Oakley Sound Systems

Eurorack Modular Series

Dual VCO

Main Board issue 2

Builder's Guide

V2.4

Tony Allgood
Oakley Sound Systems
CARLISLE
United Kingdom

Introduction

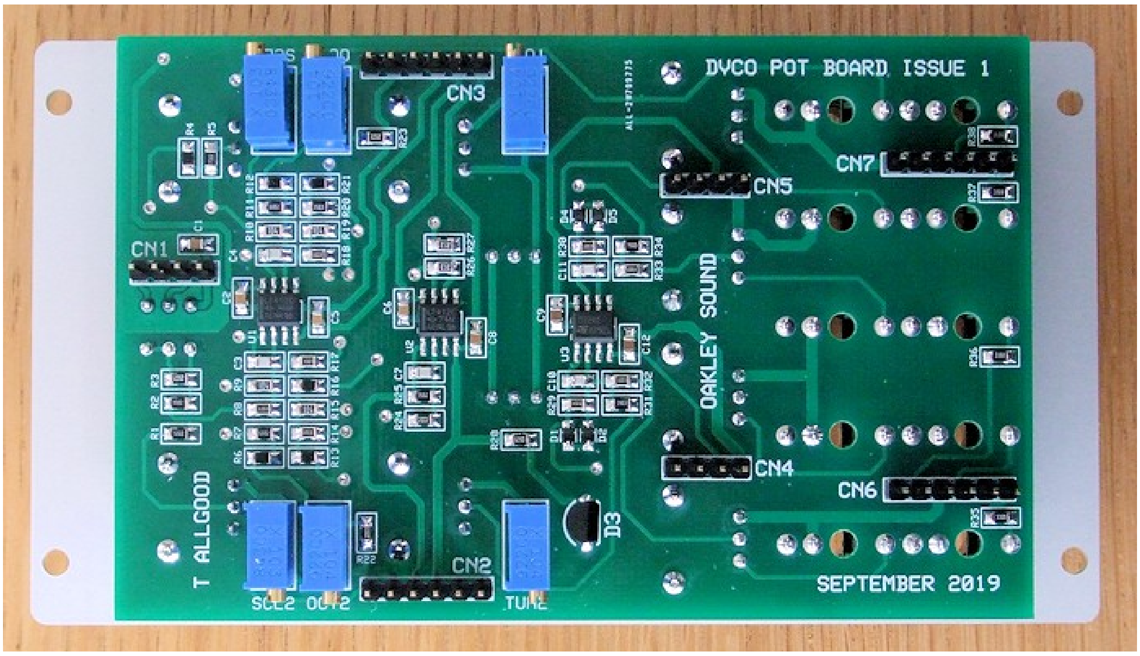
This is the Project Builder's Guide for the issue 2 Dual VCO Eurorack module from Oakley Sound. This document contains a basic introduction to the board set, a full parts list for the components needed to populate the boards, some basic help on how to purchase parts and to build the project, a simple test procedure, and calibration.

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, and mounting front panel components please see our generic Construction Guide at the project webpage or http://www.oakleysound.com/construct.pdf.

The Dual VCO PCB Set

The electronics of the Oakley Dual VCO are built on two printed circuit boards (PCBs). The Pot board holds the eight pots, three switches, ten input and output sockets, the control voltage (CV) processing circuitry, and the voltage references. All the front panel components are directly soldered to the pot board. The pot board is a double sided design meaning that there are electrically conductive copper tracks on the top and bottom surfaces of the board. The surface mount components are all soldered to the top side of the board while the pots, switches, and sockets are soldered to the underside which faces the inside surface of the front panel.



The original issue 1 pot board fitted to the front panel. Note that all the surface mount components, headers, and trimmers are fitted to this side. The pots, switches, and sockets are fitted to the underside of the board.

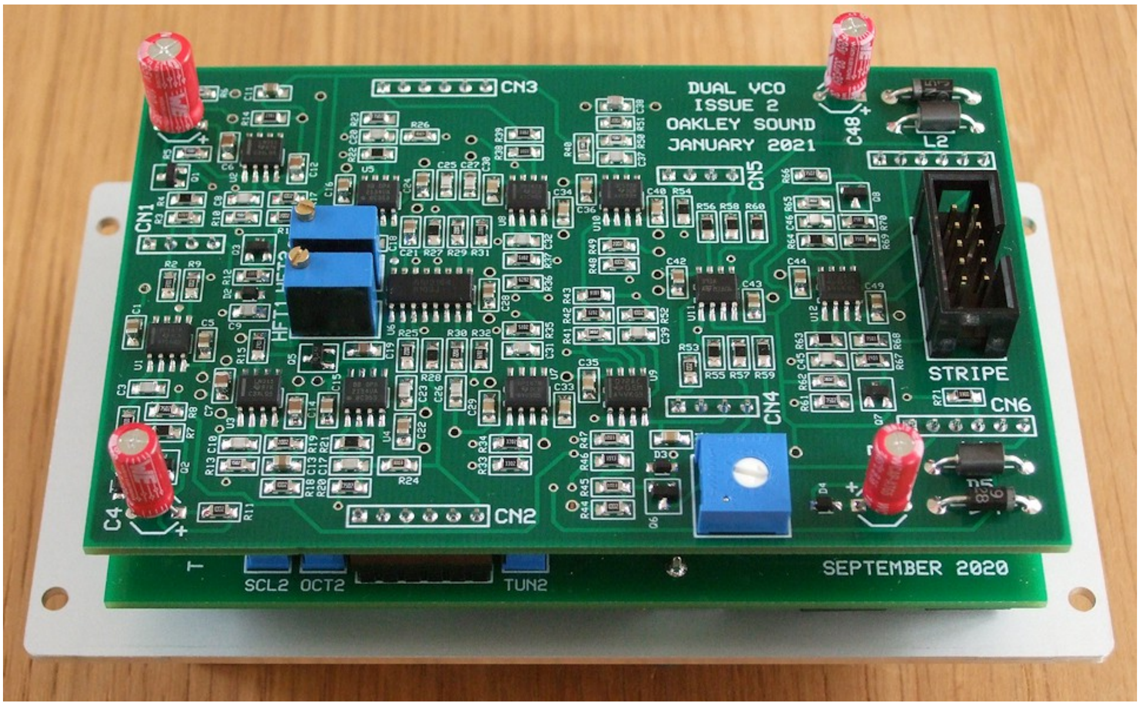
The second board is called the main board. This holds the two VCO sawtooth cores, the exponential convertors, the sawtooth to pulse and triangle wave circuitry, the power supply conditioning, and the power inlet. The main board is a four layer design. This means that the board has layers of copper on top and bottom sides, as well as two internal copper layers. The top internal layer is solely reserved for the 0V connections – sometimes called module ground – used for the main and top board's electronics.

The components, again a mixture of through hole and surface mount devices, are mostly soldered to the top of the board. The main board's components are all accessible from the rear of the module. Although this means that you need to be a little careful when handling the module, it does mean that fault finding is much easier than it would be if the main board was facing the other way and none of the components would be visible.

The surface mount components are mostly of relatively large geometries to make the build suitable even for beginners in surface mount soldering. The resistors and capacitors are all

0805 and the ICs are narrow body SOIC. Any transistors are SOT-23. The larger capacitors, ferrite beads, power diodes, and all the interconnects are through hole parts.

Both circuit boards are the same size, that is, 68 mm (wide) x 107 mm (high). The boards are designed to go behind a panel that is 14HP wide.



The module comprises of two circuit boards connected together with four 6 way 0.1" and three 4 way SIL headers and sockets.

The grip of the seven SIL interconnects is strong enough to hold the boards together for most uses. Should you require more rigidity then a **small** blob of silicone (neutrally curing RTV) sealant across the join between the plastic housings of CN2, CN3, CN6 and CN7 would hold everything together tightly. However, it is best not to do this until your unit has been thoroughly tested.

The design requires plus and minus 12V supplies. The power supply should be adequately regulated. The current consumption is around +75mA and -85mA at +/-12V.

Dual VCO Parts Lists

The components are grouped into values, the order of the component names is of no particular consequence.

Many of the parts for this circuit board are surface mount devices but not all of them. Take special care when ordering your parts that you order the correct type of part. This parts list shows the type of part needed whereas the circuit diagram does not.

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. For electrolytic capacitors the maximum working voltage is normally given with the value, eg. 1uF, 63V is a one microfarad capacitor with a working DC voltage of 63V.

To prevent loss of th 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.

Main Board issue 2 Parts List

Resistors

All resistors are surface mount, size 0805 (or metric 2012) 1% 125mW metal film.

75R	R6, R40, R71
220R	R25, R29, R30, R31
390R	R1, R2
2K4	R67, R70
3K3	R14, R15
7K5	R68, R69
10K	R9, R11, R17, R18, R43, R44, R48, R52, R53, R54, R57, R58, R59, R60
12K	R42
15K	R5, R10, R13, R50
20K	R16, R19, R49, R51
22K	R4, R63, R64
33K	R33, R34, R38, R39
36K	R41, R62, R65
51K	R35, R37
62K	R32, R36
75K	R8, R20, R23, R61, R66
82K	R7
100K	R3, R12, R45, R47
150K	R21, R22
191K	R46
300K	R24, R26
1M	R27, R28, R55, R56

Capacitors

The following capacitors are surface mount, size 0805 (or metric 2012) multilayer ceramic, dielectric C0G (or NP0), working voltage 50V, tolerance +/-5%.

4p7	C17, C20
10pF	C45, C46
27pF	C8, C10
100pF	C3, C9, C31, C32, C37
470pF	C39
1n2	C23, C25, C26, C27
2n2	C18, C19
22nF	C11, C38

The following capacitors are surface mount, size 0805 (or metric 2012) multilayer ceramic, dielectric X7R, working voltage 25V or preferably 50V, tolerance +/-5% or +/-10%.

100nF	C29, C30, C33, C34, C35, C36, C40, C41,
1uF	C1, C5, C13, C15, C16, C21, C22, C24, C28, C42, C43, C44, C49
4u7	C6, C7, C12, C14

The following capacitors are standard through hole electrolytic capacitors with 0.1" (2.5mm) or 0.2" (5mm) radial leads.

2u2, 50V	C4
33uF, 25V	C47, C48
100uF, 16V	C2

Discrete Semiconductors

The following devices are surface mount parts. The transistors are in SOT-23 packages.

1N4148WS signal diode	D1, D2, D3
BAT42WS Schottky diode	D4
BC850C NPN transistor	Q1, Q3, Q6, Q7, Q8
BC860C PNP transistor	Q2
MMBF4391LT1G JFET	Q4, Q5

The following devices are standard through hole parts.

1N5819 Schottky diode	D5, D6

Integrated Circuits

The following parts are all surface mount devices. All are small outline (SOIC) narrow body packages.

LM311DR dual comparator	U2, U3
LM393DR dual comparator	U11
OPA1678IDR dual op-amp	U7, U8, U10
OPA2134UA dual op-amp	U4, U5
TL072ACD dual op-amp	U1, U9, U12
SSI2164 quad VCA	U6

Trimmer (Preset) Resistors

Both HFT trimmers are top adjust multiturn types. For example, the Bourns 3296W series.

5K multiturn	HFT1, HFT2

TRI is a top adjust 5/8" trimmer. For example, the Bourns 3386F series.

20K single turn	TRI

Miscellaneous

Axial ferrite bead	L1, L2
2 x 5 0.1" boxed header	STRIPE
4-way SIL 0.1" socket	CN1, CN4, CN5
6-way SIL 0.1" socket	CN2, CN3, CN6, CN7

Special care must to be taken to ensure that connectors CN1 to CN7 are mounted perpendicular to the board surface.

Pot Board issue 1.1 Parts List

Resistors

Most resistors are surface mount, size 0805 (or metric 2012) 1% 125mW metal film. However, some resistors, labelled with a "/0.1%", are required to be thin film types with a 0.1% tolerance to ensure accurate oscillator tuning.

330R	R35, R36, R37, R38, R39
620R	R28
1K	R4

15K	R2, R25
20K/0.1%	R24, R26, R27
22K	R3, R22, R23
51K	R1
59K	R7, R11
75K	R5
100K	R8, R14, R17, R18, R29, R30, R32, R33
100K/0.1%	R9, R10, R15, R19
140K	R31, R34
180K	R20
200K	R16
680K	R6, R12
750K	R13, R21

Capacitors

The following capacitors are surface mount, size 0805 (or metric 2012) multilayer ceramic, dielectric C0G (or NP0), working voltage 50V, tolerance +/-5%.

47pF	C3, C4
100pF	C10, C11
470pF	C7

The following capacitors are surface mount, size 0805 (or metric 2012) multilayer ceramic, dielectric X7R, working voltage 25V or preferably 50V, tolerance +/-5%.

100nF	C1, C9, C12
1uF	C2, C5, C6, C8

Discrete Semiconductors

The following devices are surface mount parts.

BZX384-B6V2	D1, D2, D4, D5

The following device is a through hole part.

LM4040-10V reference	D3

Integrated Circuits

The following parts are surface mount devices. All are small outline (SOIC) narrow body packages.

OPA1678IDR dual op-amp	U1, U2
TL072ACD dual op-amp	U3

Trimmer (Preset) Resistors

All trimmers are side adjust multiturn types. For example, the Bourns 3296X series.

10K multiturn	SCL1, SCL2
100K multiturn	OCT1, OCT2, TUN1, TUN2

Potentiometers

All pots are Alpha 9mm vertical types. The pot's shaft type will depend on the control knob chosen for that particular pot. The front panel was designed so that the top four pots use 13mm diameter control knobs, and the four CV depth pots use 'slip on' micro control knobs. I used four 13mm Davies 1900H clones, and four Thonk T18 Micro knobs.

These pots are Alpha 9mm vertical pots with 6.35mm round shafts.

50K linear	MASTER_TUNE, VCO2_TUNE, PW_1, PW_2

These pots are Alpha 9mm vertical pots with 6mm splined (T18) shafts.

50K linear	PWM_1, PWM_2
50K log	FM_1/2, FM_2

The pots are to be fitted to the underside of the board and their pins soldered from the topside. Note that there is no component identification on the reverse side of the original issue 1 board so use the front panel as guide to make sure the parts go into the correct locations.

Miscellaneous

DPDT on/on switch	SYNC
SPDT on/off/on switch	OCT_1, OCT_2

3.5mm 'Thonkiconn' socket	1V/OCT, SAW1, SAW2, PULSE1, PULSE2, FM1/2, FM2, PWM1, PWM2, TRI2

The three switches and ten 3.5mm sockets are to be fitted to the underside of the board and their pins soldered from the topside. See later for more details.

4-way SIL 0.1” header	CN1, CN4, CN5
6-way SIL 0.1” header	CN2, CN3, CN6, CN7

Special care must to be taken to ensure that connectors CN1 to CN3 are mounted perpendicular to the board surface.

Parts Sourcing

For general information regarding where to get parts and suggested part numbers for Oakley projects please see my Parts Guide at the project webpage or direct from here:

http://www.oakleysound.com/parts.pdf.

The front panel can be obtained either from Schaeffer in Germany, or Front Panel Express (FPE) in the US. The database for the panel is provided on the project webpage and this file can be opened, edited and ordered using the Frontplatten Designer program available free from Schaeffer or FPE. The cost of the 14HP wide panel was around 37 Euros at the time of writing. The panel is 2.5mm thick and has a natural silvery finish. The black text is printed, although it is possible to edit the database to have the text engraved.

The pots are Alpha 9mm vertical pots as sold by Thonk and others. I use Thonk's standard ones with 6.35mm (0.25") round and 6mm splined shafts. Other shaft types are available, like D-type, and you should purchase those that are compatible with your choice of control knob. I prefer the round shafts for the larger controls as they require control knobs that have a fixing screw. Although these knobs take more time to place and secure, the height at which the knob sits on the pot shaft is under your control. Push fit knobs can sometimes not sit at the right height which is unsightly if they are too high, or graunch against the pot's securing nut and washer if they are too low.

For the knobs used on my prototype I used two dark grey 13mm Davies 1900H clones, two light grey 1900H clones, and four Thonk T18 dark grey Micro knobs. These need four 1/4" round shaft pots, and four 6mm T18 splined shaft pots.

The toggle switch is a standard sub-miniature type that is designed to fit directly into a PCB. The SPDT on-off-on switches are available from Thonk as their DW2 sub-miniature switch. The DPDT on-on switch is also available from Thonk as their DW3 switch. They are made by Dailywell and offer good performance for their price.

The ten 3.5mm sockets are available from Thonk known either by their Thonkiconn moniker or as part number PJ398SM.

The fixed 2.54mm (0.1") interconnects are in two parts, the male header, and the female socket or receptacle. I use one 10-way and two 6-way single in line (SIL) connectors in this project. The ones I use are made by Multicomp, although more expensive types are available which may offer increased longevity. Whichever part you choose the spacing between the two boards must be at least 11mm so as to allow the four multiturn trimmers to fit on the pot board. These are the Multicomp part numbers for the parts I used:

4 way socket	2212S-04SG-85
4 way header	2211S-04G
6 way socket	2212S-06SG-85
6 way header	2211S-06G

The SSI2164 is available from Thonk, CESYG, and AmazingSynth in the UK, CabinTech Global in the US, and several other guitar and synth part shops elsewhere in the world. I have not tested the Cool Audio V2164 in this module but it is unlikely to have as good as performance as the SSI part.

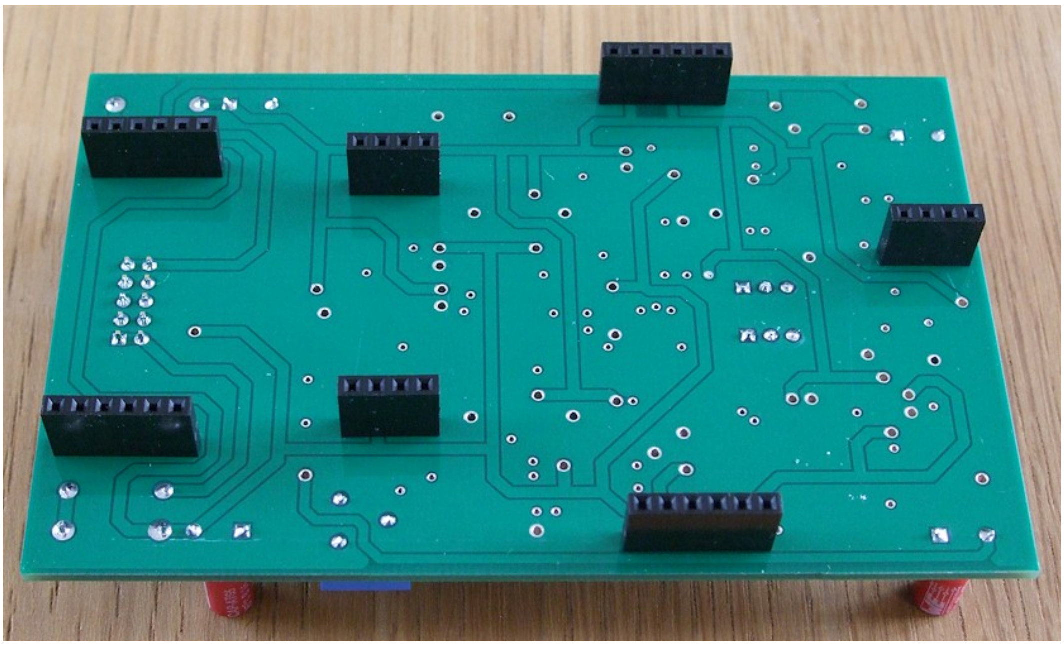
Populating the Circuit Boards

For general information on how to build Oakley modules, including circuit board population, mounting front panel components and making up board interconnects please see my generic Construction Guide at the project webpage or http://www.oakleysound.com/construct.pdf.

Main Board Construction

All the surface mount components should be soldered first. Take care to treat all transistors, diodes and ICs as static sensitive devices. I usually solder the resistors first, then the capacitors, then the discrete semiconductors, and then the ICs.

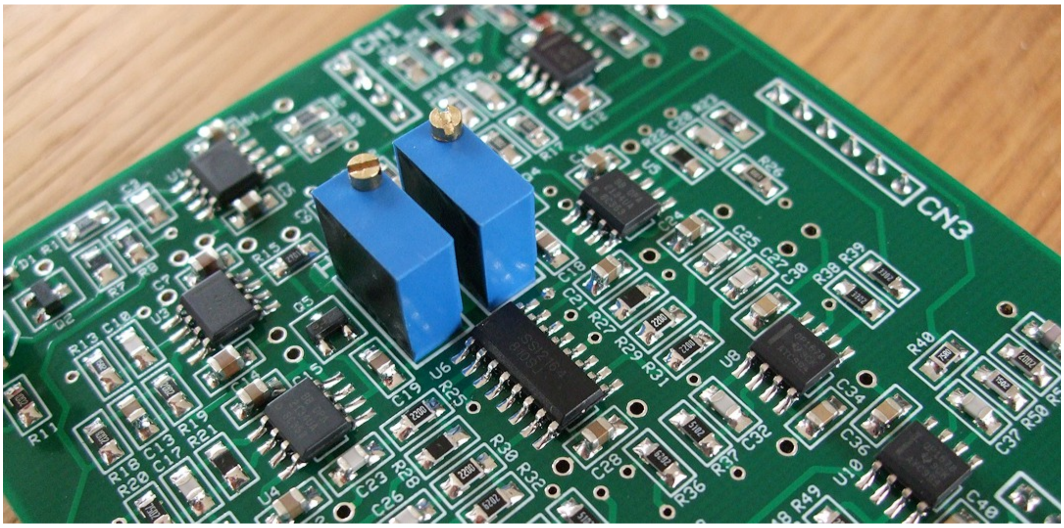
The next items to be soldered are the single in line (SIL) sockets. These are to be fitted to the underside of the board and soldered from the top side.



This is the underside of the main board.

Special care should be taken to ensure that each SIL socket sits at right angles to the board surface. One way to do this is to temporarily fit the SIL headers into the SIL sockets and fit the Main board and Pot board together with the headers and sockets in between. Then solder the headers to the main board. Pulling the two boards apart should reveal all the sockets neatly in place and at the correct angle.

The next items to be soldered will be the through hole components. Remember that diodes and electrolytic capacitors are polarised so they need to be fitted the right way around. You should especially make sure that the boxed header is correctly orientated. Pin 1 is normally designated with a little arrow shape on the plastic housing of the header and this should align with the square pad on the board. Also, the hole in the housing should correspond to the little box shape on the board's printed legend.



The two multiturn trimmers on the main board can be fitted either way into the board.

Pot Board Construction

Except for the pots, switches, and sockets all the parts are to be fitted to the topside of the board. The surface mount parts should again be soldered first.

Now fit the SIL headers into place and solder from the underside of the board. It may be worth temporarily fitting the Pot board to the Main Board so as to hold the headers exactly at right angles while you solder.

All six trimmers should be fitted so that they can adjusted from the side of the module. That is TUN1, OCT1, and SCL1 should be facing right. And TUN2, OCT2, and SCL2 should be facing left.

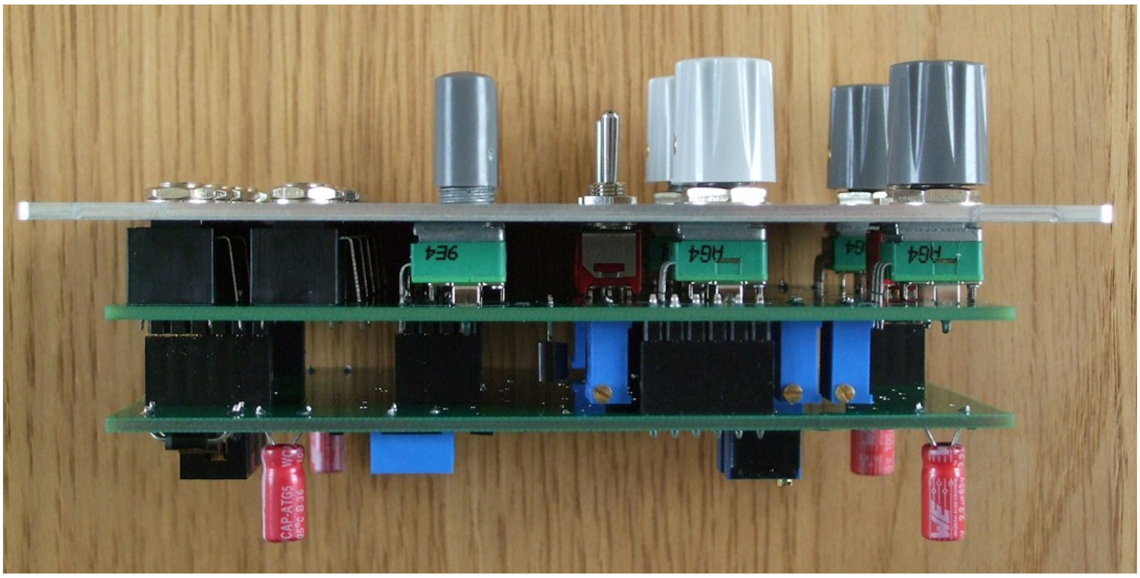
The remaining parts are the front panel components and these will be fitted to the underside of the board and soldered from the top of the board. There are no legends on the underside of the early issue 1 board to indicate where the parts will go but using the front panel it should be clear where they need to be fitted. To ensure the correct alignment of these parts before soldering you should have your front panel ready. The panel will be used as a jig to hold the parts in the correct place while you solder. Failure to use the panel as a jig prior to soldering could mean that the panel will not be able to slide onto the components.

The first parts to place, but not solder, will be the pots. The pots should be fitted so that the three pot pins go into the board first, then ease in the two lugs into their holes and push in firmly so that the pot clicks into place. The pot will sit securely in the board even without soldering.

Now fit the ten sockets and switches into their places on the board but again do not solder yet. Place a toothed washer, that came with the switches, onto each of the switches' mounting bush.

Now ease the panel down onto the pots, switch and sockets making sure that all their threads are sitting snugly in their holes. Place a washer and a nut on each of the top four pots and all the sockets, but not the four CV depth pots nor the switches. Tighten the nuts but not too tightly. Turn the module over to reveal the topside of the circuit board. Now solder all the pots and sockets, but not the switches yet.

Flip the module over again and fit a single nut, and if you have one, a flat dress washer, to the exposed thread of each of the three switches. You can ignore the other nut that came with the switches, as well as any washers that have locating lugs. Gently tighten the nuts taking care not to scratch the panel. The switches will be pulled towards the panel and slightly off the board's top surface when you tighten the nuts. The module can be turned over and each of the switches' three leads soldered.



The completed module from the side. Note firstly the side adjust trimmers that allow the trimming to be done from the side of the module, and secondly, that the pots with the micro control knobs do not have any mounting nuts and washer fitted.

Initial Testing

If you have a bench power supply that allows you to select the current limit then set both the +12V and -12V supplies to a current limit of 100mA. This should prevent any serious meltdowns if there is a problem with the build.

Power up the completed module. If you can measure power supply current then it should be around -85mA from the negative rail and +75mA from the positive rail. Anything significantly more than this, like 100mA, will indicate a problem. If you can't measure current then check that no devices are getting warm.

If you have an oscilloscope it is worth checking the outputs. Even uncalibrated both the VCOs should be generating signals on all of their outputs. Each output should be oscillating with the correct waveform between +5V and -5V, although the triangle wave may be slightly different to this as it has yet to be calibrated.

If you do not have an oscilloscope then you can simply listen to the outputs individually. Check that each is working as you would expect. Check that each of the Pulse pots control the pulse width of their respective pulse wave output. Ensure that you can hear the hollow sound of a square wave when the pulse pot is in its middle position.

Check that the octave switches change the frequency of their respective oscillator. They will not produce a perfect octave shift as this needs to be calibrated, but each switch should change the frequency very noticeably. Check that the Master Tune varies the pitch of both oscillators by just a small amount, and that the VCO2 Tune control only changes the pitch of VCO2.

Now check that setting the Sync switch to its down position engages the synchronisation of VCO2 to VCO1. With both octave switches in their middle positions, listen to VCO2's sawtooth output. When you rotate the VCO2 Tune control you should hear the typical screeching 'sync' sound. This effect should be more pronounced with VCO2's octave switch in the 4' position.

Finally, it is worth checking the four CV inputs and their associating level pots individually. Use a triangle or sine wave low frequency oscillator (LFO) signal as a modulation source. Check that FM1/2 alters the pitch of both oscillators. Check that PWM1 alters the pulse width of VCO1's pulse output. Check that FM2 alters only the pitch of VCO2. Check that PWM2 alters the pulse width of VCO2's pulse output.

Calibration

Although you can adjust the trimmers with a small blade screwdriver, Vishay, Bourns, and others make special trimmer adjusters, which are easier to use and less likely to damage the trimmers.

Power up the module and make sure it has been powered up for at least twenty minutes prior to calibration. It is a good idea to have the room temperature close to what it would normally be when playing your modular. VCO1 and VCO2 are to be treated similarly but VCO1 should be trimmed first if the unit has not been calibrated before.

SCL1

This is the scale trimmer for VCO1. Use this to generate a perfect 1V/octave scaling.

Set VCO1 to 4' using the switch on the front panel. Set the Master Tune pot to its central position.

Plug your midi-CV convertor or 1V/octave keyboard into the Dual VCO's VCO1/2 1V/Oct socket. Play a very high note. To adjust SCL1 properly we will need to negate the actions of the high frequency tracking compensation circuitry. Adjust HFT1 on the main board so that the pitch **drops** as far as it will go.

Now set the VCO to 8' and play a lowish note on the keyboard, then play two octaves higher. Adjust SCL1 until the interval is **exactly** two octaves. I normally try to work between the two A notes of 110Hz and 440Hz.

Note we are only setting the interval and not the actual frequency. It does not have to be a perfect A when A is being pressed on the keyboard. It could be an F or whatever. The important thing is that with SCL1 we are setting the musical gap between the notes. If you do need to alter the actual pitch of the VCO to help you tune then use the TUN1 trimmer.

For any interval, if you find the higher note is flat, then turn the SCL1 trimmer to make it flatter still. This actually reduces the range between the two notes. Conversely, if you find your interval is bigger than it should be, turn the trimmer to make the top note even higher. I always adjust SCL on the high note of any interval, and only adjust the TUN1 trimmer on the lower.

This will probably require some patience and plenty of twiddling. But you will get there. Once you get the hang of it, it is pretty straightforward. I can do it in about one minute but I've had a lot of practice.

You should be able to get it as accurate as +/-1 cent.

Now leave it on for a further 20 minutes and then check the scaling again. Re-adjust if necessary. You can of course move onto calibrating the scale of VCO2 while VCO1 is bedding in.

HFT1

This is the high frequency tracking trimmer and it compensates for the slight flattening of pitch when running the VCO at high frequencies. If you don't go above 3kHz that often there is a good chance you won't even have to touch this one. Like the SCL trimmer it will have a small knock on effect on the absolute pitch of the VCO lower down too.

If you only have a small keyboard use the keyboard's octave transpose setting to get the VCO playing a really high note. I normally work between the two A notes of 3520Hz and 7040Hz, although you can work an octave below that if you wish. Once again, you can ignore the actual pitch, it's the interval we are wanting to get right. Once you have set up the perfect octave at these frequencies, then check down at the lower end that everything is still responding to 1V/octave.

Remember, if you have skimped on the SCL1 trimming, no amount of tweaking of HFT1 will get it to play in tune.

TUN1

This is the tune trimmer and it sets the range over which VCO1 acts. As far as I am aware there is no standard amongst modular systems that defines what pitch corresponds to what CV input. However, I now choose to make my VCOs produce C2 (65.4Hz) when there is no 1V/octave input applied and the octave switch is set to its middle position.

TUN1 is therefore adjusted to give a perfect C2 (65.4Hz) when the octave is set to 8', the Master Tune control is set central, and no external CV's are applied.

OCT1

This sets the interval of the octave switch for VCO1. It has no effect on the pitch in the 8' position but effects equally the 4' and 16' settings. Set the switch to 8'. Play an A above middle C and using the front panel tune pot set the frequency to be exactly 440Hz. Now flip the switch up to its 4' position. Adjust OCT1 so that the note heard is 880Hz +/- 1 cent. Flipping the switch down to 16' should give you 220Hz +/- 1 cent.

SCL2, HFT2, TUN2, and OCT2

These are treated similarly to VCO1's trimmers. Note that VCO2 has an additional pitch control pot, VCO2 Tune, on the front panel. Prior to calibrating VCO2 this pot should be set so that the pointer lines up with the Unison line on the panel at the 9 o'clock position. Care must be taken that this pot doesn't move during the trimming process. Once trimming has been done it's worth checking that the turning this pot will shift the pitch of VCO2 by one octave when it is moved from the 9 o'clock position to the 3 o'clock position. Make sure that the Sync switch is off, ie. in the up position, while trimming VCO2.

TRI

This adjusts the shape of the triangle waveform output of VCO2. If you have access to an oscilloscope then adjust the TRI trimmer so that the waveform at the 'Tri 2' output looks like a triangle wave and any obvious discontinuities at the top part of the waveform are minimised. You may notice a small narrow spike at the top of the waveform. This is normal and is part of the sawtooth to triangle wave conversion process.

If you do not have a scope then simply listen to the triangle wave output at around A = 110Hz. Adjust TRI so that the buzzy or fizzy part of the sound is minimised.

Final Comments

If you have any problems with building 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 and you are in the UK, 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 the great people on the Synth-diy and Analogue Heaven mailing lists and those at Muffwiggler.com.

Tony Allgood at Oakley Sound

Cumbria, UK