

**Kilpatrick Format**  
**Technical Specifications**

**A Specification and Guide for Module Designers**

**Copyright 2014: Kilpatrick Audio / Andrew Kilpatrick**

**Written by: Andrew Kilpatrick**

## Table of Contents

Introduction.....	4
A Few Words of Welcome.....	5
Use of the Kilpatrick Format Specification.....	6
Naming Requirements.....	6
Keep Kilpatrick Audio Informed.....	6
Errors, Omissions and Suggestions.....	6
Physical Specifications.....	7
Module Stack-up Overview.....	7
Panel Material.....	8
Panel Retaining Screw.....	9
Module Power Plugs.....	10
Module Stack-up Details.....	11
Panel Dimensions and Thickness.....	12
PCB Dimensions and Thickness.....	12
Panel to Top PCB Spacing.....	12
Top PCB to Bottom PCB Spacing.....	13
Enclosures.....	14
Module Mounting Plate.....	15
Power Supply.....	16
Active / Passive Enclosure Interconnect.....	17
Connecting Multiple Active Enclosures.....	17
Power Wiring and Power Supplies.....	18
Analog and Digital Grounds.....	18
System Power Grounding.....	19
Power Supplies on Modules.....	19
Audio and Control Signals.....	20
Signal Impedance.....	20
Input and Output Voltage Range.....	20
Gates and Pulses.....	21
Audio and CV Signals.....	21
Indicator LEDs.....	21
Module Design Techniques.....	22
Module Power Supply Example.....	22
Pulse Input Circuit.....	23
+3.3V to +5V Pulse Amplifier.....	24
Bi-colour LED Driver.....	25

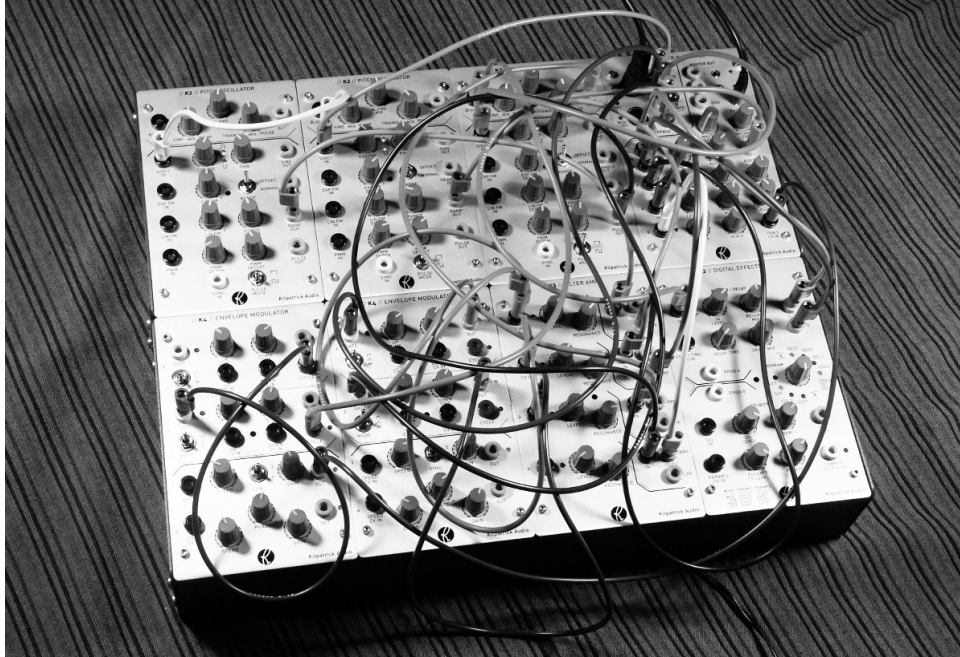
# Kilpatrick Format

## Technical Specifications



---

Split Supply Using an Opamp.....	26
Going Between AGND and DGND.....	27
Appendix A – Part Reference.....	28
Appendix B – Module Reference Drawings.....	29
Appendix C – Enclosure and Power Supply Drawings.....	29



## Introduction

The Kilpatrick Format is a unique and flexible modular synthesizer format with many useful features. The format can be applied to modular synthesizers, audio equipment, lighting and video system, and any system where low-power modules, straight-forward module design, high quality construction and easy module installation and removal is desirable.

### Main Features:

- **4U (7") panel height** - makes designing attractive and functional modules enjoyable
- **Easy Plug-in System** - makes installing and removing modules easy – no panel screws used
- **Simple module construction** – improves design work flow and removes guess-work – all modules fit all enclosures
- **Improved Electrical Properties** – 15V rails plus separate analog and digital grounds provide a better electrical environment for circuit designers
- **Banana Cables for Patching** – the use of standard banana connectors offer a high quality, stackable, colour-coded connector which is low-cost and easy to assemble on PCBs
- **Off-the-Shelf Components** – no custom connectors or tooling means parts are available from most distributors

### *A Few Words of Welcome*



*On behalf of Kilpatrick Audio I thank you for taking the time to get to know more about the Kilpatrick Format. After many years searching for the “ultimate” format for my own designs I developed the Kilpatrick Format to solve a number of problems I saw when designing for other modular systems.*

*After experimenting with 5U Modcan style and 3U Eurorack formats and being frustrated by both, I realized that 4U is the “right” size for modular synths. Buchla and Serge definitely had it right, and although I could have copied their proprietary formats, there were aspects that bothered me.*

*I finally came up with what I feel lends itself to easy module design. Products can be built in small quantities. (important if you want to offer a lot of modules on a built-to-order basis) It has good electrical characteristics, feels good physically, and uses all off-the-shelf parts which should make boutique designs somewhat future-proof. The enclosure and power supply design are low-cost and reliable.*

*I hope that you are inspired to make your own modules in the Kilpatrick Format and I look forward to seeing and hearing what you come up with!*

*Andrew Kilpatrick - 2014*

## Use of the Kilpatrick Format Specification

The goal of this specification is to encourage the use the Kilpatrick Format by both commercial manufacturers and DIY builders. Please follow the specification as closely as possible, or contact Kilpatrick Audio if your needs are not accounted for here. With so many low-quality products available for other formats, strict compatibility is necessary to maintain the quality of the system. If your goal is to make the cheapest possible products then please choose a different format. However, if you want to make excellent modules that are cost-effective and very high quality then you are probably in the right place!

### *Naming Requirements*

Somewhere within your advertised specifications, you must indicate that your product is a “Kilpatrick Format” module or accessory. Use of the name means that the module or accessory meets the requirements set out within this specification, or whichever version of the spec is current at the time you undertake your design. This help customers who purchase modules to know that they are getting a quality product that will work well with existing and future module designs from other manufacturers.

### *Keep Kilpatrick Audio Informed*

Use of the Kilpatrick Format is free of charge, but you must tell us if you release a module so that we can keep track of products available in the format. We will also offer a module swap service so that builders can put together nice systems at low cost. When you have a module ready let us know and we'll arrange to swap a module of similar value with yours. We hope you will extend this opportunity to other builders as well.

If you don't want to trade modules, sending some info that we can post on our website would be great also. We are interested in linking to both commercial and DIY sites if you want to become part of the family. Prospective buyers often ask what other modules are available.

### *Errors, Omissions and Suggestions*

Please help to improve this specification by reporting any errors, information that is missing or difficult to understand, and any other ideas that would help to improve it.

## Physical Specifications

The Kilpatrick Format is built around panels which are one or more *spaces* wide. A space is set as 1/4 of a rack width, and 4U (7") tall. Four spaces occupy one rack-mountable enclosure. Wider enclosures are possible, with 5 or 6 spaces being the most useful. Spaces are 4.250" x 7.000", but panels are manufactured as 4.240" x 6.990" to compensate for slight manufacturing tolerances and also alignment when the modules are plugged into the system. The dimensions should be reduced by 0.005" on each edge so that all holes, etc. are centered within the panel.

One and two space panels are the most useful sizes, although three and four spaces can be made as well. You must not make modules wider than four spaces because all modules should fit into a rack-mounted enclosure. The corners of modules are always rounded with a 0.125" radius to make them less sharp and also hide small alignment problems when the modules are sitting next to each other. If you have an idea for a huge module it might make more sense to break it up into several smaller designs.

### Module Stack-up Overview

Before we go into detail on the each part of a module, have a look at the following diagram which shows the components of a module as a section view. All modules are built with the same stack-up and spacing between layers.

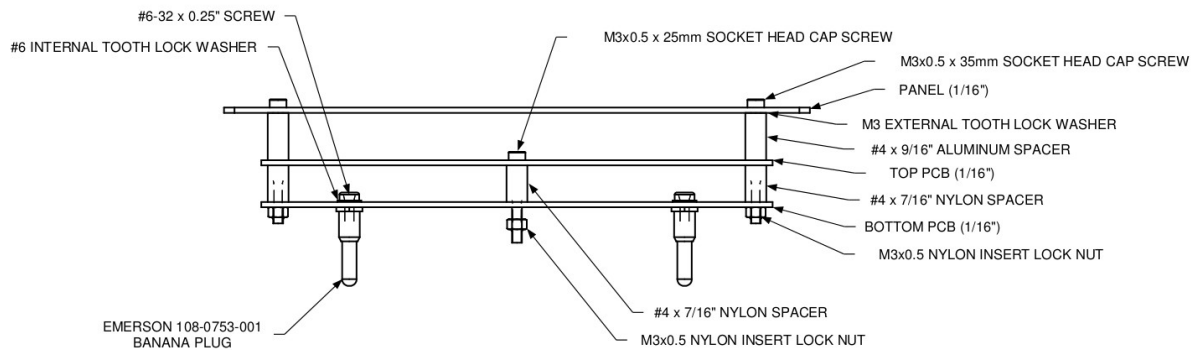


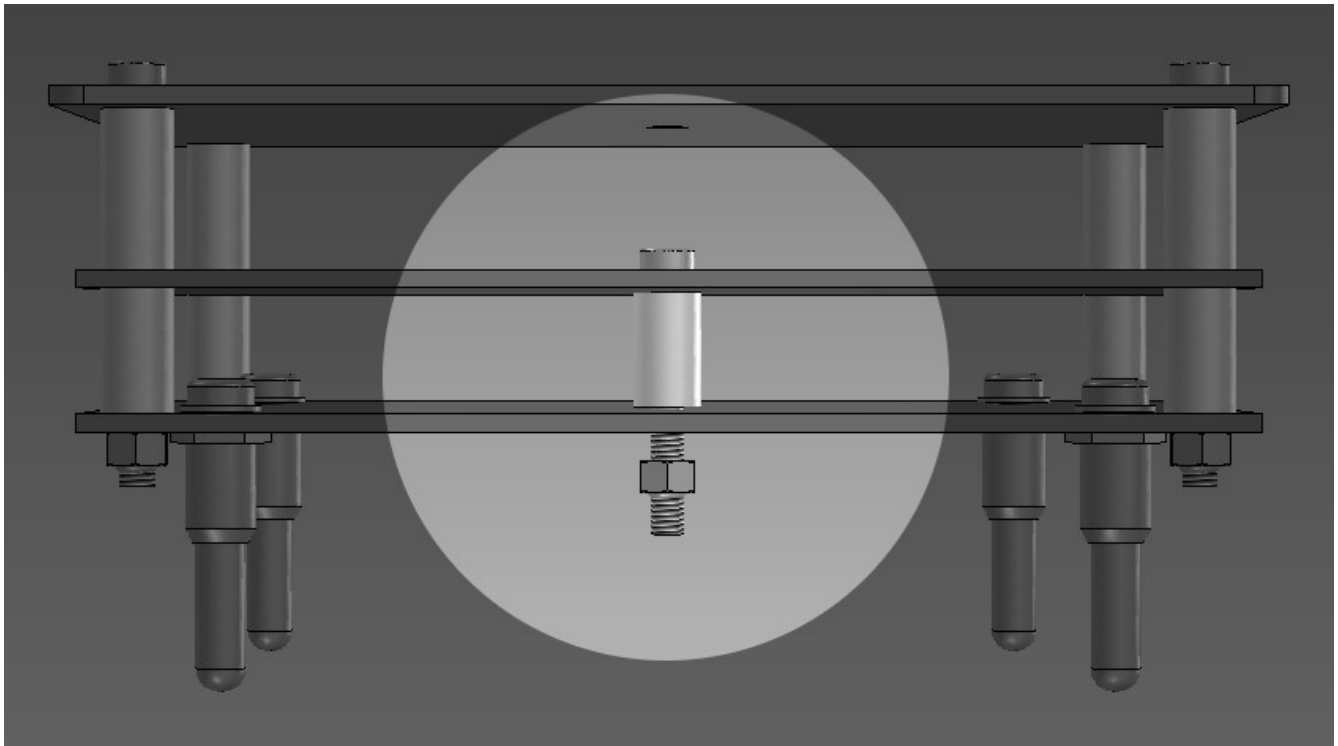
Fig 1 - Module Stack-up – Side View





### ***Panel Retaining Screw***

Below each module space in an enclosure is a blind M3x0.5 standoff used to secure a module to the enclosure. Each module must contain a captive M3x0.5 x 25mm hex head cap bolt that uses a 2.5mm hex key. The bolt is installed between the two PCB layers with a spacer between PCBs. The retaining feature is accomplished by a nylon insert lock nut underneath the PCB. A hole in the top panel gives access to the bolt. The module can be secured by gently tightening the bolt. When banana cables are pulled out many at a time, the bolt keeps the module from pulling out of the enclosure. In production the nut should be tightened part way to allow some play in the bolt. The spacer prevents over-tightening and damage to the PCBs.



*Fig 3 - Retaining Screw – Side View*

### Module Power Plugs

The main parts that secure a module into an enclosure are the power plugs. The plugs are male banana plugs of the same type used for panel patching. These are available as metal plugs supplied with #6-32 bolts which screw into the back of the plug. Four plugs are secured to the PCB using additional internal toothed lock washer on the top side of the lower PCB. Loctite blue (medium strength) is used sparingly on each bolt to help keep the bolts from loosening, but not enough to prevent good electrical contact as the bolts are used to couple power to the lower PCB.

The plugs supply the four power signals: +15V, -15V, AGND and DGND. Note that the AGND plug is aligned differently, thus providing a keying to prevent backwards installation.

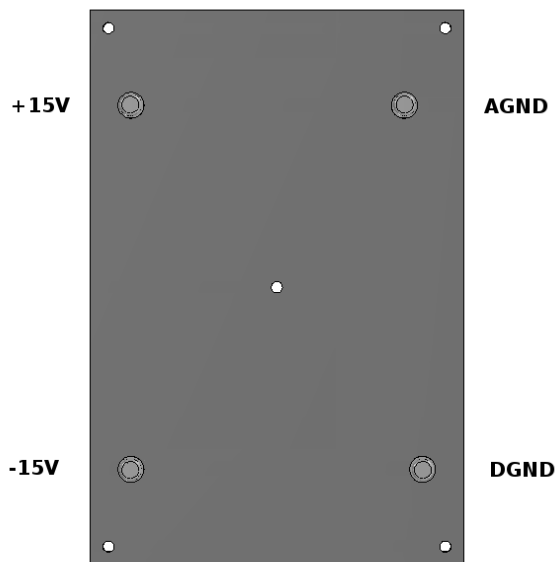
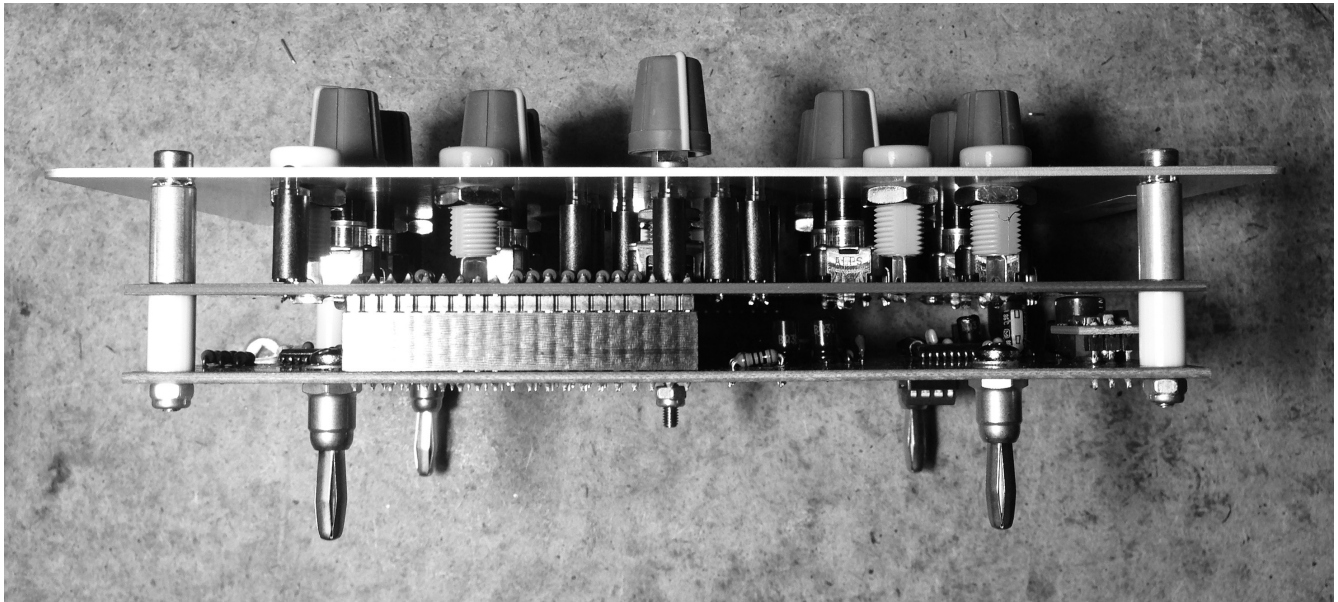


Fig 4 - Power Plugs – Bottom PCB - Top View

### ***Module Stack-up Details***

The module stack-up is integral to the physical robustness and overall height of a module. The module assembly is designed to use standard components and be easy to assemble. The spacing between the panel and PCBs is a compromise, but must be kept within a tight tolerance to avoid height problems when plugging the module into an enclosure.



*Fig 5: Module Stack-up - Side View*

#### **Notes about the photo:**

- LED spacers used throughout
- banana jacks metal tab soldered to top PCB through 0.197" hole
- 30mm pots and standard toggle switches can be used
- shorter parts and specialty displays, etc. should use daughter PCB mounted to top PCB

### ***Panel Dimensions and Thickness***

The panels are nominally 14GA aluminum 0.062" (1/16") thick. A brushing / anodizing operation usually removes a small amount of material. The overall dimensions of a single-space panel is 4.240" wide and 6.990" tall. Each of four corners is rounded off with a 0.125" (1/8") radius. Detailed drawings can be found in Appendix B of this document.

### ***PCB Dimensions and Thickness***

All PCBs are nominally 0.062" (1/16") thick. Including 1oz copper and a solder mask this thickness is actually about 0.067". The overall dimensions of a single-space PCB is 4.100" wide and 6.100" tall. Detailed drawings can be found in Appendix B of this document.

Wider PCBs can be made for modules of 2-4 spaces. In the case of wider modules some of the power connections can be omitted. For instance in a 3 space module power plugs are used on space 1 and 3 but not in the center (2) space. Similarly only two retaining bolts are used.

### ***Panel to Top PCB Spacing***

The spacing from the panel to the top PCB is nominally 0.562" (9/16") plus the thickness of an M3 external tooth lock washer. The overall height is approx. 0.587". Round, un-threaded aluminum spacers are used between the panel and top PCB to create a ground connection to the top panel. The external tooth lock washer ensures a good connection since anodized panels are non-conductive on the surface. The metal panel is always connected to AGND so that the entire system is shielded.

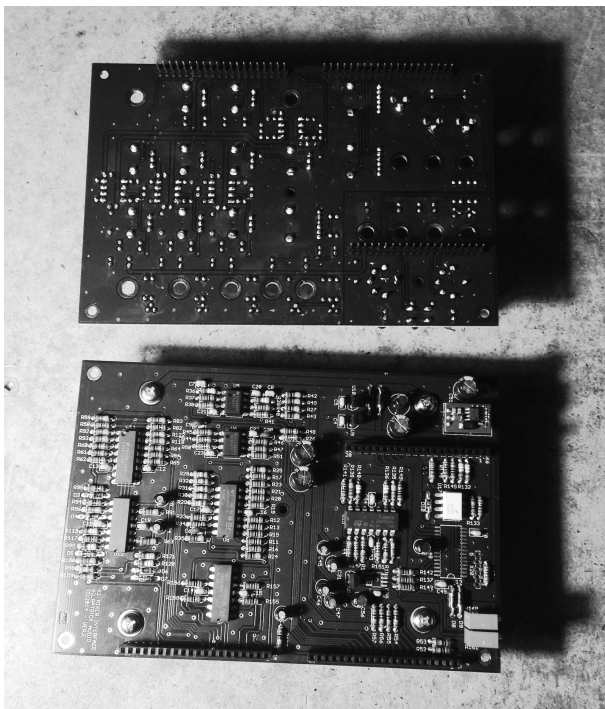
The spacing from the panel to the top PCB allows standard Emerson banana jacks to be soldered to the top PCB. It also allows the use of standard mini toggle switches. For shorter components like pushbuttons, etc. a small sub-assembly PCB may be required to support these types of components closer to the panel. How this is implemented is up to the designer.

### ***Top PCB to Bottom PCB Spacing***

The spacing from the top PCB to the bottom PCB is nominally 0.437" (7/16") Nylon spacers are used between the top and bottom PCBs for low-cost. A spacer is required in each of four corners plus one in the center where the retaining screw is held captive.

Connecting signals between the top and bottom PCBs is possible by using standard 0.100" stacking header connectors. Kilpatrick Audio uses 20 pin single-row connectors on all designs. The possible location of the headers is chosen per design. Alternately a dual-row header could be used for denser modules. The combination of a standard male and female header results in precisely 0.437" (7/16") spacing between PCBs.

When choosing stacking headers, the male header protrudes from the bottom of the top module, and the female header protrudes from the top of the bottom module. This ensures that during prototyping, assembly and testing, sensitive circuits on the bottom PCB do not have their pins exposed. Top PCBs usually only contain passive parts and LEDs.



*Fig 6: Module Stacking Headers*

## Enclosures

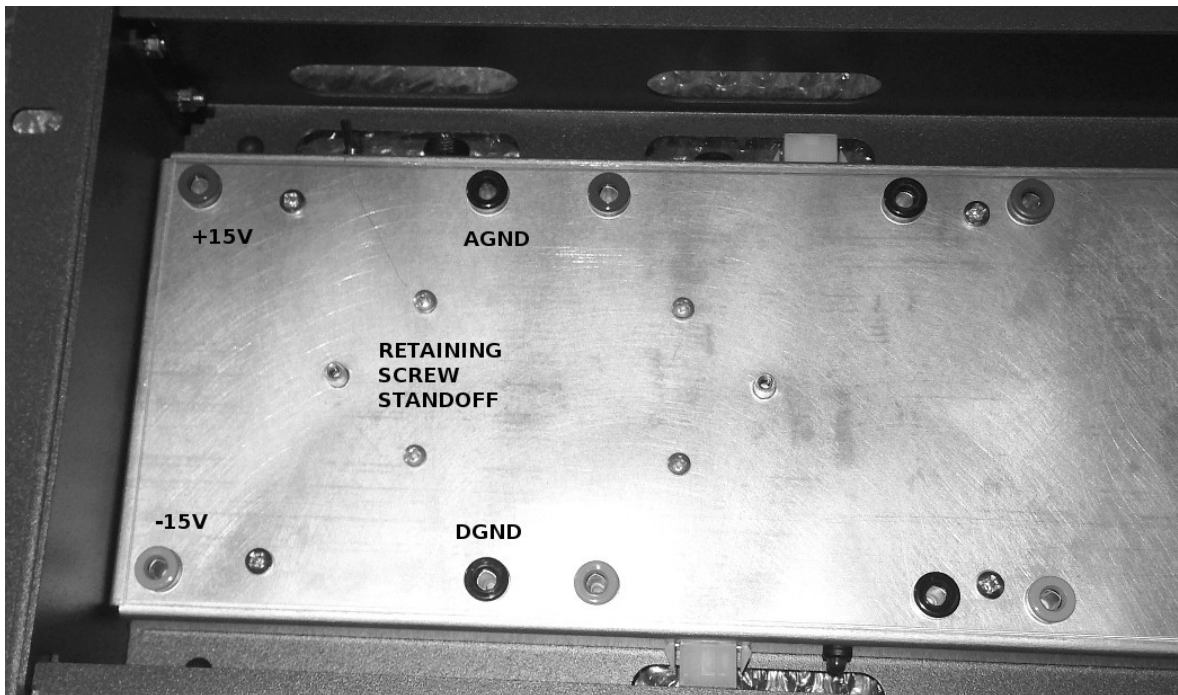
Enclosures are designed to be low-cost and easy to manufacture in small quantities. The existing Kilpatrick Audio enclosure and power supply design is offered for use free-of-charge and drawings are available in Appendix C of this document. These included drawings are for reference only. For the latest drawings including DXF or IGES files of the enclosure for metal manufacturers please contact Kilpatrick Audio or see our website for download info.



*Fig 7: Enclosure - 4 Space Active Enclosure*

### **Module Mounting Plate**

The main part of the enclosure serves only to cover the sides of the modules and provide mounting points to attach rack ears or stacking brackets for connecting two enclosures together. The important interface between the modules and the enclosure is through the *module mounting plate*. This part is mounted in the bottom of the enclosure on 0.875" (7/8") standoffs which provide an electrical connection to the main enclosure, as well as supporting the plate at the correct height for modules to be installed. #6 internal tooth lock washers used between the top and bottom screws and the metal ensures a good electrical connection so that the entire chassis is grounded to AGND.

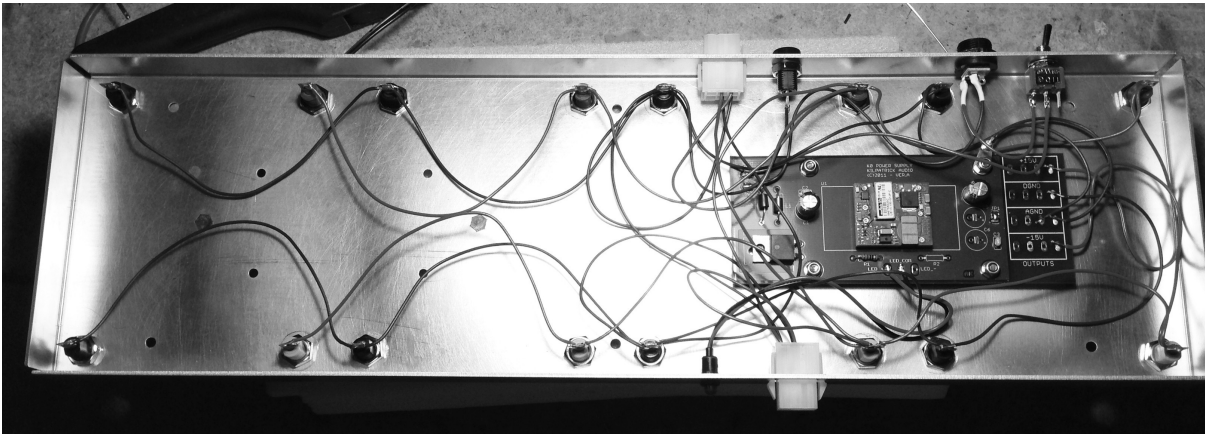


*Fig 8: Module Mounting Plate - Top View*

#### **Notes about the photo:**

- banana jack colours are:
  - +15V = red
  - -15V = grey
  - AGND and DGND = black

Underneath the plate is ample room for wiring the module power jacks, inlet power socket, switch, power LED, and the actual power supply PCB. The power supply is mounted upside-down on the underside of the module mounting plate which protects it and the associated wiring.



*Fig 9: Module Mounting Plate Underside - Active Type*

### **Power Supply**

The power supply is a very simple module using an off-the-shelf DC-DC converter. The power input must be regulated +15V and is simply passed through a reverse polarity protection diode (Schottky type) and filtered. This raw supply is fed to the +15V jack on every module. The on-board DC-DC module produces -15V with 10W max. output. This is filtered and fed to the -15V jack on every module.

This scheme offers limited -15V power (but plenty for most designs) but allows the +15V supply to be increased simply by using a larger external power supply. For digital modules that contain embedded computers, for instance, it might be necessary to have many watts of power on a single module. The most economical route to this is to allow the end-user to upgrade their external adapter. A 24W unit is supplied by Kilpatrick Audio and is suitable for up to eight modules. The typical wiring in a system should handle +15V at 40-60W (3-4A) without any trouble. The input protection diode for the system is rated for up to 7.5A, and designers who wish to build their own power supplies should keep in mind that users may want to upgrade their +15V power supply at a later time for higher power use.

**Note:** The use of ungrounded (2-wire) external power supplies is preferred over grounded types. (more on this below)



### ***Active / Passive Enclosure Interconnect***

The enclosure is designed with front/rear and bottom cutouts to allow flexibility in wiring the DC power and inter-enclosure power cables. Normally two enclosures are used together. The top one contains the power supply and is called the *active* enclosure whereas the bottom enclosure is *passive* and contains wiring only. Connectors on the module mounting plate allow a short cable to be attached to the front or rear of the plate. Four wires are needed to connect active and passive enclosures together. For very low-power modules such as MIDI controllers, it might be possible to connect two or even three passive enclosures to a single active enclosure. Passive enclosures can be installed above or below the main enclosure, but generally they are installed below because this allows better access to the power input jack and power switch on the rear of the active enclosure.

An important note about grounding is that the digital ground (DGND) from all modules and enclosures is returned to the power supply PCB where it is connected to analog ground (AGND) at a single point. This prevents ground loops and noise from being injected into sensitive circuits. AGND and DGND must never be tied together except at the power supply PCB of an active enclosure.

### ***Connecting Multiple Active Enclosures***

If a system grows beyond eight modules it is likely to require more than one active enclosure. In this case it is necessary to connect the ground between the two systems. A black banana jack is provided on the rear of each enclosure which is internally connected to AGND. A standard banana patch cable can be used to connect multiple sets of enclosures together. Each active enclosure requires its own external power supply.

## Power Wiring and Power Supplies

Power wiring within a system uses a simple methodology which keeps wires short. In most cases the wiring between modules within a single enclosure are daisy-chained. These groups of jacks are then attached to the connectors which feed to the next and previous enclosures, and to the power supply in the case of an active enclosure.

The topology is not particularly important for the most part. The most crucial aspect is that analog ground (AGND) and digital ground (DGND) must be kept separate throughout an entire system and only joined together at a single point within the power supply. Systems with multiple powered enclosures must have their analog grounds connected together. Each module has an analog ground connection (banana jack) on the back of the enclosure for this purpose.

### *Analog and Digital Grounds*

For optimum CV and audio performance it is crucial that noisy signals and larger loads which switch on and off not be allowed to interfere with sensitive signals. Because banana cables are a single wire, the signal return (analog ground) is provided inside the enclosure. Thus any noise on the internal return will be added to the patched signal. Large or noisy loads within a module that draw current in and out of the ground connection will cause voltage drops on the ground wiring within a system which will be added to CV and audio signal paths.

The Kilpatrick Format system uses separate analog and digital grounds (AGND and DGND) to solve this problem. Analog grounds are used for signal returns, references for analog circuits, ADCs and DACs, and other low-noise circuits.

Digital grounds are used for noisy circuits such as DC-DC converter grounds, microcontroller power supplies, LED grounds and other loads that could be noisy. In most cases it is easy to keep these two grounds separate except in a few cases which will be covered in detail in the **Module Design Techniques** section.

Power supplies (+15V and -15V) are shared between both analog and digital circuits. These supplies are also not guaranteed to be quiet or particularly well regulated meaning that they should never be used to directly power sensitive circuitry. Instead every module uses local voltage regulators and power supplies to deliver voltages to the various stages. A typical hybrid module containing both analog and microcontroller circuitry might have the following supplies:

- +12V and -12V linear voltage regulators for op amp supplies –fed from +15V and -15V
- +3.3V DC-DC buck converter for microcontroller power supply – fed from +15V
- +3.3V linear regulator connected to the +12V supply for ADC and DAC power supplies

### ***System Power Grounding***

One flaw of many modular systems is the use of a grounded power cord. Although this may be required for regulatory purposes, it often causes ground loops and hum in typical systems. Almost always a user will have a computer and/or a mixing console which will be grounded to the electrical supply. (third prong) Kilpatrick Audio uses power supplies that require only two wires. The audio cables provide a ground reference from the studio mixing console, and no ground loops exist within the system.

In higher power systems where a two prong power supply is not possible, or where the synthesizer is the central mixing point for an entire system it may be preferable to use a grounded power supply. But generally power supplies with 2-prong input plugs will offer the best noise and hum performance in a typical setup.

### ***Power Supplies on Modules***

It is important that the voltage drop and tolerance of the main power supply and linear regulators on modules be taken into account. Kilpatrick Audio modules use Schottky diodes on both the main power supply and also the +15V and -15V inputs on each module. This offers minimal voltage drop and permits the use of standard linear voltage regulators for +12V and -12V.

For +3.3V linear supplies for DACs and the like, using the +12V regulated supply will enable more choices of low voltage regulators as they have to withstand a lower maximum input voltage than if they were fed from the +15V input.

Input filtering on modules should be moderate to avoid excessive capacitance on the supplies for a full system. Particularly on the -15V side, many DC-DC converters have a maximum capacitance they can handle on the load. Kilpatrick Audio uses 100uF for the +15V supply on each module and 10uF for the -15V on each module. These capacitors are installed after the input protection diodes. As the input is already smooth DC this has proven more than adequate.

## Audio and Control Signals

Audio and control signals are interchangeable on a Kilpatrick Format system. There are two types of signals and four types of jacks. The jack colours used on modules must follow the same standard. Additional colours can be used for jacks which serve a different purpose such as interfacing other kinds of non-audio or CV signals.

- **Gate / Pulse Signals** – A gate or pulse signal is 0V when off and 5V when on. These are output on red banana jacks and input on white jacks. Inputs should be set up to trigger when the voltage is above about 1V.
- **Audio / CV Signals** – Audio and CV signals range from about -5V to +5V nominally. These signals are output on grey banana jacks and input on black jacks. An oscillator or LFO should output a 10Vpk-pk signal. (-5V to +5V) The center point in the range of an input is 0V, thus when a cable is disconnected the input should be terminated so that it defaults to 0V.
- **Pitch CV Signals** – Pitch signals calibrated to musical pitch are specified as 1V/octave. 0V is the centre of the range, with +5 and -5 octaves (volts) possible.

### *Signal Impedance*

All outputs must have an output impedance of 1K ohm or less. A 1K series resistor is the most common way to lead a signal out to a jack. For pitch outputs specifically the output impedance should be 100 ohms. This helps to avoid tuning errors with pitch oscillators.

All inputs must have an input impedance of 20K ohms or more. Generally 30-50K is best as this allows multiple inputs to be fed from a signal output without appreciable loss of signal level. Pitch V/octave inputs on oscillators should have an input impedance of 100K or more.

Grounded when off: All outputs should be grounded when the circuit is off. This is especially true for modules that interface with other audio equipment such as mixers and interfaces. Trace back the signal from the output to ensure that it has a resistive path to ground of less than a few hundred K ohms. If not be sure to terminate the output. Ensure that the output termination does not introduce unwanted voltage drop at the output jack.

### *Input and Output Voltage Range*

Signals are nominally -5V to +5V. However a typical TL084 or similar op-amp running off a +/-12V supply can produce outputs of at least -10V to +10V. This range of voltages is completely acceptable in the case of a circuit which adds gain to a signal.

Inputs should be designed to withstand -15V to +15V without damage. Inputs with attenuators can accept any voltage range and allow the user to adjust the sensitivity of the input. Inputs without attenuators should be carefully set up so that an input of -5V to +5V cause the full range of desired

control. If in doubt a slightly smaller range which clamps at the endpoints is more desirable than a wider range which requires a larger input signal to reach all possible input values.

### ***Gates and Pulses***

A gate is used for controlling an envelope generator or other type of input which is held in an “on” state while the gate is high.

A pulse is used to trigger a condition like causing an event to occur or restarting a sequencer. A pulse should be high for at least 1ms to allow the receiving device to “catch” it.

### ***Audio and CV Signals***

An audio signal is at the nominal level when it is 10V<sub>pk-pk</sub>. This offers the best noise immunity however the headroom is limited to only about 6dB. Filters, mixers and other modules that increase the signal level should be designed to “save” some headroom by attenuating the input signal internally.

An envelope or other signal which has a range of lowest to highest value should range from -5V to +5V, with -5V being the “at rest” state in the case of an envelope generator. This may seem odd but it maintains compatibility between all kinds of signals. When an envelope is triggered it rises from -5V, through 0V to +5V and then back down again. VCAs and VCFs should be designed to handle this range of input. This solves a common problem on other systems where there are both unipolar and bi-polar signals which are not inter-compatible.

### **Indicator LEDs**

Although the display and user interface choice is up to the designer, several LED colour standards have been adopted by Kilpatrick Audio to help differentiate various signal types. It is not mandatory to use the same colours but it might help to make a module seem more familiar along side other modules.

- **Red LEDs** – For modes, on-off settings, pulses and gates generally red LEDs are used.
- **Clear amber LEDs** – For audio signal levels clear amber LEDs are used to show the relative level.
- **Bi-colour red/green LEDs** – For bi-polar signal indicators on envelope generator outputs or other circuits where the amplitude and polarity of a signal is important a bi-colour LED is used. Red means negative and it gets brighter with more negative signal. Green means positive and gets brighter with more positive signal. At 0V neither LED is lit. A two-lead LED is used with back-to-back LEDs so that it can be easily driven from a signal op-amp output.

## Module Design Techniques

Good module design techniques and “best practice” rules will help to ensure maximum compatibility between modules from different manufacturers. Some tips and tricks are shown here which might be useful. Some are just good engineering practice and others were devised for the Kilpatrick Format and seem to work well.

### Module Power Supply Example

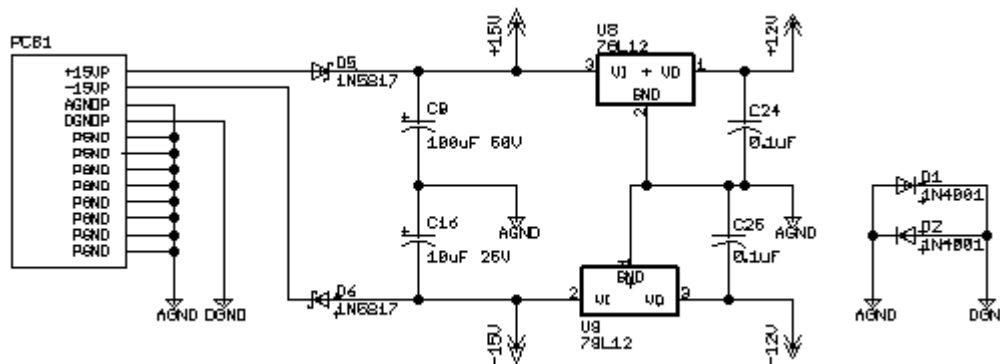
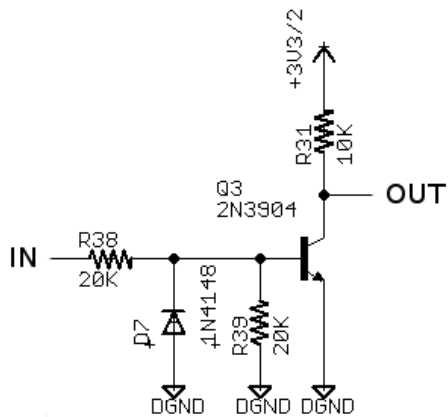


Fig 10 - Power Supply - Example +/-12V

#### Notes about the example:

- D5,6 are Schottky diodes for minimal voltage drop
- C16 is 10uF to prevent too much capacitance on -ve supply
- D1,2 help to protect the module in case one of the grounds is missing – standard silicon diode is used for low capacitance (10pF for a 1N4001)

### *Pulse Input Circuit*



*Fig 11 - Pulse Input Circuit*

#### **Notes about the example:**

- input resistors set the input impedance at approx. 40K and also shift the threshold voltage to just over 1V for a typical small signal transistor
- diode prevents negative base voltage
- transistor collector can be pulled up to whatever voltage the output needs
- output signal is inverted

### +3.3V to +5V Pulse Amplifier

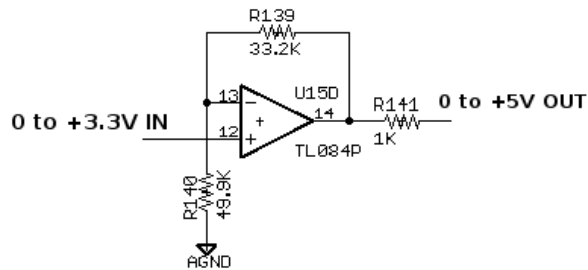


Fig 12 - +3.3V to +5V Pulse Amplifier

#### Notes about the example:

- input and output are in phase
- different configurations can be chosen for different gain and offsets
- a simple unity gain buffer can be used for +5V signals



### Bi-colour LED Driver

For a bi-colour LED driver it is easy to use an op-amp to drive an LED. Usually a separate amplifier is used for the LED because the load changes depending on whether the LED is in conduction or not. This could cause distortion if the same amplifier were used for signal output as well. In many cases, however simply using a single amplifier is sufficient.

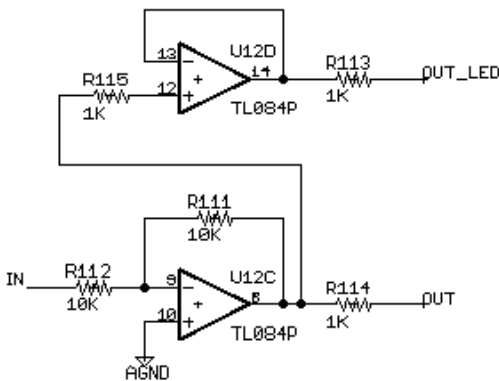


Fig 13: Bi-colour LED Driver with 2 Amps

**Note:** Most of the circuitry driving a bi-colour LED will be referenced to AGND. However the cathode of the LED should be tied to DGND. This prevents the large LED current from returning into AGND and potentially causing voltage drops on signal returns.

### Split Supply Using an Opamp

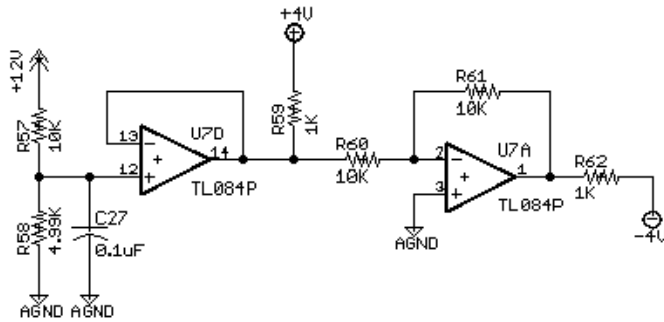


Fig 14: Split Supply Op-amp Circuit

#### Notes about the example:

- for making low current split references
- useful for powering 4000 series CMOS muxes which require <20V
- voltage is easily adjusted with a resistor divider
- small filtering and bypassing should be used at loads

### ***Going Between AGND and DGND***

When going between AGND and DGND references it is important to avoid a condition where the two supplies are at very different voltages. To protect against this condition in case of a missing power connection, modules which use both AGND and DGND include a pair of back-to-back 1N4001 silicon diodes between grounds. These diodes have very low capacitance to avoid coupling noise between grounds, and also require an imbalance of around 0.6V in either direction before they will conduct.

For ADC and DAC digital signals connecting between microcontrollers or DSPs (on DGND) and the converters (on AGND) some series resistors (100 ohms works for speeds up into the MHz) will prevent excessive current flow in case the chip supplies on each side are not equal. This is also good practice to help absorb reflections and minimize EMI.

### Appendix A – Part Reference

Type	Manufacturer	Manufacturer Part	Notes
pot – single gang	Alps	RK09D1130A1N	most standard pots
pot – stereo audio	Alps	RK12L12C0A0G	stereo volume pots
3mm amber LED	Lite-On	LTL1CHKYKNN	signal levels
3mm red LED	Lumex	SSL-LX3044LID	pulses, gates, modes
3mm red/green LED	Kingbright	WP937EGW	bi-polar indicators
+12V regulator	ON Semiconductor	MC78L12ACPG	analog supply
-12V regulator	ON Semiconductor	MC79L12ACPG	analog supply
small pushbutton	TE	FSM16JH	configuration, resetting, test
LED spacer (0.500")	Bivar	LTM-500	all LEDs
stacking header (male)	FCI	68001-220HLF	board to board
stacking header (female)	Sullins	PPPC201LFBN-RC	board to board
banana jack (black)	Emerson	108-0903-001	audio / CV input
banana jack (grey)	Emerson	108-0913-001	audio / CV output
banana jack (white)	Emerson	108-0901-001	pulse / gate input
banana jack (red)	Emerson	108-0902-001	pulse / gate output
banana plug (module power)	Emerson	108-0753-001	module power pin
3.5mm minijack	CUI	SJ5-43502PM	audio / headphone interface
5 pin DIN jack	CUI	SD-50BV	MIDI interface

## Appendix B – Module Reference Drawings

Module reference drawings are offered to help develop modules quickly and accurately.

**Note: These files come with no warranty and should be used as reference only. It is up to the user to verify accuracy before any design or manufacturing.**

- `kilpatrick-module_ref-verA.zip` – module / panel templates and PCB library

## Appendix C – Enclosure and Power Supply Drawings

The following documents are available regarding enclosures and power supplies. These are free to use as long as they are not made or sold as Kilpatrick Audio branded products.

**Note: These files come with no warranty and should be used as reference only. It is up to the user to verify accuracy before any design or manufacturing.**

- `andrew_enclosure-verC.zip` – 4 space rack enclosure design
- `KO-power_supply-verA.zip` – power supply to be used with 4 space enclosure
- `andrew_enclosure_wiring-verA.zip` – enclosure wiring diagrams and example photos