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S12ZVM EFP RDB Hardware User Guide

Contents

Chapter 1
RDB Introduction and Features

This user guide introduces hardware related information of PMSM fuel pump reference design of S12ZVM-EFP. It inlcudes the hardware block diagram, schematics, connectors, interface, BOM and etc. BLDC and PMSM have become popular in automotive industry. The application involving the fuel pump is one of the most popular application in the automotive industry. To accelerate customer development period in BLDC or PMSM fuel pump application, NXP has developed the S12ZVM-EFP RDB. S12ZVM-EFP is not only suitable for fuel pump application, but it can also be used in HVAC blower or other power range below 250W BLDC and PMSM application.

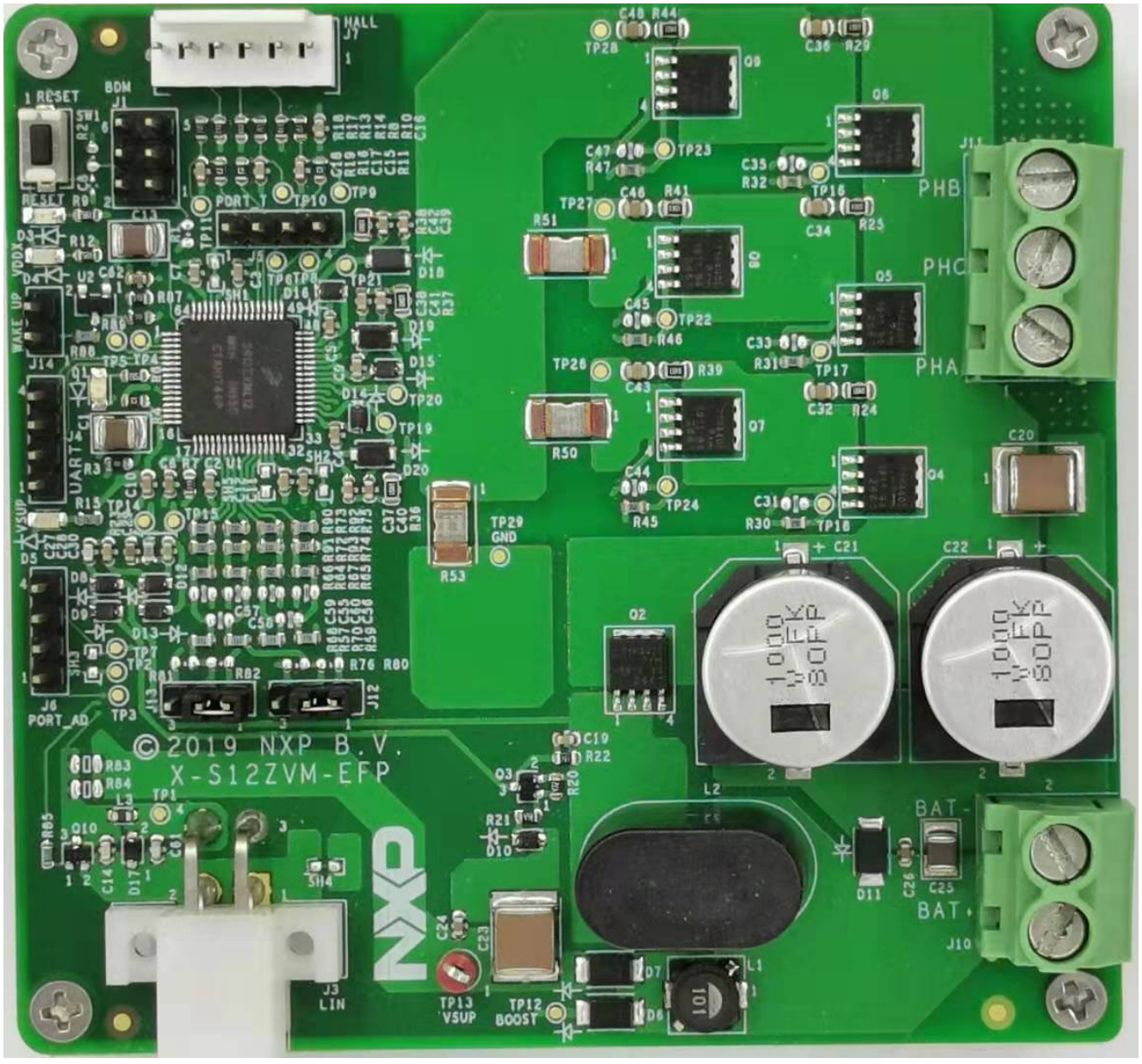


Figure 1. S12ZVM-EFP RDB

The RDB is based on NXP S12ZVM high-integrated (MCU, motor driver, power supply and other analog modules are integrated) automotive-grade MCU and provides the following features:

- Support 12 V power supply system with up to 250 W automotive BLDC/PMSM motor control system
- Implement two types of current sampling solutions:
  - Single shunt
  - Dual shunts
- Support multiple diagnose and protection covering UV, OV, OT, OC, Short, Stall Detection, etc
- Support speed/control commands from LIN/PWM

The following table provides a list and description of acronyms used throughout this document

Table 1. Acronyms and abbreviations

Abbreviation	Description
RDB	Reference Design Board
HW	Hardware
SW	Software
QSP	Quick Start Package
POR	Power-On Reset
BLDC	Brushless Direct Current
PMSM	Permanent-Magnet Synchronous Motor

Chapter 2
Hardware System Block Diagram

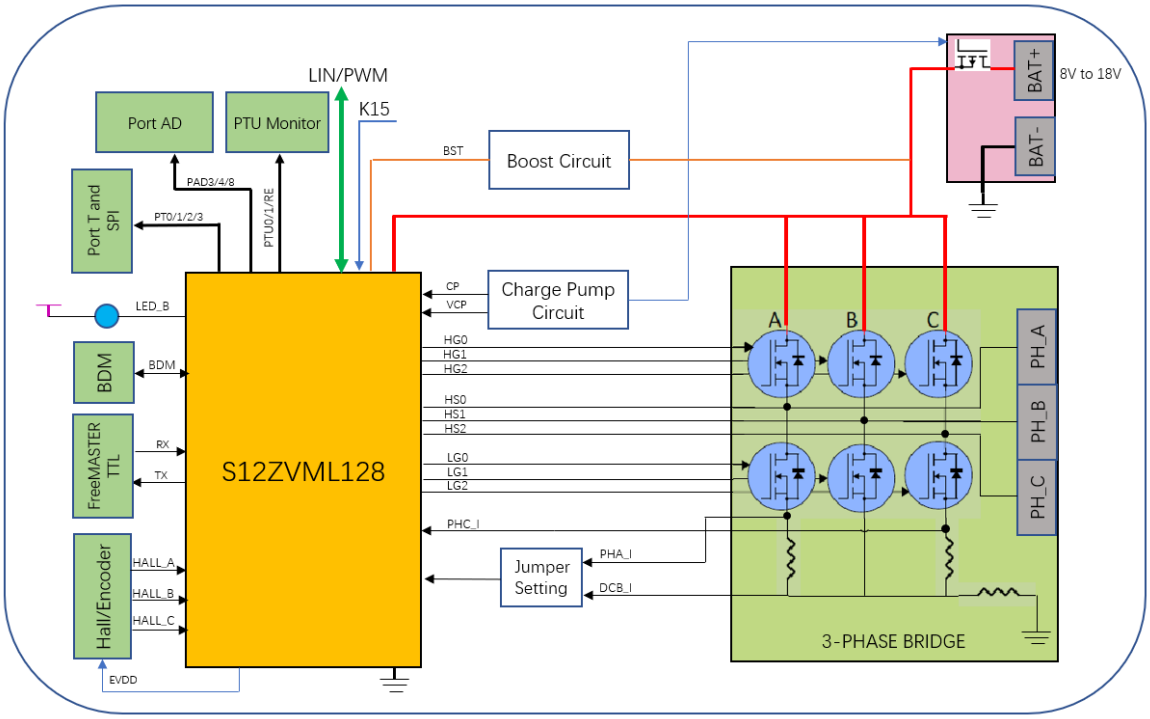
This RDB is designed to deliver a total solution for BLDC or PMSM fuel pump application in 12 V automotive system.

To achieve the function features the 8~16V VBAT input is firstly connected in an anti-reverse protection circuit and get output of VIN. The VIN then is connected to three phase inverter bridge and charge pump circuit. The charge pump circuit can pump the input voltage to a higher voltage and make sure the reverse circuit can work correctly. VIN is also connected to boost circuit and then to the VSUP PIN of S12ZVML128. If boost circuit is enabled, the input voltage can be down to 3.5 V. There are three shunts in three phase inverter bridge circuit, two shunts are in the phase A and phase C leg, one shunt is in the minus bus to GND. There are two jumper settings for single shunt and dual shunt switch, the default setting is dual shunt.

The RDB has Hall/Encoder interface for position sensor support. For debug purpose, not only BDM and FreeMASTER TTL (SCI) are placed, but also the PTU monitor (PTU0/1/RE) is placed. Meanwhile, some other PINs, like Port AD and T, one SPI which would be used are placed for reference.

The following is the RDB hardware system block diagram.

Figure 2. The RDB hardware system block diagram



The main devices used in the RDB are:

- S12ZVML128: High integrated automotive grade 16bit MCU using NVM+UHV technology. The chip integrated S12Z core based MCU, and 40 V analog components (VREG, GDU, LIN PHY), which make it suitable for single chip BLDC or PMSM control. Memory including 128K flash, 8K RAM, 512 B EEPROM all with ECC. The operating junction temperature can up to 175℃
- BUK7J1R4-40H: N-channel FET with LFPAK56 (Power-SO8) package

Chapter 3
RDB Sub Mdule Function Circuit Design Details

The RDB hardware sub-module function circuit design details are described in this chapter.

3.1 Power supply circuit

Power supply circuit includes two parts, one is “Power Input” and another is “Reverse Battery and Charge Pump”.

For “Power Input” portion, the details is shown in the following fgure. TVS D11 is used to power input protection. C25, C26 and L2 are used for three phase bridge input filter. L1 and D6 are used for BOOST components and D7 for S12ZVM supply VSUP protection and isolation.

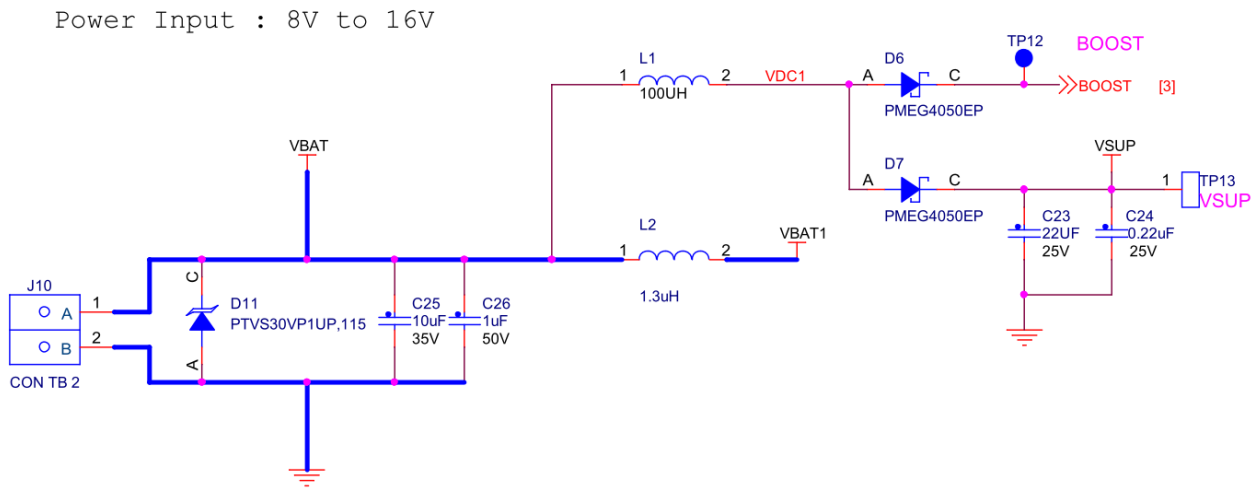


Figure 3. Power input circuit

For “Reverse Battery and Charge Pump” portion D12, D13, C28 and C29 are grouped as charge pump circuit which can make sure the upper MOSFET can remain turned ON 100% during duty cycle. The same time, charge pump can supply a positive gate-source voltage and turn the Q2 ON by using D8, D9, C27 and C19. R20, R21 and D10 are used to turn the Q2 OFF if the battery is reverse connected.

C21 and C22 are 1000 uF, 35 V AL Capacitors which used to stable the voltage in three phase inverter bridge circuit for high current application.

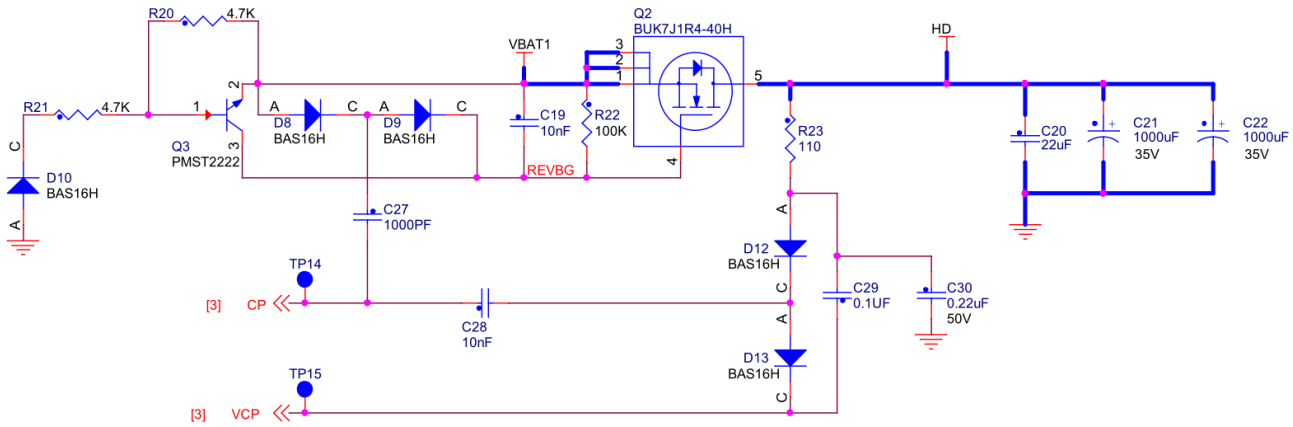


Figure 4. Reverse battery and charge pump circuit

3.2 MCU circuit

For S12ZVM MCU, refer to AN5207 , add a 0.22 uF bypass capacitor for each VDD, VDDF, two VDDX pin, and place these capacitors as close as possible to these pin, besides, a 10 uF bulk capacitor is used on the VDDX to keep its stable. For VDDA, a 0.22 uF and a 1 uF capacitor are added. Refer to the following figure.

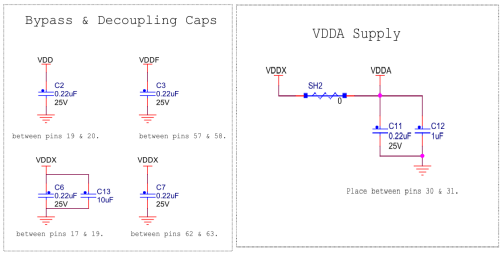


Figure 5. MCU power supply circuit one

For VSUP pin, a 22 uF(C23) and two 0.22 uF(C10 and C24) are used for VSUP decouple and bulk. Refer to the following figure.

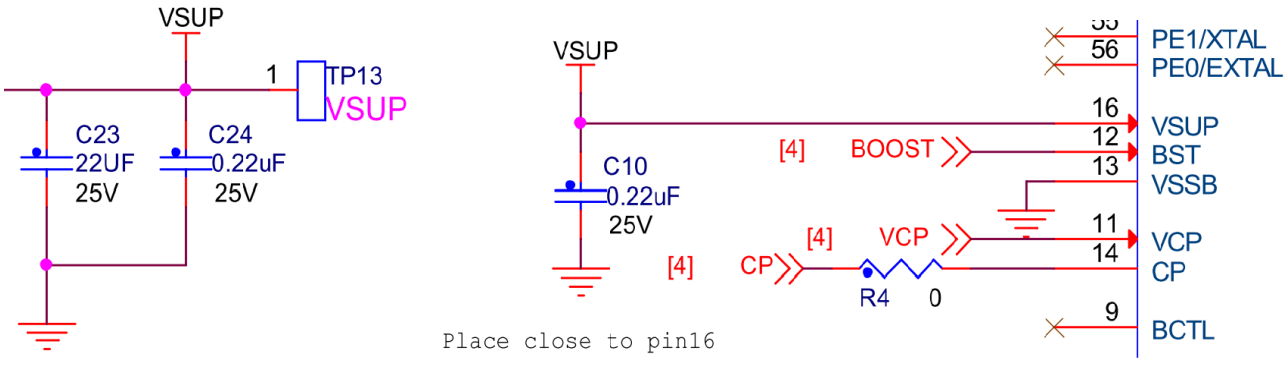


Figure 6. MCU power supply circuit two

EVDD is used for external supply, compared with VDDX, EVDD can be easily controlled (ON or OFF). EVDD has the function for current monitor, so recommend EVDD for external hall sensor supply. Refer to the following figure.

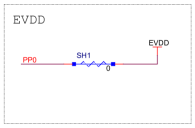


Figure 7. MCU power supply circuit three

S12ZVM MCU integrated S12Z based MCU, VREG, three phase motor driver, LIN PHY and some analog modules which simplify the system design for motor control, especially for three phase BLDC and PMSM control.

From S12ZVML128 pin 32 to pin 49, these pins are used for three phase inverter driver. Pins 21 to 29 are used for dual shunt or single shunt current sampling. Dual OPAMPs are integrated in GDU model which make S12ZVML128 very suitable for dual shunt PMSM application. Dual shunt application has less current distortion than single shunt. .

EP_PAD is the exposed pad in the bottom of chip which is used for heat dispassion. The EP_PAD should connect to GND to make sure the chip can work normally. Refer the following figure for more information.

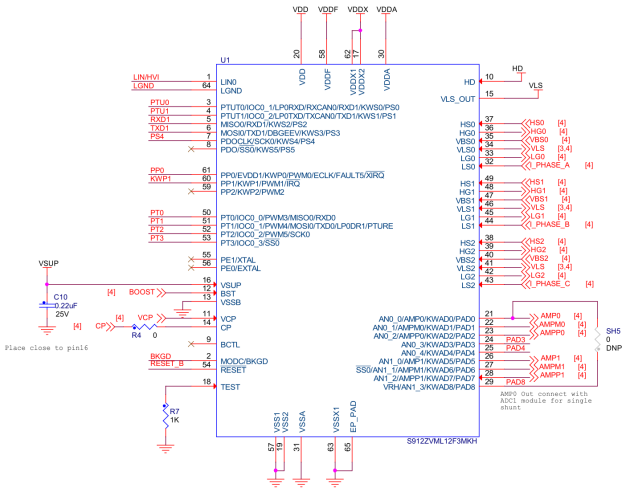


Figure 8. MCU function circuit one

Other portion of MCU interface are listed in the following figure.

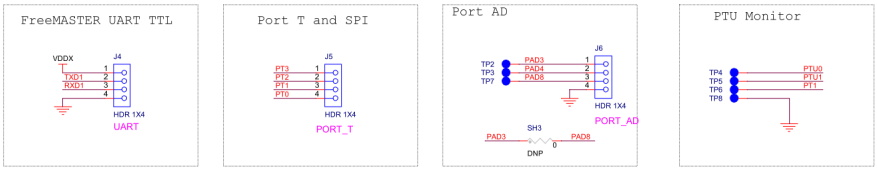


Figure 9. MCU function circuit two

For BDM interface and reset circuit is shown in the following figure.

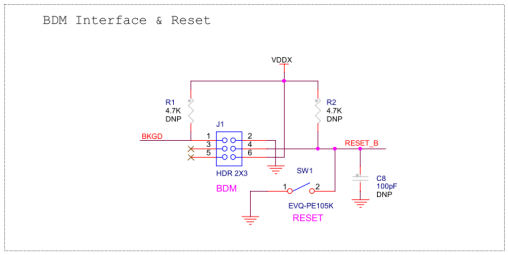


Figure 10. MCU BDM interface and RESET circuit

There are four LEDs indicators. D5 for VSUP indicator, D4 for VDDX indicator, D3 for reset indicator and D1 for user application. Following figure shows more information.

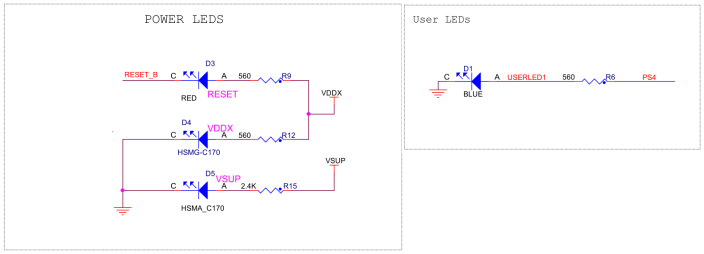


Figure 11. LEDs for power indicator and user

3.3 Three phase bridge and signal condition circuit

Six N-channel MOSFET (BUK7J1R4-40E) are used to construct three half-bridge power stage for three phase motor control.

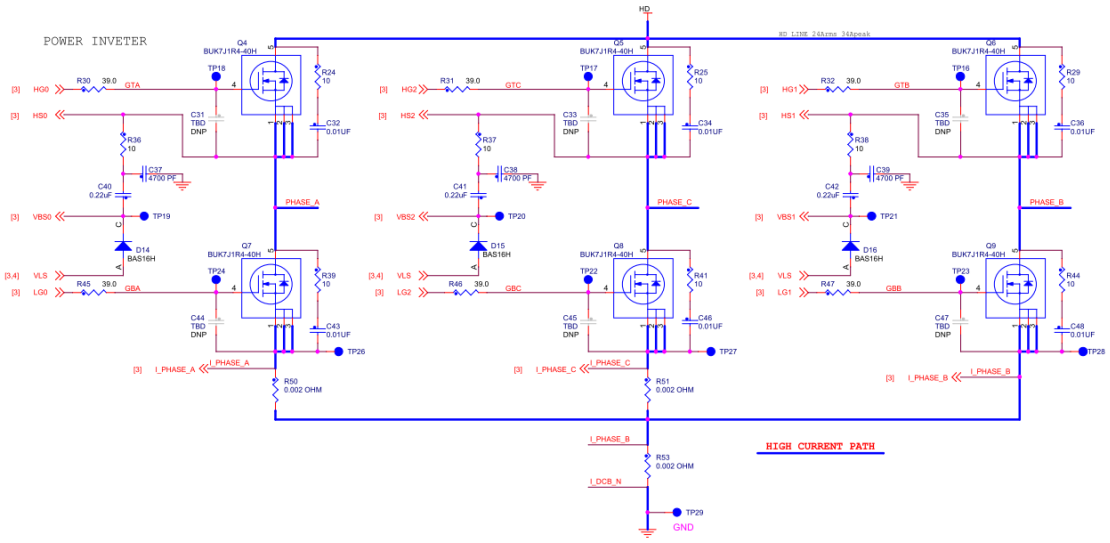


Figure 12. Power stage circuit

Two 2m shunt resistors(R50 and R51) are used for phase current sample by using dual shunt method. One 2mΩshunt resistor R53 IS used for single shunt current sampling.

The voltage signal of the shunt is very small, so there is no need to amplify these small signals. It is due to the internal integrated two OPAMPs, S12ZVML128 is suitable for both dual shunt and single shunt FOC.

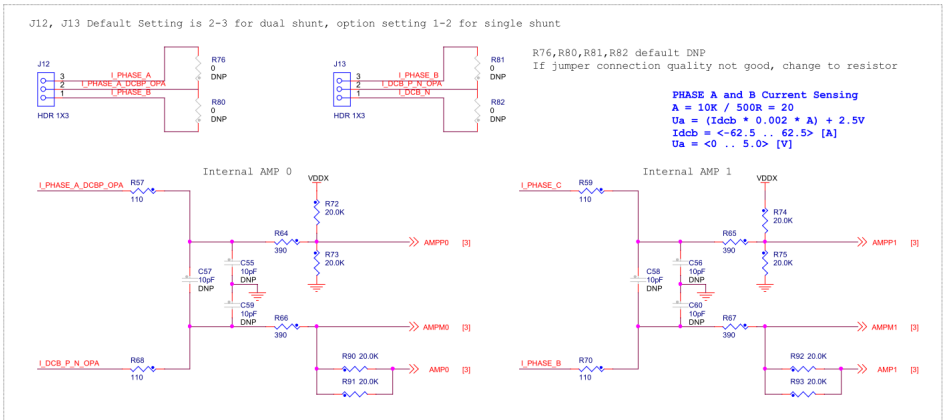


Figure 13. Phase current signal condition circuit

The signal condition circuit has two jumper settings. The default one is for dual shunt and another one is for single shunt. For more information refer to the above figure.

3.4 LIN/HVI PHY communication circuit

LIN PHY is integrated in S12ZVML128. The motor ECU is used as LIN slave, so the pull up resistances are not positioned. If you use the HVI PHY function then you can input the PWM (voltage as high as VBAT) to the MCU's HVI pin by an inductance or direct. For the PWM controlled ECU, the system needs to diagnose the signal output though the PWM line. One PWM line achieves both the function, it receives the PWM input and feedback the output. The feedback uses the PT0 to control the Q10 and Pull the PWM line to low, the PWM sender samples the level of PWM line and release the control to S12ZVML128.

The following figure shows the circuit of LIN/HVI PHY.

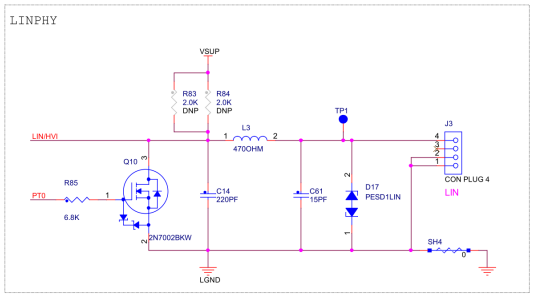


Figure 14. LIN/HVI PHY circuit

Chapter 4
Connector/Interface Overview

The RDB connector function and pin allocation are described in this chapter.

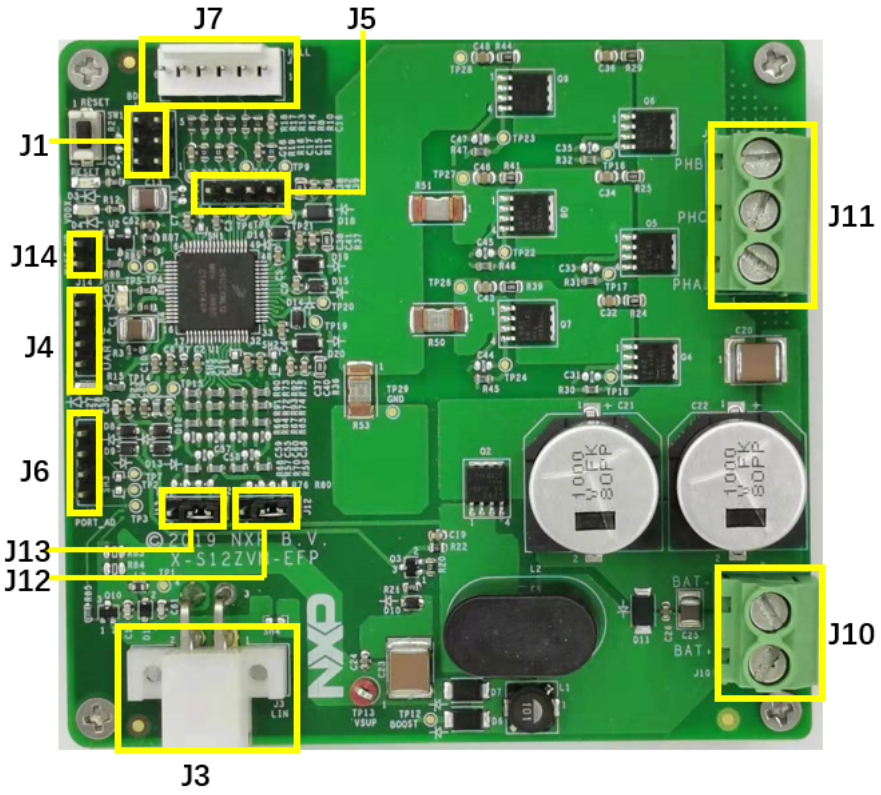


Figure 15. The connector distribution on the RDB

Power input connector, the RDB is designed for 12 V system, so the recommend VBAT input voltage range is 8 V DC to 16 V DC.

Connector	pin	function
J10	J10-1	VBAT+
	J10-2	VBAT-

3-phase motor connector.

Connector	pin	function
J11	J11-1	PHA
	J11-2	PHC
	J11-3	PHB

Debug interface connector, the RDB debugger BDM port is routed to J1.

Connector	pin	function
J1	J1-1	BKGD
	J1-2	GND
	J1-3	NC
	J1-4	RESET_B
	J1-5	NC
	J1-6	VDDX

Hall sensor connector.

Connector	pin	function
J7	J7-1	EVDD
	J7-2	GND
	J7-3	HALL_A
	J7-4	HALL_B
	J7-5	HALL_C
	J7-6	NC

FreeMASTER UART TTL communication connector.

Connector	pin	function
J4	J4-1	VDDX
	J4-2	TXD1
	J4-3	RXD1
	J4-4	GND

LIN communication connector.

Connector	pin	function
J3	J3-1	GND

Table continues on the next page...

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Connector	pin	function
	J3-2	GND
	J3-3	NC
	J3-4	LIN

K15 Line interface.

Connector	pin	function
J14	J14-1	K15 line
	J14-2	GND

Port AD interface for extended use.

Connector	pin	function
J6	J6-1	PAD3
	J6-2	PAD4
	J6-3	PAD8
	J6-4	GND

Port T and SPI interface for extended use.

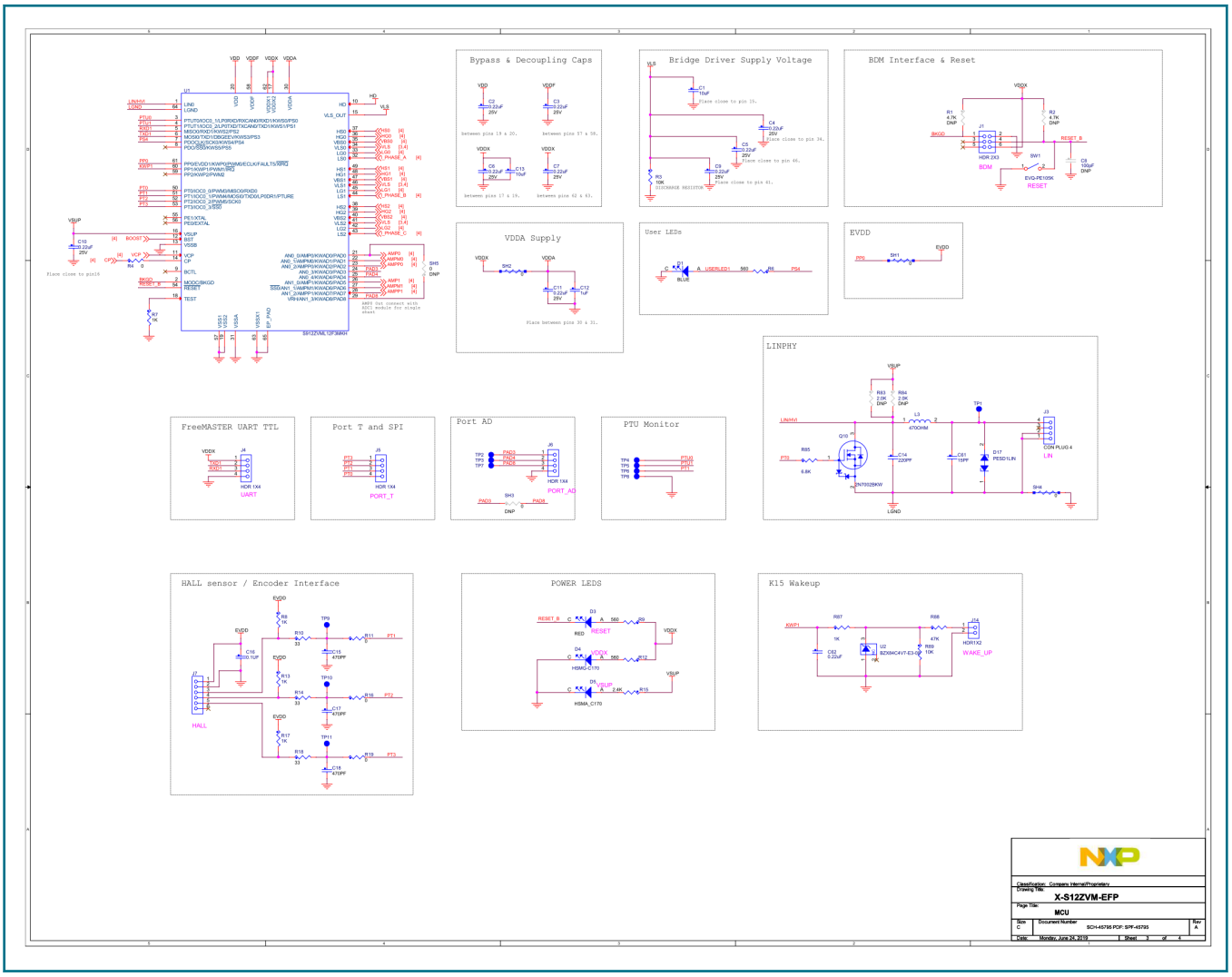
Connector	pin	function
J5	J5-1	PT3/SS0
	J5-2	PT2/SCK0
	J5-3	PT1/MOSI0
	J5-4	PT0/MISO0

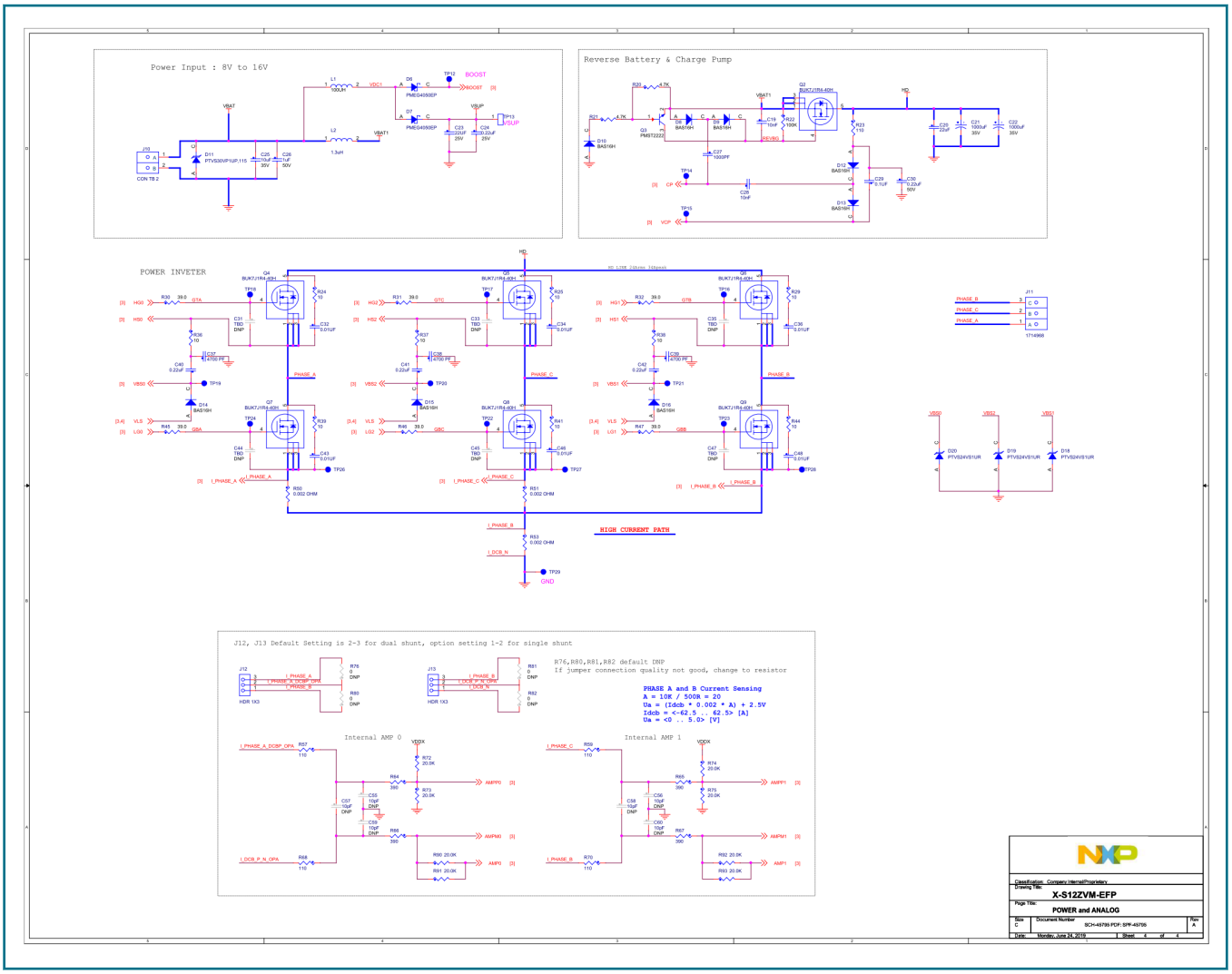
Dual shunt and single shunt selection jumper setting.

Function	Connector	pin
Dual shunt setting (Default Setting)	J12	Position J12-2 and J12-3
	J13	Position J13-2 and J13-3
Single shunt setting	J12	Position J12-1 and J12-2
	J13	Position J13-1 and J13-2

Chapter 5
Schematic and PCB Gerber File

The complete schematic and PCB gerber files of the RDB are included in the QSP, you can download it from swww.nxp.com.




Power Input : 8V to 16V
Reverse Battery & Charge Pump
POWER INVETER
HIGH CURRENT PATH
J12, J13 Default Setting is 2-3 for dual shunt, option setting 1-2 for single shunt
R76,R80,R81,R82 default DNP
If jumper connection quality not good, change to resistor
PHASE A and B Current Sensing
A = 10K / 500R = 20
Ua = (Idcb * 0.002 * A) + 2.5V
Idcb = <-62.5 .. 62.5> [A]
Ua = <0 .. 5.0> [V]
Internal AMP 0
Internal AMP 1
X-S12ZVM-EFP
POWER and ANALOG

Chapter 6
BOM list

The followin table provides the list if BOM for RDB.

Table 2. S12ZVM-EFP board BOM

Part reference	Quantity	Value	DESCRIPTION	Manufacturer
C1,C13,C25	3	10uF	CAP CER 10uF 35V 10% X7R 1210	MURATA
C2-C7,C9-C11,C24,C40-C42	13	0.22uF	CAP CER 0.22uF 25V 10% X7R 0603	KEMET
C8	1	100pF	CAP CER 100pF 50V 5% C0G AEC-Q200 0402	MURATA
C12,C26	2	1uF	CAP CER 1uF 50V 10% X5R AEC-Q200 0603	TDK
C14	1	220PF	CAP CER 220PF 50V 5% C0G 0603	AVX
C15,C17,C18	3	470PF	CAP CER 470PF 50V 10% X7R 0603	AVX
C16,C29	2	0.1UF	CAP CER 0.1UF 50V 10% X7R 0603	AVX
C19,C28	2	10nF	CAP CER 0.01UF 50V 5% X7R 0603	AVX
C20	1	22uF	CAP CER 22uF 50V X7S 20% 2220	TDK
C21,C22	2	1000uF	CAP ALEL 1000uF 35V 20% --- AEC-Q200 SMT	NIPPON CHEMI-CON CORPORATION
C23	1	22UF	CAP CER 22.0UF 25V 20% X7R 2220	TDK
C27	1	1000PF	CAP CER 1000PF 50V 5% C0G 0603	MURATA
C30,C62	2	0.22uF	CAP CER 0.22uF 50V 10% X7R AEC-Q200 0603	Murata
C31,C33,C35,C44,C45,C47	6	TBD	0603 Place holder -Layout element only - NO PART TO ORDER	N.A
C32,C34,C36,C43,C46,C48	6	0.01UF	CAP CER 0.01UF 100V 5% X7R 0805	KEMET
C37-C39	3	4700 PF	CAP CER 4700PF 50V 5% X7R 0603	AVX
C55-C60	6	10pF	CAP CER 10PF 50V 10% X7R 0603	AVX
C61	1	15PF	CAP CER 15PF 50V 5% C0G 0603	YAGEO AMERICA

Table continues on the next page...

Table 2. S12ZVM-EFP board BOM (continued)

Part reference	Quantity	Value	DESCRIPTION	Manufacturer
D1	1	BLUE	LED BLUE SGL 20MA SMT 0805	LITE ON
D3	1	RED	LED RED SGL 25MA 0805	DIALIGHT
D4	1	HSMG-C170	LED GREEN SGL 2.2V 20MA 0805	AVAGO TECHNOLOGIES
D5	1	HSMA_C170	LED AMBER SGL 25MA SMT	AVAGO TECHNOLOGIES
D6,D7	2	PMEG4050EP	DIODE SCH RECT 5A 40V AEC-Q101 SOD128	NEXPERIA
D8-D10,D12-D16	8	BAS16H	DIODE SW 200MA 75V SOD323	On Semiconductor
D11	1	PTVS30VP1UP,115	DIODE TVS 600W AEC-Q101 SOD-128	NEXPERIA
D17	1	PESD1LIN	DIODE ESD PROTECTION 23KV AEC-Q101 SOD323	NEXPERIA
D18-D20	3	PTVS24VS1UR	DIODE TVS 400W 24V AEC-Q101 SOD123W	NEXPERIA
J1	1	HDR 2X3	HDR 2X3 TH 100MIL CTR 344H AU 118L	WURTH ELEKTRONIK
J3	1	CON PLUG 4	CON 2X2 PLUG SHRD RA TH 4.2MM CTR 394H AU 138L	Molex
J4-J6	3	HDR 1X4	HDR 1X4 TH 2.54MM SP 344H AU 118L	WURTH ELEKTRONIK
J7	1	HEADER 1X6	HDR 1X6 TH 100MIL SP 460H SN	MOLEX
J10	1	CON TB 2	CON 1X2 TB TH 6.35MM SP 846H SN 201L	PHOENIX CONTACT
J11	1	1714968	CON 1X3 TB TH 6.35MM SP 847H -- 201L	PHOENIX CONTACT
J12,J13	2	HDR 1X3	HDR 1X3 TH 2.54MM SP 344H AU 118L	WURTH ELEKTRONIK
J14	1	HDR1X2	HDR 1X2 TH 100MIL SP 342H AU 118L	WURTH ELEKTRONIK
L1	1	100UH	IND PWR 100UH@100KHZ 420MA 20% SMT	TDK

Table continues on the next page...

Table 2. S12ZVM-EFP board BOM (continued)

Part reference	Quantity	Value	DESCRIPTION	Manufacturer
L2	1	1.3uH	IND CHK 1.3uH@20kHz 30A -- TH	NIPPON CHEMI-CON CORPORATION
L3	1	470OHM	IND FER BEAD 470OHM@100MHZ 500MA 25% 0603	MURATA
Q2,Q4-Q9	7	BUK7J1R4-40H	TRAN NMOS 40V 120A AEC-Q101 LFPAK56	NEXPERIA
Q3	1	PMST2222	TRAN BJT NPN PWR 600MA 40V AEC-Q101 SOT-323	NEXPERIA
Q10	1	2N7002BKW	TRAN NMOS 310mA 60V AEC-Q101 SOT323	NEXPERIA
R1,R2,R20,R21	4	4.7K	RES MF 4.7K 1/10W 5% 0603	VISHAY INTERTECHNOLOGY
R3,R89	2	10K	RES MF 10K 1/10W 1% AEC-Q200 0603	VISHAY INTERTECHNOLOGY
R4,R11,R16,R19,R76,R80-R82,SH3,SH5	10	0	RES MF ZERO OHM 1/10W -- AEC-Q200 0603	PANASONIC
R6,R9,R12	3	560	RES MF 560 1/10W 5% 0603	YAGEO AMERICA
R7,R8,R13,R17,R87	5	1K	RES MF 1K 1/10W 1% AEC-Q200 0603	YAGEO
R10,R14,R18	3	33	RES MF 33 OHM 1/10W 5% AEC-Q200 0603	VISHAY INTERTECHNOLOGY
R15	1	2.4K	RES MF 2.40K 1/10W 1% AEC-Q200 0603	KOA SPEER
R22	1	100K	RES MF 100K 1/10W 5% 0603	BOURNS
R23,R57,R59,R68,R70	5	110	RES MF 110 OHM 1/8W 1% AEC-Q200 0603	KOA SPEER
R24,R25,R29,R36-R39,R41,R44	9	10	RES MF 10.0 OHM 1/8W 1% 0805	BOURNS
R30-R32,R45-R47	6	39.0	RES MF 39.0 OHM 1/10W 1% 0603	WALSIN TECHNOLOGY CORP.

Table continues on the next page...

Table 2. S12ZVM-EFP board BOM (continued)

Part reference	Quantity	Value	DESCRIPTION	Manufacturer
R50,R51,R53	3	0.002 OHM	RES PWR 0.002 OHM 5W 1% AEC-Q200 2512	ISABELLENH¨¨TTE HEUSLER GMBH & CO. KG
R64-R67	4	390	RES MF 390 OHM 1/8W 1% AEC-Q200 0603	KOA SPEER
R72-R75,R90-R93	8	20.0K	RES MF 20.0K 1/10W 1% AEC-Q200 0603	KOA SPEER
R83,R84	2	2.0K	RES MF 2.0K 1/8W 5% 0805	PANASONIC
R85	1	6.8K	RES MF 6.8K 1/8W 0.1% AEC-Q200 0603	VISHAY INTERTECHNOLOGY
R88	1	47K	RES MF 47K 1/10W 1% AEC-Q200 0603	VISHAY INTERTECHNOLOGY
SH1,SH2,SH4	3	0	ZERO OHM CUT TRACE 0603 PADS; NO PART TO ORDER	LAYOUT ELEMENT ONLY
SW1	1	EVQ-PE105K	SW SPST NO 0.05A 12V SMD	PANASONIC
TP1-TP12,TP14-TP24,TP26-TP29	27	TPAD_040	TEST POINT PAD 40MIL DIA SMT, NO PART TO ORDER	NOTACOMPONENT
TP13	1	TEST_POINT	TEST POINT RED 70X220 MIL TH	KEYSTONE ELECTRONICS
U1	1	S912ZVML12F3MKH	IC SoC (MCU + LIN + GDU) 16-BIT S12Z 128K FLASH 6K RAM LQFP64	NXP SEMICONDUCTORS
U2	1	BZX84C4V7-E3-08	DIODE ZNR 4.7V 300mW 5% SOT23	VISHAY INTERTECHNOLOGY

Chapter 7
Appendix A. Reference

1.AN5207, Hardware Design Guidelines for S12ZVM Microcontrollers (REV 2)

2. MC9S12ZVM Family - Reference Manual and Datasheet (REV 2.13)

How To Reach Us

Home Page:

nxp.com

Web Support:

nxp.com/support

For more information, please visit: http://www.nxp.com

For sales office addresses, please send an email to: salesaddresses@nxp.com

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