DATA SHEET

HT RM440 Family

HITAG™ Proximity Reader Module
Hardware

Product Specification
Revision 2.1

February 1999

PHILIPS

Table of Contents

Definitions

Data sheet status	
Objective specification	This data sheet 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 section of the 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.	

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.

1.   Introduction

hitag™ - is the name of one of the universal and powerful product lines of our 125 kHz family. The contactless proximity read/write system that works with passive transponders is suitable for various applications. Inductive coupling helps you to achieve reading ranges up to 200 mm and the use of cryptography guarantees highest data security.

The HITAG Proximity Reader Module provides you with a universal, cost-effective, small and complete reader unit.
It enables communication with the 125 kHz transponders HITAG 1 and HITAG 2.

Easy integration and application of the HITAG Proximity Reader Module is due to:

$\Rightarrow$ small size

$\Rightarrow$ uncomplicated interfaces

2.   System Overview

The following drawing shows the HITAG Proximity Reader Module as part of a complete Radio Frequency Identification (RFID) system.

```
┌──────────────┐   ┌──────────────┐
│I/O Functions │   │Power Supply  │
└──────┬───────┘   └──────┬───────┘
       │                  │
┌────────┐   ┌──────────────┐   ┌─────────┐      ── HITAG1
│ Host   │───│HTRM440 with  │───│ Antenna │
│ System │   │serial interface│ │         │
└────────┘   └──────────────┘   └─────────┘      ── HITAG2
```
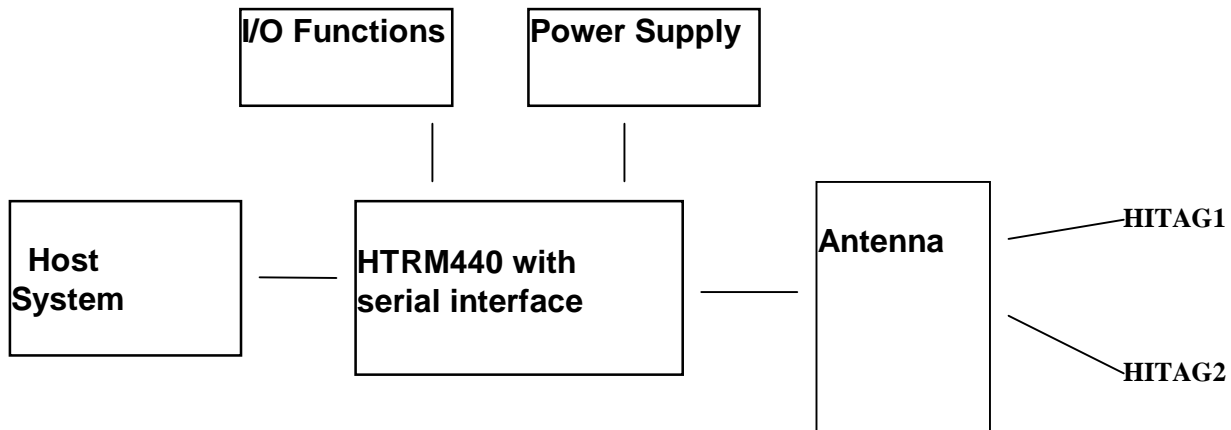
2.1.   Transponders

The HITAG Proximity Reader Module communicates with HITAG 1 and HITAG 2
transponders. Software commands are used to switch between the different transponder modes.

2.2.   Host

The connection to the host (e.g.: µC or PC) is a serial interface on RS232 level (version
HT RM440/AIE) for data transmission. Optionally wired interface drivers for RS422 (version
HT RM440/BIE) and RS485 (version HT RM440/CIE) are integrated on the HITAG Proximity
Reader Module.

2.3.   I/O - Functions

Two lines of the HITAG Proximity Reader Module are wired as inputs from e.g. switches, two as
outputs to drive LEDs.
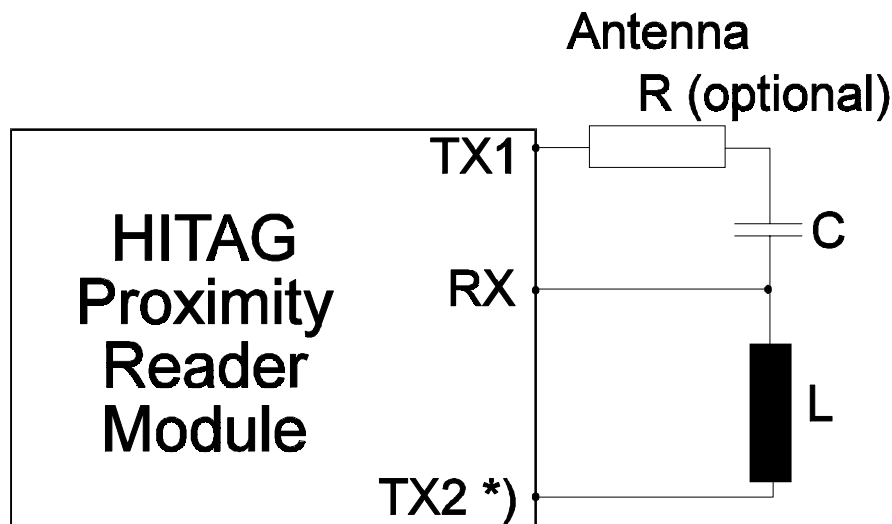On the read/write device space is reserved to connect three LEDs as well as to connect e.g. two
switches.

2.4.   Connecting the Antenna

There is space reserved on the HITAG Proximity Reader Module for tuning capacitors to tune the antenna in case there is no tuning capacity used on the antenna itself.

The antenna has to be mounted in the following way:

*) TX2 is used as GND

C is used for tuning the antenna. For more detailed information please see Chapter 6.1 (Building HITAG Proximity Antennas).

2.5.   Behaviour with Several Transponders

If several HITAG transponders arrive *simultaneously* within the communication field of the antenna of a HITAG Proximity Reader Module, the "stronger" transponder (the nearer one) takes over or - under special circumstances - no communication takes place. If the transponders arrive into the field one after the other, communication is established with the first one, all the other transponders are ignored.

Nevertheless it is possible to mute transponders, so that several HITAG transponders can be accessed sequentially.

This ensures that no two (or several) HITAG transponders will ever be processed (above all written to!) accidentally at the same time.

3.   Specifications

3.1.   Electrical Specifications

3.1.1.   Power Supply

Power Supply	Supply Current
9 - 16 VDC	150 mA max.

3.1.2.   Modulation

3.1.2.1.   Read/Write Device $\Rightarrow$ Transponder

Type of Modulation	Modulation Ratio
amplitude shift keying (ASK)	100 %

That means the carrier is periodically blanked completely, the information is located in the intervals between the pauses.

3.1.2.2.   Transponder $\Rightarrow$ Read/Write Device

Type of Modulation	Modulation Ratio
amplitude shift keying (ASK)	depending on the distance between transponder and read/write device

3.1.3.   Interface

An interface driver for RS232 (version HT RM440/AIE) is integrated on the HITAG Proximity Reader Module.
Optionally drivers are RS422 (version HT RM440/BIE) and RS485 (version HT RM440/CIE)

3.1.4.   Metallic Environment, Interferences

The communication range is impaired by metallic environment and electromagnetic interferences (e.g.: monitors, keyboards). Therefore, you should keep a distance of at least the antenna's diameter to metallic surfaces or loops as well as to electromagnetic interferences. If this is not possible, you have to take preventive measures such as using ferrites or shielding for transponder and antenna.

3.1.5.   Distance between Two Antennas

In order to be able to operate two systems side by side without negative influence on communication ranges, you must place the antennas at a minimum distance of four times the antenna diameter. If you place them at a closer distance be sure to use suitable shielding or synchronisation.

3.1.6.   Temperature Range

-25° C to +85° C (operating)

-40° C to +85° C (storage)

3.2. Mechanical Specifications

3.2.1. Mechanical Dimensions

The following drawing (not to scale) shows the outer dimensions of the HITAG Proximity Reader Module with the six mounting holes, top view.
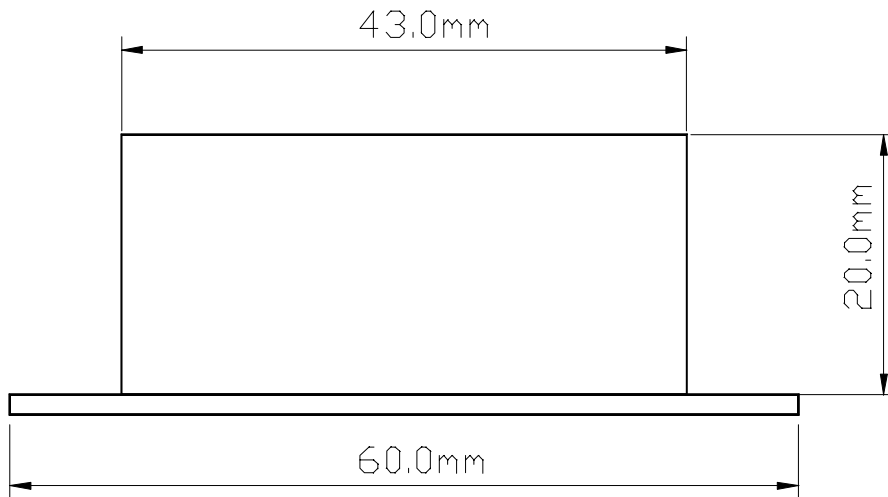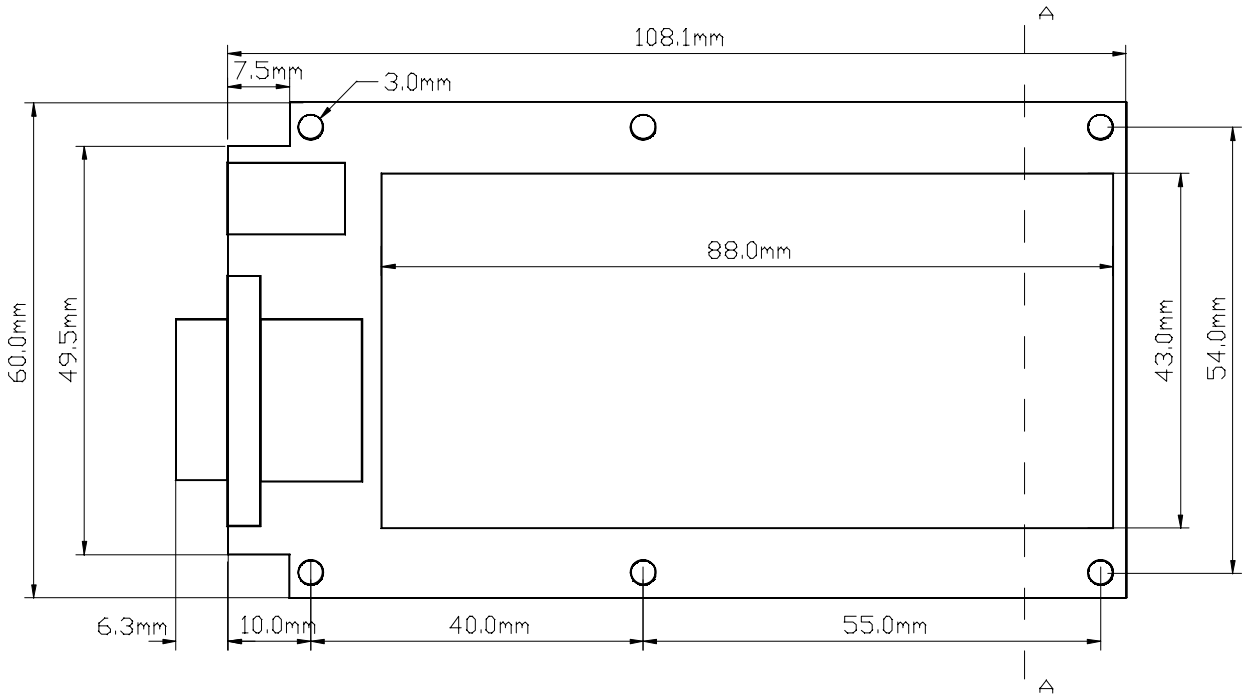
Section A-A

3.2.2.   Pin Assignment

The following drawing (not to scale) shows the pin assignment of the HITAG Proximity Reader Module (top view).

The three spare places for antenna tuning are also shown in this drawing.
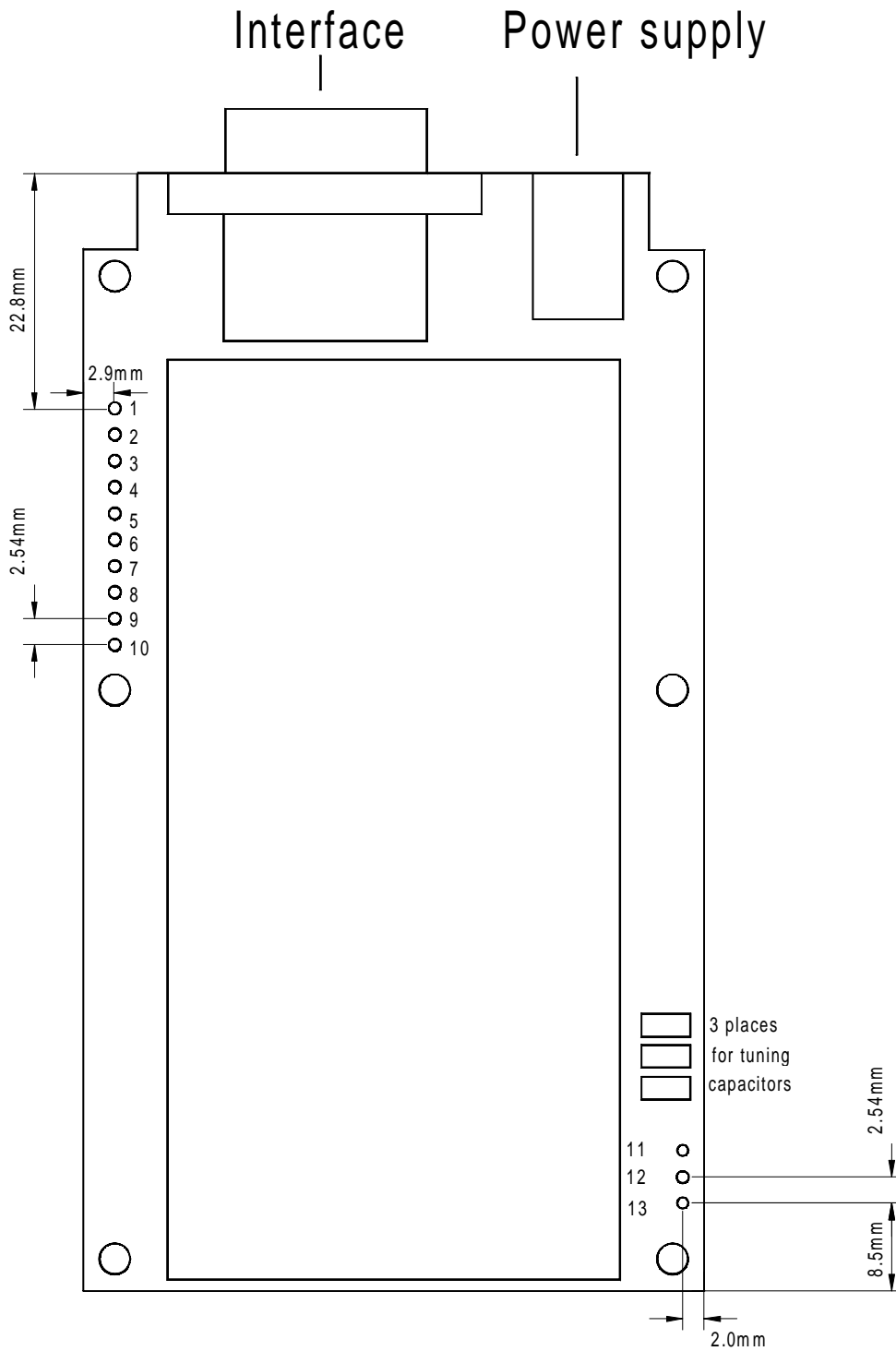
The following table shows the pin assignment of the HITAG Proximity Reader Module, pin types and functions:

Pin Number	Pin Name	Type	Function
1	D1 Cathode	PWR	Connection of
2	D1 Anode	O	Power LED
3	D2 Cathode	PWR	Connection of
4	D2 Anode	O	LED No. 1
5	D3 Cathode	PWR	Connection of
6	D3 Anode	O	LED No. 2
7	SW1 a	I	Connection of
8	SW1 b	GND	Switch No. 1
9	SW2 a	I	Connection of
10	SW2 b	GND	Switch No. 2
11	RX	I	Receiver Input
12	TX1	O	Transmitter
13	TX2	GND	Antenna Ground

I	input pin
O	output pin
PWR	power supply pin
GND	power supply pin

3.2.3.   Pin Function Description

Pin 1-2	These pins can be used to connect a power LED.
Pin 3-6	These pins can be used to connect LEDs which are driven by the output pins of the Core Module.
P7 - P10:	These pins can be used as inputs for switches and are internally connected to pins 17 and 18 (of the HITAG Core Module).
Pin 11:	This antenna signal input has to be connected to the input line of the antenna. (See also Chapter 2.3).
Pin 12:	This antenna signal output has to be connected to the output line of the antenna. (See also Chapter 2.3).
Pin 13:	This pin is used as GND - pin. The GND - line of the antenna has to be connected to this pin. (See also Chapter 2.3)

3.2.4.   SubD Pin Description

Connecting the serial interface use the following pin description:

	1	2	3	4	5	6	7	8	9
RS232	NC	RxD	TxD	NC	GND	NC	IC	IC	NC
RS485	NC	A-	A+	NC	GND	NC	IC	IC	NC
RS422	NC	A-	A+	NC	GND	NC	B+	B-	NC

3.2.5.   Power supply connector

The inner pin of the DC-connector has to be connected to positive voltage, the outer one has to be connected to ground. The connection is fail save.

4.   Description of the Reader Module Functions

4.1.   Block Diagram
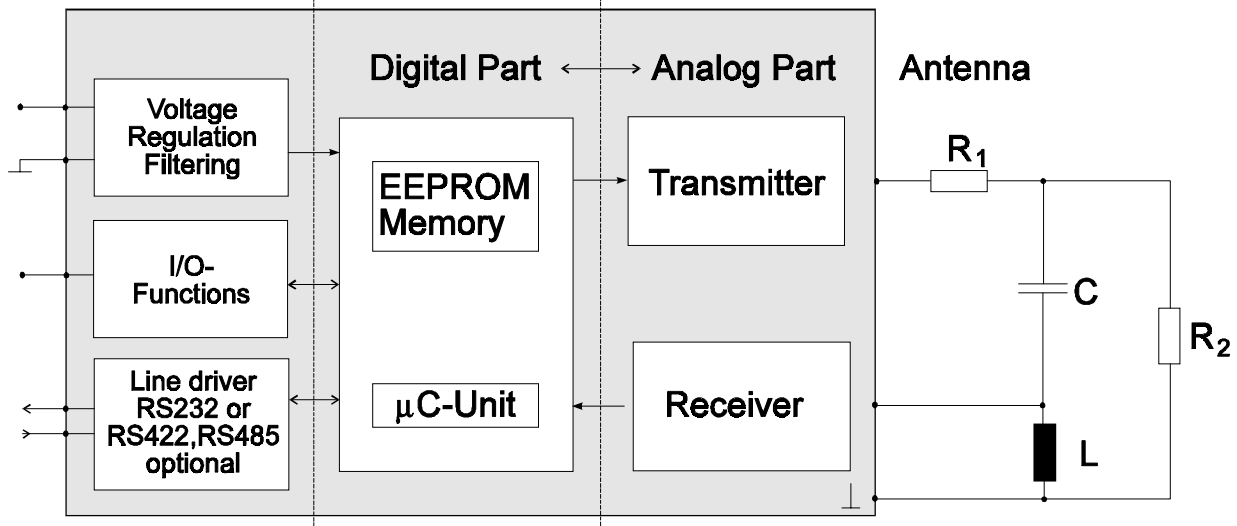
Note: R2 has only to be used for antenna cable lengths of more than 500 mm.

4.1.1.   EEPROM

The EEPROM is used to store non-volatile data such as personalization data, keys, passwords, configurations and status information.

4.1.2.   Micro Controller

The micro controller processes the protocol for the communication between the transponders and the read/write unit. The interface signals are converted in a way, that HITAG 1 and HITAG 2, transponders are able to process them and the outgoing signals from the transponder are converted into interface-compatible signals.

The second essential micro controller function is its control function. The micro controller activates and deactivates the transmitter, switches the receiver between the modes for the different transponders reception and selects the EEPROM.

4.1.3.   Interface: Micro Controller - HOST

The device communicates with the host (processor, PC, ...) via a serial interface using a baud rate of 9600 baud. Data transfer details are: 1 start bit, 8 data bits, 1 stop bit and no parity bit, the Least Significant Bit is sent first.

4.1.4.   Line driver

An RS232 interface driver is integrated on the HITAG Proximity Reader Module. Optionally an RS422 or an RS485 interface driver is possible.

4.1.5. Transmitter and Receiver

The transmitter receives data from the micro controller and modulates the carrier.

The receiver demodulates the received data and passes them on to the micro controller for further processing.

4.1.6. Antenna

To the design of HITAG Proximity Antennas see Chapter 6.1.

4.1.7. Filtering of Power Supply

Disturbances on the supply pins may reduce the performance of the system. For that reason the supply is filtered but also to limit the spurious emissions at the supply connections caused by the digital parts of the module.

4.1.8. I/O Functions

Two lines of the HITAG Proximity Reader Module are wired as inputs from e.g. switches, two as outputs to drive LEDs.
On the read/write device space is reserved to connect LEDs as well as to connect e.g. two switches.

5.   Postal Approval

The postal approval can only be granted for final products, not just for components like the HITAG Proximity Reader Module. But the read/write device is designed in a way that it is possible to get the postal approval for a device including the HITAG Proximity Reader Module.

Electromagnetic emissions comply with the guidelines in FTZ 17 TR 2100 and ETS 300 683, electromagnetic immunity complies with the guidelines in ETS 300 683.

6. Connection of the Reader Module

6.1. Building HITAG Proximity Antennas

The antenna is an important part in the data transmission process between read/write device and transponder. Therefore, you should be particularly careful when implementing the antenna in order to achieve optimum results.

An essential aspect in dimensioning HITAG antennas is the ratio between the antenna diameter and the diameter of the transponder coil. This ratio should be within the limit values 3 and 1. If the ratio is too big or too small read/write distances can decrease and difficulties during data transmission may occur.

For applications in which the transponders are to be only read, you can also use antennas that diverge from above mentioned instruction.

6.1.1. Basics

The following block diagram shows the general architecture of a HITAG Proximity antenna and its connection to the HITAG Proximity Reader Module.

f = 125 kHz   with Antenna Equivalent Circuit

HITAG Core Module   Antenna
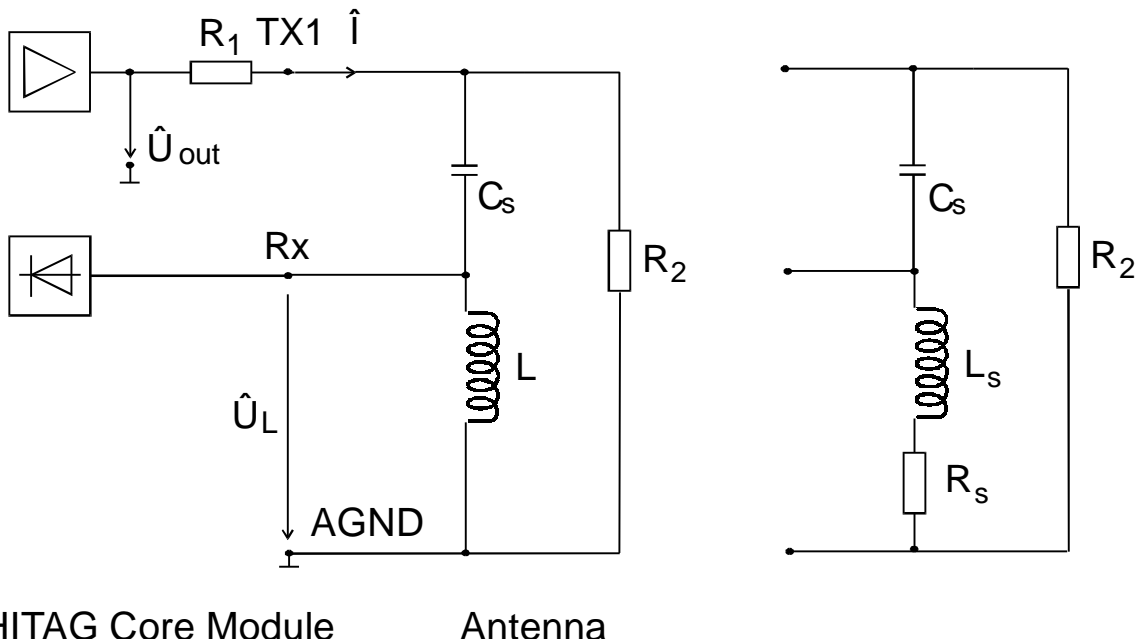
When developing an antenna, it is important to take into consideration the read/write device limits, i.e. maximum antenna current and maximum voltage at the receiver input. With an output voltage $\hat{U}_{out}$ of about 2.5 V_p the following limits apply to the read/write device:

maximum antenna current: 100 mA_p
maximum input voltage (at the receiver ($\hat{U}_L$)): 32 V_p

The resistance R_1 (22 Ohm) in the block diagram is used as current limiter. It protects the output stage in the event of a possible short circuit in the antenna and is already integrated in the read/write device. R_2 (approx. 600 ... 1000 Ω) has only to be used for antenna cable lengths of more than 500 mm.

6.1.2. Antenna Coil

The inductance of the coil should be between 350 and 500 µH.

The antenna quality factor should be approximately Q = 40.

$$Q = \frac{2 \cdot \pi \cdot f \cdot L}{R_s}$$

Is the Q factor too high it must be reduced with an additional resistor. It is the aim not to need this additional resistor but use a lower wire diameter of the coil.

The following formula describes the approximate calculation of the number of windings for a desired inductance and antenna geometry:

$$L = 2 \cdot a \cdot \ln\left(\frac{a}{D} - K\right) \cdot N^{1.9}$$

The abbreviations read as follows:

L	...	desired inductance [nH]
a	...	antenna circumference [cm]
D	...	wire diameter [cm]
N	...	number of windings
K	...	geometrical constant
		circular antenna : K=1.01
		square antenna : K=1.47

Note: The factor K is normally much smaller than a/D and can be therefore left out:

$$N \approx \sqrt[1.9]{\frac{L}{2 \cdot a \cdot \ln(a/D)}}$$

6.1.3. Measuring the Inductance

The inductance of the coil designed following above listed instructions can be measured using the following measuring set-up:
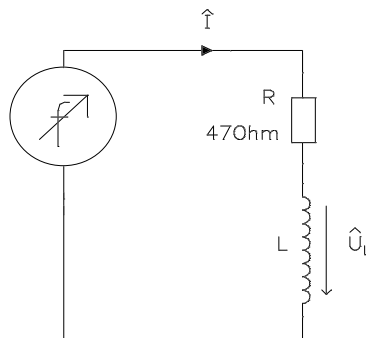
A sinus signal of 125 kHz is fed using a function generator. If you measure the current $\hat{I}$ and the antenna voltage $\hat{U}_L$ you can calculate the inductance according to the following formula:

$$L = \frac{\hat{U}_L}{\omega \cdot \hat{I}} \qquad\qquad \omega = 2 \cdot \pi \cdot f$$

6.1.4. Antenna Cable Length

For optimal performance the antenna cable length should not exceed 5 m.

6.1.5. Antenna Tuning

You have to tune the antenna in its final form with the connecting cable. You must not make any changes to the antenna coil or the connecting cable after you finished tuning because mechanical changes influence the electrical values and the antenna is detuned again.
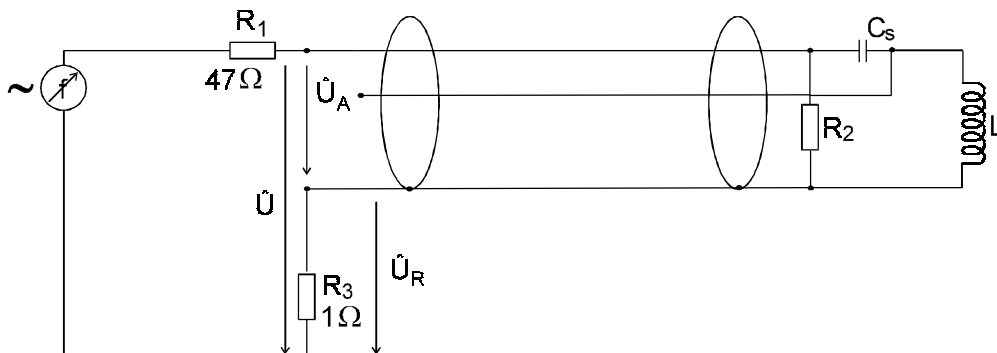
A sinus signal of 125 kHz is fed to the antenna using a frequency generator. You measure the voltages $\hat{U}$ and $\hat{U}_R$ with an oscilloscope. Then you change the frequency until $\hat{U}$ and $\hat{U}_R$ are in phase. If the resonance frequency thus arrived at is too high, you have to increase C_S, if it is too low, you have to decrease C_S.

The aim is to arrive at a resonance frequency of 125 kHz using C_S.

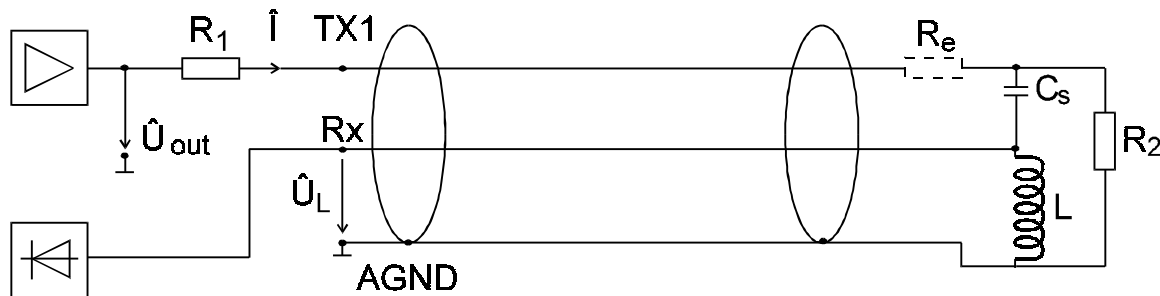Tune the antenna to a frequency of 125kHz $\pm$ 4kHz.

6.1.6.   Determining the Serial Resistance of the Antenna

Use an oscilloscope to measure $\hat{U}_A$ and $\hat{U}_R$ at a frequency of 125 kHz.
You can calculate the serial resistance R_S with the following formula:

$$\hat{I} \; = \; \frac{\hat{U}_R}{R_3} \qquad \Rightarrow \qquad R_s = \frac{\hat{U}_A}{\hat{I}}$$

6.1.7.   Checking the Antenna Voltage $\hat{U}_L$

Before connecting the antenna to the read/write device as shown in the illustration below, you must carry out a check calculation of the input level of the read/write device according to the formulas further down in order to prevent damage.

$$\hat{I} \; = \; \frac{\hat{U}_{out}}{R_1 \; + \; R_s + (R_e)}$$

$$\hat{U}_{out} \approx 2.5 \; V_p \qquad\qquad \hat{U}_L = L \cdot \omega \cdot \hat{I} \qquad\qquad \omega = 2 \cdot \pi \cdot f \;\; (f = 125 \text{ kHz})$$

The maximum value for $\hat{U}_L$ reads 32 V_p , safeguarding against damage to the input level of the read/write device.

     With $\hat{U}_L < 32 \; V_p$ the resistance R_e can be omitted

     With $\hat{U}_L > 32 \; V_p$ you have to calculate and insert R_e according to the following formula:

$$R_e = L \cdot \omega \cdot \frac{\hat{U}_{out}}{\hat{U}_{L\max}} - R_1 - R_s \qquad \Rightarrow \qquad R_e \geq L \cdot \omega \cdot 0{,}078 - 22 - R_s$$

6.1.8.   Procedure for Practical Antenna Design

The procedure how to design a HITAG Proximity antenna is described in the previous chapters. The main steps are the following:

1. The desired inductance for the antenna coil can be chosen in a range between 350 and 500 μH, e.g. L = 420 μH).

2. The number of windings N can be calculated with the following formula:

$$N = {}^{1.9}\!\sqrt{\frac{L\ [nH]}{2 \cdot a \cdot \ln(a\ /\ D)\ -\ K}}$$

for L = 420 μH:

$$N = {}^{1.9}\!\sqrt{\frac{420\ 000}{2 \cdot a \cdot \ln(a\ /\ D)\ -\ K}}\ =\ \frac{633}{{}^{1.9}\!\sqrt{a \cdot \ln(a\ /\ D)}}$$

Note: The factor K (see also Chapter 6.1.2.) normally is much smaller than a/D and can be therefore left out.

3. Now the antenna can be built up with the desired dimensions ($\Rightarrow$ circumference a) with the calculated number of turns.

Note: The antenna coil must not be changed afterwards because with the mechanical dimensions the electrical specifications are changing too. That means the number of turns, the shape, arrangement of the coil windings and antenna supply cable must be in their final form.

Note: Metal influences the electrical characteristics of the antenna very much. That is why all future tasks have to be done with the antenna in its final environment if metal will be in the antenna's neighbourhood (distance of the metal < maximum antenna diameter).

4. Measurement of the inductance L of the antenna is described in Chapter 6.1.3.

5. Determination of the serial capacitor C_S is described in Chapter 6.1.5.

Note: The capacitance of the antenna supply cable can be measured or found out in the data sheet of the cable (e.g. C_p = 180 pF/m).

6. Now the antenna has to be tuned according to Chapter 6.1.5.
   The tuning is acceptable if the resonance frequency is within a range of 125kHz ± 4kHz.

7. The serial resistance R_S of the antenna is the impedance of the tuned antenna and is an ohmic resistance at the resonance frequency (f = 125 kHz). It can be calculated as shown in Chapter 6.1.6.

8. To get a satisfactory reading distance the quality factor of the antenna **coil** (for non-metal environment) should be about Q = 40. The quality factor of a coil is calculated as follows:

$$Q = \frac{\omega \cdot L}{R_s} = \frac{2 \cdot \pi \cdot f \cdot L}{R_s}$$

9. By knowing R_S and the dropping resistor ($R_1 = 22\ \Omega$) it is possible to calculate the current $\hat{I}$ and the antenna voltage $\hat{U}_L$.
   It is very important to calculate the antenna voltage before connecting the antenna to the HITAG Proximity Reader Module to avoid damage. Is the calculated value of $\hat{U}_L$ higher than $\hat{U}_L = 32\ V_p$ a resistor R_e has to be integrated to protect the module output circuit. The resistor has to be placed as shown in Chapter 6.1.7.

10. After checking the antenna voltage as described in point 9. connect your antenna to the HITAG Proximity Reader Module and measure the read/write distances with your transponders.
    If the read/write distances do not fulfil your expectations, the following points should be considered:

   * The size of the antenna and the size of the transponder have to be in a defined ratio (between 3 and 1).
     That means, if you increase the antenna over a certain size, the maximum read/write distances will decrease by the use of the same transponder.

   * The optimal shape of the antenna coil is a circle. The performance of a square shaped coil is much better than that of a rectangular shaped coil (with the same circumference).

   * To get better read/write distances the quality factor of the antenna **coil** should be increased, but it must not be higher than Q = 40. This can be reached by the following measures:

     - All conducting material has to be removed from the antenna environment.
     - A thicker wire can be used for the coil.
     - Ferrite can be placed behind the antenna coil to concentrate the field.
     - Extension of the antenna area.
     - There can be better results by trying another number of turns.

Attention: All these measures must not differ from the antenna design instructions of Chapter 6.1.

Note: With additional dropping resistor R_1 and resistor R_e the quality factor of the complete antenna system is about Q = 15.

6.1.9.   Reference Antennas

Designing an antenna in the way described in this chapter you could use the following values:

- ∅ 0.4 mm Cu - laqueur wire
- 35 turns
- Diameter of the turns (internal):   145 mm
- Tuning frequency: 125 kHz
- Tuning Capacity depending on: - length of the antenna cable
  - exact way of winding

This antenna is best suitable for HITAG. In this performance reading distances of about 140 mm for cards and 130 mm for discs should be achieved.

A further antenna configuration is:

- ∅ 0.224 mm Cu - laqueur wire
- 52 turns
- Diameter of the turns (internal):   65 mm
- Tuning frequency: 125 kHz
- Tuning Capacity depending on: - length of the antenna cable
  - exact way of winding

In this case cards and coins can be used and the following approximate communication distances should be achieved:

read distance with HITAG 1 and HITAG 2 card: 105 mm
read distance with HITAG 1 and HITAG 2 coin: 65 mm

The third antenna configuration is the smallest one:

- ∅ 0.224 mm Cu - laqueur wire
- 85 turns
- Diameter of the turns (internal):   35 mm
- Tuning frequency: 125 kHz
- Tuning Capacity depending on: - length of the antenna cable
  - exact way of winding

Using this antenna coins and pills can be operated up to the following approximate distances:

read distance with HITAG 1 coin: 50 mm
read distance with HITAG 1 pill: 28 mm

All distances are given in free air at room temperature.

Specifications subject to change without notice.

6.2.   Possible Sources of Errors by Connecting the HITAG Proximity Reader Module

The following error list should be checked if any error (e.g. read/write distances that do not reach the specified values) occurs:

- Power supply cable not mounted correctly.

- Power supply not in the specified range (U = 9 - 16VDC)

- Serial interface not connected correctly.

- Interference received by the antenna because of an external noise source (e.g. monitor, keyboards).
  Remedial measure: Removal of the antenna from the interfering area.

- Connecting cables of the antenna changed by mistake.

- Antenna is mounted in metal environment.
  Remedial measure: Mount a non-metal space keeper between the antenna and the metal.

- Antenna is not designed following the design instructions of Chapter 6.

- Inductance of the antenna is too high.

- Quality factor of the antenna is too high (> 40).

- Antenna current is too high.

- Antenna voltage is too high.

7. Security Considerations

Developing the HITAG Proximity Reader Module special consideration was given to aspects of security. The following items represent the fundamental framework of the security concept:

- cryptography
- mutual authentication
- password verification and
- Cyclic Redundancy Check (CRC)

7.1. Operating Security

The following mechanisms ensure the operation security of the HITAG system.

7.1.1. Anticollision Mode

Anticollision Mode in Long Range applications permits you to process several transponders simultaneously. Theoretically up to 2^{32} transponders can be processed simultaneously. In practice this number is limited, because of the mutual influence of the transponders - they detune each other, if there are too many too close to each other.

In proximity applications using HITAG 1 or HITAG 2 transponders, only one transponder is handled even if there are several transponders within the communication field of the antenna. In this case either no communication takes place or the "stronger" or closer transponder takes over.
By muting a selected transponder (HALT Mode) another transponder that is to be found in the communication field of the antenna can be recognised.

7.1.2. Monitoring the Supply Voltage

Supply voltage is controlled by a watch dog circuit which triggers a system reset if the supply voltage drops below 4.75 V or if the micro controller fails.

7.1.3. Antenna Rupture, Antenna Short Circuit

The HITAG Proximity Reader Module does not get permanently damaged in case of an antenna rupture or a brief antenna short circuit.

7.2.   Data Privacy

The use of cryptography (Stream Cypher), mutual authentication, and password verification prevents monitoring and copying the data channel. Therefore, the area of the transponder that only can be accessed enciphered is called "secret area".

To make use of cryptography for HITAG 1 transponders you need keys and logdata.

> **Keys** are used to **initialise the crypto block**
> and **logdata** are used for **mutual authentication**.

To make use of cryptography for HITAG 2 transponders you need a key and passwords.

> The **Key** is used to **initialise the crypto block** using HITAG 2 in Crypto Mode
> and **passwords** are used for **authentication** for HITAG 2 in Password Mode.

The transponders and the HITAG Proximity Reader Module are provided with identical transport keys and transport logdata so that you can start operating them right away.

The KeyInit Password is set to 0x00000000, HITAG 1 Keys and Logdata are set to 0x00000000, HITAG 2 Key is set to 0x4D494B524F4E, HITAG 2 Password TAG to 0xAA4854 and HITAG 2 Password RWD to 0x4D494B52 by PHILIPS (predefined *transport* values).

In order to offer our OEM clients high flexibility, the configuration of the transponder memory, password, keys and logdata can be changed.
We strictly recommend to rigorously restrict these possibilities for the end customers (by setting the configuration page to read only, setting password, keys and logdata to neither read nor write).

8.   Ordering Information

Type Name	Description	Ordering Number
HT RM440/AIE	HITAG Proximity Reader Module, Interface RS232	9352 338 70122
HT RM440/BIE	HITAG Proximity Reader Module, Interface RS422	9352 338 80122
HT RM440/CIE	HITAG Proximity Reader Module, Interface RS485	9352 338 90122

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Argentina: see South America
Australia: 34 Waterloo Road, NORTHRYDE, NSW 2113,
Tel. +612 9805 4455, Fax. +612 9805 4466
Austria: Computerstraße 6, A-1101 WIEN, P.O.Box 213,
Tel. +431 60 101, Fax. +431 30 101 1210
Belarus: Hotel Minsk Business Centre, Bld. 3, r.1211, Volodarski Str. 6,
220050 MINSK, Tel. +375172 200 733, Fax. +375172 200 773
Belgium: see The Netherlands
Brazil: see South America
Bulgaria: Philips Bulgaria Ltd., Energoproject, 15th floor,
51 James Bourchier Blvd., 1407 SOFIA
Tel. +3592 689 211, Fax. +3592 689 102
Canada: Philips Semiconductors/Components,
Tel. +1800 234 7381
China/Hong Kong: 501 Hong Kong Industrial Technology Centre,
72 Tat Chee Avenue, Kowloon Tong, HONG KONG,
Tel. +85223 19 7888, Fax. +85223 19 7700
Colombia: see South America
Czech Republic: see Austria
Denmark: Prags Boulevard 80, PB 1919, DK-2300 COPENHAGEN S,
Tel. +4532 88 2636, Fax. +4531 57 1949
Finland: Sinikalliontie 3, FIN-02630 ESPOO,
Tel. +3589 61 5800, Fax. +3589 61 580/xxx
France: 4 Rue du Port-aux-Vins, BP 317, 92156 SURESNES Cedex,
Tel. +331 40 99 6161, Fax. +331 40 99 6427
Germany: Hammerbrookstraße 69, D-20097 HAMBURG,
Tel. +4940 23 53 60, Fax. +4940 23 536 300
Greece: No. 15, 25th March Street, GR 17778 TAVROS/ATHENS,
Tel. +301 4894 339/239, Fax. +301 4814 240
Hungary: see Austria
India: Philips INDIA Ltd., Shivsagar Estate, A Block, Dr. Annie Besant Rd.
Worli, MUMBAI 400018, Tel. +9122 4938 541, Fax. +9122 4938 722
Indonesia: see Singapore
Ireland: Newstead, Clonskeagh, DUBLIN 14,
Tel. +3531 7640 000, Fax. +3531 7640 200
Israel: RAPAC Electronics, 7 Kehilat Saloniki St., TEL AVIV 61180,
Tel. +9723 645 0444, Fax. +9723 649 1007
Italy: Philips Semiconductors, Piazza IV Novembre 3,
20124 MILANO, Tel. +392 6752 2531, Fax. +392 6752 2557
Japan: Philips Bldg. 13-37, Kohnan 2-chome, Minato-ku, TOKYO 108,
Tel. +813 3740 5130,Fax. +813 3740 5077
Korea: Philips House, 260-199, Itaewon-dong, Yonsan-ku, SEOUL,
Tel. +822 709 1412, Fax. +822 709 1415
Malaysia: No. 76 Jalan Universiti, 46200 PETALING JAYA, Selangor,
Tel. +60 3750 5214, Fax. +603 757 4880
Mexico: 5900 Gateway East, Suite 200, EL PASO, Texas 79905,
Tel. +9 5800 234 7381
Middle East: see Italy

Netherlands: Postbus 90050, 5600 PB EINDHOVEN, Bldg. VB,
Tel. +3140 27 82785, Fax +3140 27 88399
New Zealand: 2 Wagener Place, C.P.O. Box 1041, AUCKLAND,
Tel. +649 849 4160, Fax. +649 849 7811
Norway: Box 1, Manglerud 0612, OSLO,
Tel. +4722 74 8000, Fax. +4722 74 8341
Philippines: Philips Semiconductors Philippines Inc.,
106 Valero St. Salcedo Village, P.O.Box 2108 MCC, MAKATI,
Metro MANILA, Tel. +632 816 6380, Fax. +632 817 3474
Poland: Ul. Lukiska 10, PL 04-123 WARSZWA,
Tel. +4822 612 2831, Fax. +4822 612 2327
Portugal: see Spain
Romania: see Italy
Russia: Philips Russia, Ul. Usatcheva 35A, 119048 MOSCOW,
Tel. +7095 247 9145, Fax. +7095 247 9144
Singapore: Lorong 1, Toa Payoh, SINGAPORE 1231,
Tel. +65350 2538, Fax. +65251 6500
Slovakia: see Austria
Slovenia: see Italy
South Africa: S.A. Philips Pty Ltd., 195-215 Main Road Martindale,
2092 JOHANNESBURG, P.O.Box 7430 Johannesburg 2000,
Tel. +2711 470 5911, Fax. +2711 470 5494
South America: Rua do Rocio 220, 5th floor, Suite 51,
04552-903 Sao Paulo, SAO PAULO - SP, Brazil,
Tel. +5511 821 2333, Fax. +5511 829 1849
Spain: Balmes 22, 08007 BARCELONA,
Tel. +343 301 6312, Fax. +343 301 4107
Sweden: Kottbygatan 7, Akalla, S-16485 STOCKHOLM,
Tel. +468 632 2000, Fax. +468 632 2745
Switzerland: Allmendstraße 140, CH-8027 ZÜRICH,
Tel. +411 488 2686, Fax. +411 481 7730
Taiwan: Philips Taiwan Ltd., 2330F, 66,
Chung Hsiao West Road, Sec. 1, P.O.Box 22978,
TAIPEI 100, Tel. +8862 382 4443, Fax. +8862 382 4444
Thailand: Philips Electronics (Thailand) Ltd.,
209/2 Sanpavuth-Bangna Road Prakanong, BANGKOK 10260,
Tel. +662 745 4090, Fax. +662 398 0793
Turkey: Talapasa Cad. No. 5, 80640 GÜLTEPE/ISTANBUL,
Tel. +90212 279 2770, Fax. +90212 282 6707
Ukraine: Philips Ukraine, 4 Patrice Lumumba Str., Building B, Floor 7,
252042 KIEV, Tel. +38044 264 2776, Fax. +38044 268 0461
United Kingdom: Philips Semiconductors Ltd., 276 Bath Road, Hayes,
MIDDLESEX UM3 5BX, Tel. +44181 730 5000, Fax. +44181 754 8421
United States: 811 Argues Avenue, SUNNYVALE, CA94088-3409,
Tel. +1800 234 7381
Uruguay: see South America
Vietnam: see Singapore
Yugoslavia: Philips, Trg N. Pasica 5/v, 11000 BEOGRAD,
Tel. +38111 625 344, Fax. +38111 635 777

PHILIPS Semiconductors, Mikron-Weg 1, A-8101 Gratkorn, Austria Fax: +43 3124 299 270

For all other countries apply to: Philips Semiconductors, Marketing & Sales Communications,   Internet:
http://www.semiconductors.philips.com
Building BE-p, P.O.Box 218, 5600 MD EINDHOVEN, The Netherlands, Fax: +3140 27 24825

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