Development of a High-End Phono Preamp

Enhanced Listening Pleasure thanks to Isolation Milling with the LPKF ProtoMat S64

Bild: Denis Volpe

Development of a High-End Phono Preamp

Isolation milling improves the playback of vinyl records.

Pull your cell phone out of your pocket, plug in the earphones, and play. This is the way most people enjoy listening to their music. These days music is a part of everyday life, whether on the radio or played through streaming services. Due to the rising popularity of digital media, sales of analog media such as records have been dwindling since 1984, with the CD ousting the vinyl record from the market and MP3 in the following years becoming the dominant format for downloads on music platforms. However, sales figures for vinyl records have been improving again since 2016.

[Image: Denis Volpe

Throughout the world, enthusiasm for this audio format is growing. In Great Britain alone, year-over-year sales rose by 26.8 percent from 2016 to 2017 [1]. The fascination for this medium remains a mystery for non-vinyl lovers. To get to the bottom of this phenomenon, you have to ask yourself why it is precisely records that are enjoying such great popularity. As in other areas such as art, where old motifs are also taken up again, in music, records are making a comeback. This is because, for one thing, younger people are also discovering this medium and, for another thing, people would rather have and hold music than just stream it and not really own it. However, one argument against records is that the sound is falsified because unevenness on the record affects the needle and thus also causes noise during playback. On the other hand, the not completely sterile sound is what makes vinyl what it is. Unlike the sound from a CD, which is played back in exactly the same way every time, the sound from a record is "alive." People don't just listen to a record; they celebrate the entire process of listening to the music, already starting with the haptics of the album cover when they take out the record. With its processing and texture, the cover, which is generally made of cardboard, exudes a quality that is lacking in the plastic jewel case of a CD. Also, due, e.g., to the size of an album cover, it offers much greater design freedom.

RIAA Equalization Curve for Records

The music information is not transferred to the vinyl record linearly over the frequency. This is because the analog music signal is applied to a copper matrix with a stylus. This matrix is then used for pressing the vinyl

discs. Due to physical constraints, the matrix is cut non-linearly over the frequency using the RIAA (Record Industry Association of America) equalization curve of the cutting machine. The curve used is the recording curve. For playback of the record, this “pre-emphasis” must be reversed via de-emphasis using the so-called playback curve.

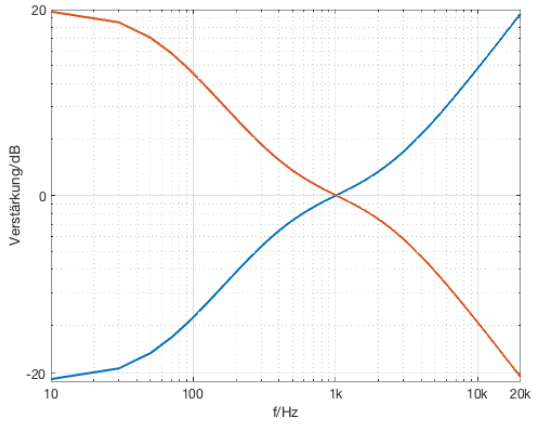

Fig. 1: The recording curve is shown in blue. The record is then played back with the playback curve, which is shown in red. Superposition of the two curves yields a linear curve.

Pickup

Moving coil (MC) and moving magnet (MM) cartridges are predominantly used for playback of vinyl records. These pickup systems can each be represented as a generator with a certain internal resistance. With MC systems, a very small coil moves in a static magnetic field with an inductance of a few tens of microhenries (µH). A voltage is induced according to the deflection in the record groove. The voltage is approx. 0.5 mV and of course depends on the deflection (e.g., 5 cm/s).

The internal ohmic resistance is in the range of 1 to 20 ohms due to the small number of coil windings. MC systems are usually terminated with a resistance of 20 to 1000 ohms in the phono preamp. This is not the case with MM systems. As the name suggests, the magnet moves and the coil is stationary. The coil inductance is in the range of 300 to 800 millihenries (mH), and the output voltage is accordingly higher (approx. 5 mV). The internal resistance is typically a few kiloohms (kΩ). MM systems are terminated with a 47 kΩ resistor. For them, the capacitive termination is more decisive. Phono preamps offer capacitance levels of typically 20 to 680 pF.

High-End Phono Preamp

Taking all the findings from the above two sections together, you can see that the phono preamp has to assume a variety of tasks: Depending on whether an MM or an MC system is connected, it must be terminated with the appropriate resistor and/or capacitor. It must also be possible to adjust the gain to a suitable level. The gain required by MC systems is ten times that required by MM systems. However, even for the same system type, there are differences. And ultimately, the decision depends on the individual taste of the listener. A good phono preamp offers selectable gains of 30 dB to more than 70 dB.

Another important function is the de-emphasis on the music signal supplied by the pickup system. The playback curve must be precisely followed here. Finally, even with a gain of 70 dB, you don’t want to hear any humming noises originating from the 50 Hz line frequency.

Microcontroller Board

Selection of different inputs for MM and MC cartridges, connection of a terminating resistor and/or capacitor, and setting of the appropriate gain are done via a microcontroller board. It can also display all selected parameters and can be controlled comfortably via remote control. The heart of the control board in this case is a microcontroller from Microchip Technology in a TQFP housing with a pitch of 0.5 mm.

The double-sided printed circuit board was manufactured with the LPKF ProtoMat S64 via isolation milling. The conductive pattern was produced without any etching chemicals and, thanks to the software-controlled process, extremely quickly. During the structuring, the high-frequency spindle carved the traces out of the coated board: the milling tool milled the insulating channels; the narrow traces remained. Thanks to the high spindle speed, the substrate could be processed precisely and without excessive stresses. The operator time was kept to a minimum through the automated

tool change, camera-controlled fiducial recognition, and integrated milling width control.

With the LPKF ProConduct method, through-hole plating of the double-sided printed circuit board was possible. With the compact LPKF ProConduct system for chemical-free through-hole plating of double-sided – or multilayer – printed circuit boards, all holes were plated through in a parallel process. This is a method of through-hole plating that uses a special paste coating. The holes to be plated are drilled through a protective film into the board. With the help of a doctor blade and a vacuum table, the conductive paste is pulled through the holes and cured in the oven. The protective film is then removed. The process is simple and led to fast startup for the present application. The individual steps that were performed for through-hole plating are also shown in Figure 4.

Audio Measurements

Once the phono preamp was completely built, signal measurements were carried out on it. The amplitude response is very linear and only shows a slight increase of about 1 dB starting at 20 kHz. Thus, the RIAA de-emphasis succeeded very well because there are hardly any measured deviations and absolutely no audible deviations.

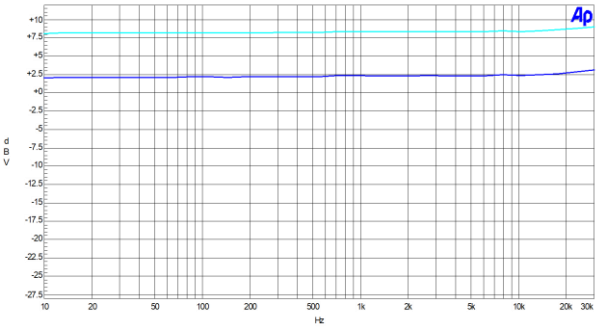

Fig. 2: RIAA equalization error of the phono preamp for an MC cartridge. The behavior is shown for a difference in gain of 6 dB (low 66 dB/high 72 dB). The measurements were performed with an Audio Precision System One.

The harmonic distortion measurements using a test tone of 1 kHz at an amplitude of almost 10 dBV were also noteworthy. The measurement at 3 kHz shows a harmonic distortion that is approx. 90 dB below the test tone and thus imperceptible. The 50 Hz hum is at 60 dBV and thus differs from the desired signal by 70 dB.

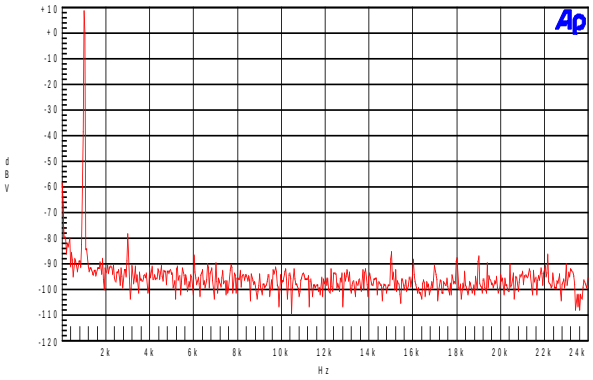

Fig. 3: Harmonic distortion and hum are at a very low, imperceptible level. The noise is below -90 dBV.

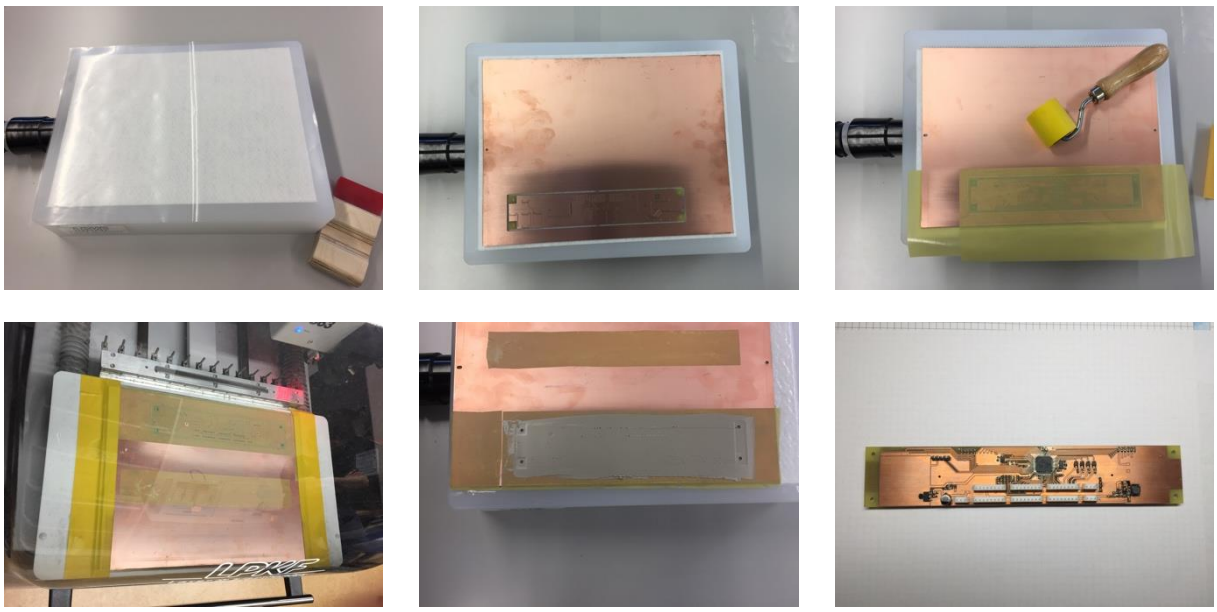

Fig. 4: Steps for through-hole plating of the circuit board: Preparation of vacuum table (1), positioning of milled PCB on vacuum table (2), placement of coverlayer for ProConduct paste (3), drilling of holes for through-hole plating with the ProtoMat S64 (4), application of the ProConduct paste and generation of a vacuum (5), finished microcontroller board (6).

Conclusion

With the combination of LPKF ProtoMat S64 and ProConduct paste, there was less than an hour between the final PCB layout and the produced PCB. The etch chemical-free process allows through-plated PCBs to be produced in a micro-computer lab without the need for special chemical precautions. The ProtoMat S64's accuracy allows for the precise and small structures required for components with fine pitch.

Literature

[1] https://www.vinyl-fan.de/blog/466-vinyl-schallplatten-verkaeufe-2017.html

Author:

Prof. Dr. Francesco P. Volpe
Microcomputer Technology Laboratory
Aschaffenburg University of Applied Sciences
Würzburger Str. 45, 63743 Aschaffenburg, Germany

LPKF Contact:

LPKF Laser & Electronics AG
Osteriede 7 Tel. +49 (0) 5131 7095-0
30827 Garbsen Fax +49 (0) 5131 7095-90
www.lpkf.com