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SL900A

EPC Class 3 Sensory Tag Chip - For Automatic Data Logging

General Description

The SL900A is an EPCglobal Class 3 sensory tag chip optimized for single-cell and dual-cell, battery-assisted smart labels with sensor functionality. The chip is ideal for applications using thin and flexible batteries but can also be powered from the RF field (electromagnetic waves from an RFID reader).

The chip has a fully integrated temperature sensor with a temperature range -40°C to 90°C. The external sensor interface provides a flexible way of adding additional sensors to the system and supports up to 2 external sensors.

Ordering Information and Content Guide appear at end of datasheet.

Key Benefits & Features

The benefits and features of SL900A, EPC Class 3 Sensory Tag Chip - For Automatic Data Logging are listed below:

Figure 1:
Added Value of Using SL900A 4

Benefits	Features
• Versatile temperature and data logging	• Operating temperature range: -40°C to 125°C
• Temperature sensor on chip	• Temperature range -40°C to 90°C
• Worldwide EPC compliant	• Frequency: 860 to 960 MHz
• Works fully passive or in BAP mode	• Battery supply: 3V or 1.5V

• Programmable logging modes with various sensors	• Data logging from:
	  • On-chip temperature sensor
	  • 2 external sensors

• Works with EPC readers	• EPC Class 1 and Class 3 compliant
• Provides supply for external sensors	• Energy harvesting from reader field
• Autonomous data logging with timestamp	• Real-time clock for data logging
• Sensor alert function	• External sensor interrupt capability
• Supports fast communication via slave SPI	• Serial peripheral interface

Benefits	Features
• Storage up to 841 temperature measurements	• On-chip 9kbit EEPROM
• Alert for shelf life expiration	• Integrated dynamic shelf life calculation
• Programmable sensor limits	• Advanced logging with 4 user-selectable limits
• Package options	• 16-pin QFN (5mm x 5mm), engineering sample only • Tested sawn wafer on foil (8”)

Applications

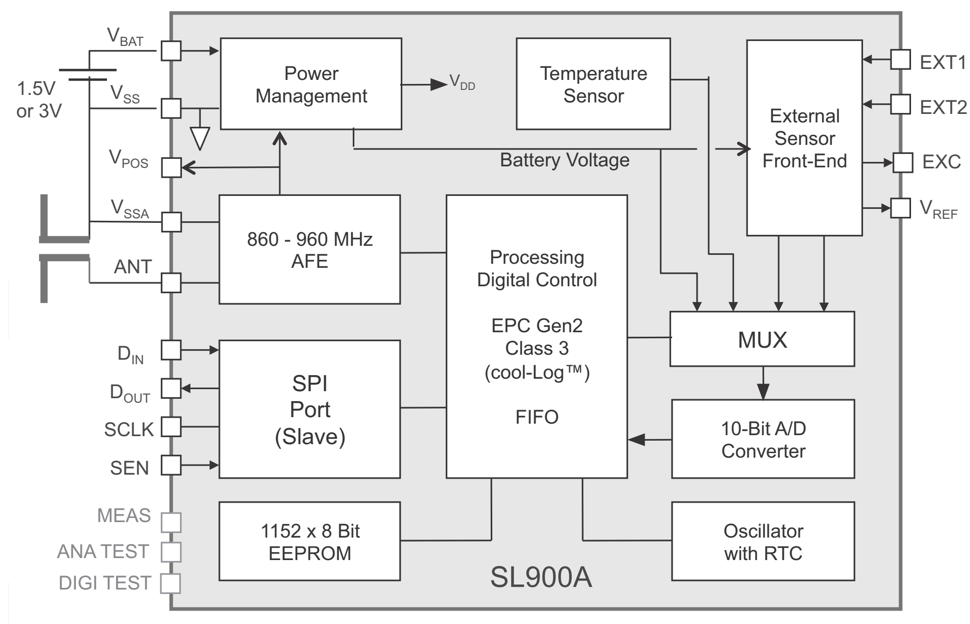
The SL900A device is ideal suited for:

- Monitoring and tracking of temperature-sensitive products
- Temperature monitoring of medical products
- Pharmaceutical logistics
- Monitoring of fragile goods transportation
- Dynamic shelf life applications
- RFID to SPI interface

Block Diagram

The functional blocks of this device are shown below:

Figure 2:
SL900A Block Diagram



SL900A Block Diagram: Basic block diagram of SL900A

Pin Assignment

The SL900A QFN-16 pin assignments are described below.

Note(s): The QFN are for ES only and the temperature performance is not guaranteed.

Figure 3:
QFN-16 Pin Layout

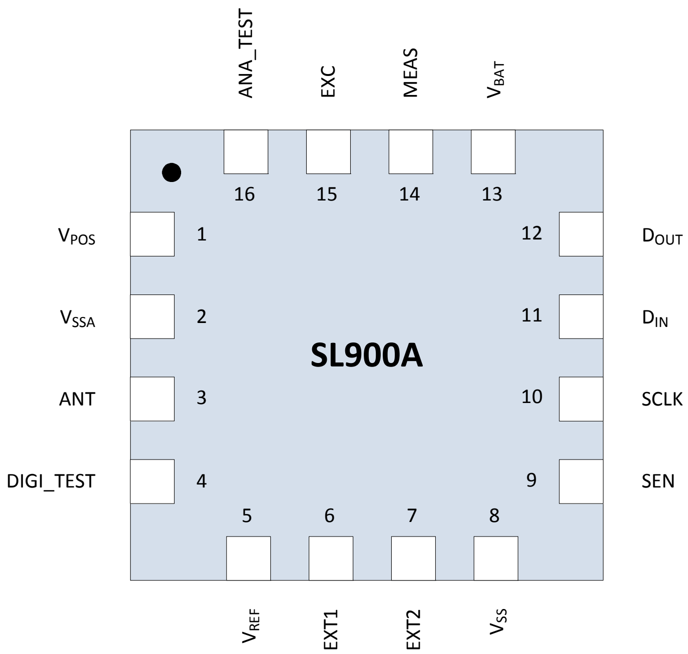


Figure 4:
QFN-16 Pin Description

Pin Number	Pin Name	Description
1	V_{POS}	RF rectifier output
2	V_{SSA}	Chip substrate ground – connect to antenna ground
3	ANT	Antenna connection
4	DIGI_TEST	Test input – must be left open
5	V_{REF}	Reference voltage output (Vo2)
6	EXT1	Analog input for external sensor
7	EXT2	Analog input for external sensor
8	V_{SS}	Chip substrate ground – connect to negative battery terminal. Recommended to connect to V_{SSA}.
9	SEN	Enable input for the SPI interface (Active high)
10	SCLK	SPI clock
11	D_{IN}	SPI data input

Pin Number	Pin Name	Description
12	D_{OUT}	SPI data output (note that this does not support Tri-state)
13	V_{BAT}	Positive supply input
14	MEAS	Test pin for use during test – must be left open
15	EXC	Supply voltage for the external sensors or a AC signal source for external sensors
16	ANA-TEST	Analog test pin – must be left open

Pin Description: This table shows a detailed pin description of the SL900A.

Bare Die Pads Layout

Pad Diagram

Figure 5:
Pad Location Diagram

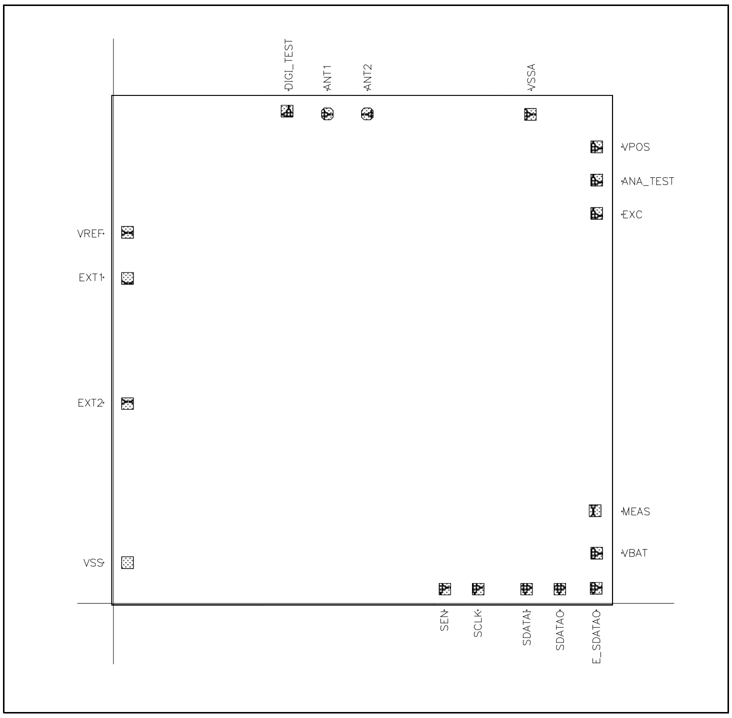
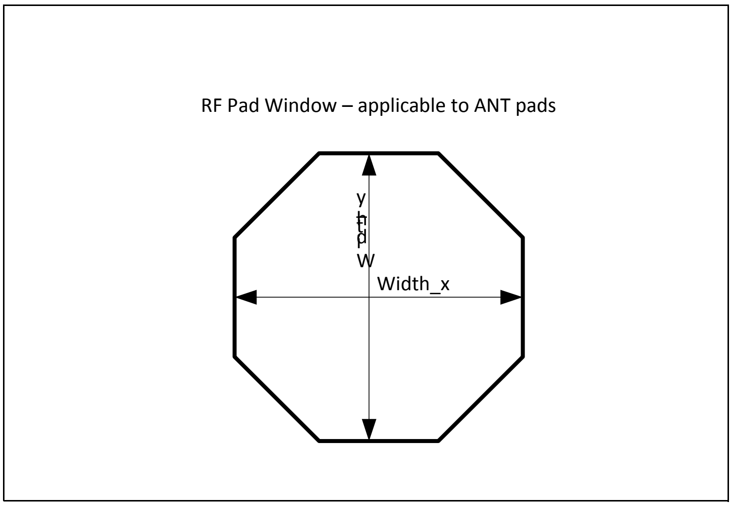
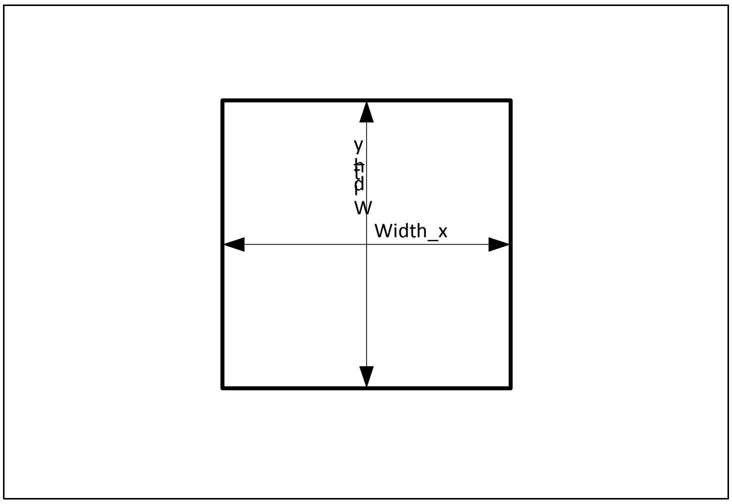


Figure 6:
RF Pad Window (applicable to ANT1 and ANT2 pads)



- RF pads have only top metal layers connected to ANT1 and ANT2.
- An additional polysilicon shield is connected to the substrate supply ring (VSS).
- Overlap of metal over passivation opening is 7µm.
- Overlap of polysilicon shield over Metal is 2.8µm.

Figure 7:
Pad Window (applicable to all pads except ANT1 and ANT2)



- Regular bonding pads have all metal layers connected, no other different layers except metal underneath the pads.
- Overlap of all Metal layers over passivation opening is 5µm.

Pad Description

Figure 8:
Pad Parameters

<table>
<tr><th>Pad Name</th><th>X Position (µm)</th><th>Y Position (µm)</th><th>Pad Window (µm)</th><th>Type</th><th>Bumps size (µm)</th></tr>
<tr><td>V_{REF}</td><td>77.5</td><td>2040.5</td><td>64x64</td><td>Analog output</td><td>70x70</td></tr>
<tr><td>EXT1</td><td>77.5</td><td>1787.5</td><td>64x64</td><td rowspan="2">Analog input/output</td><td rowspan="2">70x70</td></tr>
<tr><td>EXT2</td><td>77.5</td><td>1098.5</td><td>64x64</td></tr>
<tr><td>V_{SS}</td><td>77.5</td><td>223.5</td><td>64x64</td><td>Supply</td><td>70x70</td></tr>
<tr><td>S_{EN}</td><td>1822.5</td><td>77.5</td><td>64x64</td><td rowspan="3">Digital input</td><td rowspan="2">70x70</td></tr>
<tr><td>SCLK</td><td>2005.5</td><td>77.5</td><td>64x64</td></tr>
<tr><td>SDATAI</td><td>2271.5</td><td>77.5</td><td>64x64</td><td>70x70</td></tr>
<tr><td>SDATAO</td><td>2454.5</td><td>77.5</td><td>64x64</td><td>Digital output</td><td rowspan="2">70x70</td></tr>
<tr><td>E_SDATAO</td><td>2653.5</td><td>82.5</td><td>64x64</td><td>Test</td></tr>
<tr><td>V_{BAT}</td><td>2657.5</td><td>275.5</td><td>64x64</td><td>Supply</td><td>70x70</td></tr>
<tr><td>MEAS</td><td>2648.3</td><td>509.15</td><td>64x64</td><td>Test</td><td rowspan="2">70x70</td></tr>
<tr><td>EXC</td><td>2657.5</td><td>2144.5</td><td>64x64</td><td>Analog output</td></tr>
<tr><td>ANA_TEST</td><td>2657.5</td><td>2327.5</td><td>64x64</td><td>Test</td><td>70x70</td></tr>
<tr><td>V_{POS}</td><td>2657.5</td><td>2510.5</td><td>64x64</td><td>Analog output</td><td rowspan="2">70x70</td></tr>
<tr><td>V_{SSA}</td><td>2292.5</td><td>2689.5</td><td>64x64</td><td>Supply</td></tr>
<tr><td>ANT2</td><td>1395.25</td><td>2692.25</td><td>See note (1)</td><td rowspan="2">Radio-frequency</td><td>70x70</td></tr>
<tr><td>ANT1</td><td>1176.75</td><td>2692.25</td><td>See note (1)</td><td rowspan="2">70x70</td></tr>
<tr><td>DIGI_TEST</td><td>955</td><td>2707.5</td><td>64x64</td><td>Test</td></tr>
</table>

Pad Locations: Pad locations are measured from lower left chip edge to pad centre.

Note(s):

1. Octagonal – See RF Pad window. For bare die: ANT1 should be left unconnected, ANT2 connected to one side of the dipole antenna and VSSA+VSS connected to the other side of the dipole antenna.
2. Pad top layer metal thickness: 925nm
3. Nominal bump height:15 µm
4. Nominal bump height tolerance: ±3 µm

Absolute Maximum Ratings

Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated under Operating Conditions is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Figure 9:
Absolute Maximum Ratings (operating free-air temperature range, unless otherwise noted)

Symbol	Parameter	Min	Max	Units	Comments
	Input voltage range	-0.3	3.7	V	All voltage values are with respect to substrate ground terminal V_{SS}
	Maximum current V_{POS}		100	mA	ANT pin
ESD_{HBM}	Electrostatic discharge, rating, HBM	±2		kV	All pins except ANT
		±500		V	RF input pin ANT
T_J	Maximum operating virtual junction temperature		150	°C	
T_{Strg}	Storage temperature range	-65	150	°C	
T_{Body}	Package body temperature, (soldering, 10s)		260	°C	IPC/JEDEC J-STD-020 The reflow peak soldering temperature (body temperature) is specified according to IPC/JEDEC J-STD-020 “Moisture/Reflow Sensitivity Classification for Non-hermetic Solid State Surface Mount Devices.” The lead finish for Pb-free leaded packages is “Matte Tin” (100% Sn).
RH_{NC}	Relative humidity (non-condensing)	5	85	%	
MSL	Moisture sensitivity level	3			Maximum floor life time of 168h

Symbol	Parameter	Min	Max	Units	Comments
t_{STRG_WP}	Storage time for WP/Wafers or Die in waffle pack		6	months	17-28°C 40-60% relative humidity storage in original Ultrapack boxes
t_{STRG_WP}	Storage time for WP/Wafers or Die in waffle pack		2	years	19-25°C <15% relative humidity storage in closed cabinet with dry air
t_{STRG_WP}	Storage time for WP/Wafers or Die in waffle pack		5	years	19-25°C <5% relative humidity storage in closed cabinet with dry air
t_{STRG_WP}	Storage time for WP/Wafers or Die in waffle pack		10	years	19-25°C <5% relative humidity storage in closed cabinet and closed Ultrapak box with safeguarded Nitrogen atmosphere

Electrical Discharge Sensitivity

This integrated circuit can be damaged by ESD. We recommend that all integrated circuits are handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure.

Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet the published specifications. RF integrated circuits are also more susceptible to damage due to use of smaller protection devices on the RF pins, which are needed for low capacitive load on these pins.

Operating Conditions

Figure 10:
Operating Conditions

Symbol	Parameter	Min	Typ	Max	Units
V_{BAT3V}	Input supply voltage with 3V battery	2.3	3.0	3.4	V
V_{BAT1_5V}	Input supply with 1.5V battery	1.2	1.5	1.8	V
T_A	Operating ambient temperature range	-40		125	°C

Electrical Characteristics

All limits are guaranteed. The parameters with min and max values are guaranteed with production tests or SQC (Statistical Quality Control) methods.

T_A = -40°C to 125°C, V_{BAT} = 3.0V, unless otherwise noted. Typical values are at T_A = 25°C [(1)].

Figure 11:
Electrical Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{BAT3V}	Operating input voltage 3V battery	T_A = 25°C	2.3		3.4	V
V_{BAT1_5}	Operating input voltage 1.5V battery	T_A = 25°C	1.2		1.8	V
$V_{BAT(SU)}$	Minimum start-up input voltage	T_A = 25°C		1.3		V
$I_{BAT-OP15}$	Operating current into V_{BAT}	Temperature conversion, V_{BAT}=1.5V		200	250	µA
$I_{BAT-OP30}$	Operating current into V_{BAT}	Temperature conversion, V_{BAT}=3V		283	350	µA
$I_{BAT-Q15}$	Active mode current into V_{BAT}	V_{BAT} = 1.5V; RTC on		1.6		µA
$I_{BAT-Q30}$	Active mode current into V_{BAT}	V_{BAT} = 3.0V; RTC on		3.2		µA
$I_{BAT-SD15}$	Standby mode current into V_{BAT}	V_{BAT} = 1.5V, RTC off		0.5		µA
$I_{BAT-SD30}$	Standby mode current into V_{BAT}	V_{BAT} = 3.0V; RTC off		0.7		µA
I_{EXT}	Maximum current from V_{POS} pin	In electromagnetic field		200		µA
V_{POS-l}	V_{POS} limiter point	In electromagnetic field		3.4		V
ANTI-QFN	Antenna pad impedance	Measured at 915MHz, QFN package for PCB assembly		123-j303		Ω
ANTI-DIE	Antenna pad impedance	Measured at 915MHz, bare die for inlay assembly [(2)]		218-j386		Ω
ANTS	Antenna pad sensitivity	Measured at 900MHz, battery assisted mode		-15		dBm
ANTS-QFN	Antenna pad sensitivity	Measured at 915MHz, without battery, QFN package for PCB assembly		-6.9		dBm
ANTS-DIE	Antenna pad sensitivity	Measured at 915MHz, without battery, bare die for inlay assembly		-7		dBm

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{IL}	Voltage input threshold, low (SEN, SCLK, DIN)	V_{BAT} = 1.5V		0.4		V
		V_{BAT} = 3V		1		V
V_{IH}	Voltage input threshold, high (SEN, SCLK, DIN)	V_{BAT} = 1.5V		1		V
		V_{BAT} = 3V		2.1		V
V_{OL}	Voltage output threshold low, D_{OUT} pin	V_{BAT} = 1.5V, I_{DOUT} = 1mA	V_{SS}		450	mV
		V_{BAT} = 3V, I_{DOUT} = 1mA	V_{SS}		300	mV
V_{OH}	Voltage output threshold high, D_{OUT} pin	V_{BAT} = 1.5V, I_{DOUT} = -1mA	1		V_{BAT}	V
		V_{BAT} = 3V, I_{DOUT} = -1mA	2.7		V_{BAT}	V
f_{SCLK}	SCLK serial data clock	V_{BAT} = 1.5V			1	MHz
		V_{BAT} = 3V			5	MHz
f_c	Carrier frequency		860		960	MHz
T_{S-R}	Default temperature sensor range		-40		90	ºC
T_{SRB}	Temperature sensor accuracy	0ºC to 40ºC in logging mode, no RF field present [(3)]	-1.0		1.0	ºC
A/D_{DNL}	A/D differential non-linearity			0.5		LSB
A/D_{INL}	A/D integral non-linearity			4		LSB
t_{sens}	Measurement interval	Programmable	1		32768	s
t_{RTC-I}	Real-time clock, interval			1		s
t_{RTC-A}	Real-time clock, accuracy	Over -20ºC to 60ºC temperature range, VBAT=2.4 - 3.4V	-3		+3	%
t_{RTC-CA}	Real-time clock, calibration accuracy	T_A = 35°C	-0.2		+0.2	%
EW_{CYC}	EEPROM erase/write cycles	T_A = 25°C	100000			Cycles
t_{DR}	EEPROM data retention time	T_A = 125°C	20			Years
$t_{E/W}$	EEPROM erase/write speed		7		7.5	ms

Symbol	Parameter	Conditions	Min	Typ	Max	Units
r_{EXC}	EXC pin output resistance	EXC internally connected to V_{BAT} for ext. sensor supply		400		Ω
r_{EXT}	External sensor interface pads resistance (EXT1, EXT2, V_{REF})			200		Ω

Note(s):

1. Limits are 100% production tested at T_A = 35°C. Limits over the operating temperature range are guaranteed by design.
2. Assembled die impedance will vary from the die impedance shown here due to factors such as the material used e.g. copper or aluminium, glue used and pressure during assembly.
3. Temperature accuracy is based on measured performance on wafer at 3.0V. Assembly method can influence the temperature sensor accuracy.

Figure 12:
Typical Current Consumptions at 3V Over Temperature -20°C to 85°C

Symbol	Description	-20°C	25°C	85°C
IBAT-SD @ 3V	Standby current from VBAT. RTC off	0.7 µA	0.69 µA	1.65 µA
IBAT-Q @ 3V	Active current from VBAT. RTC on	3.25 µA	3.20 µA	4.1 µA
IBAT-OP30 @ 3V t_{Tlog} IBAT-PK30	Average logging current- temperature only	280 µA	283 µA	278 µA
	Average logging time – temperature only	20.2 ms	20.4 ms	21 ms
	Peak current	1.85 mA	2.3 mA	2.45 mA

Short Description

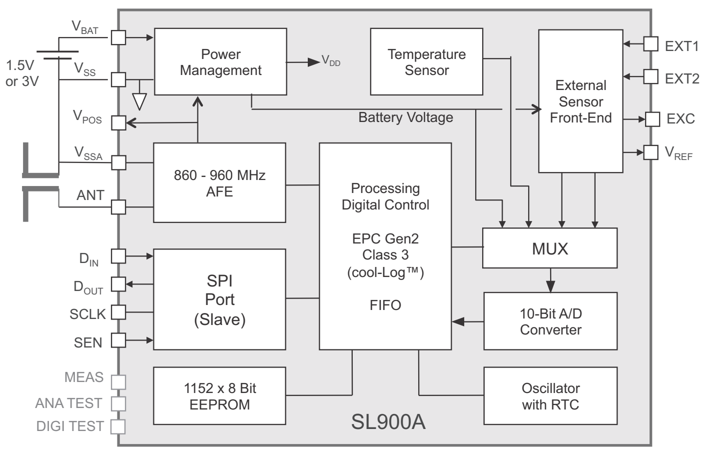
The SL900A is designed for use in smart active labels (SAL), semi-passive labels and passive labels. Smart active labels are defined as thin and flexible labels that contain an integrated circuit and a power source. SAL includes in its definition both "fully active" smart labels, and semi-active smart labels, also known as battery-assisted back-scattered passive labels, both of which enable enhanced functionality and performance over passive labels. The IC includes sensor functionality and logging of sensor data (see Figure 13 below).

The SL900A is operating at 860 to 960 MHz and is fully EPCglobal Class 1 compliant. The chip is supplied from a single-cell battery of typically 1.5V, or from a dual cell battery (3V).
3V batteries are recommended because of the wider operating voltage range. The on-chip temperature sensor and real-time clock (RTC) accommodate temperature data logging.

Supply Arrangement

The SL900A is supplied from either the battery or through the electromagnetic waves from a reader. The device is normally supplied from the battery unless there is no battery attached (passive label), or when the battery is drained. In Battery Assisted Passive Mode the chip can be supplied by either a 3V or a 1.5V battery. A 3V battery is recommended as there is a wider operating voltage range with 3V. At power up a battery check is carried out to determine if a 3V or 1.5V battery is connected. It is strongly recommended after first connection of a battery that an inventory round is performed and the custom command Get Battery Level with battery retrigger is executed. This will repeat the battery check when the battery voltage is stable and ensure the correct battery type 3V or 1.5V type selection is selected.

Figure 13:
Block Diagram



Analog Front End (AFE)

The analog front end is designed according to EPC Gen 2. The forward link (reader to tag) is amplitude modulated and the backward link (tag to reader) is amplitude modulated (load modulation is used). Please note for QFN the ANT pin is connected to one side of the dipole antenna and VSSA+VSS are connected to the other side as shown in Figure 13. For bare die ANT1 should be left unconnected, ANT2 should be connected to one side of the dipole and VSSA+VSS connected to the other.

Processing and Digital Control

The SL900A is fully EPC Class 1 compliant, with additional custom commands for extended functions. The maximum transponder to interrogator data rate according to Class 1/Gen.2 is 640 kbit/s. The maximum interrogator to transponder data rate is 160 kbit/s.

Figure 14:
Supported Data Rates

Data Rate	Min	Max
Interrogator to transponder	40 kbit/s	160 kbit/s
Transponder to interrogator	5 kbit/s	640 kbit/s

Serial Interface (SPI Slave)

The integrated serial interface (SPI) can be used to initialize the chip and to set the parameters. The logging procedure can be started and stopped with the SPI. The SPI bus can also be used for the communication between a microcontroller that is attached to the SL900A and the RFID reader.

Real-Time Clock (RTC)

The on-chip real-time clock (RTC) is started through the START LOG command in which the start time is programmed in UTC format. The interval for sensing and data logging can be programmed in the range from 1 second up to 9 hours. The accuracy of the timer is ±3%. The timer oscillator is calibrated at 35 °C within ±0.2%.

Temperature Sensor

The on-chip temperature sensor is set with a default temperature range of -40ºC to 90ºC and can measure the temperature in the range from 0ºC to 40ºC with an accuracy of ±1.0ºC. The temperature sensor is calibrated at VBAT=3.0V and accuracy is only guaranteed in logging mode and not in the presence of a strong RF field. A strong RF field can produce self heating of the chip. Please note the assembly method used can affect the temperature sensor accuracy.

The temperature sensor can be reconfigured for other temperature ranges but the sensor will need recalibrating if the range is changed from the default values.

External Sensors

The on-chip external sensor front end provides a flexible interface for analog external sensors. It has an auto-range and interrupt function. It supports various types of analog sensors from pressure, humidity, temperature, light …

Analog to Digital Converter

The chip has an integrated 10-bit analog to digital converter with selectable voltage references. It is used for conversion of temperature, external sensors and battery voltage.

External Sensor Interrupt

The external sensor inputs EXT1 and EXT2 can be used for event-triggered logging. In this mode, the logging is not triggered in predefined time intervals from the internal timer, but can be triggered externally, either with a sensor, switch or a microcontroller.

The interrupt source can be the EXT1, EXT2 input or both, were the EXT1 input has the higher priority. The user application can select which measurements are triggered by the interrupt event.

In the interrupt mode, the sensor value is stored together with the 32-bit real time clock value. For a correct real-time clock value, the correct Start time has to be supplied. The interrupt mode is started with the START LOG command and the correct setting in the registers (SET LOG MODE command).

Data Protection

Additional to the Gen2 lock protection, the SL900A offers read/write protection using 3 password sets for 3 memory areas. Each 32-bit password is divided into 2 16-bit passwords, where the lower 16 bits are reserved for the Write protection and the higher 16 bits are reserved for the Read/Write protection.

Shelf Life

The SL900A device has an integrated shelf life algorithm that can dynamically calculate the remaining shelf life of the product. It has an automatic alarm function for the shelf life expiration. This can be used to directly drive a LED or as an interrupt for an external microcontroller.

Memory Arrangement

The SL900A device has an integrated 9kbit EEPROM. It is organized into 5 memory banks shown below.

Figure 15:
Memory Arrangement

Memory Bank	Bank Size (bits)	Comments
SYSTEM	512	System parameters like calibration data and log parameters. Individual areas of System memory are accessible over RF using a range of cool-Log commands (EPC Custom commands) but not Read or Write commands.
RESERVED	64	Access and Kill password
EPC	144	PC and EPC value
TID	80	Unique identifier – programmed and locked during production
USER	8416	Application and measurement data

System Description

Figure 17 shows the different states and their interactions. Figure 25 shows the command overview.

Initializing the Chip

A virgin chip (not initialized) can be initialized either through the SPI port or through the electromagnetic field from a reader in the standby mode. The power source is either from a battery (V_{BAT}) or extracted from the RF field via the AFE circuit. After the initializing procedure, the chip will enter the ready mode. To ensure correct operation of the chip in BAP mode, after first connection of a battery an inventory round should be completed and the custom command Get Battery Level with battery retrigger should be executed. This will ensure the correct battery type 1.5V or 3V is selected.

Power Modes

Standby Mode

In passive mode, all blocks in the chip including the RTC are turned off and only the leakage current is flowing. When the label enters an RF field, it will go from Standby mode to Ready mode. If the SEN pin rises high, the chip will go from the Standby mode to the serial mode

Ready Mode

In the ready mode, all parameters can be set, read and changed through a reader with the appropriate passwords.

Active Mode

In active mode, the real-time clock (RTC) is running, the desired parameters are set, and the on-chip temperature sensor is in standby.

Interrupt Mode

In the interrupt mode, the external sensor interrupt block is running with minimal power consumption. When the external sensor value exceeds a specified threshold, the chip goes into the logging mode where the selected sensor values and real time of the event are stored to the EEPROM.

In Interrupt mode the chip must be powered by the battery.

Logging Mode

A log flag from the timer will enable the logging mode in which the sensor and the A/D converter will be activated, and the measured value will be stored in the EEPROM together with the time of the event. If the external sensor flag is set, the external sensors will also be activated and the measured data stored. The A/D converter can be multiplexed between internal temperature sensor, external sensors or battery voltage. After the event, the chip will return to the active mode.

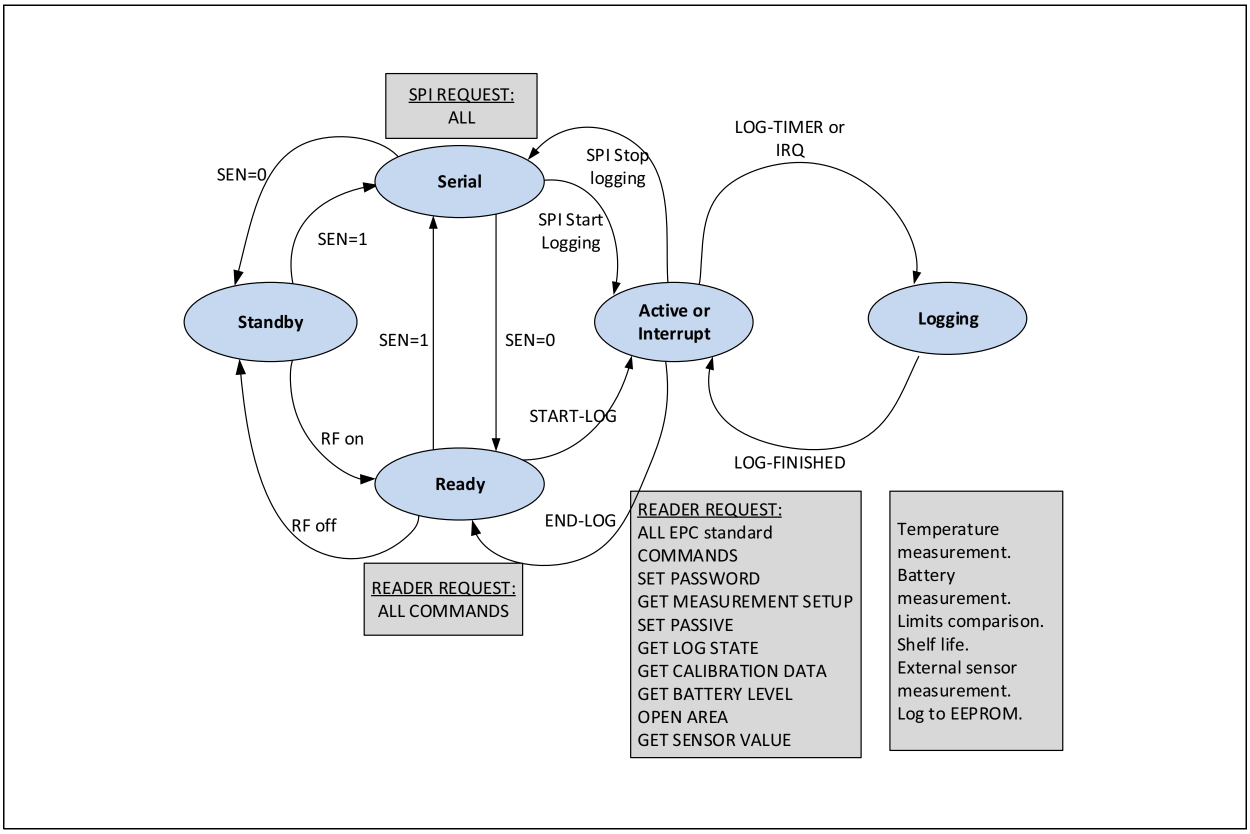
In logging mode, the chip must be powered by the battery.

Figure 16:
Modes of Operation

Mode	Description	IBAT (Typ.)	Power from AFE
Standby	In passive mode the chip is turned off and only the leakage current is flowing. RTC is off.	0.1 µA	No
Serial	Enables initializing and executing of all commands via the SPI bus	50 µA	No
Ready	Chip is initialized and all commands can be executed via the reader	50 µA	Yes
Active	• RTC running • Sensor standby	2 µA	No
Interrupt	• RTC running • External sensor minimum supply	2.5 µA	No
Logging	• Sensor reading (on-chip temperature sensor, battery voltage level and/or external sensor through the MMI pin) • Measured data stored in EEPROM • RTC time stored in EEPROM	180 µA	No

State Diagram

Figure 17:
State Transition Diagram



Data Protection

Additional to the Gen2 lock protection, the SL900A offers read/write protection using 3 password sets for 3 memory areas. The System area is protected by the System password, the Application area is protected by the Application password, and the Measurement area is protected by the Measurement password. Each 32-bit password is divided into 2 16-bit passwords, where the lower 16 bits are reserved for the Write protection and the higher 16 bits are reserved for the Read/Write protection.

The password can be set either with the custom RFID command SET PASSWORD, or through the SPI, by writing the password to the password locations.

The password protection is activated immediately after the SET PASSWORD command. In case the passwords are written with the SPI interface, the protection is activated when the transponder re-enters an RF field.

Password protection does not block any read/write operation on the SPI interface; it is active only for the RFID interface.

Figure 18:
Password Storage in System Memory

Address	Data	Function
0x000	System Password [31:24]	System Password – read/write protect
0x001	System Password [23:16]	
0x002	System Password [15:8]	System Password - write protect
0x003	System Password [7:0]	
0x004	Application Password [31:24]	Application Password – read/write protect
0x005	Application Password [23:16]	
0x006	Application Password [15:8]	Application Password - write protect
0x007	Application Password [7:0]	
0x008	Measurement Password [31:24]	Measurement Password – read/write protect
0x009	Measurement Password [23:16]	
0x00A	Measurement Password [15:8]	Measurement Password - write protest
0x00B	Measurement Password [7:0]	

Data Log Functions

The SL900A device supports various flexible data log formats. The data log format depends on the Logging form. The data log formats are defined in Figure 26.

The Logging form is set with the SET LOG MODE command and is stored in "Logging form [2:0]" (SPI address 0x026) bits in the EEPROM.

Figure 19:
Supported Logging Formats

Bit 2	Bit 1	Bit 0	Logging From	Description
0	0	0	Dense	All values are stored to the measurement area. No additional time information is stored to the measurement area.
0	0	1	All values out of limits	All values that are out of the specified limits are stored to the measurement area. Additional to the sensor value, also the measurement number is stored, so the application can reconstruct the time-sensor points.
0	1	1	Limits crossing	Only the crossing point of each limit boundary is stored. Additional to the sensor value, also the measurement number is stored, so the application can reconstruct the time-sensor points.
1	0	1	IRQ, EXT1	Interrupt triggered on the EXT1 external sensor input. At each trigger event the selected sensor values are stored. Additional to the sensor values, also the real-time clock offset is stored.
1	1	0	IRQ, EXT2	Interrupt triggered on the EXT2 external sensor input. At each trigger event the selected sensor values are stored. Additional to the sensor values, also the real-time clock offset is stored.
1	1	1	IRQ, EXT1, EXT2	Interrupt triggered on the EXT1 and EXT2 external sensor input. At each trigger event the selected sensor values are stored. Additional to the sensor values, also the real-time clock offset is stored.

When the "IRQ + timer enable" bit (Initialize command, SPI address 0x02A) is set to 1, the logging will be triggered on the selected time interval (timer) and also on an interrupt from external sensor1, sensor 2 or both – depending on the selected logging mode.

The Storage rule bit defines what happens when the logging area in the EEPROM is full.

Figure 20:
Storage Rule

Bit	Storage Rule	Description
0	Normal	When the logging area in the EEPROM is full, the chip does not store any new sensor data to the EEPROM, but it will still increment the measurement counter and RTC.
1	Rolling	When the logging area is full, the chip continues with writing new sensor data to the EEPROM form the beginning of the logging area. Thus the chip overwrites the old stored data and increments the "Number of memory replacements [5:0]" field in the System status group.

Limits Counter

The Limits counter can be used as an advanced alarm mechanism. It is enabled in all log formats and it will display the cumulative number of measurements that are outside limits. The application does not have to read the whole EEPROM content in order to determine if the temperature limits have been exceeded, just the Limits counter block. The Limits counter block can be read out with the GET LOG STATE command.

The system uses 4 limits that can be set by the user:

- Extreme upper limit
- Upper limit
- Lower limit
- Extreme lower limit

There is a dedicated 8-bit counter for each of the 4 limits in the Limits counter block. The appropriate counter will increment each time a sensor value is outside a limit.

The user can select which sensor will be used in the limits comparison. The internal temperature sensor is selected by default. Other sensors can be selected with the SET SFE PARAMETERS command with the "Verify sensor ID[1:0]" field (SPI address 0x018):

Figure 21:
Modes of Operation

Verify Sensor ID Bit 1	Verify Sensor ID Bit 0	Sensor Selected for Limits Comparison
0	0	Internal temperature sensor - DEFAULT
0	1	External sensor 1
1	0	External sensor 2
1	1	Battery voltage

Logging Timer

The SL900A device has an integrated RC oscillator that is calibrated to 1024Hz. This oscillator drives the logging timer. The logging timer resolution is 1 second. The maximum period is 9.1 hours (32768 seconds). The logging interval is programmed with the SET LOG MODE command.

The measurement real time is derived from 4 parameters - the Start time (ST), the Delay time (DT), the log interval (LT), and the # of the measurement (NM). This value has to be calculated in the reader by the equation:

(EQ1) Real time = ST+DT+LT*NM

Delay Time

The SL900A supports delayed start of the logging procedure. The Delay time has a resolution of 8 minutes - 32 seconds (512 seconds) and a maximum value of 582 hours (12 bits). The delay time value is set with the Initialize command, while the Delay time counter starts counting when the device receives the START LOG command.

The delay time can also be disabled and an external push button can be used for starting the logging procedure.

Analog to Digital Conversion

The chip has an integrated analog to digital converter with 10-bit resolution and selectable voltage references. By default, the references are selected as: Vo1 = 0mV and Vo2 = 310mV. This results in a voltage input range of 310mV ~ 620mV, for the temperature conversion this is nominally -89.3°C ~ 94.6°C.

The voltage references are individually selectable in 50mV steps with a fine adjustment for offset calibration. Additionally, the Vo1 reference voltage can be tied directly to ground if the bit "gnd_switch" in the SET CALIBRATION DATA command is set to 1 (SPI address 0x012).

Figure 22:
AD Reference Voltages

Calibration Code	Vo1	Vo2
0b000	160mV	260mV
0b001	210mV	310mV
0b010	260mV	360mV
0b011	310mV	410mV
0b100	360mV	460mV
0b101	410mV	510mV
0b110	460mV	560mV
0b111	510mV	610mV

The Vo2 voltage defines the lower temperature limit for the temperature conversion.

Note(s): Normal operation is not guaranteed below -40 ºC.

The temperature sensor produces an output Voltage V_{SENS} whose value is V_{SENS}= (T+273.15)/593.12 where T is the temperature in ºC. This formula can be used to calculate the lower temperature limits for the different Vo2 values.

Figure 23:
Theoretical Lower Temperature Limit

Vo2	Lower Temperature Limit
260mV	-118.9 ºC
310mV	-89.3 ºC (default)
360mV	-59.6 ºC
410mV	-30.0 ºC
460mV	-0.3 ºC
510mV	29.3 ºC
560mV	59.0 ºC
610mV	88.7 ºC

Note(s): The lowest operating temperature for the chip is -40ºC so in practice the lower temperature limit cannot be lower than -40ºC.

The voltage difference between the Vo2 and Vo1 references define the resolution and temperature range.

Figure 24:
Temperature Conversion Resolution and Range

Vo2 - Vo1	Resolution	Range
310mV (default)	0.18 °C	183.9 °C
50mV	0.029 °C	29.7 °C
100mV	0.058 °C	59.3 °C
150mV	0.086 °C	89.0 °C
200mV	0.116 °C	118.6 °C
250mV	0.145 °C	148.3 °C
260mV	0.151 °C	154.2 °C
300mV	0.174 °C	177.9 °C
350mV	0.203 °C	207.6 °C
360mV	0.209 °C	213.5 °C
400mV	0.232 °C	237.2 °C

Example:

Vo1 = 0mV, Vo2 = 310mV -> A/D conversion temperature range = -89.3°C ~ 94.6 °C.

Temperature resolution = 0.18 °C.

The converted voltage can be calculated from the following equation:

(EQ2) $$V_{SENS} = code \cdot \frac{Vo2 - Vo1}{1024} + Vo2$$