Oakley Sound Systems

Equinoxe Issue 1

Voltage Controlled Phaser Module

User's Guide

V1.2

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Introduction

The Oakley Equinoxe is a classic four stage OTA based phaser, similar in sound to the phaser used by Jean Michel Jarre on Oxygene and Equinoxe albums.

My version of this unit allows the centre frequency of the phase shifter to be controlled by an external control voltage (CV). Thus allowing envelope generators to be used to sweep the phaser to create filter type effects. It also contains a low frequency oscillator that is connected internally to the phase shifter when a CV is not being applied.

The module has four pots:

Frequency: this controls the frequency of the two notches created by the phase shift network.

Emphasis: this accentuates the feedback signal within the phaser to create a deeper effect.

Modulation depth: A simple attenuator to adjust the level of the internal LFO or incoming CV.

LFO rate: adjusts the speed of the LFO.

The internal LFO produces a triangle wave output which is also available from a front panel socket. This allows you to use the internal LFO for other modulation purposes. The LFO signal is automatically routed to the modulation depth pot when no jack is inserted in the CV input.

The unit is designed to work with standard MOTM/Oakley signal levels, although it could be easily converted to be run straight from a guitar.

The design requires plus and minus 15V supplies. These should be adequately regulated. The current consumption is about 25mA for each rail. Power is routed onto the PCB by a four way 0.156" Molex type connector. Provision is made for the two ground system as used on all new Oakley modular projects, and is compatible with the MOTM and Blacet systems. See later for details. This unit will run from a +/-12V supply with a slight reduction in dynamic range.

Circuit Description

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

The 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 synthesiser. The Equinoxe uses just four all pass stages to achieve its sound. Each all pass stage is identical. The core of each stage is an 3080 OTA acting as current controlled resistor and invertor 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 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 short chain. The input signal enters the chain through C10 and leaves it via C3 and R15. R15 and R16 provide the necessary mixing effect at their junction for the notches to be created. U6 acts as another buffer circuit and also amplifies the mixed signal up to the high levels associated with modulars.

Q1 and Q2 form a discrete input circuit which inverts and buffers the 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... so I just let my ears to 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 very effective.

The OTAs are all controlled from one current source. This is clever current source though. Based around Q12 and Q7, its 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 Q12.

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

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

The first TL072 op-amp, U1a (1,2,3) 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 C6 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.

The second half of the TL072 op-amp 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 C6 to get different range of sweep speeds. Setting C6 at 470nF, we can go through the very slow at one cycle per minute to around 10Hz.

Components

Most of the parts are easily available form your local parts stockist. I use Rapid Electronics, RS Components, Maplin and Farnell, here in the UK. The Equinoxe 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. But note that none of these now sell the pot brackets. The pot kit that I supply contains all four pots and the pot brackets.

The resistors are generally ordinary 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!

For the capacitors, there are no set rules. 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. In my prototype I used polypropylene capacitors for the four 6n8 (6.8nF) capacitors in the phase shifter itself. These are higher quality components and have a better tolerance. Again try to get the ones that are radially mounted and come in little rectangular boxes.

The horizontal preset or trimmer resistor is just an ordinary carbon type. No need to buy the expensive cermet types. Carbon sealed units have more resistance to dust than the open frame types. Piher make a suitable type to use here. Pin spacing is 0.2” at the base, with the wiper 0.4” away from the base line.

L1 and L2 are leaded ferrite beads. These are little axial components that look like little blackened resistors. They are available from most of the mail order suppliers. Find them in the EMC or Inductor section of the catalogues. Farnell sell them as part number: 108-267.

The BC550 and BC560 devices are discrete low noise transistors. You can replace them with BC549 and BC559 types respectively, although the voltage rating of the BC550 and BC560 is higher. Quite often you see an A, B or C suffix used, eg. BC549C. This letter depicts the gain or grade of the transistor (actually hfe of the device). The Equinoxe is designed to work with any grade device although I have used BC549B and BC559B throughout in my prototypes.

Please note: Q2’s legend on the PCB has been printed the wrong way. You must fit Q2 opposite to that shown on the board. In other words, the flat of the transistor must line up with the rounded side of the white silk-screen. All other transistors have been correctly printed.

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 3080 is an operational transconductance amplifier, and is some times not to be found in the op-amp section of your parts catalogue. It may be down as ‘special’ or ‘OTA’. Sometimes the part is marked CA3080E or LM3080.

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.

Finally, if you make a component change that makes the circuit better, do tell me so I can pass it on to others.

Parts List

This is an early issue of the documentation, I have checked the parts list, but I can miss things. If in doubt, check against the circuit diagram, this is always correct. Please e-mail me if you find any discrepancies.

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.

Resistors

All resistors 5% or better. 0.25W types.

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

Capacitors

100nF, 63V polyester	C4, C11, C2, C20, C21
22uF, 25V elect	C5, C1, C13, C12, C14, C15, C8, C7
470nF, 63V polyester	C10, C9, C3, C6
6n8, 63V polyprop	C16, 17, 18, 19

Discrete Semiconductors

BC550	Q1, 3, 4, 5, 6, 7, 8, 9, 10, 11
BC560	Q2**, Q12

** Don’t forget that Q2 must be mounted facing the opposite way to the board legend

Integrated Circuits

TL072	U6, U1
CA3080E	U2, 3, 4, 5

Others

10KB	EMPHASIS
47KA	FREQ, DEPTH
47KB	RATE
470K trimmer	TUNE

Ferrite beads	L1, L2
Bicolour LED 5mm	LED
LED Clip	
1/4” sockets	IN, OUT, CV, LFO
8pin DIL IC sockets	Six off

A small amount of insulated multistrand wire is needed. This will be used to connect the sockets, and perhaps the LED, to the board.

IC sockets are to be recommended, especially if this is your first electronics project. You need six 8 pin DIL sockets. Choose ‘turned pin’ or ‘dual wipe’ types.

Building the Equinoxe

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 a few times across the whole range of Oakley PCBs. The most common error with four 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.

If you have put a component in the wrong place, then the best thing to do is to snip the component’s lead off at the board surface. Then using the soldering iron and a small screwdriver prize the remaining bit of the leg out of the hole. Use wick or a good solder pump to remove the solder from the hole. Filling the hole with fresh solder will actually make the hole easier to suck clean!

I alway use water washable flux in solder these days for my board manufacture. In Europe, Farnell and Rapid sell Multicore’s Hydro-X, a very good value water based product. You must wash the PCB at least once every two or so hours 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. I usually put the board above a radiator for a few hours. 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 new type of ‘no-clean’ solder.

I have found that if you are using a very hot soldering iron it is possible to run your iron so hot as to boil the flux in the ‘water washable flux’ or some types of ‘no-clean’ solder. This is not a good idea as it can create bubbles in the solder. If you prefer to have a traditional uncontrolled iron, then it is best to get a 18W one for this purpose. I use an ordinary Antex 240V 25W iron with a Variac power supply running at 200V. This seems to work well for me.

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.

IC sockets are 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.

For the transistors match the flat side of the device with that shown on the PCB legend. Push the transistor into place but don’t push too far. Leave about 0.2” (5mm) of the leads visible underneath the body of transistor. Turn the board over and cinch the two outer leads on the flip side, you can leave the middle one alone. Now solder the middle pin first, then the other two once the middle one has cooled solid.

Please note: Q2’s legend on the PCB has been printed the wrong way. You must fit Q2 opposite to that shown on the board. In other words, the flat of the transistor must line up with the rounded side of the white silk-screen. All other transistors have been correctly printed.

Sometimes transistors come with the middle leg preformed away from the other two. This is all right, the part will still fit into the board. However, if I get these parts, I tend to ‘straighten’ the legs out by squashing gently all the three of them flat with a pair of pliers. The flat surface of the pliers’ jaws is parallel to the flat side of the transistor.

The polyester and polypropylene 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, IC sockets, small non-polar capacitors, transistors, electrolytic capacitors. Then the final water wash. You can now fit the trimmer to the board with no-clean or ordinary ‘ersin’ flux solder. Do not fit the pots or the LED at this stage. The mounting of the pots and the LED requires special attention. See the next section for more details.

Mounting the Pots and LED

If you are using the recommended Omeg ECO or Piher PC16 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 1MB is a 1 megohm log 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.

The LED may be able to be soldered directly into the board if its leads are long enough. You’ll have to bend the leads at ninety degrees near the body of the LED. It doesn’t matter which lead goes into which hole of the LED pad. However, I like to make the LED go red when the LFO output goes positive. The integral red LED’s cathode must then go to the cathode as depicted on the PCB silk-screen. This is the round pad, the square pad being the anode.

If your LED does not have sufficiently long leads to reach to board from the panel hole, then you may have to wire it to the board with some small pieces of insulated wire. Keep the wires as short as possible without being taut. Use a little heatshrink tubing to insulate the LED’s leads from rubbing together..

Connections

This module is very easy to connect up. There are just four sockets in the suggested layout.

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. The tags are actually labelled in the plastic next to the tag. The signal lug is called 'T' for tip, the NC lug is labelled 'T/S' for tip-switched. But I have only just noticed this after using these jacks for nearly twenty years!

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 PNL pad. I fit the sockets so that the bevel on the side of the socket is facing top left as you look at the rear of the panel. The wire frame is then made by first soldering one piece of solid wire across the top two sockets, joining the two earth lugs together. Do the same for the bottom two sockets. The two horizontal pieces of wire are then bridged by a single piece of wire running down the middle, soldered in place and cut to size.

The other pads that are going to be connected to your four sockets are IN, OUT, CV and LFO. The LFO pad has two wires that need to be soldered to it. There is space for two wires to fit into the one hole. You will have to make five more connections in all.

I have used slightly different names for the front panel sockets. The table below shows which is connected to which:

PCB	Front Panel Socket Connection
IN	'Audio in' signal lug
OUT	'Audio out' signal lug
CV	'CV in' signal lug
LFO	'LFO out' signal lug **and** NC lug on 'CV in'

Use small lengths of insulated wire to make your connections. There is no need to use screened cable. Remember to connect the NC tag on the CV IN socket to the LFO pad on the PCB. This will allow the LFO to operate the phaser when there is no CV input. Leave the NC tags unconnected on the audio in, audio out and LFO out sockets.

The PNL pad 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. For a suitable power distribution board you may want to consider the Oakley 'Dizzy' PCB.

The 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/PNL	3
-15V	4

At the rear of this user guide I have included a 1:1 drawing of the suggested front panel layout. Actual panels can be obtained from Schaeffer-Apparatebau of Berlin, Germany. The cost is about £18 per panel. All you need to do is e-mail the fpd file that is found on the Equinoxe 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 3mm thick anodised aluminium. The fpd panel can be edited with the Frontplatten Designer program available on the Schaeffer web site.

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

Apply power to the unit making sure you are applying the power correctly. The LED should now flash 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 50 seconds to around 10 cycles a second.

Now input 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 FREQ pot. Do you hear the characteristic phase sweep? If not, you have got a problem. If yes, now turn up the EMPHASIS. Using the FREQ pot again, does the sweep have a more metallic ring to it. It'll probably be a bit louder too.

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.

Trimmers

There is only one trimmer to set up and its pretty easy to do. Set the FREQ and EMPHASIS pots to their maximum value and the MOD DEPTH and LFO rate to the minimum values. Now turn the trimmer to its fully clockwise position. Power the unit up and input a sawtooth waveform into the input. Any frequency will do, but a low to medium note is best. Listen to the output through your normal listening set up.

Now slowly turn the trimmer in anti-clockwise direction. The moment the sound alters in texture stop turning. You may have to go back a little bit until you get it right. It'll probably be somewhere between half way and ¾ of the way around. Its not terribly important that you set this accurately, so don't worry about it if you can't get it absolutely right.

Final Comments

I hope you enjoy building and using the Oakley Equinoxe VC-phaser.

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 or the Oakley Synths list on Yahoo groups. Sometimes, it can be the simplest things that can lay out a project. If we still can't get the completed and undamaged module going together, you can send it back to me to fix, but you will have to pay for postage both ways, any parts required and my time at £15 per hour. This service is taken up only very rarely, so it just goes to show how easy it is to get an Oakley project to work first time.

Occasionally, there may be an error in the parts list. I have checked the documentation again and again, but experience has taught me to expect some little error to creep past. The schematic is always the correct version, since the parts list is taken from the schematic. So if there is any problem, use the schematic as the guide. If you do notice any error, please get in touch. You will be credited on the ‘Updates and Mods’ page, and you may get a free PCB if its a real howler.

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 especially to all those nice people on the Oakley-synths, Synth-diy and MOTM mailing lists.

Tony Allgood. July 2003

Version. 1.2

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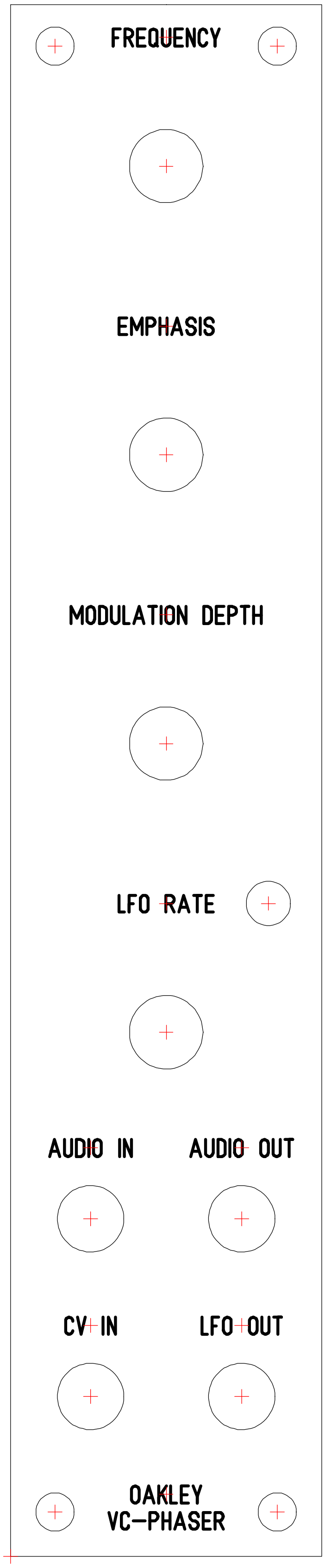
Errors will always occur in the preparation of a document. Please forward any errors found to me so I can correct them.


FREQUENCY
EMPHASIS
MODULATION DEPTH
LFO RATE
AUDIO IN
AUDIO OUT
CV IN
LFO OUT
OAKLEY
VC-PHASER