All About The Phono Preamp

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As most of today's amplifiers or pre-amplifiers don't have a socket marked turntable, a phono preamp is what you need to connect a turntable to on your audio or hi-fi system.

Phono Preamp and Hi-Fi System Basics

The phono preamp is an electronic circuit or stage that deals with the correct amplification of the phono cartridge and sends it to the input of an amplifier, a pre-amplifier, or an audio system. It is commonly called a phono preamp, phono stage, phono preamplifier, RIAA preamp or turntable preamp, just to confuse matters further for the non-technical.

A phono preamp therefore is a separate box you would have to purchase and connect between your turntable and your amplifier, but what does it do? And with so many phono preamps or phono stages at several different prices to choose from, will any do?

By answering "what does it do", I hope it should guide you to making the right choice.

Firstly for those who don't know, I'll explain in the most basic terms I can, what a preamp in general is. A preamp is short for pre-amplifier - a little amplifier that deals with tiny or small signals, boosting them up so they're big enough to drive a power amplifier which then drives your loudspeakers. A general purpose hi-fi amplifier is a one box unit that comprises a pre-amplifier and power amplifier. Its proper name is an "integrated" amplifier because it integrates the functions of pre-amplifier and power-amplifier in one box.

In yesteryear before the digital revolution, people had tape decks or cassette decks, FM radio tuners, turntables (*or record players*), and maybe an old eight-track or the output of a video player which they'd connect to "the stereo" and hear through the speakers. The amplifier was therefore presented by a number of different signal voltages from all these musical sources which it had to pre-amplify by different amounts to make them all the same so the power-amp stage could get on with the job of driving the speakers. And therefore the inputs would be marked accordingly: "tape", "tuner (*or radio*)", "turntable (*or disc, or records*)", and "aux" to cover anything that was auxiliary such as the eight-track or video player.

Then CD (*compact disc*) came along, and amplifiers started to feature an input marked "CD". Some amplifiers featured a "CD-direct" button that bypassed the preamp stage completely, delivering the signal from the CD player directly to the volume control just before the power-amp stage.

As the use of vinyl records declined, many integrated amplifiers stopped featuring an input for the record player or turntable. And today, with virtually all signal sources being of digital origin, with similar signal voltages in the region of half to one volt, the preamp-stage itself is no longer required, being replaced by a switch or bank of switches that simply select one of a number of identical inputs, feeding them to a volume control and from there directly to the power-amp stage.

Henceforth was born the "passive preamp" for those who like the preamp and power-amp stages in separate boxes. But there is absolutely no preamp in a "passive preamp", just switches, relays, or solid state devices that route the chosen signal to the power-amp.

The Phono Preamp

The problem is that the output of the pick-up cartridge on a turntable isn't sufficiently large enough to drive the power-amp stage. And there is the added problem that the output from a pick-up cartridge isn't "flat" which, in a nut-shell, means the treble is louder than the mid-range, and the mid-range is louder than the bass. So all you'll hear by hooking-up the turntable straight to an amplifier's "line" or "aux" input is tinny but quiet treble.

Unless, that is, you buy one of those new fangled "line-output" turntables that have a phono preamp built in! The problem there is you are stuck with the sound quality or performance the turntable manufacturer has decided upon in their choice of phono-stage electronics. Unless it is quite an expensive line-output turntable that includes a good state-of-the-art phono preamp, you would be better buying a turntable that simply uses the output from the pick-up cartridge itself; a conventional turntable.

That leads us to the accessory called the phono preamp or phono stage. All you have to do is obtain one of them, hook-up the turntable to it, and hook-up the output from the phono preamp to your amplifier - done!

The performance you'll get will depend on a few different factors. Firstly, it is doubtful that you'll get any satisfaction at all from a "dirt-cheap" phono preamp. You could go the other way and just throw money at it, but that isn't a guarantee of satisfaction either - there are a

surprising number of "dirt-cheap" phono preamp circuits dressed in expensive looking boxes just waiting to relieve you of your hard-earned cash and leave you very disappointed. Somewhere in-between there are some (*a minority I guess*) of excellent performers.

Now to get technical...

Phono Preamps and RIAA Equalisation

The difference between an ordinary preamp and a phono preamp is its frequency response: The phono preamp has to "equalize" the different frequencies which are reproduced by magnetic cartridges at different levels, so they come out "flat".

So why don't they make phono cartridges who's output is "flat" to start with?

Well they did, but magnetic cartridges rule-the-roost and records are cut for magnetic cartridges and that's a fact of life. So even though the output of a ceramic or crystal cartridge which used to feature on mass produced British record players, is flat, the record, being cut for magnetic cartridges isn't, causing a dip in the response right in the mid frequencies where our hearing is most sensitive (which you couldn't really tell on a cheap record player). They too could be equalized but that costs more money, so the better-bet was on the "*more common in USA hi-fi circles*" magnetic cartridge - and it won.

The need for equalisation (*EQ*) is all down to the "mechanics". The stylus that cuts the record has to fit about 25 minutes of continuous groove on a 12 inch diameter LP (*or 10 minutes for a modern "hot pressing" 12 inch 33.3 rpm single*). So, on the average LP there is 33.3 x 25 = 832 spirals side by side to fit in, plus the run-in and run-out sections, plus the label.

Putting it very simply (*and without going into how they pull-off the stereo separation by cutting a vee-groove with left and right information in opposite groove walls*), the record groove is a lateral-cut which moves the stylus side to side to generate an output from the pick-up cartridge. The voltage a magnetic phono cartridge generates is proportional to the speed (*or more correctly, the velocity*) from it being moved side to side while travelling along the groove (*the record turning under it*).

To get the same output at all frequencies, the side to side movement for the bass frequencies would have to be very wide compared to the treble frequencies, and the lateral-cut would break over into adjacent groove spirals. If the amount of lateral cut were reduced to fit the bass frequencies there would be hardly any output at treble frequencies, in fact, it would be swallowed-up by the noise caused by the vinyl surface (*even though the cutting stylus is heated to make the vinyl smooth*).

Therefore the record should ideally be cut at constant amplitude and because the output from a magnetic cartridge (*which is velocity dependant*) falls with falling frequency, the phono preamp could easily equalize the signal by doing the inverse or opposite which is a straight-line graph, and is easily implemented in electronics.

However, the headroom it requires would be much greater than is practical, so in real-life, the frequency range is split below and above a mid frequency reference (*The 1 kHz reference so commonly referred to in cartridge specifications*).

Therefore between 500Hz and 2.122 kHz it's cut at constant velocity instead of constant amplitude, the theory being that by doing so, the output from the magnetic cartridge doesn't change between those two points, saving about 20dB of headroom.

In reality we end up with a rather complex looking curve when represented as a graph, and it changes direction at three points. This "curve" is the result of many years of trial and error and earlier "curves" such as Decca's FFRR "Full Frequency Recording Range". The "curve" we are talking about here was adopted by the record industry in 1953 and is the RIAA curve (*Recording Industries Association of America*) still in use today.

The job of the phono preamp is to make that complex looking curve "flat" by applying just the right amount of boost to the bass while applying just the right amount of cut to the treble, and at the same time, amplifying the whole lot up to the "line-level" required by an "aux" or "line" input on the amplifier.

That therefore is the simplest explanation of what a phono preamp does, however I ought to explain that there is a little more to it than that. There are other design considerations that can make a phono preamp really outstanding in the way it sounds and communicates the music.

Moving Magnet and Moving Coil Phono Preamps

So far we've looked at how a phono preamp works for use with a magnetic pick-up cartridge, but we've yet to consider what type of magnetic pick-up cartridge? There are basically two types: Moving Magnet and Moving Coil.

Moving Magnet has a comparatively high output - around 5 mV (*milli-volts*) on average, whereas Moving Coil has a comparatively low output - around 0.5 mV on average. Remember the 1 kHz reference frequency from earlier in this article? These outputs are at 1 kHz, so their outputs at bass frequencies - let's go for 20Hz - will be lower - nearly 10 times lower; and at treble frequencies - let's go for 20 kHz - will be higher - nearly 10 times higher. From this we can see that with a moving coil pick-up cartridge, the phono preamp is under much more stress than it would be for a moving magnet pick-up cartridge. So why do people rush out to buy a moving coil cartridge?

Mostly the reason is hype. The moving coil makes more money. For a start, they're generally more expensive for you to buy, but with fewer coil windings, probably cost just the same as a moving magnet to make considering all the trade-offs. Also, as the user can't fit a replacement stylus because they're a fixed stylus, when the "needle" wears out or gets damaged, you have to buy a whole new cartridge.

The technical reasons for the moving coil's "superiority" are: low moving mass - enabling it to reach a higher frequency before roll-off; much lower inductance because of the fewer turns of coil wire - again enabling it to reach a higher frequency before roll-off; and, because of it's low generator impedance, there's less chance of radio frequency interference (*RFI*) being picked up on the wires to the phono preamp.

That last reason no longer holds true with the dawning of "mega-high" frequency radio transmission that is all around us in these modern times - the moving coil may be much lower inductance, but inductance rises with frequency, meaning the impedance rises quite a lot on reaching these new extra-high radio frequencies, and without that low generator impedance effectively shorting out the RFI falling upon the wires to the preamp, the extra high frequency RF interference we have today, can be picked-up.

The moving coil still however, finds a bigger audience in hi-fi than the moving magnet - probably because people don't bother to read in-depth articles like this one. Skim reading and catchy "bites" sell product, whereas lengthy technical articles like this one tend to be overlooked through lack of time or patience.

With such a low output, especially at bass frequencies, the moving coil cartridge needs at least 10 times more preamp gain than its moving magnet counterpart. With a typical output of just 0.05mV at 20Hz, the signal has to be boosted ten-thousand fold by the phono preamp. That's something a few transistors, valves or tubes, cannot do alone (*without the help of a step-up transformer - and they can be very expensive*), and unless you want to spend thousands of pounds or dollars on a specialist phono preamp that's been slaved over for days to build, the amplification is better done using a "chip" called an op-amp, and the type of op-amp has to be chosen very carefully by the phono preamp designer.

Introducing The Wideband Phono Preamp

Then the electronic noise produced by the op-amp and it's supporting circuit components must be carefully considered. In fact, low-noise is the overriding factor in moving coil phono preamp design. And thereby hangs the problem - a sort of "catch-22" or "devil in the detail" problem that mostly cancels-out all the high frequency benefits of using moving-coil. The simple fact is, that surrounded as we are with all sorts of technological "miracles", there is still no way you can have both the low-noise electronics required for such a low output device, and high frequency electronics at the same time or in the same place. As people my age may remember the saying "you can't have your cake and eat it!" A low noise circuit can't do the high frequencies that vinyl reproduction requires to sound outstandingly good. The most you will ever get is an acceptable musical performance, and unless your vinyl is virgin, it will be bedeviled by scratches, clicks and pops. However, if you talk to owners who've invested lots of money into their moving coil ownership, they may tell you otherwise - wouldn't you? - To save your embarrassment?

But all is not lost: By carefully trading-off some of the noise performance for improved high frequency performance, things can be improved, if you have the knowledge. Vinyl surface noise (*excluding scratches, crackles and pops*) is approximately 58 decibels below the record's maximum output. You may think that's a pretty horrible signal to noise ratio, and yes it would be if it were not for the fact that in analogue audio you can hear signal below the noise floor. Conversely, with digital, the noise floor has to be extremely low, because below it you can't hear anything - there's nothing there - it's like looking into a pond of milk. With vinyl which is analogue, the analogy is like looking into a pond of slightly dirty water - you can see what's below it.

Most phono preamp designers try very hard to make their phono preamps extremely low-noise so that you can listen to the equipment without a record playing and be impressed by the silence, but is it worth it? After all, the equipment is for playing records - if you want silence, don't play records and turn the volume down.

You see, even with a phono preamp that only does a few dB better than the vinyl itself, the vinyl's surface noise will dominate. If the customer can bring him or herself to live with this situation, which is easy to do - just play records and listen to the music - then the experienced phono preamp designer can trade some of the noise performance for a much better high frequency performance.

Wideband design does the trick! Wideband design isn't new, but is in the main forgotten. This is probably due to poor marketing, and let's face it, getting the devil out of the detail isn't as easy as coining a few words of spin! If you've read this far, I may have a chance of convincing you, but be assured you're now in a minority - most people went away several paragraphs ago.

Wideband design is about extending performance as far as possible up the high frequency end, while still maintaining the all important low frequency end that underpins a musical performance, and everything in between.

Most people think that the frequency response of vinyl is curtailed at 20kHz like it is with CD, but that isn't the case - it extends at full output from the master-tape to 25kHz and thereafter in most cases only rolls-off gradually at 6dB per octave (*the signal voltage is only halved on reaching 50kHz*), instead of the "brick-wall" characteristic of CD.

The "proof of the pudding" was an event that happened back in the 1970's called quadraphonic sound, the forerunner of today's surround sound. The quadraphonic coded information was recorded *commercially* between 25kHz and 50kHz - the rear channels were stuck on the "upper deck" to be decoded by the quadraphonic decoder, and that proves that cutting heads are quite capable of reaching 50kHz "flat" (*measured after phono preamp equalization*), and thereafter the frequency response would only roll-off gradually.

This property of vinyl means that the all-important spatial information defined by the harmonic structure of the music is preserved. These are frequencies we can't hear, but they characterize the shape of the musical waveform producing undertones we can hear. We don't hear the high frequency harmonics in a live performance, but we hear the spatial information contained. Therefore, if these harmonics are reproduced by the phono preamp, we hear that same spatial information and the correct timbre of the musical instruments, and that's what Stereophile reviewer: Michael Fremer, heard from our Elevator EXP/Era Gold Reflex moving coil combination phono preamp in his September 2007 review shortly after hearing the same music played live.

Even if the recording isn't as wideband as this, there is another major benefit of wideband phono preamp design, and that's the marked reduction in record defect noises (*clicks, crackles and pops*). This is because the wideband phono preamp is capable of resolving higher frequencies than the conventional approach would have. Here is where we coin the phrase "fast phono stage". The reason why we usually hear so much annoying noises from vinyl isn't actually the fault of the vinyl, or the cartridge, or the arm. It is because the typical phono preamp designed, as it is, for lowest possible noise (*e.g. hiss*) doesn't have the speed to resolve the "clicks" properly and overshoots. When it overshoots it is out of control and can easily "clip" its power rails, and it "rings" or sustains the "click" for far longer than it actually exists. This is because, at the leading edge frequency of the "click", it's output has gone so far out of phase that the preamp becomes a poor form of oscillator waiting to be triggered and that trigger is the "click". In this state, the phono preamp is unstable and the negative feedback which usually controls its behaviour has become positive feedback, and without control, the "click's" amplitude grows rapidly to several times its original size. And that is why you hear so much distracting noise using a low-noise phono preamp! Less is more...?

There is a lot to be gained from designing the phono preamp to trade a slightly poorer noise performance for greater bandwidth. It means that the user is able to play records that would have otherwise been committed to the garbage bin. Manufacturers can no longer use the excuse that you should go out and buy a brand new copy - that option expired many years ago for many of us, and re-mastering suites will say the same. Record cleaners can help, but with a fast phono stage, you'll find yourself playing records more of the time and cleaning them less.

So far we've concentrated on the Moving Coil pick-up cartridge, but the same approach works wonders with the lower cost Moving Magnet. It too can do the "magic" and many thousand vinyl users have reached their "destination" with a moving magnet cartridge and

one of our "fast phono stage" phono preamps.

Moving magnet cartridges need a little more care, or "good-housekeeping" when setting up the vinyl front-end. They are more susceptible to pick-up of "unfriendly" magnetic fields that can easily stray onto wiring and the cartridge itself. This is because a moving magnet cartridge, along with its higher output, is more inductive due to the larger number of windings on its fixed coils. But then again, because of its high output, the lower gain requirement of the phono preamp used for moving magnet makes it less sensitive to RFI. Provided properly shielded signal cables (*interconnects*) are used (*and I don't mean braided cables however highly they're hyped*) both from the tone-arm/turntable, and from the phono preamp to the amplifier, RF interference is seldom an issue. Hum pick-up however is, and here again, it can be avoided through "good-housekeeping" and remembering that the coils are essentially the secondary of a transformer - you just need something else inductive close-by, or even coupled to it by being stood on a trendy metal hi-fi rack, and that's your primary! Anything containing a mains transformer will do the dirty. Even a turntable's AC motor! The answer here is a non-metal rack - try wood. Another source of hum is the TV screen or computer monitor and any wiring or equipment carrying or amplifying the raster information it requires, which is in the region 50Hz to 100Hz - the hum frequencies.

Modern life can interfere with the moving magnet based vinyl front-end, but more so with a wideband phono preamp. The only answer is to move it away from modern life - as well as making sure the turntable ground wire is actually attached and not broken inside... (*Exceptions are the Rega arms that don't use a separate ground wire*). Another thing to watch out for when using either cartridge with a wideband phono preamp is the breed of high capacitance tone-arm cables. They can destabilize a wideband phono stage, but worse than that, prematurely curtail the frequency response of a moving magnet cartridge. I won't mention any names but will give you a clue - these arms are designed for moving coil. You can call such manufacturers snobbish if you want? And they do cause us the occasional problem.

Phono Preamp Burners/Burn-in

The last word really belongs to a thing called "burn-in". Because of modern time saving production techniques, electrolytic capacitors aren't fully formed when placed into circuit - even the good expensive ones we use. It means that our high performing phono preamps will not deliver their great performance from out the box cold. It takes roughly 2 weeks for the foils to build-up an anodic film on their slit edges. It's something we've tried in vain to tell some reviewers, but probably they're up-against a break-neck deadline? You can tell who they are - they're the minority who were not amused...

Take a look at some phono preamps

Also, take a look at these References (especially "Great Sounding Records" by Kevin Gray - it will open your eyes!)

Great Sounding Records, Kevin Gray, 1997 (*online*)

Audio/Radio Handbook, National Semiconductor, 1980 (*page 2-23 to page 2-25*)