Industrial Ethernet Designs with MCUs- a Hands on Introduction

Class 5: Industrial Ethernet Examples

12/15/2017

Warren Miller

This Week's Agenda

12/11/17 An Overview of Ethernet

12/12/17 An Introduction to Industrial Ethernet

12/13/17 Industrial Ethernet Applications

12/14/17 Industrial Ethernet Implementations

12/15/17 Industrial Ethernet- examples

Course Description

- Industrial Ethernet is still a key communication technology for factory control.
- It is built on the long legacy of Ethernet, but adds significant capabilities for increasing robustness and reliability.
- This course will provide an overview of the key differences between our familiar Ethernet protocol and the Industrial version.
- A hands on example will use easily available software and development boards to dig into some of the key details of an actual Industrial Ethernet implementation. Students can optionally obtain the hardware and software to follow along with the implementation.

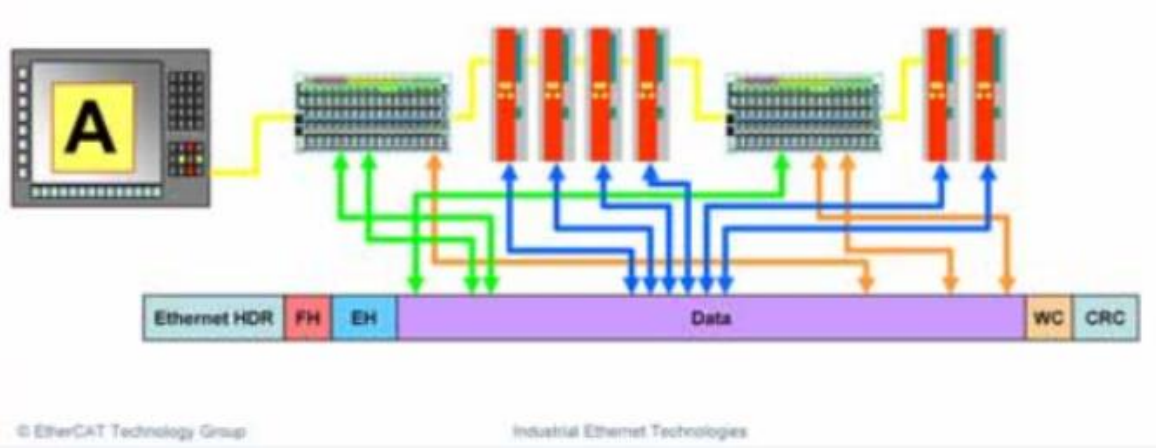
Today's Topics

This class will provide an example implementation using one of the target platforms described in the previous class and the focus of the design resources will be based on input from the students during the first two classes.

- Industrial Ethernet in real applications
- A robust reference design- TI AMIC110 and Concerto C2000
- Other reference platforms

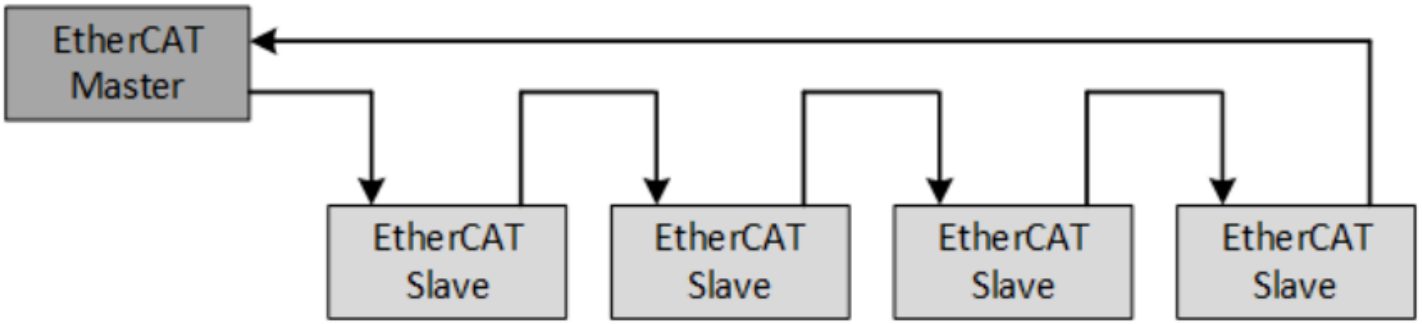
EtherCAT Overview

- EtherCAT is:
  - Industrial Ethernet down to the I/O Level
  - Flexible Wiring and simple Configuration
  - Lower cost, Well proven, An Open technology
- Key Principle: Frame processing on the fly
- Master used standard Ethernet controllers



Typical EtherCAT Network

EtherCAT has exactly one master node per network. The master can be implemented on a standard Ethernet media access controller (MAC) without an additional communication processor. This MAC has to provide a full-duplex 100 Mbit/s interface. The figure below shows a daisy-chain network EtherCAT can also be implemented in a line, tree, or star configuration.

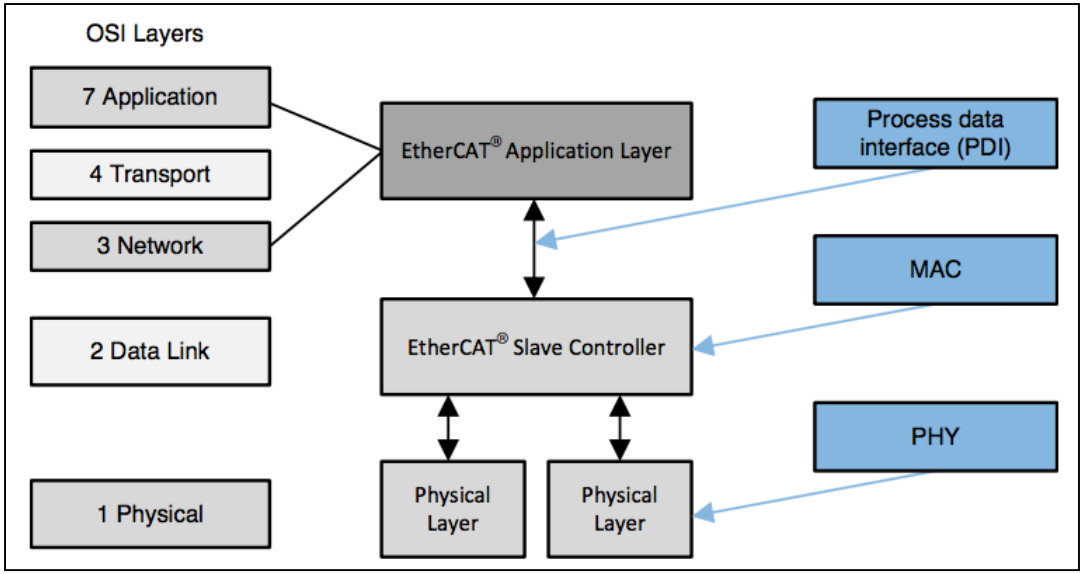


Contrary to the operation of standard Ethernet, the EtherCAT slave processes the EtherCAT frames on the fly. This means that the transmission of the new EtherCAT packet start as soon as possible before completely receiving the incoming data packet.

Typical EtherCAT Network

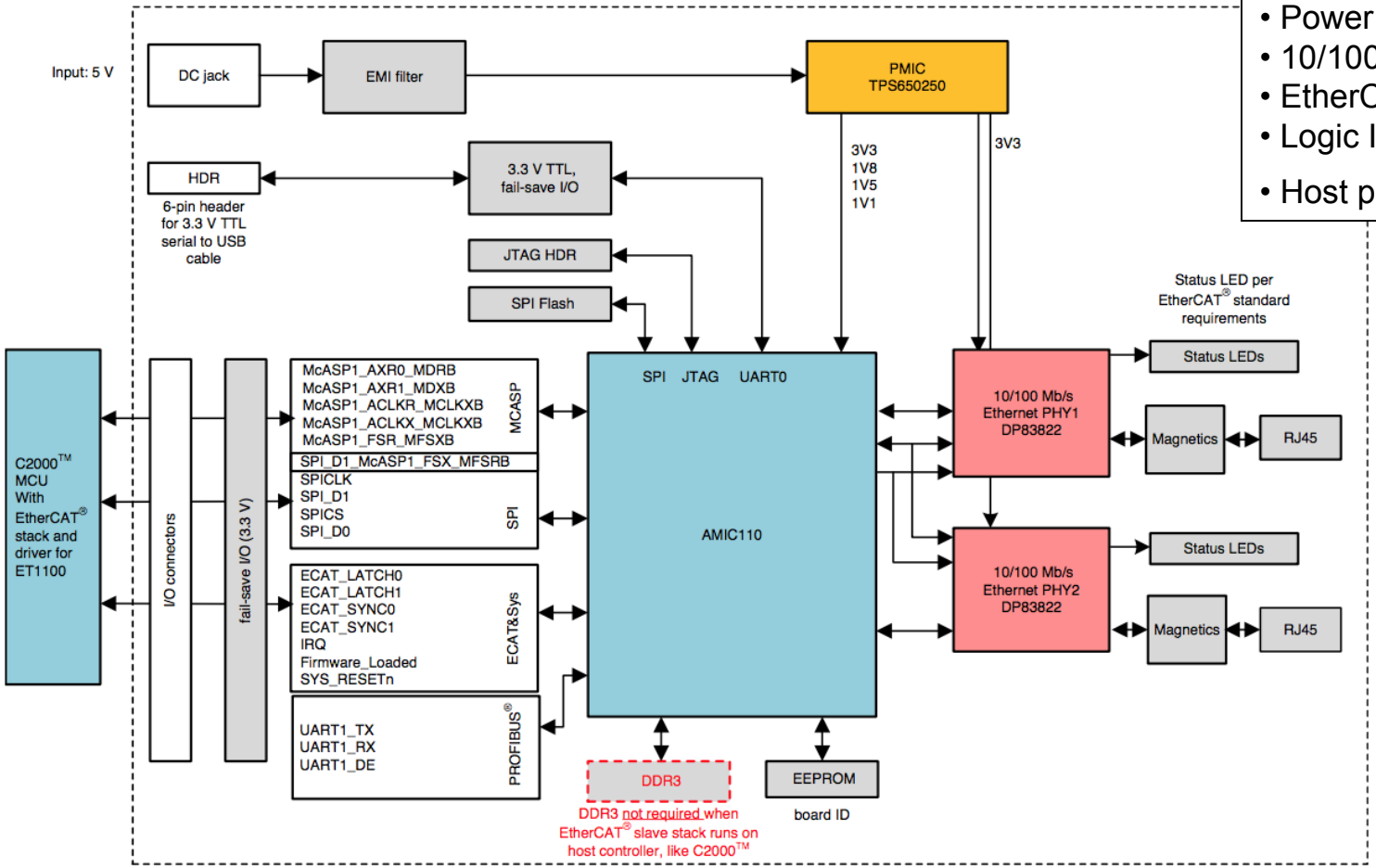
Physical Layer: 100BASE-TX copper, 100BASE-FX optical fiber, or E-bus (Ethernet-Klemmenbus) based on LVDS signaling as a transmit medium.

EtherCAT MAC Layer: The MAC layer is implemented according to the EtherCAT standard specification IEC61158. The implementation has to support the standard TCP-IP and UDP-IP protocols besides handling the EtherCAT data frames.



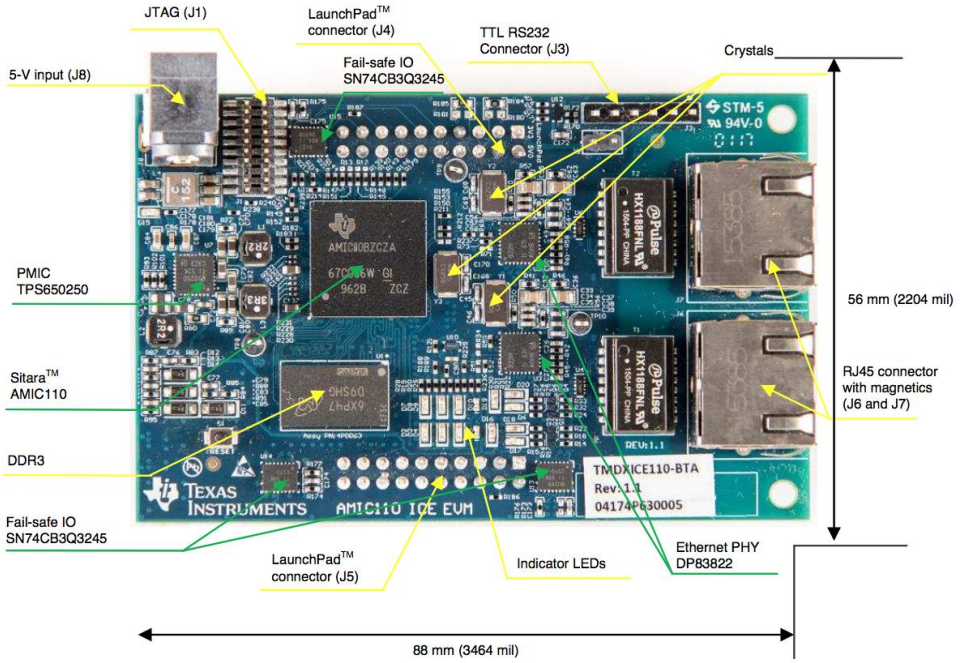
Application Layer: Different process data interfaces (PDI) are available, depending on the chosen ESC. Typical interface options vary from 32-bit to 8- or 16-bit parallel IO interfaces or serial interfaces like SPI. In the application layer the EtherCAT slave processes data or executes various functions, which are defined in specific profiles.

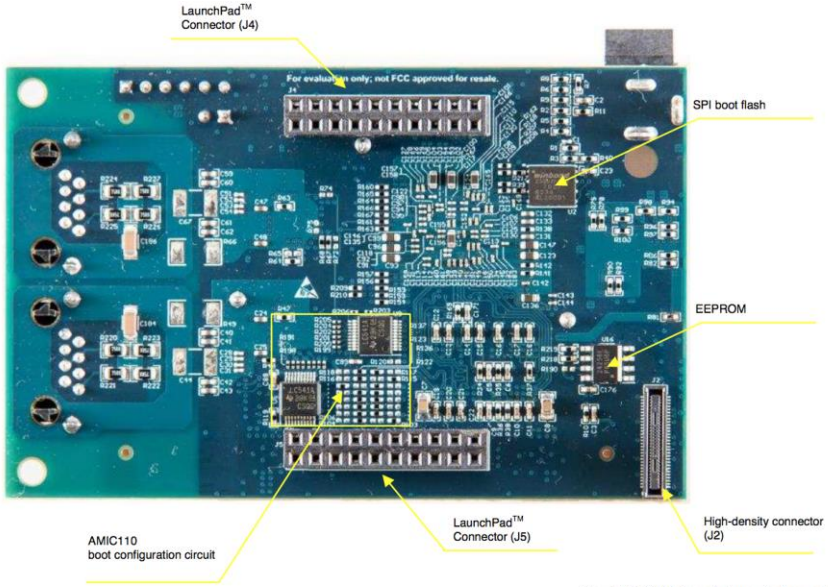
Design Block Diagram

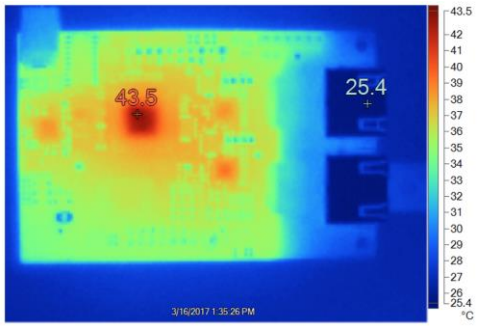


- Power management
- 10/100 Mbit Ethernet PHY
- EtherCAT controller
- Logic IC
- Host processor interface

Reference Design Board

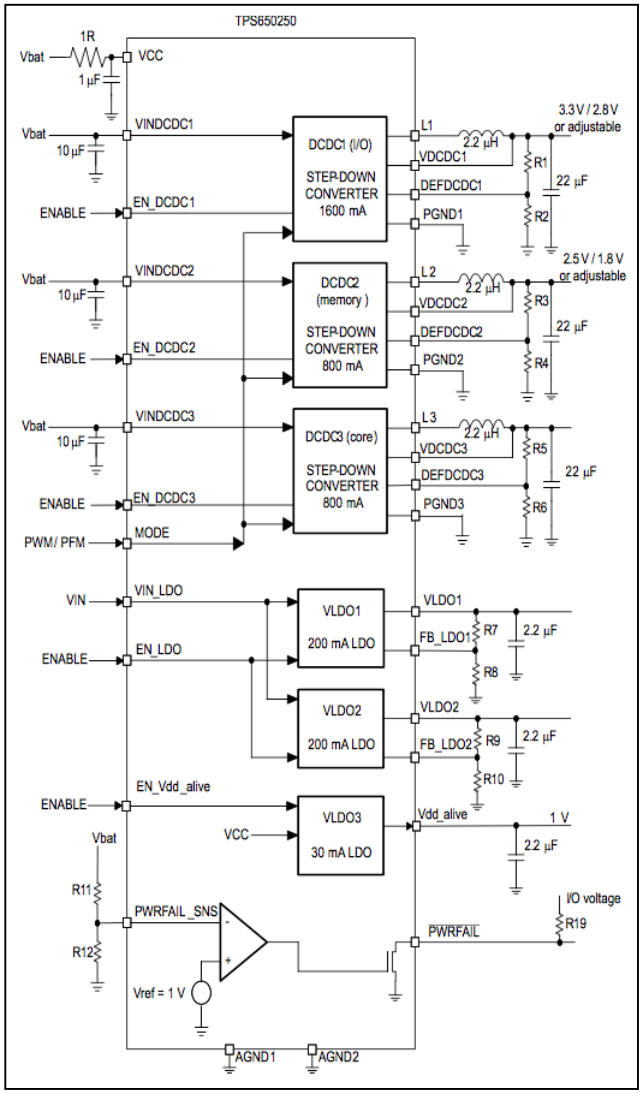






RAIL	TPS650250 MAXIMUM OUTPUT CURRENT	TECHNOLOGY	CURRENT CONSUMPTION	POWER CONSUMPTION
1.1 V	1600 mA	SMPS	349 mA	0.384 W
1.5 V	800 mA	SMPS	35.8 mA	0.054 W
1.8 V	400 mA	LDO	26.23 mA	0.047 W
3.3 V	800 mA	SMPS	128 mA	0.422 W

Design: Power Management



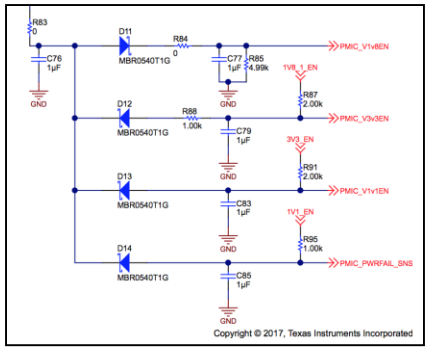
VOLTAGE OPTION	PARAMETER	VOLTAGE	MAXIMUM POWER CONSUMPTION	COMMENT
One	IO supply	3.3 V	261 mW	Choose voltage depending on power budget on different rails
	Analog supply	3.3 V		
Two	IO supply	1.8 V	126 mW	Choose voltage depending on power budget on different rails
	Analog supply	1.8 V		

RAIL	SITARA	DDR3
1.1 V	~420 mA	—
1.5 V(1)	~120 mA	~140 mA
1.8 V	~33 mA	—
3.3 V	~34 mA	—

(1) is DDR3 interface using 1.5 V

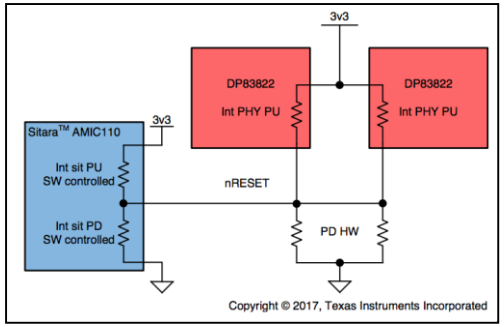
RAIL	FLASH	GLUE LOGIC	LEDS	DRIVING IO
3.3 V	~25 mA	~10 mA	~16 mA	~83 mA

RAIL	AMIC110	DDR3	SINGLE SUPPLY DP83822	EXTERNAL CIRCUIT
1.1 V	~420 mA	—	—	—
1.5 V(1)	~120 mA	~140 mA	—	—
1.8 V	~33 mA	—	—	—
3.3 V	~34 mA	—	~159 mA	~138 mA

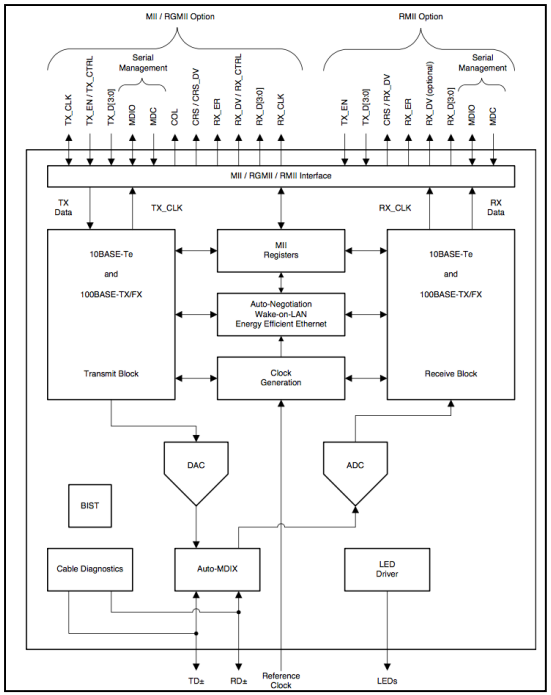


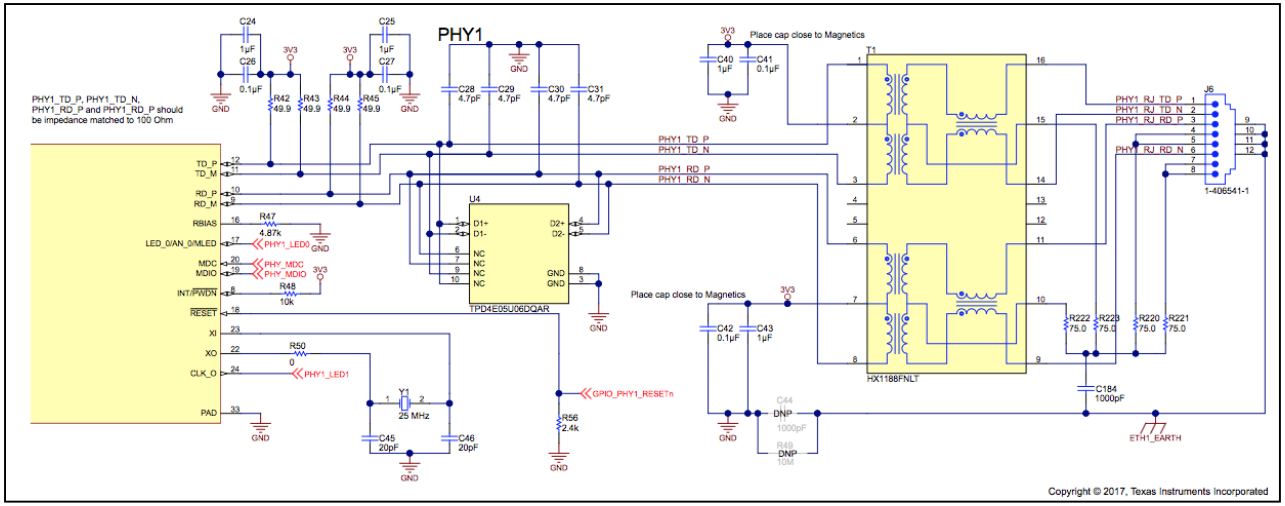
Design: PHY

- Reset Circuitry
- Interface- MII
- Interface PHY to Jack



DESCRIPTION	NET NAME	PINS
Transmit clock	PHYx_TXCLK	1
Transmit data	PHYx_TXDn	4
Transmit enable	PHYx_TXEN	1
Receive clock	PHYx_RXCLK	1
Receive data	PHYx_RXDn	4
Receive error	PHYx_RXER	1
Receive data valid	PHYx_RXDV	1
Collision detect	PHYx_COL	1
Carrier sense	PHYx_CRS	1
Total	—	15

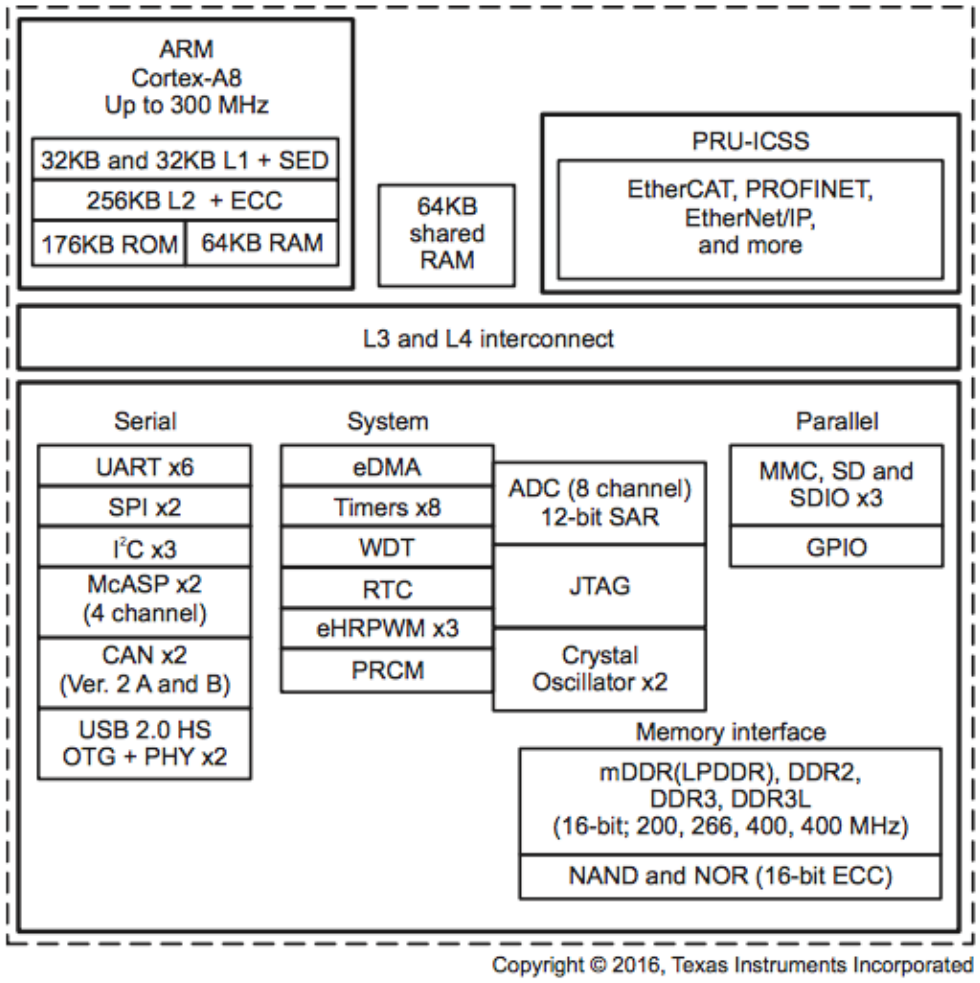




AMIC110 Processor

- ARM Cortex-A8
- L1 and L2 cache
- ROM and RAM
- Shared RAM
- PRU-ICSS

  Programmable Real-Time Unit Subsystem and Industrial Communications Subsystem
- Peripherals

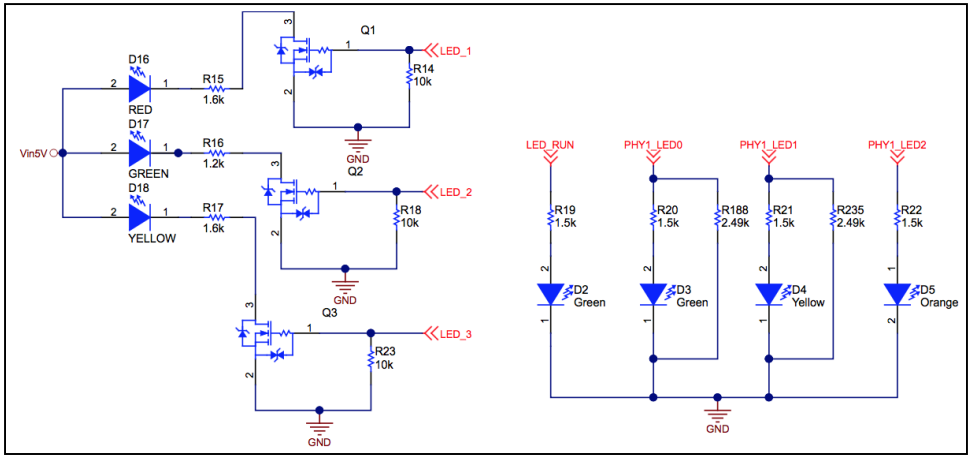


Design: AMIC110 Memory I/O

- DDR3: Because only one DDR3 memory chip is necessary, the termination of the DDR3 data lines can be neglected if the layout is done correctly. The characteristic impedance of each trace must match that of the DDR3 IC.
- SPI Flash: The flash chip was chosen to have a cost-optimized boot option. The boot configuration pins of the AMIC110 are set so that it will boot from the SPI flash.
- I2C EEPROM: The EEPROM memory is used for board identification purposes. The Ethernet MAC addresses can also be stored there.

Design: AMIC110 Peripheral I/O

- LEDs
- Pins during Boot
- Unused circuits
- SPI, UART0/1, GPIO, EtherCAT, Host I/F



GROUP	1	2	3	4	5	6	7	8	9	10	11	12	13
ZCZ BALL NUMBER	B6	C7	B7	A7	C8	B8	A8	C9	C18	B18	C17	C16	R6
PD OR PU OR Z	Z	Z	Z	Z	Z	Z	Z	Z	PD	PU	PU	PU	PD
ZCZ BALL NUMBER	R1	R2	R3	R4	T1	T2	T3	T4	U1	U2	U3	U4	V2
PD OR PU OR Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z
ZCZ BALL NUMBER	V3	V4	T5	R5	V5	U5	B15	B4	B5	D14	A17	A16	C15
PD OR PU OR Z	Z	Z	Z	PD	PD	PD	Z	Z	Z	PD	PU	PU	PU
ZCZ BALL NUMBER	B17	B16	E16	E18	E15	E17	D15	D16	D17	D18	A9	B9	A15
PD OR PU OR Z	PU	PU	PU	PU	PU	PU	PU	PU	PU	PU	Z	Z	PD

Table 15. Disabling AMIC110's Real-time Clock Subsystem

PIN	CONNECT TO
VDDS_RTC	1.8V
CAP_VDD_RTC	1.1V(VDD_CORE)
RTC_KALDO_ENn	1.8V(VDDS_RTC)
RTC_PWRONRSTn	GND(VSS)
PMIC_POWER_EN	NC
EXT_WAKEUP	GND(VSS)
RTC_XTAL	NC
VSS_RTC	GND(VSS)

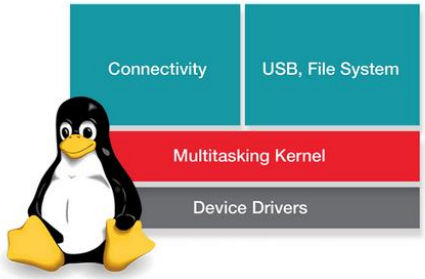
Table 16. Disabling AMIC110's USB Interface

PIN	CONNECT TO
VDDA1P8V_USB	1.8V
VDDA3P3V_USB	3.3V or GND
VSSA_USB	GND
USBx_DP	NC or GND
USBx_DM	NC or GND
USBx_CE	NC
USBx_ID	NC or GND
USBx_DRVVBUS	NC
USBx_VBUS	NC or GND

Accessing the Software Platform

Download Software

- The TI Processor SDK is a unified software platform for TI's newest Processor families.
- Features scalable Linux, TI-RTOS and Android support
- Includes complete board support packages, documentation, libraries, benchmarks, utilities, and code examples
- Allows you to seamlessly reuse and migrate software across TI processor families
- Maintained and released on a quarterly basis
- Downloadable from TI's website, free of charge
- Supported by TI's E2E forums
- Benefits from the ongoing TI contributions, via up-streamed patches, to Mainline Linux



Reference Design Software

- The Processor SDK for AMIC110 comes with the bootloader (MLO).
- To program the onboard SPI memory, the SDK comes with a flash tool, which can also be found in this package.
- The bootloader has to be configured to boot from SPI flash. This configuration can be completed by picking the correct build option.
- A user guide, the EtherCAT libraries, prebuilt binaries, and example source code can be found at:[PRU-ICSS-ETHERCAT-SLAVE]

Title	Description	Size
PRU-ICSS EtherCAT Slave 01.00.04.02		
PRU-ICSS EtherCAT Slave Linux Installer	EtherCAT Slave package	5988K
PRU-ICSS EtherCAT Slave Windows Installer	EtherCAT Slave package	7812K
Prebuilt binaries	PRU-ICSS EtherCAT Slave pre-built binaries	552K
Industrial Protocol Packages Software Developers Guide	Software Developers Guide	
Industrial Protocol Packages Getting Started Guide	Getting Started Guide	
PRU-ICSS EtherCAT Slave User Guide	User Guide	
PRU-ICSS EtherCAT Slave Release Notes	Release Notes	
Software Manifest	Software Manifest of the components in the package	24K
Firmware Datasheet	Firmware Datasheet	556K
Processor SDK RTOS documentation		
Processor SDK RTOS documentation	Developers guide for Processor SDK RTOS	
AM335x EVM Documentation		
AM335x Industrial Communications Engine Quick Start Guide	Quick Start Guide included in the EVM kit	
AM437x EVM Documentation		
AM437x Industrial Development Kit Quick Start Guide	Quick Start Guide included in the EVM kit	
AM57xx IDK Documentation		
AM572x IDK Quick Start Guide	Quick Start Guide that was included in the EVM kit	
AM571x IDK Quick Start Guide	Quick Start Guide that was included in the EVM kit	
PRU-ICSS-EtherCAT_Slave Checksums		
md5sum_ethercat_slave.txt	MD5 Checksums for EtherCAT Slave package	4K

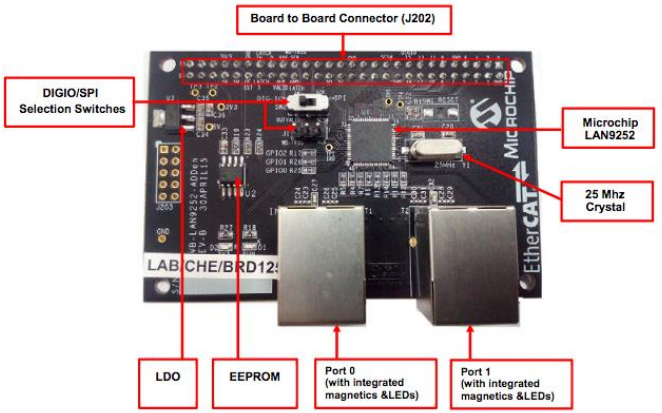
Legend

Fill in Form. Approved users receive download URL in 1 minute.
Fill in Form. TI will contact you in 1-2+ business days.

Other Reference Designs

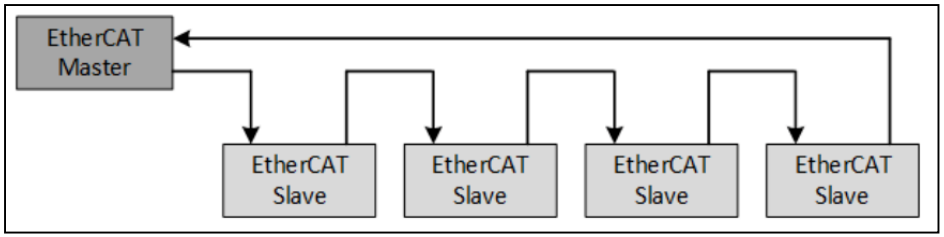
- The NXP QorIQ® communications processors include single-, dual-, quad- and multicore processor architectures with integrated support for communications protocols such as EtherCAT. Fact Sheet Order at Digi-Key

- The Microchip LAN9252 is a 2-port EtherCAT Slave Controller (ESC) with dual-integrated Ether-net PHYs which each contain a full-duplex 100BASE-TX transceiver and support 100Mbps (100BASE-TX) operation. 100BASE-FX is supported via an external fiber transceiver. Fact Sheet Order at Digi-Key

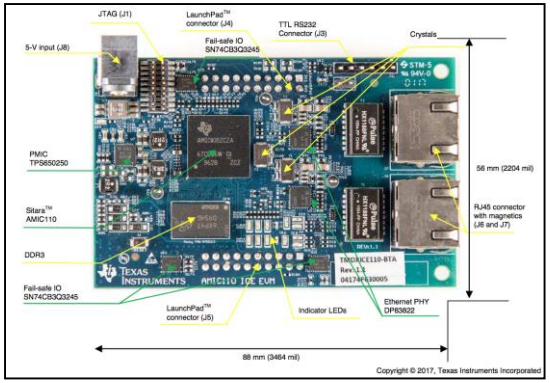


Conclusion

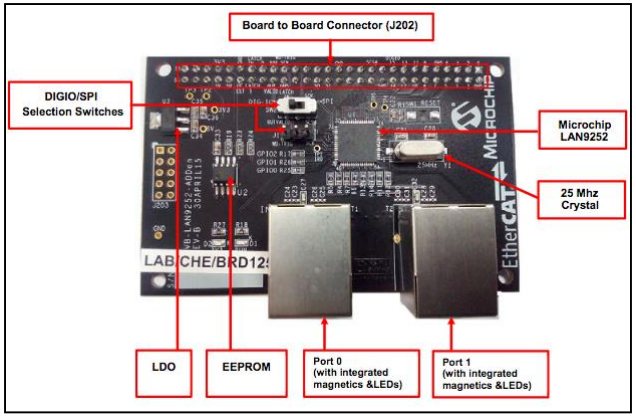
EtherCAT Refresher



EtherCAT Implementation



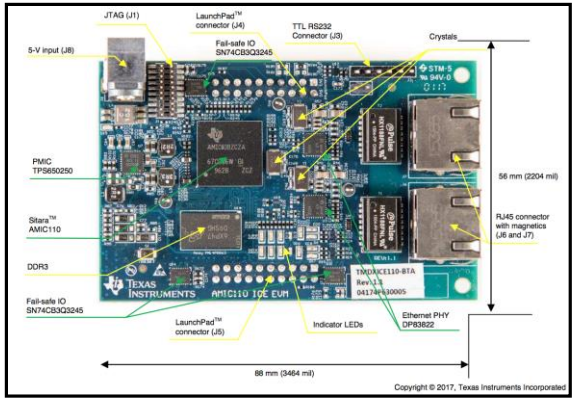
Other Reference Designs



Class Resources

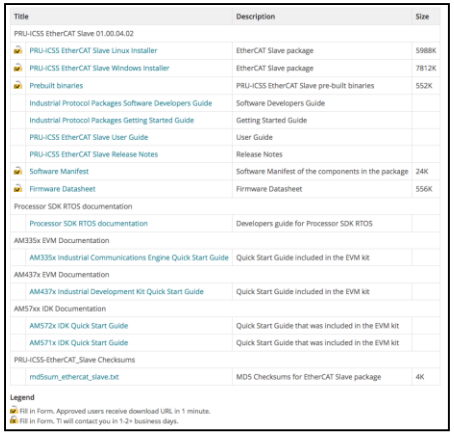
TI Industrial Control with Concerto MCU

- https://dkc1.digikey.com/IE/en/TOD/Texas_Instruments/Connectivity-Control-Systems/Connectivity-Control-Systems.html



AMIC110 Platform

- http://www.ti.com/lit/ug/tidud02/tidud02.pdf
- http://processors.wiki.ti.com/index.php/PRU_ICSS_EtherCAT



Other Platforms

- NXP Order at Digi-Key
- Microchip Order at Digi-Key

Course Resources

Industrial Ethernet Overview- TI

•http://www.ti.com/lit/wp/spry254/spry254.pdf

Industrial Communications Kit

•https://www.digikey.com/en/product-highlight/t/texas-instruments/industrial-communications-engine-using-tis-am3359

EtherCAT Article

•https://www.digikey.com/en/articles/techzone/2015/aug/mcus-and-ethercat-gear-up-for-the-industrial-internet-of-things

Connectivity and Control Systems- TI

•https://dkc1.digikey.com/IE/en/TOD/Texas_Instruments/Connectivity-Control-Systems/Connectivity-Control-Systems.html

Embedded Ethernet- MicroChip

•https://dkc1.digikey.com/IE/en/TOD/microchip/EmbeddedEthernet/EmbeddedEthernet.html

•https://dkc1.digikey.com/IE/en/TOD/Microchip/Ethernet_Controller_Solution/Ethernet_Controller_Solution.html

Introduction to Industrial Ethernet

•http://www.bb-elec.com/Learning-Center/All-White-Papers/Ethernet/Introduction-to-Industrial-Ethernet/AnIntroductionToIndustrialEthernet-WP12B-R1_1112.pdf

Additional Resources

•http://www.ti.com/lit/wp/spry254/spry254.pdf

•https://www.ethercat.org/download/documents/Industrial_Ethernet_Technologies.pdf

•https://www.youtube.com/watch?v=gphJtw0pluo&list=PLgUXqPkOStPum60jqifNt7lDY9_0a0_rX&index=14

This Week's Agenda

12/11/17 An Overview of Ethernet

12/12/17 An Introduction to Industrial Ethernet

12/13/17 Industrial Ethernet Applications

12/14/17 Industrial Ethernet Implementations

12/15/17 Industrial Ethernet- an example

Done!