Application Note

SmartTune User Guide: How to Quickly Setup and Spin Your 3-Phase BLDC Motor

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ABSTRACT

Field oriented control (FOC) is getting popular in BLDC motors for best-in class acoustics and load-dynamic performance, however this needs intense tuning effort to get the best motor performance. MOTORSTUDIO is an easy-to-use graphical user interface (GUI) that simplifies the tuning process of TI's Brushless DC (BLDC) motor drivers to reduce device evaluation and product development time.

SmartTune is an intelligent auto configuration tool in MOTORSTUDIO. This tool helps users to tune startup time, acceleration, efficiency and control loop parameters for the BLDC motor drive in 2 minutes, by taking only 3 parameters which are system voltage, rated motor current and rated motor speed.

This document firstly introduces the application scenario of SmartTune and the issue users can encounter during setting up. Then, detailed tuning steps are listed so that users can follow them to set up and spin the motor. Finally, tips for setting SmartTune parameters are provided to help users eliminate faults caused by inappropriate parameter input.

This document is currently applicable for the following devices:

- MCF8315C
- MCF8316C

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Trademarks

1 Introduction

BLDC drivers are used across industrial and automotive applications for higher efficiency, higher speed, reliable and quiet system design. Field oriented control (FOC) is a popular control method because of best-in class acoustics and load-dynamic performance. However, to successfully run a motor with FOC control method, much effort is needed to tune a large number of parameters.

TI's MOTORSTUDIO is an easy-to-use graphical user interface (GUI) to simplify the tuning process of TI's Brushless DC (BLDC) motor drivers. SmartTune is an intelligent auto configuration tool in MOTORSTUDIO, which can help users, especially beginners, to quickly set up and spin the motor with only 3 parameters input.

1.1 Benefits of SmartTune

SmartTune is especially useful in the following two scenarios:

- Users that want to quickly verify if TI's motor driver can drive the motor to achieve the expected speed under specific voltage and current conditions.
- Users that are not familiar with TI's motor driver's register map setting and want to quickly obtain a set of configuration parameters which can spin the motor.

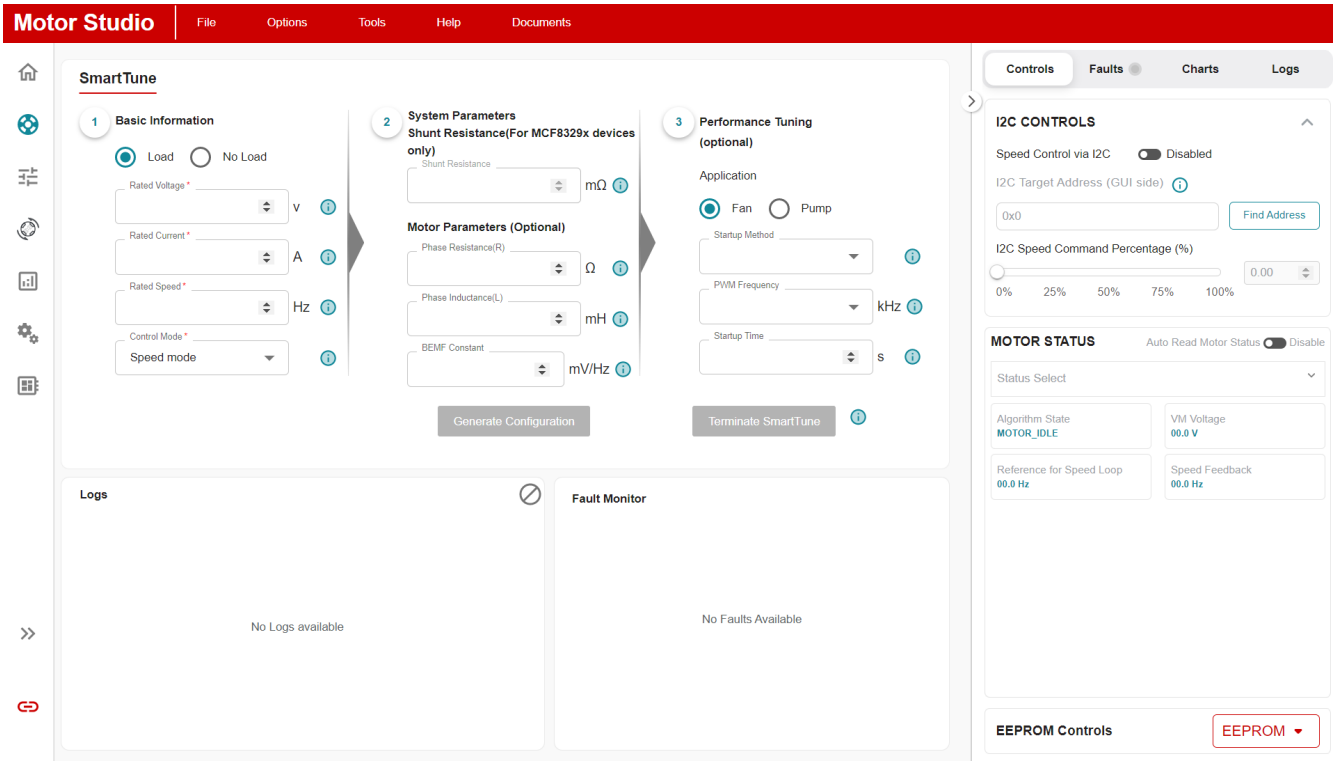

Figure 1-1. SmartTune Page in MOTORSTUDIO

As shown in Figure 1-1, in traditional tuning of FOC, before successfully spinning the motor, users need to configure both motor parameters and system parameters, tune control parameters in start-up, open loop and closed loop, and set fault handling parameters, which is time-consuming and effort-taking.

With SmartTune, all the steps mentioned above can be saved. Users only need to input rated voltage, current and speed according to the application requirement, and SmartTune generates configuration file automatically for you. With the configuration file, users can spin the motor immediately, or optimize parameters based on the file for specific performance.

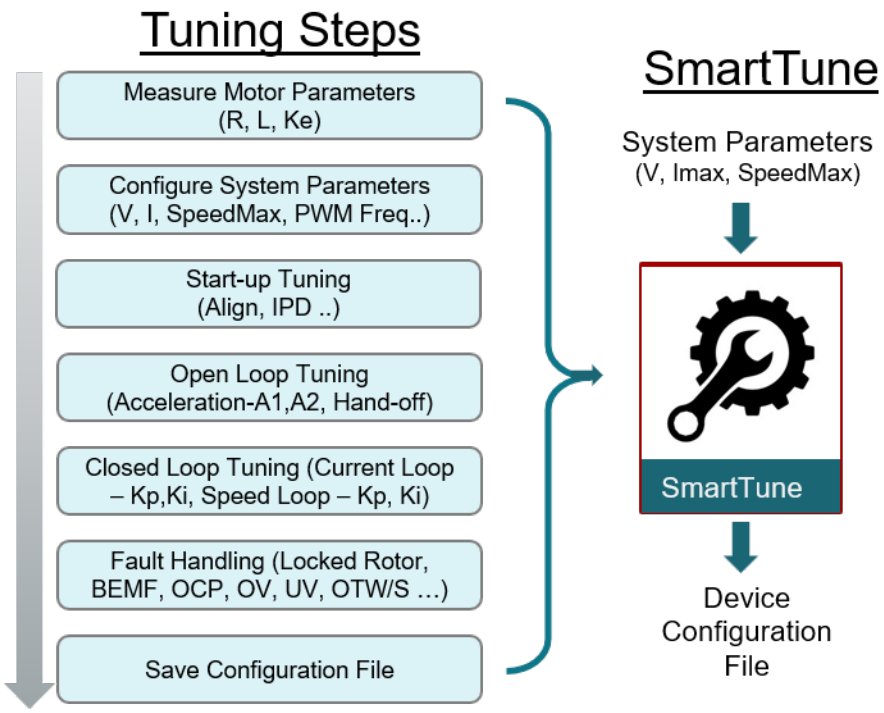

Figure 1-2. Auto Configuration Steps of SmartTune

1.2 Definition of SmartTune Input Parameters

Only three system parameters need to be input for SmartTune. The three key system parameters are: rated voltage, rated current and rated speed. The definition is listed below:

- Rated voltage: The rated DC supply voltage for the 3-phase BLDC motor. Device VM needs to be set to this rated voltage.
- Rated speed: The maximum rated speed of the 3-phase BLDC motor (in Hz). If the mechanical speed is in RPM (N), convert the value to electrical frequency (f in Hz) using the formula: f = P x N / 120. P is the number of rotor poles.
- Rated current: The rated peak phase current value for the 3-phase BLDC motor **when this is driven at rated speed and rated voltage with load**.

Typically, you can find the three parameters above in the data sheet. An example of motor data sheet is in shown in Figure 1-3.

BG 45 | cont. 80 W, peak 168 W

- Highly dynamic 3-phase EC motor with 8-pole neodymium magnet
- Version with Hall sensors for rotor position detection
- Available in 2 motor lengths
- Standard with plug version
- On request, this motor can be manufactured in different voltage versions
- For connection cable up to 3 m (Longer cables up to 10 m on request)*

- Hochdynamischer 3-strängiger EC-Motor mit 8-poligem Neodymmagnet
- Ausführung mit Hallsensoren zur Rotorlageerfassung
- Verfügbar in 2 Baulängen
- Standardmäßig mit Steckerausführung
- Diese Motoren werden auf Anfrage auch in anderen Spannungsvarianten hergestellt
- Für Anschlusskabel bis 3 m (Längere Kabel bis 10 m auf Anfrage)*

Feedback integrated | Supply voltage versions | Premium efficiency | Protection class (up to) | Certification | Certification (>36 V only) | Vibration resistance | EPLAN Data Portal

Data/ Technische Daten		BG 45x15		BG 45x30		BG 45x45
Nominal voltage/ Nennspannung	VDC	12	24	12	24	24**
Nominal current/ Nennstrom	A¹	5.66	2.24	8.5	4.2	5.56
Nominal torque/ Nennmoment	Nm¹	0.139	0.138	0.217	0.219	0.324
Nominal speed/ Nenndrehzahl	rpm¹	3327	3380	3530	3440	3400
Stall torque/ Anhaltemoment	Nm¹	0.745	0.746	1.53	1.52	2.25
Maximum torque/ Maximales Moment	Nm¹	0.745	0.746	1.53	1.52	2.25
No load speed/ Leerlaufdrehzahl	rpm¹	4340	4390	4195	4110	4200
Nominal output power/ Dauerabgabeleistung	W¹	48.4	48.8	80	79	109
Maximum output power/ Maximale Abgabeleistung	W	84	86	168	156	226
Torque constant/ Drehmomentkonstante	Nm A^{-1}¹	0.0221	0.055	0.0239	0.059	0.055
Terminal Resistance/ Anschlusswiderstand	Ω	0.28	1.1	0.14	0.53	0.3
Terminal inductance/ Anschlussinduktivität	mH	0.19	0.75	0.1	0.43	0.25
Starting current/ Anlaufstrom	A¹	34.2	17.3	64.6	31.4	45
No load current/ Leerlaufstrom	A¹	0.6	0.3	0.82	0.4	0.5
Demagnetisation current/ Entmagnetisierungsstrom	A¹	≥ 29	≥ 15	≥ 53	≥ 26	≥ 37
Rotor inertia/ Rotor Trägheitsmoment	gcm²	24	24	44	44	64
Weight of motor/ Motorgewicht	kg	0.36	0.36	0.56	0.56	0.76

Figure 1-3. Snapshot of Dunkermotoren BG 45 Motor's Data Sheet

Figure 1-3 is a snapshot of Dunkermotoren BG 45 motor's data sheet. As you can see, the rated voltage is 12V, the rated speed is 8*3327/120 = 221.8Hz and the rated current is 1.42A. You can input them into SmartTune, and successfully spin the motor by following the tuning steps in Section 2.

But in many cases, users can have different application needs from the data sheet, or sometimes the data sheet is unavailable. In these cases, randomly inputting unknown parameters can lead to faults reported by system and unsatisfying performance of motor. To eliminate faults, Section 3 provides some practical tips for setting SmartTune parameters.

2 SmartTune Tuning Steps

2.1 Definition of SmartTune Parameters

Step 1: Enter SmartTune

As shown in Figure 2-1:

1. Power the EVM, launch MOTORSTUDIO, select your device.
2. Set up hardware.
3. Click SmartTune. The SmartTune page appears as shown in: Figure 1-1.

Please refer to *Getting Started with MOTORSTUDIO* for more information of Step (1)(2) .

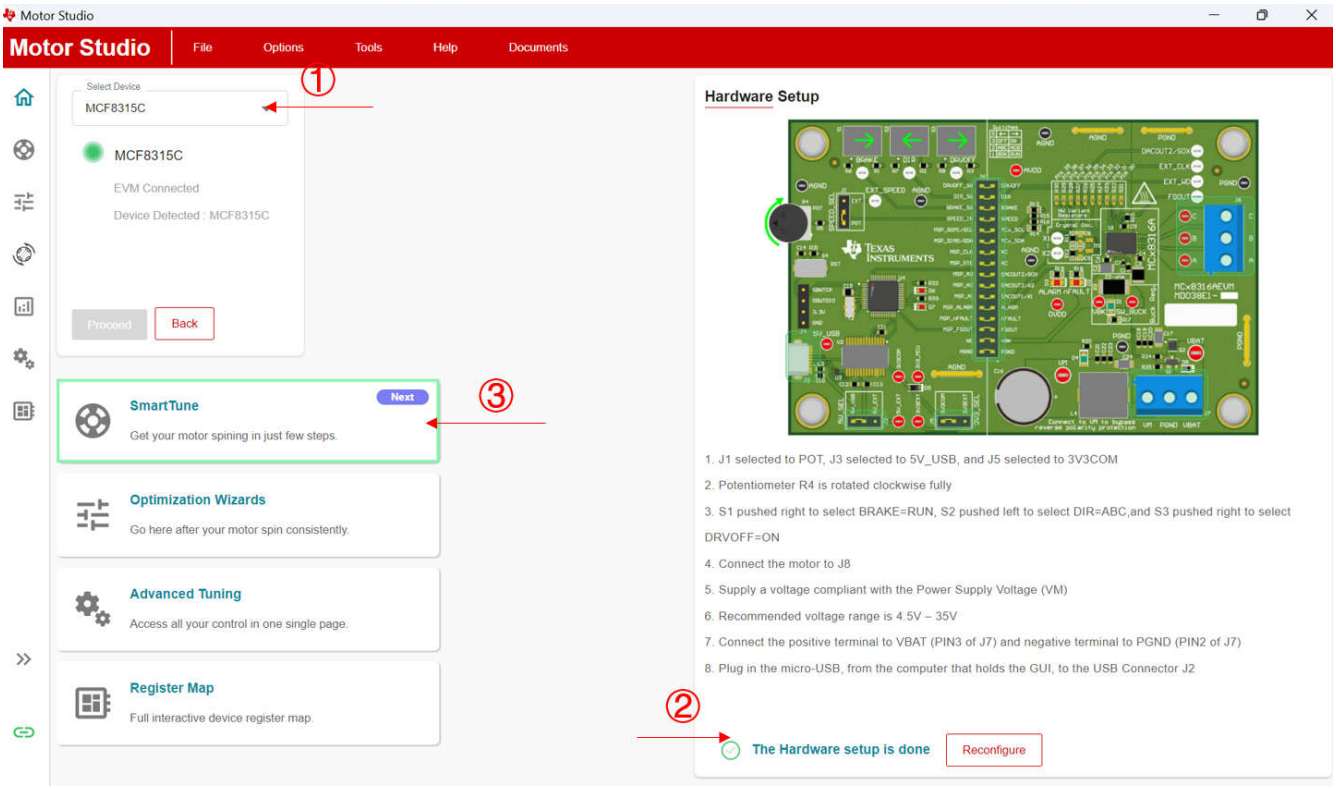

Figure 2-1. Enter SmartTune

Step 2: Configure SmartTune

As shown in Figure 2-2:

1. Choose whether the motor has a load or not.
2. Enter rated voltage, rated current, and rated speed found in motor data sheet. The definition of these parameters can be found in Section 1.1.
3. Choose whether you want the motor to run in speed mode (constant speed, with both speed loop and current loop enabled) or torque mode (constant torque/current, with speed loop disabled and current loop enabled). For more information about speed mode and torque mode, please refer to Section 6.3.12 of *MCF8315C Sensorless Field Oriented Control (FOC) Integrated FET BLDC Driver*, data sheet.
4. Click on Generate Configuration.

Other inputs on the panel like motor parameters, startup method, and so on are optional. With these inputs set properly, SmartTune can run more efficiently and motor performance can be improved. If you do not know the value, just ignore them, and SmartTune can still work.

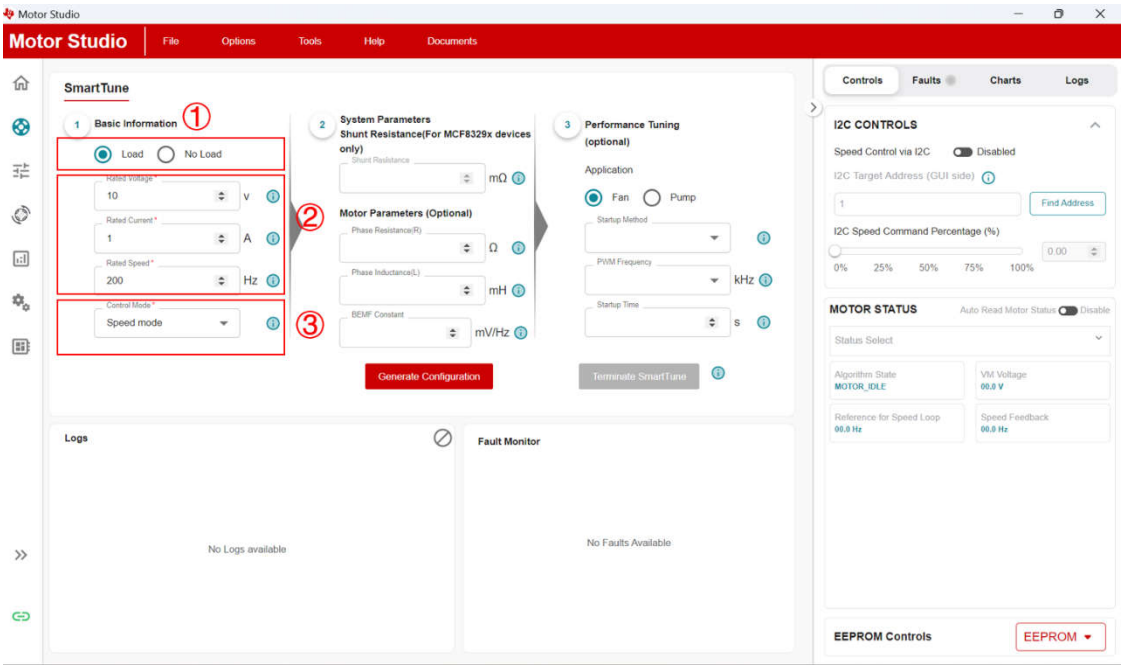

Figure 2-2. Configure SmartTune

Step 3: Generate Configuration

As shown in Figure 2-3.

1. Enable Auto Read Motor Status to observe the status during SmartTune.
2. Enable Auto Read Fault Status on the Faults panel to observe faults during SmartTune.
3. Click on Generate Configuration.

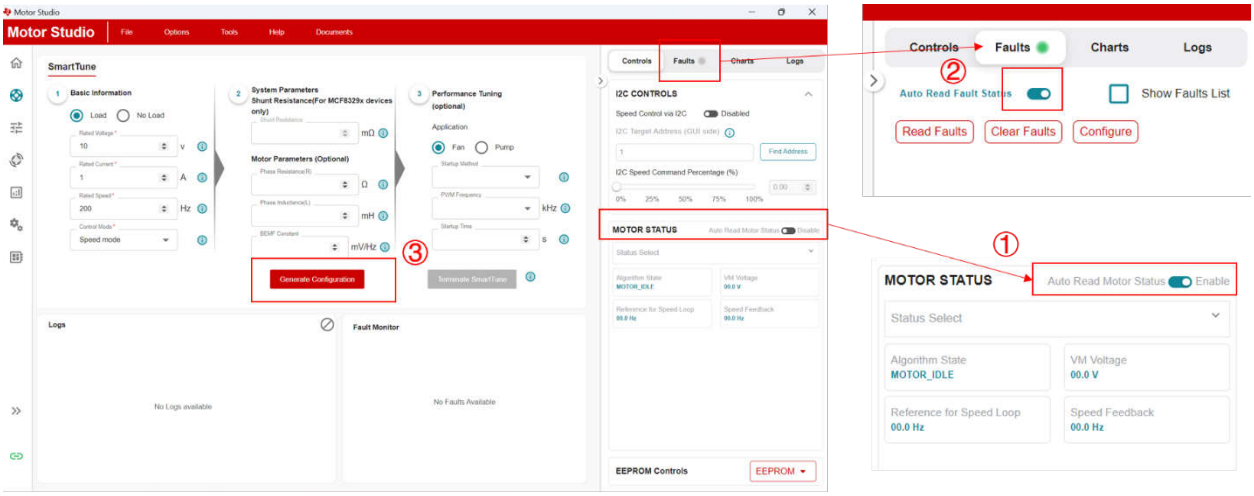

Figure 2-3. Generate Configuration

Step 4: Run SmartTune

As shown in Figure 2-4, when SmartTune is running, you can:

1. Read logs.
2. Observe faults in the Fault Monitor.
3. Watch motor status changes.

Step (1)(2)(3) helps to locate the problem when faults happen and configuration fails.

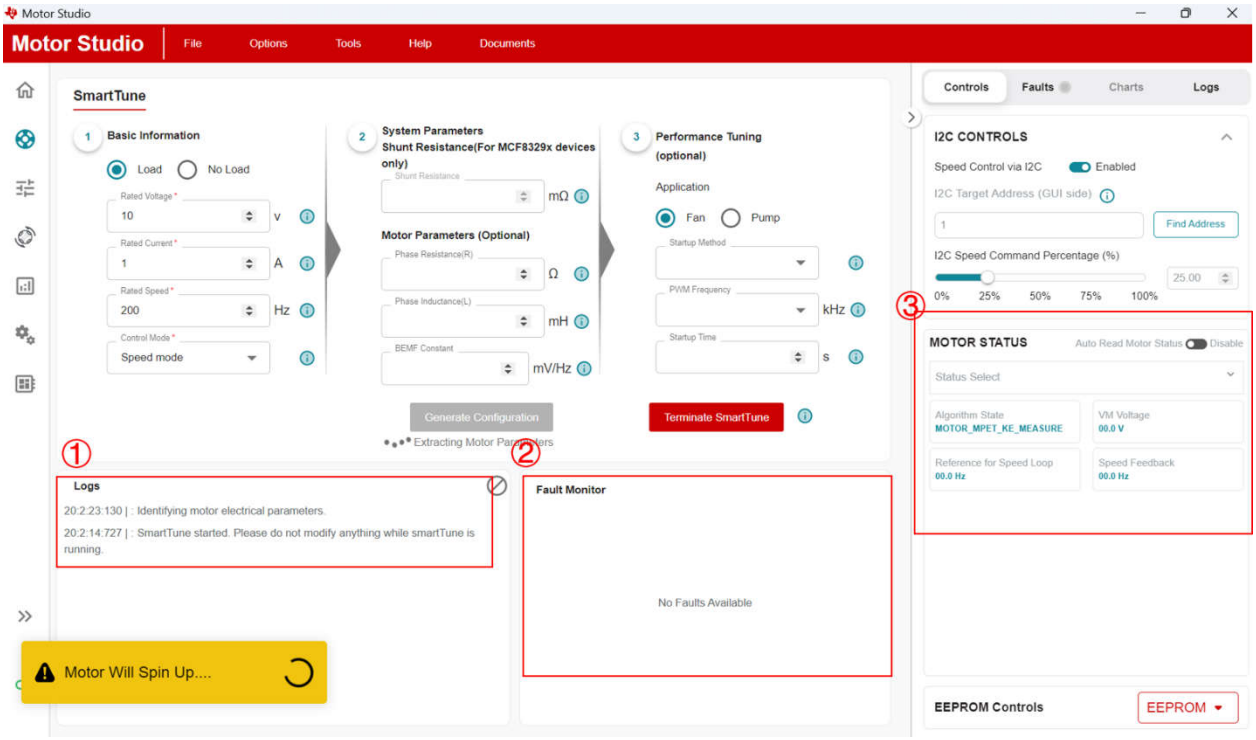

Figure 2-4. Run SmartTune

Step 5: Use SmartTune Result to Spin Motor

As shown in Figure 2-5, when a green Configuration Successful is shown, the Generate Configuration button turns into Regenerated Configuration. DO NOT click this button unless you want to re-run SmartTune. To spin the motor, you can:

1. Drag the round button of I2C Speed Command Percentage to tune speed from 0% to 100% of rated speed.
2. Observe the Speed Feedback in the Motor Status to see if motor has reached the reference speed.
3. Observe faults in the Fault Monitor to see if there is something wrong when motor cannot spin.

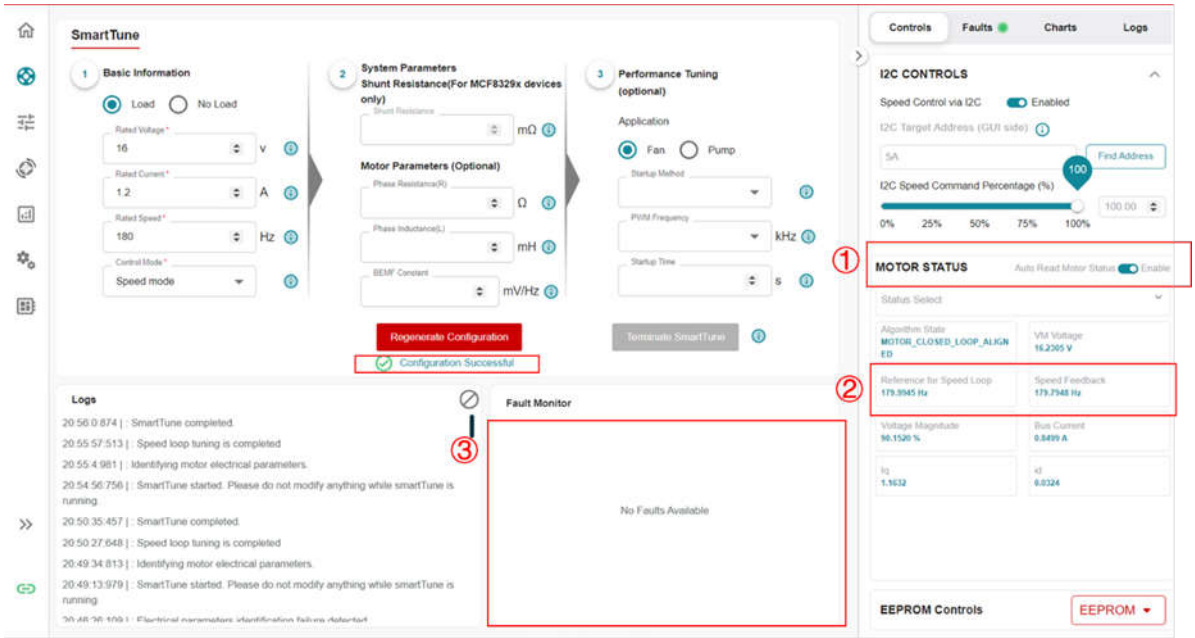

Figure 2-5. Use SmartTune Result to Spin Motor

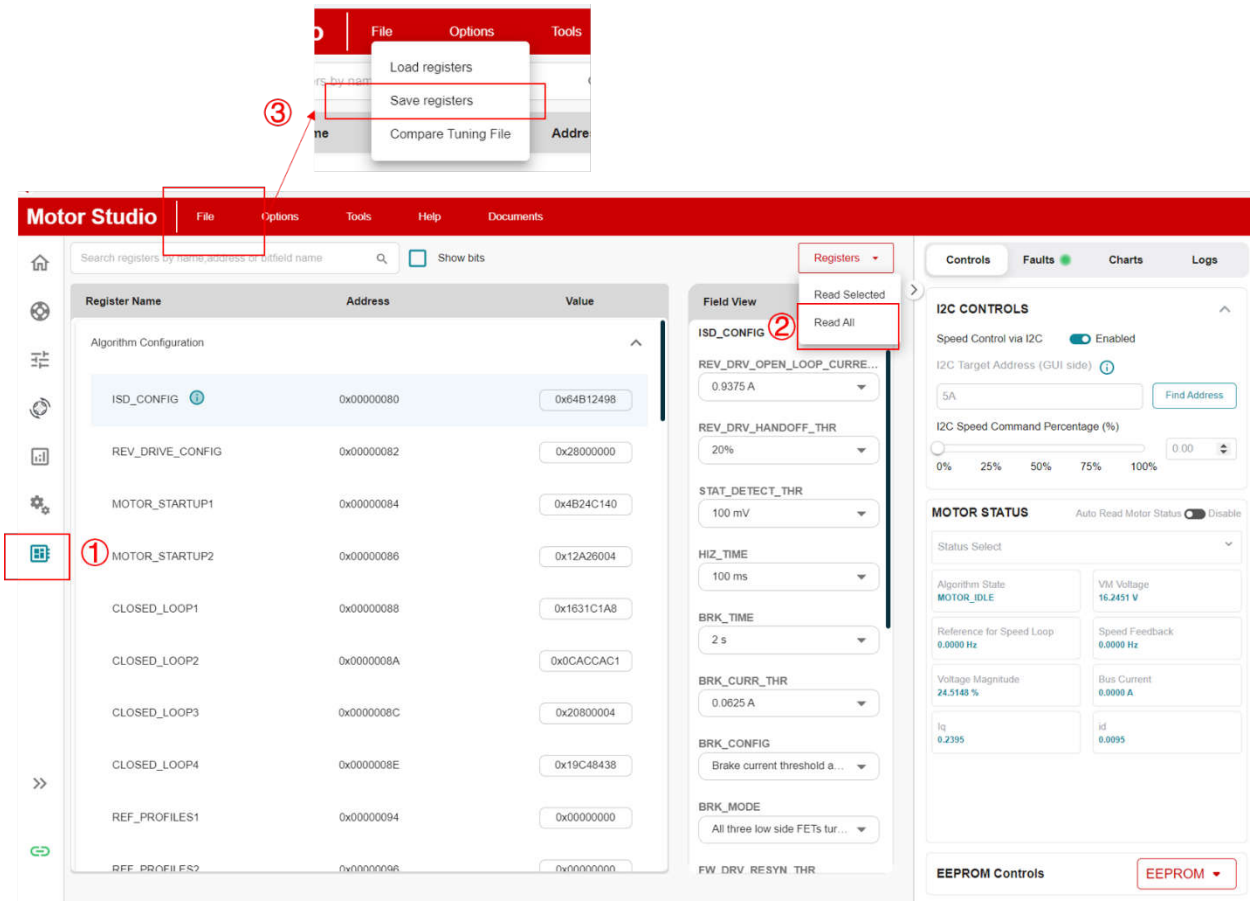

Figure 2-6. Save Register Setting

Step 6: Save Register Setting

As shown in Figure 2-6, if you want to save the configuration generated by SmartTune:

1. From the left navigation bar, click the last icon which is Register Map.
2. Click Registers and choose Read All. Then configuration is all read into corresponding registers.
3. From the top navigation bar, click File and choose Save registers. Then you can save the register setting into a .json file.

Next Time when you want to use this configuration, from the top navigation bar, click File choose Load registers, and then select the .json file you saved.

3 Practical Tips for Setting SmartTune Parameters

In many cases, the system level voltage and expected speed are usually different from those specified by the motor data sheet (or in some cases, users even do not have a data sheet). And therefore, the current value when motor is driven at this voltage and speed is unknown. If users randomly set the current value, fault can be triggered and motor cannot achieve the expected speed. This section introduces some tips for users about what to do when fault happens and how to set the proper current value.

First, **the rated current parameter must be set less than motor drivers' peak output current capability**. This value can be found in the data sheet of motor driver. Also, **the current limit of the external power supply needs to be higher than the current needed from the motor** to avoid current clamping of the power supply.

Then, supposing your current setting is already less than motor driver's peak output current, if one of the following situations occurs, this indicates that your current setting is still too high and you can reduce the current value a little bit and try again:

- SmartTune configuration failed and the fault monitor shows MPET_IPD_FAULT.

This indicates that the setting current value is so high that SmartTune fails to calculate motor parameters. To make sure this fault not happens, the current needs to also be less than V/R, where R is motor phase resistance.

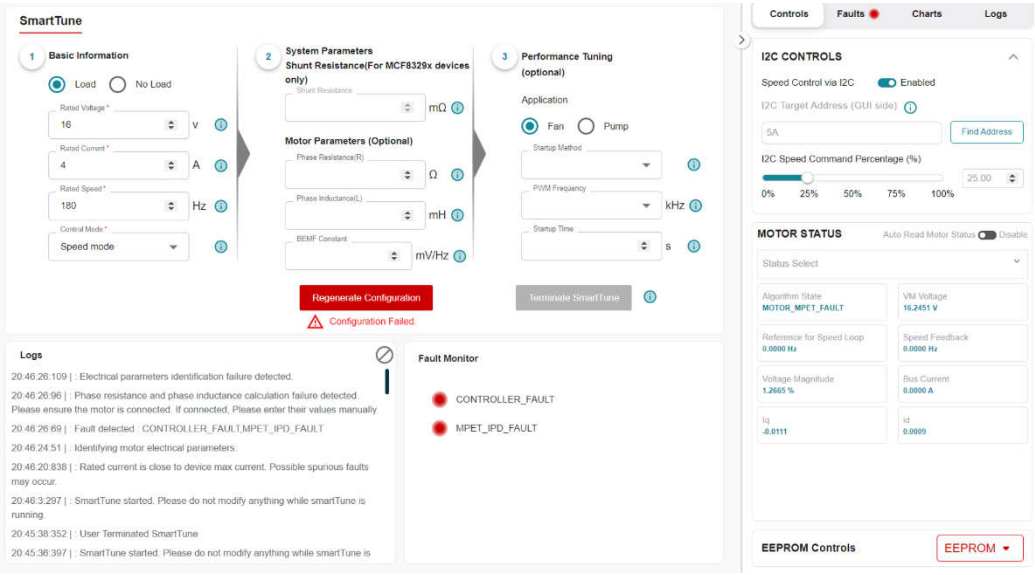

Figure 3-1. SmartTune Configuration Failed and MPET_IPD_FAULT

- SmartTune configuration failed and the fault monitor shows CURRENT_LOOP_SATURATION.

This indicates that even if PWM duty is set to nearly 100%, the rated current still cannot be reached. Check the Voltage Magnitude in the Motor Status panel (if not shown, click on the Status Select and tick on this parameter), and you can see that Voltage Magnitude is nearly 100%.

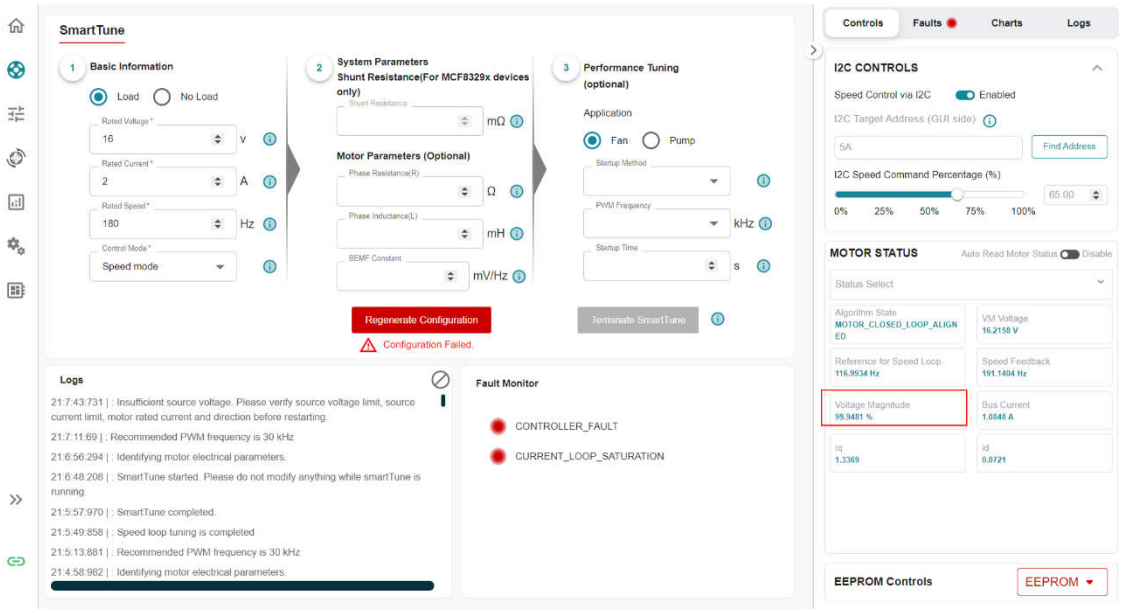

Figure 3-2. SmartTune Configuration Failed and CURRENT_LOOP_SATURATION

If one of the following situations occurs, this indicates that your current setting is too low and you can increase the current value a little bit and try again:

- SmartTune configuration failed and the fault monitor shows MPET _BEMF_FAULT.

This indicates that before the speed level is not enough for SmartTune to detect BEMF and calculate BEMF constant.

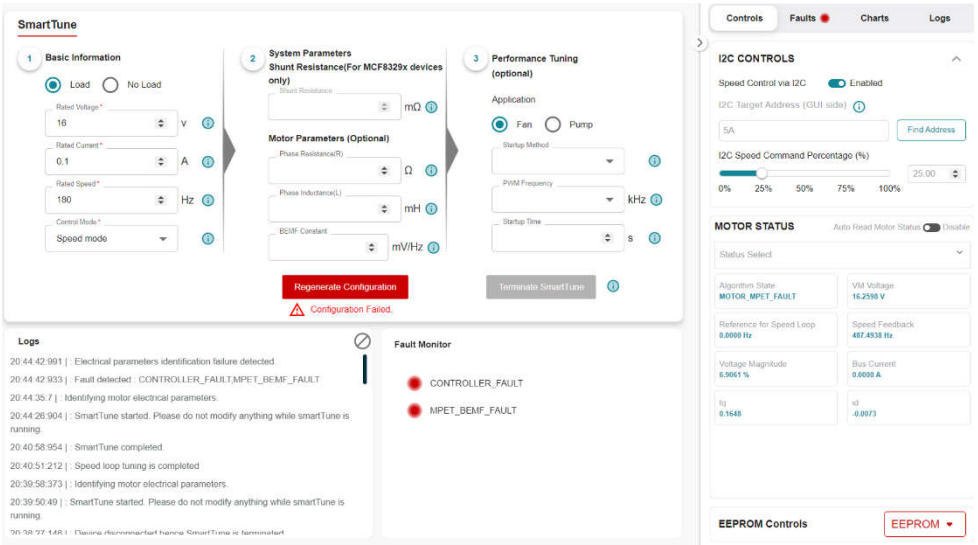

Figure 3-3. SmartTune Configuration Failed and MPET_BEMF_FAULT

- SmartTune configuration successful, but when you set the speed to 100% (maximum), the fault monitor keeps showing SPEED_LOOP_SATURATION.

This indicates that current is clamped before motor reaches rated speed. Check the Speed Feedback in the Motor Status panel (if not shown, click on the Status Select and tick on this parameter), and you can see that the Speed Feedback is less than Reference for Speed Loop. At this time, Voltage Magnitude is far less than 100%, so there is still margin for PWM duty but the current threshold has been reached.

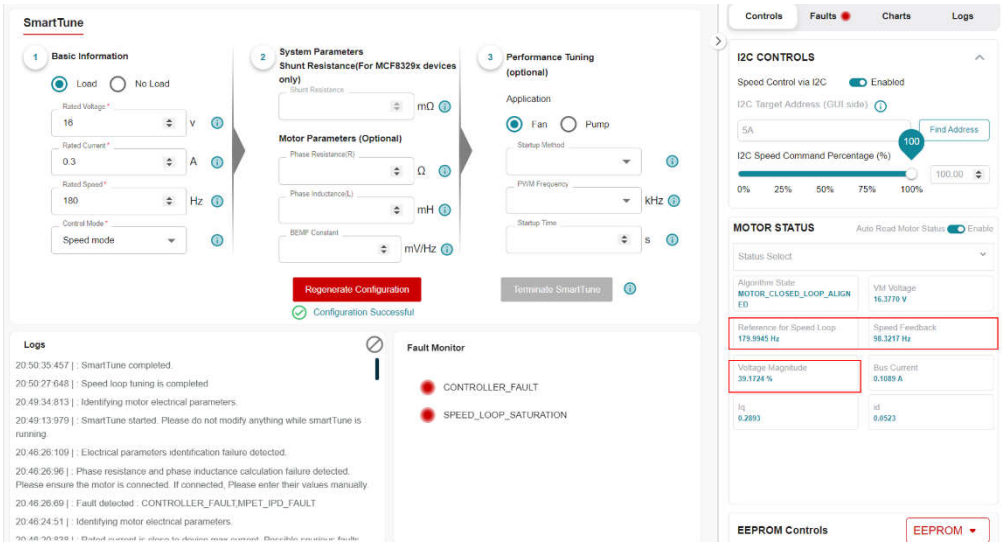

Figure 3-4. SmartTune Configuration Successful and SPEED_LOOP_SATURATION

If the following situation occurs, this indicates that the system voltage is not high enough to achieve the expected speed with SmartTune configuration, and you need to either increase the rated voltage or reduce the rated speed.

- SmartTune configuration successful, but when you set the speed to 100%, the fault monitor keeps showing both SPEED_LOOP_SATURATION and CURRENT_LOOP_SATURATION.

This indicates that PWM duty is set to nearly 100%, but both the rated current and the rated speed cannot be reached. Check the Voltage Magnitude and Speed Feedback in the Motor Status panel (if not shown, click on the Status Select and tick on this parameter), and you can see that Voltage Magnitude is nearly 100%, but the Speed Feedback speed is less than Reference for Speed Loop.

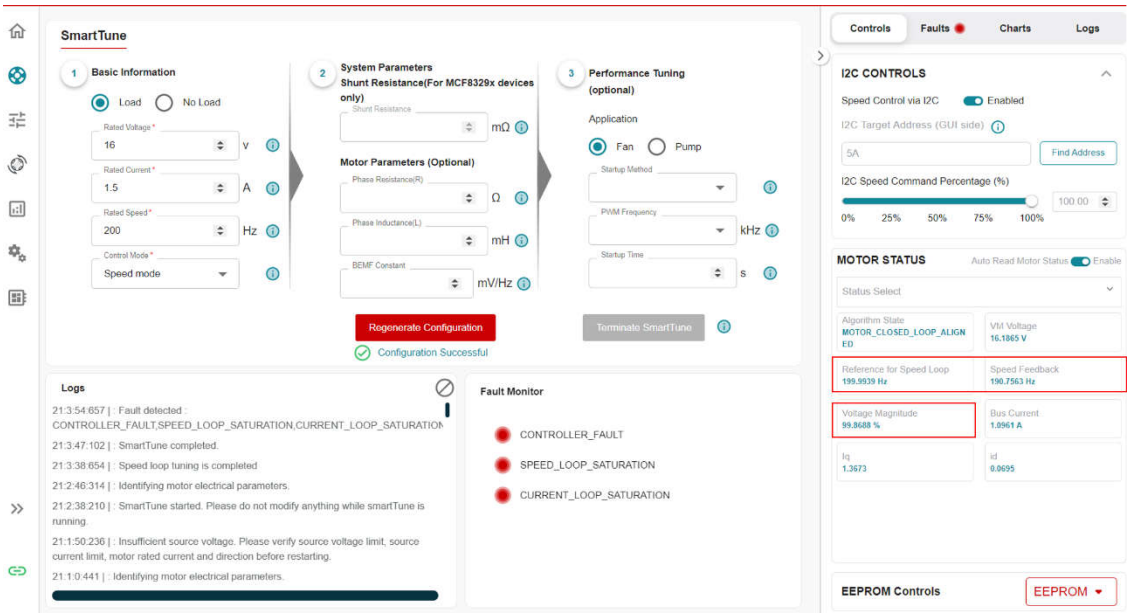

Figure 3-5. SmartTune Configuration Successful, SPEED_LOOP_SATURATION and CURRENT_LOOP_SATURATION

Figure 3-6 summarizes all the fault situations above and the tuning tips:

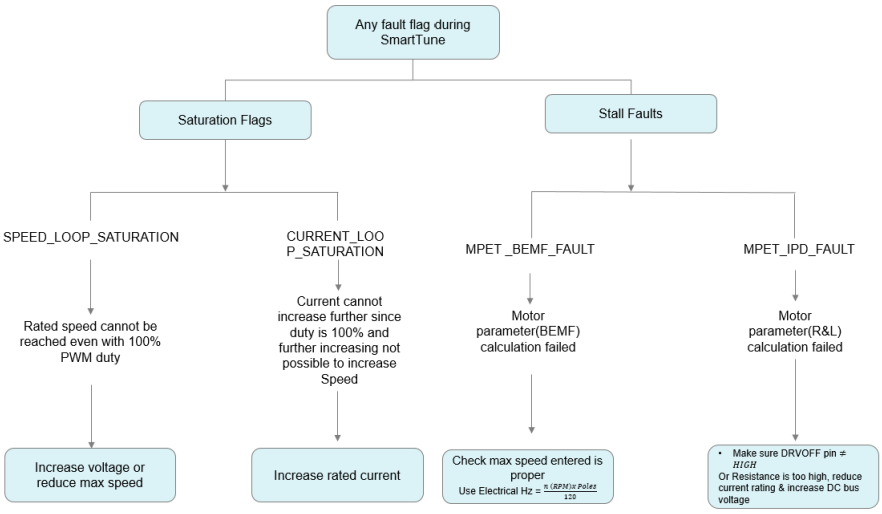

Figure 3-6. Faults and Tuning Tips

4 Summary

SmartTune is a useful tool to help users quickly verify if TI's motor driver can drive the motor to achieve the expected speed under specific voltage and current conditions. It automatically generates a set of configuration parameters to spin motor based on input of only three parameters (rated voltage, rated current and rated current), which is both easy-to-use and time/effort-saving.

Appropriate input of the three parameters is crucial for SmartTune to generate configuration and spin motor successfully. Please follow the tuning tips provided by this document to eliminate faults and unsatisfying performance caused by mismatch of input parameters.

5 References

1. Texas Instruments, *Getting Started with MOTORSTUDIO*, application note.
2. Texas Instruments, *MCF8315C Sensorless Field Oriented Control (FOC) Integrated FET BLDC Driver*, data sheet.
3. Dunkermotoren, *BG 45*. data sheet.

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