Passive Distribution Systems

Currently, the main type of distribution system can be classified as a centralised or passive distribution system in which a system contains, usually, a single regulated DC dual-rail power supply feeds a number of passive busboards which then distribute that regulated supply to module power outlets spread around the system.

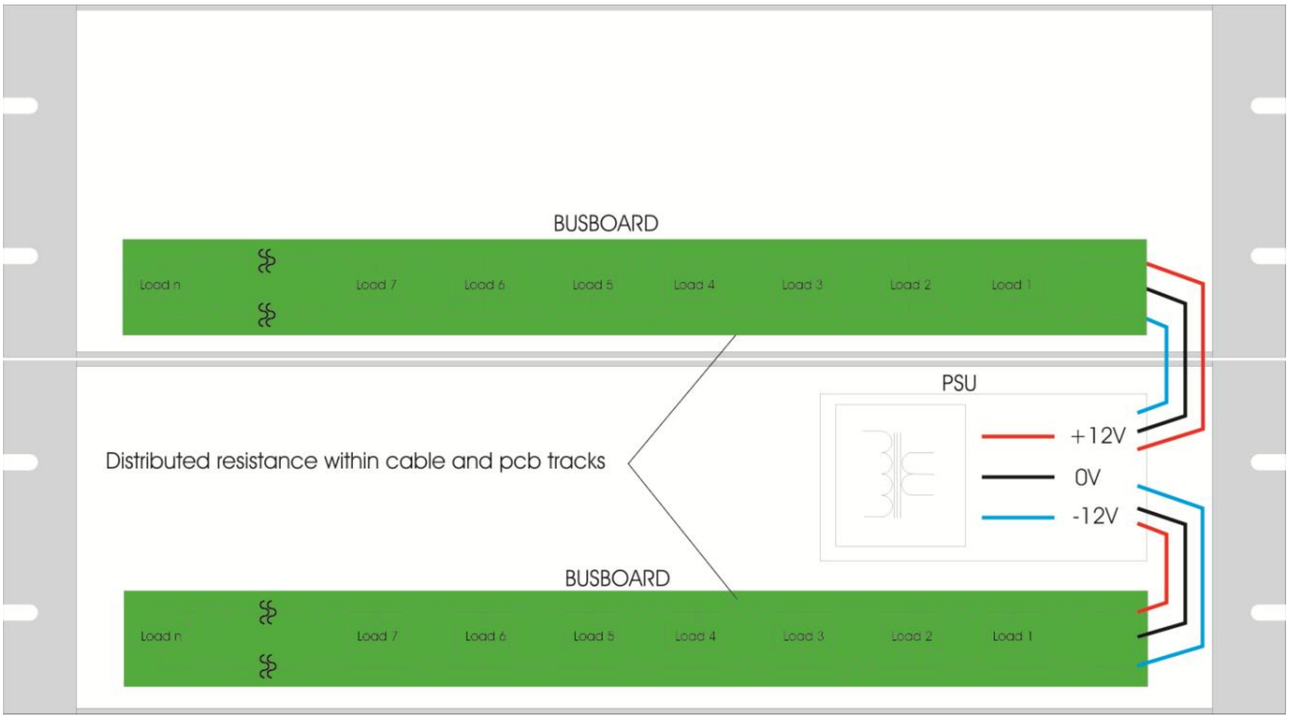

Figure 1 – a typical Passive Distribution system

Figure 1 shows a typical arrangement of this design. A single AC/DC Power Supply (note that in some designs the mains section may be external to the system) at lower right feeds a regulated dual-rail supply to a busboard in each 3U section of the system. Each busboard then feeds these power rails to each module connected to it.

One of the main limitations of this type of configuration is the inability of the power supply to maintain stable and clean power rails throughout the whole system, as it is only capable of monitoring the voltage at the output of the power module itself. Resistances in the wiring, connectors and PCB tracks will result in small drops in the power rail voltages, with each voltage drop adding to the previous as they get further away from the power supply. For example, if we assume an equal distribution of resistance and that each load results in a drop of, say, 1mV, then whereas ‘Load 1’ would see virtually the full power voltage, ‘Load 2’ would see a 1mV drop on the rail voltage, ‘Load 3’ would see a 2mV drop while ‘Load 7’ would see a 6mV drop. As the power supply is only able to ‘sense’ the power rail voltages at its immediate output, it is not able to compensate for this increasing voltage drop around the system. In itself this may not be a problem - as long as the voltage drops remain small and stable then most modules will function correctly with the lower power rail voltages (there will be a nominal level below which the power rails voltage should not drop if it is desired to maintain stable and reliable operation of a module and a minimum level of, say, 11.5VDC would be a good reference point to start from).

However, the voltage drop problem may be compounded by any module that has a high - or worse still - varying load demand upon the power rails. As the loading from the module varies up and/or down, the power rail voltage at that module's connector may also change. An example of this would be a module that is regularly switching an LED that is fed directly from the power rails. At each 'on' point, the current loading would suddenly be increased by the current draw through the LED, causing the power rail voltage to dip. The current loading is decreased by the same amount when the LED is turned off, causing the power rail voltage to rise back up. Some modules may adversely react to these fluctuations in the supply rail causing the module to 'misbehave'. This could be something like a VCO exhibiting frequency modulation even though it has no inputs connected.

Another problem often seen with typical passive distribution systems is that of noise pollution. Given that many busboard designs provide minimal (if any) filtering, they rely entirely on the power supply's own filtering. Any noise injected in to the power rails at any point downstream from the power supply will experience progressively less filtering the further downstream they go. This can be a significant problem with modules that generate high-frequency noise from clocking circuits, such as in microcontroller-based designs or switchers.

The common solutions to these sorts of problems are:-

1) to try and identify the fault causing module(s) and to move them to the end of the busboard (far left in Figure 1) or,
2) Move such modules on to another busboard. You will observe in Figure 1 that each busboard is fed directly from the power supply which effectively isolates its power rail voltages from any problems associated with the other busboard. This solution will NOT work if the busboards are daisy-chained together. In fact daisy-chaining busboards will COMPOUND the problem and spread it further around the system.

A different philosophy needs to be applied to the whole system design if the user is to be able to concentrate of the business of making sounds and not continually fretting over misbehaving modules and system instabilities.

The next section describes a busboard system philosophy that seeks to address many of these issues.

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Active Distribution Systems

Alternative approaches to the type of system described above are distributed or active distribution systems. In this configuration the busboards distribute a higher voltage around the system with each module output having its own dedicated regulation circuit.

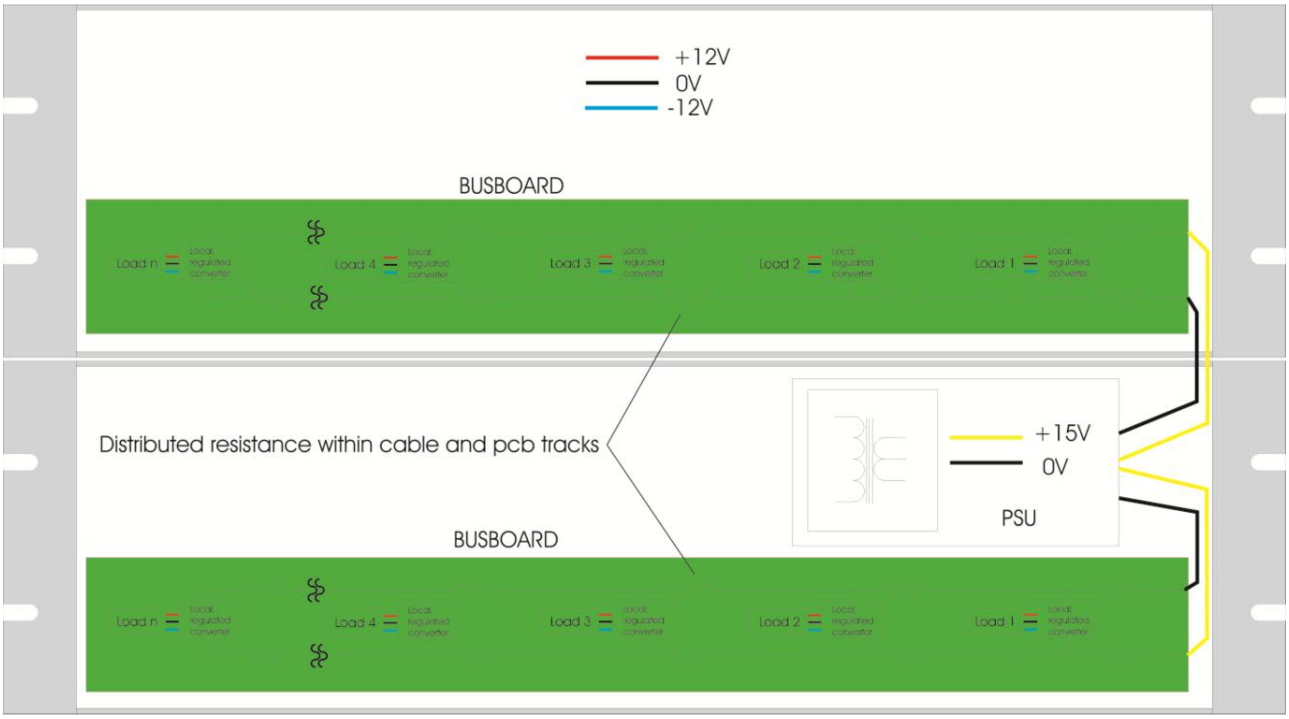


Figure 2 – an Active or Distributed Distribution system

Figure 2 shows such an arrangement. Although we still have similar distributed resistances as in the passive system, any voltage drops as a result of them are constrained to the ‘main’ or ‘raw’ supply (+15V in this particular design) where the system has a substantially greater tolerance to small changes in the power rails. Each module connection has its own **local regulator supply** and as long as the ‘main’ supply remains above the regular circuits minimum input requirements, then any variation in the ‘main’ supply is effectively irrelevant.

Each load, having its own dedicated regulator (or power supply) is now isolated from other modules in the system. In addition, each regulator circuit is now effectively monitoring and regulating its output dependent of the loading from its connected module. This means that **each and every module is getting exactly the same power rail voltage** (within the tolerances of the regulator circuits). As part of the regulator circuit design, each power rail output incorporates dedicated filtering which greatly improves the quality of the power rail voltages presented to each module.

It should be noted that in an ideal system, each regulator circuit would utilise ‘remote sensing’ to monitor the power rail voltage at the module end of its power cable. However as no modules currently implement remote sense points, and that doing so would require additional wiring in the power leads, it is assumed that any losses across a module’s power lead are minimal and well within specification.

The isolation provided by each load's regulator circuit also helps address the problems with injected noise, as the regulator circuits would include some form of filtering that would 'trap' this noise and prevent it from being passed back into the main system.

The table below compares some of the main features of Passive and Active distributed power systems:-

Parameter	Passive	Active
Fault tolerance and isolation	Difficult to achieve	Inherent
Regulation and remote sense	Difficult for large systems	Simple and inherent
Protection for overvoltage and overcurrent	Global, affects all subsystems	Local, isolates subsystems
IR drops and losses	Small for low-power modules, significant problem for high-power modules	Insignificant to module or system
Power conductors	Small for low-power modules, large and heavy for high-power modules	Very small
Expansion capability	Simple for low-power modules; capacity must be built into the power supply resulting in large and heavy supplies in large systems	May be as simple as plugging in another subsystem module

ED111 – Active Distribution Busboard

The ED111 busboards provide a fully-distributed power system providing 12 independently regulated module outputs on a board designed to fit in to a 42HP wide section of a system. Multiple ED111s can be connected together to fit 84HP, 126HP and 168HP systems.

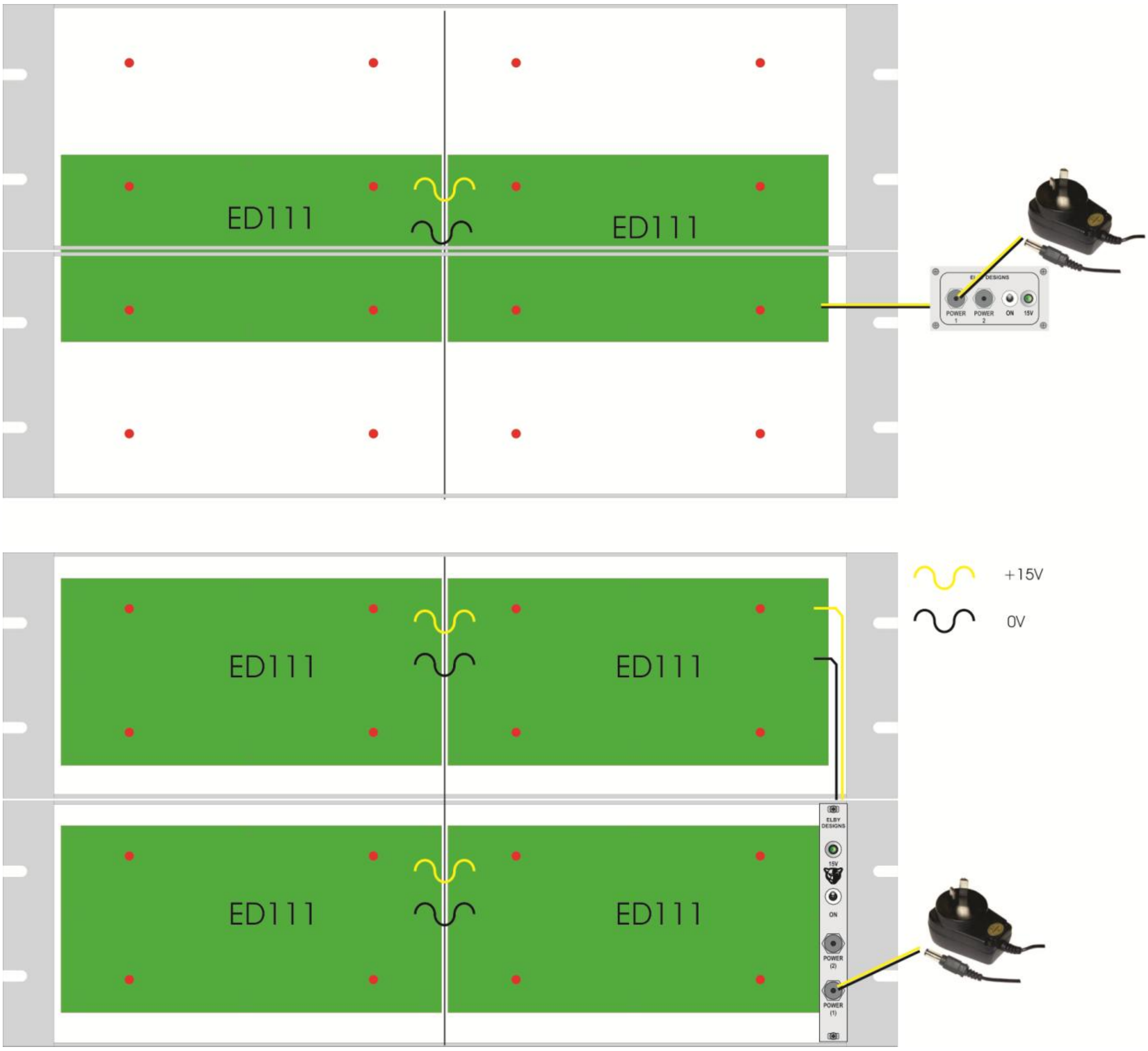


Figure 3 – the Elby Designs Active Distribution System

Figure 3 shows a couple of typical configurations for a 6U 84HP system. In the top arrangement, 2x ED111 busboards are mounted centrally in each 6U 42HP section of the system, providing a total of 24 fully regulated module outputs. The connection to the external power supply is via the ED111 Power Plate which is a small (64mm x 35mm) plate which can be mounted on the back or side of the system as desired. Power is input via a standard 2.5mm DC power connector. An ON/OFF switch and power status LED are included for user convenience.

In the bottom arrangement we have a full complement of ED111 busboards offering a total of 48 module outputs. This configuration also shows an alternate means of connecting to the external power by utilising the ED111 3HP Power Panel. Like the Power Plate, it uses a 2.5mm DC power connector and includes an ON/OFF switch and power status LED.

Both connector panels include a 2nd 2.5mm DC (*) power connector which is provided to allow for a power connection to a 2nd system. This is ideal for portable installation where it is desired that only one external power source is used for powering multiple systems (in principle, several systems can be daisy-chained this way but the limiting factor is the power rating of the 2.5mm DC power connectors and connecting cables which sets the limit in the order of 5A for the complete installation – for larger loaded system we recommend using 4-pin DC power connectors for which a mounting hole is provided at the back of each 42HP Desktop Skin).

Each module output is nominally rated to +12V @ ~500mA (**) and -12V @ ~300mA (**). The -12V total loading for a single ED111 is limited to a maximum of 1A. We also recommend limiting the total +12V loading to around 2A per ED111 but the boards have been designed to carry a much larger capacity (in excess of 7A). The size of the external power source is equivalent to the sum of the total loads for the +12V and -12V rails added together. So, considering the top arrangement in Figure 3, if each ED111 has a nominal total module loading of, say, +12V @ 2.4A and -12V @ 1.0A, then the total module loading is 2.4 + 1.0 = 3.4A. An allowance of an additional 1A should be added to cover supplementary loading such as that provided by the power supplies themselves. So the external supply should have a minimum loading of 3.4 + 1.0 = 4.4A

The design of the regulator circuits is such that the external power source may be a linear power supply or switch-mode power supply (SMPS) as the regulator circuits themselves are linear designs and offer the best quality power output irrespective of the external source quality (the only requirement for the external power source is that it have a minimum output voltage of 15V under full load. Output voltages in excess of 17VDC will result in the individual regulator circuits dissipating more heat and consequently may require the output ratings per module be derated accordingly).

Power dissipation is kept to a minimum by maintaining a low input-output differential voltage and by setting realistic load limits on the power rails. A 15V power source sets the minimum required input-output differential while the nominal ratings for each rail are initially set as follows:-

- +12V @ 500mA
- -12V @ 300mA
- 5V @ 200mA

These loads are PER MODULE and should be sufficient for all but the most power hungry devices. The ED111 circuits themselves are able to deliver significantly more than these figures, but doing so may increase the heat dissipation of the associated components, and this may need to be factored in to any system design. The recommended installation of the ED111 includes the use of our Carrier Plate. As well as reducing the number of mounting points required to mount the busboard into a case, the Carrier Plate also provides the ED111 with additional heatsinking capacity, further distributing any heat over a wider area which also helps to unify temperature profiles within a system.

A Mixed Active-Passive System

Where a user has only a handful of modules that are known to be 'power sensitive' and a fully active is not desired, it is feasible to combine both a passive and an active system together. In this manner, the active system supports a number of 'key' modules, and is combined with passive support for the 'non-sensitive' modules.

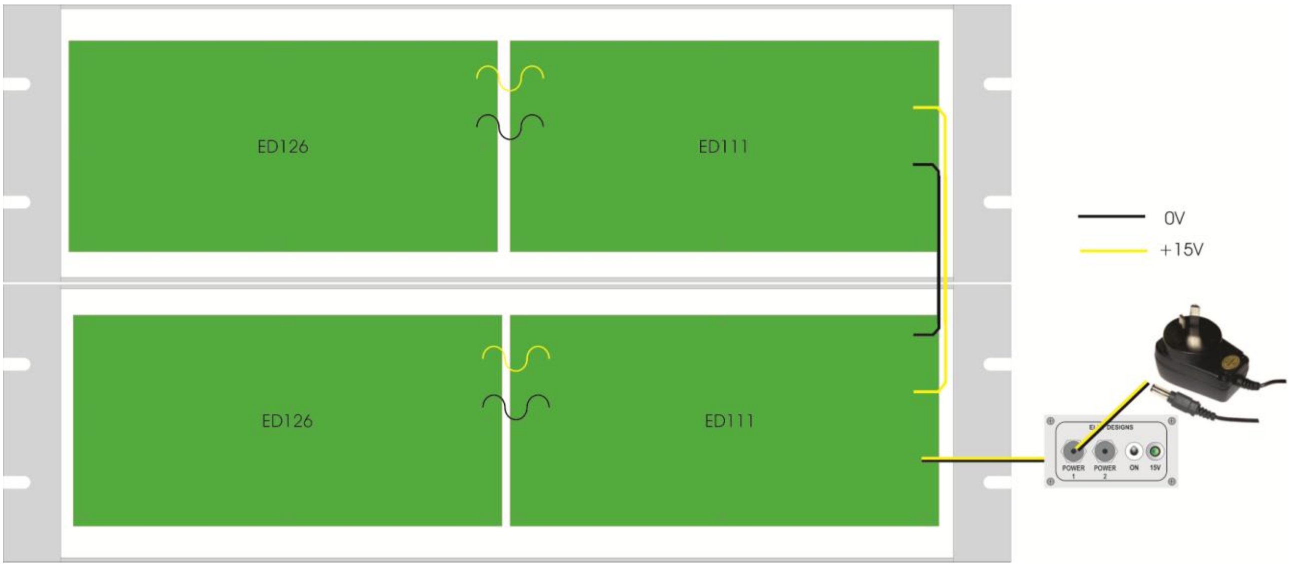


Figure 4 – A Passive-Active System (1)

Figure 4 shows such a combination. The ED111s provide the active module support while the ED126s provide the passive support. This arrangement provides 24 active outputs and 24 passive outputs.

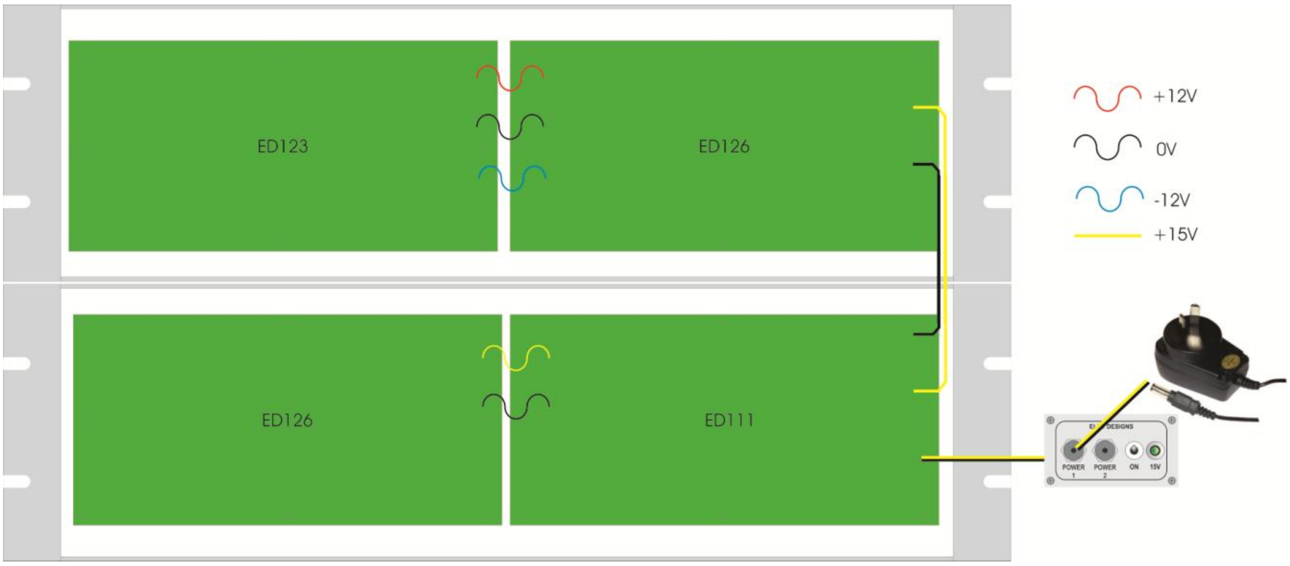


Figure 5 – A Passive-Active System (2)

Figure 5 shows another combination. This arrangement provides 12 active outputs and 36 passive outputs.

5V Power

There is often a need to provide a 5V power rail for one or more modules. Current solutions include installing a separate 5V power module to feed one or more busboards, or installing a small adaptor unit onto one of the power outlets that injects 5V back in to the busboard.

A separate power unit has the inconvenience of requiring additional wiring, and may require connection to a mains inlet for power. The adaptor unit has the limitation that it can supply only a limited amount of current while both solutions suffer from previously discussed problems including module interaction where excessive loading by one or more modules results in an unstable 5V rail.

The solution offered by Elby Designs is in the form of an inline adaptor. This adaptor simply connects in series with the power cable to your module providing the module with its own dedicated 5V supply. The adaptor is able to provide, typically, up to 500mA (**) and so should be adequate for all but the hungriest of modules. As the 5V supply is dedicated to the connected module, there is reduced possibility of interaction between modules through fluctuations in the 5V supply. Also, as long as the 16V power supply is adequately rated, installation of these adaptors for all relevant modules allows for a much greater 5V loading capacity than can be achieved through other means.

Where it is known that a minimal loading is required on the 5V supply and/or only 1 or 2 modules need 5V, then all 3 busboards offered incorporate a common 5V rail connection through the module outputs, allowing each busboard to share a common 5V supply. Our EURO-5V Adaptor has a factory build option of having a link installed to allow the 5V output to be fed back in to the busboard system.

IDC or KK Cables

In the EuroRack world the IDC ribbon cable is the common cable format used for power cables. Although the IDC offers a quick and cost-effective termination method (and thus making them suitable for DIY construction), they are not the ideal cable format for this type of application. The larger 5U format systems use a (much) larger cable format that uses a connector typified by the Molex KK family of connectors. These have a large wire gauge crimp terminal with, typically, a 4-pin connection with terminals spaced on a 0.156” grid. This larger cable/connector format provides a more ideal power cable, offering lower resistance per unit length and generally better immunity to noise pickup and radiation.

Although it is unlikely that EuroRack will ever change to this larger (or similar) format (***), it is still possible to build your system using these cables.

The IDC-KK adaptor is a small PCB (approximately 26mm x 21mm) that can be used to convert the IDC power connector on a EuroRack module to a KK connector. With the adaptor installed into the IDC power cable of your modules, you can then use higher-rated KK power cables to power your modules.

The use of KK cables can reduce voltage drops across longer power cable runs and also help reduce problems from radiated noise.

If a system utilises the CV/GATE/5V connections catered for on 16-way IDC power cables, then a 3-way 0.1" KK cable can also be fitted to allow modules access to these extra signals/power.

External Power Supplies (! See notes below)

All of the designs documented here show an external power supply in the form of a plug-pack or wall-wart. There a few reasons for this with the essential ones being:-

(1) Moving the mains voltage (90VAC to 240VAC) and low-frequency (50Hz to 60Hz) parts of the power supply outside the system improve the system's immunity to picking hum and stray voltages often generated by these components. Placing the transformer close to signal cables and DC power leads can result in induced low-frequency noise on the cables which can affect power stability and module performance
(2) Potential exposure to lethal, high voltages is eliminated, providing a safe environment not only for the equipment and modules, but also anyone coming into contact with the system.

Manufacturers and suppliers (****) of synthesiser cases and systems have a legal obligation to ensure that the equipment complies with the relevant electrical safety standards relevant to the country in which the equipment is sold. In Australia, for example, this is generally covered by the R-Tick standards, whilst Europe has CE approvals.

One of the aspects addressed by these standards is the safety of the equipment and the (in)ability of the user being able to make contact with any high-voltage points in the system. This would include, for example, the wiring and terminals for the power inlet, switches and/or fuses and terminations to transformers, and for any other mains power-related aspect. The standards also cover fault conditions and ensure that the user is insulated from these high voltages in situations such as faulty or broken wiring that could result in exposed wiring coming in contact with conductive surfaces such as the case or module parts.

By utilising a commercially available power pack that meets the relevant approvals, the concerns for the builder relating to these specific mains-related safety requirements are greatly eased.

(*) A larger power connector would have been more desirable but this would then require modifying the external power source which could impact any warranty on that product.
(**) Subject to change
(***) All Panther modules are designed with dual-footprint power connectors allowing them to be built with either the more common IDC header or a KK header
(****) Manufacturers only have the obligation for equipment manufactured and sold within their own legislative region. Suppliers (importers, resellers etc.) are obligated by the legislative laws in the country they import and sell to.
(!) The statements made here are very general and it is the responsibility of the reader to ensure that, when supplying equipment incorporating mains related componentry, they are fully aware of their legal obligations and legislative requirements for the equipment.

Adopting a standard?

There is no real defined standard for EuroRack power supplies but we have built all of our modules and busboards around the format defined by Doepfer, which is followed by many other manufacturers.

CONNECTOR DEFINITION:

A 16-pin IDC connector is used at both ends of the power cable connecting a module to a busboard.

Two connector parts are used in the system:-

1. Header, these are mounted on the busboard and modules
2. Socket, these are mounted on the interconnecting cable

The pitch between pins is 2.54mm.

The connector has 2 rows of 8 pins.

The header is boxed and has a polarising keyway.

The socket has a mating keyway and incorporates a cable strain relief clamp.

PIN DEFINITION:

Pin Numbers	Signal
1,2	-12V
3,4	0V
5,6	0V
7,8	0V
9,10	+12V
11,12	+5V
13,14	CV
15,16	GATE

When assembling, the IDC cable is always inserted in to the socket assembly <u>with the identifying marker (usually a red stripe) at Pin 1</u>.

Where space is at a premium, there is the option of using a 10-pin IDC Header at the module end, with this arrangement there is no access for the module to 5V, CV or GATE.

Active & Passive DC Distribution Systems

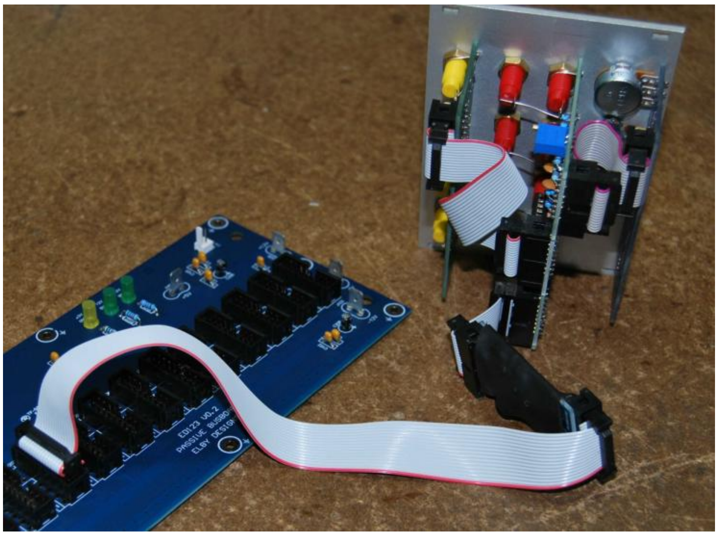
Although the definition provides for a +5V rail, this is provided mainly for backwards compatibility. It is strongly recommended that any module requiring a 5V supply generates this internally within the module, and that the +5V rail remains unused.

This could allow future systems to change the +5V rail into a +12V rail, thus more than double the loading capacity of the +12V rail and providing for improved busboard and power distribution layout.

To support backwards compatibility for modules that require an external 5V supply, only the insertion of an inline 5V adaptor into the relevant module’s power cable is required. Our EURO-5V Adaptors are ideal for this task and can supply, typically, up to 500mA. We offer 2 configurations:-

1) Module Only, and
2) Loopback

(1) The Module Only configuration is the recommend configuration and simply means that 5V is available to only the module that is connected to the output end of the adaptor. The module has access to the full power capacity of the adaptor.
(2) The Loopback configuration means that he 5V is ALSO fed back to the busboard so that any module connected to that busboard has access to the 5V rail. Obviously the total loading from all 5V modules must be less than the maximum rating of the adaptor.



The EURO-5V Adaptor installed

As the adaptor is an inline adaptor, you do not loose a power module outlet when using the adaptor. The adaptor simply connects between the busboard and the module.

Typical Passive Distribution Configurations

Below we show some example configurations using the ED123 and ED126.

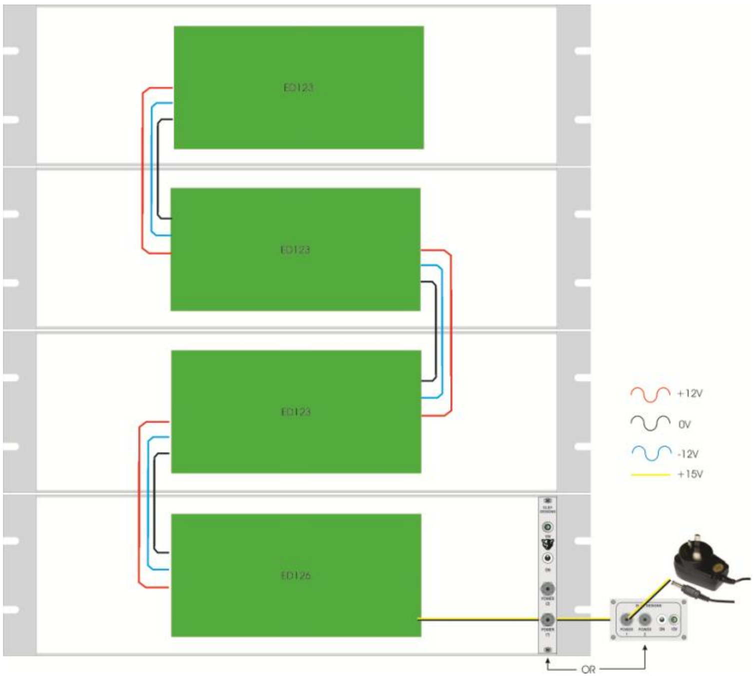


Figure 6a – 12U minimum power system

This example uses a single ED126 to feed a further 3x ED123 busboards, providing for a total of 48 modules with a maximum system loading of over 1.2A per rail.

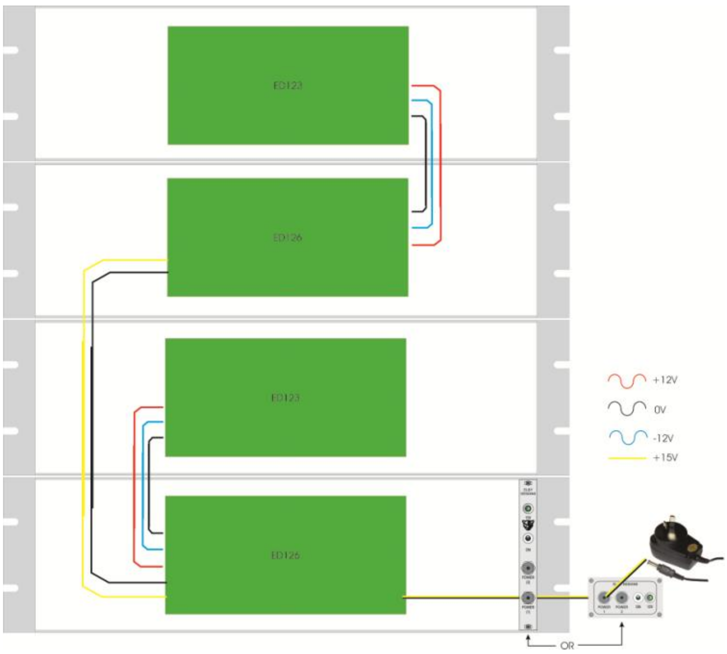


Figure 6b – 12U medium power system

In this example we use 2x ED126 and 2x ED123. Again we have support for up to 48 modules but this time the total system capacity is over 2A per rail. It is important to note that each ED126/ED123 combination is limited to around 1.2A per rail.

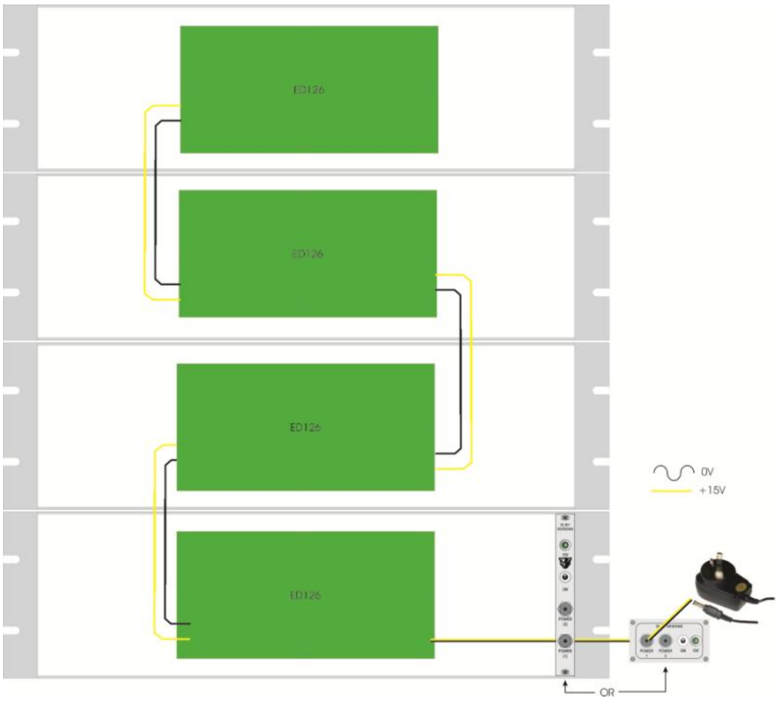


Figure 6c – 12U maximum power solution

In this example we use 4x ED126 to get a maximum system capacity in excess of 4.5A per rail.

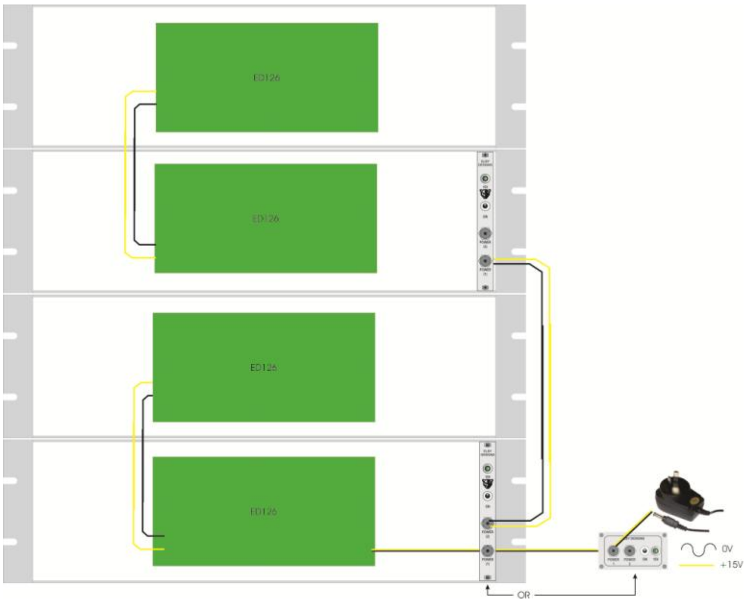


Figure 6d – 12U split system

In this last example we show a solution where you have a system that you may wish to split so that, for example, you can take one section out on the road. This solution separates the busboards into two groups, with each group having its own Power Panel. The 2nd Power socket on the Power Panel is then used to connect the external power supply to both sections. Each section has its own ON/OFF switch allowing for one section to be powered down when not in use to help conserve power. Although we show this system split in to two sections you could, of course, split the system further in to three or even four sections, each with its own power supply and Power Panel. In the above example, one ED126 in one or both sections can be replaced with an ED123.

All of these configurations will also work for 104HP and 126HP systems although you may need some longer power modules cables for the end modules in the 126HP configurations.

External Power Supply Rating

To determine the size of the external power supply:-

1. Add together the ‘total current loading’ of all modules in the system (add both the +12V and -12V loadings in to a single value). If used, add 300mA for each ED111 in the system
2. Multiply the ‘total current loading’ by 1.5 to get the ‘recommended running load’ for the supply.
3. Multiply the ‘total current loading’ by 2 to get the recommended ‘maximum loading capacity’ of the supply.

So if your system capacity is, for example, +12V @ 1.4A and -12V @ 700mA, then

1. ‘total current loading’ = 1.4A + 0.7A = 3.1A
2. ‘recommended running load’ = 3.1A x 1.5 = 4.65A
3. ‘maximum loading capacity’ = 3.1A x 2 = 6.2A

Your external power supply should, therefore, have a current capacity of between 4.65A and 6.2A. You should only select a larger capacity (> 6.2A) supply if you have calculated the ‘total current loading’ for the current selection of modules and that you intend, in the near future, to add additional modules to your system.

The ‘recommended running load’ has been calculated to allow for variations in the actual running load for things like peak surges due to, for example, LED switching.

Checking Power Ribbon Cables

Unfortunately not all Power Ribbon Cables are assembly correctly and it is important that you always check a cable the first time it is used. This simple test will identify good and bad cables:-

1. hold each end of the ribbon cable in your 2 hands
2. the stripe should be uppermost
3. the 2 IDC connectors should be hanging down
4. feeling with your thumbs and fingers the polarising bar should be on the left for both connectors

If they are then the cable is both mechanically and electrically correct and can be safely used on all systems irrespective of whether they use boxed or open headers. The stripe correctly identifies the -12V end of the connector.

Any other combination of tab orientations indicates an incorrectly assembled cable. Although useable on systems using only open headers, there will be a high risk of cables being incorrectly connected causing power problems and potential damage to your system components. You will also not be able to apply the basic rule "stripe at the bottom"*(*)*.

The bottom image shows the cable orientation while being checked.
The top image shows the cable flipped over so that you can see the polarising tabs and their orientation.

We would recommend you discard any cable that does not satisfy this simple check.

(*) This rule makes the basic assumption that ALL power connectors are vertical and have -12V at the bottom edge, this may not be the case for all modules or busboards.