Oakley Sound Systems

Small Format Series

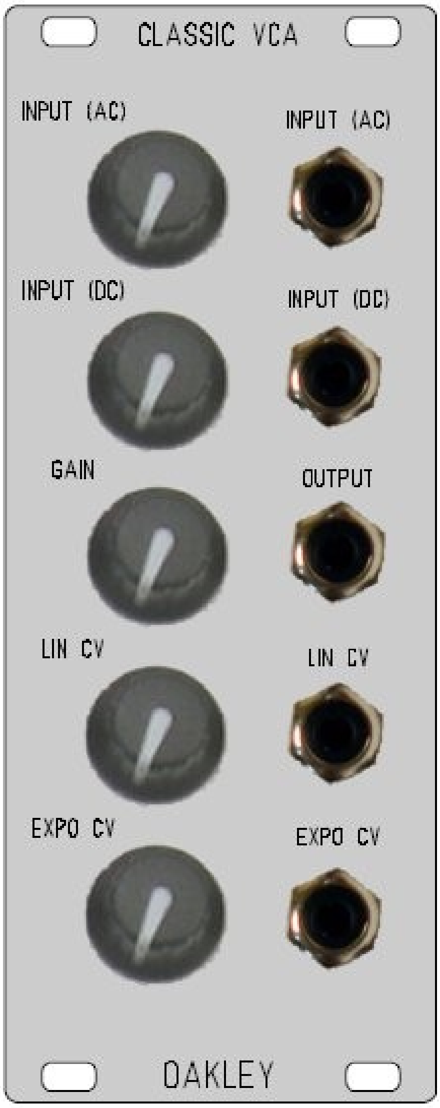
Classic 4019-VCA

Discrete Core Voltage Controlled Amplifier

User Manual and Builder's Guide

V1.04

Tony Allgood B.Eng PGCE
Oakley Sound Systems
CARLISLE
United Kingdom



The suggested front panel design in 3U high Euro style format. The Scheaffer database for this 10HP panel is available from the Oakley Sound website.

Introduction

This is a vintage voltage controlled amplifier design. It is based on the classic ARP4019 sub-module which was used on the wooden case ARP2600P semi-modular synthesiser. The design has a fully discrete core but uses a single op-amp for output amplification.

The unit features both linear and exponential control voltage (CV) inputs. Both can be used together or individually.

Two signal inputs are provided, one DC coupled and the other AC coupled. The former allows audio and low frequency signals to be processed. While the latter provides a DC block to process only alternating frequencies. Both inputs can be used simultaneously and each one features an input level control.

A gain control is also available to provide a fixed bias to set the initial gain of the VCA. This way a negatively going CV can reduce the overall gain of the VCA. The gain pot can also be used a volume control.

Power Supplies

This module is designed to run from plus and minus 12V or 15V supplies. These should be adequately regulated. The current consumption is about 20 mA per rail. Power is routed onto the PCB by either:

1. A four way 0.156" MTA or Molex type connector. This the standard Oakley power supply that is also suitable for MOTM and Fractional rack systems. The four pins are positive rail, ground, panel, negative rail. 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 panel connection is normally connected to 0V either on the power supply or on the power distribution board.

2. A 2 x 5 way 0.1" (2.54mm) header for compatibility with Euro format modular systems. The top pins on the header are connected to the +12V supply. The module's electronics can be damaged if the connector is attached incorrectly.

If you have bought your module ready assembled from us then your module will be fitted with the appropriate connector for your chosen format.

Using the Classic VCA

The VCA (Voltage controlled Amplifier) is device used to control the level of one signal by the application of another. Traditionally, the *controlled* input to the VCA is called the INPUT, whilst the *controller* input is called the CV, or control voltage. A typical system will have the input as the audio output from a filter or oscillator, and the CV from an envelope generator. As the envelope generator's output voltage rises and falls, so the output of the VCA becomes louder and softer.

It should be noted though that the CV input can actually be an audio input, and that the INPUT can be a control voltage. Its up to you what you put into the module. The nomenclature refers only to the original and common usage of the input sockets on a VCA module.

The term *amplifier* is actually slightly different to the one you normally use too. It doesn't really amplify in so far as it doesn't normally make the input signal bigger. The amplification, or gain, actually varies from nearly zero, ie. the VCA is closed or off, to about one, ie. the output level is the same input voltage.

The Oakley Classic VCA features two input signals, INPUT (AC) and INPUT (DC), and each has its own level control. In this way, the Classic VCA can be used to mix or sum two signals together before they are processed by the VCA core. One of the inputs, INPUT (DC), is directly coupled to the VCA core. All signals, CV and audio, connected to this input can therefore be controlled by the VCA. The other input, INPUT (AC), goes via a capacitor and is what is called 'AC coupled'. The capacitor acts to block very low frequency signals and steady state voltages. You can think of it as being a high pass filter with a very low cut-off frequency.

The GAIN pot controls the 'initial gain' of the module. This is used to partially open the VCA, even when there are no other signals applied to either of the CV inputs. If any positive CV is applied then this will open the VCA further. While the addition of a negative CV will actually cause the VCA to close.

Two control voltage inputs are provided, LIN CV and EXP CV. Each one has its own level pot which controls the depth of the effect.

The LIN CV input has a linear response. This means that doubling the CV will double the output amplitude. In general this is the most useful response for general VCA duties. With the gain pot at its minimum, and the LIN CV pot at its maximum, +5V at the LIN CV input will produce a gain of around one.

The EXP CV input has an exponential response. This means that a rising CV will produce a proportional change in gain measured in decibels. In practice this means that the output signal appears not to quickly increase in level until the input CV is close to 5V. This affect tends to produce wonderfully plucky sounds when used with a conventional ADSR as the CV source.

The Classic VCA issue 1 PCB

This is one of our smaller format PCBs. We are expecting most builders to be using the smaller 3U Euro/Frac sized panel with this module. The pots are specified as Alpha/ALPS 16mm types. The pot spacing on this module is 21mm (0.827”) instead of our usual 41.3mm (1.625”).

The size of the board is 102mm high by 79mm deep. The board is fitted to the front panel by either the pots alone, or additionally with two of our small pot brackets.

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 this particular module.

Circuit description

The Oakley Classic VCA is based around the old ARP module 4019. This module 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 not 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 4019 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 types are easier to repair since it is now possible, with some 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.

Interestingly the very first 2600 synthesisers had the 4010 VCA module installed. I have not been able to find out much about this particular module suffice to say that it was physically smaller and probably less reliable than the later version. The fact that it was smaller surely meant that it contained less circuitry compared to its successor.

Purchasers of the Oakley Classic VCA PCB will be able to obtain a copy of the schematic. On the schematic it should be noted that the power supplies are shown as +/-15V, but these can also represent +/-12V. The circuit will run from either supply although there is one small resistor value different depending on which supply you are using. The circuit itself looks pretty unusual but it can be split up into two smaller parts to make understanding it a bit easier.

The first part of the schematic we will look at is the CV processing. This takes the two CV inputs, processes them and turns them into a small current that will control the gain of the VCA core. You can find the CV processing circuit on the left hand side of the schematic.

The linear and exponential inputs are processed separately. The top left hand circuit, based around Q9 and Q10, deals with the exponential input. The CV input is controlled by its own level pot, EXPO_CV, and is configured as the usual voltage divider. As the wiper moves up and down a proportion of the input voltage is fed into R21.

Q9 and Q10 form a standard ARP style exponential convertor. The precise actions of this go beyond this simple document, but it can be shown that for every 18mV increase in Q9’s base voltage we double the current going through Q10. Q10 draws this current from the VCA core of which we will discuss later.

EXP is a trimmer, a set and forget type of device, and allows adjustment of the maximum gain of the VCA from the exponential CV input.

The linear input is also controlled by a pot, this time LIN_CV, and it is passed via R14 to a summing node at the junction of R15, R16 and R17. This node is held at around 0V by the actions of Q8 and D3. Q8 and Q7 form an old style DC coupled amplifier. Q8 does all the amplification while Q7 provides some level shifting and output buffering. Negative feedback is provided by the trimmer LIN and R16. LIN therefore provides some adjustment over the gain of the amplifier block and thus sets the sensitivity of the linear CV input.

Note the GAIN pot, this is one of the front panel pots. The wiper of this pot can go from +15V (or +12V) to 0V. This voltage is turned into a current by R15 and injected into the summing node. Thus both the CV input and GAIN pot control the output voltage of the little amplifier circuit.

R27 and Q11 then turn this output voltage into a current which, in tandem with Q10, controls the VCA core.

Now let us look at the VCA core itself. This comprises of the two transistor arrays, U1 and U2, and the surrounding circuitry. It can be found in the middle of the schematic.

The basic topology of the VCA core is fairly standard. Its a transconductance amplifier built almost entirely from discrete transistors. The unusual thing about it, at least as far as most synth designs go, its upside down. The input transistors, U2 pins 8, 9, 10 & 5, 6, 7, are PNPs. Most designs use NPNs. However, lets put that aside and see if we can work out how it works.

The signal enters the VCA via either, or both, of the two socket connections, AC_IN and DC_IN. They are both identical except for the addition of a 470nF capacitor, C1, on the AC_IN. This capacitor acts to block steady state voltages (DC) and very low frequencies. In other words it acts like a high pass filter. The cut-off varies a little with the position of the AC_INPUT pot, but it is approximately 10Hz.

R3 and R2 carry their respective signals to attenuate (reduce) and sum together at R4. The voltage across R4 being a tiny fraction, approximately 0.2%, of what it was at the socket inputs. Both inputs are applied to the right hand input PNP transistor. The other input transistor, the left hand one, is simply connected to a very low voltage that is generated by the OFFSET trimmer, R8 and R9. We use this trimmer to manually balance the left and right sides of the VCA core.

The voltage supply to the transconductance stage is fixed by diodes. The series combination of D7, D9, D10 provide a steady +1.8V for the top of the circuit. While the series combination of D6 and D8 provide a steady -1.2V for the bottom of the circuit. When current passes through a diode it tends to have 0.6V across it. +1.8V and -1.2V may appear to be a very small range of supply voltage for a module that can handle nearly +/- 10V input signals. But remember the actual input transistors will only be working with that tiny fraction of the input signal to prevent them from distorting the signal.

U1 (pins 6, 7, 8 & 1, 2, 3) and Q6 make a special circuit which engineers call the Wilson current mirror. It is a clever little design and is found in many different circuits. The Wilson current mirror is a programmable current source. Its programmed by the CV processing circuitry which we discussed earlier. Any current drawn out from the collector of transistor U1 (pins 6, 7, 8) by the CV processing circuit is then replicated by the mirror and provided to the circuitry connected to the collector of Q6. Thus the input transistors of the VCA core are supplied with a current that is directly controlled by the CV signals.

The two NPN transistors from U2 (pins 12, 13, 14 & 1, 2, 3), along with Q5 and D5 act as another current mirror. The current drawn down by each NPN transistor in U2 will be the same due to the actions of the mirror. However, when an input signal is applied to one of the input PNP transistors this equality of current is challenged. But the current mirror will do its very best to maintain equilibrium so any 'excess' current is taken away by the op-amp U3. This current is the VCA core's output signal and it should be reiterated that it is a current not a voltage. Indeed, if you were to slap your 'scope probe on this point you would see very little happening. The voltage remains, due to the actions of the op-amp, firmly stuck at around zero volts.

It should be noted at this point that the current output of the VCA core, the transconductance amplifier, is directly proportional to the current being supplied by Q6. After all this is where the input transistors get their current from in the first place. Remember that no significant current is actually taken from the input signal via the base of the PNP transistors. So if the output current is dependant on the current provided by Q6, then controlling this current allows us to control the gain of the whole transconductance amplifier. This is why our CV processing circuit is tied to the top current mirror of the core. It has direct control over the gain and this is what makes it a VCA.

The op-amp is configured 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'. The 'gain' of the transimpedance amplifier is primarily set by R12. The output of the op-amp passes via R11 to the output socket of the module.

A standard transimpedance amplifier is just an op-amp and a resistor. This one looks more complex – its has four additional capacitors, two extra resistors and also a trimmer. C2, C5 and C4 all act to ensure stability of the circuit. No real life circuit is perfect, and without getting into the maths of it, unwanted characteristics of the components and board layout act to sometimes make the circuit unhappy. Typically this means it will oscillate when it shouldn't, or more commonly it will nearly oscillate when it shouldn't. The latter is called ringing and it is a resonance effect. In other words the circuit has a tendency to bounce around at a particular frequency when excited by an input signal.

When using a TL071 and not fitting any of the capacitors, the VCA would ring horribly at a very high frequency. This is way above human hearing but any ringing is not a good thing. Using all the values that ARP used made the circuit very stable, ie. no ringing, but it reduced the overall frequency response so that it had a negative impact on the audio bandwidth of the VCA. This raised an interesting question regarding the frequency response of a real ARP2019 since the drop in high frequency audio is audible. If you want to stick to the original values make C2 and C4 both 100pF. C5 can be 33pF. It is these values that are on the schematic and in the parts list.

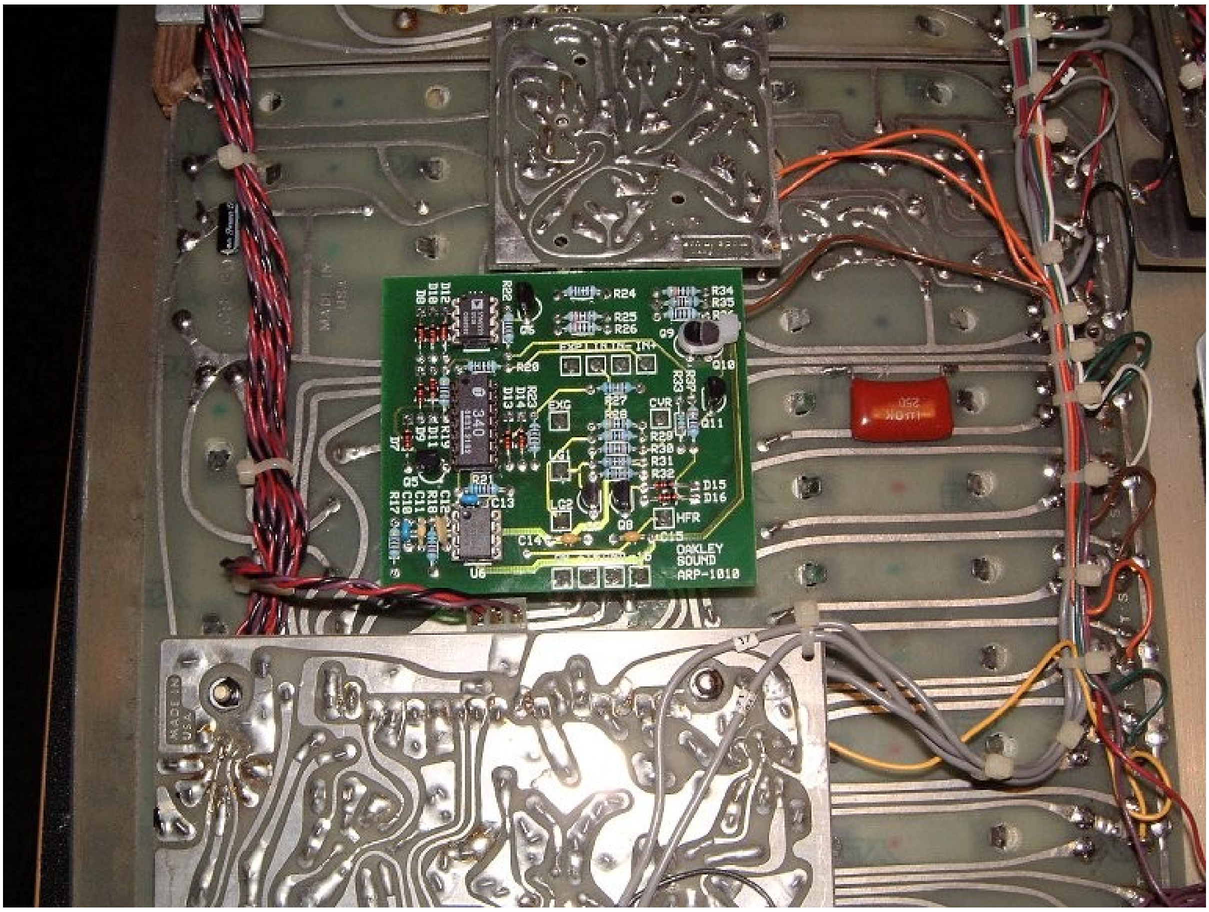
If you would like the VCA to have a full bandwidth then reduce the values of C2 and C4 and omit C3 and C5 entirely. I have used 18pF for C2 and C4 with excellent results.

R13 provides the op-amp with equal resistances on its inputs. The inverting input 'sees' only R12 since the resistance of the transimpedance amplifier is so high one can normally ignore it. However, the TL071 is very forgiving about imbalances of resistance on its inputs (it has very low bias currents because it is a FET amplifier) so R13 would normally be unnecessary. I have left it in to be faithful to the original ARP module. It also allows us to use the NULL trimmer.

The NULL trimmer is designed to pass back a proportion of the input signal to C3. C3 acts in conjunction with R12 to make a high pass filter. This means that only the very highest audio frequencies are passed into the non-inverting input of the op-amp. Since they expected the transconductance core to leak a little at high frequencies, one could then, in theory, cancel these leaks out by subtracting the core output with a high pass filtered version of the input. It seems it didn't work since the ARP say in their service notes, with regards to the trimmer, 'no adjustment necessary'. However, for the sake of accuracy the circuit has been replicated here in full. I didn't find it particularly helpful reducing high frequency breakthrough either, but there may be some scope for experimenting here.

Power is supplied via the usual four way MTA or Molex connector and 10 way Euro style power 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 C10 and C18 for the positive rail, and C11 and C9 for the negative rail. Additional decoupling is also provided elsewhere on the board by the other capacitors shown at the top 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.

The Prototype



This is very first version of the Oakley Classic VCA fitted to a real ARP2600C. This one off clone was built to replace a dead 'all epoxy' 4019 which in itself had replaced an older 4010. Note the pin out placement to accommodate the smaller 4010 module.

I later compared this 2600C to an early 2600P fitted with a standard 4019 and the differences were negligible in all but the increased frequency response in the clone.

The large red polypropylene capacitor fitted to the underside of the main circuit board is a modification done to provide DC blocking to the VCA on one of its inputs. The ARP2600 is predominantly DC coupled, but this tends to unbalance the VCA since many of the VCO waveforms are unipolar, ie. all positive. This positive bias of the VCA input leads to thumping at fast attack and release settings. The capacitor removes the bias and allows for fast thump free sounds. The action of the red capacitor is much the same as the INPUT (AC) on this module.

Buying The Components

For general information regarding where to get parts and suggested part numbers please see our useful Parts Guide at the project webpage or http://www.oakleysound.com/parts.pdf.

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 Classic VCA 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. I tend to go for 1% 0.25W metal film resistors throughout, since these are very cheap nowadays and I use them a lot in other projects that do need the accuracy and stability. However, note that R26 is a 1M5 resistor and you may find it difficult to get these in 1% metal film. For this value you can just use an ordinary 5% type.

The PCB is laid out for a certain type of pot and its matching pot bracket. The two 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 modulars.

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. However, do note that there are no mounting holes provided on this board so the pots, and their brackets, are the most practical way to fix the board to the 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 mass produced 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 then 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 all the pots is given as 50K. You may find that your supplier cannot sell this value, but instead offers 47K. This is perfectly fine as either value will do. Indeed, when you measure the track resistance of most commercial grade pots you will normally find it to be out as much as 10% from the stated value.

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, each with their own type of dielectric. 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, C4 and C5, 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 single multiturn 100K trimmer is the one that has 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 three trimmers are standard sealed carbon units. These are adjusted from the top and, as such, are called horizontally mounted types. Piher and other companies make suitable types. Lead spacing is 0.2” for the track ends, and the wiper is 0.4” away. Rapid, Farnell and RS sell these parts at reasonable cost. You can use the more expensive cermet types if you wish, but stability is not critical for this application.

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; TL071CN and THAT340P are both DIL packaged devices. Note that with the TL071 it is made by many different manufactures and each one will confusingly use different suffixes. Generally, most suppliers will make it clear that any device is a SMD device and these should be avoided in this module.

The PNP/NPN array is the THAT340 from THAT Corp in the US. The PNP array is the Analog Devices' SSM2220. Farnell sell both these parts at reasonable prices – although do check on our website because it is likely that we have them in stock too.

U3 can be replaced with an OPA134. This is a very high performance part, but I didn't actually detect any significant advantage in using it.

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. 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. However, note that many sockets often have NC lugs as standard. In this case, you can simply buy them but leave the NC lugs unused. I will say now that I prefer to use insulated sockets, ie. plastic ones. This stops the module ground being connected to the chassis earth and in theory prevents earth loops and audible hums. However, a great many of the new Euro modulars makers are using metal sockets and no one has yet complained of any problems.

This module is entirely suitable for the fitting of 4mm banana sockets. I'd be tempted to recommend these but for the fact that most Euro systems are exclusively 3.5mm sockets.

This module uses an eight way 0.1" header, SKT, 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.

Alternatively 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 Classic VCA modules 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 option is to not fit the SKT 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 or desoldering.

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	R9, R4
470R	R17
1K	R11, R7, R5, R24
3K3	R23
4K7	R10, R6, R1
18K	R27
33K	R18
47K	R21, R14, R16
62K	R13, R12
100K	R3, R2, R20
180K	R19
470K	R25
680K	R8
1M5	R26

The values of R15 and R22 depend whether you are building your module for +/-15V (Oakley 5U & Frac Rack) or for +/-12V (Euro format).

For +/-15V, R15 is 150K, R22 is 180K

For +/-12V, R15 is 120K, R22 is 150K

Capacitors

Components marked with a asterisk see Circuit Description section for alternative values.

33pF low-K ceramic	C3*, C5*
100pF low-K ceramic	C2*, C4*
100nF axial multilayer ceramic	C6, C7, C8, C9

470nF, 63V polyester	C1
2.2uF, 25V electrolytic	C10, C11

Discrete Semiconductors

1N4148 signal diode	D1, D2, D3, D4, D5, D6, D7, D8, D9, D10
BC550 NPN transistor	Q5, Q10, Q11
BC560 PNP transistor	Q6, Q7, Q8, Q9

Integrated Circuits

TL071 single op-amp	U3
THAT340P NPN/PNP array	U2
SSM2220 PNP array	U1

Variable Resistors

100K multiturn trimmer	OFFSET
100K horizontal trimmer	EXP, LIN
10K horizontal trimmer	NULL
50K logarithmic Alpha 16mm pot	DC_INPUT, AC_INPUT
50K linear Alpha 16mm pot	GAIN, EXPO_CV, LIN_CV
Oakley **small** pot brackets	Two off

Miscellaneous

0.156" MTA 4-way header	PWR – Fit for Frac/Oakley systems only
2x5 0.1” header	PSU – Fit for Euro systems only
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	Five off
3.5 sockets	Five off
DIL14 pin IC sockets	One off
DIL 8 pin IC sockets	Two off
Wire Link	LINK – See text

Hook up wire (26awg) in several different colours

Populating the Oakley Classic VCA Circuit Board

Warning:

Oakley PCBs are supplied with a RoHS compliant 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 solder plating since this can cause premature tarnishing of the finish. Shelf life is hard to predict but we recommend soldering in all the components less than one year from when you receive your board.

Neither I nor Paul Darlow 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 discrete 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.

Note that Q9 and Q10 face each other. This is deliberate because we want the two devices to be touching each other and so be at the same case temperature. Once you have soldered them in, use a pair of pliers to gently squash the two flat faces of the devices together. Then use a small plastic cable tie to hold them in place. You could even use some thermally conductive paste to ensure the two surfaces are bonded thermally – but this can be a bit messy and is likely not to have any great affect on the performance of the module.

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 any water wash to work. Cinch and solder the leads as you would resistors.

The low-K ceramic capacitors are quite fragile. Be careful you don't bend their legs otherwise their casing can crack and let moisture in.

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 slightly different to that of the Spectrol or TT pots you may have used on our 5U 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 probably support the PCB on their own. Their legs when soldered into the double sided board give good mechanical strength for most situations. However, for additional rigidity I recommend fitting the specially manufactured pot brackets.

When constructing the board, fit the two pot brackets to their 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 threaded 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 3U front panel layout. 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 2mm thick uncoloured 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.

I have designed the panel with a 10HP width. It is mechanically possible to fit the Classic VCA into a 8HP panel. However, I prefer a bit more space around my controls and sockets.

Connections

All Oakley 3U format modules come with two power supply possibilities.

1. Power connection PWR is the standard Oakley 4-way 0.156" MTA socket. Friction lock types are recommended. This system is backward compatible with MOTM and Blacet systems.

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

Note that the third pin is separate to the main module ground. This is the standard Oakley power specification and allows for the front panel to be grounded to earth at the power distribution board rather than locally through the module. However, other than in Oakley modular systems it is not widely used. See comment about the wire link below.

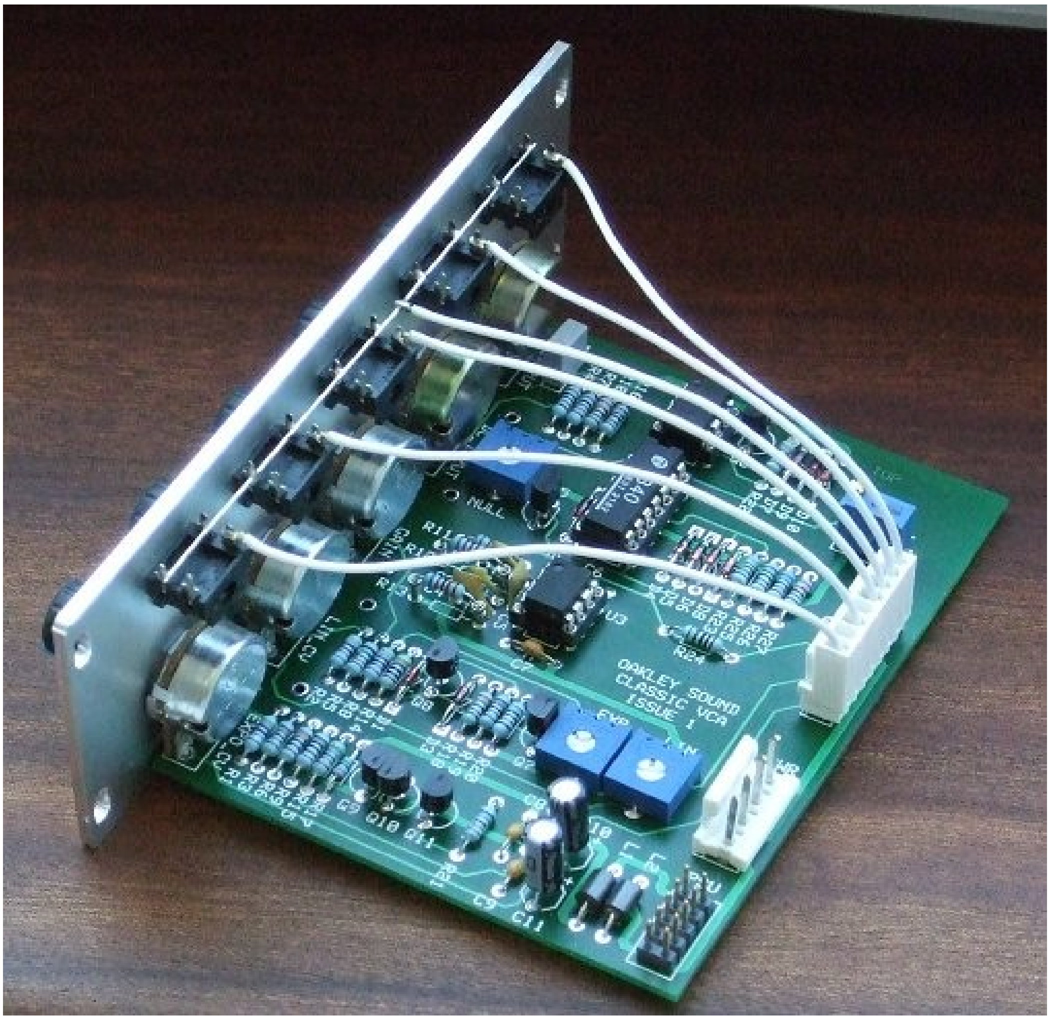
2. Power connection PSU is the 10 pin Doepfer style power supply connection. This is a 2 x 5 0.1" header and will fit 0.1" Flat ribbon IDC sockets. +12V goes to the top two pins of the header, that is the ones nearest the legend PSU. It is imperative that the power be supplied correctly. Damage to the module will result if the power supply is connected up the wrong way.

For Fractional Rack and Euro sized systems please solder a small wire link into the board where it is labelled LINK. This connects the module ground and earth together and will make the module behave the same way as your other modules.

For assembly into Oakley 5U and 3U complete systems you can omit the wire link.

All audio and CV connections are via a eight way 0.1" header on the PCB called 'SKT'. 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, you can solder your wires directly to the PCB from the various socket lugs if you wish.



This the prototype Euro module in the exemplar 10HP wide panel with the sockets mounted to the right of the pots. This early version of the PCB design differs slightly from the production runs. Note that both power sockets have been fitted – this normally would not be done, but I wanted my module to be tested on both +/-12V and +/-15V systems. If you look closely you will see some turned pin sockets being used for some of the resistors. This allows me to tweak the design simply without desoldering components.

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 3U high 10HP panel with the five 3.5mm sockets to the right of the PCB.

For my prototype I used Cliff jack sockets. I used these because they are relatively cheap and provide insulation between the module panel and the module ground. The module panel will be grounded or earthed via the rack casing. It is usually a good idea not to allow any local module ground to come into contact with the chassis at multiple points as this has the *potential* to cause ground loops and hums in your audio outputs.

Furthermore, as far as I can see it, most Euro rack systems are wired in such a way as to allow an additional ground pathway to occur whenever a patch cable is plugged from one module to another. However, since there has not been a chorus of complaints regarding multiple earth loops and hum problems, I think we can take it that it is not a major problem. The Oakley 5U system circumvents this whole complicated issue by using a second ground connection to provide a panel earth on each module. Thus panels and local grounds are distinct except for at one point near the power supply.

If you have used the little Cliff sockets you will see that they have four connections. One is the earth lug or ground tag. The second is the signal tag which will be connected to the tip of the jack plug when it is inserted. The third and fourth tag are the normalised tags, or NC (normally closed) lugs. The NC lugs are each internally connected to the ground and signal tags when a jack plug is not inserted. These connections should be automatically broken when you insert a jack. Pushing a jack plug into an unconnected socket and looking carefully at the various contacts will reveal the actions of the NC lugs.

Fit the five sockets onto the panel so that the all the socket's tags face left as you look at the rear of the panel, ie. away from the PCB.

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 so we only need one piece of insulated interconnection wire to ground all the sockets. I normally do this part of the wiring without the PCB or pots in place on the panel. I use thin uninsulated tinned copper wire, its just stiff enough so as to retain its shape. Solder a length of this solid core wire right across all the tags nearest to the panel. These are the earth tag, and its corresponding NC tag if you have them, on all the sockets. Trim off any excess wire that sticks out on either end. This single wire will eventually be connected to the printed circuit board via pin 3 of the SKT header.

If your chosen sockets do not have an earth NC lug, this is fine. Simply make sure that all your socket grounds are connected together.

Fit the Classic VCA PCB against the front panel if you haven't done so already. For my prototype I used Molex KK headers and housings to connect my module's sockets to the circuit board.

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 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	*Header SKT Pin number*
INPUT (AC)	1
INPUT (DC)	2
OUTPUT	4
LIN CV	6
EXPO CV	8

Finally Pin 3 is connected to the single uninsulated wire that joins the socket ground tags. Pins 5 and 7 of the header are left unconnected.

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 INPUT (AC). Listen to the output signal from the VCA module. For the moment you should hear nothing.

Turn up the INPUT (AC) pot to full. Again, you shouldn't hear anything, but maybe you will hear a little triangle wave bleedthrough. Now slowly turn up the GAIN 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 the INPUT (DC) pot should have no effect on the sound, but that INPUT (AC) behaves also like a volume control. It should seem that both INPUT (AC) and GAIN do the same thing. They do not of course, since INPUT (AC) is altering the signal level going into the VCA circuit, and GAIN is adjusting the amplification within the VCA's core.

Swap the input signal over to the INPUT (DC) input. It should be quiet again. Turning up the INPUT (DC) pot should bring back the signal.

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 LIN CV input. Use a sine or triangle wave signal at a lowish frequency, say 1Hz or so.

Turn the GAIN down to about 50% and the LIN CV up. Listen to the resultant sound. It should be the triangle wave you can hear again, but it will plusate evenly up and down with LFO signal. You should hear it go up and down in volume once for every cycle of the LFO.

Now remove the LFO signal from the LIN CV socket and connect it to the EXPO CV socket. Turn up the EXPO CV pot and you should hear the same sort of pulsating sound. However, it should be slightly different, spending more time loud than quiet..

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

Trimmers

There are four trimmers on the PCB which need adjusting correctly to get the best out of the VCA 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 VCA module to warm up for at least 15 minutes.

OFFSET: Turn the GAIN pot to its maximum level. Ensure all other pots are at their minimum settings. Measure the output voltage from the output socket with a good digital voltmeter. Adjust OFFSET with a jeweller's screwdriver or equivalent until the output voltage is 0.000V +/- 5mV.

LIN: Insert a 5V peak triangle wave signal at roughly 440Hz to the INPUT(AC) input. Turn the GAIN and the INPUT(AC) pots to their maximum. All other pots should be at their minimum settings.

Now with a scope measure the output voltage and adjust LIN until the input and output signals are the same level. It doesn't have to be that accurate – within 250mV will be fine.

If you do not have a scope, all you need to do is compare the input signal to the output signal. Adjust LIN until the two signals are the same volume. The best way to do this is to use a multiple. Connect the triangle wave from your VCO to the multiple, and then with another cable into the VCA input as above. Connect up your monitoring system to the same multiple and adjust your monitoring volume to suit. Then simply swap the monitoring system's jack plug from the mult to the VCA's output and adjust LIN accordingly. It doesn't have to be that accurate, just try to get the two signals sounding roughly the same.

EXP: Insert a 5V peak triangle wave signal at roughly 440Hz to the INPUT(AC) input. Turn the INPUT(AC) pots to its maximum. All other pots, including the GAIN pot, should be at their minimum settings. Connect a 5V source to the EXPO CV input. This could be a fixed voltage source, a triggered envelope generator or midi-CV convertor – anything that will give you a +5V output signal.

Now with a scope measure the output voltage and adjust EXP until the input and output signals are the same level. Again it doesn't have to be that accurate – within 250mV will be fine.

Likewise, if you do not have a scope then repeat the same procedure as the LIN trimmer, but this time adjust EXP to ensure that input and output are the same volume.

NULL: This is designed to reduce audio breakthrough. Thus NULL needs to be adjusted so that any signal on the signal inputs are not passed onto the main VCA output when the VCA is off. However, the original ARP documentation says any trimming procedure is worthless and that the trimmer should left as you find it. After various experiments I would have to agree with this for my version too. However, until told otherwise I would recommend that it should be simply turned fully clockwise, ie. off.

If you do feel like experimenting a bit then you should use a highish frequency square wave, say around 5kHz, and present this to either of the input sockets. Turn the relevant input level pot to its maximum, but ensure all the other pots are at their minimum points. Now listen carefully to the output of the VCA. You will probably hear some bleedthrough, in other words the VCA will leak a little. The theory is that adjusting NULL will reduce this bleedthrough. Like I say in practice I found it made very little difference.

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 Sound Forum at Muffwiggler.com. Paul Darlow and I are on this group, as well as many other users and builders of Oakley modules.

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 25GBP per hour. Most faults can be found and fixed within one hour, and I normally return modules within a week. The minimum charge is 25GBP plus return postage costs.

If you have a comment about this builder's guide, or have a found a mistake in it, then please do let me know. But please do not contact me or Paul Darlow directly with questions about sourcing components or general fault finding. Honestly, we would love to help but we do not have the time to help everyone individually by e-mail.

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

Tony Allgood at Oakley Sound

Cumbria, UK
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