10-BIT BINARY TO 3-DIGIT BCD CONVERSION USING THE ADC-10Z AS A 3-DIGIT BCD CONVERTER

by Jim Fishbeck

Three-digit BCD* analog-to-digital conversion (1000 codes) at moderate-to-high speeds is usually performed by a 12-bit binary successive-approximations converter with rescaled interquad coefficients, somewhat less-rigorous testing, and wanton wastage of 3096 perfectly-good (possibly) codes.

It can also be performed by a 10-bit binary A/D converter (1024 codes) and binary-to-BCD decoding. Such decoding used to be rather arduous, involving counters and great expenditure of time. However, with the advent of such low-cost devices as the SN74185A 5-bit binary-to-BCD converter, the decoding by the A/D-converter user becomes quite practical, with often-negligible time delay. There are several good reasons for using 10-bit converters:

1. If the data is to be processed, but BCD is desired for visual monitoring from time to time (via numeric readouts in one or more locations), binary A/D conversion, followed by binary/BCD, will provide both the binary input needed by the processor and the BCD for the readout. If the data is acquired and converted to binary at some distance from the readout and processor, only 10 data lines are needed, instead of 12.

2. 10-bit conversion is, in general, less costly than 12-bit conversion, since less board area and fewer connectors, flip-flops, switches, and resistors are used. (However, it is only fair to note that the requirements on 12-bit conversion for BCD coding are not stringent, since the resolution is only 1:1000 instead of 1:4096; also, the cost of additional logic for binary/BCD conversion is low, but not negligible.)

3. If speed is important, a successive-approximations converter will probably be used. It will require less time to convert 10 bits than is needed for 12 bits.

4. If data is transmitted serially, two fewer bits are required for each 10-bit binary word than for the corresponding BCD word.

5. The 1024 binary codes are a close (but conservative) match to the 1000 codes inherent in 3 BCD digits.

THE SCHEME

Figure 1 shows the connections for economical analog to BCD conversion, via 10-bit binary, using five SN74185A binary/BCD converters. The logic converter functions as a read-only memory, directly decoding each 10-bit binary number into its 3 BCD equivalent. There are no counting schemes involved, which means that the logic converter's speed is limited only by the propagation delay through 4 IC's, about 100ns in the worst case. When the ADC-10Z† is appropriately calibrated, a BCD display connected to the BCD outputs will read directly in volts for an analog input range of 0 to +10V.

IMPLEMENTATION

When using the ADC-10Z as a BCD-output converter, the 10-volt input range (pin 5) is used. However, since nominal full-scale is calibrated for 1024 codes, the gain must be modified slightly by connecting a 75kΩ resistor between pins 15 and 23 (direct input and ground). The unit is externally jumpered for *unipolar* operation (pin 16 to pin 19). Operation in this connection does not adversely affect scale factor or coding for ADC-10Z's supplied with the optional input buffer follower.

Zeroing and scale-factor (gain) adjustment are performed in the same way as for binary, except that the input test voltage for zero adjustment is 5.00mV (transition from 00...00 to 00...01), and the gain is adjusted for the BCD transition from 9.98 to 9.99 (1001 1001 1000 to 1001 1001 1001) at 9.985V.

OVERVOLTAGE

If the analog input is 10.00 volts or more, the most-significant digit will have an "illegal" BCD code of 1010 (800 + 200). As shown in Figure 1, a simple *and* gate will detect this state and furnish a "1" to indicate out-of-scale operation.

OUTPUT LOADING AND TIMING

Maximum output load is 7 TTL unit-loads for each bit, except for the LSB (pin 52 of the ADC-10Z), which is limited to 4 unit-loads. Because successive-approximations is used, and the LSB (the last bit to be converted) is not involved in the binary/BCD conversion, all the delay through the digital conversion occurs before the ADC-10Z finishes the A/D conversion. Hence, the BCD output is valid on the "1" to "0" "end-conversion" transition of the ADC-10Z's status output, allowing clocking of data on that edge, if desired.

The scheme described here can be extended to develop "3 ¾-digit" BCD from 12-bit binary, using 4000 of the 4096 available codes. In the reverse direction, SN74184 BCD-to-binary devices may be used, e.g., to permit 3 ¾ BCD-to-analog conversion with a 12-bit binary D/A converter. ▶▶▶

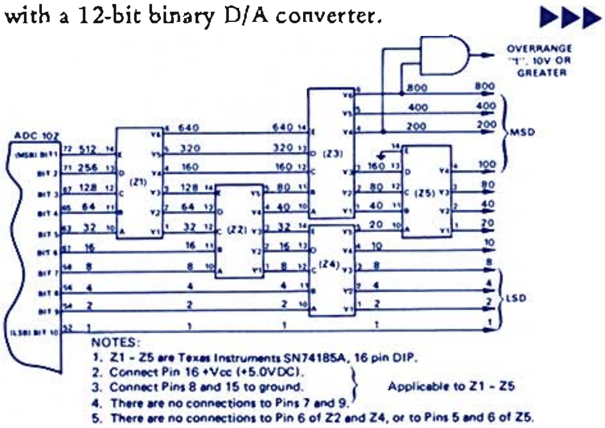

Figure 1. 10 Bit Binary-to-BCD Converter.

THE AUTHOR

Jim Fishbeck is Converter Product Marketing Specialist at Analog Devices. Armed with degrees in both E.E. and Marketing from Michigan State University, he has designed flight control equipment for jet aircraft at Collins Radio Company, and marketed electromechanical control components at Texas Instruments.

*Binary-coded decimal (e.g., 396 → 0011 1001 0110)
†See page 7, this issue.