
**Supply voltage configuration of 3-phase BLDC automotive
MOSFET driver L9907**

Introduction

Aim of this application note is to provide criteria for proper configuration of the supply voltage and correct driving of L9907 in 12 V, 24 V and 48 V applications. All the solutions have been evaluated using the EVAL-L9907 available on www.ST.com (see [Appendix A: References documents](#)).

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1 Purpose and benefits

L9907 is a smart power device realized in STMicroelectronics® advanced BCD-6s technology. It is able to drive majority of power MOSFETs transistors for 3-phase BLDC motor applications. The circuit is suitable to operate in environments with high supply voltage such as double battery. Supply related pins are capable of withstanding up to 90 V.

Voltage present at VB and VCC pins is monitored in order to inhibit driver and/or boost functionality in case of under/over voltage detection. Level of monitored voltage present at VB pin can be adjusted by setting of VBov2 and VBov1 (B3-B2) bits in CMD1 register to select over voltage threshold for single or double battery application. The specific levels are visible in [Table 1](#).

Table 1. VB over voltage thresholds for single or double battery applications

VBov	B3=VBov2	B2=VBov1
27.5 – 34.5 V	1	0
36-42 V (default settings)	0	1
N.A.	0	0
N.A.	1	1

The purpose of the internal boost converter in L9907 driver is to generate a voltage around 10 V higher than the one present at VDH monitor pin. This voltage is used to supply HS drivers (through dedicated regulators) and LS drivers (through VCAP regulator).

The regulated voltage is present at BST_C pin. A fixed voltage threshold on BST_C is implemented, in order to avoid the boost voltage exceeding a safety level in case of high voltage on VDH monitor pin. In case the overvoltage protection is not needed (e.g. for applications where high voltage is present on the VDH rail), L9907 provides a disabling bit in CMD3 register by SPI command (DIS_BSTov).

The aim of this paper is to provide criteria for proper configuration of the supply voltage and correct driving of L9907 in 12 V, 24 V and 48 V applications. All the solutions have been evaluated using the EVAL-L9907 available on www.ST.com (see [Appendix A: References documents](#)).

2 Description of L9907 supply voltage configuration for 12 V and 24 V applications

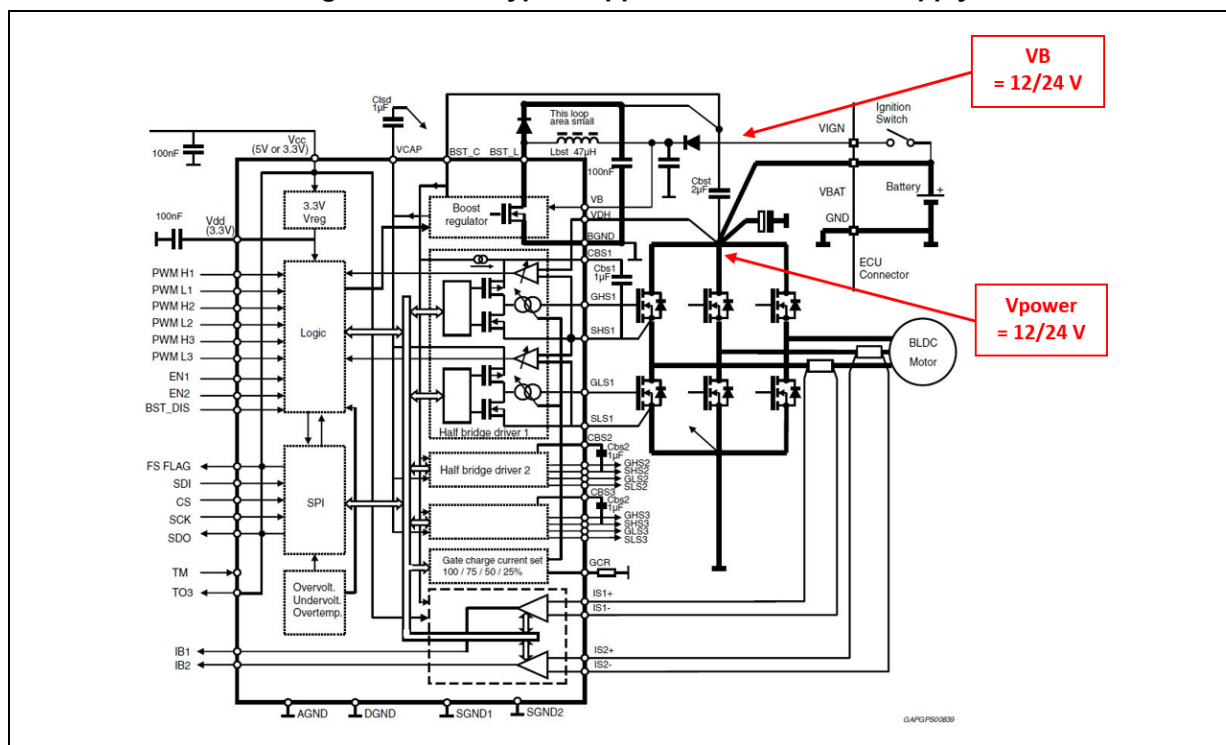
The level of monitored voltage present at VB pin can be adjusted by setting VBoV2 and VBoV1 (B3-B2) bits in CMD1 register to select over voltage threshold for single battery 12 V or double battery 24 V application.

From purpose of L9907 voltage supply definition is:

- VB – Supply voltage for the L9907 over VB pin
- VPOWER – Supply voltage for power inverter consist from 3-ph half bridge (B6 configuration)

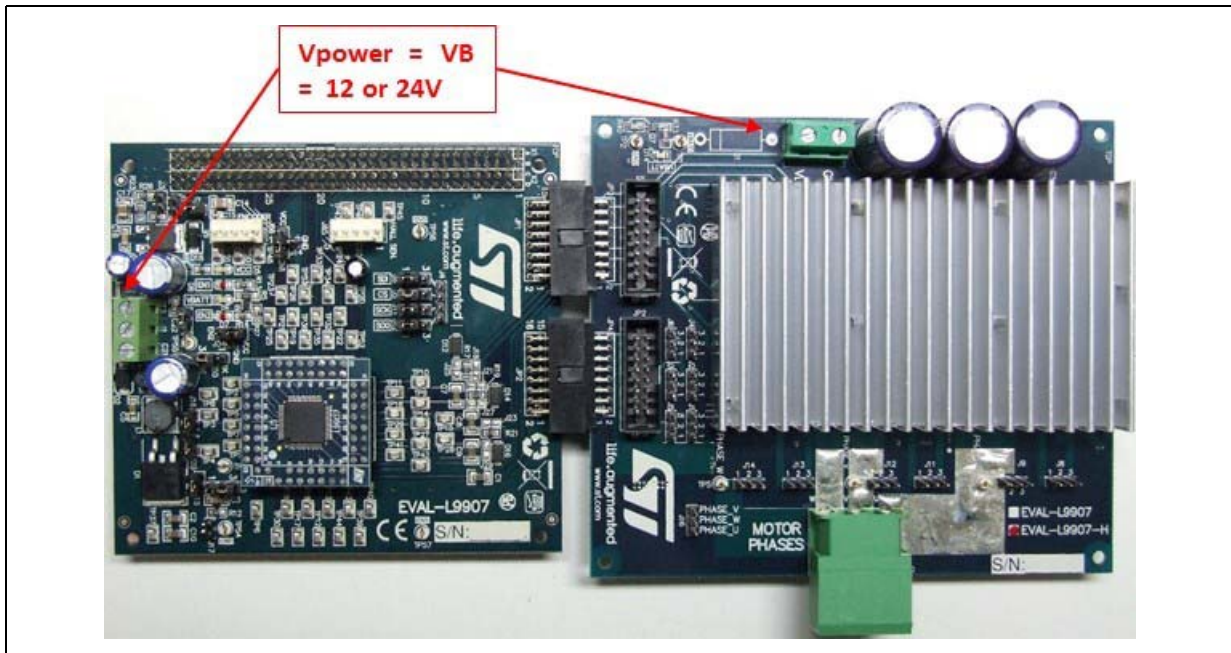
A typical application circuit of L9907 with supply voltage definition is shown in [Figure 1](#).

Figure 1. L9907 typical application circuit with supply definition



Above guidelines need to be applied on EVAL-L9907 and EVAL-L9907-H accordingly
[Figure 2](#).

Figure 2. EVAL-L9907/L9907-H supply with 12 V or 24 V supply

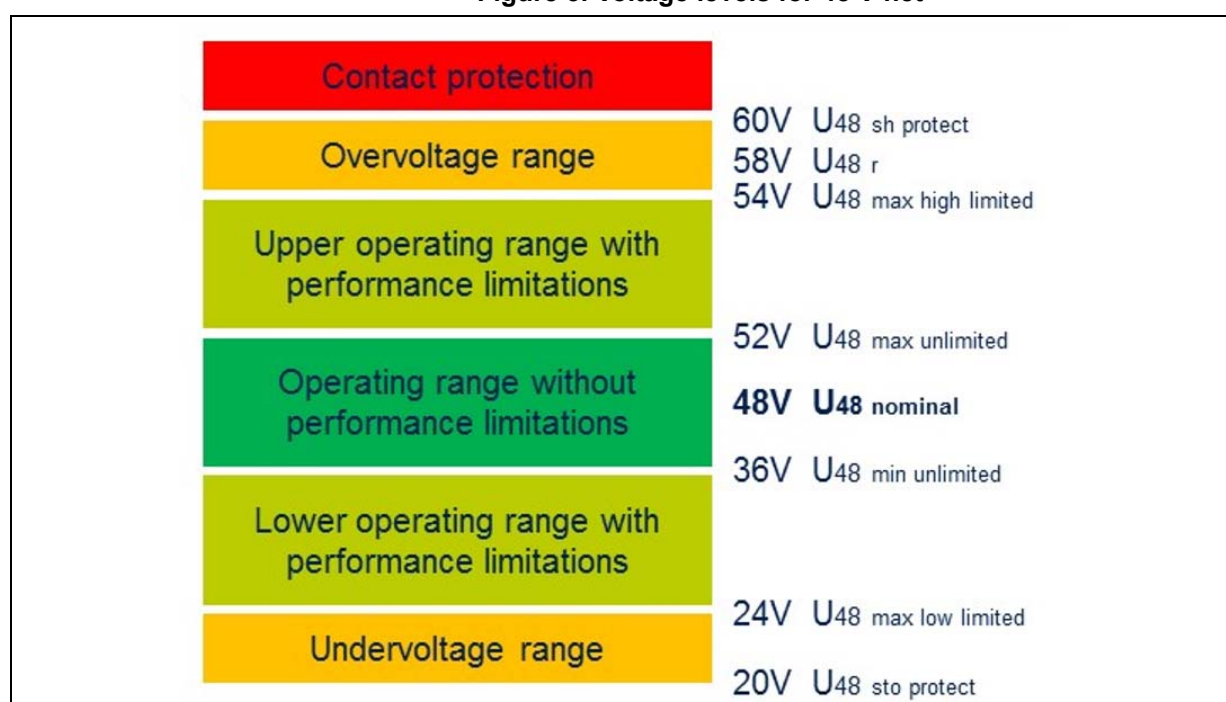


Note: For more details please refer to the EVAL-L9907 / L9907-H hardware manual available on www.st.com (see [Appendix A: References documents](#)).

3 Description of L9907 supply voltage configuration for 48 V applications

The VDA Recommendation 320 published document defines requirements, test conditions and tests performed on electric, electronic and mechatronic components and systems for motor vehicles application with a 48 V on-board power supply. It was defined in the VDA's project group "48-Volt power Supply". According to this recommendation a set of voltages for a 48 V net has been defined (see [Figure 3](#)).

Figure 3. Voltage levels for 48 V net



Though L9907 automotive 3 phase BLDC driver is well suitable for any application supplied from 48 V net the designed overvoltage levels are suitable only for single or double battery voltage levels. The OV threshold of the L9907 have default value with typical level of 36 V, if 48 V is applied to VB pin of the L9907 it returns an OV error at start (B11)='1' in DIAG register and the FS_FLAG pin will be low.

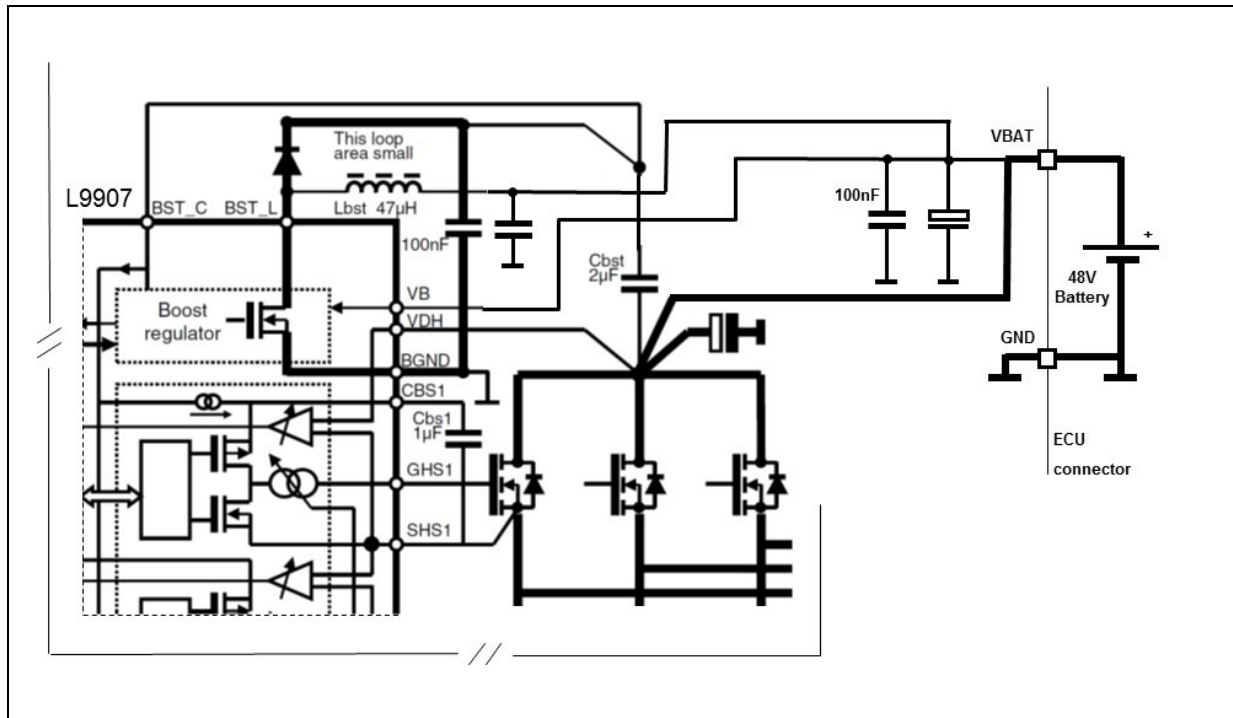
There are mainly three solutions that can be applied to solve this problem.

1. Direct supply of VB pin from 48 V and disable all diagnostic related to the OV.

In this case the overvoltage protection VBov (B9) has to be disabled setting '0' in CMD1 register. Furthermore the overvoltage protection settled in BST_C pin need to be disabled (this bit defaults is set to '0'). This will be done setting bit DIS_BSTov (B12) in CMD3 register to '1'. This bit is accessible for writing only if AND(EN1,EN2) = '0'. Trying to write it without lowering AND(EN1,EN2) will not generate any SPI error but command will be simply ignored for the specific bit. Once set to '1', CMD3 B12 disables the over voltage protection on the boost regulator BST_C pin. However, this solution does not allow to use the FS_FLAG pin (which would always be low) to trigger the microcontroller in case of error. This is due to the fact that even if the VBov (B9) has been set to '0', only the fault effect is

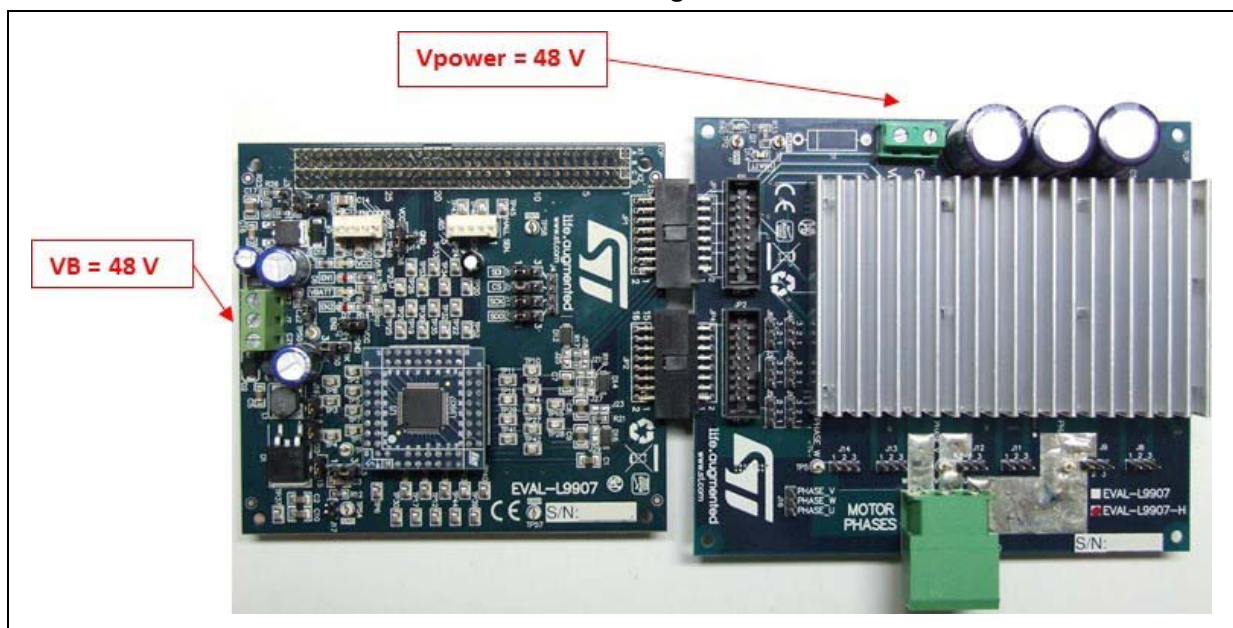
disabled, but the fault is anyway latched in the SPI register DIAG. A continuous polling must be done to query the device in order to verify if errors are present.

Figure 4. L9907 supply with 48 V net with disable overvoltage diagnostic



Above guidelines need to be applied on EVAL-L9907 and EVAL-L9907-H accordingly [Figure 5](#).

Figure 5. EVAL-L9907/L9907-H supply with 48 V net with disable overvoltage diagnostic



Since in LM217 the V_{in} - V_{out} absolute maximum ratings is 40 V is preferable to get the $V_{cc} = 5 / 3.3$ V from the microcontroller adopting the following jumper setup:

- Jumper J7 = OFF
- Jumper J1 = ON

Note: For more details please refer to the EVAL-L9907 / L9907-H hardware manual available on www.st.com (see [Appendix A: References documents](#)).

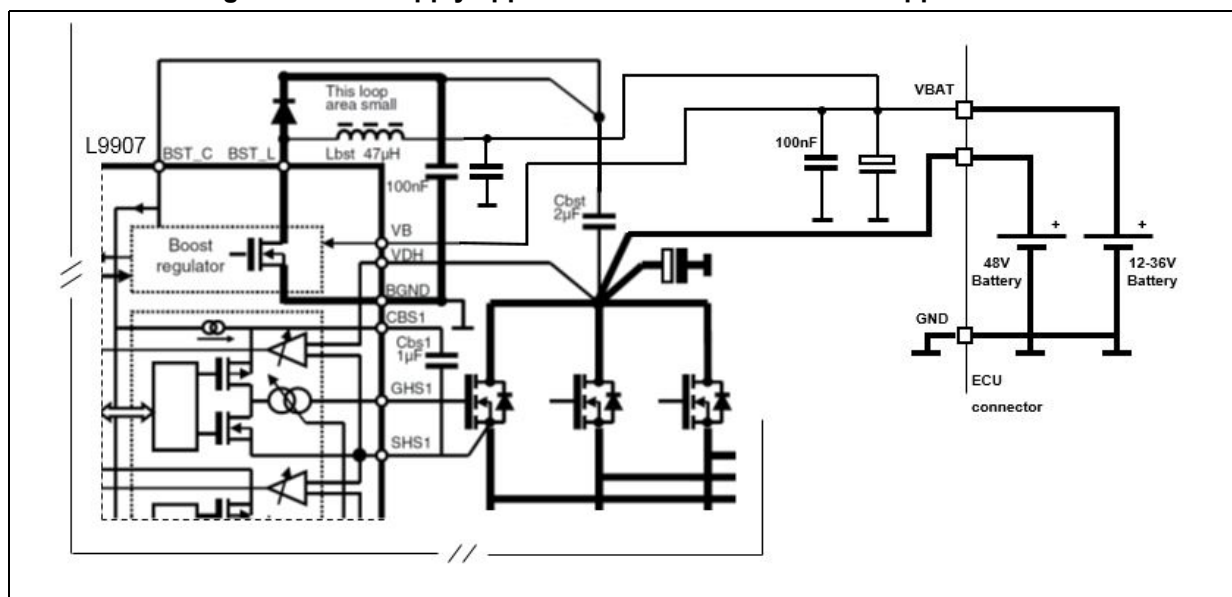
2. Dual supply mode - apply 12-36 V supply line to VB pin and 48 V to power stage.

In this case only boost overvoltage Vboost-ov protection have to be disabled. This will be done with set bit DIS_BSTov (B12) in CMD3 register to '1'. With this solution, the FS_FLAG pin will not be set low at start and can be used in order to trigger the microcontroller in case of error.

This solution could be implemented in two ways with respect to supply of internal boost converter:

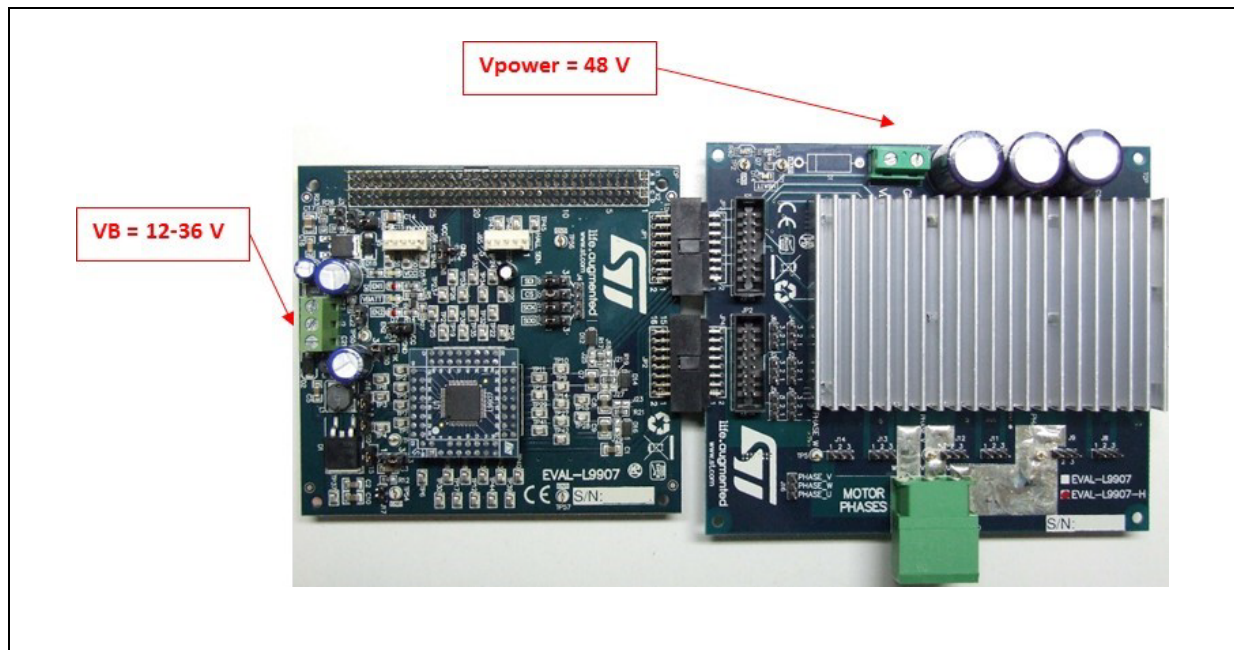
- a) Boost converter supplied from 12-36 V bus.
With this approach the input of boost converter is tied to a 12-36 V net according [Figure 6](#).

Figure 6. Dual supply approach with boost converter supplied from 12-36 V net



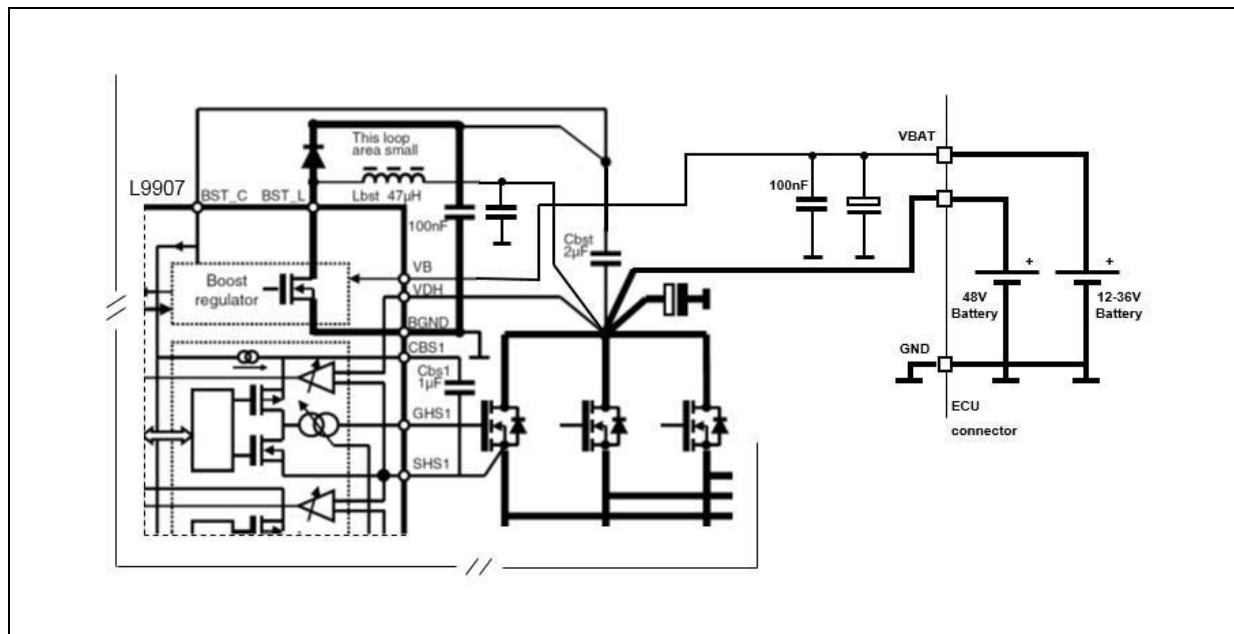
These guidelines need to be applied on EVAL-L9907 and EVAL-L9907-H accordingly [Figure 7](#).

Figure 7. EVAL-L9907/L9907-H with dual supply with boost supply from 12-36 V net



- b) Boost converter supplied from 48 V bus.
With that approach the input of boost converter is tied to a dedicated 48 V battery supply net. Advantage of this solution compared with the previous one (A) is that boost converter operates in a more efficient way with lower duty cycle. This connection is described in [Figure 8](#).

Figure 8. Dual supply approach with boost converter supplied from 48 V net

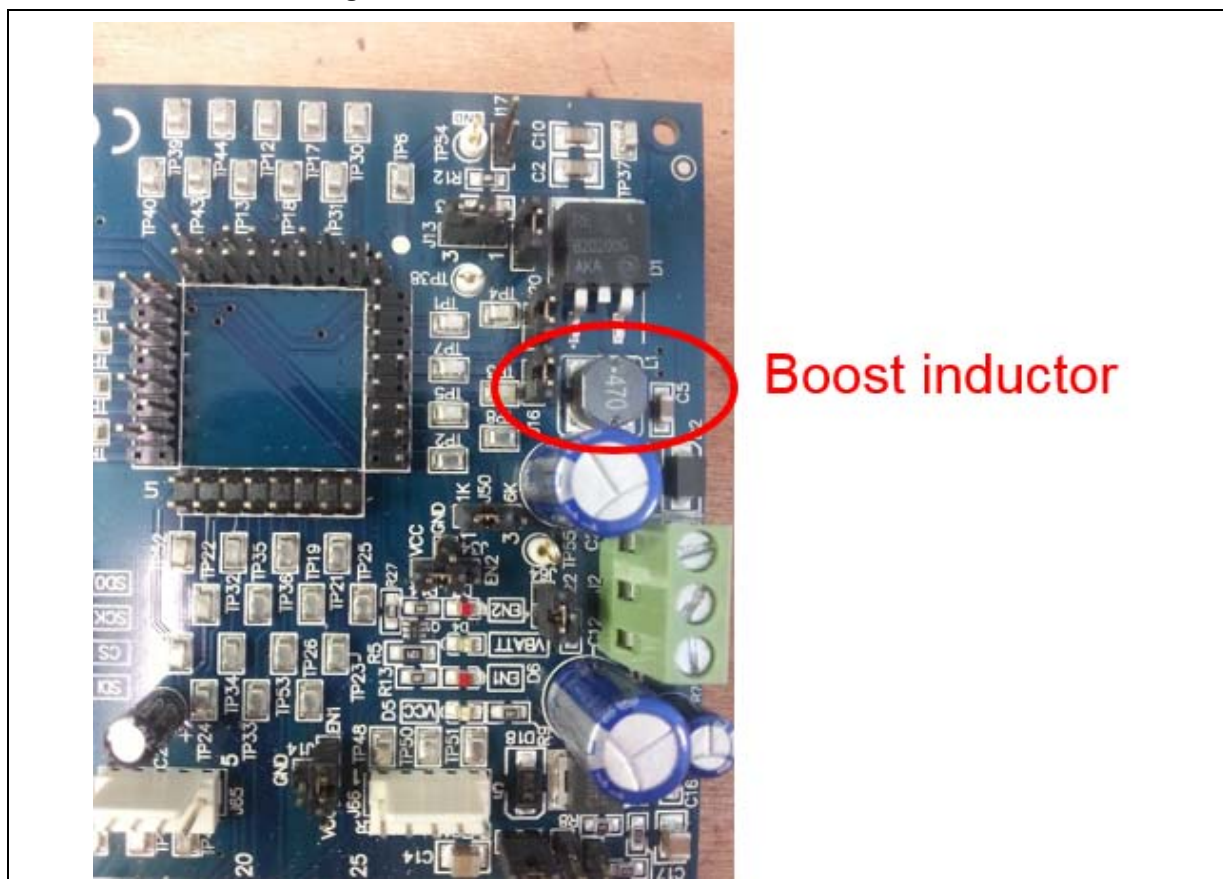


To implement this solution in 48 V applications, some hardware modifications are required on the EVAL-L9907 /L9907-H.

Below the steps to be followed are shown:

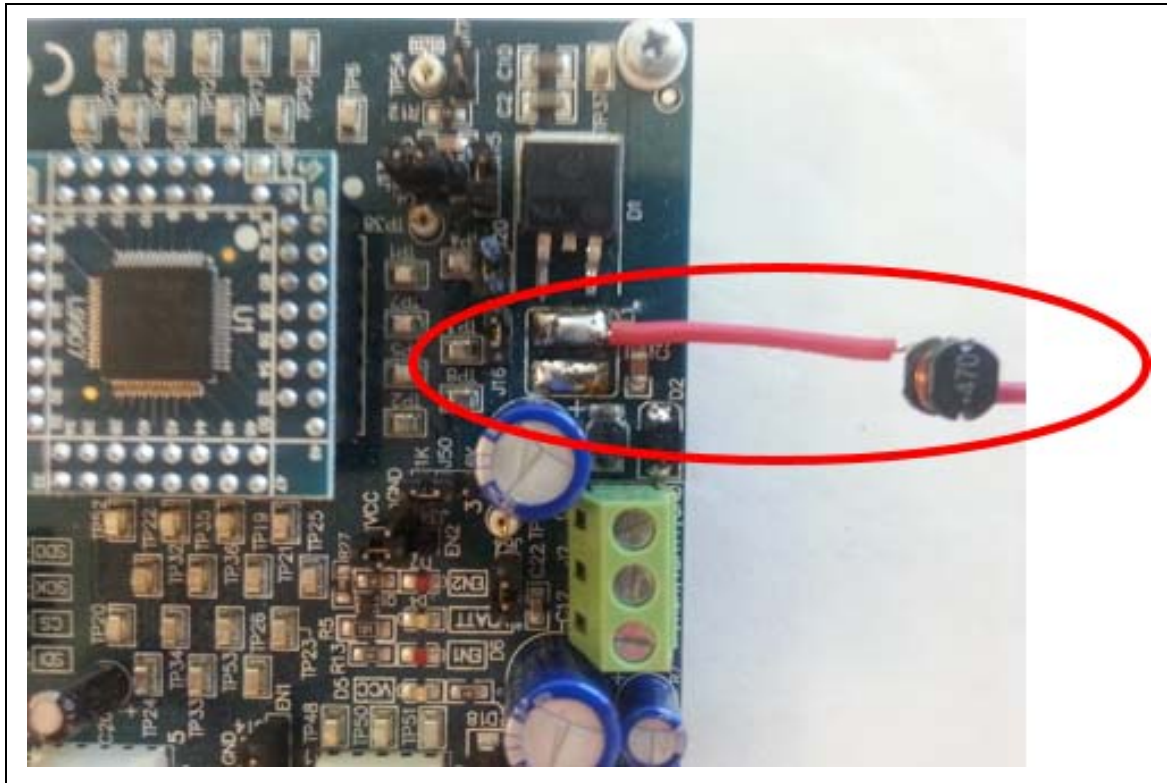
- Remove the boost inductor L1 47 μ H from the board (see [Figure 9](#)).

Figure 9. Remove boost inductor from EVAL-L9907/L9907-H



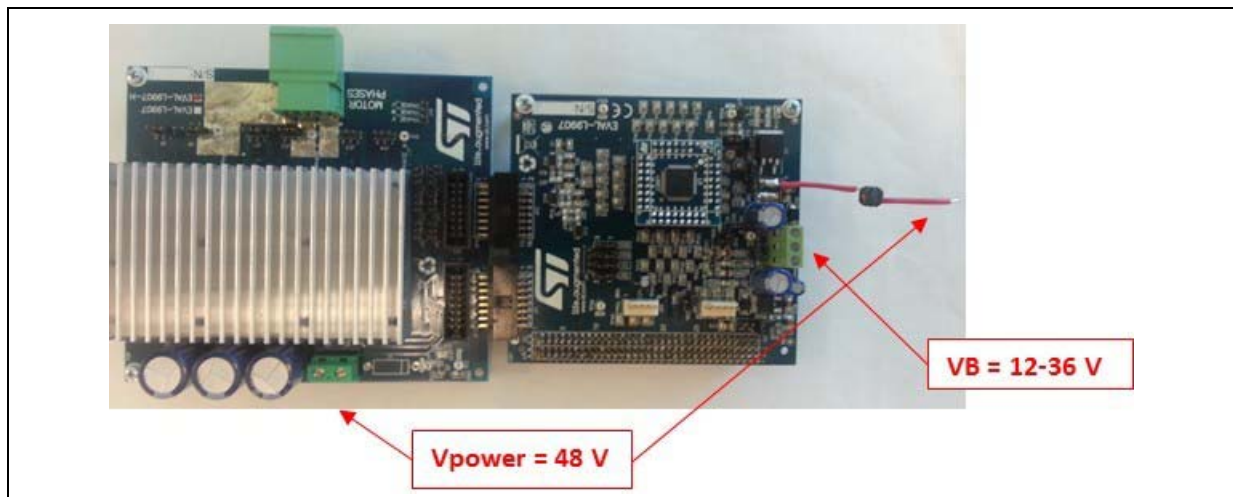
- Connect two wires to the removed inductor and connect one side on the board on the point connected to the Boost Diode D1 and the other side to 48 V, as shown in [Figure 10](#).

Figure 10. Boost inductor wire connection on EVAL-L9907/L9907-H



- Connect power supply lines as shown in [Figure 11](#).

Figure 11. Supply connection and boost inductor on EVAL-L9907/L9907-H



Please note that this board elaboration could have impact on increasing of emitted EMI level of the application.

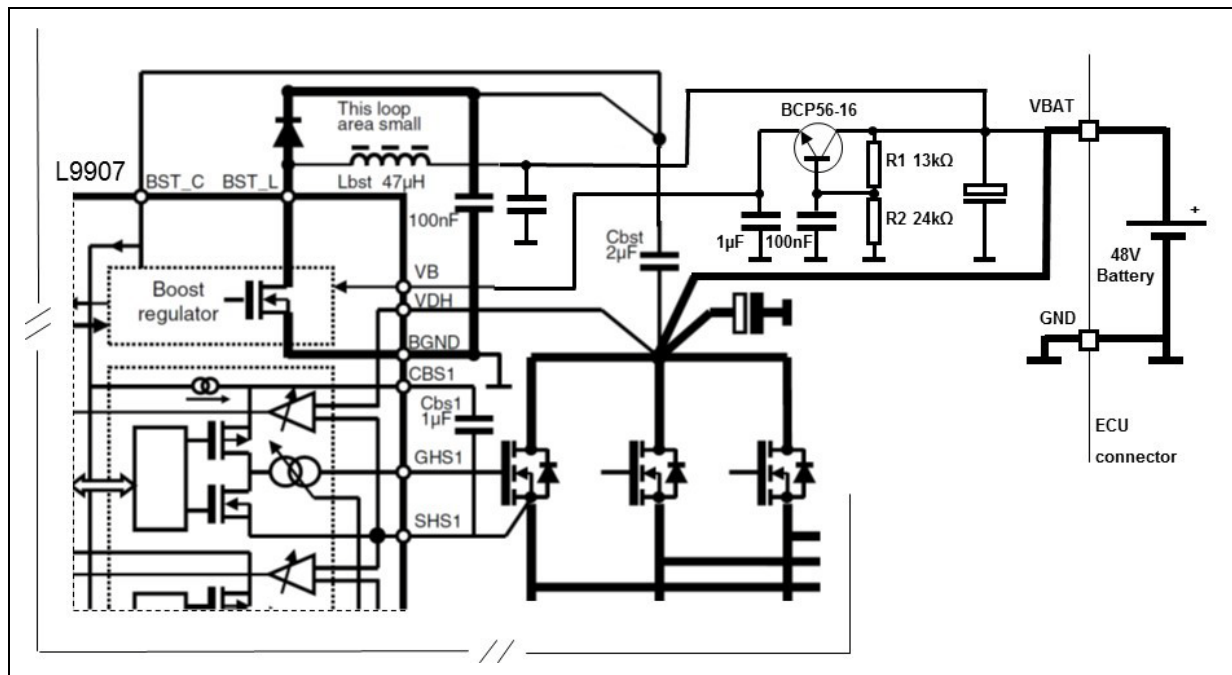
3. Dual supply mode – supply of VB pin over voltage scale-down regulator from 48 V net.

Monitoring 48 V net voltage over VB pin in order to inhibit the driver in case of over voltage detection. This can be achieved using simple hardware circuit working like a voltage scale

divider. The purpose of this circuit is to scale down 48 V battery net voltage to be compliant with double voltage battery levels. In this way the thresholds which are implemented in L9907 driver can be used. According to thresholds levels for VB pin of L9907 mentioned in [Table 1](#) and required levels for 48 V net according VDA 320 recommendation (see [Figure 1](#)) the optimal ratio for applied scale divider is 1.5. Such a value of dividing scale prevent from any possible false triggering of overvoltage protection over all spread of VBOV trigger level according to datasheet specification.

The simplest solution for scale-down voltage is based on a bipolar junction transistor (BJT) working in linear mode with a resistive divider to achieve 1.5 scale ratio for input to output voltage. [Figure 12](#) shows an example of modified schematic.

Figure 12. Dual supply approach with supply from scale divider from 48 V net



The value of resistor divider R1/R2 is chosen accordingly to above statement and to keep relative low bias current not to dramatically increased stand-by consumption when the motor is not running and the driver is in STB mode. The ratio resistors itself is little higher versus the suggested value since voltage drop on base-emitter of BJT which is usually around 0.6 V needs to be considered. The gain of the BJT have to be chosen according to this bias current and keep stabilized output voltage over all required I_C by L9907. The suggested value h_{FE} is in range 100-1000. The required I_C should be calculated according to formula described in L9907 datasheet (Table 9):

$$I_C = 7.2 Q f_{PWM} \left(1 + \frac{V_{BOOST} - V_B}{V_B} \right) + 6 \frac{2.81}{GCR} \left(1.5 + \frac{V_{BOOST}}{0.85 V_B} \right) + I_{BST_C}$$

Below is an estimation of V_B supply current (I_{VB}) at a given power supply voltage level (V_B), PWM frequency (f_{PWM}) and gate charge (Q) for each MOSFET. According to measurements in practice the I_C is usually in range 10 - 50 mA and depend on applied PWM switching frequency and on gate charge of assembled MOSFETs. This power dissipation over BJT are roughly equal to:

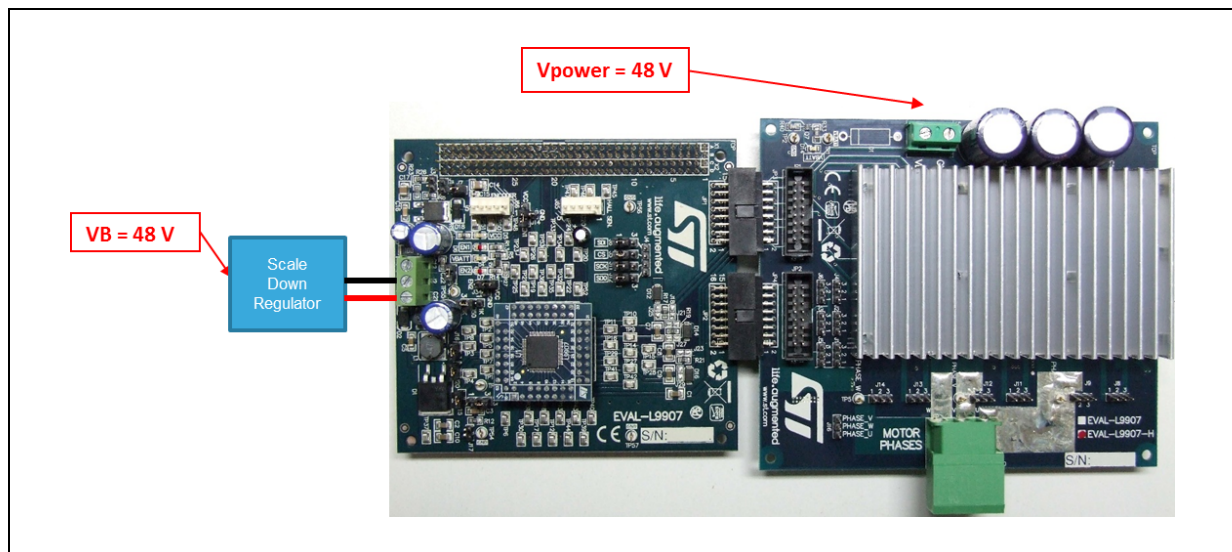
$$P_{DIS} = (V_{48BAT} - V_B)I_C$$

To avoid any power dissipation increase due to the internal boost converter supply over BJT scale divider, the boost choke is supplied directly from +48 V net offering overall higher efficiency of boost converter.

With V_{BOV2} and V_{BOV1} (B3-B2) bits in CMD1 register set 0:1 what is default value after reset is L9907 driver able to monitor 48 V net over V_B pin for overvoltage event. To have a correct function of 48 V net it is also necessary to disable overvoltage protection settled in BST_C pin. This will be done with set bit DIS_BSTov (B12) in CMD3 register to '1'. This bit is accessible for writing only if $AND(EN1, EN2) = '0'$. Trying to write it without lowering $AND(EN1, EN2)$ will not generate any SPI error but command will be simply ignored for the specific bit. Once set to '1', CMD3 B12 disables the over voltage protection on the boost regulator BST_C pin. This bit defaults to '0'.

The simplest way to implement the solution described in this section is to add voltage scale divider based on separated PCB module.

Figure 13. EVAL-L9907/L9907-H supply with 48 V and scale down regulator



Appendix A References documents

1. *Automotive FET driver for 3 phase BLDC motor* (DS11800, DocID029666)
2. *EVAL-L9907* (UM1994, DocID028709)
3. *EVAL-L9907-H* (UM2074, DocID029410)

Revision history**Table 2. Document revision history**

Date	Revision	Changes
12-Mar-2018	1	Initial release.

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