# DUAL VCA

## The Project 80 family grows. The latest addition - this Dual VCA design by R.C. Blakey

A voltage controlled amplifier (VCA) when used in conjunction with an envelope shaper provides dynamic control over the amplitude of signals. Although the advantage of customised ICs for electronic music has been demonstated in previous modules this dual VCA effectively illustrates their cost-performance benefits. It is a true dual VCA with each half having facilities for exponential or linear control; 0 to 100% linear amplitude modulation (tremelo); an external control of amplitude (expression). Furthermore, one can almost forget about overloading the VCAs and causing distortion, since they will accept ± 10 V signals and yet their low inherent noise is such that much smaller signal levels are acceptable. Each VCA also has a dynamic control range of some 80 dB using our standard 0 to + 10 V control voltages

## Design Features

The design is based on the CEM 3330 Dual VCA IC produced by Curtis Electromusic Specialties, as used in Module 80-4 VCM.

A VCA is normally employed in conjunction with an ADSR envelope generator to provide the contour of sound dictated by this controller. Ideally the response to the envelope shaper voltage should be exponential since the human ear responds to loudness in a logarithmic manner. This facility is provided with a response of approximately 8 dB/volt. The overall response is such as to avoid problems arising from small levels of control voltage feedthrough from the envelope shaper. A linear control input is also included for other purposes but may be used with an envelope shaper to obtain a different type of response. In this instance, however, small amounts of control voltage feedthrough from the ADSR may be audible, although this can be cancelled out by applying an external positive voltage into the AM input. Increasing this voltage will bury the envelope voltage, that is, the attack and decay voltages will begin and end, respectively, at a voltage equal to the voltage applied to the AM input. The aural effect is more realistic since it effectively shortens the exponential decay time of the envelope — a technique adopted in some commercial synthesisers.

Another use of a VCA is for amplitude modulation (tremelo) and the design allows 0 to 100% amplitude modulation using any of the 0 to + 10 V signals from the VCLFO (or VCO). The linear input or the linear AM input may also be used for loudness control, or expression, by using a foot pedal outputting a control voltage or by taking a control voltage from, say, the keyboard. Another feature incorporated into the linear control input is a 'STOP' facility. In live performance it can be disconcerting when the rest of the group stops sharply at the end of a piece and the synthesiser is still playing as the envelope shaper continues its decay time.

Normally the signal into the VCA will be AC coupled, but if the VCA is being used for electronic control over the amplitude of signals which are to be processed further then a DC input is useful. Signals up to ± 10 V may be used and *either* AC *or* DC coupled. Mixing of signals at the VCA is not included since other ETI 80 modules have ample facilities for mixing prior to the VCA. Likewise the gain is fixed at about 0.6 so as to retain a very high signal to noise ratio for signals which will undergo further treatment and in other circumstances the output can be attenuated at the input of the power amplifier. If necessary the gain may be adjusted by using external control voltages, as described above

**The CEM 3330, from Curtis Electromusic Specialties, contains two voltage controlled amplifiers each of which consists of a variable gain cell and a log converter. The gain cell is the current-in, current-out type with an exponential control scale. The log converter generates the logarithm of the linear control input current while transmitting the exponential control input unchanged to its output, thus providing simultaneous linear and exponential controls.**

**Only one VCA using pins 1 to 9 of the CEM 3330 will be described since the other VCA using pins 10 to 18 is identical. The exponential control input (pin 6 of IC1) has a scale sensitivity of 18 mV/−6 dB and an increasing positive control voltage decreases gain. To reverse the polarity, so as to accept the 0 to + 10 V control voltages used in the ETI 80 modules, IC2b with R12 and R14 provide a unity gain inverting stage and the voltage is attenuated by R15 and R16 to acceptable levels. R13 connected to − 15 V produces a nominal 253 mV at pin 6, which sets the minimum level, and a + 10 V control voltage applied to R12 will result in about − 16.5 mV for maximum gain. Thus the nominal control range at this input is about 90 dB.**

**The overall gain of the VCA is given by**

$$A_V = \frac{R_F}{R_i} \times \frac{I_{CL}}{I_{REF}} e^{-V_{CE}/V_T}$$

**where $R_F$ is the value of the output resistor (R24); $R_i$ the signal input resistor (R17); $I_{CL}$ the linear control current developed across**

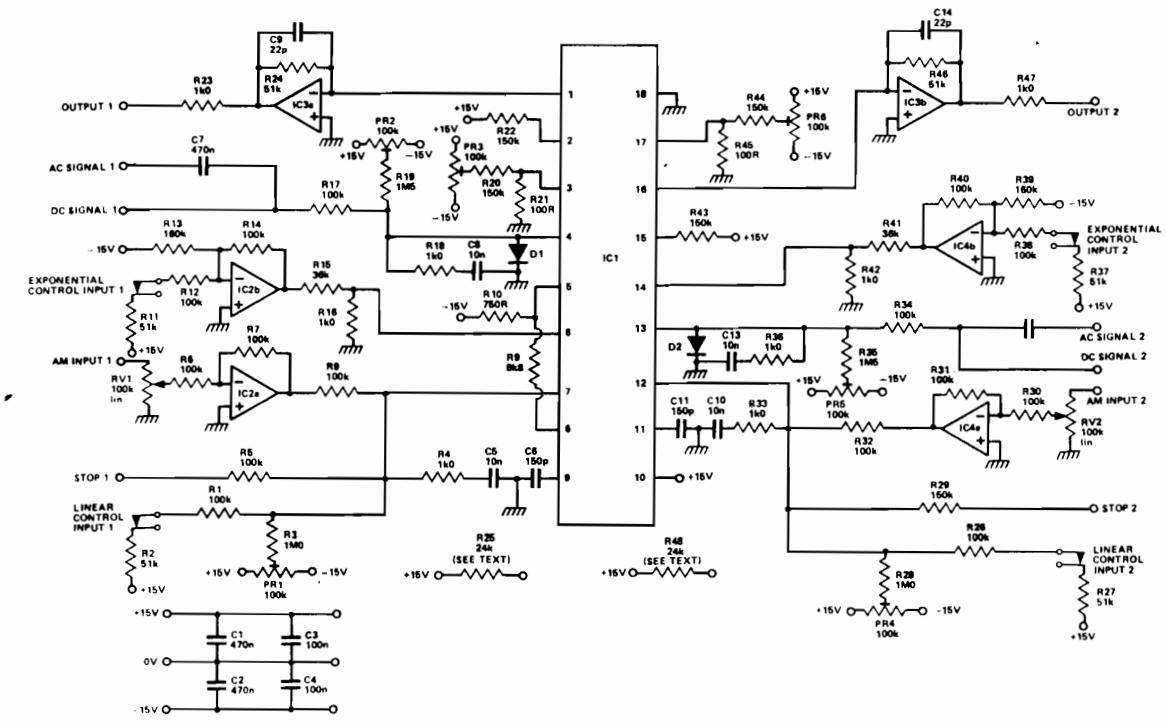



Fig.1. Circuit diagram of the Project 80 Dual VCA.

## HOW IT WORKS

R1; $I_{REF}$ the current input to pin 2 via R22 which has been set to 100 uA for best overall performance; and $V_{CE}$ the exponential control voltage discussed above. Thus +10 V into pin 7 via R1 (100k) produces maximum gain. By using jack socket inputs to both linear and exponential controls and connecting these to +15 V via R2 and R11 respectively, the VCA is operating at maximum gain. With a signal applied via R17 and no jack plugs inserted into either control socket the signal will pass through at maximum gain (about 0.75), which is a useful facility when setting up or tuning the synthesiser. A 0 to +10 V control voltage applied to either control socket will attenuate the signal over the full control range and with the appropriate control characteristics. These same facilities can be obtained by switches and R25 is included on the PCB for this purpose; it is connected via a switch to both control inputs (R1, R12) so as to allow signals to pass through the VCA at maximum gain. Normally the exponential input is used in conjunction with an ADSR envelope shaper and the linear control input used for amplitude modulation (tremelo). 0 to 100% amplitude modulation is obtained from the linear input using any 0 to +10 V waveform applied via RV1 and the inverting stage built round IC2a. Thus +10 V with RV1 at zero resistance will result in 100% modulation of the control voltage applied to the exponential input. PR1 and R3 are provided to balance the control voltage applied to the linear input, via R1 and R2, with the voltage applied to the AM input. Also connected to the linear input is a 'STOP' facility via R5 which may be activated externally by push button or foot switch connected to −15 V. Since a negative current at this input cuts the VCA completely off the 'STOP' action is functional at all times and allows the synthesiser output to be stopped on demand. Alternatively, a foot pedal switch containing a 9 V battery (positive to jack socket ground) can be used if R5 and R29 are changed to 91k. Components R4 and C5 are for compensation purposes.

The signal input may be AC coupled via C7 and R17 or DC coupled direct to R17. R18, C8 and C6 are compensation components and D1 prevents latch up. PR2 and R9 allow trimming of control voltage feedthrough. The current output from pin 1 is converted to a voltage using IC3a and R24.

To operate the CEM 3330 from the standard ±15 V supply a current limiting resistor must be added between pin 5 and the negative supply, which in the present application may be calculated from the formula $R_{EE} = (V_{EE} - 7.2)/0.010$; which for −15 V supply requires a 750R resistor (R10).

One of the unique features of the CEM 3330 is that the operating point of the amplifiers may be set anywhere from Class A to Class B according to which parameters are most important in a particular application. The quiescent standby current of the signal carrying transistors is varied by placing a resistor between the $I_{EE}$ pin (pin 5) and the idle current adjust pin (pin 8). For this VCA application the amplifiers are run Class AB with the 6k8 resistor (R9) providing a standby current of about 7 uA.

When operating the VCAs less than Class A, internal transistor mismatches will cause the gain during the positive portion of the input signal to differ from that during the negative portion, thus introducing even harmonic distortion — predominantly second. In this design the untrimmed distortion is typically less than 1%, at 1 kHz and 10 dB below clipping, but this can be improved by about a factor of ten if a small voltage is injected into the distortion trim pin (pin 3). R3, R20 and R21 provide an adjustment of ±10 mV for this purpose, if required.

By employing jack sockets for the inputs the VCAs are normally open, that is, a signal applied to the input of either will be present at the appropriate output at a level governed by the maximum gain of the VCA. As soon as a jack plug is inserted into either the linear or exponential control input then the VCA is under the control of the external voltage and with O V at either input the signal is completely cut off. The normally open VCA is useful while tuning the VCOs and setting up patches. This same facility may also be obtained using switches. The necessary resistors are incorporated into the PCB layout to cope with the different methods of construction.

Other advantages of having a true dual VCA incorporating the controls described above are:

(1) The ability to use the VCAs for auto panning by applying the signals to both (the same or different signals) and controlling pan by, say, a sawtooth wave into the linear control input of one and into the AM control of the other. Many panning variations are possible by using the exponential control, the inverted voltages from the 80-5 processor module, and so on;

(2) Taking the output from one VCA whose signal has been amplitude modulated and applying further modulation in the second VCA.

A truly versatile module.

## Construction

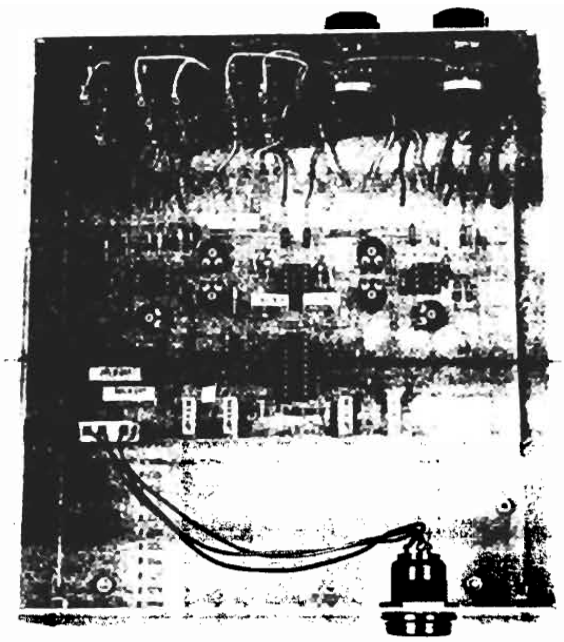
The module is designed for control voltages of 0 to +10 V and so if it is to be used in conjunction with ETI 80-8, whose peak voltage may reach +11 V, then resistors R11 and R37 should be replaced by 39k and R12 and R38 by 110k. This alteration is to prevent excessive output voltages and the substitute resistors are included in the kit of parts. R5 and R29 should also be changed to 91k if a footswitch with a 9 V battery is used to operate the 'STOP' control, as described in the previous section.

R25 and R48 need not be installed if jack sockets are used for the control inputs. With the latter method of construction R1, R12, R26 and R38 are wired to the jack socket connection which makes contact with a jack plug while R2, R11, R27 and R37 go to the respective socket connections which are disabled when a jack plug is inserted. If jack sockets are not used then a three position double pole slide switch may be employed for each VCA. For example, with VCA 1 the switch should be wired to connect R2 to R1 (position '1' to enable the exponential control); connect R11 to R12 (position '2' to enable the linear control); connect R25 to both R1 and R12 (position '3' to by-pass the VCA during tuning, etc.)

## Calibration

Although there are three trimmers on each side the calibration can be carried out quickly with a minimum of equipment. During calibration the VCA must be in the open position, ie no jack plugs inserted into the control inputs (or R24/R48 switched to both control inputs). Set all trimmers to their mid position.

1. To balance the AM input control voltage against the voltage applied to the linear control input via R2 and R27. Turn the AM control, RV1 or RV2, fully clockwise (minimum resistance) and apply a 10 V VCO signal to the DC input. Apply exactly +10VO to the AM input, using a potentiometer as a voltage divider and either examine the output of the VCA being calibrated with an oscilloscope set to its maximum sensitivity or listen to the output by connecting it to an amplifier. Turn PR1 (PR4) so that the



The Dual VCA board fitted into the Teko Alba A23G case (available from West Hyde Developments).

## PARTS LIST

**RESISTORS** ¼W 5% carbon film unless stated

| | |
|---|---|
| R1,6,7,8,12*,14,17, 26,30,31,32,34,38*, 40 | 100k |
| R2,11*,27,37* | 51k |
| R3,28 | 1M0 |
| R4,16,18,23,33,36, 42,47 | 1k0 |
| R5,20,29,44 | 150k |
| R9 | 6k8 |
| R10 | 750R |
| R13,39 | 160k |
| R15,41 | 36k |
| R19,35 | 1M5 |
| R21,45 | 100R |
| R22,43 | 150k (1% metal film) |
| R24,46 | 51k (1% metal film) |
| R25,48 | 24k |

*see text

**CAPACITORS**

| | |
|---|---|
| C1,2,7,12 | 470n polyester |
| C3,4 | 100n polyester |
| C5,8,10,13 | 10n polyester |
| C6,11 | 150p polystyrene |
| C9,14 | 22p polystyrene |

**TRIMMERS**

| | |
|---|---|
| PR1,2,3,4,5,6 | 100k carbon |

**POTENTIOMETERS**

| | |
|---|---|
| RV1,2 | 100k linear |

**SEMICONDUCTORS**

| | |
|---|---|
| IC1 | CEM3330 |
| IC2,4 | LM1458 |
| IC3 | TL072CP |
| D1,2 | 1N4148 |

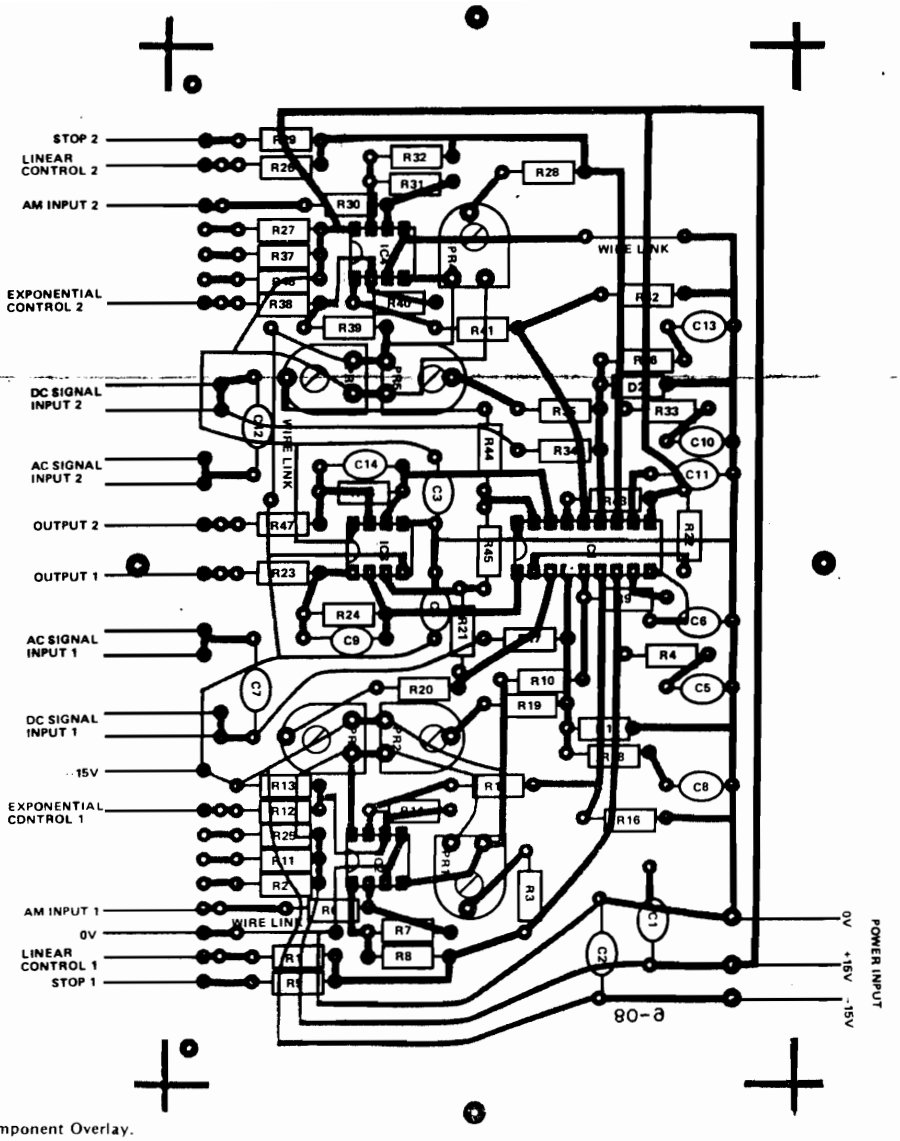



Fig.2. Component Overlay.

signal is seen (or heard) then reverse direction until the signal is *just* cut off

2. Trimming distortion. Connect the output to a voltmeter and adjust PR3 (PR6) for zero output. Next connect a fresh 9 V battery to the DC signal input with the positive terminal to R17(R34) and the negative terminal to a ground point on the module. Measure the voltage at the output as accurately as possible. Reverse the battery leads and measure voltage again. Adjust PR3 (PR6) until the voltage obtained between +V applied and no voltage applied is exactly the same as that obtained with −V and no voltage. This difference must take into account any drift from zero output, with no voltage applied, as PR3 (PR6) is adjusted. The polarity reversal may have to be carried out several times to achieve the calibration step. NOTE. For those that find this step difficult or who are content with up to about 1% distortion then components PR3, R20 and R21 (PR6, R44 and R45) may be omitted and the PCB connections for R21 and R45 replaced by wire links. In this event only calibration steps 1 and 3 are required.

3. Trimming control voltage feedthrough. With no connections to any VCA inputs adjust PR2 (PR5) to give exactly OV output.