Sky Quality Meter – Lens USB - Datalogger

SQM-LU-DL

User manual

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1 Theory of operation

The SQM-LU-DL measures the darkness of the night sky to provide readings of magnitudes per square arc second through a USB connection, and is capable of internally recording readings.

A light sensor (TSL237) provides the microcontroller with a light level, and readings from the temperature sensor are used to compensate the light sensor readings for various operating temperatures.

Commands sent from a PC through the USB cable to the USB interface are relayed to the microcontroller.

The microcontroller responds to commands by sending data strings to the USB interface which are then relayed to the PC.

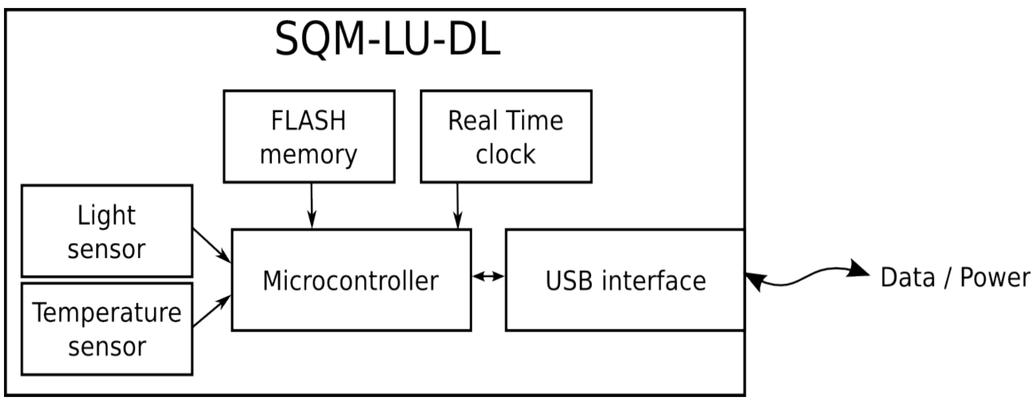

Illustration 1: SQM-LU-DL block diagram

1.1 Quick start

1. Your computer must have the FTDI VCP driver installed. You can get the most updated driver for your operating system from here: http://ftdichip.com/Drivers/VCP.htm
2. If you are using Windows, then download and install the latest Knightware SQM-Reader from www.knightware.biz/sqm . Follow the instructions for installing and using that software.
3. If you are using Windows, Linux, or Mac, you can use the Perl scripts supplied on the CD.
4. Plug unit into USB port of computer.
5. Set the real time clock using the Perl script supplied (sqmutil)
6. Allow the internal Super-cap to charge up for at least a few hours, it will last many days un-powered.

2 Specifications

USB connection	USB B connector (5m USB A to USB B cable supplied) USB FTDI VCP driver, serial port emulator at 115200baud.
Physical Size	5.5” x 2.6” x 1.1"
Meter precision	Each SQM-LU-DL is factory-calibrated. The absolute precision of each meter is believed to be ±10% (±0.10 mag/arcsec²). The difference in zero-point between each calibrated SQM-L is typically ±10% (±0.10 mag/sq arcsec)
Power requirement	18mA (from the 5V USB connection). Can be put to sleep and woken up for battery operated logging.
Operating temperature range	-40°C to 85°C
Temperature Accuracy	± 2°C maximum at 25°C
Temperature update rate	4.3 seconds, 256 samples taken at 60Hz then averaged.
Data logging capacity	1MB Flash chip, 16 bytes per record= 32768 records total.
Real Time Clock accuracy	+1.73s/day @25°C, -2.27s/day @50°C, per Citizen crystal CFS206-32.768KDZB-UB

Illustration 2: Front of unit

Illustration 3: Back of unit

3 Hardware connections

The SQM-LU-DL requires one connection to a USB hub or a PC, or a battery connection with the supplied battery adaptor

The maximum length cable per the USB specification is 15ft (3 meters). USB extenders exist on the market, some work up to 198ft (60m).

1.2 Battery operation

The SQM-LU-DL may be operated by an external batter using the supplied battery to USB adaptor. The lifetime of the battery can be determined as follows:

$$
\begin{aligned}
I_{Quiescent} &= 600\text{nA} \\
I_{Wake} &= 10\text{mA} \\
I_{Measure} &= 55\text{mA}
\end{aligned}
$$

Illustration 4: Current consumption values

$$
\begin{aligned}
t_{Quiescent} &= 1-(t_{Wake}+t_{Measure}) \\
t_{Wake} &= \frac{3\text{s}}{60\text{s}} \\
t_{Measure} &= \frac{5\text{s}}{n*60\text{s}} \\
n &= \textit{number of minutes between samples}
\end{aligned}
$$

Illustration 5: Current consumption timing

$$I_{Average}=t_{Quiescent}\cdot I_{Quiescent}+t_{Wake}\cdot I_{Wake}+t_{Measure}\cdot I_{Measure}$$

Illustration 6: Current consumption formula

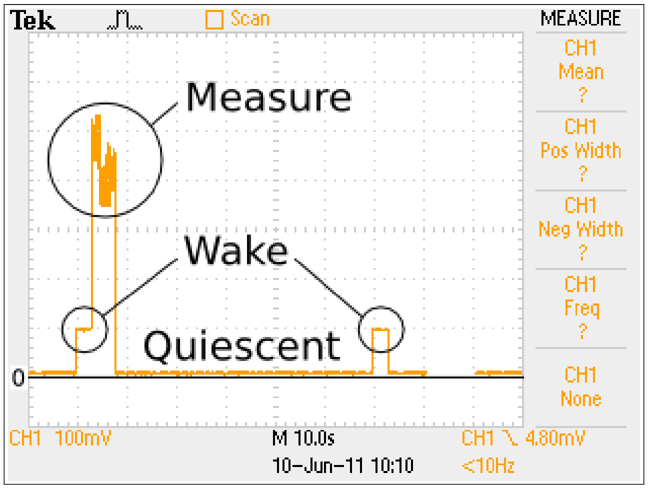

Illustration 7: Current supply current profile using 10Ω current shunt.

As an example for determining battery life of a 3AH battery with sampling every 5 minutes.

$$\begin{aligned}
T_{Batt} &= \frac{AH_{Rating}}{I_{Average}} \\
&= \frac{AH_{Rating}}{\left(I_{Quiescent} + t_{Wake} \cdot I_{Wake} + t_{Measure} \cdot I_{Measure}\right)} \\
&= \frac{AH_{Rating}}{\left(I_{Quiescent} + t_{Wake} \cdot I_{Wake} + \frac{5\text{s}}{n \cdot 60\text{s}} \cdot I_{Measure}\right)} \\
&= \frac{3\text{AH}}{\left(500\text{nA} + \frac{3\text{s}}{60\text{s}} \cdot 10\text{mA} + \frac{5\text{s}}{5 \cdot 60\text{s}} \cdot 55\text{mA}\right)} \\
&= 2117\,\mathit{hours}\text{, or } 88\,\mathit{days}\text{, or } 2.8\,\mathit{months}
\end{aligned}$$

Illustration 8: Battery lifetime calculation example

Note that measuring is still performed for "Threshold" settings, even when it is too light to record a reading. Measuring is performed to determine this "measure" state, and $I_{Measure}$ still applies.

2 Software development

The SQM-LU-DL communicates as a standard serial port device using the FTDI software drivers which are available for all major operating system platforms. http://ftdichip.com/ . The SQM-LU-DL uses the FTDI FT232R chip.

Once the driver is installed, commands can be sent to the SQM-LU-DL using a serial terminal emulator to the serial communications port that the device routes to.

When connecting the SQM-LU_DL to a PC where the FTDI device driver is loaded, the serial port label will be determined at connection time.

Each SQM-LU-DL has a unique serial number usually with a prefix of “FT........”. This serial number can be used to identify the exact SQM-LU-DL device from other USB devices.

Interface Program overview:
- Data commands are sent to the SQM-LU-DL, and it responds with a string of characters.
- A connection must be made to the serial port assigned to the SQM-LU-DL.

4 Commands and responses

The SQM-LU-DL accepts a sequence of characters as a command, then executes those commands and usually provides a response of a sequence of characters.

4.1 Commands

Commands consist of a string of characters.

The first character is the command type. The following is a list of the "Standard" commands:

Command	Description
`rx`	Reading request
`cx`	Calibration information request
`ix`	Unit information request (note lower case "i")
`zcalAx`	Arm Light Calibration command
`zcalBx`	Arm Dark Calibration command
`zcalDx`	Disarm Calibration command
`zcal5########x`	Manually Set Light Calibration Offset
`zcal6########x`	Manually Set Light Calibration Temperature
`zcal7########x`	Manually Set Dark Calibration Time Period
`zcal8########x`	Manually Set Dark Calibration Temperature
`0x19`	Reset microcontroller (see bootloader). Hexadecimal value 19.
`:`	Intel Hex firmware upgrade initiation (see bootloader)
`P#########x`	Set period (in seconds) for interval reporting to EEPROM and RAM for booting and immediate use. Firmware feature=13.
`p#########x`	Set period (in seconds) for interval reporting to RAM for immediate use. Firmware feature=13.
`T#########x`	Set threshold (in mag/arcsec^2) for interval reporting only to EEPROM and RAM for booting and immediate use. Firmware feature=13.
`t#########x`	Set threshold (in mag/arcsec^2) for interval reporting only to RAM for immediate use. Firmware feature=13.
`Ix`	Request interval settings (note upper case "I"). Firmware feature=13.
`sx`	Request reading of internal variables
`S.....x`	Simulate internal calculation

Table 1: Standard Command summary

The following is a list of the "Data logger" commands:

Command	Description
L0	Report on FLASH chip Manufacturer ID, and Device ID
L1	Report on logging pointer
L2	Erase entire FLASH chip contents
L3	Log one record.
L4	Return one record.
L5	Get battery voltage
LM	Set Logging trigger mode, next digit defines mode.
Lm	Get Logging trigger mode
LI	Logging Interval settings requested
LP	Logging Interval period set, next char defines unit
LT	Logging Threshold for interval reports set
Lc	Get real time clock data
LC	Set real time clock data
Ls	Put unit to sleep
La	Get alarm data

Table 2: Datalogger Command summary

4.2 Response details

4.2.1 Reading request

The “Reading” request “`rx`” commands the SQM-LU-DL to provide the current darkness value as well as all variables used to generate that result.

The format of the response is:

Column	Value	Description
0	`r`	Indicates that a reading is being returned.
2-8	` 06.70m`	Reading in magnitudes per square arc second. Leading space for positive value. Leading negative sign (-) for negative value. A reading of `0.00m` means that the light at the sensor has reached the upper brightness limit of the unit.
10-21	`0000022921Hz`	Frequency of sensor in Hz.
23-33	`0000000020c`	Period of sensor in counts, counts occur at a rate of 460.8 kHz (14.7456MHz/32).
35-46	`0000000.000s`	Period of sensor in seconds with millisecond resolution.
48-54	` 039.4C`	Temperature measured at light sensor in degrees C. Leading space for positive value. Leading negative sign (-) for negative value.
55-56		Carriage return (0x0d), Line feed (0x0a).

Table 3: Reading request response

An example is:

```
r, 06.70m,0000022921Hz,0000000020c,0000000.000s, 039.4C
```

0123456789[10]123456789[20]123456789[30]123456789[40]123456789[50]123456

Future revisions of this reading string will only modify reported values beyond position 54. Characters 0 to 54 may be considered stable.

4.2.2 Calibration information request

The calibration information request "`cx`" returns all data about the specific light sensor in the unit required for to calculate a reading.

The format of the response is:

Column	Value	Description
0	`c`	Indicates that the calibration information is being returned.
2-13	`00000017.60m`	Light calibration offset in magnitudes per square arc second.
15-26	`0000000.000s`	Dark calibration time period in seconds with millisecond resolution.
28-34	` 039.4C`	Temperature in degrees C measured during light calibration. Leading space for positive value. Leading negative sign (-) for negative value.
36-47	`00000008.71m`	Offset of light sensor based on manufacturing category.
49-55	` 039.4C`	Temperature in degrees C measured during dark calibration. Leading space for positive value. Leading negative sign (-) for negative value.
56-57		Carriage return (0x0d), Line feed (0x0a).

Table 4: Calibration information request response

An example is:

```
c,00000017.60m,0000000.000s, 039.4C,00000008.71m, 039.4C
```

`0123456789`^{10}`123456789`^{20}`123456789`^{30}`123456789`^{40}`123456789`^{50}`1234567`

4.2.3 Light calibration command

Calibration of the SQM-LU-DL is done at the factory in a controlled light and temperature environment.

Executing the Light calibration command "`zcalAx`" arms the light calibration mode. Flipping the switch to "unlock" triggers the light calibration and modifies the calibration values in the unit.

A calibrated light source of approximately 13.5fc is supplied to the sensor

The format of the response is:

Column	Example value	Description
0	`z`	Indicates that a "Calibration" response is being returned.
1	`A`	Light Calibration
2	`a`	armed
3	`L`	L = Locked; Wait for unlock before calibrating after Arm command, firmware upgrades are disabled. U = Unlocked; Calibrate immediately after Arm command, Enable firmware upgrade.
4-5		Carriage return (0x0d), Line feed (0x0a).

Table 5: Light calibration response

An example is:

```
zAaL
012345
```

4.2.4 Dark calibration command

Dark Calibration is done at the factory along with Light calibration and calibration temperature recording.

Executing the dark calibration command "`zcalBx`" arms the dark calibration mode. Flipping the switch triggers the dark calibration and modifies the calibration values in the unit.

Dark calibration is performed in a completely dark environment. Check a reading to ensure that the period is correct after entering the dark environment, it could take a few minutes to collect an accurate dark period. A dark period of only a few seconds is too small.

The format of the response is:

Column	Example value	Description
0	`z`	Calibration response is being returned.
1	`B`	Dark Calibration.
2	`a`	Armed.
3	`L`	L = Locked; Wait for unlock before calibrating after Arm command, firmware upgrades are disabled. U = Unlocked; Calibrate immediately after Arm command, Enable firmware upgrade.
4-5		Carriage return (0x0d), Line feed (0x0a).

Table 6: Dark calibration response

An example is:

```
zBaL
012345
```

4.2.5 Disarm calibration command

The Disarm calibration command "`zcalDx`" disarms calibration modes from being triggered by the unlock mode.

The format of the response is:

Column	Example value	Description
0	z	Calibration response is being returned.
1	x	All calibration modes.
2	d	Disarmed.
3	L	L = Locked; Wait for unlock before calibrating after Arm command, firmware upgrades are disabled. U = Unlocked; Calibrate immediately after Arm command, Enable firmware upgrade.
4-5		Carriage return (0x0d), Line feed (0x0a).

Table 7: Disarm calibration response

An example is:

```
zxdL
012345
```

4.2.6 Unit information

Unit information command "`ix`" provides details about the software in the microcontroller.

The format of the response is:

Column	Example value	Description
0	`i`	Indicates that the unit information response is being returned.
2-9	`00000002`	**Protocol number** (8 digits). This will always be the first 8 characters (after the "`i,`" response). This value indicates the revision number of the data protocol to/from the SQM-LU. The protocol version is independent of the feature version.
11-18	`00000003`	**Model number** (8 digits). The model value identifies the specific hardware model that the firmware is tailored for.
20-27	`00000001`	**Feature number** (8 digits). The feature value identifies software features independent of the data protocol.
29-36	`00000413`	**Serial number** (8 digits). Each unit has its own unique serial number.
37-38		Carriage return (0x0d), Line feed (0x0a).

Table 8: Unit information request response

An example is:

```
i,00000002,00000003,00000001,00000413
0123456789¹⁰123456789²⁰123456789³⁰12345678
```

4.2.7 Manually set light calibration offset

Calibration is done at the factory, however, in the case where calibration values must be restored or set to something else, this command allows a new calibration value to be placed into the SQM-LU.

Executing the command “`zcal5########.##x`” manually sets the light calibration offset to the value specified in “`########.##`”. The units are $\frac{magnitudes}{arcsecond^2}$.

The format of the response is:

Column	Example value	Description
0	z	Calibration response is being returned.
2	5	Manual Set Light Calibration Offset
4-15	00000017.60m	Value that was set into EEPROM
16-17		Carriage return (0x0d), Line feed (0x0a).

Table 9: Response for manual setting of light calibration offset

An example is:

```
z,5,00000017.60m
0123456789¹⁰1234567
```

4.2.8 Manually set light calibration temperature

Calibration is done at the factory, however, in the case where calibration values must be restored or set to something else, this command allows a new calibration value to be placed into the SQM-LU.

Executing the command "`zcal6########.##x`" manually sets the light calibration temperature to the value specified in "`########.##`". The units are ºC.

Note: The SQM-LU-DL records the temperature in a raw value with different resolution, so the reply back may not be exactly the same as the value sent.

The format of the response is:

Column	Example value	Description
0	`z`	Calibration response is being returned.
2	`6`	Manual Set Light Calibration Offset
4-9	`019.0C`	Value that was set into EEPROM
10-11		Carriage return (0x0d), Line feed (0x0a).

Table 10: Response for manually setting of light calibration temperature

An example is:

```
z,6,019.0C
0123456789101
```

4.2.9 Manually set dark calibration time period

Calibration is done at the factory, however, in the case where calibration values must be restored or set to something else, this command allows a new calibration value to be placed into the SQM-LU.

Executing the command "`zcal7#######.###x`" manually sets the light calibration offset to the value specified in "`#######.###`". The units are in seconds.

The format of the response is:

Column	Example value	Description
0	`z`	Calibration response is being returned.
2	`7`	Manual Set Light Calibration Offset
4-15	`0000300.000s`	Value that was set into EEPROM
16-17		Carriage return (0x0d), Line feed (0x0a).

Table 11: Response of manually setting dark calibration time period

An example is:

```
z,7,00000300.00s
0123456789¹⁰1234567
```

4.2.10 Manually set dark calibration temperature

Calibration is done at the factory, however, in the case where calibration values must be restored or set to something else, this command allows a new calibration value to be placed into the SQM-LU.

Executing the command "`zcal8########.##x`" manually sets the light calibration offset to the value specified in "`########.##`". The units are ºC.

Note: The SQM-LU-DL records the temperature in a raw value with different resolution, so the reply back may not be exactly the same as the value sent.

The format of the response is:

Column	Example value	Description
0	`z`	Calibration response is being returned.
2	`8`	Manual Set Light Calibration Offset
4-9	`019.0C`	Value that was set into EEPROM
10-11		Carriage return (0x0d), Line feed (0x0a).

Table 12: Response for manually setting of light calibration temperature

An example is:

```
z,8,019.0C
0123456789¹⁰1
```

4.2.11 Setting interval reporting parameters

For firmware feature 13 and above, the SQM-LU-DL is capable sending timed interval reports. Each interval report is the same as the reading request report except that the serial number (feature 14 and above) is attached at the end so that numerous reporting SQM-LUs can be distinguished from each other.

The format of the interval report is:

Column	Value	Description
0	`r`	Indicates that a reading is being returned.
2-8	` 06.70m`	Reading in magnitudes per square arc second. Leading space for positive value. Leading negative sign (-) for negative value. A reading of `0.00m` means that the light at the sensor has reached the upper brightness limit of the unit.
10-21	`0000022921Hz`	Frequency of sensor in Hz.
23-33	`0000000020c`	Period of sensor in counts, counts occur at a rate of 460.8 kHz (14.7456MHz/32).
35-46	`0000000.000s`	Period of sensor in seconds with millisecond resolution.
48-54	` 039.4C`	Temperature measured at light sensor in degrees C. Leading space for positive value. Leading negative sign (-) for negative value.
55-63	`00000413`	**Serial number** (8 digits). Each unit has its own unique serial number.
64-65		Carriage return (0x0d), Line feed (0x0a).

Table 13: Interval report

An example is:

```
r, 06.70m,0000022921Hz,0000000020c,0000000.000s, 039.4C,00000413
0123456789¹⁰123456789²⁰123456789³⁰123456789⁴⁰123456789⁵⁰123456789⁶⁰12345
```

Interval reporting is available for sending timed reports to a listening program.

To prevent reports being sent during daylight when the meter is saturated with light, a threshold value can be set. Readings exceeding the threshold (dark) will be reported, low readings (too bright) will be suppressed.

Due to the construction nature of EEPROM, there is a limited number of times that this memory can be written to before it becomes unreliable. In the case of the SQM-LU, the erase/write cycle is 1 million times. For this reason, it is recommended that frequent parameter changes be done in RAM rather than in EPROM. Only set the parameter to EEPROM when you want the unit to boot up with your setting. See following sections for how to set EEPROM or RAM.

Loading firmware clears resets the micro-controller effectively copying the EEPROM values into RAM.

4.2.11.1 Interval reporting period setting

Executing the command "`P##########x`" (note upper case "P") sets the period of the timed interval reports to the EEPROM and RAM for booting and immediate use.

Executing the command "`p##########x`" (note lower case "p") sets the period of the timed interval reports to RAM only for immediate use.

The units are seconds. For example, `p0000000360x` sets the reporting time to once every 360 seconds.

4.2.11.2 Threshold setting for interval reporting

Executing the command "`T########.##x`" (note upper case "T") sets the threshold of the timed interval reports to EEPROM and RAM for boot and immediate use.

Executing the command "`t########.##x`" (note lower case "t") sets the threshold of the timed interval reports to RAM for immediate use only.

The units are $\frac{magnitudes}{arcsecond^2}$. For example, `t00000016.00x` limits reporting to values only over 16.00 $\frac{magnitudes}{arcsecond^2}$.

4.2.11.3 Interval setting response

Either making the request “Ix” (note upper case “I”) or any request to set the interval report setting produces the following response:

Column	Example value	Description
0	`I`	Interval settings from EEPROM and RAM are being returned.
2-12	`0000000360s`	Interval period that was set into EEPROM
14-24	`0000300360s`	Interval period that was set into RAM
26-37	`00000017.60m`	Threshold value that was set into EEPROM
39-50	`00000017.60m`	Threshold value that was set into RAM
51-52		Carriage return (0x0d), Line feed (0x0a).

Table 14: Response of viewing or setting interval reporting parameters

An example response is:

`I,0000000360s,0000000360s,00000017.60m,00000017.60m`

0123456789^{10}123456789^{20}123456789^{30}123456789^{40}123456789^{50}1

4.2.12 Simulation commands

The following simulation commands will help to determine the results of mpsas readings derived from the light and temperature sensors

To read the internal values, issue the “**sx**” command, the response will be

Column	Example value	Description
0-1	`s,`	Confirmation of sx command.
2-12	`0000000360c`	Number of counts
14-24	`0000000360f`	Frequency in Hz
26-37	`0000000244t`	Temperature ADC value as seen by the CPU
38-39		Carriage return (0x0d), Line feed (0x0a).

Table 15: Response of asking for internal values (sx)

An example response is:

```
s,0000000360c,0000000360f,0000000360t
0123456789¹⁰123456789²⁰123456789³⁰12345678
```

To set the internal values and read the calculated response, issue the "S**x**" command with the following format, the response will be

Column	Example value	Description
0-1	`S,`	Initiation of Sx command.
2-12	`0000000360`	Simulated counts
12	`,`	Separation character (can be anything except x)
13-22	`0000000360`	Simulated Frequency in Hz
23	`,`	Separation character (can be anything except x)
24-33	`00244`	Simulated Temperature ADC value
34	`x`	Terminating character

Table 16: Response of sending for simulation values (S....x)

An example command is:

```
S,0000000360,0000000360,0000000360x
0123456789¹⁰123456789²⁰123456789³⁰1234
```

The result of the “S...x” is:

Column	Example value	Description
0-1	`S,`	Confirmation of S...x command.
2-13	`0000094000c,`	Simulated counts
14-25	`0000000000f,`	Simulated frequency in Hz
26-37	`0000000245t,`	Simulated temperature ADC value
38-39	`r,`	Beginning of calculated readings
40-47	` 18.04m,`	Calculated mpsas
48-60	`0000000000Hz,`	Frequency used for calculation
61-72	`0000094000c,`	Counts used for calculation
73-85	`0000000.204s,`	Calculated period from counts
86-92	` 029.0C`	Temperature used for calculation
93-94		Carriage return (0x0d), Line feed (0x0a).

Table 17: Response of asking for internal values (S...x)

An example response is:

```
S,0000094000c,0000000000f,0000000245t,r, 18.04m,0000000000Hz,0000094000c,0000000.204s, 029.0C
01234567891012345678920123456789301234567894012345678950123456789601234567897012345678980123456
```

4.2.13 Datalogger

2.1.1.1 *Datalogging GUI*

A Perl GUI exists for controlling the datalogger as part of the Perl SQM utility. The software is shipped on the CD and has been tested under Windows and Linux.

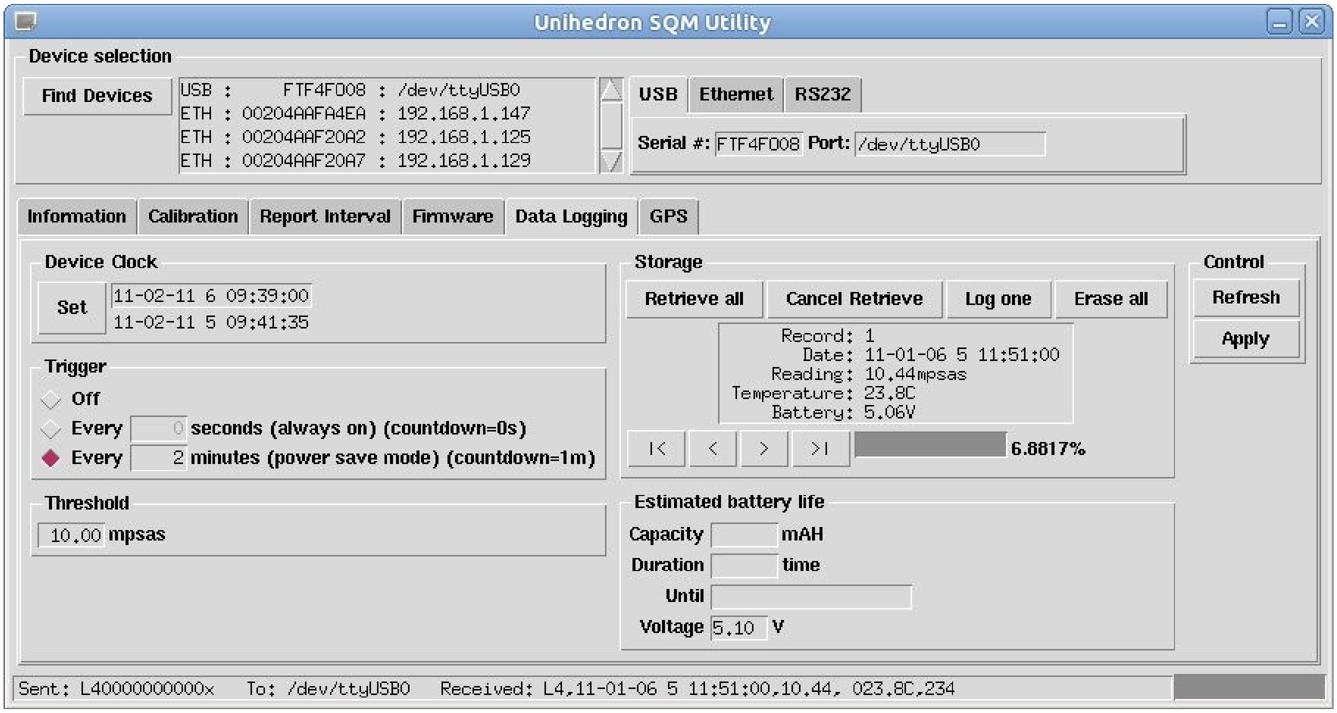

Illustration 9: Datalogging GUI

The estimated battery life calculation has not been finalized yet.

2.1.1.2 Datalogger commands

All datalogging commands begin with "L":

4.2.13.1 FLASH ID report

To get a report on FLASH chip Manufacturer ID, and Device ID, use "`L0x`". The response is:

Column	Example value	Description
0-2	`L0,`	Confirmation of command
3-5	`000`	Manufacturer ID
6-8	`000`	Device ID
9-10		Carriage return (0x0d), Line feed (0x0a).

Table 18: Response of requesting the FLASH chip ID

An example response is:

```
L0,000,000
0123456789¹⁰1
```

4.2.13.2 Logging pointer report

To get a report on current logging pointer position, use "`L1x`". The response is:

Column	Example value	Description
0-2	`L1,`	Confirmation of command
3-8	`000000`	Pointer position
9-10		Carriage return (0x0d), Line feed (0x0a).

Table 19: Response of requesting the data logging pointer

An example response is:

```
L1,000000
0123456789¹⁰
```

4.2.13.3 Erase entire FLASH memory

Erasing the entire FLASH memory takes about 1.1 seconds to complete and provide a send a response. The user must come back and check for validation of erasure. To erase the entire FLASH memory, use "`L2x`". There is no response.

4.2.13.4 Log one record

To force the unit to record one record, use "`L3x`".
The record will not be logged if the threshold is set too high. To ensure that a record will be logged, set the threshold to 0.
The response includes the logging pointer:

Column	Example value	Description
0-2	`L3,`	Confirmation of command
3-8	`000000`	Pointer position
9-10		Carriage return (0x0d), Line feed (0x0a).

Table 20: Response of requesting to log one record

An example response is:

```
L3,000000
0123456789¹⁰
```

4.2.13.5 Return one logged record

To get one entire record, use "`L4...x`" as request and response are as follows:

Column	Example value	Description
0-2	`L4`	Command
2-11	`0000000000`	Pointer position of record to return
12	`x`	end of request
13-14		Carriage return (0x0d), Line feed (0x0a).

Table 21: Request to return one logged record

Column	Example value	Description
0-2	`L4,`	Confirmation of command
3-22	`11-01-06 5 11:51:00,`	Date, Day of week (1=Sunday), and time of recording
23-28	`10.44,`	Reading with sign
29-36	` 023.8C,`	Temperature in degrees C
37-39	`234`	Battery voltage ADC value
40-41		Carriage return (0x0d), Line feed (0x0a).

Table 22: Response of requesting the FLASH chip ID

An example response is:

```
L4,11-01-06 5 11:51:00,10.44, 023.8C,234
0123456789[10]123456789[20]123456789[30]123456789[40]1
```

4.2.13.6 Get internal voltage

When operating from the external battery to USB connector, the unit is normally supplied 5V. As the external battery voltage drops below 5V (plus the voltage regulator overhead of about 0.1V), the internally supplied unit voltage will drop below 5V. The unit will continue to work while the internal voltage is above 3.3V. This internal voltage can be reported. To get the internal voltage value, use "`L5x`". The response is:

Column	Example value	Description
0-2	`L5,`	Confirmation of command
3-5	`238`	Internal voltage ADC value Internal Voltage = (2.048 + (3.3 * $ADCValue)/256.0)
6-7		Carriage return (0x0d), Line feed (0x0a).

Table 23: Response of requesting internal voltage

An example response is:

```
L5,238
01234567
```

4.2.13.7 Set and read logging trigger mode

The unit has three possible modes of logging data while the eternal battery is being used for power:

Mode	Description
`LM0x`	No automatic logging
`LM1x`	Logging granularity in seconds and not powering down.
`LM2x`	Logging granularity in minutes and powering down between recordings.
`LM3x`	Logging every 5 minutes on the 1/12th hour, and powering down between recordings.
`LM4x`	Logging every 10 minutes on the 1/6th hour, and powering down between recordings.
`LM5x`	Logging every 15 minutes on the 1/4 hour, and powering down between recordings.
`LM6x`	Logging every 30 minutes on the 1/2 hour, and powering down between recordings.
`LM7x`	Logging every hour on the hour, and powering down between recordings.

Table 24: Request to set the logging trigger mode

The response of setting the mode is simply an acknowledgement of the trigger mode. Also, reading the mode can be done with "`Lmx`", both will produce the following response:

Column	Example value	Description	
0-2	`LM,`	Confirmation of command	
3	`0`	0 = Off 1 = Seconds 2 = Minutes	3= Every 5 minutes on the 1/12th hour 4 = Every 10 minutes on the 1/6th hour 5 = Every 15 minutes on the 1/4 hour 6 = Every 30 minutes on the 1/2 hour 7 = Every hour on the hour
4-5		Carriage return (0x0d), Line feed (0x0a).	

Table 25: Response of setting or getting the log trigger mode

An example response is:

```
LM,0
012345
```

4.2.13.8 Logging Interval setting response

Either making the request “LIx” or any request to set the logging interval report setting produces the following response:

Column	Example value	Description
0-1	`LI`	Logging interval settings from EEPROM and RAM are being returned.
3-13	`0000000360s`	Logging interval period in **seconds** that was set into EEPROM
15-25	`0000000005m`	Logging interval period in **minutes** that was set into EEPROM
7-37	`0000000121s`	Current interval period in **seconds** from RAM
39-49	`0000000004m`	Current interval period in **minutes** from RAM
51-62	`00000017.60m`	Threshold value that was set into RAM
63-64		Carriage return (0x0d), Line feed (0x0a).

Table 26: Response of viewing or setting logging interval reporting parameters

An example response is:

```
LI,0000000360s,0000000005m,0000000121s,0000000004m,00000017.60m
```

0123456789[10]123456789[20]123456789[30]123456789[40]123456789[50]123456789[60]1234

4.2.13.9 Logging interval reporting period setting

Executing the command “`LPS##########x`” sets the seconds period of the timed interval reports to the EEPROM and RAM for booting and immediate use. The units are seconds. For example, `LPS0000000360x` sets the reporting time to once every 360 seconds.

Executing the command “`LPM##########x`” sets the seconds period of the timed interval reports to the EEPROM and RAM for booting and immediate use. The units are seconds. For example, `LPS0000000005x` sets the reporting time to once every 5 minutes.

4.2.13.10 Logging threshold setting for interval reporting

Executing the command “`LT########.##x`” sets the threshold of the timed interval reports to EEPROM and RAM for boot and immediate use.

The units are $\frac{magnitudes}{arcsecond^2}$. For example, `LT00000016.00x` limits reporting to values only over 16.00 $\frac{magnitudes}{arcsecond^2}$.

4.2.13.11 Set and read logging Real Time Clock

The SQM-LU-DL model contains a Real Time Clock (RTC) powered by a large storage capacitor.

The RTC is set with the "LCx" command as follows:

Column	Example value	Description
0-1	LC	Confirmation of command
2-21	11-01-06 5 11:51:00x	Date, Day of week (1=Sunday), and time.
22-23		Carriage return (0x0d), Line feed (0x0a).

Table 27: Setting the RTC

The RTC is read with the "Lcx" command. The response of both setting and getting the RTC value is:

Column	Example value	Description
0-2	LC,	Confirmation of setting command
0-2	Lc,	Confirmation of getting command
3-21	11-01-06 5 11:51:00	Date, Day of week (1=Sunday), and time.
22-23		Carriage return (0x0d), Line feed (0x0a).

Table 28: Response of getting the RTC values

An example response is:

```
Lc,11-01-06 5 11:51:00
0123456789¹⁰123456789²⁰123
```

4.2.13.12 Put datalogging unit to sleep

For tests purposes, the SQM-LU-DL can be put to sleep with the "`Lsx`" command so that battery current can be measured. The unit must be awakened by re-applying power (cold-start).

4.2.13.13 Gather alarm 0 data from RTC

For tests purposes, the SQM-LU-DL RTC "Alarm 0" data can be retrieved with the "`Lax`" command. The response is:

Column	Example value	Description
0-1	`La,`	Confirmation of command
3-6	`000,`	Address 07H, Seconds See "`DS1305N`"+ RTC chip information for details
7-10	`128,`	Address 08H, minutes
11-14	`128,`	Address 09H, hours
15-18	`128,`	Address 0AH, day
19-21	`001,`	Address 0FH, Control register
22-23		Carriage return (0x0d), Line feed (0x0a).

Table 29: Response of getting the RTC "Alarm 0" value

An example response is:

```
La,000,128,128,128,001
0123456789¹⁰123456789²⁰123
```

5 Electrical connection

The SQM-LU-DL uses a voltage regulator to bring the incoming USB 5VDC voltage down to 3.3VDC.

6 Mechanical installation

Unihedron sells an enclosure that is suitable for mounting either the SQM-LE or SQM-LU-DL into. You can read more about it, including plans to build your own here:

http://unihedron.com/projects/sqmhousing/

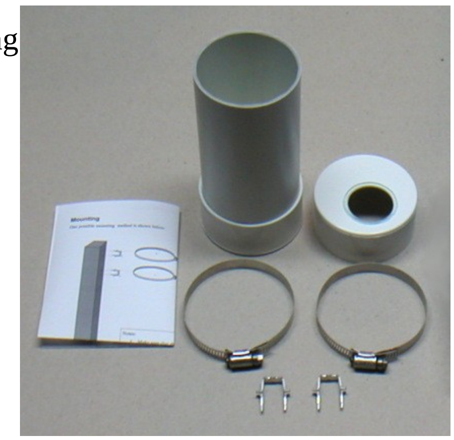

Illustration 10: Housing

6.1 Cover selection

If the unit is to be mounted in exposed location, we recommend an acrylic dome. Acrylic domes will last 2-3 years but eventually weather on the surface. It is not clear that this will affect the reading much. The best test would be to swap a weathered and new one back and forth when changing one out. Presumably the main consideration would be to keep the domes clean every so often and to make sure that the mounting plane is painted black to that it doesn't reflect light back to the inside of the dome and then back into the meter.

Source of Acrylic domes: http://www.globalplastics.ca/domes.htm

6.2 Cover calibration

Since the SQM-LU-DL is not weather-proof, it must be protected in some way from the elements. A plastic dome is recommended. This may reduce the incoming light by about 15-20%.

Because a covering will reduce the incoming light, the resultant reading will be darker (higher magnitudes per arcsecond^2 value). The offset determined by a simple light experiment should be subtracted from the reading.

A pending firmware edition will allow for built in manual offset. Apply this subtraction offset as a negative value, i.e. if you measured 16.60 outside the covering, then 16.75 under the dome, then an offset of -0.15 should be applied to all readings.

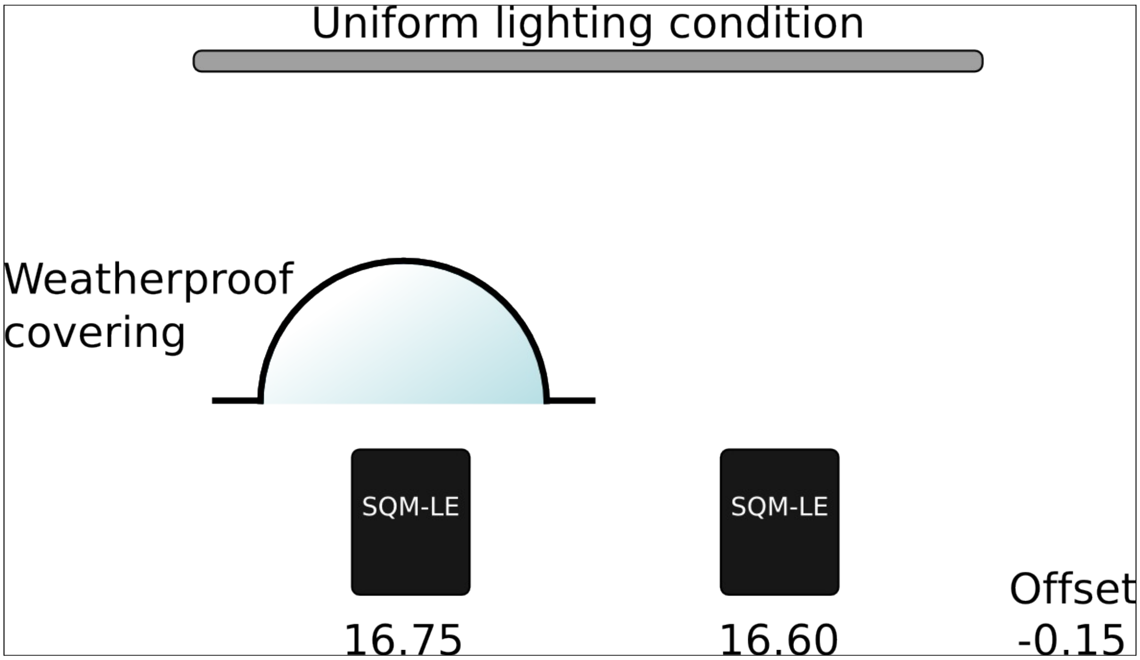

Illustration 11: Example cover calibration

6.3 Cover maintenance

Keep the covering clean of dust, water, ice, and bird droppings.

7 Default settings

The FTDI interface has not been altered from its default. There should be no reason to alter the FTDI chip settings. The baud rate is defined by the VCP driver side when a terminal program connects to the SQM-LU.

8 Troubleshooting

Reading: too bright, too hot, inspect lens for IR filter.

Problem	Cannot get a reading
Cause	Driver is not installed or the SQM-LU-DL is not connected
Solution	For Windows, check that the unit is registered using the registry editor from the Start menu, select Run, then type in `regedit` and press OK. For Windows XP and Windows 2000, look here for your device HKEY_LOCAL_MACHINE\\ SYSTEM\\ Enum\\ FTDIBUS\\ VID_0403+PID_6001+*Serial_Number*\\ 0000\\ PortName For Windows 98 and Windows ME, look here for your device HKEY_LOCAL_MACHINE\\ SYSTEM\\ Enum\\ FTDIBUS\\ VID_0403+PID_6001+*Serial_Number*\\ 0000\\ PortName The *Serial_Number* is printed on the bottom of the unit. The above will identify which COM port the SQM-LU-DL has been assigned. If the SQM-LU-DL is plugged in, the active COM port will show up in this list: HK_LOCAL_MACHINE\\ HARDWARE\\ DEVICEMAP\\ SERIALCOMM For Linux and Mac, use **`lshal`** to determine which device the FTDI driver has attached the SQM-LU-DL to. The CD contains a Perl script **`findftdi.pl`** to filter out the lshal output.

9 Company contact information

Mailing address	Unihedron 4 Lawrence Avenue Grimsby, Ontario L3M 2L9 Canada
Telephone	(905) 945-1197
Fax	(905) 945-6770
Website	unihedron.com
Email	info@unihedron.com

10 Glossary

EEPROM	**Electrically Erasable Programmable Read Only Memory** is a type of memory that retains its contents after the power has been removed. This type of memory has a limited write/erase cycle as well as a lifetime for data retention. .In the SQM-LU, the parameters in the micro-controller can be written 1 million times and last for 100 years.
SQM-LU-DL	**Sky Quality Meter** with lens and USB connectivity, and with datalogging capabilities.
RTC	Real Time Clock. A circuit that is used to keep "real time" data like date/time. Computations for leap year and weekday are performed in this circuit.
USB	Universal Serial Bus

11 Appendix A – revision history

11.1 Manual revision history

Revision	Description
1.0	Initial product release.
1.1	Add datalogging memory spec, and GUI image.
1.2	Battery lifetime (current consumption) calculation added.
1.3	LIx command response details corrected.
1.4	LMx command updated with synchronized RTC logging.
1.5	Define current shunt for current supply testing.
1.6	Day of week defined.
1.7	Clarify internal voltage reading (not battery voltage).
1.8	Clarify that log one records will only work if threshold is set low enough.
1.9	Add RTC clock drift specification.

11.2 Protocol revision history

Revision	Description
3	Initial SQM-LE product release.
4	Interval report (reading) includes serial number at end. SQM-LE.

11.3 Feature revision history

Revision	Description
9	Initial SQM-LE product release.
10	Power up default reset for command busy. SQM-LE.
11	Ability to manually sett calibration values. SQM-LE.
12	Temperature averaging added. SQM-LE.
13	Interval report feature added. SQM-LE.
14	Interval report includes serial number.
16	Rx report includes serial number.
17	Provide no temperature reading until fully averaged after power-up.
18	Addition of averaging algorithm for period mode.
19	Addition of simulation commands.
20	DL model, logging synchronized to RTC feature added.