5dB
100Ω	91dB	91dB
10Ω & short circuit	91dB	91.5dB

The above tests were made with a 20Hz to 20kHz bandwidth, unweighted.
*Approximately equivalent to a Stanton 500 cartridge.



Four 2SC2545 transistors are used in each channel for optimum MC signal/noise ratio.



If the best signal-to-noise ratio figures are to be achieved the case needs to be of all-steel construction.

results we achieved with them. As originally presented this amplifier showed a change of only 1dB for an input termination change from 100Ω to 10Ω. This wasn't as bad as it sounds, considering that it was a dual purpose. MM/MC amplifier which was not really optimised for either mode.

4dB improvement

Subsequently, we investigated the possibility of improving on these figures by optimising the characteristics for MC cartridges – albeit with a probable trade-off in S/N ratio for MM cartridges. And we are pleased to report that we have been able to achieve a 4dB improvement in S/N ratio when operating from a 10Ω source.

As expected, the S/N ratio for the MM mode deteriorated (by approximately 1.5dB), but which is still a more than satisfactory performance. And it does seem to prove that, in its original form, this offered what was probably the best compromise between the MM and MC codes.

So, if you are interested in the MC mode, here's how to get that extra 4dB of shush. The design of a low noise preamplifier hinges on using low-noise input transistors with a very low intrinsic base resistance. Intrinsic base resistance varies inversely as the collector current density, but tends to level off as the current density is increased above a level where the transistor characteristics become non-linear.

To further complicate matters, transistor noise increases directly as the collector current is increased, so that there is an optimum current density beyond which the increase in noise offsets the decrease in intrinsic base resistance (and the decrease in noise which it provides).

At the time of writing the two transistors best suited to this circuit are the National Semiconductor LM394 (as used in the original), and the Hitachi 2SC2545. The latter was tried in the original circuit, and its high order of performance confirmed, but it was not available in quantity. This situation has now changed. (There may be other types which would suit, but we are not aware of them.)

Investigating the 2SC2545 we found that it is capable of approximately 2dB better noise than the LM394 when operating from source resistance of 10Ω or less. In fairness, however, the situation appears to reverse when the source resistance is increased above 1000Ω, the LM394 giving slightly better results in these circumstances.

By paralleling the first stage transistors we halve the intrinsic base resistance (provided the h_{ie} figures are reasonably matched) and this is the major contribution to the 4dB improvement. However, it was also necessary to increase the current density to optimise the 2SC2545 operating conditions.

The exact changes are shown on the accompanying modified circuit, but are as follows.

(1) The 2.2kΩ decoupling resistor between the +15V rail and the 5.6V zener diode is reduced to 1.2kΩ.

(2) The two LM394s are replaced with four 2SC2545 connected as parallel pairs.

(3) The 2N5485 FET is changed to a 2N5486, with a 2N5489 as a second but less desirable choice.

(4) The 2.7kΩ resistor between the 2SC2545 emitters and the 2N5486 drain is reduced to 1kΩ.

(5) The 390Ω resistor between the 2N5486 source and gate is changed to a value, determined experimentally, which increases the total input stage current density from an original 1.7mA to 4.9mA.

(Component numbers quoted are for one channel only.)

Some of the voltages shown on the original circuit will also be changed as follows.

Input stage collectors: +3.6V (was +4.9V)
Input stage bases: −0.3V (was 0.1V)
Input stage emitters: −0.9V (was −0.7V)
FET drain: −5.8V (was −5.5V)

Details of the improved performance figures are given in the accompanying panel.

Hitachi low-noise 2SC2545 transistors are available as a stock item from Jaycar Pty Ltd.