Oakley Sound Systems

Euro Power Supply Unit (EPSU)

PCB Issue 2 and 2.1

Project Builder's Guide

V2.7

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Introduction

This is the Project Builder's Guide for issue 2 of the Euro PSU circuit board from Oakley Sound. This document hopefully contains everything you need to know to build and install the Oakley euro power supply unit.

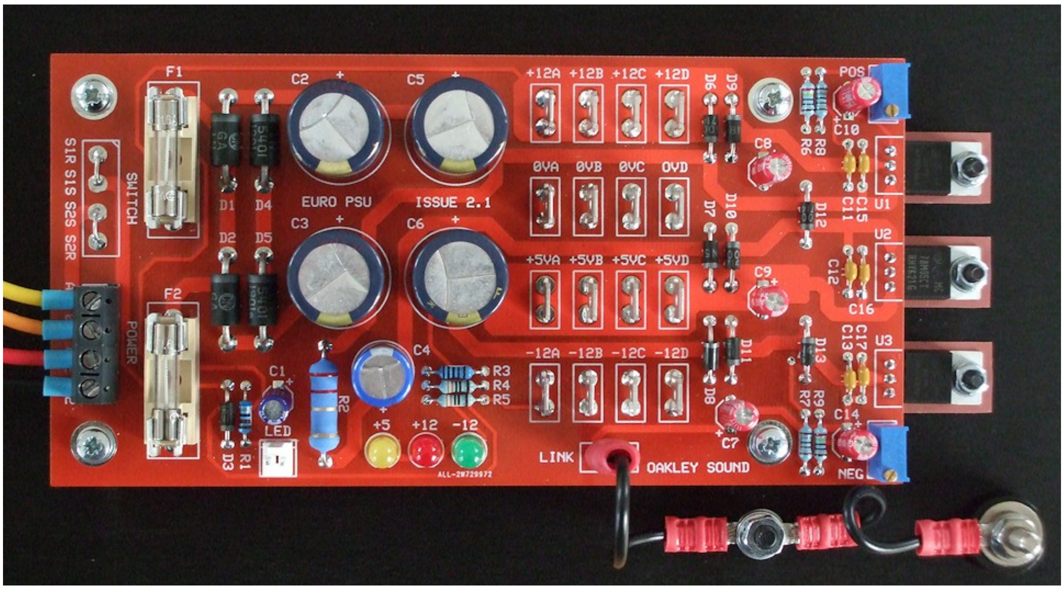
The Oakley Euro PSU allows for various options in the installation. You can use the unit either in full wave rectification mode for connection to tapped linelumps or twin transformer secondaries, or in half wave rectification for single phase AC output wallwarts and linelumps. If all this sounds very 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 or three 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.

Issue 2 of the EPSU is almost identical to the issue 1 board. The only major difference is that the locations of the power and switch screw terminals have been swapped to allow easier wiring. The bottom right mounting hole of the PCB is no longer connected to the LINK terminal as it was felt that a better 0V connection could be made with a dedicated earthing bond on the panel itself.

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.



The issue 2.1 Euro PSU board mounted on a 6U high 19" rack panel with linear option for the +5V.

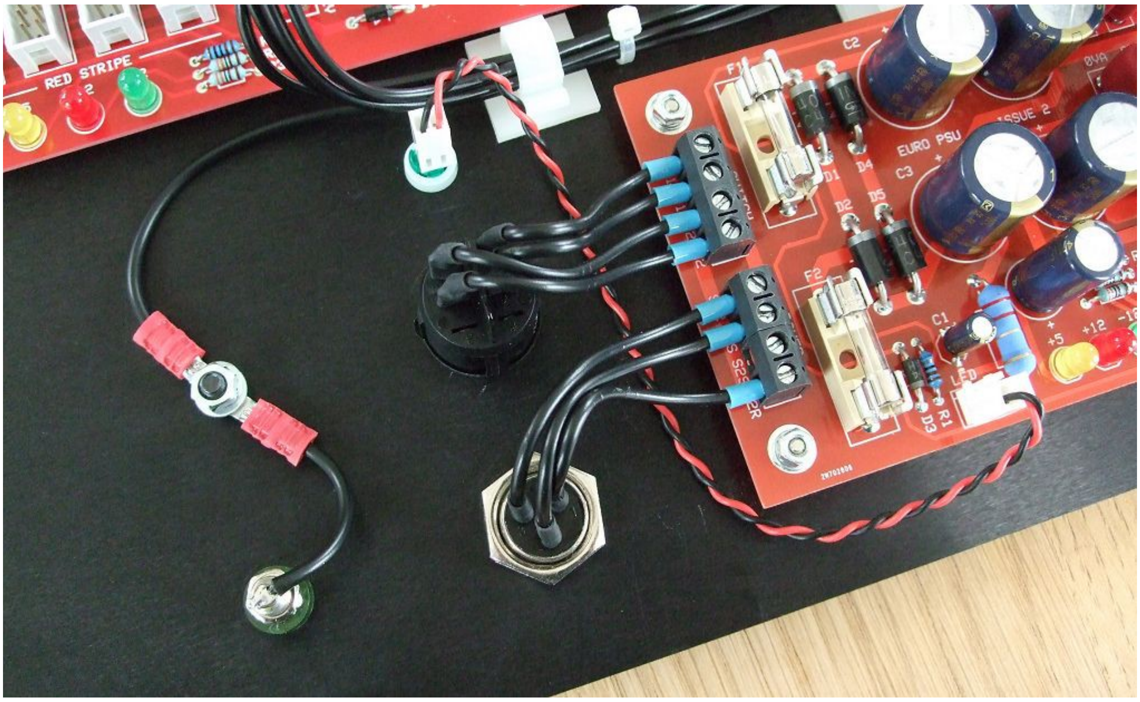
Safety Warning

The Euro PSU 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 recommended way of doing things with safe low voltage wiring, a solid earth bond for the metal panel and a 4mm socket for linking 0V between multiple cases. Boot lace ferrules are crimped on to the ends of the wires that fit into the screw terminals for neatness.

The Oakley Euro Power Supply Board

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 your eurorack modular. The module is designed to be fitted to a suitably large metal panel, usually the rear facing panel of your modular synthesiser, which functions as a heatsink for the regulators connected to the Euro PSU circuit board. This metal panel should have adequate airflow around it. An example of such a panel is a standard 4U or 6U high 19” rack blank panel. These are particularly suitable if you are mounting your modular synth in a 19” rack case. The greater surface area on the 19” blank panel allows you to mount not only the power supply module but also up to four Euro Dizzy power distribution boards.

A standard 6U high 19” panel with a mains powered Oakley Euro PSU and four Euro Dizzy boards. Note the earth bond the left of the main power inlet, and the 0V bond and banana socket below the EPSU board.

The voltage output of the power supply module is a split rail 12V supply. This means it generates both +12V and -12V. That is, two power rails, one of a positive voltage, the other a negative one. These voltages are measured with respect to a common ground which is normally connected, via your house's wiring, to the earth that you stand on. The voltage across both rails is 24V, with the common ground sitting exactly in the middle of this at 0V.

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. Also, when lit some front panel LEDs may increase the current draw.

The eurorack standard power supply bus also contains +5V, originally conceived as to provide power for digital circuitry. Most eurorack modules, even digital ones, have no need for a +5V supply but it can be wise to provide it all the same. To provide the +5V the Oakley Euro PSU can be built with either a simple linear design which provides only a limited amount of current to drawn from the +5V rail, or with a switch mode DC-DC convertor module with the potential to provide a lot more current. Neither has to be fitted if you have no requirement for +5V.

To supply the power to the Oakley Euro PSU I recommend that you use a Yamaha PA-20 or PA-30 'linelump' power supply. These are neat and 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 both the +12V and -12V rail. While the PA-30 will allow up to 780mA (0.78A) for each. Any current taken from the +5V rail must also be considered. The current drawn from the +5V rail comes from the same supply that supplies the +12V. So with the linear option the current from the +12V and +5V together must not exceed 520mA (or 780mA).

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 you take not much 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 +12V supply and 125mA from the -12V supply.

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

Some linelumps, like the recommended Yamaha PA-20 and PA-30 mentioned above, use a split AC output or a centre tapped AC output. This means it has three wires coming from it and will use a different plug from the usual round barrel one you see on the single phase AC wallwarts.

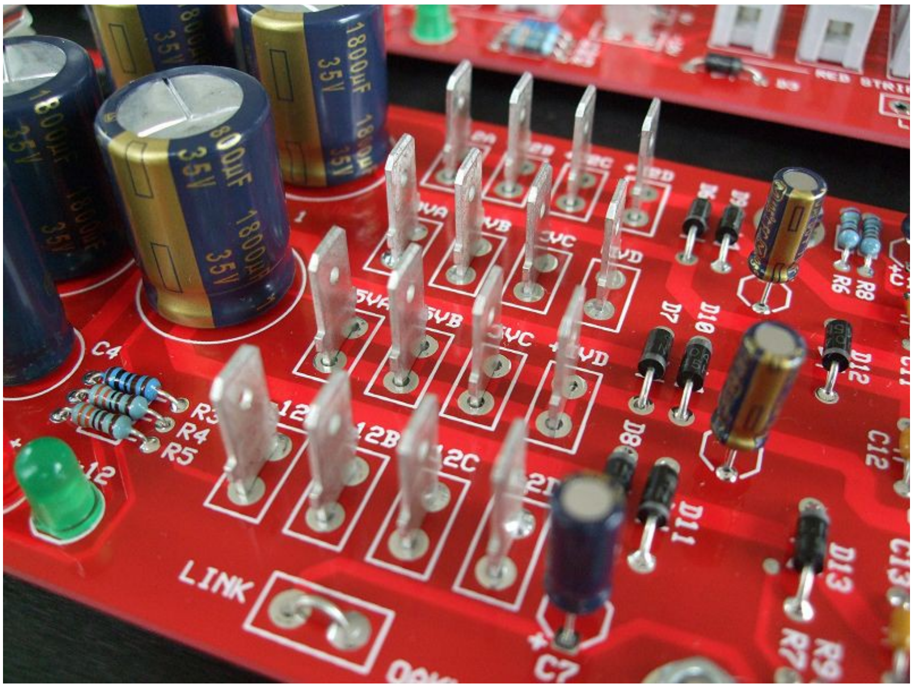
The Oakley Euro PSU can be used with full wave or half wave rectification. The former allows it to utilise split AC outputs very effectively. With full rectification and using a centre tapped power supply the amount of current taken from each 12V rail can be up to just over half the rated current output 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 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.

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.

Three on-board LEDs, a red one for +12V, a green one for -12V and a yellow one for +5V and an externally mounted green one for the AC input, provide a quick visual reference that all is well. All four LEDs could be fitted externally to the board and be mounted on a front panel. However, the recommended way is to mount only the AC indicator on the front of the synthesiser along with the AC power standby switch.

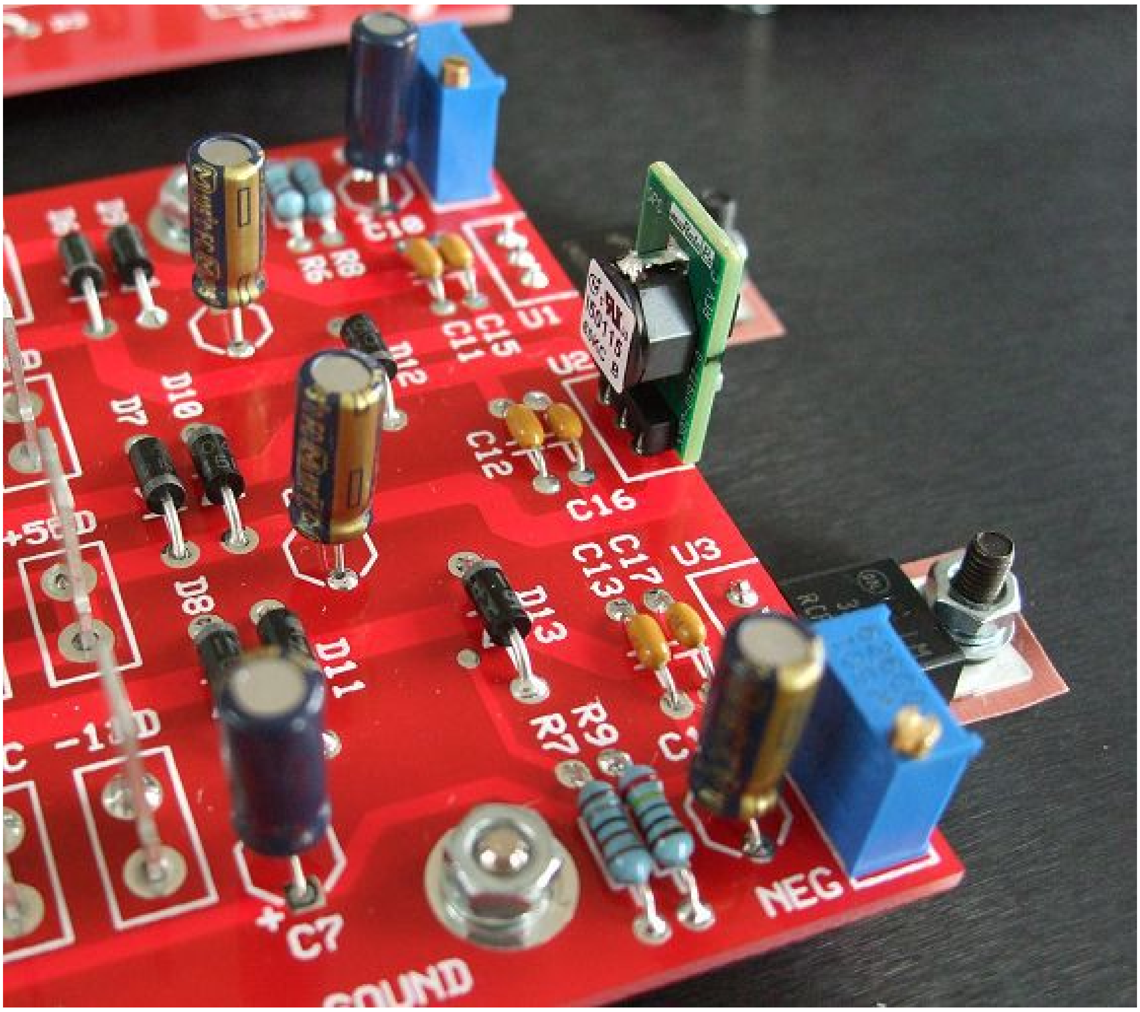


The output voltages are available from an array of single 1/4” (6.35mm) 'faston' blade terminals. Great care must be taken when connecting your distribution system to these terminals to ensure the cables go to the correct places.

* 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.

+5V: Linear or Switch Mode?



The switch mode DC-DC convertor option can provide more current and an easier build.

The Oakley Euro PSU can create the +5V rail with either a traditional low noise linear regulator (for currents less than 100mA) or use a more modern switch mode DC to DC convertor module (for higher currents).

The DC-DC convertor module is a miniature switch mode power supply that uses high frequency current switching and an inductor to create a stable +5V supply. It is reliable and is easy to use as it requires no additional heatsinking even though it can supply more current than its linear counterpart. The device I am using is the OKI-78SR-5/1.5-W36-C and it is pin compatible with traditional 7805 linear regulators. The disadvantage with using this device is that it is more expensive and creates a small amount of high frequency noise that is both transmitted through the air and into the power rails. The amount of noise depends on the current draw on the +5V line with greater currents creating more noise.

The linear design, which uses a 78M05, is comparatively silent in terms of electrical noise and is the preferred option in an all analogue or mostly analogue modular synthesiser. It should be noted, however, that it is unlikely that any well designed analogue modules would be significantly and detrimentally affected by the switch mode option.

Note that the lower current 78M05 device is used instead of the more common and more powerful 7805. Generally I would not recommend taking more than 500mA from the +5V of the Euro PSU with the linear option even if you fitted a powerful enough mains transformer. A linear +5V regulator creates its output by effectively turning the difference between its input voltage and output voltage into heat. In the Euro PSU it is possible that the +5V linear regulator will have to drop over 15V between its input and output terminals. With a load of 500mA on the +5V rail that is over 7.5W of power to be dissipated in the device which will produce a significant rise in temperature.

The benefits of using a 78M05 over the 7805 are its inherent current limiting during fault conditions. Whereas a 7805 would be happy supplying well over 1.5A into a near short circuit and potentially destroying the transformer, the 78M05 limits at just over 600mA which should be low enough not to cause any damage.

The current drawn from the +5V supply comes from the same supply that drives the +12V. With the linear option this can present us with a big problem if the current required by the +5V line is relatively large. For example, if the maximum current the PSU will supply is 520mA and you are already taking 420mA from the +12V supply, the +5V supply cannot supply any more than 100mA without possible damage to the transformer or mains adapter.

The DC-DC convertor is far more efficient that the linear design because it uses a switch mode power supply. However, the maximum current draw cannot be calculated quite so easily as it partly depends on the raw supply voltage coming from the mains adapter or power transformer. One can roughly calculate that for every 100mA that is taken from the +5V only around 35mA is taken from the mains adapter or transformer when you use the switch mode option. This means in the example given above you might be able to get away with drawing not just 100mA but 290mA from the +5V rail without causing damage to the main power supply. Thus the switch mode option is the one to go for if you need to draw a lot more current from the +5V. That said the absolute maximum current you can take from the OKI-78SR-5/1.5-W36-C device is 1.5A irrespective of the rest of the power supply.

The amount of current drawn by the DC-DC convertor can be easily found once your modular is all connected. Simply measure the voltage across R2 and apply ohm's law. The voltage divided by 10 ohms will give you the current. If you have, say 2V across R2, then you are drawing 0.2A or 200mA.

Note that the value of R2 will be different according to the option chosen. For the linear version R2 is only 2.2 ohms. While for the switch mode option, R2 is 10 ohms. Both, however, are 3W resistors.

If you have no need of +5V in your system then you can omit either power device and all their ancillary components. This would be R2, C4, C9, C12, C16, D7, D10 and U2

Labelling error on early issue 2 PCBs

Please note this error has been corrected for later versions of the board. These later boards are labelled issue 2.1 – the issue number is found between the positions of the big capacitors C5 and C6. However, if you have a board that is labelled issue 2, and not issue 2.1, then the following is for you.

The issue 2 board works just as I had intended but please note there is a labelling error on the boards. Issue 1 boards have the switch and power screw terminals in different locations compared to the issue 2. However, when I moved the terminals and their names for the new layout I unfortunately did not relocate the printed text on the edge of the board to match.

Therefore the text to the left of the both the switch and power screw terminal locations is incorrect. You should ignore this text and work from the location of the wires in the wiring diagrams in this Builder's Guide when you connect up your board.

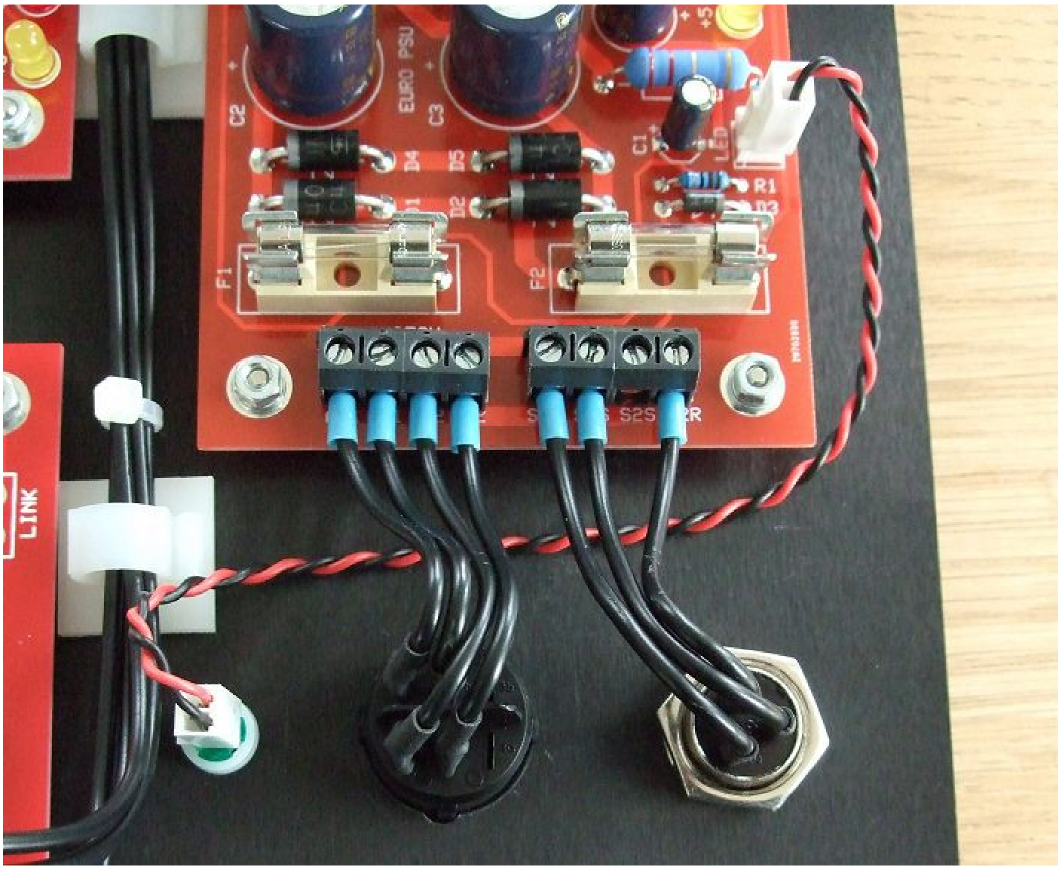
The incorrect text beside the switch terminal is AC1, 0V1, 0V2 and AC2, which should read S1R, S1S, S2R and S2S.

The incorrect text beside the power terminal is S1R, S1S, S2R and S2S, which should read AC1, 0V1, 0V2 and AC2.

Most, but not all, of the photographs in this document show an issue 2 board with the mistake present. The position of the wires in the photographs are however correct. Remember that this is a labelling error not a component placement error.

I was tempted to scrap the boards but there is enough waste generated in our world without adding a set of working PCBs to it. I do, however, apologise for any confusion that this labelling error may cause.

Our Recommended Power Supply



The early issue 2 Euro PSU is wired up for full wave rectification and using a three pole power inlet (bottom right). Both fuses and all four big rectifier diodes are fitted. Note the use of a twisted wire to connect to the standby LED to keep things neat.

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

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. We do have permission from Yamaha-Kemble in the UK to use this particular part for the Oakley system, but in other countries this may be not so clear cut. The liability issue once again rears its ugly head and they may not want to sell power items for third party use. If you are buying these direct from Yamaha and, for some reason, are asked why, the best thing is to say it is for your <u>own</u> MG12/4 mixer.

Once rectified, smoothed and regulated the Yamaha PA-20 can deliver up to 0.52A continuously into both 12V rails.

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

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

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 Euro 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

5% 1/4W carbon or better (1/4W 1% metal film is recommended)

1K	R3
3K3	R4, R5
6K8	R1

1% 1/4W metal film

240R	R6, R9
1K8	R7, R8

3W metal film or metal oxide (5% or better) mounted 5mm above the surface of the board.

Linear option:

2R2	R2

Switch mode option:

10R	R2

Capacitors

100nF, 63V multilayer axial ceramic	C12, C15, C17, C16, C11, C13
10uF, 35V or 50V electrolytic	C10, C14, C7, C8, C9
22uF, 35V or 50V electrolytic	C1
1800uF, 35V or 50V electrolytic	C2, C3, C5, C6

470uF, 35V electrolytic	C4

C2, C3, C5 and C6 are 105 degree Celsius radial types and have standard wire ended leads. Lead spacing is 7.5mm. I recommend Panasonic type EEUFK1V182S but any decent 105 degree part, with a ripple current rating of over 1.5A, and that will fit on the board can be used.

Integrated Circuits

LM317T 1A variable regulator	U1
LM337T 1A variable regulator	U3

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 Euro PSU board later in this document.

Linear option:

MC78M05CTG	+5V 500mA regulator	U2

As above do not fit this into the board just yet.

Switch mode option:

OKI-78SR-5/1.5-W36-C	+5V 1.5A DC-DC convertor	U2

This can be soldered into the board as it is populated. See pictures for orientation.

Discrete Semiconductors

1N4004 rectifier diode	D3, D6, D10, D11, D12, D13
1N5819 Schottky diode	D7, D8, D9
1N5401 rectifier diode	D1, D2, D4, D5

For D3, D6, etc. you can use any other 1N400X part such as 1N4001, 1N4002, etc.

D4 and D5 do not need to be fitted if you are using a single phase wall wart or line lump. However, for full wave rectification D4 and D5 are required. So if you are using a split output line lump or an internal transformer with twin secondaries D4 and D5 have to be fitted.

5mm red LED	+12V
5mm green LED	-12V, LED
5mm yellow LED	+5V

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

Trimmer

500R multiturn cermet trimmer*	POS, NEG

* For example, Bourns 3296W-1-501

Miscellaneous

20mm fuseholder PC mount	F1, F2 (F2 is not required for single phase inputs)
4-way screw terminal 5mm	POWER, SWITCH
1/4" Faston blades	17 off for +12V, -12V, 0V, -5V & LINK
Power switch DPST	Standby or power switch
2-way 0.1" Molex KK	LED (header for front panel LED)
0.1" Molex KK or MTA housing	2 off for LED cable

Two anti-surge (time lag or slo-blo) fuses to suit.

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

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.

Linear option:

3 off TO-220 insulator	For mounting of U1, U2 and U3 to panel
3 off TO-220 insulating bush	For mounting of U1, U2 and U3 to panel
Heatsink paste	For mounting of U1, U2 and U3 if using mica insulators

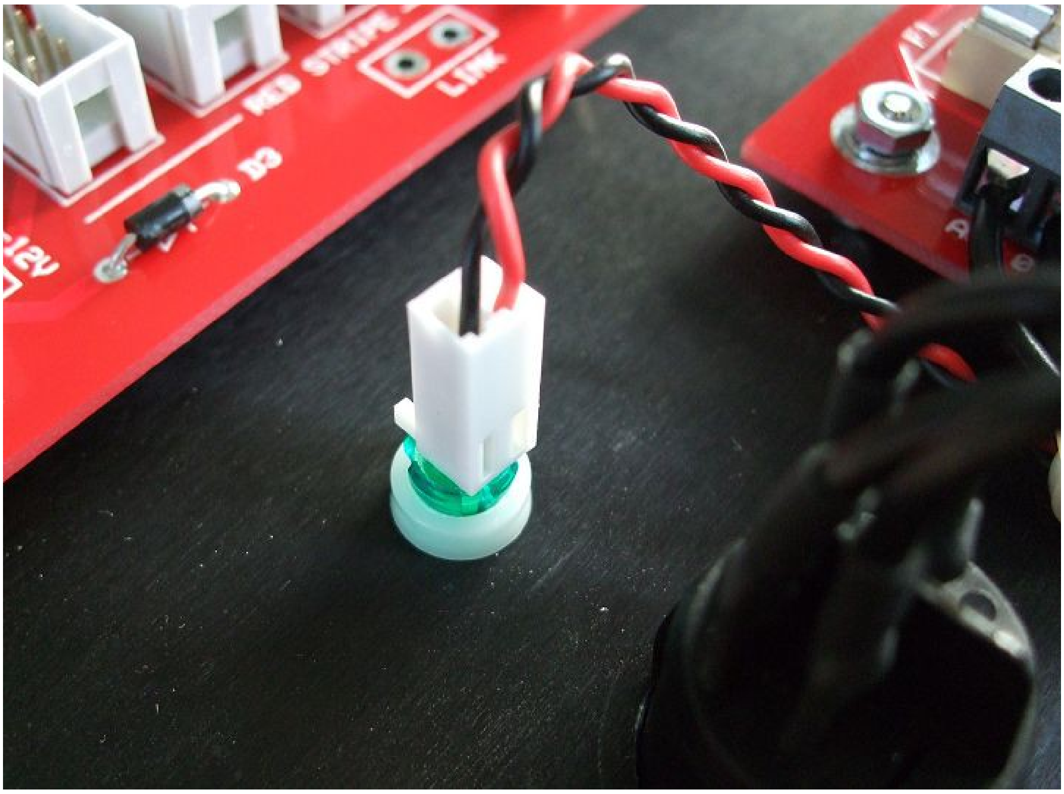
Switch mode option:

2 off TO-220 insulator	For mounting of U1 and U3 to panel
2 off TO-220 insulating bush	For mounting of U1 and U3 to panel
Heatsink paste	For mounting of U1 and U3 to panel if using mica plates

Mounting hardware for 19” rack panel

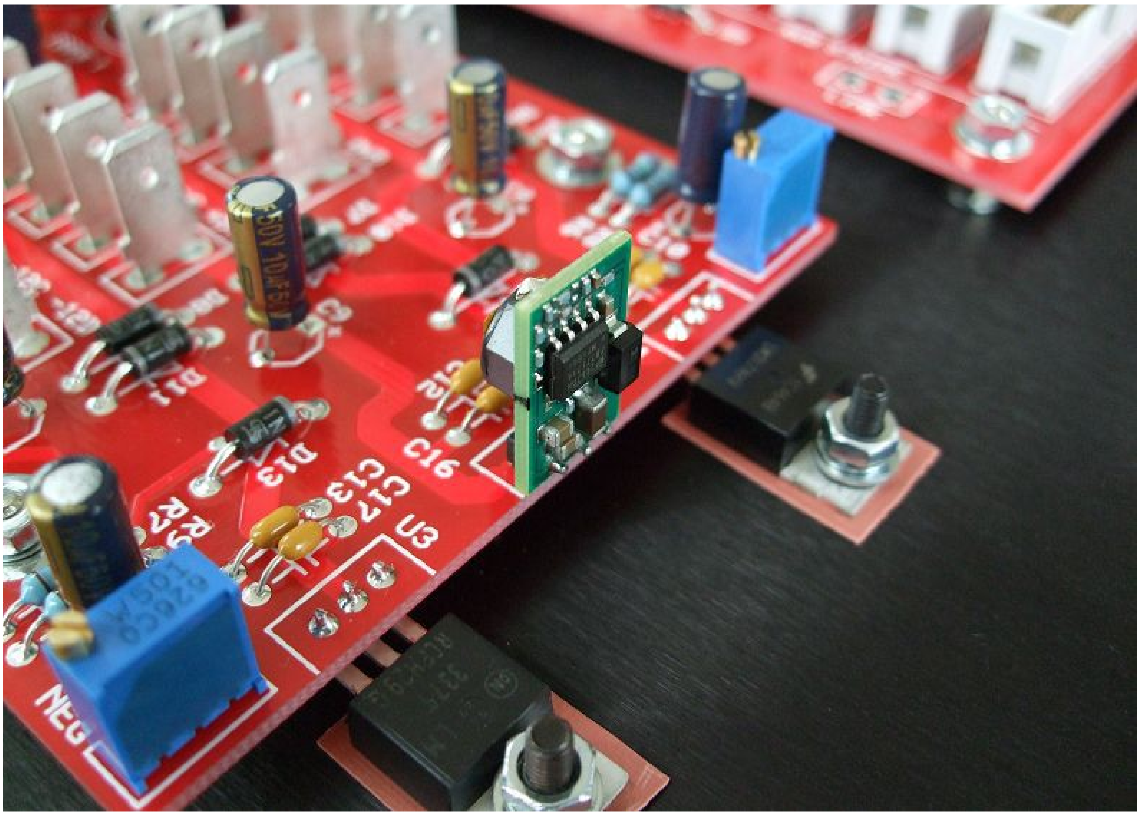
M3 6mm pan head screws	4 off
M3 10mm or 12mm pan head screws	For power devices, ie. 2 or 3
M3 hex threaded 5mm male-female spacers	4 off
M3 star washers	8 off
M3 plain metal washers	For power devices, ie. 2 or 3
M3 hex nuts	For power devices, ie. 2 or 3
M3 spring washers	For power devices, ie. 2 or 3

And any mounting hardware for the Dizzy boards if needed.



My usual way of mounting and connecting LEDs. I use a two way 2.54mm Molex KK housing to hold crimped 7/0.2 wires. These simply slide onto the LED's leads and will stay in place until one needs to remove the connection by simply pulling on the housing. The 5mm green LED is held in place by a low profile green LED clip and mounting ring. The LED needs to be wired so that the anode is connected to the positive connection, ie. the square pad.

Attaching the Power Devices



In this build the two regulators are insulated from the panel with pink insulating pads from Multicomp (pt. no. MK3306/S). Note that with the +5V DC-DC convertor 'switch mode' option only two power devices need to be fitted to the heatsink.

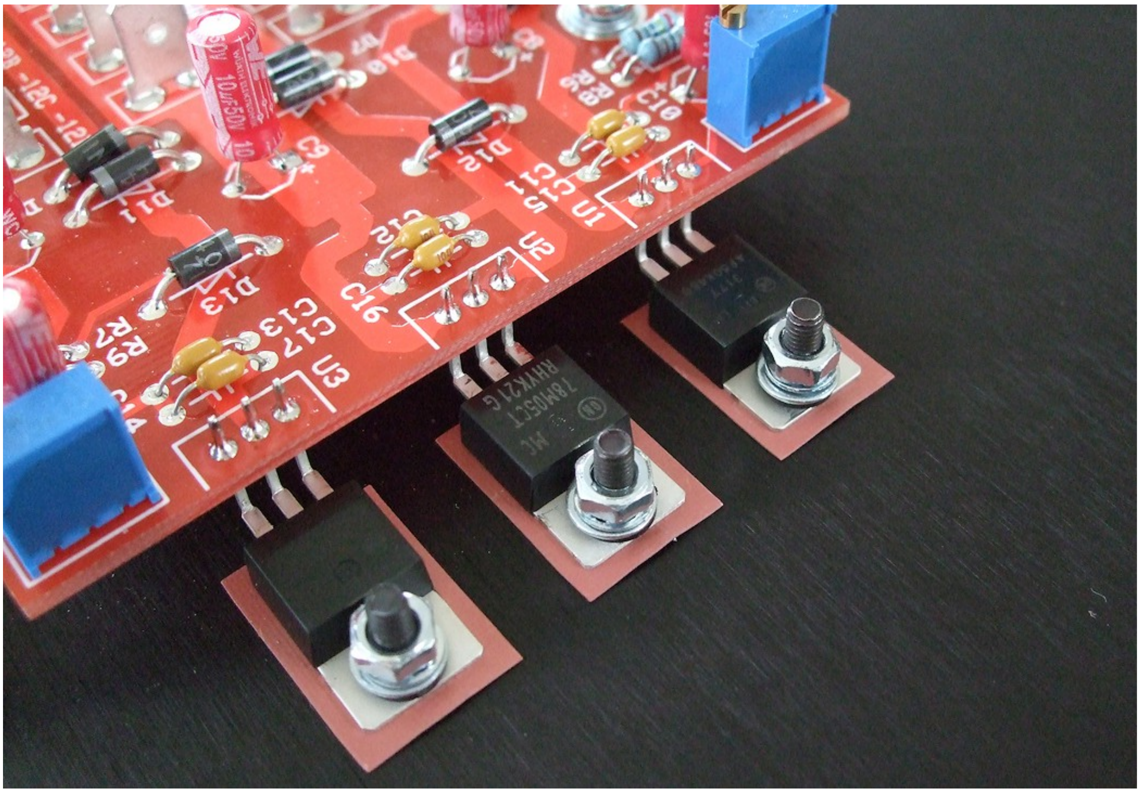
The Euro PSU PCB needs to be fitted to your case metalwork. Use the PCB as a template for marking the panel and then drilling the four 3.5mm holes needed for the mounting pillars. The board should be spaced high enough off the panel with suitable mounting pillars (spacers) so as to not short out any of the components' leads should the board be flexed downward. The mounting pillars should also not be too long so that the leads from the regulators can't reach through the board to be soldered. I find either a 5mm or 8mm spacer works very well.

Now you need to prepare the leads of the two (or three if you are building the linear option) power devices. 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 90 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 power devices to the board by poking their legs up through the bottom of the board. Do not solder them but fit the board back into place. Use the hole in each regulator 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 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 the 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 plus 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.



The three regulators used for the linear option. The small 'top hat' black plastic insulating bush can just be seen underneath the flat metal washers on each power device.

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 spring washer and nut onto the screw but don't tighten it up just yet. Do the same for the other regulator, or regulators, 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.

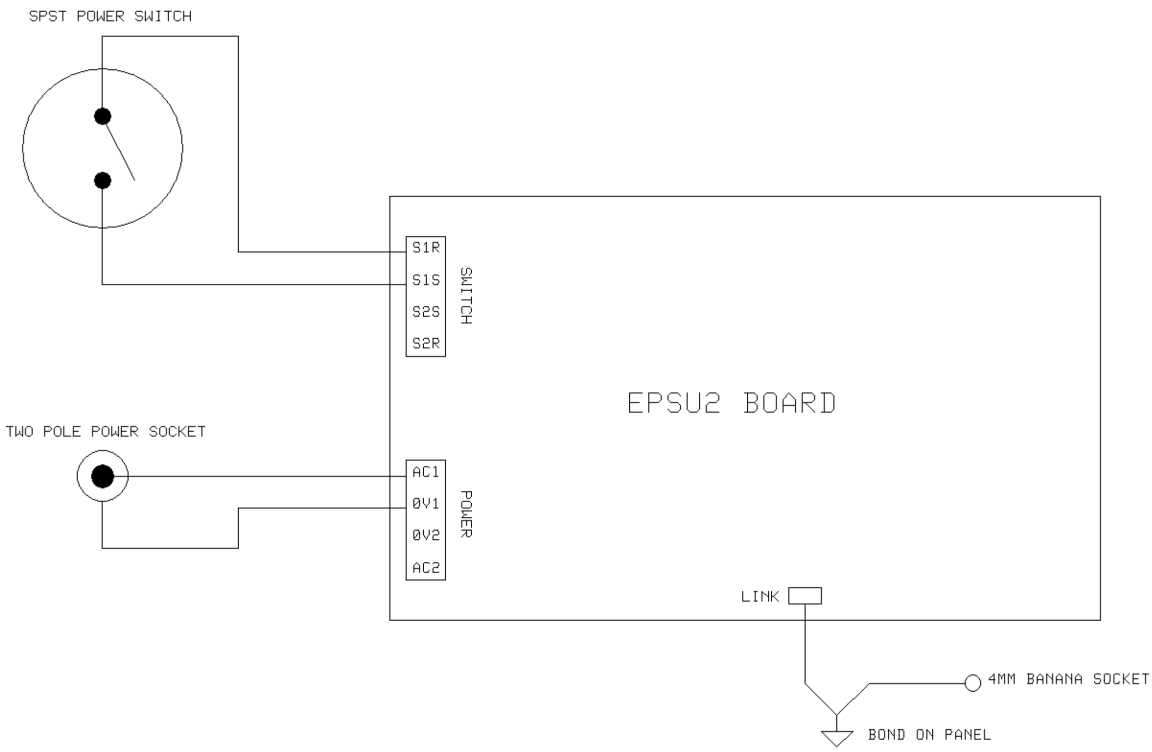
With both the board and power devices secured to the panel with their mounting hardware you can now solder the regulators' leads from the top side of the board. Snip off any excess lead lengths above the solder joints.

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 0V2 wired to the power socket. AC2 and 0V1 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 permanently. 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 earth or grounding connection can be made. 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.

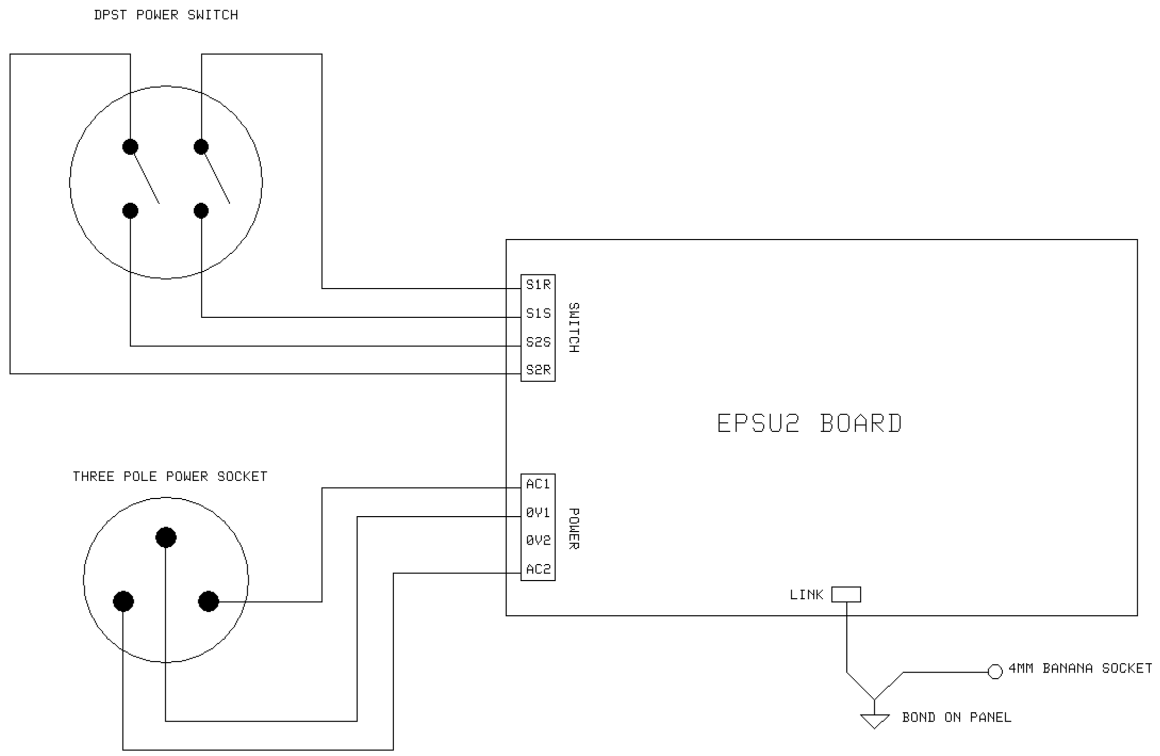


Figure 2. Linelump wiring with centre tapped output, eg. Yamaha PA-20

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 permanently. 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 earth or grounding connection can be made. See next section for more details.

Linelumps and Wallwarts: Grounding Point and Case Ground

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 or ground 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.

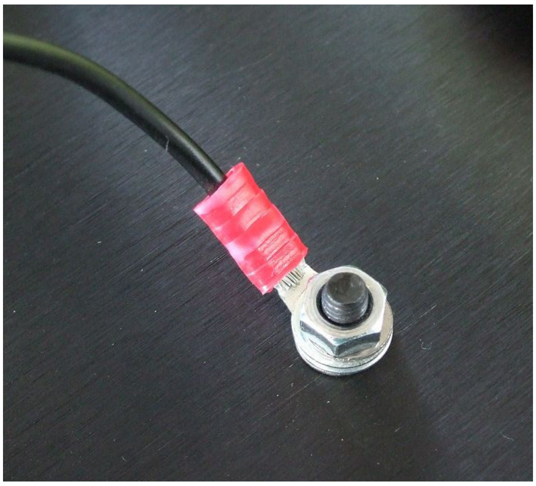
Let us consider a more simpler scenario for the moment. Say we have built ourselves two modular cases and we would like to connect the modules in them together to form an awesome monster patch. Each case has its own Euro PSU and each one is powered by a Yamaha PA-20. It is useful in this situation to ensure that both PSUs are grounded together. In other words, the two 0V lines from each power supply are firmly connected together. Although this will be done the moment that one patch lead goes from one case to the other it is beneficial to link them together with a dedicated thick bonding wire. The reason for doing so is that the electrical current flows as part of a circuit. For every signal, CV or audio, there is a return path that completes the circuit. The return path in a modular system happens via the 0V network, either within the modular's own power distribution system or via the screening of the patch leads and cables. Since multiple signals are being returned along the same network it is possible to have noticeable and unwanted interactions between the signals. This is called crosstalk and excessive resistance within the complicated mesh of all those 0V connections can cause unwanted clicks, noises, detuning and other artefacts. By adding a low resistance pathway for return signals to travel through reduces the amount of crosstalk, hopefully to point where it is no longer a problem.

We can do this in a variety of ways but one useful method involves having a 4mm banana socket mounted near each power supply. The banana socket is then connected to 0V on the Euro PSU board.

If both power supplies have a banana socket then it is a simple matter of patching the two power supplies 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 PSUs 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 those designed for loudspeaker connections.

You can connect the banana socket to one of two places on the EPSU board. The best place is any one of the four 0V faston blade terminals, 0VA, 0VB, 0VC or 0VD. However, if you will be using all four of these to connect to your distribution boards then the next best choice is to use the faston terminal blade in the LINK position. In any system with four Dizzy boards this is the option to use. Although, the middle two terminals on the power inlet are also connected to 0V, do not connect either the earth bond or the linking socket to these points.



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.

The recommended method for any build using the EPSU is to have both a 0V linking banana socket, and to bond your panel to 0V. This can be done easily enough by connecting the banana socket to the panel bond with one wire, and another wire which connects the panel bond back to the EPSU either at 0VD or LINK.

A 4mm banana socket is taken to the panel bond point which then is connected to the EPSU's 0VD or LINK 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

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:

15-0, 15-0 (or for a single tapped secondary 15-0-15)

80VA

This will give you a power supply that should be theoretically capable of supplying of 1A into each of the +12V and -12V rails assuming your heatsink and smoothing capacitors are up to the job. The maximum current taken from the +5V rail depends on whether you are using the linear or switch mode options. If using the linear option then the maximum current to be taken from the +5V must not exceed 1.4A less the current taken by the +12V rail. In other words the total current taken by both the +12V and +5V rails must not exceed 1.4A.

Remember that the maximum output current rating of the transformer is valid 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 power supplies as the AC output of the transformer has to be rectified, smoothed and then regulated. 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.

$$I_{ac} = 1.8 \times I_{dc}$$

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 12V rails will require 1.8A(RMS) of secondary current. And if you want to give yourself some leeway, so as to keep the transformer cool, then you can use a factor of 2 instead of 1.8.

As an example of the equation's usage I will use an 15-0, 15-0, 80VA transformer.

Total AC root mean square (RMS) voltage across both secondaries is 15 + 15 = 30V

The power rating is 80VA and so the maximum RMS current drawn can be 80/30 = 2.67A

The maximum DC load is therefore approximately 2.67/1.8 = 1.48A

Because we have considered both secondaries together this means that we can take 1.48A from the +12V and +5V together, **and** 1.48A from the -12V. However, if we do take this much then we would will heat the transformer up by the amount specified by the manufacturer of the transformer. A quick look at the datasheet reveals that the temperature rise under maximum load is surprisingly large and is normally 55C over the ambient temperature. Running a large device at this temperature is not what we want inside 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 allowable current drawn using a 80VA transformer falls to just 1.33A 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.

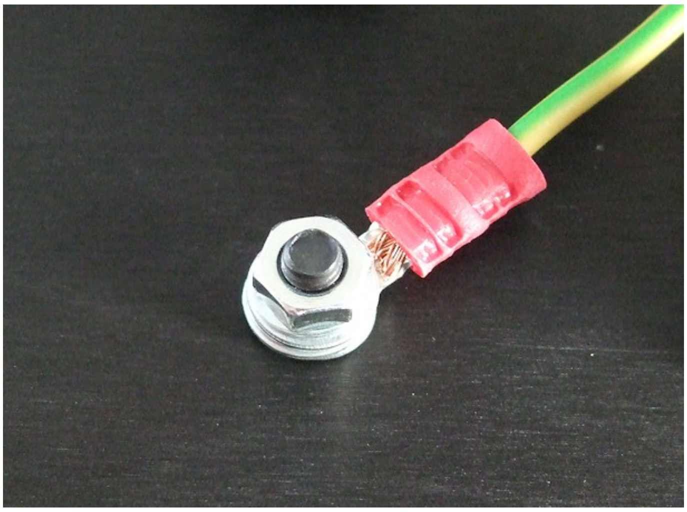
There is no need to fit an AC standby switch since you will be fitting a proper mains power on switch in series with the transformer primary coil. So you should link S1S to S1R, and S2S to S2R, on the PCB. Note these terminals are labelled incorrectly on the early issue 2 EPSU boards.

Earthing

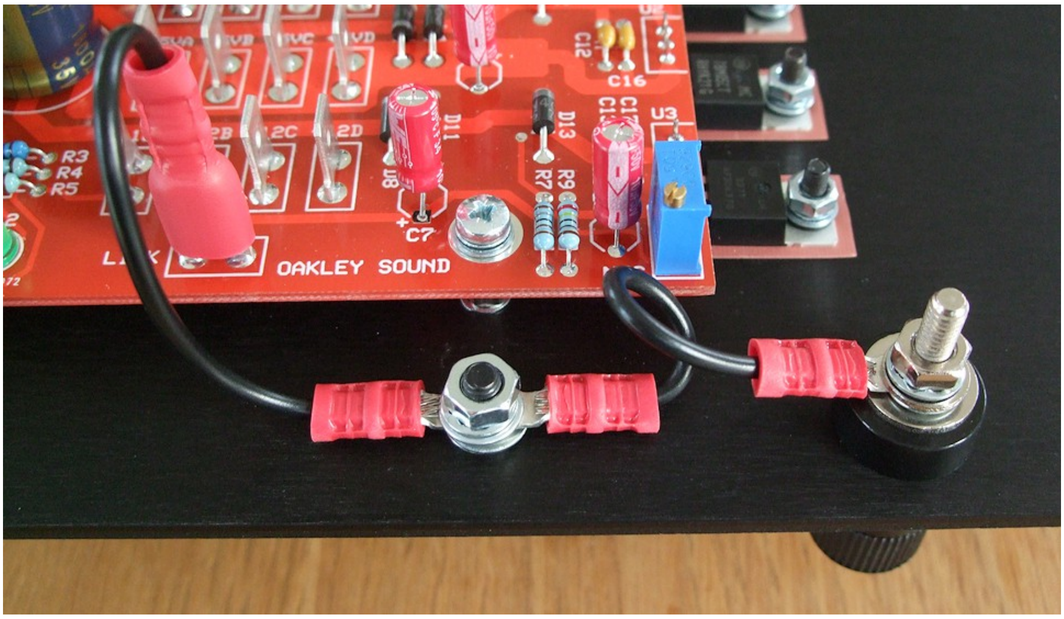
Remember it is up to you, the builder of the equipment, to make sure that your item is safe and is built to the required safety standard in your country. These notes are only a guidance and it is up to the reader to establish the exact obligations required in their own country.

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 on the which the EPSU and transformer are mounted is earthed. It should be securely bonded to earth via a thick piece of wire back to the earth tang of the IEC power inlet or a common earth bonding point.



A bonding point using a crimped ring terminal onto a M4 bolt secured to the panel. The wire connects to the earth tag on the mains inlet IEC socket. All paint or anodising coating must be removed around the hole to ensure a good electrical contact between the panel and the earth connection.



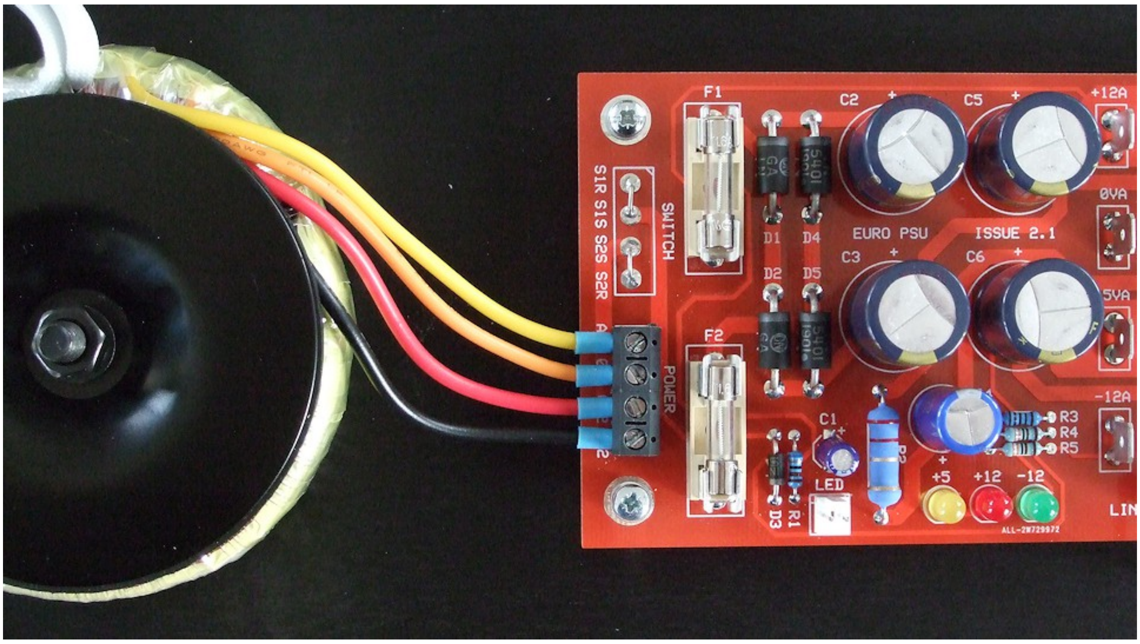
Here the optional 4mm banana socket is taken to the second panel bond point which then is connected to the EPSU's LINK terminal. Because the 0V bond is mounted onto the already earthed panel it is also connected to mains earth. The banana socket can be used to connect to other modular cases that may not have an earth, or to reinforce the 0V connection so as to reduce unwanted crosstalk between signals.

Secondly, the 0V connection of the EPSU must also be connected to earth. Connect the LINK terminal, or 0VD if it is free, on the EPSU board either back to the panel's earth bonding point using at least 24/0.2 wire, or preferably connect it to a second bonding point on the panel. For the latter, you then 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 EPSU board, for the 0V panel bond and optional 4mm banana socket connection. In this way the metal panel serves as a low resistance connection between the two bonding points. By using two separate bonding points 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 to the local 0V.

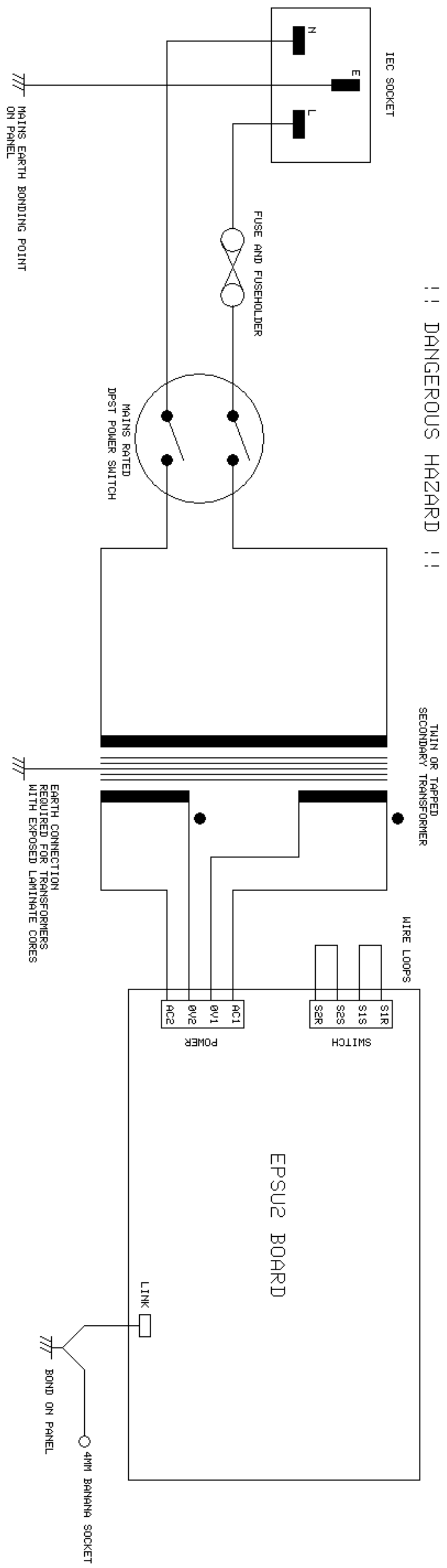
You will also need to provide earthing to any exposed transformer core. This does not apply to toroidal types but the rectangular EI types should have their metal frame earthed.

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.

It is possible that by earthing the front panel you may introduce a type of earth loop when you connect your mixer to the sockets of one of the modules. The outcome of this is audible humming at 50/60Hz and its harmonics. It is produced by earth currents travelling down the screen of the connecting cable(s). This can be avoided by careful studio wiring and/or by using balanced audio lines to pipe signals to and from the modular and mixing desk. Most mixing desks will have balanced outputs and inputs.

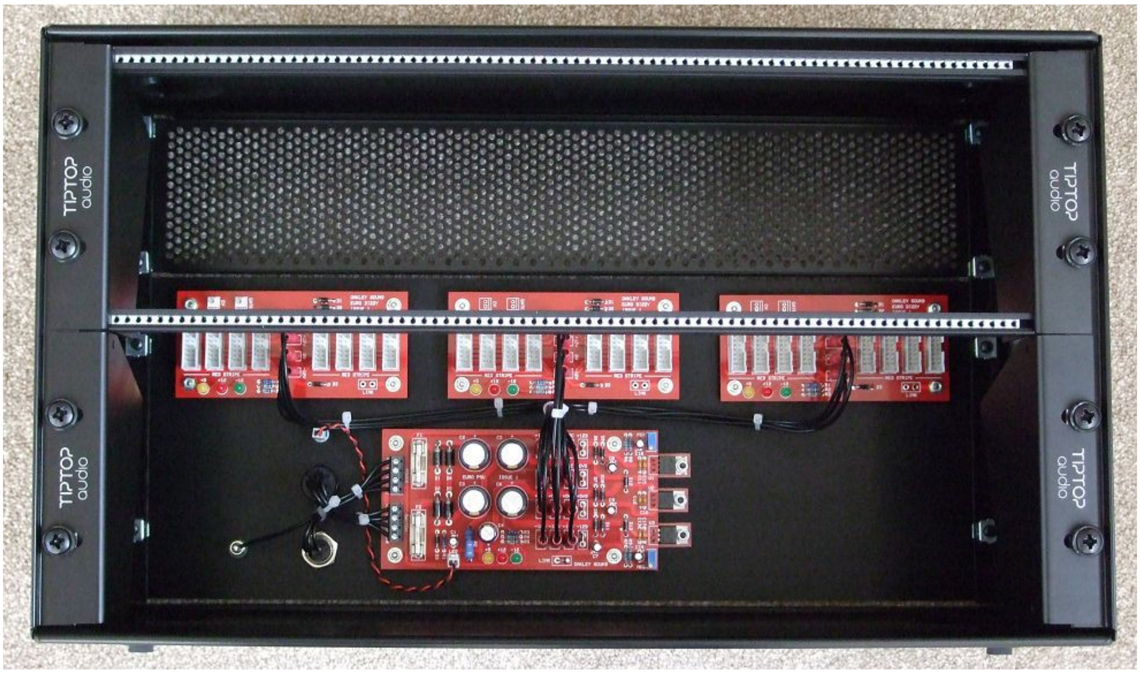


A toroidal transformer directly connected to EPSU board. Note the two short wire links in the switch position.



Mains wiring diagram. For experienced builders only!

Testing and Calibration



A complete 24 way power supply system with one E-PSU and three E-Dizzies fitted to a 6U 19" rack case.

All testing must be done with the heatsink or panel attached to the power devices.

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. All three onboard LEDs should be lit and none of them should be too bright or too dim. Check too 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 0VD terminal blade. Measure the voltage on +12VD and check that is within +10.5 and +13.5V. Now measure the voltage on +5V and check that this is around +5.0V. And now check that the voltage on -12VD is between -10.5V and -13.5V.

Leave the unit for about ten more minutes. Now adjust the voltages with the trimmers (multiturn presets) on the board. Adjust POS to make the +12VD terminal equal +12.00V. Adjust NEG to make -12VD equal to -12.00V.

The 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 trimmers when you add more modules to your system.

Final Comments

I hope that the Oakley Euro PSU 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 document, or have a found a mistake in it, then please do let me know.

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.

Tony Allgood at Oakley Sound

Cumbria, UK