KTRD9Z1-638-12V-CUG

RD9Z1-638-12V-C reference design

Rev. 1.1 — 2 March 2018 User manual

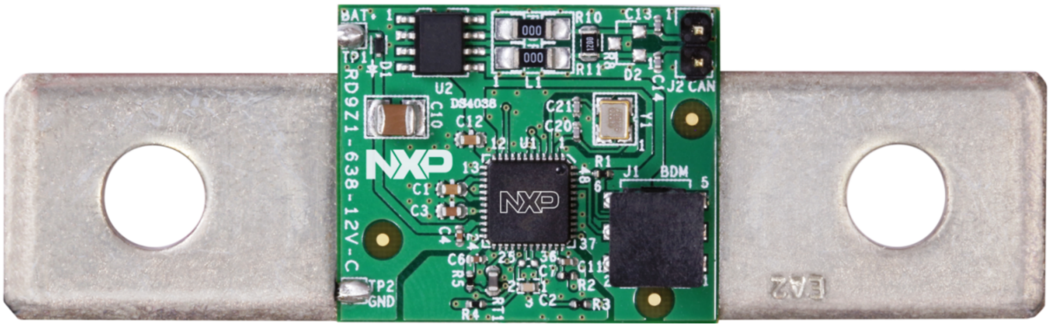
Document information

Information	Content
Keywords	KTRD9Z1-638-12V-CUG, MC33901, RD9Z1-638-12V-C, Battery Management System (BMS), SENSOR, lead-acid, CAN, interface
Abstract	The RD9Z1-638-12V-C reference design is a Battery Management System (BMS) for 12 V lead-acid battery applications and features the MM9Z1J638 Battery Sensor module.

Revision history

Rev	Date	Description
v.1.1	20180302	• Updated Section 3 • Deleted Jump start • Fixed broken links
v.1	20160603	Initial version

1 RD9Z1-638-12V-C



2 Important notice

NXP provides the enclosed product(s) under the following conditions:

This reference design is intended for use of ENGINEERING DEVELOPMENT OR EVALUATION PURPOSES ONLY. It is provided as a sample IC pre-soldered to a printed circuit board to make it easier to access inputs, outputs, and supply terminals. This reference design may be used with any development system or other source of I/O signals by simply connecting it to the host MCU or computer board via off-the-shelf cables. Final device in an application will be heavily dependent on proper printed circuit board layout and heat sinking design as well as attention to supply filtering, transient suppression, and I/O signal quality.

The goods provided may not be complete in terms of required design, marketing, and or manufacturing related protective considerations, including product safety measures typically found in the end product incorporating the goods. Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge. In order to minimize risks associated with the customers applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards. For any safety concerns, contact NXP sales and technical support services.

Should this reference design not meet the specifications indicated in the kit, it may be returned within 30 days from the date of delivery and will be replaced by a new kit.

NXP reserves the right to make changes without further notice to any products herein. NXP makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does NXP assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. “Typical” parameters can and do vary in different applications and actual performance may vary over time. All operating parameters, including “Typical”, must be validated for each customer application by customer’s technical experts.

NXP does not convey any license under its patent rights nor the rights of others. NXP products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the NXP product could create a situation where personal injury or death may occur.

Should the Buyer purchase or use NXP products for any such unintended or unauthorized application, the Buyer shall indemnify and hold NXP and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges NXP was negligent regarding the design or manufacture of the part. NXP and the NXP logo are trademarks of NXP B.V. All other product or service names are the property of their respective owners. © NXP B.V. 2018.

3 Getting started

The NXP analog product development boards provide an easy-to-use platform for evaluating NXP products. The boards support a range of analog, mixed-signal and power solutions. They incorporate monolithic integrated circuits and system-in-package devices that use proven high-volume technology. NXP products offer longer battery life, a smaller form factor, reduced component counts, lower cost and improved performance in powering state-of-the-art systems.

The tool summary page for RD9Z1-638-12V-C is located at http://www.nxp.com/RD9Z1-638-12V-C. The overview tab provides an overview of the device, product features, a description of the kit contents, a list of (and links to) supported devices, list of (and links to) any related products and a **Get Started** section.

The **Get Started** section provides links to everything needed to start using the device and contains the most relevant, current information applicable to the RD9Z1-638-12V-C.

- Go to http://www.nxp.com/RD9Z1-638-12V-C.
- On the **Overview** tab, locate the **Jump To** navigation feature on the left side of the window.
- Select the **Get Started** link and review each entry.
- Download an entry by clicking on the title.
- After reviewing the **Overview** tab, visit the other product related tabs for additional information:
  - **Documentation**: download current documentation
  - **Software & Tools**: download current hardware and software tools
  - **Buy/Parametrics**: purchase the product and view the product parametrics

After downloading files, review each file, including the user guide which includes setup instructions. If applicable, the bill of materials (BOM) and supporting schematics are also available for download in the **Get Started** section of the **Overview** tab.

3.1 Kit contents/packing list

The RD9Z1-638-12V-C contents include:

- Assembled and tested 100 µOhm shunt mounted to the reference design board in anti-static bag
- Quick start guide
- Warranty card

3.2 Required equipment

This kit requires the following items:

- Power supply 12 V
- USB-enabled PC with Windows 7 or higher
- CodeWarrior 10 for MCUs (Eclipse IDE) family installed http://www.nxp.com/CWMCU10
- P&E USB Multilink Universal http://www.nxp.com/UMultilink

This kit requires the following additional items for testing and debugging:

- CAN bus Master or CAN test tool

- 12 V Lead-Acid battery
- Battery load or current source
- Shunt-compatible power cable and plugs (screws + nuts)
- Oscilloscope (preferably 4-channel)
- Digital Voltmeter and Ammeter

3.3 System requirements

The kit requires the following to function properly with the software:

- Windows® XP, Windows 7, or Vista in 32- and 64-bit versions
- The latest PE micro interface drivers must be installed on your system

4 Getting to know the hardware

4.1 Board overview

The RD9Z1-638-12V-C reference design is a Battery Management System (BMS) for 12 V lead-acid battery applications and features the MM9Z1J638 Battery Sensor module. The RD9Z1-638-12V-C is built to demonstrate the product capabilities in a 12 V lead-acid application where high EMC performance is required to obtain high accuracy measurements on key battery parameters.

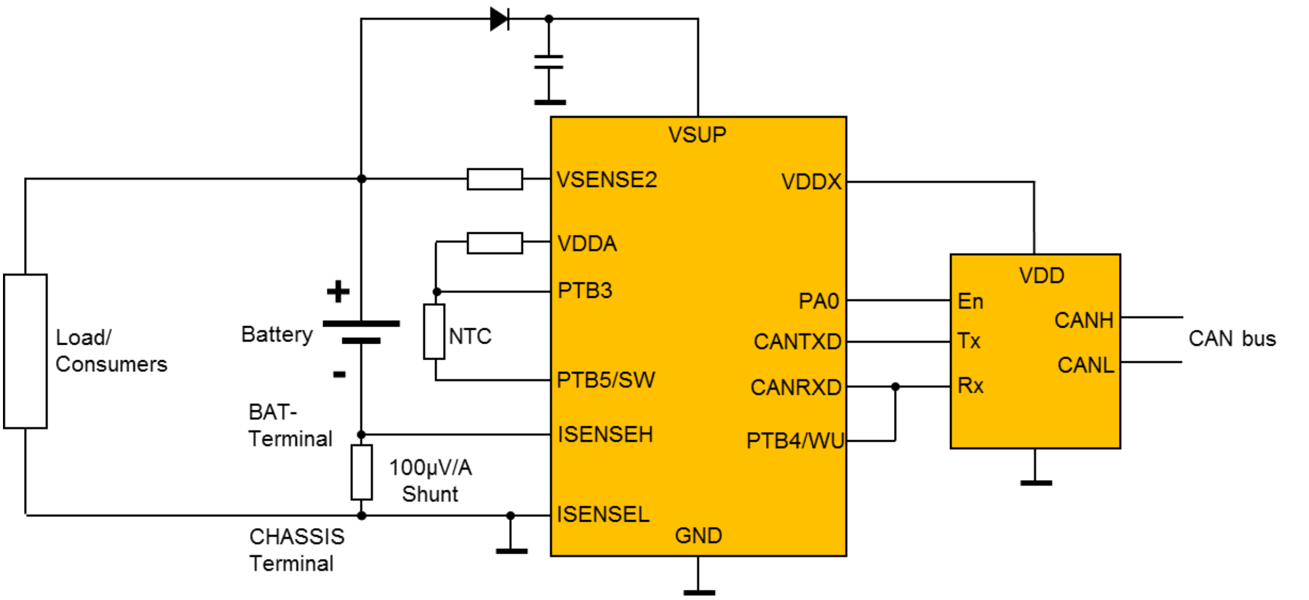


Figure 1. Application diagram

The key measurement parameters are battery voltage, current and temperature. The embedded microcontroller obtains those parameters and calculates the battery State-of-Charge (SOC), State-of-Health (SOH) and State-of-Function (SOF).

4.2 Board features

The board features are as follows:

- Embedded S12Z microcontroller with:
  - 128 KB on-chip flash with ECC
  - 4.0 KB on-chip EEPROM with ECC
  - 8.0 KB on-chip SRAM with ECC
- Embedded power management
- Battery voltage sensing input (VSENSE2)
- Battery current sensing via mounted shunt (ISENSE)
- On-board NTC for battery temperature sensing/estimation (PTB3)
- Internal temperature sensing
- CAN Interface
- BDM interface (for programming and debugging)
- Reverse polarity protection with a Schottky diode

4.3 Board description

The board consists of a small PCB board mounted on top of a precision 100 μV/A current measurement shunt. The MM9Z1J638 IC contains all required analog blocks (power management, sigma delta ADCs) together with a microcontroller with embedded memories (RAM, FLASH, EEPROM). The MC33901 CAN Transceiver connects the reference design to a CAN bus.

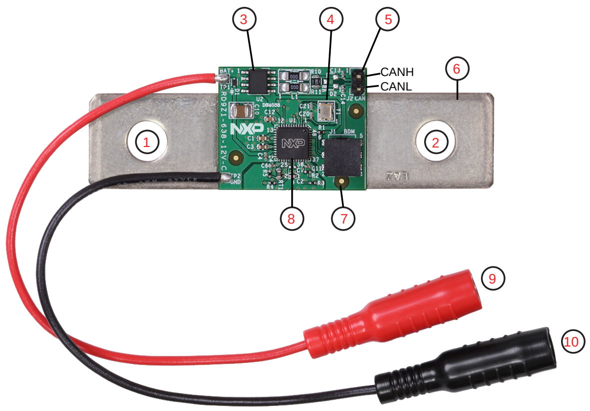


Figure 2. Board description

Table 1. Board description

Number	Description
1	CHASSIS terminal
2	BAT− terminal
3	MC33901 CAN Transceiver IC
4	16 MHz Quarz required for accurate CAN timing
5	Connector for CAN bus (CANH and CANL signals)
6	Precision 100 μV/A current measurement shunt
7	BDM interface for debugging and programming the MM9Z1J638
8	MM9Z1J638 Intelligent battery sensor IC
9	BAT+ connection to supply the circuitry and to measure the battery voltage

Number	Description
10	Optional GND connection in case shunt CHASSIS terminal is not used

4.3.1 BAT and GND connectors

The reference design has wires with a 4 mm banana socket soldered to the BAT+ (TP1) and GND (TP2) pads.

The BAT connector should be connected to the battery positive (+) terminal to power the board.

The GND pad is an optional connection path for ground, in case the shunt is not connected to the chassis. The **CHASSIS** side on the shunt is used for grounding.

4.3.2 CAN interface

This reference design provides a CAN physical interface using the MC33901 CAN Transceiver. This CAN interface has high robustness against EM disturbances, ESD, and a very low EM emission level. An ESD diode (D2) and/or a common mode choke (L1) can be added to further improve performances.

The MC33901 limits the V_{SUP} range for CAN communication to about V_{SUP} > 4.8 V (4.5 V VDDX).

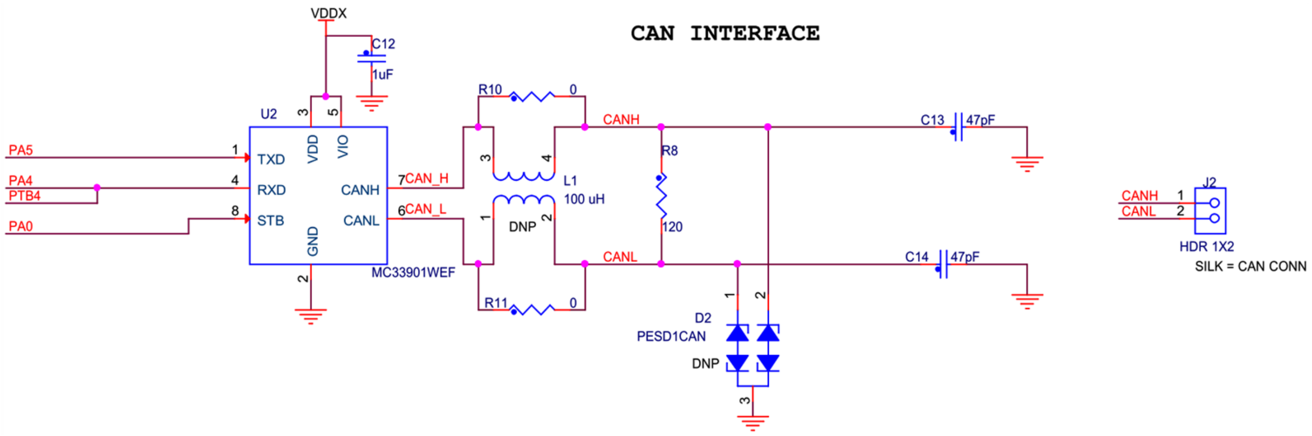


Figure 3. CAN circuit

4.3.3 BDM1 Connector

BDM1 should be connected to P&E's USB Multilink Universal adapter (or equivalent) to enable programming and debugging the MM9Z1J638 with the NXP CodeWarrior Suite.

For programming the MM9Z1J638, connect a 470 nF capacitor between RESET and GND signal on the adapter side. The capacitor suppresses the Analog die window watchdog periodically resetting the microcontroller (depending on the MM9Z1J638's Window Watchdog state). The programming capacitor is used only for programming and removed for normal operation.

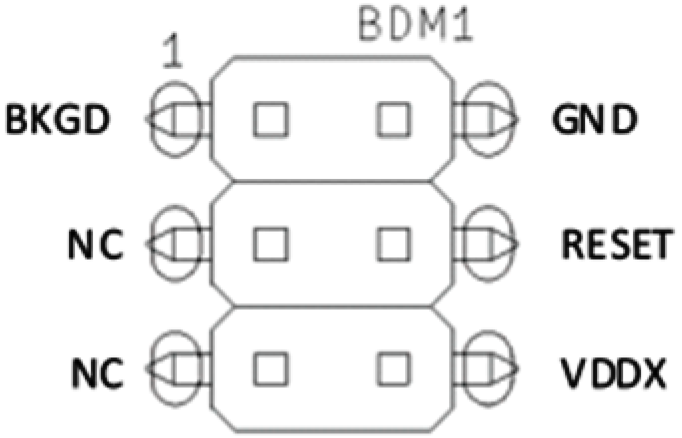


Figure 4. BDM1 connector

Use an adapter to enable attach or detach the 470 nF programming capacitor.

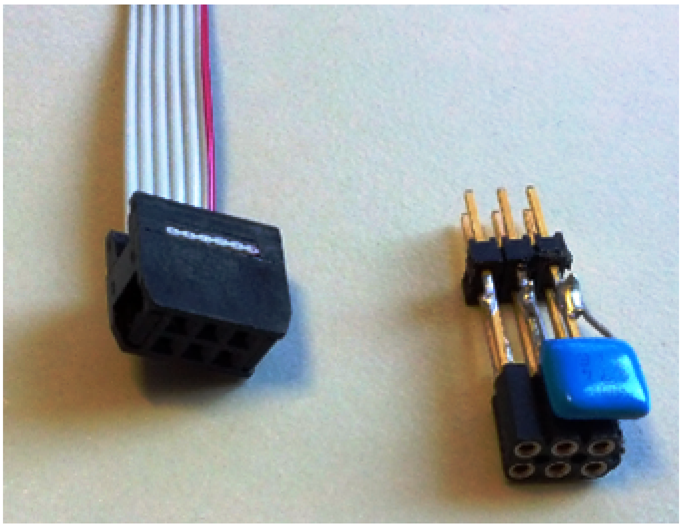


Figure 5. Example of a 470 nF Adapter

Note:

The VDDX maximum load current available for external supply, with VSUP > 5.5 V and for all external loads is 100 mA.

4.3.4 Shunt

The soldered shunt is used for current measurement. The system ground should be connected to the CHASSIS terminal and the battery minus pole to the BAT- terminal. This setup is a low-side current measurement. Therefore, the system ground (GND) is the CHASSIS terminal and should be used as the reference.

This setup permits measurement of both load and board (I_{SUP}) current. This ensures accurate current measurement at any time.

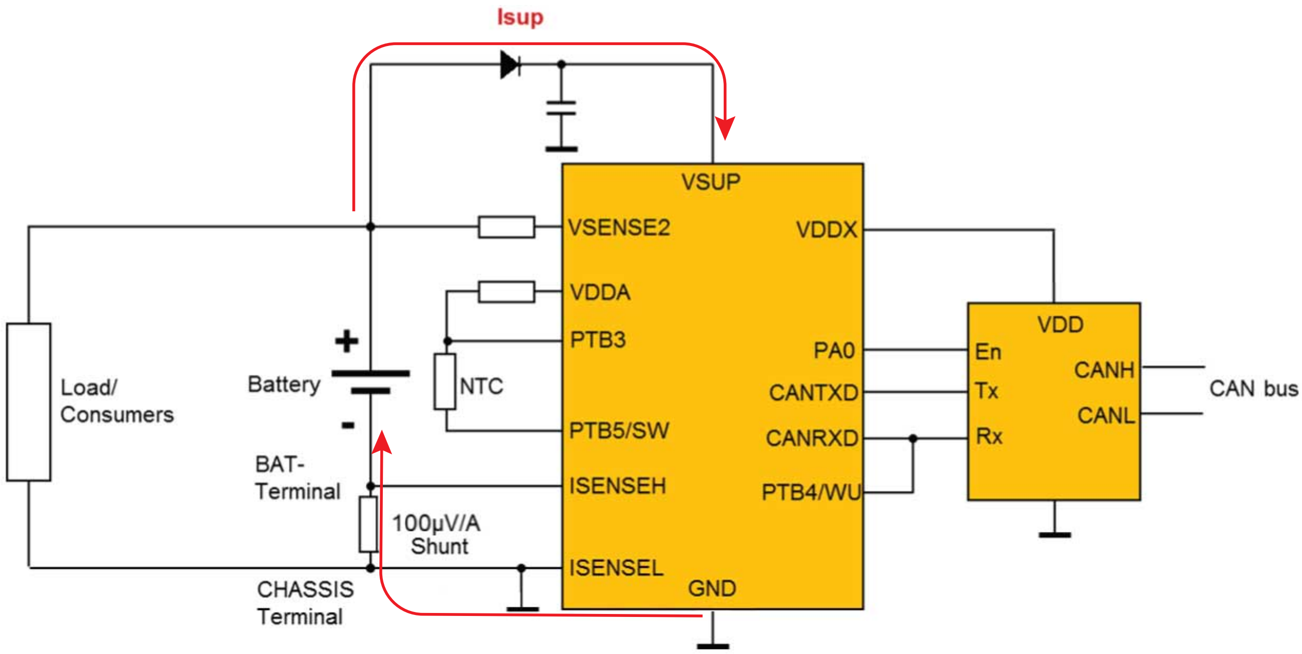


Figure 6. Board supply current

4.3.5 Voltage and current measurement

The MM9Z1J638 has four voltage measurement channels called VSENSE[3..0]. The VSENSE2 pin is used with a 2.2 kΩ serial protection resistor to sense the battery voltage. The other three VSENSE[3,1,0] pins are connected to GND.

The VSENSE2 voltage measurement is referenced to GND (CHASSIS).

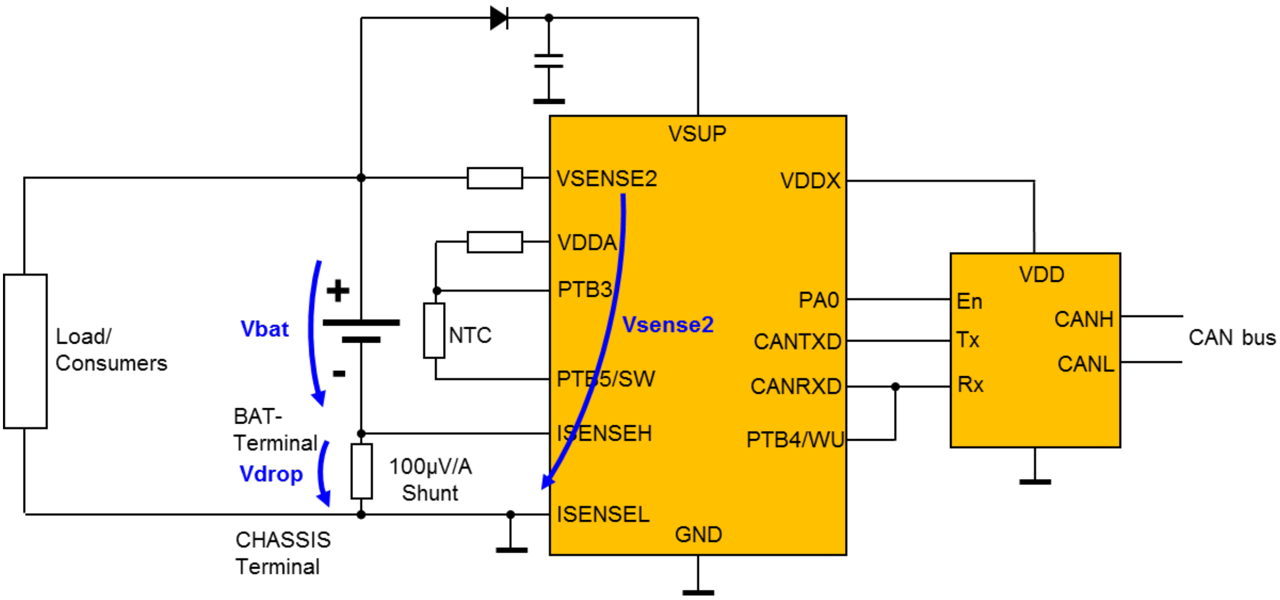


Figure 7. V_{BAT} versus VSENSE2 measurements

A software calculation is needed to know the battery voltage V_{BAT}. The software has to include the voltage drop of the shunt V_{DROP} (ISENSE differential voltage) to get the correct battery voltage.

In order to handle dynamic effects, the voltage and current measurement should be synchronized and samples taken at the same time have to be used.

$V_{BAT} = V_{SENSE2} – V_{DROP}$

where

$V_{DROP} = I_{SHUNT} * R_{SHUNT}$

This reference design provides a very high EMC tolerant current sensing circuit due to symmetrical layout traces (see Section 7 "Board layout") along with a dual balanced capacitor (C2) improving differential and common attenuation.

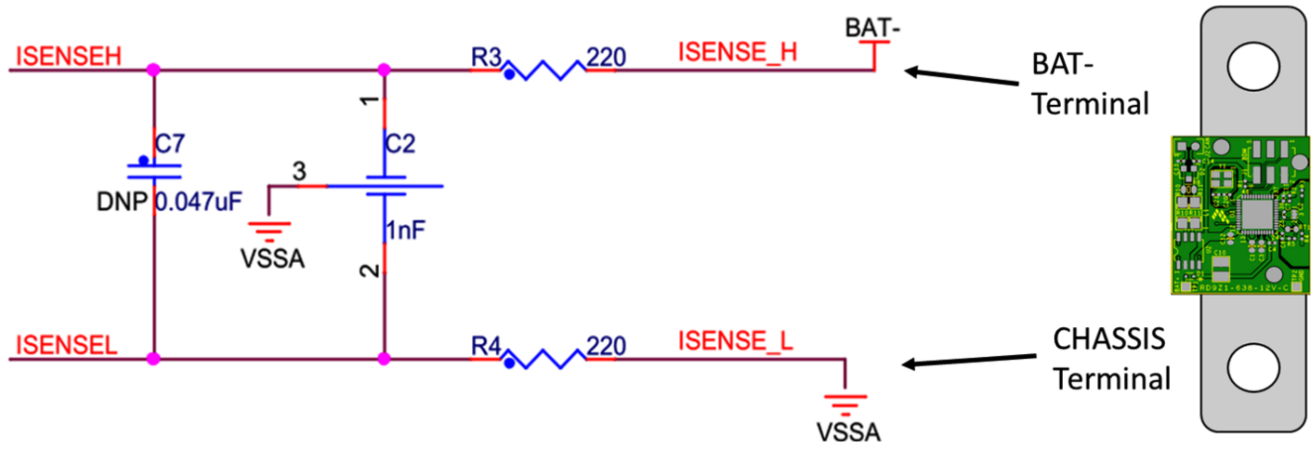


Figure 8. Current sensing circuit

4.3.6 Embedded temperature sensing

This reference design provides temperature sensing with an NTC (Negative Temperature Coefficient) resistor on the PCB board.

The thermistor is located above a thermal convection point. The low thermal resistance of the shunt and PCB pads (solder interconnects between shunt and PCB board) provides a good approximate reading of battery temperature (negative battery terminal) without the need of any additional PCB-board components.

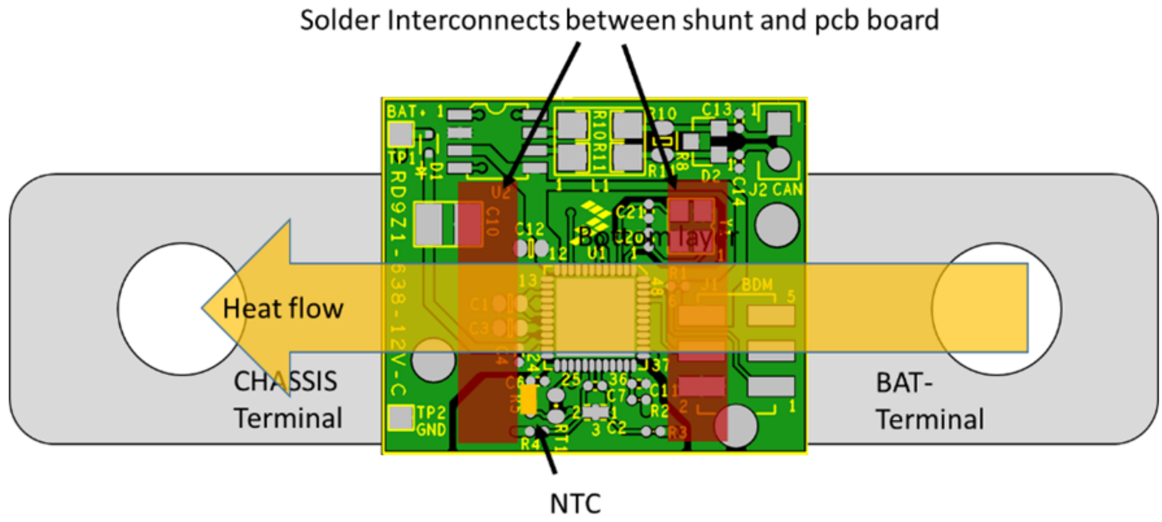


Figure 9. Embedded temperature sensing

Alternatively, the MM9Z1J638's internal chip temperature sensor is used for shunt/battery temperature sensing, however self-heating caused by chip internal power dissipation needs to be considered.

5 Installing the software and setting up the hardware

In order to perform the demonstration examples, first setup the board hardware and software as follows.

5.1 Install CodeWarrior 10 for MCU

If required download and install the CodeWarrior 10 for MCU on a USB enabled PC running Windows:

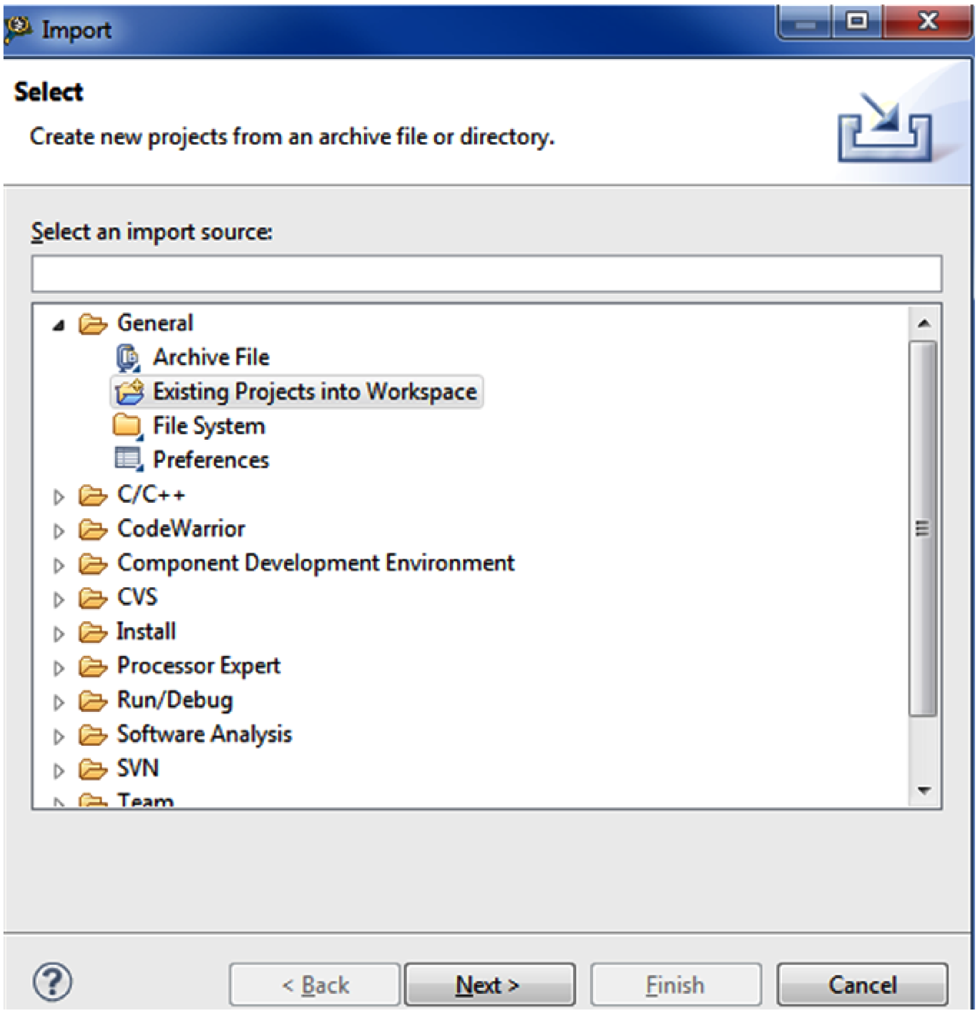
1. Download CodeWarrior 10 for MCU (CW-MCU10).
2. Install CodeWarrior on a USB-enabled PC.
   a. Follow the instructions during the software installation and ensure **S12Z support** is activated.

5.2 Import and run reference design software in CodeWarrior

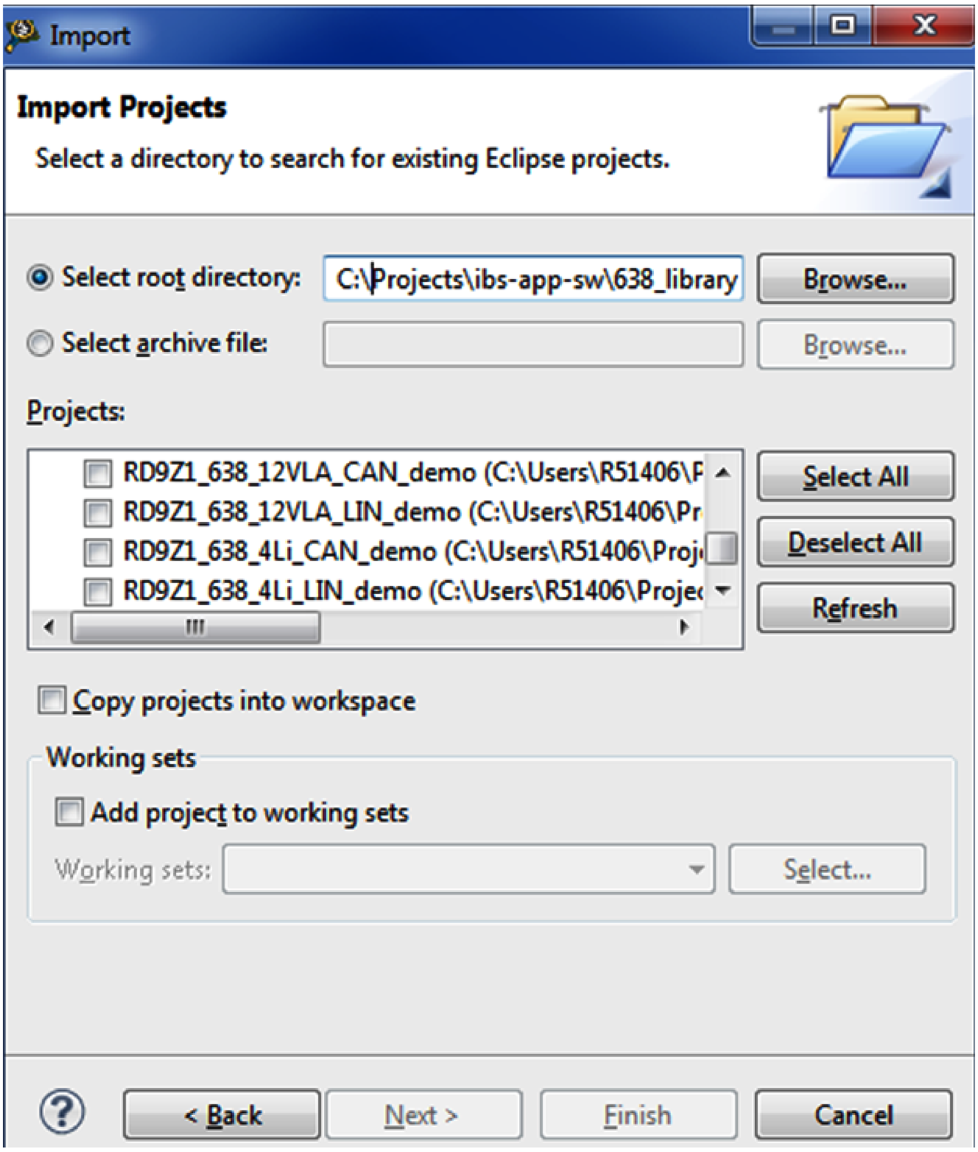
Download and import the reference design software in CodeWarrior and run the demo software:

1. Connect the BDM cable from the P&E's adapter (or equivalent) to the BDM1 connector on the board, using a 470 nF capacitor (see Section 4.3.3 "BDM1 Connector") between RESET and GND signal on the adapter side.
2. Connect the power supply to the RD9Z1-638-12V-C board (see Section 5.3 "Reference design configuration")
3. Download the reference design software (RD9Z1-638-12-C-APPSW) using the instructions in Section 3 "Getting started".
4. Extract or save the downloaded file on your local drive.
5. To start CodeWarrior:

a. Go to **File** > **Import** .
b. Choose **General** > **Existing Project into Workspace**, and then click **Next**.

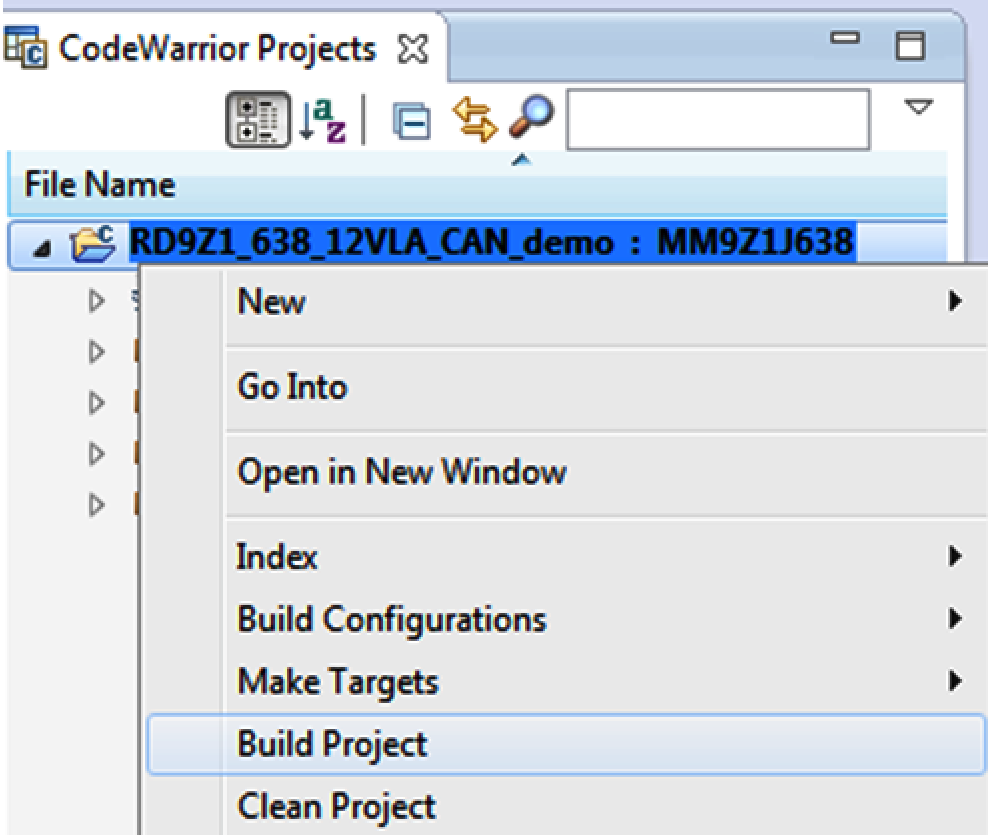


c. Select **Select root directory**. Click **Browse** and locate folder used in step 4.

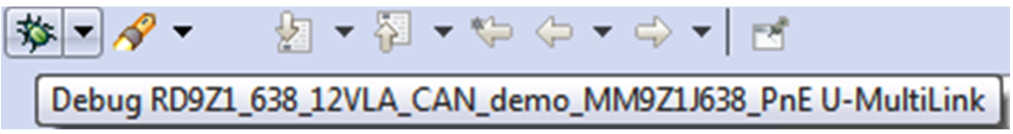


d. Select the **RD9Z1_638_12VLA_CAN_demo** project in the Projects section and click **Finish**.

6. Go to the Project tab and right-click on the **RD9Z1_638_12VLA_CAN_demo project**, and then select **Build Project**.



7. To debug the software, select **Debug**.



The reference design is fully functional now. The data or variables can be monitored in the CodeWarrior tool or by monitoring the CAN bus.

For more details, see the documentation available with the **RD9Z1-638-12-C-APPSW** software package.

5.3 Reference design configuration

This section explains the overall setup of the reference design.

Figure 10 shows how to setup the system using a DC power supply rather than a battery, which is more practical and safer than using a battery.

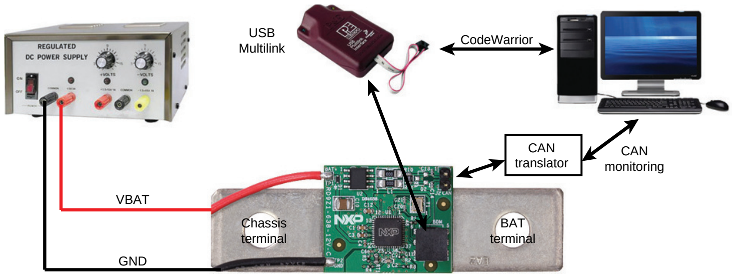


Figure 10. System configuration with power supply

The GND connection between the power supply and the RD9Z1-638-12V-C can be either to the GND connector (4mm banana socket) or to the CHASSIS terminal.

Note:

In this setup, only the load current is measured by the IC.

To include the board consumption current in this setup, connect the power supply negative terminal (-) to the BAT− shunt terminal instead.

Figure 11 shows how to setup the system using a battery.

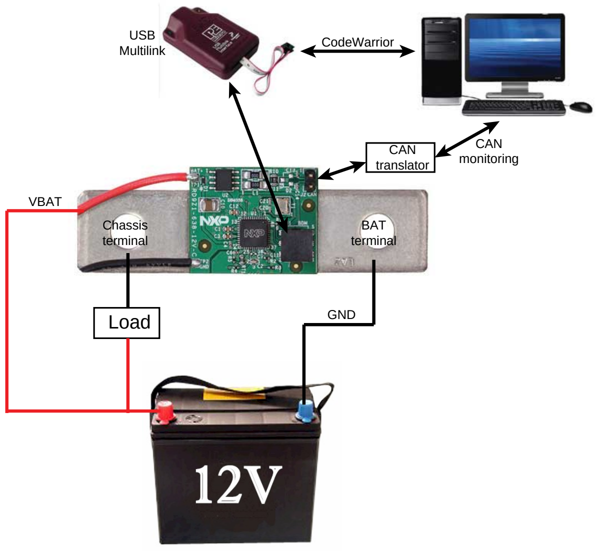


Figure 11. System configuration with battery

6 Schematics

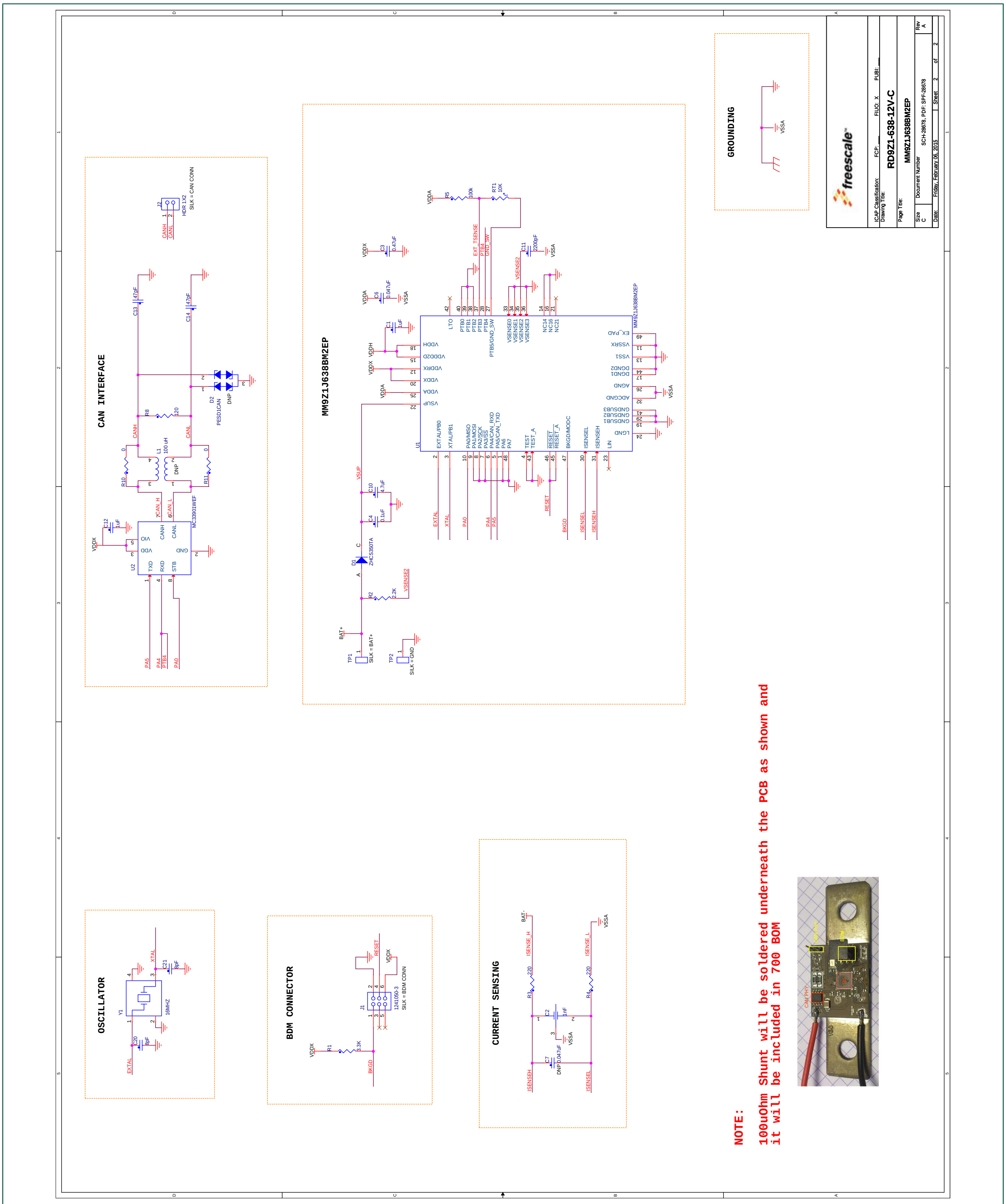


Figure 12. Schematic

7 Board layout

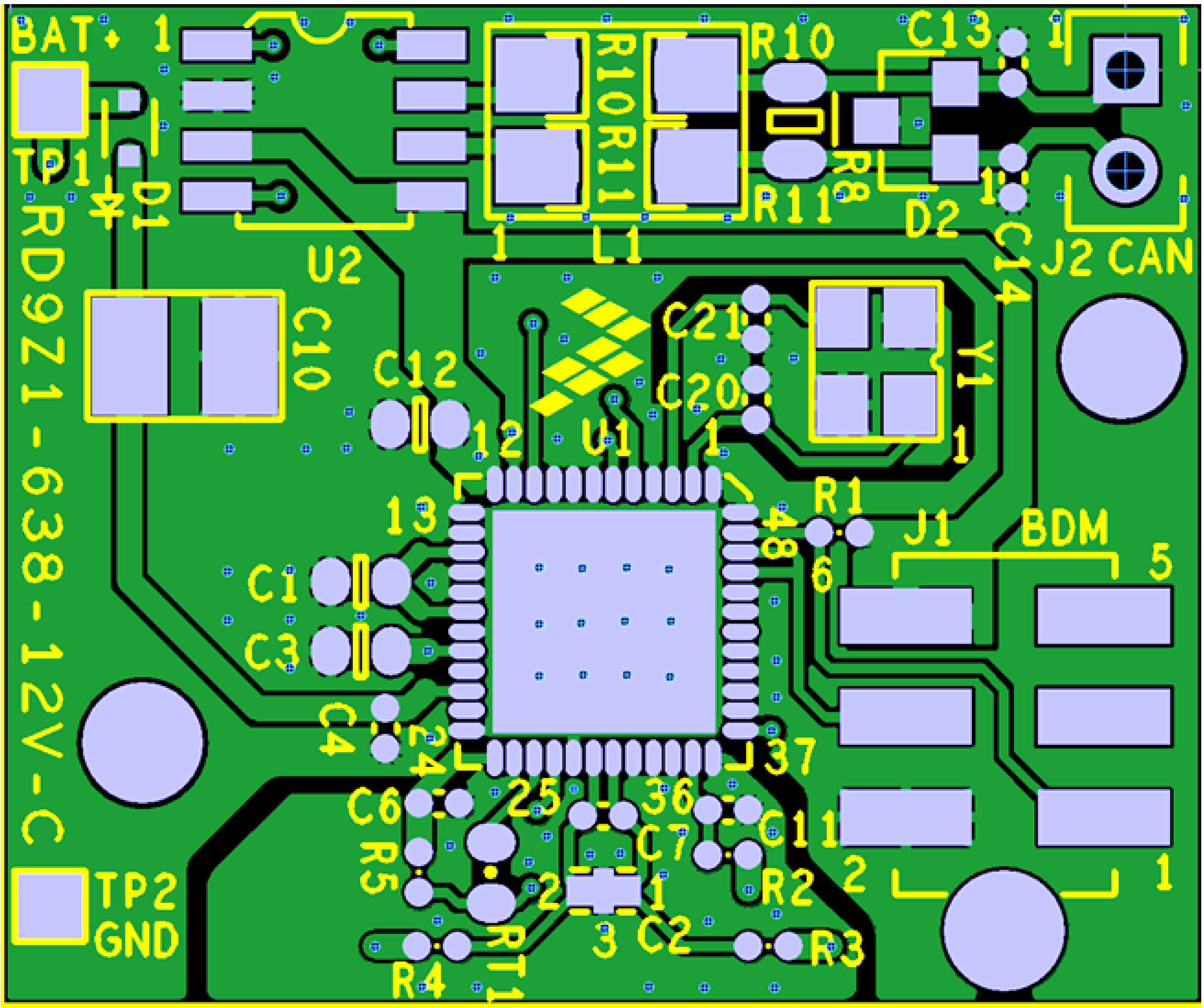


Figure 13. Assembly

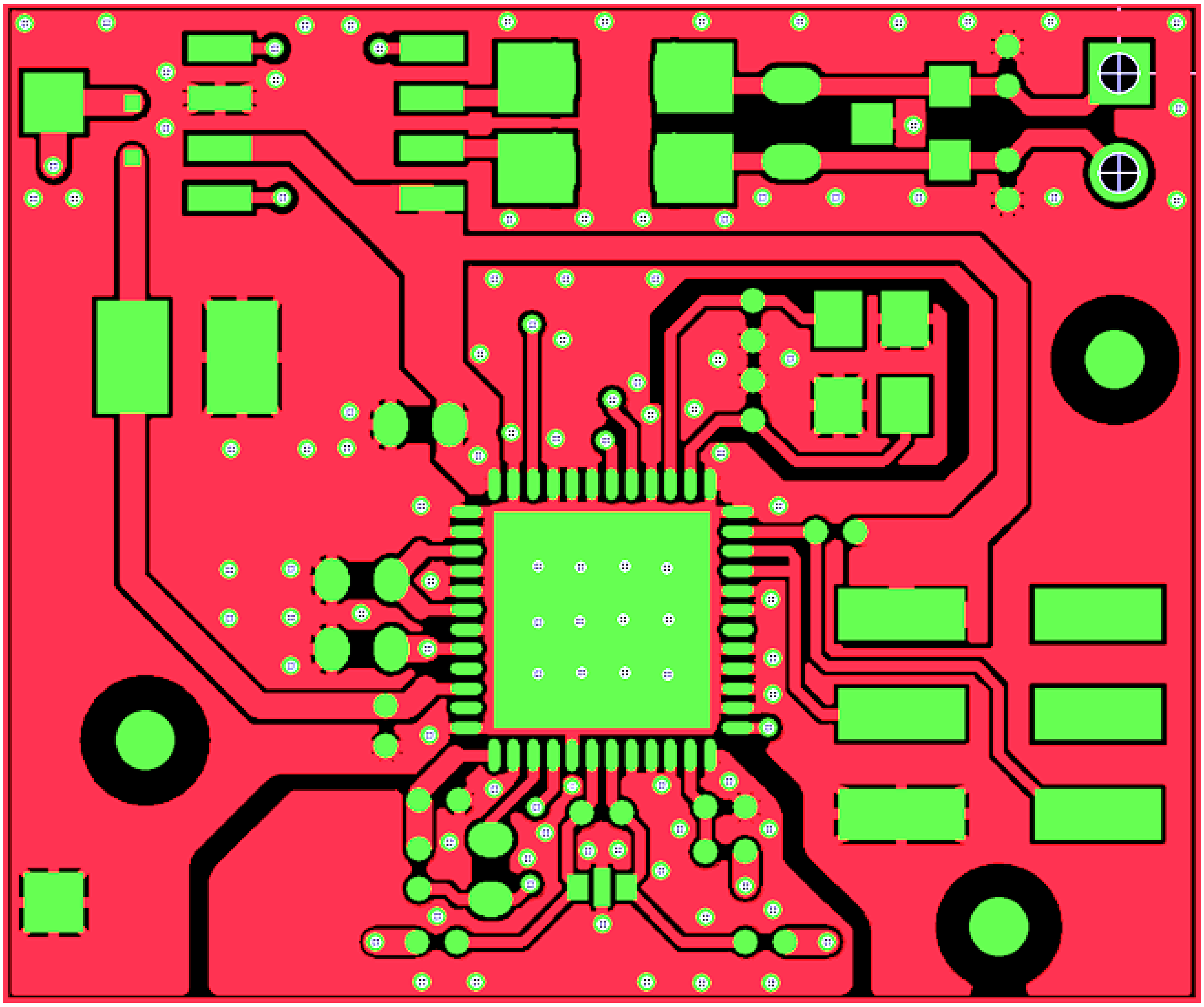


Figure 14. Top layer

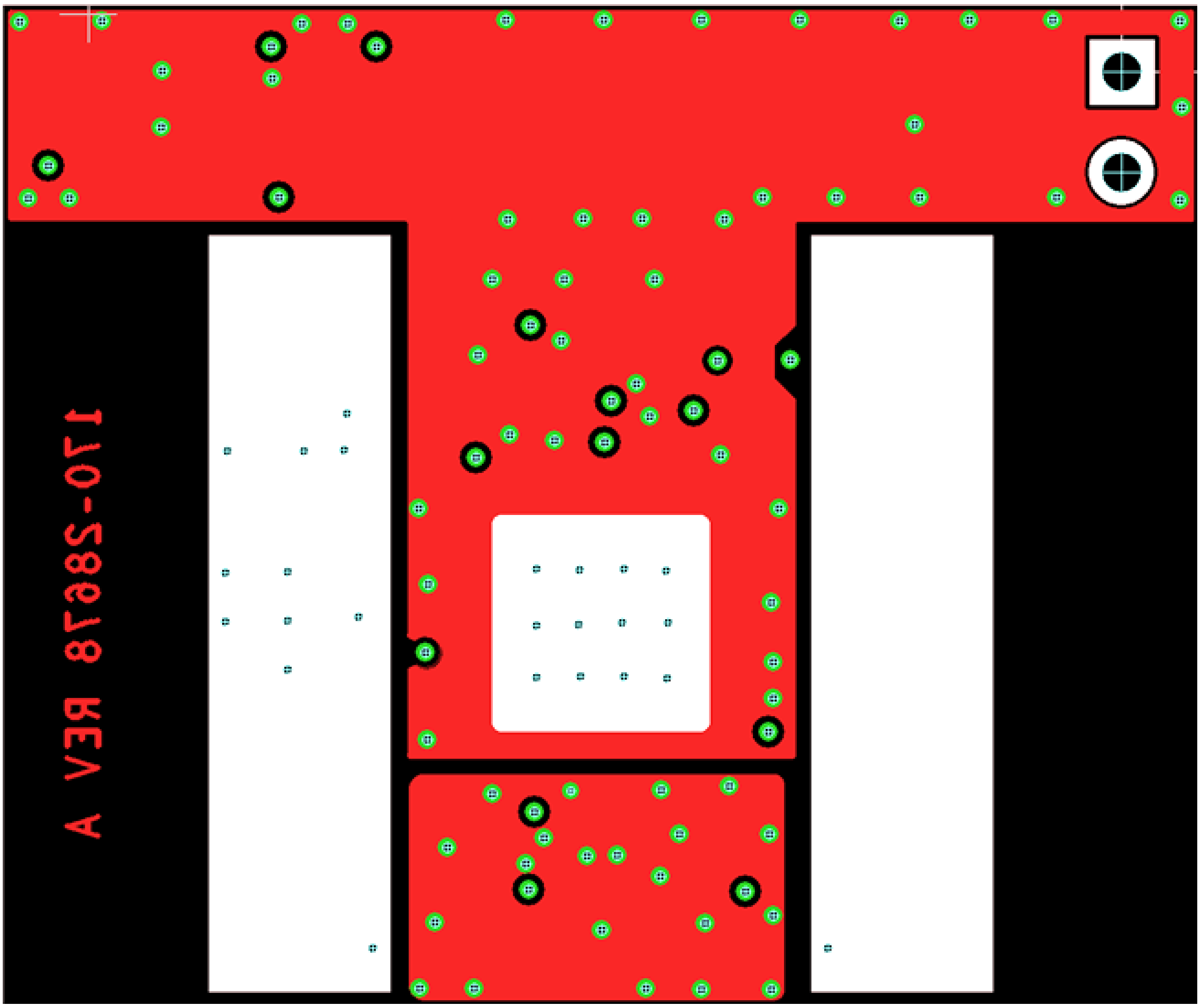


Figure 15. Bottom layer

8 Bill of materials

Table 2. Bill of Materials

Item	Qty	Schematic label	Value	Description	Part number	Assy opt
Active components						[1]
1	1	U1	–	NXP MM9Z1J638BM2EP, QFN48EP	MM9Z1J638BM2EP	[2]
2	1	U2	–	CAN Transceiver, SOIC8	MC33901	[2]
Quarz						[1]
3	1	Y1	CX3225 SA	16 MHz quarz	CX3225SA	
Diodes						[1]
4	1	D1	ZHC350	Schottky diode 40 V, IF = 350 mV, SOD-523	ZHCS350TA	
5	0	D2	DNP	CAN Protection diode, SOT23	PESD1CAN	[3]
Capacitors						[1]
6	1	C1, C12	1.0 µF	16 V, 10 %, X7R, 0603	C1608X7R1C105K080AC	
7	1	C2	1.0 nF	X2Y capacitor, MLCC X2Y 0402 50 V +/-20 %	500X07W102MV4T	
8	4	C3	470 nF	25 V, 10 %, X7R, 06033	CGA3E3X7R1E474K080AB	
9	1	C4	100 nF	50 V, 10 %, X7R, 0402	CGA2B3X7R1H104K050BB	
10	1	C6	47 nF	50 V, 10 %, X7R, 0402	C1005X7R1C473K050BC	
11	0	C7	47 pF			[3]
12	1	C10	47 pF	50 V, 10 %, X7R, 1210	MC1206B475K500CT	
13	1	C11	47 pF	50 V, 10 %, X7R, 0402	C1005X7R1H222K050BA	
14	2	C13, C14	47 pF	50 V, 5 %, C0G (NP0), 0402	CGA2B2C0G1H470J	
15	2	C20, C21	47 pF	50 V, +/-0.5 pF, C0G (NP0), 0402	CGA2B2C0G1H080D	
Resistors						[1]
16	1	R1	3.3 kΩ	50 V, 1 %, 0402	CRCW04023K30FKED	
17	1	R2	2.2 kΩ	50 V, 1 %, 0402	CRCW04022K20FKED	
18	2	R3, R4	220 Ω	50 V, 1 %, 0402	CRCW0402220RFKED	
19	1	R5	100 kΩ	50 V, 1 %, 0402	CRCW0402100KFKED	
20	1	R6	10 kΩ	NTC 10 k, 1 %	NCP18XH103F03RB	
21	1	R8	120 Ω	150 V, 1 %, 0805	CRCW0805120RFKEA	
22	2	R10, R11	0 Ω	1206	CRCW12060000Z0EA	
Switches, connectors, jumpers and test points						[1]
23	1	J1	3x2	Pinheader 2.54 mm 3x2	1241050-3	
24	1	J2	2x1	Pinheader 2.54 mm 2x1	826936-2	
25	0	L1	100 µH	Common mode choke, 100 µH	B82789 (100 µH)	[3]
26	1	Shunt	100 µΩ	Precision shunt resistor, 100 µΩ, 0.5 %	Isabellenhuette BAS-M-R0001-5.0	[2]

[1] NXP does not assume liability, endorse, or warrant components from external manufacturers that are referenced in circuit drawings or tables. While NXP offers component recommendations in this configuration, it is the customer’s responsibility to validate their application.
[2] Critical components. For critical components, it is vital to use the manufacturer listed.
[3] Do not populate

9 References

Following are URLs where you can obtain information on related NXP products and application solutions:

NXP.com support pages	Description	URL
RD9Z1–638–12V–C	Tool summary page	http://www.nxp.com/RD9Z1-638-12V-C
MM9Z1_638	Product summary page	http://www.nxp.com/MM9Z1_638
MC33901	Product summary page	http://www.nxp.com/MC33901
CW–MCU10	CodeWarrior for MCUs	http://www.nxp.com/CWMCU10
U–MULTILINK	Product summary page	http://www.nxp.com/UMultilink

10 Legal information

10.1 Definitions

Draft — The document is a draft version only. The content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included herein and shall have no liability for the consequences of use of such information.

10.2 Disclaimers

Limited warranty and liability — Information in this document is believed to be accurate and reliable. However, NXP Semiconductors does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. NXP Semiconductors takes no responsibility for the content in this document if provided by an information source outside of NXP Semiconductors. In no event shall NXP Semiconductors be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory. Notwithstanding any damages that customer might incur for any reason whatsoever, NXP Semiconductors' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the Terms and conditions of commercial sale of NXP Semiconductors.

Right to make changes — NXP Semiconductors reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

Applications — Applications that are described herein for any of these products are for illustrative purposes only. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification. Customers are responsible for the design and operation of their applications and products using NXP Semiconductors products, and NXP Semiconductors accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the NXP Semiconductors product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products. NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using NXP Semiconductors products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). NXP does not accept any liability in this respect.

Export control — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from competent authorities.

Evaluation products — This product is provided on an "as is" and "with all faults" basis for evaluation purposes only. NXP Semiconductors, its affiliates and their suppliers expressly disclaim all warranties, whether express, implied or statutory, including but not limited to the implied warranties of non-infringement, merchantability and fitness for a particular purpose. The entire risk as to the quality, or arising out of the use or performance, of this product remains with customer. In no event shall NXP Semiconductors, its affiliates or their suppliers be liable to customer for any special, indirect, consequential, punitive or incidental damages (including without limitation damages for loss of business, business interruption, loss of use, loss of data or information, and the like) arising out the use of or inability to use the product, whether or not based on tort (including negligence), strict liability, breach of contract, breach of warranty or any other theory, even if advised of the possibility of such damages. Notwithstanding any damages that customer might incur for any reason whatsoever (including without limitation, all damages referenced above and all direct or general damages), the entire liability of NXP Semiconductors, its affiliates and their suppliers and customer's exclusive remedy for all of the foregoing shall be limited to actual damages incurred by customer based on reasonable reliance up to the greater of the amount actually paid by customer for the product or five dollars (US$5.00). The foregoing limitations, exclusions and disclaimers shall apply to the maximum extent permitted by applicable law, even if any remedy fails of its essential purpose.

Translations — A non-English (translated) version of a document is for reference only. The English version shall prevail in case of any discrepancy between the translated and English versions.

10.3 Trademarks

Notice: All referenced brands, product names, service names and trademarks are the property of their respective owners.

CodeWarrior — is a trademark of NXP B.V.

SMARTMOS — is a trademark of NXP B.V.

Tables

Figures

Contents

Date of release: 2 March 2018