Microcontroller

AP90001

Hardware Description
Low Voltage Inverter

Application Note

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Low Voltage Inverter

Revision History: V1.0, 2009-01-29

Previous Version(s):
none

Page	Subjects (major changes since last revision)

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1 Overview

The Low Voltage Inverter is designed to provide a robust power inverter including feedback signals for 24 V and 48 V motors. The Inverter offers a seamless fit to the DriveCards offered by Infineon.

A PMSM motor board is available in addition to the low voltage inverter, and is also described in this application note.

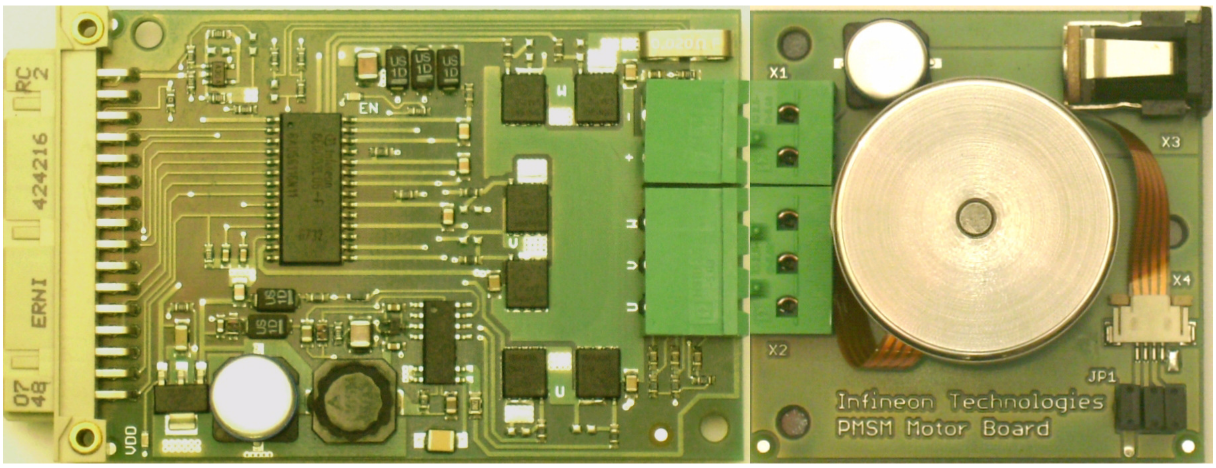


Figure 1 Low Voltage Inverter with PMSM Motor

1.1 Key Features

Low Voltage Inverter

- 3 phase full bridge inverter with n-channel MOSFETs 19.6 mΩ, 100 V
- Integrated driver with bootstrap technology 6ED003L06-F
- On Board power supply
  - Switch mode power supply (15 V) for MOSFET driver ICE3B0565JG
  - low drop voltage regulator (5 V) for MCU TLE4264-2
- Voltage range: 23 V .. 56 V
- Maximum DClink current: 7.5 A
- Seamless connection of Infineon Technologies DriveCards, Microcontroller boards dedicated for motor control

Pluggable PMSM Motor Board

- Easy to use with 24 VDC plug-in power supply
- Additional filter capacitor (100 µF, 50 V) on board
- Motor connections fed via jumpers for easy current measurement
- Small PMSM motor on board (24 V, 15 W) (Maxon EC flat 32)

1.2 Block Diagram

Figure 2 shows the block diagram of the Inverter and motor board. The design targets robustness, compatibility to standard Inverter designs and flexibility. The Inverter's power devices are MOSFETs with an $R_{DS(ON)}$ of less than 20 mΩ, the driver is based on SOI technology with a voltage rating up to 600 V, and the motor is placed on a separate board which can be unplugged.

The Inverter board contains a Switch Mode Power Supply (SMPS) providing 15 V for the gate driver. A low drop voltage regulator generates the 5 V supply for the microcontroller board, which can be plugged onto the system. The DClink current can be measured via a 20 mΩ shunt and an operational amplifier adjusted to a gain of 34. For sensorless block commutation algorithms, the output voltages can be measured via voltage dividers by the microcontroller.

The pluggable motor board contains, next to the motor, an EC flat motor from Maxon Motors, a filter capacitor. This motor board is intended to provide an easy start with motor control algorithms provided as software packages by Infineon Technologies. As soon as the first step is taken, the motor board can be unplugged and a custom motor can be connected directly to the low voltage Inverter.

Note: Remember to connect a filter capacitor at the supply voltage with a power rating that fits to that motor.

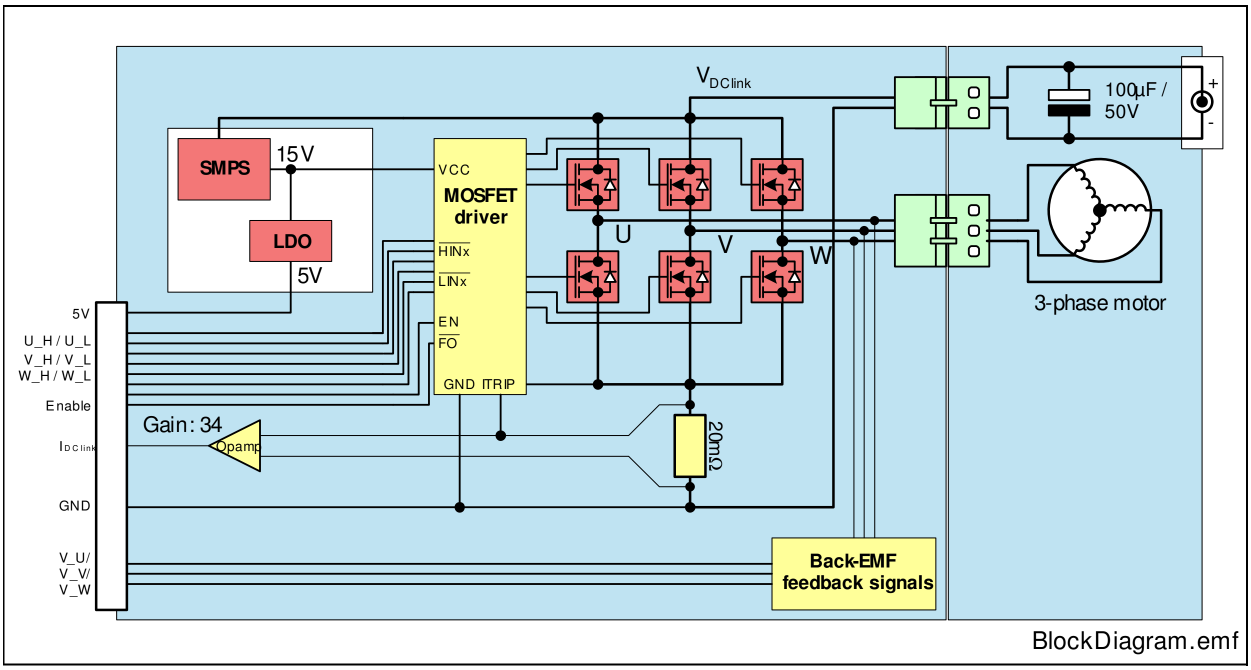


Figure 2 Block Diagram of Low Voltage Inverter

2 Hardware Description

2.1 Connectors

The power supply for the Low Voltage Inverter is connected to X1. The SMPS is designed to start operation at supply voltages greater than 23 V. For correct operation with high peak currents, it is recommended to add a filter capacitor externally unless the motor board is connected. The motor board itself is equipped with a filter capacitor. The 3 phase motor is connected at X2. See **Figure 3** for details:

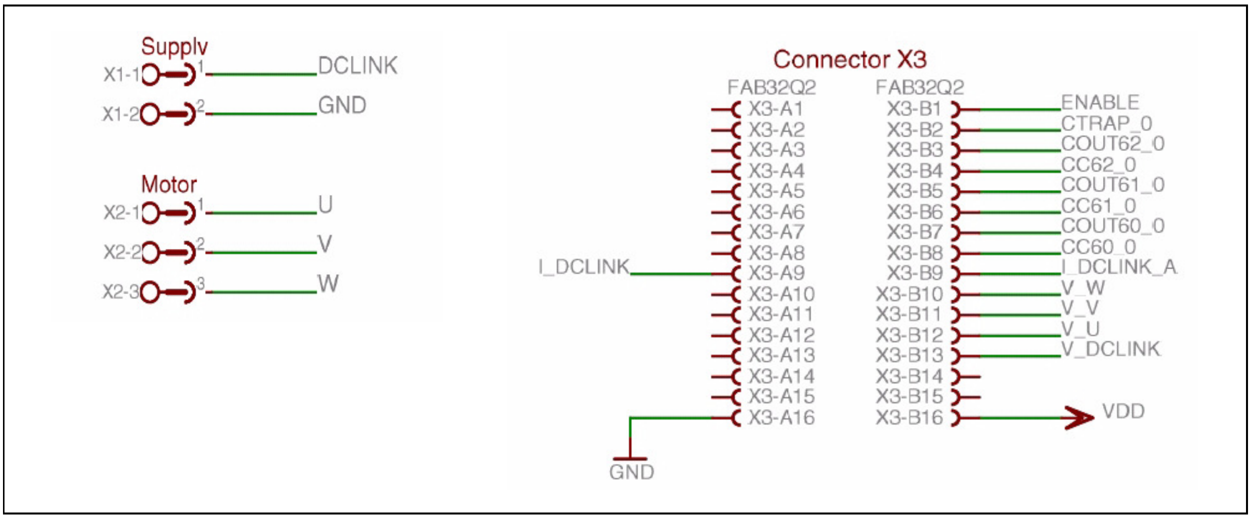


Figure 3 Power Supply Connector X1, Motor Connector X2 and Drive Card Connector X3

The standard 32-pin connector (DIN 41612, Q/2) provides all connectivity to a microcontroller. The lowside (_L) and highside (_H) switches of the three power stages U, V and W are to be connected to the PWM signals of the MCU.

A low signal at the CTRAP pin switches all power stages in passive state and acts as an emergency shut-down for the Inverter. A 5 V power supply is provided at pins A1-B1 of connector X3 of the Inverter board in order to supply the MCU and peripheral components.

Table 1 lists the signals available at the DriveCard connector X3 and the appropriate signals of the available DriveCards.

The DriveCards listed below can be used together with the Low Voltage Inverter:

Order Code	MCU	Algorithm Example
KIT_XC886_DC_V1	XC886CM	sensorless FOC for PMSM Motor
KIT_XC878_DC_V1	XC878CM	sensorless FOC for PMSM Motor + digital PFC

Order Code	MCU	Algorithm Example
KIT_XC164CM_DC_V1	XC164CM	Encoder based FOC for PMSM Motor
KIT_XE164_DC_V1	XE164F	Two sensorless, encoder based or resolver based FOC algorithms + digital PFC

Table 1 Signal Connections to Drive Cards

XE164	XC164	XC878	XC886	X3				XC886	XC878	XC164	XE164
GND	GND	GND	GND	GND	A16[1)]	B16[1)]	VDD 5 V	VCC	VCC	VCC	VCC
P0.6	P1H.5	P5.3& P5.4	-	-	A15	B15	-	-	P5.2	P9.1	P0.5
ADC1-ch5	AN14	-	-	-	A14	B14	-	-	P5.5	AN6	ADC1-ch6
ADC0-ch5	AN15	-	-	-	A13	B13	V_DC	AN1	AN1	AN4	ADC1-ch15
ADC1-ch0	AN10	-	-	-	A12	B12	V_U	AN7	AN7	AN0	ADC0-ch0
ADC1-ch2	AN11	-	-	-	A11	B11	V_V	AN6	AN6	AN1	ADC0-ch3
ADC01-ch11	AN12	AN2	AN2	-	A10	B10	V_W	AN5	AN5	AN2	ADC01-ch9
ADC01-ch10	AN13	AN3	AN3	IDCLINK	A9	B9	IDCLINK A	AN4	AN4	AN3	ADC01-ch8
P1.7	-	P4.0	-	-	A8	B8	CC60	P3.0	P3.0	P1L.0	P10.0
P1.5	-	P4.1	-	-	A7	B7	COUT60	P3.1	P3.1	P1L.1	P10.3
P1.6	-	P4.4	-	-	A6	B6	CC61	P3.2	P3.2	P1L.2	P10.1
P1.4	-	P4.5	-	-	A5	B5	COUT61	P3.3	P3.3	P1L.3	P10.4
P1.2	-	P4.6	-	-	A4	B4	CC62	P3.4	P3.4	P1L.4	P10.2
P1.1	-	P4.7	-	-	A3	B3	COUT62	P3.5	P3.5	P1L.5	P10.5
P1.0	-	P4.3	-	-	A2	B2	CTRAP	P3.6	P3.6	P1L.7	P10.6
P0.1	-	P5.1	-	-	A1	B1	ENABLE	P4.0	P5.0	P1H.3	P0.0

1) A: Lower and inner row, B: Upper and outer row

2.2 MOSFET Driver

The gate driver (6ED003L06F) is a full bridge driver to control power devices like MOS-transistors or IGBTs in 3-phase systems with a maximum blocking voltage of +600V. Based on the use of SOI-technology, there is an excellent ruggedness on transient voltages. No parasitic thyristor structures are present in the device. Hence, no parasitic latch up can occur at all temperature and voltage conditions.

This full-bridge driver provides signal interlocking of every phase to prevent cross-conduction.

Figure 4 shows the schematics of the gate driver including the bootstrap circuitry. Figure 5 shows the schematics of the MOSFET power stages.

The gates of the MOSFETs are connected via resistors to the driver. By changing these resistors, the switching behavior (especially slew rate) of the MOSFETs can be adjusted to the application's needs. Of course, the MOSFETs can be changed if required. Please refer to: **www.infineon.com/MOSFETS**.

There are resistive voltage dividers at the outputs of the full bride. They are intended to be used for back EMF measurement at block commutating algorithms.

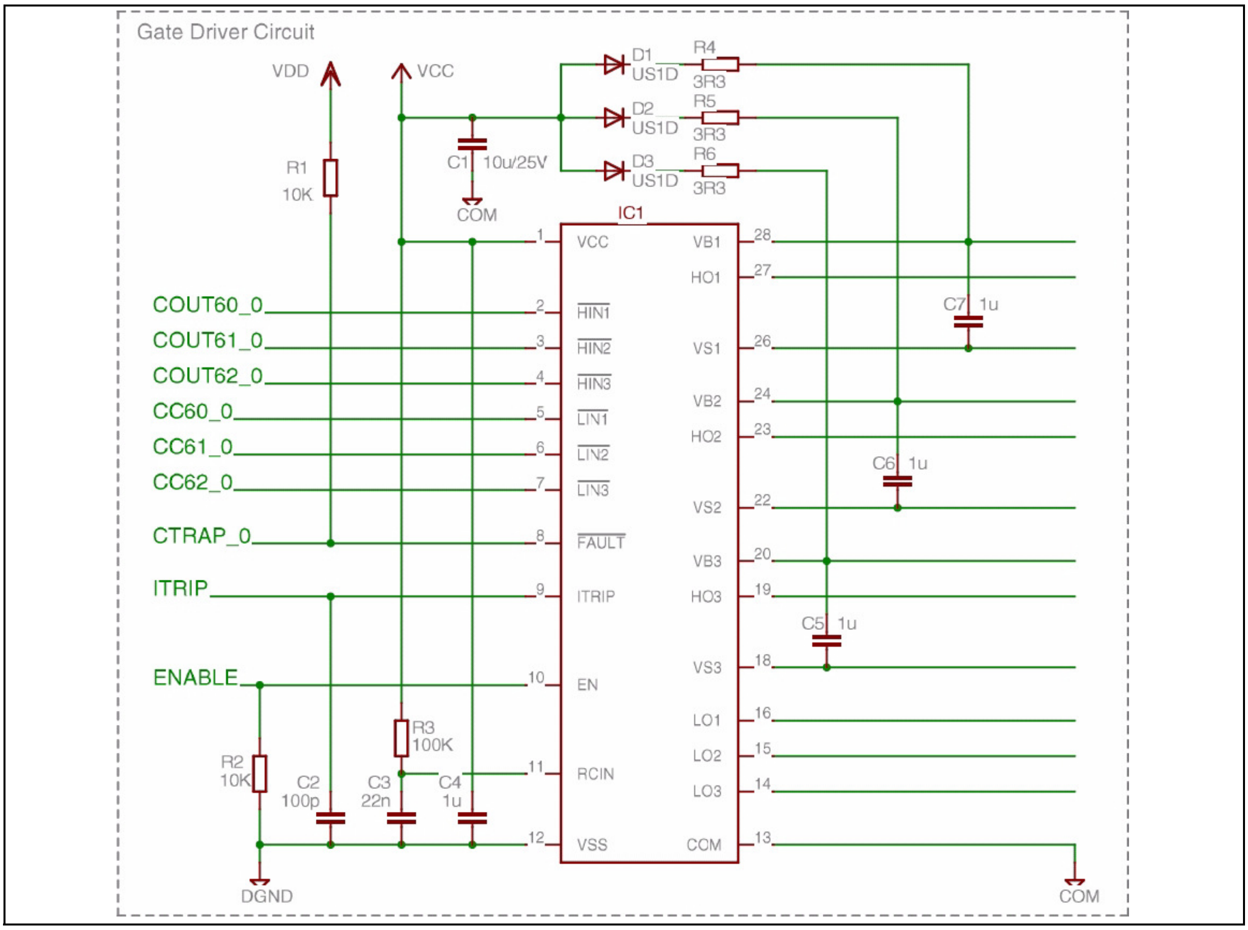


Figure 4 Gate Driver

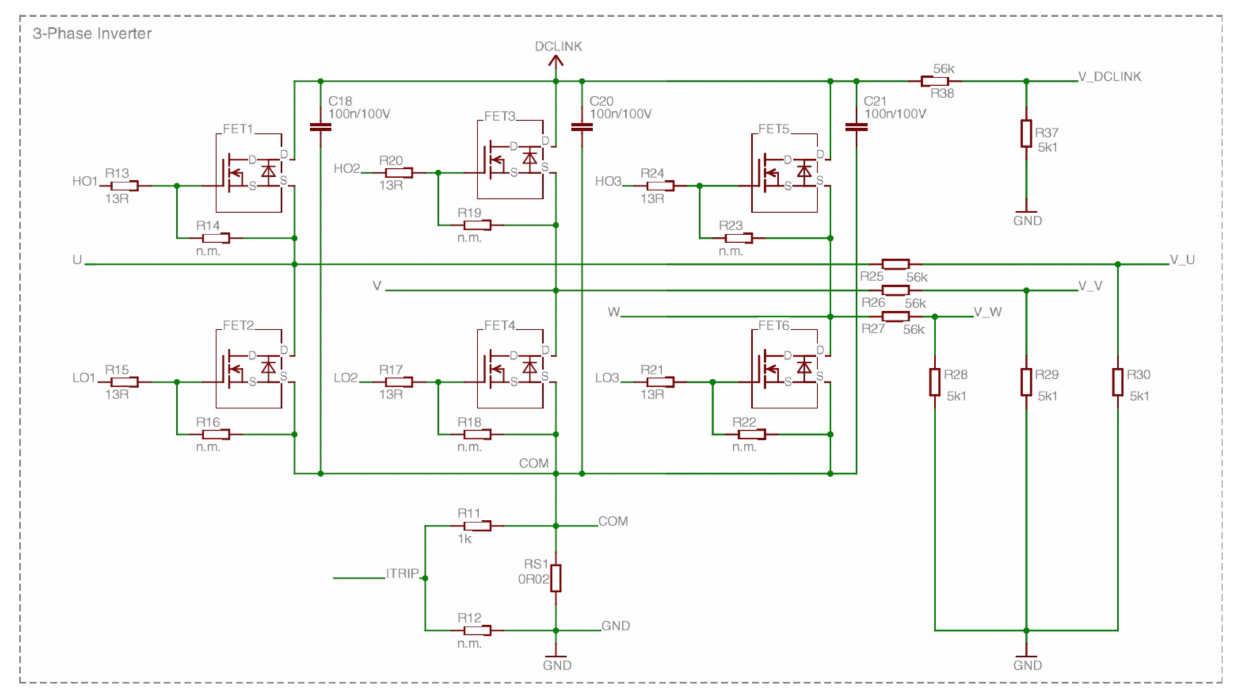


Figure 5 Power MOSFETs and Back EMF Resistors

The shunt resistor RS1 is used by the gate driver both to detect heavy over load and for DC-link current measurement.

2.3 DC-Link Current Measurement

A differential amplifier is provided in order to measure the DC-Link current via a single shunt in the common lowside path of the MOSFETs. The bandwidth of this amplifier is chosen to enable the phase current reconstruction from the common DC-Link current. The amplifier is adjusted to a gain of 34.

The current measurement ratio $U_{\text{IDClink}} / I_{\text{DC\_Link}}$ = 0.68 V/A.

As a result, the maximum current which can be measured by a 5 V A/D converter is 7.35 A.

A mounting option R40 is available in order to adjust an additional offset voltage to the measurement. In case negative voltages have to be measured as well, it is recommended to mount the resistors R9, R39 and R40 with 16 kΩ. As a result, the offset voltage is 2.5 V and the gain is 17. The measurement range is then extended to +/- 7.35 A.

Please refer to **Figure 6** for details of the DC-Link current measurement circuitry.

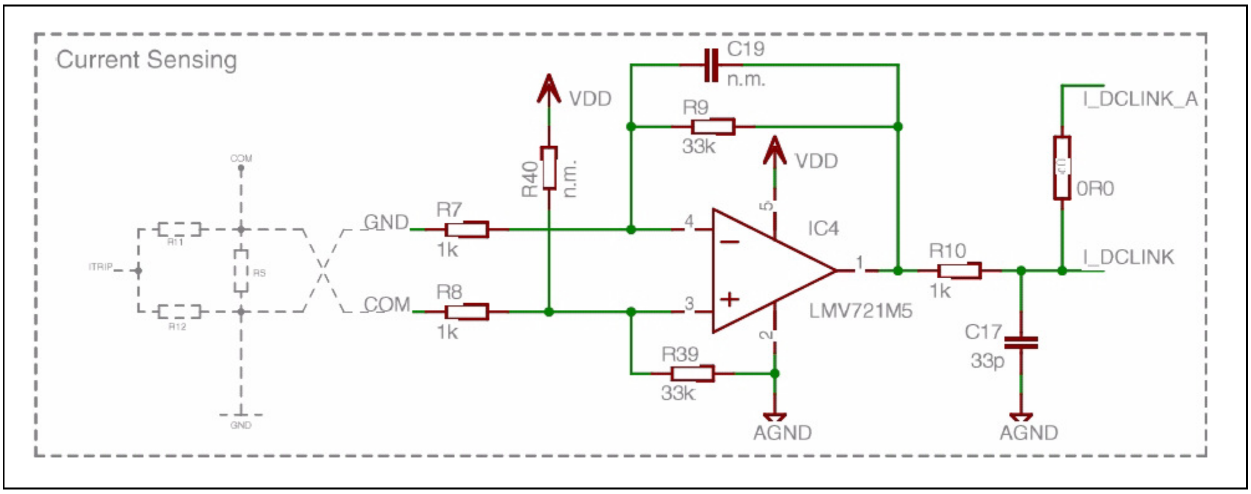


Figure 6 DC-Link Current Measurement

Note: Although the system is adjusted to 7.35 A, it can be easily enhanced to motors with lower impedance by replacing the MOSFETS, the shunt resistor and/or the gain of the operational amplifier.

2.4 Power Supply

There are three power domains at the Low Voltage Inverter. First the main power supply that is used for the power Inverter. The main power supply voltage (DC-link) is fed to a switch mode power supply circuit (SMPS) which will provide a 15 V power supply for the gate driver, the second power domain VCC. Please see **Figure 7** for details.

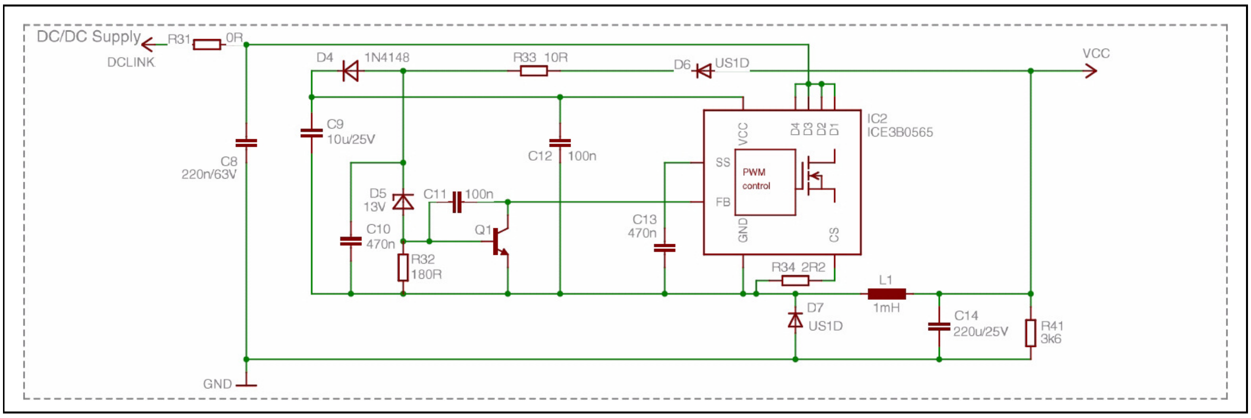


Figure 7 Switch Mode Power Supply (SMPS)

The CoolSET™-F3 (ICE3B0565JG) meets the requirements for Off-Line Battery Adapters and low cost SMPS for the lower power range. The switching frequency is fixed to 67 kHz with frequency jittering for low EMI. The CoolSET F3 family provides the highest output power with the lowest losses available in the industry.

The CoolSET-F3 is designed for voltages up to 600 V, but can be used for low voltage applications as well. This wide operating range is limited for the lowest voltages, which could cause the startup circuit to fail. It is recommended not to use the board below 23 V.

The output voltage of the SMPS is taken by a Low Drop Voltage regulator (LDO) which provides a 5 V power supply. This third power supply domain VDD is used by the operational amplifier and the MCU which is connected at the DriveCard connector X3.

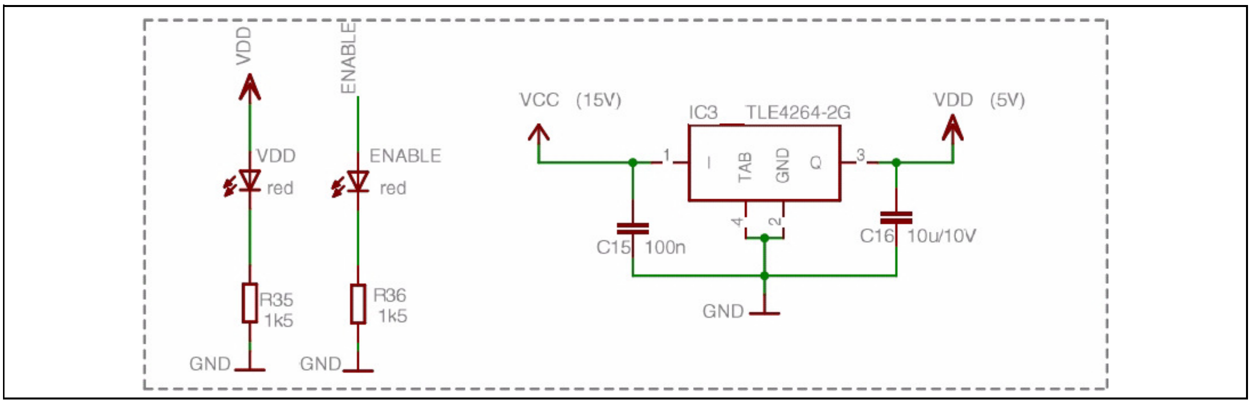


Figure 8 Low Drop Voltage Regulator (LDO)

An LED is mounted to the board signaling the availability of the 5 V supply voltage.

2.5 PCB Layout

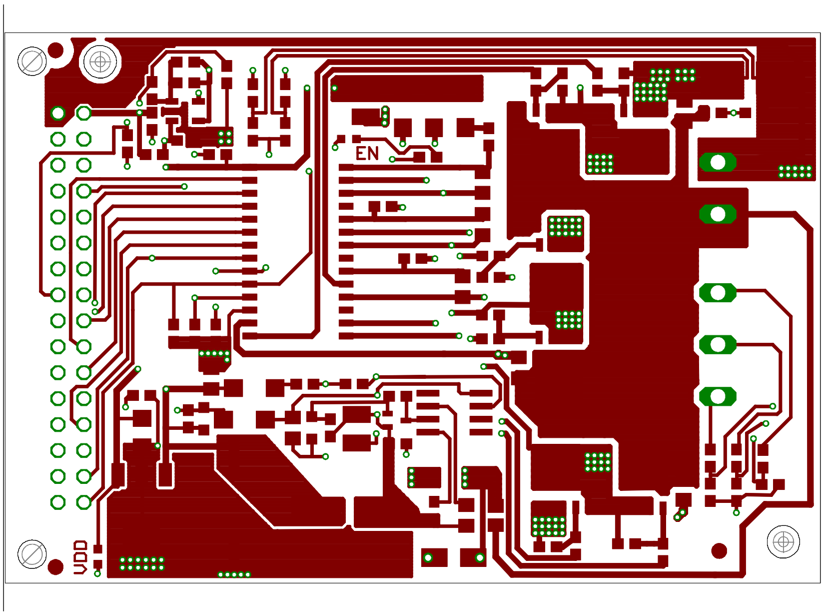


Figure 9 PCB Layout Top Layer

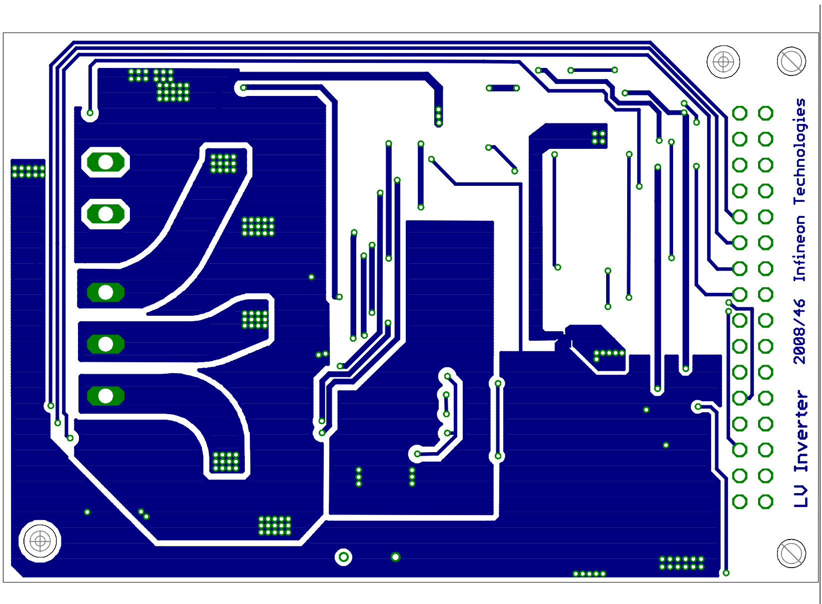


Figure 10 PCB Layout Bottom Layer

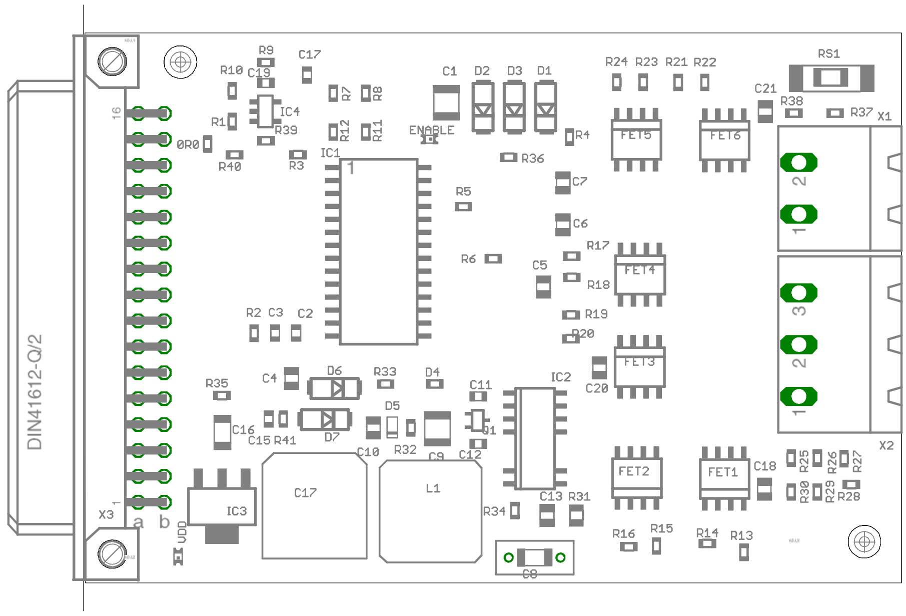


Figure 11 PCB Layout Component Placement

2.6 Bill of Materials

Component	Value	Package/Size
C1	10u/25V	C1210
C2	100pF	C0603
C3	22n	C0603
C4	1u/25V	C0805
C5	1u/25V	C0805
C6	1u/25V	C0805
C7	1u/25V	C0805
C8	220n/63V	C_CASE_RADIAL and SMD
C9	10u/25V	C1210
C10	470n	C0805
C11	100n	C0603
C12	100n	C0603
C13	470n	C0805
C14	220u/25V	CASEG
C15	100n	C0603
C16	10u/10V	C1206
C17	33pF	C0603
C18	100n/100V	C0805

Component	Value	Package/Size
C19	n.m.	C0603
C20	100n/100V	C0805
C21	100n/100V	C0805
D1	US1D fast recovery	DO214AC
D2	US1D fast recovery	DO214AC
D3	US1D fast recovery	DO214AC
D4	1N4148	R0603
D5	13V zener diode	SOD110-R
D6	US1D fast recovery	DO214AC
D7	US1D fast recovery	DO214AC
0R0	0R	R0603
R1	10K	R0603
R2	10K	R0603
R3	100K	R0603
R4	3R3	R0603
R5	3R3	R0603
R6	3R3	R0603
R7	1k	R0603
R8	1k	R0603
R9	33k	R0603
R10	1k	R0603
R11	1k	R0603
R12	n.m.	R0603
R13	13R	R0603
R14	n.m.	R0603
R15	13R	R0603
R16	n.m.	R0603
R17	13R	R0603
R18	n.m.	R0603
R19	n.m.	R0603
R20	13R	R0603
R21	13R	R0603
R22	n.m.	R0603
R23	n.m.	R0603
R24	13R	R0603
R25	56k	R0603
R26	56k	R0603
R27	56k	R0603

Component	Value	Package/Size
R29	5k1	R0603
R30	5k1	R0603
R31	0R	R0805
R32	180R	R0603
R33	10R	R0603
R34	2R2	R0603
R35	1k5	R0603
R36	1k5	R0603
R37	5k1	R0603
R38	56k	R0603
R39	33k	R0603
R40	n.m.	R0603
R41	3k6	R0603
RS1	0R02	R1206 and metal strip
L1	1mH	SMD10X10
X1	GMSTBA2MSTBA	PHOENIX
X2	GMSTBA3MSTBA	PHOENIX
X3	FAB32Q2	female, 32pins type Q/2
FET1	BSC196N10NS	SuperSO08, TDSON
FET2	BSC196N10NS	SuperSO08, TDSON
FET3	BSC196N10NS	SuperSO08, TDSON
FET4	BSC196N10NS	SuperSO08, TDSON
FET5	BSC196N10NS	SuperSO08, TDSON
FET6	BSC196N10NS	SuperSO08, TDSON
IC1	6ED003L06-F-GATEDRIVER	P-DSO-28
IC2	ICE3B0565	P-DSO16
IC3	TLE4264-2G	SOT223
IC4	LMV721M5	SOT23-5
Q1	BCR108W	SOT323
ENABLE	LED 0603 red	CHIPLED_0603
VDD	LED 0603 red	CHIPLED_0603

3 PMSM Motor Board

The Pluggable Permanent Magnet Synchronous motor board is intended to be used as a reference motor together with software packages for motor control.

3.1 Schematics

The schematics in **Figure 12** contains the connectors to the Inverter board X1 and X2, the power supply connector X3 and the motor connector X4.

The jumper JP1 can be used for current measurement as well as a connector for your custom motor.

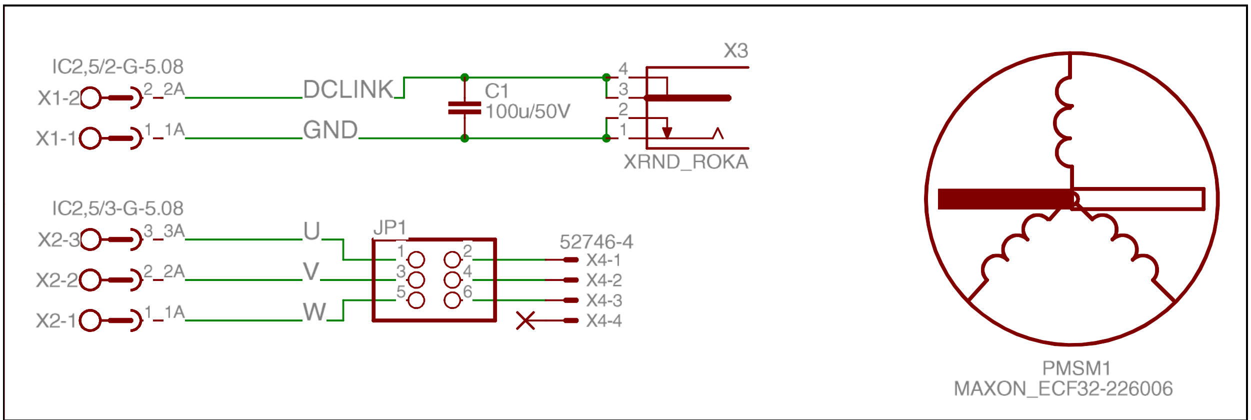


Figure 12 Schematics of PMSM Motor Board

3.2 Board Layout

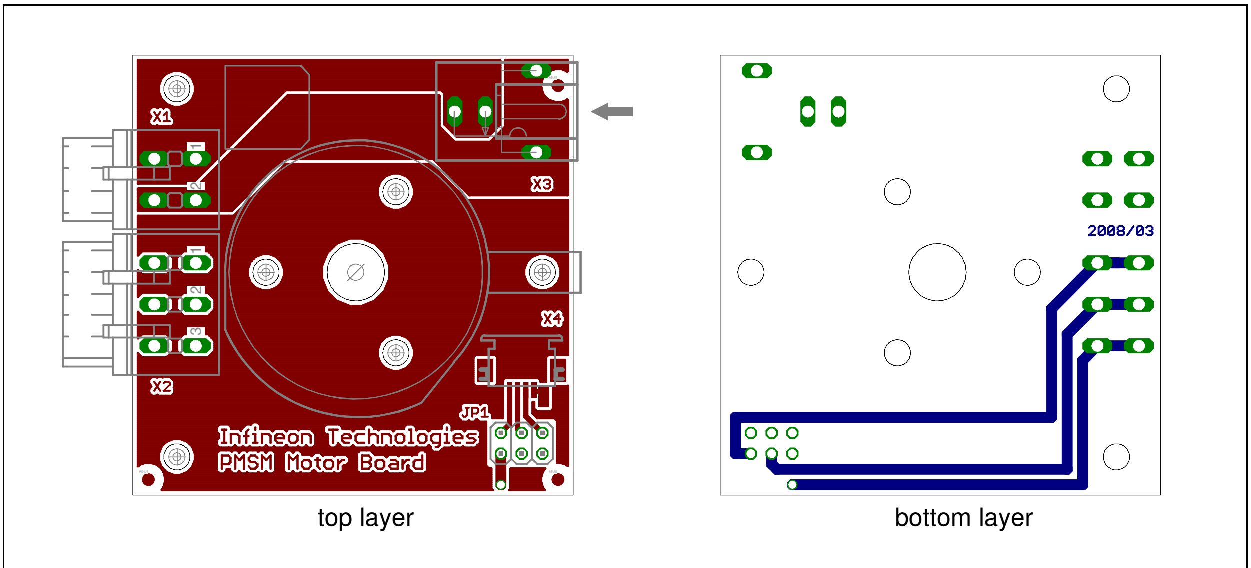


Figure 13 Layout of PMSM Motor Board

3.3 Motor

In this section, the technical data (revision April 2006) of the motor can be found.

Please refer directly to Maxon Motor internet page **http://www.maxonmotor.com** for the latest information about this ECflat motor.

3.3.1 Motor Data

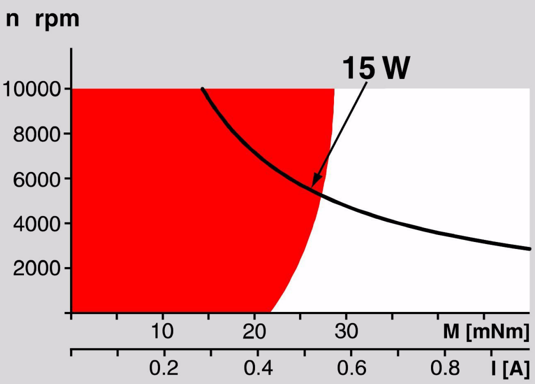
	Motor Data		226006
	Values at nominal voltage		
1	Nominal voltage	V	24.0
2	No load speed	rpm	4390
3	No load current	mA	73.4
4	Nominal speed	rpm	2740
5	Nominal torque (max. continuous torque)	mNm	24.2
6	Nominal current (max. continuous current)	A	0.506
7	Stall torque	mNm	85.8
8	Starting current	A	1.75
9	Max. efficiency		64
	Characteristics		
10	Terminal resistance phase to phase	Ω	13.7
11	Terminal inductance phase to phase	mH	7.73
12	Torque constant	mNm / A	49.0
13	Speed constant	rpm / V	195
14	Speed / torque gradient	rpm / mNm	54.5
15	Mechanical time constant	ms	20.0
16	Rotor inertia	gcm^2	35.0

Connection	**sensorless**
Pin 1	Motor winding 1
Pin 2	Motor winding 2
Pin 3	Motor winding 3
Pin 4	⅄ neutral point

Figure 14 Motor Data

3.3.2 Operating Range

Operating Range | Comments



Continuous operation
In observation of above listed thermal resistance (lines 17 and 18) the maximum permissible winding temperature will be reached during continuous operation at 25°C ambient.
= Thermal limit.

short term operation
The motor may be briefly overloaded (recurring).

Assigned power rating

Figure 15 Operating Range

3.3.3 Geometry

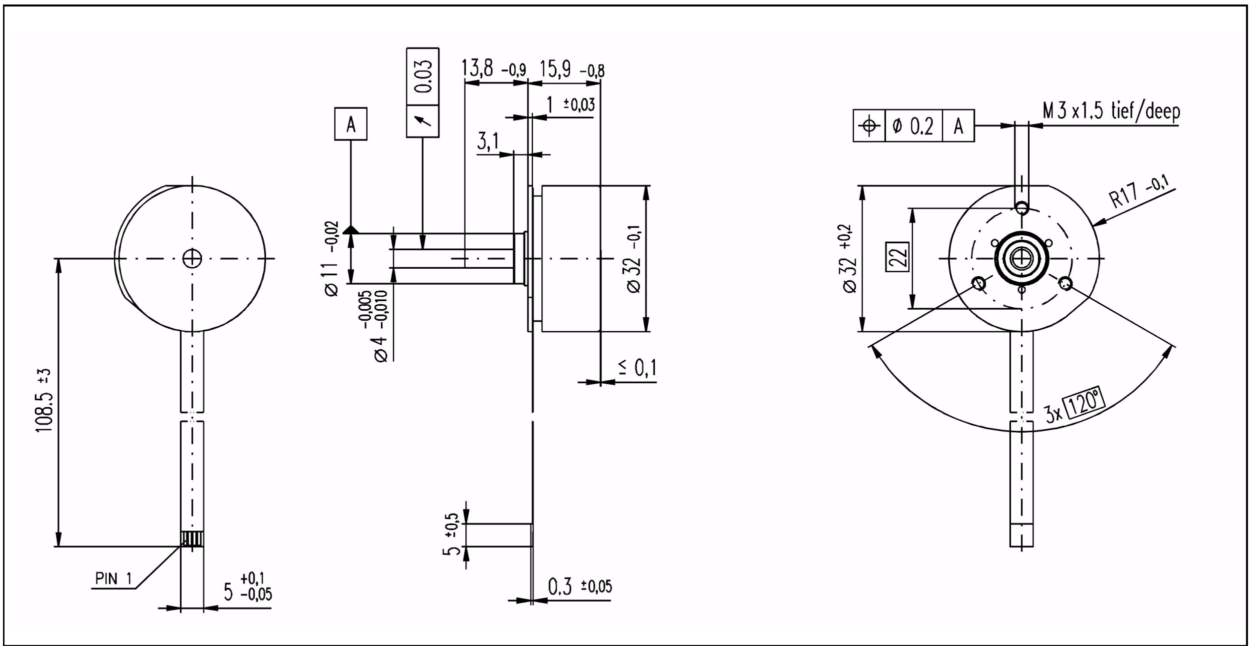


Figure 16 Geometry

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