Oakley Sound Systems

5U Oakley Modular Series

Dual-Low Frequency Oscillator

D-LFO issue 1 & 1.1

Builder's Guide

V1.5

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Introduction

This is the Builder's Guide for the issue 1 and 1.1 Dual Low Frequency Oscillator (Dual-LFO) 5U module from Oakley Sound. This document contains a basic introduction to the board, a full parts list for the components needed to populate the board or boards, and a list of the various interconnections.

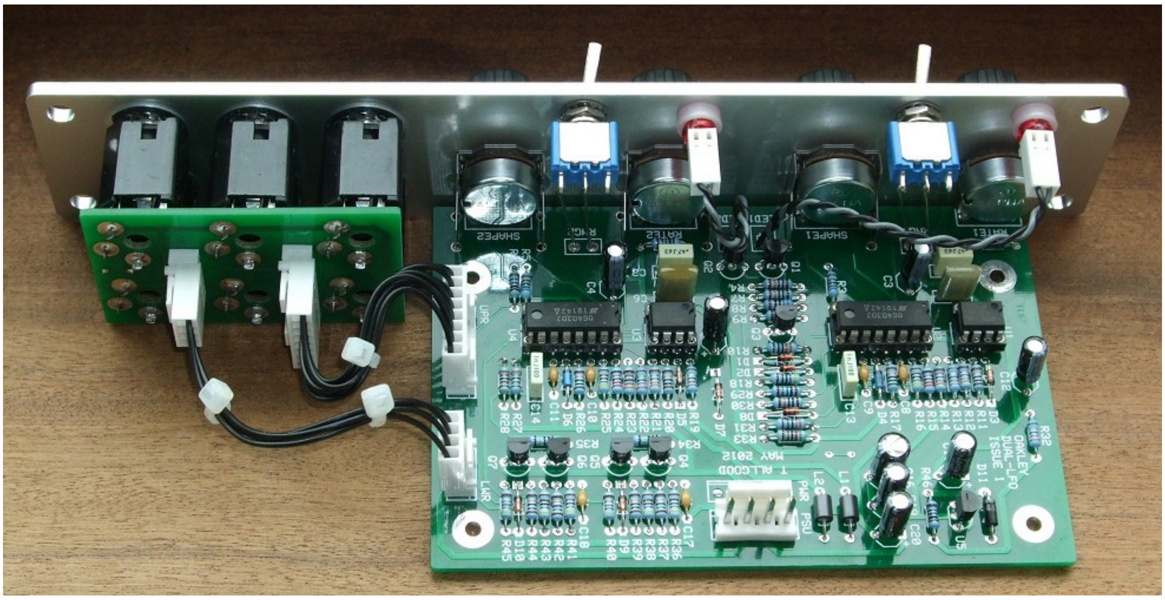
For the User Manual which contains an overview of the operation of the unit, please visit the main project webpage at:

http://www.oakleysound.com/d-lfo.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 Oakley Dual-LFO



The original issue 1 Dual-LFO module behind a natural finish 1U wide Schaeffer panel.

On the printed circuit board I have provided space for the four main control pots. If you use the specified 16mm Alpha pots and matching brackets, the PCB can be held very firmly to the panel without any additional mounting procedures. The pot spacing on this board is different to many of our other 5U modules, instead of 1.625” it is 1.375”. Used in conjunction with smaller 20mm diameter knobs this still allows for an attractive module design and finger friendly tweaking.

The design requires plus and minus 15V supplies. The power supply should be adequately regulated. The current consumption is around +30mA and -10mA. Power is routed onto the main PCB by either our standard four way 0.156” MTA156 type connector or the special five way Synthesizers.com MTA100 header. 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 four mounting holes for M3 bolts, one near each corner. These are not required for panel mounting if you are using the three 16mm pot brackets. The board size is 109mm (deep) x 124mm (high).

The main board has been laid out to accept connection to our Sock6 socket board. This small board speeds up the wiring of the six sockets and reduces the chances of building mistakes.

Dual-LFO issue 1 and 1.1 Parts List

For general information regarding where to get parts and suggested part numbers please see our useful Parts Guide at the project web page 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

1% 0.25W or 0.4W metal film resistors are recommended.

22R	R19, R13, R32, R22
100R	R46, R1, R2
330R	R10
680R	R8
1K	R29, R6
3K3	R27, R31
4K7	R36, R38, R43, R41, R16, R25
6K8	R3, R5, R18
8K2	R28, R33
22K	R24, R15
33K	R23, R14, R12, R21
47K	R40, R45
100K	R26, R44, R37, R39, R17, R11, R20, R42
220K	R4, R7, R9, R30
1M	R34, R35

Capacitors

100nF axial ceramic	C17, C18, C9, C11, C8, C10
1nF polyester	C13, C14
47nF polyester	C6, C5
470nF polyester	C1, C2
2u2, 63V electrolytic	C19, C20, C15
22uF, 35V electrolytic	C12, C7, C3, C4
47uF, 35V electrolytic	C16

Discrete semiconductors

1N4001 diode	D11
1N4148 signal diode	D3, D9, D8, D5, D7, D2, D1, D10
BAT42 Schottky diode	D6, D4
BC549C NPN transistor	Q1, Q2, Q4, Q5, Q6, Q7
BC559 PNP transistor	Q3

Light emitting diodes

5mm red* LED	LED1, LED2
5mm red* LED lens	
5mm retaining ring	

* Any colour LED, except white or blue, can be used.

Integrated Circuits

78L10 100mA 10V regulator	U5
DG403 analogue switch	U2, U4
TL072	U1, U3

Potentiometers (Pots)

All pots Alpha 16mm PCB mounted types

10K log	RATE1, RATE2
1M linear	SHAPE1, SHAPE2

Three 16mm pot brackets.

Switches

Two single pole ON-ON (SPDT) or ON-OFF (SPST) toggle switches are required for the slow/fast selection.

Both switches are mounted on the panel and wired to the board with fly wires – see later for details.

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	UPR	– for connecting to sockets
Molex/MTA 0.1” housing 8-way	UPR	– for connecting to sockets
Molex/MTA 0.1” header 4-way	LWR	– for connecting to sockets
Molex/MTA 0.1” housing 4-way	LWR	– for connecting to sockets
Molex/MTA 0.1” housing 2-way	2 off	– for connecting the two LEDs.

Other Parts Required

Switchcraft 112APC 1/4” sockets Six off mounted either on the Sock6 board or on panel

Four 20mm knobs.

Around 2m of insulated multistrand hook up wire for the switch and socket connections.

Components required if using optional Sock6 board

Molex/MTA 0.1” header 8-way	UPR
Molex/MTA 0.1” housing 8-way	UPR
Molex/MTA 0.1” header 4-way	LWR
Molex/MTA 0.1” housing 4-way	LWR
112APC Switchcraft 1/4” socket	SK1, SK2, SK3, SK4, SK5, SK6

A wire link, L1 on the Sock6 PCB, is to be fitted. Simply solder a wire hoop made from a resistor lead clipping to join the two pads of L1 together.

If using Molex KK you'll also need at least 24 crimp terminals.

Suitable lengths of wire to make up the two interconnects and four cable ties.

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.

It's worth filling the empty holes of the PWR pads with solder.

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 the pin in location 2 is 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 ground (0V)	4	3
-15V	5	4
Socket Ground *	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 and using it with a standard MU power distribution system, you will also need to connect together the middle two pads of the PSU header on the main board. This link connects the socket and panel ground with the module ground. Simply solder a solid wire hoop made from a resistor lead clipping, or bit of solid core wire, to join to the two middle pads of PSU.

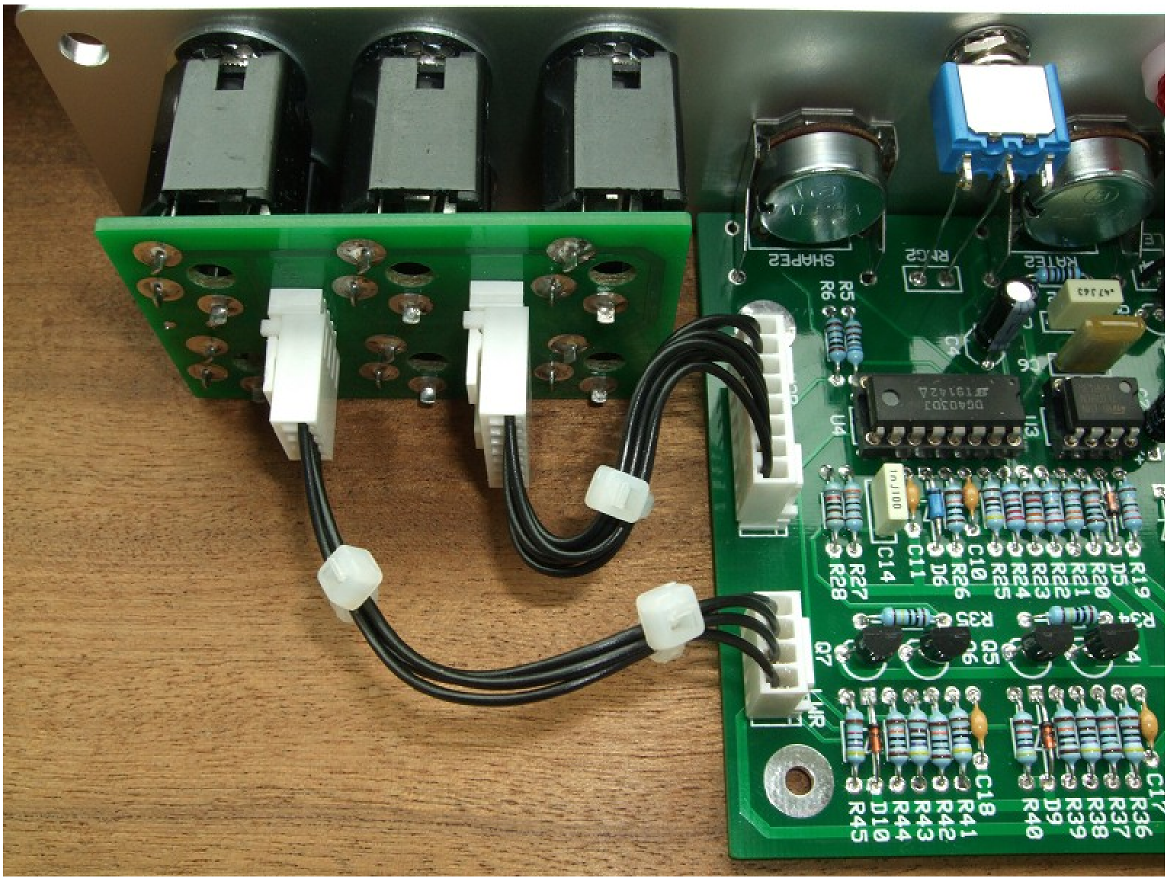
* The later issue 1.1 Dual-LFO boards connect the normally unused pin 6 of the MU connector to socket ground. With the link on PSU not fitted, and using an Oakley MU Dizzy distribution board with a five way power cable, will allow the socket ground to be kept separate from module ground to prevent ground loops.

Building the Dual-LFO module using the Sock6 board

This is the simplest way of connecting all the sockets to the main board. The Sock6 board should be populated in the way described in our construction guide found on the project webpage. There are only two headers, UPR (for upper) which is eight way, and LWR (for lower) which is four way. Both headers are fitted to the bottom side of the board.

The wire link L1 should be fitted to the Sock6 board. Simply solder a wire hoop made from a resistor lead clipping to join the two pads of L1 together.

You need to make up two interconnects. The eight way one should be made so that it is 95mm long. The four way should be made to be 110mm.



The Sock6 board makes it much easier to build the module. Here I have used Molex 0.1" KK headers and housings. This is a 'strip and crimp' system that is cheap but very reliable.

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 LWR. 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:

<u>UPR</u>

Pin	*Pad name*	*Socket*	*Lug Type*
Pin 1	Not Used		
Pin 2	TRI_OUT2	TRI 2	Signal
Pin 3	Not Used		
Pin 4	PULSE_OUT2	PULSE 2	Signal
Pin 5	Not Used		
Pin 6	PULSE_OUT1	PULSE 1	Signal
Pin 7	Not Used		
Pin 8	TRI_OUT1	TRI 1	Signal

<u>LWR</u>

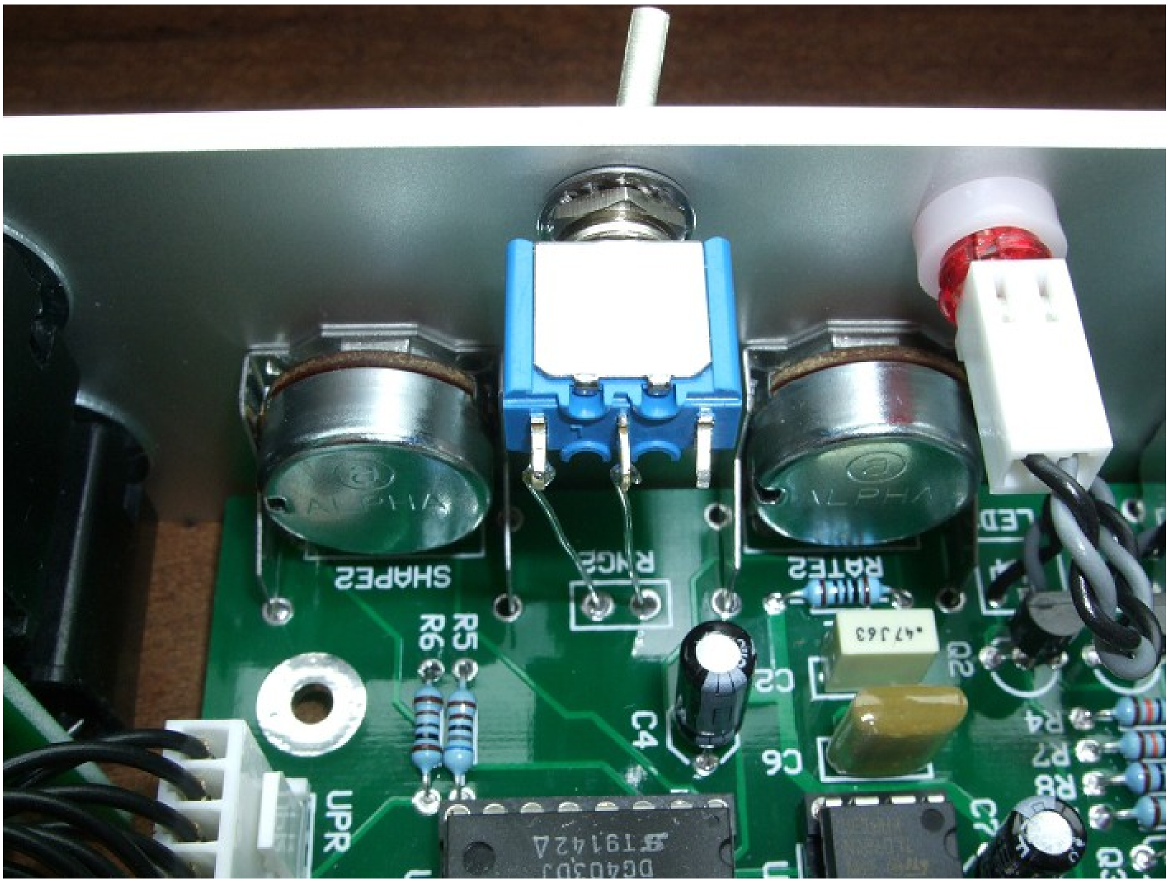
Pin	*Pad name*	*Socket*	*Lug Type*
Pin 1	Panel ground	Connects to all sockets	Ground lugs
Pin 2	SYNC_IN2	SYNC 2	Signal
Pin 3	Module ground	SYNC 1 & SYNC 2	NC
Pin 4	SYNC_IN1	SYNC 1	Signal

Wiring the Switches

The Dual-LFO features two of the same type of switch. They are two position ON-OFF (or ON-ON) switches.

You should wire each switch as you would other Oakley modules. I typically use thin solid core wire rather than insulated multi-strand wire. This keeps the connection firmly in place and very neat. I normally bend the wire at one end into a hook and place the straight end into the PCB pad's hole. I then loop the hooked end around the switch tang and squash the hook into place before soldering it. The solder pad on the board can then be soldered from the underside and the excess wire on snipped off.

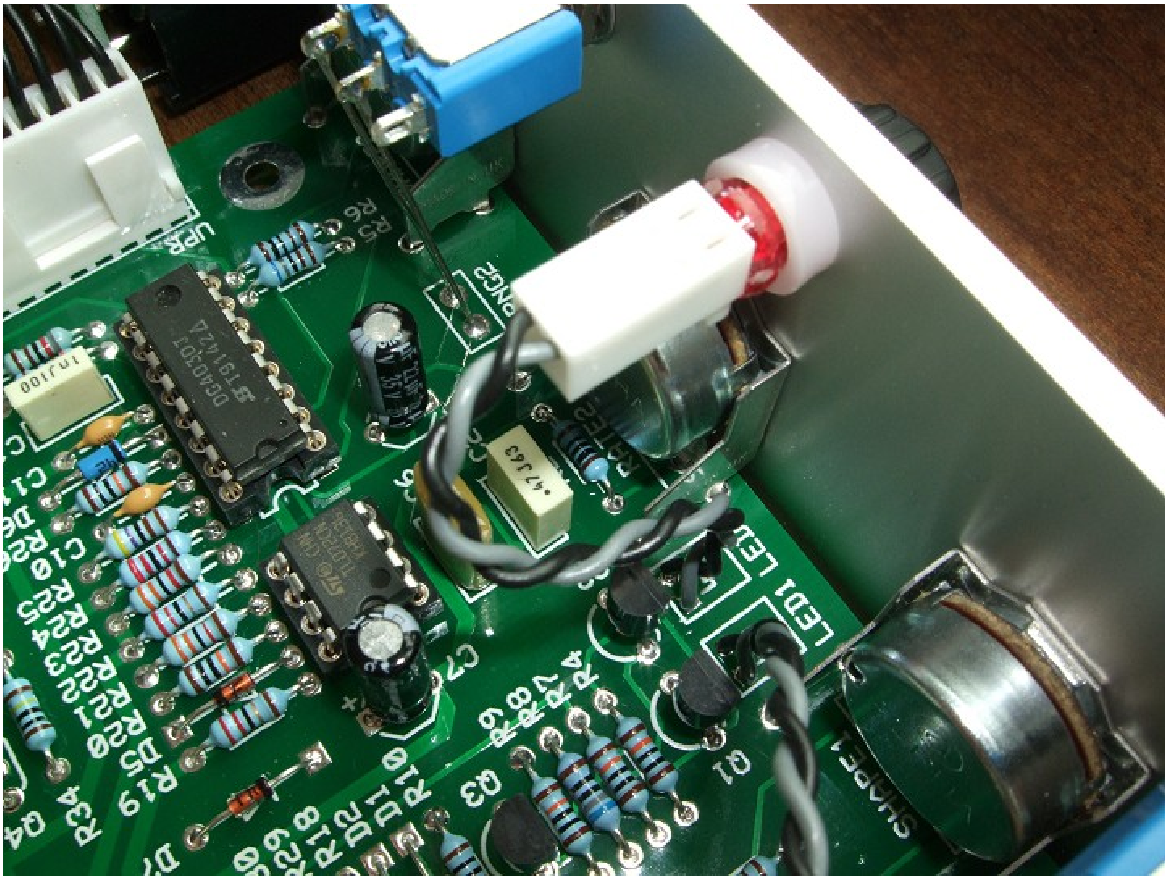
If building the module using the standard panel design then you need to connect the lower two switch tangs to the board. This ensures that the LFO goes into fast mode when the switch is in the down position.



This is an Apem SPDT (on-on) toggle switch. Note that for both switches it is the lower two tangs of the switch that connect to the PCB.

Wiring the LED

The Dual-LFO features two red LEDs and these are wired in similar fashion to other Oakley 5U modules. I recommend that you use a twisted wire pair to connect each LED to the board.



Here I have used a Molex 0.1" KK header and crimps to attach the LED to the PCB. The LED is thus not soldered to the wiring allowing the board to be easily removed from the front panel.

Testing the Dual-LFO

Apply power to the unit making sure you are applying the power correctly. Check that no device is running hot. Any sign of smoke or strange smells turn off the power immediately and recheck the polarity of the power supply, the direction of the ICs in their sockets and the polarity of the diodes and the electrolytic capacitors.

The module is pretty straightforward to test. As soon as it is powered up the LEDs should start to flash. Set each SHAPE pots to their middle positions. Check that the RATE pots control the speed of the flashing for each LFO's LED. The LEDs should simply go on and off and not fade in and out. When on they should indicate a low state from the pulse output, and falling voltage from the triangle wave output.

Check that the SHAPE pot for each LFO will alter the time that each LED is on compared with the the time it is off. Fully counter-clockwise the LED should be mostly on. Fully clockwise the LED should be just flickering.

If you have a oscilloscope it will be worth checking the output waveforms at this point. The pulse waveform should go from 0V to around 9V. The triangular waveform should ramp between -4.5V and +4.5V.

If you don't have a 'scope then you may wish to plug your module into the rest of your modular and try modulating another module. The pitch of a VCO or self-oscillating VCF is a good modulation input to chose because you'll be able to hear very clearly what the LFO is doing.

To test the SYNC input you can either use a gate signal from your midi-CV converter, controller or sequencer. You can also use another LFO, and since the Dual-LFO has two, you can use one to test the other. Using the pulse output from one LFO (the master) to trigger the sync input of the other (the slave), you should find that you can control the speed of the slave with the master's rate control. Note that if the master's rate is lower than the slave's rate then the slave will oscillate as normal but will occasionally hiccough when the master's pulse output goes high.

If all this happens, the chances are that you have a working module. There is no calibration to be done on this module.

Circuit Description

The Dual-LFO circuit is, as you would expect, two identical low frequency oscillator circuits sharing a common power supply and interface.

Power enters the board via one of two means: Firstly, the usual Oakley/MOTM four way header, labelled PSU. Secondly, the five pin (but six pin spaced) special Synthesizers.com power supply header, PWR.

Once connected to the board the power supply lines are filtered and decoupled by simple LC networks based around L1 and C19 for the positive rail, and L2 and C20 for the negative rail. Two grounds are provided, one for the circuit itself, and one for the earthing of the jack sockets on the front panel.

The power supplies to the four main integrated circuits (ICs), U1 to U4, are shown separately to avoid cluttering the main circuit diagram.

U5 provides a stable +10V supply for the DG403's digital input circuitry, the two sync input circuits and the LEDs. U5 is a three terminal device which regulates the +15V down to +10V. R46 and C16 provide some decoupling from the +15V supply so that sudden current demands from the +10V supply aren't instantly passed back to the rest of the modular.

Since both LFO circuits are identical we will discuss only LFO-1 which is shown on the first page of the schematic.

The core of the LFO circuit is built from three parts. A changeover switch (U2 pins 1, 3, 4 & 16), an integrator (U1a, pins 1, 2 & 3) and a schmitt trigger (U1b, pins 5, 6 & 7). The output from each feeds into the next one in the chain, and then right round again. We will start by looking at each bit in turn.

The first TL072, U1a, op-amp forms part of the integrator. Any positive voltage applied to the left of R3, will cause the voltage to fall at the output of the op-amp. The speed at which the voltage falls is controlled by C5 (and C1 if the range switch is set to slow) and the size of the voltage applied to R3. If the applied voltage is negative the op-amp's output will rise, while if it is positive the output will fall. It is the integrator's output that will be used as the source for the triangle output.

The DG403 is configured as four electronically controlled switches. They are arranged in pairs, so that when one switch of the pair is closed the other is open. When a switch is closed the signal can pass through pretty much unaffected. The second half of the DG403, on the right, is wired so that the output of the integrator passes straight to the schmitt trigger. This connection can be broken when the sync pulse is applied, but more about this later.

The schmitt trigger is a simple circuit block based around the second half of the TL072 op-amp. Its input is essentially the left hand side of R12. The schmitt trigger's output is either high at +13V, or low at -13V. If the output of the schmitt is initially low, it requires +5V at R12 to make it go high. And conversely the integrator will need to produce an output of -5V to make the Schmitt go low again.

To make any oscillator you normally require an output to be fed back into the input. In a standard LFO, the integrator is directly 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....

In the Dual-LFO, the amount of signal applied from the Schmitt trigger to the integrator is controlled by two items:

Firstly, the 'Rate' pot. This allows a only a controlled proportional of the schmitt's output voltage to reach the integrator. If the proportion is large, the voltage on R3 is large, and the integrator sweeps fast. If the proportion is small the integrator sweeps slowly. R1 sets the minimum speed. Don't be tempted to lower this value any more to get really slow sweeps. Errors within the integrator op-amp will take over and your LFO won't oscillate any more.

The second control for the speed of the integrator is the first half of the DG403 switch coupled to the 'Shape' pot. The switch is controlled by the schmitt trigger's output. When it is high, the top switch is closed, and the resistance between the top of the pot and the wiper will determine the rate of fall in the integrator output. When it is low, it is the bottom of the pot that is switched in, and this controls the rise of the integrator's output. If the rate pot is central, then both halves of the pot are equal, and the rise and fall times are also equal. If, however, the pot is moved towards one of its ends, then the rise and fall times of the output will be different, but the overall frequency will be roughly the same.

D3 allows only positive voltages to control the DG403. Negative voltages can damage the device, and must be removed from the control pin, pin 15. R15 and R16 reduce the control voltage to around +10V. The pulse output is also taken from D3. R31 and R33 attenuate the signal to approximately 10V peak. The output impedance is about 1K5 when the output is high.

The triangle output is taken from the integrator's output via R29. The output level, is controlled by the schmitt trigger's R11 and R12 and is set at +/-5V approximately.

D8 feeds the LED driver circuit. I will talk about this later.

The LFO has a synchronisation input. When activated by a gate type signal it is designed to force the integrator's output momentarily to zero.

A gate signal is typically 0 volts when off and any positive voltage greater than 3V when on. The input circuit should be easily able to handle a wide range of input voltages without damage. R39 restricts the amount of current going into Q5, while D9 protects Q5 from any unwanted negative inputs. When a positive gate arrives, Q5 turns on and pulls its collector down to ground or 0V. This turns off Q5 and the collector of Q5 is pulled up to +10V by R36. R34 provides a little positive feedback to speed up switching times. The action of positive feedback allows slowly increasing control voltages (CVs), such as that from other LFOs, to reliably trigger the synchronisation function.

The inverted and beefed up version of the applied gate signal found at the collector of Q5 is sent then to a CR network that acts as a differentiator. This circuit, based around C13 and R17, produces a positive voltage spike when the gate goes high. The duration of the spike is determined principally by the values of C13 and R17. D4 prevents a negative spike being produced when the gate returns low.

When no sync pulse is present, and pin 10 is low, U2 (pins 5, 6, 8 & 9) allows the integrator output to pass straight to the Schmitt trigger. However, when a spike generated by the CR network is present at pin 10 of the DG403, two things happen. Firstly, the integrator output is cut off from the schmitt trigger by the opening of the FET switch between pins 5 and 6. R14 will then force the schmitt trigger's input low and the Schmitt's output will be set low. Secondly, the integrator capacitor will be shorted out, by the closing of the FET switch between pins 8 and 9. This will set the integrator's output at zero volts. When the 'sync' spike fades away, the switch opens and the integrator will then start to ramp positive due to the negative voltage from the schmitt trigger. If we did not force the Schmitt low, then the integrator may either ramp down or up. A good LFO should have a predictable behaviour, and ramping up is the most sensible.

On the right hand side of the third page of the schematic we can see the LED driver. This looks a complicated circuit considering that the normal way to light an LED from an LFO's pulse output is simply just to connect it via a suitable resistor. However, this generates variations in current draw from the module. As each LED turns on there would be an additional 2mA or so being taken from the power supply. This can produce audible clicking or interference to other modules. The Dual-LFO uses a constant current circuit, based around Q3, D1 and D2, to drive both LEDs in series. The constant current circuit takes a fixed 4mA from the +10V supply whether the LEDs are on or off. The LEDs are individually turned on and off by transistors, Q1 for LED1 and Q2 for LED2. When the transistor is turned on by a high output from the LFO core it shorts out the LED turning it off.

R10 sets the current running through the LEDs which in this case is around 2mA. The base of Q3 is held at 1.2V below the +10V supply by the actions of the two diodes, D1 and D2, and resistor R18. Q3 will act to ensure that its emitter is always 600mV higher than its base. This means, within certain limits, that R10 always has 600mV across it irrespective of its value. By changing the value of R10 you can thus control the amount of current running through Q3.

$i = V / r$

where:

i = current through LED in mA
V = 600mV
r = resistance of R10 in ohms

eg. Making R10 150 ohm would give a current of 4mA.

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 EU, 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.

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