Date: June 19, 1986

To: John B. Lohmeyer, X3T9.2 Chair
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Subject: SCSI Interface Redefined Similar to IPI Level 1

Enclosed please find on the diskette containing revised text
for the Tape Model another file containing text for the SCSI
physical link definition in the style of IPI Level 2. This
completes one of my outstanding work items. The diskette is
formatted for an IBM PC, DOS, Release 2.0, in a double sided
format.

The file of interest is SCSIINTF.SCT.

Attached is a print of the file for inclusion in the next
mailing after you assign an appropriate number.

Gary R. Stephens

SCSI PHYSICAL INTERFACE

The physical interface provides a communication path between
multiple (up to 8) SCSI devices together with the protocol
necessary for physical path control, information transfers,
and resets.

PHYSICAL LINK PROTOCOL

This section provides signal, state and sequence
definitions. The terms Out or Output indicate data moving
from an initiator to a target. The terms In or Input
indicate data moving from a target to an initiator.
Relative signal timing and tolerance are defined in SCSI,
Section 4. (Definition and use of delay times is defined in
SCSI, Section 5.)

The purpose of the physical protocol is to exchange
information between connected SCSI devices.

CONVENTIONS

The following conventions are followed relative to the use
of the DATA BUS.

1. Messages sent between an initiator and a target are for
    the purpose of path control.

2. Commands sent by an initiator are associated with
    operations of the logical interface. Status sent by a
    target is associated with reports of interface
    conditions to the logical interface and for reporting
    logical command execution results.

3. Information transfer refers to the transfer of commands,
    messages, and data which are transferred transparently
    by the physical interface.

4. In the figures that follow an "*" listed for a data byte
    (unless redefined in a figure) indicates that the DATA
    BUS is undefined and not necessarily released. The
    contents are unpredictable. Parity may not be valid and
    is not to be checked by the receiver of the DATA BUS.

5. If the DATA BUS is marked as released then the contents
    appear to be zero with incorrect parity and is not to be
    checked by the receiver of the DATA BUS.

6. The SCSI ID is a single bit on the DATA BUS whose
    position corresponds to the unique SCSI address for the
    SCSI device (DB(7)-DB(0)). All of the 7 other bits are

released by the device. Parity is not checked during the ARBITRATION phase and may not be valid. During the SELECTION and RESELECTION phases, parity is valid when the SCSI ID(s) are placed on the DATA BUS and checked by the receiver.

STATES

The defined states of the interface are not unique values and require some prior state history for interpretation. If such history is required it will be defined in the particular state description section. The states of the interface are defined by the condition of the following signals:

BUSY
SELECT
ACK
REQ
RESET
I/O
MSG
C/D

The RESET signal is not interlocked to any other signal at any time. The signals, I/O, MSG, and C/D are fixed during information transfer but are not interlocked while in the BUSY (or XFRRDY) state in preparation for entering an information transfer phase or going to the BUS FREE phase. The states are tabulated in Figure -- on page ---page=yes. and Figure -- on page ---page=yes.. The condition of the signals and the DATA BUS during state transitions are summarized in Figure -- on page ---page=yes. and Figure -- on page ---page=yes..

BUS FREE

The BUS FREE state is the name given to indicate that no SCSI device is actively using the SCSI bus. (See SCSI, Section 5.1.1.) This is the only state defined in the BUS FREE phase.

ARBSTART

The ARBSTART state is the name given to indicate the start of the ARBITRATION phase. Each SCSI device needing to obtain control of the SCSI bus does the following:

● Wait for the BUS FREE phase to occur.

● Assert the BSY signal and place its SCSI ID (a bit) on

the DATA BUS.

● Parity (DB(P)) may not be valid at this time and is not asserted by any SCSI device during the ARBITRATION phase.

● Examine the DATA BUS to determine if any higher priority SCSI ID bit is asserted.

- If at least one higher priority SCSI ID bit is asserted the SCSI device has lost arbitration. The SCSI device releases BSY and its SCSI ID bit signals to return to the logical BUS FREE phase for this device. The device may attempt arbitration again after the BUS FREE phase has been detected.

  NOTE: The physical SCSI bus will not indicate the BUS FREE phase at this time since the SCSI device that won arbitration continues to assert BSY.

- If there are no higher priority SCSI ID bits asserted on the DATA BUS, the device has won arbitration and may assert SEL to go to the ARBWINNER state.

It is not an error for the SCSI device that won arbitration to go to the BUS FREE phase by releasing BSY and its SCSI ID bit from the DATA BUS since the SELECTION phase is not entered until the SCSI device that won arbitration releases BSY with SEL asserted. (See SCSI, Section 5.1.2.)

ARBWINNER

The SCSI device that won arbitration asserts SEL to go to the ARBWINNER state. Other arbitrating SCSI devices must release BSY and their SCSI IDs from the bus within a specified delay after SEL is asserted. The SCSI device may change the DATA BUS after a specified delay. This state is part of the ARBITRATION phase.

Both BSY and SEL are asserted at this time. The device prepares to perform the SELECTION phase or the RESELECTION phase at this state. Alternatively, the SCSI device may release BSY, SEL, and its SCSI ID from the DATA BUS to go to the BUS FREE state. (See SCSI, Section 5.1.2.)

SELECT

The SELECT state is the first state of the SELECTION phase. The SCSI device ensures this interpretation by negating I/O (I/O, when asserted, identifies the RESELECTION phase). There are two ways to enter this state:

1. This state may be entered directly from BUS FREE in non-arbitrating systems. Initiators are not permitted to use this implementation. Target devices (usually I/O devices) must implement detection of this form of selection to permit attachment to older implementations.

2. The SELECT state may also be entered from the ARBITRATION phase from the ARBWINNER state.

The SELECT state identifies the SCSI device that won arbitration as an initiator.

In non-arbitrating systems the initiator places the target SCSI ID on the DATA BUS plus, optionally, its own SCSI ID with correct parity and asserts SEL to enter the SELECT state. Initiators are not permitted to use the single SCSI ID option. Targets must recognize and respond correctly to this implementation to permit attachment to older implementations.

In arbitrating systems, the SCSI device that won arbitration has both BSY and SEL asserted. The SCSI device releases I/O to become an initiator, places the target SCSI ID and, optionally, its own SCSI ID on the DATA BUS with good parity. The SCSI device then releases BSY. Targets must recognize and respond correctly to this implementation to permit attachment to older implementations. If the selecting initiator does not set its SCSI ID on the data bus then disconnection/reselection by the target is prohibited. The device must implement control mechanisms at the selected points where disconnection is implemented to bypass disconnection if the initiator has indicated the single initiator option during selection.

If the target does not respond by asserting BSY, the initiator will time out, release SEL and go to the BUS FREE phase. If the target responds within the time-out period, go to the SELACK state. (See SCSI, Sections 5.1.3.1-5.1.3.4.)

SELACK

Once the initiator enters SELECT, the target determines that it is selected by recognizing SEL true, DATA BUS parity is valid, its SCSI ID is true on the DATA BUS, BSY and I/O are released, and that no more than 2 SCSI IDs are asserted. When these conditions are met, the target device asserts BSY, within the SELECTION time-out period, to enter the SELACK state. The SELACK state is part of the SELECTION phase. (See SCSI, Section 5.1.3.3.)

RESELECT

The RESELECT state is the first state of the RESELECTION phase. The SCSI device ensures this interpretation by asserting I/O. There is only one way to enter this state. The RESELECT state is entered from the ARBITRATION phase from the ARBWINNER state. The RESELECT state identifies the SCSI device that won arbitration as a target.

The SCSI device that won arbitration has both BSY and SEL asserted. The SCSI device asserts I/O to become a target, places the target SCSI ID and its own SCSI ID on the DATA BUS with good parity. The target then releases BSY to enter the RESELECT state.

If the initiator does not respond by asserting BSY, the target will time out, release SEL and I/O and go to the BUS FREE phase. If the initiator responds within the RESELECTION time-out period, go to the RESELACK state. (See SCSI, Sections 5.1.3.1-5.1.3.4.)

RESELACK

From RESELECT, an initiator determines that it has been reselected when SEL and I/O are asserted, DATA BUS parity is valid, its SCSI ID is asserted, exactly two SCSI IDs are asserted, and BSY is false. The SCSI ID of the reselecting target can be identified by examining the DATA BUS for one other SCSI ID to be asserted. If the conditions are not met, the initiator does not assert BSY and the SCSI bus does not enter the RESELACK state; the target will time out from the RESELECT state and go to BUS FREE. When the conditions are met, the initiator asserts BSY to go to the RESELACK state.

The target detects BSY and therefore the RESELACK state. It then asserts BSY also to permit transfer of control of the BSY signal to the target during the Selected condition. After a specified time, the target releases SEL to go to the BUSY state. The RESELACK state is part of the RESELECTION phase. (See SCSI, Section 5.1.4.1.)

BUSY

The BUSY state is a common state of the both the SELECTION and RESELECTION phases and defines the Selected state of a target with a specific initiator and the non-idle state of the SCSI bus. Signals SEL, ACK, and REQ are released.

BUSY is entered from three states:

1. From the SELACK state, the initiator recognizes BSY and

releases SEL to go to the BUSY state.

2. From RESELACK, the target has detected BSY from the initiator and asserted BSY in response. After a specified delay, the target releases SEL to go to the BUSY state. When SEL is detected as false at the initiator, the initiator releases BSY to complete the transfer of control of the BSY signal to the target.

3. From the pseudo-state XFRRDY in preparation to go to BUS FREE phase. The XFRRDY state is an alias for the BUSY state.

The physical path from the initiator to the target has been established. The path to a logical unit may not have been established. The target then uses various information transfer phases to perfrom the logical function of the SCSI bus between the target and its initiator. The target may perform any amount of information transfer phases returing each time to the BUSY state. When the work is complete or, in the case of disconnection, at a pause point, the target releases BSY, I/O, MSG, and C/D to go to the BUS FREE phase. Going to the BUS FREE phase does not indicate that the logical operation is complete. Completion or disconnection information is transmitted through information transfer phases to the logical level immediately prior to going to the BUS FREE phase.

XFRRDY

XFRRDY is not a true state. The XFRRDY state is an alias for the BUSY state. XFRRDY is a set of six pseudo-states used to define the combination of values of the I/O, MSG and C/D signals just prior to entering an information transfer phase. There are six valid combinations of the eight possible combinations which define a specific type of information transfer phase to follow.

I/O	MSG	C/D	CODE	Information Transfer Phase
0	0	0	DO	DATA OUT
0	0	1	CD	COMMAND (Out)
0	1	0	--	Reserved
0	1	1	MO	MESSAGE OUT
1	0	0	DI	DATA IN
1	0	1	ST	STATUS (In)
1	1	0	--	Reserved
1	1	1	MI	MESSAGE IN

One of the valid phases must be selected and the corresponding signal values asserted or released and then fixed at that value for the length of the desired information transfer phase. The value of these three signals is not to be interpreted and acted upon until the target goes to the XFRST state to begin the information

transfer. The DATA BUS is not valid in these pseudo-states. These values must be established prior to asserting REQ to go to the XFRST-xx state for the first byte and not changed until after ACK is released to return to the XFRRDY-xx state after the last byte of the selected information transfer phase has been transferred.

XFRST

Like XFRRDY, the XFRST state is a set of six pseudo-states, one for each type of information transfer defined for the SCSI bus. The XFRST-xx state, caused by asserting REQ, initiates the transfer of a byte of information to or from the initiator.

Since the values of I/O, MSG, and C/D are not permitted to change once REQ is asserted from the XFRRDY-xx state to enter one XFRST-xx state, the specific information transfer phase entered can be ignored for discussions related to the actual mechanics of transferring data on the DATA BUS except the state of the I/O signal which defines the direction of data movement.

The content of the DATA BUS is defined as follows:

● If I/O is one, indicating Input of data to the initiator, the target must place data with valid parity (if enabled) on the DATA BUS prior to asserting REQ to enter the XFRST state.

● If I/O is zero, indicating Output of data to the target, the DATA BUS content is not valid.

XFRACK

Like XFRST, the XFRACK state is a set of six pseudo-states, one for each type of information transfer defined for the SCSI bus. The XFRACK-xx states are an acknowledgement from the initiator to the target that the information transfer phase is continuing.

The content of the DATA BUS is defined as follows:

● If I/O is one, indicating Input of data to the initiator, valid data is on the DATA BUS when the initiator asserts ACK to enter the XFRACK state. Prior to asserting ACK, the initiator checks the DATA BUS for valid parity and captures the data byte from the DATA BUS. If parity is bad, the initiator asserts ATN to flag the error and to request an appropriate message be sent to the target. The phase is then completed. The intent of raising ATN is to interrupt the information transfer to inform the target of the error. The target

responds to the ATN at a device determined time which may not be at the end of the current phase. Since ATN is not valid in a BUS FREE or an ARBITRATION phase, the target must process the message prior to going to the BUS FREE phase.

It is a catastrophic error for a target to go to BUS FREE and not handle messages associated with the ATN signal from the initiator.

The initiator should not consider the DATA BUS valid once it asserts ACK. When ACK is detected as true at the target, the DATA BUS content may be changed.

- If I/O is zero, indicating Output of data to the target, the DATA BUS content is valid since the initiator must place data with valid parity (if enabled) on the DATA BUS before asserting ACK. When ACK becomes true at the target, the target checks for valid parity and captures the data byte.

If the target detects a parity error, it enters an error recovery procedure that involves the initiator data pointers to cause the data to be retransmitted from the last checkpoint with the initiator. (See SAVE DATA POINTER message and RESTORE DATA POINTER message in SCSI, Section 5.5.2.)

XFREND

Like XFRACK, the XFREND state is a set of six pseudo-states, one for each type of information transfer defined for the SCSI bus. The target releases REQ to indicate to the initiator that the data byte has been transferred. The XFREND-::: states are an acknowledgement from the target to the initiator that the information transfer phase is continuing, and for Output, that the data has been captured by the target.

The initiator releases ACK in response to the target releasing REQ to return to the XFRRDY state. The initiator may change the DATA BUS when REQ is detected as false at the initiator.

The content of the DATA BUS is defined as follows:

- If I/O is one, indicating Input of data to the initiator, the data is not to be considered valid.

- If I/O is zero, indicating Output of data to the target, the DATA BUS content is not considered valid.

SCSI BUS STATE DEFINITIONS

The SCSI bus states are tabulated in Figure -- on page ---page=yes. and Figure -- on page ---page=yes.. The hexadecimal encoding of the signals provides a shorthand method of referring to a specific bus state. States marked in the "DEFINITION" column with an "*" are invalid states which may exist only under catastrophic failure conditions. The RST signal when asserted during one of these failure states is an attempt to clear the interface and therefore defines a transitory state' which may not be cleared as expected. Multiple mnemonic names for a state indicate aliases assigned to the same signal pattern that have a different state path history.

SCSI BUS USAGE

The condition of the signals and the DATA BUS during state transitions are summarized in Figure -- on page ---page=yes. and Figure -- on page ---page=yes.. Each state and state transition is numbered for cross reference' purposes. The state number is a fractional hexadecimal number developed from the value of the eight signals identified above. The first four signals form the integer part of the number; the last four signals form the fractional part of the number. No real numerical value is implied by this convention and neither is any order to be inferred. The bus state diagram, Figure -- on page ---page=yes., shows the relationship of the various states and also includes the valid transition lines (and arrows) with a number corresponding to the bus usage figures identified above.

```
----- SIGNAL STATE -----
      B S A R   R I M C
      S E C E   S / S /
CODE  Y L K Q . T O G D  MNEMONIC    DEFINITION
----  -----------------  --------    --------------------
0.0   0 0 0 0 . 0 0 0 0  BUS FREE    Interface is idle
1.x   0 0 0 1 . x x x x              * (16 States)
2.x   0 0 1 0 . x x x x              * (16 States)
3.x   0 0 1 1 . x x x x              * (16 States)
4.0   0 1 0 0 . 0 0 0 0  SELECT      Selected
4.1         . 0 0 0 1                 *
4.2         . 0 0 1 0                 *
4.3         . 0 0 1 1                 *
4.4         . 0 1 0 0  RESELECT   Reselected
4.5         . 0 1 0 1                 *
4.6         . 0 1 1 0                 *
4.7         . 0 1 1 1                 *
4.8-        . 1 x x x                 *
4.F
5.x   0 1 0 1 . x x x x              * (16 States)
6.x   0 1 1 0 . x x x x              * (16 States)
7.x   0 1 1 1 . x x x x              * (16 States)
8.0   1 0 0 0 . 0 0 0 0  ARBSTART    Beginning of Arbitration
                         BUSY        Selected and Busy
                         XFRRDY-DO   DATA OUT Transfer phase
8.1         . 0 0 0 1  XFRRDY-CD   COMMAND Transfer phase
8.2         . 0 0 1 0              *
8.3         . 0 0 1 1  XFRRDY-MO   MESSAGE OUT Transfer phase
8.4         . 0 1 0 0  XFRRDY-DI   DATA IN Transfer phase
8.5         . 0 1 0 1  XFRRDY-ST   STATUS Transfer phase
8.6         . 0 1 1 0              *
8.7         . 0 1 1 1  XFRRDY-MI   MESSAGE IN Transfer phase
8.8-        . 1 x x x              *
8.F
9.0   1 0 0 1 . 0 0 0 0  XFRST-DO    DATA OUT Start Transfer
9.1         . 0 0 0 1  XFRST-CD    COMMAND Start Transfer
9.2         . 0 0 1 0              *
9.3         . 0 0 1 1  XFRST-MO    MESSAGE OUT Start Transfer
9.4         . 0 1 0 0  XFRST-DI    DATA IN Start Transfer
9.5         . 0 1 0 1  XFRST-ST    STATUS Start Transfer
9.6         . 0 1 1 0              *
9.7         . 0 1 1 1  XFRST-MI    MESSAGE IN Start Transfer
9.8-        . 1 x x x              *
9.F

*  Undefined State (except possibly during Reset)
```

Figure 1. State Definitions (1 of 2)

```
----- SIGNAL STATE -----
      B S A R   R I M C
      S E C E   S / S /
CODE  Y L K Q . T O G D  MNEMONIC    DEFINITION
----  -----------------  --------    --------------------
A.0   1 0 1 0 . 0 0 0 0  XFREND-DO   DATA OUT End Transfer
A.1         . 0 0 0 1  XFREND-CD   COMMAND End Transfer
A.2         . 0 0 1 0              *
A.3         . 0 0 1 1  XFREND-MO   MESSAGE OUT End Transfer
A.4         . 0 1 0 0  XFREND-DI   DATA IN End Transfer
A.5         . 0 1 0 1  XFREND-ST   STATUS End Transfer
A.6         . 0 1 1 0              *
A.7         . 0 1 1 1  XFREND-MI   MESSAGE IN End Transfer
A.8-        . 1 x x x              *
A.F

B.0   1 0 1 1 . 0 0 0 0  XFRACK-DO   DATA OUT Ack. Transfer
B.1         . 0 0 0 1  XFRACK-CD   COMMAND Ack. Transfer
B.2         . 0 0 1 0              *
B.3         . 0 0 1 1  XFRACK-MO   MESSAGE OUT Ack. Transfer
B.4         . 0 1 0 0  XFRACK-DI   DATA IN Ack. Transfer
B.5         . 0 1 0 1  XFRACK-ST   STATUS Ack. Transfer
B.6         . 0 1 1 0              *
B.7         . 0 1 1 1  XFRACK-MI   MESSAGE IN Ack. Transfer
B.8-        . 1 x x x              *
B.F

C.0   1 1 0 0 . 0 0 0 0  ARBWINNER   Arbitration Winner Ack.
                         SELACK      Selection Ack.
C.1         . 0 0 0 1              *
C.2         . 0 0 1 0              *
C.3         . 0 0 1 1              *
C.4         . 0 1 0 0  RESELACK    Reselection Ack.
C.5         . 0 1 0 1              *
C.6         . 0 1 1 0              *
C.7         . 0 1 1 1              *
C.8-        . 1 x x x              *
C.F

D.x   1 1 0 1 . x x x x              * (16 States)
E.x   1 1 1 0 . x x x x              * (16 States)
F.x   1 1 1 1 . x x x x              * (16 States)

*     Undefined State (except possibly during Reset)
Ack.  Acknowledgement
```

Figure 2. State Definitions (2 of 2)

NO	State From	State To	XFR	DATA BUS	ASSERT/NEGATE
0	BUS FREE	BUS FREE		RELEASED	
1	ARBSTART	BUS FREE		RELEASED	/BSY
2	ARBWINNER	BUS FREE		RELEASED	/BSY & /SEL
3	SELECT	BUS FREE		RELEASED	/SEL
4	RESELECT	BUS FREE		RELEASED	/SEL & /I/O
5	BUSY	BUS FREE		*	/BSY & /I/O
					/MSG & /C/D
6	RESET	BUS FREE		RELEASED	/RST
7	ANY STATE	RESET		*	RST
8	BUS FREE	ARBSTART		SCSI ID(s) w/o Parity	BSY - Any
9	ARBSTART	ARBSTART		SCSI ID w/o Parity	/BSY Each Device Losing Arb.; Winner Keeps BSY Asserted
10	ARBSTART	ARBWINNER		SCSI ID(s) w/o Parity	SEL
11	BUS FREE	SELECT		SCSI ID(s) With Parity	SEL
12	ARBWINNER	SELECT		SCSI ID(s) With Parity	/I/O & /BSY
13	ARBWINNER	RESELECT		SCSI ID(s) With Parity	I/O & /BSY
14	SELECT	SELACK		SCSI ID(s) With Parity	BSY
15	RESELECT	RESELACK		SCSI ID(s) With Parity	BSY - Init. Followed by BSY - Target

LEGEND:

XFRxxx-xx   xxx -- Info Transfer Phase State (1 of 4)
             -xx -- one of 6 valid I/O, MSG, and C/D combinations
Data Byte   8-bit value plus parity

Figure 1. Bus Usage (1 of 2)

NO	State From	State To	XFR	DATA BUS	ASSERT/NEGATE
16	SELACK	BUSY	*		/SEL
17	RESELACK	BUSY	*		/SEL Followed by /BSY - Init
18	XFRRDY	BUSY	*		/I/O,/MSG,/C/D
19	BUSY	XFRRDY-DO	Out *		/I/O,/MSG,/C/D
		-CD	Out *		/I/O,/MSG,/C/D
		-MO	Out *		/I/O, MSG, C/D
		-DI	In *		I/O,/MSG,/C/D
		-ST	In *		I/O,/MSG, C/D
		-MI	In *		I/O, MSG, C/D
20	XFRRDY-xx	XFRRDY-xx	Out *		Set Once for Info Xfer Phase
			In	Data Byte	Other Signals Fixed @ XFRRDY
21	XFREND-xx	XFRRDY-xx	Out *		/ACK
			In *		Other Signals Fixed @ XFRRDY
22	XFRRDY-xx	XFRST-xx	Out *		REQ
			In	Data Byte	Other Signals Fixed @ XFRRDY
23	XFRST-xx	XFRACK-xx	Out	Data Byte	ACK
			In	Data Byte	Other Signals Fixed @ XFRRDY
24	XFRACK-xx	XFREND-xx	Out *		/REQ
			In *		Other Signals Fixed @ XFRRDY

LEGEND:

XFRxxx-xx   xxx -- Info Transfer Phase State (1 of 4)
             -xx -- one of 6 valid I/O, MSG, and C/D combinations
Data Byte   8-bit value plus parity

Figure 2. Bus Usage (2 of 2)