User's Manual, V 1.2, Sep. 2006

Low Voltage Motor Driver Board (MDB_LV45G_V1.1)

Microcontrollers

Infineon technologies

Never stop thinking.

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Revision History: **Sep. 2006** V 1.2

Previous Version: none

Page	Subjects (major changes since last revision)
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1 Introduction

This User's Manual describes the Mechanical and Electrical Hardware features, quick setup pertaining to XC866 8 bits Microcontroller and the usage of the Low Voltage Motor Driver Board.

1.1 About this Document

This document is designed to be read primarily by System Engineers and Hardware Engineers who need a detail setup description of the Low Voltage Motor Driver Board.

Detail technical guidelines, characteristics of the board and installation procedures are given to the users needed to operate and care for the Motor Driver Board. For long and trouble-free use, users are encourage to read it carefully and follow the instructions. This is a low-power motor drive system, and the know how knowledge in power-electronics and technology is essential to install the system.

1.2 Terminology

Terms that are used throughout the document are defined in **Table 1-1**.

Table 1-1 Common Terms and Their Definitions

Term	Definition
BLDC	Brushless DC
LV-MDB	Low Voltage Motor Driver Board
EMI	Electromagetic Interference
BEMF	Back-Electromotive Force
CAPCOM	Capture/Compare Unit
AD	Analog-Digital

1.3 Safety Measures

- All system ports are not galvanically isolated. Do not touch any part of the system when it is still connected to the main line, and while the DC-Link capacitors are still charged.
- Do not dissemble or alter any part of the Motor Driver Board except where expressly described by this manual. Non-expert handling of the device may damage it or caused a high-voltage electrical shock.
- Do not operate the equipment if it emits smoke or noxious fumes. Unplug the power cord immediately.

- Do not allow the equipment to come into contact with , or become immersed in, water or other liquids.
- Do not drop, knock or shake the Motor Driver Board. Rough handling can damage the electronics of the Board.
- Do not store the Motor Driver Board in humid or dusty areas. Storage in such areas could result in electrical shock or other damage.
- Do not expose the Motor Driver Board to ambient temperatures above 80 degree celsius since this will damage the components or reduce their lifetime considerably.
- Do not use any ordinary oscillscope probe for any voltage or current measurement on the Motor Driver Board. A differential probe is to be used at all time when measuring the Gate potential difference; U, V, W.

1.4 Intended Use

The Low Voltage Motor Driver Board is used as a generic Motor Drive Demonstration Kit or Evaluation Board. In case of installation in machineries, commissioning of the Evaluation Board for Industrial usage is strictly prohibited. Infineon Technologies AG holds no responsibilities to any damages due to the above-mentioned installation.

The technical data as well as information concerning the supply conditions shall be taken from the documentation and must be strictly observed.

2 Low Voltage Motor Driver System Overview

The Low Voltage Motor Driver Board development provides the user with a basic Generic Motor Control System application solution. It allows user to understand the functionality of all newly developed Infineon Microcontrollers and to evaluate their features and performance on motor drive control. Based on the provided design and development environment, the user can develop a prototype after knowing the requirement of the application in a shorter time frame.

2.1 LV-MDB System Features

The LV-MDB System configuration includes the Infineon Microcontrollers, Hardware compatibility interface, components and features

- Compatible Infineon Microcontrollers
- **8-bits Microcontroller**
  - C868
  - XC866
  - XC866C
  - XC886/8CLM
- **16-bits Microcontroller (Easy-Kit)**
  - XC164-16

Note: Depending on the Microcontroller Starter-kits design, the LV-MCB supports all Infineon Microcontrollers.

- **SPB80N08S2-07 Infineon OptiMOS Power-Transistor**
  - N-Channel
  - Enhancement mode
  - 175°C operating temperature
  - Avalance rated
  - dv/dt rated
  - Vds = 75V
  - Rds = 7.1mΩ
  - Id = 80A
- Individual phase current sensing
- Shunt for DC bus current sensing
- 3-Phase Bridge Driver
- Single power source supply to the Starter-kit and LV-MCB
- Adjustable Input Voltage Reference with respect to the Main Input Supply
- BEMF voltage sensing and zero crossing detection circuitry
- Support BLDC control; Hall effect sensor and sensorless control
- Support Encoder, Resolver, Tachometer, PMSM

Note: A mathematical calculation model is required in the user application code for the PMSM Control.

- Infineon Microcontroller Interface
- Motor Speed and Direction Control Interface
- Generic Motor Interface
- Microcontroller Design Tool (**DAVE**)

2.2 Motor Driver System Architecture and BLDC Control Block Diagram

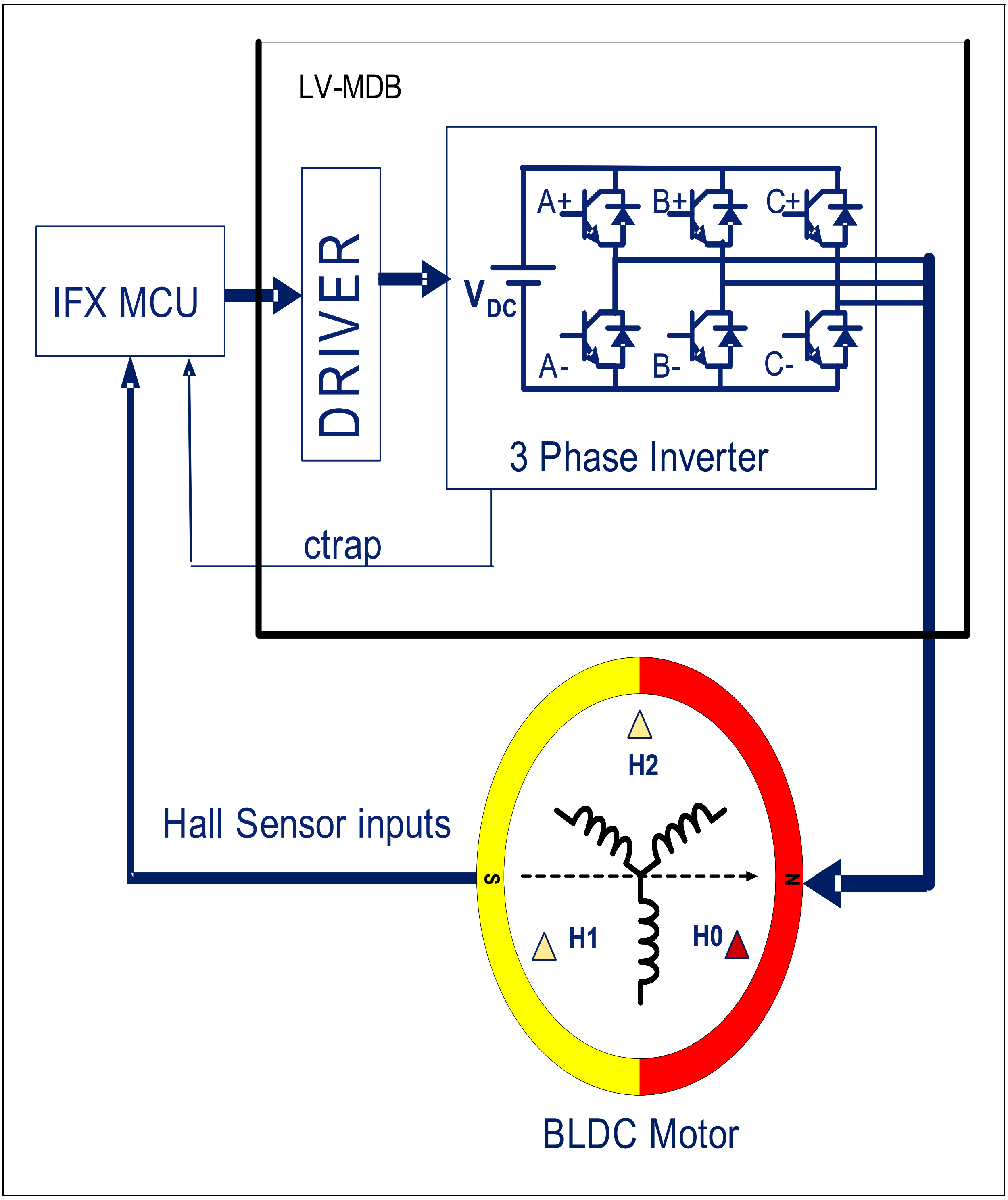

Figure 2-1 LV-MDB BLDC System Architecture

3 Low Voltage Motor Driver Board

3.1 System Hardware Overview

The Motor Driver Board, with a power rating of 350W, has a high level of usage flexibility underlines by its modular assembly and is built primarily for the 8 bits Infineon Microcontroller operation of Brushless DC motor in the E-bike Motor Control System Development. The secondary usage of LV-MDB board includes the operation of BLDC sensorless, Resolver, Tachometer, Encoder and PMSM control methodology without the need of any add-on hardware.

As an Evaluation Board, this drive inverter is not a certified inverter. It does not have a protection housing and galvanic isolation. In case of improper use, wrongful installation or misuse, there is a danger of serious physical injury and damage to the property. Direct contact to the voltage links, hot surfaces and any part of the system must be avoided when the motor is running. A differential probe must be used when measuring the gate voltage; V_u, V_v, V_w.

When connecting the Motor Driver Board to the isolating line transformer, copper wires with a cross-section of at least $0.75mm^2$ (AWG 20) must be used.

For continuous operation, a heatsink with a better thermal performance is needed, which depend on the maximum ambient temperature, and mounting proposals for the use of thermal grease and other interfacing materials.

The BEMF circuitry is not populated on the Motor Driver Board. It is implemented when the microcontrollers other than the Infineon Technologies microcontorllers without the ADC peripherals are used. The user is recommended to use LM339D comparator for the BEMF circuitry.

All operations serving transport, installation and commissioning as well as maintenance are to be carried out by skilled personnel. For the purpose of safety, “Skilled personnel” is referred to Engineers who are familiar with the installation, mounting, commissioning and operation of the Motor Driver Board. A protection housing is required if the Motor Driver Board is operated in areas where it is accessible by unskilled operators.

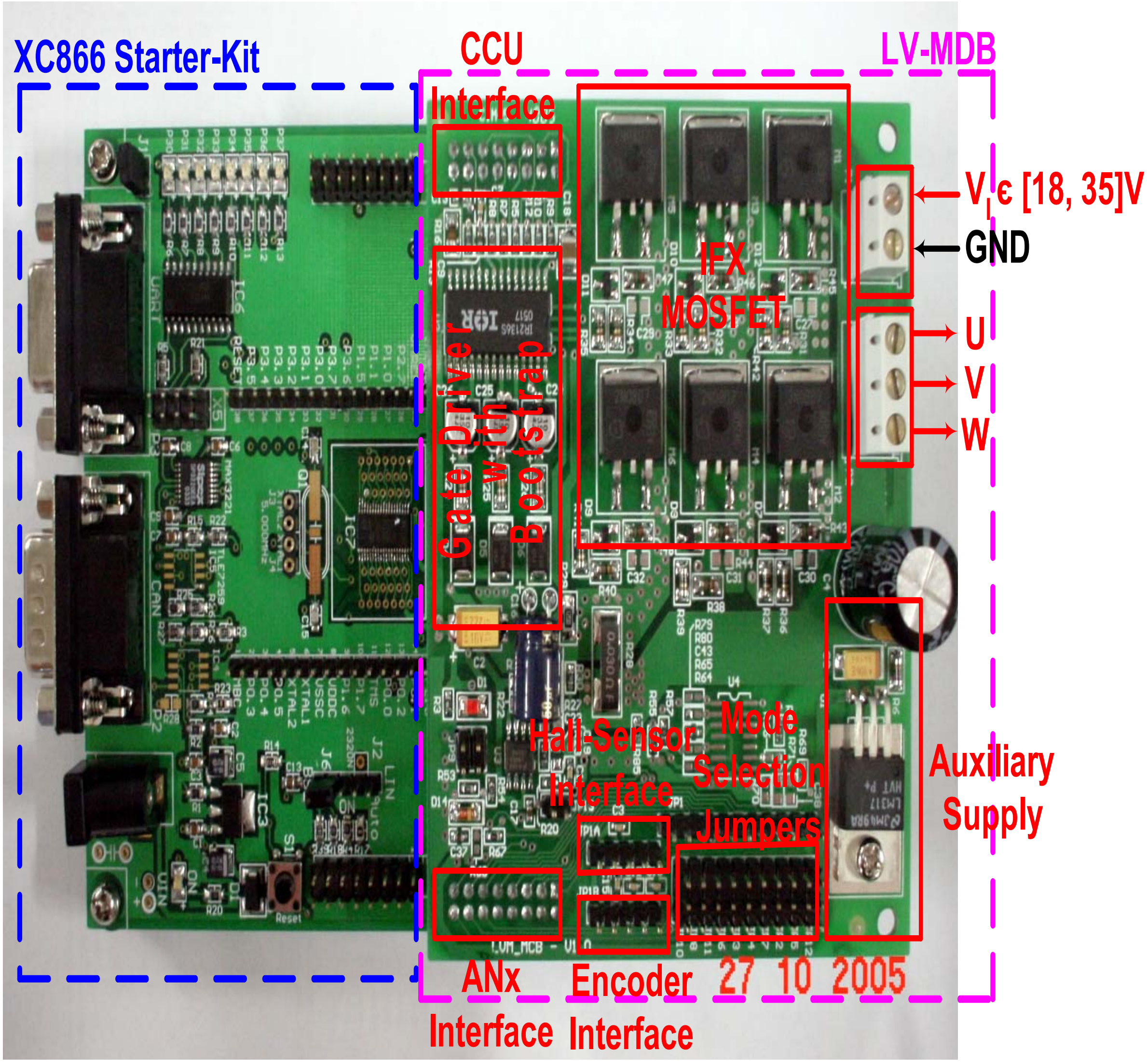

Figure 3-1 XC866 Starter-kit and Motor Driver Board

3.2 Motor Driver System Block Diagram

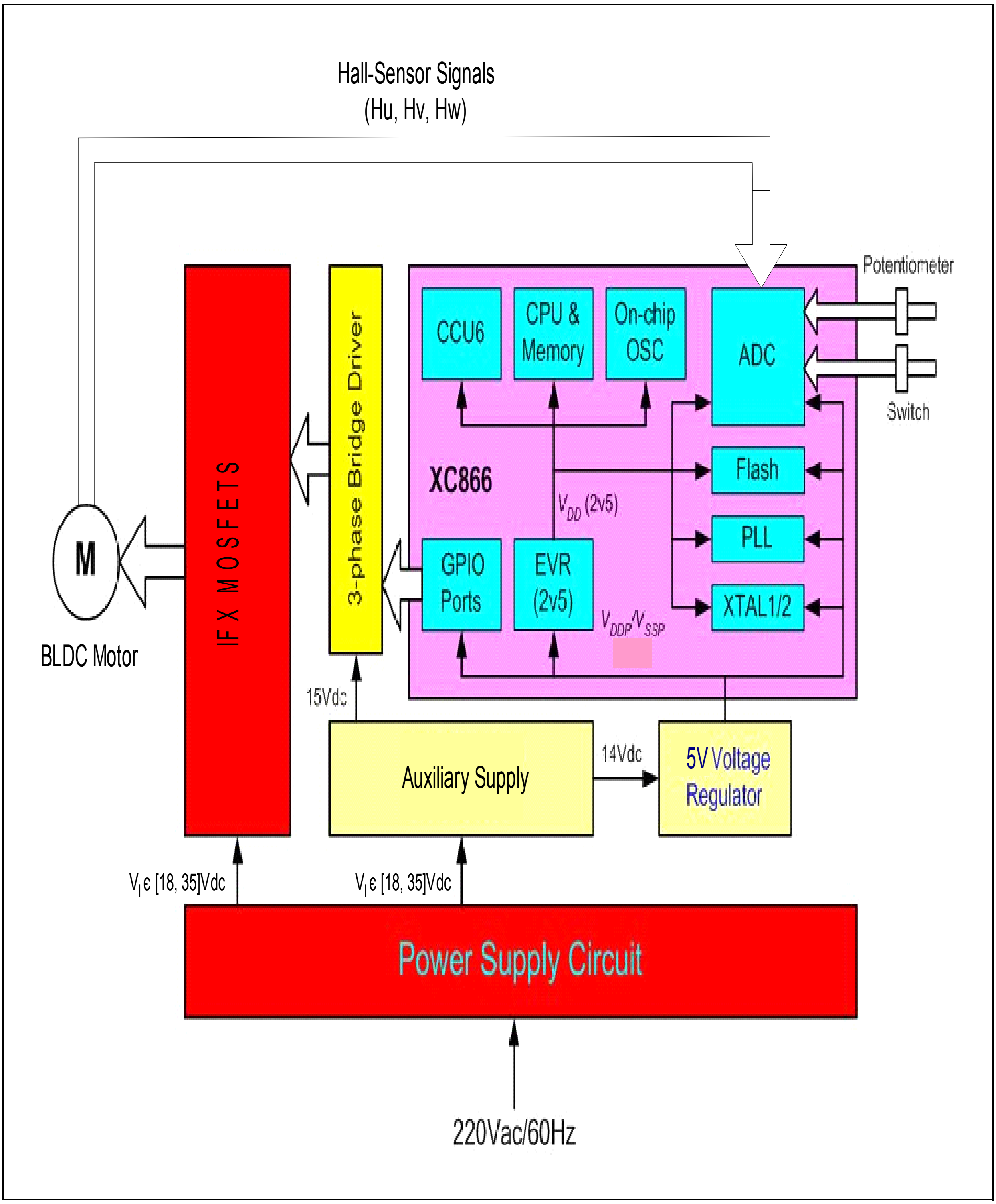

Figure 3-2 Motor Driver System Block Diagram

3.3 Power Stage and Overcurrent Protection

3.3.1 Power Stage

The power stage includes the Infineon Technologies OptiMOS Power-Transistor modules, SPB80N08S2-07, the gate driver IC and a shunt-resistor for current measurement and over-current protection.

The minus potential of the Terminal Block , N-, is the Reference ground for the entire control circuitry. With that the polarity of the shunt signal fits to the pins of the gate driver IC, no additional signal inverter is needed in the over-current protection path. However, special attention is needed when ploting the PCB layout with this configuration.

The ground tracks of the Microcontroller section (VSSP), the current signal amplifier (VAGND) and the power ground (N-) are connected in star configuration at the minus potiential of the Terminal Block, at the side of the current measurement shunt. They must be kept strictly separated before converging to the common reference point. The bootstrap buffer capacitor (C16) must be connected to the common reference trace (N2X) of the low-side MOSFETs with an individual copper trace.

Note: Do not connect the bootstrap buffer capacitor (C16) to the signal ground. The high peak current in the bootstrap current loop will cause ground noises and it is often the main reason for the unstable performance and operation of the board.

The current amplifier (U3) is connected to the AD input, P2.3 (AN3), of the Microcontroller via Jumper JP13 to enable easy software current control loop implementation.

3.3.2 Over-current Protection

A shunt resistor is placed at the minus potential path of the Terminal Block for over-current and short-circuit protection purpose. This is the most inexpensive solution which provides a full proteciton against over-current causes by an overloaded motor or a short-circuit between the three motor phases; Vu, Vv, Vw.

However, a short-circuit between the three motor outputs (U,V,W), the minus potential of the Terminal Block and at any of the metallic parts which are connected to the Reference Ground (RG) cannot be readily detected. It can destroy the Motor Driver Board immediately.

The voltage across the shunt resistor (R28) is filtered by R19, R29 and C14 and fed to the over-current comparator of the gate driver IC (ITRIP). This is to turn-off and pull-down all MOSFETs gates when the voltage at this comparator exceeds the internal reference voltage.

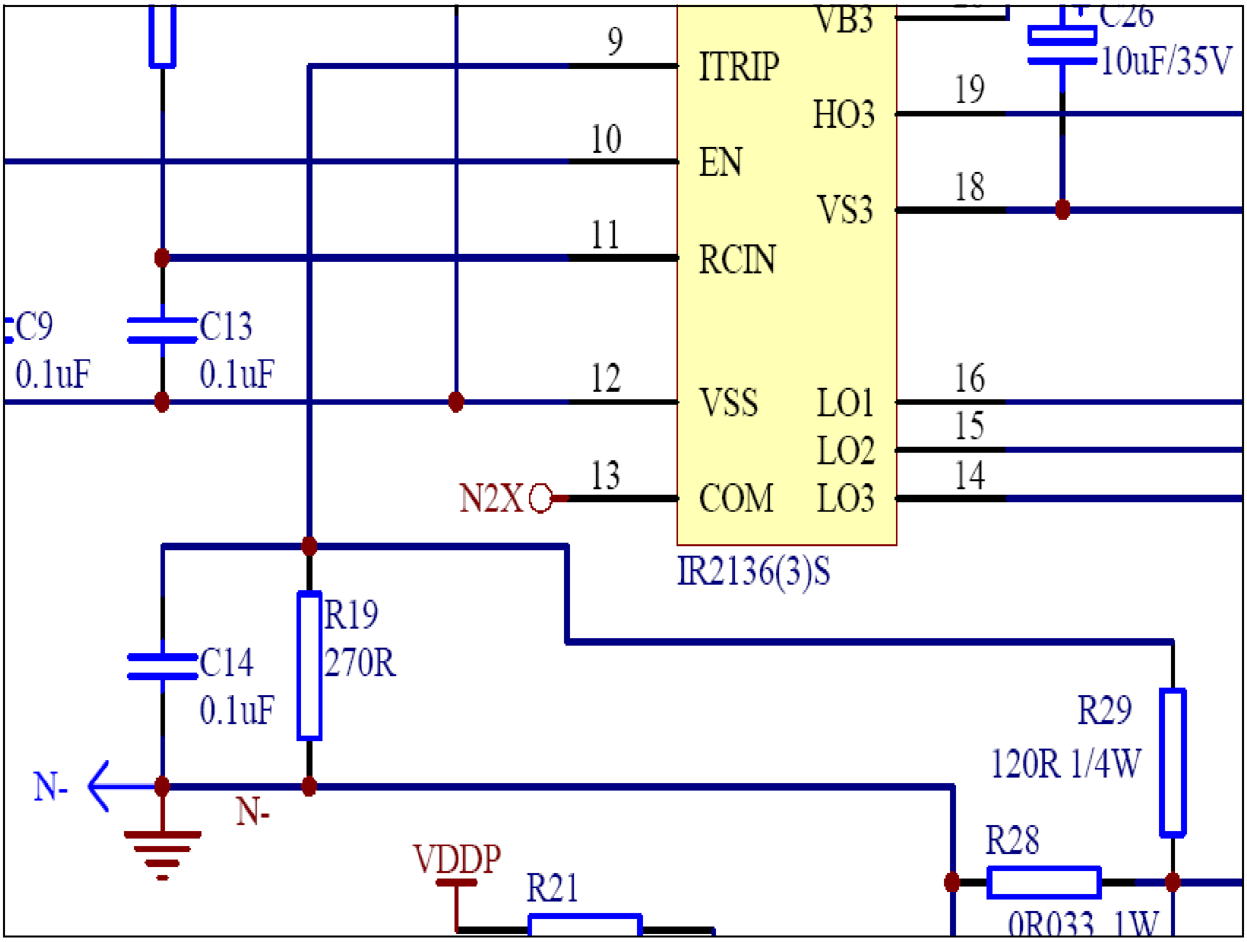

Figure 3-3 Over-current and Short-circuit protection circuit.

The ITRIP input specification of driver IC IR2136S is stated in Table 3-1:

Table 3-1 Datasheet sheet of the Driver IR2136S

Symbol	Definition	Min.	Typ.	Max.	Unit.
$V_{IT,TH+}$	ITRIP positive going threshold	0,37	0,46	0,55	V
$V_{IT,HYS}$	ITRIP input hysteresis		0,07		V
I_{TRIP+}	“high” ITRIP input bias current	---	30	100	uA
I_{TRIP-}	“low” ITRIP inpur bias current		0	1	uA
tITRIP	ITRIP to output shutdown propagation delay	500	750	1000	nS
tFLT	ITRIP to fault propagation delay	400	600	800	nS

The static over-current threshold $I_{sc,th}$ is calculated from **Equation [3.1]**:

:

$$I_{sc,\,th} = V_{IT,\,TH} \cdot ((R_{19} + R_{29}) / (R_{28} \cdot R_{19}))$$

[3.1]

With the chosen values, the Static Over-current Threshold is shown in **Table 3-2**:

Table 3-2 Static Over-current Threshold

	Min.	Typ.	Max.	Unit.
$I_{sc,th}$	16.1	20.1	24	A

The noise filter capacitor C14 causes non-negligible signal (turn-off) delay, which can be calculated from **Equation [3.2]**:

$$t_{d,\,sc} = -C_{14} \cdot \left[\left(R_{19} \cdot R_{29}\right) / \left(R_{19} + R_{29}\right)\right] \cdot \ln\left(1 - \left(V_{IT,\,TH} / \left(I_{sc} \cdot R_{28}\right) \cdot \left(R_{19} + R_{29}\right) / R_{19}\right)\right)$$

[3.2]

where I_{sc} is the actual short-circuit or over-load current.

3.4 Auxiliary Supply

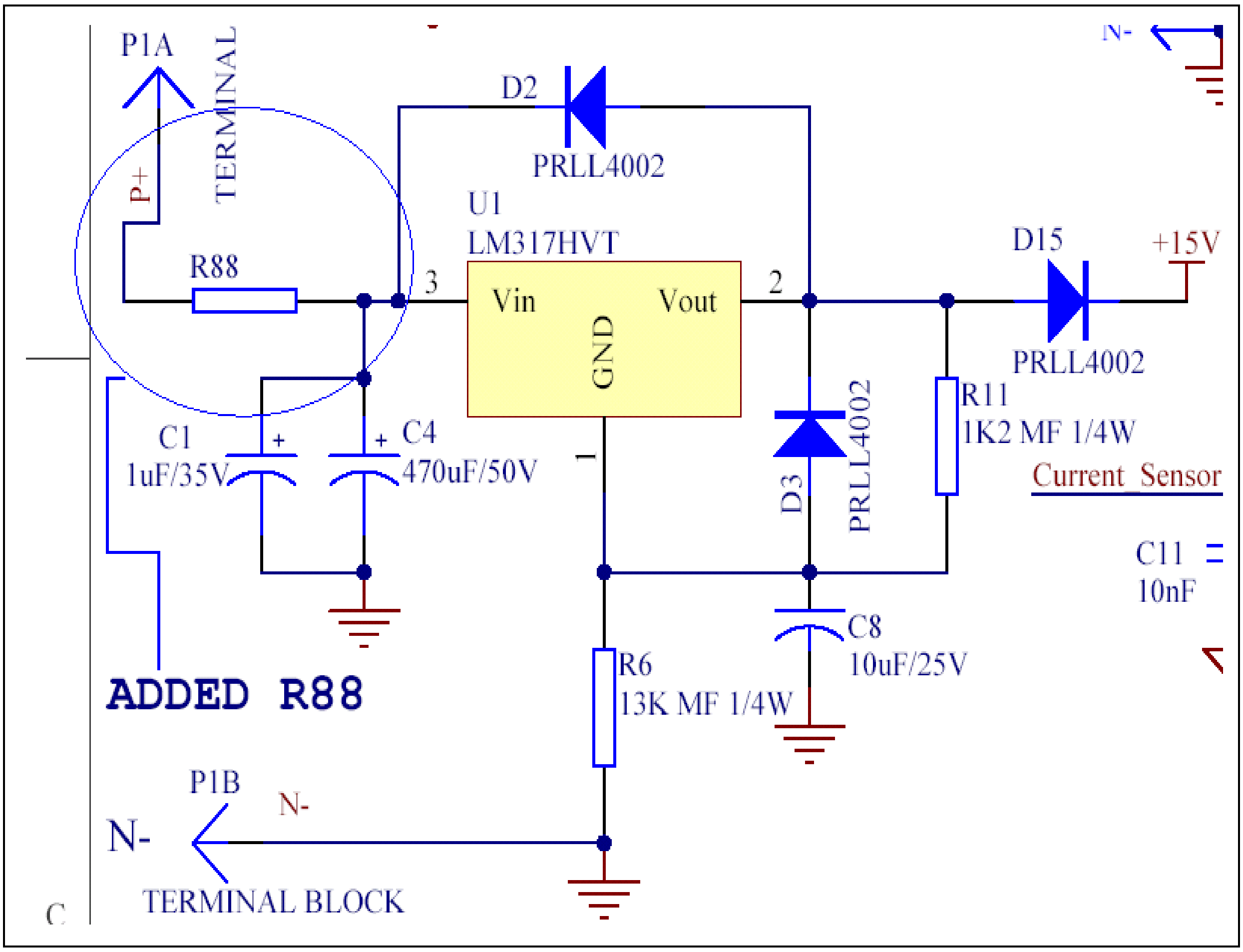

Figure 3-4 Auxiliary Supply Circuitry

In order to have one power supply source to the boards, an auxiliary supply circuitry is included into the LV-MDB.

When the power source is plugged in, the auxiliary supply circuitry implemented on the LV-MDB provides a voltage supply, VS = 15Vdc, to the Starter-kit via the header CN2 Pin 4. A reverse supply of VDDP from the Start-kit is supplied to the LV-MDB via the header CN2 Pin 2.

***Note:** If input Voltage P+ > 35V, remove C1, and you may add an additional resistor at R88 to reduce the power dissipation on U1; if P+ > 45V, remove the auxiliary supply circuitry. +15V is supplied separately via CN2 Pin 4 either from the external source or the Starter-Kit independent supply.*

***Note:** During the testing and implementation stage, it is advisable to power the Starter-kit and LV-MDB separately.*

3.5 Thermal Management

If high output power is required, a better thermal resistance heatsink with a better cooling behaviour is needed.

4 Hardware Parameters

4.1 Electrical Properties

Table 4-1 Absolut Maximum Ratings

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit.
$I_{in,rms}$	Line input current (rms)	V_{in}=15 to 45 V_{dc}, T_{amb}<60°C			10	A
V_{in}	Line input voltage		15	20	45	V
I_{UVW}		V_{in}=15 to 35 V_{ac}, T_{amb}<60°C			TBD	A
V_{pot+}		Voltage referred to V_{pot-}	0		5	V
V_{dig}		Voltage referred to GND	0		5	V
T_{amb}			-20		60	°C
T_{case}			-20		60	°C
$I_{s,15V}$	Current from Auxiliary Suppy	TBD				mA

Note: The parameters given in Table 4-1 must be strictly observed and within the absolut maximum rating under all operation conditions.

4.2 Hardware Pinning Configuration

- Signals at 3 Pin Power Connector P1

Table 4-2 Pin Definitions for Power Line Input

Definition	Signal	Pin
P+	Line Input (15 to 35V)	1
N-	Line Input (GND)	2

- Signals at 3-Phase Motor Output Connector P2

Table 4-3 Pin Definitions for 3-Phase Motor Output Connector

Definition	Signal	Pin
W	Motor Phase Output (V_W)	1
V	Motor Phase Output (V_V)	2
U	Motor Phase Output (V_U)	3

- Signals at Analog Input Header11 JP1

Table 4-4 Pin Definitions for Header JP1

Definition	Signal	Pin
P2.7	GPIO/AN7	1
P2.6	GPIO/AN6	2
P2.5	GPIO/AN5	3
P2.4	GPIO/AN4	4
P2.3	GPIO/AN3	5
P2.2	GPIO/AN2/CCPOS2_0	6
P2.1	GPIO/AN1/CCPOS1_0	7
P2.0	GPIO/AN0/CCPOS0_0	8
P1.7	GPIO/CCPOS2_1	9
P1.6	GPIO/CCPOS1_1	10
P1.5	GPIO/CCPOS0_1	11

- Signals at Motor Signals Input Header3 JP2

Table 4-5 Pin Definitions for Motor Signals Input Header3 JP2

Definition	Signal	Pin
P1.5	GPIO/CCPOS0_1	1
ENC_A	ENCODER INPUT SIGNAL (A)	2
P2.0	GPIO/AN0/CCPOS0_0/RESOLVER_1 INPUT SIGNAL	3

- Signals at Motor Signals Input Header3 JP3

Table 4-6 Pin Definitions for Motor Signals Input Header3 JP3

Definition	Signal	Pin
P1.5	GPIO/CCPOS0_1	1
Hall_U	HALL INPUT SIGNAL (H_U)	2
P2.0	GPIO/AN0/CCPOS0_0	3

- Signals at Motor Signals Input Header3 JP4

Table 4-7 Pin Definitions for Motor Signals Input Header3 JP4

Definition	Signal	Pin
BEMF_U	BEMF INPUT SIGNAL (B_U)	1
P2.0	GPIO/AN0/CCPOS0_0	2
ADC_U	ANALOG INPUT SIGNAL	3

- Signals at Motor Signals Input Header3 JP5

Table 4-8 Pin Definitions for Motor Signals Input Header3 JP5

Definition	Signal	Pin
P1.6	GPIO/CCPOS1_1	1
ENC_B	ENCODER INPUT SIGNAL (B)	2
P2.1	GPIO/AN1/CCPOS1_0/RESOLVER_2 INPUT SIGNAL	3

- Signals at Motor Signals Input Header3 JP6

Table 4-9 Pin Definitions for Motor Signals Input Header3 JP6

Definition	Signal	Pin
P1.6	GPIO/CCPOS1_1	1
Hall_V	HALL INPUT SIGNAL (H_V)	2
P2.1	GPIO/AN1/CCPOS1_0	3

- Signals at Motor Signals Input Header3 JP7

Table 4-10 Pin Definitions for Motor Signals Input Header3 JP7

Definition	Signal	Pin
BEMF_V	BEMF INPUT SIGNAL (B_V)	1
P2.1	GPIO/AN1/CCPOS1_0	2
ADC_V	ANALOG INPUT SIGNAL	3

- Signals at Motor Signals Input Header3 JP8

Table 4-11 Pin Definitions for Motor Signals Input Header3 JP8

Definition	Signal	Pin
P1.7	GPIO/CCPOS2_1	1
ENC_I	ENCODER INPUT SIGNAL (INDEX)	2
P2.2	GPIO/AN2/CCPOS2_0/TACHOMETER SIGNAL INPUT	3

- Signals at Motor Signals Input Header2X2 JP9

Table 4-12 Pin Definitions for Analog Input Control Connector

Definition	Signal	Pin		Signal	Definition
POT2+	External Potentiometer 2	1	3	External Potentiometer 2	POT2-
POT1+	External Potentiometer 1	2	4	External Potentiometer 1	POT1-

- Signals at Motor Signals Input Header3 JP10

Table 4-13 Pin Definitions for Motor Signals Input Header3 JP10

Definition	Signal	Pin
P+_VAREF	ANALOG REFERENCE VOLTAGE P+	1
VAREF	ANALOG REFERENCE VOLTAGE	2
VDDP	VDDP INPUT VOLTAGE	3

- Signals at Motor Signals Input Header3 JP11

Table 4-14 Pin Definitions for Motor Signals Input Header3 JP11

Definition	Signal	Pin
P1.7	GPIO/CCPOS2_1	1
Hall_W	HALL INPUT SIGNAL (H_W)	2
P2.2	GPIO/AN2/CCPOS2_0	3

- Signals at Motor Signals Input Header3 JP12

Table 4-15 Pin Definitions for Motor Signals Input Header3 JP12

Definition	Signal	Pin
BEMF_W	BEMF INPUT SIGNAL (B_W)	1
P2.2	GPIO/AN2/CCPOS2_0	2
ADC_W	ANALOG INPUT SIGNAL (W)	3

- Signals at Motor Signals Input Header2 JP13

Table 4-16 Pin Definitions for Motor Signals Input Header3 JP13

Definition	Signal	Pin
Current_Sensor	CURRENT SENSOR INPUT	1
P2.3	GPIO/AN3	2

- Signals at Motor Signals Input Con5a JP1A and JP1B

Table 4-17 Pin Definitons for Motor Signals Input Con5a JP1A and JP1B

Definition	Signal JP1A	Pin		Signal JP1B	Definition
Hall_U	HALL INPUT SIGNAL(U)	1	1	ENCODER INPUT SIGNAL (A)	ENC_A
Hall_V	HALL INPUT SIGNAL(V)	2	2	ENCODER INPUT SIGNAL (B)	ENC_B
Hall_W	HALL INPUT SIGNAL(W)	3	3	ENCODER INPUT SIGNAL (INDEX)	ENC_I
VDDP	VDDP INPUT VOLTAGE	4	4	VDDP INPUT VOLTAGE	VDDP
GND	GND	5	5	GND	GND

- Signals at Motor Signals Input Header8X2 CN1

Table 4-18 Pin Definitons for Motor Signals Input Header8X2 CN1

Definition	Signal	Pin		Signal	Definition
P3.0/CC60_0	AL (CC60_0) OUTPUT SIGNAL	1	2	NC	NC
P3.1/COUT60_0	AH (COUT60_0) OUTPUT SIGNAL	3	4	NC	NC
P3.2/CC61_0	BL (CC61_0) OUTPUT SIGNAL	5	6	NC	NC
P3.3/COUT61_0	BH (COUT61_0) OUTPUT SIGNAL	7	8	NC	NC
P3.4/CC62_0	CL (CC62_0) OUTPUT SIGNAL	9	10	NC	NC
P3.5/COUT62_0	CH (COUT62_0) OUTPUT SIGNAL	11	12	NC	NC
P3.6/CTRAP_0	STOP (CTRAP_0)	13	14	NC	NC
P3.7/COUT63_0	COUT3 (COUT63_0)	15	16	NC	NC

- Signals at Motor Signals Input Header8X2 CN2

Table 4-19 Pin Definitons for Motor Signals Input Header8X2 CN2

Definition	Signal	Pin		Signal	Definition
P2.7	GPIO/AN7	1	2	VDDP	INPUT VOLTAGE (+5V)
P2.6	GPIO/AN6	3	4	+15V (VS)	OUTPUT VOLTAGE (+15V)
P2.5	GPIO/AN5	5	6	VSSP	DIGITAL GROUND
P2.4	GPIO/AN4	7	8	VAGND	ANALOG GROUND
P2.3	GPIO/AN3	9	10	VAREF	REFERENCE VOLTAGE
P2.2	GPIO/AN2/CCPOS2_0	11	12	P1.7	GPIO/CCPOS2_1
P2.1	GPIO/AN1/CCPOS1_0	13	14	P1.6	GPIO/CCPOS1_1
P2.0	GPIO/AN0/CCPOS0_0	15	16	P1.5	GPIO/CCPOS0_1

4.3 Hardware Schematics

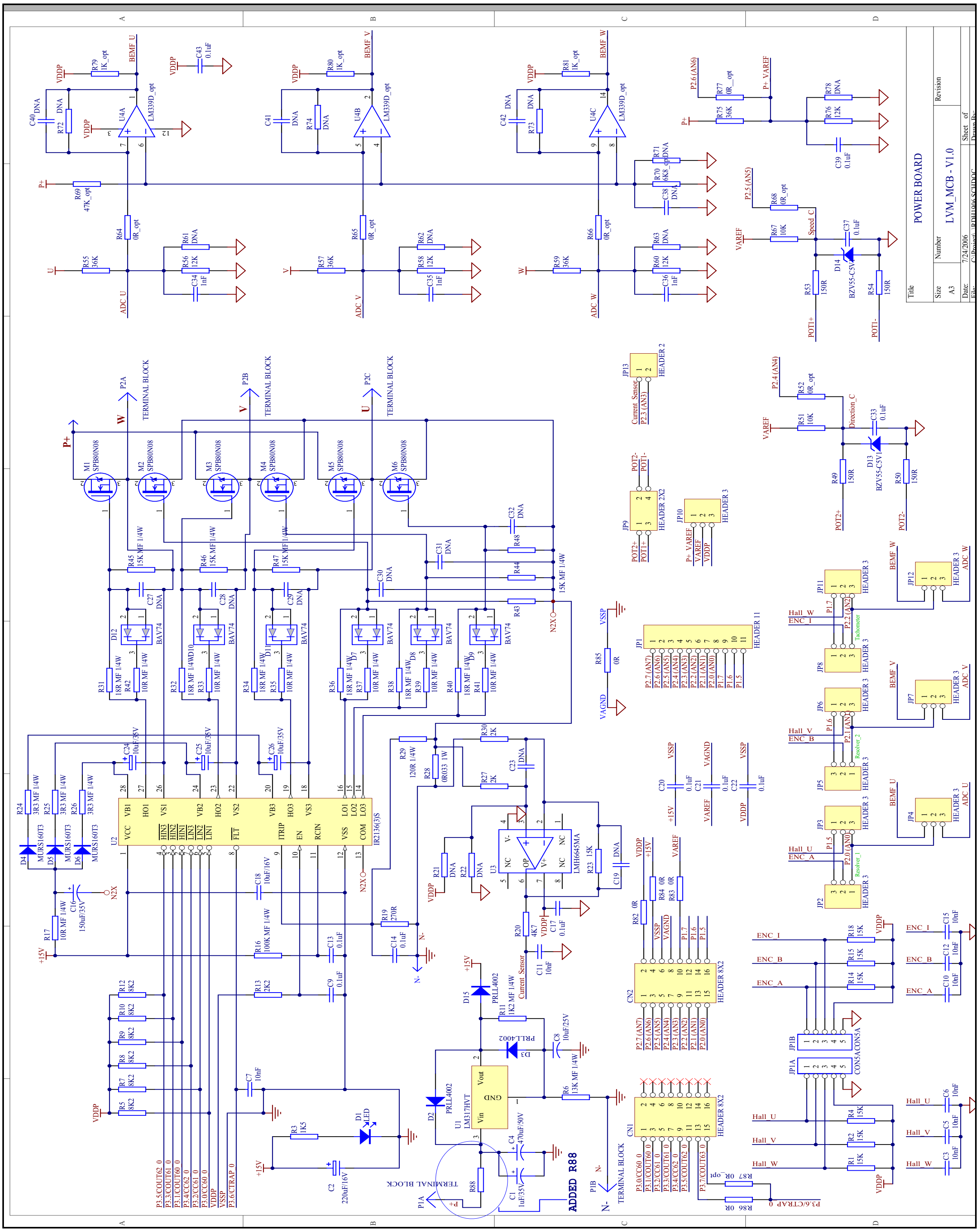

Figure 4-1 Schematic Motor Driver Board

5 Hardware Installation Guide

This system comprises Infineon XC866 Microcontrollers Starter-kit and Motor Driver Board.

5.1 Hardware Installation Overview

The installation and cooling of the appliances shall be in accordance with the specification in the relevant documentation.

The Motor Driver Board must be protected against excessive strains. No components must be bent or isolating distances altered in the course of transportation or handling.

The Motor Driver Board contains electrostatic sensitive components which are liable to damage through improper use or handling. Electric components must not be mechanically damaged or destroyed (potiential health risks).

5.1.1 Electrical Connection

The Motor Driver Board is tuned to power up with an input voltage supply of 20V. Installation which include the XC866 Starter-kit and Motor Driver Board shall be equipped with additional control and protective devices in accordance with the relevant application safety requirements, e.g. accident prevention rules etc. Changes to the Motor Driver Board by means of the Operating Software is admissible.

The electrical installation must be carried out in accordance with the relevant requirements(e.g. cross-sectional areas of conductors, fusing, PE connection). Observance of the limit values required by EMC laws is in the responsibility of the user.

After disconnection of Motor Driver Board from the voltage supply, live appliance parts and power terminals must not be touched immediately because of possibly charged capacitors.

The capacitor C1 must be removed if the input voltage is greater than 35V. If the input voltage is greater than 45v, the auxiliary supply circuitry must be removed from the Motor Driver Board.

Note: The maximum voltage rating of board is limited by the voltage regulator LM317HVT. The maximum voltage rating of the MOSFETs is 75V.

The resistors values of R55, R56, R57, R58, R59, R60, R75 and R76 must be recalculated should the input voltage deviate from the normal operating input voltage, P+ = 20V.

Note: The mentioned resistors must be verified and change accordingly before increasing the input voltage, P+. The reference voltage, ADC and P+_VAREF, which has a voltage limit of 5V increases with P+. The incremental reference voltage will damage the microcontroller when it exceeds the microcontroller's port voltage tolerant.

5.1.2 Step-by-Step DC Power Installation Guide

- Power up the DC power supply and adjust the voltage supply to 20Vdc. Limit the current supply to 500mA.
- Connect the DC power supply to Terminal Block P1. The connection polarity is important here.
- When the power connection is correctly done, the auxiliary power LED D1 will illuminate.

5.1.3 Step-by-Step Motor Setup Guide

- Connect the 3-Phase BLDC Motor wires to the Connector P2.
- Polarity orientation is important here and is subjective to the motors used.
- Connect the Hall sensor wires to JP 1A.
- Set the Jumpers of JP3, JP6 and JP11 to Hall-sensor mode. (Place the Jumpers to Pin 2 and 3 of JP3, JP6 and JP11).
- Hold on to the reset button on the Starter-kit before powering up the boards. Release the reset button when the board is power up.
- The BLDC motor will spin when the connection is down correctly.

Note: The software need to be modified to accomodate to different motors used.

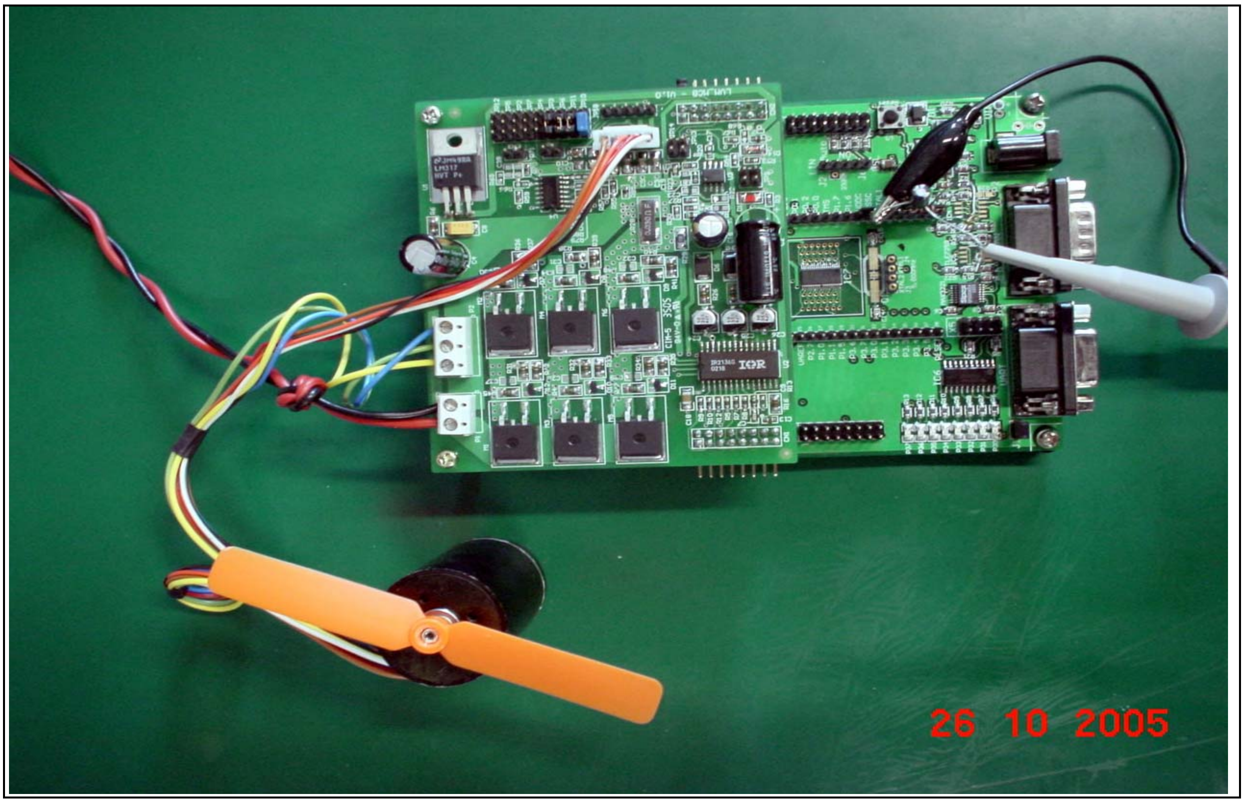

Figure 5-1 BLDC Motor Driver Board Hardware Setup

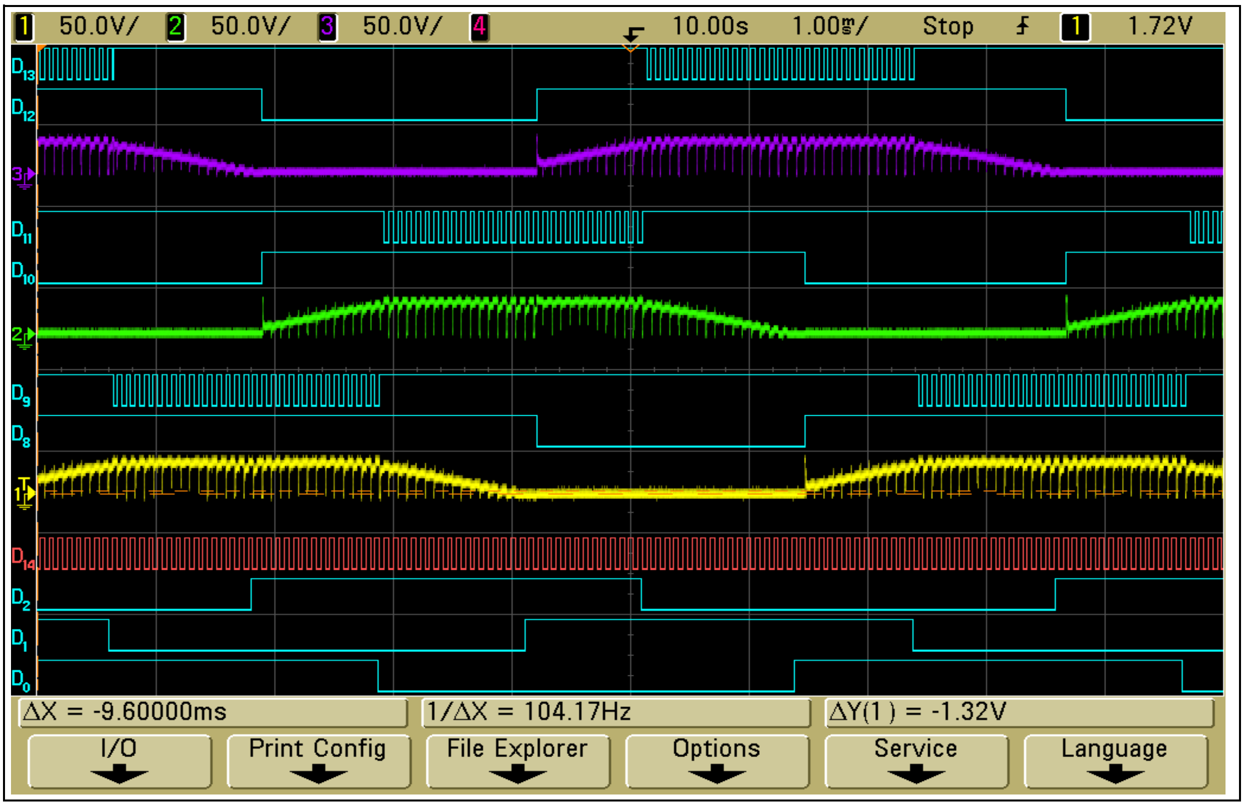

Figure 5-2 BLDC Motor Signals Output

- The Yellow Signal is V_U , Green Signal is V_V and the Purple Signal is V_W .
- The D_0 , D_1 and D_2 are the Hall-Sensor signals.
- The above wavesignals could be obtained when the hardware is correctly setup.

6 Hardware Update

6.1 Current Sensor Modification

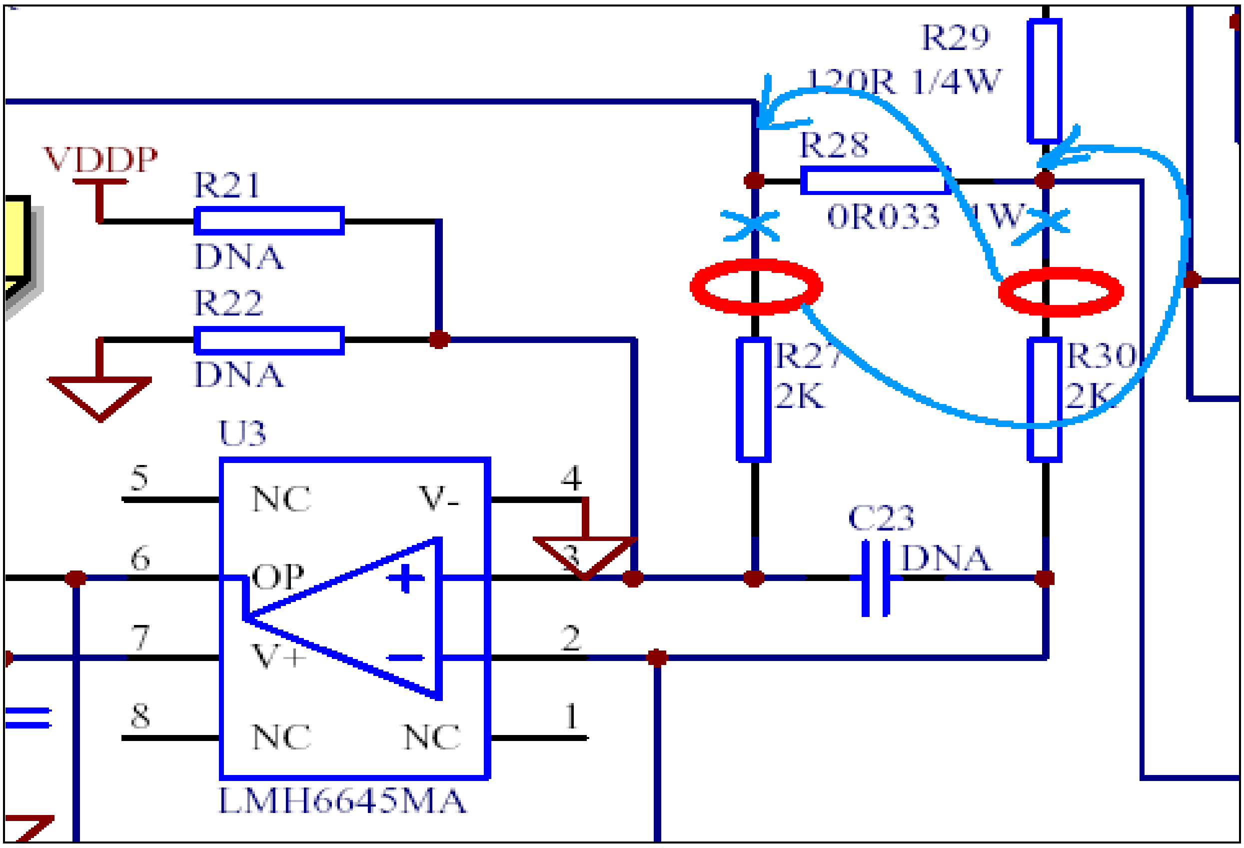

Figure 6-1 Current Sensor Comparator Hardware modification

The original hardware connection will result in having a negative signal output from the comparator U3. Therefore one end of the resistor R27 is to connect to the high side of the shunt resistor R28 and the low side of the shunt resistor is to be connected to the other end of resistor R30.

7 Function Setting

Table 7-1 Function Setting

	Hall Sensors	Encoder	BEMF	ADC
JP2/JP3	(1-2)/(2-3)	(3-2)/(1-2)	X	X
JP5/JP6	(1-2)/(2-3)	(3-2)/(1-2)	X	X
JP8/JP11	(1-2)/(1-2)	(2-3)/(2-3)	X	X
JP4	X	X	(1-2)	(2-3)
JP7	X	X	(1-2)	(2-3)
JP12	X	X	(1-2)	(2-3)

- The “X” represents non-connection.
- “(1-2)” represents placing a jumper at pin 1 and pin 2 to the respective jumper.

8 Reference

The following reference links are directed to the Infineon tool-partners.

- **KEIL Software**

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