THE VANDERVEEN MC-10

The high-end stepup transformer for moving coil cartridges.

The MC-10 transforms the small output voltages of a moving coil cartridge into a 10 times larger voltage for direct connection to the MM input of a pre amplifier. The frequency range is very wide, eminent core material with inaudible low granulation distortion (Barkhausen noise), linear phase and differential phase, critical damping of the MC cartridge, large magnetic headroom with inaudible low frequency distortion, easy mounting for asymmetrical (RCA) and symmetrical (XLR-3) inputs and outputs, precise adjustment to any MC cartridge by means of three external components, …

Introduction

Gramophone discs surely have not left the high-end scene. Their quality is still unbeaten and sound lovers are willing to spend fast amounts of money for high quality turntables and cartridges. My new Vanderveen MC-10 stepup transformer is designed for these quality lovers, for those men and women who wish to enjoy the goodies of the disc. They focus on pure quality of sound, deep emotions and nostalgia. What is wrong with the latest?

For many years the quality of audio reproduction has been my main topic of research. One of the results of this research and study has been my Vanderveen toroidal output transformer for valve amplifiers. With these transformers I was able to fundamentally change a warm sounding valve amp into a broad bandwidth undistorted high quality product. It has taken me more than 40 years to do this job and I am still not ready (will I ever be?). The new Vanderveen MC-10 leans on this fast experience. Now I have decided to focus on the other side of the valuable high-end chain. Not a new study about amps or loudspeakers, but attention to the most sensitive part of the sound system: the moving coil cartridge. The MC-10 has been intended to amplify its small voltages to reasonable values. This time I don't speak about Watts, I deal with micro Volts!

Inside a moving coil (MC) cartridge a coil is swinging in a stationary magnetic field. Moving Magnet (MM) cartridges have, as their name says, a moving magnet with a stationary coil. The advantages of MC versus MM are a lower moving mass and less resonances above 20 kHz. However, the main disadvantage of MC is its very low output voltage. At 1 kHz and 2.5 cm/s cutting speed they generate about 0.1 to 0.4 mV. This output voltage is too small for direct input to a standard MM pre amp with its RIAA correction. The standardized input sensitivity for MM equals 4.7 mV and normal MC cartridges are not able to deliver such voltages. There are two solutions to solve this problem: a) Take an active pre amp (with valves or semiconductors or IC's) with an amplification factor of 10 –or- b) apply a stepup transformer between the MC cartridge and the MM input. My experience has taught me that passive solutions (a transformer) mostly sound superior to active solutions (pre-pre amp). So I decided to follow the transformer trail. The new Vanderveen MC-10 magnifies the MC voltages with a factor of 10. Also the optimal load to the MC cartridge can be adjusted easily.

On exploration tour

Figure 1 shows dimensions and pin numbers of the Vanderveen MC-10. It is a small transformer, only 23 by 17 mm (groundplane) by 15 mm height. It is placed inside a mu metal can stopping any magnetic interference. Wires can be soldered directly to the pins or the transformer can be placed on a PCB. Internally are two windings: the primary between the pins 1 and 2 for direct connection to the MC cartridge. The secondary, between pins 4 and 5, is connected to the input of the MM pre amp. Pin 3 is directly connected to the mu metal can for electrostatic shielding.

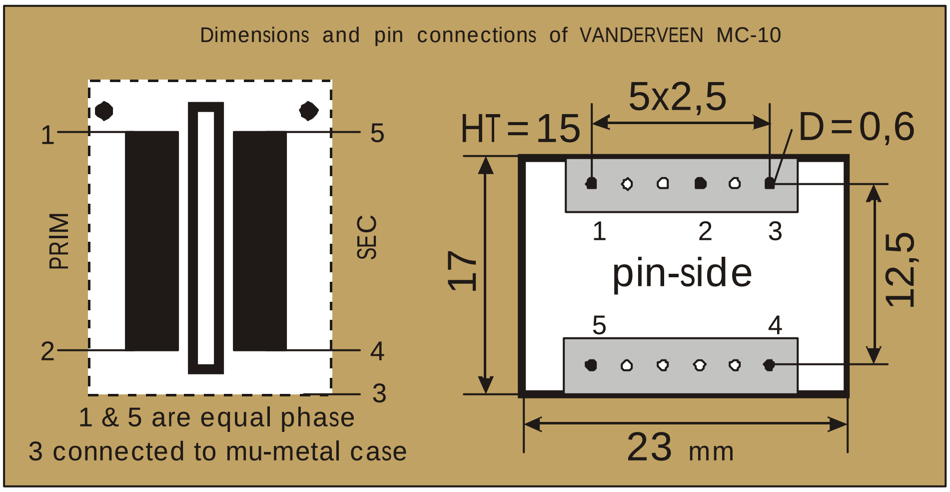

Figure 1: pins and numbers plus dimensions of the MC-10

Figure 2 looks inside the transformer and the MC cartridge and the input section of the MM pre amp. The MC cartridge on the left side is represented by a voltage source with the wire resistance R_{DC} of the moving coil in series. The input section of the MM pre amp is represented by its input impedance, which forms a load to the secondary of the stepup transformer. This input impedance consists of R_L (mostly 47 kOhm) and the input capacitance C_L of the pre amp plus the interlink (close to 100 pF). Central in figure 2 is the MC-10 with its windings N_p and N_s, wire resistances R_{ip} and R_{is} plus the inductances L_p and L_s. The leakage inductance L_{ss} plus the internal capacitors (actually between the turns and windings) C_{is} and C_{ps} together determine the high frequency behavior of the stepup transformer. In red, three components have been drawn: R_{in}, R_C and C_C. With these external components a very precise adjustment for optimal load and frequency transfer from any moving coil cartridge to the MM pre amp input can be realized.

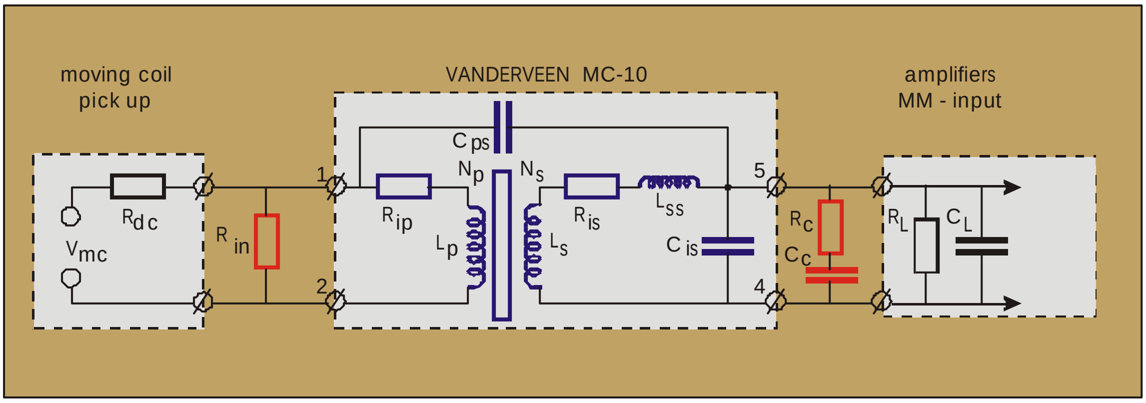

Figure 2: equivalent scheme of the total MC chain

In the next chapters the following issues will be discussed: 1) how to connect the MC-10, 2) optimal loading of the MC cartridges, 3) high frequency adjustments, 4) specifications plus additional info and hints.

How to connect the MC-10

The MC-10 can be placed inside the console of the turntable, or in a separate metal box, or (if place is available) inside the MM pre amp. In all cases the methods of mounting are equal. Therefore I take as example the separate metal box with two MC-10 transformers (for left and right channel).

This box is placed between the turntable and the MM pre amp and connected with high quality interlinks. Two methods for connecting are possible: an asymmetric connection with RCA-cinch connectors or a symmetric connection with XLR-3 connectors. The asymmetric connection is the most common and therefore will be discussed now.

Asymmetric connection

Figure 3 shows the metal box, bottom view, with 4 high quality RCA panel sockets. Also a grounding screw has been included for grounding of the turntable to the metal box. With silicon glue the transformers can be glued to the metal box (easy to remove). Use high quality mounting wire (silver wire is an excellent choice) and solder the wires (with silver solder). The resistors R_{in} and R_C plus the capacitor C_C have not been drawn yet. They will be discussed later on.

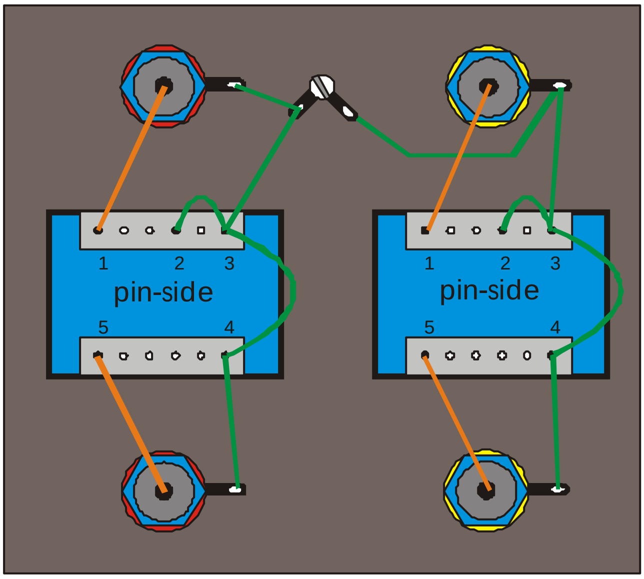

Figure 3: asymmetric connection

Figure 4 shows the schematics of this asymmetric connection. The transformer pins 2 and 3 and 4 are connected to each other and tight to the ground of the metal case. The MC signal goes to pin 1 directly, while the output signal to the MM input comes from pin 5.

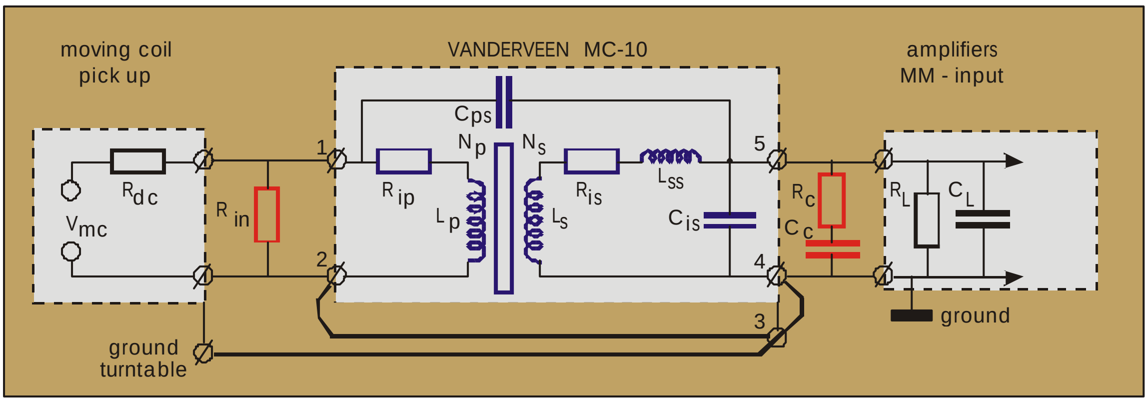

Figure 4: asymmetric connection scheme

Balanced or symmetric connection

I will start with a **warning**: all wires inside and outside the turntable, starting at the MC cartridge, up to the MC-10 input, should be high quality electrostatic shielded. This shielding should be firmly connected to the turntable ground. The signal wires from MC cartridge to MC-10 should be balanced and shielded and correctly connected to a XLR-3M plug. Suppose above is not the case, then stop using this balanced connection scheme. Nasty humming will be the reward and that is not my or your aim. This hum is very difficult to remove. Only perfect electrostatic shielding, all along the signal lines, is able to stop it.

Figure 5 again shows the metal box. Two XLR-3F audio panel sockets have been drawn at the input side, while the output has two RCA-sockets, assuming that the MM pre amp is asymmetric. For symmetric MM input, the correct method of connecting will be discussed later on.

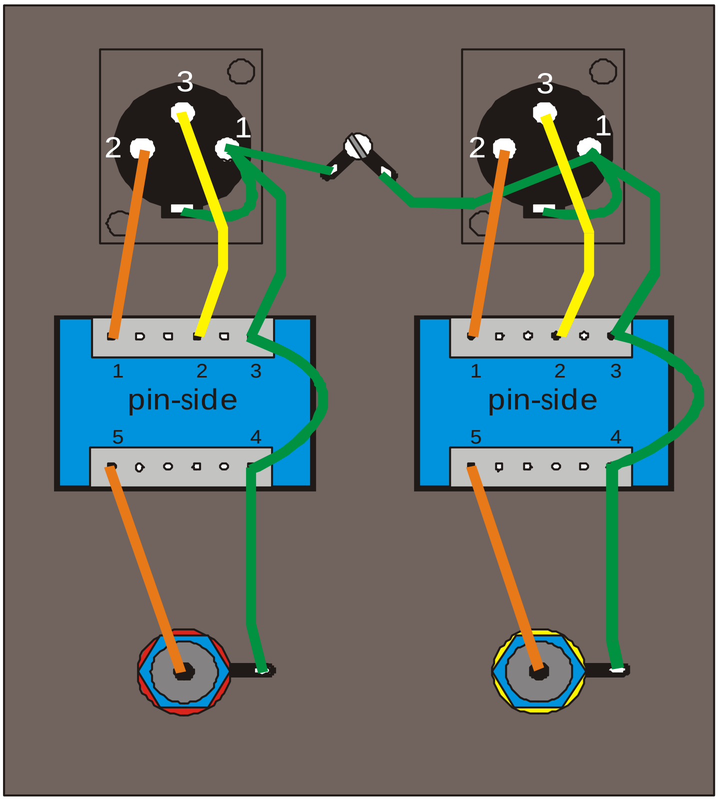

Figure 5: balanced connection

The convention for balanced connections is as follows: pin-1 of XLR-3F is to ground, pin-2 of XLR-3F comes from the in-phase side of the MC cartridge, pin-3 comes from the out-of-phase side of the MC cartridge. The numbers are clearly indicated on the plugs and sockets, assuming they are of good quality. Neutrix Gold is an example of such high quality plugs and sockets.

Figure 5 shows the internal wiring in the metal box. Again the components R_{in} and R_C and C_C have not been drawn. They will be discussed later on. Figure 6 shows the connection scheme. There is clearly visible that MC-10-pin-1 is connected to the in-phase signal of the cartridge, while MC-10-pin-2 is connected to the out-of-phase MC cartridge signal. This means that the cartridge is directly connected over the primary and is floating. Shielding and grounding do not interfere with the signal flow. This is one of the reasons why professionals apply balanced connections for high quality audio.

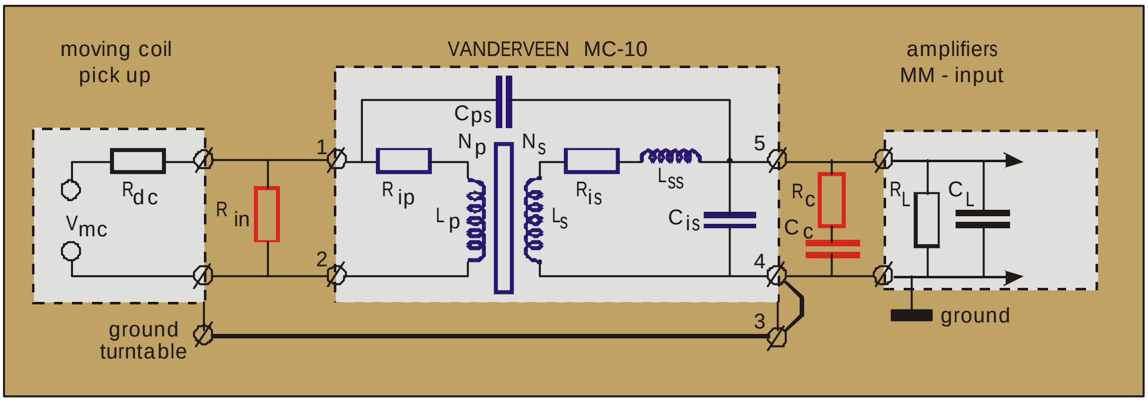

Figure 6: symmetric connection scheme

Suppose your MM input at the pre amp has a balanced socket as well. How to proceed? Then MC-10-pin-4 should go to panel plug XLR-3M-pin-3; MC-10-pin-5 should go to XLR-3M-pin-2 and the grounding plus MC-10-pin-3 should go to XLR-3M-pin-1. If these lines create dizziness, then make a small drawing as I did in figure 5; that surely will help.

Optimal electrical load of the MC cartridge

Each MC cartridge needs an electrical load to prevent high frequency resonances (ringing). These resonances are understandable when we realize that a MC cartridge is a mass-spring system, which resonates per definition. These resonances should be damped (with Q between .5 and .7). Therefore the manufacturer of the cartridge specifies an optimal electrical load impedance Z_L. In this case the extra resistor R_{in} plus the input impedance at the primary side of the MC-10 have to fulfill this job.

Together with the input impedance (R_L and C_L) of the MM pre amp, the MC-10 transformer creates a certain load to the MC cartridge. This load equals 344 Ohm. Suppose that this is exactly the optimal load as advised by the manufacturer, then no further actions should be taken. But life is hard, such a chance is seldom. So lets stick to reality and accept that the manufacturer advises a smaller electrical load than the 344 Ohm given. In case the manufacturer of the MC cartridge advises a larger value than 344 Ohm, then please do not use my MC-10 transformer; it will not be optimal for such specific cartridges.

As an example, I now discuss a cartridge with an optimal load Z_L = 150 Ohm. To realize this value, the extra resistor R_{in} should be inserted. Its value can be calculated by the following formula: R_{in} = (344 * 150) / (344 – 150) = 267 Ohm (take the E12 standard value of 270 Ohm). Another example: suppose the optimal value of Z_L should be equal to 67 Ohm. Then R_{in} = (344 * 67) / (344 – 67) = 83 Ohm (take the E12 standard value of 82 Ohm).

Because every specific MC cartridge has its own optimal Z_L, it is impossible to deliver all possible values of R_{in} with the MC-10. If you need them, buy resistors from the E12 range with values closest to the values calculated. Metal film resistors of ¼ W power handling are fine, high precision wire wound (non-inductive) is better for noise reasons. Table 7 gives more values for R_{in} to support your calculations.

Summary: with one external resistor R_{in} optimal loading of the MC cartridge can be realized very precisely. In agreement with the specifications of the MC manufacturer an optimal electrical load prevents high frequency resonance above 20kHz.

Z_L	R_{in}	R_{in} according to E12
344	Infinite	place no resistor
300	2345	2k2
250	915	1k2 and 3k9 in parallel = 918
200	478	470
150	267	270
100	141	220 and 390 in parallel = 141
50	58,5	56 + 2,7 in series
30	32,9	33
20	21,2	22
10	10,3	15 and 33 in parallel = 10,3
[Ohm]	**[Ohm]**	**[Ohm]**

Table 7: Examples of various R_{in} values related to Z_L

Where to place R_{in}: directly between pins 1 and 2 of the MC-10 with the shortest leads possible. See figure 8 for more details.

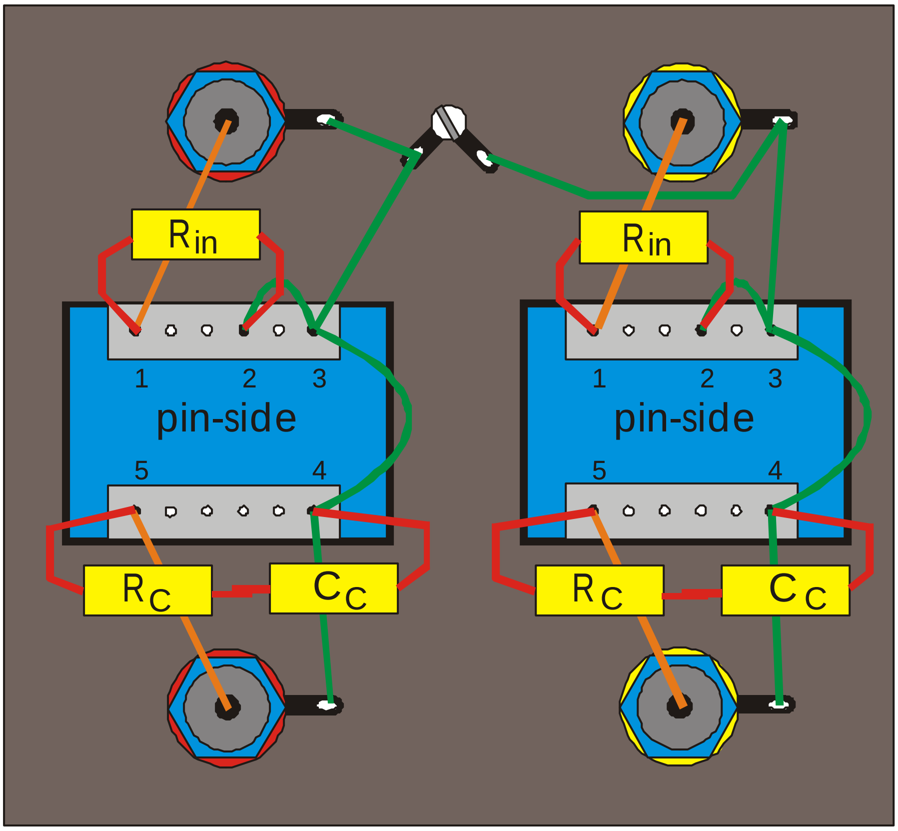

Figure 8: the mounting of R_{in} , R_C and C_C

High frequency adjustments of the MC-10

Inside the MC-10 various resistors, inductors and capacitors are present. In physics language this means that electrical resonances might occur. The MC-10 is designed in such a manner that under most conditions these resonances are well damped. However, when the wire resistance R_{DC} of the coil of the MC cartridge is smaller than 20 Ohm, an external correction is needed for. Now R_{DC} is the critical factor. Refer to the manufacturer specifications of your MC cartridge to find its value.

It is mandatory to remove high frequency resonances inside the transformer. Suppose you don't, then at high frequencies the amplitude will get larger and will last longer. This effect is described in literature as "ringing". When listening to it the character of the sound will be too fresh, too sharp and thin. Probably you will get tired of listening to it. An extra effect is a strong deviation in the time behavior of the signal. Phase deviations will occur. Even worse is severe differential phase distortion. The latest tells about a sound complex (a sound burst comprising many frequencies, like the sound of a drum kit) with its envelope. When differential phase distortion occurs, low frequencies are delayed more than high frequencies. As a result the envelope of the sound burst is distorted. Our hearing mechanism not only detects frequencies and times of arrival, but also detects the nature of the envelope (this is done by the a-linear amplitude transfer of the ear, in fact by a distortion mechanism inside the ear). As a consequence, the differential phase distortion should be very small, and therefore high frequency resonances should be well damped.

To solve all these nasty issues, a very simple activity should be performed: add R_C and C_C. The resistor R_C and capacitor C_C are placed in series, directly between the pins 4 and 5 of the MC-10 transformer, with shorted wires possible. See figure 8. Use metal film ¼ W resistors (wire wound is disadvantageous in this case). For the capacitor C_C: any working voltage is right; Styroflex is fine, Mica is better.

Table 9 shows values of R_C and C_C for cartridges with R_{DC} smaller than 20 Ohm. Please notice that there is a difference now between unbalanced and balanced use of the MC-10 transformer. The reason why is the different influence of C_{ps} for both connection schemes. No further formulas are given because the calculation of R_C and C_C is rather complex. Their values are based on minimal phase distortion, which is a different goal than broadest bandwidth. Listening tests have shown that phase distortion is well related to listening tiredness. So I have aimed at minimal phase distortion. In practice: select/buy R_C and C_C values from the E12 range closest to those given in table 9.

R_{DC}	**R_C unbal.**	**C_C unbal.**	**f_{-3H} unbal.**	**R_C bal.**	**C_C bal.**	**f_{-3H} bal.**
3	15k	150	70	3k8	330	90
5	18k	120	70	4k7	270	90
10	18k	100	70	6k8	180	100
15	47k	47	60	15k	100	>100
20	None	none	50	22k	56	>100
21	None	none	50	none	none	100
[Ohm]	**[Ohm]**	**[pF]**	**[kHz]**	**[Ohm]**	**[pF]**	**[kHz]**

Table 9: high frequency MC-10 correction with R_C and C_C for R_{DC} < 20 Ohm

Specifications of the MC-10

During manufacturing, small deviations always occur. Table 10 shows the values of the important quantities inside the MC-10 transformer plus maximum allowable (accepted) deviations. See figure 2 for details of the meaning of any quantity.

MC-10	**value**	**deviation**	**unit**
N_s / N_p	12,0	+/- 1 %	[-]
R_{ip}	11,0	+/- 5 %	[Ohm]
L_P	1,0	+/- 4 %	[H]
R_{is}	1k62	+/- 1 %	[Ohm]
C_{is}	202	+/- 7 %	[pF]
C_{ps-eff}	427	+/- 9 %	[pF]
L_{ss}	5.9	+/- 15 %	[mH]
$V_{p,max}$	100	20Hz @ 1% THD	[mVrms]
R_C & C_C	table 9	table 9	table 9
R_L & C_L	47k//100p	Standard MM-input	[Ohm] & [F]

Table 10: MC-10 specifications

Those who love maths will be very happy with these specs. Later on I will tell more about how to construct and calculate the transfer formulas.

The deviations allowed in L_{ss}, C_{is} and C_{ps} seem to be remarkably large. Their values have been measured in a very specific manner, which leads to these deviations. Under various conditions the internal resonance frequencies inside the transformer are measured. These frequency values are subtracted to calculate the leakage inductance and internal capacitors. Then per definition each deviation in frequency results in an enlarged deviation in final inductance or capacitance value. In spite of this mathematical disadvantage, I will stick to this method. Its results are amazingly precise in predicting the actual frequency transfer of the MC-10 transformer.

The primary inductance L_P is measured at 80 mV_{pp} @ 1 kHz. When enlarging this measurement voltage up to 8 V_{pp}, the value of L_P hardly changes. With larger voltages than 8 V_{pp}, core saturation might occur, blurring the measurement. Also notice the very important specification $V_{p,max}$. It tells about the large magnetic headroom inside this small transformer. Overloading of this transformer at the lowest frequencies is virtually impossible, resulting in unhearable low frequency distortion.

The coupling capacitor C_{ps} between primary and secondary windings is not totally active in the frequency domain. The part that influences the frequency transfer is given by $C_{ps,eff}$. In the balanced connection scheme only C_{is} is active. In unbalanced connection C_{is} plus $C_{ps,eff}$ are active and their values should be summed to find the total capacitance at the secondary side. This also explains the difference in –3dB high frequency range (indicated by f_{-3H}) between unbalanced and balanced connection. See table 11 for more details.

R_{DC}	f_{-3L}	f_{-3H} unbal.	f_{-3H} bal.
10	3	70	100
20	4	50	>100
30	5	40	90
40	7	38	90
50	8	32	80
60	9	27	70
70	10	25	60
80	11	20	50
90	12	19	50
[Ohm]	**[Hz]**	**[kHz]**	**[kHz]**

Table 11: -3dB frequency range of the MC-10 as function of R_{DC}

It is not so difficult to create the frequency transfer functions of the MC-10 transformer, when using the following hints. Cut the total transfer in three separate parts. The low frequency part only considers the resistances and L_p, where the secondary side resistors are transformed to the primary side by factor 12^{-2}. The midfrequency part deals with an ideal transformer and resistances only. The high frequency section again uses an ideal transformer, omits L_P, but now takes the capacitors and the leakage inductance into account.

As an example figure 12 shows the calculated (and measured) transfer function of the MC-10 for the R_{DC} = 50 Ohm case.

Figure 13 shows phase and differential phase distortions. Remarkably low is the differential phase distortion up to 30 kHz (smaller than 1 degree), which is a very fine result.

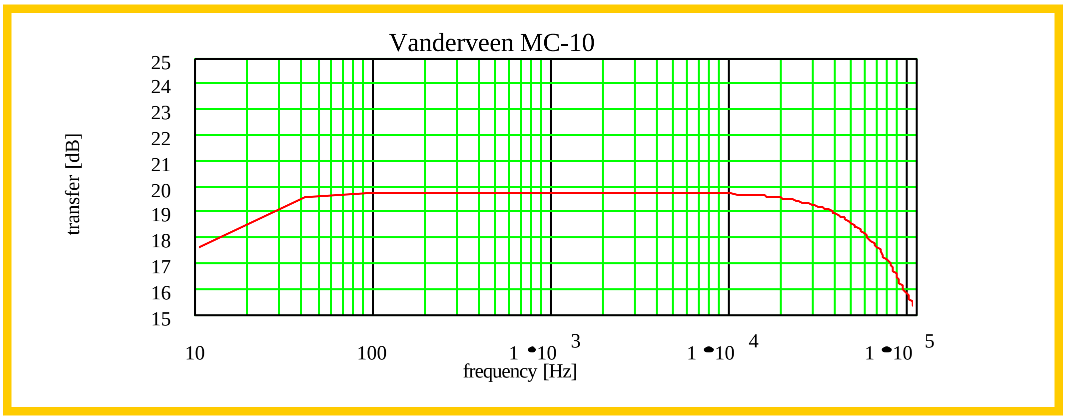

Figure 12: transfer characteristic of the MC-10, R_{DC} = 50 Ohm, balanced connection.

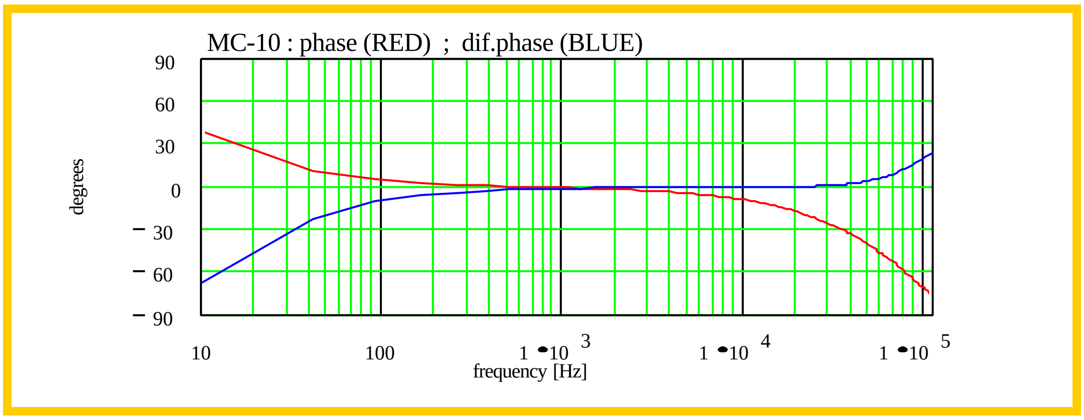

Figure 13: phase characteristics of the MC-10 for R_{DC} = 50 Ohm, balanced connection

Final remarks

It might surprise the reader that so many details are told about such a small moving coil stepup transformer. The answer is: physics and electronics deliver many details, which should not be omitted. Some products are only described with unclear words. Then you only can hope that these words tell the whole story. Mostly this is not the case and a real disappointment is the net result. Therefore, tell the whole story, and everyone at his/her level will find the important clues. “Maths-type” persons will grab their calculator. “Measurement is knowing” persons will spend evenings behind the oscilloscope, while “listeners” now will understand why the soundstage is open without getting tired. I have always aimed at delivering much information about my toroidal transformers. I have written books about them plus scientific papers. The net results are that my clients know very much about my products. Exactly the same happens here with the MC-10.
However, this also means that when I formulate a warning about possible hum, this warning should not be forgotten. It is true that the balanced connection only functions well under electrostatic shielded conditions. If the shielding is incomplete, 50 or 60 Hz interference surely will cause a nasty humming sound stage.
Ground loops can cause hum as well, where the magnetic leakage of a near by EI-transformer create problems. This issue is very important. I will not go into further details now. My website is patient; maybe in the near future an extra article will follow.

Now lets deal with the subjective side of the matter. Before the introduction of the MC-10 transformer, I sent samples all over the world, asking for scientific and listening opinions. Many remarks were the result and they were dealt with. What stroke me in all the subjective comments was the following: “the richness in details is extreme”. For me as designer this simply means that I have selected the right core material and high frequency adjustments. “After some hours the MC-10 comes to rest and starts to blossom”. Again this is understandable. During production all the specs of the MC-10 are checked. These measurements can leave a residual magnetic field inside the core. After some listening hours in actual application, the mean magnetic flux density ‘swings’ back to zero, where distortion and Barkhausen noise are lowest. As you see, science and listening are very closely connected here. I really hope that this small MC-10 transformer will deliver you pure enjoyment.

The Netherlands, Zwolle,
March 16 2004
ir. Menno van der Veen
ir. bureau Vanderveen