Oakley Sound Systems

Small Format Series

RM-4014

Four Quadrant Multiplier or Ring Modulator

User’s Guide

V1.02

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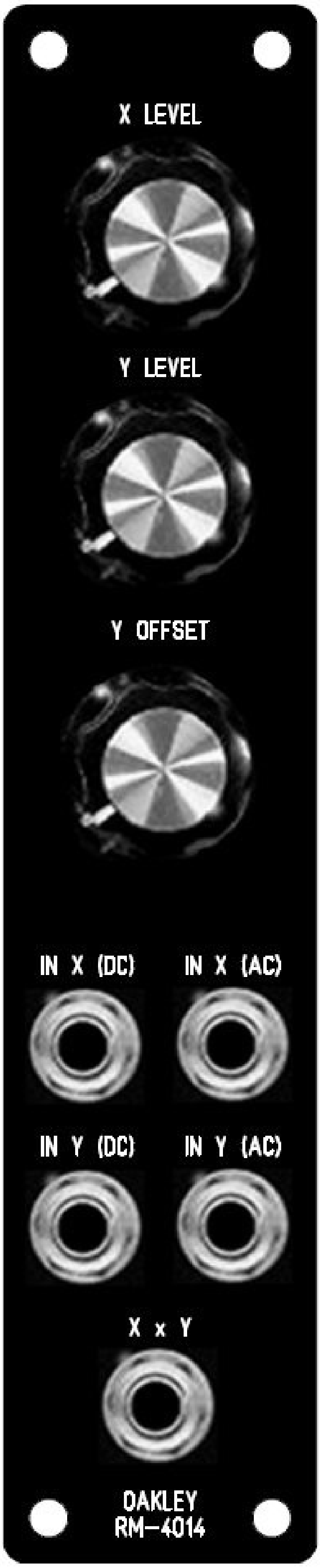

X LEVEL
Y LEVEL
Y OFFSET
IN X (DC)
IN X (AC)
IN Y (DC)
IN Y (AC)
X x Y
OAKLEY
RM-4014

Introduction

This is a vintage ring modulator design with bags of character. It is based on the classic ARP4014 sub-module which was used on the ARP2500 modular and ARP2600 semi-modular synthesisers. The design has a fully discrete core but uses two op-amps for input and output amplification.

A ring modulator has two main inputs, usually called X and Y, and one output. The output voltage is the product of the two input voltages. In other words it multiplies the two input signals together to produce a new and different sounding output. If you have two sine wave input signals then the output will have both the sum and difference frequencies. For example, if X is a 440Hz sinewave and Y a 40Hz, you would get a 480Hz and a 400Hz sinewave from the output. However, this is only really true in a perfect ring modulator, and this ring modulator is not that. Each input has its own differing non-linearities or imperfections. This greatly adds to the character of the resultant output.

The Oakley Ring Modulator features three rotary control pots. Each input has its own attenuator, and there's also a offset control for the Y input. In conjunction with the Y attenuator, this third pot effectively acts as a wet-dry control for the X input. But because of the non-linearities inherent in the design it also acts in more subtle ways.

You can also use the Oakley Ring Mod as a standard VCA. Just use the Y input as your CV input and X will be shaped accordingly. Each input can be either direct coupled (DC) or high pass filtered (AC). The former allows DC and low frequency signals to be processed. While the latter provides a DC block to process only alternating frequencies. The standard panel design makes both types of input available with each having its own socket. However, you can use a one socket on each and then use a switch to select between the two modes if you prefer.

Power Supplies

This module is designed to run from plus and minus 15V supplies. These should be adequately regulated. The current consumption is about 25 mA per rail. Power is routed onto the PCB by a four way 0.156" MTA or Molex type connector. You could, of course, wire up the board by soldering on wires directly. The four pins are +15V, ground, panel, -15V. The panel connection allows you to connect the metal front panel to the power supply's ground without it sharing the modules' ground line.

This unit will also run from a +/-12V supply with a slight reduction in dynamic range.

The Ring Mod issue 1 PCB

This is one of our smaller format PCBs. The module can be either built as a standard 5U Oakley panel design, or as a smaller 3U Euro/Frac sized panel. To allow this to happen the pots are Alpha/ALPS 16mm types with our special matching brackets. The pot spacing on this module is 36.8mm (1.45”) instead of our usual 41.3mm (1.625”). The power supply is +/-15V and is admitted onto the board with our usual 0.156" MTA/Molex connectors.

The PCB has four mounting holes for M3 bolts, one near each corner. These are not required if you are using our specially made pot brackets. The size of the board is 96.5mm high by 86.4mm deep.

The input and output sockets are wired to the board via an eight way 0.1” Molex or MTA interconnect. This makes removing the board from the panel very easy. It also offers the possibility of connection to a socket board like our VCO and other modules. However, at this moment in time we have no plans to release a socket board for either the 5U or 3U versions.

Circuit description

A ring modulator is sometimes described as a four quadrant multiplier, and while this certainly sounds more grand, it also explains the action of the device in more detail. The four quadrants refer to the four quarters of a standard XY graph with the origin in the middle. The idea being that this device allows two inputs, we will call them X and Y, of either positive or negative voltage, to be multiplied together. The output is therefore either positive when both X and Y are the same polarity, or negative when they are different.

A standard voltage controlled amplifier (VCA) can be considered as two quadrant multiplier since one of its inputs can only be of a positive value. The two quadrants where Y is negative are not computed, and the output normally remains at zero when Y is not positive.

In audio when an input signal is processed so that it changes from a positive value to a negative one we say it has been inverted, or that it is 180 degrees out of phase with the original. In this way, a ring modulator may be considered to change the phase of one of its inputs depending on the polarity of the other.

In a perfect ring modulator the inputs X and Y can be considered as having the same functions as each other.

ie. X x Y = output = Y x X

In our real life ring modulator this is not true. Imperfections in the circuit topology means that the output will sound different, or behave differently, depending on which signal you insert into X and which into Y. Generally, we will use X as our input signal (sometimes called the carrier), and Y as our modulator. That is, Y will shape X. In many applications it doesn't make too much difference which is which, so experimentation is the key here.

The Oakley Ring modulator is based around the old ARP module 4014. This was built on an incredibly tightly cramped circuit board which was then securely potted, with a very hard epoxy compound, into a small plastic box. The various interconnections were made to some thin gold plated legs that stuck out from the hard epoxy on the underside. It is almost impossible to remove the circuitry from its hard plastic shell and all encompassing resin. I suppose this was mostly down to Alan Pearlman's previous history in making op-amps for the aerospace industry – enclosing circuits like this would make them less likely to drift with temperature and be affected by surrounding humidity. However, one might also think that they did it to keep out the prying eyes of their competitors.

Later versions of the 4014 used soft and rubbery silicone to pot the circuitry into its shell with only a thin layer of epoxy on the underside to seal it all in. These are easier to repair since it is now possible, with great care, to remove the delicate circuitry from its shell and potting compound. Various folk have since reverse engineered this circuit and it can be found in various places on the internet.

The basic function of the 4014 is of two complementary VCA circuits, both controlled by a single driver, and each feeding a common current to voltage output stage. The driver features a non linear gain that acts as a pre-distortion device which compensates for some of the non linearities in the VCA sections.

U3, a dual op-amp, is configured as two voltage followers, one for each input. The signal level to each one is controlled via its own level pot. The source of the signal can come from either a direct coupled input via a single resistor, or AC coupled via a capacitor. The capacitor in conjunction with the resistor following it and the pot itself will act as a high pass filter. This will attenuate very low frequency signals with a -3dB point of around 1Hz. It is possible to use both the AC and DC inputs simultaneously thus creating a crude two channel mixer. However, although no harm to the unit will come about, it does cut down the overall signal level presented to the input level pot.

Both U3 halves act as protective buffers for the relatively high output impedance of the level pots. The lowish input resistances of the ring modulator input stages would otherwise detrimentally affect the pots' apparent taper, the cut-off frequency of the AC coupled input, and perhaps also the output stage of the connected modules.

The ring modulator core is built from two transconductance amplifiers that are complementary to one another. A transconductance amplifier is basically a 'voltage in, current out' device whose gain, in this case, is controlled by another modulating current. And complementary in this definition means identically opposite, mirrored if you like. In other words they behave mostly the same but one is modulated by positive currents from the driver, the other negative currents. Since the driver is common to both of them and its own output is either positive or negative, only one of the transconductance stages is active at any one time.

I have tried to draw the schematic so you can see the two complementary halves of the core easily. Each one appears identical but for the type of transistors used. Where one uses a NPN, the other will use a PNP, and vice versa. Note too, that the X input is applied to different sides of the transconductance stages resulting in one of them being of opposite phase to the other. The left hand side deals with Y modulation signals that are positive in value. The right hand side deals with Y modulations that are negative in value.

Each transconductance amplifier is made from five transistors. Four are two sets of matched pairs. A matched pair is exactly that; two devices that share with almost identical characteristics. This cannot usually be obtained from simply buying two transistors of the same type, since in manufacturing there are small discrepancies that make every device slightly unique. In the original 4014 module, ARP would have hand selected their transistors by trying hundreds out and grouping them together into large bins with contained those devices with similar characteristics. Each pair would then be made by selecting two devices from the same bin. This would take too much time when you only want to build one or two Oakley Ring Modulators, so I have used pre-matched quad transistor arrays. The THAT300 is four matched NPN transistors, and the THAT320 is four matched PNP transistors. The electronic matching is near perfect and they are also made onto the same silicon die and in the same housing thus ensuring a good thermal matching too.

The voltage at the top of each transconductance stage is fixed by diodes to be 1.2V for the left hand side one and -1.2V for the right hand side. C4 and C17 provide some additional decoupling to reduce any noise or audio signal bleedthrough at these points. C4 and C17 were not in the original design, but I have added them here to reduce any chance of extraneous noise pick up.

The output of both transconductance stages go to the inverting input of the output op-amp, U2, pins 1, 2 and 3. This is wired as an inverting transimpedance amplifier, which is a 'current in, voltage out' device and essentially the opposite of a transconductance amplifier. A transconductance amplifier followed by a transimpedance amplifier make an amplifier, ie. 'voltage in, voltage out'.

To make sure the overall gain of the ring modulator is positive for Y being positive, we use the inverting outputs from each transconductance amplifier. These are found on the collector of the left hand transistor of the input pair, ie. U14, pin 14 and U1, pin 7.

The gain of the transconductance amplifiers is controlled by the driver circuit. The output of the driver circuit is converted to a current by R18 which in turn affects the current through the input pairs and hence the amplitude of the current output. However, the response of gain versus input current is not linear when the output of U2 is less than 0.6V for the left hand amplifier and above 0.6V for the right hand one. This is because to control the gain of the transconductance amplifiers the voltage at the bottom of R18 must be enough to overcome the inherent base-emitter voltage and turn on either of the input transistor pairs. This would give rise to a dead zone of operation if it were not for the deliberate non linearity introduced in the driver circuit.

Q3 and Q4 are wired as diodes in the feedback of the driver op-amp. This means for output voltages between -0.6V and +0.6V the gain of the op-amp is very high indeed as it is pretty much set solely by the ratio of R12 and R11. Thus even a small voltage on the Y input will lead to either +0.6V or -0.6V depending on the polarity of the input. Once this voltage has been achieved any increase in input voltage will decrease the gain as either Q3 or Q4 turns increasingly on. Eventually, the gain tends to the ratio of R15 and R11, a much smaller figure.

Unlike the original circuit application, the Oakley Ring Modulator allows you to add a positive offset voltage to the Y input voltage. Thus effectively increases the gain of the left hand transconductance amplifier thus allowing the non inverted X signal to pass through to the output even when no positive Y input is present.

Power is supplied via the usual four way MTA or Molex connector. As is the custom for Oakley modules, I have used ferrite beads to act as high frequency filters on the power lines. Decoupling at the point of entry is provided by C13 and C15 for the positive rail, and C14 and C16 for the negative rail. Additional decoupling is also provided elsewhere on the board by the other capacitors shown at the bottom of the schematic. All these capacitors keep the power supply clean of noise, and provide a reservoir for the little bursts of current that the circuit takes in normal operation.

Buying The Components

Most of the parts are easily available from your local parts stockist. I use Rapid Electronics, RS Components and Farnell, here in the UK. The Ring Modulator module was designed to be built mostly from parts obtainable from Rapid Electronics.

The resistors can be 5% carbon 0.25W types except where stated. However, I would go for 1% 0.25W metal film resistors throughout, since these are very cheap nowadays.

The PCB is laid out for a certain type of pot and its matching pot bracket. The pot brackets make mounting the board to the front panel very easy. They hold the board at the correct angle to the panel, and can provide all the support the board needs in normal usage. The pots suggested are Alpha or ALPS 16mm carbon types. These are very much an industry standard part and are used in all sorts of gear, including most of the Doepfer and Analogue Systems gear.

You could use any pot type you want, but not all pots have the same pin spacing so may not fit on the PCB. Of course, the pin spacing will not be a problem if you are not fitting the pots into the board and are hand wiring them to the front panel.

Now this is where it gets complicated. Even if you buy 16mm Alpha or ALPS pots you still need to make sure you have the correct pot shaft. It is the shaft that the knob will fit onto. They come in three basic types; splined, round, and D-shaft. The knobs you will need to buy should then fit onto the shaft you have chosen. The D-shaft types are probably not going to be easy to find although they are the most common in commercial applications. The most likely one you will see from the parts suppliers is the 6mm diameter splined shaft which work with low cost push fit knobs. The shaft is split down the middle so that the natural springiness of the metal holds the knob in place. Round types have perfectly smooth cylindrical shafts and tend to be found on the ALPS pots you can buy. However, you need to use the more expensive grub screw or collet knobs on these.

Grub screw knobs can be used with splined shafts. However, you have to be very careful that you don't overtighten the screw other wise the shaft can become distorted. Generally, I haven't found this to be a problem on this module. The grub screw tends to line up with the split in the splined shaft and thus makes a good contact with both halves of the shaft.

Now just to make things really annoying, the shaft length also varies with vendor. In most cases a longer shaft can be simply cut down with a hack saw to the smaller lengths. It is a good idea to use a file to round off any sharp edges though.

In the UK, Rapid sell the most of the Alpha pots we need at a very good price. However, the Rapid pots have long shafts that need to be cut down if you want to use their excellent 'soft touch' knobs for splined shafts.

Banzai are in Germany, but deliver worldwide, also sell Alpha pots. These come with a nice short shaft, so they don't need cutting down.

In the parts list the value of one of the pots is given as 50KA. You may find that your supplier cannot sell this value, but only offers 47KA. This is perfectly fine as either value will do.

The PCB is another Oakley board to feature axial ceramics for the power supply decoupling. These are good components with an excellent performance. The PCB legend for these devices features a lead spacing of 0.3". Various types of axial ceramics exist. There are the more expensive C0G types from Farnell, but the other types like Y5V and X7R are perfectly good in this application too. I use Rapid part number: 08-0240.

For the small ceramic capacitors in positions C2, C3, C5, C11 and C12, you should use good quality capacitors. All the ceramics have 5mm (0.2") lead spacing. You should use low-K types, these are the better quality ones with higher stability and lower noise. They are sometimes described as NP0 or C0G types. You can chose either radial multilayer types, or ordinary plate types. RS-Components sell the former, whilst plate types can be bought from pretty much anywhere.

The three multiturn trimmers are the ones that have the adjustment on the top of the box. Spectrol and Bourns make these. Some types are 20 turns, while others are 25 turns. Either will do. They should have three pins that are in a line at 0.1" pitch. I generally use the Bourns 3296 series.

The BC550 and BC560 devices are discrete low noise transistors. The former is NPN, while the latter is PNP. You can replace the NPN with BC549, and the PNP with BC559. Quite often you see an A, B or C suffix used, eg. BC550C. This letter depicts the gain or grade of the transistor (actually hfe of the device). This module is designed to work with any grade device.

All ICs are dual in line (DIL or DIP) packages. These are suffixed accordingly in their part numbers to differentiate them with the much smaller surface mount versions. For example; TL072CP and THAT300P are both DIL packaged devices. Note that with the TL072 it is made by many different manufactures and each one uses different suffixes. Generally, most suppliers will make it clear that any device is a SMD device and thus should be avoided in this module.

The two arrays are from THAT Corp in the US. Farnell sell these parts at reasonable prices.

I have recently been using the LF412 as a replacement for the TL072 in more critical positions. Although there is very little audible difference I recommend trying an LF412 in positions U2 and U3 and see what you think.

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: 9526820. Rapid sell them as part number: 24-4860.

Input and output sockets are not board mounted. You can choose whichever type of sockets you wish. I use the excellent Switchcraft 112A as used on the Moog and MOTM modulars. If you are mounting this module in a Frac or Euro sized format then you will need to chose a decent 3.5mm socket to use. Normalised sockets are not required in this module.

This module uses an eight way 0.1” header to connect the sockets' leads to the PCB. I have specified Molex KK connectors, but you could also use Amp's MTA system instead. Both require a special, and the in the MTA case, an expensive, tool to make up the connector ends. The MTA is an insulation displacement system where the wires are forced into the housing by the special tool. The Molex KK system is based on individual crimped contacts that are inserted into the housing once crimped.

However, with the Molex system you can simply solder your wires into the little metal contacts before pushing them into the eight way housing. If I were making a lot of ring modulators I would use MTA – but if you are building just the one, go for Molex KK types and purchase a cheap crimper or solder the wires into the little crimps.

The other alternative is to not fit the header at all. This way you can solder your connecting wires directly into the PCB. There is nothing wrong with doing it this way – indeed, it could be said that this is more reliable. However, remember that the solder pads are quite small and could be damaged if overheated when soldering.

Finally, if you make a change that makes the circuit better, do tell the ‘Oakley-synths’ mailing list or myself directly. Any updates are added to the current user guide as quick as possible.

UK builders should know that there is a ‘Oakley Preferred Parts List’ online which is updated periodically by myself. This can be found at www.oakleysound.com/parts.pdf.

Parts List

The components are grouped into values, the order of the component names is of no particular consequence. Please read the above section for more details about the parts used in this module.

A quick note on European part descriptions used on schematics or circuit diagrams as we like to call them. R is shorthand for ohm. K is shorthand for kilo-ohm. For capacitors: 1uF = 1000nF. 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, 4n7 is a 4.7 nF capacitor.

For Alpha or ALPS pots: A = logarithmic or audio taper, B = Linear taper

Resistors

All 5% carbon 1/4W or better, except where stated.

220R	R20
470R	R19
680R	R6, R16
1K	R10
4K7	R22, R4
10K	R9, R1, R2, R8
12K	R14
15K	R11
18K	R7, R15, R18
39K	R3, R21
56K	R13
1M	R12
2M2	R5, R17

Capacitors

Some capacitors are optional; they were used in the original ARP-4014 module but are not really necessary for this design. These are marked with a *.

12pF low-K ceramic	C11
47pF low-K ceramic	C3, C2*, C12*
100pF low-K ceramic	C5*
100nF axial multilayer ceramic	C7, C8, C9, C10, C15, C16
1.5uF, 63V polyester	C1, C6
2.2uF, 25V electrolytic	C4, C17, C13, C14

Discrete Semiconductors

1N4148 signal diode	D1, D2, D3, D4, D5, D6
BC550 NPN transistor	Q2, Q4
BC560 PNP transistor	Q1, Q3

Integrated Circuits

TL072 dual op-amp	U2, U3
THAT320P PNP array	U1
THAT300P NPN array	U4

Variable Resistors

50K or 100K multiturn trimmer	BAL1, BAL2, GAIN
100K linear Alpha 16mm pot	X-LEVEL, Y-LEVEL
50K linear Alpha 16mm pot	Y-OFFSET
Oakley **small** pot brackets	Three off

Miscellaneous

0.156" MTA 4-way header	PSU
0.1" 8-way Molex or MTA header	SOCKETS – board mounted
0.1" 8-way Molex or MTA housing	SOCKETS – wire harness
Leaded ferrite beads	L1, L2
Knobs to fit 6mm shafts	Three off
1/4" sockets	Five off
DIL14 pin IC sockets	Two off
DIL 8 pin IC sockets	Two off

Hook up wire (26awg) in several different colours

Populating the Oakley Ring Modulator Circuit Board

Warning:

Oakley Modular PCBs are supplied with a RoHS compliant Ni/Au finish. This is a high quality finish but does possess slightly different soldering characteristics to the traditional lead based HASL finish. Handle the boards with care, and avoid touching the Ni/Au plating since this can cause premature tarnishing of the finish. Shelf life is hard to predict but Oakley Modular recommend soldering in all the components less than one year from when you receive your board.

Neither I nor Oakley Modular are responsible for any accidents caused whilst working on these boards. It is up to you to use your board responsibly and sensibly.

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. The most common error with most 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!

Sometimes people like to substitute parts in place of my own recommendations. Feel free to do this, but remember that there is normally a good reason why I have selected that particular part. If you do find that, say changing an op-amp with another one, makes an improvement, please do let me know either via the Oakley-Synths list or directly to 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.

The diodes can be treated much like the resistors. However, they must go in the right way. The cathode is marked with a dark 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.

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. Also, make sure that any water drops left between the pins of the sockets are fully dried up before switching the board on.

For the four 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.

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 capacitors, if you have ordered these, are like little blue, green 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 sockets, small non-polar capacitors, transistors, electrolytic capacitors. Then the final water wash if you are using water washable solder. You can then solder the trimmers in place, but do not mount the pots just yet. The mounting of the pots requires special attention. See the next section for more details.

Mounting the Pots

NOTE: This procedure is rather different to that of the Spectrol/Vishay pots you may have used on other Oakley boards.

If you need to cut down the length of the pot shaft to fit your choice of knob then now is the time to do it. Although you can cut the pot shafts when they have been fitted to the panel, its far more difficult to do than when they are loose. Make sure when you are cutting the shaft that you do not get any metal filings inside the pot mechanism.

If you are using the recommended Alpha pots, then they can support the PCB with the 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. Do not solder the pot bracket at this stage.

When you have soldered all the pots you should remove the nuts and washers carefully. Now fit the board to your front panel. Position the PCB at right angles to the panel, the pot's own pins will hold it fairly rigid for now. Refit the washer and nut onto each pot and tighten gently.

Now you can solder each of the brackets. This will give you a very strong support and not stress the pot connections.

The Alpha pots are labelled with an A or B suffix. For example: 50KB or 1MA. Alpha and ALPS do the opposite to our European convention and use A = log and B = linear. So a 50KB is a 50 kilo-ohm linear taper pot.

Pots are often 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. If I do see any grease near the top of the bush, I tend to wipe it clean with a bit of kitchen paper before I mount the pot.

The Front Panel

On the website I have included a FPD database of the suggested 1U front panel layouts in both standard black and a nice new look natural finish. Actual panels can be obtained from Schaeffer-Apparatebau of Berlin, Germany. The cost is about £20 for the panel and slightly more for the natural finish thanks to the additional colours used in the legending. VAT and the postage is extra, so it usually helps to order a few panels at the same time.

All you need to do is e-mail the fpd file to Schaeffer in Germany, or Frontpanel Express in the US, and they do the rest. You can also use the Frontplatten Designer program's own online ordering procedure which also works very well.

The panel itself is made from 3mm thick black anodised aluminium. The fpd panel can be edited, including changing the colour, with the Frontplatten Designer. The program available on the Schaeffer web site but it should be noted that the program is for Windows only.

Connections

Power connections are via the standard Oakley 4-way 0.156" MTA socket labelled 'power'. Friction lock types are recommended. This system is backward compatible with MOTM systems although it should be remembered that if using any single stock MOTM module in an Oakley modular system you will lose the benefits from the separated grounds.

Power	*Pin number*
+15V	1
Module GND	2
Earth/panel metal	3
-15V	4

All audio and CV connections are via a eight way 0.1" header on the PCB called 'sockets'. This may be different to other Oakley PCBs you may have built. Doing it like this allows you to remove the board from the front panel easily, and allows the potential for additional socket boards to be used in any future production run of the board.

You don't have to use a header in your PCB. In this case you can solder your wires directly to the PCB from the various socket lugs.

How you wire your input and output sockets up will very much depend on your panel design and choice of sockets. I will only go into the details of wiring up the standard 5U high panel with the five 1/4" sockets underneath the PCB, but any Frac or Euro rack construction will be similar.

If you have used Switchcraft 112A or 112APC sockets you will see that they have three connections. One is the earth lug or ground tag, this is indicated by a bevel in the socket's housing. The second 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) lug. The NC lug is internally connected to the signal tag when a jack plug is not inserted. This connection is automatically broken when you insert a jack.

In this module we are going to 'common' the sockets' ground lugs. This means that the sockets' earth lugs are going to be joined together. I normally do this part of the wiring without the PCB or pots in place on the panel.

Fit the four input signal sockets onto the panel so that the bevel on the side of the socket is facing top right as you look at the rear of the panel. Then fit the output socket in the lowest hole, but attach it so that its bevel faces to the top left.

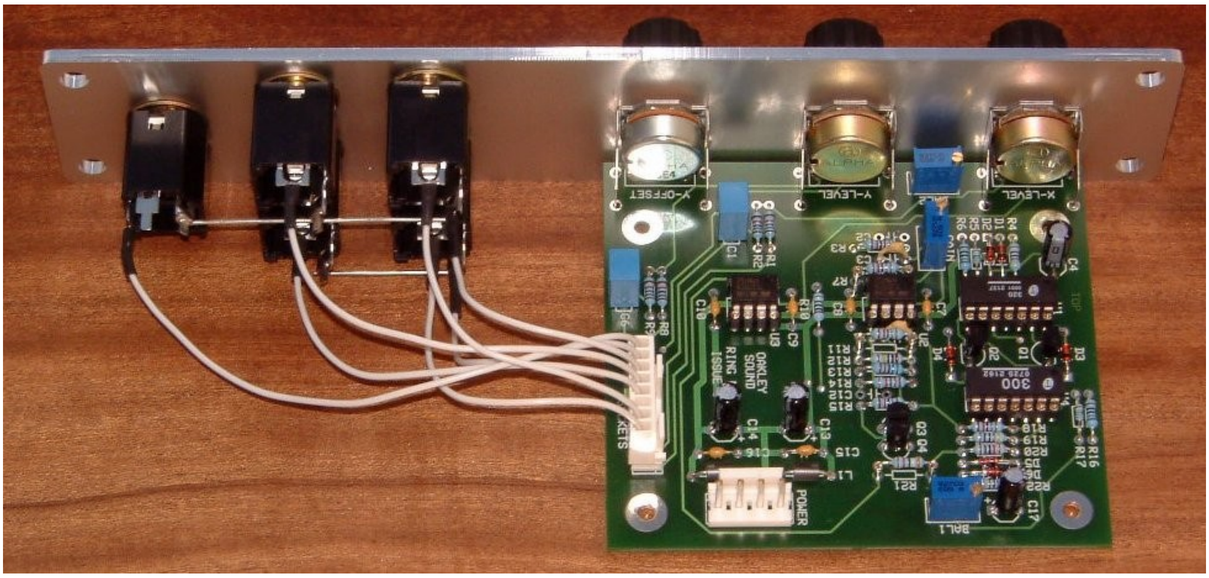
Now lay the panel on its side with the front panel facing away from you and the bottom of the panel to your right. The five sockets' pins should be facing you.

The first lugs we are connecting together will be the ground or earth tags on the two sockets on the top row, the two DC input sockets. I use 0.91mm diameter tinned copper wire for this job. Its nice and stiff, so retains its shape. Solder a length of this solid core wire right across the two earth tags on the top row. Trim off any excess that sticks out on either end.

Then do the same on the lower three sockets, that is the two AC inputs and the single output sockets. Because of the different orientation of the output socket you'll find that the output socket's earth tag lines up roughly with the other two's tags.

Fit the Ring-modulator PCB against the front panel if you haven't done so already.

I used Molex KK headers and housings to connect my ring modulator together. I also use the Switchcraft 112APC sockets, and not the 112A that MOTM uses. These types are the ones that are designed to be soldered directly to a PCB, however, they also allow direct wiring and fitting of a heatshrink sleeving for strain resist. See the photograph below:



Use multistrand hook up wire to connect each socket lug to the relevant pin on the header. Keep your wires short but not too short and you can use as many different colour wires as you can – although I tend to use one colour because I'm a minimalist. There is absolutely no need to use screened cable for such short runs.

The connections of the lugs of the CV and audio output sockets that go directly to the PCB are summarised in the table below. They are given in the order in which I would recommend that they be soldered.

Socket Name	***Lug type***	***Header Pin number***
IN X (DC)	Earth	8
IN X (DC)	Signal	1
IN Y (DC)	Signal	4
X x Y	Signal	7
IN X (AC)	Earth	6
IN Y (AC)	Signal	5
IN X (AC)	Signal	2

NB. Pin 3 is not used.

Once that is done, your module is ready for testing and calibration.

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

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, and the direction of the ICs in their sockets.

Assuming everything is OK so far, it is time to apply an audio input. Use a signal like a triangle output from a VCO. Middle A, 440Hz is a good note to use. Turn down all the pots to their minimum setting and insert your triangle wave signal into IN X (AC). Listen to the output signal from the ring modulator module. For the moment you should hear nothing.

Turn up the X LEVEL pot to full. Again, you shouldn't hear anything, but maybe you will hear a little triangle wave bleedthrough. Now slowly turn up the Y OFFSET pot. If all is well this should behave like a volume control, increasing the level of the triangle wave as it is turned up.

Ensure that altering Y LEVEL should have no effect on the sound, but that X LEVEL behaves also like a volume control. It should seem that both X LEVEL and Y OFFSET do the same thing. They do not of course, since X LEVEL is altering the signal level going into the ring modulator circuit, and Y OFFSET is adjusting the gain of the amplification within the ring modulator.

Swap the input signal over to the IN X (DC) input. This should have no apparent effect on the sound.

There is a very good chance your circuit is working correctly if you have got this far with no problems. However, we still need to check a few other things and you'll need another signal source to do this. Connect a LFO or VC-LFO to the IN Y (DC) input. Use a sine or triangle wave signal at a lowish frequency, say 1Hz or so.

Turn the Y OFFSET down and the X LEVEL up. Now slowly turn the Y LEVEL up and listen to the resultant sound. It should be the triangle wave you can hear again, but it will pulse up and down with LFO signal. You should hear it go up and down in volume twice for every cycle of the LFO, ie. at 2Hz if you have set your LFO to 1Hz. This is because, unlike an ordinary VCA, the triangle wave is being multiplied by both the positive and negative parts of the LFO's waveform. Thus you get a rise in volume with increasing positive voltages and a rise volume with increasing negative ones.

If you increase the Y OFFSET pot to its maximum value, you should find that you now have only one cycle of volume change per LFO cycle. The offset pot has added a positive voltage to the Y input thus making it solely positive in value.

If all is well, then you have a working ring modulator module.

Trimmers

There are three trimmers on the PCB which need adjusting correctly to get the best out of the ring modulator module. It is important that you adjust these in your modular as the settings are affected by the power supply voltages.

Allow the modular and ring modulator to warm up for 15 minutes.

BAL1: Turn down X LEVEL and Y LEVEL pots to their minimum settings. Turn the Y OFFSET pot to its maximum level. Measure the output voltage from the output socket with a good digital voltmeter. Adjust BAL1 until the output voltage is 0.000V +/- 5mV.

BAL2: Insert a triangle wave signal at 440Hz to the IN Y AC input. Turn down the Y OFFSET pot to its minimum setting. Turn up the Y LEVEL to full. If you have a 'scope then adjust BAL2 until the signal seen at the output socket is minimised as much as possible. It will not go away completely. If you haven't got a scope then use your ears with your monitoring amp turned up somewhat. Adjust BAL2 until the sound from the output socket is at its smallest level. You will not get rid of it completely, the ring modulator is not perfect and as such it will leak or bleedthrough. Once you have done this remember to turn your amp down if you have turned it up high.

GAIN: Ensure that the Y LEVEL is set to minimum, but the other two pots to their maximum. Insert an audio signal into IN X (DC) and adjust GAIN so that the output signal is at the same level or volume as the input. That is, if you have a 5V peak signal inserted into IN X, then you should adjust GAIN for a 5V peak signal at the output.

Once that is completed the unit is ready to be used to make music, or just daft noises...

Final Comments

If you have any problems with the module, an excellent source of support is the Oakley-Synths Group that can be found at http://launch.groups.yahoo.com/group/oakley-synths/

If you can't get your project to work, then Oakley Sound Systems are able to offer a 'get you working' service. If you wish to take up this service please e-mail me, Tony Allgood, at my contact e-mail address found on the website. I can service either fully populated PCBs or whole modules. You will be charged for all postage costs, any parts used and my time at 20GBP per hour. Most faults can be found and fixed within one hour, and I normally return modules within a week. The minimum charge is 20GBP plus return postage costs.

Your comments and questions are important to both Oakley Sound and Oakley Modular. In the first instance, please use the Oakley Synths Group where a wealth of experience resides! Please do not contact me or Oakley Modular directly with questions about sourcing components or general fault finding.

Last but not least, can I say a big thank you to all of you who helped and inspired me. Thanks especially to all those nice people on the Synth-diy, Oakley-Synths and Analogue Heaven mailing lists.

Tony Allgood at Oakley Sound

Cumbria, UK
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