Observe precautions! Electrostatic sensitive devices!

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TABLE OF CONTENT

1 MODULE VARIANTS AND RELATED DOCUMENTS

The LSTM 300 Scavenger Transceiver Module is available in following operating frequency variants:

LSTM 300U: 902.875 MHz

This document describes operation of LSTM 300U module with their built-in firmware. If you want to write own firmware running on the integrated micro controller or need more detailed information on the Dolphin core please also refer to:

- Dolphin Core Description
- Dolphin API Documentation

In addition we recommend following our application notes, in particular:

- AN102: Antenna Basics – Basic Antenna Design Considerations for EnOcean based Products
- AN105: 315 MHZ Internal Antenna Design – Considerations for EnOcean based Products
- AN207: ECS 300/310 Solar Panel - Design Considerations
- AN208: Energy Storage – Design Considerations
- AN209: STM 300 THERMO OR BATTERY POWERED – Power Supply Alternatives to Solar Panel

2 GENERAL DESCRIPTION

2.1 Basic functionality

The extremely power saving RF transmitter module LSTM 300U enables the realization of wireless and maintenance free sensors and actuators such as room operating panels, motion sensors or valve actuators for heating control.
Power supply is provided by an external energy harvester, e.g. a small solar cell (e.g. EnOcean ECS 3x0) or a thermal harvester.
An energy storage device can be connected externally to bridge periods with no supply from the energy harvester.
A voltage limiter avoids damaging of the module when the supply from the energy
harvester gets too high.

The module provides a user-configurable cyclic wake up.
After wake up, a radio telegram (input data, unique 32 bit sensor ID, checksum) will be transmitted in case of a change of any digital input value compared to the last transmission or in case of a significant change of measured analogue values (different input sensitivities can be selected).
In case of no relevant input change, a redundant retransmission signal is sent after a user configurable number of wake-ups to announce all current values. In addition, a wake up can also be triggered externally.

Features with built-in firmware

- 3 A/D converter inputs
- 4 digital inputs
- Configurable wake-up and transmission cycle
- Wake-up via Wake pins
- Voltage limiter
- Threshold detector
- Application notes for calculation of energy budgets and management of external energy storages

Product variants

- LSTM 300U

Features accessible via API

Using the Dolphin API library it is possible to write custom firmware for the module.
LSTM 300U is in-system programmable. The API provides:

- Integrated 16 MHz 8051 CPU with 32 kB FLASH and 2 kB SRAM
- Receiver functionality
- Various power down and sleep modes down to typ. 0.2 µA current consumption
- Up to 16 configurable I/Os
- 10 bit ADC, 8 bit DAC

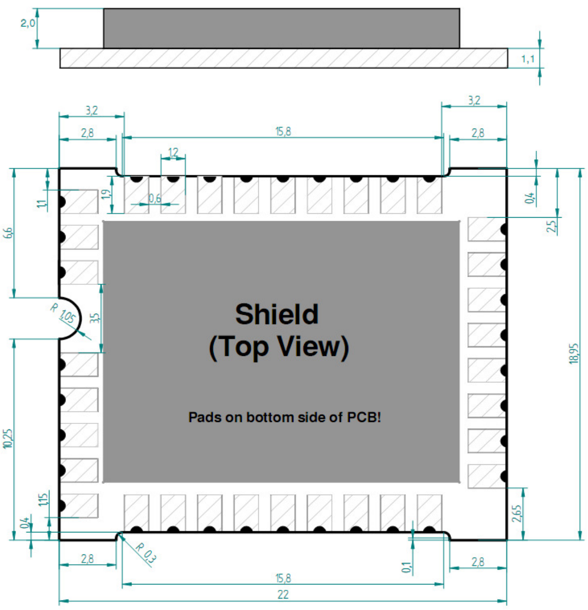
2.2 Technical data

Antenna	External whip or 50 Ω antenna mountable
Frequency	LSTM 300U: 902.875 MHz (FSK)
Data rate	125 kbps
Receiver Sensitivity (at 25 °C) only via API	typ. -98 dBm[2)] (902.875 MHz)
Conducted Output Power **@50Ω min / typ /max**	LSTM 300U: 7 dBm
Power Supply	2.1 V–4.5 V, 2.6 V needed for start-up
Current Consumption	Deep Sleep mode : typ. 0.2 µA Transmit mode: typ. 24 mA, max. 33 mA Receive mode (via API only): typ. 33 mA, max. 43 mA
Input Channels	4x digital input, 2x WAKE input , 3x analog input Resolution: 3x 8 bit or 1x 10 bit, 1x 8 bit, 1x 6 bit
Radio Regulations	LSTM 300U: FCC (US) / ISED (CA)

1) according to ISO/IEC 14543-3-10
2) @ 0.1% telegram error rate (based on transmitted sub-telegrams)

2.3 Physical dimensions

PCB dimensions	22 x 19 x 3.1 mm
Weight	1.9 g



LSTM 300U (pads on bottom side of PCB!)

Unless otherwise specified dimensions are in mm.

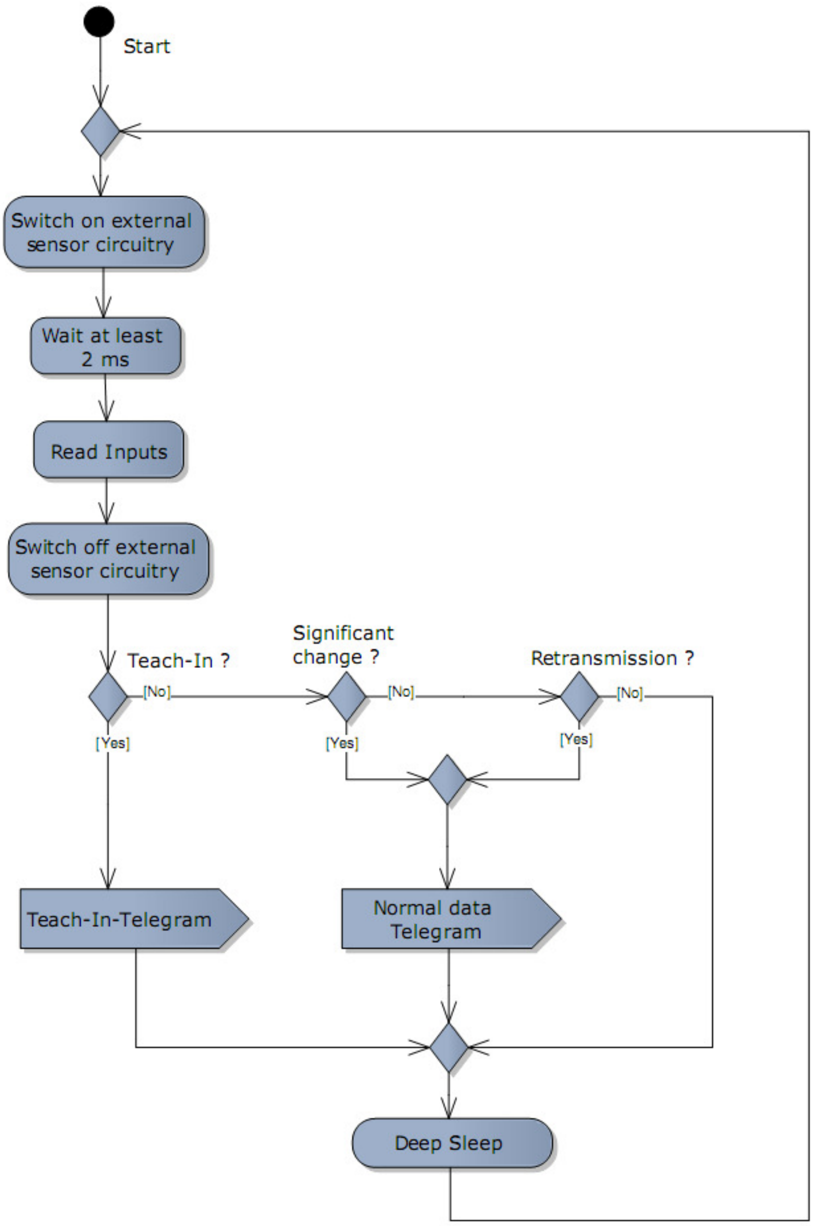
Tolerances:
PCB outline dimensions ±0.2 mm
All other tolerances ±0.1 mm

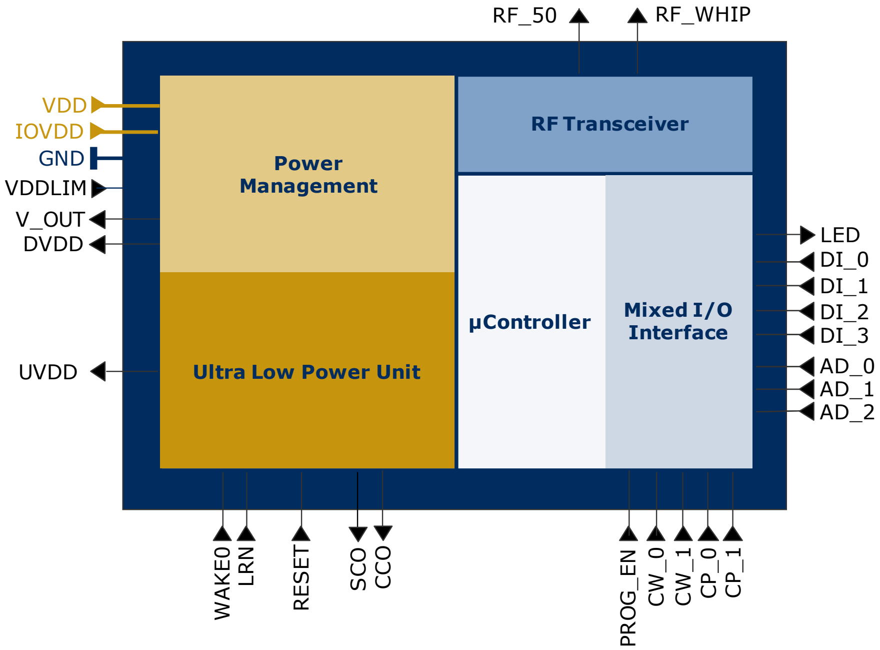
2.4 Environmental conditions

Operating temperature	-25 °C … +85 °C
Storage temperature	-40 °C … +85 °C
Storage temperature in tape & reel package	-20 °C … +50 °C
Humidity	0% … 93% r.h., non-condensing

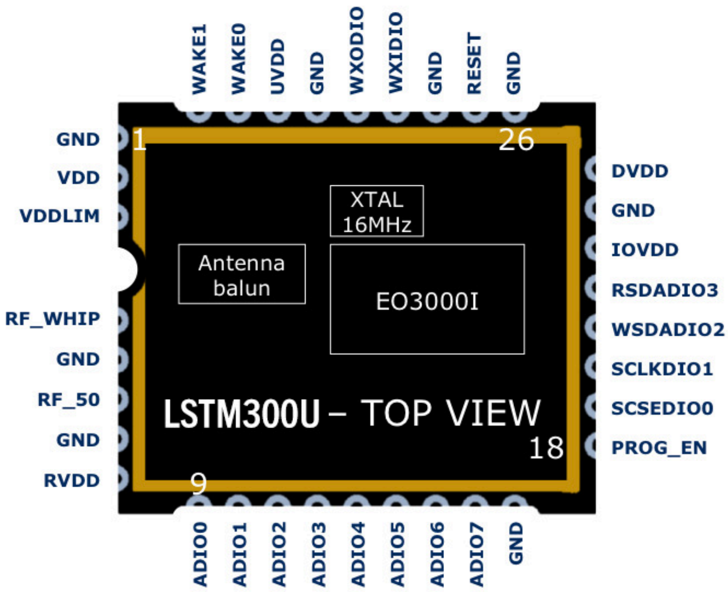
3 FUNCTIONAL DESCRIPTION

3.1 Simplified firmware flow chart and block diagram





3.2 Hardware pin out



The figure above shows the pin out of the LSTM 300U hardware. The pins are named according to the naming of the EO3000I chip to simplify usage of the DOLPHIN API.
The table in section 3.3 shows the translation of hardware pins to a naming that fits the functionality of the built-in firmware.

When writing own firmware based on the DOLPHIN API please refer to the Dolphin Core Description and use this manual only for information regarding the module hardware, such as pin out, layout recommendations, charging circuitry, antenna options, and approvals.

3.3 Pin description and operational characteristics

LSTM 300x Hardware Symbol	LSTM 300x pin #	LSTM 300x Firmware Symbol	Function	Characteristics
GND	1, 5, 7, 17, 24, 26, 28, 31	GND	Ground connection	Must be connected to GND
VDD	2	VDD	Supply voltage	2.1 V – 4.5 V; Start-up voltage: 2.6 V Maximum ripple: see 3.6
RVDD	8	V_OUT	RF supply voltage regulator output	1.8 V. Output current: max. 10 mA. See 0! Supply for external circuitry, available while not in deep sleep mode.
DVDD	25	DVDD	Digital supply voltage regulator output	1.8 V. Output current: max. 5 mA Supply for external circuitry, available while not in deep sleep mode.
UVDD	32	UVDD	Ultra low power supply voltage regulator output	Not for supply of external circuitry! For use with WAKE pins, see section 4.3. Max. 1 µA output current!
VDDLIM	3	VDDLIM	Supply voltage limiter input	Limitation voltage: 4.5 V Maximum shunting current: 50 mA
IOVDD	23	IOVDD	GPIO supply voltage	Must be connected to desired interface supply voltage as specified in 3.5, e.g. to DVDD. See also 0
RESET	27	RESET	Reset input Programming I/F	Active high reset (1.8 V) Connect external 10 kΩ pull-down.
PROG_EN	18	PROG_EN	Programming I/F	HIGH: programming mode active LOW: operating mode Digital input, connect external 10 kΩ pull-down.
ADIO0	9	AD_0	Analog input	Input read ~2 ms after wake-up. Resolution 8 bit (default) or 10 bit. See also 3.3.2.
ADIO1	10	AD_1	Analog input	Input read ~2 ms after wake-up. Resolution 8 bit (default) or 6 bit. See also 3.3.2.
ADIO2	11	AD_2	Analog input	Input read ~2 ms after wake-up. Resolution 8 bit. See also 3.3.2.

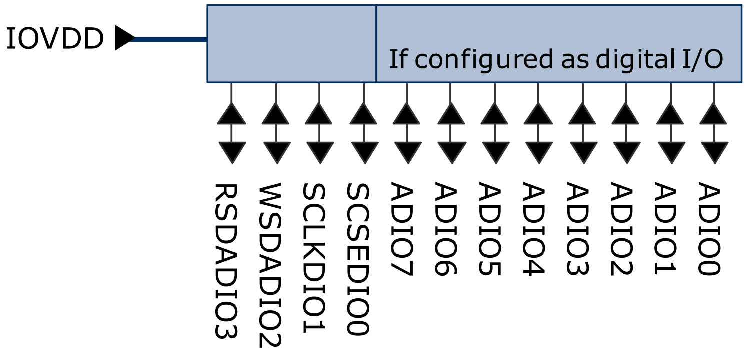
ADIO3	12	DI_0	Digital input	Input read ~2 ms after wake-up. See also 3.3.2.
ADIO4	13	DI_1	Digital input	Input read ~2 ms after wake-up. See also 3.3.2.
ADIO5	14	DI_2	Digital input	Input read ~2 ms after wake-up. See also 3.3.2.
ADIO6	15	DI_3	Digital input	Input read ~2 ms after wake-up. See also 3.3.2.
ADIO7	16	LED	Transmission indicator LED	Max. output current: 2 mA @ IOVDD=3.3 V 0.65 mA @ IOVDD=1.8 V
			Programming I/F	
SCSEDIO0	19	CW_1	Encoding input for wake-up cycle	Leave open or connect to GND
			Programming I/F	
SCLKDIO1	20	CW_0	Encoding input for wake-up cycle	Leave open or connect to GND
			Programming I/F	
WSDADIO2	21	CP_1	Encoding input for retransmission	Leave open or connect to GND
			Programming I/F	
RSDADIO3	22	CP_0	Encoding input for retransmission	Leave open or connect to GND
			Programming I/F	
WXIDIO	29	SCO	Sensor control	Digital output, max. current 15 µA HIGH ~x ms before analog inputs are read (x=0…508 ms; default 2 ms.) LOW at wake-up and after reading of analog inputs Polarity can be inverted, delay time can be programmed, see 3.8.2.
WXODIO	30	CCO	Charge control	Max output current 15 µA See 3.7 for description of behaviour.
WAKE0	33	WAKE0	Wake input	Change of logic state leads to wake-up and transmission of a telegram. See also 4.3.
WAKE1	34	LRN	LRN input	Change of logic state to LOW leads to wake-up and transmission of teach-in telegram if a manufacturer code is programmed. See also 3.9.2 and 4.3.
RF_WHIP	4	RF_WHIP	RF output	Output for whip antenna
RF_50	6	RF_50	RF output	50 Ohm output for external antenna

3.3.1 GPIO supply voltage

For digital communication with other circuitry (peripherals) the digital I/O configured pins of the mixed signal sensor interface (ADIO0 to ADIO7) and the pins of the programming interface (SCSEDIO0, SCLKDIO1, WSDADIO2, RSDADIO3) may be operated from supply voltages different from DVDD.
An interface supply voltage pin IOVDD is available for such use cases which can be connected either to DVDD or to an external supply within the tolerated voltage range of IOVDD.
Note that the wristwatch XTAL I/Os WXIDIO and WXODIO are always supplied from UVDD.

⚠ If DVDD=0 V (e.g. in any sleep mode or if VDD<VOFF) and IOVDD is supplied, there may be an unpredictable and varying current flow from IOVDD caused by internal floating nodes. It must be ensured that the current into IOVDD does not exceed 10 mA while DVDD=0 V.
If DVDD=0 V and IOVDD is not supplied, do not apply voltage to any above mentioned pin. This may lead to unpredictable malfunction of the device.

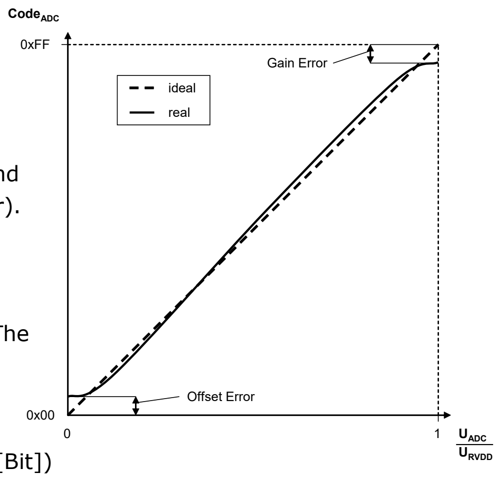
⚠ For I/O pins configured as analog pins, the IOVDD voltage level is not relevant! However, it is important to connect IOVDD to a supply voltage as specified in 3.5.



3.3.2 Analog and digital inputs

Parameter	Conditions / Notes	Min	Typ	Max	Units
Analog Input Mode					
Measurement range	Single ended Internal reference RVDD/2	0.067		RVDD-0.12	V
Input coupling			DC		
Measurement bandwidth[1]			62.5		kHz
Input impedance	Single ended against GND @ 1 kHz	10			MΩ
Input capacitance	Single ended against GND @ 1 kHz			10	pF
Effective measurement resolution			10		Bit
10 bit measurement					
Offset error			23	36	LSB
Gain error			32	62	LSB
INL	Code <=200		+3 -14	+6 -23	LSB
	Code >200		+3 -4	+6 -10	LSB
DNL				<±0.5	LSB
8 bit measurement					
Offset error			6	9	LSB
Gain error			8	16	LSB
INL	Code <=50		+1 -4	+2 -6	LSB
	Code >50		+1 -1	+2 -3	LSB
DNL				<±0.125	LSB

Offset Error: Describes the offset between the minimal possible code and code 0x00.
Gain Error: Describes the offset between maximum possible code and full scale (e.g. 0x3FF for 10 bit measurements).
Integral Non-Linearity (INL): Describes the difference between the ideal characteristics and the real characteristics. Only values between minimum and maximum possible code are considered (excluding offset error and gain error).
Differential Non-Linearity (DNL): Measures the maximum deviation from the ideal step size of 1 LSB (least significant bit).
Effective resolution: Results from the signal-noise ratio of the ADC and is given in Bit. The number describes how many bits can be measured stable. The criterion selected here is that the noise of DNL is <±0.5 LSB.
Measurement Bandwidth: The measurement bandwitdh is internally limited by filters. A quasi static signal must be applied as long as the filter needs to settle. SettlingTime= 1/(MeasurementBandwidth)*ln(2^resolution[Bit])



For further details please refer to the Dolphin Core Description.

[1] 3 dB input bandwidth, resulting in 111 µs settling time to achieve a deviation of an input signal <1 LSB (<0.098% @ 10 bit resolution).

Parameter	Conditions / Notes	Min	Typ	Max	Units
Digital Input Mode					
Input HIGH voltage		2/3 IOVDD			V
Input LOW voltage				1/3 IOVDD	V
Pull up resistor	@IOVDD=1.7 … 1.9 V	90	132	200	kΩ
	@IOVDD=3.0 … 3.6 V	38	54	85	kΩ

3.4 Absolute maximum ratings (non operating)

Symbol	Parameter	Min	Max	Units
VDD VDDLIM	Supply voltage at VDD and VDDLIM	-0.5	5.5	V
IOVDD	GPIO supply voltage	-0.5	3.6	V
GND	Ground connection	0	0	V
VINA	Voltage at every analog input pin	-0.5	2	V
VIND1	Voltage at RESET, WAKE0/1, and every digital input pin except WXIDIO/WXODIO	-0.5	3.6	V
VIND2	Voltage at WXIDIO / WXODIO input pin	-0.5	2	V

3.5 Maximum ratings (operating)

Symbol	Parameter	Min	Max	Units
VDD VDDLIM	Supply voltage at VDD and VDDLIM	VOFF	4.5	V
IOVDD	GPIO supply voltage (see also 0)	1.7	3.6	V
GND	Ground connection	0	0	V
VINA	Voltage at every analog input pin	0	2.0	V
VIND1	Voltage at RESET, WAKE0/1, and every digital input pin except WXIDIO / WXODIO	0	3.6	V
VIND2	Voltage at WXIDIO / WXODIO input pin	0	2.0	V

3.6 Power management and voltage regulators

Symbol	Parameter	Conditions / Notes	Min	Typ	Max	Units
Voltage Regulators						
VDDR	Ripple on VDD, where Min(VDD) > VON				50	mV_{pp}
UVDD	Ultra Low Power supply			1.8		V
RVDD	RF supply		1.7	1.8	1.9	V
DVDD	Digital supply		1.7	1.8	1.9	V
Voltage Limiter						
VLIM	Limitation voltage			4.5		V
ILIM	Shunting current				50	mA

Threshold Detector						
VON	Turn on threshold		2.3	2.45	2.6	V
VOFF	Turn off threshold	Automatic shutdown if VDD drops below VOFF	1.85	1.9	2.1	V

Voltage Limiter
LSTM 300U provides a voltage limiter which limits the supply voltage VDD of LSTM 300U to a value VDDLIM which is slightly below the maximum VDD ratings by shunting of sufficient current.

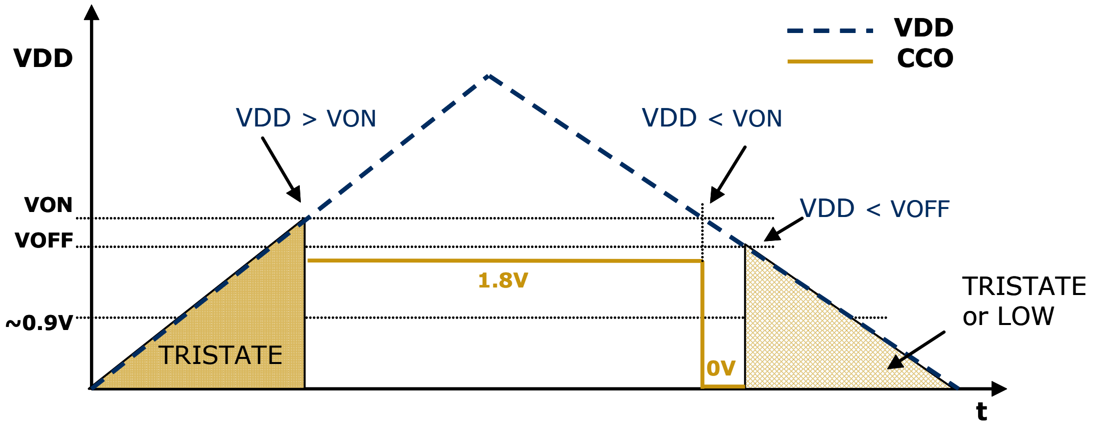
Threshold detector
LSTM 300U provides an ultra low power ON/OFF threshold detector. If VDD > VON, it turns on the ultra low power regulator (UVDD), the watchdog timer and the WAKE# pin circuitry. If VDD ≤ VOFF it initiates the automatic shut down of STM 300x.

3.7 Charge control output (CCO)

After start-up LSTM 300U provides the output signal of the threshold detector at the CCO output pin. CCO is supplied by UVDD. The CCO output value remains stable also when LSTM 300U is in deep sleep mode.

Behaviour of CCO

- At power up: TRISTATE until VDD>VON then HIGH
- if VDD>VON then HIGH
- if VDD<VON then LOW
- if VDD< VOFF then LOW or TRISTATE



For definition of VON and VOFF please refer to 3.6.

3.8 Configuration

LSTM 300U provides several encoding input pins allowing to configure certain parameters. LSTM 300U checks the status of these pins at every wake-up. It is possible to override these hardware-defined configuration settings by software. Both mechanisms are described below.

3.8.1 Hardware-defined configuration settings

On LSTM 300U it is possible to define wake-up cycle time and redundant transmission frequency via dedicated configuration inputs.

Wake-up cycle time configuration

Two input pins – CW_0 and CW_1 – define the wake-up cycle time. Each of these pins can either be connected to GND or left unconnected. The resulting wake-up cycle time is shown in the table below.

CW_0	CW_1	Wake-up cycle time
NC	NC	1 s ±20%
GND	NC	10 s ±20%
NC	GND	100 s ±20%
GND	GND	No cyclic wake-up

Redundant retransmission

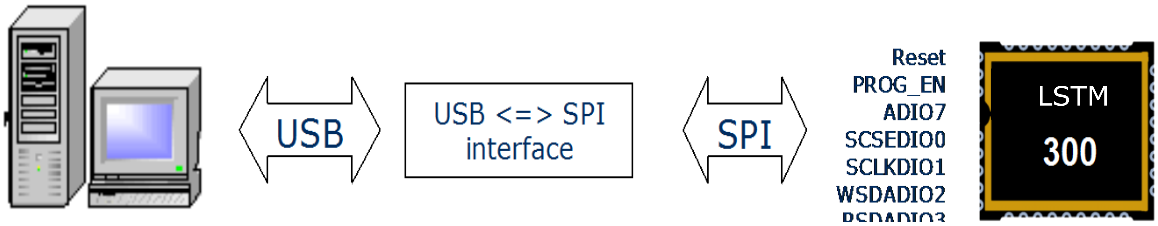
Two input pins – CP_0 and CP_1 – control an internal counter which is decreased at every wake-up signal. Once the counter reaches zero the redundant retransmission signal is sent. Each of these pins can either be connected to GND or left unconnected.
The resulting wake-up cycle time is shown in the table below.

CP_0	CP_1	Number of wake-ups that trigger a redundant retransmission
NC	NC	Every timer wake-up signal
GND	NC	Every 7th - 14th timer wake-up signal, affected at random
NC	GND	Every 70th - 140th timer wake-up signal, affected at random
GND	GND	No redundant retransmission

⚠ A radio telegram is always transmitted after wake-up via WAKE pins!
After transmission the counter is reset to a random value within the specified interval.

3.8.2 Configuration via programming interface

Via the programming interface the parameters stored in the configuration area can be modified which provides a lot more configuration options.
Note that values set via programming interface override hardware settings.
Note also that these settings are read only after RESET or power-on reset and not at every wake-up of the module.
The interface is shown in the figure below:



EnOcean provides EOPX (EnOcean Programmer, a command line program) and Dolphin Studio (Windows application for chip configuration, programming, and testing) and the USB/SPI programmer device as part of the EDK 350 developer´s kit.

Configurable Parameters
The table below summarizes the parameters that can be configured via the programming interface.

Parameter	Configuration via pins	Configuration via programming interface
Wake up cycle	See section 3.8.1	Value can be set from 1 s to 65534 s
Redundant Retransmission cycle	See section 3.8.1	Min…Max values for random interval If Min=Max -> random switched off
Threshold values for analog inputs	No	The default values are: 5 LSB at AD_1 input, 6 LSB at AD_0 and 14 LSB at AD_2. The threshold value can be set between 0 and full scale for every input individually.
Resolution of the analog inputs	No	Default: AD_0: 8 bit, AD_1: 8 bit, AD_2: 8 bit Option: AD_0: 10 bit, AD_1: 6 bit, AD_2: 8 bit
Input mask	No	A digital input mask for ignoring changes on digital input pins. At default all input bits are checked.
Delay time between SCO on and sampling moment	No	Value can be set from 0 ms to 508 ms in steps of 2 ms. Default delay time is 2 ms.
Source of AD_2	No	Select if AD_2 contains measurement value of external ADIO2 pin or from internal VDD/4
Polarity of SCO signal	No	Polarity can be inversed.
Edge of wake pin change causing a telegram transmission	No	Every change of a wake pin triggers a wake-up. For both wake pins it can be configured individually if a telegram shall be sent on rising, falling or both edges.
Manufacturer ID and EEP (EnOcean Equipment Profile)	No	Information about manufacturer and type of device. This feature is needed for “automatic” interoperability of sensors and actuators or bus systems. Information how to set these parameters requires an agreement with EnOcean. Unique manufacturer IDs are distributed by the EnOcean Alliance.

3.9 Radio telegram

3.9.1 Normal operation

The diagram below summarized the content of a data telegram as seen at programming interface of LSTM 300U or at DOLPHIN API:

ORG = 0x07 (Telegram type "4BS")

Data_Byte1..3
3x8bit mode:
DATA_BYTE3 = Value of AD_2 analog input
DATA_BYTE2 = Value of AD_1 analog input
DATA_BYTE1 = Value of AD_0 analog input

1x8bit, 1x6it, 1x10bit mode:
DATA_BYTE3 = Value of AD_2
DATA_BYTE2 = Upper 2 bits of AD_0 and value of AD_1
DATA_BYTE1 = Lower 8 bits Value of AD_0 analog input

<table>
<tr><td colspan="8">DATA_BYTE3</td><td colspan="8">DATA_BYTE2</td><td colspan="8">DATA_BYTE1</td></tr>
<tr><td colspan="8">AD_2</td><td colspan="6">AD_1</td><td colspan="10">AD_0</td></tr>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
</table>

DATA_BYTE0 = Digital sensor inputs as follows:
Bit 7 Bit 0

Reserved, set to 0	DI_3	DI_2	DI_1	DI_0

ID_BYTE3 = module identifier (Byte3)
ID_BYTE2 = module identifier (Byte2)
ID_BYTE1 = module identifier (Byte1)
ID_BYTE0 = module identifier (Byte0)

The voltages measured at the analog inputs can be calculated from these values as follows:

$U=(\text{Value of AD\_x})/(2^n)\text{x}1.8\ V$ n=resolution of channel in bit

3.9.2 Teach-in telegram

If a manufacturer code is programmed into the module then the module transmits – instead of a normal telegram – a dedicated teach-in telegram if:

- Digital input DI_3=0 at wake-up or
- Wake-up is triggered via WAKE1 pin (LRN input)

With this special teach-in telegram it is possible to identify the manufacturer, the function and the type of a device. There is a list available from the EnOcean Alliance describing the functionalities of the respective products.

If no manufacturer code is programmed then the module does not react to events on WAKE1 (LRN input)!

ORG = 0x07 (Telegram type “4BS”)

DATA_BYTE0..3 see below
LRN Type = 1
LRN = 0
DI0..DI2: current status of digital inputs
Profile, Type, Manufacturer-ID defined by manufacturer
RE0..2: set to 0

ID_BYTE3 = module identifier (Byte3)
ID_BYTE2 = module identifier (Byte2)
ID_BYTE1 = module identifier (Byte1)
ID_BYTE0 = module identifier (Byte0)

ORG	Data_Byte3	Data_Byte2	Data_Byte1	Data_Byte0	ID

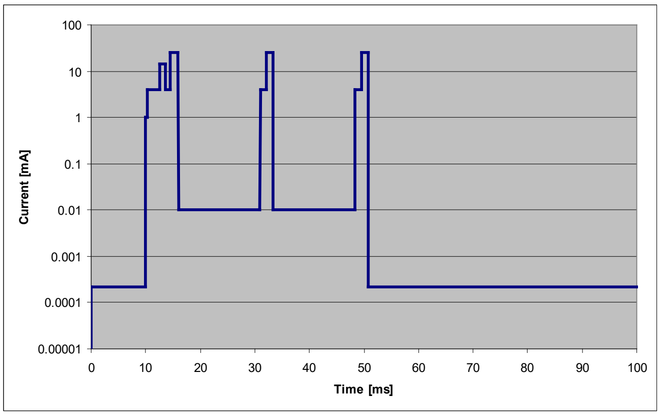
Function 6 Bit	Type 7 Bit	Manufacturer-ID 11 Bit	LRN Type 1Bit	RE2 1Bit	RE1 1Bit	RE0 1Bit	LRN 1Bit	DI2 1Bit	DI1 1Bit	DI0 1Bit

3.10 Transmit timing

The setup of the transmission timing allows avoiding possible collisions with data packages of other EnOcean transmitters as well as disturbances from the environment. With each transmission cycle, 3 identical subtelegrams are transmitted within 40 ms.
Transmission of a subtelegram lasts approximately 1.2 ms. The delay time between the three transmission bursts is affected at random.

If a new wake-up occurs before all sub-telegrams have been sent, the series of transmissions is stopped and a new series of telegrams with new valid measurement values is transmitted.

3.11 Energy consumption



Current Consumption of LSTM 300U

Charge needed for one measurement and transmit cycle: ~130 µC
Charge needed for one measurement cycle without transmit: ~30 µC
(current for external sensor circuits not included)

Calculations are performed on the basis of electric charges because of the internal linear voltage regulator of the module. Energy consumption varies with voltage of the energy storage while consumption of electric charge is constant.

From these values the following performance parameters have been calculated:

Wake cycle [s]	Transmit interval	Operation Time in darkness [h] when storage fully charged	Required reload time [h] at 200 lux within 24 h for continuous operation	24 h operation after 6 h illumination at x lux	Illumination level in lux for continuous operation	Current in µA required for continuous operation
1	1	0.5	storage too small	storage too small	5220	130.5
1	10	1.7	storage too small	storage too small	1620	40.5
1	100	2.1	storage too small	storage too small	1250	31.3
10	1	5.1	storage too small	storage too small	540	13.5
10	10	16	21	storage too small	175	4.4
10	100	20	16.8	storage too small	140	3.5
100	1	43	7.8	260	65	1.6
100	10	98	3.6	120	30	0.8
100	100	112	3	100	25	0.6

Assumptions:
- Storage PAS614L-VL3 with 0.25 F, Umax=3.2 V, Umin=2.2 V, T=25°C
- Consumption: Transmit cycle 100 µC, measurement cycle 30 µC

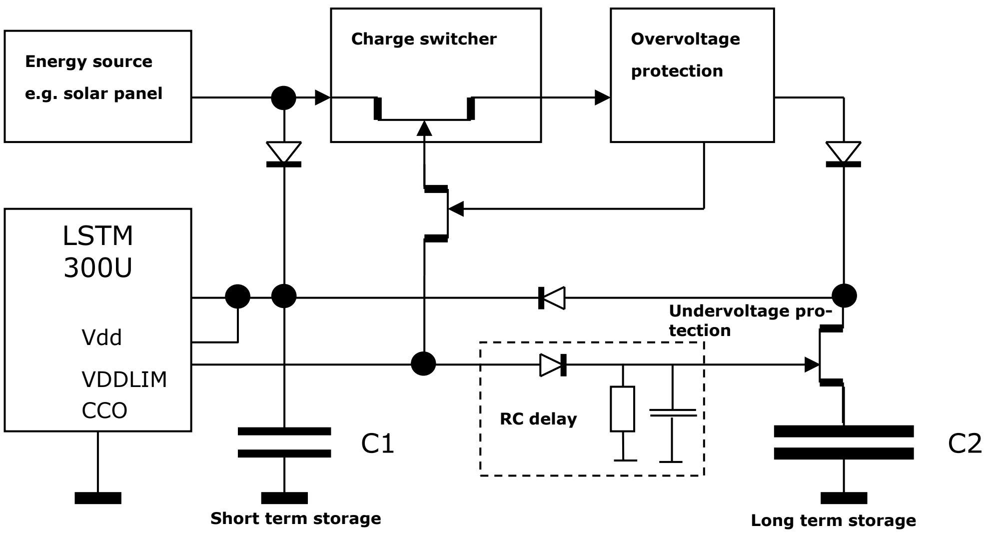
- Indoor solar cell, operating values 3 V and 5 µA @ 200 lux fluorescent light (e.g. ECS 300 solar cell)
- Current proportional to illumination level (not true at very low levels!)

These values are calculated values, the accuracy is about +/-20%!

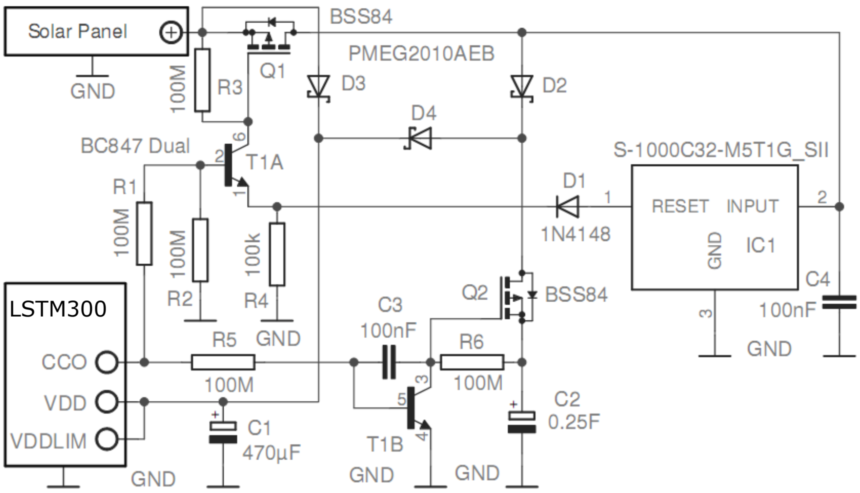
4 APPLICATIONS INFORMATION

4.1 How to connect an energy harvester and energy storage

LSTM 300U is designed for use with an external energy harvester and external energy storage. In order to support both a fast start-up time and long term operation with no energy supply available usually two different types of energy storages are used.
A small (short term) energy storage fills quickly and allows a fast start-up while a large (long term) energy storage fills more slowly but can provide a large buffer for times where no energy is available, e.g. at night in a solar powered sensor.
Both short term and long term storage are typically implemented as capacitors. The short term storage capacitor is usually in the range of 470 to 1000 µF while for the long term storage a capacity of 0.25 F is suggested.
LSTM 300U provides a digital output CCO (see also 3.7) which allows controlling the charging of such two storages.
The block diagram below shows a typical implementation of a suitable charging circuit.
There, capacitor C1 acts as short term storage while capacitor C2 provides the long term storage.
If both energy storages are depleted and the supply voltage is below the VON voltage level then only the small storage is charged. Once the VON threshold is reached, the CCO output signal changes and the system will start to charge the large storage.



The circuit below is designed for an energy storage capacitor specified for 3.3 V (e.g. PAS614L-VL3).



Charge switcher functionality

The charge switcher as shown above connects both short term storage (C1) and long term storage (C2) parallel to the energy source as soon as the LSTM 300U supply voltage reaches the typical VON threshold of 2.45 V.

If VDD subsequently falls below VON, the energy source will be switched back to short term storage alone which will enable faster recharging. As long as the voltage of the long term storage remains below VON, the charge switcher will continuously switch the energy source between short term and long term storage, trying to ensure continuous device operation.

This mechanism mitigates the effect of a potentially long charge time required to charge the long term storage sufficiently for the start of operation.

In addition, the short term storage will not be charged over the VON threshold until the voltage on the long term storage also exceeds VON.

Charge switcher is the PMOS transistor Q1, driven from the LSTM 300U charge control output CCO over T1A. If the LSTM 300U VDD voltage is below the VON threshold, only the small storage (C1) is filled via D3.

Once the VON threshold is reached, the CCO control signal goes High, T1B and Q2 are turned on and the long term storage (C2) will be filled via Q2.

Overvoltage protection

Typical long term storage solutions have a rated operating voltage that must be not exceeded. Overvoltage protection is therefore an essential aspect of the supply circuit design.

In the circuit suggested above, overvoltage protection is implemented by an S-1000C32-M5T1x voltage detector from Seiko (SII) - or alternatively a member of the NCP300LSN30T1G series from ON Semiconductor - which limits the maximum charging voltage to 3.3 V in order to avoid damaging long term energy storage. If a different voltage limit is required, this voltage detector has to be replaced by a suitable voltage variant.

As soon as the voltage on the voltage detector input exceeds the selected threshold, the voltage detector transitions to a logic "High" level on its output which is connected to the T1A emitter. The T1A base will then have a lower voltage than its emitter and the transistor T1A will be turned off. That will result in the load switch Q1 being turned off as well which will switch off the supply to the long term storage.

The selected voltage detector must both have an ultra-low quiescent current in the operating range and an appropriate threshold voltage in accordance to the parameters of the selected long term energy storage (e.g. a 3.2 V nominal threshold for a 3.3 V capacitor).

If the selected threshold is too low then energy would be wasted. If the nominal threshold is too high then energy storage life expectation might be affected. The S-1000C32-M5T1x voltage detector with a 3.2 V nominal threshold provides a good compromise between those two constraints.

Undervoltage protection

Certain types of long term energy storage elements (such as PAS capacitors) should not be deep discharged to voltages below 1.5 V to avoid long term degradation of their capacity and lifetime. Therefore undervoltage protection is essential for systems containing such devices.

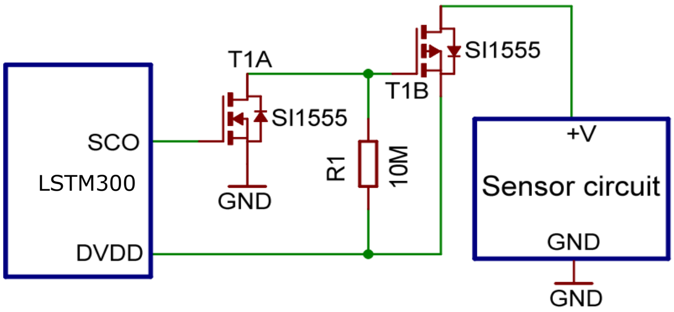
In the circuit above, undervoltage protection is controlled through Q2.
In normal operation, when VDD reaches the VON threshold, the LSTM 300U charge control output pin (CCO) goes high, T1B rapidly discharges C3 to GND and Q2 turns on long term storage.

If VDD falls below the VOFF threshold then the LSTM 300U charge control CCO goes low and the C3 charge recovers very slowly over R6. If VDD remains below VOFF (and CCO consequently remains low) for a longer time then C3 will be charged sufficiently to turn off Q2 and thus switch off the discharge path from the long term storage C2 via D4 to LSTM 300U thus avoiding deep discharge of C2.

For more details and alternative circuits please refer to application note AN208.

4.2 Using SCO pin

LSTM 300U provides an output signal at SCO which is suited to control the supply of the sensor circuitry. This helps saving energy as the sensor circuitry is only powered as long as necessary.
In the default configuration SCO provides a HIGH signal 2 ms (delay time) before the analog inputs are read. It is possible to adjust the delay time and also the polarity of the signal via the programming interface (see 3.8.2).



The figure above illustrates the use of the SCO pin (with default polarity) to control an external sensor circuit.

Do not supply sensors directly from SCO as this output can only provide maximum 15 µA!

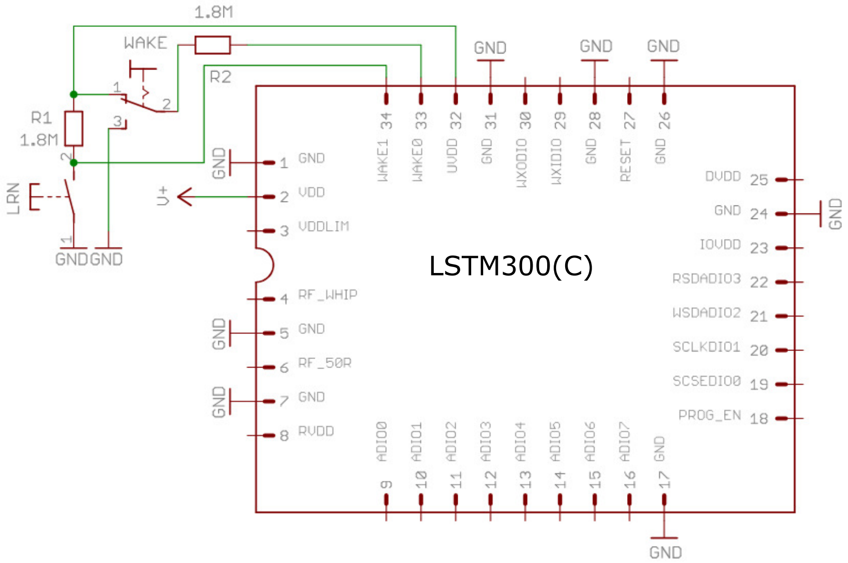
4.3 Using WAKE pins

The logic input circuits of the WAKE0 and WAKE1 pins are supplied by UVDD and therefore also usable in "Deep Sleep Mode" or "Flywheel Sleep Mode" (via API only). Due to current minimization there is no internal pull-up or pull-down at the WAKE pins.
When LSTM 300U is in "Deep Sleep Mode" or "Flywheel Sleep Mode" (via API only) and the logic levels of WAKE0 and / or WAKE1 are changed then LSTM 300U starts up.

There are no internal pull-up or pull-down cells at the WAKE pins.
External circuitry is required to ensure that the WAKE pins are at a defined logic level at any time.

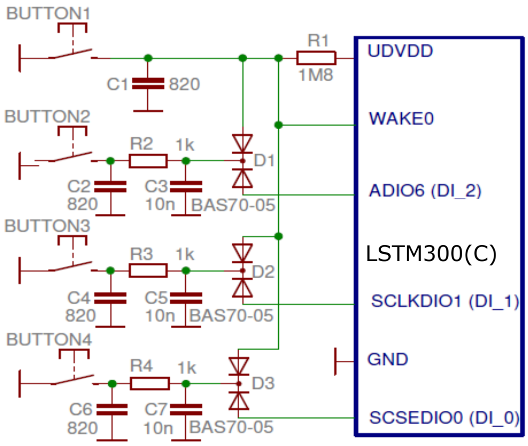
When using the UVDD regulator output as source for the logic HIGH of the WAKE pins, it is strongly recommended to protect the ultra low power UVDD voltage regulator against (accidental) excessive loading by connection of an external 1.8 MΩ series resistor.

To avoid keybounce we strongly recommend adding a PI filter at wake inputs with buttons or keys.



The figure above shows two examples how the WAKE inputs may be used. When the LRN button is pressed WAKE1 is pulled to GND and a teach-in telegram is transmitted. As long as the button is pressed a small current is flowing from UVDD to GND. WAKE0 is connected to a toggle switch. There is no continuous flow of current in either position of the switch.

If more digital inputs with WAKE functionality are needed in an application then WAKE0 can be combined with some of the digital inputs as shown below. This circuit includes also PI filters against keybouncing. The proposed resistor and capacitor values can be adapted to customer needs.



4.4 Using RVDD

If RVDD is used in an application circuit a serial ferrite bead shall be used and wire length should be as short as possible (<3 cm). The following ferrite beads have been tested: 74279266 (0603), 74279205 (0805) from Würth Elektronik. During radio transmission and reception only small currents may be drawn (I<100 µA).
Pulsed current drawn from RVDD has to be avoided. If pulsed currents are necessary, sufficient blocking has to be provided.

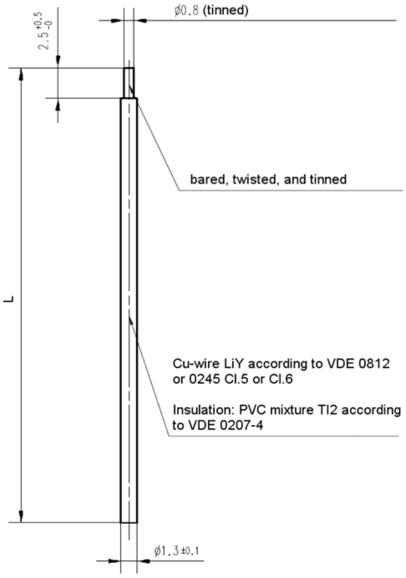
4.5 Antenna options LSTM 300U

4.5.1 Overview

Several antenna types have been investigated by Magnum Energy Solutions. Please refer to application notes AN102, and AN105 (EnOcean Website) which give an overview on our recommendations.

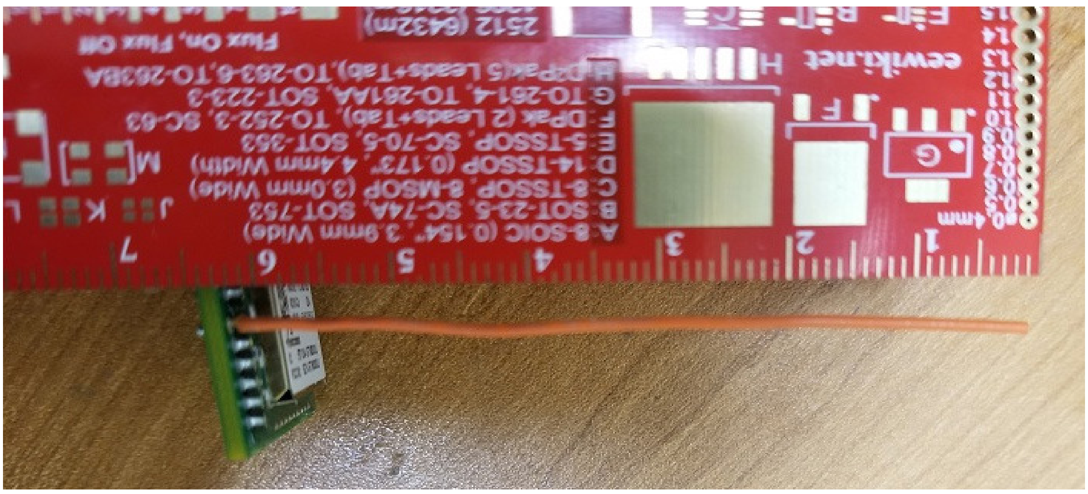
902.875 MHz modules (LSTM 300U) please note that a full approval is needed if modules are used with antennas other than the specified antennas.

4.5.2 Whip antenna



902.875 MHz
Antenna: 64 mm wire, connect to RF_WHIP
Minimum GND plane: 50 mm x 50 mm
Minimum distance space: 10 mm

Antenna Test Procedure:
For production, the optimum antenna length 64mm should be used, two bridgeable (short, few mm optional soldering) in production fine tuning elements (e.g. L+/- 5%) to increase the tolerances for the later mass production (different PCB materials or suppliers, specific device mounting undergrounds) can also be implemented like in the ex-ample shown below:



The inspection will be 5% of the production batch to make sure the length and the part number is correct.

4.5.3 External Antenna (ANT-916-CW-RCS, ANT-916-CW-HWR-RPS Linx Technologies)

The RCS Series is ideally suited for products requiring an attractive, yet compact, ¼-wave antenna in a right-angle form factor. The antennas attach via a Part 15 compliant RP-SMA connector.

The HWR Series ½-wave center-fed dipole antennas deliver outstanding performance in a rugged and cosmetically attractive package. The articulating base allows the antenna to tilt 90 degrees and rotate 360 degrees. The antenna's internal counterpoise eliminates external ground plane dependence and maximizes performance. HWR Series antennas attach via a standard SMA or Part 15 compliant RP-SMA connector. Custom colors and connectors are available for volume OEM customers.

RCS Series Electrical Specifications	HWR Series Electrical Specifications
Center Frequency: 916MHz Recom.	Center Frequency: 916MHz
Freq. Range: 886–946MHz	Recom. Freq. Range: 900–930MHz
	Bandwidth: 30MHz
Wavelength: ¼-wave	Wavelength: ½-wave
VSWR: < 1.9 typical at center	VSWR: ≤ 2.0 typical
Peak Gain: 3.3dBi	Peak Gain: 1.2dBi
Impedance: 50-ohms	Impedance: 50-ohms
Oper. Temp. Range: –20°C to +85°C	Connection: RP-SMA
Connector: RP-SMA	Oper. Temp. Range: –30°C to +80°C

Mounting 50 W antennas

For mounting the receiver at bad RF locations (e.g. within a metal cabinet), an external 50W antenna may be connected. The whip antenna must be removed

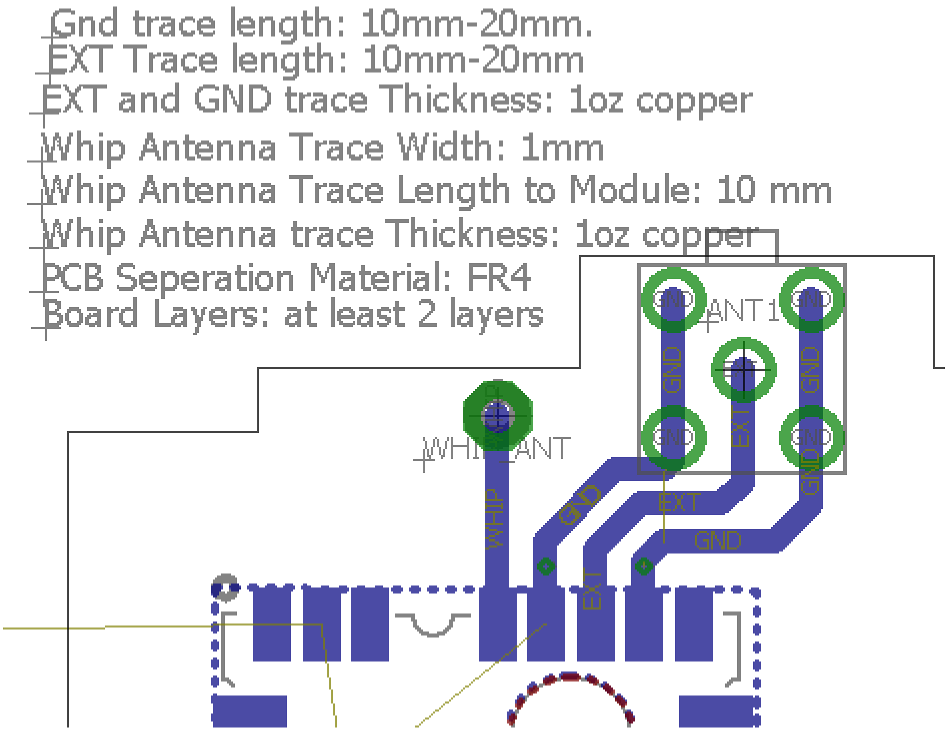
Modification procedure:

- LTCM 300U: Remove whip antenna, then mount RP-SMA connector.
- LTCM 310U: Remove whip antenna, then mount RP-SMA connector.
- LSTM 300U: Remove whip antenna, then mount RP-SMA connector.

The module should provide soldering pads for an RP- SMA connector, e.g. from Molex, LLC:

Part number : 0733910320

4.6 Host PCB Trace Layout Considerations



4.7 Positioning of the whip antenna

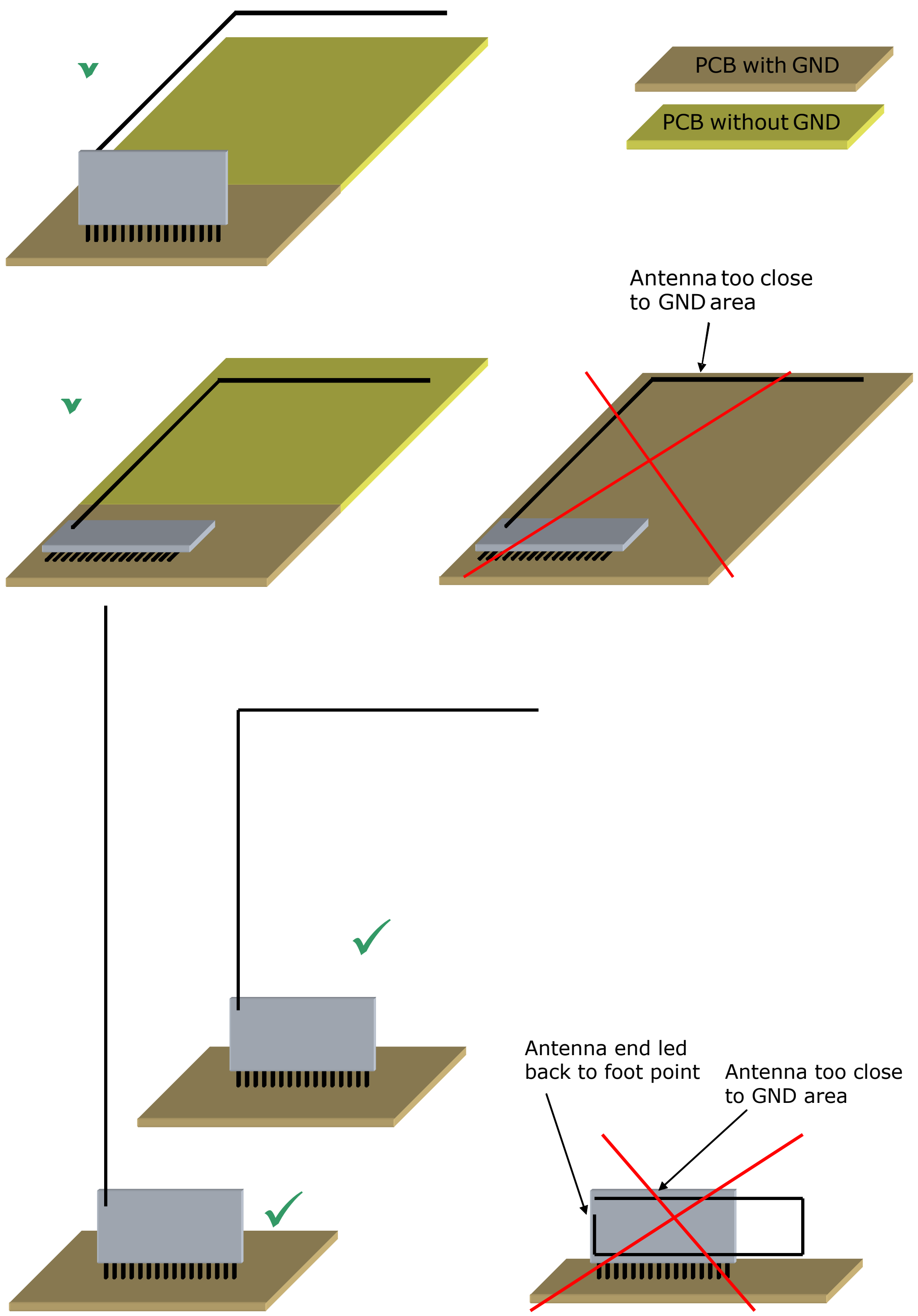
Positioning and choice of receiver and transmitter antennas are the most important factors in determining system transmission range.

For good receiver performance, great care must be taken about the space immediately around the antenna since this has a strong influence on screening and detuning the antenna. The antenna should be drawn out as far as possible and must never be cut off. Mainly the far end of the wire should be mounted as far away as possible (at least 15 mm) from all metal parts, ground planes, PCB strip lines and fast logic components (e.g. microprocessors).
Do not roll up or twist the whip antenna!

Radio frequency hash from the motherboard desensitizes the receiver. Therefore:

- PCB strip lines on the user board should be designed as short as possible
- A PCB ground plane layer with sufficient ground via is strongly recommended
- Keep antenna away from noise generating parts of the circuit. Problems may especially occur with switching power supplies!

4.7.1 Recommendations for laying a whip antenna



4.8 Layout recommendations for foot pattern

⚠ The length of lines connected to I/Os should not exceed 5 cm.

⚠ It is recommended to have a complete GND layer in the application PCB, at least in the area below the module and directly connected components (e.g. mid-layer of your application PCB).

Due to non-isolated test points there are live signals accessible on the bottom side of the module.

Please regard the following advices to prevent interference with your application circuit:

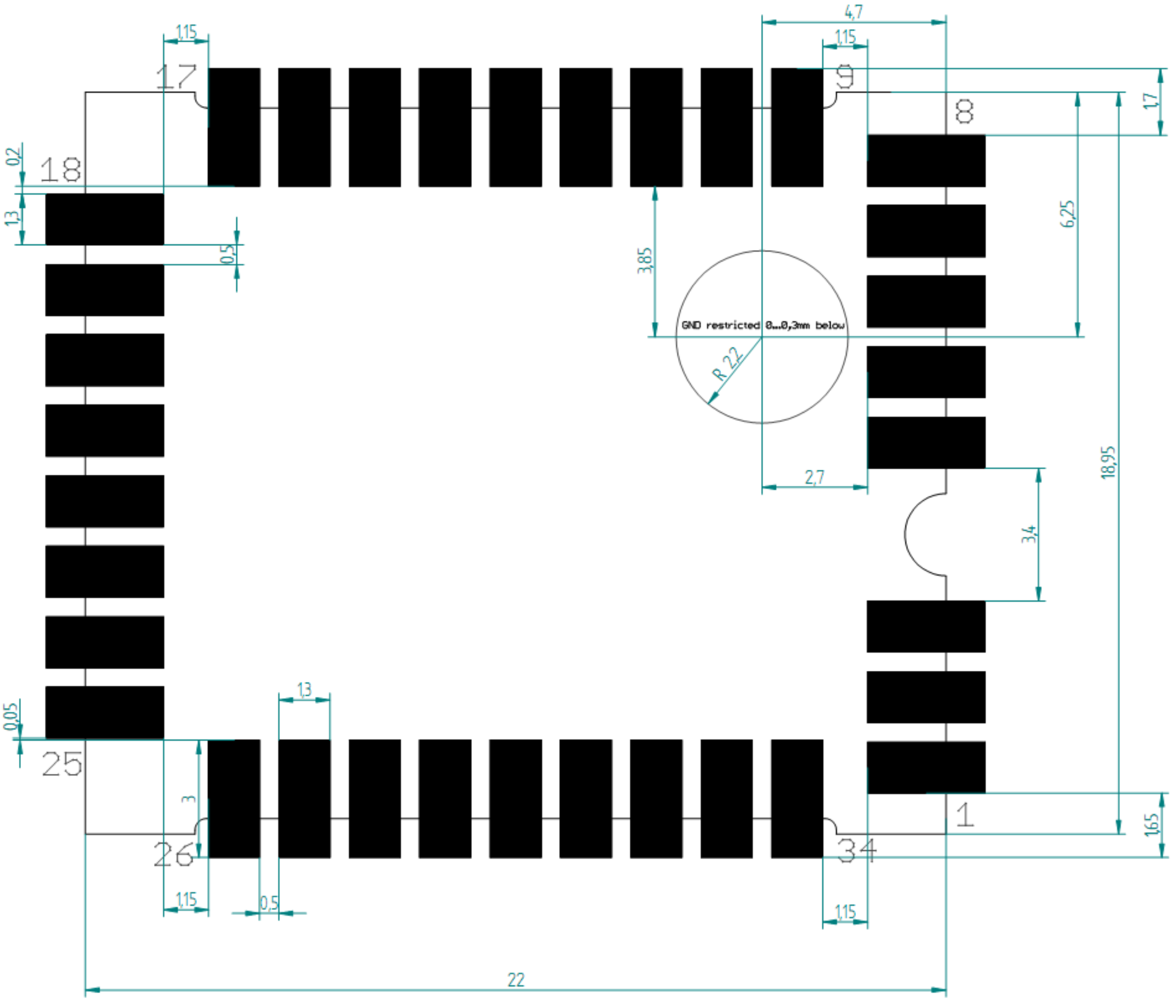
- Avoid any copper structure in the area directly underneath the module (top-layer layout of your application PCB). If this is not possible in your design, please provide coating on top of your PCB to prevent short circuits to the module test pads. All bare metal surfaces including via have to be covered (e.g. adequate layout of solder resist).
- It is mandatory that the area marked by the circle in the figure below is kept clear of any conductive structures in the top layer and 0.3 mm below. Otherwise RF performance will be degraded!

Furthermore, any distortive signals (e.g. bus signals or power lines) should not be routed underneath the module. If such signals are present in your design, we suggest separating them by using a ground plane between module and these signal lines.

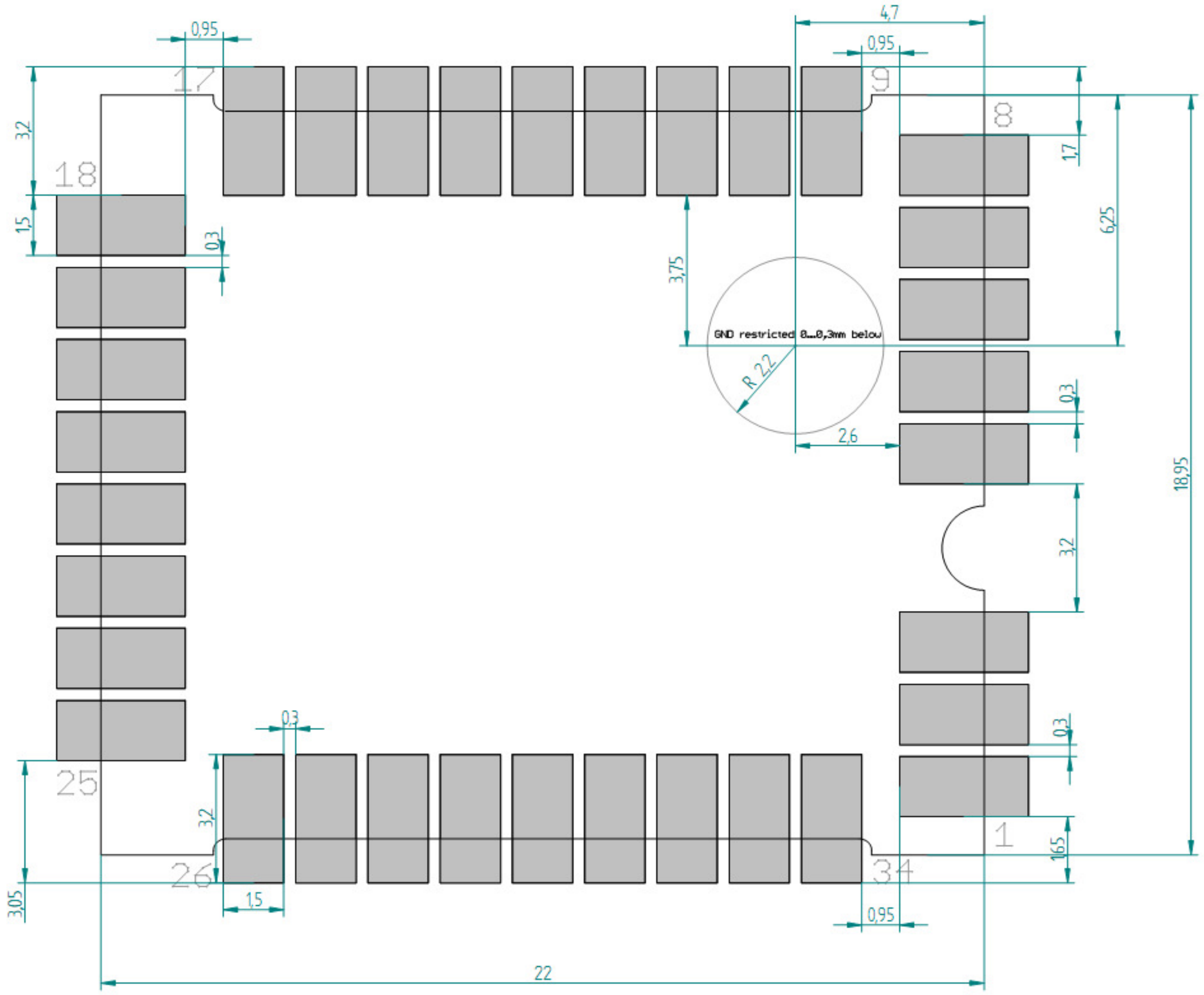
⚠ The RVDD line should be kept as short as possible. Please consider recommendations in section 0.

4.8.1 Recommended foot pattern

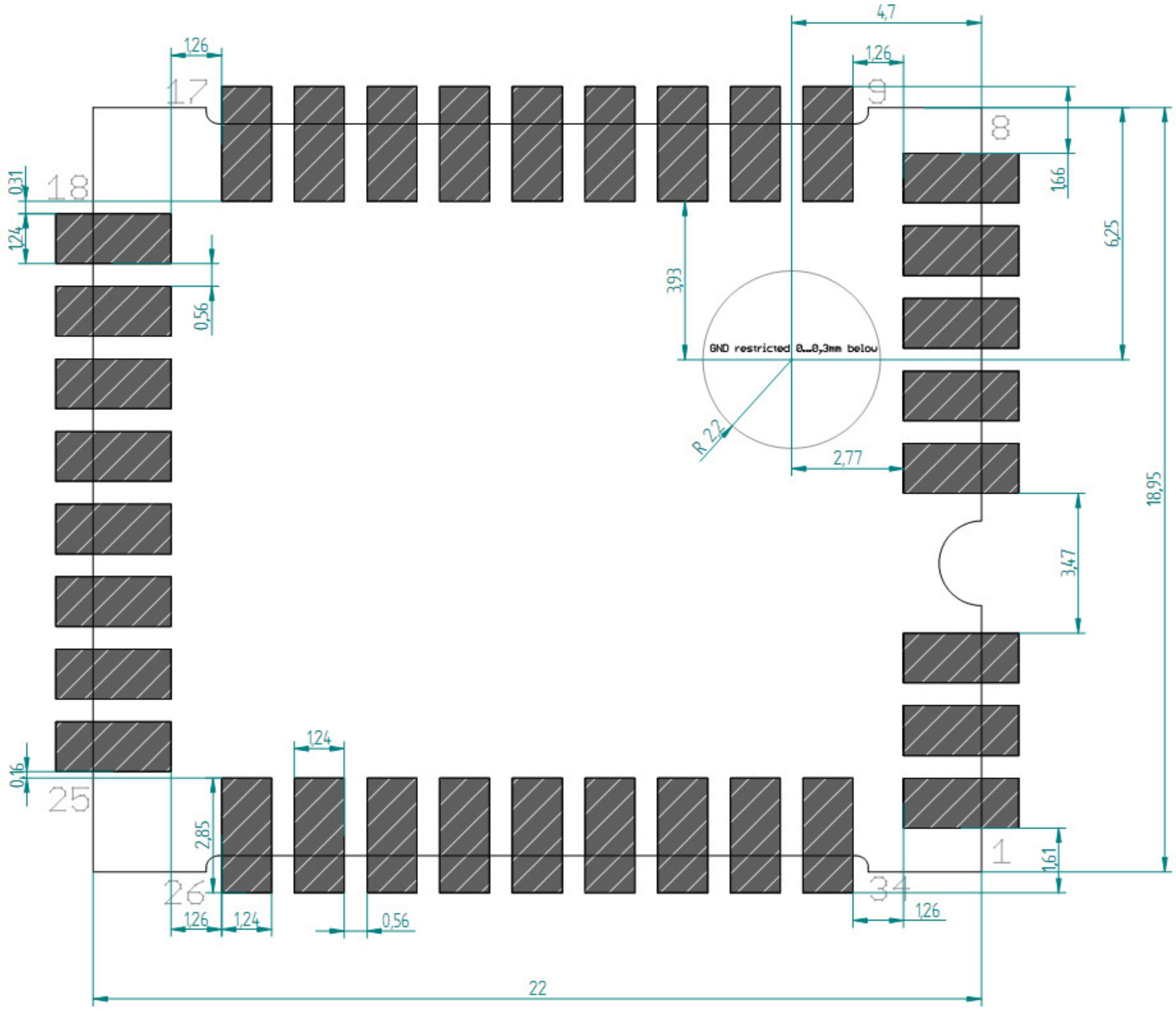
Top layer



Solder resist top layer



Solder paste top layer



The data above is also available as EAGLE library.

In order to ensure good solder quality a solder mask thickness of 150 µm is recommended.

In case a 120 µm solder mask is used, it is recommended to enlarge the solder print. The pads on the solder print should then be 0.1 mm larger than the pad dimensions of the module as specified in chapter 2.3. (not relative to the above drawing).

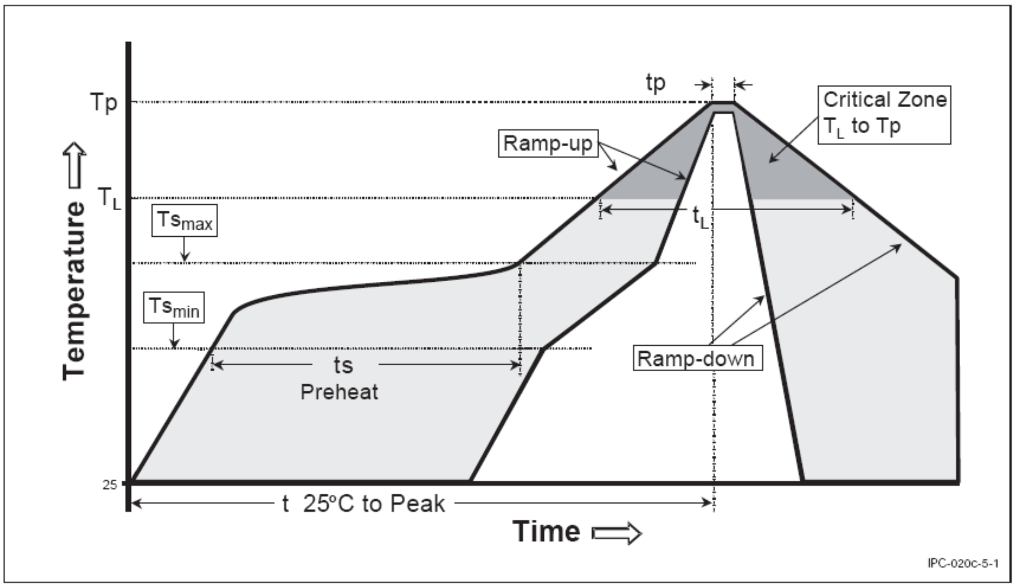
Nevertheless an application and production specific test regarding the amount of soldering paste should be performed to find optimum parameters.

4.9 Soldering information

LSTM 300U has to be soldered according to IPC/JEDEC J-STD-020C standard.

Profile Feature	Pb-Free Assembly
Average Ramp-Up Rate (Ts_{max} to Tp)	3° C/second max.
Preheat – Temperature Min (Ts_{min}) – Temperature Max (Ts_{max}) – Time (ts_{min} to ts_{max})	150 °C 200 °C 60-180 seconds
Time maintained above: – Temperature (T_L) – Time (t_L)	217 °C 60-150 seconds
Peak/Classification Temperature (Tp)	260 °C
Time within 5 °C of actual Peak Temperature (tp)	20-40 seconds
Ramp-Down Rate	6 °C/second max.
Time 25 °C to Peak Temperature	8 minutes max.

Note 1: All temperatures refer to topside of the package, measured on the package body surface.



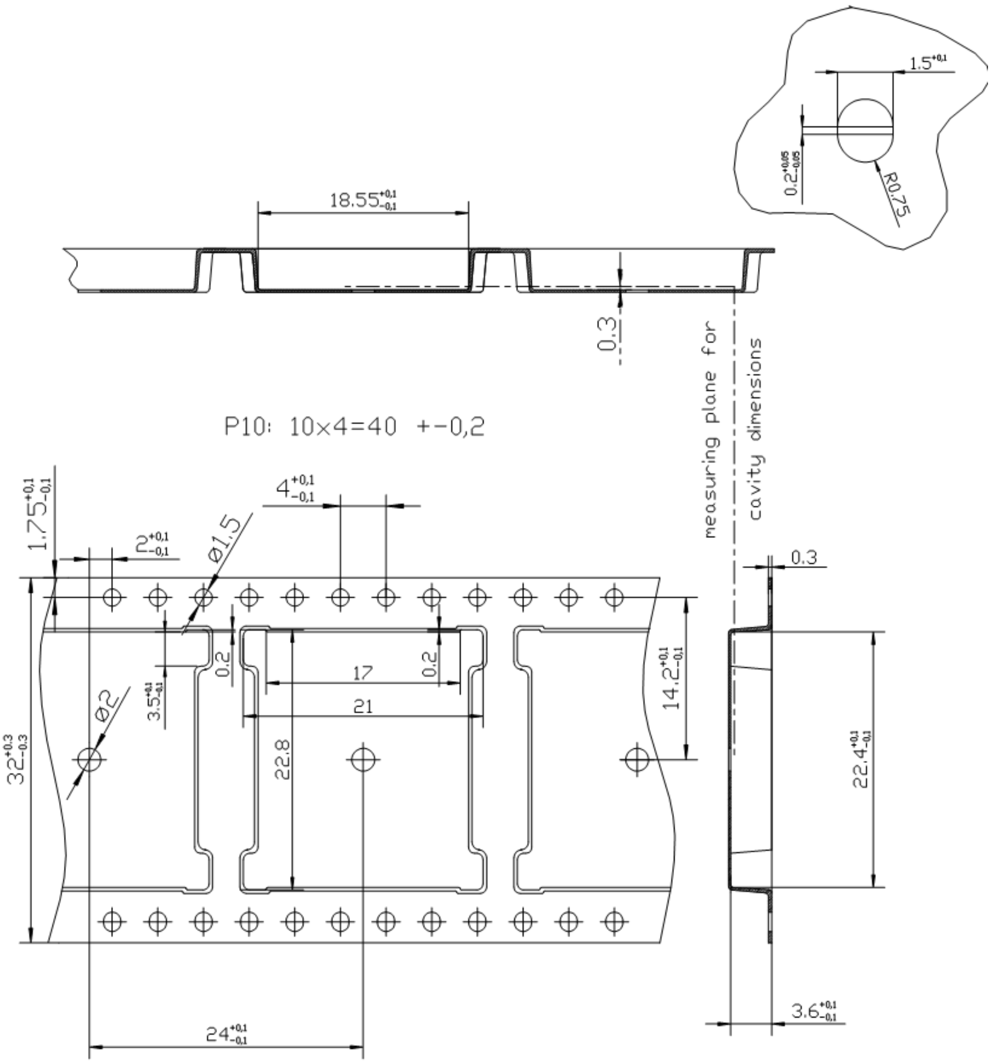
LSTM 300U shall be handled according to Moisture Sensitivity Level MSL4 which means a floor time of 72 h. LSTM 300U may be soldered only once, since one time is already consumed at production of the module itself.

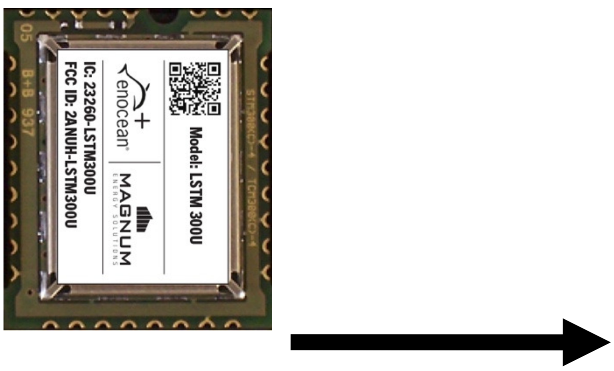
Once the dry pack bag is opened, the desired quantity of units should be removed and the bag resealed within two hours. If the bag is left open longer than 30 minutes the desiccant should be replaced with dry desiccant. If devices have exceeded the specified floor life time of 72 h, they may be baked according IPC/JEDEC J-STD-033B at max. 90°C for less than 60 h.

Devices packaged in moisture-proof packaging should be stored in ambient conditions not exceeding temperatures of 40 °C or humidity levels of 90% r.h.

LSTM 300U modules have to be soldered within 6 months after delivery!

4.10 Tape & Reel specification





Tape running direction

4.11 Transmission range

The main factors that influence the system transmission range are type and location of the antennas of the receiver and the transmitter, type of terrain and degree of obstruction of the link path, sources of interference affecting the receiver, and "Dead" spots caused by signal reflections from nearby conductive objects. Since the expected transmission range strongly depends on this system conditions, range tests should categorically be performed before notification of a particular range that will be attainable by a certain application.

The angle at which the transmitted signal hits the wall is very important. The effective wall thickness – and with it the signal attenuation – varies according to this angle. Signals should be transmitted as directly as possible through the wall. Wall niches should be avoided. Other factors restricting transmission range:

- Switch mounted on metal surfaces (up to 30% loss of transmission range)
- Hollow lightweight walls filled with insulating wool on metal foil
- False ceilings with panels of metal or carbon fiber
- Lead glass or glass with metal coating, steel furniture

The distance between LSTM300U receivers and other transmitting devices such as computers, audio and video equipment that also emit high-frequency signals should be at least 0.5 m

5 AGENCY CERTIFICATIONS

LSTM 300U modules have been tested to fulfil the approval requirements for FCC/IC (LSTM 300U) based on the built-in firmware.

⚠ **When developing customer specific firmware based on the API for this module, special care must be taken not to exceed the specified regulatory limits, e.g. the duty cycle limitations!**

5.1 FCC (United States) Certification

LSTM 300U LIMITED MODULAR APPROVAL
This is an RF module approved for Limited Modular use operating as an intentional transmitting device with respect to 47 CFR 15.247(a-c) and is limited to OEM installation. The module is optimized to operate using small amounts of energy, and may be powered by a battery.
The module transmits short radio packets comprised of control signals, (in some cases the control signal may be accompanied with data) such as those used with alarm systems, door openers, remote switches, and the like.
The module does not support continuous streaming of voice, video, or any other forms of streaming data; it sends only short packets containing control signals and possibly data.
The module is designed to comply with, has been tested according to 15.247(a-c), and has been found to comply with each requirement.
Thus, a finished device containing LSTM 300U radio module can be operated in the United States without additional Part 15 FCC approval (approval(s) for unintentional radiators may be required for the OEM's finished product), under Magnum's FCC ID number. This greatly simplifies and shortens the design cycle and development costs for OEM integrators.
The module can be triggered manually or automatically, which cases are described below.

Manual Activation
The radio module can be configured to transmit a short packetized control signal if triggered manually. The module can be triggered, by pressing a switch, for example.
The packet contains one (or more) control signals that is(are) intended to control something at the receiving end. The packet may also contain data.
Depending on how much energy is available from the energy source, subsequent manual triggers can initiate the transmission of additional control signals. This may be necessary if prior packet(s) was(were) lost to fading or interference.
Subsequent triggers can also be initiated as a precaution if any doubt exists that the first packet didn't arrive at the receiver. Each packet that is transmitted, regardless of whether it was the first one or a subsequent one, will only be transmitted if enough energy is available from the energy source.

Automatic Activation
The radio module also can be configured to transmit a short packetized control signal if triggered automatically, by a relevant change of its inputs or in response to receiving a signal from another transmitter, for example. Again, the packet contains a control signal

that is intended to control something at the receiving end and may also contain data. As above, it is possible for the packet to get lost and never reach the receiver. However, if enough energy is available from the energy source, and the module has been configured to do so, then another packet or packets containing the control signal may be transmitted at a later time.

The device is capable to operate as a repeater, which can receive signals from the following list of FCC/IC approved transmitters, and retransmit the signals.

LSTM 300U: (902.875 MHz)

LSTM 300U	FCC ID:2ANUH-LSTM300U	IC:23260-LSTM300U
LTCM 300U	FCC ID:2ANUH-LSTM300U	IC:23260-LSTM300U
LTCM 310U	FCC ID:2ANUH-LSTM300U	IC:23260-LSTM300U

OEM Requirements

In order to use Magnum's FCC ID number, the OEM must ensure that the following conditions are met:

- End users of products, which contain the module, must not have the ability to alter the firmware that governs the operation of the module. The agency grant is valid only when the module is incorporated into a final product by OEM integrators.
- The end-user must not be provided with instructions to remove, adjust or install the module.
- The Original Equipment Manufacturer (OEM) must ensure that FCC labeling requirements are met. This includes a clearly visible label on the outside of the final product. Attaching a label to a removable portion of the final product, such as a battery cover, is not permitted. The label must include the following text:

LSTM 300U:

Contains FCC ID: 2ANUH-LSTM300U
The enclosed device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (i.) this device may not cause harmful interference and (ii.) this device must accept any interference received, including interference that may cause undesired operation.

When the device is so small or for such use that it is not practicable to place the statement above on it, the information required by this paragraph shall be placed in a prominent location in the instruction manual or pamphlet supplied to the user or, alternatively, shall be placed on the container in which the device is marketed. However, the FCC identifier or the unique identifier, as appropriate, must be displayed on the device.

The user manual for the end product must also contain the text given above.

- The module must be used with only the following approved antenna(s):

Part Number	Type	Gain
N.A.	Wire/Monopole	1.0 dBi
ANT-916-CW-RCS	RP-SMA Antenna	3.3 dBi
ANT-916-CW-HWR-RPS	RP-SMA Antenna	1.2 dBi

5.2 FCC (United States) Regulatory Statements

This device complies with part 15 of the FCC rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. Any changes or modifications not expressly approved by manufacturer could void the user’s authority to operate the equipment.

IMPORTANT! Any changes or modifications not expressly approved by the party responsible for compliance could void the user’s authority to operate this equipment.

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/ TV technician for help.

5.3 ISED (former Industry Canada) Certification

In order to use Magnum’s IC number, the OEM must ensure that the following conditions are met:

- Labeling requirements for Industry Canada are similar to those required by the FCC. The Original Equipment Manufacturer (OEM) must ensure that IC labeling requirements are met. A clearly visible label on the outside of a non-removable part of the final product must include the following text:

  STM 300U:
  Contains IC: 23260-LSTM300U
  Contient le module d'émission IC: 23260-LSTM300U

- The OEM must sign the OEM Limited Modular Approval Agreement with Magnum

Pour utiliser le numéro IC Magnum, le OEM doit s'assurer que les conditions suivantes sont remplies:

- Les exigences d'étiquetage pour Industrie Canada sont similaires à ceux exigés par la FCC. Le fabricant d'équipement d'origine (OEM) doit s'assurer que les exigences en matière d'étiquetage IC sont réunies. Une étiquette clairement visible à l'extérieur d'une partie non amovible du produit final doit contenir le texte suivant:

  LSTM 300U:
  Contains IC: 23260-LSTM300U
  Contient le module d'émission IC: 23260-LSTM300U

- L'OEM doit signer l'accord OEM limitée Approbation modulaire avec Magnum

5.4 ISED (former Industry Canada) Regulatory Statements

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

IMPORTANT! Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate this equipment.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, meme si le brouillage est susceptible d'en compromettre le fonctionnement.

IMPORTANT! Tous les changements ou modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actioner cet équipment.

This Class B digital apparatus complies with Canadian ICES-003.
Cet appareil numérique de la classe B est conforme à la norme NMB-003 du Canada