Oakley Sound Systems

5U Oakley Modular Series

Dual Comparator and Gate Delay

CV and Audio Processor

PCB Issue 2

Builder's Guide

V2.1

Tony Allgood
Oakley Sound Systems
CARLISLE
United Kingdom

The suggested 1U wide panel layout for the issue 2 Dual Comparator and gate delay module.

Introduction

This is the Project Builder's Guide for the issue 2 Dual Comparator and Gate Delay 5U module from Oakley Sound.

This document contains a basic introduction to the board, a description of the schematic, a full parts list for the components needed to populate the boards, and help with the various interconnections.

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.

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 generic Construction Guide at the project webpage or http://www.oakleysound.com/construct.pdf.

The issue 2 PCB

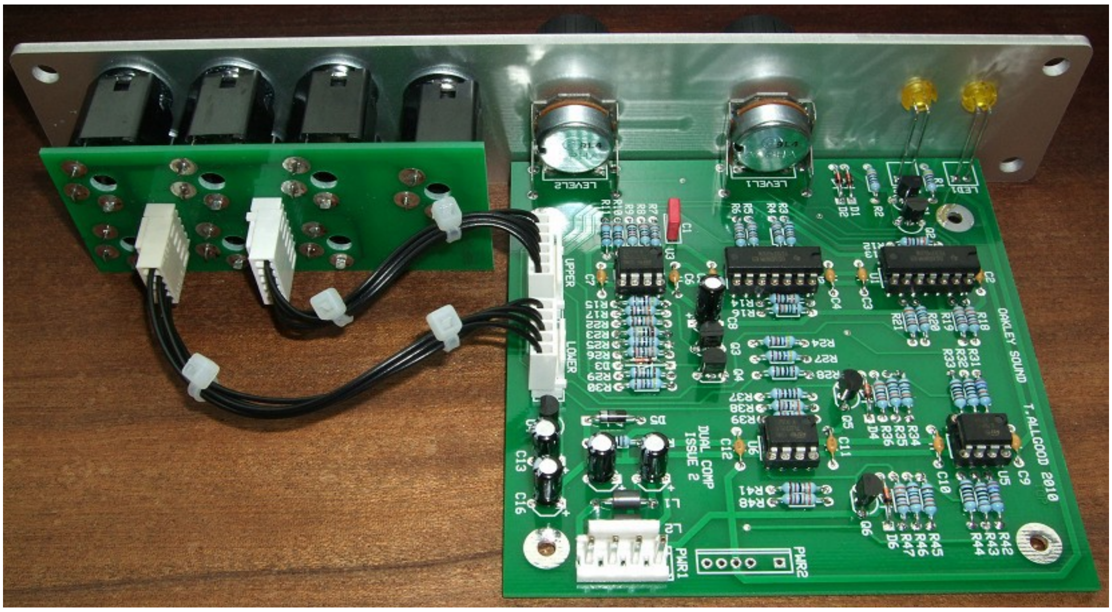
The main PCB is 104mm x 104mm in size. Both boards use double sided copper traces and have through plated holes. The solder pads are large and are easy to solder and de-solder if necessary. They have a high quality solder mask on both sides for easier soldering, and have clear legending on the component side for easier building.

If you are building the standard design there are no components mounted off the boards. All components including sockets and pots are soldered directly to the boards.

Previously, many Oakley modules have had the sockets, switches and extra pots wired to the board by individual wires. This module allows all the socket wiring to be done via the socket PCB and two MTA solderless or Molex connections. If you are building this module in the standard Oakley format this new system will reduce assembly time and possible wiring errors.

Some people will wish to use this Oakley design in a non standard format, such as fitting it to another manufacturer's rack or one of their own invention. This is perfectly easy to do. Simply do not use the socket board and wire the main board to the sockets as per usual.

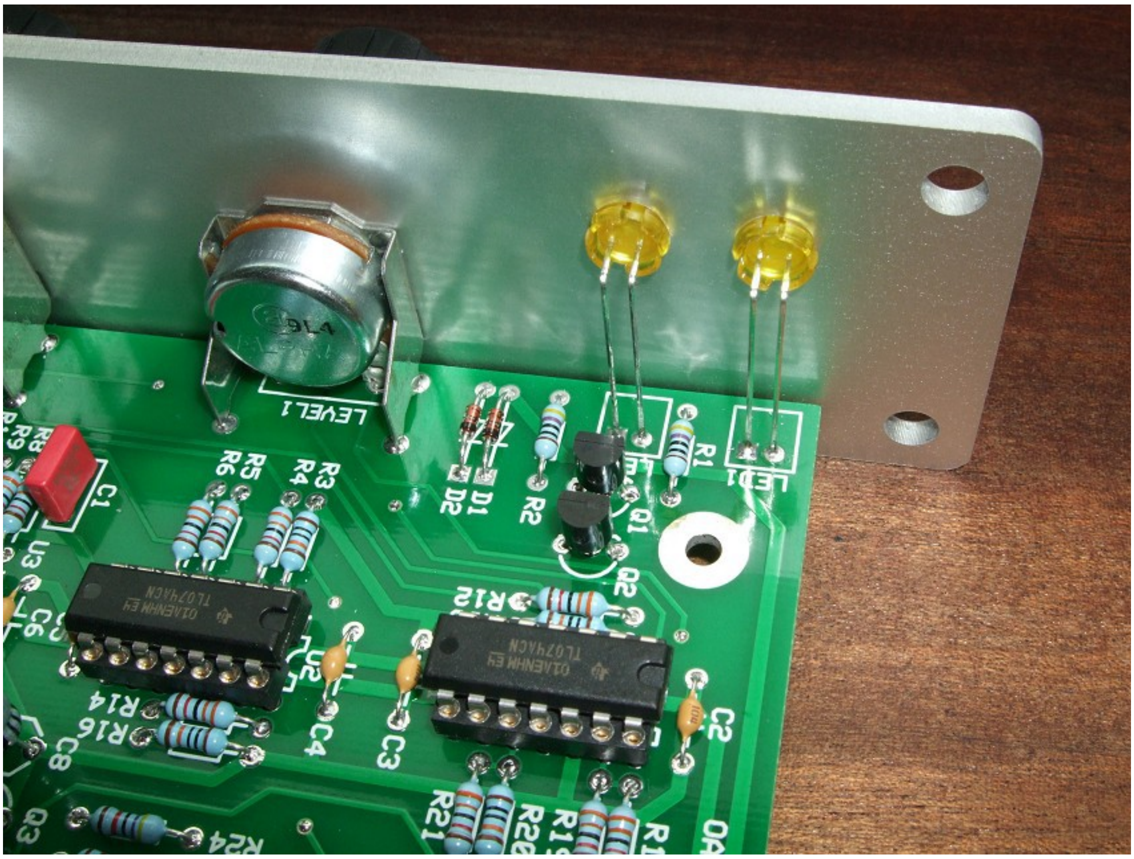
I have provided space for the two control pots on the PCB. These can be mounted away from the PCB, but in the standard build they form part of the mounting process. If you use the specified pots and brackets, the PCB can be held very firmly to the front panel. The pot spacing is 1.625" and is the same as MOTM modular synthesiser. The board is fully MOTM panel compatible if the board is fitted vertically, ie. in a 1U wide panel. Four M3 sized holes are provided on the main PCB for supporting the board if you choose to use other methods of mounting.



The issue 2 Dual Comparator module fitted behind a 1U wide natural finish panel. Note the use of the special socket board to facilitate the building of the unit. I have used Molex KK 0.1" headers and housings for the interconnections in this project. The power header is our usual MTA156.

Power supply requirements

The design requires plus and minus 15V supplies. The power supply should be adequately regulated. The current consumption is about 35mA for each rail. Power is routed onto the PCB by a four way 0.156” MTA156 type connector or the special five way Synthesizers.com MTA100 header. You could, of course, wire up the board by soldering on wires directly. The four pins are used on the four way header are +15V, ground, earth/panel ground, -15V. The earth/panel connection allows you to connect the metal front panel to the power supply’s ground without it sharing the modules’ ground line. More about this later.



A close up of the LED mounting technique I use. These are standard 5mm yellow LEDs fitted into Maplin's Cliplite lenses.

Circuit Description

There are three main circuit blocks within the Dual comparator module. The power supply, the comparators, of which there are two, and the ramp generator. The two identical comparator circuits are shown on page 1 of the schematic. The power supply and ramp generator are shown on page two.

Let us first look at the power supply section on the lower part of page two. Power is initially supplied via the usual four way MTA header, or special five way Synthesizers.com connector. As is the custom for Oakley modules, I have used ferrite beads to act as high frequency filters on the power lines. Decoupling at the point of entry is provided by C14 for the positive rail, and C15 for the negative rail. Additional decoupling is also provided elsewhere on the board by the other capacitors shown. These capacitors keep the power supply clean of noise, and provide a reservoir for the little bursts of current that the circuit takes in normal operation.

Two grounds are provided, one for the circuit itself, and one for the earthing of the jack sockets on the front panel.

There are five ICs, U1, 2, 3, 5 and 6, that require power. The power supply to each IC is shown separately from the main schematic to avoid cluttering the diagram.

To reduce noise on the main power supply lines a dedicated +5V supply is created with the circuitry based around U4. This is a simple 'three terminal regulator' and provides a stable voltage output for the LEDs and comparator output stages. R40 and C16 effectively isolate the +5V line from the +15V supply from which the regulator takes its power.

The dual comparator and ramp generator circuits require a 'reference' voltage to work correctly. It doesn't have to be hugely stable and the current demands are very low. This is created with one half of a dual op-amplifier, U3a (pins 1, 2, 3) and associating circuitry. The non inverting pin 'sniffs' the voltage of the +5V supply rail. R7 and R8 set the gain of the amplifier to exactly two, so the output at pin 1 is +10V. R10 and R11 pass the reference voltage to the output board via pins 2 and 3 of the UPPER interconnect. More about this later.

The ramp generator can be seen at the top left hand side of the schematic on page 2. Its job is to generate a rising voltage from -10V to +10V the moment a gate signal is detected. A gate signal is traditionally the control signal derived from a keyboard when any note is pressed. In an Oakley modular it is more likely to come from the gate output of the midiDAC. This is a 'logic' type output that goes to +5V when a midi note-on is detected and drops to zero volts when a note-off is received. You can also use the pulse output of a VCO or LFO to drive the ramp generator's gate input. But the circuit won't work reliably with a slow moving signal such as that from a sine wave output.

Let us first consider what the circuit does with no gate signal applied. The first transistor, Q4, is turned off since there is no base current injected into pin 2. Its collector (pin 1) is being pulled high by R26 so the voltage at the collector is in a high state. Q3's base is directly connected to Q4's collector and so Q3 is turned on. The voltage across C8 is therefore held low by Q3.

When a gate is applied, Q4 will turn on thus drawing current through R26 and pulling the base of Q3 low. Without any base current, Q3 will turn off leaving its collector to float. C8 will then be charged up via R23. The speed at which it charges will determined by the size of both C8 and R23. It is pretty slow, taking around 4 seconds to get up to around 10V.

The moment the gate is removed, Q3 will turn on again dragging the voltage down on C8. R15 reduces the amount of current through Q3 during the discharge process to a respectable level.

U3 is configured as a non-inverting amplifier with a gain of two. However, unlike a normal non-inverting amplifier, this one takes its reference from +10V instead of ground. The output from the amplifier thus goes from -10V, when C8 is fully discharged to around +10V when fully charged.

The ramp generator's output is fed to the normally closed (NC) contacts on both of the INPUT A sockets on the front panel. This means that when a jack plug is not inserted into a one of these sockets, the first input signal to that particular comparator channel is fed from the ramp generator.

Why generate a ramp signal? To create the delayed gate output we need to create a signal that goes high at a determined time after a gate signal is detected. So when the gate arrives the ramp slowly charges up. The comparator's threshold point is set by the front panel pot or signal level into input B. When the ramp and the threshold point are the same the output of the comparator will swing high creating our delayed version of the gate. The moment the gate is removed the ramp signal falls quickly low. The comparator detects the loss of the ramp signal and its output drops accordingly.

Let us see how the comparator part of the circuit actually works. Both sets of comparator circuit are identical and they are both shown on the first page of the schematic. We'll consider only the top one, which is comparator channel 1.

Channel 1 takes its two inputs, INPUT A1 and INPUT B1, from the socket board. However, by clever arrangement of the NC contacts of the input sockets, the inputs themselves can come from different sources. As we have seen, INPUT A1 can come from either the ramp generator or an inserted input jack plug. But INPUT B1 can also be affected from two sources as well. As we would expect an inserted jack can carry a signal into B1. But if there is no jack inserted then a +10V reference is automatically fed to the B1 signal line. This allows us to compare INPUT A1 with a fixed reference voltage whose actual value can adjusted with the front panel pot.

INPUT A1 is firstly attenuated and buffered by U1c (pins 8, 9, 10) and associating circuitry. The signal is attenuated to around 75% of its value by R21 and R20. This protects the op-amp from static damage and also stops any 'naughties' from the op-amp itself. The TL07X series of op-amps will do some horrible things if their inputs get anywhere near the supply rails. Cutting the input down a bit reduces any chance of getting near the supply rails.

A buffer is a circuit that merely 'sniffs' the input voltage and creates a copy of that signal at its output. Buffering the input with the op-amp has double benefits. One, it reduces any loading by the Dual Comparator module. That means that this module merely ‘sniffs’ at the input signal, ie. it doesn’t take any significant current from it. Secondly, it allows the comparator circuit itself to receive a low impedance signal. This helps maintain a good clean switch when the comparator’s output changes state.

INPUT B1 goes through a more complicated procedure before reaching the comparator. Its circuit path is made from three op-amps. U1a (pins 1, 2, 3) acts simply as a voltage buffer like in the previous input circuit. Its output signal is split between feeding one end of the LEVEL1 pot and the input to another op-amp circuit, U1d (pins 12, 13, 14).

As we can see this is a different circuit to the one around U1a. This one is an amplifier with a gain of -1. This means that its output is the opposite polarity to the input voltage. The input voltage is sensed by R19, and the current flowing through R19 is matched by an equal current flowing in R18. The op-amp does this because it tries to adhere to the ‘golden rules’.

Now the golden rule in question is that an op-amp with negative feedback must move its output so that its two input pins are both the same voltage. The negative feedback is provided by the resistor R18. So as the input signal tries to inject current into the op-amps inverting (-) pin via R19, the output will move against this by taking that current away through R18.

So a positive input voltage at R19 will lead to the output going negative. The ratio of the resistors will determine the gain of the inverting circuit. Making both the resistors the same value will mean that the gain of the op-amp is -1. That is 2V at the input gives us -2V at pin 14. The inverted output feeds the other end of the LEVEL1 pot.

We now have the two versions of the input signal, B1, placed across the two ends of the level pot. As the wiper moves from one side to the other, it will tap off a proportion of each signal. Consider what will happen with a +10V input signal at B1. This will give +7.5V at the output of U1a and -7.5V at the output of U1b. The wiper of the pot can thus move from +7.5V to -7.5V. In the middle position, both voltages take equal precedence and the voltage at the wiper is zero.

The voltage at the wiper is connected to another buffer amplifier based around U1b (pins 5, 6, 7). So a voltage of +7.5V at the wiper of the pot, will give +7.5V at the op-amp’s output. It is this pot controlled voltage that will then be fed to the comparator.

A comparator simply compares two voltages and its output will be determined by which of its inputs is more positive in value. The output can change from a low value, in this case 0V to a high value, in this case +5V. It will produce a high value when its + input is higher in voltage than its - input.

The comparator chip is basically an op-amp that has been designed especially for this one purpose only. In this design we use half of the dual comparator chip, the LM2903. It is a medium speed comparator and it's been around for many years now. But, like any comparator, it can be a temperamental beastie especially if you don’t know what sort of inputs it will see. In a modular synth, our comparator will see both rapidly moving audio signals as well as very slow moving control voltages (CVs). The problem for any comparator is what to do when both inputs are roughly the same. Because of noise, interference and the general jittery nature of any electrical signal, the comparator will struggle to deliver a clean output signal around this transition point. By ‘clean’ I mean a quick transition from one output state to the other. An unclean transition would some show sign of indecisiveness; an output that would rapidly flip from one state to the other before finally settling down.

So to keep the output clean this circuit incorporates a couple of methods of control. R31 and R33 create hysteresis around the comparator. This means once the comparator flips, it will take a larger input change in the opposite direction to turn it back around again. Think of it a bit like a door latch. Once closed, you can’t open it again without a bit of effort. Hysteresis is a form of positive feedback. The input is reinforced with the output to prevent those unwanted bursts of indecisiveness.

Unfortunately, with a relatively speedy device like the LM2903, this is not always enough. Now, we could add a heap more hysteresis, but this makes our device less accurate. All that positive feedback is altering the actual input voltage we are trying to compare. So in this design I deliberately starve the internal output drive transistor of the chip by making R34 high in value. This has the effect of slowing down the output because the limited current cannot charge any circuit capacitance up fast.

There is some scope for playing with the values around the comparator. There is a trade off here with speed, stability and accuracy. I think I have found a good compromise, but if you do play around and get a faster, more stable circuit, please let me know.

To provide a cleaner output from the comparator, a simple switching transistor circuit, based around Q5, is used. D5 removes the negative excursions of the comparator chip's output which would otherwise damage Q5. The output of the transistor switch is then fed to a non-inverting amplifier with a gain of two, and a reference of +5V. This turns our 0 to +5V input signal into a -5V to +5V output signal suitable for use with the rest of the modular. It must be noted that if want a unipolar output, ie. 0 to +5V, then all you need to do is not fit R38 (and R48 on the B channel)

For a visual indication of output state an LED is provided. Q1 provides the current switching to drive the LED. The LED is driven from the +5V supply to prevent excess switching noise from reaching the sensitive +15V rail. D2 prevents Q1 from being damaged by the negatively going output of U6.

R37 provides the usual protection for the output. This stops the output amplifier from oscillating when driving long cables, and also prevents damage should you accidentally patch two outputs together.

Issue 2 Dual Comparator 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. R is shorthand for ohm. K is shorthand for kilo-ohm. R is shorthand for ohm. So 22R is 22 ohm, 1K5 is 1,500 ohms or 1.5 kilohms. For capacitors: 1uF = one microfarad = 1000nF = one thousand nanofarad.

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, 6n8 is a 6.8 nF capacitor.

Resistors

5% 1/4W carbon or better.

47R	R15
100R	R32, R40, R43
470R	R1, R2
1K	R25, R28, R33, R37, R44
3K9	R10, R11
10K	R9
33K	R12, R19, R18, R38, R39, R36, R21, R4, R5, R6, R14, R47, R48, R41, R26, R17, R22, R7, R8
47K	R24, R27, R30
100K	R35, R46, R13, R20, R3, R16, R29, R34, R45
270K	R31, R42
1M	R23

Capacitors

10nF, 63V polyester box	C1
100nF axial ML ceramic	C2, C4, C9, C11, C6, C3, C5, C10, C12, C7
1uF, 63V electrolytic	C8
2u2, 63V electrolytic	C13, C14, C15
22uF, 25V electrolytic	C16

Discrete Semiconductors

5mm Yellow LED	LED1, LED2
1N4001 rectifier diode	D5
1N4148 signal diode	D1, D2, D3, D4, D6
BC549 NPN transistor	Q1, Q2, Q3, Q4, Q5, Q6

Integrated Circuits

TL072CN dual Bi-FET op-amp	U3, U6
TL074ACN quad Bi-FET op-amp	U1, U2
LM2903 low power comparator	U5
78L05 5V 100mA regulator	U4

IC sockets can also be used. You need two 14 pin DIL sockets and three 8 pin DIL sockets.

I recommend the ACN variation of the TL074 which has lower offset voltages.

Pots

50K or 47K Linear Alpha 16mm	LEVEL1, LEVEL2
Alpha pot brackets	2 off

Miscellaneous

MTA156 4 way header	PWR1 – Oakley/MOTM power supply	
MTA100 6-way header	PWR2 – Synthesizers.com power supply	
Leaded ferrite beads	L1, L2	
5-way 0.1” header	Lower (Main PCB and I/O PCB)	2 off
5-way 0.1” housing	Lower cable	2 off
6-way 0.1” header	Upper (Main PCB and I/O PCB), LED	2 off
6-way 0.1” housing	Upper cable	2 off
5mm yellow LED clip/lens	LED	2 off
Sockets	Switchcraft 112APC	7 off

Around 2 m of insulated multistrand wire (26awg) and four cable ties.

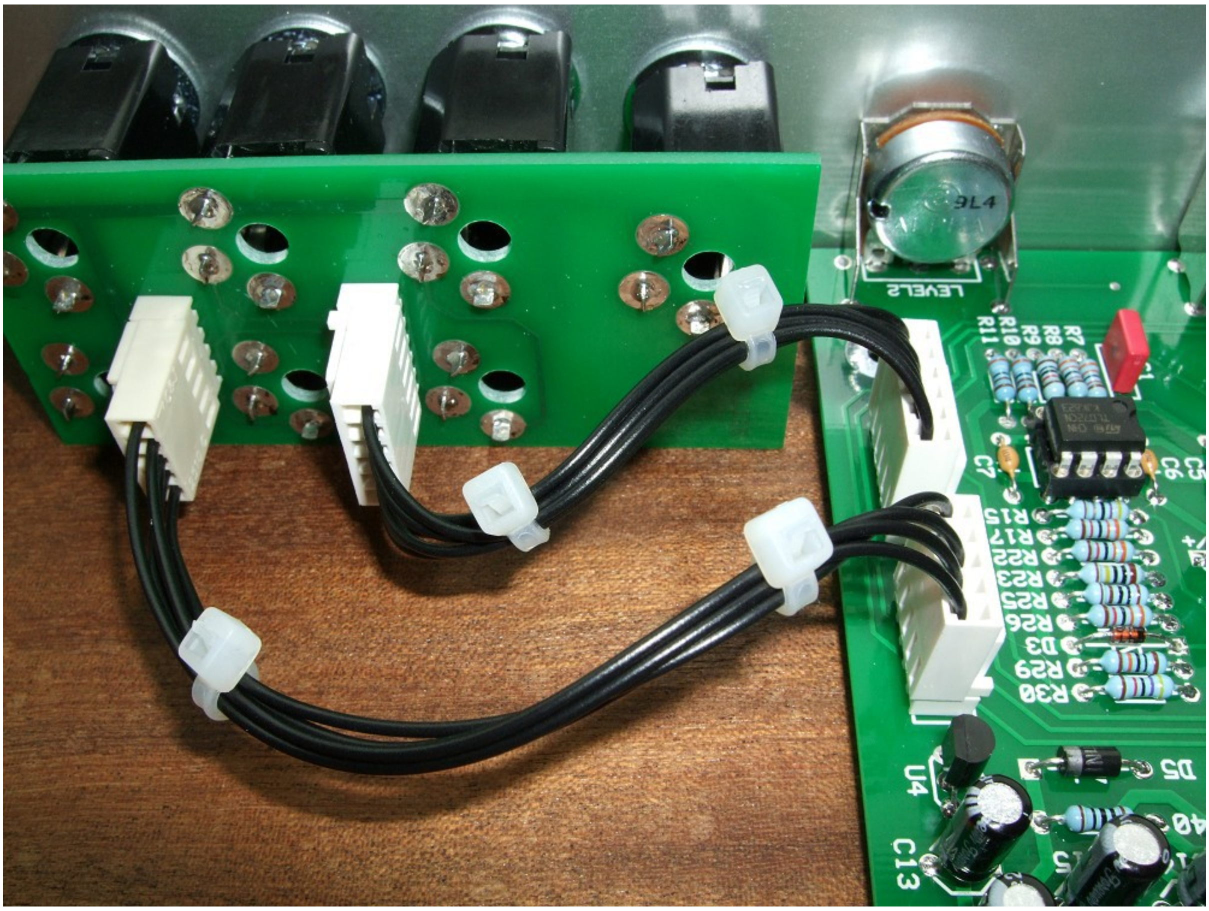
Connections

If you are using the recommended MTA or Molex KK interconnections this section will be very easy indeed. All the wiring between the sockets and the main board is done with one 5-way jumper and one 6-way jumper.

Make up the five way jumper first. This should be made from wires 130 mm long. Make sure you get pin 1 going to pin 1 on the other housing, pin 2 to pin 2, etc. This cable will connect to the headers called LOWER on each board.

The second lead is a 6-way interconnect. This is made up to be 110 mm long. This should connect the UPPER headers on the I/O board and the main board.

You can use some cable ties to bundle the wires in each interconnect together. This is best done once all the interconnects are in position.



Both board interconnects made up and cable tied into place for neatness. This is the cheaper but perfectly decent Molex KK 0.1" header system

Power supply connections

Power connections – MOTM and Oakley

The PWR1 power socket is 0.156" MTA 4-way header. Friction lock types are recommended. This system is compatible with MOTM systems.

Power	***Pin number***
+15V	1
Module GND	2
Earth/PAN	3
-15V	4

The earth/pan connection has been provided to allow the ground tags of the jack sockets to be connected to the powers supply ground without using the module's 0V supply. Earth loops cannot occur through patch leads this way, although screening is maintained. Of course, this can only work if all your modules follow this principle.

Power connections – Synthesizers.com

The PWR2 power socket is to be fitted if you are using the module with a Synthesizers.com system. In this case you should not fit the PWR1 header. The PWR2 header is a six way 0.1" MTA, but with the pin that is in location 2 removed. In this way location 3 is actually pin 2 on my schematic, location 4 is actually pin 3 and so on.

Power	***Location number***	***Schematic Pin number***
+15V	1	1
Missing Pin	2	
+5V	3	2
Module GND	4	3
-15V	5	4
Not connected	6	5

+5V is not used on this module, so location 3 (pin 2) is not actually connected to anything on the PCB.

If fitting the PWR2 header, you will also need to link out pins 2 and 3 of PWR1. This connects the panel ground with the module ground. Simply solder a solid wire hoop made from a resistor lead clipping to join the middle two pads of PWR1 together.

Final Comments

If you have any problems with 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 can't get your project to work, then Oakley Sound Systems are able to offer a 'get you working' service. If you wish to take up this service please e-mail me, Tony Allgood, at my contact e-mail address found on the website. I can service either fully populated PCBs or whole modules. You will be charged for all postage costs, any parts used and my time at 25GBP per hour. Most faults can be found and fixed within one hour, and I normally return modules within a week. The minimum charge is 25GBP plus return postage costs.

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

Last but not least, can I say a big thank you to all of you who helped and inspired me. Thanks especially to all those nice people on the Synth-DIY and Analogue Heaven mailing lists and the Muffwiggler.com forum.

Tony Allgood at Oakley Sound

Cumbria, UK