Oakley Sound Systems

PSU2

PCB Issue 1

Project Builder's Guide

V1.4

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Introduction

This is the Project Builder's Guide for issue 1 of the power supply unit, PSU2, circuit board from Oakley Sound. This document hopefully contains everything you need to know to build and install the Oakley power supply unit.

The PSU2 allows for various options in the installation. You can use the unit either in full wave rectification mode for connection to tapped linelumps or twin transformer secondaries, or in half wave rectification for single phase AC output wallwarts and linelumps. If all this sounds very confusing at the moment, do not worry, in this manual I will try to make it clearer so that you make the right decision about what power source you will need.

It is designed to be mounted onto a metal panel which is used as a heatsink for the two power devices used on the board. Mounting your power supply to a metal panel on the outside of your case helps keep your modular cool.

For general information regarding where to get parts and suggested part numbers please see our useful Parts Guide at http://www.oakleysound.com/parts.pdf.

For general information on how to build our modules, including circuit board population, mounting front panel components and making up board interconnects please see our Construction Guide at http://www.oakleysound.com/construct.pdf.

Safety Warning

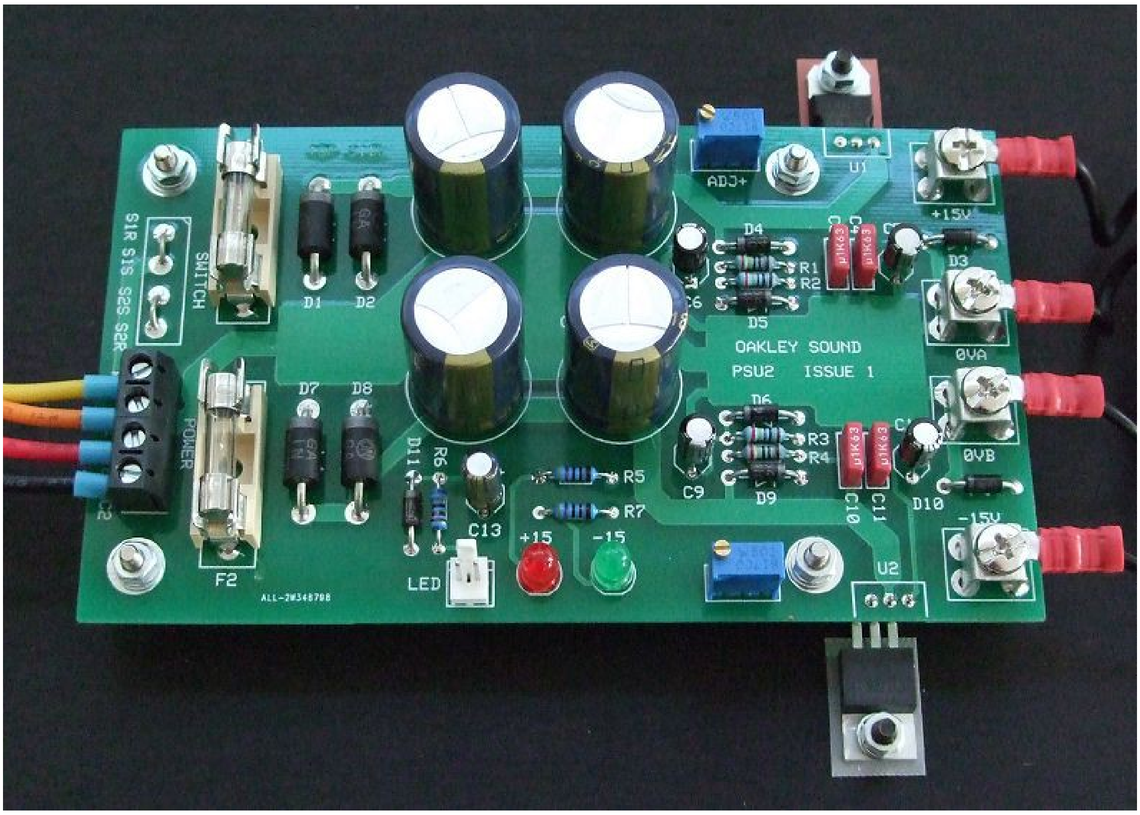
The PSU2 has been designed to work with isolated low voltage AC inputs. Connection to any other supply, such as an internally mounted mains transformer, is done at your own risk. Low voltage is classified as being less than 25V with respect to the ground potential. Voltages above this level can, and often are, lethal to living creatures.

Oakley Sound Systems will not advise on building or modifying this board to allow for direct connection to the mains, or other high voltage sources, further to what is provided in this document. Please do not ask me for any additional information pertaining to direct mains connections or using internally mounted transformers as I will not give it.

For safety and legal reasons I cannot recommend powering this board from any other supply than low voltage AC output mains adapters.

Oakley Sound Systems are not liable for any damages caused by the misuse of this product. It is your responsibility to use this product safely. If you have any doubt about installing a safe power supply, then please do not attempt to do so.

The Oakley Power Supply Board

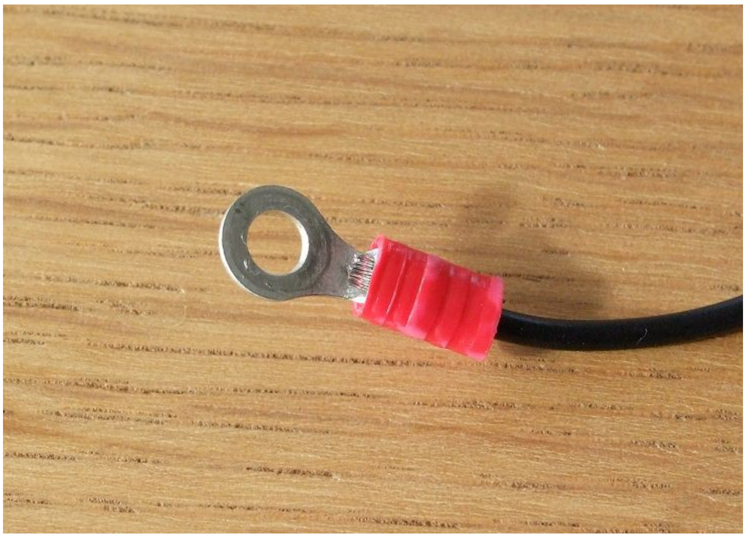


The issue 1 PSU2 board from Oakley Sound Systems.

The power supply board will allow the conversion of a suitable low voltage alternating current (AC) to be rectified, smoothed and regulated for operation with the Oakley Modular. The module is designed to be fitted to a suitably large metal panel which functions as a heatsink for the regulator ICs. This metal panel should have adequate airflow around it. The recommended method is to use a 4U or 5U high 19” rack blank panel. These are particularly suitable if you are mounting your modular synth in a 19” rack. The large surface area on a 19” blank panel allows you to mount not only the power supply module but also any Dizzy or MU-Dizzy PCBs used for power distribution. And the large surface area also allows the power supply's regulators to dissipate heat safely.

The voltage output of the power supply module is a split rail or bipolar 15V supply. This means it generates both +15V and -15V. That is, two power rails, one of a positive voltage, the other a negative one. It's sometimes written as +/-15V. These voltages are measured with respect to a common 0V (typically called 'ground') which is normally connected, via your house's wiring, to the earth that you stand on. The voltage across both rails is 30V, with the common ground sitting exactly in the middle of this at 0V. Both output voltages can be finely adjusted with their own trimmers.

The output current capability is the maximum current you can draw out of the power supply. The current taken from the supply is, for the most part, determined by the amount and type of modules you are connecting to the power supply. However, the actual patch also has an effect on the current draw – the more outputs that are connected to inputs increases the current draw slightly. It may also increase when any LEDs light up.



An M4 ring terminal crimped to 24/0.2 insulated wire. This sort of connector is suitable for connecting to the output terminals of the PSU2.

I recommend that you use a Yamaha PA-20 or PA-30 power supply. These are neat tidy external power supplies that keep the dangerous mains voltage away from your modular. The PA-20 will allow a maximum current of 520mA (0.52A) to be drawn from each rail. While the PA-30 will allow up to 780mA (0.78A). Both the PA-20 and PA-30 are centre tapped AC supplies with three wires within their output cable and use a three pole connector.

Other power supplies are available and they come in lots of different variations. Other than AC output voltage the two key specifications are output current (please don't call it 'ampage'), and whether the output is centre tapped or single phase. In almost all cases the outputs of standard AC output power supplies are single phase. You can tell because they only have a cable with two wires inside which terminates in a two pole connector.

A single phase AC output supply will allow only slightly more than a quarter of its rated current output. For example if you are using a 500mA (or 0.5A) AC wallwart* then the most current you can take from this power supply module is around 125mA from each rail. That is, take no more than 125mA from either the +15V supply and 125mA from the -15V supply.

Various companies make linelumps** with a greater capacity than 500mA. If you can get a single phase 1A output one than this will be able to drive up to 250mA per rail.

The Oakley PSU2 can be used with full wave or half wave rectification. The former allows it to utilise split AC outputs. With full rectification and using a centre tapped power supply the amount of current taken from each 15V rail can be up to just over half the rated current output of the power supply. The Yamaha PA-20 supply is rated to give an output voltage of 35Vac (with a centre tap) at a load of 0.94A. Once rectified and smoothed this means that a maximum current of 0.52A can be drawn from each rail.

Two sets of screw terminal blocks are provided for connecting the low voltage AC power source to the board and the optional power switch. If you are using a single phase wallwart to power the PSU module than you need only to use two terminals per terminal block.

The PSU2 board uses chunky individual screw terminals for the outputs. These allow good solid connections to suitable ring terminals which are crimped onto your connecting wires. Four output terminals are provided, +15V, 0VA, 0VB, and -15V. 0VA and 0VB are connected together on the PSU2 board. I recommend that the metal panel the PSU module is mounted onto be securely connected to 0V. This can be done either via the PSU2's 0VA or 0VB terminal, or using a suitable point on your distribution system.

The power supply has two integral fuse holders in case of a problem with the power supply circuitry itself. Two fuses are needed if you are using full wave rectification, but only one, F1, is required for ordinary half wave rectification. The fuse type should be a slow blow or anti-surge type. The size is 20mm. It should be rated at between one and two times the maximum current of your wallwart. Thus a 500mA AC output mains adapter should have a fuse that is rated between 500mA and 1A, ideally 750mA. A 1A linelump should have a fuse that is between 1A and 2A, ideally 1.25A.

Two on-board LEDs, a red or orange one for +15V, and a green one for -15V, provide a quick visual reference that all is well. These two LEDs could be fitted externally to the board and be mounted on a front panel. A third LED is supported, normally a red one, which lights when any AC power is applied to the unit. This would normally be mounted on the outside of the unit alongside the AC power switch and as such the PSU2 makes space for a 0.1" (2.54mm) two way header to connect to this LED.

The board has four mounting holes for stable placement onto your modular case. Care should be taken so that the board's various board mounted components do not come into contact with any part of your modular's enclosure. Use of 8mm hex spacers between the board's bottom surface and the panel is the preferred option.

The PSU2's output terminals must be connected to the modular's power distribution system with the shortest and thickest wires possible. I normally use 24/0.2 wire but the both the 1/4" Faston blades and the screw terminals will support larger wires with the correct crimps.

Multiple Dizzy and MU-Dizzy boards should never be connected in daisy chain fashion. That is, each Dizzy board should always go back to the PSU2 separately and with the shortest and thickest wire you can use.

* A wallwart is the vernacular term for a low voltage mains adapter that plugs directly into the wall. These take the form of a black plastic block that is shaped like an oversized mains plug. It is called a wart simply because its appearance is somewhat uglier than a normal slimline plug.

** A linelump does the same job as a wallwart but it generally can handle greater currents. Because of its increased size it cannot be made so that it will safely fit into a plug socket directly. Thus the adapter sits in a black plastic box and connects to the wall via a cable and traditional mains plug. It is therefore a black plastic lump connected to a line. The Yamaha PA-20 and PA-30 are such linelumps.

Our Recommended Power Supply

The safest available option is to use a ready made 'wallwart' or ‘line lump’ supply. As already mentioned one can use any 15V or 18V AC output wallwart of linelump you can source. The current capability of the mains adapter will be the chief limiting factor in determining the maximum current draw of your PSU. For a variety of reasons I recommend the Yamaha PA-20 and PA-30 supplies.

Yamaha PA-20

The European version of the PA-20. Other country's units are similar but will have the local mains connector fitted.

This is a linelump supply and features a fixed 17.5-0-17.5 volt AC output at 0.94A maximum. This means it gives us two AC outputs with a centre tap or mid point reference voltage. So unlike the single phase AC adapter output with two leads, this one has three. This means you need to use the Oakley PSU in full wave rectification mode.

The PA-20 is made for Yamaha products and they are available from Yamaha spares departments as well as many music shops, eg. Thomann. These are CE approved and connect to the mains via your local mains connector. They will be different types depending on the country you need them for. It comes with a handy three way plug at the low voltage end that you can use with an appropriate socket. If you wish you can ditch their connector and use your own. Oakley Sound sell a suitable three way connector to fit the Yamaha one perfectly.

In the UK the line lump’s part number is V9812300 and the total cost is around £30 including VAT and postage.

Once rectified, smoothed and regulated the Yamaha PA-20 can deliver up to 0.52A continuously into both 15V rails.

You should fit both fuses and both should be anti-surge types and rated at either 1A or 1.25A.

Yamaha PA-30

This is essentially a bigger version of the PA-20 as detailed above which supplies 18V-0-18V at 1.4A maximum. Once rectified, smoothed and regulated it can supply up to 0.78A continuously. You should again fit both fuses and both should be 2A anti-surge types.

If you have successfully used the Oakley PSU with any other types of power pack please do let people know via the Oakley Sound forum at www.muffwiggler.com

Parts List

For general information regarding where to get parts and suggested part numbers please see our useful Parts Guide at the project webpage or http://www.oakleysound.com/parts.pdf.

The components are grouped into values, the order of the component names is of no particular consequence.

A quick note on European part descriptions:

For resistors: R is shorthand for ohm. K is shorthand for kilo-ohm. M is shorthand for mega-ohm

For capacitors: 1uF = 1,000nF = 1,000,000pF. Sometimes the F is not included on the circuit diagram to indicate a capacitor's value, ie. 100n = 100nF.

To prevent loss of the small '.'as the decimal point, a convention of inserting the unit in its place is used. eg. 4R7 is a 4.7 ohm, 4K7 is a 4700 ohm resistor, 4n7 is a 4.7 nF capacitor.

Resistors

1% 0.25W metal film are recommended

240R	R2, R3
2K4	R1, R4
4K7	R5, R7
6K8	R6

Capacitors

100nF, 63V polyester film	C3, C4, C10, C11
10uF, 35V electrolytic	C5, C6, C9, C12
22uF, 35V electrolytic	C13
1800uF, 35V or 50V electrolytic	C1, C2, C7, C8

Note: C1, C2, C7, and C8 should be 105 degree Celsius radial types and have standard wire ended leads. The lead spacing is 7.5mm. For example, Panasonic type EEUFC1V182 or EPCOS B41888-C6188-M, but any decent 105 degree part that will fit on the board will do. 50V parts will have a longer lifetime than 35V parts but will be physically slightly larger.

Integrated Circuits

LM317T 1A variable regulator	U1
LM337T 1A variable regulator	U2

Ensure that both devices are TO-220 types and not any surface mounting or TO-3 packages. I much prefer the devices that are made by National Semiconductor. They are available from other manufacturers but National's devices have a thicker and more rigid heatsink tab.

Do not fit solder these into the board just yet. They are only to be soldered once the board is fitted to the panel. See the section on mounting the PSU2 board later in this document.

Discrete Semiconductors

1N4004 rectifier diode	D4, D5, D6, D9, D11
1N5819 Schottky diode	D3, D10
1N5401 rectifier diode	D1, D2, D7, D8

For 1N4004 you can use any other 1N400X part such as 1N4001, 1N4002, etc.

D2 and D8 do not need to be fitted if you are using a single phase wall wart or line lump.

5mm green LED	-15V
5mm red or orange LED	+15V

LED cathodes are denoted by the square pad on the PCB. LEDs will not light up if fitted the wrong way.

The component marked as LED is the optional front panel power on or standby indicator. This LED connected to the board via wires and is not fitted to the board.

5mm red LED	LED

Trimmer

500R multiturn (eg. Bourns 3296W)	ADJ+, ADJ-

Miscellaneous

20mm fuseholder PC mount	F1, F2	
Antisurge 20mm fuse	F1, F2	For current rating see page 5
4-way screw terminal 5mm	POWER, SWITCH	
TO-220 insulator pad.	U1, U2	

Suitable power switch

Suitable power inlet socket

Keystone 8191 PCB terminal & screw	+15V, 0VA, 0VB, -15V
4mm 'banana' socket	Optional – fitted on panel. *
4mm ring terminals (crimp/solder)	For connection to outputs
2-way 0.1” Molex KK header	LED (optional)

You will also need thick wire to connect between the power inlet, switch and any connected distribution boards. I recommend 24/0.2 (0.75 sq. mm) insulated wire.

If the standby LED is to be fitted then you will also need standard hook up wire – I use 7/0.2 for all my low current connections. The thicker 24/0.2 wire would be too thick for this.

For internal mains transformer (or any installation not requiring a standby switch) then you do not need to fit the screw terminal SWITCH.

F2 and its associating fuse does not need to be fitted if you are using a single phase wallwart or linelump.

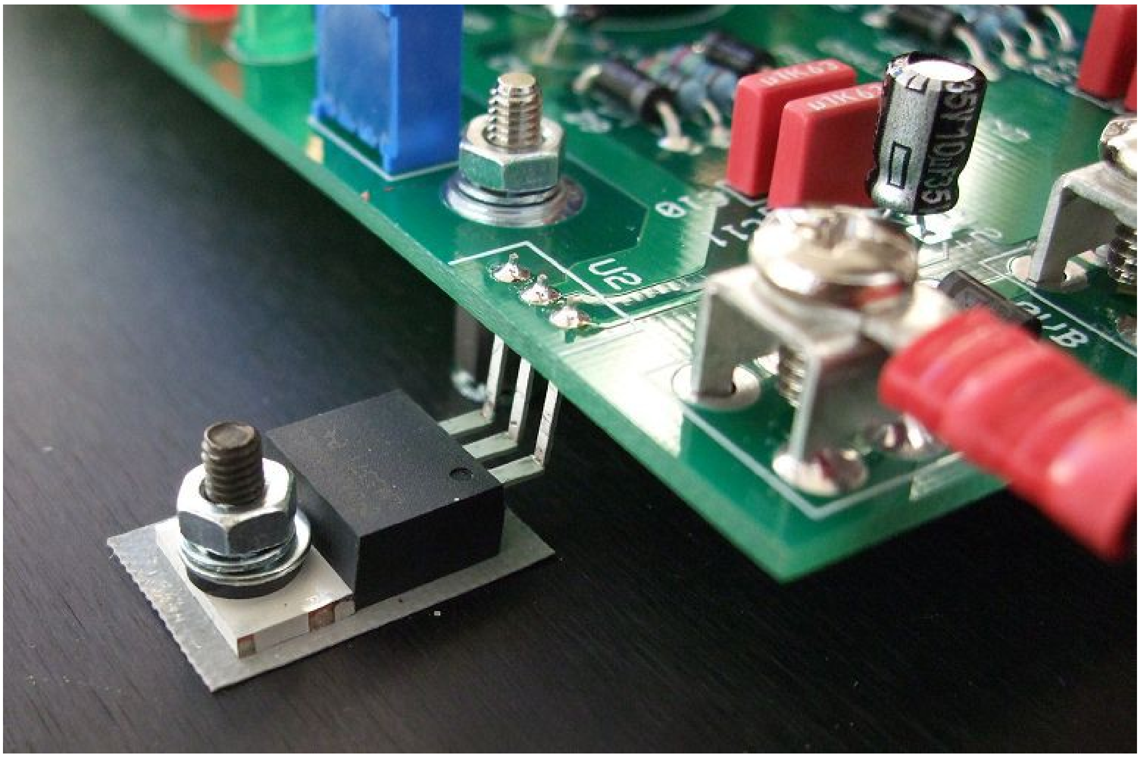
* See sections on 'Fitting a Grounding Point' and 'Using an Internal Mains Transformer'.

Mounting hardware

M3 6mm pan head screws	4 off	For PCB
M3 20mm pan head screws	2 off	For power devices
M3 hex threaded male-female 8 mm spacers	4 off	For PCB
M3 shakeproof washers	10 off	For PCB and power devices
M3 plain washers	6 off	For PCB and power devices
M3 hex nuts	6 off	For PCB and power devices
M4 16mm pan head screw	1 off	For 0V/Earth bond point
M4 washer	2 off	For 0V/Earth bond point
M4 star washer	2 off	For 0V/Earth bond point

And any mounting hardware for the Dizzy boards if needed.

Mounting the PSU2 Board to the Panel



The LM337, U2, fitted into a 5U 19" rack panel. Note the grey TO-220 insulator pad underneath the regulator IC.

The PSU2 PCB needs to be fitted to your chosen panel. Use the PCB as a template for marking the panel and then drilling the four 3.5mm holes needed for the mounting pillars. The board should be spaced high enough off the panel with suitable mounting pillars so as to not short out any of the components' leads should the board be flexed downward, and also not be too high so that the leads from the regulators can't reach through the board to be soldered. I find an 8mm spacer is best.

For the four PCB mounting holes, insert a 6mm screw through each of the four holes in the panel. Fit a star washer over the exposed thread on the inside of the panel. Now fit a hex male-female 8mm spacer over the washer and tighten. Check that the four holes in the PCB line up with the threaded tops of the hex spacers by temporarily fitting the PCB onto the spacers. Loosen and re-align any spacer if it does not fit properly.

Now you need to prepare the leads of the two regulator ICs. The three legs need to be bent upwards so that the PCB can be fitted over them. Note that the top surface of the device is marked with the name of the component and it is the flat side on the bottom of the device that will be in contact with the panel. You should be able to see that the leads have a thicker section close to the body of the device. Make a ninety degree bend upwards at the point where the lead thickness changes. Do this for all three legs of the device.

Remove the board from the panel and fit the regulators to the board by poking their legs up through the bottom of the board. Do not solder them and fit the board back into place on the panel. Use the hole in each regulator's metal tab to mark out where you need to drill the mounting hole for the two devices. Now remove the board and regulators. Carefully drill a 3.8 or 4mm hole in the panel for each of the regulators. Clear off any swarf and, twisting with your hand only, use an 8mm drill bit to lightly deburr the edges of the holes on both sides. There should be no bumps around the holes.

The linear regulators are TO-220 power devices. They need to be fitted to the panel mechanically and thermally, but not electrically. This means that the metal tab on each device should not be in direct 'metal to metal' contact with the panel. To achieve both thermal transfer and electrical insulation we use a special insulator. These can be made of a 'soft' flexible material in the form of an insulating pad, or a rigid thin glass like plate made from mica. If using mica you will also need to use a small amount of heat transfer paste that needs to be spread very thinly across each side of the mica.

Since the paste is somewhat messy I recommend you use the insulating pads. However, mica and paste does offer better performance in terms of keeping the power device cool so if you are planning to draw over an amp from your power supply it may be better to use mica and paste. Mica also has the advantage of being reusable should the devices need to be taken off the heatsink in the future. The flexible pads are probably OK being reused but they do get a little deformed when the nuts are tightened so it is probably a good idea to replace them each time the devices are removed from the heatsink.

Both types of insulation are normally available in 'mounting kits'. The kit also contains a mounting bush. This top hat shaped piece of stiff plastic prevents the mounting screw from touching the regulator's metal tab.

To fit the device to the panel first place the mounting bush into the hole of the power device, with the flange of the bush lying on the top side of the device. Normally, but not always, the plastic bush fits tightly enough so that it tends to stay in place after it has been pushed through the metal tab. Now take one of the insulating pads and place it against the rear of the regulator. Match up the hole in the pad with the bush that is sticking out from the underside of the tab. If you have used a flexible pad you may find that it will happily stay put held in place by the mounting bush.

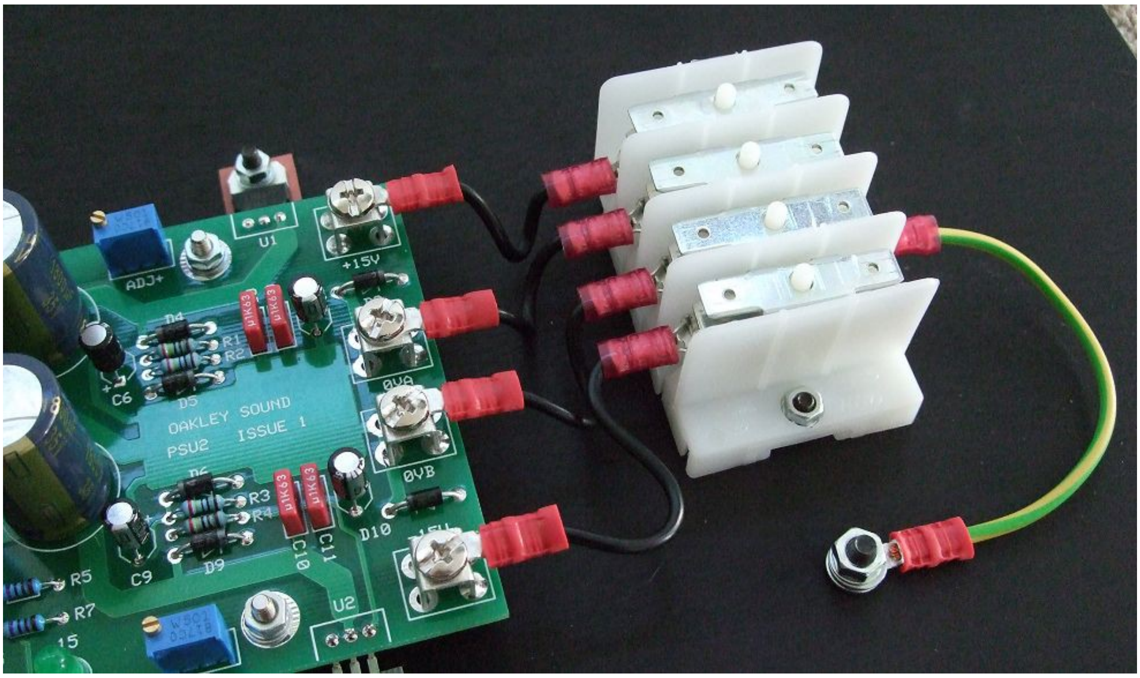
Now place the power device, bush and pad flat against the rear of the panel so that the bush fits into the panel. Make sure the pad does not slip out of place when you do this. Insert a 10mm or 12mm M3 screw into the hole from the reverse side of the panel, and fit a flat washer, a shakeproof washer and nut onto the screw but don't tighten it up just yet. Do the same for the other regulator making sure, of course, that each one is in the correct hole.

Now if you have done all this correctly, you should find that the when the power supply PCB is presented back onto the four threaded spacers, you can coax the power devices’ legs through the respective solder pads on the board. Because the power devices have not been fully tightened you will still be able to move them about a bit on the panel to ensure a good fit. Make sure also that the insulating pads are sitting square under the devices and haven't slipped out of position.

Fit the washers and nuts onto the four PCB mounting screws. Tighten to secure the board in place. Do not over tighten the nuts as this will damage the board. Now gently tighten the nuts on the power devices. Do not tighten these too much as this will distort the mounting tab and squash, or even tear, the insulating pad. All the nuts need to do is hold the power devices up against the panel.

With both the board and power devices secured to the panel with their mounting hardware you can now solder the regulators' leads from the top side of the board. Snip off any excess lead lengths above the solder joints.

Assuming you haven't wired up the PSU2 board to any earth bond or distribution system yet, it is worth checking the insulation under the two regulators is working correctly. Check with your continuity tester, or using the resistance setting on your multimeter, that there is a very high resistance between the tab of each regulator and the metal panel. That is, there should be no continuity between the tab and the screw that runs through it.



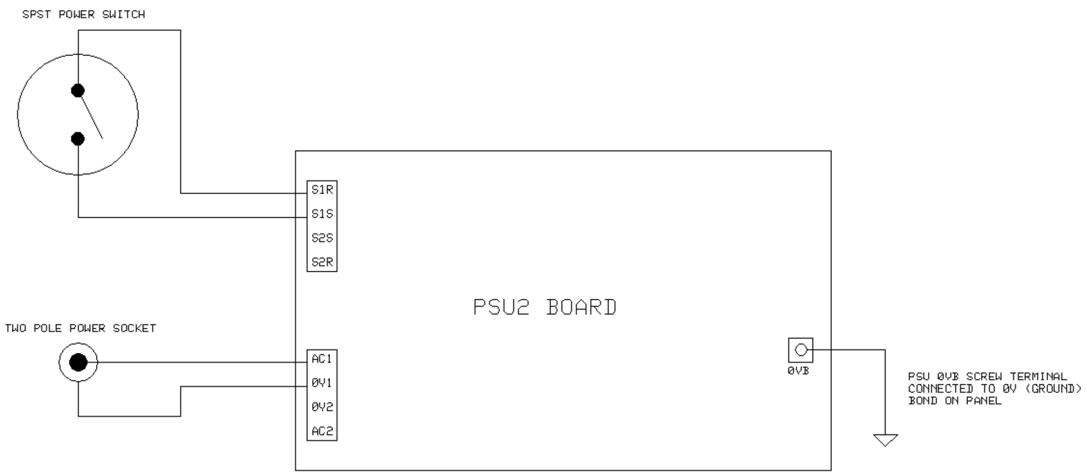
Power distribution comes in many shapes and forms. The Oakley Dizzy and MU-Dizzy modules make it easy to distribute power to multiple modules, however, if you have just a few modules then one of these Faston blocks can be used for a cheap but very good solution. This particular set up allows just four modules, actually in this case it's two Oakley ASVs, to be connected via 1/4" blade terminals.

Linelumps and Wallwarts: Wiring Diagrams

Input wiring will depend on the type of wallwart or linelump you will be using.

Standard AC output wallwart

Single phase, two wire, wallwarts or linelumps need to use half wave rectification so the Oakley PSU can generate both positive and negative supplies simultaneously. They only need the terminal's AC1 and 0V1 wired to the power socket. AC2 and 0V2 are left unused.



Wallwart with single phase AC output.

The front panel switch is a single pole single throw (SPST) switch which simply connects S1R and S1S together when switched on. You can replace the switch with a simple wire link, but I do recommend that a switch be fitted so the socket doesn't have to take the full surge current when you insert it with the wallwart powered up.

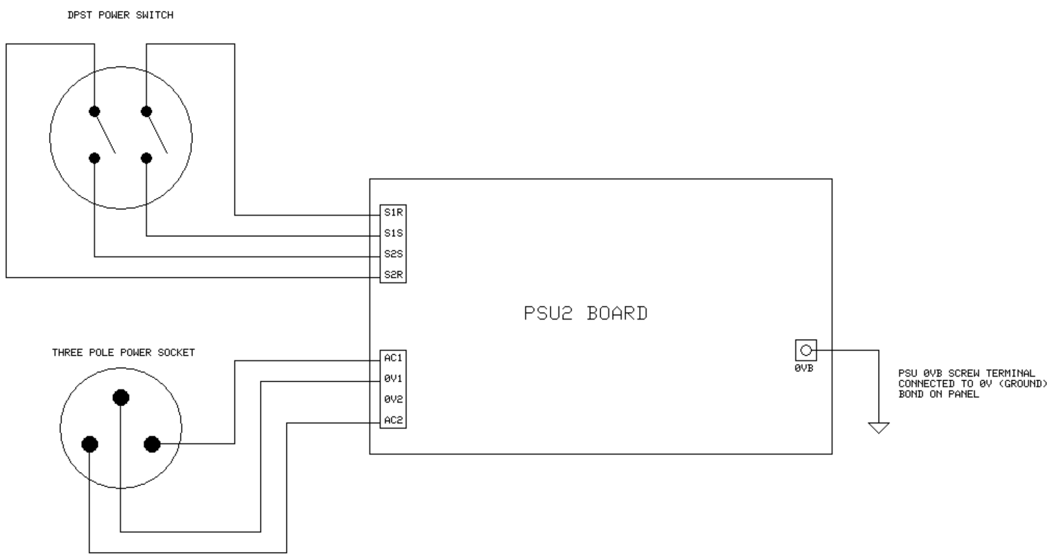
I also recommend fitting the AC indicator LED too. This is so you know the wallwart or linelump is on. The AC indicator is designed to indicate the status of incoming power and is not determined by the position of the standby switch.

The standby switch should not be used to turn the unit off for any long length of time. This should be done by either switching the adapter off at the mains socket, or by pulling the adapter's plug out of the mains socket.

An optional 0V or grounding connection can be made via the 0VB terminal. See later for more details.

Recommended Option: Centre tapped wallwarts and linelumps

Centre tapped linelumps like the Yamaha PA-20 will have three wires coming from their connector. It will have two AC outputs and one 0V. Take one of the AC outputs to terminal AC1 and the other AC output to terminal AC2. It should not matter which AC output goes to AC1 or AC2. The 0V should go to the 0V1 terminal. The 0V2 terminal is left unused.



Linelump wiring with centre tapped output, eg. Yamaha PA-20

The front panel switch is a double pole single throw (DPST) switch which connects S2R and S2S together, and S1R and S1S together, when switched on. You can replace the switch with two wire links, but I do recommend that a switch be fitted so the socket doesn't have to take the full surge current when you insert it if the linelump is powered up.

I also recommend fitting the AC indicator LED too. This is so you know the linelump is on. The AC indicator is designed to indicate the status of incoming power and is not determined by the position of the standby switch.

The standby switch should not be used to turn the unit off for any long length of time. This should be done by either switching the adapter off at the mains socket, or by pulling the adapter's plug out of the mains socket.

An optional 0V or grounding connection can be made via the 0VB terminal. See later for more details.

Fitting a Grounding Point and Grounding the Panel

Using double insulated wallwarts and linelumps mean that you do not have to have a mains safety earth fitted to your modular. However, if your modular is to talk to the rest of the studio you need to make sure that the modular's 0V is tied to earth somewhere in your system. The most usual way of doing this is via the connecting cable's shield or screen connection. Your mixing desk or monitoring equipment will be earthed and simply connecting a cable to any module within your modular will tie the modular's 0V to the other equipment's earth. This seems pretty straightforward and it is so long as you have a small system and only have one or two interconnecting cables in use.

However, a larger more complex system will have perhaps more than one modular, more than one mixing desk and perhaps a heap of other outboard equipment. This is when it makes sense to look at grounding your modular cases together.

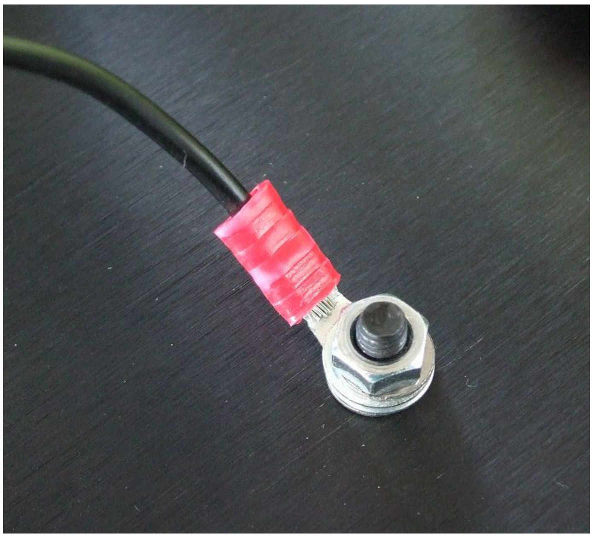
The additional 4mm socket to the right of the power inlet provides a way of connecting the 0V lines between cases

Let us consider a more simpler scenario for the moment. Say we have built ourselves two modular cases and we would like to connect the modules in them together to form an awesome monster patch. Each case has its own PSU and each one is powered by a Yamaha PA-20. It is useful in this situation to ensure that both PSUs are grounded together. In other words, the two 0V lines from each power supply are electrically connected together. Although this will be done the moment that one patch lead goes from one case to the other it is beneficial to do this with a dedicated thick bonding wire. The thicker the wire the lower the resistance which reduces any unwanted voltage drops as return currents travel through the wiring.

This can be done in a variety of ways but one useful and simple method involves having a 4mm banana socket mounted near each power supply. The banana socket is then connected to 0V, using either the 0VA or 0VB screw terminal on the PSU2 board. Use at least 24/0.2 wire to make this connection.

If both the power supplies have a banana socket then it is a simple matter of patching the two modular cases together with a banana patch lead. The great thing about bananas is that they are stackable so it's easy even if you have more than two cases to connect up.

I recommend that you use thick multistrand cable to make your grounding leads and that you use good quality 4mm banana sockets and plugs like the type sold for speaker connections and not those used for cheap test equipment.



A single M4 crimped ring terminal secured to a panel bonding point. A solder tag with a 4mm hole could also be used but for thicker wires, like this 24/0.2 wire, crimping offers better performance and is simpler.

To reduce electrical noise it is wise to ground the panel on which the power supply is mounted. To make a 0V bonding point is straightforward. Simply drill a 4mm hole in your panel. Scrape back around the hole any finish on the inside surface, such as paint or anodising, to reveal the shiny metal underneath. Fit an M4 screw from the front and pop on a toothed shakeproof washer and flat washer on the rear. Fit your ring terminal (or terminals) onto the screw, place another flat washer and shakeproof washer on top of that. Secure tightly with an M4 nut. This should ensure that the panel is robustly connected to 0V.

A 4mm banana socket is taken to panel bond point which then is connected to the PSU2's 0VB terminal.

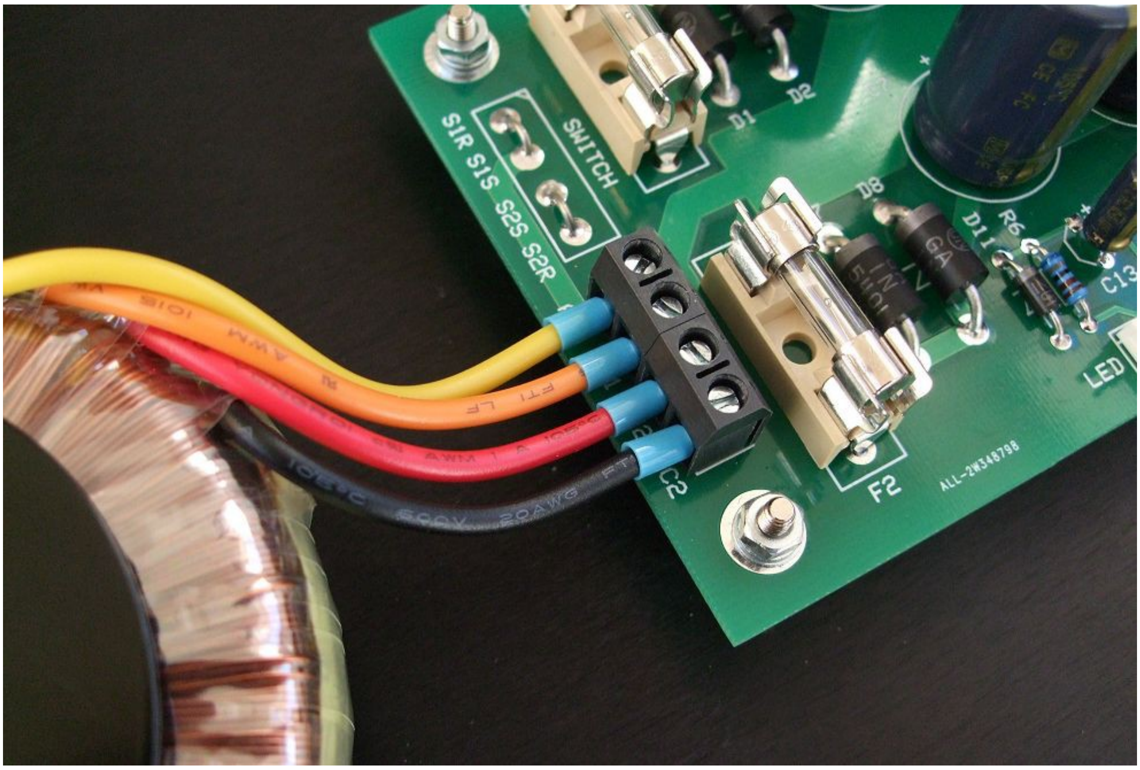
Personal Note...

One has to a little careful when using the word 'ground'. I sometimes talk about local ground and 0V as being the same thing. This is technically incorrect but it is used a lot. I worked at Marconi in the 80s and Soundcraft in the early 90s, and ground and 0V were used interchangeably even by seasoned engineers. We'd talk about chassis ground, dirty ground, signal ground and clean ground. They'd all be connected to 0V somewhere in the system but the term ground was in common usage.

Ground, when used in this way, is then a local common reference connection tied to the 0V of the unit's power supply. It is not the same as mains earth. Indeed, it may not even be tied to mains earth in the unit in question.

Strictly speaking, electrical ground is mains earth and historically it was solely referred to as that, but usage, incorrect or not, has meant a shift in the meaning. Ideally, we should call our common reference connection within our unit as 0V and not use the term ground.

Using an Internal Mains transformer



A 50VA toroidal transformer powering an Oakley PSU2 designed to deliver up to 750mA per rail. Note the wire loops fitted to the pads where normally the terminal block for the standby switch goes.

Be afraid, be very afraid...

Some of you old hands will laugh about the level of hysteria that surrounds direct mains connection to DIY projects. However, this fear is more to do with our litigious society than the real danger to the builder. Even so, I have had more than my fair share of high voltage shocks over the years and it is not something I would want any builder to have to experience. It has been purely luck that has saved me in several of those cases.

So I will say again – do not attempt to build a mains transformer into your modular case, or any other project, without realising that to do so carries a risk of death to either you, or to the person who may inadvertently put their fingers into your half built construction. Furthermore, it is up to you as the builder of such an item to make sure, that once built, the item is safe to use and meets all current safety legislation.

This is not a complete set of instructions on how to fit a transformer into a piece of electronic equipment. This information is offered only as a guide and should not be considered as your only source of information. No further information, other than that included here, will be provided by me regarding the construction of mains powered items.

The mains transformer's secondaries should be rated:

18-0, 18-0 (twin secondaries), or 18-0-18 (centre tapped), at 80VA

This will give you a power supply that should be theoretically capable of just over 1A each rail assuming your heatsink and smoothing capacitors are up to the job.

Mounting your PSU2 on a 4U or 5U 19" panel as detailed earlier will be more than adequate for a 1A supply. However, it is up to you to verify that your chosen panel is up to the job of keeping the two power devices cool. Remember that air flow to the panel is essential so make sure any tests you make are representative of the situation your heatsink will eventually be fitted to.

The transformer secondary voltage is suggested to be 18V and it is not wise to use any more than this as this will require more heat to be dissipated, and stress the smoothing capacitors and regulators. You may be able to use a 15V transformer. I have found that here in the UK 15V transformers work very well in this application as we typically have a 240V mains supply compared to the rated transformer input of 230V which gives a little higher output voltage than the specified 15V.

Remember that the maximum output current rating of the transformer is true only for a simple resistive load on the secondary. That is, the manufacturer has specified their device when taking a sine wave current from the transformer. This is not the case for most real life power supplies as the AC output of the transformer has to be rectified, smoothed and then regulated. Therefore the current drawn from a transformer secondary when connected to a standard linear power supply is about as far from a pure sine wave as you can get. It is a complex task to calculate the exact secondary current so a quick rule of thumb is often used to calculate the approximate secondary current with any given load on the output of the PSU. I have found that this rule of thumb is surprisingly robust given the amount of variables that actually affect the current.

Iac = 1.8 x Idc

Iac is the RMS current flowing through the secondary winding and ***Idc*** is the load current attached to the power supply. So drawing 1A from each your 15V rails will require 1.8A(RMS) of secondary current. And if you want to give yourself some leeway, so as to keep the transformer cooler, then you can use a factor of 2 instead of 1.8.

As an example of the equation's usage I will use an 18 – 0, 18 – 0, 80VA transformer.

Total AC root mean square (RMS) voltage across both secondaries is 18 + 18 = 36V

The power rating is 80VA and so the maximum RMS current drawn can be 80/36 = 2.22A

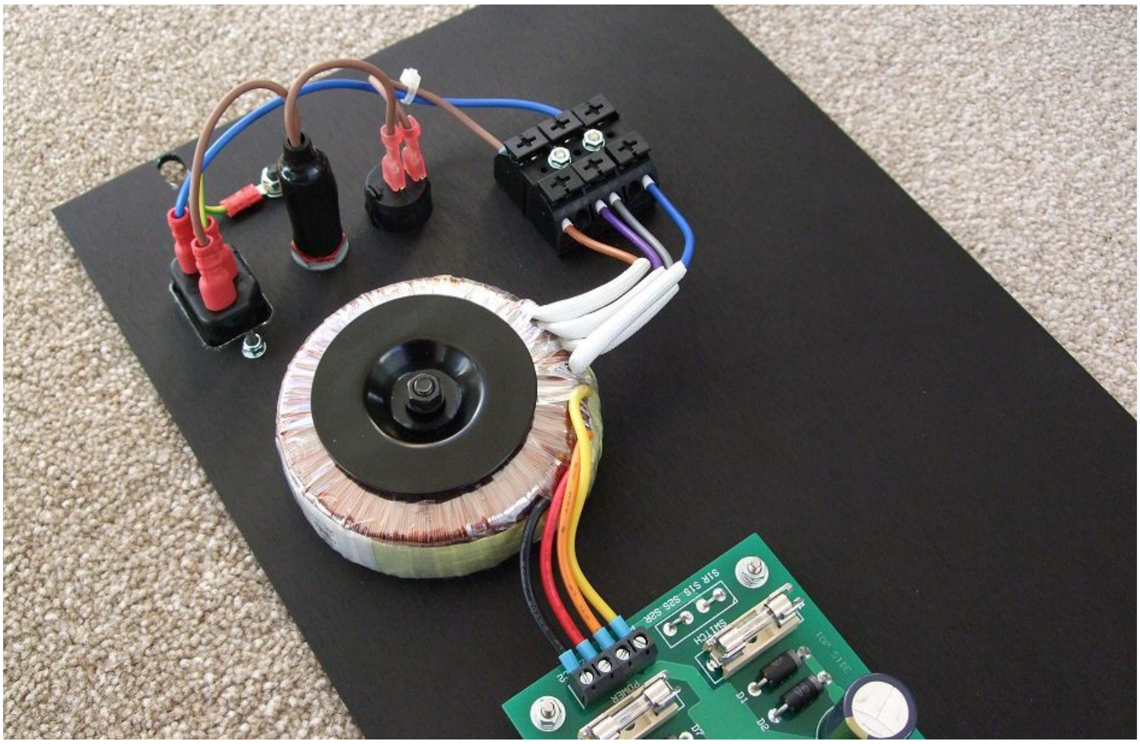
The maximum DC load is therefore approximately 2.22/1.8 = 1.22A

Because we have considered both secondaries together this means that we can take 1.22A from the +15V **and** 1.22A from the -15V. This, however, will heat the transformer up by the amount specified by the manufacturer. And the temperature rise under maximum load is surprisingly large, normally 55C, which is probably not what we want in our modular case. So restricting the current to below 90% of maximum will keep the transformer somewhat cooler. Hence the factor of two mentioned above is probably more realistic. Using a factor of two the maximum current drawn from our 80VA transformer is now 1.11A from both rails.

In the wiring diagram shown I have included a suggested wiring method for connecting up a mains transformer. Not all mains transformers are the same, some have additional windings, others have tapped windings. I have simply used a single primary, double secondary type for example only.

For the mains fuse you should use a 500mA anti-surge type. All wiring at mains potential should be adequately insulated and protected from straying fingers.

There is no need to fit an AC standby switch since you will be fitting a proper mains power on switch in series with the transformer primary coil. So you should link S1S to S1R, and S2S to S2R, on the PCB.



Here I have used a SPST switch for mains switch, a standard IEC socket and a separate 20mm fuseholder. This transformer has two 115V primary windings which for a 240V input need to be wired in series. The three pole Wago block to the top right provides a safe way of connecting the primary windings in the right fashion. Note the rubber boot around the fuseholder and shrouded Faston crimps on the wiring to protect straying fingers from high voltages

Earthing

Remember it is up to you, the builder of the equipment, to make sure that your item is safe and is built to the required safety standard in your country. These notes are only a guidance and it is up to the reader to establish the exact obligations required in their own country.

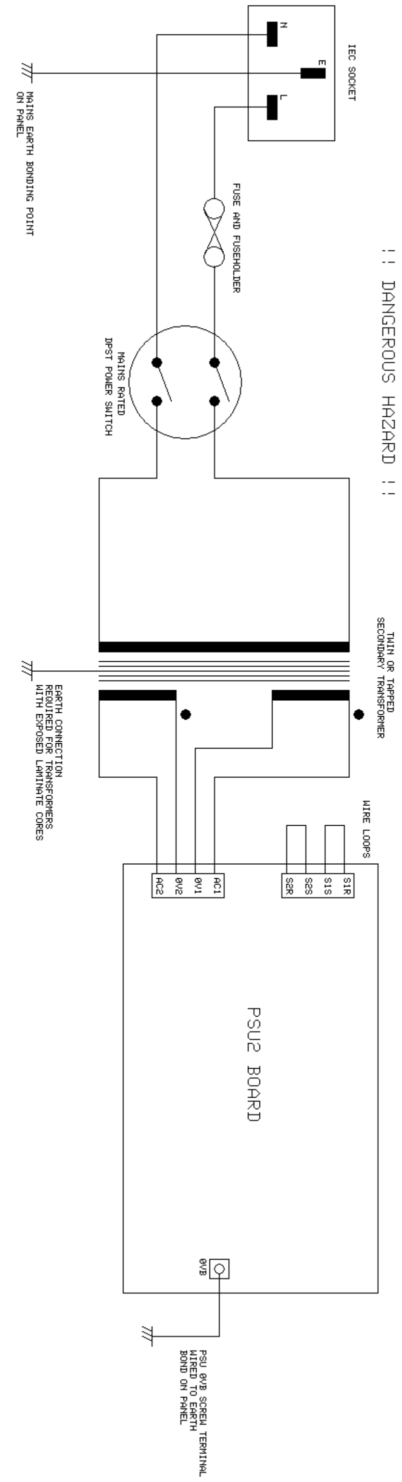
It is essential that everything you build, that has both live mains inside and a metal case or panels, has a safety earth fitted. UK legislation says that any metal panelling should be adequately insulated, ie. double insulated, or connected to earth. Since making a double insulated case is not practical you should ensure that any exposed metal parts be properly earthed.

Firstly you need to ensure that the heatsink panel is earthed. Given its size and required air flow this will certainly be an exposed piece of metal and thus should be earthed well. It should be bonded to earth via a short thick piece of wire back to the earth tang of the IEC mains inlet socket.

An earth bonding point using an M4 screw, two washers, two toothed washers and nut. The earth wire uses a crimped 4mm ring terminal.

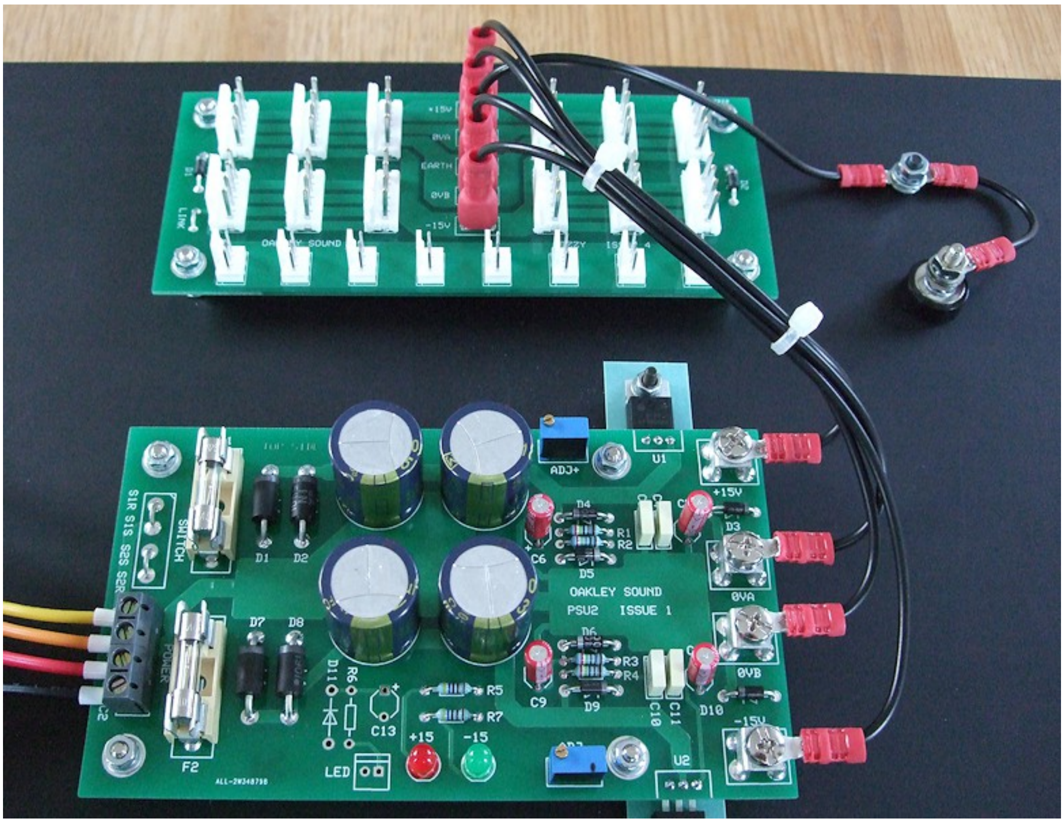
The PSU board should be securely mounted (using all four mounting holes) onto the earthed heatsink using appropriate screws and star or spring washers. Connect the 0VB screw terminal, either directly or via the distribution system, either back to the panel's earth bonding point using at least 24/0.2 wire, or by making a second bonding point on the panel. For the latter, you have one bonding point solely for the mains earth which can be located near the mains IEC inlet socket, and another, located next to the PSU2 board, for the PSU's 0VB and optional 4mm banana socket connections. The metal panel serves as a low resistance connection between the two bonding points – although you must ensure that any paint or anodising is scraped off around the bonding hardware. By using two bonding points in this way keeps the 0V wiring as short as possible and reduces the risk of the grounding wires coupling with the transformer and introducing mains hum on the local 0V. You will also need to provide earthing to any exposed transformer core. This does not apply to toroidal types but EI types should have their metal frame earthed.

None of this, however, may be sufficient for a solid safety earth bond as required by your local regulations. Ideally all modular panels should be earthed directly, either with their own direct connection to the earth bond near the power inlet, or via the modular's earthed metal mounting rails and suitable toothed washer and screw. This isn't always practical though so is not often done.



Mains wiring diagram. For experienced builders only!

The Oakley Power Bus



An Oakley PSU2 module connected to a single Dizzy board. Note that in this build the local 0V bond to the panel and 4mm socket is made via the Dizzy's 'Earth' connection and not directly from the PSU2's 0VB terminal.

In an ideal world I wanted the Oakley power bus to be based on a five way 0.156" MTA or Molex connector. This would contain +15V, -15V and three 0V or grounds. One ground would be the safety ground; this would be connected to the power supply's 0V, the modules' front panels and to the mains earth. The second would be a clean ground for all the analogue modules to take their supply reference, the true zero volt line, ie. 0V. The third would be a dirty ground. This would be the ground reference for things like the noisy digital circuitry and LED switching. All three would be connected together but only at the power supply. However, this system would be incompatible with the popular MOTM modular system which only has a four way connector for its analogue modules. So the question now remained, how could I make my system work with MOTM, yet still retain some of the features I needed.

The chosen Oakley power bus comprises of +15V and -15V lines with two separate 0V connections. These 0V are not connected together in each module as they are in MOTM modules. They are joined only at the power supply in a wholly Oakley Modular.

In an Oakley modular one of the grounds, pin 2, is solely used for the electronics in the module. I call this module ground or module 0V, it's the reference point for all the circuitry used in a module. Unfortunately, it is also the dumping point for some hefty current but I try to reduce this to a minimum by certain design choices in the modules.

The second ground is on pin 3. This is also connected to the power supply's 0V output. This ground is connected only to the metal lugs of the sockets on each module, and therefore the panel itself, and nothing else on the module. This way it is impossible for any signal return currents to travel down the inserted patch cords since the panel is isolated from the system ground except at one point, the PSU.

MOTM modules can be modified to allow full Oakley compatibility although this should be done as you are building the module. Modifying a completed MOTM module is possible, but the reverse side of the PCB must be accessed so that you can cut the required tracks.

However, note that the MOTM and Oakley power systems are still compatible. Any Oakley module will work in a MOTM system. And MOTM modules will work in an Oakley system – the only downside being that some of the benefits of a two ground system are increasingly lost as you add more MOTM modules to the mix.

Testing and Calibration

After wiring the unit according to the instructions given in this document you should apply power to the unit. Check that no device is running hot. Any sign of smoke or strange smells turn off the power immediately and recheck the all the external wiring first, and then the components on the board. Both onboard LEDs should be lit and none of them should be too bright or too dim. Check too, if you have one, that the standby LED is lit.

Assuming everything is OK so far, it is time to check the output voltages. Measure the output voltages with respect to ground. This means connect your black lead of your voltmeter to the 0VA terminal screw. Measure the voltage on the +15V terminal and check that is within +14 and +16V. Now measure the voltage on -15V and check that this is between -14V and -16V.

Leave the unit powered up for about ten minutes. Now adjust the voltages with the trimmers on the board. Adjust ADJ+ to make the +15V terminal equal +15.00V. Adjust ADJ- to make -15V equal to -15.00V.

The output voltages will vary a little with load. That is, it will change marginally depending on how many modules you connect up to the power supply board. Feel free to re-adjust the two trimmers when you add more modules to your project.

Final Comments

I hope that the Oakley PSU2 lives up to your expectations and provides you with a reliable source of power for your modular system.

If you have any questions about the module, an excellent source of support is the Oakley Sound Forum at Muffwiggler.com. I am on this group, as well as many other users and builders of Oakley modules.

If you have a comment about this builder's guide, or have a found a mistake in it, then please do let me know. But please do not contact me directly with questions about sourcing components or general fault finding. Honestly, I would love to help but I do not have the time to help everyone individually by e-mail.

Last but not least, can I say a big thank you to all of you who have helped and inspired me over the years. Thanks especially to all those nice people at Muff's and the Synth-DIY and Analogue Heaven mailing lists.

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