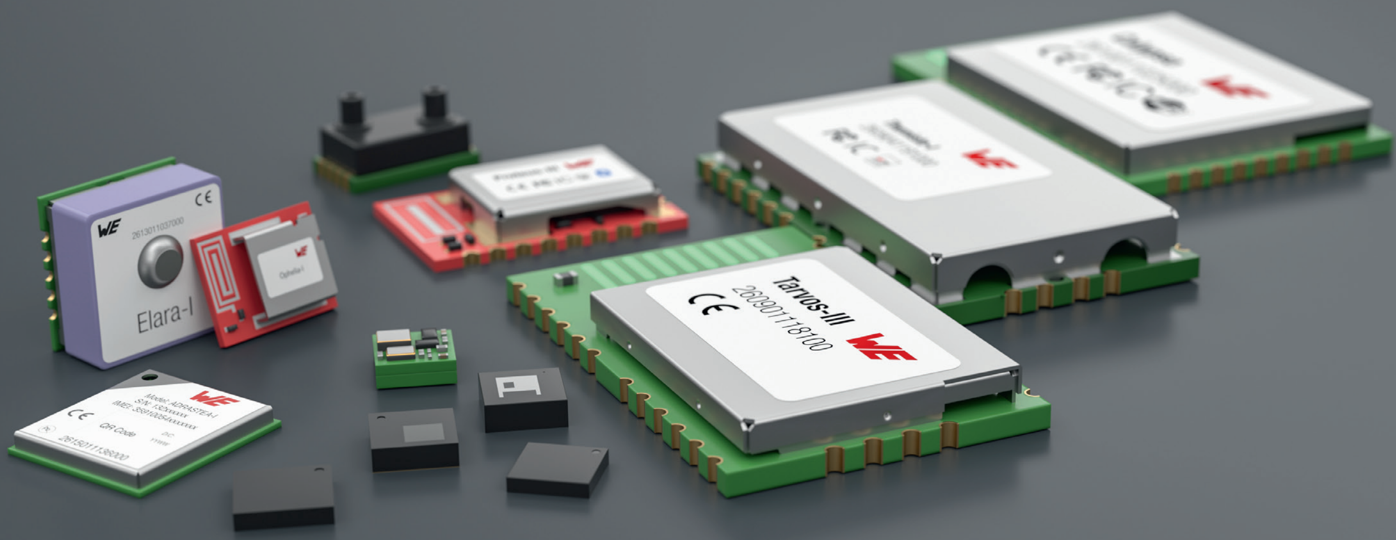


USER MANUAL

RCDS SENSOR

79100200X

VERSION 1.2

OCTOBER 10, 2024

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

Revision history

Manual version	Product version	Notes	Date
1.0	000.001	• Initial release of the manual	September 2024
1.1	000.001	• Update Chapter 6: Patent Information	October 2024
1.2	000.001	• Update Chapter 6: Patent Information	October 2024

Abbreviations

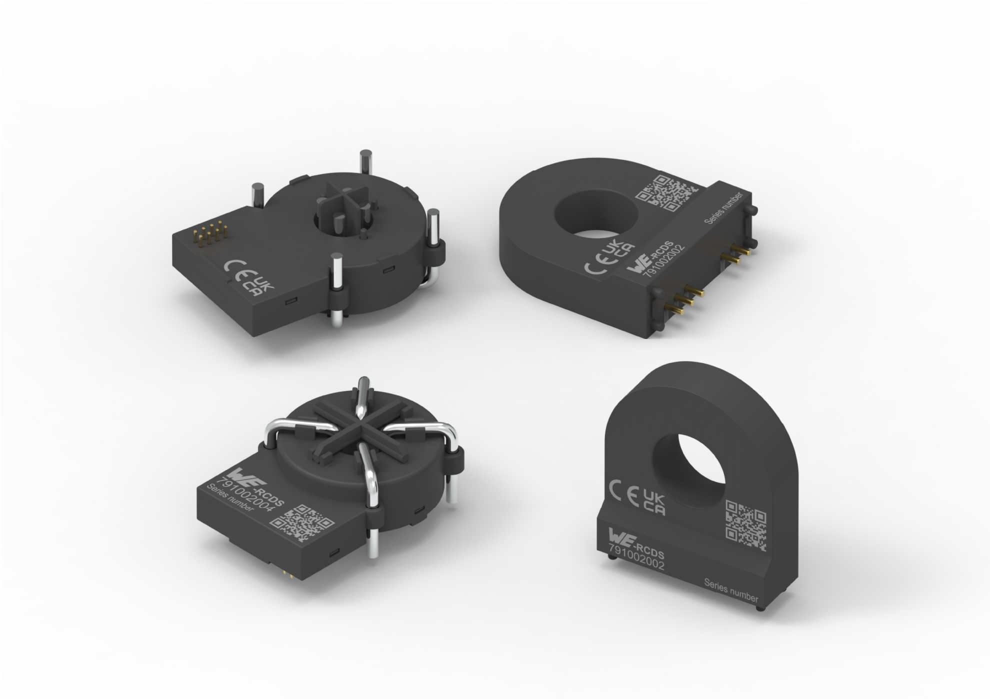
Abbreviation	Description
EV	Electric Vehicle
IEC	International Electrotechnical Commission
PCB	Printed Circuit Board
IoT	Internet of Things
DC	Direct Current
RDC-M	Residual Direct Current Monitoring
ANSI	American National Standards Institute
UL	Underwriters Laboratories
EMC	Electromagnetic compatibility
EN	European Standards
MCU	Micro Controller Unit
ZCT	Zero-phase current transformers
ADC	Analog to Digital Converter
RMS	Root Mean Square
PWM	Pulse Width Modulation
IC-CPD	In Cable Control and Protection Device

Contents

1 Product description

1.1 Introduction

The residual current detection sensors 791002002, 791002004 are sensors designed for Mode 3 EV stationary charging application according to IEC 62955: 2018.It is an open loop flux gate current sensor with toroidal core and designed for PCB mounting.



1.2 Sensor Feature

- Compact design for PCB board mounting
- Cable through hole (only for 791002002)
- 3-phase primary conductors on module (only for 791002004)
- DC 6mA residual direct current detecting RDC-M-Module for Mode 3 EV charging
- Digital open-drain output, 6mA DC trip indication
- Supply voltage drop monitoring
- Heart Beat or Error output for system fault indication
- Designed to meet standard: IEC 62955: 2018
- Module Software certified according to ANSI/UL 1998, Class 1
- Partially EMC tested according to IEC 62955: 2018 and EN 60730-1

1.3 Block diagram

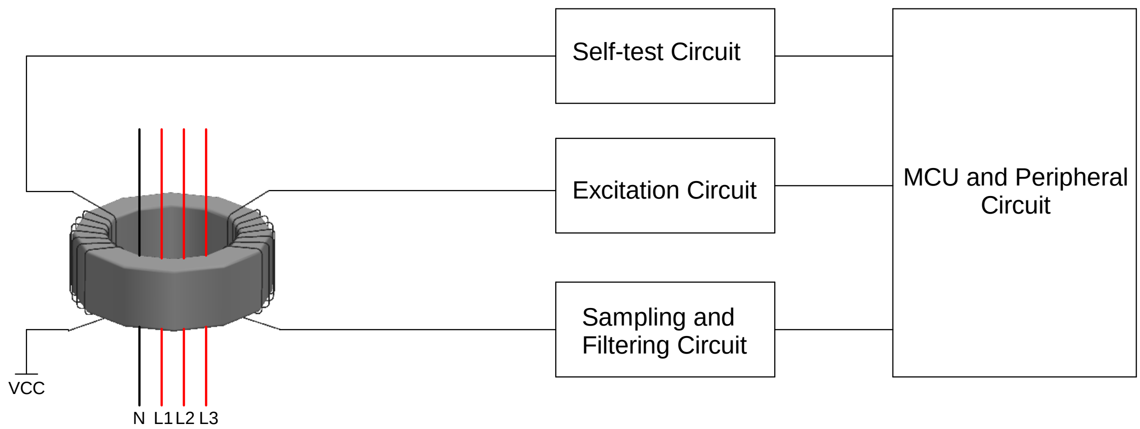


Figure 1: Block diagram

WE-RCDS use the open-loop fluxgate principle and the excitation and pickup coil are the same coil. The excitation coil drives the magnetic core into saturation and back to unsaturation and into saturation in negative direction. The external flux generate by fault current will be draw in or pushed out by the coils. If there is no external magnetic field exist, the voltage induced to sampling resistor will be symmetrical in positive and negative direction. Otherwise, the voltage will be different in positive and negative direction and the fault current can be acquired and demodulated out from it.
As shown in the block diagram WE-RCDS is composed of self-test circuits, excitation circuit, sampling circuit, filtering circuit and MCU and peripheral circuit.

- MCU and Peripheral Circuit

  All interfaces are connected to MCU, and MCU is intended to monitor or control all function circuits.

- Product Self-test Circuit

  Circuit is designed for generating 6.5mA DC fault in current transformer (ZCT), MCU will initiate test signal when test request from TEST-IN is detected.

- Excitation Circuit

  Excitation circuit is designed to generate periodic varying signal to ZCT, the exciting frequency is controlled by MCU.

- Sampling and Filtering Circuit

  The inducted current in coil is filtered and sampled by MCU ADC.

1.4 Ordering information

WE order code	Version	Type	$I_{\Delta n}$	$I_{\Delta P}$	Operating Temperature
791002002	Horizontal	3-Phase primary conductor	6 mA DC	80 / 40 A max.	-40 ℃ to +105℃
791002004	Vertical	Cable Through Hole	6 mA DC	40 A max.	-40 ℃ to +105℃
$I_{\Delta n}$:Rated Residual Operating Current; $I_{\Delta P}$:Primary Current					

Table 1: Ordering information

2 Sensor and electrical specification

2.1 Electrical Specification

2.1.1 Electrical property of 791002002

Symbol	Description	Min.	Typ	Max	Unit
I_P	Primary rated current (1phase / 3phase)			80 / 40	A
$I_{\Delta DC}$	Residual DC operating current		6		mA
$I_{\Delta DC\_tol}$	Trip tolerance	3	4.6	6	mA
$I_{\Delta R\ DC}$	Recovery current level for $I_{\Delta DC}$ (absolute value DC)			2.5	mA
f_{BW}	Detection frequency range		DC		
PWM	Heartbeat signal frequency for system monitoring	940	1000	1060	Hz
	Heartbeat signal duty cycle for system monitoring	49%	50%	51%	
$V_{\_PWM\_out}$	PWM output voltage			4.7	V
$V_{TEST\_IN,}$ low	TEST-IN input voltage, low level			0.6	V
$V_{TEST\_IN,}$ high	TEST-IN input voltage, high level	3.1			V
$V_{TRIP,}$ low	TRIP output voltage, low level			0.4	V
$V_{TRIP,}$ high	TRIP output voltage, high level			+Vcc	V

Table 2: Electrical properties of 791002002

2.1.2 Electrical property of 791002004

Symbol	Description	Min.	Typ	Max	Unit
I_P	Primary nominal RMS current		32	40	A
$I_{\Delta DC}$	Residual DC operating current		6		mA
$I_{\Delta DC\_tol}$	Trip tolerance	3	4.6	6	mA
$I_{\Delta R\ DC}$	Recovery current level for $I_{\Delta DC}$ (absolute value DC)		2.5		mA
X	Resolution @ $I_{\Delta DC}$			0.2	mA
PWM_{freq}	Frequency	7.52	8	8.48	kHz
PWM_{out}	PWM duty cycle of the DC component $I_{\Delta DC}$ (for monitoring purpose only)		3.33		%/mA
$V_{\_PWM\_out}$	PWM output voltage		4.7		V
f_{BW}	Frequency Range		DC		
$V_{TEST\_IN,}$ low	TEST-IN input voltage, low level			0.6	V
$V_{TEST\_IN,}$ high	TEST-IN input voltage, high level	3.1			V
$V_{TRIP,}$ low	TRIP output voltage, low level			0.4	V
$V_{TRIP,}$ high	TRIP output voltage, high level			+Vcc	V

Table 3: Electrical properties of 791002004

2.2 General Properties

Symbol	Description	Min.	Typ.	Max.	Unit
D-in	Inner diameter	16.8	17	17.2	mm
$+V_{DD}$	Supply voltage	4.85	5	5.15	V
$+V_{CC}$	Pull up voltage			5.5	V
I_{CC}	Consumption current	17	22	30	mA
$Sclear_{ps}$	Clearance (primary to secondary)	not applicable*			
$Screep_{ps}$	Creepage (primary to secondary)	not applicable*			
Plastic Housing Flammability Rating		UL94 V-0			

Table 4: General properties of 791002002

*The sensor is manufactured and designed to use with insulated cables. The product user must evaluate the correct insulated cables by themselves or needs to make sure that the required clearances and creepage distances are ensured.

Symbol	Description	Min.	Typ.	Max.	Unit
$+V_{DD}$	Supply voltage	4.85	5	5.15	V
$+V_{CC}$	Pull up voltage			5.5	V
I_{CC}	Consumption current	17	24	30	mA
$Sclear_{pp}$	Clearance (primary to primary)[1]	5.7			mm
$Screep_{pp}$	Creepage (primary to primary)[1]	6.5			mm
$Sclear_{ps}$	Clearance (primary to secondary)[2]	6.15			mm
$Screep_{ps}$	Creepage (primary to secondary)[2]	6.15			mm
Plastic housing flammability rating		UL94 V-0			

Table 5: General properties of 791002004

[1] Fulfill the requirements with installed spacer provided by WE.

[2] Designed and manufactured based on reinforced insulation, insulation material group IIIa, pollution degree 2, altitude $\leq$ 3000m and overvoltage category III (In accordance with IEC 60664-1:2007). Assume the mounting PCB to be at least material group IIIa.

2.3 Absolute Maximum Ratings

Symbol	Description	Min.	Max.	Unit
U_{MAX}	Maximum rated voltage (AC RMS) of primary conductors (Phase against neutral voltage/ Phase against phase voltage)		250/440	V
$+V_{DD}$	Supply voltage	-0.3	5.5	V
$+V_{CC}$	Pull up voltage	-0.3	5.5	V
V_{TRIP}, input	Input voltage of TRIP	-0.3	5.5	V
I_{TRIP},sink	Maximum sink current of TRIP		20	mA
$V_{TEST\text{-}IN}$,input	Input voltage of TEST-IN	-0.3	5.5	V
$I_{TEST\text{-}IN}$,sink	Maximum sink current of TEST-IN		±5	mA

Table 6: Absolute maximum rating of 791002002

Conditions above these ratings may cause permanent damage and may impact the reliability. Therefore, exceeding these values or others are not permitted.

Symbol	Description	Min.	Max.	Unit
I_P	Primary nominal RMS current		40	A
U_{MAX}	Maximum rated voltage (AC RMS) of primary conductors (Phase against neutral voltage/ Phase against phase voltage)		250/440	V
$+V_{DD}$	Supply voltage	-0.3	5.5	V
$+V_{CC}$	Pull up voltage	-0.3	5.5	V
V_{IN}	Input voltage of digital output (PINs 1,3,4)	-0.3	5.5	V
I_{sink}	Maximum sink current of digital output (PINs 1,3,4)		20	mA
$V_{TEST\text{-}IN}$,input	Maximum input voltage of TEST-IN		5.5	V
$I_{TEST\text{-}IN}$,sink	Maximum sink current of TEST-IN		±5	mA

Table 7: Absolute maximum rating of 791002004

Conditions above these ratings may cause permanent damage and may impact the reliability. Therefore, exceeding these values or others are not permitted.

2.4 Certifications

Certification	Standard
RoHS Approval	Compliant [2011/65/EU&2015/863]
REACH Approval	Conform or declared [(EC)1907/2006]
Halogen Free	Conform [JEDEC JS709B]
Halogen Free	Conform [IEC 61249-2-21]
Software Functional Safety	Compliant [ANSI/UL 1998, Class 1]

Table 8: Certifications of 791002002 and 791002004

3 Application

The residual current detection sensor WE-RCDS are designed for Mode 3 stationary electrical vehicles charging devices. The following figure shows a simplified, typical block diagram of a Mode 3 stationary electrical vehicle (EV) charging, which is also typically known as a wallbox station.

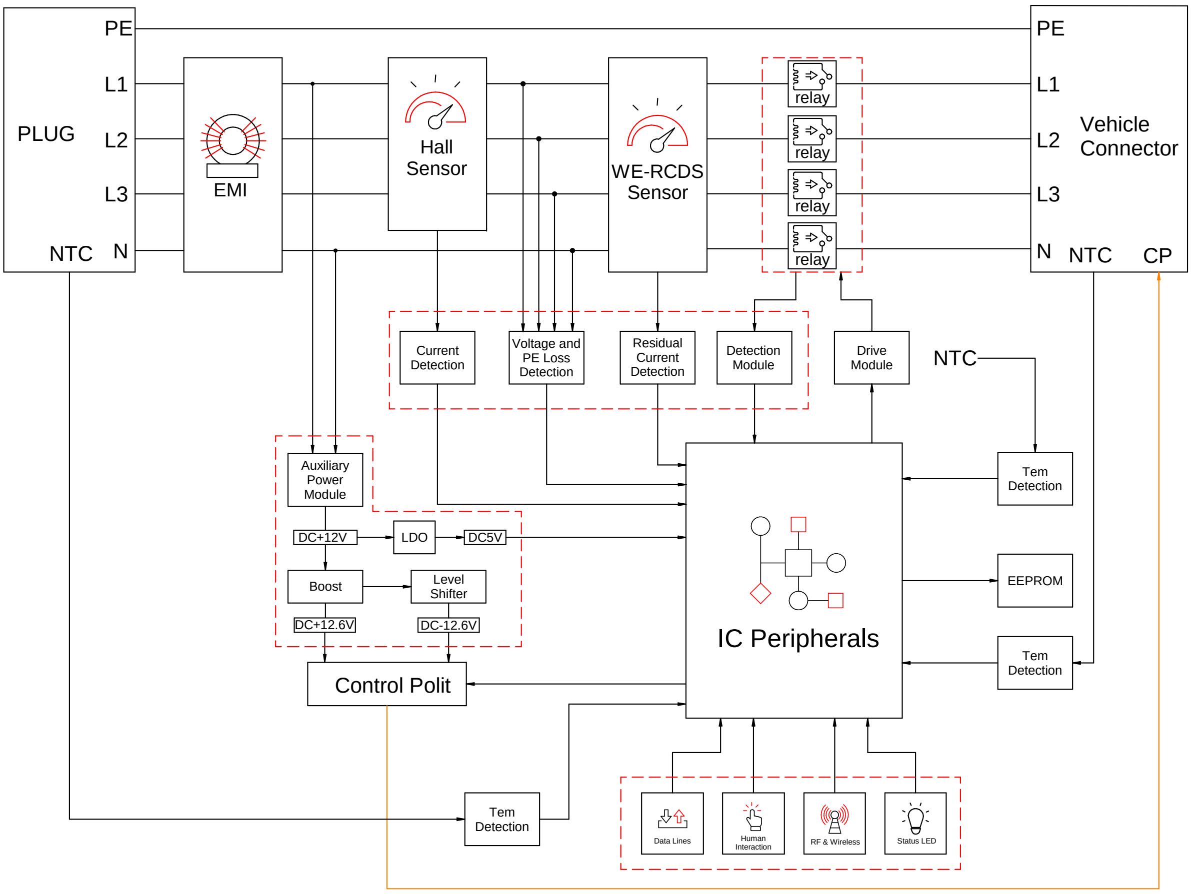


Figure 2: Simplified typical block diagram of Mode 3 EV charging station

3.1 Common electrical charging mode

Electric vehicles are normally loaded at different times, in different places or different feed points, requiring different energy input. In order to provide the necessary safety and charging energy to match the demand, four different charging modes are defined in IEC 61851-1.

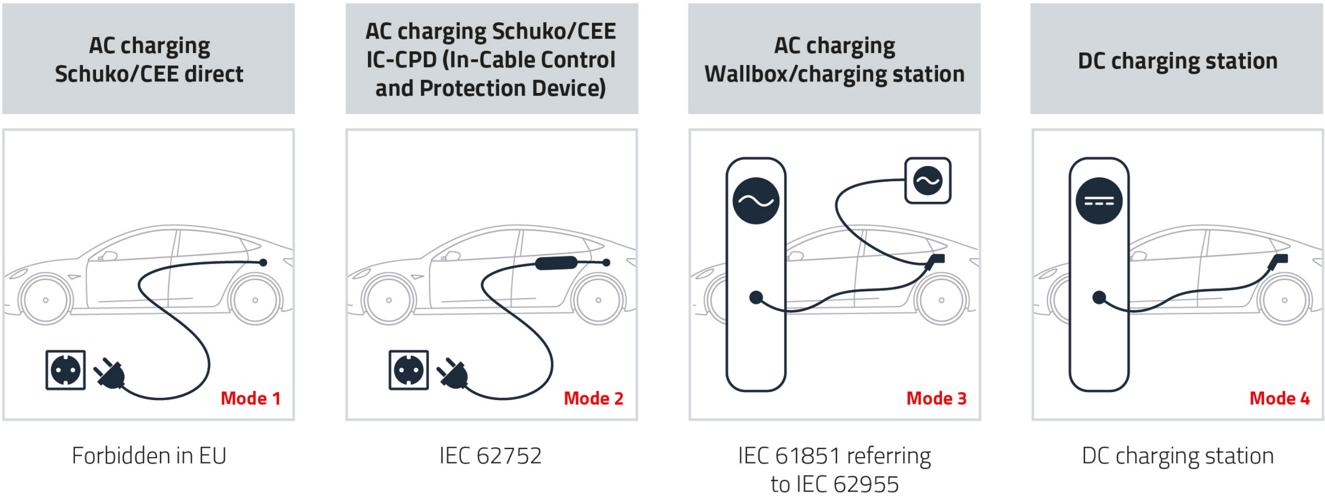


Figure 3: Different charging modes as defined in IEC 61851-1

- Mode 1: The EV directly connects to a household socket.

  Maximum Current: 16 A.
  Voltage: Up to 250 V (single-phase) or 480 V (three-phase).
  Communication: No communication between the EV and the charge point.
  Use: Prohibited or restricted in many countries due to its simplicity and lack of safety features.

- Mode 2: Uses a special charging cable equipped with an in-cable control and protection device (IC-CPD).

  Maximum Current: 32 A.
  Voltage: Up to 250 V (single-phase) or 480 V (three-phase).
  Safety: IC-CPD ensures control and safety functions.
  Use: Safer than Mode 1 for long-term charging from household sockets.

- Mode 3: AC current delivered to the EVs on-board charger.

  Safety: Employs control and protection functions for public safety.
  Use: Commonly found in public charging stations or home appliances

- Mode 4: Delivers DC current directly to the battery, bypassing the on-board charger.

  Use: Typically used for fast charging stations in public areas

3.2 General residual current detection requirement in EV charging

According to IEC 60364-7-722, each connecting point should be protected by its own RCD of at least type A, having a rated residual operating current not exceeding 30 mA. Additional protective measures against DC fault currents need to be taken. The appropriate measures are:

- RCD type B, or
- RCD type A and appropriate equipment that ensures the switching of the supply in case of a DC fault current above 6 mA.

To ensure that the proper functionality of RCDs type A or type F is not impaired by DC residual currents above 6 mA.
WE- RCDS are designed to meet the operating characteristics based on IEC62955 to build a Residual direct current detecting device to avoid costs of RCD type B

3.3 Main verification points of the operating characteristics of a residual current detecting device

Based on IEC62955 which is a related product reference standard of our WE-RCDS sensor. The exact verification procedure and the necessary repetitions of the tests are described in this standard.

3.3.1 Tripping current

- Steady increase of smooth DC residual current
  - RCD module shall trip within the limits of 3 mA and 6 mA DC.
- Residual direct currents which may result from rectifying circuits supplied from two phases
  - RCD module shall trip within the limits of 3.5 mA to 7 mA.
- Residual direct currents which may result from rectifying circuits supplied from three phase
  - RCD module shall trip within the limits of 3.1 mA to 6.2 mA.

3.3.2 Break time

- Verification of correct operation on a smooth DC residual current.
- Residual direct currents supplied from two phases.
- Residual direct currents supplied from three phases.

The break times shall be in compliance with the values given in Table of Maximum values of break times for residual direct currents below.

Residual direct current	Max. Break time
6 mA	10.0 s
60 mA	0.3 s
200 mA	0.1 s

Table 9: Maximum values of break times for residual direct currents

3.3.3 Non-operating time for alternating residual currents

The following test shall be made at each of the remaining value of the alternating residual current specified in the table of Minimum values of non-operating time for alternating residual currents (RMS values). The residual current is suddenly established, and the break time being measured.

Alternating Residual current(RMS)	Non-operating time
up to 30 mA	no tripping
60 mA	0.3 s
150 mA	0.08 s
5 A	0.08 s

Table 10: Minimum values of non-operating time for alternating residual currents (RMS values)

3.4 Necessity of DC Current detection

Electric vehicles use rectifiers to convert AC from the power grid to DC for battery charging, which can result in small amounts of DC current flowing back into the AC grid. Additionally, insulation faults or coupling effects in the charging equipment or vehicle can cause DC current to leak into the grounding conductor. Both issues can lead to DC residual currents in the main line of the Mode 3 charging station that not be detected by standard AC residual current devices (RCDs Type A). In case a DC residual current occur, the magnetic material of the ZCT of upstream type A RCD will be pre magnetized and thus insensitive to any further residual currents. Type A RCD will "become blind" and its protective function is thus overridden.

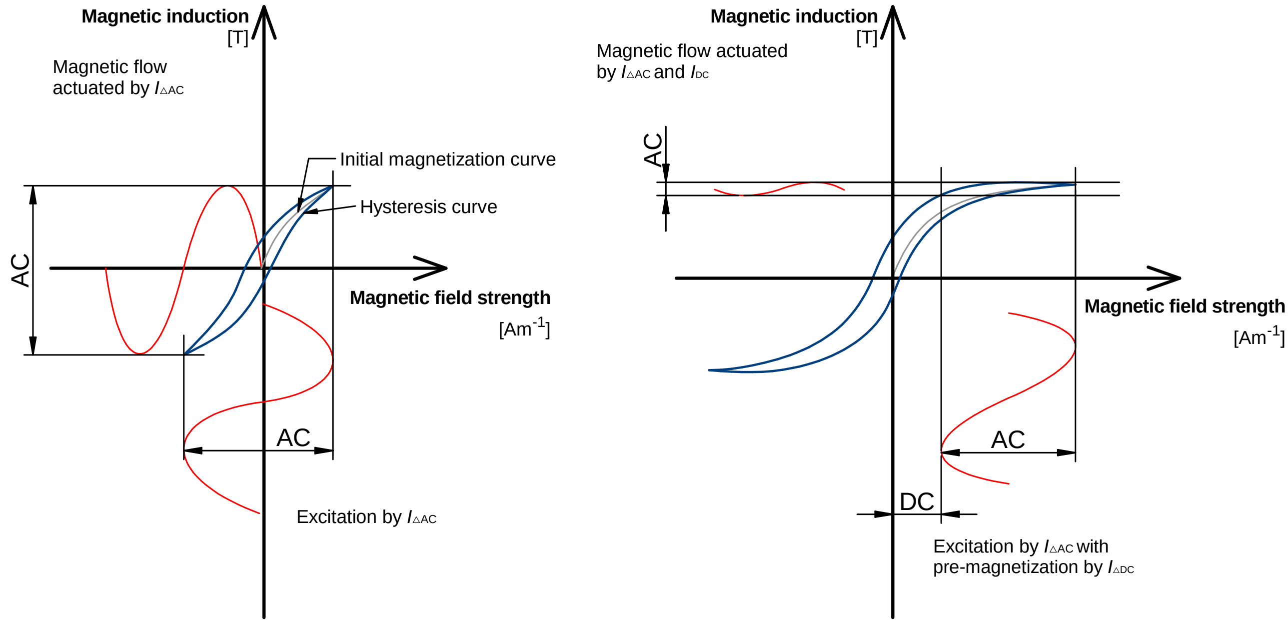


Figure 4: Magnetization by AC and DC

4 RDC-M-module Characteristics

RDC-M-module capable of 6 mA DC residual current detection and evaluation electrically coupled to a separate protective or switching device.

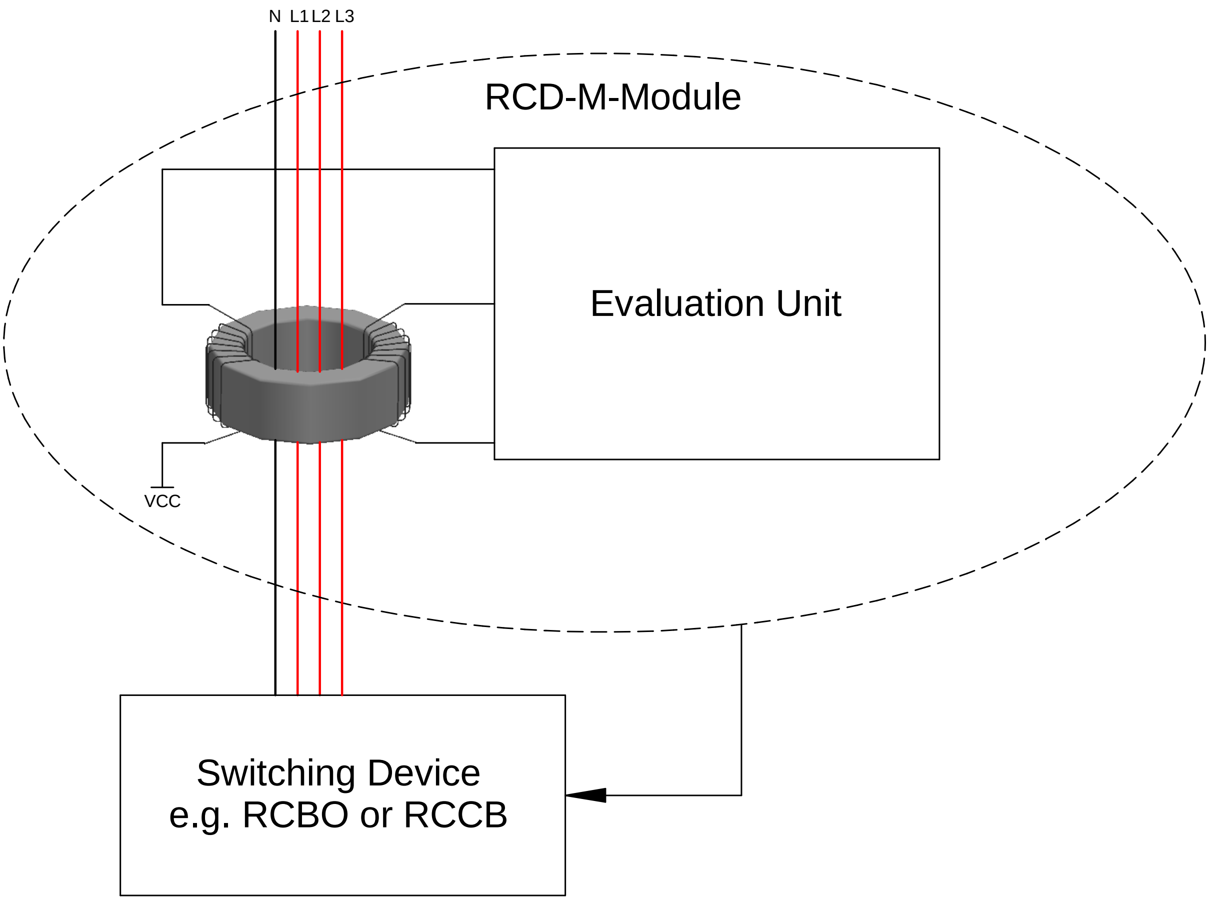


Figure 5: RDC-M-module schematic

The tripping time specified for WE-RCDS Modules is the time from residual current suddenly established to the tripping signal generated by the sensor. The total tripping time should be considered from customer side with including for example the response time of relay and all control units.

4.1 Operation Characteristic

According to IEC62955 the operating characteristics for smooth DC, two phase pulsating DC, and three phase pulsating DC need to be verified in terms of tripping current and break time. The typical residual current waveforms shown as below.

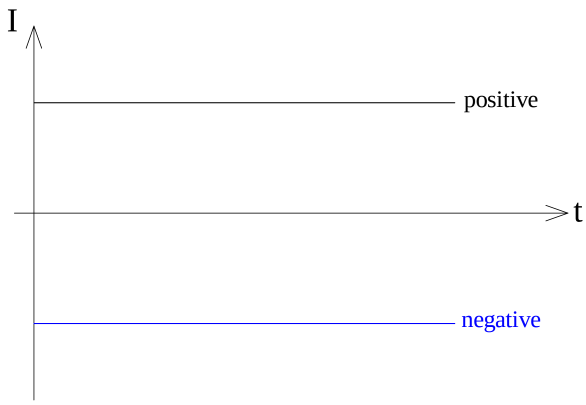


Figure 6: smooth DC characteristic

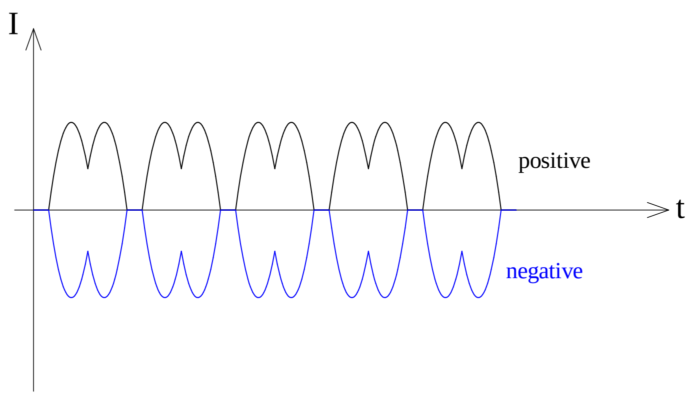


Figure 7: two phase pulsating DC characteristics

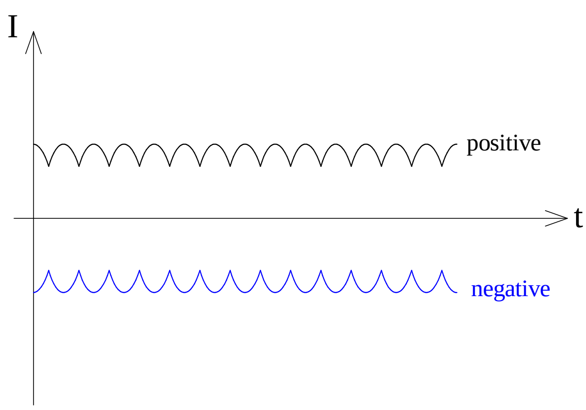


Figure 8: three phase pulsating DC characteristics

- Tripping current

Different types of residual current being applied respectively, and the residual current is steadily increased starting from a value to reach a certain value in 30 s in accordance with the requirements of the standard.
And WE-RCDS modules performs as follows:

For 791002002:

Wave	Frequency	Min.	Typ.	Max.	Unit
Smooth DC	0H	3.0	4.6	6.0	mA
Two phase DC	50Hz	3.5	5.3	7.0	mA
Three phase DC	50Hz	3.1	4.6	6.2	mA

Table 11: Residual trip current for 791002002

For 791002004:

Wave	Frequency	Min.	Typ.	Max.	Unit
Smooth DC	0H	3.0	4.6	6.0	mA
Two phase DC	50Hz	3.5	5.2	7.0	mA
Three phase DC	50Hz	3.1	4.6	6.2	mA

Table 12: Residual trip current for 791002004

- Break time

Different types and sizes of residual current is suddenly established respectively, and the break time being measured.
For 791002002:

Wave	Frequency	Current	Typ.	Max. time limit	Unit
Smooth DC	0Hz	6mA	115	10000	ms
Smooth DC	0Hz	60mA	45	300	ms
Smooth DC	0Hz	200mA	45	100	ms
Two phase DC	50Hz	60mA	50	300	ms
Two phase DC	50Hz	200mA	55	100	ms
Three phase DC	50Hz	60mA	45	300	ms
Three phase DC	50Hz	200mA	45	100	ms

Table 13: Break time for 791002002

For 791002004:

Wave	Frequency	Current	Typ.	Max. time limit	Unit
Smooth DC	0Hz	6mA	128	10000	ms
Smooth DC	0Hz	60mA	49	300	ms
Smooth DC	0Hz	200mA	49	100	ms
Two phase DC	50Hz	60mA	55	300	ms
Two phase DC	50Hz	200mA	58	100	ms
Three phase DC	50Hz	60mA	50	300	ms
Three phase DC	50Hz	200mA	49	100	ms

Table 14: Break time for 791002004

- Non-Operation

The alternating currents of different sizes are applied as requested and the non-operation behaviors of WE-RCDS shown as below.

For 791002002:

Wave	Frequency	Current	Min.	Low-limit	Unit
AC	50Hz	Up to 30mA	∞	∞	ms
AC	50Hz	60mA	∞	300	ms
AC	50Hz	150mA	100	80	ms
AC	50Hz	5A	80	80	ms

Table 15: Non-operation time for 791002002

For 791002004:

Wave	Frequency	Current	Min.	Low-limit	Unit
AC	50Hz	Up to 30mA	∞	∞	ms
AC	50Hz	60mA	∞	300	ms
AC	50Hz	150mA	100	80	ms
AC	50Hz	5A	80	80	ms

Table 16: Non-operation time for 791002004

4.2 Schematic

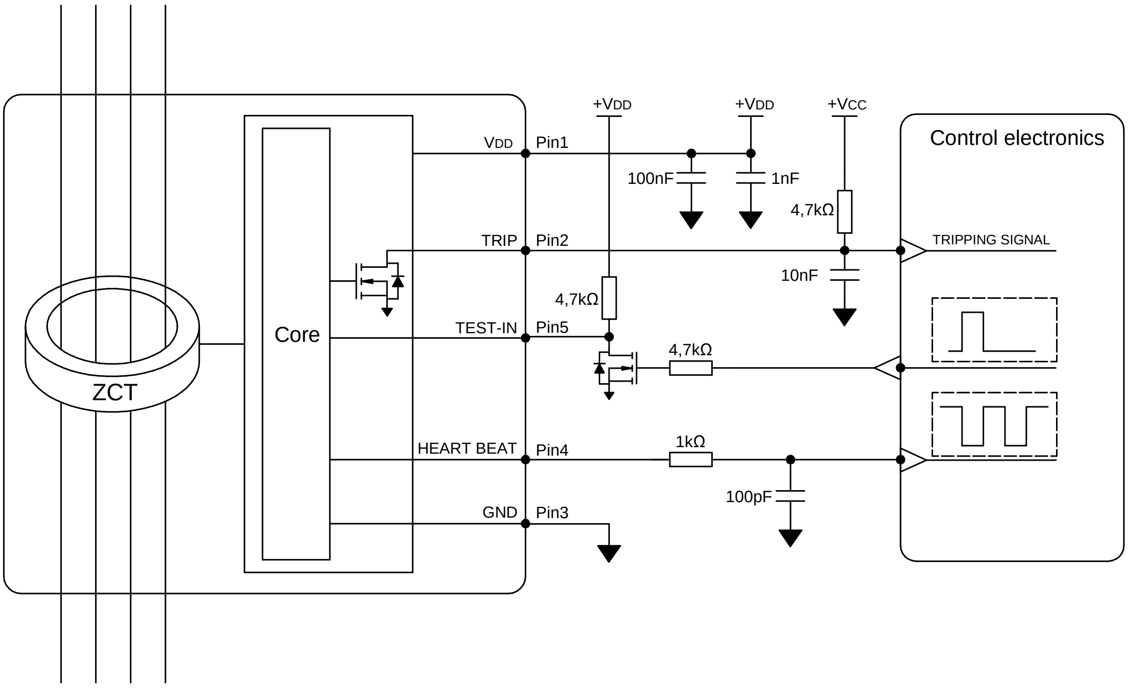


Figure 9: Application circuit for 791002002

Pin No.	Pin Symbol	Description
Pin 1	$+V_{DD}$	Module's power supply Current output capability should be $>$ 100mA Ripple voltage should be $\leq$ 150mV The voltage should remain approximately monotonically increasing as it rises from 10% to 90%
Pin 2	TRIP	If residual current is lower than the pre-set DC trip value, the output of Pin 2 would be in a low level. In any other case, the output of pin 2 would be in a high impedance state.
Pin 3	GND	Ground
Pin 4	HEART BEAT	Heartbeat signal output In normal condition the heartbeat signal is typically 1KHz with a duty cycle of 50% and will change in an event of system fault. Abnormal frequency or duty cycle of heartbeat signal are considered as a system anomaly and the main circuit must be switched off.
Pin 5	TEST-IN (Self-test)	By pulling down this pin to GND (low level) for a period of 50ms to 1000ms, the module will calculate the zero-point drift and store the value to the internal register to finish the calibration operation. After the calibration is finished, the system will internally generate a simulated residual current to check whether the module provides the correct response.

Table 17: Pin description of 791002002

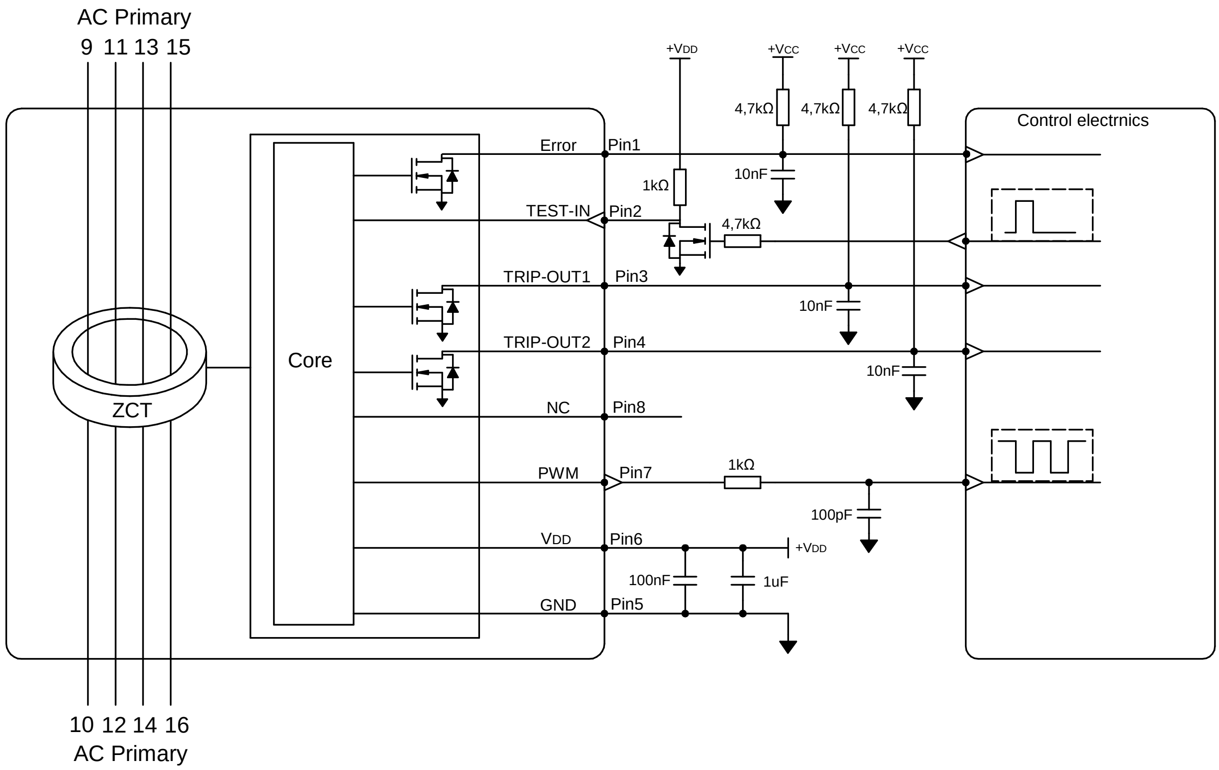


Figure 10: Application circuit for 791002004

Pin No.	Pin Symbol	Description
Pin 1	Error	Open-drain output pin for system fault condition indication. In normal operation this pin will be conducted to GND. In case a fault occurs, the impedance of this pin will be high.
Pin 2	TEST-IN	By pulling down this pin to GND (low level) for a period of 50ms to 1000ms, the module will calculate the zero-point drift and store the value to the internal register to finish the calibration operation. After the calibration is finished, the system will internally generate a simulated residual current, to check whether the module provides the correct response.
Pin 3	TRIP-OUT1	If residual current is below pre-set DC trip value, Pin 3 would be in a low level state. In any other case, Pin 3 would be in a high impedance state.
Pin 4	TRIP-OUT2	If residual current is below pre-set DC trip value, Pin 4 would be in a low level state. In any other case, Pin 4 would be in a high impedance state.
Pin 5	GND	Ground
Pin 6	$+V_{DD}$	Module's power supply Current output capability should be $>$ 100mA Ripple voltage should be $\leq$ 150mV The voltage should remain approximately monotonically increasing as it rises from 10% to 90%.
Pin 7	PWM	Indicating of DC residual current from 2.5–30mA DC with duty-cycle of 8kHz PWM. Fluctuation range of duty-cycle of PWM at 6mA DC is from 17% to 21%.
Pin 8	NC	Not connected
Pin 9, 11, 13, 15	AC Primary	AC main circuit input
Pin 10, 12, 14, 16	AC Primary	AC main circuit output

Table 18: Pin description of 791002004

The filtering and decoupling capacitors, Pull-up and current limiting resistors have been applied in the recommended application circuit and all evaluations and specifications have been defined and verified with this recommended application diagram, Besides the EMC verification is done with this schematic either and the EMC test reports can be shared by the request.

4.3 Calibration process and Self Test

Calibration process and self- test is a crucial process to ensure the sensor work accurately and properly and the process starts when the right test-in signal is applied.

During this process the current status will be written into the relevant register to eliminate the influence of the drift due to aging, environmental factors etc.

Afterwards, a simulated fault current generates internally and corresponding responses such as tripping signal, PWM signal etc. will be made. User can detect these signals and use them to determine if the sensor is working properly or not.

For 791002002

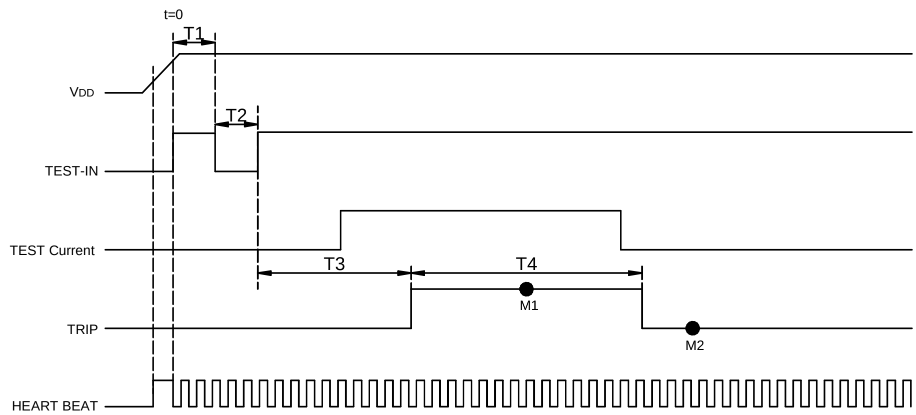


Figure 11: Timing Diagram for 791002002

- The ramp-up time for stable 5V of $+V_{DD}$ should be less than 15ms.
- T1: waiting time for system stabilization. $T_1 \geq 100$ ms.
- T2: pulling down time of TEST-IN signal. 50 ms $\leq T_2 \leq$ 1000 ms.
- T3: waiting time. $T_3 \approx 265$ ms.
- T4: self-test indication duration time. $T_4 \approx 1.3$ s. It is suggested to read the TRIP signal after 300ms (M1).

During the complete self-test procedure, the main circuit must be switched off to ensure that no residual current is flowing. The frequency and duty cycle of the heartbeat signal should be in the normal range. The tripping signal can be detected at M1, and TRIP has to be low level at M2. After this, the sensor self-test procedure is finished. Abnormal power up timing sequence must be considered as system anomaly and the main circuit must be switched off in such a case.

For 791002004

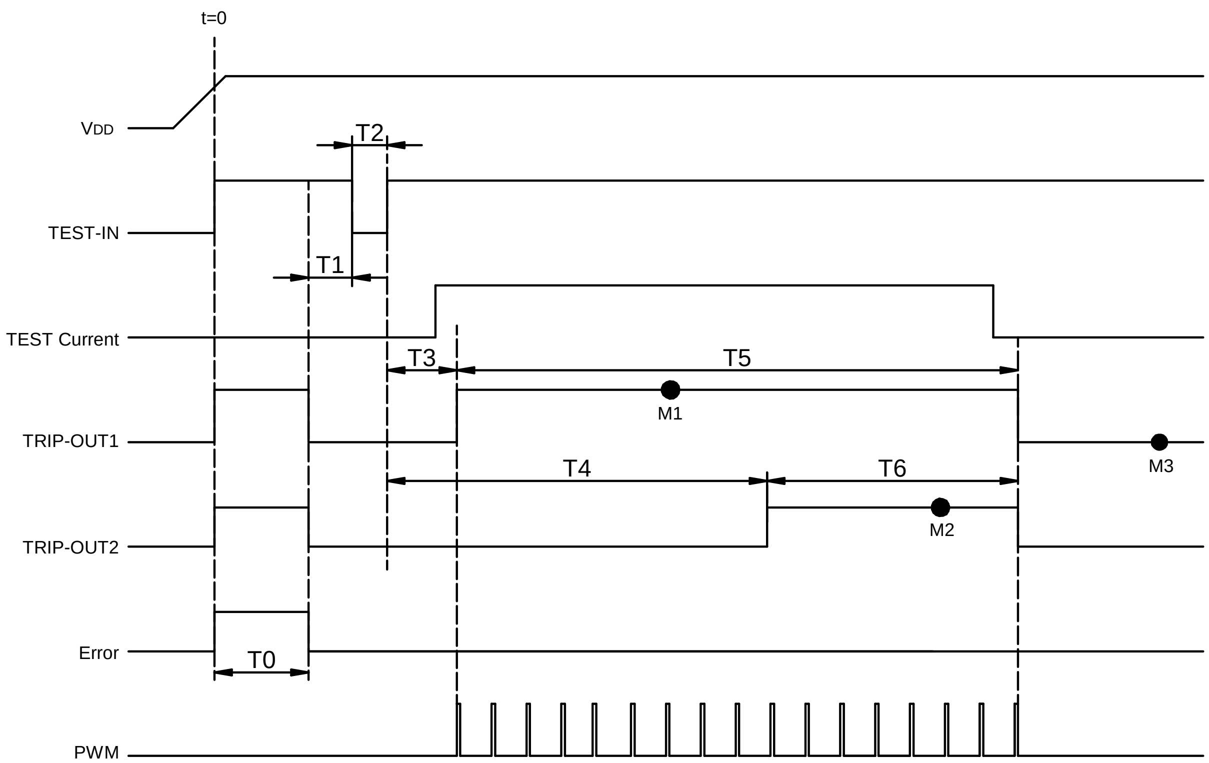


Figure 12: Timing Diagram for 791002004

- The ramp up time for stable 5V of V_{DD} should be less than 15ms.
- T0: waiting time for system stabilization. T0 $\approx$ 270ms
- T1: withstanding time of high level TEST-IN signal. T1 $\geq$ 100ms .
- T2: pulling down time of TEST-IN signal. 50ms $\leq$ T2 $\leq$ 1000ms.
- T3: waiting time for TRIP-OUT1 signal generation T3 $\approx$ 200ms.
- T4: waiting time for TRIP-OUT2 signal generationT4 $\approx$ 690ms.
- T5: self-test indication duration time. T5 $\approx$ 1580ms. It is suggested to read the TRIPP-OUT1 signal after 300ms (M1)
- T6: self-test indication duration time. T6 $\approx$ 1090m. It is suggested to read TRIPP-OUT2 signal after 300ms (M2).

During the complete self-test procedure, the main circuit must be switched off to ensure no residual current is flowing. As if there is residual current flowing in this procedure the current state with residual current will be considered as no residual current state written to the register and the sensor will be calibrated incorrectly.
The frequency of the PWM signal should be in the specified range during the self-test indication duration time T5. TRIP-OUT1 and TRIP-OUT2 have to be high level at M1 and M2 separately and low level at M3.
After this, the sensor self-test procedure is finished. Abnormal power up timing sequence must be considered as system anomaly and the main circuit must be switched off in such a case.

4.4 Supply voltage monitoring

The purpose of supply voltage monitoring function is to monitor the supply voltage to avoid inaccuracy measurement or improperly operation caused by undervoltage.

- Supply voltage monitoring for 791002002

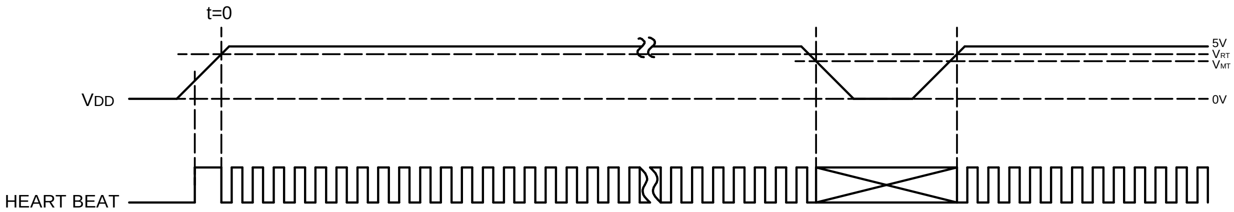


Figure 13: Supply Voltage Monitoring Diagram for 791002002

The heartbeat signal will change from PWM signal (1kHz, 50 % duty cycle) to high level when $+V_{DD}$ drops to the supply voltage threshold(V_{MT}). The heartbeat signal will recover to the normal PWM signal (1kHz, 50 % duty cycle) when $+V_{DD}$ returns to the supply voltage recovery threshold (V_{RT}). The heartbeat signal will change from PWM signal to low level if when $+V_{DD}$ drops to a value such that the system does not work at all. The main circuit must be switched off when the abnormal HEARTBEAT signal is detected in terms of frequency and duty cycle.

- Supply voltage monitoring for 791002004

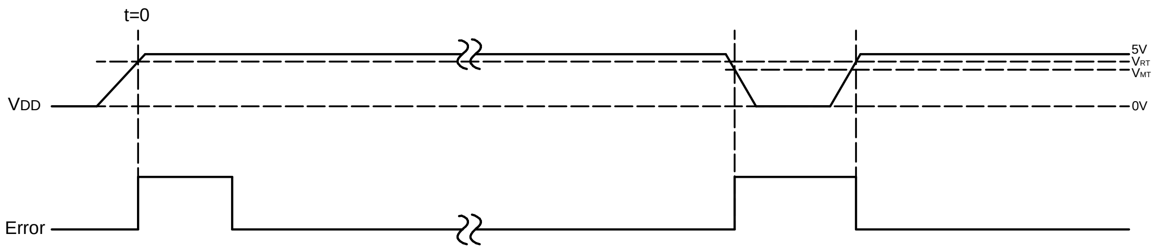


Figure 14: Supply Voltage Monitoring Diagram for 791002004

The Error pin state changes to high impedance if $+V_{DD}$ drops to the supply voltage threshold(V_{MT}) and the Error pin state will be back to low level when $+V_{DD}$ returns to supply voltage recovery threshold(V_{RT}). Due to the safety reasons the main circuit must be switched off when the error signal is detected.

4.5 Watchdog function

A watchdog is used to protect our system from software or hardware failures that may cause the system to stop responding.
Watchdog is composed of timer + counter and the timer define a time base. If MCU is working normally, MCU do the counter clearing before counting to the set value, in case of MCU out of control, MCU will not clear the counter, the counter number reaches to the set value, then the timer will reset the MCU.
If the watchdog timer monitors MCU fault to reboot the system, there will be different behaviors for 791002002 and 791002004.

- Watchdog function for 791002002

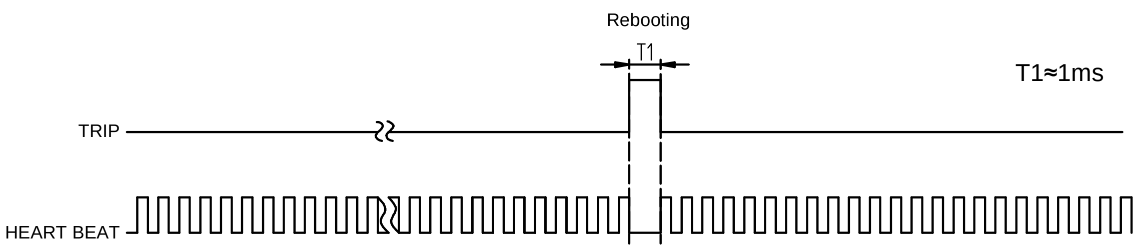


Figure 15: Watchdog function diagram for 791002002

During rebooting process pin 2 (TRIP) will be in high impedance state and heartbeat signal will be low level.
The pin 2 (TRIP) will change to low level and heartbeat signal will return to normal condition if the MCU is under control after rebooting.
Once a trip signal or an abnormal heartbeat signal is detected the main circuit must be switched off and a restart of the Self-test procedure has to be followed.

- Watchdog function for 791002004

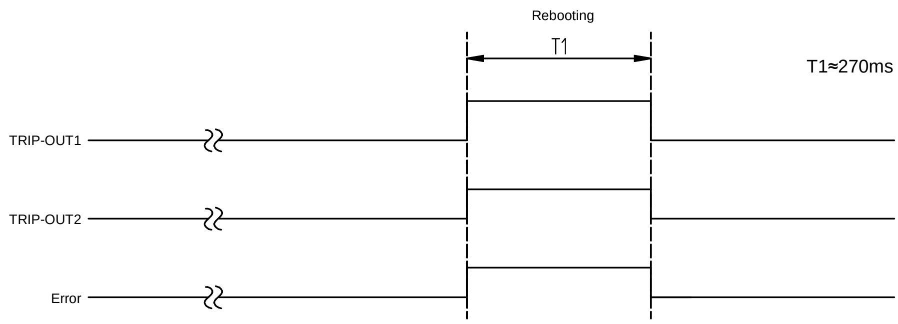


Figure 16: Watchdog function diagram for 791002004

During rebooting process pins of TRIP1-OUT1, TRIP-OUT2 and Error will be in high impedance state. Pins of TRIP1-OUT1, TRIP-OUT2 and Error will return to low level if the MCU is under control after rebooting.
Once a trip or an error signal detected the main circuit must be switched off and a restarting self-test procedure has to be followed.

4.6 PWM signal indication

The PWM signals of 791002002 and 791002004, respectively indicate different information.

- PWM signals of 791002002

PWM signal of 791002002 is so called heartbeat signal which the frequency is 1kHz with the tolerance of +/-6%and the duty cycle is 50Hz with the tolerance of +/-2%. The heartbeat signal is used to indicate the system status (supply voltage, watchdog etc.) in terms of frequency and duty cycle. If the heartbeat is failed which means the frequency or duty cycle is out of tolerance, rebooting the system is strongly suggested to reach a higher reliability.

- PWM signal of 791002004

PWM signal of 791002004 The PWM signal of 791002004 which the frequency is 8kHz with the tolerance of +/-1% is used to indicate DC fault current from 2.5mA to 30mA by the size of duty cycle (3.33%/mA).

4.7 Switching/recovery level

To avoid signal oscillation(Trip pin of 791002002 , TRIP-OUT1, TRIP-OUT2 pin of 791002004), tripping signal output flipping has been set with tripping threshold and recovery threshold.

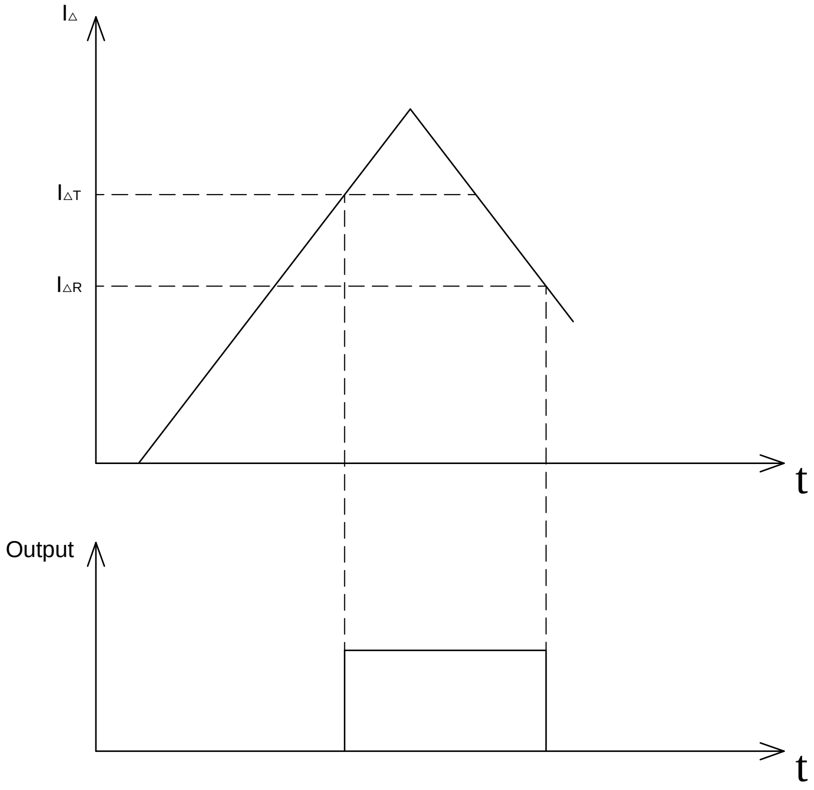


Figure 17: Switching/recovery level diagram

When the residual current exceeds the threshold $I_{\triangle T}$, TRIP-OUT1, TRIP-OUT2 pin of 791002004 and Trip pin of 791002002 will change from low level to high impedance and when the residual current decrease to the recovery threshold $I_{\triangle R}$, TRIP-OUT1, TRIP-OUT2 pin of 791002004 and Trip pin of 791002002 will be back to low level state. $I_{\triangle T}$ is set as 100% typical tripping value, and $I_{\triangle R}$ is set as 55% typical tripping value.

4.8 State explanation

- State for 791002002:

Pin 2	Pin 4	State
Low level	1kHz 50% PWM	Normal Condition
High impedance	1kHz 50% PWM	$I_{\Delta dc} \geq$ 6m ADC
High impedance	1kHz 50% PWM	System fault
High impedance	Low level	Rebooting
Low level/High impedance	High level/low level	V_{DD} fault

Table 19: Pin state for 791002002

Normal condition: There is no residual current in the system, the power supply is normal, and the WE-RCDS module is working properly.

$I_{\Delta\, dc} \geq$ 6 mA DC: The power supply is normal and the WE-RCDS module is working properly, but there is residual current exceeding or equal to 6mA in the system.

System fault: There is a system failure happening, such as an open circuit of the winding.

Rebooting: The system is rebooting, caused by events such as watchdog monitoring.

V_{DD} fault: The power supply is undervoltage, which means the supply voltage is lower or equal to the supply voltage threshold. The state of Pin2 (TRIP) and Pin4 (HEART BEAT) is not consistent during a V_{DD} fault, and it depends on how low the supply voltage is. If the supply voltage is lower than the threshold but the system still works, Pin2 (TRIP) is at a low level and Pin4 (HEART BEAT) is at a high level. However, if the supply voltage drops to the point where the system does not work anymore, Pin2 (TRIP) is in high impedance, and Pin4 (HEART BEAT) is at a low level.

- State for 791002004:

Pin 1	Pin 3	Pin 4	State
Low level	Low level	Low level	Normal Condition
Low level	High Impedance	High Impedance	$I_{\Delta dc} \geq$ 6m ADC
Low level	High impedance	High impedance	System fault
High impedance	High impedance	High impedance	+V_{DD} fault
High impedance	High impedance	High impedance	Rebooting

Table 20: Pin state for 791002004

Normal condition: There is no residual current in the system, the power supply is normal, and the WE-RCDS modules are working properly.

$I_{\Delta\,dc} \geq$ 6 mA DC: The power supply is normal, and the WE-RCDS modules are working properly, but there is a residual current exceeding or equal to 6mA in the system.

System fault: There is a system failure, such as an open circuit of winding.

V_{DD} fault: The power supply is undervoltage, meaning the supply voltage is lower than or equal to the supply voltage threshold.

Rebooting: The system reboots due to causes such as watchdog monitoring.

The conditions $I_{\Delta\,dc} \geq$ 6 mA DC and System fault are indicated by the same pin states, and +V_{DD} fault and Rebooting are also indicated by the same pin states. This is because $I_{\Delta\,dc} \geq$ 6 mA DC and System fault are considered the most critical failures, and the main circuit must be switched off without hesitation.

4.9 Operating temperature

An operating temperature refers to the allowable temperature range in which an electrical or mechanical device can function effectively. This range varies based on the device's purpose and context. The operating temperature range of WE-RCDS is -40℃ up to +105℃. It has to be ensured that WE-RCDS is not driven out of this specified range. Otherwise the function is may not given or permanent damage could be appear. Thermal management has to be considered to ensure that the environment and the self-heat of the WE-RCDS cause drive out of this temperature range.

5 PCB design Guidelines

5.1 Recommended trace design

- Recommended land pattern

The recommended land patterns are specified in the respective specification and all the verifications were performed with taking these recommended land patterns.

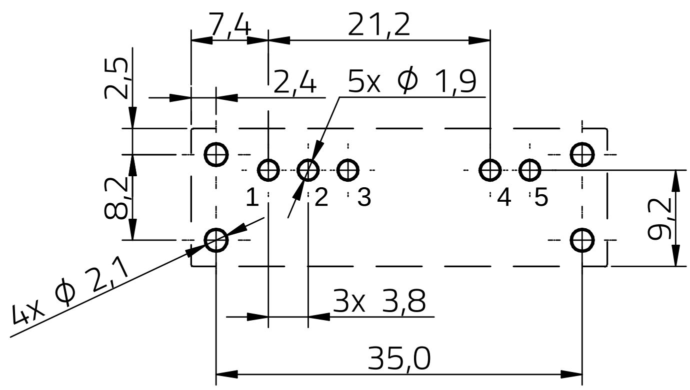


Figure 18: Recommended land pattern for 791002002

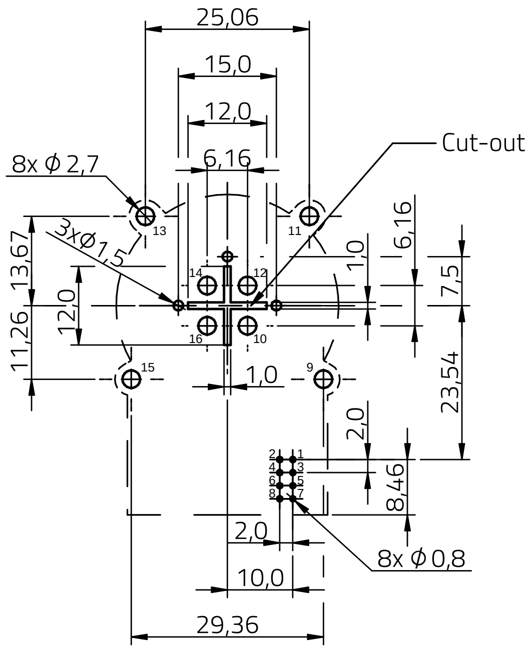


Figure 19: Recommended land pattern for 791002004

5.2 PCB Trace Layout design for 791002004

The PCB layout should be verified and tested in the application of the user considering the operating temperature mentioned in 4.9. With considering the existing structure of the product of 791002004 and the limited trace space on PCB two trace layouts are recommended and user can design according to their actual application. The copper layers for this recommended PCB trace are 70 μm for top and bottom layer and 35 μm for the interior layers.
The following trace layouts are just only for reference as example.

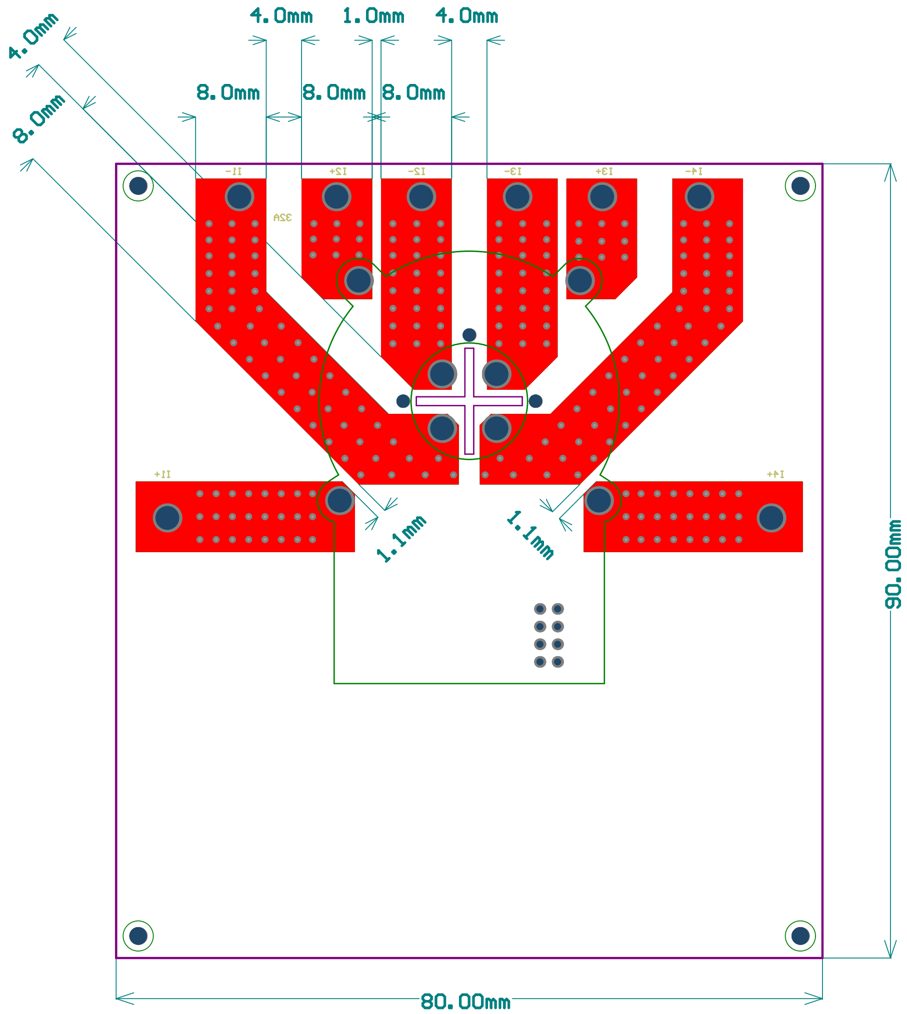


Figure 20: PCB Trace Layout design example 1

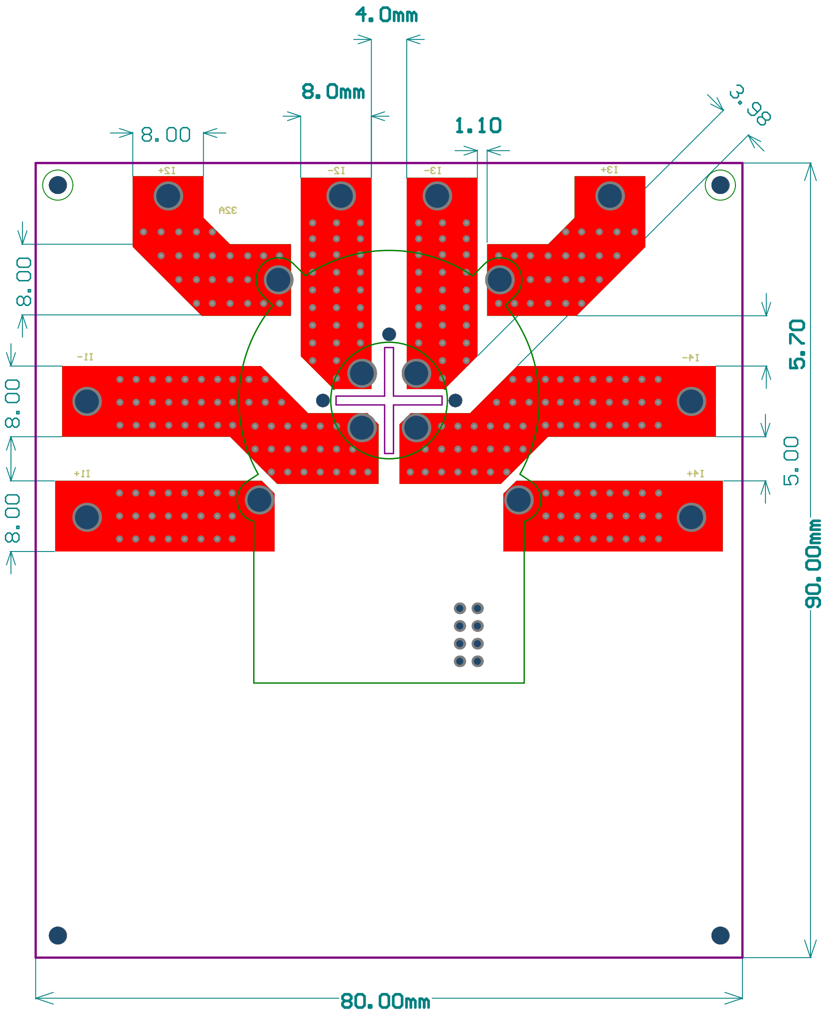


Figure 21: PCB Trace Layout design example 2 with improved temperature characteristic

6 Patent Information

WE-RCDS Residual Current Detection Sensor is designed to support IEC 6181-1 (ensuring supply disconnection in the event of a DC fault) and is therefore suitable to building up a disconnection device in accordance with IEC 62955. We would like to inform you that, depending on the use and implementation of this switch-off device, a patent infringement may occur.

It is your responsibility to integrate and evaluate our sensors in your application by respecting patents and intellectual property.

Specifically, we would like to refer to the European Patent EP 2 571 128 B3 (which is valid in Austria, Switzerland/Liechtenstein, Germany, Spain, France, Great Britain and Norway) and parallel intellectual property rights CN 103 001 175 B, US 9,397,494 B2 and DE 10 2011 082 941 A1 and corresponding:"Electrical monitoring device and method for securing the protective function of a residual current safety device (RCD type A)" which should be taken into account.

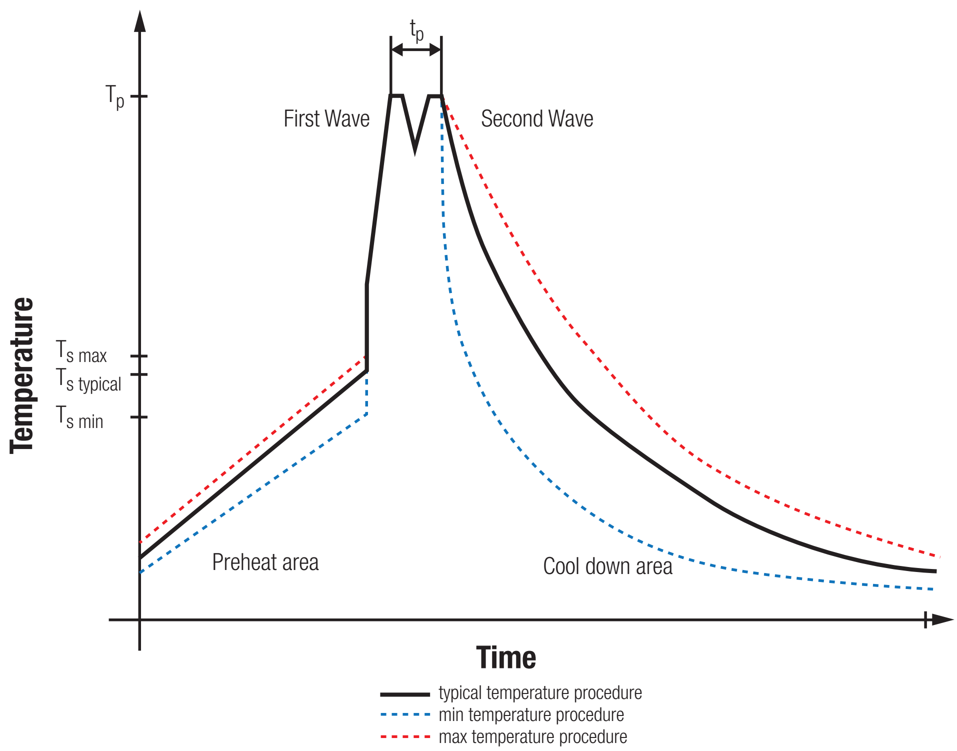
The patent holder offers a corresponding license agreement which has to be signed in advance of any infringing action. The use of the WE-RCDS in conjunction with a switch-off device may infringe the intellectual property rights described above and make it necessary to contact the patent holder for clarification. If you have any questions, please do not hesitate to contact us (wcs@we-online.com).

7 Manufacturing information

7.1 Wave soldering

Profile feature		Pb-free assembly	Sn-Pb assembly
Preheat temperature, min	T_s min	100 ℃	100 ℃
Preheat temperature, typical	$T_{typical}$	120 ℃	120 ℃
Preheat temperature, max	T_s max	130 ℃	130 ℃
Preheat time t_s from T_s min to T_s max	t_s	70 seconds	70 seconds
Ramp-up rate	ΔT	150 ℃ max.	150 ℃ max.
Peak temperature	T_p	250 ℃ - 260 ℃	235 ℃ - 260 ℃
Time of actual peak temperature	t_p	max. 10 seconds max. 5 seconds each wave	max. 10 seconds max. 5 seconds each wave
Ramp-down rate, min		~2 K/second	~ 2 K/second
Ramp-down rate, typical		~ 3.5 K/second	~ 3.5 K/second
Ramp-down rate, max		~5 K/second	~5 K/second
Time 25 ℃ to 25 ℃		4 minutes	4 minutes

Table 21: Classification wave soldering profile



After wave soldering, visually inspect the board to confirm proper alignment

7.2 Cleaning and washing

- Do not clean the product. Any residue cannot be easily removed by washing. Use a "no clean" soldering paste and do not clean the board after soldering.
- Washing agents used during the production to clean the customer application might damage or change the characteristics of the component. Washing agents may have a negative effect on the long-term functionality of the product.
- Using a brush during the cleaning process may damage the component. Therefore, we do not recommend using a brush during the PCB cleaning process.

7.3 Potting and coating

- If the product is potted in the customer application, the potting material might shrink or expand during and after hardening. Shrinking could lead to an incomplete seal, allowing contaminants into the body, pins or termination. Expansion could damage the components. We recommend a manual inspection after potting to avoid these effects.
- Conformal coating may affect the product performance. We do not recommend coating the components.

7.4 Storage conditions

- A storage of Würth Elektronik eiSos products for longer than 12 months is not recommended. Within other effects, the terminals may suffer degradation, resulting in bad solderability. Therefore, all products shall be used within the period of 12 months based on the day of shipment.
- Do not expose the components to direct sunlight.
- The storage conditions in the original packaging are defined according to DIN EN 61760 - 2.
- For a moisture sensitive component, the storage condition in the original packaging is defined according to IPC/JEDEC-J-STD-033. It is also recommended to return the component to the original moisture proof bag and reseal the moisture proof bag again.
- ESD prevention methods need to be followed for manual handling and processing by machinery.
- The storage conditions stated in the original packaging apply to the storage time and not to the transportation time of the components.

7.5 Handling

- Violation of the technical product specifications such as exceeding the absolute maximum ratings will void the warranty and also the conformance to regulatory requirements.
- The applicable country regulations and specific environmental regulations must be observed.

- The PWM signal can only be used to indicate the leakage current (from 2.5 mA to 30 mA) and it can't be used for functional safety related purposes.
- Abnormal frequency of PWM signal (during internal residual current simulation at power-up stage),abnormal power up time sequence or an error output signal detected are considered as system abnormalities and the main circuit must be switched off in these situations.
- The error signal should be monitored permanently and the main circuit must be switched off if an error signal appears.
- Do not disassemble the component. Evidence of tampering will void the warranty.
- The temperature rise of the component must be taken into consideration. The operating temperature is comprised of ambient temperature and temperature rise of the component.
- The operating temperature of the component shall not exceed the maximum temperature specified.
- Due to physical product characteristics, the measuring accuracy of the module can be affected by strong temperature changes, therefore a self-test and calibration of the module is recommended at certain time intervals. Especially after a high self-heating of the entire application where this module is placed.
- Direct mechanical impact to the component must be prevented as the material of the body, pins or termination could flake or, in the worst case, could break. As these devices are sensitive to electrostatic discharge, proper IC handling procedures must be followed.
- If a component drops, it has to be sorted out as it might change its characteristics.
- Avoid touching damaged components. These cautions and warnings comply with the state of the scientific and technical knowledge and are believed to be accurate and reliable. However, no responsibility is assumed for inaccuracies or incompleteness.

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List of Figures

List of Tables

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