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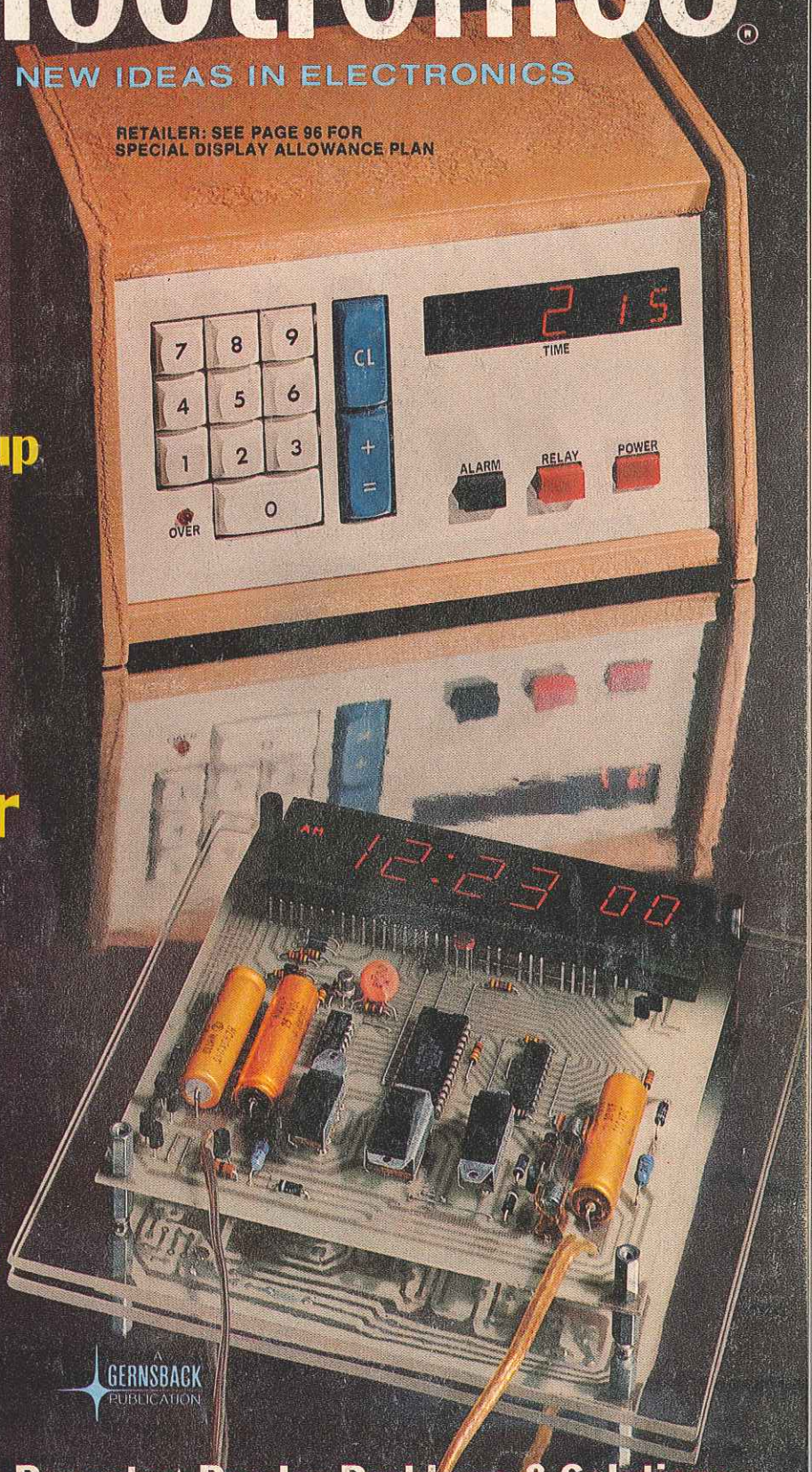

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KOMPUTER KORNER

DAVID LARSEN, PETER RONY, and JOHN TITUS*

THIS MONTH, WE SHALL DISCUSS THE INterfacing of an 8080-based microcomputer to a very versatile laboratory instrument, the Keithley model 160B digital multimeter and model 1602B digital output. We purchased this multimeter one year ago and found it to be an excellent example of what manufacturers can do to facilitate the interfacing of their instruments.

The Keithley model 160B is a general-purpose 3½-digit multimeter than can function as a DC voltmeter, DC ammeter, or ohmmeter. A total of twenty-six 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 ± 1 digit. Thus, a display reading of 1.000 mV will have an uncertainty of ± 0.002 mV, or 2 μV. The highest possible readings associated with the three different ranges are 1200 V, 1999 mA and 1999 megohms, with the megohm reading being accurate to only ± 30%.

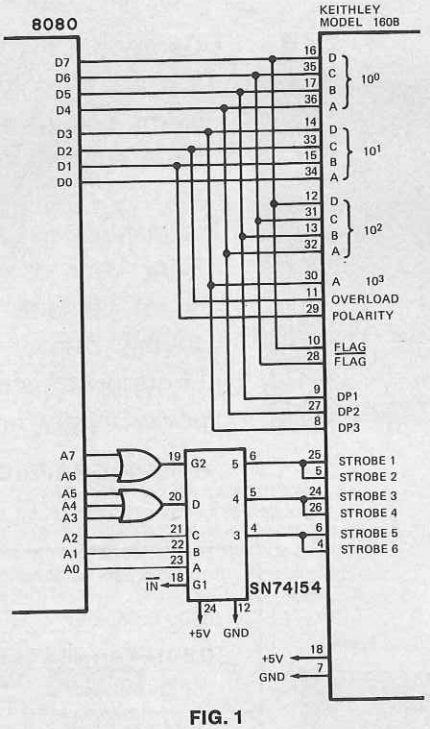

FIG. 1

The model 160B multimeter is basically a sophisticated analog-to-digital converter (ADC) that can handle most laboratory requirements for digital data acquisition provided that the rate is no greater than one measurement per second. Switching between the twenty-six 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 interface circuit between the Keithley model 160B and a small 8080-based microcomputer is shown in Fig. 1. The two OR gates and the SN74154 decoder generate three different device-select pulses that are required to input data from the Keithley meter to the 8080 microcomputer. Note the $\overline{IN}$ signal at pin 18 of the SN74154 decoder. This interface circuit takes advantage of the fact that the outputs from the model 1602B digital-output board are open collector and can be bussed together as is shown in Figure 1. Notice how pins 16, 12, and 10 on the model 160B are connected to the same 8080 microcomputer input, D7. 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; and so on. The eight inputs to the 8080, D0 through D7, comprise an eight-bit data bus over which information passes, one group at a time, from the Keithley multimeter to the 8080 microcomputer.

Only one transfer of information can take place at any one time. In Fig. 1, this transfer is accomplished with the aid of the three sets of strobe inputs. When a logic 0 is applied at strobes 1 and 2, the BCD codes corresponding to the 10^0 and 10^1 digits are transferred to the accumulator of the 8080. Similarly, strobes 3 and 4 and also strobes 5 and 6 permit the acquisition by the microcomputer of the remaining output data from the Keithley multimeter. Therefore, three device-select pulses permit the strobing of 20-bits of data from the multimeter to the microcomputer over a set of eight data bus-lines D0 through D7.

A simple program that accomplishes the data transfer 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 21μs, a time that is fast when compared to the rate 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 is input into the accumulator.

Not shown in Fig. 1 are eight 4700-ohm resistors that are the required pull-up re-

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*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.

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sistors 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 volts, 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 Keithley multimeter. The 8080 data bus normally employs an alternative bussing technique called three-state bussing. The interface circuit shown in Fig. 1 is actually the combination of two bussing-techniques, open collector and three-state. The 4700-ohm 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 1 mA current produced by the 4700-ohm pull-up resistor.

At the beginning of this column, we stated that the Keithley multimeter is an example of what manufacturers can do to facilitate the interfacing of their instruments. In this case, what Keithley did was to provide open-collector outputs for all twenty 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 as well as Keithley has done with the model 160B. **R-E**

TABLE 1—DATA ACQUISITION PROGRAM

LO memory address	Instruction byte	Mnemonic	Clock cycles	Description
000	333	IN 5	10	Generate device select pulse that strobes the 10^0 and 10^1 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	Generates 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	MOV D,A	4	Move accumulator contents to register D
006	333	IN 3	10	Generate device se*lect* pulse that strobes the Flag, DP1, DP2, and DP3 outputs into the accumulator
007	003	—	—	Device code for strobe inputs 5 and 6
010	137	MOV E,A	4	Move accumulator contents to register E
•				
•				At this point, twenty 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 (DP = Decimal Point), 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.
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"I want it installed in the attic. No need to advertise the fact I have a color TV!"