GPIB Tutorial

Bus History

The IEEE-488 bus was developed to connect and control programmable instruments, and to provide a standard interface for communication between instruments from different sources. Hewlett-Packard originally developed the interfacing technique, and called it HP-IB. The interface quickly gained popularity in the computer industry. Because the interface was so versatile, the IEEE committee renamed it GPIB (General Purpose Interface Bus).

IEEE-488 Overview

Almost any instrument can be used with the IEEE-488 specification, because it says nothing about the function of the instrument itself, or about the form of the instrument's data. Instead the specification defines a separate component, the interface, that can be added to the instrument. The signals passing into the interface from the IEEE-488 bus and from the instrument are defined in the standard. The instrument does not have complete control over the interface. Often the bus controller tells the interface what to do. The Active Controller performs the bus control functions for all the bus instruments.

System Controller & Active Controller

At power-up time, the IEEE-488 interface that is programmed to be the System Controller becomes the Active Controller in charge. The System Controller has several unique capabilities including the ability to send Interface Clear (IFC) and

Remote Enable (REN) commands. IFC clears all device interfaces and returns control to the System Controller. REN allows devices to respond to bus data once they are addressed to listen. The System Controller may optionally Pass Control to another controller, which then becomes Active Controller.

Listeners, Talkers and Controllers

There are 3 types of devices that can be connected to the IEEE-488 bus (Listeners, Talkers, and Controllers). Some devices include more than one of these functions. The standard allows a maximum of 15 devices to be connected on the same bus. A minimum system consists of one Controller and one Talker or Listener device (i.e., an HP 700 with an IEEE-488 interface and a voltmeter).

It is possible to have several Controllers on the bus but only one may be active at any given time. The Active Controller may pass control to another controller which in turn can pass it back or on to another controller. A Listener is a device that can receive data from the bus when instructed by the controller and a Talker transmits data on to the bus when instructed. The Controller can set up a talker and a group of listeners so that it is possible to send data between groups of devices as well.

Interface Signals

The IEEE-488 interface system consists of 16 signal lines and 8 ground lines. The 16 signal lines are divided into 3 groups (8 data lines, 3 handshake lines, and 5 interface management lines).

Data Lines

The lines DIO1 through DIO8 are used to transfer addresses, control information and data. The formats for addresses and control bytes are defined by the IEEE 488 standard. Data formats are undefined and may be ASCII (with or without parity) or binary. DIO1 is the Least Significant Bit (note that this will correspond to bit 0 on most computers).

Handshake Lines

The three handshake lines (NRFD, NDAC, DAV) control the transfer of message bytes among the devices and form the method for acknowledging the transfer of data. This handshaking process guarantees that the bytes on the data lines are sent and received without any transmission errors and is one of the unique features of the IEEE-488 bus.

The NRFD (Not Ready for Data) handshake line is asserted by a Listener to indicate it is not yet ready for the next data or control byte. Note that the Controller will not see NRFD released (i.e., ready for data) until all devices have released it.

The NDAC (Not Data Accepted) handshake line is asserted by a Listener to indicate it has not yet accepted the data or control byte on the data lines. Note that the Controller will not see NDAC released (i.e., data accepted) until all devices have released it.

The DAV (Data Valid) handshake line is asserted by the Talker to indicate that a data or control byte has been placed on the data lines and has had the minimum specified stabilizing time. The byte can now be safely accepted by the devices.

Handshaking

The handshaking process is outlined as follows. When the Controller or a Talker wishes to transmit data on the bus, it sets the DAV line high (data not valid), and checks to see that the NRFD and NDAC lines are both low, and then it puts the data on the data lines.

When all the devices that can receive the data are ready, each releases its NRFD (not ready for data) line. When the last receiver releases NRFD, and it goes high, the Controller or Talker takes DAV low indicating that valid data is now on the bus.

In response each receiver takes NRFD low again to indicate it is busy and releases NDAC (not data accepted) when it has received the data. When the last receiver has accepted the data, NDAC will go high and the Controller or Talker can set DAV high again to transmit the next byte of data.

Note that if after setting the DAV line high, the Controller or Talker senses that both NRFD and NDAC are high, an error will occur. Also if any device fails to perform its part of the handshake and releases either NDAC or NRFD, data cannot be transmitted over the bus. Eventually a time-out error will be generated.

The speed of the data transfer is controlled by the response of the slowest device on the bus, for this reason it is difficult to estimate data transfer rates on the IEEE-488 bus as they are always device dependent.

Interface Management Lines

The five interface management lines (ATN, EOI, IFC, REN, SRQ) manage the flow of control and data bytes across the interface.

The ATN (Attention) signal is asserted by the Controller to indicate that it is placing an address or control byte on the data bus. ATN is released to allow the assigned Talker to place status or data on the data bus. The Controller regains control by reasserting ATN; this is normally done synchronously with the handshake to avoid confusion between control and data bytes.

The EOI (End or Identify) signal has two uses. A Talker may assert EOI simultaneously with the last byte of data to indicate end-of-data. The Controller may assert EOI along with ATN to initiate a parallel poll. Although many devices do not use parallel poll, all devices should use EOI to end transfers (many currently available ones do not).

The IFC (Interface Clear) signal is asserted only by the System Controller in order to initialize all device interfaces to a known state. After releasing IFC, the System Controller is the Active Controller.

The REN (Remote Enable) signal is asserted only by the System Controller. Its assertion does not place devices into remote control mode; REN only enables a device to go into remote mode when addressed to listen. When in remote mode, a device should ignore its local front panel controls.

The SRQ (Service Request) line is like an interrupt: it may be asserted by any device to request the Controller to take some action. The Controller must determine which device is asserting SRQ by conducting a serial poll. The requesting device releases SRQ when it is polled.

Device Addresses

The IEEE-488 standard allows up to 15 devices to be interconnected on one bus. Each device is assigned a unique primary address, ranging from 0-30, by setting the address switches on the device. A secondary address may also be specified,ranging from 0-30. See the device documentation for more information on how to set the device primary and optional secondary address.

Physical Characteristics

You can link devices in either a linear, star or combination configuration using a shielded 24-conductor cable. The standard IEEE-488 cable has both a plug and receptacle connector on both ends. This connector is the Amphenol CHAMP or Cinch Series 57 MICRO RIBBON type. Special adapters and nonstandard cables are available for special interconnect applications.

The IEEE-488 bus specifies a maximum total cable length of 20 meters with no more than 20 devices connected to the bus and at least two-thirds of the devices powered on. A maximum separation of 4 meters between devices and an average separation of 2 meters over the full bus should be followed. Bus extenders and expanders are available to overcome these system limits.

The bus uses standard TTL level negative logic. When NRFD is true for example it is a TTL low level, and when NRFD is false, it is a TTL high level.

Summary

The IEEE-488.1 standard greatly simplified the interconnection of programmable instruments by clearly defining mechanical, hardware, and electrical protocol specifications. For the first time, instruments from different manufactures were connected by a standard cable. This standard does not address data formats, status reporting, message exchange protocol, common configuration commands, or device specific commands.

The IEEE-488.2 standard enhances and strengthens the IEEE-488.1 standard by specifying data formats, status reporting, error handling, controller functionality, and common instruments commands. It focuses mainly on the software protocol issues and thus maintains compatibility with the hardware- oriented IEEE-488.1 standard. IEEE-488.2 systems tend to be more compatible and reliable.