

Oakley Sound Systems
‘Basic Series’
Voltage Controlled Amplifier Module

User’s Guide

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Introduction

This is a voltage controlled amplifier module designed primarily for use in modular synthesisers. However, it is possible to use this VCA in a polyphonic synthesiser system. Its simple design and the use of PCB mounted pots makes this an ideal starter module for beginners to my modular synthesiser projects.

The VCA 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. The term *amplifier* is actually slightly different to the one you normally use. Here, the amplification is more like attenuation. The gain actually varies from nearly zero, ie. the VCA is closed or off, to about two, ie. the output is double the input voltage.

This VCA features two pots mounted onto the PCB. One controls the sensitivity of the CV, and the other sets the initial gain. The latter is used to partially open the VCA. Any positive CV applied will then open the VCA further, while a negative CV will actually cause the VCA to close.

A good VCA will be able to amplify any input including other CVs, as well as audio inputs. Thus you could use a VCA to adjust the output level of a low frequency oscillator. The CV for the VCA could be derived from the aftertouch output of a midi-CV convertor. Thus when the keys are pressed harder, you could introduce vibrato to the synth's main oscillators.

This VCA has a linear response. This means that doubling the CV will double the output amplitude. In general this is the most useful response, although other types are available from other designs.

All the parts are easily obtainable, although the BA6110 OTA used can be difficult to trace in North America. Because of this I have a plentiful stock of these devices at a reasonable price. See my web pages for details.

The PCB

The PCB is small and almost cute at just 7.3 x 4.8cm in size. It uses double sided copper traces and has through plated holes. It has solder mask both sides for easier soldering, and has component legending on the top side for easier building.

I have provided space for the two control pots on the PCB. These do not have to be fitted for correct operation of the VCA, but they do form part of the mounting process, as no holes are provided on the PCB for supporting the board. If you use the specified pots and brackets, the PCB can be held very firmly to the front panel. The pot spacing is 1.625" and is the same as MOTM modular synthesiser. The board is fully MOTM panel compatible if the board is fitted horizontally, ie. in a 2U wide panel. The pots, from left to right, are; initial gain and CV sensitivity. I have included a suggested front panel layout at the back of this document.

The design requires plus and minus 15V supplies. These should be adequately regulated. The current consumption is about 8mA per rail. Power is routed onto the PCB by a four way 0.1"

header. You could, of course, wire up the board by soldering on wires directly. The four pins are +15V, ground, earth, -15V. The earth connection allows you to connect the metal front panel to the power supply's ground without it sharing the modules' ground line. More about this later. The connector used is different to my other larger module designs. The reason for this was to keep board space at a minimum. The current drawn by this module is very small, and 0.1" headers are very reliable at this level. Performance will not be impaired. Also the use of smaller connectors, aids the fitting of multiple boards in one modular panel.

Circuit Description

The VCA circuit is very simple, but let's run through the design carefully. Looking at the right of the schematic you can see the four way header, labeled PWR. Power enters the board here, and is immediately filtered by a simple RC networks based around R78 and C26 for the positive rail, and R77 and C25 for the negative rail. Two grounds are provided, one for the circuit itself, and one for the earthing of the jack sockets on the front panel. There are just two ICs on this PCB, and each requires power. The power supplies are shown separately to avoid cluttering the main circuit diagram.

The signal that is to be controlled enters the VCA by the connector IN. The signal is reduced, or 'potted down' to about a third of its original value by R72 and R64. This is to prevent overloading of the BA6110's input. It is assumed that signal level at the IN connector will not exceed 13V peak, if it does, distortion will result at the output. If you expect higher (!) levels than this, you may want to increase the value of R72.

The heart of this VCA is the BA6110 IC. This is an *operational transconductance amplifier*, or OTA for short. The OTA is different in several respects to a usual op-amp. Firstly, its output is a current, not a voltage. Secondly, its gain is controlled by a current injected into the Iabc pin. 'I' is for current, 'abc' stands for amplifier bias current. The bigger this current the higher the gain of the OTA. However, the current into the Iabc pin of a BA6110 must not exceed 0.75mA otherwise damage will result to the OTA.

The OTA amplifies the *differential voltage* between pin 1 and pin 2, by the amount set by the Iabc. The differential voltage is quite simply the voltage between pin 1 and pin 2 when measured on a voltmeter. Pin 2 of the OTA is the inverting input, so any positive going voltage here will produce a negative going current at the output. Pin 1 is held at roughly ground by R71. I say 'roughly' because we deliberately add a small offset voltage to pin 1 through the trimmer OFFSET and R70. This offset is very small, millivolts, but it is necessary to compensate for unwanted imbalances in the BA6110. If not corrected, the output of the VCA will have a small copy of the input CV at the output. One can never compensate for it completely, but we can do our best. Why do we want to get rid of it? Imagine a standard VCA whose job is to control the final output of a synthesiser. The input comes from a filter, and the CV comes from an envelope generator. If the envelope is very fast, a badly set VCA will produce an audible click every time a note is pressed. Most people find this objectionable. As an aside, there is a Edgar Froese album, which has a synth rattling away in a sequence constantly clicking every time a note is triggered. Yuk.. it sends me mad every time I hear it. Edgar get that synth serviced now...

The BA6110 may seem an odd choice as the OTA in this design. The National Semiconductor parts, the 3080 and 13700, are more common for this application. So why chose an OTA from a Japanese source? Well, I first came across the BA6110 when looking for a modern day

replacement to the classic Roland OTA, the BA662. This part turns up in the TB303 and many other Roland synths of the late 70s and early 80s. The BA662 part was probably made by R-Ohm for Roland, and the BA6110 is their improved replacement. But there are a few differences between these two parts. They both sound the same, but the BA6110 has a secret weapon, the linearising diodes. These diodes are also present on the LM13700 and the classic 13600, but are not nearly as good as the BA part. To get the LM13700 to behave, without significant distortion, the signal level must be as low as +/-100mV, even with these diodes switched on. The BA6110 works wonderfully well up to +/-4V or so, with its diodes switched on. This creates a better signal to noise ratio, and I think they sound better... but that's not a very good engineering statement, so ignore that bit!!

The output current of the OTA must be turned into a voltage to make it compatible with the rest of our synth. An op-amp in transconductance mode comes into use. This is quite simply an inverting amplifier with no input resistor. Any current flowing towards pin 6 of the TL072 will be matched by a current flowing through the feedback resistor, R67. No current flows into pin 6 at all, the op-amp makes sure that both currents are always evenly matched. R67 controls just how many mA from the OTA are turned into volts at the output of the opamp. A 1K resistor protects the opamp's output from abuse and unstabilising capacitive loading.

The Iabc current is created with a clever little circuit based around the first half of the TL072 called a *voltage controlled current source*. Three CVs are combined to give the Iabc we need. The pot labeled CV allows a proportion of the input CV to be applied to the current source circuit. R74 sets the maximum sensitivity of the CV input. 22K will make the overall gain of the VCA roughly unity when a +5V signal is applied to the CV input. The initial gain for the VCA is set by a pot labeled GAIN. The wiper of this pot travels between +15V and -0.6V. R73 sets the sensitivity to give the VCA a gain from nothing at all, ie off, to unity. The lower end is taken to just below 0V to guarantee the VCA is turned off. D4 and R76 act as a simple -0.6V supply. An additional CV is allowed through CV2, the sensitivity of this is set by R75. In my modular, I have not used this input at all, but it is there if you need it.

The op-amp acts so that any current heading towards pin 2 is offset by another current flowing towards the emitter of Q4. And any current flowing through the emitter junction will flow out of the collector towards the OTA. Actually, this is not strictly not true as some current is required to feed the base, but this is very small and can be ignored here. C24 provides stability to the circuit at high frequencies. D5 protects Q4 from reversed biasing of the base, which is possible at some input levels and at start up. R65 provides a very important job, it limits the maximum current into the OTA's Iabc pin. This must not exceed 750uA ever. Don't change this resistor unless you fancy replacing the OTA as well. Other OTAs are more sturdy in this respect, but the BA6110 wins in other ways.

Final point, you may be wondering why the component values start from high numbers and not from R1, C1 etc. This is because to keep the cost of this board down, I fitted the VCA PCB layout onto the same EDWin database as the VCO and EG projects. This way, only one set of photoplots was created for the three boards, and only one set of tooling costs were incurred. So you, dear customer, didn't have to pay too much for the boards.

Components

All the parts are easily available from your local parts stockist. I use Maplin and Farnell, here in the UK. In North America, companies called Mouser and Digikey are very popular.

The OTA can be difficult to trace, although CPC in the UK do carry a small stock. However, they have a small order charge for non account holders. I also carry a large stock of these as they are used in my TB3030 and WaveFolder projects.

The pots are Omeg Eco types with matching brackets. You could use any type you want, but not all pots have the same pin spacing. Not a problem, of course, if you are not fitting them to the board. In the UK, Maplin and Rapid Electronic sell the Omeg pots at a very good price. Omeg will also sell direct, but this is only viable for large orders. All three have web sites. Again, I also carry a stock of these.

I would go for 1% 0.25W metal film resistors throughout, but you could use 5% types with no problem.

For the capacitors, there are no set rules of type. All the electrolytics should be over 25V and radially mounted. The pitch spacing of the ceramic capacitor, C23, is 0.2". While the pitch spacing of the polyester layer capacitor, C24, is 0.3". I like the open frame Siemens polyester layer types.

The horizontal trimmer is a standard sealed carbon unit. These are adjusted from the top, and are horizontally mounted.

Please be careful with the orientation of the electrolytic capacitors, diodes and the transistor. **Please note:** The TL072 has pin 1 at the **top** left hand. The BA6110 has pin 1 at the **bottom**. Pin 1 is depicted on the board by a square pad for both ICs.

Paul Schreiber of SynthTech has won me over to water washable flux in solder. The quality of results is remarkable. In Europe, Farnell sell Multicore's Hydro-X, a very good value water based product. You must wash the PCB at least once an hour while building, but the end result is worth the extra hassle. You will end up with bright sparkling PCBs with no mess, and no fear of moisture build up which afflicts rosin based flux. Most components can be washed in water, although, it is probably not a good idea to wash a board with trimmers and pots on. These can be soldered in after the final wash with conventional solder or the new type 'no-clean' solder.

The PCB has been laid out to accept 0.1" headers for all the interconnects including the power supply. Pin 1 is depicted by the square pin. For a modular setup, it is probably best to solder wires into the pads. All the CV inputs are fitted onto 2-pin headers, pin 2 of which is connected to ground. This can be used for normalising your jacks, or for providing screening. See later for more details.

Finally, if you make a circuit change that makes the circuit better, do tell me so I can pass it on to others. Any updates are added to the current user guide, and posted on the 'Mods' page on my web site.

Parts List

The components are grouped into values, the order of the component names is of no particular consequence.

Resistors: all 1% metal film

22R	R77, 78
1K	R66
2K2	R69
10K	R71, 76
15K	R64
22K	R74, 75*
27K	R65
33K	R72
68K	R73
75K	R67
150K	R68
680K	R70

*Optional for third CV input.

Capacitors

22uF,25v elect	C25, 26
68pF ceramic	C23
1n polylayer	C24

Discrete Semiconductors

1N4148	D4, 5
BC560	Q4

Integrated Circuits

TL072
BA6110

Miscellaneous

1M horiz trimmer	OFFSET
4-way 0.1" lockable header	PWR
47K lin Eco pot	GAIN
22K lin Eco pot	CV
Pot bracket for Eco pots	(2 off)

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

Mounting the Pots

If you are using the recommended Eco pots, then they can support the PCB with specially manufactured pot brackets. You will not normally need any further support for the board. When constructing the board, fit the pot brackets to the pots by the nuts and washers supplied with the pots. But only solder the three pins that connect to the pot. Do not solder the pot bracket at this stage. When you have completed the PCB, you can fit it to your front panel. Position the PCB at right angles to the panel. Now you can solder each of the brackets. This will give you a very strong support and not stress the pot connections.

Connections

I would normalise all the input sockets to the local ground. On the PCB pin 2 of each CV input has been provided for this purpose. This prevents unwanted hum pick up when a jack is not inserted. Do not normalise the output jacks to ground as this will short the outputs when no jack is inserted.

The power socket is 0.1" 4-way header. Friction lock types are recommended.

<i>Power</i>	<i>Pin number</i>
+15V	1
Module 0V	2
Earth/Screen	3
-15V	4

The SCR pad on the PCB has been provided to allow the ground tags of the jack sockets to be connected to the powers supply ground without using the modules 0V supply. Earth loops cannot occur through patch leads this way, although screening is maintained. Of course, this can only work if all your modules follow this principle. The SuperLadder does not do this, and the midiDAC has a need for two separate grounds anyway. However, I am planning to have all my new modules to fit this standard. It will be still compatible with the MOTM systems, although they use the larger 0.156" Molex connectors.

At the rear of this user guide I have included a 1:1 drawing of the suggested front panel layout for a triple VCA panel. This, as the name suggests, contains three VCA PCBs. The pots on each board hold the PCB firmly to the front panel. Power can be supplied to each one individually, or just to one of them, and then routed by three wires to the other two PCBs. The nine jacks are wired up by small pieces of insulated wire. Colour coding the wires makes it easy to connect, and gives an attractive finish.

Actual panels can be obtained from Schaeffer-Apparatebau of Berlin, Germany. The cost is about £25 per panel. All you need to do is e-mail the fpd file that is found on the VCA web page on my site to Schaeffer, and they do the rest. The panel is black with white engraved legending. The panel itself is made from 3 mm thick anodised aluminium. The fpd panel can be edited with the Frontplatten Designer program available on the Schaeffer web site.

Trimmers

In the UK we call them 'presets'. Most horizontal presets can be adjusted with a small 2mm blade screwdriver. Alternatively, specially made trimmer adjusters can be used. It is probably worth investing in one of these, they are very cheap, and the plastic handle makes it easier to poke into live circuits.

The OFFSET preset is easy to set up. Connect a square wave of about 200 Hz to the CV input, turn up the sensitivity. Listen to the output of the VCA, or display it on a scope. Adjust the OFFSET preset until the output level reduces to a minimum level. You will not be able to get rid of it completely, but you will be able to get it down to an acceptable level.

Final Comments

I hope you enjoy building the 'Basic Series' VCA. Please feel free to ask any further questions about construction or setting up. If you cannot get your project to work, do get in touch with me, and I will see what I can do. Sometimes, it can be the simplest things that can lay out a project. Occasionally, there may be an error in the parts list. I have checked the documentation again and again, but experience has taught me to expect some little error to creep past. The schematic is always the correct version, since the parts list is taken from the schematic. So if there is any problem, use the schematic as the guide. If you do notice any error, please get in touch. You will be credited on the 'Updates and Mods' page, and you may get a free PCB.

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

Tony Allgood. February 2000

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