INTEGRATED CIRCUITS

DATA SHEET

PCF7931XP/C
Programmable Identification Transponder (PIT)

Preliminary device specification

November 1994

Philips Semiconductors

PHILIPS

CONTENTS

1. FEATURES

- Identification Transponder for use in contactless applications
- Programmable read only operation
- Non volatile memory of 1024 bits (768 bits user data, 256 bits control data)
- Periodically data read out during READ MODE
- Data transmission and supply energy via RF link
- Write protection
- 7 byte password
- Operating/resonance frequency 125 kHz nominal
- 20 years non–volatile data retention
- 100 erase/write cycles per byte
- Extended temperature range –40°C to +85°C
- Assembled as plastic stick

2. GENERAL DESCRIPTION

The PCF7931XP/C is a high–specification "Programmable Identification Transponder" (PIT) which transmits data bidirectionally, in half duplex mode, between base station and transponder.

Data are stored in the transponder in a non–volatile memory (EEPROM). The transponder requires no internal power supply; it derives its power from the magnetic component of the RF signal generated by the base station. Data are transmitted by modulating the signal.

PIT has been specially designed for identification purposes where reprogramming of the identification code or storage of additional data is required.

The EEPROM has a memory capacity of 128 bytes and is organized in eight blocks, each having 16 bytes. Capacity is split into six blocks (96 bytes) for programming/reading of user data and into two blocks (32 bytes) for control of the memory access.

The PCF7931XP/C's contactless interface generates the power supply and system clock from the resonant circuit by inductive coupling to the base station. The interface also demodulates data that are transmitted from the base station to the PIT, and modulates the electromagnetic field for data transmission from PIT to station.

When the PIT enters an RF field the contactless interface generates a reset and then goes into READ MODE. In this mode the PIT cyclically transmits all data blocks to the base station.

Modulation and coding of data in READ MODE (PIT to base station) is carried out by Amplitude Key Shifting with Diphase Coding. As a result of the inductive coupling between the circuit and base station antenna, the current in the antenna is also modulated, resulting in low–level amplitude modulation.

3. BASIC CHARACTERISTICS

PARAMETER	VALUE	UNIT
Carrier frequency (nominal)	125	kHz
Magnetic flux density – read – program	 25 170	 μWb/m^2 (min.) μWb/m^2 (typ.)
Data transmission mode	half–duplex	
Transfer rate – read – program	 1.95 0.98	 kbit/s kbit/s
Memory size	128	byte
Memory organization	8 blocks	each 16 byte
Package dimensions	3 x 6 x 12	mm
Coding – read – program	 CDP (conditioned diphase) PPM (pulse position modulation)	
Modulation	ASK (amplitude shift keying)	
Weight	0.427	g

Electro magnetic susceptibility	according to DIN 40839, part 4
Special features	– 7 byte password – blockwise write protection – user defined irreversible write protection

4. ORDERING INFORMATION

EXTENDED TYPE NUMBER	IC VERSION	PACKAGE	DRAWING	TEMPERATURE RANGE (°C)
PCF7931XP/C	V0	stick	see Figure 7	–40 to +85

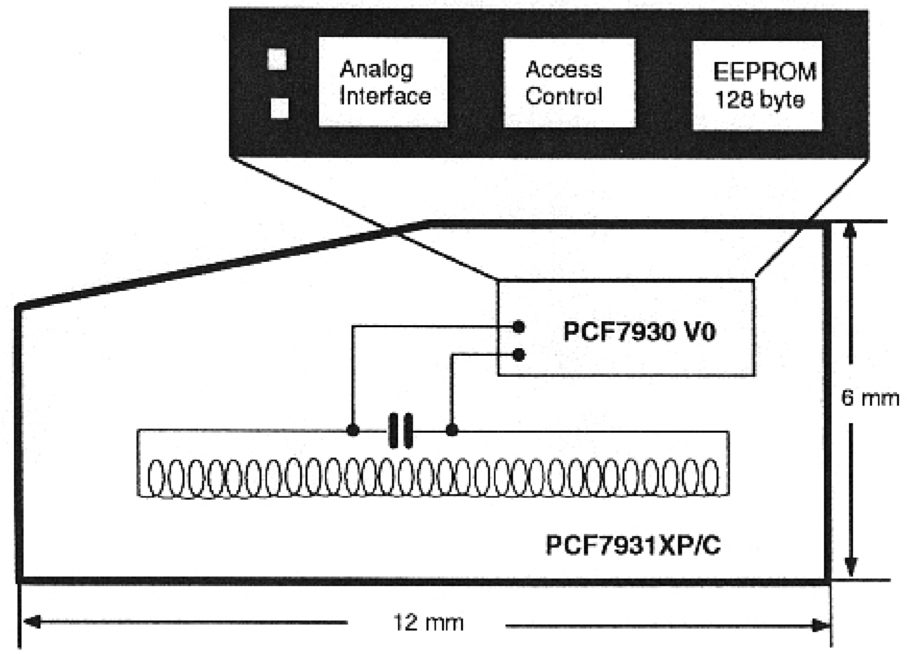


Fig. 1 Blockdiagram transponder

5. MODULE (STICK)

5.1. General Functional Description

The "Programmable Identification Transponder" (PIT) allows the contactless reading and programming of data into a memory. Data are transmitted bidirectionally in half duplex mode between basestation and the PIT. Data are stored in a non volatile memory (EEPROM). The PIT does not require any additional external power supply. It derives its power supply from the magnetic component of the RF–radiation which is generated by the basestation. Data are transmitted by modulating the RF–radiation.

The PIT has especially been designed for identification purposes where reprogramming of the identification code or storage of additional information is required. A block diagram of the system is given in Figure 2.

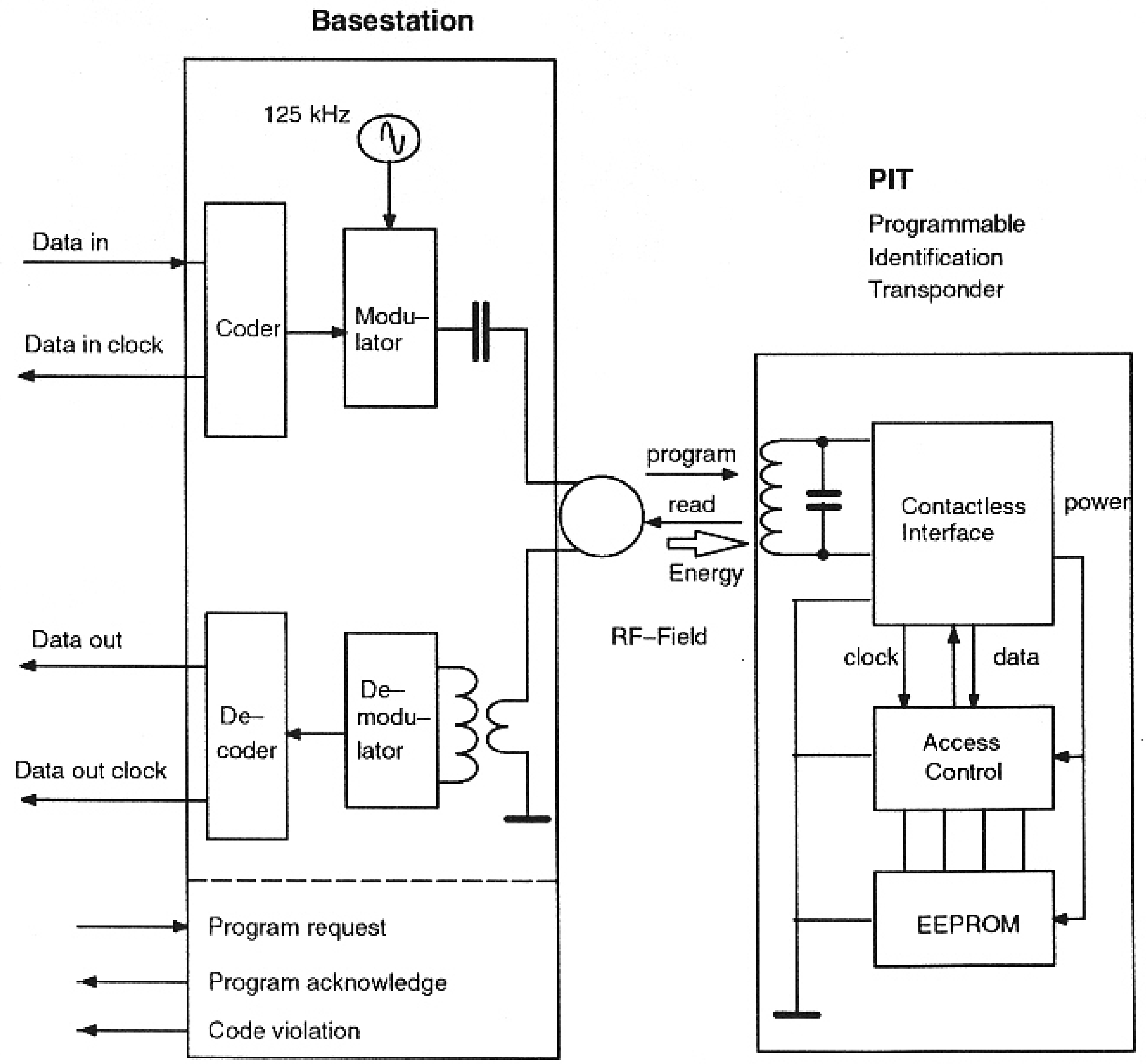


Fig. 2 Transponder System Configuration.

The PIT consists of a coil, a capacitor and the IC. On the IC the following functions are integrated:

- EEPROM: 128 byte non volatile memory
  (96 byte user, 32 byte control)
- CIF (contactless interface): power supply, clock recovery, data handling.

The basestation generates a RF–field with a frequency of nominal 125 kHz. The PIT is synchronized on this "system clock".

The two operating modes of the PIT are READ MODE and PROGRAM MODE. The PIT is switched between these two modes under control of the basestation.

The READ MODE is entered, when the PIT senses a field with sufficient magnetic strength. Then the PIT transmits cyclically repeating the content of the EEPROM to the basestation.

To enter the PROGRAM MODE, a programming pulse must be given from the basestation. Then data can be written bytewise or blockwise (16 bytes) into the EEPROM. If the PIT detects improper signal conditions during PROGRAM MODE, it returns immediately back to READ MODE. This avoids unintentional destruction of stored information.

The sequence of reading can be interrupted by a "soft reset". With this "soft reset" the PIT can be forced to send data starting as if newly brought into the RF–field.

When returning from PROGRAM MODE back to READ MODE, a "read after write" procedure is initiated by default. Instead, a "soft reset" or the continuation of pro– gramming may be initiated from the basestation.

Several bytes of the memory are reserved for data protection and for memory access control. To prevent malicious or un– intentional modification of stored information, password and block write protections can be set. If desired, the user can handle the protection bits so that some information is unalterable forever.

The user can store/alter the address range in the PIT for access control, so that only relevant information is read out. Furthermore, a "Sync–pattern" can be stored which clearly allows to identify the block number when data are read out of the PIT (the PIT does not provide the block number explicitly).

5.2. Limiting values

All values are in accordance with the Absolute Maximum Rating System (IEC 134).

PARAMETER	MIN.	MAX.	UNIT
Operating temperature range	–40	85	°C
Storage temperature range	–55	125	°C
Magnetic flux density (resistivity against magnetic pulses)		0.2	Wb/m^2
Vibration – 20 – 2000 Hz – 3–axis – IEC 68–2–6, Test Fc		20	g
Shock – 3–axis – IEC 68–2–27, Test Ea		1500	g

5.3. Electrical Characteristics

SYMBOL	PARAMETER	CONDITION	TEMPERATURE	MIN.	MAX.	UNIT
f_{RES}	Operating/resonance frequency	Measured contactless (1) transponder inactive	T_{amb} = –40°C ... +85°C	121.9	128.1	kHz
B_W	Bandwidth	Measured contactless (2) transponder inactive	T_{amb} = –40°C ... +85°C	2.3		kHz
B_{THR}	Magnetic field Strength Threshold in Read Mode	$f_{CARRIER}$ = 125 kHz	T_{amb} = –40°C ... +85°C	25		$\mu Wb/m^2$
B_{READ}	Field Absorption in Read Mode	$f_{CARRIER}$ = 125 kHz B_{FIELD} = 100 $\mu Wb/m^2$	T_{amb} = –40°C ... +85°C	4		$\mu Wb/m^2$
MI_{PRG}	Modulation Index in Program Mode	$f_{CARRIER}$ = 125 kHz B_{FIELD} = 170 $\mu Wb/m^2$ Damping Value preset to 200	T_{amb} = +17°C... +27°C	95		%
t_{RESET}	Reset time				20	ms

SYMBOL	PARAMETER	CONDITION	MIN.	MAX.	UNIT
$N_{E/W}$	ERASE/WRITE cycles per byte	T_A = +22 to +70°C	100		
t_S	Data retention time	T_A = +22°C	20		years

NOTES

1. Measured contactless with network analyzer HP 4194A using 150mV amplitude
2. Measured contactless with network analyzer HP 4194A using 150mV amplitude (45°C phase criterion)

f_{RES}	Resonant Frequency
f_{CARIER}	Frequency of the carrier field supplied
B_{FIELD}	Field strength of the carrier field supplied
B_{THR}	Threshold of the field strength for activation of read mode
B_{READ}	Field absorption in read mode
MI_{PRG}	Modulation index of the field applied in program mode
Reset time	Start of modulation after the field is applied
T_A	Ambient temperature

5.4. READ MODE

Measuring setup

Figure 3 is showing the testing set–up for measuring the threshold and the field absorption of the transponder.
In Figure 4 the dimensioning of the coil parameters is given.

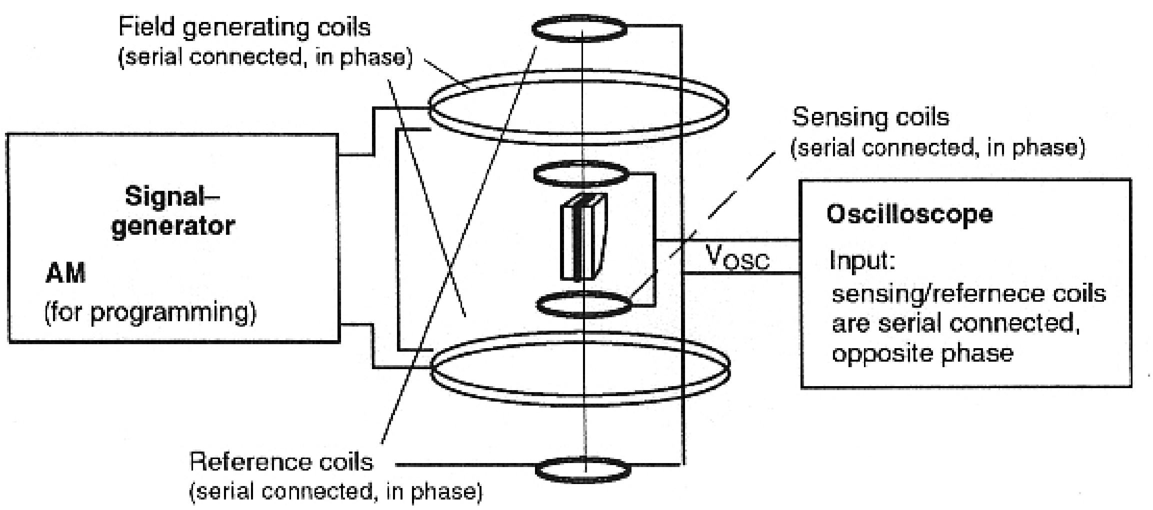


Fig. 3 General testing set–up

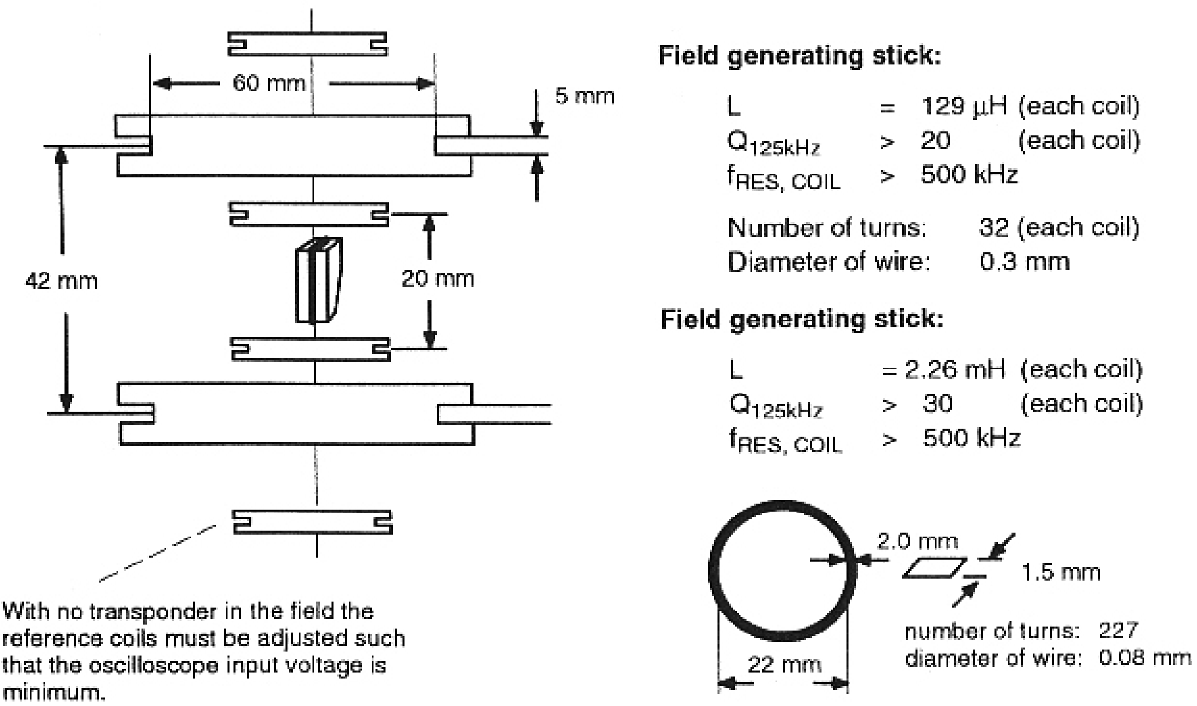


Fig. 4 Coil parameters

The magnetic flux density has to be adjusted (without transponder) by measuring the voltage over both (serial connected) sensing coils.

The voltage induced into the two serial connected sensing coils is proportional to the magnetic flux:

1V_{PP} is equivalent to 8.9 μWb/m²

The transponder has to be placed in the center of the Helmholtz arrangement. The transponder starts modulating the magnetic field.

Two different values of the magnetic flux density B will be applied to the transponder in order to verify the following physical characteristics:

Minimum power B_{THR}

Modulation of the transponder at a minimum value of B, ensuring that the threshold of minimum required energy for operating the transponder is surpassed.

Minimum modulation depth B_{READ}

Modulation of the transponder at the typical value of B, ensuring that the the transponder modulation is in saturation. The minimum value of absorption of the transponder at this value of B is given in Section 5.3.

The difference of the voltages between sensing coils and reference coils ($V_{sense} - V_{reference}$) is proportional to the mag– netic flux density absorbed by the transponder. The pro– portional factor is as given above (8.9 μWb/m²/V_{PP}). The oscillogram is given in Figure 5.

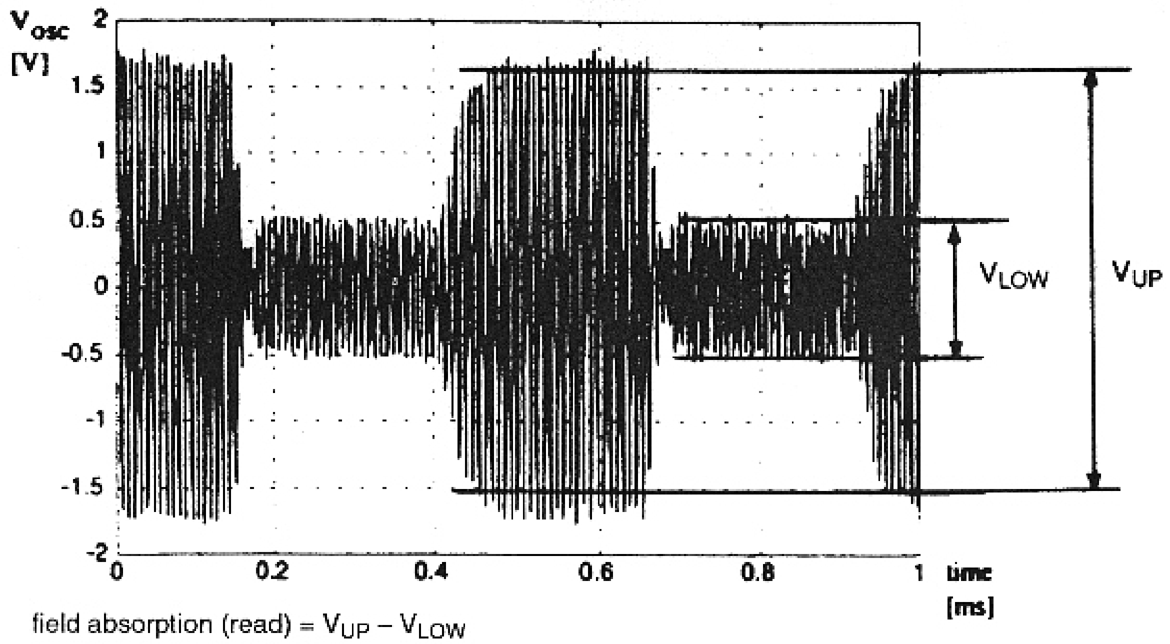


Fig. 5 Modulation caused by transponder

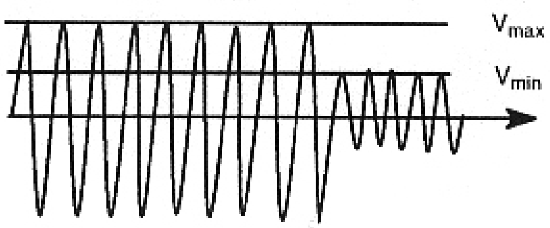
5.5. PROGRAM MODE

The modulation index for programming the transponder is measured using the set–up described in chapter 5.4. The reference coils are not needed.

The magnetic flux density and the modulation index of the AM signal generator has to be adjusted according to the values given in Section 5.3. The definition of the modulation index is given in Figure 6.

The transponder has to be placed in the middle of the Helmholtz arrangement. Programming is successful over the specified temperature range.

On delivery the transponder memory is cleared, i.e. all bytes of all memory blocks are set to 00H (subject for future alteration!).



Modulation index MI_{PRG} is given by:

$$MI_{PRG} = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$$

Fig. 6 Definition of modulation index

5.6. Mechanical Characteristic

The transponder is sealed in epoxy resin moulding compound (Sumikon EME6210, Sumitomo). The outline of the package is given in Figure 7.

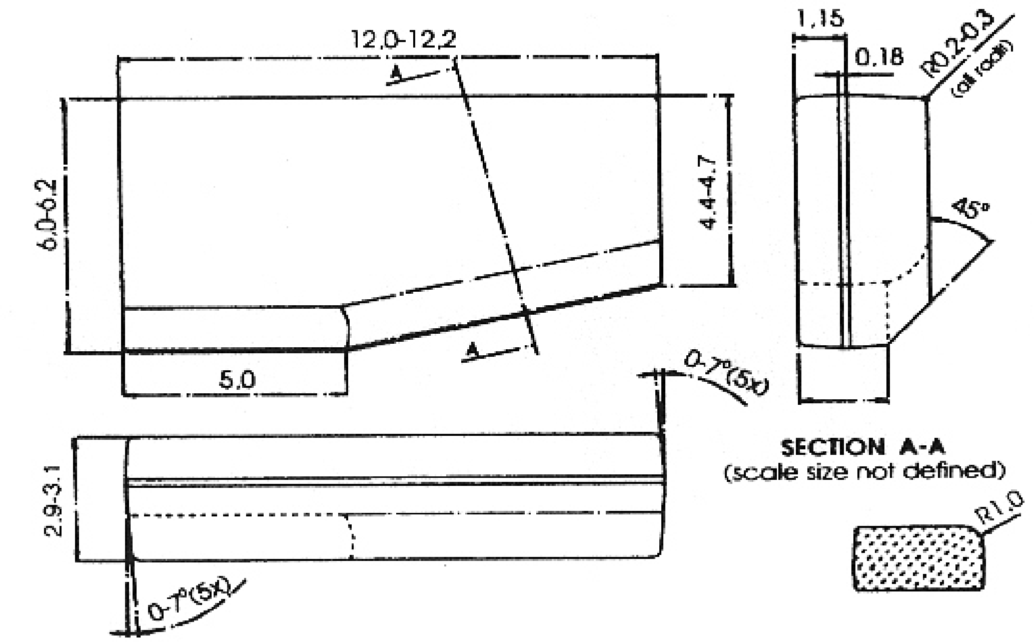


Fig. 7 Package outlines

6. FUNCTIONAL DESCRIPTION OF THE IC

6.1. Memory organization and access

The EEPROM provides a memory capacity of 128 bytes. It is organized in 8 blocks, each block consisting of 16 bytes. This capacity is split into 6 blocks (=96 bytes) for programming/reading of user data and into 2 blocks (=32 bytes) for the control of the memory access. The memory organization is given in Figures 8 and 9.

The access to the memory depends on the mode of operation: PROGRAM MODE or READ MODE. If the PIT is in PROGRAM MODE, data can be programmed bytewise or blockwise with auto increment. During READ MODE the EEPROM is cyclically read out.

Block 0 and block 1 store information for access control. The intention of these blocks is to provide some flexibility for different applications in terms of data security and access to relevant information. The following access procedures can be performed.

Password/PAC: The password is 56 bits long. If the pass–word check is enabled (PAC=1), data sent to the PIT are checked for correctness of the password. In case of failure, programming is inhibited and the PIT returns to READ MODE. In READ MODE the password is superseded by 0. If the password check is disabled (PAC=0), the password is readable (not superseded).

Protection: Each block (excluding block 1) of the user data can be protected separately against programming by setting the block write protection (BWP=1). This implies, that if block 0 is write protected, the bits of this block can never be changed. The special effect of this protection is, that information stored in any write protected block can never be altered. It is frozen. With this feature the user memory is split into changeable and unchangeable address ranges.
Block 1 is excluded from write protection.

Sync–pattern: In these 8 bytes any kind of data can be stored. The purpose of this feature is, that if RB1 is enabled, the Sync–pattern is always the first information that is transmitted from the PIT to the basestation. Therefore the Sync–pattern should be programmed with a pattern, which allows the basestation to detect the blockposition unambiguously.

Selection: First and last block to be transmitted from PIT to the basestation are given by RFB and RLB. Starting with RFB the last block will be reached by modulo counting. So the value of RFB may be higher than that one of RLB. In this case the PIT wraps around from block 7 to block 0. In case when block 1 is enabled (RB1=1), block 1 is always sent before RFB.

All information sent to or received from the PIT (addresses and data) is transmitted with the lowest bitposition first.

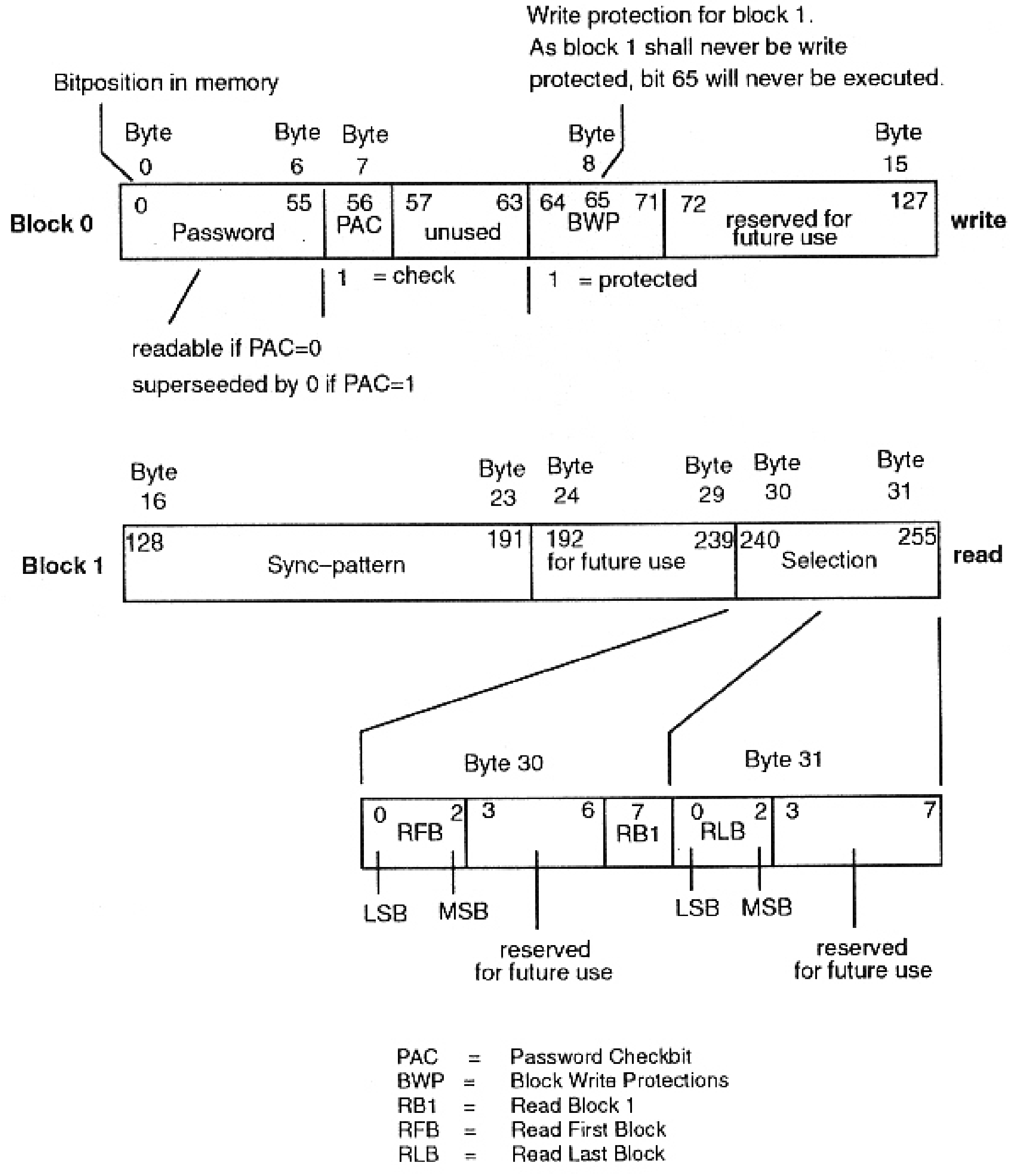


Fig. 8 Memory Organization: Memory Access Control, 32 Bytes

	Byte 32	Byte 47
Block 2	256	383
	Byte 48	Byte 63
Block 3	384	511
	Byte 64	Byte 79
Block 4	512	639
	Byte 80	Byte 95
Block 5	640	767
	Byte 96	Byte 111
Block 6	768	895
	Byte 112	Byte 127
Block 7	896	1023

Fig. 9 Memory Organization: User Memory, 96 Bytes

6.2. Contactless Interface

The Contactless Interface (CIF) generates power supply and system clock from the received signal in the resonance circuit. The interface further demodulates data that are transmitted from the basestation to the PIT and modulates the electromagnetic field for data transmission from the PIT to the basestation. In detail the CIF provides the following functions:

Supply voltage: A bridge rectifier together with a voltage stabilizer provides a constant supply voltage for the IC.

Reset: When the supply voltage is below a threshold voltage, a reset signal forces the IC into initial conditions. Immediately after reset the PIT goes into READ MODE.

System clock: The CIF recovers the system clock from the RF–field as given from the basestation. The IC works correctly with frequencies in the range from 60 kHz to 150 kHz.

Modulation/Coding: The communication between base–station and PIT operates half duplex. In both directions (PROGRAM MODE, READ MODE) different modulating/ coding techniques are used. In PROGRAM MODE the CIF is able to detect transmission errors. Modulator/Coder and Demodulator/ Decoder are part of the CIF.

Logic: Sequential/Combinatorial logic for programming/ reading and the evaluation of password, protection, selection and PROGRAM MODE CHECK.

6.3. Data Transmission from PIT to basestation (READ MODE).

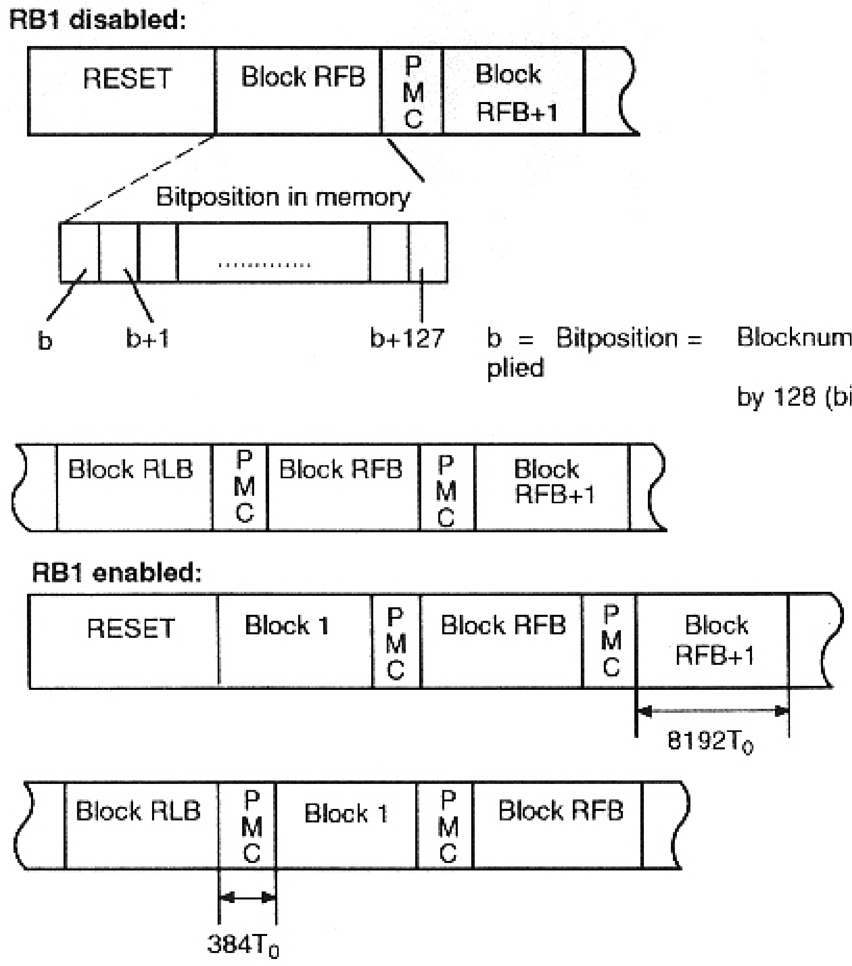
When the PIT enters a RF–field with sufficient strength, the CIF generates a reset and then goes into READ MODE. In this mode the PIT cyclically repeating transmits the contents of internal memory between RFB and RLB to the basestation. If RB1 is enabled, block1 is always sent before each occurrence of block RFB.

Modulation and coding of data in READ MODE is done by Amplitude Shift Keying with Diphase Coding (ASK–CDP). The ASK is realized by alternatingly clipping the voltage of the resonance circuit to two different levels. These levels are switched according to the value of the CDP coded data stream. The switching of clipping levels modulates the voltage of the resonance circuit. Due to the inductive coupling between resonance circuit and the antenna of the basestation, the current in the antenna is also modulated, resulting in a binary level amplitude modulation.

In order to unambigously detect the beginning of a sequence transmitted from the PIT to the basestation, the first transmitted CDP coded databit always starts with the lower clipping level.

Figure 10 shows the block sequence in READ MODE.

Figure 11 shows the coding of the data sent to the basestation.

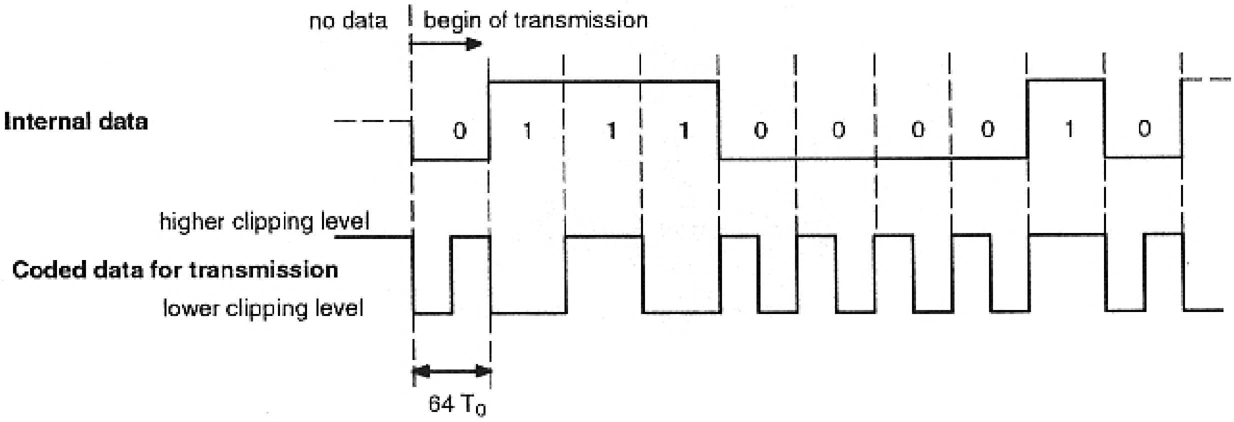


Note: T_0 = Carrier Period Time (1/125 kHz nominal)

PMC = PROGRAM MODE CHECK
all PMCs without programming pulse from basestation (READ MODE)

Fig. 10 READ MODE

Data	Coded
1	Change of state after full bitframe read (64 T_0)
0	Two changes of state after half bitframe read (32 T_0) each.



Note: First bit of a block always starts with lower clipping level
T_0 = Carrier Period Time ($^1/_{125}$ kHz nominal)

Fig. 11 CDP coded signal

6.4. Switching between read and program (PROGRAM MODE CHECK).

Between all blocks transmitted from the PIT to the basestation, a short time interval with no data transfer occurs, before the transmission of the next block is started. During this interval the PIT can be switched into PROGRAM MODE. Therefore this interval is named PROGRAM MODE CHECK.

The basestation recognizes the PROGRAM MODE CHECK by a special pattern sent from the PIT.

The PROGRAM MODE is entered/held when the base-station sends a pulse of $3T_0$ during PROGRAM MODE CHECK and when there is sufficient field strength (power check). The PIT leaves the PROGRAM MODE, when no pulse or a pulse of $6T_0$ ("soft reset") is given. When no pulse is given, the PIT first sends the last programmed block (read after write) followed by a PROGRAM MODE CHECK and continues then as after reset.

In case of "read after write" that block is transmitted in which the latest programming took place. This is also valid if the last programmed block is not in the range specified by RFB and RLB. The PIT then continues as after reset. Figure 12 shows the timing of the PROGRAM MODE CHECK.

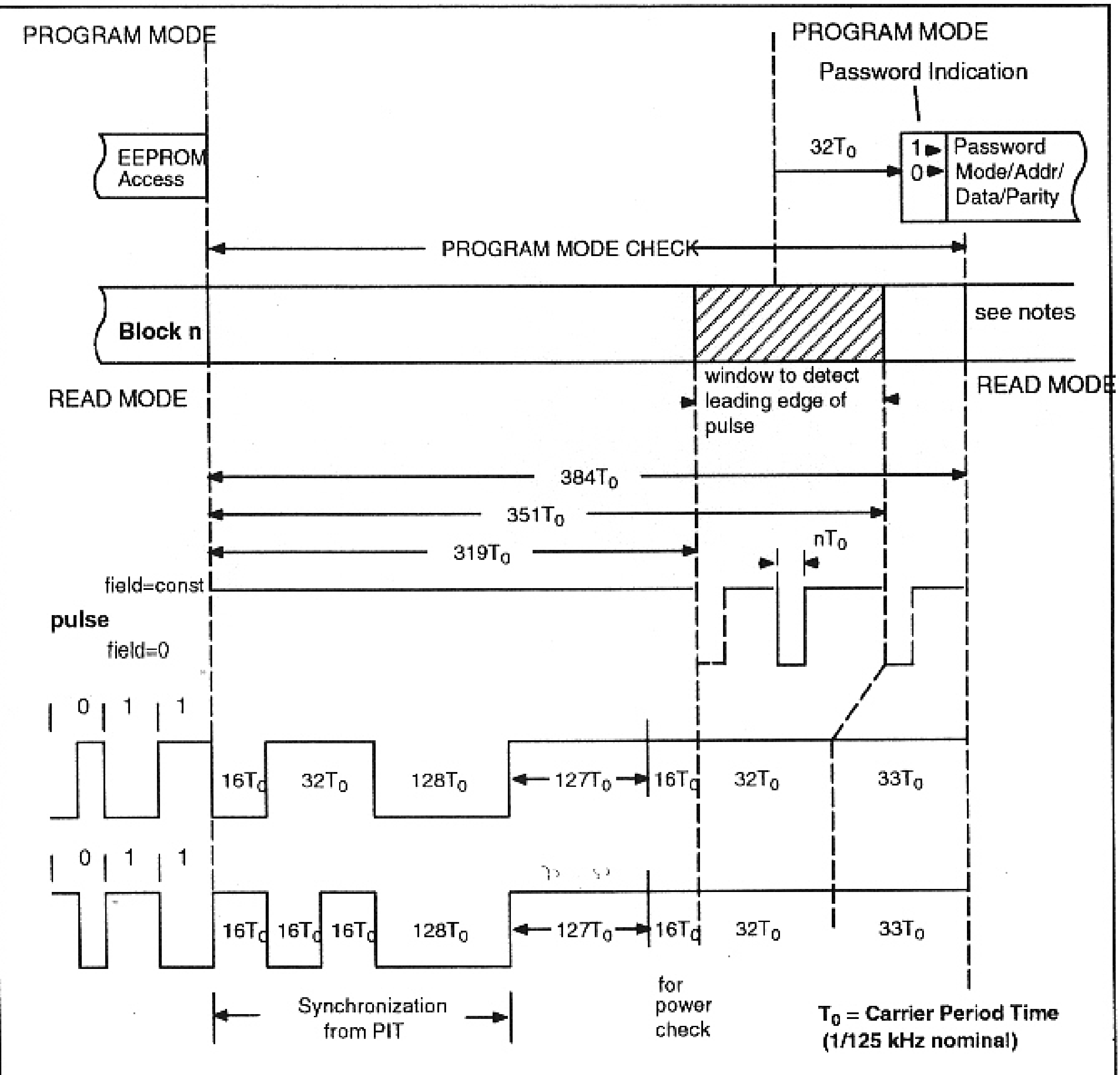


Fig. 12 Timing Conditions of PROGRAM MODE CHECK

NOTES TO FIGURE 12:

	To READ MODE	To PROGRAM MODE
From READ MODE	if n=0: block n+1 if n=6: Soft–Reset	n=3
From PROGRAM MODE	if n=0: Last programmed block followed by PMC of which n=0 is handled as n=6 if n=6: Soft–Reset	n=3

Soft–Reset: PIT starts as if newly put into RF–field

6.5. Data transmission from basestation to PIT (PROGRAM MODE)

After the PROGRAM MODE CHECK the PIT expects a password indication bit, signaling whether the basestation will send the password (=1) or not (=0). The PIT checks this bit against the PAC bit stored in block 0.Two possible conflicts might occur. They are resolved as follows:

PAC = 1 and password indication = 0
—> PIT returns immediately into READ MODE

PAC = 0 and password indication = 1
—> PIT ignores password and programs (read after write) data that are received after the password

Password indication and (if indicated) password are sent only once, when the PIT is switched from READ MODE to PROGRAM MODE. Fig. 13 and Fig. 14 show the transmission protocols for bytewise and blockwise programming, respectively. The password is followed by the MODE bit, block address, byte address, the data byte and a parity bit. The MODE bit indicates whether bytewise (=0) or blockwise mode (=1) is applied. With bytewise programming each byte of the memory can directly by accessed.
With blockwise programming only the blockaddress is given and the byteaddress is internally incremented. The parity bit (parity even) completes all bits from MODE bit on to an even number of 1's.

For finally storing the data into the EEPROM, a time of about 5ms (at carrier frequency of 125 kHz) is needed (EEPROM access). During this time the basestation is checking for CDP coded modulation from the transponder. If no modulation is detected, proper programming of the PIT can be assumed. If the basestation detects modulation, the PIT has quit the PROGRAM MODE caused by faulty operating conditions.

The PIT quits the PROGRAM MODE of a byte under the following conditions:

- the power supply for programming is too low
- PAC=1 and password indication =0
- wrong password
- wrong parity bit
- attempt to write to a write–protected block
- detection of transmission error
  e.g. pulse position or pulse width incorrect

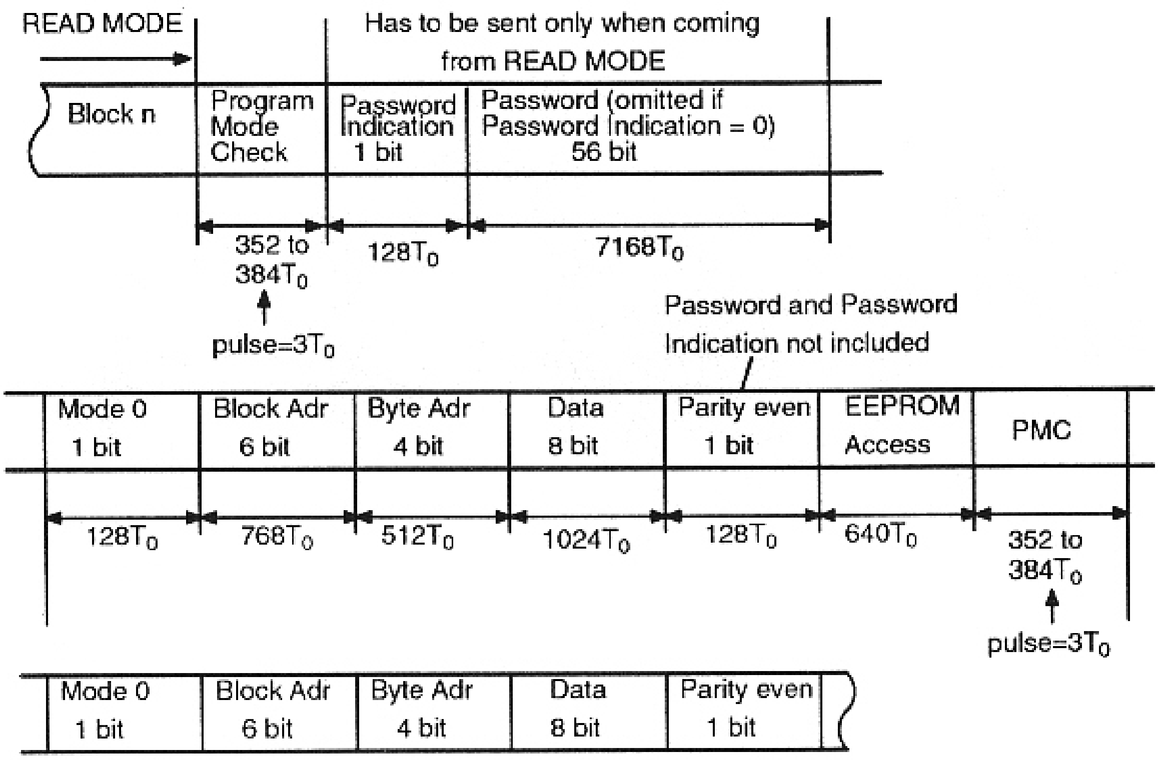
In each of these cases the PIT returns to READ MODE, starting with the block as after reset.

Each bit of the password or address/data field is transmitted using pulse position modulation by reducing the amplitude of the field strength.

The PIT is not synchronized by the databit–pulses. It just counts periods of the carrier frequency from PMC onwards.

Attention: See also chapter 8. "anomaly notes", note 2.

Program: Bytewise (MODE 0)



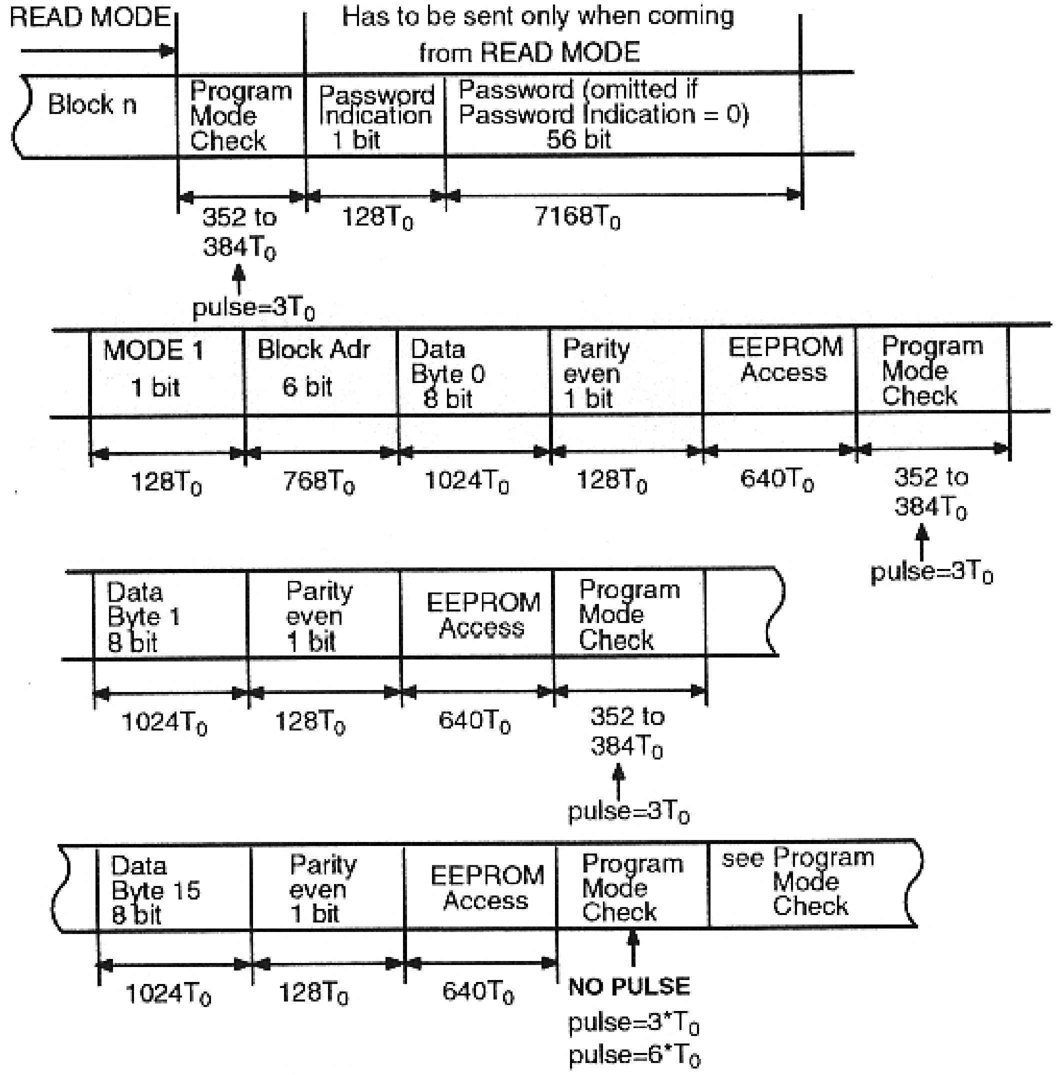
PMC = Program Mode Check

T_0 = Carrier Period Time ($^1/_{125}$ kHz nominal)

SEE ALSO NOTES TO FIGURE 12

Fig. 13 PROGRAM MODE, bytewise

Program: Blockwise (16Byte, MODE 1)



T_0 = Carrier Period Time ($^1/_{125}$ kHz nominal)

SEE ALSO NOTES TO FIGURE 12 AND CHAPTER 8., "ANOMALY NOTES", NOTE 2

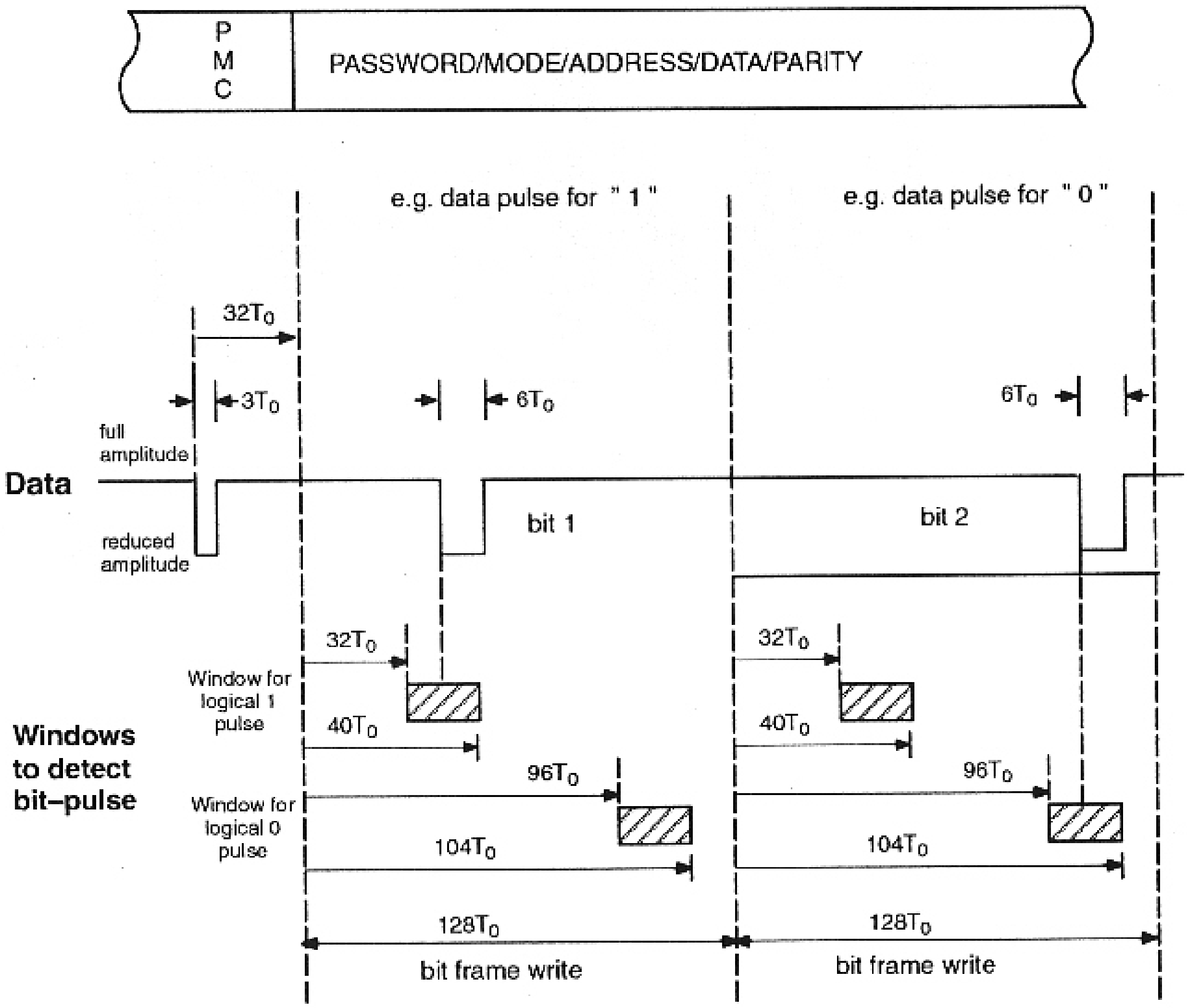
Fig. 14 PROGRAM MODE, blockwise

NOTES TO FIGURES 13, 14:

Bytewise and Blockwise programming can arbitrarily be appended without going in between into READ MODE.

1. If the PIT expects a password (PAC=1) and Password Indication = 0
   —> PIT goes immediately into READ MODE
2. If the PIT expects no password (PAC=0) and Password Indication = 1
   —> PIT ignores password and programs data that are received after the password
3. In case of faulty conditions during PROGRAM MODE —> PIT goes immediately into READ MODE and starts as after reset
4. Blockwise programming can be stopped before the last byte of the block is reached by either sending no pulse or a "soft reset" pulse during PMC
   —> PIT goes into READ MODE as defined by PROGRAM_MODE_CHECK (see Figure 12)

The transmission time of a bit is 128 clock cycles of the carrier frequency. The logical value of the data bits are defined by the time window during which they occur. The falling edge of the pulse must be within this window. The pulselength must be $6T_0$. If pulses are detected outside these windows or if more than one pulse occurs within one bit frame, the PIT switches to READ MODE.



T_0 = Carrier Period Time ($^{1}/_{125}$ kHz nominal)

Fig. 15 Transmission of databits (PROGRAM MODE)

7. STRUCTURE OF CIRCUIT

The functional diagram of the PIT is shown by figure 17. The IC has the following functional units:

- Rectifier
- Voltage clamp
- CDP data clamp
- Clock generator
- Demodulator
- Control logic + EEPROM
- Damping circuitry
- Charge pump
- Power–on reset

Rectifier

The incoming signal received on coil A and coil B is symmetrically rectified by a bridge rectifier and flattened by a load capacitor.

Voltage clamp circuit

The clamp has to serve two purposes:

- Overvoltage protection
- Supply voltage regulation

CDP data clamp

The clamp has to serve:

- Modulation of the output data onto the RF amplitude.

Clock generator

The clock for the operation of the full control logic is derived from the incoming RF signal by amplification.

Demodulator

The demodulator detects the incoming signal in the modulated and non modulated case, respectively and synchronizes it to the system clock.

Control logic + EEPROM

The control logic handles the transmission protocol and controls the EEPROM–access.

Damping circuit

When the PIT is in PROGRAM MODE an additional damping becomes active.

The damping value is programmed during manufacturing. In most cases the value of D200 is appropriate, it is set by default.

Charge pump

The charge pump generates the programming voltage for the EEPROM cells.

Power–on reset

The Power–on reset generates an internal Power–on clear signal (POC), if the voltage between coil A and coil B is in a low range below V_{POR} (see figure 16). Increasing the voltage causes release of the circuit and starts an initialization phase with reset of the registers before entering the READ MODE.

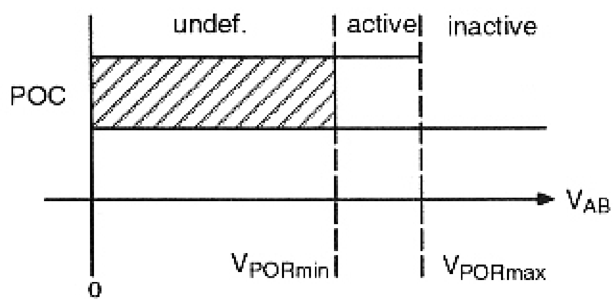


Fig. 16 **Power–on clear signal**

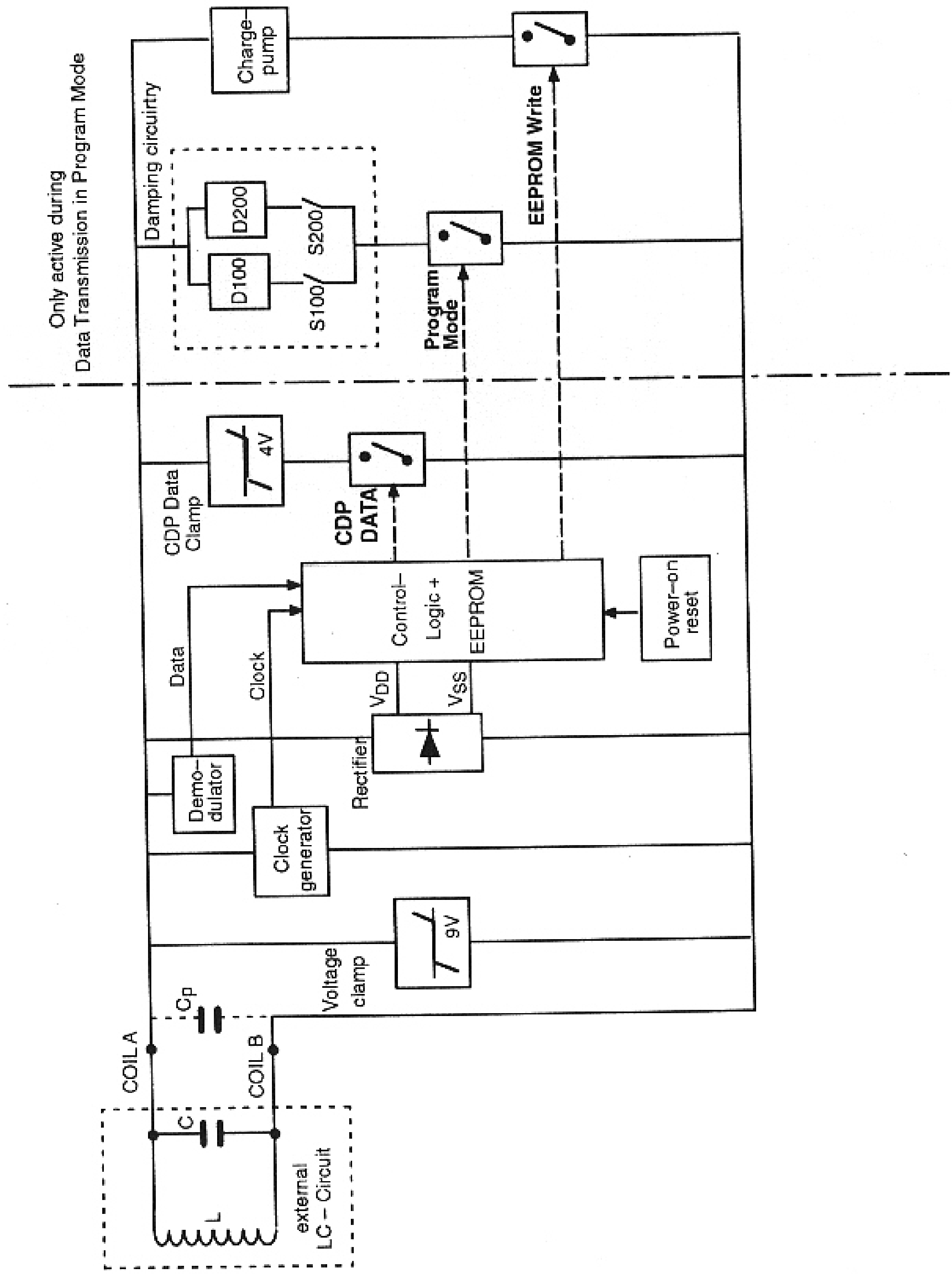


Fig. 17 Functional Diagram

8. ANOMALY NOTES (VERSION V0)

Note 1 Programming of the PCF7931XP/C is only possible in the temperature range T = +22°C ... +85°C.

Note 2 If a sequence of bytes is written into the PIT memory in blockwise mode, a byte address offset may be added to the correct start address in two cases:

A) using password transmission the address offset results in seven bytes.

B) immediately after a bytewise programming the resulting address offset results in the byte address + one.

This is due to a missing reset of the write position after the password (A) / byte (B) being transmitted.

A blockwise programming of data should always be preceded by a read operation. Having switched to program mode the data block can be programmed correctly and can then be followed by any bytewise program operations.

9. DEFINITIONS

Data sheet status	
Objective specification	This data contains target or goal specifications for product development.
Preliminary specification	This data sheet contains preliminary data; supplementary data may be published later.
Product specification	This data sheet contains final product specifications.
Limiting values	
Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of this specification is not implied. Exposure to limiting values for extended periods may affect device reliability.	
Application information	
Where application information is given, it is advisory and does not form part of the specification.	

10. LIFE SUPPORT APPLICATIONS

These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Philips customers using or selling these products for use in such applications do so on their own risk and agree to fully indemnify Philips for any damages resulting from such improper use or sale.

INTEGRATED CIRCUITS

DATA SHEET

ADDENDUM

PCF 7931XP/030612
PCF 7931XP/C
PCF 7930XP/030612
Programmable Identification Transponder (PIT)

Addendum to Specification

November 1994

Philips Semiconductors

PHILIPS

1. ADDENDUM

This Addendum applies for the specifications of

PCF7931XP/030612
PCF7931XP/C
PCF7930XP/030612

2. LIMITING VALUES

T_{amb} = −40°C to +85°C

PARAMETER	MIN.	MAX.	UNIT
Mechanical stress during operation, note 1		10	N/cm^2

NOTE

1. This value (F_{max}) is to be measured as given in Figure 1 and is valid for <u>ALL</u> surfaces.

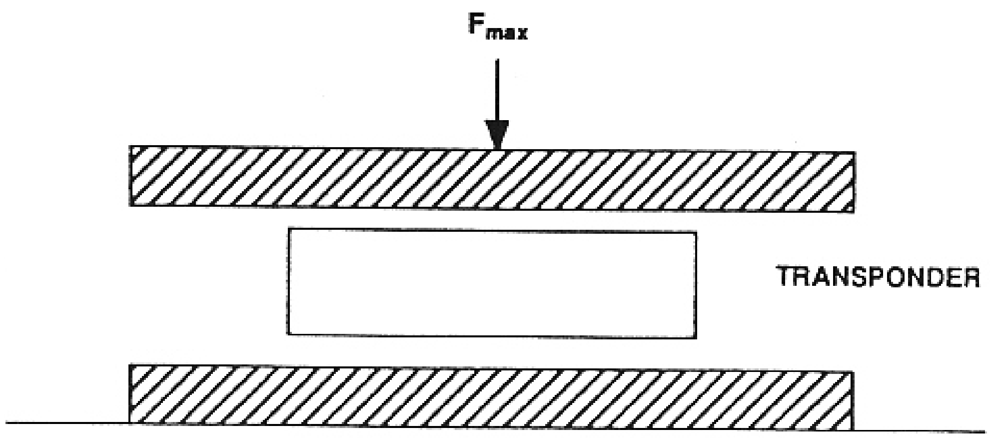


Figure 1.