Network Notes

November 27, 2021

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Chapter 1

The Network Protocol

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1.1 Overview

Loconet is a peer to peer distributed network system on which all devices can monitor the network data flow. The network is event driven by different devices in time, and is not polled by a centralised controller in normal operation. The normal the network state is idle, with no data traffic unless a device has information to send. With no traffic flow, the network is quiet.

The network data is sent in asynchronous format using 1 start bit, 8 data bits and 1 stop bit. The 8 bit data is transmitted least significant bit first. The bit times are 60.0 μS or 16,660 baud +/- 1.5%. A computer can connect to a Digitrax USB interface at higher baud rates and the device will make the necessary conversion. Bytes may be transmitted back-to-back, with a start bit immediately following the stop bit of the previous character.

Any message that has format or framing errors, data errors or is a fragment caused by noise glitches and does not completely follow the message format will be ignored by all receivers, and a new opcode will be scanned for re-synchronisation.

The OPC_BUSY opcode is included to allow the master to keep the network active whilst it is performing a task that requires a response, and entails a significant processing delay, i.e. it can ensure no new requests are started until it has responded to the last message. This OPC_BUSY opcode should be simply stripped and ignored.

If a device disconnects from the network and so does not access or reference a slot within the system purge time, the command station will force the un-accessed slot to common status

so other system devices can use the slot. The typical purge time of a command station is about 200 seconds. A good "ping" or slot update activity is about every 100 seconds, i.e. if a user makes no change to a throttle/slot within 100 seconds, the throttle/device should automatically send another speed update at the current speed to reset the purge timeout for that slot.

1.2 Message Format

All the network communications are via multi-byte messages. The command station is defined as the device that is maintaining the refresh stack for DCC packet generation and is actively generating the DCC track data. Refresh of information is typically only performed for mobile decoders. Stationary type decoders are not refreshed and individual immediate commands are sent out to the track as requested.

The command station is only privileged in respect to performing the task of maintaining the locomotive refresh stack and generating DCC packets. In this way other network transactions may occur that the command station does not need to be involved with or understand, as long as they follow the message protocol and timing requirements. i.e. other devices may have a dialog on the network without disturbing or involving the command station. Devices on the network monitor the messages, check for format and data integrity and parse good messages to decode if action is required in the context. Devices such as throttles, input sensors, computer interfaces and control panels may generate the network messages without needing prompting or polling by a central controller.

Devices frequently will be added and removed from an operating the network. The devices and protocol are tolerant of electrical and data transients. The format chosen gives a good degree of data integrity, guaranteed quick network-state synchronisation, high data throughput, good distribution of access to many competing devices and low event latency. Also, the devices may be operated without need for unique ID or other requirements that can make network administration awkward.

The data bytes on the Network are defined as 8 bit data with the most significant bit as an opcode flag bit. If the most significant bit, d7, is 1 then the 7 least significant bits are interpreted as a network opcode . The opcode byte may only occur once in a valid message and is the first byte of a message. All the remaining bytes in the message must have a most significant bit of 0, including the last checksum byte. The checksum is the 1's complement of the byte wise exclusive or of all the bytes in the message, except the checksum itself. To validate data accuracy, all the bytes in a correctly formatted message are exclusive or'ed. If this resulting byte value is 0xFF, then the message data is accepted as good.

The opcodes may be examined to determine message length and if subsequent response

message is required. Data bits d6 and d5 encode the message length. The message length includes the opcode and the checksum bytes. The bit d3 = 1 implies that a follow-on message or reply is expected.

d7	d6	d5	d4	d3	d2	d1	d0	
1	0	0	E	D	C	B	A	2 byte message
1	0	1	E	D	C	B	A	4 byte message
1	1	0	E	D	C	B	A	6 byte message
1	1	1	E	D	C	B	A	Variable length message. The next byte in the message is a 7 bit byte count.

The A,B,C,D,E are bits available to encode 32 opcodes per message length.

1.3 Refresh Slots

The command station standard refresh stack is an array of up to 120 read/write refresh slots. The slot address is a principal component and is generally the second byte or 1st argument of a message to the master. The standard refresh slot contains up to 10 data bytes relating to a locomotive and also controls a task in the track DCC refresh stack. Most mobile decoder or locomotive operations process the slot associated with the locomotive to be controlled. The slot number is a similar shorthand ID# to a file handle. Slot addresses 120-127 are reserved for system and command station control. Slot #124 (0x7C) is allocated for read/write access to the programming track, and the format is not the same as a standard slot. The DCS240 command station has 400 read/write refresh slots. The additional slots in excess of the 120 standard slots are accessed by using extended opcodes. The DCS210 also supports the extended opcodes though it only has 100 refresh slots.

1.3.1 Slot Format

Standard Slot - 0 to 119

Byte 0:

0	n	n	n	n	n	n	n	<SLOT#>	Slot number in the range 0x00 to 0x7F. Slot 0x00 is a special slot, and slots in the range 0x70 to 0x7F are reserved to Digitrax.

Byte 1:

d7	d6	d5	d4	d3	d2	d1	d0	<STAT1>	Slot status 1.

d7	d6	
0	0	Free, no consist linking.
0	1	Consist sub-member.
1	0	Consist top-member.
1	1	Consist Mid-Consist member.

Note: d7 is set to 0 in the message by the command station and so may not correctly reflect the actual setting in the slot table.

d5	d4	
0	0	Free slot, no valid data. Not refreshed.
0	1	Common. Locomotive address in this slot. Refreshed.
1	0	Idle. Locomotive address in this slot. Not refreshed.
1	1	In Use. Locomotive address in this slot. Refreshed.

d3	
0	No slot consist linked into this slot.
1	Slot consist linked into this slot.

d2	d1	d0	
0	0	0	28 step decoder. 3-byte packet regular mode
0	0	1	28 step decoder. Generate trinary packets for this mobile address
0	1	0	14 step decoder.
0	1	1	128 step decoder.
1	0	0	28 step decoder. Allow advanced consisting
1	0	1	reserved
1	1	0	reserved
1	1	1	128 step decoder. Allow advanced consisting

Byte 2:

0	n	n	n	n	n	n	n	<ADR>	Low address.

Byte 3:

0	n	n	n	n	n	n	n	<SPD>	Speed in the range 0x00 to 0x7F. 0x00 means inertial stop and 0x01 means emergency stop. Other values mean increasing speed.

Byte 4:

0	d6	d5	d4	d3	d2	d1	d0	<DIRF>	Locomotive direction and state of functions F0 to F4.

d6 Reserved. Set to 0.
d5 Locomotive direction. 1 means forward, 0 means backwards.
d4 F0 state. 1 means on, and 0 means off.
d3 F4 state. 1 means on, and 0 means off.
d2 F3 state. 1 means on, and 0 means off.
d1 F2 state. 1 means on, and 0 means off.
d0 F1 state. 1 means on, and 0 means off.

Byte 5:

0	d6	d5	d4	d3	d2	d1	d0	<TRK>	Global system track status.

d6 Reserved. Set to 0.
d5 Reserved. Set to 0.
d4 Reserved. Set to 0.
d3 1 means the programming track is busy.
d2 1 means this master implements the Network version 1.1 capability, 0 means the master is a DT200.
d1 0 means the track is paused, broadcast an emergency stop.
d0 1 means the DCC packets are on in the master, global power up.

Byte 6:

0	d6	d5	d4	d3	d2	d1	d0	<SS2>	Slot status 2.

d6 Reserved. Set to 0.
d5 Reserved. Set to 0.
d4 Reserved. Set to 0.
d3 1 means expansion in ID1/2, 0 means encoded alias.
d2 1 means expansion ID1/2 is not ID usage.
d1 Reserved. Set to 0.
d0 1 means this slot has suppressed advanced consist.

Byte 7:

0	n	n	n	n	n	n	n	<ADR2>	High address.

Byte 8:

0	d6	d5	d4	d3	d2	d1	d0	<SND>	Slot sound / function mode II packets.

d6	Reserved. Set to 0.
d5	Reserved. Set to 0.
d4	Reserved. Set to 0.
d3	Sound 4 / F8.
d2	Sound 3 / F7.
d1	Sound 2 / F6.
d0	Sound 1 / F5.

Byte 9:

0	n	n	n	n	n	n	n	<ID1>	7-bit ls ID code written by throttle when STAT2.4 = 1.

Byte 10:

0	n	n	n	n	n	n	n	<ID2>	7-bit ms ID code written by throttle when STAT2.4 = 1.

Slot 0x7F

OST1 to OST6 encode the command station's option switch table. The narrative is based upon information in the the DCS210 and DCS240 user manuals. A bit value of 1 means that the switch is closed and a value of 0 means that a switch is thrown. OpSw 8, OpSw 16, OpSw 24, OpSw 32 and OpSw 40 cannot be read due to bit 7 being cleared in the message format. The manual shows these switches as defaulting to thrown, i.e. 0, and are flagged in all cases except OpSw 40 as "do not change".

Byte 0:

0	n	n	n	n	n	n	n	<SLOT#>	Slot number in the range 0x00 to 0x7F. Slot 0x00 is a special slot, and slots in the range 0x70 to 0x7F are reserved to Digitrax.

Byte 1:

0	d6	d5	d4	d3	d2	d1	d0	<OST1>	Option switch table byte 1.

Bit	Switch #	Default	Effect on system operation
d6	OpSw 07	t	do not change
d5	OpSw 06	t	t = check for decoder before programming c = program without checking for device
d4	OpSw 05	t	do not change
d3	OpSw 04	t	do not change
d2	OpSw 03	t	t = command station's booster normal c = command station's booster is auto reversing
d1	OpSw 02	t	t = command station mode c = booster only mode.
d0	OpSw 01	t	do not change.

Byte 2:

0	d6	d5	d4	d3	d2	d1	d0

<OST2> Option switch table byte 2.

Bit	Switch #	Default	Effect on system operation
d6	OpSw 15	t	t = purging will not change loco speed c = purging will force a loco to 0 speed
d5	OpSw 14	t	t = loco address purging enabled c = loco address purging disabled
d4	OpSw 13	t	t = loco address purge time 200 seconds c = loco address purge time 600 seconds
d3	OpSw 12	t	do not change
d2	OpSw 11	t	do not change
d1	OpSw 10	c	do not change
d0	OpSw 09	c	do not change

Byte 3:

0	d6	d5	d4	d3	d2	d1	d0

<OST3> Option switch table byte 3.

Bit	Switch #	Default	Effect on system operation
d6	OpSw 23	t	SW23
d5	OpSw 22	c	SW22
d4	OpSw 21	c	SW21
d3	OpSw 20	t	t = enable address 0x00 or analog stretching for conventional locos . c = disable address 0x00 or analog stretching for conventional locos
d2	OpSw 19	t	do not change
d1	OpSw 18	t	t = normal command station booster short circuit shutdown time c = extended command station booster short circuit shutdown time
d0	OpSw 17	t	t = automatic advanced decode (FX) consists are enabled c = automatic advanced decode (FX) consists are disabled

SW21	SW22	SW23	Global system default type for new locos
t	t	t	28 step mode
t	t	c	reserved
t	c	t	14 step mode
t	c	c	reserved
c	t	t	reserved
c	t	c	reserved
c	c	t	128 step mode
c	c	c	128 step FX mode

Byte 4:

0	d6	d5	d4	d3	d2	d1	d0

<OST4> Option switch table byte 4.

Bit	Switch #	Default	Effect on system operation
d6	OpSw 31	t	t = normal route/switch output rate when not trinary c = fast route/switch output rate when not trinary
d5	OpSw 30	t	do not change
d4	OpSw 29	t	do not change
d3	OpSw 28	t	t = enable interrogate commands at power on c = disable interrogate commands at power on
d2	OpSw 27	t	t = enable normal switch commands, a.k.a. the "Bushby bit" c = disable normal switch commands, a.k.a. the "Bushby bit" (allows attached computer to handle switch control logic)
d1	OpSw 26	c	t = disable routes c = enable routes
d0	OpSw 25	t	t = enable route echo over the Network c = disbale route echo over the Network

Byte 5:

0	d6	d5	d4	d3	d2	d1	d0

<TRK> Global system track status.

d6 Reserved. Set to 0.
d5 Reserved. Set to 0.
d4 Reserved. Set to 0.
d3 1 means the programming track is busy.
d2 1 means this master implements the Network version 1.1 capability, 0 means the master is a DT200.
d1 0 means the track is paused, broadcast an emergency stop.
d0 1 means the DCC packets are on in the master, global power up.

Byte 6:

0	d6	d5	d4	d3	d2	d1	d0

<OST5> Option switch table byte 5.

Bit	Switch #	Default	Effect on system operation
d6	OpSw 39	t	c = clear all internal memory states, including OpSw 36 and 37
d5	OpSw 38	t	t = loco reset button activates OpSw 39 c = loco reset activates slot zero
d4	OpSw 37	t	c = clears all routes
d3	OpSw 36	t	c = clears all mobile decoder info and consists
d2	OpSw 35	t	t = enables loco reset buttone c = disable loco reset button
d1	OpSw 34	t	t = disallow track to power up to run state, if set to run prior to power up c = allow track to power up to run state, if set to run prior to power up
d0	OpSw 33	c	t = track power off at power on c = allow track power to restore to prior state at power on

Byte 7:

0	d6	d5	d4	d3	d2	d1	d0

<OST6> Option switch table byte 6.

Bit	Switch #	Default	Effect on system operation
d6	OpSw 47	t	t = normal program track setting c = program track is brake generator when not programming. Braking is DCC set to speed 0 (not emergency stop) for address 0, light on, broadcast to all addresses.
d5	OpSw 46	t	do not change
d4	OpSw 45	t	t = enable reply for switch state request c = disable reply for switch state request
d3	OpSw 44	t	do not change
d2	OpSw 43	t	t = enable the Network update of command station's track status c = disable the Network update of command station's track status
d1	OpSw 42	t	t = enable 2 short beeps when loco address purged c = disable 2 short beeps when loco address purged
d0	OpSw 41	t	t = diagnostic click disabled c = diagnostic click when valid the Network commands incoming and routes being output

Byte 8:

0	d6	d5	d4	d3	d2	d1	d0

Unknown.

d6
d5
d4
d3
d2
d1
d0

Byte 9:

0	n	n	n	n	n	n	n	<CSM>	Command station model.

CSM	Model
0x1B	DCS210
0x1C	DCS240

Byte 10:

0	d6	d5	d4	d3	d2	d1	d0		Unknown.

d6
d5
d4
d3
d2
d1
d0

1.3.2 Extended Slot Format

Byte 0:

0	0	0	0	0	d2	d1	d0	<SLOTP#>	Extended slot page number in the range 0x0 to 0x7.

Byte 1:

0	n	n	n	n	n	n	n	<SLOTL#>	Extended slot number in the range 0x00 to 0x7F.

Byte 2:

0	d6	d5	d4	d3	d2	d1	d0	<STAT1>	Slot status 1.

d5	d4	
0	0	Free slot, no valid data. Not refreshed.
0	1	Common. Locomotive address in this slot. Refreshed.
1	0	Idle. Locomotive address in this slot. Not refreshed.
1	1	In Use. Locomotive address in this slot. Refreshed.

Byte 3:

0	n	n	n	n	n	n	n	<ADR>	Low address.

Byte 4:

0	n	n	n	n	n	n	n	<ADR2>	High address.

Byte 5:

0	d6	d5	d4	d3	d2	d1	d0	<TRK>	Global system track status.

d6 Reserved. Set to 0.
d5 Reserved. Set to 0.
d4 Reserved. Set to 0.
d3 1 means the programming track is busy.
d2 1 means this master implements the Network version 1.1 capability, 0 means the master is a DT200.
d1 0 means the track is paused, broadcast an emergency stop.
d0 1 means the DCC packets are on in the master, global power up.

Byte 6:

0	d6	d5	d4	d3	d2	d1	d0	Unknown.

d6
d5
d4
d3
d2
d1
d0

Byte 7:

0	d6	d5	d4	d3	d2	d1	d0	Unknown.

d6
d5
d4
d3
d2
d1
d0

Byte 8:

0	d6	d5	d4	d3	d2	d1	d0

Unknown.

d6
d5
d4
d3
d2
d1
d0

Byte 9:

0	d6	d5	d4	d3	d2	d1	d0

Unknown.

d6
d5
d4
d3
d2
d1
d0

Byte 10:

0	d6	d5	d4	d3	d2	d1	d0

Unknown.

d6
d5
d4
d3
d2
d1
d0

Byte 11:

0	d6	d5	d4	d3	d2	d1	d0

Unknown.

d6
d5
d4
d3
d2
d1
d0

Byte 12:

0	d6	d5	d4	d3	d2	d1	d0

Unknown.

d6
d5
d4
d3
d2
d1
d0

Byte 13:

0	d6	d5	d4	d3	d2	d1	d0

Unknown.

d6
d5
d4
d3
d2
d1
d0

Byte 14:

0	d6	d5	d4	d3	d2	d1	d0

Unknown.

d6
d5
d4
d3
d2
d1
d0

Byte 15:

0	d6	d5	d4	d3	d2	d1	d0

Unknown.

d6
d5
d4
d3
d2
d1
d0

Byte 16:

0	d6	d5	d4	d3	d2	d1	d0

Unknown.

d6
d5
d4
d3
d2
d1
d0

Byte 17:

0	d6	d5	d4	d3	d2	d1	d0

Unknown.

d6
d5
d4
d3
d2
d1
d0

1.4 Standard Address Selection

To request a mobile or locomotive decoder task in the refresh stack, a throttle device requests a locomotive address for use (OPC_LOCO_ADR). The command station responds with a slot data read for the slot (OPC_SL_RD_DATA), that contains this locomotive address and all of its state information. If the address is currently not in any slot, the command station will load this new locomotive address into a new slot (speed=0, direction

forwards, functions off and 128 step mode) and return this as a OPC_SL_RD_DATA. If no inactive slots are free to load the new locomotive address, the response will be the OPC_LONG_ACK with a fail code 0x00.

The throttle/computer must then examine the slot data bytes to work out how to process the command station response. If the slot status 1 byte shows the slot to be common idle or new the throttle may change the slot to in use by performing a null move instruction (see OPC_MOVE_SLOTS) on this slot. This activation mechanism is used to guarantee proper slot usage interlocking in a multi-user asynchronous environment.

If the slot return information shows the locomotive requested is in use or up-consisted (i.e. the SL_CONUP, bit 6 of slot status 1 = 1) the user should not use the slot. Any up-consisted locomotives must be unlinked before usage. Always process the result from the OPC_LINK_SLOTS and OPC_UNLINK_SLOTS commands, since the command station reserves the right to change the reply slot number and can reject the linking tasks under several circumstances. Verify the reply slot number and the link UP/DN bits in slot status 1 are as you expected.

The throttle will then be able to update speed, direction and function information. Whenever slot information is changed in an active slot , the slot is flagged to be updated as the next DCC packet sent to the track. If the slot is part of linked consist slots the whole consist chain is updated consecutively.

If a throttle is disconnected from the the Network, upon reconnection (if the throttle retains the slot state from before disconnection) it will request the full status of the slot it was previously using. If the reported status and speed, function data etc., from the command station exactly matches the remembered slot state the throttle will continue using the slot. If the slot data does not match, the throttle will assume the slot was purged free by the system and will go through the setup log on procedure again.

With this procedure the throttle does not need to have a unique ID number. slot addresses do not imply they contain any particular locomotive address. The system can be mapped such that the slot address matches the locomotive address within, if the user directly reads and writes to slots without using the command station to allocate locomotive addresses.

1.5 Opcodes

OPC_BRD_OPSW

Operation: Read and write board option switches.

Group: 6-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	1	0	1	0	0	0	0	0xD0	Opcode.

Byte 1:

0	1	1	d4	0	0	1	d0	The bit d0 is the most significant bit of the board id. Bit d4 indicates read/write direction. 1 means write and 0 means read.

Byte 2:

0	n	n	n	n	n	n	n	<BIDL>	Least significant 7 bits of the board id.

Byte 3:

0	n	n	n	n	n	n	n	<BTYPE>	Board type code.

Board	Type Code
PM4	0x70.
BDL16	0x71.
SE8C	0x72.
DS64	0x73.

Byte 4:

0	d6	d5	d4	d3	d2	d1	d0	Byte and bit number. The high nibble encodes the byte number, and the low nibble the bit number.

The byte number is calculated as (OpSw# - 1) >> 3 and the bit number is (OpSw# - 1) - byte number × 8.

Byte 5:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

Response:

OPC_LONG_ACK.

Notes:

None.

OPC_BUSY

Operation: Indicates that the master is busy.

Group: 2-Byte Message

Direction: ↔ Command Station

Encoding:

Byte 0:

1	0	0	0	0	0	0	1	0x81	Opcode.

Byte 1:

0	1	1	1	1	1	1	0	0x7E	Checksum.

Description:

This message indicates that the master is busy. When sent to a command station it responds with an OPC_PEER_XFER message.

Response:

None.

Notes:

None.

OPC_CONSIST_FUNC

Operation: Set function bits in a consist uplink element.

Group: 4-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	0	1	1	0	1	1	0	0xB6	Opcode.

Byte 1:

0	n	n	n	n	n	n	n	<SLOT#>	Slot number in the range 0x00 to 0x7F.

Byte 2:

0	d6	d5	d4	d3	d2	d1	d0	<DIRF>	Consist element's direction and state of functions F0 to F4.

d6	Reserved. Set to 0.
d5	Locomotive direction. 1 means forward, 0 means backwards.
d4	F0 state. 1 means on, and 0 means off.
d3	F4 state. 1 means on, and 0 means off.
d2	F3 state. 1 means on, and 0 means off.
d1	F2 state. 1 means on, and 0 means off.
d0	F1 state. 1 means on, and 0 means off.

Byte 3:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This function sets the consist element's direction and function F0 to F4 states.

Response:

None.

Notes:

None.

OPC_GPOFF

Operation: Global power off request.

Group: 2-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	0	0	0	0	0	1	0	0x82	Opcode.

Byte 1:

0	1	1	1	1	1	0	1	0x7D	Checksum.

Description:

This command turns off the track power.

Response:

None.

Notes:

None.

OPC_GPON

Operation: Global power on request.

Group: 2-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	0	0	0	0	0	1	1	0x83	Opcode.

Byte 1:

0	1	1	1	1	1	0	0	0x7C	Checksum.

Description:

This command sends a global power on request.

Response:

The on power on the command station sends an OPC_RQ_SL_DATA message for slot 0x7F. It also sends a sequence of OPC_SW_REQ messages with the following values of SW1 and SW2:

SW1	SW2	Purpose
0x78	0x27	
0x79	0x27	
0x7A	0x27	
0x7B	0x27	
0x78	0x07	Interrogate all PM4 inputs?
0x79	0x07	Interrogate all BDL16 input reports?
0x7A	0x07	Interrogate all SE8 input reports?
0x7B	0x07	Interrogate all DS64 input reports.

Notes:

None.

OPC_IDLE

Operation: Force idle state and broadcast emergency stop.

Group: 2-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	0	0	0	0	1	0	1	0x85	Opcode.

Byte 1:

0	1	1	1	1	0	1	0	0x7A	Checksum.

Description:

This command forces the Network into the idle state and broadcasts an emergency stop.

Response:

None

Notes:

None.

OPC_IMM_PACKET

Operation: Send n-byte packet immediate.

Group: Variable-Byte Message

Direction: → command station

Encoding:

Byte 0:

1	1	1	0	1	1	0	1	0xED	Opcode.

Byte 1:

0	0	0	1	0	0	0	0	0x0B	Message length (11 bytes).

Byte 2:

0	1	1	1	1	1	1	1	0x7F	Source id in the range 0x00 to 0x7F.

Byte 3:

0	d6	d5	d4	d3	d2	d1	d0	<REPS>	Number of immediate bytes and repeat count.

d6 N2. Number of immediate bytes.
d5 N1. Number of immediate bytes.
d4 N0. Number of immediate bytes.
d3 A4. Reserved. Set to 0.
d2 R2. Repeat count.
d1 R1. Repeat count.
d0 R0. Repeat count.

Byte 4:

0	0	1	d4	d3	d2	d1	d0	<DHII>	High bits of IM1 to IM5.

d4 IM5.7. High bit.
d3 IM4.7. High bit.
d2 IM3.7. High bit.
d1 IM2.7. High bit.
d0 IM1.7. High bit.

Byte 5:

0	d6	d5	d4	d3	d2	d1	d0	<IM1>	Data item 1 low 7 bits.

Byte 6:

0	d6	d5	d4	d3	d2	d1	d0	<IM2>	Data item 2 low 7 bits.

Byte 7:

0	d6	d5	d4	d3	d2	d1	d0	<IM3>	Data item 3 low 7 bits.

Byte 8:

0	d6	d5	d4	d3	d2	d1	d0	<IM4>	Data item 4 low 7 bits.

Byte 9:

0	d6	d5	d4	d3	d2	d1	d0	<IM5>	Data item 5 low 7 bits.

Byte 10:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

Send n-byte packet immediate.

Response:

OPC_LONG_ACK.

Notes:

None.

OPC_INPUT_REP

Operation: General sensor input report.

Group: 4-Byte Message

Direction: General sensor →

Encoding:

Byte 0:

1	0	1	1	0	0	1	0	0xB2	Opcode.

Byte 1:

0	d6	d5	d4	d3	d2	d1	d0	<IN1>	Sensor address A7 to A1.

d6 A7.
d5 A6.
d4 A5.
d3 A4.
d2 A3.
d1 A2.
d0 A1.

Byte 2:

0	1	d5	d4	d3	d2	d1	d0	<IN2>	Switch address A11 to A8 and sensor input state.

d5 A0.
d4 Input state. 1 means sensor input >= 6V, and 0 means sensor input = 0V.
d3 A11.
d2 A10.
d1 A9.
d0 A8.

Byte 3:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

General sensor report.

Response:

None.

Notes:

None.

OPC_LINK_SLOTS

Operation: Link slots.

Group: 4-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	0	1	1	1	0	0	1	0xB9	Opcode.

Byte 1:

0	n	n	n	n	n	n	n	<SL1>	Slot number in the range 0x00 to 0x7F.

Byte 2:

0	n	n	n	n	n	n	n	<SL2>	Slot number in the range 0x00 to 0x7F.

Byte 3:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This function links slot SL1 to slot SL2. The command station setsSL_CONUP/DN flags appropriately. Invalid link will return a fail acknowledgement.

Response:

OPC_SL_RD_DATA or OPC_LONG_ACK.

Notes:

None.

OPC_LOCO_ADR

Operation: Request a slot number for a locomotive.

Group: 4-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	0	1	1	1	1	1	1	0xBF	Opcode.

Byte 1:

0	n	n	n	n	n	n	n	<ADR2>	High address.

Byte 2:

0	n	n	n	n	n	n	n	<ADR>	Low address.

Byte 3:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This message requests the slot number for the selected locomotive address. If the locomotive is found in the slot table then the command station returns an OPC_SL_RD_DATA message with the slot information. If it is not found then the command station will put the locomotive into a free slot and then return an OPC_SL_RD_DATA message with the slot information. If there are no free slots then the command station returns an OPC_LONG_ACK error code.

Note that regular short 7 bit NMRA addresses are denoted by <ADR2> = 0. The Analog, zero stretched, locomotive is selected when both <ADR2> = 0 and <ADR> = 0. <ADR> is always a 7 bit value. If <ADR2> is non-zero then the master will generate NMRA type 14 bit or long address packets using all 14 bits from <ADR2> and <ADR> with <ADR2> being the most significant address bits. Note that a DT200 Master does not process 14 bit address requests and will consider the <ADR2> to be zero. You can check the <TRK> return bits to see if the master is a DT200.

Response:

OPC_SL_RD_DATA if success, otherwise OPC_LONG_ACK.

Notes:

The the Network 1.1 specification specifies that <ADR2> value is 0x00.

OPC_LOCO_ADR_EXT

Operation: Request an extended slot for a locomotive.

Group: 4-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	0	1	1	1	1	1	0	0xBE	Opcode.

Byte 1:

0	n	n	n	n	n	n	n	<ADR2>	High address.

Byte 2:

0	n	n	n	n	n	n	n	<ADR>	Low address.

Byte 3:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This message requests the slot number for the selected locomotive address. If the locomotive is found in the slot table then the command station returns an OPC_SL_RD_DATA_EXT message with the slot information. If it is not found then the command station will put the locomotive into a free slot and then return an OPC_SL_RD_DATA_EXT message with the slot information. If there are no free slots then the command station returns an OPC_LONG_ACK error code.

Note that regular short 7 bit NMRA addresses are denoted by <ADR2> = 0. The Analog, zero stretched, locomotive is selected when both <ADR2> = 0 and <ADR> = 0. <ADR> is always a 7 bit value. If <ADR2> is non-zero then the master will generate NMRA type 14 bit or long address packets using all 14 bits from <ADR2> and <ADR> with <ADR2> being the most significant address bits. Note that a DT200 Master does not process 14 bit address requests and will consider the <ADR2> to be zero. You can check the <TRK> return bits to see if the master is a DT200.

Response:

OPC_SL_RD_DATA_EXT if success, otherwise OPC_LONG_ACK.

Notes:

None.

OPC_LOCO_DIRF

Operation: Set locomotive direction and function F0 to F4 states.

Group: 4-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	0	1	0	0	0	0	1	0xA1	Opcode.

Byte 1:

0	n	n	n	n	n	n	n	<SLOT#>	Slot number in the range 0x00 to 0x7F.

Byte 2:

0	d6	d5	d4	d3	d2	d1	d0	<DIRF>	Locomotive's direction and state of functions F0 to F4.

d6 Reserved. Set to 0.
d5 Locomotive direction. 1 means forward, 0 means backwards.
d4 F0 state. 1 means on, and 0 means off.
d3 F4 state. 1 means on, and 0 means off.
d2 F3 state. 1 means on, and 0 means off.
d1 F2 state. 1 means on, and 0 means off.
d0 F1 state. 1 means on, and 0 means off.

Byte 3:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This function sets the locomotive's direction and function F0 to F4 states.

Response:

None.

Notes:

None.

OPC_LOCO_DIRF_EXT

Operation: Set locomotive direction and function F0 to F28 states for extended slots.

Group: 6-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	1	0	1	0	1	0	0	0xD4	Opcode.

Byte 1:

0	0	1	0	0	d2	d1	d0	0x2<SLOTP>	Bits d2 to d0 contain the extended slot page number in the range 0x0 to 0x7.

Byte 2:

0	n	n	n	n	n	n	n	<SLOT#>	Extended slot number.

Byte 3:

0	0	0	0	0	1	0	0	<SUBC>	Subcode.

Byte 4:

0	d6	d5	d4	d3	d2	d1	d0	<DIRFX>	Direction and function sates.

SUBC	d6	d5	d4	d3	d2	d1	d0
0x05	0	0	0	0	F28	F20	F12
0x06	0	DIR	F0	F4	F3	F2	F1
0x07	F11	F10	F9	F8	F7	F6	F5
0x08	F19	F18	F17	F16	F15	F14	F13
0x09	F27	F26	F25	F24	F23	F22	F21

For the direction bit (DIR) 1 means forwards and 0 means backwards. For the function bits 1 means on and 0 means off.

Byte 5:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This function sets the locomotive's direction and function F0 to F28 states.

Response:

None.

Notes:

None.

OPC_LOCO_FN_EXT

Operation: Set locomotive function states for extended slots.

Group: 6-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	1	0	1	0	1	0	0	0xD4	Opcode.

Byte 1:

0	0	0	d4	d3	d2	d1	d0	<SLOTP>	Bits d2 to d0 contain the extended slot page number in the range 0x0 to 0x7. The bit d4 contains the function state where 1 means on and 0 means off. The bit d3 contains the high bit of the function number (bit 14).

Byte 2:

0	n	n	n	n	n	n	n	<SLOT#>	Extended slot number.

Byte 3:

0	n	n	n	n	n	n	n	<FN0>	Function number bits 0 to 6.

Byte 4:

0	n	n	n	n	n	n	n	<FN1>	Function number bits 7 to 13.

Byte 5:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This function sets the locomotive's function F0 to F32767 states.

Response:

None.

Notes:

None.

OPC_LOCO_RESET

Operation: Loco reset button has been pressed on the command station.

Group: 2-Byte Message

Direction: Command Station →

Encoding:

Byte 0:

1	0	0	0	1	0	1	0	0x8A	Opcode.

Byte 1:

0	1	1	1	0	1	0	1	0x75	Checksum.

Description:

The Loco reset button has been pressed.

Response:

None, this is a response.

Notes:

None.

OPC_LOCO_SND

Operation: Set locomotive sound functions.

Group: 4-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	0	1	0	0	0	1	0	0xA2	Opcode.

Byte 1:

0	n	n	n	n	n	n	n	<SLOT#>	Slot number in the range 0x00 to 0x7F.

Byte 2:

0	d6	d5	d4	d3	d2	d1	d0	<SND>	Locomotive's function F5 to F8 states.

d6 Reserved. Set to 0.
d5 Reserved. Set to 0.
d4 Reserved. Set to 0.
d3 Reserved. Set to 0.
d3 Sound 4 / F8.
d2 Sound 3 / F7.
d1 Sound 2 / F6.
d0 Sound 1 / F5.

Byte 3:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This function sets the locomotive's function F5 to F8 states.

Response:

None.

Notes:

None.

OPC_LOCO_SPD

Operation: Set locomotive speed.

Group: 4-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	0	1	0	0	0	0	0	0xA0	Opcode.

Byte 1:

0	n	n	n	n	n	n	n	<SLOT#>	Slot number in the range 0x00 to 0x7F.

Byte 2:

0	n	n	n	n	n	n	n	<SPD>	Locomotive speed in the range 0x00 to 0x7F. 0x00 means inertial stop and 0x01 means emergency stop. Other values mean increasing speed.

Byte 3:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This function sets the locomotive's speed.

Response:

None.

Notes:

None.

OPC_LOCO_SPD_EXT

Operation: Set locomotive speed for extended slots.

Group: 6-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	1	0	1	0	1	0	0	0xD4	Opcode.

Byte 1:

0	0	1	0	0	d2	d1	d0	<SLOTP>	Bits d2 to d0 contain the extended slot page number in the range 0x0 to 0x7.

Byte 2:

0	n	n	n	n	n	n	n	<SLOT#>	Extended slot number.

Byte 3:

0	0	0	0	0	1	0	0	0x04	Subcode.

Byte 4:

0	n	n	n	n	n	n	n	<SPD>	Locomotive speed in the range 0x00 to 0x7F. 0x00 means inertial stop and 0x01 means emergency stop. Other values mean increasing speed.

Byte 5:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This function sets the locomotive's speed.

Response:

None.

Notes:

None.

OPC_LONG_ACK

Operation: Long acknowledge.

Group: 4-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	0	1	1	0	1	0	0	0xB4	Opcode.

Byte 1:

0	n	n	n	n	n	n	n	<LOPC>	Opcode that this message is a response to with the most significant bit set to 0.

Byte 2:

0	n	n	n	n	n	n	n	<ACK1>	Response code.

Byte 3:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This message provides a response code from a command.

Response:

None, it is the response.

Notes:

Responding Opcode	<LOPC>	<ACK1>	Meaning
OPC_SW_ACK	0x3D	0x00	DCS100 FIFO is full, command rejected.
OPC_SW_ACK	0x3D	0x7F	DCS100 command accepted.
OPC_MOVE_SLOTS	0x3A	0x00	Illegal move.
OPC_LINK_SLOTS	0x39	0x00	Invalid link, link failed.
OPC_SW_REQ	0x30	0x00	Command failed.
OPC_LOCO_ADR	0x3F	0x00	No free slot, command failed.
OPC_IMM_PACKET	0x7D	0x7F	Command OK, if not limited master.
OPC_IMM_PACKET	0x7E	<lim address>	Command OK, if limited master.
OPC_IMM_PACKET	0x7D	0x00	Internal buffer busy or full.
OPC_WR_SL_DATA_EXT	0x6E	0x7F	Command OK.

OPC_MOVE_SLOTS

Operation: Move slot.

Group: 4-Byte Message

Direction: → Switch

Encoding:

Byte 0:

1	0	1	1	1	0	1	0	0xBA	Opcode.

Byte 1:

0	n	n	n	n	n	n	n	<SRC>	Source slot number in the range 0x00 to 0x77.

Byte 2:

0	n	n	n	n	n	n	n	<DEST>	Destination slot number in the range 0x00 to 0x77.

Byte 3:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

Move slots.

SRC	DEST	Action
0x00	Don't Care	Dispatch get. Return slot read of dispatch slot.
SRC	SRC	Null move. SRC is set to in use.
SRC	0x00	Dispatch put. Mark slot as dispatch.
SRC	DEST	Move slot data from SRC to DEST if not in use. Clear SRC.

Response:

OPC_SL_RD_DATA or OPC_LONG_ACK.

Notes:

None.

OPC_MOVE_SLOTS_EXT

Operation: Move extended slots.

Group: 6-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	1	0	1	0	1	0	0	0xD4	Opcode.

Byte 1:

0	0	1	1	1	d2	d1	d0	<SRCP>	Bits d2 to d0 contain the extended source slot page number in the range 0x0 to 0x7. The higher bits are a sub-code for this operation.

Byte 2:

0	n	n	n	n	n	n	n	<SRC>	Extended source slot number. In the range 0x00 to 0x7F

Byte 3:

0	0	0	0	0	d2	d1	d0	<DESTP>	Bits d2 to d0 contain the extended destination slot page number in the range 0x0 to 0x7.

Byte 4:

0	n	n	n	n	n	n	n	<DEST>	Extended destination slot number. In the range 0x00 to 0x7F.

Byte 5:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

Move slots.

SRC	DEST	Action
0x00	Don't Care	Dispatch get. Return slot read of dispatch slot.
SRC	SRC	Null move. SRC is set to in use.
SRC	0x00	Dispatch put. Mark slot as dispatch.
SRC	DEST	Move slot data from SRC to DEST if not in use. Clear SRC.

Response:

OPC_SL_RD_DATA_EXT or OPC_LONG_ACK.

Notes:

None.

OPC_PEER_XFER

Operation: Move 8 bytes peer to peer.

Group: Variable-Byte Message

Direction: device → device

Encoding:

Byte 0:

1	1	1	0	0	1	0	1	0xE5	Opcode.

Byte 1:

0	0	0	1	0	0	0	0	0x10	Message length (16 bytes).

Byte 2:

0	n	n	n	n	n	n	n	<SRC>	Source id in the range 0x00 to 0x7F.

Byte 3:

0	n	n	n	n	n	n	n	<DSTL>	Destination id low in the range 0x00 to 0x7F.

Byte 4:

0	n	n	n	n	n	n	n	<DSTH>	Destination id high in the range 0x00 to 0x7F.

Byte 5:

0	d6	d5	d4	d3	d2	d1	d0	<PXCT1>	Address type code and high bits of D1 to D4.

d6 XC2. Address type code.
d5 XC1. Address type code.
d4 XC0. Address type code.
d3 D4.7. High bit
d2 D3.7. High bit
d1 D2.7. High bit
d0 D1.7. High bit

XC2	XC1	XC0	Meaning
0	0	0	7 bit peer to peer addresses.
0	0	1	reserved.
0	1	0	reserved.
0	1	1	reserved.
1	0	0	IPL download.
1	0	1	reserved.
1	1	0	reserved.
1	1	1	reserved.

Byte 6:

0	n	n	n	n	n	n	n	<D1>	Data item 1. Low 7 bits.

Byte 7:

0	n	n	n	n	n	n	n	<D2>	Data item 2. Low 7 bits.

Byte 8:

0	n	n	n	n	n	n	n	<D3>	Data item 3. Low 7 bits.

Byte 9:

0	n	n	n	n	n	n	n	<D4>	Data item 4. Low 7 bits.

Byte 10:

0	n	n	n	n	n	n	n	<PXCT2>	Data type code and high bits for D5 to D8.

d6 XC5. Data type code.
d5 XC4. Data type code.
d4 XC3. Data type code.
d3 D8.7. High bit
d2 D7.7. High bit
d1 D6.7. High bit
d0 D5.7. High bit

XC5	XC4	XC3	Meaning
0	0	0	ANSI text string. IPL download setup subcode.
0	0	1	IPL download address subcode.
0	1	0	IPL download send data subcode.
0	1	1	IPL download verify data subcode.
1	0	0	IPL download end of operation subcode.
1	0	1	reserved.
1	1	0	reserved.
1	1	1	reserved.

Options flags

```
private static final int DO_NOT_CHECK_SOFTWARE_VERSION = 0x00;
    private static final int CHECK_SOFTWARE_VERSION_LESS = 0x04;

    private static final int DO_NOT_CHECK_HARDWARE_VERSION = 0x00;
    private static final int REQUIRE_HARDWARE_VERSION_EXACT_MATCH = 0x01;
    private static final int ACCEPT_LATER_HARDWARE_VERSIONS = 0x03;
```

Byte 11:

0	n	n	n	n	n	n	n	<D5>	Data item 5. Low 7 bits.

Byte 12:

0	n	n	n	n	n	n	n	<D6>	Data item 6. Low 7 bits.

Byte 13:

0	n	n	n	n	n	n	n	<D7>	Data item 7. Low 7 bits.

Byte 14:

0	n	n	n	n	n	n	n	<D8>	Data item 8. Low 7 bits.

Byte 15:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This command sends the data from one device to another peer to peer.

SRC	DSTL	DSTH	Comments
0x00			Source is command station.
Don't Care	0x00	0x00	Broadcast Message.
0x70 to 0x7E			Reserved.
0x7F	0x00	0x00	Broadcast throttle message transfer.
0x7F	ID1	ID2	Throttle message transfer. ID1 and ID2 encode ID.

Response:

None

Notes:

None.

OPC_PEER_XFER_20

Operation: Move bytes peer to peer.

Group: Variable-Byte Message

Direction: device → device

Encoding:

Byte 0:

1	1	1	0	0	1	0	1	0xE5	Opcode.

Byte 1:

0	0	0	1	0	1	0	0	0x14	Message length (20 bytes).

Byte 2:

0	n	n	n	n	n	n	n	<SRC>	Source id in the range 0x00 to 0x7F.

Byte 3:

0	n	n	n	n	n	n	n	<DSTL>	Destination id low in the range 0x00 to 0x7F.

Byte 4:

0	n	n	n	n	n	n	n	<DSTH>	Destination id high in the range 0x00 to 0x7F.

Byte 5:

0	n	n	n	n	n	n	n	<HOST>	Device host identifier.

This should be 0x00 for discover devices broadcast.

Host Id	Device
0x01	LNRP
0x04	UT4
0x0C	WTL12
0x14	DB210 Opto
0x15	DB210
0x16	DB220
0x1A	DCS210+
0x1B	DCS210
0x1C	DCS240
0x23	PR3
0x24	PR4
0x2A	DT402
0x32	DT500
0x33	DCS51
0x34	DCS52
0x3E	DT602
0x51	BXPA1
0x58	BXP88
0x5C	UR92
0x63	LNWI

Byte 6:

0	n	n	n	n	n	n	n	Hardware version.

Host Id	Device
0x00	Slave all
0x18	Slave RF24

Byte 7:

0	n	n	n	n	n	n	n	Reserved.

Byte 8:

0	d6	d5	d4	d3	d2	d1	d0	Software Version Number.

d6 version number bit 3
d5 version number bit 2.
d4 version number bit 1
d3 version number bit 0
d2 subversion number bit 2
d1 subversion number bit 1
d0 subversion number bit 0

e.g. 0x09 decodes as version 1.1.

This is set to 0x00 for discover devices broadcast message.

Byte 9:

0	d6	d5	d4	d3	d2	d1	d0	<PXCT1>	Address type code and high bits of D1 to D4.

d6 XC2. Address type code.
d5 XC1. Address type code.
d4 XC0. Address type code.
d3 D4.7. High bit
d2 D3.7. High bit
d1 D2.7. High bit
d0 D1.7. High bit

XC2	XC1	XC0	Meaning
0	0	0	7 bit peer to peer addresses.
0	0	1	reserved.
0	1	0	reserved.
0	1	1	reserved.
1	0	0	reserved.
1	0	1	reserved.
1	1	0	reserved.
1	1	1	reserved.

Byte 10:

0	n	n	n	n	n	n	n	<D1>	Data item 1. Low 7 bits.

Byte 11:

0	n	n	n	n	n	n	n	<D2>	Data item 2. Low 7 bits.

This should be 0x01 for a discover devices broadcast message.

Byte 12:

0	n	n	n	n	n	n	n	<D3>	Data item 3. Low 7 bits.

Byte 13:

0	n	n	n	n	n	n	n	<D4>	Data item 4. Low 7 bits.

Byte 14:

0	n	n	n	n	n	n	n	<PXCT2>	Data type code and high bits for D5 to D8.

d6	XC5. Data type code.
d5	XC4. Data type code.
d4	XC3. Data type code.
d3	D8.7. High bit
d2	D7.7. High bit
d1	D6.7. High bit
d0	D5.7. High bit

XC5	XC4	XC3	Meaning
0	0	0	ANSI text string.
0	0	1	reserved.
0	1	0	reserved.
0	1	1	reserved.
1	0	0	reserved.
1	0	1	reserved.
1	1	0	reserved.
1	1	1	reserved.

Byte 15:

0	n	n	n	n	n	n	n	<D5>	Data item 5. Low 7 bits.

Byte 16:

0	n	n	n	n	n	n	n	<D6>	Data item 6. Low 7 bits.

Byte 17:

0	n	n	n	n	n	n	n	<D7>	Data item 7. Low 7 bits.

Byte 18:

0	n	n	n	n	n	n	n	<D8>	Data item 8. Low 7 bits.

Byte 19:

0	n	n	n	n	n	n	n

<CHK> Checksum.

Description:

This command sends the data from one device to another peer to peer.

SRC	DSTL	DSTH	Comments
0x0F	0x08	0x00	Discover devices broadcast message.
0xoF	0x10	0x00	Discover device response.

Response:

OPC_PEER_XFER_20 for discover devices.

Notes:

The discover response decoded peer transfer message encodes as follows:

D1	IPL Version Number
D2	Serial Number - low byte
D3	Serial Number - high byte
D4	
D5	Serial Number 2 - low byte
D6	Serial Number 2 - high byte
D7	
D8	

The IPL version number is encoded as follows:

d6	version number bit 3
d5	version number bit 2.
d4	version number bit 1
d3	version number bit 0
d2	subversion number bit 2
d1	subversion number bit 1
d0	subversion number bit 0

e.g. 0x09 decodes as version 1.1.

These came from DigiPLII:

message Length = 20 e5 14 0f 10 00 24 00 00 00 02 00 08 07 00 00 00 00 00 00 38

message Length = 20 e5 14 0f 08 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 08

message Length = 20 e5 14 0f 10 00 24 00 00 00 00 00 57 13 00 00 00 00 00 00 71

message Length = 20 e5 14 0f 10 00 1b 00 00 03 02 00 54 10 00 00 00 00 00 00 4f

It reports PR4 with serial number 0x0788 ver 0 PR4 with serial 0x1357 ver 0 DCS240 with SN 0x0AAB ver 0.3 DCS210 with SN 0x10D4 ver 0.3

OPC_RQ_SL_DATA

Operation: Request slot data or status block.

Group: 4-Byte Message

Direction: → Switch

Encoding:

Byte 0:

1	0	1	1	1	0	1	1	0xBB	Opcode.

Byte 1:

0	n	n	n	n	n	n	n	<SLOT#>	Slot number in the range 0x00 to 0x7F. 0 returns the command station status block

Byte 2:

0	d6	0	0	d3	d2	d1	d0	<SLOTP>	Bits d2 to d0 contain the extended slot page number in the range 0x0 to 0x7. The bit d3 does something but its function is not yet known. When bit d6 is 1 then extended slot data is returned for all slots, when it is 0 standard slot data is returned for slots 0x00 to 0x7F.

Byte 3:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

Request slot data or status block.

Response:

if SLOTP = 0x00 then OPC_SL_RD_DATA, otherwise OPC_SL_RD_DATA_EXT.

Notes:

None.

OPC_SL_RD_DATA

Operation: Returns slot data.

Group: Variable-Byte Message

Direction: Command Station →

Encoding:

Byte 0:

1	1	1	0	0	1	1	1	0xE7	Opcode.

Byte 1:

0	1	1	1	1	1	1	0	0x0E	Message length (14 bytes).

Bytes 2 to 12 encode as per slot bytes 0 to 10.

Byte 13:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This message is sent by the command station in response to a slot data request.

Response:

None.

Notes:

None.

OPC_SL_RD_DATA_EXT

Operation: Returns extended slot data.

Group: Variable-Byte Message

Direction: Command Station →

Encoding:

Byte 0:

1	1	1	0	0	1	1	0	0xE6	Opcode.

Byte 1:

0	0	0	1	0	1	0	1	0x15	Message length (21 bytes).

Bytes 2 to 19 encode as per extended slot bytes 0 to 17.

Byte 20:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This message is sent by the command station in response to an extended slot data request.

Response:

None.

Notes:

None.

OPC_SLOT_STAT1

Operation: Set slot status 1.

Group: 4-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	0	1	1	0	1	0	1	0xB5	Opcode.

Byte 1:

0	n	n	n	n	n	n	n	<SLOT#>	Slot number in the range 0x00 to 0x7F.

Byte 2:

0	d6	d5	d4	d3	d2	d1	d0	<STAT1>	Slot status 1.

Byte 3:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This function sets the slot's status 1 values.

Response:

None.

Notes:

None.

OPC_SV_PROG

Operation: Program system variables.

Group: Variable-Byte Message

Direction: device → device

Encoding:

Byte 0:

1	1	1	0	0	1	0	1	0xE5	Opcode.

Byte 1:

0	0	0	1	0	1	0	0	0x14	Message length (20 bytes).

Byte 2:

0	n	n	n	n	n	n	n	<SRC>	Source id in the range 0x00 to 0x7F.

Byte 3:

0	n	n	n	n	n	n	n	<SV_CMD>	Specifies the SV access type.

Byte 4:

0	n	n	n	n	n	n	n	<DSTH>	Destination id high in the range 0x00 to 0x7F.

Byte 5:

0	n	n	n	n	n	n	n	<HOST>	Device host identifier.

This should be 0x00 for discover devices broadcast.

Host Id	Device
0x01	LNRP
0x04	UT4
0x0C	WTL12
0x14	DB210 Opto
0x15	DB210
0x16	DB220
0x1A	DCS210+
0x1B	DCS210
0x1C	DCS240
0x23	PR3
0x24	PR4
0x2A	DT402
0x32	DT500
0x33	DCS51
0x34	DCS52
0x3E	DT602
0x51	BXPA1
0x58	BXP88
0x5C	UR92
0x63	LNWI

Byte 6:

0	n	n	n	n	n	n	n	Hardware version.

Host Id	Device
0x00	Slave all
0x18	Slave RF24

Byte 7:

0	n	n	n	n	n	n	n	Reserved.

Byte 8:

0	d6	d5	d4	d3	d2	d1	d0	Software Version Number.

d6 version number bit 3
d5 version number bit 2.
d4 version number bit 1
d3 version number bit 0
d2 subversion number bit 2
d1 subversion number bit 1
d0 subversion number bit 0

e.g. 0x09 decodes as version 1.1.

This is set to 0x00 for discover devices broadcast message.

Byte 9:

0	d6	d5	d4	d3	d2	d1	d0	<PXCT1>	Address type code and high bits of D1 to D4.

d6 XC2. Address type code.
d5 XC1. Address type code.
d4 XC0. Address type code.
d3 D4.7. High bit
d2 D3.7. High bit
d1 D2.7. High bit
d0 D1.7. High bit

XC2	XC1	XC0	Meaning
0	0	0	7 bit peer to peer addresses.
0	0	1	reserved.
0	1	0	reserved.
0	1	1	reserved.
1	0	0	reserved.
1	0	1	reserved.
1	1	0	reserved.
1	1	1	reserved.

Byte 10:

0	n	n	n	n	n	n	n	<D1>	Data item 1. Low 7 bits.

Byte 11:

0	n	n	n	n	n	n	n	<D2>	Data item 2. Low 7 bits.

This should be 0x01 for a discover devices broadcast message.

Byte 12:

0	n	n	n	n	n	n	n	<D3>	Data item 3. Low 7 bits.

Byte 13:

0	n	n	n	n	n	n	n	<D4>	Data item 4. Low 7 bits.

Byte 14:

0	n	n	n	n	n	n	n	<PXCT2>	Data type code and high bits for D5 to D8.

d6 XC5. Data type code.
d5 XC4. Data type code.
d4 XC3. Data type code.
d3 D8.7. High bit
d2 D7.7. High bit
d1 D6.7. High bit
d0 D5.7. High bit

XC5	XC4	XC3	Meaning
0	0	0	ANSI text string.
0	0	1	reserved.
0	1	0	reserved.
0	1	1	reserved.
1	0	0	reserved.
1	0	1	reserved.
1	1	0	reserved.
1	1	1	reserved.

Byte 15:

0	n	n	n	n	n	n	n	<D5>	Data item 5. Low 7 bits.

Byte 16:

0	n	n	n	n	n	n	n	<D6>	Data item 6. Low 7 bits.

Byte 17:

0	n	n	n	n	n	n	n	<D7>	Data item 7. Low 7 bits.

Byte 18:

0	n	n	n	n	n	n	n	<D8>	Data item 8. Low 7 bits.

Byte 19:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This command sends the data from one device to another peer to peer.

SRC	DSTL	DSTH	Comments
0x0F	0x08	0x00	Discover devices broadcast message.
0x0F	0x10	0x00	Discover device response.

Response:

OPC_PEER_XFER_20 for discover devices.

Notes:

The discover response decoded peer transfer message encodes as follows:

D1	IPL Version Number
D2	Serial Number - low byte
D3	Serial Number - high byte
D4	
D5	Serial Number 2 - low byte
D6	Serial Number 2 - high byte
D7	
D8	

The IPL version number is encoded as follows:

d6	version number bit 3
d5	version number bit 2.
d4	version number bit 1
d3	version number bit 0
d2	subversion number bit 2
d1	subversion number bit 1
d0	subversion number bit 0

e.g. 0x09 decodes as version 1.1.

These came from DigiPLII:

message Length = 20 e5 14 0f 10 00 24 00 00 00 02 00 08 07 00 00 00 00 00 00 38

message Length = 20 e5 14 0f 08 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00 08

message Length = 20 e5 14 0f 10 00 24 00 00 00 00 00 57 13 00 00 00 00 00 00 71

message Length = 20 e5 14 0f 10 00 1b 00 00 03 02 00 54 10 00 00 00 00 00 00 4f

It reports PR4 with serial number 0x0788 ver 0 PR4 with serial 0x1357 ver 0 DCS240 with SN 0x0AAB ver 0.3 DCS210 with SN 0x10D4 ver 0.3

OPC_SW_ACK

Operation: Request switch command with acknowledge.

Group: 4-Byte Message

Direction: → Turnout controller

Encoding:

Byte 0:

1	0	1	1	1	1	0	1	0xBD	Opcode.

Byte 1:

0	d6	d5	d4	d3	d2	d1	d0	<SW1>	Switch address A6 to A0.

d6 A6.
d5 A5.
d4 A4.
d3 A3.
d2 A2.
d1 A1.
d0 A0.

Byte 2:

0	d6	d5	d4	d3	d2	d1	d0	<SW2>	Switch address A10 to A7 and switch control bits.

d6 Reserved. Set to 0.
d5 Direction. 1 means closed/green, and 0 means thrown/red.
d4 Output. 1 means on, and 0 means off.
d3 A10.
d2 A9.
d1 A8.
d0 A7.

Byte 3:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

Command a turnout controller to a specified state and send acknowledge.

Response:

OPC_LONG_ACK.

Notes:

None.

OPC_SW_REP

Operation: Turnout sensor report.

Group: 4-Byte Message

Direction: Turnout sensor →

Encoding:

Byte 0:

1	0	1	1	0	0	0	1	0xB1	Opcode.

Byte 1:

0	d6	d5	d4	d3	d2	d1	d0	<SN1>	Sensor address.

SN2.d6 = 1		SN2.d6 = 0	
d6	A7.	d6	A6.
d5	A6.	d5	A5.
d4	A5.	d4	A4.
d3	A4.	d3	A3.
d2	A3.	d2	A2.
d1	A2.	d1	A1.
d0	A1.	d0	A0.

Byte 2:

0	d6	d5	d4	d3	d2	d1	d0	<SN2>	Sensor address and sensor state.

SN2.d6 = 1

- d6 Report type. 1 means the report is an input report, and 0 means the report is an output report.
- d5 A0.
- d4 Input sensor state, 1 means sensor >= 6V, 0 means sensor = 0V.
- d3 A11.
- d2 A10.
- d1 A9.
- d0 A8.

SN2.d6 = 0

- d6 Report type. 1 means the report is an input report, and 0 means the report is an output report.
- d5 0 means closed output line is off, 1 means the closed output line is on.
- d4 0 means thrown output line is off, 1 means the thrown output line is on.
- d3 A10.
- d2 A9.
- d1 A8.
- d0 A7.

Byte 3:

0	n	n	n	n	n	n	n

<CHK> Checksum.

Description:

Turnout sensor report.

Response:

None.

Notes:

None.

OPC_SW_REQ

Operation: Request switch command.

Group: 4-Byte Message

Direction: → Turnout controller

Encoding:

Byte 0:

1	0	1	1	0	0	0	0	0xB0	Opcode.

Byte 1:

0	d6	d5	d4	d3	d2	d1	d0	<SW1>	Switch address A6 to A0.

d6 A6.
d5 A5.
d4 A4.
d3 A3.
d2 A2.
d1 A1.
d0 A0.

Byte 2:

0	d6	d5	d4	d3	d2	d1	d0	<SW2>	Switch address A10 to A7 and switch control bits.

d6 Reserved. Set to 0.
d5 Direction. 1 means closed/green, and 0 means thrown/red.
d4 Output. 1 means on, and 0 means off.
d3 A10.
d2 A9.
d1 A8.
d0 A7.

Byte 3:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

Command a turnout controller to a specified state.

Response:

OPC_LONG_ACK if command failed, otherwise no response.

Notes:

The on power on the command station sends a sequence of OPC_SW_REQ messages with the following values of SW1 and SW2:

SW1	SW2	Purpose
0x78	0x27	
0x79	0x27	
0x7A	0x27	
0x7B	0x27	
0x78	0x07	Interrogate all PM4 inputs?
0x79	0x07	Interrogate all BDL16 input reports?
0x7A	0x07	Interrogate all SE8 input reports?
0x7B	0x07	Interrogate all DS64 input reports.

OPC_SW_STATE

Operation: Request state of switch.

Group: 4-Byte Message

Direction: → Switch

Encoding:

Byte 0:

1	0	1	1	1	1	0	0	0xBC	Opcode.

Byte 1:

0	n	n	n	n	n	n	n	<SW1>	Switch address A6 to A0.

Byte 2:

0	d6	d5	d4	d3	d2	d1	d0	<SW2>	Switch address A10 to A7 and switch control bits.

d6 Reserved. Set to 0.
d5 Direction. 1 means closed/green, and 0 means thrown/red.
d4 Output. 1 means on, and 0 means off.
d3 A10.
d2 A9.
d1 A8.
d0 A7.

Byte 3:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

Request state of switch.

Response:

OPC_LONG_ACK.

Notes:

This needs to be tested to see what the real purpose is.

OPC_TRANS_REP

Operation: Transponder input report.

Group: 6-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	1	0	1	0	0	0	0	0xD0	Opcode.

Byte 1:

0	n	n	n	n	n	n	n		A value of 0x20 means the positive detection of a transponder, 0x00 means no longer detected.

Byte 2:

0	0	0	0	n	n	n	n	<ZONE#>	Zone indicator (0x0 = A, 0x2 = B, 0x4 = C, 0x6 = D).

Byte 3:

0	n	n	n	n	n	n	n	<ADR>	Locomotive address low bits.

Byte 4:

0	n	n	n	n	n	n	n	<ADR2>	Locomotive address high bits.

Byte 5:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

Response:

None.

Notes:

None.

OPC_UNLINK_SLOTS

Operation: Unlink slots.

Group: Variable-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	0	1	1	1	0	0	0	0xB8	Opcode.

Byte 1:

0	n	n	n	n	n	n	n	<SL1>	Slot number in the range 0x00 to 0x7F.

Byte 2:

0	n	n	n	n	n	n	n	<SL2>	Slot number in the range 0x00 to 0x7F.

Byte 3:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This command unlinks slot SL1 from slot SL2.

Response:

Returns OPC_SL_RD_DATA or OPC_LONG_ACK.

Notes:

None.

OPC_WR_SL_DATA

Operation: Write slot data.

Group: Variable-Byte Message

Direction: → Command Station

Encoding:

Byte 0:

1	1	1	0	1	1	1	1	0xEF	Opcode.

Byte 1:

0	1	1	1	1	1	1	0	0x0E	Message length (14 bytes).

Bytes 2 to 12 encode as per slot bytes 0 to 10.

Byte 13:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This command sends the slot data to the command station.

Response:

Returns OPC_LONG_ACK.

Notes:

None.

OPC_WR_SL_DATA_EXT

Operation: Write extended slot data.

Group: Variable-Byte Message

Direction: Command Station →

Encoding:

Byte 0:

1	1	1	0	1	1	1	0	0xEE	Opcode.

Byte 1:

0	0	0	1	0	1	0	1	0x15	Message length (21 bytes).

Bytes 2 to 19 encode as per extended slot bytes 0 to 17.

Byte 20:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

Description:

This command sends the slot data to the command station.

Response:

Returns OPC_LONG_ACK.

Notes:

None.

Chapter 2

Fast Clock

2.1 Summary

The command station provides a system fast clock and parameters are stored in slot #123 (0x7B). Use OPC_WR_SL_DATA to write new clock information, The current slot information can be read using OPC_RQ_SL_DATA. This will return an OPC_SL_RD_DATA message containing the fast clock information. This message is called the "sync". Other throttles will update to this sync. Note that all attached display devices keep a current clock calculation based on this sync read value, i.e. devices must not continuously poll the clock slot to generate time, but use this merely to restore sync and follow current rate etc. The clock slot is typically "pinged" or read every 70 to 100 seconds, by a single user, so all attached devices can synchronise any phase drifts. Upon seeing a sync read, all devices should reset their local sub-minute phase counter and invalidate the sync update ping generator.

2.2 Slot #123 Encoding

Byte 0:

0	1	1	1	1	0	1	1	0x7B	Slot number.

Byte 1:

0	n	n	n	n	n	n	n	<RATE>	Clock rate. 0x00 means freeze clock, 0x01 means 1:1 rate, 0x0A means 10:1, etc. The maximum value 0x7F means 128:1.

Byte 2:

0	n	n	n	n	n	n	n	<FRACL>	Sub-minute counter low bits.

Byte 3:

0	n	n	n	n	n	n	n	<FRACH>	Sub-minute counter high bits.

The implementation and meaning of FRACL and FRACH depend upon the specific clock generator. These values should not be used externally. These values are reset when a valid sync message is seen.

That said, the following timing was derived for the DCS240.

Get:

maxTick = 0xBFF

ticks = maxTick - (0x3FFF - ((<FRACL> & 0x7F) — ((<FRACH> & 0x7F) << 7)))

seconds = 60.0 * ticks / (maxTick + 1)

Set:

temp = ticks - maxTick + 0x3FFF

<FRACL> = temp & 0x7F

<FRACH> = (temp >> 7) & 0x7F

Byte 4:

0	n	n	n	n	n	n	n	<MINS>	Fast clock minutes. This is encoded.

Get:

temp = ((255 - <MINS>) & 0x7F) mod 60

minutes = (60 - temp) mod 60

Set:

<MINS> = (255 - (60 - minutes)) & 0x7F

Byte 5:

0	d6	d5	d4	d3	d2	d1	d0	<TRK>	Global system track status.

d6	Reserved. Set to 0.
d5	Reserved. Set to 0.
d4	Reserved. Set to 0.
d3	1 means the programming track is busy.
d2	1 means this master implements the Network version 1.1 capability, 0 means the master is a DT200.
d1	0 means the track is paused, broadcast an emergency stop.
d0	1 means the DCC packets are on in the master, global power up.

Byte 6:

0	n	n	n	n	n	n	n	<HRS>	Fast clock hours. This is encoded.

Get:

temp = ((256 - <HRS>) & 0x7F) mod 24

hours = (24 - temp) mod 24

Set:

<HRS> = (256 - (24 - hours)) & 0x7F

Byte 7:

0	n	n	n	n	n	n	n	<DAYS>	Fast clock days. Number of 24 hour clock rolls.

Byte 8:

0	d6	0	0	0	0	0	0	<CNTRL>	The bit d6 indicates valid clock information. 1 means good and 0 means ignore.

Byte 9:

0	n	n	n	n	n	n	n	<ID1>	Device ID low bits.

Byte 10:

0	n	n	n	n	n	n	n	<ID2>	Device ID high bits.

ID1 and ID2 indicate the device that last set the clock. 0x00, 0x00 means that not set has happened. 0x7F, 0x7X are reserved for computer use.

Chapter 3

Updating Firmware

3.1 Bootloader Protocol 1

3.2 Bootloader Protocol 2

1. The IPL Setup message is sent twice to initiate the download.
2. Each block is sent,
3. The IPL End Operation message is sent.

A block consists of an IPL Address message following by 1 or more IPL Data messages.

3.2.1 IPL Setup

Byte 0:

1	1	1	0	0	1	0	1	0xE5	OPC_PEER_XFER opcode.

Byte 1:

0	0	0	1	0	0	0	0	0x10	Message length (16 bytes).

Byte 2:

0	1	1	1	1	1	1	1	0x7F	Broadcast id.

Byte 3:

0	1	1	1	1	1	1	1	0x7F	Broadcast id.

Byte 4:

0	1	1	1	1	1	1	1	0x7F	Broadcast id.

Byte 5:

0	1	0	0	d3	d2	d1	d0	<PXCT1>	Download code 0x40 and high bits of D1 to D4.

d3 D4.7. High bit
d2 D3.7. High bit
d1 D2.7. High bit
d0 D1.7. High bit

Byte 6:

0	n	n	n	n	n	n	n	<D1>	Manufacturer code. Low 7 bits.

Code	Manufacturer
0x00	Digitrak

Byte 7:

0	n	n	n	n	n	n	n	<D2>	Product code. Low 7 bits.

Byte 8:

0	n	n	n	n	n	n	n	<D3>	Hardware version. Low 7 bits.

Byte 9:

0	n	n	n	n	n	n	n	<D4>	Software version. Low 7 bits.

Byte 10:

0	0	0	0	n	n	n	n	<PXCT2>	Setup download type code 0x00 and high bits for D5 to D8.

d3 D8.7. High bit
d2 D7.7. High bit
d1 D6.7. High bit
d0 D5.7. High bit

Byte 11:

0	n	n	n	n	n	n	n	<D5>	Options. Low 7 bits.

Byte 12:

0	0	0	0	0	0	0	0	<D6>	Reserved always 0x00. Low 7 bits.

Byte 13:

0	n	n	n	n	n	n	n	<D7>	Number of blocks to erase 7. Low 7 bits.

This is calculated as INT(0.5 + (Last Address - First Address) / Erase Blk Size).

Byte 14:

0	0	0	0	0	0	0	0	<D8>	Reserved always 0x00. Low 7 bits.

Byte 15:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

3.2.2 IPL Address Message

Byte 0:

1	1	1	0	0	1	0	1	0xE5	OPC_PEER_XFER opcode.

Byte 1:

0	0	0	1	0	0	0	0	0x10	Message length (16 bytes).

Byte 2:

0	1	1	1	1	1	1	1	0x7F	Broadcast id.

Byte 3:

0	1	1	1	1	1	1	1	0x7F	Broadcast id.

Byte 4:

0	1	1	1	1	1	1	1	0x7F	Broadcast id.

Byte 5:

0	1	0	0	d3	d2	d1	d0	<PXCT1>	Download code 0x40 and high bits of D1 to D4.

d3 D4.7. High bit
d2 D3.7. High bit
d1 D2.7. High bit
d0 D1.7. High bit

Byte 6:

0	n	n	n	n	n	n	n	<D1>	Address High Byte. Low 7 bits.

Byte 7:

0	n	n	n	n	n	n	n	<D2>	Address Mid Byte. Low 7 bits.

Byte 8:

0	n	n	n	n	n	n	n	<D3>	Address Low Byte. Low 7 bits.

Byte 9:

0	0	0	0	0	0	0	0	<D4>	Reserved always 0x00. Low 7 bits.

Byte 10:

0	0	0	1	n	n	n	n	<PXCT2>	Address type code 0x10 and high bits for D5 to D8.

d3 D8.7. High bit
d2 D7.7. High bit
d1 D6.7. High bit
d0 D5.7. High bit

Byte 11:

0	0	0	0	0	0	0	0	<D5>	Reserved always 0x00. Low 7 bits.

Byte 12:

0	0	0	0	0	0	0	0	<D6>	Reserved always 0x00. Low 7 bits.

Byte 13:

0	0	0	0	0	0	0	0	<D7>	Reserved always 0x00. Low 7 bits.

Byte 14:

0	0	0	0	0	0	0	0	<D8>	Reserved always 0x00. Low 7 bits.

Byte 15:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

3.2.3 IPL Data Message

Byte 0:

1	1	1	0	0	1	0	1	0xE5	OPC_PEER_XFER opcode.

Byte 1:

0	0	0	1	0	0	0	0	0x10	Message length (16 bytes).

Byte 2:

0	1	1	1	1	1	1	1	0x7F	Broadcast id.

Byte 3:

0	1	1	1	1	1	1	1	0x7F	Broadcast id.

Byte 4:

0	1	1	1	1	1	1	1	0x7F	Broadcast id.

Byte 5:

0	1	0	0	d3	d2	d1	d0	<PXCT1>	Download code 0x40 and high bits of D1 to D4.

d3 D4.7. High bit
d2 D3.7. High bit
d1 D2.7. High bit
d0 D1.7. High bit

Byte 6:

0	n	n	n	n	n	n	n	<D1>	Data Byte 1. Low 7 bits.

Byte 7:

0	n	n	n	n	n	n	n	<D2>	Data Byte 2. Low 7 bits.

Byte 8:

0	n	n	n	n	n	n	n	<D3>	Data Byte 3. Low 7 bits.

Byte 9:

0	n	n	n	n	n	n	n	<D4>	Data Byte 4. Low 7 bits.

Byte 10:

0	0	1	0	n	n	n	n	<PXCT2>	Data type code 0x20 and high bits for D5 to D8.

d3 D8.7. High bit
d2 D7.7. High bit
d1 D6.7. High bit
d0 D5.7. High bit

Byte 11:

0	n	n	n	n	n	n	n	<D5>	Data Byte 5. Low 7 bits.

Byte 12:

0	n	n	n	n	n	n	n	<D6>	Data Byte 6. Low 7 bits.

Byte 13:

0	n	n	n	n	n	n	n	<D7>	Data Byte 7. Low 7 bits.

Byte 14:

0	n	n	n	n	n	n	n	<D8>	Data Byte 8. Low 7 bits.

Byte 15:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

D1 is the lowest addressed byte and D8 is the highest addressed byte.

3.2.4 IPL End Operation Message

Byte 0:

1	1	1	0	0	1	0	1	0xE5	OPC_PEER_XFER opcode.

Byte 1:

0	0	0	1	0	0	0	0	0x10	Message length (16 bytes).

Byte 2:

0	1	1	1	1	1	1	1	0x7F	Broadcast id.

Byte 3:

0	1	1	1	1	1	1	1	0x7F	Broadcast id.

Byte 4:

0	1	1	1	1	1	1	1	0x7F	Broadcast id.

Byte 5:

0	1	0	0	d3	d2	d1	d0	<PXCT1>	Download code 0x40 and high bits of D1 to D4.

d3 D4.7. High bit
d2 D3.7. High bit
d1 D2.7. High bit
d0 D1.7. High bit

Byte 6:

0	0	0	0	0	0	0	0	<D1>	Reserved always 0x00. Low 7 bits.

Byte 7:

0	0	0	0	0	0	0	0	<D2>	Reserved always 0x00. Low 7 bits.

Byte 8:

0	0	0	0	0	0	0	0	<D3>	Reserved always 0x00. Low 7 bits.

Byte 9:

0	0	0	0	0	0	0	0	<D4>	Reserved always 0x00. Low 7 bits.

Byte 10:

0	0	0	1	n	n	n	n	<PXCT2>	End Operation type code 0x40 and high bits for D5 to D8.

d3 D8.7. High bit
d2 D7.7. High bit
d1 D6.7. High bit
d0 D5.7. High bit

Byte 11:

0	0	0	0	0	0	0	0	<D5>	Reserved always 0x00. Low 7 bits.

Byte 12:

0	0	0	0	0	0	0	0	<D6>	Reserved always 0x00. Low 7 bits.

Byte 13:

0	0	0	0	0	0	0	0	<D7>	Reserved always 0x00. Low 7 bits.

Byte 14:

0	0	0	0	0	0	0	0	<D8>	Reserved always 0x00. Low 7 bits.

Byte 15:

0	n	n	n	n	n	n	n	<CHK>	Checksum.

3.3 Firmware Parameters

PC	Device	DT	BV	HV	SV	CK	DL	OP	PB	EB	ED	DC
0x01	LNRP	09OCT15	1	0	3	64	8	1	64	64	8	0x50
0x04	UT4											
0x06	UT6	05APR21	2	0	1	64	11	2	512	4096	40	0x2E
0x0C	WTL12											
0x14	DB210O	06MAR20	2	1	2	64	7	2	512	4096	25	0x08
0x15	DB210	06MAR20	2	1	2	64	7	2	512	4096	25	0x08
0x16	DB220	06MAR20	2	1	2	64	7	2	512	4096	25	0x08
0x1A	DCS210+											
0x1B	DCS210	06MAR20	2	1	3	64	5	2	256	2048	40	0x2C
0x1C	DCS240	06MAR20	2	1	3	64	5	2	256	2048	40	0x2C
0x23	PR3	12FEB14	1	0	8	64	5	1	-	1024	-	0x14
0x24	PR4	05JAN18	0	0	0	64	5	2	256	2048	60	0x1C
0x2A	DT402	10OCT16	1	0	17	64	15	1	64	64	15	0x73
0x2A	DT402	05AUG16	1	0	17	64	15	1	64	64	15	0x4B
0x32	DT500	10OCT16	1	0	1	64	15	1	64	64	15	0x0E
0x33	DCS51	06OCT14	1	0	5	64	12	1	-	-	-	0x0E
0x34	DCS52	17JUN21	2	0	1	64	11	2	512	4096	40	0x2C
0x3E	DT602	15JUL21	2	0	1	64	11	2	512	4096	40	0x30
0x51	BXPA1	18JUN21	2	0	1	64	6	2	512	4096	41	0x0A
0x58	BXP88	21OCT17	2	0	2	64	50	2	256	2048	100	0x18
0x5C	UR92	07DEC15	0	1	8	64	16	1	64	64	16	0x24
0x5D	UR93	30AUG21	2	0	0	64	5	2	512	4096	25	0x0A
0x63	LNWI	11MAR21	2	1	2	64	5	2	512	4096	25	0x12

EBS	LNRP	DT402	DT500	DCS51	DCS52
32	0x20	0x65	0x1B	-	0x00
64	0x50	0x73	0x0E	0x0E	0x00
128	0x28	0x3A	0x47	-	0x00
192	0x1B	0x7C	0x05	-	0x2B
256	0x14	0x5D	0x64	-	0x40
1024	0x05	0x18	0x19	-	0x30
2048	0x03	0x0C	0x0D	-	0x58
4096	0x02	0x06	0x07	-	0x2C
8192	0x01	0x03	0x04	-	0x16
16384	-	0x02	0x02	-	0x0B
32768	-	0x01	0x01	-	0x06
65536	-	-	-	-	0x03

3.4 DMF File Format

The manufacturer's DMF file format is a modified form of the Intel Hexadecimal Object File Format. Character encoding is ASCII. The file consists of multiple "records" each terminated by an ASCII linefeed character (0x0A). There are four types of record and they appear in the file in the following order:

1. Sync records
2. Parameter records
3. Data records
4. End of File record

3.4.1 Sync Records

Sync records are used to identify the file as a DMF file. There are six sync records each consisting of a single ASCII # character (0x23).

Example:

```
#
#
#
#
#
#
```

3.4.2 Parameter Records

PARAM MARK	PARAMETER NAME	NAME TERMINATOR	VALUE
! (0x21) <SPC> (0x20)	ASCII text	: (0x3A) <SPC> (0x20)	decimal value
2 bytes	variable bytes	2 byte	variable bytes

PARAMETER RECORD FORMAT

Parameter records start with a two byte PARAM MARK. This consists of the ASCII code for the exclamation mark (0x21) followed by the ASCII code for the space character (0x20). The PARAMETER NAME is next. The PARAMETER NAME is ASCII encoded text identifying the parameter. The PARAMETER NAME may include spaces. It is terminated by the NAME TERMINATOR which consists of the ASCII code for a colon

(0x3A) followed by the ASCII code for a space character (0x20). The last field is the VALUE field. This is a decimal numeric value encoded as ASCII text.

The following parameters have been identified and they are presented in the following order (it is not known if the order is significant):

1. Bootloader Version
2. Manufacturer Code
3. Product Code
4. Hardware Version
5. Software Version
6. Chunk Size
7. Delay
8. Options
9. First Address
10. Last Address
11. Prog Blk Size
12. Erase Blk Size
13. Erase Dly

Example:

```
! Bootloader Version: 2
! Manufacturer Code: 0
! Product Code: 88
! Hardware Version: 0
! Software Version: 2
! Chunk Size: 64
! Delay: 50
! Options: 2
! First Address: 24576
! Last Address: 73728
! Prog Blk Size: 256
! Erase Blk Size: 2048
! Erase Dly: 100
```

3.4.3 Data Records

RECORD MARK (:)	RECLEN	LOAD OFFSET	RECTYP	DATA	CHKSUM
1 byte	2 bytes	6 bytes	2 bytes	n bytes	2 bytes

DATA RECORD FORMAT

The data record provides a set of hexadecimal digits that represent the ASCII code for data bytes that make up a portion of a memory image.

Each data record begins with a RECORD MARK field containing the ASCII code for the colon (:) character (0x3A).

Each record has a RECLEN field which specifies the number of bytes of data which follows the RECTYP field of the record. Note that one data byte is represented by two ASCII characters. The maximum value of the RECLEN field is hexadecimal "FF" or 255. Although the maximum is 255, the manufacturer seems to prefer 64.

Each record has a LOAD OFFSET field which specifies the 24-bit starting load offset of the data bytes.

The RECTYP field for data records is "00".

Each record has a variable length DATA field, it consists of zero or more bytes encoded as pairs of hexadecimal digits.

Each record ends with a CHKSUM field that contains the ASCII hexadecimal representation of the two's complement of the 8-bit bytes that result from converting each pair of ASCII hexadecimal digits to one byte of binary, from and including the RECLEN field to and including the last byte of the DATA field. Therefore, the sum of all the ASCII pairs in a record after converting to binary, form the RECLEN field up to and including the CHKSUM field, is zero.

The contents of the individual fields within the record are:

RECORD MARK	This field contains 0x3A, the encoding of the ASCII colon (:) character.
RECLEN	The field contains two ASCII hexadecimal digits that specify the number of data bytes in the record. The maximum value is "FF" or 0x4646 (255 decimal).
LOAD OFFSET	This field contains six ASCII hexadecimal digits representing the address at which the first byte of the data is to be placed. Most significant digit is presented first.
RECTYP	This field contains 0x3030, the hexadecimal encoding of the ASCII characters "00", which specifies the record type to be a data record.
DATA	This field contains pairs of ASCII hexadecimal digits, one pair for each data byte.
CHKSUM	This field contains the check sum on the RECLEN, LOAD OFFSET, RECTYP, and DATA fields.

Example:

```
:400060000057AAC3880FAAC388559AC38855AAC388553AC38855AAC38855AAC3884A0
0C38855AAC38855AAC3882DFCC38861B8C3882DFCC38861B8C3882DFCC38861B8C3886D
```

3.4.4 End of File Record

RECORD MARK (:)	RECLEN "00"	LOAD OFFSET "000000"	RECTYP "01"	CHKSUM "FF"
1 byte	2 bytes	6 bytes	2 bytes	2 bytes

END OF FILE RECORD FORMAT

The End of File Record specifies the end of the file.

The contents of the individual fields within the record are:

RECORD MARK	This field contains 0x3A, the encoding of the ASCII colon (:) character.
RECLEN	The field contains 0x3030, the hexadecimal encoding of the ASCII characters "00". Since this record does not contain any DATA bytes, the length is zero.
LOAD OFFSET	This field contains 303030303030H, the hexadecimal encoding of the ASCII characters "000000", since this field is not used for this record.
RECTYP	This field contains 0x3031, the hexadecimal encoding of the ASCII characters "01", which specifies the record type to be an End of File Record.
CHKSUM	This field contains the check sum on the RECLEN, LOAD OFFSET, and RECTYP fields. Since all the fields are static, the check sum can also be calculated statically, and the value is 4646H, the hexadecimal encoding of the ASCII characters "FF".

Example:

```
:0000000001FF
```

Appendix A

Reference Tables

LSD	MSD	0 000	1 001	2 010	3 011	4 100	5 101	6 110	7 111
0	0000	NUL	DLE	SPC	0	@	P	‘	p
1	0000	SOH	DC1	!	1	A	Q	a	q
2	0010	STX	DC2	”	2	B	R	b	r
3	0011	ETX	DC3	#	3	C	S	c	s
4	0100	EOT	DC4	$	4	D	T	d	t
5	0101	ENG	NAK	%	5	E	U	e	u
6	0110	ACK	SYN	&	6	F	V	f	v
7	0111	BEL	ETB	’	7	G	W	g	w
8	1000	BS	CAN	(	8	H	X	h	x
9	1001	HT	EM	)	9	I	Y	i	y
A	1010	LF	SUB	*	:	J	Z	j	z
B	1011	VT	ESC	+	;	K	[	k	{
C	1100	FF	FS	,	<	L	\	l	|
D	1101	CR	GS	-	=	M	]	m	}
E	1110	SO	RS	.	>	N	^	n	~
F	1111	SI	US	/	?	O	_	o	DEL

TABLE A-1. ASCII Character Set (7-Bit Code)