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Interfacing a digital multimeter

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THIS MONTH, we shall discuss the interfacing of an 8080-based microcomputer to a very versatile laboratory instrument, the Keithley model 160B digital multimeter with model 1602B digital output. After a year's use, we have found this multimeter to be an excellent example of what manufacturers can do to facilitate the interfacing of their instruments.

The model 160B is a general-purpose $3\frac{1}{2}$-digit multimeter that can function as a de voltmeter, dc ammeter, or ohmmeter. A total of 26 different ranges exist for the multimeter in its three modes of operation. The lowest range scales provide maximum readings of 1.999 mv, 19.99 nA, and 1.999 Ω. The 1.999 mv scale has an accuracy of ±0.1% of reading ±l digit. Thus, a display reading of 1.000 mv will have an uncertainty of ±0.002 mv, or 2 J.1v. The highest possible readings associated with the three different modes of operation are 1200 v, 1999 mA, and 1999 MΩ, with the megohm reading being accurate to only ±30%. This multimeter can be viewed as the digital complement of the ubiquitous multirange chart-paper recorder. The multimeter is basically a sophisticated analog-to-digital converter (ADC) that can handle most laboratory requirements for digital data acquisition provided that the data acquisition rate is no greater than one data point per second.* Switching between the 26 different ranges is performed manually. We would expect that, in the future, such switching will be performed by a built-in microprocessor operating under the control of an external computer.

The basic concern of this month's column is the full interface circuit, shown in *Figure* 1, between the model 160B and a small development 808o-based microcomputer. The two 0 R gates and the SN74154 decoder generate the three different *device select pulses'* required to input data from the multimeter to the 8080 microcomputer. Note the IN input at pin 18 of the SN74154 decoder. This interface circuit takes advantage of the fact that all outputs from the model 1602B digital output board are *open collector* and can be *bussed* together as is done in Figure 1. The noun, *bus,* can be defined as follows' : 'A path over which digital information is transferred, from any of several sources to any of several destinations. Only one transfer of information can take place at anyone time. While such transfer is taking place, all other sources that are tied to the bus must be disabled.

Notice how pins 16, 12, and 10 on the model 160B are connected to the same input, D7, to the 8080 microcomputer. These three pins are said to be bussed together. Pins 35, 31, and 28 are bussed together to input D6; pins 17, 13, and 9 are bussed together to input D5; pins 36, 32, and 27 to input D4; and so on. The eight inputs to the 8080, DO through D7, comprise an eight-bit data bus over which information passes, one group at a time, from the multimeter to the 8080 microcomputer.

In the definition of a bus, it is indicated that only one transfer of information can take place at any one time. In Figure 1, this transfer is accomplished with the aid of the three sets of two strobe inputs. When a logic 0 is applied at strobes 1 and 2, the BCD codes corresponding to the 10° and 10' digits are transferred to the accumulator of the 8080. The strobe signal for strobe inputs 1 and 2 is provided as a negative device select pulse from channelS 0 f the SN74154 decoder chip. In a similar manner, strobes 3 and 4 and also 5 and 6 permit the acquisition by the microcomputer of the remaining output data from the multimeter. In summary, three device select pulses permit the strobing of 20 output bits of data from the multimeter to the microcomputer over a set of eight data bus lines labeled DO through D7.

A simple program that accomplishes the transfer of 20 bits of data over the eight-bit data bus from the multimeter to the microcomputer is provided in *Table 1.* The entire data acquisition and movement of data to registers C, D, and E occurs in 21 *usee,* a time that is fast when compared to the rate

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*The settling time of the multimeter is about 2 sec. Although five data conversions can be made per second, it may take about 1 sec for the precision of a typical data point to reach 0.1% or 0.2%.

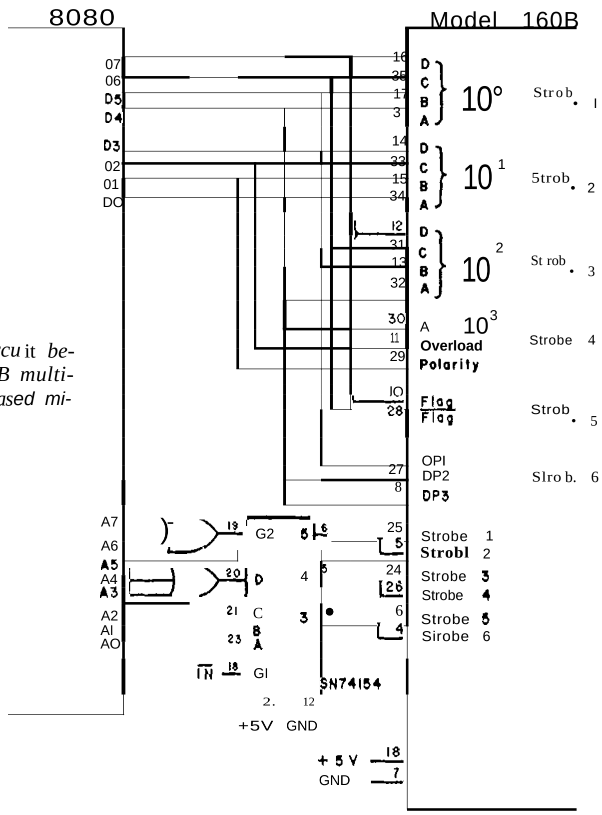

Figure 1 *Interface circu*it *between the model 160B multimeter and an BOBD-based microcompu ter.*

of five conversions per second by the multimeter. Clearly, considerable time is still available to the microcomputer to manipulate the acquired data before new data are input to the accumulator.

Some additional explanation of Figure I is appropriate. Not shown in the figure are eight 4700-Ω resistors that are the required *pull-up resistors* for the eight open collector bus lines. One pull-up resistor is required for each of the eight data bus inputs. One end of the resistor is tied to +5 v, and the other end to the bus line. These resistors are not shown in the diagram because they can be added to the circuit board within the multimeter. The 8080 data bus normally employs an alternative bussing technique called *three-state bussing.* The interface circuit shown in Figure I represents a marriage of the two bussing techniques, open collector and three-state. The 4700-Ω resistors do add a load to the data bus, but this does not prevent other devices from being tied to the bus, provided that each bus connection in the other devices can sink, in the logic 0 state, the additional l-mA current produced by the 4700-Ω pull-up resistor.

The multimeter discussed here shows how interfacing has been facilitated by providing open collector outputs for all 20 output pins on the model 1602B digital output board. The added cost was small when compared to the added value of the instrument. We expect future instruments to be microcomputer-oriented in the sense that data bus outputs will be provided to permit the direct interfacing of the instruments to microcomputers via simple wire interconnections. We hope that these columns encourage manufacturers to provide minicomputer- and microcomputer-oriented digital outputs, and also to document such outputs.

Table 1

Microcomputer program for transfer of data

LO memory address	Instruction byte	Mnemonic	Clock cycles	Description
000	333	IN 5	10	Generate device select pulse that strobes the 10° and 10' digits into the accumulator
001	005			Device code for strobe inputs 1 and 2
002	117	MOV C,A	4	Move accumulator contents to register C
003	333	IN 4	10	Generate device select pulse that strobes the 10^2 digit, the 10^3 bit, and the overload and polarity outputs into the accumulator
004	004			Device code for strobe inputs 3 and 4
005	127	Mav D,A	4	Move accumulator contents to register D
006	333	IN 3	10	Generate device select, pulse that strobes the Flag, Flag, DP1, DP2, and DP3 outputs into the accumulator
007	003			Device code for strobe inputs 5 and 6
010	137	MaV E,A	4	Move accumulator contents to register E

At this point, 20 data bits are stored in registers C, D, and E. The microcomputer can now take this information and manipulate it in different ways. With the aid of the BCD digits and DP1, DP2, and DP3, it can determine the magnitude of the input decimal number. With the aid of the polarity input, the sign of the decimal number can be determined.

References

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