High Voltage Digital Motor Control Kit (R1.1) Quick Start Guide

Fig1: TMDSHVMTRPFCKIT

The High Voltage Digital Motor Control (DMC) and Power Factor Correction (PFC) kit (TMDSHVMTRPFCKIT), provides a great way to learn and experiment with digital control of high voltage motors.

The High Voltage Digital Motor Control Kit contains:

- F28035 and F28335 controlCARDs
- High Voltage DMC board with slot for the controlCARD
- 15V DC Power Supply
- AC power Cord, Banana Plug Cord, USB Cable
- CCSv5 CD & USB Stick with Quick Start GUI and Guide

WARNING

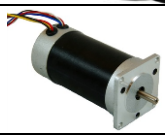
This EVM should be used only by qualified engineers and technicians who are familiar with the risks associated with handling electrical and mechanical components, systems and subsystems. The EVM operates at voltages and currents that can result in electrical shock, fire hazard and/or personal injury if not properly handled or applied. Users must use the equipment with necessary caution and employ appropriate safeguards to avoid serious injury. Users must not touch any part of the EVM while energized.

Features of the High Voltage Motor Control and PFC Board:

- 3-Phase Inverter Stage capable of sensorless and sensored field oriented control (FOC) of high voltage ACI and PMSM motor and trapezoidal & sinusoidal control of high voltage BLDC motor. 350V DC max input voltage and 1kW* maximum load in the configuration shipped.
- Power Factor Correction stage rated for 750W*, Takes rectified AC input (110V AC or 220V AC). 400V DC Max output voltage.
- AC Rectifier stage rated for 750W* power. Accepts 110V AC or 220V AC input.
- Aux Power Supply Module (400Vto15V&5V module) generates 15V and 5V DC from rectified AC voltage or the PFC output (input Max voltage 400V, min voltage 90V).
- Isolated CAN, SCI & JTAG
- Four PWM DAC's to observe the system variables on an oscilloscope.
- Hardware Developer's Package available which includes schematics & bill of materials.
- Open source software available through controlSUITE for each type of the motor and control type.

**For detailed feature list and power ratings and safety related information refer to the kit's HW Reference guide*

The software available with the kit is pre-optimized for the motors that are available with the kit. The software is completely open source, and hence can be easily modified to tune and run a different motor. The following motors are available with the kit:

AC Induction Motor (HVACIMTR) *(220V , 3 phase AC, 0.25 HP)*	
PMSM Motor (HVPMSMMTR) *(200V, 3 Phase AC, 0.4KW)*	
BLDC Motor (HVBLDCMTR) *(160-170V, 3 Phase AC)*	

Note: The BLDC motor being shipped with the kit is rated for 160V in regions having mains supply > 120V AC a step down transformer needs to be used. Otherwise the GUI would give an over voltage error and disconnect from the controller.

Hardware Overview

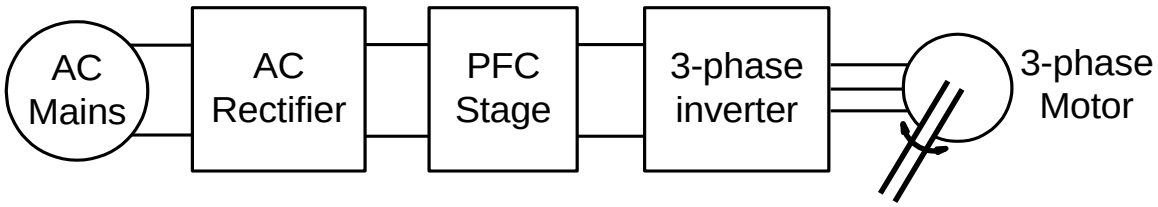


Fig2: Block Diagram for a typical motor drive system using power factor correction

Fig 2, illustrates a typical motor drive system running from AC power and various blocks that make up such a system. All these power/control blocks are present on the TMDSHVMTRPFCKIT board in form of macro blocks. Below is a list of all the macro blocks names and numbers present on the board and a short description of it's function, Fig 3, shows the location of these block on the motor control board and a few key connector location.

- **HVDMC Main Board [Main]** – Consists of controlCARD socket, communications(isoCAN) block, Instrumentation(DAC's), QEP and CAP connection and routing of signals in b/w the macros and to the control card.
- **AC-Power Entry [M1]** – Takes input AC power from mains/wall power supply and rectifies it. This rectified voltage can then be used for input of the PFC stage or used to generate the DC bus for the inverter directly.
- **Aux Power Supply Module [M2]** – This module can take up to 400V input and generate 5V and 15V DC power. Rectified AC input can directly be connected to this module or output from the PFC stage cane be used with appropriate jumper settings.
- **Iso-USB-to-JTAG Macro [M3]** – Provided on board isolated JTAG connection through USB to the host. Can also be used for SCI (isolated) communication for connection with GUI.
- **PFC-2PhiL Macro [M4]** - Two-phase interleaved PFC stage can be used to increase efficiency of operation.
- **Inverter2Ph-HV-3shunt Macro [M5]** - Three-phase inverter, provides the inverter stage to enable control of high voltage motors.
- **DC-PwrEntry Macro [M6]** - DC power entry, used to generate the 15V, 5V and 3.3V for the board from 15V DC power supply supplied with the kit.

Nomenclature: To easily find a component let's say a jumper they are referred with their macro number in the brackets. For example, [M3]-J1 would refer to the jumper J1 located in the macro M3 and [Main]-J1 would refer to the J1 located on the board outside of the defined macro blocks.

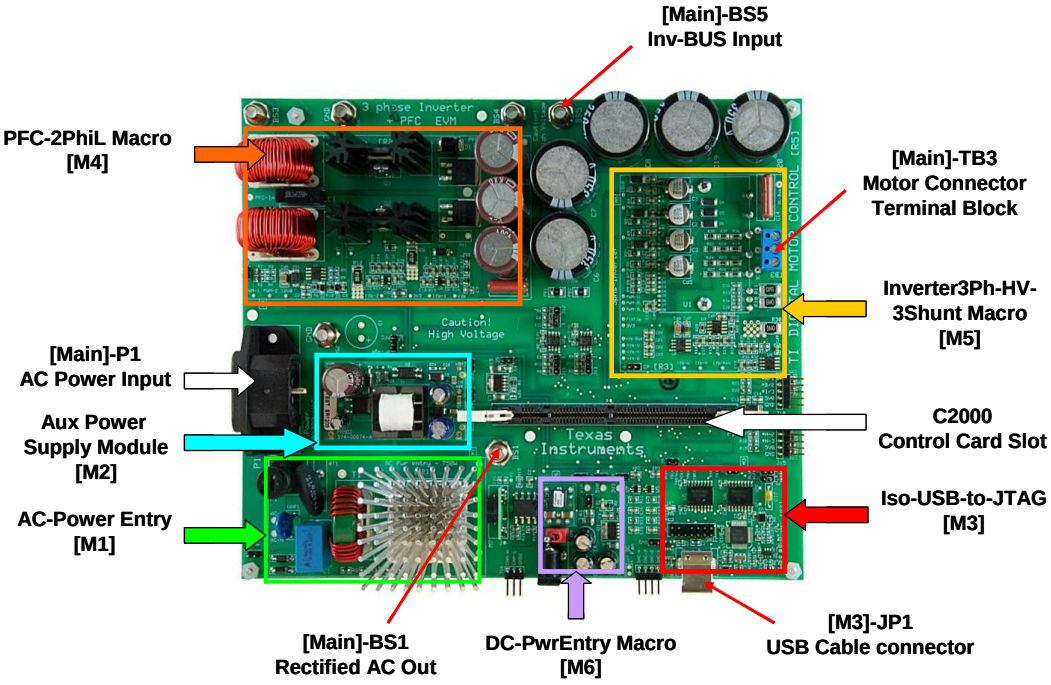


Fig3: HVDMCMTRPFCKit Board Macros

Quick Start GUI

The kit comes with a GUI which provides a convenient way to evaluate the functionality of the kit and the F28035 device without having to learn and configure the underlying project software or install CCS. The interactive interface using sliders, buttons, textboxes and graphs enables easy demo of sensorless control of ACI, PMSM and BLDC Motors.

Hardware Setup

Note: Do not apply AC power to board before you have verified these settings!
The kit ships with the control card inserted and the jumper and switch settings pre done for connecting with the GUI. However the user must ensure that these settings are valid on the board. To validate these settings and connect the motor the lid of the kit needs to be unscrewed. The lid can be screwed back once these settings are verified.

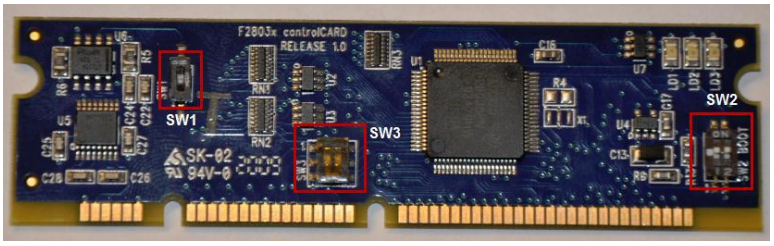
1) Make sure nothing is connected to the board, and no power is being supplied to the board.

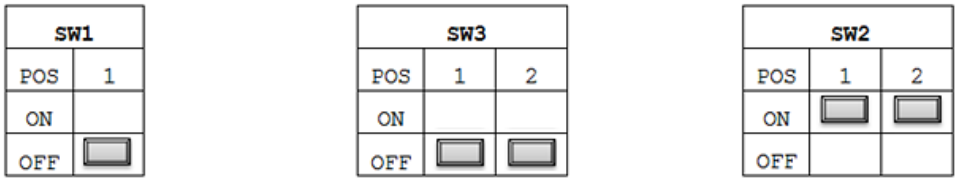
2) Insert the Control card into the [Main]-J1 controlCARD connector if not already populated.

4) Make sure the following jumpers & connector settings are valid i.e.
   a. [Main]-J3, J4, J5 and J8 are populated
   b. [Main]-J2 is populated with a jumper b/w bridge and the middle pin
   c. [Main]-J9 and [M3]-J5 is not populated
   d. [Main]-J7 is populated between pins 2-3 (pins furthest from the DIMM 100 socket)
   e. Banana cable b/w [Main]-BS1 and [Main]-BS5 is installed

5) Make sure that the following switches are set as described below on the F28035 control card to enable boot from flash and connection to the SCI

   a. SW1 is in the OFF position
   b. SW2 on controlCARD, Position 1 = ON, Position 2 = ON
   c. SW3 on controlCARD, Position 1 = OFF, Position 2 = OFF





6) Connect a USB cable from [M3]-JP1 to the host computer. [M3]-LD1 would light up indicating that the USB is powered. Windows would then search for a driver for the device. If the computer has CCSv5 or prior versions of it installed which supported XDS100 emulator, Windows should be able to find the driver successfully. If not you would be prompted to install the driver. **Installing driver for USB to serial** : Do not let Microsoft search for the driver, instead browse to the following location on the USB stick drive shipped with the kit <Drive Name:\CDM 2.06.00 WHQL Certified>, windows should now be able to find the driver and would install it. If Windows still does not find the driver, you may have to repeat the process and point to the location pointed out previously. You may have to reboot the computer for the drivers to come into effect. Once installed you can check if the installation was completed properly by browsing to ControlPanel-> System->Hardware->Device Manager and looking for USB Serial Port under Ports(COM&LPT). Note this port number down.

7) Connect the motor you want to spin to the terminal block [Main]-TB3 on the board, (Only the Red, White and Black wire need to be connected to TB3, the Green wire is ground and should not be connected to the [Main]-TB3)

8) Re-fit the Lid on the kit.

9) The AC rectifier generates the DC voltage the ground of which is floating from the protective earth ground. Hence appropriate caution must be taken while connecting scopes and other test equipment to the board.

10) Connect one end of the AC cord to [Main]-P1, Do not connect the other end to wall supply. Use an arrangement which allows for a switch b/w the wall supply and the board.

Software Setup

The QSG GUIs (HVMTRPFCKIT-PM-ACI-GUI.exe and HVMTRPFCKIT-BLDC-GUI.exe) are located in the drive that is shipped with the kit or once controlSUITE is installed at the following location:

controlSUITE\developement_kits\HVMotorCtrl+PfcKitv_2.0\~GUI HVMTRPFCKIT-PM-ACI-GUI.exe (default)

controlSUITE\developement_kits\HVMotorCtrl+PfcKit_v2.0\~GUI HVMTRPFCKIT-BLDC-GUI.exe

The kit ships with a F28035 controlCARD which is pre-flashed with the PM & ACI code that enables interface to PM-ACI GUI. The flash image can be re-flashed using CCS if needed. In order to run the BLDC GUI, the user has to re-flash the BLDC flash image in the same folder. Please refer to CCSv5HowToFlashcontrolCARDS.txt file for the details.

The GUI is developed using Crosshair Interface Designer and the source code is located at:

controlSUITE\developement_kits\HVMotorCtrl+PfcKit_v2.0\~GUI

The GUI requires Microsoft .NET framework 3.5 SP1 or higher to run. Please ensure that this software is installed prior to running this program.

The kit ships with a F28035 Control Card which is pre-flashed with the code that enables interface to this GUI. The flashed code is optimized for running sensorless FOC on ACI and PMSM motor. Note that the performance of the motor with the flashed image is not a metric of quality of control and performance levels achievable using the TI DMC library. Please refer to the individual system software and corresponding literature for details. These can be downloaded through controlSUITE. The flash images can be re-flashed using CCSv5 if need be. The image can be found in the drive shipped with the kit or at the following location:

controlSUITE\developement_kits\ HVMotorCtrl+PfcKit_v2.0\~GUI HVMTRPFCKIT-PM-ACI-GUI.*out* (default)
controlSUITE\developement_kits\ HVMotorCtrl+PfcKit_v2.0\~GUI HVMTRPFCKIT-BLDC-GUI.*out*

Running the GUI

1) Make sure all the jumper and connector setting are as described in the Hardware setup section.

2) Browse to and double click on *HVMTRPFCKIT-PM-ACI-GUI.exe* The GUI window should pop up (Fig 4). If this is the first time you would have to go through a license agreement. The GUI is divided into the following sections

   - *Motor Select Box:* Allows the user to select the motor type that is connected to the board. It also notifies the type of control being used for each type of motor.
   - *Motor Status LED:* This LED becomes yellow when the motor control code is running and red when the code is not running or PWMs tripped due to fault conditions.
   - *Motor Enable/Disable :* These buttons used to run and stop the motor.
   - *Over voltage protection status LED:* This LED turns red when the applied voltage is more than the system can handle.
   - *Over current protection status LED:* This LED turns red when the current protection circuit trips PWMs.
   - *DC bus level status LED:* This LED turns red when the applied bus voltage is not sufficient for the commanded speed.

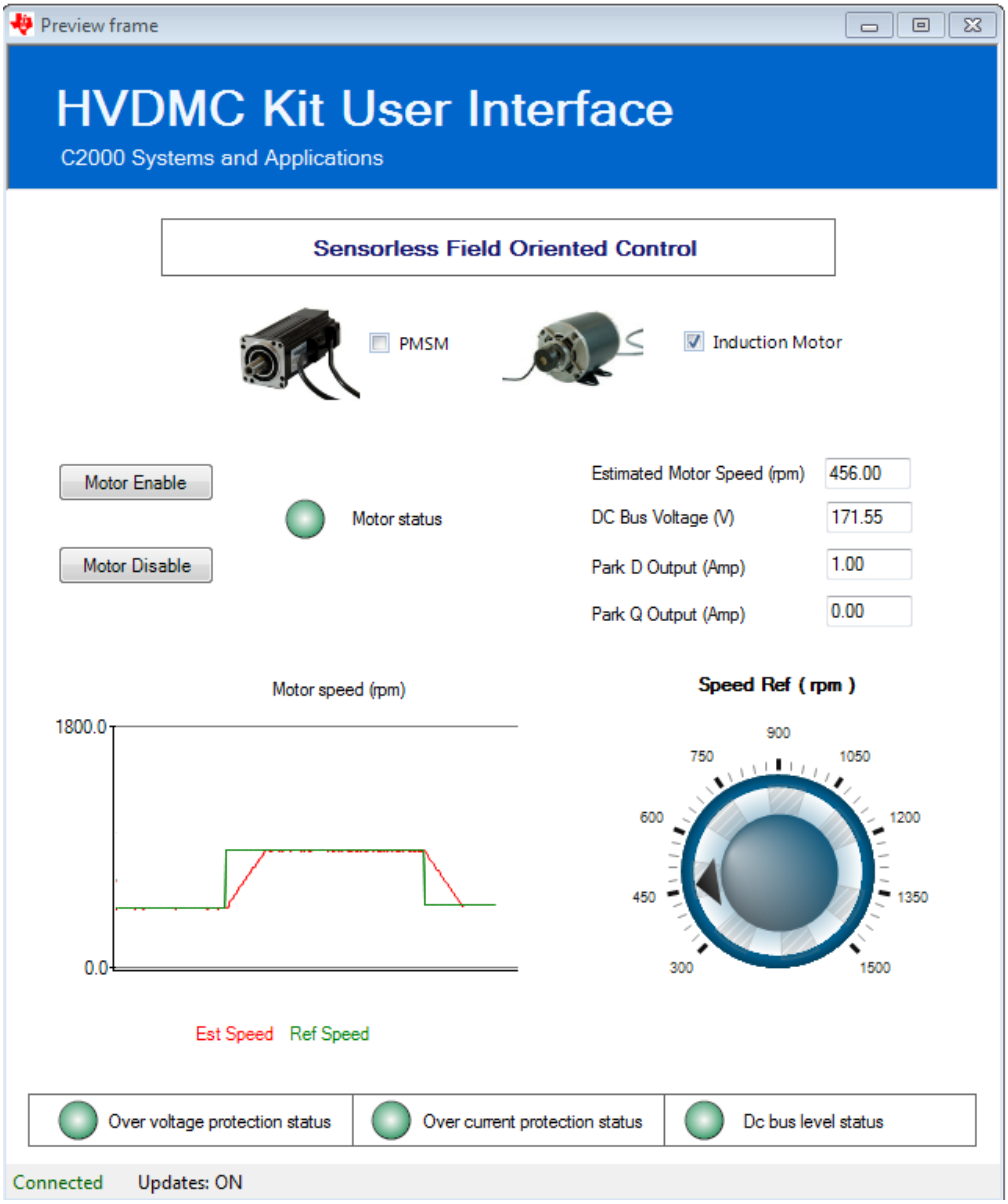


Fig4: GUI Startup for PM and ACI motors

3) If an incorrect image is flashed on the controlCARD, the connection will fail. In this case it is recommended to reflash the controlCARD with the correct image.

4) Now connect the other end of the AC power cord to mains/wall power outlet. Use an assembly such that a switch is in place between the mains supply and the board. For example this can achieved using an extension cable.

5) Once the mains is connected the board would power up and you would see that the [Main]-LD1 on the board is green (indicating power) and LD3 (Red) on the board is blinking slowly indicating that code is running on the control card.

6) The GUI should auto-detect and connect to your HVDMC Kit. If auto-connect fails you will need to set up the connection manually. The Connection Wizard is accessed through the Connection menu. Click on “Connect to engine” to view a list of available targets. Now setup the Connection Wizard Dialog to match Fig 5. Select Piccolo 28035 from the Target list and Serial for connection method. You will need to determine the correct COM port number for your system. This can be found by going to Control Panel->System->Hardware tab->Device Manager->Ports(COM & LPT). And look for the one which is described as USB Serial Port or similar. Hit Connect once done. Now select the appropriate COM port. This can be found out by going to

Control Panel->System->Hardware tab->Device Manager->Ports (COM & LPT).

And look for the one which is described as USB Serial Port or similar. Hit OK once done.

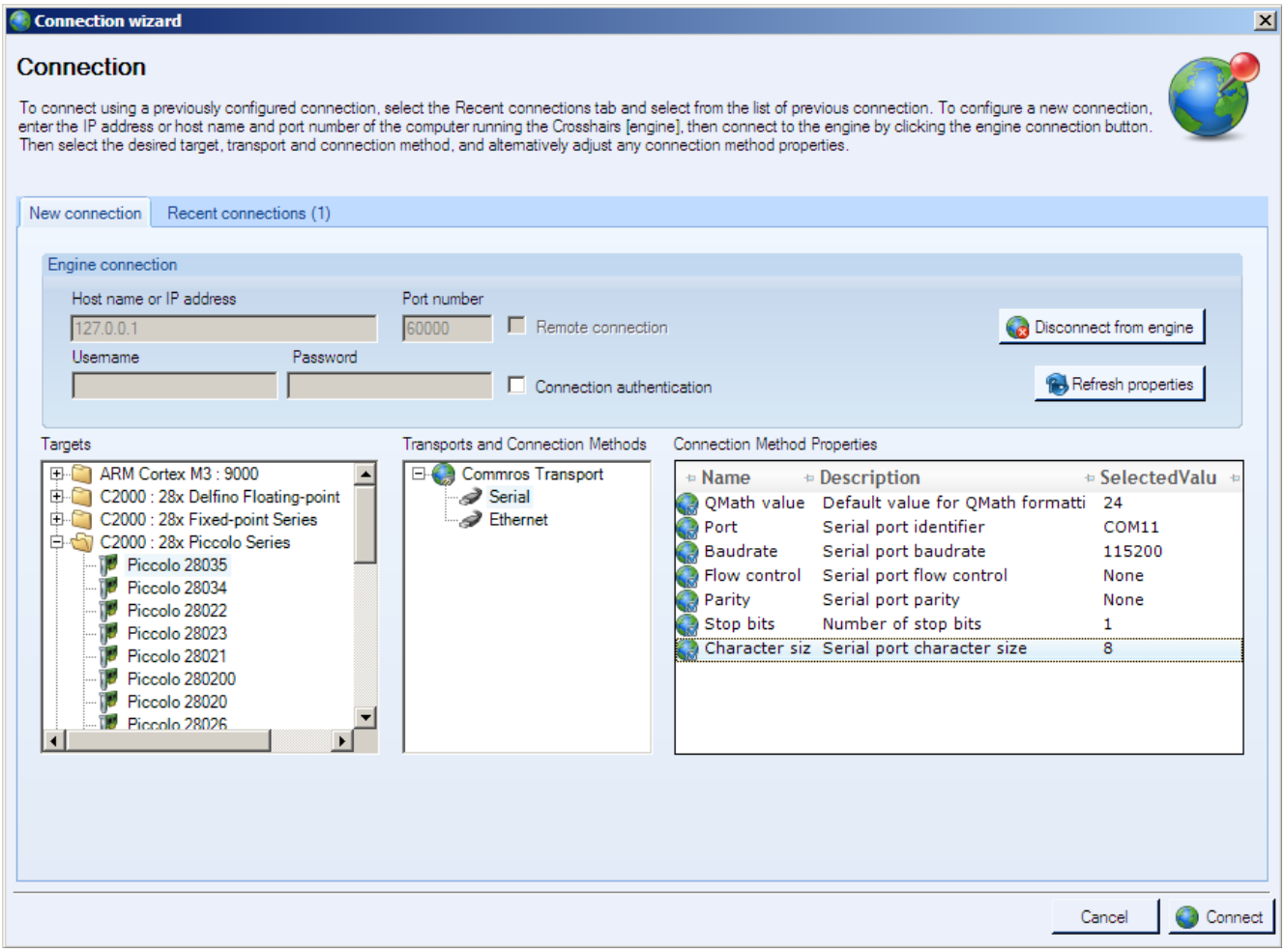


Fig5: GUI Setup Connections

7) After the connection is established to the controller the type of motor can be selected by clicking on the check box. Also note if BLDC motor is being used with wall supply of >120V AC a step down transformer must be used as the BLDC motor is rated for 160V, otherwise an over voltage condition flag would be displayed.

8) The motor control/status box would now become active. The variables being displayed in the box would change depending on the type of motor selected. Following is a description of each of these controls:

   - **DC Bus Voltage Textbox**: Textbox displays the rectified AC voltage. This voltage should be around 154V for 110V AC supply but can go as high as 180V depending on line conditions. For 220 AC line this voltage would be close to 311V. Note that the PWMs trip when the voltage >180V for BLDC and >400V for ACI and PM motors.
   - **Estimated Speed Textbox**: This text box displays the speed of the motor as estimated by the sensorless algorithm (absolute rpm value is displayed).
   - **Park Q & Park D output Textboxes** (for ACI and PMSM motors only): these two text boxes display the park Q and park D values as computed by the sensorless algorithm. These can be observed to change as the motor is loaded. Note for the PMSM motor Park D value would remain close to zero.

9) Once the Motor Enable button is clicked, the motor accelerates to the speed reference value and the speed loop is closed. The time taken for motor to ramp up to a particular speed would depend on motor type. Hence provide for enough time for the motor to ramp up to the speed set The motor can be stopped and started number of times. Note that each time the motor is stopped you may observe a surge in the DC bus voltage.

10) The parameters in the pre-flashed image have been tuned for light loads over the range for DC bus voltage generated from 110V AC line or 220v AC line. The motor can be loaded and the result in case of load observed on the GUI.

11) Once finished evaluating, click on the Motor Disable button to stop the motor. Once motor comes to a full stop click on disconnect. Now switch off/ unplug the AC power. As the capacitors are charged the LED on the control card may remain ON for a couple of seconds. Do not touch the board unless these LED's go OFF.

12) All future updates/enhancements to the GUI and/or Flash image would be made available through controlSUITE.

13) Please note that the Flash image is meant for quick demonstration purpose only. For a more detailed explanation and understanding on the control algorithm being used and tradeoffs refer to the individual project for the motor type and control method being implemented under

    controlSUITE\developement_kits\HVMotorCtrl+PFCKit_v2.0.

References

For more information please refer to the following:

- Download and Install ControlSUITE
  www.ti.com/controlSUITE

- F28xxx User's Guides
  http://www.ti.com/f28xuserguides

After controlSUITE install

- HighVoltageMotorCtrl+PFC HW Reference Guide – provides detailed information on the High voltage motor control and PFC kit hardware.
  controlSUITE\development_kits\HVMotorCtrl+PfcKit_v2.0\~Docs

- HighVoltageMotorCtrl+PFC-HWdevPkg – a folder containing various files related to the hardware on the kit board (schematics, bill of materials, Gerber files, PCB layout, etc).
  controlSUITE\development_kits \HVMotorCtrl+PFCKit_v2.0\~HVMotorCtrl+PfcKit_HWdevPkg\

- HighVoltageMotorCtrl+PFC How to Run Guide- presents more information on the HW setup required and software installation that need to be done for using projects associated with the kit.
  controlSUITE\development_kits \HVMotorCtrl+PFCKit_v2.0\~Docs

- All the projects for different motors and sensored and sensorless implementations can be found at
  controlSUITE\development_kits \HVMotorCtrl+PFCKit_v2.0\ HVACISensorless
  \ HVACISensored
  \ HVPMSensorless
  \ HVPMSensored
  \ HVBLDCSensorless
  \ HVBLDCSensored