# Motor Control Software Libraries BASIC for TLE987x

## Getting started

**TLE987x-eSL-BAS**

## About this document

### Scope and purpose

This document provides the first steps to control a 12-V BLDC motor using the Motor Control Software Libraries BASIC for TLE987x on the TLE987x EvalKit hardware.

### Product information

| | |
|---|---|
| Product name: | TLE987x-eSL-BAS |
| Release number and version: | 1.3.0 |
| Type of release: | Productive |
| Compiler support: | Arm®[1)] Compiler 6 |
| Processor platform: | Arm® Cortex®-M3 |
| Date: | 2022-09-30 |
| Previous release number and version: | 1.2.0 |

### Target devices

| | | |
|---|---|---|
| TLE9877QXA40<br>TLE9877QXW40<br>TLE9877QTW40 | TLE9879QXA40<br>TLE9879-2QXA40<br>TLE9879QXW40<br>TLE9879QTW40 | TLE9872QXA40<br>TLE9872-2QXA40<br>TLE9872QTW40 |

The following constraints apply for testing:

- Device variants with $f_{sys}$ < 40 MHz not tested
- Device variants with RAM < 6 kB RAM not tested
- Verification performed on BF-step only

### Intended audience

This document is written for qualified and skilled technical staff. The technical staff must be qualified for laboratory usage, sufficient to identify and control any hazard that arise from the usage of an evaluation board connected to an electrical motor.

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# 1 Introduction

## 1.1 TLE987x FOC BASIC sensorless example

The getting started steps are based on an application software example provided in the delivery package, named `TLE987x FOC BASIC Sensorless Example`. This application example integrates the relevant software components of the Motor Control Software Libraries BASIC for TLE987x and the low-level driver to run on the TLE987x EvalKit in a Keil® µVision®5 software project.

This software example is designed to drive a motor in two configurable control modes:

- Sensorless FOC mode
- V-to-F (voltage to frequency) mode

## 1.2 Overview how to get a motor running

**Table 1 Getting started steps**

| | |
|---|---|
| Step 1 | Load the provided application software example project FOC.uvprojx in Keil® µVision®5 |
| Step 2 | Configure the motor parameters in Config Wizard |
| Step 3 | Build the Keil® µVision®5 project<br>Expected result: compiled successfully without any error or warning |
| Step 4 | In Keil® µVision®5, configure the connection to the target device to use the J-LINK / J-TRACE Cortex |
| Step 5 | In Keil® µVision®5, download the compiled code to the target flash memory |
| Step 6 | In the debugger watch window:<br>• Switch on "Enable power stage"<br>• Switch on "Enable control"<br>Set a reference motor speed from the cursor Expected result: The motor starts turning. |
| Step 7 | If the motor does not turn as expected, see Troubleshooting |

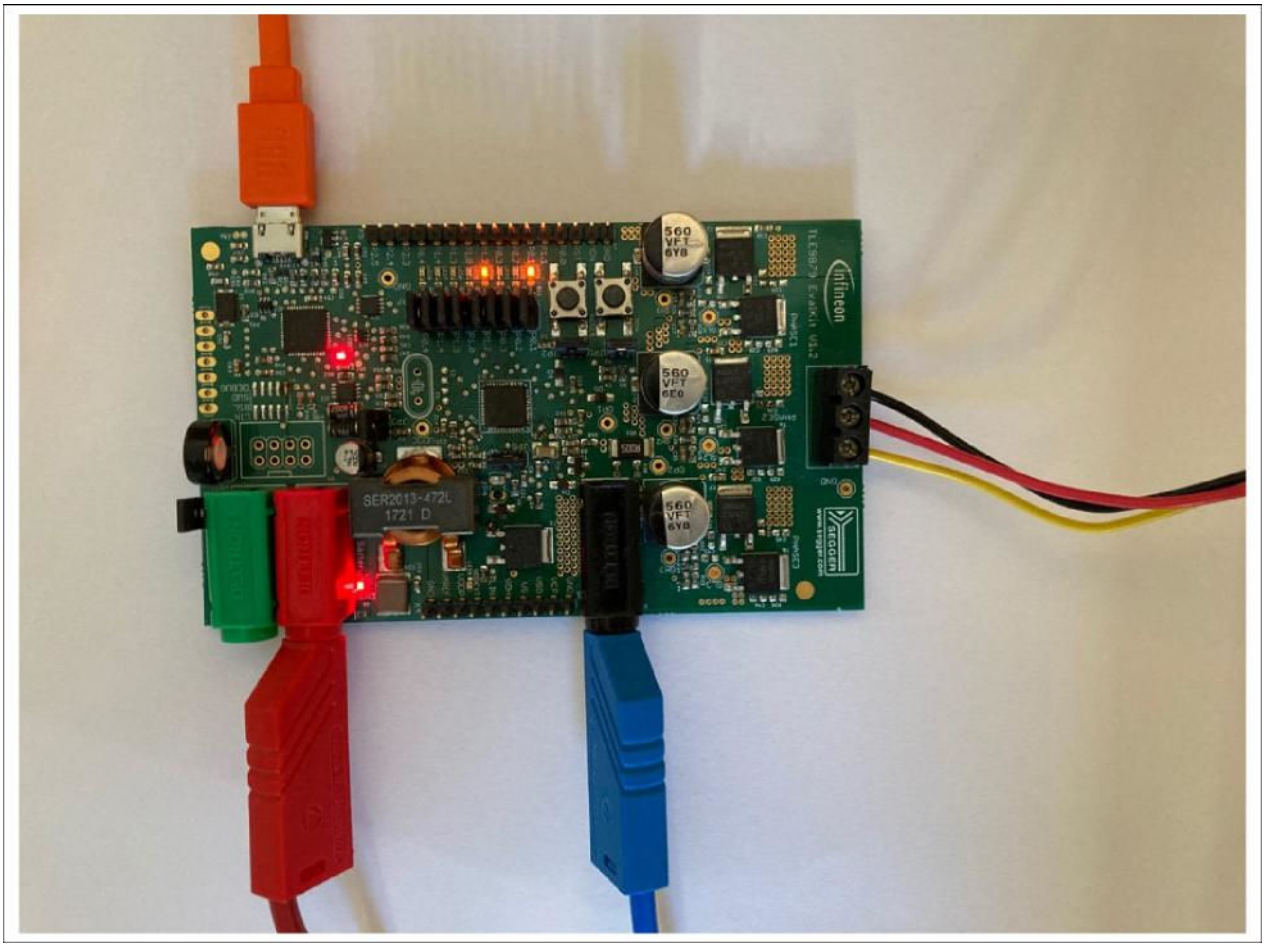
More details on the steps to get the motor running are provided in Appendix A.2.

# 2 Prerequisites

## 2.1 Hardware requirements

For the evaluation of the TLE987x-eSL-BAS Motor Control Library using the demo software example, the following hardware is necessary:

- A 12-V bipolar (4Q) power supply with adjustable output voltage that is capable to backsupply (in generator mode) and to deliver a current sufficient for turning the designed motor
- The TLE987x EvalKit connected to the power supply and connected to the PC via J-LINK / J-TRACE Cortex interface as shown, for example, in the following figure:



- A 12-V BLDC motor designed for the target application with the three phases connected to the TLE987x EvalKit and the EvalKit is powered up
- An oscilloscope or scope capable of measuring the phase currents with three current probes connected to measure the currents on each motor phase

*Note: The provided example project is configured for the reference application motor, which is the QBL4208-61-04-013. Refer to the datasheet of this motor and in the ConfigWizard to understand how to enter the parameters from the datasheet in the ConfigWizard.*

## 2.2 Software requirements

For the evaluation of the TLE987x-eSL-BAS Motor Control Library using the demo software example, the following software tool chain in MS Windows is required:

- Arm® Keil® µVision®5, an integrated development environment (IDE)
- Infineon Embedded Power SDK (LLD) integrated in Keil® µVision®5
- Segger J-Link Driver
- Infineon ConfigWizard installed in Infineon Toolbox

How to achieve the software prerequisites is described in Appendix A.3.

# 3 Steps to get a motor running in FOC mode

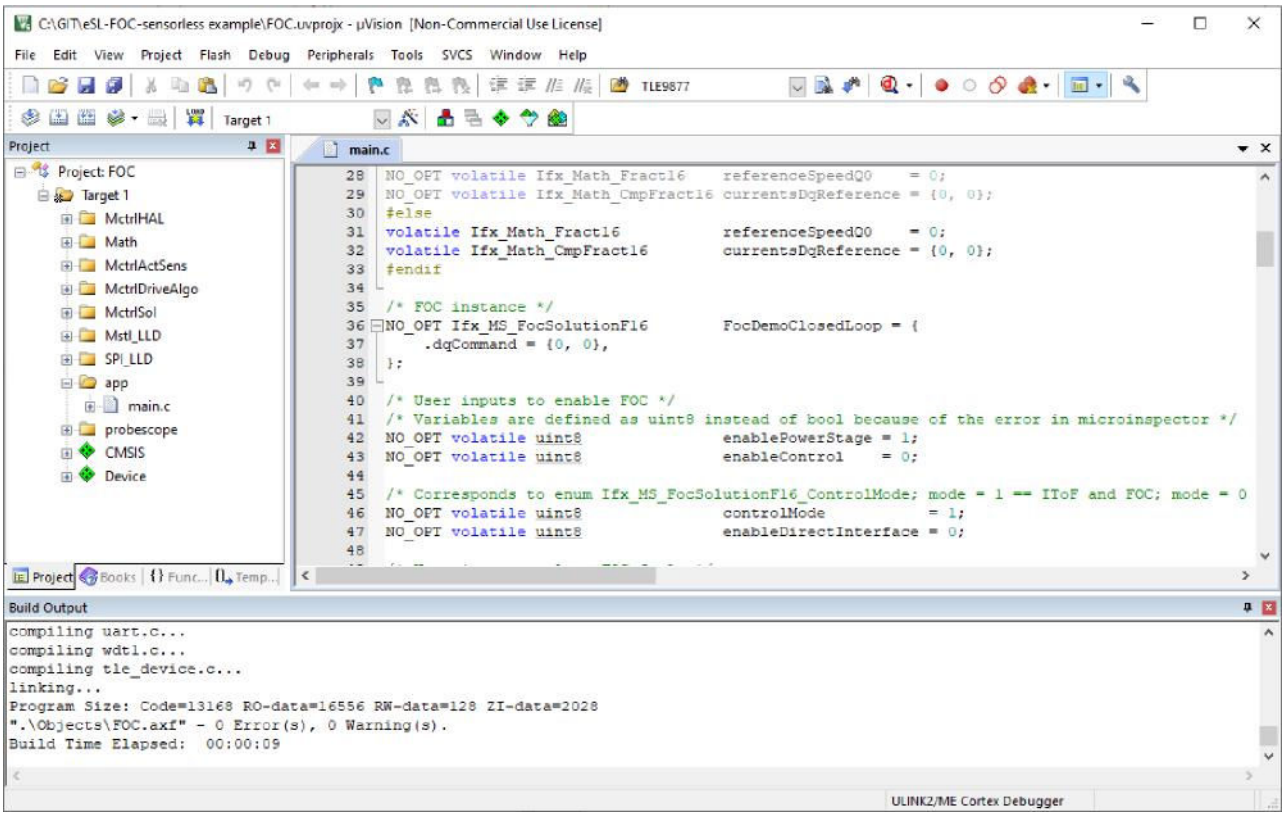
**Before you begin**

The preconditions described in Prerequisites are fulfilled.

**Steps**

1. Load the provided application software example project FOC.uvprojx in Keil® µVision® 5: Click **Project > Open Project** and select `FOC.uvprojx`.
2. Configure the motor parameters in the ConfigWizard:
   a. In Keil® µVision® 5, click **Tools > ConfigWizard V2.6.4**.
   b. In the ConfigWizard, select the **MCTRL Solution** tab.
   c. Provide the following parameters with values according to the connected motor. The parameters with the most important influence are:
      - **System base voltage**: the maximum voltage that can be represented in the software
      - **System base current**: the maximum current that can be represented in the software
      - **System base mechanical speed**: the maximum motor rotation speed that can be represented in the software
      - **Phase resistance**: phase resistance is equal to half of the line-to-line resistance, no matter if it is delta connection or star connection
      - **Phase inductance**: phase inductance in d axis and in q axis
      - **Number of pole pairs**: the number of motor pole pairs
      - **Start-up current**: the current required for the motor to start turning
   d. Configure the CSA gain. If the power class of the motor used in the application differs from the standard motor, then the maximum current is different. In this case the CSA gain needs to be configured in order to achieve measurement of the maximum phase current with sufficient resolution. For information on how to adjust the CSA gain, please consult the user manual of the TLE987x target device.
   e. Save the configuration: In ConfigWizard, click **File > Save**.
   By saving the configuration, `<swc>_defines.h` files are generated for each software component (abbreviated as SWC) in the `RTE\Device\TLE987xXXXXX` directory.
3. Build the Keil® µVision® 5 project: **Click Project > Build Target**.
   The project compiles successfully (0 errors, 0 warnings).

## 3 Steps to get a motor running in FOC mode

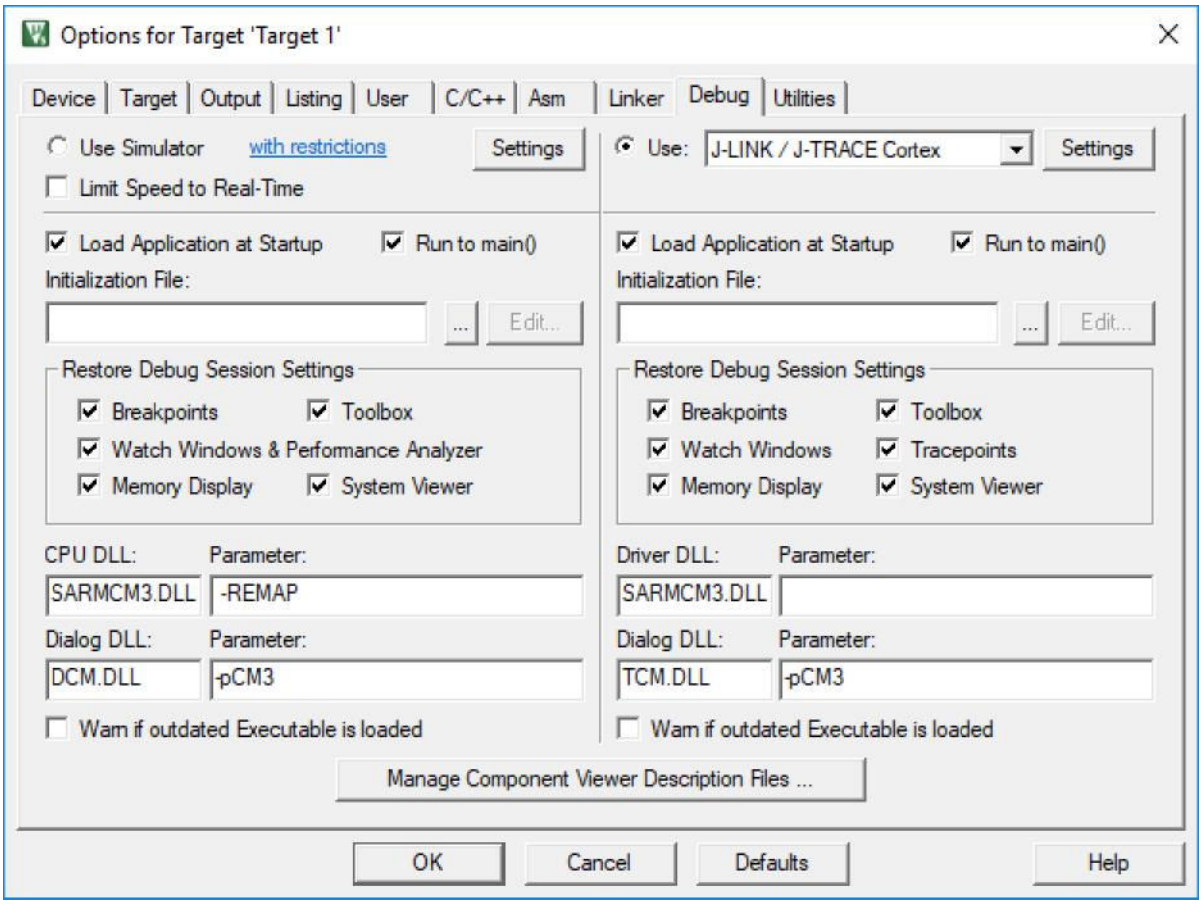



The next steps describe how to connect to the target create a software development basis for a motor control application in a compilable Keil® µVision®5 project. This involves integrating the Motor Control Software Libraries BASIC for TLE987x, configure the project settings, and generate the static configuration files.

**4.** Configure the connection from Keil® µVision®5 to the target device to use J-LINK / J-TRACE Cortex.

**a.** In Keil® µVision®5, click **Project > Options for Target**.

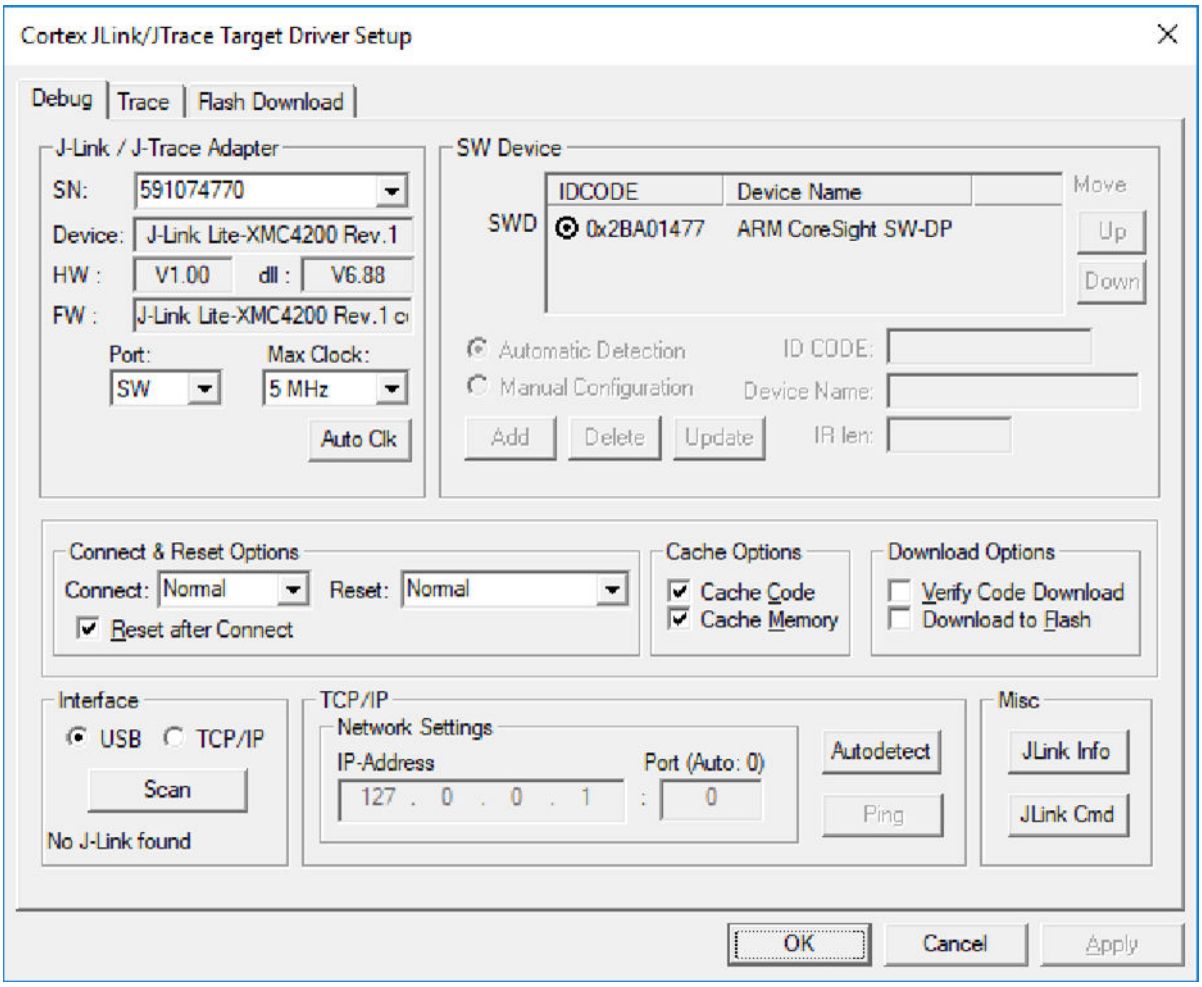
## 3 Steps to get a motor running in FOC mode




**b.** Open the J-Link Target Driver Setup Window, in the options windows, click **Settings**.

**c.** Configure the **Port** to SW.

## 3 Steps to get a motor running in FOC mode




**d.** In the drop-down menu under **Port**, select the entry **SW**.
The indication that the connection was successful is when the IDCODE of the device gets displayed in the SW device section.

**e.** In order to test the connection to the target, click on **Scan**.
Below the button, the result of the scan is shown.

**5.** In Keil® µVision®5, download the compiled code to the target flash memory: **Flash > Download (F8)**.

**6.** In the debugger watch window:

**a.** The software runs in debug mode on the target device.

**b.** Click **Enable power stage** to put it to **ON**.

**c.** Click **Enable Control** to put it to **ON**.

**d.** Set the reference speed.

### Results

The motor should start turning, controlled by the compiled Motor control software library software in FOC mode.

The "Estimated speed" graph (speed estimated based on current measurement) should follow the "Rate limited speed" (Ref. speed).

If the motor does not start or does not turn as expected, see Troubleshooting.

# 4 Troubleshooting

**Table 2 Toubleshooting**

| Trouble | Possible root cause | Solution |
|---|---|---|
| Project does not build successfully | Older version of the ConfigWizard | Use ConfigWizard V2.6.4 |
| Motor does not turn at all or motor does not turn as expected | The motor parameters are not configured optimally | Make sure that the motor parameters are correct (especially if the motor parameters were not updated, the per defaults used according to the reference motor may not fit). Ideally the motor phase resistance, motor phase inductance should be measured, the motor start-up current should be identified, and the measured and identified motor parameters should be updated in the configuration |
| | The connection between EvalKit and motor might be faulty or the current sensing might be faulty | In order to prove the HW setup, the reference application motor QBL4208-61-04-013 can be used |
| | | Alternatively, switch to V-to-F mode, check the phase currents with the oscilloscope and check the measured currents by CSA module. Details are provided in Appendix A.2 |

# A Appendix

## A.1 main.c and control variables

### Structure of the main.c

The main.c integrates the software components of the Motor Control Software Libraries BASIC for TLE987x and it is structured in the following sections:

- Includes: required dependencies
- Control variables: variables used to configure and re-configure the software application parameters during execution
- Control defines: configuration of software application parameters at compilation step
- Counter variables: variables used to view internal data, like rotor alignment attempts, control loop execution steps, etc.
- Interrupt subroutines: function called at interrupts
- Initialization: the initialization APIs of the software components used are integrated at the beginning of the main() function
- Cyclic execution loop: the cyclic execute() APIs of the software components are integrated in an endless loop in the main() function

**Table 3 Control variables**

| Name | Description | Default value |
|---|---|---|
| referenceSpeedQ0 | Set the demanded motor rotation speed in rpm | 0 rpm |
| currentsDqReference | Configures the reference currents:<br>• CurrentsDqReference.real: D-current reference<br>• CurrentsDqReference.imaginary: Q-current reference | {0 A, 0 A} |
| FocDemoClosedLoop.dqCommand | Current command, in d-q reference frame:<br>• FocDemoClosedLoop.dqCommand.real: D-current command<br>• FocDemoClosedLoop.dqCommand.imaginary: Q-current command | {0 A, 0 A} |
| enablePowerStage | Enables or disables the power stage based on the value:<br>• 0: Disabled<br>• 1: Enabled | Enabled |
| enableControl | Enables or disables the speed control under conditions that are managed by a state-machine:<br>• Angle estimation is either disabled or it is done<br>• There are no active faults<br>• Power stage is enabled<br>Based on the value:<br>• 0: Disabled<br>• 1: Enabled | Disabled |
| controlMode | Selects one of the two available control modes:<br>• 0: Executes voltage-to-frequency control (V-to-F)<br>• 1: Executes field oriented control (FOC) | FOC |

**(table continues...)**

**Table 3 (continued) Control variables**

| Name | Description | Default value |
|---|---|---|
| enableDirectInterface | Enables or disables the direct currents (DQ) command based on the value:<br>• 0: Disabled<br>• 1: Enabled | Disabled |
| clrFaultFoc | User input to clear FOC fault:<br>• 0: No input<br>• 1: Clear fault command | 0 |
| enableSpeedPreControl | Enables or disables the speed precontrol based on the value:<br>• 0: Disabled<br>• 1: Enabled | Disabled |
| enableStartAngleIdent | User input to enable start angle identification:<br>• 0: No request<br>• 1: Request to start angle identification | 0 |

## A.2 Steps to get a motor running in V-to-F mode

The V-to-F mode can be used in order to simplify the use case when a motor in FOC is not running:

- Generate sinusoidal phase currents of constant amplitude at desired constant rotation speed in order to measure them on the oscilloscope
- Check that the phase currents measured by the CSA and available in the software variables are consistent Or it can be used as simpler method to turn a motor

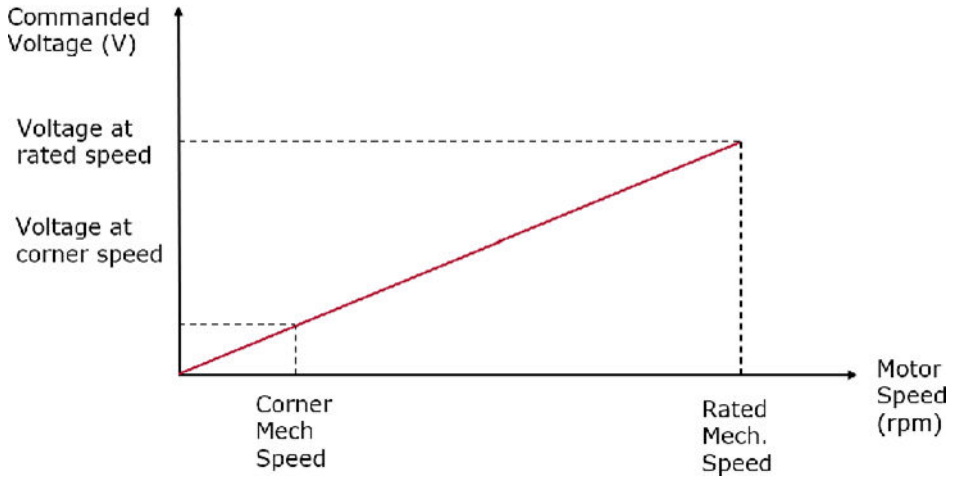
The switch to V-to-F can be done without any re-flash of the target, but if the V-to-F characteristic parameters do not match to the motor, then these parameters must be configured in the ConfigWizard, saved, and the code must be rebuilt and the target must be re-flashed.

**Steps**

1. Configuring the V to F parameters to fit to the target motor: In ConfigWizard, in **MCTRL Drive algorithm > V/f**, adjust the parameters:
   a. **Rated mechanical speed**: this parameter should be chosen according to the motor's datasheet.
   b. **Rated voltage**: this parameter should be chosen according to the motor's datasheet.
   c. **Corner mechanical speed**: this parameter can be estimated and set as approximately 10% of the of the rated speed.
   d. **Corner voltage**: This parameter can be calculated by linear interpolation using rated speed and rated voltage as pictured by the figure below The figure illustrates the linear interpolation of the voltage at corner speed.

      The following figure shows the linear interpolation of the voltage at corner speed:

## A Appendix




**e.** **Voltage at minimum speed**: This parameter helps increasing the amplitude of the phase current at low motor speeds, in addition to the corner voltage and corner speed. A bit higher current is sometimes necessary in order to start the motor, which would require a higher voltage at a low speed, starting with 0 rpm.

**2.** Once the parameters are configured in the ConfigWizard, update the parameters on the target:

**a.** Press **Save** (in the ConfigWizard) to generate the new configuration files.

**b.** Rebuild the project in Keil® µVision® 5.

**c.** Download the code to target and start debug session (in Keil® µVision® 5).

**3.** Switching to V-to-F control mode in the Keil debugger window:

**a.** The software runs in debug mode on the target evaluation board.

**b.** Switch **Enable Control** to `OFF`.

**c.** Click on the button **Control Mode** The indicator changes to `VToF`.

**d.** Switch **Enable Control** to `ON`.

**e.** Shift the **Ref. Speed (rpm)** slider slowly upwards until reaching the desired reference speed.

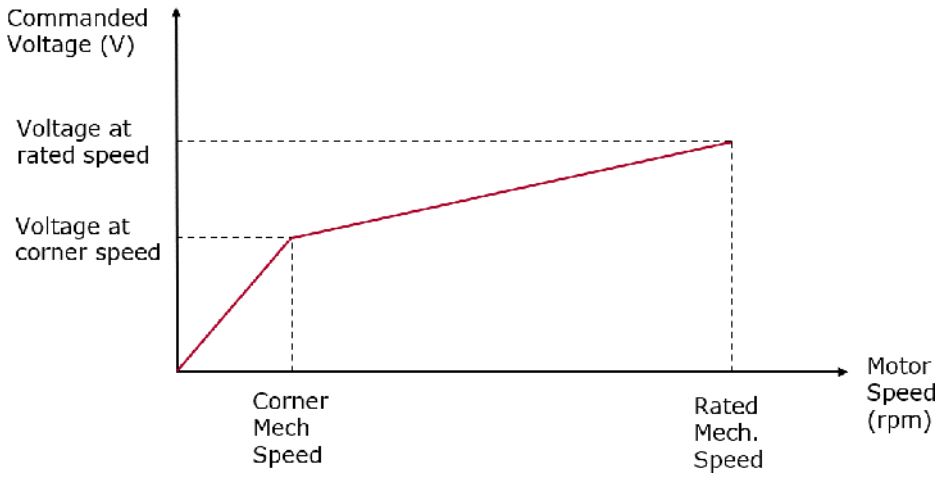
Then the

- Motor starts turning
- Phase currents measured by the current probes should have a sinusoidal shape (as much as permitted by the disturbance due to the induced currents by a turning rotor) on the scope
- DC current consumption on the DC power supply should not be too high, that means according to the characteristics of the motor used

If the motor does not start turning, check if the phase currents amplitude is sufficient to start the motor. If this amplitude is not sufficient, it can be increased by increasing the voltage at minimum speed and the voltage at corner speed.

The following figure shows the increased voltage at corner speed:

## A Appendix




If the currents are not sufficient, increase the voltage at corner speed and return to Step 2.

If the currents have a sufficient sinusoidal shape and the amplitude of the currents is sufficient to start the motor and the motor still does not turn as expected, then the connection to the motor is the cause and it should be debugged. Otherwise, if the currents are not generated as expected, then the configuration of the bridge driver, the pattern generator and the modulator have to be debugged.

## A.3 Toolchain installation

### A.3.1 Overview of the toolchain installation

**Table 4 Toolchain installation overview**

| Toolchain installation steps | | Supplier | Description |
|---|---|---|---|
| Step 1 | Download and install Keil® µVision® 5 | | Arm® Keil® µVision® 5 is an integrated development environment which consists of code editor, compiler and debugger.<br>The evaluation version can handle up to 32 kB code size |
| Step 2 | Download and install Infineon Toolbox | | The Infineon Toolbox provides tools and configuration programs to use Infineon devices |
| Step 3 | Install the ConfigWizard | | Configuration tool for static configuration |
| Step 4 | Download and install Segger J-Link Driver J-Link Driver | | Driver for on-board or stand-alone debugger |
| Step 5 | Download the SDK via Keil® µVision® 5 PackInstaller<br>(See step 1) | | Device database for TLE987x:<br>Device support for flashing/erasing SFR description for register debugging.<br>Device description for the ConfigWizard.<br>Includes SDK (Software Development Kit).<br>Example code included |

A detailed guide for toolchain installation steps is provided in the following chapter.

*Note: To improve performance:*

- *Use O3 optimization and*
- *Enable link-time optimization (LTO) (only possible if you have a Keil® license)*

## A.3.2 Steps to install the toolchain

The toolchain must be installed on a Windows computer.

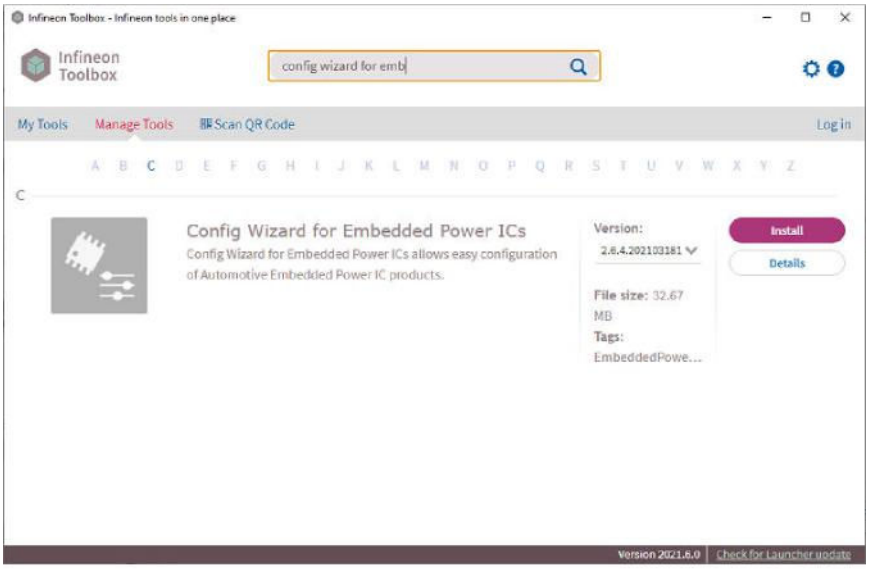
**Steps**

1. Download Keil® µVision®5.
   Download it from: https://www.keil.com/demo/eval/arm.htm.




2. Install the Infineon Toolbox and start the tool.
   For more details about the Infineon Toolbox installation, please read the Installation manual.
   Within the Infineon Toolbox:

   **a.** Select the tab **Manage tools**, search for **Config Wizard for Embedded Power ICs** and click **Install**.




   **b.** Start the ConfigWizard once to trigger the integration into Keil® µVision®5.

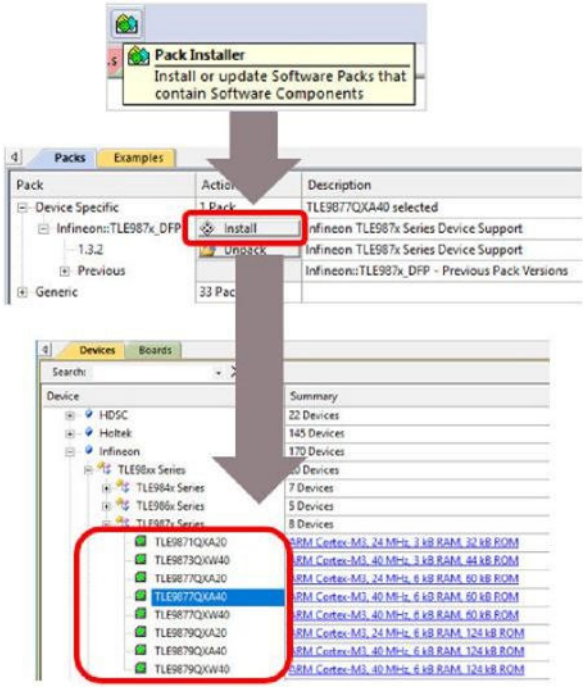



   **c.** Close the ConfigWizard and the toolbox.

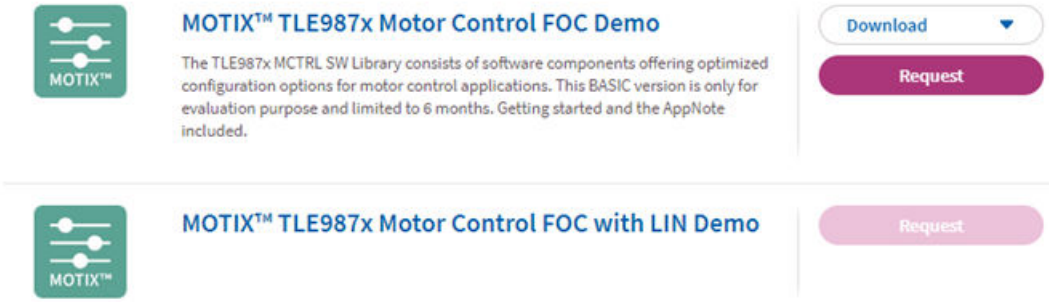
## A Appendix

**3.** 3. Install the Segger J-Link LITE driver.
Download it from: https://www.segger.com/downloads/jlink/JLink_Windows.exe

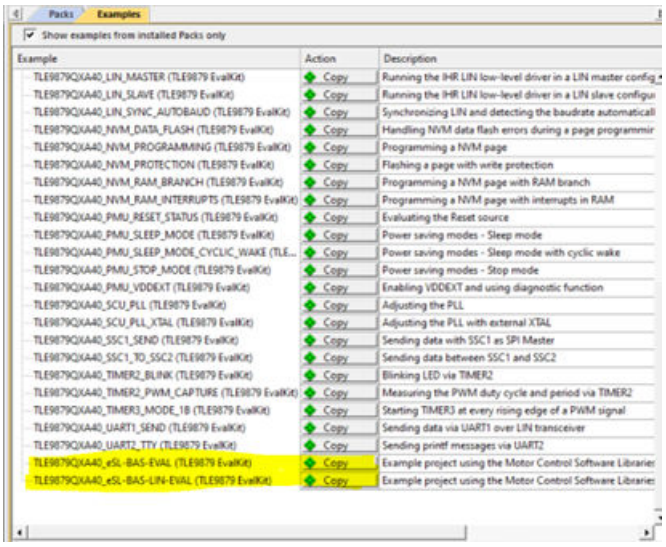
**4.** In Keil® µVision®5, load the pack-file SDK-TLE987x_v1.5.0 (2021-06-30).




**5.** Download the latest software from the Infineon developer center. The LIN Demo software is also available for download.




**6.** Extract the zip file. The MOTIX™ software will be automatically added to the example programs.

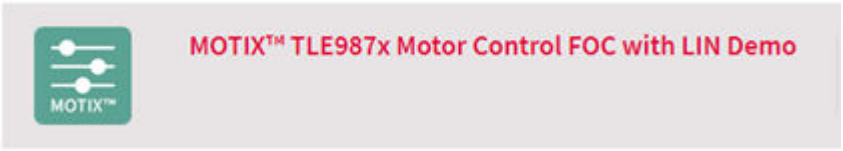



## A.3.3 Steps to get a motor running in FOC LIN mode

The MOTIX™ FOC LIN Demo as a slave works along with the LIN master example from the SDK.

**Steps**

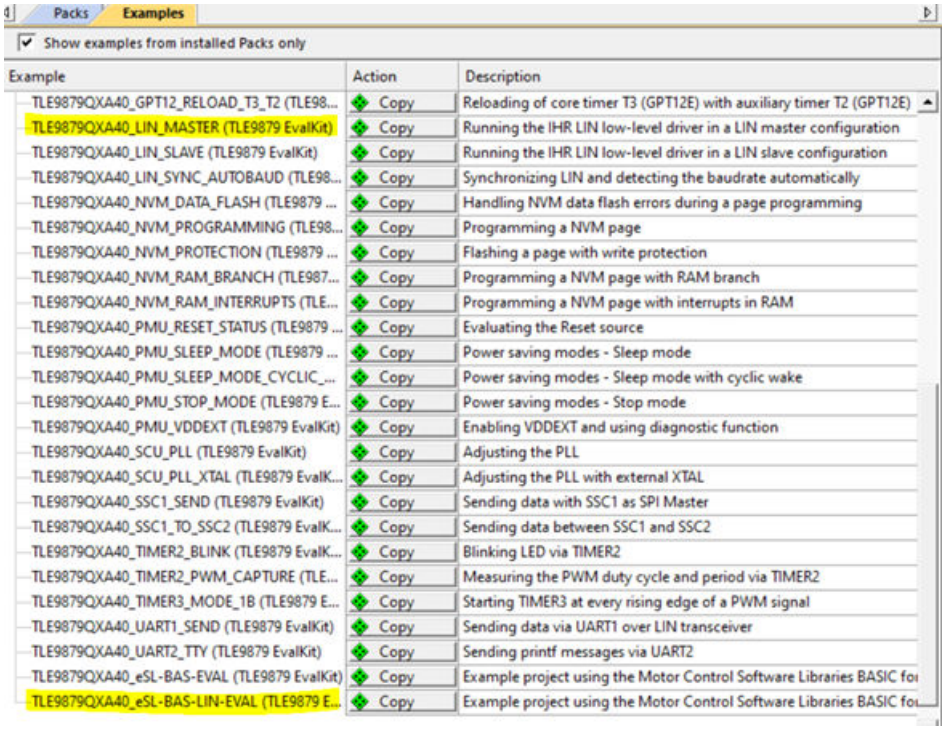
**1.** Download the MOTIX™ FOC LIN Demo software from Infineon developer center.




**2.** Two TLE987x EvalKits (evaluation boards) are needed: one for master, one for FOC LIN slave.

**a.** Flash the LIN master software to one TLE987x board.

**b.** Flash the FOC LIN software to the other TLE987x board.

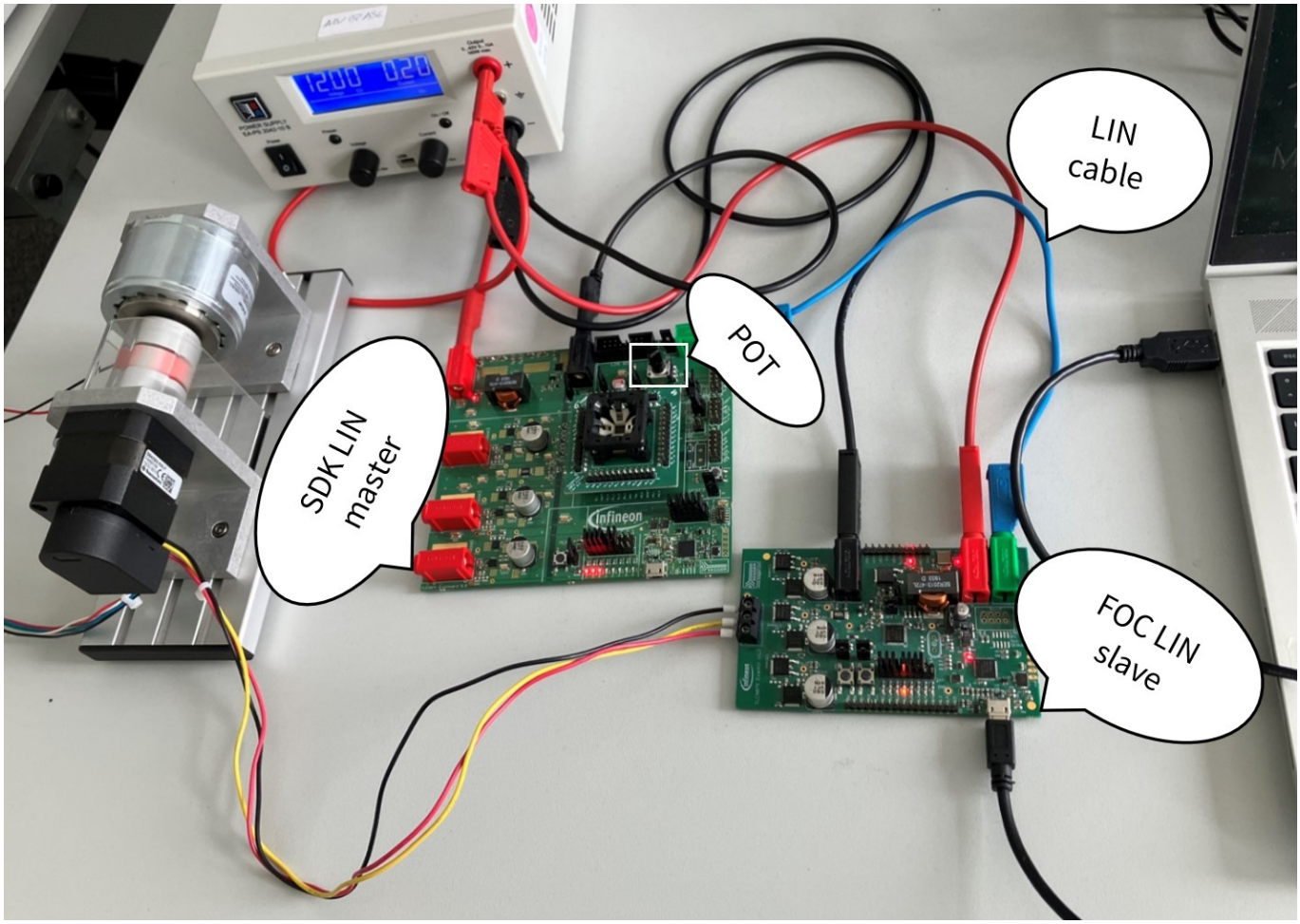


**c.** Connect a cable from the master LIN port to the slave LIN port to establish the LIN communication.

**d.** If you change (rotate) the potentiometer value on the LIN master board, the LEDs on the master board glow sequentially depending on the POT value (if the POT value is maximal, all LED's glow on the master LIN board).

*Note: If the LIN master or slave are not responding, reset the controller and watch the reference speed and the POT value in the debugger window.*

**Hardware setup**



# Revision history

| Document version | Date of release | Description of changes |
|---|---|---|
| Rev. 1.01 | 2023-11-17 | Updated release number and version |
| Rev. 1.0 | 2023-07-21 | Initial version |

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