MLX83203-2 Automotive BLDC Pre-Driver

EVB83203 for Brushed DC Applications with MLX83203-2

Stefan Poels

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Transportstraat 1
3980 Tessenderlo
Phone: +32 13 67 07 95
Mobile: +32 491 15 74 18
Fax: +32 13 67 07 70
www.melexis.com

VAT BE 0435.604.729

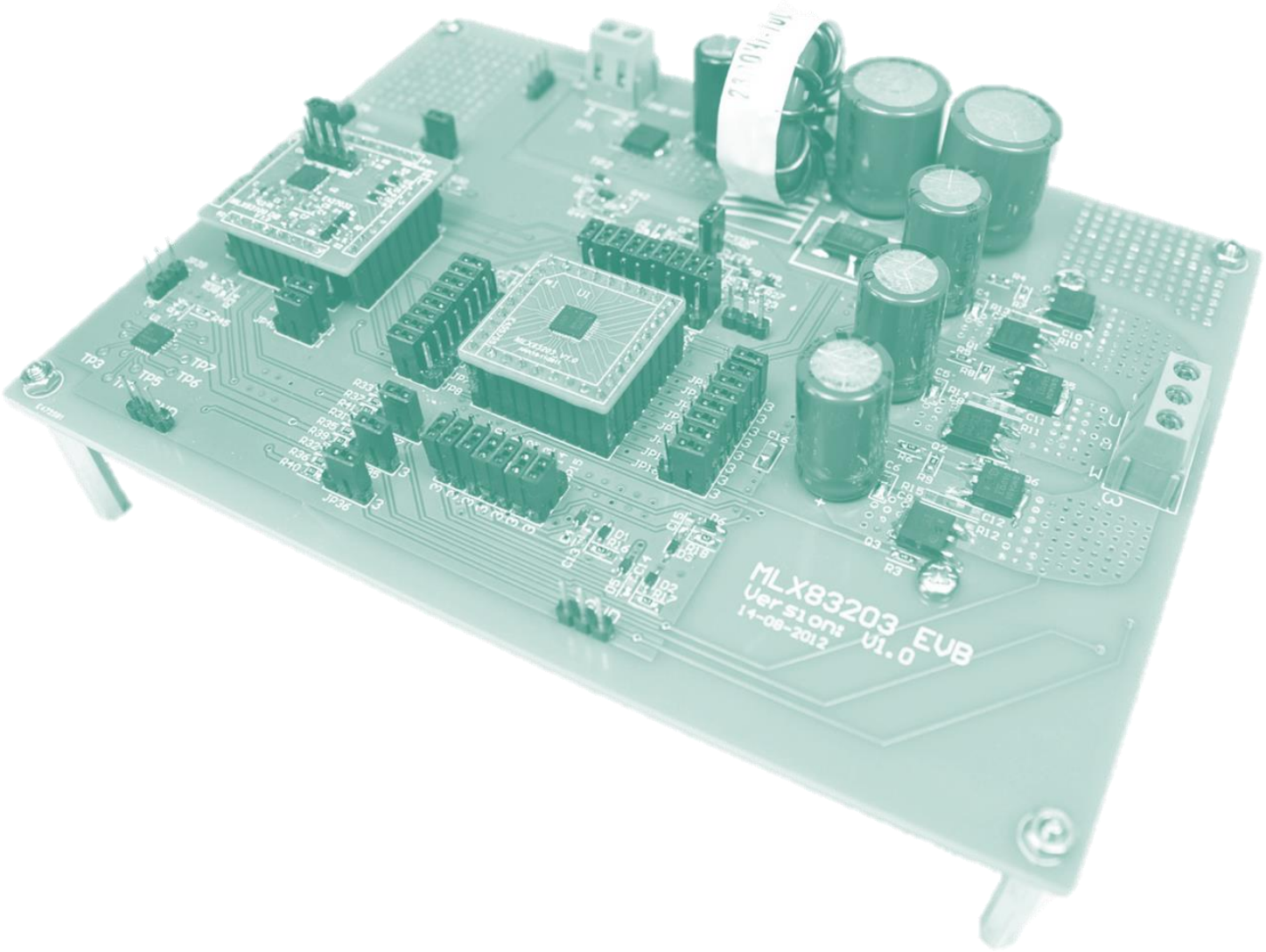
Contents

1. Scope

This application note is to be used in combination with the pre-driver MLX83100 datasheet.

This application note describes the Melexis pre-driver evaluation board. It should help the user to make the system setup and get the motor running with the Melexis pre-driver to get familiar with all the features.

Further it describes all different sections: supply system, driver stage, current sensing, and auxiliary parts. The application note also gives some recommendations to customers who will be developing their own application board regarding to the schematic, components and layout.



2. Description

The MLX83100 is a full-bridge pre-driver (also called 'bridge' or 'gate' driver) IC with integrated current sense amplifier. This device is used to drive brushed DC motors in combination with a microcontroller and four discrete power N-FETs.

The evaluation board "EVB83203" described in this document allows customer to evaluate the pre-driver for applications in the typical range off 12V-30A. The absolute maximum operating voltage is limited by the external N-FETs to 40V, all auxiliary components on the board can also support 40V or higher. This means the evaluation board can be used to evaluate the pre-driver for 24V applications as well.

The pre-driver IC is supplied from the battery via a CLC filter and reverse polarity protection. Supply for the pre-drivers' digital IO's and current sense amplifier is realized by voltage regulator in the MLX80051 LIN SBC. This VDD supply is routed to the microcontroller connector in order to supply the microcontroller from the same supply.

The device is able to control six external N-FETs in the supply range from 4.5V to 28V, by means of the integrated charge pump. The high side gate drivers are supplied via bootstrap circuits on the PCB. The trickle charge pump allows 100% PWM operation despite the use of bootstrap capacitors. The bootstrap voltage regulator is optimized for gate charges up to 350nC per FET at 20 kHz PWM.

The device comprises various monitoring and protection functions, including under voltage and over voltage detection at multiple internal voltage nodes, over temperature detection, drain-source and gate-source voltage monitoring of the external N-FETs and over current detection. The ICOM diagnostics interface is routed to the microcontroller connector to inform the microcontroller of any fault condition.

An integrated fast, high-bandwidth, low offset current sense amplifier measures and amplifies voltage sensed over the shunt resistor. Via a resistive divider from VDD a bias voltage is applied on the output of the current sense amplifier through VREF, allowing to measure negative currents as well.

The MLX83203-2 provides an EEPROM for configurability, avoiding the need for a high pin-count package and/or external components for configuration. The configuration allows the customer to optimize the pre-driver's operation for different applications through the custom SPI interface with the microcontroller.

3. Application Setup – Start Guide

The MLX83100 is a full-bridge pre-driver (also called 'bridge' or 'gate' driver) IC used to drive brushed DC motors in combination with a microcontroller and 4 discrete power N-FETs in the supply range from 4.5V to 28V.

3.1. Supply Connection

The board power supply is connected to the battery connector CON1 VBAT-GND at the top left corner.

Via jumper JP33 the charge pump mode can be selected. In position 1-2 the pre-driver will regulate the boosted voltage relative to VSUP, in position 2-3 the boosted voltage is regulated relative to GND.

The Melexis LIN SBC MLX80051provides the digital supply for the pre-driver and the microcontroller. In order to put the pre-driver in sleep mode the digital supply has to be disabled. This is done by putting the LIN SBC in sleep mode, by pulling VDD_EN low via one of the pins of the microcontroller connector or by shorting pins 1-2 of jumper JP40. The LIN SBC wakes up either by sending a LIN message or by shorting pins 1-2 of jumper JP39

3.2. Motor Connection

The brushed DC motor can be connected via the CON3-connector V-W on the right side of the board.

3.3. Microcontroller Connection

The evaluation board is delivered without microcontroller as the focus off Melexis is on the analog performance of the motor driver system, being the pre-driver, rather than on the motor control algorithm in software.

However the evaluation board does provide the option to connect the microcontroller via the dedicated pin headers on the left of the board. These pin headers provide the necessary supply voltages and all necessary signals to interface with the pre-driver and control the motor:

- P4-header
  - The microcontroller can either be supplied with battery supply or with the 5V logic supply, both available on this header
- P3-header
  - 3-6 PWM signals to the pre-driver inputs for independent control of the 6 external N-FETs
  - Enable input to the pre-driver to enable the gate driver outputs
  - ICOM bidirectional interface for diagnostics communication
- P2-header
  - 3 ADC inputs for back-EMF measurements for sensor less motor control, if jumpers JP35-37 are present between pins 2-3
  - 1 ADC inputs for the current sense measurement, via JP34 the amplified current sense voltage can be biased with either 2.5V (jumper position 1-2) or via resistive divider from VDD
- P1-header
  - LIN connection

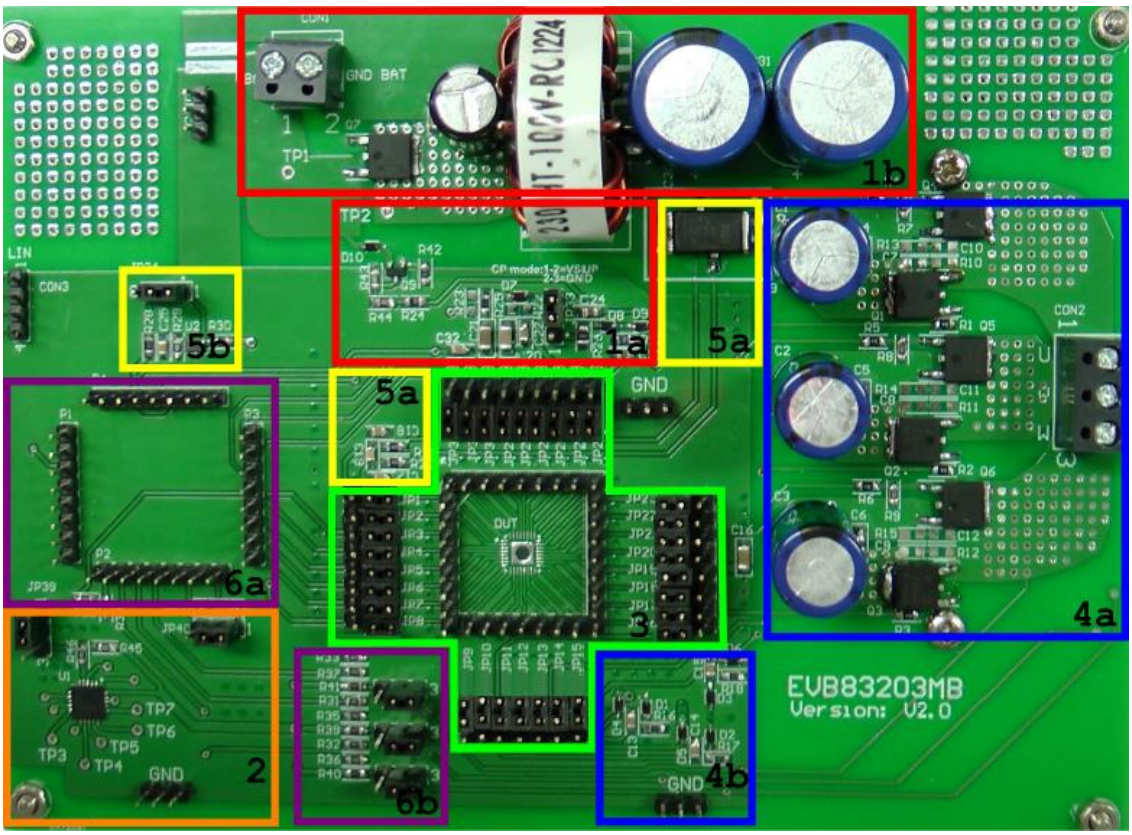


Figure 3-1 Picture of the EVB showing different sections

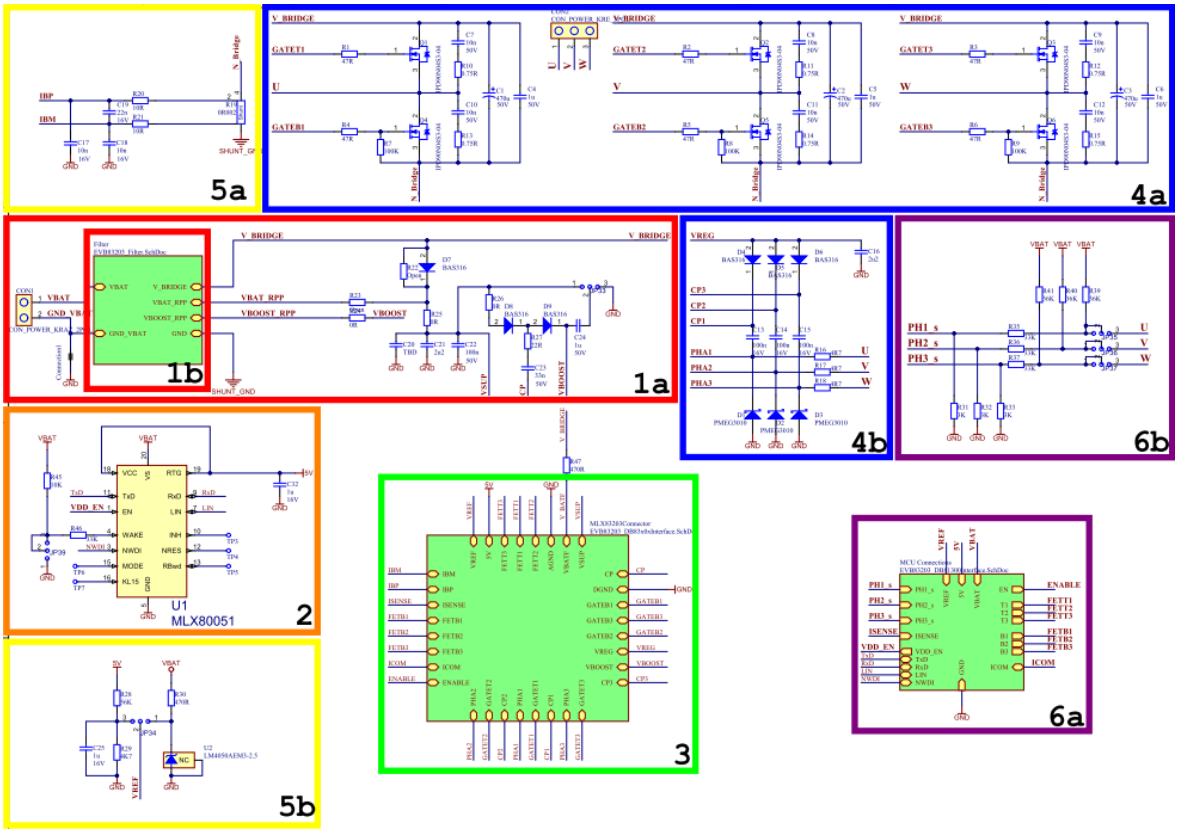


Figure 3-2 Schematic of the EVB showing different sections

4. Functional Description

4.1. Supply System

The evaluation board is supplied via the battery connector CON1. The pre-driver is supplied via pins V_{SUP} and V_{DD}. V_{SUP} supplies the internal operation, whereas the V_{DD} supply is used for the digital IO's and the current sense amplifier.

4.1.1. Power Supply V_{SUP}

VSUP supplies the internal operation and charge pump. The charge pump guarantees functional operation even at low battery voltage. This charge pump needs to be configured with two external silicon diodes, a charge pump capacitor and a boost capacitor. See Figure 4-1 for more details.

The charge pump can regulate the boost voltage, V_{BOOST}, in two modes. The standard mode of operation is when the boost voltage is regulated to ground, in which case the boost capacitor is connected to ground. Alternatively the charge pump can regulate the boost voltage relative to the power supply. In this case the boost capacitor should be connected to the power supply. This mode is used to drive a high side reverse polarity NFET. The mode of operation is determined by a bit in EEPROM and the boost capacitor connection can be changed with the position of jumper JP33.

The minimum charge pump capacitor is calculated from the supply voltage, the maximum load current and charge pump frequency as specified in the datasheet. In the standard application where 12V supply is used, this means the charge pump capacitor needs to be >25nF. On the evaluation board a 33nF capacitor is used.

If the charge pump is only configured with a 33nF capacitor, the charge pump will generate large current spikes, and will thus have bad EMC performance. Therefore a series resistance is added to slow down the switching of the charge pump. Based on the charge pump frequency and the 33nF capacitor, a 22Ω resistor is selected. To further improve the EMC behaviour a 2.2uF capacitor is put in parallel with the 100nF minimum capacitance on VSUP.

The boost capacitor should be at least an order of magnitude larger than the charge pump capacitor. A 1uF capacitor is selected after consideration of the number of charge pump cycles needed to recharge the boost voltage and the time between two charge pump events.

On the evaluation board it is possible to measure the current consumed by V_{SUP} and CP via sensing resistors R25 and R26 respectively. The default values of these sensing resistors are 0Ω.

V_{BRIDGE} is used as supply for the external high side MOSFETs in the driver stage. This voltage is connected to V_{BATF} to monitor drain-source voltages of the high side MOSFETs.

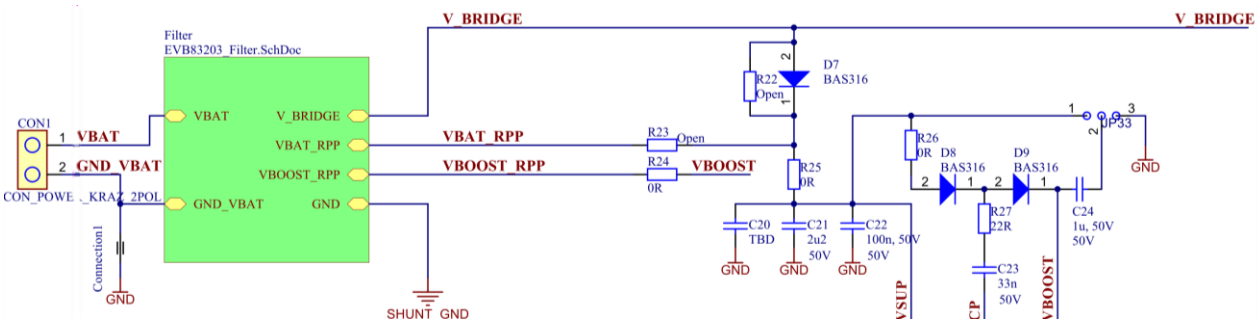


Figure 4-1 Power Supply

4.1.2. Motor Supply V_{BRIDGE}

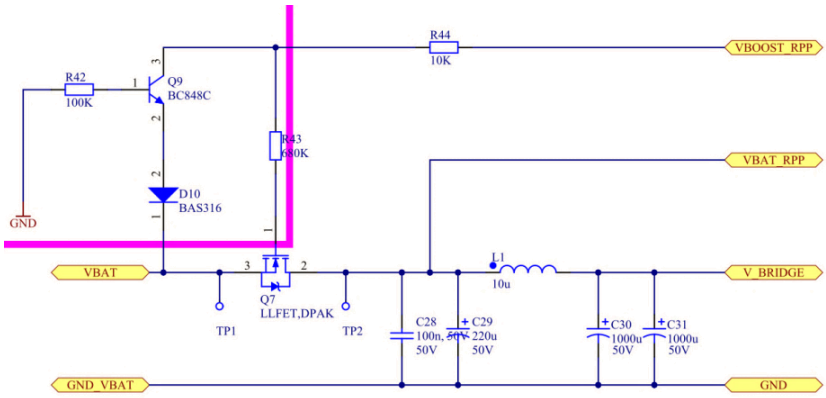


Figure 4-2 Reverse Polarity N-FET and CLC-filter

The pre-driver is protected against reverse polarity via diode D7 in Figure 4-1, or via logic level NFET Q7 in Figure 4-2.

The motor is supplied from V_{BRIDGE}. A CLC filter is implemented to reduce the noise on the power supply.

All capacitors are 50V rated for the case load dump can be applied.

4.1.3. Digital Supply V_{DD}

The pre-driver is supplied from V_{SUP} and V_{DD}. V_{DD} is used to supply the digital IO's and the current sense amplifier.

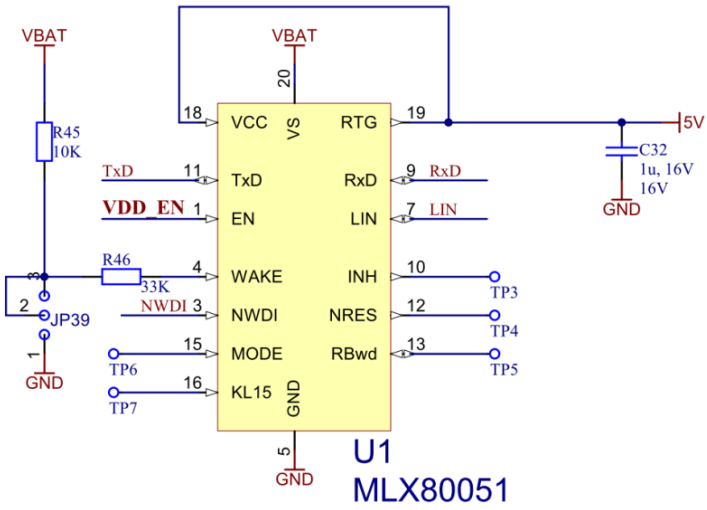


Figure 4-3 Digital Supply from the MLX LIN SBC

To supply V_{DD}, the MLX80051 is used, see Figure 4-3. This Melexis System Basis IC provides both LIN transceiver and 5V voltage regulator. The 5V voltage regulator is capable to deliver 70mA and is used to supply V_{DD} to the pre-driver and to supply the microcontroller (MCU). The regulated 5V is decoupled with a 1uF capacitance.

It is possible to put the pre-driver in sleep mode by pulling V_{DD} to ground. Since V_{DD} is supplied from the MLX80051, it is necessary to put the LIN SBC in sleep mode. This can be done by pulling VDD_EN to ground via jumper JP40 or via the microcontroller.

Wake-up from sleep can be realized locally by pulling the WAKE-pin low via jumper JP39, or remotely via the LIN-communication. The internal voltage regulator will be switched on and the pre-driver will wake-up.

The MLX80051 can also be used as LIN transceiver. The LIN-pin is connected to the LIN-connector on the evaluation board. The pins TxD and RxD are routed to the MCU connector.

The MLX80051 also offers a window watchdog with adjustable watchdog time defined by an external bias resistor and a reset unit. This functionality is accessible on the evaluation board via the test pins TP3-TP6.

4.2. Pre-driver connection

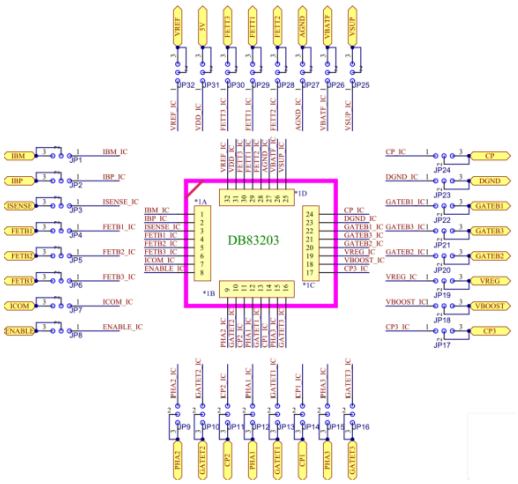


Figure 4-4 Pre-Driver Connection

The MLX83100 can be connected to the evaluation board by soldering on a dedicated daughterboard with socket that can be plugged on the provided pin headers.

In this way the same evaluation board can be used for both brushed and brush-less DC applications with the MLX83100 or MLX83203-2 pre-driver IC's.

Further a ring of jumpers, JP1-JP32, is soldered on the evaluation board. These can be used to interrupt signals if wanted. It also allows easily connecting scope probes on the different IC pins.

4.3. Gate Drivers

The evaluation board is designed for BLDC/PMSM applications, thus 3 half bridges are present on the evaluation board. For brushed DC applications only two half bridges are necessary. Each of the half bridges consists of a high side N-FET and a low side N-FET. Bootstrap circuits are used for driving the high side gates. To reduce the switching noise, decouple capacitors are present and footprint for snubber circuits are provided. See Figure 4-5 for the schematic of the driver stage.

The MOSFETs on the evaluation board are IPD90N04S3-04. These automotive N-FETs have a break down voltage of 40V, can conduct 90A and have a typical total gate charge of 80nC.

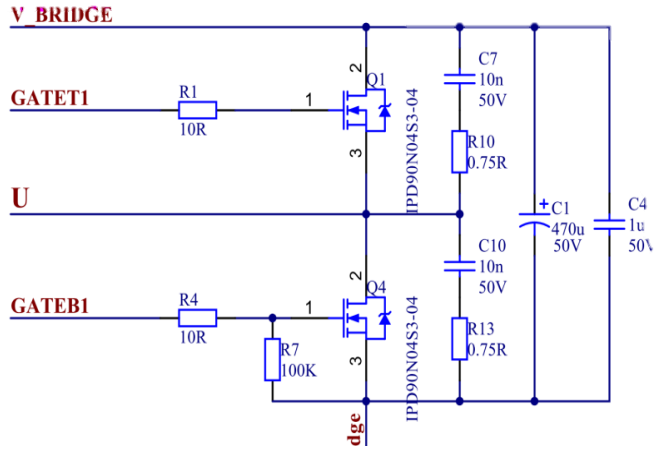


Figure 4-5 2x Half-bridges

In order to control the slope of the output phases, external gate resistors are used for both high side and low side N-FET gates. These resistors decrease the switching speed and reduce the resulting voltage spikes. In case the standard EEPROM configuration is used, the dead time is set to 1µs. Based on the total gate charge of the MOSFETs the resistor values are set to 10Ω. To further reduce the switching noise decouple capacitors of 470µF//1µF are present and footprints are provided for snubber circuits.

When the high side N-FET is switched on, the phase voltage is pulled high. The intrinsic Cgd and Cgs capacitors of the low-side N-FET create a capacitive voltage divider between the phase voltage and low side gate voltage. This can result in parasitic turn-on of the low side N-FET. In order to eliminate this effect, 100kΩ pull-down resistors are placed between gate and source of all low-side N-FETs.

4.4. Bootstrap Circuits

4.4.1. Voltage Regulator

The pre-driver has an integrated 12V voltage regulator. The V_{REG} output is used for the bootstrap circuits and can supply currents < 40mA.

4.4.2. Bootstrap Circuits

In order to switch on the high side N-FETs it is necessary to pull the gate voltage ~12V above the phase voltage. This means the gate voltage should be pulled ~12V above battery level. Therefore external bootstrap circuits are used, see Figure 4-6.

The overdrive gate voltage for the high side N-FET is provided by the bootstrap capacitor. This capacitor is charged by the VREG voltage through the bootstrap diode during the time when the device is off (assuming that the source of the N-FET swings to ground during that off-time). The bootstrap capacitor is discharged only when the high side gate is switched on.

If the bootstrap capacitor is too high, charging of the capacitor will limit the PWM frequency and duty cycle. If the capacitance is too low, there can be a large voltage drop at the time the charge is transferred from the bootstrap capacitor to the N-FET gate.

The value of the bootstrap capacitor is chosen to be 100nF, such that it is one order of magnitude larger than the N-FET gate capacitance. The V_{REG} tank capacitor in turn is one order of magnitude bigger than the bootstrap capacitor and is thus set to 2.2µF.

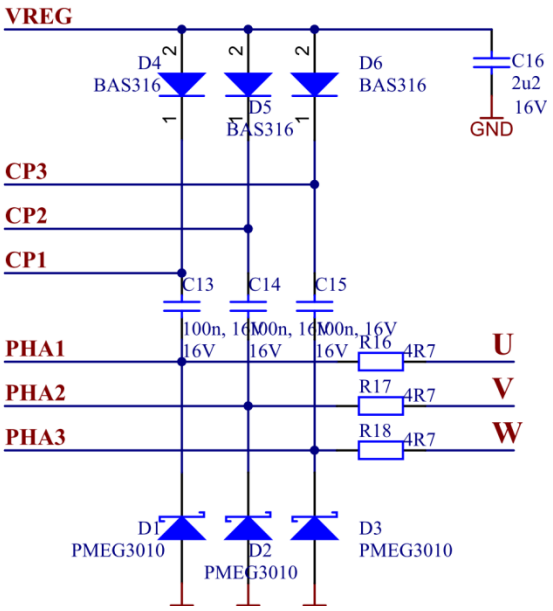


Figure 4-6 Bootstrap Circuits

Due to the motor inductance and the diode reverse recovery effect, it is possible that the phase voltages are pulled below ground. To protect the pre-driver IC against negative voltages on the phase pins, diodes and phase resistors are used to clamp the negative voltages, see Figure 4-6.

4.5. Current Sense Amplifier

The pre-driver has an integrated current sense amplifier. The current sense amplifier is supplied from the digital supply VDD. It senses the voltage over the low-side shunt via input pins IBP-IBM, amplifies it with the gain programmed in EEPROM and adds the offset provided on VREF. The output of the amplifier is available on ISENSE.

A single, common shunt of 2.2 mΩ is used. The positive and negative signals of the shunt are filtered via 10Ω series resistors and 10nF capacitors, complemented with an additional 22nF differential capacitor.

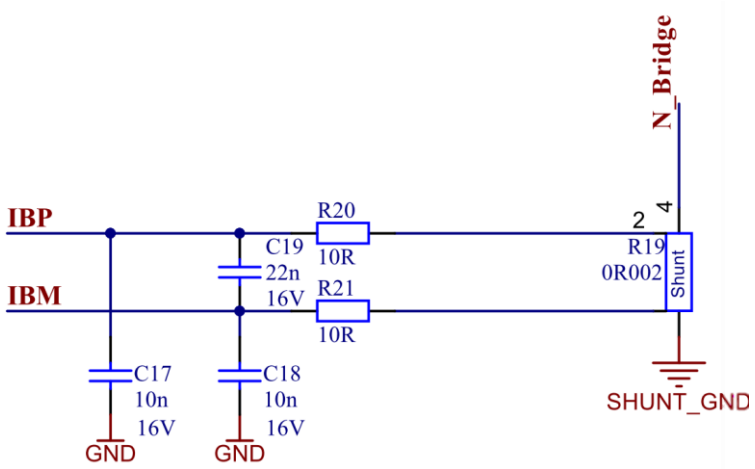


Figure 4-7. Current Sense Input Filter

The evaluation board provides two options to bias the ISENSE output voltage. The selection is made via jumper JP34. First option is to apply the bias from a resistive divider from the digital supply V_{DD}. The second option is via the LM4050AEM3-2.5V precision voltage reference.

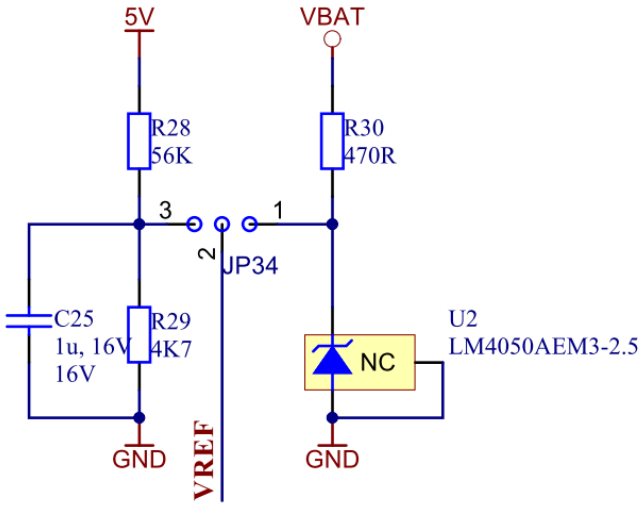


Figure 4-8. Current Sense Output Bias Voltage

4.6. Microcontroller Connection

The pre-driver is controlled by a microcontroller (not provided with the evaluation board). Pin headers are provided on the evaluation board to connect a microcontroller or plug on a daughterboard with the microcontroller.

All necessary pins to control the pre-driver/motor are routed to this microcontroller connectors:

- Microcontroller supply (P4-header)
  - **Battery supply and ground**
  - **5V VDD** from the LIN SBC voltage regulator
  - **Ground**
  - **VDD_EN** (P2-header): to put LIN SBC and pre-driver in sleep mode
- Control of the pre-driver/motor (P3-header)
  - **EN**: pre-driver input to enable/disable the gate driver outputs
  - **FETTx**: pre-driver input signals to control the high side N-FETs
  - **FETBx**: pre-driver input signals to control low side N-FETs and used for the custom SPI interface to read/program the pre-drivers' EEPROM
  - **ICOM**: bidirectional, serial interface for diagnostics communication and used as CS for the custom SPI interface to read/program pre-drivers' EEPROM
- Motor control (P2-header)
  - **ISENSE**: output of the current sense amplifier
- LIN Communication (P1-P2-header)
  - LIN connection for microcontroller on P1-header
    - TxD, RxD signals from the LIN SBC for microcontrollers without LIN transceiver

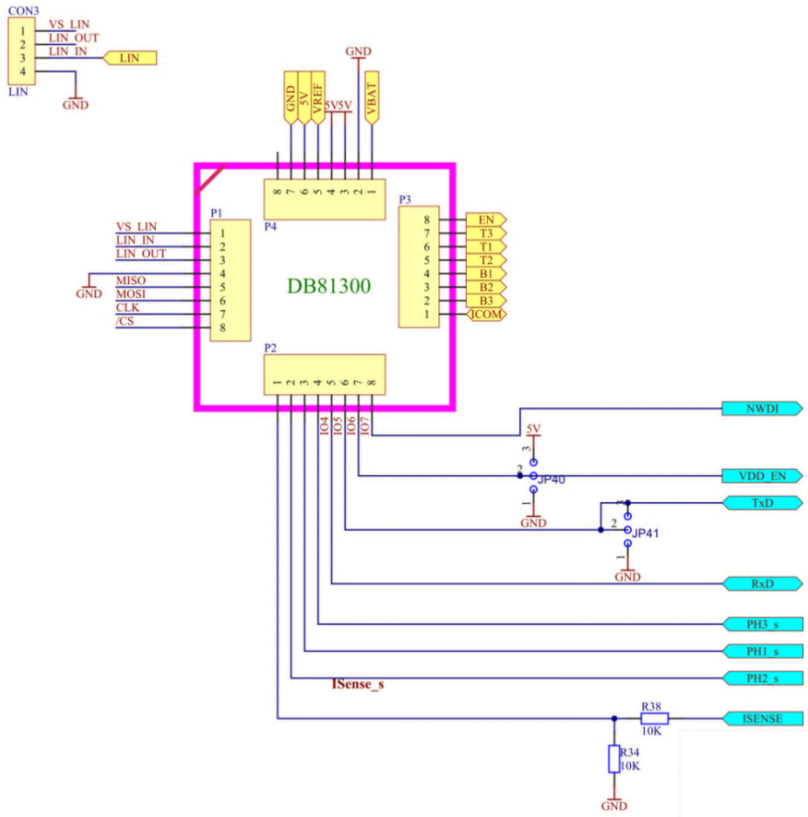


Figure 4-9 Microcontroller Connection

5. General Guidelines for Components Placement

- For reliable operation both AGND-DGND should be shorted as close as possible to the pre-driver IC.
- All supply decouple capacitors are to be placed as close as possible to the IC.
- All current sense filter components are to be placed as close as possible to the IC.
- All bootstrap components are to be placed as close as possible to the IC.
- The VBATF series resistor is to be placed next to the IC.
- Each of the 2 bulk and ceramic capacitors are to be placed close to the corresponding half-bridge.
- The components within one half bridge should be placed as close as possible to each other. High side MOSFET, low side MOSFET, bulk capacitor CB and ceramic capacitor CC (CB and CC are in parallel) and the shunt resistor form a loop that should be as small and tight as possible. The traces should be short and wide.

6. General Layout Recommendations

- Divide the PCB in two parts. One part for the low power traces and components, the other part for the high power circuits. Place all half bridges and related components on the high power side. The pre-driver IC, and all components related to it, should be placed on the low power side.
- Consider a star point for the ground and the supply, to guarantee that the high currents will never flow through or across the low power side.
- Apply a ground plane. Especially on the bottom layer below the pre-driver IC, the MCU and all paths in between.
- Short the AGND and DGND pre-driver IC pins together, close to the IC.
- Connect the exposed pad to the ground plane.
- All connections between the pre-driver and the half bridges should be as short as possible and symmetrical. Use the same trace width and aim for equal trace lengths for all these nets. These rules also apply for the IBP and IBM paths.
- For the best performance the PCB needs to be optimized. The focus should be on design quality rather than flexibility. This means any optional components/features should be avoided if they are not required.

Note:

The EVB83203 should not be considered as an overall reference layout. The focus of this board is on flexibility in order to allow the user the opportunity to use all functionalities and to get familiar with the Melexis pre-driver.

7. Revision History

Revision	Date	Description
2.0	26-02-13	First release
3.0	22-07-14	General update according to new template
4.0	14-09-16	New Melexis branding

Table 7-1 Revision history

8. Disclaimer

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