Protocol for Communications Between Hand-held Cabs and DCC Command Stations

This document applies to command stations from:
NCE Corporation (Webster, NY),
Wangrow Electronics Inc. (Park Ridge, IL),
PSI Dynatrol (Boston)

1. Overview of Controller Bus

The controller bus connects up to 63 Hand-Held Cab Controllers to the Command Station. Data on the bus runs at 9600 bps with 8 data bits, no parity, **2 stop bits** and meets RS-485 specifications. Controllers are continually in receive unless specifically addressed by the command station at which time the command station relinquishes the bus to allow the controller to respond. All communications sent from the command station to the Hand-Held Controllers must have bit 7 =1. A "ping" has bit 6 = 0 and all other commands or data have bit 6 = 1. All communications from the cab controllers to the command station have bit 7 = 0. The maximum length of the bus is 1000 feet and should be a continuous daisy chain without "branches" of any significant length (longer than 20 feet). An RJ-12 is the recommended "basic" connector for the bus for cost reasons. Only the center 4 wires of the bus are normally used. A 5 pin 180 degree DIN connector is also acceptable especially when wired to be compatible with the Lenz pinout.

DIN Wiring is as follows:

PIN 1	+12 Volts (nominal)
PIN 2	Ground
PIN 3	"A" lead of RS-485 signal
PIN 4	"B" lead of RS-485 signal

RJ-11 Wiring:
Pin 1 is on the right when looking into the end of jack with the wires at the top of the jack

PIN 1	Signet ground (future expansion)
PIN 2	+12 Volts DC
PIN 3	"A" (non-inverted) lead of RS-485 (to pin 6 of 75176 chip)
PIN 4	"B" (inverted) lead of RS-485 (to pin 7 of 75176 chip)
PIN 5	Ground
PIN 6	Signet signal (future expansion)

In normal operation up to sixty-three controllers are polled (pinged) for changes of status. A cab, when addressed, will answer with a two byte response indicating button press (1st byte) and speed (2nd byte). The cab starts sending it's response approximately 780 µSec. after the end of the last stop bit from the command station. Cab 0 is the "broadcast" address. Cab #1 is reserved for future applications (such as linking two command stations). Cabs are not necessarily polled in numerical order. This is to provide very active cabs with more (temporary) bandwidth for intensive operations. Active cabs are polled on a continuous basis. Periodically, inactive cab addresses are polled to find new cabs on the bus.

2. Normal Bus Operation

1. Base "pings" an address.
2. Controller answers with a 2 byte response, the first byte is a key press response, the second byte is speed. If no controller response, jump to step 1. It is not necessary for a cab to answer if there is nothing to send.
3. If base has any commands or data for the controller it will send the command/data immediately after receiving a ping response from the controller. Data will start within 300us of last stop bit from cab.
4. Jump back to step 1 to ping next address.

3. Power Up Operation of Command Station

1. Command station sends nothing for 1-2 seconds to allow Hand-Held controllers to 'settle down' (and user time to read address or other information on LCD)
2. Command station "pings" cab zero.
3. Command station "pings" cab a cab address.
4. Cab returns a one byte “cab type” starting at 60h ('a' for cabs with LCD displays, 'b' for cabs without display capabilities, type 'c' is reserved for operation through the computer port, 'd' is for Auxiliary Input Units, ‘e’ is for Cab-Bus/X-bus Bridge Units, ‘f’ for Cab Bus/Loconet bridge unit.
1. If a response is received from the pinged cab the command station sends
2. Start normal operations.

4. Power Up Operation of Controller

Cabs fall in to two basic types, those with LCD displays (type “a”) and those without (other types, typically type “b”). A cab without an LCD operates in essentially the same manner are a cab with a display except it ignores commands to display information. It is a good idea to incorporate an LED or other indicator that responds to cursor on and off commands to indicate when a display-less cab that has data input capability is in “data entry” mode. The command station transmit display data only to type “a” cabs.

1. Wait for ping to cab number 0. By waiting to hear a ping for cab 0 you will be able to easily "sync up" with the cab bus.
2. Wait for ping this cab, then return a key press code of 0x7E (refresh LCD command) to the command station. If this is a total system power up for the system the command station will ignore the request. The command station keeps an image of each cab's LCD screen in memory so the cab LCD can be refreshed as the cab is plugged from location to location on the cab bus.
3. Respond to commands from the command station.
4. Goto step 1 of normal bus operation.

6. Description of Command Station Transmissions

NOTE: all transmissions from command station must begin with the most significant bit set to 1. Cabs are not required to support all of the following commands.

7. Ping (1 byte, but a multi-byte command may follow after cab answers)

10 <address> 6 bit address 1-63 are normal cab addresses, 0 is the broadcast address.
A ping is the only transmission from the command station with bit 6 cleared to 0.

8. Commands (multi-byte)

All bytes of the command from base to cab must have bits 6 and 7 of a multi-byte command set to 1. Only ASCII characters in the range of 20h-5Fh may be printed. The command station sets bit 6 if bit 5 is set before transmitting it, the cab is expected to adjust the bits back [ie. if bit 5=1 then clear bit 6, if bit 5=0 don't clear bit 6] The LCD display of type A cabs is assumed to be a 2x16 or 4x16 character display.

11000000 print next 8 chars to 1st line left LCD (addr = 80h)
11000001 print next 8 chars to 1st line right of LCD (addr = 88h) Note: this is where the clock prints
11000010 print next 8 chars to 2nd line left of LCD (addr = C0h)
11000011 print next 8 chars to 2nd line right of LCD (addr = C8h)
11000100 print next 8 chars to 3rd line left of LCD (addr = 90h)
11000101 print next 8 chars to 3rd line right of LCD (addr= 98h)
11000110 print next 8 chars to 4th line left of LCD (addr = D0h)
11000111 print next 8 chars to 4th line right of LCD (addr = D8h)
11001000 move cursor to LCD address in following byte
<C8h> <80h> move cursor to address 80 (home)
11001001 print char TTY fashion to LCD, back up cursor to same spot
<C9h> <B9h> print "9" and return cursor to same position
11001010 print char TTY fashion to LCD, move cursor to next location
<CAh><B9h> print "9" to LCD, let cursor advance to next spot
11001011 upload 1st following byte graphic location with next 8 bytes. Bits 5,6,7 must be reset in the controller. Ex: program graphic location 00 with a vertical line. Note: the graphic char value (0-7) is last.
<CBh><D0h><D0h><D0h><D0h><D0h><D0h><D0h><D0><C0h>
11001100 print graphic char indicated by following byte (bits 6,7 are set in the second byte to comply with bits 7 and 6 must be set rule)
<CCh><C3h>
11001101 clear display and home cursor <CDh>
11001110 cursor off <CEh> (LED OFF in basic cabs)
11001111 cursor on <CFh> (LED ON in basic cabs)
11010000 shift LCD to display the 'right half' of the screen on a two line display. <D0h>
11010001 non-destructive home screen back to 'left half' <D1h>
11010010 cab returns a one byte "cab type" starting at 60h ('a' for cabs with LCD displays, 'b' for cabs without display capabilities, type 'c' is reserved, 'd' is for Auxillary Input Units, 'e' is for Cab-Bus/X-bus Bridge Units, 'f' for Cab Bus/Loconet bridge unit.
11010011 cab enters it's own setup mode (to set it's address) <D3h>
11010100 light up green cab signal on cab (clears yellow and red)
11010101 light up yellow cab signal on cab (clears green and red)
11010110 light up red cab signal on cab (clears yellow and green)
11010111 Activate buzzer or other attention getting device on cab ("Beep" operator)
11011000 reserved
11011001 reserved
11011010 Reserved

11011011 4 bytes following this byte contain information about the currently controlled locomotive
Byte 1 <DBh> (4 bytes of loco info follow)
Byte 2 bit 5 = direction (1=forward, 0=reverse)
bit 4 = \
bit 3 = \
bit 2 = > 5 most sig. bits of current speed
bit 1 = /
bit 0 = /
Byte 3 bit 5 = \ 2 least sig. bits of current speed
bit 4 = /
bit 3 = \
bit 2 = \ 4 most sig. bits of loco addr high byte. bit 2 (bit 6 of addr hi byte) =1 if in
bit 1 = / 128 speed mode, bit 2=0 if 14/28
bit 0 = /
Byte 4 bit 5 = \
bit 4 = \
bit 3 = / 4 least sig. bits of loco address high byte
bit 2 = /
bit 1 = \
bit 0 = / 2 most sig. bits of loco address low byte
Byte 5 bit 5 = \
bit 4 = \
bit 3 = \ 6 least sig bits of loco address low byte
bit 2 = /
bit 1 = /
bit 0 = /

11011100
through
11111111 reserved for factory test modes
NOTE: commands C0h-CDh, D0h and D1h ignored by cabs which have no LCD display.

9. Description of Hand-Held Controller Transmissions

NOTE: All transmissions from Hand-Held controller begin with 0

10. Ping Response

FIRST BYTE (key press or other information. NOTE: 7Fh never sent in 1st byte):
Type a, b and c cabs:

010xxxxx	Key press info (40h-7Ch)
01111101	No key to report <7Dh>
01111110	Repeat current screen <7Eh>

Type d cabs:

0xxxxxxx	Type 'd' auxillary input units bit map for inputs 1-7, bit 0 is input 1, bit 6 is input 7.

SECOND BYTE (speed when using knob):
Type a, b and c cabs:

0xxxxxxx	Speed control from knob (range 0-126, 127 = knob not used)
01111111	No speed to report, keys are being used <7Fh>

Type d cabs:

0xxxxxxx	Type 'd' auxillary input units bit map for inputs 8-14, bit 0 is input 8, bit 6 is input 14

KEY CODES:

40 - Enter	60 - Assign Cab -> loco
41 - "Program" Key	61 - Program on Mainline
42 - Recall	62 - Set Clock
43 - Direction Toggle	63 - Program on Setup track
44 - Setup Consist	64 - Setup command station
45 - Add Loco to Consist	65 - Setup cab (cab enters its own setup mode)
46 - Delete Loco from Consist	66 - Setup macros
47 - Kill Consist	67 - Setup brute force consist
48 - Select Loco (by address)	68 - Setup advanced consist
49 - Horn/Whistle key down	69 - Toggle LCD between left/right half
4A - 1 step faster	6A - Set direction to forward
4B - 1 step slower	6B - Set direction to reverse
4C - Emergency stop	6C - reserved
4D - Bell	6D - reserved
4E - Enter Accessory mode	6E - reserved
4F - Expansion key	6F - reserved
50 - Headlight Toggle/0	70 - reserved
51 - F1 Toggle/1	71 - reserved
52 - F2 Toggle/2	72 - reserved
53 - F3 Toggle/3	73 - reserved
54 - F4 Toggle/4	74 - reserved
55 - F5 Toggle/5	75 - reserved
56 - F6 Toggle/6	76 - reserved
57 - F7 Toggle/7	77 - reserved
58 - F8 Toggle/8	78 - reserved
59 - 9 (type 'b' direction)	79 - reserved
5A - 5 steps faster	7A - reserved
5B - 5 steps slower	7B - Alternate momentary key pressed
5C - Macro select	7C - Alternate momentary key up
5D - 14/28 speed toggle	7D - report that no key is pressed
5E - Brake (set speed to zero)	7E - repeat last LCD display (also requests info on current loco)
5F - Horn/Whistle key up	7F - Using keys for speed control

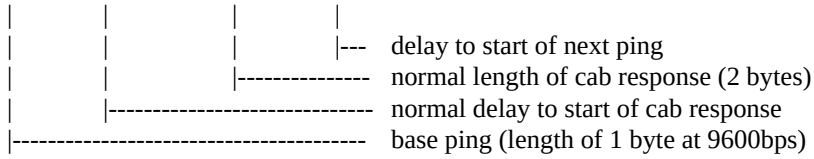
11. Timing Of Cab Bus

At 9600,N,8,2 each byte takes 1.144 mS

HARD AND FAST RULE: Hand-Held Controller must start to respond within 900 uS to a ping or not respond at all.

Therefore a complete round of 64 pings with simple responses will take:

(1.140 mS +0.78 mS + 2.280 mS + .1 mS) * 64pings = 275 mS (3 to 4 pings/second)



This is worst case assuming 64 cabs in use. A “normal” load of about 10 Cabs comes out to about 23 pings/second per cab.

NOTE: If a cab does not start to respond within 900uS the second byte is not waited for and the command station will then ping the next cab. This has the effect of speeding up the ping process to remaining cabs.

NOTES: Starting with command station software dated 7/29/95 and later:

- Cabs are not necessarily pinged in numerical order.
- If a cab is off the bus for several pings the command station will drop the cab from it's "ping list". That cab will then only be pinged on an occasional basis until it again responds to a ping. This dynamic ping list replaces the DIP switch setting of the maximum number of cabs inside the command station. It also dramatically speeds up cab response when more than 30 cabs are in use.