Moving Coil Preamp

May I humbly present for your approval, a simple amplifier for Moving Coil cartridges.

WIRELESS WORLD JULY 1981 75

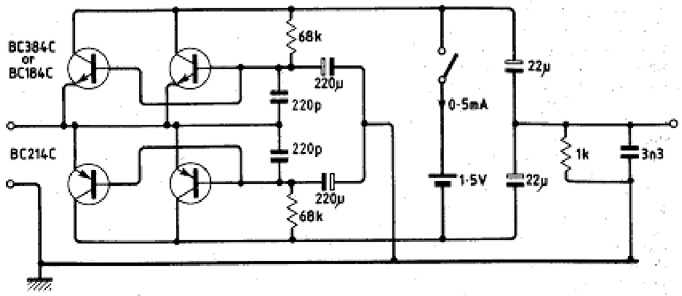
CIRCUIT IDEAS

Low noise moving-coil preamp

Noise performance of this design is about 3dB below many similar commercial units, and the high-frequency response is −1dB at 150kHz without the 3n3 output capacitor. The output clips at about 500mV and, below 150mV, distortion is caused solely by the push-pull input stage. Cartridges with high impedances will give lower distortion. High quality components must be used throughout and the circuit layout should be neat with no long connections. The circuit shown has been optimised for an Ortofon moving-coil cartridge, but other types should also be suitable.

Performance

Voltage gain	35dB
Input impedance	20Ω



Noise (unweighted 10Hz to 15.7kHz) referred to input (includes hum)

o.c	74nV	
s.c.	52nV	4 transistors as shown
	74nV	2 transistors only

Frequency response
−1dB at 15Hz
−3dB at 50kHz (see text)

Output harmonic distortion (mainly 3rd)

	R_s 3Ω	6Ω
400mV		0.32%
150mV	0.13%	0.1%
100mV	0.1%	0.056%
50mV	0.05%	

R. Lee
Bradford

A version using Hitachi 2SA1084 / 2SC2546 and running about 3mA is probably the **lowest noise such device in the known universe**. 3dB NF for 5R source. Less than 40nV over 20kHz. ie <0.28nV/rtHz

This one running about 0.5mA is optimized for 20R source for which it gives 3dB NF. It was actually designed for an Ortofon MC20 which has much less resistance but is still quieter than anything else I could find for it. Only a large, very expensive Denon transformer is close in practice and nothing else even from the specs of other devices.

A Denon DL103 & 303 also performed very well with this version though again the source is not optimized. Better in fact than with the above matching Denon transformer.

The Hitachi transistors have rbb (the effective voltage noise resistor above a perfect transistor) probably around 5R7 and are better than Toshiba 2SA970 / 2SC2240 which I have also tried.

The WW battery circuit shows the input connected to the 'chassis' cos the input & output sockets were adjacent to each other. Hence the 'chassis' is really a continuation of the cable shielding braid with all the guts inside the cable.

The 220p capacitors are NPO / COG ceramics as close to the transistors and the input socket as possible. The 3n3 on the output should be a high quality film, polypropylene preferably.

The critical electrolytics are the 220u which should be Panasonic Low Leakage with very low ESR. The loop around these, the Vbe of the transistors and the input socket should be as small as physically possible. Uwe Beis recommends Sanyo OSCON caps as having very low ESR but I haven't tried them. I would use much higher voltage than what's required; maybe 25V to get the best ESR. But listen to the noise of any caps you try. It's easy with this circuit. Just increase the output resistor described here for loadsa extra gain.

The 1k resistor on the output must be non-inductively wound with the hair of Bradford virgins on an Unobtainium core. OK just use a Holco or other high quality Metal Film resistor .. 8>D

Why is it so good?

As you know, I like resistors. They have much less noise & distortion than other stuff. But for certain applications, resistors .. well they resist the flow of electrons. In this circuit, no resistors get in the way of the signal. Only the output resistor affects the sound. Transistors on the other hand, transist .... 8>D

Why is it common base?

I'd much rather have common emitter as the best common base can do is 3dB NF. However ..

As it has no feedback, the distortion characteristics are important even at the small signal levels here. I assumed the distortion would be similar to a long tailed pair and did a full analysis when I got some unbelievably good figures. Common emitter gives more distortion.

With common base, the operating conditions for power matching are the same as for lowest noise. This is often used at RF. Serendipity?

The electrolytic capacitors are much more effective on the base than on the emitter. These are critical and investigating these was a major reason for my prejudice against Tantalums. Its worth listening to the capacitors you use to hear what the noise sounds like and what happens when you get a signal near the noise floor. Tants give a crackly, popcorn almost like 1/f noise or insufficient dither. And the best ones aren't what the loonie press .. I mean the Golden Pinnae brigade recommend.

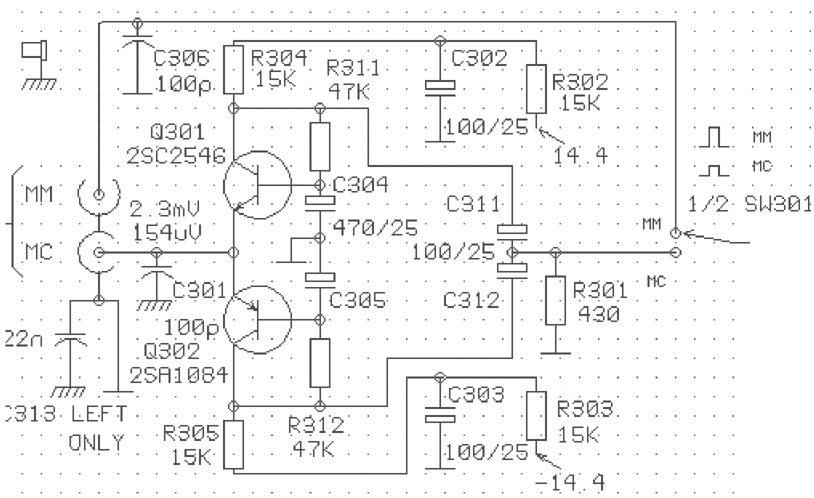
Common emitter doesn't have enough gain for virtual earth on this circuit and having found so many good 'features' with common base, was reluctant to spend the time investigating another configuration fully. The tried & tested item already met the objective of being the lowest noise such device ...

Why no feedback?

Feedback would allow common emitter, lots of current and even better NF. A virtual earth is best; no resistors in the way.

I tried a virtual earth incorporating an OPA in the feedback loop ala Mk4 Soundfield … but it didn't actually give better results than the 3mA battery version. One reason was it had power supplies and hum and other stuff got in the way. The 1.5V prototype was in a little round Duraglit metal tin with one C size cell / channel and made no difference to the noise of a good RIAA preamp fed by a 1K resistor. Ortofons, which have very low voltage (but high power) output, are quieter with this circuit than moving magnets into a good RIAA amp.

Powered version



This, the most successful powered version, overcomes the main disadvantage of the battery circuit; that the gain goes down and noise goes up as it runs down. But at 0.5mA, a C size R14 alkaline lasts for months before you notice any deterioration. And this more complex version may put current through the input. (in practice not a problem for MC cartridges)

C301 is a NPO ceramic and goes directly to the chassis. Must be very close to C313, Q301/2 and the input socket.

The critical electrolytics are C304/5 which should be Panasonic Low Leakage. The loop around these, the Vbe of Q301/302 and the input socket should be as small as physically possible.

But I didn't have time to work on this fully as it had to go into a commercial design which was required yesterday, in the usual fashion.

Note the different earthing arrangements & placement of the 100p ceramics for this device built as part of an integrated amplifier.

This little 50W amplifier now (2012) has a cult following in certain circles more than 20 yrs on … almost certainly due to its MC amplifier stage.

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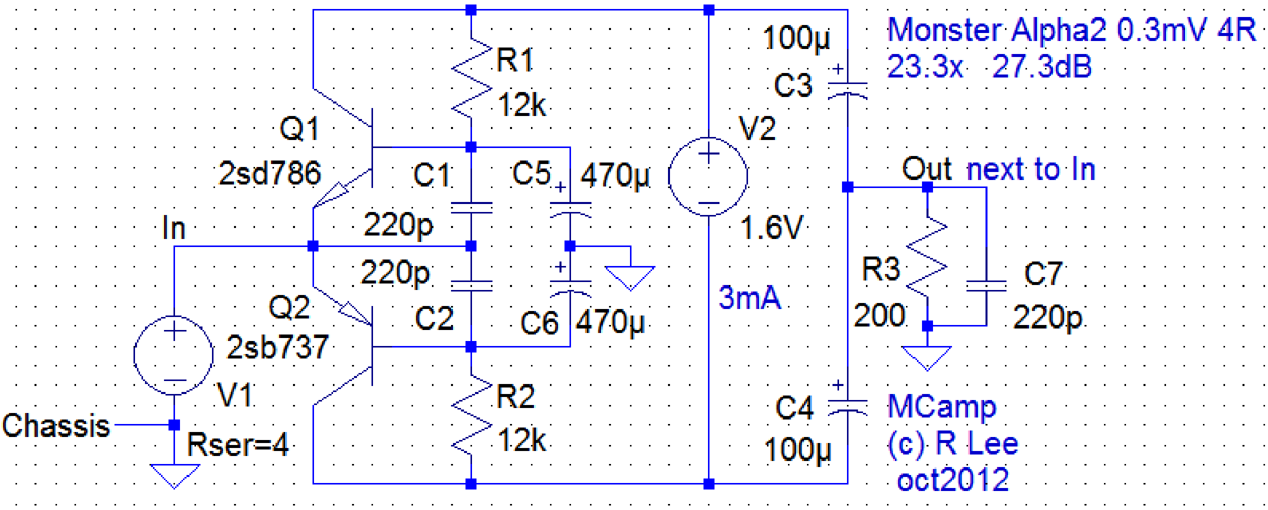
the quietest MC step up

I was asked to resurrect this design as it appears to be *still* the lowest noise such device in the known universe. *There are quieter amps for specialist applications but none sensible for MC cartridges.*



Anyone with a Moving Coil cartridge these days will be a Golden Pinnae so I make no apologies for taking an uncompromising approach … including discarding any Golden Pinnae myths that get in the way of good sound. It is NOT a beginners project as the layout & PCB design skills need to be of the highest order not to compromise the noise performance.

The recommended circuit is the battery powered one. It's so simple that you might as well knock one up and use it while you spend the next 30 yrs trying to equal it with a powered version.

Best enclosure is soft iron with overlapping seams like the Duraglit tin in which I built the prototype.

http://www.thecrowdcontroller.com/images/duraglit.jpg
http://www.heritagelanterns.com/hlart/lanterns/p25c.gif

If no such a beast is attractive enough for you, avoid ferrous enclosures entirely. An all Aluminium case doesn't provide any protection from hum fields but at least the non-overlapping edges won't concentrate the hum flux in unwanted places like a ferrous box with edges.

The most important measure against hum is to make the *PCB as small as possible.* Have a look at LNprimer.doc in my MicBuilders Files directory … but here, *everything* is a critical **input loop**.

Tightly twist all leads including those to the switch & battery.

Matching

The two earlier versions ran 0.5mA and were actually optimised for 20-25R MC cartridges. At that time (1980 - 1990), even without correct matching, they were still quieter than any other device or amp I could find; including some very expensive transformers.

However, common-base has a best NF of 3dB so there are significant advantages for optimal matching including much better distortion.

Cartridge DC	R1/2	Current I
24R4	68k	0.51mA
12R9	36k	0.97
6R6	18k	1.9
4R2	12k	2.9

Don't agonise too much over this. Choose a *resistor slight greater* (*slightly less current*) if you can't get it exact. *Don't go over 3mA*. *Keep the physical layout small*.

Once the input is matched to the cartridge, select R3 for the gain you want.

Gain = R3 x I / 25R I in mA.

I suggest a gain that takes the nominal sensitivity of the cartridge to 5 – 7mV @ 5cm/s. With a noisy RIAA preamp with a lot of extra overload capacity (eg a tube preamp), use more gain up to 15mV. An RIAA preamp with poor overload, like many with passive RIAA EQ, should have the gain adjusted for 5mV @ 5cm/s.

R3 = 7mV x 25R / (I x OCsens) OCsens : Open circuit sensitivity of cartidge in mV @ 5cm/s
= 175 / (I x OCsens) for 7mV output

Examples	DC	**OCsens**	R1/2	I mA	R3	Gain		O/P 5cm/s
Audio Technica AT-37	3R	0.1mV						
Denon DL-103	40R	0.3						
DL-303	40R	0.2						
Koetsu Black	5R	0.6						
Monster Alpha2	4R	0.3	12k	2.9	200	23.2x	27.3dB	6.96mV
Ortofon MC20 Super	5R	0.25	15k	2.4	270	25.9x	28.3	6.48
Rowen MC-06	20R	0.565						
Rowen Absolute	3R9	0.381						

R3 can be tweaked to correct any imbalance between the 2 channels of the cartridge.

C7 in conjuction with R2 can provide the 75us EQ in an RIAA network but I don't recommend this. Among the cons, it upsets the finely judged noise performance. Also the size of a high quality capacitor for 75us will be huge and brings serious problems with RFI & hum etc. Remember, this is the *quietest* such device in the known universe.

Parts DO NOT substitute Golden Pinnae stuff for Critical parts. They are OK for other bits as long as they do not increase the size of the PCB layouts and the **input loops**. DO NOT add Golden Pinnae capacitors in parallel with stuff here.

Critical

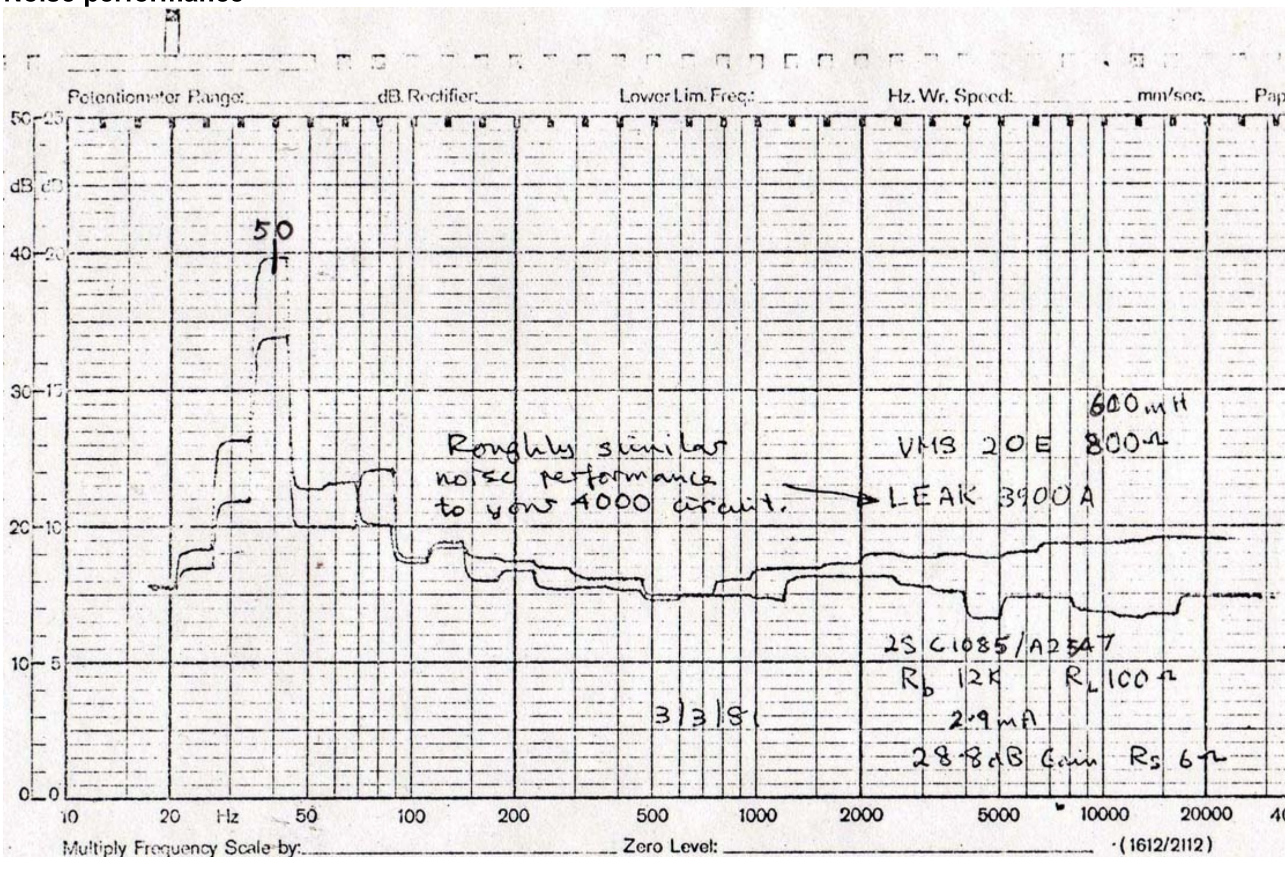
	R1/2		good 0W4 1% metal film
*	R3		good 0W4 1% metal film. Golden Pinnae stuff OK here if small
*	C1/2	220p	NPO/COG ceramic. Must come from the same batch
	C3/4	100u	16V Aluminium Electrolytic

*	C5/6	470u	*Aluminium* Lo ESR electrolytic. 'Small' size. Most difficult item to specify. Leave PCB space to try different ones. see text	
	C7	220p	NPO/COG ceramic	
*	V2	1.5V	*Alkaline* C size dry cell for each channel. 3 mth life for the 3mA versions. Up to 12 mths for the 0.5mA version	
*			*2 pole switch to turn off both channels when not in use*.	
*	Q1	Rohm 2sd786, Toshiba 2sc3329, Hitachi 2sc2545/6/7 still available from international futurelec.com stores		in order of preference
*	Q2	Rohm 2sb737, 2sa1316, 2sa1084/5/6 If you know of a source for any of these, please email me.		all sadly Unobtainium.

If you can't get the recommended transistors, Toshiba 2sc2240 & 2sa970 are probably the best of the rest. You may need more than two pairs in parallel to equal the noise performance of the recommended devices if your source is 4R. Higher resistance cartridges are less critical.

Some medium power devices can be suitable but they have to be selected for noise. I no longer recommend these as 1/f noise is usually larger too. If you use transistor sockets to select devices, make sure you remove them and *solder the transistors directly in place* for the final item.

Noise performance



Here's a 1/3 8ve noise plot. The B&K 2307 chart recorder has slipped by 1 tooth so 50Hz (hum) appears at 40Hz. 1dB/division

The MM is an Ortofon VMS20E. The Ortofon MC, either MC20-2 or MC10. The MC preamp is set for very high gain 28.8dB (22.8dB if calculated according to the above formula) so if adjusted for equal loudness from the 2 cartridges, the noise advantage of my little circuit is even better.

What this shows is that with the common noise weightings, the MC with this circuit is at least *3dB better than the MM* into a good MM RIAA preamp. But the character of the noise is nicer too. With RIAA, MM noise is whitish while MC is redder than pink and less obtrusive.

At the time, every other MC step up device was at least 6 - 10 dB worse (usually much worse) depending on how you measured the noise. So you normally don't see this cos the noise of the step up device dominates.

If you can match a MC properly, you'll get better S/N than MM. MCs have quite high power output even if voltage is low. MM is inherently inefficient in comparison. Also the inductance doesn't let you get close to true efficiency except for 1 frequency.

Does ultra low noise on vinyl playback matter?

I think so. From analysing my listening test results and ignoring any obvious Golden Pinnae raving, there is a sense of less grittiness and also the system seems to disassociate clicks, pops & record noise from the music. Maybe a noise modulation effect. But I'm probably pontificating from the wrong orifice and it was 30+ yrs ago.

I'm very proud of the battery design as it is best of breed and very simple. Unlike the Soundfield Mk4 which is best of breed but not simple.

The history of this design is that a friend built http://users.ece.gatech.edu/mleach/headamp/

and was disappointed with the performance so I said I'd make him a better one. This is a good example how understanding a circuit thoroughly can transform its performance from mediocre to "best of breed".

This version has MUCH better noise and distortion compared to the Leach version(s) and its commercial copies; especially with a real MC cartridge.

http://www.synaesthesia.ca/LNschematics.

This is what prompted me to re-visit noise performance. A cursory look at these very detailed pages suggests he’s finally achieved my 0.28nV/rtHz performance. Closer examination says some of his noise measurements are wonky and I don’t believe his rbb figures at all. He does mention some of the things which need addressing though there is no need to adopt his supa methods. The bottom line is his *slightly* (??) more complex circuit is not as quiet and probably has more THD with real MCs. Overload recovery probably OK.

Comments, good or bad, especially from anyone who has tried the circuit with a real Moving Coil vinyl replay system to

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Needed a place to put some info on MM noise from **Boston Audio Soc 1975** test on noise
http://www.vinylengine.com/turntable_forum/viewtopic.php?t=22874

Their noise plots are constant bandwidth. Note effect of loading caps.

Phono Cartridge Noise: A New Low

In the accompanying figure, RIAA A-weighted noise curves are plotted for some new ADC cartridges: the Super XLM Mk II, the XLM Mk II, and the VLM Mk II. Data for the Shure V-15III, taken from a previous Speaker , are also plotted for reference.

The equalized and weighted noise voltages for the Super XLM Mk II are 0.24 µV, compared with 0.32 µV for both the XLM and VLM Mk II (both have identical specifications). The Shure reference is 3 to 5 dB noiser at 0.45 µV.

This low noise in the ADC's results from their very low dc resistance, as seen in the table below:

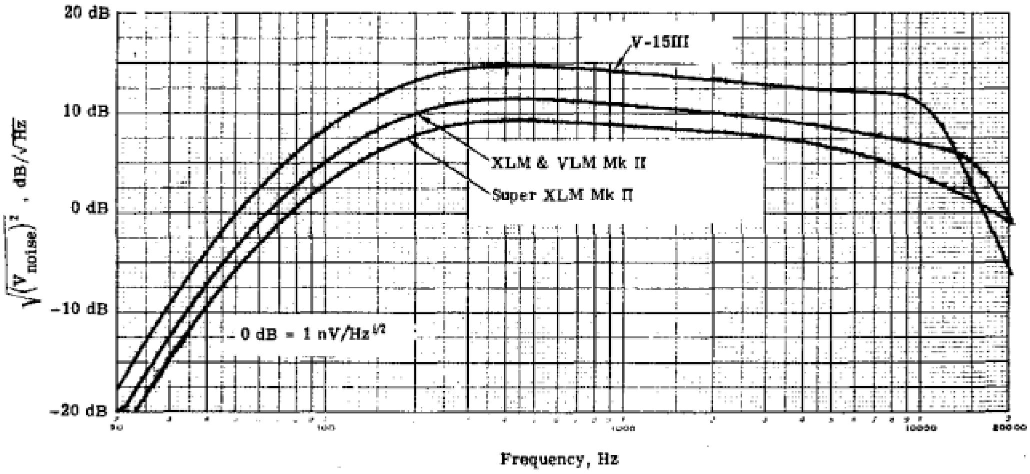
Super XLM:	R = 375 ohms, L = 300 mH, and C = 100 pF
XLM and VLM Mk II:	R = 635 ohms, L = 350 mH, and C = 450 pF
Shure V-15III:	R = 1350 ohms, L = 500 mH, and C = 450 pF.

47-kohm load and RIAA for all

Using values as listed in the 1975 Buyer's Guide , it seems that nearly all cartridges have nominal 3.5-mV outputs at this level, while the XLM Mk II has been measured at a larger 5.25 mV. As seen in the following S/N ratios, the ADC's are clearly the most impressively quiet line of cartridges to date:

Shure V-15III	78 dB	Micro-Acoustics QDC-1	79 dB
XLM Mk II	84 dB	Super XLM	83 - 87 dB for 3.5 - 5.25 mV nom.

Harry Zwicker.



History
4feb14 to MicBuilders
13oct Rowen MC-06 & Absolute
17sep13 MM noise from Boston Audio Soc
26oct12 separated from README.doc & 3mA version described in detail. To Andreas & MicBuilders