STEVAL-IHM038V1: 3-phase BLDC/PMSM motor drive up to 50 W, suitable for fan controllers

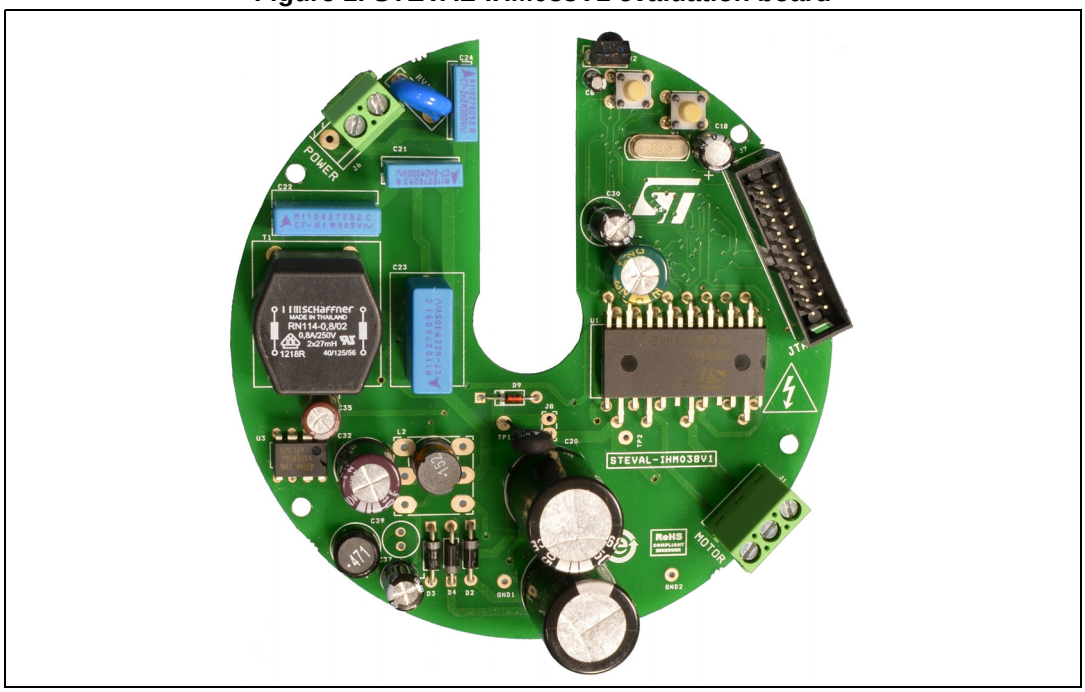
Introduction

This document describes the STEVAL-IHM038V1 evaluation board, a complete BLDC/PMSM 3-phase motor drive suitable for mains supplied motor control systems up to 50 W and particularly suitable for fan controllers. The board is based on SLLIMM™-nano (small low-loss intelligent molded module) STGIPN3H60 and Microcontroller STM32F100C6T6. The evaluation board enables 3-phase permanent magnet motor field oriented control (FOC) in sensor-less mode. For power factor correction, a passive PFC stage is implemented to achieve a power factor of up to 0.90 (in line with many norms such as the ones prevalent for ceiling fans in India). An on-board IR demodulator allows speed adjustment using a remote control.

The inverter stage is implemented using the Intelligent power module SLLIMM™-nano STGIPN3H60, which embeds 600 V IGBTs with gate drivers, op-amp for current sense and a comparator in a single NDIP-26L package for reliable and compact system design.

The control part, including field oriented control with sensor-less control algorithm, fault detection and speed setting via on-board switches and remote control (IR receiver) are all handled by the STM32F100C6T6B microcontroller of the STMicroelectronics™ ARM® Cortex™-M3 core-based low density STM32™ MCU family.

Figure 1. STEVAL-IHM038V1 evaluation board



Contents

1 Main features

1.1 Features

The STEVAL-IHM038V1 has the following features:

- maximum input voltage: 265 V AC or 375 V DC
- minimum input voltage: 90 V AC or 128 V DC
- maximum output power for applied motor: up to 50 W (continuous)
- +15 V auxiliary power supply based on VIPer16LN in a non-isolated buck configuration
- compact design using SLLIMM™-nano STGIPN3H60 featuring 600 V IGBTs with gate drivers, op-amp for current sense and comparator
- passive PFC circuit for power factor correction: Passive PFC is a standard Valley fill design where the two power supply capacitors are charged in series and discharged in parallel using three diodes to reduce the ripple current. This in turn improves the power factor as compared to a single capacitor configuration.
- infrared (IR) receiver/demodulator on board for speed and on/off control via IR remote
- external EEPROM M24C01 for last speed and on/off state recovery
- overcurrent hardware protection
- overtemperature protection with NTC thermistor
- overvoltage and undervoltage detection
- based on 32-bit ARM® Cortex™-M3 core-based microcontroller STM32F100C6T6B
- firmware example available on STM32 PMSM FOC SDK, fully customized for the ceiling fan application
- FOC (field oriented control) sensor-less algorithm
- PCB size customized to fit ithe ceiling fan form factor
- PCB diameter: 105 mm
- double side layout

1.2 Safety and operating instructions

1.2.1 General terms

Warning: **During assembly, testing, and normal operation, the evaluation board poses several inherent hazards, including bare wires, moving or rotating parts and hot surfaces. There is danger of serious personal injury and damage to property if the kit or components are improperly used or installed incorrectly. The kit is not electrically isolated from the AC/DC input. The evaluation board is directly linked to the mains voltage. No insulation is ensured between the accessible parts and the high voltage. All measuring equipment must be isolated from the mains before powering the board. When using an oscilloscope with the demo, it must be isolated from the AC line. This prevents shock from occurring as a result of touching any single point in the circuit, but does NOT prevent shock when touching two or more points in the circuit. Do not touch the evaluation board after disconnection from the voltage supply; several parts and power terminals, which contain energized capacitors, must be allowed to discharge.**

All operations involving transportation, installation and use, as well as maintenance, are to be carried out by skilled technical personnel (national accident prevention rules must be observed). For the purpose of these basic safety instructions, “skilled technical personnel” are considered as suitably qualified people who are familiar with the installation, use, and maintenance of power electronic systems.

1.2.2 Evaluation board intended use

The STEVAL-IHM038V1 evaluation board is designed for evaluation purposes only and must not be used in final applications. The technical data, as well as information concerning the power supply conditions, must only be taken from the relevant documentation and must be strictly observed.

1.2.3 Evaluation board installation

The installation and cooling of the evaluation board must be in accordance with the specifications and the targeted application

- The motor drive converters are protected against excessive strain. In particular, no components are to be bent or isolating distances altered during the course of transportation or handling.
- No contact must be made with other electronic components and contacts.
- The boards contain electrostatically sensitive components that are prone to damage if not used properly. Electrical components must not be mechanically damaged or destroyed.

1.2.4 Electrical connections

Applicable national accident prevention rules must be followed when working on the main power supply. The electrical installation must be carried out in accordance with the appropriate safety requirements. A system architecture which supplies power to the evaluation board must be equipped with additional control and protective devices in accordance with the applicable safety requirements (e.g. compliance with technical equipment and accident prevention rules).

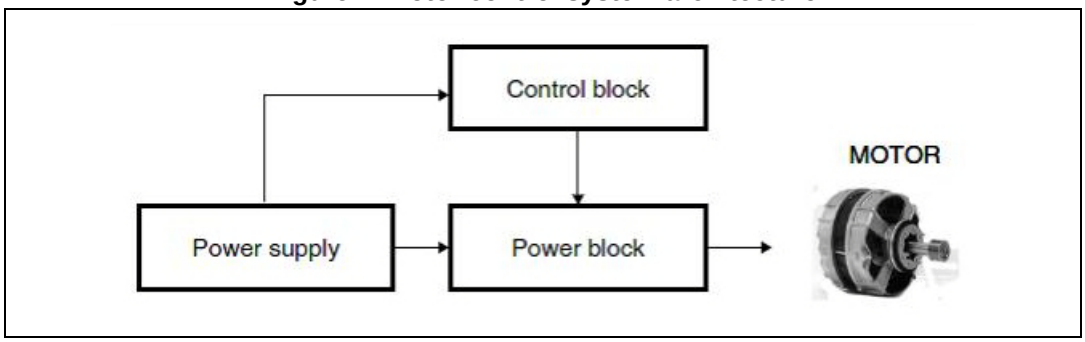
2 Board description

2.1 System architecture

A generic motor control system can be divided into four main blocks (see *Figure 2*).

- **Control block** - Its main task is to accept user commands and motor drive configuration parameters. It provides all the digital signals to implement the proper motor driving strategy. The STM32F100C6T6B MCU belongs to the value line medium and low density STM32 MCU family and was selected as the key component of the control block.
- **Power block** - Is based on the 3-phase inverter topology. The heart of the power block is the STGIPN3H60 small low-loss intelligent molded module which contains all the necessary active components. Please refer to the STGIP3H60 datasheet for more information.
- **Motor** - The STEVAL-IHM038V1 evaluation board is able to properly drive any BLDC or PMSM up to 50 W of nominal continuous power.
- **Power supply block** - Able to function from 90 VAC to 265 VAC or corresponding DC voltage from 128 VDC to 375 VDC. The power block is based on a buck converter with VIPer16LN controller.

Figure 2. Motor control system architecture



Note: The STEVAL-IHM038V1 does not include any motors.

2.2 Board schematics

Figure 3. Power section

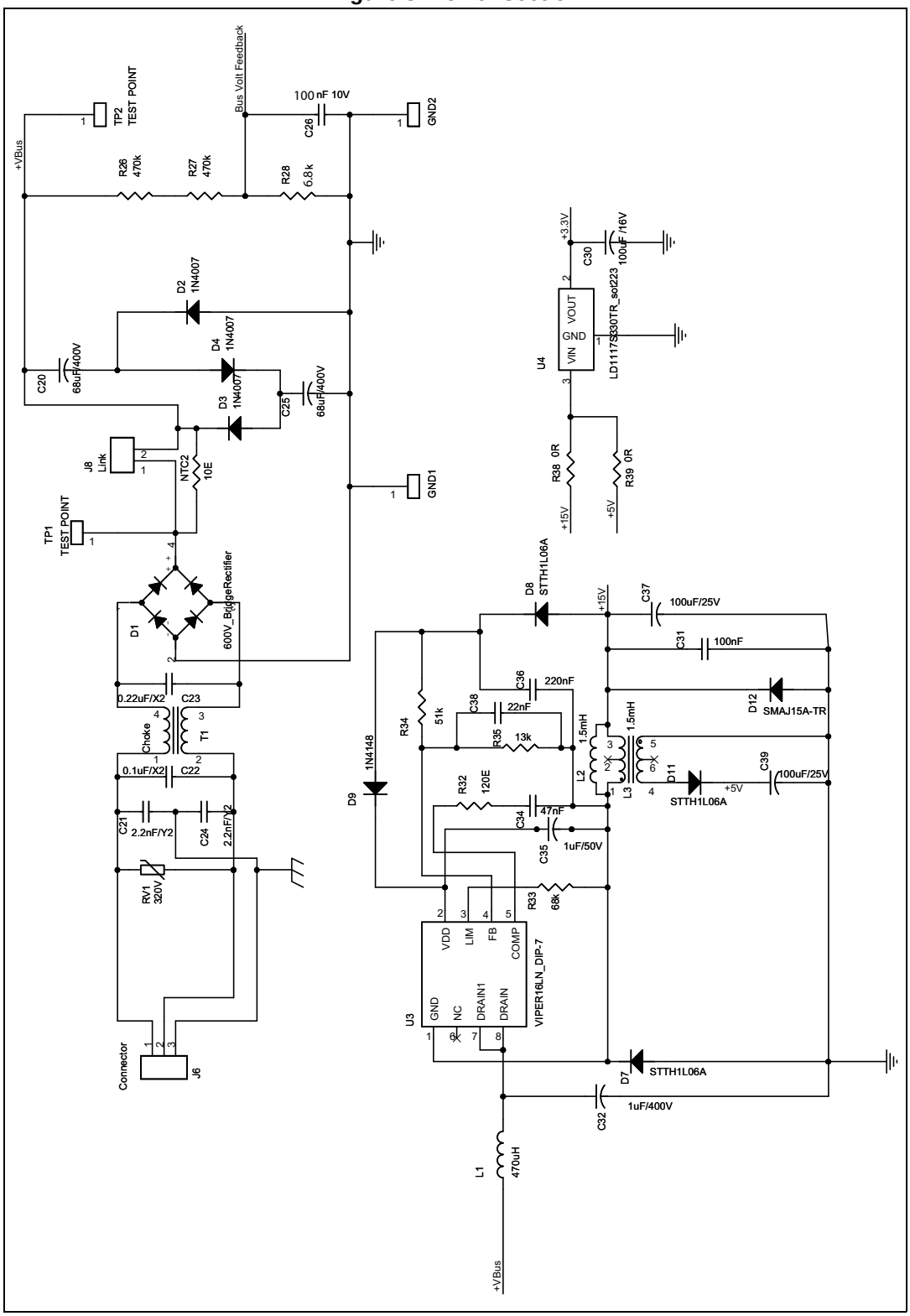


Figure 4. Microcontroller

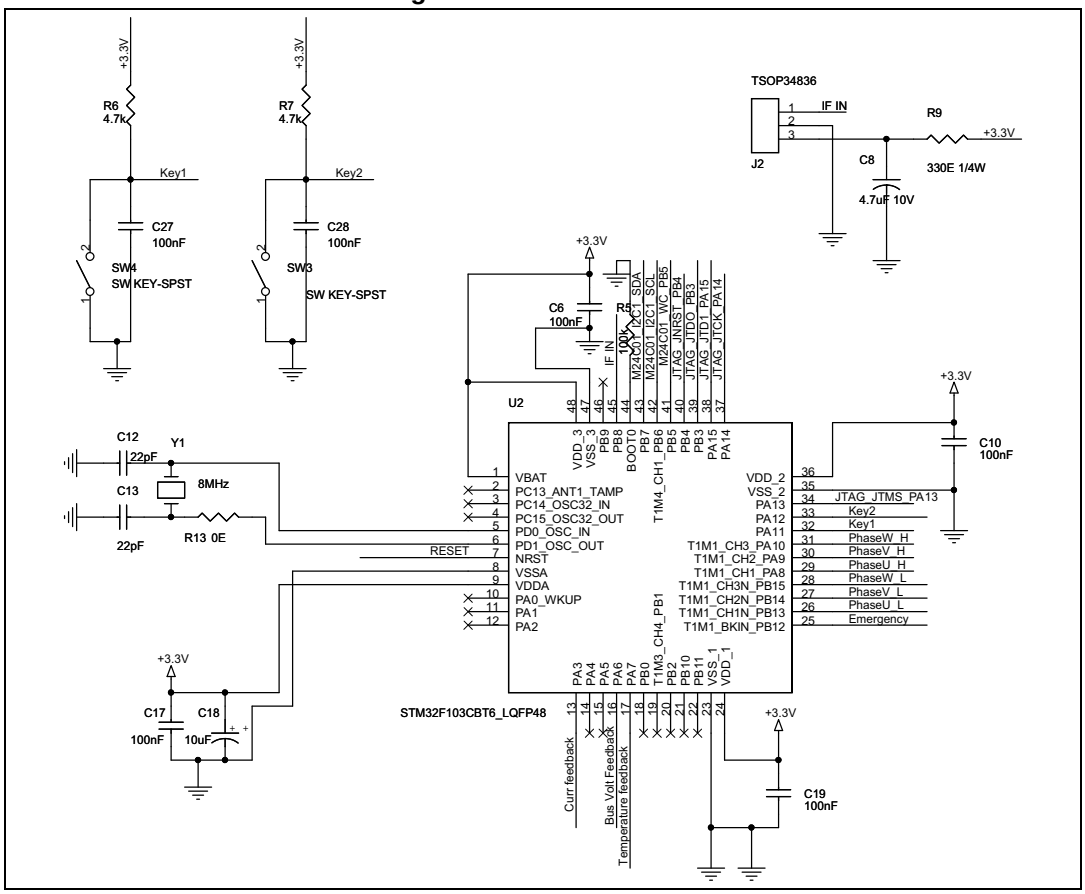


Figure 5. JTAG connector

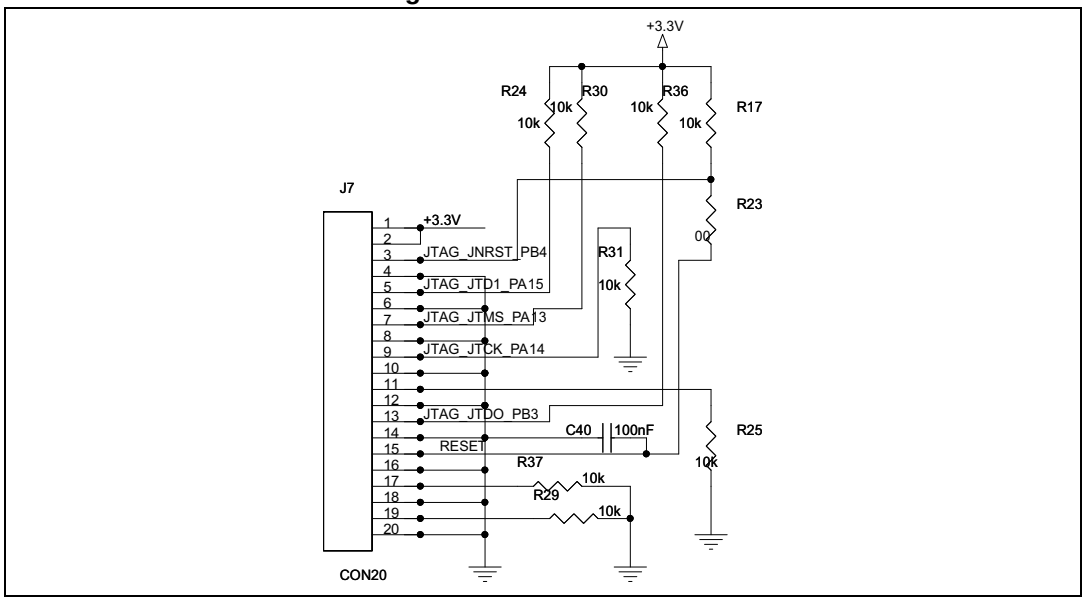


Figure 6. EEPROM section

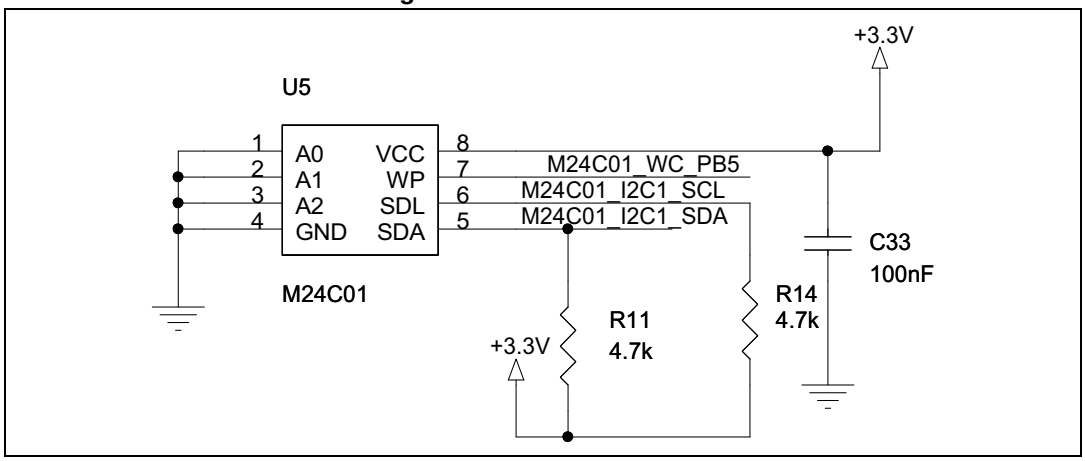
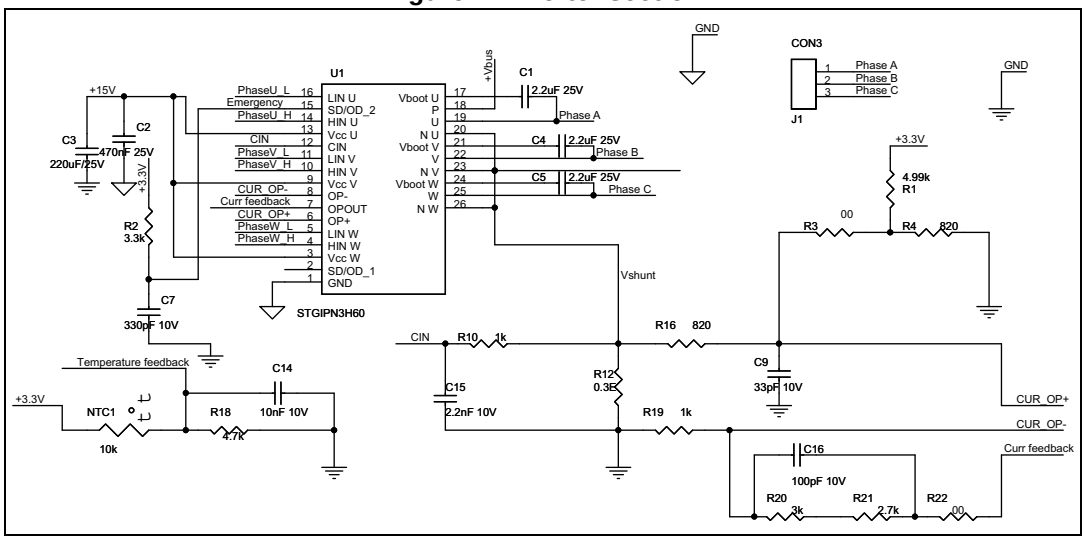


Figure 7. Inverter section



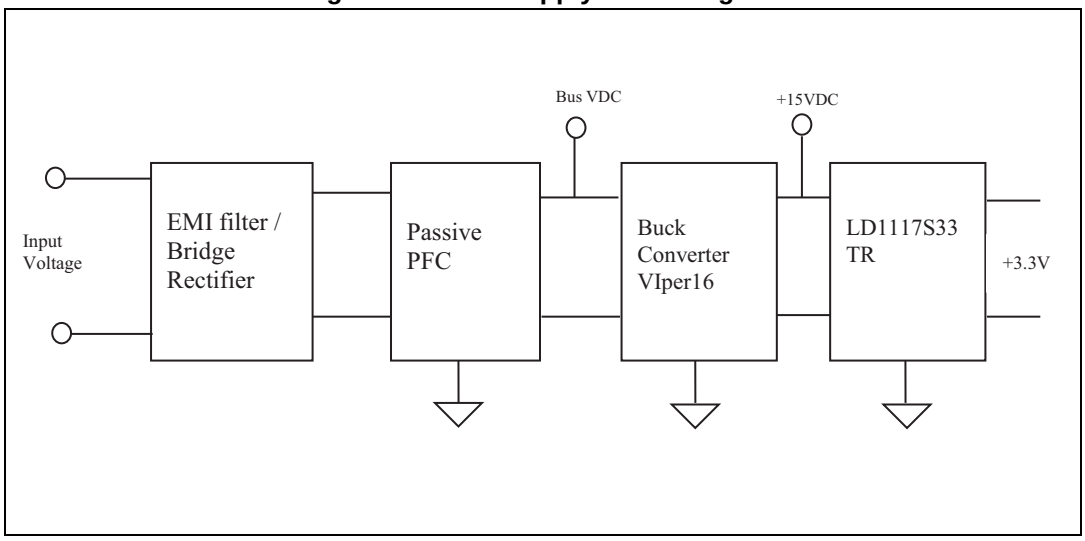
2.2.1 Power supply

The power supply on the STEVAL-IHM038V1 evaluation board is designed for a 230 VAC supply. The supported range of input voltage is from 90 VAC or 128 VDC to 265 VAC or 375 VDC. The auxiliary power supply for all active components on the evaluation board is implemented as a buck converter based on VIPer16. The output voltage of the converter is +15 VDC. Voltage is fed into the intelligent power module (IPM) as supply voltage, as well as to the linear regulator LD1117S33TR. The linear regulator provides +3.3 VDC for the MCU, operational amplifiers and Infrared (IR) receiver/demodulator TSOP 34838 and other associated components on the evaluation board. Please refer to STMicroelectronics VIPer16LN datasheet for more information.

Information regarding the value of the supply bus voltage on the main filtering capacitors is sensed with the voltage divider built around R26, R27 and R28 and is fed to the MCU analog to digital converter (ADC). The proper voltage multiplication for applied resistor dividers is 139.

Figure 8 shows the power supply block diagram.

Figure 8. Power supply block diagram



2.2.2 Control block

The control stage of the STEVAL-IHM038V1 evaluation board is designed around STM32F100C6T6B microcontroller. It belongs to the STMicroelectronics™ ARM® Cortex™-M3 core-based low density STM32™ MCU family. The LQFP48 pin package is used on the board.

The output signals from the microcontroller are six PWMs.

The input signals are:

- break input signal in case of overcurrent detection
- current sense feedback
- bus voltage sense feedback and temperature feedback from NTC resistor to the ADC inputs
- Infrared receiver/demodulator
- EEPROM interface using I2C
- JTAG interface for debugging/programming

2.2.3 Power block based on SLLIMM™-nano

The IGBT SLLIMM™ module STGIPN3H60 consists of high rugged IGBT power switches and three smart drivers. STGIPN3H60 is provided with advanced gate smart drivers and many features such as integrated comparators for overcurrent or short-circuit protection; free operational amplifier and ‘SMART SHUTDOWN’ functions are also available. Please refer to the STMicroelectronics STGIPN3H60 device datasheets for more information.

2.2.4 Overcurrent protection

Hardware overcurrent protection (OCP) is implemented on the board. This feature takes advantage of STGIPN3H60 SLLIMM™ module where an internal comparator is implemented. Thanks to the internal connection between the comparator output and

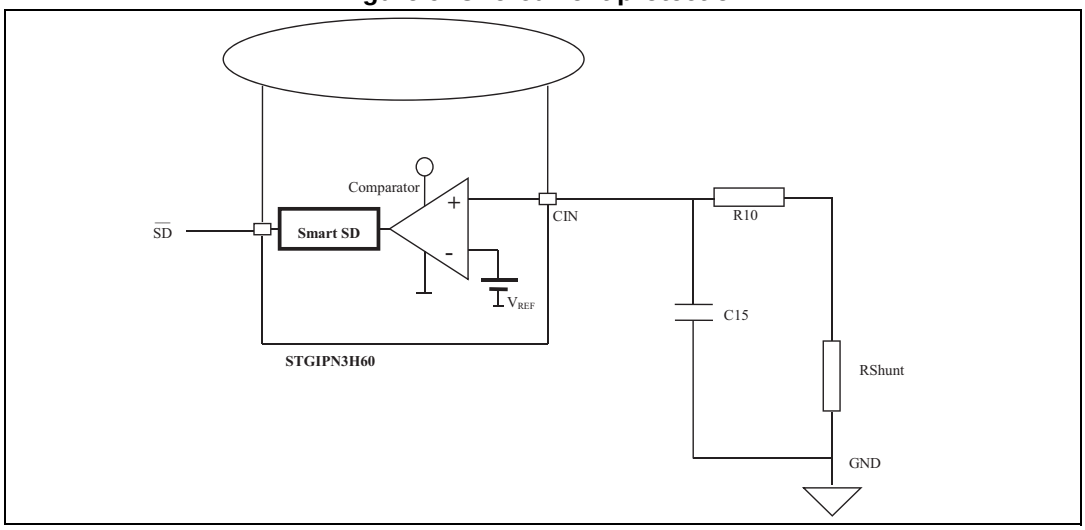
shutdown block of the IPM, overcurrent protection involves extremely low intervention times of slightly above 200 ns (see *Figure 9*).

Overcurrent protection acts as soon as the voltage on the C_{IN} pin rises above the internal voltage reference (typical VREF_INT value is 0.5 V). Given the default value of the OCP shunt resistor, the maximum allowed current is:

Equation 1

$$ICP = \frac{VREF}{RShunt} \cong 1.66A$$

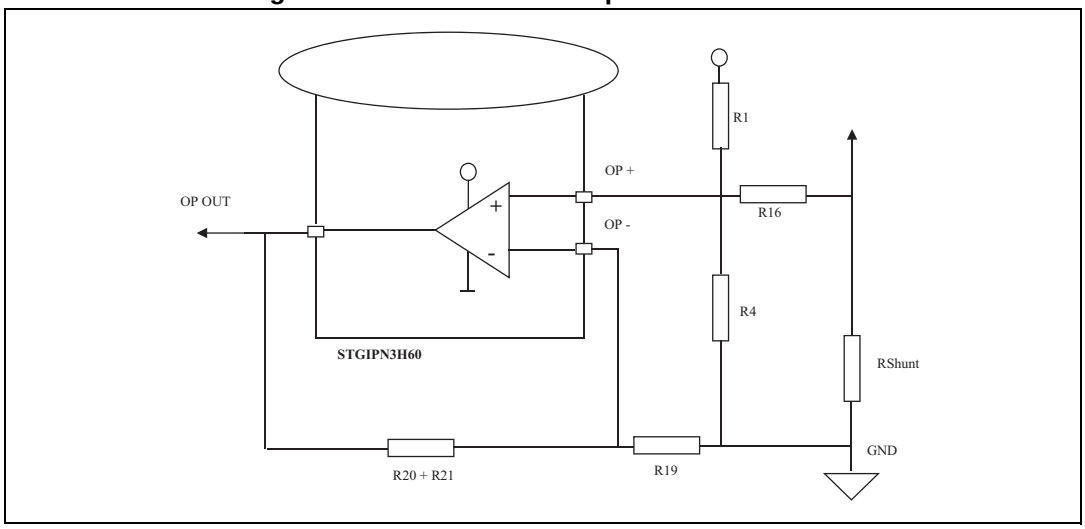
Figure 9. Overcurrent protection



2.2.5 Single shunt current sensing amplification network

The single shunt current sense configuration with field oriented control (FOC) is implemented in the STEVAL-IHM038V1. The current sense through sense resistor is amplified by the op-amp in the SLLIMM™ module. The current sense amplifier gain is set using the resistor network as shown in *Figure 10*. The alternating signal on the shunt resistor, with positive and negative values, must be converted to be compatible with the single positive input of the microcontroller A-D converter used to read the current value. The output signal from the op amp is made up of two terms: a bias voltage V_{Bias} and an amplification of voltage drop across the shunt resistor (G). The formulas below show the relationships between network components and signal values.

Figure 10. Current sense amplification network



The voltage at the ‘current sensing’ node is the sum of a bias and a signal component respectively equal to:

Equation 2

$$VBias = 3.3\text{V} * \frac{(\text{R4}||\text{R16})}{\text{R1} + (\text{R4}||\text{R16})} * (1 + \frac{R20 + R21}{R19})$$

Equation 3

$$Vsign = I * RShunt * \frac{(R1||R6)}{R4 + (R1||R6)} * (1 + \frac{(R20 + R21)}{R19})$$

with the default values, this returns:

V_{Bias} = 1.68 V

V_{Sign} = 3.09*I*RShunt

As such, the maximum current amplifiable without distortion is equal to:

Equation 4

$$\text{IMAX} = \frac{3.3 - 1.68}{3.09 * \text{RShunt}} = 1.74A$$

R_{Shunt} = 0.3 Ω

2.2.6 Temperature feedback

Temperature feedback is implemented on the STEVAL-IHM038V1 evaluation board. This feature fully protects the IPM module against damage when the temperature on the junction on the IPM overruns a defined value. The temperature is sensed through an NTC resistor, RT1. The measured signal is fed to the MCU control unit to be read with an ADC.

3 Using STEVAL-IHM038V1 with the motor control firmware library

The STM32 PMSM FOC SDK motor control firmware library handles the field-oriented control of a permanent magnet synchronous motor (PMSM) in both sensor and sensor-less configurations.

It is possible to configure the firmware to use the STEVAL-IHM038V1 as a controller for the ceiling fan application.

This section describes the modifications to be applied to the STM32 PMSM FOC SDK motor control firmware library in order to make the firmware compatible with the STEVAL-IHM038V1.

3.1 Environmental considerations

Warning: The STEVAL-IHM038V1 evaluation board must only be used in a power laboratory. The voltage used in the drive system presents a shock hazard.

The kit is not electrically isolated from the DC input. This topology is very common in motor drives. The microprocessor is grounded by the integrated ground of the DC bus. The microprocessor and associated circuitry are hot and MUST be isolated from user controls and communication interfaces.

Warning: All measuring equipment must be isolated from the main power supply before powering up the motor drive. To use an oscilloscope with the kit, it is safer to isolate the DC supply AND the oscilloscope. This prevents a shock occurring as a result of touching any SINGLE point in the circuit, but does NOT prevent shock when touching two or more points in the circuit.

An isolated AC power supply can be constructed using an isolation transformer and a variable transformer.

Note: Isolating the application rather than the oscilloscope is highly recommended in any case.

3.2 Hardware requirements

To run the STEVAL-IHM038V1 together with the STM32 FOC firmware library, the following is required:

- the STEVAL-IHM038V1 board
- a high voltage insulated AC power supply up to 230 VAC
- J-Link programmer or ST-Link (not included in the package)
- J-Link insulating board (not included in the package)
- 3-phase brushless fan motor (not included in the package)
- insulated oscilloscope (as required)
- insulated multimeter (as required)

3.3 Software requirements

A tool chain must be installed to open, compile and download the STM32 PMSM FOC firmware library. Please check its availability on the STMicroelectronics website or contact your nearest STMicroelectronics office for documentation regarding the STM32 PMSM FOC SDK motor control firmware library (see www.st.com). The firmware for STEVAL-IHM038V1 was customized with a free 32 kB limited version of the IAR™ tool, EWARM v6.xx.

3.4 STM32 PMSM FOC firmware library customization

The STM32PMSM FOC SDK includes the STFOC firmware library and PC GUI SW, the ST MC Workbench able to configure and manage the MC library (see www.st.com).

To customize the STM32 PMSM FOC SDK, the required parameters for the power stage and control stage are provided in *Table 1*.

Table 1. STEVAL-IHM038V1 motor control workbench parameters

Parameter	STEVAL-IHM038V1	Unit
Power stage parameters		
ICL shutout	Disabled	
Dissipative brake	Disabled	
Bus voltage sensing	Enabled	
Bus voltage divider	1/… 139	
Min. rated voltage	140	V
Max. rated voltage	375	V
Nominal voltage	325	V
Temperature sensing	Enabled	
V0	1055	mV
T0	25	°C
ΔV/ΔT	29	mV/°C
Max. working temperature on sensor	90	°C
Overcurrent protection	Enabled	
Comparator threshold	0.50	V
Overcurrent network gain	0.30	V/A
Expected overcurrent threshold	1.66	A
Overcurrent feedback signal polarity	Active-low	
Overcurrent protection disabling network	Disabled	
Current sensing	Enabled	
Current reading topology	One shunt resistor	
Shunt resistor(s) value	0.30	Ω
Amplifying network gain	3.10	
T-rise	2000	Ns
Power switches - minimal deadtime	1500	Ns
Power switches - max. switching frequency	25	kHz
U, V, W driver - high side driving signal Active	Active-high	
U, V, W driver - low side driving signal complemented from high side	Disabled	
U, V, W driver - low side driving signal polarity	Active-low	
Control stage – Digital I/O		
Timer	TIM1	
TIM1 remapping	No remap	

Table 1. STEVAL-IHM038V1 motor control workbench parameters (continued)

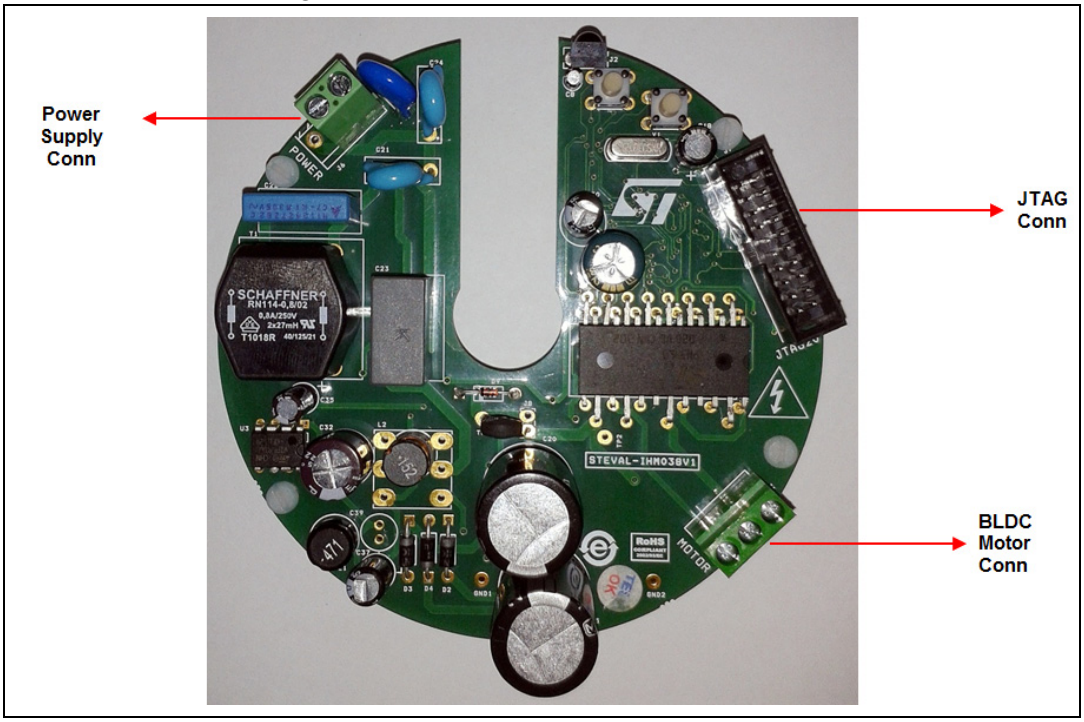
Parameter	STEVAL-IHM038V1	Unit
Control stage – analog input		
Analog input - ADC channel for current reading	ADC12_IN3	
Analog input - bus voltage feedback	ADC12_IN6	
Control stage – MCU and clock frequency		
MCU selection- STM32 subfamily	Value line medium density	
Clock settings – CPU frequency	24MHz	
Supply voltage- Nominal MCU supply voltage	3.3V	
Drive management		
Drive management - user interface - joystick, LCD, button	Disabled	

4 Description of STEVAL-IHM038V1 connections

Table 2. STEVAL-IHM038V1 connections

Connector name	Description
J6	Power Supply
J7	JTAG
J1	BLDC motor

Figure 11. STEVAL-IHM038V1 actual board



5 Bill of material

Table 3. Bill of material (part 1)

No.	Ref.	Description	Package	Manufacturer
ST device				
1	U1	SLLIMM-nano Intelligent Power Module (IPM) 3A	NDIP-26L	ST
2	U2	STM32 (32-bit Microcontroller)	LQFP48	ST
3	U3	VIPer16 SMPS Controller	DIP8	ST
4	U4	3.3V voltage regulator	SOT-223	ST
5	U5	EEPROM	TSSOP8	ST
6	D7,D8	Ultrafast Diode	SMA	ST
7	D11	Ultrafast Diode	SMA	ST
Capacitors				
1	C1,C4,C5	2.2µF/25V (Multilayer Ceramic Capacitors)	SMD 1206	TDK
2	C2	470nF 25V Ceramic	SMD0805	Any
3	C3	220µF/25V Electrolytic	6.3mm/2.5mm Pitch Through Hole	Any
4	C6,C10,C17,C19, C26,C27,C28, C31,C33	100nF Ceramic	SMD0805	Any
5	C7	330nF/10V Ceramic	SMD0805	Any
6	C8	4.7µF/10V Electrolytic	5mm/2.5mm Pitch Through Hole	Any
7	C9	33pF/10V Ceramic	SMD0805	Any
8	C12,C13	22pF Ceramic	SMD0805	Any
9	C14	10nF 10V Ceramic	SMD0805	Any
10	C15	2.2nF	SMD0805	Any
11	C16	100pF 10V Ceramic	SMD0805	Any
12	C18	10µF/50V Electrolytic	6.3mm/2.5mm pitch through hole	Any
13	C20,C25	68µF/250V Electrolytic	16mm/7.5mm pitch through hole	Any
14	C21,C24	2.2nF/Y2	10mm pitch through hole	EPCOS
15	C22	0.1µF/X2	18mm x 7.5mm/15mm pitch	EPCOS
16	C23	0.22µF/X2	18mm x 7.5mm/15mm pitch	EPCOS

Table 3. Bill of material (part 1) (continued)

No.	Ref.	Description	Package	Manufacturer
17	C30,C37	100µF /25V	6.3mm/2.5mm pitch through hole	Any
18	C32	1µF/400V	6.3mm/2.5mm pitch through hole	Any
19	C34	47nF	SMD1206	
20	C35	1µF/50V	5mm/2.5mm pitch through hole	Any
21	C36	220nF	SMD1206	Any
22	C38	22nF	SMD0805	Any
23	C40	100nF Ceramic	SMD0402	Any
24	C39	100µF /25V	6.3mm/2.5mm pitch through hole	Any
Diodes				
1	D1	600V/1.5A Bridge Rectifier	SMD	Diodes incorporated
2	D2,D3,D4	1N4007	Through hole	Any
3	D9	1N4148	Through hole	Any
4	D12	BZV55-C18 Zener 18V	SOD80C	Any
Resistors				
1	NTC1	10k	SMD0805	Vishay
2	NTC2	10E	22mm Dia/7.5mm Pitch	EPCOS
3	RV1	320V MOV	10mm Dia/7.5mm Pitch	EPCOS
4	R1	4.99k	SMD0805	Any
5	R2	3.3k	SMD0805	Any
6	R3,R13,R22,R23, R38	0R	SMD0805	Any
7	R4,R16	820R	SMD0805	Any
8	R5	100k	SMD0805	Any
9	R6,R7,R11,R14,R 18	4.7k	SMD0805	Any
10	R9	330E 1/4W	SMD1206	Any
11	R10,R19	1k	SMD0805	Any
12	R12	0.3E/2W	SMD2512	Any
13	R17,R24,R25,R2 9,R30,R31,R36,R 37	10k	SMD0805	Any
14	R20	3k	SMD0805	Any
15	R21	2.7k	SMD0805	Any

Table 3. Bill of material (part 1) (continued)

No.	Ref.	Description	Package	Manufacturer
16	R26,R27	470k	SMD1206	Any
17	R28	6.8k	SMD0805	Any
18	R32	120E	SMD0805	Any
19	R33	68k	SMD0805	Any
20	R34	51k	SMD0805	Any
21	R35	13k	SMD0805	Any
22	R39	0R	SMD0805	Any
Other devices				
1	J1, J6	3 pin Screw Terminal		Any
2	J2	38kHz IR Demodulator	Through hole	Vishay
3	J7	10X2 2.5mm Header	Through hole	Any
4	L1	470uH	8.7mm Dia/5mm pitch through hole	Wurth Electronics
5	L2	1.5mH	7.8mm Dia / 5mm pitch through hole	Wurth Electronics
6	L3 (Note 3)	1.5mH		Magnetica
7	SW1, SW2	Tactile Switch	Through hole	TE Connectivity
8	T1	Common Mode Choke	Through hole	Schaffner
9	Y1	8MHz Crystal	Through hole	Any

Table 4. Bill of material (part 2)

No.	Manufacturer's order code	Supplier	Supplier order code	Quantity
ST device				
1	STGIPN3H60			1
2	STM32F100C6T6			1
3	VIPER16LN DIP-7			1
4	LD1117S33TR			1
5	M24C01WDW6TP			1
6	STTH1L06A			2
7	STTH1L06A			1
Capacitors				
1	CGA5L2X7R1E225K	Mouser	810-CGA5L2X7R1E225K	3

Table 4. Bill of material (part 2) (continued)

No.	Manufacturer's order code	Supplier	Supplier order code	Quantity
2				1
3				1
4				9
5				1
6				1
7				1
8				2
9				1
10				1
11				1
12				1
13				2
14	B32021A3222M	Mouser	871-B32021A3222M	2
15	B32922C3104M	Mouser	871-B32922C3104M	2
16	B32922C3224M289	Mouser	871-B32922C3224M289	1
17				2
18				1
19				1
20				1
21				1
22				1
23				1
24				1
Diodes				
1	DF1506S-T	Mouser	621-DF1506S-T	1
2				1
3				1

Table 4. Bill of material (part 2) (continued)

No.	Manufacturer's order code	Supplier	Supplier order code	Quantity
4				1
Resistors				
1	NTCS0805E3103JMT	Mouser	594-2381-615-53103	1
2	B57237S100M	Mouser	871-B57237S100M	1
3	B72210S0321K101	Mouser	871-B72210S321K101	1
4				1
5				1
6				5
7				2
8				1
9				5
10				1
11				2
12				1
13				8
14				1
15				1
16				2
17				1
18				1
19				1
20				1
21				1
22				1
Other devices				
1				2
2	TSOP34838	Mouser	782-TSOP34838	1
3				1
4	744741471	Digikey	732-3732-ND	1
5	768772152	Digikey	732-3263-ND	1

Table 4. Bill of material (part 2) (continued)

No.	Manufacturer's order code	Supplier	Supplier order code	Quantity
6				1
7	FSM10JH	Digikey	450-1647-ND	2
8	RN114-0.8-02	Mouser	631-RN114-0.8-02	1
9				1

Note: D11, C39, L3 and R39: Not mounted.

C20,C25 and C32 must be low ESR type rated at 105 °C operation.

L3 is a custom 1.4mH/0.17A inductor with aux winding from Magnetica part no.05455: not mounted.

6 Ordering information

The evaluation board is available through the standard ordering system, the ordering code is: STEVAL-IHM038V1. The items delivered include the assembled evaluation board, board documentation, and PCB fabrication data such as Gerber files, assembly files (pick and place), component documentation and firmware with commented source code.

7 Conclusion

The 3-phase motor control STEVAL-IHM038V1 evaluation board based on the SLLIMM™ module STGIPN3H60 and STM32F100C6T6 MCU is a comprehensive solution for BLDC/PMSM motor-based ceiling fans.

8 Revision history

Table 5. Document revision history

Date	Revision	Changes
05-Nov -2015	1	Initial release.