Performance

The input transistor originally chosen was the 2N4403, a type that was acknowledged as superior for this kind of application for some years, due to its low R_b of about 40 Ω. A single device used in the circuit of Figure 10.5 gives an EIN of −138 dB with a 4 mA collector current and a 3.3 Ω source resistance. The Johnson noise from 3.3 Ω is −147.4 dBu, so we have a noise figure of 9.4 dB. It was then consistently found that putting devices in parallel without any current-sharing precautions whatsoever always resulted in a significant improvement in noise performance. On average, adding a second transistor reduced noise by 1.2 dB, and adding a third reduced it by another 0.5 dB, giving an EIN of −139.7 dBu and an NF of 7.7 dB. Beyond this further multiplication was judged unprofitable, so a triple-device input was settled on. The current-sharing under these conditions was checked by measuring the voltage across 100 Ω resistors temporarily inserted in the collector paths. With 3.4 mA as the total current for the array, it was found after much device-swapping that the worst case of imbalance was 0.97 mA in one transistor and 1.26 mA in another. The transistors were not all from the same batch. It appears that, for this device at least, matching is good enough to make simple paralleling practical.

A superior device for low source impedances was the purpose-designed 2SB737, with a stunningly low R_b of 2 Ω. Three of them improved the EIN to −141.0 dBu and the NF to 6.4 dB, albeit at significant cost. Sadly it is now obsolete (why, for heaven's sake?) but can still be obtained from specialised suppliers such as the Signal Transfer Company [4]. It is generally agreed that the best replacement for the 2SB737 is the Zetex ZTX951. Although its voltage noise performance is not specified, *The Art of Electronics (Third Edition)* gives the measured R_b of the ZTX951 as approximately 1.2 Ω, which is better than the 2SB737, though performance may not be so consistent. The ZTX851 is the NPN complement, with a measured R_b of approximately 1.4 Ω.

You will have spotted that R7, at 3.3 Ω, generates as much noise as the source impedance; this only degrades the noise figure by 1.4 dB, rather than 3 dB, as most of the noise comes from the transistors.

It would be instructive to compare this design with other MC preamplifiers, but it is not at all easy as their noise performance is specified in so many different ways that it is virtually impossible to reduce them all to a similar form, particularly without knowing the spectral distribution of the noise (this chapter uses unweighted noise referred to the input, over a 400 Hz–20 kHz bandwidth and with RIAA equalisation *not* taken into account). Nonetheless, I suggest that this design is

TABLE 10.3 MC head amp performance figures

Input overload level.	48 mVrms
Equivalent input noise.	−141.0 dBu, unweighted, without RIAA equalisation. (3.3 Ω source res)
Noise figure.	6.4 dB (3.3 Ω source res)
THD.	Less than 0.002% at 7 Vrms out (maximum gain) at 1 kHz Less than 0.004% 40 Hz–20 kHz
Frequency response.	+0, −2 dB, 20 Hz–20 kHz
Crosstalk.	Less than −90 dB, 1 kHz–20 kHz (layout dependent)
Power consumption.	20 mA at ±15 V, for two channels

quieter than most, being within almost 6 dB of the theoretical minimum and so with limited scope for further improvement. Burkhard Vogel has wrote an excellent article on the calculation and comparison of MC signal-to-noise ratios [5], and this has been much expanded and incorporated in his remarkable book *The Sound of Silence* and goes into more detail than there is space for here [6]. It is highly recommended.

The performance is summarised in Table 10.3. Careful grounding is needed if the noise and crosstalk performance quoted is to be obtained.

When connected to a RIAA-equalised MM stage as described in Chapter 9, the noise output from the MM stage is −93.9 dBu at 10 times MC gain and −85.8 dBu at 50 times. In the ten times case, the MC noise is actually 1.7 dB lower than for MM mode.

Note the noise figure is 6.4 dBu; there is definitely room for improvement.

Opamp arrays for MC preamps

Now and again I have pondered the possibility of making a rough-and-ready MC preamp by paralleling 5532 opamps; a technique that appears in many places in this book, especially Chapter 1. The 5532 is pretty much the only opamp that is cheap enough and quiet enough to make this practical. If we take a single 5532 section (half a package) and completely ignore the effects of current noise and Johnson noise in the multiple—feedback networks, the EIN is calculated as −120.4 dBu (22–22 kHz, RMS), which is a hefty 21 dB noisier than my aforementioned design. Four opamp sections (two packages), theoretically at least, reduces the EIN by 6 dB to −126.4 dBu, and 16 sections (eight packages) gets the EIN to −132.4 dBu, which is sort of a practical option and is starting to get in sight of our goal of −141 dBu (see Table 1.14 in Chapter 1). But to actually reach it we need 128 sections (64 packages), which is neither practical nor economic—don't forget that's just one channel, so stereo is 128 packages and really not on. And don't forget we have ignored current noise and Johnson noise. This is not a good route unless a mediocre noise performance is acceptable.

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