Stellaris® MCU Day

Serial to Ethernet: Solutions ready to implement

Stellaris® ARM® Cortex™-M3 Microcontroller Solutions

Texas Instruments

Embedded Series 2011

Texas Instruments Authorized Distributor

ARROW ELECTRONICS AND TEXAS INSTRUMENTS

Embedded Series

MAKE THE SWITCH

arrow.

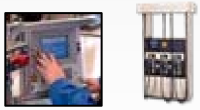
CERTIFIED USB
EETIMES ee PRODUCTCENTER
ULTIMATE PRODUCTS
3.1 Winner
TEXAS INSTRUMENTS
EETIMES'
Ultimate Products
4.2
Winner
StellarisWare®
best electronic design
2006
jaguar
TEXAS INSTRUMENTS
JUST ADD MOTOR
eG3
Editors Tech Choice
EDN
HOT 100 products
ARM POWERED®
Cortex
Intelligent Processors by ARM®
FRC
FIRST Robotics Competition
CROWN SUPPLIER
Embedded COMPUTING DESIGN
Editor's Choice
products

Stellaris Day Agenda

1. Stellaris Family
2. StellarisWare®
3. Serial to Ethernet Converter
4. Designing a Serial to Ethernet Converter
5. S2E RDK Overview
6. Industrial Control Demo Overview
7. Proof of Concept: S2E Converter Demo

TI Embedded Processors Portfolio

TI Embedded Processors

Microcontrollers (MCUs)		ARM®-Based Processors		Digital Signal Processors (DSPs)	
16-bit ultra-low power MCUs	32-bit real-time MCUs	32-bit ARM Cortex™-M3 MCUs	ARM Cortex-A8 MPUs	High-performance DSPs	Ultra Low power DSP
MSP430™	C2000™ Delfino™ Piccolo™	Stellaris® ARM® Cortex™-M3	Sitara™ ARM® Cortex™-A8 & ARM9	C6000™ DaVinci™ OMAP™	C5000™
Up to 25 MHz	40MHz 300 MHz	Up to 80 MHz	300MHz to >1GHz	300MHz to >1Ghz +Accelerator	Up to 300 MHz +Accelerator
Flash 1 KB to 256 KB	Flash, RAM 16 KB to 512	Flash 8 KB to 256 KB	Cache, RAM, ROM	Cache RAM, ROM	Up to 320KB RAM Up to 128KB ROM
Analog I/O, ADC LCD, USB, RF	PWM, ADC, CAN, SPI, I2C	USB, ENET MAC+PHY CAN, ADC, PWM, SPI	USB, CAN, PCIe, EMAC	USB, ENET, PCIe, SATA, SPI	USB, ADC McBSP, SPI, I^{2}C
Measurement, Sensing, General Purpose	Motor Control, Digital Power, Lighting, Ren. Energy	Connectivity, Security, Motion Control, HMI, Industrial Automation	Industrial computing, POS & portable data terminals	Test & Meas., Video, audio, security, imaging, infrastructure	Audio, Voice Medical, Biometrics
$0.49 to $9.00	$1.50 to $20.00	$1.00 to $8.00	$5.00 to $20.00	$5.00 to $200.00	$3.00 to $10.00
					

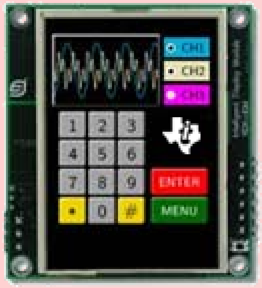
Texas Instruments Developer Network

Software & Dev. Tools

Texas Instruments eXpressDSP™

Scalable solutions across all ARM® cores

Industrial automation



- Connectivity: Ethernet, USB, serial
- Display: Up to QVGA 320 x 240
- Real-time sensor handling

- Connectivity: USB, Ethernet
- Display: Up to WXGA resolution
- Rich user interface: 3D graphics capability of 10M polygons per second

Stellaris® Cortex™-M3 Scalable Sitara™ Cortex™-A8

Point-of-sale

- Connectivity: Ethernet, USB, serial
- Machine-to-machine interface (still camera or low res video)
- Real-time sensor handling

- Connectivity: USB, Ethernet
- Display: Up to WXGA
- 3D graphics

What is ARM® Cortex™-M3?

- The **Cortex family of ARM processors** provides a range of solutions optimized around specific market applications across the full performance spectrum.
- Cortex underlines ARM's strategy of aligning technology around specific market applications and performance requirements.
- The ARM Cortex family is comprised of three series, which all implement the Thumb-2 instruction set to address the increasing performance and cost demands of various markets:
  - **ARM Cortex-A Series**,
    - Applications processors for complex OS and user applications
    - Supports the ARM, Thumb and Thumb-2 instruction sets
  - **ARM Cortex-R Series**
    - Embedded processors for real-time systems
    - Supports the ARM, Thumb, and Thumb-2 instruction sets
  - **ARM Cortex-M Series**
    - Deeply embedded processors
    - Optimized for cost-sensitive applications
    - Supports the Thumb-2 instruction set only

Did You Know?

Texas Instruments is the lead partner for ARM Cortex A8, R4, M3, and M4!

Note:

- ARM Code 32-bit instructions / 32-bit data
- Thumb Code 16-bit instructions / 32-bit data
- Thumb-2 Code mostly 16-bit & some 32-bit (25% Faster, 26% Smaller)

Cortex™

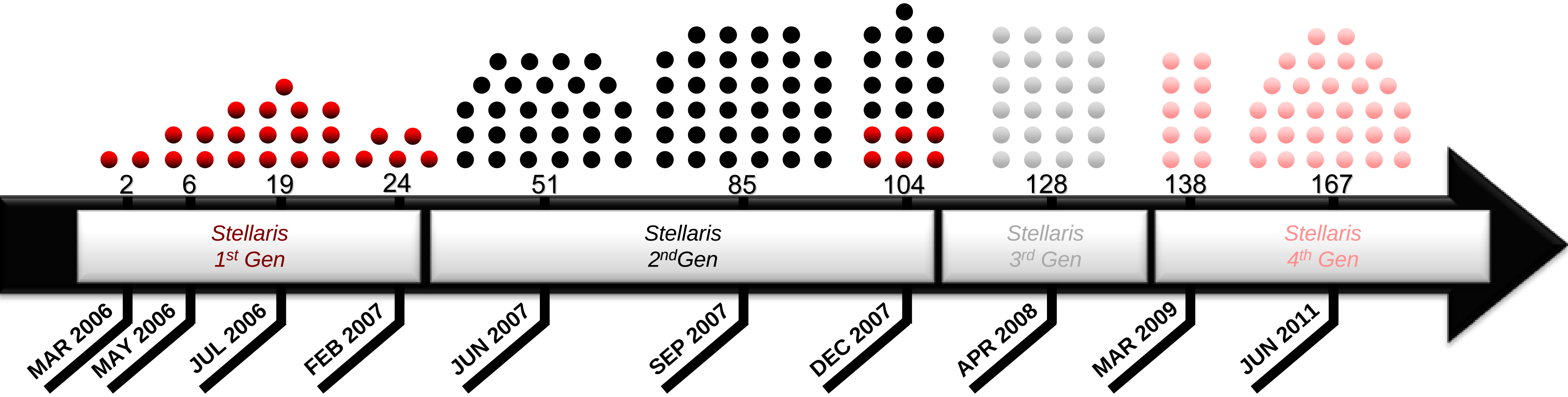
Intelligent Processors by ARM®

Stellaris®: First in ARM Cortex-M3 Microcontrollers

- In May of 2009, TI acquired Luminary Micro, Inc.
  - Luminary Micro was ARM’s lead partner for Cortex-M3 architecture
  - TI now offers four generations of Stellaris ARM Cortex-M3 MCUs – today!

ARM POWERED® Cortex Intelligent Processors by ARM®

- Stellaris® family has over 160 microcontrollers!
  - Broad line card of mixed-signal microcontrollers focused on applications in energy, security, and connectivity markets
  - Unique IP for motion control applications, real time connectivity (Ethernet, Controller Area Network, and USB), intelligent analog functionality, and power conservation
  - Experience fastest time-to-market for the most cost effective, standardized, market-leading solutions through extensive Stellaris hardware tools, StellarisWare® software, documentation, technical support, and ARM’s vast 3rd party ecosystem



Stellaris® Family Technology

ARM® Cortex™-M3 v7-M Processor Core
- Up to 80 MHz

On-chip Memory
- 256 KB Flash; 96 KB SRAM
- ROM loaded with Stellaris Driver Library, BootLoader, AES tables, and CRC

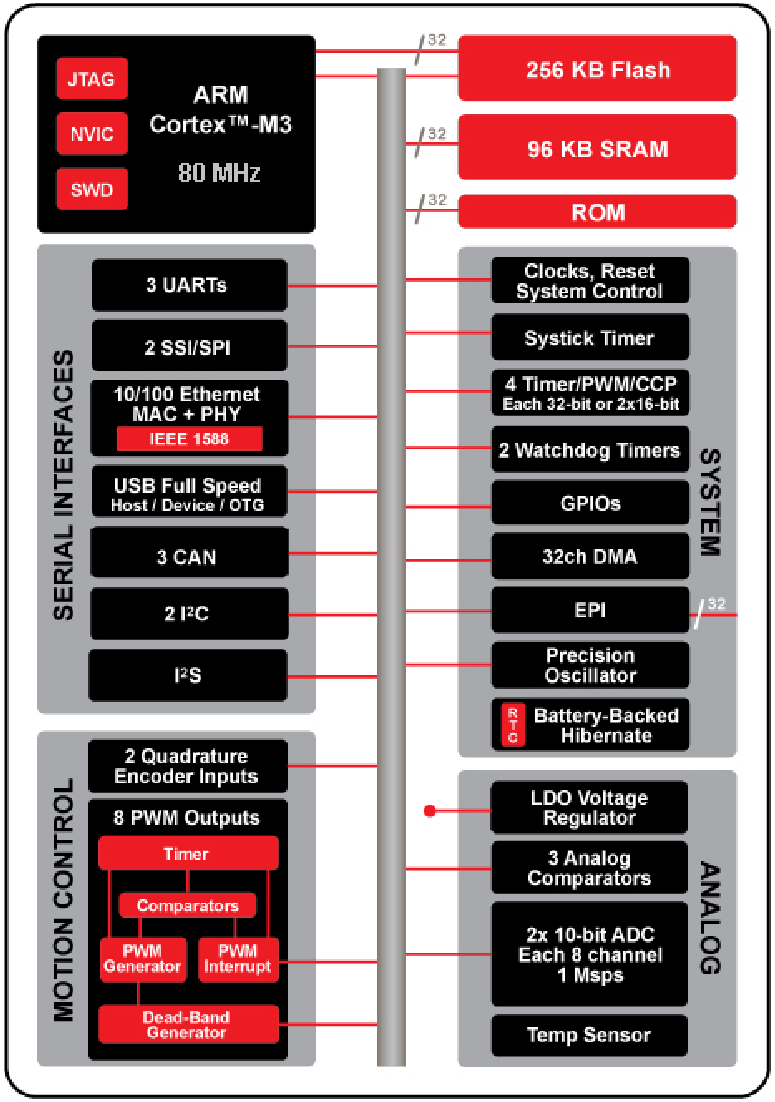
External Peripheral Interface (EPI)
- 32-bit dedicated parallel bus for external peripherals
- Supports SDRAM, SRAM/Flash, M2M

Advanced Serial Integration
- 10/100 Ethernet MAC and PHY
- 3 CAN 2.0 A/B Controllers
- USB (full speed) OTG / Host / Device
- 3 UARTs with IrDA and ISO 7816 support*
- 2 I2Cs
- 2 Synchronous Serial Interfaces (SSI)
- Integrated Interchip Sound (I2S)

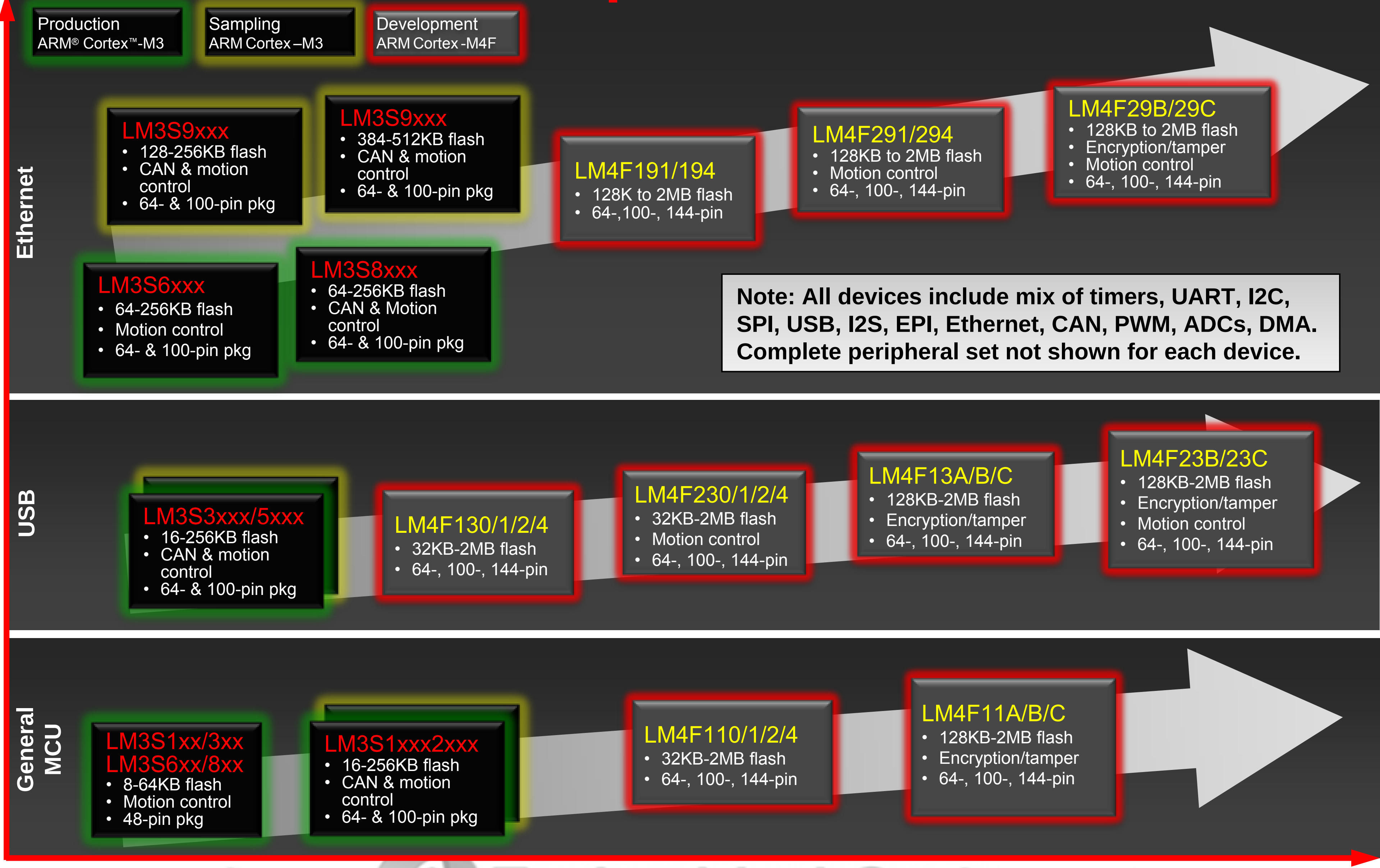
System Integration
- 32-channel DMA Controller
- Internal Precision 16MHz Oscillator
- Two watchdog timers with separate clock domains
- ARM Cortex Systick Timer
- 4 32-bit timers (up to 8 16-bit) with RTC capability
- Lower-power battery-backed hibernation module
- Flexible pin-muxing capability

Advanced Motion Control
- 8 advanced PWM outputs for motion and energy applications
- 2 Quadrature Encoder Inputs (QEI)

Analog
- 2x 8-ch 10-bit ADC (for a total of 16 channels)
- 3 analog comparators
- On-chip voltage regulator (1.2V internal operation)



Stellaris® Roadmap



Production
ARM® Cortex™-M3

Sampling
ARM Cortex –M3

Development
ARM Cortex -M4F

Ethernet

LM3S9xxx
- 128-256KB flash
- CAN & motion control
- 64- & 100-pin pkg

LM3S9xxx
- 384-512KB flash
- CAN & motion control
- 64- & 100-pin pkg

LM3S6xxx
- 64-256KB flash
- Motion control
- 64- & 100-pin pkg

LM3S8xxx
- 64-256KB flash
- CAN & Motion control
- 64- & 100-pin pkg

LM4F191/194
- 128K to 2MB flash
- 64-,100-, 144-pin

LM4F291/294
- 128KB to 2MB flash
- Motion control
- 64-, 100-, 144-pin

LM4F29B/29C
- 128KB to 2MB flash
- Encryption/tamper
- Motion control
- 64-, 100-, 144-pin

Note: All devices include mix of timers, UART, I2C, SPI, USB, I2S, EPI, Ethernet, CAN, PWM, ADCs, DMA. Complete peripheral set not shown for each device.

USB

LM3S3xxx/5xxx
- 16-256KB flash
- CAN & motion control
- 64- & 100-pin pkg

LM4F130/1/2/4
- 32KB-2MB flash
- 64-, 100-, 144-pin

LM4F230/1/2/4
- 32KB-2MB flash
- Motion control
- 64-, 100-, 144-pin

LM4F13A/B/C
- 128KB-2MB flash
- Encryption/tamper
- 64-, 100-, 144-pin

LM4F23B/23C
- 128KB-2MB flash
- Encryption/tamper
- Motion control
- 64-, 100-, 144-pin

General MCU

LM3S1xx/3xx
LM3S6xx/8xx
- 8-64KB flash
- Motion control
- 48-pin pkg

LM3S1xxx2xxx
- 16-256KB flash
- CAN & motion control
- 64- & 100-pin pkg

LM4F110/1/2/4
- 32KB-2MB flash
- 64-, 100-, 144-pin

LM4F11A/B/C
- 128KB-2MB flash
- Encryption/tamper
- 64-, 100-, 144-pin

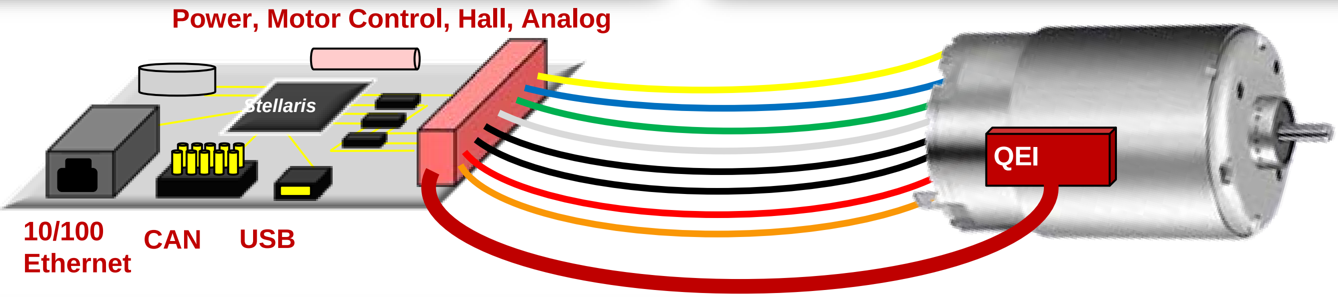
The Stellaris Full-Solution Approach

Fully Integrated Stellaris MCUs

- ARM Cortex-M3 core with single-cycle Flash
- Advanced motion control
- Integrated deterministic connectivity
- Easy adoption / learning curve through 10-min out-of-the-box evaluation kits

Production-ready Modules

- Customizable modules for drop-in implementation
- Multiple motors supported
- Multiple connectivity options
- Copy-exactly with open-tooled HW and SW



Complete Open-tooled RDKs

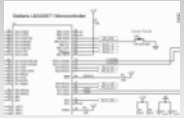
- Open-tooled HW/SW Reference Design Kits
- Motor included for out-of-the-box demonstration
- Fully documented, available for download, and in stock

Proof-of-Concept

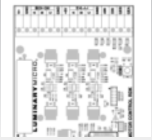
- Stellaris MCUs / Modules
- Putting our motion control to the test before you do.

End-to-End Solution Source Files

Royalty-Free



Schematics



Placement

Bill of Materials

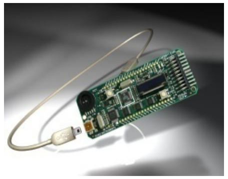
Gerbers

Motor App and StellarisWare® Source

Control / Config GUI

Stellaris® Evaluation Kits

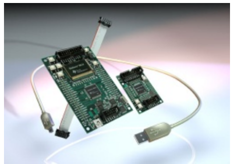
- Start in 10 minutes or less
- Evaluation board packages includes:
  - Cables
  - A choice of evaluation tools suites for popular development tools
  - Documentation (QuickStart guide, User’s guide, …)
  - StellarisWare® software
  - Applications notes



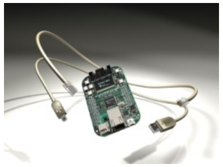
EK-LM3S811
Low pin count
49 USD

EK-LM3S1968
High pin count
59 USD

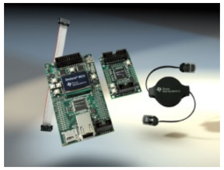
EK-LM3S2965
CAN Functionality
79 USD



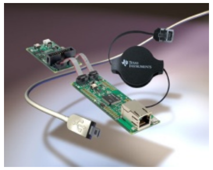
EK-LM3S3748
USB Host/Device
109 USD



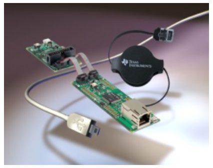
EK-LM3S6965
Ethernet MAC+PHY
69 USD



EK-LM3S8962
Ethernet+CAN
89 USD



EK-LM3S9B90
Ethernet+USB OTG
99 USD



EK-LM3S9B92
Ethernet+OTG+MC
99 USD

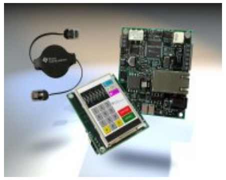
- Function both as an evaluation platform and as a serial in-circuit debug interface for any Stellaris microcontroller-based target board

Stellaris Reference Design Kits

- Speed to market with rapid evaluation
- Reference design kit includes:
  - Motors, adapter, cables
  - Design files – layout, BOM's, schematic
  - Kit User Guide Documentation
  - StellarisWare® software
  - GUI interface firmware

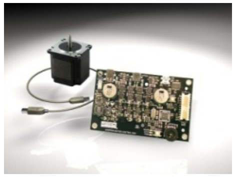
RDK_IDM
Landscape touch screen
219 USD

RDK_IDM_SBC
Single board touch screen
299 USD



RDK_IDM
Touch-screen + POE
219 USD

RDK_ACIM
AC
Induction Motor
379 USD



RDK_STEPPER
Stepper motor
199 USD

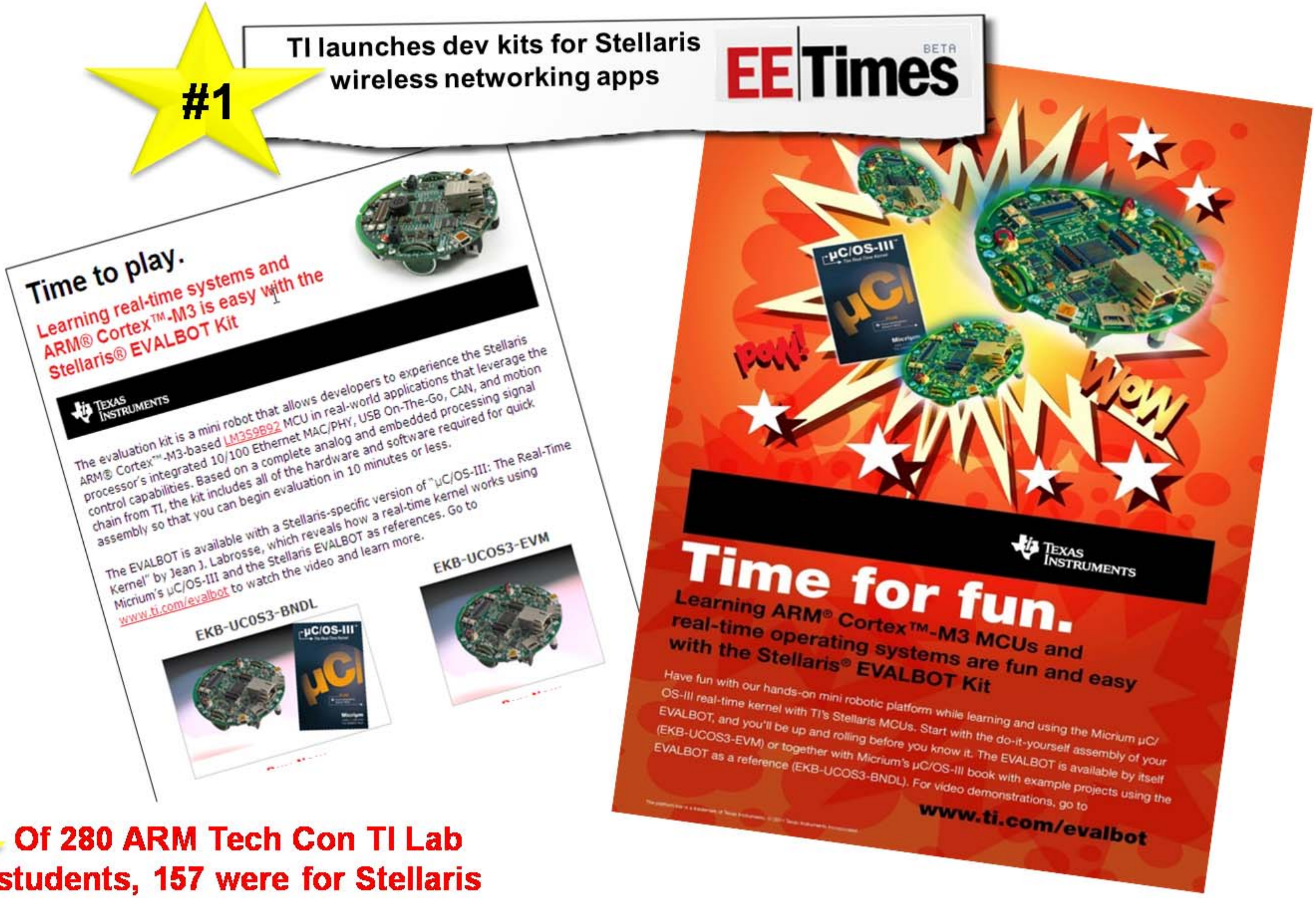
RDK_S2E
Serial –to -Ethernet
139 USD

RDK_BDC
CAN + BDC Motor
199 USD

RDK _BLDC
CAN + Ethernet + BLDC Motor
219 USD

- RDK's are complete design solution, all open-tooling

EVALBOT: Educating the MCU market



TI launches dev kits for Stellaris wireless networking apps

EE Times BETA

Time to play.

Learning real-time systems and ARM® Cortex™-M3 is easy with the Stellaris® EVALBOT Kit

TEXAS INSTRUMENTS

The evaluation kit is a mini robot that allows developers to experience the Stellaris ARM® Cortex™-M3-based LM3S9B92 MCU in real-world applications that leverage the processor's integrated 10/100 Ethernet MAC/PHY, USB On-The-Go, CAN, and motion control capabilities. Based on a complete analog and embedded processing signal chain from TI, the kit includes all of the hardware and software required for quick assembly so that you can begin evaluation in 10 minutes or less.

The EVALBOT is available with a Stellaris-specific version of "µC/OS-III: The Real-Time Kernel" by Jean J. Labrosse, which reveals how a real-time kernel works using Micrium's µC/OS-III and the Stellaris EVALBOT as references. Go to www.ti.com/evalbot to watch the video and learn more.

EKB-UCOS3-BNDL

EKB-UCOS3-EVM

TEXAS INSTRUMENTS

Time for fun.

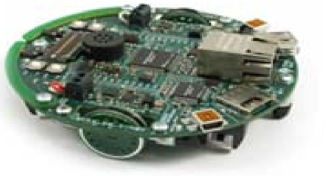
Learning ARM® Cortex™-M3 MCUs and real-time operating systems are fun and easy with the Stellaris® EVALBOT Kit

Have fun with our hands-on mini robotic platform while learning and using the Micrium µC/OS-III real-time kernel with TI's Stellaris MCUs. Start with the do-it-yourself assembly of your EVALBOT, and you'll be up and rolling before you know it. The EVALBOT is available by itself (EKB-UCOS3-EVM) or together with Micrium's µC/OS-III book with example projects using the EVALBOT as a reference (EKB-UCOS3-BNDL). For video demonstrations, go to

www.ti.com/evalbot

Of 280 ARM Tech Con TI Lab students, 157 were for Stellaris

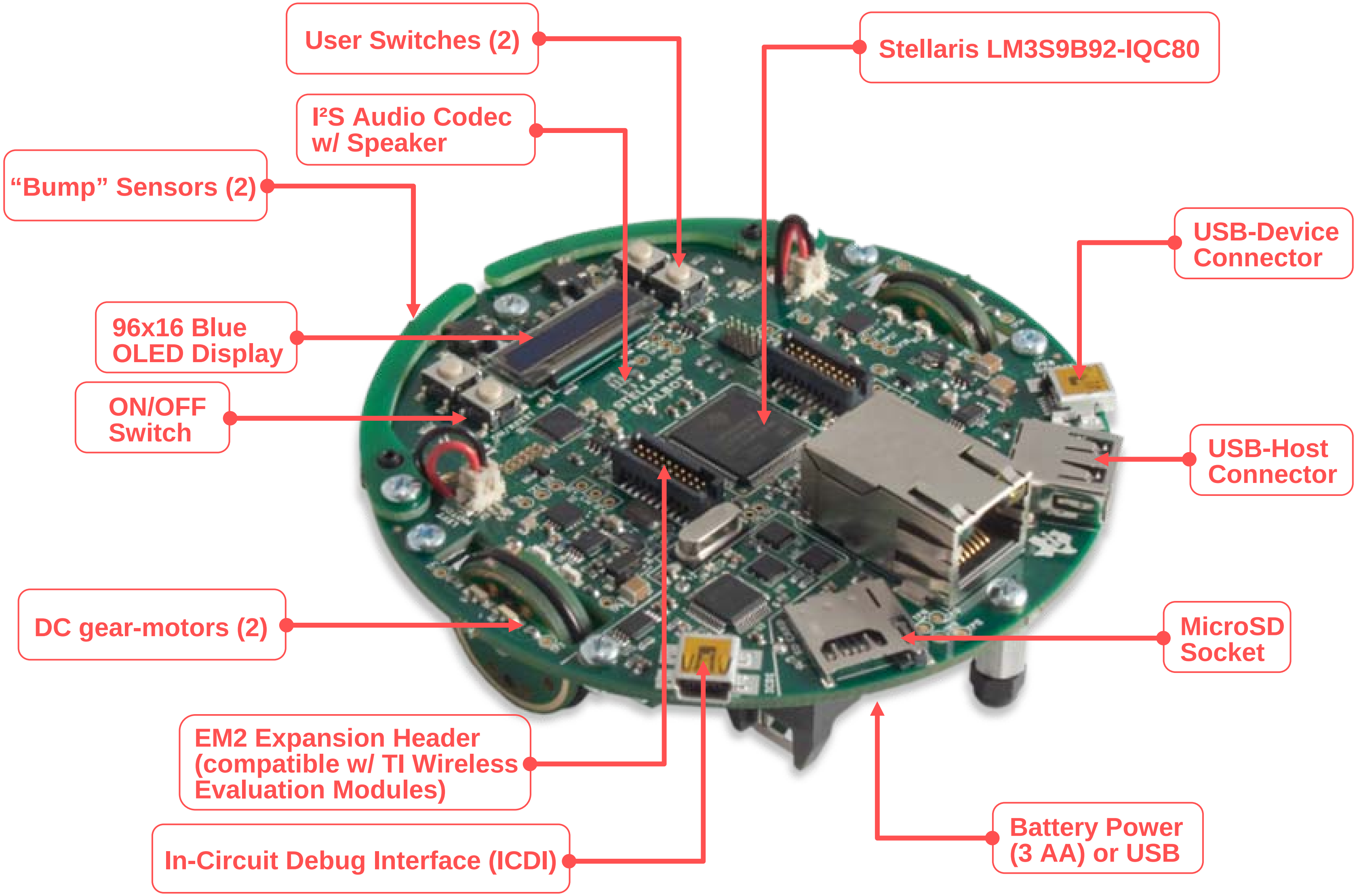
Stellaris® LM3S9B92 EVALBOT Robotic Evaluation Board



- Stellaris® EVALBOT for more flexibility & fun with microcontrollers & robotics
- Offers more tool & software options for more experimentation/dev
  - Keil MDK-ARM, IAR EWARM, TI Code Composer Studio, Code Red Technologies Red Suite & CodeSourcery G++
- This EVALBOT is preloaded with a StellarisWare® application & includes more example projects in source code
- Highlighted LM3S9B92 EVALBOT features
  - Integrated 10/100 Enet MAC/PHY, USB OTG, motion control
  - Bright 96x16 OLED display, SD card I/F, CAN I/F, I^2S audio codec
  - TI wireless module I/F (promotes 3rd party extensions)
- Includes Chronos-SimpliciTI demo code that enables wireless control of EVALBOT using Chronos watch*
- $149 USD MSRP
- www.ti.com/evalbot

**wireless module & watch sold separately*

Texas Instruments EvalBot Overview



User Switches (2)

Stellaris LM3S9B92-IQC80

I²S Audio Codec w/ Speaker

“Bump” Sensors (2)

USB-Device Connector

96x16 Blue OLED Display

ON/OFF Switch

USB-Host Connector

DC gear-motors (2)

MicroSD Socket

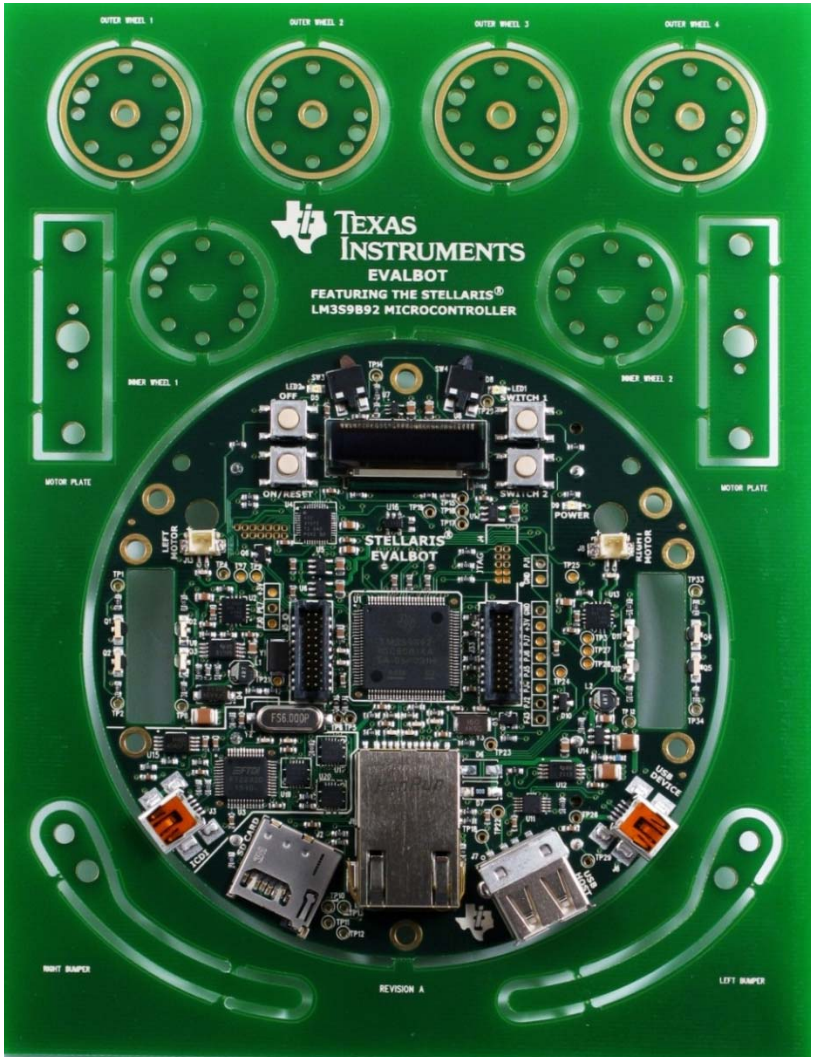
EM2 Expansion Header (compatible w/ TI Wireless Evaluation Modules)

Battery Power (3 AA) or USB

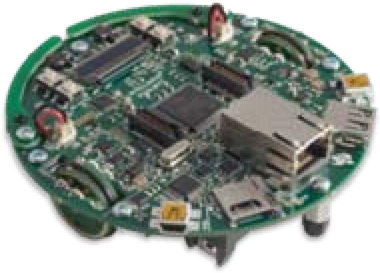
In-Circuit Debug Interface (ICDI)

The Texas Instruments EvalBot Unassembled

- Board Overview & Setup
  - 4-inch diameter circuit board
  - ~ 30 minutes of mechanical assembly
  - Factory-installed quickstart software resides in on-chip Flash memory
  - Texas Instruments analog components for:
    - Motor Drive
    - Power Supply
    - Communications Functions



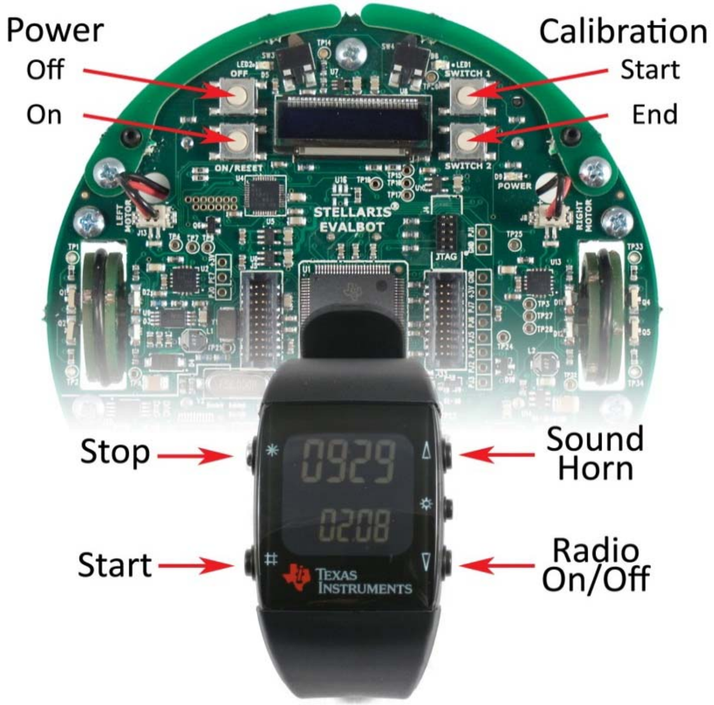
Wireless Kit for Evalbot: Chronos Remote Control & SmartRF®04



EVALBOT

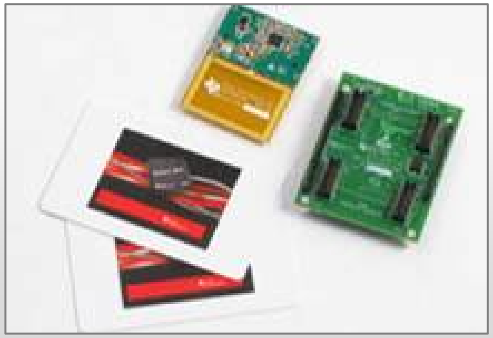
CC1101EMK868-915

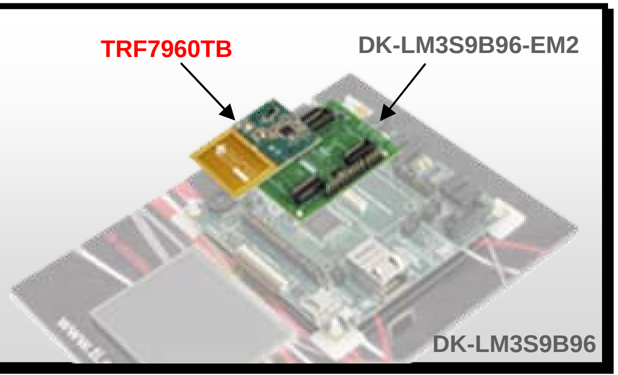
eZ430-Chronos



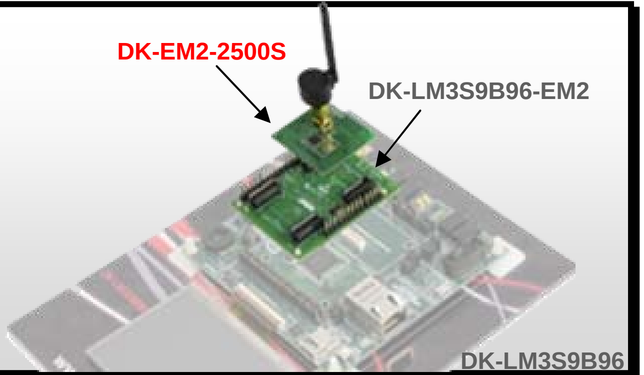
Wireless Solutions for Stellaris

Stellaris 13.56MHz RFID Wireless Kit

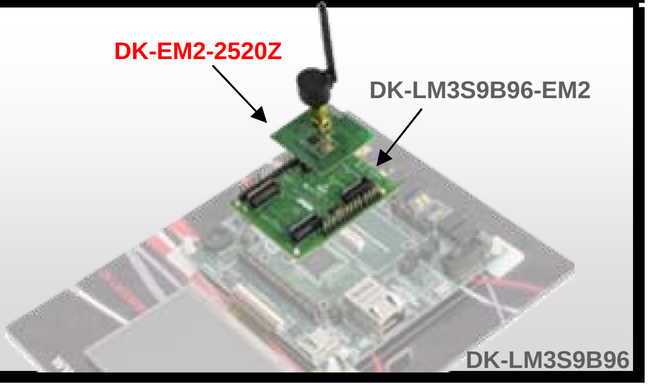




Stellaris 2.4 GHz SimpliciTI Wireless Kit (<1GHz compatible)



Stellaris ZigBee® Networking Kit



Stellaris Day Agenda

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7. Proof of Concept: S2E Converter Demo

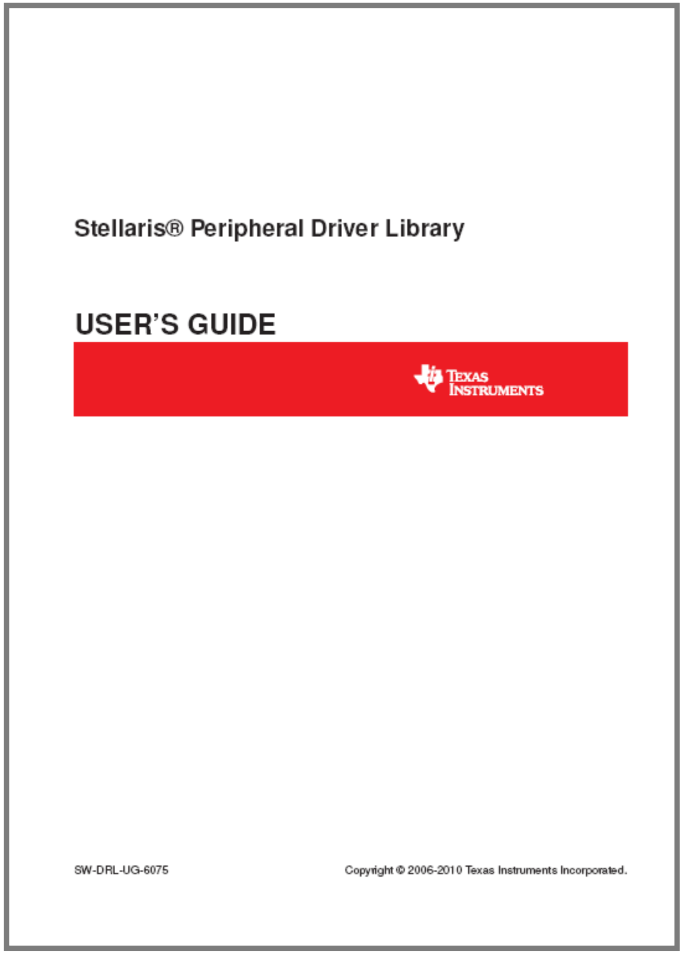
StellarisWare®

- Free license and royalty-free source code:
  - Peripheral Driver Library
  - Graphics Library
  - USB Library
  - Boot Loader
  - IEC 60730 Library
  - Code examples for each kit
  - Supports different compilers and IDEs
    - TI CCS, Keil, IAR, Code Red, CodeSourcery G++

Enabling our customers with the ability to rapidly develop and deploy their products at competitive costs yielding a higher overall value for the Stellaris solution!

Stellaris® Peripheral Driver Library

- High-level API interface to complete peripheral set
- Free license and royalty-free use
- Simplifies and speeds development of applications
- Available as object library and as source code
- Works with all supported IDEs
  - TI CCS, Keil, IAR, Code Red, CodeSourcery G++
- Driver library functions are preprogrammed in ROM on select Stellaris MCUs



Stellaris® Peripheral Driver Library

USER'S GUIDE

SW-DRL-UG-6075

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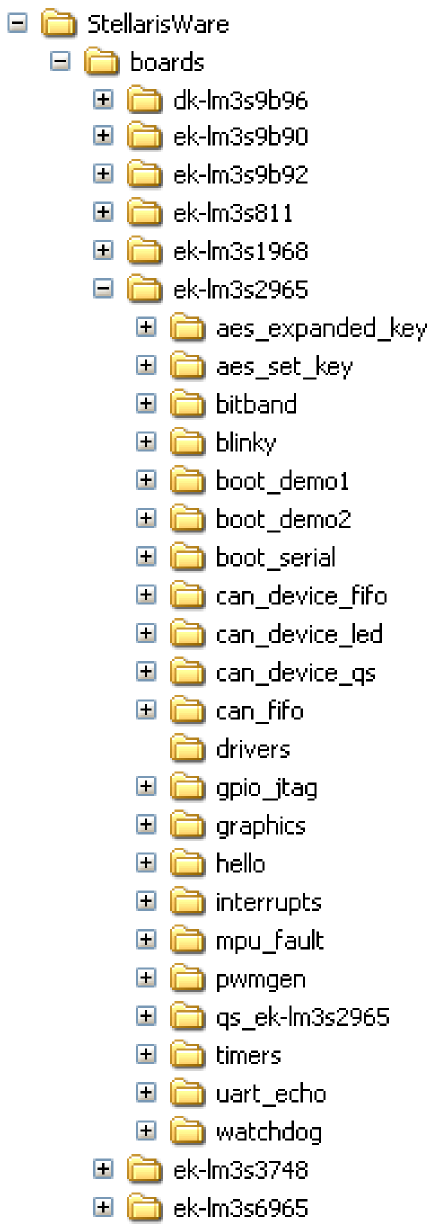
StellarisWare® CAN

StellarisWare driver library CAN API’s

- •All functions needed to implement a interrupt driven CAN stack
- •Configuration of CAN module and data handlings
- •Configuration and control the interrupts (interrupt-driven)
- •CAN message objects

CAN Example code

- •can_device_fifo
- •can_fifo
- •qs_bldc



- StellarisWare
  - boards
    - dk-lm3s9b96
    - ek-lm3s9b90
    - ek-lm3s9b92
    - ek-lm3s811
    - ek-lm3s1968
    - ek-lm3s2965
      - aes_expanded_key
      - aes_set_key
      - bitband
      - blinky
      - boot_demo1
      - boot_demo2
      - boot_serial
      - can_device_fifo
      - can_device_led
      - can_device_qs
      - can_fifo
      - drivers
      - gpio_jtag
      - graphics
      - hello
      - interrupts
      - mpu_fault
      - pwmgen
      - qs_ek-lm3s2965
      - timers
      - uart_echo
      - watchdog
    - ek-lm3s3748
    - ek-lm3s6965

On-chip Software Enhancements (ROM)

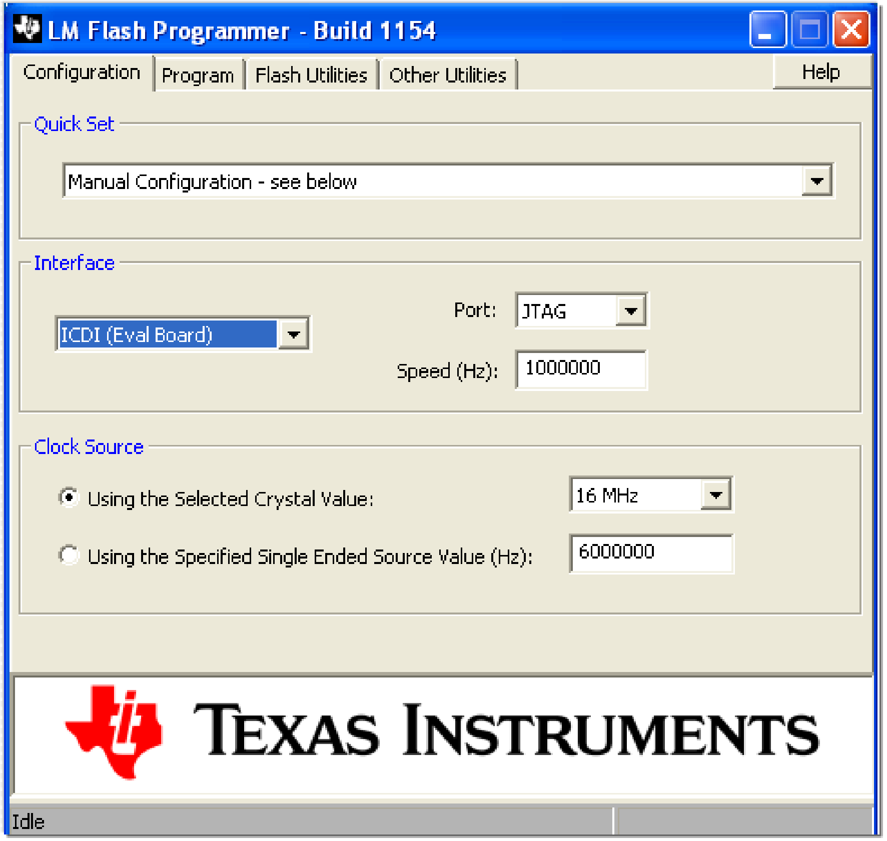
- StellarisWare® Driver Library
  - High-level API interface to complete peripheral set.
  - Simplifies and speeds development of applications.
  - Saves user flash by storing peripheral setup and configuration code
  - Allows programmer focus to be on the application—not setup
- StellarisWare ® Bootloader
  - Download code to flash memory for firmware updates
  - Interface options include UART (default), I2C, SSI, Ethernet
- Other flash memory-saving options
  - Advanced Encryption Standard (AES) tables – for cryptography
    - Supported by the current AES example application
    - Covers all three sizes: 128, 192, 256
- Cyclic Redundancy Check (CRC) functionality – for error detection

StellarisWare® In-System Programming Options

- Stellaris Serial Flash Loader
  - Small piece of code that allows programming of the flash without the need for a debugger interface
  - Stellaris MCUs without a ROM ship with this pre-loaded in flash
  - Interface options include UART or SSI
  - TI supplies a Windows®-based application (GUI or command line) that makes full use of all commands supported by the serial flash loader (LMflash.exe)
- Stellaris Boot Loader
  - Small piece of code that can be programmed at the beginning of flash to act as an application loader
  - Also used as an update mechanism for an application running on a Stellaris microcontroller
  - Interface options include UART (default), I2C, SSI, Ethernet, USB
  - Included in the Stellaris Peripheral Driver Library with full applications examples
  - Preloaded in ROM on select Stellaris Microcontrollers

StellarisWare® Serial Flash Programming GUI

- LM Flash Programming GUI
  - Simple graphical user interface
  - Support for all Evaluation Kits
  - Key features include:
    - Program
    - Verify
    - Erase
    - Read memory



Quick Set

Manual Configuration - see below

Interface

ICDI (Eval Board)

Port: JTAG

Speed (Hz): 1000000

Clock Source

● Using the Selected Crystal Value: 16 MHz

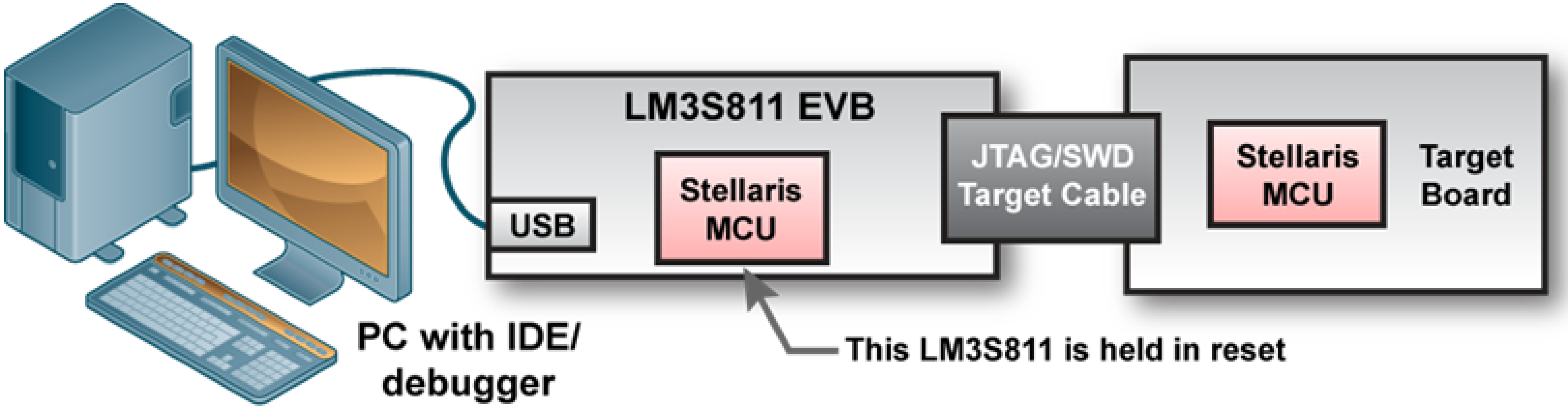
○ Using the Specified Single Ended Source Value (Hz): 6000000

Idle

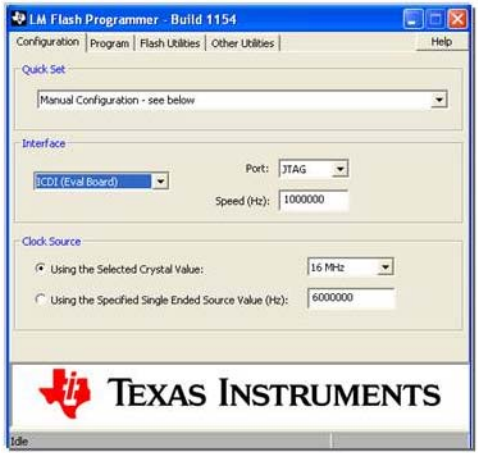
- Available now
  http://focus.ti.com/docs/toolsw/folders/print/lmflashprogrammer.html

Programming Options – JTAG/SWD

- If debug is needed, or a flash image is erased you can always use the JTAG/SWD interface to load a binary into the flash.
- Remember, Stellaris evaluation kits can act as In-Circuit Debug Interfaces (ICDIs), meaning you can use them to program/debug other boards, such as the RDKs.



Flash Programming GUI supports:



LM Flash Programmer - Build 1154

Quick Set: Manual Configuration - see below

Interface: ICDI (Eval Board)

Port: JTAG

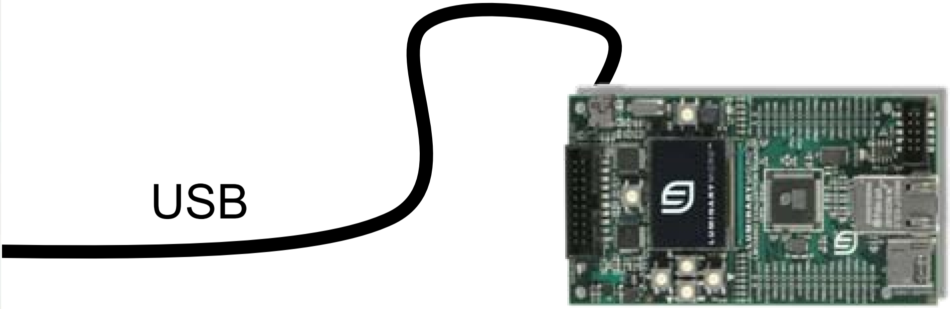
Speed (Hz): 1000000

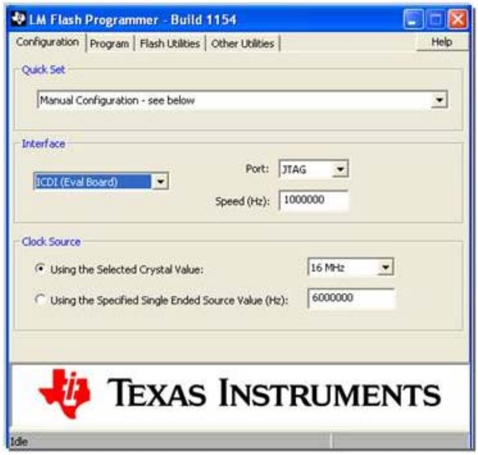
Clock Source

● Using the Selected Crystal Value: 16 MHz

○ Using the Specified Single Ended Source Value (Hz): 6000000

Programming evaluation kits (EVM) directly





LM Flash Programmer - Build 1154

Quick Set: Manual Configuration - see below

Interface: ICDI (Eval Board)

Port: JTAG

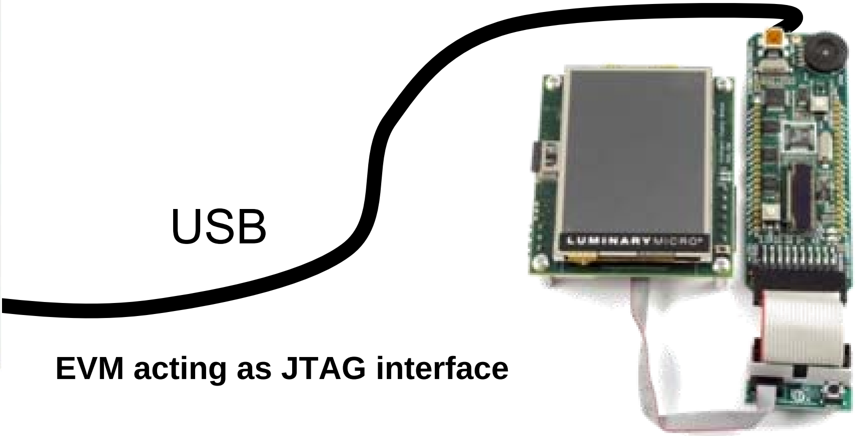
Speed (Hz): 1000000

Clock Source

● Using the Selected Crystal Value: 16 MHz

○ Using the Specified Single Ended Source Value (Hz): 6000000

Programming target HW indirectly via EVM



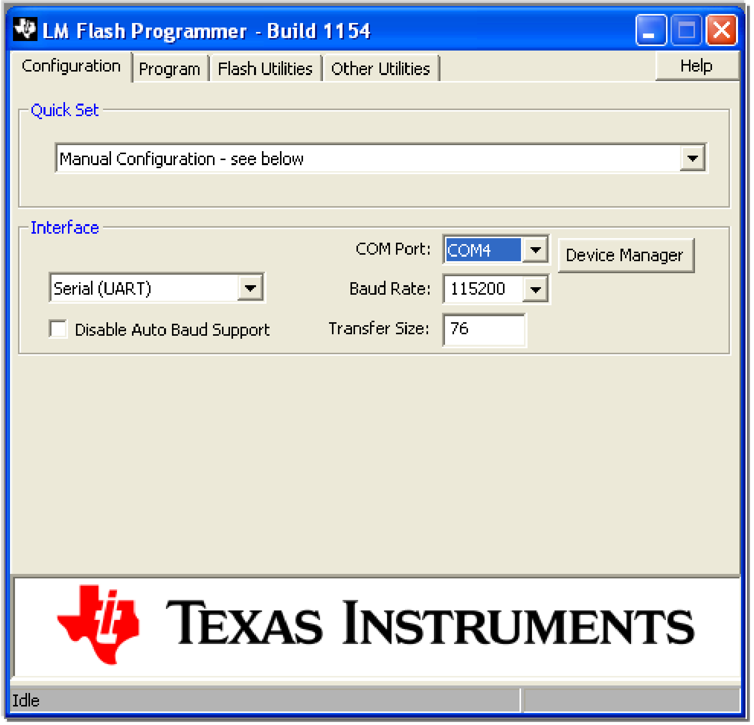
EVM acting as JTAG interface

Note: Target must be powered

Programming Options – Boot Loader

- To update using the boot loader, the LM Flash Programmer utility is the easiest option. It can be downloaded from the Stellaris section of the TI website.
  http://focus.ti.com/docs/toolsw/folders/print/lmflashprogrammer.html

No Ethernet, use UART



Quick Set: Manual Configuration - see below

Interface: Serial (UART)

COM Port: COM4

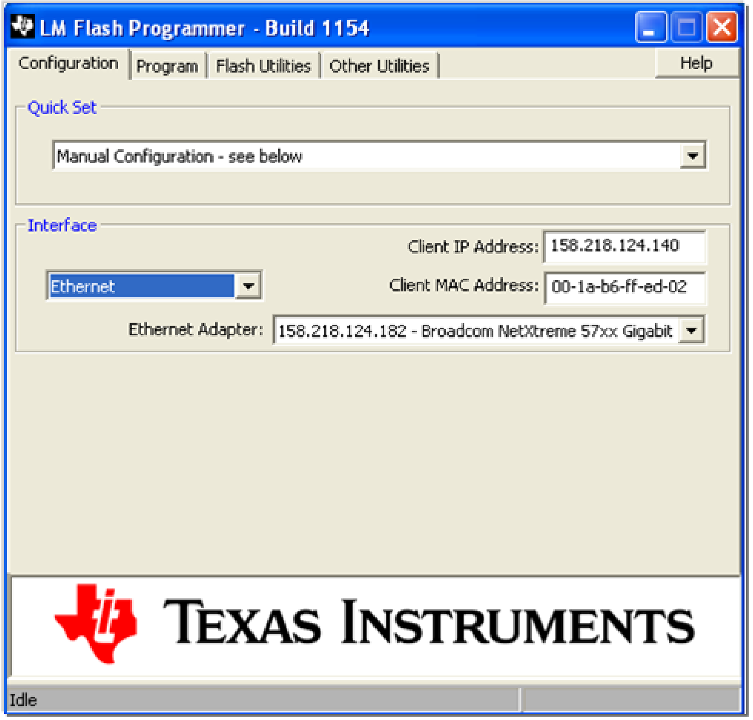
Baud Rate: 115200

Transfer Size: 76

☐ Disable Auto Baud Support

Idle

With Ethernet



Quick Set: Manual Configuration - see below

Interface: Ethernet

Client IP Address: 158.218.124.140

Client MAC Address: 00-1a-b6-ff-ed-02

Ethernet Adapter: 158.218.124.182 - Broadcom NetXtreme 57xx Gigabit

Idle

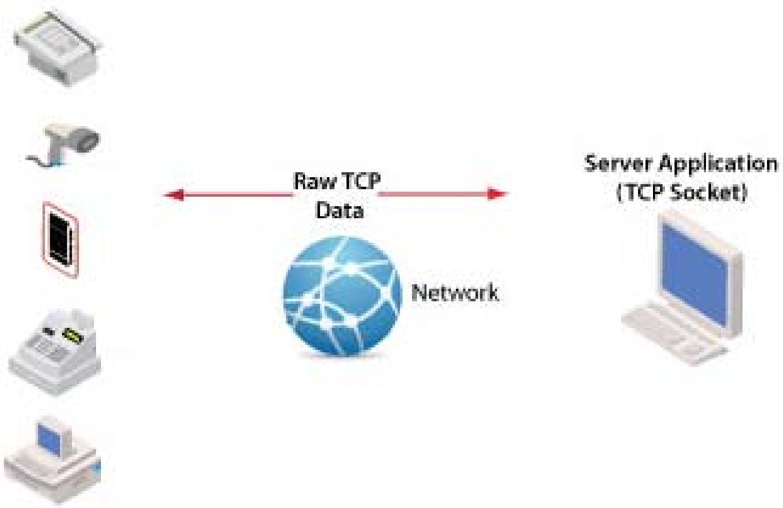
Stellaris Day Agenda

1. Stellaris Family
2. StellarisWare®
3. Serial to Ethernet Converter
4. Designing a Serial to Ethernet Converter
5. S2E RDK Overview
6. Industrial Control Demo Overview
7. Proof of Concept: S2E Converter Demo

Serial to Ethernet Converters: Applications

- Retro fitting legacy device
  - PC
  - I/O Control Modules
  - Home/building controls

- Add Interface
  - Industrial automation systems
  - Remote monitoring
  - Remote control



Serial to Ethernet Converters: Features

- General Features
  - RS232 Port
  - 10/100Mbps Ethernet w/ auto detect
  - Auto MDI/MDIX cross-over correction
  - Network Management Interface
  - Virtual COM software
  - Selectable baud rates
  - Programmable web server

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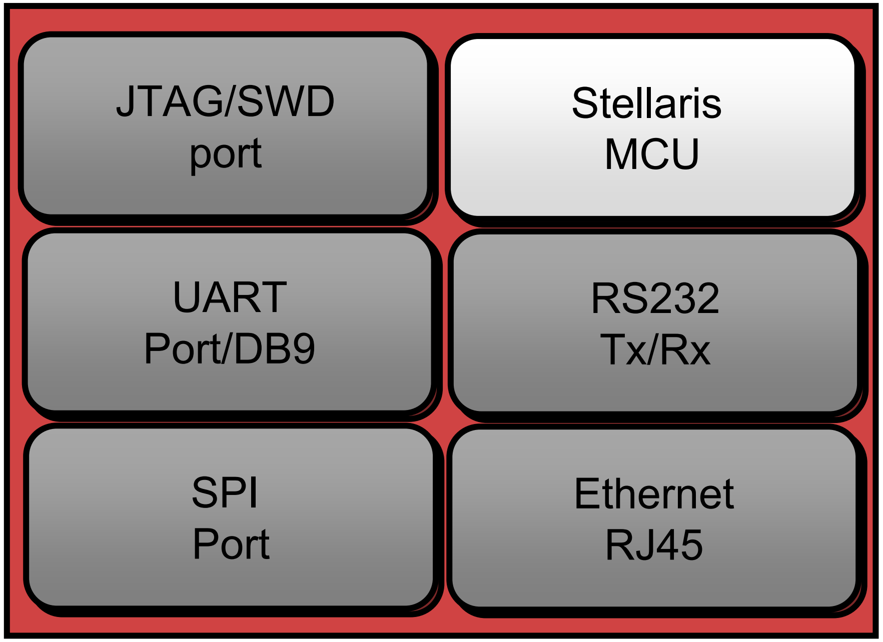
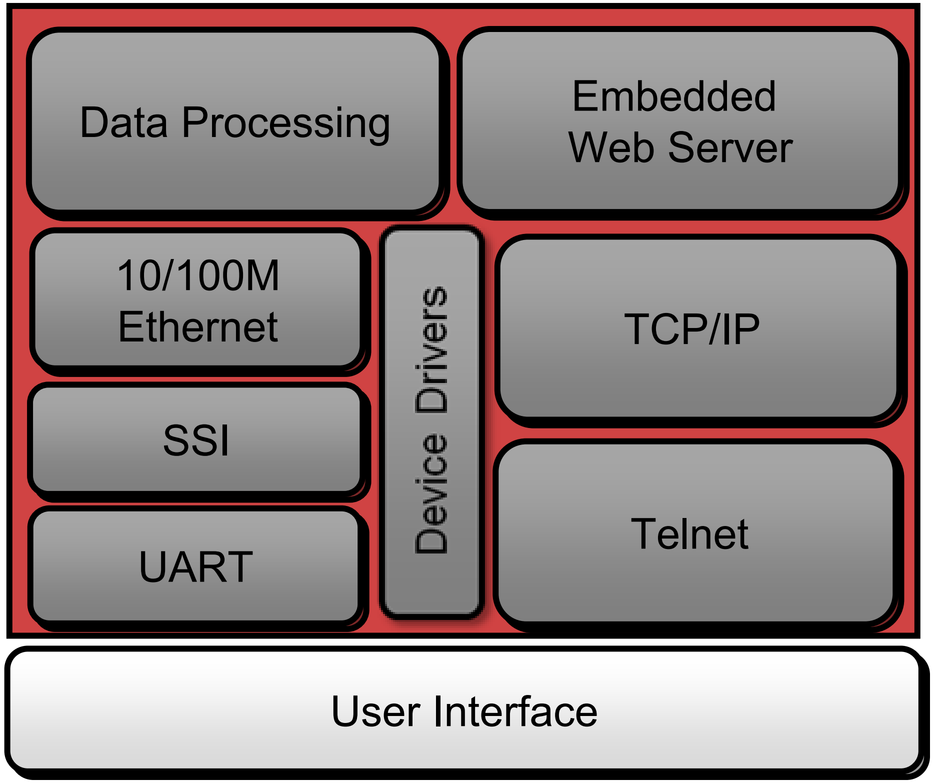
Designing a Serial to Ethernet Converter

- Typical design considerations
  - Hardware
    - MCU: embedded Ethernet + UART
    - Connection ports: RS232 + RJ45
    - Consider other comms: SPI, I/O
  - Software
    - Code for MCU to configure and drive embedded Ethernet, UART, and perform data conversion
    - Web server with TCP/IP stack
    - Interface for configuration and status

Serial to Ethernet Hardware Block Diagram



Serial to Ethernet Software Block Diagram

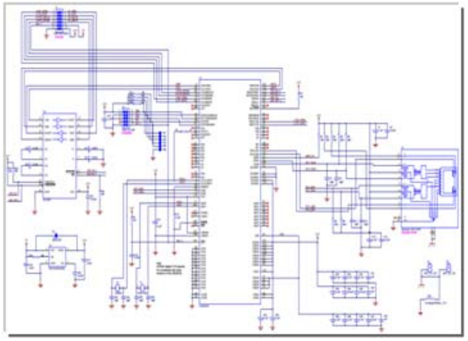


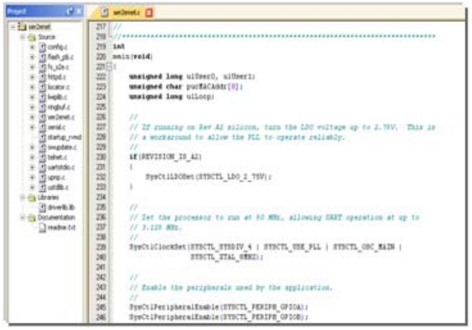
Serial to Ethernet User Interface: Configuration and status

- S2E Kit
  - Finder Utility – MAC & IP Address
  - LM S2E Browser Application
- Manual Configuration
  - com0com
  - com2tcp

Serial to Ethernet Design Solution:

S2E = Hardware + Software + Interface



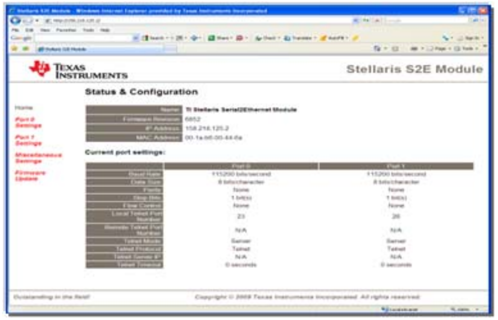


```
//
//*****************************************************************************
int
main(void)
{
    unsigned long ulUser0, ulUser1;
    unsigned char pucMACAddr[6];
    unsigned long ulLoop;

    //
    // If running on Rev A2 silicon, turn the LDO voltage up to 2.75V.  This is
    // a workaround to allow the PLL to operate reliably.
    //
    if(REVISION_IS_A2)
    {
        SysCtlLDOSet(SYSCTL_LDO_2_75V);
    }

    //
    // Set the processor to run at 50 MHz, allowing UART operation at up to
    // 3.125 MHz.
    //
    SysCtlClockSet(SYSCTL_SYSDIV_4 | SYSCTL_USE_PLL | SYSCTL_OSC_MAIN |
                   SYSCTL_XTAL_8MHZ);

    //
    // Enable the peripherals used by the application.
    //
    SysCtlPeripheralEnable(SYSCTL_PERIPH_GPIOA);
    SysCtlPeripheralEnable(SYSCTL_PERIPH_GPIOB);
```


Stellaris S2E Module - Windows Internet Explorer provided by Texas Instruments Incorporated
Texas Instruments
Home
Port 0 Settings
Port 1 Settings
Miscellaneous Settings
Firmware Update

Stellaris S2E Module

Status & Configuration

Name	TI Stellaris Serial2Ethernet Module
Firmware Revision	6852
IP Address	158.218.120.2
MAC Address	00-1a-b6-00-44-6a

Current port settings:

	Port 0	Port 1
Baud Rate	115200 bits/second	115200 bits/second
Data Size	8 bits/character	8 bits/character
Parity	None	None
Stop Bits	1 bit(s)	1 bit(s)
Flow Control	None	None
Local Telnet Port Number	23	26
Remote Telnet Port Number	N/A	N/A
Telnet Mode	Server	Server
Telnet Protocol	Telnet	Telnet
Telnet Server IP	N/A	N/A
Telnet Timeout	0 seconds	0 seconds

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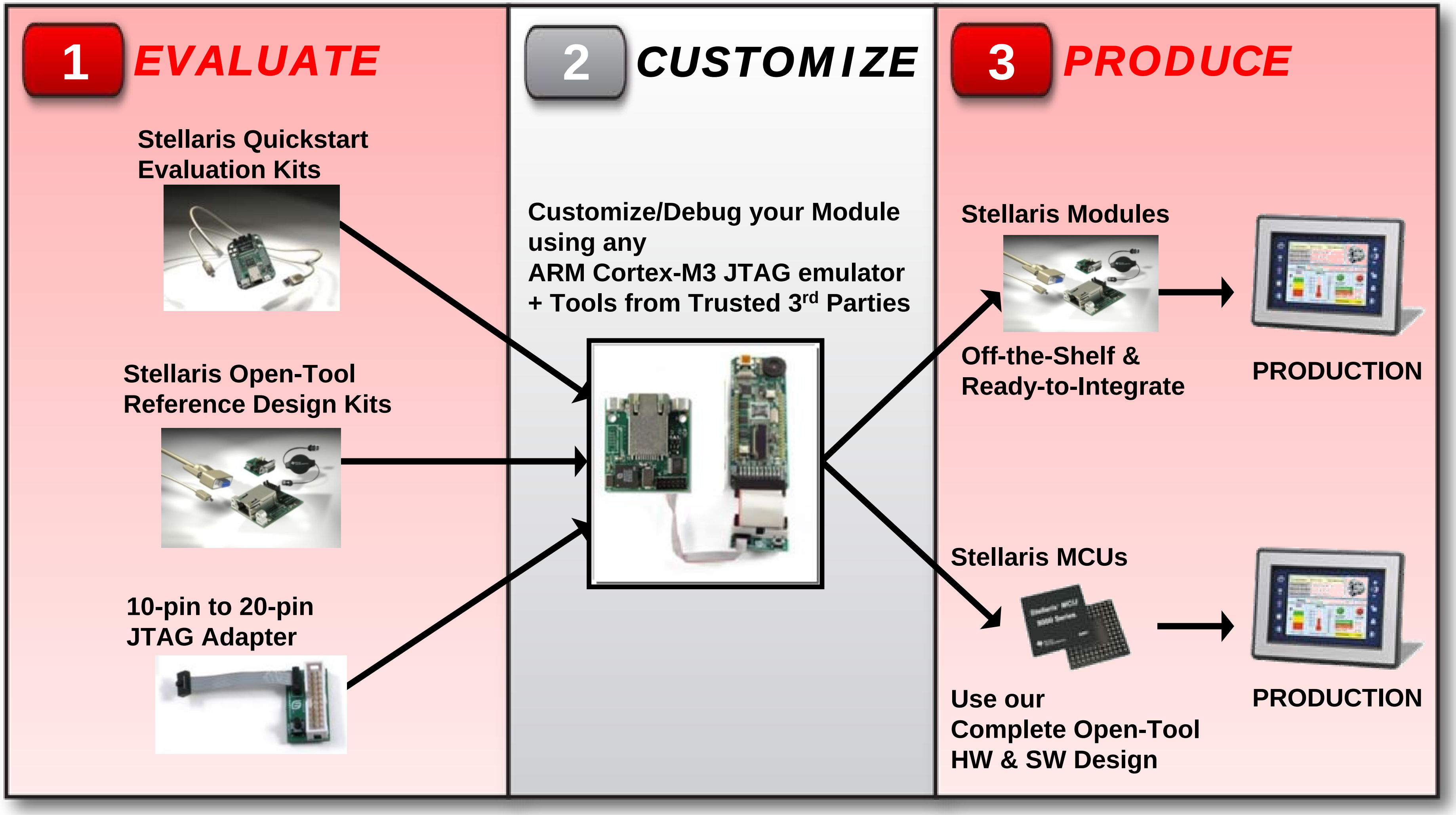
Options in Building a Serial to Ethernet with Stellaris



1 EVALUATE

Stellaris Quickstart Evaluation Kits

Stellaris Open-Tool Reference Design Kits

10-pin to 20-pin JTAG Adapter

2 CUSTOMIZE

Customize/Debug your Module using any ARM Cortex-M3 JTAG emulator + Tools from Trusted 3rd Parties

3 PRODUCE

Stellaris Modules

Off-the-Shelf & Ready-to-Integrate

PRODUCTION

Stellaris MCUs

Use our Complete Open-Tool HW & SW Design

PRODUCTION

Stellaris Day Agenda

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Serial-to-Ethernet RDK and Module

RDK-S2E
$139

Example applications:

- SCADA Remote Terminal Units (RTUs)
- Electronic Flow Meters (EFMs)
- Medical Point-of-Care and Retail Point-of-Sales Machines
- CCTV RS-232 Recorders
- RS-232 Stepper Motor Controller Systems

LM3S6432 in a 10 x 10 mm BGA package for reduced board size

10/100 Mbit Ethernet port

- Auto MDI/MDIX cross-over correction
- Traffic and link indicators

Serial ports

- UART0 has RS232 levels, transceiver runs at up to 230.4 K baud
- UART1 has CMOS/TTL levels, can run at 1.0 M baud
- UART ports include RTS/CTS for flow control
- Both ports can be used simultaneously

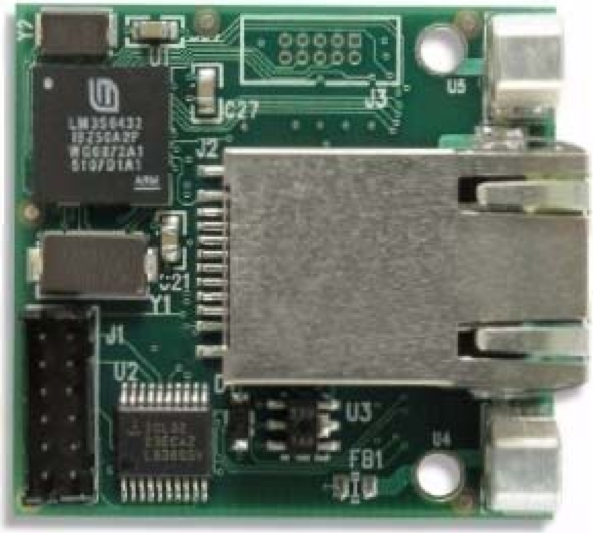
Software

- IP configuration with static IP address or DHCP
- Telnet server for access to serial port (VCP software included)
- Web server for module configuration
- Universal plug and play (uPnP) for device discovery
- Telnet client for Ethernet-based serial port extender

Module supports 5 V and 3.3 V supplies

Multiple mounting options

JTAG port pads for factory programming



RDK-S2E resale: 139 USD
MDL-S2E single unit resale: 49 USD

RDK S2E Kit

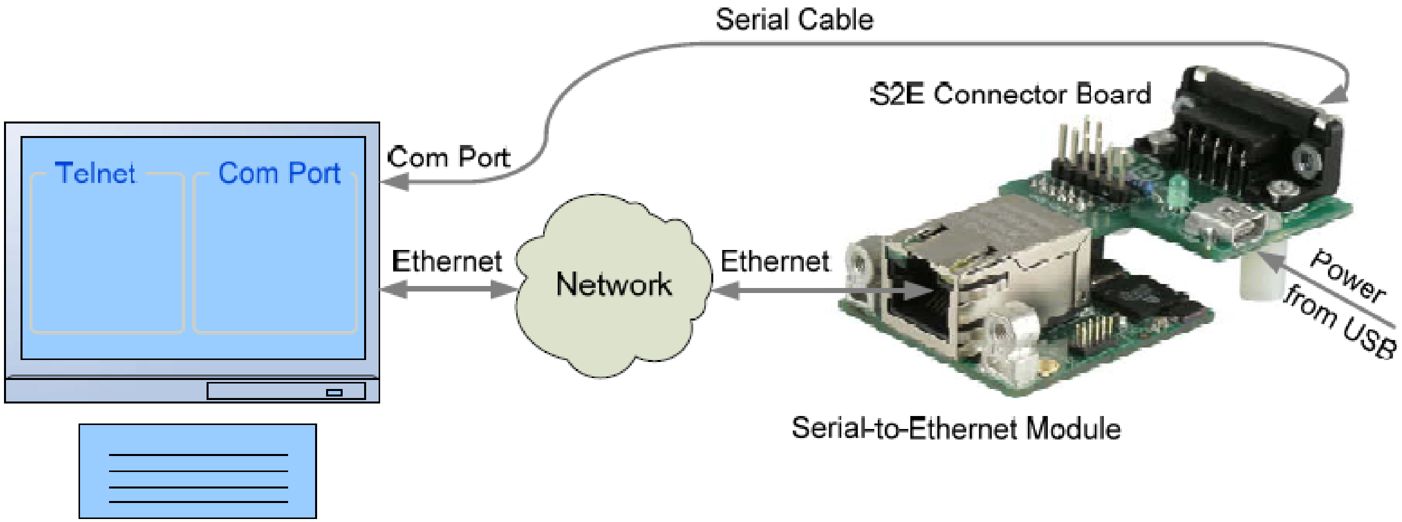
- Hardware
  - S2E board (pre-programmed with Quickstart application: ser2enet.c)
  - RS-232 adaptor board

- Cables
  - DB9 serial cable
  - Ethernet cable
  - USB cable (power source)
- Reference Design Kit on public website
  - Documentation: Quickstart, ReadMeFirst,Software Reference Manual, Board Data Sheet, BOM, schematics, and gerbers
  - Software: Stellarisware, LM Flash Programmer, Interface applications

http://focus.ti.com/docs/toolsw/folders/print/rdk-s2e-cd.html

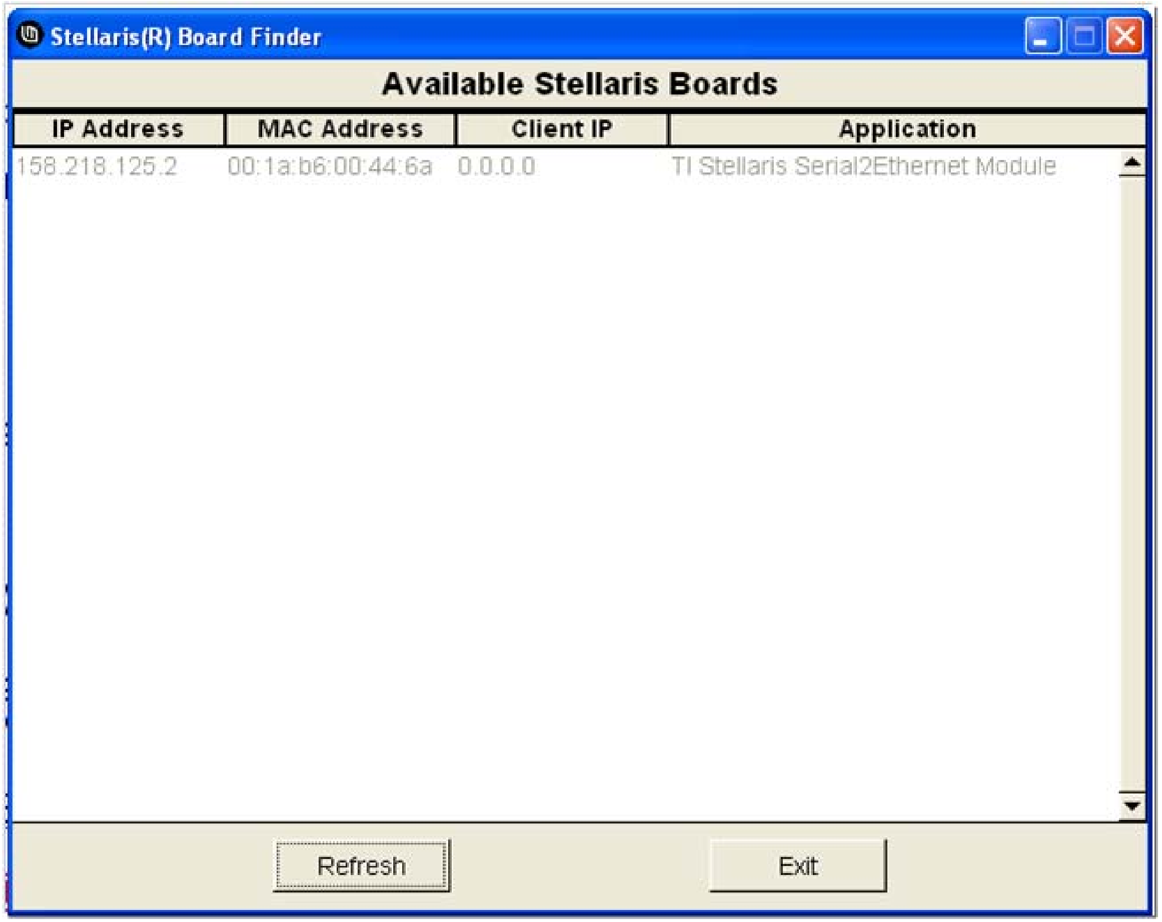
RDK S2E Quickstart

Connect and power



RDK S2E Quickstart

- Finder Utility
  - Get the IP address
  - Using PnP protocol

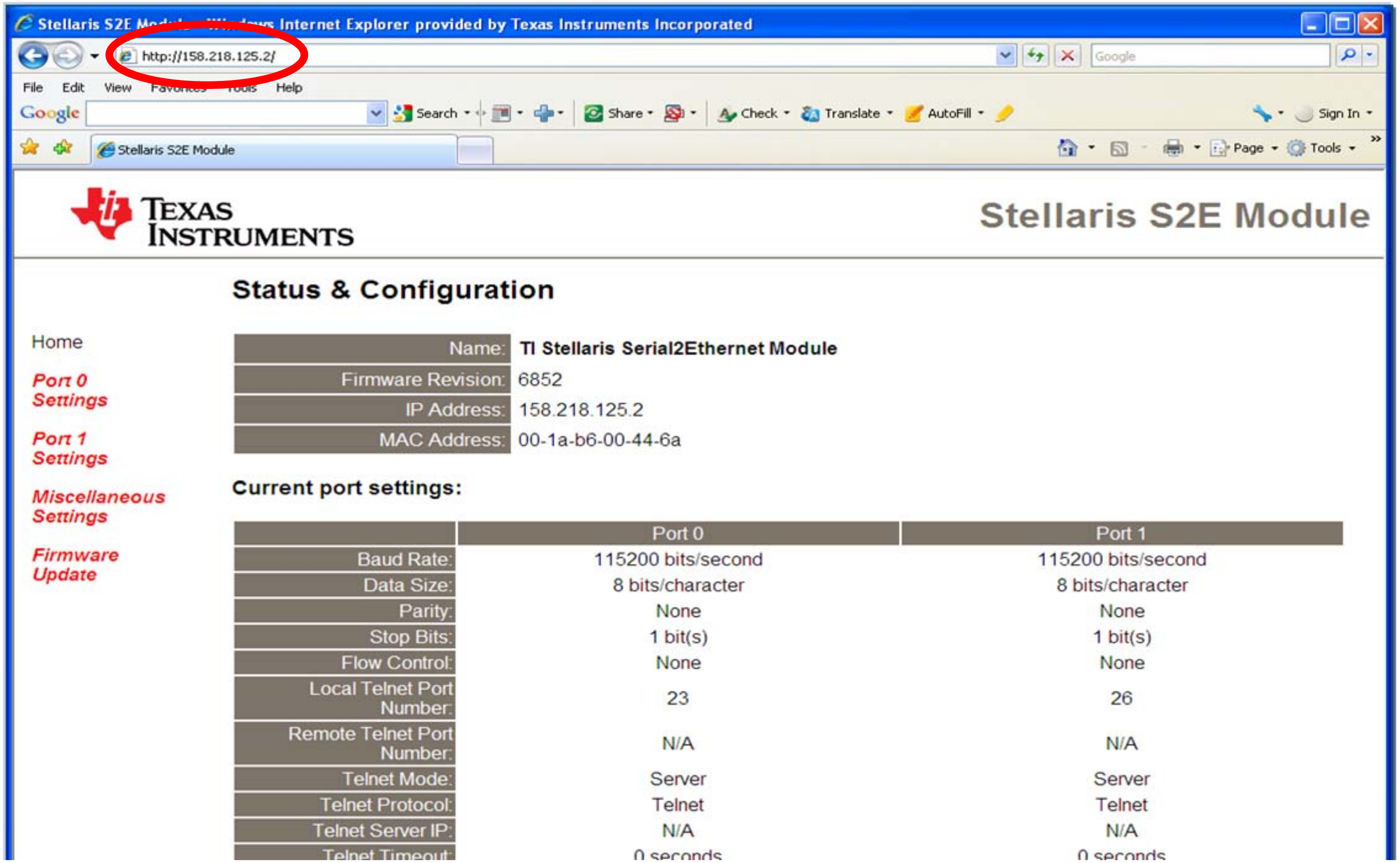


Available Stellaris Boards

IP Address	MAC Address	Client IP	Application
158.218.125.2	00:1a:b6:00:44:6a	0.0.0.0	TI Stellaris Serial2Ethernet Module

RDK S2E Quickstart

- Use IP address to launch Configuration and Status Website
  - Open Internet Explorer window
  - Type in IP address from Finder Utility in browser


Stellaris S2E Mod... Windows Internet Explorer provided by Texas Instruments Incorporated
http://158.218.125.2/
Google
File Edit View Favorites Tools Help
Google
Search
Share
Check
Translate
AutoFill
Sign In
Stellaris S2E Module
Page
Tools
Texas Instruments

Stellaris S2E Module

Status & Configuration

Home

Port 0 Settings

Port 1 Settings

Miscellaneous Settings

Firmware Update

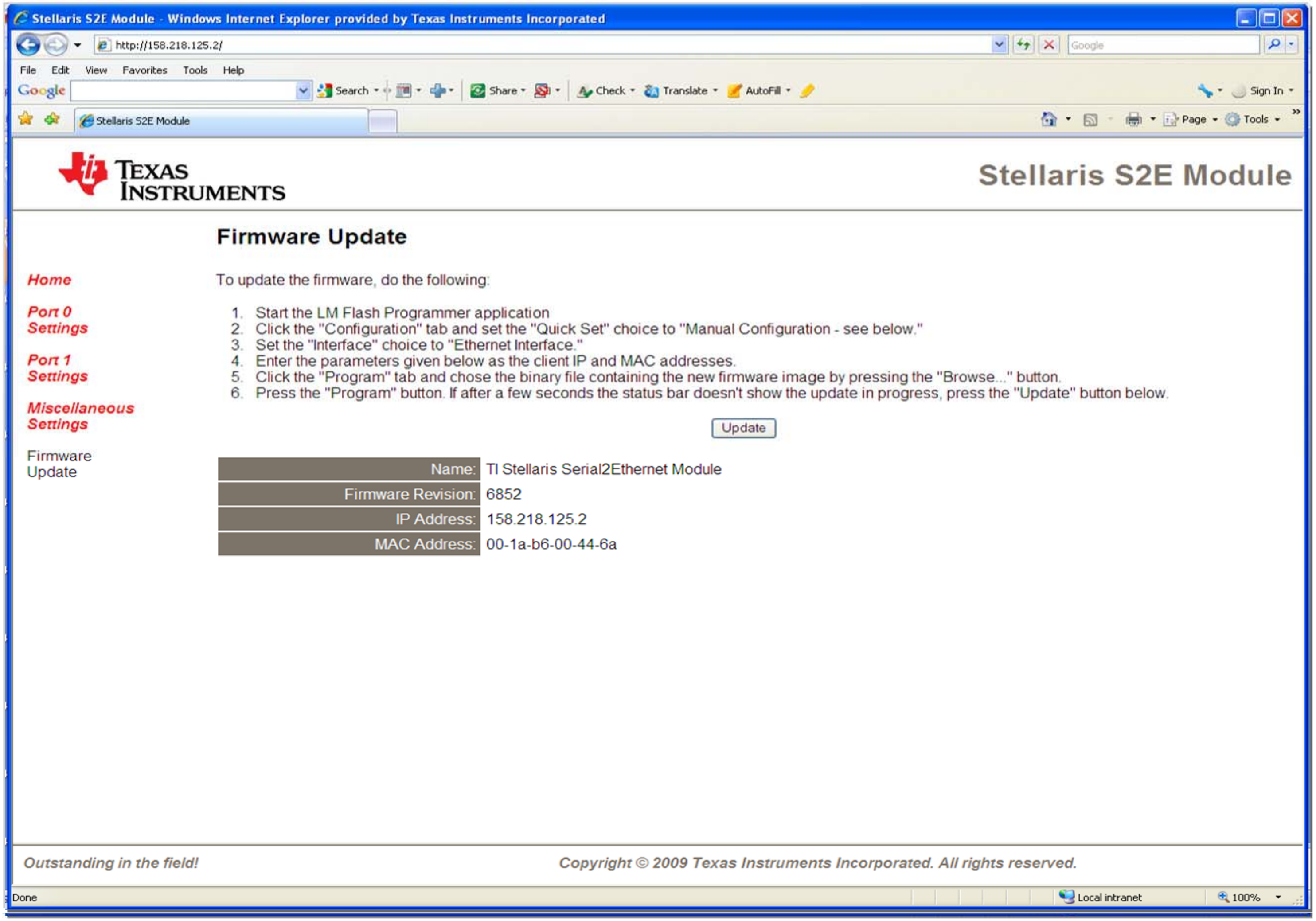
Name:	**TI Stellaris Serial2Ethernet Module**
Firmware Revision:	6852
IP Address:	158.218.125.2
MAC Address:	00-1a-b6-00-44-6a

Current port settings:

	Port 0	Port 1
Baud Rate:	115200 bits/second	115200 bits/second
Data Size:	8 bits/character	8 bits/character
Parity:	None	None
Stop Bits:	1 bit(s)	1 bit(s)
Flow Control:	None	None
Local Telnet Port Number:	23	26
Remote Telnet Port Number:	N/A	N/A
Telnet Mode:	Server	Server
Telnet Protocol:	Telnet	Telnet
Telnet Server IP:	N/A	N/A
Telnet Timeout:	0 seconds	0 seconds

RDK S2E Quickstart

- Configuration and Status Settings


Stellaris S2E Module - Windows Internet Explorer provided by Texas Instruments Incorporated
http://158.218.125.2/
File Edit View Favorites Tools Help
Google
Search
Share
Check
Translate
AutoFill
Sign In
Stellaris S2E Module
Page
Tools
Done
Local intranet
100%

Texas Instruments

Stellaris S2E Module

Home

Port 0 Settings

Port 1 Settings

Miscellaneous Settings

Firmware Update

Firmware Update

To update the firmware, do the following:

1. Start the LM Flash Programmer application
2. Click the "Configuration" tab and set the "Quick Set" choice to "Manual Configuration - see below."
3. Set the "Interface" choice to "Ethernet Interface."
4. Enter the parameters given below as the client IP and MAC addresses.
5. Click the "Program" tab and chose the binary file containing the new firmware image by pressing the "Browse..." button.
6. Press the "Program" button. If after a few seconds the status bar doesn't show the update in progress, press the "Update" button below.

Update

Name:	TI Stellaris Serial2Ethernet Module
Firmware Revision:	6852
IP Address:	158.218.125.2
MAC Address:	00-1a-b6-00-44-6a

Outstanding in the field!

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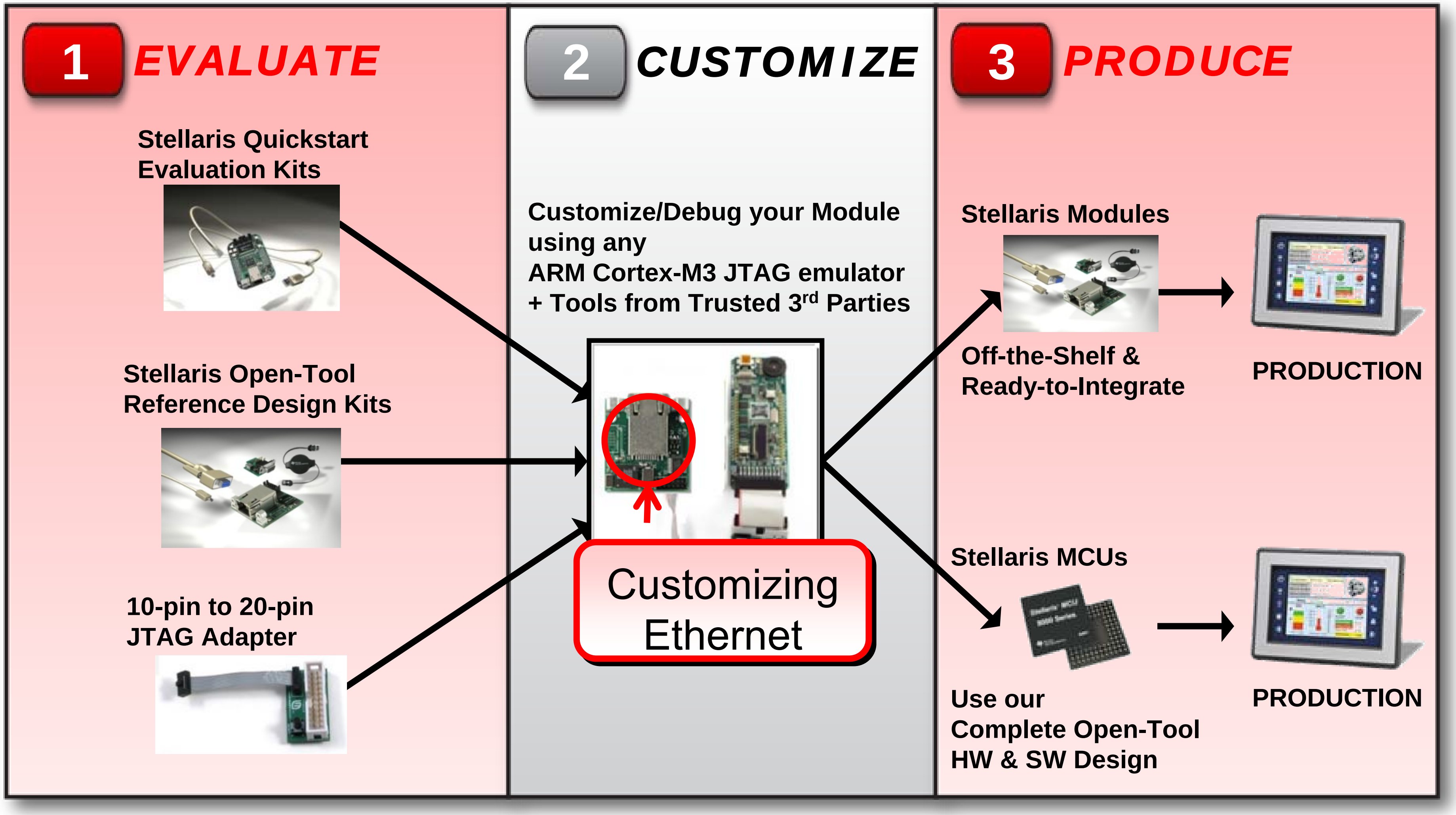
Options in Building a Serial to Ethernet with Stellaris



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Customize/Debug your Module using any ARM Cortex-M3 JTAG emulator + Tools from Trusted 3rd Parties

Customizing Ethernet

3 PRODUCE

Stellaris Modules

Off-the-Shelf & Ready-to-Integrate

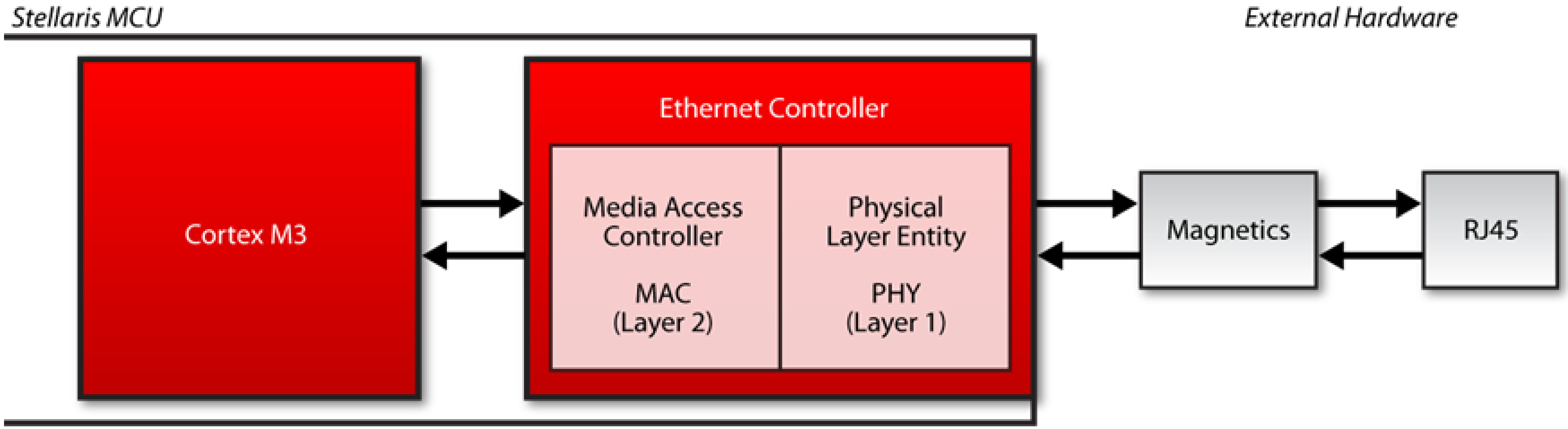
PRODUCTION

Stellaris MCUs

Use our Complete Open-Tool HW & SW Design

PRODUCTION

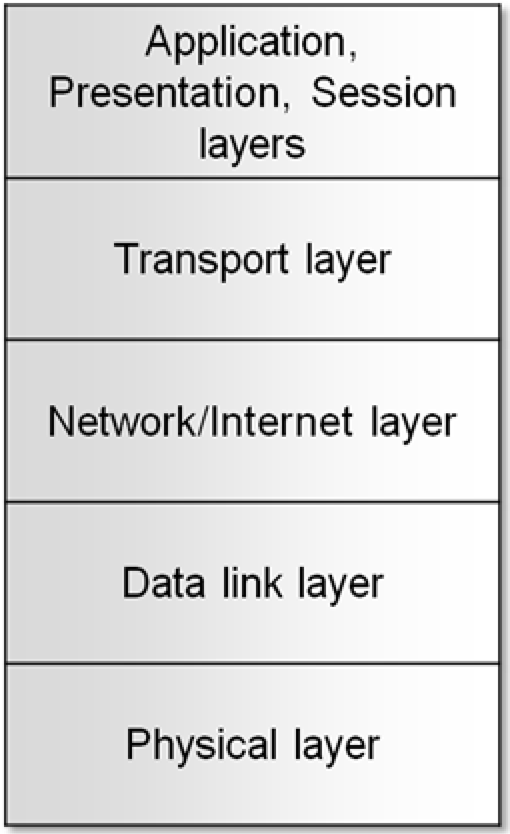
Stellaris Ethernet in Embedded Systems



- RJ45 - That “Ethernet” Connector.
- Magnetics (Isolation Transformer) - Part of the Physical layer used to decouple PHY from the physical Ethernet cable.
- Physical Layer (PHY) - The most basic network layer, providing only the means of transmitting raw bits rather than packets over a physical data link connecting network nodes.
- Media Access Controller (MAC) – Part of the Data Link Layer. The MAC provides addressing and channel access control mechanisms that make it possible for several terminals or network nodes to communicate within a multipoint network.

OSI (Open System Interconnect) Model

- OSI defines a set of rules to enable computers to communicate over a network.
- It specifies how data is packaged, addressed, and routed to the right destination.



Application, Presentation, Session layers

Transport layer

Network/Internet layer

Data link layer

Physical layer

Application/Presentation/Session Layers: Higher layer protocols provide the user interface to the network.

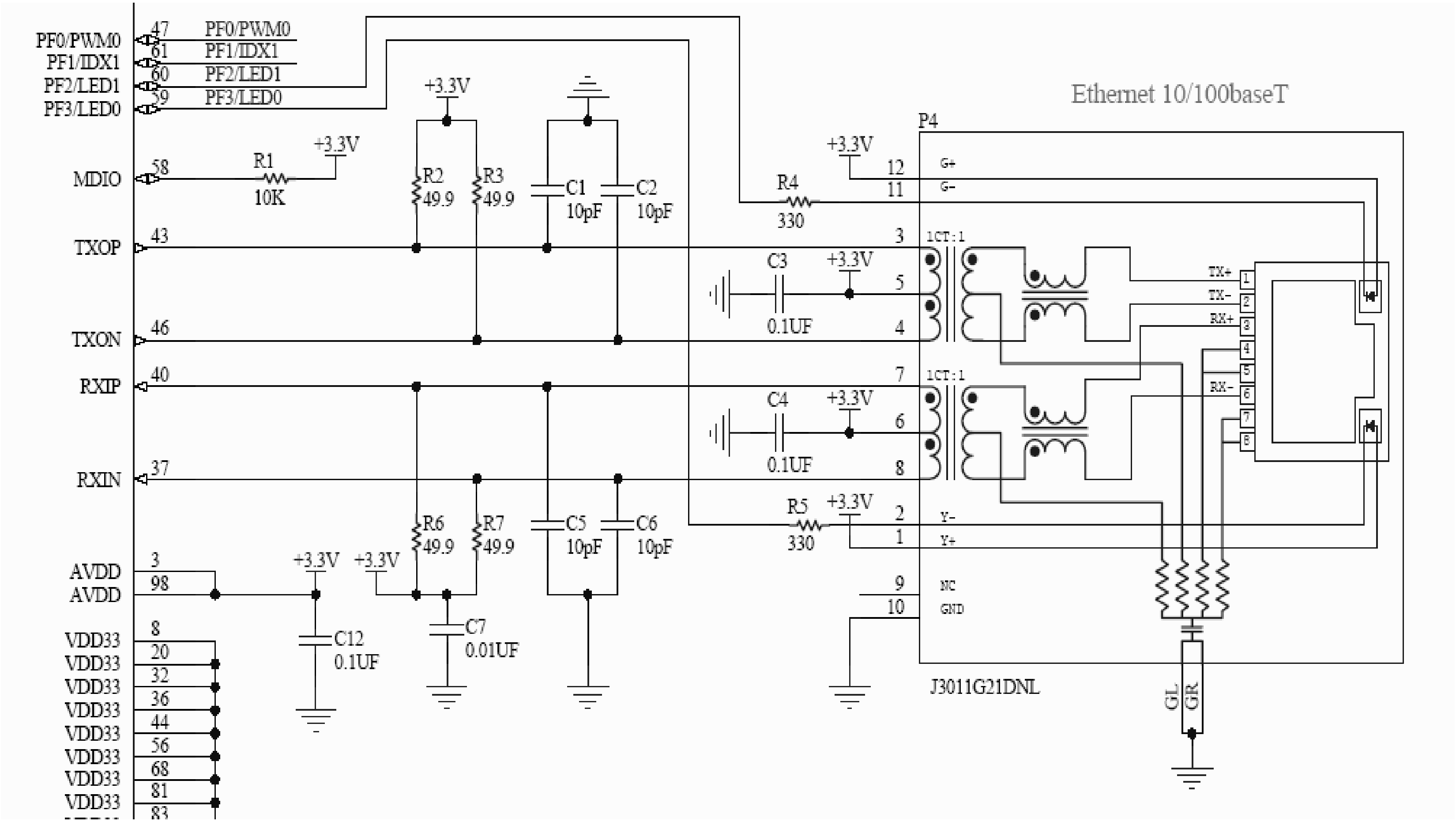
Transport Layer: concerned with error-free, in sequence data delivery with or without loss or duplication. Examples: TCP/IP, UDP

Network/Internet Layer: provides for the raw transfer of information between end systems

Data Link Layer: concerned with error detection and control. The MAC (media access controller hardware) is part of this layer.

Physical Layer: The physical interface between devices, transport media (e.g., twisted pair), bit stream protocol, electrical representation of bits. The PHY hardware is part of this layer.

Ethernet Hardware: Simple Hardware Design



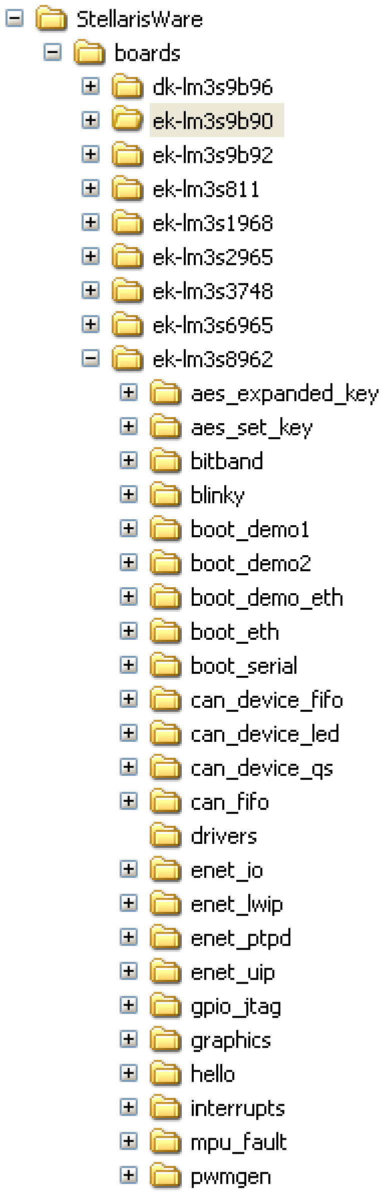
full schematic in <u>Stellaris LM3S8962 Evaluation Board User's Manual</u>

General Ethernet PCB & Layout Guidelines

- No power planes under the Ethernet signals to avoid unwanted capacitive coupling.
- Avoid having other signals cross the Ethernet signals on other layers.
- Distance between PHY and Magnetics should be less than 2 inches.
- Differential pairs need to be routed together on same layer (e.g., TX+, TX-, RX+, RX-).
- Differential pairs need to be close in length, < 700 mils, and be separated from each other by at least 0.050”, necessary to avoid cross-coupling between the RX and TX.
- Ethernet resistors should be located a close as possible to the Stellaris MCU.
- 10pF capacitors should be located close to the Ethernet transformer.
- The ground plane should not extend under the transformer unless it is shielded on all sides.
- Do not extend the ground plane under the signals from the transformer to the connector.
- A ground plane is not strictly a requirement for Ethernet signaling. The benefits of retaining the ground plane between the MCU and the transformer are:
  - Provide a low-impedance connection point for the 10pF filter capacitors for improved EMC
  - Impedances are easier to control with a ground-reference plane. Without the plane, small dimensional variations in the PCB have a more significant impact on the differential impendance.
  - Smaller trace geometries are possible. Without a plane, simulations show that 0.023” traces with 0.007” spacing are needed for a typical two-layer FR-4 design.

StellarisWare® Ethernet

- StellarisWare driverlib API’s
  - Configure and control the MAC
  - Access the register set on the PHY
  - Transmit and receive Ethernet packets
  - Configure and control the interrupts (Interrupt-driven)
- Ethernet Example code
  - boot_demo_eth
  - boot_eth_ext
  - enet_io
  - enet_lwip
  - enet_ptpd
  - enet_uip
- Stellaris extras
  - lwip-1.3.2
  - uip-1.0
  - ptpd-1rc1
  - fatfs

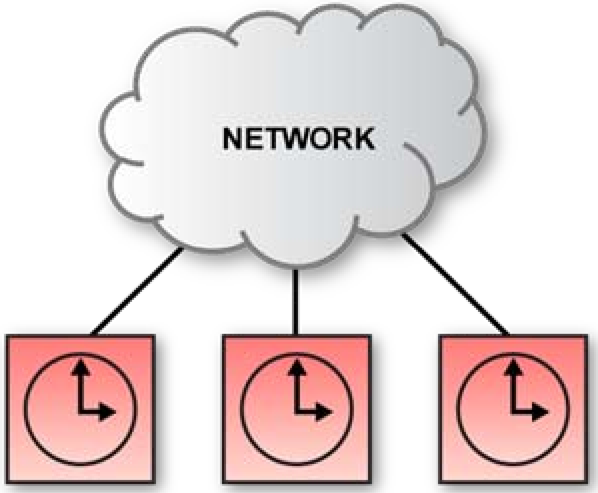


- ⊟ StellarisWare
  - ⊟ boards
    - ⊞ dk-lm3s9b96
    - ⊞ ek-lm3s9b90
    - ⊞ ek-lm3s9b92
    - ⊞ ek-lm3s811
    - ⊞ ek-lm3s1968
    - ⊞ ek-lm3s2965
    - ⊞ ek-lm3s3748
    - ⊞ ek-lm3s6965
    - ⊟ ek-lm3s8962
      - ⊞ aes_expanded_key
      - ⊞ aes_set_key
      - ⊞ bitband
      - ⊞ blinky
      - ⊞ boot_demo1
      - ⊞ boot_demo2
      - ⊞ boot_demo_eth
      - ⊞ boot_eth
      - ⊞ boot_serial
      - ⊞ can_device_fifo
      - ⊞ can_device_led
      - ⊞ can_device_qs
      - ⊞ can_fifo
      - drivers
      - ⊞ enet_io
      - ⊞ enet_lwip
      - ⊞ enet_ptpd
      - ⊞ enet_uip
      - ⊞ gpio_jtag
      - ⊞ graphics
      - ⊞ hello
      - ⊞ interrupts
      - ⊞ mpu_fault
      - ⊞ pwmgen

Time Synchronization over Ethernet

IEEE-1588 PTP

- What is IEEE1588?
  - IEEE 1588 is “Precision Clock Synchronization Protocol for Network and Control Systems” or Precision Time Protocol (PTP)
  - IEEE 1588 is a protocol designed to synchronize real-time clocks in the nodes of a distributed system that communicate using a network (Ethernet) at a high degree of accuracy

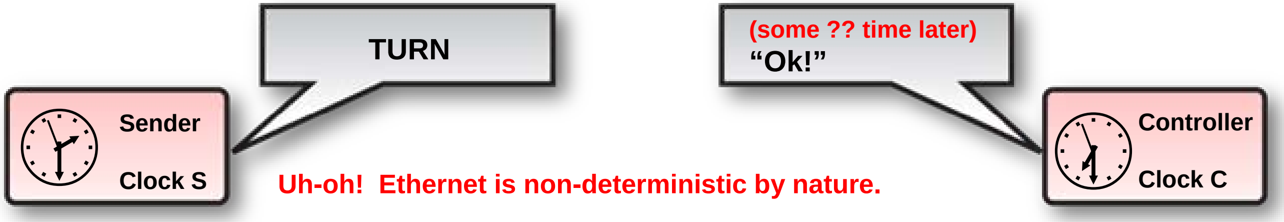


Application Area	Required synchronization accuracy
Low speed sensors (e.g. pressure, temperature)	Milliseconds
Common electro-mechanical devices (e.g. relays, breakers, solenoids, valves)	Milliseconds
General automation (e.g. materials handling, chemical processing)	Milliseconds
Precise motion control (e.g. high speed packaging, printing, robotics)	A few microseconds
High speed electrical devices (e.g. synchrophasor measurements)	Microseconds
Electronic ranging (e.g. fault detection, triangulation)	Sub microsecond

Stellaris implementation:
Open source lwIP + PTPd : within 500nS of master clock, jitter +/- 500nS
This represents a greater than tenfold improvement over typical SW-only implementations

Visualizing the Benefits of IEEE 1588

- Before IEEE 1588, Ethernet communication in control applications occurred without absolute determinism:
  - Assume ***Sender*** sends a control instruction ***Turn*** to ***Controller***
  - Assume also that ***Clock S*** and ***Clock C*** are not synchronized
  - If ***Sender*** asks ***Controller*** to ***Turn*** upon receipt of the instruction, then there is no telling when ***Controller*** will receive ***Turn***.



TURN

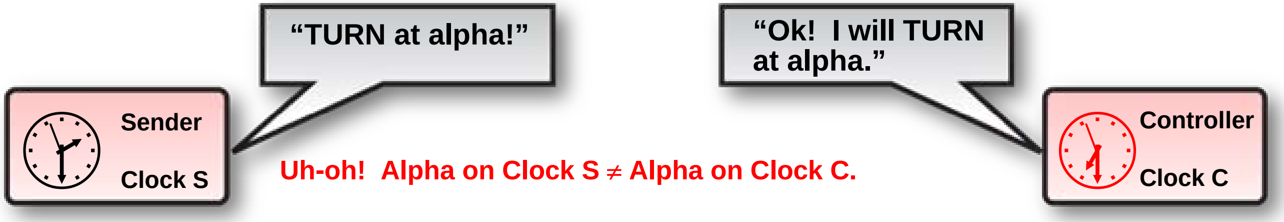
(some ?? time later)
"Ok!"

Sender
Clock S

Controller
Clock C

Uh-oh! Ethernet is non-deterministic by nature.

  - Even if *Sender* asks *Controller* to *Turn* at a given time *alpha*, there is still the problem of unsynchronized clocks.



"TURN at alpha!"

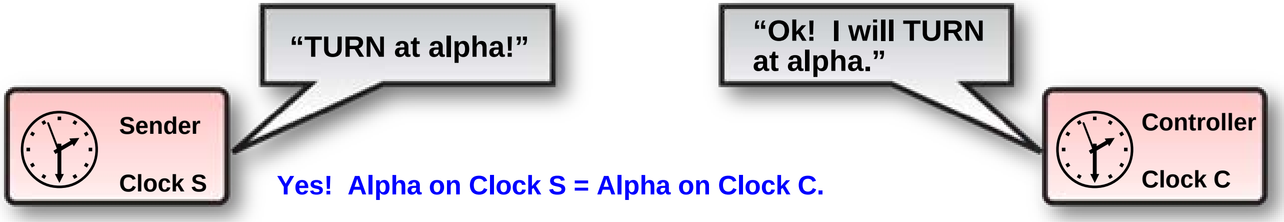
"Ok! I will TURN at alpha."

Sender
Clock S

Controller
Clock C

Uh-oh! Alpha on Clock S ≠ Alpha on Clock C.

  - But if *Sender* asks *Controller* to *Turn* at a given time *alpha*, and the clocks are synchronized to a master, then determinism is achieved.



"TURN at alpha!"

"Ok! I will TURN at alpha."

Sender
Clock S

Controller
Clock C

Yes! Alpha on Clock S = Alpha on Clock C.

TCP/IP Communications Stacks for Stellaris

µC/TCP-IP Protocol Stack	Micriµm µC/TCP-IP
expresslogic	Express Logic NetX™ TCP/IP protocol stack
CMX SYSTEMS	CMX-MicroNet™ protocol stacks
interniche technologies, inc.	InterNiche TCP/IP NicheStack™, NicheLITE™, and add-on modules such as HTTP, SNMP, and security protocols
RTA REAL TIME AUTOMATION	EtherNet/IP™ protocol stacks
free RTOS	FreeRTOS.org Open-Source µIP Embedded web server
µIP	Open source TCP/IP stack for small footprint embedded systems
lwIP	Open source light-weight implementation of the TCP/IP stack for small RAM embedded systems
IXXAT	IEEE 1588 PTP (Precision Time Protocol)
SEVENSTAX EMBEDDED TECHNOLOGIES	SEVENSTAX TCP/IP Protocol Stack

Networking stacks supporting Stellaris

TPV	Product	Stack	ARP	AutoIP	BOOTP	BSD	DHCP	DNS	FTP	HTTP	ICMP	IGMP	IKE	IP	IPSec	NAT	POP3	PPP	PTP	RARP	RIP	RTP	SLIP	SMTP	SNMP	SNTP	SSL	TCP	Telnet	TFTP	UDP	802.11
CMX Systems	CMX-MicroNET	TCP/IP	●		●						●	●		●				●					●					●			●	
CMX Systems	CMX Add Ons	Networking SW Options					●	●	●	●							●	●						●	●	●				●		●
Express Logic	NetX	TCP/IP	●								●	●		●						●								●			●	
Express Logic	NetX Add Ons	Networking SW Options		●		●	●	●	●	●						●	●	●						●	●	●			●	●		
Interniche	NicheLITE	TCP/IP	●		●		●	●			●			●														●		●	●	
Interniche	NicheStack	TCP/IP	●		●	●	●	●	●		●	●		●														●	●	●	●	
Interniche	Interniche Add Ons	Networking SW Options					●	●	●	●			●		●	●	●	●			●	●		●	●	●	●		●			
Micriµm	µC/UDP-IP	UDP/IP	●			●					●			●																	●	
Micriµm	µC/TCP-IP	TCP/IP	●			●					●			●														●			●	
Micriµm	Micriµm Add Ons	Networking SW Options					●	●	●	●							●							●		●			●	●		
SEVENSTAX	SEVENSTAX TCP/IP	TCP/IP									●															●		●			●	
SEVENSTAX	SEVENSTAX Add Ons	Networking SW Options	●		●		●	●		●				●			●	●						●								
SEGGER	embOS/IP	TCP/IP	●		●		●	●	●	●	●	●		●			●			●				●			●	●	●		●	
uIP	open source	TCP/IP	●									●		●														●			●	
lwIP	open source	TCP/IP	●	●			●	●			●	●		●				●							●			●			●	

List is subject to change

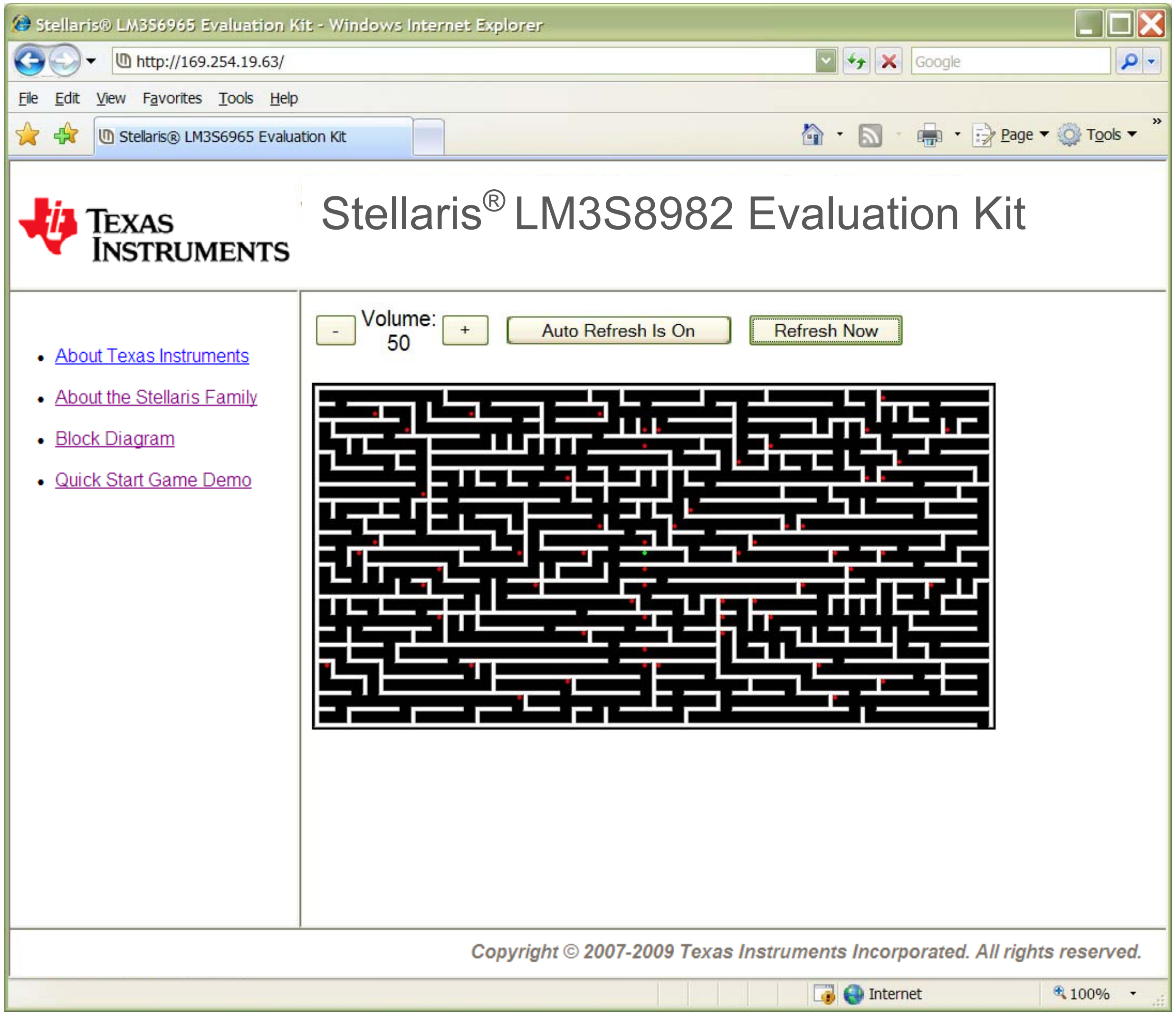
Typical Stack Options

	Acronym	Translation	Wikipedia Link	High-level Purpose
–	TCP	- Transmission Control Protocol	wikipedia Link	(guarantee delivery)
–	IP	- Internet Protocol	wikipedia Link	(data oriented)
–	UDP	- User Datagram Protocol	wikipedia Link	(fire-and-forget)
–	ARP	- Address Resolution Protocol	wikipedia Link	(finding a address)
–	RARP	- Reverse Address Resolution Protocol	wikipedia Link	(finding a address)
–	BOOTP	- Bootstrap Protocol	wikipedia Link	(finding a address)
–	DHCP	- Dynamic Host Configuration Protocol	wikipedia Link	(adding devices to a network)
–	BSD	- Berkeley Socket	wikipedia Link	(connecting to the internet)
–	ICMP	- Internet Control Message Protocol	wikipedia Link	(error message generation)
–	IGMP	- Internet Group Management Protocol	wikipedia Link	(manage IP multicast groups)
–	PPP	- Point-To-Point Protocol	wikipedia Link	(direct point-to-point connection)
–	SLIP	- Serial Line Internet Protocol	wikipedia Link	(direct point-to-point connection)
–	DNS	- Domain Name System	wikipedia Link	(translate host name to address)
–	FTP	- File Transfer Protocol	wikipedia Link	(transfer files point-to-point)
–	TFTP	- Trivial File Transfer Protocol	wikipedia Link	(FTP, but for smaller files)
–	RIP	- Routing Information Protocol	wikipedia Link	(routing internal networks)
–	RTP/RTCP	- Real-time Transport (Control) Protocol	wikipedia Link	(send audio/video over internet)
–	Telnet	- Terminal Emulation	wikipedia Link	(remote access)
–	HTTP	- Hypertext transfer Protocol Server	wikipedia Link	(publish/retrieve web pages)
–	SNMP	- Simple Network Management Protocol	wikipedia Link	(manage/monitor client status)
–	SMTP	- Simple Mail Transport Protocol	wikipedia Link	(send email over internet)
–	POP3	- Post Office Protocol-3	wikipedia Link	(retrieve email over internet)
–	SNTP	- Synchronized Network Time Protocol	wikipedia Link	(network clock synchronization)
–	PTP*	- Precision Time Protocol (also called IEEE1588)	wikipedia Link	(deterministic synchronization)
–	NAT	- Network Address Translation	wikipedia Link	(network privacy)
–	SSL	- Secure Sockets Layer	wikipedia Link	(secure communication)
–	IPSec	- Internet Protocol Security	wikipedia Link	(virtual private network)
–	IKE	- Internet Key Exchange	wikipedia Link	(security key/certificate sharing)

***Several Stellaris MCUs integrate hardware assistance for IEEE1588 PTP.**

LM3S8962 Evaluation Kit Web Server Demo

- QS/lwip
  - Serves map for arcade game
- enet_lwip
  - Serves web pages from internal flash or from user micro-SD card
  - Extended support for SSI & CGI added to lwIP HTTPD
  - Utility supports easy generation of web site file system images
- enet_uip
  - Serves basic single page



Stellaris® LM3S6965 Evaluation Kit - Windows Internet Explorer

http://169.254.19.63/

Stellaris® LM3S8982 Evaluation Kit

- About Texas Instruments
- About the Stellaris Family
- Block Diagram
- Quick Start Game Demo

Volume: 50

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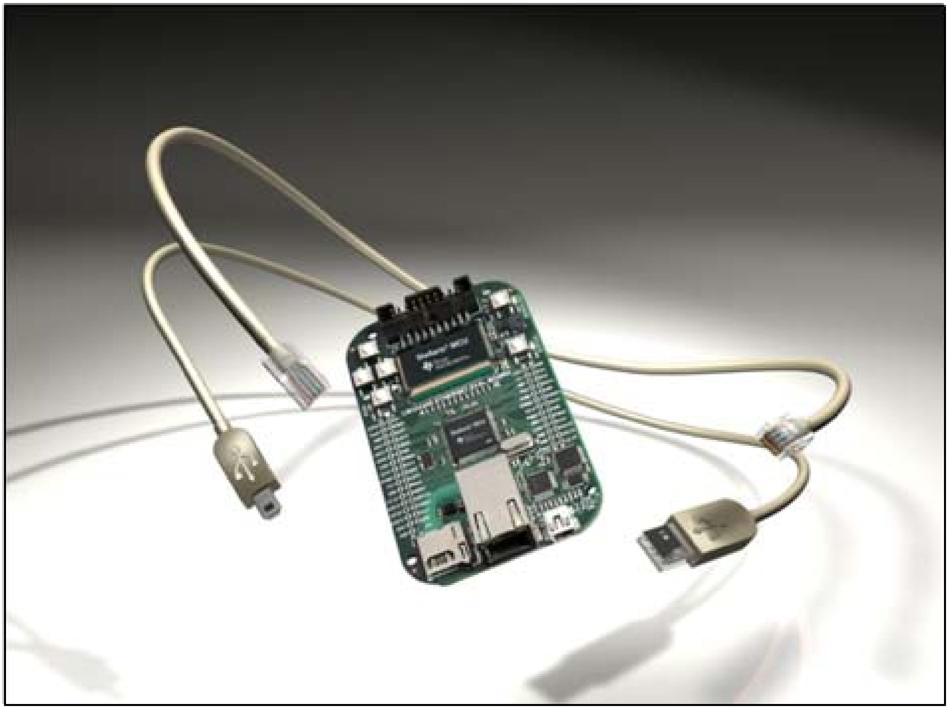
EK-LM3S6965: Evaluation Kit Overview

Stellaris LM3S6965 Evaluation Kit:

- LM3S6965 Evaluation Board
  - Stellaris LM3S6965 microcontroller with fully-integrated 10/100 Ethernet controller
  - Simple setup
  - OLED graphics display with 128 x 64 pixel resolution
  - User LED, navigation switches, and select pushbuttons
  - Magnetic speaker
  - LM3S6965 I/O available on labeled break-out pads
  - Standard ARM® 20-pin JTAG debug connector with input and output modes
  - MicroSD card slot
- Included µIP and lwIP IP stacks with Web Servers
- Retractable Ethernet Cable, USB cable, and JTAG cable
- Kit contains:
  - Evaluation software tools
  - Device documentation
  - Quickstart guide
  - Stellaris Peripheral Driver Library
  - Example source code



Stellaris Day Agenda

1 Stellaris Family

2 StellarisWare®

3 Serial to Ethernet Converter

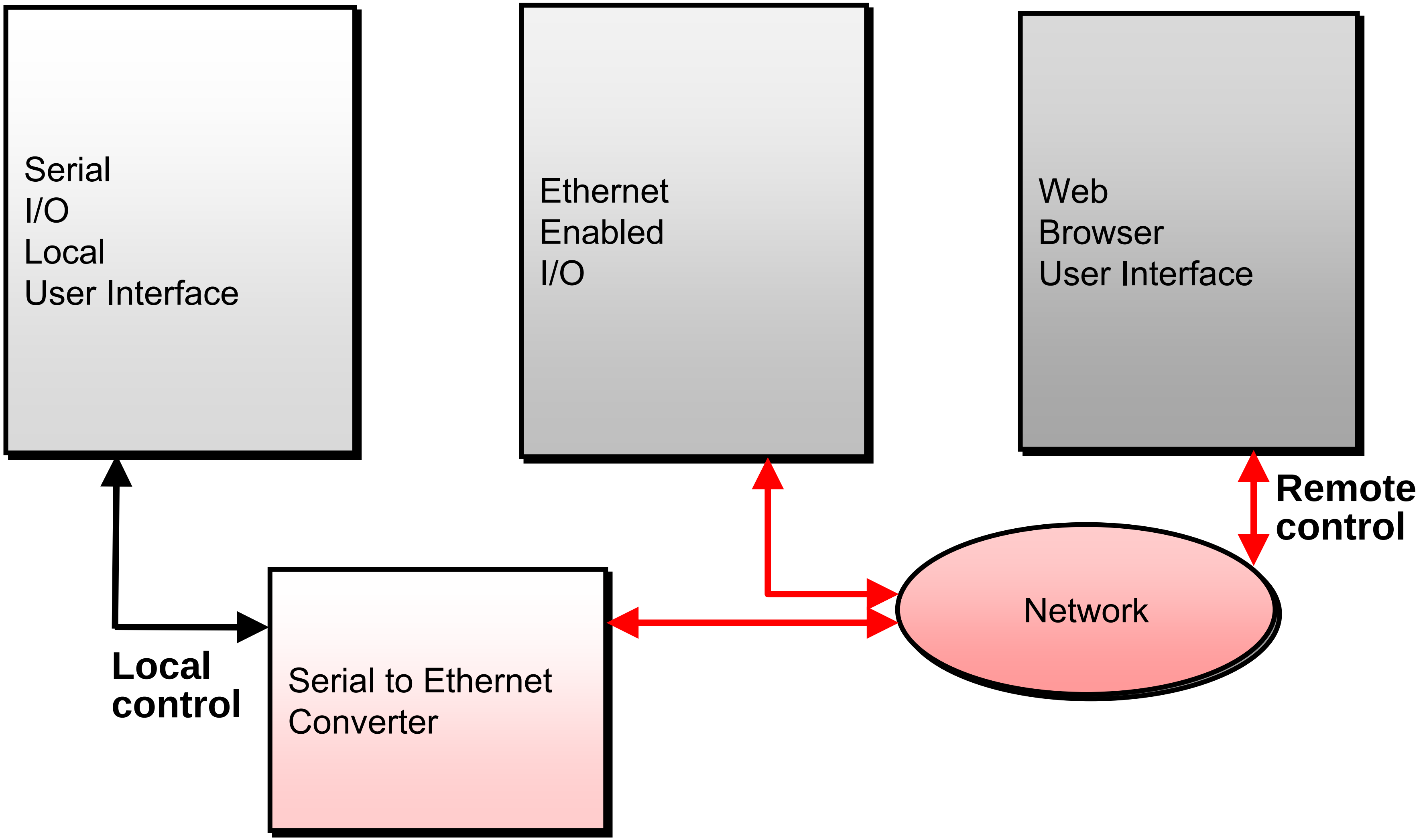
4 Designing a Serial to Ethernet Converter

5 S2E RDK Overview

6 Industrial Control Demo Overview

7 Proof of Concept: S2E Converter Demo

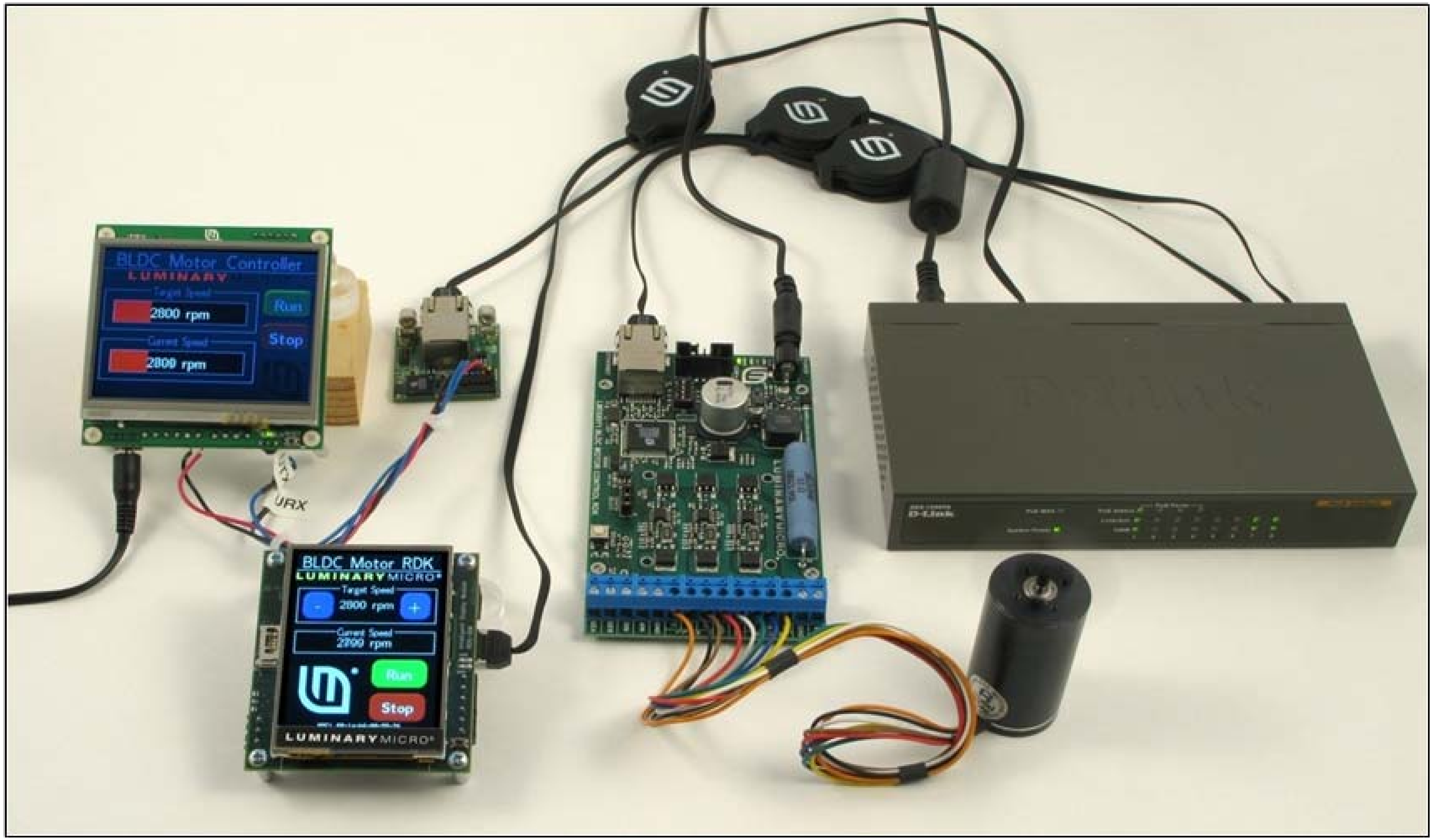
Proof-of-Concept: Industrial Control Demo



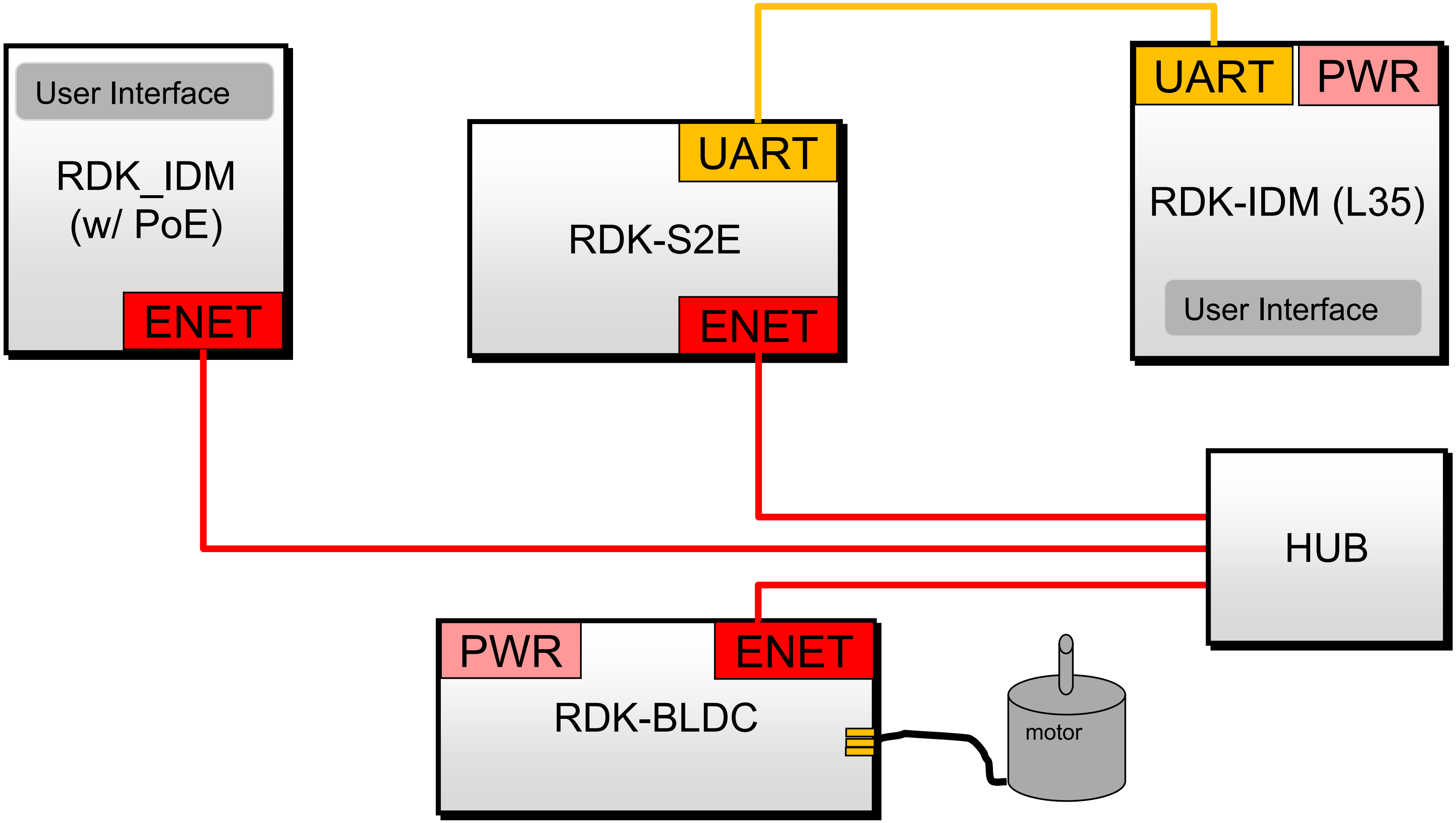
Stellaris Day Agenda

1. Stellaris Family
2. StellarisWare®
3. Serial to Ethernet Converter
4. Designing a Serial to Ethernet Converter
5. S2E RDK Overview
6. Industrial Control Demo Overview
7. Proof of Concept: S2E Converter Demo

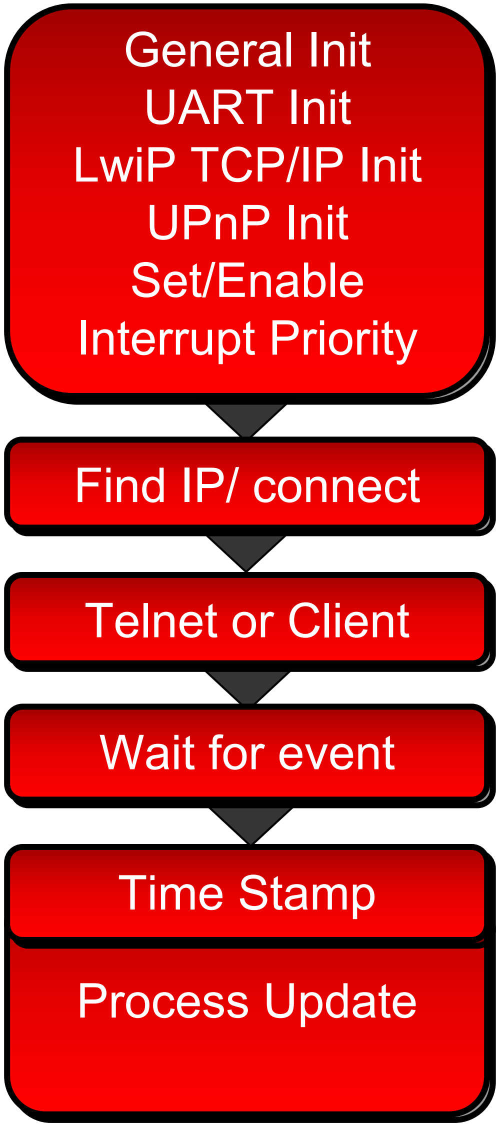
Proof-of-Concept: S2E Converter Demo



Proof-of-Concept: Hardware



Proof of Concept: S2E Software



General Init
UART Init
LwiP TCP/IP Init
UPnP Init
Set/Enable
Interrupt Priority

Find IP/ connect

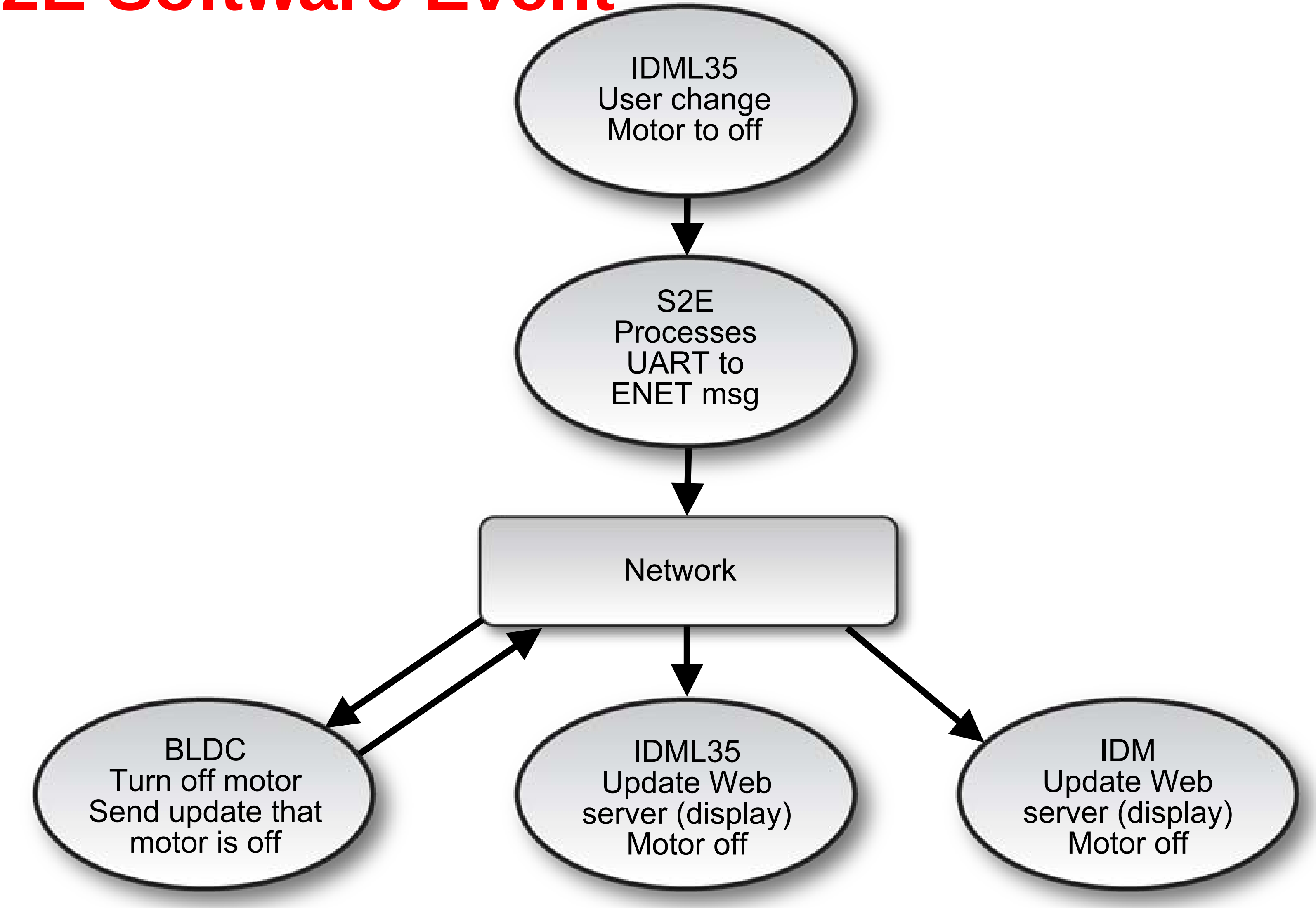
Telnet or Client

Wait for event

Time Stamp

Process Update

Proof of Concept:
S2E Software Event


IDML35
User change
Motor to off

S2E
Processes
UART to
ENET msg

Network

BLDC
Turn off motor
Send update that
motor is off

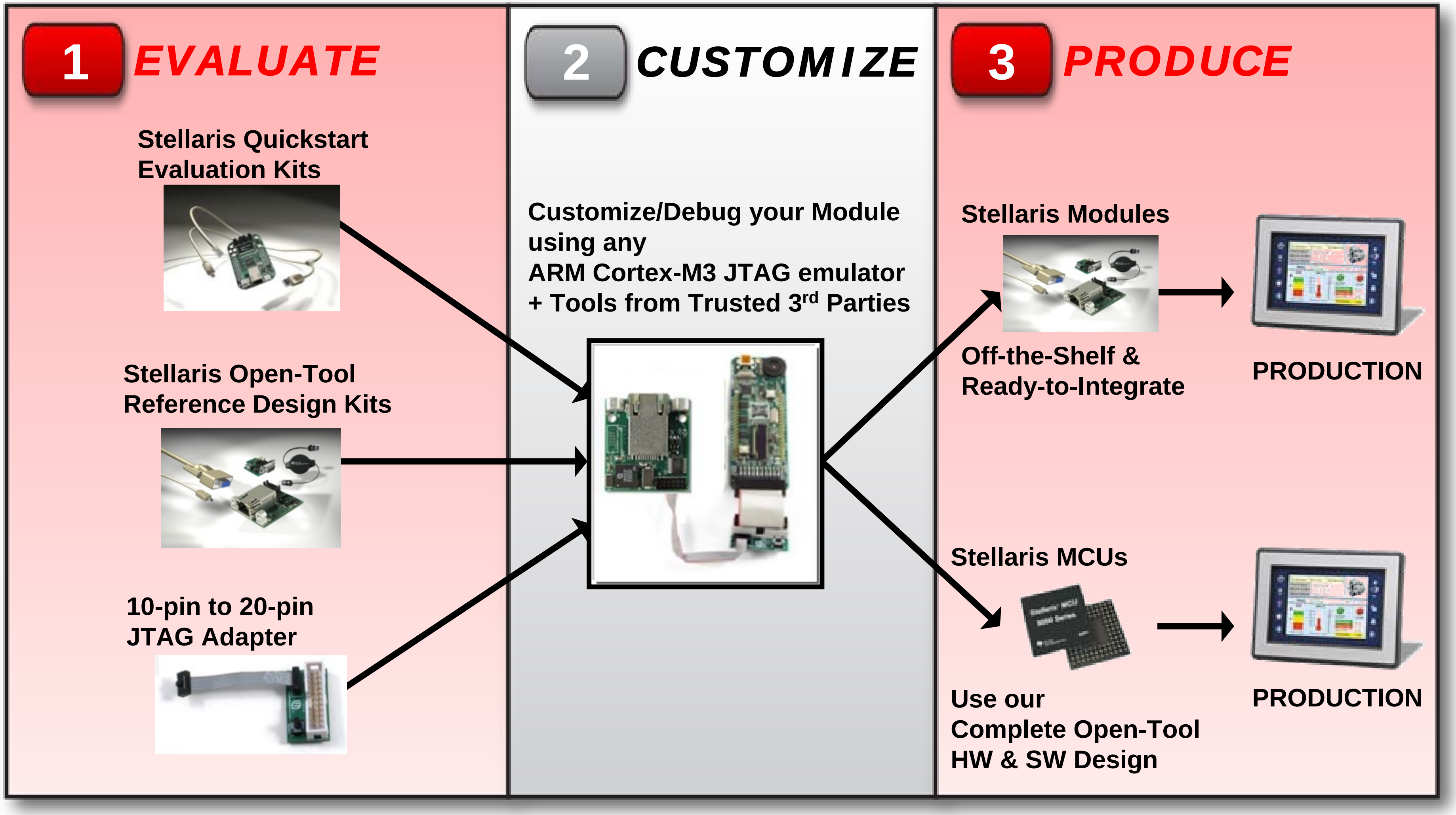
IDML35
Update Web
server (display)
Motor off

IDM
Update Web
server (display)
Motor off

Proof of Concept: S2E Demo

- Basic theory of operation
  - S2E Operating in Raw Mode: Data received in UART is Transmitted back out the Ethernet
  - Changing the motor on either the IDM or IDML35 interface will cause an event. An update is then sent to network:
    - BLDC receives and processes update, adjusts the motor speed
    - BLDC transmits updated motor speed to network
    - IDMs receives and processes update, refresh web server page with new motor speed

Options in Building Demo



1 EVALUATE

Stellaris Quickstart Evaluation Kits

Stellaris Open-Tool Reference Design Kits

10-pin to 20-pin JTAG Adapter

2 CUSTOMIZE

Customize/Debug your Module using any
ARM Cortex-M3 JTAG emulator
+ Tools from Trusted 3rd Parties

3 PRODUCE

Stellaris Modules

Off-the-Shelf & Ready-to-Integrate

PRODUCTION

Stellaris MCUs

Use our Complete Open-Tool HW & SW Design

PRODUCTION

Stellaris 3.5" Landscape IDM

RDK-IDM-L35
$219

Example applications:

- Security Systems & Building Access Controllers
- White Goods and other Home Appliances
- Factory Automation
- System Status and Configuration

Bright QVGA LCD touch-screen display

- 3.5" QVGA 240 x 320 pixels
- 16-bit color
- White LED backlight
- 4-wire resistive touch panel

Serial connectivity options

- Headers provide TXD and RXD signals
- RS232 signal levels
- UART serial port with TTL signal levels
- Default 115.2k,8,n,1 operation

High performance and memory

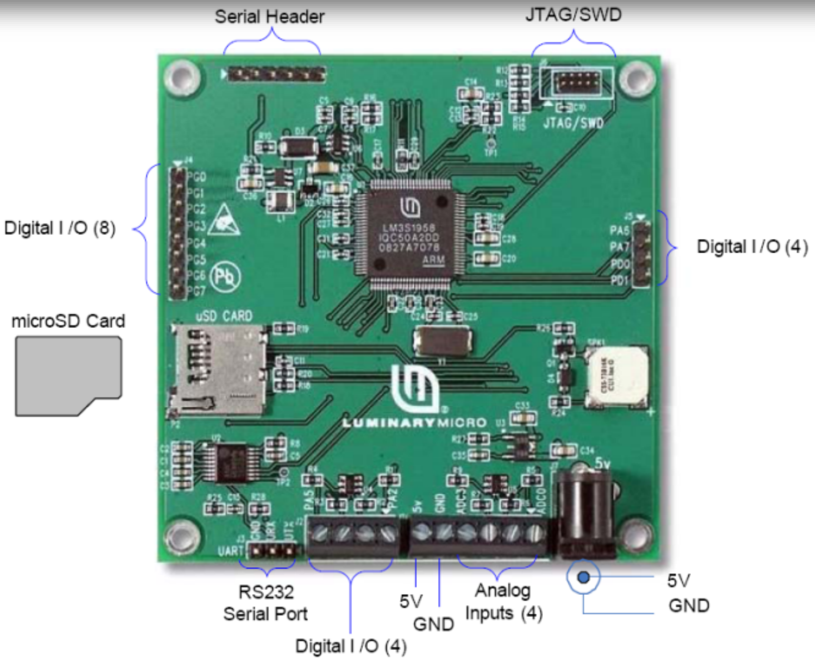
- 32-bit ARM Cortex-M3 core
- 256KB Main Flash memory, 64KB SRAM
- MicroSD slot (typically 1GB storage)

Flexible power supply options

- 5 V DC jack, 5 V Terminal block, and 5 V Serial header

Peripherals

- Four analog measurement inputs
- 16 digital I/O lines
- Magnetic buzzer, PWM controlled



Any Stellaris evaluation kit can function as
an ARM Cortex-M3 USB-to-JTAG emulator.

RDK-IDM-L35 resale: 219 USD
MDL-IDM-L35 single unit resale: 185 USD

Intelligent Display RDK and Modules

RDK-IDM
$219

Example applications:
- Security Systems & Building Access Controllers
- White Goods and other Home Appliances
- Factory Automation
- System Status and Configuration

Bright QVGA LCD touch-screen display

- 2.8” QVGA 240 x 320 pixels
- 16-bit color
- White LED backlight
- Resistive touch panel

Ethernet and Serial connectivity options

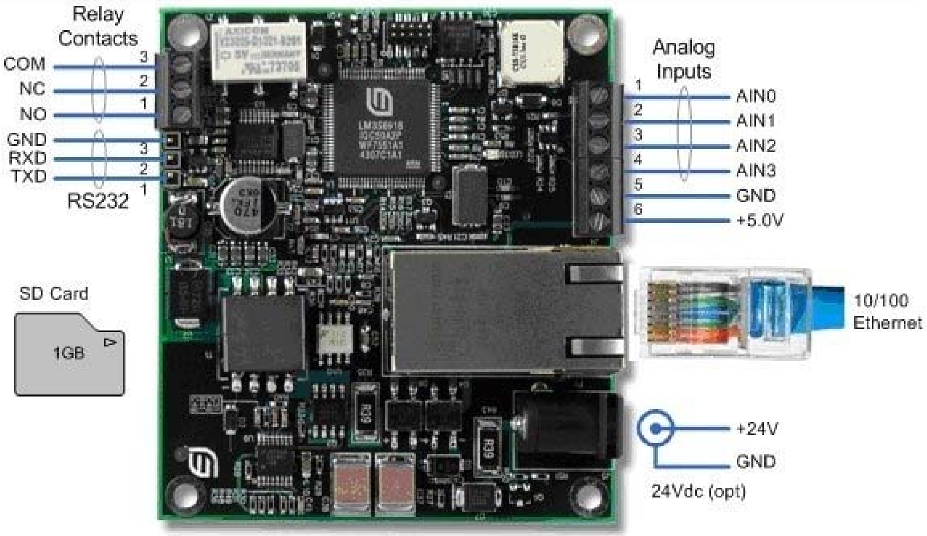
- 10/100 Ethernet with Auto MDI/MDIX and Traffic /Link indicator LED
- Header provides TXD and RXD signals
- RS232 signal levels
- Default 115.2k,8,n,1 operation
- Ethernet boot loader for reprogramming

High performance and memory

- 32-bit ARM Cortex-M3 core
- 256KB Main Flash memory, 64KB SRAM
- MicroSD slot (typically 1GB storage)

Flexible power supply options

- Power over Ethernet (IEEE 802.3af compliant)
  - (MDL-IDM only)
- 24V DC power jack
- 5V DC terminals



RDK-IDM resale: 219 USD
MDL-IDM single unit resale: 199 USD
MDL-IDM28 single unit resale: 185 USD

Any Stellaris evaluation kit can function as an ARM Cortex-M3 USB-to-JTAG emulator.

RDK-IDM Board Options

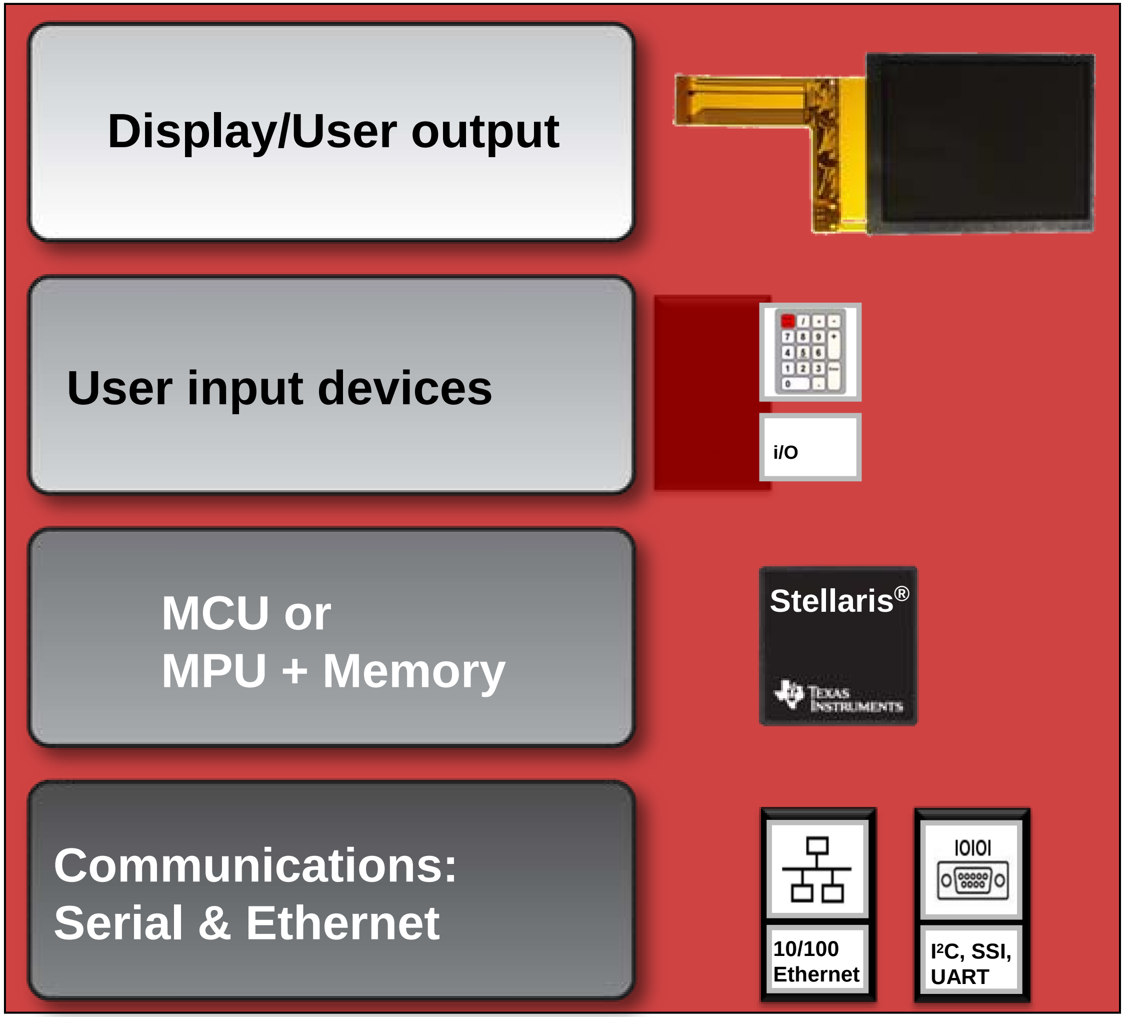
RDK-IDM

- Bright QVGA LCD touch-screen display
  - 2.8" QVGA 240 x 320 pixels
- Ethernet and Serial connectivity options
  - 10/100 Ethernet with Auto MDI/MDIX
  - Header provides TXD and RXD signals
- MicroSD slot (typically 1 GB storage)
- Flexible power supply options
  - Power over Ethernet (IEEE 802.3af compliant)
  - 24V DC power jack
  - 5V DC terminals
- Additional Peripherals
  - Four analog measurement inputs
  - One relay output (1 form C / SPDT contacts)

RDK-IDML35

- Bright QVGA LCD touch-screen display
  - 3.5" QVGA 320 x 240 pixels
- Serial connectivity options
  - RS232 serial port with RS232 signal levels
  - UART serial port with TTL signal levels
- MicroSD slot (typically 1-2 GB storage)
- Flexible power supply options
  - 5 V power supply with DC regulator that generates 3.3 V for powering the board
  - Through UART header

HMI Hardware Block Diagram



Display/User output

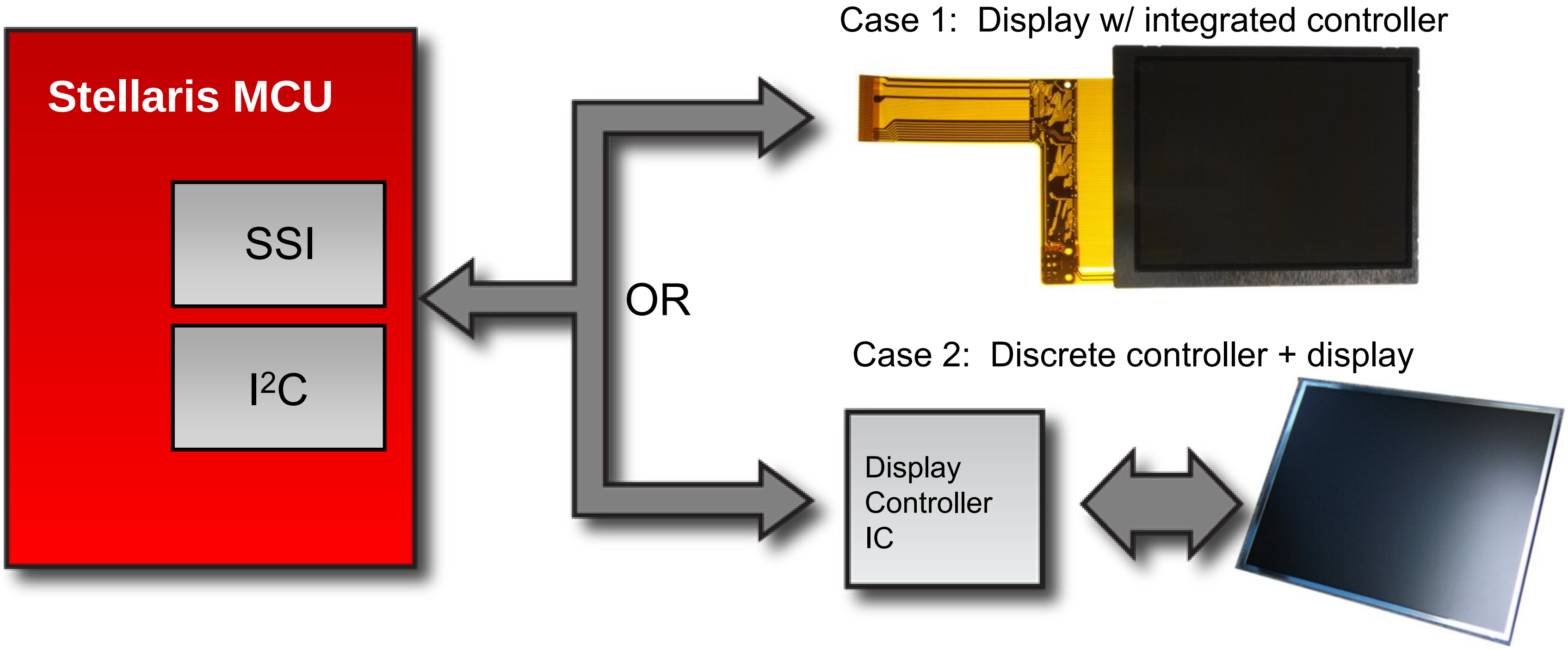
User input devices

MCU or
MPU + Memory

Communications:
Serial & Ethernet

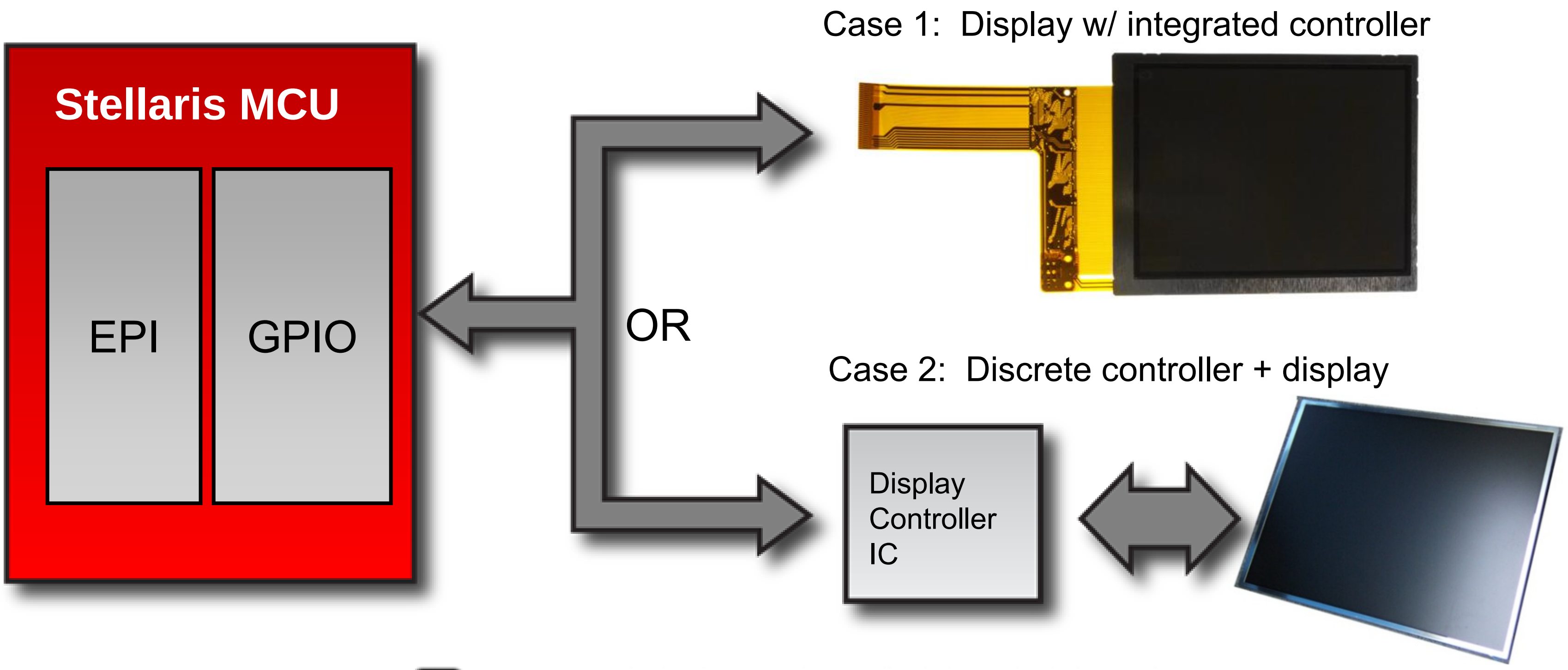
Interface Options - Serial

- The most common serial interfaces supported by display controller ICs are SSI/SPI and I^{2}C.
- Pros: Fewer signals, decent speed (SSI, up to ½ system clock)
  Cons: Slower (I^{2}C), not as common for larger displays
- Examples: EK-LM3S2965, EK-LM3S6965, EK-LM3S8962, EK-LM3S811


Stellaris MCU
SSI
I^{2}C
OR
Case 1: Display w/ integrated controller
Case 2: Discrete controller + display
Display
Controller
IC

Interface Options - Parallel

- The most common parallel interfaces supported by display controller ICs are 8/16-bit 6800- or 8080-compatible interfaces.
- Pros: High speed due to parallel nature
  Cons: Resource hog (lots of pins/signals)
- Examples: EK-LM3S3748, DK-LM3S9B96, all RDK-IDM boards



Case 1: Display w/ integrated controller

Stellaris MCU

EPI

GPIO

OR

Case 2: Discrete controller + display

Display
Controller
IC

Interface Options

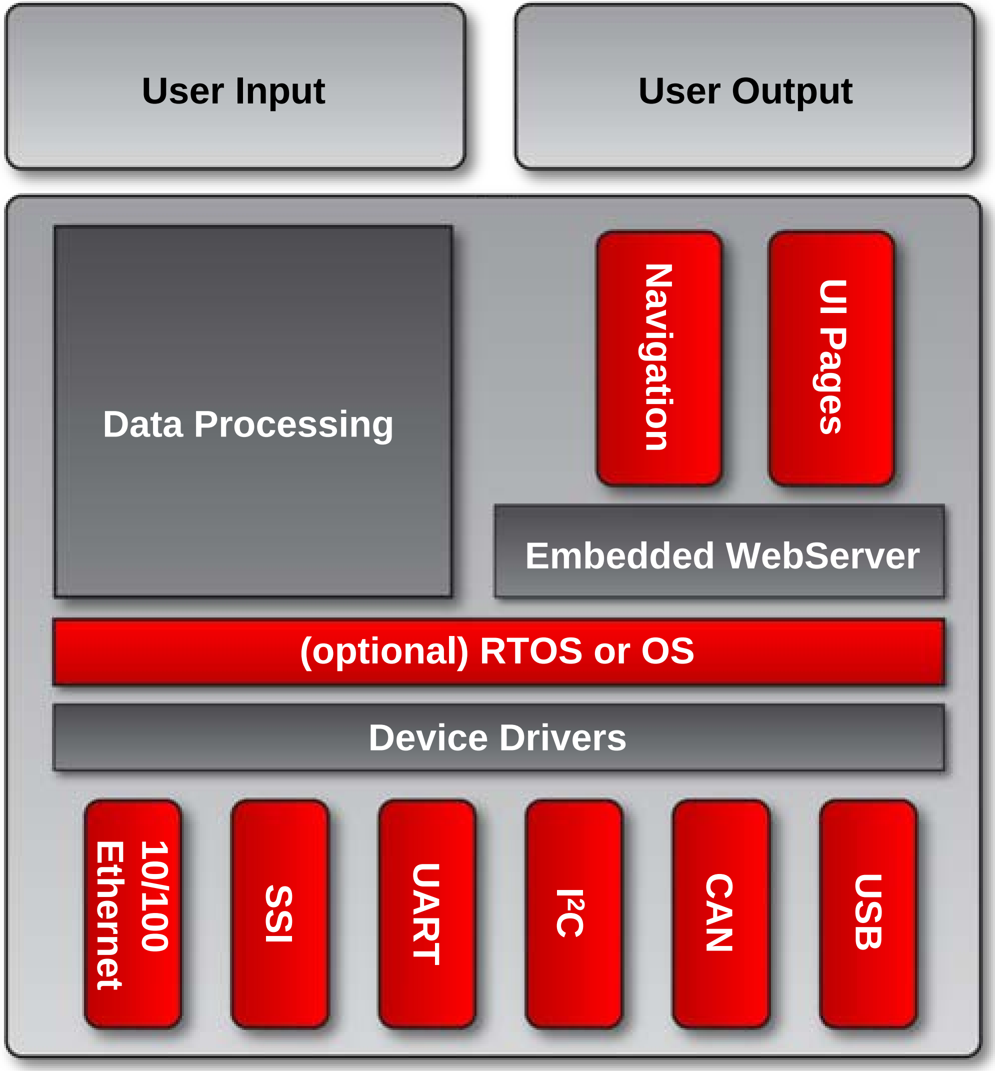
Serial Interface

- SSI/SPI and I^2C.
- Very popular
- Pros - Fewer signals, decent speed (SSI, up to ½ system clock)
- Cons - Slower (I^2C), not as common for larger displays
- Examples: EK-LM3S2965, EK-LM3S6965, EK-LM3S8962, EK-LM3S811

Parallel Interface

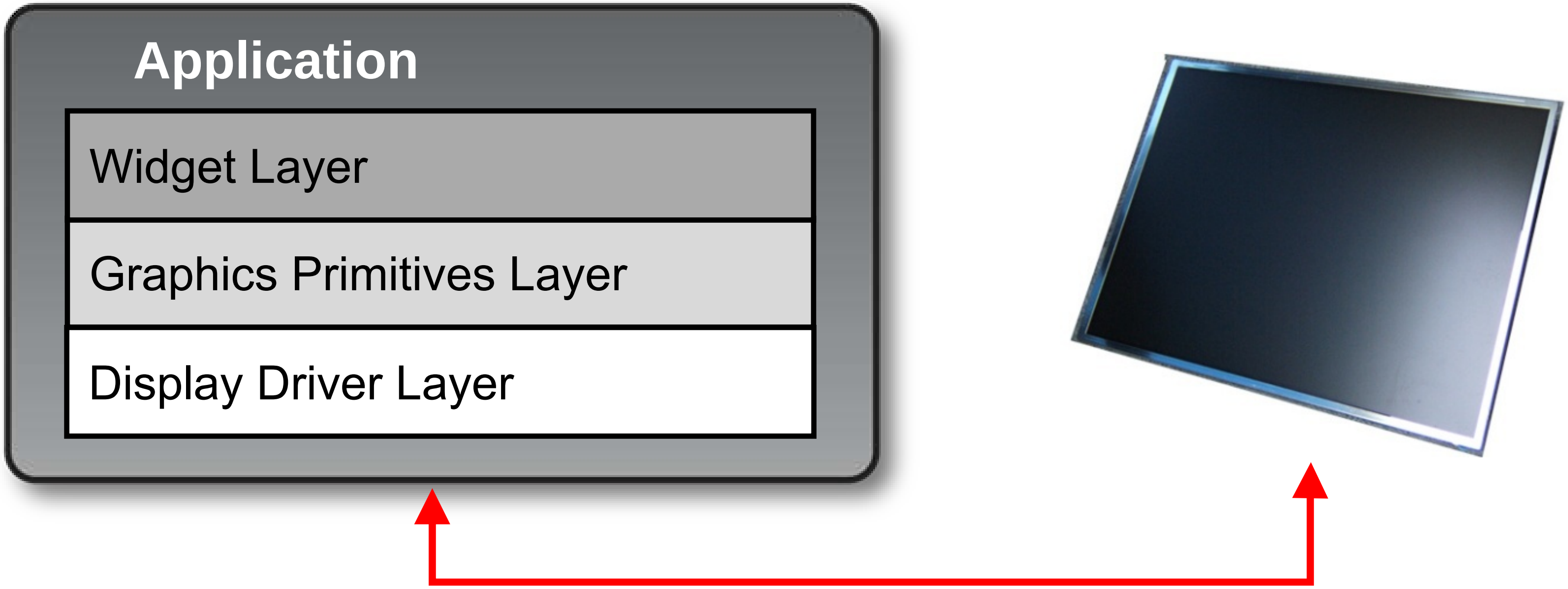
- High-speed Stellaris GPIO (bit-banging) or the Stellaris EPI
- Simple host-bus type interfaces with either 8- or 16-bit data paths, 6800- or 8080-compatible interfaces.
- Pros - High speed due to parallel nature
- Cons - Resource hog (lots of pins/signals)
- Examples: EK-LM3S3748, DK-LM3S9B96, all RDK-IDM boards

HMI Software Block Diagram



StellarisWare® Graphics Library

- Set of graphics primitives and widgets for use on Stellaris MCUs.
- Three layers of functionality:
  - Display Driver Layer
  - Graphics Primitives Layer
  - Widget Layer



Application

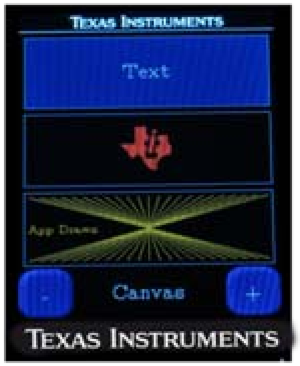
Widget Layer

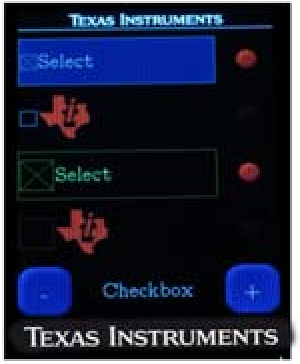
Graphics Primitives Layer

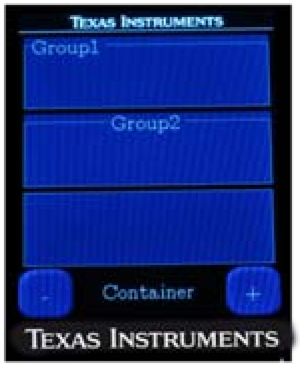
Display Driver Layer

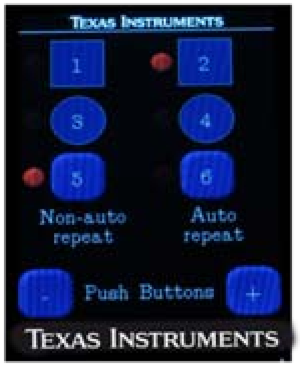
Graphics Library – Widget Layer

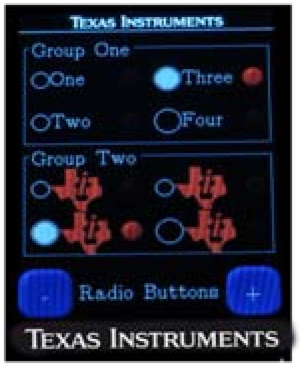
- The Graphics Library built-in widgets include:
  - Canvas, Checkbox, Container, Push Button, Radio Button, Image Button, Slider, ListBox
- The appearance of push button and slider widgets can be customized with any image.
  - The widget framework also allows for customizable widgets, if what you need doesn’t exist.
  - A utility (pnmtoc) is provided in StellarisWare to help convert the image from PNM format to a C array that can be linked into an application.
- A user application periodically services the widget messages in the queue by calling WidgetMessageQueueProcess( ). Without processing the queue, changes do not show up on the screen.
- Application code (widget handlers, ISRs, etc.) can add and remove widgets by calling WidgetAdd(…) or WidgetRemove(…), or can pass messages for processing using WidgetMessageQueueAdd(…).

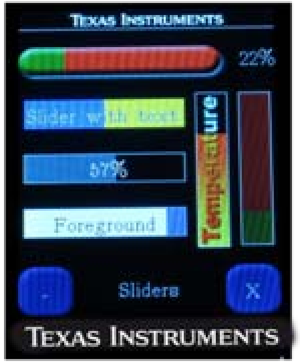






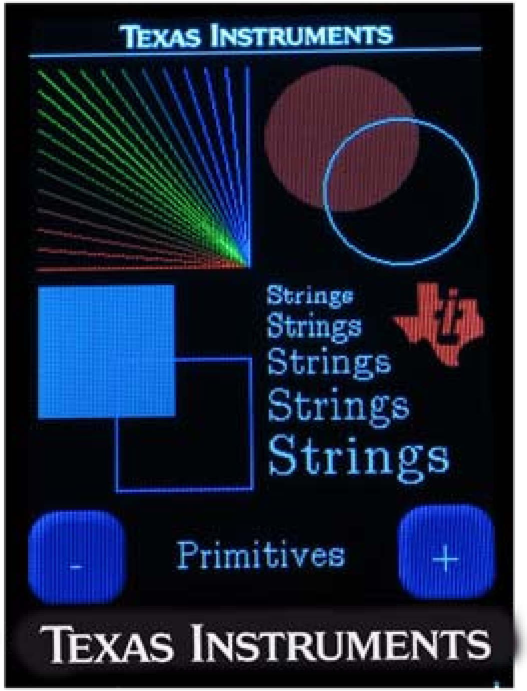






Graphics Library – Primitives Layer

- Graphics Primitives:
  - Point, Line, Rectangle, Circle, Font, Image, Context, Buffer
  - 134 Computer Modern predefined fonts available
  - Up to 24-bit color (~150 common colors conveniently referenced in GraphicsLib)



- The widget library uses graphics primitives to construct widgets.
  - For example, a checkbox uses the rectangle, font and line primitives – rectangle for drawing the container, line for drawing the “x” for checked, and font for the text.
  - It’s possible to make calls to the primitives layer (for example, to draw static text or an image), but if an application is widget based, it’s not necessary.

Graphics Library – Display Driver Layer

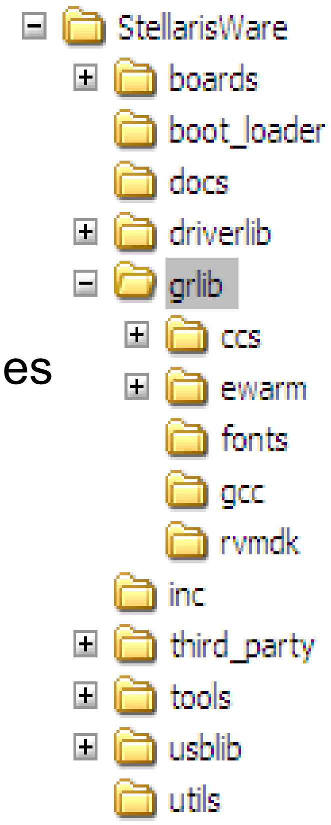
- The Graphics Library can be made to work with just about any display, of any size (within reason, of course).

- The graphics primitives use a structure describing the display to figure out how to talk to it. This structure contains:
  - Basic display info such as width/height, that determines display orientation.
  - Functions for basic tasks such as single pixel draw, pixel draw multiple, line draw horizontal, line draw vertical), rectangle color fill, color translate (from 24-bit RGB to display-specific colors), and cache flush.

- If a display controller is not supported in the Graphics Library, creating a driver with the functions listed above will allow it to be used with the Graphics Library.

StellarisWare® Graphics Library File Organization

- StellarisWare\grlib contains all Graphics Library related files
  - Compiler-specific project information
  - Graphics-Library-specific ‘.c’ source and ‘.h’ header files for all graphics objects
    - Canvas, checkbox, circle, container, context
    - Image, line, listbox, pushbutton, radiobutton, imagebutton
    - Rectangle, string, slider, widget
  - Other generic Graphics Library related ‘c’ source and header files
  - Supports different compilers and IDEs
    - TI CCS, Keil, IAR, Code Red, CodeSourcery G++
  - StellarisWare\grlib\fonts contains Graphics Library font-specific files
  - Graphics Library User Guide (click link for download)
  - Graphics Library utilities
  - StellarisWare\tools\ftrasterize for creating fonts
  - StellarisWare\tools\pnmtoc for creating images



```
⊟ StellarisWare
  ⊞ boards
    boot_loader
    docs
  ⊞ driverlib
  ⊟ grlib
    ⊞ ccs
    ⊞ ewarm
      fonts
      gcc
      rvmdk
    inc
  ⊞ third_party
  ⊞ tools
  ⊞ usblib
    utils
```

RDK-BLDC – Featuring Stellaris LM3S8971

Example applications:
- Factory automation
- Small appliances
- Electric wheelchairs and mobility devices
- Pumping and ventilation systems

Advanced motor control for three-phase brushless DC motors up to 36 V 500 W

Flexible platform accelerates integration process

Uses a Stellaris LM3S8971 microcontroller

10/100 Ethernet and CAN interfaces

Four quadrant operation for precise control

Hall Effect, Quadrature, and Sensorless operation modes

On-board braking circuit

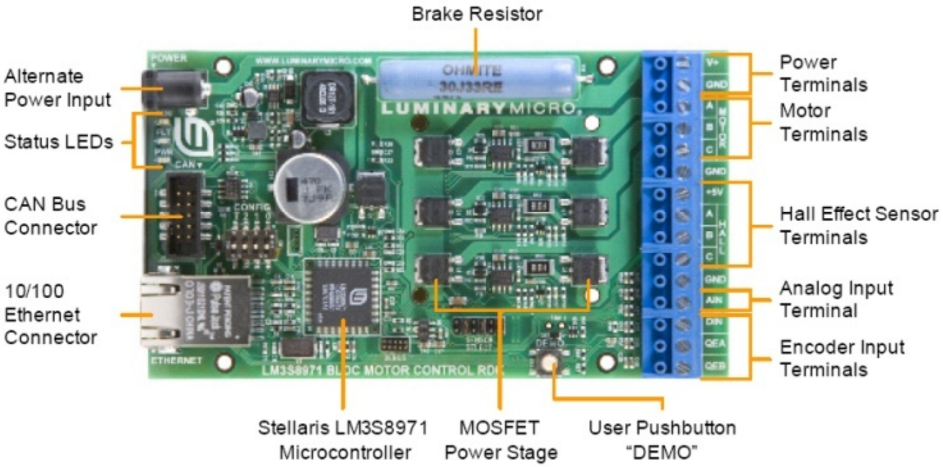
Incremental quadrature encoder input

Analog and digital control inputs

Status LEDs indicate Power, Run, and Fault conditions

Optional power-managed fan for forced-air cooling

JTAG/SWD port for software debugging

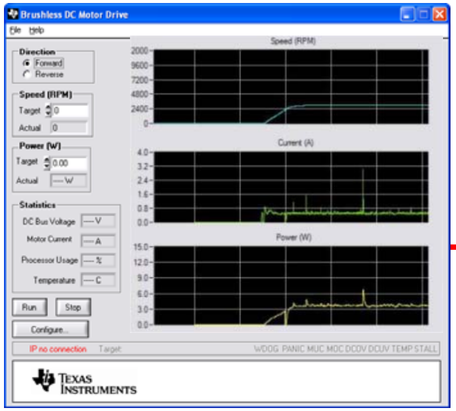


RDK-BLDC resale: 219 USD
MDL-BLDC single unit resale: 149 USD

Any Stellaris evaluation kit can function as an ARM Cortex-M3 USB-to-JTAG emulator.

Example Solution – BLDC Motor Control + Ethernet

- 3-phase BLDC with Ethernet and CAN (RDK-BLDC)
  - 3-phase Brushless DC Motion Control
  - Ethernet commands and monitoring
  - Communicating with a multicast CAN network


Brushless DC Motor Drive

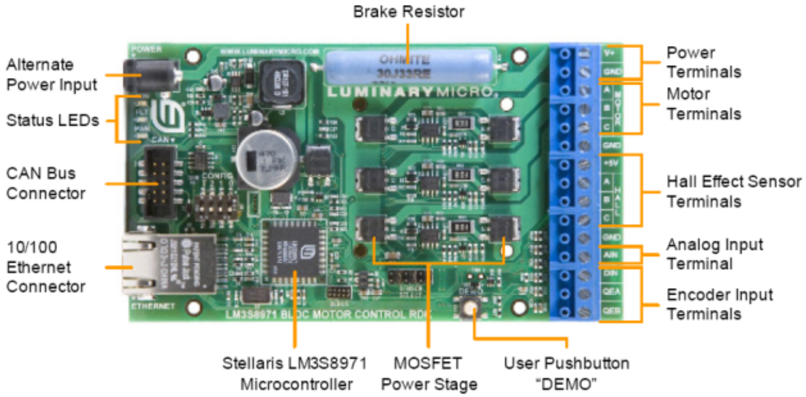
Direction: ● Forward ○ Reverse

Speed (RPM)
Target: 0
Actual: 0

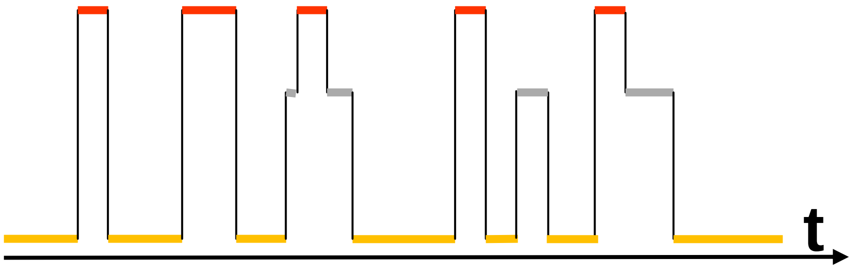
Power (W)
Target: 0.00
Actual: --- W

Statistics
DC Bus Voltage: --- V
Motor Current: --- A
Processor Usage: --- %
Temperature: --- C

IP no connection Target:



40% of 50 MHz bandwidth left to application!



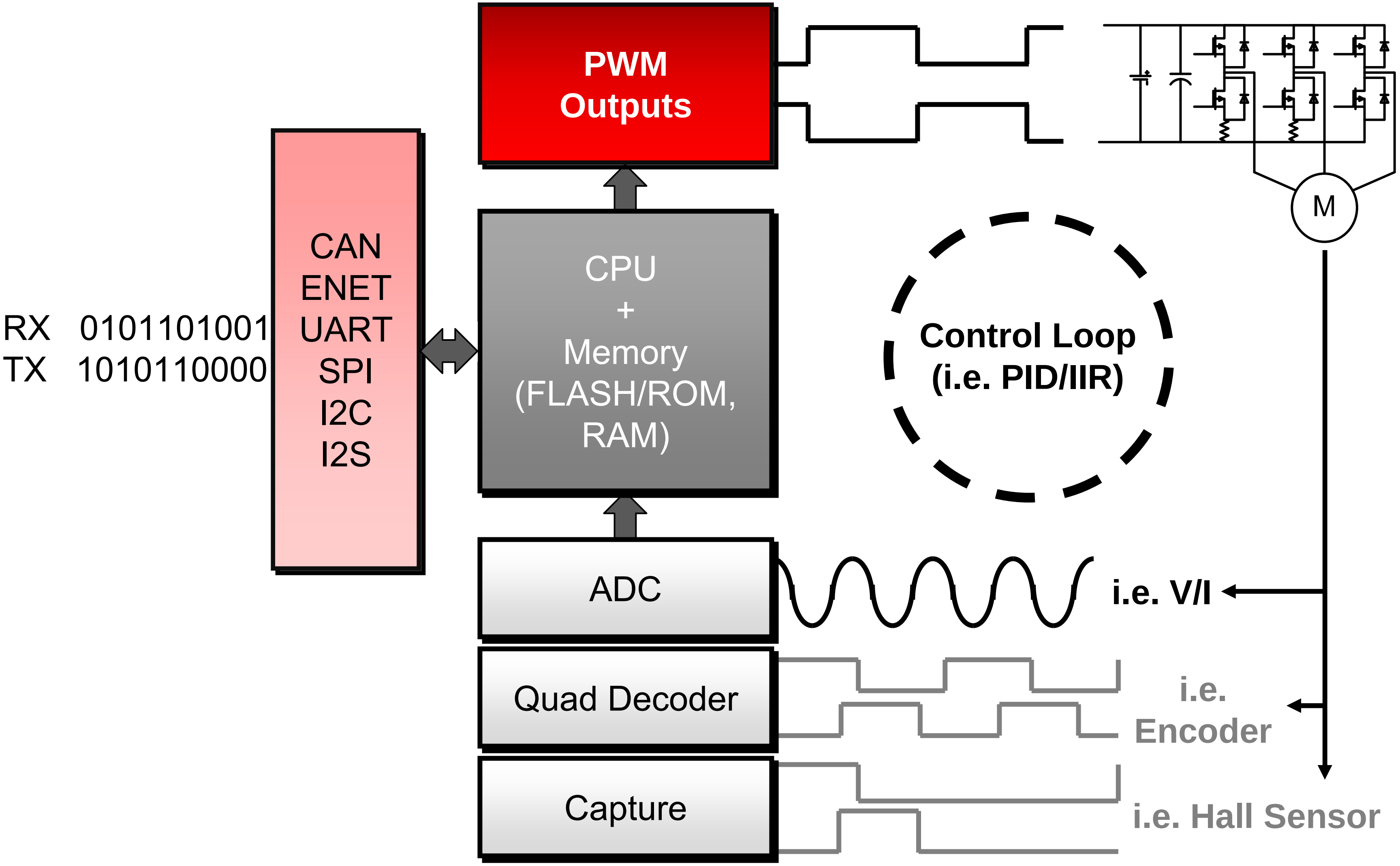
Motor control ISRs (e.g. PWM, ADC)

Communication ISRs (e.g. ENET, CAN)

Main application (foreground)

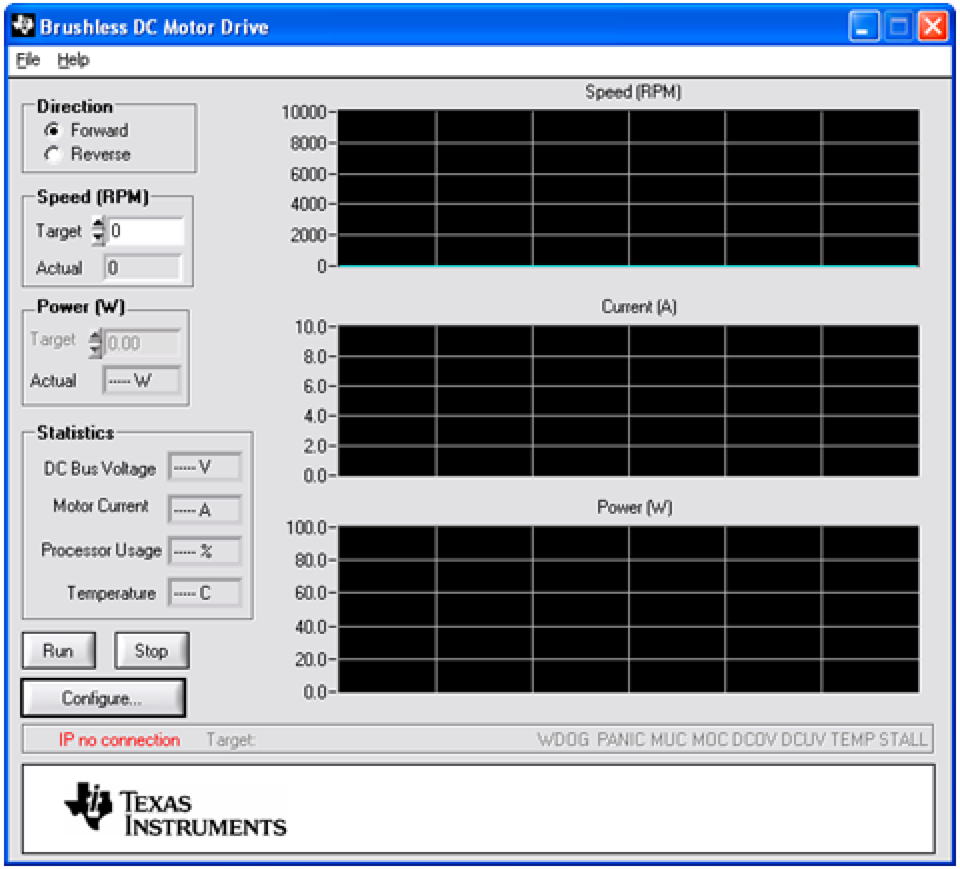
Return

Digital Motor Control concept



RDK-BLDC

- GUI interface tool
  - Main Window
    - Direction
    - Speed/Power target
    - Run/Stop/Configure
    - Speed/Current/power graphs
    - Instantaneous speed and power
    - Status (motor current, bus voltage, etc.)



Direction
● Forward
○ Reverse

Speed (RPM)
Target 0
Actual 0

Power (W)
Target 0.00
Actual ----- W

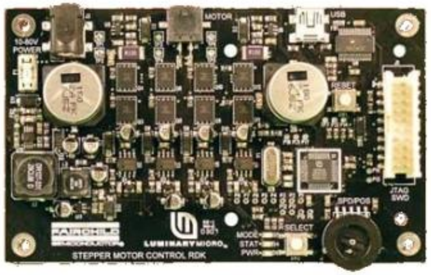
Statistics
DC Bus Voltage ----- V
Motor Current ----- A
Processor Usage ----- %
Temperature ----- C

IP no connection Target:

Stellaris Motor RDK’s

Brush DC Motor Control
MDL-BDC24

Ethernet+CAN BLDC Motor Controller
MDL-BLDC



STEPPER Motor Control
MDL-STEPPER

AC Induction Motor Control
MDL-ACIM

Stellaris® is The Industrial Connectivity solution!

Performance

20-100 MHz ARM Cortex-M3 MCU

- Optimized for single-cycle flash usage
- Thumb-2 ISA with high code density
- Flexible clock system sources up to 8 timers
- Single-cycle multiply and hardware divide
- Three power modes and battery-backed hibernation with non-volatile memory
- Integrated 32-ch DMA for ease of use & high data rate without CPU overhead

Broad Portfolio

- *Largest ARM MCU portfolio in the world with over 160 devices*
- 8KB-256KB Flash and 96KB RAM
- 10-bit, 8ch ADCs from 250ksps-1MSPS
- Up to 8 advanced PWM modules
- RTC, BOR, and integrated LDO
- Analog comparators and temp sensor
- 48 to 108 pin in LQFP, LQFN, BGA

Connectivity

Only family in the industry with:

- Ethernet MAC & PHY with 1588 PTP support
- USB Host, Device, or On-The-Go
- CAN 2.0 A/B with 32 mailboxes
- Integrated UART, I^{2}C, SSI modules
- Integrated I^{2}S master or slave
- External Peripheral Interface supporting SRAM, SDRAM, M2M, FPGA, CPLD

Ease of Use

- C friendly IDE and compilers from industry leaders
- Low cost development tools
- Application specific and advanced development kits
- Production-ready application modules
- StellarisWare on ROM includes driver and peripheral libraries to ease development

Thank you for attending Stellaris® MCU Day

Human Machine Interface applications made easy with
Stellaris® ARM® Cortex™-M3 Microcontroller Solutions

Always available online to answer your questions:
TI E2E Support Community/Stellaris

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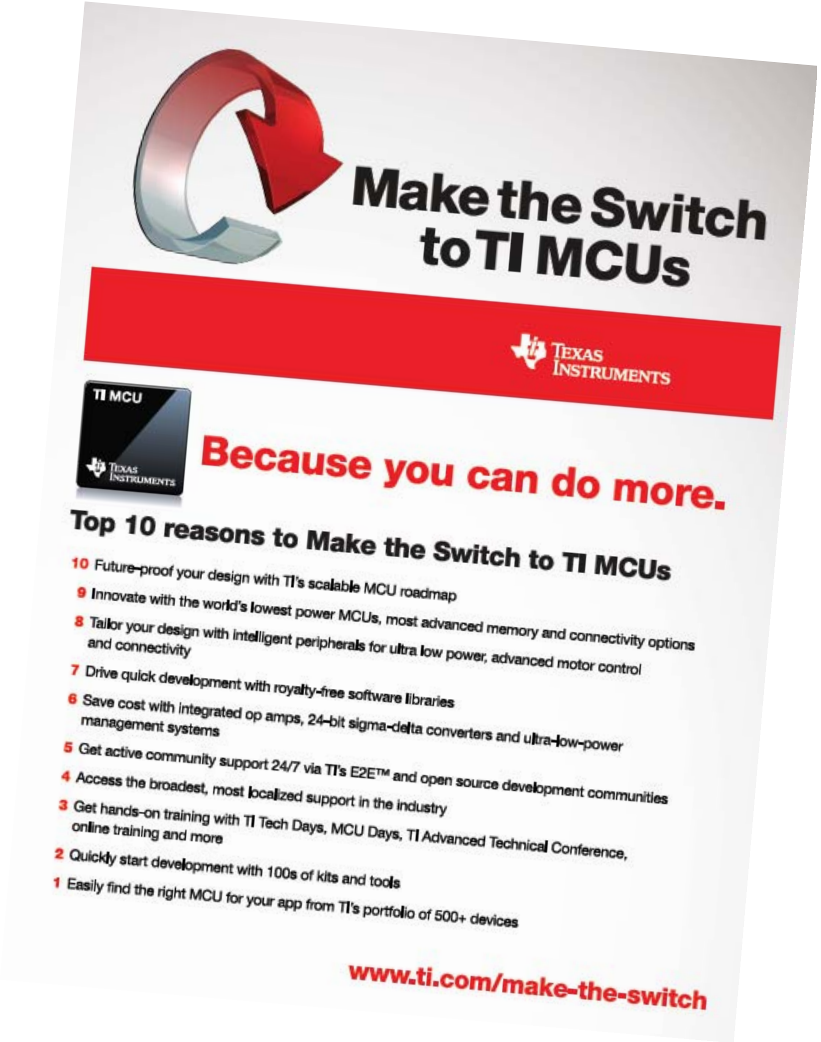

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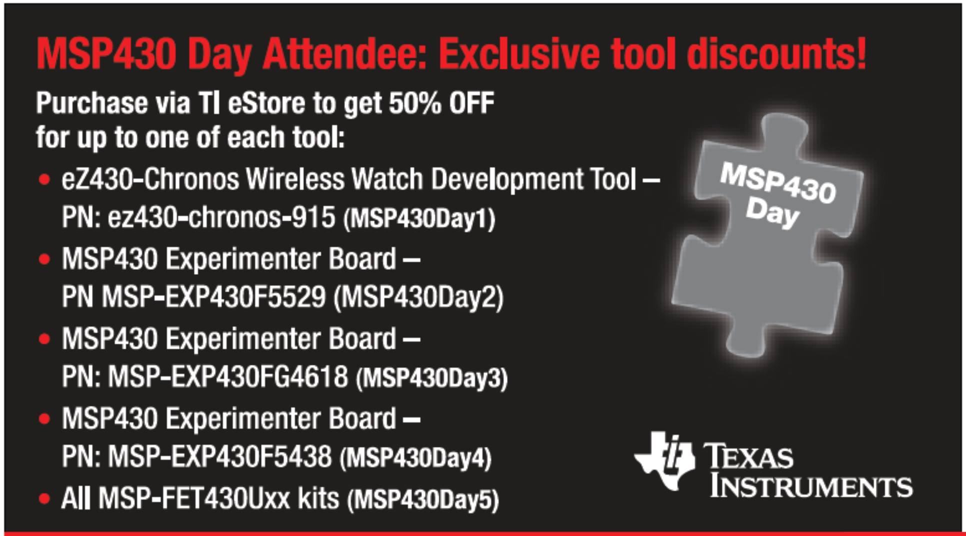
8 Tailor your design with intelligent peripherals for ultra low power, advanced motor control and connectivity
7 Drive quick development with royalty-free software libraries
6 Save cost with integrated op amps, 24-bit sigma-delta converters and ultra-low-power management systems
5 Get active community support 24/7 via TI's E2E™ and open source development communities
4 Access the broadest, most localized support in the industry
3 Get hands-on training with TI Tech Days, MCU Days, TI Advanced Technical Conference, online training and more
2 Quickly start development with 100s of kits and tools
1 Easily find the right MCU for your app from TI's portfolio of 500+ devices

www.ti.com/make-the-switch

EXCLUSIVE MSP430 and Stellaris Tool Discounts!



MSP430 Day Attendee: Exclusive tool discounts!

Purchase via TI eStore to get 50% OFF for up to one of each tool:

- eZ430-Chronos Wireless Watch Development Tool – PN: ez430-chronos-915 (MSP430Day1)
- MSP430 Experimenter Board – PN MSP-EXP430F5529 (MSP430Day2)
- MSP430 Experimenter Board – PN: MSP-EXP430FG4618 (MSP430Day3)
- MSP430 Experimenter Board – PN: MSP-EXP430F5438 (MSP430Day4)
- All MSP-FET430Uxx kits (MSP430Day5)

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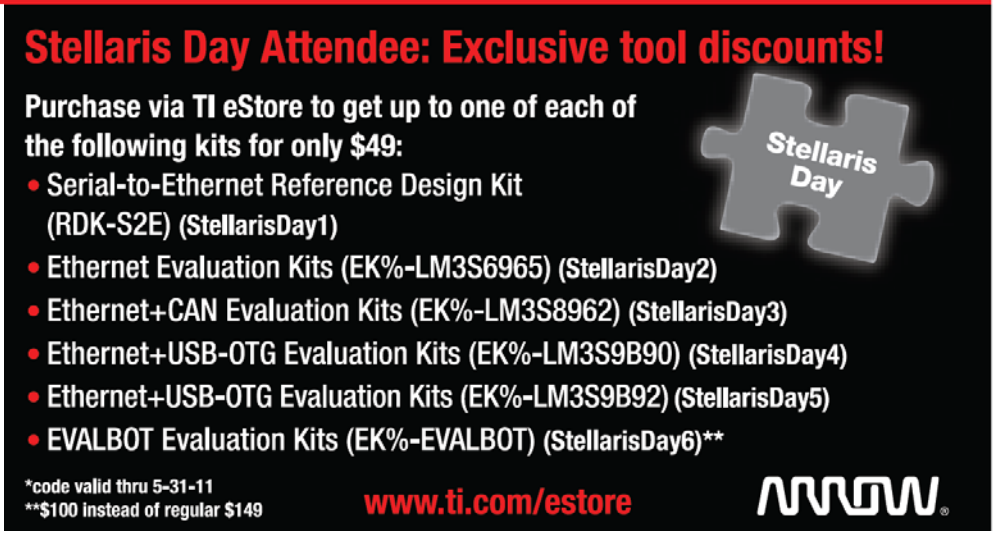
Pick up a promo card and take advantage of these great deals!

Codes will be live for a month after the event and will expire May 31st

Presentations will be posted on
www.ti.com/embeddedseries
the day of the event



Stellaris Day

Stellaris Day Attendee: Exclusive tool discounts!

Purchase via TI eStore to get up to one of each of the following kits for only $49:

- Serial-to-Ethernet Reference Design Kit (RDK-S2E) (StellarisDay1)
- Ethernet Evaluation Kits (EK%-LM3S6965) (StellarisDay2)
- Ethernet+CAN Evaluation Kits (EK%-LM3S8962) (StellarisDay3)
- Ethernet+USB-OTG Evaluation Kits (EK%-LM3S9B90) (StellarisDay4)
- Ethernet+USB-OTG Evaluation Kits (EK%-LM3S9B92) (StellarisDay5)
- EVALBOT Evaluation Kits (EK%-EVALBOT) (StellarisDay6)**

*code valid thru 5-31-11
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External Peripheral Interface (EPI)

- Multiple device types supported
  - Machine-to-Machine: Wide parallel interfaces for fast communications
    - For instance, CPLDs and FPGAs
    - Data widths up to 32-bits, data rates up to 150 Mbytes/second
    - Optional address sizes from 4 bits to 20 bits
    - Optional clock output, read/write strobes, framing (with counter-based size), and clock-enable input
- Other features
  - General parallel GPIO, FIFOed with speed control – for custom peripherals or digital controls
  - Blocking and non-blocking reads
  - FIFOed writes separate the processor from timing details
  - Direct memory access (DMA)

Interface Options – Why not drive directly?

- LCD interfaces could theoretically be driven directly from the MCU when there are enough pins.
- If no controller IC is present, EVERY pixel needs to be re-drawn multiple times per second (typically 60) to avoid screen flicker.
- Pixel data to be written needs to be stored locally. Assuming 16-bit color, that's 16 bits per pixel. Simple example:

Screen: 320x240, 16-bit color
Assumptions: Single cycle GPIO writes, ignoring VSYNC and HSYNC, signaling requires 3 GPIO ports (2 for data, 1 for control)

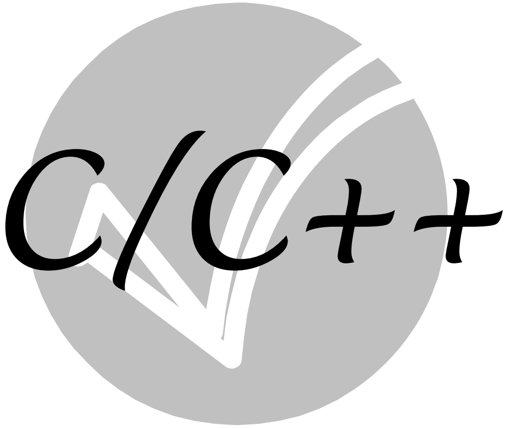
320 * 240 = 76,800 pixels
16-bit color = 76,800 x 16 bits (2 bytes) = 153,600 bytes for frame buffer
76,800 * 3 cycles (1 for each GPIO port write) = 230,400 cycles
60 fps = 230,400 * 60 = 13,824,000 cycles

Interface Options – Why not drive directly?

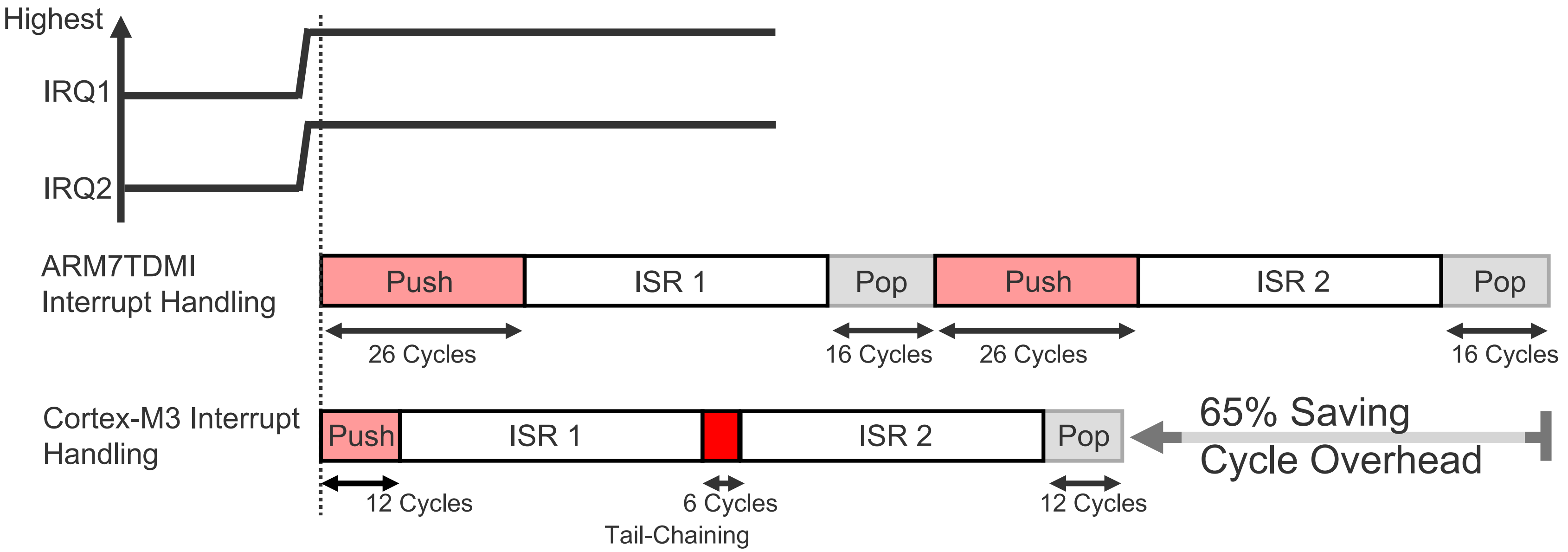
- From the example, it takes 13,824,000 cycles per second just to draw the frame buffer.
  - This does not take into account memory access for the frame buffer.
  - This does not take into account HSYNC and VSYNC.
- Stellaris devices don’t have enough internal SRAM to locally store the frame buffer on most displays.
  - External, slower memory is required to store frame buffer.
  - Assuming 4 cycles per pixel (16-bit parallel interface via EPI), that’s an additional 18,432,000 cycles per second. In reality it will most likely take more than 4 cycles per access.
- When factoring in access to external memory and the precise timing requirements required for the SYNC signals, doing something simple like drawing the frame buffer consumes most (if not all) of the CPU cycles!

No Assembly Required!

- Cortex-M3 has complete hardware support for interrupts
  - Interrupt Service Routines (ISRs) are purely written in C/C++
  - Interrupt setup is easily done in C/C++
    - C/C++ array which contains the vectors (pointers to the C/C++ functions)
    - Pointer to the stack (a C/C++ array)
- No boot code ASM, no system configuration ASM
  - ARM7 compilers normally come with an ASM boot routine (in object form) that does setup
  - For Cortex-M3, no boot routine is needed
    - Cortex-M3 hardware loads the stack pointer from memory and the initial PC from memory and enters as a normal C function
  - User C/C++ code is all that is required
- Entire software code base can be written in C/C++
  - ISRs
  - RTOS
  - Application code



Interrupt Response – Tail Chaining



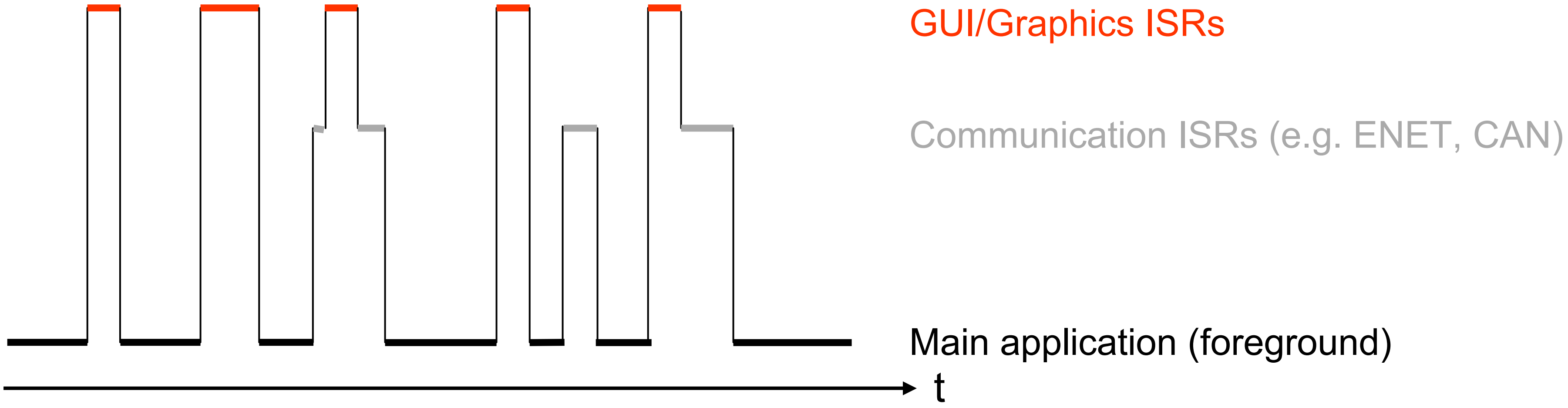
ARM7TDMI

- 26 cycles from IRQ1 to ISR1
  - (up to 42 cycles if in LSM)
- 42 cycles from ISR1 exit to ISR2 entry
- 16 cycles to return from ISR2

Cortex-M3

- 12 cycles from IRQ1 to ISR1
  - (Interruptible/Continual LSM)
- 6 cycles from ISR1 exit to ISR2 entry
- 12 cycles to return from ISR2

How it works on Cortex-M3


GUI/Graphics ISRs
Communication ISRs (e.g. ENET, CAN)
Main application (foreground)
t

- Main application runs as foreground (base level)
  - Easy to write since no "factoring" – just normal application or RTOS based
  - Can use PLC style state-machine poll loop safely: ISRs keep data available
- ISRs for the GUI and graphics are highest priority(ies)
  - This keeps the UI responsive and fast
- ISRs for communications below that
  - Ethernet, CAN, serial, etc.
- May use other priorities as needed
  - Very fast interrupt response time, true nested interrupts, priority masking, easy ISR setup all contribute to making an easy solution
  - Application uses priority masking vs. interrupt-disable if needs critical region

RTOS Support for Stellaris

KEIL An ARM® Company	RTX flexible royalty-free RTOS with source code
IAR SYSTEMS	PowerPac™ fully featured RTOS combined with a high performance file system
CMX SYSTEMS	CMX-RTX™ RTOS offering small footprint, fast context switch times
SEGGER	embOS RTOS for embedded applications designed
Quadros Systems Inc.	RTXC for embedded applications
SCIOPTA	SCIOPTA real-time operating system for safety-critical applications
RoweBots	Unison Ultra Tiny Embedded Linux and POSIX Compatible RTOS
Micrium	Portable, scalable, preemptive real-time, multitasking kernel (RTOS)
expresslogic	ThreadX advanced RTOS designed specifically for deeply embedded applications
freeRTOS™	FreeRTOS.org™ Open-Source mini real time kernel

RTOS Support for Stellaris

Industry RTOS Basics	FreeRTOS
Scheduler (policy, threads)	Pre-emptive (3 thread types)
Small footprint, fast execution	Very small (<5KB), fast (uC-specific)
Dynamic/static declarations	Threads (dyn), data (static/dynamic)
Object based	Yes
User APIs (via library or src)	3 C source files provide entire kernel
File Mgmt (nice-to-have)	yes, but not built in
Cost – $0+	$Free$

OPENRTOS

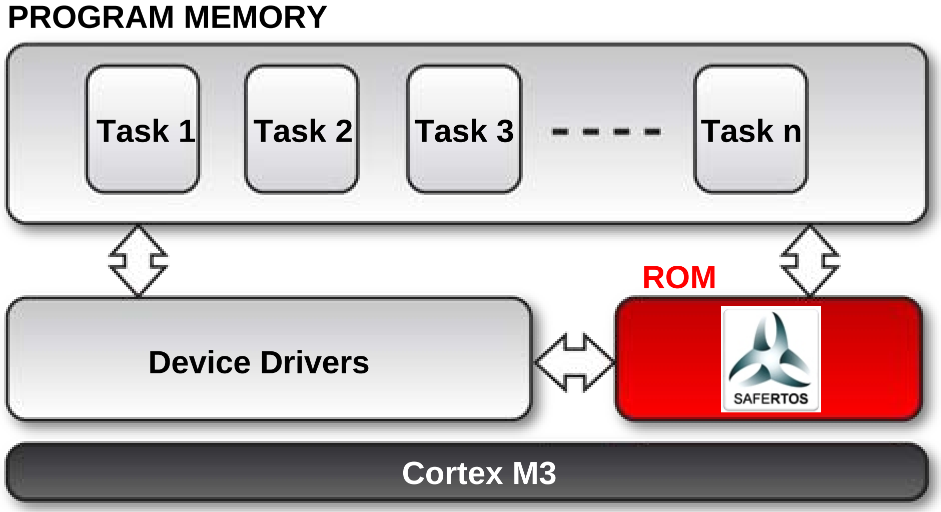
- Can upgrade from freeRTOS
- <5KB (ROMable)
- Supports MSP430 and Stellaris
- Commercial license ($2500+)

SAFERTOS

- Can upgrade from freeRTOS
- Certified IEC 61508 (TUV SUD) SIL3 (Safety Integrity Level)
- Aerospace/medical apps
- $65K license
- ROM'd (LM3S9B96)

SAFERTOS included in the LM3S9B96

- High-integrity RTOS in ROM
- Can be used as a standard operating system *OR* as part of a high-integrity application which requires certification to **IEC61508** or **FDA510(k)**
- RTOS **value $65k free** with Tempest LM3S9B96



- Integrated hardware/software solution shortens the time to market and significantly reduces cost for **Industrial** and **Medical** Applications
- Innovative *Design Assurance Pack* available separately from WITTENSTEIN provides **complete turnkey evidence** and process documentation