RD9Z1-638-12V Reference Design

Intelligent 12 V Lead-acid Battery Management with LIN Interface
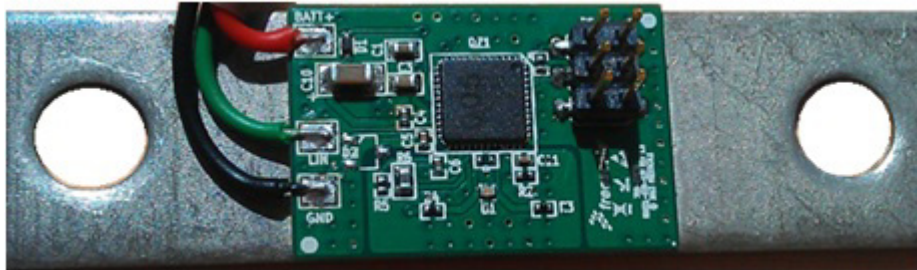

Figure 1. RD9Z1-638-12V Reference Design

Contents

freescale

1 Kit Contents/Packing List

- Assembled and tested 100 μΩ shunt mounted to the board in an anti-static bag
- Warranty card

2 Jump Start

- Go to www.freescale.com/analogtools
- Locate your kit
- Review your Tool Summary Page
- Look for

  ↗ Jump Start Your Design

- Download documents, software, and other information

3   Important Notice

Freescale 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 Freescale 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.

Freescale reserves the right to make changes without further notice to any products herein. Freescale makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does Freescale 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.

Freescale does not convey any license under its patent rights nor the rights of others. Freescale 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 Freescale product could create a situation where personal injury or death may occur.

Should the Buyer purchase or use Freescale products for any such unintended or unauthorized application, the Buyer shall indemnify and hold Freescale 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 that Freescale was negligent regarding the design or manufacture of the part.Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners.

© Freescale Semiconductor, Inc. 2014

4   Introduction

The RD9Z1-638-12V 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 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.

5   Reference Design Features

The RD9Z1-638-12V reference design features are as follows:

- Embedded MCU: 16-bit S12Z MCU
- Embedded power management
- Battery voltage sensing input (VSENSE2)
- Internal temperature sensing
- Embedded NTC for temperature sensing (PTB4)
- Battery current sensing via mounted shunt (ISENSE)
- LIN 2.2/2.1/2.0 interface
- BDM interface (For MCU programming and debugging)

6 Device Features

6.1 MM9Z1_638 Device Features

The MM9Z1_638 is a fully integrated BMS. The device supports precise current measurement via an external shunt resistor. It features four voltage measurements via an internal calibrated resistor divider or use of an external divider. It includes an internal temperature sensor, allowing close proximity battery temperature measurements, plus four external temperature sensor inputs. The MM9Z1_638 integrates a S12Z microcontroller and a SMARTMOS analog control IC into a single package solution.

- Wide range battery current measurement; On-chip temperature measurement
- Four battery voltage measurements with internal resistor dividers, and up to five direct voltage measurements for use with an external resistor divider
- Measurement synchronization between voltage channels and current channels
- Five external temperature sensor inputs with internal supply for external sensors
- Low-power modes with low-current operation
- Multiple wake-up sources: LIN, timer, high-voltage input, external CAN interface, and current threshold and integration
- Precision internal oscillator and connections for external crystal
- LIN 2.2/2.1/2.0 protocol and physical interface
- msCAN protocol controller, and supply capability for 8 and 14-pin CAN interfaces
- MM9Z1_638: S12Z microcontroller with 128 kByte Flash, 8.0 kByte RAM, 4.0 kByte EEPROM

6.2 S12Z MCU

The MM9Z1J638 enables precision measurement of key battery parameters in automotive, industrial and other applications. The device integrates a S12Z microcontroller and a SMARTMOS analog control IC into a single package solution. The analog die combines system basis and application specific functions, including 3 dedicated 16-bit sigma delta analog to digital converters (ADC) for synchronous measurement of battery voltage, current, and temperature.

The Embedded MCU includes these features:

- S12Z CPU core (S12ZCPU)
- 128 KB on-chip flash with ECC
- 4.0 KB on-chip EEPROM with ECC
- 8.0 KB on-chip SRAM with ECC
- Phase locked loop (IPLL) frequency multiplier with internal filter
- 4.0 - 16 MHz amplitude controlled Pierce oscillator
- 1.024 MHz internal RC oscillator
- 50 MHz bus frequency
- One CAN module (msCAN)
- One serial peripheral interface (SPI) module
- On-chip voltage regulator (VREG) for regulation of input supply and all internal voltages
- Die to Die Initiator (D2DI)

7   Accessory Interface Board

The RD9Z1-638-12V reference design may be used with the P&E's USB BDM Multilink (shown below), which provides a USB-to-BDM interface. This accessory will be needed to flash the MCU using Freescale **CodeWarrior** 10.4 or higher. See USB BDM Multilink.

Figure 2. P&E's USB BDM Multilink

8   Required Equipment

Minimum required equipment:

• 12 V DC Power supply
• USB-enabled PC with Windows XP or higher
• P&E's USB BDM Multilink
• Freescale **CodeWarrior** 10.4 or higher

The following additional equipment is needed to fully use this reference design.

• 12 V Lead-Acid battery
• Battery load or current source
• Shunt-compatible power cable and plugs (screws + nuts)
• LIN bus Master
• Oscilloscope (preferably 4-channel)
• Digital voltmeter and ammeter

Having all of these items will allow testing and debugging of the system.

9 Reference Design Configuration
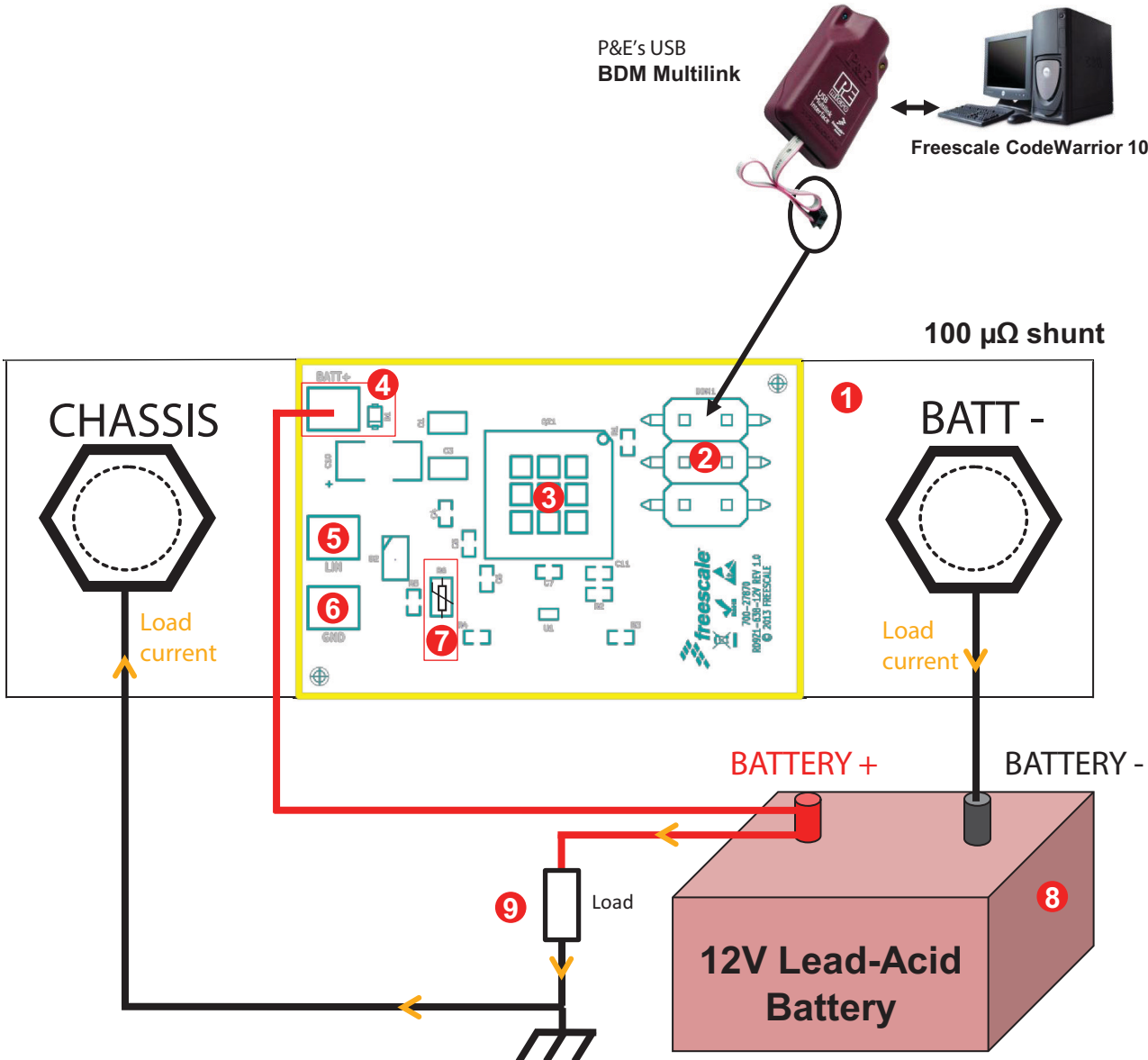
Figure 3. RD9Z1-638-12V Board with Battery Configuration

In Figure 3, current goes from battery positive through the load, into the ground (chassis), through the shunt (where it creates voltage measured by the MM9Z1_638) and goes back to the battery minus. Figure 3 shows key component and connector locations.

The following table is a description of the numbers listed on Figure 3.

Table 1. Key Component and Connector Locations

Item	Description	Note
1	100 μΩ shunt for current measurement, providing ground terminal (CHASSIS) and battery minus pole terminal (BATT-)	
2	BDM Connector (BDM1), add 470 nF between RESET and GND signal for programming only	
3	Freescale MM9Z1J638 Battery Sensor (U1)	
4	Battery positive pole input pad (BATT+), reverse protected by D1 diode	(1)
5	LIN pad	
6	GND pad	(2)
7	Embedded NTC thermistor (R6). Provide close-to-battery temperature measurement	
8	12 V Lead-Acid Battery	
9	External battery load (for current measurement). A current source can also be used	

Notes
1. If no battery is available, connect a 12 V power supply to BATT+, see Figure 4 and Figure 5.
2. If the shunt CHASSIS terminal is not used, connect the power supply ground to GND pad.

The board is protected against reverse battery voltage by diode D1. This diode can withstand up to 350 mA continuous forward current.

9.1   Setup with DC Power Supply (CHASSIS)

This setup is optional and used when no battery is available. In this case, the board is powered by a 12 V DC Power supply.
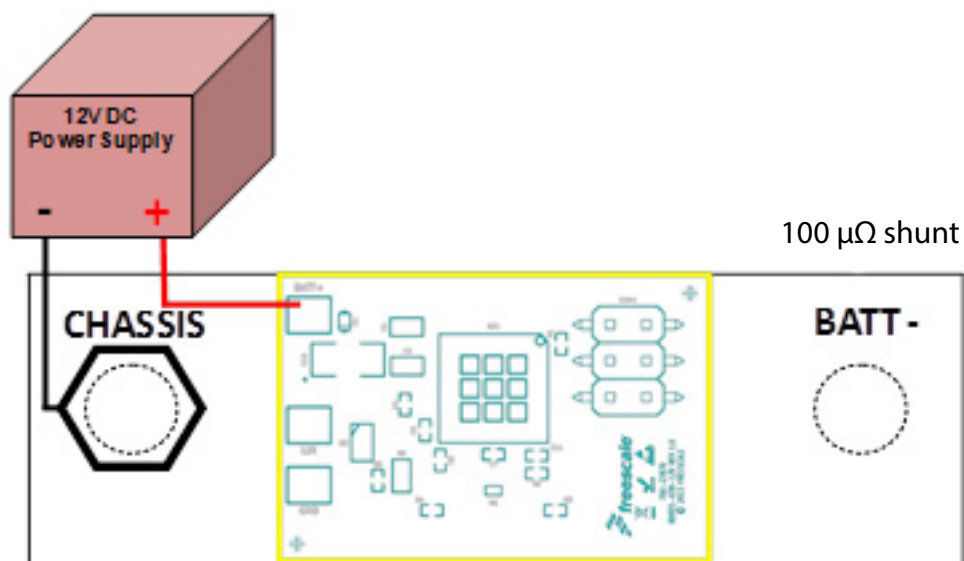
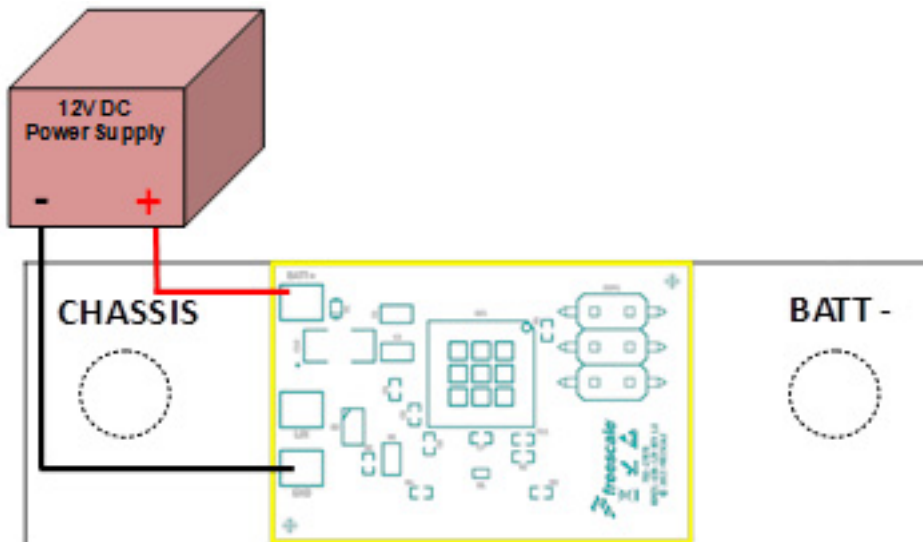**Figure 4. Setup with DC Power Supply (CHASSIS)**

Note: In this setup, only the load current will be measured by the IC.

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

9.2   Setup with DC Power Supply (GND Pad)

This setup is optional and used when no battery is available. In this case, the board is powered by a 12 V DC Power supply.

Figure 5. Setup with DC Power Supply (GND Pad)

Note: In this setup, only the load current will be measured by the IC.

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

Note: Connecting power ground to the GND pad will provide the same board functionality as connecting it to the CHASSIS terminal.

10 Setting Up and Using the Hardware and Software

In order to perform the demonstration examples, first set up the board hardware and software as follows:

1. Download **CodeWarrior** 10.4 or higher and the example software using the instructions in the "Jump Start" section.

2. Install **CodeWarrior** Suite on a USB-enabled PC running Windows XP or higher.

3. Connect a 470 nF capacitor between RESET and GND signal on the adapter side.

4. Connect the BDM cable from the P&E's adapter (or equivalent) to the BDM1 connector on the board with ribbon cable coming from left side of the board.

5. Connect the battery minus pole (-) or the ground line from the supply to the BATT- terminal on the shunt.

   Note: If the shunt CHASSIS terminal is not used, connect the power supply ground to GND pad.

6. Connect the battery positive pole (+) or the positive voltage output (set at +12 V) of the DC power supply to the BATT+ terminal on the board.

7. Place the project example folder obtained in step 1 into the **CodeWarrior** Suite workspace folder. By default the folder is located at C:\Users\YOUR_USER_NAME\workspace.

8. Launch the **CodeWarrior** Suite.

   a. Go to File>Import in the **CodeWarrior** Suite. Choose Existing Project into Workspace, click Next.

   b. Select "select root directory". Click Browse and locate the workspace folder. The Project starts loading.

   c. Select the Example Software in the Projects section and select Copy Project Into Workspace. Click Finish.

   d. An example project is ready to be used. It is located in the "**CodeWarrior** Projects" window, on the left.

   e. Go to the Project tab and click Build All to compile the project.

   f. Go to the Run tab and select Run. To debug the MCU, select Debug instead of Run.

Once the steps above are all accomplished, go to **Jump Start Your Design** at freescale.com to download the RD9Z1-638-12V_APPSP.zip file.

10.1   Hardware Description

This reference design features one MM9Z1J638 (Battery Sensor) IC. Below is a board-level logic diagram.
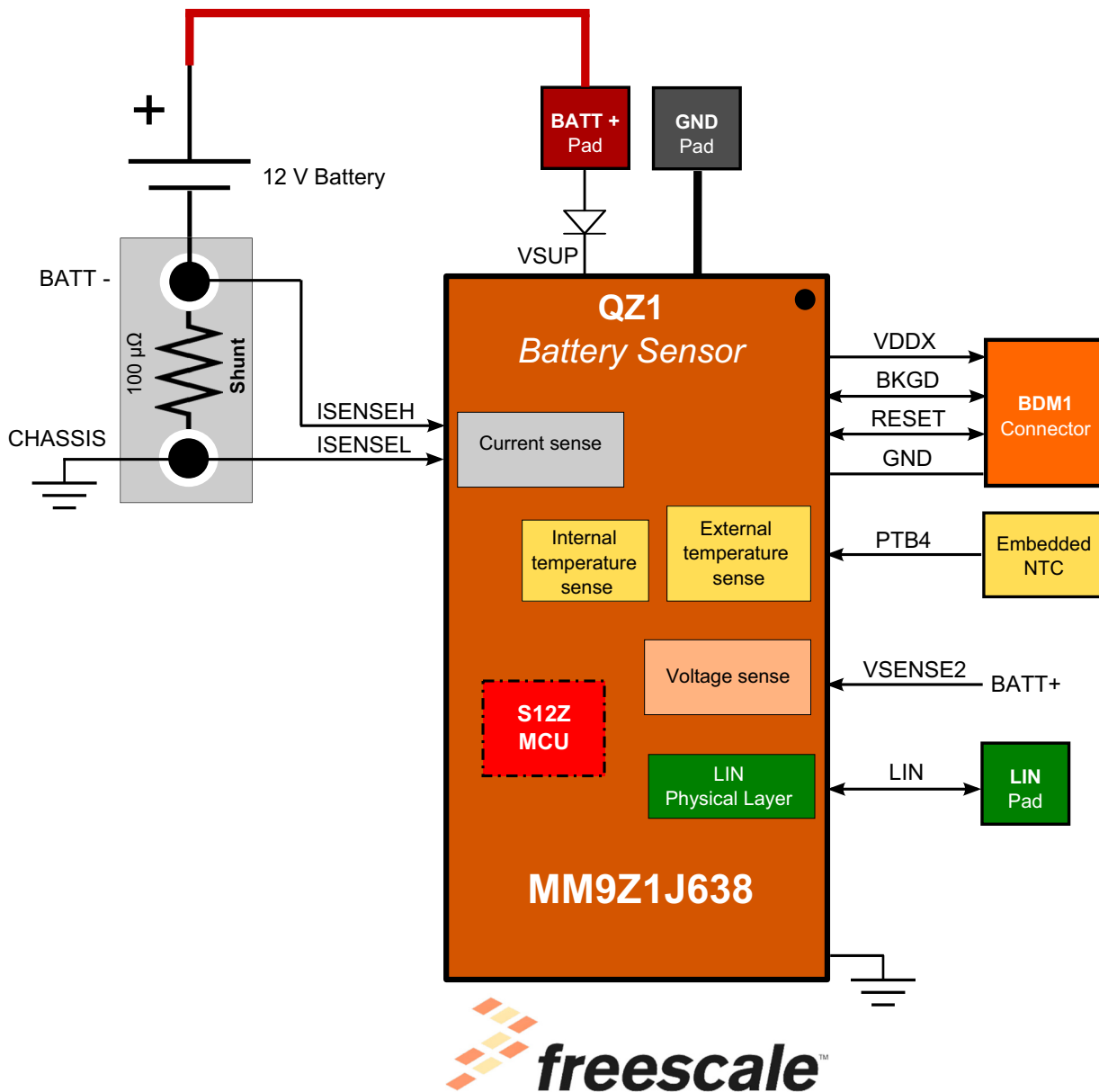

Figure 6. RD9Z1-638-12V Block Diagram

10.2   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 BATT- 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 current. This insures accurate current measurement at any time.

10.3　Voltage and Current Measurement

The MM9Z1J638 has four voltage measurement channels called VSENSE. For sensing the battery voltage, the VSENSE2 pin is used and protected against ESD by a 2.2 kΩ serial resistor. Measurement results are referenced to GND. A software calculation is needed to know the battery voltage.

The software has to include the voltage drop of the shunt (ie.ISENSE differential voltage) to get the correct battery voltage. In this case, the current acquisition must be ON when voltage acquisition is ON.

When using the MM9Z1J638 in a low side current sensing setup, the actual voltage for the battery is:

$$V_B = VSENSE2 + V_{SHUNT}$$

$$\text{Where } V_{SHUNT} = \text{Load current} \times 100 \text{ } \mu\Omega = -V_{DROP}$$

$$\text{And where } V_{DROP} = I_{SENSEH} - I_{SENSEL}$$

If current is positive (or $V_{DROP} < 0$), the data returned into ACQ_CURR (current acquisition register) will be negative.

If current is negative (or $V_{DROP} > 0$), the data returned into ACQ_CURR (current acquisition register) will be positive.
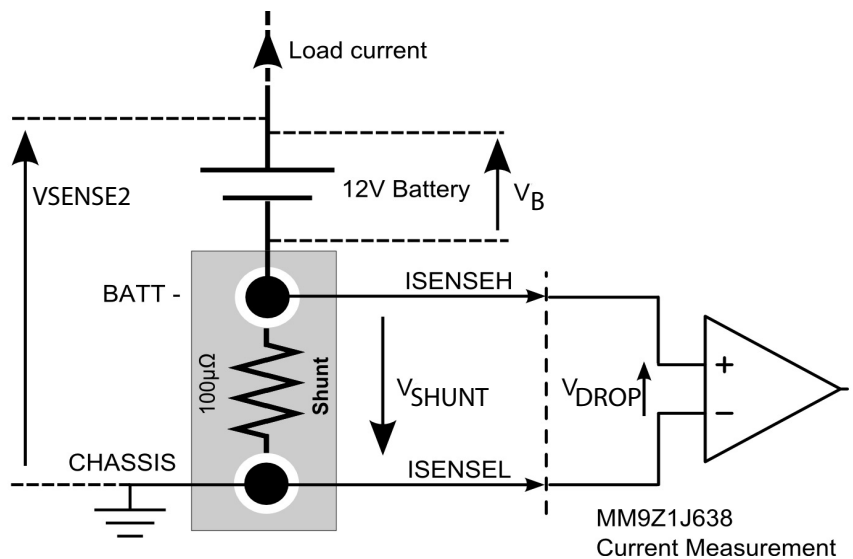
Figure 7. RD9Z1-638-12V Low-side Current Sensing

This reference design provides a very high EMC tolerant current sensing circuit thanks to symmetrical layout traces along with a dual balanced capacitor (C2) improving differential and common attenuation.
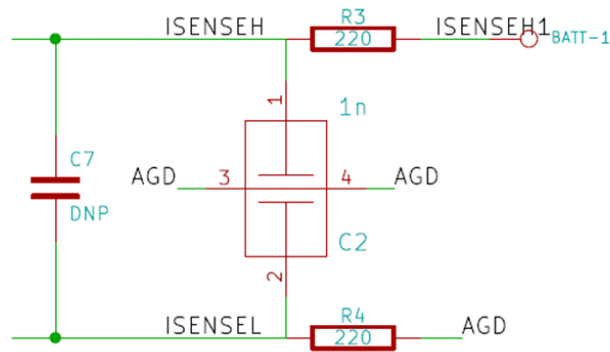
Figure 8. Current Sensing Circuit

10.4   LIN Interface

This reference design provides a LIN 2.2/ 2.1/ 2.0 protocol and physical interface. This LIN interface has a high robustness against EM disturbances, ESD and has a very low EM emission level. An ESD diode (D2) can be added to further improve performances.

10.5 Embedded Temperature Sensing

This reference design provides temperature sensing embedded on the PCB. The thermistor is located above a thermal convection point. Thanks to the low thermal resistance of the shunt and PCB pads, this design gives the user an approximate reading of battery temperature without the need of any additional external components.
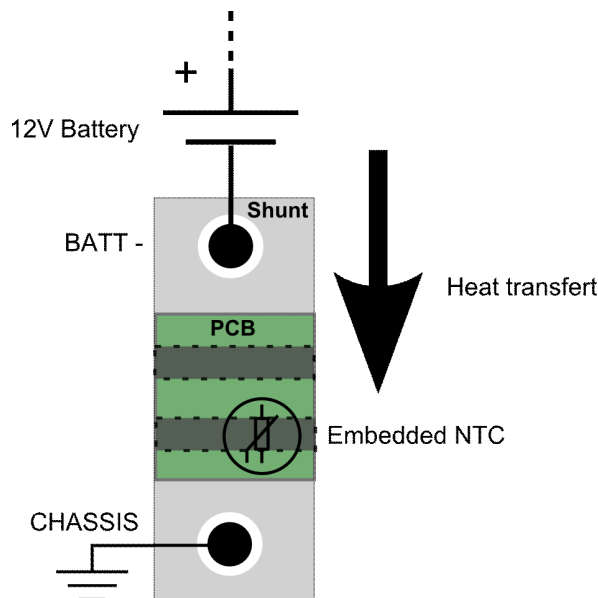
Figure 9. Embedded Temperature Sensing

10.6 BDM1 Connector

BDM1 should be connected to P&E's USB BDM Multilink adapter (or equivalent) in order to enable programming and debugging the MM9Z1J638 with the Freescale **CodeWarrior** Suite. For programming the MM9Z1J638, connect a 470 nF capacitor between RESET and GND signal on the adapter side. It is due to the RESET pin being connected to the RESET_A pin with the analog watchdog enabled. The programming capacitor shall be removed after programming.
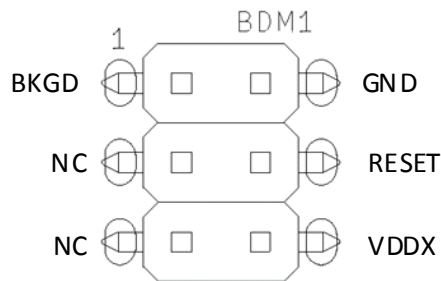
Figure 10. BDM1 Connector

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

10.7   BATT+, LIN and GND Pads

The BATT+ pad should be connected to the battery positive (+) terminal in order to power the board. An 18 or 16 gauge wire should be used and soldered directly on the pad footprint. This insures enough flexibility over the application constraints. The LIN pad should be connected to a LIN bus, if any. The GND pad is an optional connection path for ground, in case the shunt is not connected to the chassis. Preferably, the "CHASSIS" side on the shunt should be used for grounding.
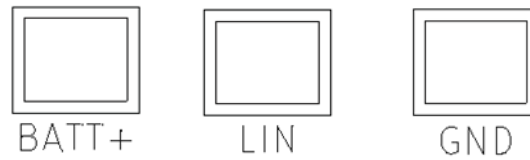
Figure 11. BATT+, LIN and GND Pads

11   Schematic

12 Board Layout

12.1 Assembly Layer Top
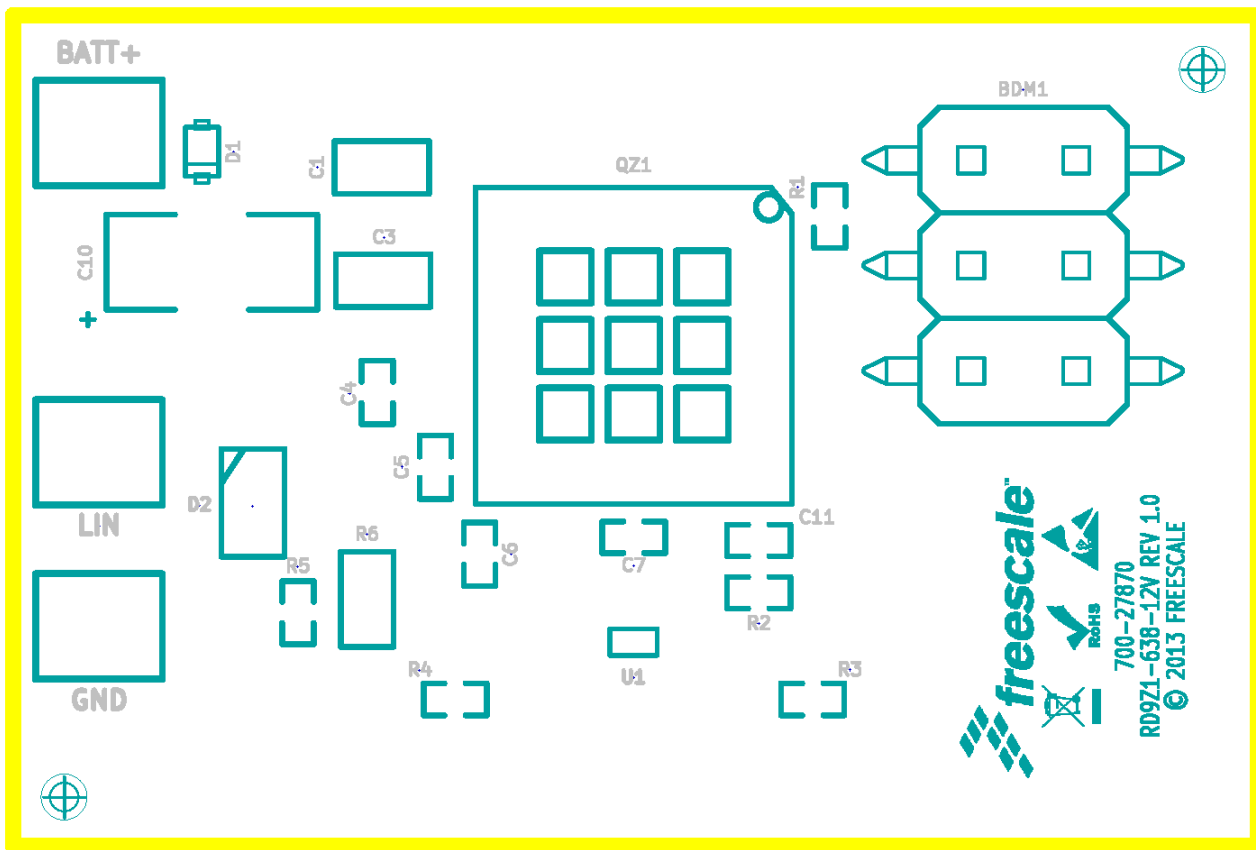
12.2 Top Layer Routing
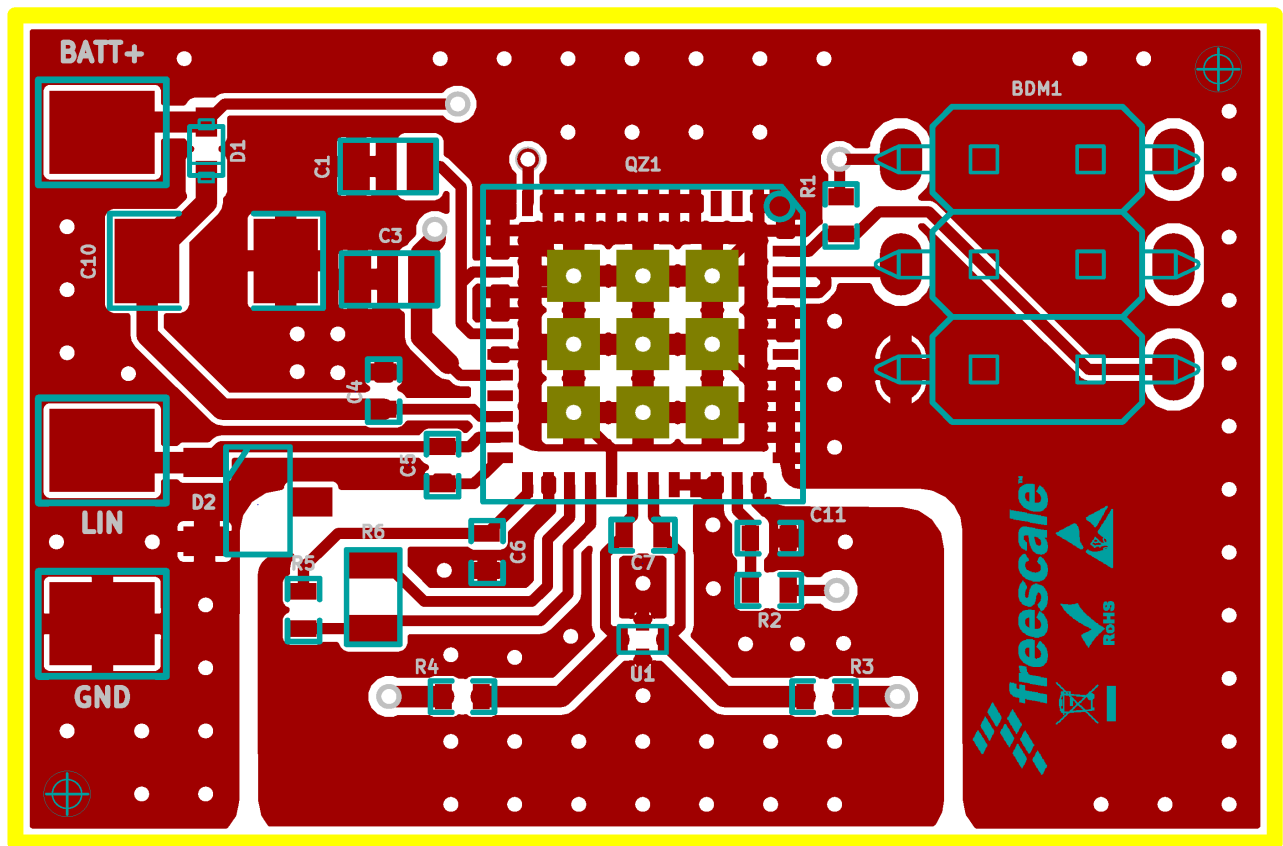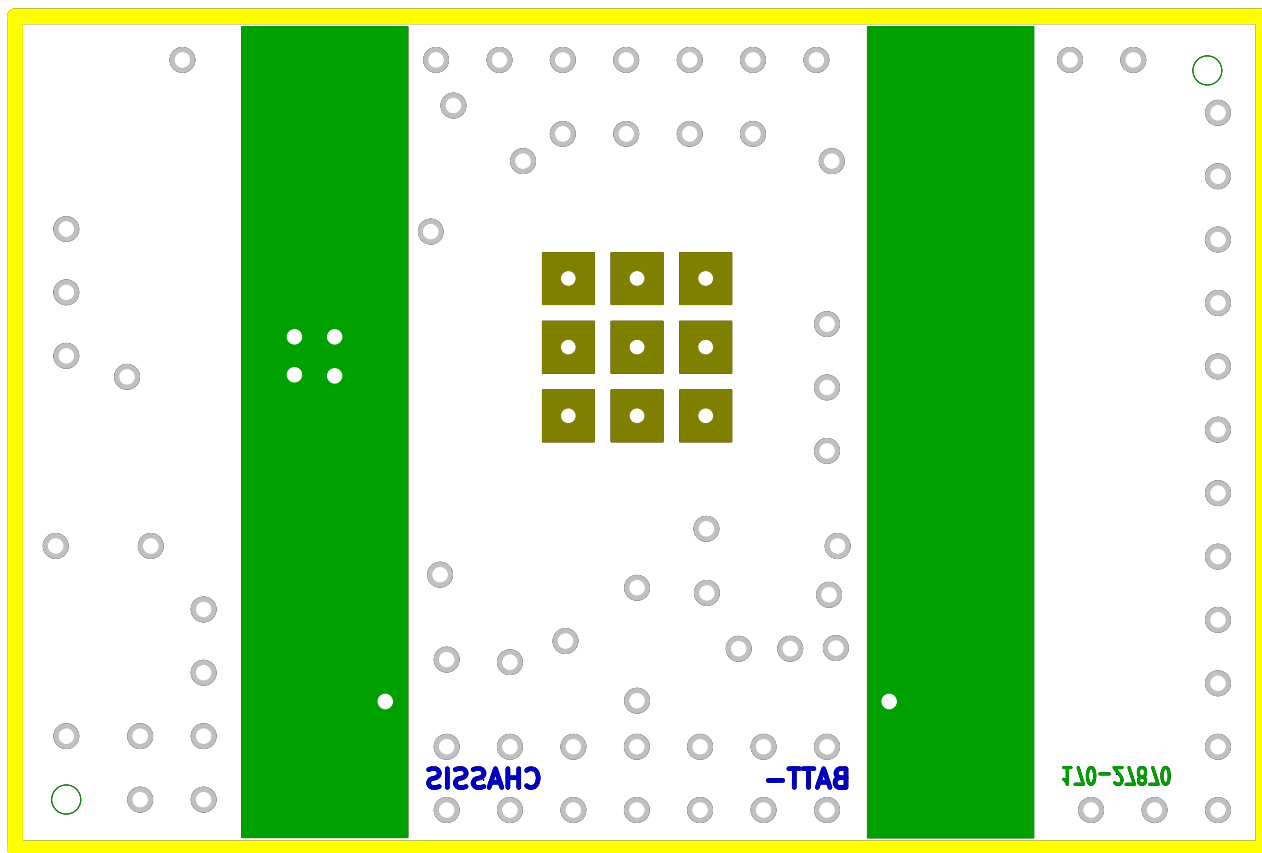
12.3   Layer 2 Routing

12.4 Layer 3 Routing

KTRD9Z1-638-12VUG User's Guide Rev. 1.0 4/2014

20
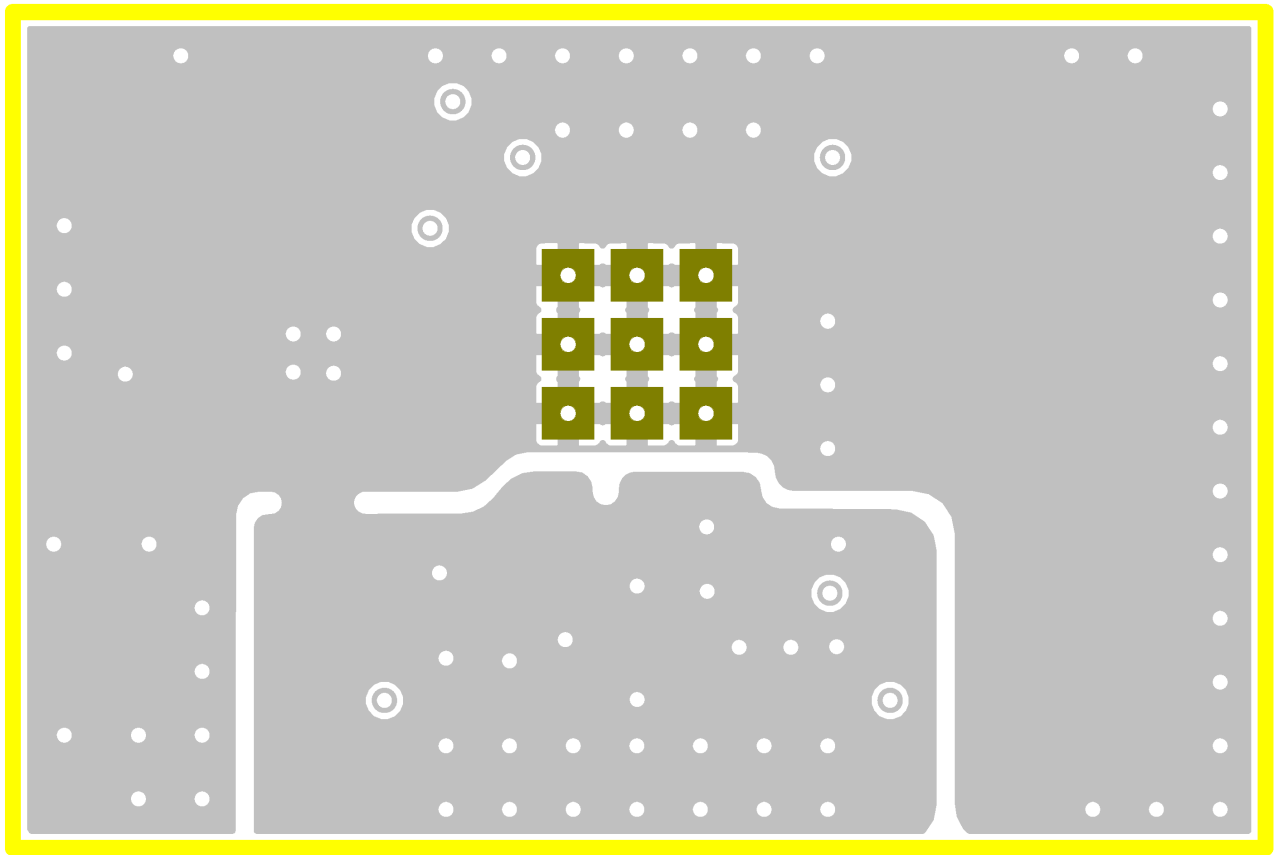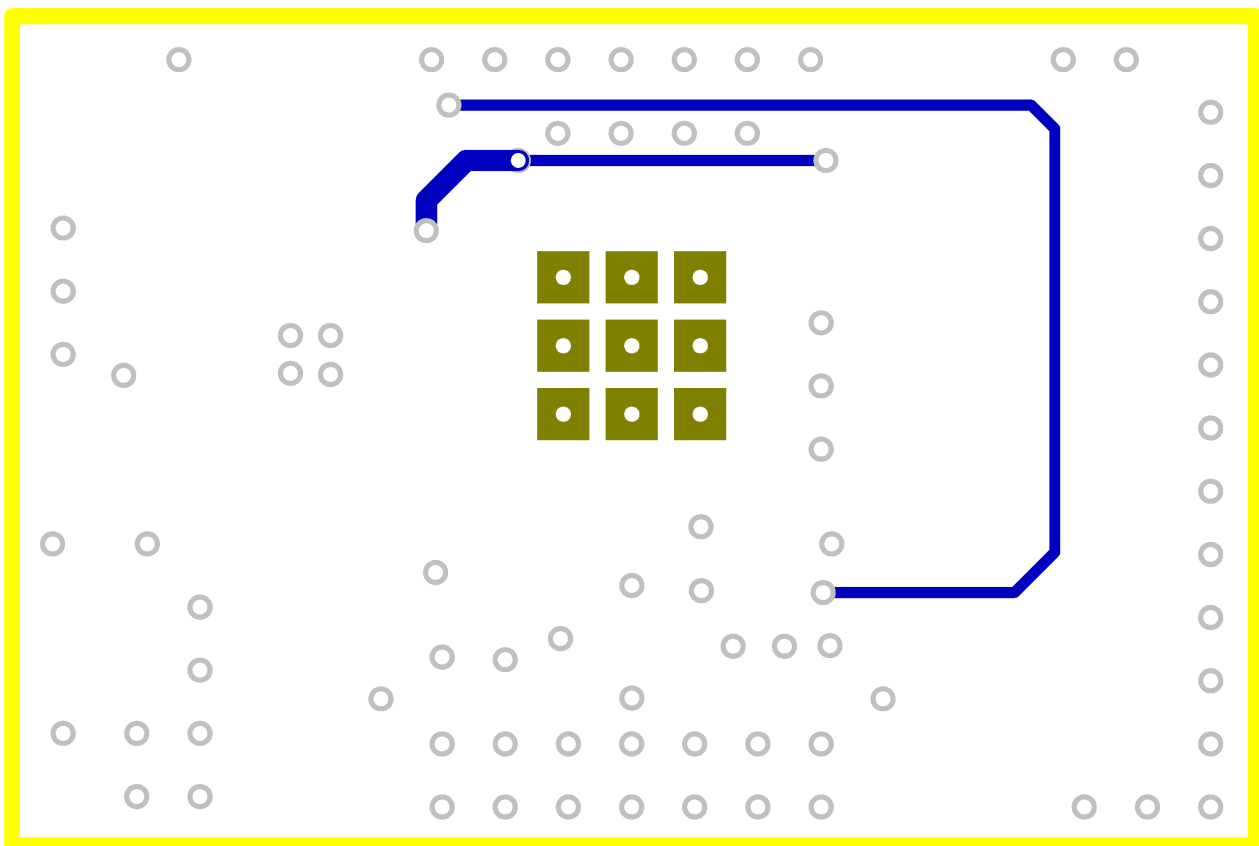
12.5   Bottom Layer Routing

Note: This image is an exception to the standard top-view mode of representation used in this document. It has been flipped to show a bottom view.

13   Bill of Materials

Table 2. Bill of Materials [1]

Qty	Schematic Label	Value	Description	Package	Assy Opt
Integrated Circuit					
1	QZ1	N/A	Freescale MM9Z1J638BM2EP	48-PIN QFN	[3]
Diodes					
1	D1	N/A	ZHCS350 350 mA SOD-523 - 55 °C to + 125 °C AEC-Q101 ROHS Lead-Free	SOD-523	
1	D2	DNP	MMBZ27VCLT1 recommended	SOT-23	[2]
Capacitors					
1	C1	1 uF	GCM188R71C105KA64 16 V 10 % X7R 0603 - 55 °C to + 125 °C AEC-Q200 ROHS Lead-Free	SM0603	
1	U1	1 nF	500X07W102MV4T 50 V 20 % X7R 0402 - 55 °C to + 125 °C ROHS Lead-Free	X2Ycap-0402-b	
1	C3	470 nF	CGA3E3X7R1E474K080AB 16 V 10 % X7R 0603 - 55 °C to + 125 °C AEC-Q200 ROHS Lead-Free	SM0603	
1	C4	100 nF	CGA2B3X7R1H104K050BB 50 V 10 % X7R 0402 - 55 °C to + 125 °C AEC-Q200 ROHS Lead-Free	SM0402	
1	C5	220 pF	GCM155R71H221KA37D 50 V 10 % X7R 0402 - 55 °C to + 125 °C AEC-Q200 ROHS Lead-Free	SM0402	
1	C6	47 nF	GCM155R71C473KA37D 16 V 10 % X7R 0402 - 55 °C to + 125 °C AEC-Q200 ROHS Lead-Free	SM0402	
1	C7	DNP	GCM155R71H222KA37D 50 V 10 % X7R 0402 - 55 °C to + 125 °C AEC-Q200 ROHS Lead-Free	SM0402	
1	C10	4.7 uF	GCM32ER71H475KA55L 50 V 10 % X7R 1210 - 55 °C to + 125 °C AEC-Q200 ROHS Lead-Free	SM1210	
1	C11	2.2 nF	GCM155R71H222KA37 50 V 10 % X7R 0402 - 55 °C to + 125 °C AEC-Q200 ROHS Lead-Free	SM0402	

Table 2. Bill of Materials [1] (continued)

Resistors

1	R1	4.7 k	CRCW04024K70FKED 50 V 1 % 0402 - 55 °C to + 155 °C AEC-Q200 ROHS Lead-Free	SM0402	
1	R2	2.2 k	CRCW04022K20FKED 150 V 1 % 0805 - 55 °C to + 155 °C AEC-Q200 ROHS Lead-Free	SM0402	
2	R3 R4	220	CRCW0402220RFKED 50 V 1 % 0402 - 55 °C to + 155 °C AEC-Q200 ROHS Lead-Free	SM0402	
1	R5	100 k	CRCW0402100KFKED 50 V 1% 0402 - 55 °C to + 155 °C AEC-Q200 ROHS Lead-Free	SM0402	

Thermistor

1	R6	10 k	NCP18XH103F03RB 10 kOhms 1% 0603 - 40 °C to + 125 °C AEC-Q200 ROHS Lead-Free	SM0603	

Connectors

1	BDM1	CONN_3X2	15-91-3060 2.54 mm smd 3x2 ROHS Lead-Free	2.54 mm smd 3x2	

Shunt

1	N/A	0.1 mOhm	BAS-M-R00001-5.0E	N/A	[3]

Cables and Jacks

1	N/A	N/A	WH18-02-25 Red 18AWG 15 cm wire	N/A	
1	N/A	N/A	WHS18-00-25 Black 18AWG 15 cm wire	N/A	
1	N/A	N/A	BU-P5167-2 Red Banana Jack	N/A	
1	N/A	N/A	BU-P5167-0 Black Banana Jack	N/A	

Notes

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

14   References

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

Freescale.com Support Pages	Description	URL
MM9Z1_638	Product Summary Page	http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=MM9Z1_638
P&E's USB BDM Multilink	Tool Summary Page	http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=USBMULTILINKBDM
Analog Home Page	Home Page	http://www.freescale.com/analog
Automotive Home Page	Home Page	http://www.freescale.com/automotive

14.1   Support

Visit www.freescale.com/support for a list of phone numbers within your region.

14.2   Warranty

Visit www.freescale.com/warranty for a list of phone numbers within your region.

15 Revision History

Revision	Date	Description of Changes
1.0	4/2014	• Initial Release

Document Number: KTRD9Z1-638-12VUG
Rev. 1.0
4/2014