SonoQ

Focus on Performance

SQ-PCB-3S
On-Board-Ultrasound Liquid Level Module with SPI-Interface
for
SQ-Eval-Kit–A1
and
SQ-Eval-Kit–G1

Product Overview

The non-invasive control of liquid levels is essential for many applications assuring proper functionality of components and systems. The ability of ultrasound to propagate through solids and liquids provides an almost ideal technology to implement this task. A preferred implementation for liquid level metering (LLM) attaches an ultrasound transducer to the bottom of the wall of the liquid container. A short ultrasound wave is transmitted from the transducer passing the container wall and travels through the liquid to the liquid air interface. This interface acts as an ideal reflector returning the ultrasound wave back to the transducer, where the time of arrival is registered or time of flight is estimated via ultrasonic signal processing. An increased delay of the arriving signals indicates a higher level, a reduced time of arrival a lower level. However, level metering requires the speed of sound in the fluid to be known. This knowledge is either obtained by calibrating or by measuring separately this parameter.

An appropriate technology here is the use of ultrasonic waves with their ability to pass layers like vessel walls and nontransparent, conductive and non-conductive materials. The usual method here is the echo sonography, where an ultrasound transducer produces a sonic wave which passes the liquid up to the liquid/air interface on top of the liquid where most of the wave will be reflected back. This wave is again received by the transducer. By estimation of the speed of sound inside the liquid and measuring the travel time of the bouncing ultrasound wave, the liquid level may be calculated.

One of the main advantages of the used ultrasound technology beside the non-contact measurement through the containers wall is the detection of foam/liquid boundaries.

Often the ultrasonic altimeter is - even though best applicable - not used because there is a need of certain knowledge about ultrasound signal processing and ultrasonic transducers.

However, SonoQ’s easy to integrate module offers the possibility to add an ultrasonic level measurement into an existing system or to simplify the design of new products.

The PCB operates in two different modes:

Stand-alone-mode: The module is configured with the Evaluation Board or application specific parameters are provided by SonoQ. The on-board Open Collector output raises a signal at specified liquid levels (with defined hysteresis).

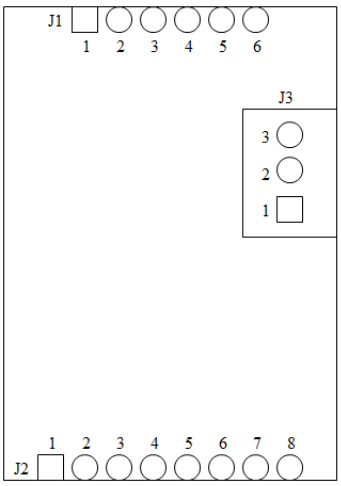
Integrated-mode: If the modules SPI-interface is used, all parameter settings and read out of actual liquid level are available for customers control unit.

There are three components available:

- PCB
- Standard or application specific ultrasonic transducers
  - Dry-coupling version for easy container removal
  - Low-cost glue on version
  - Customized transducers
- Evaluation board for quick putting into operation and configuration

After installation of the transducer and electronic module, there is only the need to teach-in two known levels. For example, a first fill level at 20% and a second level at 80%. In a second step the switching level may be defined inclusive sign of logic and hysteresis.

Pinning



(Top View)

J1: VCC

Pin	Name	Description
1	VCC	+12V Power Supply
2		
3	OC	Open Collector Output
4		
5	GND	Ground
6		

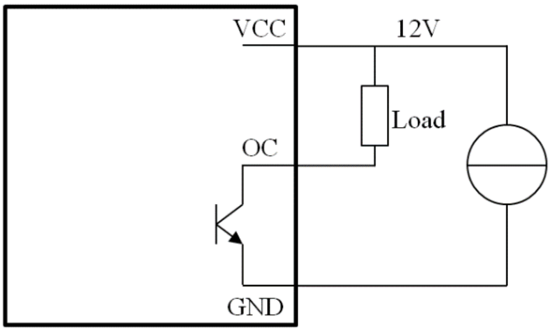
J2: SPI (optionally)

Pin	Name	Description
1	nSS	SPI Slave Select Input (low-active)
2	SDO	SPI Data Output
3	SCK	SPI Clock Input
4	SDI	SPI Data Input
5	-	**do not connect**
6	-	**do not connect**
7	-	**do not connect**
8	-	**do not connect**

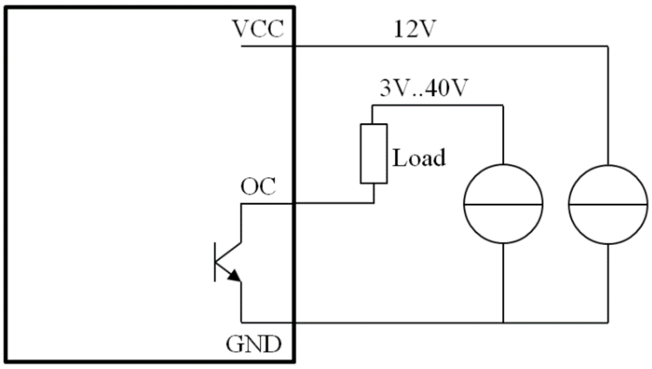
J3: Transducer

Pin	Name	Description
1	TXRX	Transducer Signal
2	AGND	Transducer Ground
3	SHIELD	Shielding

Open Collector connection option 1:



Open Collector connection option 2:



Specifications

Designed as an on-board module, the board does not have any over-voltage-protection or over-current-protection at the SPI interface, the power supply pins or the open collector. Protective settings have to be provided by user control.

Power & Environmental

Supply Voltage	12V ±10%
Supply Current	typ. 15mA
Operating Temperature	-10°C - +70°C
Storage Temperature	-40°C - +85°C
Humidity	PUR-coating of board upon request

Level Measurement

(clear water, 23°C)

Accuracy	up to 2mm (according to transducer and coupling/temperature)
Repeatability	up to 1mm (according to transducer and coupling/temperature)
Minimum Measure Range	depending on sonic-wall-transmission and coupling
Maximum Measure Range	optional up to 750mm with adequate transducer
Response Time	0.5s/5s/50s (according to settings)
Power-Up Time	20ms + Response Time

Open Collector

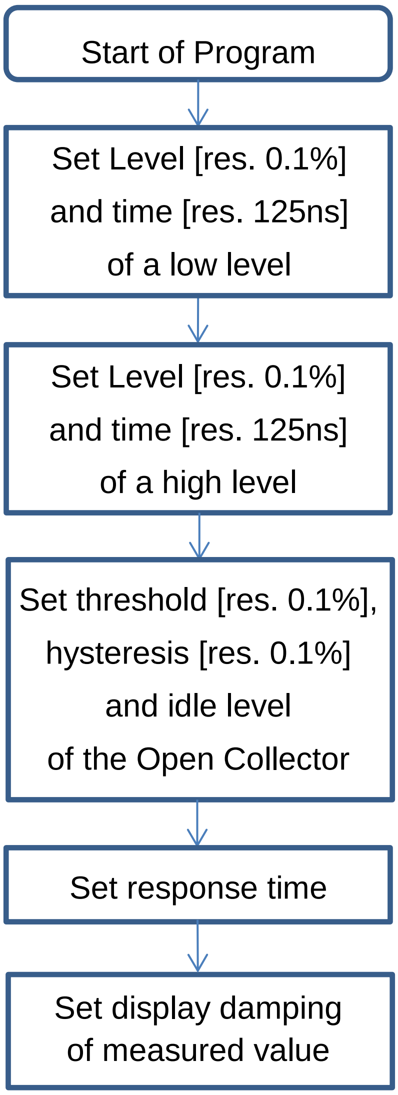
Output Voltage	max. 40V
Output Current	max. 50mA
Hysteresis	up to 10% of the current measurement range (programmable)

Implementation Overview

The level is calculated from the time needed for the ultrasonic wave to travel from transducer to the liquids surface and back using a fixed speed of sound. In most cases, the speed of sound is not known. Therefore, during initialization, the value of the speed of sound and the offset time (e.g. time needed to pass the vessels wall) are defined by measuring two known levels. This procedure needs to be done only once for a specific application. The effect of temperature variation and the resulting change in speed of sound is not considered but can be implemented by SonoQ upon request.

Initialization

For the first time you have to initialize the module.

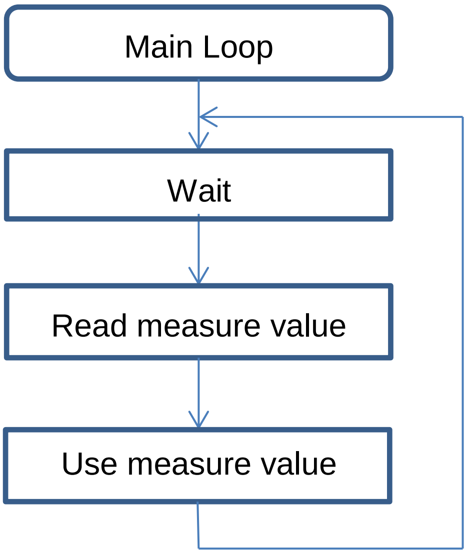


After the first initialization the module can operate as a level sensor or a level switch (stand-alone).

Level Switch

Once initialized the module runs with the settings, also after a reset. Therefore the module needs no main processor yet and works like a level switch.

Level Sensor



Operating as a level sensor a re-initialization is also not necessary. But it's an option to recalibrate.

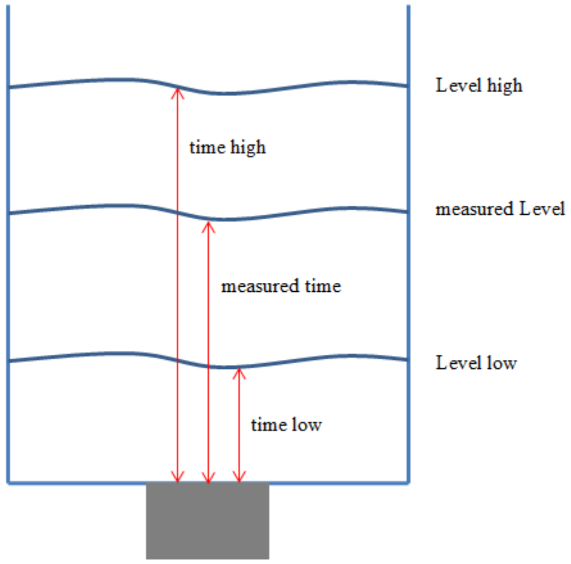
Detail of functionality

Level value

The level module does include neither a temperature sensor nor a reference line. So it doesn't know the current speed of sound of the liquid.

This is caused by the adaptability of the dry-coupled sensor, several liquids and several tanks.

Therefore, it can only be read the measured level time ($t_{average}$). To get out the level in percent ($L_{average}$), the module has to be learned.



$$L_{average} = \frac{t_{average} - t_{low}}{t_{high} - t_{low}} \cdot (L_{high} - L_{low}) + L_{low}$$

So it has to be written the measured times (t_{low} & t_{high}) and the corresponding level values (L_{low} & L_{high}) by the registers LLOT and LHIT as well as LLOP and LHIP.

$$LAVP = \frac{LAVT - LLOT}{LHIT - LLOT} \cdot (LHIP - LLOP) + LLOP$$

To get an inverted range both times or both level values can easily be switched.

If the current level is too low to be measured or there is actually no tank coupled at the ultrasound transducer the output value will be zero.

Open Collector

The module can also be used as a level switch. Therefore a threshold level can be programmed by the register LOCP.

To avoid the Open Collector switches permanently a hysteresis is implemented and can be changed by the HOCP-register. Also a zero hysteresis is possible.

Condition	State
LAVP > (LOCP + HOCP)	Idle
LAVP < (LOCP - HOCP)	Active

At start-up no hysteresis is present as long as no level is measured. Only then the hysteresis gets active.

Also the Open Collector can be programmed as active-high or active-low by the OCIL-bit in the STAT-register.

The current state of the Open Collector is available in the OCST-bit of the STAT-register.

Response time and damping

The response of the module can be controlled by other parameters in the STAT registers.

The PRF bits vary the measure rate to get a faster or slower response time.

The DAMP bits change the average method. If the liquid surface is stable a low damping value results in a fast response. But if the liquid surface sloshes a low damping value results in a fluctuating level value. That's way in this case a high damping value is recommended.

Signal evaluation options

1 echo analysis

Normally at startup 2 echoes are necessary to determine the level. Caused by the interaction between wall thickness and material and the desired maximum level, it is not possible to achieve these 2 echoes. It is possible to activate a 1-echo-analysis for an adjustable time (register TMIN1E).

That means at startup for a time of flight equal and more than this value, the level will be determined.

The risk is that the sensor calculates a wrong level caused by a tilted position or by baffles in the liquid.

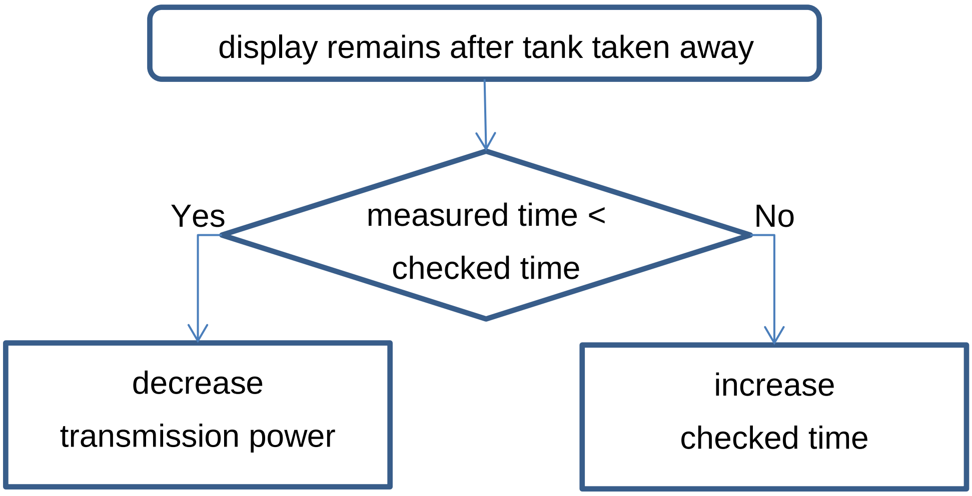
Minimum and maximum

To reduce this risk, there is also the option to set limits (minimum and maximum) for the measured time (register TMIN and TMAX).

Checking transmission power at short times

In case the tank is taken away from the sensor and the level signal remains the same please undertake the following action:

If the SQ-Level system does not detect a clear level signal, the system increases automatically the transmission power. In this case, it is possible that the sensor measures a time in the ringing signal of the transducer. To avoid this wrong result, the sensor checks the effect of the transmission power and potentially discards the measurement result. To adjust this functionality, you can change the relevant maximum time or/and maximum transmission power (register TMAX1E and XMAX1E).



The checked time (TMAX1E) should not exceed the 1-echo-analysis (TMIN1E).

Comparator level

The sensor automatically uses 2 different comparator levels to detect the right echo. Depending on the measurement situation the smaller level could be too high. In this case there is the option to add an additional smaller comparator level. In the COMP register it is possible to adjust the transmission power. For a transmission power equal or higher than the register value, the smaller comparator level will be used. In this way it is easier to detect higher levels. For a value larger than 31, this option is disabled.

Transmission power

Normally the system automatically adjusts the transmission power depending on the signal strength of the echoes. By the XPOW register it is possible to disable this regulation and set a static transmission power. Selecting a static transmission power the system uses a static comparator level.

Ringing measurement

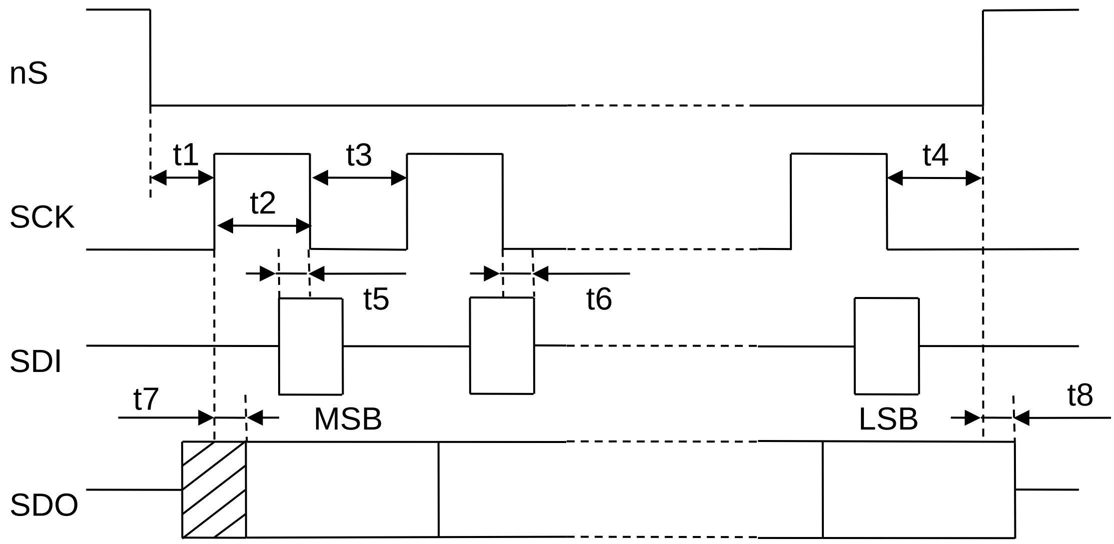
Instead of measuring the time, it is possible to measure the ringing of the transducer (in the XPOW register). This option can be helpful by using the system as a level switch.

The idea is, that the ringing changes, if there is air or liquid in the tank. This option will only work correctly if you use static transmission power.

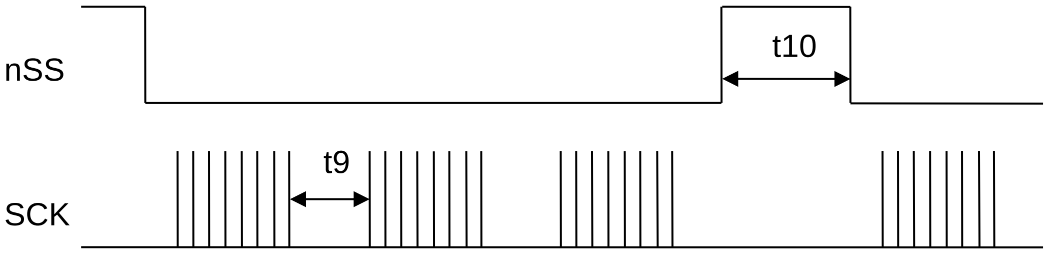
SPI-Interface

As an interface the level module has a 4-wire-SPI interface. There can be ordered either a 3.3V version or a 5V version.

Timing



Name	Description	Min	Max
t1	nSS active to SCK rising edge	250ns	-
t2	SCK high time	300ns	-
t3	SCK low time	300ns	-
t4	nSS idle after SCK falling edge	450ns	-
t5	SDI setup time	200ns	-
t6	SDI hold time	200ns	-
t7	SDO output valid time	0 ns	100ns
t8	SDO output high-impedance time	10ns	100ns



Name	Description	Min
t9	time between 2 bytes	20µs
t10	time between 2 requests (after a read)	100µs
	time between 2 requests (after a write)	10ms

Frame

Byte 1 – W	Byte 2 – R/W	Byte 3 – R/W
Command	Data word MSB	Data word LSB

Command

Command-Byte:

7	6	5	4	3	2	1	0
CMD1	CMD0	ADR5	ADR4	ADR3	ADR2	ADR1	ADR0

Bit 7-6 CMD<1:0>: command
1x = reserved
01 = write register
00 = read register

Bit 5-0 ADR<5:0>: address

Data

Addresses:

Hex	Name	Description	Unit	R/W	Min	Max
00	LAVT	Averaged Level	0.125µs	R	0	-
01	LAVP	Averaged Level	0.1%	R	0	1000
02	LLOT	Level Low	0.125µs	R/W	0	8000
03	LLOP	Level Low	0.1%	R/W	0	1000
04	LHIT	Level High	0.125µs	R/W	0	8000
05	LHIP	Level High	0.1%	R/W	0	1000
06	LOCP	Switching Threshold Open Collector	0.1%	R/W	0	1000
07	HOCP	Hysteresis Open Collector	0.1%	R/W	0	100
08	STAT	State	-	R/W	-	-
09	VERS	Firmware-Version	-	R	-	-
0A	COMP	Minimum transmission power for very low comparator level (>31=disable)	-	R/W	0	255
0B	TMIN	Minimum time	0.125µs	R/W	0	-
0C	TMAX	Maximum time	0.125µs	R/W	0	-
0D	TMAX1E	Maximum time for checking transmission power	0.125µs	R/W	0	-
0E	XMAX1E	Maximum transmission power for times less than TMAX1E	-	R/W	0	31
0F	TMIN1E	Minimum time for 1 echo evaluation	0.125µs	R/W	0	-
10	XPOW	Transmission power static	-	R/W	-	-

STAT:

15	14	13	12	11	10	9	8
-	-	-	-	-	-	-	-
7	**6**	**5 – R/W**	**4 – R/W**	**3 – R/W**	**2 – R/W**	**1 – R**	**0 – R/W**
-	-	DAMP1	DAMP0	PRF1	PRF0	OCST	OCIL

Bit 15-6 unimplemented

Bit 5-4 DAMP<1:0>: factor for damping of averaged level value

11 = 0 (disable)

10 = 200

01 = 50

00 = 20

Bit 3-2 PRF<1:0>: response time

11 = reserved

10 = 50s

01 = 5s

00 = 0.5s

Bit 1 OCST: current state Open Collector

OCST = 0, if LAVP ≤ LOCP

OCST = 1, if LAVP > LOCP

Bit 0 OCIL: idle level Open Collector

Open Collector open, if OCIL = OCST

Open Collector closed, if OCIL ≠ OCST

XPOW:

15 – R/W	14	13	12	11	10	9 – R/W	8 – R/W
MEAS	-	-	-	-	-	COMP	AUTO
7	**6**	**5**	**4 – R/W**	**3 – R/W**	**2 – R/W**	**1 – R/W**	**0 – R/W**
-	-	-	PULS4	PULS3	PULS2	PULS1	PULS0

Bit 15 MEAS: measurement mode
1 = time
0 = ringing (AUTO = 0 is mandatory)

Bit 14-10 unimplemented

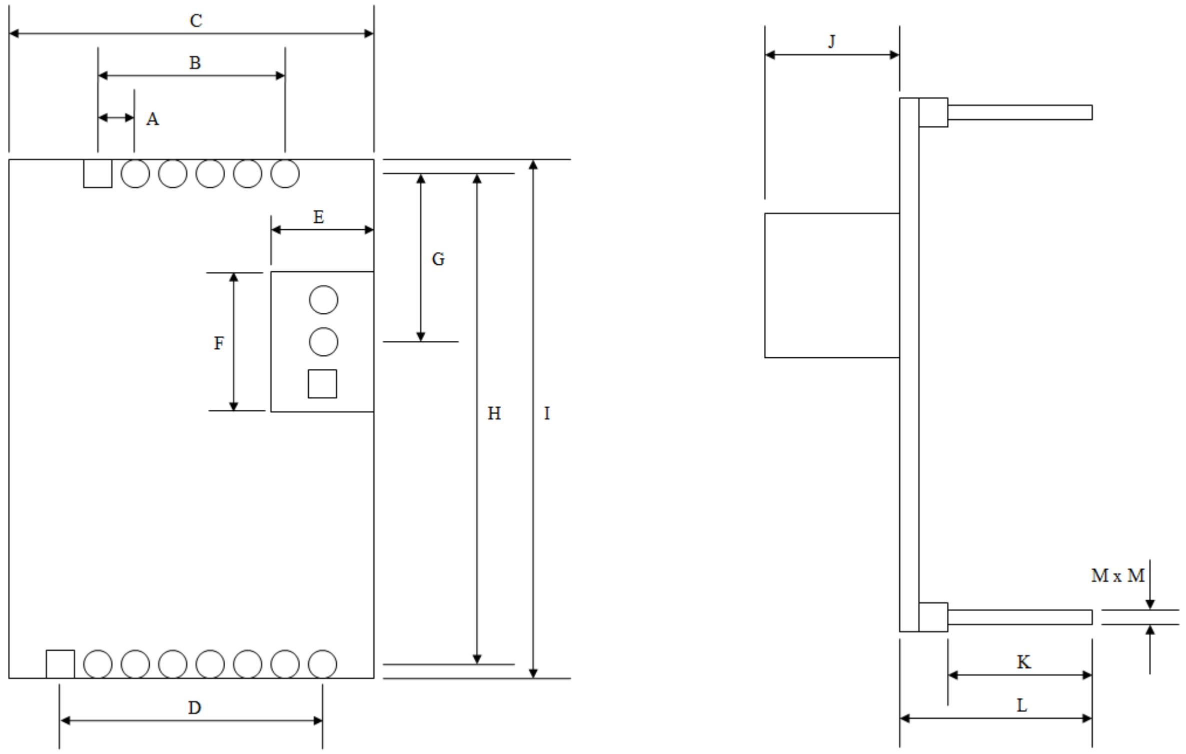
Bit 9 COMP: static comparator level
only used if AUTO = 1
1 = 1V
0 = 250mV or 200mV (depending on COMP register)

Bit 8 AUTO: transmission power static/automatic
1= automatic regulation of transmission power and comparator level
0 = static transmission power and comparator level

Bit 7-5 unimplemented

Bit 4-0 PULS<4:0>: transmission power static
only used if AUTO = 1

Dimensions



Dimension	mil	mm
A	100	2.54
B	500	12.70
C	1000	25.40
D	700	17.78
E	270	6.86
F	320	8.13
G	510	12.95
H	1350	34.29
I	1450	36.83
J	400	10.16
K	240	6.10
L	440	11.20
M	25	0.64

Ordering Information

Part Number	Description
SQ-PCB-3S	PCB with 3.3V SPI
SQ-PCB-5S	PCB with 5V SPI (coming soon)
SQ-PCB-xxx	PCB as a customized version

Revision History

Version	Date	Changes
1.1	13.06.2014	Initial release
1.4	16.01.2015	Open Collector connection options and data Dimensions Ordering information
1.5	29.03.2016	Title
1.6	12.04.2016	Shielding Connection
1.7	17.07.2017	Small changes
1.8	16.04.2018	PEWATRON-Logo added and IS-LINE Logo removed
1.9	18.04.2018	Overview small changes 750mm optional Ringing removed
1.10	10.08.2018	Signal evaluation options SPI registers several changes
1.11	25.09.2018	Details of functionality updated

For any question please contact:

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