Uneeda Audio
Universal Pad Board

Sometimes you need a fixed attenuator when you are designing a sound system. Sometimes this is to force a microphone input to accept a line level signal, sometimes it is to get the clipping points of various devices in the system to line up correctly, and sometimes is just *because*.

The Uneeda Audio Universal Pad Board is designed for all of these things and more. It's small, easy to build, and easy to mount (just one hole needed). It can be configured with all of the commonly used pad topologies: H, T, L, U, O, Pi, Bridged Tee. It can be configured for balanced or unbalanced circuits. You can solder the i/o connections or you can use screw terminals. It's all in how you stuff the board.

It's beyond the scope of this manual to discuss what a pad does. If you're here already, then you've got this much figured out. If not, then refer to the following web page for that introduction: ***http://www.uneeda-audio.com/pads/*** You'll find design information at the end of this document.

Selecting a Circuit

With so many circuits to choose from, what's a person to do? The circuit board could have been designed for only one or two circuits, but then there was always the possibility that *someone* would ask why the board didn't accommodate *their* pet circuit. It just made more sense to make the board applicable to *all* of the major circuits. The only circuit that the board doesn't handle directly is the Lattice pad, which is a variant of an O pad. With some creative forcing, you could manage even that configuration although it might take a bit of creativity and there are no pads dedicated to making this configuration work.

That said, the H, U, and Bridged Tee configurations are probably most often used. All perform their task as designed. We won't argue sonics here.

Table 1 shows the more common configurations and points out some of the important differences. Right off, see that the Bridged-Tee configuration only requires two different resistors and two that are always equal to the line impedance.

Table 2 shows which resistors are stuffed for each pad configuration. Figures 3 through 10 are stuffing diagrams for each pad configuration.

Calculating Values

You can use the formulas and values from the Pads section of the Uneeda Audio website. For pads used in an all-matched (i.e. 600R input and output) system, refer to Table 4, at the end of this document. A spreadsheet program is probably the easiest way to do the math involved (which is really simpler than it looks), or you can use a calculator. With the K-factor table, a four-banger calculator will do the job.

Component Selection

We won't argue sonics here either. That's a personal religious preference.

The board was laid out with ¼-watt resistors in mind. These could be carbon film 5% tolerance units, carbon composition units, or precision 1% metal film units.

As calculated, the resistor values are guaranteed to come out in oddball values. Generally speaking, unless you own a resistor factory, you can just convert the values to the nearest standard value and you'll be close enough. This is certainly not a case of sound vs no sound. There is a standard value conversion program available from the Uneeda Audio website.

In the *Olde Days*, many pads were made using carbon composition resistors and a small hand grinder (i.e. a Dremel tool). You'd start with a resistor of lower than desired value and you'd grind the body away until the ohmmeter read the magic number. A dab of varnish over the incision sealed things up against moisture.

Construction

Simple:

1. Decide on a configuration.
2. Calculate values.
3. Decide on resistor type.
4. Procure.
5. Figure out where things go.
6. Stuff parts.
7. Solder.
8. Swage the mounting standoff.
9. Installation.

Where Things Go

See Table 2.

Inputs and Outputs

You have two choices:

- Solder directly to the board.
- Use a 4-pin Phoenix connector (p/n: 17 25 67 2 / MPT 0,5/4-2,54).

Note that the unbalanced configurations use a different set of pins than the balanced configurations.

Swaging the Standoff

You need a solid surface that can survive a hammer hit, a #2 phillips screwdriver, and a hammer. Insert the standoff into the hole in the board. Place the board, with the larger end of the standoff on the work surface. Put the screwdriver into the smaller end of the standoff, and smack the handle of the screwdriver with the hammer, deforming the end of the standoff and attaching it to the board.

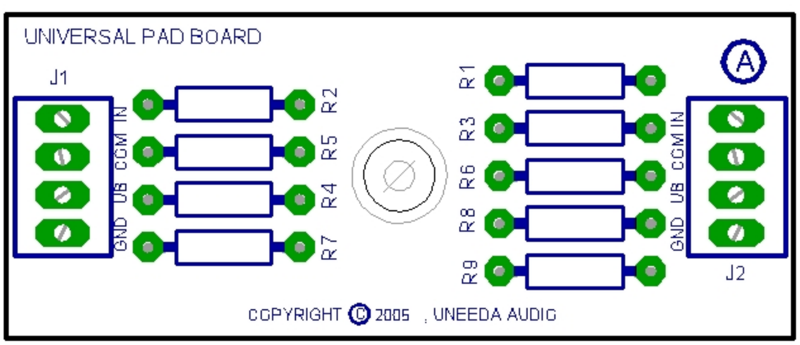

Figure 1. Top View
Board Dims: 2.062 x 0.85

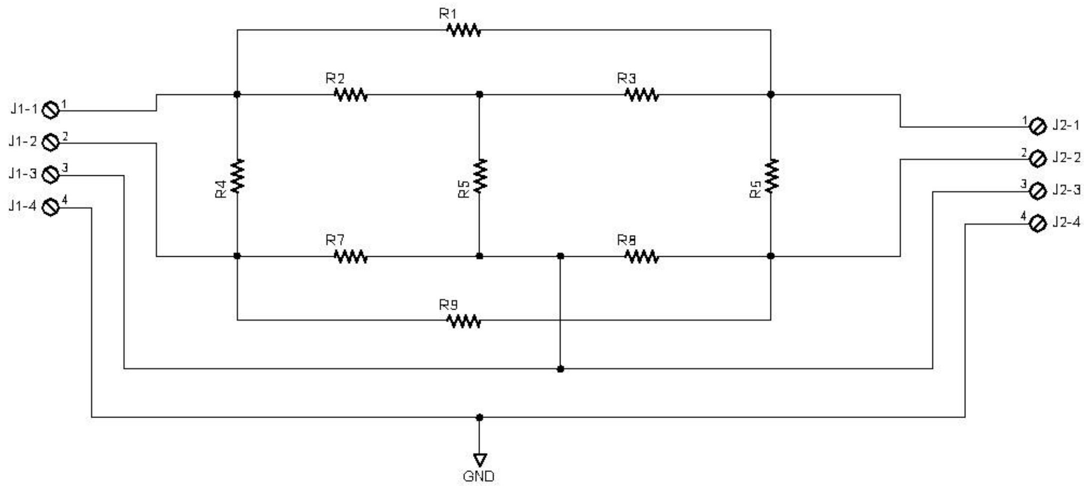

Figure 2. Schematic Diagram

Configuration	Number of unique resistor values	Number of non-unique resistor values	Remarks
T and H	3, sometimes 2		Can work between asymmetrical impedances.
U and L	2	0 (sort-of)	The output resistor value is generally the pad output impedance, except at low values of attenuation. This configuration normally does not attempt to match the source.
Bridged Tee (balanced or unbalanced)	2	2	Only between equal impedances

Table 1. Pad Configurations and Resistor Values.

Configuration	Stuff these parts	I/O pins	Remarks
L	R2, R5	1, 3, 4	R3 is 0-ohm jumper
U	R1, R9, R6	1, 2, 4	
T	R2, R5, R3	1, 3, 4	
H	R2, R7, R5, R3, R8	1, 2, 4	
Pi	R4, R1, R6	1, 3, 4	R7, R8 are 0-ohm jumpers
O	R4, R6, R1, R9	1, 2, 4	
Bridged-tee	R1, R5, R2, R3	1, 3, 4	R2 = R3 = Z
Balanced Bridged Tee	R1, R9, R2, R3, R7, R8, R5	1, 2, 4	R2 = R3 = ½ Z R7 = R8 = ½ Z

I/O Connections: Pin 1 is always signal hot . The balanced configurations use pins 1 and 2 for the signal connections. Unbalanced configurations use pin 1 for signal hot, pin 3 for ground. Use pin 4 for the cable shield, when needed.

Table 2. Stuffing Guide.

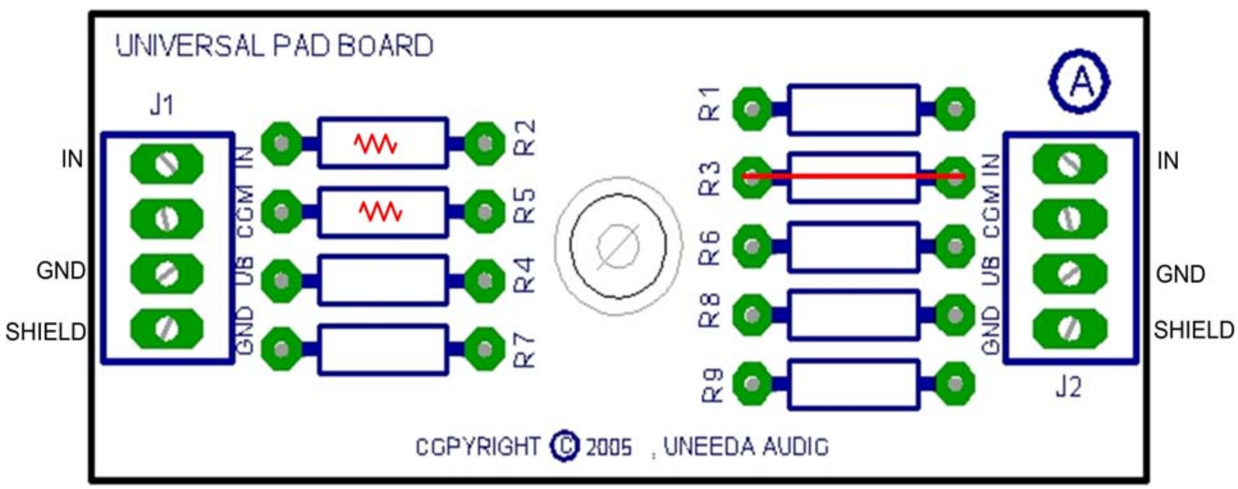

Figure 3. L Pad

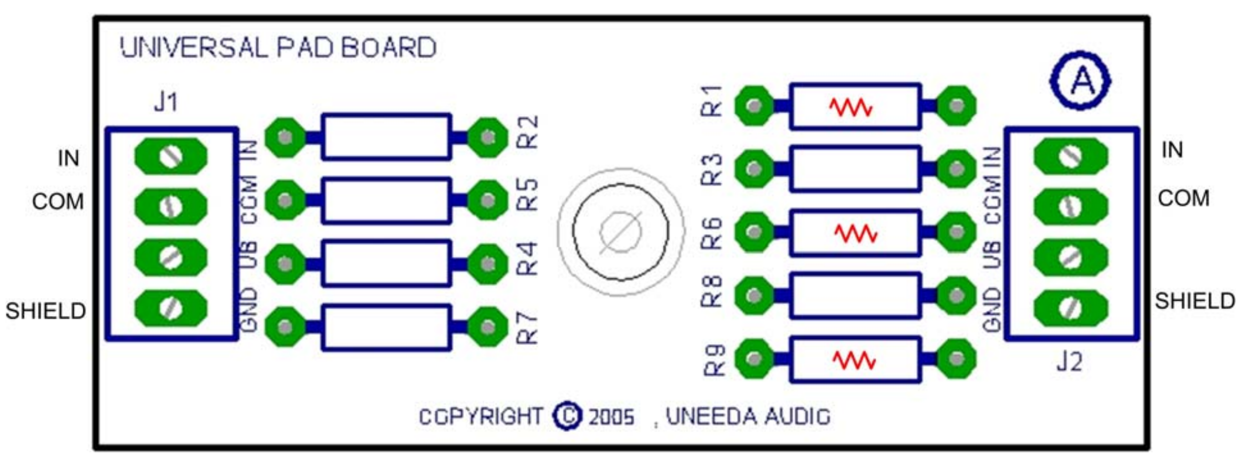

Figure 4. U Pad

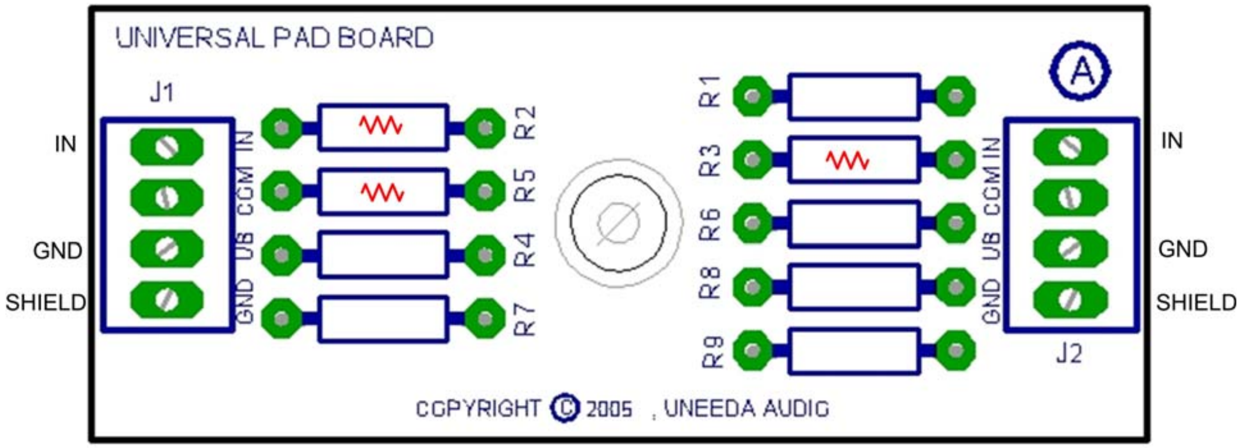

Figure 5. T Pad

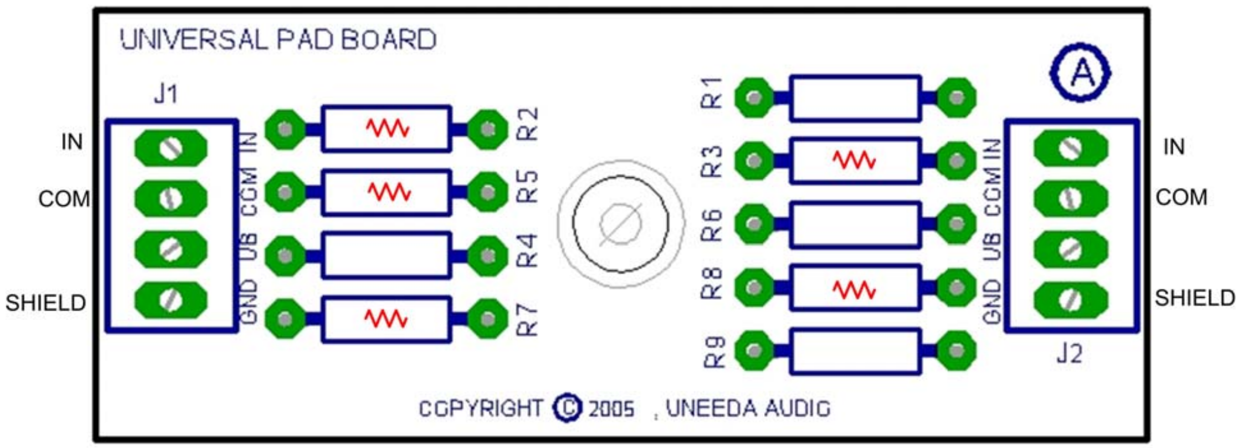

Figure 6. H Pad

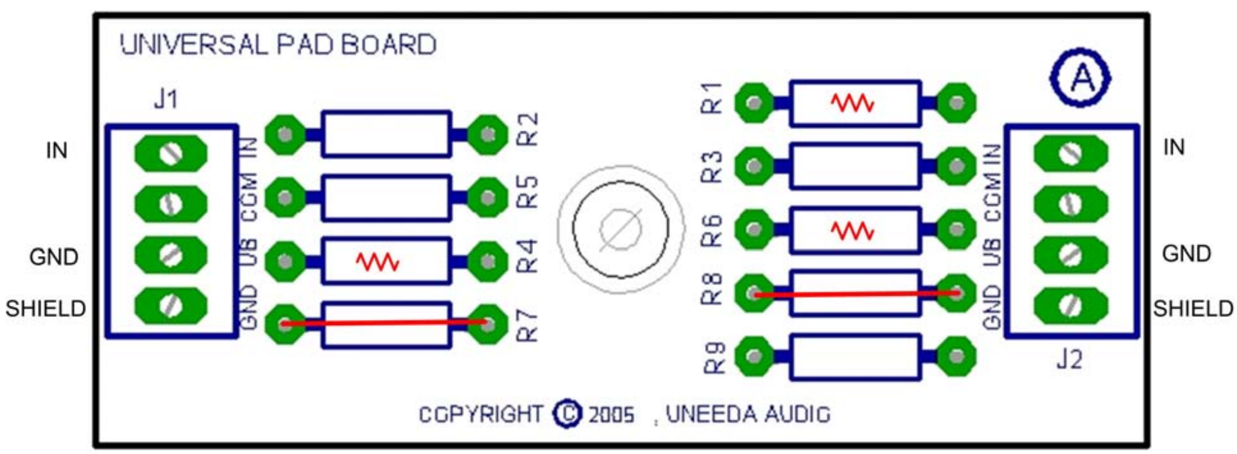

Figure 7. Pi Pad

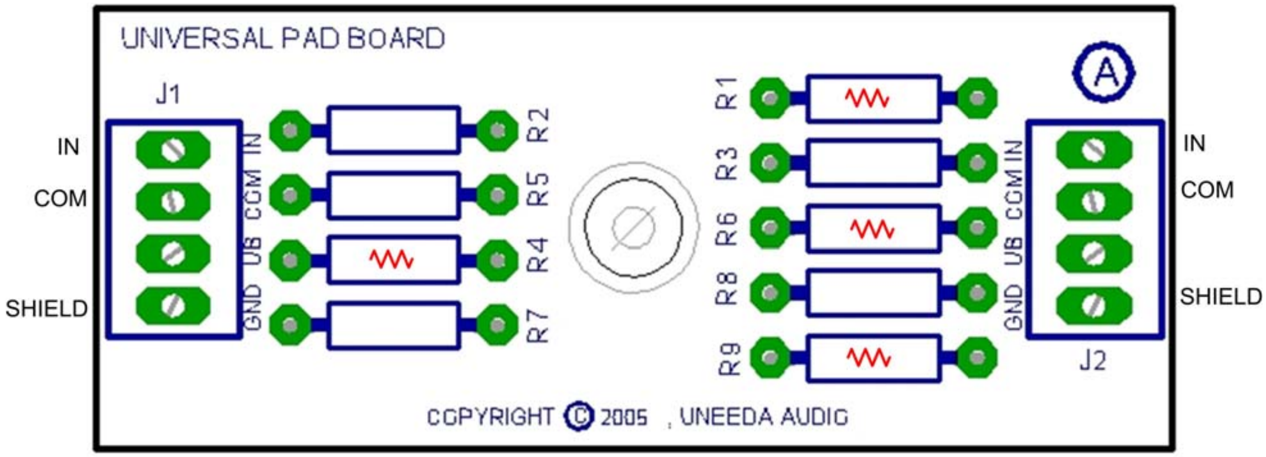

Figure 8. O Pad

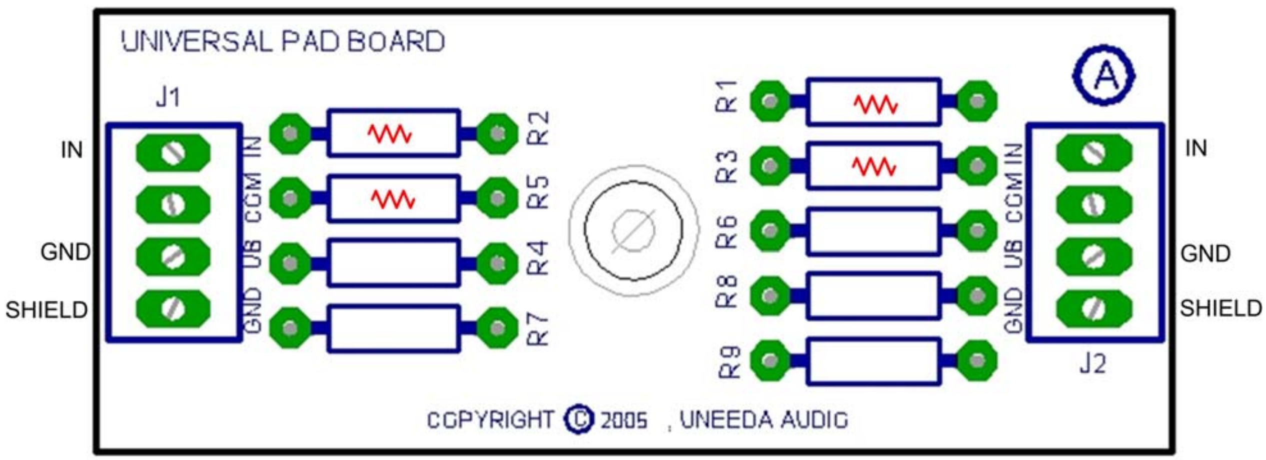

Figure 9. Bridged T Pad

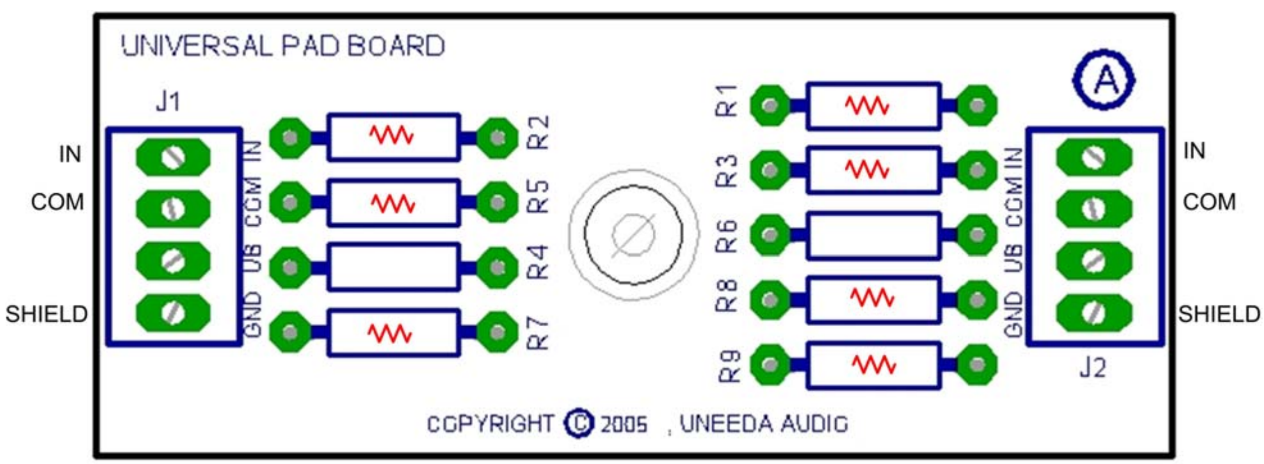

Figure 10. Balanced Bridged T Pad

Pads For Use in Matched Systems

The pad values calculated here are for use in matched systems, where the source impedance equals the pad impedance and the pad impedance equals the load impedance. ***This is ancient practice and is somewhat useable in modern sound system design, provided that the equipment is capable of operating in a 600-ohm environment.***

The generalized procedure is:

1. Decide on a configuration. Locate your configuration in Table 4.
2. Calculate the values needed. The K-factors can be found in Table 3.
3. Look up the nearest 1% resistor values. Purchase the parts needed.
4. Stuff the board.
5. Solder all connections.
6. Swage the standoff in place.
7. Installation.

Example using the k-factor tables

Design a tee-pad to provide 25dB attenuation with 600-ohm input and output impedances.

1. Locate the formulas. Since Zi = Zo, the formulas to use are in the bottom left cell of table 4a.
2. In the k-factor table, locate the row representing 25dB.
3. For R_2, in the 25dB row, find the column that says $k\text{-}1/k^{+}1$. The value is 0.8935. Multiply that by 600. = 536.1-ohms.
4. For R_3, in the equal impedance case, $R_3 = R_2$.
5. ForR_5, it's $k/k^2\text{-}1$, but this time it is just multiplied by 2Z. So, 1200*0.0564= 67.68-ohms.

As you can see, the k-factor table just saved you from having to do a bunch of really yukky math.

Rolling your own K-Factors

If you need k-factors for values not in Table 3, you can download the Excel spreadsheet that created the table at: http://www.uneeda-audio.com/pads/k-factors.xls. Although I can imagine how tables like this were created before the spreadsheet era, I prefer not to.

Standard Resistor Values

The results from the formulas are exact values. Unless you're really lucky, you can't buy resistors with these values. If you own a resistor factory (or have a relative who does), then you can buy what you want. So can Bill Gates. The rest of us must make do.

Resistors are available in standardized values. These values are equally spaced on a logarithmic scale. The number of values available per decade (a spread of 10x) varies according to tolerance: 10% = 12, 5% = 24, 1% = 96. The table of preferred values is usually referred to by putting the letter "e" ahead of the number of values in the series. The 1% series is known as the "e-96" series. As you can see, tighter tolerance means more values to choose from. The values follow a predictable pattern, although I don't know anyone who has memorized the e-96 value series.

Uneeda Audio has a freeware program available that tells you what the standard value is for your exact value. Get that program at: http://www.uneeda-audio.com/pads/stdval.htm. As a bonus, it can also tell you what 2 5% values you can parallel to approximate your exact value.

Pads For Bridging Systems

Bridging systems are voltage based, and don't depend on precise source impedances and load impedances. They are the basis for nearly ALL modern audio systems. Discussion of the pros and cons, ins and outs is beyond the scope of this manual. Instead, here are two websites:

The Uneeda Audio page about Pads and Pad Design: http://www.uneeda-audio.com/pads/

Richard Hess' excellent article about voltage-based transmission systems: http://www.richardhess.com/be/aes-80.htm

Since these pads don't depend upon impedance matching, one design suffices, the U pad. Refer to Table 5 or to the Uneeda Audio page for the design equations and/or values.

Unbalanced Operation

The layout of the board allows keeping the low-side (usually grounded) of the signal off of the chassis ground. It's up to you to decide how you'll treat this in your installation. Usually the simple thing to do is to insert the pad into the signal wiring, ignoring the connection labeled "SHIELD." When you mount the pad board, the chassis ground connection connects to the pad board's ground plane and that should be sufficient.

n(dB)	r = 1/k	k	k-1	K^2	(k-1)/(k+1)	(k+1)/(k-1)	$k/(k^2-1)$	$k^2-1/k=k-r$	k^2+1/k^2-1	k-1/k=1-r	k/k-1=1/1-r	1/k-1	n(dB)
1	0.8913	1.1220	0.1220	1.2589	0.0575	17.3910	4.3334	0.2308	8.7242	0.1087	9.1955	8.1955	1
2	0.7943	1.2589	0.2589	1.5849	0.1146	8.7242	2.1524	0.4646	4.4194	0.2057	4.8621	3.8621	2
3	0.7079	1.4125	0.4125	1.9953	0.1710	5.8480	1.4193	0.7046	3.0095	0.2921	3.4240	2.4240	3
4	0.6310	1.5849	0.5849	2.5119	0.2263	4.4194	1.0483	0.9539	2.3229	0.3690	2.7097	1.7097	4
5	0.5623	1.7783	0.7783	3.1623	0.2801	3.5698	0.8224	1.2159	1.9250	0.4377	2.2849	1.2849	5
6	0.5012	1.9953	0.9953	3.9811	0.3323	3.0095	0.6693	1.4941	1.6709	0.4988	2.0048	1.0048	6
7	0.4467	2.2387	1.2387	5.0119	0.3825	2.6146	0.5580	1.7920	1.4985	0.5533	1.8073	0.8073	7
8	0.3981	2.5119	1.5119	6	0.4305	2.3229	0.4731	2.1138	1.3767	0.6019	1.6614	0.6614	8
9	0.3548	2.8184	1.8184	8	0.4762	2.0999	0.4059	2.4636	1.2880	0.6452	1.5499	0.5499	9
10	0.3162	3.1623	2.1623	10	0.5195	1.9250	0.3514	2.8460	1.2222	0.6838	1.4625	0.4625	10
12	0.2512	3.9811	2.9811	16	0.5985	1.6709	0.2681	3.7299	1.1347	0.7488	1.3354	0.3354	12
14	0.1995	5.0119	4.0119	25	0.6673	1.4985	0.2078	4.8123	1.0829	0.8005	1.2493	0.2493	14
15	0.1778	5.6234	4.6234	32	0.6980	1.4326	0.1836	5.4456	1.0653	0.8222	1.2163	0.2163	15
16	0.1585	6.3096	5.3096	40	0.7264	1.3767	0.1626	6.1511	1.0515	0.8415	1.1883	0.1883	16
18	0.1259	7.9433	6.9433	63	0.7764	1.2880	0.1279	7.8174	1.0322	0.8741	1.1440	0.1440	18
20	0.1000	10.0000	9.0000	100	0.8182	1.2222	0.1010	9.9000	1.0202	0.9000	1.1111	0.1111	20
25	0.0562	17.7828	16.7828	316	0.8935	1.1192	0.0564	17.7266	1.0063	0.9438	1.0596	0.0596	25
30	0.0316	31.6228	30.6228	1000	0.9387	1.0653	0.0317	31.5912	1.0020	0.9684	1.0327	0.0327	30
35	0.0178	56.2341	55.2341	3162	0.9651	1.0362	0.0178	56.2163	1.0006	0.9822	1.0181	0.0181	35
40	0.0100	100.0000	99.0000	10000	0.9802	1.0202	0.0100	99.9900	1.0002	0.9900	1.0101	0.0101	40
45	0.0056	177.8279	176.8279	31623	0.9888	1.0113	0.0056	177.8223	1.0001	0.9944	1.0057	0.0057	45
50	0.0032	316.2278	315.2278	100000	0.9937	1.0063	0.0032	316.2246	1.0000	0.9968	1.0032	0.0032	50
55	0.0018	562.3413	561.3413	316228	0.9964	1.0036	0.0018	562.3395	1.0000	0.9982	1.0018	0.0018	55
60	0.0010	1000.0000	999.0000	1000000	0.9980	1.0020	0.0010	999.9990	1.0000	0.9990	1.0010	0.0010	60
65	0.0006	1778.2794	1777.2794	3162278	0.9989	1.0011	0.0006	1778.2788	1.0000	0.9994	1.0006	0.0006	65
70	0.0003	3162.2777	3161.2777	10000000	0.9994	1.0006	0.0003	3162.2773	1.0000	0.9997	1.0003	0.0003	70
80	0.0001	10000.0000	9999.0000	100000000	0.9998	1.0002	0.0001	9999.9999	1.0000	0.9999	1.0001	0.0001	80

Table 3. K-Factors

L	Where Zi = Zo $R_2 = Z\left(\frac{K-1}{K}\right)$ $R_5 = Z\left(\frac{1}{K-1}\right)$	Where Zi > Zo $R_2 = \left(\frac{Z_i}{S}\right)\left(\frac{KS-1}{K}\right)$ $R_5 = \left(\frac{Z_i}{S}\right)\left(\frac{1}{K-S}\right)$ $s = \sqrt{\frac{Zi}{Zo}}$	Where Zi<Zo $R_2 = Z\left(\frac{K-1}{K}\right)$ $R_5 = Z\left(\frac{1}{K-1}\right)$	Minium loss between two impedances $R_2 = \sqrt{Zi(Zi-Zo)}$ $R_5 = \frac{Z_1 Z_2}{R_2}$ $\text{Loss} = 20\log\left(\sqrt{\frac{Zi}{Zo}} + \sqrt{\frac{Zi}{Zo} - 1}\right)$
U (balanced L)	Where Zi = Zo $R_1 = R_9 = \frac{Z}{2}\left(\frac{K-1}{K}\right)$ $R_6 = Z\left(\frac{1}{K-1}\right)$	Where Zi > Zo $R_1 = R_9 = (0.5)\left(\frac{Z_i}{S}\right)\left(\frac{KS-1}{K}\right)$ $R_6 = \left(\frac{Z_i}{S}\right)\left(\frac{1}{K-S}\right)$ $s = \sqrt{\frac{Zi}{Zo}}$	Where Zi < Zo $R_1 = R_9 = \frac{Z}{2}\left(\frac{K-1}{K}\right)$ $R_6 = Z\left(\frac{1}{K-1}\right)$	Minimum loss between two impedances $R_1 = R_9 = \frac{\sqrt{Zi(Zi-Zo)}}{2}$ $R_6 = \frac{Z_1 Z_2}{R_2}$ $\text{Loss} = 20\log\left(\sqrt{\frac{Zi}{Zo}} + \sqrt{\frac{Zi}{Zo} - 1}\right)$
T	Where Zi = Zo = Z $R_2 = R_3 = Z\left(\frac{K-1}{K+1}\right)$ $R_5 = 2Z\left(\frac{k}{k^2-1}\right)$	Where Zi $\neq$ Zo $R_2 = Zi\left(\frac{K^2+1}{K^2-1}\right) - 2\sqrt{ZiZo}\left(\frac{k}{k^2-1}\right)$ $R_3 = Zo\left(\frac{K^2+1}{K^2-1}\right) - 2\sqrt{ZiZo}\left(\frac{k}{k^2-1}\right)$ $R_5 = 2\sqrt{ZiZo}\left(\frac{k}{k^2-1}\right)$		

Table 4a. Pad Value Calculations for Impedance Matched Systems

H (Balanced T)	Where Zi = Zo $R_2 = R_3 = Z\left(\frac{k-1}{k+1}\right)$ $R_5 = 2Z\left(\frac{k}{k^2-1}\right)$	Where Zi $\neq$ Zo $Ra = Zi\left(\frac{K^2+1}{K^2-1}\right) - 2\sqrt{ZiZo}\left(\frac{k}{k^2-1}\right)$ then R2 = R7 = Ra $Rb = Zo\left(\frac{K^2+1}{K^2-1}\right) - 2\sqrt{ZiZo}\left(\frac{k}{k^2-1}\right)$ then R3 = R8 = Rb $R_5 = 2\sqrt{ZiZo}\left(\frac{k}{k^2-1}\right)$
BT	Unbalanced Bridged T $R_2 = R_3 = Z$ $R_1 = Z(k-1)$ $R_5 = Z\left(\frac{1}{k-1}\right)$	Balanced Bridged T $R2 = R3 = R7 = R8 = \left(\frac{Z}{2}\right)$ $R1 = R9 = \frac{Z}{2}(k-1)$ $R5 = Z\left(\frac{1}{k-1}\right)$
PI	Where Zi = Zo = Z $R_4 = R_6 = Z\left(\frac{k+1}{k-1}\right)$ $R_1 = \left(\frac{Z}{2}\right)\left(\frac{k^2-1}{k}\right)$	Where Zi $\neq$ Zo and $s = \sqrt{\frac{Zi}{Zo}}$ then $R_4 = Zi\frac{k^2-1}{k^2-2ks+1}$ $R_1 = \left(\frac{\sqrt{Z^1Z^2}}{2}\right)\left(\frac{k^2-1}{k}\right)$ $R_4 = Zi\left(\frac{k^2-1}{k^2-2\frac{k}{s}+1}\right)$
O (Balanced PI)	Where Zi = Zo = Z: Design for unbalanced case (PI). $R_1 = R_9 = \frac{R_1}{2}$ Where R1 is the value calculated for the PI pad.	Where Zi $\neq$ Zo: Design for the unbalanced case (PI) $R_1 = R_9 = \frac{R_1}{2}$ Where R1 is the value calculated for the PI pad.

Table 4b. Pad Value Calculations for Impedance Matched Systems

U	**Microphones** Pick Zin > K_r (Z_{mic}) K_r is the bridging ratio, typically 5. It should approximate the preamp's input impedance. Pick Zout = Z_{mic} R1 = $\frac{R_6(k-1)}{2}$ **Check:** $K \cong k_r$ if not, the pad's input impedance will be too low.	**Line Level Sources** Pick R_6 = Z_{out} = 604R *it can be some other value too.* R1 = $\frac{R_6(k-1)}{2}$ Check: Zin = $R_1 + R_1 + R_6$ This should be a value that the source can drive. If it is too low, then choose a higher value for R6 and recomputed.

Table 5. Pad Value Calculations for Voltage based Systems (Bridging)

Revision History

A.1 birth