An Introduction to TMS570LS Microcontrollers from Texas Instruments
Agenda

• Introduction and Roadmap
• Development Tools: Hardware kits, Software tools
• Safety Overview and Modules
  – Lab 1: TMS570 Safety MCU Demos
• TMS570LS Architecture: Memory Map, Clocking, Exceptions
• Embedded Flash Memory tools: nowECC, nowFlash, Application Programmer Interface (API)
• Real Time Interrupt (RTI)
• Vectored Interrupt Manager (VIM)
• Direct Memory Access (DMA)
• General-purpose I/O (GIO)
• Programmable Timer Unit with Transfer Unit (NHET/HTU)
  – Lab 2: Using NHET as GIO
• Multi-Buffered Serial Peripheral Interface (MibSPI)
• Controller Area Network (DCAN)
• FlexRay Interface with Transfer Unit (ERAY/FTU)
• Local Interconnect Network (LIN) / Serial Communication Interface (SCI)
  – Lab 3: PC to SCI Communication
• External Memory Interface (EMIF) / Parameter Overlay (POM)
• Multi-buffered Analog-to-Digital Converter (MibADC)
• Support Structure: Web, Forum, WIKI
TMS570LS: Introduction and Roadmap
# TI Embedded Processing Portfolio

## Microcontrollers

<table>
<thead>
<tr>
<th>16-bit</th>
<th>32-bit</th>
<th>32-bit</th>
<th>32-bit</th>
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<tbody>
<tr>
<td>32-bit Real-time</td>
<td>M3 ARM</td>
<td>R4F ARM</td>
<td>ARM+DSP</td>
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### MSP430
- Ultra-low Power
- Up to 25 MHz
- Flash 1 KB to 256 KB
- Analog I/O, ADC, LCD, USB, RF
- Measurement, Sensing, General Purpose
- $0.49 to $9.00

### C2000
- Fixed & Floating Point
- Up to 300 MHz
- Flash 32 KB to 512 KB
- PWM, ADC, CAN, SPI, I²C
- Motor Control, Digital Power, Lighting
- $1.50 to $20.00

### Stellaris-M3
- Industry Std Low Power
- <100 MHz
- Flash Up to 512 KB
- USB, ENET, ADC, PWM, CAN
- $1.00 to $7.00

### TMS570
- Floating Point
- Up to 220 MHz
- Flash
- Up to 3 MB
- USB, ENET, ADC, PWM, CAN
- Safety SIL3 Control
- $8.00 to $20.00

### ARM9/ARM Cortex-A8
- Industry-Std Core, High-Perf GPP
- Accelerators
- MMU
- USB, LCD, MMC, EMAC
- Linux/WinCE User Apps
- $8.00 to $35.00

### ARM9/Cortex-A8 plus C64x+
- Industry-Std Core + DSP for Signal Proc.
- 4800 MMACs/1.07 DMIPS/MHz
- MMU, Cache
- VPSS, USB, EMAC, MMC
- Lin/Win O/S + Video, Imag, MM
- $12.00 to $65.00

### C55x, C64x+ C647x
- Leadership DSP Performance
- 24,000 MMACS
- Up to 3 MB L2 Cache
- 1G EMAC, SRIO, DDR2, PCI-66
- Comm, WiMAX, Industrial/Medical Imaging
- $4.00 to $99+

## ARM Core Offerings

<table>
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<th>ARM9</th>
<th>ARM Cortex-A8</th>
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<td>MMU</td>
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<tr>
<td>MMU, Cache</td>
<td>Lin/Win O/S + Video, Imag, MM</td>
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## Applications Processors / DSP

- ARM9
- ARM Cortex-A8

## Software, Tools & BSPs
TMS570: MCU for Transportation

Traditional Auto Safety
- Airbag
- ABS/ESC

Growing Auto Market
- Steering
- Chassis Domain
- HEV/EV

Growing Transportation
- Railway
- AeroSpace
- Off Road Equipment
- Marine Engine
TMS570 Setting the Standard for Safety-Critical Automotive & Transportation Applications

Real-Time Control
ARM Cortex-R4F with floating point allows development of complex real-time control algorithms

Safety Architecture
Safety architecture specifically developed to simplify SIL3 / ASIL D system implementations

System Approach
Proven scalability, integration, support and broad automotive portfolio get customers to market fast
TMSx70 Family Roadmap

Broad and Scalable for Transportation Applications

- **Sampling**
- **Development**
- **Concept**

**LS2x Series**
- Lockstep dual R4F
- up to 160MHz/250 DMIPS
- up to 2MB Flash; 160kB RAM
- TMS 4Q10

**TMS470M**
- up to 80MHz/96 DMIPS
- up to 640 kB Flash; up to 128KB E2emu
- up to 64kB RAM
- TMS 4Q10

**MC4x Series**
- Lockstep or Multicore Dual R4F
- over 225MHz on R4
- up to 4MB Flash; 512kB RAM
- TMS 3Q13

**LS3x Series**
- Lockstep dual R4F
- up to 180MHz/
- up to 3MB Flash; 256kB RAM
- TMS 3Q12

**LS1x Series**
- Lockstep dual R4F
- up to 160MHz/250 DMIPS
- up to 2MB Flash; 160kB RAM
- TMS 4Q10

**Lower Cost Roadmap**

Samples available NOW 2011 2012
TMS570LS Development Tools
# MCU development support

## Software Development Support

<table>
<thead>
<tr>
<th>IDE (Compiler/Linker/Debugger)</th>
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<tr>
<td>• TI Code Composer Studio, iSYSTEM WINIDEA, Lauterbach TRACE32, ARM RealView, etc…</td>
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<tr>
<th>AutoSAR 3.0</th>
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<tr>
<td>• MCAL and RTE available from Vector</td>
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<tr>
<th>FlexRay™ Drivers</th>
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<td>• Available from Elektrobit and TTTech Automotive</td>
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## Hardware Emulation Tools

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<tr>
<th>TMS570 supports “Standard ARM” Coresight™ debug components</th>
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<tr>
<td>• ETM with up to 32b external bus and internal FIFO for improved throughput</td>
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<th>JTAG debug and trace solutions:</th>
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<td>• iSYSTEM, Lauterbach, Sophia, Spectrum Digital</td>
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<tr>
<th>TMS570 Evaluation Modules (EVMs) with integrated JTAG</th>
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## Prototyping Tools

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<th>TMS570 provides high bandwidth interfaces for bypass and calibration</th>
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<tr>
<td>• Vector VX1000 provides up to 3MB/sec using RTP/DMM</td>
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<th>Auto-code Generation</th>
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<tr>
<td>• Mathworks Real Time Workshop, ETAS ASCET</td>
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<th>Bypass processing and calibration</th>
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<tr>
<td>• Vector VX1000/CANape</td>
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Development Kits

- TMDX570LS20SMDK
  - $695
  - Full Featured TMS570 Microcontroller Development Kit

- TMDX570LS20SUSB
  - $79
  - Low Cost TMS570 Evaluation Kit

- Software Included in Each Kit:
  - CCStudio v4.1 IDE
    - Includes C/C++ Compiler/Linker/Debugger
  - HalCoGen Peripheral Driver Generation Tool
  - Flash programming integrated into CCS
  - HET GUI/Simulator/Assembler
  - Demo Project/Code Examples
Microcontroller Development Kit (MDK)

• CPU Card
  – Connects to COMM Board
  – On Board XDS100v2 emulation via USB
  – Trace Connectors
  – Access to Peripheral Pins

• COMM Board
  – Light & Temperature Sensors
  – Sensor Interfaces
  – FlexRay/CAN/LIN Transceivers
  – Color Touch Screen TFT

• DEV Kit
  – $695 USD (CPU + COMM Board)
  – Orderable Part #TMDX570LS20SMDK
  – CCS 4.1 SW IDE included
  – Power Supply
Microcontroller USB Kit

- **Main Features**
  - USB Powered
  - On Board USB XDS100v2 JTAG Debug
  - On Board SCI to PC Serial Communication
  - Access to Select Signal Pin Test Points
  - LEDs, Temp Sensor, Light Sensor and CAN transceiver
  - 144 QFP Packaged CPU

- **$79 USD (CPU + COMM Board)**
  - Orderable Part #TMDX570LS20SUSB
  - CCS 4.1 SW IDE included
  - Power Supply
Code Composer Studio v4.1

- Based on Eclipse industry standard for embedded debug tools
  - Modern window environment
  - Advanced source code editor
  - Scalable multi-core/processor environment
  - Program and Debug Application via JTAG
  - Test Automation via Scripting

- Low cost tools enable developers to easily evaluate and start development
  - Develop with CCS for <$100

- TMS570 Debug Features
  - 6 Hardware Breakpoints
  - Unlimited Software Breakpoints
  - Integrated Flash Programming
Code Composer Studio Components:
Fully Integrated, Easy to Use Development Tools

Menus or Icons

Target Connection
- Source & object files
- File dependencies
- Compiler, assembler & linker build options

Source Code View

Disassembly Window

CPU Window

Memory Window

Watch Window

Help
HalCoGen: Hardware Abstraction Layer Code Generator

Features
- User Input on High Abstraction Level
  - Graphical-based code generation
  - Easy configuration
  - Quick start for new projects
- Generates C Source Code
  - ANSI Conforming
  - Clear, structured, coding style
  - Customizable code for user maintenance
- Supported Peripherals
  - System Module
  - RTI
  - GIO
  - SCI/LIN
  - CAN
  - SPI
  - ADC
  - Timer Co-processor (nHET)
- Interactive Help System
  - Describes tool features and functions
  - Provides detailed dependency graphs
  - Provides useful example code
  - Tool tip help available
- Hierarchical project code viewing
HET GUI / Simulator

Helps Customers Not Familiar With High End Timer Module to Program the Timer with a Graphical Interface
HET GUI w/ SynaptiCAD - Waveform Display

Select pins for waveform

Allows for input waveform generation
Tools Roadmap

External Tools:

- IDE’s
  - Lauterbach, iSystems, IAR, Keil / ARM, Hitex
- Compiler
  - IAR, ARM, GCC, …
- Emulator
  - Spectrum Digital, Lauterbach, iSystems, IAR, Keil, Blackhawk, Segger, Signum Systems, …
- Operating System
  - ETAS, Vector, Sciopta, Wittenstein, Micrium, …
- AutoSAR
  - Vector, ElectroBit
- Trace / Calibration
  - Lauterbach, iSystems, Vector, ETAS, Sophia Systems
- Production Flash Programming
  - BP Microsystems, Data-IO
- Rapid Prototyping
  - Matlab/Simulink, dSpace
Safety Features on TMS570LS Microcontrollers
Exida Has Certified TMS570LS20216S SIL3 Capable
Rationale of TI Safety Concept

• “Safe Island” approach

• Region of device common to all safety functions is heavily protected by hardware diagnostic measures
  – CPU
  – CPU Interrupts
  – System control of power, reset, clock
  – OS critical IP: DMA, OS timer

• Once a known safe region can be guaranteed, logic in this region can be used to provide diagnostic coverage on other regions

• This partition has shown to give strong safety metrics while minimizing impact of safety on system BOM cost
Safety Features Overview

- Dual Core Lockstep - Cycle by Cycle CPU Fail Safe Detection
- CPU Self Test Controller requires little S/W overhead
- ECC for Flash / RAM Evaluated inside the Cortex R4F
- Parity on all Peripheral, DMA and Interrupt controller RAMS
- Memory BIST on all RAMS allows fast memory test at startup
- On-Chip Clock and Voltage Monitoring
- Error Signaling Module w/ External Error Pin
- CRC, IO Loop Back, ADC Self Test, …
- 3 domains identified:
  - Not safety critical functions (black)
  - Core functionality common to all Safety Instrumented Functions (red)
  - Peripheral functionality specific to specific Safety Instrumented Functions (blue)
1001D Dual Core Safety Concept

• Unique design to reduce common cause failures (βIC)
  – Second CPU mirrored and rotated
  – Minimum distance 100µm between CPUs
  – Cycle delayed lockstep
  – Guard ring per CPU
  – Duplicated clock tree per CPU

• CPU Compare Module
  – Self-test capability
  – Self-test error injection/error forcing
  – Output error injection
CPU Self Test Controller (STC/LBIST)

- Provides High Diagnostic Coverage
- Significantly Lowers S/W and Runtime Overhead
- No SW BIST (Built In Self Test) Code overhead in Flash
- Simple to configure and start BIST via register
Flash / RAM ECC Protection

- ECC evaluated in the Cortex R4F CPU
  - Single Bit Error Correction and Double Bit Error Detection
  - ECC evaluated in parallel to processing data/instructions
  - No latency or performance impact
  - Protects Busses from CPU to Flash and RAM
Programmable Memory BIST (PBIST)

- All on-chip RAMS can be tested
- Run at startup
- Multiple Memory Test Algorithms
- Detects multiple failure modes
Safety Aspects of Network Interfaces

- Networked peripherals (FlexRay, DCAN, and SCI/LIN) are considered grey-channel / black-channel communications

- In such communications application level protocols (time redundancy, CRC in data packet, etc.) are necessary

- When such assumption is made, the Dangerous Undetected Failure from the network is effectively not measurable (<0.001 Failure In Time (FIT))

- Detailed fault data available upon request
Error Signaling Module (ESM)
ESM Features

• ESM functions
  – Up to 96 error channels, divided into 3 different groups
    • 32 channels with configurable output for interrupt and error behavior
    • 32 channels with predefined output for interrupt and error behavior
    • 32 channels with predefined output for error behavior
  – Error pin to signal severe device failure
  – Configurable timebase for error signal
  – Error forcing capability for self test

• ESM hardware
  – Indicates severe device failure at an external pin (nERROR)
  – Hardware assistance for prioritizing error sources
Additional Safety Features

- Supply monitor (VMON)
  - Asserts reset if core or I/O supply exceeds defined min/max thresholds

- Clock monitoring
  - Oscillator monitor
    - Detects failure if oscillator frequency exceeds defined min/max thresholds
    - Selectable hardware response on oscillator fail
  - PLL slip detector
    - Indicates PLL slip if phase lock is lost
    - Selectable hardware response on PLL slip
    - Internal backup ‘low power oscillator’ (LPO) clock source
  - External clock prescaler
    - Allows external monitoring of CPU clock frequency

- Dedicated Memory Protection Units for each bus master
LAB1: TMS570LS Safety Features Demo
Lab1: TMS570 Safety MCU Demos