RedRoo PR5 Moving Coil Step-up Transformer Installation

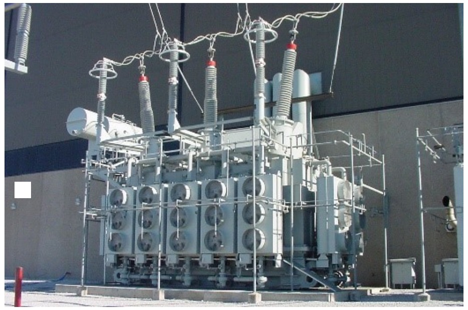
Please test the PR5 preamplifier for correct operation with a moving magnet phono input prior to performing this procedure.

The RedRoo PR5 moving coil (MC) option requires inserting two Ludnahl LL9226 step-up transformers, placing shorting-links on the PC board, and selecting values for the two impedance matching resistors (R-MC) and possibly two capacitors (C-MC). The actual configuration depends on the particular MC cartridge used.

It's worthwhile taking some time to understand the theory behing the MC step-up transformer option, and why the correct configuration is important to the sound.

A selection of Lundahl moving-coil cartridge step-up transformers.

(Photo: Lundahl Transformers).



A 345 kV 360 MVA transformer used for high voltage power distribution

(Photo: Mitsubishi Electric).

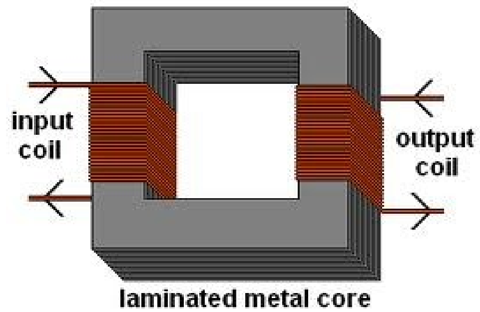
Transformers come in all shapes, sizes, and applications. They range from miniature transformers you can hardly see for microwave radio frequency applications, to huge oil cooled hundreds-of-megawatt 50/60 Hz mains-power distribution transformers. They all work on the same basic principle of 'magnetic induction'.

Transformers are most often used to transform AC voltages, but in doing so they also transform current and impedance. They can also be used to provide voltage isolation, where a sensitive circuit needs to be isolated from a higher voltage, or where an 'unbalanced' circuit connected to earth/ground needs to interface with a 'balanced' circuit i.e., one without a common ground/earth connection.

Transformer Construction and Mutual Inductance

Most transformers have an input coil, called a **primary winding**, and an output coil called a **secondary winding**. Some transformers have multiple primary or secondary windings. A varying AC current through the primary winding creates a changing **magnetic flux** in the transformer's core, which flows around through the core, and induces an AC voltage in the secondary winding.

This effect is called **mutual inductance**: the induction of a voltage in one coil in response to a change in current in the other coil.



In mains power transformers, and other low frequency transformers, the primary and secondary winding's are wound around a **ferromagnetic** core such as steel. In audio frequency transformers materials such as **grain-orientated** or **amorphous** steel cores are often used, and in radio frequency transformers a non-conductive **iron-powder** or **ferrite-powder** core is used. Radio frequency transformers may also be **air-cored.**

Regardless of their size, construction, shape, or frequency of operation, all transformers have the same basic electromagnetic property **– they step-up or step-down an AC voltage in direct proportion to the turns-ratio** of two magnetically coupled inductors. In doing this they also transform current and impedance.

Impedance (Z)

Let's assume you are familiar with Ohms Law. What some people don't realise is that Ohms law can be applied equally to DC and AC circuits. Impedance is the combination of resistance and inductive or capacitive reactance, which together impede the flow of an AC current, however in this application we can assume resistance and impedance to be identical. Impedance is signified by the letter 'Z'.

Let's now also assume that we have an 'ideal' transformer, that is, one without loss, where the power going into the transformer primary exactly equals the power taken out from its secondary.

Voltage Transformation

In an **ideal transformer**, the output voltage from a secondary winding (V_s) exactly equals the voltage applied to the primary winding (V_p) multiplied by the turns-ratio. The relationship between primary and secondary voltages for a step-up transformer is described by the following equation:

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

Where: V_S is secondary voltage**;** V_P is primary voltage**;** N_S is number of secondary turns**;** N_P is number of primary turns

Or putting it another way, **V Secondary = V Primary x Turns Ratio**

Current Transformation

In our ideal transformer the power into the primary winding must exactly equal the power taken out from the secondary windings. From Ohms law we know, for a constant power, if the voltage is changed the current must also change. So, we can now include a current factor into the transformer equation:

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{I_S}{I_P}$$

Where: I_P is the primary current; I_S is the secondary current

Or putting it another way, **I Secondary = I Primary / Turns Ratio**

Impedance Transformation

Ohms law also tells us that, if the ratio of a voltage to a current is changed, the resistance will also change. Because we are transforming AC voltages and AC currents, we are also transforming the impedance by the square of the turn's ratio:

$$N^2 = \frac{Z_P}{Z_S}$$

Where: n is the turns ratio; Z_p is the primary impedance; Z_s is the secondary impedance

Impedance is transformed by the square of the turns ratio. A 10:1 turns ratio transformer will change the impedance by 100 times.

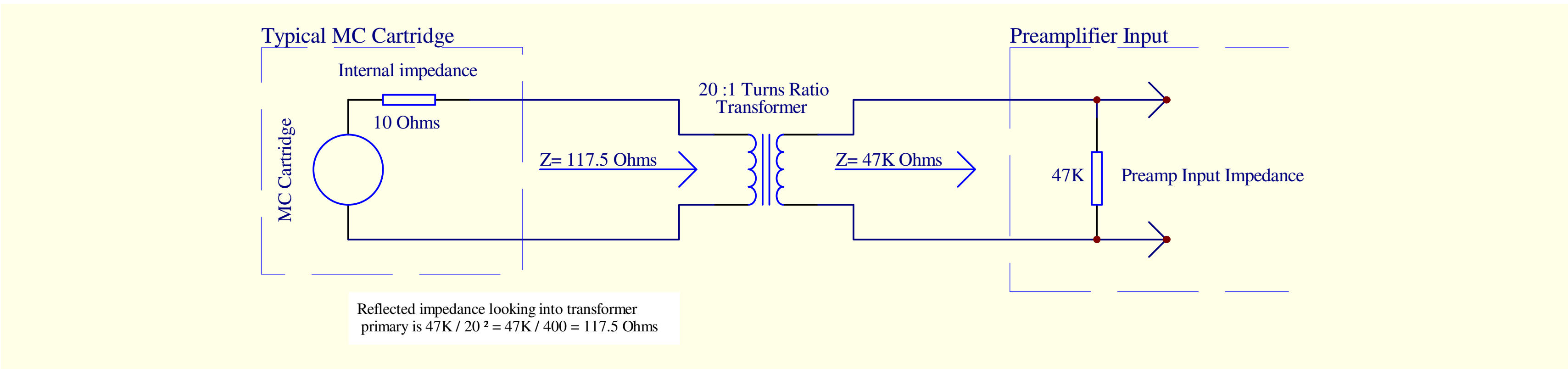
Transformers make load impedance's "look" bigger or smaller depending on their turns ratio. This is called the **reflected impedance;** it is a transformed image of the impedance connected to the other winding.

Say a transformer has a primary winding of 100 turns, and a secondary winding of 200 turns. The turn's ratio is 2. For a step-up transformer, the voltage across the secondary would be twice the voltage across the primary and, because an 'ideal' transformer has no power loss, the current flow into the primary would be exactly twice that flowing from the secondary.

The AC impedance ratio between primary and secondary would be 2 squared, or 4. If an impedance of 50 Ohms was attached across the primary winding, it would appear as a 200 ohms impedance if you were looking into the secondary winding, and vice versa.

This impedance transformation characteristic of transformers is very useful in many electronic applications, especially in audio frequency and radio frequency circuits where impedance's need to be changed or 'matched'. The diagram below shows how a 47K ohm impedance at the input of a preamplifier is transformed to 117.5 ohms across a moving coil cartridge with a 20:1 step-up transformer.

Naturally, a step-down transformer would be the reverse.



Transformer Losses

Unfortunately, ideal transformers simply don't exist; there is always some unwanted loss due to the resistance of the winding's losing power as heat, core losses due to eddy currents, magnetic hysteresis (when magnetic induction lags behind the magnetising force in the core magnetisation and de-magnetisation process), and leakage inductance (magnetic flux leaking from the transformer into the surrounding space).

With high quality MC step-up transformers these losses are so small they can be mostly ignored, but they are major factors in power transformers and tube audio output transformers.

Impedance Matching

When the impedance of a voltage source is the same as the impedance of a load, the system is said to be matched. Radio enthusiasts will know that to achieve maximum power transfer to an antenna, a radio transmitter needs to be matched to the impedance of the transmission line, and the transmission line needs to be matched to the antenna A proper match, called a 'complex-conjugate' match, occurs when the reactive components in the source and load impedance's are of equal and opposite phase.

<u>MC cartridges are different</u> as we are only concerned with stepping-up the voltage, not transferring maximum power. An MC cartridge is usually a very low impedance (about 5-50 ohms) but most manufacturers specify a load impedance of at least 100 ohms. A 10:1 impedance ratio is also common. This is because, if an MC cartridge is required drive into a matching low impedance it needs to do more work, and it will be less able to accurately reproduce high frequencies.

In the PR5 preamplifier, the impedance across the MC cartridge is the reflected preamplifier input impedance (47K) transformed down by the turns-ratio of the MC step-up transformer.

Setting-up the RedRoo PR5 MC Option.

The RedRoo PR5 uses two Lundhal LL9226 step-up transformers. These transformers have two primary winding's and two secondary winding's wound around a cobalt based uncut amorphous strip core. The whole assembly is housed in a mu-metal can.

Turns ratios of 5, 10, and 20, are selected by changing shorting-links on the RedRoo PC board, which rearrange the connections of the various winding's, with corresponding reflected impedance ratios of 25, 100, and 400.

In some cases the MC manufacturer may recommend a lower impedance than can be achieved by the turns-radio of the transformer alone. In this case a resistor (R-MC) may be required across the 47K ohm input of each preamplifier channel in order to further lower the reflected impedance across the MC cartridge.

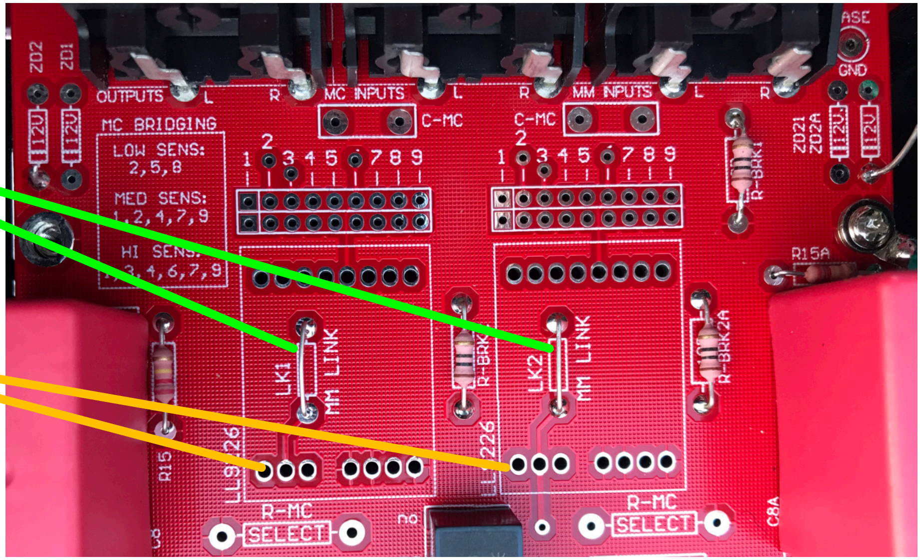
The following instructions describe how to set up the RedRoo PR5 preamplifier for various cartridges.

The tables on pages 7-8 show the recommended settings for some common MC models.

Step 1 - Remove the MM links, if inserted

Remove LK1 and LK2 if they are inserted. Make sure there is no high solder left on the board which may touch the metal case of the transformers.

These are marked MM Link on the PC Board.



Step 2 - Mount the two LL9226 MC transformers

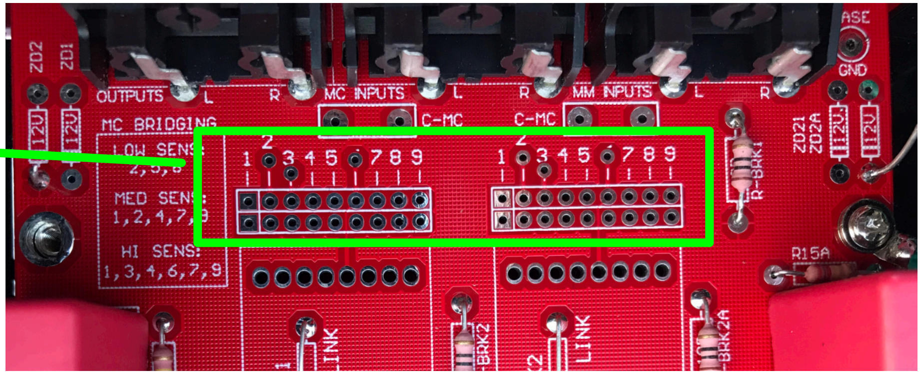
The MC transformers will only mount in their correct orientation.

Step 3 - Set the Turns-ratio - See the table for recommendations

The gain of the PR5 preamplifier at 1kHz is about 50dB, which is a voltage ratio of 316, so for one volt output the input sensitivity would be 3mV. Two volts output would require 6mV at the input, etc. For convenience, let's say the input sensitivity is 5mV, which would drive all but the most demanding power amplifiers.

We need to select a suitable turns-ratio for the transformer to step-up the voltage from the MC cartridge used to about 5mV.

Insert the links as shown below:



Turns Ratio	Insert Links	Sensitivity
5:1	2,5,8	Low
10:1	1,2,4,7,9	Medium
20:1	1,3,4,6,7,9	High

Step 4 - Select the value for R-MC - See the table for recommendations

Knowing the turns ratio from the step above, we now need to set the reflected impedance presented to the MC cartridge. This impedance is not critical and most manufacturers simply recommend at least 100 ohms, though 10 times the cartridge impedance is also commonly used.

The input impedance of most preamplifiers is 47K. If we are using a 1:20 turns ratio step-up transformer the impedance transformation is 1:400, so the reflected impedance looking into the primary side would be 117.5 Ohms – close enough to 100 ohms. If we are using a 10:1 transformer the reflected impedance would be 470 ohms, or a 5:1 would be 1.88K – probably too high.

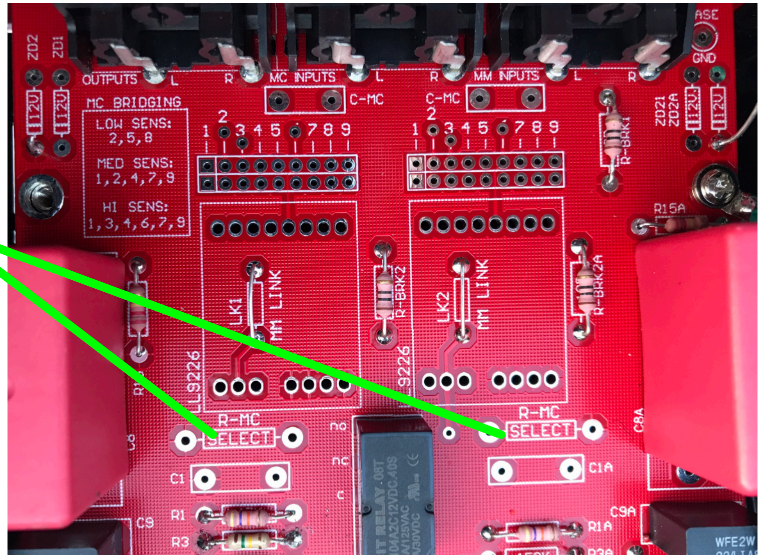
We can lower the reflected impedance across the MC cartridge by lowering the 47K preamplifier input impedance, easily done by placing a fixed resistor (R-MC) in parallel with each preamp input.

To determine the value of R-MC you will need to use a parallel resistor calculator, such as:

www.digikey.com.au/en/resources/conversion-calculators/conversion-calculator-parallel-and-series-resistor

The object is to lower the total impedance at the input of the preamplifier so the reflected impedance through the transformer is close to the MC cartridge manufacturers recommendation.

The value of R-MC is not critical so you can use standard 5% resistor values. Use a low-noise metal-film or wire-wound resistor in this position.



The impedance loading on the cartridge will have an effect on the sound if it is too high or too low. As a general rule, increase resistance of R-MC if the sound is muddy, and decrease R-MC if you hear harshness in the treble (which may be caused by ‘ringing’ type oscillation in the cartridge response to transients).

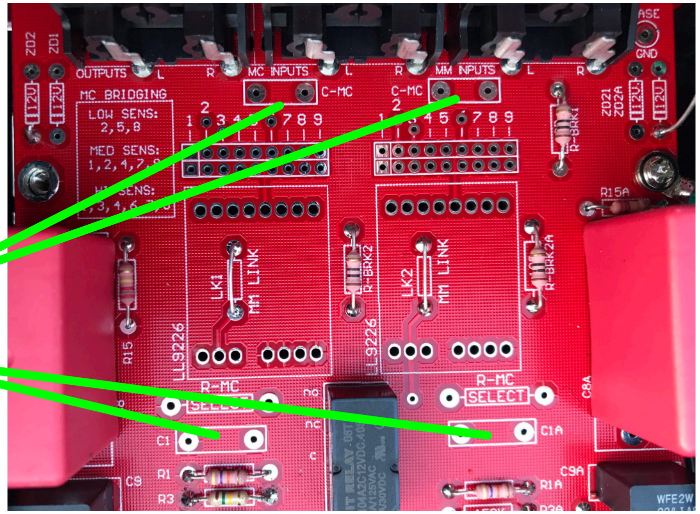
Cartridge Model	Cartridge Output	Cartridge Impedance (Ohms)	Recommended Load Impedance (Ohms)	Turns Ratio	Shorted Links	R-MC Value (Ohms)
Denon:						
DL304	0.18mV	40	Not Stated	20:1	**1,3,4,6,7,9**	**No Resistor**
DL103(R)	0.25mV	14	100	20:1	**1,3,4,6,7,9**	**No Resistor**
DDL-301mkII	0.4mV	33	100	10:1	**1,2,4,7,9**	**12K**
DL-110	1.6mV	160	47K *	5:1	**2,5,8**	**No Resistor**

* The DL-110 is a high output cartridge intended to directly drive a 47K impedance moving-magnet input. However a 5:1 step-up will ensure any power amplifier is driven to its full output.

Cartridge Model	Cartridge Output	Cartridge Impedance (Ohms)	Recommended Load Impedance (Ohms)	Turns Ratio	Shorted Links	R-MC Value (Ohms)
Audio Technics:						
ATOC9ML3	0.4mV	12	100 min.	10:1	**1,2,4,7,9**	**18K**
AT-ART9X1	0.5mV	12	100 min.	10:1	**1,2,4,7,9**	**18K**
AT-ART9XA	0.2mV	12	100 min.	20:1	**1,3,4,6,7,9**	**No Resistor**
AT-33EV	0.3mV	10	100 min.	20:1	**1,3,4,6,7,9**	**No Resistor**

Cartridge Model	Cartridge Output	Cartridge Impedance (Ohms)	Recommended Load Impedance (Ohms)	Turns Ratio	Shorted Links	R-MC Value (Ohms)
Soundsmith:						
Paua MkII	0.4mV	Not Stated	470 Ohm min.	10:1	**1,2,4,7,9**	**No Resistor**
Goldring:						
Eroica LX	0.5mV	Not Stated	100	10:1	**1,2,4,7,9**	**12K**
Elite	0.5mV	8	100	10:1	**1,2,4,7,9**	**12K**
Legacy	0.25mV	**7**	100	20:1	**1,3,4,6,7,9**	**No Resistor**
Ortofon						
Quintet Red/Blue	0.5mV	7	>20	10:1	**1,2,4,7,9**	**8.2K**
Quintet Bronze/Black	0.3mV	5	>20	20:1	**1,3,4,6,7,9**	**39K**

What About loading Capacitance ?



You will often see recommendations for capacitance loading across a cartridge. Capacitance loading has a much greater effect on moving magnet (MM) cartridges and a lesser effect on MC cartridges. With MC you may not notice any difference.

The RedRoo PC board has a 47pF capacitor (C1) across the preamplifier input which is in parallel with both MM inputs. This capacitance also forms a very small component of the reflected impedance across the MC input, but so small it can be ignored.

If you wish to add a capacitor across the MC input, place capacitors in the positions C-MC.

If you wish to change the capacitance across a MM cartridge change the value of C1/C1A.

Remember that, in both cases, the total value of the capacitance across the cartridge includes the cable capacitance which may be considerable for long or very low cost phono cables.

Subtract the cable capacitance from the manufacturers recommended capacitance to derive the required capacitor value. Use a mica or polypropelyne capacitor.

Before You Connect an MC Cartridge

Moving coil cartridges are very delicate and very expensive. Althought the PR5 PC board has been designed to provide the largest possible degree of voltage isolation between the moving coil inputs and the amplifier circuitry, the following check is recommended to make sure there are no wiring errors, loose wires, or short circuits that could cause voltages to be present across the MC cartridge.

Before connecting the MC inputs from the cartridge, use a voltmeter to check there is no voltage present across each MC input at the RCA connectors. Repeat the measurement with the input selector switch in both the MM and MC positions.

You are now Ok to connect the phono inputs. We hope you enjoy your RedRoo PR5 preamplifier with moving coil cartridge inputs.