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How to Spin a BLDC Motor Using ecoSpin™ Family

ECS640A Development Platform

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Prepared by: **Rogerio Romariz Ferreira**
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Description

This document discusses the accelerating trend toward energy efficiency improvement and how this impacts offline−powered application design. Highly efficient electrical motor technologies (such as BLDC motors) become more attractive as the industrial, automotive, and appliance industries adjust their products to meet government energy efficiency targets, leading the movement of environmentally sustainable products forward. The ecoSpin 600 V ECS640A motor control device is presented as an "easy to use" solution to design an application that runs with BLDC motor technology. The ecoSpin development platform enables a BLDC motor sample to spin even faster. This document describes a step−by−step process for setting up the ECS640A evaluation board unit with ecoSpin motor controller graphical user interface (ecoSpin DTFC* GUI) application to get a BLDC motor spinning. And lastly, a section on issuing BLDC motor movement commands using ecoSpin DTFC* GUI is also described below.

*DTFC − Direct Torque and Flux Control is a motor vector control methodology

The ECS640A development platform comprises various features, including:
- User−friendly ecoSpin DTFC GUI application
- ECS640A EVB unit with embedded motor control DTFC firmware
- Configurable "BLDC motor and motor control" parameters set for Direct Torque and Flux Control (DTFC)
- Seamless motor electromechanical characterization using a single set of closed−loop control parameters
- BLDC motor start/stop commands and clockwise (CW) and counterclockwise (CCW) speed reference selection
- Live motor performance variables monitoring in a display or graphical waveform interfaces
- Isolated USB communication

In January 2023, the USA Department of Energy (DOE) will increase the minimum allowed efficiency of HVAC equipment—the second efficiency level increase in the last five years. Commercial and residential HVAC systems are being affected, with an expected 7% increase for the residential units.

The increase in energy efficiency trend is not new and has been pushing all offline powered systems to comply with specific market targets globally. New technologies are becoming available to tackle this goal, and the adoption of a brushless DC (BLDC) motor topology has been successfully applied. BLDC topology has replaced the well−known split phase induction motor topology and can deliver an average of 30% consumed energy reduction depending on the power application level. A BLDC motor topology requires less raw material for the same power application level, leading to higher output power−to−motor frame size ratio than the split−phase induction motor.

Using simple driving circuits (e.g., 12 Vdc relay element) rated for the motor starting current (roughly 7−10 times the motor rated current) can realize the fixed speed operation of a split phase induction motor. A BLDC motor topology requires a more specialized circuitry to start and perform variable speed control (e.g., a 3−phase voltage stiff inverter).

Figure 1 depicts a typical offline powered sensored or sensorless BLDC motor speed control circuitry.
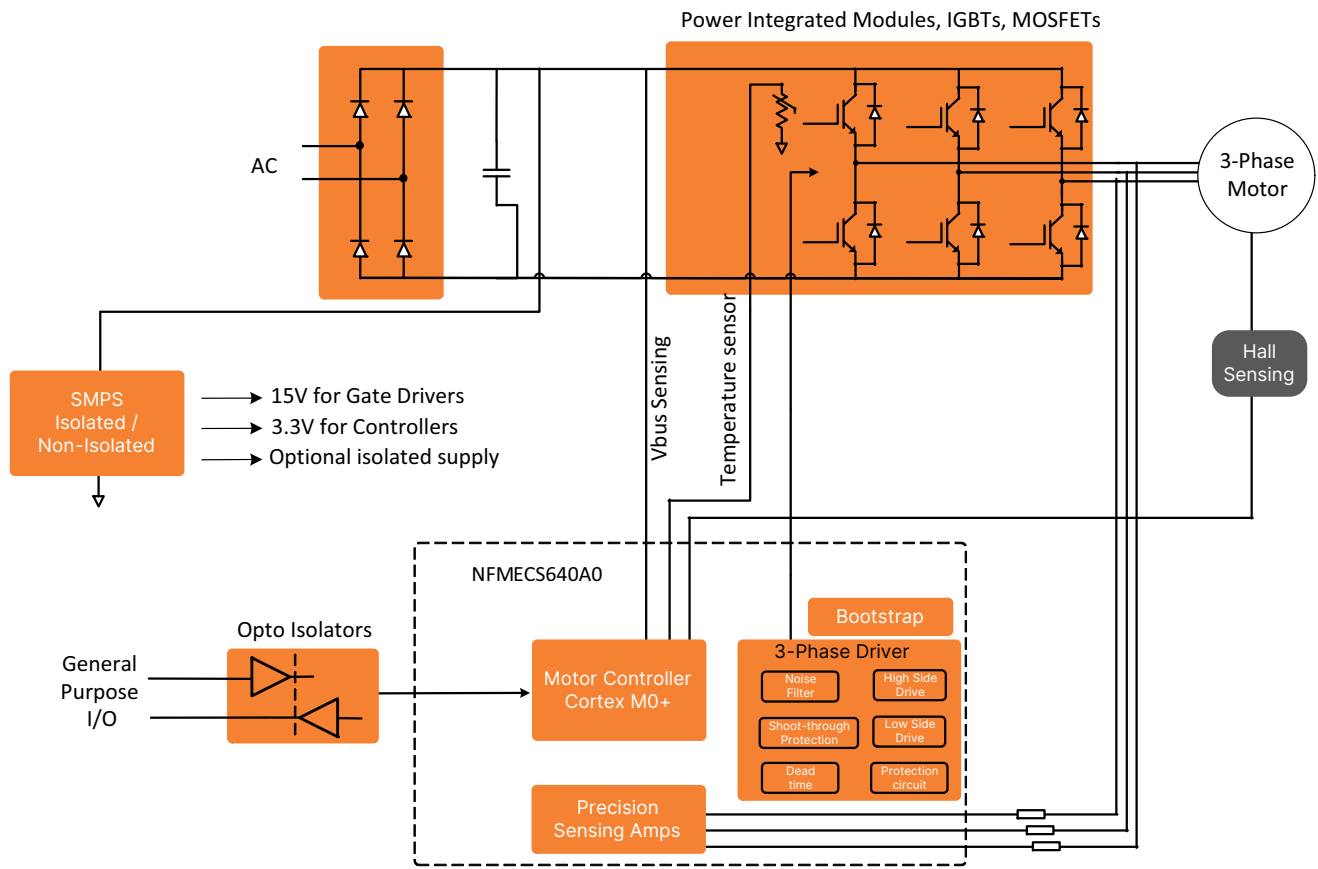

Figure 1. Offline Sensored/Sensorless Motor Control Topology using ECS640A

Aside from new electronic hardware parts, the software control algorithm adds a vital piece to the BLDC motor migration process. Specialized BLDC motor control software is available in several flavors (e.g., Trapezoidal or Six–step control, Field Oriented Control (FOC), and Direct Torque and Flux Control), each addressing specific motor speed dynamics needed in the final system application. Electronic hardware and software integration is key to achieving good motor performance results—specifically implementing a BLDC sensorless vector control application. Transitioning from a simple DC relay activation to a 3–phase voltage stiff inverter control requires specialized and experienced electronics hardware and software motor control team.

The journey into higher efficiency motor applications is not simple and requires multiple design cycles to reach the desired performance. Therefore, **onsemi** is excited to announce a new level of performance in 600 V BLDC motor control application by combining the power of an Arm® Cortex®–M0+ core with world–class gate drivers and feedback circuitry. With its small footprint and high level of integration, **onsemi** simplifies embedded motor control systems.

The ecoSpin ECS640A system–in–package (SiP) IC enables scalable BLDC motor solutions by integrating cutting–edge Arm® Cortex®–M0+ core capable of supporting traditional motor control techniques such as trapezoidal and vector control (e.g., FOC). Most notably, the ECS640A can drive a more complex DTFC algorithm supporting high voltage and power via a scalable 3–phase half–bridge topology. It supports communication interfaces (SPI, UART, I2C, and GPIOs) and can receive a wide variety of complex proprietary protocols down to general–purpose motor speed profile commands. The 2–way communication interface nature also enables feeding back motor performance–related information. Sensorless and sensored operations are both supported. Figure 2 shows a detailed ECS640A device internal diagram.
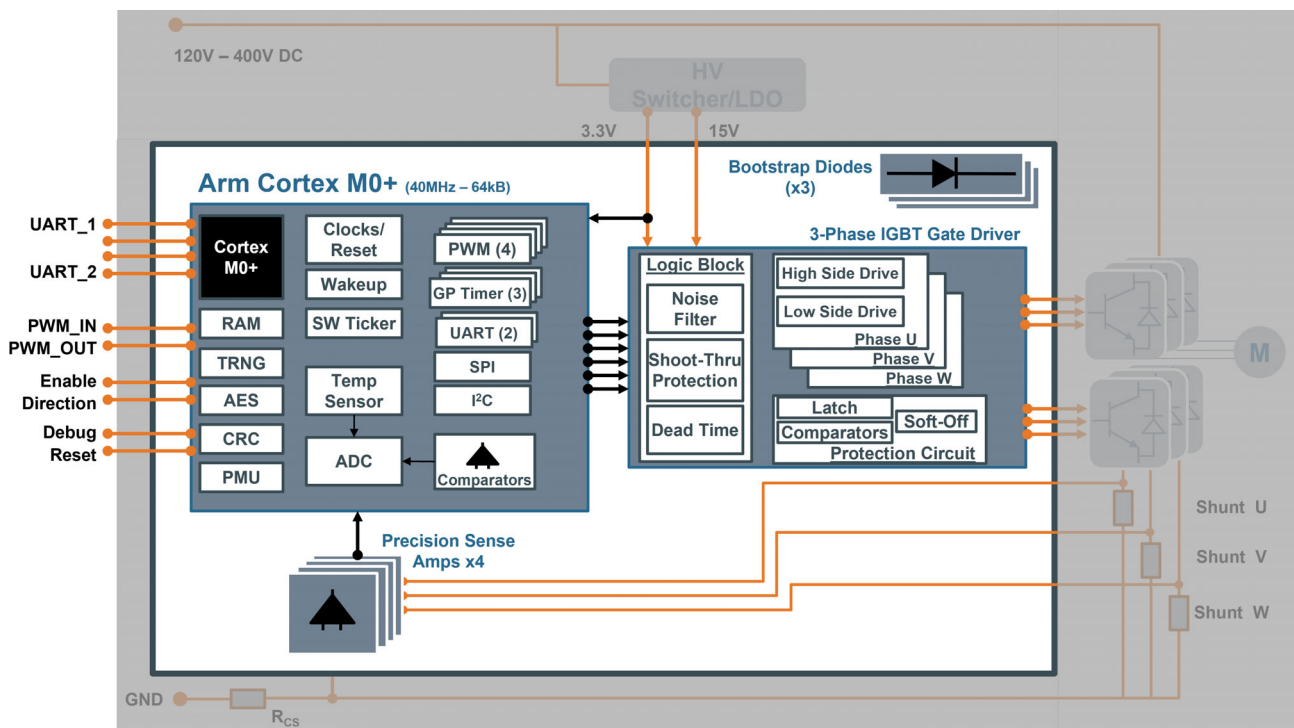

Figure 2. ECS640A Internal Diagram

ecoSpin ECS640A's embedded 600 V gate driver and dedicated motor control engine can issue the required DTFC PWM modulation signals to external discrete power IGBTs and capture BLDC motor corresponding 3−phase currents through external shunt current feedback. Using the embedded op−amp structure ideally paired to the ARM Cortex−M0+ microcontroller and maintaining signal integrity can condition these three motor current signals internally. The unprecedented flexibility and integration in a single IC package redefine BLDC motor control performance in a tiny form factor of 10 mm x 13 mm (0. 5 mm pitch). The compact footprint allows for optimized power stage placement and reduced noise.

The highly integrated QFN surface−mount solution reduces time−to−market by eliminating the need for design cycles on the microcontroller, gate driver, bootstrap diode, and op−amp selection and simplifies solution reuse when scaling BLDC motor power level requirements. Replacing many of the larger, more complex devices improves reliability while at the same time shrinking the PCB routing area to deliver an overall compact solution.

onsemi's partnership with Theta Power Systems International empowers your BLDC motor system solution with the required technical expertise to reduce time−to−market and ease adoption. The ECS640A may ship with a DTFC algorithm optimized for your BLDC motor as a purchase option—DTFC is a custom BLDC motor algorithm optimized to your required BLDC motor power level.

ECS640A Development Platform

The ECS640A development platform has three basic elements as listed below:

1. ECS640A evaluation board (STR–ECS640A– GEVB)
2. ecoSpin DTFC Motor Controller Graphical Interface (ecoSpin DTFC GUI application)
3. Embedded Motor Control "Direct Torque and Flux Control" (DTFC) firmware

Each element is essential to enable a target 3–phase BLDC motor operation. Figure 3 shows the elements' roles and how they are linked. ECS640A evaluation board is embedded with "DTFC Motor Control" firmware. The embedded firmware enables data communication with the "ecoSpin DTFC GUI" application running on a Windows–based computer.
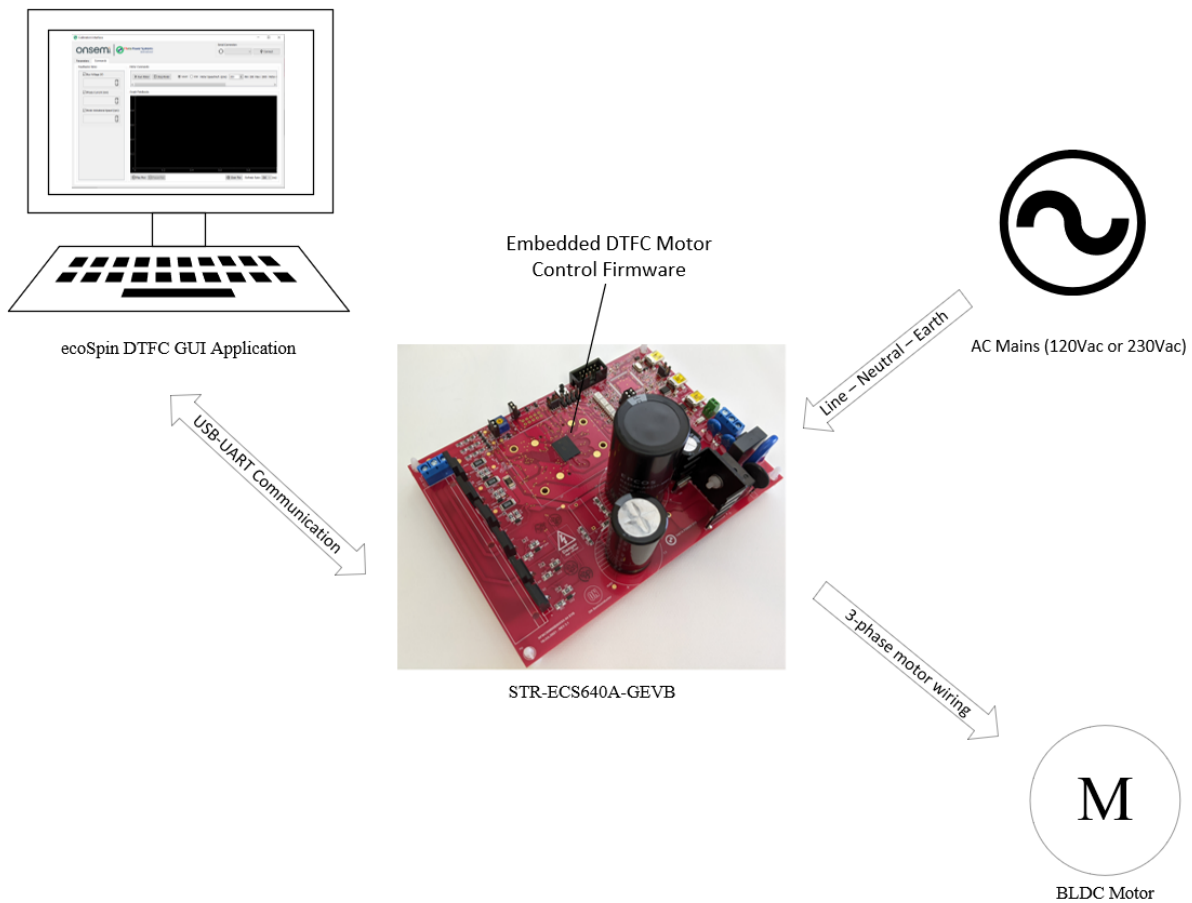
Figure 3. ECS640A Development Platform

ECS640A Evaluation Board

onsemi developed the evaluation board to support customers during their first steps in designing applications with the ecoSpin ECS640A motor control system–in–package. Some of the evaluation board features are listed below:

- Single ECS640A packaged device containing logic controller, 600 V gate drivers, bootstrap diodes, and operational amplifiers
- Output Power up to 650 W
- Input AC rectification enables DC bus configuration for 120 Vac or 230 Vac mains input voltages
- Sensing capability: 3–phase motor current, DC bus voltage, ambient temperature, Hall sensors (optional)
- Serial Interfaces: J–link SWD, SPI, USB–UART
- Power Stage Inverter composed of six **onsemi** IGBTs (FGPF15N60UNDF)
- NCP10970 DC/DC Converter designed to provide both 15 VDC (Buck Topology) and 3.3 VDC (embedded LDO)

ecoSpin DTFC GUI Application

The ecoSpin DTFC GUI is a windows–based application designed to enable a high–level interface with the EVB and DTFC motor control firmware and quickly start testing on a BLDC motor control system. The ecoSpin DTFC GUI allows the user to configure new electromechanical motor parameters and send and load this data to and from ecoSpin ECS640A flash memory. Save and load motor control parameters files allows easy setup change when testing different motors' specifications. Also, using quick access buttons performs motor run and stop movements while visualizing live motor performance data. Figures 4 and 5 show all these features in a single window application.

- User–friendly GUI
- Configurable BLDC motor and motor control parameters for Direct Torque and Flux Control (DTFC) algorithm
- Seamless motor electromechanical characterization using a single set of closed–loop control parameters
- Enables motor start/stop commands and clockwise (CW) and counterclockwise (CCW) speed reference selection
- Live motor performance variables monitoring in a display or graphical waveform interfaces.
- Isolated USB communication
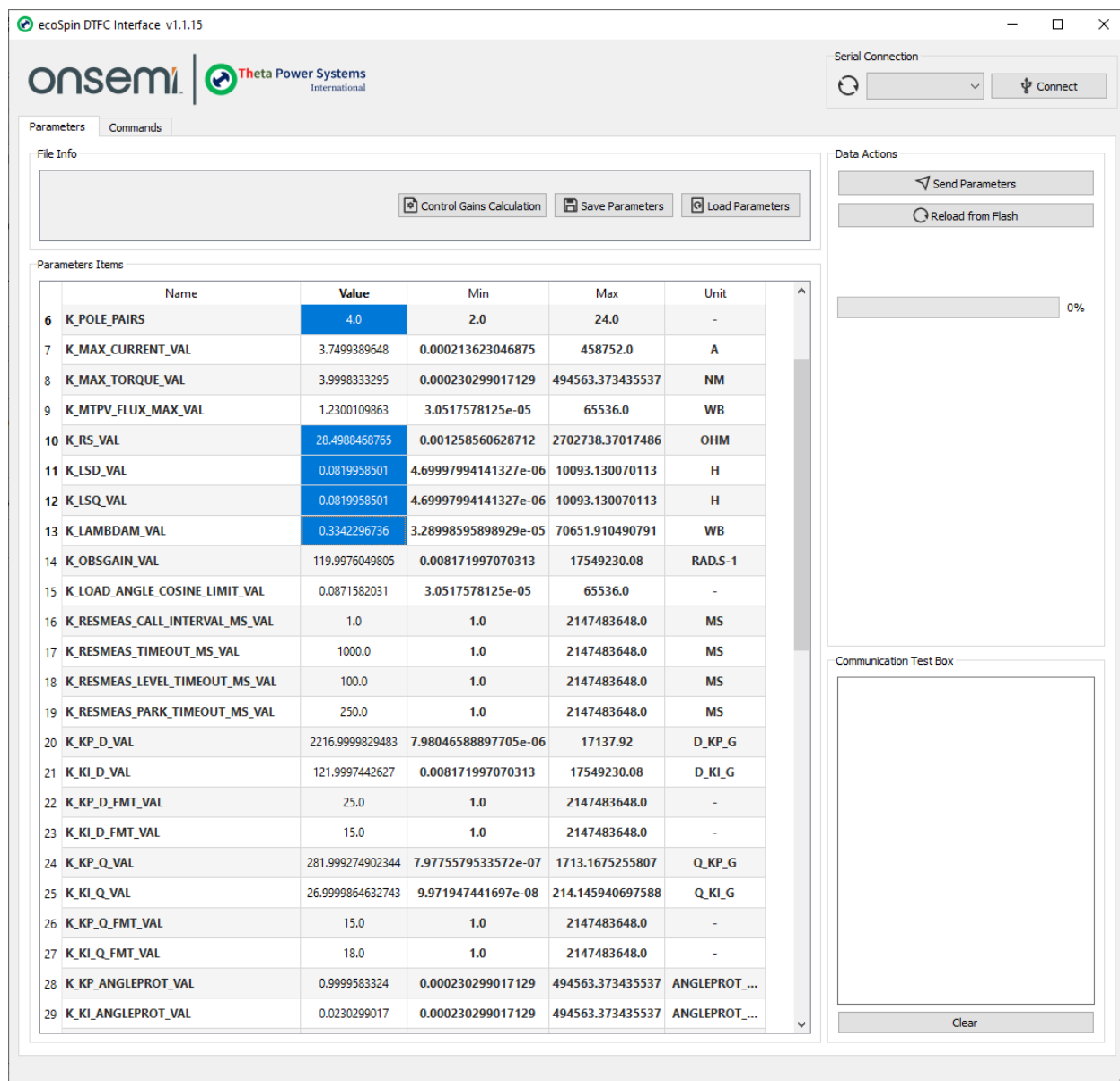
Figure 4. ecoSpin DTFC GUI Main Window – Parameters Tab
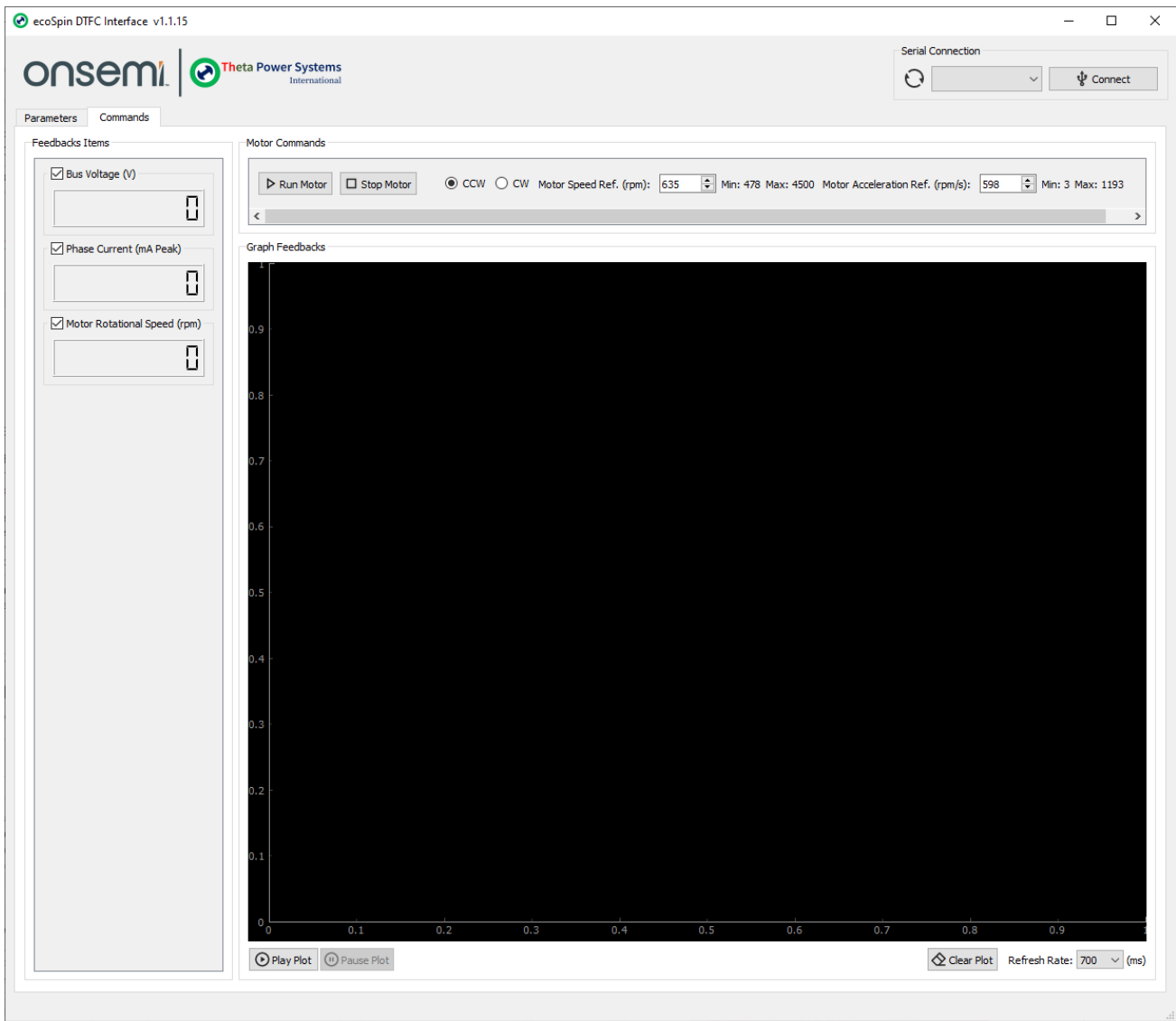
Figure 5. ecoSpin DTFC GUI Motor Commands Tab

ecoSpin DTFC Software

The ECS640A evaluation board ships with embedded "Direct Torque and Flux Control" (DTFC) algorithm flashed in ECS640A non−volatile memory. This software allows direct communication with ecoSpin DTFC interface GUI running on a Windows−based laptop. The GUI−EVB communication runs on a USB cable that connects a laptop and EVB unit.

The Trapezoidal motor control algorithm is also available through download from **onsemi** ECS640A Strata developer Studio

(visit www.onsemi.com/design/tools−software/strata−developer−studio).

Get Started with the ECS640A Development Platform

After briefly introducing each ecoSpin ECS640A development platform element, one can evaluate the following steps to achieve your system's BLDC motor spinning goal.

Step 1: Visit the ecoSpin ECS640A product page on **onsemi**.com (www.onsemi.com/products/motor−control/ecospin−motor−controllers/ecs640a) and get access to the latest technical information.

Step 2: Contact **onsemi** sales or preferred distributor to order an ECS640A evaluation board (P/N STR−ECS640A−GEVK).

Step 3: Visit the **onsemi** Strata Developer Studio page (www.onsemi.com/design/tools−software/strata−developer−studio) and download the cloud−connected evaluation board's management tool software. Launch the Strata Developer Studio application and search for ECS640A (see Figure 6) to browse the latest documentation and software tools (e.g., ecoSpin DTFC GUI application).
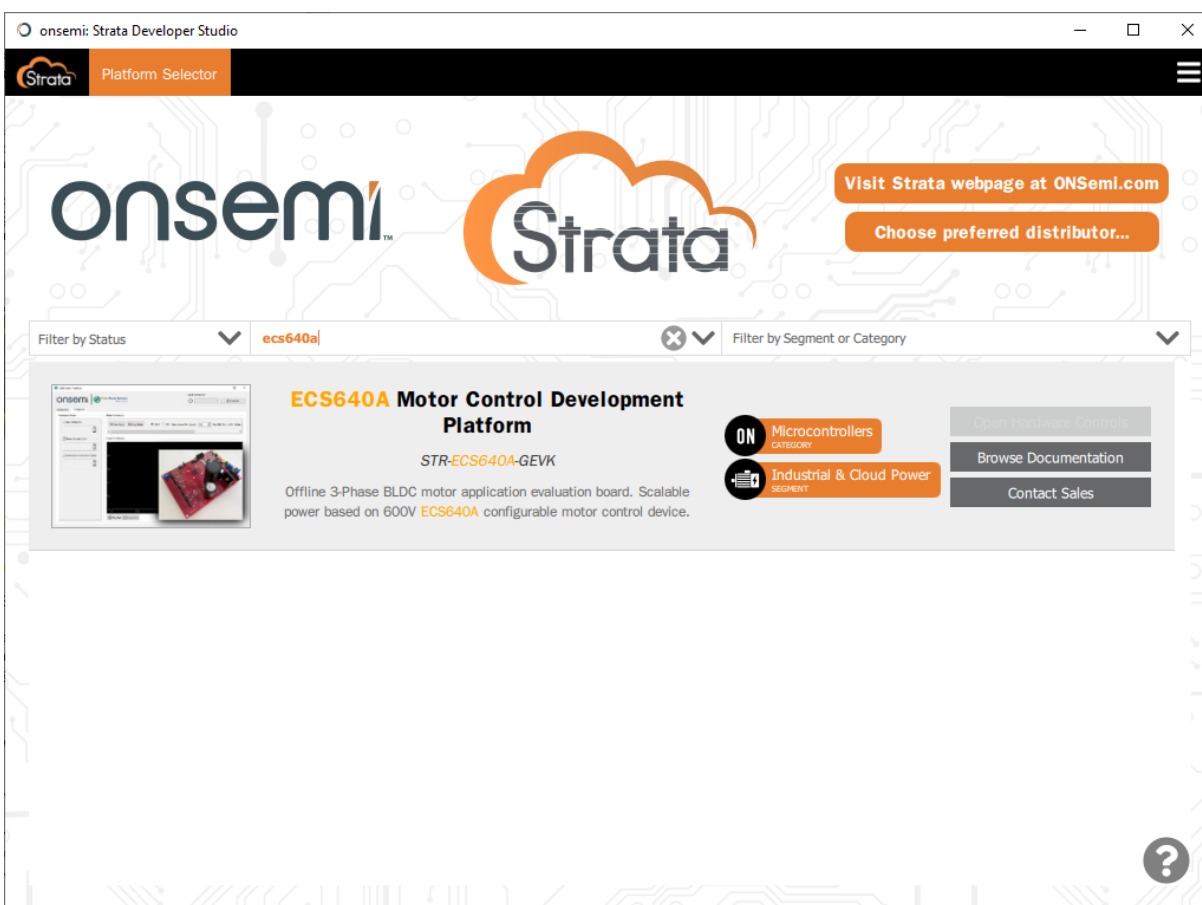
Figure 6. Strata Developer Studio Application – ECS640A Search Result

Step 4: Download the "ecoSpin DTFC Interface.exe" application from the ECS640A Download section (see Figure 7).
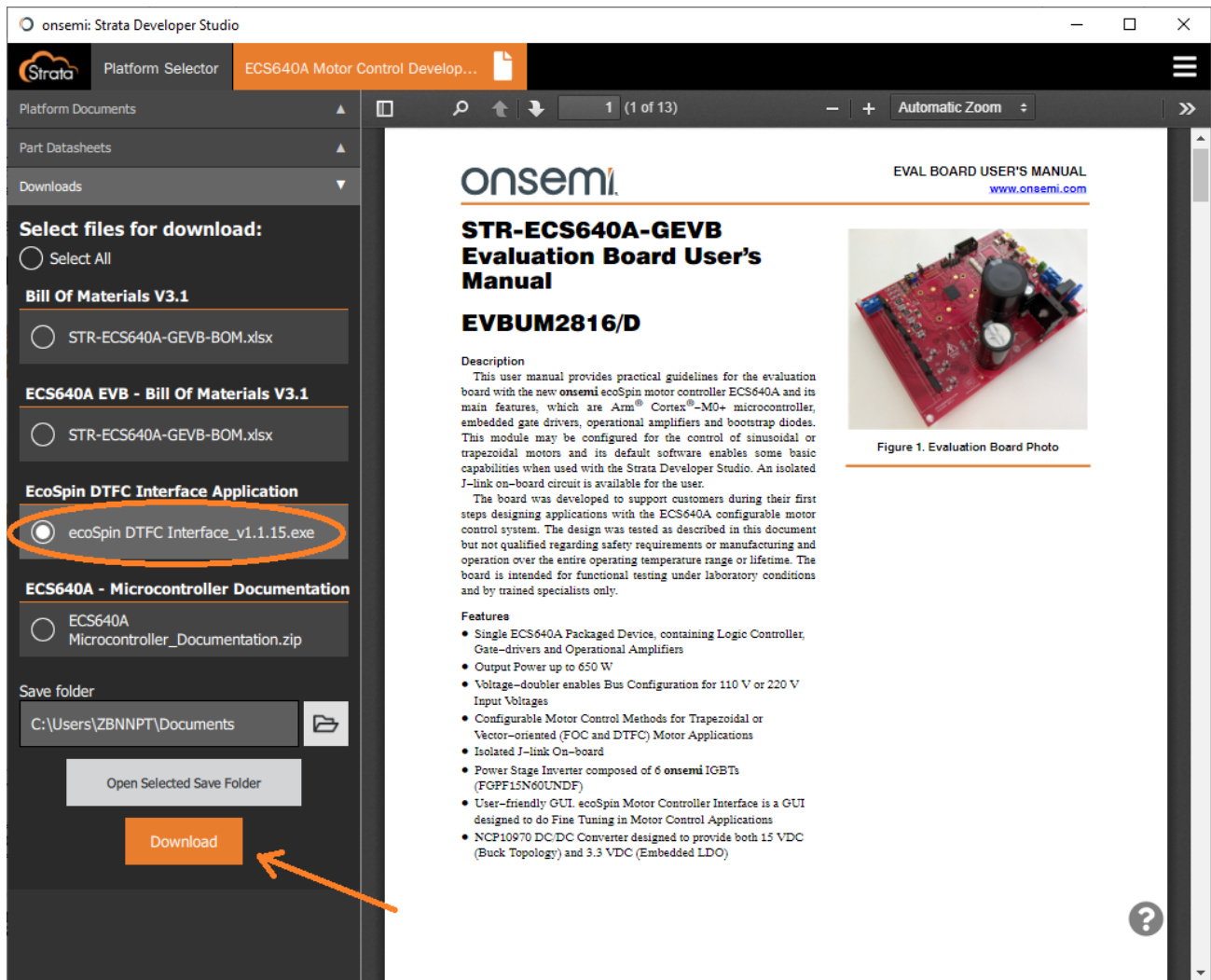
Figure 7. ecoSpin DTFC Interface Download and EVB User's Manual

Step 5: Browse the "ECS640A EVB User Manual" (EVBUM2816/D file) and become familiar with ECS640A development board connectors and interfaces in the Strata Developer Studio environment (see Figure 7).

Step 6: Launch the "ecoSpin DTFC Interface.exe" application on a Windows–based laptop. Browse the "ecoSpin DTFC GUI User Manual" (UM70067 file) and follow the "New 3–phase BLDC Motor Setup Process" section (see Figure 8). This user manual section describes capturing BLDC motor parameters and filling in the ecoSpin DTFC GUI parameter list. The DTFC parameter list enables ecoSpin DTFC embedded software on the ECS640A EVB to spin the target BLDC motor properly.
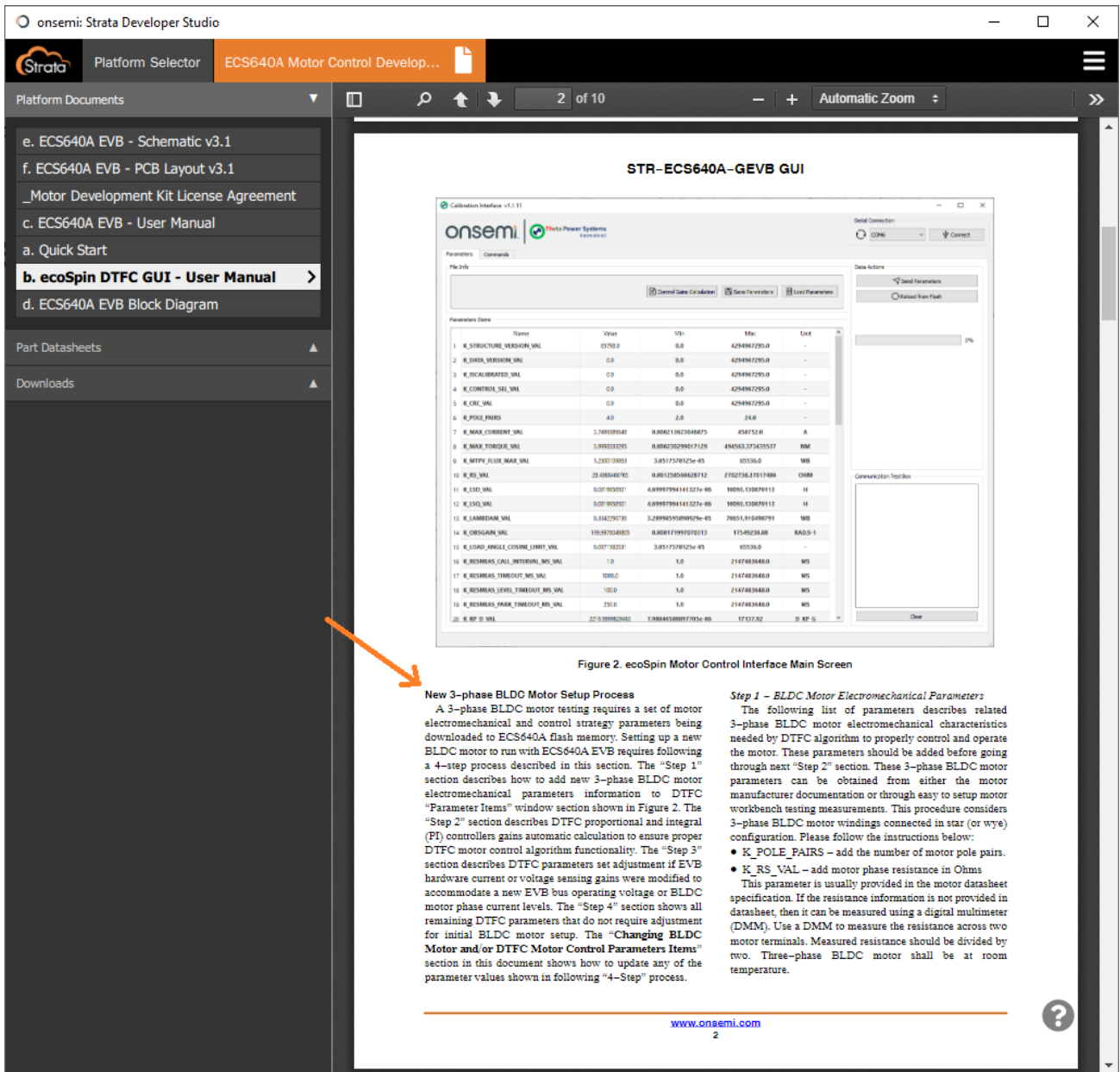
Figure 8. ecoSpin DTFC GUI User Manual – New 3–phase BLDC Motor Setup

Step 7: Connect ECS640A EVB J3 serial communication connector to the laptop USB port using the USB cable provided in the ECS640A EVB box. See J3 connector details in Figure 9.
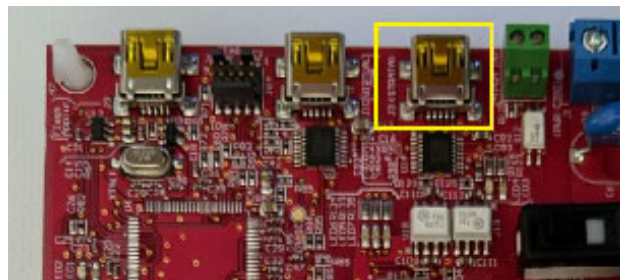
Figure 9. ECS640A EVB USB Connector (J3)

Step 8: Connect 3−phase motor wiring to ECS640A EVB J2 following phase sequence depicted on PCB silkscreen. See Figure 10 for details.
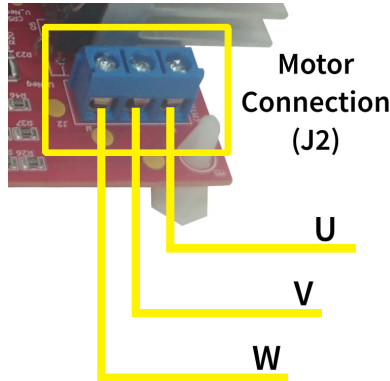
Figure 10. ECS640A EVA BLDC Motor Connection (J2)

Step 9: Connect the AC mains wiring cable to ECS640A EVB J1 connector and power up the EVB unit. Ensure the EVB input rectification topology matches the AC mains voltage level (ECS640A EVB unit ships with 120 Vac default AC input configuration). See Figure 11 for details.
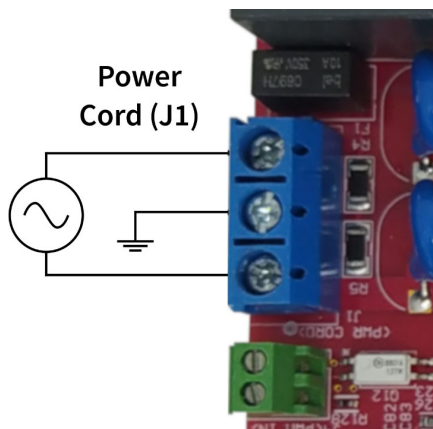
Figure 11. ECS640A EVB AC Mains Connection (J1)

Step 10: Enable ecoSpin DTFC GUI USB communication with ECS640A EVB and download parameters set to ECS640A flash memory. The "USB Connection" and "ECS640A EVB Send and Reload Parameters" sections in the "ecoSpin DTFC GUI User Manual" document (UM70067 file) describe the detailed process.

Step 11: Issue 3−phase BLDC "Run Motor" command using the "ecoSpin DTFC GUI" application. Default "Motor Speed Reference" and "Motor Acceleration Reference" levels are automatically generated based on the target BLDC motor parameters. The "BLDC Motor Commands" section in the "ecoSpin DTFC GUI User Manual" document (UM70067 file) describes the detailed process.

Step 12: Plot motor live−performance data in the "Graph Feedbacks" window and finetune PI speed gains based on your system application behavior. The "Plot Window" section in the

"ecoSpin DTFC GUI User Manual" document (UM70067 file) describes the "Graph Feedback" window functionality.

Keep up to date ECS640A documentation by visiting the Strata Developer Studio environment.

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