

## Features

- High Accuracy
- TSYS01:  $\pm 0.1^\circ\text{C}$  @ Temp.:  $-5^\circ\text{C} \dots +50^\circ\text{C}$   
TSYS01-1:  $\pm 0.1^\circ\text{C}$  @ Temp.:  $-20^\circ\text{C} \dots +70^\circ\text{C}$
- Adjustment of high accuracy temp. range on request
- Low Current,  $<12.5 \mu\text{A}$  (standby  $< 0.14 \mu\text{A}$ )
- SPI / I2C Interface
- Small Package: QFN16
- Operating Temperature Range:  $-40^\circ\text{C} \dots +125^\circ\text{C}$

## Applications

- Industrial Control
- Replacement of Thermistors and NTCs
- Heating / Cooling Systems
- HVAC

# TSYS01-FAMILY

## Digital Temperature Sensors

### Specifications

- High Accuracy Temperature Sensor
- TSYS01:  $\pm 0.1^\circ\text{C}$  @ Temp.:  $-5^\circ\text{C} \dots +50^\circ\text{C}$
- TSYS01-1:  $\pm 0.1^\circ\text{C}$  @ Temp.:  $-20^\circ\text{C} \dots +70^\circ\text{C}$
- 16/24 bit Resolution
- Low Power
- SPI/I2C Interface
- QFN16 Package

The TSYS01 is a single device, versatile, new technology temperature sensor. The TSYS01 provides factory calibrated temperature information. It includes a temperature sensing chip and a 24-bit  $\Delta\Sigma$ -ADC. The essence of the digital 24-bit temperature value and the internal calibration values lead to highly accurate temperature information accompanied by high measurement resolution.

The TSYS01 can be interfaced to any microcontroller by an I2C or SPI interface. This microcontroller has to calculate the temperature result based on the ADC values and the calibration parameters.

The basic operating principle is:

- Converting temperature into digital 16/24 bit ADC value
- Providing calibration coefficients
- Providing ADC value and calibration coefficients by SPI or I2C interface.

## Absolute maximum ratings

Absolute maximum ratings are limiting values of permitted operation and should never be exceeded under the worst possible conditions either initially or consequently. If exceeded by even the smallest amount, instantaneous catastrophic failure can occur. And even if the device continues to operate satisfactorily, its life may be considerably shortened.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Supply Voltage	$V_{DD}$	---	-0.3	---	+3.6	V
Operating Temperature	$T_{op}$	---	-40	---	+125	°C
Storage temperature	$T_{stor}$	---	-55	---	+150	°C
ESD rating	ESD	Human Body Model (HBM) pin to pin incl. $V_{DD}$ & GND	-4	---	+4	kV
Humidity	Hum	---	Non condensing			---

## Operating conditions

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Operating Supply Voltage	$V_{DD}$	Stabilized	2.2	---	3.6	V
High Accuracy Supply Voltage	$V_{DD}$	To achieve Acc1	3.2	---	3.4	V
Supply Current	$I_{DD}$	1 sample per second	---	---	12.5	μA
Standby current	$I_S$	No conversion, $V_{DD} = 3V$ $T = 25^{\circ}C$ $T = 85^{\circ}C$	---	0.02 0.70	0.14 1.40	μA μA
Peak Supply Current	$I_{DD}$	During conversion	---	1.4	---	mA
Conversion time	$T_{CONV}$		7.40	8.22	9.04	ms
Serial Data Clock SPI	$F_{SCLK}$		---	---	20	MHz
Serial Data Clock I <sup>2</sup> C	$F_{SCL}$		---	---	400	kHz
$V_{DD}$ Capacitor	---	Place close to the chip	---	100nF	---	---

## Operational characteristics

If not otherwise noted, 3.3V supply voltage is applied.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Temp. Measurement Range	$T_{RANG}$	---	-40	---	+125	°C
Accuracy 1	$T_{ACC1}$	TSYS01 $-5^{\circ}C < T < +50^{\circ}C$ $V_{DD} = 3.2V - 3.4V$	-0.1	---	+0.1	°C
		TSYS01-1 $-20^{\circ}C < T < +70^{\circ}C$ $V_{DD} = 3.2V - 3.4V$				
Accuracy 2	$T_{ACC2}$	$-40^{\circ}C < T < +125^{\circ}C$ $V_{DD} = 3.2V - 3.4V$	-0.5	---	+0.5	°C
Power Supply Reject Ratio	PSRR	$V_{DD} = 2.7 - 3.6$ $T = 25^{\circ}C, C = 100nF$	---	---	0.2	°C
Temperature Resolution	$T_{RES}$	---	---	---	0.01	°C
Time Constant	$T_{liquid}$	$t_{63} (t_1 \rightarrow t_2)$ $t_1 = 25^{\circ}C$ (air 0m/s) $t_2 = 75^{\circ}C$ (liquid) PCB 900mm <sup>2</sup> x 1.5mm FR4	---	3	---	s
	$T_{air}$	$t_{63} (t_1 \rightarrow t_2)$ $t_1 = 25^{\circ}C$ (air 0m/s) $t_2 = 75^{\circ}C$ (air stream 60m/s) PCB 900mm <sup>2</sup> x 1.5mm FR4	---	4	---	s
Self Heating	$SH_1$	10 samples/s, 60s, still air	---	---	0.02	°C

## Analogue to digital converter

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Output Word	---	---		24		bit
Conversion Time	$t_c$	---	7.40	8.22	9.04	ms

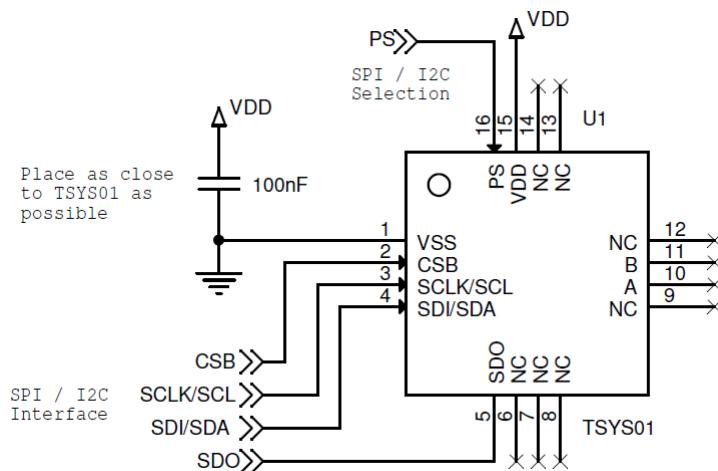
## Digital inputs (SCLK, SDI, CSB, PS)

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Input High Voltage	$V_{IH}$	$V_{DD} = 2.2\dots 3.6V$	$0.7 \cdot V_{DD}$	---	$V_{DD}$	V
Input Low Voltage	$V_{IL}$	$V_{DD} = 2.2\dots 3.6V$	$0.0 \cdot V_{DD}$	---	$0.3 \cdot V_{DD}$	V
CS low to first SCLK rising	$t_{CSL}$	---	21	---	---	ns
CS high to first SCLK rising	$t_{CSH}$	---	21	---	---	ns
SDI setup to first SCLK rising	$T_{DSO}$	---	6	---	---	ns
SDI hold to first SCLK rising	$T_{DO}$	---	6	---	---	ns

## Digital outputs (SDA, SDO)

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Output High Voltage	$V_{OH}$	$I_{Source} = 1mA$	$0.8 \cdot V_{DD}$	---	$V_{DD}$	V
Output Low Voltage	$V_{OL}$	$I_{Sink} = 1mA$	$0.0 \cdot V_{DD}$	---	$0.2 \cdot V_{DD}$	V
SDO setup to first SCLK rising	$t_{QS}$	---	10	---	---	ns
SDO hold to first SCLK rising	$t_{QH}$	---	0	---	---	ns

## Connection diagram



**Pin function table**

Pin	Name	Type	Function
1	V <sub>SS</sub>	G	Ground
2	CSB	DI	SPI: Chip Select (active low) I <sup>2</sup> C: Address Selection
3	SCLK/SCL	DI	SPI: Serial Data Clock I <sup>2</sup> C: Serial Data Clock
4	SDI/SDA	DIO	SPI: Serial Data Input I <sup>2</sup> C: Data Input / Output
5	SDO	DO	SPI: Serial Data Output
6 – 14	NC	---	Not connected / Do not connect
15	V <sub>DD</sub>	P	Supply Voltage
16	PS	DI	Communication protocol select (0=SPI, 1=I <sup>2</sup> C)
---	DAP	---	Die Attach Pad, suggested to connect to V <sub>SS</sub>

**Interface description****PROTOCOL SELECTION**

PS pin input level has to be defined in dependence to protocol selection.

- PS = 0 activates SPI.
- PS = 1 activates I<sup>2</sup>C.

**I<sup>2</sup>C INTERFACE**

A I<sup>2</sup>C communication message starts with a start condition and it is ended by a stop condition. Each command consists of two bytes: the address byte and command byte.

**I<sup>2</sup>C ADDRESS SELECTION**

The I<sup>2</sup>C address can be selected by CSB pin.

- CSB=1 the address is 1110110x.
- CSB=0 the address is 1110111x.

Therefore, two TSYS01 can be interfaced on the same I<sup>2</sup>C bus.

**SPI INTERFACE**

The serial interface is a 4-wire SPI bus, operating as a slave. CS (chip select), SCLK (serial clock), SDI (serial data in), and SDO (serial data out) are used to interact with the SPI master.

Communication with the chip starts when CS is pulled to low and ends when CS is pulled to high.

SCLK is controlled by the SPI master and idles low (SCLK low on CS transitions, mode 0).

A mode where the clock alternatively idles high is also supported (mode 3).

## COMMANDS

The commands are the same for SPI and I<sup>2</sup>C interface.

There are four commands:

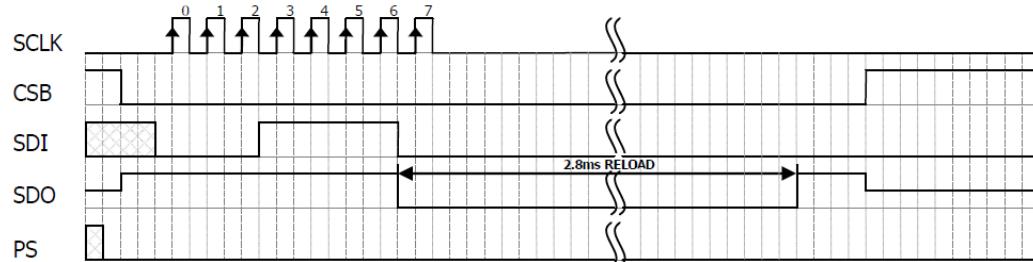
- Reset
- Read PROM (calibration parameters)
- Start ADC Temperature conversion
- Read ADC Temperature result

Command	Hex Value
Reset	0x1E
Start ADC Temperature Conversion	0x48
Read ADC Temperature Result	0x00
PROM Read Address 0	0xA0
PROM Read Address 1 (Coefficient k <sub>4</sub> )	0xA2
PROM Read Address 2 (Coefficient k <sub>3</sub> )	0xA4
PROM Read Address 3 (Coefficient k <sub>2</sub> )	0xA6
PROM Read Address 4 (Coefficient k <sub>1</sub> )	0xA8
PROM Read Address 5 (Coefficient k <sub>0</sub> )	0xAA
PROM Read Address 6 (SN <sub>23..8</sub> )	0xAC
PROM Read Address 7 (SN <sub>7..0</sub> and Checksum)	0xAE

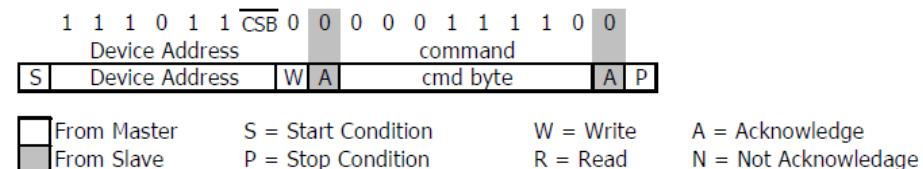
## RESET SEQUENCE

The Reset sequence has to be sent once after power-on. It also can be used to reset the device ROM from an unknown condition.

### SPI



### I<sup>2</sup>C

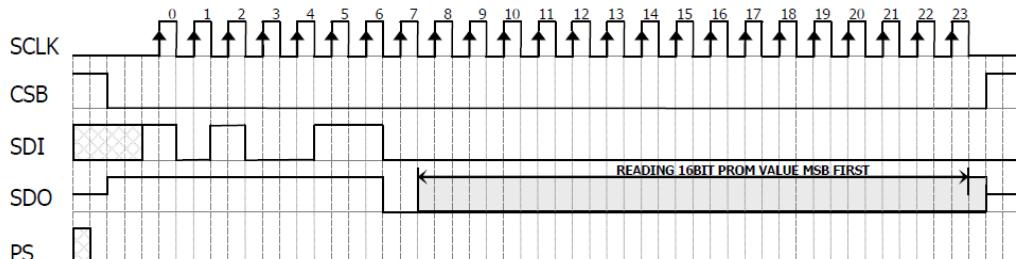


## PROM READ SEQUENCE

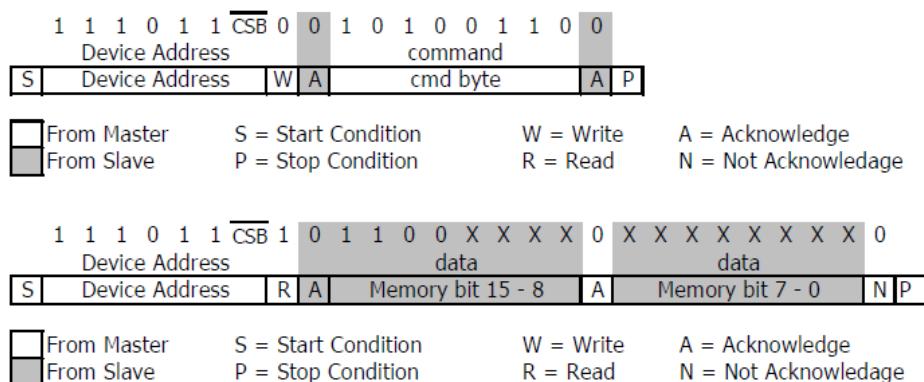
The PROM Read command consists of two parts. First command sets up the system into PROM read mode. The second part gets the data from the system.

Below examples are sequences to read address 3 (command 0xA6).

### SPI



### I<sup>2</sup>C

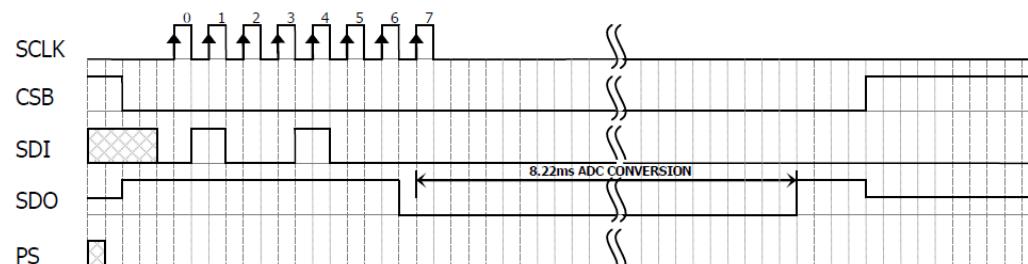


## CONVERSION SEQUENCE

A conversion has to be started by sending this command. The sensor stays busy until conversion is done. When conversion is finished the data can be accessed by using ADC read command

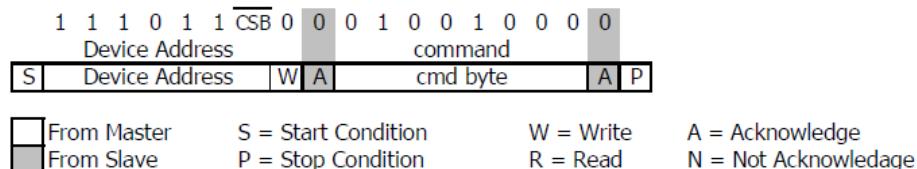
### SPI

The last clock will start the conversion which TSYS01 indicates by pulling SDO low. SDO goes high when conversion is completed.

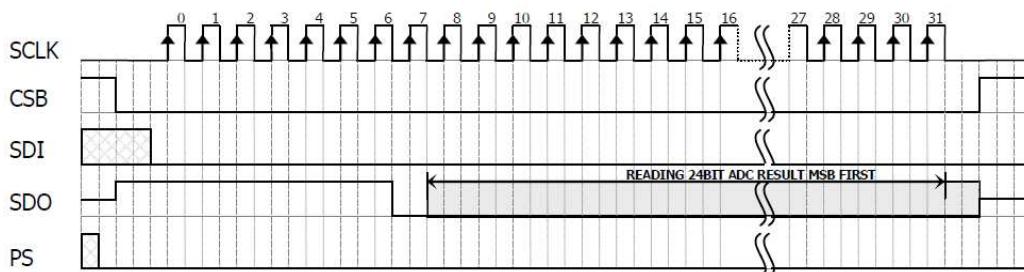
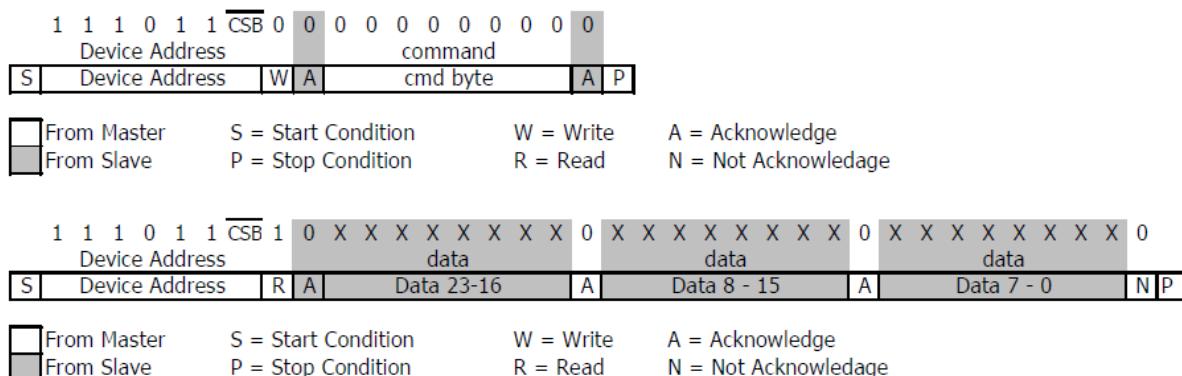


**I<sup>2</sup>C**

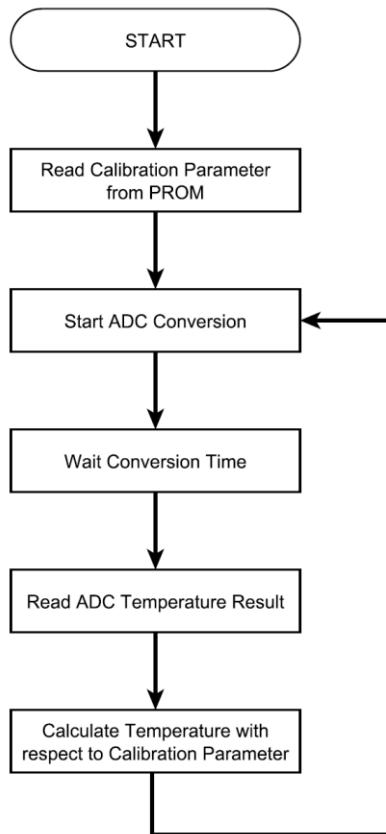
When the command is sent the TSYS01 stays busy until the conversion is done. All other commands except the reset command will not be executed during this time. When the conversion is finished the data can be accessed by sending a ADC read command, when an acknowledge appears from TSYS01.

**READ ADC RESULT**

After the conversion command the ADC result is read using ADC read command. Repeated ADC read commands, or command executed without prior conversion will return all 0 as result.

**SPI****I<sup>2</sup>C**

## Temperature calculation



## CALIBRATION PARAMETER

Variable	Description	Command	Size / bit	Min	Max	Example
$k_4$	Coefficient $k_4$ of polynomial	0xA2	16	0	65535	28446
$k_3$	Coefficient $k_3$ of polynomial	0xA4	16	0	65535	24926
$k_2$	Coefficient $k_2$ of polynomial	0xA6	16	0	65535	36016
$k_1$	Coefficient $k_1$ of polynomial	0xA8	16	0	65535	32791
$k_0$	Coefficient $k_0$ of polynomial	0xAA	16	0	65535	40781

## TEMPERATURE POLYNOMIAL

ADC24:      ADC value  
 ADC16:      ADC24 / 256

$$T / ^\circ\text{C} = (-2) * k_4 * 10^{-21} * \text{ADC16}^4 + 4 * k_3 * 10^{-16} * \text{ADC16}^3 + (-2) * k_2 * 10^{-11} * \text{ADC16}^2 + 1 * k_1 * 10^{-6} * \text{ADC16} + (-1.5) * k_0 * 10^{-2}$$

**EXAMPLE**

ADC24: 9378708

ADC16: 9378708 / 256 = 36636

$$\begin{aligned}
 T / ^\circ C = & (-2) * 28446 * 10^{-21} * 36636^4 + \\
 & 4 * 24926 * 10^{-16} * 36636^3 + \\
 & (-2) * 36016 * 10^{-11} * 36636^2 + \\
 & 1 * 32791 * 10^{-6} * 36636 + \\
 & (-1.5) * 40781 * 10^{-2}
 \end{aligned}$$

T / °C = 10.59

**Serial number**

Content / Description		Command	Size / bit	Example
Bit 16 ... 8	Bit 7 ... 0			
SN <sub>23...8</sub>		0xAC	16	0x0005 (H <sub>0</sub> = 0x00, L <sub>0</sub> = 0x05)
SN <sub>7...0</sub>	Checksum	0xAE	16	0x96D9 (H <sub>0</sub> = 0x96, L <sub>0</sub> = 0xD9)

Serial number =  $2^8 \times SN_{23...8} + SN_{7...0}$

**EXAMPLE**

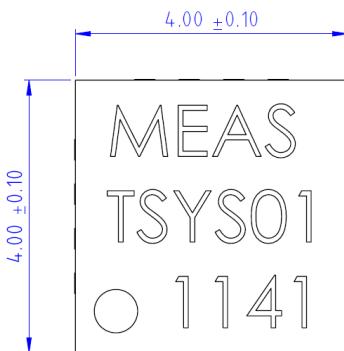
Serial number:  $2^8 \times 5 + 150 = 1430$

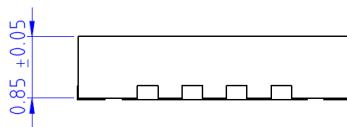
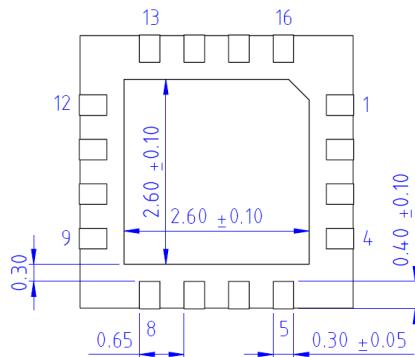
**Checksum**

In order to check communication and integrity of PROM content, the PROM includes a checksum. By summarization of the complete PROM content in a byte by byte way, the verification can be performed. The lower byte of the sum result has to be 0x00.

**Dimensions****TOP VIEW**

All dimensions shown in mm

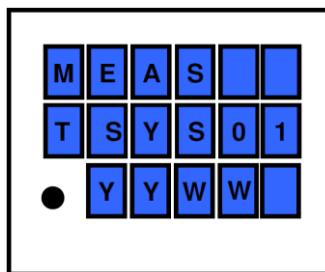


**SIDE VIEW****BOTTOM VIEW**

Die Attach Pad, suggested to connect to VSS

**Marking**

Line	Description	Example
1	Manufacturer	MEAS
2	Product Name	TSYS01
3	Pin 1 Dot, Date Code YYWW	1141

**Order information**

Please order this product using following:

Part Number

G-NICO-018

G-NICO-023

Part Description

TSYS01 Digital Temperature Sensor

TSYS01-1 Digital Temperature Sensor

**EMC**

Due to the use of these modules for OEM application no CE declaration is done. Especially line coupled disturbances like surge, burst, HF etc. cannot be removed by the module due to the small board area and low price feature. There is no protection circuit against reverse polarity or over voltage implemented. The module

will be designed using capacitors for blocking and ground plane areas in order to prevent wireless coupled disturbances as good as possible.

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