32-mm Glass-Encapsulated Multipage Transponders

Reference Guide

Literature Number: SCBU053
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Introduction

The TI 32-mm glass transponder is a key product in low-frequency RFID systems that can be used for a variety of applications and is especially useful for those applications that require a robust and waterproof transponder.

This document describes the RI-TRP-DR2B 32-mm glass-encapsulated multipage transponder with 17 R/W pages (MPT 0/17). For more information, visit www.ti.com/rfid.

Chapter 1 describes the physical and electrical characteristics of the transponders and their shipping packaging. Chapter 2 describes the use and operation of the transponders.

Abbreviations

BCC	Block Check Character
CRC	Cyclic Redundancy Check
DBCC	Data BCC
EEPROM	Electrical Erasable Programmable Read Only Memory
FBCC	Frame BCC
LSB	Least Significant Bit
MPT	Multipage Transponder
MSB	Most Significant Bit
RO	Read-Only
R/W	Read/Write

Conversion Formulas

Conversion formula between magnetic flux, magnetic field strength, and electric field strength.

$$B = \mu_0 \times H$$

$$E = Z_F \times H$$

$$H = \frac{E}{dB\mu V \div m} - 51.5 \frac{dB\mu A}{m}$$

$$[H] = \frac{dB\mu A}{m}$$

$$[E] = \frac{dB\mu V}{m}$$

B = Magnetic flux [tesla = Wb/m^2 = Vs/m^2]; 1 mWb/m^2 = 0.795 A/m
H = Magnetic field strength (A/m or in logarithmic term dBA/m)
E = Electrical field strength (V/m or in logarithmic term dBV/m)
μ_o = Magnetic field constant = 1.257×10^{-6} Vs/Am
Z_F = Free space impedance = 120π Ω = 377 Ω

Transponder Characteristics

1.1 Transponder Packaging

Figure 1-1 shows the dimensions of the transponder. The transponder is hermetically sealed. For applications in which read range is not the most critical consideration, the transponder can be mounted or used in such a way that the orientation is not controlled.

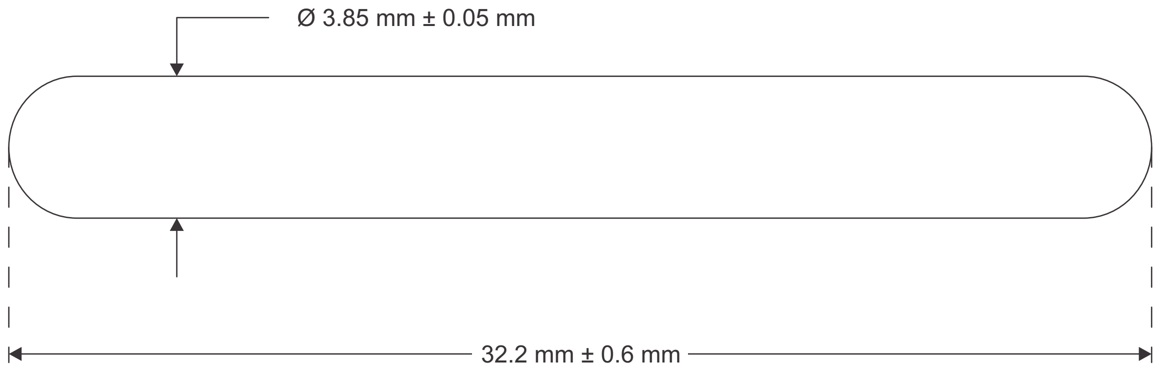


Figure 1-1. Dimensions of the TI 32-mm Transponder

1.2 Product Specification Data

Table 1-1. Absolute Maximum Ratings

PARAMETER	SYMBOL	NOTE	MIN	MAX	UNIT
Storage temperature	Ts		–40	100	°C
Field strength	Hexc	134.2 kHz		220	dBµV/m

Table 1-2. Recommended Operating Conditions[1]

PARAMETER	SYMBOL	MIN	NOM	MAX	UNIT
Operating free-air temperature, read program	TaR Tap	–25		85	°C
Transmitter frequency	ftx	134.16	134.20	134.24	kHz
Charge time	ttx		50		ms
Write bit duration	tbit		2		ms
Write pulse pause/low bit	toffL		0.3		ms
Write pulse pause/high bit	toffH		1		ms
Programming time	tprog	15			ms

(1) At a free-air temperature of 25°C (unless otherwise noted) and at a transmitter field strength of 160 dBµV/m at 3 m free air (unless otherwise noted)

Table 1-3. General Characteristics[1]

PARAMETER	SYMBOL	NOTE	MIN	TYP	MAX	UNIT
Typical reading range	Dread	[2]		70	100	cm
Typical programming range	Dprg	[2]		35		cm
Mechanical shock	IEC 68-2-27, Test Ea; 300 g half-sine, 3 ms, 2 axes					
Vibration	IEC 68-2-6, Test Fc; 3 g, 5 – 50 Hz, 2 axes, 24 hours per axis; 20 g, 10 – 2000 Hz, 2 axes, 2.5 hours per axis					

(1) At a free-air temperature of 25°C and at a transmitter field strength of 160 dBµV/m at 3 m free air (unless otherwise noted)
(2) Depending on RF regulation in country of use, and the Reader Antenna configuration used in a low RF noise environment.

Table 1-4. Frequency of Packaged Product[1]

PARAMETER	SYMBOL	NOTE	MIN	TYP	MAX	UNIT
Operating quality factor	Qop	[2]	62			
Resonant circuit frequency	FRES	[3]		135.2		kHz
		[4]		134.2		
Low bit transmit frequency	RCLKL		132.2	134.3	136.2	kHz
High bit transmit frequency	RCLKH		121	122.9	125	kHz
Low bit transmit frequency	RCLKL	–40°C to 85°C	131.5		139	kHz
High bit transmit frequency	RCLKH	–40°C to 85°C	120		128	kHz

(1) At a free-air temperature of 25°C (unless otherwise noted)
(2) Specified Qop must be met in the application over the required temperature range.
(3) Low activation field strength test setup (spectrum analyzer) that keeps the internal power supply voltage (VCL) less than 1.5 V.
(4) Activation field strength test setup that keeps the internal power supply voltage greater than 1.5 V.

Table 1-5. Mechanical Specifications

Dimensions	Length	32.2 ± 0.6 mm
	Diameter	3.85 ± 0.05 mm
Package Material		Glass
Weight		0.85 gram

1.3 ESD

TI transponders are not sensitive to ESD as defined in IEC 801.

1.4 Packaging Material

The transponders are delivered in tape on reel.

1.4.1 Labeling of Reel

The label on the reel contains:

- Originator
- Country of origin
- TI part number
- Date of origin
- Quantity

1.4.2 Packing Size

Minimum packing size is 2000 units.

Transponder Operation

2.1 Overview

The TI transponder is a key product in low frequency RFID systems that can be used for a variety of applications.

Electromagnetic signals are used to power the passive (batteryless) device and to transmit the identification number to a reader unit or to program the device with new data. Figure 2-1 show this basic principle.

The transponder comprises an antenna, a charge capacitor, a resonance capacitor, and the integrated circuit (see Figure 2-2). The antenna inductance and a capacitor form a high-quality resonant circuit.

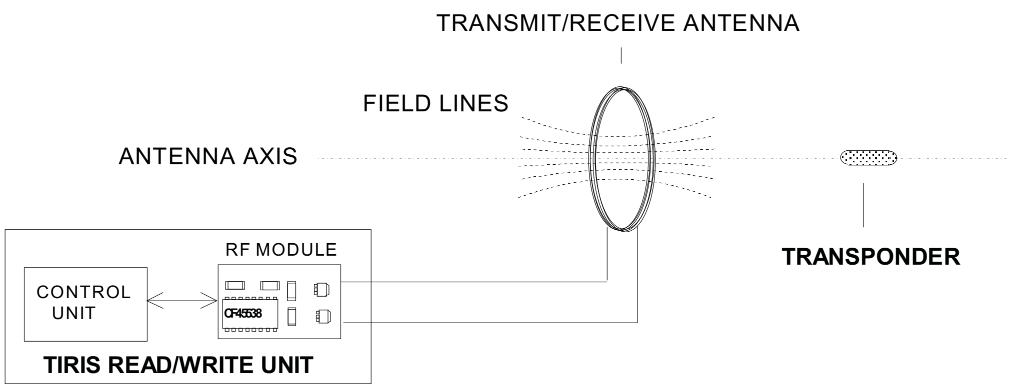


Figure 2-1. System Configuration Showing the Reader, Antenna, and Transponder

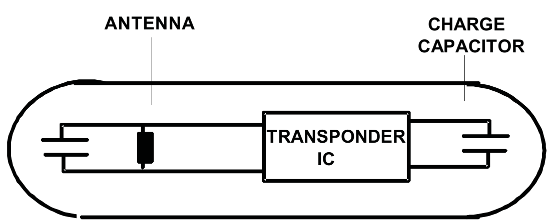


Figure 2-2. Block Diagram of a TI Transponder

2.2 Operation

2.2.1 Memory Organization

Figure 2-3 shows the memory organization of the EEPROM cells for the MPT 0/17. The memory organization described and shown here is that used by TI RFID readers. If you use readers other than TI RFID readers (customer designed) the allocation of the 64 data bits depends on the reader software.

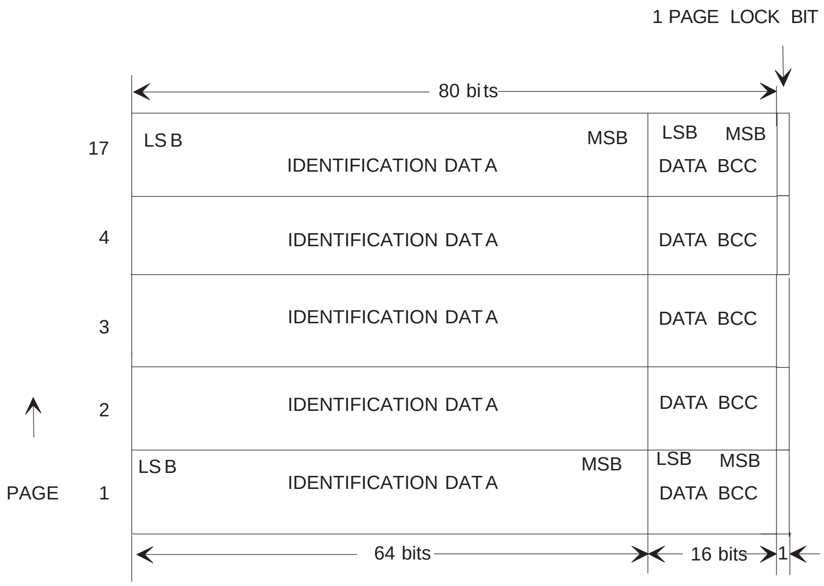


Figure 2-3. Memory Organization of the MPT 0/17

The memory is organized into 17 pages each containing 80 data bits and one lock bit each. 64 bits are used for identification data, and 16 bits are used for protection data (Data BCC). The page lock bit can be set by sending the corresponding command to the transponder. Once a page is locked it cannot be reset (unlocked). The pages are organized so that each page is readable, user programmable, and lockable.

2.2.2 *Read and Write Data Formats*

2.2.2.1 Read Data Format

The following read data format is sent out by all multipage transponders after receiving a read, program or lock command.

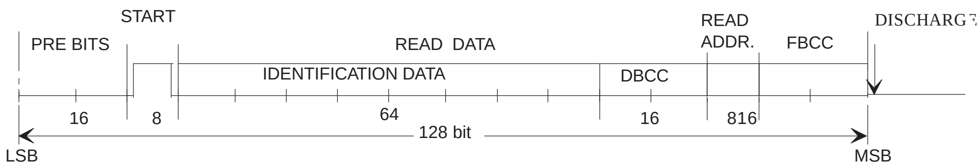


Figure 2-4. MPT Read Data Format

Description	Bits	Value (Hex)		Comment
		MSB	LSB	
Pre Bits	16	0000		
Start Byte	8	7E		x: identification data
Read Data	80	yyyyxxxxxxxxxxxxxxxx		y: data BCC
Read Address	8	ps s		ps: page + status
Read Frame BCC	16	zzzz		
TOTAL	128			

All parts of the multipage transponder read data format are transmitted with LSB first. The data format starts with 16 pre bits (0000h) and ends with the Read Frame Block Check Character (Read FBCC). To be ready for a new activation, the transponder discharges the charge capacitor during bit 129.

80 read data bits are located between the start byte (7Eh) and the read address. The read data bits are user programmable and lockable. The read data is split into 64 identification data bits which are transmitted first, followed by 16 protection data bits (DBCC). Because it allows optimum data security, CRC-CCITT is used as protection algorithm for both DBCC and FBCC.

The read address consists of a 2-bit status field and a 6-bit page field. The status field transmitted first, provides information about the function the multipage transponder has executed, and the page field shows which page was affected.

Read Address

	Page (MSB PPPPPP LSB)	Status (MSB SS LSB)	
Page 1	000001	00	Read unlocked page
Page 2	000010	01	Programming done
⋮	⋮	10	Read locked page
Page 16	010000	11	Reserved(1)
Page 17	010001		
	000000	00	Read unlocked page, locking not correctly executed
	000000	01	Programming done, but possibly not reliable
	000000	10	Read locked page, but locking possibly not reliable

(1) If the status indicates Reserved, the read data cannot be interpreted as identification data.

2.2.2.2 Write Data Format

The write function is used to transfer commands, addresses, and data to the transponder to activate certain functions. Writing is started after the charge phase. It is achieved by switching the RF module's transmitter off and on according to the data bits. The duration of the transmitter deactivation defines whether it is a low bit or a high bit (see Section 2.4.2 for detailed information).

Becayse the memory of the multipage transponder is structured in multiple pages, the reader must send the write address to the transponder to read, program, or lock a specified page.

Write Address

MSB LSB MSB LSB
PPPPPP CC
Page Command

Page 1	000001	00	General read page
Page 2	000010	01	Program page
⋮	⋮	10	Lock page
Page 16	010000		
Page 17	010001		

The write address byte consists of a 2-bit command field and a 6-bit page address. The command field which is transmitted first (LSB first), determines the function to be executed in the transponder. The page field defines the affected page.

2.2.3 Functions

The following functions can be performed by the multipage transponders:

Charge Only Read: The contents of page 1 can be read without a specific page address by just powering-up the transponder.

General Read Page: A page is addressed by sending a page address to the transponder. The content of the addressed page is returned during the subsequent read Phase.

Program Page: A 64-bit identification and a 16-bit BCC are sent to the transponder and programmed into the specified page. The transponder responds with the new contents of the page.

Lock Page (Disable Reprogramming): A specified page can be locked to create a read-only page. The transponder responds with the contents of the addressed page and conformation that the page has been locked.

2.2.3.1 General Read Page

The general read page function is provided to allow a selected page to be read. Figure 2-5 shows the data format to be sent to the transponder to read a specified page.

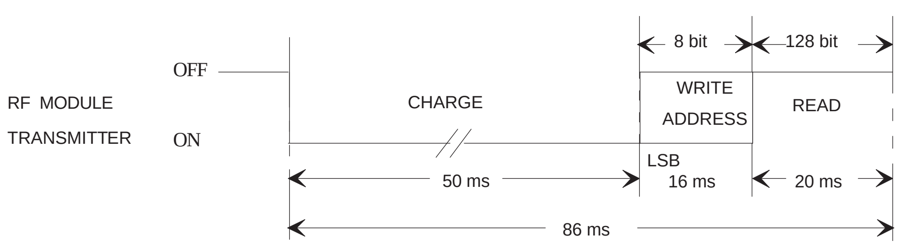


Figure 2-5. Data Format of the General Read Page Function

For additional information about the write address, see Section 2.2.2.2.

NOTE: If page 1 of an MPT 0/17 is to be read, the page address does not need to be sent. The read phase can start immediately after the charge phase.

If the general read page command is corrupted, the transponder could detect the wrong command. If the number of bits in the write data format are not correct, the transponder discharges its charge capacitor (no response).

After having received the data format of the general read page function the multipage transponder responds with the read data format (see Section 2.2.2.1). Table 2-1 shows the possible responses. The reader must check the response and repeat the command if necessary.

Table 2-1. Responses to General Read Page

Write Address		Read Address		Description
Command	Page	Status	Page	
General Read Page	x	Read unlocked page	x	General read page of unlocked page x executed
General Read Page	x	Read locked page	x	General read page of locked page x executed
General Read Page	x	Read unlocked page	y	General read page of unlocked page y executed, y>x: write address was not correctly received
General Read Page	x	Read locked page	y	General read page of locked page y executed, y>x: write address was not correctly received
General Read Page	x	Read unlocked page	z	General read page of unlocked page z executed, z<x: maximum page or write address was not correctly received
General Read Page	x	Read locked page	z	General read page of locked page z executed, z<x: z = maximum page or write address was not correctly received
General Read Page	x	Reserved	x	No identification data in page x
General Read Page	x	Reserved	y	No identification data in page y, y>x: write address was not correctly received
General Read Page	x	Reserved	z	No identification data in page z, z<x: z = maximum page or write address was not correctly received
General Read Page	0	No response		Page 0 is not valid

2.2.3.2 Program Page

The program page function is used to program the write data into a specified page of a multipage transponder. For that purpose the following data format must be sent to the transponder with LSB first.

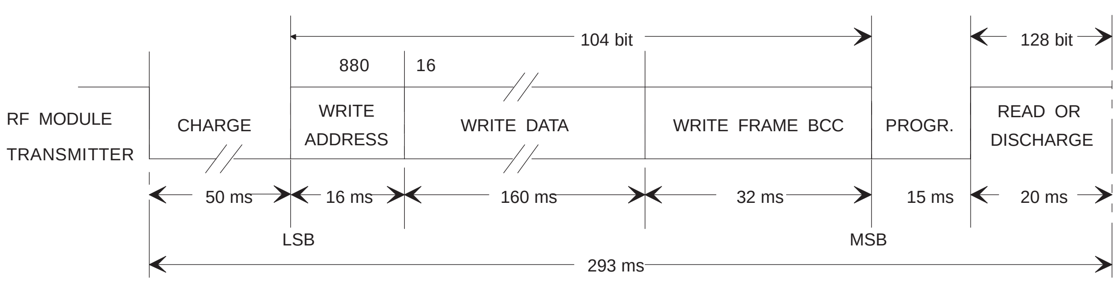


Figure 2-6. Data Format of the Program Page Function

Description	Bits	Value (Hex)		Duration (ms)	Comment
		MSB	LSB		
Write Address	8	pc		16	pc: page + command
Write Data	80	yyyyxxxxxxxxxxxxxxxx		160	x: identification data and protection data
Write Frame BCC	16	zzzz		32	z: protection data
TOTAL	104			208	

For additional information on the write address, see Section 2.2.2.2.

The 80-bit write data split into 64 identification data bits and 16 protection data bits (DBCC) must be transmitted consecutively.

Because it provides optimum data security, CRC-CCITT is used as protection algorithm for the calculation of the DBCC and the 16-bit write frame block check character (write FBCC), which protects the write address and the write data.

The multipage transponder checks the received data using a hardware CRC generator. The program page function is executed if:

- the program page command is detected
- the write data format has the correct number of bits
- the write FBCC check is OK
- the RF field strength is high enough to generate a reliable programming voltage

After receiving the data format of the program page function, the multipage transponder responds in the read data format (see Section 2.2.2.1). Table 2-2 shows the possible responses. The reader must check the response and repeat the command if necessary.

Table 2-2. Responses to Program Page

Write Address		Read Address		Description
Command	Page	Status	Page	
Program Page	x	Programming done	x	Programming of page x correctly executed
Program Page	x	Programming done	0	Programming of page x executed, but probably not reliable
Program Page	x	Read locked page	x	Programming of locked page x not executed
Program Page	x	Read unlocked page	x	Programming of unlocked page x not executed, RF field strength too low
Program Page	x	No response		Programming not executed because of CRC error or framing error
Program Page	x	Read unlocked page	z	Programming not executed, z<x: page x not available, page z = maximum page and is unlocked
Program Page	x	Read locked page z	x	Programming not executed, z<x: page x not available, page z = maximum page and is locked
Program Page	x	Reserved	z	No identification data in page x
Program Page	x	Reserved	z	No identification data in page z, z<x: z = maximum page
Program Page	0	No response		Page 0 is not valid

2.2.3.3 Lock Page

The lock page function is used to lock the content of a specified page of a multipage transponder. For that purpose the following data format must be sent to the transponder with LSB first.

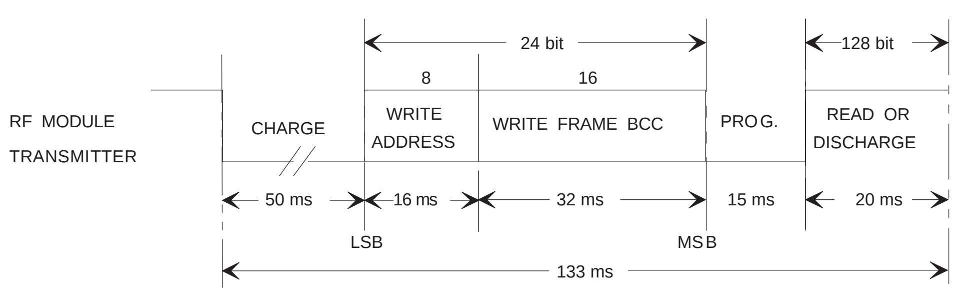


Figure 2-7. Data Format of the Lock Page Function

Description	Bits	Value (Hex)		Duration (ms)	Comment
		MSB	LSB		
Write Address	8	pc		16	pc: page + command
Write Frame BCC	16	zzzz		32	z: protection data
TOTAL 128	24			48	

For additional information on the write address see Section 2.2.2.2.

The 16-bit Write Frame Block Check Character (Write FBCC) which protects the write address must be generated by the CRC-CCITT algorithm.

The data format of the lock page function is checked by the transponder using the hardware CRC Generator. The lock page function is executed by the transponder if:

- the lock page command is detected
- the write data format has the correct number of bits
- the write FBCC check is positive
- the RF field strength is high enough to generate reliable programming voltage

After having received the data format of the lock page function the multipage transponder responds in the read data format (see Section 2.2.2.1). Table 2-3 shows the possible responses. The reader has to check the response and repeat the command if necessary.

Table 2-3. Responses to Lock Page

Write Address		Read Address		Description
Command	Page	Status	Page	
Lock Page	x	Read locked page	x	Locking of page x correctly executed
Lock Page	x	Read locked page	0	Locking of page x executed, but probably not reliable
Lock Page	x	No response		Locking not executed, because of CRC error or framing error
Lock Page	x	Read unlocked page	x	Locking of page x not executed, RF field strength too low. Page is not locked
Lock Page	x	Read unlocked page	0	Locking of page x not executed because field strength dropped. Page is not locked.
Lock Page	x	Read unlocked page	z	Read unlocked page z, z<x: page x not available, z = maximum page. Lock page was not executed.
Lock Page	x	Read locked page	z	Read locked page z, z<x: page x not available, z = maximum page. Lock page was not executed
Lock Page	x	Reserved	x	No identification data in page x
Lock Page	x	Reserved	z	No identification data in page z, z<x: z = maximum page
Lock Page	0	No response		Page 0 is not valid

2.3 EMI and EMC Performance

2.3.1 General

For any given RFID system, the EMI and EMC performance is determined by three factors:

1. The reader design and the resulting noise immunity performance.
2. The signal strength of the transponder and signal-to-noise ratio at the receiver input.
3. The transponder immunity to EM fields:
   - The most critical EMI factor or component in a system is the reader immunity.
   - A high transponder data signal facilitates reader design through the higher signal-to-noise ratio.
   - The least critical component is the transponder. Immunity levels are generally very high.

All EMI sources can be classified into three different categories:

- Broadband "industrial" noise of sporadic or continuous nature.
- Discrete radio-frequency signals that are unmodulated or FM or FSK modulated.
- Discrete radio-frequency signals that are AM or ASK modulated.

2.3.2 CE Declaration

CE

The products described in this document comply fully with the European EMC directive 89/336/EEC as tested according to pr ETS 300 683.

2.3.3 System Performance

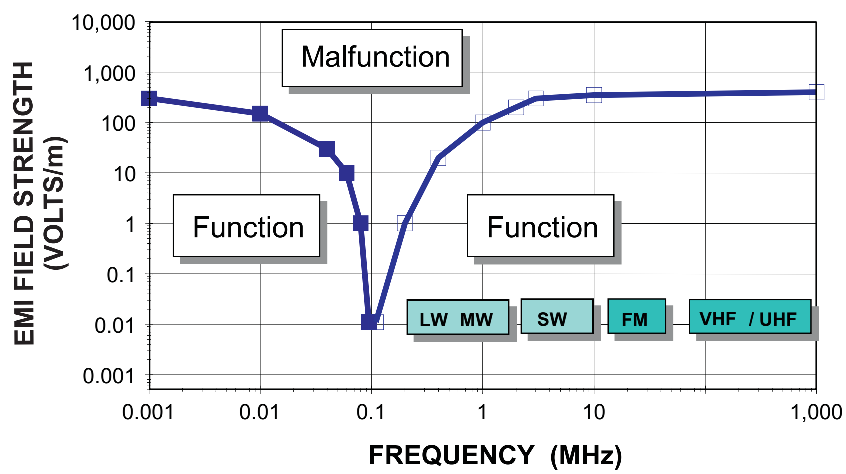


Figure 2-8. System Immunity over a Spectrum of Six Decades

The graph shows the EMI immunity level in V/m as function of the frequency range from 1 kHz to 1000 MHz. Measurement condition: minimum 90% read probability at maximum read range using a standard TI RFID reader.

2.4 Read and Write Principle

This section describes the modulation principle used in the transponder for sending out its telegram (read) and the principle for sending data to the transponder (write or program).

2.4.1 Read

After reading, programming, or locking of a specified page, the transponder sends out its protocol using FSK modulation.

The typical data low-bit frequency is 134.2 kHz, the typical data high-bit frequency is 123.2 kHz. The low and high bits have different durations, because each bit takes 16 RF cycles to transmit. The high bit has a typical duration of 129.2 µs, and the low bit has a typical duration of 119.9 µs. Figure 2-9 shows the FM principle used.

Data encoding is done in non return to zero (NRZ) mode. The clock is derived from the RF carrier by a divide-by-16 function.

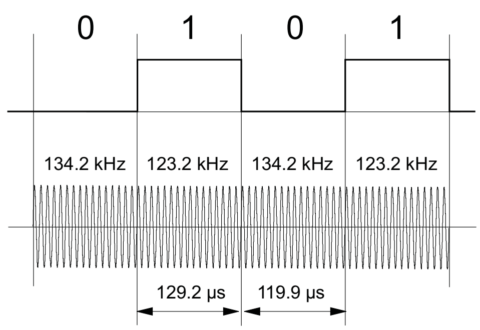


Figure 2-9. FM Principle Used for the Read Function of TI Transponders

2.4.2 Write and Program

The write function is used to transfer commands, addresses, and data to the transponder to activate certain functions. Writing is started after the charge phase (RF transmitter on for 15 to 50 ms using a frequency of 134.2 kHz). Writing is done by switching the RF module's transmitter off and on according to the data bits. The modulation index of this amplitude modulation is 100%.

A write bit has a typical duration of tbit = 2 ms. The duration of the transmitter deactivation (pulse duration) defines whether it is a low bit or a high bit. During a high bit, the transmitter is deactivated for toffH and then activated for tonH. During a low bit, the transmitter is deactivated for toffL and then activated for tonL. Figure 2-10 shows the RF module's transmitter during write and program function.

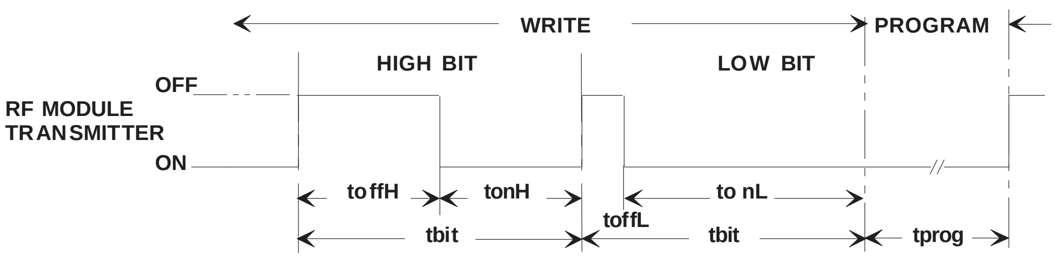
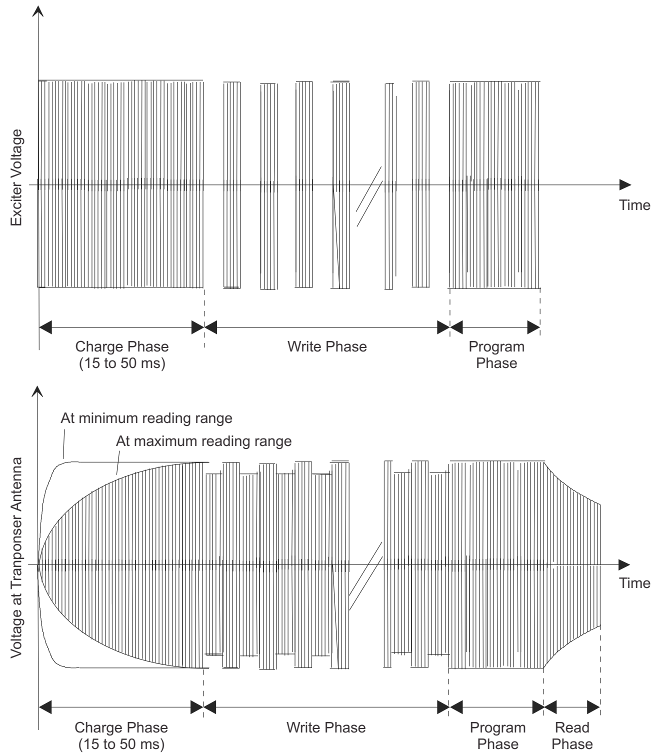


Figure 2-10. Write and Program Function

Figure 2-11 shows the write and programming function by showing the transmitter output signal and the transponder RF input signal.



Charge: Continuous RF module transmitter output signal
Write: Pulse width modulation of the RF module transmitter output signal
Program: Continuous RF module transmitter output signal
Read: Frequency shift keying of the transponder resonant circuit oscillation

Figure 2-11. Charge, Write, and Program Principle, Showing the Voltage at the Exciter (Reader) and Transponder Antenna Coil

2.5 Measurement Setups

This section describes typical measurement setups that can be used to determine transponder relevant data such as the resonant frequency, bandwidth, quality factor, powering field strength, and transponder signal field strength as listed in Section 1.2.

The examples and figures here use a 32-mm glass transponder as a representative device, but the principles are the same for all package types.

2.5.1 Measurement Setup: Resonance Frequency, Bandwidth, Quality Factor of Transponder

This test setup is suitable for resonant frequency (fres) measurements as well as the determination of the 3-dB bandwidth (Δf) of the transponder. The quality factor Q of the transponder resonance circuit can be calculated with Equation 1.

$$Q = f_{res} / \Delta f \quad (1)$$

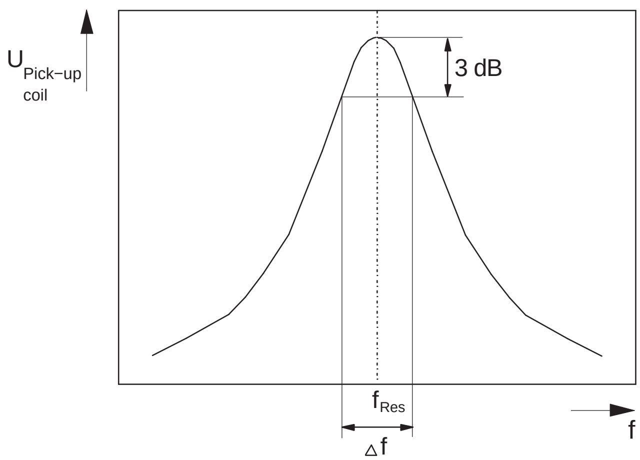


Figure 2-12. Determination of the Resonance Frequency and -3dB Bandwidth by Monitoring the Pick-Up Coil Voltage

The wires of the pick-up coil should be very thin to avoid influence on the measurement results (for example: by damping). The choice of a 1 M. input resistor at the spectrum analyzer is recommended. Figure 2-13 shows the test setup. The relation between pick-up coil voltage and frequency is shown in Figure 2-12.

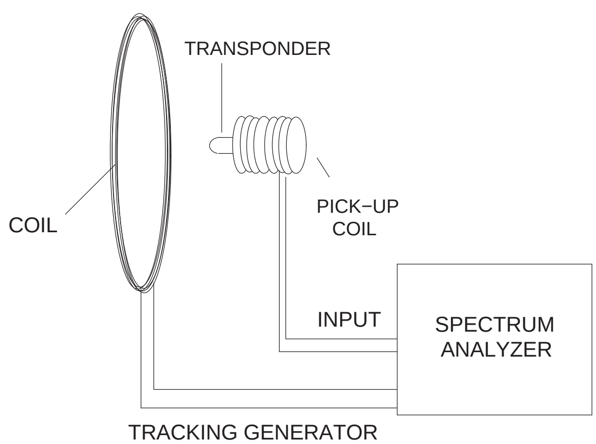


Figure 2-13. Measurement Set-up for the Determination of Transponder Resonance Frequency, Bandwidth, and Quality Factor

2.5.2 Measurement Setup: Powering Field Strength

Figure 2-14 show the setup that is used to determine the minimum required powering field strength.

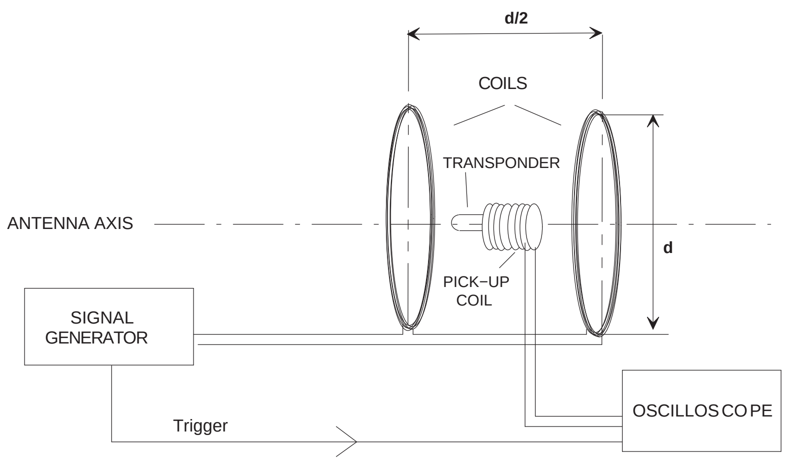


Figure 2-14. Test Set-up for Powering Field Strength Determination

The field between both serial connected coils is homogeneous, due to the fact that the aperture is built according to the Helmholtz setup. The circular coils are positioned in parallel on one axis. The distance between the coils is half of the coil diameter. The transponder is positioned in the middle of the coil axis.

Determination of the minimum powering field strength is possible by changing the field strength through increasing the coil current. The relation between the generated magnetic flux or field strength and coil current can either be measured with a calibrated field probe or calculated as shown in Equation 2.

$$B = \frac{4}{5} \cdot \sqrt{\frac{4}{5}} \cdot \frac{\mu o \cdot \mu r \cdot N \cdot I}{d/2} = \mu 0 \cdot \mu r \cdot H$$

where

- B: magnetic flux (tesla = Wb/m^2)
- H: magnetic field strength (A/m)
- N: Number of Helmholtz coil windings
- d: Coil diameter (m)
- I: Coil current (A)
- µ0: magnetic field constant (Vs/m) = $4\pi \times 10^{-7}$ Vs/Am
- µr: relative magnetic field constant (in air: 1) (2)

The Helmholtz coil can be used for the specification of transponders in the temperature range from -40°C to 85°C. However, Tests show that deviations of the field strength caused by temperature are negligible.

The data telegram of the transponder can be captured by a pick-up coil (for example: 10 windings, thin wire to minimize influence) wrapped around the transponder. The pulse-modulated signal can be adjusted at the signal generator. The measurement of the power pulse and transponder diagram can be done with the help of an oscilloscope triggered by the generator signal (see Figure 2-15). As soon as a data telegram is completely detected, the minimum necessary field strength (calculated with Equation 2) can be monitored.

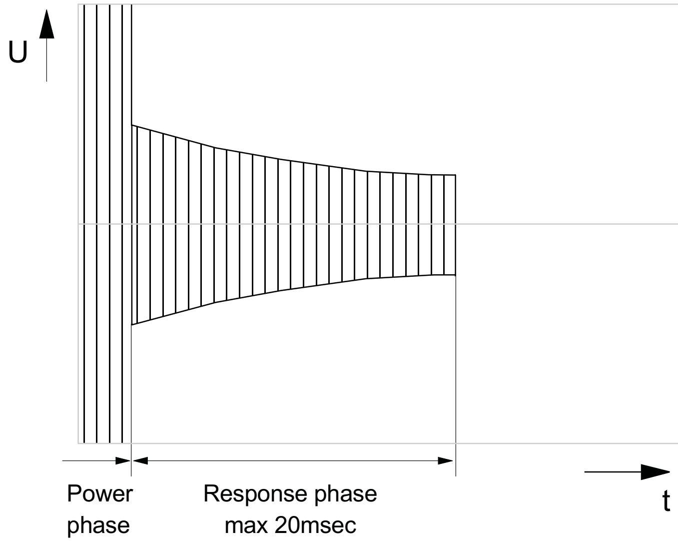


Figure 2-15. Received Signal at the Pick-up Coil, If Power Field Strength is Sufficient

2.5.3 Measurement Setup: Transponder Signal Strength

The transponder must be located in a homogeneous field (Helmholtz coil). The pulsed power signal is generated by a signal generator. A calibrated field strength probe picks up the transponder signal. The field strength can be calculated by using the calibration factor of the field strength probe.

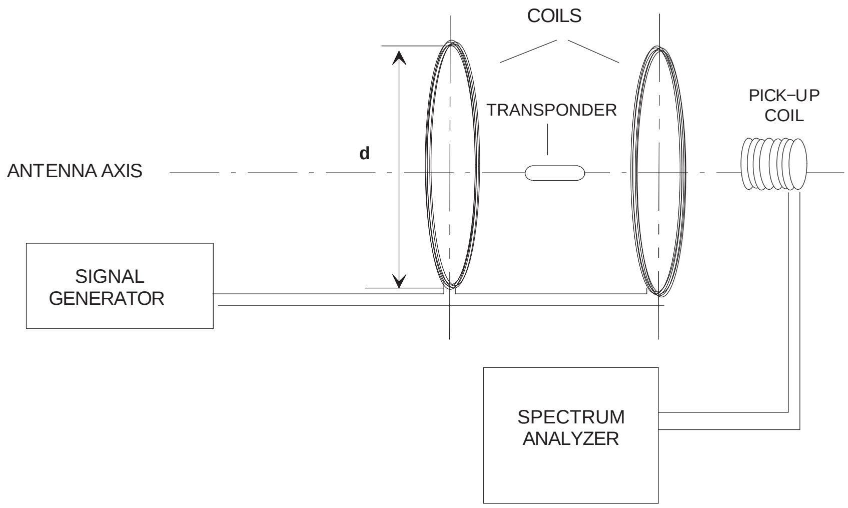


Figure 2-16. Determination of the Transponder Signal Strength (Data Transmission Signal Strength) With Helmholtz Aperture

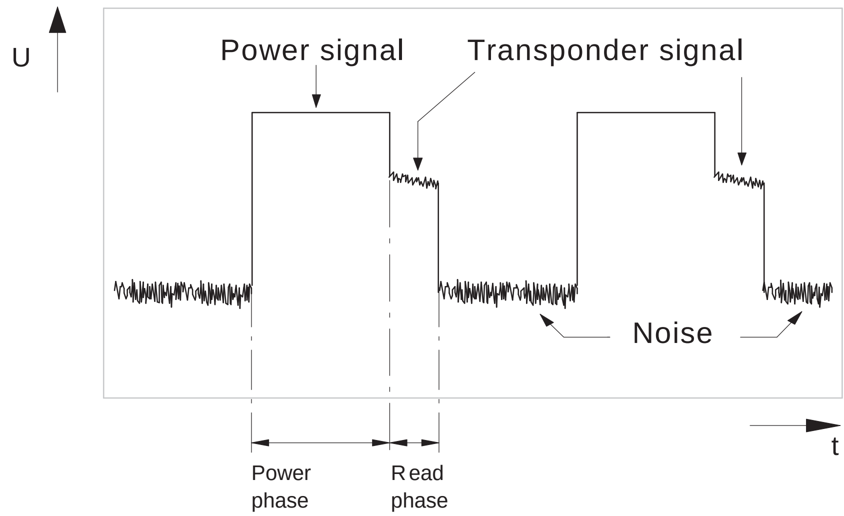


Figure 2-17. Monitored Signal Voltage at the Spectrum Analyser (Time Domain Mode)

2.6 General Product Data

2.6.1 Memory

PARAMETER	DATA
Memory size	1360 bits
Memory organization	17 pages, 80 bits each
Identification data	1088 bits
Error detection (Data BCC)	CRC-CCITT, 16 bit

2.6.2 Data Retention

For the evaluation of programming endurance and data retention time of user programmable multipage transponders, the test sequence shown in Figure 2-18 has been passed.

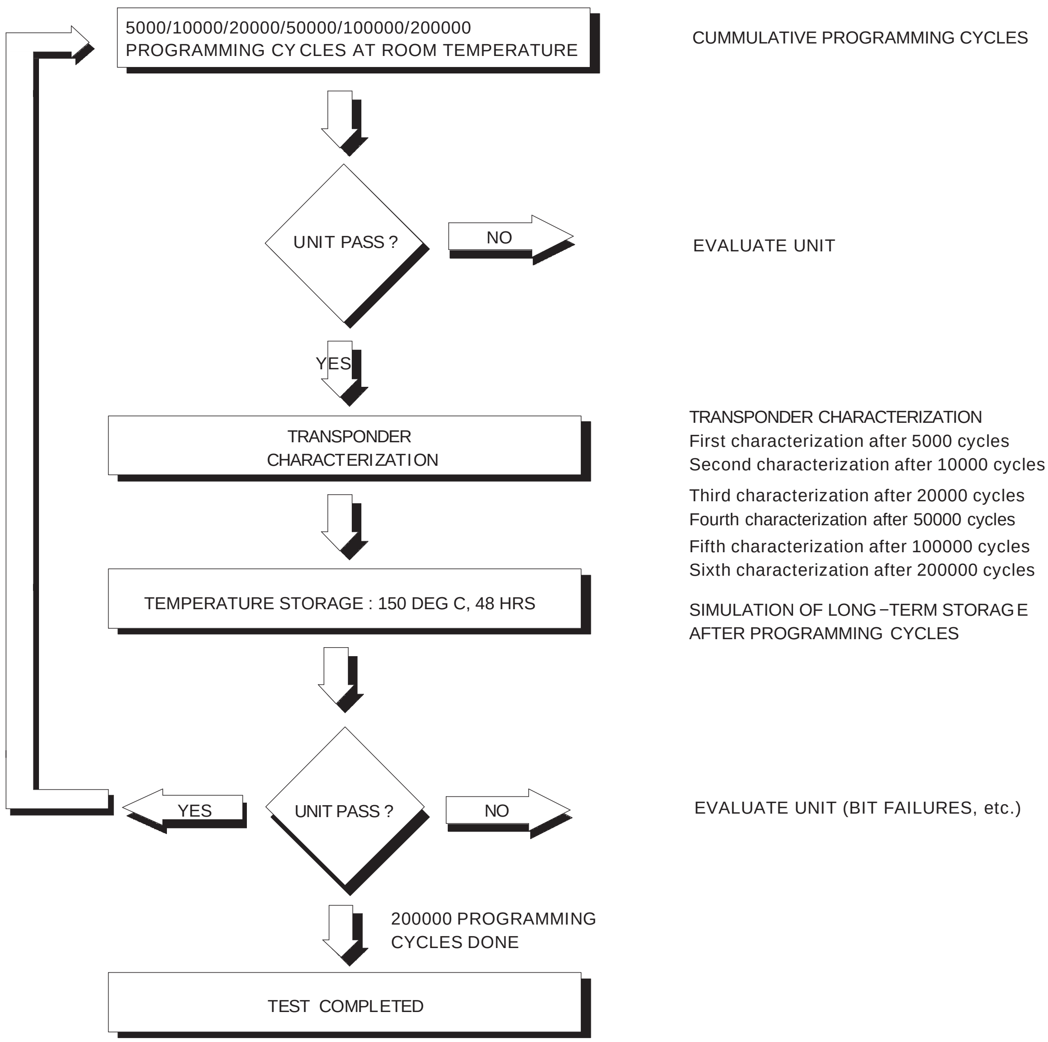


Figure 2-18. Test Sequence

Figure 2-19 shows the equivalent extended data retention time at different ambient temperatures after completion of 100000 programming cycles. Temperature data are derived from measured results at 150°C and 48-hr storage with an acceleration factor of 0.8 eV.

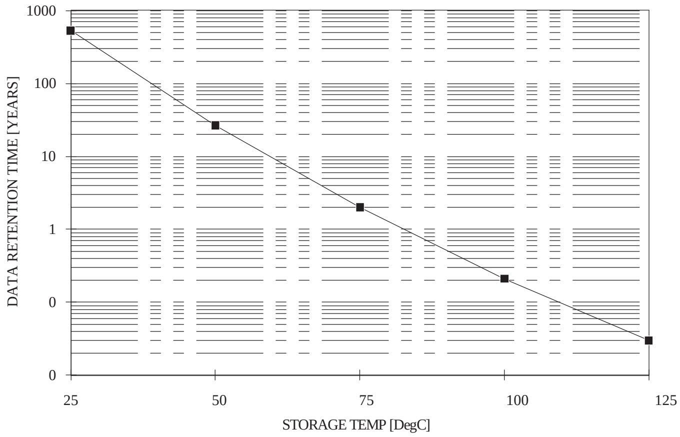


Figure 2-19. Data Retention Time