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Borrowing Pro Audio Technology To Optimize ADCs

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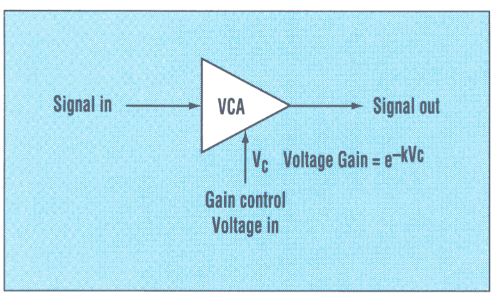
Methods developed for pro audio applications can be applied to many other industries, such as data-acquisition, instrumentation, and industrial process control—wherever a wide dynamic range signal must be accepted by electronics with limited dynamic range. For example, professional audio electronics must accept analog signals in the frequency range of at least 20 Hz to 20 kHz up to a dynamic range of 130 dB, which frequently translates into digital signals with 16-, 20-, or even 24-bit resolution.

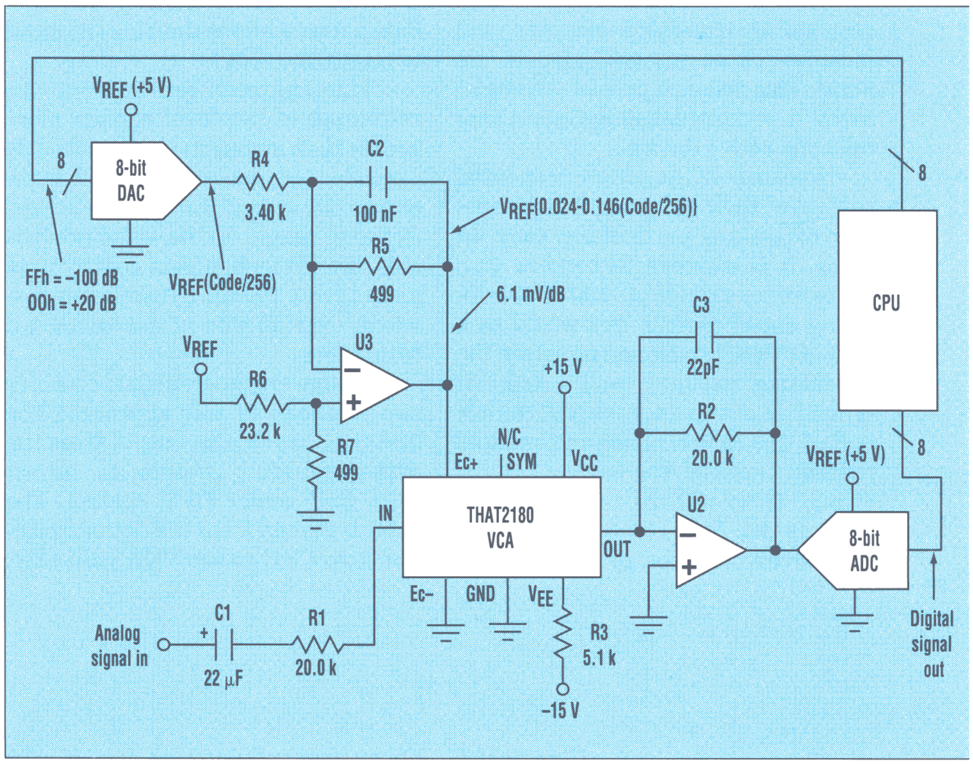
This sort of work has been done for decades with extreme attention to accuracy in professional audio equipment. Recent advances in ICs for pro audio offer more options to instrumentation designers to reduce costs and complexity. But some of these techniques are virtually unknown outside the audio world.

Because most ADCs operate best near full-scale, keeping the input signal near full-range helps make the most out of the data. This also is true of audio "data-acquisition" systems (more commonly known as tape recorders). The first step in borrowing pro audio technology is understanding the techniques used.



1 The VCA is a two-quadrant multiplier with exponential scaling from the control port.

In pro audio, the simplest technique for dealing with wide dynamic range is manual control over level, otherwise known as "gain riding."



2 The voltage-controlled amplifier (VCA) gain is set by a drive from the CPU host to maximize the ADC operation.

Automatic techniques have been developed to aid human operators. Perhaps the most common method is analog-level compression of audio signals. In this process, the signal is passed through a special-purpose IC called a Voltage-Controlled Amplifier (VCA).

The basic VCA is a low-distortion, variable-gain amplifier with an exponentially-responding control port or ports *(Fig. 1)*. An analog voltage at the control port scales the input signal by a factor which is exponential with the applied voltage. In actuality, a VCA is a special case of a two-quadrant multiplier, where the control port has exponential scaling instead of the more familiar linear scale.

Because the signal passes through the VCA during processing, it is critical to preserve signal integrity while accurately controlling level. Typical VCAs from Analog Devices and THAT Corp. (the THAT2150-series) have an audio-band dynamic range of 114 dB (the difference between the noise floor and the maximum signal level), while providing accurate, predictable scaling of analog signal levels. In fact, some newer parts boast a 120-dB dynamic range with particularly low distortion (as low as 0.003% at unity gain, where VCAs usually perform best). All THAT VCAs are current-in, current-out devices that maximize application flexibility and dynamic range.

Various techniques are used to sense signal levels in pro audio. Response weightings range from average to quasi-peak to RMS. Regardless of the weighting, better audio detectors scale their output logarithmically, so their output voltage directly represents dB. When combined with an exponentially-controlled VCA, a log detector offers very precise and predictable control over an extremely wide range of gain and attenuation.

Log-responding audio detectors are available, as are ICs which combine a VCA with a log-responding detector. The THAT4301 utilizes a log-responding true-RMS detector, and includes three general-purpose op amps. This makes it possible to implement a complete compressor using only one active device.

Because VCAs offer exponential control of their gain, achieving a specific dB gain is particularly easy. In audio, it is common to require gain control over a range of –100 to +20 dB. Using linear control, this would be a gain of 0.00001 to 10, and offsets in the processing circuitry would make it difficult to achieve accuracy at the low end of this range. Using exponential control, however, the control voltage change from +20 dB to 0 dB is the same as that from –80 dB to –100 dB.

Here's how the pro audio techniques can be applied. In any data-acquisition system, if an analog signal must be converted to a digital representation, the digital dynamic range is often insufficient to match the analog original. Rather than use a higher-resolution ADC, it is often more cost-effective and efficient to adjust system gain with analog techniques before the ADC. This allows lower-cost converters and narrower data paths, while optimizing the input to match the ADC.

This approach can improve the resolution of low-level signals more simply than increasing a-d resolution. Consider that an additional bit is required for every 6 dB of additional dynamic range. VCAs offer predictable, low-distortion gain control over more than a 100-dB dynamic range—worth over 16 bits of additional a-d resolution.

Design engineers should consider two methods to this approach. The first is to provide an output from the data-acquisition system to adjust VCA gain under CPU control. The DAC is driven from the data-acquisition host CPU to set VCA gain *(Fig. 2)*. Software in the host senses when the ADC is over- or under-range, and adjusts the VCA gain accordingly. If the ADC is linear, each bit represents 6 dB of signal level, so the software mathematics is easy.

The second method would be to use a linear analog compressor in front of the ADC. Since all gain decisions are made in the analog domain, no CPU resources are required. If the compression ratio is finite, there is a one-to-one correspondence between output and input levels, so the data-acquisition system may determine the signal level with precision, provided that the input signals are not changing very quickly.

For dynamic input signals, digitized VCA gain control signals can be used, or a sample-and-hold amplifier can be included in the control loop to freeze the gain during signal acquisition. Designers also can combine the automatic analog system with another input from the host via a DAC to produce additional control voltages. The possibilities are nearly endless. ED