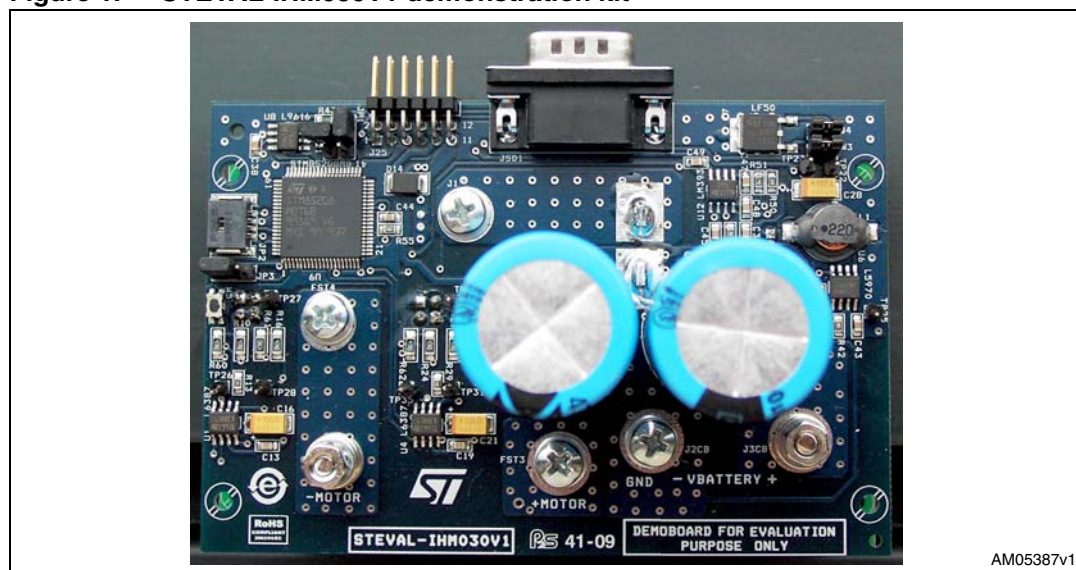


### 24 V, up to 2 kW brushed DC motor drive demonstration kit based on the STM8S microcontroller

## Introduction

The STEVAL-IHM030V1 is brushed DC motor (BDC) demonstration kit which provides a platform to introduce users to a 24 V, up to 2 kW brushed DC motor drive. A typical use for the kit is in traction system applications. The kit contains two stacked modular boards: a power stage board and a control board. It represents a compact solution and provides efficient power dissipation due to the mounting of the power MOSFET on a dedicated IMS layer. This document describes the features of the STEVAL-IHM030V1, provides information on its use, and explains how it performs bidirectional speed control of a brushed DC motor. The brain of the system is the STM8S 8-bit microcontroller, which drives the full H-bridge topology, implements the PI closed loop control speed, manages the encoder signal feedback using the dedicated timer peripheral and manages the commands motor and PI configuration messages through the CAN bus. In the example application described, the supported brushed DC motor is supplied by 24 V and is powered up to 2 kW. The demonstration board, shown in [Figure 1](#) below, is available through order code STEVAL-IHM030V1.

**Figure 1. STEVAL-IHM030V1 demonstration kit**



- STEVAL-IHM030V1 main features:
  - Bidirectional drive for a 24 V brushed DC motor up to 2 kW
  - Configurable PI closed speed loop
  - Motor commands and PI parameter messages via CAN bus
  - H-bridge topology
  - Efficient power dissipation with power MOSFETs mounted on a dedicated IMS layer
  - Program and debug capability
  - Security functions: current and voltage bus monitoring

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# 1 Getting started

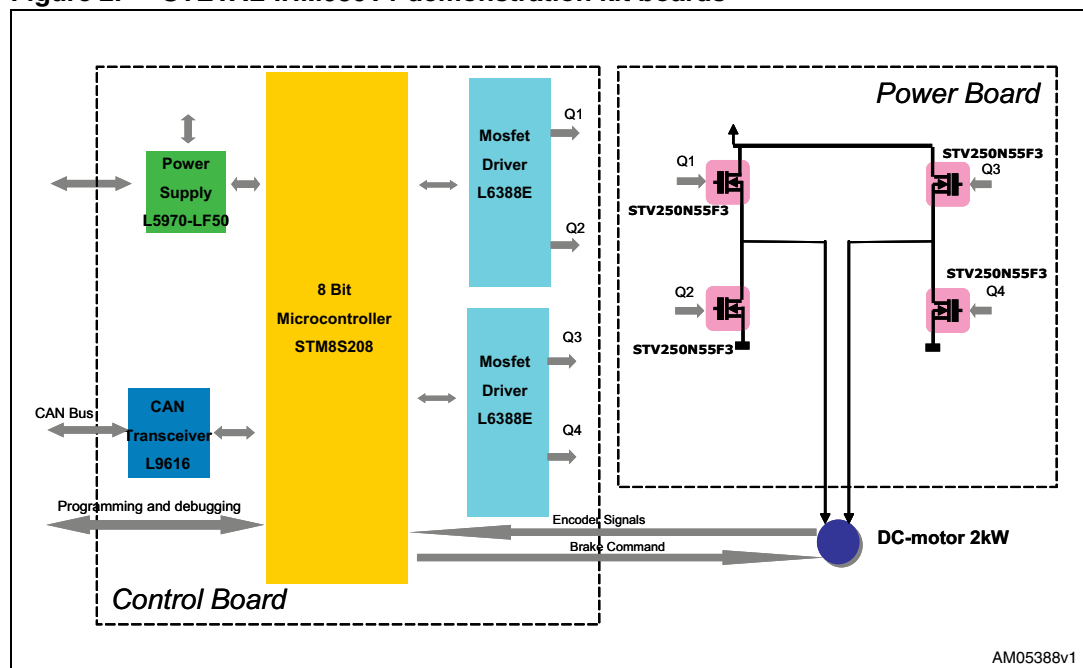
This section provides information on the system architecture and hardware configuration to power up the board.

## 1.1 System architecture

The STEVAL-IHM030V1 demonstration kit consists of 2 separate boards:

- Control board
- Power board

**Figure 2. STEVAL-IHM030V1 demonstration kit boards**



## 1.2 Power-up

The system is powered by a battery voltage of up to 24 V. The battery connector is described in the following section.

## 2 Hardware and connectors

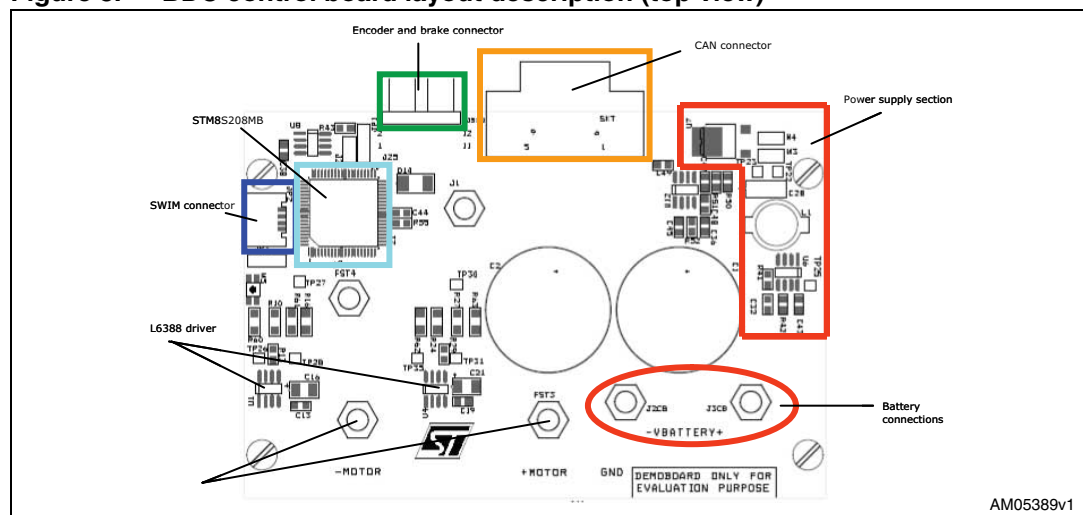
### 2.1 BDC control board

The core device of the STEVAL-IHM030V1 is the STM8S208 microcontroller, which manages the motor driver and the CAN communication. The main blocks of the BDC control board are:

- Power supply
- Motor connections
- CAN communication
- DC current and voltage monitoring
- Program and debug capability

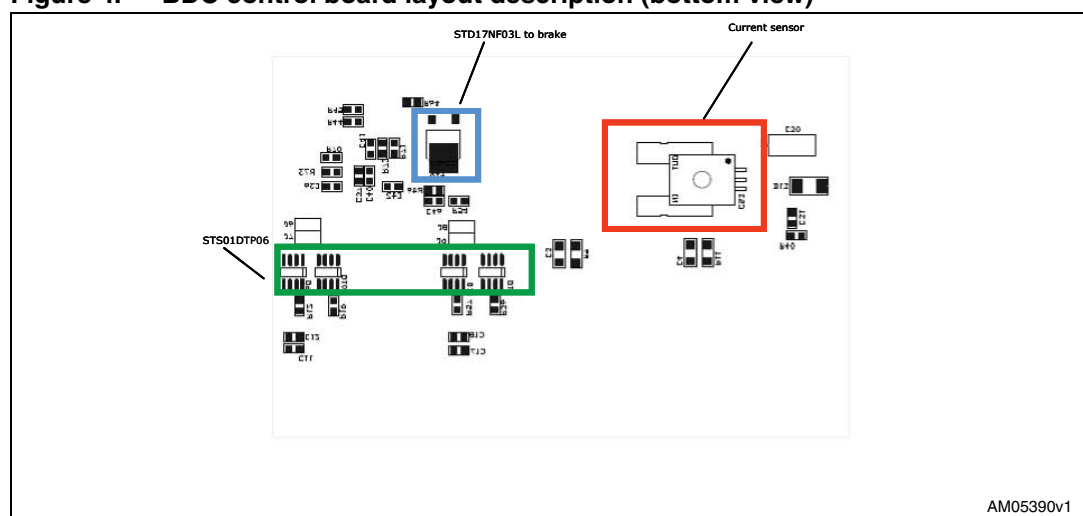
In [Figure 3](#) and [4](#), the BDC control board layout is shown.

**Figure 3. BDC control board layout description (top view)**



AM05389v1

**Figure 4. BDC control board layout description (bottom view)**



AM05390v1

## 2.1.1 Power supply

The entire system requires an input voltage up to 24 V, which can be provided by a battery. The battery input is labeled -VBATTERY+ (see [Figure 3](#)). The driver section requires a 15 V power supply, which is generated by the L5970D step-down switching regulator, fed by the main 24 V. The L5970D is a monolithic power switching regulator capable of delivering up to 1 A, at output voltages from 1.2 V to 35 V. In this application, it is configured to deliver a 15 V output voltage.

In the last stage, an LF50 very low drop voltage regulator is necessary to obtain the 5 V input voltage, which supplies the rest of the control board.

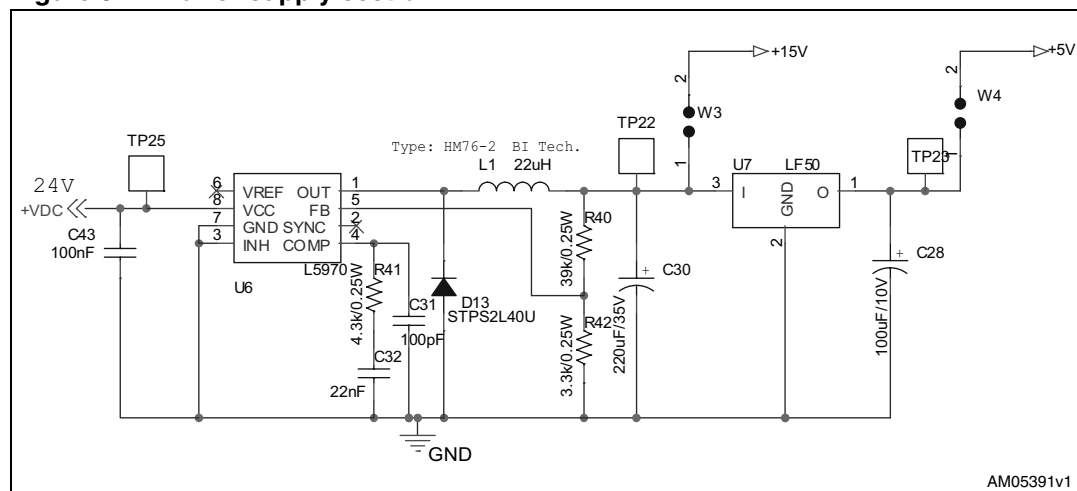
The board provides the possibility to disconnect the system powered by 15 V and 5 V respectively (see table below).

**Table 1. Power related jumpers**

Jumper	Description
W3	If fitted, 15 V is delivered to the related system
W4	If fitted, 5 V is delivered to the related system

[Figure 5](#) below shows the schematic of the power section.

**Figure 5. Power supply section**



## 2.1.2 Motor connections

The motor is connected to connectors labeled -MOTOR and +MOTOR (see [Figure 3](#)). The control board is also organized to manage the encoder signal and the brake signals coming from the motor.

[Table 2](#) describes the pin of the related connector (J25).

**Table 2. Motor connector description (J25)**

PIN	Description
1,3	Encoder
5	VDD
9,11	Brake
2,4,6,8,10,12	GND
7	Not connected

## 2.1.3 DC current and voltage monitoring section

The system implements a DC current and voltage monitoring section. Refer to the relevant section of the schematic diagram in [Section Appendix A: Schematics](#).



The DC current section is designed to detect a current threshold fixed by the R50, R51, R52 resistors (it can be changed according to the user application). When the current reaches the upper or lower limit, the configuration generates a fault signal. The microcontroller detects the fault as an external interrupt and stops the motor.

DC voltage monitoring is implemented by using an external resistor divider connected between the battery voltage and ground. The voltage on R55 is read by the ADC of the microcontroller. When the voltage at the ADC channel (pin 34) goes lower than 1.8 V (this value corresponds to the 18 V battery voltage and can be changed in the firmware based on user needs), the microcontroller disables the control and stops the motor.

## 2.1.4 Reset and SWIM connector

The microcontroller pin reset (PA0) can be connected to reset the push button and the SWIM connector. Refer to [Table 3](#) to configure the reset in the two different modes.

**Table 3. Reset related jumpers**

Jumper	Description
J3	 Reset is connected to the push button reset when JP3 is set as shown.
	 Reset is used for programming/debugging mode when JP3 is set as shown.

In-circuit debugging/programming mode is managed through a SWIM (single-wire interface module) which is a hardware interface featuring ultra-fast memory programming. Coupled



with an in-circuit debugging module, it also offers a non-intrusive emulation mode, making the in-circuit debugger extremely powerful, and similar in performance to a full-featured emulator.

The SWIM connector (JP2) is detailed in [Table 4](#) below.

**Table 4. SWIM connector description (JP2)**

Pin number	Description
1	VDD
2	PD1
3	GND
4	PA0 (reset)

*Note: The SWIM connector gives users the capability to modify the firmware according to specific requirements. This increases the flexibility of the kit.*

### 2.1.5 CAN

The STEVAL-IHM030V1 is equipped with a CAN (controller area network) connector. The STM8S208xx supports CAN2.0A/B compliant CAN bus communication based on 5 V CAN transceiver. High-speed and low-speed modes are available and can be selected by setting JP1 accordingly (see [Table 7](#)). The physical interface with the bus is realized through the L9616D transceiver.

Standard male DB9 connectors (JSD1) are used to connect the CAN channel.



**Table 5. CAN connector pin description (JSD1)**

PIN	Signal
2	CAN L
7	CAN H
3,5,6	GND
1,4,8,9	Not connected

**Table 6. STM8S CAN pin description**

STM8S pin	Signal
CAN_TX	TX0
CAN_RX	RX0

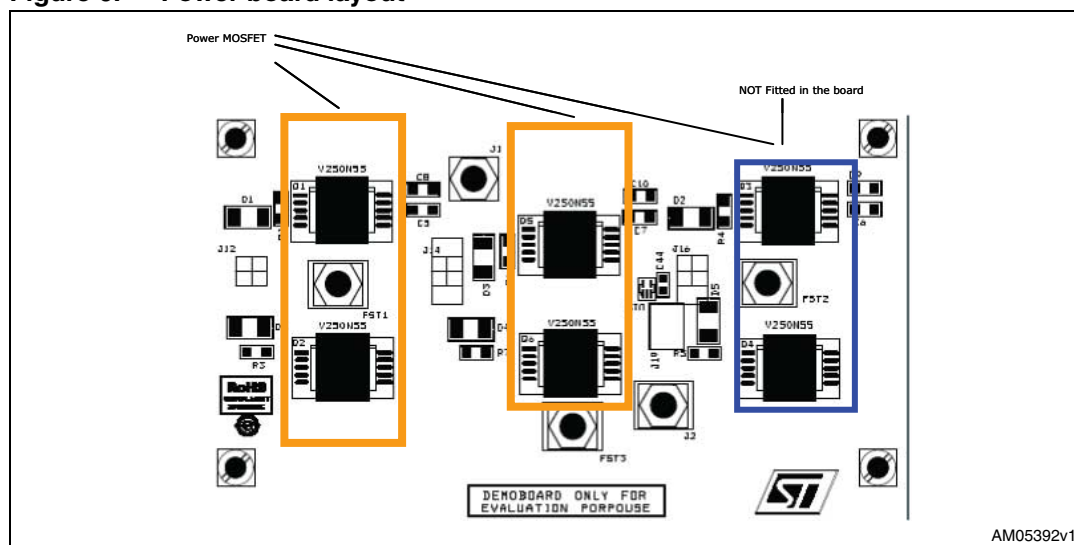
**Table 7. CAN setting**

Jumper	Description
JP1	<div style="display: flex; align-items: center;"> <div style="margin-right: 10px;">           1 2 3   </div> <div>           CAN transceiver operates in low-speed mode when JP1 is set as shown.         </div> </div>
	<div style="display: flex; align-items: center;"> <div style="margin-right: 10px;">           1 2 3   </div> <div>           CAN transceiver operates in high-speed mode when JP1 is set as shown. This is the default setting.         </div> </div>
J21	CAN terminal resistor is enabled when J21 is fitted. Default setting: not fitted.

## 2.2 Power board

The power board is based on power MOSFETs configured in an H-bridge topology. The power MOSFETs used are the STV250N55F3.

The board provides a compact solution and efficient power dissipation with the power MOSFETs mounted on a dedicated IMS layer. The board layout is illustrated in [Figure 6](#) below.

**Figure 6. Power board layout**

**Note:** The power board is designed to drive a 3-phase motor also. In this case, two additional power MOSFETs must be used and the control board replaced as appropriate.

### 3 STM8S208MB firmware

The brain of the entire system is the STM8208MB 8-bit microcontroller. The source code performs the basic functions:

- Full H-bridge control to drive the motor
- Motor position measurement based on the encoder
- PI algorithm calculation for speed regulation
- Current and voltage monitoring
- CAN communication

The related peripherals used in this application are as follows:

- Full H-bridge control: TIM2 general-purpose is used to generate the two PWM on the H-bridge high side. PH0 and PH1 are general-purpose I/O's used to drive the low side.
- Encoder: TIM1 on CH1 and CH2 is configured as encoder interface.
- PI algorithm calculation: TIM4 internal timer system. The ISR of the timer performs Calc\_Speed() and the control().
- Brake: GPIO PG4 is used to enable/disable the brake directly commanded by the microcontroller.
- DC voltage bus monitoring: ADC channel
- DC current bus monitoring: ADC channel and external interrupt
- CAN communication: the CAN peripheral

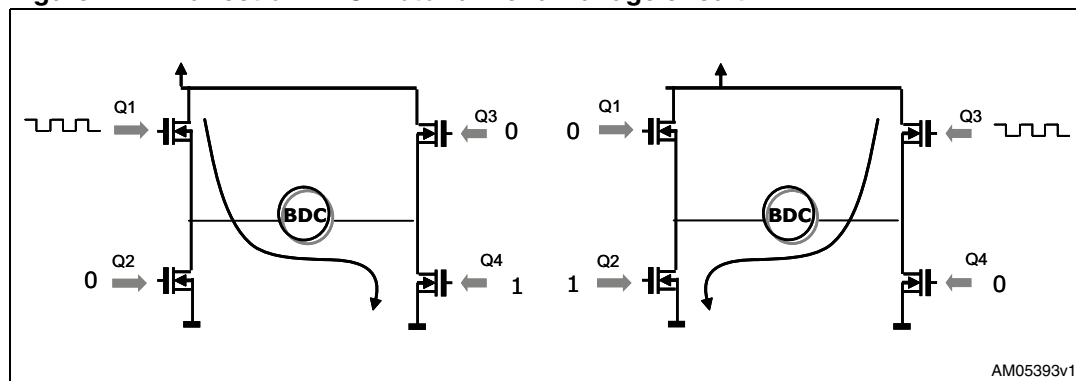
*Note:* All the firmware is developed in standard C language using the Cosmic compiler (CxSTM8 16K version 4.2.4) and the STVD IDE (version 4.1.1 patch1). The programmer debugger used is the Raisonance STX-RLINK.

#### 3.1 Control algorithm

The following paragraph describes full H-bridge control to drive the motor, motor position measurement based on encoder, PI algorithm calculation, and current and voltage monitoring.

The full H-bridge topology is driven by the microcontroller through the L6388E drivers. The H-bridge can be separated into two sides: Q1, Q2 and Q3, Q4. Each of these half-bridges switches one side of the brushed DC motor to the potential of the supply voltage or ground. The motor direction changes according to the following commands:

**Figure 7. Bidirection BDC motor drive full-bridge circuit**



The arrow shows the resulting current flow for this configuration. The applied PWM is used to modulate the motor speed; it is proportional to the duty cycle. By turning on Q1, putting the Q3 gate at high level and leaving Q2 off, the motor goes in a forward direction. Otherwise the motor will turn in the opposite direction.

The motor and direction speed is measured using the TIM1 peripheral configured as encoder interface.

The PI control software requires the following:

- An input coming from the CAN bus, to set the speed and the direction at the which the motor should run
- An interrupt to measure the motor speed. It is performed by the TIM1 configured as encoder interface
- A periodic interrupt to calculate the difference between the actual measured speed and the target speed. It is also performed every 10 ms by the ISR of TIM4
- The conversion of speed error into a variable duty-cycle of PWM to give a controllable average voltage to the motor

The PI algorithm implemented is approximated according to the following formula:

#### Equation 1

$$\text{Output} = K_p \cdot (\text{error\_speed}) + K_i \cdot \Sigma (\text{previous\_error\_speeds})$$

where  $K_p$  and  $K_i$  are proportional and integral gain, respectively. The PI algorithm is implemented in the control routine reported below:

```
void Control(void)
{
    Err_old = Err;
    Err = (CountTarget - CountEncoder) / ERROR_SCALING;
    Int_Sum += Err * ki * Int_Term / 100;
    if (Int_Sum > wind_int) Int_Sum = wind_int;
    if (Int_Sum < -wind_int) Int_Sum = -wind_int;
    Prop_t = kp * Err / 100;
    Duty_Per = (Prop_t + Int_Sum) + Duty_Old;
    if (ABS(Duty_Per) > max_duty) Duty_Per = DIR(Duty_Per) * max_duty;
    CCR2_Val = ABS(Duty_Per);
    DIRECTION = DIR(Duty_Per);
    .....
}
```

Current and voltage bus monitoring is described in [Section 2.1.3](#).

## 3.2 CAN communication

The CAN protocol has been implemented to manage motor commands and PI configuration messages. The motor commands enable/disable the motor, set speed and unlock the brake. The PI configuration messages send the  $k_p$  and  $k_i$  parameters.

The CAN is configured to send and receive the CAN frame as follows:

- Bit rate = 1 Mbit/s
- CAN clock = internal (HSI)
- ID filter = all identifiers are allowed
- RTR = data
- DLC = from 1 to 8 bytes according the message type

The CAN frame is a standard data frame 11-bit identifier. CAN receiving is implemented using the CAN peripheral ISR. The received frame contains the command and the data to switch the system from one state to a new one. The possible states are described in [Figure 8](#) below.

**Table 8. CAN frame details**

State command	Description	ID frame	Data length
Motor_Control_Enable	Enable the control loop routine	0x100	1
Motor_Control_Disable	Disable the control loop routine	0x101	1
Brake_Unlock	Disable the motor brake	0x102	1
Set_Speed	Set the motor speed and direction	0x103	3
Set_Parameter	Configure PI parameters	0x104	3

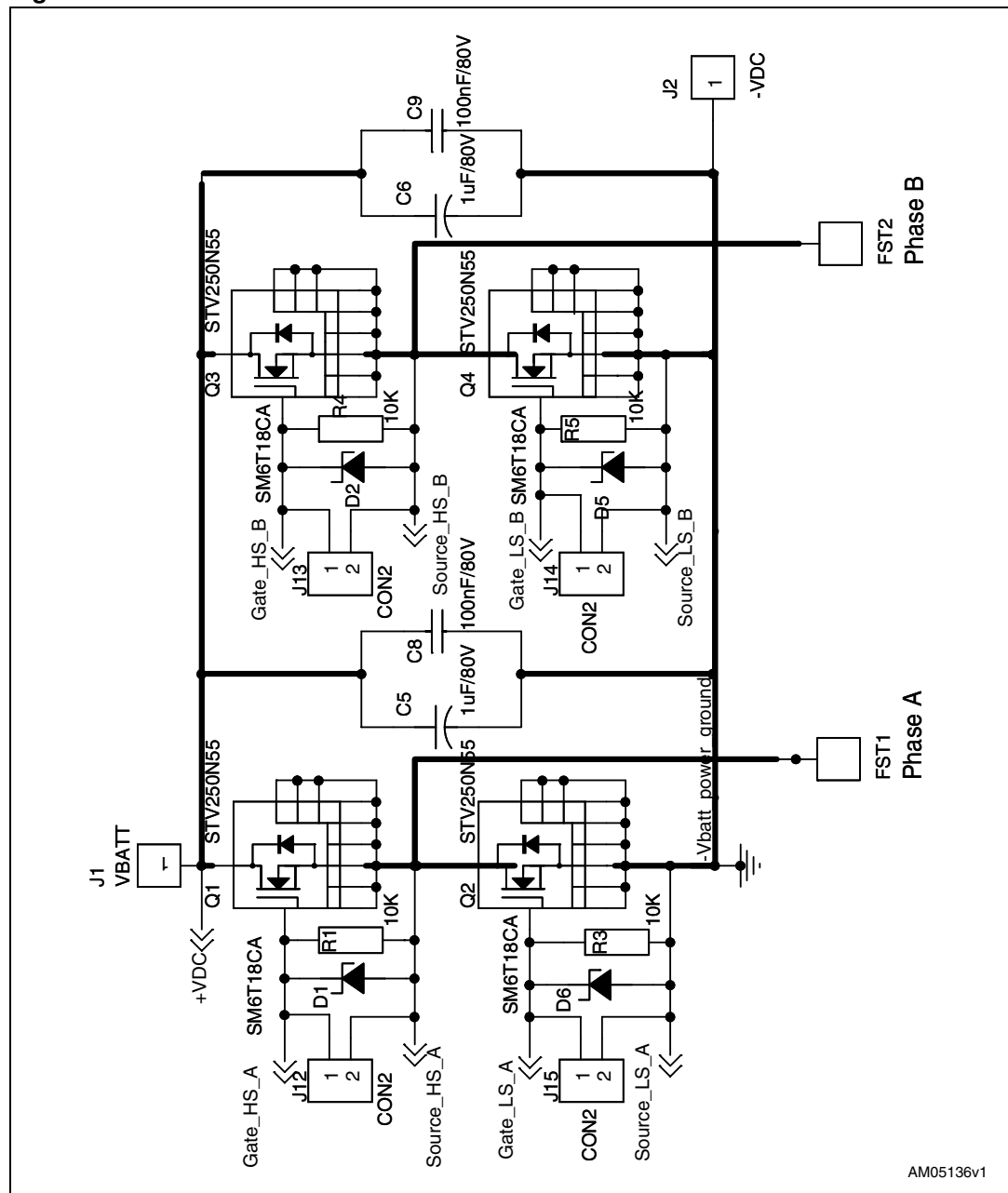
The control board transmits a CAN frame to inform the host of the status of the system. This information is sent every 10 ms.

## Appendix A Schematics

**Figure 8. Control board**



**Figure 9. Power board**



## Appendix B Bill of material

**Table 9. Bill of material**

Reference	Part / value	Voltage	Manufacturer
CS3	ACS756A-100B-PFF-T		Allegro
C1,C2	4700 $\mu$ F	63 V	Panasonic
C3,C4,		50 V	
C36,C38, C39,C43, C44, C45, C46,C47, C48,C49	100 nF	50 V	
C5,C6	1 $\mu$ F	50 V	
C8,C9	100 nF	50 V	
C11,C12, C17,C18	1 $\mu$ F	50 V	
C13,C19, C40,C41, C42	10 nF	50 V	
C16,C21	10 $\mu$ F	20 V	AVX
C28	100 $\mu$ F	10 V	AVX
C30	100 $\mu$ F	20 V	AVX
C31	100 pF	50 V	
C32	22 nF	50 V	
C37	470 nF	50 V	
D1,D2,D5, D6	SM6T18CA		STMicroelectronics
D13	STPS2L40U		STMicroelectronics
D14	STPS340U		STMicroelectronics
FST1,FST3	Phase A		
FST2,FST4	Phase B		
JP1,JP3	HEADER 3		
JP2	SWIM connector		ERNI
JSD1	SUBD9C_M_COUDE		
J1	VBATT		
J2CB			
J2			
J3CB			
J6,J7,J8,J9,J21	CON2		
J21			
J12,J13,J14,J15			
J25	CON12		
L1	22 $\mu$ H / 1.4 A		



Table 9. Bill of material (continued)

Reference	Part / value	Voltage	Manufacturer
Q1,Q2,Q3, Q4	STV250N55F3		STMicroelectronics
Q9,Q10, Q11,Q12	STS01DTP06		STMicroelectronics
Q14	STD17NF03LT4		STMicroelectronics
R1,R3,R4, R5	10 k $\Omega$		
R9,R11	68 k $\Omega$ / 1/4 W		
R10,R16, R24,R27, R60,R61, R62,R63	47 $\Omega$		
R12,R19, R36,R57	22 $\Omega$		
R13,R29	0 $\Omega$		
R40	39 k $\Omega$		
R41	4.3 k $\Omega$		
R42	3.3 k $\Omega$		
R43	120 $\Omega$		
R44	100 $\Omega$		
R45	4.7 k $\Omega$		
R49,R55, R64,R73	10 k $\Omega$		
R50,R52	2 k $\Omega$		
R51	24 k $\Omega$		
R54	90 k $\Omega$		
R70	0		
R71,R72	1 k $\Omega$		
TP22,TP23,TP25	Test point		
TP26,TP27,TP28,TP30,TP31,TP35	Test point		
U1,U4	L6388ED		STMicroelectronics
U6	L5970D		STMicroelectronics
U7	LF50CDT-TR		STMicroelectronics
U8	L9616		STMicroelectronics
U9	STM8S208MBT6B		STMicroelectronics
U12	LM393D		STMicroelectronics
W3,W4	JUMP1		
W5	Push button		

## Revision history

**Table 10. Document revision history**

Date	Revision	Changes
08-Feb-2009	1	Initial release.
26-Mar-2010	2	Inserted manufacturer in reference Q1, Q2, Q3, Q4 Modified: <a href="#">Figure 1</a>

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