GUI Quick Start Guide: InstaSPIN UNIVERSAL

Version 1.0.1 *Motor Solutions*

Overview

InstaSPIN UNIVERSAL is a GUI Composer developed GUI that allows you to instrument and interact over a JTAG connection with an appropriate MotorWare generated target binary (.out) to evaluate InstaSPIN™-FOC on an appropriate Piccolo MCU. GUI Composer is included with latest CCStudio IDE installations.

Supports:

- Piccolo InstaSPIN enabled controllers
    - LAUNCHXL-F28027F LaunchPad for InstaSPIN-FOC
        - Includes on-card XDS100v2 JTAG (isolated)
    - TMDSCNCD28027F controlCARD for InstaSPIN-FOC
        - Does NOT include on-card emulation or isolation
        - Note that you will have to select the XDS100v1 emulator when executing the GUI
    - TMDSCNCD28069MISO controlCARD for InstaSPIN-FOC and InstaSPIN-MOTION
        - Includes on-card XDS100v2 JTAG (isolated)
- Any InstaSPIN enabled Piccolo devices on custom hardware with a JTAG connection

- 3-phase Inverters
    - The GUI itself has no dependence on the inverter
    - Build an appropriate MotorWare binary using the supplied board/inverter specific projects
    - Build a MotorWare based binary for your own custom inverter

Version: 1.0.1

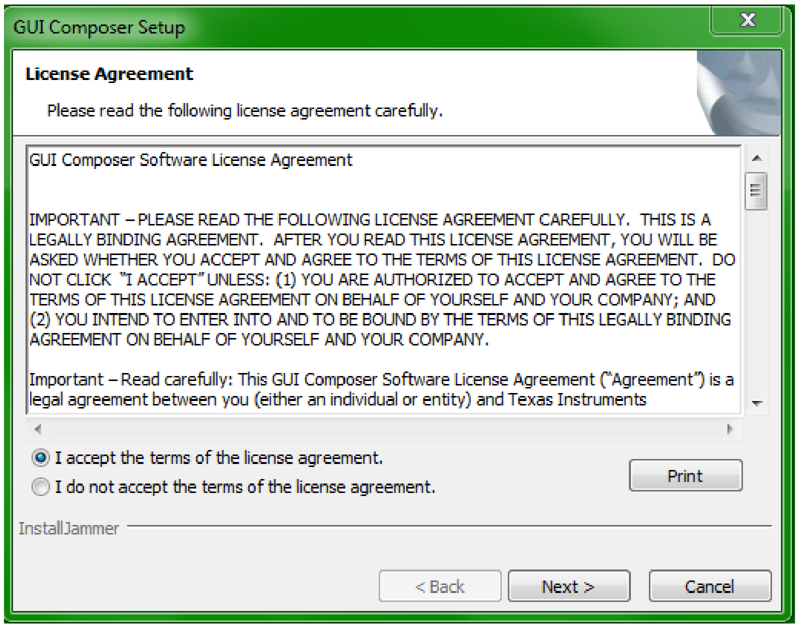
Revision History:

1.0.1	**October 30, 2013**	**First release**

Table of Contents

Installation

1. Run the UNIVERSAL GUI installation .exe using the latest version from http://www.ti.com/tool/instaspinfocmotorwaregui
   a. Accept the license agreement



License Agreement

Please read the following license agreement carefully.

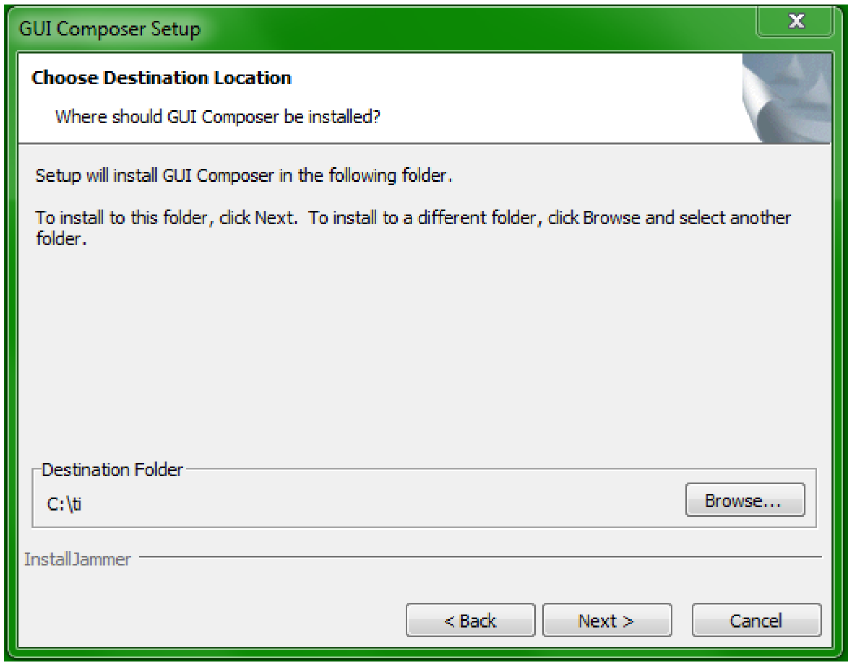
GUI Composer Software License Agreement

IMPORTANT – PLEASE READ THE FOLLOWING LICENSE AGREEMENT CAREFULLY. THIS IS A LEGALLY BINDING AGREEMENT. AFTER YOU READ THIS LICENSE AGREEMENT, YOU WILL BE ASKED WHETHER YOU ACCEPT AND AGREE TO THE TERMS OF THIS LICENSE AGREEMENT. DO NOT CLICK "I ACCEPT" UNLESS: (1) YOU ARE AUTHORIZED TO ACCEPT AND AGREE TO THE TERMS OF THIS LICENSE AGREEMENT ON BEHALF OF YOURSELF AND YOUR COMPANY; AND (2) YOU INTEND TO ENTER INTO AND TO BE BOUND BY THE TERMS OF THIS LEGALLY BINDING AGREEMENT ON BEHALF OF YOURSELF AND YOUR COMPANY.

Important – Read carefully: This GUI Composer Software License Agreement ("Agreement") is a legal agreement between you (either an individual or entity) and Texas Instruments

[✓ I accept the terms of the license agreement.]
I do not accept the terms of the license agreement.

   b. Recommended to keep default destination location



Choose Destination Location

Where should GUI Composer be installed?

Setup will install GUI Composer in the following folder.

To install to this folder, click Next. To install to a different folder, click Browse and select another folder.

Destination Folder: C:\ti

2. Install Code Composer Studio v5.5+ from http://processors.wiki.ti.com/index.php/Download_CCS

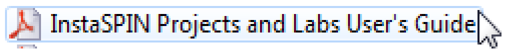
Hardware Set-up

1. Please review the quick start and/or hardware guides for your particular controlCARD / LaunchPad and motor drive kit – available through MotorWare - for details of hardware set-up, including jumper and switch settings

Overview of Process for using the GUI

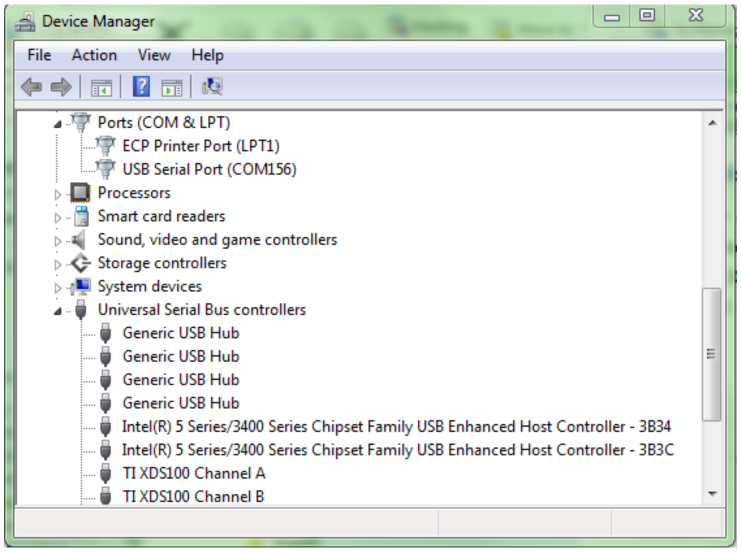
1. Create Binary from MotorWare Project using CCStudio
2. Launch GUI Composer UNIVERSAL GUI using either method:
    a. Standalone
    b. Inside of CCStudio

Create Binary

1. **This GUI only allows you to instrument bound variables that exist in the compiled .out that will be loaded onto the Piccolo MCU**
   a. Variables that you interact with are primarily in the gMotorVars structure
   b. A variable existing in gMotorVars does NOT mean that the variable is being used in the source project
      i. Ex: the ability to change the Speed Kp is not made available until proj_lab05b
         1. CTRL_setKp(ctrlHandle,CTRL_Type_PID_spd,gMotorVars.Kp_spd);
      ii. If you compile and load proj_lab03.c do not be surprised when changing Speed Kp has no effect!!
   c. Insure variables you want to instrument are actually interfaced to in the .c that is compiled. Doing a text search in the .c for the gMotorVars.xxxx will tell you if it is being updated in that project.
2. **You must use CCStudio to compile an appropriate MotorWare project into a .out**
   a. CCS version and compiler version notes
      i. CCS (download)
         1. For using the GUI inside of CCS GUI Composer you must use CCSv5.5+
         2. If not using the GUI inside of CCS you may use CCSv5.4
      ii. Compiler (download or through Help → Check for Updates)
         1. Recommend 6.2.3+, or if necessary version 6.1.5
         2. Do NOT use compiler versions 6.2.2 or 6.2.1, they include an IQMath compiler bug
3. **You should select the MotorWare project that meets your application needs**
4. **This project should be built with the appropriate user.h settings selected**
   a. It is recommended to follow the InstaSPIN Projects & Labs User's Guide in MotorWare
   
   InstaSPIN Projects and Labs User's Guide
   b. See the "Use Example" section of this document for a quick overview and example

GUI Connection

1. With the DC bus powered, connect USB from your PC to J1 on controlCARD
2. If using the high voltage kit, proceed with connecting to the target before energizing the high voltage AC input (110-220Vac) or high voltage DC Bus (50-350Vdc)
3. You can verify that you connected to the FTDI XDS100v2 emulator by checking your Windows Device Manager for Ports: USB Serial Port (COMxxx) and TI XDS100 Channel A and B

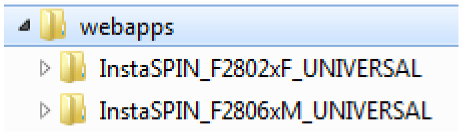


```
Ports (COM & LPT)
    ECP Printer Port (LPT1)
    USB Serial Port (COM156)
Processors
Smart card readers
Sound, video and game controllers
Storage controllers
System devices
Universal Serial Bus controllers
    Generic USB Hub
    Generic USB Hub
    Generic USB Hub
    Generic USB Hub
    Intel(R) 5 Series/3400 Series Chipset Family USB Enhanced Host Controller - 3B34
    Intel(R) 5 Series/3400 Series Chipset Family USB Enhanced Host Controller - 3B3C
    TI XDS100 Channel A
    TI XDS100 Channel B
```

Running the GUI

Standalone GUI .exe

1. Two “webapps” are provided during installation at C:\ti\guicomposer\webapps



webapps
InstaSPIN_F2802xF_UNIVERSAL
InstaSPIN_F2806xM_UNIVERSAL

   a. The only difference between the content of these two folders is the “.appsetting” file, which assigns the default MCU, Emulator, and points to the .out to be programmed.

      i. Default XDS100v2 emulator, F28069 or F28027 MCU, appProgram.out

   b. All other content in the folders is 100% identical

2. **The compiled .out that you have built must be renamed appProgram.out and copied to the appropriate webapp folder**

   a. Note: If you plan to use the standalone GUI often with a new compile from a single project you can update the default naming of “appProgram.out” to anything you like (ex: “proj_lab05b.out” or “my_project.out”) to save yourself having to rename the file each time.

      i. Use a text editor to update the .appsettings file

3. Run the executable from the webapp folder: **InstaSPIN_UNIVERSAL.exe**

4. The GUI Composer application will start

5. GUI Composer will initialize, then:

   a. attempt to connect through the XDS100v2 emulator

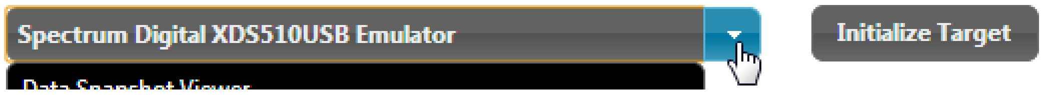
   b. to the Piccolo device

   c. load \appProgram.out into the memory of the Piccolo device.

      i. a, b, c are all specified in .appsettings and may be permanently changed if required by using a text editor

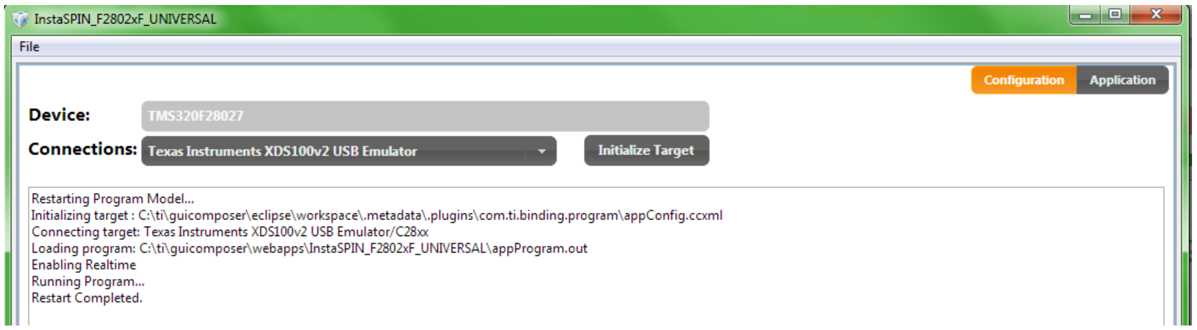
d. If you are using a different emulator the connection will fail

i. you can permanently change the default emulator in the .appsettings file or select the appropriate one from the drop-down menu and then click Initialize



6. This launching process should take less than 1-3 minutes

   a. In rare cases we have seen it take an usually long amount of time. This is likely due to software running on your PC that is redirecting HTTP or browser sockets. Try to disable any software of this type.



Device: TMS320F28027

Connections: Texas Instruments XDS100v2 USB Emulator

```
Restarting Program Model...
Initializing target : C:\ti\guicomposer\eclipse\workspace\.metadata\.plugins\com.ti.binding.program\appConfig.ccxml
Connecting target: Texas Instruments XDS100v2 USB Emulator/C28xx
Loading program: C:\ti\guicomposer\webapps\InstaSPIN_F2802xF_UNIVERSAL\appProgram.out
Enabling Realtime
Running Program...
Restart Completed.
```

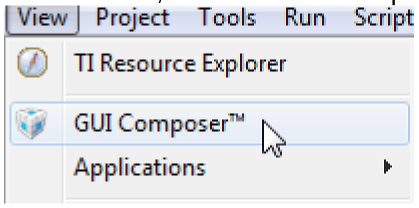
Configuration Tab of a successful GUI Launch

GUI inside CCStudio IDE

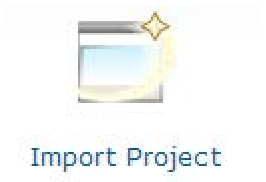
1. Zip one of the “webapps” folders, ex:

   a. C:\ti\guicomposer\webapps\InstaSPIN_F2802xF_UNIVERSAL

2. In CCSv5.5+, VIEW → GUI Composer



3. Select Import Project Icon, and point to the Zip you created



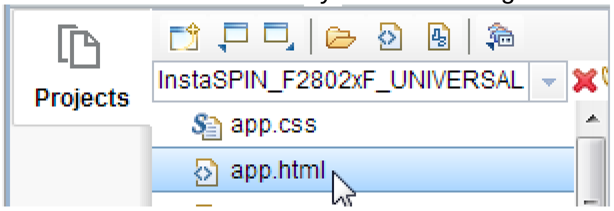
   a.

4. This will create a webapp folder in your CCS workspace

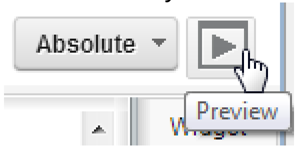
   a. You select this location each time you start CCStudio

b. ex: C:\workspace\.GUIComposerWS\InstaSPIN_F2802xF_UNIVERSAL

5. The GUI can be selected by double clicking on the Projects app.html file:



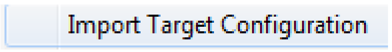
6. The GUI opens in edit mode. To view in preview mode (interact like it is a standalone GUI) select the Play arrow:



7. To use the GUI in CCS you still need to follow the steps that are done automatically by the standalone .exe

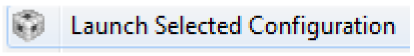
   a. Import an emulation+cpu “Target Configuration”

      i. View → Target Configurations

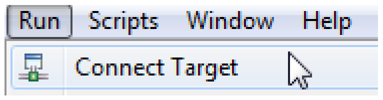
      ii. Right Click → 

      iii. \sw\ide\ccs\ccs5\targetConfigs\TMS320F28027_xds100v2.ccxml

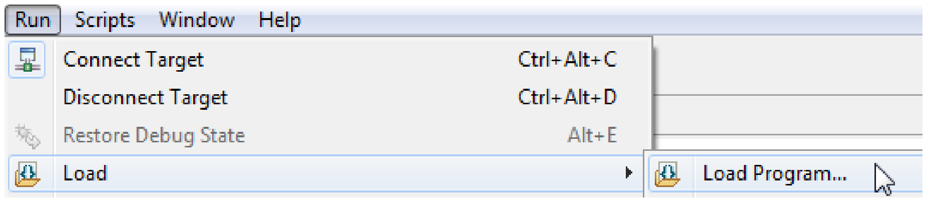
   b. Launch deubg session

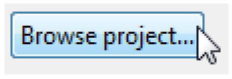
      i. Right Click on the .ccxml file → 

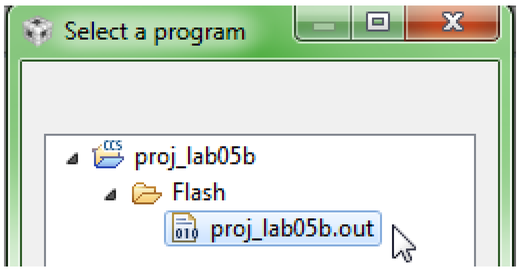
   c. Connect target

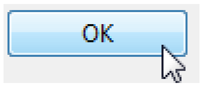
      i. 

   d. Load compiled .out Program (or symbols if program is already in MCU flash)

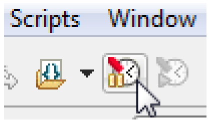
      i. 
Run
Scripts
Window
Help
Connect Target Ctrl+Alt+C
Disconnect Target Ctrl+Alt+D
Restore Debug State Alt+E
Load
Load Program...

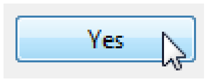
      ii. 

iii. 

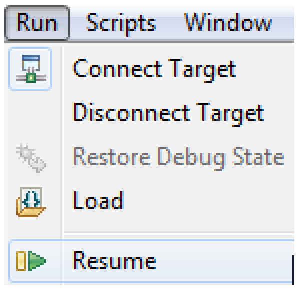
iv. 

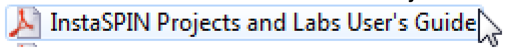
e. Enable silicon realtime mode

i. 

ii. To enable realtime mode select 

f. Run → Resume

i. 

g. See the MotorWare InstaSPIN Projects and Labs User's Guide for more details: 

8. You can now use the GUI to instrument the code running on the MCU

9. For details on how to customize this GUI, create your own, or export for standalone use please see the GUI Composer Wiki Site.

Use Example

Controller: LAUNCHXL-F28027F

Inverter: BOOSTXL-DRV8301

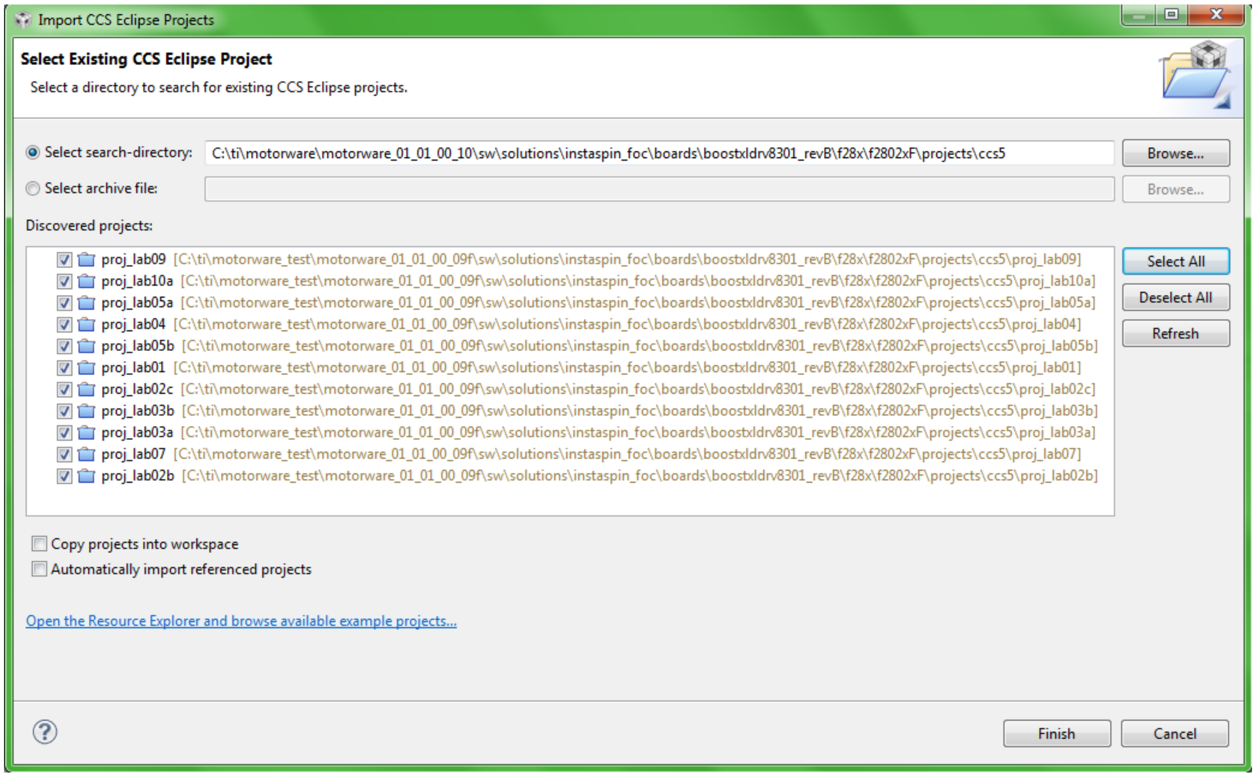
Motor: Anaheim Automation BLY172S-24V-4000: 24V, 8 poles, 4K RPM

Hardware Set-up

- Per the Kit Readme First and HW Guide Documents, set-up hardware
  - Example for LAUNCHXL-F28027F and BOOSTXL-DRV8301
  - LaunchPad
    - Removed JP1, 2, 3 so power can come from BoosterPack
    - S1 set to ON-ON-ON to allow JTAG
    - S4 set to OFF to allow LaunchPad to drive the BoosterPack Fault LEDs
  - BoosterPack
    - Motor phase wires connected (order only effects direction of motor)
    - DC power with appropriate 6-24V bus and up to 14A peak currents

Software Projects

- In CCS, Projects → Import → and point to the latest version of the MotorWare "CCS5" directory for your combination of solution, board, and MCU
  Ex: InstaSPIN_FOC, the BoosterPack, F2802xF
  C:\ti\motorware\motorware_01_01_00_10\sw\solutions\instaspin_foc\boards\boostxldrv8301_revB\f28x\f2802xF\projects\ccs5


Import CCS Eclipse Projects

Select Existing CCS Eclipse Project

Select a directory to search for existing CCS Eclipse projects.

[✓ Select search-directory:] C:\ti\motorware\motorware_01_01_00_10\sw\solutions\instaspin_foc\boards\boostxldrv8301_revB\f28x\f2802xF\projects\ccs5

Select archive file:

Discovered projects:

- ✓ proj_lab09 [C:\ti\motorware_test\motorware_01_01_00_09f\sw\solutions\instaspin_foc\boards\boostxldrv8301_revB\f28x\f2802xF\projects\ccs5\proj_lab09]
- ✓ proj_lab10a [C:\ti\motorware_test\motorware_01_01_00_09f\sw\solutions\instaspin_foc\boards\boostxldrv8301_revB\f28x\f2802xF\projects\ccs5\proj_lab10a]
- ✓ proj_lab05a [C:\ti\motorware_test\motorware_01_01_00_09f\sw\solutions\instaspin_foc\boards\boostxldrv8301_revB\f28x\f2802xF\projects\ccs5\proj_lab05a]
- ✓ proj_lab04 [C:\ti\motorware_test\motorware_01_01_00_09f\sw\solutions\instaspin_foc\boards\boostxldrv8301_revB\f28x\f2802xF\projects\ccs5\proj_lab04]
- ✓ proj_lab05b [C:\ti\motorware_test\motorware_01_01_00_09f\sw\solutions\instaspin_foc\boards\boostxldrv8301_revB\f28x\f2802xF\projects\ccs5\proj_lab05b]
- ✓ proj_lab01 [C:\ti\motorware_test\motorware_01_01_00_09f\sw\solutions\instaspin_foc\boards\boostxldrv8301_revB\f28x\f2802xF\projects\ccs5\proj_lab01]
- ✓ proj_lab02c [C:\ti\motorware_test\motorware_01_01_00_09f\sw\solutions\instaspin_foc\boards\boostxldrv8301_revB\f28x\f2802xF\projects\ccs5\proj_lab02c]
- ✓ proj_lab03b [C:\ti\motorware_test\motorware_01_01_00_09f\sw\solutions\instaspin_foc\boards\boostxldrv8301_revB\f28x\f2802xF\projects\ccs5\proj_lab03b]
- ✓ proj_lab03a [C:\ti\motorware_test\motorware_01_01_00_09f\sw\solutions\instaspin_foc\boards\boostxldrv8301_revB\f28x\f2802xF\projects\ccs5\proj_lab03a]
- ✓ proj_lab07 [C:\ti\motorware_test\motorware_01_01_00_09f\sw\solutions\instaspin_foc\boards\boostxldrv8301_revB\f28x\f2802xF\projects\ccs5\proj_lab07]
- ✓ proj_lab02b [C:\ti\motorware_test\motorware_01_01_00_09f\sw\solutions\instaspin_foc\boards\boostxldrv8301_revB\f28x\f2802xF\projects\ccs5\proj_lab02b]

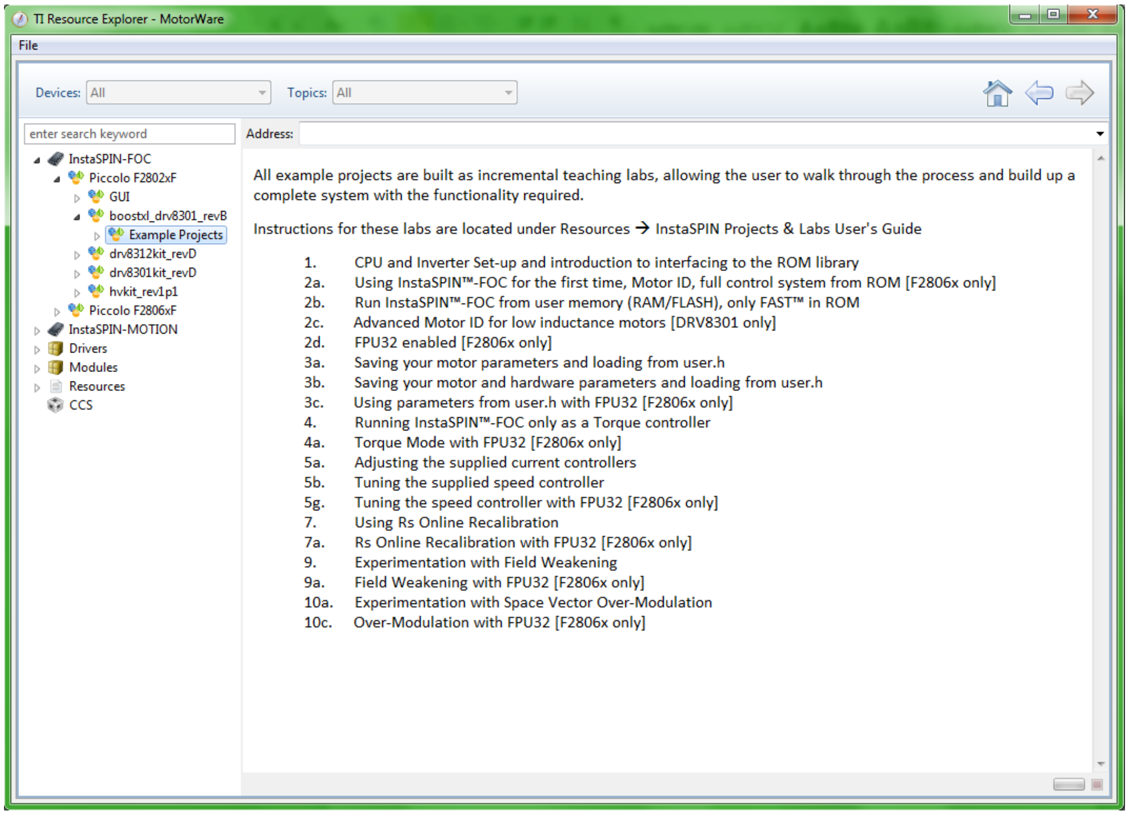
Copy projects into workspace

Automatically import referenced projects

Open the Resource Explorer and browse available example projects...

  - You may select any or all of the projects
    - Make sure you do NOT select to "Copy projects into workspace" or the project will not find appropriate file references during build. We recommend working directly out of the C:\ti\motorware\   directory.
    - The main projects you will likely want to use, in order
      - Lab5b – interface to tune the current and speed controllers
      - Lab9 – field weakening
      - Lab10a – over-modulation
      - Lab5a – Torque control with PI tuning, no speed controller

TI Spins Motors



All example projects are built as incremental teaching labs, allowing the user to walk through the process and build up a complete system with the functionality required.

Instructions for these labs are located under Resources → InstaSPIN Projects & Labs User's Guide

1.	CPU and Inverter Set-up and introduction to interfacing to the ROM library
2a.	Using InstaSPIN™-FOC for the first time, Motor ID, full control system from ROM [F2806x only]
2b.	Run InstaSPIN™-FOC from user memory (RAM/FLASH), only FAST™ in ROM
2c.	Advanced Motor ID for low inductance motors [DRV8301 only]
2d.	FPU32 enabled [F2806x only]
3a.	Saving your motor parameters and loading from user.h
3b.	Saving your motor and hardware parameters and loading from user.h
3c.	Using parameters from user.h with FPU32 [F2806x only]
4.	Running InstaSPIN™-FOC only as a Torque controller
4a.	Torque Mode with FPU32 [F2806x only]
5a.	Adjusting the supplied current controllers
5b.	Tuning the supplied speed controller
5g.	Tuning the speed controller with FPU32 [F2806x only]
7.	Using Rs Online Recalibration
7a.	Rs Online Recalibration with FPU32 [F2806x only]
9.	Experimentation with Field Weakening
9a.	Field Weakening with FPU32 [F2806x only]
10a.	Experimentation with Space Vector Over-Modulation
10c.	Over-Modulation with FPU32 [F2806x only]

Updating software for your motor (user.h)

- Open the associated src\user.h file in CCS Project Explorer or using a text editor
  C:\ti\motorware\motorware_01_01_00_10\sw\solutions\instaspin_foc
  \boards\boostxldrv8301_revB\f28x\f2802xF\src\user.h

- **User.h can look overwhelming, but do not fear!**
  - **Most #define variables should not be modified and many are pre-compile calculations**
    - In future MotorWare versions this will be updated so only the most relevant are made visible and the rest will be accessible if required

- **Update these key user.h variables in each section**
  - **//! \brief CURRENTS AND VOLTAGES**
    - **#define USER_IQ_FULL_SCALE_FREQ_Hz (600.0)**
      - Set to the highest speed you want to run,
        where Hz = RPM * poles / 120
      - My example
        - 4 kRPM 8 pole motor = 267 Hz, but unloaded it will run faster and I expect to use field weakening to double my speed
        - **Use (600) Hz as my maximum**
    - **#define USER_IQ_FULL_SCALE_VOLTAGE_V (42.0)**
      - We will use the GUI Variable Overflow Checks to set this value once we identify the flux
      - For very low flux motors often used with the BoosterPack+LaunchPad to maximize variable resolution we may be updating to as low as half of
        #define USER_ADC_FULL_SCALE_VOLTAGE_V (26.314)
      - This variable effects the SMALLEST flux value that can be identified
        - Ex: 0.002 V/Hz is a very small flux typically seen in high speed 12V hobby motors
        - Smallest flux = IQ_FULL_SCALE / Effective Estimation Frequency / 0.7
          - Effective Estimation Frequency is set in the DECIMATION section below and = PWM_FREQ / PWM_TICKS_PER_ISR / ISR_TICKS_PER_CTRL / EST_TICKS_PER_CTRL
          - Ex for 45V and 10 kHz effective estimation, smallest flux value = 0.0064 V/Hz
          - To give some headroom we could solve for 0.0015 V/Hz * 0.7 / 15 kHz estimation = 15.75 V

        - For Motor ID an IQ_FULL_SCALE value of (15) with estimation frequency of 15 KHz should work

    - My example
        - **Using default of (42.0), may update after ID**

- **//! \brief CLOCKS & TIMERS**
    - **#define USER_PWM_FREQ_kHz (30.0)**
        - Very low inductance, high short circuit currrent motors will require 45-60 kHz typical; most other motors you will PWM in the 8-30 KHz range, using lower PWMs when possible to reduce switchign losses.
        - My example
            - **Using default of (30) KHz**

- **//! \brief DECIMATION**
    - Determines rates of the control loops and effects interrupt loading
    - ISR = PWM_FREQ / **USER_NUM_PWM_TICKS_PER_ISR_TICK**
        - Uses ePWM 1st/2nd/3rd event hardware to trigger the ADC start of conversion; the ADC conversion done interrupt acts as the main ISR for the control system
        - Best if ISR is <= 15 KHz maximum, and <= 10 KHz typical
            - If not possible be sure to test using FEM and CPU_USAGE functions using lab3b
    - CTRL = ISR / **ISR_TICKS_PER_CTRL**
        - Insure CTRL is effective <=15 kHz
            - Be careful of 15 KHz rates on 60 MHz MCUs, you may over flow the interrupt as more system code is added, especially during the motor identification process
            - If unsure, test using FEM and CPU_USAGE functions using lab3b
        - CURRENT = CTRL / **CTRL_TICKS_PER_CURRENT**
            - 5-15 KHz typical
        - EST = CTRL / **CTRL_TICKS_PER_EST**
            - Whole divisor of CURRENT, 2.5-15 KHz typical
        - SPEED = CTRL / **CTRL_TICKS_PER_SPEED**
            - 1 KHz typical
        - TRAJ = CTRL / **CTRL_TICKS_PER_TRAJ**

- Same as speed, 1 KHz typical

- My example
  - **ISR (3) to get effective 30 kHz / 3 = 10 kHz ISR**
  - **CTRL (1) for 10 kHz**
  - **EST (1) and CURRENT (1) for 10 kHz**
  - **TRAJ (10) and SPEED (10) for 1 kHz**

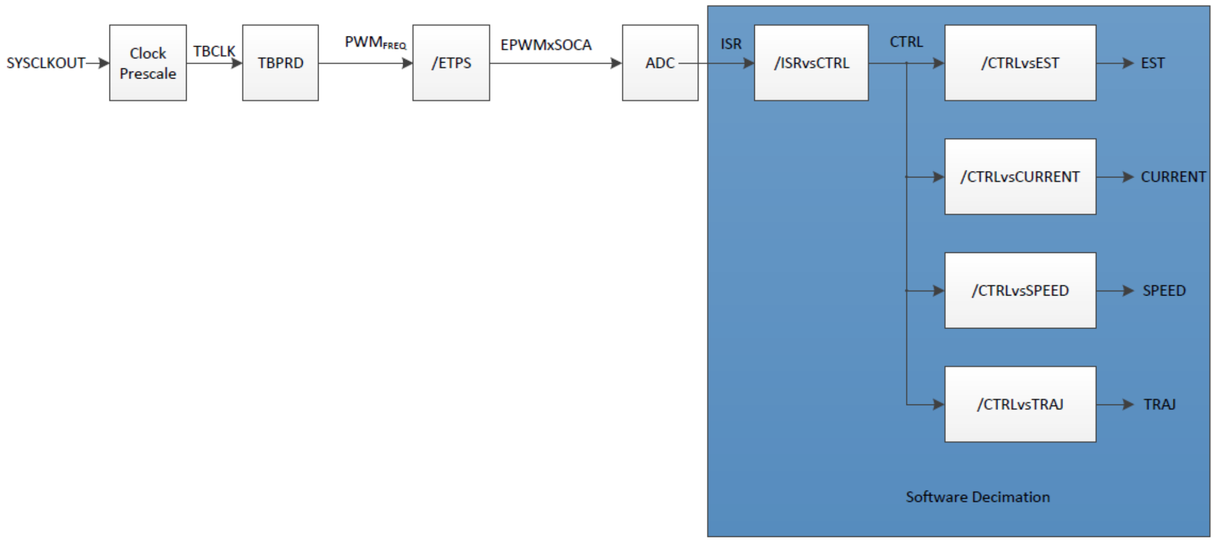


Figure 9-3. Real-Time Scheduling Tick Rates

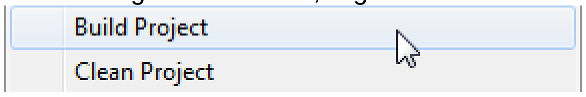
- **//! \brief LIMITS**
  - **#define USER_ZEROSPEEDLIMIT   (0.002)**
    - **ZEROPSPEEDLIMIT * USER_IQ_FULL_SCALE_FREQ_Hz**
      If the ForceAngle flag is set during opertation, this will be the +/- Hz region where the angle feedback used in the control is generated from a ForceAngle instead of FAST estimation
    - My example
      - **USER_ZEROSPEEDLIMIT (0.005)**
      - ForceAngle = 0.005 * 600 = 3 Hz = +/- 45 RPM
- **//! \brief USER MOTOR & ID SETTINGS**
  - Each motor saved must have a unique enumeration
    - #define Anaheim_BLY172S   102
    - **#define My_Motor   103**
  - **Comment out (//) all but one USER_MOTOR selection**

  - //#define USER_MOTOR Anaheim_BLY172S
  - **#define USER_MOTOR My_Motor**
- Set-up your motor
  - #elif (USER_MOTOR == My_Motor)
  - **#define USER_MOTOR_TYPE MOTOR_Type_Pm**
  - **#define USER_MOTOR_NUM_POLE_PAIRS (4)**
    - if # of poles is incorrect it only effects the relationship between the RPM command (which is coverted to a Hz command based on the POLE_PAIRS) and the real shaft of the motor as well as the Torque calculation; there is no effect on the quality of control
    - If you don't know your pole pair number exactly you can take a guess to start, and once motor is identified and running you can command a multiple of 60 RPM to see if the motor is making the expected number of revolutions per second (60 RPM = 1 rev/sec; 180 RPM = 3 rev/sec, etc)
      - faster than 1 rev/sec then poles should be reduced
      - slower than 1 rev/sec then poles should be increased
  - #define USER_MOTOR_Rr (NULL)
    - ID'd for ACI motors only
  - #define USER_MOTOR_MAGNETIZING_CURRENT (NULL)
    - ID'd for ACI motors only
  - **#define USER_MOTOR_Rs (NULL)**
    - Update after Motor ID
  - **#define USER_MOTOR_Ls_d (NULL)**
    - Update after Motor ID
  - **#define USER_MOTOR_Ls_q (NULL)**
    - Update after Motor ID
    - Set same as Ls_d unless different Ls_d and Ls_q are known by design; FAST can compensate for this saliency
  - **#define USER_MOTOR_RATED_FLUX (NULL)**
    - Update after Motor ID
  - **#define USER_MOTOR_RES_EST_CURRENT (0.4)**
    - ~10% of rated current

- Used to ineject current for Rs test AND to start-up motor for Ramp_Up. For high cogging torque motors increase RES_EST_CURRENT until the motor spins

- **#define USER_MOTOR_IND_EST_CURRENT** **(-0.4)**
    - NEGATIVE ~10% of rated current
    - Used to weaken the field during Ls testing
- **#define USER_MOTOR_MAX_CURRENT** **(4.0)**
    - Rated current of motor
    - This is maximum Iq torque command produced by the Speed PI controller, IF using the speed PI controller
- **#define USER_MOTOR_FLUX_EST_FREQ_Hz** **(30.0)**
    - ~10% of rated max speed = 267 Hz * 10%
    - Important to that this is high enough as we measure the voltage produced by flux (V/Hz) which will be larger at higher Hz, especialy for low flux (high speed) motors
    - Also note resolution comments in the USER_IQ_FULL_SCALE_VOLTAGE_V section

- After saving the user.h file, Right Click on and build the appropriate project



Using the GUI

- For Standalone Mode, follow the instructions in the section above:

  Running the GUI   Standalone GUI .exe

  - Copy the .out just built to the appropriate Webapp folder, and rename to "appProgram.out" ex:

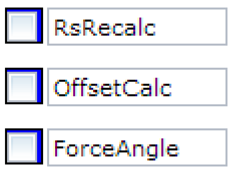
    …\sw\solutions\instaspin_foc\boards\boostxldrv8301_revB\f28x\f2802xF\projects\ccs5\proj_lab05b\Flash\proj_lab05b.out

    to the appropriate webapp folder:

    C:\ti\guicomposer\webapps\InstaSPIN_F2802xF_UNIVERSAL\appProgram.out

  - Run the executable C:\ti\guicomposer\webapps\InstaSPIN_F2802xF_UNIVERSAL\InstaSPIN_UNIVERSAL.exe

Start-up Options



RsRecalc

If ENABLED - when Run is enabled - Performs a recalculation of Rs.

If DISABLED – when Run is first enabled – uses the most recent value of Rs.

Rs accuracy is critical for low speed operation. Rs changes as the motor windings heat from high current usage = high torque demanded from the motor. Loaded washing agitation is a good example. See the Rs On-line (always running recalibration) feature in MotorWare Lab7 if required.

OffsetCalc

If ENABLED – when Run is enabled - performs a recalculation of the ADC offsets.

Length of this recalibration is adjustable, see the User's Guide.

Values can be saved and loaded from user.h, bypassing this calculation in the future.

Important Notes:

- **If the USER_IQ_FULL_SCALE_VOLTAGE or CURRENT values are changed the saved offsets must be changed as well.**
- **If DISABLED the offset values / adcBias will be loaded from user.h settings only. Only ever DISABLE if the final values are in user.h!!!**

ForceAngle

Force Angle can be thought of as trajectory generation for the angle feedback (replacing FAST over a user set area) to the FOC controller. It creates an estimated angle that rotates at a user set rate (in user.h).

It should be used whenever FAST is not producing an accurate angle estimate, i.e. at initial start-up and if trying to operate continuously at very low speeds.

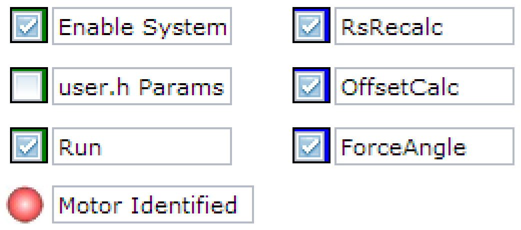
It should be ENABLED when first starting and then DISABLED for normal operation, unless you plan to run continuously at very low speed or have a very slow transition through zero speed.

While application/motor/sense/acceleration dependent, once the motor is running you will often continue to track through zero speed well enough (depending on Bemf and deceleration rate).

Motor ID

To perform a Motor Identification:

- SELECT Enable System
- user.h Params is NOT selected
- Start-up Options
    - o Recommend keeping OffsetCalc, RsRecal and ForceAngle selected
- SELECT Run


✓ Enable System
☐ user.h Params
✓ Run
● Motor Identified
✓ RsRecalc
✓ OffsetCalc
✓ ForceAngle

user.h Params

If user.h Params is enabled when Run is selected, the control system will bypass Motor ID and

- Load all settings from user.h, including Offsets and all USER_MOTOR settings
- Do not select until you have updated the user.h fully

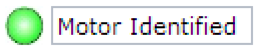
Motor Identification States

This is fully covered in the User's Guide Chapter 6. Following is the example for the PM Synchronous Motor.

EST_State_RoverL

- OffsetRecalc is performed before the Motor ID process begins

- EST_State_
    - RoverL
        - Injects ½ of **USER_MOTOR_RES_EST_CURRENT** at **USER_R_OVER_L_EST_FREQ_Hz**
    - Rs
        - Injects **USER_MOTOR_RES_EST_CURRENT**
    - RampUp
        - Starts motor using current amplitude of **USER_MOTOR_RES_EST_CURRENT** at a rate of **USER_MAX_ACCEL_EST_Hzps** until speed of **USER_MOTOR_FLUX_EST_FREQ_Hz**
        - **Motor must continue spinning until Idle or ID results should be considered invalid**
    - RatedFlux
        - Current is minimized while keeping speed to detect Flux
    - Ls
        - Injects **USER_MOTOR_IND_EST_CURRENT** into Id (field weakening) to detect the inductance
    - RampDown
        - ID process ends and motor slows to 0 speed
    - Idle
- While you should insure that the Motor Identified light turns green, this does NOT mean that the identified parameters are correct, just that the identification state finished without a serious error
    - You can start ID without a motor even attached and still get a green light. This only alerts you to very specific and serious errors



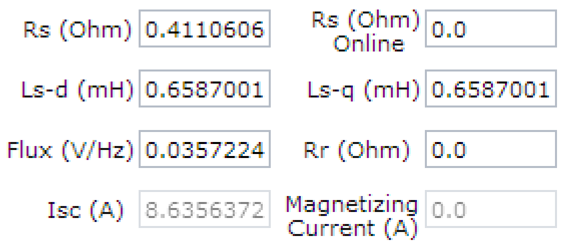
Motor ID Tips

- **Scaling of hardware Vph and USER_IQ_FULL_SCALE_VOLTAGE is critical, especially for low inductance (high speed motors)**
- Note that during Motor ID there are wait time time-outs established for each step. These times may need to be increased for the RampUp especially if you increase the ID speed or decrease the Estimation Frequency
    - See “user.c”
- RoverL

- If RoverL is >= 2000 there is a variable overflow, so you MUST use lab2c to attempt ID (this happens with low Ls / high speed motors)
- Can also increase **USER_R_OVER_L_EST_FREQ_Hz** to **(300)** for low Ls motors

- Rs
  - Be very sure to use 10% of I-rated for **USER_MOTOR_RES_EST_CURRENT**
  - important not to overheat the motor with too high a current
- Ramp_Up
  - High Cogging Torque motors may not start-up
    - Increase **USER_MOTOR_RES_EST_CURRENT**
  - When **USER_MOTOR_FLUX_EST_FREQ_Hz** is increased (see Ls) the Ramp_Up may time out
    - Increase **USER_MAX_ACCEL_EST_Hzps** to hit the target speed before time-out
- Rated_Flux
  - If the motor stops spinning increase **USER_MOTOR_FLUX_EST_FREQ_Hz**
  - The smallest flux that can be ID'd = **USER_IQ_FULL_SCALE_VOLTAGE_V** / FAST_EST_Hz / 0.7
    - For small flux machines (small motors, high speed) lower **USER_IQ_FULL_SCALE_VOLTAGE_V** to increase the resolution
- Ls
  - If the motor stops spinning or the Ls values are not stable and consistent increase **USER_MOTOR_FLUX_EST_FREQ_Hz**
  - Increase PWM frequency to 30, 45, 60, and use lab2c

Values Returned for this example



Rs (Ohm)	0.4110606	Rs (Ohm) Online	0.0
Ls-d (mH)	0.6587001	Ls-q (mH)	0.6587001
Flux (V/Hz)	0.0357224	Rr (Ohm)	0.0
Isc (A)	8.6356372	Magnetizing Current (A)	0.0

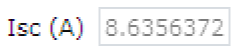
Motor ID Sanity Checks

- Rs / Ls

Rs / Ls 624.04 Hz

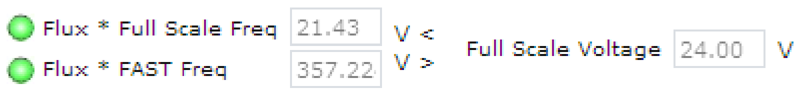
  - R/L gives a theoretical limitation of speed with a stable voltage source
    - **Note: the GUI displays Ls in mH, not H**
  - Is this larger than your MAX_Hz? Does it seem reasonable for your motor?
    - ~2.5x my rated max frequency is reasonable
  - Note that High speed motors are often mis-designed with very low Ls, resulting in Rs / Ls much larger than MAX_Hz

- Flux / 2pi / Ls = Short Circuit Current = Isc


Isc (A) 8.6356372

  - Typically 2x+ the rated current and often much larger for small Ls machines
  - Large Isc = low Ls = high speed, high current
  - Larger Isc will require faster PWM (30-60 KHz) and possibly faster current control (15 KHz)

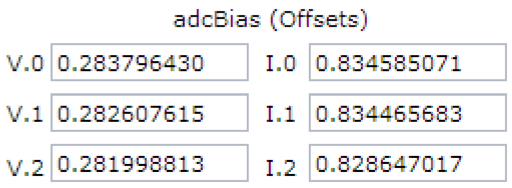
- Overflow / Resolution Checks, adjustment of IQ_VOLTAGE


● Flux * Full Scale Freq 21.43 V <
● Flux * FAST Freq 357.22 V >
Full Scale Voltage 24.00 V

  - Minimize Full Scale Voltage vs. Full Scale Frequency to maximize resolution
    - For Low flux motors this often means reducing the IQ_FULL_SCALE_VOLTAGE
      - For my example, I will update user.h to **(24.0)**
    - For High flux motors this often means increasing the IQ_FULL_SCALE_VOLTAGE to support the Bemf voltage at highest speeds
      - For example a 1.2 V/Hz motor will produce 1200V at 1KHz!
  - FAST Frequency vs. Full Scale Voltage
    - Alerts that low flux motors should use a smaller IQ_FULL_SCALE_VOLTAGE to increase resolution or run the FAST EST_FREQ at a higher rate

Update user.h settings

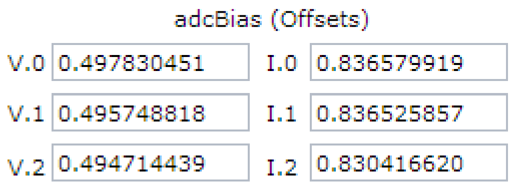
adcBias (Offsets) for Example Hardware



adcBias (Offsets)

V.0	0.283796430	I.0	0.834585071
V.1	0.282607615	I.1	0.834465683
V.2	0.281998813	I.2	0.828647017

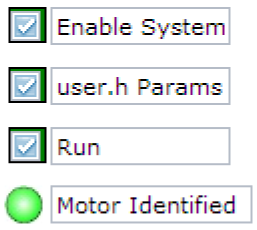
- Copy and paste the adcBias 0/1/2 values to the I_A/B/C_offset and V_A/B/C_offset #defines
  - Note, since I chose to change my IQ_VOLTAGE from (42.0) to **(24.0)** in previous section these offsets are no longer valid as they change with your IQ scaling.
  - After recompiling and running again, update the adcBias in user.h



adcBias (Offsets)

V.0	0.497830451	I.0	0.836579919
V.1	0.495748818	I.1	0.836525857
V.2	0.494714439	I.2	0.830416620

- Copy and paste the identified motor parameters to the USER_MOTOR #defines
  - **Note: The GUI displays inductance in mH while the user.h is in H.**
  - **Be sure to paste the GUI Ls_d / Ls_q value with a leading 0.000**
- Recompile and use the .out with your GUI if you want to be able to skip Motor ID in the future (enable the user.h Params before you select Run)



✓ Enable System

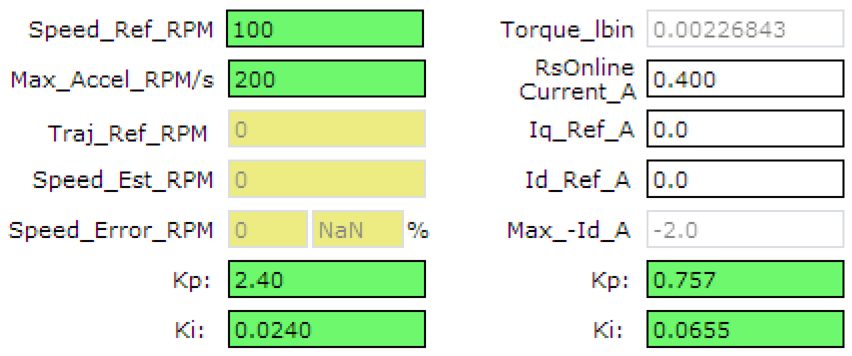
✓ user.h Params

✓ Run

● Motor Identified

Controller Tuning

Default Controller Tuning



Speed			Current & Torque	
Speed_Ref_RPM	100		Torque_lbin	0.00226843
Max_Accel_RPM/s	200		RsOnline Current_A	0.400
Traj_Ref_RPM	0		Iq_Ref_A	0.0
Speed_Est_RPM	0		Id_Ref_A	0.0
Speed_Error_RPM	0	NaN %	Max_-Id_A	-2.0
Kp:	2.40		Kp:	0.757
Ki:	0.0240		Ki:	0.0655

Note that both current and speed controller gains are effected by the IQ scaling variables and decimation timing, they will need to be changed as well if you update these user.h settings.

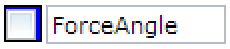
Current Controllers

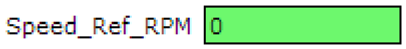
- The Iq and Id Current PI controller gains are numerically calculated & initialized
  - Kp = ¼ * Bandwidth
    - Bandwidth = [Ls / CTRL_FREQ_Hz * IQ_CURRENT / IQ_VOLTAGE]
    - This ¼ factor is just to loosen the controller to support initial motor bring-up
    - For high speed and high dynamics you must increase Kp by up to a factor of 4
  - Ki = CTRL_FREQ_Hz / Ls * Rs
- These can be changed simply through the GUI, which instruments the following user code
  - gMotorVars.Kp_Idq = CTRL_getKp(ctrlHandle,CTRL_Type_PID_Id);
  - CTRL_setKp(handle,CTRL_Type_PID_Id,gMotorVars.Kp_Idq);
- Some applications may want to do step response testing to meet desired response of over/undershoot and settling time
- **Note, current controllers can only be updated starting in proj_lab5a, previous to this any changes to those variables in the GUI will have no effect**

Speed Controller

- The PI Speed Control **cannot be auto tuned** based on the motor or system parameters

- Speed control relies on knowledge of inertia, mechanical linkages, and desired response
- Speed Gains are initialized using a "rule of thumb", which works decently for larger flux motors
  - Kp = 0.02 * MAX_HZ * MAX_CURRENT / IQ_CURRENT
  - Ki = 2.0 * CTRL_HZ * MAX_HZ * MAX_CURRENT / IQ_CURRENT
  - Experience shows that for low inertia motors a good starting point is to reduce the default Kp and Ki by /4

- Tuning
  - Tune by testing various speeds and loads or tune by step response inputs (most popular)
  - May need to "gain stage", different KpKi sets for different speeds/loads/accelerations
  - May be able to empirically calculate if you know inertia (see Labs/UG)
  - Zero Speed tuning & experiment
    - Disable ForceAngle 

    - Set 0 speed 
      Speed_Ref_RPM 0
    - Quickly rotate the motor shaft 90-180 deg and then let go
      - Now set Speed Kp to 0.2, Ki to 0.004
        - example for Anaheim motor under test
        - Notice how the motor shaft behaves like a spring-damper system, "compressing" as you turn and then "returning" once you remove the load
      - Increase Kp until the spring feeling is gone
      - Increase Ki to increase the stiffness of the motor
      - At this point the system might be slightly unstable, the following can help stabilize the system:
        - Increase Kp to increase the dampening
        - Reduce Ki to reduce oscillations
- These can be changed simply through the GUI, which instruments the following user code
  - gMotorVars.Kp_spd = CTRL_getKp(ctrlHandle,CTRL_Type_PID_spd);
  - CTRL_setKp(handle,CTRL_Type_PID_spd,gMotorVars.Kp_spd);
- **Note, speed controllers can only be updated starting in proj_lab5b, previous to this any changes to those variables in the GUI will have no effect**

Next Steps

- Continue to follow the InstaSPIN Projects & Labs User's Guide in MotorWare
  InstaSPIN Projects and Labs User's Guide
- Read through the User's Guide on relevant topics for your application
  InstaSPIN-FOC and InstaSPIN-MOTION User's Guide
- Ask questions on the **InstaSPIN e2e forum**

WARNING

Do not close the GUI until the drive has been stopped. Failure to do so will leave the program running or put the processor into an unknown state, causing the system to continue to draw current, possibly damaging the controlCARD, board, host computer, motor and posing a fire hazard. After proper shut-down always disconnect the power supplies and remember that **capacitors are charged and will take time to dissipate!**