TI Designs Two-Phase Embedded Metering Firmware Upgrade

TEXAS INSTRUMENTS

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Design Resources

TIDM-2PHASE-SUBMTR-FW2	

MSP430i2041

Tool Folder Containing Design Files Product Folder



ASK Our E2E Experts WEBENCH® Calculator Tools

Design Features

- Adds Functionality and Flexibility to Original Firmware on TIDM-2PHASE-SUBMTR
 - I²C Communication Capability in Parallel With Universal Asynchronous Receiver/Transmitter (UART) Communication
 - Fundamental Voltage, Current, and Power and Voltage; Current Total Harmonic Distortion (THD) Measurement of Voltage and Current
 - Flexible Assignment of Analog-to-Digital Converter (ADC) Channels in Application Level Without Touching the Metrology Library

Featured Applications

- Home Appliances
- Power Supplies
- Home Security and Automation



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1 System Overview

1.1 Cautions and Warnings



CAUTION

Read the user guide before use.



WARNING

HIGH VOLTAGE: Electric shock is possible when connecting a board to a live wire. The board should be handled with care by a professional. For safety, TI recommends the use of isolated equipment with overvoltage and overcurrent protection.

This firmware upgrade is designed to run on the TIDM-2PHASESUBMTR hardware. Please read the TIDM-2PHASESUBMTR design guide before running the code on the corresponding hardware.

1.2 System Description

This document discuss the firmware upgrade to the original two-phase power measurement application (TIDM-2PHASE-SUBMTR) using a simple, low-cost MSP430i2041 microcontroller (MCU) from Texas Instruments. This design includes enhancements to the metrology library, which has measurements of fundamental voltage, fundamental current, and fundamental power as well as the total harmonic distortion for voltage and current. The design also modifies how the ADC is accessed so that the assignment of ADC channels for different voltage and current measurements can be done at the application level, instead of fixing these values at the library level. This design also modifies the communication architecture so that both Inter-Integrated Circuit (I²C) and UART are supported and can operate simultaneously. This design guide provides detailed descriptions of these features in later sections.

The TIDM-2PHASE-SUBMTR-FW2 original firmware includes features that were not considered during the design of the TIDM-2PHASE-SUBMTR [1] and corresponding firmware 1.0. The firmware 2.0 design implements several enhancements.

The purpose of the enhancement to the communication sub-system is to support the communication between connected units so that the measurement of more than two sets of voltage and current channels is possible when wiring several boards with the same hardware are connected. As an example, the I²C (slave mode) is chosen as the target of implementation. The same concept can be applied to easily add or move the support of other communication protocols, such as the serial peripheral interface (SPI).

Enhancements to the ADC driver sub-system allow an application-level change of the assignment of ADC channels that vary from the suggested hardware design without having to access and recompile the metrology library. This new feature may help simplify the PCB layout allowing better noise immunity and accuracy in a user application board.

The third major enhancement is the addition of measurement parameters, which some applications require.

2 Enhancement Details

2.1 Enhanced Communication System

Figure 1 and Figure 2 show the architectural change in the two versions of firmware of the communication sub-system. Notice that the individual communication ports HAL has been separated from the original communication layer to form the ports HAL and an intermediate layer. This change in architecture allows several communication ports to operate simultaneously on the same protocol or each on an individual protocol.

This change takes most parts of the original *emeter-communication.c* and modifies it to *emeter-uart.c*; keeping only the application program interfaces (API) serial_config and serial_write. These two APIs are then rewritten to perform the dispatch, port configuration, and port writing to the port specified in the API.

The change in *emeter-dlt645.c* is minimal and mainly to cope with the way the communication port is handled in the new architecture.

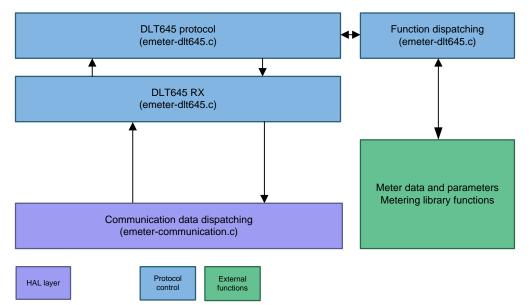


Figure 1. Communication Sub-System Architecture in Firmware 1.0

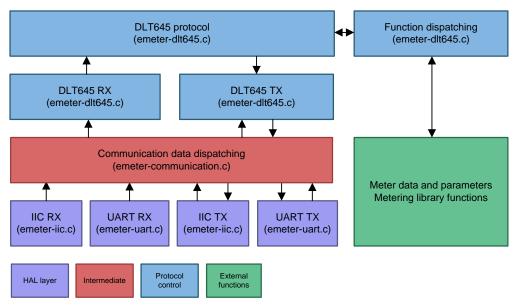


Figure 2. Communication Sub-System Architecture in Firmware 2.0



Enhancement Details

2.1.1 HAL Implementation

The HAL of the communication sub-system provides a unified view to the upper layer and removes the requirement for hardware specific code in the upper layer.

To keep the HAL for communication in this firmware as simple as possible, only the following APIs are required to provide for the HAL. The "xxx_" below indicates the communication port (for example, iic_).

- xxx_configure: Configure or initialize the communication port
- xxx_write: send data to the communication port
- serial_rx_callback: Callback function to the emeter-communication layer to handle the process when a byte is received
- serial_tx_callback: Callback function to the emeter-communication layer to handle the process when a byte has been transmitted
- serial_comm_abort: Callback function to the emeter-communication layer to abort a communication
 process in cases where an unrecoverable error has been encountered

In the implementation, the xxx_configure sets the port up with a proper pin configuration, register setting for the specified bit rate, and register setting for the interrupt, if necessary. The xxx_write performs the setup of necessary pointers and counters for data transmission and then enables the interrupt, if necessary. If a port interrupt is enabled, the HAL must also include the handling of interrupts generated and any error conditions encountered.

The *emeter-communication.c* is an intermediate layer to further abstract the HAL, creating a unified view of the upper layer. The *emeter-communication.c* is responsible for the following:

- Receives the call to configure/initialize all the communication ports involved and call to the HAL layer individually for performing the configuration/initialization.
- Receives the call to write data to a specific communication port.
- Transfer callback functions from HAL back to the upper layer for unified data byte transmit and receive handling.

When adding a HAL for another communication port, the user must also modify the *emeter-communication.c* and *emeter-communication.h* files to handle the additional port.



2.2 Enhanced ADC Channel Assignment Scheme

Figure 3 and Figure 4 show the architectural change in the two versions of firmware in the ADC driver sub-system. In the firmware 1.0 the assignment of the ADC to different current and voltage channel sensors is fixed in the metrology library at compile time. The problem with this firmware version is that a different library version is required to assign the ADC differently. This firmware update adds a layer called ADC assignment matrix to improve this version and further isolate the metrology library from user applications.

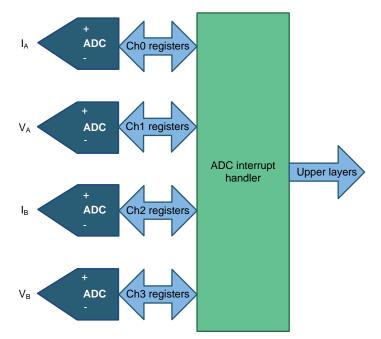


Figure 3. ADC Driver Sub-System Architecture in Firmware 1.0

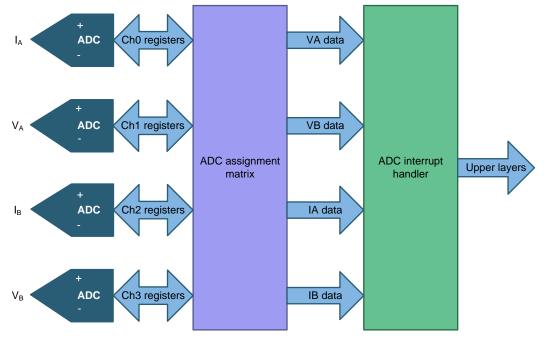


Figure 4. ADC Driver Sub-System Architecture in Firmware 2.0



Enhancement Details

With the addition of the ADC assignment matrix, the metrology computation no longer accesses the ADC through direct register access, but rather accesses the ADC abstracted as voltage channels and current channels. The assignment of an abstract channel to a physical channel is stored in an array, and the physical channel is accessed by using the abstract channel as an index into this array. When the physical channel is identified, the physical address for ADC access transmits from the matrix named SD24_Channel as defined in the *emeter-sd24.c* file (in the application layer).

The emeter-sd24.c file is the HAL for the SD24 ADC. The HAL includes the following APIs:

- SD24_Channel matrix: This matrix consists of the address of registers for accessing individual channels in SD24
- Function SD24_Init: This is function calls to initialize the SD24 to the proper clock and reference voltage
- Function ADC32_OSR256, ADC32_OSR128, and ADC32_OSR64: These are the functions called to get the 24-bit result for different OSR settings (the metrology library for the TIDM-2PHASE-SUBMTR device and this TI design fix the OSR to 256)

With the new architecture changing the channel assignment is simple. Channel assignment is defined in the *metrology-calibration-defaults.c* file and the assignment is defined in the array VoltageADCAssign and CurrentADCAssign. For example, in the following code the voltage channel 0 is using ADC channel 1, voltage channel 1 is using ADC channel 0, current channel 0 is using ADC channel 3, and current channel 1 is using ADC channel 2. The length of these two arrays is not important as long as it covers the required number of channels for voltage and current.

const uint16_t VoltageADCAssign[] = {1, 0, 0, 0, 0, 0, 0};

const uint16_t CurrentADCAssign[] = {3, 2, 0, 0, 0, 0, 0};

2.3 Enhanced Measurements

Firmware 1.0 for the TIDM-2PHASE-SUBMTR provides the most basic measurement required for nearly every application. The firmware 2.0 provides additional functionalities with the available CPU bandwidth. Figure 5 shows the software data flow for the calculation of the measured parameters for a phase. For each phase each sample undergoes the process to yield the measurement parameters. The next subsection summarizes the measurements provided and equations used for computation in firmware 1.0, and the additional functionality provided in firmware 2.0.

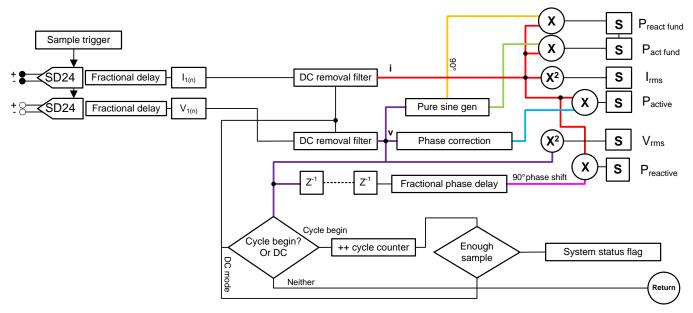


Figure 5. Software Data Flow of a Phase



2.3.1 Measurements Provided in Firmware 1.0

$$\begin{split} V_{RMS} &= VGAIN \times \sqrt{\frac{1}{N} \sum_{i=1}^{N} V_{samp}(i) \times V_{samp}(i)} \\ I_{RMS} &= IGAIN \times \sqrt{\frac{1}{N} \sum_{i=1}^{N} I_{samp}(i) \times I_{samp}(i)} \\ P_{active} &= PGAIN \times \frac{1}{N} \sum_{i=1}^{N} V_{samp}(i) \times I_{samp}(i) \\ P_{reactive} &= PGAIN \times \frac{1}{N} \sum_{i=1}^{N} V_{samp,90}(i) \times I_{samp}(i) \end{split}$$

$$\mathsf{P}_{apparent} = \sqrt{\mathsf{P}^2_{active} \times \mathsf{P}^2_{reactive}}$$

$$\mathsf{PF} = \mathsf{cos}\phi = \frac{\mathsf{P}_{\mathsf{active}}}{\mathsf{P}_{\mathsf{apparent}}}$$

2.3.2 Additional Measurements Provided in Firmware 2.0

$$V_{RMS_fund} = VGAIN \times \sqrt{\frac{1}{N} \sum_{i}^{N} V_{samp(i)} \times V_{pure(i)}}$$

$$P_{active_fund} = PGAIN \times \frac{1}{N} \sum_{i}^{N} I_{samp(i)} \times V_{pure(i)}$$

$$P_{reactive_fund} = PGAIN \times \frac{1}{N} \sum_{i}^{N} I_{samp(i)} \times V_{pure(\pi/2)(i)}$$

$$V_{THD} = \frac{\sqrt{V_{RMS}^2 - V_{RMS_fund}^2}}{V_{RMS_fund}}$$

$$I_{RMS_fund} = \frac{\sqrt{P_{active_fund}^2 + P_{reactive_fund}^2}}{V_{RMS_fund}}$$

$$I_{THD} = \frac{\sqrt{I_{RMS}^2 - I_{reactive_fund}^2}}{I_{RMS_fund}}$$



2.4 Other Changes

In addition to all of the major changes previously discussed, there were a few minor changes made to the firmware version 2.0.

The metrology version number is now retrieved by an API call to the metrology library rather than taking the constant defined by the application in *metrology-calibration-defaults.c* and *metrology-calibration-template.h*. This new way or retrieving the metrology version isolates the metrology library from the application and allows the reported version number to remain consistent.

The meter protocol version is now defined in "#define METER_PROTOCOL_VERSION" in the *dlt645-decs.h* file. This definition isolates the communication version from the user application and allows the reported version number to remain consistent.

The meter configuration is now retrieved by an API call to the metrology library rather than composing this configuration within the *emeter-dlt645.c* file. This new way of retrieving the meter configuration isolates the metrology library from the application and allows the reported meter configuration to report the functionality of the metrology library consistently.

The metrology library has a new name "emeter-metrology-i2041-2-phase.r43", which has changed from "emeter-metrology-i2041.r43" in firmware 1.0.

Firmware 2.0 allows measurement of DC voltage and current up to 190-V DC or up to 380-V DC depending on the configuration set for a two phase measurement. Other operation ratings are the same as for the TIDM-2PHASE-SUBMTR device. Please refer to the design guide of TIDM-2PHASE-SUBMTR [1] for details about the two configurations for two-phase measurement and the operation ratings.



3 Tests

3.1 Accuracy Test

As the computation algorithm and the hardware is the same as in firmware 1.0, the accuracy test is merely testing whether the ADC assignment using the SD24_Channel matrix is correct or not.

3.1.1 Apparatus

TI recommends the following list of instruments to perform the calibration and test.

- AC meter test set (see http://bit.ly/1CgeVH4)
- A reference meter capable of giving AC parameter readings based on the voltage, current, and phase setting from the AC meter test set (see <u>http://bit.ly/1Fgh2LF</u>)

3.1.2 Setup

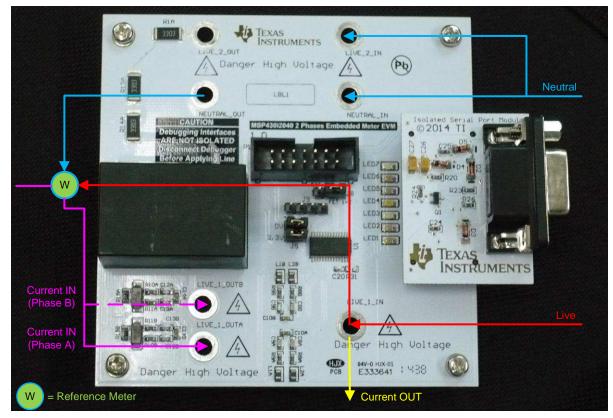


Figure 6. Connection to AC Meter Test Set



3.1.3 Test Results

Tests

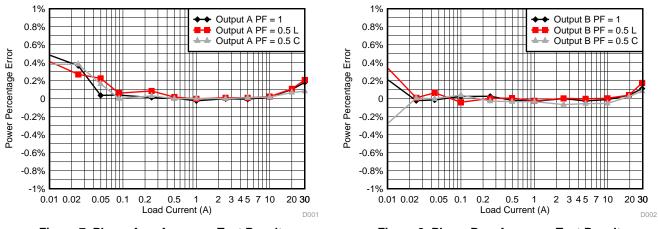


Figure 7. Phase A — Accuracy Test Result

Figure 8. Phase B — Accuracy Test Result

3.1.4 Accuracy Test Summary

When comparing the accuracy of the 1.0 firmware to the 2.0 firmware there is no significant difference in the level of accuracy observed for these parameters.

With the proper test settings and calibration, this design achieves an accuracy of < 0.2% error over a 30-mA to 30-A range, and a < 0.5% error over a 10-mA to 30-A range. The higher percentage error in the low current range is due to noise present on the shunt resistor. The effect of the noise diminishes as the test current increases. The error starts to increase at 20 A due to the heat generated on the shunt, which causes thermal drift to the shunt resistance.

3.2 THD Test

The THD test is conducted using the same generator as the accuracy test with a reference meter that measures THD in current. See the Yokogawa website for the meter used in this test: http://bit.ly/1aCONil.

In the test, a 5-A sinusoidal current is applied with an additional odd harmonic selected at approximately 25% in magnitude. The reading of the THD from the reference meter and the unit under the test is recorded. The percentage deviation from the reading of the reference meter is calculated.

HARMONIC	REF METER READING (%)	UUT READING (%)	DIFFERENCE
3rd	22.63	22.55	-0.08
5th	22.38	22.05	-0.33
7th	22.96	22.15	-0.81

Table 1	THD	Accuracy	Test	Result
		Accuracy	1636	ncount



3.3 Communication Test

The I²C slave communication capability is tested with three units connected together by an I²C host to an RS232 converter. As Figure 9 shows, the test unit has a three-phase voltage applied (120° between phases) and each of the test boards applies two of the three phases. Note that there are more than one power supply units in all of the boards together. As Figure 10 shows, all but one power supply is removed. The VDD and VSS of the boards is connected with the remaining power supply so that the system runs on a single rail.

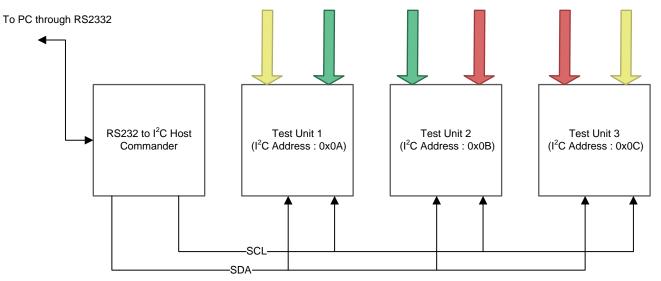


Figure 9. I²C Functional Test Setup

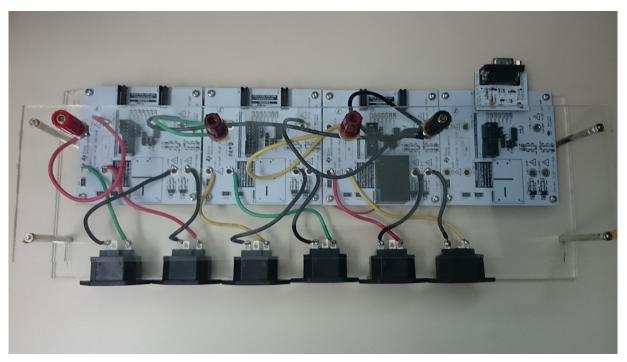


Figure 10. I²C Test Unit

3.4 *fC* Functionality Test Result

The test setup is set to run for four hours of continuous reading from each board at a reading interval of 160 ms with no read error reported.

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Design Files

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4 Design Files

4.1 Software Files

To download the software files, source code, and the metrology library, see the software files at: <u>TIDM-2PHASE-SUBMTR-FW2</u>.

5 References

- 1. Texas Instruments, Two-Phase Embedded Metering, User's Guide, (TIDU641)
- 2. Texas Instruments, MPS430i2xx Family, User's Guide, (SLAU335)

6 About the Author

MARS LEUNG received his Bachelor of Engineering at Hong Kong Polytechnic University and Master of Science at Chinese University of Hong Kong. He is an experienced field application engineer specialized in MCU application support and development; senior smartcard application engineer specialized in smart card payment system definition and implementation; staff engineer specialized in MCU and new module definition; staff engineer in analog system applications specializing in digital system and video processing of dynamic LED backlight control. He is now a staff engineer in Texas Instruments in the Smartgrid Application Team, which specializes in embedded electricity metering applications.



Appendix A Example Application Code

A.1 Introduction

Project structure:

- *emeter-communication.c* source code for intermediate level communication interface
- emeter-dlt645.c source code for the polling mode protocol implementation
- *emeter-iic.c* source code for I²C driver
- emeter-iic.h header code for I²C driver
- *emeter-main.c* source code for system initialization, main loop, callback functions implementation, and interrupt vector placement
- emeter-metrology-i2041-2-phase.r43 embedded metering library object code
- *emeter-setup.c* source code for low-level system initialization
- emeter-template.h source code for configuration
- emeter-uart.c source code for UART driver
- *emeter-uart.h* header code for UART driver
- metrology-calibration-default.c source code to put the user defined default calibration parameter into a proper data structure (should only modify the const VoltageADCAssign and CurrentADCAssign for assignment of ADC and must not modify the other part of this file)
- metrology-calibration-template.h source code of user defined default calibration parameter

A.2 RS232 to PC Master Application

The emeter-iic-master-i2040 is a standalone application project written to test the I²C functionality of firmware 2.0. The application acts as a bridge to convert the RS232 command and the I²C command to and from three units of the TIDM-2PHASE-SUBMTR device. The result makes the whole connected test setup function as a six-channel metering unit. The application is also designed to run on the same hardware as TIDM-2PHASE-SUBMTR.



A.3 Preparing the Application Code to Run

- 1. After launching the IAR Embedded Workbench® IDE Version 5.5, click on *File* \rightarrow *Open* \rightarrow *Workspace*
- 2. Select *emeters.eww* when prompted to open *Workspace*.

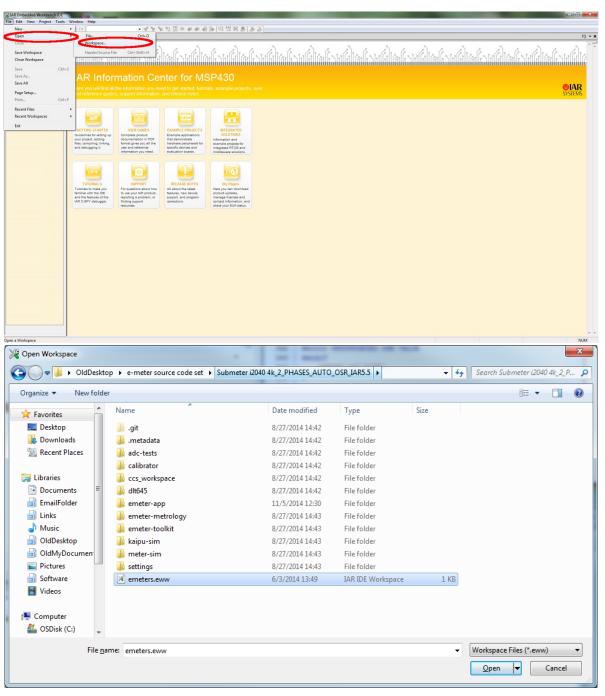


Figure 11. Opening Workspace

3. Select the *emeter-app-i2041* project tab at the bottom of the *Workspace* window.



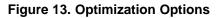
4. Check project options by right clicking the project name and select *Options...* from the pop-up menu (see Figure 12).

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Figure 12. Project Tab

5. When the options appear, select C/C++ Compiler on the left-hand column. Then select the *Optimizations* tab on the right-hand side and check the optimization settings as shown in Figure 13.

Options for node "emeter-app	-i2041"	x
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Preparing the Application Code to Run

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6. Select *FET Debugger* on the left-hand column, then select the *Setup* tab. The EVM uses *Spy-Bi-Wire* for its code downloading and debugging. Check to make sure the options are as shown in Figure 14.

Options for node "emeter-app-i	i2041"	X
Category: General Options C/C++ Compiler Assembler Custom Build Build Actions Linker TI ULP Advisor Debugger FET Debugger Simulator	Factory Settings Setup Download Breakpoints Cgnnection Texas Instrument USB-IF Automatic Parallel port 1 Debug protocol Automatic Ogendection Automatic Ogendection Target VCC Ogende default Target VCC (in Volt): 3.4 Setting time (in ms): Disable memory gache Debug LPMx.5	

Figure 14. Debugger Options

7. Select the Download tab. Under Flash erase, do not choose Erase main memory and Information memory; this option erases both sets of data and cannot be recovered. Instead, choose Erase main memory as the download option to preserve these factory parameters: system clock calibration, ADC calibration, and internal reference calibration (see Figure 15). However, metrology calibration stored in the main memory, such as VGAIN, IGAIN, PGAIN, and so on, are always erased after downloading.

Cotorony Eastery Softings	Options for node "emeter-app	i2041"	×
Category. Totatiy Settings General Options CyC++ Compler Assembler Custom Build Duid Actions Image: Complexity Settings Linker Ti ULP Advisor Debugger Alow erase/write access to locked flash memory PET Debugger Stemal code gownload Bash erase © grase main and Information memory © East in unchanged memory © Compare with image on target © Compare with image gached on PC Erase main and Information memory inc. IP PROTECTED area JTAG password:	C/C++ Compiler Assembler Custom Build Build Actions Linker TI ULP Advisor Debugger FET Debugger	Verfit download Allow erase/write access to locked flash memory Allow erase/write access to ESL flash memory External code gownload Eash erase @ Erase main memory @ Erase main and Information memory @ Genpare with image on target @ Compare with image cached on PC @ Erase main and Information memory inc. IP PROTECTED area JTAG password:	.el

Figure 15. Download Options

8. Click OK after completing all of the changes.



9. Rebuild the project by right-clicking on the project and select *Rebuild All* from the pop-up menu (see Figure 16). Three warnings will be reported during rebuilding (see Figure 17), which are safe to ignore. To open the project workspace and modify, compile, and download the code, the user must have IAR Embedded Workbench 5.5 installed with a valid license. If a valid license is not available, the user can still download the object code. See Section A.4 for downloading procedures.

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Figure 16. Compiling the Application

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	108 // Support for placing functions in read/write memory 109 //		
	109 77		
	111 -QCODE_I=CODE_ID		
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	115 // Placement directives		
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	117 118 //		
	119 // Bead/write memory		
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	121		-
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Figure 17. Warnings



10. Make sure the jumper on J8 is short properly and the the jumpers on J5 are open. Connect the 14-pin connector P1 to MSP-FET430UIF by a flat cable as Figure 18 shows.



CAUTION

The debugging interface is NOT ISOLATED. Make sure to properly isolate between the EVM and the PC used for debugging with the AC or DC high voltage connected.

NOTE: Connection to debugging interface is optional for the operation of the EVM. The EVM can operate without a debugger connected.

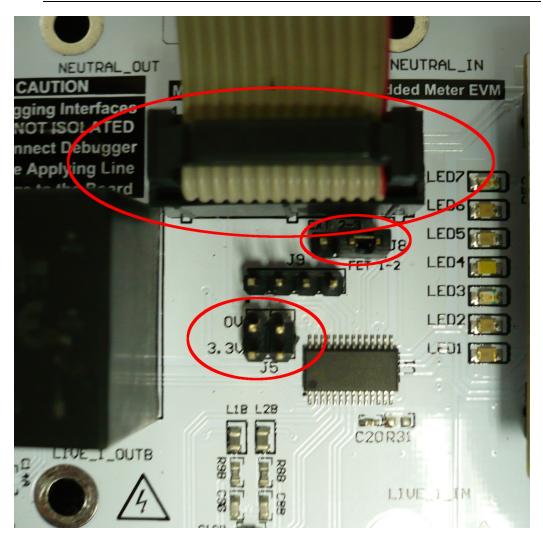


Figure 18. Connecting EVM and FET



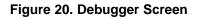
11. Click the *Download and Debug* button to download and debug (see Figure 19).

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	erreter-	45.c emeter-template h dit645-decs.h metrology-foreground.c metrology-template h dit645-decs.h metrology-template h dit64	f0 • ×
Debug	- 116	if NUM_PRASES == 1	
	117	edefine ph 0	· · · · · · · · · · · · · · · · · · ·
Files B	118	eciae -	
🗉 🗇 emeter-app-i2041 - Debug	119	int chr	
Hereiter-communication c	120	endif	
He emeter-dt645.c	121	<pre>#if defined(TR00_STUPCOT)</pre>	
HB emeter-main c	122	uintlé t rendy:	
amate-metricre-i2041 r43	123	and if	
emeter-metrology-12041 r43	124	#if defined(TRNZ_FURITY_TESTS)	
L British starby	125	int fips_result;	
emeter-template h emeter-tv c	126	*endif	
The Comparison	127	// static int32 t x:	
The second	128	int phase state:	
-B C metrology-calibration-defaults.c	179	#if (defined(FMASE_RAVERSED_DETECTION_SUPPORT) as defined(FMASE_REVERSED_IS_TAMPERING)) defined(FMASE_NUBALANCED_DETECTION_SUPPORT)	
metrology-calibration-template.h	130	int metrology_state;	-
Les Output		fendif	
	132		
	199	<pre>#if !defined(_HSP430_)</pre>	
	134	if (start_bost_ervincement(arpc, argv) < 0)	
	135	<pre>a (stat_inst_inst_instantionality, algo) < 0) exit();</pre>	
	100	RAIL(4);	
	137	metrology_init();	
	138	sector(yy_inte()) s	
	130	Wydram_metcap(): PCTL2 = PMEY PX5 PS5ELJ	
	139	PULLZ = PWREI PNO POSELLJ	
	140	#if defined (TRNG_PURITY_TESTS)	
	141	fips_init();	
	142		
	143	fendif	
	144		
	145	#if defined(IEC62034_SUPPORT)	
	146	<pre>serial_timer_init();</pre>	
	147	isc62056_init();	
	148	Vendif .	
	149		
	150		
	151	<pre>#if defined(ESP_SUPPORT)</pre>	
	152	esp_start_measurement();	
	153	tendif Emulator	
	154		
	155	#if defined(MULTI_FAITE_SUFFORT) Downloading and verifying application	
	156	tariff initialize():	
	157	Pendif	
	158		
	159	fif defined (AUTORIFORT SUPPORT)	
	160	init_autoreport ();	
		fendif	
	162		
	163	for (rr)	
	164		
	165	kick_watchdog();	
	166	vrok ¹ accord(),	
	100	#if defined(IEC62056_SUPFORT)	
	168	iicolistelisteseseit	
	100	and a second and a second a se	
	107	*EDJ1 #16 defined(DL7645_SUPFORT)	
	171	dickservice();	
	171	<pre>a_teva_service(); endif</pre>	
		*eddi	
	173	_BIS_SR(LRMO_bite);	
	174	"DI0"DV(rLUN"D1/0) 1	
	175		
	176	#id defined(TEND_STREPROT)	
	177	<pre>#if defined(TRBD)TURITY_TEST3) /* Perform IFSE testing of the true random number operator */</pre>	
	178		
	179	if (trng(srandy) == 0)	
emeter-app-fe427 emeter-app-fe4272 emeter-app-fe4276 emeter-app-i2041 emeter-app-i4020 .	180		
* Messages		File Line	
mussagus		rite Lite	
Building configuration: emeter-app-i2041 - Debug			
Updeting build tree			
Configuration is up-to-date.			
Build [Find in Files Tool Output Debug Log Ambiguous Definitions	_		
Ready			Errors 0, Warnings 0 NUM

Figure 19. Code Downloading

12. After successfully completing the download, Figure 20 appears. Click the Go button to run the application.

						828855 X
						8 " #H - C. ⊕ III - 0 % - CP
	× 1			Watch 1		background.c metrology-calibration-template.h eneter-communication.c emeter-main.c metrology-template.h
CPU Registers • Go to 0xbr9c • Memory • 🗈	Туре	Location	Value	Expression		#if BUM_HHASES 1
PC = 0xB56E Disassembly	struct celli	Memory:0x8814	(struct) Error (col 1); Unknow	 calibration_delouits phase cal 		#define ph 0 #else
SP = 0x009E subc.w R10,R10 ESR = 0x0003 000538 2308 mbc w D10 D10	struct into	Memory:0x8000	(struct)	 mv_pams 		int phr
BSR = 0x0003 008538 7A0A subc.w R10,R10 R4 = 0x0000 add.w y 18,0(x)		Memory:0x62	'0' (0x30) '\0' (0x00)	REFCALO		<pre>#endif #if defined(TBSO_SUPFORT)</pre>
R5 = 0x0000 00853A 5E8C 0000 add.w R14.0x0(R12)	unsigned unsigned	Memory:0x63 Memory:0xBF	'\f' (000)	REFCAL1 SD24TRIM		uinti6 t randvr
R6 = 0x034C addc.w y_ms,2(x)	unsigned	Memory:0x52	' ' (0x7C) 'A' (0xC0)	CSIRFCAL		+endif +if defined(TENS_FURITY_TE3T3)
R7 = 0x0000 00853E 6F8C 0002 addc.w R15,0x2(R12) R8 = 0x0392 addc.w R10,4(x)	unsigned	Memory:0x53	'Å' (0xCO) 'e' (0x65)	CSIRTCAL		int fips_result;
R9 = 0x0392 000542 6A8C 0004 addc.w R10,0x4(R12)	unsigned unsigned	Memory:0x54 Memory:0x55	'\0' (0265) '\0' (0200)	CSERFCAL		+endif
R10 = 0xAEE0 pop.w R10	struct met	Memory:0x274	(struct)	working_data		// static int32_6 x/ int phase_state;
R11 = 0x013C 008546 413A pop.w R10	int	Memory:0x26A	0	raw_temperature_trom_adc	PERING)	#if (defined(PHASE_REVERSED_DETECTION_SUPPORT) 44 defined(PHASE_REVERSED_IS_TAMPERIN
R12 = 0x03E0 xret R13 = 0x01E0 008548 4130 ret	int	Memory:0x260	Error (col 37): Unkno	temperature_in_celsius 10.*/i/rew temperature from adc) - pal info->temperatur		int metrology_state; #endif
add.w 0(y).0(x)			Error (col 31): Unkno	(iraw temperature from add) - cal info->temperature_se .		
R15 = 0x03E0 = 0x03E0 = 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0			Error (col 1): Unknow Error (col 1): Unknow	cal_into->temperature_sensor_intercept		#if !defined(_MS0430_)
addo.w 2(v).2(x)			Error (col 1): Unknow Error (col 1): Unknow	cal_into phase->metrology.V_dc_estimate_logged		<pre>if (start_host_environment(argc, argv) < 0) exit(2);</pre>
00854E 6D9C 0002 0002 addc.w 0x2(R13),0x2(R12)				click to edite		tendif
CCSTEP = 0 addc.w 4(y),4(x) CCSTEP = 0 008554 6D9C 0004 0004 addc.w 0x4(R13),0x4(R12)						<pre>setrology_init(); system_setup();</pre>
Test and						FCTL2 = FW0EY FN5 FS3EL1;
00B55A 4130 ret						#if defined(TRNG_FURITY_TESTS)
sub.w 0(y),0(x) decun48.48:						fips_init(); fips_result = -1;
00055C 8DAC 0000 sub.w @R13,0x0(R12)						fendif
subc.w 2(v),2(x)						#if defined(IEC62056 SUPPORT)
008560 7D9C 0002 0002 subc.w 0x2(R13),0x2(R12) subc.w 4(y),4(x)						serial timer init[];
B000566 7D9C 0004 0004 subc.w 0x4(R13),0x4(R12)						iec62056_init();
aret						
DOBS6C 4130 ret						
metrology_init(); main:						esp_start_measurement();
00B56E 12B0 B982 call Mmstrology_init						fendif
system_setup(); 00B572 12B0 AF60 call #system_setup						#if defined(NULTI BATE SUPPORT)
FTL2 = FWEV FWS FSELL;						tariff initialize();
008576 4082 A5A0 012A mov.w #0xA5A0.6FCTL2						- fendid
kick_watchdog(); 00B57C 40B2 SAOC 0120 mov.w #0x5A0C.6WDTCTL						#if defined(AUTOREPORT SUPPORT)
dlt645_service();						init_sutoreport (); #endif
00B582 12B0 BB26 call #dlt645_service						*eaol:
_BIS_SR(LFM0_bits); 008586 D032 0010 bis.w #0x10.SR						for (;;)
if (operating_mode != OPERATING_MODE_NORMAL)						kick_watchdog[];
00B58A 93C2 03DF tst.b Soperating_mode						
DOB58E 2402 jeq OxB594 BIS SR(LFM0 bits);						<pre>#if defined(IEC62036_SUPPORT) lec62036 service();</pre>
008590 D032 0010 bis.w #0x10.SR						fendif
phase state = phase status(ph);						#if defined(DCT645_SUPPORT)
008594 430C clr.w R12 008596 1280 887E call Wphase_status						dlt645_mervice(); #endif
if ((phase_state & PHASE_STATUS_NEW_LOG))						
00859A B31C bit.w #0x1.R12						_BIS_SR(LEMO_bits):
00B59C 2BEF jnc OxB57C calculate_phase_readings();						#if defined(TRNG_SUPPORT)
00B59E 12B0 9818 call #calculate_phase_read						4if defined(TRNS_FURITY_TESTS) () Devices FUEC testion of the store parties compared to all
if (abs32[active_power(ph]) < RESIDUAL_POWE						if (trng(erendy) == 0)
008582 430C CIT.W R12 008584 1280 A17C call Wattive_power				(
<	×			Workspece Watch 1		<pre>if ((fips_result = fips_test(randy)) := -1) </pre>
00859C 28EF colculate_phase_rear 00859E 12E0 9818 coll 1 if [sbs12]sctive_pco 0085A2 430C clr.w	×		0			<pre>if define(INNE_DIFFERI) if define(INNE_DIFFERI) // Ferdual Type testing of the rise random number generator */ if (Inne(Innews)) = () if ((Inn_greant + fung_rent(-fung_rent)) !=-1))</pre>





Preparing the Application Code to Run

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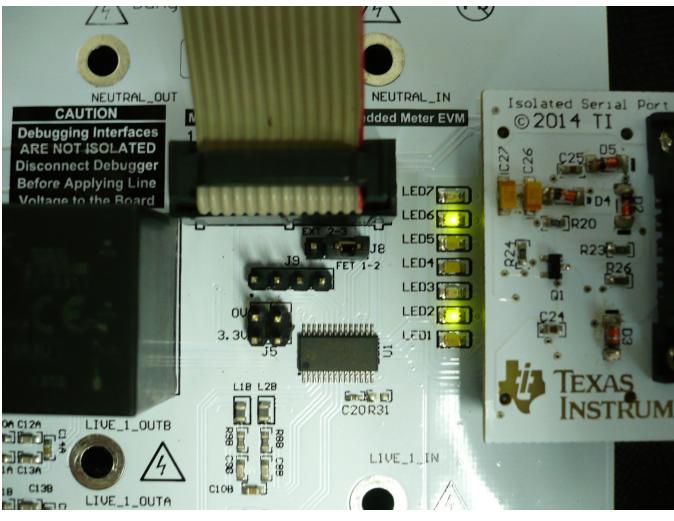


Figure 21. EVM Running



Downloading Without an IAR License

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A.4 Downloading Without an IAR License

If a valid IAR Embedded Workbench 5.5 license is not available, download the executable code to the board with the following steps using the installed IAR Embedded Workbench 5.5.

- 1. Open the project workspace as described in Section A.3, <u>Steps 1 through 7</u>. Then connect the board to the MSP-FET430UIF as described in <u>Step 10</u> in Section A.3.
- 2. Select Project→Download→Download File... from the menu (see Figure 22).
- When prompted to select a file, go to the folder [Submeter i2040 4k_2_PHASES_AUTO_OSR_IAR5.5]\emeter-app\emeter-app-i2041\Debug\Exe and select the file named "emeter-app-i2041.d43" (Figure 23).

The executable code then downloads to the board.

	bedded Workbench IDC			
File Edit View	Project Emulator Tools Window			
0 📽 🖬 🕼	Add Files		· · · · · · · · · · · · · · · · · · ·	
Viorkspace	Add Group		metrology-background.c metrology-template.h metrology-calibration-template.h metrology-dr-table.c emeter-main.c emeter-autoreport.c	f0 - ×
Debug	Import File List	1	25 · DATA, OR PROFITS; OR BUSINESS INTERROPTION) HOREVER CAUSED AND ON ANY	
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-El emeter-	Remove		22 ···································	
-0 emeter-			34 befüre OR 256	-
-0 emeter	Create New Project		36 #define AVERAGE 3	
- meter-	Add Existing Project		37 #define IEC_THD_SUPPORT	
-meter-	Options	Alt+F7	38 //wasdaf IEC_IND_SUBFORT 39	1
-0 emeter	Version Control System		40 /*! This selects the number of phases. */	
- B lpk4302	version Control System		41 #define STM_HHAIES 3	
- Ink430/2	Make	F7	42 #define REDEX_CVLI 1G. 52 //define CARACTOR COMENSATE OF	
-E metrolo	Compile	Ctrl+F7	44 funder CAPACITOR COMPENSATE OF	
Cutput	Rebuild All			
Ha Demet	Clean		46 ///define TIRE RESIDENCE_COMMENDATE 47 eutor: NIRE RESIDENCE_COMMENDATE	
- B ernet	Batch build	FB	48 2010 0 2010 0 2010 0 2010 0 2010	
- C ernet	Stop Build	Ctrl+Break	49 #setim VOIIMag_ISONI_IS_CONBENT 50 ///wardf VOIIAng_ISONI_IS_CONBENT	
	Download and Debug	Ctrl+D	51 31 /// This switch enables menitoring of the petral leaf for anti-fread purposes, in	
	Debug without Downloading		53 T either single phase or 3-phase meters. */	
	Make & Restart Debugger	Chi+R	54 //#define NEUTRAL MENITOR_SUPPORT	
	Restart Debugger	Chi-Shift+R	55 Funder NETTRAL_PORTING_NETFORT 561 1//1 Emis arith ability the use of 24 bit values for the current signal, where the	
	Download		Development and a static static is a static static of the static	
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			42 //! ADC channel allocation // 43 determine BERKE 1 AUTOR BDC COMPRET. 0	
			63 edufine FRAIT_LVDITAGE_ALCC_CRAINEL 0 64 edufine FRAIT_LVDIENT_ALC_CRAINEL 1	
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			(7) (//define NUTFAIL CONNECT 2 (//define NUTFAIL CONNECT 2 (//define NUTFAIL CONNECT 2//2	
			49 INTERNATIONAL INTE	
			76 □ /*/ This switch enables use of the MEP430's internal temperature diode to	
0	ter-app-i2041 emeter-metrology-	and the second	71 because the meter's temperature. */	
Overview ema	ten-app-2041 emeter-metiology-	~2041	The second s	- +
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Figure 22. Download Executable File

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Figure 23. Select File to Download

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