ANALOG DEVICES

AN-131
APPLICATION NOTE

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A Two-Channel VCA Level (Volume) Control Circuit

The dual-channel voltage-controlled amplifier (VCA) level control circuit describes a useful application of the SSM-2122 dual VCA, SSM-2134 low noise op amp, and PMI's OP-215BP JFET/bipolar op amp. This circuit is very handy when extremely close gain matching of a stereo audio source is desired, such as in ON-AIR and production audio consoles.

The design features a balanced input buffer amplifier and VCA driven by a level shifting amplifier which is controlled by a single 10kΩ linear potentiometer. Additionally, there are fully adjustable and independent gain limit and maximum attenuation trim controls. The VCA circuit has a nominal attenuation range greater than 95dB and has input overdrive protection. The signal-to-noise ratio exceeds 100dB with a gain of 10dB, and headroom of 32dB. The amplitude varies less than ±0.1dB over the frequency range 20Hz to 20kHz. Typical THD and IMD are less than 0.005% and 0.02%, respectively.

As shown, the circuit includes two line-level inputs designed for a −10dBu input signal level. The SSM-2134 (U_2 and U_4) input buffer amplifiers can be connected for balanced or unbalanced inputs with inverting or noninverting inputs. The input loading impedance is 10kΩ unbalanced and 20kΩ balanced. The input buffer amplifier also limits step function slewing voltages from entering following stages. Other input levels can be accommodated by adjusting the feedback resistor R_{F2}. For example: for a nominal input level of 0dBu, R_{F2} should be changed to 3.16kΩ, or for a nominal input level of +10dBu, R_{F2} changed to 1kΩ to provide the optimal current drive to the VCA. C_F should also be changed to 68pF and 220pF, respectively, for both U_2 and U_3.

For other input levels, R_{F2} can be calculated:

$$R_{F2} = 10 \times 10^3 \times \mathrm{EXP}\left(\frac{10 + \mathrm{dBu}}{-20}\right)$$

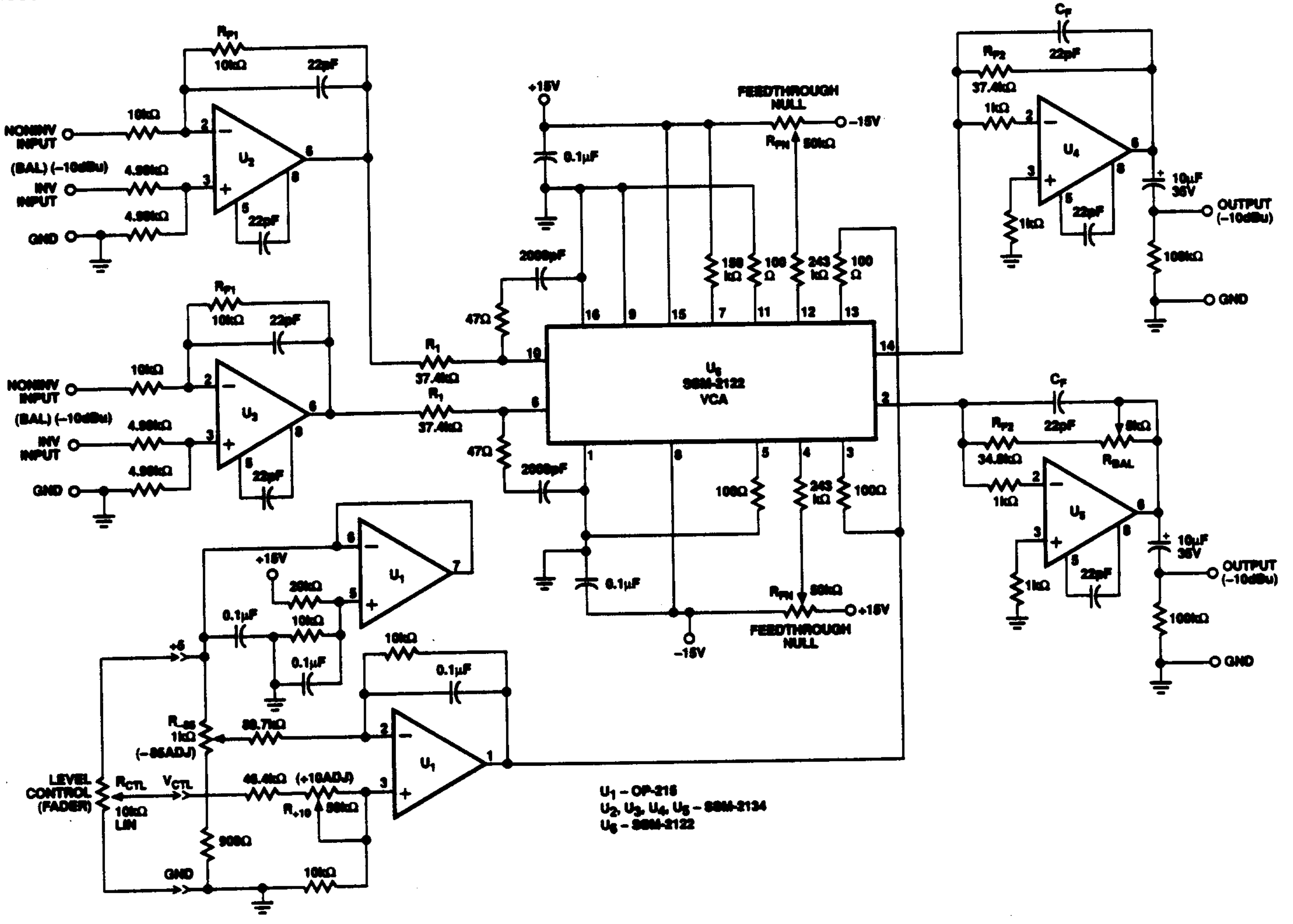

FIGURE 1: *Two-Channel VCA Level Control*

The SSM-2122 has a current-in and current-out structure. The input current is set by resistor R_1 and the virtual ground input of the SSM-2122. Similarly the transimpedance amplifier at the output converts the output current into a voltage. All devices in this design operate on $\pm 15V_{DC}$ power supply rails. The 37.4kΩ VCA input and output resistors optimize its dynamic range and minimize distortion. The SSM-2122 is a monolithic device, so the VCA gains remain uniform over a wide change in ambient temperature.

The SSM-2122 has two gain control ports that have a sensitivity of –6mV/dB. 0.0 volts at the gain control ports will yield 0dB overall gain; +60mV produces +10dB gain and –0.513V corresponds to a –85dB attenuation. The feedthrough trim null controls R_{FN} are not imperative for most applications. However, for very high performance requirements they will reduce attenuation control voltage feedthrough to less than 750µV. To adjust the null trim controls R_{FN}, inject a 100Hz sinewave into the control port through a 1kΩ resistor and a 100µF, 10V capacitor, and set the signal generator to 0.5 V_{RMS}. The control ports of U_6 are pins 3 and13. Adjust the level control R_{CTL} (fader) for 0dB gain, with the signal inputs shorted, then adjust R_{FN} for minimum 100Hz signal at the outputs.

The output amplifier(s) U_4 and U_5 are virtual ground connected current-to-voltage converters. The 37.4kΩ feedback resistors set the circuit voltage gain to 0dB with zero volts applied to the VCA control ports. Variable resistor R_{BAL} is used to balance the signal path gain of the two audio circuits. With the circuit gain set to 0dB and a test signal applied to the inputs, R_{BAL} is adjusted for equal output levels.

The VCA provides 10dB of additional gain at maximum level setting (+60mV at the VCA control ports). The THD is extremely low within the characteristic gain range of +10dB to –20dB.

The VCA control circuit is designed around U_1, the high input impedance OP-215 dual op amp. One half of U_1 is used to develop the 5V reference voltage for the level control element. This is a fail-safe design – with no voltage applied or an open connection at terminal V_{CTL}, the gain will descend to –85dB. Level control trimming is as follows: with the fader control set to minimum (0V), the trim control R_{-85} is adjusted for maximum attenuation of –85dB or $-0.513V_{DC}$ at pin 1 of U_1. Then with the fader set to its maximum (5V), trim control R_{+10} is adjusted for maximum circuit gain of +10dB or +60mV. Since there is no interaction when adjusting R_{+10} for +10dB gain, the setting for R_{-85} will remain unaffected. Other max-attenuation values can be used. R_{-85} has an attenuation range of –45dB(270mV) to –93dB (560mV).

TABLE 1: Circuit Performance Specifications

Input Voltage (Nominal for –10dBu Out)	–10dBu or 245mV_{RMS}
Input Impedance, Unbalanced	10kΩ
Imput Impedance, Balanced	20kΩ
Headroom (Nominal for –10dBu In &Out)	32dB
Feedthrough, Trimmed	<750µV
Gain Control Range (Nominal)	+10dB to –85dB
Gain Control Voltage (+10dB to –85dB)	$5V_{DC}$ to $0V_{DC}$
Frequency Response (20Hz to 20kHz)	±0.1dB
S/N Ratio @ 10dB Gain	100dB
THD + Noise (20Hz to 20kHz, +22dBu)	0.005%
IMD (SMPTE 60Hz & 4kHz, 4:1, +22dBu)	0.02%
Output Voltage Slew Rate	6V/µs
Output Voltage (1kΩ Load)	+22dBu or 10V_{RMS}
Output Impedance	<10Ω