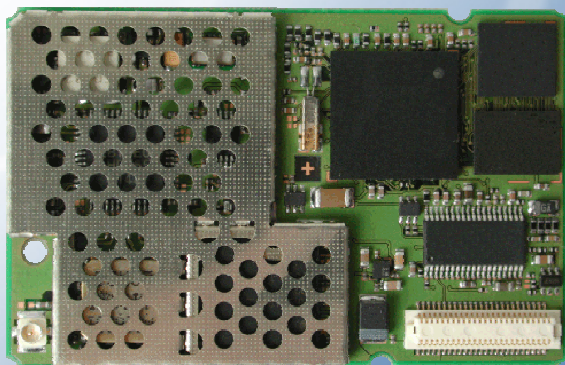# SIEMENS

MC45
Siemens Cellular Engine

Hardware Interface Description

Version 00.02
DocID: MC45_HD_01_V00.02a

Wireless Modules

Document Name:	**MC45 Hardware Interface Description**
Version:	**00.02**
Date:	**August 12, 2002**
DocId:	**MC45_HD_01_V00.02a**
Status:	**PRELIMINARY**

General notes

With respect to any damages arising in connection with the described product or this document, Siemens shall be liable according to the General Conditions on which the delivery of the described product and this document are based.

This product is not intended for use in life support appliances, devices or systems where a malfunction of the product can reasonably be expected to result in personal injury. Siemens AG customers using or selling this product for use in such applications do so at their own risk and agree to fully indemnify Siemens for any damages resulting from illegal use or resale.

Applications incorporating the described product must be designed to be in accordance with the technical specifications provided in these guidelines. Failure to comply with any of the required procedures can result in malfunctions or serious discrepancies in results.

Furthermore, all safety instructions regarding the use of mobile technical systems, including GSM products, which also apply to cellular phones must be followed.

Handheld applications such as mobile phones or PDAs incorporating the described product must be in accordance with the guidelines for human exposure to radio frequency energy. The Specific Absorption Rate (SAR) of the application must be evaluated and approved to be compliant with national and international safety standards or directives.

Subject to change without notice at any time.

Contents

Figures

Tables

0   Version History

Preceding document: "MC45 Hardware Interface Description" Version **00.02**
New document: "MC45 Hardware Interface Description" Version **00.02a**

Chapter	Page	What is new
Throughout this manual: Replaced product photo of MC45.		
1.4	15f	Added notes regarding compliance with FCC guidelines

Preceding document: "MC45 Hardware Interface Description" Version **00.01**
New document: "MC45 Hardware Interface Description" Version **00.02**

Chapter	Page	What is new
Throughout this manual: All RS-232 signals, /IGT signal and /EMERGOFF are now preceded by "/" to indicate that the signals are active low.		
2.1 3.5	18ff 47	Deleted CMOS. The RS-232 interface operates at 2.65V.
2.1	18ff	Deleted statements on current consumption and storage temperature Serial interfaces: Autobauding also supported at 230kbps
2.2	21	Modified block diagram.
3.2 3.9	25 61	VDD pin recommended, for example, for LED or level shifter.
3.2.1	25	Deleted parameter of CHARGE pin.
3.2.3	27	Revised description of trickle and fast charging.
3.3.2	36	Revised information on power saving.
3.7.2	55	Figure 20 updated. Note regarding capacitors C1205 and C1206 added.
3.9	61ff	Changed numbering of pins. Corrected comments on BATT+ pin, VDD pin, VDDLP pin. Corrected signal parameters of RS-232 interfaces and associated comments (no more necessary to connect unused input pins to VDD). Corrected input voltage (peak to peak).
4	65	Removed introduction.
5.1	66ff	Updated MC45 drawings. Added bottom view and information about test points and ground pad.
5.2	69	Added recommendations for installation.
5.3	70	Table 21: Corrected HRS number of DF12C receptacle. Table 22: Added insertion and withdrawal force.
5.4.1	72ff	Added specifications of U.FL-LP-(V)-040(01
6.1	76	Table 26: Added differential load resistance between EPN and EPP
6.2	76	Corrected description (without modifying operating temperatures).
6.3	77	Added information about reliability characteristics and temperature.
6.5	81	Added test points

6.4.1	79ff	Added current consumption during transmit burst.
6.5	81ff	Added notes on AT commands where applicable.
		Table 31: Modified MIC input signal in modes 5 and 6.
		Table 32: Added Differential load capacitance 1000pF.
		Table 33: Voiceband transmit path: Corrected input voltage (peak to peak).
6.6	86	Updated Table 34: Air Interface
8	89	Added ordering information for VOTRONIC handset

1 Introduction

This document describes the hardware interface of the Siemens MC45 module that connects to the cellular device application and the air interface. As MC45 is intended to integrate with a wide range of application platforms, all functional components are described in great detail.

So this guide covers all information you need to design and set up cellular applications incorporating the MC45 module. It helps you quickly retrieve interface specifications, electrical and mechanical details and, last but not least, information on the requirements to be considered for integrating further components.

1.1 Related documents

[1]   MC45 AT Command Set for Version 00.02
[2]   MC45 GPRS Startup User's Guide (in preparation)
[3]   MC45 Remote-SAT User's Guide, as of Version 00.02 (in preparation)
[4]   DSB45 Support Box - Evaluation Kit for Siemens Cellular Engines
[5]   Application Note 16: Upgrading MC45 Firmware (in preparation)
[6]   Application Note 14: Audio and Battery Parameter Download
[7]   MC45 Multiplexer User's Guide, as of Version 00.02 (in preparation)

Prior to using the MC45 engines be sure to carefully read and understand the latest product information provided in the Release Notes (not available for release 00.02.)

To visit the Siemens Website you can use the following link:
http://www.siemens.com/wm

1.2 Terms and abbreviations

Abbreviation	Description
ADC	Analog-to-Digital Converter
AFC	Automatic Frequency Control
AGC	Automatic Gain Control
ARFCN	Absolute Radio Frequency Channel Number
ARP	Antenna Reference Point
ASIC	Application Specific Integrated Circuit
B	Thermistor Constant
B2B	Board-to-board connector
BER	Bit Error Rate
BTS	Base Transceiver Station
CB or CBM	Cell Broadcast Message
CE	Conformité Européene (European Conformity)
CHAP	Challenge Handshake Authentication Protocol
CPU	Central Processing Unit
CS	Coding Scheme
CSD	Circuit Switched Data
CTS	Clear to Send
DAC	Digital-to-Analog Converter
DAI	Digital Audio Interface
dBm0	Digital level, 3.14dBm0 corresponds to full scale, see ITU G.711, A-law
DCE	Data Communication Equipment (typically modems, e.g. Siemens GSM engine)
DCS 1800	Digital Cellular System, also referred to as PCN
DRX	Discontinuous Reception
DSB	Development Support Box
DSP	Digital Signal Processor
DSR	Data Set Ready
DTE	Data Terminal Equipment (typically computer, terminal, printer or, for example, GSM application)
DTR	Data Terminal Ready
DTX	Discontinuous Transmission
EFR	Enhanced Full Rate
EGSM	Enhanced GSM
EMC	Electromagnetic Compatibility
ESD	Electrostatic Discharge
ETS	European Telecommunication Standard

Abbreviation	Description
FDMA	Frequency Division Multiple Access
FR	Full Rate
GMSK	Gaussian Minimum Shift Keying
GPRS	General Packet Radio Service
GSM	Global Standard for Mobile Communications
HiZ	High Impedance
HR	Half Rate
I/O	Input/Output
IC	Integrated Circuit
IMEI	International Mobile Equipment Identity
ISO	International Standards Organization
ITU	International Telecommunications Union
kbps	kbits per second
LED	Light Emitting Diode
Li-Ion	Lithium-Ion
Mbps	Mbits per second
MMI	Man Machine Interface
MO	Mobile Originated
MS	Mobile Station (GSM engine), also referred to as TE
MSISDN	Mobile Station International ISDN number
MT	Mobile Terminated
NTC	Negative Temperature Coefficient
PA	Power Amplifier
PAP	Password Authentication Protocol
PBCCH	Packet Switched Broadcast Control Channel
PCB	Printed Circuit Board
PCL	Power Control Level
PCM	Pulse Code Modulation
PCN	Personal Communications Network, also referred to as DCS 1800
PCS	Personal Communication System, also referred to as GSM 1900
PDU	Protocol Data Unit
PLL	Phase Locked Loop
PPP	Point-to-point protocol
PSU	Power Supply Unit
R&TTE	Radio and Telecommunication Terminal Equipment
RAM	Random Access Memory
RF	Radio Frequency

Abbreviation	Description
RMS	Root Mean Square (value)
ROM	Read-only Memory
RTC	Real Time Clock
Rx	Receive Direction
SAR	Specific Absorption Rate
SELV	Safety Extra Low Voltage
SIM	Subscriber Identification Module
SMS	Short Message Service
SRAM	Static Random Access Memory
TA	Terminal adapter (e.g. GSM engine)
TDMA	Time Division Multiple Access
TE	Terminal Equipment, also referred to as DTE
Tx	Transmit Direction
UART	Universal asynchronous receiver-transmitter
URC	Unsolicited Result Code
USSD	Unstructured Supplementary Service Data
VSWR	Voltage Standing Wave Ratio
Phonebook abbreviations	
FD	SIM fixdialling phonebook
LD	SIM last dialling phonebook (list of numbers most recently dialled)
MC	Mobile Equipment list of unanswered MT calls (missed calls)
ME	Mobile Equipment phonebook
ON	Own numbers (MSISDNs) stored on SIM or ME
RC	Mobile Equipment list of received calls
SM	SIM phonebook

1.3 Type approval

MC45 is designed to comply with the directives and standards listed below. Please note that the product is still in a pre-release state and, therefore, type approval and testing procedures have not yet been completed.

European Directives

99/05/EC	Directive of the European Parliament and of the council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity, in short referred to as R&TTE Directive 1999/5/EC
89/336/EC	Directive on electromagnetic compatibility
73/23/EC	Directive on electrical equipment designed for use within certain voltage limits (Low Voltage Directive)

North American Approval

FCC	US Equipment Authorization
UL	Product Safety Certification

Standards of type approval

ETS 300 607-1	Digital cellular telecommunications system (Phase 2); Mobile Station (MS) conformance specification; (equal GSM 11.10-1=>equal 3GPP51.010-1)
ETSI EN 301 511	V7.0.1 (2000-12) Candidate Harmonized European Standard (Telecommunications series) Global System for Mobile communications (GSM); Harmonized standard for mobile stations in the GSM 900 and DCS 1800 bands covering essential requirements under article 3.2 of the R&TTE directive (1999/5/EC) (GSM 13.11 version 7.0.1 Release 1998)
ETSI EN 301 489-7	V1.1.1 (2000-09) Candidate Harmonized European Standard (Telecommunications series) Electro Magnetic Compatibility and Radio spectrum Matters (ERM); Electro Magnetic Compatibility (EMC) standard for radio equipment and services; Part 7: Specific conditions for mobile and portable radio and ancillary equipment of digital cellular radio telecommunications systems (GSM and DCS)
EN 60 950	Safety of information technology equipment (2000)
UL 60 950	Safety requirements
CFR Title 47	Code of Federal Regulations, Part 2 and Part 15 (Telecommunications, PCS)

Requirements of quality

IEC 60068	Environmental testing
DIN EN 60529	IP codes

SAR requirements specific to handheld mobiles

Mobile phones, PDAs or other handheld transmitters and receivers incorporating a GSM module must be in accordance with the guidelines for human exposure to radio frequency energy. This requires the Specific Absorption Rate (SAR) of handheld MC45 based applications to be evaluated and approved for compliance with national and/or international regulations.

Since the SAR value varies significantly with the individual product design manufacturers are advised to submit their product for approval if designed for handheld operation. For European and US markets the relevant directives are mentioned below. It is the responsibility of the manufacturer of the final product to verify whether or not further standards, recommendations of directives are in force outside these areas.

Products intended for sale on US markets

ES 59005/ANSI C95.1   Considerations for evaluation of human exposure to Electromagnetic Fields (EMFs) from Mobile Telecommunication Equipment (MTE) in the frequency range 30MHz-6GHz

Products intended for sale on European markets

EN 50360   Product standard to demonstrate the compliance of mobile phones with the basic restrictions related to human exposure to electromagnetic fields (300 MHz - 3 GHz)

1.4 Safety precautions

The following safety precautions must be observed during all phases of the operation, usage, service or repair of any cellular terminal or mobile incorporating MC45. Manufacturers of the cellular terminal are advised to convey the following safety information to users and operating personnel and to incorporate these guidelines into all manuals supplied with the product. Failure to comply with these precautions violates safety standards of design, manufacture and intended use of the product. Siemens AG assumes no liability for customer failure to comply with these precautions.

When in a hospital or other health care facility, observe the restrictions on the use of mobiles. Switch the cellular terminal or mobile off, if instructed to do so by the guidelines posted in sensitive areas. Medical equipment may be sensitive to RF energy.

The operation of cardiac pacemakers, other implanted medical equipment and hearing aids can be affected by interference from cellular terminals or mobiles placed close to the device. If in doubt about potential danger, contact the physician or the manufacturer of the device to verify that the equipment is properly shielded. Pacemaker patients are advised to keep their hand-held mobile away from the pacemaker, while it is on.

Switch off the cellular terminal or mobile before boarding an aircraft. Make sure it cannot be switched on inadvertently. The operation of wireless appliances in an aircraft is forbidden to prevent interference with communications systems. Failure to observe these instructions may lead to the suspension or denial of cellular services to the offender, legal action, or both.

Do not operate the cellular terminal or mobile in the presence of flammable gases or fumes. Switch off the cellular terminal when you are near petrol stations, fuel depots, chemical plants or where blasting operations are in progress. Operation of any electrical equipment in potentially explosive atmospheres can constitute a safety hazard.

Your cellular terminal or mobile receives and transmits radio frequency energy while switched on. Remember that interference can occur if it is used close to TV sets, radios, computers or inadequately shielded equipment. Follow any special regulations and always switch off the cellular terminal or mobile wherever forbidden, or when you suspect that it may cause interference or danger.

Road safety comes first! Do not use a hand-held cellular terminal or mobile when driving a vehicle, unless it is securely mounted in a holder for handsfree operation. Before making a call with a hand-held terminal or mobile, park the vehicle.

Handsfree devices must be installed by qualified personnel. Faulty installation or operation can constitute a safety hazard.

SOS

IMPORTANT!
Cellular terminals or mobiles operate using radio signals and cellular networks cannot be guaranteed to connect in all conditions. Therefore, you should never rely solely upon any wireless device for essential communications, for example emergency calls.

Remember, in order to make or receive calls, the cellular terminal or mobile must be switched on and in a service area with adequate cellular signal strength.

Some networks do not allow for emergency calls if certain network services or phone features are in use (e.g. lock functions, fixed dialling etc.). You may need to deactivate those features before you can make an emergency call.

Some networks require that a valid SIM card be properly inserted in the cellular terminal or mobile.

Compliance with FCC guidelines

Fix-mount and mobile devices incorporating MC45 modules must be designed to maintain a minimum separation distance of 20 cm between the antenna and the end user to satisfy RF exposure requirements for mobile transmitting devices.

For portable devices incorporating MC45 modules the manufacturer of the final device is responsible to perform SAR measurements.

2 Product concept

Designed for use on any GSM network in the world, Siemens MC45 is a tri-band GSM/GPRS engine that works on the three frequencies GSM 900 MHz, GSM 1800 MHz and GSM 1900 MHz. MC45 features GPRS multislot class 10 and supports the GPRS coding schemes CS-1, CS-2, CS-3 and CS-4.

To save space on the application platform, MC45 comes as an extremely slim and compact module. This makes it ideally suited for a broad range of mobile computing devices, such as laptops, notebooks, multimedia appliances, and particularly offers easy integration with PDAs, pocket organizers or miniature mobile phones.

The tiny MC45 module incorporates all you need to create high-performance GSM/GPRS solutions: baseband processor, power supply ASIC, complete radio frequency circuit including a power amplifier and antenna interface. The power amplifier is directly fed from the supply voltage BATT+. The MC45 software is residing in a flash memory device. An additional SRAM enables MC45 to meet the demanding requirements of GPRS connectivity.

The physical interface to the cellular application is made through a board-to-board connector. It consists of 50 pins, required for controlling the unit, transferring data and audio signals and providing power supply lines.

MC45 comprises two serial (RS-232) interfaces giving you maximum flexibility for easy integration with the Man-Machine Interface (MMI).

An extremely versatile audio concept offers various audio interfaces, each available on the board-to-board connector: a digital audio interface (DAI) and two analog audio interfaces. This allows you to connect up to three audio devices in any combination, all at the same time. Using AT commands you can easily switch back and forth and select different audio modes.

The external dual-band or triple-band antenna can be connected optionally to a connector on the top side or to a pad on the bottom side.

For battery powered applications, MC45 features a charging control which can be used to charge a Li-Ion battery. The charging circuit must be implemented outside the module on the application platform.

2.1 MC45 key features at a glance

Table 1: MC45 key features

Feature	Implementation
Power supply	Single supply voltage 3.3V – 4.5V
GSM class	Small MS
Frequency bands	• Tri-band EGSM 900, GSM 1800, GSM 1900 • Compliant to GSM Phase 2/2+
Transmit power	• Class 4 (2W) at EGSM900 • Class 1 (1W) at GSM1800 and GSM 1900
GPRS connectivity	• GPRS multi-slot class 10 • GPRS mobile station class B
Temperature range Temperature control and auto switch-off	• Normal operation: -20°C to +55°C • Restricted operation: -25°C to -20°C and +55°C to +70°C • Constant temperature control prevents damage from the module when the specified temperature is exceeded.
DATA *GPRS:* *CSD:* *WAP:*	• GPRS data downlink transfer: max. 85.6 kbps (see Table 2) • GPRS data uplink transfer: max. 21.4 kbps (see Table 2) • Coding scheme: CS-1, CS-2, CS-3 and CS-4 • MC45 supports the two protocols PAP (Password Authentication Protocol) and CHAP (Challenge Handshake Authentication Protocol) commonly used for PPP connections. • Support of Packet Switched Broadcast Control Channel (PBCCH) allows you to benefit from enhanced GPRS performance when offered by the network operators. • CSD transmission rates: 2.4, 4.8, 9.6, 14.4 kbps, non-transparent, V.110 • Unstructured Supplementary Services Data (USSD) support • WAP compliant
SMS	• MT, MO, CB, Text and PDU mode • SMS storage: SIM card plus 25 SMS locations in the mobile equipment • Transmission of SMS alternatively over CSD or GPRS. Preferred mode can be user-defined.
FAX	Group 3: Class 1, Class 2

Feature	Implementation
SIM interface	• Supported SIM card: 3V • External SIM card reader has to be connected via interface connector (note that card reader is not part of MC45)
External antenna	Connected via 50 Ohm antenna connector or antenna pad
Audio interfaces	Two analog audio interfaces, one digital audio interface (DAI)
Speech codec	• Half Rate (ETS 06.20) • Full Rate (ETS 06.10) • Enhanced Full Rate (ETS 06.50 / 06.60 / 06.80)
Two serial interfaces: RS-232(0), RS-232(1)	• 2.65V level, bi-directional bus for AT commands and data • RS-232(0) – full-featured RS-232 interface. Supports RTS0/CTS0 hardware handshake and software XON/XOFF flow control. Multiplex ability according to GSM 07.10 Multiplexer Protocol. • RS-232(1) - 4-wire RS-232 interface. Supports RTS1/CTS1 hardware handshake. • Baud rate: 300bps ... 230kbps on RS-232(0), RS-232(1) • Autobauding: RS-232(0) only: Supported baud rates are 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200, 230400 bps
Phonebook management	Supported phonebook types: SM, FD, LD, MC, RC, ON, ME
SIM Application Toolkit	Supports SAT class 3, GSM 11.14 Release 98
Real time clock	Implemented
Timer function	Programmable via AT command
Physical characteristics	Size: 53 $\pm$0.2 x 34 $\pm$0.2 x 3.5$\pm$0.3 mm Weight: 10g
Firmware upgrade	Firmware upgradable over serial interface and SIM interface
Evaluation kit	The DSB45 Support Box is an evaluation kit designed to test and type approve Siemens cellular engines and provide a sample configuration for application engineering. See Chapter 8 for ordering information.

Table 2: Coding schemes and maximum net data rates over air interface

Coding scheme	1 Timeslot	2 Timeslots	4 Timeslots
CS-1:	9.05 kbps	18.1 kbps	36.2 kbps
CS-2:	13.4 kbps	26.8 kbps	53.6 kbps
CS-3:	15.6 kbps	31.2 kbps	62.4 kbps
CS-4:	21.4 kbps	42.8 kbps	85.6 kbps

Please note that the values stated above are maximum ratings which, in practice, are influenced by a great variety of factors, primarily, for example, traffic variations and network coverage.

2.2 Circuit concept

Figure 1 shows a block diagram of the MC45 module and illustrates the major functional components:

- GSM / GPRS baseband processor
- Power supply ASIC
- Flash
- SRAM
- GSM RF section incl. transceiver and RF power amplifier
- Antenna interface
- Application interface (board-to-board connector)
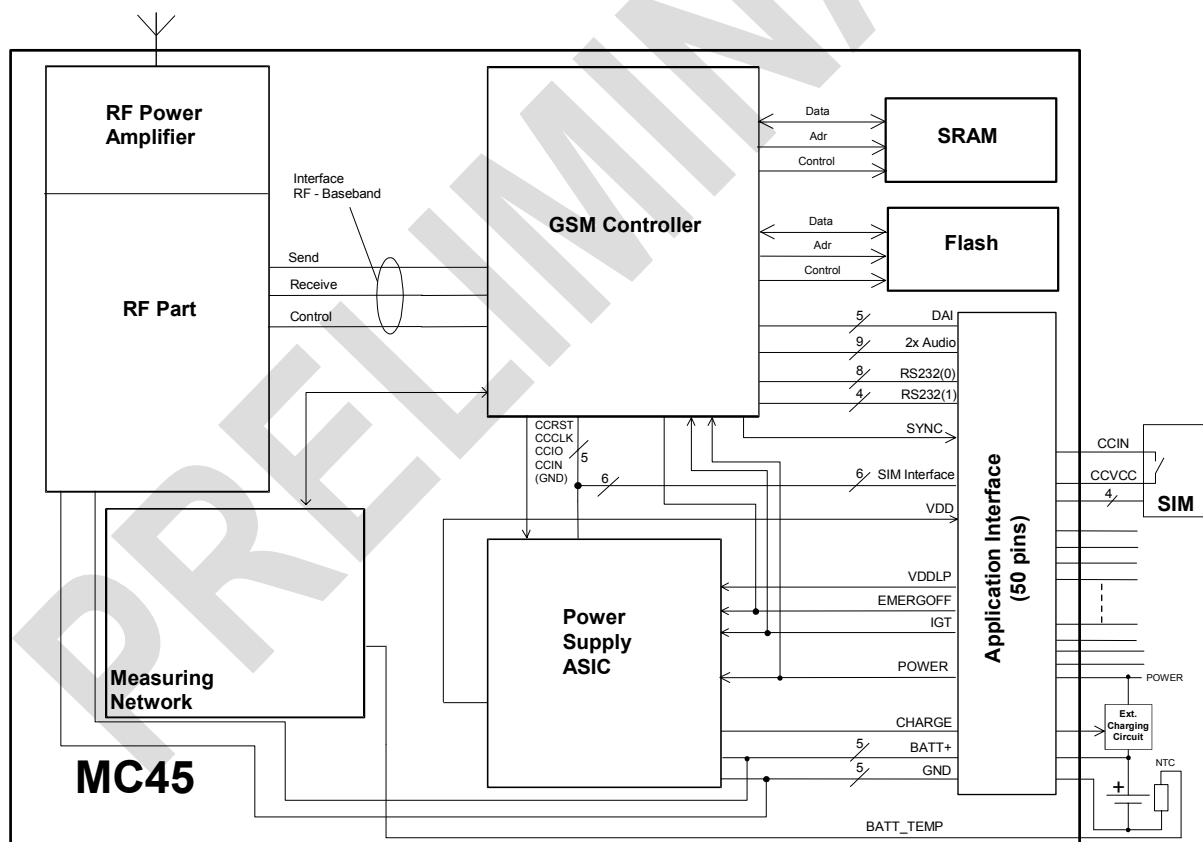
Figure 1: MC45 block diagram

3   Application Interface

MC45 is equipped with a 50-pin 0.5mm pitch board-to-board connector that connects to the cellular application platform. The host interface incorporates several sub-interfaces described in the following chapters:

- Power supply and charging control (see Chapters 3.2 and 3.3)
- Dual serial interface (see Chapter 3.5)
- Two analog audio interfaces and a digital audio interface (see Chapter 3.6)
- SIM interface (see Chapter 3.7)

Electrical and mechanical characteristics of the board-to-board connector are specified in Chapter 5.3. Ordering information for mating connectors and cables are included.

3.1 Operating modes

The table below briefly summarizes the various operating modes referred to in the following chapters.

Table 3: Overview of operating modes

Mode	Function	
Normal operation	GSM / GPRS SLEEP	Various powersave modes set with AT+CFUN command. Software is active to minimum extent. If the module was registered to the GSM network in IDLE mode, it is registered and paging with the BTS in SLEEP mode, too. Power saving can be chosen at different levels: The NON-CYCLIC SLEEP mode (AT+CFUN=0) disables the AT interface. The CYCLIC SLEEP modes AT+CFUN=5, 6, 7 and 8 alternatingly activate and deactivate the AT interfaces to allow permanent access to all AT commands.
	GSM IDLE	Software is active. Once registered to the GSM network, paging with BTS is carried out. The module is ready to send and receive.
	GSM TALK	Connection between two subscribers is in progress. Power consumption depends on network coverage individual settings, such as DTX off/on, FR/EFR/HR, hopping sequences, antenna.
	GPRS IDLE	Module is ready for GPRS data transfer, but no data is currently sent or received. Power consumption depends on network settings and GPRS configuration (e.g. multislot settings).
	GPRS DATA	GPRS data transfer in progress. Power consumption depends on network settings (e.g. power control level), uplink / downlink data rates and GPRS configuration (e.g. used multislot settings).
POWER DOWN	Normal shutdown after sending the AT^SMSO command.	
	The Power Supply ASIC (PSU-ASIC) disconnects the supply voltage from the baseband part of the circuit. Only a voltage regulator in the PSU-ASIC is active for powering the RTC. Software is not active. The RS-232 interfaces are not accessible.	
	Operating voltage (connected to BATT+) remains applied.	

Mode	Function
Alarm mode	Restricted operation launched by RTC alert function while the module is in POWER DOWN mode. Module will not be registered to GSM network. Limited number of AT commands is accessible. If application is battery powered: No charging functionality in Alarm mode.
Charge-only mode	Limited operation for battery powered applications. Enables charging while module is detached from GSM network. Limited number of AT commands is accessible. There are several ways to launch Charge-only mode: • From POWER DOWN mode: Connect charger to the POWER pin of MC45 when engine was powered down by AT^SMSO. • From Normal mode: Connect charger to the POWER pin of MC45, then enter AT^SMSO.
Charge mode during normal operation	Normal operation (SLEEP, IDLE, TALK, GPRS IDLE, GPRS DATA) and charging running in parallel. Charge mode changes to Charge-only mode when the module is powered down before charging has been completed.

See Table 10 and Table 12 for the various options of waking up MC45 and proceeding from one mode to another.

3.2 Power supply

The power supply of MC45 has to be a single voltage source of V_{BATT+}= 3.3V...4.5V. It must be able to provide sufficient current in a transmit burst which typically rises to 2A. Beyond that, the power supply must be able to account for increased current consumption if the module is exposed to inappropriate conditions, for example antenna mismatch. For further details see Chapters 3.2.2 and 6.4.1.

All the key functions for supplying power to the device are handled by an ASIC power supply. The ASIC provides the following features:

- Stabilizes the supply voltages for the GSM baseband using low drop linear voltage regulators.
- Controls the module's power up and s procedures.
  A watchdog logic implemented in the baseband processor periodically sends signals to the ASIC, allowing it to maintain the supply voltage for all digital MC45 components. Whenever the watchdog pulses fail to arrive constantly, the module is turned off.
- Delivers, across the VDD pin, a regulated voltage of 2.9V. The output voltage VDD may be used to supply, for example, an external LED or a level shifter. However, the external circuitry must not cause any spikes or glitches on voltage VDD. This voltage is not available in POWER DOWN mode. Therefore, the VDD pin can be used to indicate whether or not MC45 is in POWER DOWN mode.
- Includes a switch to provide power to the SIM interface.

The RF power amplifier is driven directly from BATT+.

3.2.1 Power supply pins on the board-to-board connector

Five BATT+ pins of the board-to-board connector are dedicated to connect the supply voltage, five GND pins are recommended for grounding. The POWER and CHARGE pins serve as control signals for charging a Li-Ion battery. VDDLP can be used to back up the RTC.

Table 4: Power supply pins of board-to-board connector

Signal name	I/O	Description	Parameter
BATT+	I/O	Positive operating voltage	3.3 V...4.5 V, $I_{typ} \leq 2$ A during transmit burst The minimum operating voltage must not fall below 3.3 V, not even in case of voltage drop.
GND	-	Ground	0 V
POWER	I	This line signalizes to the processor that the charger is connected.	
CHARGE	O	Control signal for external charging transistor	
VDDLP	I/O	Can be used to back up the RTC when V_{BATT+} is not applied. See Chapter 3.4	$U_{OUT.max} < V_{BATT+}$ $U_{IN} = 2.0$ V...5.5 V $R_i = 1k\Omega$ $I_{in,max} = 30\mu A$

3.2.2 Minimizing power losses

When designing the power supply for your application please pay specific attention to power losses. Ensure that the input voltage V_{BATT+} never drops below 3.3 V on the MC45 board, not even in a transmit burst where current consumption can rise to peaks of 2A. It should be noted that MC45 switches off when exceeding these limits. Any voltage drops that may occur in a transmit burst should not exceed 400mV. For further details see Chapter 6.4.

The best approach to reducing voltage drops is to use a board-to-board connection as recommended, and a low impedance power source. The resistance of the power supply lines on the host board and of a battery pack should also be considered.

Note: If the application design requires an adapter cable between both board-to-board connectors, use a flex cable as short as possible in order to minimize power losses.

Example: If the length of the flex cable reaches the maximum length of 200mm, this connection may cause, for example, a resistance of 50mΩ in the BATT+ line and 50mΩ in the GND line. As a result, a 2A transmit burst would add up to a total voltage drop of 200mV. Plus, if a battery pack is involved, further losses may occur due to the resistance across the battery lines and the internal resistance of the battery.
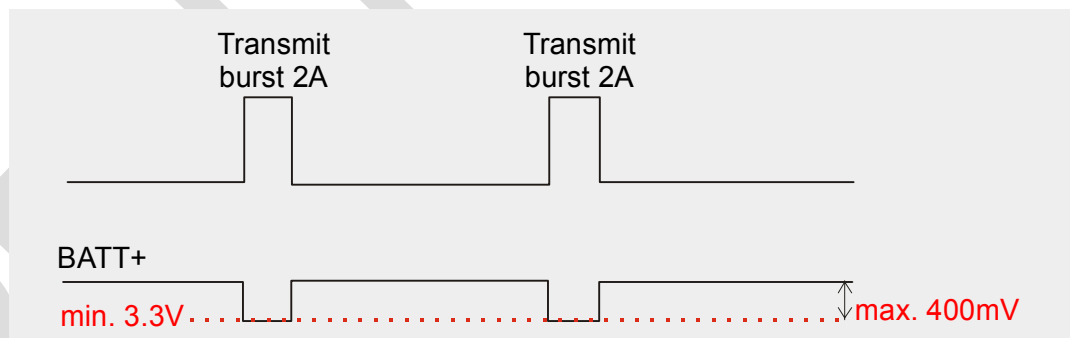
Figure 2: Power supply limits during transmit burst

3.2.3 Charging control

MC45 integrates a charging management for Li-Ion batteries. You can skip this chapter if charging is not your concern, or if you are not using the implemented charging algorithm.

MC45 has no on-board charging circuit. To benefit from the implemented charging management you are required to install a charging circuit within your application. In this case, MC45 needs to be powered from a Li-Ion battery pack, e.g. as specified in Table 6.

The module only delivers, via its POWER line and CHARGE line, the control signals needed to start and stop the charging process. The charging circuit should include a transistor and should be designed as illustrated in Figure 3. A list of parts recommended for the external circuit is given in Table 5.
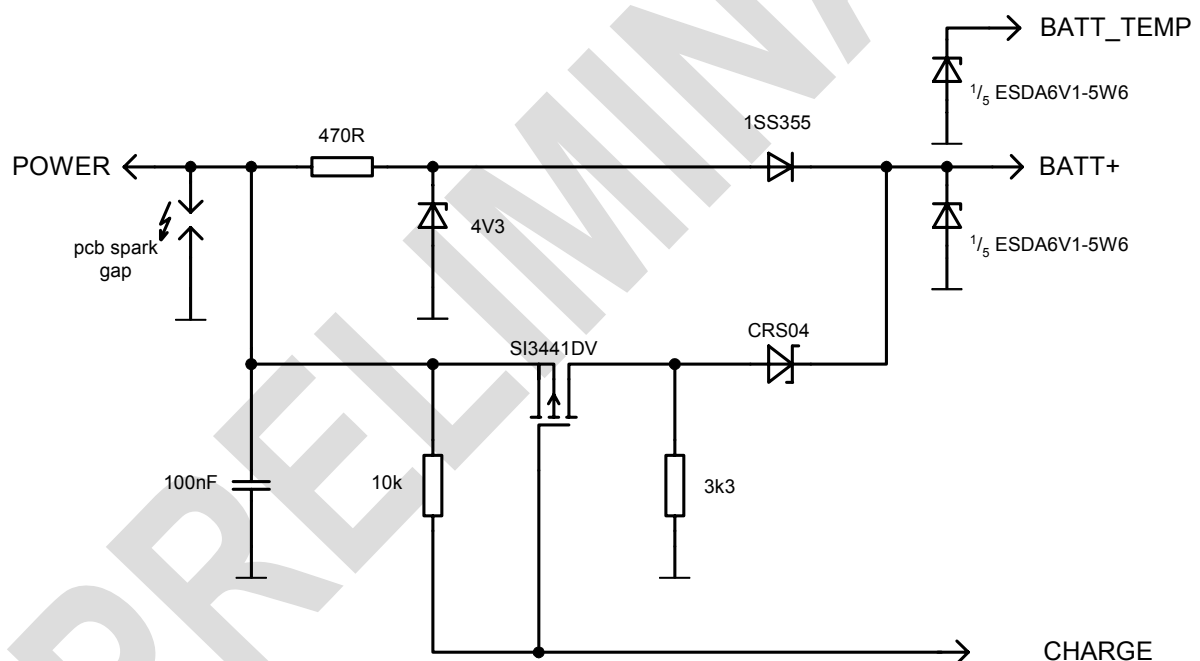
Figure 3: Schematic of approved charging transistor, trickle charging and ESD protection

Table 5: Bill of material for external charging circuit

Part	Description	First supplier	Second supplier
SI3441DV	p-chan 2.5V (G-S) MOSFET (TSOP-6)	VISHAY: SI3441DV-T1	NEC: UPA1911TE-T1
1SS355	100mA Si-diode (UMD2)	ROHM: 1SS355TE-18	Toshiba: 1SS352TPH3
CRS04	1A Shottky diode	Toshiba: CRS04	-
4V3	250mW; 200mA; 4.3V Z-Diode (SOD323)	Philips: PDZ4.3B	ROHM: UDZS4.3B UDZ4.3B
ESDA6V1-5W6	ESD protection transil array	STM: ESDA6V1-5W6	-
470R, 3k3, 10k	Resistor, e.g. 0805 or 0603	-	-
100nF	Ceramic capacitor 50V	-	-
PCB spark gap	0.2mm spark gap on PCB	-	-

3.2.3.1 Battery pack characteristics

The charging algorithm has been optimized for a Li-Ion battery pack that meets the characteristics listed below. It is recommended that the battery pack you want to integrate into your MC45 application is compliant with these specifications. This ensures reliable operation, proper charging and, particularly, allows you to monitor the battery capacity using the AT^SBC command (see [1] for details). Failure to comply with these specifications might cause AT^SBC to deliver incorrect battery capacity values. A battery pack especially designed to operate with MC45 modules is specified in Chapter 3.2.3.2.

- Li-Ion battery pack specified for a maximum charging voltage of 4.2 V and a capacity of 800 mAh. Battery packs with a capacity down to 600 mAh or more than 800 mAh are allowed, too.
- Since charging and discharging largely depend on the battery temperature, the battery pack should include an NTC resistor. If the NTC is not inside the battery it must be in thermal contact with the battery. The NTC resistor must be connected between BATT_TEMP and GND. Required NTC characteristics are: *10 kΩ $\pm$5% @ 25°C, $B_{25/85}$ = 3435K $\pm$3%* (alternatively acceptable: *10 kΩ $\pm$2% @ 25°C, $B_{25/50}$ = 3370K $\pm$3%*). Please note that the NTC is indispensable for proper charging, i.e. the charging process will not start if no NTC is present.
- Ensure that the pack incorporates a protection circuit capable of detecting overvoltage (protection against overcharging), undervoltage (protection against deep discharging) and overcurrent. The circuit must be insensitive to pulsed current.
- On the MC45 module, a built-in measuring circuit constantly monitors the supply voltage. In the event of undervoltage, it causes MC45 to power down. Undervoltage thresholds are specific to the battery pack and must be evaluated for the intended model. When you evaluate undervoltage thresholds, consider both the current consumption of MC45 and of the application circuit.
- The internal resistance of the battery and the protection should be as low as possible. It is recommended not to exceed 150mΩ, even in extreme conditions at low temperature. The battery cell must be insensitive to rupture, fire and gasing under extreme conditions of temperature and charging (voltage, current).
- The battery pack must be protected from reverse pole connection. For example, the casing should be designed to prevent the user from mounting the battery in reverse orientation.
- The battery pack must be approved to satisfy the requirements of CE conformity.

Figure 4 shows the circuit diagram of a typical battery pack design that includes the protection elements described above.
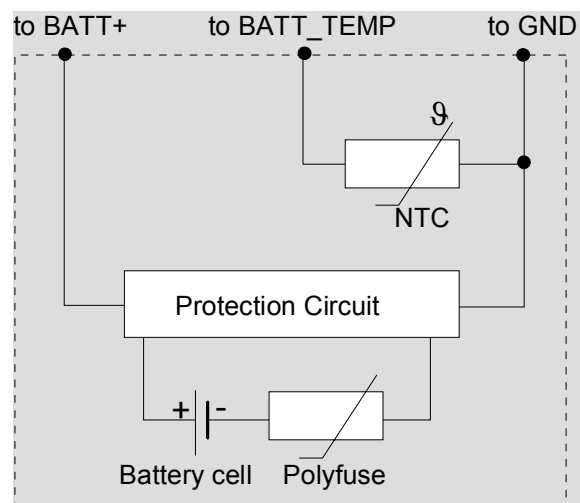
Figure 4: Battery pack circuit diagram

3.2.3.2 Recommended battery pack

The following battery pack has been especially designed for use with MC45 modules.

Table 6: Specifications of XWODA battery pack

Product name, type	XWODA, Li-Ion, 3.6V, 800mAh

Vendor
 	
        To place orders or obtain more information please contact:
	Shenzhen Xwoda Electronic Co., Ltd
	Unit 3003, Yingjingyuan,Zhongdian Garden, Shenzhen 518032
	P.R.China
	
	Contact:
	    Edward Lau or Andy Zhao
	    Phone: +86-755-7623789 ext. 314
	    Fax: +86-755-7623078
	    Email: Edward-lau@xwoda.com.cn
	    Email: Andy-zhao@Xwoda.com.cn

Nominal voltage	3.6V
Capacity	800mAh
NTC	10kΩ ± 5% @ 25°C, B (25/85)=3435K ± 3%
Overcharge detection voltage	4.325 ± 0.025V
Overcharge release voltage	4.075 ± 0.025V
Overdischarge detection voltage	2.5 ± 0.05V
Overdischarge release voltage	2.9 ± 0.5V
Overcurrent detection	3 ± 0.5A
Nominal working current	<5µA
Current of low voltage detection	0.5µA
Overcurrent detection delay time	8~16ms
Short detection delay time	50µs
Overdischarge detection delay time	31~125ms
Overcharge detection delay time	1s
Internal resistance	<130mΩ

3.2.3.3 Implemented charging technique

If the external charging circuit follows the recommendation of Figure 3, the charging process consists of trickle charging and processor controlled fast charging. For this solution, the fast charging current provided by the charger or any other external source must be limited to 500mA.

Trickle charging

- Trickle charging starts when the charger is connected to the POWER pin of the external charging circuit. The charging current depends on the voltage difference between the pins POWER and BATT+ of the external charging circuit.
- Trickle charging stops when the battery voltage reaches 3.6V.

Fast charging

- After trickle charging has raised the battery voltage to 3.2V within 60 minutes $\pm$10% from connecting the charger, the power ASIC turns on and wakes up the baseband processor. Now, processor controlled fast charging begins.
  If the battery voltage was already above 3.2V, processor controlled fast charging starts just after the charger was connected to the POWER pins of the external charging circuit and of the module. If MC45 was in POWER DOWN mode, it turns on and enters the Charge-only mode along with fast charging (see also Chapter 3.3.1.3).
- Fast charging delivers a constant current until the battery voltage reaches 4.2V and then proceeds with varying charge pulses. As shown in Figure 5, the pulse duty cycle is reduced to adjust the charging procedure and prevent the voltage from overshooting beyond 4.2V. Once the pulse width reaches the minimum of 100ms and the duty cycle does not change for 2 minutes, fast charging is completed.
- Fast charging can only be accomplished in a temperature range from 0°C to +45°C.
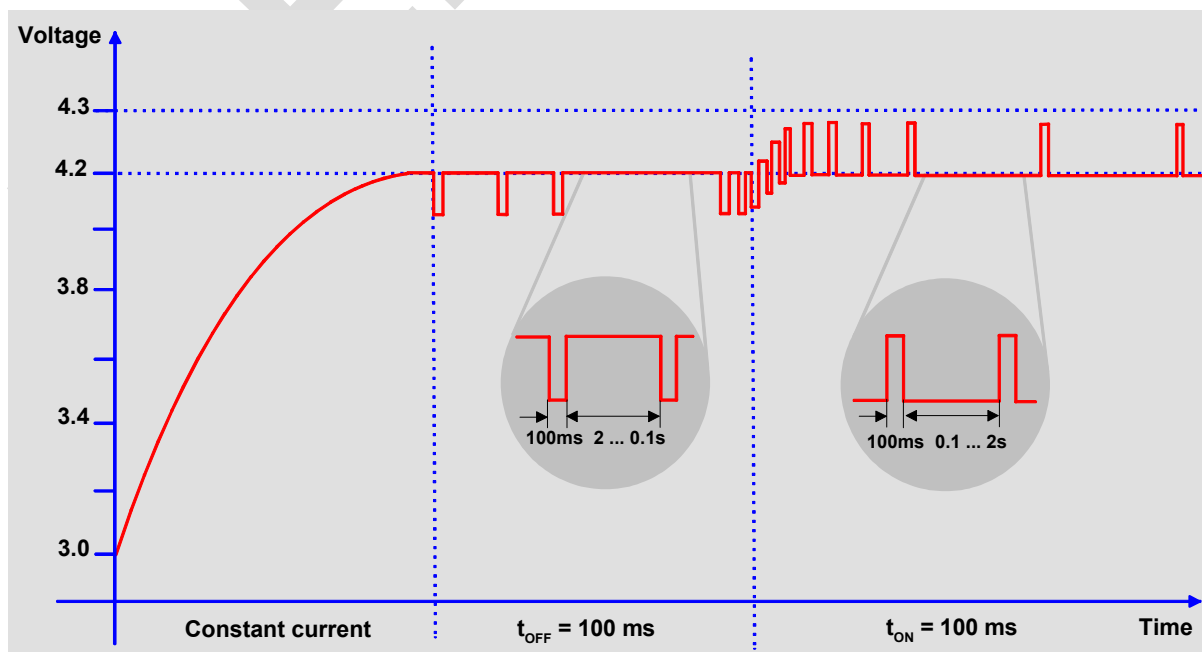
Figure 5: Charging process

Note: *Do <u>not</u> connect the charger to the BATT+ lines. Only the POWER input of the charging circuit is intended as input for charging current! The POWER pin of MC45 is the input only for indicating a connected charger!*
The battery manufacturer must guarantee that the battery complies with the described charging technique.

What to do if software controlled charging does not start up?
If trickle charging fails to raise the battery voltage to 3.2V within 60 minutes ±10%, processor controlled charging does not begin. To start fast charging you can do one of the following:

- Once the voltage has risen above its minimum of 3V, you can try to start software controlled charging by pulling the /IGT line to ground.
- If the voltage is still below 3V, driving the /IGT line to ground switches the timer off. Without the timer running, MC45 will not proceed to software controlled charging. To restart the timer you are required to shortly disconnect and reconnect the charger.

3.2.3.4 Operating modes during charging

Of course, the battery can be charged regardless of the engine's operating mode. When the GSM engine is in Normal mode (SLEEP, IDLE, TALK GPRS IDLE or GPRS DATA mode), it remains operational while charging is in progress (provided that sufficient voltage is applied). The charging process during the Normal mode is referred to as *Charge mode*.

If the charger is connected to the POWER pin while MC45 is in POWER DOWN mode, MC45 goes into *Charge-only* mode.

Table 7: Comparison Charge-only and Charge mode

	How to activate mode	Features
Charge mode	Connecting charger to the POWER pin of MC45 while MC45 is - operating, e.g. in IDLE or TALK mode - in SLEEP mode	- Battery can be charged while GSM engine remains operational and registered to the GSM network. - In IDLE and TALK mode, the RS-232 interface is accessible. AT command set can be used to full extent. - In the NON-CYCLIC SLEEP mode, the RS-232 interface is not accessible at all. During the CYCLIC SLEEP mode it can be used as described in Chapter 3.3.2.3.
Charge-only mode	Connecting charger to the POWER pin of MC45 while MC45 is - in POWER DOWN mode - in Normal mode: Connect charger to the POWER pin of MC45, then enter AT^SMSO. IMPORTANT: While trickle charging is in progress, be sure that the application is switched off. If the application is fed from the trickle charge current the module might be prevented from proceeding to software controlled charging since the current would not be sufficient.	- Battery can be charged while GSM engine is deregistered from GSM network. - Charging runs smoothly due to constant current consumption. - The AT interface is accessible and allows to use the commands listed below.

Features of Charge-only mode

Once the GSM engine enters the Charge-only mode, the AT command interface presents an Unsolicited Result Code (URC) which reads:

^SYSSTART CHARGE-ONLY MODE

Note that this URC will not appear when autobauding was activated (due to the missing synchronization between DTE and DCE upon start-up). Therefore, it is recommended to select a fixed baudrate before using the Charge-only mode.

While the Charge-only mode is in progress, you can only use the AT commands listed in Table 8. For further instructions refer to the AT Command Set supplied with your GSM engine.

Table 8: AT commands available in Charge-only mode

AT command	Use
AT+CALA	Set alarm time
AT+CCLK	Set date and time of RTC
AT^SBC	Monitor charging process
	Note: While charging is in progress, no battery capacity value is available. To query the battery capacity disconnect the charger.
	If the charger connects *externally* to the host device no charging parameters are transferred to the module. In this case, the command cannot be used.
AT^SCTM	Query temperature range, enable/disable URCs to report critical temperature ranges
AT^SMSO	Power down GSM engine

To proceed from Charge-only mode to normal operation, it is necessary to drive the ignition line to ground. This must be implemented in your host application as described in Chapter 3.3.1.1. When the engine is in Alarm mode there is no direct way to start charging, i.e. charging will not begin even though the charger connects to the POWER pin of MC45. See also Chapter 3.3.5 which summarizes the various options of changing the mode of operation.

If your host application uses the SYNC pin to control a status LED as described in Chapter 3.8.2.2, please note that the LED is off while the GSM engine is in Charge-only mode.

3.2.3.5 Charger requirements

If you are using the implemented charging technique and the charging circuit recommended in Figure 3, the charger must be designed to meet the following requirements:

a) Simple transformer power plug
- Output voltage: 5.5V...8V (under load)
- The charge current must be limited to 500mA
- Voltage spikes that may occur while you connect or disconnect the charger must be limited to a maximum of 25V and must not exceed 1ms
- There must not be any capacitor on the secondary side of the power plug (avoidance of current spikes at the beginning of charging)

b) Supplementary requirements for a) to ensure a regulated power supply
- When current is switched off a voltage peak of 10V is allowed for a maximum 1ms
- When current is switched on a spike of 1.6A for 1ms is allowed

3.3 Power up / down scenarios

3.3.1 Turn on MC45

MC45 can be activated in a variety of ways, which are described in the following chapters:
- via ignition line /IGT: starts normal operating state (see Chapters 3.3.1.1 and 3.3.1.2)
- via POWER line: starts charging algorithm (see Chapters 3.2.3.4 and 3.3.1.3)
- via RTC interrupt: starts Alarm mode (see Chapter 3.3.1.4)

3.3.1.1 Turn on MC45 using the ignition line /IGT (Power on)

To switch on MC45 the /IGT (Ignition) signal needs to be driven to ground level for at least 100ms. This can be accomplished using an open drain/collector driver in order to avoid current flowing into this pin.
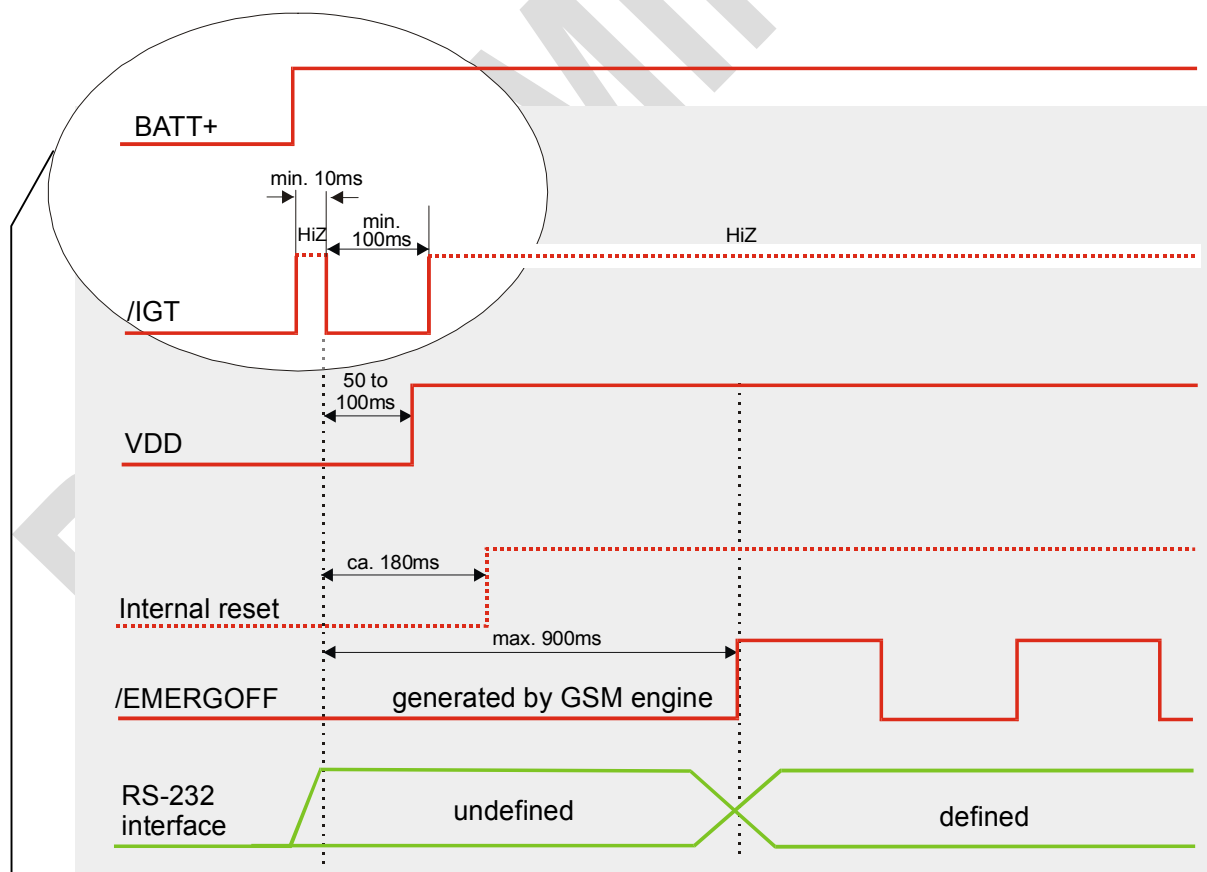
Figure 6: Power-on by ignition signal

If configured to a fix baud rate, MC45 will send the result code ^SYSSTART to indicate that it is ready to operate. This result code does not appear when autobauding is active. See Chapter AT+IPR in [1].

In a battery operated MC45 application, the duration of the /IGT signal must be 1s minimum when the charger is connected and you may want to go from charging to Normal mode.

3.3.1.2 Timing of the ignition process

When designing your application platform take into account that powering up MC45 requires the following steps.

- The ignition line cannot be operated until V_{BATT+} passes the level of 3.0V.
- 10ms after V_{BATT+} has reached 3.0V the ignition line can be switched low. The duration of the falling edge must not exceed 1ms.
- Another 100ms are required to power up the module.
- Ensure that V_{BATT+} does not fall below 3.0V while the ignition line is driven. Otherwise the module cannot be activated.
- If the VDDLP line is fed from an external power supply as explained in Chapter 3.4, the /IGT line is HiZ before the rising edge of BATT+.
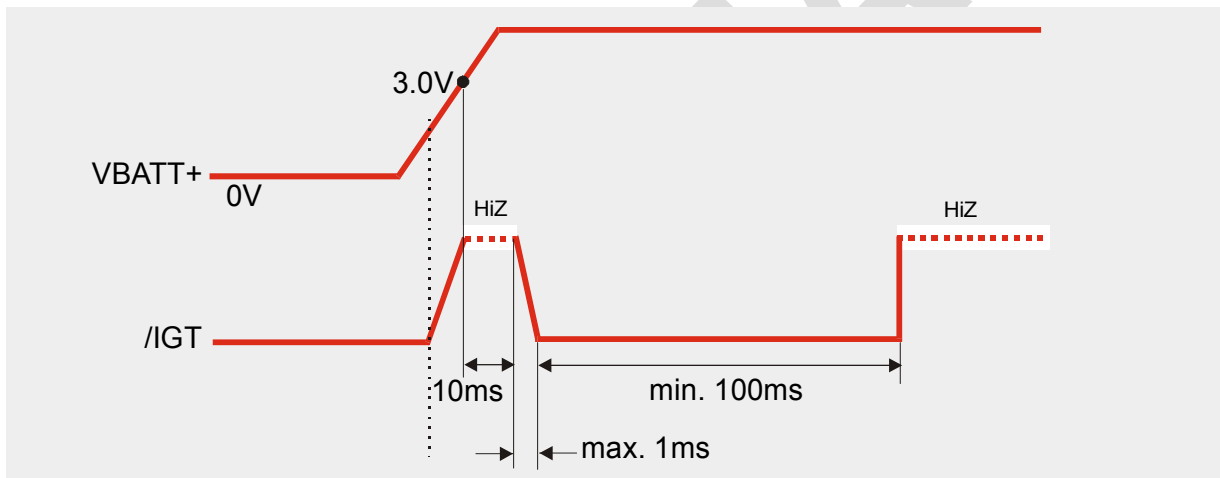
Figure 7: Timing of power-on process if VDDLP is not used
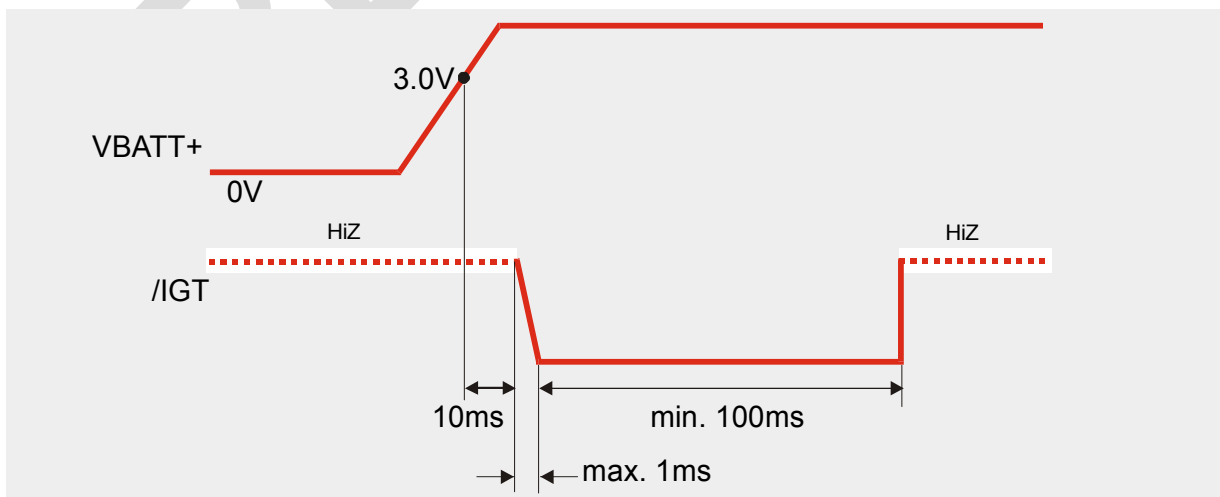
Figure 8: Timing of power-on process if VDDLP is fed from external source

3.3.1.3 Turn on MC45 using the POWER signal

As detailed in Chapter 3.2.3.4, the charging adapter can be connected regardless of the module's operating mode (except for Alarm mode).

If the charger is connected to the POWER pins of the external charging circuit and of the module while MC45 is off, processor controlled fast charging starts (see Chapter 3.2.3.3). MC45 enters a restricted mode, referred to as Charge-only mode where only the charging algorithm will be launched.

During the Charge-only mode MC45 is neither logged on to the GSM network nor is the RS-232 interface fully accessible. To switch to normal operation and log on to the GSM network, the /IGT line needs to be activated.

3.3.1.4 Turn on MC45 using the RTC (Alarm mode)

Another power-on approach is to use the RTC, which is constantly supplied with power from a separate voltage regulator in the power supply ASIC. The RTC provides an alert function which allows to wake up MC45 while power is off. To prevent the engine from unintentionally logging into the GSM network, this procedure only enables restricted operation, referred to as Alarm mode. It must not be confused with a wake-up or alarm call that can be activated by using the same AT command, but without switching off power.

Use the *AT+CALA* command to set the alarm time. The RTC retains the alarm time if MC45 was powered down by AT^SMSO. Once the alarm is timed out and executed, MC45 enters into the Alarm mode. This is indicated by an Unsolicited Result Code (URC) which reads:

    ^SYSSTART ALARM MODE

In Alarm mode only a limited number of AT commands is available. For further instructions refer to the AT Command Set.

Table 9: AT commands available in Alarm mode

AT command	Use
AT+CALA	Set alarm time
AT+CCLK	Set date and time of RTC
AT^SBC	In Alarm mode, you can only query the present current consumption and check whether or not a charger is connected. The battery capacity is returned as 0, regardless of the actual voltage (since the values measured directly on the cell are not delivered to the module).
AT^SCTM	Query temperature range, enable/disable URCs to report critical temperature ranges
AT^SMSO	Power down GSM engine

For the GSM engine to change from the Alarm mode to full operation (normal operating mode) it is necessary to drive the ignition line to ground. This must be implemented in your host application as described in Chapter 3.3.1.1. If your application is battery powered note that charging cannot be started while the engine is in Alarm mode, i.e. charging will not begin even though the charger connects to the POWER line. See also Chapter 3.3.5 which summarizes the various options of changing the mode of operation.

If your host application uses the SYNC pin to control a status LED as described in Chapter 3.8.2.2, please note that the LED is off while the GSM engine is in Alarm mode.

3.3.2 Power saving

SLEEP mode reduces the functionality of the MC45 module to a minimum and, thus, minimizes the current consumption to the lowest level. SLEEP mode is set with the AT+CFUN command which provides the choice of the functionality levels <fun>=0, 1, 5, 6, 7 or 8, all explained below. Further instructions of how to use AT+CFUN can be found in [1].

IMPORTANT: The AT+CFUN command can be executed before or after entering PIN1. Nevertheless, please keep in mind *that power saving works only while the module is registered to the GSM network*. If you attempt to activate power saving while the module is detached, the selected <fun> level will be set, though power saving does not take effect.

To check whether power saving is on, you can query the status of AT+CFUN if you have chosen CYCLIC SLEEP mode. If available, you can take advantage of the status LED controlled by the SYNC pin (see Chapter 3.8.2.2). The LED stops flashing once the module starts power saving.

The wake-up procedures are quite different depending on the selected SLEEP mode. Table 10 compares the wake-up events that can occur in NON-CYCLIC SLEEP mode and in the four CYCLIC SLEEP modes.

3.3.2.1 No power saving (AT+CFUN=1)

The functionality level <fun>=1 is where power saving is switched off. This is the default after startup.

3.3.2.2 NON-CYCLIC SLEEP mode (AT+CFUN=0)

If level 0 has been selected (AT+CFUN=0), the serial interface is blocked. The module shortly deactivates power saving to listen to a paging message sent from the base station and then immediately resumes power saving. Level 0 is called NON-CYCLIC SLEEP mode, since the serial interface is not alternatingly made accessible as in CYCLIC SLEEP mode.

The first wake-up event fully activates the module, enables the serial interface and terminates the power saving mode. In short, it takes MC45 back to the highest level of functionality <fun>=1.

3.3.2.3 CYCLIC SLEEP mode (AT+CFUN=5, 6, 7 and 8)

The functionality levels AT+CFUN=5, AT+CFUN=6, AT+CFUN=7 and AT+CFUN=8 are referred to as CYCLIC SLEEP modes. The major benefit over the NON-CYCLIC SLEEP mode is that the serial interface is not permanently blocked and that packet switched calls may go on without terminating the selected CYCLIC SLEEP mode. This allows MC45 to become active, for example to perform a GPRS data transfer, and to resume power saving after the GPRS data transfer is completed.

The four CYCLIC SLEEP modes give you greater flexibility regarding the wake-procedures: Basically, you can enter AT+CFUN=1 to permanently wake up the module. Also, MC45 can automatically resume power saving, after you have sent or received a short message or made a call. Please refer to Table 10 for more details.

The CYCLIC SLEEP mode is a dynamic process which alternately enables and disables the serial interface. The application must be configured to use hardware flow control. By setting/resetting the /CTS signal, the module indicates to the application when the UART is active. The application must wait until /CTS is set (i.e. is active low) on the physical UART before data can be sent to the module.

The module starts or resumes power saving two seconds (AT+CFUN=5 or AT+CFUN=7) or ten minutes (AT+CFUN=6 or AT+CFUN=8) after the last character was sent or received. It resets the /CTS signal, and after additional 5ms, physically deactivates the UART to save power. See Figure 10.

Note: If both serial interfaces RS-232(0) and RS-232(1) are connected, both are synchronized. Although not explicitly stated, all explanations given in this chapter refer equally to RS-232(0) and RS-232(1), and accordingly to /CTS0 and /CTS1.

3.3.2.4 Timing of the /CTS signal in CYCLIC SLEEP modes

The /CTS signal is enabled in synchrony with the module's paging cycle. It goes active low each time when the module starts listening to a paging message block from the base station. The timing of the paging cycle varies with the base station and can be determined by the following formula:

*4.615 ms (TDMA frame duration) * 51 (number of frames) * DRX value.*

DRX (Discontinuous Reception) is a value from 2 to 9, resulting in paging intervals from 0.47 to 2.12 seconds. The DRX value of the base station is assigned by the network operator.

If DRX $\geq$ 3, i.e. if paging is performed at intervals from 0.71 to 2.12 seconds, each listening period causes the /CTS signal to go active low. If DRX is 2, i.e. if paging is done every 0.47 seconds, the /CTS signal is activated with every 2nd listening period.

The /CTS signal stays active low for 20 ms. This is followed by another 5 ms UART activity. Thus, once the /CTS signal goes active low, you have 25 ms to enter characters. In the pauses between listening to paging messages, while /CTS is high, the module resumes power saving and the AT interface is not accessible. See Figure 9.
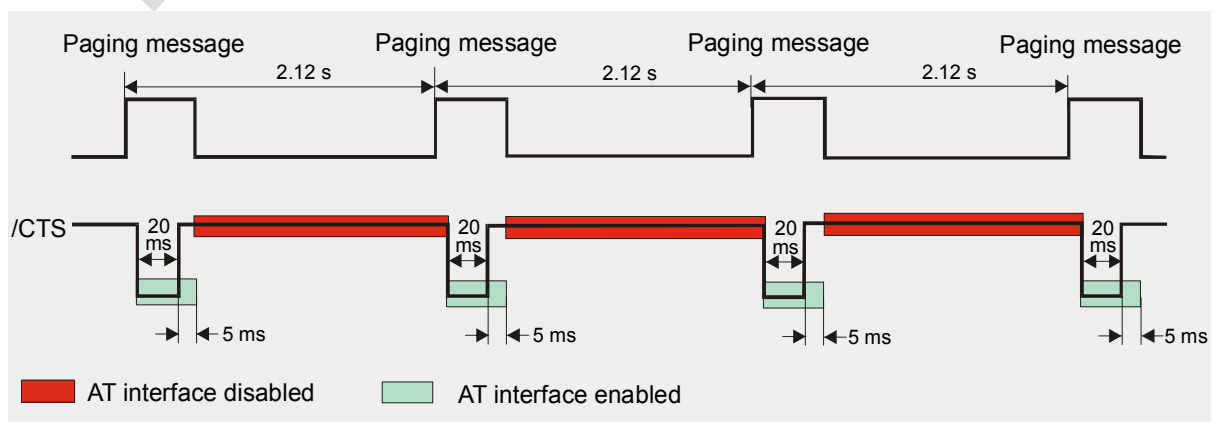
Figure 9: Timing of /CTS signal (example for a 2.12 s paging cycle)

Figure 10 illustrates the CFUN=5 mode, which resets the /CTS signal 2 seconds after the last character was sent or received. The UART is kept active for another 5 ms before power saving begins.
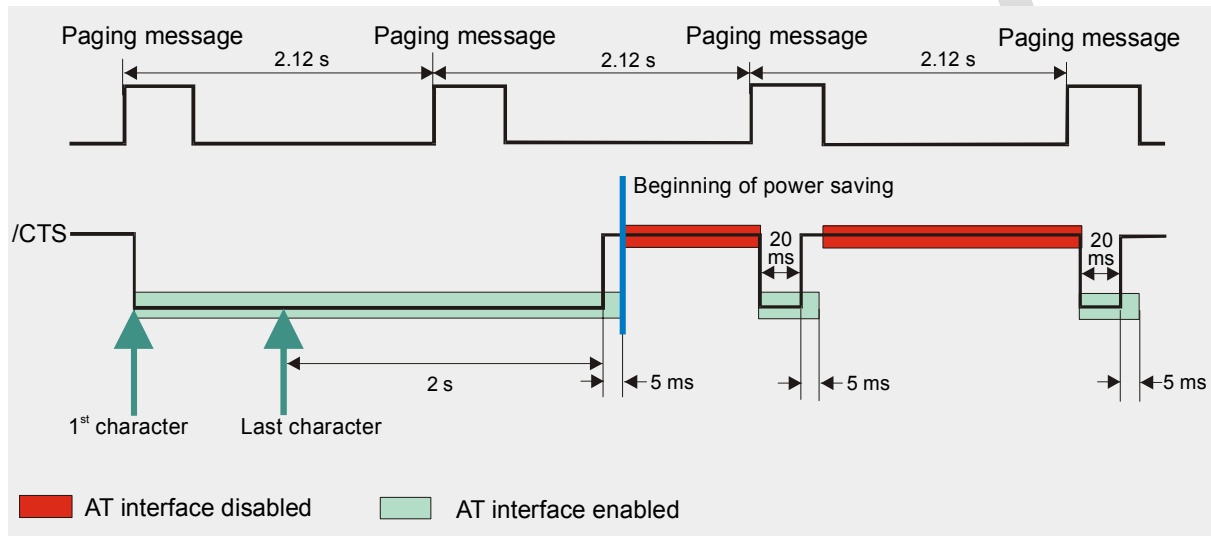
Figure 10: Beginning of power saving if CFUN=5

3.3.2.5 Wake up MC45 from SLEEP mode

A wake-up event is any event that switches off the SLEEP mode and causes MC45 to return to full functionality. In short, it takes MC45 back to AT+CFUN=1.

Definitions of the state transitions described in Table 10:
Yes = MC45 exits SLEEP mode.
No = MC45 does not exit SLEEP mode.

Table 10: Wake-up events in NON-CYCLIC and CYCLIC SLEEP modes

Event	From SLEEP mode AT+CFUN=0 to AT+CFUN=1	From SLEEP mode AT+CFUN=5 or 6 to AT+CFUN=1	From SLEEP mode AT+CFUN=7 or 8 to AT+CFUN=1
Ignition line	No	No	No
/RTS0 or /RTS1 (falling edge)	Yes	No	No
Unsolicited Result Code (URC)	Yes	Yes	No
Incoming voice or data call	Yes	Yes	No
Any AT command (incl. outgoing voice or data call, outgoing SMS)	Not possible (UART disabled)	No	No
Incoming SMS depending on mode selected by AT+CNMI: AT+CNMI=0,0 (= default, no indication of received SMS)	No	No	No
AT+CNMI=1,1 (= displays URC upon receipt of SMS)	Yes	Yes	No
GPRS data transfer	Not possible (UART disabled)	No	No
RTC alarm	Yes	Yes	No
AT+CFUN=1	Not possible (UART disabled)	Yes	Yes

Recommendation:
• In NON-CYCLIC SLEEP mode, you can set an RTC alarm to wake up MC45 and return to full functionality. This is a useful approach because, in this mode, the AT interface is not accessible.

3.3.3 Turn off MC45

To switch the module off the following procedures may be used:

- *Normal shutdown procedure*: Software controlled by sending the AT^SMSO command over the RS-232 application interface. See Chapter 3.3.3.1.

- *Emergency shutdown*: Hardware driven by switching the /EMERGOFF line of the board-to-board connector to ground = immediate shutdown of supply voltages, only applicable if the software controlled procedure fails! See Chapter 3.3.3.2.

- *Automatic shutdown*: Takes effect if undervoltage / overvoltage is detected or if battery or board (engine) temperature exceeds critical limit. See Chapter 3.3.4.

3.3.3.1 Turn off MC45 using AT command

The best and safest approach to powering down MC45 is to issue the *AT^SMSO* command. This procedure lets MC45 log off from the network and allows the software to enter into a secure state and safe data before disconnecting the power supply.

Before switching off the device sends the result code
    ^SMSO: MS is OFF

From this moment on, no further AT commands can be executed. Only the RTC is still active. The mode is referred to as POWER DOWN mode.

While MC45 is in POWER DOWN mode the application interface is switched off and must not be fed from any other source. Therefore, your application must be designed to avoid any current flow into any digital pins of the application interface. POWER DOWN is also signalized by the VDD pin, which in this mode, is off.

3.3.3.2 Emergency shutdown using /EMERGOFF pin

Caution: *Use the /EMERGOFF pin only when, due to serious problems, the software is not responding for more than 5 seconds. Pulling the /EMERGOFF pin causes the loss of all information stored in the volatile memory since power is cut off immediately. Therefore, this procedure is intended only for use in case of emergency, e.g. if MC45 fails to shut down properly.*

The /EMERGOFF signal is available on the board-to-board connector. To control the /EMERGOFF line it is recommended to use an open drain / collector driver. To turn the GSM engine off, the /EMERGOFF line has to be driven to ground for $\geq$ 3.2s.
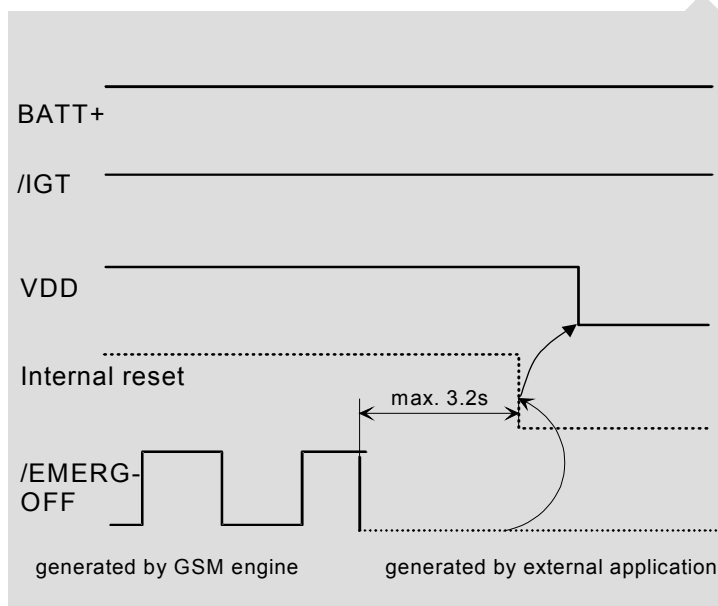
How does it work:

- Voltage V_{batt+} is permanently applied to the module.
- The module is active while the internal reset signal is kept at high level.
  During operation of MC45 the baseband controller generates watchdog pulses at regular intervals.
  Once the EMERGOFF pin is grounded these watchdog pulses are cut off from the power supply ASIC. The power supply ASIC shuts down the internal supply voltages of MC45 after max. 3.2s and the module turns off. Consequently, the output voltage at VDD is switched off.

Figure 11: Deactivating GSM engine by /EMERGOFF signal

3.3.4 Automatic shutdown

To ensure proper operation of all assemblies under varying conditions, such as temperature, input voltage, transmission power etc., MC45 features protection elements for automatic shutdown.

Automatic shutdown takes effect if
- the MC45 board is exceeding the critical limits of overtemperature or undertemperature
- the battery is exceeding the critical limits of overtemperature or undertemperature
- undervoltage is detected
- overvoltage is detected.

The automatic shutdown procedure is equivalent to the power-down initiated with the AT^SMSO command, i.e. MC45 logs off from the network and the software enters a secure state avoiding loss of data. This is not applicable to overvoltage shutdown, where power is cut off immediately.

Alert messages transmitted before the device switches off are implemented as Unsolicited Result codes (URCs). The presentation of these URCs can be enabled or disabled with the two AT commands AT^SBC and AT^SCTM. The URC presentation mode varies with the condition, please see Chapters 3.3.4.1 to 3.3.4.4 for details. For further instructions on AT commands refer to [1].

3.3.4.1 Temperature dependent shutdown

The board temperature is constantly monitored by an internal NTC resistor located on the PCB. The NTC that detects the battery temperature must be part of the battery pack circuit as described in Chapter 3.2.3. The values detected by either NTC resistor are measured directly on the board or battery and therefore, are not fully identical with the ambient temperature.

Proceeding from the measured temperature, MC45 sends an alert in the form of a URC and switches off when exceeding the critical limits:
- URCs indicating the alert level "1" or "-1" allow you to take appropriate precautions, such as protect the module or battery from exposure to extreme conditions, or save or back up data etc. The presentation of the URCs depends on the settings selected with the AT^SCTM write command:
    AT^SCTM=1: Presentation of URCs is always enabled.
    AT^SCTM=0 (default): Presentation of URCs is enabled for 15 seconds time after start-up of MC45. After 15 seconds operation, the presentation will be disabled, i.e. no alert messages can be generated.
- URCs indicating the alert level "2" or "-2" are followed by immediate shutdown. The presentation of these URCs is always enabled, i.e. they will be output even though the factory setting AT^SCTMC=0 was never changed.
- When the temperature is back to normal, again a message will be delivered. In this case, the URC indicates level "0".

Table 11 summarizes the maximum ratings and the associated URCs.

Table 11: Temperature dependent behaviour

Sending temperature alert (15 s after start-up, otherwise only if URC presentation enabled)	
^SCTM_A: 1	Caution: T_{amb} of battery close to overtemperature limit.
^SCTM_B: 1	Caution: T_{amb} of board close to overtemperature limit.
^SCTM_A: -1	Caution: T_{amb} of battery close to undertemperature limit.
^SCTM_B: -1	Caution: T_{amb} of board close to undertemperature limit.
^SCTM_A: 0	Battery back to uncritical temperature range.
^SBCTM_B: 0	Board back to uncritical temperature range.
Automatic shutdown (URC appears no matter whether or not presentation was enabled)	
^SCTM_A: 2	Alert: T_{amb} of battery equal or beyond overtemperature limit. MC45 switches off.
^SCTM_B: 2	Alert: T_{amb} of board equal or beyond overtemperature limit. MC45 switches off.
^SCTM_A: -2	Alert: T_{amb} of battery equal or below undertemperature limit. MC45 switches off.
^SCTM_B: -2	Alert: T_{amb} of board equal or below undertemperature limit. MC45 switches off.

The values stated in Table 11 are based on test conditions according to IEC 60068-2-2 (still air).

3.3.4.2 Undervoltage shutdown if battery NTC is present

In applications where the module's charging technique is used and an NTC is connected to the BATT_TEMP terminal, the software constantly monitors the applied voltage to check that the battery voltage is sufficient to set up a call. When the battery voltage decreases to V_{BATT+}<3.6V, the following URC will be presented:
  ^SBC: Undervoltage

To enable or disable the URC use the AT^SBC command. The URC will be enabled when you enter the write command and specify the power consumption of your GSM application. Step by step instructions are provided in [1].

The message will be reported, for example, when you attempt to set up a call while the voltage is close to the critical limit and further power loss is caused during the transmit burst. To remind you that the battery needs to be charged soon, the URC appears <u>several times</u> before the module switches off.

3.3.4.3 Undervoltage shutdown if no battery NTC is present

The undervoltage protection is also effective in applications, where no NTC connects to the BATT_TEMP terminal. Thus, you can take advantage of this feature even though the application handles the charging process or MC45 is fed by a fixed supply voltage. All you need to do is executing the write command AT^SBC=<current> which automatically enables the presentation of URCs. You do not need to specify <current>.

Please note, that in contrast to applications with an NTC connected to BATT_TEMP, the module will present the URC
  ^SBC: Undervoltage
only <u>once</u> and will then switch off without sending any further messages.

3.3.4.4 Shutdown in the event of overvoltage

Overvoltage protection is implemented in the PSU-ASIC. If the supply voltage raises to $V_{BATT+} > 5.8V$ MC45 switches off automatically. In contrast to undervoltage shutdown

- there is no URC function available
- and the module turns off immediately, i.e. loss of data cannot be avoided.

Remark: The PA is always connected to the supply voltage, also in case of an emergency switch off. A higher supply voltage will destroy the PA.

3.3.5 Summary of state transitions

Table 12: State transitions of MC45

The table shows how to proceed from one mode to another (gray column = present mode, white columns = intended modes)

Further mode ➔➔➔ Present mode	POWER DOWN	Normal mode[**]	Charge-only mode[*]	Charging in normal mode[*][**]	Alarm mode
POWER DOWN mode <u>without</u> charger	---	/IGT >100 ms at low level	Connect charger to POWER (high level at POWER)	No direct transition, but via "Charge-only mode" or "Normal mode"	Wake-up from POWER DOWN mode (if activated with AT+CALA)
POWER DOWN mode with charger (high level at POWER pins of MC45)	---	/IGT (if supply voltage is above 3.0V). No automatic transition, but via POWER DOWN mode without charger	100ms < /IGT < 500ms at low level	/IGT >1 s at low level	Wake-up from POWER DOWN mode (if activated with AT+CALA)
Normal mode[**]	AT^SMSO <u>or</u> exceptionally /EMERGOFF pin > 3.2s at low level	---	No automatic transition, but via "POWER DOWN"	Connect charger to POWER pin at MC45 (high level at POWER)	AT+CALA followed by AT^SMSO. MC45 enters Alarm mode when specified time is reached.
Charge-only mode[*]	Disconnect charger (MC45 POWER pin at low level) <u>or</u> AT^SMSO <u>or</u> exceptionally /EMERGOFF pin ≥3.2s at low level	No automatic transition, but via "Charge in Normal mode"	---	/IGT >1s at low level	AT+CALA followed by AT^SMSO. MC45 enters Alarm mode when specified time is reached and $V_{BATT+} \leq 3.3V$
Charging in normal mode[*][**]	Via "Charge-only mode" <u>or</u> exceptionally /EMERGOFF pin ≥3.2s at low level	Disconnect charger from POWER pin at MC45	AT^SMSO	---	No direct transition
Alarm mode	AT^SMSO <u>or</u> exceptionally /EMERGOFF pin ≥3.2s at low level	/IGT >100ms at low level	No transition	/IGT >100ms at low level	---

[*] See Chapter 3.2.3.4 for details on the charging mode   [**] Normal mode covers TALK, DATA, GPRS, IDLE and SLEEP modes

3.4 RTC backup

The internal Real Time Clock of MC45 is supplied from a separate voltage regulator in the power supply ASIC which is also active when MC45 is in POWER DOWN status. An alarm function is provided for activating and deactivating MC45.

In addition, you can use the VDDLP pin on the board-to-board connector (pin no. 43) to backup the RTC from an external capacitor or a battery (rechargeable or non-chargeable). The capacitor is charged by the BATT+ line of MC45. If the voltage supply at BATT+ is disconnected the RTC can be powered by the capacitor. The size of the capacitor determines the duration of buffering when no voltage is applied to MC45, i.e. the greater capacitor the longer MC45 will save the date and time.

The following figures show various sample configurations. The voltage applied at VDDLP can be in the range from 2 to 5.5V. Please refer to Table 19 for the parameters required.
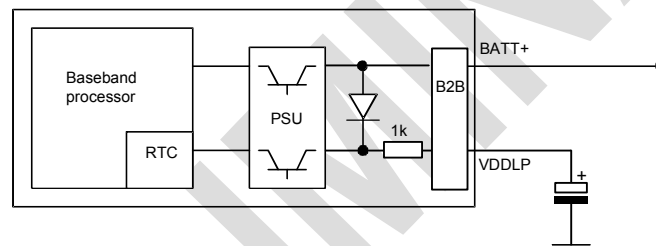
Figure 12: RTC supply from capacitor
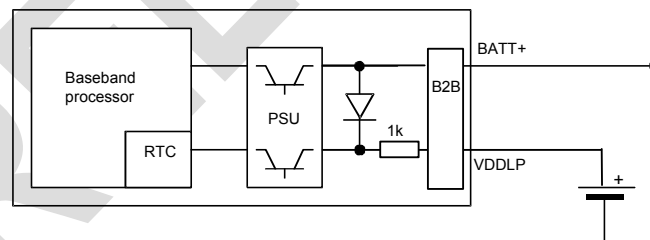
Figure 13: RTC supply from rechargeable battery
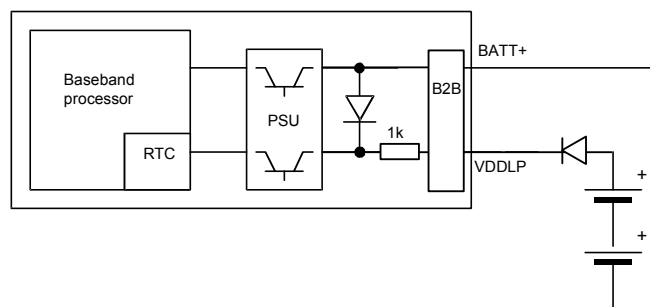
Figure 14: RTC supply from non-chargeable battery

3.5 Serial interfaces

MC45 offers two serial interfaces, each operating at 2.65V level. All RS-232 signals on the board-to-board connector are low active. Both interfaces are implemented as a serial asynchronous transmitter and receiver conforming to ITU-T RS-232 Interchange Circuits DCE.

The GSM engine is designed for use as a DCE. Based on the conventions for DCE-DTE connections it communicates with the customer application (DTE) using the following signals:

RS-232(0)
- Port /TXD @ application sends data to the module's /TXD0 signal line
- Port /RXD @ application receives data from the module's /RXD0 signal line

RS-232(1)
- Port /TXD1 @ application sends data to module's /TXD1 signal line
- Port /RXD1 @ application receives data from the module's /RXD1 signal line
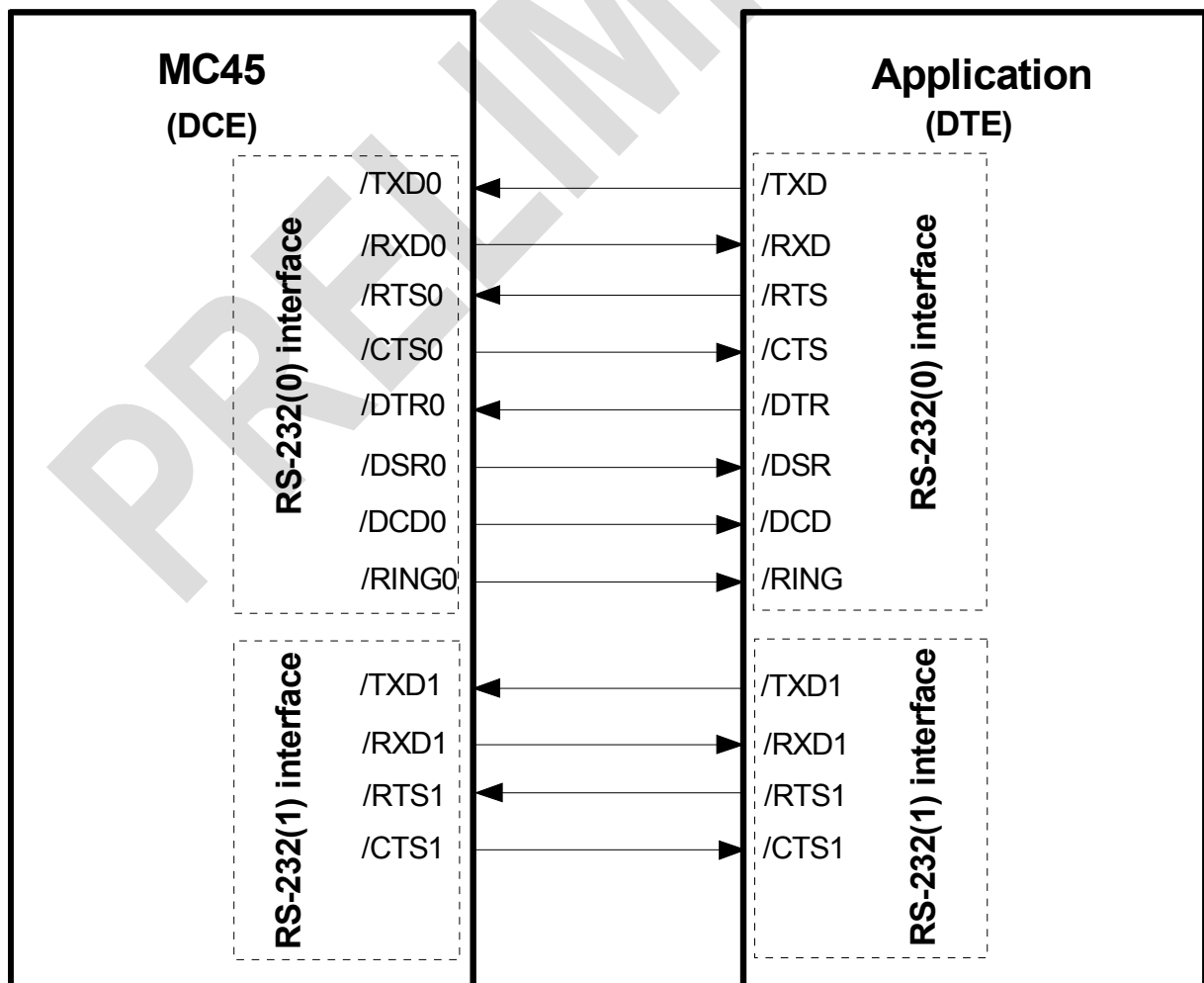
Figure 15: RS-232 interfaces

RS-232(0)

Includes the data lines /TXD0 and /RXD0, the status lines /RTS0 and /CTS0 and, in addition, the modem control lines /DTR0, /DSR0, /DCD0 and /RING0.

It is primarily designed for voice, CSD, fax and GPRS services and for controlling the GSM engine with AT commands. Full Multiplex capability allows the interface to be partitioned into three virtual channels, yet with CSD and fax services only available on the first logical channel. Please note that when the RS-232(0) runs in Multiplex mode, the RS-232(1) cannot be used.

The /DTR0 signal will only be polled once per second from the internal firmware of MC45. The /RING0 signal serves to indicate incoming calls and other types of URCs (Unsolicited Result Code).

RS-232(1)

Includes only the data lines /TXD1 and /RXD1 plus /RTS1 and /CTS1 for hardware handshake. This interface is intended for voice calls, GPRS services and for controlling the GSM engine with AT commands. It is not suited for CSD call, fax calls and Multiplex mode.

When a PPP connection is in progress, no URCs can be displayed. As a result, an incoming call or any other type of URC can only be indicated after the PPP connection was terminated.

Both interfaces are configured for 8 data bits, no parity and 1 stop bit, and can be operated at bit rates from 300bps to 230kbps. Autobauding is only selectable on RS-232(0) and supports the following bit rates: 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200, 230400 bps. XON/XOFF software flow control can be used on both interfaces.

3.6 Audio interfaces

MC45 comprises three audio interfaces available on the board-to-board connector:

- Two analog audio interfaces, each with a balanced analog microphone input and a balanced analog earpiece output. The second analog interface provides a supply circuit to feed an active microphone.
- Serial digital audio interface (DAI) using PCM (Pulse Code Modulation) to encode analog voice signals into digital bit streams.

This means you can connect up to three audio devices in any combination, all at the same time. Using the AT^SAIC command you can easily switch back and forth.
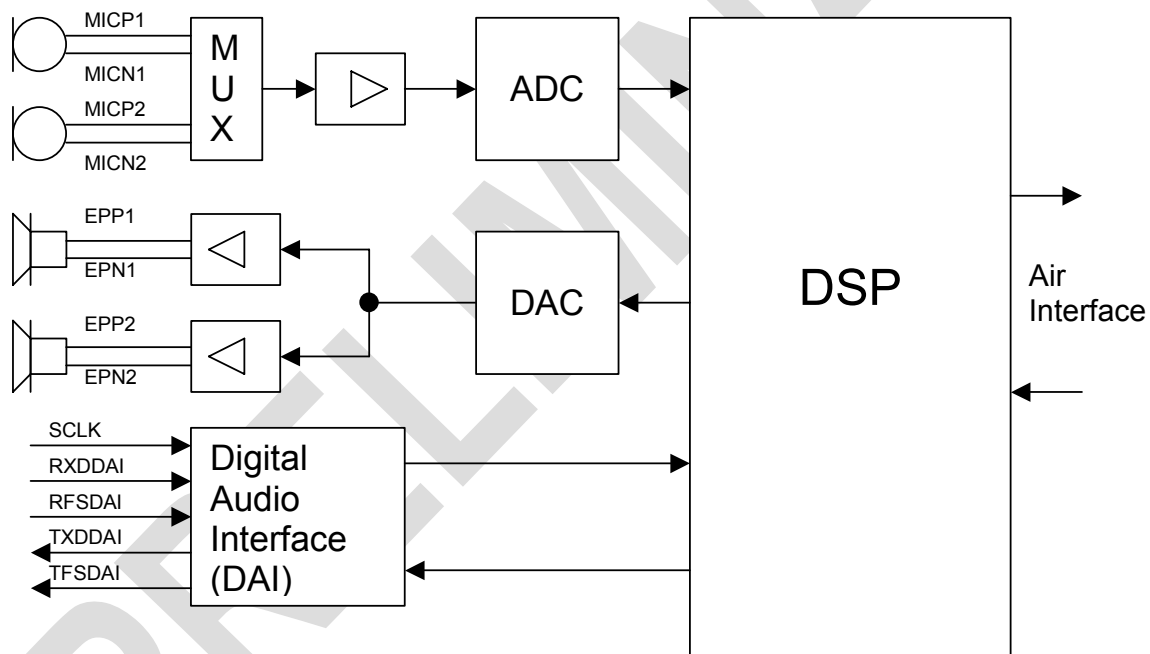
Figure 16: Audio block diagram

MC45 offers six audio modes which can be selected with the AT^SNFS command, no matter which of the three interfaces is currently active. The electrical characteristics of the voiceband part vary with the audio mode. For example, sending and receiving amplification, sidetone paths, noise suppression etc. depend on the selected mode and can be altered with AT commands (except for mode 1).

On each audio interface you can use all audio AT commands specified in [1] to alter parameters. The only exception are the DAC and ADC gain amplifier attenuation <outBbcGain> and <inBbcGain> which cannot be modified when the digital audio interface is used, since in this case the DAC and ADC are switched off.

Please refer to Chapter 6.5 for specifications of the audio interface and an overview of the audio parameters. Detailed instructions on using AT commands are presented in the "MC45 AT Command Set" [1]. Table 31 on page 83 summarizes the characteristics of the various audio modes and shows what parameters are supported in each mode.

When shipped from factory, all audio parameters of MC45 are set to interface 1 and audio mode 1. This is the default configuration optimized for the Votronic HH-SI-30.3/V1.1/0 handset and used for type approving the Siemens reference configuration. Audio mode 1 has fix parameters which cannot be modified. To adjust the settings of the Votronic handset simply change to another audio mode.

3.6.1 Microphone circuit

Interface 1

This interface has no microphone supply circuit and therefore, has an impedance of 50 kΩ. When connecting a microphone or another signal source to interface 1 you are required to add two 100 nF capacitors, one to each line.

Interface 2

This interface comes with a microphone supply circuit and can be used to feed an active microphone. If you do not use it or if you want to connect another type of signal source, for example, an op amp or a dynamic microphone, it needs to be decoupled with capacitors.

Figure 17 shows the microphone inputs at both analog interfaces of MC45.
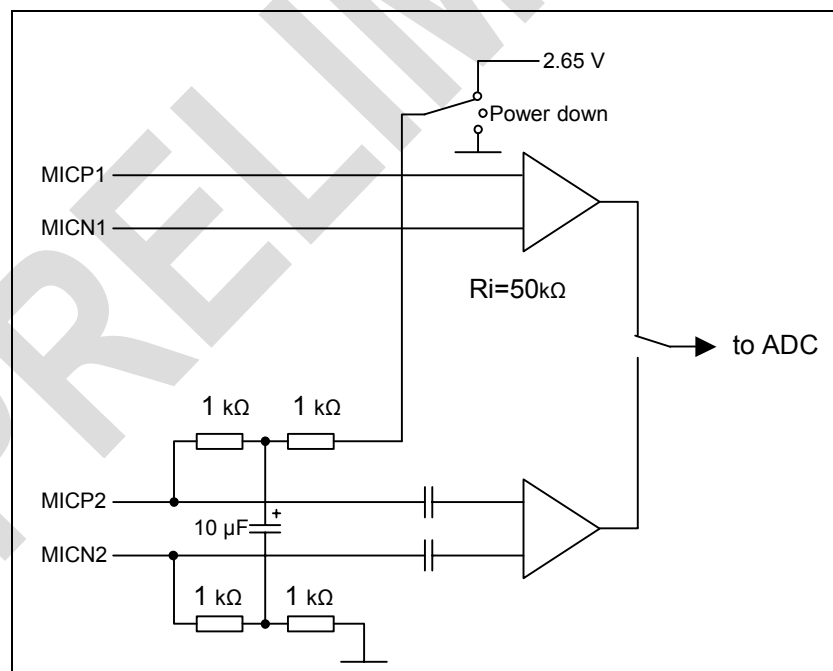
Figure 17: Schematic of microphone inputs

3.6.2 Speech processing

The speech samples from the ADC or DAI are handled by the DSP of the baseband controller to calculate e.g. amplifications, sidetone, echo cancellation or noise suppression depending on the configuration of the active audio mode. These processed samples are passed to the speech encoder. Received samples from the speech decoder are passed to the DAC or DAI after post processing (frequency response correction, adding sidetone etc.).

Full rate, half rate, enhanced full rate, speech and channel encoding including voice activity detection (VAD) and discontinuous transmission (DTX) and digital GMSK modulation are also performed on the GSM baseband processor.

Customer specific audio parameters can be evaluated by Siemens on customer request. These parameters can be downloaded to MC45 using an AT command. For further information refer to [6] or contact your Siemens distributor.

3.6.3 DAI timing

To support the DAI function, MC45 integrates a simple five-line serial interface with one input data clock line (SCLK) and input / output data and frame lines (TXDDAI, TFSDAI, RXDDAI, RFSDAI).

The serial interface is always active if the external input data clock SLCK is present, i.e. the serial interface is not clocked by the DSP of the MC45 baseband processor. SLCK must be supplied from the application and can be in a frequency range between 0.2 and 10 MHz. Serial transfer of 16-bit words is done in both directions.

Data transfer to the application is initiated by the module through a short pulse of TFSDAI. The duration of the TFSDAI pulse is one SCLK period, starting at the rising edge of SLCK. During the following 16 SLCK cycles, the 16-bit sample will be transferred on the TXDDAI line. The next outgoing sample will be transferred after the next TFSDAI pulse which occurs every 125 µs.

The TFSDAI pulse is the master clock of the sample transfer. From the rising edge of the TFSDAI pulse, the application has 100 µs to transfer the 16-bit input sample on the RXDDAI line. The rising edge of the RFSDAI pulse (supplied by the application) may coincide with the falling edge of TFSDAI or occur slightly later - it is only significant that, in any case, the transfer of the LSB input sample will be completed within the specified duration of 100 µs.

Audio samples are transferred from the module to the application in an average of 125µs. This is determined by the 8kHz sampling rate, which is derived from and synchronized to the GSM network. As SLCK is independent of the GSM network, the distance between two succeeding sample transfers may vary about ± 1 SLCK period.

The application is required to adapt its sampling rate to the TFDSDAI rate. Failure to synchronize the timing between the module and the application may cause audible pops and clicks in a conversation The timing characteristics of both data transfer directions are shown in Figure 18 and Figure 19.

Note: *Before starting the data transfer the clock SCLK should be available for at least three cycles.*
After the transfer of the LSB0 the clock SCLK should be still available for at least three cycles.
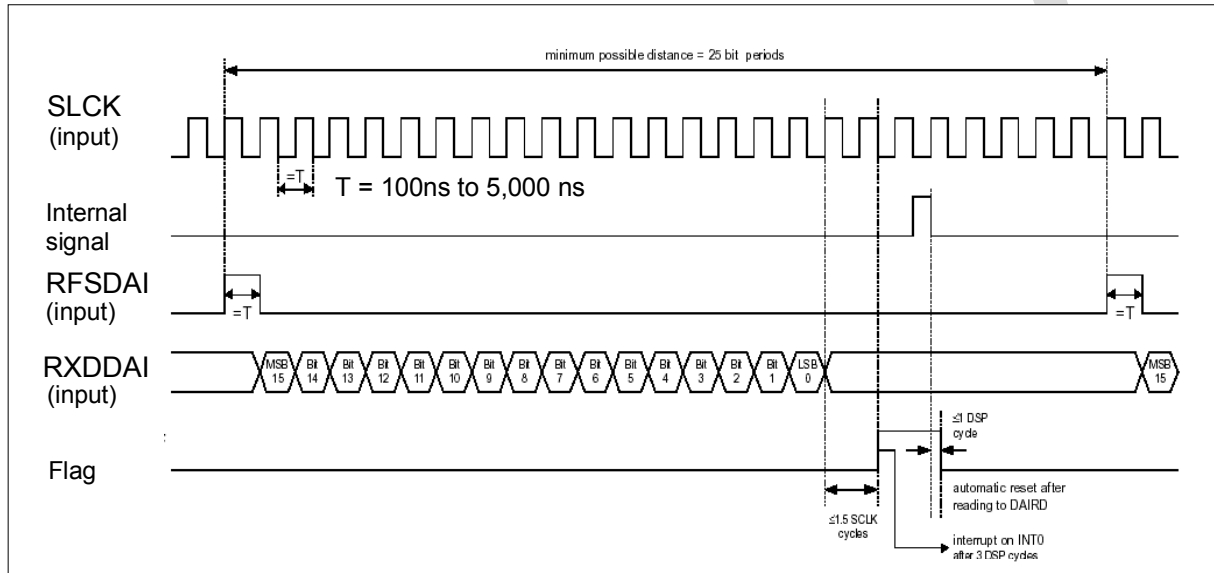
Figure 18: DAI timing on transmit path
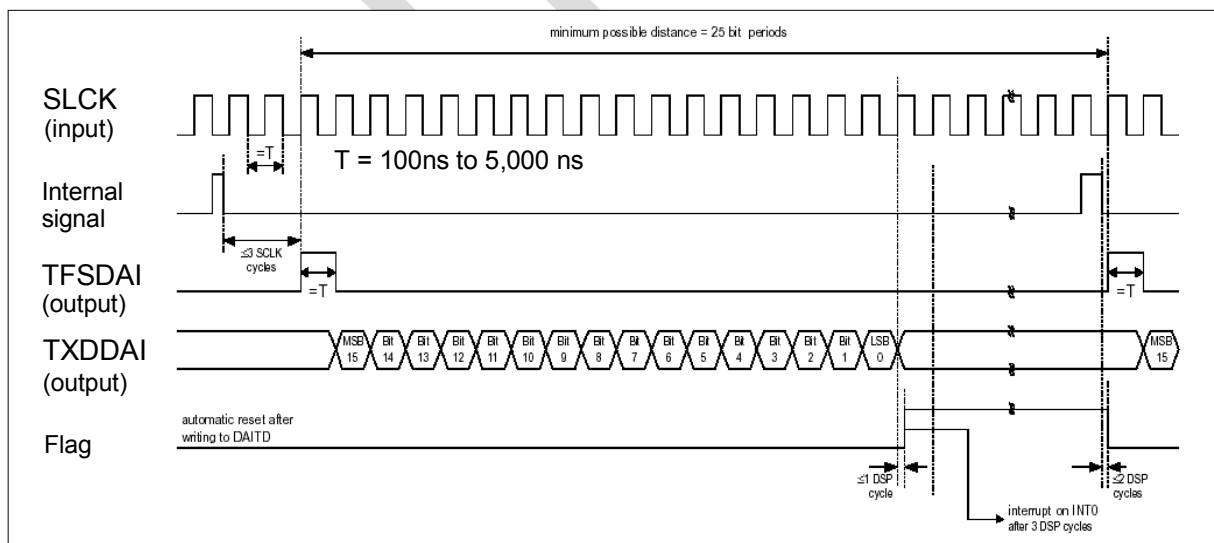
Figure 19: DAI timing on receive path

3.7 SIM interface

The baseband processor has an integrated SIM interface compatible with the ISO 7816-3 IC Card standard. This is wired to the host interface (board-to-board connector) in order to be adapted to an external SIM card holder. Six pins on the board-to-board connector are reserved for the SIM interface. Further to the five wire SIM interface according to GSM 11.11, the CCIN pin has been added. The CCIN pin serves to detect mechanically whether or not a card is present in the card holder.

To take advantage of this feature, an appropriate SIM card detect switch is required on the card holder. For example, this is true for the model supplied by Molex Deutschland GmbH, which has been tested to operate with MC45 and is part of the Siemens reference setup for type approval (Molex ordering number 91228-0001).

It is recommended that the total cable length between the board-to-board connector pins on MC45 and the pins of the card holder does not exceed 200 mm in order to meet the specifications of 3GPP TS 51.010-1 and to satisfy the requirements of EMC compliance.

Note: Before removing the SIM card or inserting a new one be sure that the GSM engine has been powered down as described in Chapter 3.3.3.1. Otherwise, you run the risk of causing damage to the card, or losing data stored on the card.

Table 13: Signals of the SIM interface (board-to-board connector)

Signal name	Description
CCCLK	Chipcard clock, various clock rates can be set in the baseband processor.
CCVCC	SIM supply voltage from PSU-ASIC
CCIO	Serial data line, input and output.
CCRST	Chipcard reset, provided by baseband processor.
CCIN	Input on the baseband processor for detecting the SIM card in the holder; if the SIM card is removed during operation the SIM interface shuts down immediately. This function is implemented to prevent destruction of the SIM card. Nevertheless, inserting or removing the SIM card during operation should be avoided (see Note above). IMPORTANT: The CCIN pin is solely intended for use with a SIM card. It must not be used for any other purposes. Failure to comply with this requirement may invalidate the type approval of MC45.
CCGND	Separate ground connection for SIM card to improve EMC.

3.7.1 Requirements for using the CCIN pin

The module's startup procedure involves a SIM card initialization performed within 1 second after getting started. A most important issue for reliable operation is whether the initialization procedure ends up with a high or low level of the CCIN signal:

a) If, during startup of MC45, the CCIN signal on the SIM interface is high, then the status of the SIM card holder can be recognized each time the card is inserted or ejected. This can be easily achieved when the card holder comprises a card detect switch. The switch causes CCIN to go and stay high when the card is present.
A low level of CCIN indicates that the holder is empty. In this case, the module keeps searching, at regular intervals, for the SIM card. Once the card is inserted, CCIN is taken high again.

b) If, during startup of MC45, the CCIN signal is low, the module will also attempt to initialize the SIM card. In this case, the initialization will only be successful when the card is present.
If the SIM card initialization has been done, but the card is no more operational or removed, then the module will never search again for a SIM card and only emergency calls can be made.

It is strongly recommended to connect the contacts of the SIM card detect switch to the CCIN input and to the CCVCC output of the module as illustrated in the sample diagram in Figure 20. The additional switch in the CCIN line shown in Figure 20 is intended for debugging purposes only and is, normally, not required in your application.

In special cases, the CCIN signal might be controlled by the host application. If so, be sure that the CCIN signal is low while the output voltage VDD is low, too. In particular, no voltage may be applied at the CCIN input, when MC45 is in POWER DOWN mode. Otherwise, proper operation of MC45 may be affected due to an electric leakage current flowing through the CCIN pin into the module.

3.7.2 Design considerations for SIM card holder

The schematic below is a sample configuration that illustrates the Molex SIM card holder located on the DSB45 Support Box (evaluation kit used for type approval of the Siemens MC45 reference setup, see [4]). X503 is the designation used for the SIM card holder in [4].
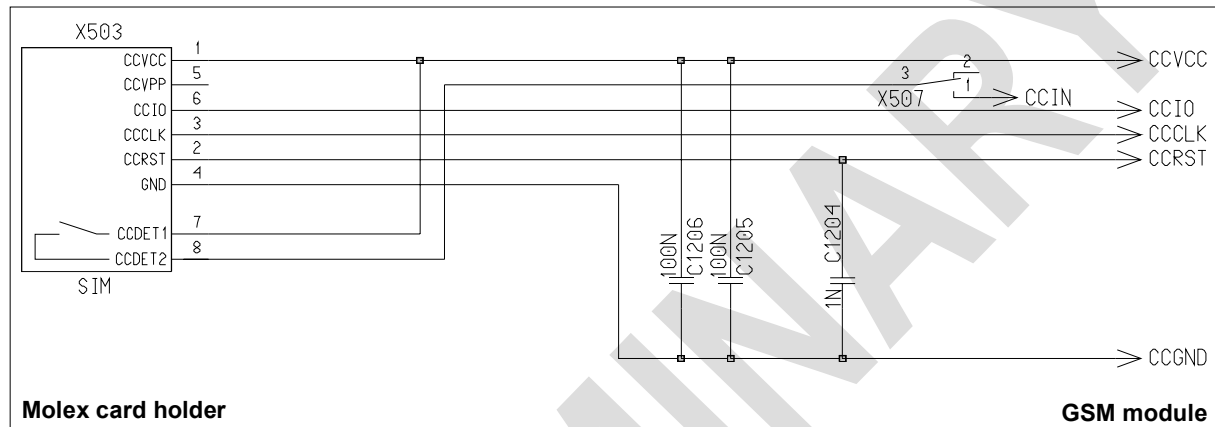
Figure 20: SIM card holder of DSB45 Support Box

Table 14 : Pin assignment of Molex SIM card holder on DSB45 Support Box

Pin no.	Signal name	I/O	Function
1	CCVCC	I	Supply voltage for SIM card, generated by the GSM engine
2	CCRST	I	Chip card reset, prompted by the GSM engine
3	CCCLK	I	Chip card clock
4	CCGND	-	Individual ground line for the SIM card to improve EMC
5	CCVPP	-	Not connected
6	CCIO	I/O	Serial data line, bi-directional
7	CCDET1	-	Connect to CCVCC
8	CCDET2		Connects to the CCIN input of the GSM engine. Serves to recognize whether a SIM card is in the holder. Removing the SIM card during operation will immediately stop further transmission of signals to the card to protect the card from damage.

Pins 1 through 6 are the minimum requirement according to the GSM Recommendations, while 7 and 8 are needed for the CCIN pin.

Place the capacitors C1205 and C1206 (or instead one capacitor of 200nF) as close as possible to the pins 1 (CCVCC) and 4 (GND) of the card holder. Connect the capacitors to the pins via low resistance tracks.

The X507 switch is not mandatory, but may be added to help the system integrator control the CCIN signal, e.g. for designing and testing purposes. When the switch is pushed open (3 is switched to 2), the line simulates an empty SIM card holder although the SIM is inserted. When closed (3 connected to 1), the line simulates that the SIM card is present.

3.7.3 Grounding the SIM interface

To ground the SIM interface you can proceed from several approaches, depending on your individual application design. The following information is just one of several options you can apply:

Potential equalization can best be achieved by applying a separate ground for the SIM interface. For example, the PCB of your application platform may be designed to include an extra ground plane for the SIM card reader, rather than connecting the CCGND pin of the board-to-board connector to the central ground on your application platform. For the SIM card ground plane, you can choose a capacitive or inductive coupling or a zero Ohm bridge. Often, a combination of capacitive and inductive coupling will yield best results.

It depends on your actual layout where to place these lines. For ease of planning and designing, you can simply place the required footprints at each side of the ground plane. This gives you the flexibility, when you test your equipment for ESD and EMC protection, to decide which of them to use, if at all.
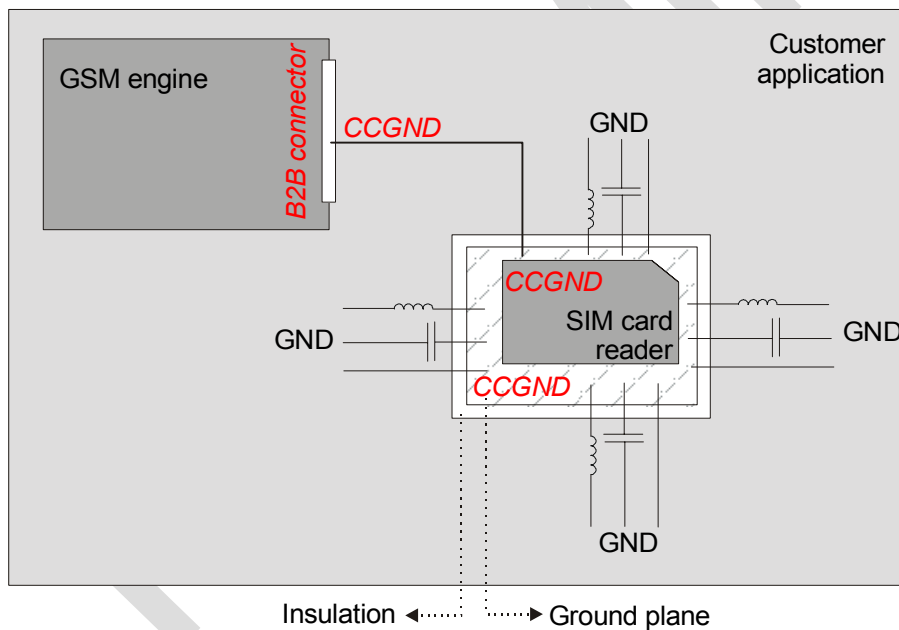
Notes:
This figure is only a simplified example to give you an idea where to place the lines.

One capacitive / inductive coupling will do, if needed at all.

Figure 21: Connecting a separate ground for SIM interface

3.8 Control signals

The following control signals are available (2.65V level).

3.8.1 Inputs

Table 15: Input control signals of the MC45 module

Signal	Pin	Pin status	Function	Remarks
Ignition	/IGT	Falling edge	Power up MC45	Active low $\geq$ 100ms (Open drain/collector driver to GND required in cellular device application). Note: If a charger and a battery is connected to the customer application the /IGT signal must be 1s minimum.
		Left open or HiZ	No operation	
Emergency shutdown	/EMERG-OFF	Low	Power down MC45	Active low $\geq$ 3.2s (Open drain/collector driver required in cellular device application). At the /EMERGOFF signal the watchdog signal of the GSM engine can be traced (see description in Table 19).
		Left open or HiZ	No operation	

(HiZ = high impedance)

3.8.2 Outputs

3.8.2.1 Synchronization signal

The synchronization signal serves to indicate growing power consumption during the transmit burst. The signal is generated by the SYNC pin (pin number 32). Please note that this pin can adopt two different operating modes which you can select by using the AT^SSYNC command (mode 0 and 1). For details refer to the following chapter and to the "AT Command Set".

To generate the synchronization signal the pin needs to be configured to mode 0 (= default). This setting is recommended if you want your application to use the synchronization signal for better power supply control. Your platform design must be such that the incoming signal accommodates sufficient power supply to the MC45 module if required. This can be achieved by lowering the current drawn from other components installed in your application. The characteristics of the synchronization signal are explained below.

Table 16: MC45 synchronization signal (if SYNC pin is set to mode 0 via AT^SSYNC)

Function	Pin	Pin status	Description
Synchronization	SYNC	Low	No operation
		High	Indicates increased power consumption during transmission.
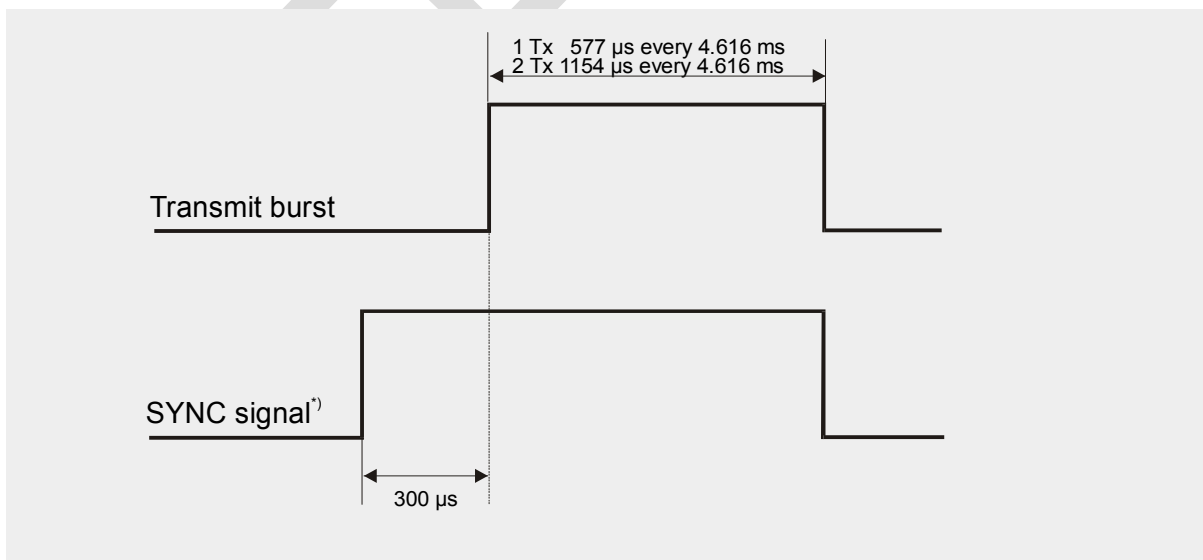
Figure 22: SYNC signal during transmit burst

*) The duration of the SYNC signal is always equal, no matter whether the traffic or the access burst are active.

3.8.2.2 Using the SYNC pin to control a status LED

As an alternative to generating the synchronization signal, the SYNC pin can be used to control a status LED on your application platform.

To avail of this feature you need to set the SYNC pin to mode 1 by using the AT^SSYNC command. For details see the "AT Command Set".

When controlled from the SYNC pin the LED can display the functions listed in Table 17.

Table 17: Coding of the status LED

LED mode	Operating status
Off	MC45 is off or run in SLEEP, Alarm or Charge-only mode
600 ms On / 600ms Off	No SIM card inserted or no PIN entered, or network search in progress, or ongoing user authentication, or network login in progress.
75 ms On / 3 s Off	Logged to network (monitoring control channels and user interactions). No call in progress.
75 ms on / 75 ms Off / 75 ms On / 3 s Off	One or more GPRS contexts activated.
Flashing	Indicates GPRS data transfer: When a GPRS transfer is in progress, the LED goes on within 1 second after data packets were exchanged. Flash duration is approximately 0.5 s.
On	Depending on type of call: *Voice call:* Connected to remote party. *Data call:* Connected to remote party or exchange of parameters while setting up or disconnecting a call.

LED Off = SYNC pin low. LED On = SYNC pin high (if LED is connected as illustrated in Figure 23)

To operate the LED a buffer, e.g. a transistor or gate, must be included in your application. A sample configuration can be gathered from Figure 23. Power consumption in the LED mode is the same as for the synchronization signal mode. For details see Table 19, SYNC pin.
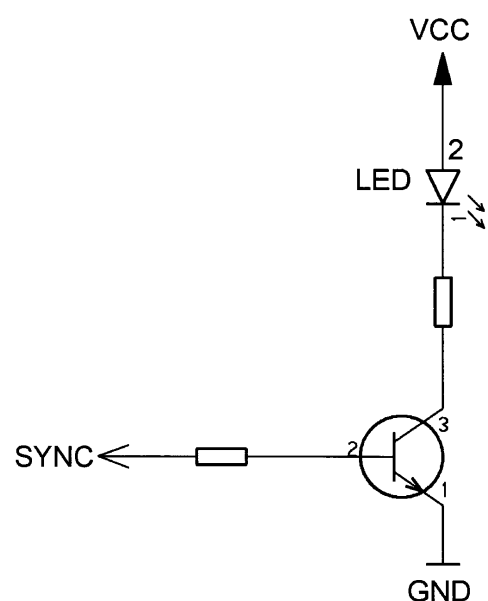
Figure 23: LED Circuit (Example)

3.8.2.3 Behaviour of the /RING0 line (RS-232(0) interface only)

The /RING0 line is available on the RS-232(0) interface. Its behaviour depends on the type of the call received.

- When a *voice call* comes in the /RING0 line goes low for 1s and high for another 4s. Every 5 seconds the ring string is generated and sent over the /RXD0 line.
  If there is a call in progress and call waiting is activated for a connected handset or handsfree device, the /RING0 line switches to ground in order to generate acoustic signals that indicate the waiting call.
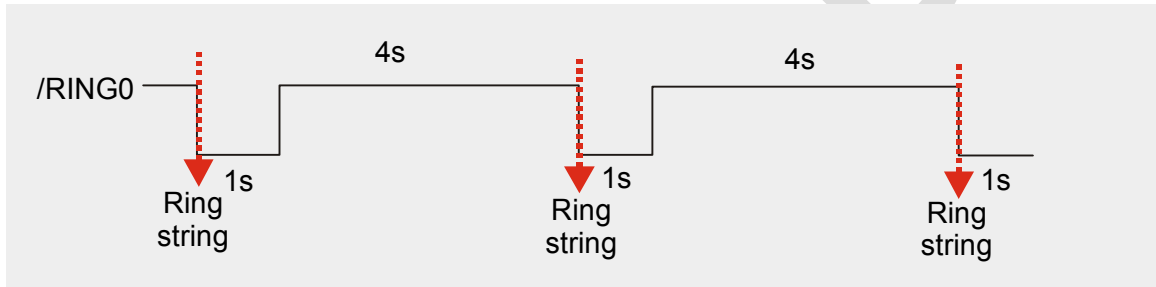
Figure 24: Incoming voice call

- Likewise, when a *Fax* or *data call* is received, /RING0 goes low. However, in contrast to voice calls, the line remains low. Every 5 seconds the ring string is generated and sent over the /RXD0 line.
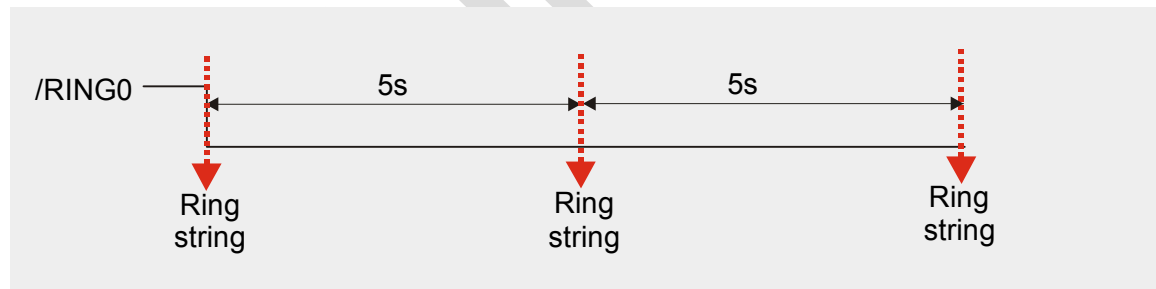
Figure 25: Incoming data call

- All types of unsolicited result codes (URCs) also cause the /RING0 line to go low, however for 1 second only.
  For example, the GSM engine may be configured to output a URC upon the receipt of an SMS. As a result, if this URC type was activated with *AT+CNMI=1,1*, each incoming SMS causes the /RING0 line to go low.
  For more detailed information on URCs please refer the "MC45 AT Command Set".
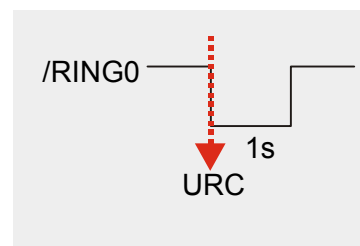
Table 18: MC45 ring signal

Function	Pin	Status	Description
Ring indication	/RING0	0	Indicates an incoming call or URC. If in SLEEP mode, the cellular device application is caused to wake up.
		1	No operation

3.9 Electrical specifications of the application interface

Please note that the reference voltages listed in Table 14 are the values measured directly on the MC45 module. They do not apply to the accessories connected.

If an input pin is specified for $V_{i,h,max}$ = 3.3V, be sure never to exceed the stated voltage. The value 3.3V is an absolute maximum rating.

The Hirose DF12C board-to-board connector on MC45 is a 50-pin double-row receptacle. The names and the positions of the pins can be seen from Figure 26 which shows the top view of MC45.

26	BATT+	GND	25
	BATT+	GND	
	BATT+	GND	
	BATT+	GND	
	BATT+	GND	
	VDD	CHARGE	
	/RING0	POWER	
	/DSR0	VDDLP	
	/RTS0	/TXD0	
	/DTR0	/TXD1	
	/RTS1	RXD0	
	/CTS0	RXD1	
	/CTS1	SYNC	
	/DCD0	BATT_TEMP	
	/EMERGOFF	RFSDAI	
	/IGT	TXDDAI	
	GND	SCLK	
	MICN1	TFSDAI	
	MICP1	RXDDAI	
	MICP2	CCGND	
	MICN2	CCIN	
	EPN1	CCRST	
	EPP1	CCIO	
	EPP2	CCVCC	
50	EPN2	CCCLK	1
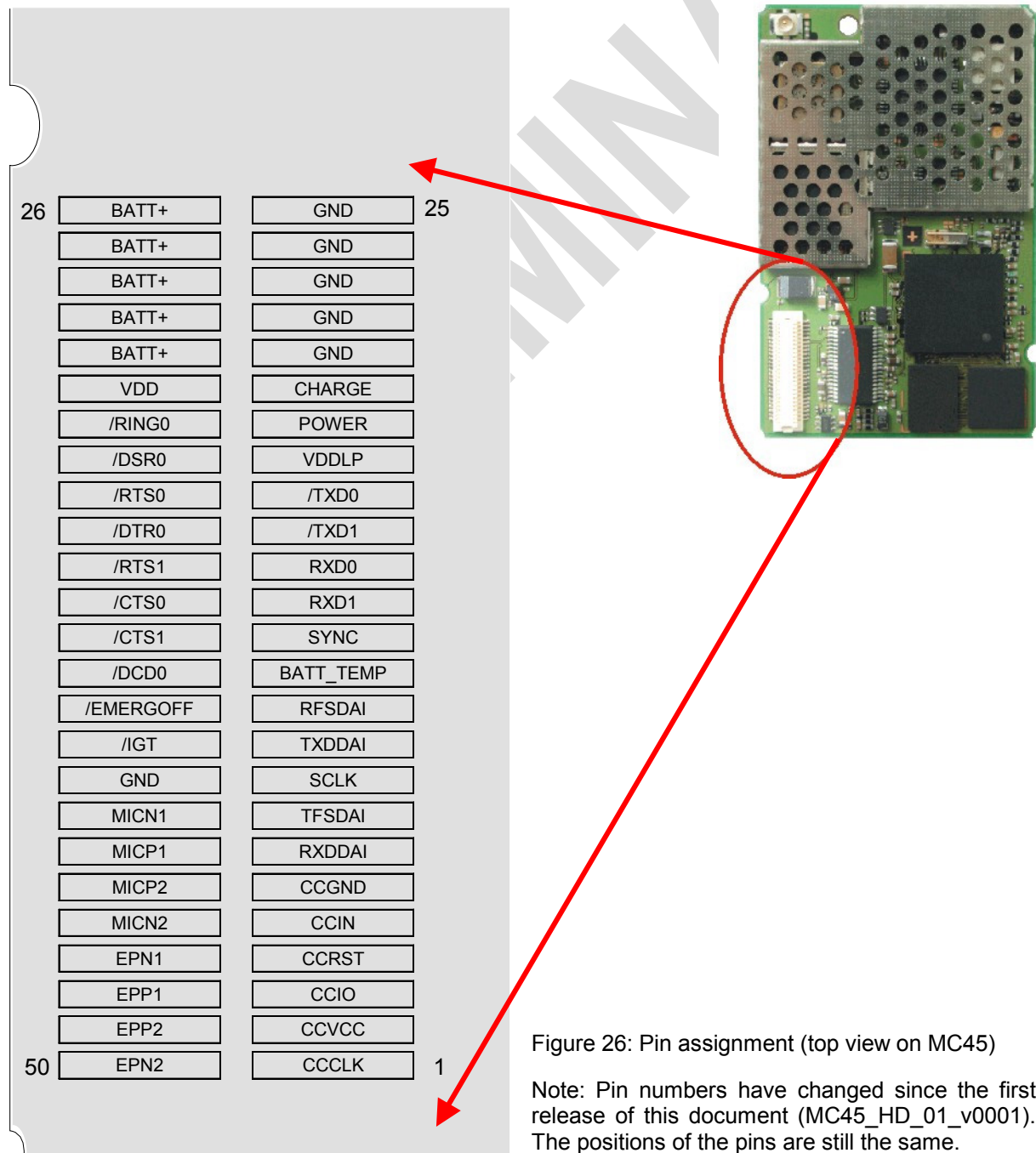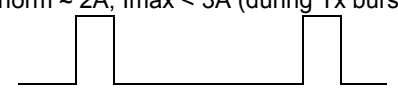
Figure 26: Pin assignment (top view on MC45)
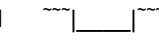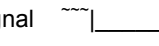
Note: Pin numbers have changed since the first release of this document (MC45_HD_01_v0001). The positions of the pins are still the same.

Table 19: Pin assignment and electrical description of application interface

Function	Signal name	IO	Signal form and level	Comments
Power supply	BATT+	I	V_I = 3.3V to 4.5V $V_I$norm = 4.1V Inorm ≈ 2A, Imax < 3A (during Tx burst) 1 Tx, peak current 577µs every 4.616ms 2 Tx, peak current 1154µs every 4.616ms	Power supply input. 5 BATT+ pins to be connected in parallel. 5 GND pins to be connected in parallel. The power supply must be able to meet the requirements of current consumption in a Tx burst (up to 3A). Sending with two timeslots doubles the duration of current pulses to 1154µs (every 4.616ms)!
	GND			
Charge interface	POWER	I	$V_I$min = 3.0V $V_I$max = 15V	This line signalizes to the processor that the charger is connected. If unused keep pin open.
	BATT_TEMP	I	Connect NTC with R_{NTC} ≈ 10kΩ @ 25°C to ground.	Input to measure the battery temperature over NTC resistor. NTC should be installed inside or near battery pack to enable the charging algorithm and deliver temperature values. If unused keep pin open.
	CHARGE	O	I_{CHARGE} = -300µA ... -600µA @ 3V < V_{CHARGE} < V_{LOAD}	This line is a current source for the charge FET with a 10kΩ resistance between gate and source. If unused keep pin open.
External supply voltage	VDD	O	VDDmin = 2.84V, VDDmax = 2.96V Imax = -10mA $C_L$max = 1µF	Supply voltage, e.g. for an external LED or level shifter. The external digital logic must not cause any spikes or glitches on voltage VDD. Not available in POWER DOWN mode. VDD signalizes the "ON" state of the module. If unused VDD keep pin open.
VDD Low Power	VDDLP	I/O	R_I =1kΩ $V_O$max ≈ 4.0V $V_I$min = 2.2V, $V_I$max = 5.5V $I_I$typ = 10µA at BATT+ = 0V Mobile in POWER DOWN mode: $V_I$min = 1.2V	Supplies the RTC with power via an external capacitor or buffer battery if no V_{BATT+} is applied. If unused keep pin open.

Function	Signal name	IO	Signal form and level	Comments
Ignition	/IGT	I	$R_I \approx 100k\Omega$, $C_I \approx 1nF$ $V_{IL}max = 0.5V$ at Imax = -20μA $V_{Open}max = 2.3V$ ON ~~|____|~~ Active Low ≥ 100ms	Input to switch the mobile ON. The line must be driven low by an Open Drain or Open Collector driver.
Emergency shutdown (Watchdog)	/EMERGOFF	I	$R_I \approx 22k\Omega$ $V_{IL}max = 0.5V$ at Imax = -100μA $V_{Open}max = 2.73V$ Signal ~~|_____|~~ Active Low ≥ 3.2s Watchdog: $V_{OL}max = 0.35V$ at I = 10μA $V_{OH}min = 2.25V$ at I = -10μA $f_Omin = 0.16Hz$ $f_Omax = 1.55Hz$	This line must be driven by an Open Drain or Open Collector driver. Emergency shutdown deactivates the power supply to the module. The module can be reset if /IGT is activated after emergency shutdown. To switch the mobile off use the AT^SMSO command. /EMERGOFF also indicates the internal watchdog function. If unused keep pin open.
Synchroni-zation	SYNC	O	$V_{OL}max = 0.2V$ at I = 1mA $V_{OH}min = 2.35V$ at I = -1mA $V_{OH}max = 2.73V$ ⎍ ⎍ ⎍ 1 Tx, 877μs impulse each 4.616ms and 2 Tx, 1454μs impulse each 4.616ms, with 300μs forward time.	Indicates increased current consumption during uplink transmission burst. Note that timing is different during handover. Alternatively used to control status LED. If unused keep pin open.
SIM interface	CCIN	I	$R_I \approx 100k\Omega$ $V_{IL}max = 0.5V$ $V_{IH}min = 2.15V$ at I = 20μA, $V_{IH}max = 3.3V$ at I = 30μA	CCIN = high, SIM card holder closed (no card recognition)
	CCRST	O	$R_O \approx 47\Omega$ $V_{OL}max = 0.25V$ at I = 1mA $V_{OH}min = 2.3V$ at I = -1mA $V_{OH}max = 2.73V$	Maximum cable length 200mm to SIM card holder. All signals of SIM interface are protected against ESD with a special diode array. Usage of CCGND is mandatory. See Chapter 3.7.3 for details on grounding.
	CCIO	IO	$R_I \approx 10k\Omega$ $V_{IL}max = 0.5V$ $V_{IH}min = 1.95V$, $V_{IH}max = 3.3V$ $R_O \approx 220\Omega$ $V_{OL}max = 0.4V$ at I = 1mA $V_{OH}min = 2.15V$ at I = -1mA $V_{OH}min = 2.55V$ at I = -20μA $V_{OH}max = 2.96V$	
	CCCLK	O	$R_O \approx 220\Omega$ $V_{OL}max = 0.4V$ at I = 1mA $V_{OH}min = 2.15V$ at I = -1mA $V_{OH}max = 2.73V$	
	CCVCC	O	$R_Omax = 5\Omega$ CCVCCmin = 2.84V, CCVCCmax = 2.96V Imax = -20mA	
	CCGND		Ground	

Function	Signal name	IO	Signal form and level	Comments
RS-232 (0) interface	/RXD0	O	V_{OL}max = 0.2V at I = 1mA V_{OH}min = 2.35V at I = -1mA V_{OH}max = 2.73V V_{IL}max = 0.5V V_{IH}min = 1.95V, V_{IH}max=3.3V /DTR0, RTS0: Imax = -90µA at V_{IN} = 0V /TXD0: Imax = -260µA at V_{IN} = 0V	First serial interface for AT commands or data stream. Please note that the /TXD0 pin draws, for 350ms, an additional current of max. 60µA when MC45 is activated. See timing characteristics in Figure 6 If unused keep pins open.
	/TXD0	I		
	/CTS0	O		
	/RTS0	I		
	/DTR0	I		
	/DCD0	O		
	/DSR0	O		
	/RING0	O		
RS-232 (1) interface	/RXD1	O	V_{OL}max = 0.2V at I = 1mA V_{OH}min = 2.35V at I = -1mA V_{OH}max = 2.73V V_{IL}max = 0.5V V_{IH}min = 1.95V, V_{IH}max=3.3V $I_I$max = -90µA at V_{IN} = 0V	Second serial interface for AT commands. Please note that the /TXD1 pin draws, for 350ms, an additional current of max. 60µA when MC45 is activated. See timing characteristics in Figure 6 If unused keep pins open.
	/TXD1	I		
	/CTS1	O		
	/RTS1	I		
Digital audio interface	RFSDAI	I	V_{OL}max = 0.2V at I = 1mA V_{OH}min = 2.35V at I = -1mA V_{OH}max = 2.73V V_{IL}max = 0.5V V_{IH}min = 1.95V, V_{IH}max=3.3V $I_I$max = 330µA at V_{IN} = 3.3V	If unused keep pins open.
	RXDDAI	I		
	SCLK	I		
	TFSDAI	O		
	TXDDAI	O		
Analog audio interfaces Explanation of signal names: P = positive, N = negative	EPP2	O	$V_O$max = 3.7Vpp See also Table 32.	The audio output is balanced and can directly operate an earpiece. If unused keep pins open.
	EPN2	O		
	EPP1	O	$V_O$max = 3.7Vpp See also Table 32.	Balanced audio output. Can be used to directly operate an earpiece. If unused keep pins open.
	EPN1	O		
	MICP1	I	$R_I \approx 50k\Omega$ differential $V_I$max = 1.03Vpp See also Table 33.	Balanced microphone input. To be decoupled with 2 capacitors (C_K = 100nF), if connected to a microphone or another device. If unused keep pins open.
	MICN1	I		
	MICP2	I	R_I = 2kΩ differential $V_I$max = 1.03Vpp See also Table 33.	Balanced microphone input. Can be used to directly feed an active microphone. If used for another signal source, e.g. op amp, to be decoupled with capacitors. If unused keep pins open.
	MICN2	I		
	AGND			Separate ground connection for external audio circuits.

4 Antenna interface (antenna reference point – ARP)

To suit the physical design of individual applications MC45 offers two alternative approaches to connecting the antenna:

The standard layout of MC45 comprises an antenna connector from Hirose assembled on the component side of the PCB (top view on MC45) plus a antenna pad placed on the bottom side. Both solutions can only be applied alternatively: Whenever an antenna is plugged to the Hirose connector, the pad must not be used. Vice versa, if the antenna is soldered to the pad, then the Hirose connector must be left empty.

Both RF interfaces have an impedance of 50Ω. MC45 is capable of sustaining a total mismatch at the antenna connector or pad without any damage, even when transmitting at maximum RF power.

To help you choose an appropriate antenna, Chapters 5.4 and 8 provide technical specifications and ordering information. The external antenna must be matched properly to achieve best performance regarding radiated power, DC-power consumption and harmonic suppression. Matching networks are not included on the MC45 PCB and should be placed in the host application.

Regarding the return loss MC45 provides the following values:

Table 20: Return loss

State of module	Return loss of module	Recommended return loss of application
Receive	$\geq$ 8dB	$\geq$ 12dB
Transmit	not applicable	$\geq$ 12dB
Idle	$\leq$ 5dB	not applicable

5 Physical characteristics

5.1 Mechanical dimensions of MC45

Figure 27 shows the top view on MC45 and provides an overview of the mechanical dimensions of the board. For further details see Figure 28.

Size: 53 ±0.2 x 34 ±0.2 x 3.5±0.3 mm

Weight: 10g
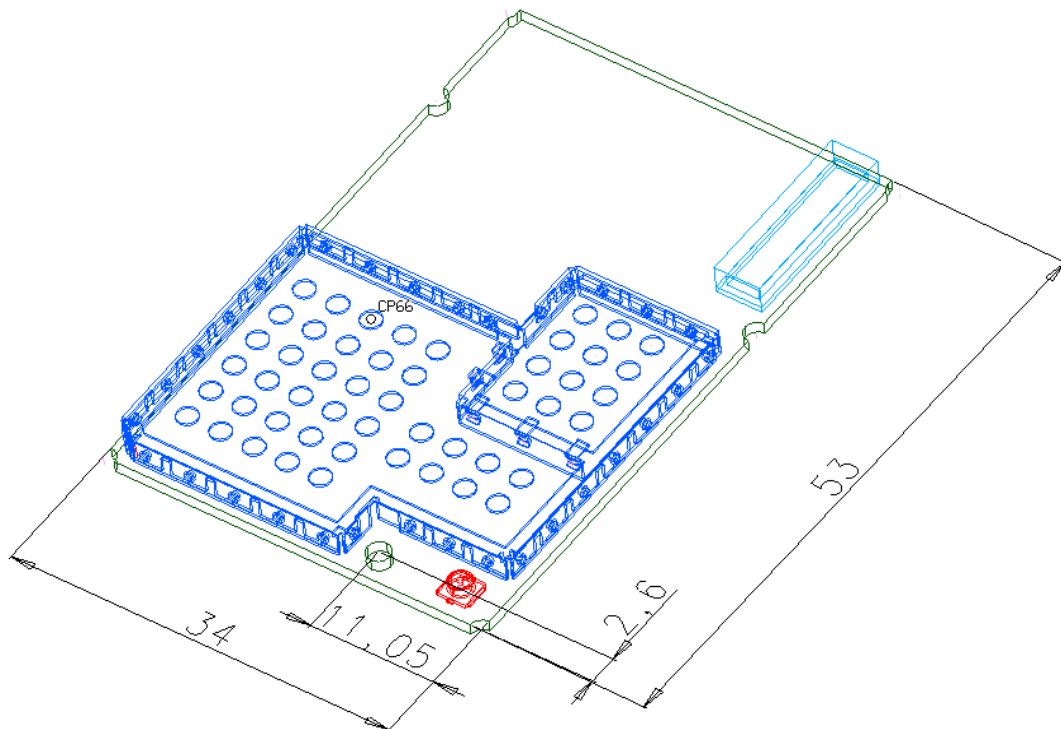
Figure 27: MC45 – top view
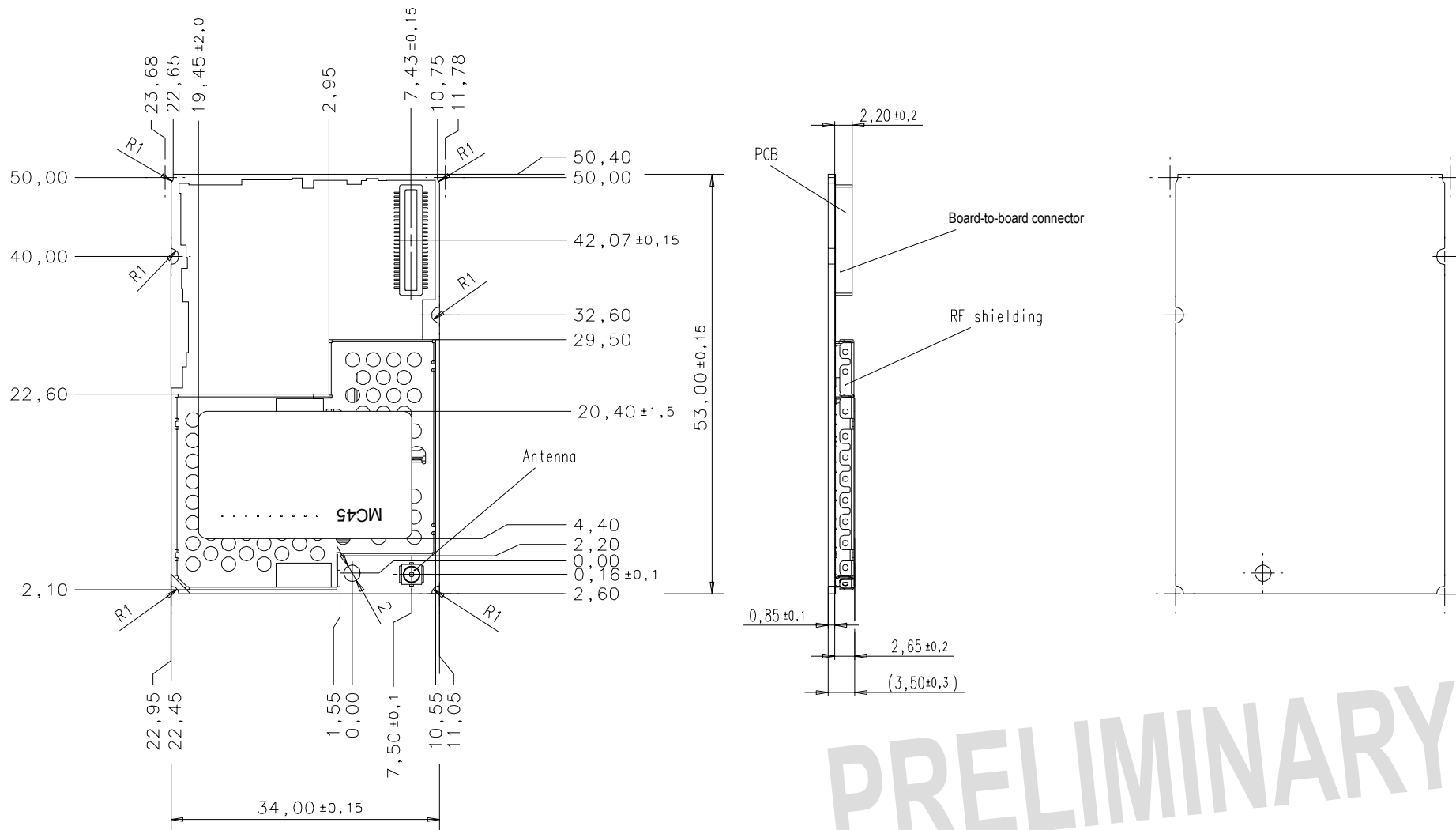
All dimensions in millimeter

Figure 28: Mechanical dimensions of MC45

Ground pad, e.g. for heat dissipator
or connection to host device

Ø1.1

TP 402

SIEMENS

TP GND

TP BATT+

14.42

4.75

0.00

10.60

26.90

24.40

15.50

0.00
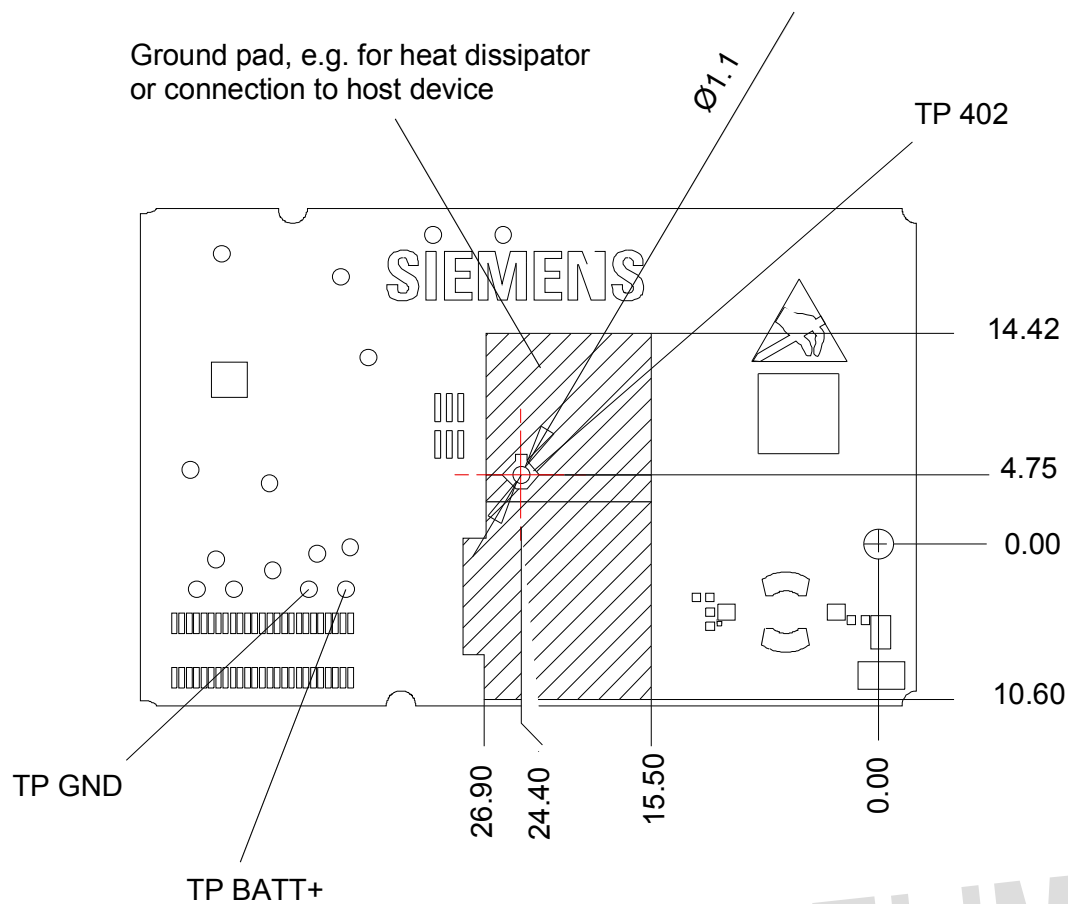
PRELIMINARY

Figure 29: MC45 bottom view

5.2 Mounting MC45 onto the application platform

There are many ways to properly install MC45 in the host device. An efficient approach is to mount the MC45 PCB to a frame, plate, rack or chassis. Fasteners can be M1.6 or M1.8 screws plus suitable washers, circuit board spacers, or customized screws, clamps, or brackets. In addition, the board-to-board connection can also be utilized to achieve better support.

If the bottom of MC45 faces the holding device, only use the ground pad for the connection. To avoid short circuits ensure that the remaining sections of the MC45 PCB do not come into contact with the host device since there are a number of test points. The ground pad can also be used to attach cooling elements, e.g. a heat sink. Figure 29 shows the ground pad on the bottom of MC45 and the positions of all test points.

Particular attention should be paid to the test point TP 402. Placed beneath the ground pad it has been added for manufacturing only. When the pad is used for grounding the unit or connecting a heat sink, extra care must be taken not to contact this test point.

The antenna pad on the bottom of the MC45 PCB must not be influenced by any other PCBs, components or by the housing of the host device. It needs to be surrounded by a restricted space as described in Chapter 5.4.2.

To prevent mechanical damage, be careful not to force, bend or twist the module. Be sure it is positioned flat against the host device.

Note: Detailed mounting instructions and recommendations for integrating MC45 into the host application shall be provided in later releases of this document.

5.3 Board-to-board connector

This chapter provides specifications for the 50-pin board-to-board connector which serves as physical interface to the host application. The receptacle assembled on the MC45 PCB is type Hirose DF12C. Mating headers from Hirose are available in different stacking heights.

Figure 30: Hirose DF12C receptacle on MC45
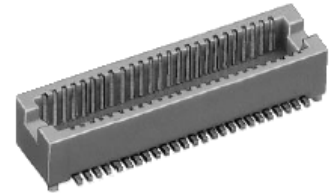
Figure 31: Header Hirose DF12 series

Table 21: Ordering information DF12 series

Item	Part number	Stacking height (mm)	HRS number
Receptacle on MC45	DF12C(3.0)-50DS-0.5V(81)	3 - 5	537-0694-9-81
Headers DF12 series	DF12E(3.0)-50DP-0.5V(81)	3.0	537-0834-6-**
	DF12E(3.5)-50DP-0.5V(81)	3.5	537-0534-2-**
	DF12E(4.0)-50DP-0.5V(81)	4.0	537-0559-3-**
	DF12E(5.0)-50DP-0.5V(81)	5.0	537-0584-0-**

Notes: The headers listed above are without boss and metal fitting. Please contact Hirose for details on other types of mating headers. Asterixed HRS numbers denote different types of packaging.

Table 22: Electrical and mechanical characteristics of the Hirose DF12C connector

Parameter	Specification (50 pin Board to Board connector)
Number of Contacts	50
Quantity delivered	2000 Connectors per Tape & Reel
Voltage	50V
Current Rating	0.5A max per contact
Resistance	0.05 Ohm per contact
Dielectric Withstanding Voltage	500V RMS min
Operating Temperature	-45°C...+125°C
Contact Material	phosphor bronze (surface: gold plated)
Insulator Material	PA , beige natural
Stacking height	3.0 mm ; 3.5 mm ; 4.0 mm ; 5.0 mm
Insertion force	21.8N
Withdrawal force 1st	10N
Withdrawal force 50th	10N
Maximum connection cycles	50

5.3.1 Mechanical dimensions of the Hirose DF12 connector
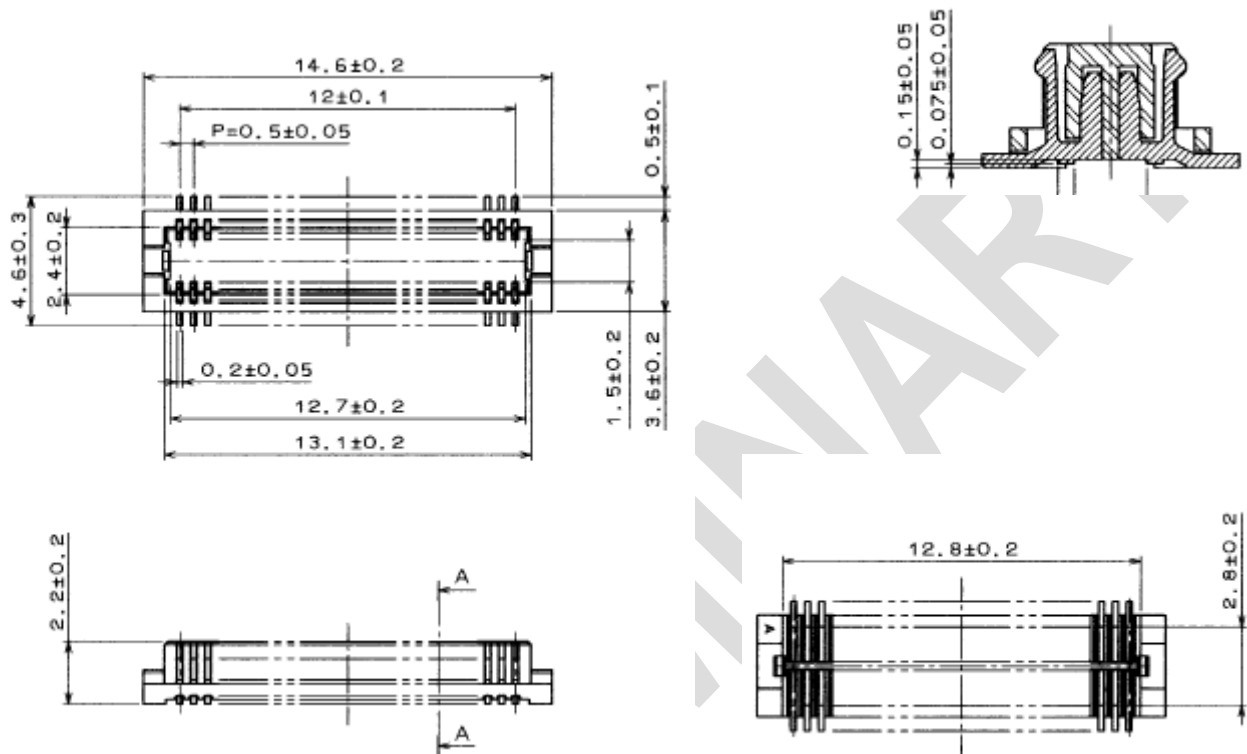
Figure 32: Mechanical dimensions of Hirose DF12 connector

5.3.2 Adapter cabling

The board-to-board connection is primarily intended for direct contact between both connectors. If this assembly solution does not fit into your application design ensure that the used adapter cable meets the following requirements:

- Maximum length: 200 mm
- Type of cable: Flexible cable or flexible printed circuit board designed to mate with the Hirose receptacle and headers specified above.

The equipment submitted for type approving the Siemens reference setup of MC45 includes a 160mm adapter cable. See Chapter 7.1.

5.4 Antenna design

This chapter describes the various options of connecting an external antenna to MC45. Be sure that all peripherals are applied according to the manufacturer's antenna specifications. For internal antenna equipment, you are advised to use the services of a consultant or full-service house.

5.4.1 Hirose antenna connector

MC45 uses an ultra-miniature SMT antenna connector supplied from Hirose Ltd. The product name is:

U.FL-R-SMT

The position of the antenna connector on the MC45 board can be seen in Figure 28.
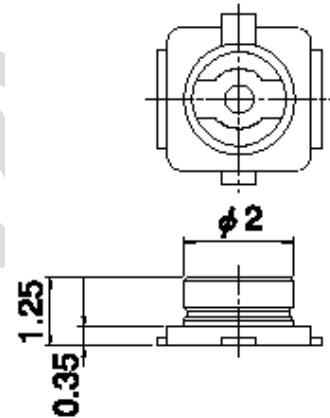
Figure 33: Mechanical dimensions of U.FL-R-SMT connector

Table 23: Product specifications of U.FL-R-SMT connector

Item	Specification	Conditions
Ratings		
Nominal impedance	50 Ω	Operating temp:-40°c to + 90°C
Rated frequency	DC to 3 GHz	Operating humidity: max. 90%
Mechanical characteristics		
Female contact holding force	0.15 N min	Measured with a $\varnothing$ 0.475 pin gauge
Repetitive operation	Contact resistance: Center 25 mΩ Outside 15mΩ	30 cycles of insertion and disengagement
Vibration	No momentary disconnections of 1 µs; No damage, cracks and looseness of parts	Frequency of 10 to 100 Hz, single amplitude of 1.5 mm, acceleration of 59 m/s^2, for 5 cycles in the direction of each of the 3 axes
Shock	No momentary disconnections of 1 µs. No damage, cracks and looseness of parts.	Acceleration of 735 m/s^2, 11 ms duration for 6 cycles in the direction of each of the 3 axes
Environmental characteristics		
Humidity resistance	No damage, cracks and looseness of parts. Insulation resistance: 100 MΩ min. at high humidity 500 MΩ min when dry	Exposure to 40°C, humidity of 95% for a total of 96 hours

Temperature cycle	No damage, cracks and looseness of parts. Contact resistance: Center 25 mΩ Outside 15mΩ	Temperature: +40°C $\rightarrow$ 5 to 35°C $\rightarrow$ +90°C $\rightarrow$ 5 to 35°C Time: 30 min. $\rightarrow$ within 5 min. $\rightarrow$ 30 min. within 5 min
Salt spray test	No excessive corrosion	48 hours continuous exposure to 5% salt water

Table 24: Material and finish of U.FL-R-SMT connector and recommended plugs

Part	Material		Finish
Shell	Phosphor bronze		Silver plating
Male center contact	Brass		Gold plating
Female center contact	Phosphor bronze		Gold plating
Insulator	Plug: Receptacle:	PBT LCP	Black Beige

Mating plugs and cables can be chosen from the Hirose U.FL Series. Examples are shown below and listed in Table 25. For latest product information please contact your Hirose dealer or visit the Hirose home page, for example http://www.hirose.com.
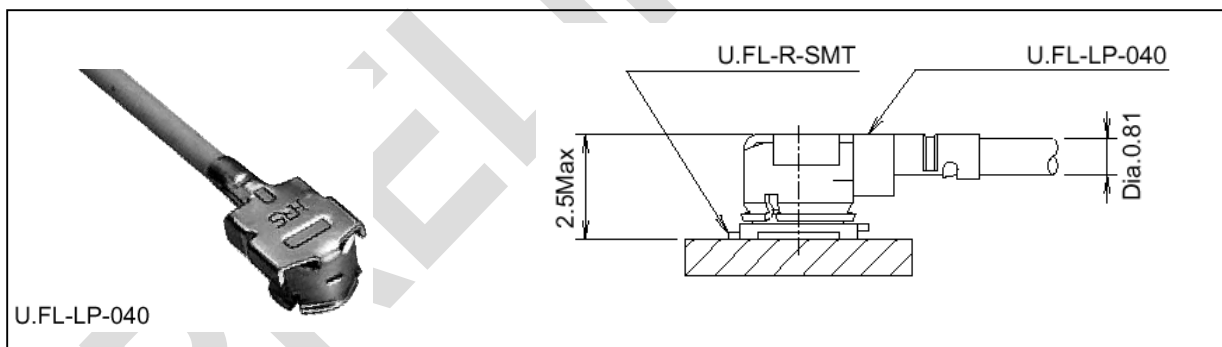
Figure 34: U.FL-R-SMT connector with U.FL-LP-040 plug
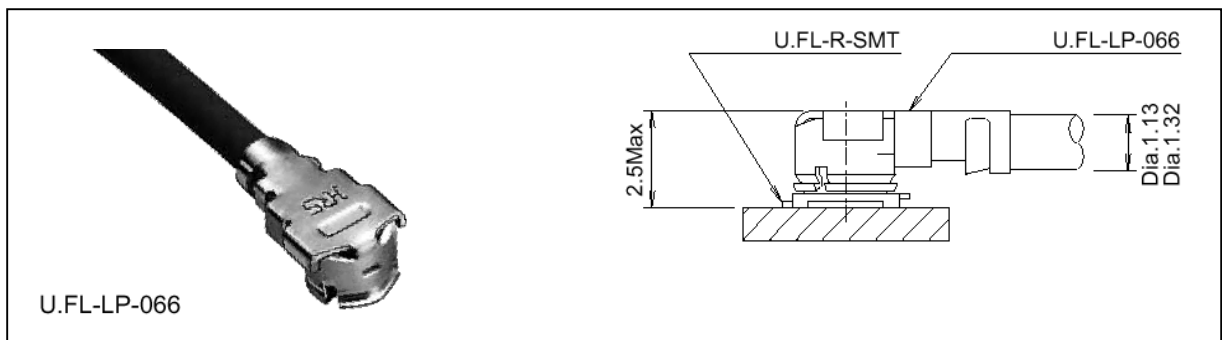
Figure 35: U.FL-R-SMT connector with U.FL-LP-066 plug

In addition to the connectors illustrated above, the U.FL-LP-(V)-040(01) version is offered as an extremely space saving solution. This plug is intended for use with extra fine cable (up to ∅ 0.81 mm) and minimizes the mating height to 2 mm. See Figure 36 which shows the Hirose datasheet.
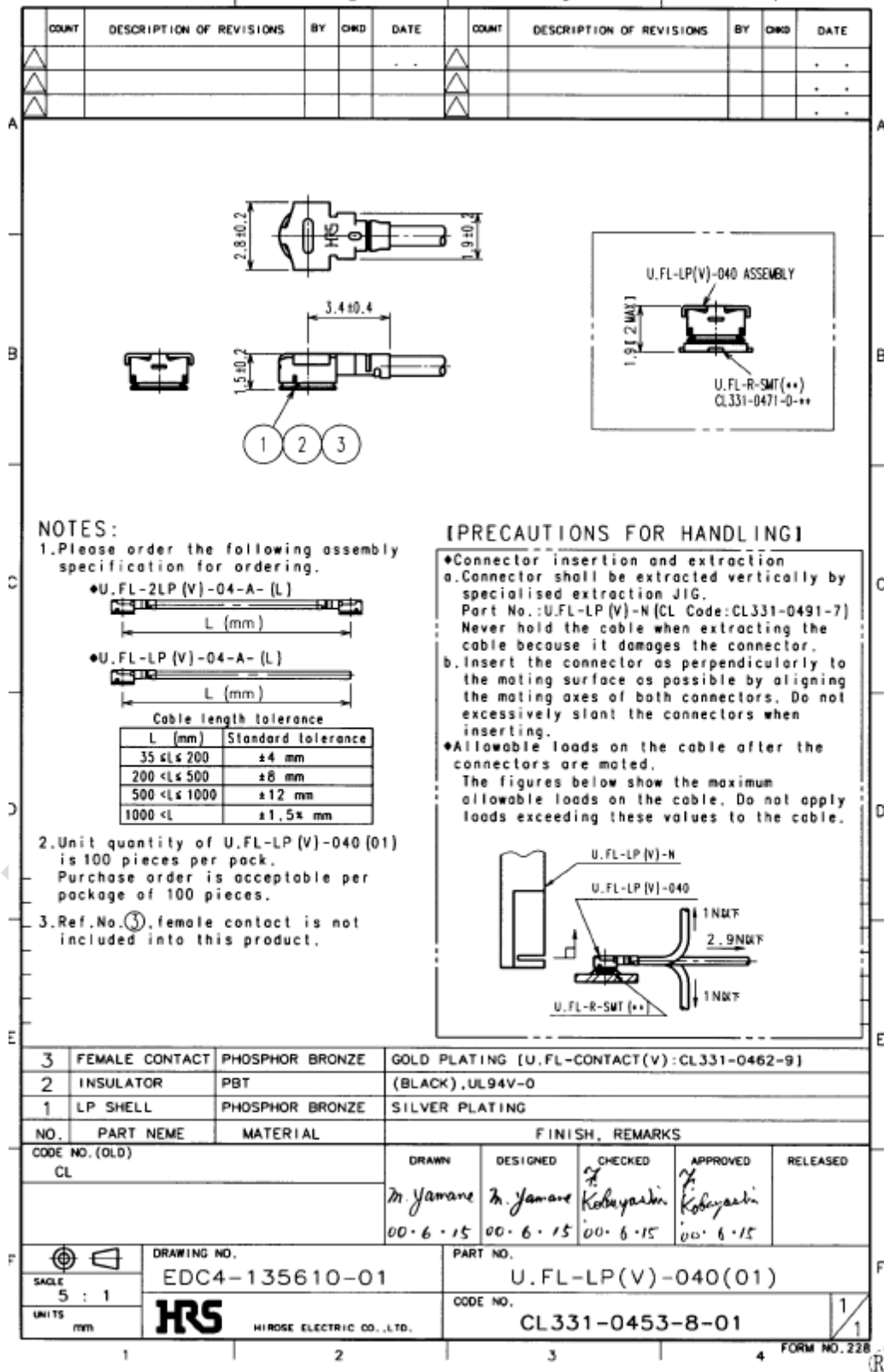
Figure 36: Specifications of U.FL-LP-(V)-040(01) plug

Table 25: Ordering information for Hirose U.FL Series

Item	Part number	HRS number
Connector on MC45	U.FL-R-SMT	CL331-0471-0-10
Right-angle plug shell for ∅ 0.81 mm cable	U.FL-LP-040	CL331-0451-2
Right-angle plug for ∅ 0.81 mm cable	U.FL-LP(V)-040 (01)	CL331-053-8-01
Right-angle plug for ∅ 1.13 mm cable	U.FL-LP-066	CL331-0452-5
Right-angle plug for ∅ 1.32 mm cable	U.FL-LP-066	CL331-0452-5
Extraction jig	E.FL-LP-N	CL331-04441-9

5.4.2 Antenna pad

The antenna pad on the bottom of the MC45 PCB must not come into contact with the holding device or any other components of the host application. The pad must be a surrounded by a restricted area filled with air, which must also be reserved 0.8 mm in height.
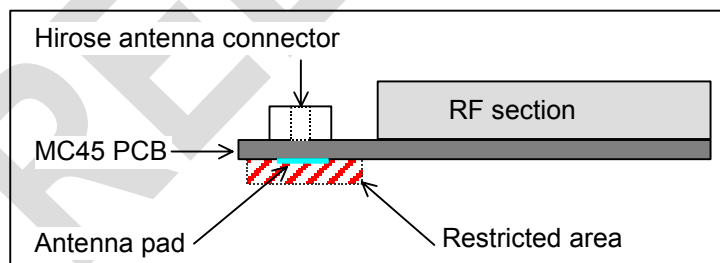
Figure 37: Restricted area around antenna pad

6 Electrical, reliability and radio characteristics

6.1 Absolute maximum ratings

Absolute maximum ratings for supply voltage and voltages on digital and analog pins of MC45 are listed in Table 26. Exceeding these values will cause permanent damage to MC45.

The power supply shall be compliant with the SELV safety standard defined in EN60950. The supply current must be limited according to Table 26.

Table 26: Absolute maximum ratings

Parameter	Min	Max	Unit
Peak current of power supply	0	4.0	A
RMS current of power supply (during one TDMA-frame)	0	0.7	A
Voltage at digital pins	-0.3	3.3	V
Voltage at analog pins	-0.3	3.0	V
Voltage at digital / analog pins in POWER DOWN mode	-0.25	+0.25	V
Voltage at POWER pin		15	V
Voltage at CHARGE pin		15	V
Differential load resistance between EPNx and EPPx	15		Ω

6.2 Operating temperatures

Test conditions were specified in accordance with IEC 60068-2 (still air).

Table 27: Operating temperatures

Parameter	Min	Typ	Max	Unit
Ambient temperature (according to GSM 11.10)	-20	25	55	°C
Restricted operation [*]	-25 to -20		55 to 70	°C
Automatic shutdown MC45 board temperature	-29		$\geq$70 [**]	°C
Battery temperature	-18		$\geq$60	°C
Charging temperature (software controlled fast charging)	0		+45	°C

[*] MC45 works, but deviations from the GSM specification may occur.
[**] $T_{amb\ max} = 70°C$, conditions: GSM 900 PCL and $V_{BATT+\ max} \leq 4.0V$

6.3 Reliability characteristics

The test conditions stated below are an extract of the complete test specifications.

Table 28: Summary of reliability test conditions

Type of test	Conditions	Standard
Vibration	Frequency range: 10-20 Hz; acceleration: 3.1mm amplitude Frequency range: 20-500 Hz; acceleration: 5g Duration: 2h per axis = 10 cycles; 3 axes	DIN IEC 68-2-6
Shock half-sinus	Acceleration: 500g Shock duration: 1msec 1 shock per axis 6 positions (± x, y and z)	DIN IEC 68-2-27
Dry heat	Temperature: +70 ±2°C Test duration: 16 h Humidity in the test chamber: < 50%	EN 60068-2-2 Bb ETS 300019-2-7
Temperature change (shock)	Low temperature: -40°C ±2°C High temperature: +85°C ±2°C Changeover time: < 30s (dual chamber system) Test duration: 1 h Number of repetitions: 100	DIN IEC 68-2-14 Na ETS 300019-2-7
Damp heat cyclic	High temperature: +55°C ±2°C Low temperature: +25°C ±2°C Humidity: 93% ±3% Number of repetitions: 6 Test duration: 12h + 12h	DIN IEC 68-2-30 Db ETS 300019-2-5
Cold (constant exposure)	Temperature: -40 ±2°C Test duration: 16 h	DIN IEC 68-2-1

6.4 Power supply ratings

Table 29: Power supply ratings

Parameter	Description	Conditions		Min	Typ	Max	Unit
BATT+	Supply voltage	Reference points on MC45: TP BATT+ and TP GND Voltage must stay within the min/max values, including voltage drop, ripple, spikes.		3.3	4.1	4.5	V
	Voltage drop during transmit burst	Normal condition, power control level for $P_{out\ max}$				400	mV
	Voltage ripple	Normal condition, power control level for $P_{out\ max}$ @ f<200kHz @ f>200kHz				50 2	mV
I_{BATT+}	Average supply current[3]	POWER DOWN mode			50	100	µA
		SLEEP mode	@ DRX = 6		TBD		mA
		IDLE mode	EGSM 900		TBD		mA
			GSM 1800/1900		TBD		
		TALK mode	EGSM 900[1]		300	400	mA
			GSM 1800/1900[2]		270		
		IDLE GPRS	EGSM 900		TBD		mA
			GSM 1800/1900		TBD		
		DATA mode GPRS, (4 Rx, 1 Tx)	EGSM 900[1]		360	460	mA
			GSM 1800/1900[2]		330		
		DATA mode GPRS, (3 Rx, 2 Tx)	EGSM 900[1]		TBD		mA
			GSM 1800/1900[2]		TBD		
	Peak supply current (during 577µs transmission slot every 4.6ms)	Power level [1]			2	3	A

[1] Power control level PCL 5

[2] Power control level PCL 0

[3] All average supply current values @ I_{VDD} = 0mA

6.4.1 Current consumption during transmit burst

The diagrams provided in Figure 38 and Figure 39 illustrate the typical current consumption of the application caused during a transmit burst. The typical peak current is shown vs. the power level for 900 MHz, 1800 MHz and 1900 MHz and vs. the return loss of the antenna.

Test conditions: All measurements have been performed at T_{amb}= 25°C, $V_{BATT+ nom}$ = 4.1V. The reference points used on MC45 are the BATT+ and GND contacts (test points are shown in Figure 29). All curves are for one TX slot, that is, for example, a voice call, CSD call or Class 8 GPRS. Figures for Class 10 GPRS activities will be published in later releases of this document.

Changing the conditions, e.g. in terms of temperature or voltage, will cause different results. The current will be maximized when the maximum supply voltage is used together with a total reflection at the RF interface.
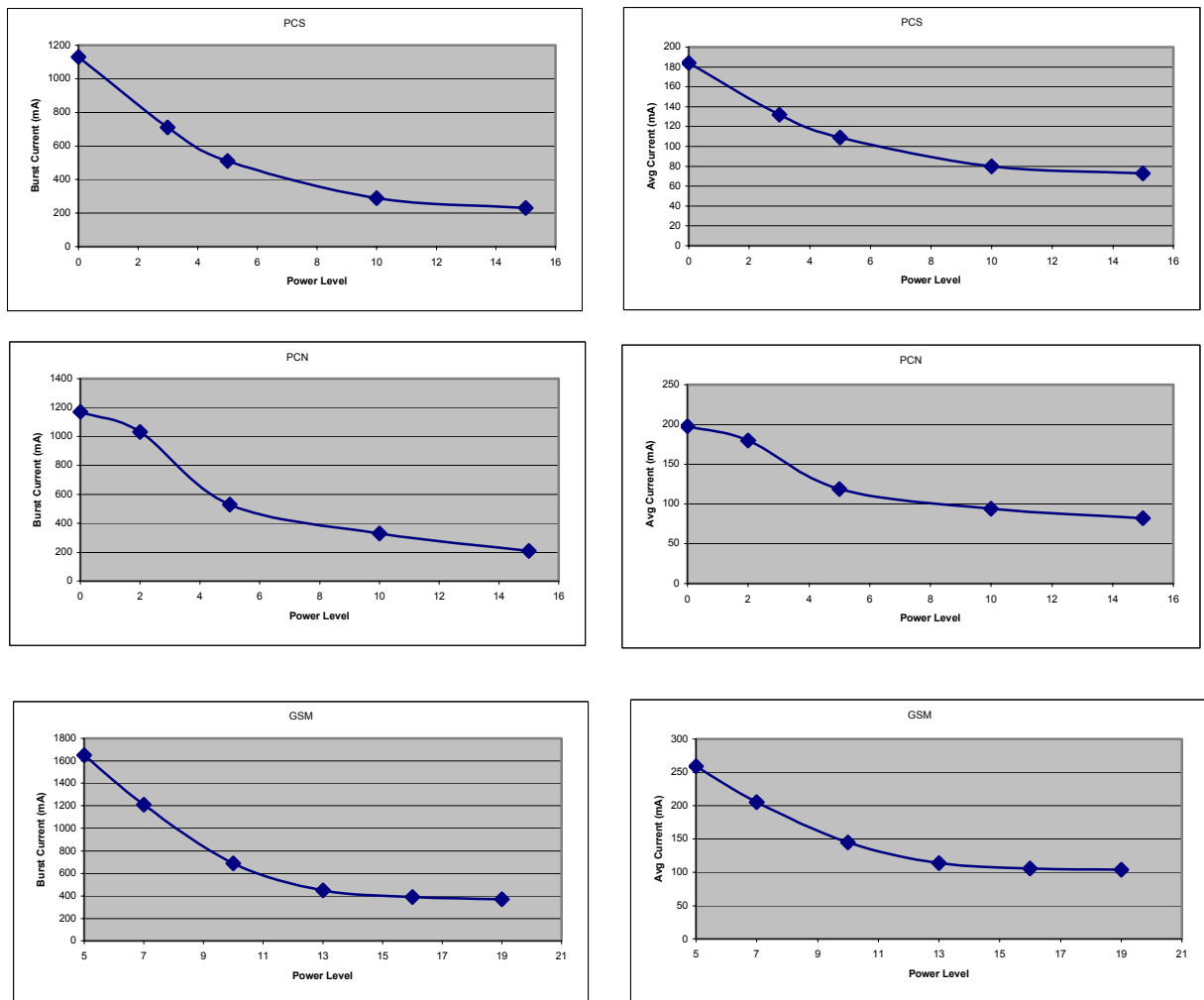
Test conditions: T_{amb}= 25°C, $V_{BATT+ nom}$ = 4.1V measured at TP BATT+ and GND, 1 TX slot

Figure 38: Typical current consumption vs. power level
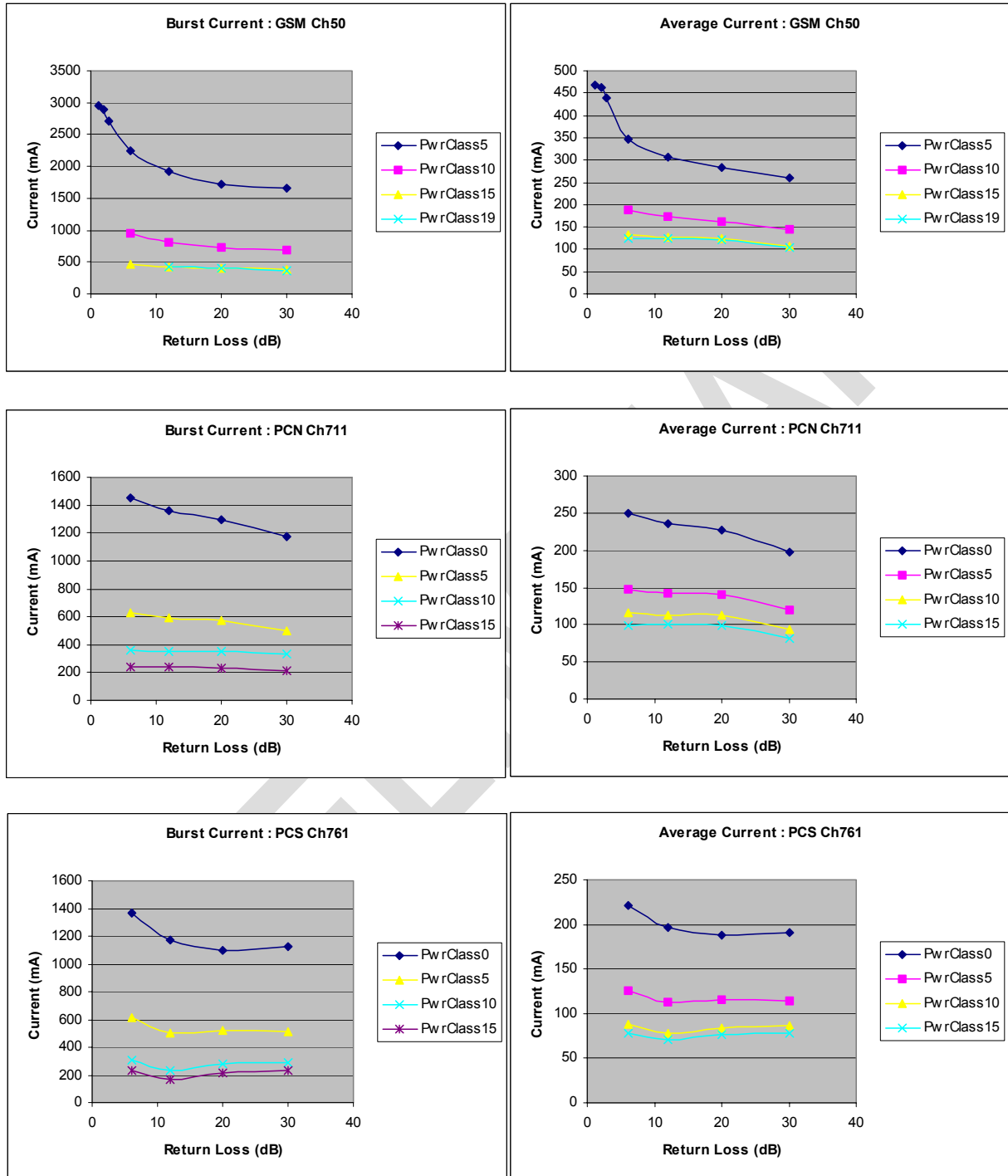
Test conditions: T_{amb}= 25°C, $V_{BATT+\ nom}$ = 4.1V measured at TP BATT+ and GND, 1 TX slot

Figure 39: Typical current consumption vs. return loss

6.5 Electrical characteristics of the voiceband part

6.5.1 Setting audio parameters by AT commands

The audio modes 2 to 6 can be adjusted according to the parameters listed below. Each audio mode is assigned a separate set of parameters.

Table 30: Audio parameters adjustable by AT command

Parameter	Influence to	Range	Gain range	Calculation
inBbcGain	MICP/MICN analogue amplifier gain of baseband controller before ADC	0...7	0...42dB	6dB steps
inCalibrate	digital attenuation of input signal after ADC	0...32767	-∞...0dB	20 * log (inCalibrate/ 32768)
outBbcGain	EPP/EPN analogue output gain of baseband controller after DAC	0...3	0...-18dB	6dB steps
outCalibrate[n] n = 0...4	digital attenuation of output signal after speech decoder, before summation of sidetone and DAC present for each volume step[n]	0...32767	-∞...+6dB	20 * log (2 * outCalibrate[n]/ 32768)
sideTone	digital attenuation of sidetone is corrected internally by outBbcGain to obtain a constant sidetone independent of output volume	0...32767	-∞...0dB	20 * log (sideTone/ 32768)

Note: The parameters inCalibrate, outCalibrate and sideTone accept also values from 32768 to 65535. These values are internally truncated to 32767.

6.5.2 Audio programming model

The audio programming model shows how the signal path can be influenced by varying the AT command parameters. The model is the same for all three interfaces, except for the parameters <outBbcGain> and <inBbcGain> which cannot be modified on the digital audio interface is being used, since in this case the DAC is switched off.

The parameters inBbcGain and inCalibrate can be set with AT^SNFI. All the other parameters are adjusted with AT^SNFO.

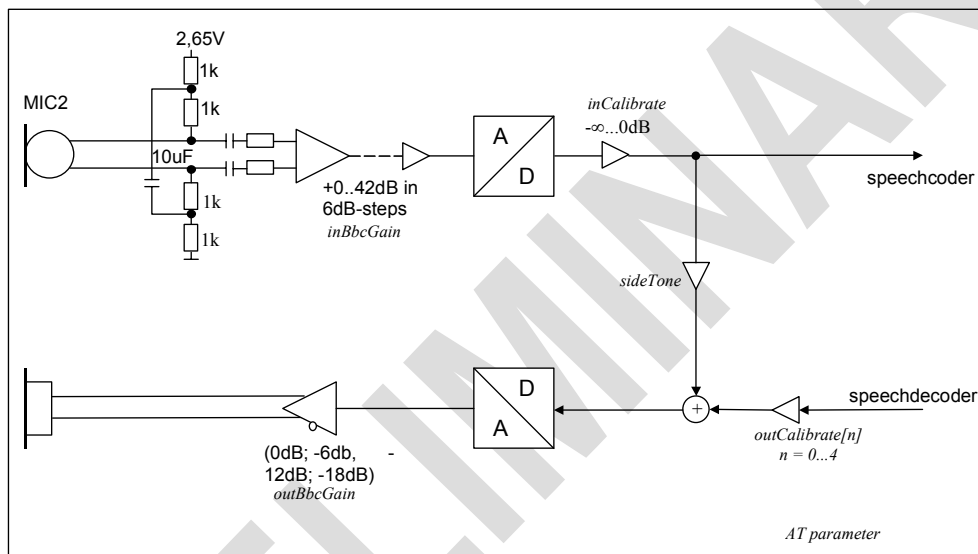Figure 40: AT audio programming model

6.5.3 Characteristics of audio modes

The electrical characteristics of the voiceband part depend on the current audio mode set with the AT^SNFS command.

Table 31: Voiceband characteristics (typical), all values preliminary

Audio mode no. AT^SNFS=	1 (Default settings, not adjustable)	2	3	4	5	6
Name	Default Handset	Basic Handsfree	Headset	User Handset	Plain Codec 1	Plain Codec 2
Purpose	DSB with M20T handset	Siemens Car Kit Portable	Siemens Headset	DSB with individual handset	Direct access to speech coder	Direct access to speech coder
Gain setting via AT command. Defaults: inBbcGain outBbcGain	Fix 4 (24dB) 1 (-6dB)	Adjustable 2 (12dB) 1 (-6dB)	Adjustable 5 (30dB) 2 (-12dB)	Adjustable 4 (24dB) 1 (-6dB)	Adjustable 0 (0dB) 0 (0dB)	Adjustable 0 (0dB) 0 (0dB)
Default audio interface	1	2	2	1	1	2 [4]
Power supply	ON	ON	ON	ON	OFF	OFF
Sidetone	ON	---	Adjustable	Adjustable	Adjustable	Adjustable
Volume control	OFF	Adjustable	Adjustable	Adjustable	Adjustable	Adjustable
Limiter (receive)	ON	ON	ON	ON	---	---
Compressor (receive)	---	ON[1]	---	---	---	---
AGC (send)	---	---	ON	---	---	---
Echo control (send)	Suppression	Cancellation + suppression	---	Suppression	---	---
Noise suppression[2]	---	up to 10dB	10dB	---	---	---
MIC input signal for 0dBm0 @ 1024 Hz (default gain)	23mV	58mV	7.5mV @ -3dBm0 due to AGC	23mV	315mV	315mV
EP output signal in mV rms. @ 0dBm0, 1024 Hz, no load (default gain); @ 3.14 dBm0	284mV	120mV default @ max volume	300mV default @ max volume	284mV default @ max volume	895mV 3.7Vpp	895mV 3.7Vpp
Sidetone gain at default settings	22.8dB	-∞ dB	Affected by AGC, 13dB @ 7.5mV (MIC)	22.8dB	0dB @ sideTone = 8192[3]	0dB @ sideTone = 8192[3]

[1]   Adaptive, receive volume increases with higher ambient noise level.
[2]   In audio modes with noise reduction, the microphone input signal for 0dBm0 shall be measured with a sine burst signal for a tone duration of 5 seconds and a pause of 2 sec. The sine signal appears as noise and, after approx. 12 sec, is attenuated by the noise reduction by up to 10dB.
[3]   See AT^SNFO command in [1].
[4]   Audio mode 5 and 6 are identical. With AT^SAIC, you can easily switch mode 5 to the second interface. Therefore, audio mode 6 is only kept for compatibility to earlier Siemens GSM products.

Note: With regard to acoustic shock, the cellular application must be designed to avoid sending false AT commands that might increase amplification, e.g. for a high sensitive earpiece. A protection circuit should be implemented in the cellular application.

6.5.4 Voiceband receive path

Test conditions:
- The values specified below were tested to 1kHz and 0dB gain stage, unless otherwise stated.
- Parameter setup: gs = 0dB means audio mode = 5 for EPP1 to EPN1 and 6 for EPP2 to EPN2, inBbcGain= 0, inCalibrate = 32767, outBbcGain = 0, OutCalibrate = 16384, sideTone = 0.

Table 32: Voiceband receive path

Parameter	Min	Typ	Max	Unit	Test condition / remark
Differential output voltage (peak to peak)	3.33	3.7	4.07	V	from EPPx to EPNx *gs* = 0dB @ 3.14 dBm0 no load
Differential output gain settings (*gs*) at 6dB stages (outBbcGain)	-18		0	dB	Set with AT^SNFO
Fine scaling by DSP (outCalibrate)	-∞		0	dB	Set with AT^SNFO
Output differential DC offset			100	mV	*gs* = 0dB, outBbcGain = 0 and -6dB
Differential output resistance		2		Ω	from EPPx to EPNx
Differential load capacitance			1000	pF	from EPPx to EPNx
Absolute gain accuracy			0.8	dB	Variation due to change in temperature and life time
Attenuation distortion			1	dB	for 300...3900Hz, @ EPPx/EPNx (333Hz) / @ EPPx/EPNx (3.66kHz)
Out-of-band discrimination	60			dB	for *f* > 4kHz with in-band test signal@ 1kHz and 1kHz RBW

gs = gain setting

6.5.5 Voiceband transmit path

Test conditions:

- The values specified below were tested to 1kHz and 0dB gain stage, unless otherwise stated.
- Parameter setup: Audio mode = 5 for MICP1 to MICN1 and 6 for MICP2 to MICN2, inBbcGain= 0, inCalibrate = 32767, outBbcGain = 0, OutCalibrate = 16384, sideTone = 0

Table 33: Voiceband transmit path

Parameter	Min	Typ	Max	Unit	Test condition/Remark
Input voltage (peak to peak) MICP1 to MICN1, MICP2 to MICN2			1.03	V	
Input amplifier gain in 6dB steps (inBbcGain)	0		42	dB	Set with AT^SNFI
Fine scaling by DSP (inCalibrate)	-∞		0	dB	Set with AT^SNFI
Input impedance MIC1		50		kΩ	
Input impedance MIC2		2.0		kΩ	
Microphone supply voltage ON Ri = 4kΩ	2.57 2.17 1.77	2.65 2.25 1.85	2.73 2.33 1.93	V V V	no supply current @ 100µA @ 200µA
Microphone supply voltage OFF ; Ri = 4kΩ		0		V	
Microphone supply in POWER DOWN mode					See Figure 17

6.6 Air interface

Test conditions: All measurements have been performed at T_{amb} = 25°C, $V_{BATT+ nom}$ = 4.1V. The reference points used on MC45 are the BATT+ and GND contacts (test points are shown in Figure 29).

Table 34: Air Interface

Parameter		Min	Typ	Max	Unit
Frequency range	E-GSM 900	880		915	MHz
Uplink (MS → BTS)	GSM 1800	1710		1785	MHz
	GSM 1900	1850		1910	MHz
Frequency range	E-GSM 900	925		960	MHz
Downlink (BTS → MS)	GSM 1800	1805		1880	MHz
	GSM 1900	1930		1990	MHz
RF power @ ARP with 50Ω load	E-GSM 900	31	33	35	dBm
	GSM 1800	28	30	32	dBm
	GSM 1900	28	30	32	
Number of carriers	E-GSM 900		174		
	GSM 1800		374		
	GSM 1900		299		
Duplex spacing	E-GSM 900		45		MHz
	GSM 1800		95		MHz
	GSM 1900		80		
Carrier spacing			200		kHz
Multiplex, Duplex		TDMA / FDMA, FDD			
Time slots per TDMA frame			8		
Frame duration			4.615		ms
Time slot duration			577		μs
Modulation		GMSK			
Receiver input sensitivity @ ARP	E-GSM 900	-102	-105		dBm
BER Class II < 2.4%	GSM 1800	-102	-105		dBm
	GSM 1900	-102	-105		dBm

6.7 Electrostatic discharge

The GSM engine is not protected against Electrostatic Discharge (ESD) in general. Consequently, it is subject to ESD handling precautions that typically apply to ESD sensitive components. Proper ESD handling and packaging procedures must be applied throughout the processing, handling and operation of any application that incorporates a MC45 module.

Special ESD protection provided on MC45:
Antenna interface: one spark discharge line (spark gap)
SIM interface: clamp diodes for protection against overvoltage.
The remaining ports of MC45 are not accessible to the user of the final product (since they are installed within the device) and therefore, are only protected according to the "Human Body Model" requirements.

MC45 has been tested and found to comply with the EN 61000-4-2 standard. The measured values can be gathered from the following table.

Table 35: Measured electrostatic values

Specification / Requirements	Contact discharge	Air discharge
ETSI EN 301 489-7		
ESD at SIM port	$\pm$ 4kV	$\pm$ 8kV
ESD at antenna port	$\pm$ 4kV	$\pm$ 8kV
Human Body Model (Test conditions: 1.5 kΩ, 100 pF)		
ESD at the module	$\pm$ 1kV	

Note: *Please note that the values may vary with the individual application design. For example, it matters whether or not the application platform is grounded over external devices like a computer or other equipment, such as the Siemens reference application described in Chapter 7.*

7 Reference Approval

7.1 Reference Equipment

The Siemens reference setup that will be submitted to type approve MC45 consists of the following components:

- Siemens MC45 cellular engine
- Development Support Box (DSB45)
- Flex cable (160 mm) from Hirose DF12C receptacle on MC45 to Hirose DF12 connector on DSB45. Please note that this cable is not included in the scope of delivery of DSB45.
- SIM card reader integrated on the DSB45
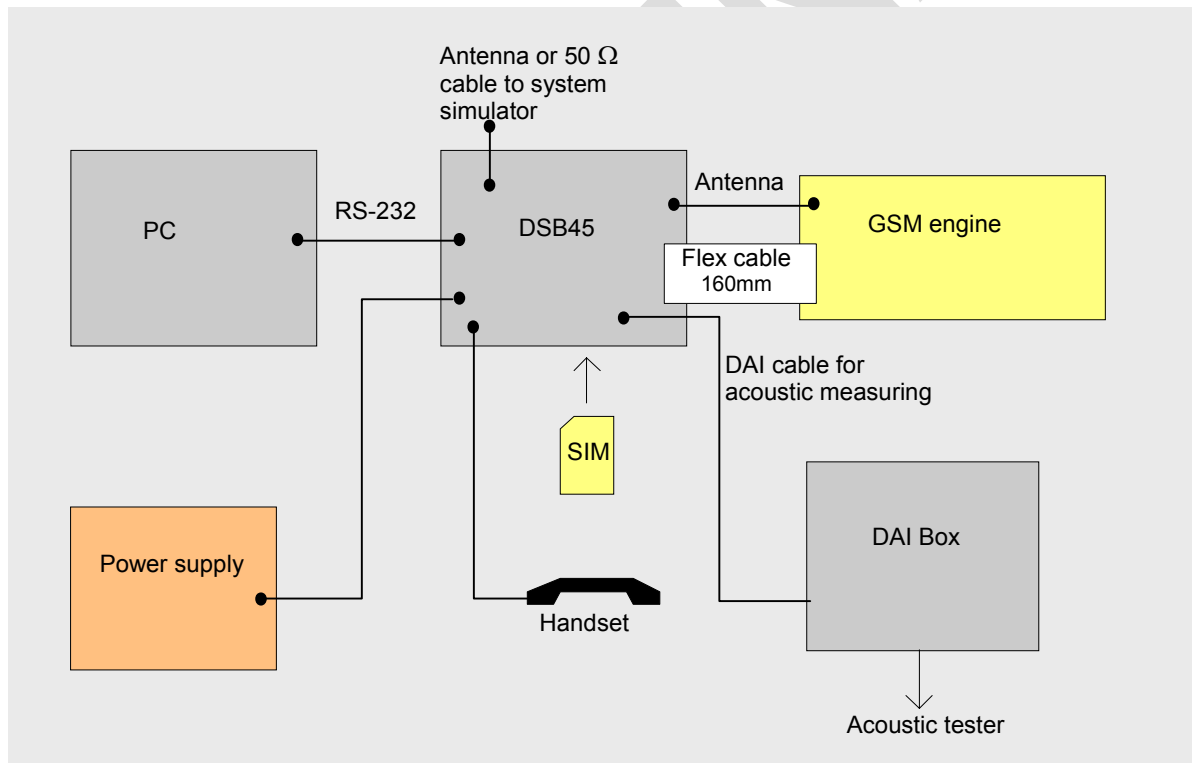- Handset type Votronic HH-SI-30.3/V1.1/0
- PC as MMI

Figure 41: Reference equipment for approval

8 List of parts and accessories

Table 36: List of parts and accessories

Description	Supplier	Ordering information
MC45	Siemens	Siemens ordering number L36880-N8300-A100
Siemens Car Kit Portable	Siemens	Siemens ordering number: L36880-N3015-A117
DSB45 Support Box	Siemens	Siemens ordering number: LS36880-N8301-A100
Votronic Handset	VOTRONIC	Votronic HH-SI-30.3/V1.1 VOTRONIC Entwicklungs- und Produktionsgesellschaft für elektronische Geräte mbH Saarbrücker Str. 8 D-66386 St. Ingbert Phone: 06 89 4 / 92 55-0 Fax: 06 89 4 / 92 55-88 e-mail: contact@votronic.com
SIM card holder incl. push button ejector and slide-in tray	Molex	Ordering numbers: 91228 91236 Sales contacts are listed in Table 37.

Battery cell XWODA	Shenzhen Xwoda Electronic Co., Ltd	To place orders or obtain more information please contact:
		
		Shenzhen Xwoda Electronic Co., Ltd
		Unit 3003, Yingjingyuan,Zhongdian Garden, Shenzhen 518032
		P.R.China
		
		Contact:
		    Edward Lau or Andy Zhao
		    Phone: +86-755-7623789 ext. 314
		    Fax: +86-755-7623078
		    Email: Edward-lau@xwoda.com.cn
		    Email: Andy-zhao@Xwoda.com.cn
		Info:
		    Http://xwoda.com.cn

DF12C board-to-board connector	Hirose	See Chapter 5.3 for details on receptacle on MC45 and mating headers Sales contacts are listed in Table 38.
U.FL-R-SMT antenna connector	Hirose	See Chapter 5.4 for details on U.FL-R-SMT connector, mating plugs and cables Sales contacts are listed in Table 38.

Table 37: Molex sales contacts (subject to change)

Molex	Molex Deutschland GmbH	American Headquarters
For further information please click: http://www.molex.com/	Felix-Wankel-Str. 11 D-74078 Heilbronn-Biberach Phone: +49(7066)9555 0 Fax: +49(7066)9555 29 Email: mxgermany@molex.com	Lisle, Illinois 60532 U.S.A. Phone: 1-800-78MOLEX Fax: 630-969-1352
Molex China Distributors Beijing, Room 1319, Tower B, COFCO Plaza No. 8, Jian Guo Men Nei Street, 100005 Beijing People's Republic of China Phone: 86-10-6526-9628 Phone: 86-10-6526-9728 Phone: 86-10-6526-9731 Fax: 86-10-6526-9730	Molex Singapore Pte. Ltd. Jurong, Singapore Phone: 65-268-6868 Fax: 65-265-6044	Molex Japan Co. Ltd. Yamato, Kanagawa, Japan Phone: 81-462-65-2324 Fax: 81-462-65-2366

Table 38: Hirose sales contacts (subject to change)

Hirose Ltd.	Hirose Electric (U.S.A.) Inc	Hirose Electric GmbH
For further information please click: http://www.hirose.com	2688 Westhills Court Simi Valley, CA 93065 Phone: 805-522-7958 Fax: 805-522-3217	Zeppelinstrasse 42 73760 Ostfildern Kemnat 4 Phone: +49 711 4560-021 Fax +49 711 4560-729 E-mail info@hirose.de
Hirose Electric UK, Ltd Crownhill Business Centre 22 Vincent Avenue, Crownhill Milton Keynes, MK8 OAB Phone:44-1908-305400 Fax: 44-1908-305401	Hirose Electric Co., Ltd. 5-23, Osaki 5 Chome, Shinagawa-Ku Tokyo 141, Japan Phone: 03-3491-9741 Fax: 03-3493-2933	Hirose Electric Co., Ltd. Eroupean Brance First class Building 4F Beechavenue 46, 1119PV Schiphol-Rijk, Netherlands Phone: 31-20-6557-460 Fax: 31-20-6557-469