MAIN ASPECTS IN THE DESIGN OF PROGRAMMABLE CALCULATORS ORIENTED TO ON-LINE APPLICATIONS

By

I. KŐRÖSI

Department of Process Control, Technical University, Budapest

Received July 25, 1976

Presented by Prof. Dr. A. FRIGYES

Development of Measuring Systems Controlled by Calculators

The increased use of computers with batch operation has estranged nonprofessional programmers from computers, and thus the programmable desk top calculators issued in the late sixties raised general interest. The programming difficulties due to the push-button-oriented machine language as well as the smaller storage capacity and the problems arising from the modest INPUT/OUTPUT possibilities are counterbalanced by the availability of the calculator. However, its application as a controlling and processing unit to measuring systems in laboratories was greatly hindered by its complicated interface system and inflexible information storage.

Automatic measuring systems are preferably controlled by small computers, microprocessors and single-purpose devices. Single-purpose devices used for controlling measuring systems are inflexible, but their costs are low. They can be programmed by means of a plug-in storage for switching on and off some optional operations depending on the place of measurement. However, they cannot expediently be used in processes requiring complicated operations.

The systems applying a small computer as control unit provide great flexibility, but their programming usually requires special knowledge and great practice. Such computers are expensive, and therefore their application appears advisable only in medium-size or large automatic measuring systems (e.g. in the automation of complex laboratories).

Microprocessors increasingly used nowadays are the cheapest of all the devices applicable as system controls. Their use, however, requires the construction of an own system of the microprocessor (connection of the stores and manipulating organs) in addition to interfacing the system to the microprocessor. Their programming and the simulation of the program are wearisome and require much work. The satisfaction of new requirements arising during use involves extension of the microstorage (modification of the hardware) and a change of the microprogram (modification of the firmware), i.e. practically the revival of the whole system.

On the other hand, an automatic measuring system built with the use of an up-to-date programmable desk top calculator exhibits several advantageous features:

a) its interface is simpler and cheaper than that of systems using small computers and microprocessors;

b) its programming and the maintenance of the programs is simpler by an order of magnitude than in any other solution. (There is no need of any supervisory program, and the debugging services are most developed in desk top calculators, etc.);

c) its application is usually periodical, and the remaining time can be used to perform engineering and scientific computations, or to subsequently process and analyze information obtained by on-line or off-line data acquisition by means of devices not connected to the calculator.

Their price lies between those of systems with microprocessors and small computers. Their on-line application can be supported by the adaptation of some computer properties and the design of a channel system facilitating the construction of the system.

The architecture and programmability of the calculator is greatly influenced by the instruction system applied, by the programming level of the calculator and by the push-button system used.

Programming of the calculator

The first calculators were programmed in the so-called keystroke language (WANG 700, WANG 600, Hewlett—Packard HP-9100, HP-9810). Later came the computers with the formula language (HP-9820, HP-9821, Tektronix 21, 31), then the calculators programmable in the BASIC language (WANG 2200, HP-9830). Nowadays, calculators programmable in the APL language are built as well (IBM 5100).

A higher-level program language is not favourable for the on-line application of the desk top calculator in every case. Although it simplifies the writing and correction of the program — thus reducing the requirements of special skill, — but the speed and the exploitation of the storage considerably decreases. A machine programmable on a program language of higher level is much more expensive than the keystroke-oriented ones.

The decrease of speed is due to the fact that the calculators interpret the source programme possibly stored in packed form. Program languages of higher level make those programming procedures wearisome or even impossible which could reduce the storage requirement.

The keystroke language increases the work required to the design of the system, but the speed and the exploitation possibility improves. The plus work can be reduced by means of a well-edited library.

Up-to-date channel to a measuring system

The first calculators had no universal interface system. The peripherial-dependent signal flow was ensured by the microprogram. Connection of new peripherials was possible only by means of auxiliary devices (I/O COUPLER, PERIPHERIAL ROM).

The design of measuring systems raised the necessity of developing some standard bus system, which makes numerous individual interface tasks avoidable. In 1972 the work group Nr. WG 3 of the Technical Committee TC-66 of the IEC (International Electrotechnical Committee) set the aim of standardizing the bus system elaborated for the measuring system suggested by the company Hewlett—Packard. This is a byte-serial bit-parallel interface system suitable for asynchronous data transfer in which a transmitter and several receivers can be operated. The standard scheme was accepted after numerous modifications. This system is suitable for the construction of measuring systems, among them of an automatic measuring system controlled by a calculator. It cannot expediently be employed for the data transfer between conventional peripherials and the calculator, since this would occupy much of the operative memory of the calculator by the numerous I/0 instructions.

Flexible architecture

A basic requirement in the design of a calculator is its widest possible applicability. Nowadays, this means that it can be used for performing simple manual calculations and complicated scientific computations, for on-line control of measuring instruments and even measuring systems, and for processing the data acquired.

It is practical to store both the data and the instructions in a common operative memory, for in this way the shares of program and data fields can change for each part task.

The relocability of the programs is a very important requirement. This may facilitate the correction of the programs and the linking of the subroutines to the main program. Writing compact programs is enhanced by the various conditional and cycle-organizing instructions. Also the possibility of indirect addressing and of instructions supporting the calculation of addresses is important.

The interactive application of the machine is greatly facilitated if the calculator is able to perform operations also with characters and strings in addition to numbers. This may be necessary also in applications for measurement, since the operator of the measuring system is not necessarily skilled in operating the calculator.

Design of the EMG 666

In 1972 the Department of Process Control Engineering joined in the development of a flexible programmable calculator. It took part in the development of the architecture of the desk top calculator, in the elaboration of the MACRO instruction system, as well as of the MICRO structure and the interface system. It prepared the complete microprogram of the calculator and tested it with computer simulation.

The hardware system and the logic design of the special microprocessor and the external and internal peripherals to be attached were developed in the Buro Machine Laboratory of the Works for Electronic Measuring Gear.

At constructing the system of the calculator the principles discussed in the foregoing were applied. In the following the most important parameters of the calculator will be outlined. An exact description of the machine can be found in [7].

The EMG 666 is a universal desk top calculator, programmable in the keystroke language. It has an alphanumerical display, a mosaic printer, a cassette unit controllable by a program, and a byte serial, bit-parallel interface. Data and instructions are stored in the operative store of 1—8 Kbyte. It has also a ROM for the most frequently used subroutines.

Its interactive use is made possible by the keys of the instructions serving for the input and output, internal movement and processing of character information and for the functions defined by the microprogram.

The relatively small-sized operative memory is suitable for performing various operations of data transfer and, with the use of two equivalent accumulators, for storing complicated programs, too. A better utilization of the space is made possible by packing in one byte those instructions which can be read in by pressing the other push buttons. The machine has directly and indirectly addressed data transport and arithmetic operation units.

The jump instructions are of searching type or self-relative, thus the programs can be relocated. The program-organizing instructions help to write the overlay programs using the cassette.

The field of application of calculators is generally decreased by the fact that they are not capable of performing operations with the instructions directly (a partial violation of the *Neumann* principle). In the EMG 666 the special instruction pair "byte up" and "byte down" permits to transform a byte on a given address into an integer or an integer into a byte. Thus, the calculator is capable of modifying or even creating a part of the program field, of handling tables in condensed byte organization or of performing string manipulations of arbitrary complication. These instructions permit the operation of program generators or utility programs in the calculator, similarly to small computers. The utility programs help to modify the programs and to list them in the memory, as well as to catalogize and maintain the programs stored in the cassette.

Another feature adopted from computers is the possibility of interrupting the program. The interface system makes possible to call the service request of the periferals. On satisfaction of the interrupt conditions a pseudo-subroutine call of the machine causes the program counter to be saved and the interrupt routine to be started.

Channel system of the EMG 666

The HP interface system recommended by the IEC mentioned at the beginning of our work to be accepted as a standard has been adapted to the calculator EMG 666.

During the development of the calculator, the original HP recommendation was repeatedly modified by the IEC; beyond formal changes concerning the names of the signal ducts, new lines and a more defined system of the addresses and data were introduced. For the channel system of the EMG 666 some restrictions were introduced compared with the original recommendation. The deviations were justified by the following facts:

a) Also the peripherals of not instrumental type (typewriter, plotter, punch tape peripherals) were intended to be connected to this bus system;

b) it was desirable to design the MACRO and MICRO control of the I/O means in compliance with the structure shaped previously;

c) disturbances may occur in the signal stream of the bus system, therefore it is desirable to limit the duration of certain asynchronous signal changes.

The most important deviation from the original HP recommendation is the compulsory order of transferring commands, addresses and information, as well as the compulsory entering of the status. In the status, too, the meaning of certain bits was defined. Another deviation is that in the identification cycle following the request for interruption an interruption address is entered which must contain an increasing number of 1 bits, as priority increases.

The bus system applied and the interface system of the peripherals are shown in Fig. 1. Names of the channels are:

8 pcs	DATA INPUT OUTPUT line	DIO
3 pcs	HANDSHAKE line	
	DATA VALID	DAV
	DATA ACCEPTED	DAC
	READY FOR DATA	RFD
1 pcs	FLAG line	
	MULTIPLE RESPONSE ENABLE	MRE
2 pcs	CONTROL line	
	SERVICE REQUEST	SRQ
	INTERFACE CLEAR	IFC

For the information stream on the bus, the process of byte transfer is of paramount importance. It is by this mechanism that the addresses, commands, data and statuses are transmitted. One TALKER and one or more LISTENERS can be connected to the bus. The MRE signal decides whether all the receivers have to take part the in data transfer (MRE = low) or only the previuosly addressed LISTENER has to answer (MRE = high). The transfer mechanism of one byte is shown in Fig. 2.

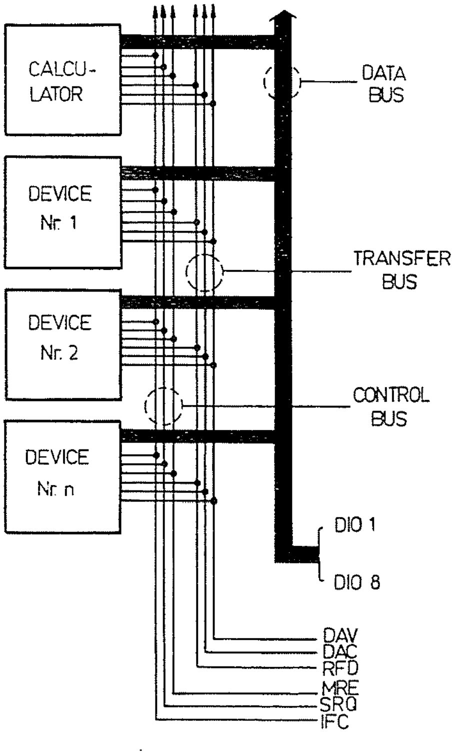

Fig. 1. The BUS system

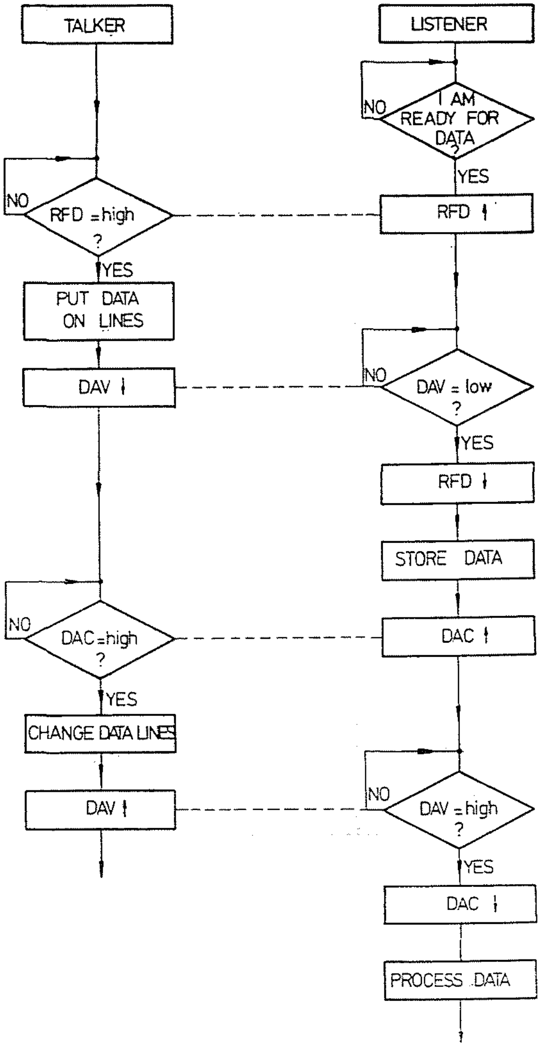

Fig. 2. The transfer mechanism of one byte

The full information flow is shown in Fig. 3. After transfer of the address and the command, the addressed organ is obliged to enter its status. This is analyzed by the calculator, then, depending on the result of the analysis, it performs the transfer or signalizes the error. In the case of an error signal the program continues if the subsequent instruction is SKIP IF NO ERROR, and this permits the entered status to be analyzed. With a status signalling a regular transfer, the calculator decides whether the data transfer is necessary, the transfer of 1 byte is sufficient, etc.

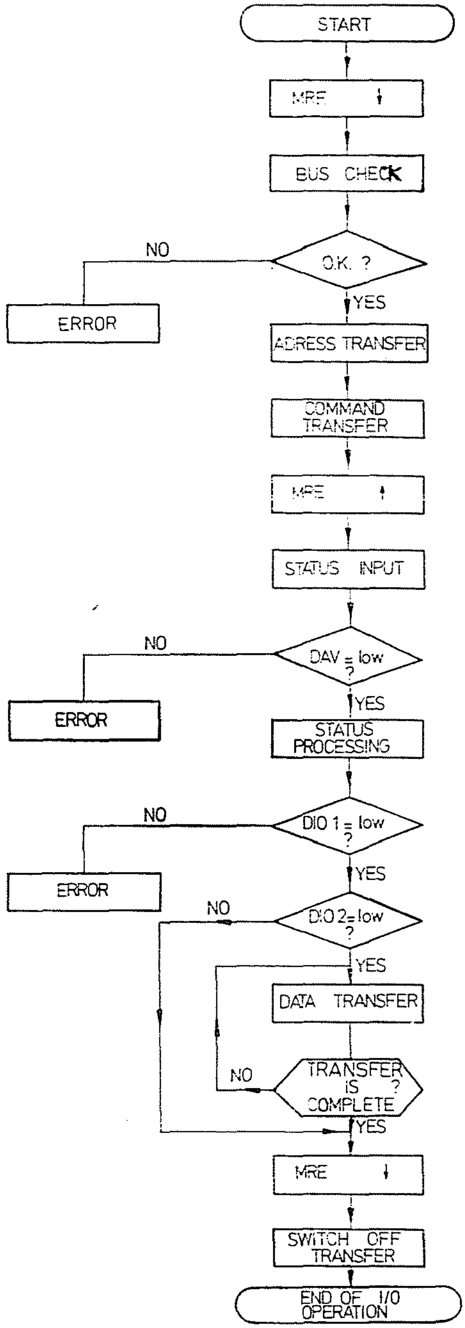

Fig. 3. **The full information flow**

The possibility that the logical methods of signal transfer can be controlled through the status entered previously, provides great flexibility. Thus it becomes possible that the same address or command byte sequence provides different transfer methods for the different peripherals.

Summary

Programmable calculators are increasingly used as control units in automated systems. The paper summarizes the features of calculators that promote their increased application for such purposes. It discusses in detail the properties of the architecture and channel system of the EMG 666 calculator that make it particularly suitable for such applications.

References

1. NELSON, Gerald E.—RICCI, David W.: A Practical Interface System for Electronic Instruments. HP Journal, 1972, October.
2. COCHRAN, David S.: Internal programming of the 9100 A Calculator. HP Journal, 1968, September.
3. RICCI, David W.—STONE, Peter S.: Putting Together Instrumentation Systems at Minimum Cost. HP Journal, 1975. Januar.
4. FISCHER, David P.—WELCH, Stephen M.: When to use a programable calculator on a microcomputer to automate a system. Electronics, 1974, May 16.
5. FISCHER, David P.—WELCH, Stephen M.: How to build an automated system around a programable calculator. Electronics, 1974, May 16.
6. KŐRÖSI, I.—NAGY, P.—VÁRHELYI, F.: Design and simulation of the microprogram for the EMG 666 calculator (in Hungarian). Conference 74 on Computer Science (Esztergom).
7. The EMG 666 programable calculator. User's Manual. Edited by Kőrösi I.

István KŐRÖSI, H-1521 Budapest