BATTERY MANAGEMENT

S-BUS

(SENTINEL 2, I-LINK 2, S-BUS CONVERTER)

USER GUIDE

REVISIONS

Document version	Sentinel Firmware	Date	Evolution
V 0.0	V1.10, V1.11	2007-11-12	Creation
V 1	V1.10, V1.11	2008.04.09	Added LEM address (page 4) + modified power supply in range (page 8) and Additional input power supply (page 9)

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1 NOTICES

This document is the user guide describing how to use the different modules developed by LEM in a complete Battery Management environment, without the general monitor product MicroGuard. Such network is based on S-Bus communication, protocol supported by LEM Sentinel-2 and I-Link-2 devices on the S-Bus and I-Bus communication links, respectively. Both are connected to any OCS (Overview and Control System) serial port through LEM RS232 to S-Bus converter.

1.1 Safety instructions

The design and manufacture of this LEM's battery Management device conforms to the latest state of technology and the safety referenced in IEC 61010-1/ 2nd edition. If used improperly, there could be a risk of damage to both persons and property.

The device may only be used indoors.

1.1.1 Qualified personnel

Only qualified personnel should operate this equipment.

This includes all persons who are familiar with the installation, assembly, connection, inspection of connections and operation of the monitoring system, and who have completed training in the following areas :

- Switching on/off, enabling, grounding, and identification of electrical circuits and devices/systems according to the applicable safety standards
- Maintenance and operation of appropriate safety gear, in accordance with the applicable safety standards
- Medium & High voltage battery applications

1.1.2 Safe operation

Ensure that all persons using the device have read and fully understood this operating manual including safety instructions.

The devices may only be used under certain ambient conditions. Ensure that the actual ambient conditions conform to the admissible conditions specified in their datasheets.

Do not use the devices for any other purpose than the measuring of voltages and currents that are within the specified operating range. Improper use shall void all warranty.

If any damage is detected to the housing, controls, power cable, connecting leads or connected devices, immediately disconnect the unit from the power supply.

Ensure that the connected devices work properly

1.1.3 Maintenance and repairs

Damaged or defective devices must be inspected/repaired by authorized technicians.

For technical assistance, please contact LEM at:

Chemin des Aulx, 8
CH-1228 PLAN-LES-OUATES
Geneva, Switzerland
www.lem.com

1.1.4 CE marking

CE

Conformity mark re. EC Low Voltage Directive 73/23/EEC and EMC Directive 89/336/EEC.

2 GENERAL DESCRIPTION

The system is composed of Sentinel transducer modules, connected to every bloc being monitored, linked together by S-BUS communication. Float and discharge current sensors are interfaced via the I-Link module.

Only use the accessories supplied with such devices, specifically available for your equipment (see table below).

DESCRIPTION	PART (CLEM) Numbers
Sentinel 2 - LV, 2V	66.61.05.000.0
Sentinel 2 - HV, 6-12V	66.61.14.000.0
I-Link 2	66.82.98.000.0
S-Bus converter	66.81.98.001.0
BM Cable power 0.25m	66.30.98.007.0
BM Cable power 0.4m	66.30.98.017.0
BM washer 06mm	66.30.98.013.0
BM washer 08mm	66.30.98.014.0
BM washer 10mm	66.30.98.015.0
BM washer 12mm	66.30.98.016.0
BM Cable comm 0.4m	66.30.98.001.0
BM Cable comm 1.0m	66.30.98.002.0
BM Cable comm 2.0m	66.30.98.003.0
BM Cable comm 5.0m	66.30.98.004.0
BM Cable comm 10m	66.30.98.005.0
BM Cable comm 15.0m	66.30.98.009.0

The Sentinel modules are connected to the bloc by Power & Sense leads, with available connection lengths: 250mm or 400mm.
Special Kelvin washers (0.8 mm thick) are available and must be used to connect the power & sense leads to the blocs in order to insure correct bloc impedance measurements.
S-Bus and I-Bus link are via RJ10 pre-terminated communication cables. Available communication lengths are: 400mm, 2m, 5m, 10m, 15m.

The Sentinels units are daisy-chained on S-Bus, as well as I-Links modules (if more than one unit is used) on I-Bus.

2.1 Communication

The LEM proprietary communication bus is generally referred to as S-Bus or I-Bus, dedicated link for I-Link modules. In practice, both have exactly same characteristics and function in the same way.
Based on serial full duplex communication, each device has an unique ID, 001-254, which identifies it on the appropriate bus.

The link is a 4-wires one (Rx, Tx, 2xGnd) and is able to support 125 devices with correct network performance.

The transmission speed is 9600 baud, with no flow control and following data frame:
Start bits: 1
Stop bits: 1
Data bits: 8
Parity: None

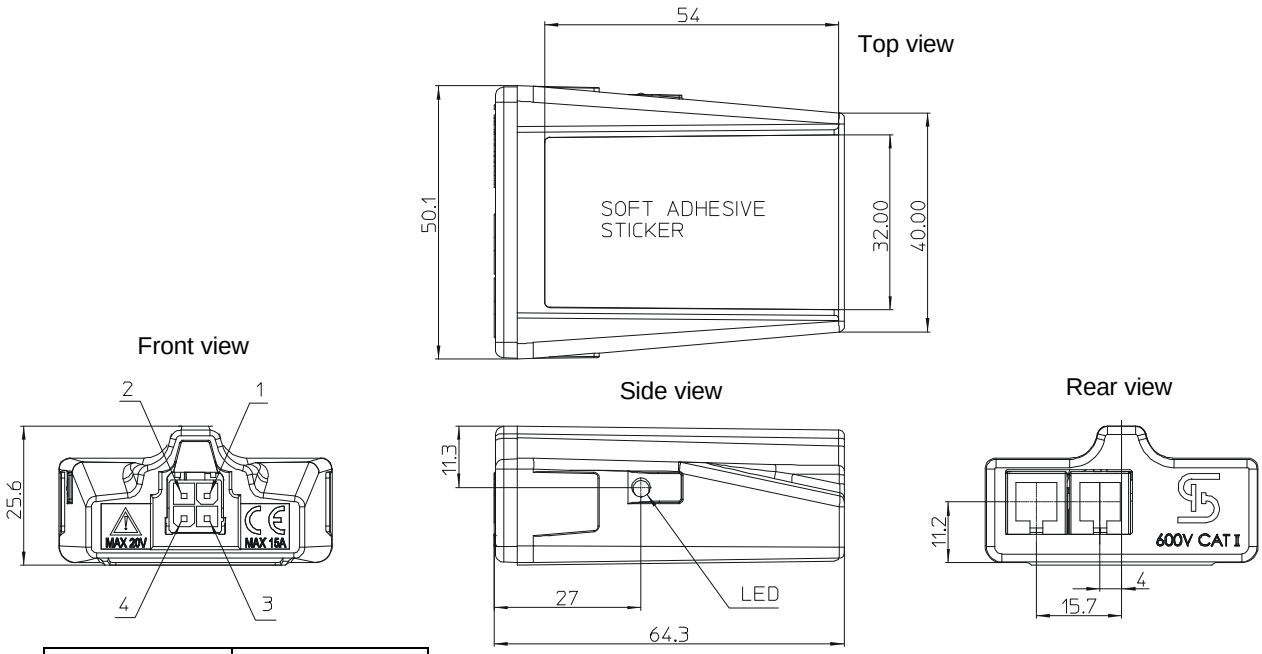
The electrical interface is custom designed. For this reason, it is not possible to directly connect Sentinel or I-Link device to the OCS. A LEM-supplied Bus Converter module is needed; it is in charge of generating the correct signal levels (note: no software protocol translation is performed).

The device is instructed by means of a command set addressed to the unit and provides data and status information in the form of a response set. It never analyzes the measured parameter by itself. It doesn't make an unsolicited or spontaneous transmission to the network. **The only exception is a "READY" announcement following a successful start-up (detailed in 3.2)**

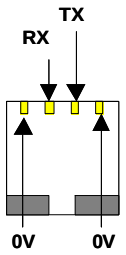
2.2 Sentinel device

The Sentinel device is a digital transducer, which measures Voltage, Temperature and Impedance of a 'Standby' Battery. Two types of modules exist: one for low voltage 2V bloc, another one for high voltage (6V or 12V).

Mechanical drawings:
The module is equipped with two S-Bus ports (refer front view), internally connected in parallel and with a power & sense connector (on rear view) towards the battery bloc:



2: Power –ve	1: Sense +ve
4: Sense -ve	3: Power +ve



S-Bus port

Care must be taken to connect the Sentinel to the positive and negative terminals of the bloc correctly. **Reversal of these leads may damage the Sentinel.**

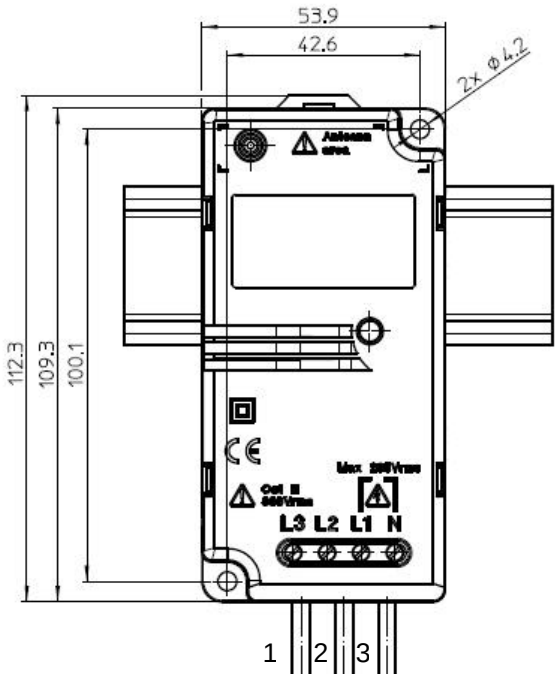
It must put on a clean and plane bloc area and fixed to it thanks to the ‘double-sided’ tape on its back. Take care to place the Sentinel in order its LED on left side being easily seen.

The Sentinel module is sealed to comply with the relevant health and safety standards; under no circumstances must it be opened. No object must be inserted into the module other than the specified connectors. If this condition is not complied with, all warranties and compliance are void.

2.3 I-Link device

The I-Link device is attached to a LEM current transducer (CT) whose output signal is measured and converted, for the purposes of transmission over the I-BUS.
It is designed to accommodate up to 2 current sensors: a combined charge/discharge sensor, and a separate 'float' (trickle) sensor.
The I-Link module can be fixed on a wall or panel with two screws (M4), using max. fastening torque 2.8 Nm or mounted on a metallic DIN Rail thanks to the clip on its back.

Mechanical drawings:
The module is 34.8 mm thick.
Cables are about 50 cm long



Cables identification:

1: CHRG/DIS CT
2: POWER Supply
3: FLOAT CT

It requires external power supply in range 18-34V.
Connection toward power supply:

Wire colour	Meaning
Red	Power Supply (18-34V)
Black	Ground

Connection toward CT:

Wire colour	Meaning
Red	Power Supply +15V
Dark blue	Power Supply –15V
Yellow	CT output
Black	CT return (0V)

In the large offer of LEM current transducers, some products are more suitable for charge/discharge measurement (bipolar and large range).

By default, I-Link device is set to accept maximal CT output voltage of 4V. Anyway, on special request, it can be set to accept 8V: this must be specified when ordered.

At this present moment, LEM recommends the following current sensors.

- For use with cables:

HTA family : 32mm round aperture, available in 100, 200, 300, 400, 500, 600 and 1000 A versions.

HTR family : split-core for retrofit applications. Available in 50, 100, 200, 300, 400 and 500 A.

- For use with bus bars:

HAX family : large 64 x 21 mm rectangular aperture. Available in 500, 600, 850, 1000, 1200, 1500, 2000 and 2500 A versions for larger applications.

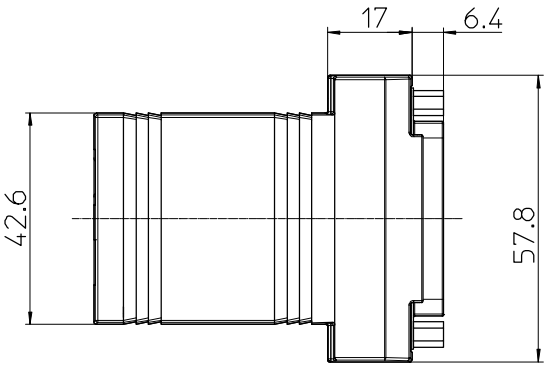
HOP family : rectangular aperture and split-core for retrofit. Available in 500, 800, 1000, 1500 and 2000 A versions

All the data sheets are available on LEM web-site.

2.4 S-Bus converter

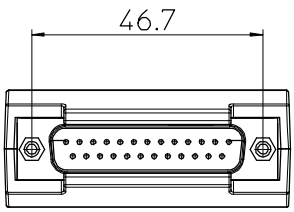
The S-Bus converter is designed to convert the LEM proprietary Sentinel & I-Link communication bus (S-Bus) to RS232 interface. Note, the module only acts on signal levels conversion, no software protocol translation is performed.

The 25-pin connector is a standard (RS232) configuration and may be directly connected to the serial port of a personal computer. Additional input power supply (7-12V), 500 mA min is required.

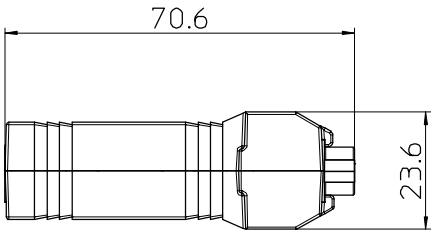


Bottom

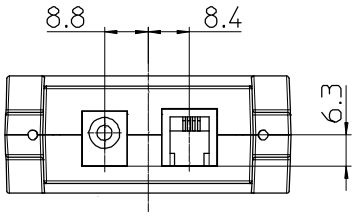
Front view



Side view



Rear view



3 PROTOCOL

3.1 Command

The Sentinel or I-Link unit expects commands from another compatible device such as a system controller attached to the network to be issued to it in 3 - byte packets, sent in big-endian format (MSB first) and accepts:

- all commands with its unique ID,
- some commands (see below) with a broadcast ID (=255) designated as global which is destined for all units on the network.

byte1	byte2	byte3
Address/ID	Instruction	Checksum

byte1 : Address/ID

Up to 254 modules can be present on the bus, each with unique bus address/ID.
This byte specifies the target.

byte1 value	**meaning**
0x00	Command for unit #0; all units have default ID to 0 from factory
0x01 .. .. 0xFE	Command for unit #1 .. .. Command for unit #254
0xFF	Command is for ALL units (broadcast); used only with specific Instruction

byte2 : Instruction

This byte specifies the action to be performed by the addressed unit.

Command set for **Sentinel** devices:

byte2 value	**meaning**
0x40	Measure Voltage and store value
0x41	Measure Temperature and store value
0x42	Measure Impedance and store value
0x20	Transmit Voltage from stored value
0x21	Transmit Temperature from stored value
0x22	Transmit Impedance from stored value
0x60	Measure and Transmit Voltage (+storage)
0x61	Measure and Transmit Temperature (+storage)
0x62	Measure and Transmit Impedance (+storage)
0xA0	Assign ID
0xFF	Soft Reset

Any other value is not user available and is purely **forbidden**, as reserved for test purpose (may have dramatic effects).

Byte3 : Checksum

The checksum is created by 'successive XOR' method on byte1 and byte2.
The unit must confirm the integrity of this check byte performing the successive XOR method on the first two bytes received in the packet.

Notes

1) It is possible to send a Measure Voltage or Temperature Instruction (0x40 or 0x41) to ALL Sentinels on the bus, simultaneously (with ID=0xFF).
Then shortly after, the measured values can be collected individually from each Unit.
This mechanism is very efficient and useful in the situation when a battery system is discharging, because it allows 'snap-shots' of the overall battery status.
The Measure Impedance Instruction (0x42) is not allowed in broadcast access. Such command with a global ID is ignored.

2) It is not necessary to use Transmit command immediately after a Measure command. Sentinel will store the measured value until a Transmit is requested.

3) For Voltage and Temperature MEASURE commands, as the measurement itself, performed by the Sentinel unit, is done in a short time (less than 10 ms), any new incoming MEASURE command is then stored to be applied once the previous one is completed.

4) Impedance test takes 6 seconds to complete, from when instruction is received.
During this period, it is recommended to not communicate with any unit on the bus.
In case of an Impedance measurement is in progress, any new incoming MEASURE command aborts the sequence and the unit executes the new command.
It is necessary to wait at least 10 minutes before requesting another Impedance test from the same Unit.
Moreover, any impedance measurement is avoided if any of both conditions occurs:

- voltage is greater than 14.4V for high voltage version or 2.5V for low voltage one
- temperature exceeds 120°F (49°C).

In practice, a daily impedance measurement is sufficient, because this specific parameter doesn't change so rapidly and moreover such measurement generates some local temperature increasing (so any immediate following temperature measurement is insignificant).
It is also not recommended to perform any impedance measurement in a 48hours delay just after a discharge, as such value would be then incorrect.

3.2 Response

The unit transmits any response as a 4-byte packet, in big-endian format (MSB first):

byte1	byte2	byte3	byte4
Address/ID	Data A (MSB)	Data B (LSB)	Checksum

byte1 : Address/ID

The unit which always answers first with its own ID.

byte1 value	**meaning**
0x00	Response from unit #0 (in insertion, all units have default ID to 0 from factory)
..	..
..	..
0xFE	Response from unit #254

byte2,3 : Data A,B

Then, the response consists in pure data return, which corresponds to the measured parameter (V, T, or Z), or information sent to the controlling device.
A flag is available on the Data A bit 7 with following status:

CLEAR: The data packet contains measurement information
SET: The data packet contains status information

The return data format is IEEE754 half-floating point, unsigned as negative values are not required.
It consists of: 1 Flag bit, 4 Exponent bits (Exp), 11 Mantissa bits (man)

byte4 : Checksum

The checksum is created by 'successive XOR' method on byte1, byte2 and byte3.
The controller must confirm the integrity of this check byte performing the successive XOR method on the first three bytes received in the packet.

Within the 2 Data bytes, these 15 bits are organized as follows:

Data A (byte 2)	bit 7 (MSB)	General flag
	bit 6	Exp #3 (MSB)
	bit 5	Exp #2
	bit 4	Exp #1
	bit 3	Exp #0 (LSB)
	bit 2	Man #10: $2^{(-1)}$ (MSB)
	bit 1	Man #9: $2^{(-2)}$
	bit 0	Man #8: $2^{(-3)}$
Data B (byte 3)	bit 7 (MSB)	Man #7: $2^{(-4)}$
	bit 6	Man #6: $2^{(-5)}$
	bit 5	Man #5: $2^{(-6)}$
	bit 4	Man #4: $2^{(-7)}$
	bit 3	Man #3: $2^{(-8)}$
	bit 2	Man #2: $2^{(-9)}$
	bit 1	Man #1: $2^{(-10)}$
	bit 0	Man #0: $2^{(-11)}$ (LSB)

Method to decode the Data

- Exponent is an integer, range = 0 to 15 (0000, 1111)
- Mantissa is a binary fraction, range = 0.0 to <1.0 (0....0, 1....1)

Man #10 is the MSB, value is $2^{(-1)}$ …

Man #0 is the LSB, value is $2^{(-11)}$

When **1 = Exponent = 14 :** value = $2^{(Exp - 7)}$ * 1.Man

When **Exponent = 0, and Mantissa ? 0 :** value = $2^{(Exp - 6)}$ * 0.Man

When **Exponent = 0, and Mantissa = 0 :** value = 0

When **Exponent = 15 and Mantissa = 0 :** value = “Infinite”

When **Exponent = 15 and Mantissa ? 0 :** value = “NaN” (Not a Number)

So, the minimum value is 0 and the maximum one is 255,9375

Measurement units used by Sentinel are:
for Voltage values: Volts (V)
for Temperature values: Farenheit (F)
for Impedance values: milli-Ohms (mO)

Here are some examples of decoded values:

Parameter	Data A, Data B	Flag, Exp, Mant	Value
Voltage	0x55, 0xA0	0 1010 10110100000	13.625 V
Voltage	0x41, 0x00	0 1000 00100000000	2.25 V
Temperature	0x69, 0xD0	0 1101 00111010000	78.5 °F
Impedance	0x3C, 0x80	0 0111 10010000000	1.5625 mO

Sentinel unit transmits “Infinite” value to indicate an overflow measure and “NaN” value to indicate a too inaccurate measure such as impedance measurement when the temperature or the voltage is too high or new impedance measurement in a delay time shorter than 10 minutes from the previous one.

On MEASURE command, the Sentinel unit doesn’t acknowledge this command.

On TRANSMIT command, the unit transmits the last specified measurement from storage, which is indefinitely retained until new measurement of same parameter.

On MEASURE & TRANSMIT command, the Sentinel unit performs the measurement then transmits that measured value

When response just includes status information for the controller and not measurement values, data format is always 2 bytes, with general flag, MSB bit 7 in first byte, SET and any unused bit cleared to 0. Examples of such response:

- SEND ID : 0xA0, 0x00
A prompt to the controlling device’s ASSIGN ID command. Indicates that the unit requires the new ID to be sent.

- ID CHANGED: 0xC0, 0xID
A response to the controlling device’s compliance in sending the new ID. The new ID must be included in the response. Specifically, the ID does not change from old to new until this response has been sent.

- TRANSMIT twice: 0x90, 0x00
If the unit determines that it has received two successive TRANSMIT commands (for the same measurement type), it doesn’t return the same value but a status (0x90 0x00) that indicates to the controlling device that this has occurred, with flag set.

- “READY” announcement : 0x80, 0xSW
Following a successful start-up, the unit issues a “READY” announcement. Take care that at this moment, **the system controller must be in listener only mode**. This is the only unsolicited transmission to the bus that the unit is allowed to make, and subject to conditions.

Its purpose is :
a) to serve as a confirmation message to the OCS that the unit **has** reset, and
b) during the system installation phase, to signal to the OCS the presence of a new Unit on the bus.

Conditions for issuing a READY announcement:

Either of the following conditions needs to met:

- the value of the ID register, hold in non-volatile memory, is 0 - indicating a virgin/unassigned Unit
- the status of the RESET flag is Active - indicating a Reset was requested by the OCS. On receiving a command to Reset, the Sentinel unit asserts the RESET flag prior to perform a soft-reset. After making the READY announcement, it deactivates this flag.

The READY announcement includes the software revision number, SW, coded as :
bits <4..0> = SWMin4 .. SWMin0: revision minor part (Min)
bits <7..5> = SWMaj2 .. SWMaj0: revision major part (Maj)

The software revision is then reported as “Maj.Min”, for instance:
0x2a = 00101010 means 1.10 ; 0x2b = 00101011 means 1.11

3.3 Specific I-Link Commands & Responses

I-Link modules are connected on dedicated S-Bus link, with exactly same characteristics. Moreover, commands and responses sent on this communication link have same format than those described before for Sentinel modules.
The two signals required to be measured are hereby designated **Float** current, and **Charge/ Discharge** current.

Command set for **I-Link** devices:

byte2 value	**meaning**
0x40	Measure Charge/Discharge current and store value
0x41	Measure Float current and store value
0x42	Reserved
0x20	Transmit Charge/Discharge current from stored value
0x21	Transmit Float current from stored value
0x22	Reserved
0x60	Measure and Transmit Charge/Discharge current (+storage)
0x61	Measure and Transmit Float current (+storage)
0x62	Reserved
0xA0	Assign ID
0xFF	Soft Reset

Any other value is not user available and is purely **forbidden**, as reserved for test purpose (may have dramatic effects).

Note: Commands 0x22, 0x42, 0x62 serve no function. **The controller must not to issue such a command to an I-Link module.**

Method to decode the Data:

Return data format is still IEEE754 half-floating point, unsigned with Mantissa defined on 11 bits and exponent on 4 bits (same as for Sentinel returned values).
Anyway the decimal value is limited to range (0-10). Moreover, for the Charge/Discharge value, it must be then shifted to range <–5 to +5> as **Discharge** signal may be negative.

Transmitted data are Voltage values, which need to be converted to Current values in regards to respectively Discharge transducer (Dis-S V, Dis-S Ipn) for the Charge/ Discharge current and Float transducer (Fl-S V, Fl-S Ipn) parameters for the float current.

Example:

The used charge/discharge sensor gives a maximal output voltage to 5V (Dis-S V) for a maximum nominal input current of 300 A (Dis-S Ipn).

Response from I-Link to commands sequence 0x40 (Discharge Measure) then 0x20 (discharge Transmit value) is: 0x05 0x48 0xB8 0xF4

00000100 01001000 10111000 11110100
(ID : 5 - Mesure : (hfloat) 0100100010111000 = 4.36 - Checksum)

With Dis-S V = 5, Dis-S Ipn = 300, we get value:

(5 - 4.36) * 300 / 5 = 38.4 A, so a recharge current as positive value.

5 is there the shift on return data which corresponds to the “Zero” reference for charge/discharge current.

4 INSTALLATION

Installation of this equipment must only be carried out by a qualified person.

4.1 System Connections

Connections to the battery blocs:

1. Secure the Kelvin washers to the bloc terminals. Be sure to position the washers such that it will be possible to attach the power/sense cables.

2. Using the push-on connectors, attach the power/sense cables to the dual tabs on each of the Kelvin washers. **Be sure to observe the correct polarity:** red wires to positive, black wires to negative terminal.

3. Attach each Sentinel to the bloc thanks to its 'double-sided' tape on its back so that the power/sense cables can easily reach power connector on Sentinel. Do **not** connect the Sentinels to the power/sense cables at this time.

4. Using the S-Bus short communication cables, connect the Sentinels to each other in a daisy-chain manner. It does not matter which port on the Sentinel is used (they are internally connected in parallel). The vacant port on the first Sentinel should be linked to the S-Bus converter port, using a shortest communication cable as possible. If the Control system is quite long away from the battery, prefer to use a longer RS232 serial cable in order to get the complete S-BUS link length in less than 20 m.

5. Install the LEM current transducer on the main positive cable from the battery. Observe correct current flow: the arrow on top of the transducer indicates positive current, so it must be pointed towards the +Ve post, if it is assumed that charge and float currents are positive (flowing into battery) and discharge current is negative (flowing out of the battery).

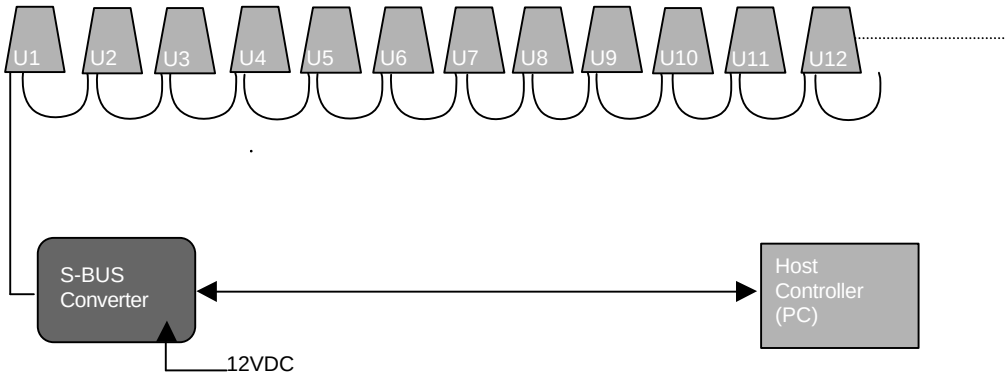
6. Connect the signal cable from the current transducer to the I-Link. Connect also power to transducer from the specific I-Link cable. Do **not** apply power to the I-Link at this time.

7. If several I-Link modules are used, connect each together in daisy-chain via the I-Bus communication cables (short ones). It does not matter which port on the I-Link is used. Connect then the I-Bus cable end to another S-Bus converter, using a short communication cable, whose serial 25-points connector is linked to any serial port on the control system.

4.2 Sequence for a new Sentinel or I-Link insertion

All Sentinel and I-Link units are delivered from factory with default Address/ID set to zero (0). However, before the units can be operated through the serial bus, each unit must be assigned an 'unique' ID number (from 1 to 254). This procedure is described below.

At this step, the Sentinel modules must not (yet) be connected to the Battery. All the units are already connected to each other in a 'daisy-chain' manner using LEM short communication cables (S-Bus), then to S-Bus converter, which itself is linked to the Host serial port:



If some I-Link modules are used, they are also connected in the same way through I-Bus short communication cables to another S-Bus converter then to a second Host serial port. Power supply is not yet applied on any of them. Same sequence as for Sentinel must be followed for assigning them unique ID.

Command sequence for assigning of ID's
During this procedure, the two-bytes Response from Sentinel takes on different meanings.

step 1)

Ensure that the controller is in Listener mode.
Connect power cable (from Battery) to the first unit on the bus, unit #1.
Immediately, the unit should transmit a “Ready” message to the Host:

Host <<<<< Sentinel : 00 80 2A AA

Byte1 is the ID of the unit: 0 in this case.
Byte2, byte3 are data: 0x80 for “Ready announcement”, 0x2A is the software revision.
Byte4 is the Checksum

step 2)

The controller will issue an Assign ID command to the Unit:

Host >>>>> Sentinel : 00 A0 A0

Byte1 is the ID of the target unit: 0.
Byte2 is the Assign ID command: 0xA0
Byte3 is the Checksum

step3)

The unit will respond with actual ID to 0, by asking for the new ID :

Host <<<<< Sentinel : 00 A0 00 A0

Byte1 is the ID of the unit: 0 in this case.
Byte2, byte3 are data: 0xA0 for “Send ID”, 0x00 for unused byte.
Byte4 is the Checksum

step4)

Immediately, the controller must send the new ID in the following command:

Host >>>>> Sentinel : 00 01 01

Byte1 is the actual ID of the unit: 0 in this case.
Byte2 specifies the new ID: 0x01 for this unit
Byte3 is the Checksum

step5)

Then, the unit will confirm change of ID, which will be effective just after this response

Host <<<<< Sentinel : 00 C0 01 C1

Byte1 is the ID of the unit: 0 in this case.
Byte2, byte3 are data: 0xC0 for ID Changed”, 0x01 for new ID.
Byte4 is the Checksum

Assign ID procedure for unit#1 is now complete: it’s ready to perform some measurements and
will now answer to standard commands. To check this, do the following optional step:

step6)

Issue a 'Measure +Transmit Voltage' command to unit#1

Host >>>>> Sentinel : 01 60 61

Byte1 is the ID of the target unit: 0x01.
Byte2 is the Measure +Transmit Voltage command: 0x60
Byte3 is the Checksum

... the unit should respond.

Steps 1) ...5) should be repeated for each Sentinel.
Remember to increment the ID byte each time!
Step 6) may be performed if desired .

The Sentinel's ID is stored in non-volatile memory, that is saved during power off.
Anyway, it can be changed again, at any time, by assigning a new ID.

LED on Sentinel alternately flashes Red, Green, Red... etc when ID is 0 (default). After Assign ID procedure complete (ID**?**0), check it flashes Green only.