TI Technology Days 2010

Essential concepts of complex SOC & Linux Development Tutorial on TI processors

Syed Mohammed Khasim

Software Architect – ARM MPU

“System on a chip”

- **TI’s Sitara™ DaVinci™ & OMAP™ family of processors truly integrate an entire embedded “system” into a single device.**
  - **ARM, Accelerators (DSP, 3D graphics, Neon) and Peripheral controllers (USB, Video ports, Camera ISP, ….)**
- **This integration offers huge benefits:**
  - **System Cost**
  - **Low Power**
  - **Form Factor**
  - **Performance**

Portfolio of TI's SOCs

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	ARM9/ARM Cortex-A8 MPUs (supports HLOS)	Application-specific processors (supports HLOS)	Low-power fixed-point DSPs	High-perf fixed/ floating-point DSPs	Multi-core DSPs
MSP430™	C2000™ Delfino™ Piccolo™	Stellaris®	Sitara™	DaVinci™ Video Processors OMAP™ mobile application processors	C5000™	C6000™	C647x

TI MCU

ARM Cortex M3

ARM 9 / Cortex A8 Accelerator
NO DSP

ARM 9 / Cortex A8 Accelerator
DSP

TI DSP
No ARM

MPUs – Microprocessors

TI SOC Positioning

OMAP

OMAP™

Smart Phones, MIDs, etc

Davinci

Davinci™ - DM

Video Centric Devices

Sitara

Sitara™ - AM

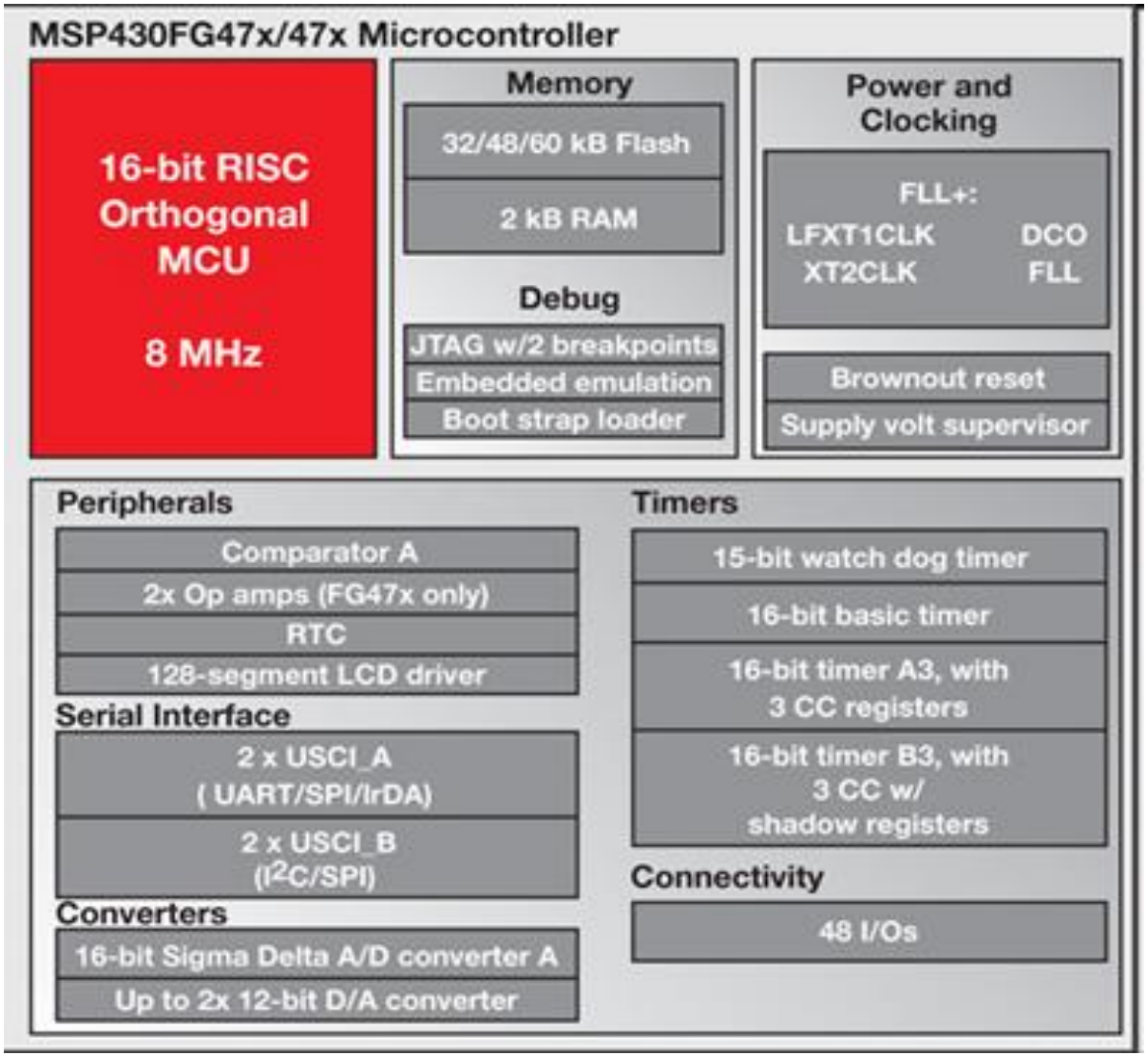
ARM Only Applications

Industrial, Instrumentation, medical

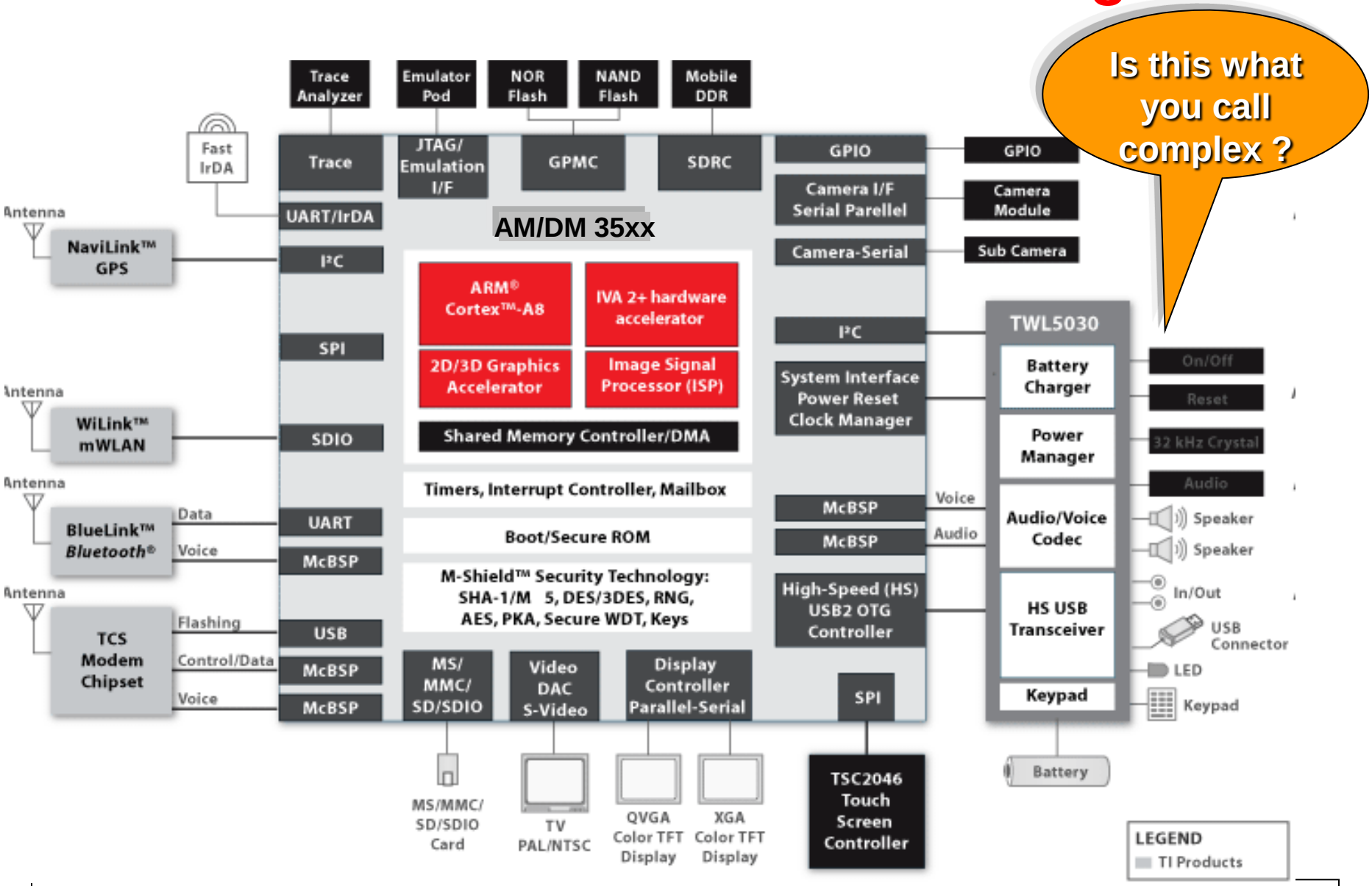
Stellaris

Low Power MCU Applications

MSP430 Microcontroller Block Diagram



OMAP35x / AM-DM 37x Block Diagram



Essential concepts of SOC

The important "essential" concepts of system with high-end SOCs are,

- ARM "High end" programming (Neon, VFB, Thum2, etc …)
- Booting
- External Pin connectivity (PIN MUX)
- Power Management
- Clock Management
- Memory configuration
- Peripheral Controller
- Multi Core Acceleration
- Flash / Storage solutions
- Debugging
- System Validation

ARM "High end" programming

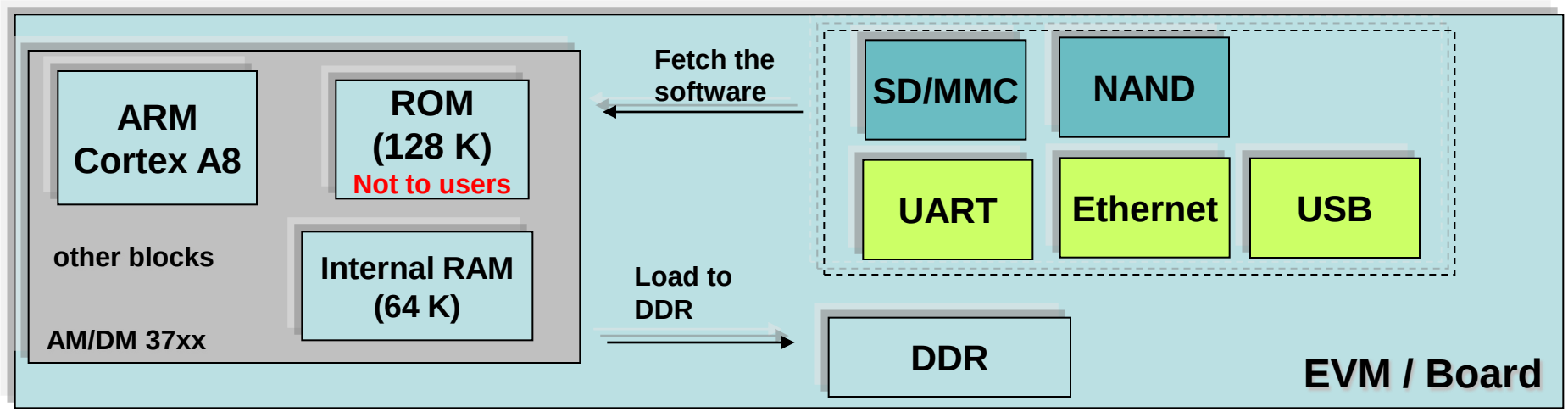
	Cortex A8	Cortex M3
Arch	ARMv7-A	ARMv7-M
Feature	VFP, NEON, Jazelle RCT, Thumb-2, 13-stage superscalar pipeline	Thumb-2 only. Hardware divide instruction.
Cache	Variable (L1+L2), MMU+TrustZone	no cache, MPU optional.
MIPS@Mhz	up to 2000 (2.0 DMIPS/MHz in speed from 500 MHz to greater than 1.5 GHz)	125 DMIPS @ 100 MHz

Detailed comparison : http://en.wikipedia.org/wiki/ARM_architecture

ARM Cortex A8 gets complex

- Software developers get many programmable options.
- Code can be optimized to use NEON, Thumb 2 and VFP accelerators
- Enabling and Handling multi level cache
- Choosing an acceptable MIPS @ MHz for a system in a range (500 – 1.5 GHz) is always confusing
- Recommended to go with an High Level Operating System

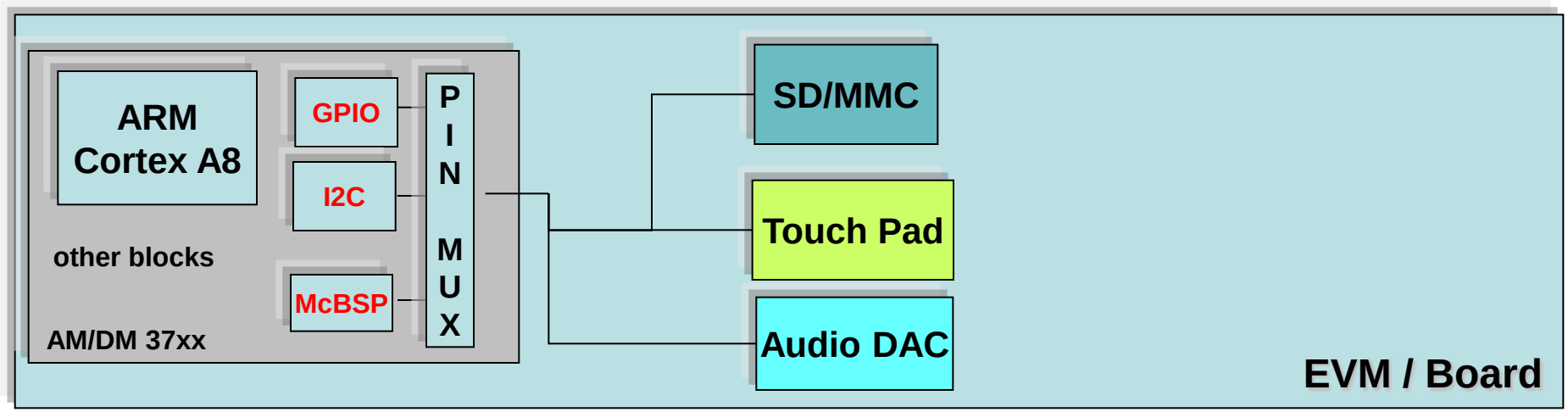
System Booting



System booting involves

- Selecting the Booting mode
  Memory booting
  SD/MMC, NAND, NOR, eMMC, etc
- Peripheral booting
  UART, USB, Ethernet, etc
- Initializing the peripheral and memory devices
- Loading the software and running the same

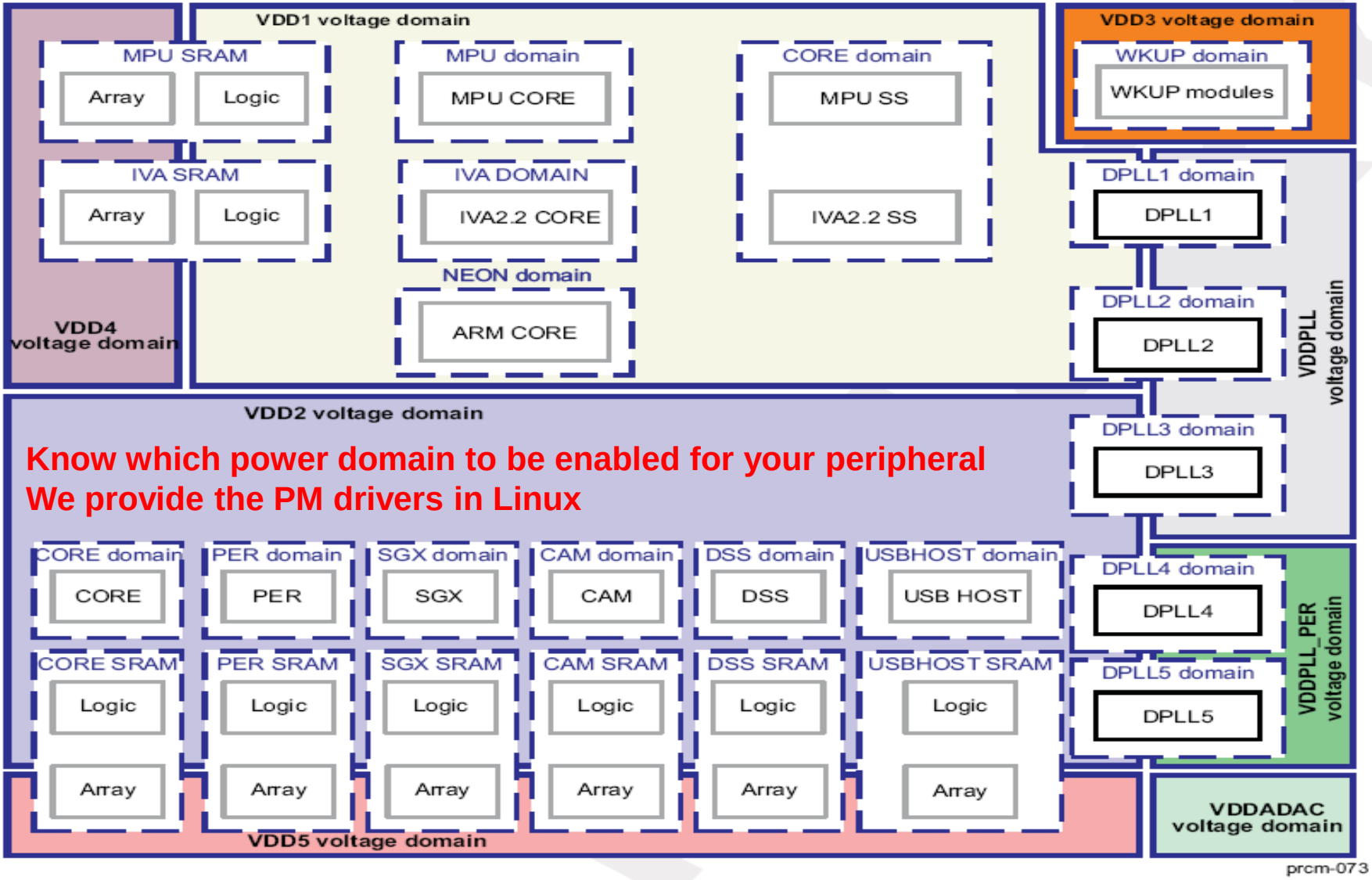
Pin Mux



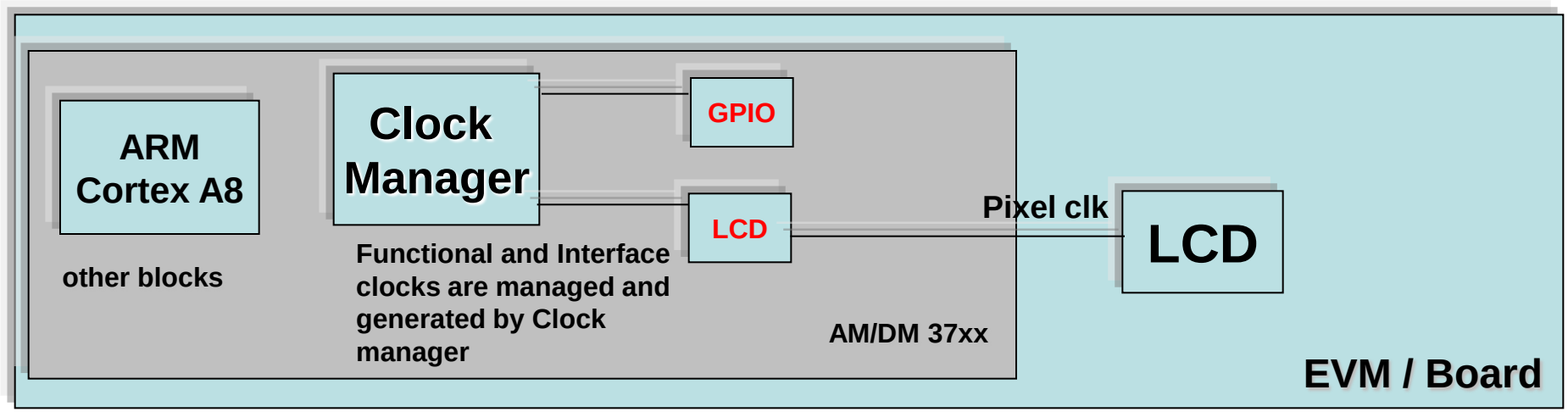
Pin Multiplexing

- The external pins available are less compared to controllers in the system
- But each controller has many instances (3 I2C, 5 McBSP, 6 Blocks of GPIO, e
- Before designing the system use Pin Mux tool
  - Analyze which instance of peripheral to use
  - Avoid clashing of pins
- Pin Mux is software controlled
  - Pin mux is done in u-boot and Linux kernel
  - Use available functions and change the Pin Mux according to the system

Power Partitioning in AM/DM 35x / 37x

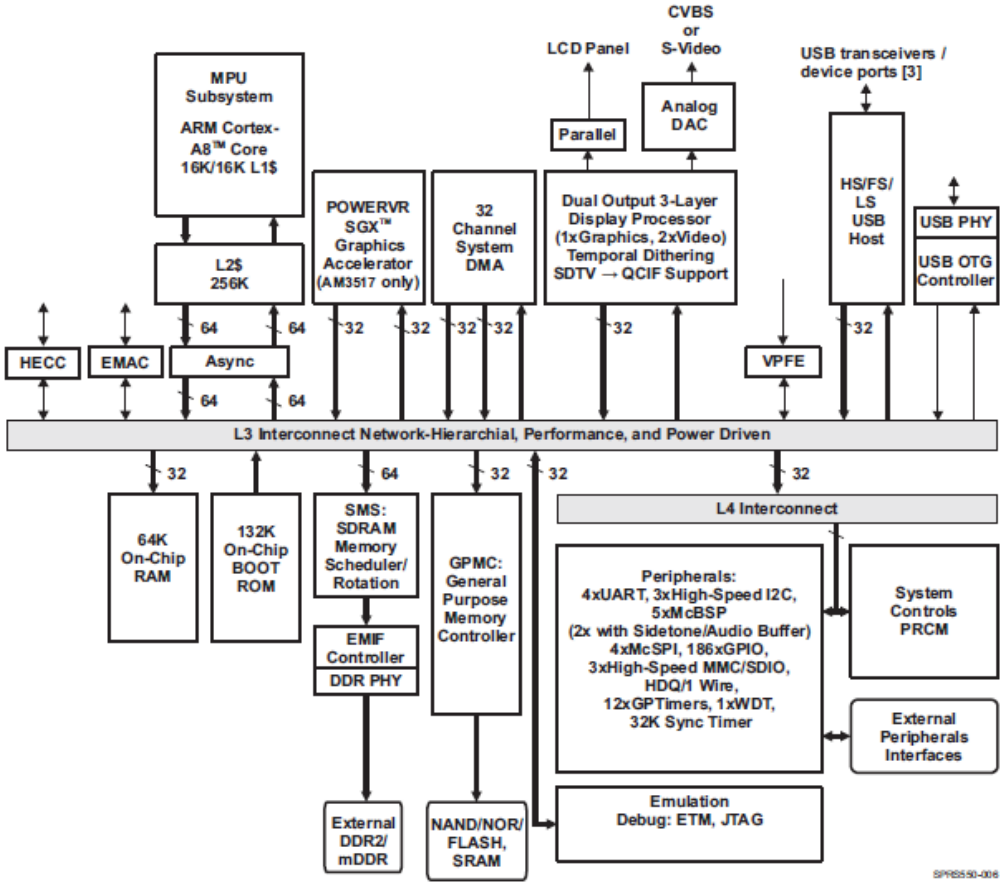


Clock Management



- Each modules needs functional and interface clocks.
- Centralized control for all clock related functionalities include
  - Status (Enable/ Disable), Rate, Dependencies (Clock Tree)
- Reference counting to avoid potential sharing conflicts
- Re-entrant code to handle simultaneous requestors
- Hierarchical
  - Clocks represented as hierarchical tree
  - Taking into account clock dependencies (parent, children)
- Standard open source solution (main lined)
- TI provides drivers, just know what clocks to enable for your product.

Peripheral Controller



TI provides

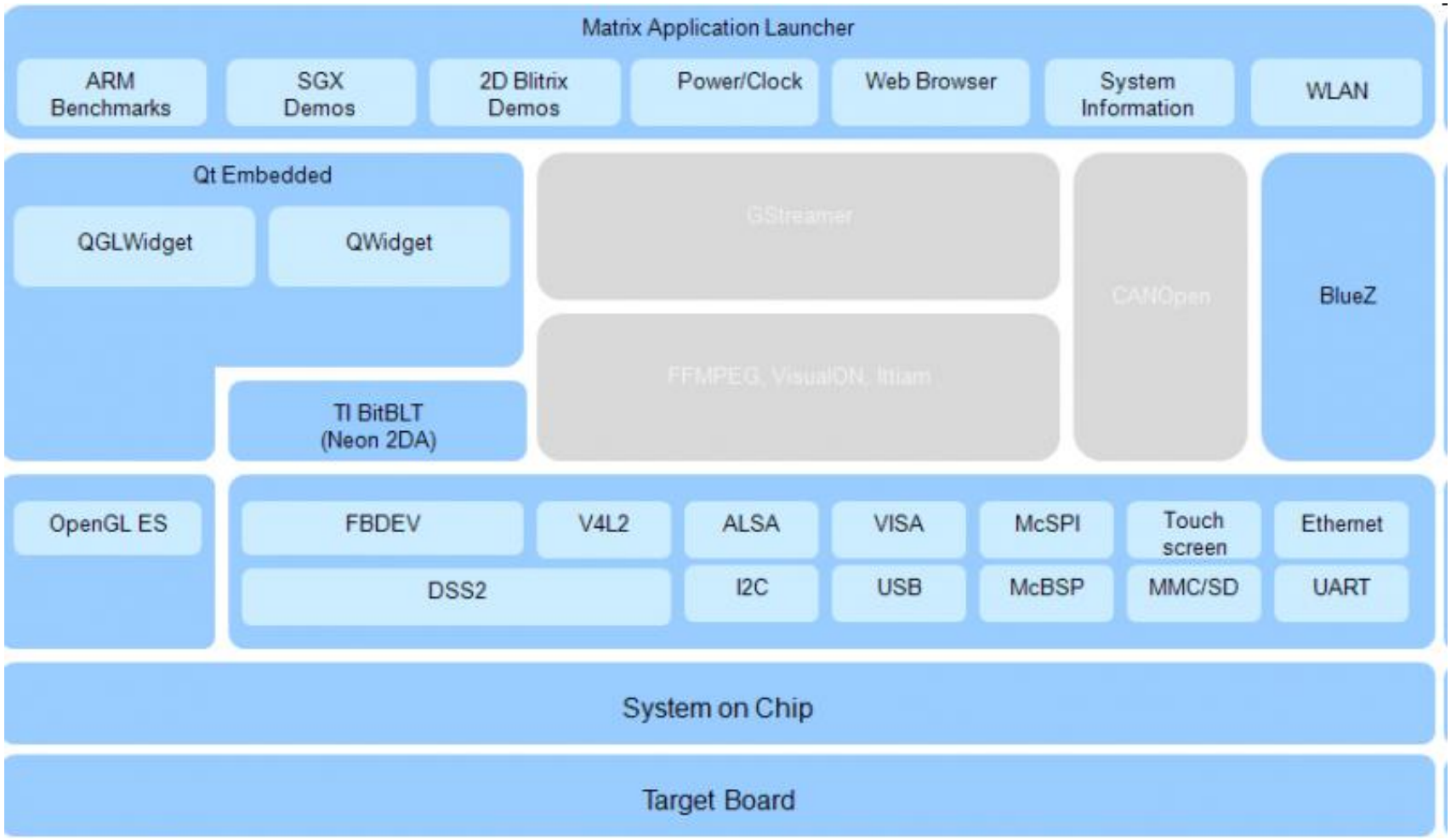
- **Linux device drivers for all the peripheral controllers**
- **Test procedure and sample tests are part of our software release**
- **Understand the peripheral used in your product and enable the Linux device driver for the same**

Handling Multi- core

- Handling Multi-core architecture is easy
- TI offers
  - Linux
  - Android
  - WinCE
- TI uses Open standards to interface multi-core accelerations
  - OpenGL – For SGX / 3D graphics accleration
  - OpenMax – For Multimedia acceleration over DSP

Moving into the world of software

Linux SDK 4.0 Stack



TI Android Stack

System wide tasks for TI include

-Validation / System testing

-Benchmarking

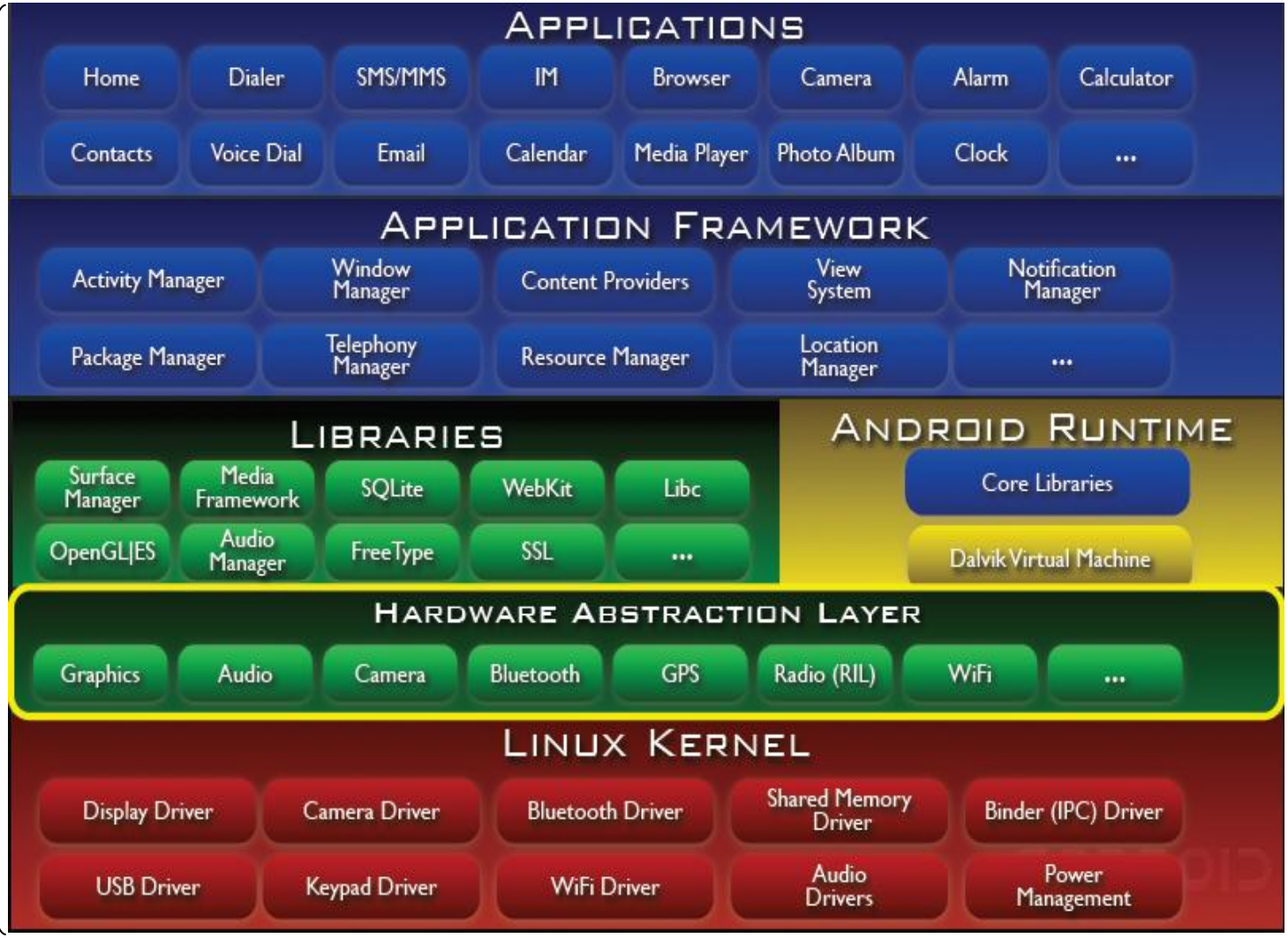
- Get Android CTS

- Design solution to customer problems (NDK, apps, etc)

- Collaterals

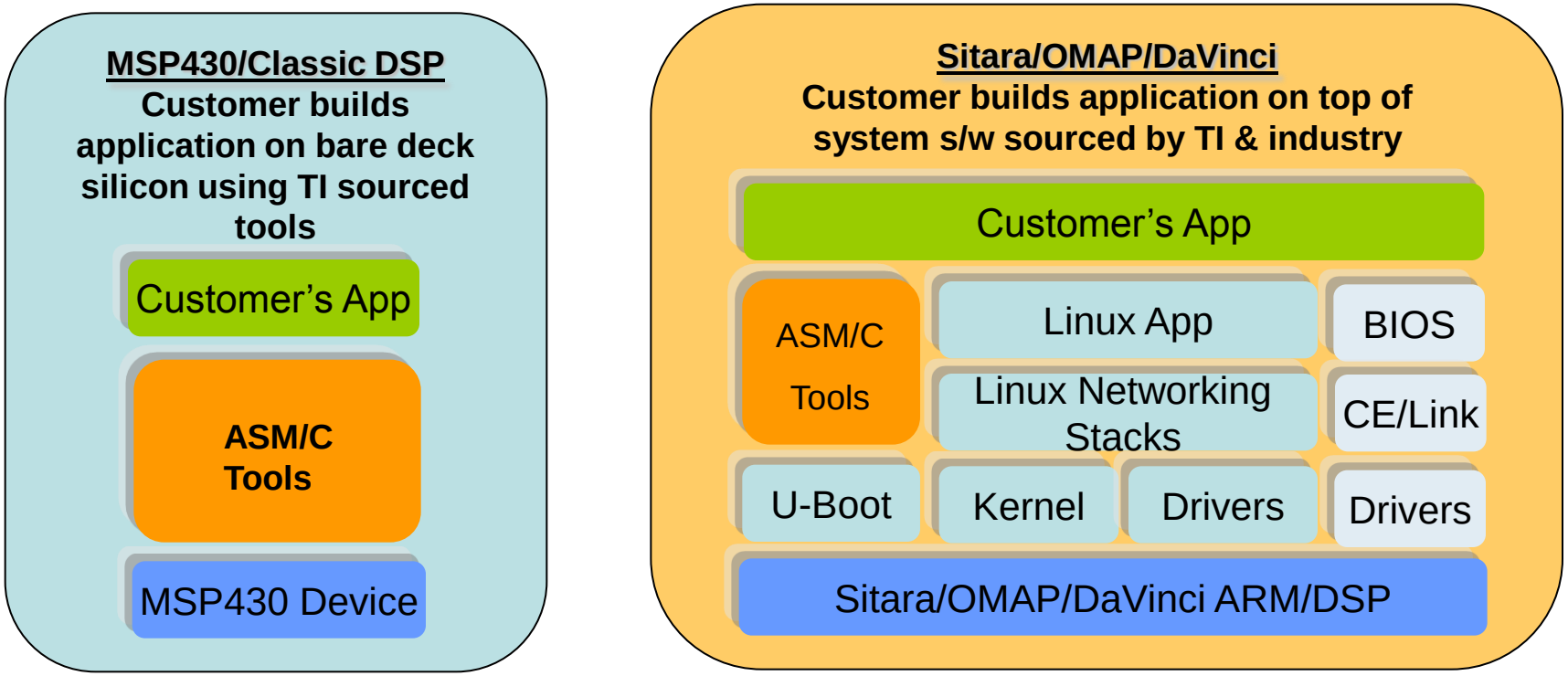
- OOB

- Package and release TI DevKit

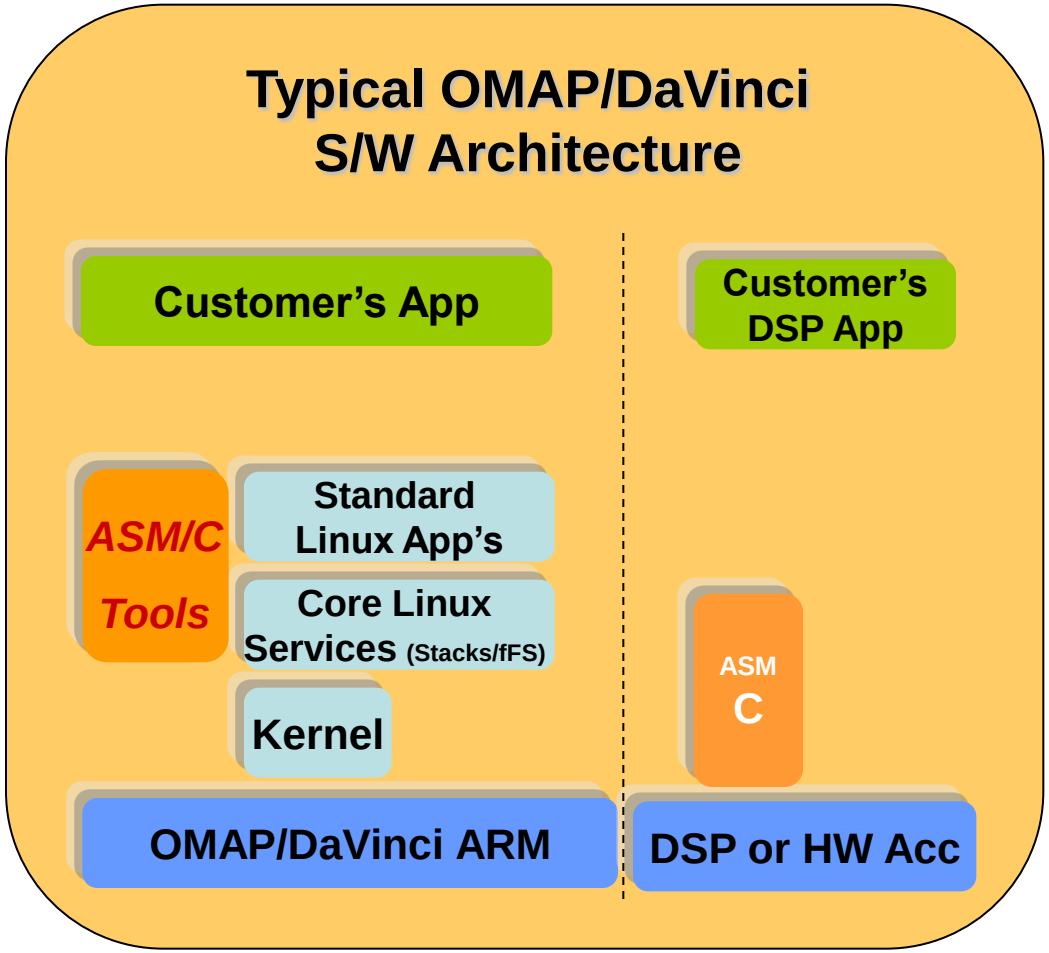


So, how can you develop successfully with Sitara/OMAP/DaVinci?

By using a combination of industry standard and proprietary s/w components, TI enables customers to start their development at the "application level" vs.. starting with the bare deck device.



Dissection of S/W Architectures

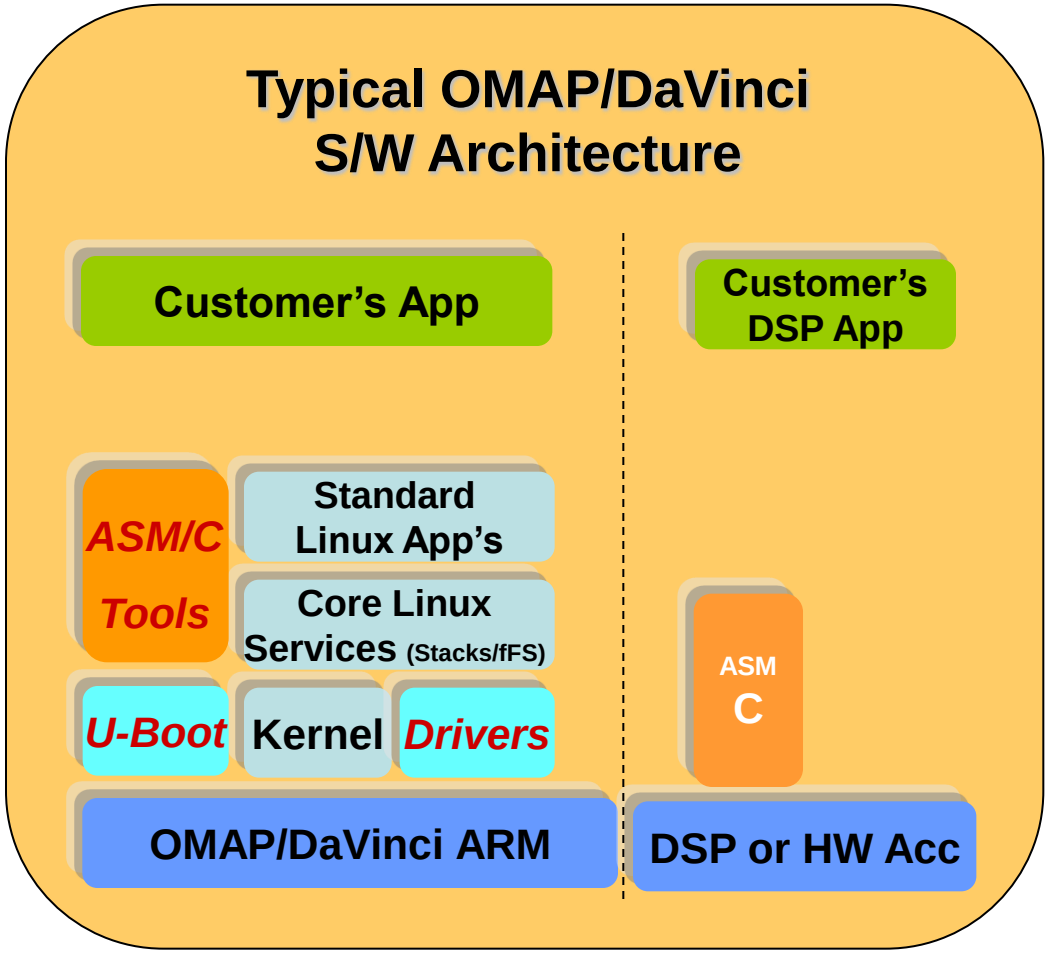


OSs: Linux/WinCE/other

OS's offer customers a "standard" interface to extract useful work from a processor. TI helps establish OS ports and may distribute OS kernels (Linux) as part of our development platforms. However, TI does not have any ownership in creating, maintaining or supporting the core OS components. There are commercial and open source OS options available on OMAP/DaVinci. OS's support many useful services and applications from it's ecosystem.

= Industry Standard OS S/W Component

Dissection of S/W Architectures



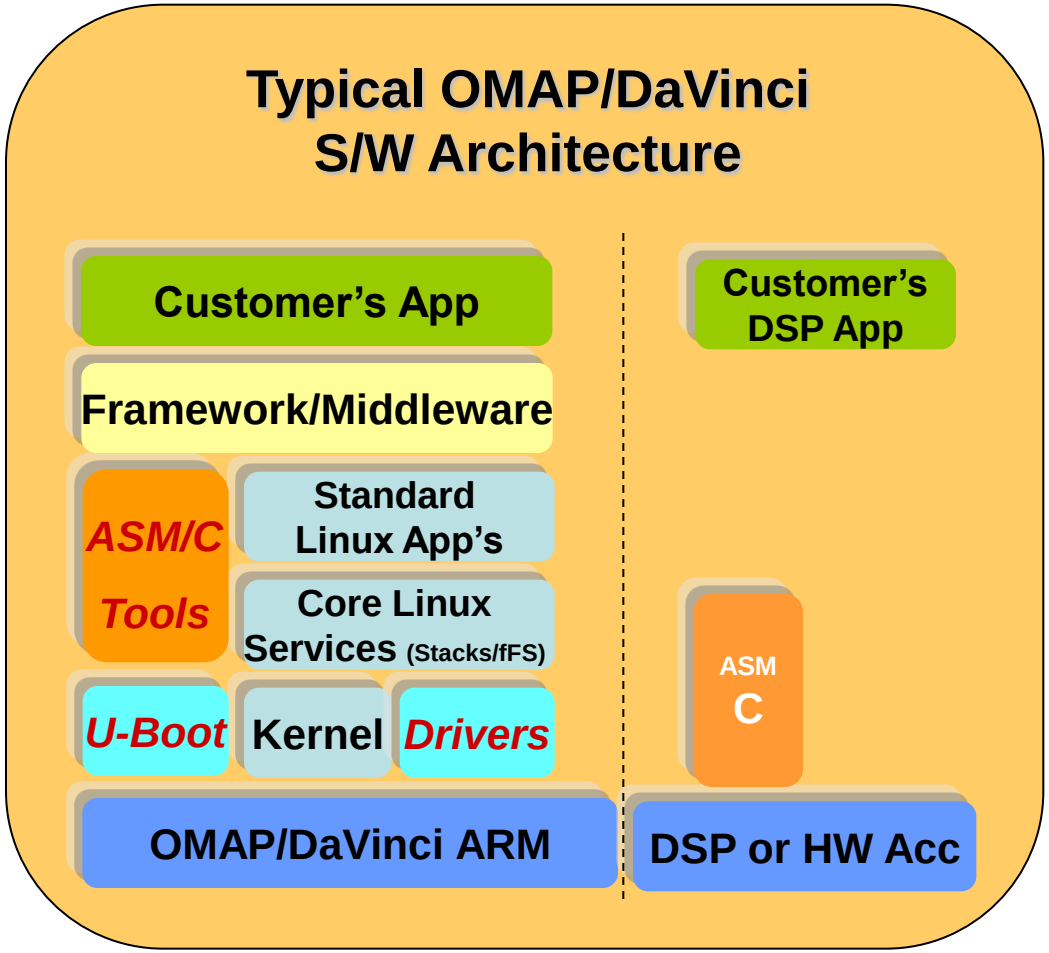
OS PSP Package (DvSDK):

OS's are created in a generic way so they are not bound to any specific processor. In order to use an OS for any specific device, like OMAP or DaVinci someone must port a device specific PSP/LSP s/w package. This work may be completed by TI, the OS vendor, a 3P, the Open Source community or the customer. This s/w is what connects the OS to the h/w and will regulate the functionality and performance of the system.

= Industry Standard OS S/W Component

= PSP/BSP Package: multiple sources

Dissection of S/W Architectures



Frameworks/Middleware

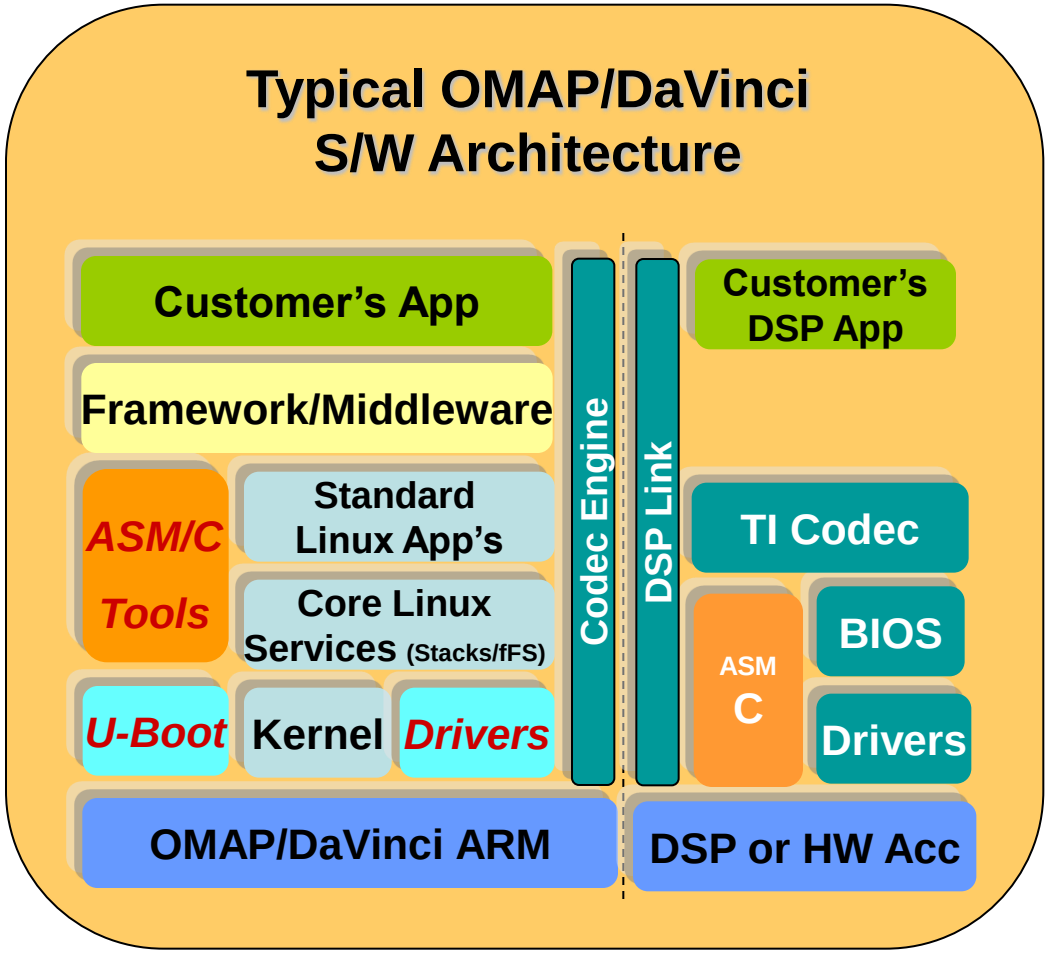
These are application specific s/w packages that use the underlying services enabled by the OS, that enable targeted functionality: MythTV, AVME, browsers (ANT), DRM, VOIP, QT, Flash. There is a large and growing number of these packages from commercial and open source entities. For targeted EE, TI may provide demo or production ready solutions.

= Industry Standard OS S/W Component

= PSP Package: multiple sources

= Frameworks/Middleware: multiple sources

Dissection of S/W Architectures

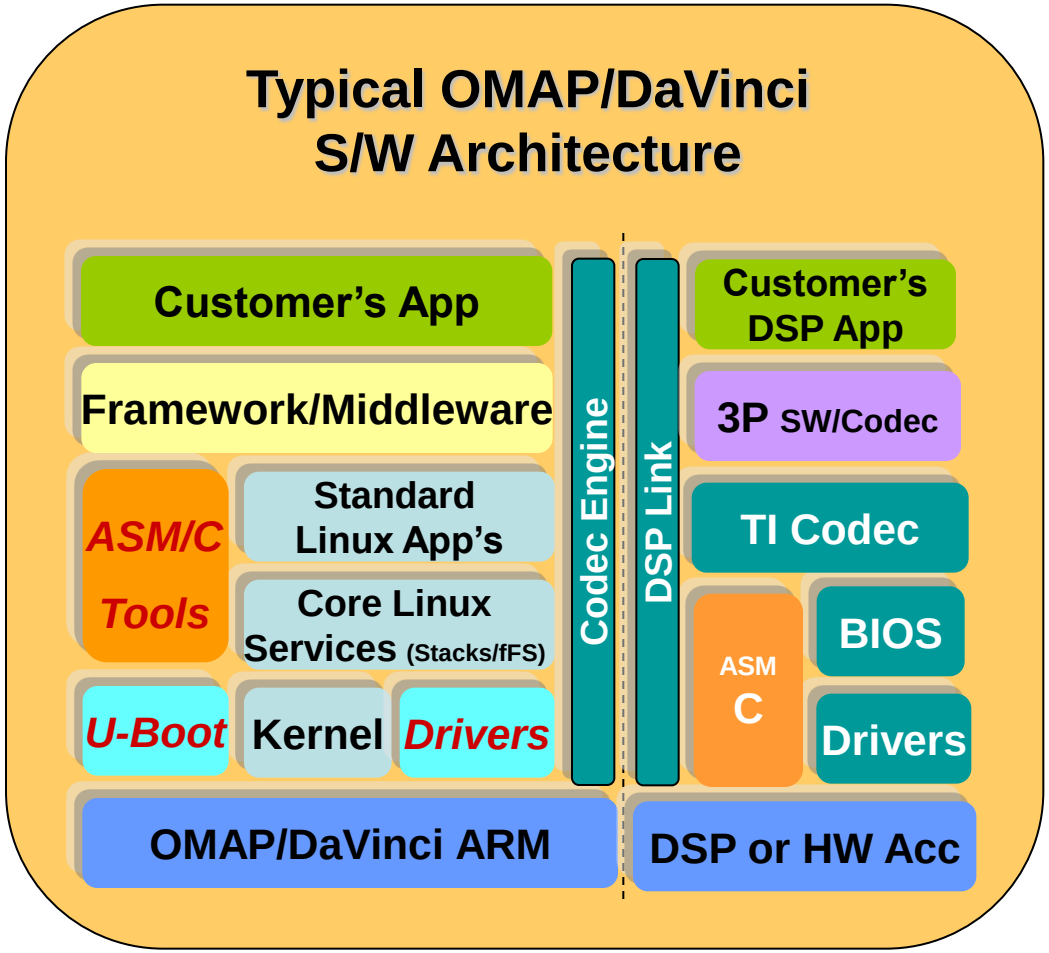


DaVinci S/W Components

TI provides customers with a standardized s/w method to accelerate applications with our DSP & H/W co-processors. This includes our DSP-specific OS (BIOS), drivers, and the Codec Engine Framework. TI also provides optimized A/V codecs for common applications.

- = Industry Standard OS S/W Component
- = PSP Package: multiple sources
- = Frameworks/Middleware: multiple sources
- = DaVinci S/W components : come from TI

Dissection of S/W Architectures

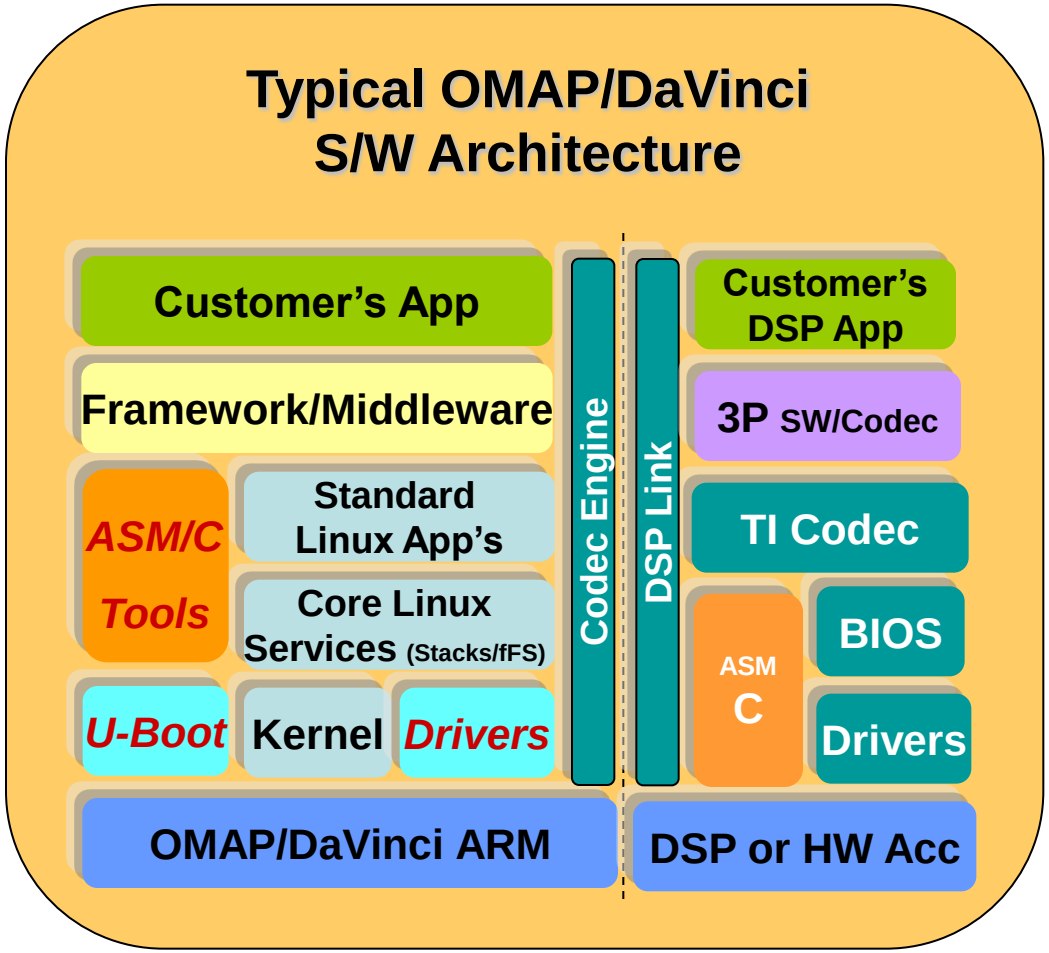


3P DSP S/W Components

TI has a large DSP s/w 3P ecosystem with optimized s/w for many different applications: (A/V codecs, AEC, analytics, VOIP, audio effects, image processing). In many cases this s/w is what differentiates our customers products and wins TI the socket.

- = Industry Standard OS S/W Component
- = PSP Package: multiple sources
- = Frameworks/Middleware: multiple sources
- = DaVinci S/W components : come from TI
- = 3P DSP S/W components : multiple sources

Dissection of S/W Architectures



Customers Application

Ultimately you, the customer, is responsible for integrating this complex matrix of s/w components. As you can imagine the challenges in debugging s/w problems in these types of systems are very high.

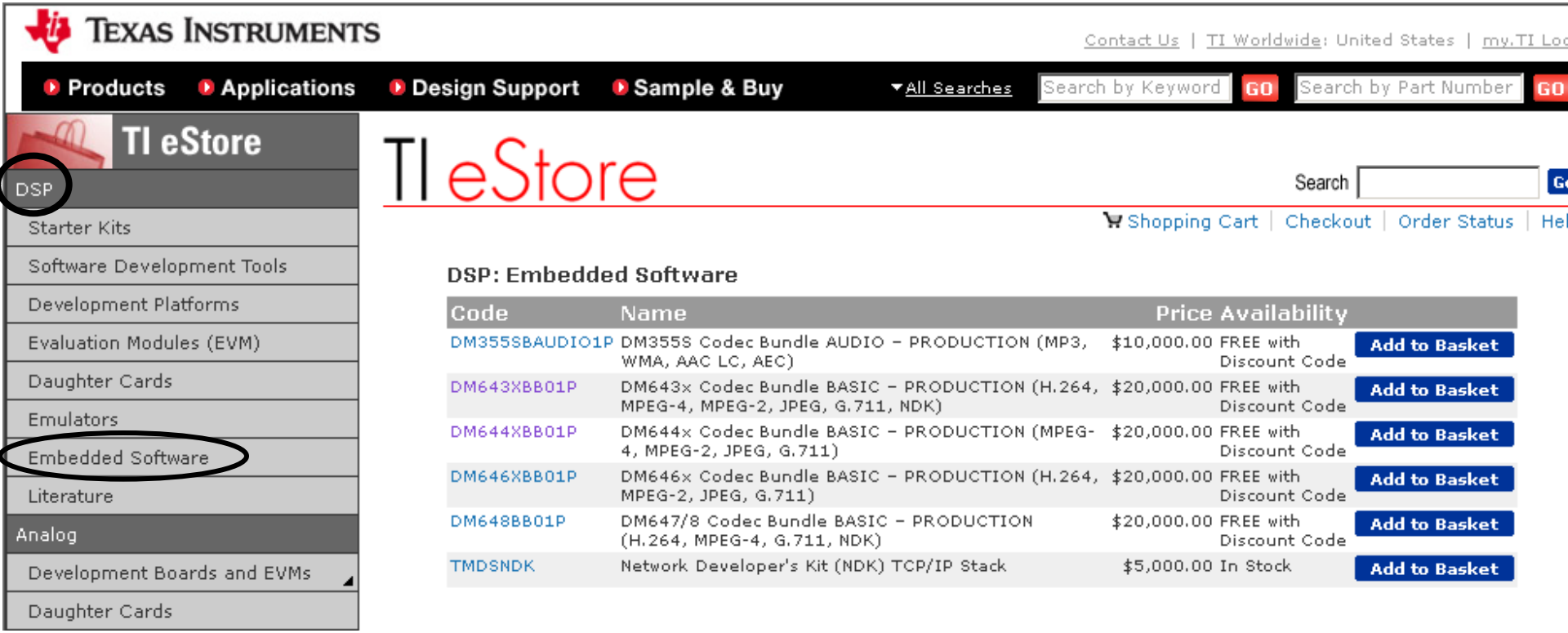
- = Industry Standard OS S/W Component
- = PSP Package: multiple sources
- = Frameworks/Middleware: multiple sources
- = DaVinci S/W components : come from TI
- = 3P DSP S/W components : multiple sources
- = Customer App : customer

Part 2: TI codec's, OS, S/W collateral and support models on OMAP and DaVinci

What should you expect from TI.

Codec Bundles Available on eStore

www.ti-estore.com - click on DSP – Embedded Software
or www.ti.com/codecbundles



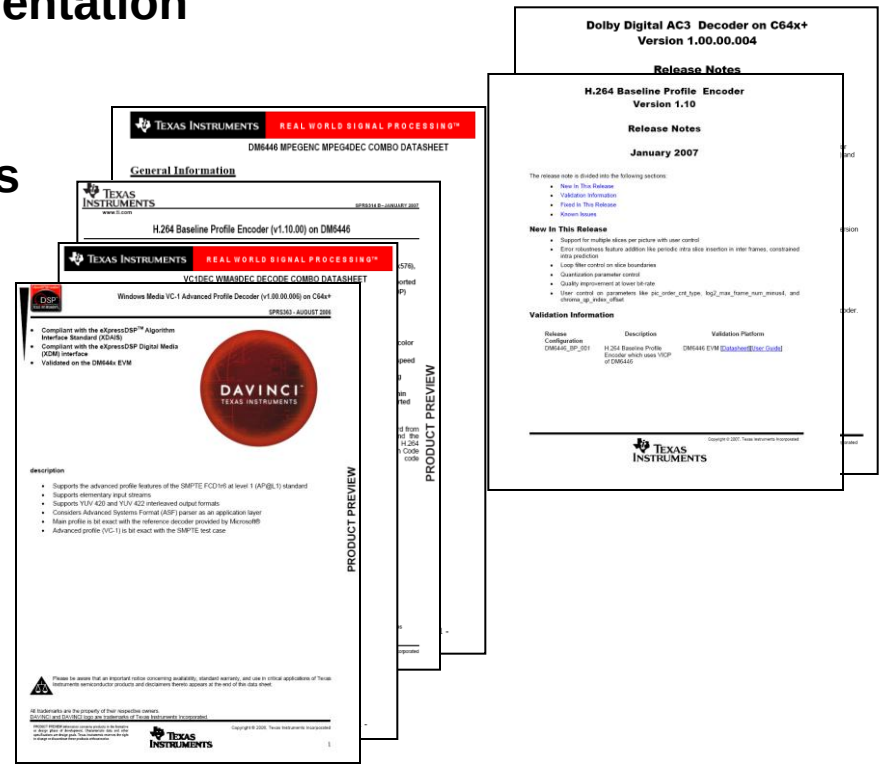
NOW AVAILABLE! – Get started today with FREE* production-ready, easy-to-use audio and video codec bundles for digital media processors based on DaVinci™ technology. Bundles include NDK, G.711, JPEG, MPEG-2, H.264 BP and MPEG-4 SP codecs.
* Production license fee will be waived if customer accepts electronic production click-wrap license and receives software via download from TI.

TI Codec Software Products

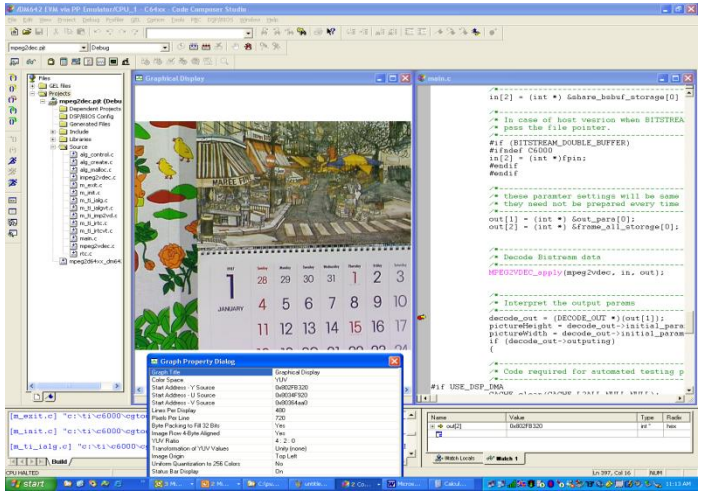
- **eXpressDSP Digital Media Software follows eXpressDSP Digital Media (xDM) Standard**
  - **Includes complete documentation requirements**
- **xDM is an extension to the earlier eXpressDSP Algorithm Interface Standard (xDAIS) specification, providing additional support for codecs**

Complete Documentation

- **Datasheets**
- **User Guides**
- **Release Notes**



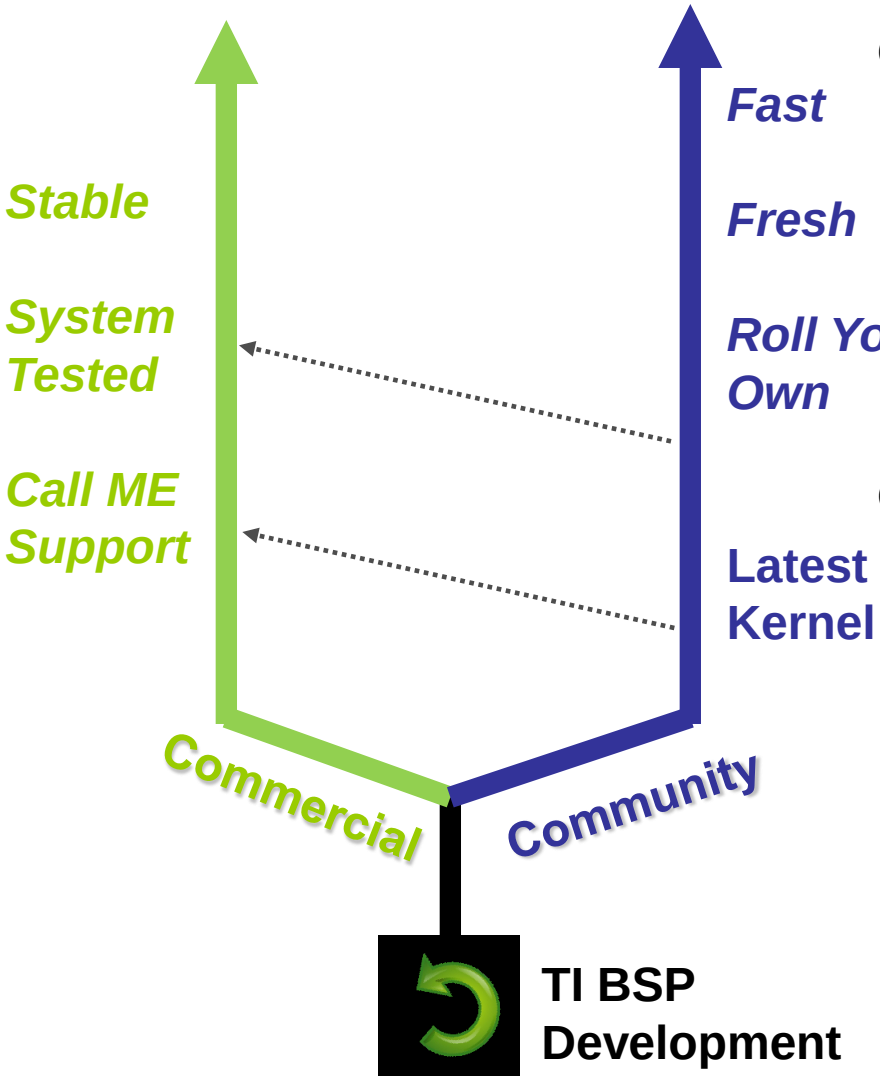
Usage Examples



Popular Operating System Options

Tool / Top features	OS	Device Support	Key Features
Code Composer Studio™ IDE Platinum Edition	DSPBIOS	DaVinci™, OMAP™, C6000 ™, C5000™, C2000™	▪IDE and royalty free DSPBIOS ▪Low level debug of ARM ▪DSP development and Debug ▪Co-debug of ARM & DSP
montavista	Linux	DM644x, DM6467, DM335, DM355	▪stable, pre-tested, supportable code base ▪Production licensing through TI ▪Indemnification
Green Hills® SOFTWARE, INC.	Integrity Linux	DM644x, OMAP35x	▪MULTI debug environment for DSP and ARM
CODESOURCERY	Linux	DM644x, DM6447, DM3x, OMAP35x	▪GNU Toolchain
timesys®	Linux	OMAP35x, DM6467 and DM644x (coming soon)	▪web-based software subscription ▪An initial Linux platform, pre-compiled for the processor ▪Customize-able Eclipse-based IDE
bSQUARE The Mobile & Embedded Systems Experts	WinCE	OMAP35x	Extensive experience and expertise with WinCE development
Mistral	WinCE	DaVinci	WinCE 6 BSP

TI processor customers can CHOOSE your Linux path: Community or Commercial



Community first path

- TI delivers LSP/DVSDK to community
- Smaller set of applications
- Customer builds up solution
- Open source assets
- Customer assets
- Faster access, newer kernels
- More customer responsibility
  - Invest own resources vs. $$

Commercial complement path

- Commercial Linux partner pulls from community
- Partner adds value: production testing, tools integration, support, application bundles, etc. for customers
- Service and subscription sales
- Executing with MontaVista, Timesys…
- Opportunities for other commercial vendors

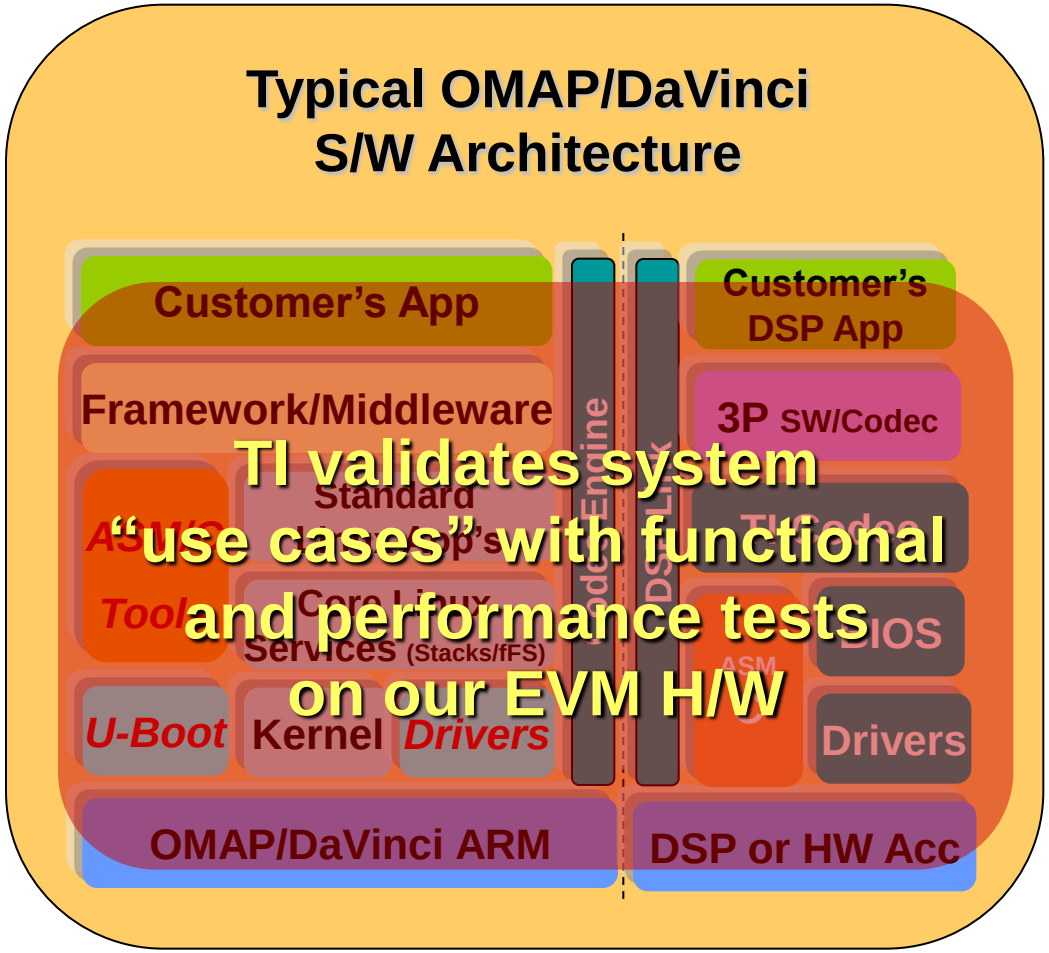
Good References

Greg Kroah Hartman on kernel development
– http://www.youtube.com/watch?v=L2SED6sewRw

Cost of Deployment Models
– See: "Embedded Linux Total Cost of Development Analyzed"
– At: http://www.embeddedforecast.com/

DaVinci™ technology & OMAP™ platform community resources
– wiki: http://wiki.davincidsp.com/ or http://wiki.omap.com/
– Wiki documents mailing list, git repositories, etc

Use Cases and the *"Tool Chain Reaction"*



Use Cases

A ***use case*** defines the specific h/w and s/w configuration TI used to test the functionality of the PSP s/w on the EVM. Customers should be able to reproduce similar results from the PSP.

If customers deviate from either the TI tool chain or the tested modes of functionality TI will be able to provide very limited support.

Make sure you review TI's supported PSP use cases

Appendix from Linux Driver Data Sheet

Texas Instruments DM644x/DM355

- 1.1 Device Drivers Summary
- 1.2 Limitations Summary
- 1.3 Linux Base Port Overview
- 1.3.1 Toolchain and Version Information
- 1.3.2 Tested Modes
- 1.3.3 Timers
- 1.4 LSP/PSP Version Information
- 1.5 Documentation Support
- 2 Linux Kernel Device Drivers
- 2.2 Video Drivers
  - 2.2.2 Video Display Driver-V4L2
  - 2.2.3 Video Display Driver-FBDev
  - 2.2.4 Video Capture Driver
  - 2.2.5 IPIPE Driver
  - 2.2.6 Previewer Driver
  - 2.2.7 Resizer Driver
  - 2.2.8 H3A Driver
- 2.3 Audio Driver
- 2.4 Ethernet Drivers
- 2.5 USB Drivers
- 2.6 IDE ATA Driver
- 2.7 MMC/SD Driver
- 2.8 NAND Driver
- 2.9 NOR Driver
- 2.10 UART Driver
- 2.11 I2C Driver
- 2.12 SPI Driver
- 2.13 PWM Driver
- 2.14 Watchdog Driver
- 2.15 GPIO
- 2.16 EDMA
- Appendix A – U-Boot Overview

Each Software component/supplier has it's own unique support model

S/W Component	Support Options	Comments
Core OS (Linux, WinCE…)	OS Vendor (MV), Open Source	Monta Vista, Greenhils(Integrity), Mistral, Bsquare, Communities
PSP Package	Supplier of PSP package	TI for Linux DvSDK(PSP) only* Otherwise it's the PSP vendor or OS community
Frameworks Middleware	Suppliers of framework or middleware package	Huge number of options depending on the customers s/w ecosystem.
DaVinci S/W components*	Mainly TI, potentially a 3P*	TI supports issues with DSP tools, BIOS, Codec Engine….
TI Codec's*	TI or ASP (Authorized SW Partner)*	TI direct support limited. Customers may need to contract ASP for support
3P S/W or Codec's	3P	Customers should make sure 3P's are contractually bound to support
Customers App (System integration)	*The customer (and everybody involved in the deal.)*	Incredibly difficult to isolate system failures. Resolutions are case specific.

*Yellow text indicates what TI directly supports

Do your own research!

- There is no one right choice
- Each project and team has its own needs
- However, many people underestimate what it takes to “DIY”?
  - Make an informed choice
  - Think about what is required for the whole product and product lifecycle
  - Learn from others

Part 4: Best Practices and Conclusions

TI Developer Network - Software

System Integrators

Wintech, SEEDdsp.com, Ittiam, DSW (Digilink), Infochips, MPC Data Limited, Trinity Convergence, ingenient technologies, TES Electronic Solutions, NUVATION, cmPOWER Empower Technologies, Clarity Design, Inc.

Browser, GUI, Flash & Media Player

bSQUARE The Mobile & Embedded Systems Experts, TES Electronic Solutions, SWELL software, calsoft labs, Windows Media Player

Hardware Support & Solutions

Clarity Design, Inc., MISTRAL ... Partners in Real Time, NUVATION, Z3 Technology, LLC

AV Frameworks
(including proprietary)

DSW (Digilink), ingenient technologies, Ittiam, DirectShow, gstreamer

ARM Codecs, Libraries & Software Modules

Ittiam, ingenient technologies, ipera, Fraunhofer Institut Integrierte Schaltungen, Adaptive Digital Technologies, Inc., DSW (Digilink)

Drivers & Connectivity

CardAccess

Operating Systems

eSOL, montavista, Linux, Green Hills Software, Inc., QNX Software Systems, Windows Embedded CE

DSP Codecs, Algorithms, Libraries & Software Modules

Ittiam, ingenient technologies, SPIRIT DSP Voice & Video Engine Experts, DSW (Digilink), Fraunhofer Institut Integrierte Schaltungen, ipera, Adaptive Digital Technologies, Inc.

Texas Instruments

Best Practices

- **Fully understand your S/W architecture before selecting your h/w or engaging in any s/w licensing contracts.**
  - **Have detailed use cases documented for all peripherals, codecs and GUIs!**
  - **Test codec's before you license them! *(especially TI codec's)***
  - **Have clear compliance testing specifications outlined for all major s/w components, especially ones your are outsourcing.**
  - **What OS makes the most sense? (Cost, boot time, security, framework..)**
  - **What codec do you really need? Where is your content coming from?**

- **Be realistic about s/w integration complexity, scope of internal expertise, and development schedules.**
  - **Cost of Third Party s/w and support may be justified.**
  - **The best solution might be to engage with multiple third parties.**

- **Get some training**
  - **Take TI's 4-Day classes – DaVinci Workshop, C6x Code Opt workshop…**
  - **Industry training (Bsquared, Free Electrons…)**

- **Plan ahead - what if things don't work - the development schedule slips?**
  - **Have clearly outlined support terms in place with all your s/w providers.**
  - **Have clauses in place to extend support beyond initial support period!**
    - **What if you have field failures with a 3P s/w codec 2 years from now?**

Ultimately system integration is owned by you "the customer"

Who moved my cheese?

- **Sitara, DaVinci & OMAP truly integrate an entire embedded "system" into a single device.**
  - **ARM, DSP, USB, Video ports ….**
- **This integration offers huge benefits:**
  - **System Cost**
  - **Power**
  - **Form Factor**
  - **Performance**

Highly integrated SOCs enable leading edge products

- **This integration also introduces new challenges:**
  - ***The key to successful product development is to fully understand your S/W architecture and have a bullet proof s/w integration plan.***

Thank You