Design of A Driver Circuit for A Brushless DC Motors using Sensorless Techniques and Application Trends

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***Abstract*— This design will be developed to be a fully functional product that will go into controller air intake into an engine in a car. The driver will require to satisfy all automotive requirements. This type of motors represents the most recent end of a long evolution of motors technology. It is known for its increased efficiency, increased reliability ,reduced noise and longer lifetime over brushed DC motors. The performance and reliability of BLDC motor drivers have been improved through sensor-less technology .The primary advantages of brushless DC motors are low maintenance, no brush sparking, high operating speeds, high efficiency. Permanent magnet (PM) motors have been widely used in a variety of applications in industrial automation ,computers, aerospace, military(gun turrents drives for combat vechicles),automotive (hybrid vechicles).The design of a driver circuit for a 3 pole star connected sensor-less brushless motor utilizing an advanced open control technique in this paper. The open loop starting is accomplished by providing a rotating stator field which increases gradually in magnitude an over from open-loop and/or frequency. The change over from open-loop to sensor-less method is made when sufficient back-EMF is generated ,so that the sensor-less method should start generating the switching instants of all transistors.**

Keywords*— *Sensorless BLDC ; Back-EMF; openloop; Direct back-EMF.

I. INTRODUCTION

Electric motors are one of the most essential components and the driving force of industry today. In general, there are two types of motors namely AC and DC.AC motors are usually less expensive, rugged and have low maintenance but hard to control. On the other hand the DC motors are more expensive, but highly controllable. The conventional DC motors are highly efficient and their characteristics make them suitable for use in different applications. However, one of their drawbacks is the need of a commutator and brushes, which are subject to aware and require maintenance. When the task of commutator and brushless are replaced by solid-state switches,

maintenance free motors were realized and the new motor called Brushless DC motors emerged. As the name implies, BLDC motors do not use brushes for commutation instead ,they are electronically commutated. In addition, the ratio of torque delivered to the size of the motor is higher, making it useful in applications where space and weight are critical factors. BLDC systems are attractive for use in many applications with PWM used as an efficient means of power transfer, where high torque and precision control are required. The control of BLDC motors can be done in sensor or sensor-less mode, but to reduce overall cost of actuating devices, sensor-less control techniques are normally used. The advantage of sensor-less BLDC motor control is that the sensing part can be omitted, and thus overall costs can be considerably reduced.

II. TECHNIQUES AND ADVANCES IN SENSORLESS CONTROL

Position sensors can be completely eliminated ,thus reducing further cost and size of motor assembly, in those applications in which only variable speed control(i.e. ,no positioning) is required and system dynamics is not particularly demanding(i.e., slowly or, at least ,predictably varying load).In fact, some control methods, such as back-EMF and current sensing, provide, in most cases, enough information to estimate with sufficient precision the rotor position and ,therefore, to operate the motor with synchronous phase currents. A PM brushless drive that does not require position sensors but only electrical measurements is called a sensor-less drive.

A. Typical Sensorless BLDC Motor Drive

In this figure, each of the three inverter phases are highlighted in a different colour, including the neutral pointed phase A, green phase B, blue phase C, and pink neutral point N. The stator iron of the BLDC motor has a non linear magnetic saturation characteristic, which is the basis from which it is possible to determine the initial position of the rotor. When the stator winding is energized,applying a DC voltage for a certain time, a magnetic field with a fixed direction will be established. Then ,the current responses are different due to inductance difference, and this variation of current responses contain the information of the rotor position. Therefore, the inductance of stator winding is a function of the rotor position.

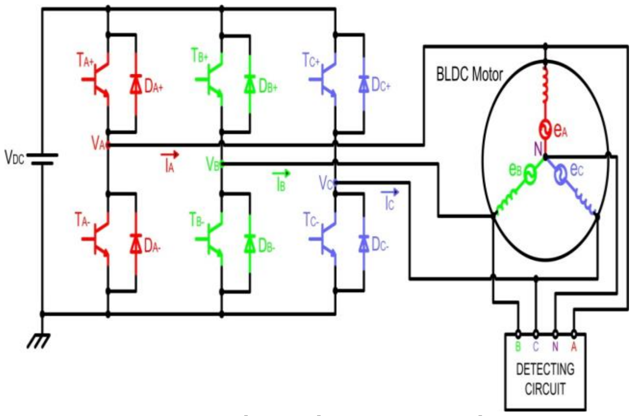


Figure 1:Typical sensor-less BLDC motor drive

B. Back-EMF Zero Crossing Detection Method (Terminal Voltage Sensing)

The zero-crossing approach is one of the simplest methods of back-EMF sensing technique, and is based on detecting the instant at which the back-EMF in the unexcited phase crosses zero .This zero crossing triggers a timer, which may be as simple as an RC time constant, so that the next sequential inverter commutation occurs at the end to this timing interval. For typical operation of a BLDC motor, the phase current and back-EMF should be aligned to generate constant torque.

- Direct back-EMF detection methods: the back-EMF of floating phase is sensed and its zero crossing is detected by comparing it with neutral point voltage.This scheme suffers from high common mode voltage and high frequency noise due to the PWM drive,so it requires low pass filters ,and voltage dividers.The methods can be classified as:

- Back-EMF Zero Crossing Detection(ZCD) or Terminal Voltage Sensing.

- Indirect back-EMF detection methods: because filtering introduces commutation delay at high speeds and attenuation causes reduction in signal sensitivity at low speeds ,the speed range is narrowed in direct back-EMF detection methods .In order to reduce switching noise , the indirect back-EMF detection methods are used .These methods are the following:

- Third Harmonic Voltage Integration, Back-EMF integration.

C.Why sensorless control?

- Rotor position must be known in order to drive a brushless dc motor. If any sensors are used to detect rotor position, sensed information must be transferred to a control unit.
- Therefore, additional connections to the motor are necessary. This may not be acceptable for some applications. There are at least two reasons why you might want to eliminate the position sensors:
  • Inability to make additional connections between position sensors and the control unit.
  • Cost of the position sensors and wiring.

III HARDWARE IMPEMENTATION
SOFTWARE USED

A.Cadsoft eagle

EAGLE stands for Easily Applicable Graphical Layout Editor in English and Einfach anzuwendender grafischer .Layout –Editor in German .It is designed and developed by Cadsoft Computer GmbH and is flexible ,expandable and scriptable ,electronic design automation (EDA) application with schematic capture editor ,printed circuit board (PCB) layout editor, auto-router and computer- aided manufacturing (CAM) and bill of materials (BOM) tools ,Premier Farnell bought EAGLE in 2008.

B. Schematic editor

Schematics can be designed in a hierarchical structure; modules are represented by module instances and connected through ports in the top level of the schematic.

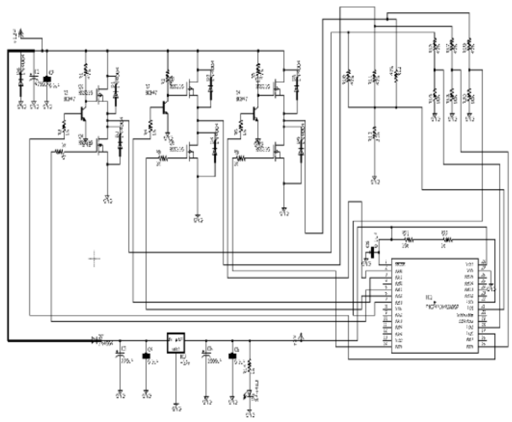


Figure 2: Schematic Diagram

C.Component used

- Capacitor
- Diode
- Resistor
- Voltage regulator
- Transistor BC847
- PIC 24F microcontroller
- MOSFET TO92

D .Layout editor

The PCB layout editor allows back annotation to the schematic and auto routing to automatically connect traces based on the connections defined in the schematic .EAGLE saves Gerber and Postscript layout files and Excellon and sieb & Meyer drill files. These standard files are accepted by many PCB fabrication companies.

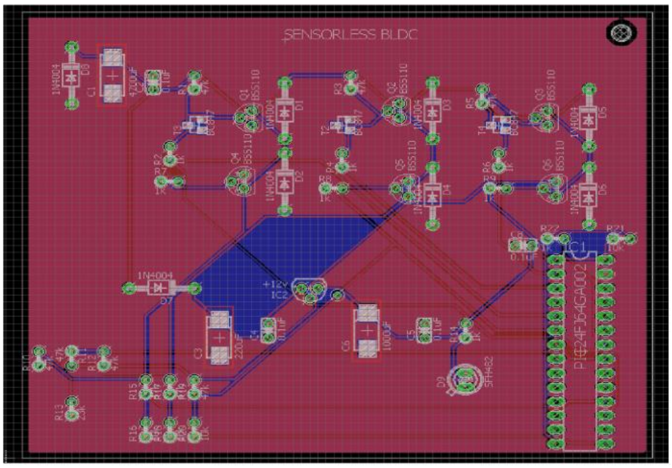
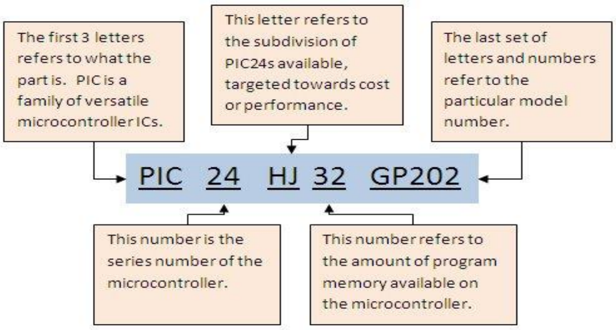


Figure 3: Layout for senseless BLDC motor drive

E.MPLAB

Here we use, 16 bit PIC microcontrollers .MPLAB is designed to work with MPLAB certified devices such as the MPLAB ICD 3 and MPLAB REAL ICE for programming and debugging PIC microcontrollers using a personal computer .PICKIT programmers are also supported by MPLAB to load the PIC program.



F. Proteus Simulation Software

Proteus is a software packages for computer-aided design, simulation and design of electronic circuits. It consists of two main parts, the ISIS the circuit design environment, which also the simulator VSM includes, and the ARES. The PCB-Designer Developer and manufacturer of the software package is the company Lab center Electronics. The microcontrollers are in the periphery and in the code fully supported. It includes a debugging environment for the program code of the microcontroller.

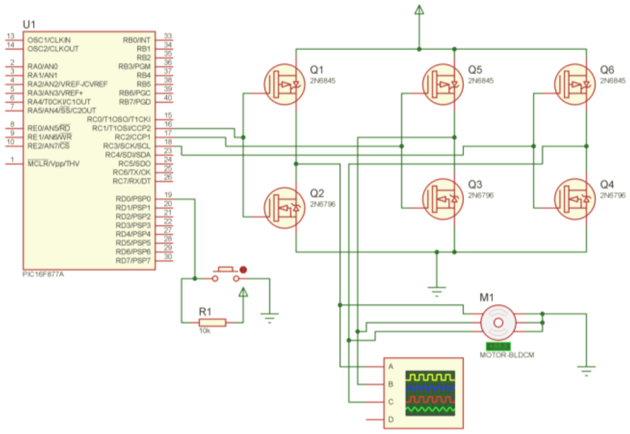


Figure 4: Animated model of schematic diagram

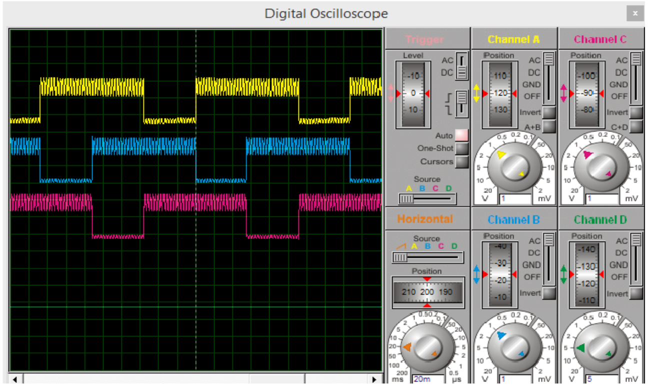


Figure 5: Simulated model of sensor-less BLDC motor drive

G.Hardware Description

The block diagram in figure (a) depicts how the BLDC motor is driven using a dsPIC24F.The six MCPWM outputs are connected to three MOSFET driver pairs(IR2110S), which in turn connected to six MOSFETs (IRFP360).These MOSFETs are connected in a three phase bridge format to the three BLDC motor windings.MOSFET drivers also require a high voltage (12V) to operate,so this voltage level needs to be provided.The motor is a 24V BLDC motor so the DC+ to DC- bus voltage is 24V.A regulated 5V is provided to drive the dsPIC24F.The sensorless inputs are connected to input pins that have change notification circuits associated with them.These inputs are enabled along with their interrupt.If a change occurs on any of these three pins, an interrupt is generated.To start and stop the motor,a push button switch is provided at RC14.

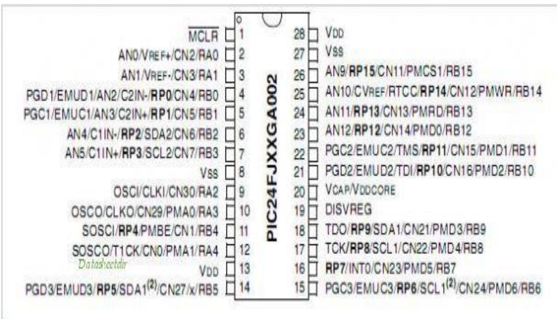


Figure 6:PIC 24F IC

H.Mosfet drivers

A P-Channel MOSFET is a type of MOSFET in which the channel of the MOSFET is composed of a majority of holes as current carriers. When the MOSFET is activated and is on, the majority of the current flowing are holes moving through the channels.This is in contrast to the other type of MOSFET, which are N-Channel MOSFETs in which the majority of current carriers are electrons.Before, we go over the construction of P-Channel MOSFETs, we must go over the 2 types that exist. There are 2 types of P-Channel MOSFETs,enhancement-type MOSFETs and depletion-type MOSFETs.

A depletion-type MOSFET is normally on (maximum current flows from drain to source) when no difference in voltage exists between the gate and source terminals. However, if a voltage is applied to its gate lead, the drain-source channel becomes more resistive, until the gate voltage is so high, the transistor completely shuts off. An enhancement-type MOSFET is the opposite. It is normally off when the gate-source voltage is 0 (VGS=0). However, if a voltage is applied to its gate lead, the drain-source channel becomes less resistive.

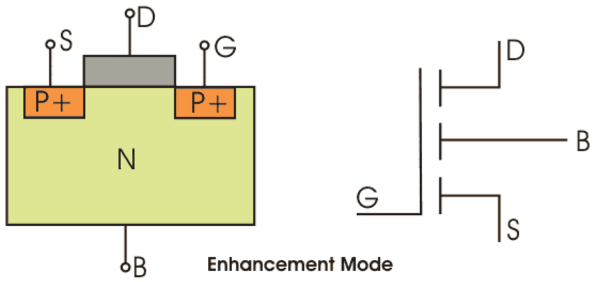


Figure 7:nchannel MOSFET

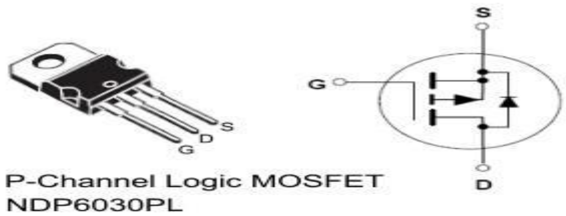


Figure 8: Q1 BSS110 T092 MOSFET

I.BC847 TRANSISTORS
NPN SILICON

These transistors are designed for general purpose amplifier applications. They are housed in the SC−70/SOT−323 which is designed for low power surface mount applications.

FEATURES

• S and NSV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC−Q101 Qualified and PPAP Capable

• These Devices are Pb−Free, Halogen Free/BFR Free and are RoHS Compliant

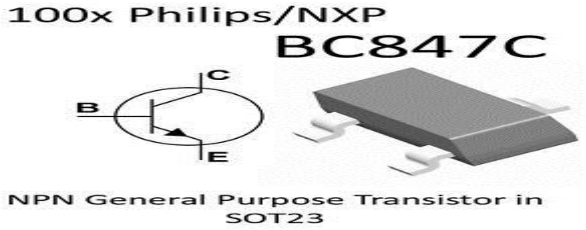


Figure 9: BC847 transistor

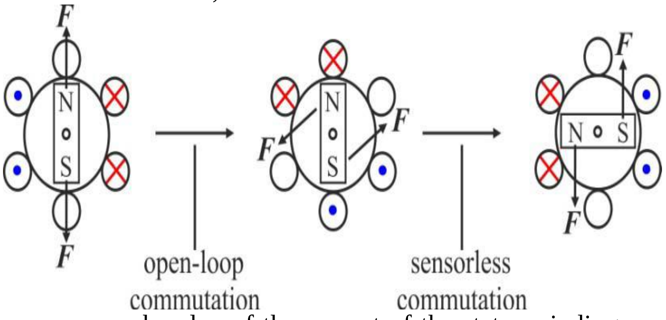
J. VOLTAGE REGULATOR

The SOT223-3 Voltage Regulator Evaluation Board is designed to provide functional evaluation of Microchip Voltage Regulators that utilize the SOT223-3 package and the following device pin out: - Pin 1 = VIN - Pin 2 = GND - Pin 3 = VOUT The SOT223-3 Voltage Regulator Evaluation Board does not come with a voltage regulator soldered onto the board. This allows the user to attach the voltage regulator of their choosing to the board and perform quiescent current, ground current, PSRR, and other desired tests.

IV. RESULTS AND DISCUSSION

A.Open Loop Control

The back-EMF detection methods cannot be applied well when the motor is at a standstill or lowspeed,since back-EMF is zero.A starting procedure is needed to start the motor from standstill.The open-loop starting is accomplished by providing a rotating stator field which increases gradually in magnitude and/or frequency.Once the rotor field begins to became attracted to the stator filed enough to overcome friction and inertia, the rotor begins to turn and the motor act as a permanent magnet synchoronous machine with the disadvantage that the initial rotor movement direction is not predictable.When stator field becomes just strong enough,the rotor could move in either direction.If the speed of the stator field is slow enough and the load torque demanded does not exceed the pullout torque the motor will operate synchronously in the desired direction.The change over from open-loop to sensorless method is made when sufficient back-EMF is generated, so that the sensorless method should start generating the switching instants of all transistors.This method is simple but the reliability is affected by the load and it may cause temporarily reverse rotation of the rotor during the start-up.This is not allowed in some applications, such as disk drives,which strictly require unidirectional motion.However, it may be satisfactory in others such as pump and fan drives.Another problem exists if the stator field is rotating at too great a speed when the rotor field picks up.This causes the rotor to oscillate ,which requires the stator field to decrease in frequency to allow starting.The stator iron of the BLDC motor has non-linear magnetcic saturation characteristisc,which is the basis for determining the initial position of the rotor. In order to overcome the drawbacks mentioned above,the rotor position detecting and speed up methods based on saturation effect of the stator iron can be applied, such as the short pulse sensing technique.This scheme adopts a voltage pulse train composed of the succesive short and long pulses to generate positive torque to speed up the motor, and it does not bring any reverse rotation and vibration during the start up process.The response speed of the stator current, and the



response peak value of the current of the stator winding can be used to detect the rotor position.Here we used to show the operation of sensorless BLDC driver circuit in Figure (a) demo board and a normal DC motor is used by varying the speed using potentiometer, in future work need to work on the indirect back-EMF in desired circuit under fabrication.

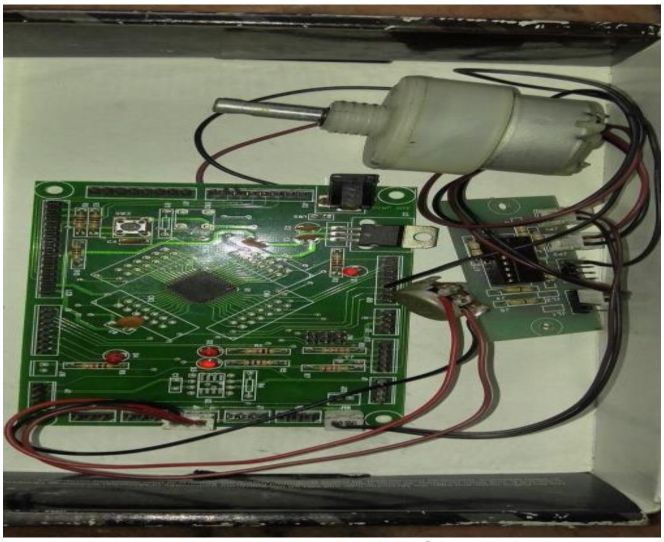


Figure 6: Demo Board

V. CONCLUSION

In this paper a review of position methods for BLDC motors has been presented.The fundamentals of various techniques have been introduced,mainly back-EMF schemes and estimators, as a useful reference for preliminary investigation of conventional methods.Closed-loop controls are used in applications that require more accurate and adaptive control of the system.These controls use feedback to direct the output states of a dynamic system. Closed loop controls overcome the drawbacks of open loop control to provide compensation for disturbances in the system, stability in unsatble processes and reduced sensitivity to parameter variations (dynamic load variation)Sensorless control has two distinct advantages: lower system cost and increased realibility.

There are two disadvantages to sensorless control:

The motor must be moving at a minimum rate to generate sufficient BEMF to be sensed.

Abrupt changes to the motor load can cause the BEMF drive loop to go out of lock.

REFERENCES

[1] Bucak, I.Ö. Position Error Compensation Via a Variable Reluctance Sensor Applied to a Hybrid Vehicle Electric Machine. *Sensors* **2010**.

[2] Su, G.J.; McKeever, J.W. Low-Cost Sensorless Control of Brushless DC Motors with Improved Speed Range. *IEEE Trans. Power Electron.* **2004**.

[3] Hernandez, W. Robust Multivariable Estimation of the Relevant Information Coming from a Wheel Speed Sensor and an Accelerometer Embedded in a Car Under Performance Tests. *Sensors* **2005**.

[4] Lin, M.; Zhang, Z.; Lin, K. A Novel and Easy-Realizing Initial Rotor Position Detection Method and Speedup Algorithm for Sensorless BLDC Motor Drives. In *Proceedings of the International Conference on Electrical Machines and Systems (ICEMS 2008)*, Wuhan, China, October 2008.

[5] Vinatha, U.; Pola, S.; Vittal, K.P. Recent Developments in Control Schemes of BLDC Motors. In *Proceedings of the IEEE International Conference on Industrial Technology (ICIT 2006)*, Mumbai, India, December 2006.

[6] Shao, J.; Nolan, D.; Hopkins, T. A Novel Direct Back EMF Detection for Sensorless Brushless DC (BLDC) Motor Drives. In *Proceedings of the Seventeenth Annual IEEE Applied Power Electronics Conference and Exposition (APEC 2002)*, Dallas, TX, USA, March 2002.

[7] Kim, T.; Lee, H.W.; Ehsani, M. Position Sensorless Brushless DC Motor/Generator Drives: Review and Future Trends. *IET Electr. Power Appl.* **2007**.

[8] Shao, J. An Improved Microcontroller-Based Sensorless Brushless DC (BLDC) Motor Drive for Automotive Applications. *IEEE Trans. Ind. Appl.* **2006**.

[9] Zhang, L.; Xiao, W.; Qu, W. Sensorless Control of BLDC Motors using an Improved Low-Cost Back EMF Detection Method. In *Proceedings of the 37th IEEE Power Electronics Specialists Conference (PESC 2006)*, Jeju, South Korea, June 2006.