Accurate Inverse RIAA Network

An Inverse RIAA Network (IRN) allows the RIAA equalization conformity of a phono amp to be tested directly using a signal generator that covers the extended audio bandwidth of circa 2 Hz to 100 kHz. This IRN is based upon the original 1971 Reg Williamson design but with the Jung-Lipshitz modifications as published in TAA in 1980, which improved the accuracy. The design includes a single sided PCB layout that can easily be etched at home by the DIY enthusiast. This project uses 0805 and 1206 SMD components and is designed for use with audio generators with Zout of 50 Ω or less for maximum accuracy. Included in this write up is a short discussion on practical RIAA EQ circuit testing using a square wave stimulus

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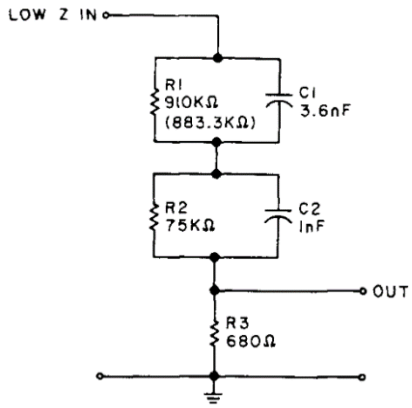
Specifications

General Description Accurate ***I***nverse ***R***IAA ***N***etwork (IRN) for testing frequency response conformity of RIAA Equalizer amplifiers. This design used SMD components arranged in parallel/series to improve the overall accuracy of the network using standard 1% or better components. The use of tighter tolerance components by the constructor will improve the accuracy further. Based upon the original Reg Williamson design published in TAA with Jung-Lipshitz modifications to improve accuracy. The IRN output is switchable between MM and MC modes

Response Conformity 20 Hz to 20 kHz	Using 0.5% tolerance components: Worst case 0.5%; typically 0.025% - see write-up for details
Required Generator Z_{source}	50 Ω; Use of 600 Ω Source impedance can degrade accuracy by a factor of 3 worst case – i.e. 1.5%
Output impedance	MM - ~600 Ω
	MC - ~40 Ω
Max Input	10V pk ~ pk
Network Attenuation factor at 1 kHz	MM: ~500mV for 3 mV output = -44 dB
	MC: 1.1 V for 500 uV output = -68 dB

Background

Shown in Fig. 1 below is the original Reg Williamson IRN published in The Audio Amateur in 1971. This gave reasonably accurate results and for many years remained the standard IRN used by designers to verify their RIAA EQ circuit conformance.



Jung and Lipshitz modified Williamson's design per Fig. 2 below to improve the accuracy to within 0.025% using *selected* standard 1% E24 value components. Of course, with the normal ±1% spread to be expected in non-selected parts, the accuracy would not be as great. However, in this design iteration, by exploiting the fact that tolerance *tightens* as devices of the same value are paralleled, or added in series, and by selecting 0.5% parts where available, theoretical accuracies of better than 0.025% are attainable without part selection.

Figure 1 - Original Reg Williamson IRN (From original TAA articale)

In Fig. 2 below, R1 is changed to 883.3 k Ω from the original 910k Ω. R2' and C2' (required for generator source impedances of ~600 Ω) are not used in the version presented here since the assumption is that the IRN will always be driven from a low Z source of 50 Ω.

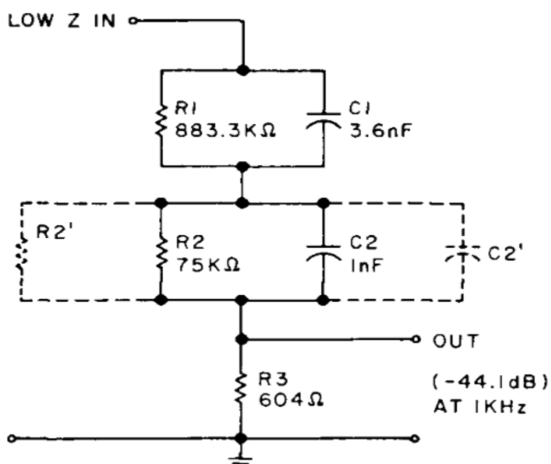


Figure 2 - Jung-Lipshitz Improved Network (From original TAA article)

The *hifisonix* IRN is shown in Fig 3. The exact component values are made up using series and parallel combinations of standard components. If normal distribution tolerance parts are used, the tolerance improves by a factor of $\sqrt{2}$ for every doubling of components used to make up the desired value. So by way of an example, if 2 1% 100pF capacitors are paralleled to create a 200 pF capacitor, the *probable* network tolerance improves to 0.707%. Place 4 in parallel, and the probable tolerance is ~0.5%, while 10 in parallel will result in about 0.35% tolerance. *The network tolerance will be <u>better than the worst case tolerance</u> of the components used – and that is the main reason or using this technique.* This approach works for series/parallel combinations as well, as shown for the 1.5nF capacitor in Figure 3 below. It is also important to note that the worst case tolerance of a network as described is that of the individual components – so if you use 1% resistors, your worst case tolerance will be 1%, while the nominal and likely accuracy will most likely be according to the effects of paralleling (or placing in series) as discussed above.

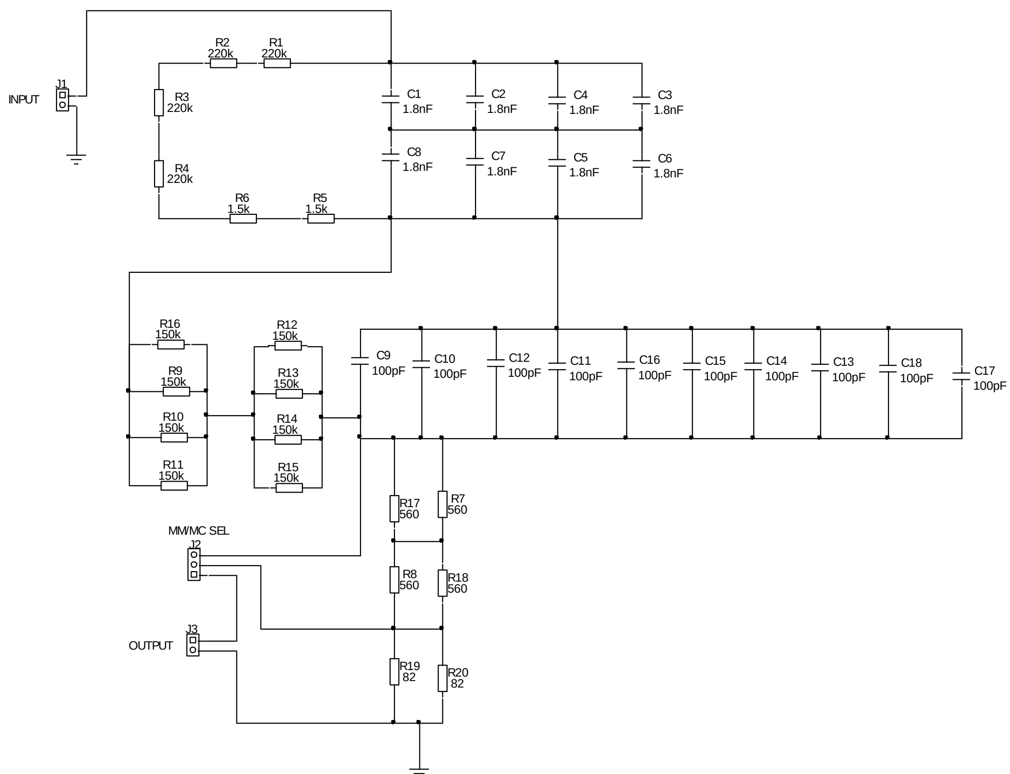


Figure 3 - Hifisonix Accurate IRN

The IRN can be used to test MC or MM RIAA EQ amplifiers – a toggle switch connected to J2 selects the appropriate attenuation.

Construction

The IRN uses all SMD components which are mounted on a simple single sided PCB. The PCB must be mounted inside a conductive metal enclosure – mild steel is recommended since it will offer some magnetic shielding, although diecast aluminum is a suitable second choice is the former is not available.

You will need two PCB's for a stereo test IRN. Use good quality phono connectors for the inputs and outputs to ensure a high quality connection and make sure the connectors are isolated from the housing to prevent earth loops. A separate earth bond point should be run from the housing to the earth bond of the phono amp under test.

Listed below are the required parts from Mouser. All the capacitors are NPO/COG types rated at 0.5 and 1%. If you can afford tighter tolerances, that is a step you should consider for even greater accuracy. Standard 1% resistors have been specified and selection to tighter tolerances can also bring benefits beyond the quoted 0.025% nominal accuracy of this IRN.

Parts List – Hifisonix Inverse RIAA Network (Mouser)

Item	Count	Label	PACKAGE	DESCRIPTION	Designation
1	8	1.8nF	1206	MSR 581-08055A182F	C1,C2,C3,C4,C5,C6,C7,C8
2	10	100pF	1206	MSR 81-GRM40C101F50D	C9,C10,C11,C12,C13,C14,C15,C16,C17,C18
3	4	220k	1206	MSR 754-RR1220P-224D	R1,R2,R3,R4
4	2	1.5k	1206	MSR 279-CPF0805B1K5E	R5,R6
5	4	560	1206	MSR 754-RR1220P-561D	R7,R8,R17,R18
6	8	150k	1206	MSR 754-RR1220P-154D	R9,R10,R11,R12,R13,R14,R15,R16
7	2	82	1206	MSR 754-RR1220Q-820D	R19,R20
8	2			PCB's single sided per layout in Appendix 1	
9	1			Mild Steel box 100mm x 60xx x 40 xx	
10	3			RCA phono sockets chassis mount	
11	1			Toggle Switch Double Pole Double Throw	
12	2			M3 female to male hex brass standoffs 10mm	
13	2			M3 hex brass standoffs 10mm	
14	1			Binding post for earth bond connection	

All Capacitors are NPO/COG 0.5% or better size 1206 or 0805

All Resistors are Thin Film 1% or better 1206 or 0805 available from Mouser

Figure 4 - Two boards are stacked one upon the other with 5mm spacers to create a stereo IRN

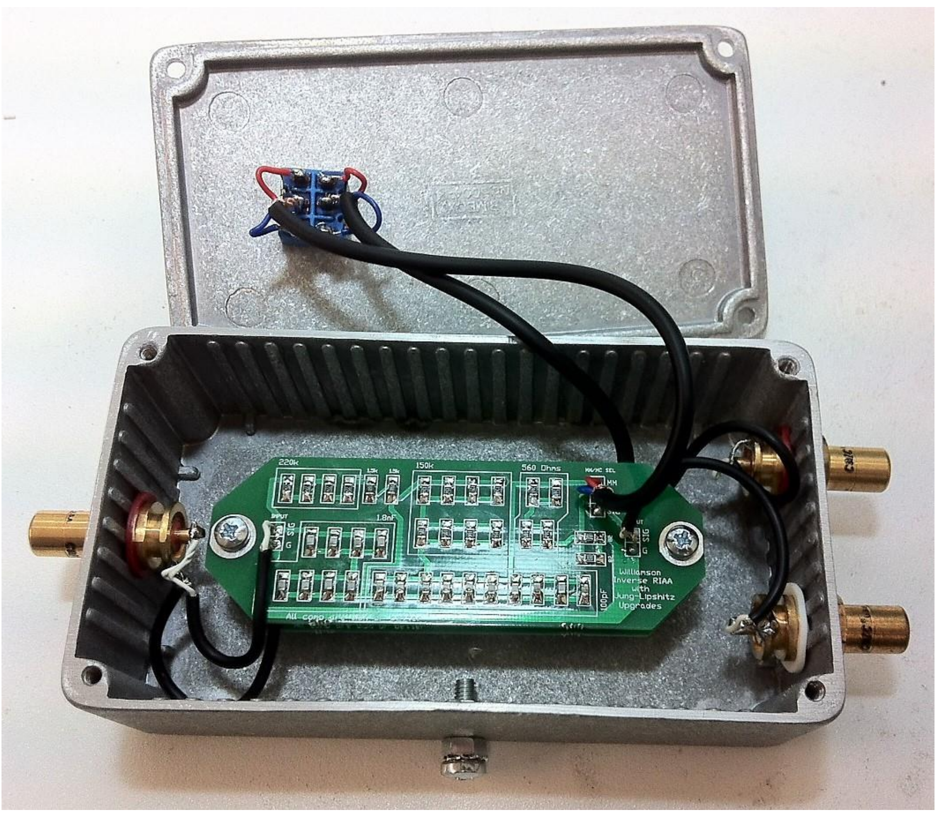


Figure 5 - View of internal wiring prior to final assembly

Using the IRN for Practical RIAA EQ Amplifier Testing

Firstly, your signal generator should have an output impedance of 50 Ω or less, although even with output impedances of 600 Ω, the IRN presented here is commendably accurate.

Sine Wave Testing

A typical sine wave test arrangement is shown in Fig. 4 below. For MM testing, set the generator to a sinewave with an output of approximately 500mV, which after passing through the IRN will deliver 3mV at its output. For MC testing, set the generator output to about 1V – for both MM and MC testing, it is important *that you do not overdrive your RIAA EQ amplifier*. Use a scope, or a voltmeter (shown in Fig. 4) to monitor the output of your RIAA equalizer. You can now sweep the generator signal across the audio band (20 Hz to 20 kHz) - the output of your RIAA amplifier should be flat. Note however that if the signal generator source output is not flat across the frequency band, this will result in changes in the output level, so you should check the signal generator levels carefully. The test needs to be conducted for both Left and Right Channels – the diagram below shows the right channel being tested.

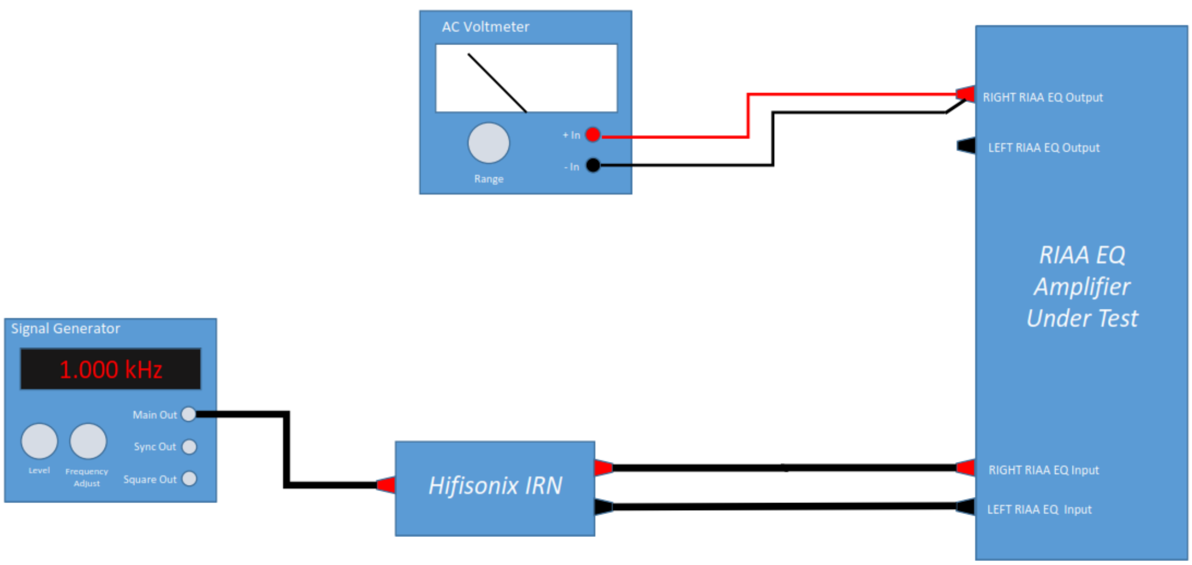


Figure 6 - Typical RIAA EQ Amplifier Sine Wave Excitation Test Setup

It is important that you look at the response beyond 20 kHz up to about 100 kHz. It should be flat, with some noticeable reduction in level between 50 kHz and 100 kHz of 1-2 dB, indicating that the HF response behavior is 1st order low pass and suffers from no anomalies like peaking or gradual increases in output level. At 200 kHz you should be 3-9 dB down on the 1 kHz level and in general the response slope should be 20 dB/decade by this stage. I would avoid situations where the output actually increases above 20 kHz – there is a lot of HF energy from scratches, pops etc on vinyl playback – amplifying this unnecessarily can lead to problems.

Square Wave Testing

An alternative and more robust method in my view is to set the generator to square wave output. If you then monitor your RIAA EQ amplifier output with a scope, you should see the square wave accurately reproduced. If any overshoot or undershoot is present, the response of your RIAA amplifier does not conform to the RIAA standard. Additionally, a lot of important information about the response of the RIAA EQ beyond the standard audio range of 20 Hz to 20 kHz can be gleaned using this methodology.

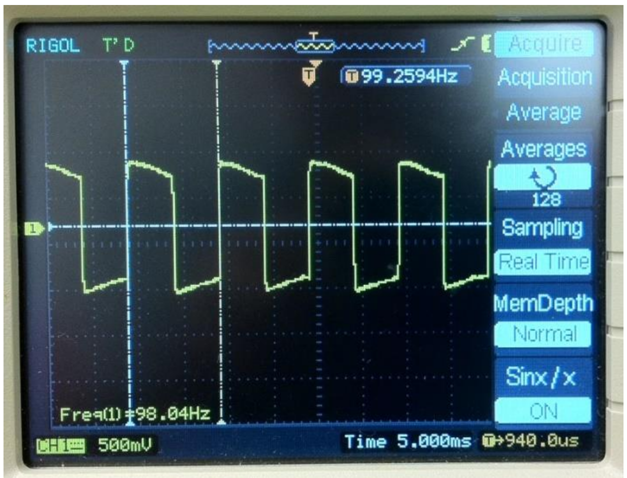


Figure 7 - 100 Hz Square Wave Response of RIAA EQ Phono Amp

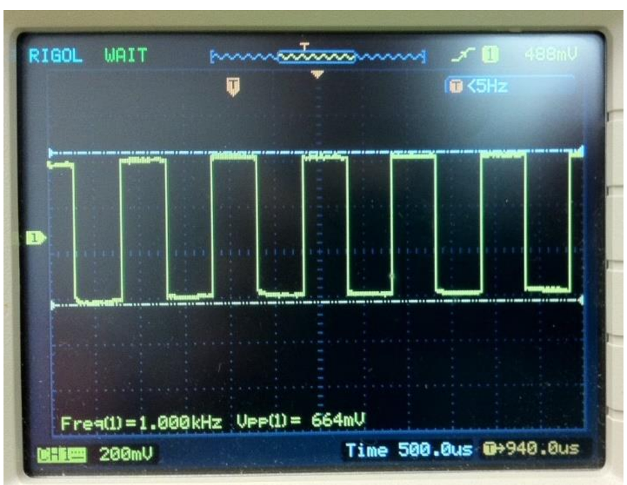


Figure 8 - 1 kHz Square Wave Response of RIAA EQ Phono Amp

The two plots above cover 100 Hz and 1 kHz testing. The rise and fall slopes are accurately reproduced. (The 100 Hz testing waveform tops slope because of the large coupling caps used and are expected at LF). The waveforms shows no HF roll off, and that immediately implies that the RIAA phono amp under test conformity between 100 Hz, 1 kHz and up to 10 kHz is accurate. If the square wave harmonics were not replicated accurately there would be undershoot (gain drops off too rapidly vs the required RIAA response) or overshoot (gain is greater than the required RIAA response). To reiterate, in the 100Hz and

1 kHz square wave tests, there should be no over or undershoot present – if there is, the RIAA EQ amp response is not accurate.

Figure 9- 10 kHz Square Wave Response of RIAA EQ Phono Amp

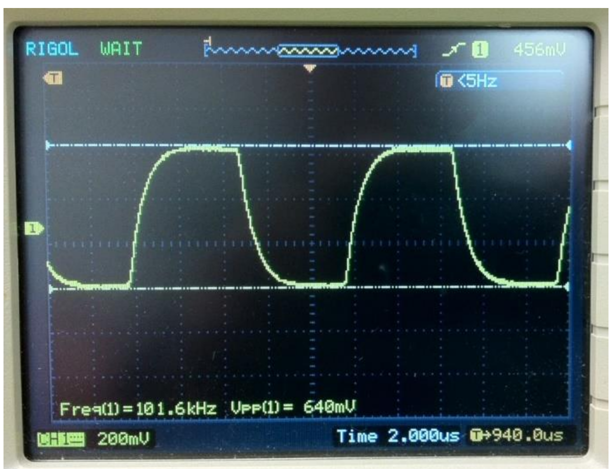


Figure 10 - 100 kHz Square Wave Response of RIAA EQ Phono Amp

In these scope shots, we see the response conformance at 10 kHz (upper shot) and then one at 100 kHz. Looking at the performance at these frequencies tells the designer a lot about the response beyond the 20 kHz upper audio band limit. In the case of this phono amp design (a single NE5534 based active stage), the 10 kHz response is clean and accurately reproduced indicating good RIAA conformance well beyond 20 kHz. As is the case with the 100 Hz and 1 kHz square wave plots, any overshoot would be a sure indication that the phono amp gain was erring on the high side vs the RIAA requirement.

As a *minimum requirement*, a well designed RIAA EQ stage should reproduce a 10 kHz square wave input stimulus via the IRN with little or no under or overshoot. This would imply accurate reproduction of harmonics i.e. response conformity out to 50 kHz or so.

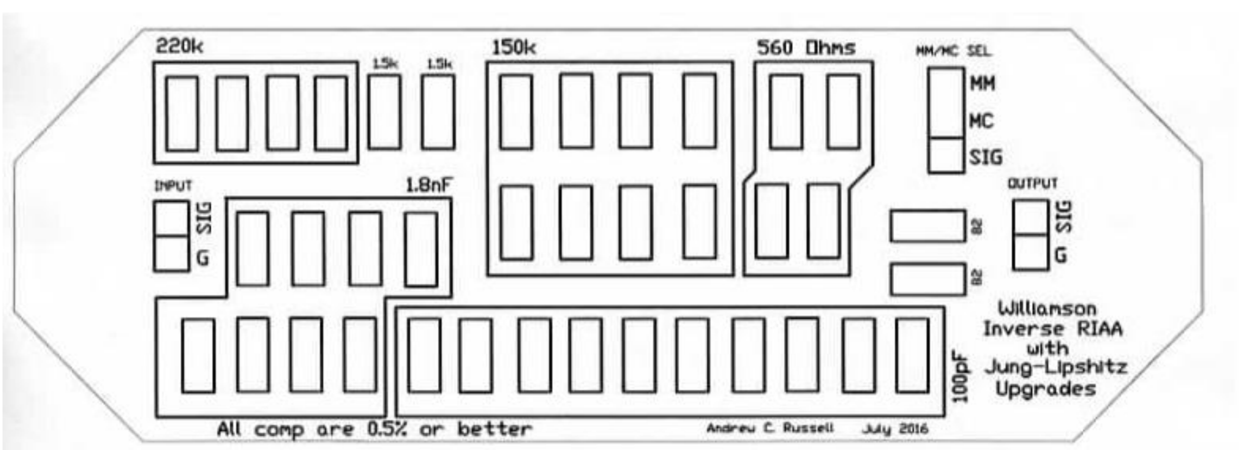
Fig. 10 shows the response at 100 kHz. I have included this since at 100 kHz, you want to see the response start to roll off at this stage indicating some bandwidth limiting.

PCB Layout and Assembly

The overlay below details part values and locations. Note the following important points when soldering SMD components: -

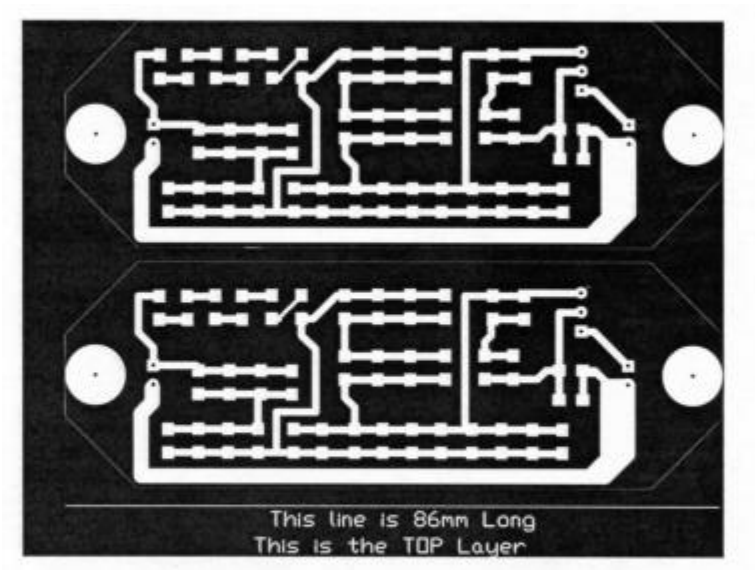
1. Use a pair of *FINE* Tipped tweezers to handle components and locate them correctly on the pads
2. Use a *FINE TIPPED* soldering iron
3. Use 0.5 or 0.4 mm diameter solder. I recommend you use LOW MELTING point solder – typically around 190˚C

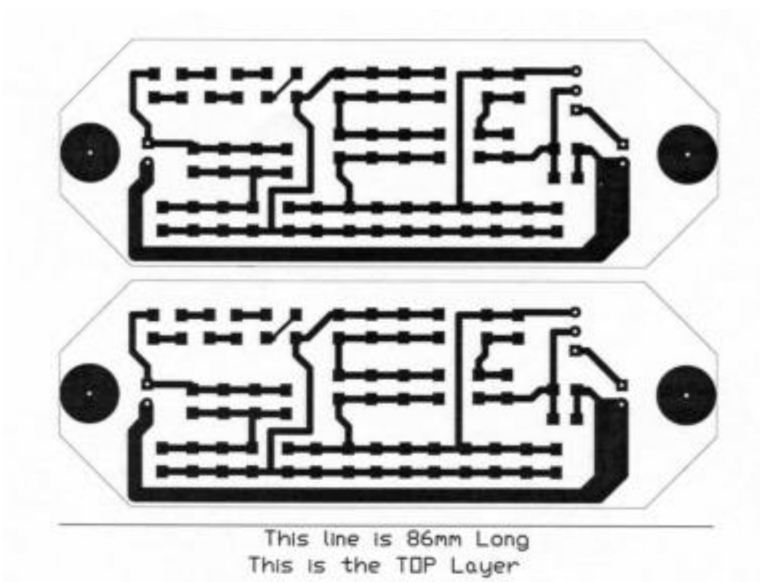
Here is a link to a short (23 seconds) YouTube video on how to solder a 1206 or 0805 SMD component Soldering 1206 SMD parts Note carefully how solder is first placed on only one of the device PCB pads, then the device is placed using a pair of tweezers, after which the second terminal of the device is soldered. This technique works for all discrete SMD parts and once mastered, is easier to do than standard leaded components.



PCB Layouts

Both a negative and a positive layouts are shown below – select the correct layout according to your PCB etching regime. Both layouts show two PCB's for a stereo test setup. You can also download the Gerbers for these boards here :- IRN PCB Gerbers





References

Walt Jung and Stanley Lipshitz – *A High Accuracy Inverse RIAA Network*

Uwe Beis - *Reverse RIAA Network*

Andrew C Russell – *RIAA Equalization Amplifiers*

Douglas Self – Small Signal Audio Design – Chapters 7 and 8