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BRIEF SURVEY OF DIGITAL INTERFACING STANDARDS

The purpose of this note is to bring together material on several different digital interfacing standards proposed or in use, to form a background for new work on computer interfacing standards. Emphasis is on the technical aspects and applications of these standards. No attempt is made to be complete or detailed; references are given for complete specifications and/or descriptions of these standards.

1. British Standard Interface For Parallel Bytes (Fig. 1)

Complete history of this simple interface for digital data collection systems is unknown to this author, but it has been in use for several years. It was formulated by the Data Processing Industry Standards Committee, which is a combination of government, professional, and industrial organizations. It does not appear to have much significance outside of Great Britain.

The BSI is a generalized standard interface "for connecting input/output data collection devices to digital systems". Although the term "computer" is not used in the specification, apparently some British computers do provide such ports. It is based on parallel transfer of 8 bit bytes between a single source and a single receiver (acceptor). An additional parity bit is also indicated. The timing of transfer is handled by strict handshaking rules involving 5 lines.

Logic levels are defined as bi-polar signals with the transmitted "1" specified $+11 \geq V \geq +5$ volts and the transmitted "0" specified $-5 \geq V \geq -11$. The receiver impedance is 3K to 7K. The receiver logic band is specified from 1 to 15 volts except for two critical handshake signals which are specified from 3 to 15 volts.

A total of 18 lines is used in this interface, and a standard 18 pin or 34 pin connector is used (the 34 pin is used for twisted pair cable). Long lines are obviously acceptable since length up to 5000 feet is listed in an Appendix, although the rate is reduced.

A data character can comprise any number of bits from 1 to 8, but when data codes are used the preferred code shall be the United Kingdom 7-bit data code (ISO-7-UK). (Same as A.S.C.I.I.)

2. RS-408 Byte Parallel Interface

This is a relatively new standard (March 1973) which specifically standardizes the byte parallel (8 bit) interface between data terminal equipment and numerical control equipment. All signals are at a nominal +5 volt level for compatibility with integrated circuits. The control approach is patterned after photoelectric tape readers, since much existing numerical control equipment is based upon the use of paper type input. The data is unidirectional, from the terminal equipment to the control equipment, and it is implied that there is one terminal device sending data to one control device. The rate of byte transfer is within the range of 50 to 10,000 characters/second.

The standard connector is a 47 pin device meeting standard MS3102A36-8 (S,P).

This standard is too new to establish its acceptance, or to judge its applicability beyond its original limited usage.

3. Proposed IEC Bus (Fig. 2)

This is a relatively new standard interface developed by Hewlett-Packard 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. Part of the standard is considered proprietary by HP and requires licensing to use. Again this is an interface standard based on parallel 8-bit byte transfers, and is to be used primarily for interconnection of programmable measuring instruments to a controller or computer. HP in fact does offer such a port for their 2100A computer.

This is a bus system capable of handling 15 devices on a single bus. Since it is not a packaging standard it is necessary that circuitry to be compatible with the bus is contained in each device (instrument). Data transfer is controlled by handshake signals, and a 1 megabyte per sec data transfer rate is achievable, with a maximum cable length of 50 feet.

The significant differences from the British Standard Interface are

(1) multiple devices on the bus (2) all signal levels are TTL compatible (3) complete flexibility of information flow; the bus is bi-directional and any device can talk to any other (4) it is primarily for electrically quiet, limited distance environments.

A very versatile communication protocol is specified with each device having any combination of functions known as Talker, Listener, Controller, and System Controller. The Listen function provides a device to be addressed to receive 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. The System Controller function provides a device with all of the Controller features, and adds the capability to initialize and terminate other system functions.

The bus consists of 8 data lines, 3 lines for the handshake (transfer bus) and 5 lines for the control bus for a total of 16 signal lines. The proposed connector is a 24 pin type 57 microribbon and the cable includes 6 twisted pairs.

The system contains a type of interrupt or service handling facility. A single service request line can be pulled down by any of the devices that want attention. The Controller then responds by asking for identification. All devices accept this command, and pull down a particular data line if service is desired. The Controller then can identify the device requesting service. Up to 8 devices can be identified using this method.

A serial poll mode for handling service requests is also possible in which the controller requests YES/NO data from each device in sequence to identify a service request.

Hewlett-Packard makes several instruments and controllers available with this new bus, including frequency synthesizers, a digital voltmeter, and a calculator (Controller), as well as an interface port for the 2100A computer.

4. Bit-Serial Interface Standards

RS-232-C (Fig. 3) is probably the most well-known digital interface standard and has been in existence for many years. It was developed by the Electronic Industries Association.

RS-232-C is a standard for low speed 0-20 KHz bit-serial transmission and is widely used for all types of long line digital communications equipment. It does not standardize the actual transmission over the lines, but only the interface to communication equipment (modems). Thus it is found on most digital equipment associated with communications, particularly CRT interactive terminals, printers, etc. Most computers have RS-232-C ports available as an option for driving single or multiple lines.

Data is bi-directional, but separate pins are specified for transmitted and received data. The standard allows both synchronous and asynchronous communication. Transmitted logic levels are essentially the same as in the British Standard Interface; that is, they are bi-polar in the range 5 to 15 volts. Minimum receiver swing is $\pm$ 3 volts and receiver impedance is 3K to 7K. Cable lengths of less than 50 feet are recommended.

The standard includes 20 control and signal lines, many with auxiliary control features, but it is not necessary to use all of these. In fact, only a minimum of 4 connections is actually necessary for asynchronous bi-directional communication.

A 25 pin connector MIL-C-24308 is the preferred standard.

Although logic levels are not TTL compatible, many commercial IC drivers and receivers compatible with RS-232-C are available.

It is significant to note that RS-232-C is a minimum specification; in reality it specifies only the electrical logic levels and various auxiliary control signals. Other significant features such as timing, coding, synchronizing, and even baud rate are not covered. However, other standards and defacto procedures have filled the gaps and made many RS-232-C devices truly plug-compatible. For example, the ASCII code has become widespread for the transmission of alphanumeric data to be used with CRT terminals. Furthermore the teletype 10 or 11 unit code is commonly used for asynchronous low speed communication.

For completeness it should be pointed out that for synchronous equipment a companion standard, RS-334, exists which carefully spells out characteristics for timing. Additional standards cover parity considerations and bit sequencing.

In general, this relatively simple standard has had considerable impact in digital communications and has led to the development of industry wide compatible hardware. The end user, of course, sees the main benefits since he can purchase equipment from different vendors and connect it without the need for additional engineering or equipment modifications.

One obvious limitation of RS-232-C is that it is based on rather unique logic levels that are not compatible with TTL levels (0 and +5V). Furthermore it is single-ended and limited in rate. To improve this situation and yet maintain compatibility of equipment the EIA is presently developing new bit serial standards. Actually two separate standards are proposed--one for unbalanced (single-ended) circuits, and one for balanced circuits. In the case of an unbalanced circuit, an operating range of 0 to 100 kilobauds is expected. The logic level for a binary "zero" is +4V to +6V, with a generator source impedance of 50Ω, and a termination of 450Ω. The logic level for a binary "one" is -4V to -6V. Note that the logic levels are bi-polar and essentially compatible with RS-232-C, the existing bit serial unbalanced standard.

In the case of the proposed balanced standard, operation to 10 megabauds is expected. The maximum open circuit voltage is specified to be 6 volts, the polarity of which is reversed to indicate the "one" or "zero" condition. The total generator source impedance must be less than 100Ω, and the voltage across a 100Ω termination must be greater than 2.0 volts.

5. The CAMAC Modular Interface Standard

The CAMAC Standard is fundamentally different from the other standards described in this note in that it fully defines a packaging standard for modules in addition to standardizing the digital interface between these modules. It is then a method of connecting standardized data handling and control modules to a computer. It is also being used as a method of connecting peripherals. Since the modules are standardized these peripheral interface modules are independent of the particular computer I/O structure.

This system has been in use for several years and was standardized primarily by an organization of European Nuclear Physics Laboratories, ESONE. The American organization of nuclear laboratories (NIM) has adopted this standard and it is now in widespread use in nuclear laboratories all over the world. Other disciplines seeing the need for standardized interfacing and packaging have begun to study and employ this standard as well. In particular the process control industry sees the advantages of such a standard and is seriously considering its implementation.

The basic unit of the system is the "crate" which houses up to 23 individual modules and a crate interface unit called a crate controller. Each module connects to a backplane or motherboard called the dataway via an 86 pin edge type printed circuit connector. All signals on the dataway are TTL levels, and data transfer is based on a maximum 24 bit read or write parallel transfer. Each module is addressed via a unique control line from the crate controller, but the remainder of the signal lines are bussed (except for one additional line described later). These include the 5 bit "function" code, and the 4 bit subaddress code (each module may contain up to 16 registers). Data transfer within the crate is synchronous, and does not depend on handshake methods. Minimum complete cycle time is specified as 1 μsec. Additional common control features termed Initialize, Clear, and Inhibit are also provided.

Out of 32 possible function codes 18 are standardized into somewhat general definitions. For example, one function is defined as "read", which simply means that up to 24 data bits are read in parallel from a register into a module.

Up to 7 crates may be connected together via a standardized bus structure called a "Branch Highway", which is interfaced to a computer through a "Branch Driver". (Fig. 4) Each crate then contains a standard crate controller with a standard interface connector of 132 pins. The cable normally consists of 66 twisted pairs. In the Branch the 24 data lines are bi-directional, and there are 5 module address lines in addition to the 5 function code bits and 4 subaddress bits. Timing along the branch utilizes a handshake method. The maximum length of the branch is not specified but practical considerations limit it to about 120 feet.

To handle interrupts each module has an individual interrupt line in the dataway returning to the crate controller, where the 23 interrupt lines may be sorted or ordered. Finally there is a single interrupt bus in the branch returning to the Branch Driver. A special single operation of the branch is then used to help identify the source of the interrupt although several other methods of interrupt identification are also provided. In general the branch provides great versatility in handling interrupts instead of a single strictly defined method.

The branch should be considered a secondary level of standardization, the crate-module pair being the first. In fact a new standard for interconnection of crates has just been published which permits bit serial or byte serial (8 bit) systems of up to 63 crates. This new standard does not modify the crate-module standard, but substitutes for the parallel branch described above. Hence a new serial crate controller is defined by this standard. Such a bit serial system, organized in loop format, may be driven by a modified asynchronous teletype port on a computer.

Other methods of connecting crates to computers have also been used. One of the most straightforward ways is to design a specialized crate controller which is compatible with the I/O bus or I/O port of a computer. This keeps the basic crate-module standard intact; hence any modules designed to the standard will be useable in the system. Such an approach simplifies the hardware, and minimizes overall system cost, particularly for a small number of crates.

In general, the CAMAC Standard is a very versatile modular data handling and interfacing system with many system options. Its applications include modular repetitive instrumentation for data acquisition, specialized instrumentation for process control, and interface packaging for standard peripherals, etc. An impressive array of commercial equipment in the CAMAC format has developed over the last few years including a wide assortment of data acquisition, control, and interfacing modules, as well as interfaces for many popular computers.

6. Computer I/O Standardization Efforts

Standardization of computer I/O bus structures would permit or at least facilitate interchangeability of peripherals. No standardization efforts in this area have as yet been successful, to this writer's knowledge. However, there is a proposal advanced in the ISO (International Standards Organization) by the Japanese, which defines a standard "channel level" interface. Figure 5 illustrates the area of standardization. Note that the channel interface is between the computer and a device controller, and that there may be many devices such as magnetic tape units, or disks on a controller. The channel type of interface is apparently more appropriate for large data processing computers, and its relation if any to minicomputer structures is not obvious. The standard is only logical in nature, and does not go into electrical compatibility.

The basic channel interface is byte parallel (8 bits + 1 parity bit) but extensions to 16, 32 and 64 bit parallel transfers are included. The channel is capable of handling up to 16 controllers, each capable of handling 16 devices. All operations over the channel are interlocked; e.g., handshake controlled. Of course the data flow is bi-directional.

Two modes of data transfer are described. In the burst mode, the controller remains connected to the channel once operation has been initiated, until all of the information bytes have been transferred. In the multiplex mode, a controller of which operation has already been initiated by the channel, requests to be connected to the channel before each transfer of an information byte.

For the basic interface (byte transfers) there are a total of 36 lines, but for the extended interface (2 byte, 4 byte, 8 byte) there are 56, 96, 176 lines respectively.

This proposal is currently being studied by a subcommittee of ANSI concerned with computer input/output standardization (ANSI X3-T9).

References

1. British Standard Interface

British Standard 4421:1969; "Specification for a Digital Input/Output Interface for Data Collection Systems".

2. RS-408 Byte Parallel Interface

RS-408, "Interface Between Numerical Control Equipment and Data Terminal Equipment Employing Parallel Binary Data Interchange", EIA Standard, March 1973.

3. Proposed IEC Bus

Nelson and Ricci: "A Practical Interface System for Electronic Instruments", HP Journal, October 1972.

Loughry: "A Common Digital Interface for Programmable Instruments: The Evolution of a System", HP Journal, October 1972.

IEC TC No. 66/WG3 (Preliminary Draft) "Standard Interface Systems for Programmable Measuring Apparatus", February 1973.

4. Bit Serial Interface

RS-232-C, "Interface Between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange", EIA Standard, August 1969.

5. CAMAC Standard

"CAMAC, A Modular Instrumentation System for Data Handling", USAEC TID-25875, July 1972 (Revised).

"CAMAC, Organization of Multi-Crate System", USAEC TID-25876, March 1972.

"CAMAC, Serial System Organization - A Description", USAEC TID-26488 December 1973.

6. Computer I/O Standardization Efforts

Japanese Proposal for an International Standard for an I/O Interface for Electronic Data Processing Systems (Logical Spec.), ISO/TC97/SC13 (Japan-1) Rev. 2, October 1972.

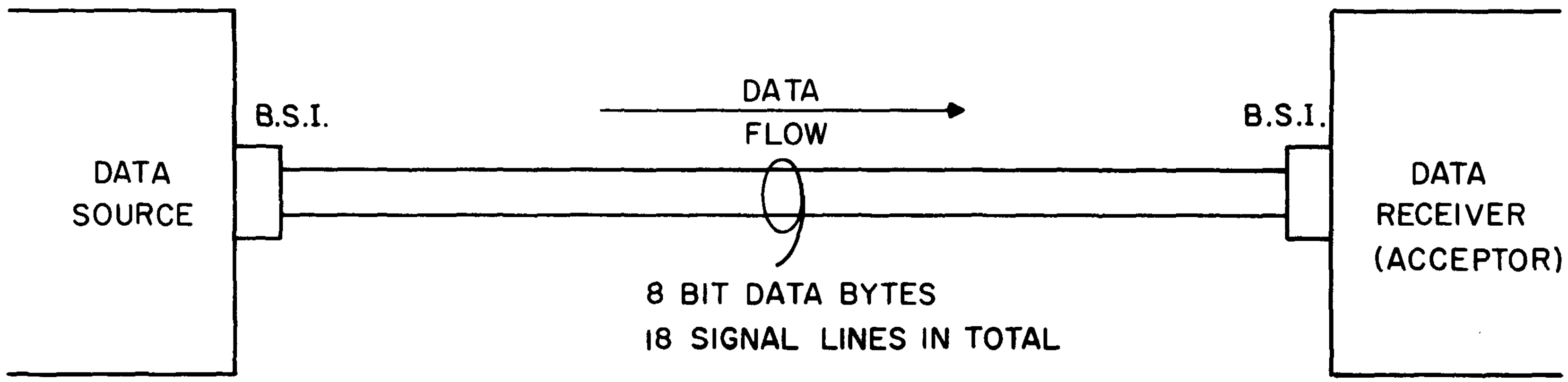

FIG. 1-BRITISH STANDARD INTERFACE

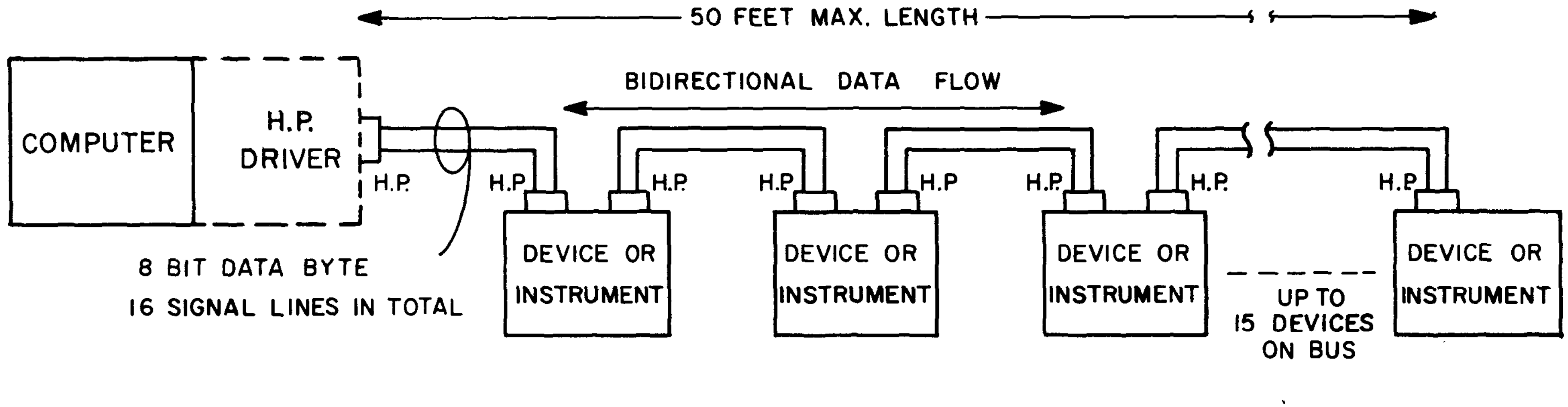

FIG. 2 - HEWLETT - PACKARD INTERFACE

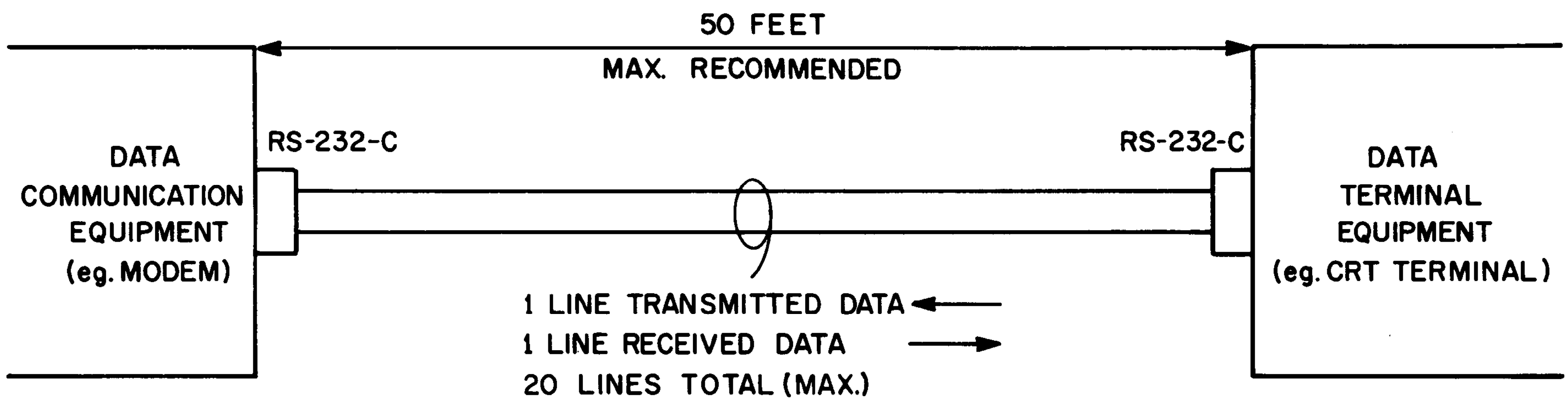

FIG. 3 - RS-232-C SERIAL INTERFACE STANDARD

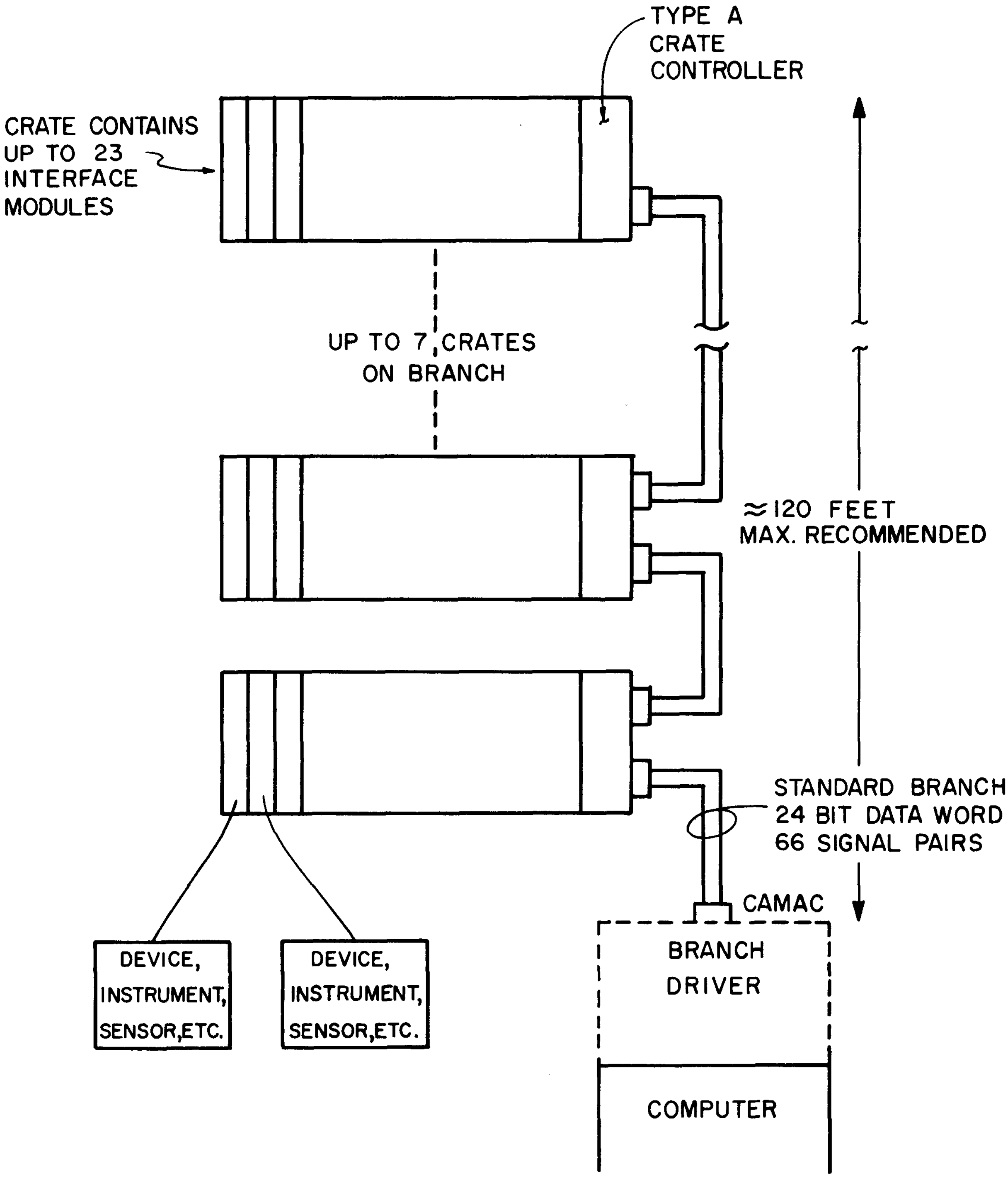

FIG. 4 - CAMAC STANDARD-PARALLEL BRANCH

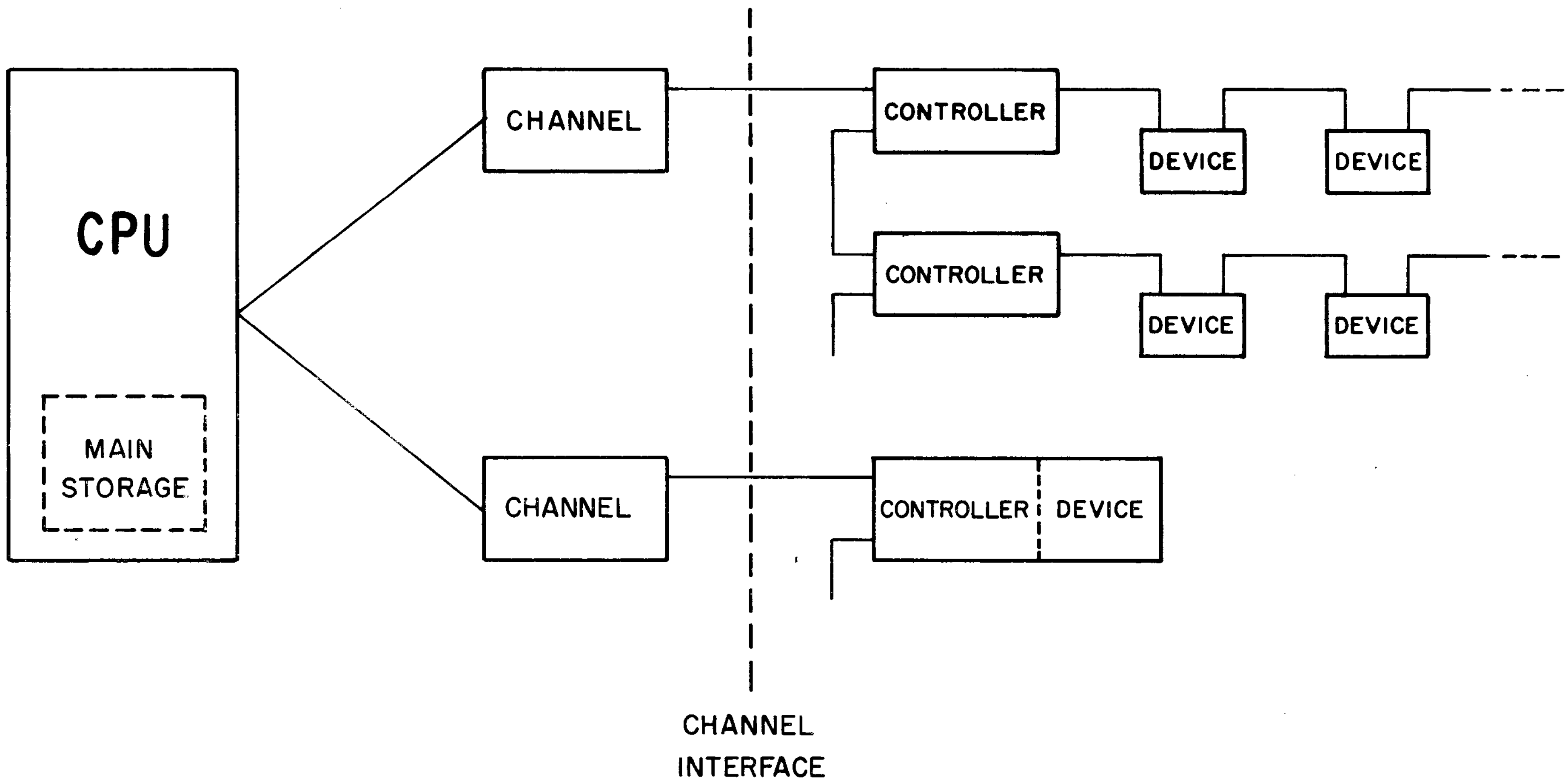

FIG. 5 – CHANNEL LEVEL INTERFACE