18000-63 Type C (Gen2) and 18000-63 Type C / 18000-64 Type D (Gen2/TOTAL) RFID IC

Description

EM4325 is a Class-3 Generation-2 (Gen2) IC that is compliant with ISO/IEC 18000-63, ISO/IEC 18000-64 (TOTAL), and EPC™ Class-1 Generation-2. The chip offers an advanced feature set leading to a performance beyond that of standard Gen2 chips and can be either battery powered or beam powered by the RF energy transmitted from a reader. In a battery assisted passive (BAP) configuration, the EM4325 offers superior reading range and reliability compared to purely passive RFID solutions.

EM4325 includes 4096 bits of high speed non-volatile memory (EEPROM) that is organized into 64 pages with 4 words per page. The chip supports either ISO or EPC™ data structures that are compliant with EPCglobal Tag Data Standards, Version 1.10, and is delivered with a Unique Identifier (UID) to ensure full traceability.

An integrated temperature sensor is included in the EM4325 and supports the temperature range from -40°C to +60°C. The temperature sensor may be used in either purely passive or BAP applications. Temperature readings can be made on demand by a reader or the chip may be programmed to perform self-monitoring with alarm conditions.

EM4325 supports advanced applications by providing programmable external interfaces for an auxiliary function and a 4-bit I/O port. The auxiliary function may be configured as an input for tamper detection or as an output for notification of RF events to external devices. The 4-bit I/O may be configured to support 4 discrete signals or as a Serial Peripheral Interface (SPI) bus. The chip may serve as either an SPI Master device or an SPI Slave device. The programmable external interfaces allow the EM4325 to function as an RF front end and protocol handler in advanced RFID tags or embedded applications. In a passive configuration, the programmable external interfaces allow the EM4325 to serve as a SPI Master with energy harvesting and provide power to external components.

Battery supply management is provided to prolong battery life in BAP applications. The chip supports programmable duty cycle control, auto-switching between battery powered and beam powered operation, and programmable enable/disable of an ultra-low power mode for extended storage applications.

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AIAG is a trademark of Automotive Industry Action Group

Features

- ISO 18000-63 (Gen2) & 18000-64 (TOTAL) compliant
- EPC™ Gen2 compliant
- AIAG™ B-11 compliant
- ATA Spec 2000 Low Memory Tag compliant
- 4096-bit non-volatile memory (EEPROM)
- 48-bit manufacturer programmed IC Serial Number
- 352 bits for UII/EPC encoding
- 3072 bits for User data / 3008 bits for TOTAL data
- 128-bit Register File
- BlockErase and BlockWrite commands for high speed memory transactions
- BlockPermalock command for User memory
- Forward link data rates: 26.7 to 128 kbps assuming equiprobable data
- Return link data rates: 40 to 640 kbps with subcarrier modulated data rates of 0.625 to 320 kbps
- TOTAL data rates: 64, 128, 160, 256, or 320 Kbps
- Coordinated Universal Time Clock (UTC)
- Integrated temperature sensor: -40°C to +60°C with typical accuracy of ±1.0°C over the full range and ±0.6°C over the typical range for cold chain
- Programmable monitoring and alarm conditions for temperature sensor including time stamp
- Programmable auxiliary function: input for tamper detection or output for notification of RF events
- Programmable 4-bit I/O port: configurable as 4 discrete signals or as a Serial Peripheral Interface (SPI) Bus
- Battery assistance for superior reading range and reading reliability
- Rectifier that allows purely passive operation in case the battery is flat or not present
- Battery supply management to prolong battery life
- Battery supply range: 1.25V to 3.6V[1)]
- Low battery alarm threshold: 1.3V or 2.2V
- Extended temperature range: -40°C to +85°C

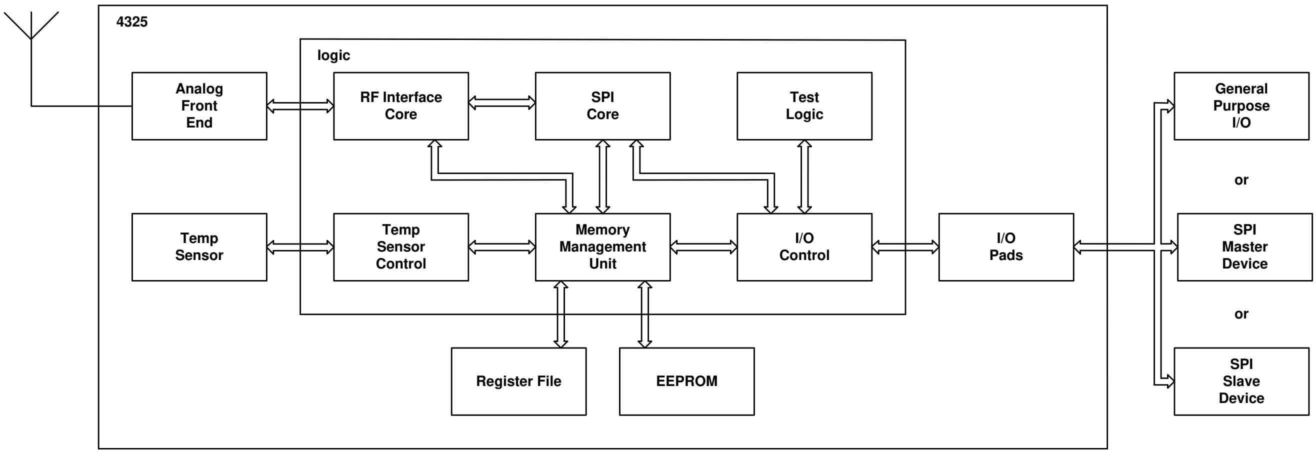
Applications

- RFID tags:
  Supply chain management, tracking and tracing, reusable containers and pallets, access control, asset control, cold chain monitoring, sensor monitoring, E-seals, Gen2 side-channel for active RFID tags
- RFID front end for embedded applications:
  Gen2 communications channel for wireless data exchange, configuration and control, RF event notification

Note 1: EEPROM write needs min 1.8V

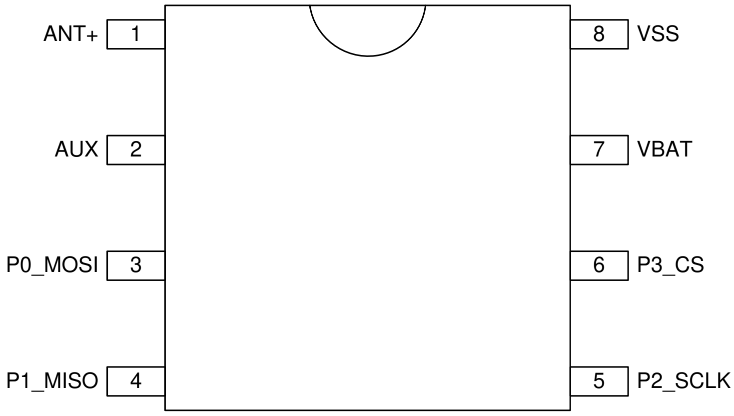
Table of Contents

Block Diagram



Pin Description

TSSOP8 PINOUT

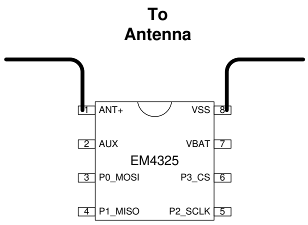


Pin	Name	I/O	Description
1	ANT+	A	Antenna +
2	AUX	I/O	Auxiliary Function
3	P0_MOSI	I/O	I/O P0 or SPI Master Output / Slave Input
4	P1_MISO	I/O	I/O P1 or SPI Master Input / Slave Output
5	P2_SCLK	I/O	I/O P2 or SPI Serial Clock
6	P3_CS	I/O	I/O P3 or SPI Chip Select (active low)
7	VBAT	A	External supply voltage for BAP operation
8	VSS	A	Supply return and Antenna -

A: Analog, I: Digital Input, O: Digital Output

Typical Applications

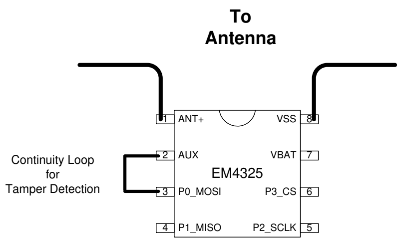
Passive tag with temperature reading on demand.



Typical System Memory Configuration:

Temp Sensor Control Word 1 = 0x0000
Temp Sensor Control Word 2 = 0x0000
Temp Sensor Control Word 3 = 0x0000
I/O Control Word = 0x0000
Battery Management Word 1 = 0x0000
Battery Management Word 2 = 0x0000
TOTAL Word = 0x0000
BAP Mode Word = 0x0000

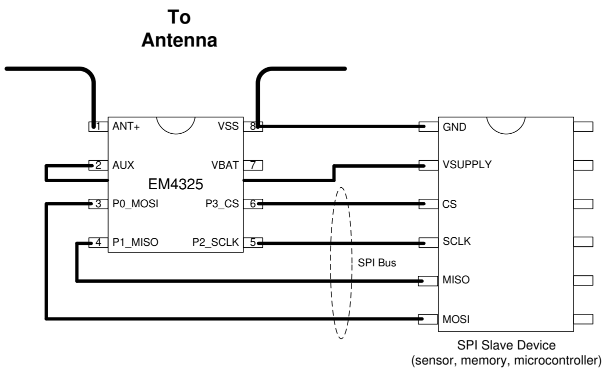
Passive tag with tamper detection and temperature reading on demand.



Typical System Memory Configuration:

Temp Sensor Control Word 1 = 0x0000
Temp Sensor Control Word 2 = 0x0000
Temp Sensor Control Word 3 = 0x0000
I/O Control Word = 0x0411
Battery Management Word 1 = 0x0000
Battery Management Word 2 = 0x0000
TOTAL Word = 0x0000
BAP Mode Word = 0x0000

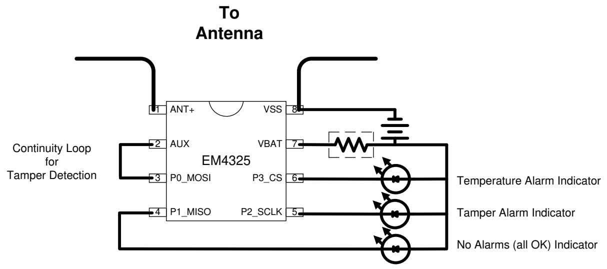
Passive tag with EM4325 as SPI Master with energy harvesting to power another component as SPI Slave.



Typical System Memory Configuration:

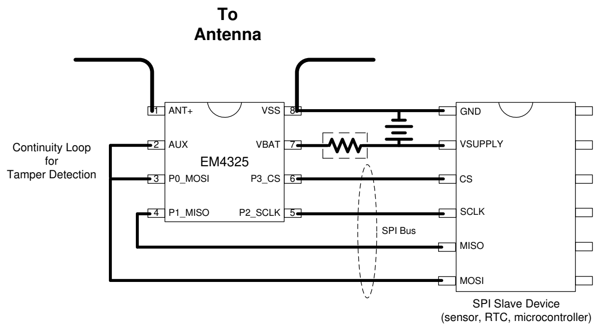
Temp Sensor Control Word 1 = 0x0000
Temp Sensor Control Word 2 = 0x0000
Temp Sensor Control Word 3 = 0x0000
I/O Control Word = 0xE600
Battery Management Word 1 = 0x0000
Battery Management Word 2 = 0x0000 (ext power when tag detects RF field)
Battery Management Word 2 = 0xC000 (ext power when tag is selected)
TOTAL Word = 0x0000
BAP Mode Word = 0x0000

BAP tag with tamper detection, temperature monitoring, and alarm indicators.



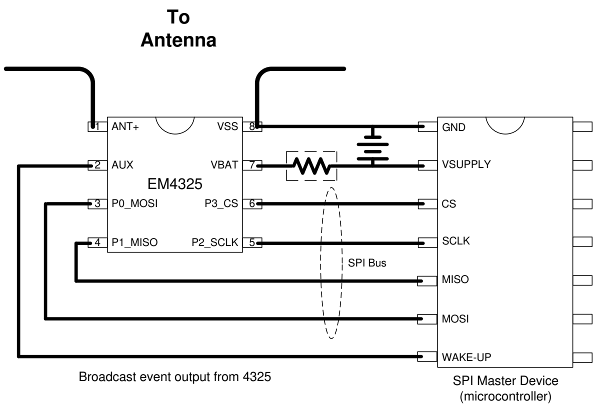
Typical System Memory Configuration:
Temp Sensor Control Word 1 = 0x4808
Temp Sensor Control Word 2 = 0x4820
Temp Sensor Control Word 3 = 0x5E4A
(monitor for 5ºC ±3ºC every 10 minutes)
I/O Control Word = 0x05FF
Battery Management Word 1 = 0xE001
Battery Management Word 2 = 0x8005
TOTAL Word = 0x0000
BAP Mode Word = 0x0001

BAP tag or embedded application with EM4325 as SPI Master and another component as SPI Slave.



Typical System Memory Configuration:
Temp Sensor Control Word 1 = 0x0000
Temp Sensor Control Word 2 = 0x0000
Temp Sensor Control Word 3 = 0x0000
I/O Control Word = 0xE400
Battery Management Word 1 = 0xE001
Battery Management Word 2 = 0x8001
TOTAL Word = 0x0000
BAP Mode Word = 0x0001

BAP tag or embedded application with EM4325 as SPI Slave and another component as SPI Master.



Typical System Memory Configuration:
Temp Sensor Control Word 1 = 0x0000
Temp Sensor Control Word 2 = 0x0000
Temp Sensor Control Word 3 = 0x0000
I/O Control Word = 0xA600 (pull resistors enabled)
I/O Control Word = 0x2600 (pull resistors disabled)
Battery Management Word 1 = 0xE001
Battery Management Word 2 = 0x8001
TOTAL Word = 0x0000
BAP Mode Word = 0x0001

Absolute Maximum Ratings

Parameter	Symbol	Min.	Max.	Unit
Storage temperature	$T_{STORAGE}$	-55	125	°C
Voltage on all pads/pins except VSS	V_{PIN}	V_{SS} - 0.1	V_{SS} + 3.65	V
RF power into pad/pin ANT+	$P_{MAX-ABS}$		25	dBm
Electrostatic discharge on all pads/pins other than ANT+[1)]	V_{ESD}	-2000	2000	V
Electrostatic discharge on pad/pin ANT+[1)]	V_{ESD_ANT+}	-1000	1000	V

Note 1: Human Body Model (HBM; 100pF; 1.5kOhm) with reference to substrate VSS.

Stresses above these listed maximum ratings may cause permanent damages to the device. Exposure beyond specified operating conditions may affect device reliability or cause malfunction.

Handling Procedures

This device has built-in protection against high static voltages or electric fields; however, anti-static precautions must be taken as for any other CMOS component. Unless otherwise specified, proper operation can only occur when all terminal voltages are kept within the voltage range. Unused inputs must always be tied to a defined logic voltage level.

Operating Conditions

Parameter	Symbol	Min.	Max.	Unit
Operating temperature[2)]	$T_{OPERATING}$	-40	+85	°C
RF power into pad/pin ANT+	P_{MAX-OP}		20	dBm
RF carrier frequency	F_{OP}	860	960	MHz
Battery operating voltage (between VBAT and VSS) [3)]	V_{BAT}	1.25	3.65	V

Note 2: Temperature sensor measurements are limited to a maximum of +64°C.

Note 3: Once Ready state occurs after applying V_{BAT}

Electrical Characteristics

NOTE: T = $T_{OPERATING}$ unless otherwise specified.

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Low Battery Detection (LBD)	$V_{LBD1.3}$	LBD 1.3V selected	1.24	1.30	1.36	V
	$V_{LBD2.2}$	LBD 2.2V selected	2.0	2.20	2.35	V
Battery voltage for EEPROM read operation	V_{BAT_RD}		1.25		3.65	V
Battery voltage for EEPROM power check, erase, and write operations	V_{BAT_WR}		1.8		3.65	V
Average battery current in Sleep mode	$I_{BAT\_S\_A}$	All I/O pins disabled; Monitor Function disabled; Field detector duty cycle = 12.5%		1.7	2.6	uA
Average battery current in Ready state	$I_{BAT\_R\_A}$	All I/O pins disabled; Monitor Function disabled		6	8.2	uA

Electrical Characteristics (continued)

NOTE: T = 25°C unless otherwise specified.

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Input impedance (between ANT+ and VSS) to be used for antenna matching optimized for BAP mode	Z_{A_BAT}	BAP Mode enabled; P_{DUT} = -30dBm; Die form f_A = 866MHz f_A = 915MHz f_A = 953MHz		6.5 - j172 7.9 - j158 9.1 - j151		Ω Ω Ω
		Same as above but in TSSOP8 f_A = 866MHz f_A = 915MHz f_A = 953MHz		7.4 - j122 7.6 - j114 7.6 - j108		Ω Ω Ω
Input impedance (between ANT+ and VSS) to be used for antenna matching optimized for passive mode	Z_{A_PAS}	BAP Mode disabled; P_{DUT} = -9dBm; Die form f_A = 866MHz f_A = 915MHz f_A = 953MHz		18.1 - j169 15.2 - j159 14.9 - j154		Ω Ω Ω
		BAP Mode disabled; P_{DUT} = -7dBm; TSSOP8 f_A = 866MHz f_A = 915MHz f_A = 953MHz		23.3 - j145 17.6 - j113 14.5 - j95		Ω Ω Ω
Read sensitivity in passive mode[4)5)]	P_{WU_PAS}	BAP Mode disabled		-8.3		dBm
Write sensitivity in passive mode[5)]	P_{WRITE_PAS}	BAP Mode disabled		-7		dBm
Read / write sensitivity in BAP mode[4)5)]	P_{WU_BAT}	BAP Mode enabled; RF Fade Control = 10; V_{BAT} > 1.8V for write sensitivity; BAP Mode sensitivity = 00		-31		dBm
		Same as above but BAP Mode sensitivity = 01		-28		dBm
		Same as above but BAP Mode sensitivity = 10		-22		dBm
		Same as above but BAP Mode sensitivity = 11		-17		dBm
Interference rejection	REJ			4		dB

Note 4: Power from simulated conjugate match 'antenna' using a high-quality tuner that can handle a high SWR (e.g. the Maury Microwave Coaxial Manual Tuner Model 8045N). EM4325 device is configured with TOTAL mode disabled, all I/O pins disabled, UII/EPC encoding of 96 bits, reader using only inventory commands with Tari = 12.5 µs and BLF = 250 KHz.

Note 5: Sensitivity values are for TSSOP8 devices and do not include antenna gain.

Timing Characteristics

NOTE: T = $T_{OPERATING}$ unless otherwise specified.

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Erase / write endurance	T_{CYC}	T = 25°C	100,000			Cycles
Retention	T_{RET}	T ≤ 100°C	10			Years

I/O DC Characteristics

NOTE: T = $T_{OPERATING}$ unless otherwise specified.

Parameter[6)]	Symbol	Conditions[7)]	Min.	Typ.	Max.	Unit
TEST, AUX, P0_MOSI, P1_MISO, P2_SCLK, P3_CS						
Input Low Voltage	V_{IL}	BAP Mode enabled; V_{BAT} ≥ 1.25V	V_{SS}		0.3*V_{BAT}	V
		BAP Mode disabled	V_{SS}		0.3*V_{CC}	V
Input High Voltage	V_{IH}	BAP Mode enabled; V_{BAT} ≥ 1.25V	0.7*V_{BAT}		V_{BAT}	V
		BAP Mode disabled	0.7*V_{CC}		V_{CC}	V
TEST						
Input pull-down	R_{PDTEST}		5K	10K	15K	Ohm
AUX						
IOL drive	I_{OLAUX}	V_{BAT} = 2.0V; V_{OL} = 0.3V	4.5	10		mA
IOH drive	I_{OHAUX}	V_{BAT} = 2.0V; V_{OH} = V_{BAT} - 0.3V		-4	-2	mA
		V_{CC} = 1.05V; V_{OH} = V_{CC} - 0.3V; BAP Mode disabled;		-0.7	-0.3	mA
Input pull-down	R_{PDAUX}	Tamper detection enabled	50K	100K	150K	Ohm
P0_MOSI, P1_MISO						
IOL (strong driver)	I_{OLP0} I_{OLP1}	V_{BAT} = 2.0V; V_{OL} = 0.3V; BAP Mode enabled and Alarms Out enabled	4.5	10		mA
IOL (weak driver)	I_{OLP0} I_{OLP0}	V_{CC} = 1.05V; V_{OL} = 0.3V; BAP Mode disabled or Alarms Out disabled	0.3	1		mA
IOH (strong driver)	I_{OHP0} I_{OHP0}	V_{BAT} = 2.0V; V_{OH} = V_{BAT} - 0.3V; BAP Mode enabled and Alarms Out enabled		-4	-2	mA
IOH (weak driver)	I_{OHP0} I_{OHP0}	V_{CC} = 1.05V, V_{OH} = V_{CC} - 0.3V; BAP Mode disabled or Alarms Out disabled		-0.7	-0.3	mA
Input pull-down	R_{PDP0}	Device is SPI Slave and Pull Enabled	50K	100K	150K	Ohm
	R_{PDP0}	Device is SPI Slave and Pull Enabled	50K	100K	150K	Ohm

I/O DC Characteristics (continued)

NOTE: T = $T_{OPERATING}$ unless otherwise specified.

Parameter[6)]	Symbol	Conditions[7)]	Min.	Typ.	Max.	Unit
P2_SCLK						
IOL (strong driver)	I_{OLP2}	V_{BAT} = 2.0V; V_{OL} = 0.3V; BAP Mode enabled and Alarms Out enabled	4.5	10		mA
IOL (weak driver)	I_{OLP2}	V_{CC} = 1.05V; V_{OL} = 0.3V; BAP Mode disabled or Alarms Out disabled	0.3	1		mA
IOH (strong driver)	I_{OHP2}	V_{BAT} = 2.0V; V_{OH} = V_{BAT} - 0.3V; BAP Mode enabled and Alarms Out enabled		-4	-2.4	mA
IOH (weak driver)	I_{OHP2}	V_{CC} = 1.05V, V_{OH} = V_{CC} - 0.3V; BAP Mode disabled or Alarms Out disabled		-0.7	-0.3	mA
Input pull-down	R_{PDP2}	Device is SPI Slave and CPOL = 0 and Pull Enabled	50K	100K	150K	Ohm
Input pull-up	R_{PUP2}	Device is SPI Slave and CPOL = 1 and Pull Enabled	50K	100K	150K	Ohm
P3_CS						
IOL (strong driver)	I_{OLP3}	V_{BAT} = 2.0V; V_{OL} = 0.3V; BAP Mode enabled and Alarms Out enabled	4.5	10		mA
IOL (weak driver)	I_{OLP3}	V_{CC} = 1.05V; V_{OL} = 0.3V; BAP Mode disabled or Alarms Out disabled	0.3	1		mA
IOH (strong driver)	I_{OHP3}	V_{BAT} = 2.0V; V_{OH} = V_{BAT} - 0.3V; BAP Mode enabled and Alarms Out enabled		-4	-2.4	mA
IOH (weak driver)	I_{OHP3}	V_{CC} = 1.05V, V_{OH} = V_{CC} - 0.3V; BAP Mode disabled or Alarms Out disabled		-0.7	-0.3	mA
Input pull-up	R_{PUP3}	Device is SPI Slave and Pull Enabled	50K	100K	150K	Ohm

Note 6: IOL (strong driver) and IOH (strong driver) values are stated for each I/O pad/pin when it is in strong driver state and all other I/O pads/pins are not.

Note 7: V_{CC} is the rectified voltage obtained from RF field and is the supply voltage used by I/O's when BAP Mode is disabled. V_{CC} is limited by design to provide a maximum of 3V and approximately 1mA of current.

Temperature Sensor Characteristics

NOTE: $T_{OPERATING}$: -40°C to 60°C, V_{BAT}: 1.25V to 3.6V, no RF field present

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Range	T_{RANGE}		-40		60	°C
Resolution	T_{RES}			±0.25		°C
Measurement time	T_{TEMP}			8		ms
Accuracy[8]						
EM Calibrated[9)10)]	T_{ERR1}	-1°C ≤ T ≤ +13°C		±0.6	±1.5	°C
	T_{ERR2}	-40°C ≤ T ≤ -1°C +13°C ≤ T ≤ +60°C (full range)		±1.0	±2.0	°C
Customer RecRecalibrated[11)]	T_{USR1}	-1°C ≤ T ≤ +13°C		±0.4	±0.8	°C
	T_{USR2}	-40°C ≤ T ≤ -1°C +13°C ≤ T ≤ +60°C (full range)		±0.5	±1.2	°C
RF Sensitivity for passive mode operation of temp sensor[12)]	P_{TS_PAS}	+5°C		-4.5		dBm

Note 8: Prolonged exposure to high level RF fields may cause self-heating within EM4325 and affect temperature measurements such that they do not achieve the specified accuracy performance.

Note 9: EM4325 is calibrated at +5.0°C on wafer during manufacturing.

Note 10: Actual accuracy may be influenced by the final product form factor.

Note 11: Improved accuracy may be achieved by calibrating the temperature sensor at +5.0°C in the final product form factor. These numbers assume a reference probe accuracy of ±0.2°C and that customer makes proper adjustments to the Fine Trim value in the Temp Sensor Calibration Word.

Note 12: Power from simulated conjugate match; Sensitivity is for TSSOP8 packaged devices and do not include antenna gain.

Functional Description

The EM4325 is used in passive, or battery assisted passive (BAP), UHF read-only or read/write transponder applications operating at 860 MHz - 960 MHz. It is powered either by a battery or by the RF energy transmitted by the reader, which is received and rectified to generate a supply voltage for the device.

The device is normally off if it is used in a passive application and normally ready to receive commands if used in a BAP application. Once the device completes its power-on reset (POR), a Boot Sequence is performed that loads configuration data and other commonly used information from EEPROM into registers and then transitions the device into either a Tag Only Talks After Listening (TOTAL) protocol or into a Reader Talk First (RTF) protocol.

In the TOTAL protocol, the devices listens for a short period of time to determine if a reader is attempting to use the RTF protocol. If the RTF protocol is not detected then the device assumes the reader is waiting for an automated response and will initiate communications. The device continues to listen for the reader to use the RTF protocol and will automatically switch to RTF protocol if it is detected and then switch back to TOTAL protocol when the RTF communications are completed.

In the RTF protocol, the reader initiates communications to the device and the device provides a response to the reader only when appropriate. Additional custom commands/responses are implemented in this device to support SPI operation and temperature readings. RTF protocol supports read/write EEPROM operations.

The device includes a programmable auxiliary function that can be used to support:

- Tamper detection feature that checks impedance of a continuity loop. Tamper detection can be implemented using a simple continuity loop, with heat sensitive fuse wire, with sensors having both high and low impedance states, or with external devices controlling an electronic switch such as a MOSFET.
- Notification of an RF event to external devices. RF events that are available for output are the detection of an RF field, the detection of Gen2/6C commands, the detection that the device has been singulated, or the present state of the Select flag.

A programmable 4-bit I/O port can be configured to provide four general purpose I/O signals or an SPI bus. The SPI bus allows communications to/from an SPI device on a tag and allows for control and data exchange between a reader and other components on a tag. The device uses the configuration data to determine if it is an SPI Master or an SPI Slave device.

An integrated temperature sensor provides an absolute temperature reading on demand. BAP applications can be programmed to set temperature alarm conditions, provide continuous temperature monitoring, and provide the time stamp for when an alarm condition occurs.

This device is in full compliance with ISO/IEC 18000-63, ISO/IEC 18000-64, EPC™ Class-1 Generation-2, AIAG™ B-11, and ATA Spec 2000 Chapter 9 Low Memory Tag Model specifications according to the following documents:

"ISO/IEC 18000-63 Information technology – Radio frequency identification for item management – Part 63: Parameters for air interface communications at 860 MHz to 960 MHz Type C"

"ISO/IEC 18000-64 Information technology – Radio frequency identification for item management – Part 64: Parameters for air interface communications at 860 MHz to 960 MHz Type D"

"EPC Radio-Frequency Identity Protocols, Class-1 Generation-2 UHF RFID, Protocol for Communications at 860 Mhz - 960 MHz, Version 1.2.0" from EPCglobal Inc.

"EPCglobal Tag Data Standards, Version 1.10" from EPCglobal Inc.

"B-11, Item Level Radio Frequency Identification (RFID) Standard", Revision 8, from Automotive Industry Action Group

"ATA Spec 2000 Chapter 9, Automated Identification and Data Capture (AIDC)", from Air Transport Association

The ISO/IEC 18000-63, ISO/IEC 18000-64, and the EPC™ Class-1 Generation-2 specifications have many optional features and the following table identifies which of them are supported by this device.

Optional Features

Spec	Optional Feature / Command	Supported	Comments
ISO & EPC	Kill Password	Yes	
ISO & EPC	Access Password	Yes	
ISO & EPC	Extended TID	Yes	Extended TID used for EPCglobal applications and includes fields for XTID Header, Serial Number, Optional Command Support, BlockWrite and BlockErase, and User Memory and BlockPermalock
ISO & EPC	User Memory	Yes	
ISO & EPC	Proprietary Commands	No	
ISO & EPC	Custom Commands	Yes	
ISO & EPC	Access Command	Yes	
ISO & EPC	BlockWrite Command	Yes	Block is defined to be one page (4 words) in EEPROM. Can write from 1 to 4 words at a time within a block. Cannot write across block boundaries. Cannot be used for page 0 of UII/EPC memory bank.
ISO & EPC	BlockErase Command	Yes	Block is defined to be one page (4 words) in EEPROM. Can erase from 1 to 4 words at a time within a block. Cannot erase across block boundaries. Cannot be used for page 0 of UII/EPC memory bank or the UTC Clock.
ISO & EPC	BlockPermalock Command	Yes	Block is defined to be one page (4 words) in EEPROM. Only for User memory.
ISO & EPC	Error Specific Codes	Yes	
ISO & EPC	ASK and/or PSK Backscatter Modulation	Yes	Only ASK.
ISO & EPC	Extended Protocol Control (XPC_W1)	Yes	
ISO & EPC	XPC_W2	No	
ISO & EPC	Recommissioning	No	
ISO only	Battery Assisted Passive (BAP)	Yes	
ISO only	BAP Persistence Maximums	No	
ISO only	Dead Battery Response (DBR)	Yes	
ISO only	Full-function Sensor	No	
ISO only	HandleSensor command	No	
ISO only	Flex_Query Command	Yes	Includes support of all M values (2, 4, 8, 16, 32, 64).
ISO only	BroadcastSync Command	Yes	Only supported in BAP mode with time stamp required for temperature sensor monitoring
ISO only	Type D	Yes	Also known as TOTAL.
ISO only	Type D PPE and/or Miller Encoding	Yes	Both are supported.

Memory Organization

The EEPROM is organized into 64 pages with each page having 4 words. The ISO/IEC 18000-63 and the EPC^{TM} Class-1 Generation-2 specifications define four memory banks: Reserved, TID, UII/EPC, and User, with the last 5 pages within the User memory bank being allocated by EM as System memory in this device. The four memory banks are contiguous in EEPROM. The TID memory bank is permalocked at time of manufacture.

The EEPROM is allocated to the four memory banks as described in the following manner:

Memory Bank	Memory Configuration
Reserved	1 page
Kill Password	32 bits
Access Password	32 bits
TID	4 pages
Maximum IC Serial Number	48 bits
UII/EPC	6 pages
Maximum UII/EPC encoding	352 bits
User (includes System memory)	53 pages
Maximum User data	3072 bits
Maximum TOTAL data	3008 bits

The memory map is available on the following page.

Memory Bank Name	Logical Page Number (decimal)	Logical Word Address (hex)	Physical Page Number (decimal)	Physical Word Address (hex)	Contents	Access Protection for RF Commands		Access Protection for SPI Commands	
						Read	Write	Read	Write
Reserved	0	00 - 01	0	00 - 01	Kill Password	STD	STD	STD	STD+SWE
		02 - 03		02 - 03	Access Password	STD	STD	STD	STD+SWE
TID	0 - 3	00 - 0F	1 - 4	04 - 13	TID	NP	STD	NP	STD+SWE
	9 (Not in EEPROM)	26 - 27	n/a	n/a	SSD Address	NP	NA	NA	NA
		28 - 29	n/a	n/a	UTC Address	NP	NA	NA	NA
UII/EPC	0	00	5	14	CRC-16 (Not in EEPROM)	NP	NA	NP	NA
		01		15	PC	NP	STD	NP	STD+SWE
		02 - 03		16 - 17	UII/EPC	NP	STD	NP	STD+SWE
	1 - 5	04 - 17	6 - 10	18 - 2B					
	8 (Not in EEPROM)	21	n/a	n/a	XPC_W1	NP	NA	NA	NA
User	0 - 47	00 - BF	11 - 58	2C - EB	User Defined	NP	STD	NP	SWE
System (User)	59 Temp Sensor Page	EC	59	EC	Temp Sensor Control Word 1	NP	STD	NP	NA
		ED		ED	Temp Sensor Control Word 2	NP	STD	NP	NA
		EE		EE	Temp Sensor Control Word 3	NP	STD	NP	NA
		EF		EF	Temp Sensor Calibration Word	NP	STD	NP	NA
	60 Control Page	F0	60	F0	I/O Control Word	NP	STD	NP	NP
		F1		F1	Battery Management Word 1	NP	STD	NP	NP
		F2		F2	Battery Management Word 2	NP	STD	NP	NP
		F3		F3	TOTAL Word	NP	STD	NP	NP
	61 SPI WE Page	F4 - F7	61	F4 - F7	SPI Write Enable Words	NP	STD	NP	NA
	62 Lock Page (A)	F8 - FB	62	F8 - FB	Lock Words (A)	BlockPermalock	BlockPermalock	NP	NA
	63 Lock Page (B)	FC - FF	63	FC - FF	Lock Words (B)	BlockPermalock	BlockPermalock	NP	NA
	64 Sensor/Clock Page (Not in EEPROM)	100	64	100	Sensor Data (MSW)	NP	NP	SPIGetSensorData	NA
		101		101	Sensor Data (LSW)	NP	NA	SPIGetSensorData	NA
		102		102	UTC Clock (MSW)	NP	NP	SPIGetSensorData	SPISetClock
		103		103	UTC Clock (LSW)	NP	NP	SPIGetSensorData	SPISetClock
	65 - 66 Register File Pages (Not in EEPROM)	104 - 10B	65 - 66	104 - 10B	Register File	NP	IOC	NP	NP
	67 I/O Page (Not in EEPROM)	10C	67	10C	I/O Word	NP	STD	NA	NA
		10D		10D	BAP Mode Word	NP	NP	NA	NA
		10E		10E	Not Used	NA	NA	NA	NA
		10F		10F	Not Used	NA	NA	NA	NA

Access Protection Codes:

BlockPermalock = RF command to access
IOC = I/O Control Word
NA = No Access (operation never allowed)
NP = No Protection (operation always allowed)
SPIGetSensorData = SPI command to access
SPISetClock = SPI command to access
STD = Standard Bits for Lock and/or Permalock
SWE = SPI Write Enable Bit for Page

Memory Definition

Reserved Memory

Reserved memory is as defined in ISO/IEC 18000-63 and EPC Class 1 Gen 2 specs.

TID Memory

TID memory is formatted by EM Microelectronic-Marin SA based on the version of the device that is ordered. There are four formats available: ISO E0, ISO E3, EPC, and legacy TOTAL.

ISO E0 Format

Word (hex)	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
0	1	1	1	0	0	0	0	0	0	0	0	1	0	1	1	0
1	0	1	Configuration (see below)						Customer Number (0x00 - 0x0F for EM)							
2	IC Serial Number [31:16]															
3	IC Serial Number [15:0]															
4	CRC-16 for the 64-bit UID															
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D	EM Temp Sensor Calibration Word															
E	EM Data Word 1 (see below)															
F	EM Data Word 2 (see below)															

ISO E3 Format

Word (hex)	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
0	1	1	1	0	0	0	1	1	0	0	0	1	0	1	1	0
1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
2	0	1	Configuration (see below)						Customer Number (0x00 - 0x0F for EM)							
3	IC Serial Number [31:16]															
4	IC Serial Number [15:0]															
5	CRC-16 for the 80-bit UID															
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D	EM Temp Sensor Calibration Word															
E	EM Data Word 1 (see below)															
F	EM Data Word 2 (see below)															

EPC Format

Word (hex)	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
0	1	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0
1	1	0	1	1	0	0	0	0	0	1	Configuration (see below)					
2	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
3	Customer Number (0x00 - 0x0F for EM)								IC Serial Number [39:32]							
4	IC Serial Number [31:16]															
5	IC Serial Number [15:0]															
6	0	0	0	1	1	1	0	1	1	1	0	1	0	1	1	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0
B	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
C	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
D	EM Temp Sensor Calibration Word															
E	EM Data Word 1 (see below)															
F	EM Data Word 2 (see below)															

Configuration Field

MSB					LSB
RFU		SMS 0: Disabled 1: Enabled	Temp Sensor 0: Calibrated 1: Uncalibrated	RFU	

Legacy TOTAL Format

Word (hex)	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
0	0	1	0	0	0	1	Customer Number									
1	IC Serial Number [31:16]															
2	IC Serial Number [15:0]															
3	TOTAL CRC-16 for the 48-bit UID															
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D	EM Temp Sensor Calibration Word															
E	EM Data Word 1 (see below)															
F	EM Data Word 2 (see below)															

EM Data Word 1

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	Demo	UID Word Count			Wafer Lot Digit 5				Wafer Lot Digit 4				Wafer Lot Digit 3			

EM Data Word 2

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	Wafer Lot Digit 2				Wafer Lot Digit 1				Wafer Number Digit 2				Wafer Number Digit 1			

UII/EPC Memory

UII/EPC memory is as defined in ISO/IEC 18000-63 and EPC Class 1 Gen 2 specs.

User Memory and System Memory

User memory (other than System memory) is as defined in ISO/IEC 18000-63 and EPC Class 1 Gen 2 specs. System memory is read during a Boot Sequence and used to configure device features. All configuration data read from EEPROM during a Boot Sequence remain valid until the next Boot Sequence occurs.

System Memory - Temp Sensor Control Words

Writing to any of these words resets the UTC Clock, Monitor Function, and the alarms for Aux, Under Temp, and Over Temp.

The Temp Sensor and Monitor Function are controlled by the three Temp Sensor Control Words. The Monitor Function is only performed when BAP Mode is enabled and it is used to monitor Tamper Detection (if enabled), Low Battery, Under Temp, and Over Temp conditions. The Monitor Function uses a programmable sampling interval that defines when to check for alarm conditions. Time is measured using a clock signal derived from the system oscillator and will be shortened by some portion of one clock period and have the same accuracy as the system oscillator. The Monitor Function uses three counters for the Under Temp Count, the Over Temp Count, and the number of Aborted Temp Measurements. Monitoring is enabled when the sampling interval is non-zero and if a time stamp is required, then the Monitor Function will not begin until the UTC Clock is set non-zero by an external command.

The Temp Sensor only supports measurements in the valid range -40.00°C to +63.75°C. Setting either the Under Temp Threshold (Low Limit) or the Over Temp Threshold (High Limit) to a value outside of the valid range will have undefined results.

Temp Sensor Control Word 1

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	0	Reset Alarms EN	Under Temp Samples Required for Alarm (Zero means no Under Temp Threshold)					Under Temp Threshold (2's complement with LSB = 0.25°C) Min value = 100000000 = -64.00°C Mid value = 000000000 = 0.00°C Max value = 011111111 = +63.75°C								

Content	Description
Reset Alarms Enable	0: Disable ResetAlarms command, 1: Enable ResetAlarms command
Under Temp Samples Required for Alarm	Number of consecutive samples below the Under Temp Threshold for an Under Temp alarm condition to occur.
Under Temp Threshold	Under Temp threshold used for monitoring function. Temperature sensor performance below that of the minimum operating temperature for the device is not specified.

Temp Sensor Control Word 2

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	RFU	Time Stamp Required	Over Temp Samples Required for Alarm (Zero means no Over Temp Threshold)					Over Temp Threshold (2's complement with LSB = 0.25°C) Min value = 100000000 = -64.00°C Mid value = 000000000 = 0.00°C Max value = 011111111 = +63.75°C								

Content	Description
RFU	Reserved for Future Use
Time Stamp Required	0: Time stamp is not required for Monitor Function, 1: Time stamp is required for Monitor Function
Over Temp Samples Required for Alarm	Number of consecutive samples above the Over Temp Threshold for an Over Temp alarm condition to occur.
Over Temp Threshold	Over Temp threshold used for monitoring function. Temperature sensor performance below that of the minimum operating temperature for the device is not specified.

Temp Sensor Control Word 3

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	Monitor Delay Units		Monitor Delay Value (Zero value means no delay)						Sample Interval Units		Sampling Interval (Zero value means no sampling)					

Content	Description
Monitor Delay Units	00: 1 Second 01: 1 Minute 10: 1 Hour 11: 1 Sampling Interval
Monitor Delay Value	Time until first measurement is performed
Sampling Interval Units	00: 1 Second 01: 1 Minute 10: 1 Hour 11: 5 Minutes
Sampling Interval Value	Time between measurements

System Memory - Temp Sensor Calibration Word

Temp sensor calibration occurs during wafer testing. It is possible to re-calibrate the temp sensor after wafer testing if desired. Writing to this word resets the UTC Clock, Monitor Function, and the alarms for Aux, Under Temp, and Over Temp.

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	NOTE: Reserved for EM and shall not be changed. (Any changes to this word must preserve these data bits)											Fine Trim 2's complement value used for offset adjustment. Min value = 10000 = -4.00°C Mid value = 00000 = 0.00°C Max value = 01111 = +3.75°C				

It is possible to re-calibrate the temp sensor after wafer testing if the Temp Sensor Page is not BlockPermalocked. A copy of the original value of the Temp Sensor Calibration Word determined during wafer testing is available in TID Memory as the EM Temp Sensor Calibration Word.

System Memory - I/O Control Word

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	Pull EN	SPI Config		SPI CPOL	SPI CPHA	AUX EN	AUX Out	SPI Slave Config								
								Alarms Out	P3 EN	P2 EN	P1 EN	P0 EN	P3 Out	P2 Out	P1 Out	P0 Out

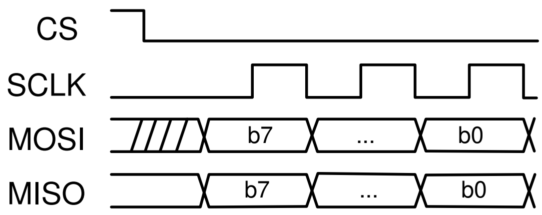
Content	Description
Pull Enable	0: Disable pull resistors on P3_CS, P2_SCLK, P1_MISO, and P0_MOSI, 1: Enable pull resistors on P3_CS, P2_SCLK, P1_MISO, and P0_MOSI when they are enabled as inputs
SPI Config	0: SPI interface disabled, 1: SPI interface enabled as SPI Slave using half-duplex communications, 2: SPI interface enabled as SPI Master using full-duplex communications, 3: SPI interface enabled as SPI Master using half-duplex communications
SPI CPOL & SPI CPHA	See text below.
AUX EN	0: Aux function disabled (HI-Z state on AUX pin), 1: Aux function enabled
AUX Out	0: Aux function is for tamper detection when device is not an SPI Slave and tamper test signal is output on MOSI pin and input on AUX pin, 1: Aux function is for an RF event condition and output on AUX pin
SPI Slave Config	When SPI Config is "1": 0: SPI Slave operation is normal and extensions are disabled, Other values: SPI Slave extensions are enabled as defined in the section on SPI Slave Extensions
Alarms Out	When SPI Config is "0" and an I/O pin is enabled for output: 0: Output for the I/O pin is from the I/O Word, 1: Output for the I/O pin is for an alarm condition P3 = Temperature Alarm (Under Temp OR Over Temp), P2 = Aux Alarm, P1 = No Alarms, P0 = Tamper test signal when Aux function enabled for tamper detection, Output in I/O Word when Aux function not enabled for tamper detection
I/O P3 EN, I/O P2 EN, I/O P1 EN, I/O P0 EN	When SPI Config is "0": 0: P(n) is high impedance (HI-Z), 1: P(n) enabled for I/O
I/O P3 Out, I/O P2 Out, I/O P1 Out, I/O P0 Out	When SPI Config is "0" and P(n) EN is "1": 0: P(n) is input, 1: P(n) is output NOTE: Outputs maintain state when device is in Sleep Mode. If P3 is enabled as an input AND the device is using TOTAL AND presently muted, then a rising edge on P3 will terminate the muting, perform the Boot Sequence, and initiate transmissions of TOTAL TagMsg's in the same manner as when a TOTAL MUTE timeout occurs. If in BAP mode AND P3 is enabled as an input AND the device is not using TOTAL AND the AUX function is configured for tamper detection, then a rising edge on P3 will indicate a tamper event and logged as an AUX alarm.

The SPI CPOL bit and the SPI CPHA bit are used to define the behaviour of SCLK and when data is latched with respect to SCLK. If the phase of the clock is zero (CPHA is "0"), data is latched at the rising edge of SCLK when CPOL is "0" and at the falling edge of SCLK when CPOL is "1". If the phase of the clock is one (CPHA is "1"), data is latched at the rising edge of SCLK when CPOL is "1" and at the falling edge of SCLK when CPOL is "0". The combination of the two bits is also known as the SPI Mode and defined as follows:

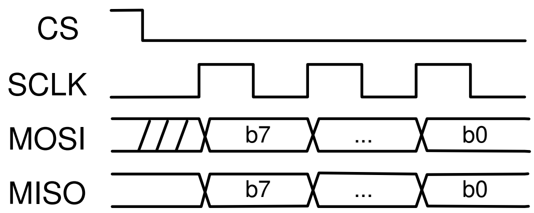
SPI Mode	CPOL	CPHA
0	0	0
1	0	1
2	1	0
3	1	1

The timing diagrams for each combination of CPOL and CPHA are shown below.

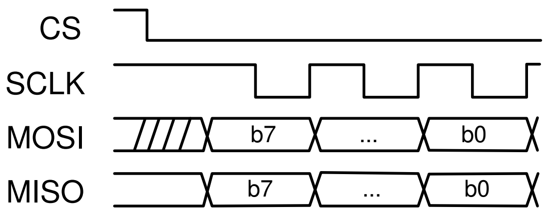
CPOL=0 CPHA=0



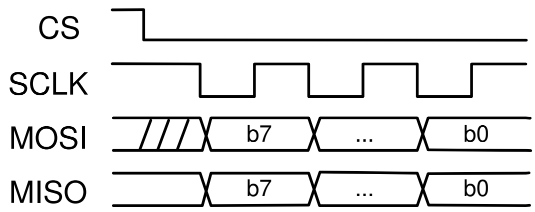
CPOL=0 CPHA=1



CPOL=1 CPHA=0



CPOL=1 CPHA=1



System Memory - Battery Management Words

These words provide a means to control the duty cycle to prolong battery life. Timed values are measured using a clock signal derived from the system oscillator and will be shortened by some portion of one clock period and have the same accuracy as the system oscillator.

Battery Management Word 1

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	RF Field Detector Duty Cycle		RF Fade Control for Active to Sleep Transition		Initial Command Detection Timeout for Active to Sleep Transition (LSB = 10 ms) (Zero means no timeout)				Idle and/or TOTAL Mute Timeout Units		Idle Timeout for Active to Sleep Transition and/or TOTAL Mute Timeout (Zero means no timeout)				BAP Mode Sensitivity	

Content	Description
RF Field Detector Duty Cycle	00: 100% duty cycle (always on), 01: 50% duty cycle (50 µs on, 50 µs off), 10: 25% duty cycle (50 µs on, 150 µs off), 11: 12.5% duty cycle (50 µs on, 350 µs off)
RF Fade Control for Active to Sleep Timeout	Amount of time that the field is no longer detected before an Active to Sleep transition will occur. Field detection for RF fade control is only performed when the device is not processing an RF command and the timing operation is reset with every RF command. RF fade control times : 00: 125 µs, 01: 1 ms, 10: 10 ms, 11: 100 ms
Idle Timeout Units	00: 10 ms, 01: 1 sec, 10: 4 sec, 11: 64 sec
BAP Mode Sensitivity	00: best (maximum) sensitivity, 01: default sensitivity, 10: degraded sensitivity, 11: most degraded (minimum) sensitivity NOTE: BAP Mode Sensitivity value is read from EEPROM and latched during a POR Boot Sequence. Writing a new value into EEPROM does not go into effect until the next POR Boot Sequence occurs. A POR Boot Sequence is initiated when the device becomes energized by an RF field and BAP Mode is disabled, by applying a sufficient voltage to VBAT when BAP Mode is enabled, or by execution of a SPIBoot command.

Timeout values are implemented such that a timeout will occur between the specified count (N) and up to one additional period (N+1). For example, setting a timeout value to 50 ms will result in having the timeout occur between 50 ms and 60 ms.

Battery Management Word 2

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	AUX EVENT		RTF IDLE TOUT EN	TOTAL MUTE TOUT EN	Sleep Timeout (Zero means no duty cyle control)			Number of TOTAL TagMsg's to Transmit Before Self Muting (Zero means no self muting)						Alarms Blink EN	LBD Level	BAP CTRL EN

Content	Description
AUX Event Condition	00: RF field is present meaning the device state is not Sleep 01: Device is participating in the current inventory round meaning the device state is Arbitrate, Reply/TagMsg, Acknowledged, Open, or Secured 10: Device is singulated meaning the device state is Acknowledged, Open, or Secured 11: Device is selected meaning the Select Flag is set. The signal is gated in Sleep state and during the Boot Sequence.
RTF Idle Timeout Enable	0: RTF Idle timeout is disabled, 1: RTF Idle timeout is enabled NOTE: This should be enabled whenever TOTAL Mute Timeout is enabled.
TOTAL Mute Timeout Enable	When TOTAL is enabled, 0: TOTAL Mute timeout is disabled, 1: TOTAL Mute timeout is enabled
Sleep Timeout	When BAP Mode is enabled and Idle Timeout is non-zero, 000: Duty cycle control disabled, 001: Duty cycle control enabled, Sleep Timeout = Idle Timeout, 010: Duty cycle control enabled, Sleep Timeout = 2X Idle Timeout, 011: Duty cycle control enabled, Sleep Timeout = 4X Idle Timeout, 100: Duty cycle control enabled, Sleep Timeout = 8X Idle Timeout, 101: Duty cycle control enabled, Sleep Timeout = 16X Idle Timeout, 110: Duty cycle control enabled, Sleep Timeout = 32X Idle Timeout, 111: Duty cycle control enabled, Sleep Timeout = 64X Idle Timeout,
Number of TOTAL TagMsg's	Number of TagMsg's to transmit before self muting occurs.
Alarms Blink Enable	When SPI Config is "0" and Alarms Out is "1" and the I/O pins are enabled for outputs, 0: Alarm outputs are continuous and active low signals, 1: Alarm outputs are active low pulses approximately 40 ms in duration and occurring approximately every 8 seconds NOTE: Blinking alarm outputs are not pulsed simultaneously and are staggered approximately one second apart.
LBD Level	0: LBD level = 1.3V; 1: LBD level = 2.2V
BAP Control Enable	0: BAP control disabled, 1: BAP control enabled NOTE: Allows a reader to change the BAP Mode setting in the BAP Mode Word and enable/disable the use of an ultra-low power mode.

System Memory - TOTAL Word

TOTAL Word

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	Page Link EN	Fixed Slot Count (7 = infinite)			Mute Function	Adaptive Hold-off EN	Include Sensor Data	Data Encoding Type		BLF		Maximum Hold-off Time		Initial Listen Time (Zero means no TOTAL)		

Content	Description
Page Link Enable	When Data Encoding Type is Miller subcarrier M=2 or M=4, 0: Page links are disabled, 1: Page links are enabled
Fixed Slot Count	Number of slots having fixed delay times before slots start using random delay times. Fixed delay time is always equal to the initial listen time.
Mute Function	0: Mute function uses RTF command decoder only, 1: Mute function uses RTF command decoder and simplified detection
Adaptive Hold-off Enable	0: Adaptive Hold-off is disabled, 1: Adaptive Hold-off is enabled
Include Sensor Data	When Sensor Page is enabled as part of the TagMsg, 0: Sensor data is not included in TOTAL Sensor page, 1: Sensor data is included in TOTAL Sensor page NOTE: When sensor data is included, the signal levels on I/O's P3, P2, P1, P0 will be stored in bit positions 31 to 28 and the temperature data for the last measurement taken will be stored in bit positions 24 to 16 of the TOTAL Sensor page
Data Encoding Type	00: PPE, 01: FM0, 10: Miller subcarrier (M = 2), 11: Miller subcarrier (M = 4)
Backscatter Link Frequency (BLF)	00: 128 KHz, 01: 256 KHz, 10: 320 KHz, 11: 512 KHz (using PPE) or 640 KHz (using non-PPE)
Maximum Hold-off Time	Maximum time between TOTAL TagMsgs's assuming no muting occurs: 00: 6.4 ms, 01: 12.8 ms, 10: 25.6 ms, 11: 51.2 ms
Initial Listen Time	Minimum time TOTAL will initially listen for RTF protocol: 000: TOTAL disabled, 001: 1 ms, 010: 2 ms, 011: 3 ms, 100: 4 ms, 101: 5 ms, 110: 10 ms, 111: 20 ms

This word provides a means to enable TOTAL mode and configure the protocol parameters. TOTAL mode is not allowed for tags in the Killed state. When TOTAL mode is enabled, User Memory pages 1 - 46 are used as TOTAL memory pages with User Memory page 47 being the TOTAL System page. See section on TOTAL operation for more information.

System Memory - SPI Write Enable Words

The SPI Write Enable Words contain bits for each EEPROM page that a user may define as having write permission for the SPI interface when operating as an SPI Slave device. If the corresponding bit is 0, then the SPI interface is not allowed to write to that EEPROM page. Note that the write enable bit is only one condition for writing to the EEPROM page and is used in conjunction with the memory lock bits (except for User memory) to control EEPROM write operations. If using the memory lock bits to prevent the SPI interface from writing to EEPROM, then both the pwd-write and permalock bits must be set.

SPI Write Enable Word 1

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	EE Pg 0	EE Pg 1	EE Pg 2	EE Pg 3	EE Pg 4	EE Pg 5	EE Pg 6	EE Pg 7	EE Pg 8	EE Pg 9	EE Pg 10	EE Pg 11	EE Pg 12	EE Pg 13	EE Pg 14	EE Pg 15

SPI Write Enable Word 2

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	EE Pg 16	EE Pg 17	EE Pg 18	EE Pg 19	EE Pg 20	EE Pg 21	EE Pg 22	EE Pg 23	EE Pg 24	EE Pg 25	EE Pg 26	EE Pg 27	EE Pg 28	EE Pg 29	EE Pg 30	EE Pg 31

SPI Write Enable Word 3

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	EE Pg 32	EE Pg 33	EE Pg 34	EE Pg 35	EE Pg 36	EE Pg 37	EE Pg 38	EE Pg 39	EE Pg 40	EE Pg 41	EE Pg 42	EE Pg 43	EE Pg 44	EE Pg 45	EE Pg 46	EE Pg 47

SPI Write Enable Word 4

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	EE Pg 48	EE Pg 49	EE Pg 50	EE Pg 51	EE Pg 52	EE Pg 53	EE Pg 54	EE Pg 55	EE Pg 56	EE Pg 57	EE Pg 58	RFU				

System Memory - Lock Words

Each Lock Word is physically mapped to two words in the EEPROM.

Lock Word 1

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	Blk 0	Blk 1	Blk 2	Blk 3	Blk 4	Blk 5	Blk 6	Blk 7	Blk 8	Blk 9	Blk 10	Blk 11	Blk 12	Blk 13	Blk 14	Blk 15

Lock Word 2

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	Blk 16	Blk 17	Blk 18	Blk 19	Blk 20	Blk 21	Blk 22	Blk 23	Blk 24	Blk 25	Blk 26	Blk 27	Blk 28	Blk 29	Blk 30	Blk 31

Lock Word 3

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	Blk 32	Blk 33	Blk 34	Blk 35	Blk 36	Blk 37	Blk 38	Blk 39	Blk 40	Blk 41	Blk 42	Blk 43	Blk 44	Blk 45	Blk 46	Blk 47

Lock Word 4

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	Kill Flag	Kill Pwd		Access Pwd		EPC Memory		TID Memory		User Memory		Blk 59	Blk 60	Blk 61	Trim Lock	Active Flag

Content	Description
Blk xx (permalock bit for block xx)	As defined in ISO/IEC 18000-63 and EPC Class 1 Gen 2 specs
Kill Flag	0: Tag alive, 1: Tag killed
Kill Pwd	As defined in ISO/IEC 18000-63 and EPC Class 1 Gen 2 specs
Access Pwd	As defined in ISO/IEC 18000-63 and EPC Class 1 Gen 2 specs
EPC Memory	As defined in ISO/IEC 18000-63 and EPC Class 1 Gen 2 specs
TID Memory	As defined in ISO/IEC 18000-63 and EPC Class 1 Gen 2 specs
User Memory	As defined in ISO/IEC 18000-63 and EPC Class 1 Gen 2 specs
Trim Lock	0: Trim values are not locked, 1: Trim values are locked NOTE: The Trim Lock bit is the permalock bit for the trim values and is considered to be Block 62 when using the BlockPermalock command.
Active Flag	0: Lock page inactive, 1: Lock page active

System Memory - Sensor Data

The sensor data is read-only and updated by the Monitoring Function. A reader can request sensor measurements be made on demand by either writing to the Sensor Data (MSW) word or using the custom command GetSensorData. The device will perform tamper detection (if enabled), low battery detection (if BAP Mode is enabled), and make a temperature measurement (if possible). The Low Battery Alarm and Aux Alarm will be updated with the new sample information. Temperature measurements on demand are not possible when BAP Mode is disabled and the RF field strength is too low. Temperature measurements made on demand are not used as part of the Monitoring function and have no effect on the Under Temp Alarm or the Over Temp Alarm. See sections on Temp Sensor Operation and Alarms for more information.

Sensor Data (MSW)

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	Low Battery Alarm	Aux Alarm	Over Temp Alarm	Under Temp Alarm	P3 Input	Monitor EN	0	Temperature (2's complement with LSB = 0.25°C) Min value = 100000001 = -63.75°C Mid value = 000000000 = 0.00°C Max value = 011111111 = +63.75°C (100000000 = invalid measurement)								

Sensor Data (LSW)

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	Aborted Temp Measurements						Under Temp Count					Over Temp Count				

Content	Description
Low Battery Alarm	0: No problem, 1: Low battery detected
Aux Alarm	0: No problem, 1: Tamper detected or SPI Alarm declared
Over Temp Alarm	0: No problem, 1: Continuous Over Temp detected when Monitor Enabled is "1"
Under Temp Alarm	0: No problem, 1: Continuous Under Temp detected when Monitor Enabled is "1"
P3 Input	Signal level on I/O P3 when used as an input pin, else zero
Monitor Enabled	0: Monitoring disabled, 1: Monitoring enabled NOTE: Monitoring is enabled when BAP Mode is enabled AND the Sampling Interval is non-zero and if a time stamp is required then the UTC Clock value must be non-zero.
Temperature	Most recent temperature measurement. Temperature sensor performance below that of the minimum operating temperature for the device is not specified.
Aborted Temp Measurements	Count of the number of temp measurements that were aborted for any reason. The count value is incremented until it achieves its max value or until an Under Temp Alarm or Over Temp Alarm is declared. The count value is reset to zero when the alarms are cleared. Aborted temp measurements have a value of -64.00.
Under Temp Count	Current count of consecutive samples that are Under Temp NOTE: This count is incremented by the Monitor Function whenever a temp measurement is made and found to be less than the Under Temp Threshold; otherwise, the count is reset to zero. If the count ever reaches the number of samples required for a sustained under temp condition, then the Under Temp Alarm will be set and the count is reset to zero. The Monitor Function will then continue to increment the count so long as the sustained under temp condition persists and will stop once the max count value is reached or when the under temp condition no longer exists and will not reset the count until the Under Temp Alarm is cleared.
Over Temp Count	Current count of consecutive samples that are Over Temp NOTE: This count functions in the same manner as described for the Under Temp Count except that it is used for temp measurements found to be greater than the Over Temp Threshold.

System Memory - UTC Clock

The UTC Clock is a 32-bit counter that is clocked approximately every second in BAP Mode and has the same accuracy as the system oscillator. The counter is enabled for counting when the 8 MSB's of the 32-bit value are not all zeroes and none of the following alarms are set: Aux, Under Temp, and Over Temp. The current time can only be set via external commands (e.g. BroadcastSync or Write) and the 8 MSB's of the 32-bit value to be written cannot all be zeroes. Additionally, the UTC Clock can only be set when none of the following alarms are set: Aux, Under Temp, and Over Temp. The UTC Clock is reset to all zeroes during POR, when BAP Mode transitions from "0" to "1", when the custom command ResetAlarms is executed, or when a reader performs a successful write operation to any word in the Temp Sensor Page.

UTC Clock (MSW)

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	Current Time (LSB = 65536 seconds)															

UTC Clock (LSW)

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	Current Time (LSB = 1 second)															

System Memory - Register File

Register File Words 1 - 8

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	User Defined															

The Register File is volatile and occupies two memory pages that are accessible to a reader and/or an SPI Master device. The first Register File page contains Words 1 - 4 and the second Register File page contains Words 5 - 8. During the Boot Sequence after POR, the 4 MSB's of Register File Word 1 are initialized to zeroes and all other bits in all of the Register File Words are in an unknown state until written by either the reader or the SPI Master device.

The Register File can be used as a communications buffer for high speed transactions between a reader and an SPI Master device. RF interface read times are the same as for other types of memory but the write times are very fast with typical T1 times being ~180 µs for one word or ~370 µs for an entire page. SPI bus read time is ~250 µs when the device is not in Sleep state (~410 µs when in Sleep state) plus the transfer time to the SPI Master. SPI bus write time is ~490 µs when the device is not in Sleep state (~650 µs when in Sleep state) plus the transfer time from the SPI Master.

If the device is configured as an SPI Slave, then the use of the Register File may be altered using SPI Slave Extensions. Either one or both of the Register File pages may be used for EPC/UII pages. These configurations prevent write access from the RF interface to the Register File pages used for EPC/UII pages. The SPI Master always has write access to the Register File pages even when the EPC/UII Memory is locked or permalocked.

The Boot Sequence that occurs after every transition from Sleep state to Ready state may also initialize the 4 MSB's of Register File Word 1 to zeroes. The contents of all other bits in Register File Words are retained during Sleep state and the transition to Ready state. The 4 MSB's of Register File Word 1 are retained when the first Register File page is being used as an EPC/UII page; otherwise, the 4 MSB's of Register File Word 1 are set to zeroes.

System Memory - I/O Word

I/O Word

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	High Field	RFU											P3	P2	P1	P0

Content	Description
High Field	High Field Present (read-only)
RFU	Reserved for Future Use
I/O P3	I/O P3 when SPI Config is “0” and P3 EN is “1”
I/O P2	I/O P2 when SPI Config is “0” and P2 EN is “1”
I/O P1	I/O P1 when SPI Config is “0” and P1 EN is “1”
I/O P0	I/O P0 when SPI Config is “0” and P0 EN is “1”

System Memory - BAP Mode Word

BAP Mode Word

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	RFU															BAP Mode

Content	Description
RFU	Reserved for Future Use
BAP Mode	0: Battery Assisted Passive Mode disabled, 1: Battery Assisted Passive Mode enabled

BAP Mode may only be changed when BAP Control Enable is “1”, the device is not configured as an SPI Slave, and the RF field strength is sufficient to perform the operation. This word is used to enable/disable the use of an ultra-low power mode to extend battery life. Transitions to or from the ultra-low power mode will occur after successfully changing the BAP Mode value and then leaving the Open or Secured States. The device will operate only in passive mode while the ultra-low power mode is enabled.

BAP Mode is required for SPI Slave operation and the use of the UTC Clock and the Monitor Function for checking alarm conditions.

Memory Restrictions on Select Command

The Select command is not allowed over the Sensor/Clock Page in System Memory (User Memory page 64).

EEPROM Delivery State

The default configurations are the following:

Memory Bank	Word(s)	Word Address (hex)	Wafer/Die Value (hex)	TSSOP8 Value (hex)	EM4325V26 Value (hex)
Reserved	Kill Password	0x00 – 0x01	0x0000	0x0000	0x0000
	Access Password	0x02 – 0x03	0x0000	0x0000	0x0000
TID	All words	0x00 – 0x0F	version defined and specified in section on TID Memory	version defined and specified in section on TID Memory	version defined and specified in section on TID Memory
UII/EPC	PC Word	0x01	0x3000	0x3000	0x3000
	UII/EPC	0x02 – 0x07	copy of TID Words 0x00 – 0x05 With 8 MSB's of TID Word 0 set to 0x00	copy of TID Words 0x00 – 0x05 With 8 MSB's of TID Word 0 set to 0x00	copy of TID Words 0x00 – 0x05 With 8 MSB's of TID Word 0 set to 0x00
		0x08 – 0x13	0x0000	0x0000	0x0000
		0x14 – 0x17	variable	variable	variable
User	All words	0x00 – 0xBF	0x0000	0x0000	0x0000
System	Temp Sensor Word 1	0xEC	0x0000	0x0000	0x0000
	Temp Sensor Word 2	0xED	0x0000	0x0000	0x0000
	Temp Sensor Word 3	0xEE	0x0000	0x0000	0x0000
	Temp Sensor Calibration Word	0xEF	variable	variable	variable
	I/O Control Word	0xF0	0x0000	0xA600	0xA680
	Battery Management Word 1	0xF1	0xE001	0xE001	0xC001
	Battery Management Word 2	0xF2	0x8001	0x8001	0x0000
	TOTAL Word	0xF3	0x0000	0x0000	0x0000
	SPI Write Enable Word 1	0xF4	0x0000	0xFFFF	0xFFFF
	SPI Write Enable Word 2	0xF5	0x0000	0xFFFF	0xFFFF
	SPI Write Enable Word 3	0xF6	0x0000	0xFFFF	0xFFFF
	SPI Write Enable Word 4	0xF7	0x0000	0xFFFF	0xFFFF
	Lock Word 1A	0xF8	0x0000	0x0000	0x0000
	Lock Word 2A	0xF9	0x0000	0x0000	0x0000
	Lock Word 3A	0xFA	0x0000	0x0000	0x0000
	Lock Word 4A	0xFB	0x0183	0x0183	0x8183
	Lock Word 1B	0xFC	0x0000	0x0000	0x0000
	Lock Word 2B	0xFD	0x0000	0x0000	0x0000
	Lock Word 3B	0xFE	0x0000	0x0000	0x0000
	Lock Word 4B	0xFF	0x0182	0x0182	0x8182

Custom Commands

Several custom commands/responses are implemented in this device to support quick access to the tag Unique ID, temperature reading, SPI operation, and to reset alarm conditions. SPI operation is only possible via the custom command but all other functions are possible via combinations of normal read/write commands.

GetUID Command

The custom command GetUID is implemented as described below. It allows a reader to get the UID from the tag with a single command.

Reader => Tag	Command Code	RN	CRC-16
# of bits	16	16	16
Description	E000 (hex)	Prior RN16 or handle	

A tag in Reply, Acknowledged, Open or Secured state backscatters {'0', UID, RN16, CRC-16} upon a GetUID command with a valid RN16 or handle. The length and format of the UID is defined by the Allocation Class which shall be either E0 (hex) or E3 (hex) for ISO, E2 (hex) for EPCglobal, or any of 44 (hex), 45 (hex), 46 (hex), 47 (hex) for legacy TOTAL applications. The state transition and link timing are the same as for the ACK command and the tag reply is analogous to the tag reply upon a Read command.

Tag => Reader	Header	UID	RN	CRC-16
# of bits	1	64, 80, or 96	16	16
Description	0	Tag Unique Identifier (Allocation Class determines length)	RN16 (Prior RN16 or handle)	CRC-16 ('0'+UID+RN)

UID for Allocation Class E0 (hex) ISO/IEC 7816-6

Class	MID	SN
8	8	48
E0 (hex)	Manufacturer ID NOTE: '00010110' for EM	IC Serial Number

UID for Allocation Class E3 (hex) ISO/IEC 7816-6

Class	MID	UM	SN
8	8	16	48
E3 (hex)	Manufacturer ID NOTE: '00010110' for EM	User Memory And Size	IC Serial Number

UID for Allocation Class E2 (hex) EPCglobal

Class	XTID	MDID	MN	XTIDHDR	SN
8	1	11	12	16	48
E2 (hex)	1	Mask Designer ID NOTE: '00000001011' for EM	Model Number	XTID Header	IC Serial Number

UID for Allocation Classes 44 (hex), 45 (hex), 46 (hex), 47 (hex) Legacy TOTAL Applications

MDID	CN	SN	CRC-16
6	10	32	16
Mask Designer ID NOTE: '010001' for EM	Customer Number	IC Serial Number	CRC-16 (MDID+CN+SN)

GetSensorData Command

The custom command GetSensorData is implemented as described below. It allows a reader to get the UID and sensor information from the tag with a single command. Sensors may also be sampled on demand from the reader when it receives this command. If the reader requests a new sample, the device will perform tamper detection (if enabled), low battery detection (if BAP Mode is enabled), and make a temperature measurement (if possible). The Low Battery Alarm and Aux Alarm will be updated with the new sample information. Temperature measurements on demand are not possible when BAP Mode is enabled and a Low Battery Alarm is declared OR BAP Mode is disabled and the RF field strength is too low. Temperature measurements that are made on demand are not used as part of the Monitoring function and have no effect on the Under Temp Alarm or the Over Temp Alarm.

Reader => Tag	Command Code	Send UID	New Sample	RN	CRC-16
# of bits	16	1	1	16	16
Description	E001 (hex)	0: Do not send UID 1: Do send UID	0: Get last sample 1: Get new sample	Prior RN16 or handle	

A tag in Reply, Acknowledged, Open or Secured state backscatters {'0', UID, Sensor, UTC, RN16, CRC-16} upon a GetSensorData command with a valid RN16 or handle. The length and format of the UID is defined above for the GetUID command and the UID field will only be included in the tag response when the UID is requested by the reader. The state transition is the same as for the ACK command and the tag reply is analogous to the tag reply upon a Read command except that the extended preamble is used regardless of the value of TRext specified in the Query. If the reader commands a new temperature measurement be made (New Sample = 1), then the link timing must allow the tag up to 20 ms to reply to the reader.

Tag => Reader	Header	UID	Sensor	UTC	RN	CRC-16
# of bits	1	64, 80, or 96	32	32	16	16
Description	0	Tag Unique Identifier (Allocation Class determines length)	Sensor Data	UTC Time Stamp	RN16 (Prior RN16 or handle)	CRC-16 ('0'+UID+Sensor+ UTC+RN)

SendSPI Command

The custom command SendSPI is implemented as described below to support SPI Master operation. It allows a reader to use the SPI interface in this device to send an SPI command to an attached SPI Slave device. The SPI command is only executed if this device is configured as an SPI Master device and SPI operation is enabled. Note that this is essentially a pass-through or bridge operation that allows a reader to communicate with an SPI Slave device that is connected to this device.

Reader => Tag	Command Code	SPI Packet	RN	CRC-16
# of bits	16	20 - 76	16	16
Description	E002 (hex)		Prior RN16 or handle	

SPI Packet

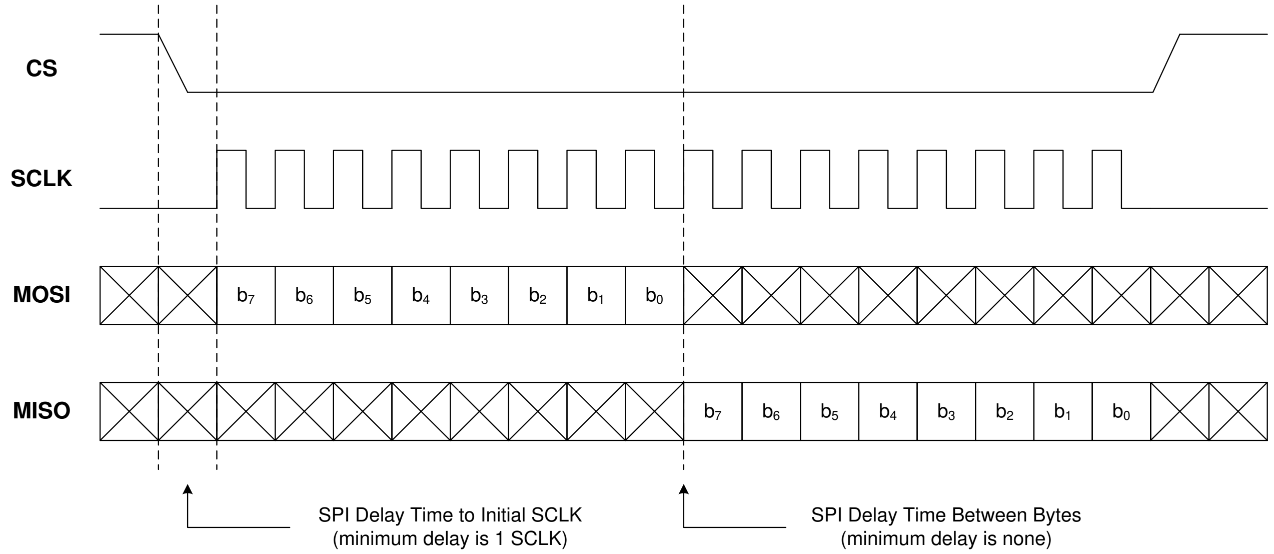
SPI Command Size	SPI Response Size	SPI SCLK	SPI Delay Time to Initial SCLK	SPI Delay Time Between Bytes	SPI Command
3	3	2	2	2	8 - 64
Number of bytes in command (0 = 8 bytes)	Number of bytes in response (0 = no response)	00: 40 KHz 01: 80 KHz 10: 160 KHz 11: 320 KHz	00: 1 SCLK 01: 50 µs 10: 500 µs 11: 5 ms	00: none 01: 50 µs 10: 100 µs 11: 500 µs	Data to SPI Slave

A tag in Acknowledged, Open or Secured state backscatters {'0', SPI-RESP, RN16, CRC-16} upon a SendSPI command with a valid RN16 or handle. There shall be no state transition, and the link timing T1 is extended by the SPI Packet communication. The tag reply is analogous to the tag reply upon a Read command except that the extended preamble is used regardless of the value of TRext specified in the Query. The SPI SCLK and SPI Delay Times are derived from the system oscillator and have the same accuracy as the system oscillator.

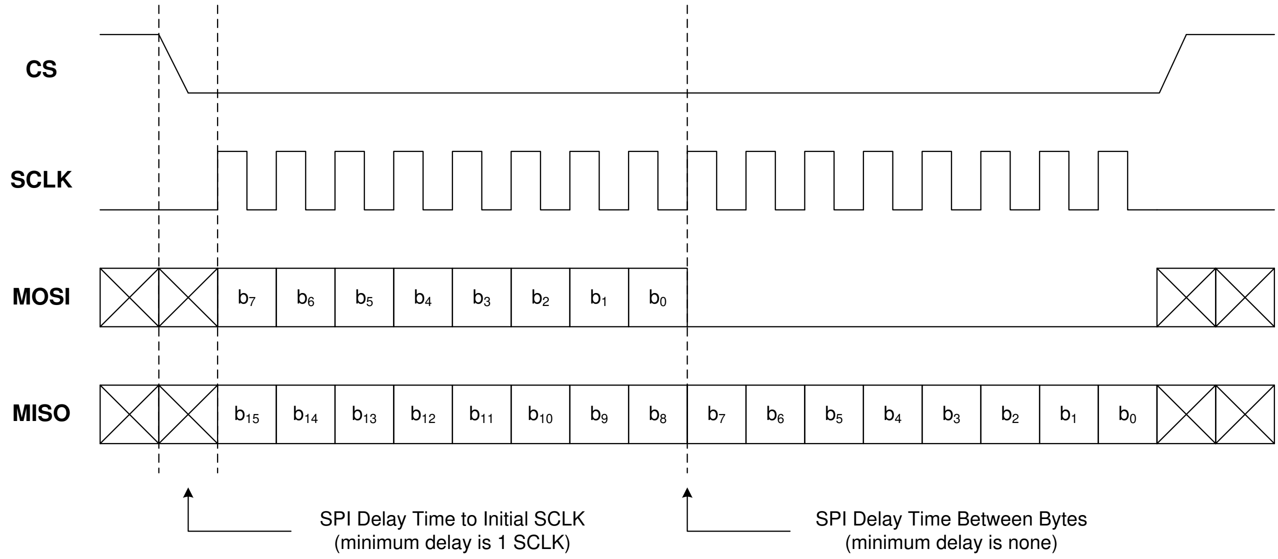
Tag => Reader	Header	SPI Response	RN	CRC-16
# of bits	1	0 - 56	16	16
Description	0	Data from SPI Slave	RN16 (Prior RN16 or handle)	CRC-16 ('0'+SPI-RESP+RN)

Three examples are provided to illustrate the use of this device as an SPI Master to communicate with an external SPI Slave device.

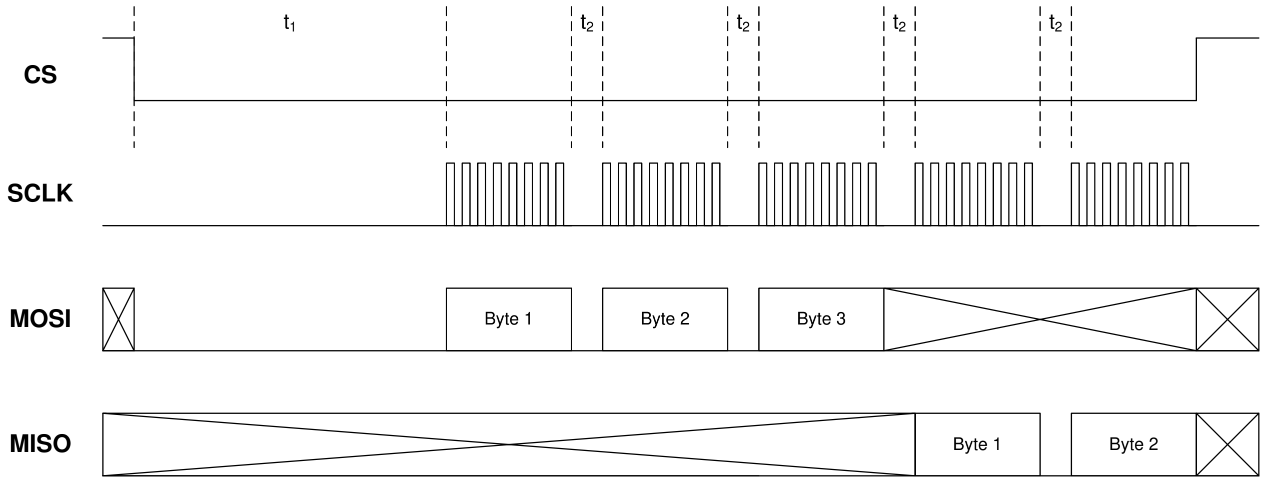
SPI Master Example #1: A single byte command is sent to the SPI Slave that will initiate a single byte response from the SPI Slave using half-duplex communication. The Delay Time to Initial SCLK is set to 1 SCLK and the Delay Time Between Bytes is set to none or no delay.



SPI Master Example #2: A single byte command is sent to the SPI Slave while a two byte response from the SPI Slave occurs using full-duplex communication. The Delay Time to Initial SCLK is set to 1 SCLK and the Delay Time Between Bytes is set to none or no delay.



SPI Master Example #3: A three byte command is sent to the SPI Slave that will initiate a two byte response from the SPI Slave using half-duplex communication. SCLK is set to 40 KHz, the Delay Time to Initial SCLK is set to 500 μs and the Delay Time Between Bytes is set to 50 μs.



t_1 = SPI Delay Time to Initial SCLK t_2 = SPI Delay Time Between Bytes

ResetAlarms Command

The custom command ResetAlarms is implemented as described below. It allows a reader to reset/clear the alarm conditions for Aux, Under Temp, and Over Temp. The command also resets the UTC Clock and the Monitor Function. This command is enabled/disabled via the Reset Alarms Enable bit in Temp Sensor Control Word 1.

Reader => Tag	Command Code	Fill	RN	CRC-16
# of bits	16	4	16	16
Description	E004 (hex)	0101	Prior RN16 or handle	

A tag in Secured state backscatters {'0', RN16, CRC-16} upon a ResetAlarms command with a valid RN16 or handle and provided the command is enabled. There shall be no state transition, and the tag reply is analogous to the tag reply upon a Read command except that the extended preamble is used regardless of the value of TRext specified in the Query, and the link timing must allow the tag up to 10 ms to reply to the reader.

Tag => Reader	Header	RN	CRC-16
# of bits	1	16	16
Description	0	RN16 (Prior RN16 or handle)	CRC-16 ('0'+RN)

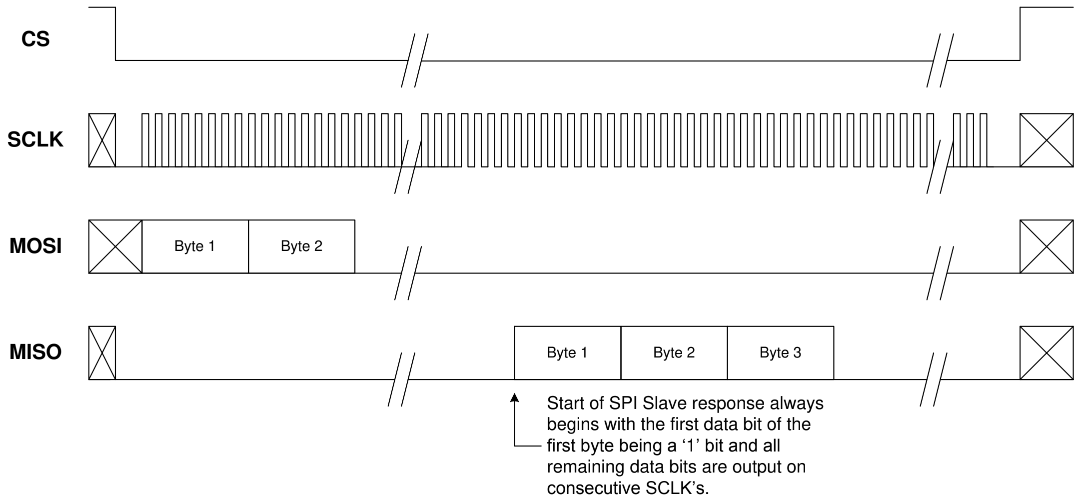
SPI Operation

A BAP tag with this device may be configured with the SPI Control word to enable the SPI interface and select between operation as either an SPI Master or an SPI Slave.

SPI Master operation requires this device to be the source of the SPI clock signal (SCLK) and also to control the SPI Chip Select (CS) for a connected SPI Slave device. The SPI polarity and phase settings are set via the SPI Control word. The actual SPI commands/responses to a connected SPI Slave device originate from a reader using the SendSPI command. Note that the SPI interface is only active starting after reception of the SendSPI command and ending with the beginning of the reply back to the reader. If using half-duplex communication, MOSI is set to high impedance (HI-Z) when the device transitions from sending to receiving to support SPI Slave devices that may only have a 3-wire SPI interface. Examples of SPI Master operation are provided with the description of the custom command SendSPI.

SPI Slave operation requires this device to accept an SPI clock that is asynchronous to all other operations within the device. SPI polarity and phase settings are set via the SPI Control word. The maximum SCLK frequency from the SPI Master shall be 4 MHz when VBAT is 1.8V or higher; otherwise, the maximum SCLK frequency shall be 2 MHz. The SPI Master must de-assert CS for a minimum of 15 µs between SPI commands. This device will output a data value of '0' on MISO before and after any reply back to the SPI Master. The maximum response time to an SPI command is 20 ms. The start of any reply always begins with a data value of '1'. The following example is provided to illustrate the use of this device as an SPI Slave to communicate with an external SPI Master device.

SPI Slave Example: A two byte command is sent from the SPI Master that will initiate a three byte response from the SPI Slave using half-duplex communication. Note that no fixed timing exists for the device to respond to the SPI Master and that the start of the response is determined by the first "1" bit that occurs on MISO.



The following commands are implemented for use as an SPI Slave device when connected to an SPI Master device. Processing times indicated for the commands do not include the transfer times for the command to be received nor the response to be sent as these are a function of the SCLK frequency being used by the external SPI Master.

Some commands require the use of a "dummy" byte to be transmitted by the SPI Master to enable the command to be processed. The "dummy" byte SCLK clock is used to synchronize the requested SPI command operation with the RF interface, and SPI Master is required to generate the SCLK frequency faster than 0.5/Tari. When no RF transaction is being processed at the same time, the requested SPI command is executed within the "dummy" byte transmission. Otherwise, the requested SPI command execution is delayed until the RF transaction is finished.

SPIRequestStatus Command

The SPI command SPIRequestStatus is implemented as described below. It allows an SPI Master to get the current status for the device. There is no processing time required for this operation.

Master => Slave	Command Code	Comment
# of bits	8	N/A
Description	E0 (hex)	Get current device status

Slave => Master	Status
# of bits	8
Description	Reply Status

The reply status is defined here and is the same for all other SPI commands.

Reply Status:

Header	Transponder	Device State	Memory Busy	Command Response
1	1	3	1	2
1	0 = Disabled 1 = Enabled	000 = Ready/Listen 001 = Arbitrate 010 = Reply/TagMsg 011 = Acknowledged 100 = Open 101 = Secured 110 = Killed 111 = Sleep	0 = Not Busy 1 = Busy	00 = ACK (command executed) 01 = NACK (invalid command) 10 = NACK (command failed) 11 = NACK (memory locked) Command failed means memory power check failed or memory was busy

SPIBoot Command

The SPI command SPIBoot is implemented as described below. It allows an SPI Master to force the device to perform the Boot Sequence in the same manner as if a POR occurred. The Boot Sequence will complete in less than 2 ms and is performed after the reply status has been sent to the SPI Master. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	Command Code	Comment
# of bits	8	N/A
Description	E1 (hex)	Force Boot Sequence to occur

Slave => Master	Status
# of bits	8
Description	Reply Status

SPITransponder Commands

The SPI commands SPITransponder are implemented as described below. They allow an SPI Master to enable/disable the transponder (RF interface) for the device. Disabling the transponder has the same effect as if a loss of RF field occurred. It may take up to 200 μs to disable the transponder when the device is in Sleep State. Once disabled, the SPI Master should wait a minimum of 50 μs before enabling the transponder. The transponder is enabled by default during the Boot Sequence. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	Command Code	Comment
# of bits	8	N/A
Description	E2 (hex)	Disable transponder (RF interface)
	E3 (hex)	Enable transponder (RF interface)

Slave => Master	Status
# of bits	8
Description	Reply Status

SPIGetSensorData Commands

The SPI commands SPIGetSensorData are implemented as described below. They allow an SPI Master to get the sensor information from the device memory. Sensors may also be sampled on demand from the SPI Master when it receives this command. If the SPI Master requests a new sample, the device will perform low battery detection and make a temperature measurement (if possible). The Low Battery Alarm will be updated with the new sample information. Temperature measurements on demand are not possible when a Low Battery Alarm is declared. Temperature measurements that are made on demand are not used as part of the Monitoring function and have no affect on the Under Temp Alarm or the Over Temp Alarm. The SPI Master must allow up to 20 ms for the reply to occur. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	Command Code	Comment
# of bits	8	N/A
Description	E4 (hex)	Get sensor data
	E5 (hex)	Get sensor data after new sample

Slave => Master	Status	Sensor	UTC
# of bits	8	32	32
Description	Reply Status	Sensor Data (MSW+LSW)	UTC Time Stamp (MSW+LSW)

SPISetFlags Command

The SPI command SPISetFlags is implemented as described below. It allows an SPI Master to set flags used in the XPC Word during response to an ACK command and make the UID anonymous. Refer to SPI Operation section for use of “Dummy Byte” and typical processing time for this operation. All settings made by the SPI Master are retained until the next POR, SPISetFlags command, or SPIBoot command occurs. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	**Command Code**	**XPC Flags**	**RFU Flags**	**UID ANON**	**Dummy Byte**	**Comment**
# of bits	8	8	8	8	8	N/A
Description	E6 (hex)	XPC Flags	RFU Flags	UID Anonymous	00000000	Set XPC flags and make UID anonymous.

XPC Flags:

X1	**X2**	**X3**	**X6**	**X9**	**XA**	**XB**	**XC**
1	1	1	1	1	1	1	1
0: Clear 1: Set	0: Clear 1: Set	0: Clear 1: Set	0: Clear 1: Set	0: Clear 1: Set	0: Clear 1: Set	0: Clear 1: Set	0: Clear 1: Set

RFU Flags:

RFU0	**RFU1**	**RFU2**	**RFU3**	**RFU4**	**RFU5**	**RFU6**	**RFU7**
1	1	1	1	1	1	1	1
0	0	0	0	0	0	0	0

UID Anonymous:

XD	**XE**	**XF**	**RFU**	**ANONYMOUS**
1	1	1	4	1
0: Clear 1: Set	0: Clear 1: Set	0: Clear 1: Set	0000	0: All TID Words are unmasked 1: TID Words 2 - F are masked (seen as zeroes) and all other TID Words are unmasked. This only applies to the RF interface.

Slave => Master	**Status**
# of bits	8
Description	Reply Status

FOR REFERENCE

Defined XPC Word

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	XEB	RFU	MOB		GA	SS	FS	BAP		TC	RFU			RECOM		
Name	X0	**X1**	**X2**	**X3**	X4	X5	**X6**	X7	X8	**X9**	**XA**	**XB**	**XC**	**XD**	**XE**	**XF**

SPIReadWord Command

The SPI command SPIReadWord is implemented as described below. It allows an SPI Master to read a word from the device memory. Typical processing time for the read operation is 75 µs but it may take up to 255 µs to perform the actual memory read operation when the transponder is enabled and the device is in Sleep State. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	Command Code	Memory Address	Comment
# of bits	8	8	N/A
Description	E7 (hex)	Word Address	Read word from physical memory address. NOTE: It is not possible to access physical memory addresses 100 - 10F (hex) using this command.

Slave => Master	Status	Data
# of bits	8	16
Description	Reply Status	Word Data

SPIWriteWord Command

The SPI command SPIWriteWord is implemented as described below. It allows an SPI Master to write a word into the device memory. The write operation is only possible when the SPI Write Enable bit is set to allow writing to the EEPROM page containing the word, and the memory lock bits (except for User memory) do not prevent writing to the EEPROM page. Typical processing time for the write operation is 7485 µs, but it may take up to 8405 µs to perform the actual memory write operation when the transponder is enabled and the device is in Sleep State. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	Command Code	Memory Address	Data	Comment
# of bits	8	8	16	N/A
Description	E8 (hex)	Word Address	Word Data	Write word to physical memory address. NOTE: It is not possible to access physical memory addresses EC - EF (hex) or F4 - 10F (hex) using this command.

Slave => Master	Status
# of bits	8
Description	Reply Status

SPIReadPage Command

The SPI command SPIReadPage is implemented as described below. It allows an SPI Master to read a page from the device memory. Typical processing time for the read operation is 150 µs, but it may take up to 335 µs to perform the actual memory read operation when the transponder is enabled and the device is in Sleep State. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	Command Code	RFU	Page Number	Comment
# of bits	8	1	7	N/A
Description	E9 (hex)	0	Page Number	Read page from memory.

Slave => Master	Status	Page Data
# of bits	8	64
Description	Reply Status	Page Data

SPIWritePage Command

The SPI command SPIWritePage is implemented as described below. It allows an SPI Master to write a page into the device memory. The write operation is only possible when the SPI Write Enable bit is set to allow writing to the EEPROM page, and the memory lock bits (except for User memory) do not prevent writing to the EEPROM page. The Register File Pages, which are not in EEPROM, are always accessible to an SPI Master for write operations. Typical processing time for the write operation to EEPROM is 7485 µs but it may take up to 8405 µs to perform the actual memory write operation when the transponder is enabled and the device is in Sleep State. Typical processing time for the write operation to the Register File is 300 µs, but it may take up to 500 µs to perform the actual memory write operation when the transponder is enabled and the device is in Sleep State. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	Command Code	RFU	Page Number	Page Data	Comment
# of bits	8	1	7	64	N/A
Description	EA (hex)	0	Page Number	Page Data	Write page into memory. NOTE: It is not possible to access physical memory pages 59 (dec), 61 - 64 (dec), or 67 (dec) using this command.

Slave => Master	Status
# of bits	8
Description	Reply Status

SPISetClock Command

The SPI command SPISetClock is implemented as described below. It allows an SPI Master to set the UTC clock provided that none of the alarm conditions exist for Aux, Under Temp, or Over Temp. There is no processing time required for this operation. A valid SPISetClock command requires having at least one of the 8 MSB's of the current time field being non-zero. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	Command Code	UTC	Comment
# of bits	8	32	N/A
Description	EB (hex)	Current Time	Set the UTC Clock to current time.

Slave => Master	Status
# of bits	8
Description	Reply Status

SPIAlarm Commands

The SPI command SPIAlarm is implemented as described below. It allows an SPI Master to set/clear the Aux Alarm state in the Sensor Data. The SPI Master must allow up to 20 ms for the reply to occur. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	Command Code	Comment
# of bits	8	N/A
Description	EC (hex)	Clear Aux Alarm condition.
	ED (hex)	Set Aux Alarm condition.

Slave => Master	Status
# of bits	8
Description	Reply Status

SPIReadRegisterFileWord Command

The SPI command SPIReadRegisterFileWord is implemented as described below. It allows an SPI Master to read a word from the Register File. Typical processing time for the read operation is 75 µs, but it may take up to 255 µs to perform the actual memory read operation when the transponder is enabled and the device is in Sleep State. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	Command Code	RFU	Register File Word	Comment
# of bits	8	5	3	N/A
Description	EE (hex)	00000	000: Word 1 001: Word 2 010: Word 3 011: Word 4 100: Word 5 101: Word 6 110: Word 7 111: Word 8	Read word from the Register File.

Slave => Master	Status	Data
# of bits	8	16
Description	Reply Status	Word Data

SPIWriteRegisterFileWord Command

The SPI command SPIWriteRegisterFileWord is implemented as described below. It allows an SPI Master to write a word to the Register File. Typical processing time for the write operation is 115 µs but it may take up to 300 µs to perform the actual memory write operation when the transponder is enabled and the device is in Sleep State. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	Command Code	RFU	Register File Word	Data	Comment
# of bits	8	5	3	16	N/A
Description	EF (hex)	00000	000: Word 1 001: Word 2 010: Word 3 011: Word 4 100: Word 5 101: Word 6 110: Word 7 111: Word 8	Word Data	Write word to the Register File.

Slave => Master	Status
# of bits	8
Description	Reply Status

SPIReqRN Command

The SPI command SPIReqRN is implemented as described below. It allows an SPI Master to obtain a random number when the device is not in Sleep state. There is no processing time required for this operation. A minimum time of 30 µs should occur between requests for random numbers. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	Command Code	Comment
# of bits	8	N/A
Description	F0 (hex)	Get a random number.

Slave => Master	Status	Random Number
# of bits	8	16
Description	Reply Status	Random Number

SPIReqNewHandle Command

The SPI command SPIReqNewHandle is implemented as described below. It allows an SPI Master to request the generation of a new handle for RF communications. Refer to SPI Operation section for use of "Dummy Byte" and typical processing time for this operation. This SPI command is only valid when the device is configured as an RF Modem using State Machine Shared operation and the device is in Acknowledged, Open, or Secured state. It is an invalid command for all other device configurations. The device state does not change as a result of this command. If the device is in Acknowledged, Open, or Secured state, the new handle immediately replaces the previous handle and it remains valid until changed by the SPI Master or the device enters into a new inventory session. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	Command Code	Dummy Byte	Comment
# of bits	8	8	N/A
Description	F1 (hex)	00000000	Request new handle.

Slave => Master	Status	New Handle	Backscatter Settings	Old Handle
# of bits	8	16	8	16
Description	Reply Status	Tag Handle	Backscatter Settings	RN16 or handle (depends on present tag state)

Backscatter Settings:

RFU	TRext	Data Encoding
3	1	4
000	0: No Pilot Tone 1: Use Pilot Tone	0000: Miller-1 (FM0) 0001: Miller-2 0010: Miller-4 0011: Miller-8 Others are not used

SPISetHandle Command

The SPI command SPISetHandle is implemented as described below. It allows an SPI Master to define a new handle for RF communications. Refer to SPI Operation section for use of “Dummy Byte” and typical processing time for this operation. This SPI command is only valid when the device is configured as an RF Modem using State Machine Shared operation and the device is in Acknowledged, Open, or Secured state. It is an invalid command for all other device configurations. The device state does not change as a result of this command. If the device is in Acknowledged, Open, or Secured state, the new handle immediately replaces the previous handle and it remains valid until changed by the SPI Master or the device enters into a new inventory session. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	Command Code	Handle	Dummy Byte	Comment
# of bits	8	16	8	N/A
Description	F2 (hex)	Handle	00000000	Set handle.

Slave => Master	Status
# of bits	8
Description	Reply Status

SPISetParams Command

The SPI command SPISetParams is implemented as described below. It allows an SPI Master to set BAP mode sensitivity, BLF clock used by the SPI Master, and some air interface protocol settings. Refer to SPI Operation section for use of “Dummy Byte” and typical processing time for this operation. This SPI command is only valid when the device is configured as an RF Modem and either State Machine Bypassed operation or State Machine Shared operation. It is an invalid command for all other device configurations. All settings are set to zero during POR and once changed by the SPI Master they are retained until the next POR, SPISetParams command, or SPIBoot command occurs. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	**Command Code**	**Params**	**Dummy Byte**	**Comment**
# of bits	8	16	8	N/A
Description	F3 (hex)	Control Params	00000000	Set control params.

Control Params:

Idle Timeout	**BAP Mode Sensitivity**	**BLF Clock for SPI Master**	**Protocol Features**
1	2	5	8
0: Timeout disabled 1: Timeout enabled Note: Feature only applies to State Machine Shared configurations and uses Idle Timeout value in Battery Management Words to time EXT_CMD being asserted. Timeout results in a transition to Sleep state.	00: Use EEPROM 01: Default 10: Default + 6 dBm 11: Default + 12 dBm Note: The EEPROM setting in Battery Management Word 1 is used until SPISetParams command occurs. Adjustments relative to default sensitivity are approximate values.	00000: 2X BLF clock derived from Query command. 11111: BLF clock derived from Query command. Other values (bbbbb): Fixed clock derived from decoder oscillator divided by [[(bbbbb) + 1] / 2]. Note: No clock signal is output in Sleep state or Killed state. Decoder oscillator clock is output after a Boot Sequence and prior to receiving a Query command for cases 00000 and 11111.	See below

Protocol Features:

RFU	**No Req_RN Command**	**No Select Command on Memory**	**RFU**	**No T2 Timeout**	**ACK Command Processing is Shared**	**No XPC Word**
2	1	1	1	1	1	1
00	0: Req_RN command is enabled. 1: Req_RN command is disabled. Note: Feature only applies to State Machine Shared with limited command set configuration.	0: Select command on memory is enabled. 1: Select command on memory is disabled meaning that only Select commands having a zero-length Mask field will be executed.	0	0: T2 Timeout processing is enabled. 1: T2 Timeout processing is disabled. Note: Feature only applies to State Machine Shared configurations.	0: All ACK commands are processed by the device. 1: ACK command processing is shared. Note: Feature only applies to State Machine Shared with limited command set configuration. The device processes ACK commands except during Open state, then ACK commands are processed externally.	0: XPC Word is enabled. 1: XPC Word and SSD reply are disabled. This means the XI bit in the PC Word is zero and the XPC_W1 Word does not exist in the UII/EPC Memory address space.

Slave => Master	**Status**
# of bits	8
Description	Reply Status

SPIGetCommParams Command

The SPI command SPIGetCommParams is implemented as described below. It allows an SPI Master to obtain the current tag state, backscatter settings, flag settings, and the handle being used for the tag. Refer to SPI Operation section for use of "Dummy Byte" and typical processing time for this operation. This SPI command is only valid when the device is configured as an RF Modem and either State Machine Bypassed operation or State Machine Shared operation. It is an invalid command for all other device configurations. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	Command Code	Dummy Byte	Comment
# of bits	8	8	N/A
Description	F4 (hex)	00000000	Get current tag state, backscatter settings, flag settings, and handle.

Slave => Master	Status	Backscatter Settings	Flag Settings	Tag Handle
# of bits	8	8	8	16
Description	Reply Status	Backscatter settings	Flag settings	RN16 or handle (depends on present tag state)

Backscatter Settings:

Valid Settings	Inventory Session	TRext	Data Encoding
1	2	1	4
0: Backscatter settings are invalid 1: Backscatter settings are valid meaning the device is participating in the current inventory round	00: S0 01: S1 10: S2 11: S3	0: No Pilot Tone. 1: Use Pilot Tone.	0000: Miller-1 (FM0) 0001: Miller-2 0010: Miller-4 0011: Miller-8 Others are not used.

Flag Settings:

RFU	Low Battery Alarm	AUX Alarm	SL	S0	S1	S2	S3
1	1	1	1	1	1	1	1
0	0: No alarm 1: Alarm	0: No alarm 1: Alarm	0: Deasserted 1: Asserted	0: A 1: B	0: A 1: B	0: A 1: B	0: A 1: B

Flag settings for SL, S0, S1, S2, and S3 are the values at the time of processing for the last Query command.

SPISetSessionFlags Command

The SPI command SPISetSessionFlags is implemented as described below. It allows an SPI Master to set the device inventory session and select flags. Refer to SPI Operation section for use of "Dummy Byte" and typical processing time for this operation. This SPI command is only valid when the device is configured as an RF Modem with State Machine Shared operation. It is an invalid command for all other device configurations. The reply status is defined above in the SPIRequestStatus command.

Master => Slave	Command Code	Session Flag Settings	Select Flag Setting and Dummy Byte	Comment
# of bits	8	8	8	N/A
Description	F5 (hex)	Session Flag Settings	Select Flag Setting	Sets the inventory session flags and select flag

Select Flag Setting:

S0 Mask	S1 Mask	S2 Mask	S3 Mask	S0	S1	S2	S3
1	1	1	1	1	1	1	1
0: Skip 1: Write	0: Skip 1: Write	0: Skip 1: Write	0: Skip 1: Write	0: A 1: B	0: A 1: B	0: A 1: B	0: A 1: B

Select Flag Setting:

SL Mask	SL	Dummy
1	1	6
0: Skip 1: Write	0: Not selected 1: Selected	000000

Slave => Master	Status
# of bits	8
Description	Reply Status

SPI Slave Extensions

SPI Slave extensions offer additional functionality when the device is configured for SPI Slave operation. The SPI Slave extensions are selected via the SPI Slave Config field in the I/O Control Word.

The signaling feature allows the SPI Slave to alert the SPI Master that a particular event is present. The general concept is that the SPI bus is used in the normal manner when the SPI Chip Select (CS) is low, and the SPI bus is used in a different manner when CS is high. Signaling may be done using either the Monitor Function indicating a temperature measurement is currently in progress, or using the Comm Buffer Semaphore indicating handshake status with a reader during high speed communication. The Comm Buffer Semaphore is the MSB of Register File Word 1.

The RF modem feature allows an external SPI Master device to receive the output of the demodulator and directly control the input to the modulator for backscatter operation. The general concept is that the SPI bus is used in the normal manner when the SPI Chip Select (CS) is low, and the SPI bus is used in a different manner when CS is high. The RF modem feature allows the SPI Master to bypass the air interface protocol processing with the device.

When using RF Modem with State Machine Bypassed, the BYPASS signal asserted enables the entire AFE, prevents transitions to Sleep state, prevents Initial Command Detection Timeout, and no command processing is performed by the device. The external SPI Master performs all command processing and tag replies while BYPASS is asserted. The device does not change states when the external SPI Master processes commands but the SPI Master can command the device to Ready state via the falling edge of BYPASS signal unless the device is in Killed state in which case it remains in the Killed state.

When using RF Modem with State Machine Shared (SMS) with limited command set, the device is responsible for five states (Sleep, Ready, Arbitrate, Reply, Acknowledged), eight commands (Select, Query, QueryAdjust, QueryRep, ACK, NAK, Req_RN, BroadcastSync), and two custom commands (GetUID, GetSensorData) if custom EM4325 command processing is enabled. Once the device has reached Acknowledged state and if Req_RN command is disabled, any command other than the eight identified commands will cause the device to transition to Open state. If EXT_STATE is asserted while in Acknowledged or Open state, any command that cannot be processed by the device will cause the EXT_CMD signal to be asserted. The EXT_CMD signal asserted enables the entire AFE, prevents transitions to Sleep state, and no command processing is performed by the device. The external SPI Master performs all command processing and tag replies while EXT_CMD is asserted and signals to the device via the falling edge of EXT_STATE that EXT_CMD shall be de-asserted. The device does not change states when the external SPI Master processes commands but the SPI Master can command the device to Ready state via the falling edge of EXT_RDY signal.

When using RF Modem with SMS with full command set, the device is responsible for all states, all mandatory and optional commands implemented in the device, and all EM4325 custom commands (if enabled). For all states except Killed, if EXT_STATE is asserted and an unknown optional command is received then it will cause the EXT_CMD signal to be asserted. Unknown optional commands must use command codes starting with either 0xC (hex), 0xD (hex), or 0xE (hex). The EXT_CMD signal asserted enables the entire AFE, prevents transitions to Sleep state, and no command processing is performed by the device. The external SPI Master performs all command processing and tag replies while EXT_CMD is asserted and signals to the device via the falling edge of EXT_STATE that EXT_CMD shall be de-asserted. The device does not change states when the external SPI Master processes commands but the SPI Master can command the device to Ready state via the falling edge of EXT_RDY signal.

SPI Slave Config field in the I/O Control Word:

Bit	MSB 7	8	9	A	B	C	D	E	LSB F
Content	RFU	SPI Bus Operation			Register File Pages		User Memory Read Protect	Custom Commands	Kill Command

Content	Description
SPI Bus Operation	00x: Normal, 010: Signaling with Monitor Function, 011: Signaling with Comm Buffer Semaphore, 10x: RF Modem with State Machine Bypassed, 110: RF Modem with State Machine Shared with limited command set. 111: RF Modem with State Machine Shared with full command set
Register File Pages	00: Both Register File pages are used normally, 01: First Register File page is used normally and the second Register File page is used to replace UII/EPC page 1, 10: Both Register File pages are used to replace UII/EPC pages 0 and 1 (except for the UMI and XI bits in the PC Word). NOTE: Unpredictable memory operations may occur when BAP Mode is enabled and the battery is depleted (VBAT < minimum battery operating voltage), 11: Both Register File pages are used to replace UII/EPC pages 1 and 2 NOTE: Register File pages replacing UII/EPC pages are write protected from the RF interface.
User Memory Read Protect	0: Disable read protection for RF interface to access User Memory, 1: Enable read protection for RF interface to access User Memory NOTE: Read protection prevents the RF interface from using either the Select or Read commands to access User Memory unless the device is in the Secured state.
Custom Commands	0: Enable all EM4325 custom commands, 1: Disable all EM4325 custom commands
Kill Command	0: Enable Kill Command, 1: Disable Kill Command

I/O Signals for SPI Slave Extensions

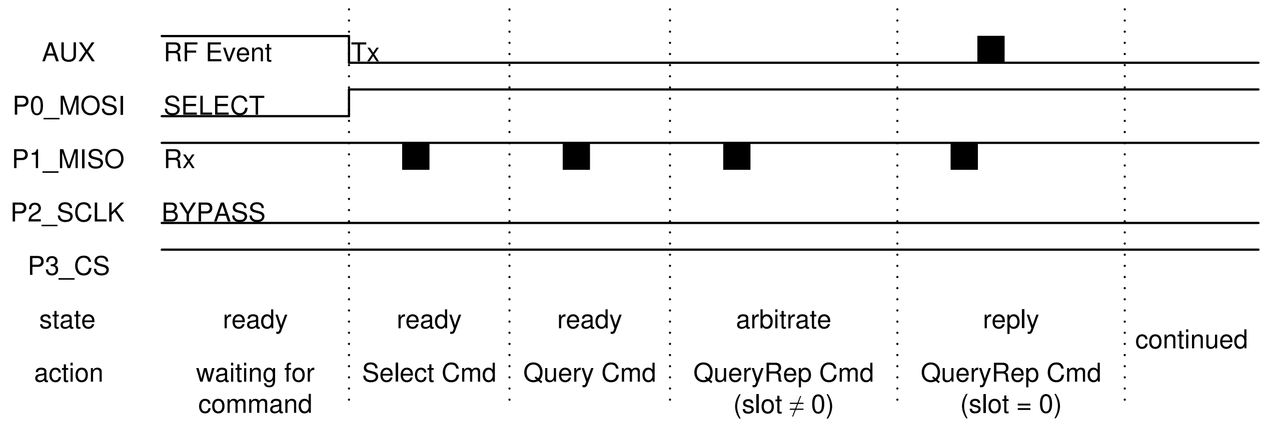
EM4325 Pads/Pins	Normal	Signaling	RF Modem with State Machine Bypass	RF Modem with State Machine Shared (SMS)
AUX Output or HI-Z	HI-Z when AUX Enable is ‘0’. Selected RF event is output when AUX Enable is ‘1’.	HI-Z when AUX Enable is ‘0’. Selected RF event is output when AUX Enable is ‘1’.	HI-Z when AUX Enable is ‘0’. Selected RF event is output when AUX Enable is ‘1’ and P3_CS is ‘0’. Selected RF event is output when AUX Enable is ‘1’, P3_CS is ‘1’, BYPASS is ‘0’, and SELECT is ‘0’. Tx is output when AUX Enable is ‘1’, P3_CS is ‘1’, BYPASS is ‘0’, and SELECT is ‘1’. (BLF clock AND RF Event) is output when AUX Enable is ‘1’, P3_CS is ‘1’, and BYPASS is ‘1’.	HI-Z when AUX Enable is ‘0’. Selected RF event is output when AUX Enable is ‘1’ and P3_CS is ‘0’. Selected RF event is output when AUX Enable is ‘1’, P3_CS is ‘1’, and EXT_STATE is ‘0’. (BLF clock AND EXT_CMD) is output when AUX Enable is ‘1’, P3_CS is ‘1’, and EXT_STATE is ‘1’. NOTE: EXT_CMD requests external processing of commands.
P0_MOSI Input	MOSI when P3_CS is ‘0’. Not used when P3_CS is ‘1’.	MOSI when P3_CS is ‘0’. Not used when P3_CS is ‘1’.	MOSI when P3_CS is ‘0’. SELECT when P3_CS is ‘1’ and BYPASS is ‘0’. Tx when P3_CS is ‘1’ and BYPASS is ‘1’.	MOSI when P3_CS is ‘0’. EXT_RDY when P3_CS is ‘1’ and EXT_STATE is ‘0’. NOTE: EXT_RDY should hold low and high levels for at least 1 µs and a falling edge on EXT_RDY commands the device State Machine to Ready state. Tx when P3_CS is ‘1’ and EXT_STATE is ‘1’.
P1_MISO Output or HI-Z	MISO when P3_CS is ‘0’. HI-Z when P3_CS is ‘1’.	MISO when P3_CS is ‘0’. Event signal (Monitor Function or Comm Buffer Semaphore) is output when P3_CS is ‘1’.	MISO when P3_CS is ‘0’. (Rx AND RF Event AND Field OK) when P3_CS is ‘1’.	MISO when P3_CS is ‘0’. (Rx AND RF Event AND (Field OK OR EXT_CMD)) when P3_CS is ‘1’. NOTE: Tx may also be observed in addition to Rx.
P2_SCLK Input	SCLK when P3_CS is ‘0’. Not used when P3_CS is ‘1’.	SCLK when P3_CS is ‘0’. Not used when P3_CS is ‘1’.	SCLK when P3_CS is ‘0’. BYPASS when P3_CS is ‘1’. NOTE: BYPASS should hold low and high levels for at least 1 µs and a falling edge on BYPASS commands the device State Machine to Ready state unless the device is in Killed state in which case it remains in the Killed state.	SCLK when P3_CS is ‘0’. EXT_STATE when P3_CS is ‘1’. There must be at leat 100ns separation between any edges on EXT_STATE with respect to any edges on EXT_RDY.
P3_CS Input	When ‘0’, SPI bus is active. When ‘1’, SPI bus is inactive.	When ‘0’, SPI bus is active. When ‘1’, SPI bus is inactive.	When ‘0’, SPI bus is active. When ‘1’, SPI bus is inactive.	When ‘0’, SPI bus is active. When ‘1’, SPI bus is inactive.

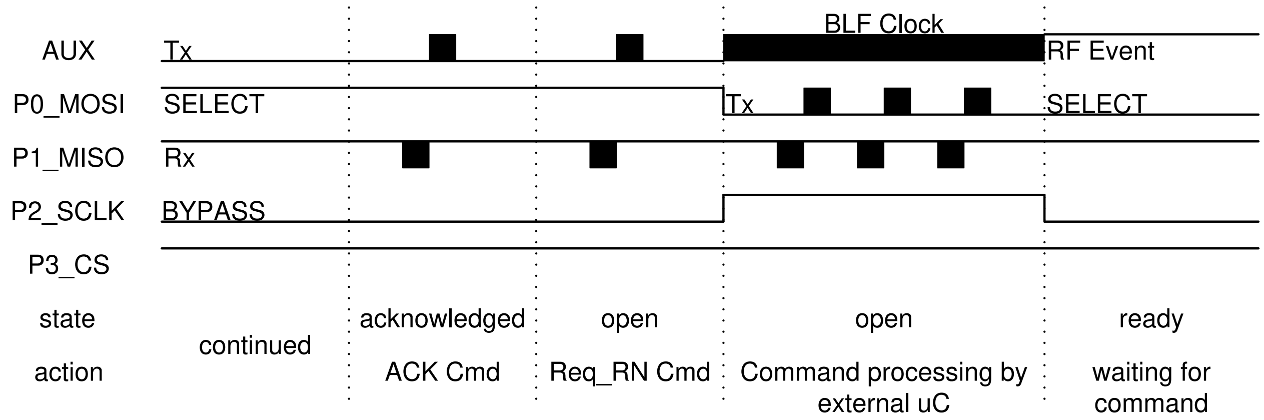
Rx = Received signal (output from demodulator)

Tx = Transmit signal (input to backscatter switch)

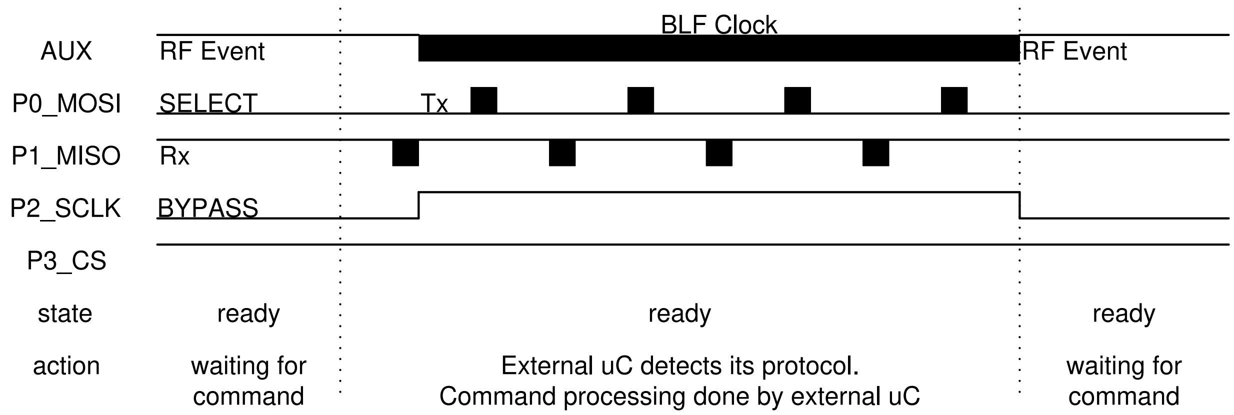
Examples using State Machine Bypass

State Machine Bypass – Gen2 Protocol Customization



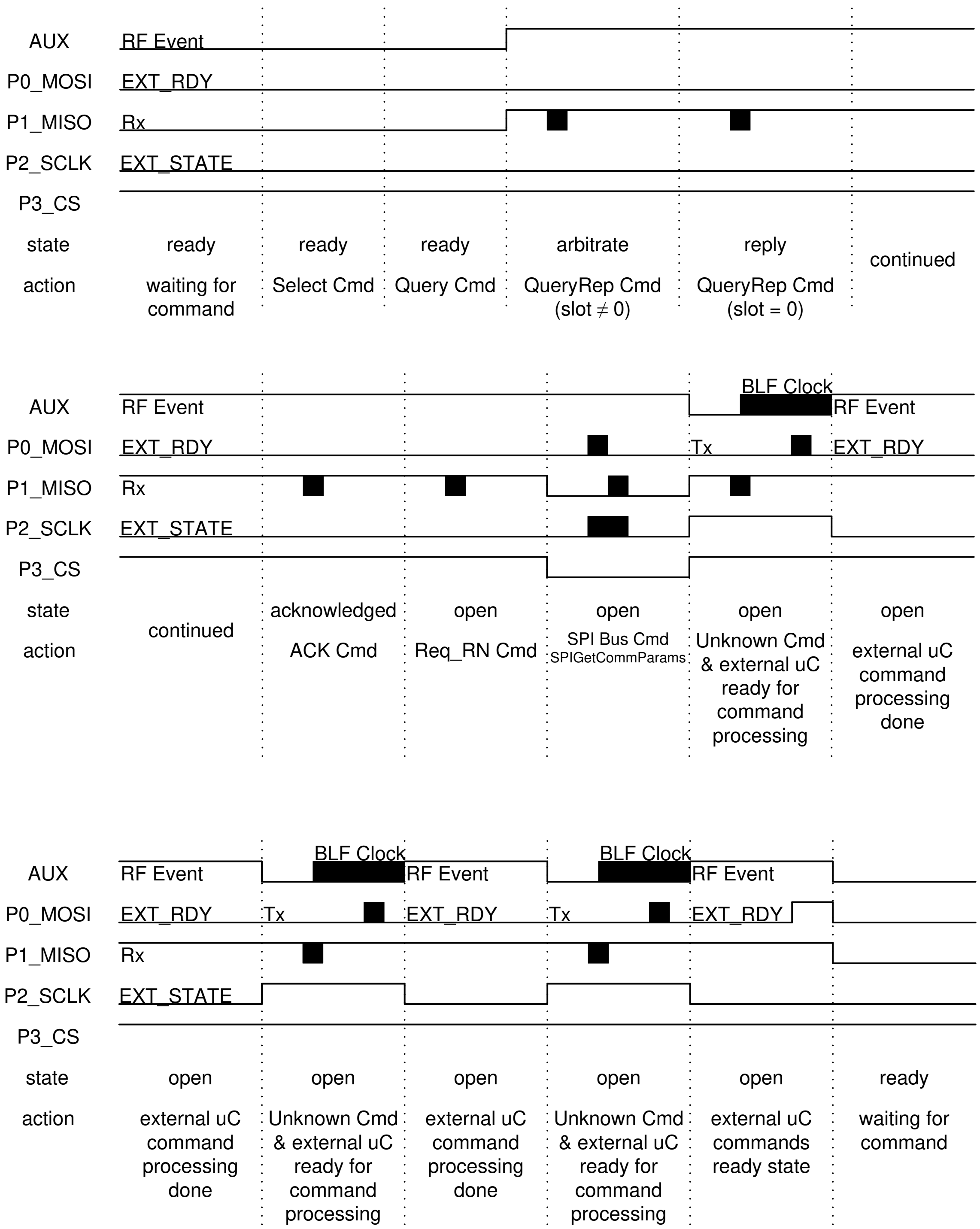


State Machine Bypass – Other Protocols



Examples using State Machine Shared (SMS)

State Machine Shared



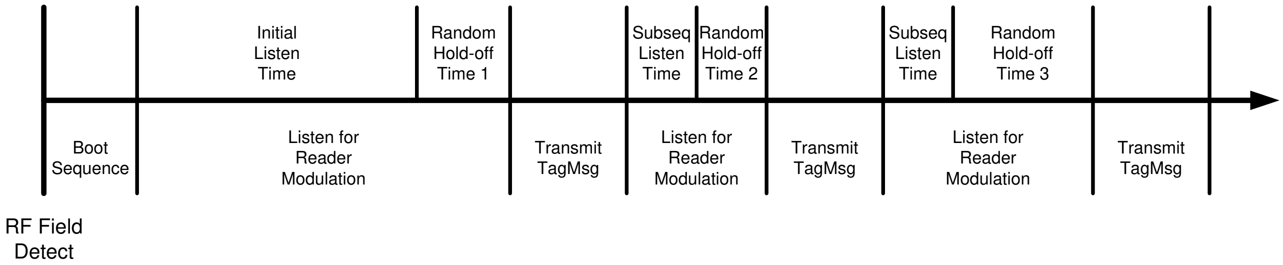
TOTAL Operation

TOTAL is an enhanced version of the IP-X™ protocol (IP-X is a trademark of IPICO) and is used for many applications. It is a simple protocol that does not require a forward link for readers to work with tags, and the tags work in a listen-before-talk manner. Once a TOTAL tag is powered up, it listens for any modulation on the reader signal, and if none is detected, it backscatters its message and then repeats the listen-and-backscatter cycle again and again. If modulation is detected, then the tag will switch into RTF to communicate with the reader using the normal Gen2/6C commands and responses.

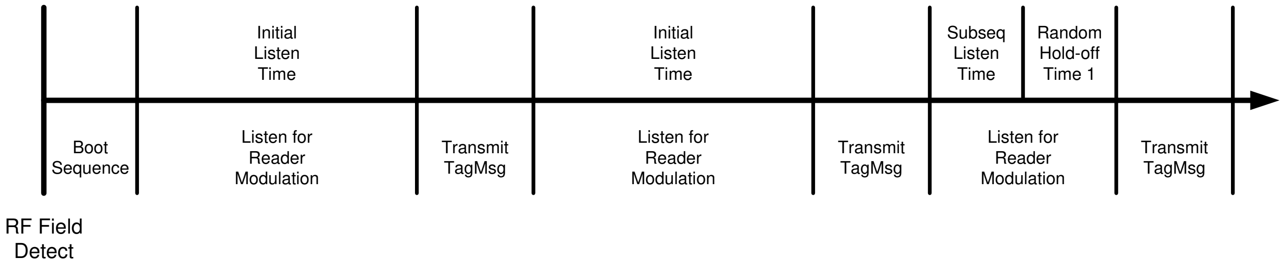
The amount of time a TOTAL tag spends listening is the sum of two components: a fixed time defined to be the minimum listening time and a random hold-off delay time. Listen times are meant to be of random duration in general as this is fundamental to the collision arbitration scheme used by the TOTAL protocol.

TOTAL backscatters a TagMsg consisting of one or more packets. Each packet contains 64 bits of data, with bit 63 being the MSB and bit 0 being the LSB. The first packet(s) always contain the TID which is stored in the TID Memory bank. The first byte (8 MSB's of the 64-bit page) is the Allocation Class and provides additional information for multi-packet TagMsg's.

There are several configuration words to enable TOTAL mode and configure the protocol parameters. The primary control word is the TOTAL Word located in the Control Page of EEPROM. The Initial Listen Time parameter in the TOTAL Word must be set non-zero to enable TOTAL. The Initial Listen Time is used to define the minimum time after RF field detection before the first TagMsg may be transmitted. A Subsequent Listen Time of 125 µs is used to define the minimum time between all other transmissions of TagMsg's except where noted below. The maximum time between transmissions of TagMsg's is defined by the Maximum Hold-off Time parameter. The general concept for the protocol is illustrated by the following figure:



A variation of the general concept is having a number of fixed time slots at the start of the TOTAL protocol. The Fixed Slot Count parameter is used to identify the number of fixed time slots to use before the start of random time slots. Fixed time slots always use the time specified by the Initial Listen Time parameter and have no additional random hold-off time added. This variation to the general concept for the TOTAL protocol is illustrated using 2 fixed times slots in the following figure:



The Data Encoding Type parameter defines what format is used for bit encoding during transmission of the TagMsg. Available formats are PPE, FM0, Miller-2, and Miller-4.

The BLF parameter defines the link frequency to be derived from the decoder oscillator. This device supports five BLF values of 1280/2 = 640 KHz, 1280/2.5 = 512 KHz, 1280/4 = 320 KHz, 1280/5 = 256 KHz, and 1280/10 = 128 KHz. The 512 KHz BLF is used only for PPE and the 640 KHz BLF is used only for non-PPE.

The Sensor Page CRC Enable parameter allows for hardware generation of a CRC-5 value for the TOTAL Sensor Page that is included as the 5 LSB's of the 64-bit data. This CRC-5 value is computed starting with the MSB of the TOTAL Sensor Page.

The Adaptive Hold-off Enable parameter allows the device to dynamically increase the Maximum Hold-off Time based upon the number of TagMsg's that have been transmitted.

If TOTAL is enabled, then the User Memory bank is also used for TOTAL user memory and the TOTAL System Page. The highest page in User memory (User page 47) is defined to be the TOTAL System Page and its format and function are described below at the end of this section. The TOTAL System Page contains two important parameters to define the first page of TOTAL user memory and the number of consecutive pages to be included in the TagMsg. If either of these parameters is zero, then there are no TOTAL user memory pages to follow the TID in the TagMsg. Since the User Memory bank is used for TOTAL, all the normal Gen2/6C commands (Read, Write, Lock, BlockErase, BlockWrite, BlockPermalock) can be used for accessing or locking the memory.

The amount of data transmitted in the TagMsg is dependent upon the settings in the TOTAL System Page. Allocation Classes E0, E2, and E3 are used for ISO structured data formats and will transmit pages in the sequence: TID Pages, then TOTAL memory pages. All other Allocation Classes use an unstructured data format and will transmit pages in the sequence: TID Page, then TOTAL memory pages (if any defined).

TagMsg with Unstructured Data Format
for Legacy Allocation Classes

Page 0
TID

TagMsg: TID only

<table>
<tr><td>Page 0</td><td>Page 1</td><td>Page 2</td><td>Page 3</td><td>...</td><td>Page n</td></tr>
<tr><td>TID</td><td colspan="5">Unstructured Data</td></tr>
</table>

TagMsg: TID + n pages of unstructured data

TagMsg with Structured Data Format
for Allocation Classes E2 (hex) and E3 (hex)

<table>
<tr><td>Page 0</td><td>Page 1</td><td colspan="2">Page 2</td><td colspan="2">Page 3</td></tr>
<tr><td>TID MSB's</td><td>TID LSB's</td><td>PC</td><td colspan="2">UII/EPC</td><td>CRC</td></tr>
</table>

TagMsg: TID with 96-bit UII/EPC

<table>
<tr><td>Page 0</td><td>Page 1</td><td colspan="2">Page 2</td><td colspan="2">Page 3</td><td colspan="2">Page 4</td><td>...</td><td colspan="3">Page n</td></tr>
<tr><td>TID MSB's</td><td>TID LSB's</td><td>PC</td><td colspan="2">UII/EPC</td><td>CRC</td><td>DSFID</td><td colspan="3">Item Related Data</td><td>CRC</td><td>Not used</td></tr>
</table>

TagMsg: TID with 96-bit UII/EPC and (n-3) pages of item related data

The TagMsg's with ISO structured data formats illustrated above will actually have all the structures and CRC's generated by a reader and stored into TOTAL memory with the exception of the TOTAL TID Pages.

ISO structured data encoding has a number of encoding segments that occur in the following sequence:

1) A mandatory UII/EPC segment that starts with the TID and is followed by the Protocol Control Word, the UII/EPC itself, and ends with a CRC-16 that is calculated over the entire UII/EPC segment. If no other segments exist for the TagMsg, then zero-filled data is used after the CRC-16 until the end of the page.

2) An optional Item Related Data segment that starts with the segment DSFID and is followed by the item related data and ends with a CRC-16 that is calculated over the entire Item Related Data segment. If needed, then zero-filled data is used after the CRC-16 until the end of the page.

The UII/EPC shall be encoded from the beginning of the first page after the TID and may require less than one complete page, exactly one page, or more than one page to encode the UII/EPC. Bit positions 63 to 48 of Page 1 shall encode the Protocol Control word. The UII/EPC is encoded from bit 47 of Page 1 until the end of the UII/EPC.

The Item Related Data segment immediately follows the UII/EPC segment and may require less than one complete page, exactly one page, or more than one page. The first byte in this segment contains the length of the segment in words and the second byte shall encode the segment DSFID and defines the encoding rules and the data format assigned to the Item Related Data for a particular application.

TagMsg's are transmitted using packets consisting of a preamble followed by a 64-bit page of data. The preamble for PPE encoded data uses 11 data symbols so the packet length is 75 bits (11 preamble bits + 64 data bits). The preamble for FM0 encoded data uses 18 data symbols and 1 ending bit so the packet length is 83 bits (18 preamble bits + 64 data bits + 1 ending bit). The preamble for Miller (M=2, M=4) encoded data uses 22 data symbols and 1 ending bit so the packet length is 87 bits (22 preamble bits + 64 data bits + 1 ending bit). TagMsg's consisting of multiple pages are transmitted as a sequence of packets with a time period equal to 8 data symbols in between transmission of consecutive packets.

A feature for multi-packet transmissions uses the concept of a page linking mechanism with a hardware generated packet down-count along with a hardware generated CRC-5 on a per packet basis. The concept is to extend each packet by an additional 8 bits after the 64-bit page data to support a 3-bit packet number followed by a 5-bit CRC value. The packet number is a modulo 8 value and represents how many additional packets are still to follow in the TagMsg. It can be used to reconstruct the entire TagMsg when not all the packets are correctly received by a reader in a single TOTAL TagMsg transmission. The CRC-5 value is to be calculated starting with the CRC-5 from the previous packet and including the 64-bit page data of the current packet plus the 3-bit packet number of the current packet. Calculating the CRC-5 for the first packet of the TagMsg shall use a zero value as the CRC-5 from the previous packet. This feature for multi-packet transmissions can only be applied when using a data encoding type that is a Miller subcarrier (M = 2 or 4) and its presence is indicated to the reader by terminating the preamble with an alternate synch pattern. The normal synch pattern of "010111" is used to indicate the page linking mechanism is not included in the packet and the alternate synch pattern of "010110" is used to indicate the page linking mechanism is included in the packet.

This device can be configured to support legacy Tag Talks Only (TTO) applications and has other features that are not included in the ISO/IEC 18000-64 spec. In order to fully comply with ISO/IEC 18000-64, the fields in the TOTAL Word must be set as follows:

Page Link Enable = 0 or 1
Fixed Slot Count = 000
Mute Function = 1
Adaptive Hold-off Enable = 0 or 1
Data Encoding = 00 or 10
BLF = 11

Maximum Hold-off Time = 11 when Adaptive Hold-off Enable = 0; otherwise, any value is compliant

Initial Listen Time = 101 or 110 or 111

(NOTE: Miller-2 data encoding is not compliant)

Definition of the TOTAL System Page (User page 47):

TOTAL Config Word (First word in TOTAL System Page)

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	RFU				First TOTAL memory page to transmit after TID (Valid range is 0 to 47) (Zero means no pages)						Number of TOTAL memory pages to transmit (Valid range is 0 to 47) (Zero means no pages)					

Proprietary Data Word 1 (Second word in TOTAL System Page)

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	Proprietary data defined by user															

Proprietary Data Word 2 (Third word in TOTAL System Page)

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	Proprietary data defined by user															

Proprietary Data Word 3 Fourth word in TOTAL System Page)

Bit	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Content	Proprietary data defined by user															

Content	Description
RFU	Reserved for Future Use
First TOTAL memory page to transmit after TID	Beginning of TOTAL memory pages to transmit in TagMsg
Number of TOTAL memory pages to transmit	Number of TOTAL memory pages to transmit in TagMsg

Temp Sensor Operation

The temp sensor can be used both in passive mode and in BAP mode. If a temperature measurement cannot be made for any reason then the temp sensor will report a value of -64°C.

A reader can request a temperature measurement be made on demand by either writing to the Sensor Data (MSW) word or using the custom command GetSensorData. Measurements made on demand are not used by the device for temperature monitoring and have no effect on temperature alarms. For passive tags, the RF field must remain on from the time a temperature measurement is requested until the result is read. This can be used to support applications using only passive tags with the temperature monitoring performed by readers.

For BAP tag applications, the Temp Sensor and Monitor Function are controlled by the three Temp Sensor Control Words. The Monitor Function is only performed when BAP Mode is enabled and it is used to monitor Low Battery, Tamper (if enabled), Under Temp, and Over Temp conditions. The Monitor Function uses a programmable sampling interval that defines when to check for alarm conditions. Time is measured using a clock signal derived from the system oscillator and will be shortened by some portion of one clock period and have the same accuracy as the system oscillator. The Monitor Function uses three counters for the Under Temp Count, the Over Temp Count, and the number of Aborted Temp Measurements. Monitoring is enabled when the sampling interval is non-zero and if a time stamp is required, then the Monitor Function will not begin until the UTC Clock is set by an external command (e.g. BroadcastSync or Write) such that the 8 MSB's of the 32-bit value are not all zeroes.

At every sample interval, the Monitor Function will perform Low Battery detection and update the Low Battery Alarm accordingly.

Custom sensor operation allows for more flexibility and increased range for programmed values. It allows for monitoring of both Under Temp and Over Temp conditions when there is a very large temperature difference between the two conditions. A reader can get detailed status of the custom sensor by using the Read command or the GetSensorData command.

Alarms

There are four alarms possible using this device: Low Battery, Aux, Under Temp, and Over Temp. The Low Battery alarm is a registered value (volatile memory) and the other alarms are both registered values and in non-volatile memory. Alarms for Aux, Under Temp, and Over Temp are reported as an OR of their corresponding registered and non-volatile values. The Sensor Alarm bit in the XPC_W1 word is an OR of all four alarms.

Low Battery detection is performed only when BAP Mode is enabled. A Low Battery condition is checked as part of the Monitor Function when the Monitor Function is performed and also checked every transition from Power-up/Sleep to Active. The battery voltage is compared against the selected LBD threshold and the Low Battery Alarm condition is set accordingly. Note that the Low Battery Alarm condition indicates only that the battery voltage was below the selected LBD threshold during the most recent comparison and any previous information is not kept. A reader cannot set or reset the Low Battery Alarm.

Tamper detection is performed regardless if BAP Mode is enabled or disabled. Tamper detection, if enabled and the Aux Alarm is not set, is checked as part of the Monitor Function when the Monitor Function is performed and also checked every transition from Power-up/Sleep to Active. Tamper detection is also performed in BAP mode with a rising edge on P3 when the AUX function is configured for tamper detection and the device is not an SPI Slave. Tamper is reported via the Aux Alarm and is in non-volatile memory and will retain its state during power-off/power-on cycles. A reader can directly reset the Aux Alarm via the custom command ResetAlarms provided the commanded is enabled in the Temp Sensor Control Words. A reader can indirectly reset the Aux Alarm by successfully writing to the Temp Sensor Calibration Word or any of the Temp Sensor Control Words.

Under Temp and Over Temp detection is performed only when BAP Mode is enabled and the Monitor Function is performed. The programmable Monitor Function determines when it is time to sample the current temperature and compare the measurement against the programmable Under Temp and Over Temp thresholds. Separate counts are kept as registered values for the number of consecutive samples that are below the Under Temp threshold or above the Over Temp threshold. When a count value reaches the programmable limit for declaring a sustained event, then the corresponding Alarm is set. The Under Temp Alarm and Over Temp Alarm are in non-volatile memory and will retain their states during power-off/power-on cycles. A reader can directly reset the Under Temp Alarm and Over Temp Alarm via the custom command ResetAlarms provided the commanded is enabled in the Temp Sensor Control Words. A reader can indirectly reset the Under Temp Alarm and Over Temp Alarm by successfully writing to the Temp Sensor Calibration Word or any of the Temp Sensor Control Words.

Battery Management

If a BAP tag is known to be in storage or a controlled area, then an ultra-low power mode exists to extend battery life. This feature is enabled via the BAP Control Enable bit in EEPROM. The ultra-low power mode is enabled/disabled by a reader command that writes to the BAP Mode bit. A reader can only change the BAP Mode bit when the RF field strength is sufficient to perform the operation. Transitions to or from the ultra-low power mode will occur after successfully changing the BAP Mode value and then returning the device to the Ready State, or if POR occurs.

The device will auto-switch between battery powered and beam powered based upon which power source is presently providing the higher voltage. Other battery management features described below are configured via the TOTAL Word and the Battery Management Words in EEPROM.

Sleep mode disables the decoder oscillator and has the lowest current consumption for BAP tags. During Sleep mode, the Field Detector in the AFE is used to determine the presence of an RF field. A 2-bit programmable value that is the RF Field Detector Duty Cycle determines how frequently the Field Detector is used to check for the presence of an RF field. Once an RF field has been detected, the Field Detector will use a 100% duty cycle to perform confirmation processing and a new field measurement is made approximately every 25 μs. If the RF field is detected for four consecutive field measurements (initial detection followed by three confirmations), then a valid RF field is declared present and a transition occurs from Sleep mode to Active mode. If the RF field cannot be confirmed, then the Field Detector returns to using its original duty cycle.

The Sleep to Active transition enables the decoder oscillator and initiates the relevant portions of the Boot Sequence. The 2-bit programmable value chosen for the RF Field Detector Duty Cycle represents a performance trade-off between:

1) Average current consumption during Sleep mode, and
2) The tag transition time to Ready/Listen state for a valid RF wake-up.

Once the device transitions from Sleep mode to Active mode, the Field Detector uses a 100% duty cycle to monitor the presence of the RF field. A 2-bit programmable value that is the RF Fade Control determines how quickly a transition occurs from Active Mode to Sleep Mode when the RF field is no longer detected. During Active mode, there are different mechanisms for battery management depending on whether TOTAL is in use or not.

For TOTAL tags not in Sleep state:

A TOTAL tag will normally transmit its TagMsg forever so long as an RF field is detected and no mute conditions are encountered. A feature exists to allow the TOTAL tag to perform self muting after transmitting a specified number of TagMsg's. This is a 6-bit programmable value that is the Number of TOTAL TagMsg's to Transmit Before Self Muting. This feature can be used for both passive tags and BAP tags.

A TOTAL tag that is muted will normally remain so until the RF field is seen to drop below the RF field detection threshold. A feature exists to use the P3 input such that a rising edge on P3 will terminate the muting and initiate transmissions of TOTAL TagMsg's again. Another feature exists to allow the TOTAL tag to terminate the mute condition after a specified amount of time and begin transmitting its TagMsg again. This is a 6-bit programmable value comprised of the 4-bit TOTAL Mute Timeout and the 2-bit Timeout Units. There is also a separate TOTAL MUTE TOUT EN bit to enable this feature. This feature can be used for both passive tags and BAP tags.

The TagMsg duty cycle is specified with the Maximum Hold-off Time value in the TOTAL Word. The tag is in its high current consumption state a short period of time during transmission of the TagMsg and then in a lower current consumption state for a much longer period of time while listening for a mute condition or valid RTF command. The self muting and mute timeout features allow for specifying a different type of duty cycle for when a BAP TOTAL tag is in the presence of long duration RF fields that may last for minutes, hours, or even days. A BAP TOTAL tag will transmit TagMsg's until self muting occurs, wait until the mute timeout occurs, reset the TagMsg counter and transmit TagMsg's until self muting occurs again, and repeat this cycle until the RF field drops below the RF field detection threshold.

Normally, a BAP TOTAL tag never returns to Sleep mode until the RF field drops below the RF field detection threshold. It is always ready to receive RTF commands except when actually transmitting the TagMsg. A feature exists to encourage a BAP TOTAL tag to enter Sleep mode and obtain a desired duty cycle for Active mode. This feature is enabled whenever BAP Mode is enabled, RTF Idle Timeout is enabled, the Sleep Timeout is non-zero, the Number of TOTAL TagMsg's to Transmit Before Self Muting is non-zero, the TOTAL Mute Timeout is non-zero, and the BAP Mode sensitivity has not been set via the SPISetParams command. This set of conditions will imply that the TOTAL MUTE TOUT EN bit is also enabled. The Active mode duty cycle that is actually achieved will depend upon the RF environment but a nominal value is approximately:

Active mode duty cycle = Active mode time / (Active mode time + Sleep mode time)

where:

Active mode time = 2 * ((time required for self muting to occur) + (time for mute timeout to occur))

Sleep mode time = time for sleep timeout to occur

For RTF tags not in Sleep state:

An RTF tag will normally remain Active but idle in the Ready state forever so long as an RF field is detected. It is always ready to receive RTF commands. A feature exists to allow the RTF tag to terminate the Active mode after a specified amount of time. This is a 6-bit programmable value comprised of the 4-bit Idle Timeout for Active to Sleep Transition and the 2-bit Timeout Units. There is also a separate RTF IDLE TOUT EN bit to enable this feature and it can be used for both passive tags and BAP tags. This feature can be used to force a duty cycle but provides only a little help in prolonging battery life because the best case Active mode duty cycle is ~93%. A forced duty cycle also results in having an off time during which a tag may not detect and cannot respond to any RTF command.

A feature exists to encourage a BAP RTF tag to enter Sleep mode and obtain a desired duty cycle for Active mode. This feature is enabled whenever BAP Mode is enabled, the Sleep Timeout is non-zero, and the Idle Timeout for Active to Sleep Transition is non-zero, and the BAP Mode sensitivity has not been set via the SPISetParams command. This set of conditions will imply that the RTF IDLE TOUT EN bit is also enabled. The feature also makes use of the 4-bit programmable value that is the Initial Command Detection Timeout that is the amount of time allowed after completion of the Boot Sequence until the initial RTF command must be detected or the tag will transition from Active mode back to Sleep mode. The Active mode duty cycle that is actually achieved will depend upon the RF environment but a nominal value is approximately:

Active mode duty cycle = Active mode time / (Active mode time + Sleep mode time)

where:

If Initial Command Detection Timeout is non-zero then

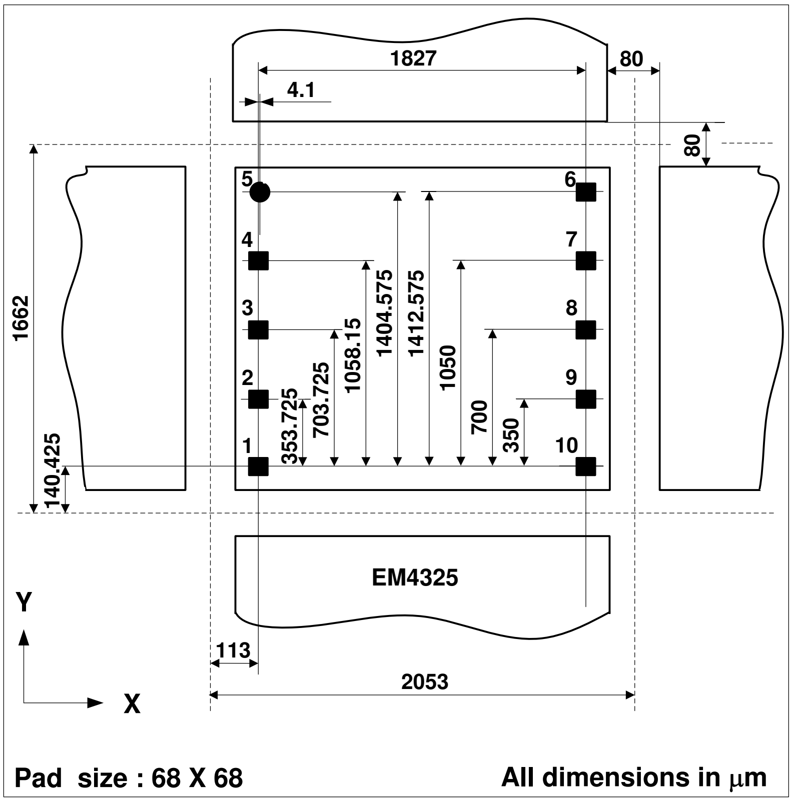
Active mode time = 6 * (time required for initial command detection to timeout)

If Initial Command Detection Timeout is zero then

Active mode time = 2 * (time required for idle timeout to occur)

Sleep mode time = time for sleep timeout to occur

Floor Plan

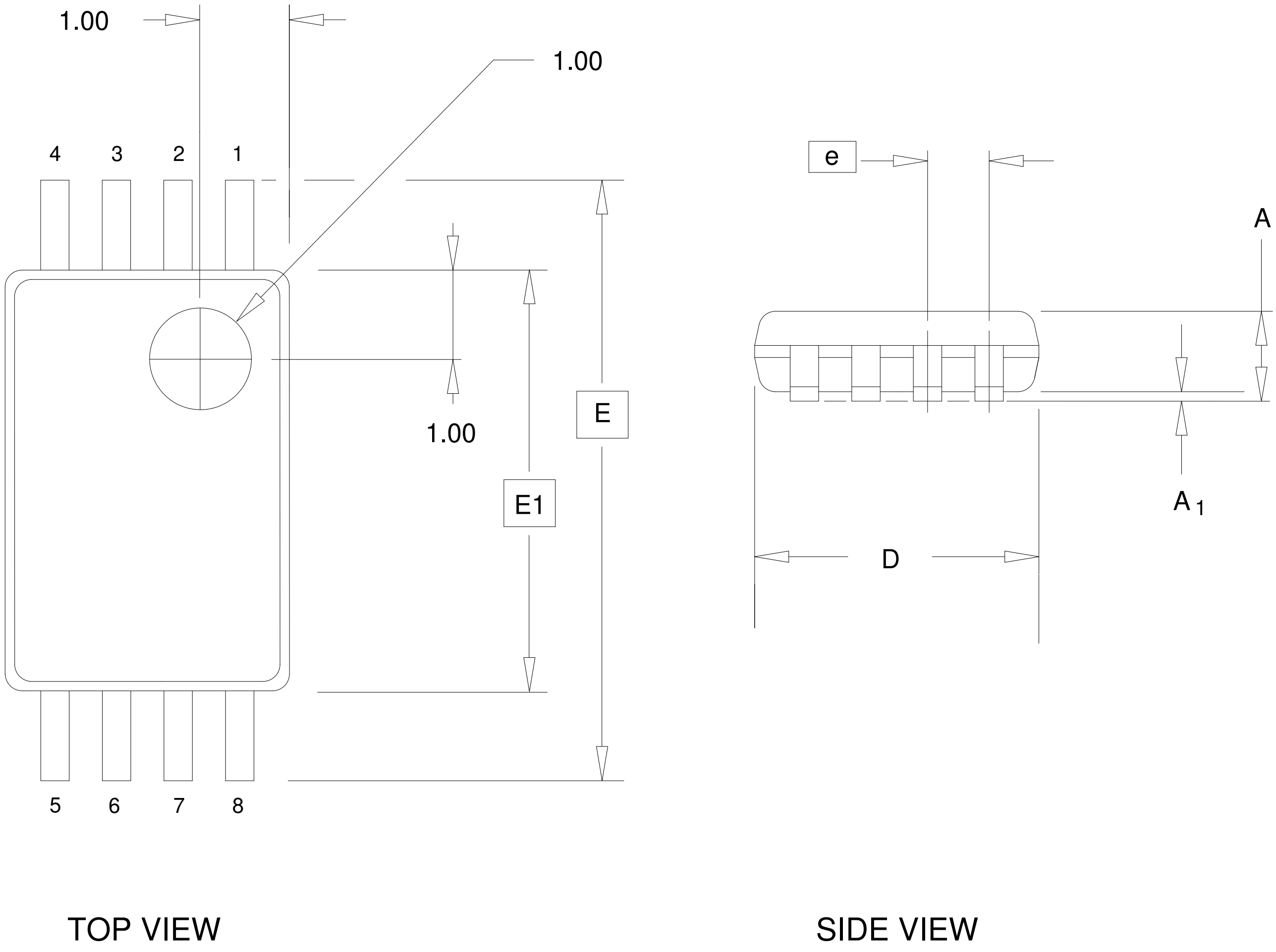


Pad	Name	I/O	Description
1	P1_MISO	I/O	I/O P1 or SPI Master Input / Slave Output (see note)
2	P0_MOSI	I/O	I/O P0 or SPI Master Output / Slave Input (see note)
3	TEST_A	A	N/A
4	AUX	I/O	Auxiliary Function (see note)
5	ANT+	A	Antenna +
6	VSS	A	Supply return and Antenna -
7	VBAT	A	External supply voltage for BAP operation
8	TEST	I	N/A (active high)
9	P3_CS	I/O	I/O P3 or SPI Chip Select (active low) (see note)
10	P2_SCLK	I/O	I/O P2 or SPI Serial Clock (see note)

A: Analog, I: Digital Input, O: Digital Output

NOTE: The pads for the AUX function and the I/O functions may be shorted together when not used for an application to ease inlay assembly if desired.

TSSOP8 Package Outline



SYMBOL	COMMON DIMENSIONS			NOTE
	MIN.	NOM.	MAX.	
A	———	———	1.10	
A_1	0.05	0.10	0.15	
D	3.00 BSC			
E	6.40 BSC			
E1	4.40 BSC			
e	0.65 BSC			

BSC - Basic Spacing between Centers

Ordering Information

The following charts show the general offering. For detailed Part Number to order, please see the table "Standard Versions" below. For wafer form delivery, please refer to EM4325 wafer specification document.

Packaged Device:

EM4325 V%% TP8B+

Version
Check table below

Package
TP8B+ = TSSOP8 (3mm x 4.4mm),
in Tape & Reel of 4000 pieces

Device in Die Form:

EM4325 V%% WS 7

Version
Check table below

Die Form
WW = Wafer
WS = Sawn Wafer/Frame

Thickness
7 = 7 mils (178um)
11 =11 mils (280um)

Bumping
(blank) = no bumping
E = with gold bumps

Versions

Versions are identified with "V" followed by a two digit code "XY" that are defined in the following tables.

X	SMS	Temp Sensor
1	No	Calibrated
2	No	Uncalibrated
3	Yes	Calibrated
4	Yes	Uncalibrated

Y	TID Format
1	EPC
2	ISO E0
3	ISO E3
4	Legacy TOTAL

Remarks:

- For ordering, please use table in "Standard Versions and Samples".
- For specifications of Delivery Form, including gold bumps, tape and bulk, as well as possible other delivery form or packages, please contact EM Microelectronic-Marin S.A.

Standard Versions and Samples

The versions below are considered standard and should be readily available. For other versions or other delivery form, please contact EM Microelectronic-Marin S.A. For samples, please order exclusively from the standard versions.

Part Number	SMS	Temp Sensor Calibrated	Package / Die Form	Delivery Form
EM4325V11WS7E	No	Yes	Sawn wafer / bumped die – thickness of 7 mils	Wafer on frame
EM4325V11TP8B+	No	Yes	TSSOP8	Tape & Reel
EM4325V21WS7E	No	No	Sawn wafer / bumped die – thickness of 7 mils	Wafer on frame
EM4325V21TP8B+	No	No	TSSOP8	Tape & Reel
EM4325V26TP8B+	No	No	TSSOP8	Tape & Reel
EM4325V31TP8B+	Yes	Yes	TSSOP8	Tape & Reel
EM4325V41TP8B+	Yes	No	TSSOP8	Tape & Reel
EM4325VXY%%%			Custom	Custom

NOTE: EM4325V26TP8B+ is intended for use as a RF / analog front end for a microcontroller and it disables all RF command processing while the SPI bus functionality remains intact. This requires an external microcontroller to implement all aspects of an air interface protocol. EM4325V26TP8B+ is the only version available for automated vehicle identification applications worldwide and is not subject to the transportation market exclusion listed in the disclaimer below.

Product Support

Check our website at www.emmicroelectronic.com under Products/RF Identification section. Questions can be submitted to info@emmicroelectronic.com .