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SL900A

EPC Class 3 Sensory Tag Chip - For Automatic Data Logging

General Description

The SL900A is an EPC global 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 typical nonlinearity of ±0.5°C over the specified temperature range. 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

Benefits	Features
Versatile temperature and data logging	High Temperature Range: -40°C to +125°C
Worldwide EPC compliant	Frequency: 860 to 960 MHz
Works fully passive or in BAP mode	Battery supply: 1.5V or 3V
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 SPI	Serial peripheral interface
Storage for up to 841 events with timestamps	On-chip 9k bit EEPROM
Alert for shelf life expiration	Integrated dynamic shelf life calculation
Programmable sensor limits	Advanced logging with 4 user-selectable limits

Package Options

The available SL900A package options are:

- 16-pin QFN (5 x 5 mm)
- Tested wafer (8”)

Applications

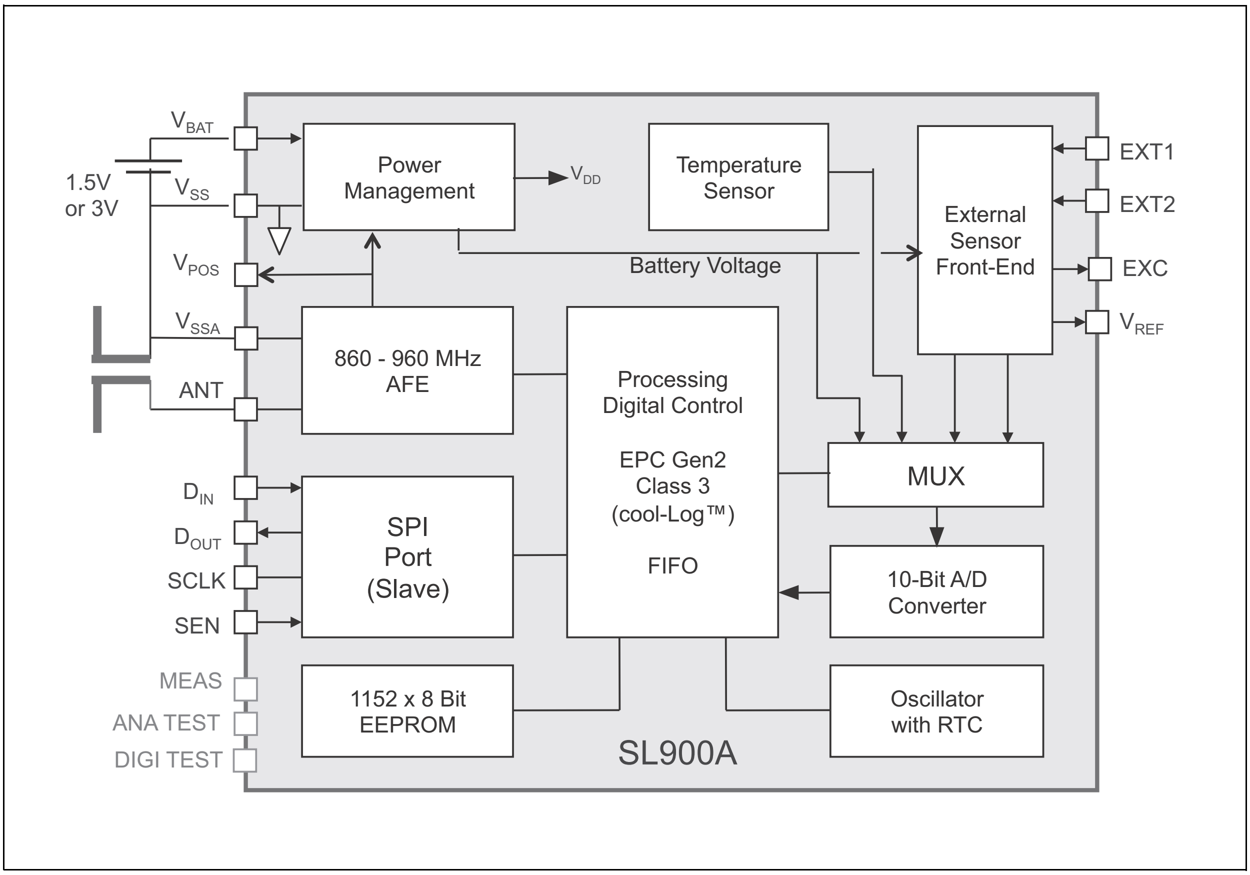
The SL900A device is ideal suited for:

- 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 for reference are shown below:

Figure 2:
SL900A Block Diagram



SL900A Block Diagram: Basic block diagram of SL900A

Pin Assignment

The SL900A pin assignments are described below.

Figure 3:
Pin Layout

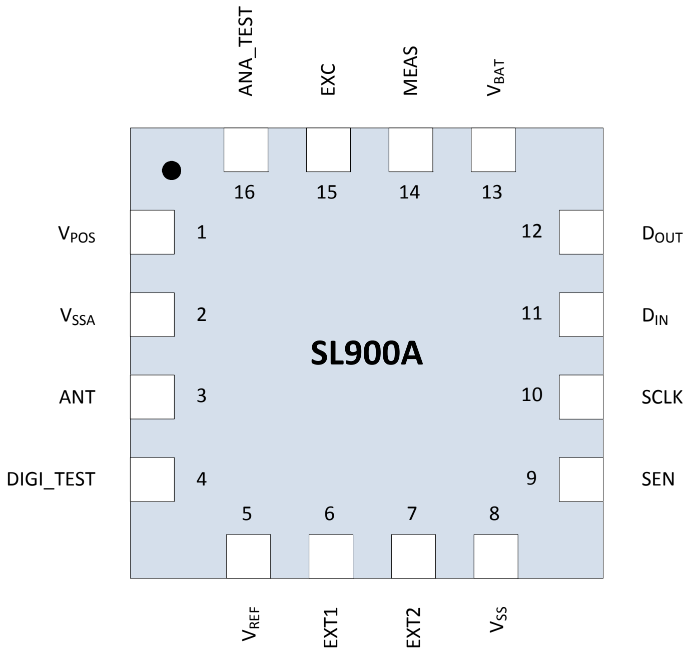


Figure 4:
Pin Description

Pin Number	Pin Name	Description
1	V_{POS}	RF rectifier output
2	V_{SSA}	Chip substrate ground – connect to antenna ground
3	ANT	Antenna coil
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
10	SCLK	SPI clock
11	D_{IN}	SPI data input
12	D_{OUT}	SPI data output

Pin Number	Pin Name	Description
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 Pad Layout

Figure 5:
Pad Location Diagram

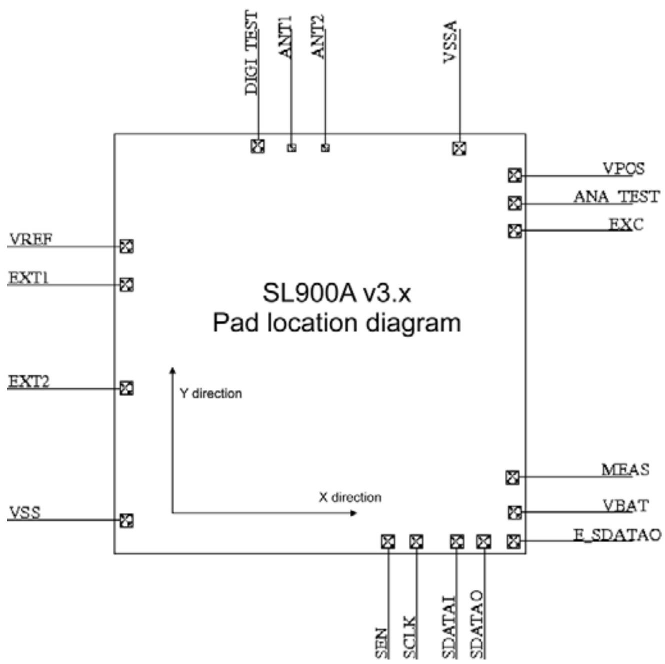


Figure 6:
Pad Parameters

Pad name	X position (µm)	Y position (µm)	Pad window (µm)	Type
V_{REF}	77.5	2040.5	85 x 85	Analog Output
EXT1	77.5	1787.5	85 x 85	Analog Input/Output
EXT2	77.5	1098.5	85 x 85	
V_{SS}	77.5	223.5	85 x 85	Supply
S_{EN}	1822.5	77.5	85 x 85	Digital Input
SCLK	2005.5	77.5	85 x 85	
SDATAI	2271.5	77.5	85 x 85	
SDATAO	2454.5	77.5	85 x 85	Digital Output
E_SDATAO	2653.5	82.5	85 x 85	Test Pad
V_{BAT}	2657.5	275.5	85 x 85	Supply
MEAS	2648.3	509.15	85 x 85	Test Pad
EXC	2657.5	2144.5	85 x 85	Analog Output
ANA_TEST	2657.5	2327.5	85 x 85	Test Pad
V_{POS}	2657.5	2510.5	85 x 85	Analog Output
V_{SSA}	2292	2689.5	85 x 85	Supply
ANT2	1396	2696	See RF pad drawing	Radio-frequency Pad,
ANT1	1177	2694	See RF pad drawing	
DIGI_TEST	955	2707.5	85 x 85	Test Pad

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

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 7:
Absolute Maximum Ratings (Operating free-air temperature range, unless otherwise noted)

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}, ANT		100	mA	
ESD Rating, HBM (all pins except ANT)		2	kV	
ESD Rating, HBM (RF input pin ANT)		500	V	
Maximum Operating Virtual Junction Temperature, T_J		+150	°C	
Storage Temperature Range, T_{stg}	-65	+150	°C	
Lead Temperature (soldering, 10 sec.)		+260	°C	

Absolute Maximum Ratings: This figure shows the absolute maximum ratings of the SL900A.

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 8:
Operating Conditions

Symbol	Parameter	Min	Typ	Max	Units
V_{BAT}	Input Supply Voltage	1.2	1.5	3.6	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} = 1.5V, unless otherwise noted.

Typical values are at T_A = 25°C [1].

Figure 9:
Electrical Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{BAT}	Operating Input Voltage	T_A = 25°C	1.2		3.6	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		290	350	µA
I_{BAT-Q}	Quiescent Current into V_{BAT}	V_{BAT} = 1.5V; timer running		1.6		µA
I_{BAT-SD}	Shutdown Current into V_{BAT}	V_{BAT} = 1.5V		0.5		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 900MHz, QFN package for PCB assembly		31-j3 20		Ω
ANTI-DIE	Antenna pad impedance	Measured at 900MHz, bare die for inlay assembly		9-j33 0		Ω
ANTS	Antenna pad sensitivity	Measured at 900MHz, battery assisted mode		-15		dBm
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

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{OL}	Voltage Output Threshold, Low D_{OUT} pin	V_{BAT} = 1.5V, I_{DOUT} = 1mA	V_{SS}		450m	V
		V_{BAT} = 3V, I_{DOUT} = 1mA	V_{SS}		300m	V
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}	Temperature Sensor Range		-20		60	ºC
$T_{S-R\ EXT}$	Extended temperature sensor range with reduced accuracy		-40		+125	ºC
T_{S-NL}	Temperature sensor nonlinearity	Inside T_{S-R}		±0.5		
T_{S-A}	Temperature Sensor Accuracy	Inside T_{S-R}		±1		ºC
t_{sens}	Measurement interval	Programmable	1		32,768	Sec
t_{RTC-I}	Real-Time Clock, Interval			1		Sec
t_{RTC-A}	Real-Time Clock, Accuracy	Over specified T_{S-R} temperature range	-3		+3	%
t_{RTC-CA}	Real-Time Clock, Calibration Accuracy	T_A = 35°C	-0.2		+0.2	%

Symbol	Parameter	Conditions	Min	Typ	Max	Units
t_{RTC-B}	Real-time Clock, Accuracy	V_{BAT}=1.3V ~ 3V		±3		%
t_{RTC-C}	Real time clock, Accuracy	V_{BAT}= 1.2V~1.3V; 3V~3.6V	-7		+5	%
EW_{CYC}	EEPROM Erase/Write Cycles	T_A = 25°C	100,000			Cycles
t_{DR}	EEPROM Data Retention Time	T_A = 125°C	20			Years
$t_{E/W}$	EEPROM Erase/Write Speed		7		7.5	ms
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) and/or Footnote(s):

1. Limits are 100% production tested at T_A = 35°C. Limits over the operating temperature range are guaranteed by design.

Short Description

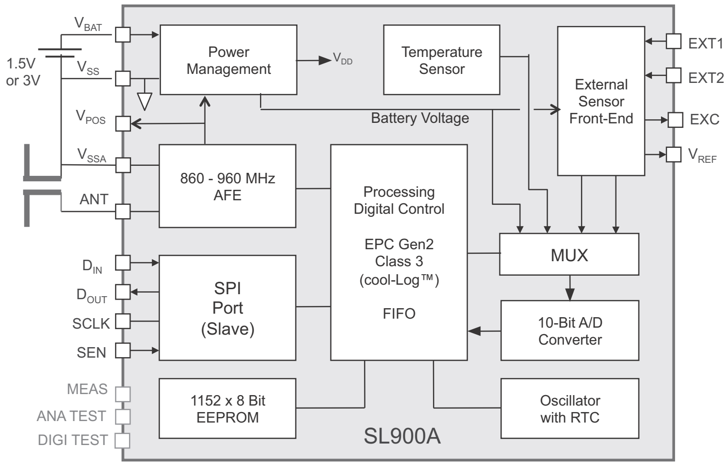
The SL900A is designed for use in smart active labels (SAL), semi-passive labels and passive labels. Smart active labels are defined as thin and flexible labels that contain an integrated circuit and a power source. SAL includes in its definition both "fully active" smart labels, and semi-active smart 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 10 below).

The SL900A is operating at 860 to 960 MHz and is fully EPC global Class 1 compliant. The chip is supplied from a single-cell battery of typically 1.5V, or from a dual cell battery (3V). 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.

Figure 10:
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).

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 11:
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)

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 ºC within ±0.2%.

Temperature Sensor

The on-chip temperature sensor can measure the temperature in the range from -20ºC to 60ºC with a typical accuracy of ±1ºC. The full temperature range of -40ºC to +125ºC has a reduced accuracy.

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 12:
Memory Arrangement

Memory Bank	Bank Size (bits)	Comments
SYSTEM	512	System parameters like calibration data and log parameters
RESERVED	64	Access and Kill password
EPC	144	PC and EPC value
TID	80	Unique identifier – programmed and locked during production
USER	8416	User and measurement data

System Description

Figure 14 shows the different states and their interactions. Figure 22 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.

Power Modes

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.

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.

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.

Stand-by Mode

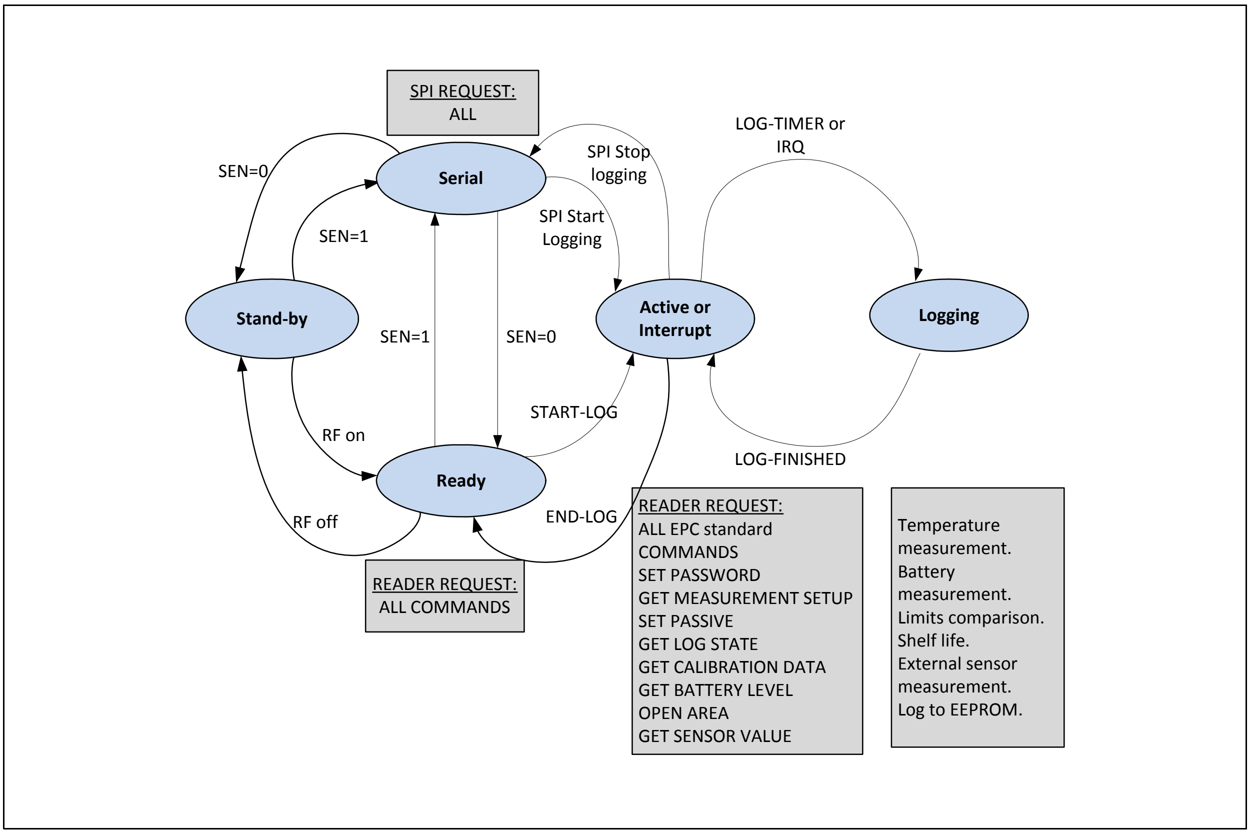
In passive mode, all blocks in the chip are turned off and only the leakage current is flowing. When the label enters an RF field, it will go from Stand-by mode to Ready mode. If the SEN pin rises high, the chip will go from the Stand by mode to the serial mode

Figure 13:
Modes of Operation

Mode	Description	IBAT (Typ.)	Power from AFE
Stand-by	In passive mode the chip is turned off and only the leakage current is flowing	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 14:
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 15:
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 23.

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 16:
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 17:
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 18:
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:

$$\text{Real time} = ST+DT+LT*NM$$

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 = 0V and Vo2 = 310mV. This results in a voltage input range of 310mV ~ 620mV, for the temperature conversion this is -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 19:
AD Reference Voltages

Calib. 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 that normal operation is not guaranteed below -40 °C.

Figure 20:
Theoretical Lower Temperature Limit

Vo2	Low. Temp. Lim.
260mV	-118.9 °C
310mV	-89.3 °C
360mV	-59.6 °C
410mV	-29.0 °C
460mV	0.3 °C
510mV	29.3 °C
560mV	59.0 °C
610mV	88.7 °C

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

Figure 21:
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	88.0 °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 = 310mV, Vo2 = 410mV -> A/D conversion temperature range = -29.3°C ~ 30.0 °C.

Temperature resolution = 0.058 °C.

The converted voltage can be calculated from the following equation:

$$V_{SENS} = \text{code} \cdot \frac{Vo2 - Vo1}{1024} + Vo2$$

Temperature Conversion

The calibration data does not have to be included in the temperature conversion equation. The temperature value calculation is dependent on the selected voltage references (See “Analog to Digital Conversion” on page 18.):

$$T \cdot (°C) = code*Resolution - Low \cdot temp \cdot limit$$

By default (factory setting), the voltage references are set: Vo1 = 0V, Vo2 = 310mV. This yields a theoretical temperature conversion range of -89.3°C ~ +94.6°C. The temperature conversion equation for this setting is:

$$T \cdot (°C) = code*0.18°C - 89.3°C$$

$$LSB = 0.18°C$$

$$Offset = (-89.3)°C$$

When the reference voltages are set to some other value, the following equation needs to be used for temperature conversion:

$$T \cdot (°C) = \frac{Vo2[mV] \cdot (code + 1024) - code \cdot Vo1[mV]}{1024 \cdot 1.686} - 273.15$$

The Vo1 and Vo2 in the above equation have to be in mV.

Battery Voltage Conversion

The battery voltage conversion is dependent on the initial battery voltage (1.5V or 3V) and on the selected voltage references (See “Analog to Digital Conversion” on page 18.). The conversion equations with factory selected voltage references (Vo1 = 0V, Vo2 = 310mV) are:

For 1.5V battery, the equation is:

- V = code*0.85mV + 873mV
- LSB = 0.85mV
- Offset = 873mV

For 3V battery:

- V = code*1.65mV + 1.69V
- LSB = 1.65mV
- Offset = 1.69V

Commands

Some commands can be password protected by 3 different passwords: System password (S), Application password (A) or Measurement password (M).

Figure 22:
EPC Gen2 and Cool-Log™ Command Overview

#	Command	Command Code	Allowed in Modes					Mode Change	Security Level	Definition
			LOGGING	SERIAL	READY	ACTIVE	STAND-BY			
01	QueryRep	0b00	-	√	√	√	-	No	/	EPC Gen2 anticollision round command
02	ACK	0b01	-	√	√	√	-	Yes	/	EPC Gen2 anticollision round command
03	Query	0b1000	-	√	√	√	-	No	/	EPC Gen2 anticollision round command
04	QuaryAdjust	0b1001	-	√	√	√	-	No	/	EPC Gen2 anticollision round command
05	Select	0b1010	-	√	√	√	-	No	/	EPC Gen2 anticollision round command
06	NAK	0xC0	-	√	√	√	-	No	/	EPC Gen2 anticollision round command
07	Req_RN	0xC1	-	√	√	√	-	No	/	Request for a new 16-bit random number
08	Read	0xC2	-	√	√	√	-	No	A or M	Reads the selected block in the specified memory bank
09	Write	0xC3	-	√	√	√	-	No	A or M	Writes the selected block in the specified memory bank
10	Kill	0xC4	-	√	√	√	-	No	/	Kills the transponder – no RFID access is possible after this command (SPI remains active)

#	Command	Command Code	Allowed in Modes					Mode Change	Security Level	Definition
			LOGGING	SERIAL	READY	ACTIVE	STAND-BY			
11	Lock	0xC5	-	√	√	√	-	No	/	Locks the selected memory banks
12	Access	0xC6	-	√	√	√	-	No	/	Puts the transponder to the secured state
13	BlockWrite	0xC7	-	√	√	√	-	No	A or M	Writes the selected block in the specified memory bank
14	BlockErase	0xC8	-	√	√	√	-	No	A or M	Erases the selected block in the specified memory bank
Note: The cool-Log commands are defined as EPC custom commands. All custom commands have a 16-bit command code, where the 1st command code is defined as 0xE0, the second command code is in the table below.										
15	Set Password	0xA0	-	√	√	√	-	No	S, M or A	Sets the passwords to EEPROM
16	Set Log Mode	0xA1	-	√	√	-	-	No	S	Sets logging mode
17	Set Log Limits	0xA2	-	√	√	-	-	No	S	Sets the measurement limits for limits logging mode
18	Get measurement setup	0xA3	-	√	√	√	-	No	S	Reads 4 system blocks - Start time, Log limits, Log mode, and Delay time + application area size
19	Set SFE parameters	0xA4	-	√	√	-	-	No	S	Sets parameter for the External sensor front end
20	Set Calibration Data	0xA5	-	√	√	-	-	No	S	Sets the calibration data for the temperature sensor and timer
21	End Log	0xA6	-	√	-	√	-	Yes	S	Stops the log procedure and returns the chip to Standby mode

#	Command	Command Code	Allowed in Modes					Mode Change	Security Level	Definition
			LOGGING	SERIAL	READY	ACTIVE	STAND-BY			
22	Start Log	0xA7	-	√	√	-	-	Yes	S	Starts the timer and the selected log procedure
23	Get Log State	0xA8	-	√	√	√	-	No	S	Gets the log state of the chip
24	Get calibration data	0xA9	-	√	√	√	-	No	S	Reads the internal and external calibration data
25	Get Battery level	0xAA	-	√	√	√	-	No	/	Measures the battery voltage
26	Set Shelf Life	0xAB	-	√	√	-	-	No	/	Set the shelf life parameters
27	Initialize	0xAC	-	√	√	-	-	No	S	Initializes the chip and sets the aapplication area size and the logging delay
28	Get Sensor Value	0xAD	-	√	√	√	-	No	/	Measures the specified sensor – temperature, ext. sensor1 or ext. sensor 2
29	Open Area	0xAE	-	√	√	√	-	No	/	Opens access to the specified EEPROM area
30	Access FIFO	0xAF	-	√	√	√	-	No	/	Reads or writes the 8-byte FIFO register (for fast SPI to RFID data transfer)

Supported EPC Gen2 Commands

QuerryREP - #01

The QUERRY_REP command instructs tags to decrement their slot counter and is specified for one out of 4 sessions. If the slot counter becomes 0 after decrementing, the tag will backscatter its RN16.

ACK - #02

When a tag receives the ACK command in the Reply state, it will transition to the Acknowledged state and backscatter the EPC. The EPC can be truncated if this has been requested by the reader in the SELECT command. The ACK command can also be processed in the Open or Secured states, but in this case no state transition will occur.

Query - #03

The QUERY command initiates and specifies an inventory round. It sets the TX and RX data rates. It also defines the number of slots used for the inventory round. When the tag receives the QUERY command, it will calculate a random RN16 if it has a matching Sel and Target. The tag will backscatter the RN16 value in case the slot counter is loaded with 0.

QueryAdjust - #04

The QUERY_ADJUST command increments or decrements the Q number (number of slots) for the current inventory round.

Select - #05

The SELECT command selects a tag population that will participate in the inventory round, based on user-defined criteria. The tag can receive any number of successive SELECT commands.

NAK - #06

When a tag receives the NAK command, it will transition to the Arbitrate state, unless it is in the Kill or Ready states. The tag will not send any reply to the NAK command.

Req_RN - #07

The REQ_RN command will instruct the tag to backscatter a new RN16. When a tag in the Acknowledged state receives a correct REQ_RN command, it will transition to the Open or Secured state. When the tag is in the Open or Secured state, it will backscatter a new RN16 and no state transition will occur.

Read - #08

The Read command instructs the tag to read and backscatter a part or all of the Reserved, EPC, TID or User memory.