TI Designs

EtherCAT® Interface for High Performance C2000™ MCU

TEXAS INSTRUMENTS

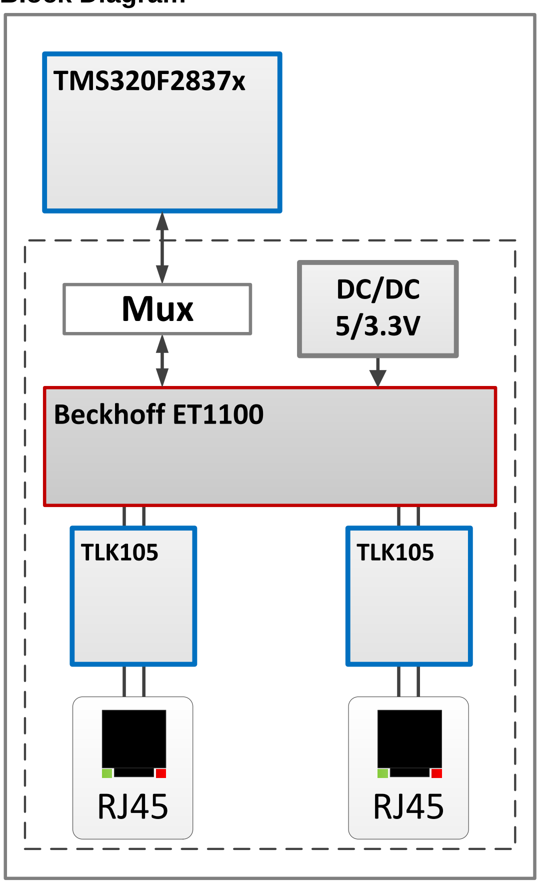
Design Overview

This reference design demonstrates how to connect an EtherCAT® ET1100 Slave Controller to a C2000™ Delfino MCU. The interface supports both demultiplexed address/data busses for maximum bandwidth and minimum latency and a SPI mode for low pin-count EtherCAT communication. The Slave Controller offloads the processing of 100Mbps Ethernet-based fieldbus communication, thereby eliminating CPU overhead for these tasks.

Design Resources

TIDM-DELFINO-ETHERCAT	Design Folder
TMS320F28377D	Product Folder
TLK105	Product Folder
LAUNCHXL-F28377S	Tools Folder

Block Diagram



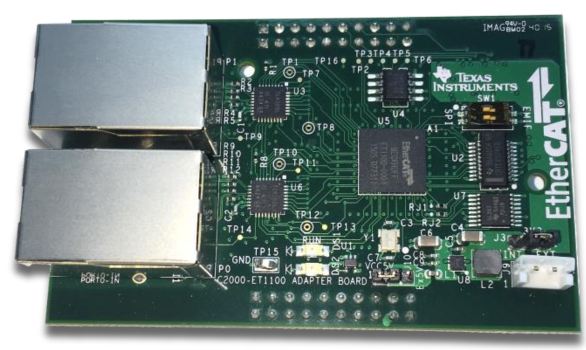
Design Features

- High-Performance Real-time Control MCU paired with low-latency Ethernet-based communication
- High-bandwidth, low-latency interface to Beckhoff ET1100 EtherCAT Slave Controller
- Supports both asynchronous parallel and SPI connections
- Glueless interface
- Eliminates CPU overhead for EtherCAT frame processing

Featured Applications

- Industrial Drives
- Servo Motor Drives
- Manufacturing Robotics
- CNC Machinery
- Remote I/O

Board Image



1 System Description

The TIDM-DELFINO-ETHERCAT is an add-on card that incorporates a Beckhoff ET1100 EtherCAT™ Slave Controller (ESC) and TI Ethernet PHYs that allows the creation of EtherCAT slave nodes when coupled with a C2000 MCU. Multiple board and interface options are supported, which includes asynchronous parallel and SPI interfaces for both TI F2837x ControlCARDs and C2000 LaunchPad Development Kits.

This TI Design illustrates how to set up the EtherCAT BoosterPack™ Plug-in module and/or ControlCARD add-on board, initialize the ET1100 subsystem for first use, and install and configure the Beckhoff TwinCAT 3 software for use as an EtherCAT master in a test setup. Example code is provided to configure both SPI and EMIF interfaces and run simple read/write tests across an EtherCAT network.

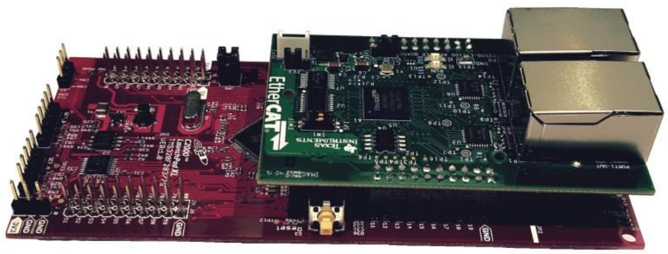


Figure 1. TIDM-DELFINO-ETHERCAT BoosterPack Plug-in Module and C2000 Launchpad

1.1 TMS320F28377D

The Delfino TMS320F2837x is a powerful 32-bit floating-point microcontroller unit (MCU) designed for advanced closed-loop control applications such as industrial drives and servo motor control; solar inverters and converters; digital power; transportation; and power line communications. Complete development packages for digital power and industrial drives are available as part of the powerSUITE and DesignDRIVE initiatives. The F2837x supports a new dual-core C28x architecture that significantly boosts system performance while integrated analog and control peripherals allow designers to consolidate control architectures and eliminate multiprocessor use in high-end systems.

In the TIDM-DELFINO-ETHERCAT design, the F2837x receives EtherCAT data from the ET1100 through either a serial (SPI) interface or an asynchronous parallel memory interface (EMIF). The figure below shows the use of EMIF2, but either EMIF can be used to interface to the ET1100. Note that GPIO93,94 are for future expansion to address a larger memory space. They are not used in the example code.

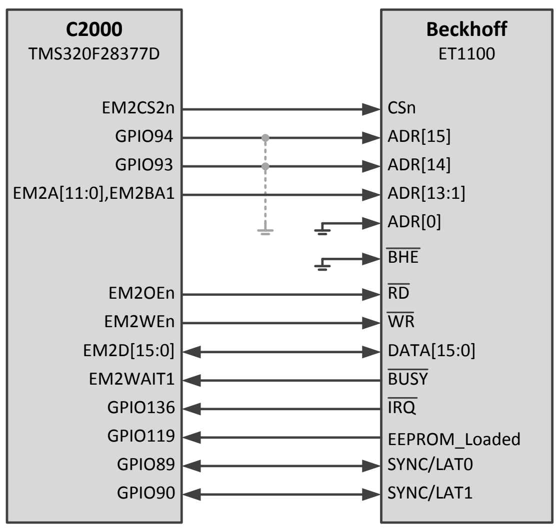


Figure 2. TMS320F2837x EMIF interface to ET1100 EtherCAT Slave Controller

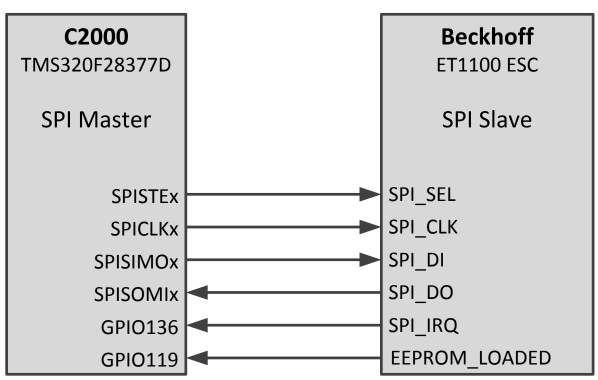


Figure 3. Delfino SPI as EtherCAT PDI

1.2 TLK105

The TLK10x is a single-port Ethernet PHY for 10Base-T and 100Base TX signaling. This device integrates all the physical-layer functions needed to transmit and receive data on standard twisted-pair cables. The TLK10x supports the standard Media Independent Interface (MII) and Reduced Media Independent Interface (RMII) for direct connection to a Media Access Controller (MAC).

1.3 TPS62063

The TPS6206x is a family of highly efficient synchronous step-down DC-DC converters. They provide up to 1.6-A output current. With an input voltage range of 2.7 V to 6 V, the device is a perfect fit for power conversion from 5-V or 3.3-V system supply rails. The TPS6206x operates at 3-MHz fixed frequency and enters power save mode operation at light load currents to maintain high efficiency over the entire load current range. The power save mode is optimized for low output voltage ripple. For low noise applications, the device can be forced into fixed frequency PWM mode by pulling the MODE pin high.

In this TI Design, the converter enables power to be supplied from either the C2000 LaunchPad, controlCARD, or from an external 5V source.

1.4 SN74LVC1G07

This single buffer/driver is designed for 1.65-V to 5.5-V Vcc operation. The output of the SN74LVC1G07 device is open drain and can be connected to other open-drain outputs to implement active-low wired-OR or active-high wired-AND functions. The maximum sink current is 32 mA.

In this design, the open-drain buffer connects a GPIO from the F2837x LaunchPad or controlCARD to the ET1100 EtherCAT slave controller reset pin, thereby enabling independent reset of both devices.

1.5 SN74CBTLV3245A

The SN74CBTLV3245A provides eight bits of high-speed bus switching in a standard '245 device pinout. The low on-state resistance of the switch allows connections to be made with minimal propagation delay. The device is organized as one 8-bit switch. When output enable (OE) is low, the 8-bit bus switch is on, and port A is connected to port B. When OE is high, the switch is open, and the high-impedance state exists between the two ports.

In this TI Design, the bus switch isolates selected ET1100 outputs from the F2837x controlCARD GPIOs when the EMIF interface is not used (SPI mode). Note that the bus switches are optional in a design using only a single interface type.

1.6 SN74CBTLV3257

The SN74CBTLV3257 device is a 4-bit 1-of-2 high-speed FET multiplexer/demultiplexer. The low on-state resistance of the switch allows connections to be made with minimal propagation delay. The select (S) input controls the data flow. The FET multiplexers/demultiplexers are disabled when the output-enable (OE) input is high.

This multiplexer connects selected GPIOs to the ET1100 depending on the interface mode (EMIF or SPI). Note that the multiplexer is optional in a design using only a single interface type.

1.6.1 Beckhoff ET1100 EtherCAT Slave Controller (ESC)

The ET1100 device is an EtherCAT Slave Controller (ESC). It handles all communications between the EtherCAT fieldbus and the F2837x interface (either SPI or EMIF).

See the Beckhoff website for more details. http://www.beckhoff.com

2 Block Diagram

Figure 4 shows the block diagram of the SPI (for the C2000 LaunchPad) and EMIF (for the C2000 ControlCARD) interfaces. In both configurations, the 'F2837x runs the EtherCAT slave stack while the ET1100 is used to offload the EtherCAT Slave Controller (ESC) frame processing, FMMU, and SyncManager operations.

Certain pins on the ET1100 are used on both the SPI and asynchronous interfaces, which thus requires the '74CBTLV3257 mux and '74CBTLV3245 buffer to steer these signals to the appropriate GPIO on the 'F2837x MCU.

The EtherCAT BoosterPack and Add-on cards feature an on-board DC-DC 5V-3.3v converter, which allows the 3.3v Vcc to be sourced from either the C2000 LaunchPad/ControlCARD, or generated locally from an off-board 5V source.

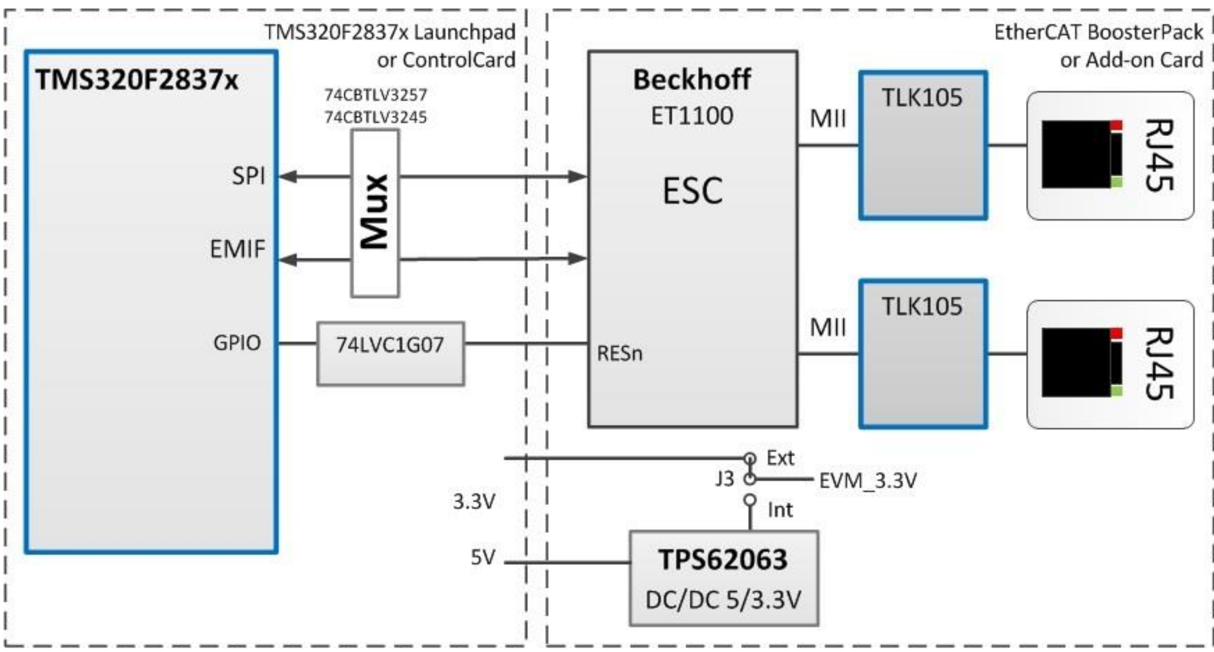


Figure 4. 'F2837x SPI and EMIF connections to the EtherCAT Slave Controller

2.1 Highlighted Products

2.1.1 TMS320F2837x Delfino Microcontroller Functional Diagram

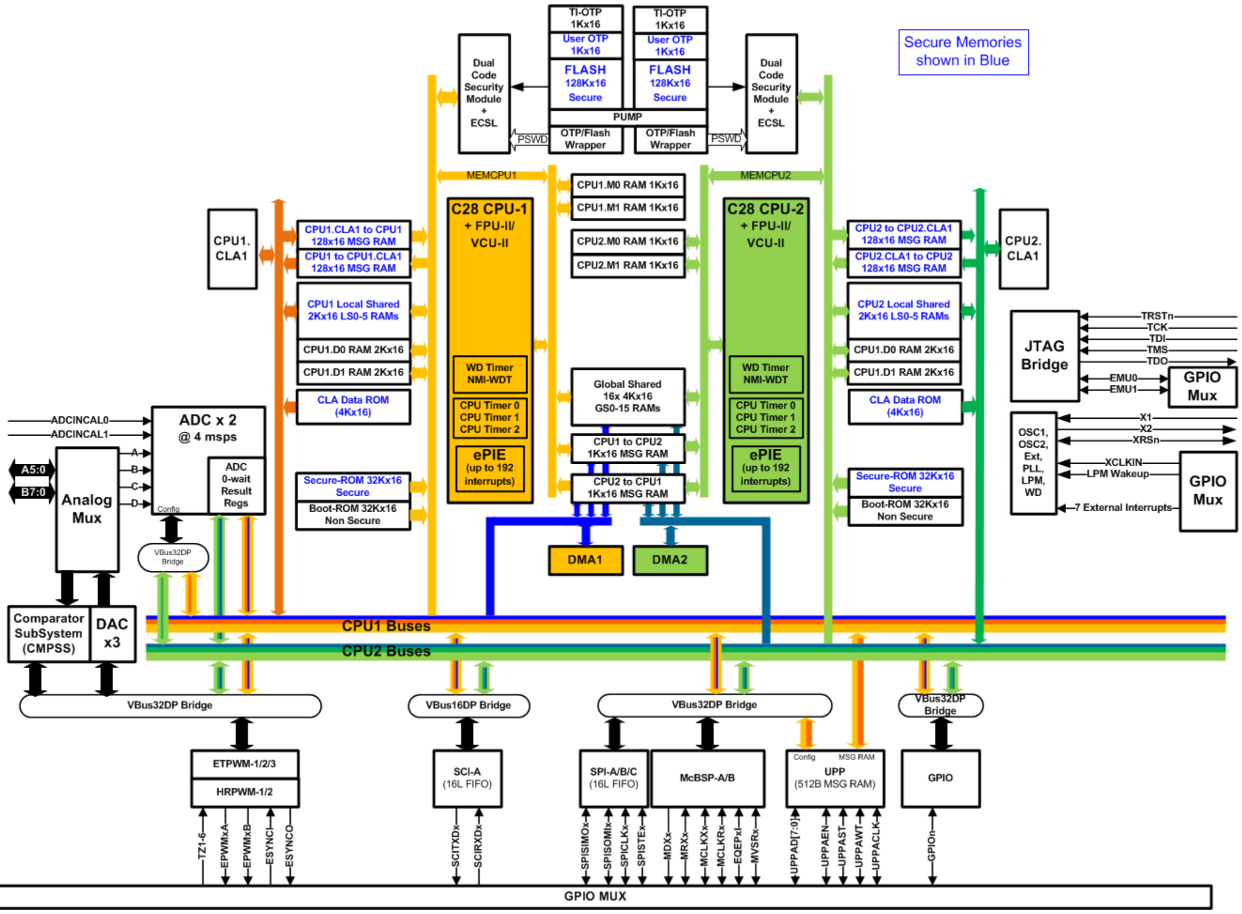


Figure 5. TMS320F2837x Functional Diagram

Ref: TMS320F2837x Datasheet, Figure 1-1.

2.1.2 TLK105 Ethernet PHY Functional Diagram

Ref: TLK105 Datasheet, http://www.ti.com/lit/ds/symlink/tlk105.pdf , Figure 1-1.

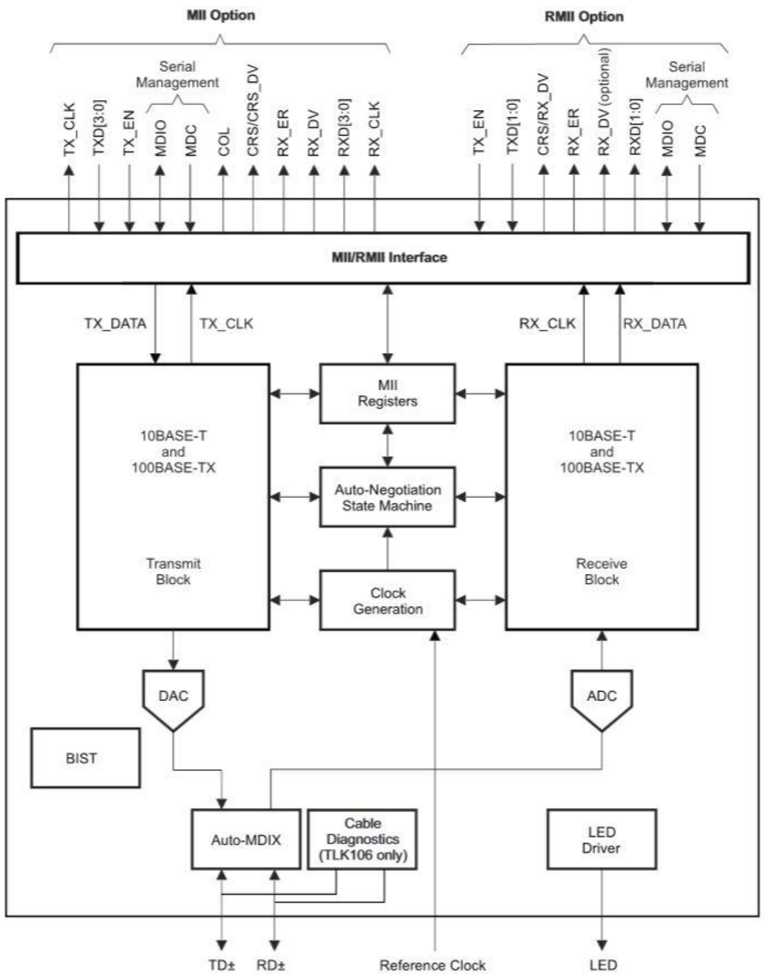


Figure 6. TLK105L Functional Diagram

2.1.3 SN74CBTLV3245A Functional Diagram

Ref: SN74CBTLV3245A datasheet, http://www.ti.com/lit/ds/symlink/sn74cbtlv3245a.pdf , Logic Diagram (Positive Logic)

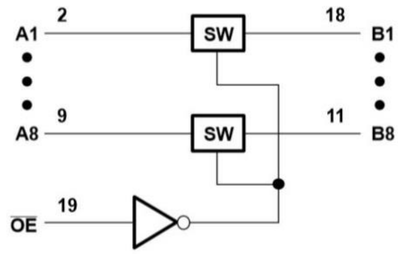


Figure 7. SN74CBTLV3245A Functional Diagram

2.1.4 SN74CBTLV3257 Functional Diagram

Ref: SN74CBTLV3257 functional diagram,
http://www.ti.com/general/docs/datasheetdiagram.tsp?genericPartNumber=SN74CBTLV3257&diagramId=SCDS040K , fbd_scds040k.gif

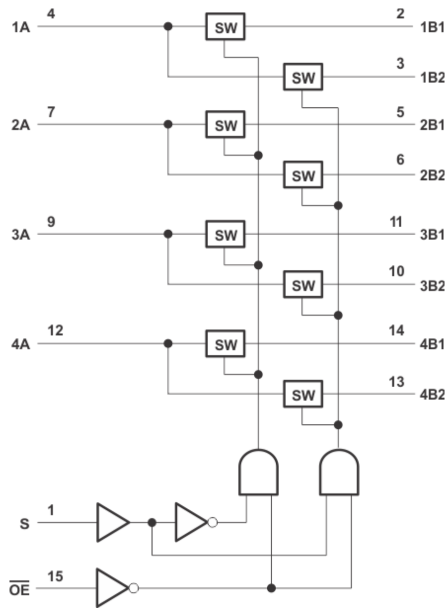


Figure 8. SN74CBTLV3257 Functional Diagram

2.1.5 ET1100 Functional Diagram

Diagram available on the Beckhoff website: http://www.beckhoff.com

http://download.beckhoff.com/download/document/io/ethercat-development-products/ethercat_et1100_datasheet_v1i9.pdf

3 Key System Specifications

Table 1 . EMIF Configuration and timing settings for ET1100 PDI

Parameter	Description	Value	Delay*
TA	Read-to-Write Turnaround time	1	5 ns
RHOLD	Address and CSn hold after OEn LH edge	1	5 ns
RSTROBE	Read Strobe time in units of EMIF Clocks	64	320 ns
RSETUP	Address and CSn to OEn assertion delay	1	5 ns
WHOLD	Write Hold time after WE deassertion	1	5 ns
WSTROBE	Write Strobe (WE) width	2	10 ns
WSETUP	Address and CSn setup time to WE assertion	1	5 ns
EW	Extended Wait Mode	ENABLE	-
SS	Strobe Select Mode	DISABLE	-

* For the given F2837x system with Fsysclk = 200 MHz

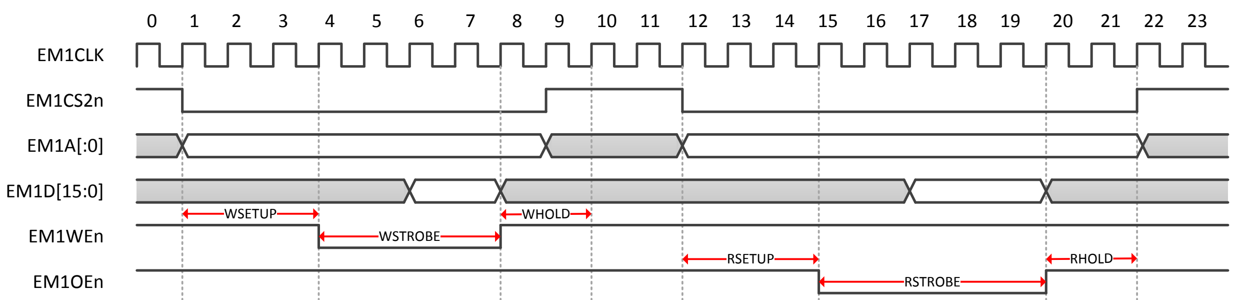


Figure 9. EMIF PDI Timing Diagram

4 Getting Started Hardware

This TI-Design describes two configurations for the EtherCAT Add-on board: a BoosterPack form factor compatible with TI LaunchPad Development kit, and an add-on card for F2837x ControlCARDs. The hardware setup described below is identical for both configurations in terms of EtherCAT connectivity and slave operation. The available Process Data Interfaces (PDIs) differs between the two boards, in that the LaunchPad has only enough pins ofr a SPI connection, whereas the controlCARD Addon has sufficient pins for either an EMIF or SPI interface. For the sake of simplicity, only the C2000 LaunchPad + BoosterPack configuration is covered here.

Figure 10. Stacked F2837x LaunchPad and EtherCAT BoosterPack

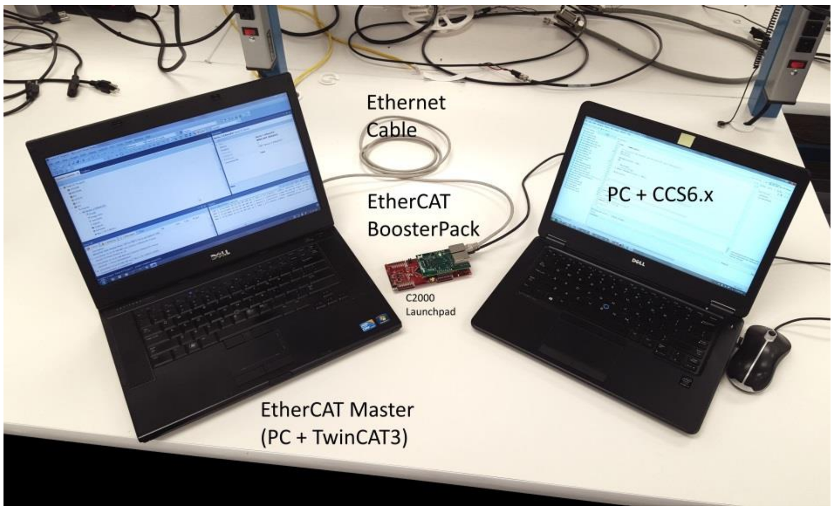


Figure 11. EtherCAT Test Setup

4.1 EtherCAT Master Configuration using TwinCAT3

4.1.1 Download and Install TwinCAT3 from the Beckhoff website

The TwinCAT3 software is available from the Beckhoff website at http://www.beckhoff.com. Follow the left sidebar to Download -> Software -> TwinCAT 3 -> TE1xxx | Engineering. The most recent version of this software as of this writing is TwinCAT 3.1 – eXtended Automation Engineering (XAE) v 3.1.4018.26.

4.1.2 Verify the TwinCAT Runtime is active

1. Check for the EtherCAT icon in the notification panel in the lower-right corner as shown below. If this is absent, open the notification panel and check in the popup window for the TCSwitchRuntime. Right-Click this icon and select Tools->TCSwitchRuntime

Figure 12. TwinCAT Runtime icon in Windows Toolbar

2. Verify that the TCSwitch Runtime is active. The "Deactivate" button should be showing as illustrated in the picture below. If this button reads "Activate", the click that button to start the TCSwitchRuntime.

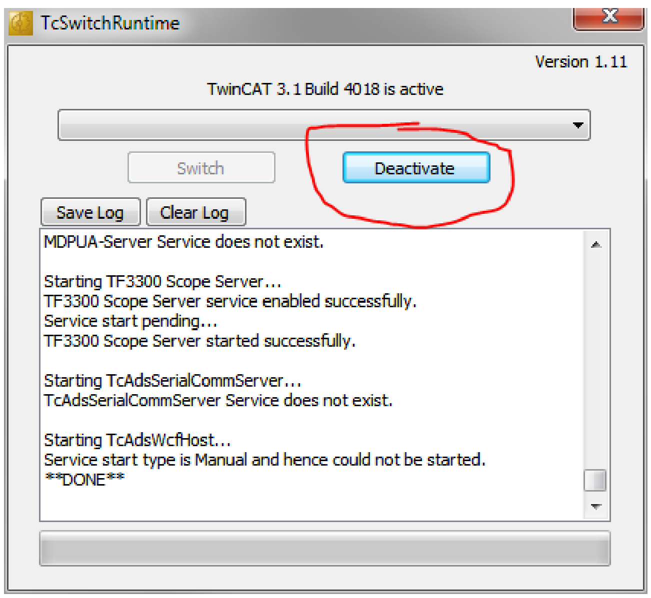


Figure 13. TwinCAT Runtime Dialog box.

3. If the TCSwitchRuntime is not found in step (a,b) above, then locate the runtime in the file system. A typical location is: "c:\TwinCAT\TcSwitchRuntime\TcSwitchRuntime.exe". Note that it is NOT commonly found in the Start Menu.

4.1.3 Start TwinCAT3 and verify that TwinCAT is running in Visual Studio

1. Locate the TwinCAT XAE, which can be found in 1 of 3 places
   a. Start menu – under Beckhoff-> TwinCAT3 – TwinCAT XAE (VS 2010)
   b. Desktop icon -

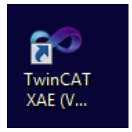


Figure 14. TwinCAT3 XAE Desktop icon

   c. Notification panel icon – Rt-click and select TwinCAT XAE (VS 2010)

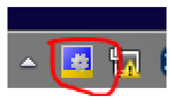


Figure 15. TwinCAT3 icon in toolbar

2. Verify that TwinCAT is running under Visual Studio. "TwinCAT" and "PLC" should both appear in the main toolbar (circled below). If these menu items are not shown, then the TC3 runtime is NOT running- Go back to step 1 to restart the TC3 runntime.

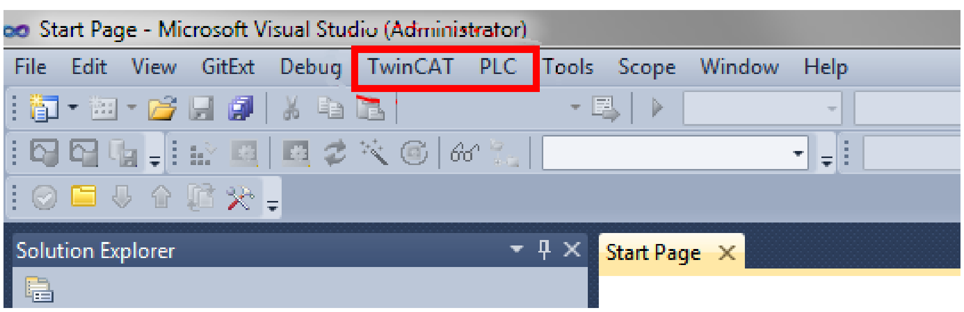


Figure 16. Visual Studio Menus for TwinCAT3

3. Open a new EtherCAT project
    a. File -> New -> Project

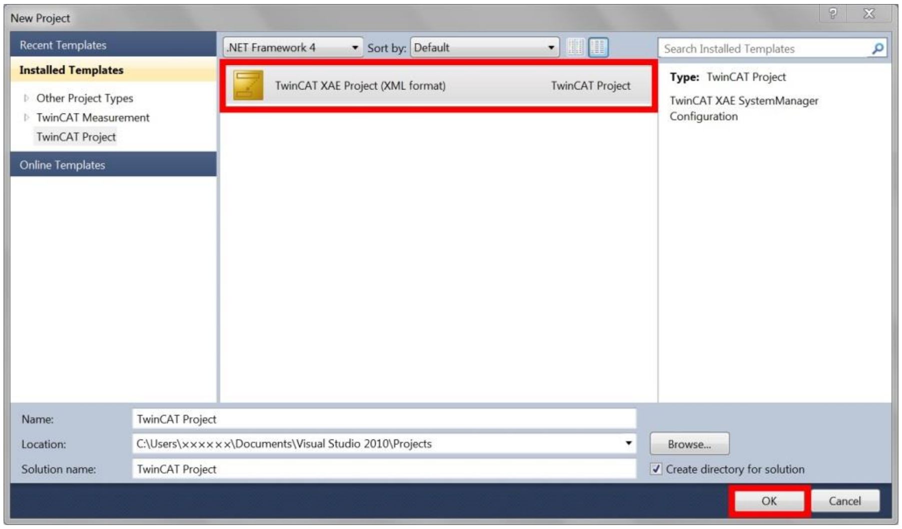


Figure 17. TwinCAT3 New Project Dialog

4. Verify that a Realtime Ethernet Adapter is installed
    a. TwinCAT – Show Realtime Ethernet Compatible Devices

If no RT adapter is installed, select one from the list of Compatible devices and click “Install”, then exit this popup.

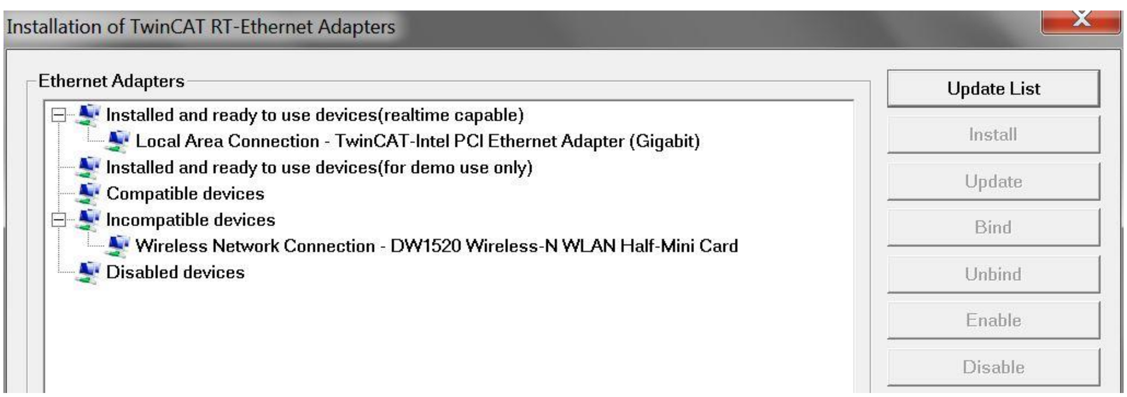


Figure 18. TwinCAT3 EtherNet Adapter Dialog

5. Scan for the newly installed Realtime adapter by clicking TwinCAT -> Scan
   a. A popup indicating TwinCAT has found the adapter should appear

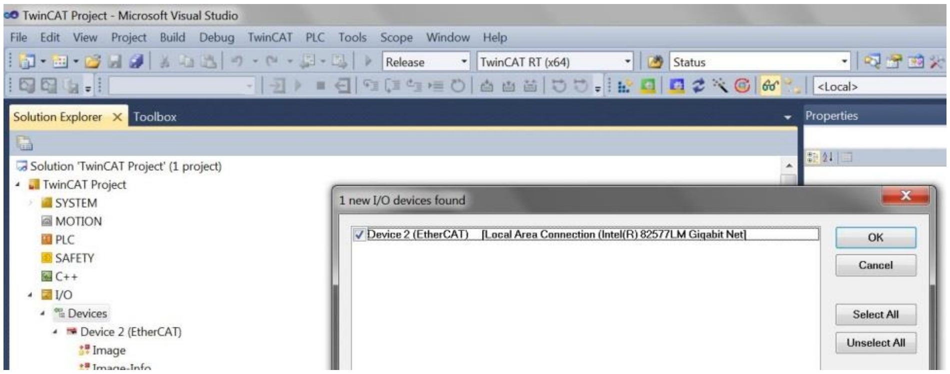


Figure 19. TwinCAT3 Discovery of Ethernet Adapter

   b. Click “OK”, then click “Yes” to the following two popups

Figure 20. TwinCAT3 Master Scan for Slaves and Free Run Activation

c. The screen view below should now be visible in TwinCAT3, indicating that the Master and Slave are connected and prepared for use. Note that “Box 1 (TI_C2kESC)” appears at the bottom of the image, indicating that TwinCAT has discovered the EtherCAT slave. If this is the first time that the slave has been connected and the EEPROM has not yet been programmed, the “Box n ()” label (i.e. “TI_C2KESC”) will not be visible.

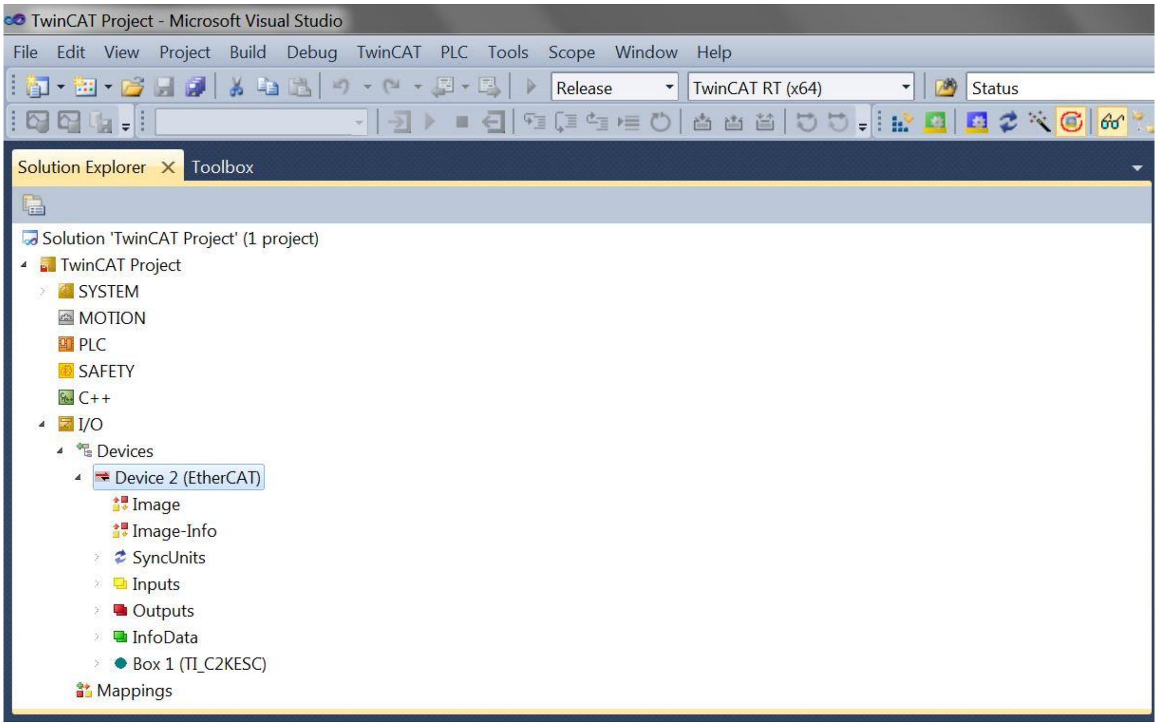


Figure 21. TwinCAT solution Explorer showing EtherCAT Master (Device 2) and Slave (Box1, TI_C2kESC)

The EtherCAT Master is now ready for communication with the Slave Device.

4.2 Configuring the EtherCAT BoosterPack interface for EMIF or SPI operation

The EtherCAT BoosterPack board must be configured prior to powerup to select between the EMIF or SPI interface from the C28x to the ET1100 slave controller. Options for power source and interface type are available through jumpers and/or DIP switches as described in the Figure and Table below.

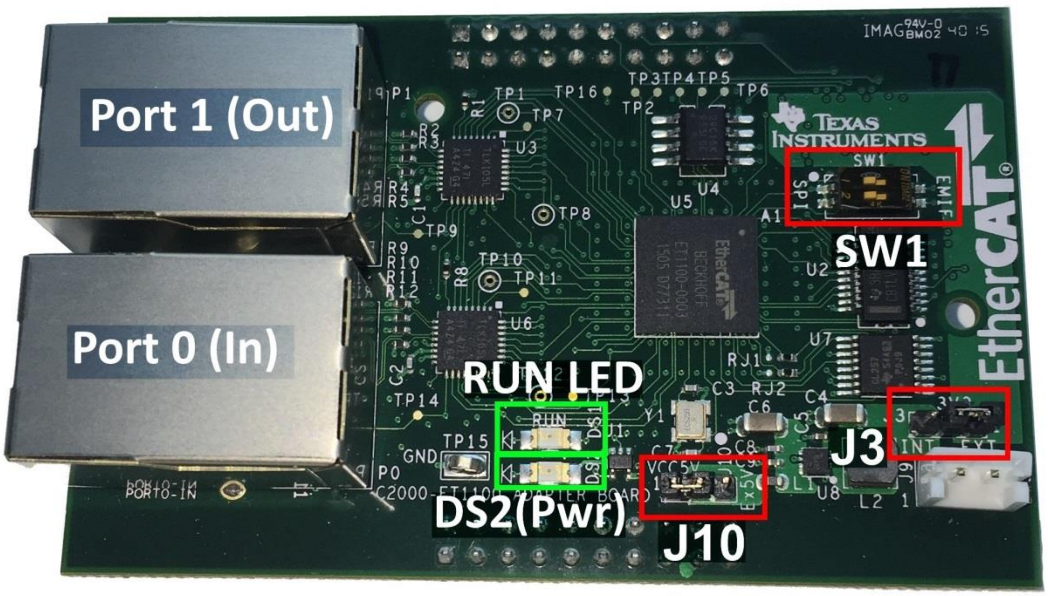


Figure 22. EtherCAT BoosterPack LED and Switch Locations

Table 2 . EtherCAT BoosterPack LED and Switch Usage Descriptions

Name	Options	Description
Switches/ Jumpers		
SW1	L – SPI R – EMIF	Selects between EMIF and SPI Interface Modes
J3	1-2 Off-board 2-3 On-board	**Off-board**: 3.3v is provided directly from attached LaunchPad or ControlCARD **On-board**: 3.3v is generated by the on-board regulator from a separate 5V supply.
J10	 1-2 On-board 2-3 Off-board	VCC_5V source: On-board: 5V provided by LaunchPad or ControlCARD Off-board: 5V provided externally through header J9.
LEDs		
RUN LED	State Machine Status*	Off: ET1100 Device is in INIT state. On: ET1100 Device is in Operational state.
DS2/PWR LED	3.3v Power	ON indicates 3.3v is being supplied to the board. See the schematics in Figure 38 for details.

* Reference: Additional RUN LED States given in Table 54 of the ET1100 datasheet at: http://download.beckhoff.com/download/document/io/ethercat-development-products/ethercat_et1100_datasheet_v1i9.pdf

4.3 Preparing the Addon board for EtherCAT communcation using TwinCAT3

After installing the TwinCAT3 software in the previous section and verifying connectivity between the EtherCAT Master and the slave node, the ESC EEPROM must be programmed to enable communication to the C28x device over either the EMIF or SPI PDI (Process Data Interface). The procedure given below writes the binary file associated with the selected PDI type into the EEPROM:

1. After starting up the TwinCAT software in section 4.1, the screen should look something like the screenshot shown below. Double-clicking the EtherCAT slave (labelled "Box 1" in the figure) brings up the EtherCAT properties window on the right. Click "Advanced Settings".

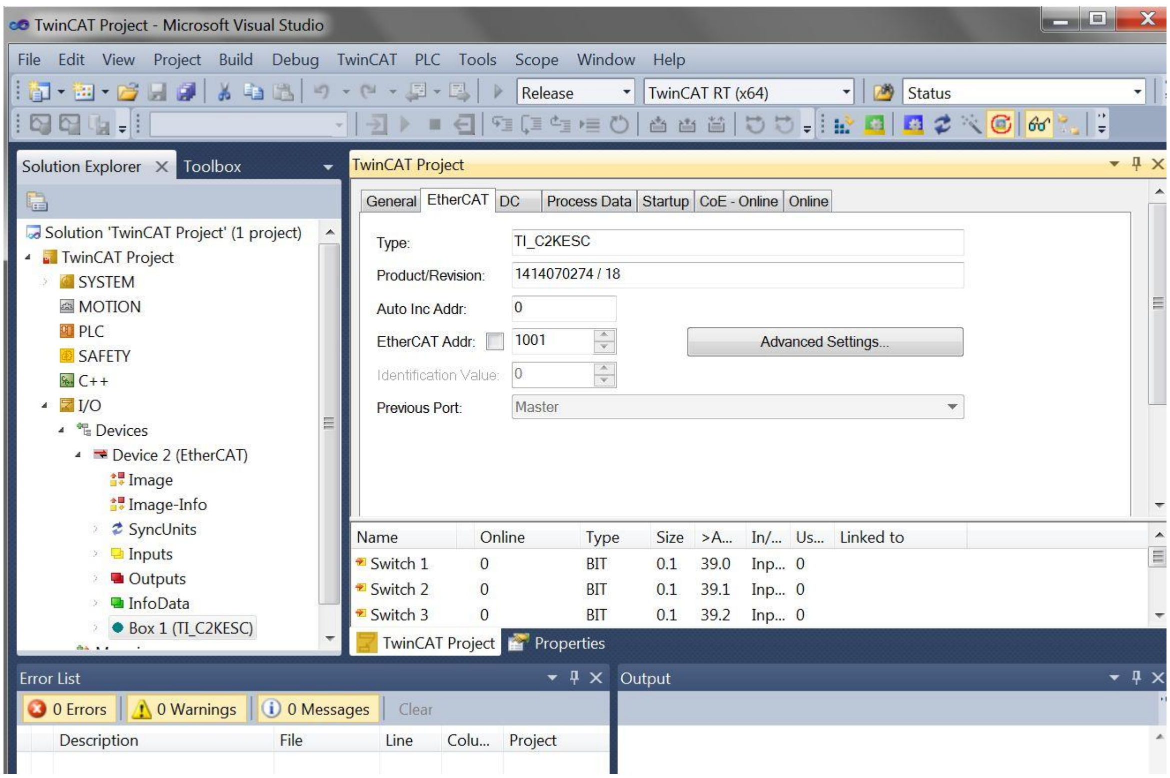


Figure 23. TwinCAT Project EtherCAT Tab

2. In the advanced settings popup windows, select “Smart View” to bring up detailed information about the EtherCAT Slave PDI. Click “Write E^{2}PROM”. Note that, prior to initialization, this view shows a “blank” configuration.

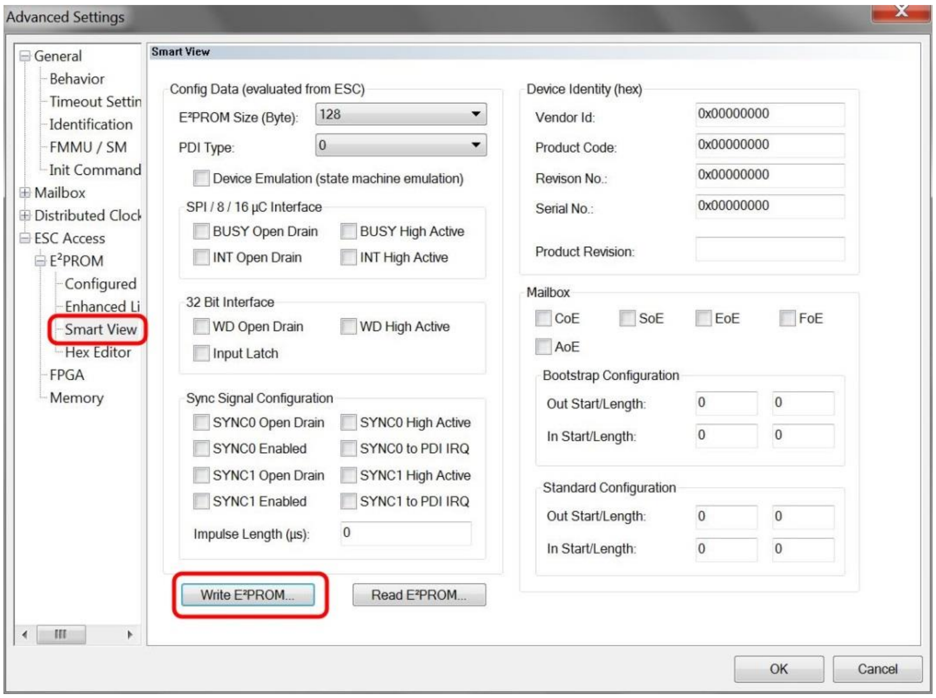


Figure 24. TwinCAT "Smart View" Slave properties Window showing Blank Slave

3. Click “Browse” to find the desired EEPROM binary associated with either the SPI or EMIF interface in the sw/master_files directory downloaded from the project site.
    a. pdi_test_app_spi.bin - for SPI interface
    b. pdi_test_app_emif.bin – for EMIF interface
    c. Click “OK”.

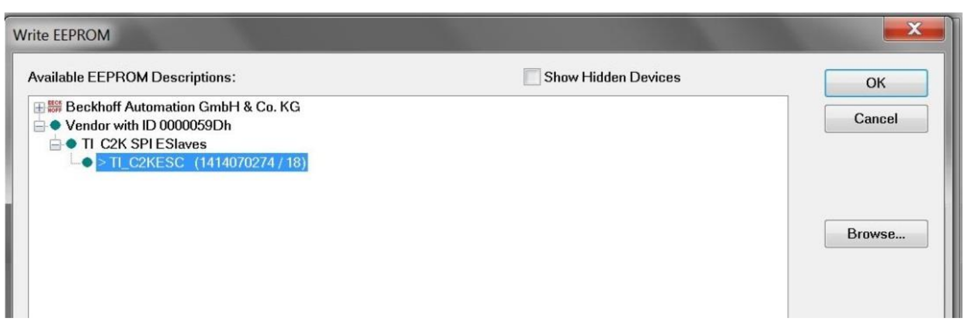


Figure 25. TwinCAT3 EEPROM File Dialog

4. After TwinCAT writes the EEPROM (in this case for the SPI), the following "Smart View" window showing a valid configuration with PDI Type = "SPI slave" should appear.

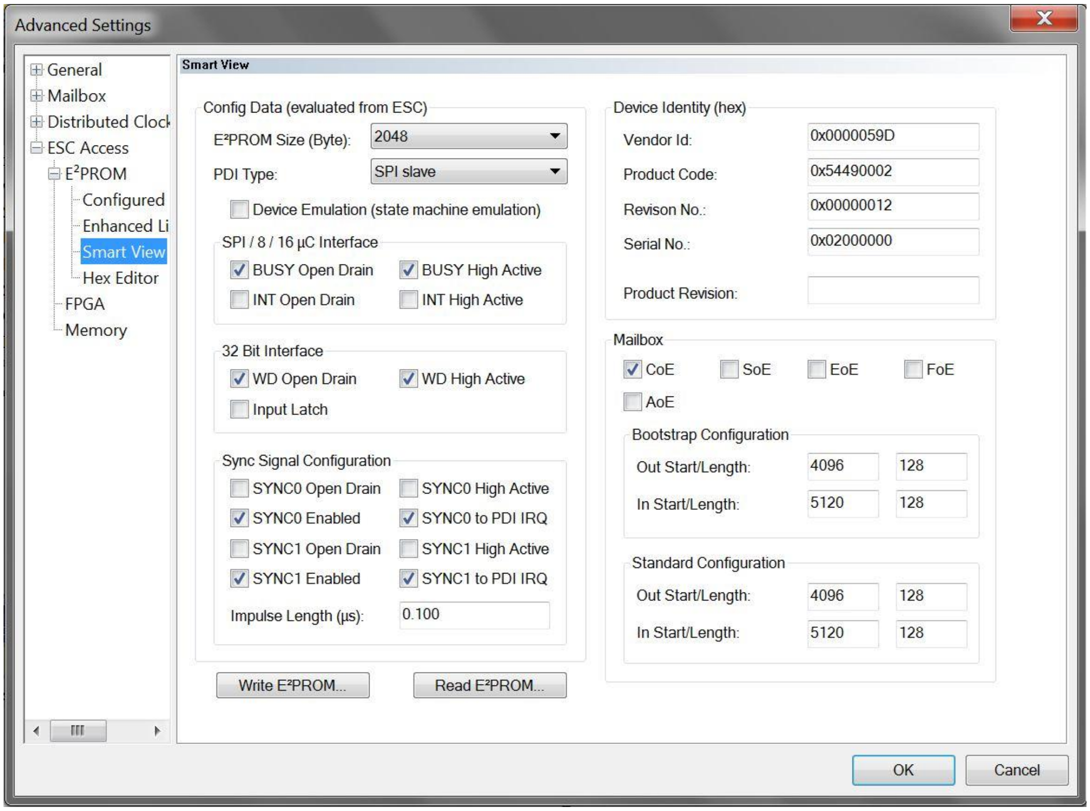


Figure 26. TwinCAT "Smart View" Slave properties Window showing programmed EEPROM

The EtherCAT Slave controller is now prepared for communication to the MCU.

5 Getting Started Firmware

A software package (project pdi_hal_test_app) is included with this TI Design that contains a Code Composer Studio (CCS) project designed for the 'F2837x. The project should be imported into CCS v6.0 or later for building and uploading to the target board. Six build configurations are provided to enable use of RAM or Flash-based designs with two board types (ControlCARD and LaunchPad) and two PDI types (EMIF and SPI).

NOTE for EtherCAT Developers:
The EtherCAT Technology Group (ETG) recommends membership for parties implementing EtherCAT in a machine or machine line. Please see the following links for additional information about EtherCAT and ETG membership:

- EtherCAT FAQs: https://www.ethercat.org/en/faq.html
- EtherCAT Technology Group site: https://www.ethercat.org

5.1 PDI Test project CCS setup (project import)

The PDI test application contains a Hardware Abstraction Layer (HAL) which handles all of the configuration details for the EMIF or SPI interface. This CCS6.x project also performs some simple Read/Write tests to verify correct functioning of communication with the ET1100 Slave controller.

The CCS project files for pdi_hal_test_app can be downloaded from the design directory at http://www.ti.com/tool/TIDM-DELFINO-ETHERCAT. Once downloaded, import this project into CCS 6.0 or later using the procedure below:

1. File -> Import… (an "Import" popup window appears)
2. Select "Code Composer Studio" -> CCS Projects. Click "Next".
3. Use "Select search-directory" and click "Browse" to find the pdi_hal_test_app source directory.
4. Select pdi_hal_test_app from the list of Discovered projects.
    a. Leave the "Automatically import referenced projects" box checked.
    b. Checking the box for "Copy projects into workspace" is optional.
    c. Click "Finish". The CCS project will appear in the project explorer window.

6 Test Setup

The main purpose of this test is to demonstrate the usage of the PDI (Process Data Interface) between the C28x processor and the ET1100 EtherCAT Slave Controller. The EtherCAT board is available as both a piggyback board for the F2837x controlCARD and a BoosterPack for use with TI LaunchPads. Both boards have identical hardware and differ only in the connectors used to attach them to their respective proccessor board.

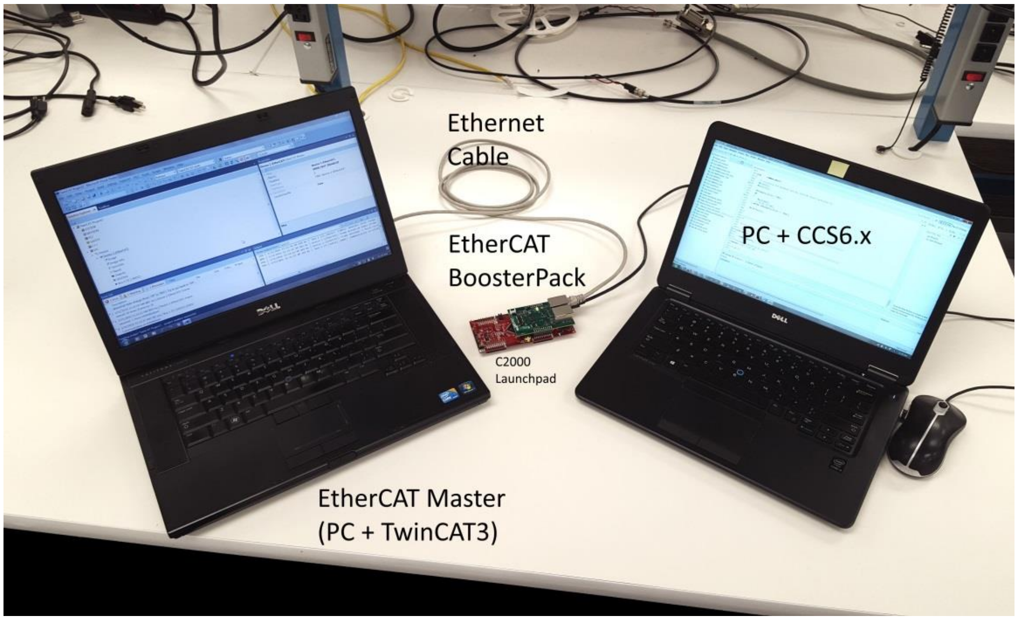


Figure 27. EtherCAT BoosterPack Test Setup

The test setup in Figure 27 shows a C2000 LaunchPad with attached EtherCAT BoosterPack and two PCs. The left PC connects to the BoosterPack through a standard Ethernet cable connected to Port 0, and runs TwinCAT 3 software, which provides EtherCAT Master functionality. The right PC connects to the LaunchPad directly through the USB connector and runs the EtherCAT Hardware abstraction layer (HAL) software on the CCS6.x development environment. The HAL software in this example performs the following functions:

1. Initialize the C28x hardware and the selected PDI interface (SPI or EMIF)
2. Execute read/writes to the ET1100 User RAM
3. Execute reads from ET1100 register space.

The intent of this project is to demonstrate the usage of the PDI (Process Data Interface). Therefore, no EtherCAT stack is included in this demo.

Note that the HAL software supports both the SPI and EMIF as PDI interfaces. The user must choose the proper settings when building the project. Correct jumper settings on the BoosterPack are also required for proper operation. These settings are described in section 4.2

6.1 Running simple ESC interface test on C28x

After downloading the software from the project directory at http://www.ti.com/tool/TIDM-DELFINO-ETHERCAT, and importing the project into CCS, perform the following steps to exercise the PDI Hardware Abstraction Layer.

1. Open the example project pdi_hal_test_app in CCS. The file **pdi_test_appl.c** has the main routine. The following code is of interest:

ESC_HWInit()	Initializes the C28x MCU and the PDI
ESC_setupPDITestInterface()	Set-up PDI interface and initialize test variables and ET1100 RAM over PDI
ESC_debugUpdateESCRegLogs()	Keep updating ET1100 registers in a loop. User can add to the list of registers to read in the escRegs data structure.

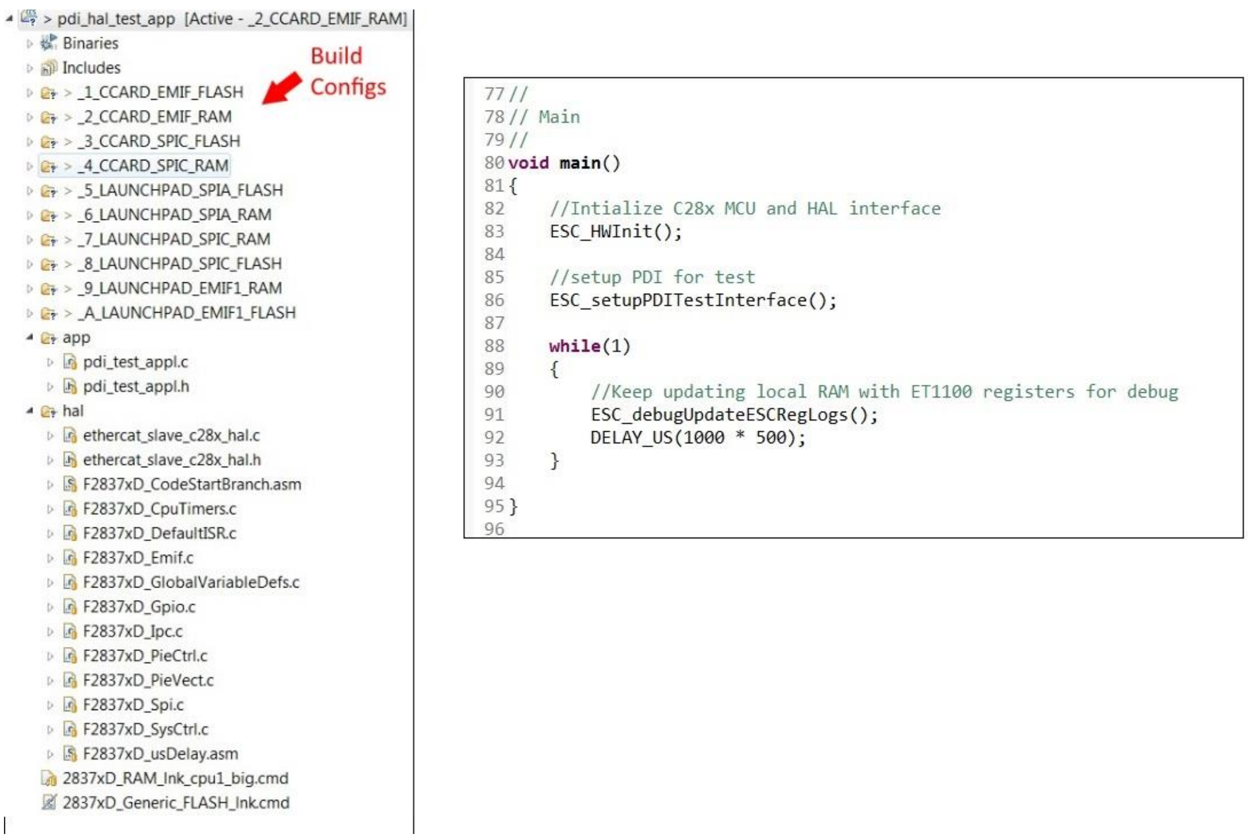


Figure 28. CCS example project: pdi_hal_test_app

2. Right click on the project and set the desired active build configuration. The figure belows shows the available configurations, which provide options for both LaunchPad and controlCARD board types, FLASH and RAM program storage, as well as interface types (EMIF, SPIA,SPIC) .

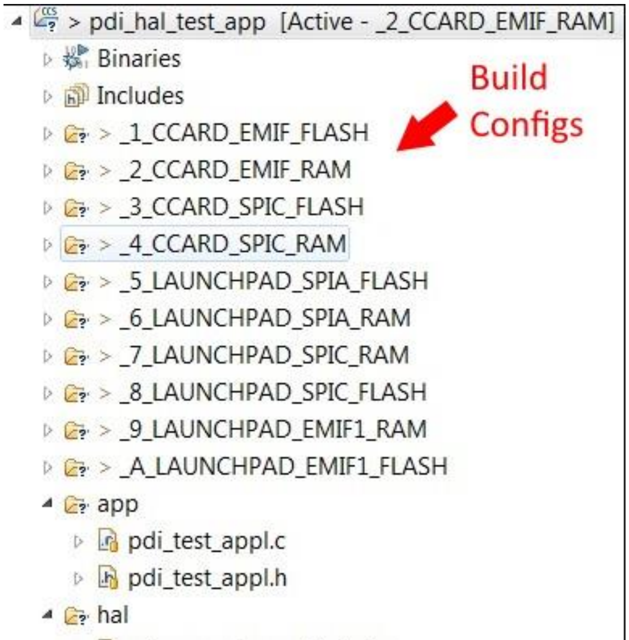


Figure 29. EtherCAT HW abstraction Layer project.

For this example, choose build configuration **(6_LAUNCHPAD_SPIA_RAM)** by right-clicking on the project name and selecting “Build Configuration” -> Set Active -> **(6_LAUNCHPAD_SPIA_RAM)**

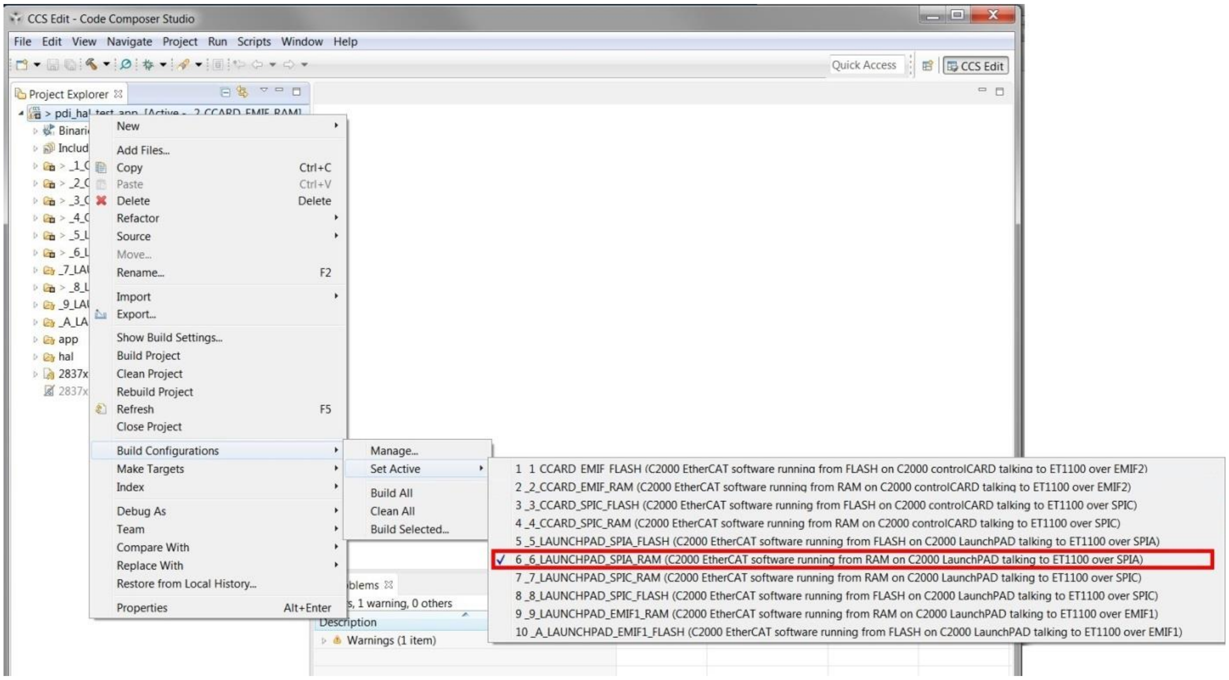


Figure 30. CCS Project Build Configuration management

Start TwinCAT3 on the EtherCAT Master PC as described in section 4.1.3. Note that double-clicking the EtherCAT slave node ("Box 2" in this figure) opens up a properties windows, from which the "Advanced Settings window" can be opened. This will be used later in the demo.

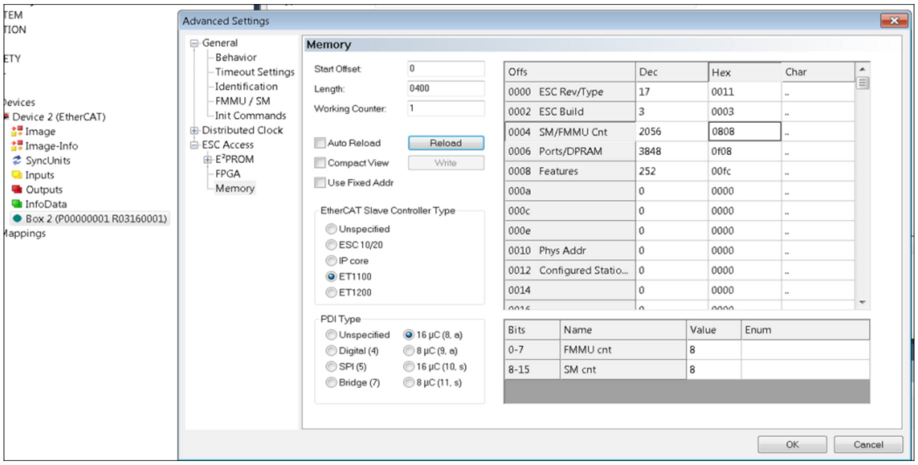


Figure 31. TwinCAT3 Advanced settings Dialog

3. Start the debugger and open the memory browser window as shown in the figure below. The "escRegs" data array contains a list of ET1100 register addresses and values. These will get updated in the ESC_debugUpdateESCRegLogs() function.

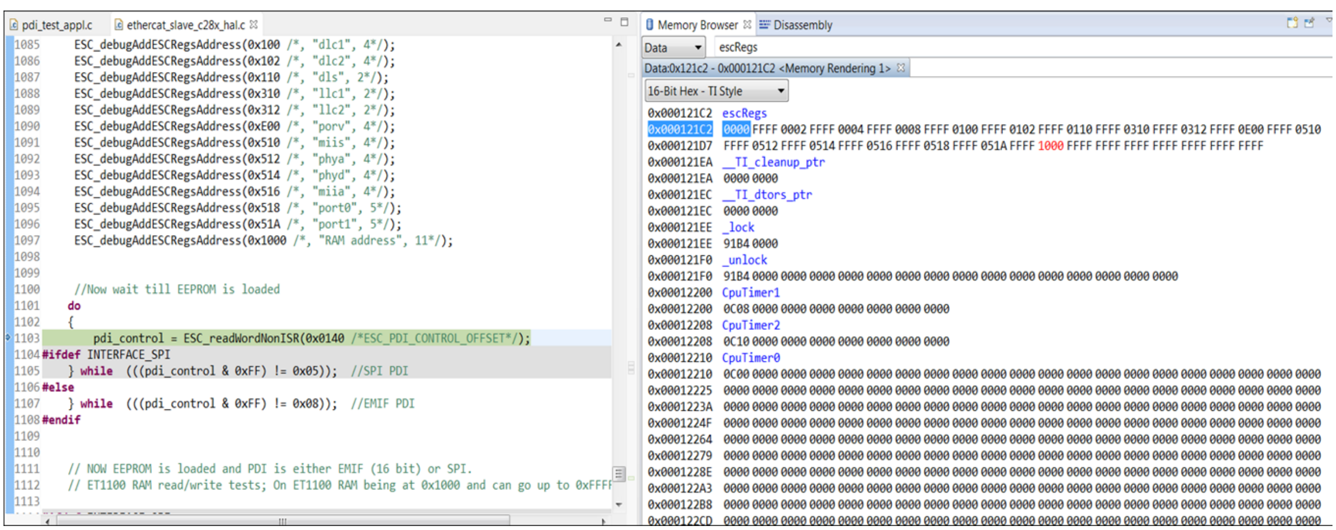


Figure 32. Device Debug memory window at INIT time.

NOTE: The ESC RUN LED will NOT be on during the memory tests described in the following sections. See the ET1100 datasheet

ESC RAM READ TEST

4. Open up the "advanced settings" window in TwinCAT3 and go to the memory browser at ESC Access -> Memory and view Start Offset = 1000h as shown in the figure below.

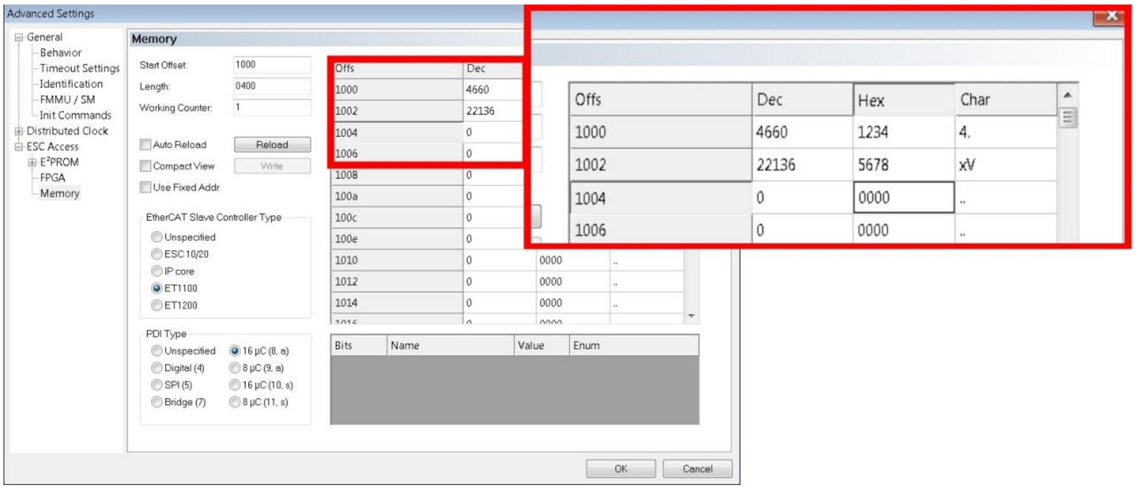


Figure 33. TwinCAT3 Memory Read Window

5. In CCS, view the Expressions window and add "escRegs" as a watched expression.
   Note that, as data is entered into the window in TwinCAT, the values read on the CCS side are identical.

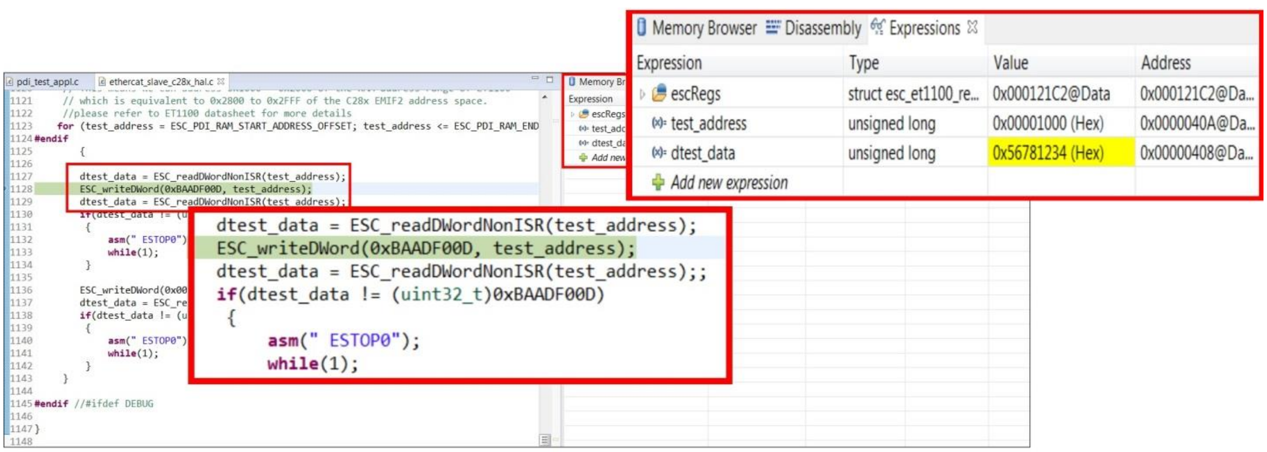


Figure 34. EtherCAT write to Memory From CCS Project

ESC RAM WRITE TEST

6. The following figure shows program control after execution of the first 32-bit write and 32-bit read from PDI to ET100 address 0x1000.

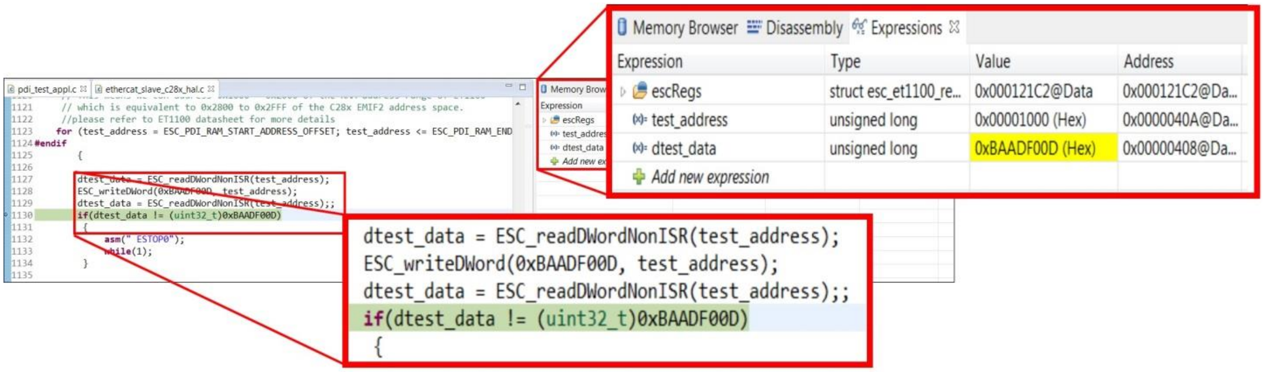


Figure 35. CCS Project Write to EtherCAT Slave

7. The TwinCAT Master view of the ESC memory address showing the results of the write from CCS.

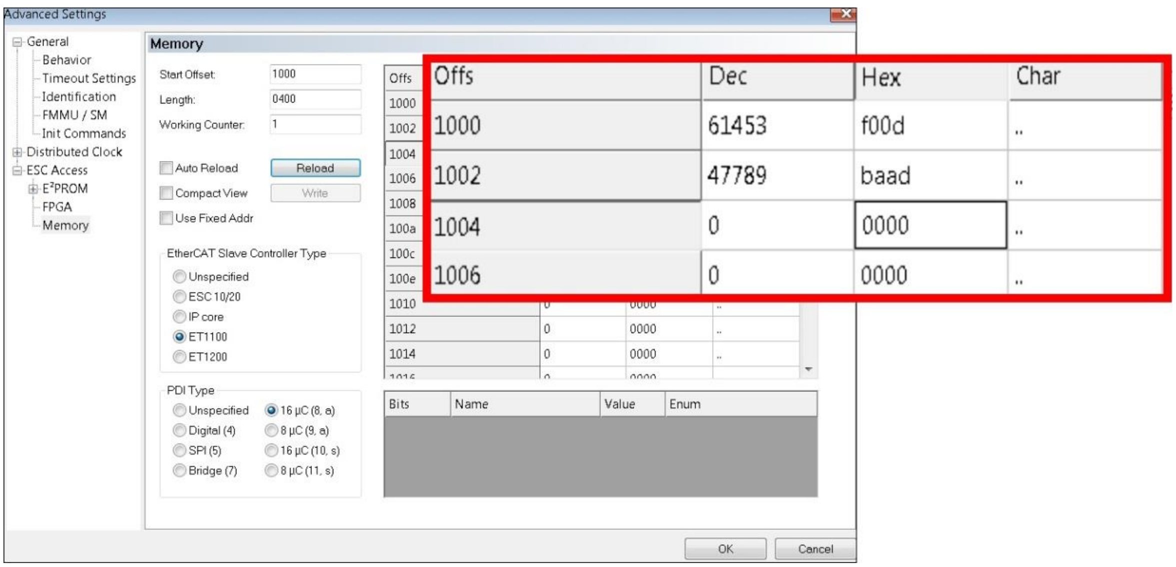


Figure 36. TwinCAT3 Master read of data written to EtherCAT slave

6.2 TwinCAT3 Troubleshooting

Common issues in TwinCAT3 usage

1. Problem: EtherCAT network fails to initialize

- Other Descriptions: "Reload Devices" fails, "Scan" for devices fails, "Restart EtherCAT in config mode" fails.
- **Solutions:**
  a) Power Cycle the LaunchPad
  b) **Check to make sure a RealTime Ethernet Driver is available**:
  TwinCAT-> "Show RealTime Ethernet Compatible Devices". This will open a popup window below.
  - Look for the 1st line "Installed and ready to use devices (realtime capable)".
  In this example there are **NO** adapters installed!
  - Select a compatible device, which here is "Local Area Connection – Intel …." and click "**Install**"
  - Close the window by clicking "X" in the upper right corner.

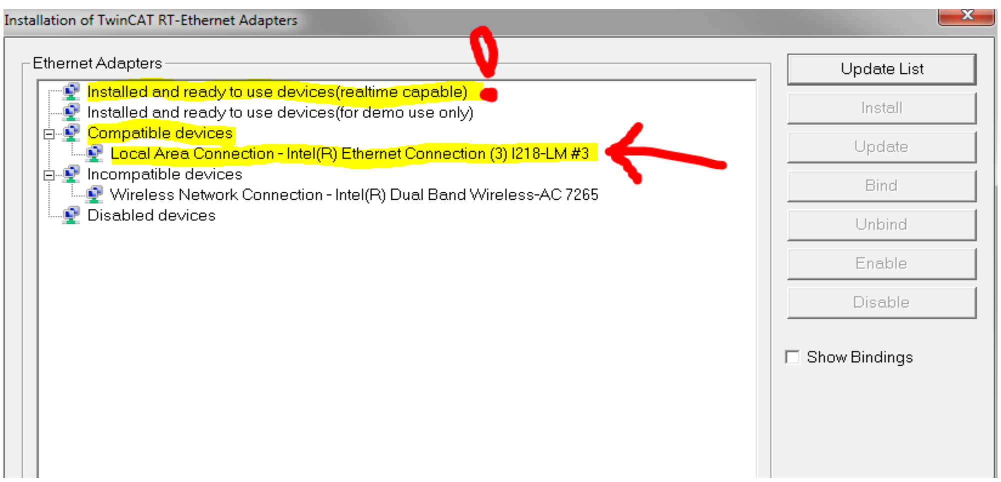


Figure 37. TwinCAT3 Ethernet Adapter installation

7 Design Files

7.1 Schematics

To download the Schematics for each board, see the design files at http://www.ti.com/tool/TIDM-DELFINO-ETHERCAT.

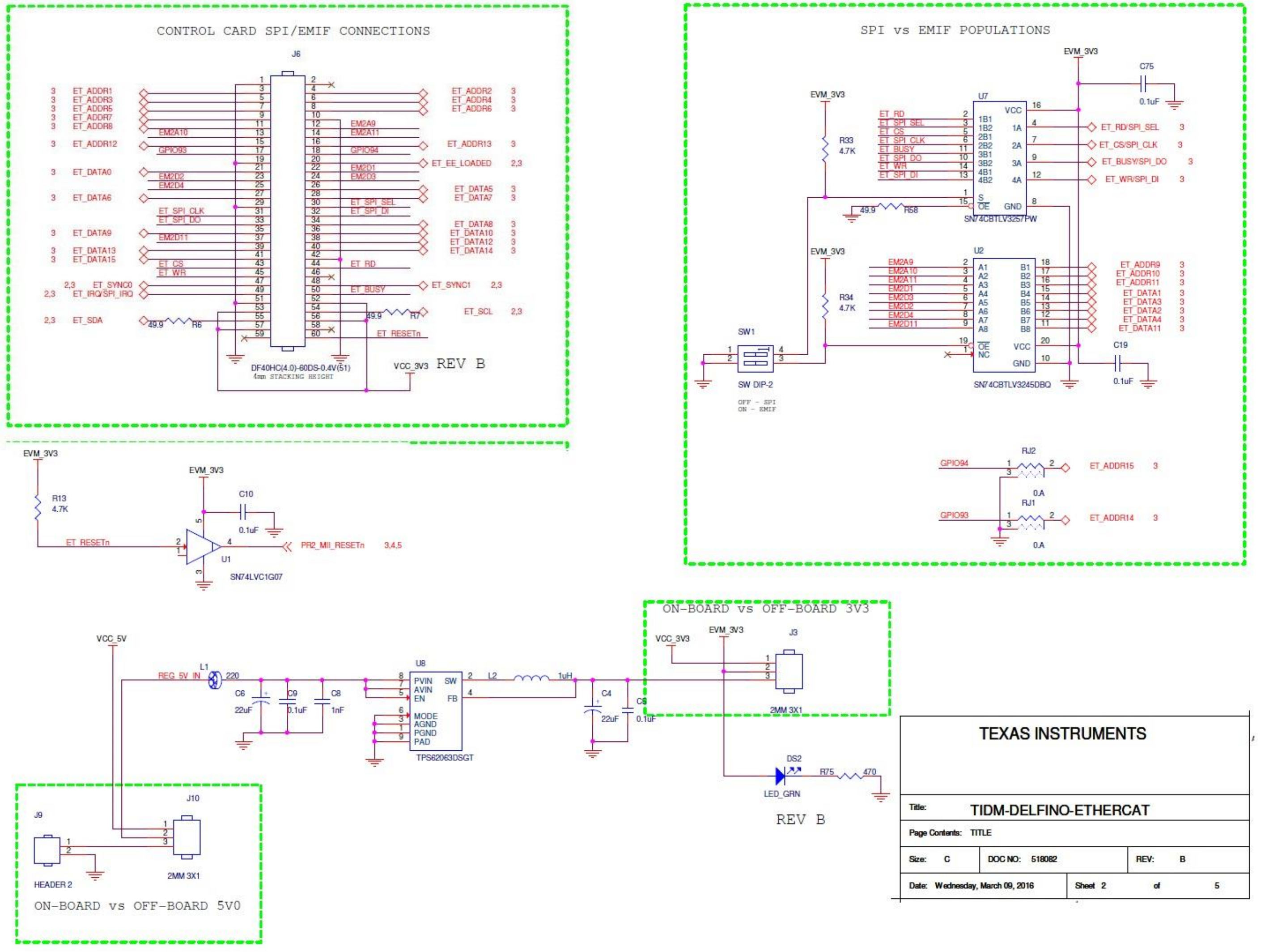


Figure 38. LaunchPad and Hi-Density Connector schematics.

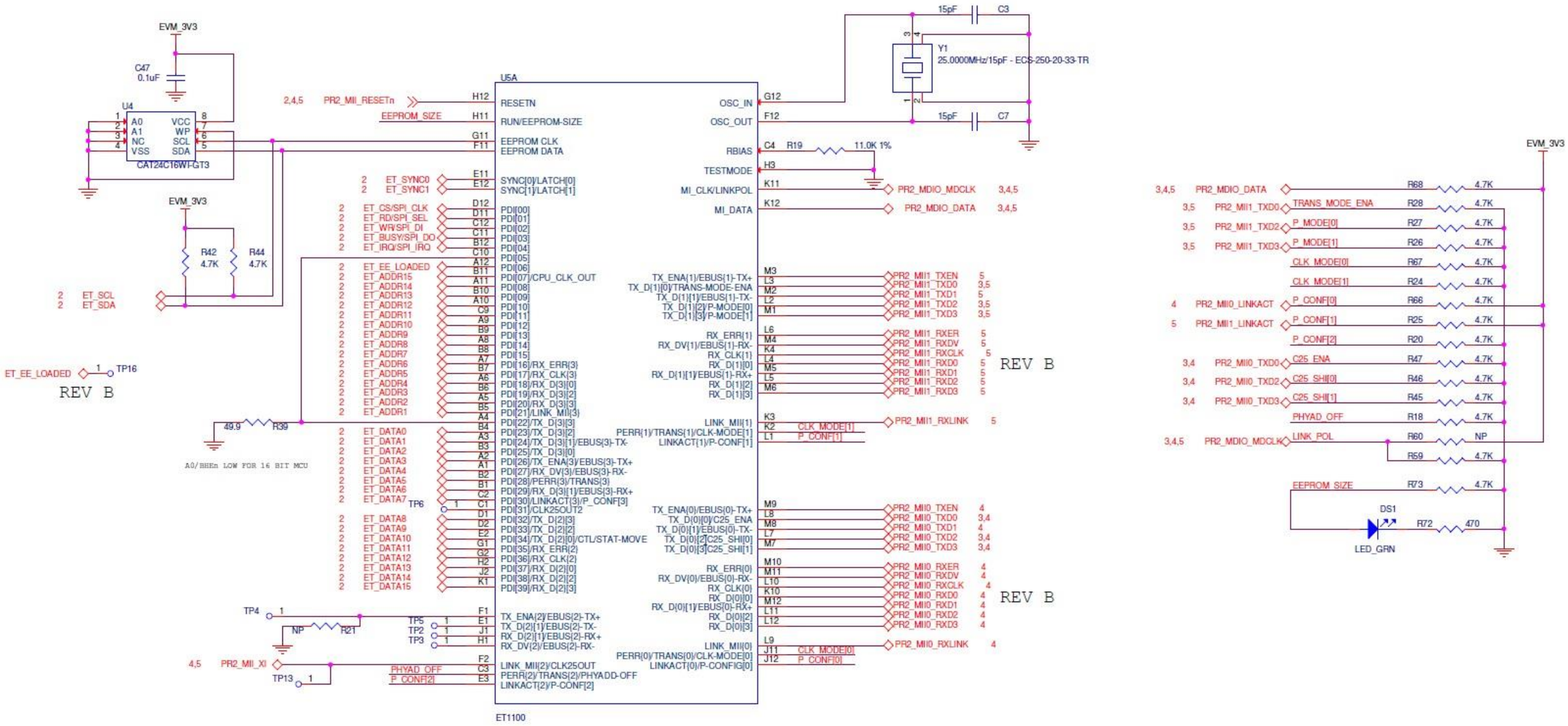


Figure 39. ET1100 EtherCAT Slave Controller schematics

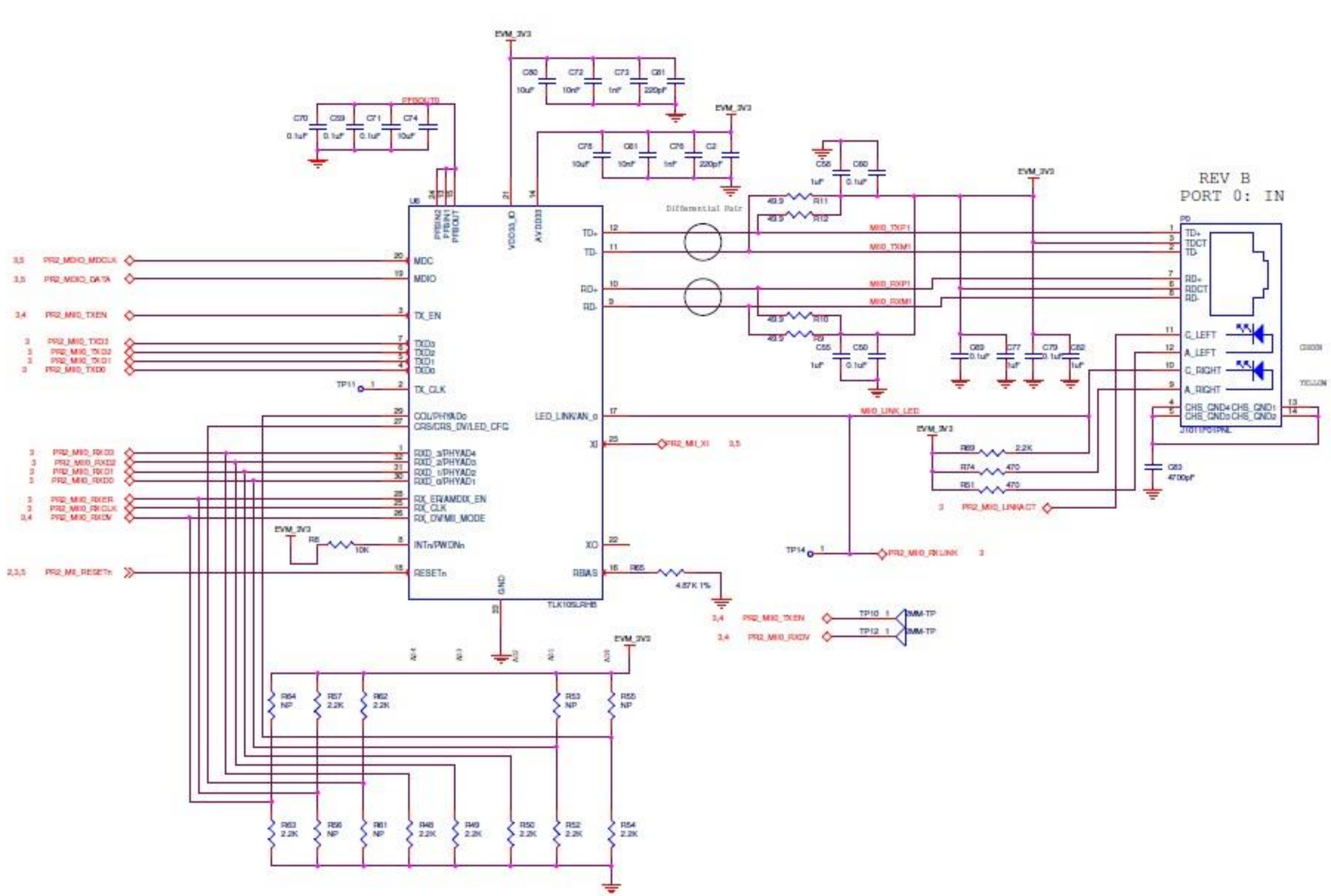


Figure 40. Ethernet PHY schematics- Port 0

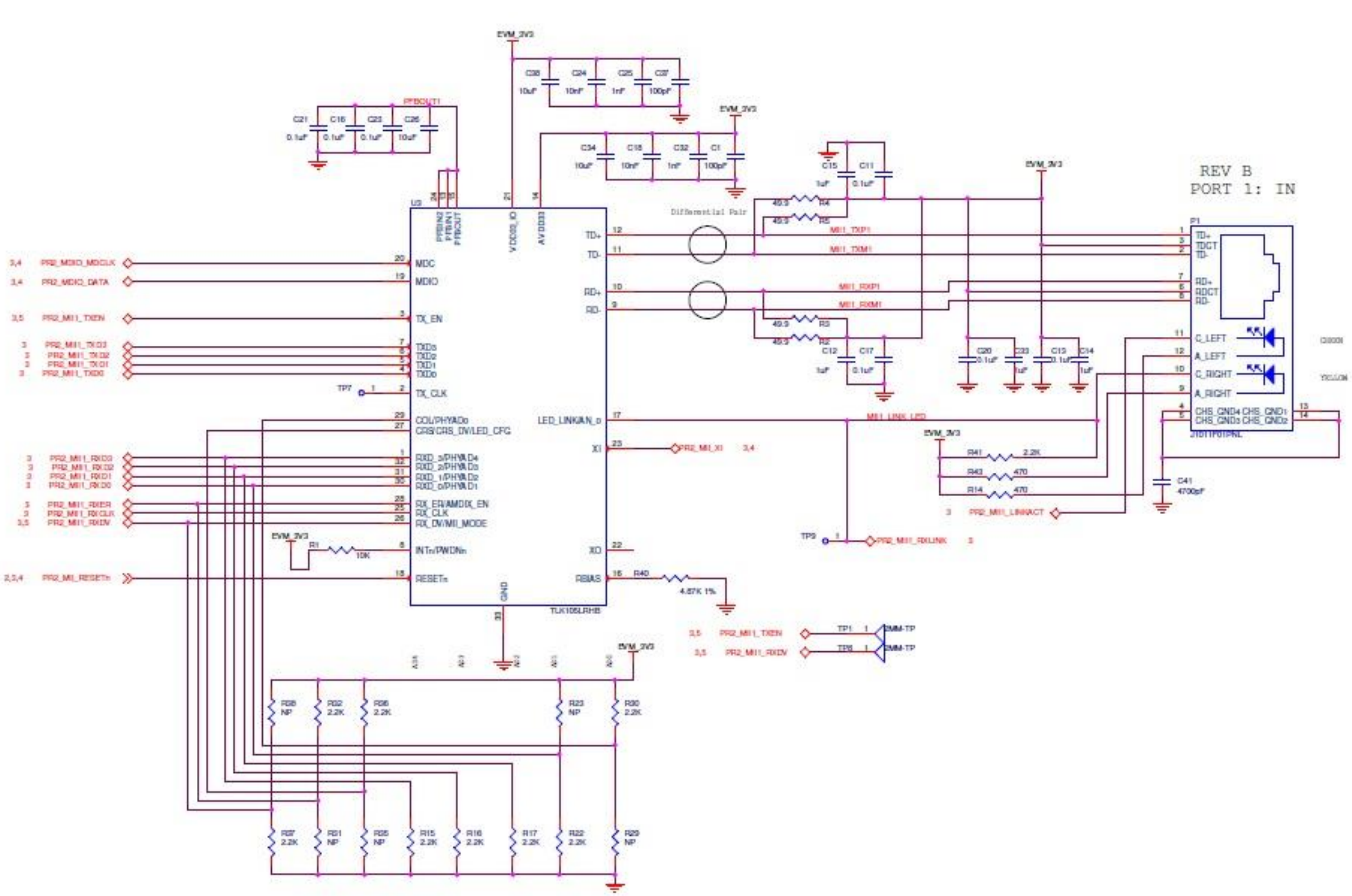


Figure 41. Ethernet PHY schematics- Port 1

7.2 Bill of Materials

To download the Bill of Materials for each board, see the design files at http://www.ti.com/tool/TIDM-DELFINO-ETHERCAT

Table 3: Bill of Materials for EtherCAT Adapter Board

Item	Qty	Reference	Value	Part Description	Manufacturer	Manufacturer Part Number	PCB Footprint
1	1			PWB,C2000-ET1100 ADAPTER BOARD			
2	1			LOGIC,C2000-ET1100 ADAPTER BOARD			
3	1	U5		IC,BGA128,.8mm,ETHERCAT SLAVE CONTROLLER	Beckhoff	ET1100	bga128-8mm
4	2	U3, U6		IC,QFN32,SINGLE PORT 10/100Mbs ETHERNET PHY TRANSCEIVER,LOW POWER	Texas Instruments	TLK105LRHBR	QFN32_202SQ
5	1	U7		IC,QSOP16,LOW VOLTAGE,QUAD 2:1 MULTIPLEXER/DEMULTIPLEXER	Texas Instruments	SN74CBTLV3257PWR	tssop16-14x70
6	1	U2		IC,QSOP20,LOW VOLTAGE,QUICK SWITCH	Texas Instruments	SN74CBTLV3245ADBQR	dbq20-14x70
7	1	U1		IC,SO5,SINGLE BUFFER/DRIVER	Texas Instruments	SN74LVC1G07DCKR	dck-5
8	1	U4	16k	IC,SO8,SERIAL EEPROM,16K-BIT	Catalyst Semiconductor	CAT24C16WI-GT3	so8-25x75-295
9	1	U8	3.3v,1.6A	IC,SON8,STEP-DOWN DC-DC CONVERTER,1.6A,3.3V	Texas Instruments	TPS62063DSGT	dsg8-11x20
10	1	Y1	25MHz	CRYSTAL,SMT,4 PIN,25MHz	ECS	ECS-250-20-33-TR	xtal4-47x51-ecx32
11	2	DS1, DS2	Green	LED,SMT 1206,GREEN	LITEON	LTST-C150GKT	led1206-59x59
12	1	L2	1uH	INDUCTOR,SMT,1uH	Murata Electronics	LQH44PN1R0NP0L	ind-LQH44p
13	1	L1	220ohm	FERRITE BEAD,SMT 0603,220 OHM	Murata Electronics	BLM18AG221SN1D	l603-35x45
14	2	C41, C83	4700pF	CAP,CER,SMT 1206,4700pF,200V,+10/-10%,X7R	AVX Corporation	12062C472KAT2A	C1206-40X70
15	2	C4, C6	22uF	CAP,CER,SMT 1206,22uF,10V	Taiyo Yuden	LMK316F226ZL-T	C1206-40X70
16	8	C12, C14, C15, C33, C55, C58, C77, C82	1uF	CAP,CER,SMT 0603,1uF,6.3V,X5R,+/-10%	Murata Electronics	GRM188R60J105KA01D	c603-35x45
17	8	C22, C26, C34, C38,	10uF	CAP,CER,SMT 0603,10uF,6.3V,X5R,+/-20%	Murata Electronics	GRM188R60J106ME47D	c603-35x45

		C44, C74, C78, C80					
18	15	C2, C27, C28, C30, C31, C43, C46, C49, C52, C57, C63, C64, C66, C67, C81	220pF	CAP,CER,SMT 0402,220pF,50V,NPO	Panasonic	ECJ-0EC1H221J	c402-25
19	2	C3, C7	15pF	CAP,CER,SMT 0402,15pF,50V,NPO	Yageo	CC0402JRNPO9BN150	c402-25
20	2	C1, C37	100pF	CAP,CER,SMT 0402,100pF,50V,+/-5%,NPO	Kemet Electronics Corporation	C0402C101J5GAC	c402-25
21	5	C8, C25, C32, C73, C76	1000pF	CAP,CER,SMT 0402,1000pF,50V,+/-5%,NPO	TDK Corporation	CGJ2B2C0G1H102J	c402-25
22	35	C5, C9, C10, C11, C13, C16, C17, C19, C20, C21, C23, C29, C35, C36, C39, C40, C42, C45, C47, C48, C50, C51, C53, C54, C56, C59, C60, C62, C65, C68, C69, C70, C71, C75, C79	0.1uF,16V	CAP,CER,SMT 0402,.1uF,16V,+/-10%,X7R,AUTOMOTIVE	Murata Electronics	GCM155R71C104KA55	c402-25
23	4	C18, C24, C61, C72	0.01uF	CAP,CER,SMT 0402,.01uF,16V,+/-10%,X7R	Kemet Electronics Corporation	C0402C103K4RAC	c402-25
24	18	R15, R16, R17, R22, R30, R32, R36, R37, R41, R48, R49, R50, R52, R54, R57, R62, R63, R69	2.2kohm	RES,SMT 0201,2.2K OHM,5%,1/20 WATT	Yageo	RC0201JR-072K2L	r201-6p6spc
25	2	RJ1, RJ2	0 ohm	RES,SMT 0402,0 OHM,1/16 WATT	Yageo	RC0402JR-070RL	r402-25
26	2	R1, R8	10kohm	RES,SMT 0402,10K,1%,1/16 WATT	Yageo	RC0402FR-0710KL	r402-25
27	1	R19	11kohm	RES,SMT 0402,11K OHM,1%,1/16 WATT	Panasonic	ERJ-2RKF1102X	r402-25
28	20	R13, R18, R20, R24, R25, R26, R27, R28, R33, R34, R42, R44, R45, R46, R47, R59, R66, R67, R68, R73	4.7kohm	RES,SMT 0402,4.7K,1%,1/16 WATT	Vishay Intertechnology	CRCW04024K70FKED	r402-25
29	2	R40, R65	4.87kohm	RES,SMT 0402,4.87K,1%,1/16 WATT	Panasonic	ERJ-2RKF4871X	r402-25

30	14	R2, R3, R4, R5, R6, R7, R9, R10, R11, R12, R39, R58, R70, R71	49.9ohm	RES,SMT 0402,49.9 OHM,1%,1/16 WATT	Panasonic	ERJ-2RKF49R9X	r402-25
31	6	R14, R43, R51, R72, R74, R75	470ohm	RES,SMT 0603,470 OHM,5%,1/16 WATT	Panasonic	ERJ-3GEYJ471V	r603-35X45
32	1	SW1		SWITCH,DIP,SMT,HALF-PITCH,2 POS.	C&K/Unimax, Inc.	TDA02H0SB1R	sw2-30x50-tda
33	1	J6		CONN,SMT,RECEPTACLE,60 POS.,.4mm SPC.,4mm STACKING HEIGHT	Hirose Electric, Inc.	DF40HC-(4.0)60DS-0.4V	df40c_60ds
34	2	P1, P0		CONN,JACK,RJ45,INTEGRATED MAGNETICS AND LED'S,8 CONTACTS,SHIELDED	Pulse Engineering	J1011F01PNL	RJ45-PULSE_J1-SHLD
35	2	J3, J10		HEADER,3 X 1,VERTICAL,2mm	Harwin	M22-2510305	hdr1x3-6040-2mm
36	1	TP15		TEST POINT,SMT,MINIATURE	Keystone Electronics Corp.	5015	TP1-70X135
37	10	TP2, TP3, TP4, TP5, TP6, TP7, TP9, TP11, TP13, TP14		(NO-POP) TEST POINT,SMT,.03" DIA.			tp30
38	10	R23, R29, R31, R35, R38, R53, R55, R56, R61, R64					r201-6p6spc
39	2	R21, R60					r402-25
40	5	TP1, TP8, TP10, TP12, TP16					
41	1	J9		CONN,HEADER,SHROUDED,2 POS	JST Corporation	B2B-EH-A(LF)(SN	conn2-eh

7.2.1 Layout Prints

To download the Layout Prints for each board, seTIDM-DELFINO-ETHERCATe the design files at
http://www.ti.com/tool/TIDM-DELFINO-ETHERCAT

TOP SILKSCREEN

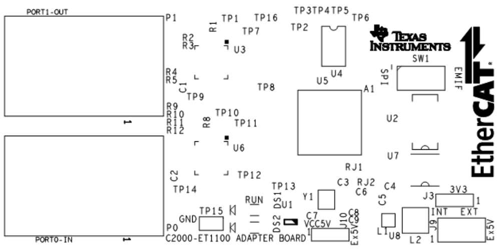


Figure 42: Layout-Top Silkscreen

TOP SOLDER MASK

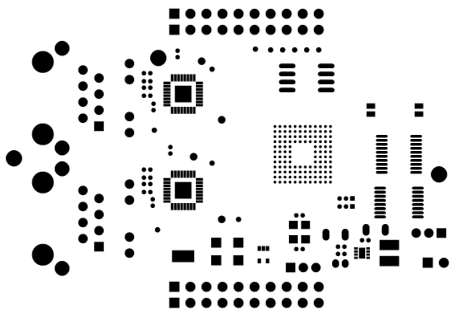


Figure 43: Layout- Top Solder Mask

TOP LAYER

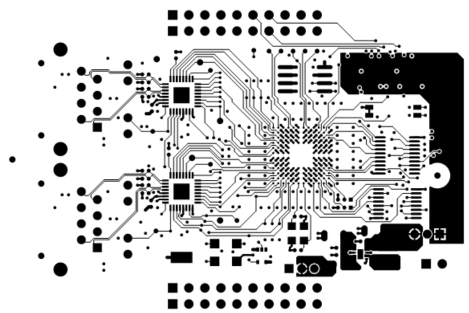


Figure 44: Layout- Top

GROUND PLANE LAYER 2

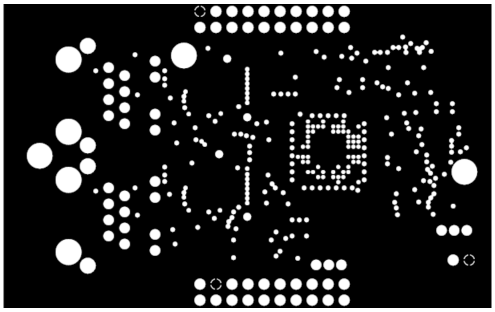


Figure 45: Layout- Ground Plane L2

BOTTOM LAYER

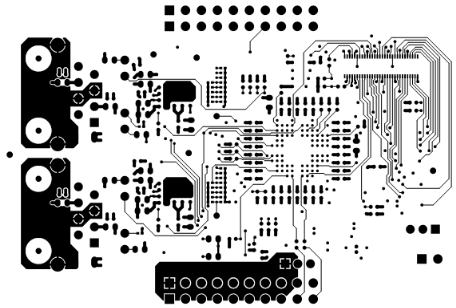


Figure 46: Layout- Bottom layer

BOTTOM SOLDER MASK

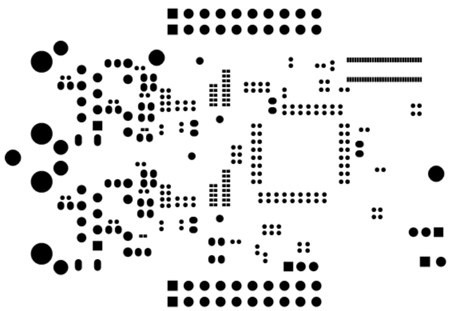


Figure 47: Layout- Bottom solder mask

BOTTOM SILKSCREEN

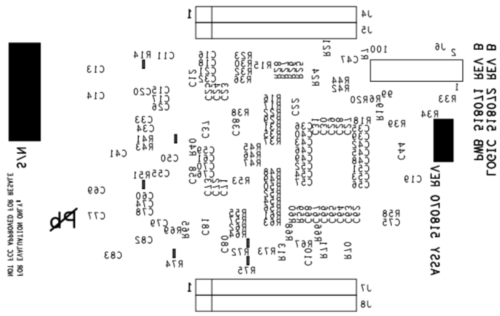


Figure 48: Layout- Bottom Silkscreen

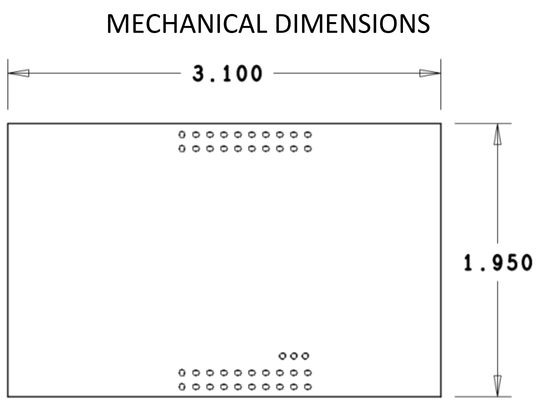


Figure 49: Layout- Physical Dimensions

7.3 Orcad Project

To download the Orcad project files for each board, see the design files at http://www.ti.com/tool/TIDM-DELFINO-ETHERCAT

7.4 Gerber files

To download the Gerber files for each board, see the design files at http://www.ti.com/tool/TIDM-DELFINO-ETHERCAT

7.5 Assembly Drawings

To download the Assembly Drawings for each board, see the design files at http://www.ti.com/tool/TIDM-DELFINO-ETHERCAT

8 Software Files

To download the software files for this reference design, please see the link at http://www.ti.com/tool/TIDM-DELFINO-ETHERCAT

9 References

1. LAUNCHXL-F28377S – C2000 Delfino MCU F28377S LaunchPad Development kit
2. TMDXDOCK28377D – F28377D Delfino MCU Experimenter Kit
3. Code Composer Studio (CCS) Integrated Development Environment (IDE)
4. Texas Instruments E2E™ online community, http://e2e.ti.com/

10 Terminology

- EMIF: External Memory Interface
- ESC: EtherCAT Slave Controller
- ETG™: EtherCAT Technology Group
- LaunchPad: An easy-to-use development tool intended for MCU-based applications.
- MCU: MicroController
- PDI: Process Data Interface
- SPI: Serial Peripheral Interface

11 About the Author

Robert Landers is a Systems Applications Engineer at Texas Instruments, where he is responsible for developing design solutions for the industrial drives segment. Robert earned his Master of Science in Electrical Engineering (MSEE) from the University of Texas Arlington. He is a member of the Institute of Electrical and Electronics Engineers (IEEE).

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