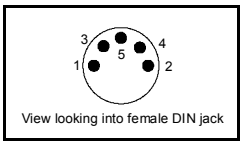
Overview of Controller Bus

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-1 1 (6-4 or 6-6) is the recommended "basic" connector of the cab 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 when wired to be compatible with the Lenz/Atlas pinout.

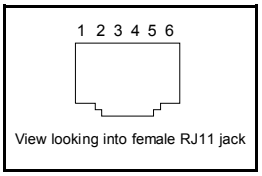
DIN Wiring is as follows

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	Reserved - currently unused
PIN 2	+12 Volts DC
PIN 3	"A" lead of RS-485 (to pin 6 of 75176 chip)
PIN 4	"B" lead of RS-485 (to pin 7 of 75176 chip)
PIN 5	Ground
PIN 6	Reserved - currently unused



In normal operation up to sixty-three controllers are polled (pinged) for changes of status. A cab, when addressed, will answer with either a two byte response indicating button press (1st byte) followed by speed (2nd byte) or a five byte response indicating device address (1st two bytes), operation (2nd two bytes) and a one byte xor checksum. The cab starts sending it's response approximately 780µSec. after the end of the last stop bit from the command station. Cab 0 is the "broadcast" address from command station to cab. 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.

Cabs.
Cabs respond to the command station with 'key codes' for any buttons pressed on the cab and the command station responds with information for the cabs user interface display (if any). This display can be either simple LEDs with on/off indications or full featured 2 or 4 line x 16 character displays. This type cab uses two byte responses to the command station.

Normal Bus Operation

1. Base "pings" a cab address.
2. Cab answers with a 2 or 5 byte response. In the case of a 2 byte response the first byte is a key press (key code) and the second byte is speed. In the case of a 5 byte response the first 2 bytes are a device address (locomotive, accessory, signal, etc.) the next two bytes indicate the action to be performed and the last byte is an xor checksum of the first 4 bytes. If there is no controller response, jump to step 1. It is not necessary for a cab to answer if there is nothing to send. Cabs cannot change their response method from 2 to 5 or 5 to 2 bytes.
3. If the command station 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.

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 address zero.
3. Command station "pings" a cab address (valid range 1-63).
4. If a cab is present with that address it will return two or five bytes of data. If it returns 5 bytes the comand station will assume that this cab will always respond with 5 bytes and is a type ‘c’ cab. If it returns two bytes the command station will then query the cab for its cab ‘type’
5. The cab will answer the query with a one byte “cab type” ('a' for cabs with LCD displays, 'b' for cabs without display capabilities, type 'd' is for Auxiliary Input Units, ‘e’ is reserved, ‘f’ is for Cab-Bus/X-bus Bridge Units, ‘g’ for Cab Bus/Loconet bridge unit.
6. Start normal operations.

Power Up Operation of Cab

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 as 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 followed by 0x7f (no speed command). 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 moved from location to location on the cab bus.
3. Respond to commands from the command station.
4. Goto step 1 of normal bus operation.

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.

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

10aaaaaa aaaaaa=6 bit cab address. 1-63 = normal cab addresses, 0 is the broadcast address.
A ping is the only transmission from the command station with bit 6 = 0.

Commands (multi-byte) for all 'dumb' cabs

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.

0xc0 print next 8 chars to 1st line left LCD (addr = 80h)
0xc1 print next 8 chars to 1st line right of LCD (addr = 88h) Note: this is where the clock prints
0xc2 print next 8 chars to 2nd line left of LCD (addr = C0h)
0xc3 print next 8 chars to 2nd line right of LCD (addr = C8h)
0xc4 print next 8 chars to 3rd line left of LCD (addr = 90h)
0xc5 print next 8 chars to 3rd line right of LCD (addr= 98h)
0xc6 print next 8 chars to 4th line left of LCD (addr = D0h)
0xc7 print next 8 chars to 4th line right of LCD (addr = D8h)
0xc8 move cursor to LCD address in following byte
<C8h> <80h> move cursor to address 80 (home)
0xc9 print char TTY fashion to LCD, back up cursor to same spot
<C9h> <B9h> print "9" and return cursor to same position
0xca print char TTY fashion to LCD, move cursor to next location
<CAh><B9h> print "9" to LCD, let cursor advance to next spot
0xcb 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>
0xcc 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>
0xcd clear display and home cursor <CDh>
0xce cursor off <CEh> (LED OFF in basic cabs)
0xcf cursor on <CFh> (LED ON in basic cabs)
0xd0 shift LCD to display the 'right half' of the screen on a two line display. <D0h>
0xd1 non-destructive home screen back to 'left half' <D1h>
0xd2 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, 'f' is for Cab-Bus/X-bus Bridge Units, 'g' for Cab Bus/Loconet bridge unit.
0xd3 cab enters it's own setup mode (to set it's address) <D3h>
0xd4 <reserved> light up green cab signal on cab (clears yellow and red)
0xd5 <reserved>light up yellow cab signal on cab (clears green and red)
0xd6 <reserved>light up red cab signal on cab (clears yellow and green)
0xd7 <reserved>Activate buzzer or other attention getting device on cab ("Beep" operator)
0xd8 two byte result of an operation performed type c cab (has no meaning for type a,b and d cabs)
<D8><byte 1>< byte 2>
Byte 1 format - 11cc 00dd (dd=2 msb to be combined with 6 lsb of following byte 2)
if cc=00 then operation is successful
if cc=01 then operation has failed
rr = 10,11 is undefined
0xd9 Reserved

0xda Reserved

0xdb 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 = /

0xdc
through
0xff reserved for factory test modes

NOTE: commands c0-cd, d0, and d1 are ignored by cabs with no LCD display (type ‘a’).
command d8 has no meaning for any cab except type c so it is ignored by all but type c cabs.

Description of Hand-Held Controller Transmissions

NOTE: All transmissions from Hand-Held controller begin with 0. 'Dumb' cabs always respond with two bytes, the first byte corresponding to the key code of any button pressed and the second byte correcponds to the position of any speed control pot on the cab.

Ping Response for type 'a' through type 'd' dumb cabs

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

40 (64) - Enter	60 (96) - Assign Cab -> loco
41 (65) - "Program" Key	61 (97) - Program on Mainline
42 (66) - Recall	62 (98) - Set Clock
43 (67) - Direction Toggle	63 (99) - Program on Setup track
44 (68) - Setup Consist	64 (100) - Setup command station
45 (69) - Add Loco to Consist	65 (101) - Setup cab (cab enters its own setup mode)
46 (70) - Delete Loco	66 (102) - Setup macros
47 (71) - Kill Consist	67 (103) - Setup brute force consist
48 (72) - Select Loco	68 (104) - Setup advanced consist
49 (73) - Horn key down	69 (105) - Toggle LCD between left/right half
4A (74)- 1 step faster	6A (106) - Set direction to forward
4B (75) - 1 step slower	6B (107) - Set direction to reverse
4C (76) - Emergency stop	6C (108) - Select Signal
4D (77) - Bell	6D (109) - reserved
4E (78) - Select Accessory	6E (110) - reserved
4F (79) - Expansion key	6F (111) - Momentum
50 (80) - Headlight Toggle/0	70 (112) - F10
51 (81) - F1 Toggle/1	71 (113) - F11
52 (82) - F2 Toggle/2	72 (114) - F12
53 (83) - F3 Toggle/3	73 (115) - reserved
54 (84) - F4 Toggle/4	74 (116) - reserved
55 (85) - F5 Toggle/5	75 (117) - reserved
56 (86) - F6 Toggle/6	76 (118) - reserved
57 (87) - F7 Toggle/7	77 (119) - reserved
58 (88) - F8 Toggle/8	78 (120) - reserved
59 (89) - F9 Toggle/9	79 (121) - reserved
5A (90) - 5 steps faster	7A (122) - 'Sticky' Shift Key (F10-F28)
5B (91) - 5 steps slower	7B (123) - Alternate momentary key pressed
5C (92) - Macro select	7C (124) - Alternate momentary key up
5D (93) - 28/128 speed toggle	7D (125) - report that no key is pressed
5E (94) - Brake	7E (126) - repeat last LCD display (also requests info on current loco)
5F (95)- Horn/Whistle key up	7F (127) - Using buttons for speed control

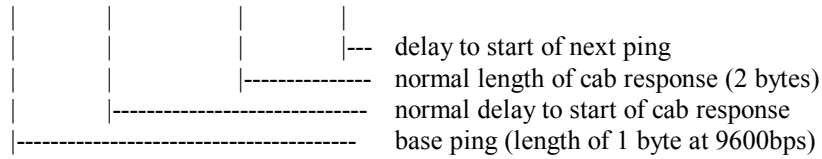
Timing Of Cab Bus

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

HARD AND FAST RULE: Hand-Held Controller must start to respond within 800 uS (but not before 100uS) 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 (and answering each ping). 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 800uS the command station will not waite for subsequent byte(s) and will 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 may 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.

NOTES: Starting with command station software dated 1/3/04 and later:
Type c 'smart' cabs are supported. A type 'c' cab always responds with 5 bytes.