1.1.1 Solinst Protocol

1.1.1.1 MESSAGE FORMAT

The Solinst protocol contains two message formats: a full address mode message to give addressability of more than 16 million units and a system address mode, where up to 255 units can be addressed. As shown in Figure 1 below, a message contains the following:

1. A Start of Message character (SOM), the hexadecimal value 0x00;
2. A single-character command (ASCII upper- or lower-case character);
3. Either a single- or 3-byte address, starting with the highest byte;
4. A data field containing 0 to 256 bytes;
5. A two-byte Cyclical Redundancy Check (CRC), high byte followed by the low byte.

The reply to a message (see Figure 1 below) contains the following:

1. A single character Byte Block Checksum (BCC);
2. A data field containing 0 to 256 bytes;
3. A two-byte Cyclical Redundancy Check (CRC), high byte followed by the low byte.

The contents of the data field are command dependent and, in some cases, may not exist at all. All other fields must always be present.

The BCC is calculated by performing an unsigned modulo 256 arithmetic sum of all the received characters. An error response from the addressed unit is the BCC+7 to indicate a CRC failure or BCC+56 for some other fault.

The CRC is calculated according to the SDI-12 CRC. Please refer to section 4.4.12.1 in the *SDI-12 A Serial-Digital Interface Standard for Microprocessor-Based Sensors V1.3* specification.

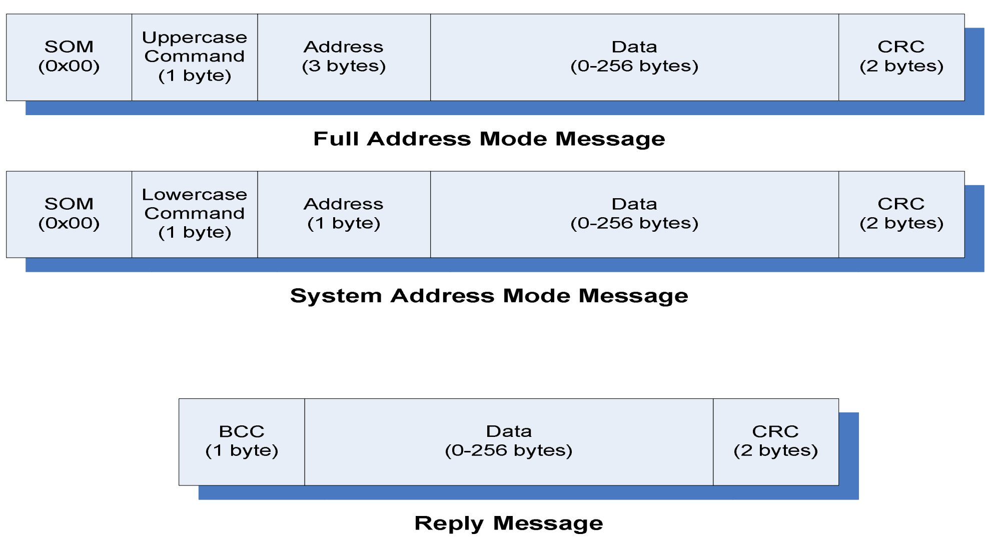


Figure 1: Solinst Protocol Messages

1.1.1.2 ADDRESSING

The full address mode is normally based on the serial number of the LTC Gold unit. This makes identification extremely easy with no need for cross-references. It allows multiple LTC Golds to share a common communication pathway.

All efforts will be made to use only full addressing. However, less expensive configurations may use the System Addressing mode. (This mode must be used to find the serial number if the number is missing on the outside of the unit).

Full Address Mode: Any number from 0 to 16777215. For LTC Golds, the full address is typically in the range from 1015101 to 4799999.

System Addressing Mode: Any single byte number from 0 to 254. The system address 255 is reserved for address-less systems where only a single LTC Gold is used on a communication link. The 255 may also be used to determine a unit's full address. The factory setting for the system address is the least significant byte in the serial number.

1.1.1.3 COMMANDS

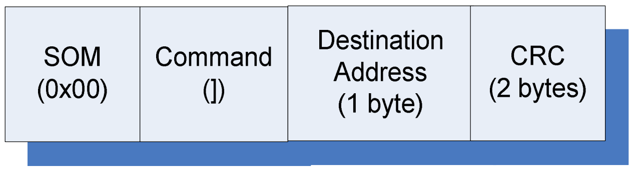
The command is a single printable character from **A** to **Z** followed by 3 full address characters or a single printable character from **a** to **z** followed by 1 System Location address character. (e.g., *<00><65><FF>CRC16* requests the current date from system unit #8. The response will be: *BCC 05/07/2005 07:35:20 CRC16*.) The following command examples will use actual *BCC* and *CRC16* values. A number *<mm>* is equivalent to the hexadecimal number 0xmm. With the exception of the address field size, all the following commands have equivalent operation when using the lowercase **a** to **z** commands. All the following commands assume a system address of <FF>. LT Gold firmware v2.005 is used for all examples.

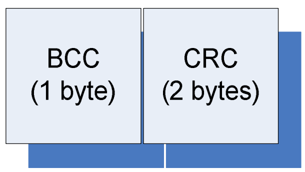
1. **[**—command to read the probe's current time stamp. Probe responds with a 4-byte unsigned integer time stamp, a 2-byte unsigned integer 1/4096 second interval., and the current 3-byte floating point temperature, This command is only supported on revision 2 hardware and is used to verify the internal real-time clock accuracy. (eg. <00><5B><FF><70><7B> gives the following reply: <45><4C><64><11><EE><97><69><43><E6><B8><14><B4>)

SOM (0x00)	Command ([)	Destination Address (1 byte)	CRC (2 bytes)

BCC (1 byte)	Temperature (3 bytes)	Time Stamp (4 bytes)	1/4096 secs (2 bytes)	CRC (2 bytes)

2. **]**—command to initiate the oscillator calibration signal output. Probe responds a BCC and CRC. Following this reply, the probe will output a nominal 32768 Hz square wave on the P5.6 port pin for five seconds. This command is only supported on revision 2 hardware and is used to calibrate the internal real-time clock accuracy. Note: while the test frequencies are being generated, no communication with the probe is possible. (eg. <00><5B><FF><D0><78> gives the following reply: <A4><BB><01>)





3. **A**—command, followed by a single byte size *n* to trigger and read the probe measurement in text mode. Probe responds with the present readings filling *n+1* characters in delimited mode. (use the **B** command for remaining characters). A special form of the **A** command where the size is 0 will result in a fixed-size reply of 128 characters with the standard probe readings followed by the raw readings in hexadecimal notation, and terminated with the battery voltage. (e.g., <00><61><FF><18><24><10> gives the following reply: <AC>+25.1296°C-1.63898m<CR><LF> <96B><BC>).

   The special form of the command where *n* is 0 (e.g., <00><61><FF><00><2E><10>) gives the following reply: <9E>+25.1758°C-1.63701m+AF7D02CH1 +8F6A01CH2 +2.96433V<CR><LF> <57><58>. The spaces following the <LF> pad out the message to a length of 128 characters total..

SOM (0x00)	Command (A)	Destination Address (3 bytes)	Size (n)	CRC (2 bytes)

SOM (0x00)	Command (a)	Destination Address (1 byte)	Size (n)	CRC (2 bytes)

BCC (1 byte)	Data (n+1 bytes)	CRC (2 bytes)

   The RRLG sends its attached Levelogger readings in order by attachment with Left 1 data, Right 1 data, Left 2 data, and Right 2 data. Unattached Levelogger positions read as three sets of 999999.0 readings with no units.

   The Rainlogger (Firmware V2.000 and up) uses a different method of reporting rainfall where a typical report will look like:
   <BCC>+1030.34mm+*12/08/2010 15:28:22<CR><LF>padding<CRC1><CRC2>*
   where the first number is the total accumulated rainfall since the start of the current log or the last logger initialization/reset and the following date/time indicates when the latest rainfall tip event occurred. If no log is active, these rainfall results will still be reported. If no tips have occurred in this log, the reported date/time will be the log start time.

   Note: The rainfall will accumulate until the total reaches a value of 250,000 mm (10,000 in) or a new log is started and will then reset to 0.

4. **B**—command, followed by a single byte size *n* to continue transferring text from the **A** command in *n+1* bytes until all data is sent, then CR (0x0D), LF (0x0A), with fill spaces up to the *n+1* size. (e.g., *<00><61><FF><09><28><D0>* requests the present readings from default address 0xFF using 9 characters. The response to the **A** command is <61+25.0022°C<88><14>. The B command *<00><62><FF><0A><29><60>* response is *<F4>-1.63761m<CR><LF>   <7D><C0>*. Spaces are used to pad up to the requested 16 characters after the <CR><LF>.

SOM (0x00)	Command (B)	Destination Address (3 bytes)	Size (n)	CRC (2 bytes)

SOM (0x00)	Command (b)	Destination Address (1 byte)	Size (n)	CRC (2 bytes)

BCC (1 byte)	Data (n+1 bytes)	CRC (2 bytes)

---

5. **C**—command to read memory banks, *n+1* bytes at a time. The data in the command after C determines the number of bytes to read (*n*) in 1 byte where 0 means read 1 byte and 255 means read 256 bytes; and start address in 3 bytes. The response will contain *n+1* bytes of data from memory. (e.g., <00><63><FF><01><00><00><00><7B><1C> gives the following response: <FA><53><4F><35><5D>)

SOM (0x00)	Command (C)	Destination Address (3 bytes)	Size (n)	Memory Add. (3 bytes)	CRC (2 bytes)

SOM (0x00)	Command (c)	Destination Address (1 byte)	Size (n)	Memory Add. (3 bytes)	CRC (2 bytes)

BCC (1 byte)	Data (n+1 bytes)	CRC (2 bytes)

6. **D**—command to write memory banks, *n+1* bytes at a time The data in the command after D determines the number of bytes to write (*n*) in 1 byte where 0 means write 1 byte and 255 means write 256 bytes and the start address in 3 bytes , then the *n+1* bytes. (e.g., <00>d<FF><00><04><1F><FF><00><CF><40> gives the following response: <94><AF><01>)

SOM (0x00)	Command (D)	Destination Address (3 bytes)	Size (n)	Memory Add. (3 bytes)	Write Data (n+1 bytes)	CRC (2 bytes)

SOM (0x00)	Command (d)	Destination Address (1 byte)	Size (n)	Memory Add. (3 bytes)	Write Data (n+1 bytes)	CRC (2 bytes)

BCC (1 byte)	CRC (2 bytes)

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7. **E**—command to read the present date, **dd/nn/yyyy hh:mm:ss** where dd is the day, nn is the month, yyyy is the year, hh is the hour, mm is the minutes, and ss is the seconds. (e.g., *<00><65><FF><10><6B>* gives the following reply: *<DF>12/08/2010 15:28:22<4E><33>*)

SOM (0x00)	Command (E)	Destination Address (3 bytes)	CRC (2 bytes)

SOM (0x00)	Command (e)	Destination Address (1 byte)	CRC (2 bytes)

BCC (1 byte)	Data (19 bytes)	CRC (2 bytes)

8. **F**—command to write the present date, **dd/nn/yyyy hh:mm:ss**. (e.g., *<00>f<08>23/04/2009 11:23:49<04><73>*, gives a response of *<96><6E><80>*)

SOM (0x00)	Command (F)	Destination Address (3 bytes)	Date/Time (19 bytes)	CRC (2 bytes)

SOM (0x00)	Command (f)	Destination Address (1 byte)	Date/Time (19 bytes)	CRC (2 bytes)

BCC (1 byte)	CRC (2 bytes)

9. **G**—command to read raw A/D values in 24 bits. The response contains a byte containing the number of channels, followed by data from all available channels with three bytes for each channel. (e.g., <00><67><FF><70><6A> gives the following response <40><02><AF><70><42><8F><6A><49><A1><B4>)

SOM (0x00)	Command (G)	Destination Address (3 bytes)	CRC (2 bytes)

SOM (0x00)	Command (g)	Destination Address (1 byte)	CRC (2 bytes)

BCC (1 byte)	n Channels (1 byte)	Raw A/D Data (n*3 bytes)	CRC (2 bytes)

The Rainlogger (Firmware V2.000 and up) shows a single raw 24 bit output which represents the number of tips in the current log. (See 'a' command for details.)

10. **H**—command to enter bootstrap mode. A single byte following the **H** command indicates whether to save the logging parameters (0x01) or not (0x00). This command only works if a successful password has been sent. Bootstrap mode only supports the **C**, **D, I**, **J**, **K**, **Y** commands. While in bootstrap mode, it is also possible to read FLASH memory. In normal mode, FLASH reads always return 0x00s. When in Bootstrap mode, the **H** command does not support any arguments and the **K** command returns zeroed voltage, battery capacity, and temperature readings.

SOM (0x00)	Command (H)	Destination Address (3 bytes)	Save Parameters (1 byte)	CRC (2 bytes)

SOM (0x00)	Command (h)	Destination Address (1 byte)	Save Parameters (1 byte)	CRC (2 bytes)

BCC (1 byte)	CRC (2 bytes)

11. **I**—command to erase a range of FLASH blocks. A single byte following the 'I' command indicates the start block to erase and the following byte indicates the last block to erase.

Logger	Block 0 - 1	Block 2 - 3	Block 4 - n	n = ?
Levelogger Gold Rainlogger Barologger Gold OYO	128 bytes	512 bytes	512 bytes	66
LTC Jr OYOC RRLG	128 bytes	512 bytes	512 bytes	112
Levelogger Edge LTC Edge Rainlogger Edge	64 bytes	64 bytes	512 bytes	236

Logger Block Sizes

A response will be sent once the FLASH blocks have been erased.

SOM (0x00)	Command (I)	Destination Address (3 bytes)	1^{st} Erase Block (1 byte)	Last Erase Block (1 byte)	CRC (2 bytes)

SOM (0x00)	Command (i)	Destination Address (1 byte)	1^{st} Erase Block (1 byte)	Last Erase Block (1 byte)	CRC (2 bytes)

BCC (1 byte)	CRC (2 bytes)

12. **J**—command to restart the normal operating mode. Before starting normal operating mode, the watchdog is started, so if proper program execution is not achieved, the boot loader will restart after about a second. This command only works in bootstrap mode. (e.g., <00>j<FF><E0><6E> gives the following response: <EF><8C><41>)

SOM (0x00)	Command (J)	Destination Address (3 bytes)	CRC (2 bytes)

SOM (0x00)	Command (j)	Destination Address (1 byte)	CRC (2 bytes)

BCC (1 byte)	CRC (2 bytes)

13. **K**—command, followed by a single byte size *n* to read the current battery charge level, battery voltage, internal CPU temperature (not very accurate), software version, bootloader version, hardware version, and one or more character extension indicating what firmware is installed. The command is terminated by CR (0x0D), LF (0x0A) and padded with spaces up to *n+1* characters. The **B** command reads the remainder of any unread string. A typical response to the command *<00>***<6B>***<FF><35><3B><F0>* would be: *<CA+1405.00mAH+3.332V+25.567°C+3.000a5SW+3.000BL+2HWS<0D><0A> <63><B1>*. Note: the version 2 hardware version ("+2HW") indicates that the connected logger is an Edge product. The extension letter "S" after the hardware gives the probe type as shown in the table below.

    If *n* is set to 0, this command will return a special status showing the internal oscillator calibration parameters. The string returns the internal error adjustment (a negative sign indicates a slow oscillator), the first and second oscillator divisors, and the temperature used to perform the last oscillator adjustment. A typical response to the command *<00>***<6B>***<FF><00><2C><30>* would be: *<C6>-134+2047.0+2048.0+25.000°C <EB><93>*.

    Conductivity probes also return the last calibration date as a final parameter, followed by a 'CD'.

Extension	Meaning
'O'	OYO hardware supporting the OYO protocol.
'E'	OYO conductivity hardware supporting the OYO protocol.
'D'	LTC hardware with Solinst protocol.
'C'	LTC Jr hardware with Solinst protocol.
'S'	LT hardware with Solinst protocol.
'J'	LT Junior hardware with Solinst protocol.
'R'	Rainlogger hardware with Solinst protocol.
'L'	RRLG hardware with Solinst protocol

SOM (0x00)	Command (K)	Destination Address (3 bytes)	Size (n)	CRC (2 bytes)

SOM (0x00)	Command (k)	Destination Address (1 byte)	Size (n)	CRC (2 bytes)

BCC (1 byte)	Data (n+1 bytes)	CRC (2 bytes)

The RRLG returns the internal battery voltage.

Hardware Revision	Hardware Description

1	Hardware with original EEPROM
2	Hardware with new EEPROM
> 2	Uniboard-compatible hardware (Edge)

Note: In order to identify new Edge probes, it is also necessary to use the hardware revision level. The table below shows the hardware revisions to uniquely identify each probe type:

The Rainlogger also requires the firmware version to identify when the new ‘a’ command and event-based tip logging came into effect::

Rainlogger Software Major Revision	Software Description
1	Rainfall/Maximum Rainfall logs and ‘a’ command with last logged data.
≥ 2	Tip time event logs and Rainfall/Tip Time ‘a’ command.

L—command to set an upper 8-bit page address which is merged with the address passed by the C/D commands to expand the total addressable memory to 32-bits or about four GBytes. A single byte following the 'L' command defines the upper 8 bit page address. If this command is not supported by a particular firmware implementation, a BCC error will be returned and a default upper address of 0x00 is assumed.

SOM (0x00)	Command (L)	Destination Address (3 bytes)	Upper Address (1 byte)	CRC (2 bytes)

SOM (0x00)	Command (l)	Destination Address (1 byte)	Upper Address (1 byte)	CRC (2 bytes)

BCC (1 byte)	CRC (2 bytes)

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14. **M**—command to read the previous Log Start Address in 3 bytes, the active header ID, the active Log Start address in 3 bytes, active Log End address in 3 bytes, the active logged lines in 3 bytes, the unused memory in 3 bytes, the active Status in 1 byte, and the active start and stop times with 4 bytes each. Note: while logging, the logging header is used and when stopped, the previous log header will be used. (e.g., <00><6D><FF><D0><6C> gives the following response: <A8><00><33><00><30><00><33><00>><00><33><36><00><00><09><03> <A9><4A><00><4C><64><07><1D><4C><64><07><24><F1><34>)

SOM (0x00)	Command (M)	Destination Address (3 bytes)	CRC (2 bytes)

SOM (0x00)	Command (m)	Destination Address (1 byte)	CRC (2 bytes)

BCC (1 byte)	Data (25 bytes)	CRC (2 bytes)

15. **N**—command to read the present Log Settings, Buffer Type in one byte, Mode in one byte, and the log interval in four bytes with 10mS resolution. (e.g., <00><6E><FF><20><6C> gives the following response: <F9><00><00><00><00><00><C8><99><68>)

SOM (0x00)	Command (N)	Destination Address (3 bytes)	CRC (2 bytes)

SOM (0x00)	Command (n)	Destination Address (1 byte)	CRC (2 bytes)

BCC (1 byte)	Data (6 bytes)	CRC (2 bytes)

16. **O**—command to initiate a sensor calibration. The sensor identifier is passed as a single byte, followed by calibration standard value as a 32-bit integer (e.g., Conductivity is expressed as nS so an 84.5 uS reading would be sent as 84500 and an 80.1024 mS solution would be sent as 80102400.) A final 32-bit integer represents the average ADC reading for the calibration point (e.g., Conductivity ADC reading might be 0x00042EE0 where the upper 16-bits represents the DAC drive). Other calibration units are shown in the Sensor ID table below.

    Sending a calibration standard value of zero when the Sensor ID is 1 (conductivity sensor) will return the current calibration pointer in four bytes.

    A negative calibration standard value indicates that the calibration parameter log in EEPROM should be advanced prior to saving the current calibration point. A calibration advance only needs to be performed on the first parameter in a multi-parameter calibration. The conductivity calibration can store up to four user calibration points. Up to a 10% variation from the nominal solution is allowed. If the solution is not recognized, an "Incorrect or missing calibration solution" code will be returned. The temperature should be close to 25°C when only standard solutions are used for calibration; otherwise, when using an accurate laboratory meter, the exact conductivity of the solution (read from the meter) should be sent as the calibration standard value. Any unused calibration points will assume the factory calibration values. Specific calibration solutions are associated with each calibration point as shown below:

Cal Point	Nominal Conductivity Solution	Units	Probe
1	1,413,000	nS	LTC/WQL
2	5,000,000	nS	LTC/WQL
3	12,880,000	nS	LTC/WQL
4	80,000,000	nS	LTC/WQL

After the calibration completes, a single-byte status is returned with a zero for a successful calibration and various codes (see below) to indicate different calibration problems.

Once all the points have been calibrated, a Sensor ID of 255 is used, along with the calculated calibration parameters to store the current calibration into EEPROM. An LTC calibration parameter save command would begin with a single byte giving the total size in bytes(where 0 represents 1 byte) of the passed calibration coefficients, followed by the calibration coefficients in little-endian IEEE-754 floating point format (e.g., <00>**<**6F**>**<FF><FF><17><0000803F><C6DC7A41><0000803F><00000000> <0000803F><00000000><7D><D5>).

For time calibration, the corresponding 'o' command is: <00><6F><FF><06><00><00><00><0A><0E><83>. The fifth to eighth bytes are the binary oscillator error in signed, big-endian binary format. The last two bytes are the CRC which needs to be calculated for each unique error. The <06> is the oscillator sensor identifier that tells the Edge logger that this is an oscillator calibration parameter. The normal reply from the logger will be <0F><00><F0><05>. The first byte will vary based on the byte checksum of the sent message. The <00> indicates that the ppm value was updated without error. A non-zero code will indicate an error has occurred.

The **O** command is supported on all conductivity and Edge/Mark II probes.

Sensor ID	Description	Units	Probe
0	Return to factory default calibration settings	–	LTC/WQL
1	Conductivity Sensor	nS	LTC/WQL
2	Dissolved Oxygen Sensor	ppm	WQL
3	pH Sensor	μpH	WQL
4	Turbidity Sensor	mNTU	WQL
5	Oxygenation Reduction Potential Sensor	μV	WQL
6	32,768 Hz Oscillator Calibration	ppm	LTC
255	Save attached calibration parameters	–	LTC/WQL

Calibration Status	Description
0	Sucessful calibration or EEPROM write
1	Incorrect or missing calibration solution
2	Sensor needs cleaning/replacement (dirty or too old)
3	Sensor missing or failed (no valid readings)

SOM (0x00)	Command (O)	Destination Address (3 bytes)	Sensor ID (1 byte)	Data (0-256 bytes)	CRC (2 bytes)

SOM (0x00)	Command (o)	Destination Address (1 byte)	Sensor ID (1 byte)	Data (0-256 bytes)	CRC (2 bytes)

BCC (1 byte)	Calibration Status (1 byte)	CRC (2 bytes)

---

17. **P**—command to start logging at the start date, **dd/nn/yyyy hh:mm:ss**. (e.g., *<00>**p**<FF>23/04/2009 13:31:52<1C><58>* to give a reply of <98><AA><01>.) To ensure an immediate start, choose a start date that is less than or equal to the current date.

SOM (0x00)	Command (P)	Destination Address (3 bytes)	Date/Time (19 bytes)	CRC (2 bytes)

SOM (0x00)	Command (p)	Destination Address (1 byte)	Date/Time (19 bytes)	CRC (2 bytes)

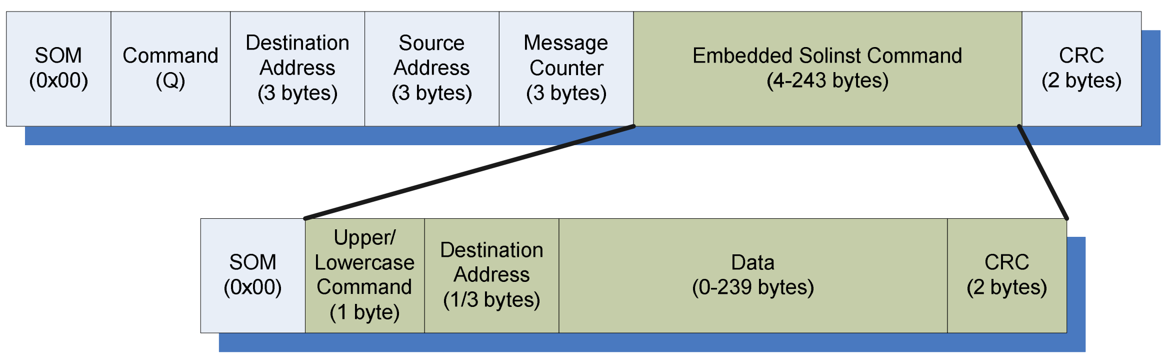
BCC (1 byte)	CRC (2 bytes)

18. **Q**—packet communication command is used to send a Solinst protocol command in a packet network where the source address and a unique message identifier are required. This command is only supported on telemetry system controllers. The destination address is followed by the source address and a 24-bit unsigned message counter (big-endian). The embedded Solinst command follows (without the SOM, which is added once the embedded command is extracted and sent). The reply for this command will be routed to the Source Address using a similar packet communication command.

    An independent Message Counter, in each hardware controller, increments by one for each originating message. Reply message counters will duplicate the message counter from the original message to ensure that all messages replies can be uniquely matched against an originating message. Since the Solinst protocol will not produce a second originating message until the first message response has either timed out or replied with an error, the reply matching mechanism will be primarily used in centralized controllers which communicate with multiple remote controllers simultaneously.

    The maximum embedded Solinst Command data size may be limited by the communication channel(s) this message must traverse. Shown here is a 256 byte maximum limitation for a cheaper radio transmitter.

    Note: The CRC in the embedded Solinst command includes an implied SOM so that it does not need to be recalculated before sending the embedded message.



19. **R**—command to stop logging immediately. The Date/Time field is ignored and is reserved for future use but it does contribute to the CRC result. (e.g., <00>**r**<FF>23/04/2009 13:41:30<5F><4C> gives the following response: <CE><94><81>)

SOM (0x00)	Command (R)	Destination Address (3 bytes)	Date/Time (19 bytes)	CRC (2 bytes)

SOM (0x00)	Command (r)	Destination Address (1 byte)	Date/Time (19 bytes)	CRC (2 bytes)

BCC (1 byte)	CRC (2 bytes)

20. **S**—command to write the System short address (1 byte). (eg. <00>s<08><FF><5B><B6> gives the following response: <8B><67><40>)

SOM (0x00)	Command (S)	Destination Address (3 bytes)	System Address (1 byte)	CRC (2 bytes)

SOM (0x00)	Command (s)	Destination Address (1 byte)	System Address (1 byte)	CRC (2 bytes)

BCC (1 byte)	CRC (2 bytes)

21. **T**—command to read the System address (1 byte). Usually the system address mode command is used to query a single unit using the global address (0xFF) to determine its current system address. (e.g., <00>t<FF><40><67> gives the following response: <1A><FF><20><4B>)

SOM (0x00)	Command (T)	Destination Address (3 bytes)	CRC (2 bytes)

SOM (0x00)	Command (t)	Destination Address (1 byte)	CRC (2 bytes)

BCC (1 byte)	System Address (1 byte)	CRC (2 bytes)

22. **U**—command to read the top address allowed in backup memory (3 bytes) and the top address allowed in data memory (3 bytes). (The bottom address allowed in backup memory is normally 0x040000 and the bottom address allowed in data memory is normally 0x000000.) (e.g., <00>u<FF><D0><66> gives the following response: <AA><04><1F><93><03><FB><FF><78><40>)

SOM (0x00)	Command (U)	Destination Address (3 bytes)	CRC (2 bytes)

SOM (0x00)	Command (u)	Destination Address (1 byte)	CRC (2 bytes)

BCC (1 byte)	Data (6 bytes)	CRC (2 bytes)

23. **V**—command to send a text string to a logger to change internal settings. The reply will be a secondary text string giving the internal logger settings in an ASCII format.

SOM (0x00)	Command (V)	Destination Address (3 bytes)	Size (n)	Text (n+1 bytes)	CRC (2 bytes)

SOM (0x00)	Command (v)	Destination Address (3 bytes)	Size (n)	Text (n+1 bytes)	CRC (2 bytes)

BCC (1 byte)	Size (m)	Text (m+1 bytes)	CRC (2 bytes)

The meaning of the text content of the sent message and the reply will be dependent on a specific logger. All the latest Edge loggers support this command. None of the original Levelogger Gold loggers support this command.

For example, the LevelSender uses the following text message to set its log/report settings and configure its attached loggers:

```
<00>v<FF><n>Probe 1
Sample Rate: 10 minutes
Report Rate: 1 hour
Logging Rate: 5 minutes
Buffer Mode: fill
Log Type: linear

Probe 2
Sample Rate: 10 minutes
Report Rate: 1 hour
Logging Rate: 5 minutes
Buffer Mode: wrap
Log Type: compressed

Start Logging: 12/20/2012 14:30:00
Start Report: 12/20/2012 15:30:00
<crc>
```

Note: optional parameters are in italics. The reply for the LevelSender is :

```
<bcc><m>LevelSender
Serial: 1093412
Battery: 78%
Sample Rate: 10 minutes
Report Rate: 1 hour

Probe 1
Location: Sumptor's Well
Type: Levelogger Gold
Serial: 1083412
Battery: 98%
Total Logs: 10000 of 40000
Logging Rate: 5 minutes
Buffer Mode: fill
Log Type: linear

Probe 2
Location: Sumptor's Stream
Type: Barologger Edge
Serial: 1083512
Battery: 95%
Total Logs: 10000 of 40000
Logging Rate: 5 minutes
Buffer Mode: wrap
Log Type: compressed
<crc>
```

24. **W**—Not Implemented. Reserved for future use.

25. **X**—change communication baud rate. The baud rate is encoded as a single byte with the following legal values:

Byte encoding	**Baud Rate**	**Logger HW**
9, 96	*9600 baud (fixed for all)*	*V1,V2*
19, 192	*19200 baud*	*V2*
38	*38400 baud*	*V2*
57	*57600 baud*	*Future*
115	*115200 baud*	*Future*
others	*unchanged*	*V2*

The baud rate will be changed immediately after a successful reply has been received. If a logger does not support changing baud rates, either an error reply or a message time-out will result. All Leveloggers with hardware V2 and up support this command and baud rate changes. If the baud rate byte encoding is not recognized or not supported, an error reply will result and the baud rate will not be changed.

SOM (0x00)	Command (X)	Destination Address (3 bytes)	Baud Rate (1 byte)	CRC (2 bytes)

SOM (0x00)	Command (x)	Destination Address (1 byte)	Baud Rate (1 byte)	CRC (2 bytes)

BCC (1 byte)	CRC (2 bytes)

Standard Levelogger Direct Read Cables, USB and RS-232 readers should be able to communicate at 19200 baud with limited length cables. With firmware changes, STS, SDI-12 cable, and RRL will also communicate at 19200 baud. The new high-speed USB readers and current RS-232 readers are the only devices able to communicate at 38400 baud with the new Leveloggers.

Note: After 5 minutes at higher baud rates, the new Leveloggers will revert to their default 9600 baud speed.

26. **Y**—unlock password to allow changes to configuration memory. (locks it with bad password). The response is a single byte with a value of 00 if the unit is unlocked and 01 if locked. When the Bootloader Program is installed, the response will be 02 if communicating with the Bootloader program and the response is 03 if communicating with the Bootloader. (e.g., <00>y<FF>password<86><93> gives the following response: <95><00><50><6F>)

SOM (0x00)	Command (Y)	Destination Address (3 bytes)	Password (4 bytes)	CRC (2 bytes)

SOM (0x00)	Command (y)	Destination Address (1 byte)	Password (4 bytes)	CRC (2 bytes)

BCC (1 byte)	Lock Status (1 byte)	CRC (2 bytes)

27. **Z**—initiates self-test, followed by a single-byte command/size indicator. If the command byte is 0x00, 0xFF, or any other value except for 0x04 and 0x08, then the CRC follows immediately with no Test Vector/Mask bytes. For all other command byte values, this byte indicates the number of bytes to follow in the Test Vector/Mask field. Currently, values of 0x04 and 0x08 are the only valid Test Vector/Mask sizes. Any other values will be interpreted as an 8-bit test vector with no Test Vector/Mask bytes. When the 0x04 size is selected, the Test Vector, Mask, and reply will consist of 2 bytes or 16 bits each. When the 0x08 size is selected, the Test Vector, Mask, and reply will consist of 4 bytes or 32 bits each. All other **Z** cmd replies will contain a single byte.

    When included, the Test Vector selects specific tests (see test bit numbers below) and the Mask Vector requests that certain test results be retained when the mask bit is '1'. This command starts the unit self-test and responds with the BCC and a one-, two-, or four-byte test status with each bit representing a single test. A set bit '1' indicates a failed test, while a '0' bit indicates a passed test. All vectors are transmitted with the high-order byte first. For testing, a set bit '1' performs a test, while a '0' bit bypasses a test. Sending all zeros for any Test Vector or command byte simply returns the previous test results without performing any new tests.

SOM (0x00)	Command (Z)	Destination Address (3 bytes)	Cmd/Size (1 byte)	Test Vector/ Mask (Optional) (0/4/8 bytes)	CRC (2 bytes)

SOM (0x00)	Command (z)	Destination Address (1 byte)	Cmd/Size (1 bytes)	Test Vector/ Mask (Optional) (0/4/8 bytes)	CRC (2 bytes)

BCC (1 byte)	Test Result (1/2/4 bytes)	CRC (2 bytes)

Logger Tests

The following will be tested during Levelogger, Rainlogger, and LTC self-test :

1) *Battery Voltage test* (Bit 0). The external A/D's battery voltage will be used to generate a power supply fault whenever the voltage is below 3.1V.
2) *Program FLASH checksum test* (Bit 1). The program memory computed checksum is compared to a 4-byte checksum stored in FLASH.
3) *Information FLASH checksum test* (Bit 2). The information memory computed checksum is compared to a 2-byte checksum stored in FLASH.
4) *FRAM test* (Bit 3). We will read/write various test patterns to the entire FRAM device. Any data in the FRAM is preserved. LTCG will only test portions of the FRAM.

5) *Logging Memory test 1* (Bit 4). Blocks of bytes are non-destructively written/verified for the first 512-byte segment of each 4096 byte logging memory page for the low-memory device.
6) *Logging Memory test 2* (Bit 5). As 5) except the high-memory device is tested.
7) *Temperature Sensor test* (Bit 6). The raw temperature sensor A/D value is read. If this reading is between 740000H and E50000H, the test will pass.
8) *Pressure Sensor test* (Bit 7). The raw pressure sensor A/D value is read. If this reading is between 810000H and B000000H, the test will pass.
9) *Full Logging memory test* (Bit 8). Blocks of bytes are non-destructively written/verified for the entire logging memory range. A full memory test of all bytes typically takes about 3 mins 15 secs with the Gold loggers and about 5 to 10 secs with the Edge loggers—depending on the amount of installed logging memory.
10) *Conductivity Sensor test* (Bit 9). If the last conductivity calibration failed or if the time between recommended calibrations has passed, this bit will be set..
11) *Bootloader FLASH checksum test* (Bit 10). The bootloader memory computed checksum is compared to a 4-byte checksum stored in FLASH.
12) *Leak Detection test* (Bit 11). If a water leak has been detected, this bit will be set.
13) Bits 12 to 31 are reserved for future use. These should be set to '0'.

RRLG Tests

The following will be tested during RRLG self-test :

1) *Battery Voltage test* (Bit 0). The internal A/D's battery voltage will be used to generate a power supply fault whenever the voltage is less than 5V or greater than 28V.
2) *Program FLASH checksum test* (Bit 1). The program memory computed checksum is compared to a 4-byte checksum stored in FLASH.
3) *Information FLASH checksum test* (Bit 2). The information memory computed checksum is compared to a 2-byte checksum stored in FLASH.
4) *FRAM test* (Bit 3). We will read/write various test patterns to portions of the FRAM device. Any data in the FRAM is preserved.
5) *Logging Memory test 1* (Bit 4). Blocks of bytes are non-destructively written/verified for the first 512-byte segment of each 4096 byte logging memory page for the low-memory device.
6) *Logging Memory test 2* (Bit 5). As 5) except the high-memory device is tested.
7) *Temperature Sensor test* (Bit 6). A failure occurs when the temperature is less than -20°C or greater than 50°C.
8) *Pressure Sensor test* (Bit 7). Not used.

9) *Full Logging memory test* (Bit 8). Blocks of bytes are non-destructively written/verified for the entire logging memory range. A full memory test of all bytes typically takes about 3 mins 15 secs.
10) *Conductivity Sensor test* (Bit 9). Not used.
11) *Bootloader FLASH checksum test* (Bit 10). The bootloader memory computed checksum is compared to a 4-byte checksum stored in FLASH.
12) *External Voltage test* (Bit 11). The RRLG indicates a failed bit when the external applied voltage is less than 8V or greater than 19V.
13) *Probe 0 test* (Bit 12). The RRLG indicates a failed bit when no readings can be obtained from the Left 1 connected Levelogger.
14) *Probe 1 test* (Bit 13). The RRLG indicates a failed bit when no readings can be obtained from the Right 1 connected Levelogger.
15) *Probe 2 test* (Bit 14). The RRLG indicates a failed bit when no readings can be obtained from the Left 2 connected Levelogger.
16) *Probe 3 test* (Bit 15). The RRLG indicates a failed bit when no readings can be obtained from the Right 2 connected Levelogger.
17) *Radio test* (Bit 16). The RRLG indicates a failed bit when there is no reply packet after a radio test packet has been sent to the home station.
18) *Vin Voltage test* (Bit 17). The RRLG indicates a failed bit when the Vin voltage is less than 5V or greater than 19V.
19) *Radio Voltage test* (Bit 18). The RRLG indicates a failed bit when the radio voltage is less than 3V or greater than 6V.
20) *Radio Power test* (Bit 19). The RRLG indicates a failed bit when the radio voltage regulator power good signal indicates the output is outside regulated specifications.
21) *Probe Power test* (Bit 20). The RRLG indicates a failed bit when the probe driver voltage power good signal indicates the output is outside regulated specifications.
22) Bits 21 to 31 are reserved for future use. These should be set to '0'.

Any '1' bits in the mask vector will force the previous corresponding test status bit to be retained. Any '0' bits in the mask vector will ignore any previous test status results and always set the test status bit according to the current test result. (e.g., a test vector of 0x000F will perform the battery voltage test, Program FLASH checksum test, Information FLASH checksum test, and the FRAM test. If the mask is 0x0008, the previous FRAM test result bit will not be cleared so that any new FRAM errors will be Ored with the original test results.) To perform all tests, the following command would be issued*:*
*<00>**z**<FF><04><03><FF><00><00><7C><0E>* where the first 0x03FF represents the tests to perform (bits 0 to 8 are '1') and the second 0x0000 represents a bit mask for all the test bits. The response to this command is *<09><00><00><02><D0>* to indicate, in this example, that all tests have passed.

1.1.1.4 DATABASE FORMAT

Memory locations are addressed in 3 transmitted bytes, each byte is aaaaaaaa to give 3*8 bits of addressing space or 16 million byte locations. The memory inside the LTC Gold is not this large. The current LTC Gold EEPROM handles only about 28,000 logs with 9 bytes/log.

Logs are stored in EEPROM memory and always have a starting memory location. The EEPROM memory which is located immediately before the starting memory location contains data about the LTC Gold, about the Log Session, and about the Status of the memory. All logged data and memory related to the log are referenced relative to the starting memory location. Locations wrap around the EEPROM memory top, (which is read using the **U** command) and then jump down to 0x000000.

Backup information is stored in FRAM memory and is recalled only as memory locations which are above the EEPROM memory area. See memory map for details.

The present LTC Gold does not allow memory operations between 0x03FC00 to 0x03FFFF and has an EEPROM top-of-memory of 0x03FBFF.

1.1.1.5 DATA FORMAT

Data Readings are kept as 3 bytes of data. The number value is represented by 20 bits, a decimal position (once converted to decimal) by 3 bits and the sign is represented by the top bit (see Figure 2). This gives the output a range of 999,999 with the decimal placed anywhere within seven digits. The range of the system is not 20 bits since the number can be a fraction as well. It is just that the maximum readable value is 999,999 and the minimum value is 0.0000001 to give about 43 bits of effective range.

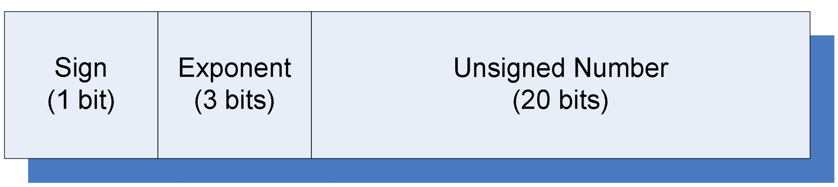


Figure 2: Floating Point Number Representation

For example, the number 0.1 (*f*) would be represented by 0x60186A0. The upper bit is zero to indicate a positive number; the decimal exponent is 6 and the hexadecimal number 0x0186A0 (100000 decimal). The exponent causes the decimal point to shift 6 places to the left so that the 100000 becomes 0.1. Mathematically, the decimal number m and exponent e form a resultant number $f = m \times 10^{e}$.

1.1.1.6 COMPRESSED DATA FORMAT

In a compressed data log the first data log for each channel must always be uncompressed. For an uncompressed floating point number, the least significant bit (if set) indicates that the following data log for this channel is compressed. A compressed log uses a single byte to represent the 24-bit pseudo floating point value. The upper bit of this byte (if set) indicates that the following data log is compressed. The remaining seven bits are a signed twos-complement integer representing a difference between the original uncompressed data logs.

An extension to this compression method was devised that can also compress times (see 1.1.1.7 below). The basic compression approach is the same in that the least significant bit of the first 32-bit word is used to indicate that the next byte is compressed data. Similarly the upper bit of the delta byte, if set, indicates the following byte is also compressed. The time compression is particularly advantageous for application to the Rainlogger where large numbers of tipping events during times of intense rainfall could be significantly compressed by up to 25%.

1.1.1.7 TIME FORMAT

Time is represented as a 32-bit unsigned number giving the number of seconds since 00:00:00, 1 January 1970.

1.1.1.8 DELTA TIME FORMAT

Delta time (in event mode) is represented as a 32-bit unsigned number giving the number of sampling intervals since the last event.

1.1.1.9 SAMPLE INTERVAL FORMAT

The sample interval is represented as a 32-bit unsigned number givng a time interval with 1/100 seconds resolution. (e.g., a 1 second sample interval would be 100.) To represent a 1/8 second interval, use either the number 12 or 13.