

Features

- Contactless Read/Write Data Transmission
- 992-bit EEPROM User Programmable in 31 Blocks $\times$ 32 Bits
- Inductively Coupled Power Supply at 125 kHz
- Basic Component: R/W IDIC[®] Transponder IC
- Built-in Coil and Capacitor for Circuit Antenna
- Starts with Cyclical Data Read Out
- Typical < 50 ms to Write and Verify a Block
- Modulation Defeat (for EAS)
- Direct Access to Each Block
- Configurable POR Delay
- Write Protection by Lock Bits
- Malprogramming Protection
- Configurable Options:
 - Bit Rate [Bit/s]: RF/16 and RF/32
 - Modulation: Manchester
 - POR Delay: 1 ms/65 ms
 - Maximum Block: 0, 1, 1 to 2, 1 to 3, 1 to 4, 1 to 31

Applications

- Industrial Asset Management
- Process Control and Automation
- Installation and Medical Equipment

Description

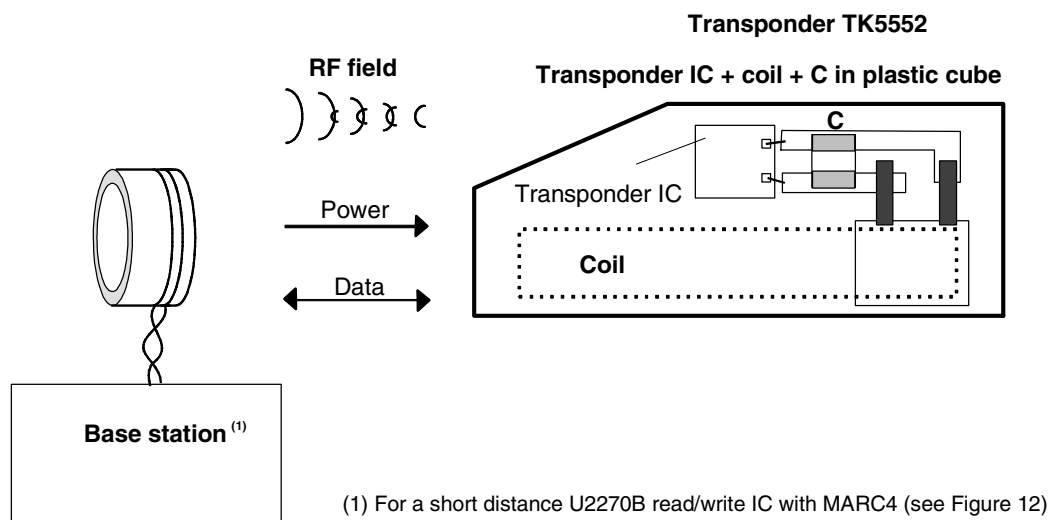
The TK5552 is a complete programmable R/W transponder that implements all important functions for identification systems. It allows the contactless reading (uplink) and writing (downlink) of data which are transmitted bi-directionally between a read/write base station and the transponder. It is a plastic cube device which accommodates the IDIC transponder IC and the antenna is realized as an LC circuit. No additional external power supply is necessary for the transponder because it receives power from the RF field generated by the base station. Data is transmitted by modulating the amplitude of the RF field (uplink mode). The TK5552 can be used to adjust and modify the ID code or any other stored data, e.g., rolling code systems. The on-chip 1056-bit EEPROM (32 blocks, 33 bits per block) can be read (uplink) and written (downlink) blockwise from the base station. The blocks can be protected against overwriting. One block is reserved for setting the operation modes of the IC.



Read/Write Transponder

TK5552

Figure 1. Transponder and Base Station



General

The transponder is the mobile part of a closed coupled identification system (see Figure 1), where the read/write base station incorporates a reader IC such as the U2270B, and the read/write transponder is based on the transponder IDIC.

The transponder is a plastic cube device consisting of the following parts:

- The transponder antenna, realized as a tuned LC circuit
- The read/write IDIC (transponder IC) with EEPROM

Transponder Antenna

The antenna consists of a coil and a capacitor for tuning the circuit to the nominal carrier frequency of 125 kHz. The coil has a ferrite core to improve the distance of read (uplink) and write (downlink) operations.

Read/Write IDIC

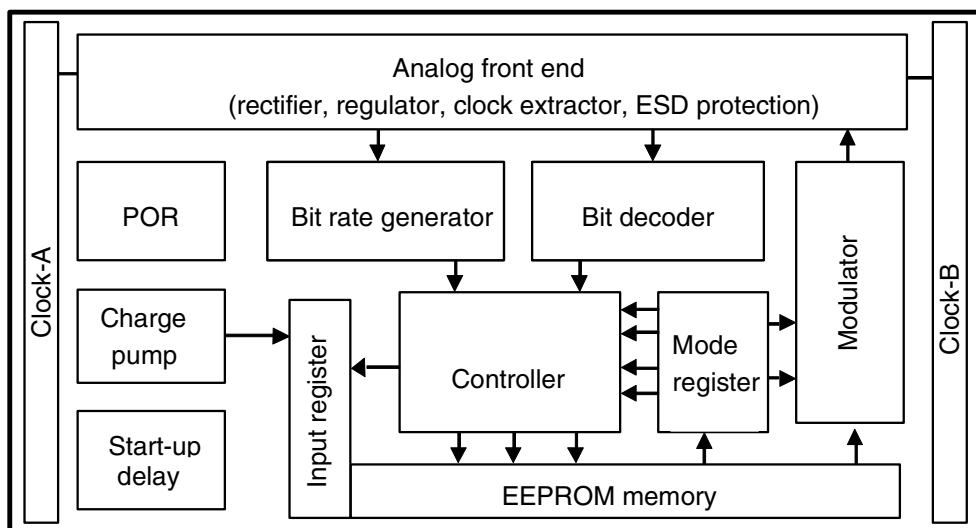
The read/write Transponder IDIC is part of the transponder TK5552. The data is transmitted bi-directionally between the base station and the transponder. The transponder receives power via a single coil from the RF signal generated by the base station. The single coil is connected to the chip and also serves as the IC's bi-directional communication interface.

Data transmission is done by modulating the amplitude of the RF signal. Reading (uplink) occurs by damping the coil by an internal load. Writing (downlink) occurs by interrupting the RF field in a specific way. The TK5552 transponder operates at a nominal frequency of 125 kHz. Different bit rates and encoding schemes are available.

The on-chip 1056-bit EEPROM (32 block, 33 bits each) can be read (uplink) and written (downlink) blockwise from the base station. The blocks can be protected against overwriting by using lock bits. One block is reserved for setting the operation modes of the IC.

See section "Transponder IC Read/Write Identification IC with 1k-bit Memory".

Figure 2. Block Diagram Transponder IC



Absolute Maximum Ratings

Parameters	Symbol	Value	Unit
Operating temperature range	T_{amb}	-25 to +75	°C
Storage temperature range	T_{stg}	-40 to +125	°C
Maximum assembly temperature, $t < 5$ min.	T_{ass}	170	°C
Magnetic field strength at 125 kHz	H_{pp}	1000	A/m

Operating Characteristics Transponder

$T_{amb} = 25^{\circ}\text{C}$, $f = 125$ kHz, RF/32 and Manchester if not otherwise noted

Parameters	Test Conditions	Symbol	Min.	Typ.	Max.	Unit
Inductance		L		4		mH
Resonance frequency	LC circuit, $H_{pp} = 12$ A/m	f_r	119	125	131	kHz
Magnetic Field Strength (H)						
Maximum field strength where tag does not modulate	No influence on other tags in the field	$H_{pp \text{ not}}$		4		A/m
Minimum Field Strength						
Uplink/downlink mode		$H_{pp \text{ 25}}$		12		A/m
Programming mode		$H_{pp \text{ 25}}$		18		A/m
Data retention EEPROM		$t_{retention}$	10			Years
Programming cycles EEPROM			100,000			
Maximum field strength		$H_{pp \text{ max}}$			600	A/m

Figure 3. Typical TK Range of Resonance Frequency

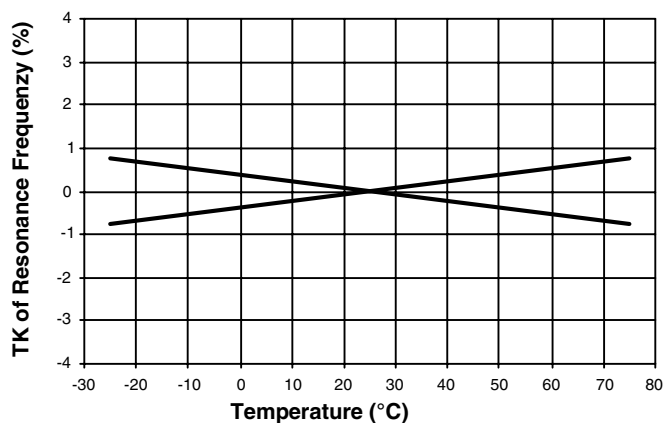


Figure 4. Degree of Modulation Measurement

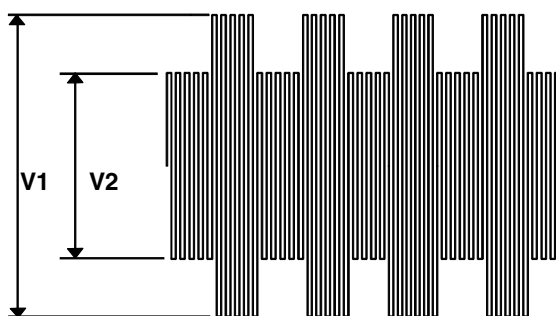
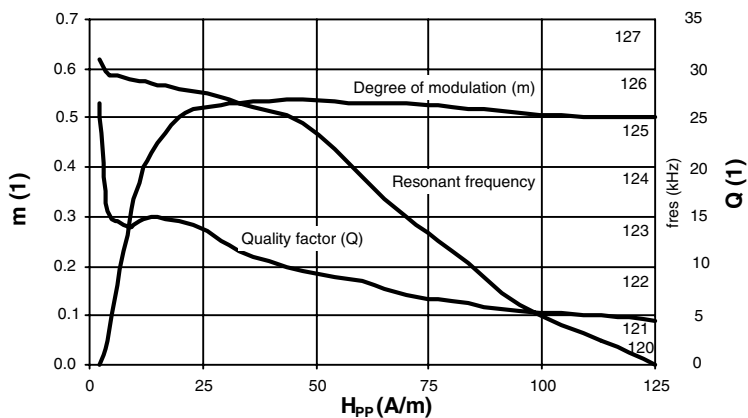


Figure 5. Typical Behaviour of Resonant Frequency, Degree of Modulation and Quality Factor versus Field Strength (by RF/32, Manchester)



Measurement Assembly

All parameters are measured in a Helmholtz arrangement, which generates a homogeneous magnetic field (see Figure 6 and Figure 7). A function generator drives the field generating coils, so the magnetic field can be varied in terms of frequency and field strength.

Figure 6. Testing Application

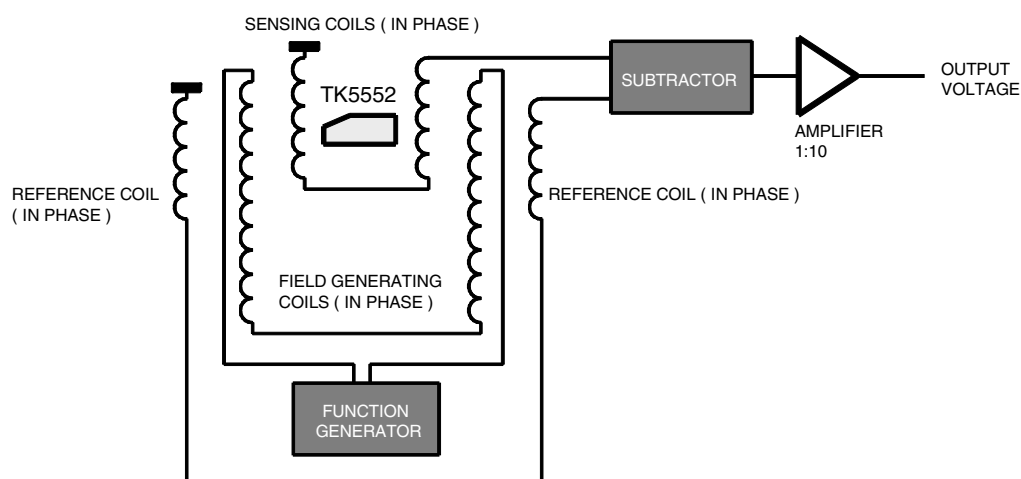
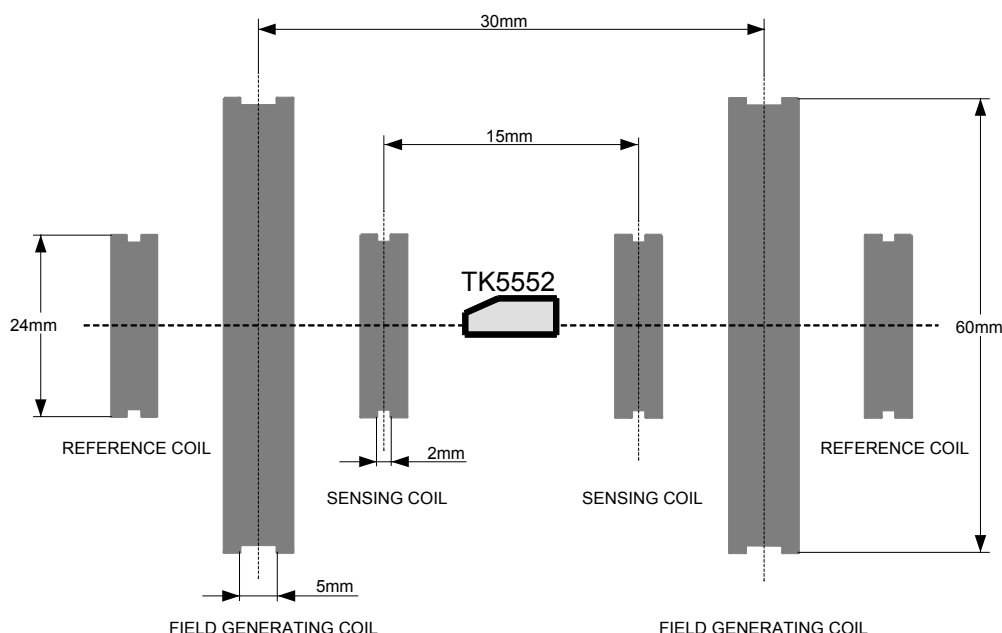


Figure 7. Testing Geometry



Downlink Operation

The write sequence (downlink mode) of the TK5552 is shown in Figure 10. Writing data into the transponder occurs by interrupting the RF field with short gaps. After the start gap the standard op code (11) is followed by the lock bit. The next 32 bits contain the actual data. The last 5 bits denote the destination block address. If the correct number of bits has been received, the actual data is programmed into the specified memory block.

Figure 8. Downlink Protocol

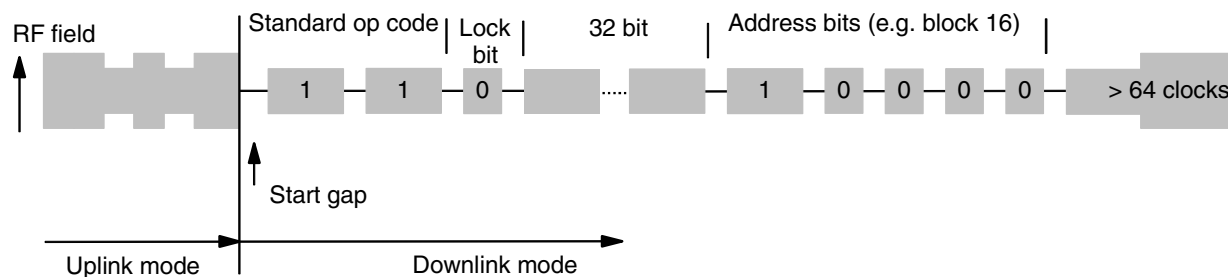
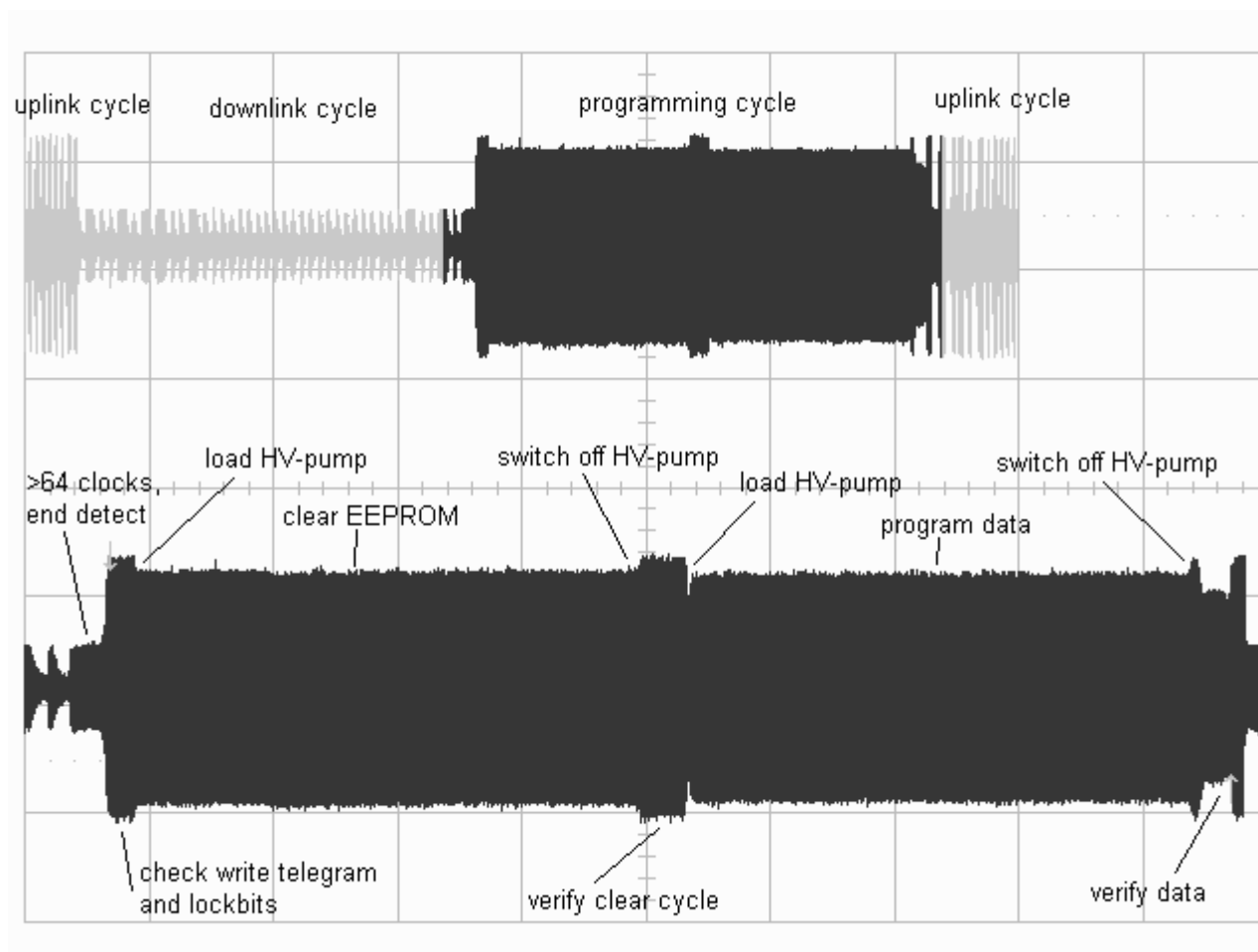


Figure 9. Explanation of the Programming Cycle



Downlink Data Decoding

The time between two detected gaps is used to encode the information. As soon as a gap is detected, a counter starts counting the number of field clock cycles until the next gap is detected. Depending on how many field clocks elapse, the data is regarded as 0 or 1. The required number of field clocks is shown in Figure 10. A valid 0 is assumed if the number of counted clock periods is between 16 and 32, for a valid 1 it is 48 or 64, respectively. If the data transmission was correct, programming is started and the written block is cycling its data back to the base station until POR.

Figure 10. Downlink Data Decoding Scheme

Field clock cycles	1	16	32	48	64
Downlink data decoder	Fail	0	Fail	1	Downlink done

Behavior of the Real Device

The TK5552 detects a gap if the voltage across the coils decreases below the threshold value of an internal MOS transistor. Until then, the clock pulses are counted. The number given for a valid '0' or '1' (see Figure 10) refers to the actual clock pulses counted by the device. There are, however, always more clock pulses being counted than applied by the base station. The reason for this is that an RF field cannot be switched off immediately. The coil voltage decreases exponentially. Even if the RF field coming from the base station is switched off, it takes some time until the voltage across the coils reaches the threshold value of an internal MOS transistor and the device detects the gap.

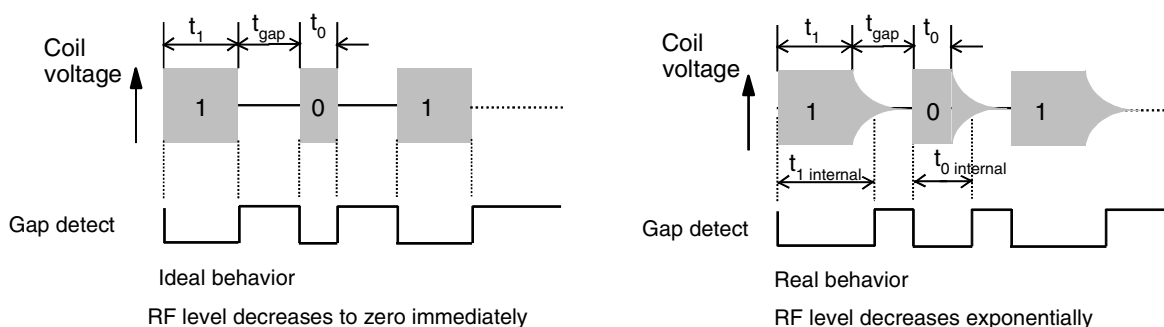
Referring to Figure 11, the device uses $t_{0 \text{ internal}}$ and $t_{1 \text{ internal}}$. The exact values for t_0 and t_1 are depend on the application (e.g., field strength, etc.)

Typical time frames are:

$$\begin{aligned} t_0 &= 70 \mu\text{s to } 150 \mu\text{s} \\ t_1 &= 300 \mu\text{s to } 400 \mu\text{s} \\ t_{\text{gap}} &= 180 \mu\text{s to } 400 \mu\text{s} \end{aligned}$$

Antennas with a high Q-factor require longer times for t_{gap} and shorter time values for t_0 and t_1 .

Figure 11. Ideal and Real Behavior of Signals



$$f_{\text{res}} = \frac{1}{2\pi\sqrt{LC}} = 125 \text{ kHz}$$

Ordering Information

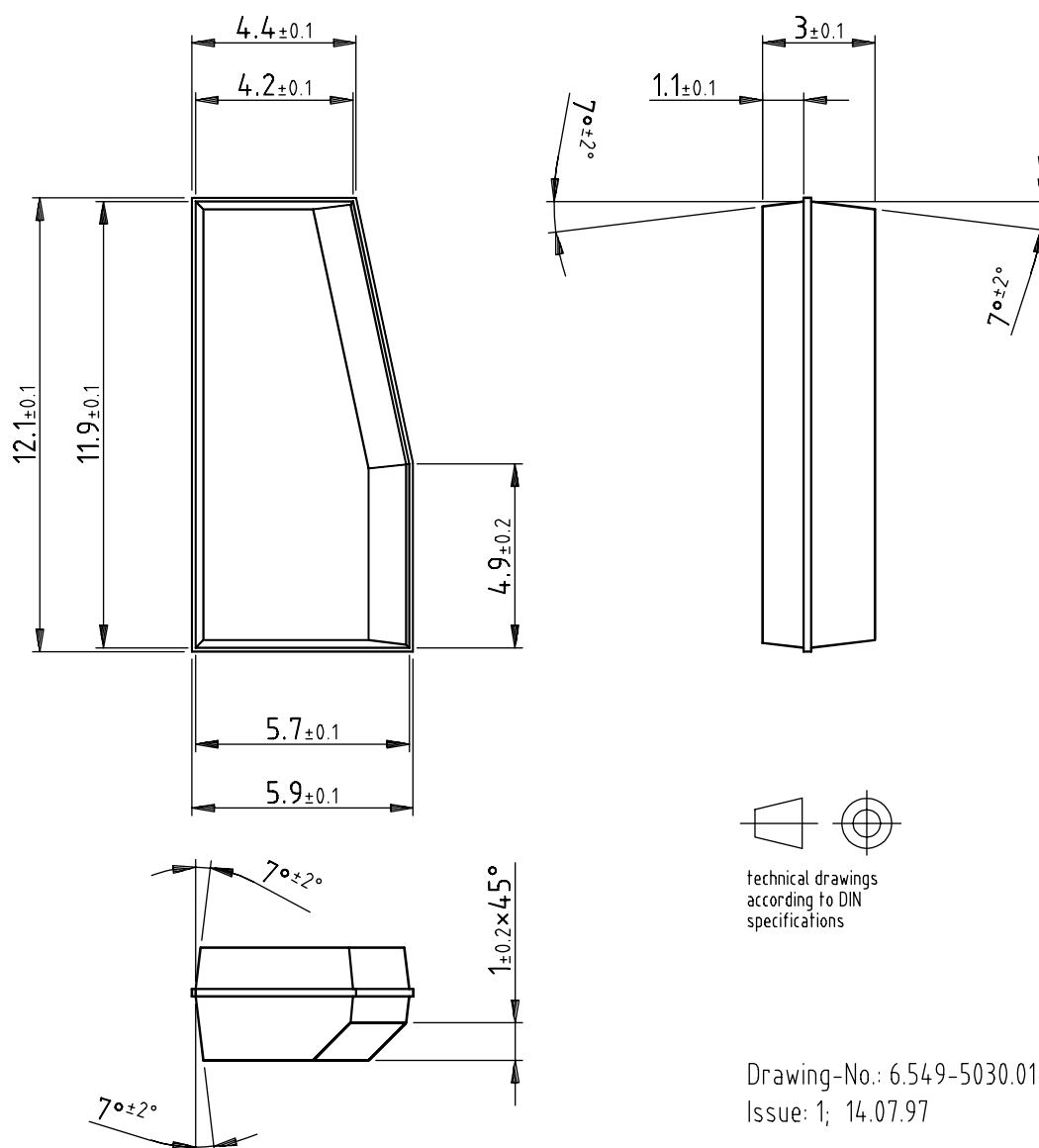
Extended Type Number	Package	Remarks
TK5552A-PP	Plastic cube	Various kinds of modulation; RF/16 and RF/32 ⁽¹⁾ Programmed by default: Manchester modulation, RF/16, MAXBLK = 1 to 31

Note: 1. See section "Transponder IC Read/Write Identification IC with 1k-bit Memory"

Package Information

Package: Transponder

Dimensions in mm



Transponder IC Read/Write Identification IC with 1k-bit Memory

Features

- Low Power, Low Voltage Operation
- ESD Protection: > 8 kV (HBM)
- Optimized for Flip Chip Die Attach Processes
- Contactless Power Supply
- Contactless Read/Write Data Transmission
- Radio Frequency (RF): 100 kHz to 150 kHz
- 1056 Bits of EEPROM Memory
- 992 Bits (31 × 32 Bits) of User Memory
- Defined Start of Data Transmission
- Auto-verify after EEPROM Programming
- Block Write Protection for Each Block
- Configurable Options Include:
 - Modulation Type: PSK/Manchester
 - Bit Rate [Bit/s]: RF/16 / RF/32
 - Number of Readable Blocks
 - Modulation Defeat
 - POR Start-up Delay: ≈ 1 ms / ≈ 65 ms

Functional Description

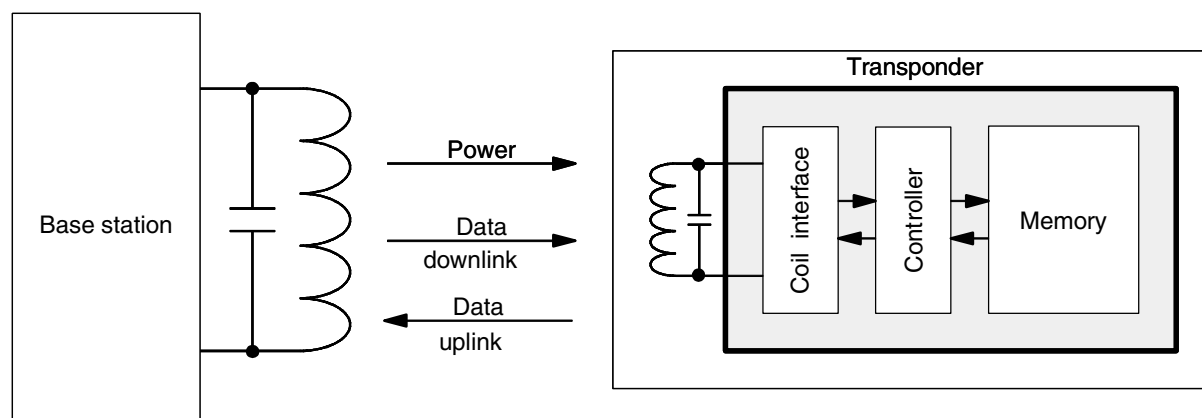
The transponder IC is a two-terminal, contactless R/W-Identification IC (IDIC) for tag applications in the 125 kHz (± 25 kHz) range. The IC uses the external RF signal to generate its own power supply and internal clock reference.

The IC contains a total of 1056 bits of EEPROM memory grouped into 32 individually addressable data blocks. Each block is made up of 32 bits of data plus an associated lock bit for block write protection. Blocks 1 to 31 are provided for user related data and block 0 for system configuration.

Data is transmitted from the IC (uplink) using reflective load (back scatter) modulation. This is achieved by damping the external RF field by switching a resistive load between the two terminals Clock-A/Clock-B. The IC receives and decodes amplitude modulated-data from the base station.

As soon as the tag including the transponder IC is exposed to an RF field (providing that the field is strong enough to derive enough energy to operate), the tag will respond by continuously transmitting stored data (uplink mode). The base station can, at any time, switch the tag to downlink mode to write new user or configuration data. Generally, the tag will automatically return to the default uplink mode when the downlink transfer is completed, interrupted or an error condition occurs.

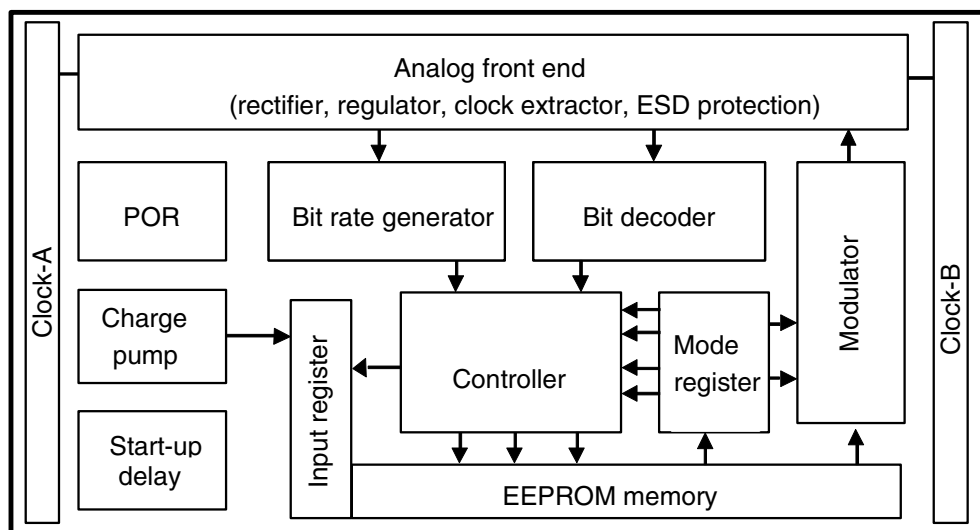
Figure 13. Transponder System Example Using Transponder IC



Functional Modules

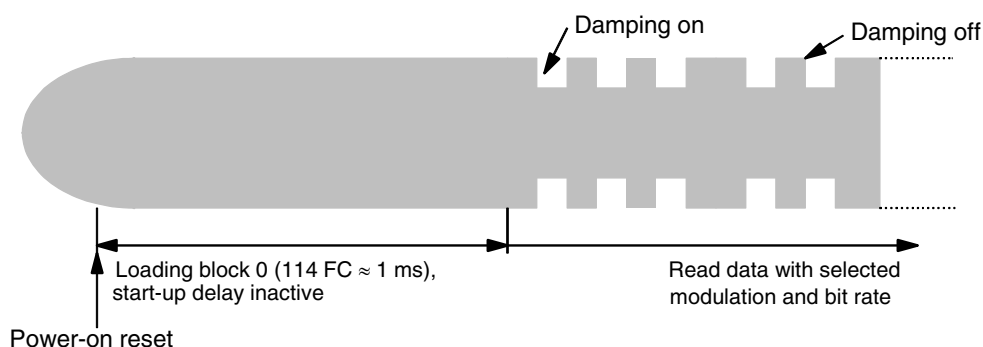
Analog Front End (AFE)	The Analog Front End (AFE) includes all circuits which are directly connected to the coil. It generates the IC's power supply and handles the bi-directional data communication with the base station. It consists of the following blocks: • Rectifier to generate a DC supply voltage from the AC coil voltage • ESD protection • Clock extractor • Switchable load between Clock-A/Clock-B for data transmission from the IC to the reader electronics (uplink mode) • Field gap detector for data transmission from the base station to the IC (downlink mode)
Controller	The control logic is responsible for the following: • Initializing and refreshing configuration register from EEPROM block 0 • Controlling read and write memory access • Handling data transmission and opcode decoding • Error detection and error handling
Clock Extraction	The clock extraction circuit generates the internal clock source out of the external RF signal.
Data Rate Generator	The data rate in uplink mode can be selected to operate at either RF/16 (nominally 7.81 kHz, default) or RF/32 (nominally 3.91 kHz).
Bit Decoder	This functional block decodes the field gaps and verifies the validity of the incoming data stream.
Charge Pump	This circuit generates the high voltage required for programming the EEPROM.
Power-On Reset (POR)	This circuit delays the IC's functionality until an acceptable voltage threshold has been reached.
Mode Register	This register holds the configuration data bits stored in EEPROM block 0. It is refreshed at the start of every block read operation.
Modulator	The modulator encodes the serial data stream shifted out of the selected EEPROM data block and controls the damping circuit in the AFE. The transponder IC front end supports PSK and Manchester encoding.

Figure 14. Functional Block Diagram



Operating the Transponder IC

Figure 15. Voltage at Clock-A/Clock-B After Power-on



General

The basic functions of the transponder IC are to supply the IC from the RF field, read data out of the EEPROM and shift them to the modulator, receive data and program these data bits into the EEPROM. An error detecting circuit prevents the EEPROM from being overwritten with wrong data.

Power Supply

The IC is supplied via a tuned LC-circuit which is connected to the Clock-A/Clock-B pads. The incoming RF induces a current into the coil. The on-chip rectifier generates the DC supply voltage. Overvoltage protection prevents the IC from damage due to high field strengths. Depending on the coil, the open-circuit voltage across the LC circuit can reach more than 100 V.

Initialization

The occurrence of an RF field triggers a power-on reset pulse, ensuring a defined start-up. The Power-On-Reset (POR) circuit remains active until an adequate voltage threshold has been reached. This in turn triggers the default start-up delay sequence. During this period of 114 Field Clock cycles (FC), the transponder IC is initialized with the configuration data stored in EEPROM block 0. This is followed by an additional delay time which is defined by the 'Start-up Delay' bit.

If the 'Start-up Delay' bit is set, the transponder IC remains inactive until 8192 RF clock cycles have occurred. If this option is deactivated, no delay will occur after the configuration period of 114 RF clock cycles (≈ 1 ms).

Any field gap occurring during initialization will restart the complete sequence.

$$T_{\text{INIT}} = (114 + 8,192 \times \text{delay bit}) / 125 \text{ kHz} \approx 65 \text{ ms}$$

After this initialization time, the transponder IC enters uplink mode and modulation starts automatically using the parameters defined in the configuration block.

Uplink Operation

All transmissions from the IC to the base station utilize amplitude modulation (ASK) of the RF carrier. This takes place by switching a resistive load between the coil pads (Clock-A and Clock-B) which in turn modulate the RF field generated by the base station (reflective back scatter modulation).

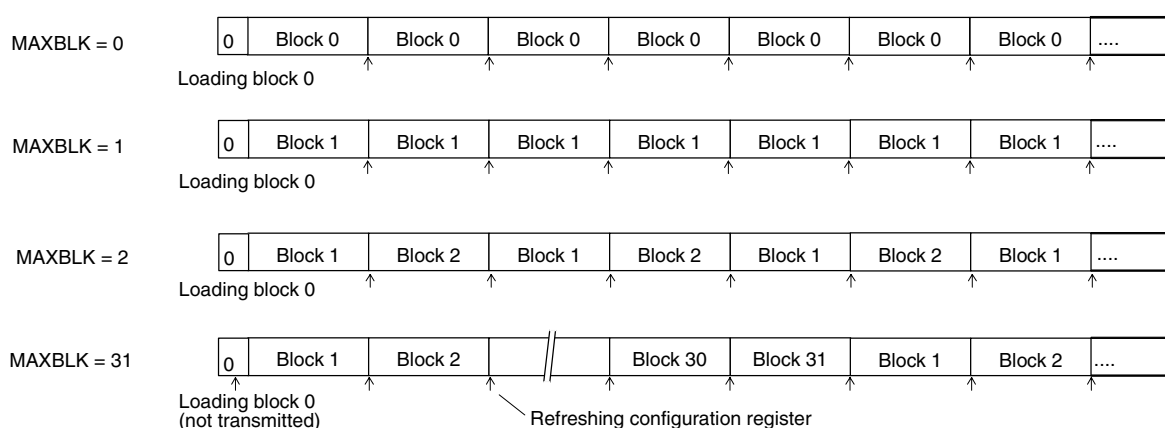
MaxBlock

Data from the memory is serially transmitted, starting with block 1, bit 1, up to the last block (MAXBLK), bit 32. The last block to will be transmitted is defined by the mode parameter field MAXBLK which is stored in EEPROM block 0. When the MAXBLK address has been reached, data transmission restarts with block 1.

The user defines the cyclic data stream by setting the MAXBLK to a value between 0 and 31 (representing each of the 32 data blocks). If set to 1, only block 1 is transmitted. If set to 31, blocks 1 to 31 will be sequentially transmitted. If set to 0, only the contents of the configuration block (normally not accessible) will be transmitted (see Figure 16).

It is also possible to access a single data block selectively, independent of the MAXBLK value, by using the direct access command (Opcode 11). Thus the addressed data block is transmitted continuously.

Figure 16. Data Stream Pattern Depending on MAXBLK



Data Encoding

When entering the uplink mode, the data stream is always preceded by a single start bit (always 0). Then the data stream continues with block 1, bit 1, etc., up to MAXBLK, bit 32. This data stream pattern cycles continuously.

The modulator is configurable for Manchester mode.

Manchester-encoded data represent a logical 1 with a rising edge and a logical 0 with a falling edge.

It is also suitable to PSK using the sub-carrier frequency $RF/2$. The PSK modulator changes its phase with each change of data. The first phase shift represents a data change from 0 to 1.

Figure 17. Example of Manchester Encoding with Data Rate $RF/16$

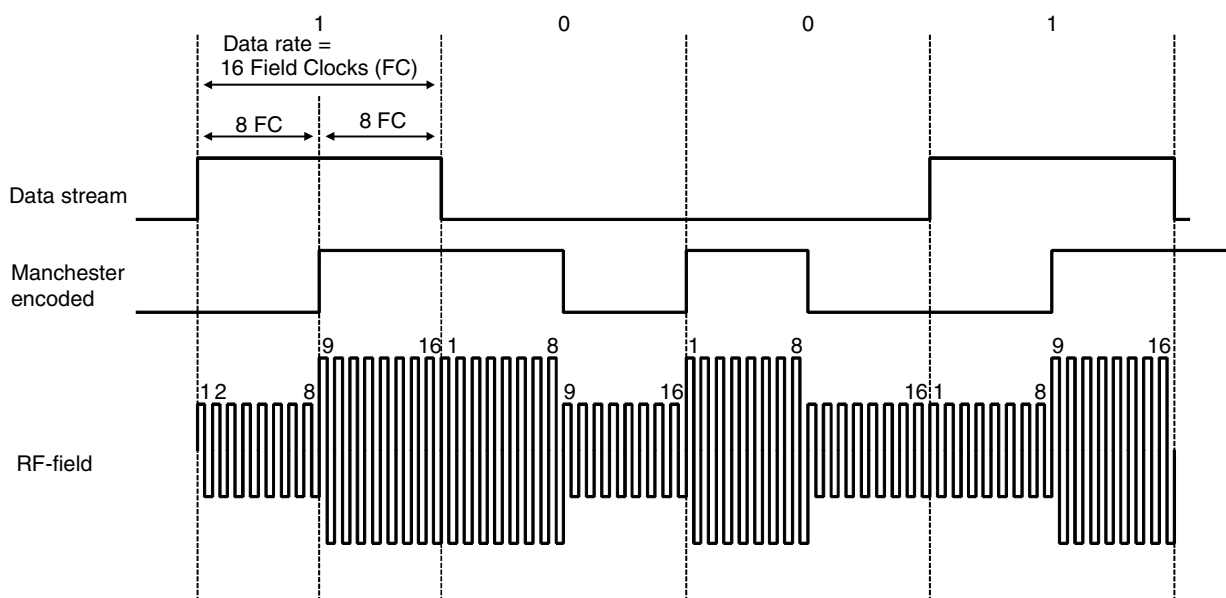
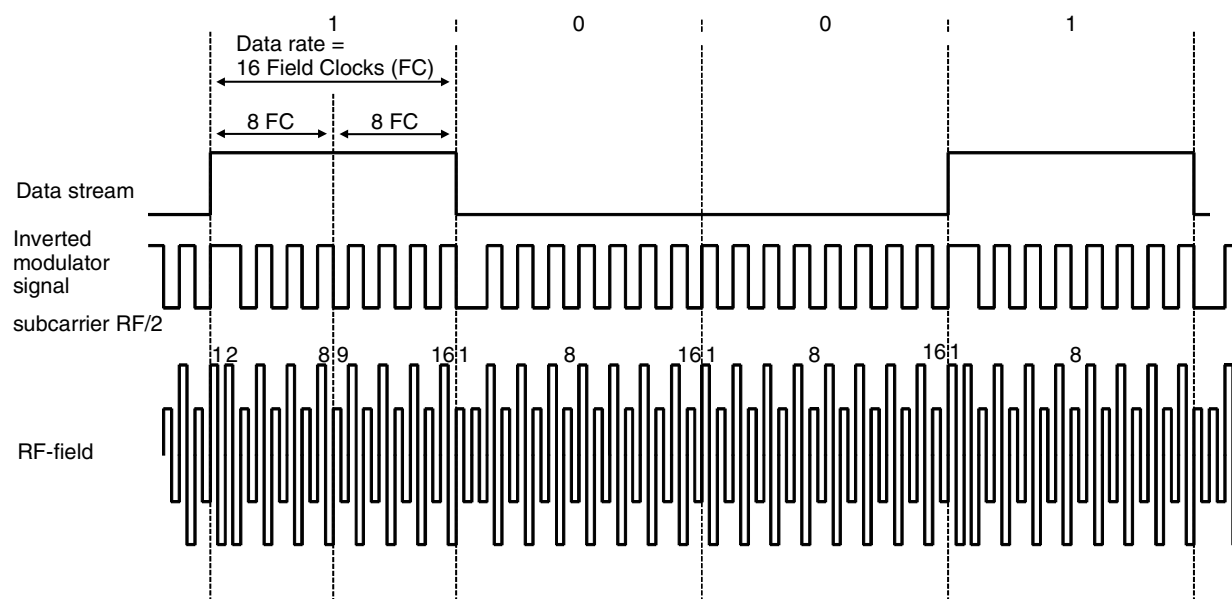


Figure 18. Example of PSK Encoding with Data Rate $RF/16$

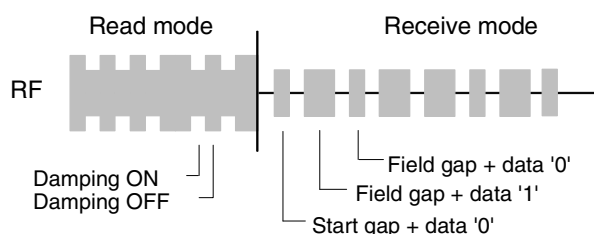


Downlink Operation

Data is transmitted from the base station by amplitude modulation of the field ($m = 1$), using a series of so called gaps. With the exception of the initial synchronization gap (start gap), all field gaps have the same duration, the logical data being encoded in the length of the unmodulated phases (see Figure 19)

A valid data stream is always preceded by a start gap which is approximately twice as long as a normal field gap. Detection of this first gap causes the transponder IC to switch immediately to downlink mode where it can receive and decode the following data stream. This stream consists of two opcode bits, followed by (0 or 33) data bits (including the lock bit) and finally (0, 3 or 5) address bits. In downlink mode the transponder damping is permanently enabled. This loads the resonant transponder coil circuit so that it comes quickly to rest when field gaps occur – thus allowing fast gap detection.

Figure 19. Entering Downlink Mode



A start gap will be accepted at any time after start-up initialization has been finished (RF field ON plus ≈ 1 ms, start-up delay inactive) if the IC is not in downlink mode.

Downlink Data Coding

The duration of a field gap is typically between 80 μ s and 250 μ s. After the start gap the data bits are transmitted by the base station whereby each bit is separated by a field gap. The bit decoder interprets 16 to 32 internal field clocks as a logical 0 and 48 to 64 internal field clocks as a logical 1 (see Figure 20). Therefore, the time between two gaps is typically 24 field clocks for a 0 and 56 field clocks for a 1.

Whenever the bit decoder detects more than 64 field clocks, the transponder IC will abort the downlink mode. The incoming data stream is checked continuously. If any error occurs, the corresponding error handling will be initiated.

The control logic initiates an EEPROM programming cycle if the correct number of bits had been received (see Figure 21).

Figure 20. Operation of Bit Decoder – Data Stream Decoder

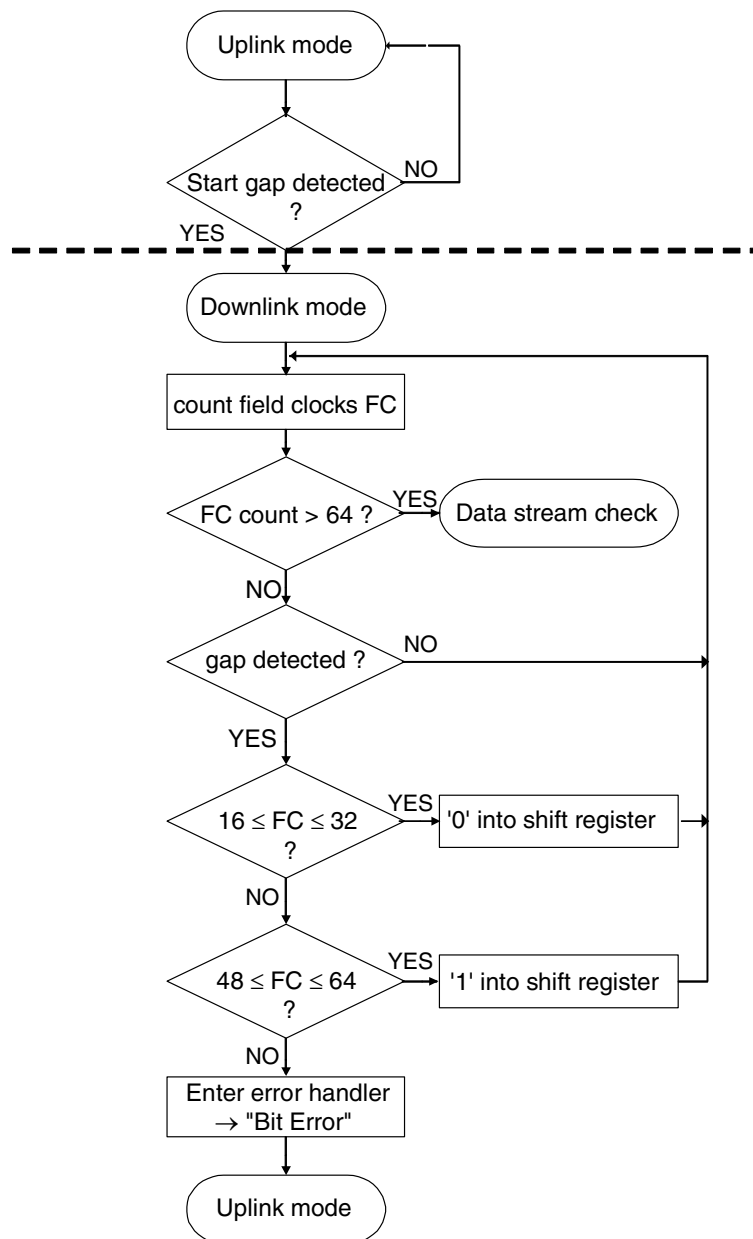
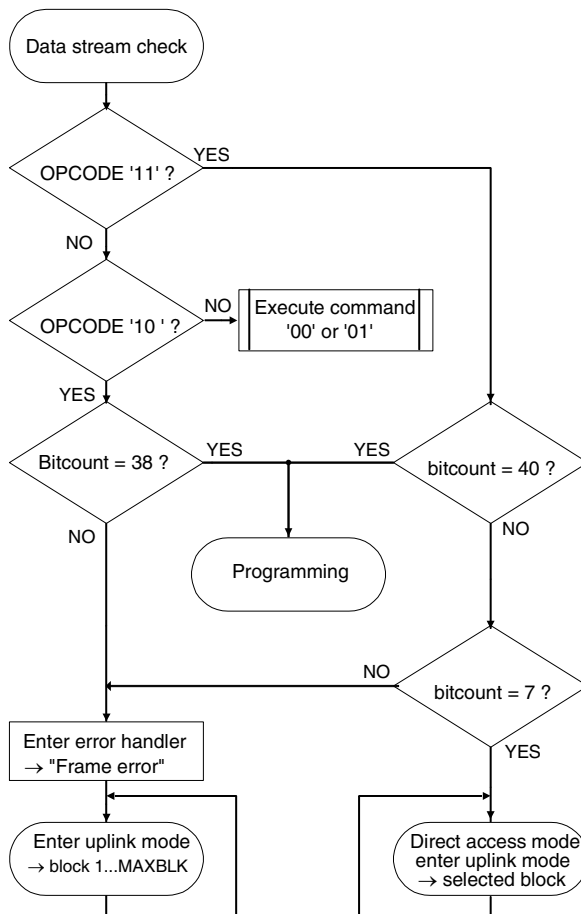


Figure 21. Data Stream Checking



Opcode Definitions

The first two bits of the data stream are decoded by the controller as the opcode bits (see Figure 22):

11: Opcode for a 5-bit address data stream

- To initiate a standard block write cycle the 2 opcode bits are followed by the lock bit, the 32 data bits and the 5-bit block address (40 bits in total)
- The direct access command consists of the opcode 11 followed by the 5-bit block address and is a read-only command (7 bits in total)

10: Opcode for a 3-bit address data stream

- Receive mode compatible to e5550
To initiate a block write cycle, the opcode 10 is followed by the lock bit, the 32 data bits and the 3-bit block address (38 bits in total)

01: Reserved for production test commands

00: Opcode for an internal reset command

Figure 22. Transponder IC Opcode Format Definition

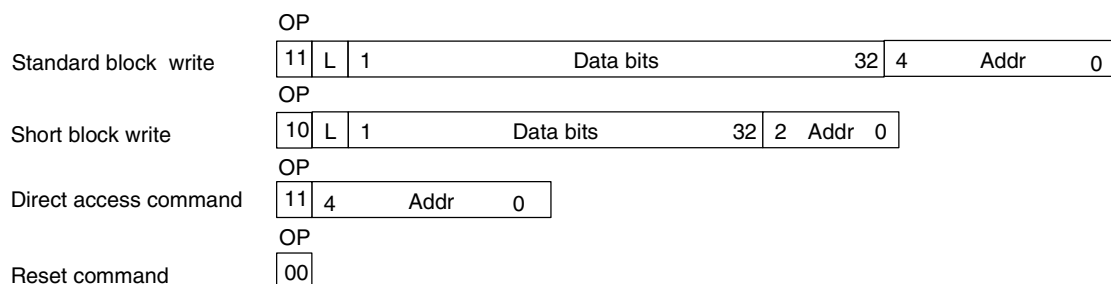
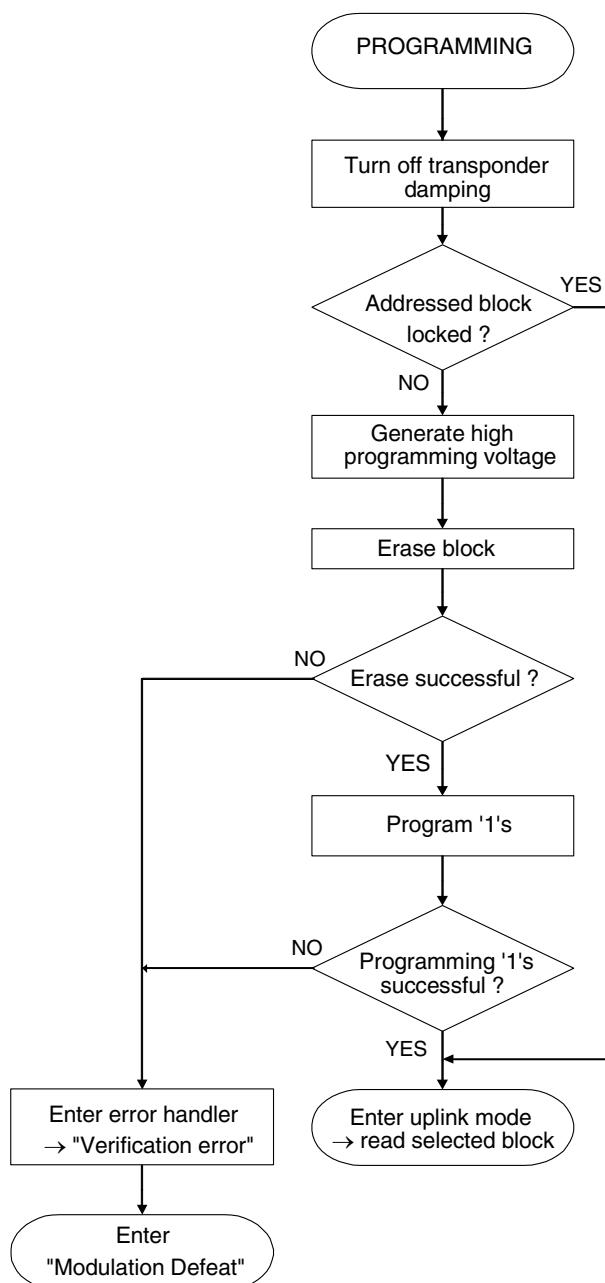


Figure 23. Programming Cycle Flow Chart



Programming

When the bit decoder and controller detect a valid data stream, the transponder IC will start an erase and programming cycle if a data write command was decoded (see Figure 23).

During the erase and programming cycle, downlink damping is turned off. The programming cycle includes a data verification read to check the integrity of the data. When EEPROM programming and verification have been finished successfully, the Transponder IC enters uplink mode, transmitting the block just programmed.

The typical programming time is ≈ 18 ms.

Error Handling

Several error conditions are detected by the transponder IC to ensure that only valid information is programmed into the EEPROM.

Errors During EEPROM Programming

There are two types of errors which will lead to dedicated actions.

- Verification error
If one of the data verification cycles fails, the transponder IC will inhibit modulation and will not return to the uplink mode. This modulation defeat state is terminated by re-entering the downlink mode with a start gap.
- Block write protection
If the lock bit of the addressed block is set, programming is disabled. In this case, the programming cycle is not initiated and the transponder IC reverts to uplink mode, transmitting the currently addressed (and unmodified) block continuously.

Errors During Data Transmission

The following errors are detected by the decoder:

- Bit error
Wrong number of field clocks between two gaps (i.e., not a valid 0 or 1 pulse stream).
- Frame error
The number of data bits received is incorrect:
 - Valid bit count for 3-bit address write is 38 bits
 - Valid bit count for 5-bit address write is 40 bits
 - 7 bits for a direct access command

If any of these conditions is detected, the transponder IC enters uplink mode starting with block 1.

EEPROM Memory Organization

The memory array of the transponder IC consists of 1,056-bits of EEPROM, arranged in 32 individually addressable blocks of 33 bits each, consisting of one lock bit and 32 data bits. All 33 bits, including the lock bit, are programmed simultaneously.

The programming voltage is generated on-chip.

Lock Bit

Each block has an associated write lock bit that protects the entire block. By default all lock bits L are reset (0).

Note: Once set, the lock bit and the content of the associated block cannot be altered.

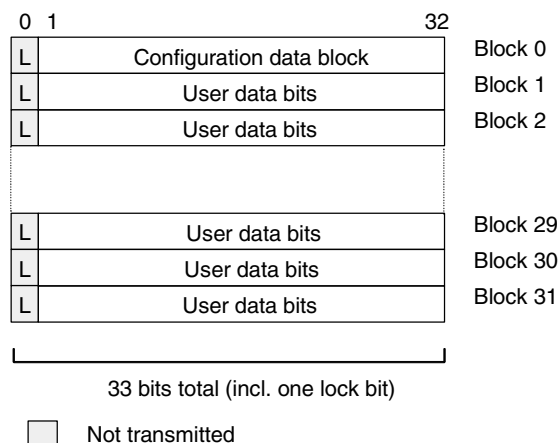
Memory Map

The configuration data of the transponder IC is stored in block 0 of the EEPROM.

The remaining 31 data blocks (1 to 31) each consist of 1 lock bit and 32 user data bits.



Figure 24. Memory Map



Configuration Data Block

This data block contains 9 configuration bits. The remaining bits of block 0 are reserved for future enhancements and should be set to 0.

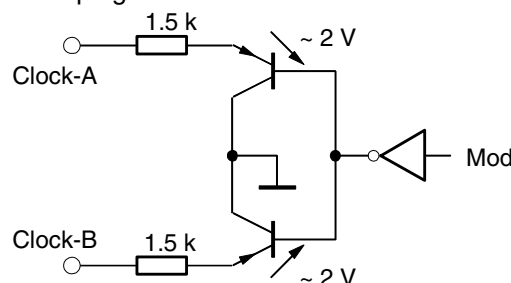
- Start-up Delay bit (SD, default: NO delay).
When set, an additional delay time of 64 ms is added after any internal reset.
- Data Rate bit (DR, default: RF/16).
Selects the data rate of RF/16 or RF/32.
- Modulation Select bit (MS, default is PSK)
Selects the type of data encoding which is either Manchester or PSK.
- Modulation Defeat bit (MD, default is OFF)
When set (to 1) the modulation output is deactivated, hence no data will be transmitted. The modulation defeat state does not impact the transponder damping function.
- MAXBLK address bits (MAXBLK, default is 31)
This 5-bit block address is used to define the upper limit of cyclic block reads.

Note: The configuration is changed by re-programming block 0 as long as the corresponding lock bit is not set. The default settings can be lost due to the die cut.

Table 1. Transponder IC Configuration Block 0 Bit Mapping

L	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										0
Lockbit	Reserved, set to '0'																						Start-up delay SD	Data rate DR	Modul. select MS	MD	MAXBLOCK 00000 = Block 0 00001 = Block 1 00010 = Block 1...2 00011 = Block 1..3					Reserved
																											Modulation Defeat					
																											0 = Normal function					
																											1 = Modulation off					
	0 = Unlocked																										0 = PSK					
1 = Locked																									1 = MANCHESTER							
	No delay = 0																						0 = RF/16									
	Delay of 8,192 field clocks																															

Figure 25. Simplified Damping Circuit



Absolute Maximum Ratings

Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device.

Parameters	Symbol	Value	Unit
Maximum DC current into Clock-A/Clock-B	I_{coil}	10	mA
Maximum AC current into Clock-A/Clock-B, $f = 125 \text{ kHz}$	$I_{\text{coil PP}}$	20	mA
Power dissipation (dice) ⁽¹⁾	P_{tot}	100	mW
Electrostatic discharge voltage according to MIL-Standard 883D method 3015 (HBM)	V_{max}	8000	V
Operation ambient temperature range	T_{amb}	-25 to +75	°C
Storage temperature range ⁽²⁾	T_{stg}	-40 to +125	°C
Maximum assembly temperature for less than 5 min ⁽³⁾	T_{sld}	+150	°C

- Notes: 1. Free-air condition, time of application: 1s
 2. Data retention reduced
 3. Assembly temperature of 150°C for less than 5 minutes does not affect the data retention

Operating Characteristics

$T_{\text{amb}} = 25^\circ\text{C}$, $f_{\text{RF}} = 125 \text{ kHz}$, reference terminal is V_{SS}

Parameters	Test Conditions	Symbol	Min.	Typ.	Max.	Unit
RF frequency range		f_{RF}	100	125	150	kHz
Supply current	Uplink and downlink mode – full temperature range	I_{DD}		5	7.5	μA
	Programming – full temperature range	I_{DD}		14	28	μA
Clamp voltage	10 mA current into Clock-A/B	V_{clamp}	7		11	V
Programming time	Per block	t_{P}		18		ms
Start-up time	⁽²⁾	t_{startup}	1		65	ms
Data retention	⁽¹⁾	$t_{\text{retention}}$	10			Years
Programming cycles	⁽¹⁾	ncycles	100,000			
Clock-A/B voltage	Uplink and downlink mode	V_{clockPP}	6			V
Clock-A/B voltage	Programming, RF field w/o damping	V_{clockPP}	12			V
Damping resistor	Each at Clock-A and Clock-B	RD		1.5		k Ω

- Notes: 1. Since the EEPROM performance is influenced by assembly and packaging, Atmel confirms the parameters for DOW (= tested Dice On Wafer) and ICs assembled in a standard package.
 2. Depends on the start-up delay bit in the configuration register.



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