XC2000/XE166 Family

AP16195

FOC Motor Drive Kit with TLE5012 Speed and Position Sensor

Application Note

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–	This is the first release …

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1 Introduction

This document describes the use of the new TLE5012 magnetic angle sensor in the FOC Motor Drive Application Kit (PMSM), using the XE162FM 16-bit microcontroller. The TLE5012 sensor enables the absolute angle and incremental rotor position of the PMSM brushless motor to be read.

TLE5012 sensors are based on GMR (Giant Magneto Resistance) technology and are used as position sensors in automotive and industrial applications. The sensor detects the orientation of an external magnetic field which is coupled to the sensor.

In the example described, the TLE5012 is replaced with the normal rotary encoder used in electrical motor applications. This provides the following advantages:

- True absolute angle position in real-time
- Improved angle precision
- Angle precision reduces the current consumption in the PMSM drive
- The motor can run at lower speeds
- System cost is much lower than for a normal rotary encoder

1.1 Setting up the Project

There are several steps required to set up this project:

- Mounting a circular magnet to the rotor shaft
- Reading the absolute angle position via an SPI interface when the motor is halted
- Configuration of the XE162 internal timer in “Incremental Interface Mode” for reading the two quadrature signals of the TLE5012 sensor when the motor is run
- Tuning the mechanics angle to the electric pole angle
- Replacing the sensorless angle position estimate on FOC with a new one provided by the TLE5012 system

After completing these steps, speed and position angle are based on the TLE5012 sensor.

2 Connection Overview

The TLE5012 is mounted on the MCU drive card and uses two flat cables to connect the Incremental interface and SSC interface to the FOC Drive Card. This new implementation allows the FOC Drive kit to determine the motor position with either the flux estimator or the TL35012 magnetic sensor. For more details on the software implementation, please refer to **Chapter 7**.

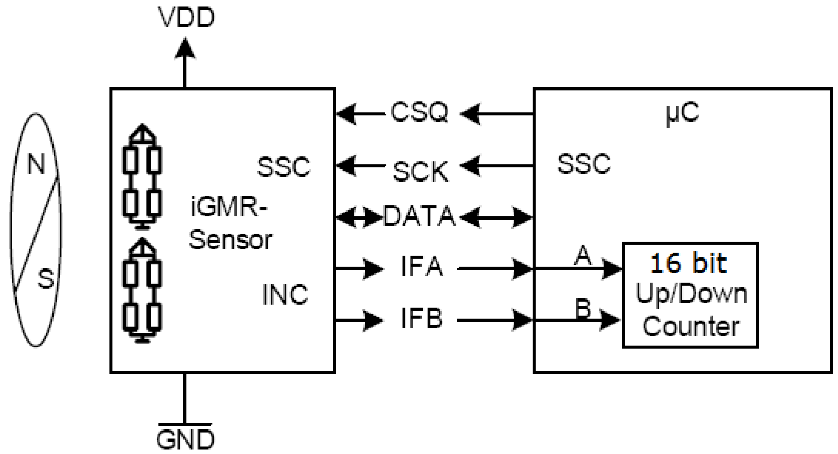

Figure 1 Connection between Incremental Interface and SPI Interface to FOC Drive Card

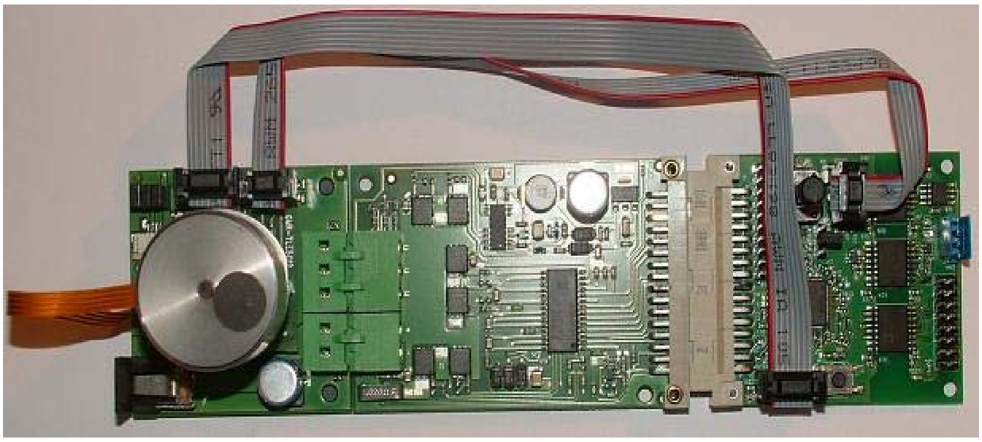

Figure 2 Top view

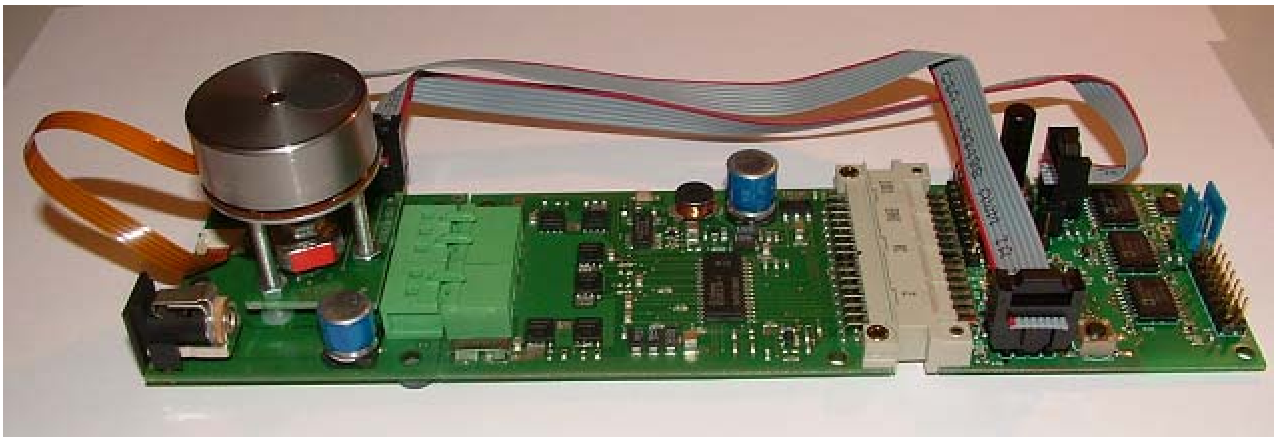

Figure 3 Side view

3 Magnet Type and Shapes

The TLE5012 sensor detects the orientation of a magnetic field, so a magnet block is required on the axis of the moator in the FOC Motor Drive Application kit. There are many types and shapes of magnet available in the market, but the FOC kit requires the following type of magnet:

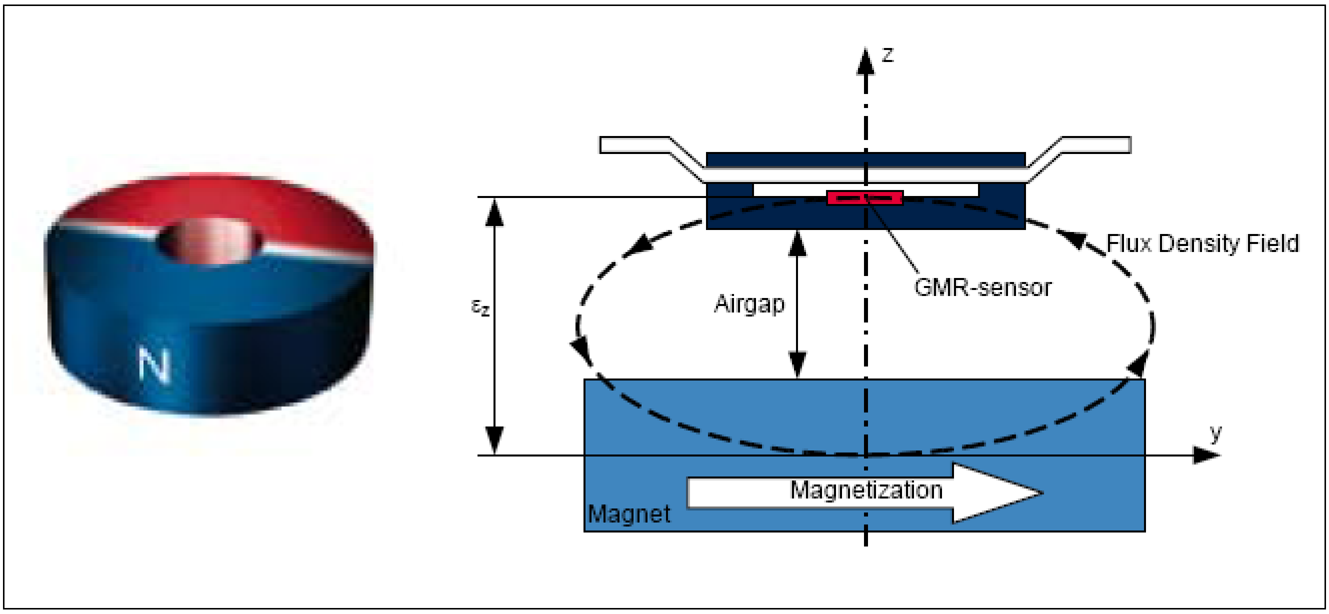

Figure 4 Magnet Diametrically Magnetized

Note: Increasing the diameter of the magnet dramatically reduces the error. 10mm is suggested as a minimum diameter.

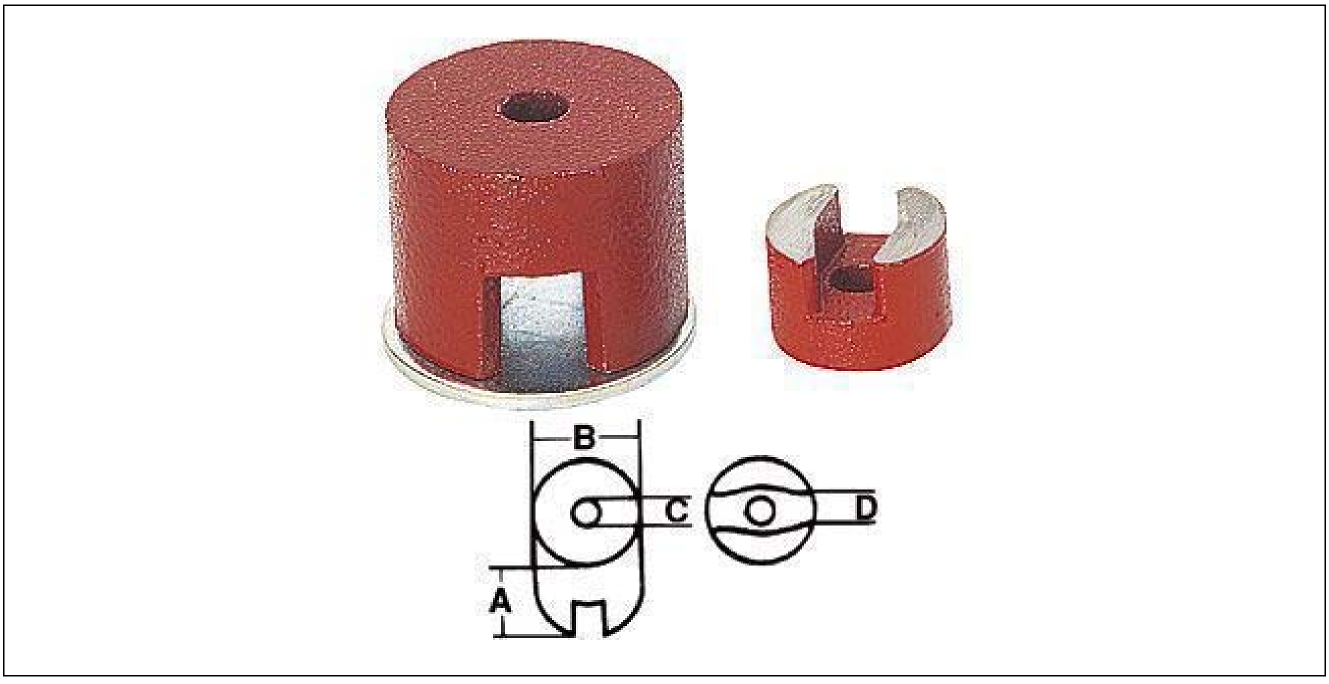

Figure 5 Permanent Magnet LTF "MAXALCO ART.26 COD.26"

For further details of this magnet, please refer to: http://www.ltf.it/scheda.asp?idart=86&marca=LTF.

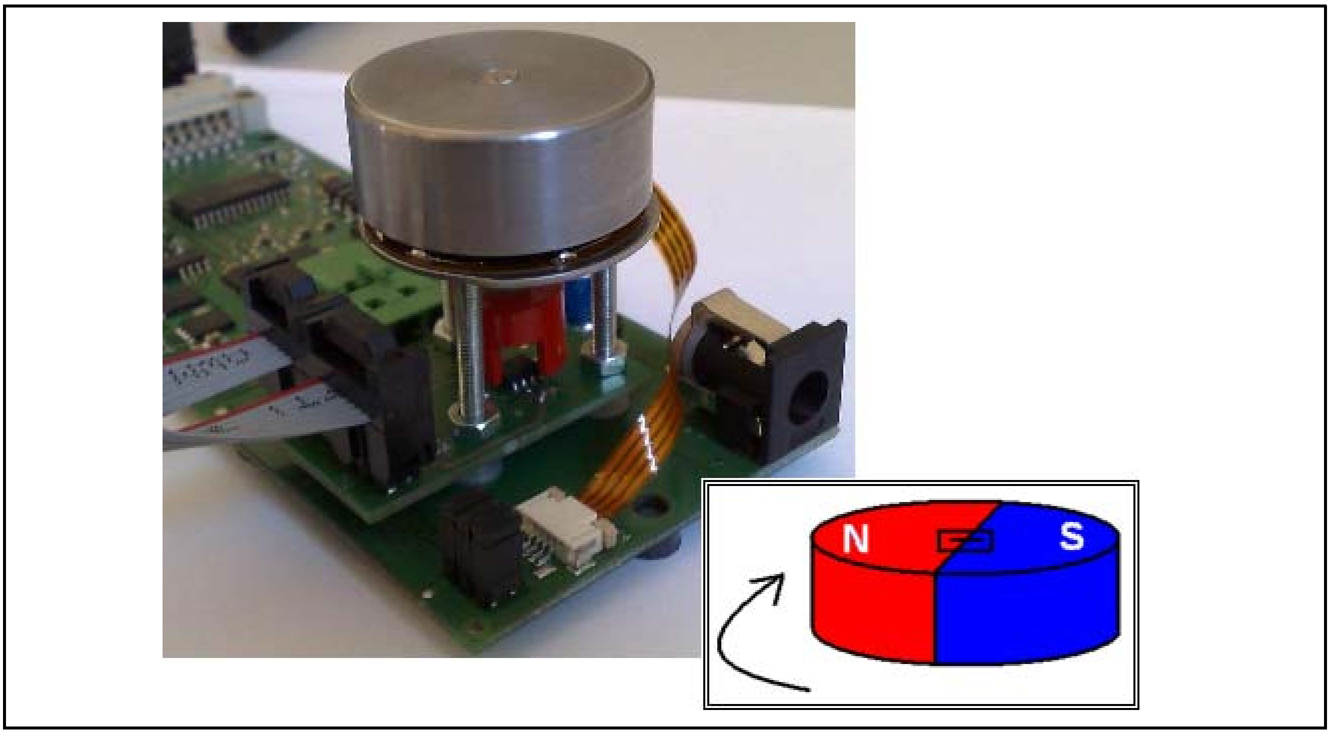

Figure 6 FOC Demo Kit with Round Type Magnet

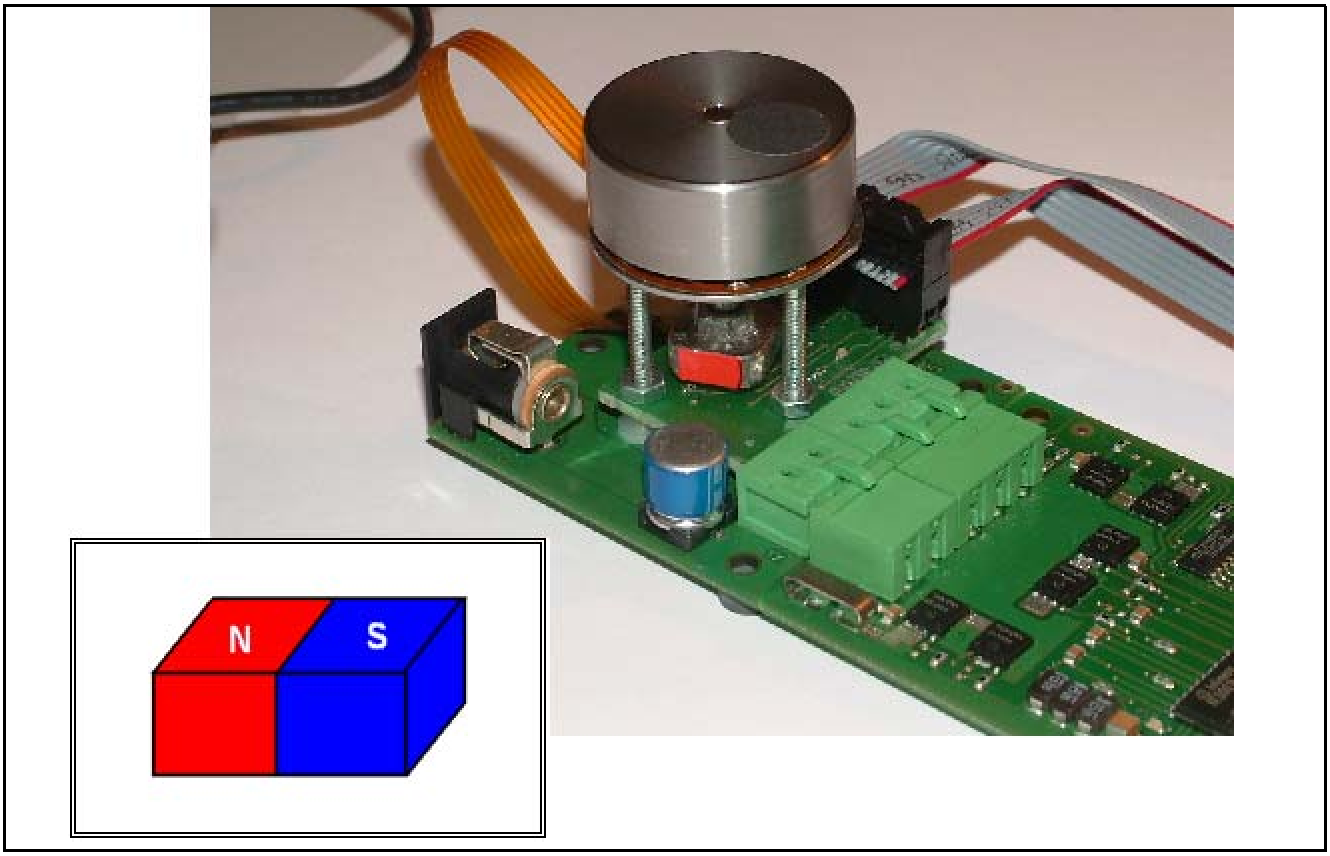

Figure 7 FOC Demo Kit with Square Type Magnet

4 FOC Demo Kit Diagram

The implemented FOC demo kit can use both the flux estimator or the TLE5012 magnetic sensor for angle position detection.

When the FOC demo kit uses the flux estimator for angle position detection, the kit is shown as per the following diagram:

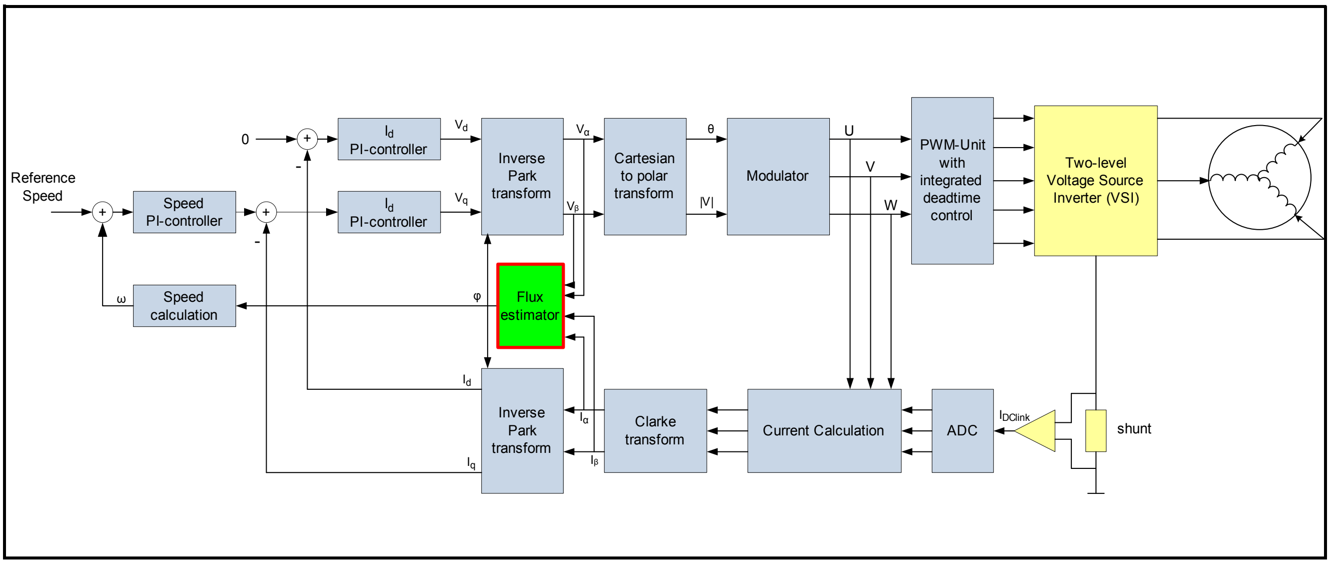

Figure 8 FOC Demo Kit with Flux Estimator

If the FOC demo kit uses the TLE5012 magnetic sensor for angle position detection, the kit is as follows:

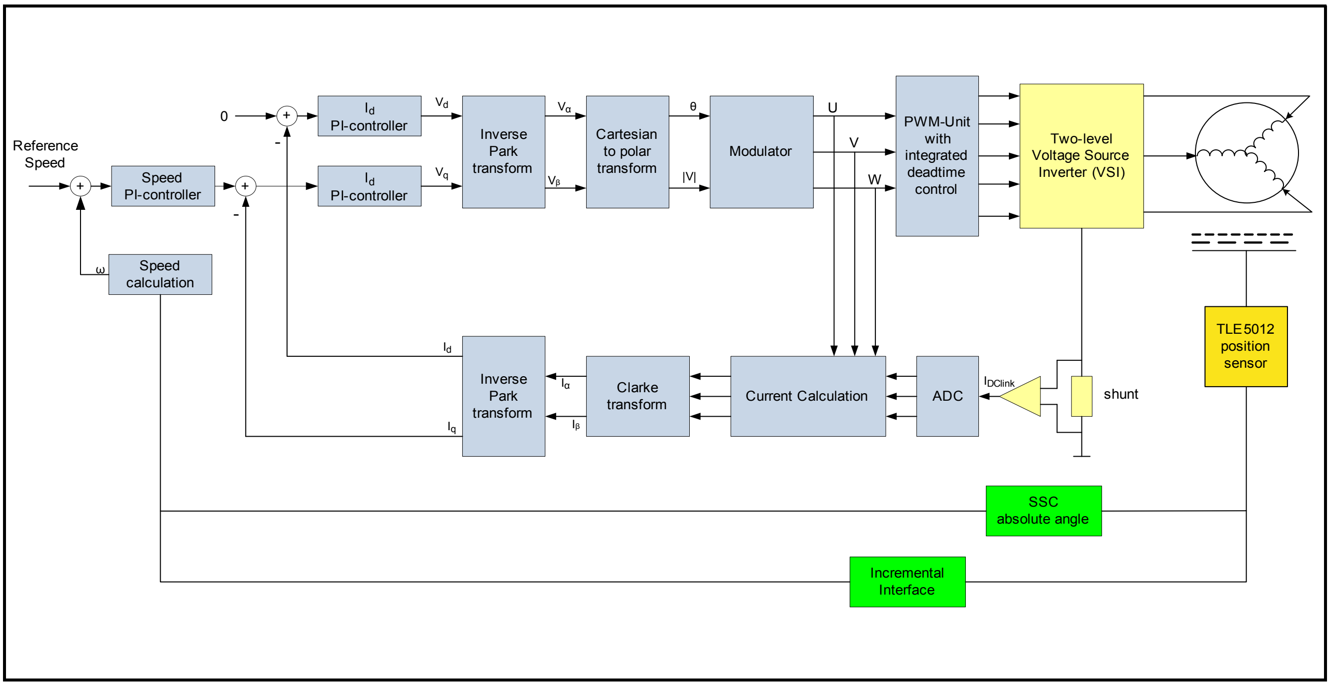

Figure 9 FOC Demo Kit with TLE5012 Speed and Position Sensor

5 TLE5012 Interface

The absolute angle is usually read via the SPI when the motor is stopped (0 RPM).

When the motor is running, the angle position can be read by the XE162 timer in Incremental Mode.

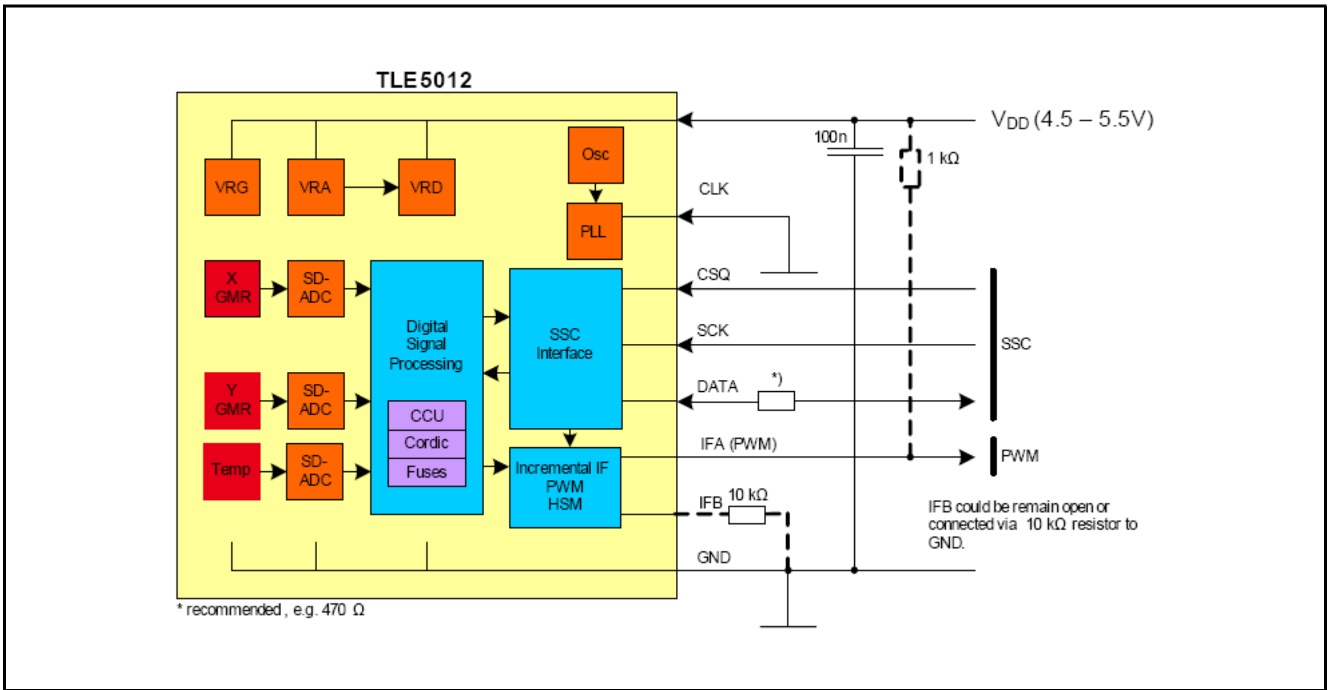

Figure 10 Application Circuit for SSC Interface

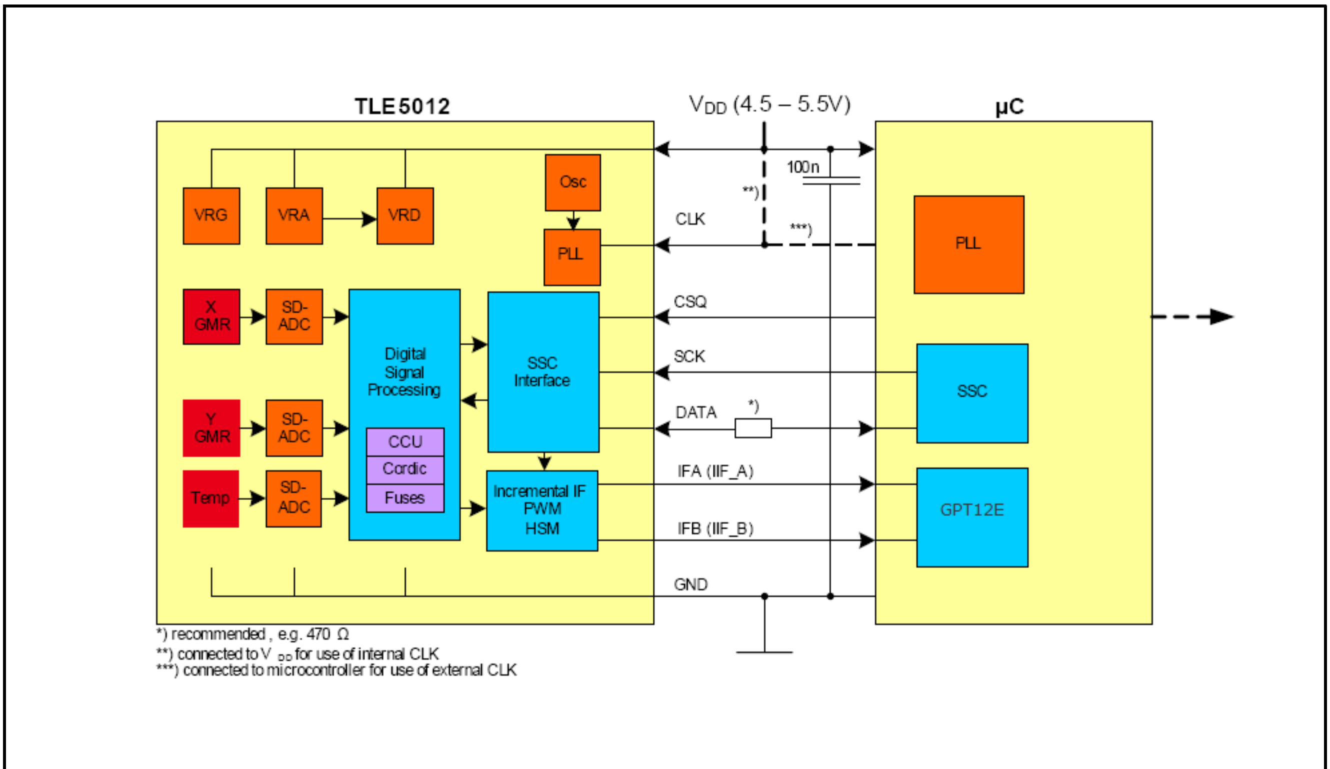

Figure 11 Application Circuit for Incremental Interface

6 Interface Function and DAVE™ Settings

6.1 Setup SSC for Absolute Angle

USIC0 channel 1 is configured to the SSC protocol.

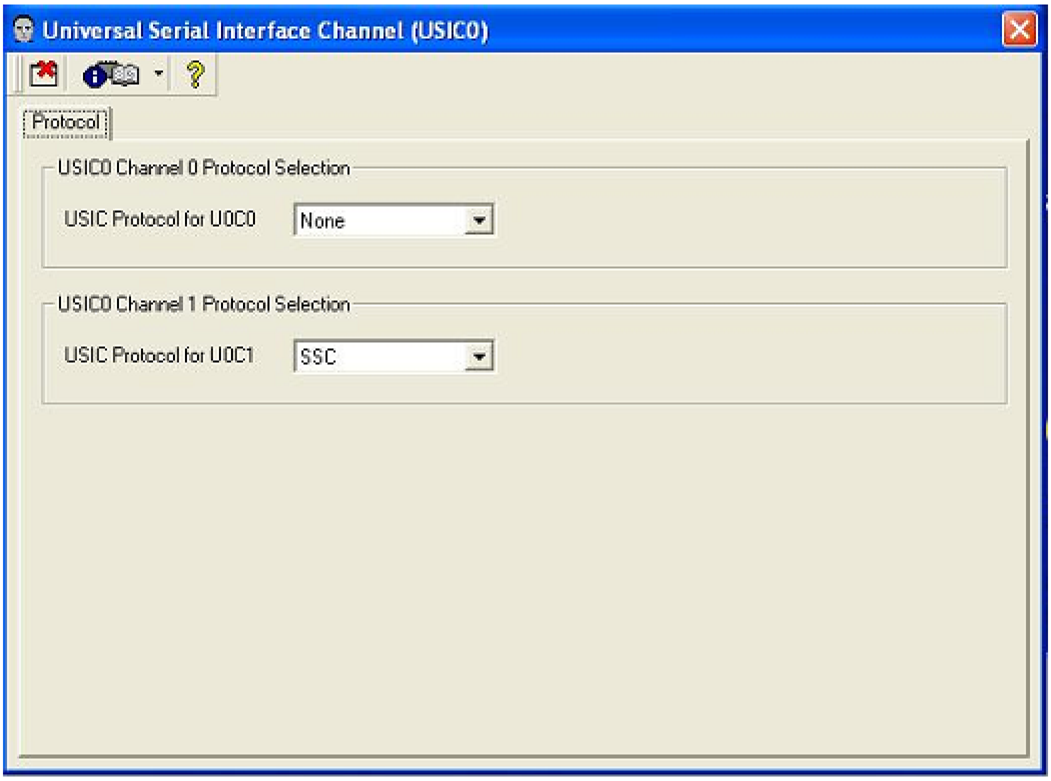

Figure 12 Setup USIC 0 Channel 1 to SSC

The USIC channel is configured as per the screen shots which follow.

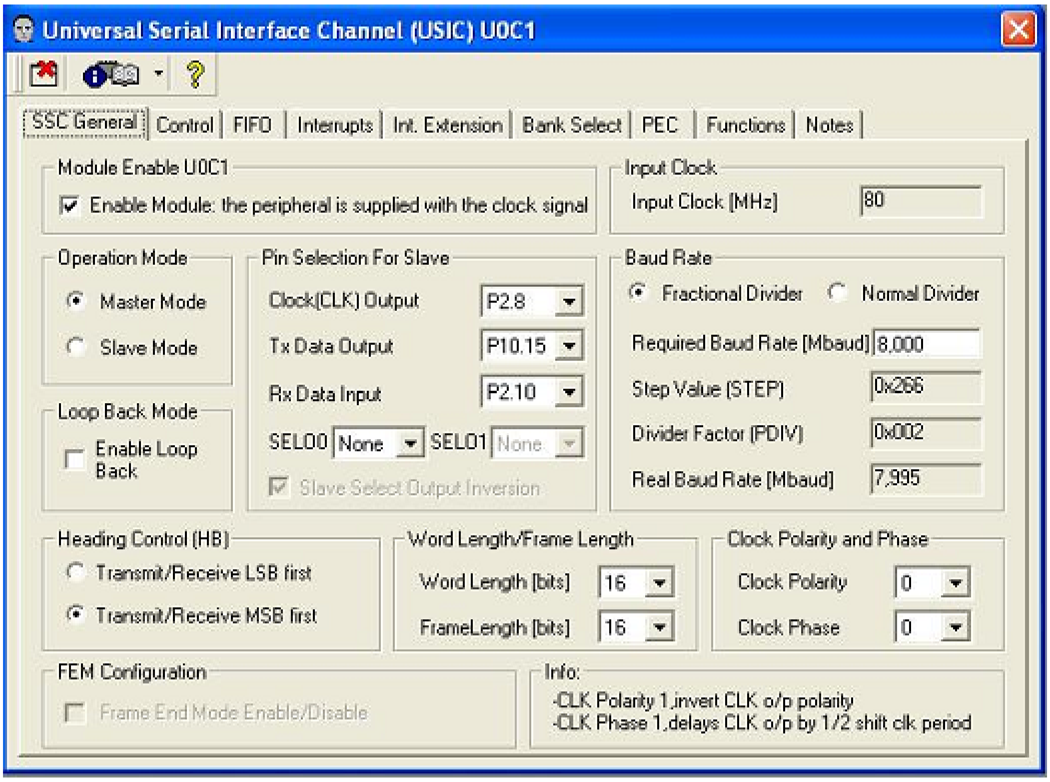

Figure 13 SSC General Tab

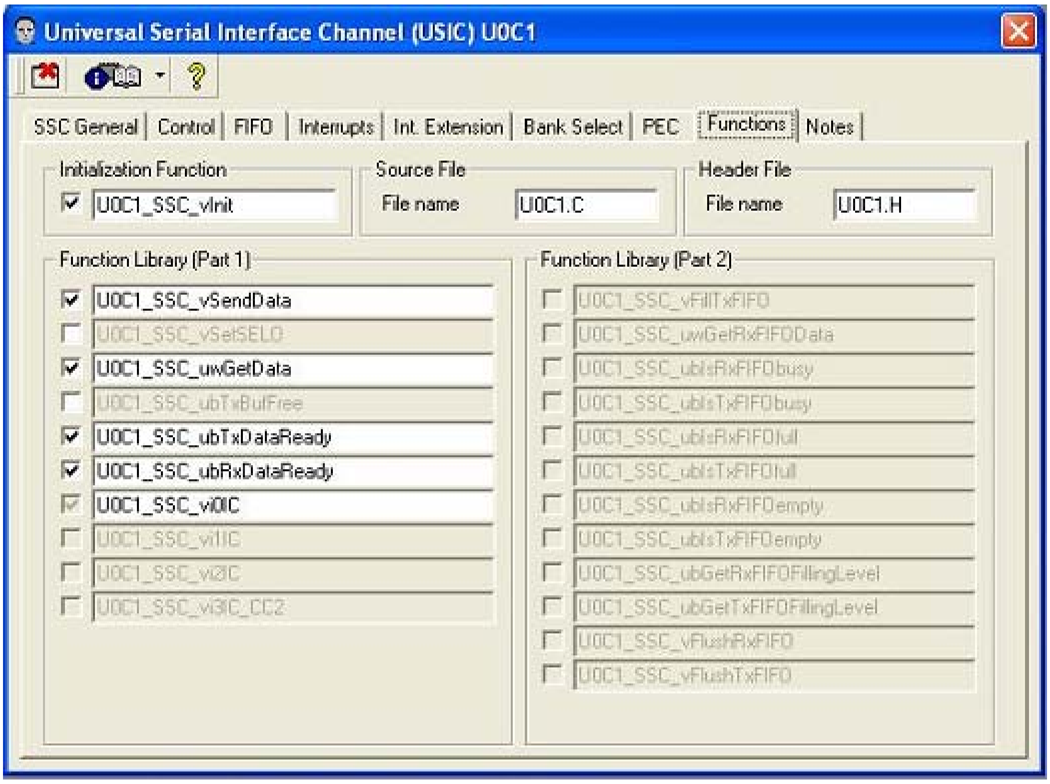

Figure 14 SSC Functions Tab

6.2 TLE5012 Command, Status and Value Registers

Table 1 Register address for TLE5012

Register Short Name	Register Long Name	Offset Address
STAT	Status Register	00_H
ACSTAT	Activation Status Register	01_H
AVAL	Angle Value Register	02_H
ASPD	Angle Speed Register	03_H
AREV	Angle Revolution Register	04_H
FSYNC	Frame Synchronization Register	05_H
MOD_1	Interface Mode2 Register	06_H
SIL	SIL Register	07_H
MOD_2	Interface Mode2 Register	08_H
MOD_3	Interface Mode3 Register	09_H
OFFX	Offset X	$0A_H$
OFFY	Offset Y	$0B_H$
SYNCH	Synchronicity	$0C_H$
IFAB	IFAB Register	$0D_H$
MOD_4	Interface Mode4 Register	$0E_H$
TCO_Y	Temperature Coefficient Register	$0F_H$
ADC_X	X-raw value	10_H
ADC_Y	Y-raw value	11_H

6.3 Setup Timer T3 in Incremental Interface

Enable Timer 3 and configure to incremental Interface mode.

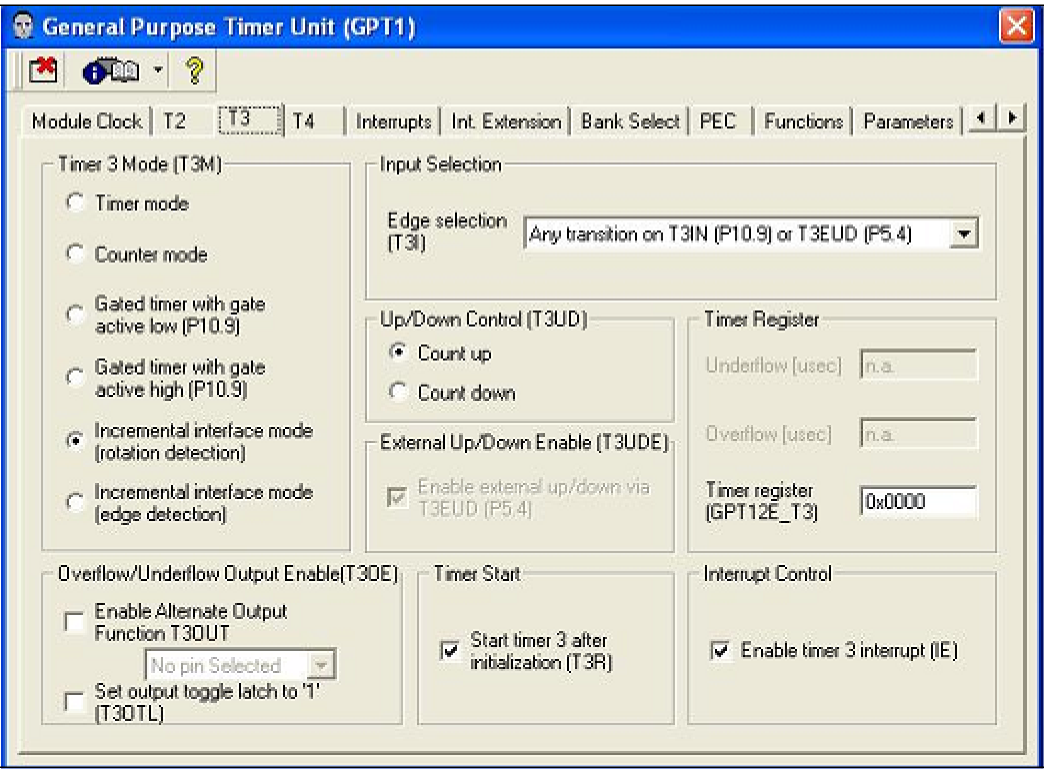

Figure 15 Timer T3

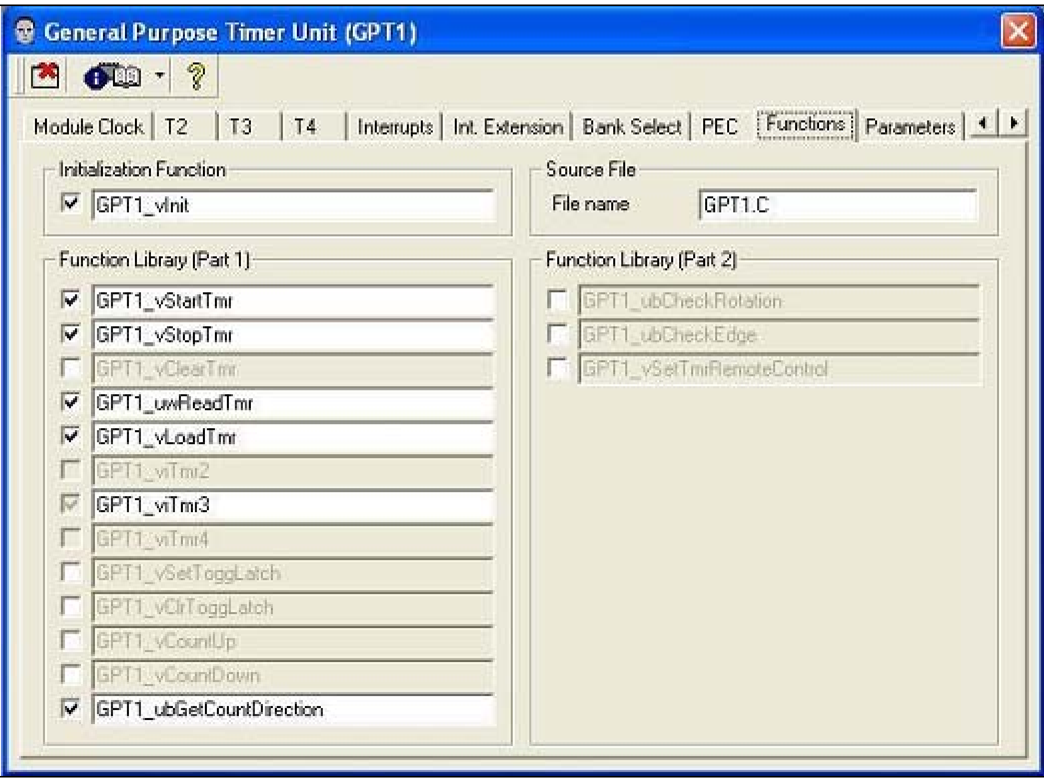

Figure 16 Enable Timer - Functions tab for GPT1

The absolute angle is read out via the SPI connection.

This absolute value is divided by 2 and loaded in to the GPT12E_T3 register.

The SPI is then disabled and the Incremental Interface is used for the read position.

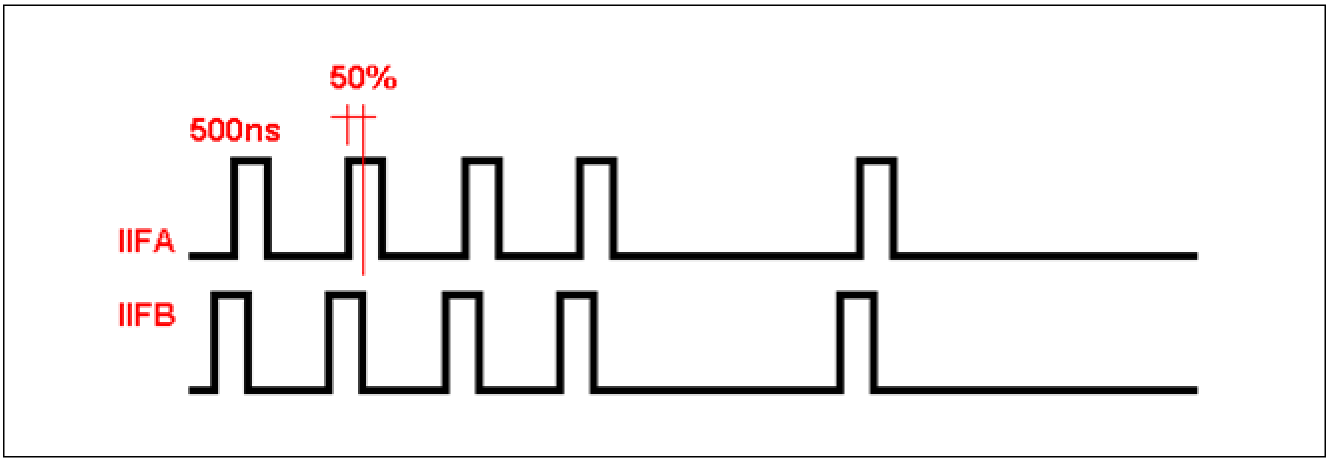

Figure 17 IIFA and IIFB Signals

Incremental angle:

- 1 rotation => 0x3FFF*(16383) tick of incremental interface
- Period of T3 => 4 rotations
- 1 mechanic rotation => 4 electrical rotation

4 timer tick every double edge of the two hardware signals (IIFA and IIFB).

Theoretical maximum speed:

- 500ns for 1 tick
- 4096 tick for 1 revolution
- 500ns x 4096 = 2.048ms/revolution
- f = 1 / 2.048ms
- RPM = f X 60
- RPMmax = 29.296rpm approximate 30.000rpm

6.4 Setup MultiCAN for Debug Communication

The Message Object (MO) in MultiCAN is used for sending all the information required to trim the system.

For more details, please refer to **Chapter 8**.

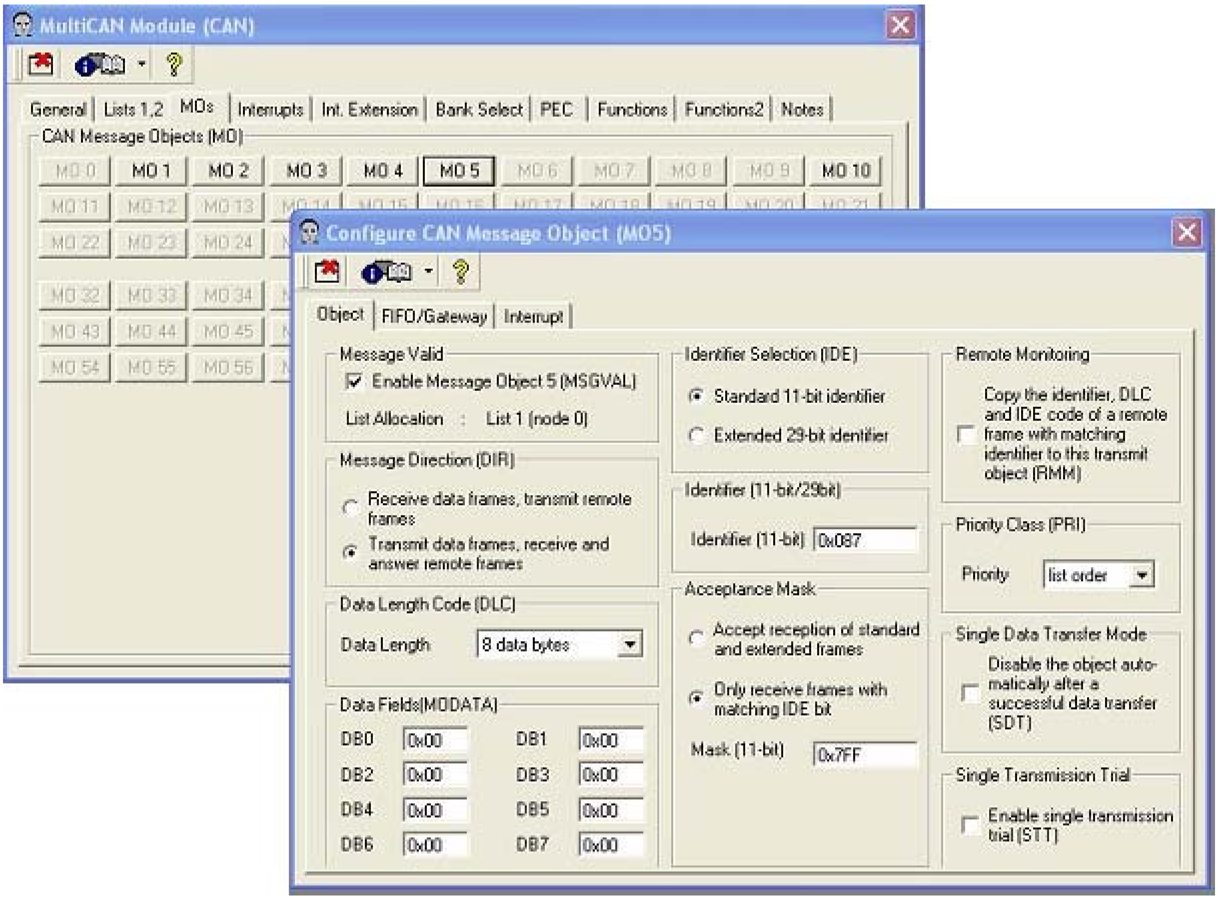

Figure 18 New Message Object in CAN Bus for Debug Interface

In the TLE5012 Board a yellow LED is mounted for general purpose use.

In this demonstration it is used for controlling the direction of the rotor.

When the LED is turned ON, the rotor turns to left and when the LED is turned OFF, the rotor turns to the right.

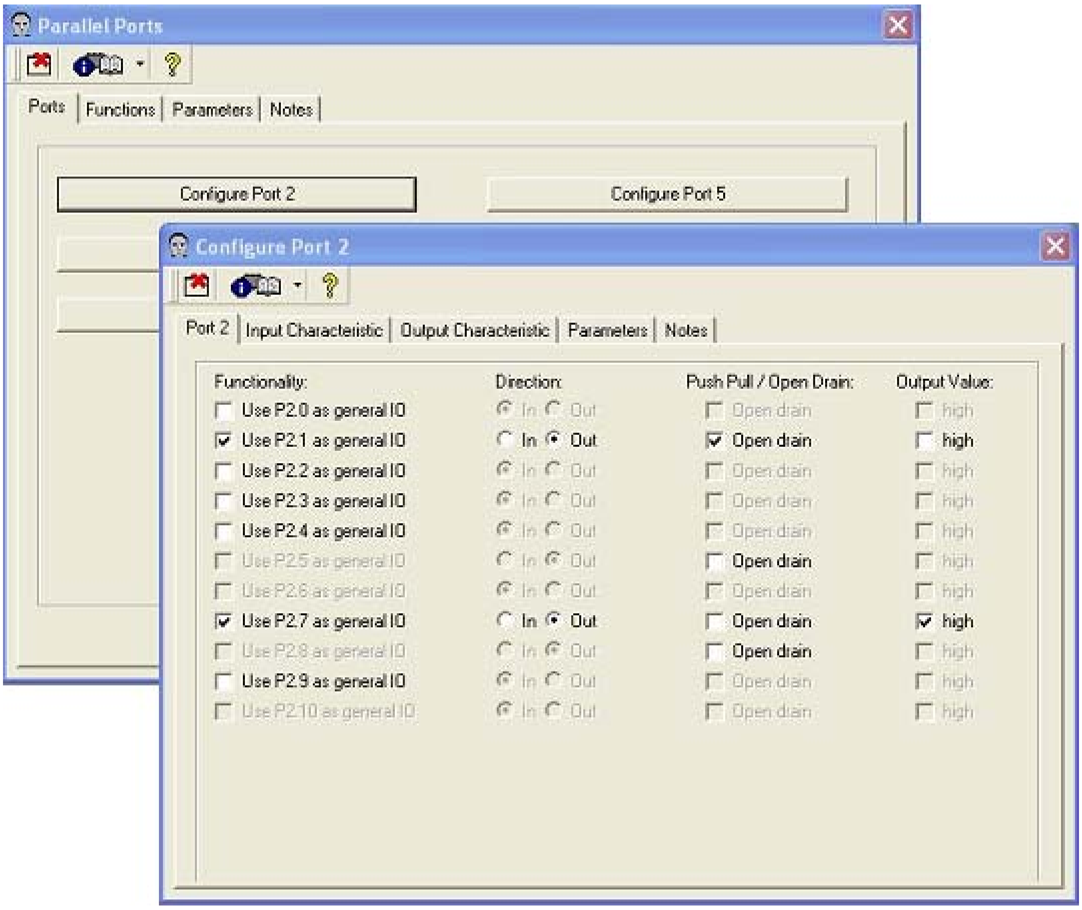

Figure 19 Setup LED for Direction Indicator

7 Firmware Information

This chapter lists the code and file changes for controlling the TLE5012 sensor.

To enable software control of the TLE5012 sensor in the FOC kit, a new macro **MAGNET_TLE5012** in **defines.h** is set to 1. If the macro is set to 0, the FOC kit will be using the flux estimator for position detection instead of the sensor.

TLE5012.c and **TLE5012.h** are new files that contain the state machine for controlling TLE5012 and Timer T3.

Main Functions:

1. Read status via SPI
2. Read absolute angle via SPI
3. Load Timer T3
4. Send debug data via CAN bus

File TLE5012.h

```
extern unsigned int  CANMO5Count;
extern unsigned int  TLE_StateMachine;
extern unsigned int  Angle;
extern unsigned int  OffsetTLE;
extern unsigned int  DeltaOffset;

#define  SPI_CS_ENABLE()    IO_vResetPin(IO_P2_7)
#define  SPI_CS_DISABLE()   IO_vSetPin(IO_P2_7)
#define  INDEX_ENABLE()     IO_vSetPin(IO_P2_7)  /* for incremental signal index */

#define  SPI_TX_OFF() P10_IOCR15 = 0x0000;
#define  SPI_TX_ON()  P10_IOCR15 = 0x00A0;

#define  TLE_ON_LED()   IO_vSetPin(IO_P2_1);
#define  TLE_OFF_LED()  IO_vResetPin(IO_P2_1);

/* SPI command for TLE5012 */
#define SPI_NULL             0x0000
#define READ_STATUS          0x8000
#define READ_ANGLE_VALUE     0x8020

/* States machine  */
#define TLE_INIT             0
#define TLE_READ_ANGLE       1
#define TLE_WAIT             2
#define TLE_ERROR            3
#define TLE_WAIT_SPI_ANGLE   4
#define TLE_WAIT_SPI_STATUS  5

/* Configuration */
#define TLE_OFFSET_ANGLE     0xB000

/* Functionality mode */
#define REFERESH_ANGLE       0
```

For the correct control and the use of the TLE5012, some code is added to the existing source file, as listed below:

File CAN.c

New MO05 message CAN bus object ID 0x087

File CCU60.c

```
#include "TLE5012.h"
#include "GPT1.H"

unsigned int Position;

Position = GPT1_uwReadTmr_GPT1_TIMER_3();  // Incremental position value
Position &= 0x3FFF;
Position = Position << 4;

// Used for setUP
DeltaOffset = Position - foc0.FluxAngle;

if (status0.sens_position==1) // CMDTLE5012
{
       TLE_ON_LED();
       foc0.Angle = Position - OffsetTLE;  //  Position Control
}
else
{
       TLE_OFF_LED();
       foc0.Angle = foc0.FluxAngle;  //  Current Control
}
```

File defines.h

```
#define MAGNET_TLE5012 to enable TLE5012 position sensor
#define SPEED_POTI for SPEED_POTI default state
```

File GPT1.c

```
New setting of timer 3 as “Incremental Interface”
Note the correction of the pin used (DAVE error)
```

File GPT1.h

```
new define for StartTmr, StopTmr, ReadTmr, LoadTmr, GetCountDirection
```

File GPT2.c

```
TaskSensorTLE5012() on timer T6 routine interrupt (every 1ms)
```

File IO.c

```
Pin P2.1 output for LED orange
Pin P2.7 output for CSQ
Pin P2.8 output for SCLK clock of SSC
Pin P2.10 input DATA SSC
Pin P5.4 input for UpDown control T3
Pin P10.9 input for count T3
Pin P10.15 output DATA SSC
```

File Main.c

```
Buffer for canbus MO5
USIC0_vInit() for SPI initialization
```

File Scheduler.h

```
New CAN bus commands
CMDTLE5012           0xA0
CMDTLE5012_OFFSET    0xA1
CMDPOTENTIOMETER     0xA2
New function for send debug MO5 via canbus
New function for set or reset speed control by potentiometer or swmonitor
```

STRUCT:

```
typedef struct
{
       bit on;
       bit off;
       bit control;
       bit ramp;
       bit ctrap;
       bit sens_position;   [0]=current/flux position [1]=tle magnetic sensor
       bit potentiometer;   [0]=potentiometer [1]=SW drivermonitor
} tStatus;
```

8 Debug Info via CAN Bus

Message Object 05 (MO05) contains the status information for TLE5012.

Time: 50ms

ID: 0x0087

DATA	L START	H START	L POSITION	H POSITION	L STATUS	H STATUS	L OFFSET	H OFFSET
BYTE	0	1	2	3	4	5	6	7
	Absolute angle position of the rotor that is read by SSC. It is read only when the rotor is stop, at 0 RPM		揑ncremental angle?on Timer T3		Difference between 搃ncremental angle?and 揺stimate angle? , useful for trim the magnet position		Different angle between rotor position and TLE5012 position	

Message Object 10 contains the TLE5012 commands.

ID:0x005

CMD 0xA0 Enable/Disable TLE5012 angle control

DATA	L START	H START	L POSITION	H POSITION	L STATUS	H STATUS	L OFFSET	H OFFSE
BYTE	X	0	0	0	0	0	A0	00

X = 0 Use normal estimation flux of FOC

1 Use the new control angle from TLE5012

CMD 0xA1 sets the offset between the rotor angle and magnet angle

DATA	L START	H START	L POSITION	H POSITION	L STATUS	H STATUS	L OFFSET	H OFFSET
BYTE	00	B3	0	0	0	0	A1	00

CMD 0xA2 Enable/Disable the POTENTIOMETER for speed control (or SW)

DATA	L START	H START	L POSITION	H POSITION	L STATUS	H STATUS	L OFFSET	H OFFSET
BYTE	X	B3	0	0	0	0	A2	00

X = 0 Default, potentiometer

1 SW DriveMonitor

9 Board Schematics

The following figures show the board schematics. User may use this as the reference to build their own adaptor board.

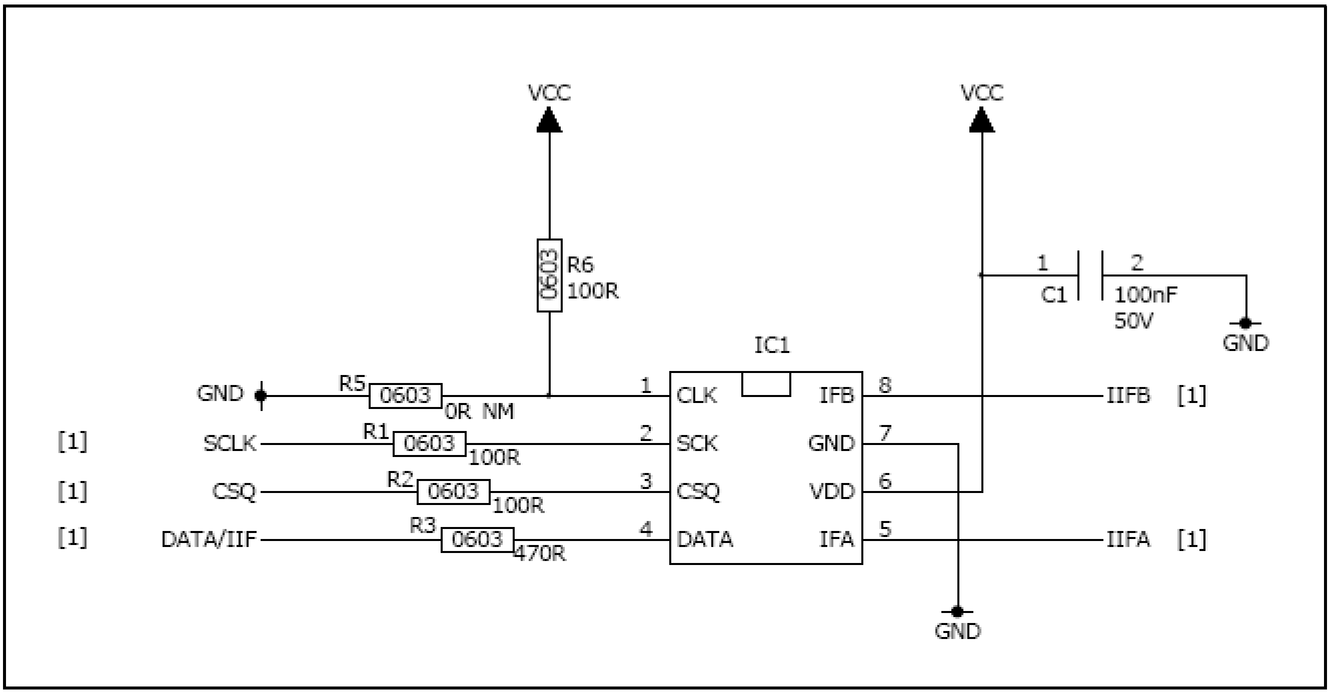

Figure 20 Angular Sensor

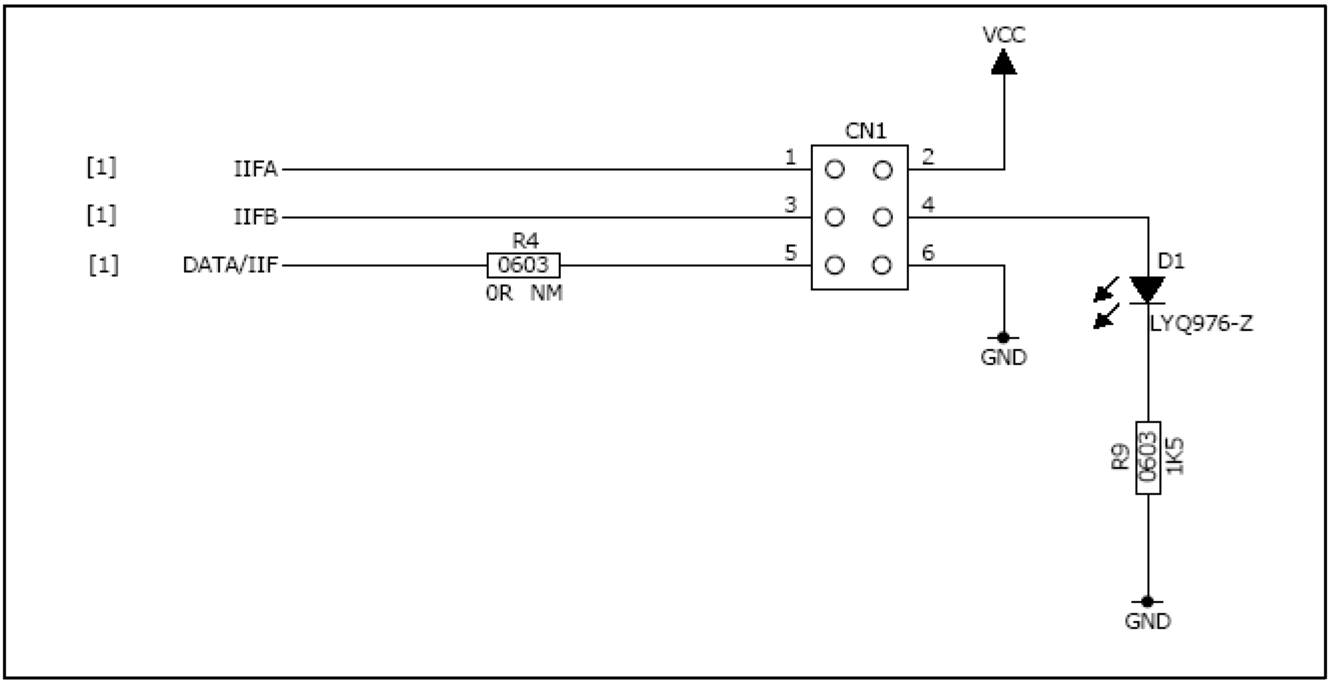

Figure 21 Incremental Interface

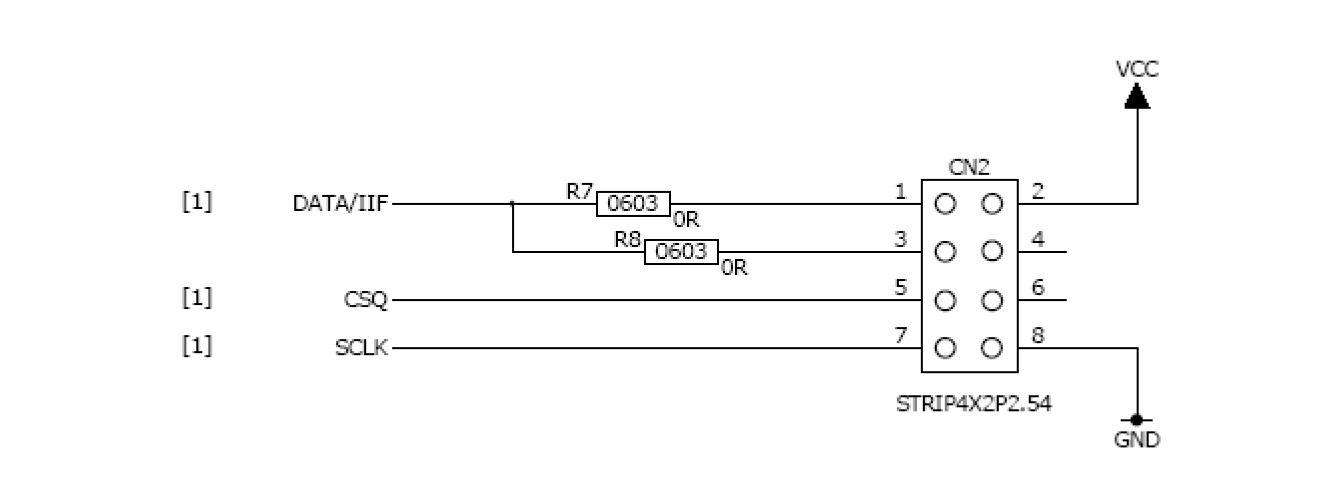

Figure 22 SPI Interface

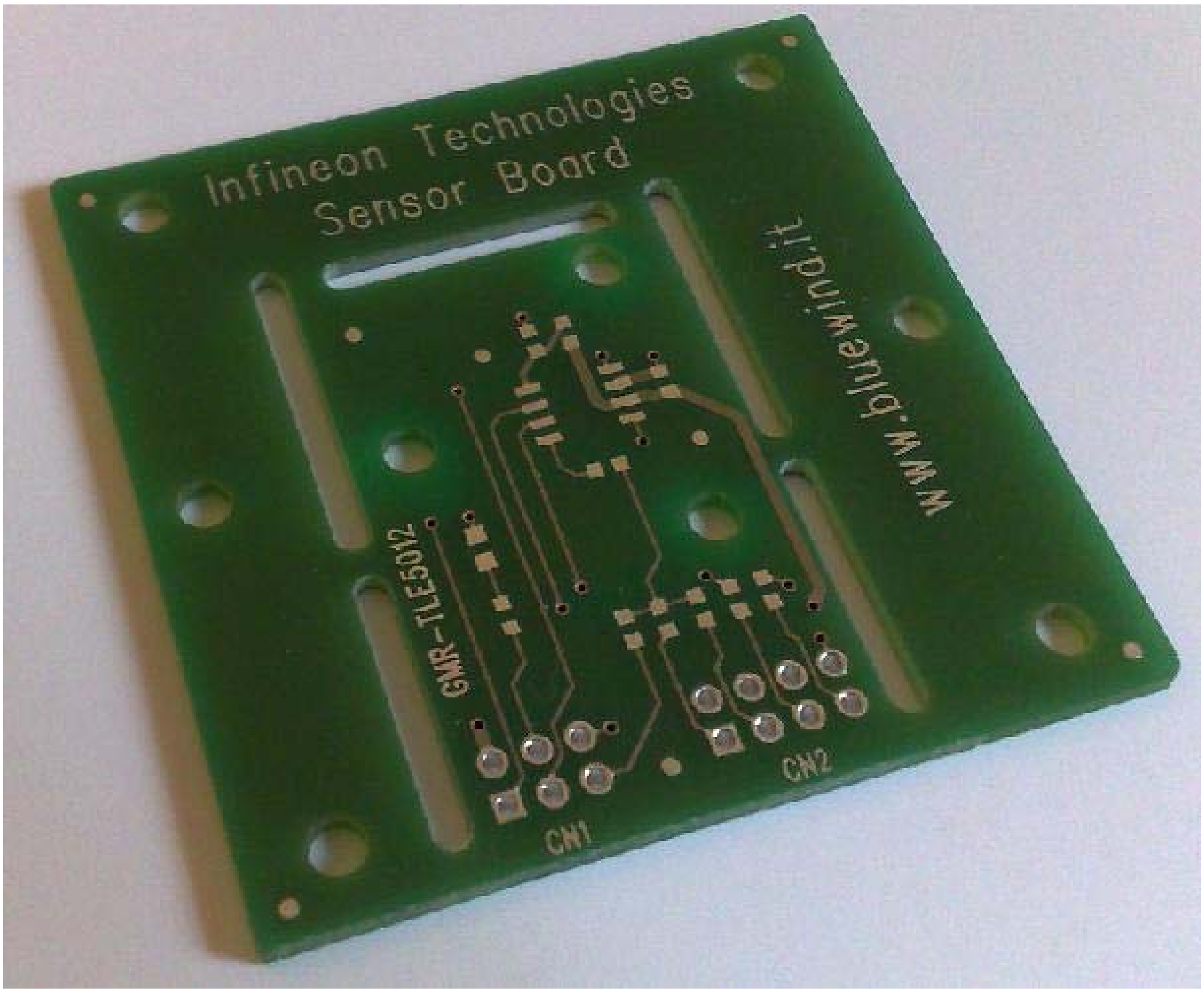

Figure 23 TLE5012 Board

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