Designing with ARM®-based Microcontrollers

Speakers:

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Product manager for IAR Embedded Workbench and the IAR RTOS partner program

Moderator: Warren Webb, OpenSystems Media,
Designing with ARM®-based Microcontrollers

15 December 2010
Where can I find an ARM-based MCU family that offers:

► MCU ease-of-use + DSP performance

► EEPROM (on-chip)

► High precision analog

► Ultra low power

► Lots of performance, memory, peripheral, and package options

► Comprehensive run time software and development tool support from one or two vendors
Design need: MCU ease-of-use + DSP performance

ARM Cortex™-M4 Processor Microarchitecture

- Backwards compatible with ARM Cortex™-M3

- New features
  - Single cycle MAC (Up to 32 x 32 + 64 -> 64)
  - DSP extensions
  - Single Precision Floating Point Unit

- Freescale IP and Innovation
  - On-chip cache for instructions and data
  - Cross-Bar Switch for concurrent multi-master/slave accessing
  - On-chip DMA for CPU off-load
  - Low-leakage Wake-up Unit adds flexibility for low power operation

- Architected for Digital Signal Processing
  - Motor Control - advanced algorithms, longer lifespan, power efficiency
  - Automation - high calculation and algorithm bandwidth at a low cost
  - Power management – designed for low/battery powered systems
  - Audio and Video – 5x performance improvement over software, making batteries last longer
**Design need: EEPROM (on-chip)**

**User Configurable As…**

**EEPROM:**
- No external EEPROMs
  - Reduced system cost
- No system resource impact
  - System performance maintained
  - No complex coding schemes
- Configurable & high endurance
  - Up to 10 Million w/e cycles
- High performance
  - Fast write time = ~100 uSec
  - Erase+write = 1.5mSec
- Use cases
  - Critical data retention (power loss)
  - Frequently updated data

**Program or Data Flash:**
- Flexibility
  - Space for future expansion needs
  - Contiguous with main program Flash
- Efficient
  - Read-while-write with the main program Flash
- Use cases
  - Program Flash: bootloader code space
  - Data Flash: large data tables

**FlexMemory**

- Or a combination of both

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Design need: High precision analog

Kinetis: Mixed Signal (Analog)

- **16-bit ADC**
  (All Kinetis families)
  - Fast, accurate signal conditioning
  - Configurable resolution, sample time, speed and power (8/10/12/16-bit)

- **12-bit DAC**
  (All Kinetis families)
  - Analog signal generation for audio applications

- **High Speed Comparator**
  (All Kinetis families)
  - Fast, accurate motor over-current protection

- **Programmable Gain Amplifier**
  (All Kinetis families)
  - x64 gain for small amplitude signal boost

- **Analog Voltage Reference**
  (All Kinetis families)
  - Accurate on-chip Vref eliminates need for external Vref - reduced system cost
### Design need: Ultra low power

#### Kinetis: Ultra low power

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>10 Flexible low power modes</strong></td>
<td>(All Kinetis families)</td>
</tr>
<tr>
<td><strong>90nm Process Technology</strong></td>
<td>(All Kinetis families)</td>
</tr>
<tr>
<td><strong>Low Leakage Wake-up Unit</strong></td>
<td>(All Kinetis families)</td>
</tr>
<tr>
<td><strong>Ultra-fast Wake-up</strong></td>
<td>(All Kinetis families)</td>
</tr>
<tr>
<td><strong>Clock &amp; Power Gating</strong></td>
<td>(All Kinetis families)</td>
</tr>
<tr>
<td><strong>Customise power usage</strong></td>
<td>to application requirements</td>
</tr>
<tr>
<td><strong>•1/3 dynamic power reduction</strong></td>
<td></td>
</tr>
<tr>
<td><strong>•1.71-3.6V flash prog. &amp; analog</strong></td>
<td>peripheral operation – more battery life</td>
</tr>
<tr>
<td><strong>Wake-up monitor for all low leakage</strong></td>
<td>stop modes - up to 8 internal modules and 16 pins as wake-up sources</td>
</tr>
<tr>
<td><strong>Quick wake-up from reduced power mode</strong></td>
<td>process data, return to sleep state</td>
</tr>
<tr>
<td><strong>Unused clocks &amp; modules shut down</strong></td>
<td>reducing leakage currents</td>
</tr>
</tbody>
</table>
## Design need: Ultra low power

### Kinetis: Power Modes

<table>
<thead>
<tr>
<th>Typical Power Modes in an embedded system</th>
<th>Cortex M4 Power Modes</th>
<th>Kinetis Extended Power Modes</th>
<th>Recovery Time</th>
<th>“Typical” Idd Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run</td>
<td>Run</td>
<td>Run</td>
<td>-</td>
<td>&lt;200uA/MHz</td>
</tr>
<tr>
<td>Wait</td>
<td>Sleep</td>
<td>VLPR</td>
<td>-</td>
<td>&lt;200uA/MHz</td>
</tr>
<tr>
<td>Stop</td>
<td>DeepSleep</td>
<td>Wait</td>
<td>4us</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>VLPW</td>
<td>4us</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stop</td>
<td>4us</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>VLPS</td>
<td>4us</td>
<td></td>
</tr>
</tbody>
</table>

### Freescale Adds Low Leakage Wake-up Unit

- Enables complete shut-down of core logic, including WIC, further reducing leakage currents in all low power modes
- Supports 16 external input pins and 8 internal modules as wakeup sources
- Wakeup inputs are activated in LLS or VLLS modes

<table>
<thead>
<tr>
<th>LLS</th>
<th>4us</th>
<th>1.2uA - 7uA</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLLS3</td>
<td>35us</td>
<td>1uA - 5uA</td>
</tr>
<tr>
<td>VLLS2</td>
<td>35us</td>
<td>750nA - 2uA</td>
</tr>
<tr>
<td>VLLS1</td>
<td>100us+EE</td>
<td>500nA – 1.5uA</td>
</tr>
</tbody>
</table>
## Kinetis Product Families

**Design need: Lots of performance, memory, peripheral, and package options**

### K70 Family
- 512KB-1MB, 196-256pin

### K60 Family
- 256KB-1MB, 100-256pin

### K50 Family
- 128-512KB, 64-144pin

### K40 Family
- 64-512KB, 64-144pin

### K30 Family
- 64-512KB, 64-144pin

### K20 Family
- 32KB-1MB, 32-144pin

### K10 Family
- 32KB-1MB, 32-144pin

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### Common System IP
- 32-bit ARM Cortex-M4 Core w/ DSP Instructions
- Next Generation Flash Memory
- High Reliability, Fast Access
- FlexMemory w/ EEPROM capability
- Memory Protection Unit
- Low Voltage, Low Power Multiple Operating Modes, Clock Gating (1.71V-3.6V with 5V tolerant I/O)
- Low-power Touch Sensing
- DMA
- -40 to 105C

### Common Analog IP
- 16-bit ADC
- Programmable Gain Amplifiers
- SRAM
- UART/SPI
- Programmable Delay Block
- External Bus Interface
- Motor Control Timers
- eSDHC
- RTC

### Digital IP
- CRC
- I²C
- SAi (I²S)
- Programmable Delay Block
- External Bus Interface
- Motor Control Timers
- Low-power Touch Sensing
- DMA

### Development Tools
- Bundled IDE w/ Processor Expert
- Bundled OS USB, TCP/IP, Security
- Modular Tower H/ware Development System
- Application Software Stacks, Peripheral Drivers & App. Libraries (Motor Control, HMI, USB)
- Broad 3rd party ecosystem

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### Kinetis Product Families

- **Sampling now (144 MAPBGA)**
- **Sampling Q2 2011 (144 MAPBGA)**
- **Sampling Q4 2011 (256 MAPBGA)**
Kinetis Tower System: Reusable, Modular Development Platform

www.freescale.com/tower

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Contents</th>
<th>Price (SRP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWR-K40X256</td>
<td>TWR-K40X256 module TWRPI-SLCD daughter card</td>
<td>$69</td>
</tr>
<tr>
<td>TWR-K40X256-KIT</td>
<td>TWR-K40X256 module TWRPI-SLCD daughter card TWR-ELEV module TWR-SER module</td>
<td>$139</td>
</tr>
<tr>
<td>TWR-K60N512</td>
<td>TWR-K60N512 module</td>
<td>$69</td>
</tr>
<tr>
<td>TWR-K60N512-KIT</td>
<td>TWR-K60N512 module TWR-ELEV module TWR-SER module</td>
<td>$139</td>
</tr>
</tbody>
</table>

- **Contents:**
  - 30 Day Evaluation version of IAR Embedded Workbench
  - Freescale MQX RTOS
  - OSJTAG Debug circuitry
  - Low power touch sensing
  - Plug in socket for expansion: Sensors, Radio, Adaptor etc…
  - SD Card
  - And more…

- Full compatible with all Tower peripheral modules

- IAR branded TWR kit will also be available and will include a J-Link lite
Free Scalable, fully-featured and proven RTOS with 32-bit MCUs

- **Full-featured and powerful**
  - BSPs incorporate tightly integrated RTOS, Middleware (USB, TCP/IP stacks), file system, and I/O drivers
  - Designed for speed and size efficiency

- **Market proven**
  - Available on Freescale processors for > 15 years
  - Used in millions of products including Medical and Heavy Industrial applications

- **Simple and scalable**
  - As small as ~10KB for smallest implementation, or scale up to support sophisticated networking and threading
  - Intuitive API & modular architecture enables straightforward fine-tuning of features
  - Production source code provided

- **Similar to other “pay-for” software OS**

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Bundled Freescale MQX™ RTOS

www.freescale.com/mqx

Software integration headache

Integrated MQX Solution

✓ Stable
✓ Upgradable
✓ Easy to maintain

$95K of free Software
IAR Systems at a glance

► World-leading provider of software tools for embedded systems since 1983
► Headquarter in Uppsala, Sweden
► Worldwide presence with offices in Sweden, USA (Silicon Valley, Dallas, Boston), Brazil, Germany, UK, Belgium, France, Japan, and China
► World's largest customer base on the MCU market; 100,000+ installed licenses
► IAR newsletter reach today more than 100,000 embedded developers
The most widely used ARM development tool

► Today the most widely used tool chain for ARM-based MCU
► Only independent quality tool chain
► Present in key market segments
► Used by Freescale Kinetis lead customers
► Long partnership with Freescale on development tools for ColdFire, ColdFire+, ARM7, ARM9, S08, S12 and now Kinetis MCUs
IAR Systems Product portfolio

IAR Embedded Workbench

- Complete integrated development environment
- Project mgr, editor, debugger,
- Ready made example projects
- RTOS awareness plug-ins

IAR visualSTATE

- Tools for graphical designing, testing and implementing embedded applications based on state machines.
- 100% accurate with your code
- Good for verification and validation

IAR KickStart Kit

- Evaluation kit
- Contains development/evaluation board, software development tools with sample projects and a hardware debug probe or emulator.
- Shipping 4000 per year

Debug probes

- Integrates seamlessly into IAR Embedded Workbench and is fully plug-and-play compatible, and in addition very easy to use.
Cutting development time

► Powerful Project Manager.
► Getting started examples and board support packages.
► Comprehensive device support
  • I/O-header files
  • Debugger definition files
Building your application

IAR Embedded Workbench

- Complete development environment
- Powerful project manager
- Highly optimized C and C++ compiler
  - Compliant with CMSIS, EABI, C99,…
  - Multi-file compilation
- Intelligent linker
- Full support for Freescale Kinetis

Optimizations

- Multiple levels of optimizations for code size and execution speed.
- Optimization level can be set on a per function basis.
- Global and core specific optimizations.
- Low power requirements
- Optimizing for low power is very much the same as optimizing for speed.
Need for floating point?

► Cortex-M4 Floating Point Unit (FPU)
  • 32-bit floats (C float)
  • conversion
  • add, sub
  • multiply-accumulate, divide
  • square root

► Compiler support
  • float: hardware or library
  • double: library
DSP - interface to the non-binary world

- Motor control, audio, sensor signal conditioning, …
- Cortex-M4: MCU + DSP = DSC (Digital Signal Controller)
  - saturated operations
  - MAC
  - SIMD - SMLAD => Sum = Sum + (A x C) + (B x D)
- Extensive DSP library
  - vector/matrix
  - FIR/IIR filters
  - convolution, correlation
  - FFT/DCT
  - PID control
How to program the flash?

- C-SPY debugger has built-in flash loader support.
- Specific flash loaders are provided for Kinetis device.
- Support for download of multiple images.
Debugging

► P&E micro OSJTAG
  • Built-in on Kinetis Kxx evaluation boards
  • Just connect USB cable to evaluation board

► J-Link & J-Link Ultra
  • JTAG/SWD/SWO support
  • low bandwidth trace
  • real-time: function profiler, interrupt log, variable watch, non-intrusive printf
  • Power debugging (J-Link Ultra)

► IAR J-Link lite
  • kit variant
Freescale Kinetis MCUs – packed with trace sources

- ITM
  - Low speed real-time trace port
  - Event trace
  - Interfaces with IAR J-Link

- ETM
  - High speed real-time trace port
  - Interfaces with IAR J-Trace for Cortex-M3

- ETB
  - High speed real-time trace to internal 2 kbyte buffer
  - Interfaces with IAR J-Link

- Trace functionality in C-SPY
  - Monitoring values of static variables
  - Non-intrusive printf()
  - Direct output via ITM stimulus ports
  - Measuring execution time
  - Interrupt graph
  - Stack/heap overflow detection
  - View the call stack graph
  - Statistical function profiling
Finding difficult bugs

► Instruction trace (ETM)
  • High bandwidth instruction trace data on a 4-bit high speed trace bus.
  • Requires trace probe, for example the IAR J-Trace for Cortex-M.

► Full instruction trace
► Call hierarchy list
► Call stack visualization
Requirements on long battery life-time and minimized power consumption.

Traditionally a design goal for hardware developers using multi-meter and oscilloscope.

Power consumption is also dependent on how the hardware is used and controlled by software.

Power debugging
- Connects power consumption to source code
- Allows optimizing software for minimized power consumption
Power samples are correlated to program counter and by that with the source code.

The C-SPY debugger visualizes power consumption data both statically and dynamically in different views.

- Power profile graph in Timeline window
- Statistical power profiling in the Function Profiler window
  - Identifies functions that consume most power in the application.
- Textual log of all power samples with timestamp and program counter in the Power log window.
Integrating RTOS and middleware

► IAR RTOS partner program
  - CMX
  - Express Logic
  - FreeRTOS
  - Micrium
  - Micro Digital SMX
  - MQX
  - Quadros
  - Sciopta
  - SEGGER
  - Wittenstein

► MQX Integration
  - Port available for IAR Embedded Workbench
  - RTOS awareness plug-in in C-SPY debugger
  - Information and example projects in IAR Information Center
IAR Embedded Workbench versions for Kinetis MCUs

- IAR Embedded Workbench
- IAR Embedded Workbench Kickstart version
- IAR Embedded Workbench Cortex-M version
- IAR Embedded Workbench Evaluation version
Summary of IAR Systems offerings for Freescale Kinetis MCUs

► The most widely used C/C++ tool chain for ARM MCUs
► Support for Kinetis 10/20/30/40/60
► Freescale MQX™ RTOS integration
► Advanced trace debug functionality
  • Power debugging
  • ETM and SWO trace support
► Project examples for the Freescale Tower system
► Professional technical support organization
► Availability: Now! Contact an IAR Systems sales office.
  • Also available via Freescale Buy Direct
Kinetis + IAR – The ARM-based MCU solution that offers:

• MCU ease-of-use + DSP performance
  ✓ ARM Cortex-M4 core – powerful, efficient and sampling now

• EEPROM (on-chip)
  ✓ FlexMemory - fast, high endurance and user-configurable

• High precision analog
  ✓ 16-bit ADCs and a whole lot more…

• Ultra low power
  ✓ Multiple power modes / wake-up options, and power-savvy technology & peripherals

• Lots of performance, memory, peripheral, and package options
  ✓ >200 devices offering 50-15MHz, 32KB-1MB, connectivity, HMI, security and external interface peripherals, and package options from 32pin to 256pin

• Comprehensive run-time software and development tool support from one or two vendors
  ✓ Free Freescale MQX RTOS, powerful & easy-to-use IAR tools and the Freescale Tower System for rapid prototyping
Questions & Answers

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Moderator: Warren Webb, OpenSystems Media
Thanks for joining us

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