Microchip Technology Inc.

User Guide

Sensor less Field Oriented Control with SAM E54

Sensorless Field Oriented Control (FOC) With PLL Observer on SAME54

Contents

1. Introduction

1.1.SAME54 Microcontroller Card for ATBLDC24V Motor Control Starter Kit

The ATSAME54MOTOR is a MCU card for Atmel® Motor control low voltage starter kits. The hardware has the ARM® M4 core -based SAME54 MCU, with integrated on-board debug support. The MCU card can be directly used with the currently available ATSAMD21BLDC24V-STK®, 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. Supported by the Atmel studio integrated development platform, the kit provides easy access to the features of SAME54 MCU and explains how to integrate the device in a custom motor control application.

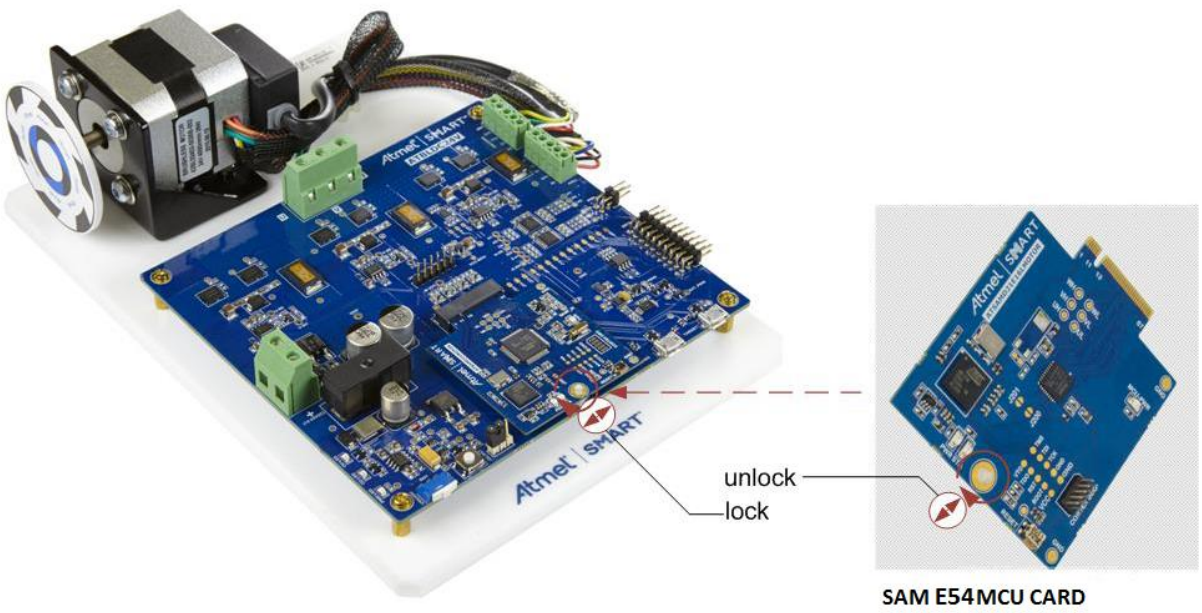

Figure 1 Atmel low voltage motor control kit

1.2.ATBLDC24V-STK Features

ATBLDC24V-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

1.3.Microchip ATSAME54 MOTOR MCU Board

1.3.1. MCU Card

SAM E54 is a high-performance Flash microcontroller (MCU) based on the 32-bit ARM® Cortex®-M4 RISC (403 CoreMark at 120MHz) processor with floating point unit (FPU). The device operates at a maximum speed of 120 MHz, features up to 1024 Kbytes of Flash, up to 4 Kbytes of TCM (Tightly Coupled Memory)and up to 256 Kbytes of SRAM.
The device is intended to work with external 12MHz oscillator. An external reset switch is connected to the MCU RESET pin.

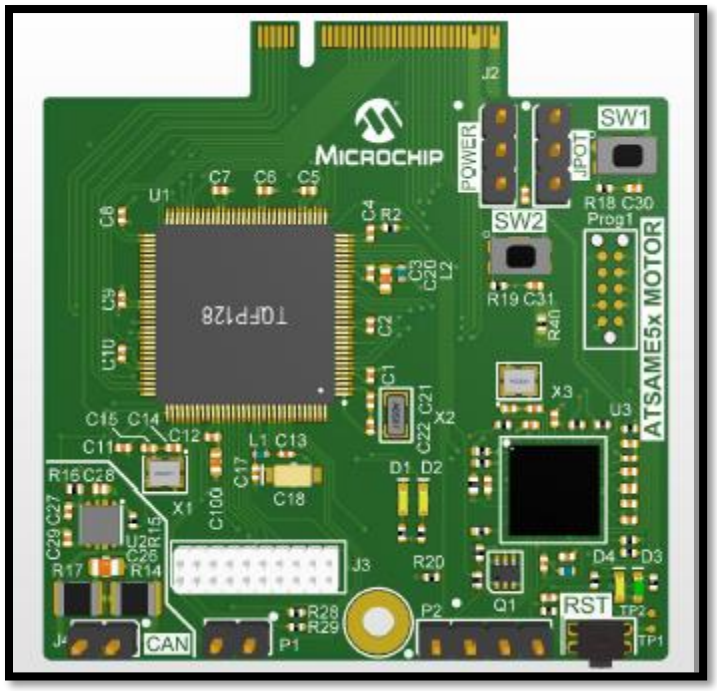

Figure 2 ATSAME54 MCU Card

1.3.2. Power Supply

The ATSAME54 MOTOR MCU card takes 3.3VDC supply from the 67-pin edge connector. Both the EDBG device and the Main MCU operate from 3.3VDC. The power supply selection jumper on the Driver board should be connected to 3V3 selection.
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1.3.3. Embedded Debugger

The ATSAME54 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 pin out. 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. ATSAME54 connected to the EDBG device, with DGI SPI interface and uses the Atmel ADP protocol.

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 EDBG is connected to the Micro-USB connecter on the driver board.

1.3.4. 67-pin MCU-DRIVER Board Interface

ATSAME54 MCU card is connected to driver board through 67-pin interface as shown below.

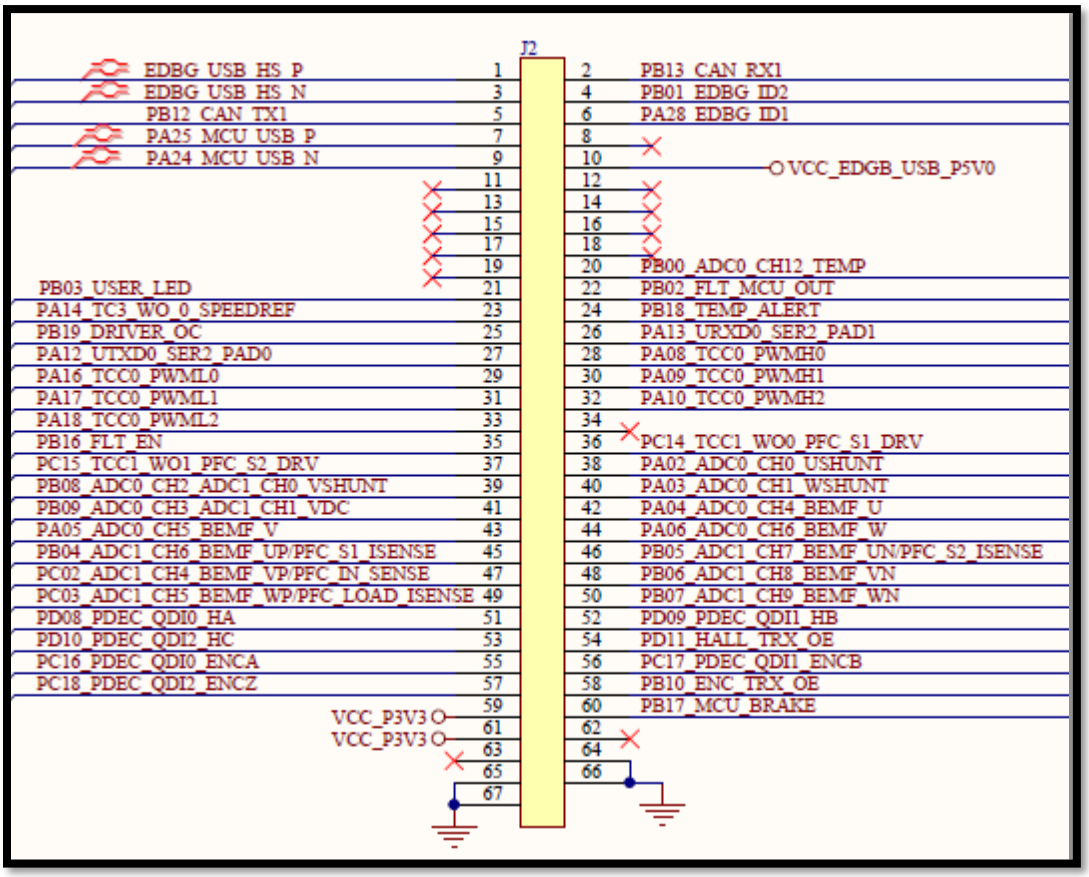


Figure 3 67 Pin MCU-Driver Board Interface

1.4.Motor Specification

Label

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

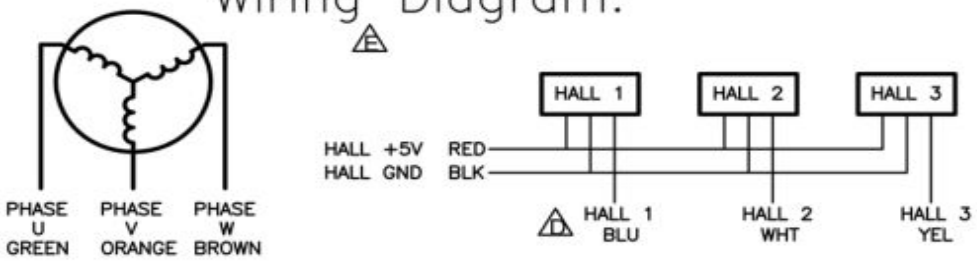
Specifications:

PART NUMBER	LD0-42BLS41EN256
NUMBER OF POLES	8 poles
LINE TO LINE RESISTANCE	1.8 Ohms ±15%
LINE TO LINE INDUCTANCE	2.4 mH ±20%
NOMINAL VOLTAGE	24 VDC
RATED TORQUE	0.0625 N.m
RATED SPEED	4000 RPM ±10%
RATED CURRENT	1.6 A
RATED POWER	26 W
NO LOAD CURRENT	0.5 A REF
NO LOAD SPEED	5600 RPM ±10%
WEIGHT	0.4 Kg APPROX.

WIRE DIAGRAM

UL1007 22AWG			UL1007 26AWG				
PHASE U	PHASE V	PHASE W	HALL +5V	HALL 1	HALL 2	HALL 3	HALL GND
GRN	ORG	BRN	RED	BLU	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

2. Software Requirement

To run this demo below mentioned software should be installed on the PC.

Software Name	Version	Description
Atmel Studio 7	7.0.1417 **OR** Higher version	IDE
Data Visualizer	2.15.651 **OR** Higher version	Real time data monitoring

3. Getting Started with ATBLDC24V-STK

This chapter is a step-by-step guide to get started with the ATSAME54 for ATBLDC24V-STK.

1. ATBLDC24V-STK kit contains a fully assembled chassis and 24VDC power adaptor.
2. Make sure switch SW1 on driver board (ATBLDC24V) is set to USB/X5V.
3. Make sure jumper (J26) on driver board (ATBLDC24V) is set to 3.3V.
4. Connect the power adaptor to the “SUPPLY-IN connector”. Connect white color cable to + PIN.

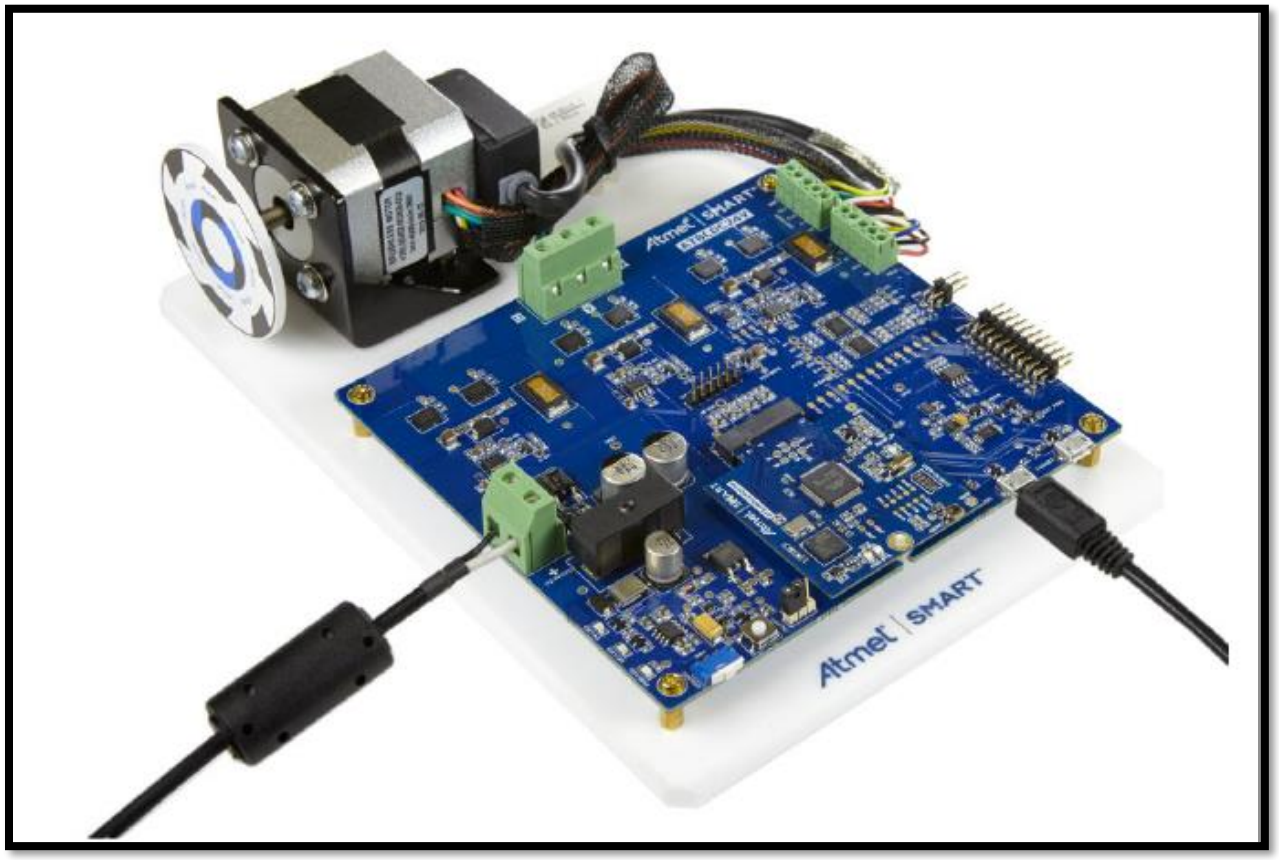


Figure 4 Kit with Power and USB Ports Connected

5. Connect the Micro-USB cable to the “EDBG-USB connector” and PC USB port.
6. Switch ON the power adaptor.
7. The power LED indications on the MCU card are now ON.
8. If MCU is pre-programmed then directly open "Data Visualizer". If it’s not, then program it through Atmel studio and run the program first and then open the data visualizer
9. In the "Data Visualizer Connect Window" select the kit from the DGI control panel's drop down list.

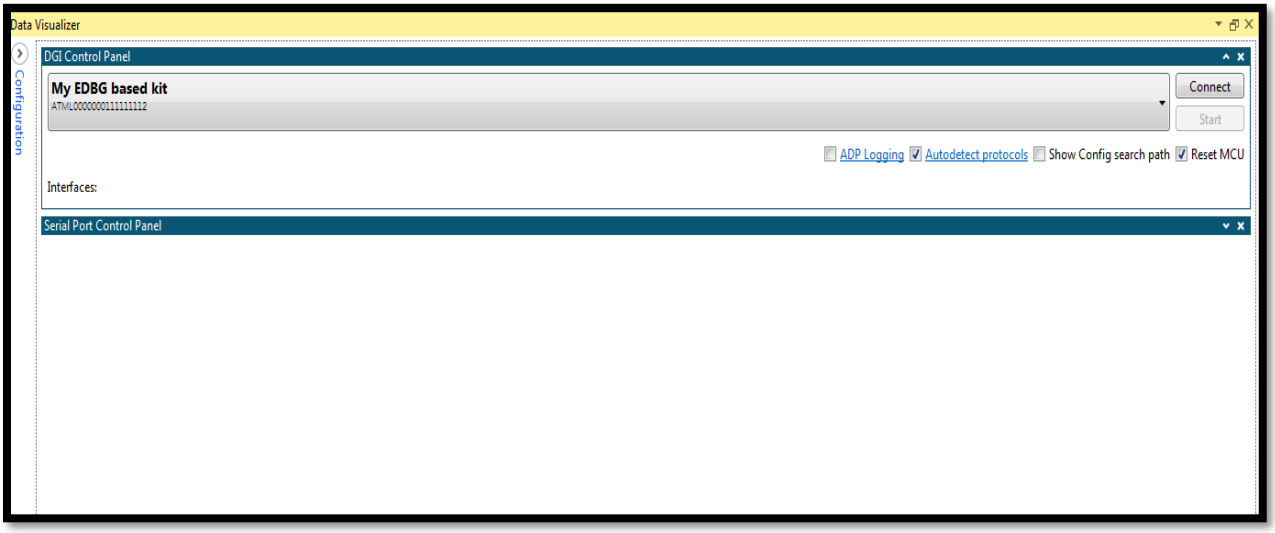


Figure 5 Data Visualizer Connect Window

10. Click "Connect".
11. The Data Visualizer default window will pop up once the connection is made. All the fields shall show default values as shown below.

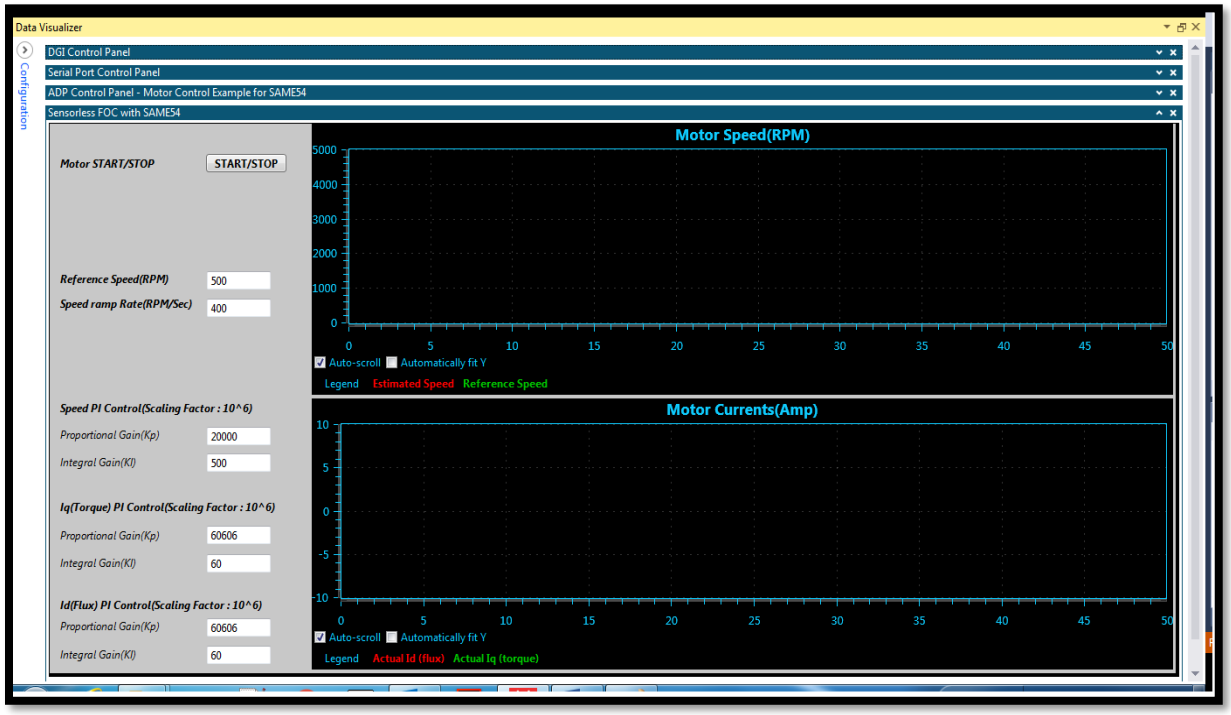


Figure 6 Data Visualizer Start Window

12. Click on "START/STOP" button to turn the motor ON with default values.

Figure 7 Data Visualizer Motor Start Window

13. One can adjust the graph by selecting checkbox "Automatically fit Y" for better visualization.
14. To change the parameter, enter the value in a input field and press "Enter". For example, to change the motor speed, type in the desired speed within the Reference Speed (RPM) input box and press "Enter".

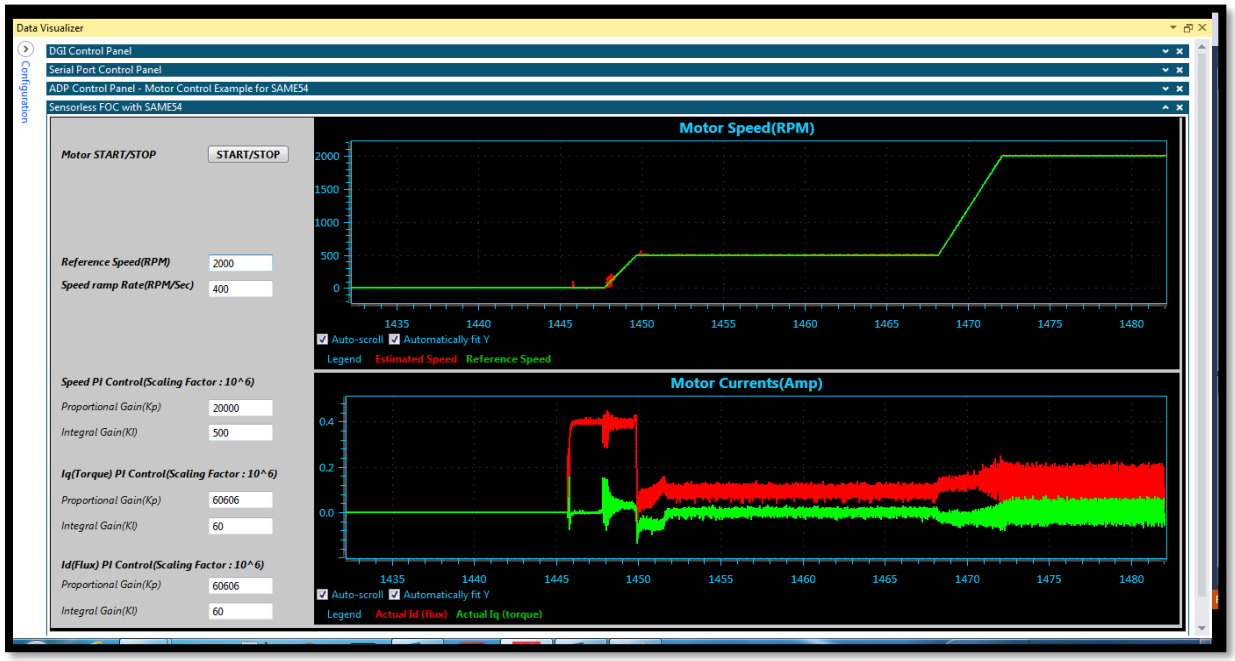


Figure 8 Data Visualizer Change Parameter Online

15. To stop the motor, click on the “Stop" button. It will ramp down and stop the motor.

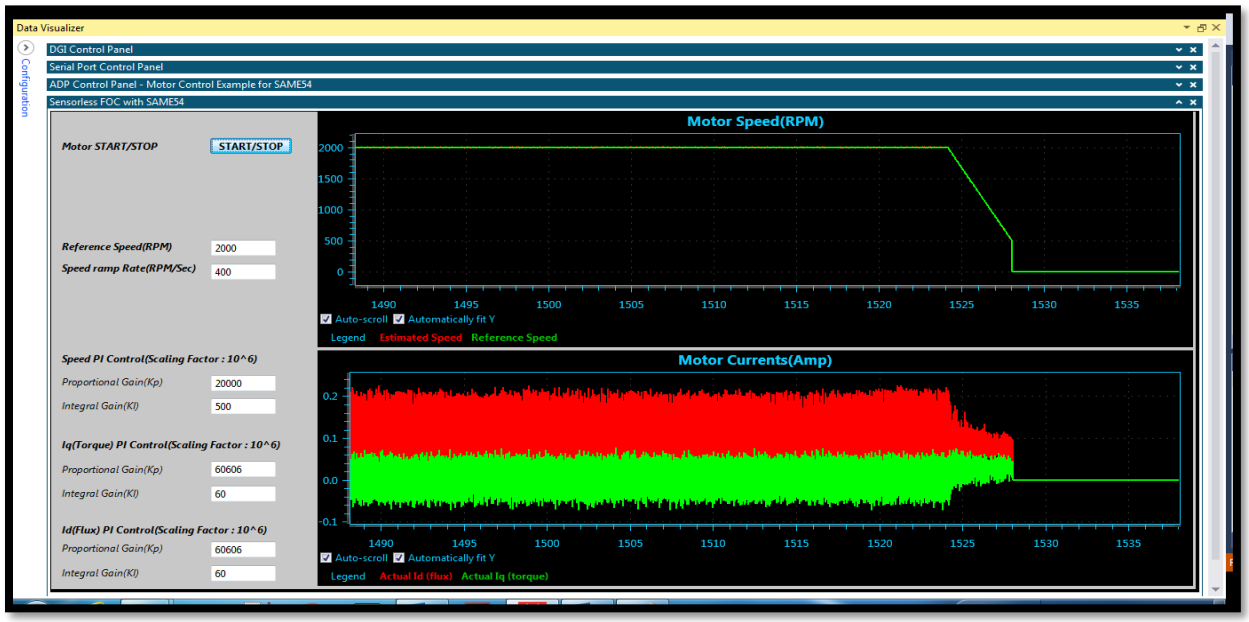


Figure 9 Data visualizer Stop motor window

4. Firmware User Configuration

Algorithm can be fine-tuned for any motor by updating motor parameters in “userparams.h” file.

Following are the configurations available for the user to modify the motor and algorithm parameters.

Sl. No.	Configuration	Description
1	ADP_DV_AVAILABLE	If data visualizer is available then enable it. Motor start/ stop and speed can be controlled by data visualizer.
2	SPEED_REF_FROM_POT	Speed reference will be taken from Potentiometer installed on the control card. Speed reference from data visualizer will not be considered if enabled.
3	OPEN_LOOP_FUNCTIONING	Motor runs only in open loop with speed as OPEN_LOOP_END_SPEED_RPM. Useful for debugging.
4	TORQUE_MODE	Enables torque control mode. Motor runs in torque control with reference current as "Q_CURRENT_REF_OPENLOOP".
5	FIELD_WEAKENING	Enables Field weakening to spin motor beyond the rated speed.
6	SLOW_LOOP_TIME_SEC	Slower control loop frequency. It should be in multiples of PWM frequency. Speed control loop will be executed from slower control loop.
7	LOCK_TIME_IN_SEC	During motor startup rotor aligns to nearby “d” axis. Alignment time is configured by this parameter. Needs to be configured based upon the load conditions.
8	OPEN_LOOP_END_SPEED_RPM	Motor switches to the close loop at this speed.
9	OPEN_LOOP_RAMP_TIME_IN_SEC	Time to reach "OPEN_LOOP_END_SPEED_RPM" in open loop.
10	CLOSE_LOOP_RAMP_RATE	Ramp rate in close loop in terms of RPM/Sec.
11	Q_CURRENT_REF_OPENLOOP	Iq reference current for current control loop during startup. Configure this value based upon the load conditions.
12	PWM_FREQUENCY	Switching frequency
13	DEAD_TIME_uS	Dead time in micro seconds based upon the switches (IGBT/MOSFET) turn on/off time.
14	D_CURRCNTR_PTERM	Flux PI control parameters
15	D_CURRCNTR_ITERM	
16	D_CURRCNTR_CTERM	
17	D_CURRCNTR_OUTMAX	
18	Q_CURRCNTR_PTERM	Torque PI control parameters
19	Q_CURRCNTR_ITERM	
20	Q_CURRCNTR_CTERM	

21	Q_CURRCNTR_OUTMAX	
22	SPEEDCNTR_PTERM	Speed PI control parameters
23	SPEEDCNTR_ITERM	
24	SPEEDCNTR_CTERM	
25	SPEEDCNTR_OUTMAX	
26	KFILTER_ESDQ	First order low pass filter coefficient for estimated BEMF Ed, Eq components.
27	KFILTER_BEMF_AMPLITUDE	First order low pass filter coefficient for estimated BEMF amplitude
28	KFILTER_VELESTIM	First order low pass filter coefficient for speed estimation
29	KFILTER_POT	First order low pass filter coefficient for Potentiometer readings
30	MOTOR_PER_PHASE_RESISTANCE	Motor Parameters - Per phase resistance in Ohm
31	MOTOR_PER_PHASE_INDUCTANCE	Motor Parameters - Per phase inductance in Henry
32	MOTOR_BEMF_CONST_V_PEAK_LL_KRPM_MECH	Motor Parameters - BEMF constant- BEMF peak voltage measured across line to line when motor spinning at 1000 RPM.
33	NUM_POLE_PAIRS	Motor Parameters - Number of Pole pairs
34	RATED_SPEED_RPM	Motor Parameters - Rated speed
35	MAX_SPEED_RPM	Motor Parameters – Maximum motor speed allowed. During field weakening maximum motor speed is restricted to this speed.

5. Software Implementation

PWM event generation unit is configured to trigger AFEC module to start adc conversion. Once the trigger is received by AFEC module, two configured phase current measurements are simultaneously sampled and conversion takes place. Phase current result ready event will generate interrupt. Then DC bus voltage is measured inside interrupt. In addition, speed POT is measured if it is enabled.

The FOC algorithm is executed inside ADC end of conversion interrupt handler. This interrupt is dedicated for fast controlling and it's in sync with PWM. If any fast controlling tasks need to be added then this is the place. Apart from this, slow control loop is also available and its frequency can be configured by "`SLOW_LOOP_TIME_SEC`" in user configurations. Slow loop execution frequency should be in multiple of PWM frequency. Speed ramp and speed PI control loop is executed from slow control loop. If any additional tasks one has to execute at slower rate, then "`SlowControlLoop()`" function is a place holder.

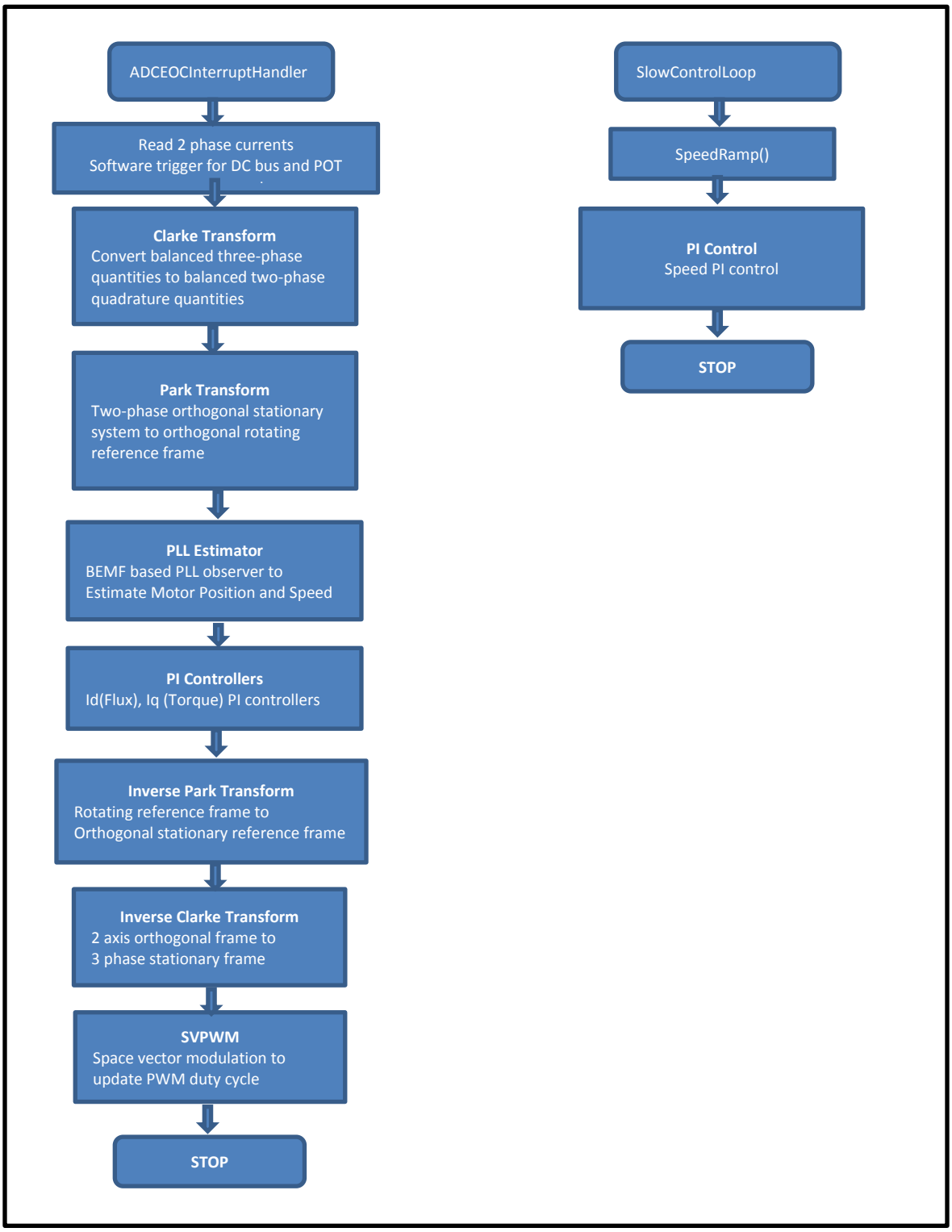


Figure 10 Control loop flow chart

6. References

App Note - http://ww1.microchip.com/downloads/en/AppNotes/00002520B.pdf

Atmel Studio 7 - http://www.atmel.com/microsite/atmel-studio/

Data Visualizer - https://gallery.atmel.com/Products/Details/0b2891f4-167a-49fc-b3f0-b882c7a11f98

7. Revision History

Doc. Rev.	Date	Description
1.0	29/05/2018	Initial document release