



SMART ARM-based Motor Control Kit

ATSAMD21BLDC24V-STK

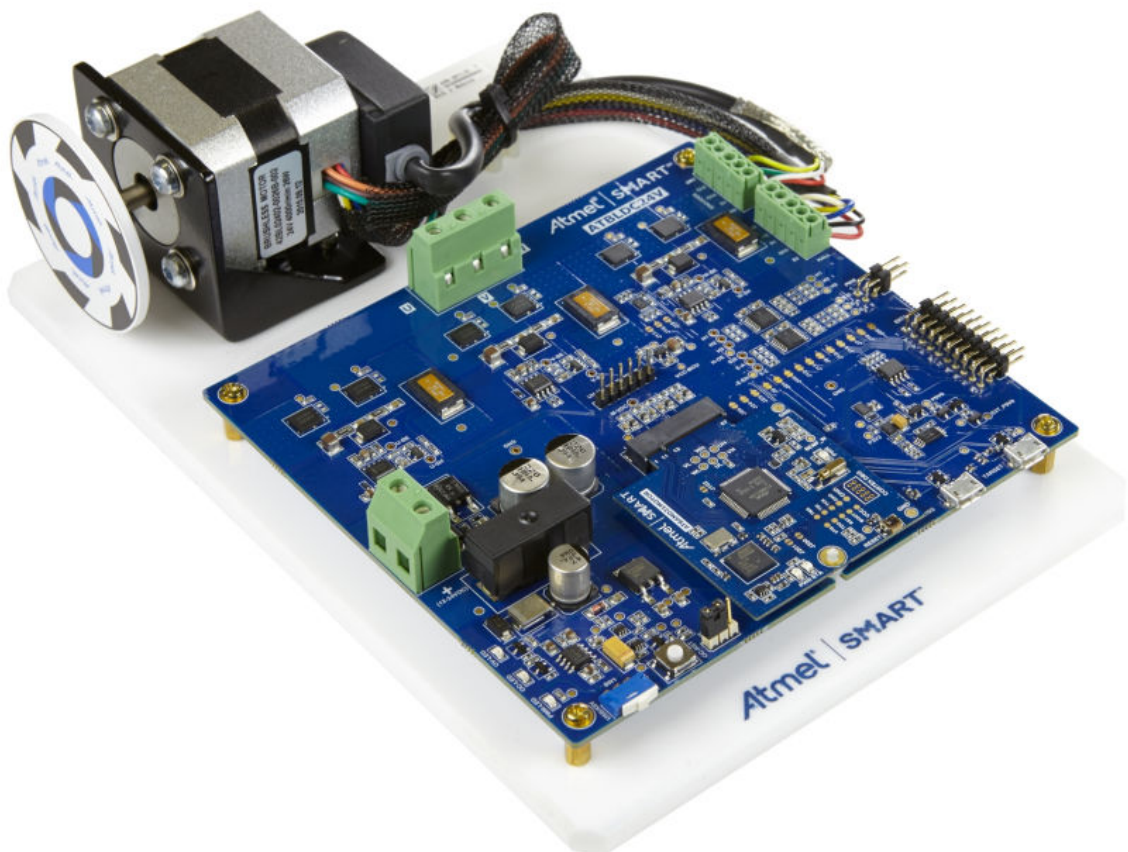
USER GUIDE

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1. Atmel Low Voltage Motor Control Starter Kit

The Atmel® ATSAMD21BLDC24V-STK is a low voltage BLDC, PMSM motor control starter kit. The kit contains a driver board hardware with half-bridge power MOSFET drivers, current and voltage sensing circuit, Hall and Encoder interface, fault protection circuits, etc. The ATSAMD21MOTOR MCU card is plugged into the driver board and has an on-board debugger. Supported by the Atmel studio integrated development platform, the kit provides easy access to the features of ATSAMD21J18A MCU and explains how to integrate the device in a custom motor control application. Pluggable MCU cards are available from Atmel, supporting other SMART ARM® MCUs.



1.1. ATSAMD21BLDC24V-STK Features

ATSAMD21BLDC24V-STK has the following features:

- Pluggable MCU card interface
- Debug support using on-board Atmel EDBG device
- Three half-bridge MOSFET driver
- Motor BEMF sensing
- Motor individual phase current sensing
- DC-bus voltage sensing

- Hall sensor interface
- Encoder sensor interface
- Over-current protection support
- Over-voltage protection at 30VDC
- 5V and 3.3V MCU card support
- Selectable MCU supply voltage
- Reverse power supply voltage protection
- Atmel Xplained Pro compatible header interface
- On board Temperature sensor
- On board serial flash
- LED fault indications
- Atmel studio plug-and-use support using unique ID device

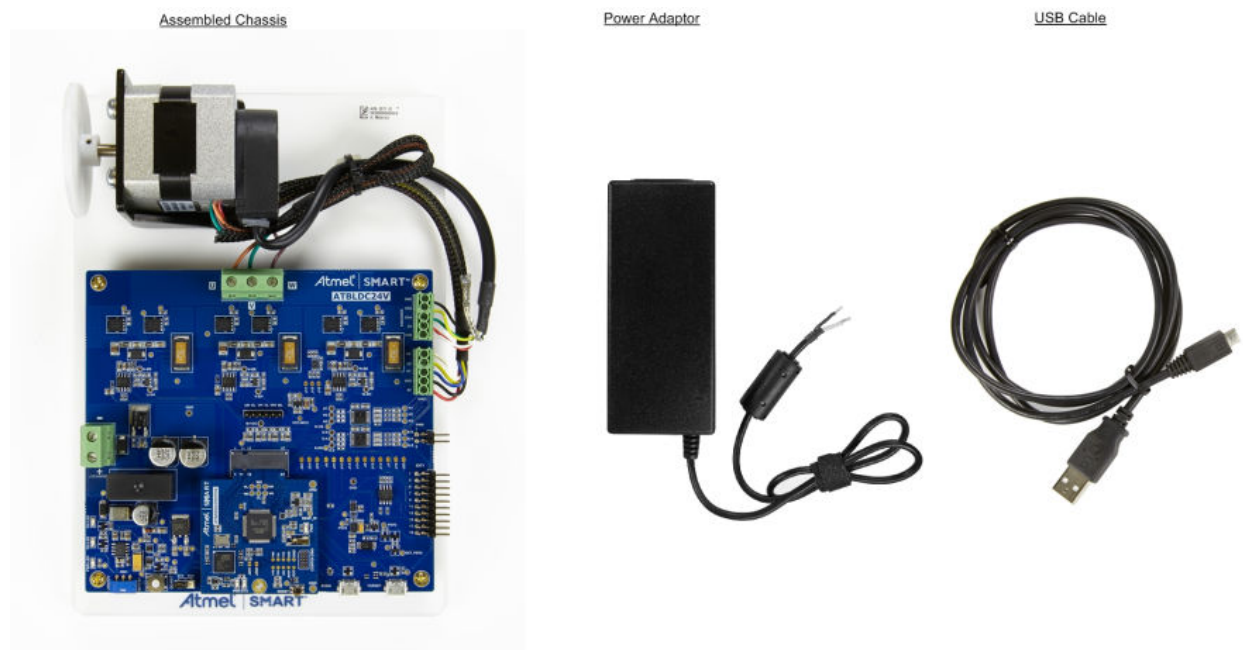
1.2. ATSAM21BLDC24V-STK Kit Content

ATSAMD21BLDC24V-STK Kit contains the PCBs, BLDC motor, power adaptor and USB cable to get started and running the motor in the kit.

The kit contains the following items:

1. AT24VBLDC driver board.
2. ATSAM21MOTOR MCU card.
3. LDO brush-less DC motor (LDO: 42BL02402-0026B-002).
4. Fully assembled chassis plate.
5. 24V, 4A AC adapter (EDAC: EA11011E-240).
6. Micro-USB cable.

Figure 1-1. ATSAM21BLDC24V-STK Kit Content



1.3. Design Documentation and Relevant Links

The following list contains links to the most relevant documents and software for ATSAMD21BLDC24V-STK:

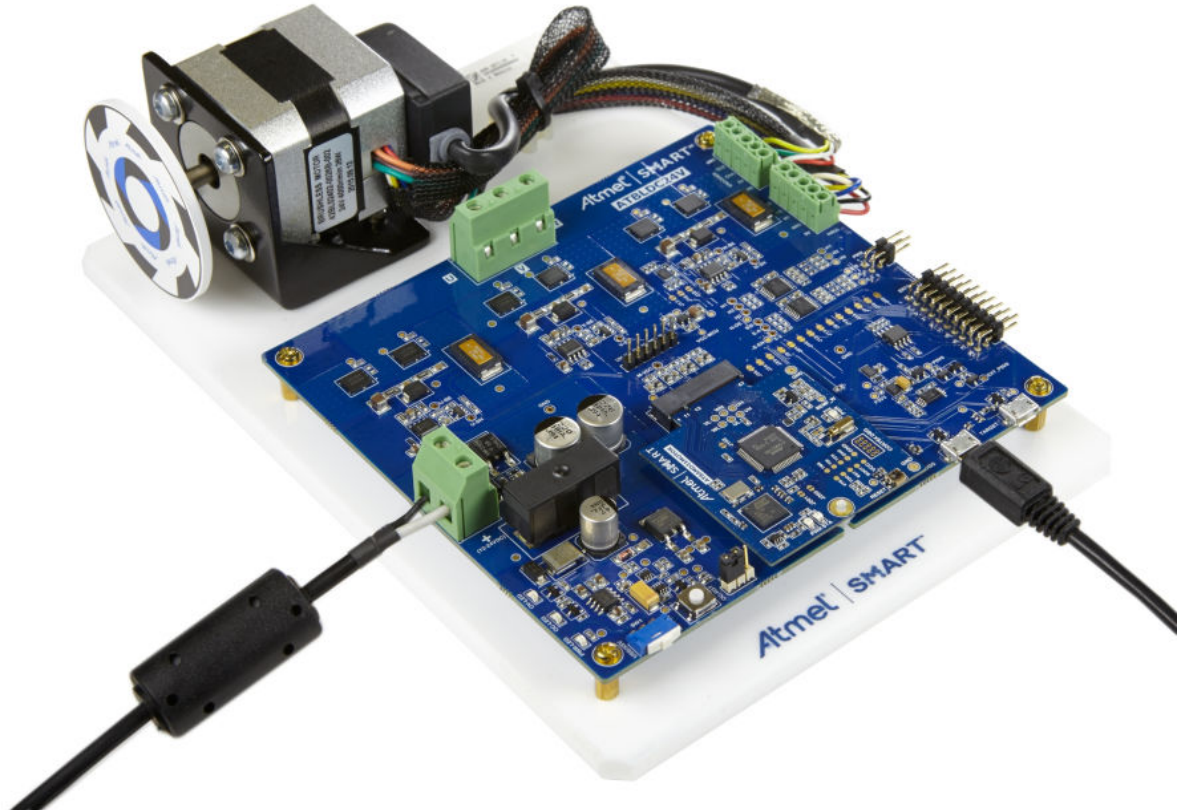
- [Xplained Pro products](#) - Atmel Xplained Pro is a series of small-sized and easy-to-use evaluation kits for Atmel microcontrollers and other Atmel products. It consists of a series of low-cost MCU boards for evaluation and demonstration of features and capabilities of different MCU families.
- [ATSAMD21BLDC24V-STK User Guide](#) - PDF version of this User Guide.
- [ATSAMD21BLDC24V-STK Design Documentation](#) - Package containing schematics, BOM, assembly drawings, 3D plots, layer plots, etc.
- [Atmel Studio](#) - Free Atmel IDE for development of C/C++ and assembler code for Atmel microcontrollers.
- [EDBG User Guide](#) - User guide containing more information about the on-board Embedded Debugger.
- [Atmel Data Visualizer](#) - Atmel Data Visualizer is a program used for processing and visualizing data. Data Visualizer can receive data from various sources such as the Embedded Debugger Data Gateway Interface found on Xplained Pro boards and COM ports.
- [ATSAMD21BLDC24V-STK](#) - Product page.
- [ATSAMD21J18A](#) - MCU datasheet.

2. Getting Started with ATSAMD21BLDC24V-STK

This chapter is a step-by-step guide to get started with the SAMD21BLDC24V-STK.

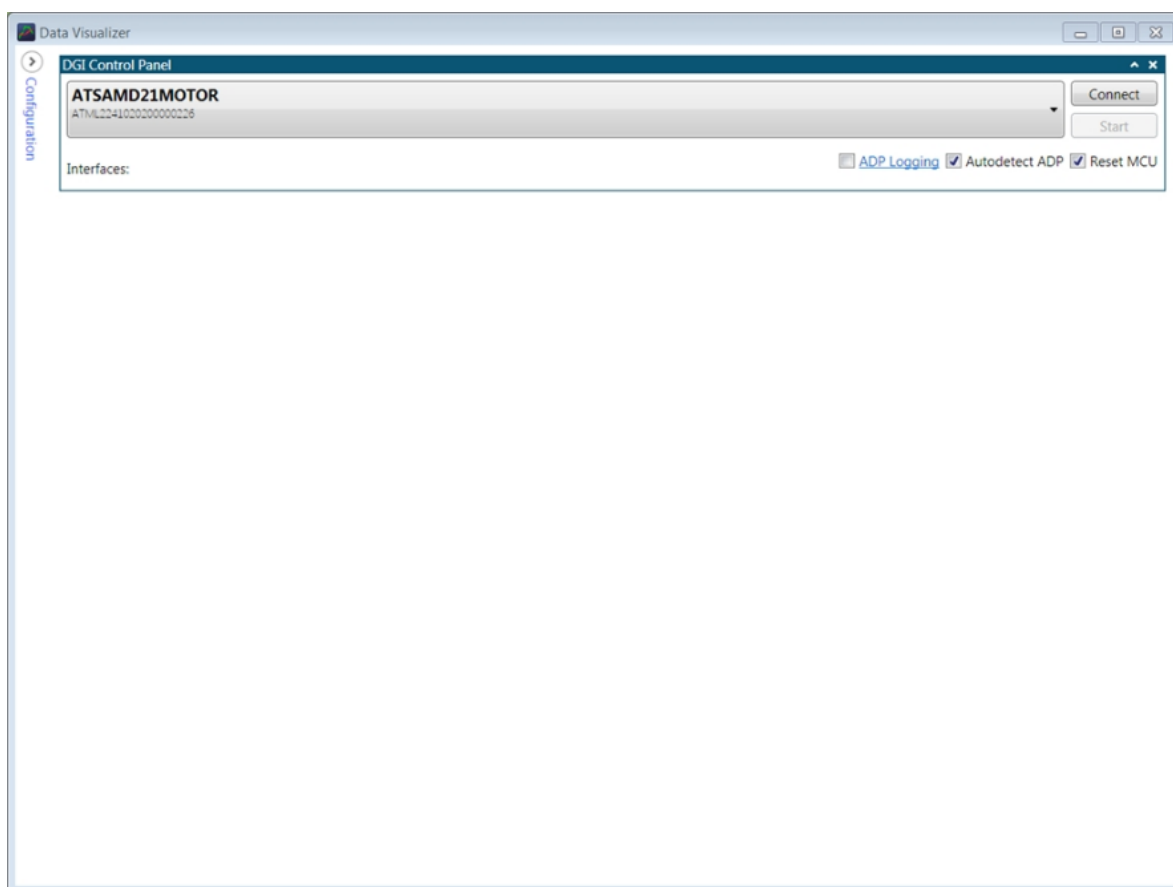
1. SAMD21BLDC24V-STK kit contains a fully assembled chassis and 24VDC power adaptor.
2. Connect the power adaptor to the "SUPPLY-IN connector". Connect white color cable to + PIN.

Figure 2-1. Kit with Power and USB Ports Connected



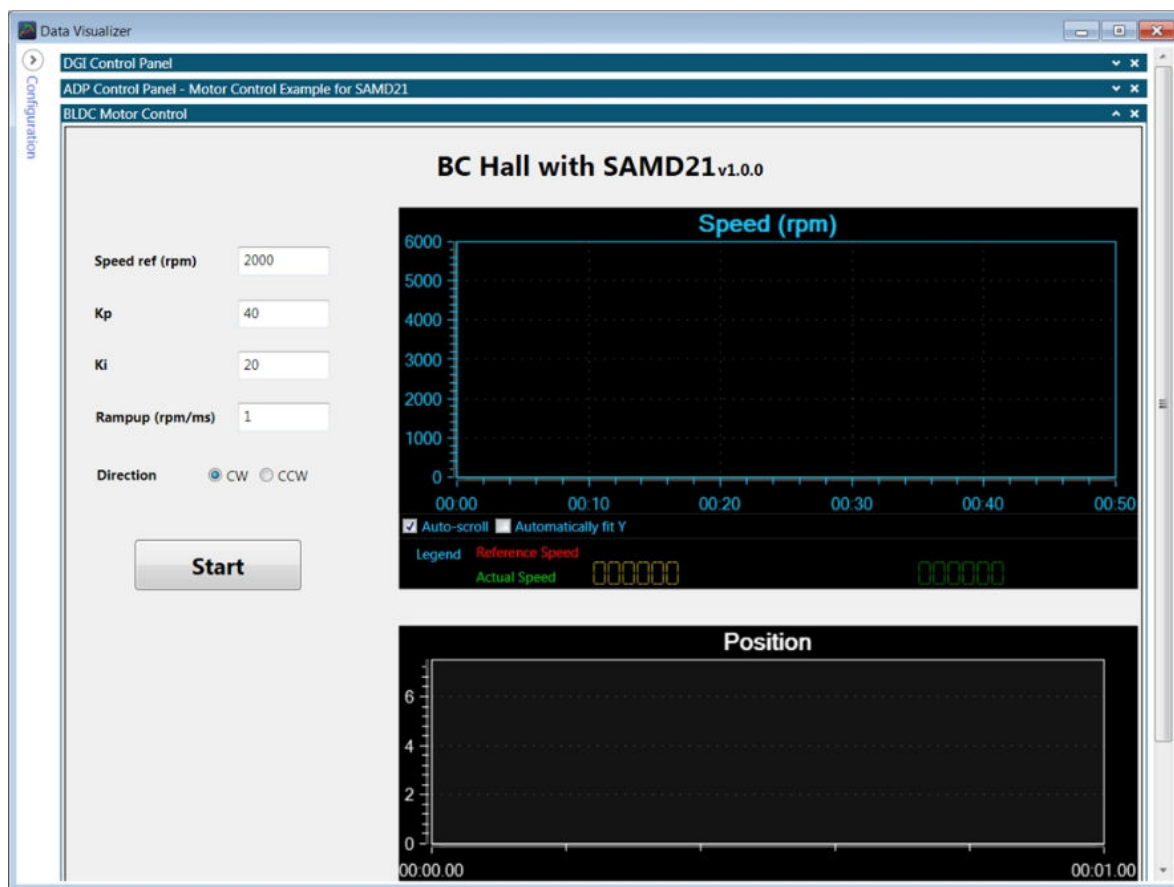
3. Switch ON the power adaptor.
4. Connect the Micro-USB cable to the "EDBG-USB connector" and PC USB port.
5. The power LED indications on the MCU board are now ON.
6. Open "Data Visualizer".
7. In the "Data Visualizer Connect Window" Choose the kit from the DGI control panel's drop down list.

Figure 2-2. Data Visualizer Connect Window



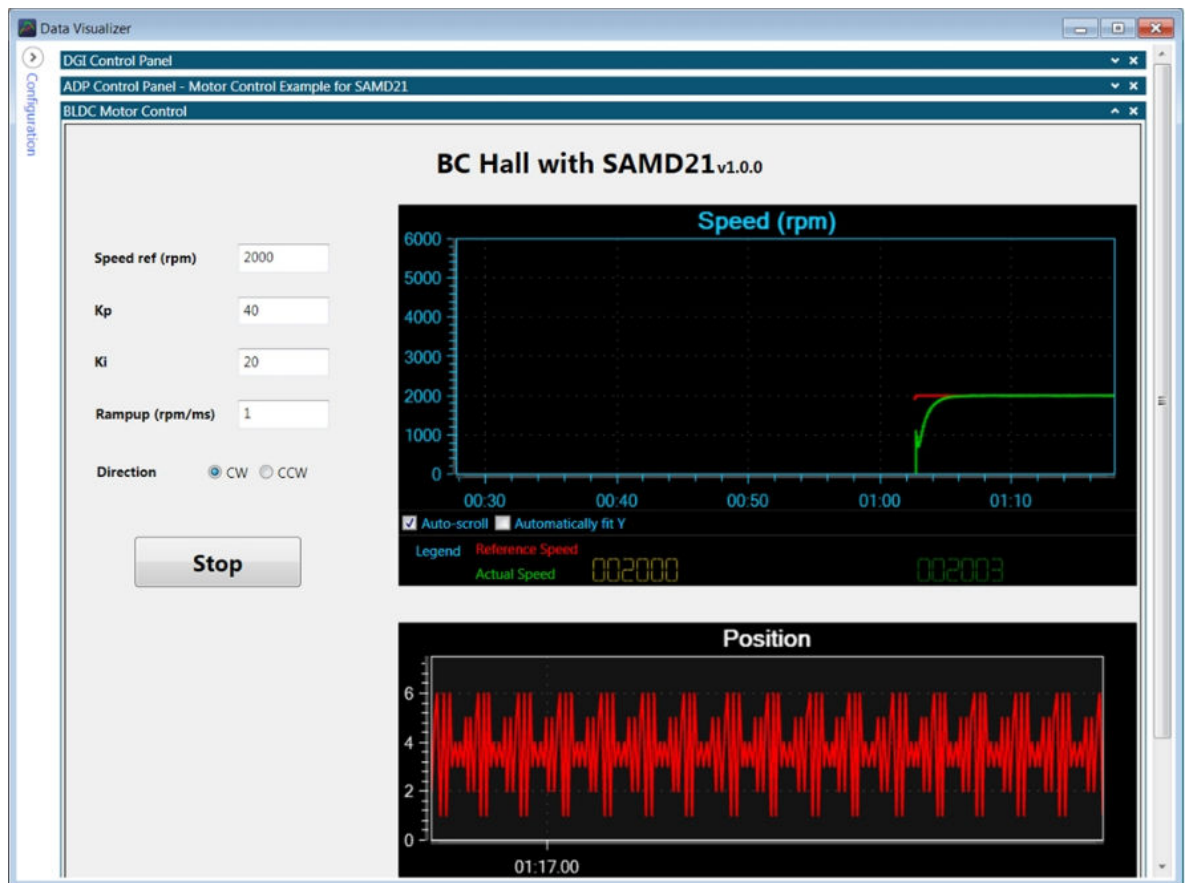
8. Click "Connect". The orange LED in the MCU board shall now blink.
9. The Data Visualizer default window will pop up once the connection is made. All the fields shall show default values.

Figure 2-3. Data Visualizer Start Window



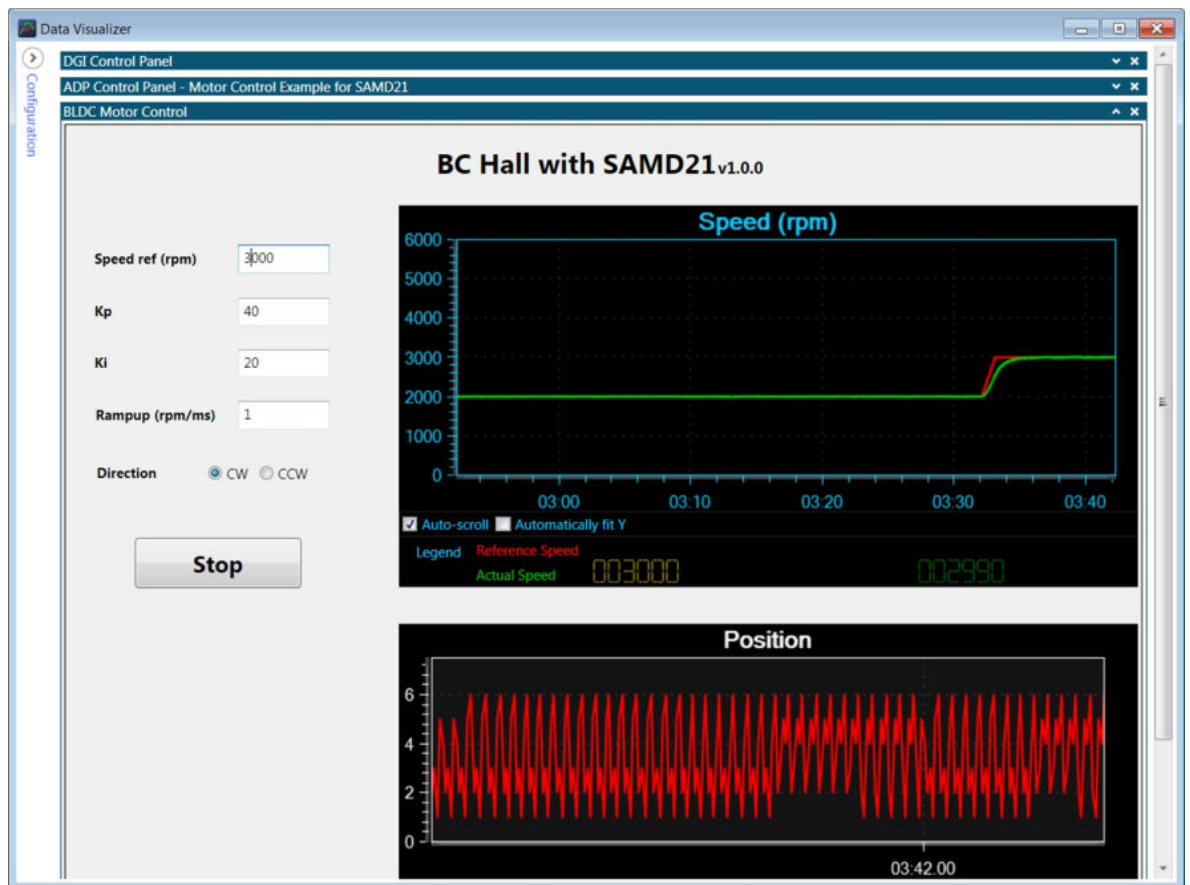
10. Click on "Start" to turn the motor ON with default values.

Figure 2-4. Data Visualizer "Start Motor" Window



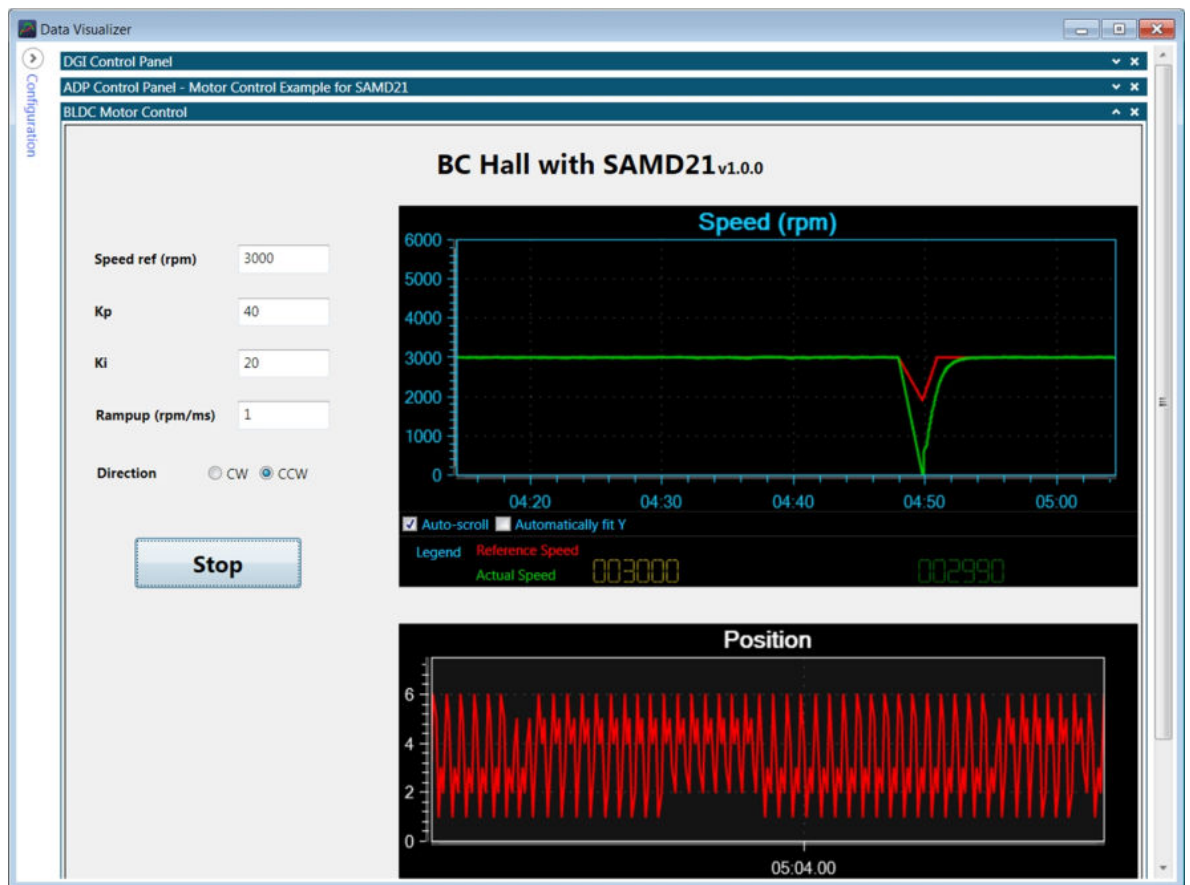
11. Change the value in a field and press "Enter". For instance, to change the motor speed, type in the desired speed within the motor's rating and press "Enter".

Figure 2-5. Data Visualizer "Change Parameter"



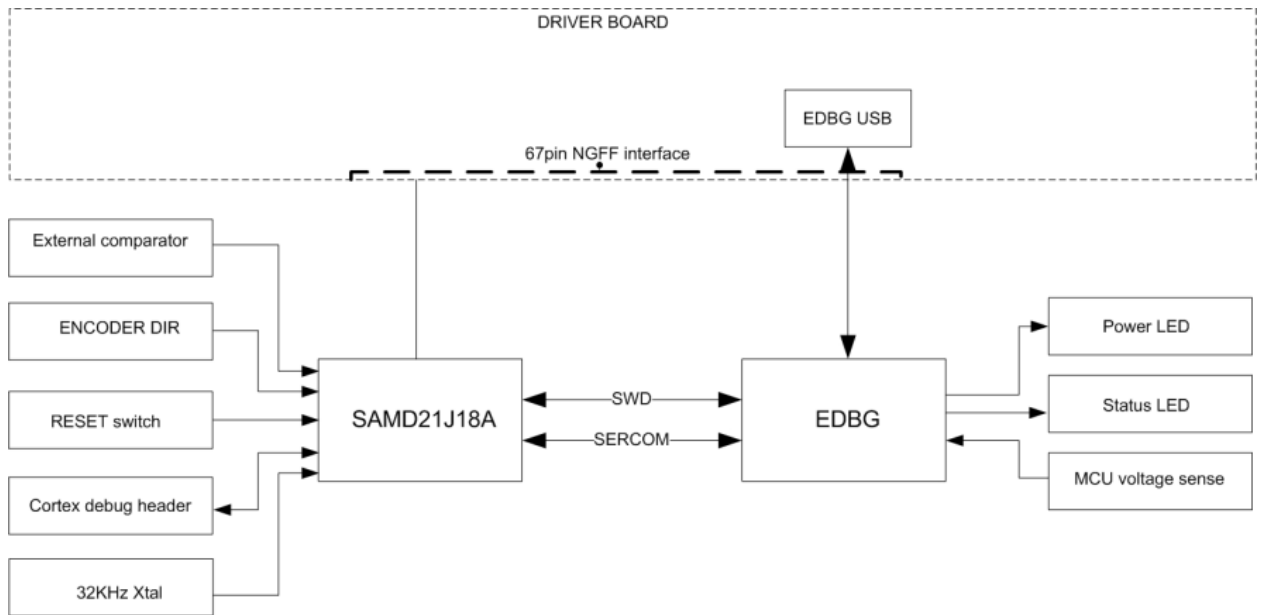
12. Stop the Motor by clicking the "Stop" button.
13. To change direction of rotation after "Stop", choose "CCW" in radio button and click "Start".

Figure 2-6. Data Visualizer "Change Direction"



14. Adjust the graph by checking "Automatically fit Y".

Figure 3-2. MCU Board Block Diagram



3.1.1. Power Supply

The ATSAMD21MOTOR MCU card takes 3.3VDC supply from the 67-pin edge connector. Both the EDBG device and the Main MCU operates from 3.3VDC. The power supply selection jumper on the Driver board should be connected to 3V3 (silk screen text) selection.

3.1.2. Main MCU Circuit

The ATSAMD21MOTOR has an ATSAMD21J18A device. The device is intended to work with MCU internal clock source. A 32.768kHz crystal is connected externally to the MCU.

3.1.3. Embedded Debugger

The ATSAMD21J18A MCU is interfaced to the EDBG debug device. The EDBG uses SWD interface for programming and debugging the main MCU. A debug header is also provided on the MCU board with ARM Cortex® debug pinout. An external debugger can be connected to this debug port.

The DGI is a proprietary communication interface used by the Atmel Data Visualizer software to communicate with the development kits through the EDBG. SERCOM4 of the ATSAMD21J18A connected to the EDBG device support DGI SPI interface and uses Atmel ADP protocol. The MCU SERCOM4 is also connected to the UART channel of the EDBG through a pair of "normally open" jumpers, the J200 and J201. Shorting these jumpers will enable the CDC UART interface for the main MCU.

High Speed USB port of the EDBG is accessible at the driver board. EDBG USB enumerates as a composite device supporting debug, DGI SPI, and CDC interfaces.

The USB port of the ATSAMD21J18A is connected to the Micro-USB connector on the driver board.

3.2. ATSAMD21BLDC24V-STK Driver Board

The driver board contains half-bridge MOSFET driver circuits for three-phase BLDC, PMSM motor drive and supports 12-24VDC recommended bus drive voltage. Individual phase current sense, bus voltage sense, and back-EMF sense circuits supports development of sensor-less motor drive algorithms. Hall and Encoder sensor interfaces enables the user to develop sensor-based motor control applications. The

driver board has over-voltage protection in hardware and over-current shutdown through the MCU input. Reverse voltage protection is available at 12-24VDC and EXT1-header external supply inputs. USB interface headers are interfaced to the main MCU and EDBG device in the MCU board. Temperature sensor, serial flash, XPRO interface header, and UID chip circuits are the other features included in the driver board hardware. The figure below shows the main components and block diagram of driver board.

Figure 3-3. ATSAMD21BLDC24V-STK Driver Board PCB

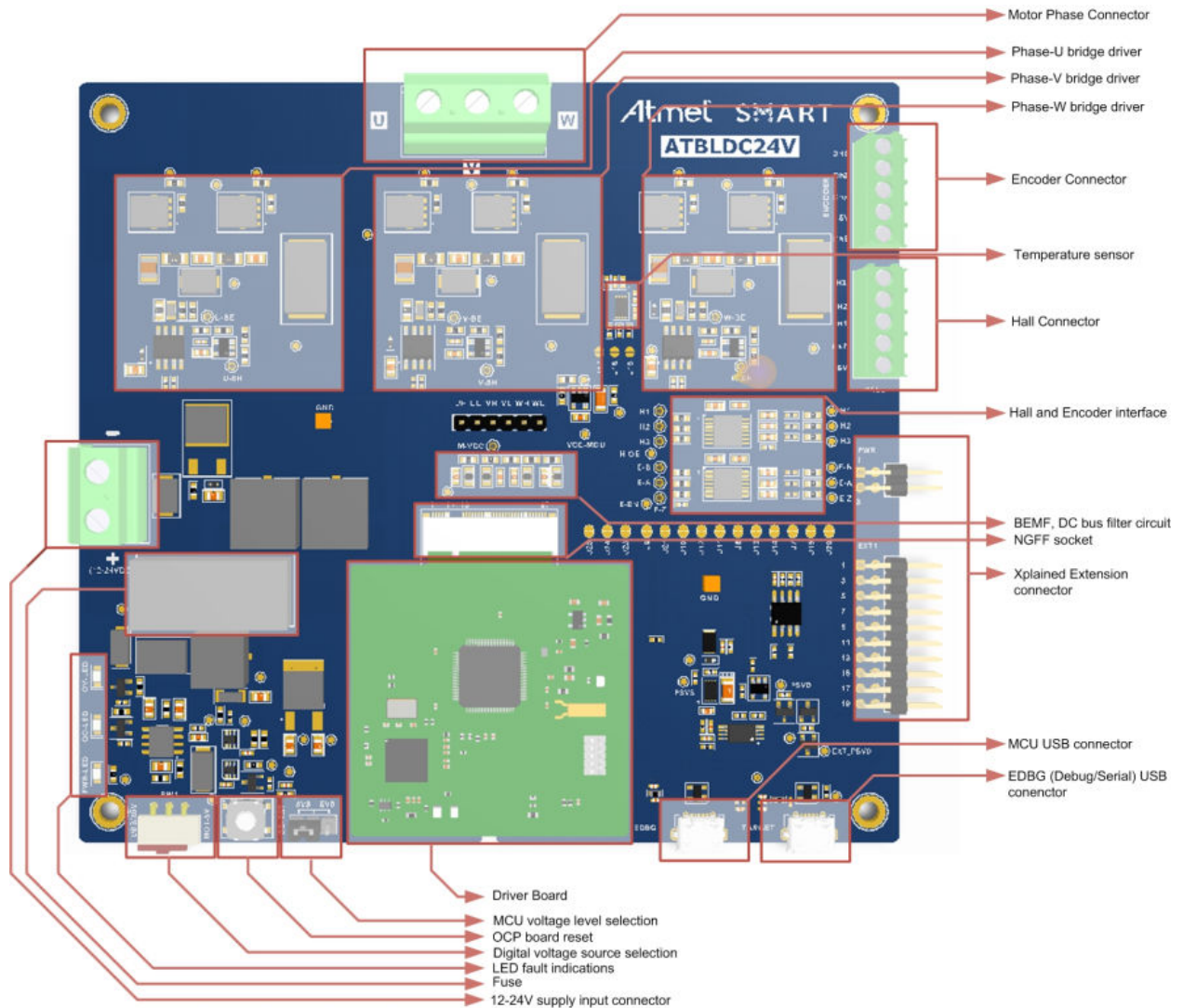
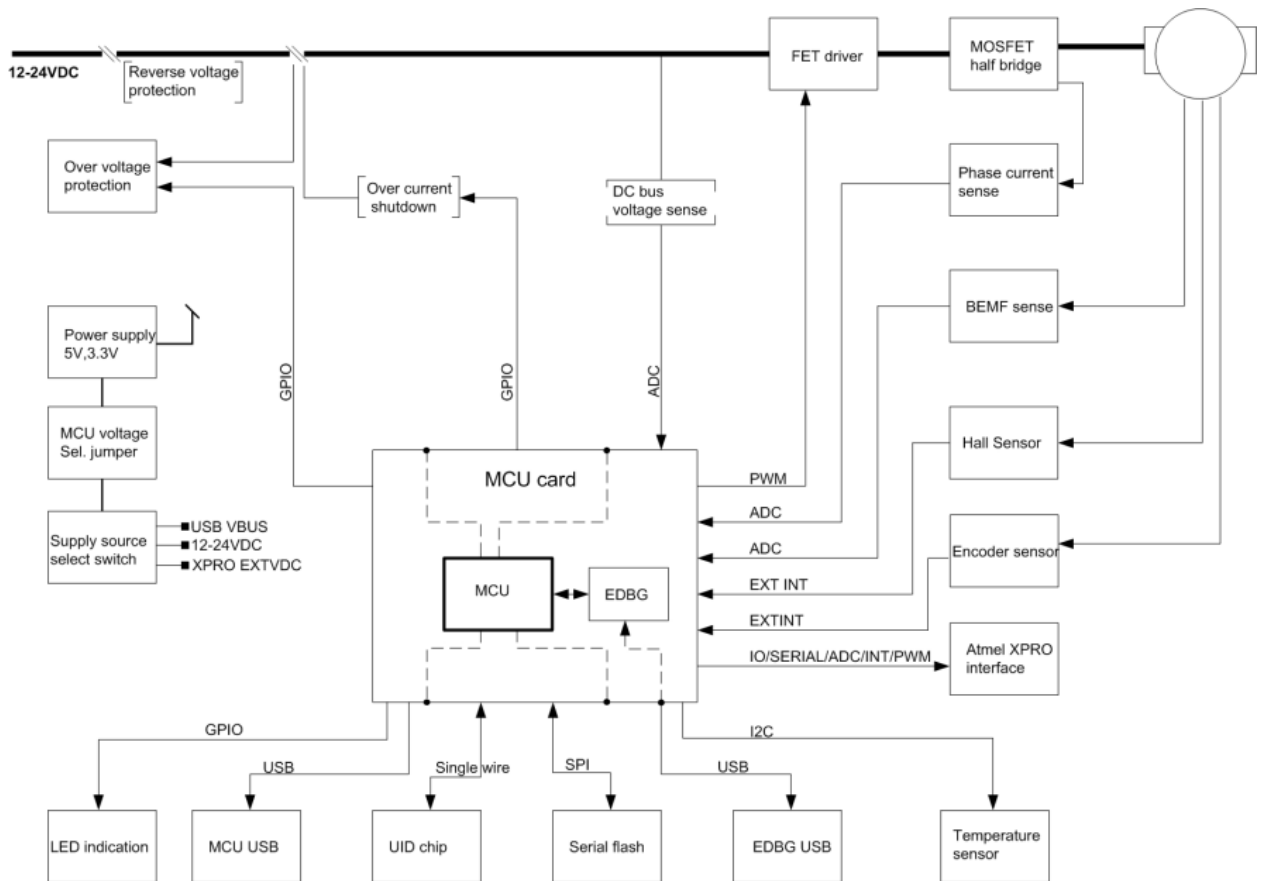


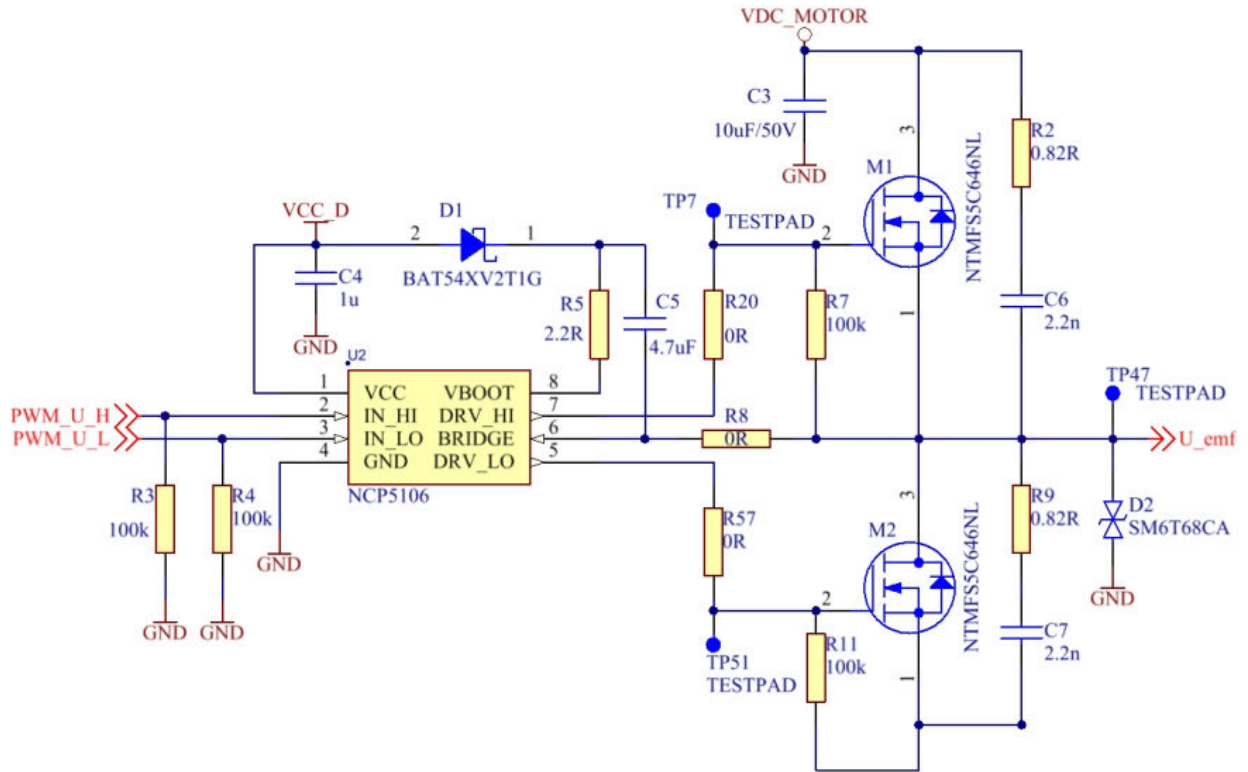
Figure 3-4. ATSAMD21BLDC24V-STK Block Diagram



3.2.1. Half-bridge FET Driver

The half-bridge circuit is based on the NTMFS5C646NL N-channel Power MOSFET. Each half-bridge is driven by the NCP5106A gate driver. The gate driver takes two independent PWM inputs from the MCU and uses bootstrap technique to drive the high side Power MOSFET in the half-bridge. The bootstrap capacitor is tied between PIN5 and PIN8 of the NCP5106 through a resistor. C5 is the bootstrap capacitor and D1 is the bootstrap diode for phase-U half-bridge, as shown in the figure below. The bootstrap capacitor value is chosen based on the total charge to be supplied by the capacitor and maximum allowable voltage drop on the bootstrap capacitor.

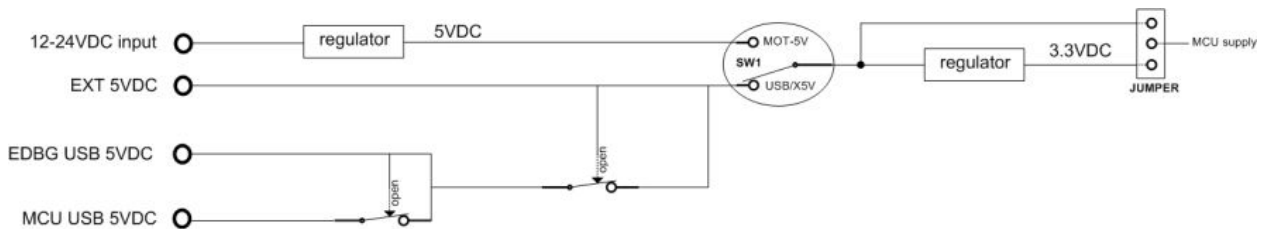
Figure 3-5. Half-bridge Driver Schematic



3.2.2. Power Supply

The driver board has multiple power supply selection options. Automatic supply input selection is similar to the Atmel Xplained Pro hardware. The block diagram shows how to use the SW1 user switch and the jumper available on the PCB to select the MCU voltage supply.

Figure 3-6. Driver Board Power Supply



3.2.3. Phase Current Sense

The current sense resistor and the differential amplifier circuit enables measurement of individual phase currents using the ADC channel of the MCU. The figure below shows the sense circuit for the U-phase and reference generator. R30 is the current shunt and op-amp U8 is configured in inverting differential amplifier configuration. Voltage offset is added to the sense output, which is the reference voltage output generated from the MCU supply voltage (MCU supply divided by 2). Solving the circuit,

$$V_{out} = V_r - (I_s \cdot R_s)(R_{52}/R_{16})$$

$$V_{out} = U_I_sense \text{ at TP13}$$

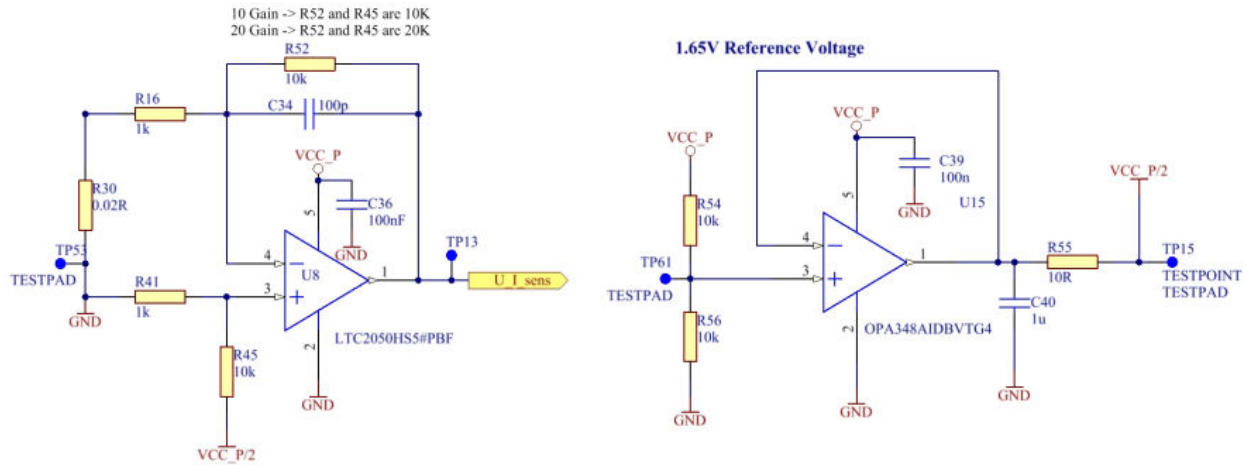
$$V_r = \text{reference voltage} (= 1.65V)$$

$$I_s = \text{phase current}$$

$$R_s = \text{shunt resistor}$$

R52 = feedback resistor
R16 = input side resistor

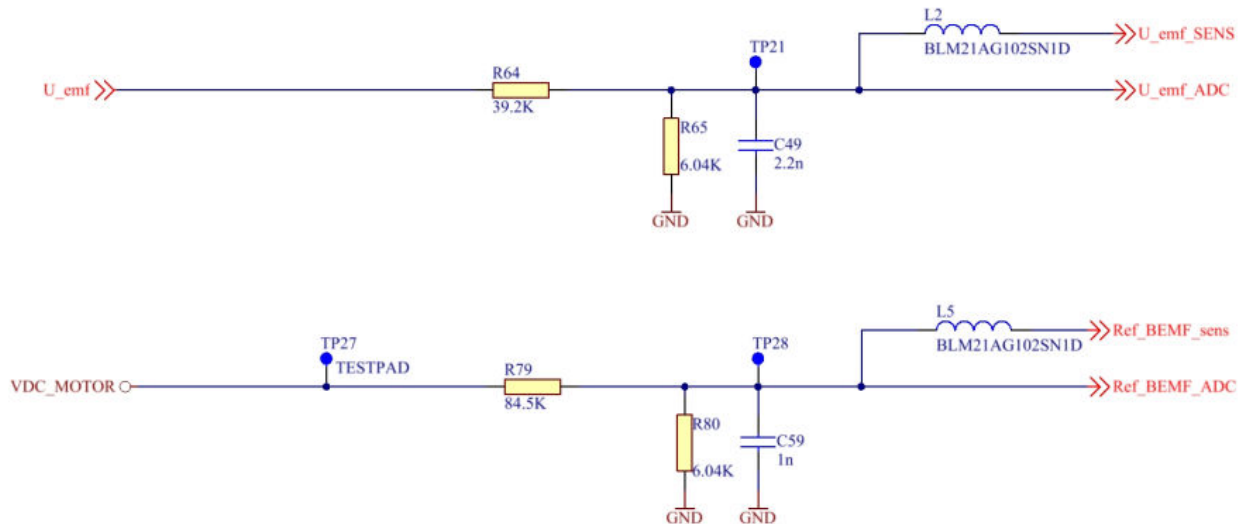
Figure 3-7. Current Sense and Reference Generation Circuit



3.2.4. BEMF, DC Bus Sense

Back-EMF generated in the phase windings can be determined from the voltage read at the individual phase terminals. A schematic drawing for the voltage scaling and the filter circuit is shown in the figure below. BEMF output is connected to the ADC and analog comparator of the MCU. Motor DC supply is divided by network R79, R80 and connected to ADC reference and analog comparator.

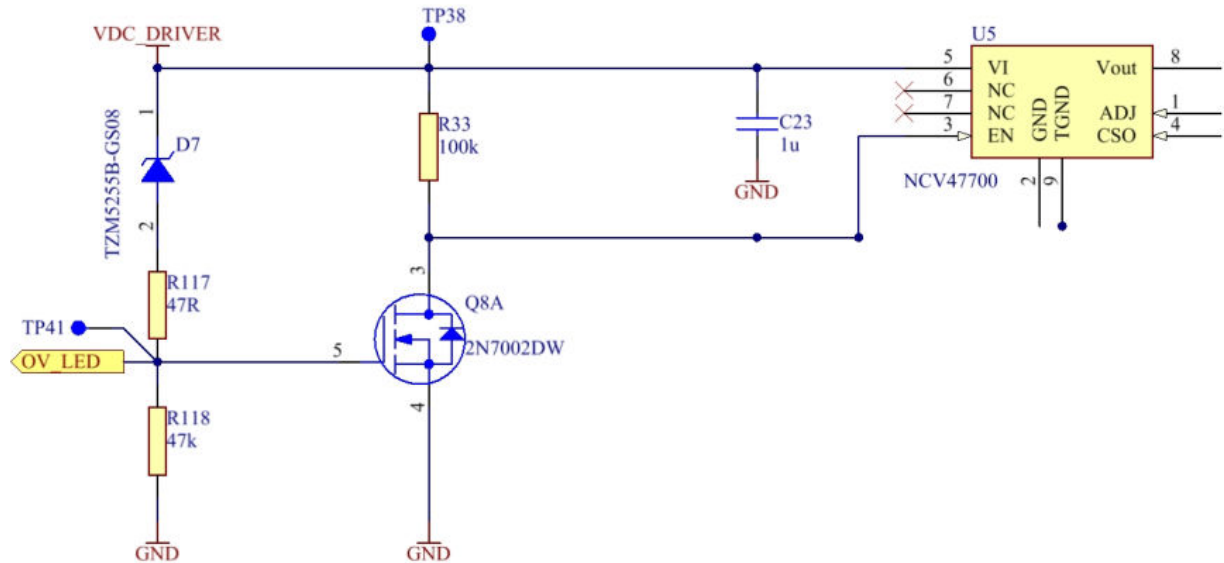
Figure 3-8. Back-EMF, DC Bus Voltage Sense Circuit



3.2.5. Over-voltage Protection (OVP)

DC bus voltage is monitored by the voltage sense circuit. If the voltage gets higher than 30VDC, the over-voltage protection will shut down the FET driver. The OVP circuit is shown in the figure below. Sense voltage is determined by the zener diode (D7) voltage (28V) and R-network R117 and R118. Vgs (threshold) of Q8A is typically 2V.

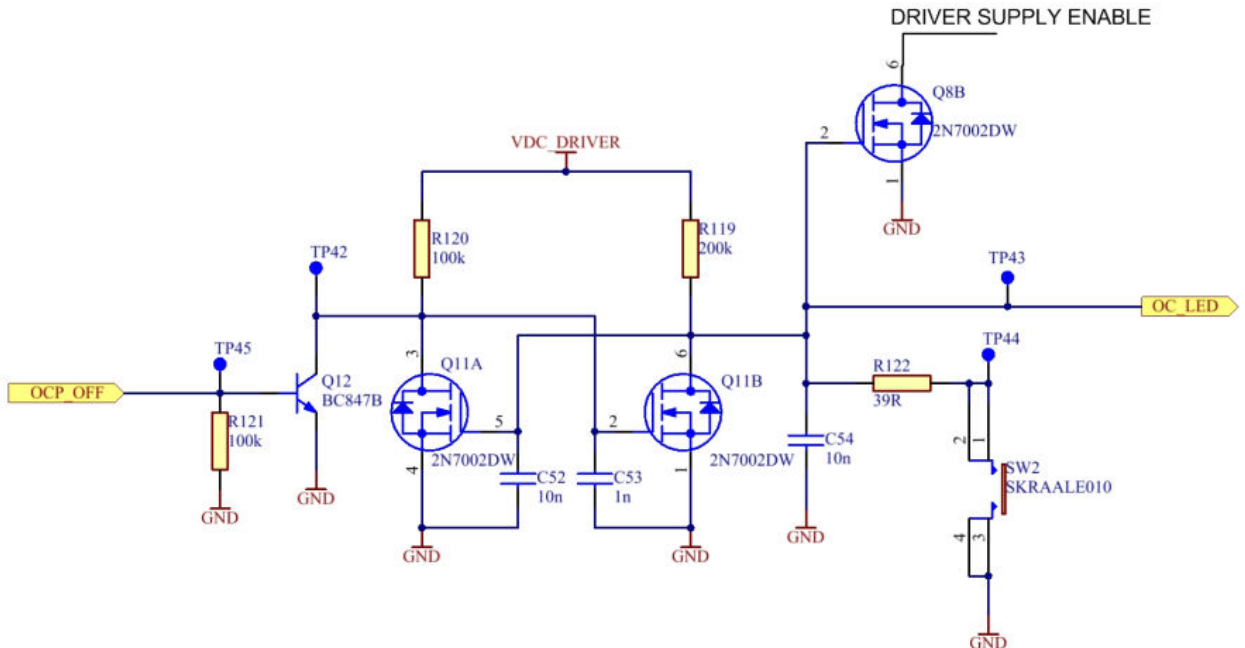
Figure 3-9. OVP Circuit



3.2.6. Over-current Protection

Over-current protection (OCP OFF) is signaled from the MCU when the total individual phase shunt current value exceeds the limit. Shutdown circuit is shown in the image below. Q8B will be OFF in normal operation and switches ON and shuts off U5 when OCP OFF triggers. Shutting down U5 will cut off the MOSFET driver and can be switched back to active condition by pressing the SW2 push button.

Figure 3-10. Over-current Protection Circuit



3.2.7. Hall Sensor Interface

The Hall sensor interface uses NTS0104 level translator. The interface is tested with motors with open drain and push pull type Hall sensor output. The LDO motor supplied with ATSAMD21BLDC24V-STK has open drain Hall sensor output type.

3.2.8. Encoder Sensor Interface

The encoder sensor interface uses a NTS0104 level translator. The interface is tested with motors with open drain and push pull type encoder sensor output. The LDO motor supplied with ATSAMD21BLDC24V-STK has open drain output type.

3.2.9. Atmel Xplained PRO Interface

The Xplained PRO compatible header has a 20-pin EXT1 connector and a 4-pin power connector. All the lines of the 20-pin header are routed to the 67-pin NGFF interface. Some pins of the header are not connected to the MCU ports, also some pins are connected to other features on the driver board. This is based on the availability of pins on the MCU card. The table below shows the pinout for both the connectors in the case of ATSAMD21MOTOR MCU card supplied with the kit.

Table 3-1. EXT1- Xplained PRO Extension Header

Pin	Pin name	67-pin interface	Driver board connections	SAMD21J18A port
1	ID_2	4	EDBG_ID2/EXT1_1	EDBG_PB01
2	GND	67	-	GND
3	ADC(+)	20	EXT_3	NC
4	ADC(-)	35	EXT1_4(GPIO10)	NC
5	GPIO5	22	EXT1_5(GPIO5)	PB31
6	GPIO6	23	EXT1_6(GPIO6)	PA17
7	PWM(+)	18	EXT1_7(GPIO1)	PA19
8	PWM(-)	19	EXT1_8(GPIO2)	PB08
9	IRQ/GPIO	37	EXT1_9(GPIO12)	NC
10	SPI_SS_B/GPIO	36	EXT1_10(GPIO11)	NC
11	TWI_SDA	12	TEMP_SDA, EXT1_11	PA22
12	TWI_SCL	13	TEMP_SCL, EXT1_12	PA23
13	UART_RX	26	RXD_EXT1_13	PA13
14	UART_TX	27	TXD_EXT1_14	PA12
15	SPI_SS_A	34	EXT1_15	PA02
16	SPI_MOSI	17	SPI_MOSI, EXT1_16	PB16
17	SPI_MISO	15	SPI_MISO, EXT1_17	PA20
18	SPI_SCK	16	SPI_SCK, EXT1_18	PB17
19	GND	67	-	-
20	VCC_P	63	VCC_P	VCC_TARGET_P3V3

Table 3-2. Xplained PRO Power Header

Pin	Signal name	Description
1	VCC_EXT_P5V0	External 5VDC input
2	GND	Ground

3	VCC_P5V0	5V
4	VCC_P	MCU Voltage

3.2.10. Temperature Sensor

The temperature sensor is placed adjacent to the MOSFET drive circuit to sense the board temperature. The AT30TSE758 temperature sensor is connected to the MCU through I²C and SMBus compatible 2-wire interface and has 7-bit I²C address 1001111.

Table 3-3. I²C Pin Connection

Signal	67Pin #	SAMD21J18A MCU pin	Indented MUX function
TEMP SDA	12	PA22	SERCOM3(PAD0)
TEMP SCL	13	PA23	SERCOM3(PAD1)
TEMP alert	24	PB30	IO

3.2.11. Serial Flash

The AT25DF0181A 8Mb serial flash is connected to the MCU through SPI interface. Some of the pins are routed to the EXT1 header as given in the table below.

Table 3-4. Flash Pin Connection

Signal	67Pin #	SAMD21J18A MCU pin	Indented MUX function	Other connection
FLASH SS	14	PA21	SERCOM5(PAD3)	
FLASH MISO	15	PA20	SERCOM5(PAD2)	EXT1_17
FLASH SCK	16	PB17	SERCOM5(PAD1)	EXT1_18
FLASH MOSI	17	PB16	SERCOM5(PAD0)	EXT1_16

3.2.12. UID Identification Chip

The UID chip is a unique ID chip used by the EDBG interface to enable automatic board identification in Atmel Studio. When the motor control evaluation board is connected to the USB port the Atmel studio recognizes it and load the necessary software and documentation.

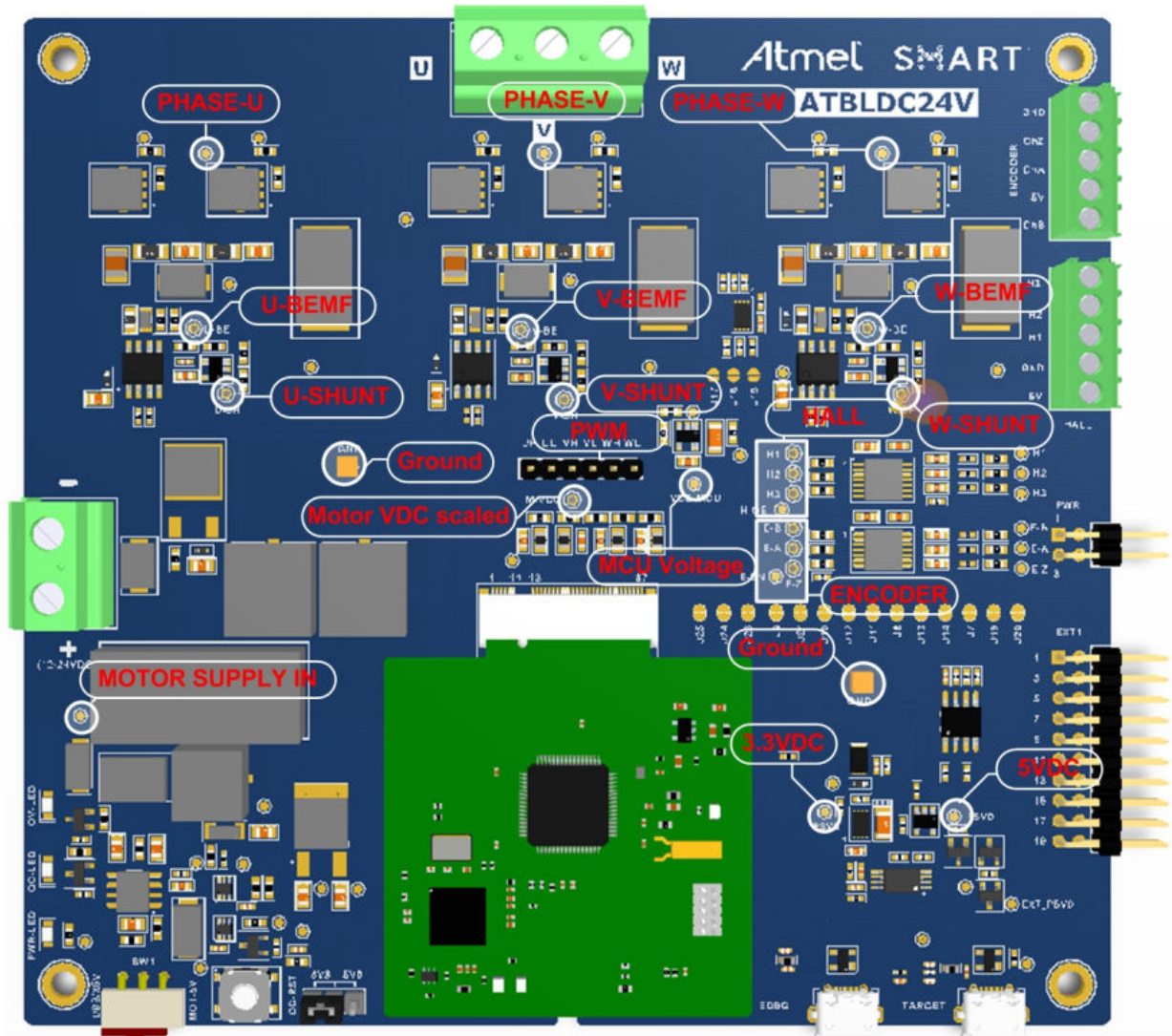
3.2.13. USB Communication Interface

The driver board has EDBG and MCU Micro-USB headers. EDBG USB is connected to the HS USB port of the EDBG device in the MCU card. MCU USB is connected to the USB port of the MCU in the MCU card plugged in.

3.2.14. Debug Test Points

Test points are available on the driver board for probing debug signals. Proper silk screen text is provided on the PCB to identify the test points. Some of the most useful test points are highlighted in the image below.

Figure 3-11. Debug Test Points on the Driver Board



3.2.15. Motor Specification

Specification and wiring for the motor are given in the figure below.

Figure 3-12. Motor Specification

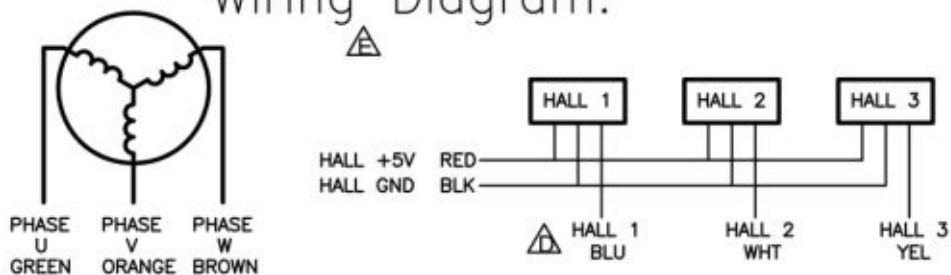
Label

Brushless Motor
42BL02402-0026B-002
24V 4000r/min 26W
YYYY.MM.DD

Specifications:

PART NUMBER	LD0-42BLS41EN256
NUMBER OF POLES	8 poles
LINE TO LINE RESISTANCE	1.8 Ohms $\pm 15\%$
LINE TO LINE INDUCTANCE	2.4 mH $\pm 20\%$
NOMINAL VOLTAGE	24 VDC
RATED TORQUE	0.0625 N.m
RATED SPEED	4000 RPM $\pm 10\%$
RATED CURRENT	1.6 A
RATED POWER	26 W
NO LOAD CURRENT	0.5 A REF
NO LOAD SPEED	5600 RPM $\pm 10\%$
WEIGHT	0.4 Kg APPROX.
WIRE DIAGRAM	
UL1007 22AWG	UL1007 26AWG
PHASE U	HALL +5V
PHASE V	HALL 1
PHASE W	HALL 2
	HALL 3
	HALL GND
GRN	RED
ORG	BLU
BRN	WHT
	YEL
	BLK

Wiring Diagram:



Drive Pattern:

ROTATION: CW VIEWED FROM THE OUTPUT SHAFT.					
SENSOR OUPUT			DRIVER OUTPUT		
H1	H2	H3	PHU	PHV	PHW
1	0	1	HIGH	LOW	X
0	0	1	X	LOW	HIGH
0	1	1	LOW	X	HIGH
0	1	0	LOW	HIGH	X
1	1	0	X	HIGH	LOW
1	0	0	HIGH	X	LOW

ROTATION: CCW VIEWED FROM THE OUTPUT SHAFT.					
SENSOR OUPUT			DRIVER OUTPUT		
H1	H2	H3	PHU	PHV	PHW
1	0	1	LOW	HIGH	X
1	0	0	LOW	X	HIGH
1	1	0	X	LOW	HIGH
0	1	0	HIGH	LOW	X
0	1	1	HIGH	X	LOW
0	0	1	X	HIGH	LOW

3.3. ATSAMD21BLDC24V-STK MCU-driver Interface

Atmel low voltage motor control solution support pluggable MCU cards. The MCU card and driver interface is a standard 67-pin interface as given in table below.

Table 3-5. MCU-driver Interface Pin-out

PIN	INTERFACE NAME	DRIVER BOARD	SAMD21J18A PIN	SAMD21 FUNCTION
1	EDBG USB HSP	EDBG_USB_HS_P	EDBG_USB_HS_P	EDBG_USB_HS_N
2	NC	NC	NC	NC
3	EDBG USB HSN	EDBG_USB_HS_N	EDBG_USB_HS_N	EDBG_USB_HS_N
4	EDBG ID2	EDBG_ID2/EXT1_1	EDBG_PB01	EDBG
5	NC	NC	NC	NC
6	EDBG ID1	EDBG_ID1	EDBG_PA28	EDBG
7	MCU USB DP	TARGET_USB_HS_P	PA25	USB_DN
8	TARGET USB VBUS	VCC_TARGET_USB_P5V0	NC	NC
9	MCU USB DN	TARGET_USB_HS_N	PA24	USB_DP
10	EDBG USB VBUS	VCC_EDBG_USB_P5V0	VCC_EDBG_USB_P5V0	VCC_EDBG_USB_P5V0
11	TARGET_USB_ID	TARGET_USB_ID	NC	NC
12	TEMP SDA	TEMP_SDA, EXT1_11	PA22	SERCOM3(PAD0)
13	TEMP SCL	TEMP_SCL, EXT1_12	PA23	SERCOM3(PAD1)
14	FLASH SS	SPI_SS	PA21	SERCOM5(PAD3)
15	FLASH MISO	SPI_MISO, EXT1_17	PA20	SERCOM5(PAD2)
16	FLASH SCK	SPI_SCK, EXT1_18	PB17	SERCOM5(PAD1)
17	FLASH MOSI	SPI_MOSI, EXT1_16	PB16	SERCOM5(PAD0)
18	MCU GPIO1	EXT1_7(GPIO1)	PA19 (0)	I/O, EXTINT8 (Encoder)
19	MCU GPIO2	EXT1_8(GPIO2)	PB08	I/O
20	MCU GPIO3	EXT_3	NC	I/O
21	MCU GPIO4	NC(GPIO4)	NC	I/O
22	MCU GPIO5	EXT1_5(GPIO5)	PB31	I/O
23	MCU GPIO6	EXT1_6(GPIO6)	PA17	I/O
24	MCU GPIO7	Temp_Alert(GPIO7)	PB30	I/O
25	OCP	OCP(GPIO8)	PB03	I/O
26	EXT1 RXD	RXD_EXT1_13	PA13	SERCOM2(PAD1)
27	EXT1 TXD	TXD_EXT1_14	PA12	SERCOM2(PAD0)

28	PWM UH	PWM_UH	PA08	W00(TCC0)
29	PWM UL	PWM_UL	PA14	W04(TCC0)
30	PWM VH	PWM_VH	PA09	W01(TCC0)
31	PWM VL	PWM_VL	PA15	W05(TCC0)
32	PWM WH	PWM_WH	PA10	W02(TCC0)
33	PWM WL	PWM_WL	PA16	W06(TCC0)
34	MCU_GPIO8	EXT_15	PA02	AIN0 (ADC)
35	ATA RESET	EXT1_4(GPIO10)	NC	I/O
36	ATA WD	EXT1_10(GPIO11)	NC	I/O
37	ATA SLEEP	EXT1_9(GPIO12)	NC	I/O
38	USHUNT_ADC	USHUNT_ADC	PB04	AIN12(ADC)
39	VSHUNT_ADC	VSHUNT_ADC	PB05	AIN13(ADC)
40	WSHUNT_ADC	WSHUNT_ADC	PA11	AIN19(ADC)
41	MOTOR VDC	MOTOR_ADC	PB02	AIN10(ADC)
42	BEMF U_ADC	BEMF_UADC	PB00	AIN8(ADC)
43	BEMF V_ADC	BEMF_VADC	PB01	AIN9(ADC)
44	BEMF_W_ADC	BEMF_WADC	PB06	AIN14(ADC)
45	BEMF UP	BEMF_UP	PA04	AIN0 (AC)
46	BEMF UN	BEMF_UN	PA05	AIN1 (AC)
47	BEMF VP	BEMF_VP	PA06	AIN2 (AC)
48	BEMF VN	BEMF_VN	PA07	AIN3 (AC)
49	BEMF WP	BEMF_WP	PB07	AIN0(AC1)
50	BEMF WN	BEMF_WN	PB07	AIN1(AC1)
51	HALL1	HALL1	PA03	EXTINT3
52	HALL2	HALL2	PA18	EXTINT2
53	HALL3	HALL3	PA28	EXTINT8
54	HALL TRX OE	HALL_TRX_OE	PB11	I/O
55	ENCODER_A	ENCODER_A	PB09	EXTINT9
56	ENCODER_B	ENCODER_B	PB10	EXTINT10
57	ENCODER_Z	ENCODER_Z	PB23	EXTINT7
58	ENCODER_EN	ENCODER_EN	PB22	I/O
59	NC	NC	NC	NC
60	NC	NC	NC	NC
61	NC	NC	NC	NC

62	3V3 SUPPLY for MCU	VCC_P	VCC_TARGET_P3V3	NC
63	3V3 SUPPLY for MCU	VCC_P	VCC_TARGET_P3V3	NC
64	GND	GND	GND	NC
65	GND	GND	GND	NC
66	GND	GND	GND	NC
67	GND	GND	GND	NC

4. Hardware Revision History and Known Issues

4.1. Identifying Product ID and Revision

The revision and product identifier of ATSAMD21BLDC24V-STK can be found by looking at the sticker on the bottom side of the PCB. The identifier and revision are printed in plain text as A09-nnnn\rr, where nnnn is the identifier and rr is the revision. Also the label contains a 10-digit serial number unique to each kit assembly that contains the PCBs, motor and chassis.

The product identifier for ATSAMD21BLDC24V-STK is A09-2671.

4.2. Revision

Kit assembly revision for initial version is A09-2671/03. Known issues in this revision are:

- The driver board should be powered OFF when the user is changing the power supply selection switch or power supply selection jumper. Overall power consumption of the board seems to be increasing otherwise.

5. Product Compliance

RoHS and WEEE

The Atmel ATSAMD21BLDC24V-STK and its accessories are manufactured in accordance to both the RoHS Directive (2002/95/EC) and the WEEE Directive (2002/96/EC).

CE and FCC

The Atmel ATSAMD21BLDC24V-STK unit has been tested in accordance to the essential requirements and other relevant provisions of Directives:

- Directive 2004/108/EC (class B)
- FCC rules part 15 subpart B

The following standards are used for evaluation:

- EN 61326-1 (2013)
- FCC CFR 47 Part 15 (2013)

The Technical Construction File is located at:

Atmel Norway
Vestre Rosten 79
7075 Tiller
Norway

Every effort has been made to minimize electromagnetic emissions from this product. However, under certain conditions, the system (this product connected to a target application circuit) may emit individual electromagnetic component frequencies which exceed the maximum values allowed by the above-mentioned standards. The frequency and magnitude of the emissions will be determined by several factors, including layout and routing of the target application with which the product is used.

6. Revision History

Doc. Rev.	Date	Description
42681A	02/2016	Initial document release.



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