# Oakley Sound Systems

# Little Low Frequency Oscillator
# Board Issue 4

# User's Guide
# V1.0


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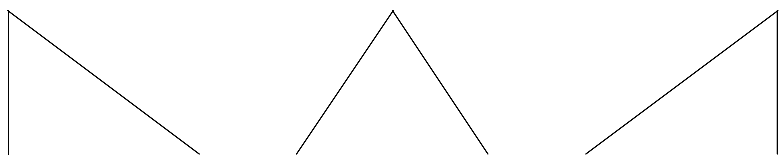
**Please make sure you have the issue 4 Little-LFO PCB. It should have the words ‘LFO ISS.4’ underneath the RATE pot.**

# Introduction

This is a simple but effective low frequency oscillator (LFO) module primarily designed for use in modular synthesisers. Its basic design and the use of PCB mounted pots makes this an ideal starter module for beginners to my modular synthesiser projects.

The design was based around the topology of the Korg MS-20’s LFO. This simple design had three op-amps and two selected FETs. The basic circuit was quite straightforward, but what made it special was the ‘Shape’ control. This enabled the ‘triangle’ and ‘pulse’ outputs to have a variable duty cycle without affecting frequency. For the triangle output, you could vary the rise-time to fall-time ratio. Thus the triangle would be able to go from a saw down waveform,



to a saw up waveform. The diagram below shows this more clearly:

The Oakley ‘Little-LFO’ takes the basic topology of the Korg design but improves it with modern components. The selected FETs, the 2SK30A-O, which are difficult to get hold of, have been replaced by a single integrated FET switch, the DG403. This gives enhanced performance with faster edges for the sawtooth waveforms. We can also lose one of the op-amps. The DG403 has two pairs of FET switches inside. The second pair of switches allows us to have a synchronisation function. When a rising edge is applied to the sync input, eg. a gate signal from a midi-CV convertor, the LFO output waveform will be reset to zero momentarily. The LFO can now be used as a simple linear envelope generator.

All the parts are easily obtainable, although the PCB mounted pots and pot brackets are available from me should you find any difficulty in getting these.

# The PCB

The PCB is small and almost cute at just 6.5 x 4.6 cm in size. It uses double sided copper traces and has through plated holes. It has solder mask both sides for easier soldering, and has component legending on the top side for easier building.

I have provided space for the two control pots on the PCB. These can be mounted away from the PCB, but they do form part of the mounting process, as no holes are provided on the PCB for supporting the board. 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 horizontally, ie. in a 2U wide panel. I have included a suggested front panel layout at the back of this document.

The design requires plus and minus 15V supplies. These should be adequately regulated. The current consumption is about 10 mA per rail, although this can rise considerably if you chose to use the bicolour LED. Power is routed onto the PCB by a four way 0.156" MTA header. The four pins are +15V, ground, earth, -15V. The earth 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 connector used is identical to all new Oakley modules.

The fourth issue of the Little-LFO board is pretty much unaltered from the first one. However there are some differences in the part numbering. Also, in common with the new range of Oakley modules, the lead spacing on all capacitors is now 0.2" or 5mm. Older boards used 0.3" or 7.5mm spacing for the polyester capacitors.

## Circuit Description

The LFO circuit is quite simple, but let's run through the design carefully. Looking at the left of the schematic you can see the four way header, labelled PSU. Power enters the board here, and is immediately filtered by a simple RC networks based around R12 and C6 for the positive rail, and R13 and C5 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.

There are just two ICs on this PCB, and each requires power. The power supply to each IC is shown separately to avoid cluttering the main circuit diagram.

The circuit is built from three parts. A changeover switch, an integrator and a schmitt trigger. 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 op-amp forms part of the integrator. Any positive voltage applied to the left of R4, will cause the voltage to fall at the output of the op-amp. The speed at which the voltage falls is controlled by C1 (and C2 if the range switch is set to low) and the size of the voltage applied to R4. 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 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. It's output is either high at +13V, or low at -13V. If the output of the Schmitt is initially low, it requires +5V at the output of the integrator to make it go high. 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 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 Little-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 R4 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. Input 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.

D1 allows only positive voltages to control the DG403. Negative ones will overheat the device, and must be removed from the control pin. The pulse output is taken from this positive only signal. R5 and R9 attenuate the signal to approximately 10V peak. The output impedance is about 1K3 when the output is high.

The triangle output is taken from the integrator's output via R3. The output level, is controlled by the Schmitt trigger and is set at +/-5V approximately.

When a pulse or gate appears at the 'sync' input, the pulse or gate is shaped by C4, R11 and D2 to give a short positive spike. This controls the second half of the DG403. Normally, as I mentioned earlier, this part of the DG403 allows the integrator output to pass straight to the Schmitt trigger. However, when a spike 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. R7 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 integrator will 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 ramp down or up. A good LFO should have a predictable behaviour, and ramping up is the most sensible.

C1 controls the overall range of frequencies produced by the Little-LFO. You may want to try different values for this capacitor. With 100nF, you get about 0.2Hz to about 25 Hz. Lower values of C1 will give you a faster oscillator, although some problems will occur if you try to get frequencies above 500Hz. I tried 1uF, and I got some very slow sweeps of around a minute or so at the bottom end. A simple switch can be made to allow a higher value capacitor, C2, to be added in parallel to C1. S1 and S2 are the solder pads that need to be connected to your chosen switch. When the switch is closed the capacitors add together to get a single larger value capacitor. For C2 I have selected 470nF, this will give a frequency range of 0.04Hz to 4Hz. This gives a reasonable overlap between the two ranges. Either way, the range with the ‘rate’ pot alone is about 100:1.

A bicolour LED may be fitted too. This is simply fixed to a current limited version of the comparator output. R2 controls the maximum current, and hence, brightness, of the LED. The LED will be one colour when the square wave output is positive and another when the output is zero. This corresponds to one colour as the ramp output is rising, and the other colour as the ramp output is falling.

## Buying your components

Most of the parts are easily available from your local parts stockist. I use Rapid Electronics, RS Components, Maplin and Farnell, here in the UK. The Little-LFO was designed to be built solely from parts obtainable from Rapid Electronics and myself only. Rapid’s telephone number is 01206 751166. They offer a traditional ‘paper’ catalogue and take VISA card orders over the telephone.

In North America, companies called Mouser, Newark and Digikey are very popular. In Germany, try Reichelt, and in the Nordic countries you can use Elfa. All companies have websites with their name in the URL.

The pots are Omeg Eco types with matching brackets. You could use any type you want, but not all pots have the same pin spacing. Not a problem, of course, if you are not fitting them to the board. In the UK, CPC, Maplin and Rapid sell the Omeg pots at a very good price. However, only Maplin sell the pot brackets. The pot kit that I supply contains both pots and the pot brackets.

The resistors can be ordinary 5% 0.25W carbon types, but I would go for 1% 0.25W metal film resistors throughout, since these are very cheap nowadays. For the UK builders, then Rapid offer 100 1% metal film resistors for less than 2p each!

All the aluminium electrolytics (abbreviated to ‘elect’ in the parts list) should be over 25V, except where stated, and radially mounted. However, don’t chose too higher voltage either. The higher the working voltage the larger in size the capacitor. A 220V capacitor will be too big to fit on the board. 25V or 35V is a good value to go for.

The pitch spacing of all the non-polar capacitors is now 5mm (0.2”). This may differ from some of the older Oakley boards you have built. For the values 100nF and 470nF, I use metalised polyester film types. These come in little plastic boxes with legs that stick out of the bottom. Try to get ones with operating voltages of 63V or 100V.

All ICs are dual in line (DIL or DIP) packages. These are generally, but not always, suffixed with a CP or a CN in their part numbers. For example; TL072CP. Do not use SMD, SM or surface mount packages. The DG403 is a dual SPDT FET switch. In the UK, this can be tricky to source. Farnell sell them, but are currently very expensive. Other sources are RS Components Ltd. who sell the DG403DJ.

As with most of the Oakley modular series the input and output sockets are not board mounted. You can choose what types of sockets to use. I used the excellent Switchcraft 112.

The LED should be a 5mm diameter bicolour LED. Do not get tri-colour types, as they have three legs not two, and cannot be made to work in this circuit. I prefer to use ‘red-green’ types, although other colours are available. The LED clips I use I get from Maplin in the UK. They have a built in lens and hold the LED firmly to the front panel. For bi-colour LEDs, it is best to get an uncoloured lens.

## Parts List

A quick note on European part descriptions. 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.

Note: 1000nF = 1uF. 1000R = 1K

**Resistors:** all 1% metal film

| | |
|---|---|
| 22R | R12, 13 |
| 100R | R6 |
| 1K | R3 |
| 1K8 | R2 |
| 2K2 | R5 |
| 4K7 | R9 |
| 6K8 | R4 |
| 33K | R7, 8 |
| 100K | R1, 10, 11 |

**Capacitors**

| | |
|---|---|
| 22uF,25V elect | C5, 6 |
| 100n polyester film | C1, 3 |
| 1n polyester film | C4 |
| 470n polyester film | C2 (optional) |

**Discrete Semiconductors**

| | |
|---|---|
| 1N4148 | D1, 2 |
| LED Bicolour | Off board (optional) |

**Integrated Circuits**

TL072 dual FET op-amp
DG403 Dual SPDT analogue FET switch

**Miscellaneous**

| | | |
|---|---|---|
| 4-way MTA/Molex 0.156" header | | PSU |
| Pot bracket for Eco pots | (2 off) | |
| | | |
| 1M lin Eco pot | Shape | |
| 10K log Eco pot | Rate | |

You may well want to use sockets for the ICs. I would recommend low profile turned pin types as these are the most reliable.

# Building the Little-LFO Module

Occasionally people have not been able to get their Oakley projects to work first time. Some times the boards will end up back with me so that I can get them to work. To date this has happened only four times across the whole range of Oakley PCBs. The most common error with three of these was parts inserted into the wrong holes. Please double check every part before you solder any part into place. Desoldering parts on a double sided board is a skill that takes a while to master properly, so it would be better if you don't make a mistake.

A few years ago Paul Schreiber of SynthTech has won over to water washable flux in solder which he supplies with his MOTM kits. The quality of results is remarkable. In Europe, Farnell sell Multicore's Hydro-X, a very good value water based product. You must wash the PCB at least once an hour while building. Wash the board in warm water on both sides, and use a soft nail brush or washing up brush to make sure all of the flux is removed. Make sure the board is dry before you continue to work on it or power it up. It sounds like a bit of a hassle, but the end result is worth it. You will end up with bright sparkling PCBs with no mess, and no fear of moisture build up which afflicts rosin based flux. Most components can be washed in water, but do not wash a board with any trimmers, switches or pots on it. These can be soldered in after the final wash with conventional solder or the newer type of 'no-clean' solder.

All resistors should be flat against the board surface before soldering. It is a good idea to use a 'lead bender' to preform the leads before putting them into their places. I use my fingers to do this job, but there are special tools available too. Once the part is in its holes, bend the leads that stick out the bottom outwards to hold the part in place. This is called 'cinching'. Solder from the bottom of the board, applying the solder so that the hole is filled with enough to spare to make a small cone around the wire lead. Don't put too much solder on, and don't put too little on either. Clip the leads off with a pair of side cutters, trim level with the top of the little cone of solder.

Once all the resistors have been soldered, check them ALL again. Make sure they are all soldered and make sure the right values are in the right place.

The diodes can be treated much like resistors. However, they must go in the right way. The cathode is marked with a band on the body of the device. This must align with the vertical band on the board. In other words the point of the triangular bit points *towards* the cathode of the diode. The two diodes used in this project are 1N4148 or 1N4448. They look like small cylinders made from a pinkish glass. The band is painted on the surface of the glass usually in black ink, but I have seen some devices with white markings. Either way, the band refers to the cathode.

An IC socket is to be recommended, especially if this is your first electronics project. Make sure, if you need to wash your board, that you get water in and around these sockets.

**Please note:** The TL072 and the DG403 have pin 1 at the **top** left hand. Pin 1 is depicted on the board by a square pad for both ICs and the 0.1” headers.

The polyester capacitors are like little blue or red boxes. Push the part into place up to the board’s surface. Little lugs on the underside of the capacitor will leave enough of an air gap for the water wash to work. Cinch and solder the leads as you would resistors.

The smaller electrolytic capacitors are very often supplied with 0.1” lead spacing. My hole spacing is 0.2”. This means that the underside of these radial capacitors will not go flat onto the board. This is deliberate, so don’t force the part in too hard. The capacitors will be happy at around 0.2” above the board, with the legs slightly splayed. Sometimes you will get electrolytic capacitors supplied with their legs preformed for 0.2” (5mm) insertion. This is fine, just push them in until they stop. Cinch and solder as before. Make sure you get them in the right way. Electrolytic capacitors are polarised, and may explode if put in the wrong way. No joke. Oddly, the PCB legend marks the positive side with a ‘+’, although most capacitors have the ‘-’ marked with a stripe. Obviously, the side marked with a ‘-’ must go in the opposite hole to the one marked with the ‘+’ sign. Most capacitors usually have a long lead to depict the positive end as well.

I would make the board in the following order: resistors, diodes, IC socket, small non-polar capacitors, electrolytic capacitors. Then the final water wash. Do not fit the pots at this stage. The mounting of the pots requires special attention. See the next section for more details.

## Mounting the Pots

If you are using the recommended Eco pots, then they can support the PCB with specially manufactured pot brackets. You will not normally need any further support for the board. When constructing the board, fit the pot brackets to the pots by the nuts and washers supplied with the pots. Now fit them into the appropriate holes in the PCB. But only solder the three pins that connect to the pot. I normally solder the middle pin first and then check if the pot is lying true. If it is not, simply reheat the middle pin’s solder joint to allow you to move the pot into the correct position. **Do not solder the pot bracket at this stage.**

Now remove all the nuts and washers from the pots and fit the board up to your front panel. Refit the washers and tighten the nuts, but not too tight other wise you will deform the pot bearing. If the pot feels rough when you turn it, the chances are that you have tightened the pot nuts too tight. Normally backing off the nut a bit is enough to free the shaft. Now carefully position the PCB at right angles to the panel. The pot’s own pins will hold the PCB fairly rigid for now. Then you can solder each of the brackets. This will give you a very strong support and not stress the pot connections.

The Omeg pots are labelled A, B or C. For example: 47KB or 100KA. Omeg uses the European convention of A = Linear, B = logarithmic and C = Reverse logarithmic. So a 1MA is a 1 megohm linear pot.

The pots shafts may be cut down with a good pair of pliers, or a junior hack saw. Try not to bend or rotate the shaft as you are cutting.

The pots are lubricated with a thick clear grease. This sometimes is visible along the screw thread of the pot body. Try not to touch the grease as it consequently gets onto your panel and PCB. It can be difficult to get off, although it can be removed with a little isopropyl alcohol on cotton wool bud.

## Wiring up the Little-LFO

The power socket is 0.156” 4-way header in common with rest of the Oakley and MOTM modules. Friction lock types are recommended.

| ***Power*** | ***Pin number*** |
| --- | --- |
| +15V | 1 |
| Module 0V | 2 |
| Earth/Screen | 3 |
| -15V | 4 |

The SCR pad on the PCB has been provided to allow the ground tags of the jack sockets to be connected to the power supply ground without using the modules 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.

If you have used Switchcraft 112 sockets you will see that they have three connections. One is the earth 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. In the Little-LFO, we have no use for the NC lugs.

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. Its nice and stiff, so retains its shape. A single piece of insulated wire can then be used to connect those connected earth tags to the SCR pad. In this module I fit the sockets so that the bevel on the side of the socket is facing top left. The wire frame is then made by soldering one piece of solid wire across the top of each row of sockets connecting all the earth tags together. The three horizontal pieces of wire are then bridged by a single piece of wire, soldered vertically and cut to size. Thus if you are building the triple LFO panel, all nine sockets are connected up to the same ground frame. Take your single piece of insulated wire, which you can connect from one point on your wire frame, to the top board's SCR pad.

The new issue four layout has given me a chance to put some extra power supply pads on the PCB. These are the three extra pads near the MTA header. These new pads are labelled +V, 0V and -V and are connected to the +15V, ground and -15V lines respectively. If you build the triple LFO panel, you don't need to use three MTA sockets with their three separate power cables. You can now power all three boards from the 'master' LFO at the top.

The top board should be fitted with the MTA header. The second board down takes its power from wires that go from the three pads on the top board to its MTA pads. A wire should connect the +V pad to pin 1 on the PSU header. 0V should go to pin 2. And -V should go to pin 4.

The third board down then takes its power from the second board's three pads, just like the second board took its power from the top one.

At the rear of this user guide I have included a 1:1 drawing of the suggested front panel layout for the 'Triple Little-LFO' panel.

For each board connect, with a piece of insulated wire, each **signal tag** on each socket to the respective pad on the PCB.

| ***Socket Name*** | ***PCB pad name*** |
|---|---|
| Triangle | TRI |
| Pulse | SQR |
| Sync | SYN |

The LEDs are wired between LD1 and GND pads. I normally wire them up to give red for positive and green for negative. Use a bit of heatshrink to prevent the wires from shorting out near the LED. Twisting the pair of wires that go to each LED keeps things tidy.

Not in the suggested layout is the option of adding a range switch. The switch needs to be a standard SPST or SPDT switch. This switch is fitted between PCB pads S1 and S2. Closing the switch will reduce the frequency of the LFO by five. Don't forget to fit C2 if you want this option.

Actual panels can be obtained from Schaeffer-Apparatebau of Berlin, Germany. The cost is about £20 per panel. All you need to do is e-mail the fpd file that is found on the Little-LFO web page on my site to Schaeffer, and they do the rest. The panel is black with white engraved legending. The panel itself is made from 3 mm thick anodised aluminium. The fpd panel can be edited with the Frontplatten Designer program available on the Schaeffer web site.

# Final Comments

I hope you enjoy building and using the Oakley Little-LFO. Please feel free to ask any further questions about construction or setting up. If you cannot get your project to work, do get in touch with me, and I will see what I can do. Sometimes, it can be the simplest things that can lay out a project. I do offer a get-you-working service. I do offer a get-you-working service. Send your completed non-working module back to me with £20 and I will fix it for you. You will also have to pay for the postage both ways and for any parts I need to replace. Make sure you wrap it carefully and include a full description of the fault. Don't forget if you are sending it from outside the EU, you must say 'for repair only' on the customs declaration.

Please further any comments and questions back to me, your suggestions really do count. If you have any suggestions for new projects, feel free to contact me. You can e-mail, write or telephone me. If you telephone then it is best to do this on Monday to Friday, between 9 am and 6 pm, British time.

Last but not least, can I say a big thank you to all of you who helped and inspired me. Thanks also to all those nice people on the Oakley-synths, Synth-DIY and MOTM mailing lists.

Tony Allgood. March 2003

Version. 1.0

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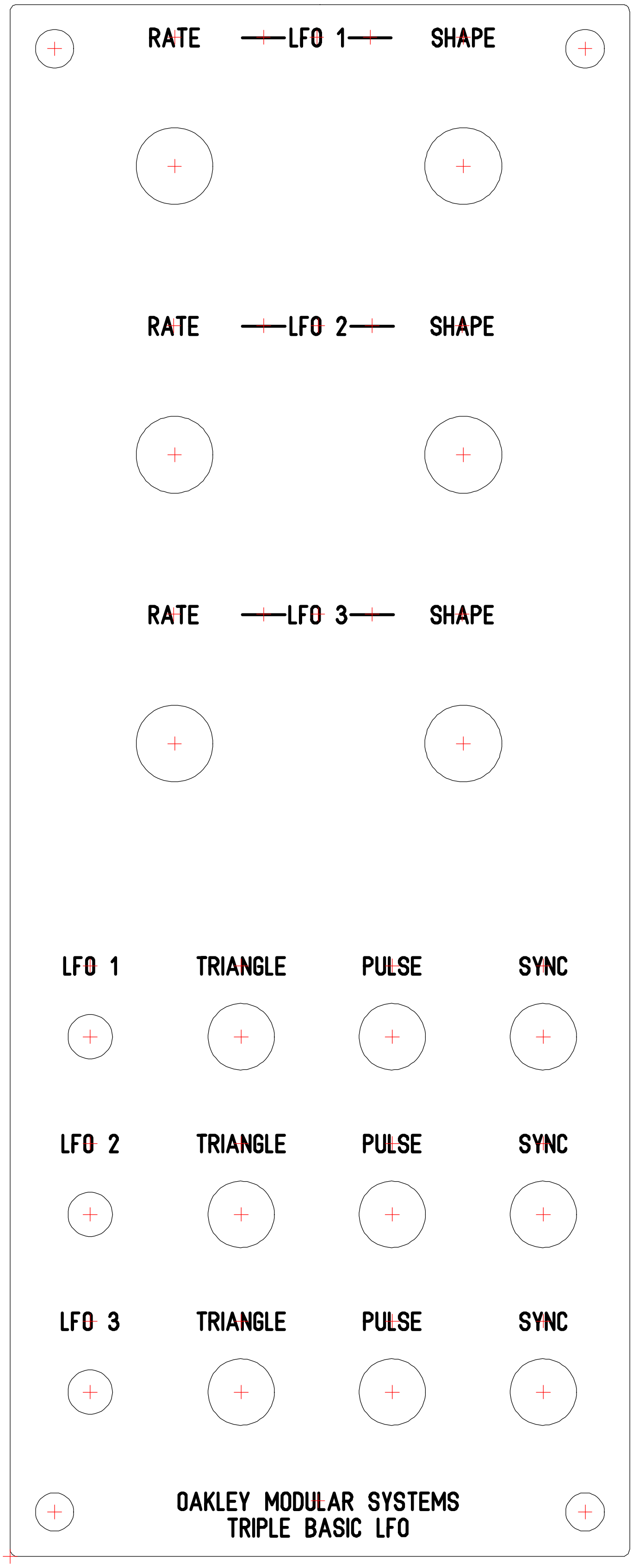
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