Motor control shield with IFX007T

For Arduino

About this document

Scope and purpose

This document describes how to use the motor control shield with IFX007T for Arduino.

Intended audience

Engineers, hobbyists and students who want to add a powerful motor control to Arduino projects.

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1 Motor control shield introduction

1.1 Motor control shield overview

The motor control shield adds powerful motor control to the Arduino projects. The shield can be controlled with the general logic IO-Ports of a microcontroller. Either an Arduino Uno or the XMC4700 Relax Kit from Infineon can be used as the master.

On board of the motor control shield are three IFX007T NovalithIC^{TM}. Each features one P-channel high side MOSFET and one N-channel low side MOSFET with an integrated driver IC in one package. Due to the P-channel high side switch a charge pump is not needed.

The IFX007T half-bridge is easy to control by applying logic level signals to the IN and INH pin. When applying a PWM to the IN pin the current provided to the motor can be controlled with the duty cycle of the PWM. With an external resistor connected between the SR pin and GND the slew rate of the power switches can be adjusted. The motor control shield can be easily connected to any Arduino board or the XMC4700 Relax Kit via headers.
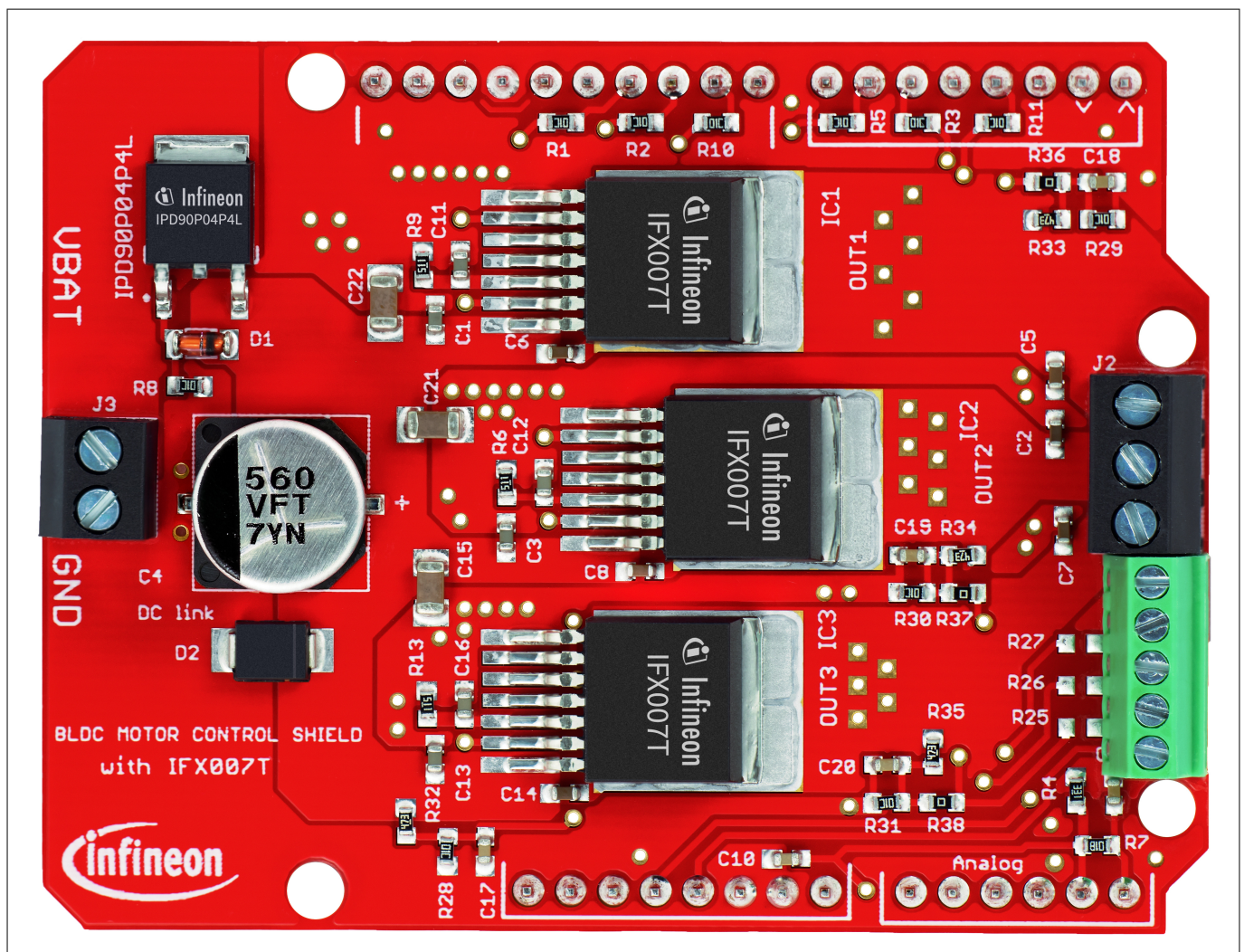

Figure 1 Motor control shield photo

1.2 Key features

The motor control shield has the following features:

- An Arduino Uno, XMC4700 Relax Kit, or similar board connected to the shield can control the three half-bridges via the general IO pins.
- Brushed DC Motor Control up to 250 W continuous load
  - 8 – 24 V nominal input voltage (max. 6 – 40 V)
  - Average motor current of 30 A restricted due to the limited power dissipation of the PCB (IFX007T current limitation @ 55 A min.)
- Drives either one brushed/brushless DC motor, one brushed bi-directional DC motor or three uni-directional DC motors.
- Capable of high frequency PWM, e.g. 25 kHz
- Adjustable slew rates for optimized EMI by changing external resistor
- Driver circuit with logic level inputs
- Status flag diagnosis with current sense capability
- Protection e.g. against overtemperature, overcurrent and cross current protection
- Reverse polarity protection with IPD90P04P4L
- Further comments:
  - Due to limited performance caused by the PCB layout, we recommend our customers to remove the capacitance C5 for high frequency applications. It is only layout related, not refer to the device.
  - The size of the DC-link capacity (C4 in schematic) with 560 µF is for most applications sufficient. But for high current applications, we recommend our customers to follow the design rule in our application note and replace the DC-link cap with a bigger one.
  - Due to the limited area of the PCB and the small DC-link cap, the demoboard shouldn't be used for short circuit test.
  - This demoboard is designed for both sensorless applications and the application with Hall sensor. But for the application with sensor, please remove R36/R37/R38 and solder R18/R19/R20/R21/R22/R23/R25/R26/R27.
  - Due to the limited pinout of the Arduino shield all IS pins of the three devices are connected together. According to different applications the value of R4 could be adjusted to achieve a better current sense performance.

2   Motor control shield description

For a safe and sufficient motor control design, discrete components are needed. Some of them must be dedicated to the motor application and some to the NovalithIC™.

Figure 2 and *Figure 3* show the schematics plus the corresponding layout of the motor control shield. The thermal performance of the shield itself limits the possible current which should be applied to the motor control shield to 30 A. To reduce the cost, we use a DC-link cap of 560 µF and have limited PCB area. Therefore, the best performance of the device could not be achieved.

2.1   Schematics

In *Figure 2* the schematics of the motor control shield is shown. The schematics are based on the application circuit in the *IFX007T datasheet*.
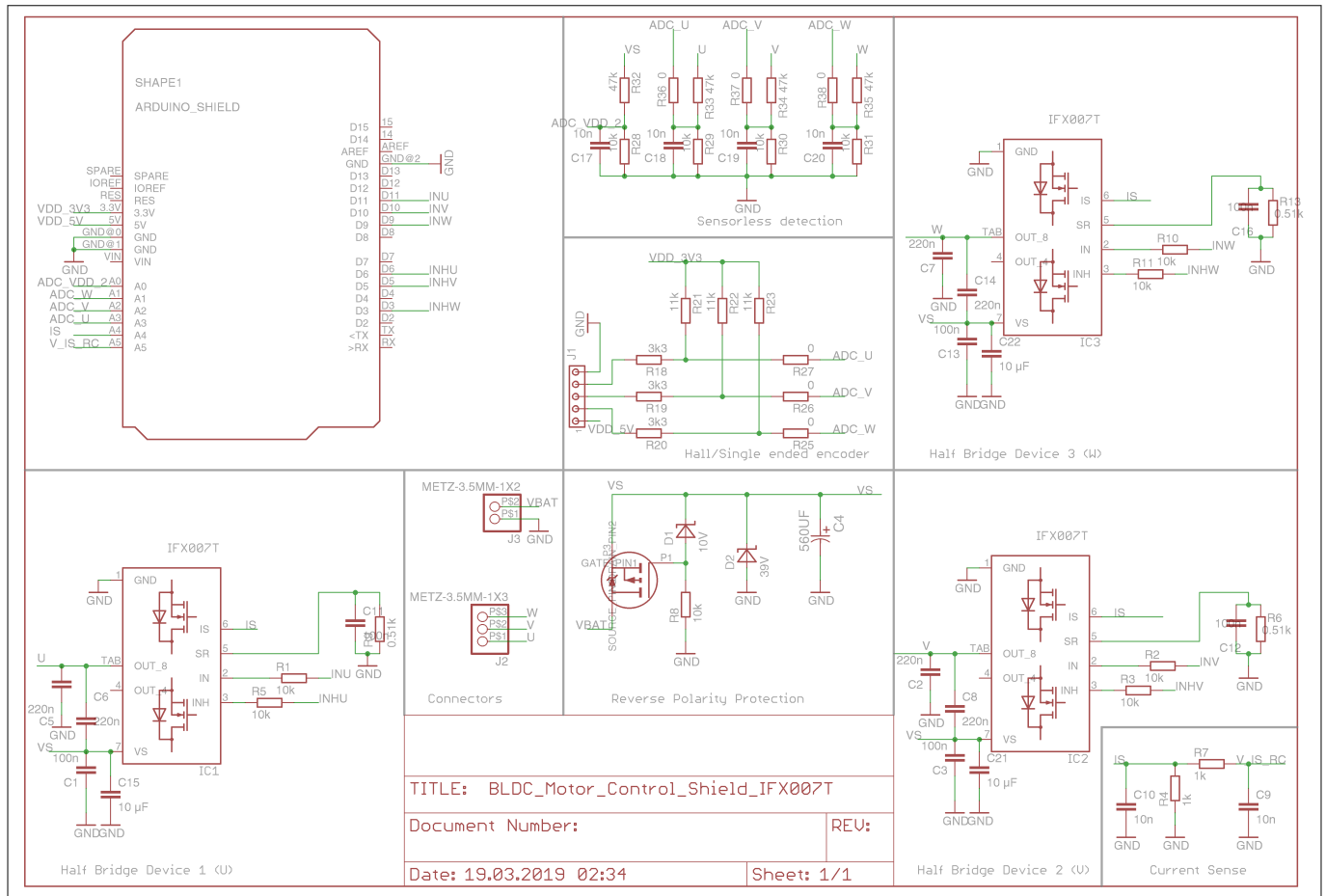
Figure 2   Schematic of motor control shield for Arduino with IFX007T

2.2   Layout

Figure 3 shows the layout of the motor control shield. The layout mainly follows the design rules in the **Application Note**. To reduce the cost, the PCB area is quite limited. Based on different applications customers could adjust the area to improve the GND plane and get better performance for their own PCB design.
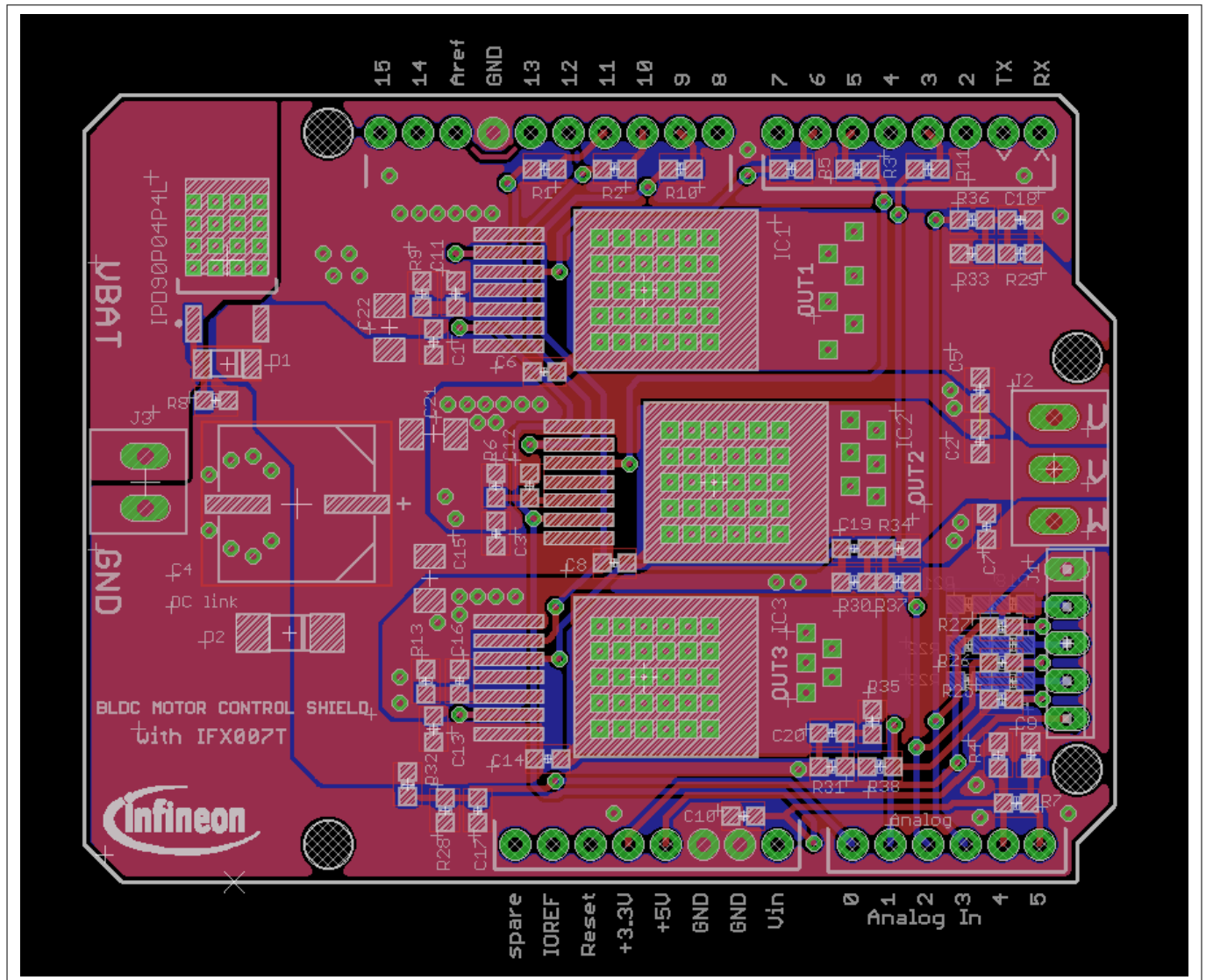
Figure 3   Motor control shield for Arduino with IFX007T - Layout

2.3   Important design and layout rules

The basis for the following design and layout recommendations is the parasitic inductance of electrical wires and design guidelines as described in Chapter 3 of the ***Application Note*** .

- C4, so called DC-link capacitor: This electrolytic capacitor is required to keep the voltage ripple at the Vs-pin of the NovalithIC™ low during switching operation (the applied measurement procedure for the supply voltage is described in Chapter 2.1 of the Application Note). It is strongly recommended that the voltage ripple at the NovalithIC™ Vs-pin to the GND-pin is kept below 1 V peak to peak. The value of C4 must be aligned accordingly. See Equation 10 in the Application Note. Most electrolytic capacitors are less effective at cold temperatures. It must be assured that C4 is also effective under the worst case conditions of the application. The layout is very important too. As shown in Figure 6, the capacitor C4 must be positioned with very short wiring close to the NovalithIC™. This must be done to keep the parasitic inductors of the PCB-wires as small as possible.

- C15/C21/C22: This ceramic capacitors support C4 to keep the supply voltage ripple low and cover the fast transients between the Vs-pin and the GND-pin. The value of these ceramic capacitors must be chosen so that fast Vs-ripples at the NovalithIC™ do not exceed 1V peak to peak. The layout wiring for C15/C21/C22 must be shorter than for C4 to the NovalithIC™ to keep the parasitic PCB-wire inductance as small as

possible. In addition the parasitic inductance could be kept low by placing at least two vias for the connection to the GND plane.

- C6/C8/C14: These ceramic capacitors are important for EMI in order to avoid entering RF into the NovalithIC™ as much as possible. Good results have been achieved with a value of 220 nF. In terms of layout, it is important to place these capacitors between "OUT" and "Vs" without significant additional wiring from C6/C8/C14 to the Vs- and OUT-line.

- C2/C5/C7: These ceramic capacitor help to improve the EMC immunity and the ESD performance of the application. Good results have been achieved with a value of 220 nF. To keep the EMC and ESD out of the board, the capacitor is most effective when positioned directly next to the board connector. In addition, the parasitic inductance could be kept low by placing at least two vias for the connection to the GND plane.

Other components:

- IC0, D1 and R8: Reverse polarity protection. See Chapter 3.5 of the Application Note.

- R6/R9/R13: Slew rate resistors according to data sheet.

- C11/C12/C16: Stabilization for slew rate resistors (R6/R9/R13).

- R4: Resistors to generate a current sensing voltage from the IS current.

- C10: Ceramic capacitors for EMC immunity improvement. GND connection with at least two GND-vias. A good value is 1nF to 10nF. In case the current should be measured during the PWM-phase this capacitor must be adapted to the ON-time inside the PWM-phase.

- R1/R2/R3/R5/R10/R11: Device protection in case of microcontroller pins shorted to Vs.

2.4　　　　Pin assignment

To use the motor control shield the necessary control signals can be applied directly at the Arduino™ connectors. There is no need to use an Arduino or XMC 4700 Relax Kit to get the motor control shield into an application. The control pins are logic level inputs which can be driven by any other microcontroller or with logic level signals. Besides the supply voltage Vbat has to be provided to the Vbat connector. *Figure 4* shows the pinout/connectors of the motor control shield.
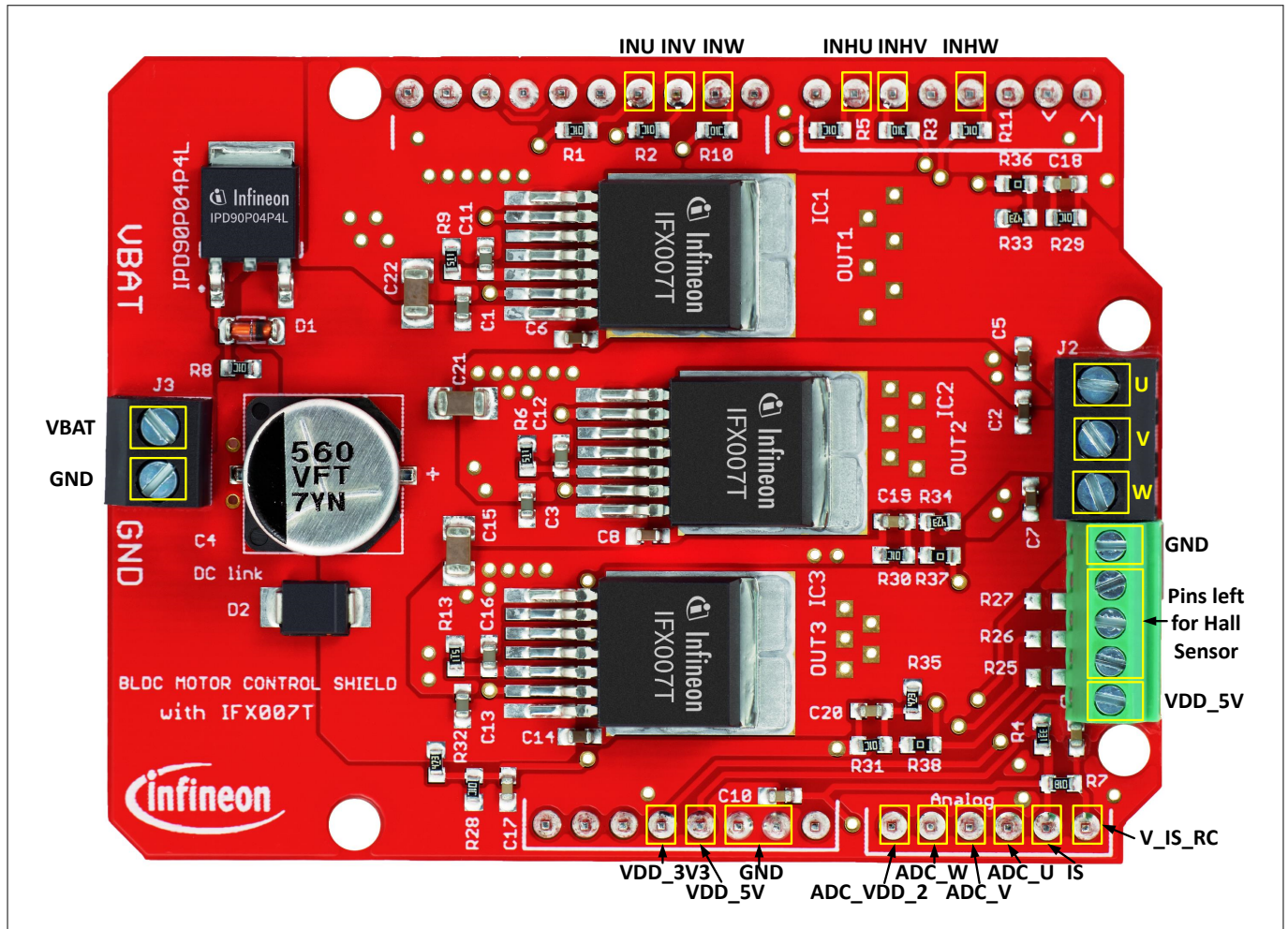
Figure 4   Motor control shield connectors

2.5   Pin definitions and functions

Table 1   Pin definitions and functions

Pin	I/O	Function
GND		Ground
VBAT		Power supply
VDD_3V3		Power supply
VDD_5V		Power supply
U	O	Output U
V	O	Output V
W	O	Output W
INHU	I	Inhibit of bridge U
INHV	I	Inhibit of bridge V
INHW	I	Inhibit of bridge W
INU	I	Input of bridge U

Table 1   **Pin definitions and functions (continued)**

Pin	I/O	Function
INV	I	Input of bridge V
INW	I	Input of bridge W
IS	O	Current sense pin of all three channels
V_IS_RC	O	Filtered current sense voltage
ADC_U	O	ADC for sensor of sensorless detection
ADC_V	O	ADC for sensor of sensorless detection
ADC_W	O	ADC for sensor of sensorless detection
ADC_VDD_2	O	Reference voltage

2.6   Operation modes

This Arduino shield can be used for both sensorless control and sensor based control. For different operation modes some resistors need to be removed/placed. All required solder places are reserved on the PCB board.

1.   Hall — Sensor based control

In order to enable motor control with hall-sensor(s) the connector J1 is provided to connect the signal to the XMC/Arduino. For this control mode, R18/R19/R20/R21/R22/R23/R25/R26/R27 have to be placed and R36/R37/R38 should be removed.

2.   Sensorless control — Back EMF

Brushless BEMF control of a BLDC motor is allowed by placing resistors R28/R29/R30/R31/R32/R33/R34/R35/R36/R37/R38 and removing R25/R26/R27. The three output voltages will be divided by the voltage divider, and the voltage of ADC_U/ADC_V/ADC_W can be measured by ADCs to detect zero-crossing.

3.   Sensorless control — Space vector modulation

Since IFX007T has current sense feature integrated, the Arduino shield should be able to control the motor based on the current measurement. Please be aware the current sense resistance R4 should be adjusted based on the application to make sure the voltage at IS pin won't be too high for current measurement.

3   IFX007T overview

The IFX007T is an integrated high current half bridge for motor drive applications. It is part of the industrial & multi purpose NovalithIC™ family containing one P-channel high-side MOSFET and one n-channel low-side MOSFET with an integrated driver IC in one package. Due to the P-channel high-side switch the need for a charge pump is eliminated thus minimizing EMI. Interfacing to a microcontroller is made easy by the integrated driver IC which features logic level inputs, diagnosis with current sense, slew rate adjustment, dead time generation and protection against overtemperature, undervoltage, overcurrent and short circuit. The IFX007T provides a cost optimized solution for protected high current PWM motor drives with very low board space consumption.

3.1 Key features of IFX007T

Summary of features:

- Path resistance of max. 12.8 mΩ @ 25°C (typ. 10.0 mΩ @ 25°C)

  High side: max. 6.5 mΩ @ 25°C (typ. 5.3 mΩ @ 25°C)

  Low side: max. 6.3 mΩ @ 25°C (typ. 4.7mΩ @ 25°C)
- Enhanced switching speed for reduced switching losses
- Capable for high PWM frequency combined with active freewheeling
- Current limitation level of 55A min.
- Status flag diagnosis with current sense capability
- Undervoltage shutdown
- Driver circuit with logic level inputs
- Adjustable slew rates for optimized EMI
- Operation up to 40V
- Protection against e.g. overtemperature, overcurrent and cross current
- Green Production(RoHS compliant)
- JESD471 Qualified

3.2 Block diagram

The IFX007T used in the motor control shield is an integrated high current half-bridge for motor drive applications. This device contains one P-channel high-side MOSFET and one N-channel low-side MOSFET with an integrated driver IC in one package. The industrial & multipurpose NovalithIC™ IFX007T is the interface between the microcontroller and the motor, equipped with diagnostic and protection functions.

As both the high-side and low side switch are placed on one single leadframe this results in many system benefits: Resulting from the low distance between the high-side MOSFET and the low-side MOSFET the stray inductance between them is minimal thus minimizing negative voltage spikes at OUT during switching and improving EMC. As the voltage level of the leadframe is on the output of the half-bridge, only one single cooling area is required (on OUT potential) for the device, thus being used for both a high-side or low-side current switching. For a state of the art N-channel solution, usually two cooling areas are required, each for the highside and low-side MOSFET.

Due to the p-channel highside switch the need for a charge pump is eliminated thus minimizing EMI. Interfacing to a microcontroller is made easily by the integrated driver IC which features logic level inputs, diagnosis with current sense, slew rate adjustment, dead time generation and protection against overtemperature, undervoltage, overcurrent and short circuit.
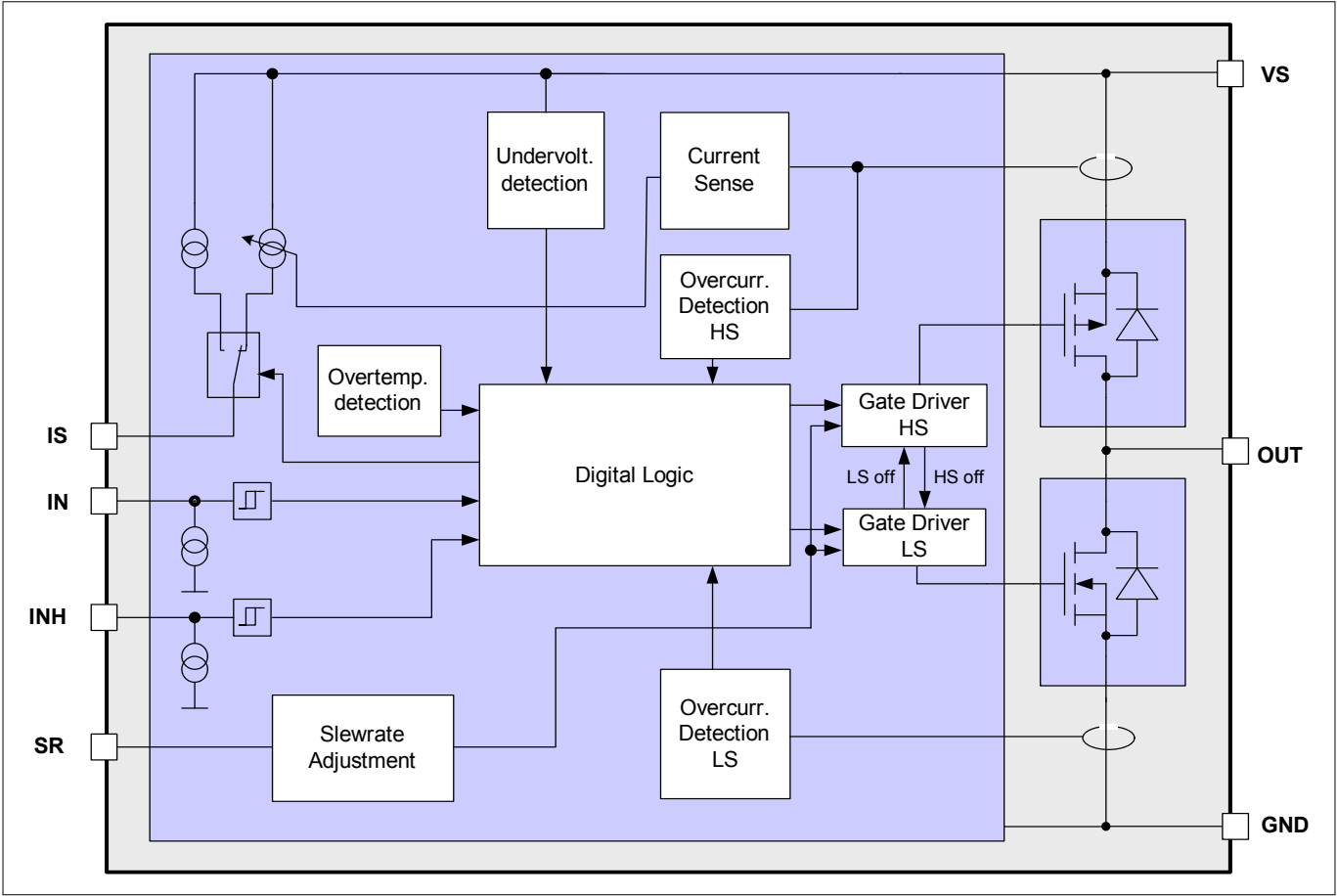
Figure 5   **Block diagram of IFX007T**

3.3   Pin assignment
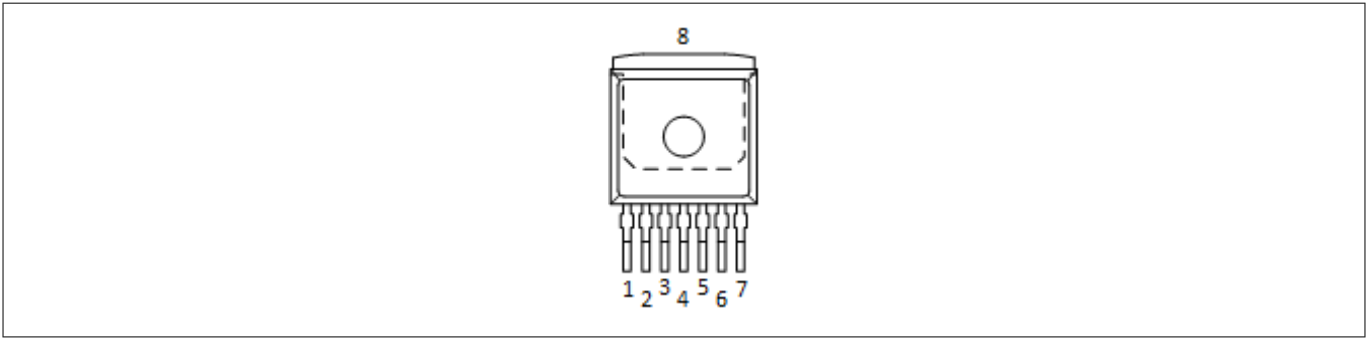

Figure 6   **Pin assignment IFX007T (top view)**

3.4   Pin definitions and functions of IFX007T

Table 2   **Pin definitions and functions**

Pin	Symbol	I/O	Function
1	GND	-	Ground
2	IN	I	Input

Table 2   **Pin definitions and functions (continued)**

Pin	Symbol	I/O	Function
			Defines whether high- or low side switch is activate
3	INH	I	Inhibit When set to low device goes in sleep mode
4, 8	OUT	O	Power output of the bridge
5	SR	I	Slew Rate The slew rate of the power switches can be adjusted by connecting a resistor between SR and GND
6	IS	O	Current sense and diagnostics
7	VS	-	Supply (VBAT at the shield connector)

4   Getting started

4.1   Target applications

The application targeted by the IFX007T devices is brushed DC/brushless DC motor control. Besides motor control any other inductive, resistive and capacitive load within the electrical characteristics of the NovalithIC™ can be driven by the IFX007T. In the motor control shield three IFX007T are used. Each is capable of driving up to 55 A. The limited thermal performance of the shield PCB limits the recommended maximum current to 30 A.

4.2   Typical target application

With the motor control shield one BLDC motor, three mid power uni-directional DC-brushed motors or one bi-directional brushed motor can be driven. The half-bridges are controlled via the IN (Input) and INH (Inhibit) pins. The slew rate of the high frequency PWM can be adjusted by connecting an external resistor between the SR pin and GND. The IFX007T also provides a sense current at the IS pin. The power shield provides a fast and easy access to motor control solutions of up to 300 W applications e.g. automation, home appliances, robotics, power tools, small robotics, drones, vacuum cleaners, medical motors, hospital beds, 3D printers, fans, pumps, etc..

4.3   Getting started

• Choose a mid-power, brushed/brushless DC motor.
• Choose a DC adapter. The nominal input of the power shield is 8 – 24 V DC. Maximum Voltage is 40 V

- Connect the power shield to Arduino Uno or XMC 4700 Relax Kit.
- Connect power supply (5 V) to the Arduino Uno or XMC 4700 Relax Kit (Micro USB).
- Program the controller board with the motor control software: **ARDUINO** or **DAVE**™
- Connect the motor to U, V and W (H-bridge)
- Connect the DC adapter to the Power Shield (Vbat, GND)
- Turn on the power

4.4 User guide of democode

Example software for Arduino are available. Please **download** demo code of half-bridge, H-bridge and BLDC motor control with/without Hall sensor on our website.

- Connect the Arduino Board with a micro USB cable to the USB port of your computer.
- Download and install **Arduino IDE** .
- Start Arduino IDE and open the demo code:

1. Select File --> Open
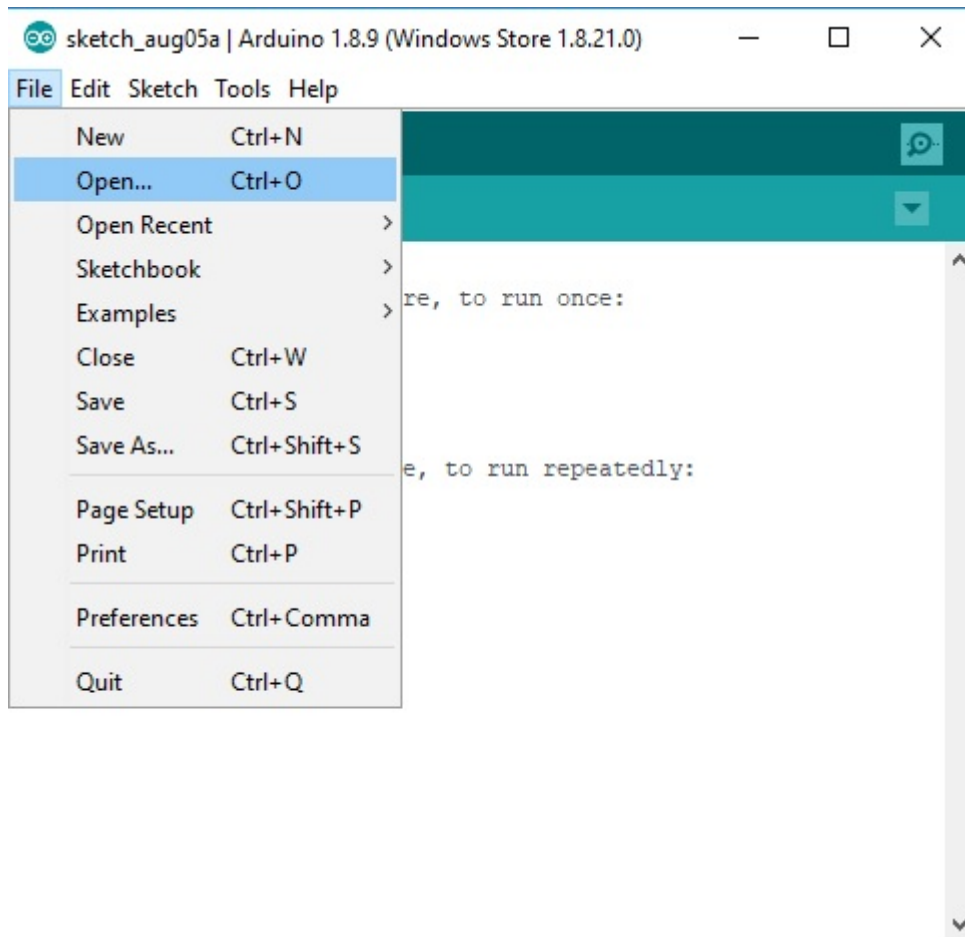
2. Choose BLDC_BEMF
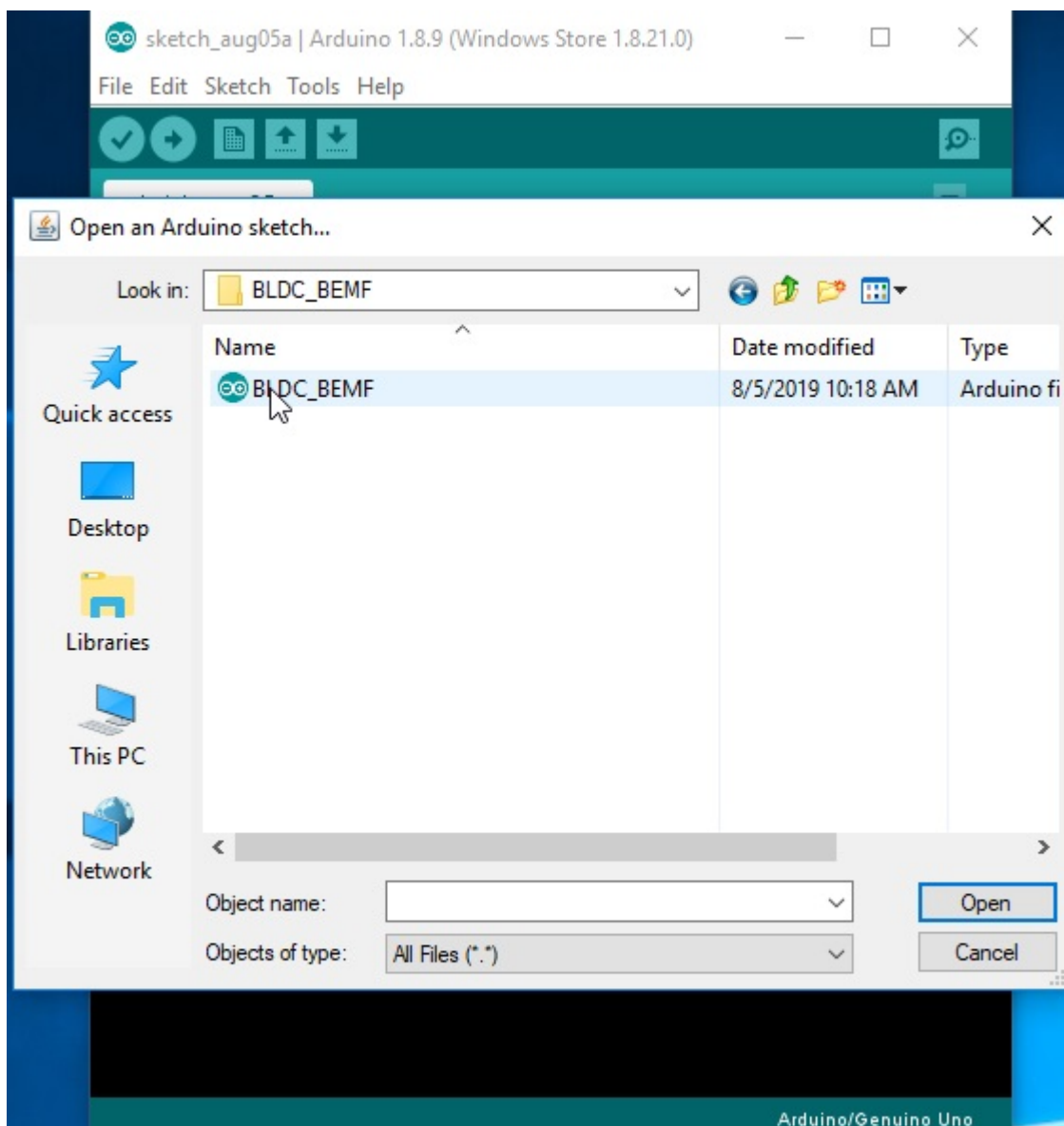
3. Verify the demo code
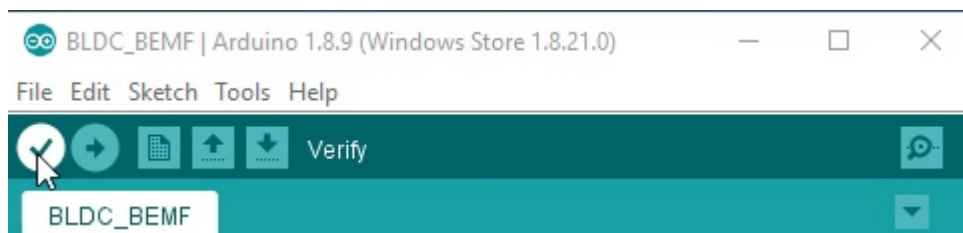
4. Upload and run the code
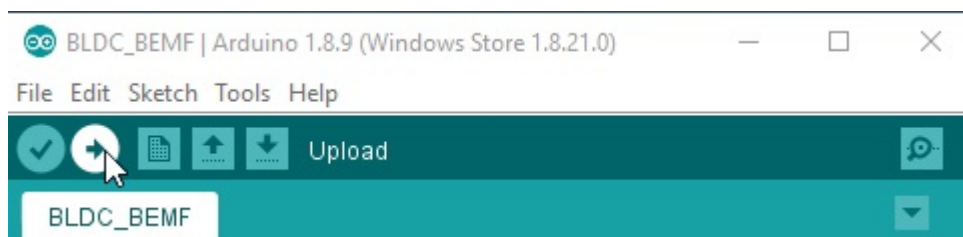
5. Open the serial monitor in the Arduino IDE.
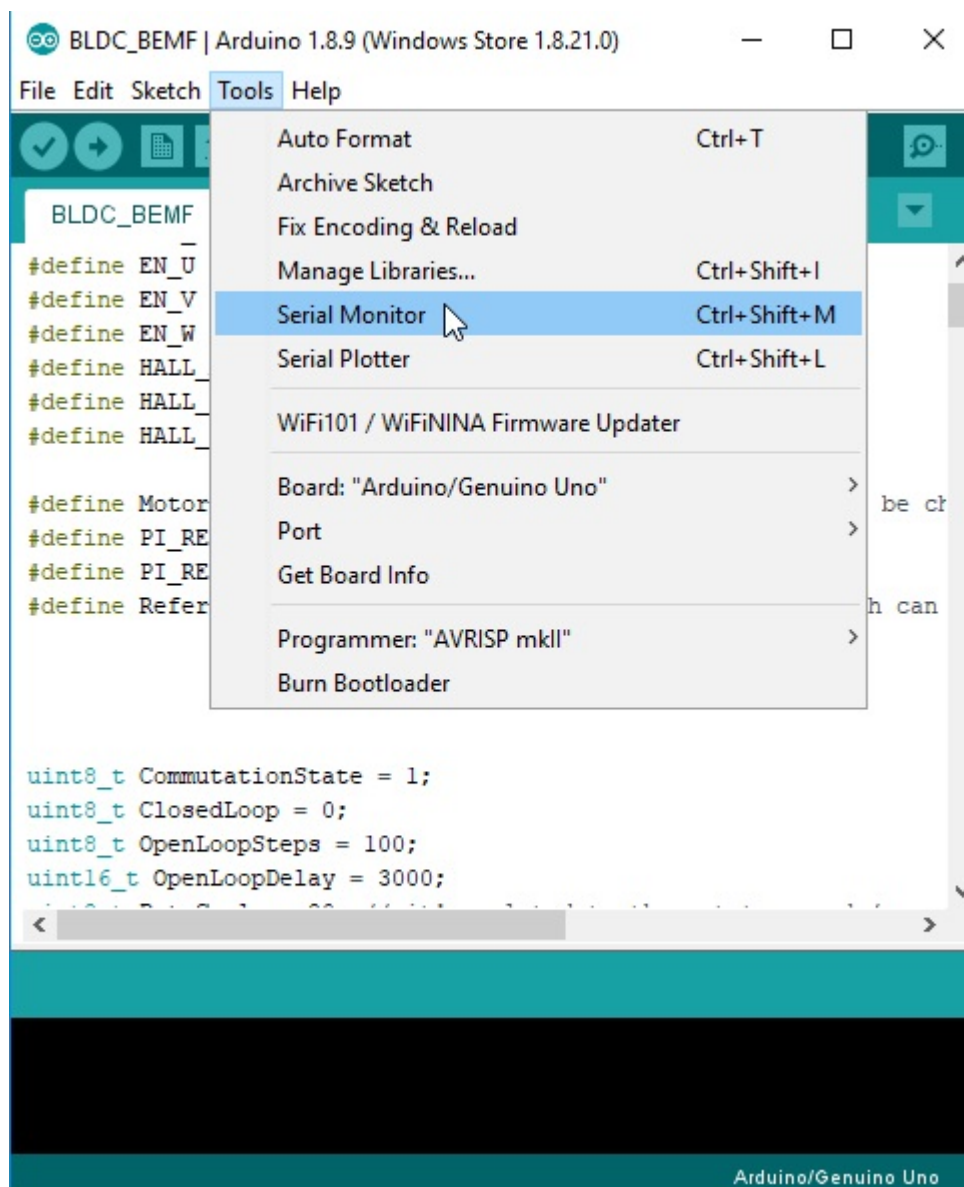
6. Adjust the motor speed by sending command in the serial monitor.
    1. +: Increase RPM by 100
    2. -: Decrease RPM by 100

Revision history

Document version	Date of release	Description of changes
Revision 1.0	2019-03-04	• Initial preliminary release
Revision 2.0	2019-08-15	• Add chapter 4.4

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