JIG II

Complete design and construction info on
latest and greatest speaker testing jig, designed
by Eric Wallin.
http://www.gti.net/wallin/audio/audio.html

Webpage converted to PDF by
Raymond van Weeghel
http://www.raymondaudio.nl

Gettin' Jiggy With It

These days your average home PC has almost everything in it to perform serious speaker testing. Measurements which are awkward and time consuming with a SPL meter or DMM such as -3dB points, impedance curves, in-room response, etc., can be made easily and fairly painlessly with these CAD tools. Other highly valuable tests, such as pseudo-anechoic gated frequency response, are just about impossible without a computer in the link. An impedance jig can also make it easy to measure passive component such as resistors, capacitors, and inductors.

Aside from the computer (with duplex souncard) you'll need some good speaker CAD software which, lucky you, is available free on the web. Additionally a speaker jig and the love of a good woman can make a huge difference. This article can help you with the jig, which is a central point for making all necessary electrical connections between the PC, device under test, and microphone preamplifier. I designed my first jig maybe five years ago, and have recently updated it in several significant ways.

It's been a while since I looked at the circuit for my original speaker test jig. Mark Zachman, author of the Speaker Workshop software, wrote to me a month or so ago and suggested a minor wiring change in it. The purpose of this change was to supply the soundcard with the electrical signal at the speaker terminals when doing frequency response measurements. With this information the program could measure and calulate phase more exactly. While the change was simple, I thought this might be a good time to give the jig an overhaul, and design it fresh from the ground up. Now that I have been gainfully employed in the electronics industry since the fall of 98, I can rightfully claim that I am bringing "years" of design experience to bear on the problem!

Messing With Success?

The original jig was pretty basic, with four switches and fairly clear functionality. Why change it? Here are a few of the things I wanted to incorporate in the new jig:

- Incorporate Mark's suggested change, but do it in a somewhat different way. I decided to design the new jig so that the left line input would always be the reference input, and the right line input would always be the measurement input. This is different than my original jig (and also different from that recommended in Speaker Workshop) where the left input was the reference input when measuring impedances, but the right input was the reference input for frequency response measurements. Nothing like consistency!
- Do a complete power audit on the circuit. Maximize wattage capacity in the cheapest and easiest ways possible.
- Remove the voltage divider from the J3 output. I figure most people won't be doing impedance testing with huge signals which might overwhelm the soundcard inputs, and the voltage divider only messes up the accuracy if it is switched to a different position after calibration. The diode clamping action should be sufficient to protect the soundcard inputs.
- Lower the impedance of the remaining voltage divider to ~1k (as in Mark's jig) and only have the option of engaging it when doing frequency response measurements (when signals may be larger due to an external amplifier). This should help with high frequency loss in the cable back to the soundcard inputs.
- Have a second position in the remaining divider to select -10dB or -20dB attenuation during FR tests, instead of the single selection of -20dB on the original jig.
- Use back-to-back 5.1V zeners to limit the voltage going to the soundcard inputs instead of LEDs.
- Use values around ~16 ohms and ~4 ohms for calibration. This gives 2/3 and 1/3 ratios with the 8 ohm divider resistor, respectively. I'm trying to minimize the numerical error in the calibration process here. (I haven't actually proven to myself that these are the best ratios, but they should work fine.)
- Use precision components for the calibration resistors to eliminate the need to measure these precisely, and thus to eliminate the frustration others have had involving this part of the jig.
- Use more gangs on the switches to reduce odd, unused modes in the jig.
- Reduce the switch count by making the calibration resistor selection also select the dB reduction of the above discussed remaining voltage divider.

- NOTE -

Be aware that the overall divide by 10 selectable voltage divider has been removed from this jig. If you built my first jig and have to use this feature in order to keep your soundcard inputs from clipping, then you are probably better off with the first jig. If your soundcard works fine with the divider switched out of circuit (x1 setting) then I recommend the new jig described here.

Switches, Jacks, & Modes

Here is a look at the faceplate of the new jig:

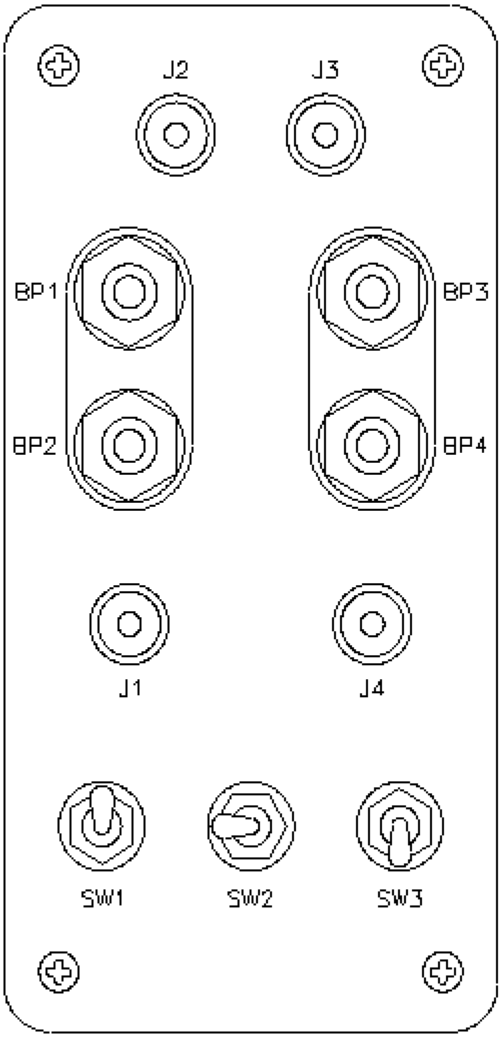


Figure 2. The faceplate of the new jig.

Here is a list of the switches and jacks on the jig, and their function:

- J1 is a soundcard speaker level input to the jig in case you want to power everything with the speaker amplifier built-in to your soundcard. This is fine for any impedance measurements you might want to make, and also works for low level frequency response testing. Note that J1 and BP1 and BP2 are electrically connected in the jig, so disconnect your soundcard speaker level connection at J1 if you use an external amplifier connected to BP1 and BP2 or you could hurt your soundcard!
- BP1 and BP2 are amplifier level inputs to the jig in case you decide to use an external amplifier to power it. BP2 is at ground potential.
- BP3 and BP4 are the test points where you connect components like caps, resistors, inductors, and speakers to be tested. BP4 is at ground potential.
- J2 and J3 are left and right line out jacks respectively, that go to the line level inputs on your soundcard.
- J4 is an input that you connect your external microphone preamp line level output to.
- SW1 is a three position switch and has a dual function. In the the impedance measuring mode it selects and switches the calibration resistors in and out of circuit. In the frequency response mode it selects between two levels of attenuation that scale the output voltage at J2. This can help match the

levels going to your soundcard when using an external amplifier to drive the speaker under test during frequency response measurements.

- SW2 and SW3 select the main modes of the jig. When SW2 is to the left and SW3 is down, the jig is in impedance mode. Here, either or one of two or none of the calibration resistors are selected by the position of SW1. When SW2 is to the right the internal 8 ohm bridge resistor is shorted out, and the amplifier output is applied directly to the test terminals BP3-4. Note that the calibration resistors are also removed from circuit. So with SW2 to the right, and when SW3 is down, then the jig is in direct mode, where the signals at J2 and J3 are the same and a channel difference calibration can be performed. When SW2 is to the right and SW3 is up, the jig is in frequency response mode, where the microphone line level input from the preamplifier at J4 is connected to J2, and the attenuation of the speaker signal at J2 is selected by the position of SW1. So the only "odd" or meaningless mode is with SW2 to the left and SW3 up.

The jig has three basic modes, Impedance, Frequency Response, and Direct, which are selected by the positions of SW2 and SW3. SW1 selects the sub modes. Here is a listing of all modes and sub modes in a handy table form:

Jig Modes

SW1	SW2	SW3	Mode	Description
U	L	D	IMPCAL16	16 ohm calibration resistor is across BP3-BP4 for jig impedance calibration.
D	L	D	IMPCAL4	4 ohm calibration resistor is across BP3-BP4 for jig impedance calibration.
C	L	D	IMPMEAS	Measure the impedance of a device across BP3-BP4.
C	R	D	DIRECT	J2 and J3 are connected to J1 for channel balance calibration.
C	R	U	FRMEAS-0DB	Mic input J4 connected to J3; no attenuation @ J2.
U	R	U	FRMEAS-10DB	Mic input J4 connected to J3; -10dB attenuation @ J2.
D	R	U	FRMEAS-20DB	Mic input J4 connected to J3; -20dB attenuation @ J2.

U=up, D=down, C=center, L=left, R=right

Here is a graphic portrayal of the seven basic modes of the jig:

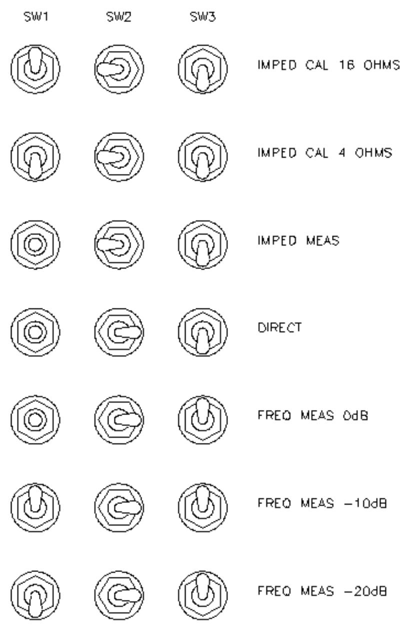


Figure 3. Switch positions and the modes of the jig.

-Notes-

- Note that as long as you are careful to have SW2 to the RIGHT when applying lots of power to the jig for frequency response tests, then there is no way to accidentally "fry" the 2W precision calibration resistors, nor the 8 ohm bridge resistor, regardless of the settings of SW1 or SW3. The 8 ohm bridge resistor is only in circuit when SW2 is to the LEFT, and the calibration resistors additionally require that S3 be in the DOWN position and S1 be in the NON-CENTERED position to be in circuit.
- Note that the -10 and -20 dB attenuation is just applied to the signal at J2 (and not to J3 also, as in my first jig) and that this attenuation is only in effect when SW3 is in the UP position.
- Next let's take a look at the schematic for the new jig, and go over some of the design calculations.

Electrical Design

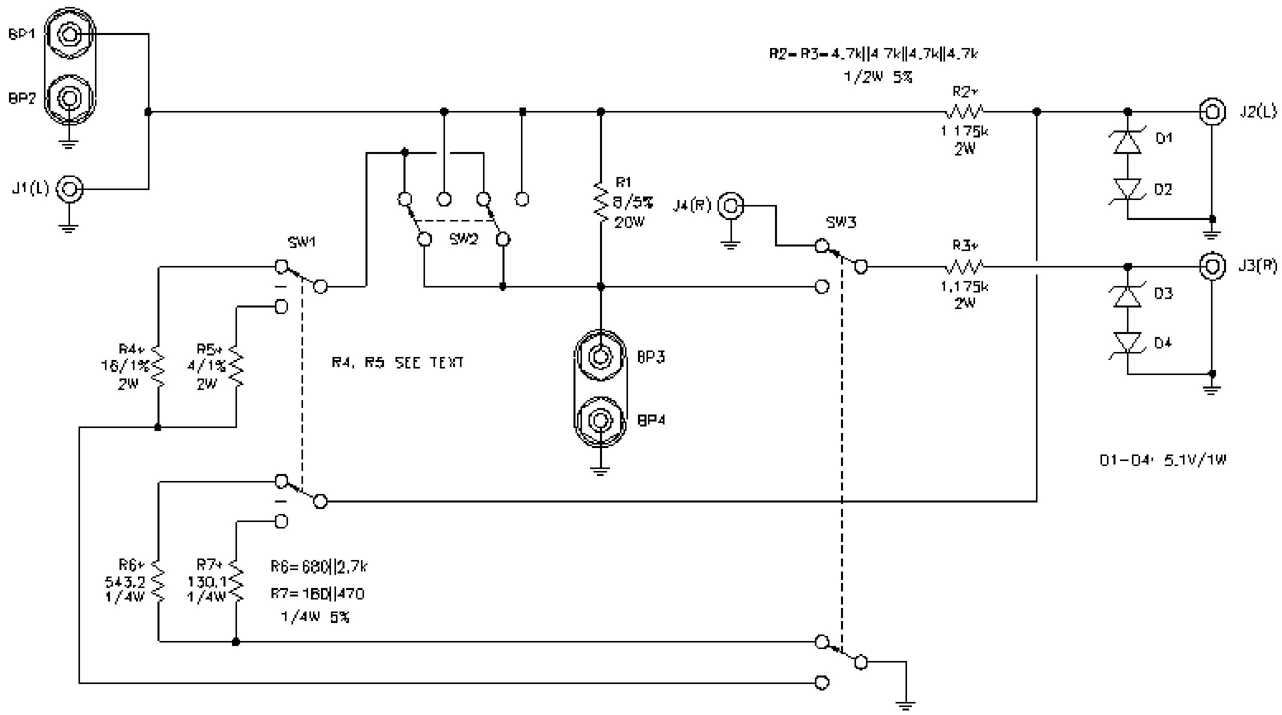


Figure 4. The jig electrical schematic.

PARTS LIST		
ITEM	RS STOCK	DESCRIPTION
B1	270-1803	Black plastic box, dimensions 5" x 2.5" x 2"
SW1	275-0664	DPDT center-off 6A mini toggle switch
SW2, SW3	275-0663	DPDT 6A mini toggle switch
BP1-2, BP3-4	274-0718	Dual binding post
J1 - J4	274-0852	RCA jacks, gold plated
R1	271-120	8 ohm non-inductive 20W resistor
R2, R3	271-1124	1.175k 2W resistor (four 4.7k 1/2W in parallel)
R4	-	16.2 ohm 2W (four 16.2 ohm ½W 1% in series/parallel)
R5	-	4.05 ohm 2W (four 16.2 ohm ½W 1% in parallel)
R6	assortment	543.2 ohm ¼W (680 ohm in parallel with 2.7k ohm)
R7	assortment	130.1 ohm ¼W (180 ohm in parallel with 470 ohm)
D1 - D4	276-0565	5.1V 1W Zener diode

-Notes-

- R2 and R3 are made by soldering four 4.7k 0.5W 5% resistors in parallel. I used heat shrink tubing to hold the resistors together before soldering. You might want to sort the individual resistors by value using a good DMM, and then combine them to get as close to 1.175k as possible for R2. This will make the dB reduction in the frequency response measurement mode more accurate. The precision of R3 is relatively unimportant, so use the remaining resistors to form this element.
- R4 is made by soldering two sets of two 16.2 0.5W 1% resistors in parallel, and then soldering these assemblies in series. R5 is made by soldering four 16.2 0.5W 1% resistors in parallel. I used a piece of heat shrink tubing to hold the resistors together both before and after soldering. You are on your own regarding the source of these - try Radio Shack mail order 900-0492 (16.0

ohms), or DigiKey BC16.2ZCT-ND (16.2 ohms). Anything around 16 ohms will do, it's the precision that's important for calibrating the jig.

- R6 is made by soldering a 680 ohm 0.25W 5% resistor in parallel with 2.7k ohm 0.25W 5% resistor. R7 is made by soldering a 180 ohm 0.25W 5% resistor in parallel with 470 ohm 0.25W 5% resistor. I got all of these from an assortment sold by RS, though they may sell them in packs of five. If you have more than one resistor of each value, try to combine them so that the values are as accurate to the nominally specified value as possible. This will the dB reduction in the frequency response measurement mode more accurate.

Design Math

Let's start the analysis at the output jacks J2 and J3. These are the left and right line level inputs to the soundcard, respectively. Unlike my first jig, where the maximum impedance seen at J2 and J3 was 10K ohms, the impedance in the new jig has been reduced to around 1k to keep cable and other stray capacitance from reducing high frequency response. The back-to-back 5.1 zener diodes protect the soundcard inputs by keeping the voltages at these jacks from exceeding 5.8V peak maximum (as opposed to LEDs limiting the voltage to +/-1.7V in the old jig).

Resistors R2 and R3 are sized as follows: assume you are doing a frequency response measurement at high wattage, and the -20dB reduction is selected to keep the voltage at J2 from clipping with the zener. R2 forms a 1/10 voltage divider with R7, so if 5.8V peak is at the output of J2, then 58V peak is across the test speaker terminals BP3-4. Calculating the RMS (sine wave) power across R2 using the equation:

$$P = \frac{0.5 \cdot V_{peak}^{\ 2}}{R3} = \frac{0.5 \cdot (58V - 5.8V)^2}{1175\Omega} = 1.16W$$

As a rule of thumb we rate R2 and R3 for double this, or 2W. What is the power dissipated by R7 in this situation?

$$P = \frac{0.5 \cdot V_{peak}^{\ 2}}{R7} = \frac{0.5 \cdot 5.8V^2}{130.1\Omega} = 0.13W$$

Which shows that a 1/4W resistor should be sufficient. The same calculation for R4 yields an even lower wattage.

By the way, 58V peak across an 8 ohm load gives:

$$P = \frac{0.5 \cdot V_{peak}^{\ 2}}{R_{Load}} = \frac{0.5 \cdot 58V^2}{8\Omega} = 210W$$

So the jig can safely be used to test the frequency response of 8 ohm loads to 210W. Can the 1W zeners handle this? Imagine 58V DC applied across B3 - B4 (an almost absurd worst-case) and R7 removed from circuit so all current flows through the diodes. The zeners would be conducting 100% of the time at the following current:

$$I = \frac{V}{R} = \frac{58V - 5.8V}{1175\Omega} = 44.4mA$$

The zener which is reverse biased (5.1V across it) dissipates most, which is:

$$P = V \cdot I = 5.1V \cdot 0.0444A = 0.226W$$

Even with this crazy DC input a 1W diode should work fine.

Now how about the calibration resistors? Most souncards can put out a couple of watts maximum. Let's make the sane assumption that you want to keep the zener diodes from clipping when measuring impedances with the jig, which means the input voltages to the jig are less than 5.8V peak. What power level is this across the 4 ohm calibration resistor?

$$P = \frac{1}{3} \cdot \frac{0.5 \cdot V_{Peak}{}^2}{R_{Load}} = \frac{1}{3} \cdot \frac{0.5 \cdot 5.8V^2}{8\Omega + 4\Omega} = 0.47W$$

In order to keep this resistor from heating excessively and thus deviating from its precision value, we pick roughly four times this power level, or 2W, for the rating of this component in the jig. A similar calculation for the 16 ohm resistor yeilds an even lower power requirement, but it turns out to be 2W also by virtue of the method of its construction.

All of the switches are rated for 6A at 125V, which is sufficient for the amperages within the jig. Since SW2 carries the most current when closed, I decided to double up the gangs just to ensure that it would withstand the full speaker currents involved in high-power frequency response testing.

Physical Design

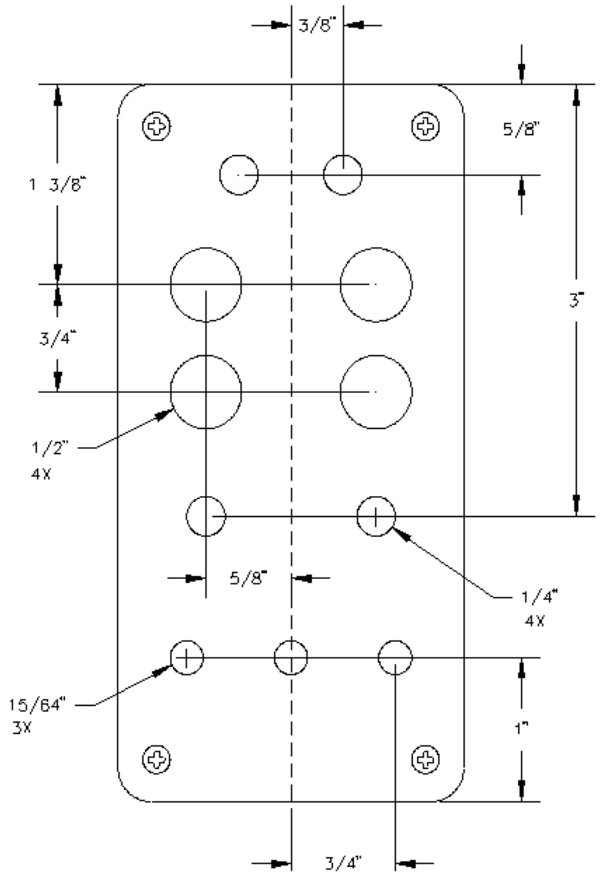


Figure 5. Suggested drilling guide.

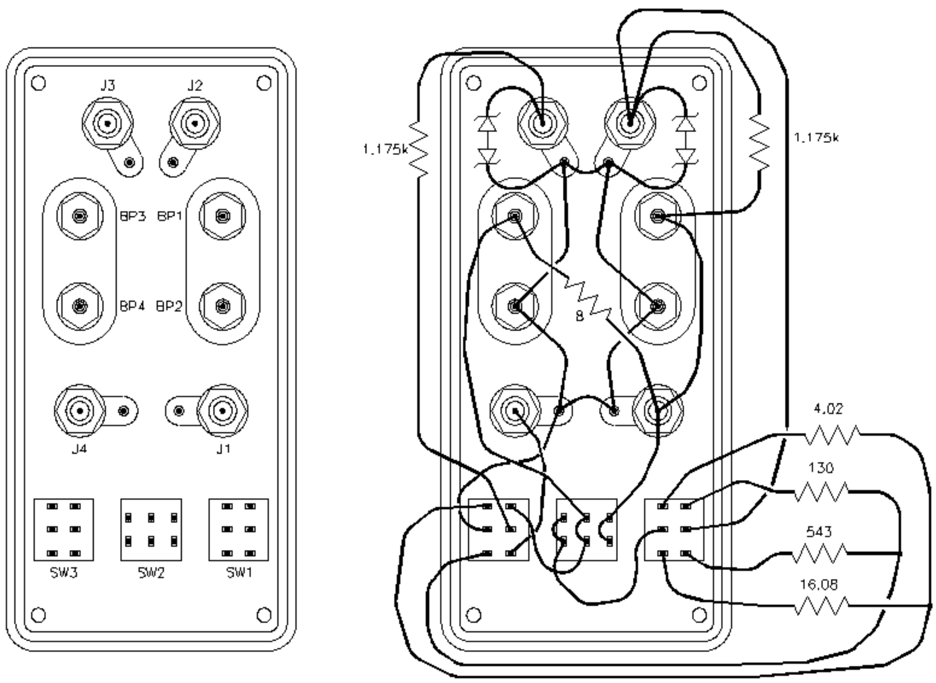
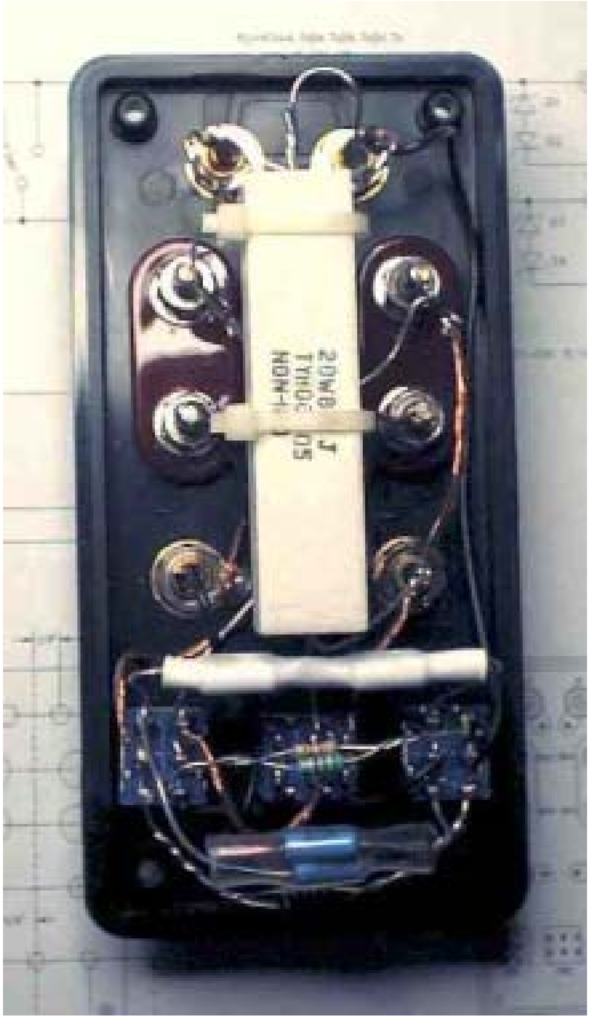


Figure 6. View of the rear of the switch panel, and suggested wiring guide.



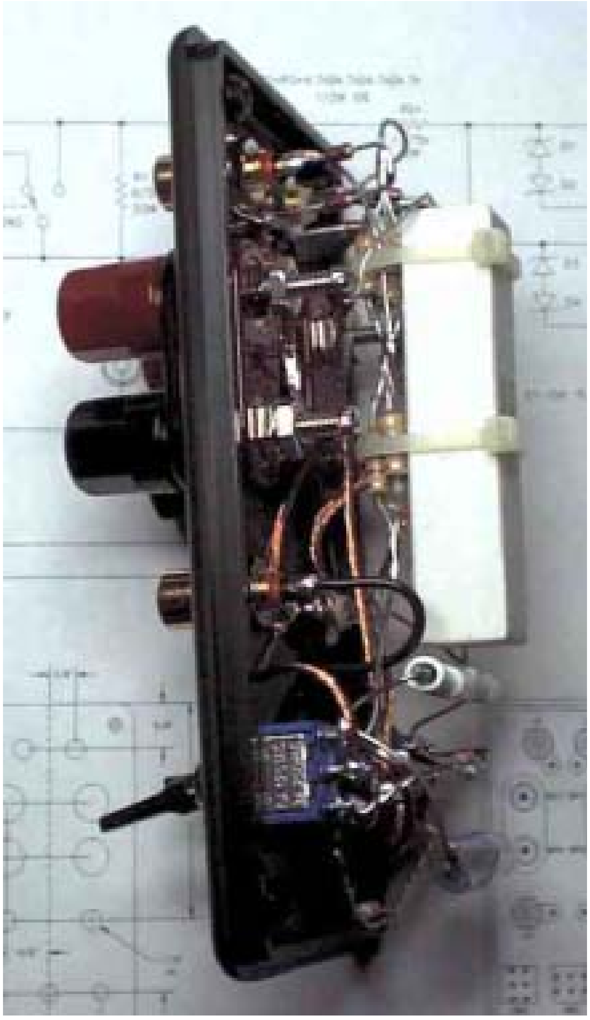


Figure 7 & 8. Photos of the wired jig. Note the cable ties securing R1 to R2 and R3. I used 4.02 ohm resistors to make R4 (blue resistors in clear heat-shrink tubing below the switches in Figure 7) and R5 (white heat shrink tubing above the switches in Figure 7) but 16.2 ohm resistors are probably easier to obtain. Try to stay away from wire-wound types here.

Construction Tips

- Mount all switches and jacks on the black cover supplied with the box - it is easier to drill and looks better to me than the aluminum cover.
- Use a sharp object like a drywall screw to make small indents at the locations of the holes before drilling. You only need hand pressure to do this in the soft plastic, and this will act as a guide for the drilling, keeping the bit from walking. To keep the plastic from cracking, start all holes with a small bit and work your way up with larger and larger bits until the holes are the appropriate size. I finished the largest holes for the binding posts using a countersink,
- working my way up slowly from each side until the plastic standoffs on the binding posts fit.
- The jacks used for J1 thru J4 come two to a package, with one white and one red. Use the white jacks for J1 and J2, and the red jacks for J3 and J4 (see figure 1 above). RED = RIGHT (I can safely say that now that the cold war is over).
- Bend the outer conductor solder tabs of J1 thru J4 up at ~45 degree angle after they are mounted to the back of the cover. This will help you run ground wires and attach components.
- For switches SW1 thru SW3, the hardware stackup is like this: switch body, nut, panel, star washer, nut. So the star washer goes on the outer side of the front panel. Don't use those funky keyed washers that may come supplied with the switch.
- "Tin" all solder lugs and wire ends before soldering them together.
- Clean the tip of your iron and add a tiny amount of fresh solder to it immediately before tinning or making a solder joint.
- Watch J1 thru J4: don't apply too much solder to the inner conductor tab or it may flow inside, making it impossible to insert RCA plugs. You pretty much have to throw out any jack that this happens to.
- Use heavier gage wire for the ground run, and also for runs going between BP1, J1, BP3, and SW2.
- Physically bind R1, R2, and R3 together using plastic cable ties. This mechanically "fixes" all three of these components, and makes them less immune to causing unintentional connectivity within the jig due to mechanical shocks and the like.

Jig Electrical Checkout

Check the wiring until you are certain that the jig is wired correctly. When you have your jig done, get an ohm meter and perform the following measurements (note that many multimeters will not read low ohms very accurately):

Electrical Tests				
SW1	SW2	SW3	Measure Between	Expected Reading
X	X	X	From barrel of J1 to barrels of J2, J3, and J4	Short (0 ohms)
X	X	X	From barrel of J1 to BP2 and BP4	Short
X	X	X	From BP1 to inner conductor of J1	Short
X	X	X	From BP1 to inner conductor of J2	1.175k +/-5%
X	X	U	From inner conductor of J4 to inner conductor of J3	1.175k +/-5%
X	X	U	From BP3 to inner conductor of J3	Open(infinite)
X	X	D	From BP3 to inner conductor of J3	1.175k +/-5%
X	X	D	From inner conductor of J4 to inner conductor of J3	Open
X	L	X	From BP1 to BP3	8 ohms +/-5%
X	R	X	From BP1 to BP3	Short
C	X	U	From the inner conductor of J2 to the barrel of J2	Open
U	X	U	From the inner conductor of J2 to the barrel of J2	543.2 ohms +/-5%
D	X	U	From the inner conductor of J2 to the barrel of J2	130.1 ohms
C	L	D	From BP3 to BP4	Open
U	L	D	From BP3 to BP4	16.2 ohms +/-1%
D	L	D	From BP3 to BP4	4.05 ohms +/-1%

U=up, D=down, C=center, L=left, R=right, X=don't care

Connecting The Jig to Your Computer

Connect a cable from the speaker output on your soundcard to J1. The wire corresponding to the left channel should be plugged into this jack, though either channel may do (use the right channel for the Ensoniq Soundscape - see my article on this card for the details of why this is so). The local Target store has a nice gold plated 1/8" stereo plug to dual RCA plug assembly for $4 that would work here, as well as for the soundcard input connection below. optionally, if you want to drive the test jig with an external power amplifier, you should run the line out from your soundcard to the line in to the amplifier, then run the speaker outputs from the amplifier to binding posts BP1 (+) and BP2 (-). Be careful to remove the soundcard connection at J1 when you do this, or you could fry the soundcard and possibly more stuff inside your computer!

Connect a cable from the line-in jack on your soundcard to J2 and J3: J2 left, J3 right. If you accidentally reverse these connections, or simply aren't sure which is which, you will find this out during the channel ID check, so don't worry too much about it now. Usually Red=Right and Black=Left for the cables I've run across in my travels.

I have an article on some slight modifications to an AudioPCI card from Ensoniq for use with the jig, and for making the I/O easier to access. If you want to go this route, you can use common phono cords for both the speaker out and the line in connections. I recommend you use the gold variety for good electrical connectivity.

Connect some test leads with pinchy clips on one end and banana plugs on the other to BP3 (+) and BP4 (-)

FAQ SECTION

> I am interested in starting to design my own speakers and I intend to
> start using Speaker Workshop to do it. I have seen the design for your
> impedence jig and I want to build that to help me.
>
> I have been looking for the necessary parts here in Brisbane Australia,
> and don't seem to be able to get the 16.2 ohm resistor. I can get 16.0 ohm,
> though. Will that be OK?
>
> I note in your text you say, "Anything around 16 ohms will do" so I
> hope that means it will be OK.
>
> However, you then go on to say "it's the precision that's important for
> calibrating the jig". What do you mean by this? Does this mean that I
> really need the 16.2 ohm resisitors? Or does it mean they all need to
> be the same resistance? Or doesn't it matter until it comes time to do the
> actual calibrating?
>
> I would really appreciate your help here.
>
> Also, it seems I can't get 6 amp switches. They seem to be about 10
> amps and are fairly large, compared to your photos. I think this will only
> mean that I will have to buy a larger box to fit them in, but that should be
> OK.

The 16 ohms should work fine. When I talk about precision, I mean the
accuracy of the actual resistance of the device compared to the nominal
resistance given by the markings on the device body. Whatever you use,
16.0 or 16.2, try to buy 1% types or better. This will keep you from having to
measure the calibration resistors - you can use their nominal value and
know that you are within the 1% tolerance, and so the calibration process in SW
should let you make impedance measurements of other components to somewhere
around this accuracy.

10A switches should work fine, the more amps the better!