



input to the output node of the VCA. Also, with the 5532s and their associated de-coupling capacitors placed close to the VCA, there should be no need for additional de-coupling around the VCA.

2. The packages of the VCAs should ideally be arranged in a line with the bodies actually touching. This arrangement helps keep the VCAs at the same temperature, and minimizes temperature dependent gain variations between devices. These VCAs are superior to ganged potentiometers with respect gain linearity and tracking, and when we do see problems, thermal mis-tracking is usually the problem. A benefit of this arrangement is that the layout is made very simple. With the VCAs in-line and all in the same orientation, GND, V+, and EC+ of all of the VCAs can be connected to each other with straight traces on one side of the board. The traces connecting EC- and V- can be on the other side of the board and run between the VCAs. The input and output are at the ends of the package and should not be difficult to route.

This design uses four linear 8-bit DACs to accomplish both overall gain adjust of all six channels and fine trim of the center, rear, and sub-woofer channels. The master volume signal is injected into all of the channels, and center, rear, and sub-woofer controls are superimposed onto the master volume signal.

The exact derivation of the component values used in these summing networks is rather tedious, and not particularly instructive. It is useful, however, to understand the actual functions of these components. In the left and right channel control path (which is buffered by U5A), the master volume signal is injected through R18 and R19, and the actual control signal develops across the parallel combination of R24 and R25:

$$R_{eq\ R24,R25} = \frac{1}{\frac{1}{2.49k\Omega} + \frac{1}{200k\Omega}} = 2.45k\Omega$$

And

$$R_{eq\ R18,R19} = 2 \times 6.81k\Omega = 13.62k\Omega$$

With a DAC reference of 5V, the control port voltage can swing

$$CV_{swing} = \frac{5V \times 2.54k\Omega}{2.45k\Omega + 13.62k\Omega} = 0.762V$$

which, in dB, is

$$CV_{dB} = \frac{0.762}{6.1 \frac{mV}{dB}} = 125\ dB$$

Since this voltage connects to EC-, this swing is from zero dB to -125 dB. R25 serves to offset this swing into the usable range of the VCA. The current through this resistor develops across the parallel combination of R24 and R18 plus R19.

$$R_{eq\ R18,R19,R24} = \frac{1}{\frac{1}{2.49k\Omega} + \frac{1}{13.62k\Omega}} = 2.11k\Omega$$

Since R25 is connected to -15V,

$$CV_{offset} = \frac{15V \times 2.11k\Omega}{2.11k\Omega + 200k\Omega} = 0.157V$$

which, in dB, is

$$CV_{dB\ off} = \frac{0.157}{6.1 \frac{mV}{dB}} = 25\ dB$$

resulting in a gain range of -100 dB to +25 dB.

The fine trim of the center, rear, and sub-woofer channels is accomplished in a similar manner. The center channel trim is injected through R5 and R6, and developed across the parallel combination of R9, R23, and R16 plus R17. R9 serves the same purpose as R25 in the previous discussion, but it must now offset both the master volume signal and the center channel trim, and its value has been reduced accordingly. R23 serves the same purpose as R24 in the discussion above, but since the master volume signal now develops across the parallel combination of R23, a reduced R9, and the series combination of R5 and R6, the value of R23 has been increased to keep the scale factor of the master volume constant.

The equivalent resistances used when calculating the center channel trim sensitivity are:

$$R_{eq\ R9,R23,R16,R17} = \frac{1}{\frac{1}{2.61k\Omega} + \frac{1}{133k\Omega} + \frac{1}{2 \times 6.81k\Omega}} = 2.15k\Omega$$

And

$$R_{eq\ R5,R6} = 2 \times 32.4k\Omega = 64.8k\Omega$$

With a DAC reference of 5V, the control port voltage can swing

$$CV_{swing} = \frac{5V \times 2.15k\Omega}{2.15k\Omega + 64.8k\Omega} = 0.161V$$

which, in dB, is

$$CV_{dB} = \frac{0.762}{6.1 \frac{mV}{dB}} = 26dB$$

Since this voltage connects to EC-, this swing is from zero dB to -26 dB. R9 serves to offset this swing and make the adjustment range symmetrical. The current through this resistor develops across the parallel combination of R23, R5 plus R6, and R16 plus R17.

$$R_{eq\ R6,R7,R16,R17,R23} = \frac{1}{\frac{1}{2.61k\Omega} + \frac{1}{2 \times 32.4k\Omega} + \frac{1}{2 \times 6.81k\Omega}} = 2.11k\Omega$$

Since R23 is connected to -15V,

$$CV_{offset} = \frac{15V \times 2.11k\Omega}{2.11k\Omega + 133k\Omega} = 0.234V$$

which, in dB, is

$$CV_{dB\ off} = \frac{0.234}{6.1 \frac{mV}{dB}} = 38.4dB$$

25 dB are used to offset the master volume as was the case in the left and right channel control path, while the remaining 13.4 dB (approximately one half of 26 dB) offset the center channel signal.

The same control path is used for the rear and sub-woofer channels. C3 through C6 and C9 through C11 are used to limit the slew rate of the control port voltage as well as serving to absorb any glitch energy from the DACs.

This approach satisfies the basic requirements for a 6 channel volume control. Using linear 8-bit DACs to generate a control voltage for the exponential control port of a VCA is a low cost way to control volume over a 125 dB range, and the use of DACs makes remote control easier to implement.

