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THE CONFUSING DIGITAL STANDARDS PICTURE-- ARE THEY RELATED?*

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Summary

Due to the realization of international competition and the recognition that perhaps the time for action has arrived, there recently has been a flurry of activity in many areas of digital interfacing standards. This paper will review the status and discuss the relation of the CAMAC system, the IEC bus, the channel interface, and the new bit serial standards in terms of the nuclear instrument, process control, and general computation communities.

Introduction

Generally, digital interfacing standards have developed within different organizations with contrasting backgrounds and application areas. The results are independent standards which must peacefully coexist, although there is some degree of overlap and competition to confuse the issue. The user and the engineering community must learn to evaluate these standards and how they fit into each particular problem.

One would wish for more signs of compatibility and unity among these efforts than presently seem to exist. One would also wish for more widespread dissemination of the activities of standards groups, even prior to formal acceptance. Consequently one of the important goals of this paper is to educate the scientific-engineering community about these standards, and to bring about more utilization, user participation, and, hopefully, unity.

Some Benefits and Limitations of Standardization

What are some of the reasons for considering digital interfacing standards--where do we stand to gain from using them? Table I lists some of the possible benefits of using such standards. It is suggested that the reader think of his own problems in terms of standards, and see how many of these factors apply.

TABLE I

POSSIBLE BENEFITS OF DIGITAL INTERFACE STANDARDIZATION

- Rapid changeover of systems
- Rapid and improved maintenance
- Improvements in second-sourcing
- Ease of system improvement
- Reduction of interface engineering time
- Rapid system debugging
- Independent testing of system components
- Less documentation

To be fair, it is clear that many of the benefits apply to the user of digital systems, not the manufacturer of commercial products. Those that do apply to the manufacturer imply mixed systems between suppliers. Convincing a large systems type of supplier to participate in, and to comply with, universal standards has not been the easiest task. Thus the user or "customer" community must be willing to participate in the development and application of standards.

What about the classical argument "Standards hold back progress"? Admittedly, standards must be carefully applied - in particular, one does not expect to find standards mandatorily applied in developmental areas near the state of the art. But there are vast areas remaining where digital electronics has a specific function to perform reliably and efficiently - in such cases, the classical statement may be irrelevant. Furthermore, one should view standards as system options, which can coexist with other nonstandard approaches where these are more suited to the task. Even within standards there are now system options which require careful consideration and selection.

Standards Organizations

Table II lists some of the groups working on digital interfacing standards, and Table III lists the formal digital standards under consideration in this paper. Although it is not possible to go into a discussion of the various groups it is important to point out that the nature and success of the standards are highly dependent on the composition, goals, and backing of the diverse groups.

TABLE II

DIGITAL INTERFACING STANDARDS ORGANIZATIONS

1. EIA
2. ANSI X3-T9 Computer I/O Standards
3. NIM-CAMAC Committee (AEC)
4. ESONE Committee
5. IEC - TC 66/WG 3 Programmable Instruments
6. ISO - TC 97/SC 13 Computers, Interconnection
7. IEEE Computer Society
8. Purdue Workshop

TABLE III

SOME DIGITAL INTERFACING STANDARDS

1. Bit serial
   RS-232-C, new proposals - SP1162A, SP1163A
2. Byte serial
   BSI, RS-408, IEC bus (proposed)
3. CAMAC system
   Parallel, serial
4. Channel interface (proposed)

Bit Serial Interface Standards

RS-232-C (Figure 1) is probably the most well-known digital interface standard and has been in existence for many

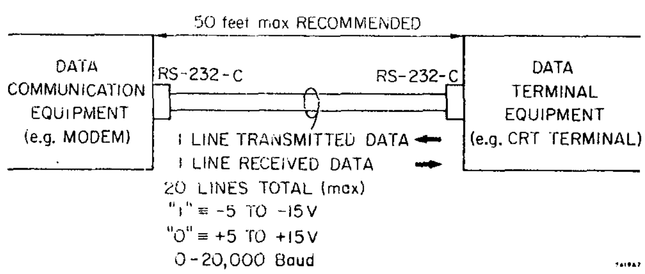

FIG. 1--RS-232-C bit serial interface.

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years. It was standardized by the EIA, and is also a CCITT standard for both synchronous and asynchronous digital communications equipment. It does not standardize the actual transmission over long lines but only the interface to communications equipment such as modems. Thus it is used on CRT interactive terminals, printers, etc. Most computers have RS-232-C ports available as an option for driving single or multiple lines. This standard has become so well accepted that it would be difficult to sell terminal equipment without it.

Although the specification includes 20 control and signal lines, in reality only 4 are necessary for asynchronous bidirectional communication. Transmission is single-ended, and the receiver impedance is 3K to 7K with a maximum threshold of ± 3V. Many IC drivers and receivers compatible with RS-232-C are available.

RS-232-C taken alone is a minimum specification; however, other standards and de facto procedures have filled the gaps and made RS-232-C devices truly plug-compatible. For example, ASCII coding has become widespread for the transmission of alphanumeric data and ANSI X3.1 has standardized the signalling rates. For synchronous equipment RS-334 spells out timing characteristics. Additional ANSI standards cover parity considerations and bit sequencing. Thus there is a wide spectrum of terminal equipment that the user can interconnect without costly engineering, or minor but annoying modifications.

Even so, the EIA has seen the limitations in the existing RS-232-C and has developed two new proposals to replace the existing one. Although not widely publicized, these are not far from adoption. Two separate general electrical standards are proposed--SP1163A (single-ended, unbalanced) and SP1162A (differential, balanced). Both of these are based upon the use of a high gain differential receiver, offer higher operating rates over longer lines, and permit multiple receivers on the line, all prior limitations of RS-232-C. The new standards are not conceptually limited to data terminal equipment. Figure 2 illustrates the basic features of the unbalanced standard. Note that the logic levels are essentially

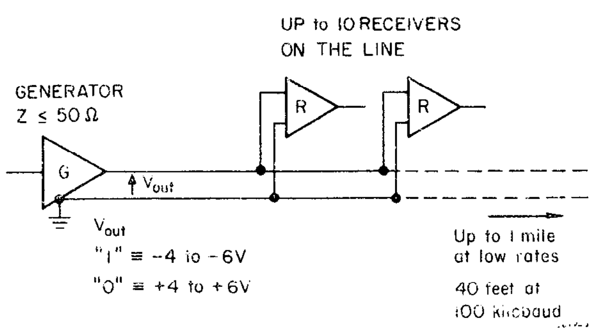

FIG. 2--Proposed single-ended bit serial standard.

compatible with RS-232-C so that interpperation with older equipment is achieved "under certain conditions". Operation to several miles at low rates is possible if common mode noise is not a problem.

The proposed balanced standard is illustrated in Figure 3. Operation to 10 megabauds at 40 feet is expected, based on 24 AWG twisted wire with a 100Ω termination.

Integrated circuit suppliers are participating in the EIA effort and are expected to offer commercial I.C.'s to meet these specs. The CAMAC Committee has already indicated that the balanced standard has become the signal standard for the serial crate controller.

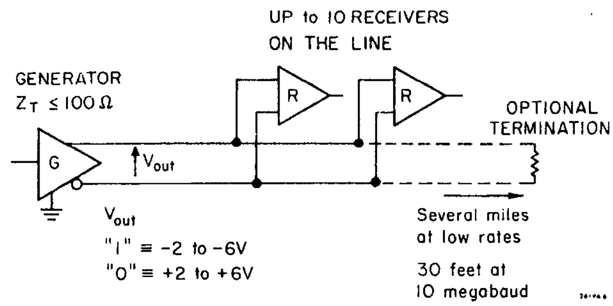

FIG. 3--Proposed differential bit serial standard.

British Standard Interface - (Byte-Serial)

Although not a serious contender for today's high performance digital systems, this British standard for data collection systems is included for historical reasons. It is based on serial transfer of 8-bit parallel bytes between a single data source and a single receiver (acceptor). (See Fig. 4.) An additional parity bit is also indicated. The timing of transfer is handled by strict handshaking rules involving 5 control lines.

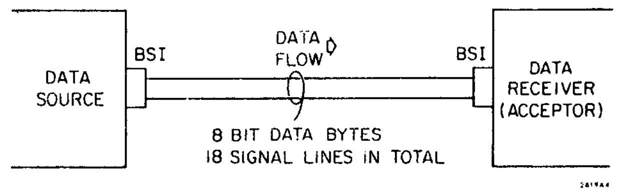

FIG. 4--British Standard Interface.

Logic levels are defined to be bipolar signals as in RS-232-C, with a range of 5 to 11 volts. A total of 18 lines is used in the interface. Timing specifications are given for 50-foot cables, but in some cases long lines up to 5000 feet may be used at reduced rates. A data character can comprise any number of bits from 1 to 8, but the preferred code is the ASCII.

Note that this standard is based upon two other international standards, RS-232-C and ASCII. Although the BSI does not appear to have international significance, commercial CAMAC modules with this port are available.

RS-408 Byte Serial Interface

This is a relatively new standard, which specifically standardizes the byte (8-bit) interface between data terminal equipment and numerical control equipment (see Figure 5).

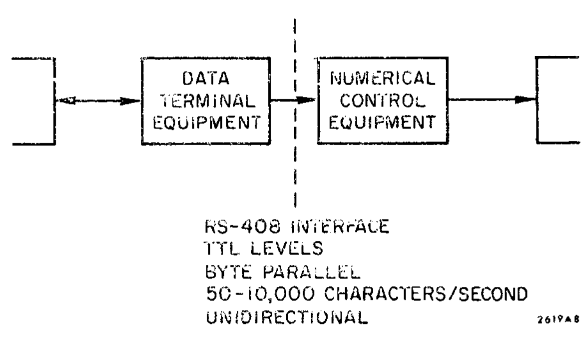

FIG. 5--RS-408 byte serial interface for numerical control equipment.

All signals are nominal TTL levels, and the control approach is patterned after photoelectric tape readers, the typical control input to such equipment. The data rate is relatively slow, 50 - 10,000 characters/sec, and the purpose rather limited, yet conceivably it could have application beyond the single application for which it was intended. The name will obviously restrict its usage.

Note that this interface is closely related to the BSI in concept, but uses the more convenient TTL levels.

IEC Bus - (Proposed)

This is a relatively new interface standard originally developed by Hewlett-Packard (H-P) and adopted by several other instrument companies. It is now being considered for international standardization by the IEC (International Electrotechnical Commission) and a subcommittee of the IEEE. Process control groups are studying its applicability. Formal adoption is about one year off although there is not yet universal agreement on a connector. Part of the standard is considered proprietary by H-P and requires licensing to use. This interface is based on serial 8-bit byte transfers with TTL levels, and was developed primarily for interconnection of programmable measuring instruments to a controller or computer (see Figure 6). H-P in fact does offer such a port for their 2100A computer, as well as voltmeters, signal sources, and calculators that are compatible with the bus.

Since it is not a packaging standard it is necessary that circuitry to be compatible with the bus be contained in each device (instrument). Data transfer between devices on the bus is controlled by handshake signals, and a 1 megabyte/sec data transfer rate is achievable with a maximum cable length of about 50 feet.

TABLE IV

SOME DETAILS OF THE IEC BUS

DATA LINES	DIO 1-8 (Bidirectional)	
HANDSHAKE CONTROL	DAV	- Data valid
	NRFD	- Not ready for data
	NDAC	- Data not accepted
INTERFACE MANAGEMENT	IFC	- Interface clear
	ATN	- Attention
	SRQ	- Service request
	REN	- Remote enable
	EOI	- End or identify

TALK AND LISTEN CODES (ATN LOW)

X	0	0	A_5	A_4	A_3	A_2	A_1	Universal commands
X	0	1	A_5	A_4	A_3	A_2	A_1	Listen address (31)
X	0	1	1	1	1	1	1	Unlisten
X	1	0	A_5	A_4	A_3	A_2	A_1	Talk address (31)
X	1	0	1	1	1	1	1	Untalk
X	1	1	A_5	A_4	A_3	A_2	A_1	Secondary commands (31)

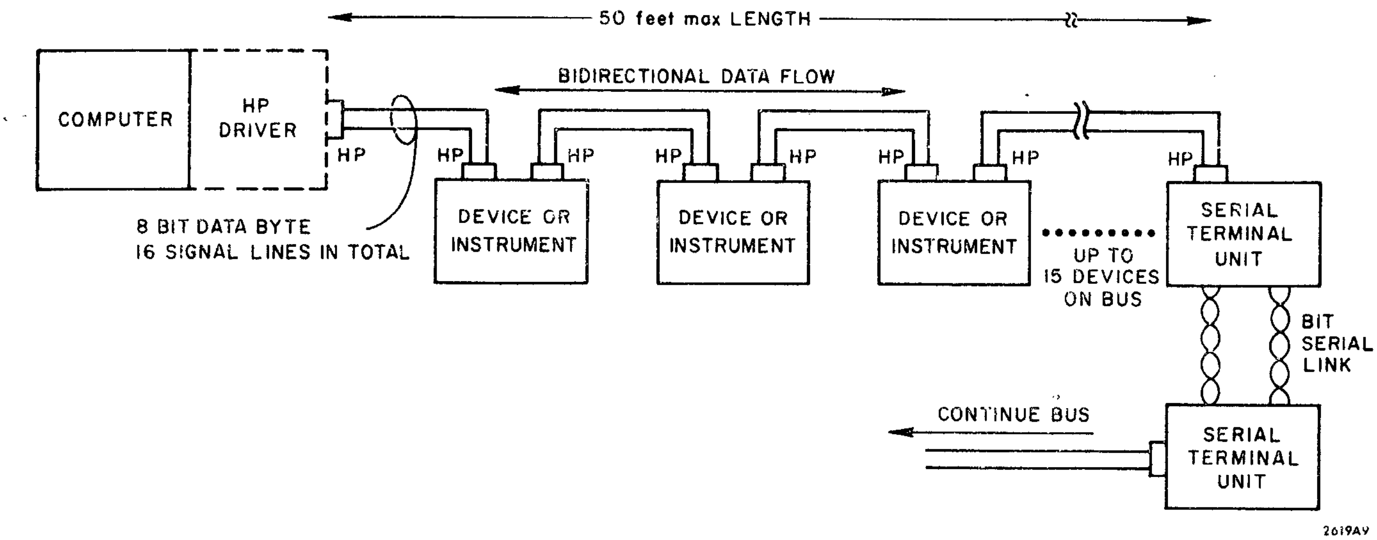

FIG. 6--Proposed IEC bus (H-P bus) for instruments.

Some details of the IEC bus operation are shown in Table IV. A very versatile communication protocol is specified, with each device having any combination of functions known as Talker, Listener, and Controller. The Listen function provides a device to be addressed to receive measurement data or control data. The Talker function provides a device to be addressed to transmit data, including control data. The Controller function provides a device with the capability to address other devices as Listeners or Talkers, and transmit command or control data to devices. As shown in Table IV, basically 31 Talker and 31 Listener addresses are provided, although secondary commands can expand on this. These addresses are switch-selected on the individual units connected to the bus. Control codes along the bus utilize ASCII, and it is recommended that data be in ASCII; hence the bus is often called the ASCII bus. Interrupt, or service, requests from devices are possible, with both parallel and serial polling modes.

A recent article by Hewlett-Packard proposes a serial terminal unit residing on the bus for extension of the bus via a bit serial link, as shown in Figure 6. This will give the system designer the possibility of configuring such systems over longer distances, indicating again that no single system standard can be expected to solve all problems optimally.

When fully implemented, the IEC bus will provide an important step in the standardization of ports on digital instruments. In addition, it provides a bus structure for simple and rapid interconnection of components in a small, standalone system although complete compatibility of devices is not guaranteed. It is also possible that this port could be used on many other digital devices, thereby further simplifying the overall computer interfacing picture, but wider use of the bus in that area is as yet uncertain.

Other applications of the IEC bus are already under consideration. One major physics laboratory visualizes the IEC bus supplementing CAMAC as a universal communication method in a control room environment to link various digital instruments in a console, over a limited distance. Use of the bus will simplify the interdevice cabling, and will automatically provide a vehicle for connection of future commercial digital instruments. In this application the IEC bus would be driven from a module in an already existing CAMAC system.

CAMAC System

By now the CAMAC system is well-known in the nuclear physics community, and has even spread into other areas, such as astronomy, medicine, and industrial process control. Obviously it has filled a vacuum--a standardized modular digital interfacing system did not exist prior to CAMAC. It should be pointed out that CAMAC was developed by a user group residing in a laboratory environment. Yet the problems were general enough, and the standard broad enough, for it to overlap into many different areas. Another point of significance is that the standards group influences a large proportion of the customer group--hence rapid dissemination and field acceptance of the standard was virtually assured.

The CAMAC system is fundamentally different from the other standards described in this paper in that it fully defines an independent packaging standard for modules, in addition to standardizing the digital interface between modules. Thus it is a method of connecting standardized data handling and control modules to a computer. These functional modules are computer-independent and hence a single design can be shared by many users. An impressive array of functional modules is now commercially available. Although not originally intended to be optimum for peripherals, CAMAC is now being used to connect conventional peripherals to computers as well, and is also being used for computer-to-computer links.

The basis of CAMAC is the crate containing the Dataway which interconnects the modules. For high speed multicrate systems there is a standard parallel branch which connects up to 7 crates via a Type A crate controller residing in each of the crates. Branch drivers (interfaces) for popular minicomputers are also available. Recently the need was seen for systems in which CAMAC crates are spaced over a considerable distance. Consequently a bit serial and/or byte serial CAMAC system has been standardized in which up to 62 crates are connected via a Type SCC L-1 crate controller residing in each crate. SCC L-1 crate controllers are now commercially available.

The NIM-CAMAC Committee is well aware of the existence of diverse digital standards, and this paper is basically the result of the awareness. As an example, the serial crate controller SCC L-1 specifies the new differential signal standard SP1162A at its input/output ports, although originally an older standard was specified.

Figure 7 shows various options and interrelations of the CAMAC system. Note that the CAMAC serial highway is being driven, for example, by a module which already exists commercially, although it is also possible to drive the serial highway directly from a computer port without the use of the parallel branch. Another module interrelating standards is the RS-232-C port, which provides an excellent way to drive CRT terminals and similar devices over long serial links. Needless to say, it is expected that commercial modules with the new bit serial standards will be available in the near future.

The IEC bus, as mentioned previously, is another candidate for connection to CAMAC via a module. Initial

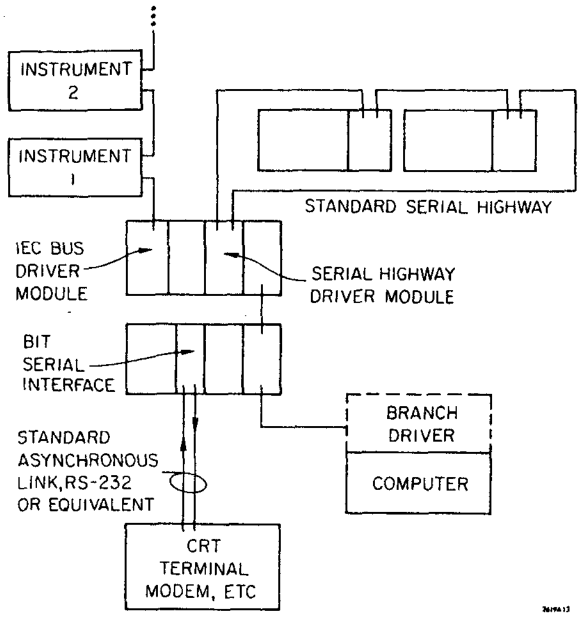

FIG. 7--CAMAC interrelations.

investigations indicate that such a device is indeed feasible, and will undoubtedly become available as the IEC bus develops. The CAMAC Committee is itself studying the feasibility and possible standardization of such a module. The IEC bus, in standardizing the ports of instruments, serves a very important function in the CAMAC community by reducing the amount of interface engineering for the user. On the other hand, it can be viewed as another digital system option to be used with or without CAMAC, as appropriate.

The CAMAC standard is being seriously studied by standards groups in other disciplines. In particular, the Purdue Workshop on Industrial Computer Systems has added it to its scope of work, although it has worked primarily in the software area, and the IEEE Computer Group-Interface Standards Subcommittee has included it as a system for consideration. The nuclear instrument group of the IEC has accepted the basic CAMAC document for an international standard. In addition, there are industrial and medical CAMAC users groups recently formed in both Europe and America.

The Channel Interface

Standardization of computer I/O bus structures would permit, or at least facilitate, interchangeability of peripherals between manufacturers. Due in part to the tremendous complexity of such an effort - technically, politically, and economically - no efforts in this area have yet been successful. However, due to a changing constituency of the responsible ANSI group (X3-T9), a positive approach was taken early this year after many years of inactivity and opposition. This reluctance is explainable, as it is apparently well-known that protection of the peripherals market remains one of the primary goals of the large data processing manufacturers. Legally this area is extremely complex, and very lucrative, as evidenced by the number of lawsuits relating to the interaction of mainframe manufacturers and peripherals suppliers. Nonetheless, a Japanese proposal advanced through the ISO for a channel interface is now being considered.

The channel is patterned very closely after the IBM/360 I/O channel, which of course is oriented towards the efficient, rapid transfer of large amounts of data from such devices as disks and tapes. The channel assembles (disassembles) computer words from (into) 8-bit bytes and requests memory access for the memory transfer, checks and generates parity, etc. Fig. 8 indicates the location of the channel interface with reference to the mainframe. The general characteristics of the Japanese proposal are shown in Table V. Table VI indicates two modes of data transfer on the channel.

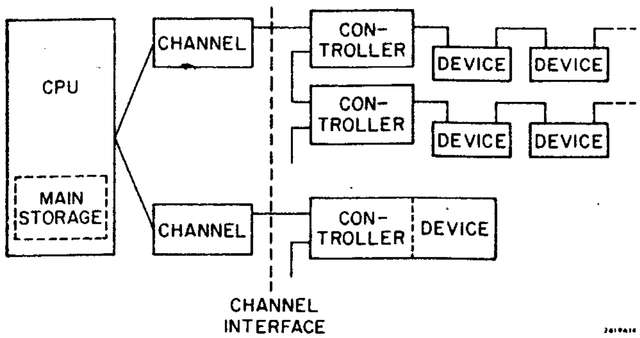

FIG. 8--Proposed channel interface for computers.

TABLE V

SOME CHARACTERISTICS OF THE CHANNEL INTERFACE

- Influenced by IBM 360 channel
- Up to 8 (optionally 16) controllers per channel
- Up to 256 devices per channel
- 48 signal lines in basic interface
- Basic bus width 8 bits; optionally 16, 32, or 64 bits
- Cable is coaxial, TTL levels
- Types of bytes:
  - Device address
  - Command byte
  - Information byte (data, control, sense)
  - Status byte
- Not necessarily software compatible, or plug-compatible

TABLE VI

MODES OF INTERFACE OPERATIONS

1. Burst mode
   - For relatively fast I/O devices
   - Controller remains connected until all of the information bytes are transferred
   - Channel burst or controller burst
2. Multiplex mode
   - For relatively slow I/O devices
   - Controller requests to be connected in the channel before each transfer

Logic levels on the channel are essentially TTL levels with the "one" state positive. Terminated coaxial cable is used with a characteristic impedance of 92 ohms. Transmitter outputs are via emitters, so that a positive OR function is achieved. It is expected that integrated circuits to meet the electrical specifications will be commercially available.

Recently, the Japanese delegation met directly with the American delegation in an ISO meeting to negotiate specific areas of disagreement, clarification, or improvement. Considerable progress was made, but major work still remains on the subject of channel switching, which the Americans feel is an important requirement of a modern interface. In any event, a redrafted proposal is to be prepared by the Japanese by the middle of 1975. Furthermore, it has been recognized recently that the proposed standard does not guarantee overall plug-to-plug interchangeability of controllers, but only a hardware compatibility. Software considerations for particular controllers and/or devices are termed "operational characteristics", and study of possible standardization efforts in this area has begun within ANSI. Another area under discussion is administration of the standard.

It is too early to tell when and if such a standard will reach official national and international acceptance. Moreover, it is not clear how the manufacturing and the user-customer community will react to such a significant change. The effect on the whole area of manufacturer-supplied operating systems software is yet another unknown since the bulk of software efforts are still supported by hardware sales. Even such routine subjects as system maintenance policy are affected by such a standard.

All in all, it appears that these problems can be worked out and such a standard could give the digital systems community a new and powerful option. Although interrelation of this standard to the others, particularly the IEC bus, has not yet been made, hopefully discussion of this possibility will continue within the various groups.

Minicomputer I/O

There are no known successful efforts so far in standardization of minicomputer I/O buses and there are no specific proposals being seriously studied by U.S. groups. In fact, it is considered by some that, since the I/O bus in a small computer couples so strongly into the architecture, such efforts at standardization are stifling and would restrict the internal architecture. In fact, a recent survey on the subject taken by ANSI, primarily among minicomputer producers, generally found disinterest and direct opposition. However, due to the interests of users, peripheral manufacturers, and others, the minicomputer effort is continuing in X3-T9, as a result of a recent vote on the subject.

Perhaps what is needed to break the logjam is a user-sponsored simple, versatile interface port, which can co-exist with other specialized interfaces in the same machine. Hopefully, the standard interface would be compatible with CAMAC and/or the IEC bus to minimize additional interfaces.

Conclusion

So far digital interfacing standards have been developed by independent groups working in generally different application areas. Although there has been very little duplication of effort, there is obviously overlap between the areas. Compatibility of the standards is purely coincidental.

Actual progress in some of the areas is extremely slow, sometimes due to disinterest, sometimes due to opposition to standardization, and in some cases due to cumbersome operating procedures of the committees involved. Success within the CAMAC community has shown how standards can benefit users, and how the users community can function with great speed where the goal is clearly set. The message is clear--more user participation in standardization efforts.

In spite of the many roadblocks, however, there has been renewed interest in standards, and hopefully results will be forthcoming. More importantly, the various groups are now communicating far more than they have in the past, and perhaps signs of unity will soon emerge.

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