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AP08060

CANmotion

Evaluation Platform with BLDC Motor featuring XC886CM Flash Microcontroller

Version 2007/10

Microcontrollers

Never stop thinking

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1 Overview

The CANmotion board was designed to provide an easy to use BLDC motor control platform. The board is equipped with a reverse polarity safe power supply with a DC/DC converter for 5 V supply line, a high performance 8 bit microcontroller with 32 kB flash memory, an operational amplifier for the DC-link current measurement, a resistor network for back EMF and DC-link voltage measurement, a CAN interface and of course an inverter with discrete gate driver.

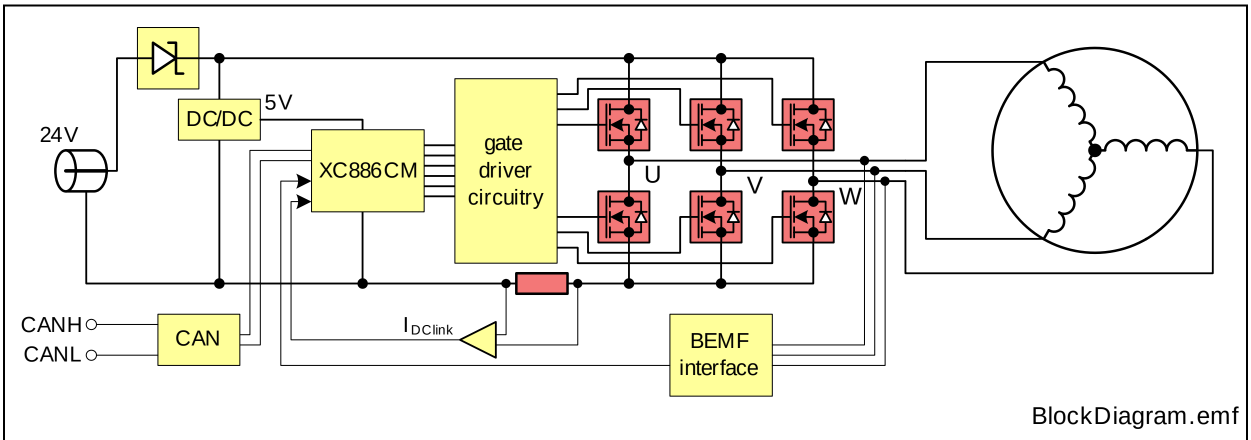

Figure 1 Block Diagram CANmotion Board

Thus, this platform can be used for various motor control schemes supporting DC-link voltage and current measurement as well as back EMF voltage measurement. As a result, sensorless block commutation can be executed as well as sinusoidal commutation schemes like sensorless FOC. The focus of this evaluation platform are sensorless control techniques. In order to provide a comprehensive platform, hall sensor based control techniques can also be taken into account. The bottom side of the PCB is equipped with test points which are directly connected to the dedicated hall sensor inputs of the microcontroller.

This application note is intended to describe the CANmotion board in detail in order to serve as a design guideline for low voltage three phase BLDC drivers with XC886C(L)M.

Although the design can be used for various control schemes, it is best for sensorless field oriented control. The gate driver is tuned in terms of minimum switching time and the current measurement is provided by a shunt in the DC-link. Please refer to the application note AP08059 for details on how to implement a sensorless FOC algorithm with the XC886/8C(L)M. There are additional application notes available describing sensorless block commutation using the Back-EMF method.

Figure 2 shows the CANmotion board mounted with the 24 V BLDC motor.

Figure 2 FOC Drive Application Kit

1.1 Key Features of XC886 which enable Field Oriented Control

- High performance 16-bit vector computer (CORDIC + MDU)
  - Vector rotation and transformations like Park and Clarke transformation
  - Normalizing and scaling
  - Interrupt based operation with minimum CPU load
- PWM unit for advanced motor control (CapCom6E)
  - 16-bit resolution for high precision space vector PWM generation
  - Dead time control for minimum hardware effort (direct control of MOSFET/IGBT)
  - CTRAP provides hardware overload protection
- A fast 10-bit A/D Converter (sample time of 0.25 µs)
  - Hardware synchronization to PWM unit reduces CPU load
  - Two out of four result registers to maximize sampling performance
  - Enables single shunt current measurement
  - Fast ADC reduces torque ripple due to minimized blind angle in sensorless FOC

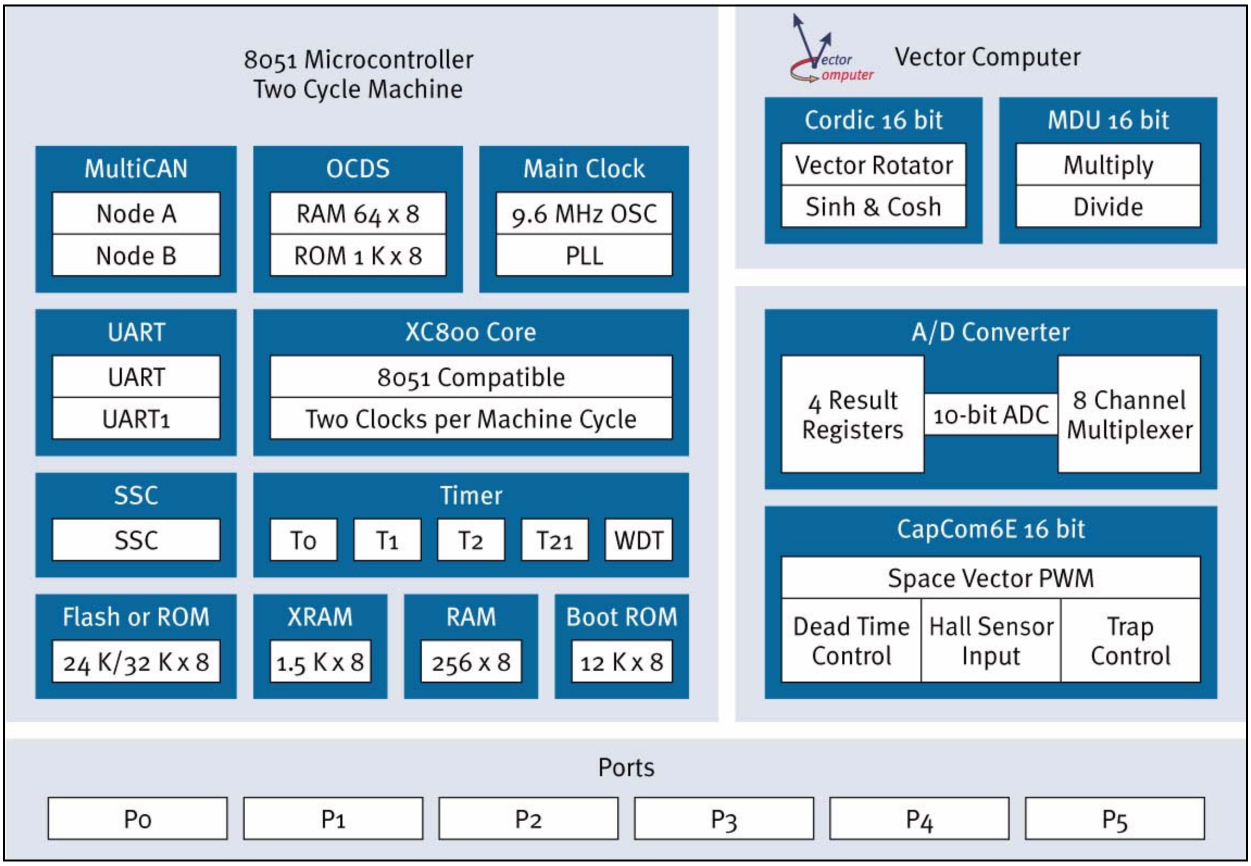

Figure 3 Block Diagram of XC886/8CM

2 CANmotion Board Design

This chapter is intended to describe the electrical design of the CANmotion evaluation platform including the circuit diagram and PCB layout. The version described here, which is also printed at the bottom layer of the PCB, is version 2007/10.

2.1 Microcontroller Unit

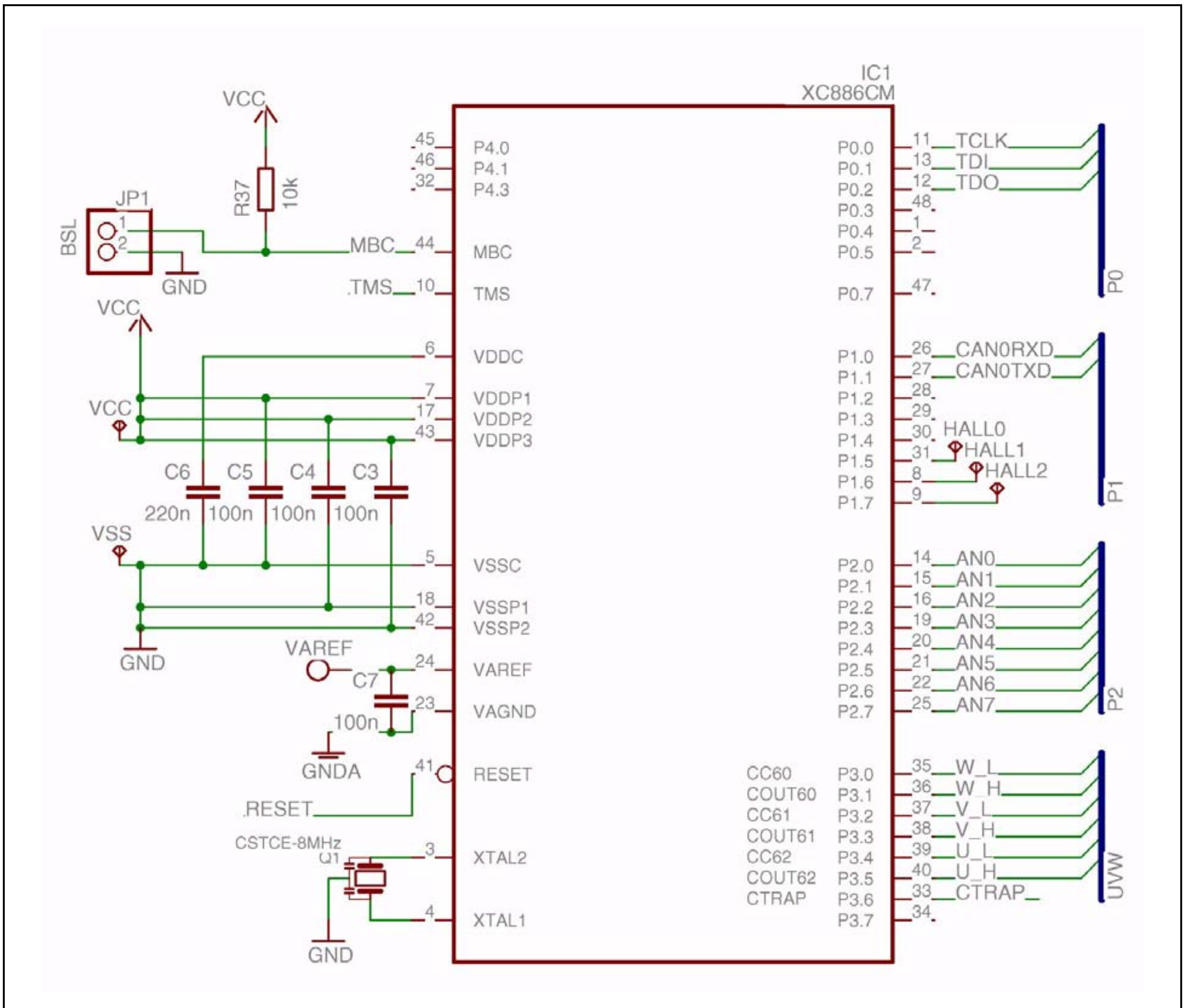

Figure 4 Microcontroller Unit

The MCU chosen for the CANmotion evaluation platform is an 8051 compatible XC886CM with 32 kilobyte flash memory. Following signals and peripherals are used for motor control:

- 10 bit fast ADC
  - Two ADC channels (ch3 & ch4) for current measurement

- Three ADC channels (ch5, ch6, ch7) for measurement of the inverter's output voltage for Back-EMF measurement
- One ADC channel (ch2) for DC-link voltage measurement

- PWM Unit CapCom6E
  - Delivering the input signals for the inverter (CC6x, COUT6x)
  - handling dead time control
  - providing emergency shut-down in overload condition (CTRAP)
  - triggering the ADC measurement by hardware events
  - Supporting hall sensor inputs (HALLx)
- CAN Interface (one of two CAN nodes)
  - used for flash download and debug communication
  - used for parameter setup like reference speed

2.2 On-Chip Debug Support

For flash download and debug purposes, a JTAG connector providing on-chip debug support is available in the design. This connector is not mounted to the board, because debugging a motor control application can easily destroy the inverter or the motor. Imagine the inverter switching and suddenly stopping operation. Stopping means maintaining the latest state as a direct current.

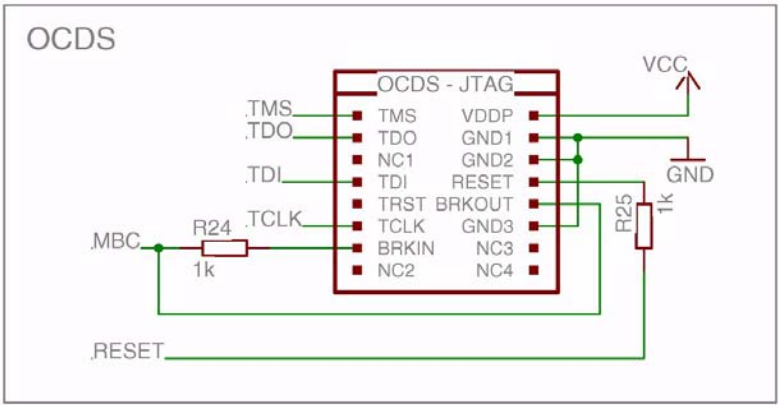

Figure 5 OCDS - JTAG Interface

The CANmotion evaluation platform provides a CAN interface, described in **Chapter 2.6**, for debug, parameter setup and download purposes.

2.3 Inverter

The inverter is designed by a discrete driver and MOSFETs. Each of the three channels for motor phase U, V and W are identically designed. In this subsection, channel U represents the design of all output channels.

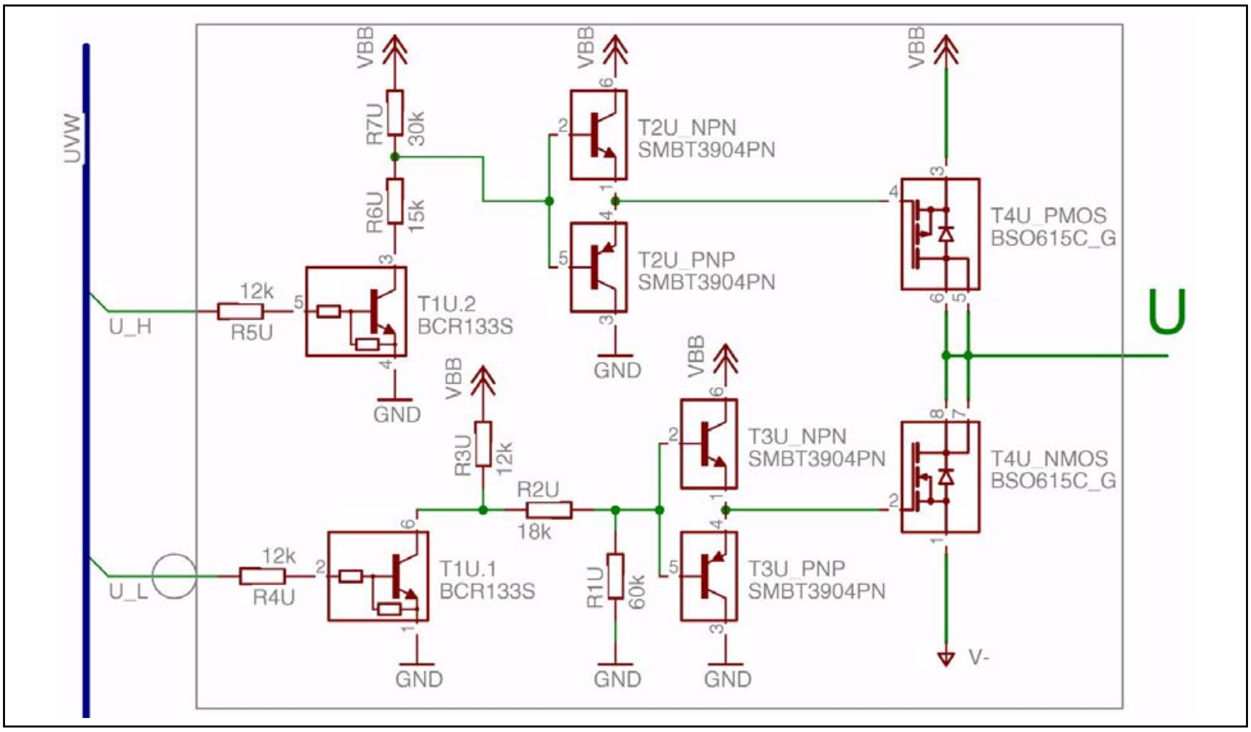

Figure 6 Inverter Design - Output Channel U

Note: This discrete MOSFET driver is realized providing no protection at all. Please note that any cross current (activation of high-side and low-side switch simultaneously) will destroy the MOSFETs.

Each output of an inverter can be divided in two main parts, the high-side and the low-side part. The high-side part is connected to the positive supply voltage. The low-side part to the negative supply voltage. The high-side and low-side switches can be realized by various concepts. Here, MOSFETs are used as power semiconductors. The gate driver and level shifter is realized by bipolar transistors.

A MOSFET is operating in it's $R_{\mathrm{DS(ON)}}$ range and showing switching behavior, when the gate-source voltage is high enough compared to the threshold voltage. On the other hand, there is a destructive upper voltage limit for the MOSFET as well. The used MOSFETs (BSO 615 C G) are rated by a maximum gate-source voltage of 20 V, the threshold voltage is less than 2 V.

The bipolar transistor pair T2 and T3 are used as collector follower, meaning they provide a current gain in both directions, but almost no voltage gain. As a result, the voltage at the input (base) is almost equal to the voltage at the output (collector).

The resistor network to the left of this current amplifier adjusts the voltages in the safe operating range of the gate-source voltage. It is adjusted to a gate-source voltage of about 16 V. The transistor T1 which is a dual NPN transistor is used as level shifter from the 5 V domain of the MCU to the 24 V domain of the inverter. It is part of the gate driver adjustment.

The switching time depends on the gate charge of the MOSFETs, the charge and discharge current of the driver and the delay time of the level shifter. Resistor R4 and R5 reduce the base voltage to make sure the level shifter is reacting as fast as possible. The switching time of the MOSFETs are defined in a constant approximation by following equation:

$$Q = C \cdot U = I \cdot t \tag{1}$$

The gate charge is equal to the multiplication of capacitance and voltage and as well equal to the current flowing to (or from) the gate multiplied by the time.

The resistor network defines the charge and discharge current, whereas the collector follower amplifies this charge current.

2.4 Voltage Measurement

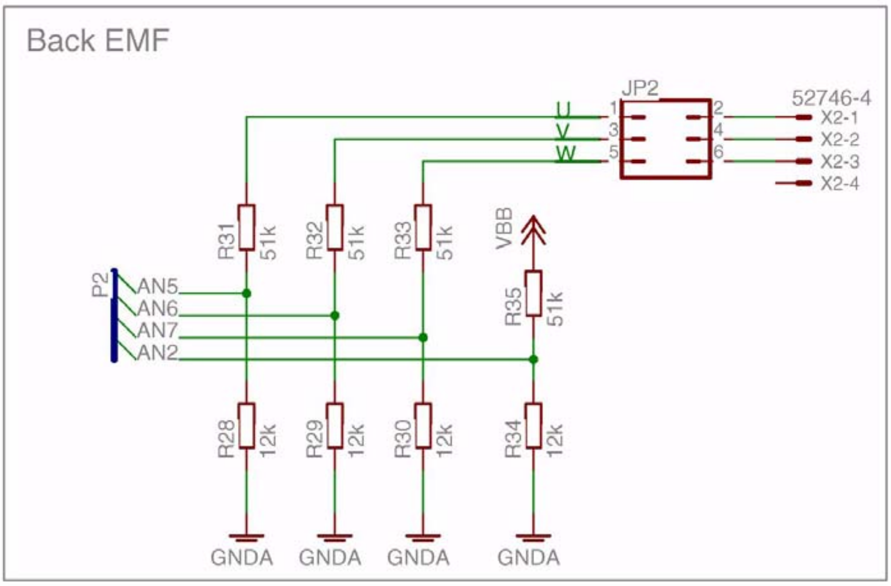

Figure 7 Back EMF and DC-link Voltage Measurement

A resistor divider is available in order to implement a Back EMF based sensorless control scheme. The divided outputs of the inverter are available at ADC channel 5, 6 and 7. Channel 2 supports monitoring of the DC-link voltage.

2.5 Current Measurement

There are two current measurement circuits available. First a current comparator in order to switch off the inverter in case of overload condition via CTRAP input pin. Second a shunt based current measurement with a difference amplifier.

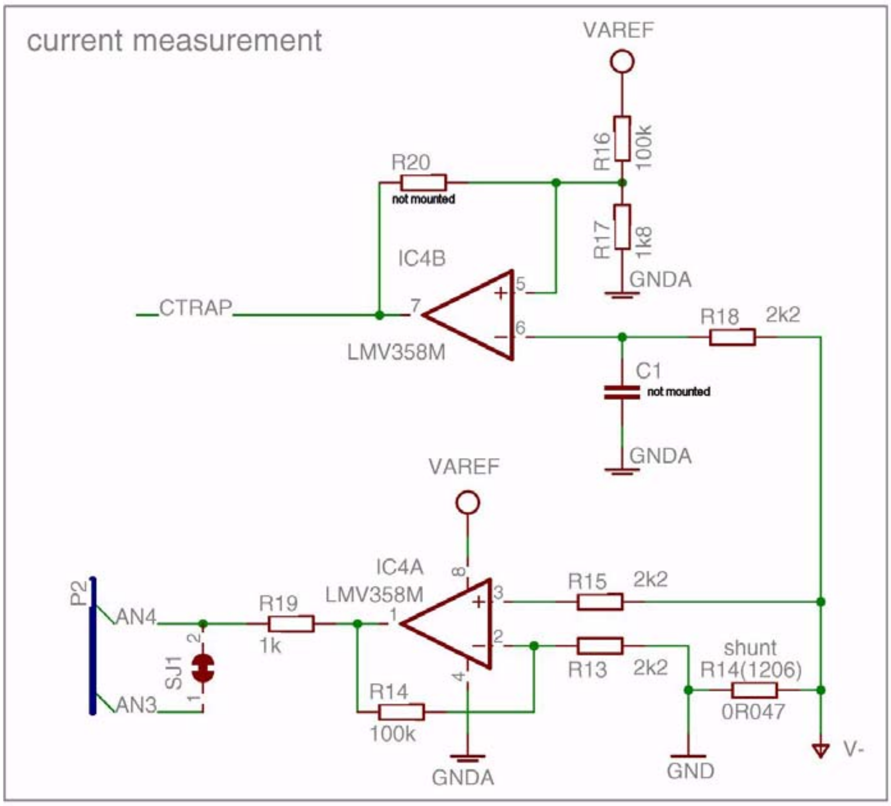

Figure 8 Current Measurement

The over load current threshold V_{cth} is setup by the reference voltage defined by R16 and R17.

$$V_{cth} = R_{shunt} \cdot I_{max} = V_{AREF} \cdot \frac{\mathrm{R17}}{\mathrm{R16+R17}} \tag{2}$$

The capacitor C1 and the resistor R20 are not mounted. By mounting C1 a delay and spike filter can be implemented, R20 can be used to implement a hysteresis.

The current amplification of the differential amplifier is defined as follows:

$$G = \frac{\mathrm{R14}}{\mathrm{R13}} \qquad , \qquad \mathrm{R15} = \mathrm{R13} \tag{3}$$

2.6 CAN Interface

The XC886CM provides a CAN interface with two CAN nodes. One CAN node is connected to the CAN transceiver TLE 6250 including the terminating resistor R21.

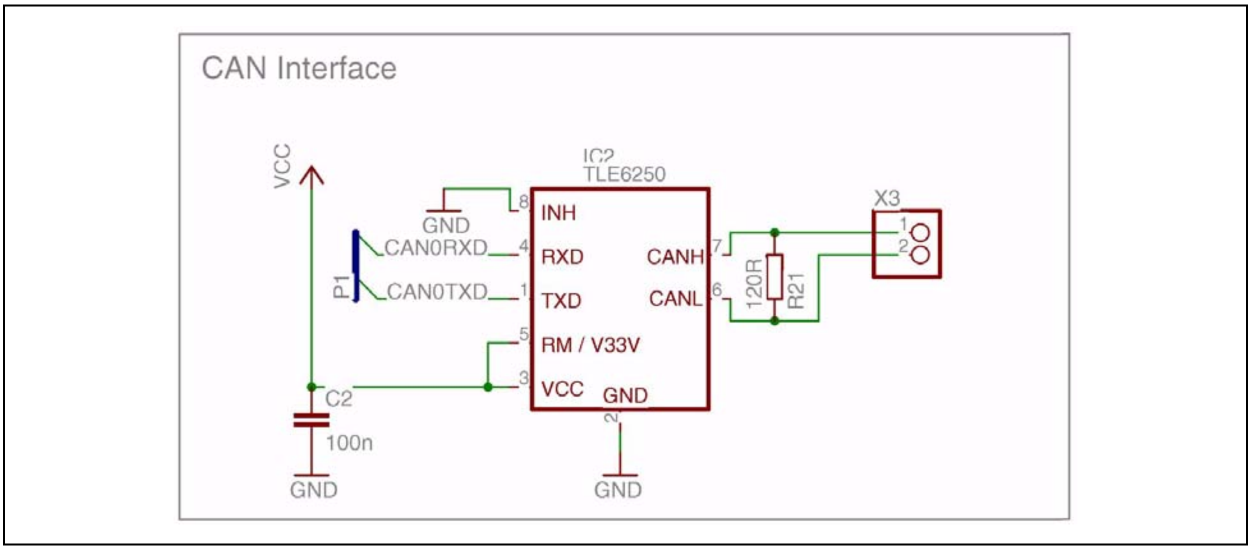

Figure 9 CAN Interface

The CAN interface can be used for bootstrap download, parameter adjustment and debugging by sending dedicated CAN messages with debug information.

2.7 Power Supply

The 5 V power supply for the MCU and the CAN transceiver is built by a DC/DC converter. The current consumption of the components does not necessarily require a DC/DC converter, but by this implementation there is enough current capability available for additional circuitry like LEDs or supply for hall sensors.

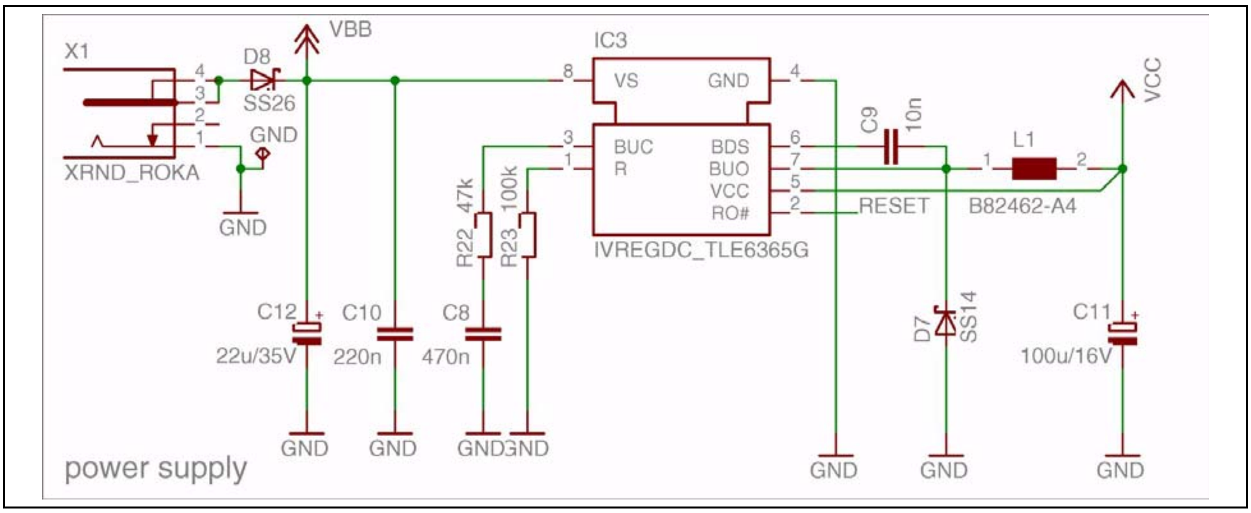

Figure 10 Power Supply

2.8 Two-Layer PCB Layout

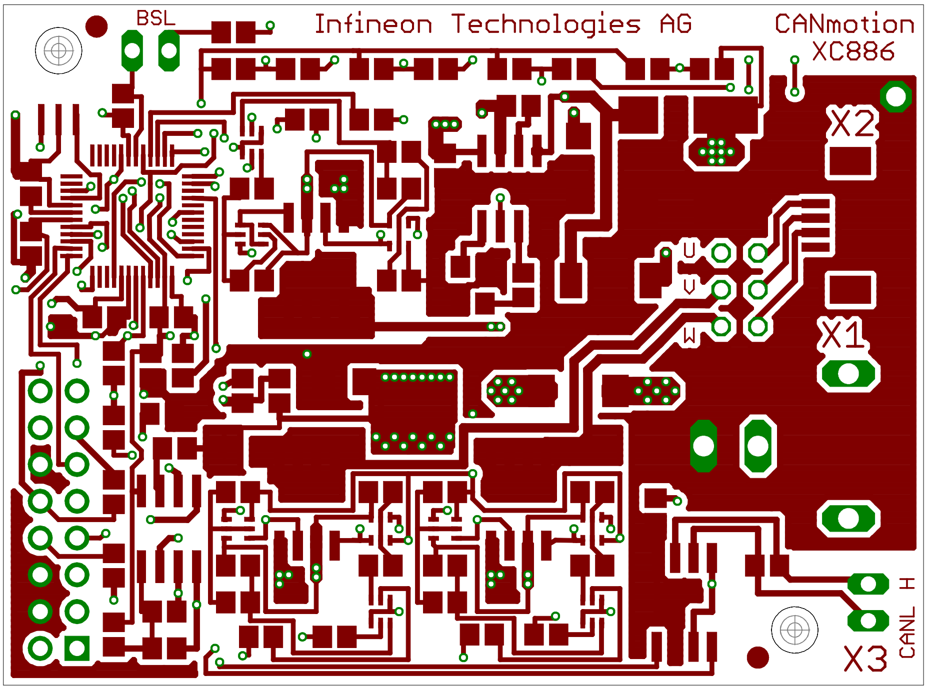

Figure 11 PCB Layout TOP Layer

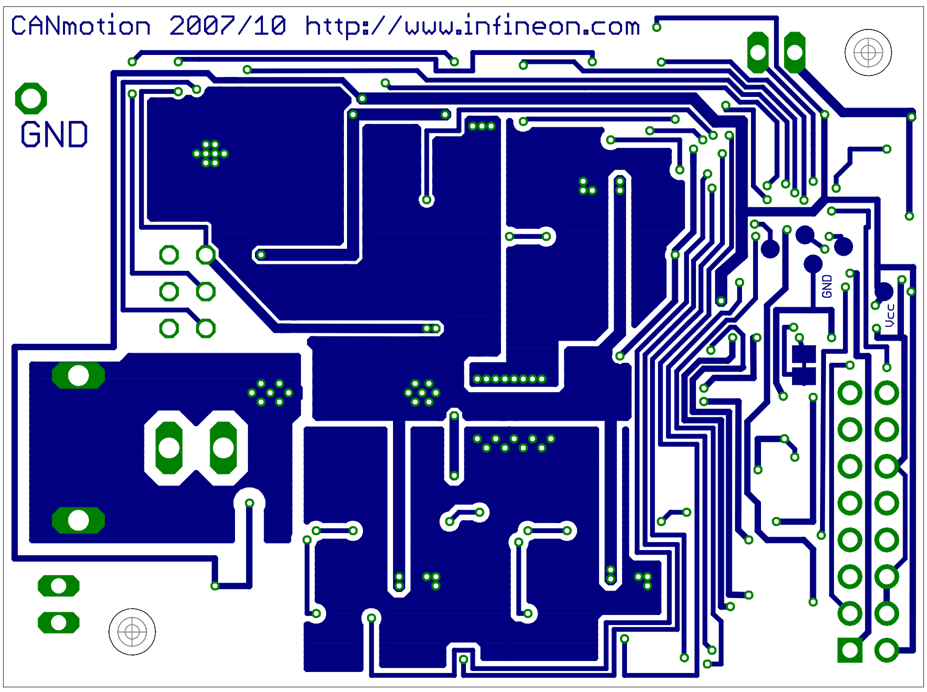

Figure 12 PCB Layout BOTTOM Layer

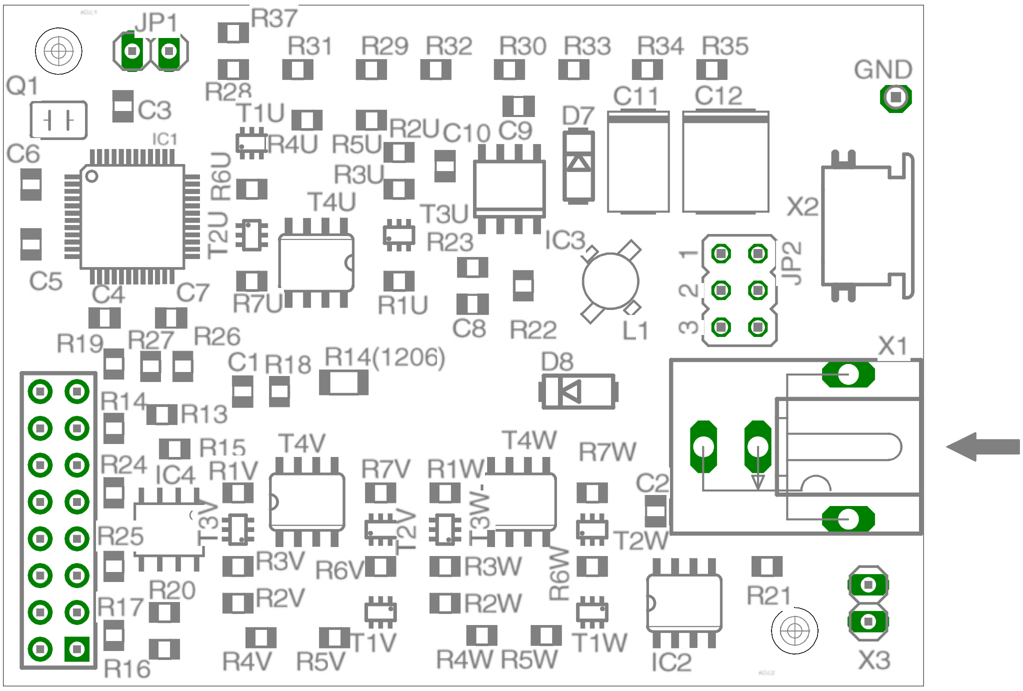

Figure 13 PCB Layout Component Names

3 Motor

The CANmotion evaluation platform comes with a BLDC motor mounted ready to use. In this chapter, the motor data (revision April 2006) can be found. Please refer directly to Maxon Motor internet page **http://www.maxonmotor.com** for the latest information.

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

3.2 Operating Range

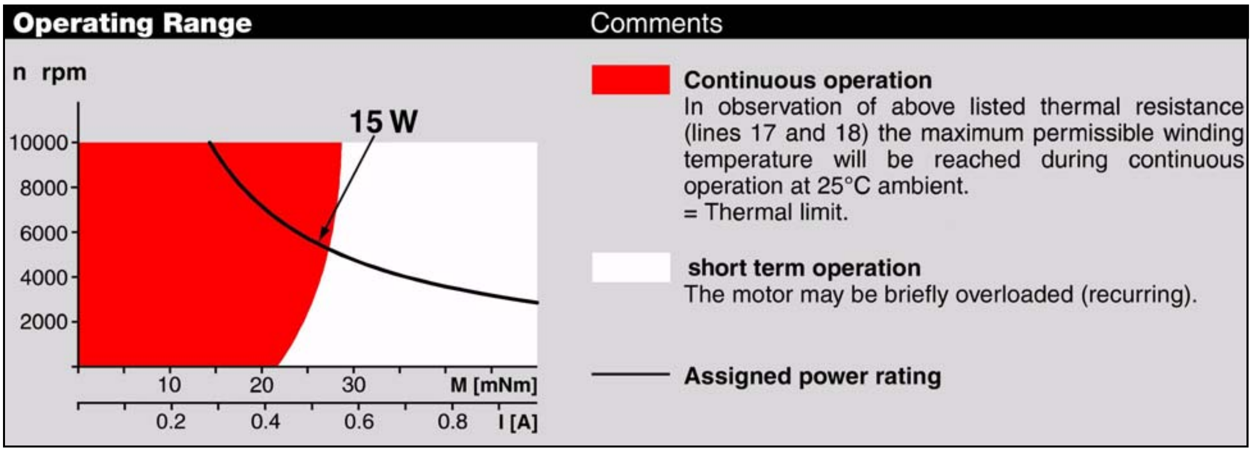

Figure 15 Operating Range

3.3 Geometry

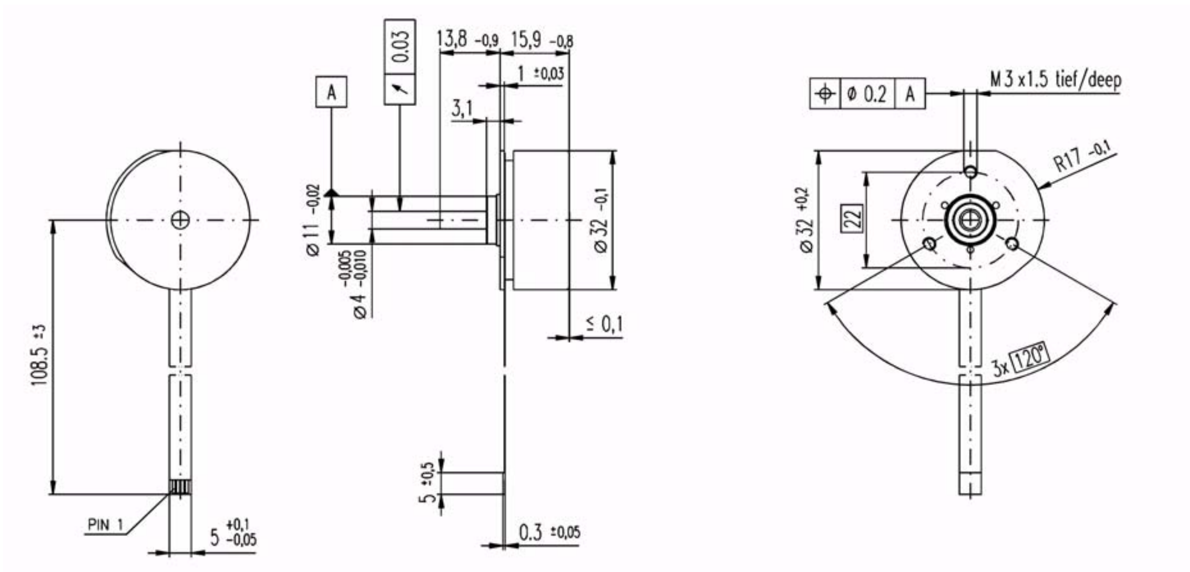

Figure 16 Geometry

w w w . i n f i n e o n . c o m

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