AUTOMATIC GAIN ADJUSTMENT USING D/A CONVERTERS

Circuit Permits Direct Readout of Concentration in Atomic-Absorption Spectrophotometer Measurements

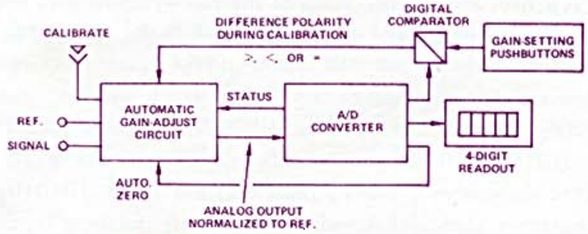
by R. Sachenbacher

In the Instrumentation Laboratory, Inc., Series 351 Atomic-Absorption Spectrophotometers*, the user can preset an arbitrary number, in appropriate physical units, corresponding to the concentration of an element in a reference solution. With the reference (or an equivalent input) applied, the instrument will then automatically calibrate its own gain, after which concentrations of the unknown element in other solutions being tested will be readable directly. The process involves setting an 8-step "coarse" gain range, and a 14-bit (1/16,384 resolution) "fine" gain adjustment. Three AD7520 monolithic multiplying D/A converters† are at the heart of this autocalibration process.

ATOMIC-ABSORPTION SPECTROPHOTOMETRY (AAS)

Atomic-absorption spectrophotometry is an analytical method for determining the concentration of metals in solution. Though used originally for detecting trace concentrations, it has developed into a tool for precision measurement of concentrations in solutions, including very high concentrations of the major components of a material. While superficially similar to flame photometry, AAS is considerably more versatile; normal flame-photometric methods permit the determination of about 10 elements, but AAS can be used successfully in the determination of some 65 different elements.

Droplets of a solution containing the element of interest are sprayed into a flame, which dries and volatilizes them, after which the compounds are broken down into clouds of neutral atoms. A light from a hollow-cathode lamp (the cathode constructed from the element of interest) shines through the flame, and the neutral atoms absorb this light, to a degree depending on the concentration of the material in the solution. Therefore, the concentration can be measured by measuring the absorption of light by the solution. Obtaining an actual measure of the concentration involves calibration against a standard solution. An automatic means is described here.



PROCEDURE

A. DESIRED FULL-SCALE OUTPUT IS SET BY PUSHBUTTONS
B. ZERO IS ADJUSTED AUTOMATICALLY WITH NO INPUT
C. THE REFERENCE IS APPLIED; PUSHING THE CALIBRATE BUTTON CAUSES THE GAIN TO BE STEPPED UNTIL THE A/D CONVERTER READS THE VALUE SET IN THE PUSHBUTTONS. CALIBRATION OCCURS IN TWO STAGES – COARSE, THEN FINE.
D. APPLIED INPUT SIGNALS WILL BE PROPERLY SCALED TO READ OUT ACCURATELY IN THEIR TRUE PROPORTION TO THE REFERENCE SETTING.

Figure 1. Block diagram of automatic gain-adjusting system.

THE BASIC SCHEME (Figure 1)

The system consists of a 4-digit BCD A/D converter, which reads out the input voltage, multiplied by the gain of the automatic gain-adjust circuit; a set of 4-digit BCD pushbuttons; a digital comparator, which compares the converter's output with the pushbuttons' state; and a logic-operated step-by-step gain adjustment in the *calibrate* mode. It adjusts the gain, in the *reference* condition, until the A/D converter output (hence its analog input) agrees with the pushbutton setting, which could be the numerical fractional concentration corresponding to the reference input. Once calibrated, the output reading will read out directly the actual concentration of an unknown signal input.

HOW IT WORKS (Figure 2)

With a numerical switch setting and a reference voltage applied (by the "scale expand" switch), the *calibrate* switch sets the AD7520 DAC (1) in the feedback path of A1 for full feedback (minimum gain), and the two AD7520's in the forward path of A2 (2 & 3) for minimum attenuation (maximum gain, about 1.5).

The ADC performs a conversion. Its BCD output is compared with the pushbutton setting (B). If A > B, the coarse gain is sufficient, and the system goes on to adjust the fine gain. If A < B, the coarse gain is insufficient; the logic decrements the input to DAC (1) by 1 bit (increasing A1's gain), a conversion is performed, the coarse test is repeated, etc., and the gain of A1 continues to be increased until A > B, following which the coarse gain is latched, and the fine-gain successive-approximation register is enabled.

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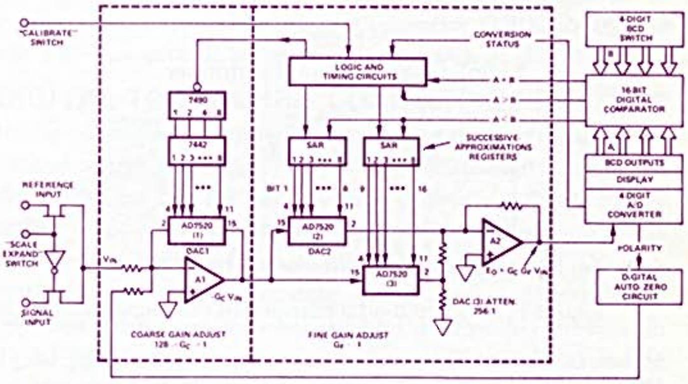

Figure 2. Functional schematic diagram of the auto-calibration circuit employing AD7520's to set gains

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*Manufactured by Instrumentation Laboratory, Inc., Jonspin Rd., Wilmington, MA 01887

†Use the reply card to request AD7520 data.

Potpourri

THE AD562 IC DAC WITH ARBITRARY RESISTORS

The AD562*, as faithful readers (and users) would know, is a high-performance D/A converter. A current-input, current-output device, it includes – for convenience – an input resistor scaled to produce the proper value of current with a 10V reference, and a set of feedback "application" resistors in the output circuit to provide a set of appropriately-scaled output voltages from the external op amp, depending on the mode of operation chosen. Because the input resistor and the application resistors track one another, and the current gain of the DAC itself is quite independent of temperature, the gain tempco overall is quite low.

The need often arises for a *different* input-output relationship, for example, different output ranges, a different value of voltage reference, an added offset, or perhaps, even, a *current* input, as in a multiplying DAC application. The important factor to recognize is that while the *tracking* of the input and the output resistors is excellent, their *absolute values* have somewhat greater drift with temperature. For best results, then, in such cases, the built-in application resistors should be ignored, and externally-connected precision resistors or matched thin-film sets should be used as the input and the output-summing-points, as required by the application. ▶▶▶

*Use the reply card to request AD562 data.

AGC IN ATOMIC ABSORPTION *(continued from p.17)*

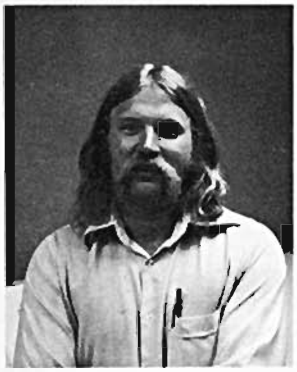
When it turns off the first bit at DAC (2), the gain is halved, a conversion is performed, and a comparison is made by the digital comparator. If $A < B$, the correction was too great, and the bit is turned on again. If $A > B$, the bit is left off. Then the second bit is turned off, another conversion, comparison, and decision are made, and the process is repeated 15 more times, or until the digital comparator indicates $A = B$. At this point, the gain of the AGC is exactly that needed to scale the reference input to the desired reading. When the "scale-expand" switch is switched to "signal", the signal input will suffer the same gain, hence will provide a properly-scaled output reading.

Note that DAC's 2 & 3 form a 16-bit DAC; if their relative scaling is correct, and if each DAC is individually monotonic for at least 7 bits, any necessary value of gain for $A = B$ will be attained. The actual overall scaling is unimportant, since the gain accuracy is determined by that of the A/D converter; the AD7520's will be adjusted to produce any needed value of gain. (Any offsets will have been eliminated by an autozero circuit before the calibration process starts.)

The AD7520's which act essentially as switched resistive attenuators having high analog linearity and symmetrical bipolar transmission, are ideal in this application, because the input to the DAC can be of either polarity or zero without affecting the programmed gain.

This technique should have interesting implications for automatic calibration and measurement in other fields besides atomic absorption spectrophotometry. ▶▶▶

Fred Pouliot (p.10) is Marketing Manager, Analog Modules, at ADI. He has a BSEE from Northeastern University and has done graduate work, while teaching undergraduate courses. He is a member of both TBΠ and HKN. After several years of designing analog circuitry, he became a marketing specialist, then Marketing Manager in the Modular Instrumentation Division.



Rudolf Sachenbacher (p.17), a native of Lenggres (Bavaria), was educated at RCA Institute in New York. Then, at RCA Aerospace, he designed test fixtures for missile-system testing, including an Apollo transponder. He has been an Engineer at Instrumentation Laboratory, Inc., for the last 7 years with project design responsibilities for many of their products.

Dennis McDonnell (p.18) is a consultant to Analog U.K. Previously, he was with Vickers Research, Ltd., after heading the Vickers electronic GW group. He has published papers on Z-transform theory and generalized Wiener-Hopf filtering equations. The founder of Fenlow Electronics, Ltd., he has designed instruments such as DVM's.

Walter G. Jung (p. 20) is a design engineer at AAI Corporation in Maryland. Specializing in analog circuitry, he is involved with op amps, A/D and D/A converters, and other circuitry used in signal-processing, test-measurement, and control. A prolific writer, he has recently authored 3 books on op amps (one of which is reviewed on page 23).

DIGITAL ELECTRONICS COURSE USES SERDEX

We have received an announcement of a short course in "Digital Electronics for Automation and Instrumentation", presented through the cooperation of Virginia Polytechnic Institute and State University at Blacksburg, Virginia, by David G. Larsen, Dr. Peter R. Rony, and Jonathan A. Titus. The 5-day laboratory/lecture course provides hands-on experience with the wiring of digital circuits of modest complexity involving TTL IC's. Mr. Larsen informs us (for the benefit of those readers interested in SERDEX) that the last two days of the course are spent on the use of Asynchronous Serial for interfacing, perhaps the only course that teaches about SERDEX in any formal manner†. Those interested should get in touch with Mr. Larsen at (703)-951-6478 or Dr. Rony at (703)-951-6756. ▶▶▶

†If other such courses exist, we would relish hearing about them. For further information about SERDEX, see †, page 6.