Oakley Sound Systems

5U Oakley Modular Series

Deep Equinoxe
Voltage Controlled Phaser

Deep Equinoxe PCB Issue 1

Equinoxe PCB issue 5

Builder's Guide

V1.0.01

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The 1U wide panel design for the standard Deep Equinoxe for MOTM format systems. The fpd file for this panel can be found on the project webpage.

Introduction

This is the Project Builder's Guide for the issue 1 Deep Equinoxe 5U module from Oakley Sound. This document contains a basic introduction to the boards, a description of the schematics, a full parts list for the components needed to populate the boards, and a list of the various interconnections.

This Builder's Guide contains the instructions for building the whole Deep Equinoxe module, which includes construction of both the Deep Equinoxe daughter board and the Equinoxe main board. Note that the Equinoxe main board has to be issue 5 or above. Earlier issue Equinoxe boards are not able to upgraded with the Deep Equinoxe PCB.

For the User Manual, which contains an overview of the operation of the unit, the history of the various board issues, and the calibration procedure, please visit the main project webpage at:

http://www.oakleysound.com/deep.htm

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 Deep Equinoxe Module

This is the issue 1 Oakley Deep Equinoxe module behind a natural finish Schaeffer panel. The Deep Equinoxe board is the smaller one mounted above the standard Equinoxe PCB. Note the use of the optional Sock4 socket board to facilitate the wiring up of the four sockets.

On the main Equinoxe board I have provided space for the four main control pots on the PCB. If you use the specified 16mm Alpha pots and matching brackets, the PCB can be held firmly to the panel without any additional mounting procedures. The pot spacing is 1.625" and is the same as the vertical spacing on the MOTM modular synthesiser and most of our other modules.

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 main PCB by either 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 +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.

The main PCB has five mounting holes for M3 bolts, one near each corner and one in the middle of the board near the front. These are not required for panel mounting if you are using the three 16mm pot brackets, however, we will be using the top three holes to mount the Deep Equinoxe PCB.

The main board size is 143mm (high) x 72mm (deep) and the Deep Equinoxe daughter board is 77mm (high) x 65mm (wide).

The main board has been laid out to accept connection to our Sock4 socket board. This small board speeds up the wiring of the eight sockets and reduces the chances of mistakes.

Circuit Description

For an excellent starter into phasers and their workings you really should visit R.G. Keen's excellent site at: www.geofex.com/Article_Folders/phasers/phase.html.

The Oakley Deep Equinoxe phaser is based around phase shift network built from operational transconductance amplifiers or OTAs. This type of shifter is not that common compared to the more numerous designs based on FETs and light sensitive devices. Other units that use the OTA are the Moog 12-stage phase shifter and the Electro-Harmonix Smallstone. It is the latter that Jean Michel Jarre used on the Equinoxe album, and the reason behind the Oakley device's name. Jarre had his unit modified by Michel Geiss, and the exact modifications are not known and have become subject to much speculation.

I wanted to create a phaser that was similar in tone to that used on the Jarre albums, but with more compatibility to modern modular synthesisers. The Deep Equinoxe uses either four, six or eight all pass stages to achieve its sound. Each all pass stage is identical. Four of the stages reside on the main board and the other four are on the Deep Equinoxe daughter board. The core of each stage is half an LM13700 OTA acting as current controlled resistor and inverter in one. This 'resistor' acts in combination with the 6.8nF capacitor to produce an all pass filter whose amplitude response is flat across the audio spectrum, but importantly, but one with a uneven phase response. At a certain frequency, determined by the current driving the OTA, the phase shift will be exactly 90 degrees.

You can think of a phase shift as being like a little time delay but for a specific input frequency only. Here's another way of looking at phase. Consider a child on a swing and then consider another child, next to her on the same length swing. He will move at the same frequency as she does, but it is unlikely that he will have started at the same time in the swing. So as he goes up, the other swing may be coming down. The two swings are out of phase, but moving at the same frequency. Only if they started at exactly the same time will they be in phase, or if he started his swing at a matching point in both their travels.

(OK, its highly unlikely that any two swings will go at the same frequency. Even with the same length of rope, there are other factors at work to make things more complicated.)

A 90 degree phase shift is equivalent to one swing reaching the top, as the other one flies past the middle point. Or vice versa...

And a 180 degree phase shift is when one swing is at the top at one end, while the other swing reaches the top at the other end. Note that the phase shift remains constant so long as both swings are still moving at the same frequency. Thus the phase shift is still 180 degrees when the swings are at any point in their travels. For example, when the two swings pass each other in the middle but going different directions. So the phase shift doesn't just describe one point in time, but the whole relationship between two oscillating bodies.

Now, an all pass filter will create a 90 degree phase shift at one frequency only. All other frequencies will be affected, but to a lesser or greater extent. 90 degrees is important, because if we cascade two **identical** all pass networks together we get 180 phase shift at one frequency. And 180 degrees is exactly half a cycle of oscillation.

Now lets take our two all pass networks and listen to the output. Well, the output doesn't sound that different. But, let us now mix the output with the input. The overall impact is the signal gets louder. However, at just one frequency, something special happens. This is the frequency at which you have 180 degrees of phase difference between the input and the output. So as the input wave at that one frequency is going up, the output wave is going down. When the two are added together, they cancel each other out. And in theory, completely. So by mixing the 'out of phase' and the 'in phase signal' we can annihilate the signal.

So if we were to look at output response over the whole audio range we would find it pretty flat but for a very large notch taken out at just one frequency. So a two stage phaser will create one notch. By cascading more stages we can create more notches. Four stages, like we have in the standard Equinoxe, means we have two notches.

By using an OTA will can vary the frequency of these two notches. All the OTAs work together, hopefully producing the same phase response. (Like the swing example, no two OTAs will behave identically, and there are other things to complicate our simple analysis, but that's the wonder of analogue electronics for you)

Each OTA network is followed by a simple Darlington follower. This two transistor circuit behaves as buffer. The voltage at the emitter of the second transistor follows the voltage on the base of the first. The nice thing is that no current is stolen by the base, and the OTA can go about its business with no fear from the outside world pinching its output.

As we have heard the all pass filters are cascaded together to form a chain. The chain can be either four, six or eight stages long. The length of which is determined by the two switches on the front panel. The input signal enters the chain through C11 and leaves the main board via the SEND pad which is pin 1 on the DEEP header. The chain continues to the Deep Equinoxe board and returns by the aptly named RETURN pad, pin 2. The two switches that control the length of the chain are connected to the daughter board and reference should be made to the Deep Equinoxe schematic to understand how they are connected.

The Deep Equinoxe board simply copies the first four stages exactly. The only additional circuitry is a simple FET buffer or voltage follower circuit based around Q5. This allows the signal to be fed into the four other stages without any stealing any additional current from the output of the fourth phase shifter.

On returning to the main board the phase shifted signal is passed on to R14 and R15 which provide the necessary mixing effect at their junction for the notches to be created. U2a (pins 1, 2, 3) acts as a buffer circuit and also amplifies the mixed signal, via C10 and R20, up to the high levels associated with modulars.

The main input signal enters the Equinoxe by means of a resistative attenuator, also called a pad. This reduces the input level so as not to cause distortion in the input stage and the rest of the circuit. R13 and R11 set the 'gain' of the pad.

Q1 and Q4 form a discrete input circuit which buffers the padded input signal. It also provides the means for some additional mixing from the EMPHASIS pot. The emphasis pot provides a resonant type effect to be heard, by creating a positive feedback path within the phaser. So not only do we get the notches we also now get peaks in the response when the output signal reinforces the input signal. The more positive feedback the more ‘peaky’ the response. Too much positive feedback, and the system gets carried away and oscillates wildly. Getting this right is too complex for me to analyse by mathematics alone... so I just let my ears do the talking (eh??). I played around with various feedback paths and listened to the sound created. In the end I went for the network of resistors and capacitors you see here. A simple solution in the end, and I think a very effective one.

It should be noted that the overall gain of the Deep Equinoxe is less than unity or 0dB, in fact, it is closer to -6dB. This is deliberate although you may find it less than convenient in some situations where you have a small input signal. The input level is expected to be the typical modular signal of 5V peak, or 10V peak to peak. With the emphasis turned up high it is possible to create large resonant peaks at some frequencies. If the through path gain of the Equinoxe was left at 0dB then these peaks would exceed the maximum allowed output level and cause distortion. If you are not going to use a 5V peak input, ie. you are connecting your module to a line level input, then you can increase the gain of the final stage [based around U2a], and decrease the padding on the input. Lowering R31 will increase the gain of the final stage, and increasing R11 will decrease the attenuation on the input pad.

The OTAs are all controlled from one current source. This is clever current source though. Based around Q7 and Q10, it is actually a simple exponential convertor. In other words a steady increase in base voltage produces a exponential rise in collector current. For every 18mV increase in Q7’s base voltage we double the current sourced by Q10. The voltage on the base of Q10 is also passed onto the Deep Equinoxe's own exponential convertor device, also called Q10. Thus all eight OTA stages should be more or less track together.

The current source is driven from a simple one op-amp inverting summer. Its inputs derived from either the FREQUENCY pot, the TUNE trimmer and the external CV input

The LFO circuit is quite simple and is based around half of one quad op-amp, U1.

One quarter of the TL074 op-amp, U1b (pins 5, 6, 7) forms part of the integrator. Any positive voltage applied to the right of R8 will cause the voltage to fall at the output of the op-amp. The speed at which the voltage falls is controlled by C8 and the size of the voltage applied to R8. If the applied voltage is negative the op-amp’s output will rise. It is the integrator’s output that will be used as the source for the triangle wave output.

Another quarter of the TL074 op-amp (pins 9, 10, 8) is used as a Schmitt trigger. It’s output is either high at +13V, or low at -13V. If the output of the Schmitt is initially low, it requires +6V at the output of the integrator to make it go high. The integrator will need to produce an output of -6V to make the Schmitt go low again.

To make any oscillator you normally require an output to be fed back into the input. Its positive feedback again. In a standard LFO like this one, the integrator is fed by the output of the schmitt trigger. Thus, a low at the output of the schmitt causes the integrator to rise. When the integrator’s output reaches a certain point, the schmitt switches state and the integrator’s output falls. The schmitt trigger changes state once again, and the process repeats itself....

The LFO_RATE pot allows only a controlled proportional of the Schmitt's output voltage to reach the integrator. If the proportion is large, the voltage on R8 is large, and the integrator sweeps fast. If the proportion is small, the integrator sweeps slowly. R6 sets the minimum speed. You can change the value of C8 to get different range of sweep speeds. Setting C8 at 470nF, we can go through the very slow at one cycle per minute to around 10Hz.

The output of the LFO is then split up to do several duties. One branch through R38 goes to drive the phaser core via the NC (normally closed) lug on the CV input socket. Another branch goes to pin 1 of the INV header and its little 2-way jumper so, if selected, to feed the LFO OUT socket via R39.

A third branch of the LFO output goes to a simple inverting amplifier based around U1d (pins 12, 13, 14). This simple circuit creates an oppositely going signal at its output, ie. when its input is +1V, the output is -1V. This inverted output goes to pin 3 of the INV header, which when the jumper is fitted to short out pins 2 and 3, the inverted output ends up at the LFO OUT socket.

The fourth branch of the LFO output is sent to the LED driver, based around U1a (pins 1, 2, 3). The bi-colour LED is in the feedback of this op-amp, so whatever current is drawn by R18, is also put through the LED. If one were to connect the LED and resistor straight across the LFO output and ground, the LED would be off when the voltage was less than its 'turn-on' voltage. This is normally around 2V which is a fair proportion of the 5V output signal. The old issue one boards did this, and although the LED did give an indication of LED speed, it would go out for some time. This special driver circuit makes the current through the LED proportional to the input voltage. So even at small LFO output levels, the LED is still giving out some light.

Parts Lists

Two PCBs, the Equinoxe and Deep Equinoxe, are needed for this project and a third one, Sock4, is optional.

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.

Issue 5 Equinoxe Parts List

Resistors

1% 0.25W metal film types are recommended.

22R	R35, R34, R50, R49
47R	R2
100R	R7, R6
1K	R18, R53, R64, R41, R24, R29, R39, R38, R60
4K7	R19, R9, R17
6K8	R11
7K5	R31
10K	R10, R42, R1, R25, R43, R57, R56, R54, R61, R30, R16
15K	R3
22K	R4
27K	R28, R59, R23, R58, R14, R51, R27, R52
30K	R22, R15
47K	R32, R33, R36
56K	R40, R13
82K	R62
100K	R44, R63, R47, R48, R55, R8, R5, R37, R26, R21
270K	R65
330K	R46
470K	R45, R12, R20

Capacitors

1nF 5mm polyester film	C5
6n8 5mm polypropylene film	C21, C22, C15, C14
100nF 5mm polyester film	C2, C19, C12, C4, C20
470nF 5mm polyester film	C11, C8, C3, C10
2u2, 63V electrolytic	C17, C18
22uF, 35V low profile electrolytic*	C7, C1, C6, C13, C16, C9

* Miniature or low profile, ie. short in height, devices are to be recommended as this will allow a decent clearance between the main PCB and the daughter board. If ordinary taller devices are used then you can simply bend them down if they do get too near the underside of the daughter board.

Discrete Semiconductors

BC550 NPN small signal transistor	Q1, Q2, Q3, Q5, Q6, Q7, Q8, Q9, Q11, Q12
BC560 PNP small signal transistor	Q4, Q10

Integrated Circuits

LM13700 dual OTA	U3, U4
TL072 dual op-amp	U2
TL074 quad op-amp	U1

IC sockets are recommended. You need two 16-pin, one 8-pin and one 14-pin DIL sockets.

Potentiometers (Pots)

All pots Alpha 16mm PCB mounted types

10K linear	EMPHASIS
47K linear	FREQUENCY, MOD_DEPTH
100K log	LFO_RATE

Three 16mm pot brackets.

Trimmer

470K horizontal	TUNE

Miscellaneous

Leaded axial ferrite beads	L1, L2

MTA156 4 way header	PSU	– Oakley/MOTM power supply
MTA100 6-way header	PWR	– Synthesizers.com power supply
Molex/MTA 0.1” header 8-way	I/O	– for connecting to sockets
Molex/MTA 0.1” housing 8-way	I/O	– for connecting to sockets
3 way 0.1” header	INV	
0.1” jumper	For fitting to INV	
Molex/MTA 0.1” housing 2-way	LED – optional connecting technique for the LED.	
5mm clear LED lens	LED	
5mm LED lens securing ring	LED (if lens is not self securing)	

Issue 1 Deep Equinoxe Parts List

Resistors

1% 0.25W metal film types are recommended.

10R	R3, R16
1K	R6, R26, R19, R11
10K	R12, R22, R20, R23, R13, R7, R1, R14, R27
27K	R5, R17, R18, R10, R9, R24, R25
30K	R4
100K	R2, R8, R21, R15

Capacitors

6n8 5mm polypropylene film	C4, C5, C7, C8
1u, 63V 5mm polyester film	C1, C2
22uF, 35V electrolytic	C3, C6

Discrete Semiconductors

BC550 NPN small signal transistor	Q1, Q2, Q3, Q4, Q6, Q7, Q8, Q9
BC560 PNP small signal transistor	Q10
J201 JFET	Q5

Integrated Circuits

LM13700 dual OTA	U1, U2

IC sockets are recommended. You need two 16-pin DIL sockets.

Switches

On-On (SPDT) toggle switches	NORM/DEEP, 6/8

Other Parts Required

Switchcraft 112APC 1/4” sockets	Four off mounted either on the Sock4 board or on panel

Four knobs

6-way 0.1” insulated jumper interconnect – this can be bought as a 8-way unit which can then be cut down with a pair of scissors.

Around 2m of insulated multistrand hook up wire for the LED and socket connections.
About 1m of thin uninsulated tinned solid core wire to connect the switches.

16mm M3 FF threaded hex spacers	3 off
6mm M3 pan head screws	6 off
M3 shake proof washers	6 off

Components required if using optional Sock4 board

Molex/MTA 0.1” header 8-way	I/O
Molex/MTA 0.1” housing 8-way	I/O

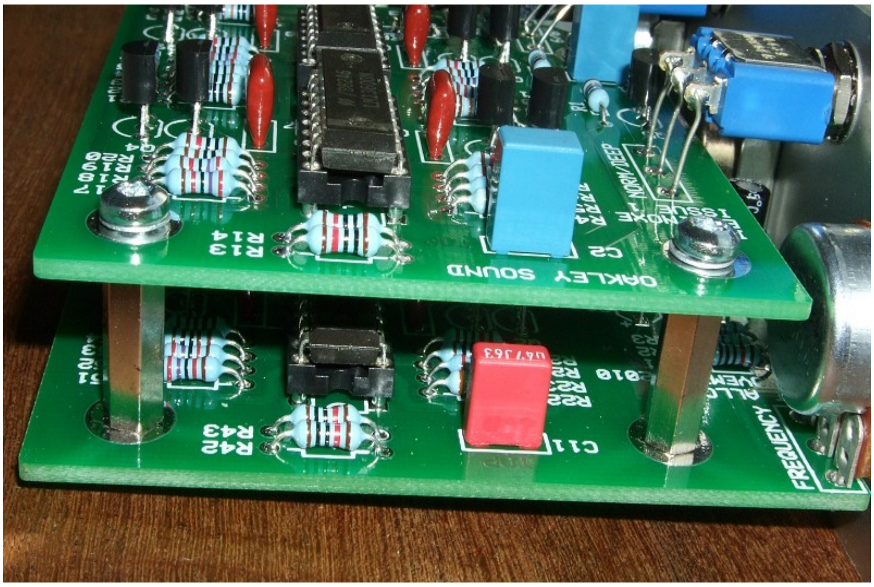
112APC Switchcraft 1/4” socket	SK1, SK2, SK3, SK4

A single wire link is to be fitted to L2 on the Sock4 PCB. L1 is left open.

If using Molex KK you'll also need at least 16 crimp terminals.

Suitable lengths of wire to make up the single 100mm interconnect and two cable ties.

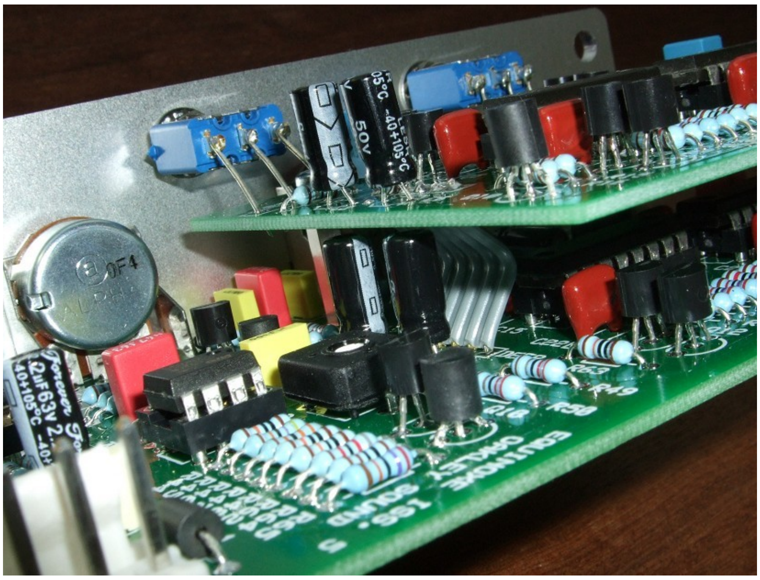
Attaching the Daughter Board



A view showing how the two boards are attached to one another..

The two boards are securely mounted together using three 16mm female-female hex spacers and six nuts and shake proof washers. It is best not to tighten the screws completely until all three spacers are in place. I recommend initially fitting the spacers before the 6-way wire link. Then when you are happy everything is going to fit, remove the top screws, and then solder in the wire link.

The six way wire link is made from a cut down piece of 8-way 0.1” insulated interconnect or jumper. You can also use bare tinned copper wire or insulated hook up wire. It's up to you.



The view between the two boards. Low profile electrolytic capacitors would probably have been better in this case as the two lower ones nearly touch the underside of the Deep Equinoxe board.

Connections

Power connections – MOTM and Oakley

The PSU power socket is 0.156” Molex/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

Pin 1 on the I/O header 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 PWR 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 PSU header. The PWR 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 5 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.

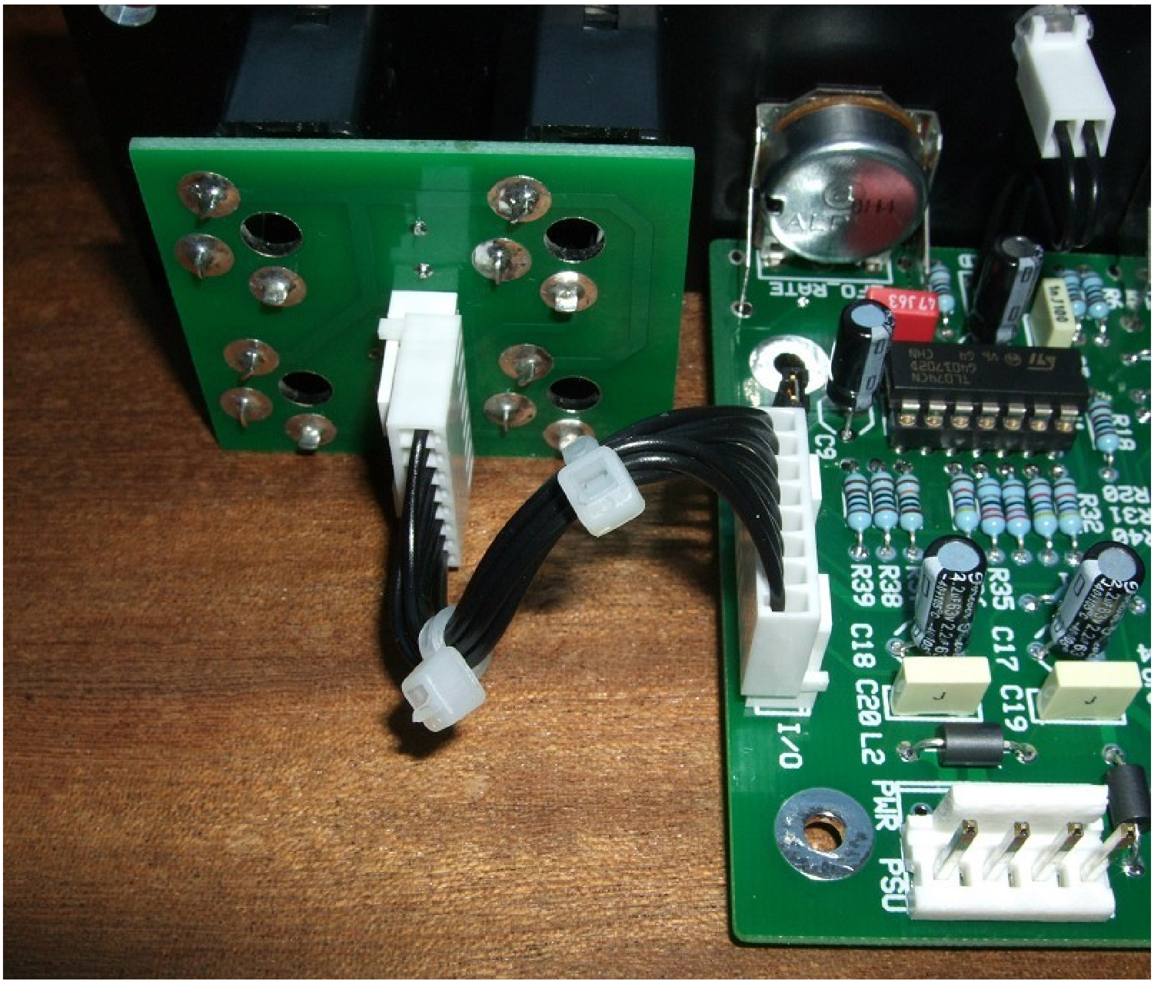
If fitting the PWR header, you will also need to link out pins 2 and 3 of PSU. This connects the panel ground with the module ground. Simply solder a solid wire hoop made from a resistor lead clipping to join the middle two pads of PSU together.

Building the Deep Equinoxe module using the Sock4 board

This is the simplest way of connecting all the sockets to the main board. The Sock4 board should be populated in the way described in our construction guide found on the project webpage. There is only one eight way header and it is to be fitted to the bottom side of the board.

Do not forget to solder in the wire link L2. Link L1 is left open.

You need to make up only one eight way interconnect. It should be made so that it is 100mm long.



The prototype Equinoxe unit showing the detail of the board to board interconnect. Here I have used the Molex KK 0.1" system to connect the Sock4 to the main PCB.

Hand wiring the sockets

If you have bought Switchcraft 112A sockets you will see that they have three connections. One is the earth or ground tag. One is the signal tag which will be connected to the tip of the jack plug when it is inserted. The third tag is the normalised tag, or NC (normally closed) tag. The NC tag is internally connected to the signal tag when a jack is not connected. This connection is automatically broken when you insert a jack.

Once fitted to the front panel the ground tags of each socket can be all connected together with solid wire. I use 0.91mm diameter tinned copper wire for this job. It is nice and stiff, so retains its shape. A single piece of insulated wire can then be used to connect those connected earth tags to pin 1 of I/O. Pin 1 is the square solder pad.

All the other connections are connected to the signal or NC lugs of the sockets. The tables below show the connections you need to make:

Pin	*Pad name*	*Socket Connection*	*Lug Type*
Pin 1	PANEL_GND	Connect to all sockets	Earth lugs
Pin 2	LFO_OUT	Connect to LFO OUT	Signal lug
Pin 3	NC	No connection	
Pin 4	AUDIO_OUT	Connect to AUDIO OUT	Signal lug
Pin 5	NC_LFO	Connect to CV IN	NC lug
Pin 6	CV_IN	Connect to CV IN	Signal lug
Pin 7	GND	Connect to AUDIO IN	NC lug
Pin 8	AUDIO_IN	Connect to AUDIO IN	Signal lug

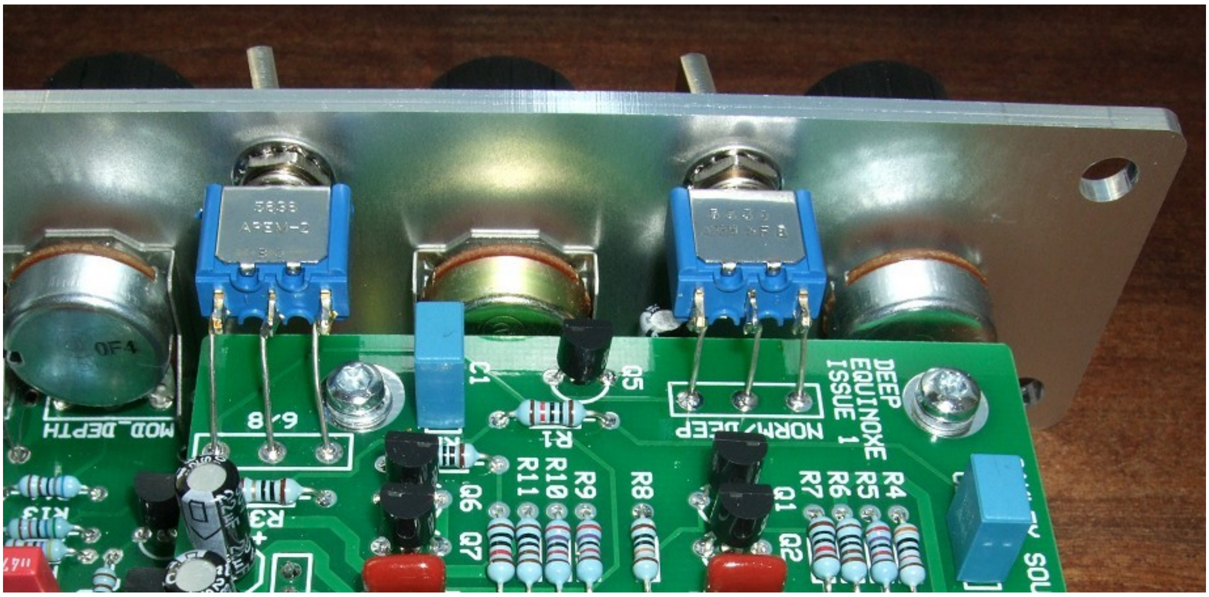
Connecting the Bi-colour LED

Using a two way Molex KK housing to connect the bi-colour LED to the circuit board. The LED is held onto the panel with a clear Cliplite lens, or equivalent, available from various places.

You may be able to wire the LED directly to the circuit board if the one you have has long enough leads. However, most of the ones I have seen won't fit directly so I have to use flying wires to connect the LED to the board. Bi-colour LEDs have just two legs and each one should go to the solder pad directly beneath it when it is mounted into the panel. I normally wire it up so that the LED goes red when the output is positive.

You can either solder your connecting wires to the LED's legs or use a MTA or Molex connector to make the connection.

Wiring the Switches



The switches are simply wired to the Deep Equinoxe board with stiff solid core wire although you can use multistrand hook up wire if you like. The solid core wire is looped around each switch lug and soldered in place. I recommend that the wire has some slack to allow the boards to flex a little.

I normally make sure the switch is in its place and tightened before soldering the leads. I always tighten from the back thus reducing the chance of scratching the front panel and I always put the little washer on the inside of the module too.

Testing, testing, 1, 2, 3...

Apply power to the unit making sure you are applying the power correctly. The LED should now throb happily. If it doesn't turn off, and check all the parts again thoroughly. If your LED is OK, and there is no smoke rising from the board (yikes!!), then try the LFO rate. It should control the LED's flashing. From around one cycle every 30 seconds to around 10 cycles a second.

Click the top switch into NORM. This will test the first four stages of the phase shifter. Now connect up an audio signal of some sort, any will do, but a simple sawtooth wave is quite sufficient. Listen to the audio output, and play with the controls. With all controls to the minimum setting, sweep the FREQUENCY pot. Do you hear the characteristic phase sweep? If not, you have got a problem. If yes, now turn up the EMPHASIS. Using the frequency pot again, does the sweep have a more metallic ring to it. It'll probably be a bit louder too.

Click the top switch into DEEP. Rotate the frequency pot and you should again hear the characteristic phase sweep. Make sure that you get a similar effect in both SIX and EIGHT modes. However, the effect should be stronger in eight stage phasing.

Now set the FREQ and EMPHASIS pots to their middle position. Turn up the MOD DEPTH. The LFO should now be modulating the phaser. Check that the RATE affects the speed of the modulation.

Final Comments

If you have any problems with the module, an excellent source of support is the Oakley Sound Forum at Muffwiggler.com. Paul Darlow and I are 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 or Paul Darlow directly with questions about sourcing components or general fault finding. Honestly, we would love to help but we 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, Oakley-Synths and Analogue Heaven mailing lists and those at Muffwiggler.com.

Tony Allgood at Oakley Sound

Cumbria, UK