Sky Quality Meter – Lens RS232

SQM-LR

User manual

Table of Contents

Illustration Index

Index of Tables

1 Theory of operation

The SQM-LR measures the darkness of the night sky to provide readings of magnitudes per square arc second through an RS232 connection.

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 RS232 cable to the RS232 interface are relayed to the microcontroller.

The microcontroller responds to commands by sending data strings to the RS232 interface which are then relayed to the PC.

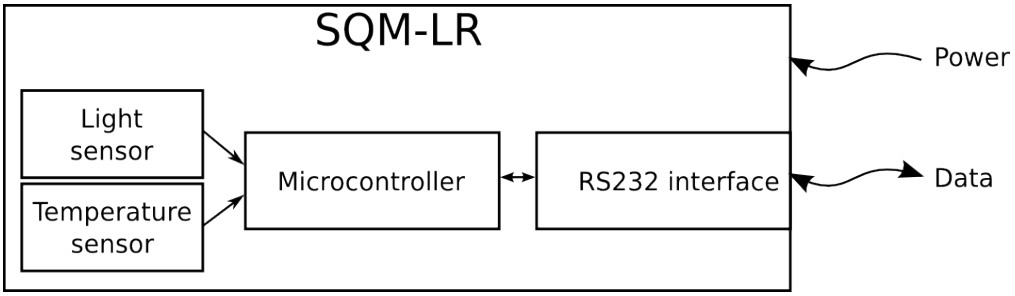

Illustration 1: SQM-LR block diagram

1.1 Quick start

1. Connect the SQM-LR to your serial port using the supplied RS232 straight through 9 pin cable.
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 or a serial terminal emulator set to 115200 baud to gather readings by typing `rx`

2 Specifications

RS232 connection	RS232 B connector (6ft 9 pin RS232 straight through cable supplied)
Physical size	3.6 x 2.6 x 1.1"
Meter precision	Each SQM-LR is factory-calibrated. The absolute precision of each meter is believed to be ±10% (±0.10 mag/arcsec²). The difference in zeropoint between each calibrated SQM-L is typically ±10% (±0.10 mag/sq arcsec)
Power requirement	19mA, 5.2V 15.7VDC. Note: Additional diodes may be used internally to raise this voltage range. Example, 4 diodes gives a voltage range of 8-17.8VDC
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.

Illustration 2: Unit photo

3 Hardware connections

The SQM-LR requires one connection to a RS232 port as well as DC power from the supplied AC adaptor.

The maximum length cable per the RS232 specification is 300ft.

2 Software Development

The SQM-LR communicates as a standard serial port device.

Commands can be sent to the SQM-LR using a serial terminal emulator to the serial communications port that the device is connected to.

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

4 Commands and Responses

The SQM-LR 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. A summary of all commands are seen in the following table:

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.
baud#######x	Change the baud rate.
Bx	Return the status of the baud rate switch.

Table 1: Command summary

4.2 Response details

4.2.1 Reading request

The “Reading” request “`rx`” commands the SQM-LR 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 2: 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 3: 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-LR 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 4: 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 5: 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 6: 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	00000004	**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-LR. The protocol version is independent of the feature version.
11-18	00000005	**Model number** (8 digits). The model value identifies the specific hardware model that the firmware is tailored for.
20-27	00000014	**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 7: Unit information request response

An example is:

```
i,00000004,00000005,00000014,00000413
0123456789[10]123456789[20]123456789[30]12345678
```

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-LR.

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 8: Response for Manual setting of Light Calibration Offset

An example is:

`z,5,00000017.60m`

`0123456789`[10]`1234567`

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-LR.

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

Note: The SQM-LR 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 9: Response for Manually setting of Light Calibration Temperature

An example is:

`z,6,019.0C`

`0123456789`[10]`1`

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-LR.

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 10: Response of Manually setting Dark Calibration Time Period

An example is:

`z,7,00000300.00s`

`0123456789`[10]`1234567`

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-LR.

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

Note: The SQM-LR 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 11: Response for Manually setting of Light Calibration Temperature

An example is:

`z,8,019.0C`

`0123456789`[10]`1`

4.2.11 Setting Interval reporting parameters

For firmware feature 13 and above, the SQM-LR 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-LRs 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 12: Interval report

An example is:

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

`0123456789`^{10}`123456789`^{20}`123456789`^{30}`123456789`^{40}`123456789`^{50}`123456789`^{60}`12345`

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-LR, 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 13: 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 Baud rate setting

To change the baud rate with software, submit the command `baud########x` where `########` is a 10 digit number representing the delay value relating to the baud rate. This delay value can be calculated as follows:

Delay = (14.7456e6/(4*Baudrate))-1

For example, to obtain the delay value for a baud rate setting of 9600 baud:

Delay = (14.7456e6/(4*9600))-1 = 383

Therefore the command is: `baud0000000383x`

There is no response to this command because the unit will have changed baud rate and an instant response to your computer will be unreadable. You must reopen your serial communication connection at the new baud rate.

By default, the SQM-LR is shipped with the ability to accept baud rate changes. A jumper on the circuit board can be used to force the baud rate to 115200baud after power up. See the next section for using this jumper.

4.2.12.1 Restoring the baud rate

In the case where the unit may not be communicating, you can force the baud rate to 115200baud as follows.

1. Remove the power and data connection from the unit.
2. Open the unit by removing the bottom 4 screws. Be careful not to allow the lens or lens-plate-cover to fall out or get dirty.
3. Position the jumper block over the “115200” jumper pins.
4. Test the communication by reconnecting the power and data then open a serial communication link at 115200 baud and type in the `rx` command.

4.2.13 Baud rate switch status

To determine the status of the baud rate switch without opening the unit, the Bx command can be sent, The response is as follows:

Column	Example value	Description
0	0	 0 is returned when the jumper is OFF. This position indicates that the baud rate can be changed in software as described on page 21.  1 is returned when the jumper is ON. This position forces the SQM-LR to 115200 baud after power up or reset.
1-2		Carriage return (0x0d), Line feed (0x0a).

Table 14: Response of viewing or setting interval reporting parameters

An example response is:

```
0
012
```

5 Electrical connection

An AC/DC adaptor is provided. The SQM-LR uses a voltage regulator to bring the incoming DC voltage down to 3.3VDC. The lowest voltage at the input should be 4.5VDC (3.3 + 1.2VDC).

For remote applications, a deep-cycle (Lead Acid) 6VDC battery can be used.

The SQM-LR unit is NOT protected against over-voltage (above 15V) .

The SQM-LR unit is protected against reverse polarity connection.

6 Mechanical Installation

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

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

Illustration 3: 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-LR 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.

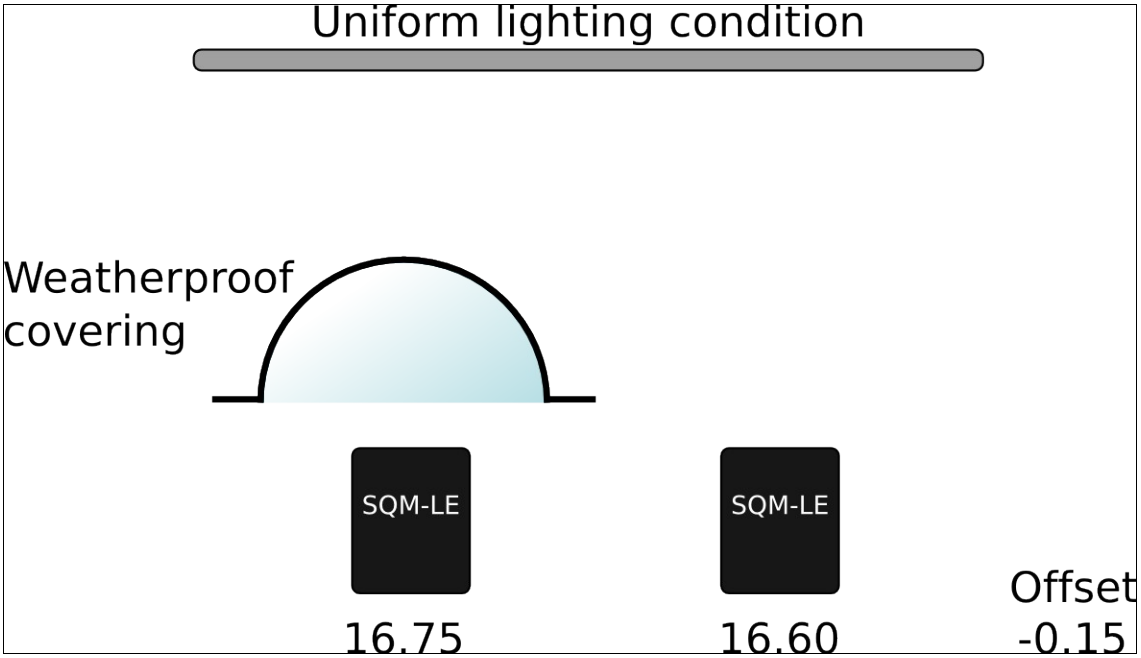

Illustration 4: Example cover calibration

6.3 Cover maintenance

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

7 Default settings

The SQM-LR comes with a factory default communication rate setting of 115200 baud. This can be changed by software of set back to the default by an internal hardware jumper. See section ___ for details.

8 Troubleshooting

Problem	Reading: too bright, too hot
Cause	IR filter may have come loose
Solution	Ensure that you can see a blue coloured filter in the lens.

Problem	Loss of communication
Cause	1. Baud rate may have been changed 2. Wrong cable used.
Solution	3. Examine the baud rate settings on page 21. 4. Make sure you are using a straight through cable for testing.

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-LR, the parameters in the micro-controller can be written 1 million times and last for 100 years.
SQM-LR	**Sky Quality Meter** with lens and RS232 connectivity.
RS232	Recommended Standard 232, used for serial data communication.

11 Appendix A Revision history

11.1 Manual Revision history

Revision	Description
1.0	Initial product release.
1.1	Troubleshooting d specification addition

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.
15	Baud rate setting for SQM-LR