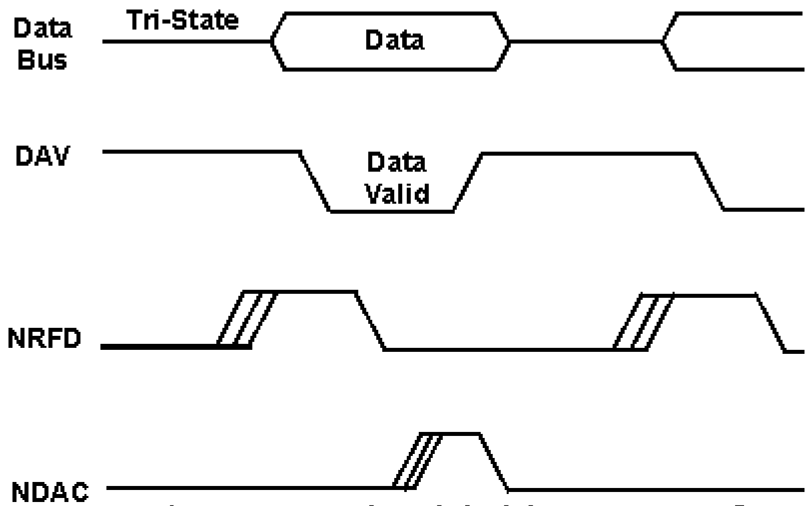
HANDSHAKING

The IEEE-488 bus uses three handshake lines in a “We're ready - Here's the data - We've got it” sequence to transfer information across the data bus. The handshake protocol assures reliable data transfer at the rate determined by the slowest Listener. The handshake lines, like all other IEEE-488 lines, are active low. DAV is controlled by the Active Talker. Before sending any data, the Talker verifies that NDAC is asserted (low) which indicates that all Listeners have accepted the previous data byte. The Talker then places a byte onto the data lines and waits until NRFD is unasserted (high), indicating that all Addressed Listeners are ready to accept the information. When NRFD and NDAC are in the proper state, the Talker asserts DAV (active low) to indicate that the data on the bus is valid. NRFD is used by the Listeners to inform the Talker that they are ready to accept the new data. The Talker must wait for each Listener to unassert this line (high), which they do at their own rates when they are ready for more data. This assures that all devices accepting the information are ready to receive it. NDAC, also controlled by the Listeners, indicates to the Talker that each device addressed to listen has accepted the information. Each device releases NDAC (high) at its own rate, but NDAC does not go high until the slowest Listener has accepted the data byte. This type of handshaking permits multiple devices to receive data from a single data transmitter on the bus. All active receiving devices participate in the data handshaking on a byte-by-byte basis and operate the NDAC and NRFD lines in a “wired-or” scheme so that the slowest active device determines the rate at which the data transfers take place.

GPIB operation

The operation of GPIB is based around the handshaking protocol. Three lines, DAV (DAta Valid), NDAC (Not Data ACepted), and NRFD (Not Ready For Data), control this. All the listeners on the bus use the NRFD line to indicate their state of readiness to accept data. If one listener holds the line low then this prevents any data transfer being initiated. This means that when all the instruments are ready as indicated by the NRFD being line is high and then data can be transferred. Once all the instruments have released the NRFD line and it is in the high state, only then can the next stage be initiated.

Data is placed onto the data lines by the talker and once this has settled, the DAV line is pulled low. This signals to all the listeners that they are able to read the data that is present. During this operation the NDAC line will be held low by all the active listeners, i.e. those which have been instructed to receive the data. Only when they have read the data will each device stop trying to hold this line low. When the last device removes its hold, the level of the line will rise and the talker will know that all the data has been accepted and the next byte of data can be transferred.



GPIB / IEEE 488 handshaking protocol

By transferring data in this way the data is placed onto the bus at a rate which is suitable for the talker, and it is held until the slowest listener has accepted it. In this way the optimum data transfer rate is always used, and there are no specifications and interface problems associated with the speeds at which data must be transferred.

IEEE 488 bus management

In addition to the comprehensive handshaking system, the GPIB also incorporates a number of very useful bus management facilities, enabling the instruments on the bus to be controlled in a very flexible manner.

Each instrument has its own address. This enables the controller or talker to talk to a specific piece of equipment. It is obviously imperative that each piece of equipment has its own unique address on the bus. If not bus conflicts occur and the operation of the system will crash.

Often different types of instrument have their own default values set for GPIB at the factory during manufacture. However in all cases it must be possible to change the GPIB address either by changing switches on the outside of the equipment or the inside. Even though only fifteen units are allowed on the bus at any one time, addresses up to 31 are allowed. This enables a certain amount of flexibility in defining specific addresses for certain types of equipment within an organisation.

Within the GPIB there are a number of lines that are dedicated to signalling and control on the bus:

1. ***Attention, ATN line:*** One of the most important lines is the ATN (Attention) line. Using this the controller is able to signal whether the data to be placed onto the data lines is control information or data. When the line is pulled low then the bus is said to be in command mode and bus commands may be placed onto the bus. These commands are the same for all bus systems and each device is programmed to respond to any commands that have a useful or applicable meaning. One of the most common bus commands is to give the address of an instrument to which data is about to be sent. In addition to this when the line is pulled low it causes any talker to relinquish its control of the DAV line and cease its data transmission. Another result is that all listeners whether active or not will listen to the control data being transmitted.

   When the ATN line is high the bus is said to be in data mode and data transfers between the instruments can take place. In command mode not all the data lines are used. Bit seven is ignored, whilst bits five and six indicate the type of information to be transmitted. It may be a bus command, a talk address, or a listen address.

2. ***Interface Clear, IFC;*** The IFC line is used by the controller to reset the bus and place it into its quiescent state. Any talker or listener which is active is stopped and control is returned to the controller. This is not used in the course of normal operation. However it can be used when the

system needs re-setting or at initial power up when the bus may be in a random state.

3. ***Remote Enable, REN:*** Remote enable (REN) is a function that is used by the controller to set instruments on the bus to local i.e. front panel control or to bus control. Bus controlled instruments may be returned to their local state by a go to local message sent in conjunction with the ATN line being pulled low.

4. ***End or Identify, EOI:*** End or Identify (EOI) is an optional GPIB function used to signify the end of a multiple byte data transfer. As an alternative, talkers can use a carriage return or carriage return line feed to terminate the message. This can then be interpreted by the controlled dependent upon how its software is configured.

5. ***Service Request, SRQ*** The next control line is SRQ or service request. Any device fitted with this function can pull the service request line low. When this happens it indicates that it wants to interrupt the current activities so that attention can be given to a particular event. One instance where this facility is needed is when a printer runs out of paper, or in another instance, an instrument may be overloaded or "over-ranged". Once the SRQ line has been pulled low, the controller then has to identify which instrument has caused the interrupt. A process called polling accomplishes this. Essentially this just requests status information from the devices on the bus.

Each of these lines provides an important function on the line. Having dedicated lines for these functions ensures that the handshaking on the interface is swift and does not have to rely on embedded messages that would take longer to action.

GPIB Polling

There are two ways in which instruments on GPIB can be polled. One is called parallel polling and the other is serial.

Parallel polling can only operate with up to eight instruments. This is because each of the devices will return a status bit one of the eight data lines. To assert a parallel poll the controller pulls the ATN and EOI lines low. When this occurs each instrument responds by transmitting a one-bit status report.

A serial poll is more flexible but takes longer to accomplish. Here the controller sends each of the instruments a serial poll enable command in turn. This is one of the GPIB commands that can be sent when the ATN line is held low. When an instrument receives a serial poll enable it responds by returning eight bits of status information. When the controller has received the status data it sends a serial poll disable command and returns the bus and instruments on it to the normal data mode.

The advantage of a serial poll is that it is far more flexible and enables eight bits of data to be returned. However it is much slower because each instrument has to be polled in turn to find out which one pulled the SRQ line in the first place.

By Ian Poole

Handshake Lines

The three handshake lines, DAV, NRFD, and NDAC, are used to transfer bytes over the data lines from the Talker to one or more addressed Listeners.

Before data is transferred, all three lines must be in the proper state. The active Talker controls the DAV line and the Listener(s) control the NRFD and NDAC lines. The handshake process allows for error-free data transmission. The handshake lines are described below.

Table 3-3: GPIB Handshake Lines

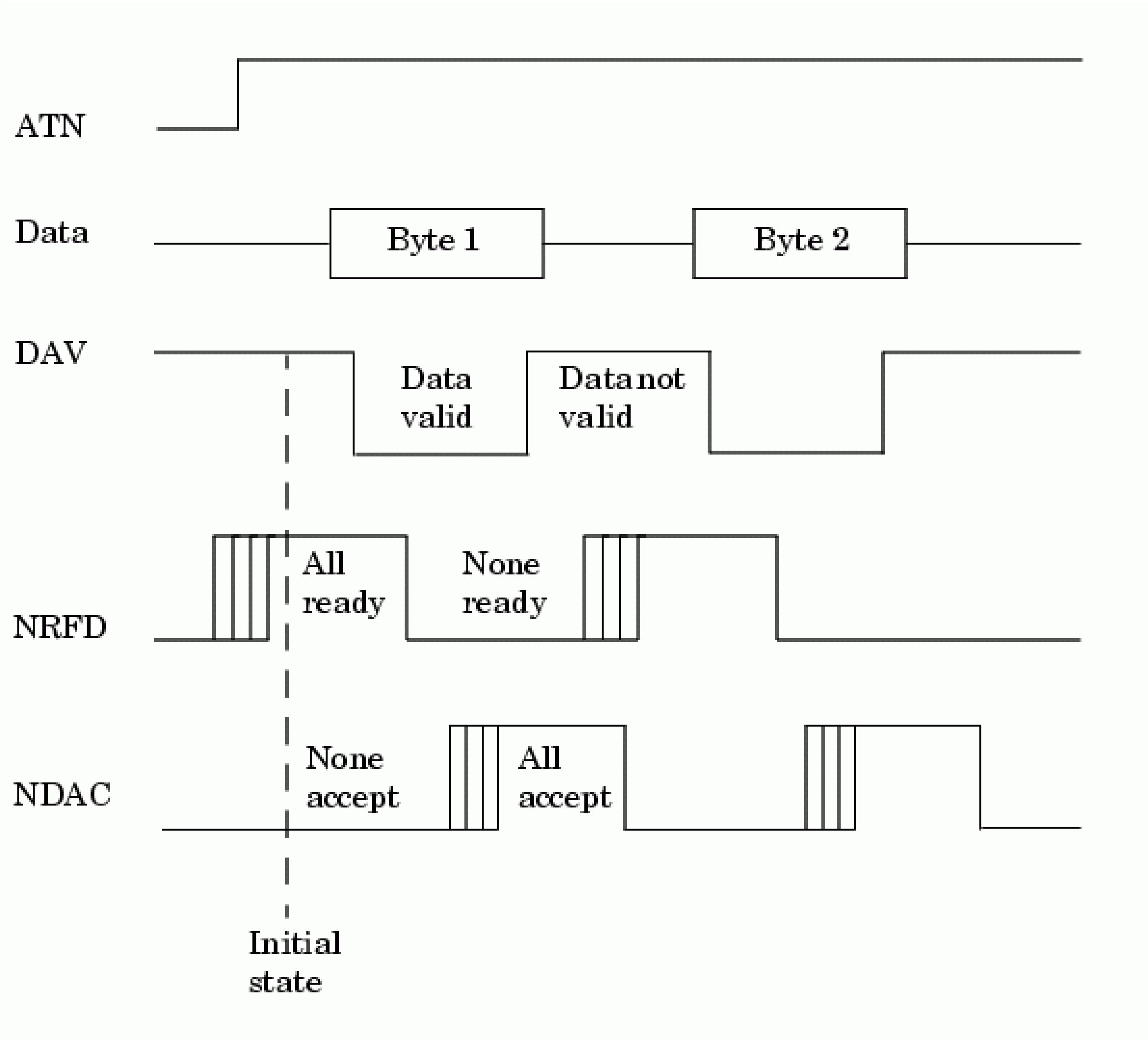
Line	Description
DAV	Used by the Talker to indicate that a byte can be read by the Listeners.
NRFD	Indicates whether the Listener is ready to receive the byte.
NDAC	Indicates whether the Listener has accepted the byte.

The handshaking process follows these steps:

1. Initially, the Talker holds the DAV line high indicating no data is available, while the Listeners holds the NRFD line high and the NDAC line low indicating it is ready for data and no data is accepted, respectively.
2. When the Talker puts data on the bus, it sets the DAV line low, which indicates that the data is valid.
3. The Listeners set the NRFD line low, which indicates that they are not ready to accept new data.
4. The Listeners set the NDAC line high, which indicates that the data is accepted.
5. When all Listeners indicate that they have accepted the data, the Talker asserts the DAV line indicating that the data is no longer valid. The next byte of data can now be transmitted.
6. The Listeners hold the NRFD line high indicating they are ready to receive data again, and the NDAC line is held low indicating no data is accepted.

> **Note** If the ATN line is high during the handshaking process, the information is considered data such as an instrument command. If the ATN line is low, the information is considered a GPIB interface message.

The handshaking steps are shown below.



You can examine the state of the handshake lines with the HandshakeStatus property.

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 and 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).

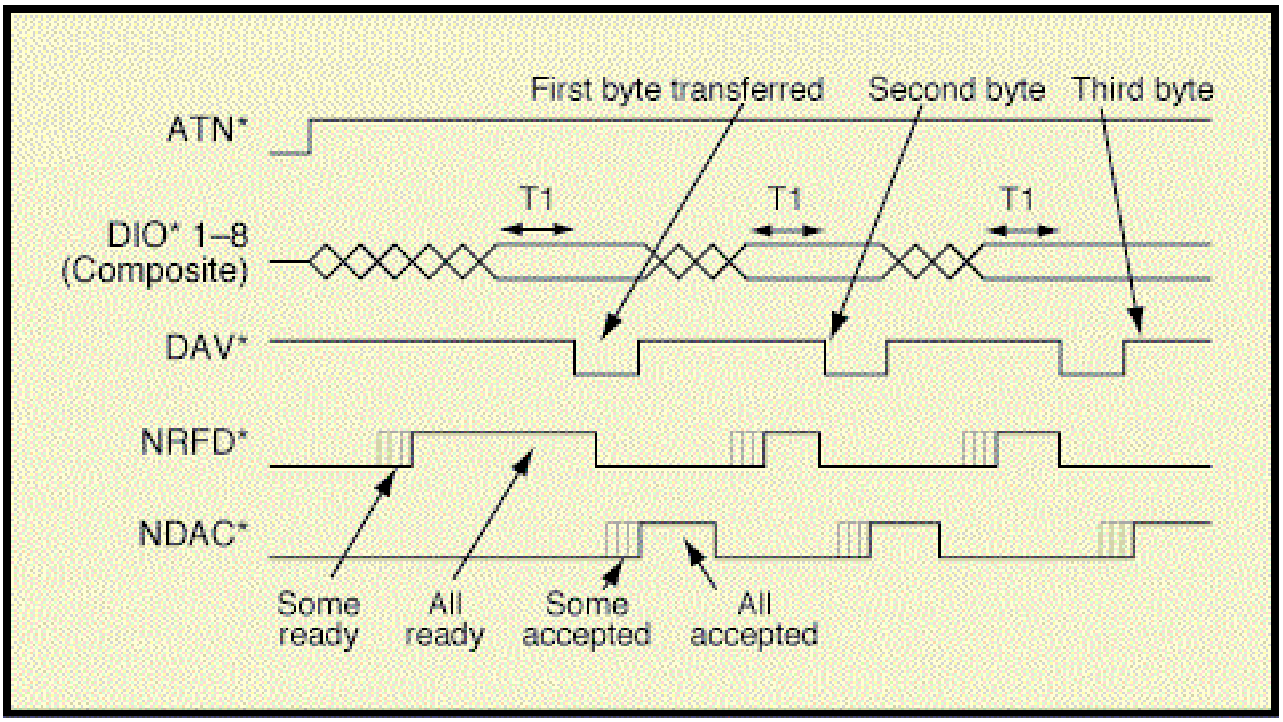


Fig. 2 IEEE 488.1 Handshake

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 timeout 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.

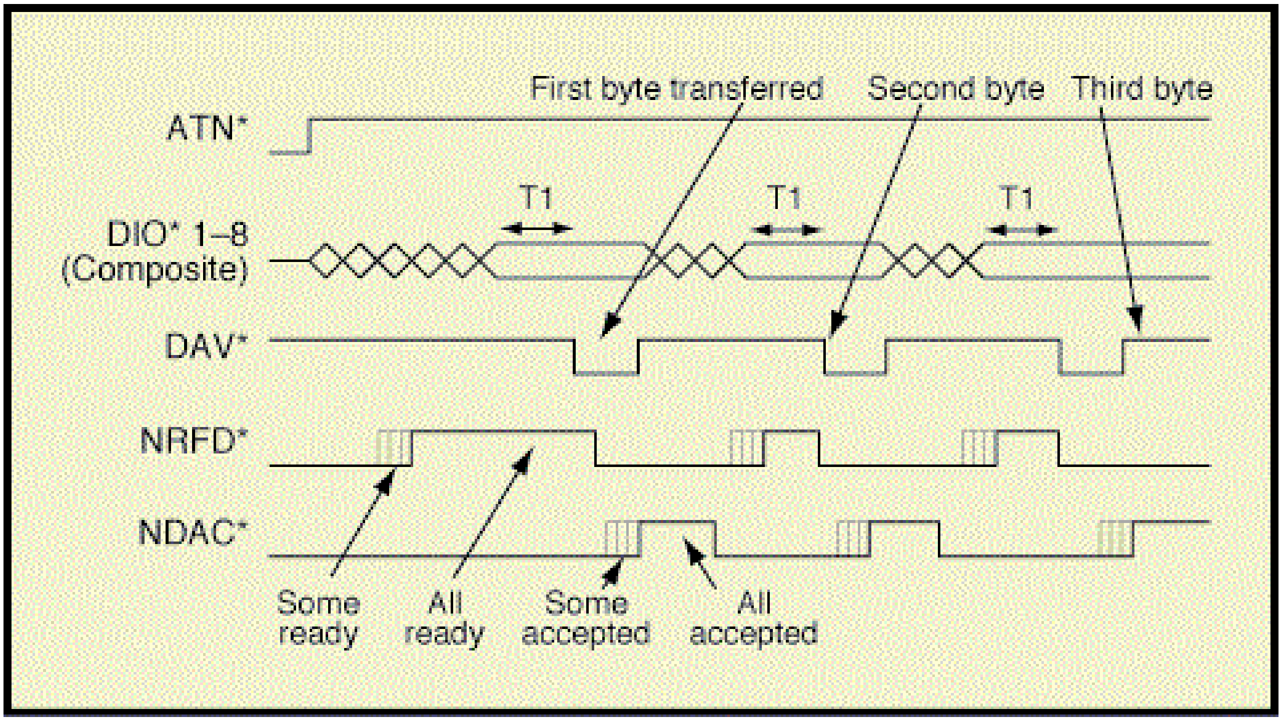


Fig. 2 IEEE 488.1 Handshake

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

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.