SL900A

Smart Sensory Tag Chip for Monitoring and Data Logging

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Agenda

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- Application cases – sensory tags
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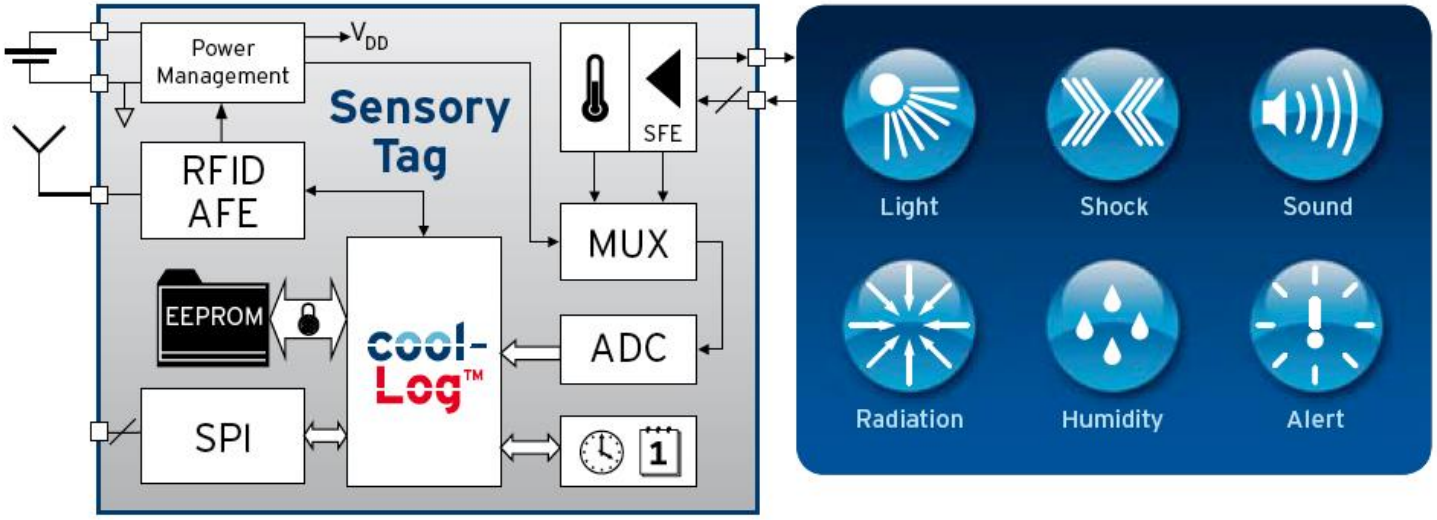
- SL900A – Analogue Sensor Front-End
- SL900A – A/D Converter
- SL900A – Antenna Front-End
- SL900A – Real Time Clock
- SL900A – Internal Memory
- SL900A – Logging Operation
- SL900A – Shelf Life Alert
- SL900A – Password Protection
- SL900A – SPI Interface
- SL900A – Demo Kit

RFID sensory tags

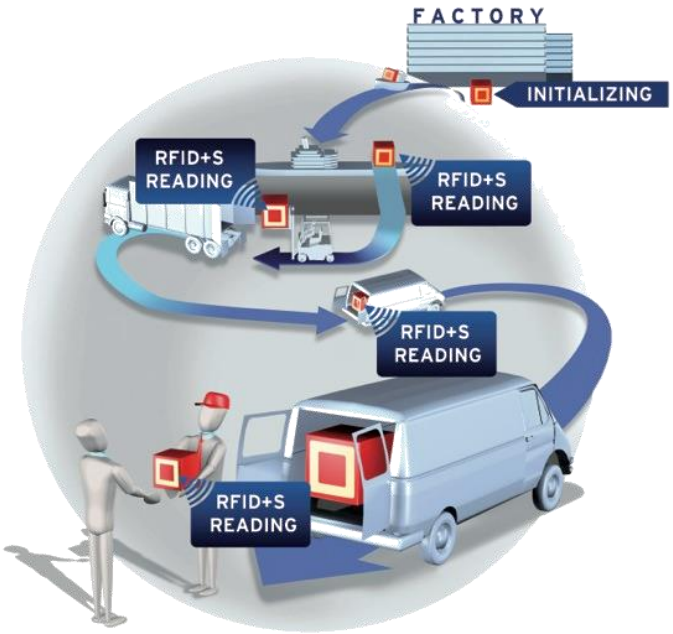
The curriculum vitae of things

- Unique ID
- Provide information about environmental conditions to which the object has been exposed.
- Work in fully passive mode as well as in battery-assisted passive mode.
- A battery is used to support autonomous data logging with the on-chip RTC.



RFID sensory tags

Markets & applications



Markets

- Medical
- Supply and Cold Chain
- Industrial Automation
- Constructions and Automotive

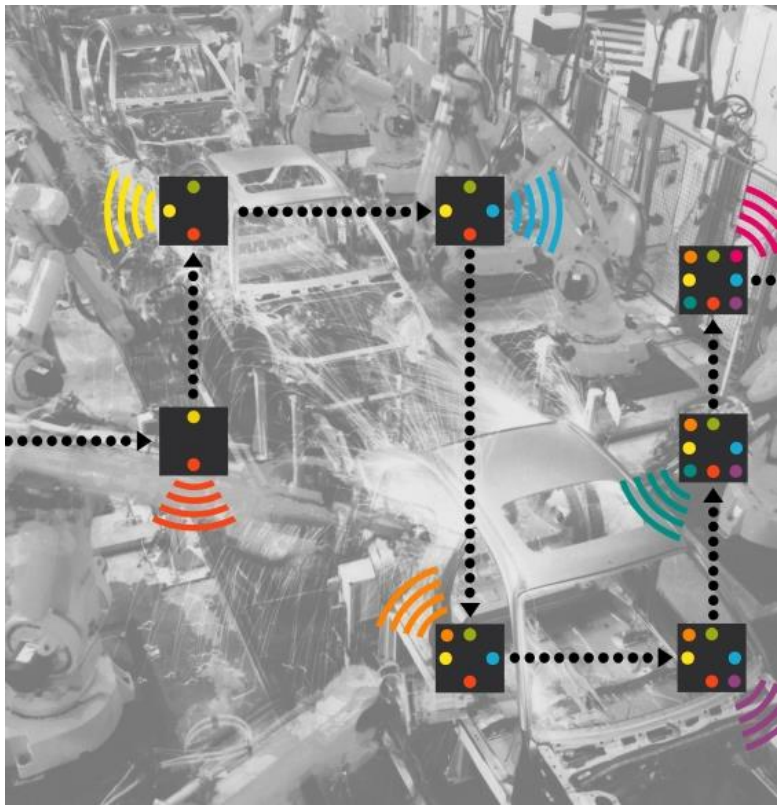
Applications

- Tracking and recording of medication
- Monitoring transportation
- Process control in factory automation
- Tracking condition and history of constructions (buildings, bridges, roads, etc.)
- Contactless metering
- Tire pressure monitoring systems (TPMS)
- Environmental monitoring

Emerging Market: Enriching RFID with sensors opens new horizons revealing new intriguing applications

Application cases – sensory tags

Process control in factory automation



- Tags control processes and their quality
- Controlling the quality of each step of the process makes manufacturing more efficient compared to relying on a final quality control of the finished product alone
- Sensory tags enable optimization of each process step to ensure best utilization of factory equipment

Application cases – sensory tags

Tire pressure monitoring system - TPMS

- Direct tire pressure monitoring systems measure, identify and warn the driver of low pressure
- Warnings based upon rapid air loss caused by a puncture
- Warnings based upon gradual air loss over time

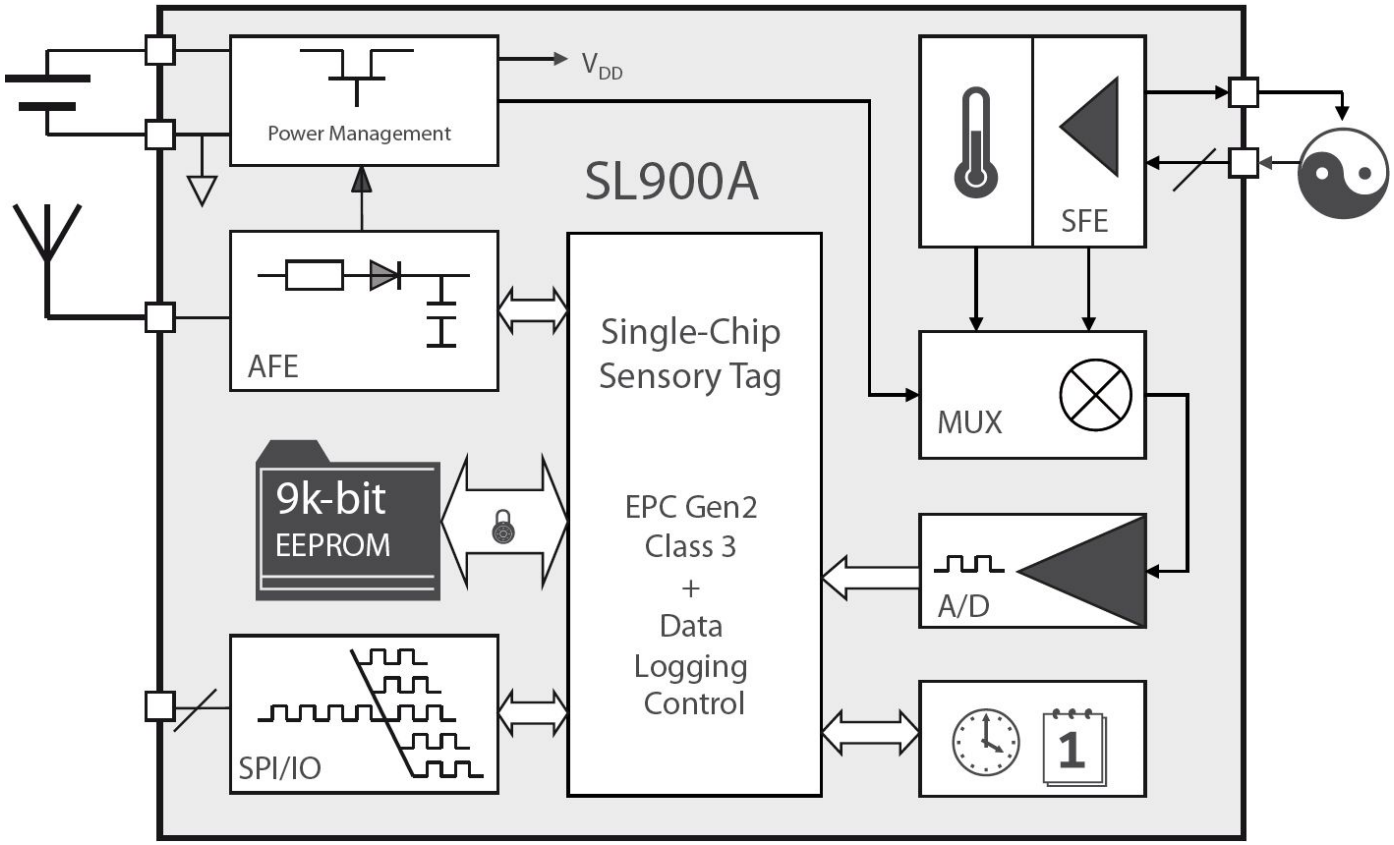
Emerging Market: Enriching RFID with sensors opens new horizons revealing new intriguing applications

SL900A – key facts

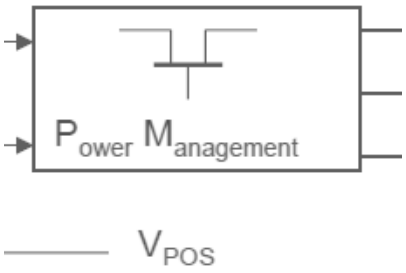
- Compatible with EPC Gen2 + Custom Command: cool-Log™
- Battery Assisted (1.2V to 3.6V) or Passive Tag
- Analog Input for various external sensor types
- 9k-bit EEPROM →max. 841 data points
- On-chip temperature sensor: -40°C to 125°C
- RTC (real-time clock) for time-stamp + Alarm function for shelf-life monitoring
- Event-driven alerts
- 10-bit dual slope A/D Converter
- User data protection with 3-level password
- SPI Interface → for control and register settings and fast communication with reader
- Energy harvesting to support external circuitry

SL900A – block diagram

Important internal building blocks



SL900A – Power management



Battery voltage range: 1.2V to 3.6V

Internal supply

- VDD = VBAT or VPOS (rectified RF)
- VREF (Vo2) = 310 mV (default), programmable from 260 mV to 610 mV

Supply for external circuitry:

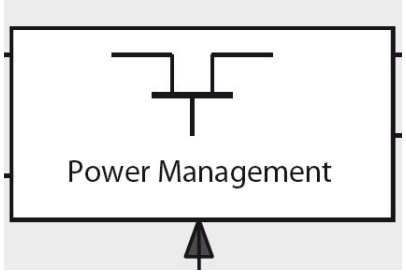
- EXC: VBAT / 400 Ω (enabled when external Log Flag is set or active alert)
  - supply external sensors or drive shelf-life expire alert LED

Typical current consumption (@1.5V):

- I_{BAT_SHTD} = 0.1 µA (typical leakage current)
- I_{BAT_OP} = 200 µA (SPI -, ready -, and logging mode)
- I_{BAT_ACT} = 1.6 µA (RTC running and sensor standby)
- I_{BAT_INT} = 2.5 µA (RTC running and external sensor in interrupt mode)

SL900A – Power management

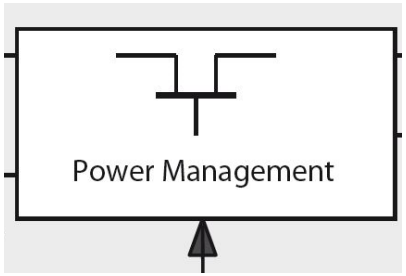
Passive Mode



- Authorized reader initiates the logging
- Sensor-data is stored in the Reader and/or SL900A (PW-protected)
- No battery (power from reader field)
- Real-time clock (RTC) disabled (time-stamp by reader)
- Lifetime virtually unlimited

SL900A – Power management

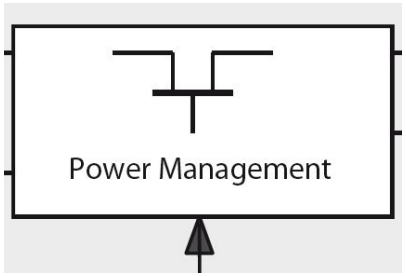
Semi-Passive Mode



- (BAP = Battery-Assisted Passive)
- SL900A performs automatic logging
- Programmed measurement intervals
- 1.5V or 3V battery is needed
- Real-time clock enabled (autonomous time-stamp)
- Lifetime depending on battery and logging intervals, typically 1 to 1.5 years
- Battery is exhausted still working in passive mode (keeping data)
- More Range

SL900A – Power management

Semi-Passive Mode



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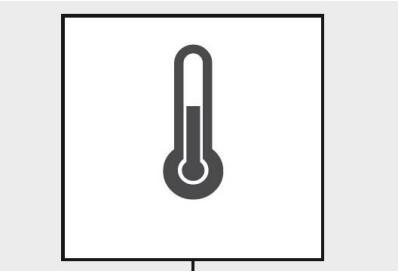
- More Range

SL900A – internal temperature sensor

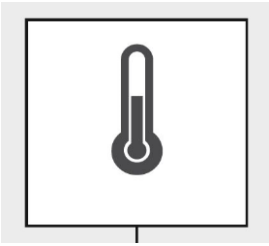
Basics



- Sensor Temperature Range → -20°C to +60°C (-40°C to +125°C)
- Resolution (default) → 0.18°C
- Temperature Range and Resolution User-definable
- Non-linearity → ±0.5°C
- Accuracy → ±1°C
- One-point calibration → +35°C
- Calibration Data → EEPROM

SL900A – Internal temperature sensor

Range and Resolution



Vo1 [mV]	V_{REF} [mV]
160	260
210	310
260	360
310	410
360	460
410	510
-460	560
510	610

$$T[^\circ C]=(V_{REF}\,[mV]*(Code+1024)-Code*Vo1[mV])/(1024*1.686)-273.15$$

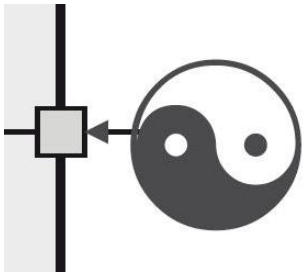
- Vo1 can be switched to GND

Example: Vo1 = 210mV; V_{REF} = 410mV

- V_{REF} defines lowest temperature value → $T_{min}[^\circ C]=410/(1.686)-273.15=-29.97^\circ C$
- Max. Temp. (10 bit □ Codemax =1023) → $T_{max}[^\circ C]=(410*(1023+1024)-1023*210)/(1024*1.686)-273.15=88.54^\circ C$
- Range: $Tmax-Tmin=88.54^\circ C+29.97^\circ C=118.51^\circ C$
- Resolution: $Range/(10\ Bit)=\ (118.51)/1024=0.115$°C

SL900A – Analogue sensor front-end

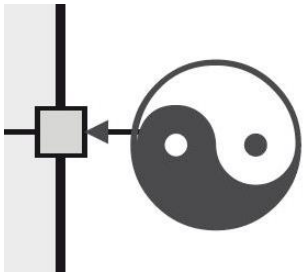
External Sensors



- Security (e.g. sealed package)
- Shock (e.g. from an accelerometer)
- Humidity (e.g. JLC International HC105)
- Pressure (e.g. Tekscan A201)
- Radiation
- Motion (e.g. ball-in-tube or MEMS accelerometer)
- Light (e.g. Hamamatsu RGB sensor S10170)
- Sound
- Event
- …

SL900A – Analogue sensor front-end

External Sensor Types



Two inputs for external analogue sensors can work with different types of sensors:

EXT1 input:

- Resistive with linear resistance
- Resistive without DC voltage (AC excitation)
- Capacitive with DC voltage (excitation with DC current)
- Capacitive without DC voltage (AC excitation)

EXT2 input

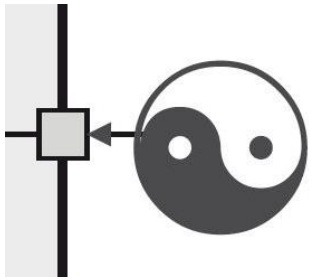
- Resistive with linear conductance
- Optical sensors (photo diode)
- Current source sensors
- Voltage source sensors

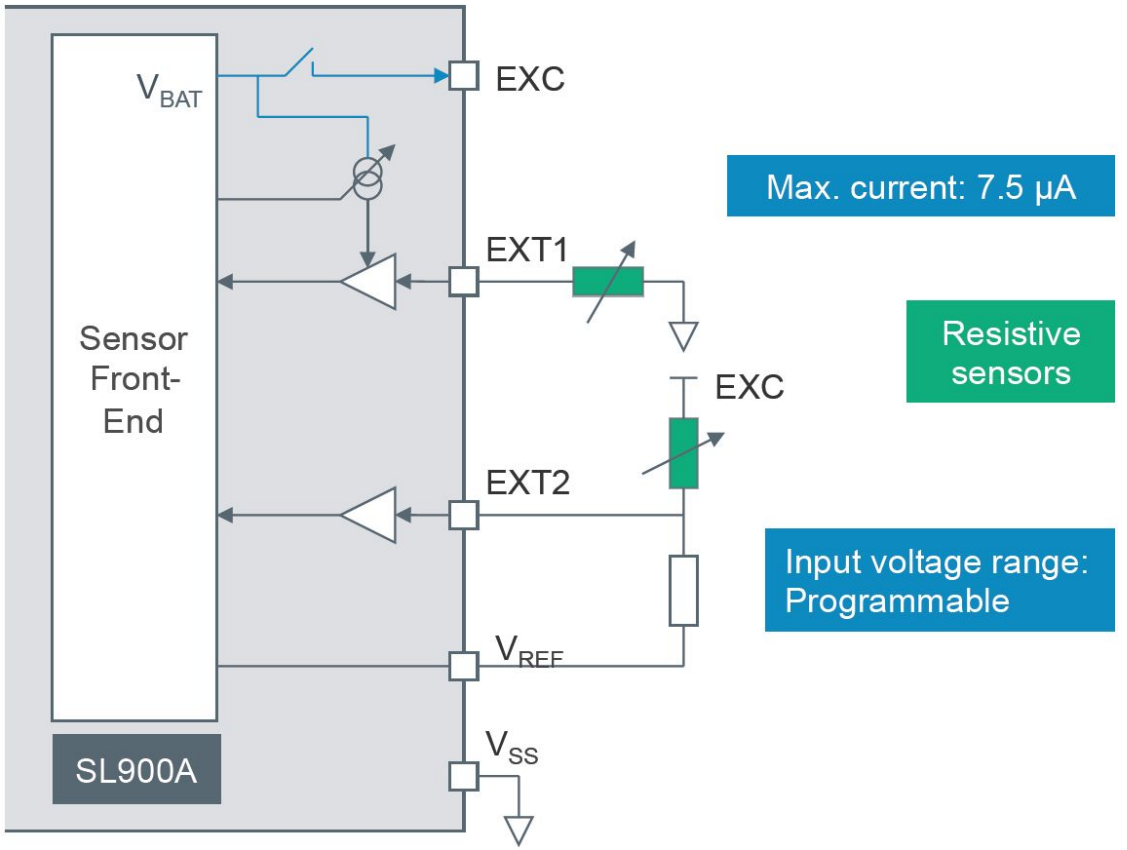
EXT1 + EXT2 inputs

- Resistive bridge

SL900A – Analogue sensor front-end

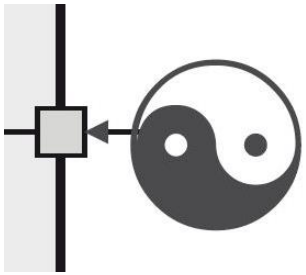
Voltage / Current Source Sensor Types

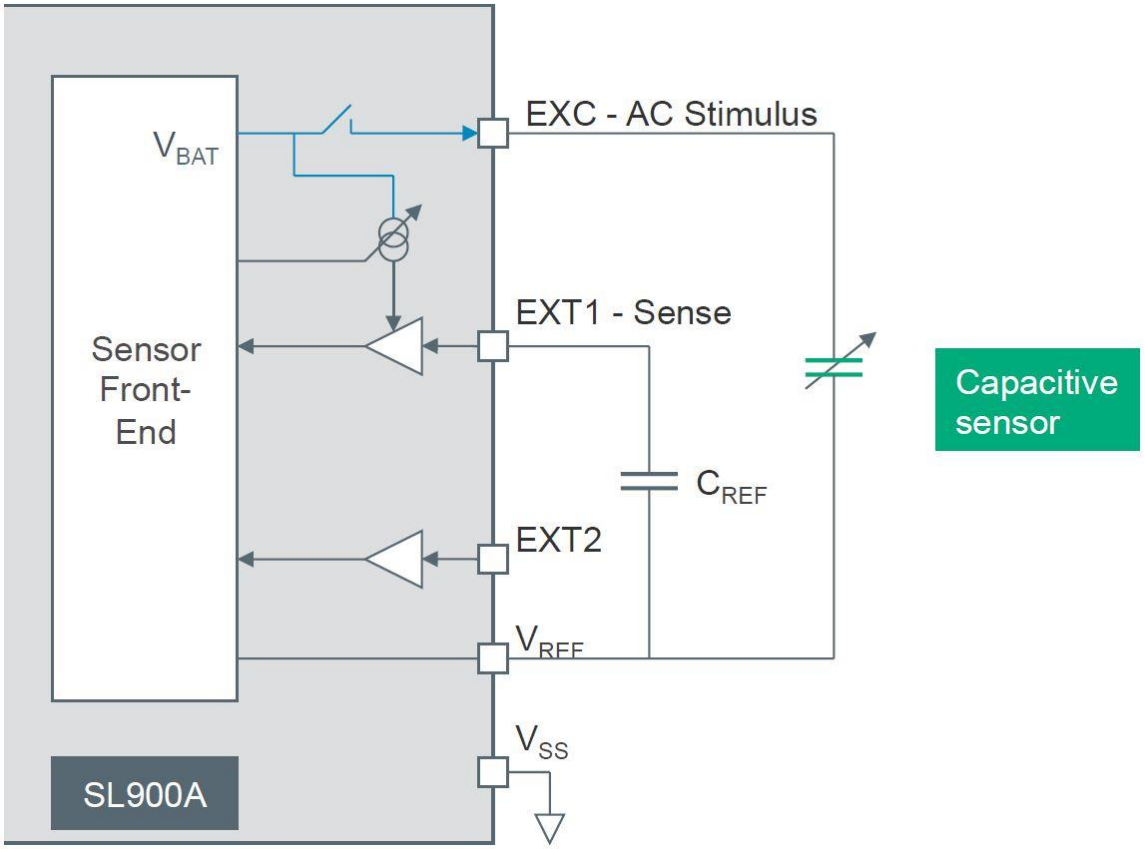




SL900A – Analogue sensor front-end

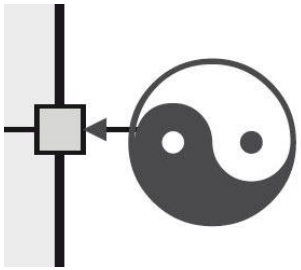
Capacitive Sensors

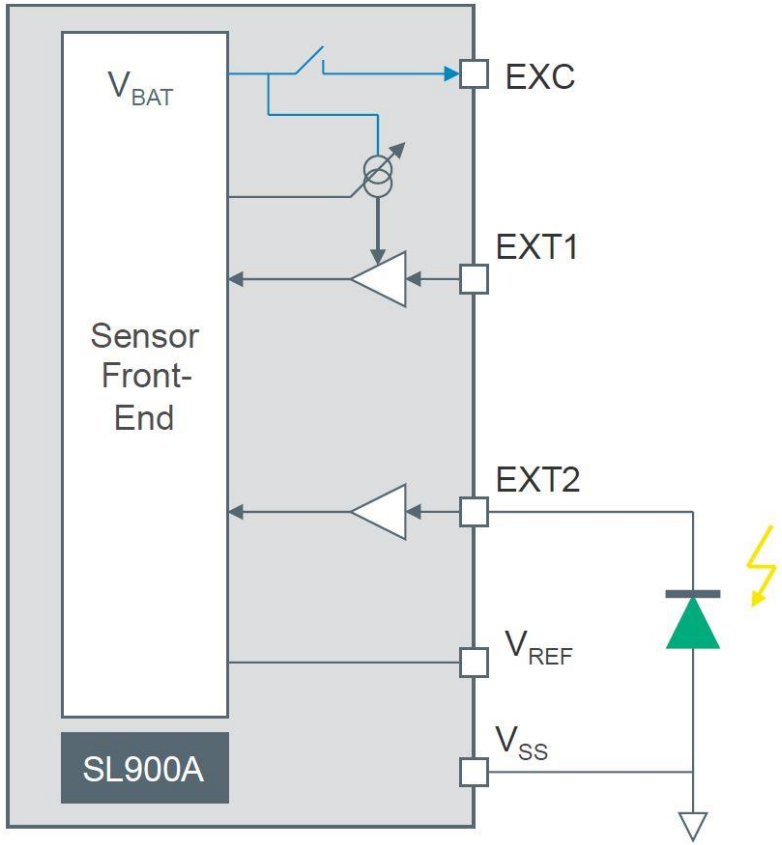




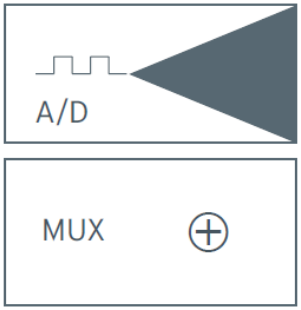
SL900A – analogue sensor front-end

Optical Sensors





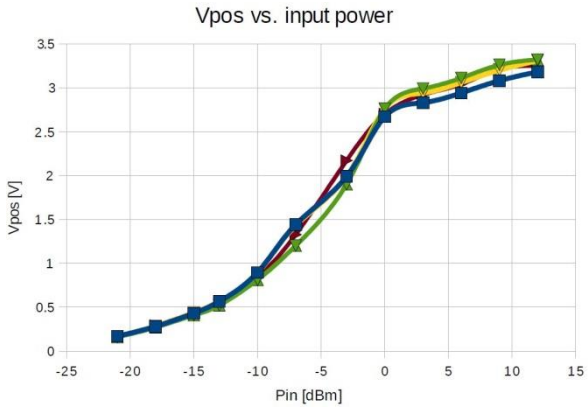
SL900A – A/D converter

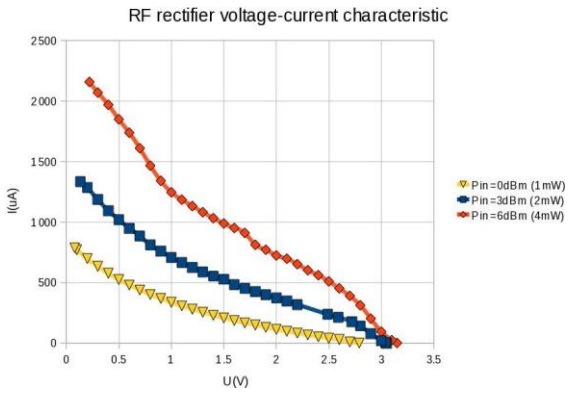


- 10- bit dual slope AD converter
- Conversion Time: 2 ms
- Adjustable full scale range (with selectable voltage references – Vo1 & VREF)
- Multiplexed inputs:
  - EXT1: External Sensor Input 1
  - EXT2: External Sensor Input 2
  - Internal Temperature Sensor
  - Battery Voltage Level
- Selected sensors will be processed and logged sequentially (1-2-3-4)

SL900A – Antenna front-end

Basics

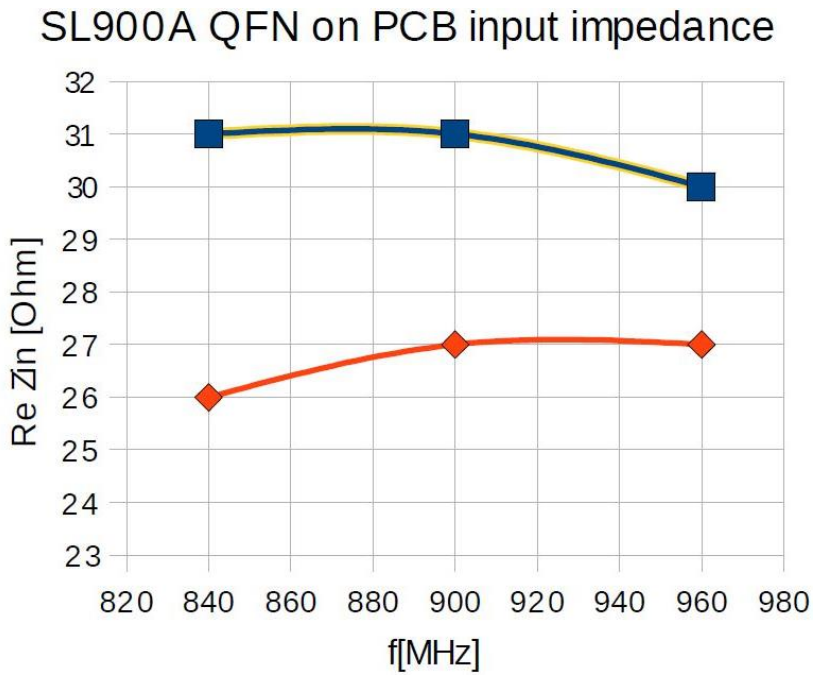


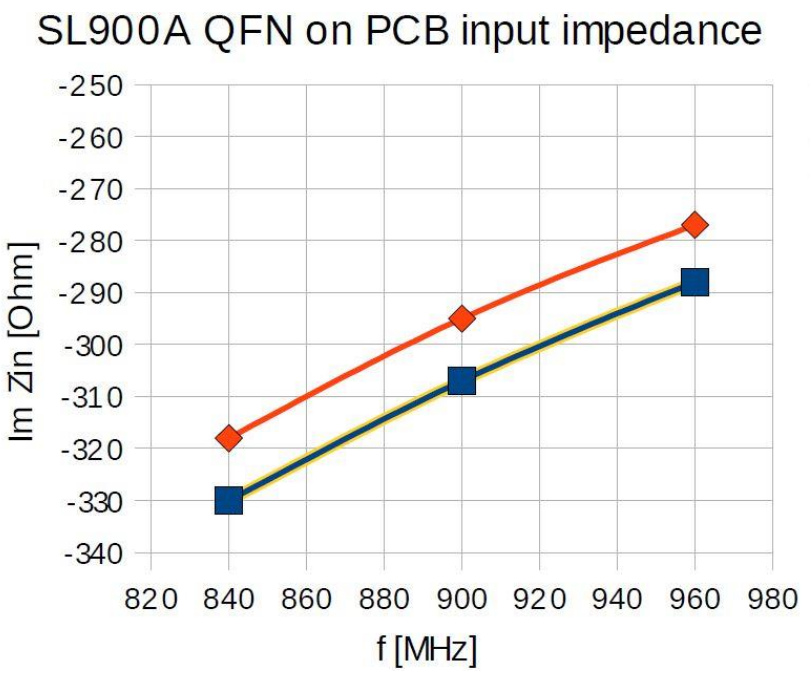


- Frequency: 840 - 960 MHz
- EPC Gen2 (ISO 18000-6C) compliant
- Data Rates:
  - Forward (reader-to-tag): 160 kbps
  - Backward (tag-to-reader): 640 kbps
- The rectifier bridge is using Schottky diodes for best usage of power from the reader field.
- Semi-passive mode, the range extended by approximately 30% due to additional power

SL900A – Antenna front-end

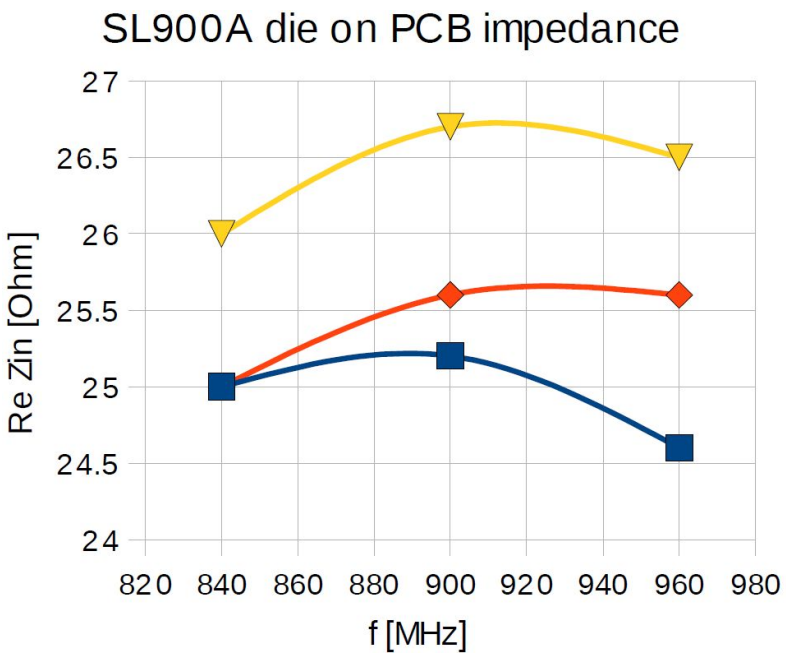
Input Impedance - QFN

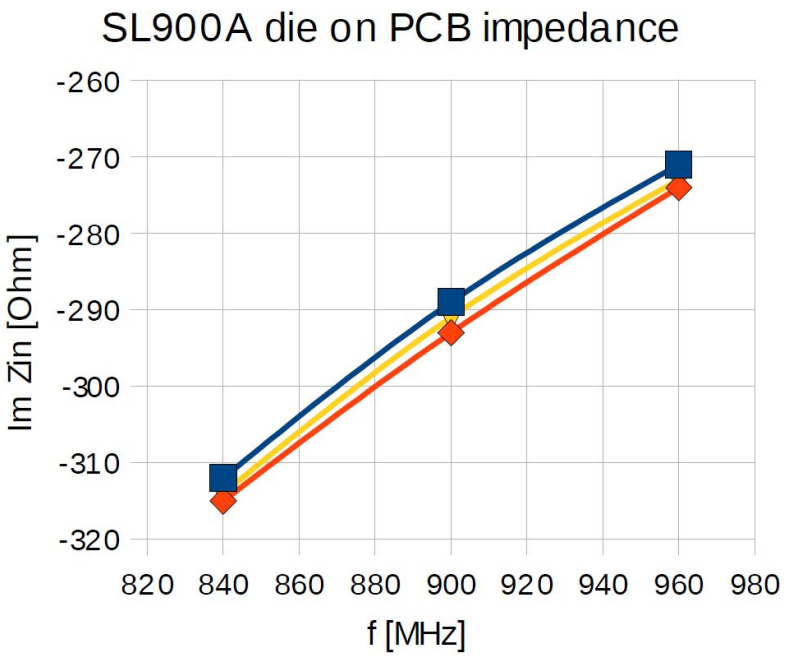




SL900A – Antenna front-end

Input Impedance - DIE





SL900A – Real time clock

Time stamp with RTC

- Only enabled with battery (semi-passive mode)
- Programmable intervals from 1 sec. to 8 hours
- Accuracy: +/- 3%
- Typical current consumption: 1.6 µA
- RTC is started by the START-LOG command
- Start time programmed in UTC format (32 bits)
- Time Stamp = start time + delay time + interval * event number

SL900A – Internal memory

Basics

Size 9k bit (1152 x 8)

Erase/write cycles: 100,000 (read unlimited)

Data retention time:

- 600 years @ 70°C
- 10 years @ 125°C

5 Memory areas:

1. Bank x: System Memory (64 bytes)
2. Bank 0: Reserved Memory (8 bytes)
3. Bank 1: PC + EPC Memory (18 bytes + 2 RAM bytes)
4. Bank 2: TID (10 bytes)
5. Bank 3: User/Measurement Memory (1052 bytes)

SL900A – Internal memory

Memory Areas

System Memory:

- 64 bytes
- Physical Address: 0x000 – 0x03F
- Contains device settings + SL900A-Passwords

Reserved Memory:

- 8 bytes
- Physical Address: 0x040 – 0x047
- Contains Gen2 Passwords (Access & Kill)

PC + EPC Memory:

- 18 bytes + 2 RAM-bytes
- Physical Address: 0x048 – 0x059
- RAM-bytes used for CRC-16
- PC = 2 bytes

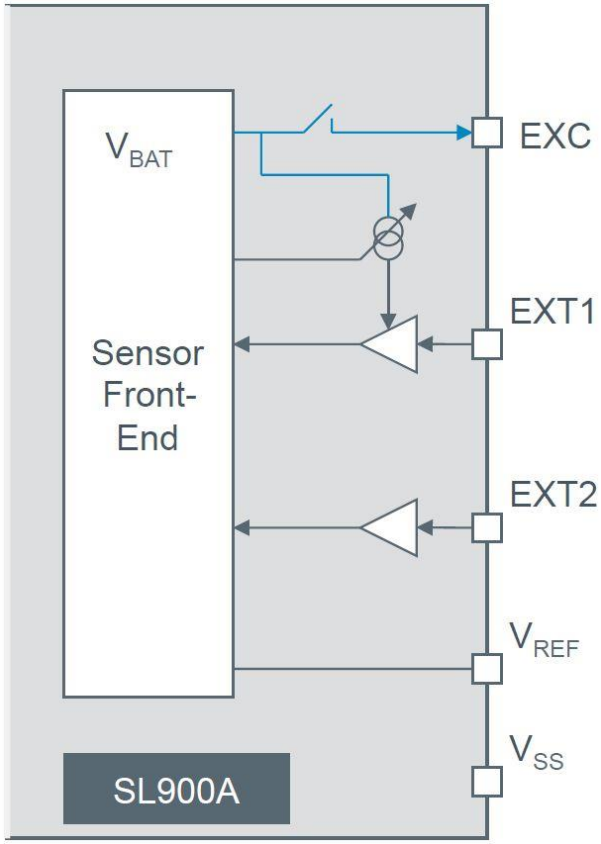
TID Memory:

- 10 bytes
- Physical Address: 0x05A – 0x063

User/Measurement Memory:

- 1052 bytes
- Physical Address: 0x064 – 0x47F

SL900A – logging operation



Sensor options:

- Internal temperature sensor,
- Battery voltage
- 2 external sensors

Shelf-Life alert

- Selectable for all sensors

Event triggered alarm/interrupt

- External sensors (EXT1/2)
- With all logging modes

Logging modes (all sensors)

- Dense (semi-passive)
- Out-of-Limit (semi-passive)
- Limit-Crossing (semi-passive)
- Direct with reader (passive)

SL900A – logging operation

Logging Modes

Dense mode (semi-passive):

- All values are stored into the EEPROM
- No Time Stamp or Measurement Number

Limit Modes:

- Out-of-limit mode (semi-passive):
  - All values that are out of the specified limits are stored
- Limit-crossing mode (semi-passive):
  - Only the crossing point of each limit boundary is stored

Event-triggered mode (semi-passive):

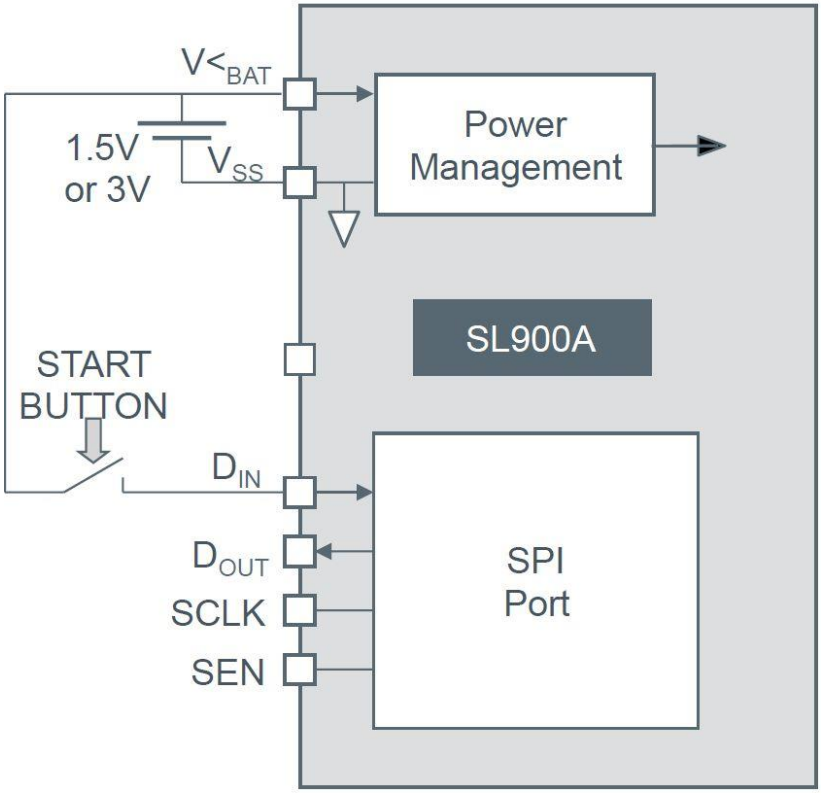
- Interrupt from external sensor inputs (EXT1 and EXT2)
- Time stamp in seconds relative to start time
- Sensor(s) to be logged upon an interrupt is programmable

Direct logging with reader (passive):

- Measured values are stored in reader and/or in SL900A
- Time stamp by reader

SL900A – logging operation

Logging Start Procedures



- The logging operation can be started immediately by the reader through Start Log command
- Delayed Start:
  - Defined delay time
  - Manually delayed with a start button
- The delay time has a resolution of 8 minutes and 32 seconds
- The maximum delay time is 582 hours (~24 days).

SL900A – logging operation

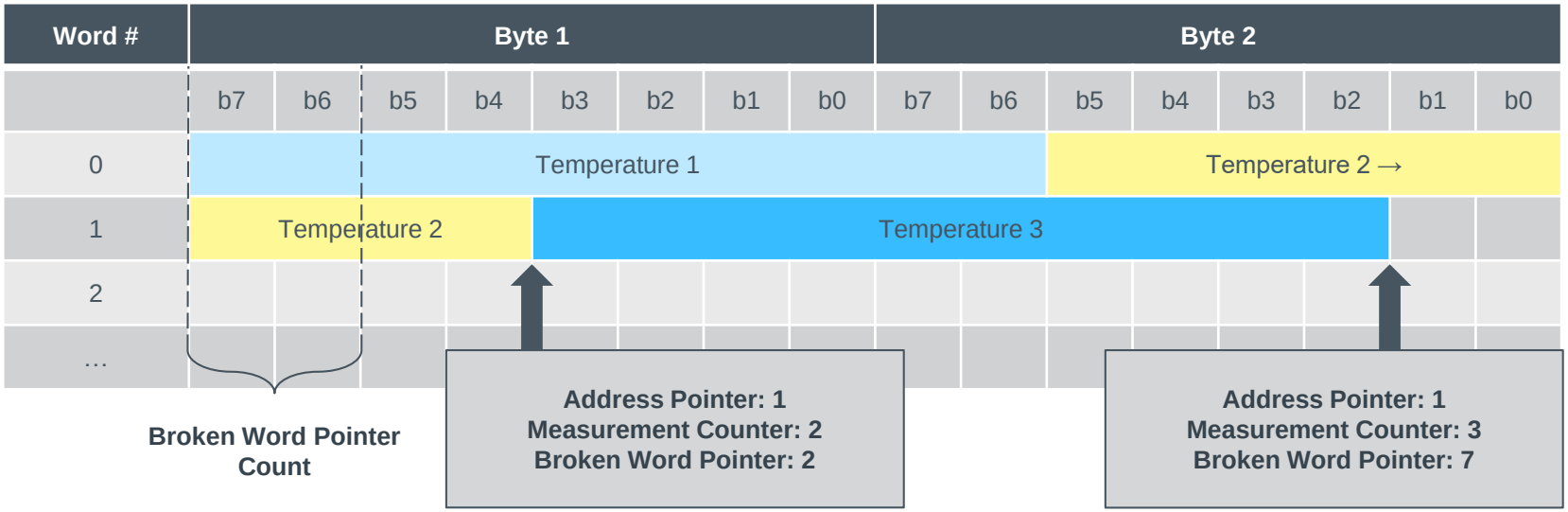
Dense Mode – Internal Temperature only

“Problem”: 10 bit sensor values & byte organized memory

→ organize in Word and introduce

- Address Pointer: Indicates the Word # to append new data
- Measurement Counter: Number of measurements
- Broken Word pointer: Counted from MSB of the Word in 2-bit steps

No measurement number is logged



SL900A – logging operation

Dense Mode – all Sensors

- One measurement cycle requires 3 Word in the Measurement Memory
- Seti[4:0]: Current source value
- Rang[4:0]: Resistor feedback ladder
- No measurement number is logged

Word #	Byte 1								Byte 2							
	b7	b6	b5	b4	b3	b2	b1	b0	b7	b6	b5	b4	b3	b2	b1	b0
0	1	Range: seti[4:0]							External Sensor 1							
1	1	Range: rang[4:0]							External Sensor 2							
2	Battery Voltage Level								Internal Temperature Measurement							
…																

SL900A – logging operation

Limit Mode – with Internal Sensors

- In case only internal sensors are activated 2 Words are filled at one measurement cycle
- A 32-bit wide measurement number is logged

Word #	Byte 1								Byte 2							
	b7	b6	b5	b4	b3	b2	b1	b0	b7	b6	b5	b4	b3	b2	b1	b0
0	Battery Voltage Level								Internal Temperature Measurement							
1	Measurement Number															
2																
…																

SL900A – logging operation

Limit Mode – with external Sensors

- Logging in limit mode is different when using external sensors
- One measurement cycle requires 4 Word in the Measurement Memory
- Seti[4:0]: Current source value
- Rang[4:0]: Resistor feedback ladder
- A Measurement Number is logged

Word #	Byte 1								Byte 2							
	b7	b6	b5	b4	b3	b2	b1	b0	b7	b6	b5	b4	b3	b2	b1	b0
0	1	Range: seti[4:0]							External Sensor 1							
1	1	Range: rang[4:0]							External Sensor 2							
2	Battery Voltage Level								Internal Temperature Measurement							
3	Measurement Number															
…																

SL900A – logging operation

Interrupt Mode – with external Sensors

- One measurement cycle requires 5 Word in the Measurement Memory
- Seti[4:0]: Current source value
- Rang[4:0]: Resistor feedback ladder
- RTC values are stored as well

Word #	Byte 1								Byte 2							
	b7	b6	b5	b4	b3	b2	b1	b0	b7	b6	b5	b4	b3	b2	b1	b0
0	1	Range: seti[4:0]							External Sensor 1							
1	1	Range: rang[4:0]							External Sensor 2							
2	Battery Voltage Level								Internal Temperature Measurement							
3	Higher - Real Time Clock Value															
4	Lower - Real Time Clock Value															
…																

SL900A – logging operation

- Measurement Memory 1052 bytes
  - 8416 bits
  - 526 Words
- If shelf life is activated 32 events less are available

Selected Sensor	Dense	Limit	Event Triggered
Only Temperature	841	263	175
Temperature + Battery	526	263	175
1 External Sensor	526	263	175
Temperature + 1 External	263	175	131
Temperature + 1 External + Battery	263	175	131
2 External Sensors	263	175	131
Temperature + 2 External Sensors	175	131	105
All 4 Sensors	175	131	105

SL900A – logging operation

Storage Rule

Normal:

- Logging is stopped when measurement memory is filled up
  - Memory Full → Indicated by status flag
  - Timer for measurement interval is still active and measurement number is increased

Rolling:

- If not enough Words are left in the memory → Memory full
- Memory full → device starts over and overwrites old data
- Status flag for measurement memory full & data overwritten
- Counter for number of memory replacements is increased → full → logging stopped

SL900A – Logging Operation

Storage Rule

Normal:

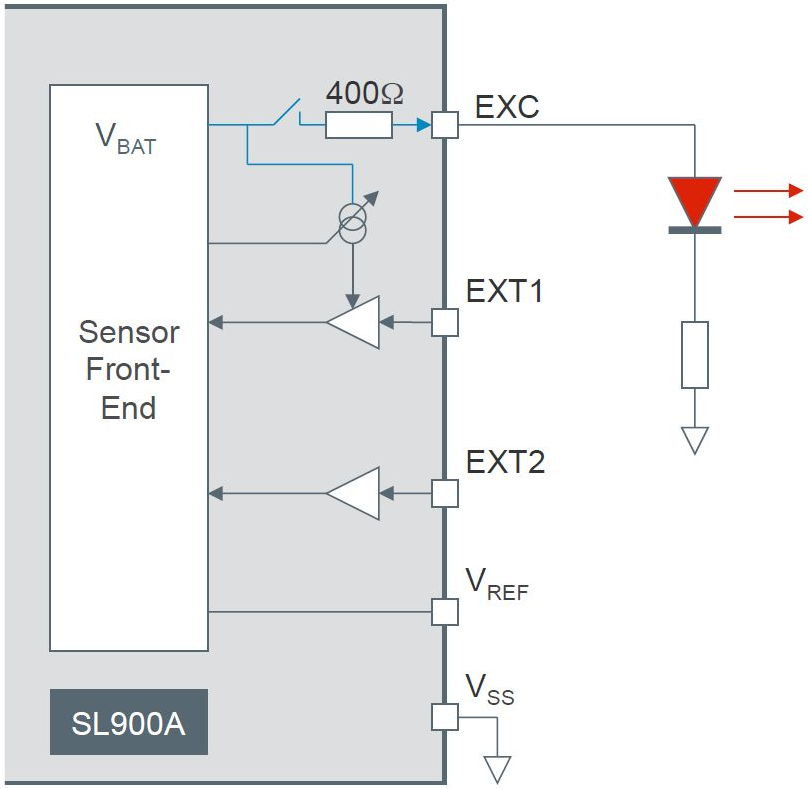
- **Logging is stopped when measurement memory is filled up**
  - Memory Full → Indicated by status flag
  - Timer for measurement interval is still active and measurement number is increased

Rolling:

- **If not enough Words are left in the memory → Memory full**
- **Memory full → device starts over and overwrites old data**
- **Status flag for measurement memory full & data overwritten**
- **Counter for number of memory replacements is increased → full → logging stopped**

SL900A – shelf life alert

Storage Rule



- Shelf life algorithm calculates dynamically the remaining shelf life of the product.
- The shelf-life algorithm is look-up table based and can be used with all sensor types.
- Look-up table (64 bytes) is located at the beginning of the User/Measurement Memory.
- Look-up table needs to be reserved as User memory by the Initialize command
- The EXC pin is pulled high when shelf-life expires!
- This signal can be used as an interrupt or can drive a LED
- Use a 3V battery to drive a LED.
- The EXC driver resistance is 400Ω

SL900A – password protection

- 3 separate passwords for EEPROM memory areas
- System memory area
- User memory area
- Measurement memory area
- Each 32 bit password is divided into two 16-bit passwords:
  - Lower 16 bits: Write protection
  - Higher 16 bits: Read/Write protection
- Data can be secured with permanent lock:
  - Data in the EEPROM cannot be changed (not even with password)
  - Data (EPC, TID and user area) can be read
- Passwords not active for SPI interface

SL900A – SPI interface

- Slave or I/O
- Main purpose:
  - Initialize the chip
  - Parameter setting
  - Alternative execution of commands
- Additional functions
  - Command for fast communication between a microcontroller (connected to SPI port) and an RFID reader (using on-chip 8-byte FIFO)
- I/O functions
  - Digital input for Start-Logging button

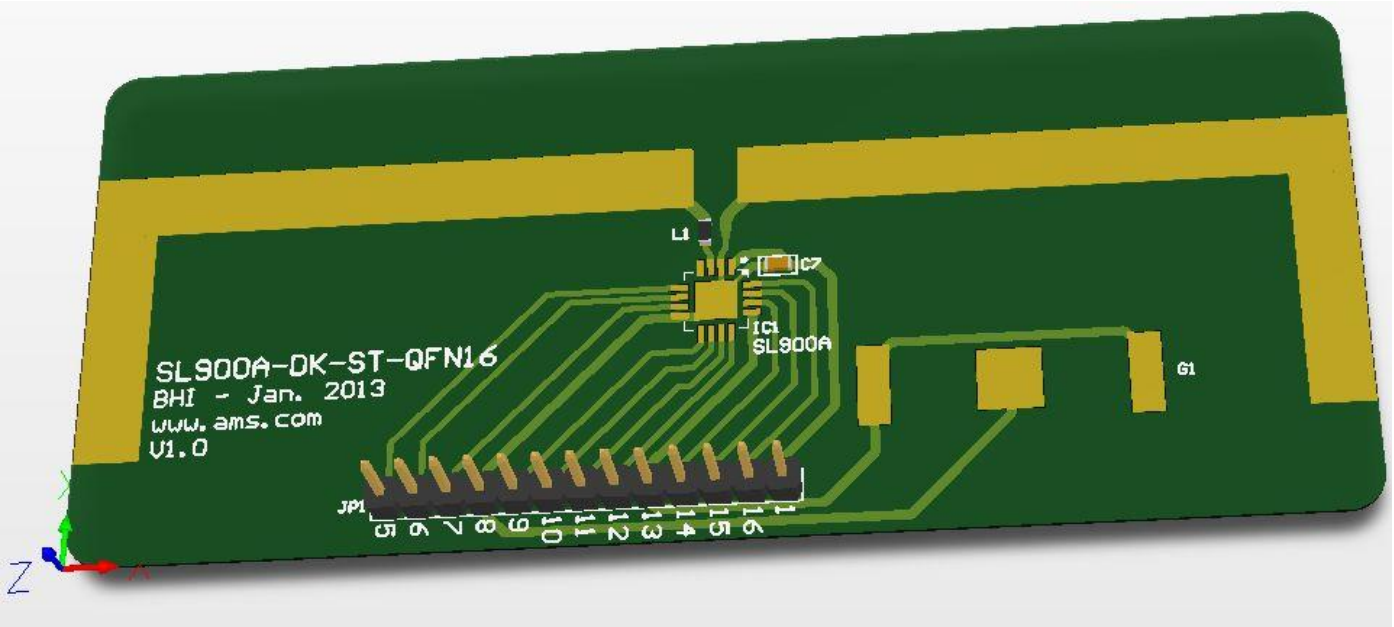
SL900A – Demo Kit

Webshop

- Demo Kits are available
- Ordering Code: SL900A-DK-STQFN16
- Kit Contents:
  - SL900A PCB
  - 3V Battery
  - USB Stick with documentation
  - PCB Design Files
  - Android App
  - GUI SW for AS3911 GP Demo Reader

SL900A – Demo Kit

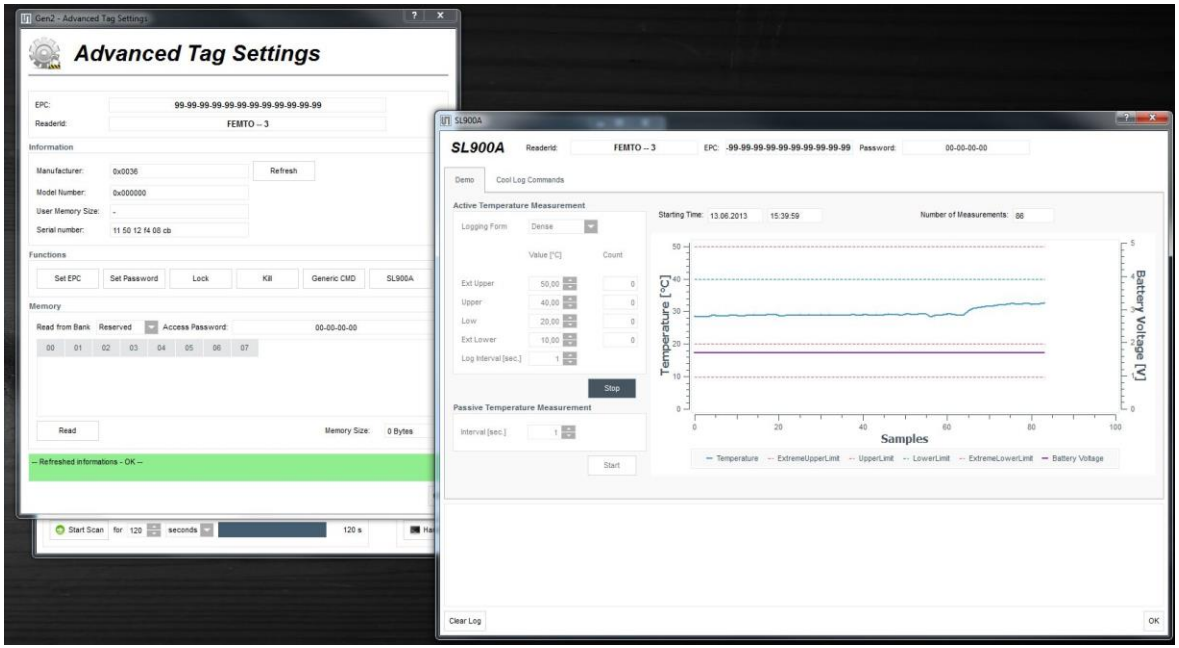
PCB

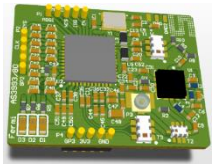


SL900A – Demo Kit

Reader (VCD)

- AS3993 Femto/ Fermi Demo Reader HW/SW:
- AS3992 Readers not implemented yet





SL900A – Demo Kit

Available Collateral

Documentation and Source files available on the Product Portal and FTP server :

	Username	Password
www.space4ams.at/user/SL900A/default.php	SL900a	5U900a2qwD

Thank you

Please visit our website www.ams.com