Oakley Sound Systems

ADSR/VCA Module

User's Guide

V1.01

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Introduction

This is my version of the classic envelope generator module primarily designed for use in modular synthesisers. Its basic design and the use of PCB mounted pots makes this an ideal starter module for beginners to my modular synthesiser projects. It uses standard parts and requires very little setting up.

The envelope generator or EG for short, generates a rising and then falling voltage at it's output when triggered by a gate signal. The gate is derived from a keyboard, switch or a midi-CV convertor elsewhere in the synthesiser system. The speed of the rise in output voltage is determined by the Attack control. The speed of the fall of the output voltage is determined by the Decay or Release controls. The output of an EG is traditionally patched to the VCA control voltage, to control the volume of the note when the keyboard is pressed, or to the VCF, where it dynamically alters the harmonic structure of the sound throughout the duration of the note played.

Traditionally there are three basic analogue EG types available:

Attack-decay (AD) This is a one shot type of generator. The output will rise and then immediately fall. The A and D pots determine the time taken to rise and fall. Removal of the gate will cause the decay phase to start prematurely on most systems.

Attack-release (AR) Very similar to the AD type, but the voltage is held high once the attack phase is completed until the gate is removed.

Attack-decay-sustain-release (ADSR) This one is controlled by four pots. When the attack phase is initiated by the gate signal, the output will rise to a predetermined level. Then the decay phase starts and the output voltage will then fall to the level set by the sustain pot. The voltage will remain at this level for as long as the gate is high. But as soon as the gate is removed the release stage is initiated. This causes the output to fall at a rate determined by the release pot. The ADSR-EG can perform both AR and AD operations simply by turning the sustain pot full up or down respectively.

Other types of envelope generators are available, especially on digital synthesisers, but the three analogue types still seem to the most musician friendly.

The Oakley ADSR module also incorporates a versatile VCA. This can be used independently as a separate VCA for audio or CV scaling. Or it can be used to modulate the output of the EG itself. For example, a velocity CV from the output of a midi to CV convertor, can automatically scale the ADSR output for touch sensitive control of the VCA or VCF. The suggested layout has the CV input to the VCA permanently connected to the output of the envelope generator circuitry.

Of Pots and Power

There are four main control pots on the PCB. The pots are **Attack**, **Decay**, **Sustain** and **Release**. If you use the specified pots and brackets, the PCB can be held firmly to the panel without any additional mounting procedures. The pot spacing is on a 1.625" grid and is the same as the vertical spacing on the MOTM modular synthesiser. The PCB has four mounting holes, one in each corner should you require additional support which you probably won't.

The design requires plus and minus 15V supplies. These should be adequately regulated. The current consumption is about 20mA. Power is routed onto the PCB by a four way 0.156” Molex type connector. Provision is made for the two ground system as used on all new Oakley modular projects, and is compatible with the MOTM systems. See later for details. This unit will run from a +/-12V supply with a slight reduction in dynamic range.

Circuit Description

The VCA and ADSR sections are essentially separate circuits that only share the same power supply. Power is applied to them through the **PWR** 4-way Molex connector. L-1 and L-2, small axial ferrite beads, provide some high frequency resistance, and along with C33, 38, 40 and 41 prevent the board from being effected by any noises on the power rails. They also help keep any noises going the other way too.

The **TRIG** input is actually a gate input. This is a switch type signal that is either at around 0 volts when off, or any positive voltage greater than 2V when on. The Oakley ADSR can easily handle greater voltages without damage. D13 protects Q6 from any negative inputs. When a positive gate arrives, Q6 turns on and pulls its collector down to ground or 0V. This inverse version of the applied gate signal is sent to three destinations. Referring to the schematic, we see that the middle destination is another transistor, Q7. This is configured as another inverter. Thus the output of Q7 produces a copy of the gate signal that swings from 0 when off to +15V when on. It is passed on to a CR network that acts as a differentiator. This circuit produces a positive voltage spike when the gate goes high. The duration of the spike is determined principally by the values of C32 and R63. D8 prevents a negative spike being produced when the gate goes low. The positive spike triggers an RS flip-flop circuit based around two NOR gates, U6.

A flip-flop is a sort of a one bit memory, or latch. Once triggered by a positive going pulse at pin 1, it stays latched. You can only reset it by removing the power or a reset pulse at its other input, pin 6. When the flip-flop is latched, pin 4 goes high and pin 3 goes low. This switches on U7 at pin 5.

U7 is a 4066 CMOS switch or analogue transmission gate. This, quite simply, behaves like an electrically controlled switch. For example, when pin 5 goes high, pins 3 and 4 are shorted together. With U7 (3,4,5) switched on C36, the main timing capacitor, begins to charge up through the Attack pot. The speed of the charging is determined by the resistance of the Attack pot.

U9 (5,6,7) acts as a voltage follower or buffer. This device ‘sniffs’ the voltage on its input and reproduces it at its own output. The voltage across C36 is therefore perfectly replicated by U9 and this then can be used as our final output. Furthermore, by buffering the capacitor’s voltage this way, the capacitor is unaffected by output loads.

Monitoring the voltage at the output is a comparator based around U8 (1,2,3) and Q5. When the voltage exceeds 9V or so, the comparator’s output goes from 0V to +15V. This tells the flip-flop that the attack phase is over and the **decay** phase is about to start. The latch is thus reset; pin 4 goes low and pin 3 goes high. The capacitor is no longer charging up.

In some circuits, the level at which the attack phase stops is set by the CMOS logic gate’s threshold voltage. In other words, the buffered capacitor voltage is fed directly to the flip-flop.

This, in my opinion, is not very good for two reasons. One, the slowly rising voltage at the input to CMOS logic is not a good idea since it produces a large heat dissipation is the device. Secondly, it can lead to false triggering. The benefit in having a reasonably precise comparator is that you can set the end of the attack phase to suit your own purposes. The timing capacitor is being charged from a +15V source through a resistor. This leads to the exponential rise in voltage over time. I prefer the attack phase to be nearly linear for a more punchy sound. By setting the maximum attack peak to a little below 5V, we get a moderate approximation to a straight line. However, it does limit the maximum attack time to below 5 seconds using 1M resistors and 10uF timing capacitor. By using a 14V peak, we can get really long maximum attack times, but a very exponential response, and in my opinion very unrealistic sounds. By using a value of 9V, we get a nice compromise between punchy attack and long maximum attack times. Feel free to adjust the value of R58 which controls the peak and the maximum sustain value and do some experimenting yourself.

In the decay phase, the capacitor is discharged to the level set by the **Sustain** pot. The rate of discharge is set by the Decay pot. In some designs the sustain pot supplies or drains the current to the timing capacitor directly. Thus the resistance of the sustain pot will effect the minimum decay time. There are two solutions: One use a very low value sustain pot, say 1K, and cope with a large current drain from the power supply. Or, do what I have done, and use another voltage follower, U8 (5,6,7) to sniff the sustain pot's voltage and provide the current.

The decay phase is controlled by the flip-flop output on pin 3. Pin 3 goes high when, as we have discussed; the attack peak has been reached. But it also goes high when the gate signal is removed. This is the signal that tells us that the **release** phase has started. C39, R81 and D11 form a differentiator which apply a pulse when the gate goes low. This is combined with the attack peak detected signal to reset the flip-flop. U6 (12,13,11 & 8,9,10) acts as the OR gate which combines the signals. To distinguish between the decay phase and the release phase, U7 (6,8,9) is used. This only allows the output of the flip-flop to enable the decay phase when the gate is high. Essentially it acts as a switch, only allowing the gate output to control the decay switch when the flip-flop output is high. If the flip-flop is reset due to the gate falling, then decay phase is not initiated.

The timing capacitor will remain charged to the sustain level for as long as the gate is high. Technically speaking the decay and sustain phase are one of the same thing. The sustain period merely being the final level of the decay process.

When the gate drops, the envelope generator will start the release phase. This can happen at any point in the ADSR cycle. The output of Q6, the inverted gate signal will go high. This turns on U7 (1,2,13) and the timing capacitor is discharged to ground through the Release pot. The flip-flop will be reset, as we have already discussed, to prevent the attack and decay pots from affecting the timing capacitor. With no gate present, the envelope generator is continually in release mode thus keeping the capacitor always discharged.

The output of the envelope generator is available at pin 7 of U9. As is custom in modulars, the output goes through a 1K resistor before reaching the output socket. This is normally used to prevent mispatching damaging the op-amp's output, but it also prevent high frequency oscillations due to unwanted cable capacitance.

In the suggested panel layout, I have hardwired the ADSR output straight to the VCA control input, CV.

The VCA is based on one dug up by Chris Crosskey in the Modulus Synth E-zine. I am sure that it originally surfaced in a Babani Paperback on audio projects, but its original designer is unnamed. However, what is clear that it is a type of Gilbert Multiplier. Now at first site it may seem to be more complex than the usual OTA based VCA. And indeed it is, but since I have designed the PCB for you, the layout has already been done. The cost of the parts is less than a single 3080, and 3046 arrays are easier to come by than the OTA. I don't think it has any real benefits over the OTA approach, but it is more unusual and it does offer excellent performance.

I have changed a few things to the original Modulus circuit. The first is a trim pot that adjusts the balance of current injected into the two current nodes, pin 2 and 6 of U10. This should be able to counteract any imbalance between the two transistors in the long tailed pair. Jorgen Bergfors also did this in his version. The benefit of this is to reduce CV breakthrough into the audio path. CV breakthrough is where the output is found to vary with control voltage even when there is no input signal. In this particular application, fast attack and decays would be heard as a thumping sound if CV breakthrough is not nulled correctly.

I added D12 as a precaution to avoid any excessive negative control voltages. Negative values of CV end up superimposed on the output, and are best avoided. This will not occur if you build the suggested layout, since the CV input is derived from the positive only ADSR output.

I added an inverter to the VCA's output, since the original circuit actually inverts the signal. However, we do use this inverted signal as an inverted ADSR output in the suggested panel layout.

Operation of this VCA is twofold. The main Gilbert multiplier is based around U11 (1,2,3,4,5) a matched transistor pair within the 3046 array. With no signal present at the IN input, the current through both transistors will be roughly the same. U10 (5,6,7) acts as a loop controller, it will try and maintain its pin 6 at zero volts. So whatever current is coming down R71 due to the CV input, it will match with an opposite current through the left hand transistor of the pair. It does this by driving the bottom of the pair, the tail, with R72. As both transistors are matched, both transistors have the same current flowing through them. The VCA's output will not be affected by any change in current through R71, since the same current is travelling through R70 from the CV input and cancelled out by the current in the right hand transistor.

Now, lets upset the perfect balance we have. By adding a small positive signal to the base of the left hand transistor, we alter the amount of current distribution in the pair. The left hand will take more. The loop controller will still try and maintain zero volts at pin 6, but it now has to push less current through the pair. Since the right hand side of the pair cannot 'see' what is happening at the base of the other transistor, this decreasing current leads to an imbalance at pin 2 of U10. This op-amp will then have to lower its output voltage to try and maintain the balance through the feedback resistors, R69 and **Level**. It is this output voltage that is our required signal, the multiplication of CV and audio signal.

However, without the actions of other transistors in the 3046 array, this VCA has a major fault. To work properly without audible distortion the input signal must be very small, in the order of tens of millivolts. However, this is not much use to us in a modular that uses signals exceeding 10V p-p. The other transistors in the array work as pre-distortion elements. They distort the signal in exactly the opposite way to that of the Gilbert pair. In essence the two systems working together cancel each other's non-linearities. U11 (6,7,8) and U11 (9,10,11) actually perform the pre-distortion, with U11 (12,13,14) providing the temperature stabilised biasing.

The little two resistor network at the bottom of the schematic creates a +5V signal that is added to the VCA's signal path when no jack plug is inserted into the CV input. This allows the ADSR output to be always available with a fixed attack peak of +5V even with no modulation input. Thus the envelope generator can be used as if the VCA were not present.

Components

Most of the parts are easily available form your local parts stockist. I use Rapid, RS Components, Maplin and Farnell, here in the UK. In North America, companies called Mouser, Newark and Digikey are very popular. In Germany, try Reichelt, and in Sweden you can use Elfa. All companies have websites with their name in the URL.

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

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

For the capacitors, there are no set rules. All the electrolytics should be over 25V, except where stated, and radially mounted. However, don't chose too higher voltage either. The higher the working voltage the larger in size the capacitor. A 220V capacitor will be too big to fit on the board. 25V or 35V is a good value to go for.

The pitch spacing of the non-polar capacitors is 7.5mm (0.3"), except the low capacitance (values in pF) ceramics which are 5mm (0.2"). For the non ceramic types I think polyester types are fine for all decoupling, coupling and filter uses. I like the open frame Siemens polyester layer types, because they are very compact and a rather nice colour! They are normally called poly-layer and are available in many different working voltages. Use 100V or 400V. But remember the pitch spacing. You could also use the Phillips C280 series and their modern replacements, eg. BC-368 series. These are metalised polyester types, but again do be sure you get low working voltages. Around 100 to 150V is best. In the UK, Farnell can supply all the capacitors.

L-1 and L-2 are leaded ferrite beads. These are little axial components that look like little blackened resistors. They are available from most of the mail order suppliers. Find them in the EMC or Inductor section of the catalogues. Farnell sell them as part number: 108-267.

The two horizontal preset or trimmer resistors are just ordinary carbon types. No need to buy the expensive cermet types. Carbon sealed units have more resistance to dust. Piher and Spectrol make suitable types. Pin spacing is 0.2" at the base, with the wiper 0.4" away from the base line.

The BC549 transistors can be pretty much any NPN transistor that corresponds to the same pin out. For example: BC550, BC548 etc. I have used BC549C throughout in my prototypes.

All ICs are dual in line (DIL or DIP) packages. These are generally, but not always, suffixed with a CP or a CN in their part numbers. For example; TL072CP. Do not use SMD, SM or surface mount packages. The 3046 can be either CA3046 from Harris or LM3046 from National. Again they may have additional suffixes, but make sure you getting the 14-pin DIL or DIP version.

Please be careful with the orientation of the electrolytic capacitors, diodes and the transistors. All the ICs have pin one to the top.

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. Wash the board in warm water on both sides, and use a soft nail brush or washing up brush to make sure all of the flux is removed. Make sure the board is dry before you continue to work on it or power it up. It sounds like a bit of a hassle, but the end result is worth it. You will end up with bright sparkling PCBs with no mess, and no fear of moisture build up which afflicts rosin based flux. Most components can be washed in water, 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 better new type of 'no-clean' solder. Make sure the board is fully dry before switching it on.

I would make the board in the following order: resistors, diodes, IC sockets, small capacitors, transistors/regulator, electrolytic capacitors. Then the final water wash. Then the pots can be soldered in with 'no clean' or ordinary rosin based solder. See later for more details on mounting the pots.

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

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.

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

Resistors

Resistors 1/4W, 5% or better.

47R	R59,60
1K	R88,87,73,74

4K7	R82,83
5K1	R85
6K8	R58
10K	R84,66,65
22K	R72
33K	R69
47K	R57,62,75,70,71
62K	R81
100K	R63,77,89,78,67,68,76,79,80
220K	R61
470K	R86
3M3	R64

Capacitors

22uF, 25V electrolytic	C40,41,30
10uF, 16V tantalum	C36
10nF, 400V polyester	C32,39
100nF, 100V polyester	C31,33,38
10p Ceramic	C34,37

Semiconductors

1N4148	D8,9,10,11,12,13
BC549	Q5,6,7
TL072	U8,9,10
CA3046 or LM3046	U11
4001	U6
4066	U7

Other

4-way 0.156" Molex/MTA connector	PSU
10K linear single gang variable resistor	SUSTAIN
1M log single gang variable resistor	ATTACK, DECAY, RELEASE
Four pot brackets to suit	
2K2 carbon trimmer (horizontal)	CV-TRIM
22K carbon trimmer (horizontal)	LEVEL
Leaded or taped ferrite beads	L-1, L-2
1m of multistrand hook up wire	
Four knobs	
Four decent quality jack sockets, eg. Switchcraft 112	

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

Important: Mounting the Omeg 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.

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

Connections

This module is very easy to connect up. There are just four sockets in the suggested layout. I have internally hardwired the ADSR output to the CV input. This means the envelope generator is always connected to the VCA. This is simply achieved by linking the CV and ADSR pads on the PCB together with a small piece of wire

If you have used Switchcraft 112 sockets you will see that they have three connections. One is the earth tag. One is the signal tag which will be connected to the tip of the jack plug when it is inserted. The third tag is the normalised tag, or NC (normally closed) tag. The NC tag is internally connected to the signal tag when a jack is not connected. This connection is automatically broken when you insert a jack.

Connect, with four pieces of insulated wire, each signal tag to the respective pad on the PCB. You should have OUT, INV, TRIG and IN. I have used different names for the front panel sockets. The table below shows which is connected to which:

PCB	**Front Panel**
TRIG	GATE IN
OUT	ADSR
INV	ADSR-
IN	CV

Leave the NC tags unconnected on the TRIG, OUT and INV sockets. Connect the NC tag on the CV socket to the NORM pad on the PCB. This will allow the ADSR outputs to function even without any CV input.

The power socket is 0.156” Molex/MTA 4-way header. Friction lock types are recommended. This system is compatible with MOTM systems.

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

The PNL 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 module’s 0V supply. Earth loops cannot occur through patch leads this way, although screening is maintained. Of course, this can only work if all your modules follow this principle.

The ground tags of each socket can be all connected together with solid wire. A piece of insulated wire can then be used to connect the tags to the PNL pad. Do not connect the ground tags to any other ground.

At the rear of this user guide I have included a 1:1 drawing of the suggested front panel layout. Actual panels can be obtained from Schaeffer-Apparatebau of Berlin, Germany. The cost is about £25 per panel. All you need to do is e-mail the fpd file that is found on the MultiLadder 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 2.5mm thick anodised aluminium. The fpd panel can be edited with the Frontplatten Designer program available on the Schaeffer web site.

Setting Up

There are just two trimmers to be set before you are finished. The LEVEL trimmer allows you to trim the output of the VCA to the desired gain. In the suggested layout, with no CV input, the ADSR output is trimmed to give +5V peak attack and sustain levels. Connect a positive gate signal to the Gate input. Set A, D, and R to their minimum positions, and set S to the maximum. Adjust LEVEL until you get +5V from the ‘ADSR’ output. Just to check you should get -5V from the ‘ADSR-’ output.

Apply a 100Hz or so, square wave to the gate input. Now connect a zero volt signal to the CV input. You can easily get this by hooking up a non-oscillating filter’s output to the CV input. Now attach the ADSR output to your final mixer or ampifier. With the volume quite low, adjust CV-TRIM until any audible 100Hz buzz is minimised. Turn the amplifier up to fine tune the control. You won’t get it absolutely silent, but it will be near enough.

That’s it you’re ready to go.

Final Comments

I hope you enjoy building and using the Oakley *ADSR/VCA Module*. Please feel free to ask any further questions about construction or setting up. If you cannot get your project to work, do get in touch with me, and I will see what I can do. Sometimes, it can be the simplest things that can lay out a project. I do offer a get-you-working service. Send your completed non-working module back to me with £10 and I will fix it for you. You will also have to pay for the postage both ways, and for any replacement parts needed. Make sure you wrap it carefully and include a full description of the fault.

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

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

Last but not least, can I say a big thank you to all of you who helped and inspired me. For this module in particular, I would like to thank Chris Crosskey, Paul Maddox and Jorgen Bergfors. Thanks especially to all those nice people on the synth-diy and MOTM mailing lists.

Tony Allgood. January 2001

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ATTACK
DECAY
SUSTAIN
RELEASE
GATE IN
CV IN
ADSR+
ADSR−
OAKLEY
OMS-803 ADSR