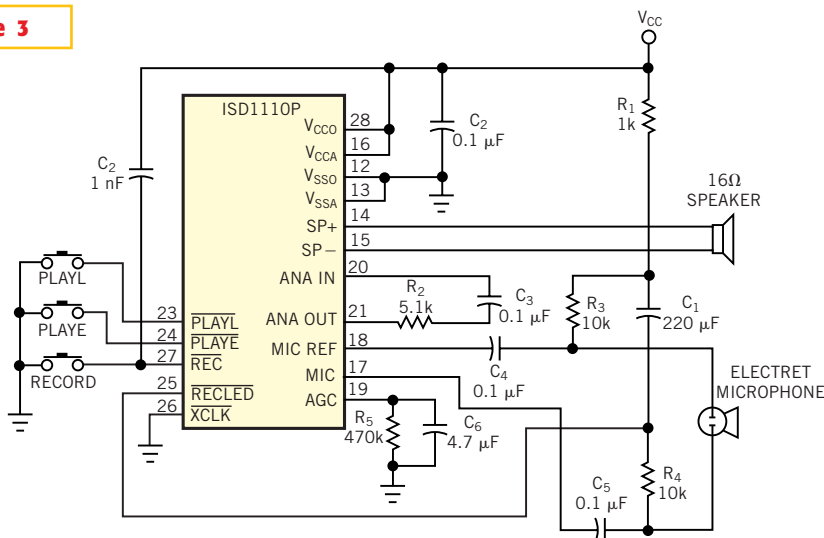


A high-efficiency stepdown converter, IC₁, allows the circuitry to operate from a supply voltage of 5 to 14V.

An optocoupler and associated front-end circuitry monitor the line, sensing when the line receives a high-voltage ringer signal (**Figure 2**). Zener diodes D₁ and D₂ prevent the on-hook voltage from activating the optocoupler. Comparator IC₃ latches LED D₃ on when a call is received, and a pushbutton switch, S₁, clears the comparator. The circuit shown in **Figure 3** records as much as 10 seconds of sound in the chip recorder's proprietary multilevel EEPROM. A switch-mode, Class D audio amplifier, IC₆, maintains high efficiency and delivers adequate power to an 8Ω speaker; even a PC speaker will work.

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Figure 3



Using the EEPROM internal to IC₁ in Figure 1, this circuit records as much as 10 seconds of sound.

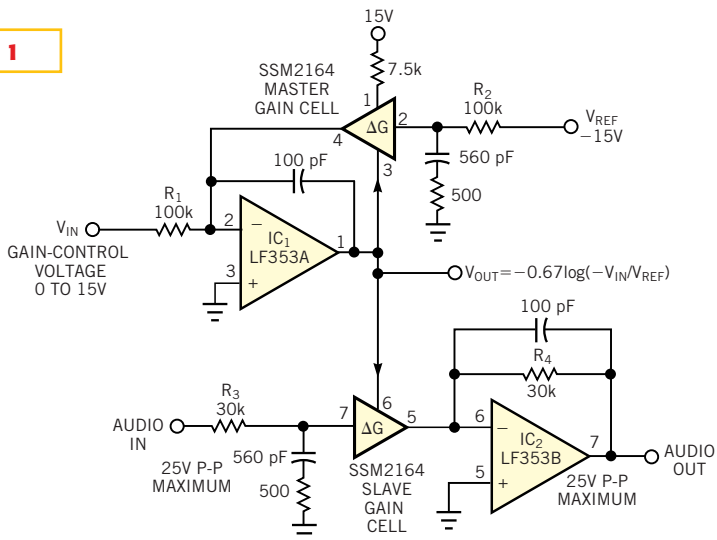
Op amp linearizes attenuator control response

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PROFESSIONAL-AUDIO equipment commonly uses Analog Devices' (www.analog.com)

high-performance, quad-voltage-controlled SSM2164 attenuator. The control response is -30 dB/V , with 0V producing unity gain. Attenuation increases as the applied control voltage increases in the positive direction. The circuit in **Figure 1** extends the range of applications for this versatile chip by providing a simple means of linearizing the control response. The result is an amplifier with gain directly proportional to the control voltage. In addition, the circuit also functions as a simple logarithm generator. You can use a single SSM2164 to make two high-quality, linear voltage-controlled amplifiers using this method. The four gain cells in the SSM2164 are tightly matched, current-in, current-out transconductance multipliers. The control response of each gain cell is: $\text{gain} = 10^{(-V/0.67)}$. The cells are noninverting structures.

Figure 1



You can obtain both a gain-controlled output and a logarithmic output using this configuration.

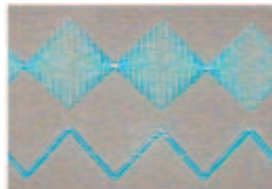
Each voltage-controlled amplifier uses two gain cells. A “master” cell in the feedback loop of an op amp generates a log-

arithmic voltage output in response to a linear voltage input. This log voltage then goes to the control pin of the second

(matching) “slave” cell, which processes the audio signal. Op amp IC₁ maintains its inverting input at virtual ground by servo-controlling the gain of the master SSM2164 cell, which connects to the negative reference voltage. The output of IC₁ is a logarithmic function of the input: $V_{OUT} = -0.67 \log[(-V_{IN} R_2)/(V_{REF} R_1)]$. V_{IN} is the gain-control voltage, and V_{REF} is the negative reference voltage. V_{OUT} then drives the control pin of the slave cell. Substituting the expression for V_{OUT} for V in the expression for gain yields the following: $\text{gain} = (V_{IN} R_2)/(V_{REF} R_1)$, which is the desired linear response.

Op amp IC₂ converts the slave cell’s output current to an audio voltage with a gain of R_4/R_3 . The overall expression for the gain is: $\text{gain} = (V_{IN} R_2 R_4)/(V_{REF} R_1 R_3)$. If $R_1 = R_2$ and $R_3 = R_4$, the expression reduces to: $\text{gain} = V_{IN}/V_{REF}$, and gain (in decibels) = $20 \log(V_{IN}/V_{REF})$. Setting V_{IN} to 15V and V_{REF} to -15V produces unity

Figure 2



The lower trace is a 0 to 3V triangle wave, which you use to modulate the 10-kHz sine wave in the upper trace. Note the linear modulation envelope.

gain with the indicated component values. The gain decreases smoothly to -70 to -80 dB as the control voltage decreases (**Figure 2**). The voltage-controlled amplifier then shuts off completely (attenuation = 100 dB) when the control voltage drops to within a few millivolts of 0V. Negative voltages make the output of IC₁ swing close to the positive rail, but IC₁ promptly comes off the rail when the control voltage returns to the

0 to 15V range. The circuit produces no audible clicks and works well at lower supply voltages, such as $\pm 5V$.

For best performance, IC₁ should be a low-offset, low-input-current unit, and IC₂ should be a high-quality, low-noise audio op amp. However, you can obtain reasonably good performance with inexpensive op amps, such as the TL072 and LF353. The prototype unit achieved a control range of 75 to 80 dB, using an OP-290 for IC₁. The control-voltage feedthrough on the audio output is minimal, varying 10 to 20 mV when you sweep the gain through a 70-dB range. The noise and distortion performance is excellent, because the design uses the gain cells in the standard configuration in the SSM2164 data sheet.

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