APPLICATION NOTE 292-1
DATA DOMAIN MEASUREMENT SERIES

Functional Analysis of the IEEE-488 Interface Bus

HEWLETT PACKARD

INTRODUCTION

HP-IB is the Hewlett-Packard implementation of IEEE Standard 488-1978. The HP Model 10066A HP-IB Probe Interface provides a convenient means of connecting an HP 1610A/B or HP 1615A Logic Analyzer to the HP-IB for monitoring and analyzing activity in an HP-IB system. This application note describes the use of the 10066A HP-IB Probe Interface in monitoring data transactions and handshake sequences on the bus.

The 10066A provides both designers and users of HP-IB systems a convenient method of monitoring transactions on the HP-IB. The 10066A and a logic analyzer can help the designer to verify correct implementation of HP-IB functions in HP-IB interfaces and software drivers, and correct responses to device dependent commands. During system integration and operation, the 10066A can be used to verify proper address sequencing and to troubleshoot problems caused by invalid commands and data transfers across the bus.

In addition to verifying that the correct commands and data are being transmitted across the bus, the 10066A and logic analyzer can monitor an HP-IB for abnormal handshake sequences. This is a valuable aid to the designer, whether he's designing a sofeware driver for the bus or an HP-IB hardware interface. Although not all abnormal handshakes will crash a system, they should be eliminated as they do represent potential problems. The abnormal handshake that causes no problems in the development environment may crash a user's system which has a different controller or has multiple instruments on the bus. The combination of the 1615A and 10066A allows the user of an HP-IB system to troubleshoot handshake problems that appear during system integration and problems caused by hardware failures during normal system operation.

Appendix A describes an HP 9825A Desktop Computer HP-IB control program written for the 1615A Logic Analyzer with HP-IB and 10066A HP-IB Probe Interface. The program reads the trace list data acquired from the monitored HP-IB system and displays the data in easily interpreted HP-IB command mnemonics and ASCII characters. Appendix B provides HP-IB message decoding tables to aid in manually decoding the logic analyzer trace lists.

THE HP-IB

The HP-IB employs a 16-line bus to interconnect up to 15 instruments. Each instrument on the bus is connected in parallel to the 16 lines of the bus. Eight of the lines are used to transmit data and the remaining eight are used for data transfer control (handshake) and bus management. Data is transferred by means of an interlocked "handshake", permitting asynchronous communication over a wide range of data rates.

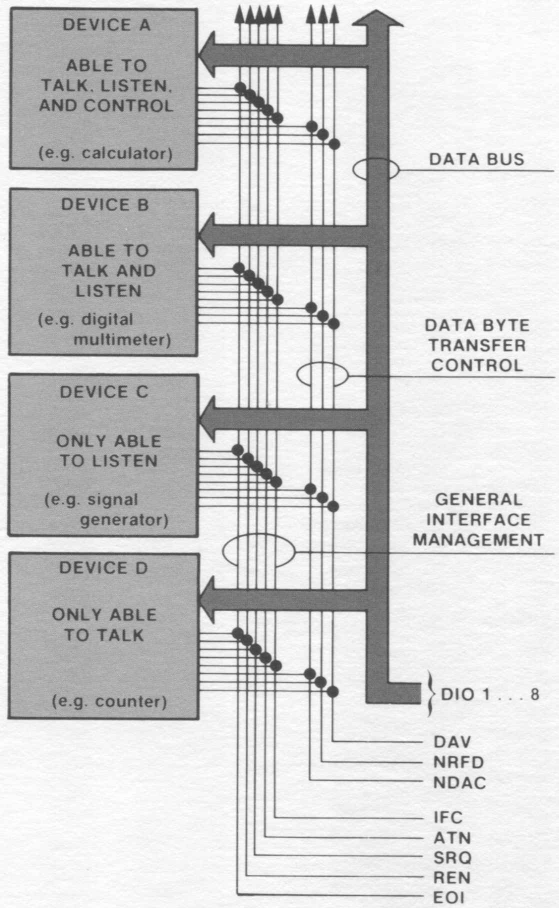


Figure 1. HP-IB interface capabilities and bus structure.

The HP-IB structure is diagrammed in figure 1. Four types of devices may be used on the bus based on their functions: (1) devices only able to talk, (2) devices only able to listen, (3) devices able to talk and listen, and (4) devices able to talk, listen, and control.

The simplest instrument is one that only talks. When signalled, this device enters its output on the data bus lines in a fixed configuration. The configuration may be altered only by front panel control.

Devices that only listen respond to data from the HP-IB data lines. In the case of a signal generator, this data could cause the instrument to output signals of different amplitude and frequency, external to the bus. Printers are frequently listen only instruments.

A digital multimeter is a device that listens and talks. The multimeter is configured by signals from the controller, takes the requested reading, and returns the results on the bus.

The controller, along with talk and listen capabilities, controls all operations on the interface bus.

As shown in figure 1, the 16 lines of the HP-IB form three functional groups: five lines for interface management, three lines for handshake (data byte transfer) control, and eight bidirectional lines for carrying data.

INTERFACE MANAGEMENT LINES

1. Attention (ATN) specifies how data on the data input/output (DIO) lines are to be interpreted, and by which devices. ATN is pulled low for commands and released for data by the controller.
2. Interface Clear (IFC) puts the entire system into a predefined quiescent state.
3. Service Request (SRQ) is used by a device to indicate the need for attention and to request an interruption of the current sequence of events.
4. Remote Enable (REN) in conjunction with other messages selects between alternate sources of device programming data (typically HP-IB vs front panel).
5. End or Identify (EOI) indicates the end of a multiple byte transfer sequence, or, with ATN executes a polling sequence.

When ATN is low (TRUE), the HP-IB is in Command Mode. In command mode the controller is active and all other devices are waiting for instructions. Command Mode instructions which can be issued by the controller fall into five groups:

a. Talker Address Group (TAG) commands enable a specific device to talk. Only one device at a time may act as the talker. When the controller addresses one device to talk, the previous talker is automatically unaddressed and ceases to be a talker.

b. Listener Address Group (LAG) commands enable a specific device to listen. Up to 14 devices at a time may be listeners.

c. Universal Command Group (UCG) commands cause all bus devices capable of responding to these commands from the controller to do so at any time regardless of whether they are addressed.

d. Addressed Command Group (ACG) commands are similar to universal commands except that they are recognized only by devices that are addressed as listeners.

e. Secondary Command Group (SCG) commands are used when addressing extended listeners and talkers, or enabling the parallel poll.

The Unlisten Address Command (UNL) unaddresses all listeners that have been previously addressed to listen. The Untalk Address Command (UNT) unaddresses any talker that had been previously addressed to talk.

HANDSHAKE LINES

1. Data Valid (DAV) indicates the availability and validity of information on the DIO lines.
2. Not Ready For Data (NRFD) indicates the state of readiness of devices to accept data.
3. Not Data Accepted (NDAC) indicates the condition of acceptance of data by device(s).

The DAV, NRFD, and NDAC signal lines operate in a three-wire interlocked handshake process to transfer each data byte across an interface (figure 2).

A handshake sequence is entered with the listener-controlled NRFD and NDAC both low. Line DAV is high. As each listener is ready to accept data, it releases its Not Ready For Data (NRFD) line. When all listeners have released the NRFD line, pull-up resistors on the line pull NRFD high. The talker signals new Data Valid by pulling the DAV line low. Listeners respond by pulling their NRFD outputs low. During the period that listeners accept data, they release the Not Data Accepted (NDAC) line. When data has been accepted by all the listeners, the NDAC line goes high. Acknowledgment by the talker releases the DAV line, and the handshake is completed by the listeners by pulling the NDAC low. A legal handshake must proceed in the manner shown in figure 2. Note that the NRFD and NDAC lines may never go high (logic 0) together.

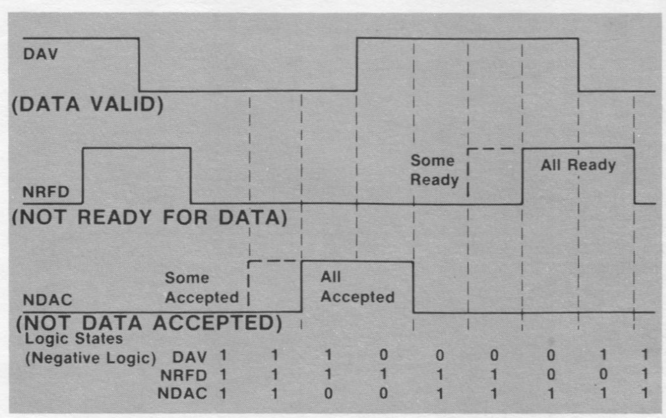


Figure 2. HP-IB Handshake Sequence.

HOOKING UP TO THE IEEE 488 BUS

The HP 10066A HP-IB Probe Interface (figure 3) obtains its inputs through a cable which connects directly into a piggyback connector on the HP-IB. The 10066A has five probe pod connectors for quick hookup of the logic analyzer. Simply plug logic analyzer data pods 3, 2, and 1 into the three connectors labeled POD 3, POD 2, and POD 1. When using a 1610, leave data pod 4 unconnected; it is not needed for bus monitoring.

Two clock pod connectors are provided on the 10066A, one for the 1610B and 1615A logic analyzers and one for the 1610A logic analyzer. Connect the logic analyzer clock probe to the appropriate connector for

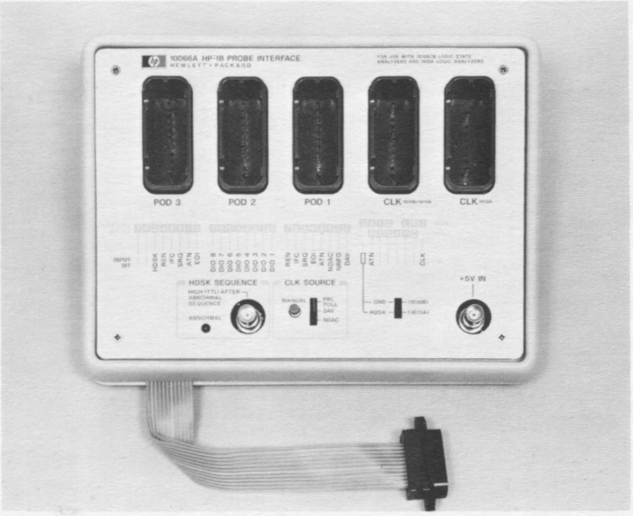


Figure 3. The 10066A HP-IB Probe Interface makes connecting a logic analyzer to the HP-IB easy.

your instrument. The CLK SOURCE switch of the 10066A allows selection of either NDAC, DAV, or a Parallel Poll as the logic analyzer clock. The falling edge of DAV clocks the logic analyzer when information on the data lines is valid (source handshake). The rising edge of NDAC clocks the logic analyzer when the last listener signals that data has been accepted (accepter handshake). The rising edge of PRL POLL clocks the logic analyzer at the end of each parallel poll. This allows the logic analyzer to monitor the listener status on the DIO lines during a parallel poll.

The 10066A requires a +5V power source to drive the interface circuitry. The 1610 logic analyzer and 1615A logic analyzers with serial prefixes of 1905A or higher have a +5V output on the rear panel. This output can be connected to the 10066A through a BNC cable.

By controlling the logic analyzer itself via the HP-IB, the HP-IB transactions monitored by the logic analyzer can be processed by a controller and the information presented in a format more easily interpreted by the user. In the measurement examples shown in this application note, all trace displays are generated by an HP-IB disassembly program executed on an HP 9825A Desktop Computer. Using software lookup tables, the program converts the 1's and 0's monitored by the logic analyzer probes into HP-IB command mnemonics and ASCII characters which are easily interpreted by the user. A comparison of a standard 1615A trace list against the corresponding HP-IB disassembly list is shown in figure 4.

A diagram showing the HP-IB measurement system setup used in the examples described in this applicaton note is shown in figure 5. The optional printer and plotter enable documentation of measurements.

MONITORING AND TROUBLESHOOTING THE BUS

The first step in viewing activity on the bus is setting up the logic analyzer format specification menu. With the 1615A, select [16 BIT & 8 BIT] mode. This allows

TRACE LIST
LISTEN
[16 BIT]

LINE NO.	A DEC	B BIN
000	213	001101
001	047	001101
002	083	001111
003	066	001111
004	049	001111
005	063	001111
006	013	001111
007	010	001111
008	063	001101
009	053	001101
010	207	001101
011	000	101110
012	063	001101
013	213	001101
014	047	001101

STANDARD 1615A TRACE LIST

REMOTE LISTEN
HP-IB DISASSEMBLY LIST
DATA*

LINE NO.	ATN	MNEM.	DEC	EOI	SRQ	IFC	REN	HSK
000	ATN	TAG21	213				REN	
001	ATN	LAG15	047				REN	
002		S	083				REN	
003		B	066				REN	
004		1	049				REN	
005		?	063				REN	
006		CR	013				REN	
007		LF	010				REN	
008	ATN	UNL	063				REN	
009	ATN	LAG21	053				REN	
010	ATN	TAG15	207				REN	
011		NUL	000	EOI			REN	ERR
012	ATN	UNL	063				REN	
013	ATN	TAG21	213				REN	
014	ATN	LAG15	047				REN	

1615A HP-IB DISASSEMBLY LIST

Figure 4. Postprocessing by an HP-IB controller enables measurement data to be displayed in a format more readily interpreted than the standard 1615A trace list.

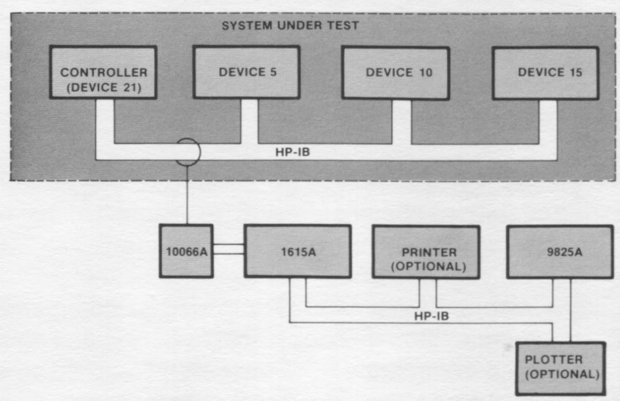


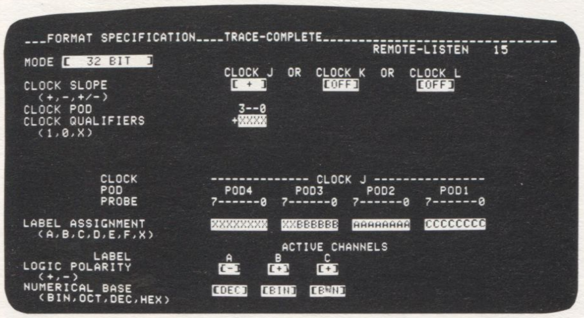
Figure 5. Measurement setup for monitoring an HP-IB system with a 1615A Logic Analyzer controlled by an HP 9825A Desktop Computer.

viewing of the abnormal Handshake signal, bus management (control) lines, and data lines on the state list and handshake and management lines on the timing diagram. The HP-IB uses negative logic on the data lines, requiring Pod 2 logic polarity to be set to [−]. The clock slope should be set to [+]. The 10066A inverts DAV so that [+] clock slope can be used for all CLK SOURCE selections. Recommended format specification menus for both the 1610B and 1615A are shown in figure 6.

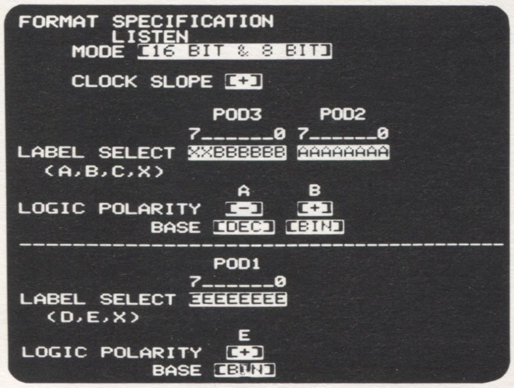
MONITORING DATA TRANSFERS

The simplest measurement to make on the bus is to trace data transactions. Setting the 10066A CLK

SOURCE switch to NDAC and executing a trace measurement causes the logic analyzer to capture any activity happening on the bus. Looking at the disassembly list (figure 7), we can readily ascertain what happened on the bus. On line 000, an Unlisten command (UNL) is shown asserted on the bus, clearing



1610A FORMAT SPECIFICATION MENU



1615A FORMAT SPECIFICATION MENU

Figure 6. The format specification menu allows the logic analyzer to be configured for compatibility with the HP-IB.

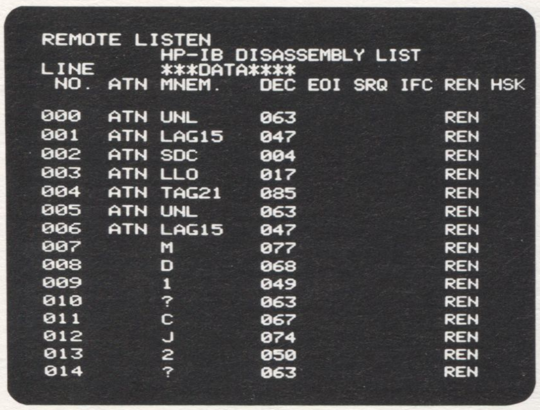


Figure 7. Disassembled display of a 1615A trace list of HP-IB activity collected with a "don't care" trace specification. The first transaction on the bus is the trigger word.

the bus of all listeners. Line 001 shows device 15 being addressed as the current listener followed by Selected Device Clear (SDC) and Local Lockout (LLO) commands. Next, device 21 is again addressed as talker, an Unlisten command is again asserted, and device 15 is addressed to listen. Device 21 then transmits a data string to device 15 (beginning at line 007). In this manner, the monitored data can be examined, showing exactly what occurred across the bus.

LOOKING AT COMMANDS ONLY

The ATN signal can be used as a clock qualifier to look at HP-IB commands only (figure 8). This allows you to obtain an overview of bus activity without sorting through long lists of data transfers (figure 9). Using the OR'ed "TRACE ONLY" terms on the 1610 Trace Specification Menu (figure 10), the 1610 can trace only TAG and LAG commands, viewing only the talk and listen commands on the bus (figure 11) or trace only commands in any other HP-IB command group.

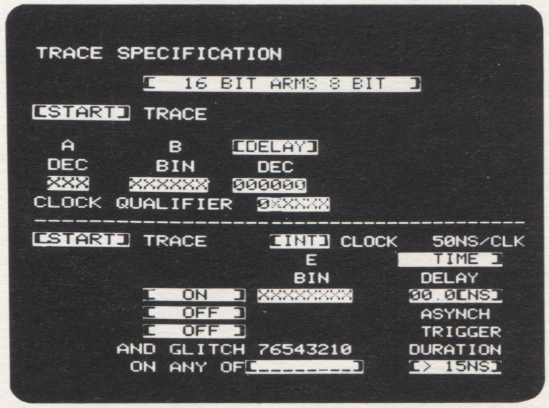


Figure 8. By qualifying the 1615A clock with ATN, only HP-IB commands are strobed into the logic analyzer trace memory.

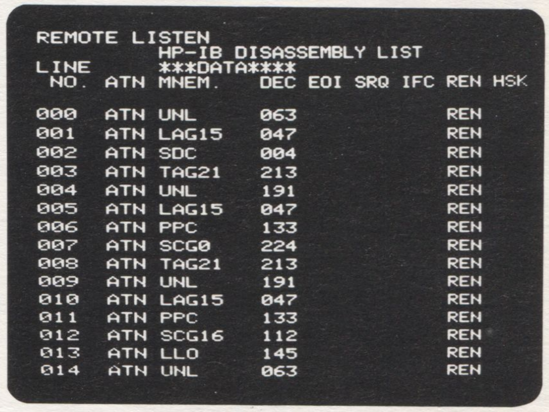


Figure 9. Trace list resulting from trace specification of figure 8 showing overview of bus commands.

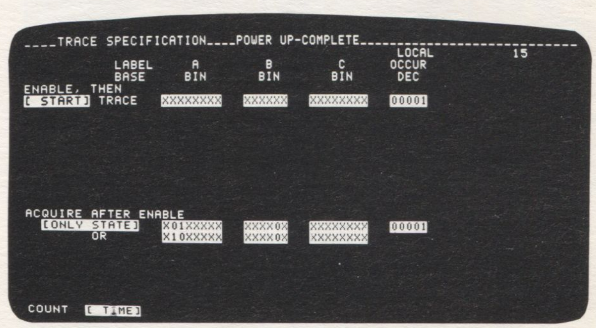


Figure 10. The 1610 can be configured to trace only specific commands using the OR'ed "trace only" terms on the 1610 trace specification menu.

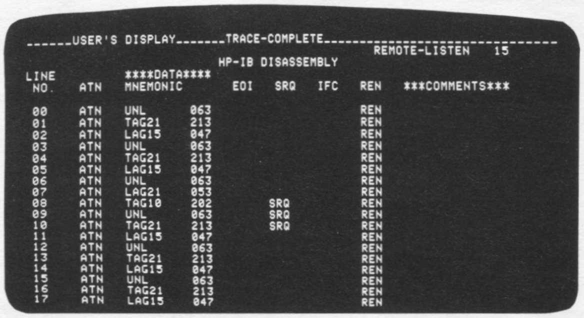


Figure 11. 1610 trace list resulting from the trace specification of figure 10 containing only activity in the talk and listen address command groups.

TRACING SPECIFIC INSTRUMENT TRANSACTIONS

Attention (ATN) is a versatile qualifier to use when viewing activity on the bus. ATN is used to control the bus mode. If ATN is true (low), the bus is in command mode; if ATN is false (high), the bus is in data mode. A measurement frequently needed on a bus is to monitor commands addressed to a specific device or replies from a specific device to verify that the device is functioning properly. Assume one wants to monitor transactions between device 21 (talker) and device 15 (listener). This is easily accomplished using the sequential triggering capability of the 1610B and enabling the logic analyzer on TAG21 (085_{10} and ATN), and triggering the logic analyzer on LAG15 (047_{10} and ATN) as shown in figure 12. The "Don't Care" sequence restart term ensures that data will be captured only after TAG21 immediately followed by LAG15 is detected. Executing a trace measurement results in a trace list beginning at the point device 21 is addressed to talk and device 15 is addressed to listen (figure 13).

In a similar manner, the logic analyzer can be triggered by any HP-IB command in the Addressed Command Group (ACG), Universal Command Group (UCG), Listen Address Group (LAG), Talk Address Group (TAG), or Secondary Command Group (SCG).

MONITORING INSTRUMENT STATUS

When implemented in a system, parallel polling permits the status of up to eight devices on the HP-IB to

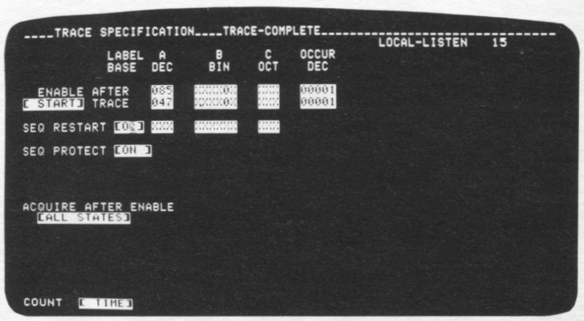


Figure 12. This specification configures the 1610A to start data collection when 85_{10} (TAG21) immediately followed by 47_{10} (LAG15) is asserted on the bus with ATN true.

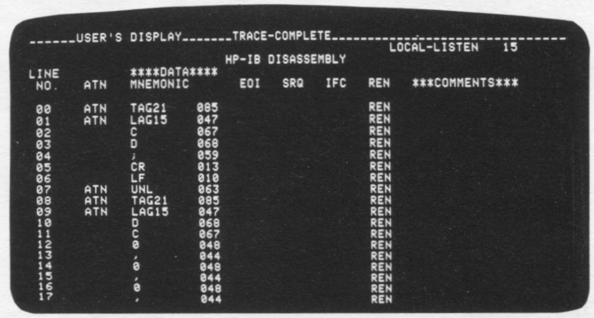


Figure 13. Disassembled trace list collected as defined by the trace specification in figure 12. The first line is TAG21, followed by LAG15, the trigger word.

be checked simultaneously. Each device is pre-programmed to output one status bit when parallel polled. The parallel poll function causes all devices capable of responding to a parallel poll to output their status bits simultaneously.

Suppose that three devices (X, Y, and Z) can respond to a parallel poll. Each device is assigned to output a different status bit when polled as shown here.

7	6	5	4	3	2	1	0
			X		Y		Z

A logical 1 for X, Y, or Z indicates that the device has sent a service request message.

By selecting PRL POLL as the 10066A clock source, the logic analyzer can monitor the status of the three devices on the bus responding to parallel polls. Figure 14 shows the trace list of device status. Label A is the status responses.

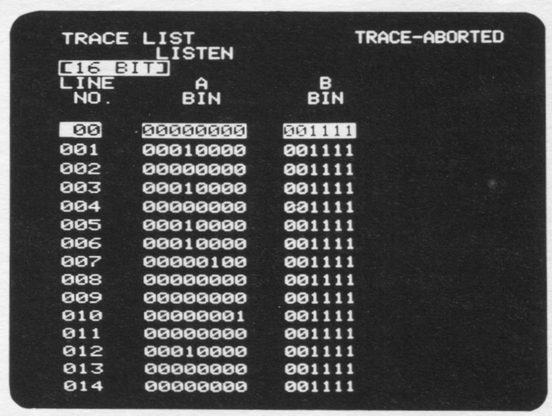


Figure 14. 1615A trace list of device status responses to parallel polls. Note that device X (bit 4 of the A label) most frequently requires service from the controller.

TESTING THE HANDSHAKE SEQUENCE

The 10066A contains circuitry that detects an abnormal handshake sequence and supplies a pulse to the logic analyzer for use as a trigger. The 10066A also provides a handshake sequence test point that can be used to trigger an oscilloscope to examine signals on the handshake lines at the moment that an abnormal handshake sequence occurs. If possible, configure the bus system to operate in a loop so that the abnormal handshake sequence will occur repetitively.

Since the 10066A supplies the Handshake signal to the EXT TRIG input of the 1615A clock pod, setting up the 1615A to trigger on the abnormal handshake is accomplished by simply selecting the [ON EXT] Trace Specification (figure 15).

In addition to viewing the abnormal handshake, a logic analyzer needs the ability to relate data transactions on the bus with abnormal handshakes to determine which device caused the abnormal handshake. Using the interactive state and time measurement capability of the 1615A by selecting [8-BIT TRIGGERS 16-BIT] and [END] TRACE modes in both the state and timing trace specifications, the 1615A can capture the data transactions leading up to the abnormal handshake. The trigger point on the timing diagram (figure 16) corresponds with the last term in the state list. By examining the events leading up to the abnormal handshake, the talker and listener(s) can be identified, enabling the device generating the abnormal handshake to be determined.

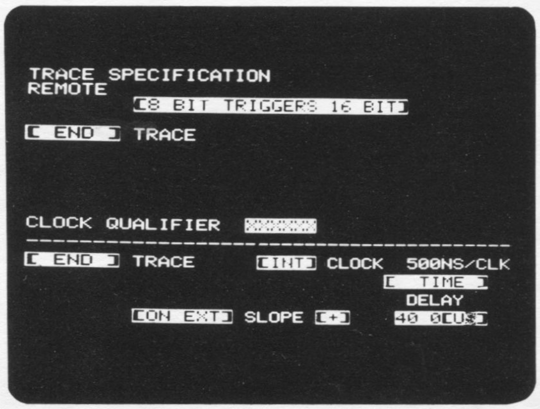


Figure 15. Selecting the [on ext] trace specification along with the [8-bit triggers 16-bit] and [end] trace fields enables the 1615A to capture data transactions leading up to an abnormal handshake sequence.

The 1610B can trace data transactions leading up to an abnormal handshake by calling up the Trace Specification menu and selecting [END] trace mode. Specifying a "1" on pod 3, bit 5 as the trigger condition will cause the 1610B to end a trace on the first occurrence of an abnormal handshake.

DEBUGGING A HUNG BUS

HP-IB system crashes can be caused by timeout problems, (the addressed device does not respond within the allowed time interval), abnormal handshake sequences, or incomplete handshake sequences. A system experiencing crashes can be troubleshot using the "never trigger" mode of the 1615A. The trace specification for the "never trigger" condition is shown in figure 17.

By setting the timing trace specification for the Boolean NOT trigger condition for a pattern of Don't Cares, the pattern on the eight timing lines can go through all 256 possible combinations without finding a trigger. Therefore, by using the [END] trace mode, the 1615A passes data through its data acquisition network until a system crash occurs that hangs the HP-IB bus up. Up to 256 bytes of data before the crash are captured and can be viewed by halting the trace measurement (figure 18). After the crash, the 10066A MANUAL clock source button can be used to strobe the quiescent state of bus lines into the logic analyzer for analysis (figure 19). See note.

NOTE: When operating the 1615A under remote control via HP-IB, the 1615A must acquire at least 256 lines of data in order to output valid trace data across the bus in [END] trace mode. In local mode (manual operation), the 1615A can display a partial trace list in [END] trace mode.

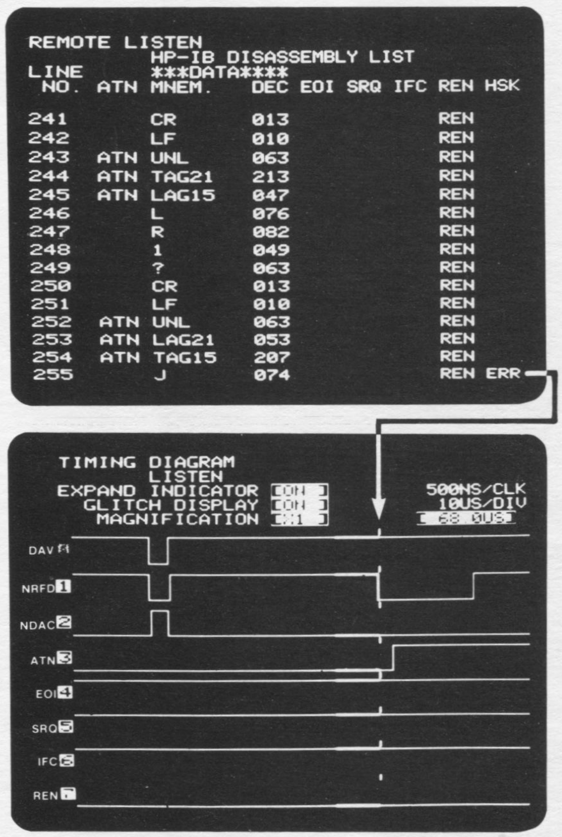


Figure 16. 1615A trace list and timing diagram resulting from the trace specification of figure 15. Note the abnormal handshake sequence with NRFD going low without a corresponding negative-going edge on DAV.

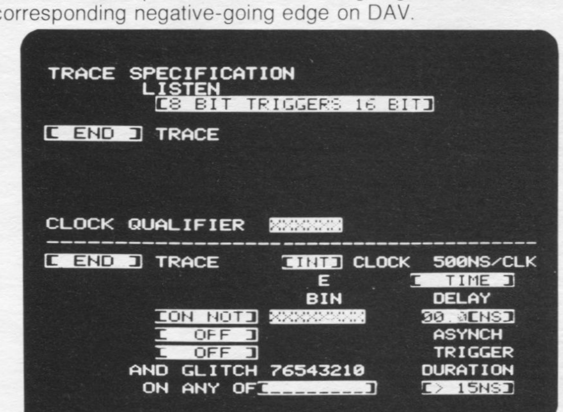
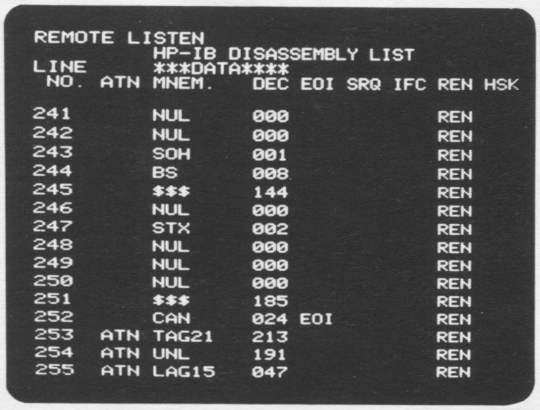


Figure 17. A "never trigger" trace specification (the logical not of "don't care") with [END] trace mode enables the 1615A to capture up to 256 bytes of data leading up to a system crash.



REMOTE LISTEN
HP-IB DISASSEMBLY LIST
DATA*

LINE NO.	ATN	MNEM.	DEC	EOI	SRQ	IFC	REN	HSK
241		NUL	000				REN	
242		NUL	000				REN	
243		SOH	001				REN	
244		BS	008				REN	
245		$$$	144				REN	
246		NUL	000				REN	
247		STX	002				REN	
248		NUL	000				REN	
249		NUL	000				REN	
250		NUL	000				REN	
251		$$$	185				REN	
252		CAN	024	EOI			REN	
253	ATN	TAG21	213				REN	
254	ATN	UNL	191				REN	
255	ATN	LAG15	047				REN	

Figure 18. Disassembled 1615A trace list resulting from trace specification of figure 17. The last line of the trace list is the last data transaction before the system crash.

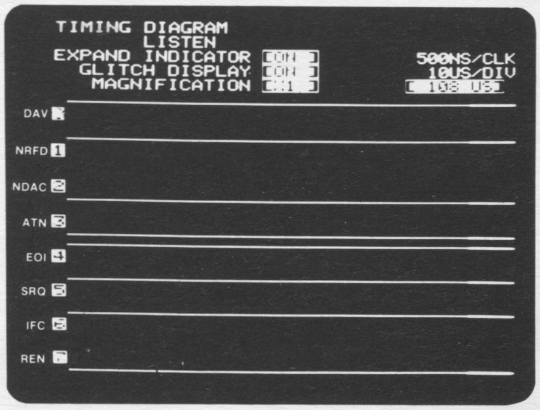


Figure 19. Timing diagram of quiescent state of handshake and bus management lines showing ATN stuck in the true (0) state.

SUMMARY

The combination of 10066A HP-IB Probe Interface and logic analyzer provides an excellent tool for debugging and troubleshooting HP-IB (IEEE 488-1978) systems. Data transactions, handshake lines, and bus management lines can be monitored interactively, yielding quick resolution of HP-IB problems.

Controlling the logic analyzer via HP-IB enhances the measurement capabilities of the logic analyzer. Measurement data can be displayed in a format more easily interpreted by the user. Frequently used measurement setups can be automated and measurements recorded for analysis at a later time. Hard copy of logic analyzer displays and trace lists simplify documentation needs.

Examples in this application note show the advantages of using a logic analyzer to troubleshoot your HP-IB system.

APPENDIX A
AN HP-IB DISASSEMBLY PROGRAM FOR 9825A AND 1615A LOGIC ANALYZER

The 1615A HP-IB disassembly lists in this application note were produced using the 9825A HP-IB Disassembly Program listed on the following pages. Table A1 lists the equipment required to execute the program. Figure A1 shows the algorithm implemented in the program. The auxiliary routines are called by 9825A Special Function keys (user-definable softkeys). Refer to table A2. The key to the disassembly program is the subroutine "Outputlines". This routine disassembles each trace list line and outputs the disassembled data to the 1615A display or system printer, line-by-line. "Outputlines" is called in each of the 1615A display routines and in the print routine. A detailed flowchart of "Outputlines" is provided in figure A2.

Table A1. Required Equipment

HP 9825A Desktop Computer, Option 002 with 98210A String-Advanced Programming ROM 98213A or 98214A General I/O-Extended I/O ROM 98034A HP-IB Interface Card
HP 1615A Logic Analyzer, Option 001
HP 10066A HP-IB Probe Interface
BNC Cable for +5V power
HP-IB Printer with 10361A, B, or C HP-IB Cable (Optional)

Table A2. 9825A Special Function Key Definitions

Special Function Keys	Definition
f0	*cont "NextPage"
f1	*cont "Print"
f5	*cont "RepeatMeas"
f6	*cont "LastPage"
f7	*cont "DspUpdate"
f8	*cont "Abort"

NOTE: The Special Function Keys should be defined as shown in Table A2 and then stored on your 9825A tape cartridge in File 1, Track 0. When you run the program,line 0 (ldk 1) will then automatically define the Special Function Keys each time you run the program.

1615A/9825A HP-IB DISASSEMBLY PROGRAM LISTING

```
0: ldk 1
1: gsb "Initialization"
2: gsb "DEV"
3: gsb "Lookup"
4: "RepeatMeas":gsb "Setup"
5: gsb "Run"
6: "Abortentry":gsb "Readdata"
7: gsb "Display"
8: stp
9:
10: "Initialization":
11: dim C$[32,3],L$[256,6],A[768],B$[4],D$[35],M$[7],K$[16]
12: buf "data",768,3
13: fmt 1,c4,fz2.0,c3,fz3.0,c37;fmt 2,fz3.0,c37
14: ret
15:
16: "DEV":
17: dev "1615",710
18: dev "PRINTER",706
19: ret
20:
21: "Lookup":dsp "CREATING LOOKUP TABLES........"
22: "NUL"→C$[1,1];"SOH"→C$[2,1];"STX"→C$[3,1];"ETX"→C$[4,1];"EOT"→C$[5,1]
23: "ENQ"→C$[6,1];"ACK"→C$[7,1];"BEL"→C$[8,1];"BS"→C$[9,1];"HT"→C$[10,1]
24: "LF"→C$[11,1];"VT"→C$[12,1];"FF"→C$[13,1];"CR"→C$[14,1];"SO"→C$[15,1]
25: "SI"→C$[16,1];"DLE"→C$[17,1];"DC1"→C$[18,1];"DC2"→C$[19,1];"DC3"→C$[20,1]
26: "DC4"→C$[21,1];"NAK"→C$[22,1];"SYN"→C$[23,1];"ETB"→C$[24,1]
27: "CAN"→C$[25,1];"EM"→C$[26,1];"SUB"→C$[27,1];"ESC"→C$[28,1];"FS"→C$[29,1]
28: "GS"→C$[30,1];"RS"→C$[31,1];"US"→C$[32,1]
29:
30: fxd 0
31: for I=1 to 16;"ACG"→L$[I,1];str(I)→K$;K$[2]→L$[I,4];next I
32: for I=1 to 16;"UCG"→L$[I+16,1];str(I)→K$;K$[2]→L$[I+16,4];next I
33: "GTL"→L$[2,1];"SDC"→L$[5,1];"PPC"→L$[6,1];"GET"→L$[9,1];"TCT"→L$[10,1]
34: "LLO"→L$[18,1];"DCL"→L$[21,1];"PPU"→L$[22,1];"SPE"→L$[25,1]
35: "SPD"→L$[26,1]
36: for I=1 to 31;"LAG"→L$[I+32,1];str(I-1)→K$;K$[2]→L$[I+32,4];next I
37: "UNL"→L$[64,1]
38: for I=1 to 31;"TAG"→L$[I+64,1];str(I-1)→K$;K$[2]→L$[I+64,4];next I
39: "UNT"→L$[96,1]
40: for I=1 to 31;"SCG"→L$[I+96,1];str(I-1)→K$;K$[2]→L$[I+96,4];next I
41: ret
42:
43: "Setup":dsp "SETTING UP FORMAT SPEC MENU....."
44: rem "1615"
45: wrt "1615","MD2;CS0;LSXXBBBBBB,AAAAAAAA;PS1,0;BS3,1;BT1;"
46: wrt "1615","TS;";lcl "1615";beep
47: beep;dsp "SETUP TRACE SPEC, PRESS ""CONT""";stp
48: ret
49:
50: "Run":dsp "EXECUTING TRACE MEASUREMENT...."
51: wrt "1615","RU;DS;"
52: if not bit(7,rds(7));jmp 0
53: ret
54:
55: "Readdata":dsp "READING TRACE DATA FROM 1615A..."
56: wait 50
57: tfr "1615","data",rds("data")
58: if rds("data")=-1;jmp 0
59: rds("data")/2→F
60: for I=1 to rds("data");rdb("data")→A[I];next I
61: 1→r1;15→r2;if r2>F;F→r2
62: ret
```

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63:
64: "Display":dsp "WRITING DISASSEMBLY LIST TO 1615"
65: wrt "1615","CD;"
66: gsb "Dspheading"
67: gsb "Outputlines"
68: ret
69:
70: "Outputlines":
71: for I=r1 to r2
72: " "→D$[1,35]
73: gsb "Controllines"
74: gsb "Dataconversion"
75: gsb "Mnemonics"
76: if r3=0;wrt "1615.1","DC0,",I-r1+3,",0,",I-1," "&D$
77: if r3=1;wrt "PRINTER.2",I-1,"   "&D$
78: next I
79: ret
80:
81: "Dspheading":
82: wrt "1615","DC0,0,0,           HP-IB DISASSEMBLY LIST"
83: wrt "1615","DC0,1,0,LINE       ***DATA****                    "
84: wrt "1615","DC0,2,0, NO. ATN MNEM.   DEC EOI SRQ IFC REN HSK"
85: ret
86:
87: "Controllines":
88: if band(32,A[2I-1]);"ERR"→D$[33,35]
89: if not band(16,A[2I-1]);"REN"→D$[29,31]
90: if not band(8,A[2I-1]);"IFC"→D$[25,27]
91: if not band(4,A[2I-1]);"SRQ"→D$[21,23]
92: if not band(2,A[2I-1]);"ATN"→D$[1,3]
93: if not band(1,A[2I-1]);"EOI"→D$[17,19]
94: ret
95:
96: "Dataconversion":
97: fxd 0
98: cmpA[2I]→C;shf(C,-8)→C;shf(C,8)→C
99: str(C)→B$
100: if len(B$)=2;"00"&B$[2,2]→D$[13,15]
101: if len(B$)=3;"0"&B$[2,3]→D$[13,15]
102: if len(B$)>=4;B$[2,4]→D$[13,15]
103: ret
104:
105: "Mnemonics":
106: if D$[1,3]="ATN";gto "Commandmode"
107: if C<32;C$[C+1]→M$
108: if C=32;"SPACE"→M$
109: if C>32 and C<127;char(C)→M$
110: if C=127;"DEL"→M$
111: if C>127;"$$$"→M$
112: gto 116
113: "Commandmode":
114: if C>127;C-128→C
115: L$[C+1]→M$
116: for J=len(M$)+1 to 7;" "→M$[J,J];next J
117: M$→D$[5,11]
118: ret
119:
120: "Print":dsp "PRINTING DISASSEMBLY LIST......"
121: 1→r3;1→I;F→r2
122: cmd "PRINTER"
123: gsb "Prtheading"
124: gsb "Outputlines"
125: 0→r3
126: stp
127:
```

```
128: "Prtheading":
129: wrt "PRINTER","          HP-IB DISASSEMBLY LIST"
130: wrt "PRINTER","LINE      ***DATA***"
131: wrt "PRINTER"," NO. ATN MNEM.   DEC EOI SRQ IFC REN HSK"
132: wrt "PRINTER"," "
133: ret
134:
135: "Abort":
136: wrt "1615","HT"
137: gto "Abortentry"
138:
139: "DspUpdate":0→r3
140: ent "ENTER LINE NUMBER...,PRESS CONT",r1;1+r1→r1
141: if r1>F;F-14→r1
142: if r1<1;1→r1
143: r1+14→r2;if r2>F;F→r2
144: gsb "Outputlines"
145: stp
146:
147: "NextPage":0→r3
148: 15+r1→r1;if r1>F;F-14→r1
149: if r1<1;1→r1
150: r1+14→r2;if r2>F;F→r2
151: gsb "Outputlines"
152: stp
153:
154: "LastPage":0→r3
155: r1-15→r1;if r1>F;F-14→r1
156: if r1<1;1→r1
157: r1+14→r2;if r2>F;F→r2
158: gsb "Outputlines"
159: stp
*22624
```

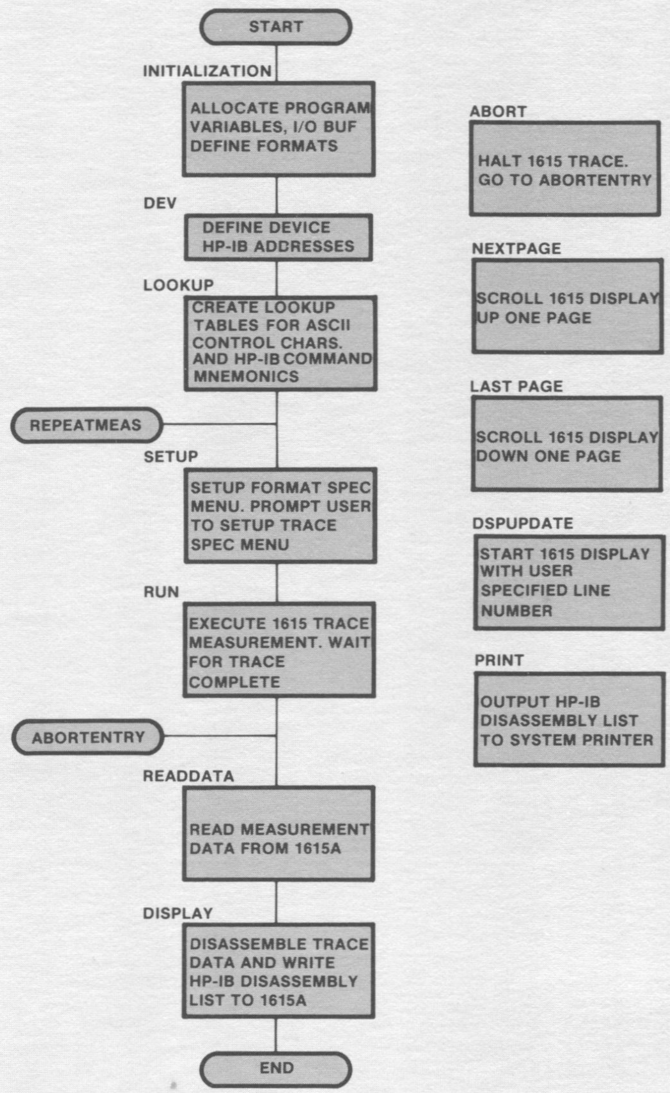

Figure A1. HP-IB Disassembly Algorithm

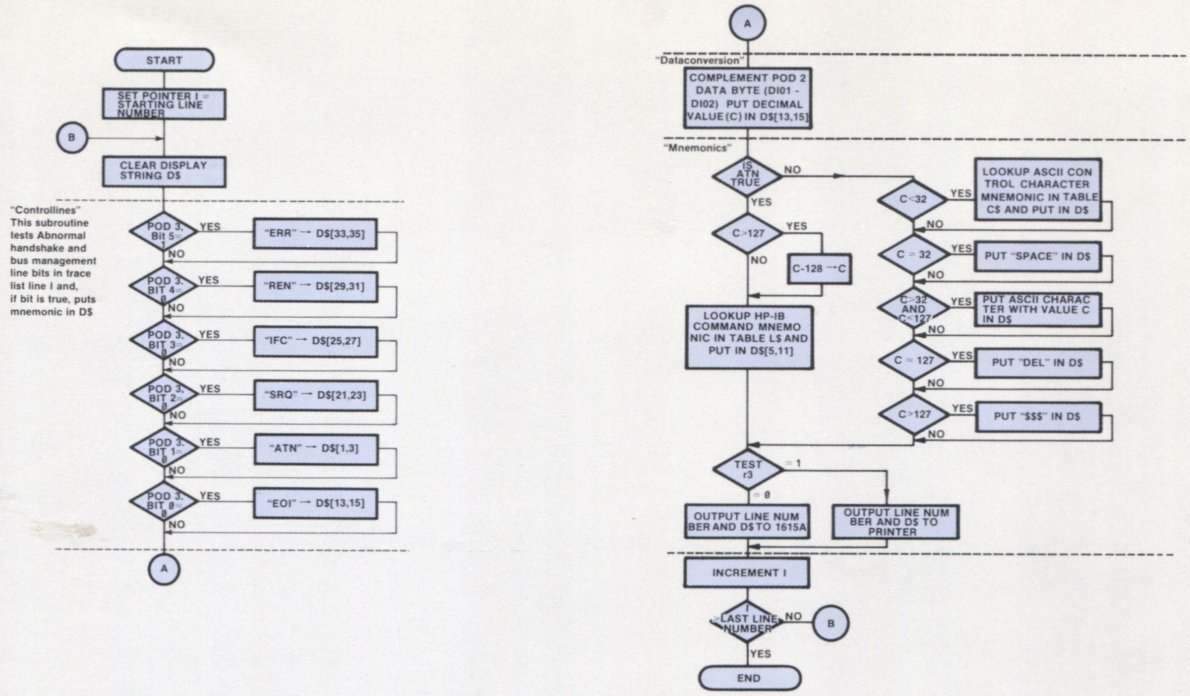

Figure A2. Flowchart for "Outputlines" Routine

APPENDIX B
HP-IB MESSAGE DECODE TABLES

Table B1. Bus State Table

	SIGNALS						
DIO8-DIO1	HDSK	REN	IFC	SRQ	ATN	EOI	MEANING
XXXXXXXX	X	X	0	X	X	X	INTERFACE CLEAR
XXXXXXXX	X	0	1	X	X	X	REMOTE ENABLE
XXXXXXXX	X	X	1	0	X	X	SERVICE REQUEST
XXXXXXXX	X	X	1	X	1	1	DATA BYTE
XXXXXXXX	X	X	1	X	1	0	LAST DATA BYTE
XXXXXXXX	X	X	1	X	0	1	COMMAND BYTE
XXXXXXXX	X	X	1	X	0	0	PARALLEL POLL

Table B2. Command Byte Table

	DATA SIGNAL (NEGATIVE LOGIC POLARITY)								
DIO	8	7	6	5	4	3	2	1	MEANING
	P	0	0	0	C	C	C	C	ADDRESSED COMMAND CCCC = 0001 GO TO LOCAL (GTL) = 0100 SELECTED DEVICE CLEAR (SDC) = 0101 PARALLEL POLL CONFIGURE (PPC) = 1000 GROUP EXECUTE TRIGGER (GET) = 1001 TAKE CONTROL (TCT)
	P	0	0	1	C	C	C	C	UNIVERSAL COMMAND CCCC = 0001 LOCAL LOCKOUT(LLO) = 0100 DEVICE CLEAR (DCL) = 0101 PARALLEL POLL UNCONFIGURE (PPU) = 1000 SERIAL POLL ENABLE (SPE) = 1001 SERIAL POLL DISABLE (SPD)
	P	0	1	D	D	D	D	D	LISTEN ADDRESS COMMAND DDDDD = 00000 - 11110 DEVICE ADDRESS DDDDD = 11111 UNLISTEN
	P	1	0	D	D	D	D	D	TALK ADDRESS COMMAND DDDDD = 00000 - 11110 DEVICE ADDRESS DDDDD = 11111 UNTALK
	P	1	1	S	S	S	S	S	SECONDARY COMMAND

NOTE: P IS USED ON SOME SYSTEMS AS A PARITY BIT FOR COMMANDS.

Table B3. Parallel Poll Table (ATN = 0, EOI = 0)

DIO	8	7	6	5	4	3	2	1	0	
	R	R	R	R	R	R	R	R	R	R = RESPONSE BIT

Assignment of bits to a specific device is system dependent.
Logic polarity of a response bit is also system dependent.

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