IEEE-488

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IEEE-488 is a short-range digital communications bus specification. It was created in the late 1960s for use with automated test equipment, and is still in use for that purpose. IEEE-488 was created as **HP-IB** (**Hewlett-Packard Interface Bus**), and is commonly called **GPIB** (**General Purpose Interface Bus**). It has been the subject of several standards.


IEEE-488 stacking connectors

Contents

Origins

In the late 1960s, Hewlett-Packard (HP)[1] was manufacturing various automated test and measurement instruments, such as digital multimeters and logic analyzers. They developed the *HP Interface Bus (HP-IB)* to enable easier interconnection between instruments and controllers (computers and other instruments).

The bus was relatively easy to implement using the technology at the time, using a simple parallel bus and several individual control lines. For example, the HP 59501 Power Supply Programmer and HP 59306A Relay Actuator were both relatively simple HP-IB peripherals implemented only in TTL, using no microprocessor.

HP licensed the HP-IB patents for a nominal fee to other manufacturers. It became known as the General Purpose Interface Bus (GPIB), and became a de facto standard for automated and industrial instrument control. As GPIB became popular, it was formalized by various standards organizations.

Standards

In 1975, the IEEE standardized the bus as *Standard Digital Interface for Programmable Instrumentation*, **IEEE-488**; it was revised in 1978 (producing IEEE-488-1978).[2] The standard was revised in 1987, and redesignated as **IEEE-488.1** (IEEE-488.1-1987). These standards formalized the mechanical, electrical, and basic protocol parameters of GPIB, but said nothing about the format of commands or data.

In 1987, IEEE introduced *Standard Codes, Formats, Protocols, and Common Commands*, **IEEE-488.2**. It was revised in 1992.[3] IEEE-488.2 provided for basic syntax and format conventions, as well as device-independent commands, data structures, error protocols, and the like. IEEE-488.2 built on IEEE-488.1 without superseding it; equipment can conform to IEEE-488.1 without following IEEE-488.2.

While IEEE-488.1 defined the hardware and IEEE-488.2 defined the protocol, there was still no standard for instrument-specific commands. Commands to control the same class of instrument, *e.g.*, multimeters, would vary between manufacturers and even models.

The United States Air Force,[4] and later Hewlett-Packard, recognized this problem. In 1989, HP developed their TML language[5] which was the forerunner to Standard Commands for Programmable Instrumentation (SCPI). SCPI was introduced as an industry standard in 1990.[6] SCPI added standard generic commands, and a series of instrument classes with corresponding class-specific commands. SCPI mandated the IEEE-488.2 syntax, but allowed other (non-IEEE-488.1) physical transports.

The IEC developed their own standards in parallel with the IEEE, with **IEC-60625-1** and **IEC-60625-2**, later replaced by IEC-60488.

National Instruments introduced a backward-compatible extension to IEEE-488.1, originally known as **HS-488**. It increased the maximum data rate to 8 Mbyte/s, although the rate decreases as more devices are connected to the bus. This was incorporated into the standard in 2003 (IEEE-488.1-2003),[7] over HP's objections.[8][9]

In 2004, the IEEE and IEC combined their respective standards into a "Dual Logo" IEEE/IEC standard **IEC-60488-1**, *Standard for Higher Performance Protocol for the Standard Digital Interface for Programmable Instrumentation - Part 1: General*,[10] replaces IEEE-488.1/IEC-60625-1, and **IEC-60488-2**,*Part 2: Codes, Formats, Protocols and Common Commands*,[11] replaces IEEE-488.2/IEC-60625-2.[12]

Characteristics

IEEE-488 is an 8-bit, electrically parallel bus. The bus employs sixteen signal lines — eight used for bi-directional data transfer, three for handshake, and five for bus management — plus eight ground return lines.

Every device on the bus has a unique 5-bit primary address, in the range from 0 to 30 (31 total possible addresses).[13][14]

The standard allows up to 15 devices to share a single physical bus of up to 20 meters total cable length. The physical topology can be linear or star (forked).[15] Active extenders allow longer buses, with up to 31 devices theoretically possible on a logical bus.

Control and data transfer functions are logically separated; a controller can address one device as a “talker” and one or more devices as “listeners” without having to participate in the data transfer. It is possible for multiple controllers to share the same bus; but only one can be the "Controller In Charge" at a time.[16]

In the original protocol, transfers use an interlocked, three-wire *ready–valid–accepted* handshake.[17] The maximum data rate is about one megabyte per second. The later HS-488 extension relaxes the handshake requirements, allowing up to 8 Mbyte/s. The slowest participating device determines the speed of the bus.[18]

Connectors

IEEE-488 specifies a 24-pin Amphenol-designed micro ribbon connector. Micro ribbon connectors have a D-shaped metal shell, but are larger than D-subminiature connectors. They are sometimes called "Centronics connectors" after the 36-pin micro ribbon connector Centronics used for their printers.

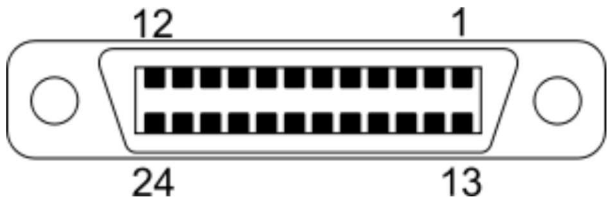
One unusual feature of IEEE-488 connectors is they commonly use a "double-headed" design, with male on one side, and female on the other. This allows stacking connectors for easy daisy-chaining. Mechanical considerations limit the number of stacked connectors to four or fewer, although a possible workaround involving physically supporting the connectors can expand this.

They are held in place by screws, either UTS (now largely obsolete) or metric M3.5×0.6 threads. By convention, metric screws are colored black, as the two threads do not mate.

The IEC-60625 standard prescribes the use of 25-pin D-subminiature connectors (the same as used for the parallel port on IBM-PCs). This connector did not gain significant market acceptance against the established 24-pin connector.

IEEE-488

Pin out



Female IEEE-488 connector

Pin 1	DIO1	Data input/output bit.
Pin 2	DIO2	Data input/output bit.
Pin 3	DIO3	Data input/output bit.
Pin 4	DIO4	Data input/output bit.
Pin 5	EOI	End-or-identify.
Pin 6	DAV	Data valid.
Pin 7	NRFD	Not ready for data.
Pin 8	NDAC	Not data accepted.
Pin 9	IFC	Interface clear.
Pin 10	SRQ	Service request.
Pin 11	ATN	Attention.
Pin 12	SHIELD	
Pin 13	DIO5	Data input/output bit.
Pin 14	DIO6	Data input/output bit.
Pin 15	DIO7	Data input/output bit.
Pin 16	DIO8	Data input/output bit.
Pin 17	REN	Remote enable.
Pin 18	GND	(wire twisted with DAV)
Pin 19	GND	(wire twisted with NRFD)
Pin 20	GND	(wire twisted with NDAC)
Pin 21	GND	(wire twisted with IFC)
Pin 22	GND	(wire twisted with SRQ)
Pin 23	GND	(wire twisted with ATN)

Capabilities

Function	Abbreviation	Description / Example
Source Handshake	SH	SH1 - complete
Acceptor Handshake	AH	AH1 - complete
Basic Talker	T	T5 - responds to serial poll; untalks when listen address received; talk only capability T6 - untalks when listen address received; no talk only T7 - no serial poll; untalks when listen address received; talk only capability
Extended Talker	TE	TE0 - no extended talker
Basic Listener	L	L3 - Listen only mode; unlistens if talk address received L4 - Unlistens if talk address received
Extended Listener	LE	LE0 - no extended listener
Service Request	SR	SR0 - no service request capability SR1 - complete
Remote-Local	RL	RL0 - no local lockout RL1 - complete
Parallel Poll	PP	PP0 - does not respond to Parallel Poll
Device Clear	DC	DC1 - complete
Device Trigger	DT	DT0 - no device trigger capability DT1 - complete
Controller	C	C0 - no controller function
	E	E1 - open collector drive electronics E2 - three state drivers

Pin 24	Logic ground

More information see Tektronix.[19]

Use as a computer interface

HP's designers did not specifically plan for IEEE-488 to be a peripheral interface for general-purpose computers; the focus was on instrumentation. But when HP's early microcomputers needed an interface for peripherals (disk drives, tape drives, printers, plotters, etc.), HP-IB was readily available and easily adapted to the purpose.

HP computer products which used HP-IB included the HP series 80, HP 9800 series,[20] the HP 2100 series,[21] and the HP 3000 series.[22] Some of HP's advanced pocket calculators of the 1980s, such as the HP-41 and HP-71B series, also had IEEE-488 capabilities, via an optional HP-IL/HP-IB interface module.

Other manufacturers adopted GPIB for their computers as well, such as with the Tektronix 405x line.

The Commodore PET (introduced 1977) range of personal computers connected their peripherals using the IEEE-488 bus, but with a non-standard card edge connector. Commodore's following 8-bit machines, including the VIC-20, C-64, and C-128, utilized a serialized version of the bus protocol. [23]

Eventually, faster, more complete standards such as SCSI superseded IEEE-488 for peripheral access.

Rear of the Commodore CBM-II showing card edge connector IEEE-488 port

Rear of the Commodore SFD 1001 floppy disk drive with IEEE-488 port

Rear of a Tektronix TDS 210 digital oscilloscope with IEEE-488 port

Rear view of an Agilent 34970A data acquisition chassis / multimeter

C64 interface

HP 7935 disc drive HP-IB Panel

Comparison with other interface standards

Electrically, IEEE 488 used a hardware interface that could be implemented with some discrete logic or with a microcontroller. The hardware interface enabled devices made by different manufacturers to communicate with a single host. Since each device generated the asynchronous handshaking signals required by the bus protocol, slow and fast devices could be mixed on one bus. The data transfer is relatively slow, so transmission line issues such as impedance matching and line termination are ignored. There was no requirement for galvanic isolation between the bus and devices, which created the possibility of ground loops causing extra noise and loss of data.

Physically, the IEEE-488 connectors and cabling were rugged and held in place by screws. While physically large and sturdy connectors were an advantage in industrial or laboratory set ups, the size and cost of the connectors was a liability in applications such as personal computers.

Although the electrical and physical interfaces were well defined, there was not an initial standard command set. Devices from different manufacturers might use different commands for the same function.[24] Some aspects of the command protocol standards were not standardized until Standard Commands for Programmable Instruments (SCPI) in 1990. Implementation options (e.g. end of transmission handling) can complicate interoperability in pre-IEEE-488.2 devices.

More recent standards such as USB, FireWire, and Ethernet take advantage of declining costs of interface electronics to implement more complex standards providing higher bandwidth. The multi-conductor (parallel data) connectors and shielded cable were inherently more costly than the connectors and cabling that could be used serial data transfer standards such as RS-232, RS-485, USB, FireWire or Ethernet. Very few mass-market personal computers or peripherals (such as printers or scanners) implemented IEEE 488.

See also

- Standard Commands for Programmable Instruments (SCPI)
- PCI eXtensions for Instrumentation (PXI)
- LAN eXtensions for Instrumentation (LXI)
- Virtual Instrument Software Architecture (VISA)
- HP series 80
- Rocky Mountain BASIC

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External links

- *IEC-60488-1: Higher performance protocol for the standard digital interface for programmable instrumentation* (http://webstore.iec.ch/webstore/webstore.nsf/artnum/032787). Part 1: General. International Electrotechnical Commission. 15 July 2004.
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