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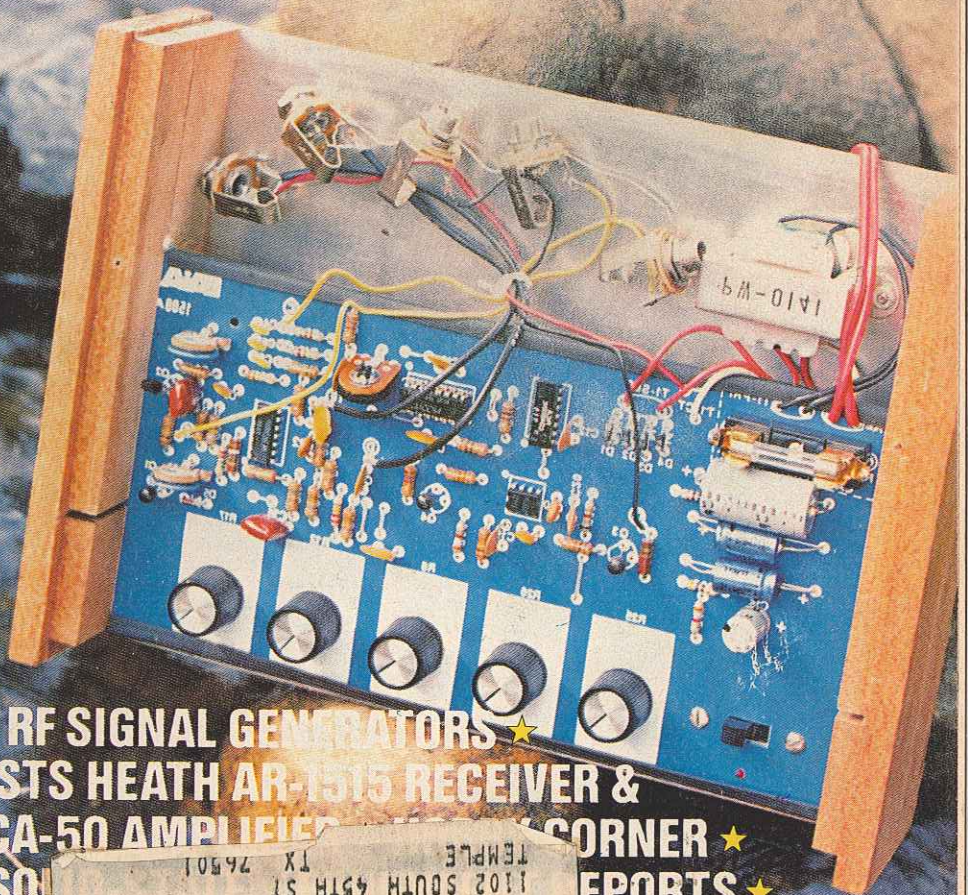

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Interfacing a D/A converter. CHRISTOPHER A. TITUS, DAVID G. LARSEN, PETER R. RONY* and JONATHAN A. TITUS

AN ANALOG-TO-DIGITAL CONVERTER (A/D converter) is an electronic device that converts analog signals to digital signals. Typical commercial converters are based upon successive approximation, dual-slope integration, staircase-ramp conversion or voltage-to-frequency conversion.[1] An A/D converter is generally used to convert the output from an analog transducer or instrument into digital form suitable for direct observation on a digital display or as input into a computer. All digital panel meters and multimeters contain built-in A/D converters. Modern A/D converters provide standard TTL outputs that can be coded in binary, binary coded decimal (BCD) or perhaps other less frequently used codes.

To demonstrate how an A/D converter can be interfaced to an 8080-based microcomputer, consider the generalized 10-bit A/D module shown in Fig. 1. In addition to the 10-bit output and analog input pins, the module also contains a START input and a DONE/$\overline{\text{BUSY}}$ output. It is obviously not possible to simultaneously transfer all 10 bits from the A/D converter into an 8-bit microcomputer. For the 10-bit converter, data is transferred by placing bits D0 through D7 (the 8 least significant bits) in the first input byte and the remaining two bits, D8 and D9 (the 2 most significant bits), in the second byte.

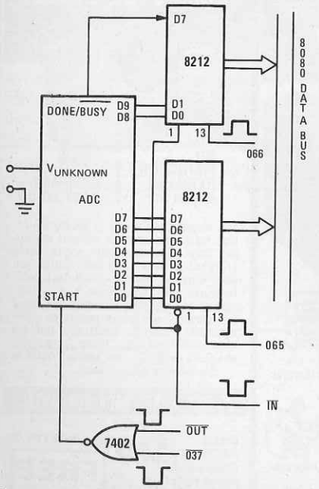

Fig. 1—ANALOG-TO-DIGITAL CONVERTER (ADC) interfaced to an 8080 microcomputer with a pair of 8212 buffer chips.

*This article is reprinted courtesy American Laboratories. Dr. Rony, Department of Chemical Engineering, and Mr. Larsen, Department of Chemistry, are with the Virginia Polytechnic Institute & State University. Mr. Titus is president of Tychon, Inc.

To gate data onto the data bus and into the 8080, 8212 8-bit 3-state buffer chips are used between the A/D outputs and the 8080 data bus. Gating is required so that the 3-state buffers are enabled only when the 8080 requests data. In the case of the 8212 buffer, the gate is incorporated within the IC, so all that is required is a negative $\overline{\text{IN}}$ control signal, and positive 065 and 066 decoded pulses derived from the address bus decoding logic.

The remaining control signals include a START pulse to reset the A/D converter and start internal conversion, and a DONE/$\overline{\text{BUSY}}$ output flag that indicates a conversion has taken place and the 10-bit digital output is ready. These important control signals synchronize the operation of the conversion. Analog-to-digital converters do not continuously convert voltages into digital outputs—the conversions take a finite period of time. The A/D converter must be pulsed or strobed to start each conversion, and a 10-bit binary value cannot be output by the converter immediately after the strobe pulse is applied. In Fig. 1, a 21-μs conversion time was required. We used a successive approximation technique that converges on the unknown voltage by making successively smaller tests and comparing the results of such tests to the unknown voltage.

The DONE/$\overline{\text{BUSY}}$ flag, which indicates the converter is either done (logic 1) or busy (logic 0), is input into the microcomputer as a single bit; since there are 6 unused bits at input port 066, bit D7 is assigned to the flag. The START pulse to initiate a conversion must be short and positive. It can be obtained by gating the control signal $\overline{\text{OUT}}$ with a negative device address pulse, $\overline{037}$, using a 7402 2-input NOR gate.

A typical software subroutine used to perform a single conversion is shown in Table 1.[3] The 10-bit binary result is left in the B and C registers of the 8080, with the least significant 8 bits in register C and the most significant 2 bits in register B in positions D0 and D1. The microcomputer spends time in the test loop as it checks and rechecks the flat bit during conversion. Our A/D conversion took only 21 microseconds, so the computer is in the loop for a short time. For other types of converters, the conversion time may take much longer, perhaps milliseconds or even hundreds of milliseconds for a digital multimeter. In such a case, the microcomputer would spend considerable time waiting for the A/D converter to "flag" the 8080, indicating that the conversion was complete.

An alternative approach is to use the DONE/$\overline{\text{BUSY}}$ flag as an interrupt input to the 8080. After initiating a conversion by outputting a START pulse, the microcomputer proceeds to some other software task during conversion. When the conversion is complete, the A/D converter interrupts the computer and points it to the A/D converter's service software, which, in this case, is located at 000 070. (A software example is provided in Table 2.[3]) In this example, the A/D converter subroutine is used only to start conversion. The subroutine at 000 070 is called by the interrupt with the aid of a jammed RST 7 instruction byte. The A/D converter interrupts the 8080 only when it has finished a conversion. The software starting at 000 070 inputs the 10 data bits and stores them in a data file. As we have stated previously,[4] interrupts should be used with caution. **R-E**

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                    /       TABLE 1   TYPICAL ADC INPUT ROUTINE FOR A
                    /       10 BIT ANALOG-TO-DIGITAL CONVERTER

                            *100 000
100 000 365  ADC,   PUSHPSW /SAVE REGISTER A & FLAGS
100 001 323         OUT     /STROBE THE ADC TO START A CONVERSION
100 002 037         037
100 003 333  TEST,  IN      /INPUT STATUS BIT AND 2 MSB'S
100 004 066         066
100 005 306         ADI     /ADD 1 TO THE FLAG BIT TO CAUSE AN
100 006 200         200     /TO CAUSE A CARRY IF IT IS SET
100 007 322         JNC     /NO OVERFLOW, CHECK IT AGAIN
100 010 003         TEST
100 011 100         0
100 012 107         MOVBA   /OVERFLOW, FLAG=1, SO SAVE MSB'S
100 013 333         IN      /INPUT THE 8 LSB'S
100 014 065         065
100 015 117         MOVCA   /STORE THEM IN REGISTER C
100 016 361         POPPSW  /RESTORE REGISTER A & FLAGS
100 017 311         RET     RETURN TO MAIN PROGRAM
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TYCHON EDITOR-ASSEMBLER V-2                          PAGE 01-001

                    /       TABLE 2   TYPICAL ADC SUBROUTINE FOR AN
                    /       INTERRUPT TYPE CONVERTER INTERFACE.  THIS
                    /       ASSUMES THE CONVERTER WILL INTERRUPT WITH
                    /       A RST7 INSTRUCTION VECTORING TO 000 070.

                            *100 000
100 000 373  ADC,   EI      /ENABLE THE 8080'S INTERRUPT
100 001 323         OUT     /START A CONVERSION
100 002 037         037
100 003 311         RET     /RETURN TO MAIN PROGRAM

                    /       THIS IS THE ADC'S INTERRUPT SERVICE SOFTWARE

                            *000 070
000 070 365  ADCSVC, PUSHPSW /SAVE REGISTER A & FLAGS
000 071 345         PUSHH   /SAVE REGISTERS H & L
000 072 052         LHLD    /GET MEMORY POINTERS INTO H & L
000 073 000         POINT   /SO THE DATA MAY BE STORED
000 074 120         0
000 075 333         IN      /INPUT 8 LSB'S
000 076 065         065
000 077 167         MOVMA   /STORE THEM IN MEMORY
000 100 043         INXH    /INCREMENT MEMORY POINTER
000 101 333         IN      /INPUT 2 MSB'S
000 102 066         066
000 103 167         MOVMA   /STORE THEM, TOO
000 104 043         INXH    /INCREMENT MEMORY POINTER AGAIN
000 105 042         SHLD    /SAVE THE STORAGE AREA ADDRESS
000 106 000         POINT
000 107 120         0
000 110 341         POPH    /RESTORE REGISTERS H & L
000 111 361         POPPSW  /RESTORE REGISTER A & FLAGS
000 112 311         RET     /RETURN TO MAIN PROGRAM

                            *120 000
120 000 000  POINT, 000     /THIS IS WHERE THE ADDRESS OF THE ADC
120 001 020         020     /STORAGE AREA IS KEPT.  IN THIS PROGRAM
                            /THE STORAGE AREA STARTS AT
                            /ADDRESS 020 000.  YOU COULD PLACE YOUR
                            /OWN POINTER ADDRESS HERE, BUT THESE
                            /TWO LOCATIONS MUST BE IN R/W MEMORY
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Reference

1. *Analog-Digital Conversion Handbook,* Analog Devices, Inc., Norwood, MA 02062. Copies may be still available for $3.95.
2. Rony, P.R., Larsen, D.G., Titus, C., and Titus, J.A., "Microcomputer Interfacing: Interfacing a 10-bit DAC," *Amer. Lab. 9* (1977).
3. The assembly language format shown is that of the resident editor/assembler developed by Tychon, Inc., for 8080 systems.
4. Titus, J. A., Larsen, D. G., and Rony, P. R., "Microcomputer Interfacing: Microcomputer interrupts," *Amer. Lab 8* (1976).

Second European CB Congress establishes a federation

CB'ers from several European countries, meeting in Geneva for a two-day conference, have set up the European CB Federation, with a president, Dirk Dewaele, from Belgium, vice president, Thierry De Pasquier, from Switzerland, and general secretary, Enrico Campagnoli, from Italy.

The new organization was constituted for the liberalization and regulation of CB in Europe. While "private radio" is permitted in some European countries, it is not in others, and some CB'ers have been operating illegally since 1970 on the 27-MHz band set aside by international convention for private radio.

At its final session the Congress voted a common proposal on CB regulation in Europe, and on the establishment of an Emergency Radio Service, in which members will monitor channel 1 for marine and channel 9 for terrestrial emergencies.

The proposals are to be forwarded to government administrations and particularly to the International Telecommunications Union (ITU) with the object of a renewal of the Geneva Convention in 1979 that will allow an adequate existence for CB in Europe.