Integrated PFC and Sensorless FOC ATPLL Estimator Demonstration ReadMe for the  
dsPICDEM™ MCHV-3 Development Board with the dsPIC33CK256MP508 External Op-Amp Motor Control PIM (MPLAB® X IDE)

1. Introduction

This document describes the setup requirements for running the the integrated application of average current mode PFC and Sensor-less FOC algorithm with a ATPLL Estimator to run compressor.

The demonstration is configured to run on dsPICDEM™ MCHV-3 Development Board in the External Op-amp configuration with the dsPIC33CK256MP508 External Op-Amp Motor Control Plug-In Module (PIM).

1. Suggested Demonstration Requirements
   1. Motor Control Application Firmware Required for the Demonstration

**Note:**

In this document, hereinafter this firmware package is referred as firmware**.**

* MCHV3\_33CK256MP508\_PFC\_Compressor.zip
  1. Software Tools Used for Testing the firmware
* MPLAB® X IDE v5.10 or later
* MPLAB® XC16 Compiler v1.36b or later

**Note:**

The software used for testing the firmware prior to release is listed above. It is recommended to use the version listed above or later versions for building the firmware.

* MPLAB® X IDE Plugin: X2C-Scope v1.2.3 or later
  1. Hardware Tools Required for the Demonstration

To set up the demonstration, you may use one of the High-Voltage Motor Control Development Boards mentioned below:

* dsPICDEM™ MCHV-3 Development Board (DM330023-3)

**Note:**

In this document, hereinafter High-Voltage Motor Control Development Board selected for setting up the demonstration is referred as Development Board**.**

* High Voltage 3-Phase Permanent Magnet Synchronous Motor
* dsPIC33CK256MP508 External Op-Amp Motor Control Plug-in module (MA330041-1)

**Note:**

All items listed under the section 2.3. Hardware Tools Required for the Demonstration are available at [microchip DIRECT](http://www.microchipdirect.com/).

1. Hardware Setup

This section describes hardware setup required for the demonstration. Motor phase current feedbacks needed by the firmware are amplified by the operational amplifiers provided on the Development Board. This is referred as ‘*external amplifier configuration*’.

Refer *dsPICDEM™ MCHV-3 Development Board User’s Guide*, for any clarification while setting up the hardware.

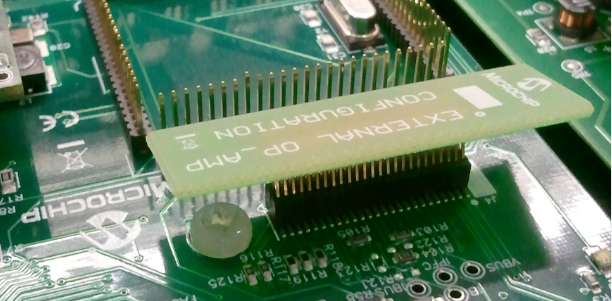
1. ***Before making any connection, verify that the Development Board is not powered, and it is fully discharged. This can be done by checking if Power on Status LED D13(Red) is off.***
2. Open the top cover of the enclosure and set up the following jumpers (if they are not in specified positions):

|  |  |  |  |
| --- | --- | --- | --- |
| **Jumper** | **Pins to Short** | **Board Reference** | **Remarks** |
| J11 | 3-4 |  | These Jumpers are present on the Development Board.*These can be accessed only after opening the top cover of the enclosure.* |
| J12 | 1-2 |
| J13 | 1-2 |
| J14 | 1-2 |
| PWM OUTPUTS | ENABLE  position |  | These Jumpers can be accessed without opening the enclosure, from the front side of the board(or enclosure). |
| USB | FOR USB position |  |

1. Connect the three phase wires from the motor to M1, M2, and M3 terminals of connector J17(there is no specific order), provided on the Development Board.



1. Connect the ‘External Op Amp Configuration Matrix board’ to matrix board header J4. Ensure the matrix board is correctly oriented before proceeding.



1. Make Sure that resistors R23, R25 are populated with zero-ohm resistors and resistors R15, R16, R17, R18, R22 are not populated on the dsPIC33CK256MP508 External Op-Amp Motor Control PIM.
2. Insert the dsPIC33CK256MP508 External Op-Amp Motor Control PIM into the PIM Socket U11 provided on the Development Board. Make sure the PIM is correctly placed and oriented before proceeding.
3. Close the top cover of the enclosure and secure it with screws.
4. Power Cord Connection. Make sure the power cord is disconnected from the AC mains before connecting the female terminal of the power cable to the AC input connector J1 of the Development Board.



1. To program the device, a mini-USB connection is required between Host PC and the Development Board. Connect a mini-USB cable from your computer to the mini-USB connector “PROGRAM/DEBUG” of the Development Board. The development board features a Built-in isolated Programmer or Debugguer (Microchip Starter Kit).



1. Power up the Development Board by connecting power cord to the mains. To verify the unit is powered, make sure LEDs D6, D13, D16 and D18 are ON.
2. Software Setup and Run
   1. Setup: MPLAB X IDE and MPLAB XC16 Compiler

Install MPLAB X IDE and MPLAB XC16 Compiler versions that support the device dsPIC33CK256MP508 assembled on the Plug-in Module (PIM). The version of the MPLAB X IDE, MPLAB XC16 Compiler and X2C-Scope plug-in used for testing the firmware are mentioned in the section Motor Control Application Firmware Required for the Demonstration. To get help on

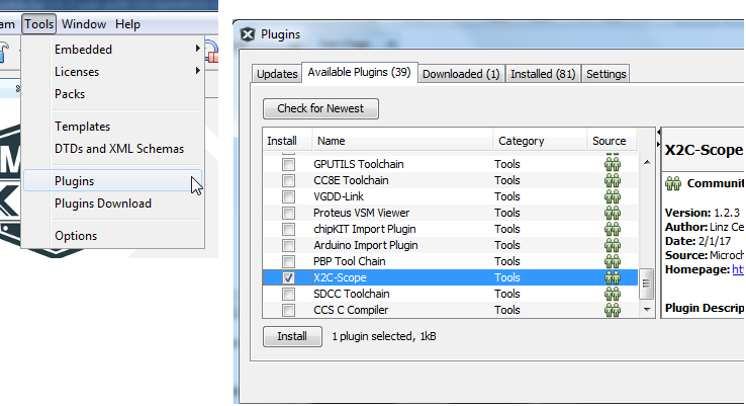
* MPLAB X IDE installation, refer [link](http://microchipdeveloper.com/mplabx:installation)
* MPLAB XC16 Compiler installation steps, refer [link](http://microchipdeveloper.com/xc16:installation)

If MPLAB IDE v8 or earlier is already installed on your computer, then run the MPLAB driver switcher (It is installed when MPLAB X IDE is installed) to switch from MPLAB IDE v8 drivers to MPLAB X IDE drivers. If you have Windows 7 or 8, you must run MPLAB driver switcher in ‘Administrator Mode’. To run the Device Driver Switcher GUI application as administrator, right click on the executable (or desktop icon) and select ‘Run as Administrator’. For additional details refer MPLAB X IDE help topic *“Before You Begin: Install the USB Device Drivers (For Hardware Tools): USB Driver Installation for Windows Operating Systems”.*

* 1. Setup: X2C - SCOPE

X2C - SCOPE is a MPLAB X IDE plugin that allows a developer to interact with an application while the application program is running. X2C-Scope enables you to read, write, and plot global variables (for motor control and PFC) in real time. It communicates with the target using the UART. To use X2C, the plugin must be installed:

* In MPLAB X IDE, select Tools>Plugins and click on the **Available Plugins** tab.
* Select X2C - SCOPE plug-in by checking its check box, and then click **Install**.
* Look for tool X2C - SCOPE under Tools>Embedded.



1. Basic Demonstration
   1. Firmware Description

The firmware version required for the demonstration is mentioned under the section Motor Control Application Firmware Required for the Demonstration.

This firmware is implemented to work on Microchip’s 16-bit Digital signal controller (dsPIC® DSC) dsPIC33CK256MP508. For more information, see the *dsPIC33CK256MP508 Family datasheet (DS70005349)*.

The Integrated PFC and Motor Control Demo application uses push button to start or stop the motor and potentiometer to vary speed of the motor.

This Integrated PFC and Motor Control Application configures and uses peripherals like PWM, ADC, UART etc. required for implementing Power Factor Correction and Sensor-less Field Oriented Control (FOC) of Permanent Magnet Synchronous Motor (PMSM).

For more details refer Microchip Application note AN1292 *“Sensorless Field Oriented Control(FOC) for a Permanent Magnet Synchronous Motor(PMSM) using a PLL Estimator and Field Weakening(FW)”* and AN1208 “Integrated Power Factor Correction (PFC) and Sensorless Field Oriented Control (FOC) System” available at [Microchip web site](http://www.microchip.com/)

**Note:**

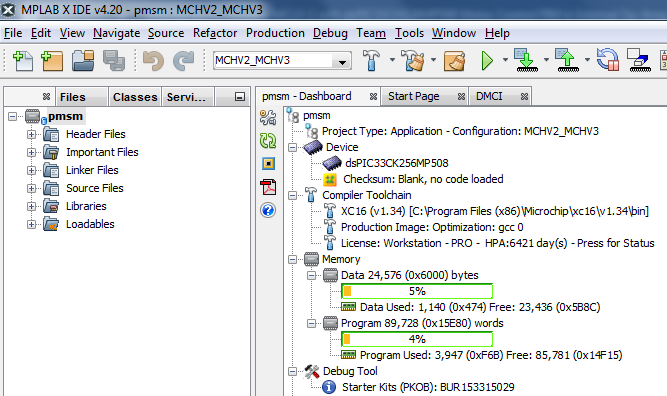
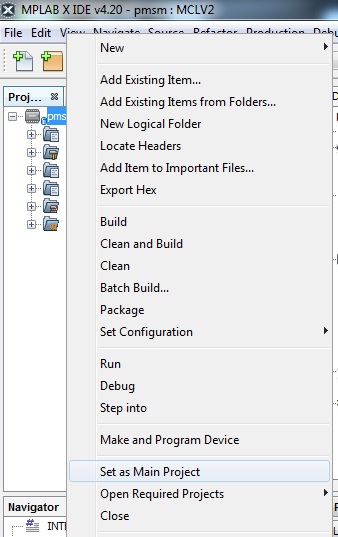
The project may not build correctly in Windows OS if Maximum path length of any source file in the project is more than 260 characters. In case absolute path is exceeding or nearing maximum length, do any (or both) of the following:

* Shorten the name of the directory containing the firmware used in this demonstration. In this case, rename directory *AN1208\_dsPIC33CK256MP508\_EXT\_INT\_MCHV3* to more appropriate shorter name. In case you renamed the directory, consider the new name while reading instructions provided in the upcoming sections of the document.
* Place firmware in a location, such that absolute path length of each file included in the projects does not exceed the Maximum Path length specified.

For details, refer MPLAB X IDE help topic *“Path, File and Folder Name Restrictions”.*

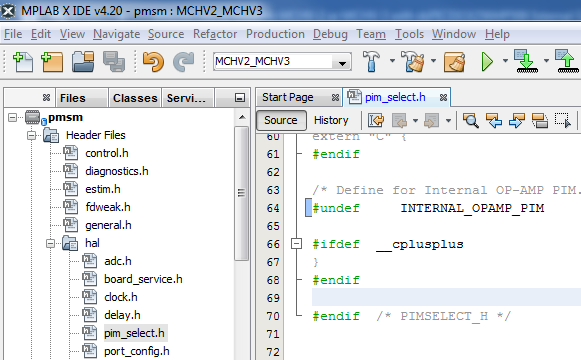
* 1. Basic Demonstration

Follow below instructions step by step to setup and run the motor control demo application:

1. Start MPLAB X IDE and open (File>Open Project) the project *pmsm.X*(..*\MCHV3\_33CK256MP508\_PFC\_Compressor\pmsm.X*) with device selection *dsPIC33CK256MP508*
2. Set the project *pmsm.X* as main project by right clicking on the project name and selecting “Set as Main Project” as shown. The project “pmsm” will then appear in **bold**. 

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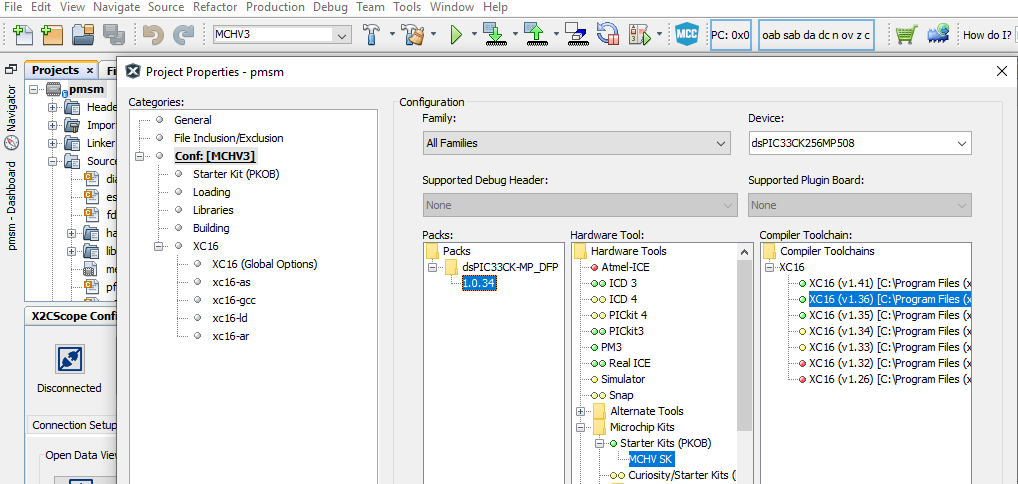
1. Open pim\_select.h (under pmsm.X->headerfiles->hal) in the project pmsm.X and ensure the macro definition INTERNAL\_OPAMP\_PIM is undefined as this demonstration is for External Op-Amp configuration.



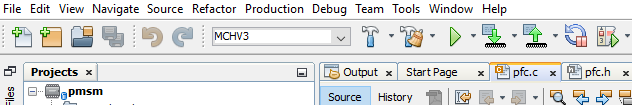
1. Open pfc\_userparams.h in the project pmsm.X and ensure that ENABLE\_PFC is defined and PFC\_POWER\_CONTROL is undefined.
2. By default, ENABLE\_PFC\_CURRENT\_OFFSET\_CORRECTION is defined in pfc\_userparams.h, undef if load is always ON at DC bus.
3. Right click on the project *pmsm.X* and select “Properties” to open its Project Properties Dialog. Click the “Conf: [MCHV3]” category to reveal the general project configuration information.

In the *‘****Conf-MCHV3’*** category window:

* Select the specific Compiler Toolchain from the available list of compilers. Please ensure MPLAB® XC16 Compiler supports the device dsPIC33CK256MP508.In this case “XC16(v1.36)” is selected. The compiler used for testing the firmware is listed in the section 2.2 Software Tools Used for Testing the firmware.
* Select the Hardware Tool to be used for programming and debugging. In this case, “MCHV-SK” is selected as the programmer from Microchip Starter Kits section.
* After selecting Hardware Tool and Compiler Toolchain, click button **Apply.**



1. To build the project (in this case *pmsm.X*) and program the device dsPIC33CK256MP508, click “**Make and Program Device Main project**” on the toolbar.



1. Remove mini-USB cable from your computer to the mini-USB connector “PROGRAM/DEBUG” of the Development Board, once Programming is completed.
2. If fault is detected on PFC section, LED D19 will be turned ON and LED D19 will automatically turned OFF if Fault is cleared.
3. Run or Stop the motor by pressing the push button **S1**(labeled as **“PUSHBUTTON”**) on the front panel of the Board.

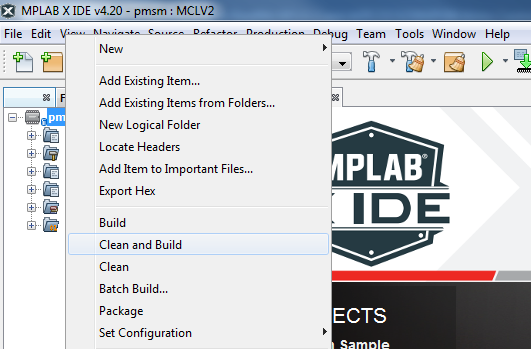
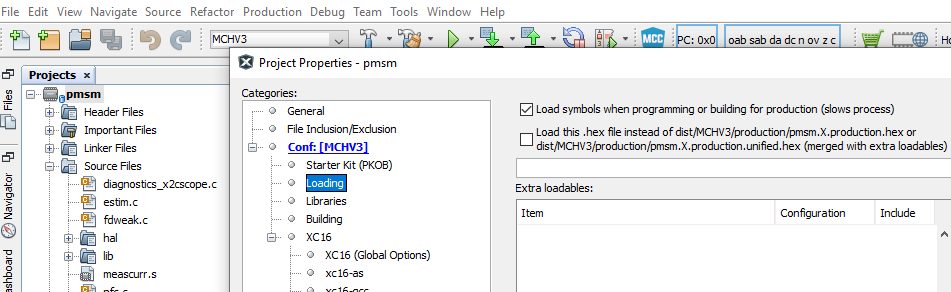


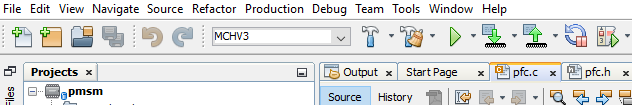
1. If desired, the motor speed can be varied using the potentiometer (labeled **“POT**”).



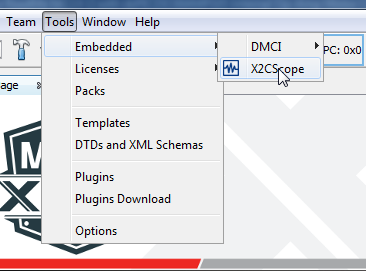
1. Press push button **S1**(labeled as **“PUSHBUTTON”** on the front panel of the Board) to stop the motor.
   1. Data visualization through X2CScope Plug-in of MPLABX

The application firmware comes with initialization required to interface Controller with Host PC to enable Data visualization through X2C Scope plug-in. X2C-Scope is a third-party plugin for MPLAB X which facilitates real-time diagnostics.

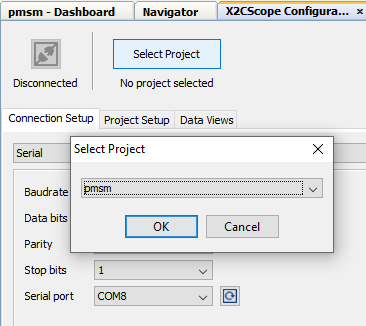
1. Ensure X2C Scope Plug-in is installed. For additional information on how to set up a plug-in refer <https://microchipdeveloper.com/mplabx:tools-plugins-available>
2. To utilize X2C communication for this demonstration, a mini-USB connection is required between Host PC and the Development Board. Connect a mini-USB cable from your computer to the J6 connector (labeled as “USB” on the front panel of the board enclosure) of the Development Board.
3. Ensure application is configured and running as described under Section Basic Demonstration by following steps 1 through 11.
4. Build the project *pmsm.X*. To do that right click on the project *pmsm.X* and select “Clean and Build”.
5. Please ensure that the checkbox “Load symbols when programming or building for production (slows process)” is checked, which is under the “Loading” category of the Project Properties window.
6. To build the project (in this case *pmsm.X*) and program the device dsPIC33CK64MC105, click “**Make and Program Device Main project**” on the toolbar.



1. Remove mini-USB cable from your computer to the mini-USB connector “PROGRAM/DEBUG” of the Development Board, once Programming is completed.
2. Open the X2C window by selecting Tools>Embedded>X2CScope.



1. In the X2CScope Configuration window, using “Select project” menu, select pmsm.X project as shown.



1. Remote Communication needs to be established, as indicated in the following figure. Ensure the communication baud rate is set to 115200 as the same is set in the application firmware, while COM port used depends on the system settings. Refresh button lists the available COM Ports. Select the COM Port as per the connection.

A screenshot of a cell phone

Description automatically generated

1. Once COM port is detected, click on “**Disconnected**”, and it will turn to “**Connected**”, if the link is established as programmed.

A screenshot of a cell phone

Description automatically generated

1. Set the “Project Setup” as shown below and click “Set Values”. Set Scope sample time as interval at which X2CScopeUpdate() is called. In this application it is every 20kHz (50µs).

A screenshot of a social media post

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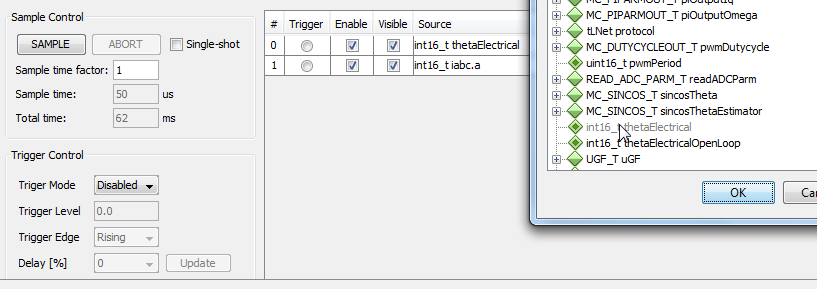
1. When the setup is established, click on Open Scope View (under sub window “Data Views”), this opens Scope Window.

A screenshot of a cell phone

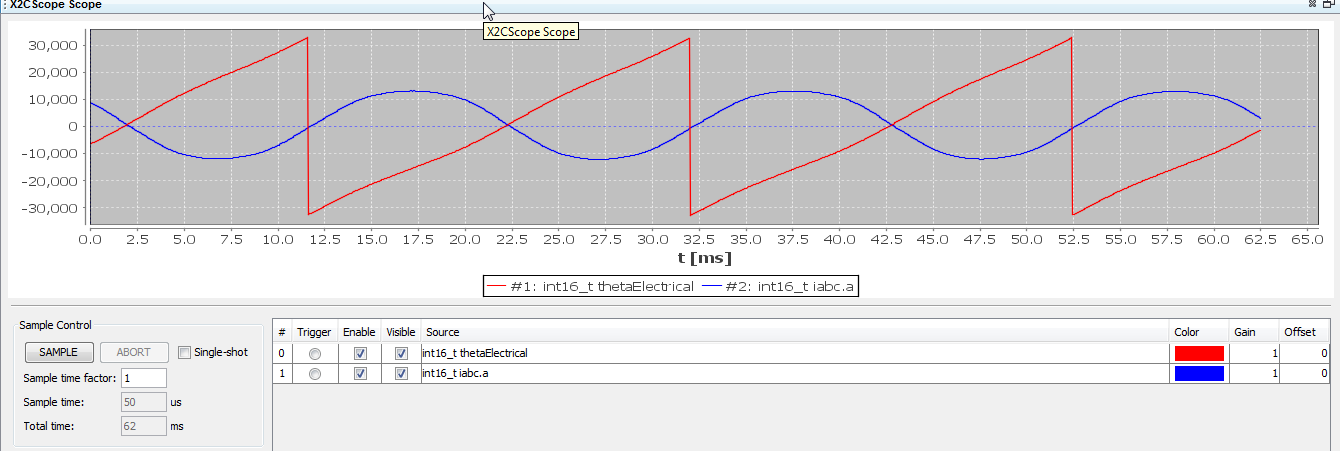
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1. In this window, select the variables that needs to be monitored. To do this, click on the source against each channel, a window Select Variables opens upon the screen. From the available list, the required variable can be chosen. Ensure check boxes Enable & Visible are checked for the variables to be plotted.

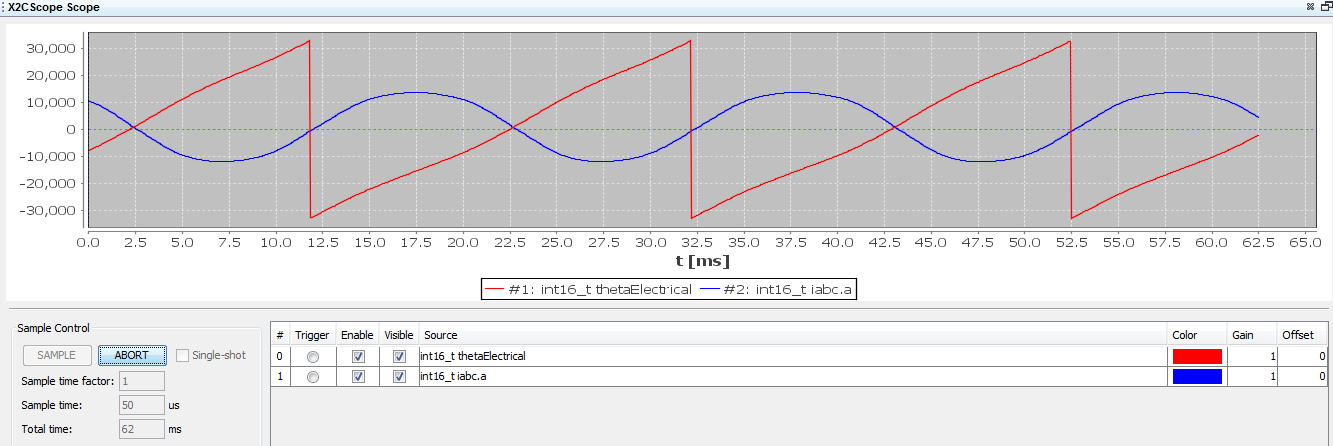
To view data plots continuously, uncheck Single-shot. When Single-shot is checked it captures the data once and stops. The Sample time factor value multiplied with Sample time determines the time difference between any two consecutive data points on the plot.



1. Click on SAMPLE, then X2C scope window shows variables in real time, which is updated automatically.



1. Click on ABORT to stop.



1. dsPIC® DSC RESOURCE USAGE SUMMARY
   1. Device Pin Mapping and Its Functionality in the Firmware:

The following table summarizes device pins configured and used in the AN1208 motor control application firmware demonstrated using the Development Board and the dsPIC33CK256MP508 External Op-Amp Motor Control PIM(MA330041-1). Refer “*dsPIC33CK256MP508 External Op-Amp Motor Control Plug-in-Module (PIM) Information Sheet (DS50002757)”* for more information.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Functional Description | PIM PIN Number | Device PIN Number | Device  Pin  Name | Signal Type | Remarks |
| **PFC,Motor Control PWMs and Fault Input** | | | | | |
| PWM1H | PIM:94 | 1 | RP46/**PWM1H**/PMD5/**RB14** | PWM  Output | Connects to Power Module U19  Input IN(UH) |
| PWM1L | PIM:93 | 3 | RP47/**PWM1L**/PMD6/**RB15** | PWM  Output | Connects to Power Module U19  Input IN(UL) |
| PWM2H | PIM:99 | 78 | TDI/RP44/**PWM2H**/PMD3/**RB12** | PWM  Output | Connects to Power Module U19  Input IN(VH) |
| PWM2L | PIM:98 | 80 | RP45/**PWM2L**/PMD4/**RB13** | PWM  Output | Connects to Power Module U19  Input IN(VL) |
| PWM3H | PIM:03 | 75 | TMS/RP42/**PWM3H**/PMD1/**RB10** | PWM  Output | Connects to Power Module U19  Input IN(WH) |
| PWM3L | PIM:100 | 76 | TCK/RP43/**PWM3L**/PMD2/**RB11** | PWM  Output | Connects to Power Module U19  Input IN(WL) |
| PWM4L | PIM: 78 | 74 | RP64/PWM4L/PMD0/RD0 | PWM  Output | Controls PFC IGBT |
| FAULT | PIM:18 | 49 | RP72/SDO2/**PCI19**/**RD8** | PWM  Input | Connected to  Over Current Fault Output |
| **Analog Inputs – Phase Currents, Speed Reference, Speed Reference, dc bus, input Voltage** | | | | | |
| POT | PIM:32 | 36 | **AN19**/CMP2C/RP75/PMA0/PMALL/PSA0/**RD11** | Analog Input | Speed Reference  Connected to Potentiometer POT |
| IA | PIM:22 | 41 | OA2OUT/**AN1**/AN7/ANA0/CMP1D/CMP2D/CMP3D/  RP34/SCL3/INT0/**RB2** | Analog Input | Connected to Motor Phase Current 1 through External Op-Amp Matrix Board and Jumper J12 |
| IB | PIM:21 | 23 | OA3OUT/**AN4**/CMP3B/IBIAS3/**RA4** | Analog Input | Connected to Motor Phase Current 2 through External Op-Amp Matrix Board and Jumper J13 |
| Vac | PIM: 24 | 18 | OA1IN-/ANA1/RA1 | Analog Input | PFC input Voltage |
| IPFC | PIM: 25 | 16 | OA1OUT/AN0/CMP1A/IBIAS0/RA0 | Analog Input | PFC Phase Current |
| VDC | PIM: 35 | 38 | AN18/CMP3C/ISRC3/RP74/PMD9/PMA9/RD10 | Analog Input | DC bus Voltage |
| **Miscellaneous Signals** | | | | | |
| BTN | PIM:68 | 24 | **RE5** | Digital  Input | Connected to Push Button S1  (labeled “PUSHBUTTON” |
| Debug LED2 | PIM:60 | 42 | **RE8** | Digital Output | Connected to LED D19 |
| Debug LED1 | PIM:01 | 44 | **RE9** | Digital  Output | Connected to LED D2 |
| PFC\_EN | PIM: 19 | 10 | RP79/PCI22/PMA2/RD15 | Digital  Output | PFC Enable signal given to PFC Gate driver |
| RX (UART) | PIM:49 | 52 | **RP71**/PMD15/**RD7** | UART1  Input | Connected to UART-USB converter to establish serial communication interface between Host PC and the dsPIC® DSC as needed by X2C Scope. |
| TX (UART) | PIM:50 | 53 | **RP70**/PMD14/**RD6** | UART1  Output | Connected to UART-USB converter to establish serial communication interface between Host PC and the dsPIC® DSC as needed by X2C Scope. |

1. References:

For additional information, refer following documents or links.

1. AN1208 “Integrated Power Factor Correction (PFC) and Sensorless Field Oriented Control (FOC) System”
2. AN1292 Application Note “Sensorless Field Oriented Control (FOC) for a Permanent Magnet Synchronous Motor (PMSM) Using a PLL Estimator and Field Weakening (FW)”
3. dsPICDEM™ MCHV-3 Development Board User’s Guide (DS50002505)
4. dsPIC33CK256MP508 External Op-Amp Motor Control Plug-in-Module (PIM) Information Sheet (DS50002757)
5. dsPIC33CK256MP508 Family datasheet (DS70005349).
6. Family Reference manuals (FRM) of dsPIC33CK256MP508 family
7. MPLAB® X IDE User’s Guide (DS50002027) or MPLAB® X IDE help
8. [MPLAB® X IDE installation](http://microchipdeveloper.com/mplabx:installation)
9. [MPLAB® XC16 Compiler installation](http://microchipdeveloper.com/xc16:installation)