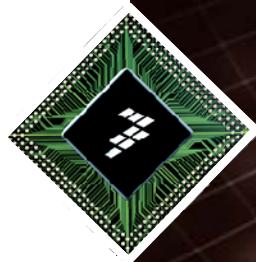




# Microcontrollers for Healthcare: Meeting Home Portable Healthcare Device Requirements

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**Donnie Garcia**  
Microcontroller Systems Engineer



Jan 31, 2012

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# Healthcare Market applications



## Portable Medical

**Wellness/Fitness**

**Blood Glucose meter**

**Blood pressure monitor**

**Thermometer**

**Weight Scale**

**ECG**

**SPO2**



## Diagnostic & Therapy

**BGM, BPM, ECG**

**Point of Care**

**Defibrilators**

**Cardiac Implant**

**Respiratory, Anaesthesia**

**Hearing Aids**

**Drug Delivery**

**Patient Monitoring**



## Imaging

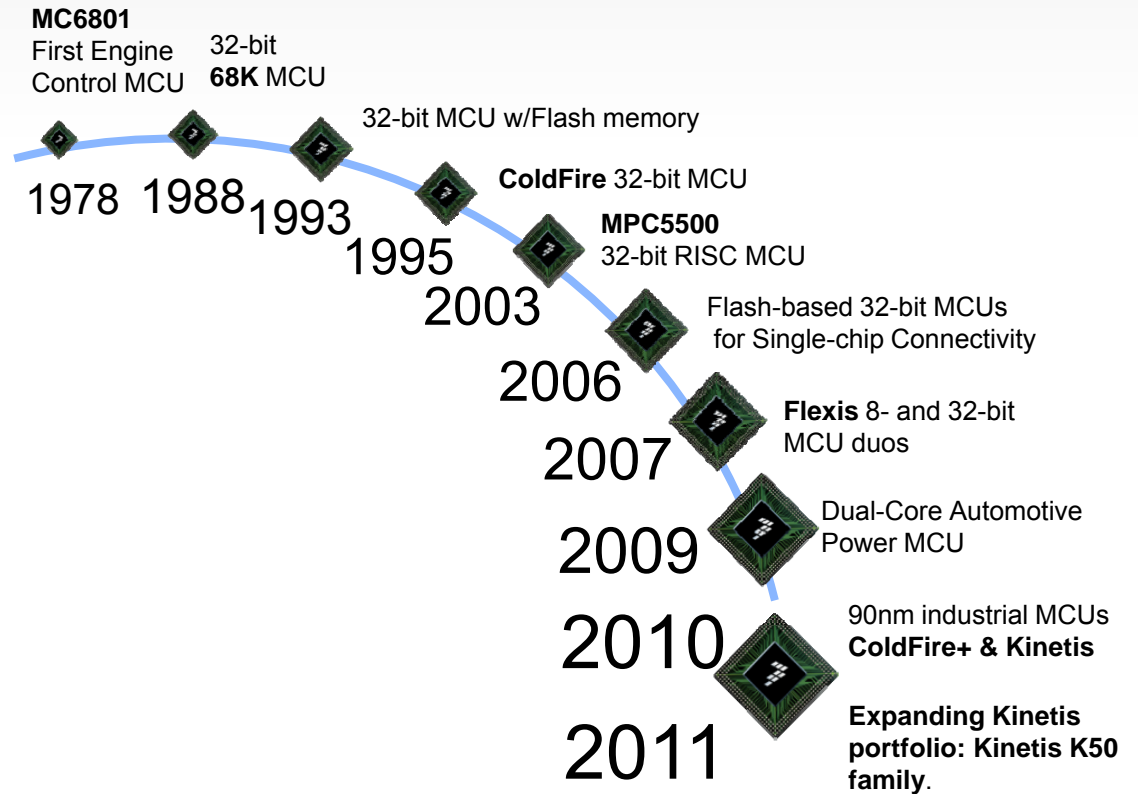
**UltraSound**

**X-Ray**

**CT**

# Agenda

- Healthcare device trends and the impact to MCU architecture
  - SoC to DoC
- Kinetis K50
  - The new standard medical controller
- Competitive Analysis
- Summary and Conclusions

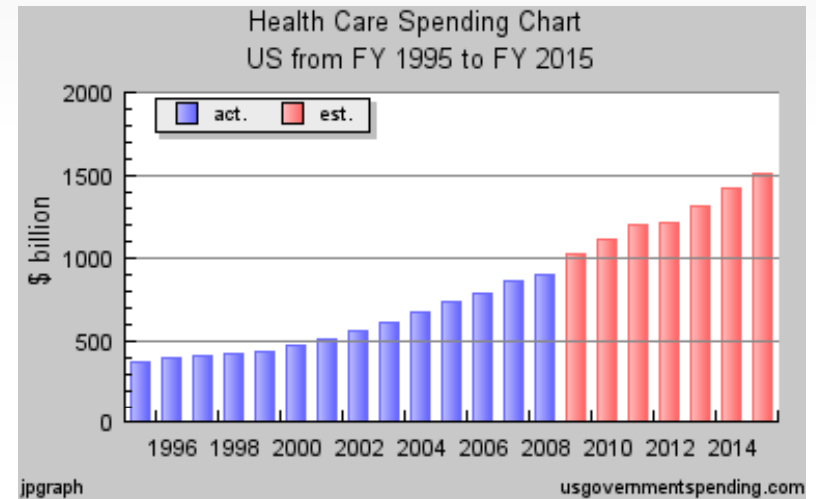




# The Challenge and the Opportunity

## Worldwide today:

- **1 billion** adults overweight
- **860 million** chronic disease patients
- **600 million** elders age 60 or older
- **75-85%** of healthcare spending is on chronic disease management
- **200K** hospitals, **18M** hospital beds



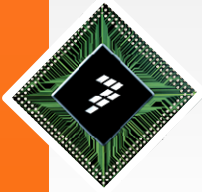
Obesity  
Diabetes  
Cardiac Disease



Rising  
Cost of Care

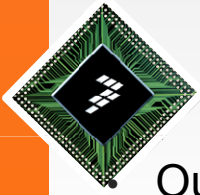


Innovation in  
Healthcare devices



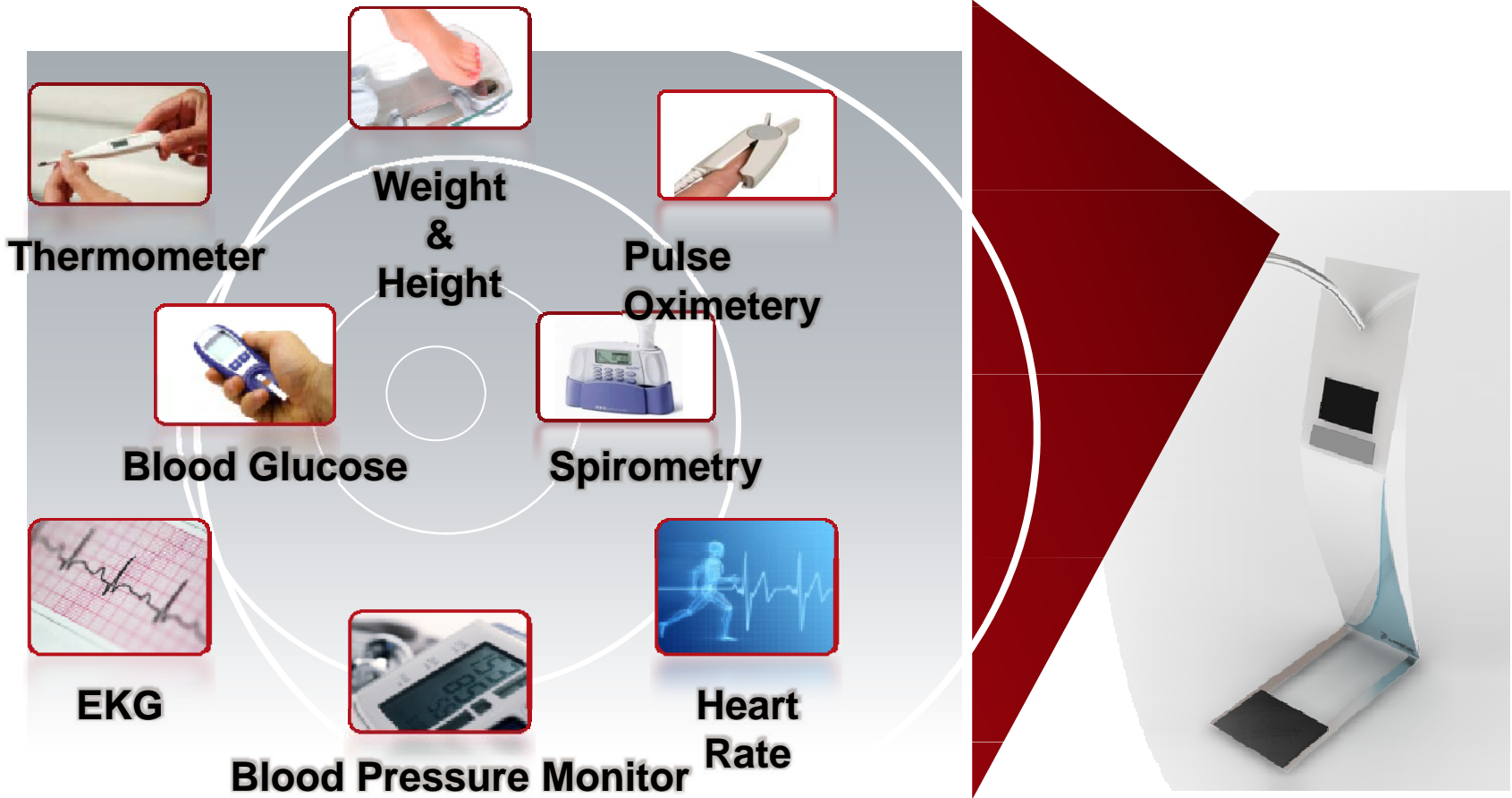
## Healthcare Device Trends

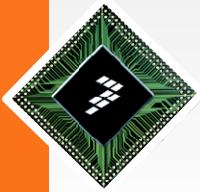
- Combinational and hub devices that provide complete diagnostic and health maintenance capabilities
- New data logging and data analysis features that improve treatment decisions
- User interfaces that adopt consumer technology trends
- Connectivity that links medical professionals to the patient and fosters patient accountability and compliance



# Intelligent Hospital

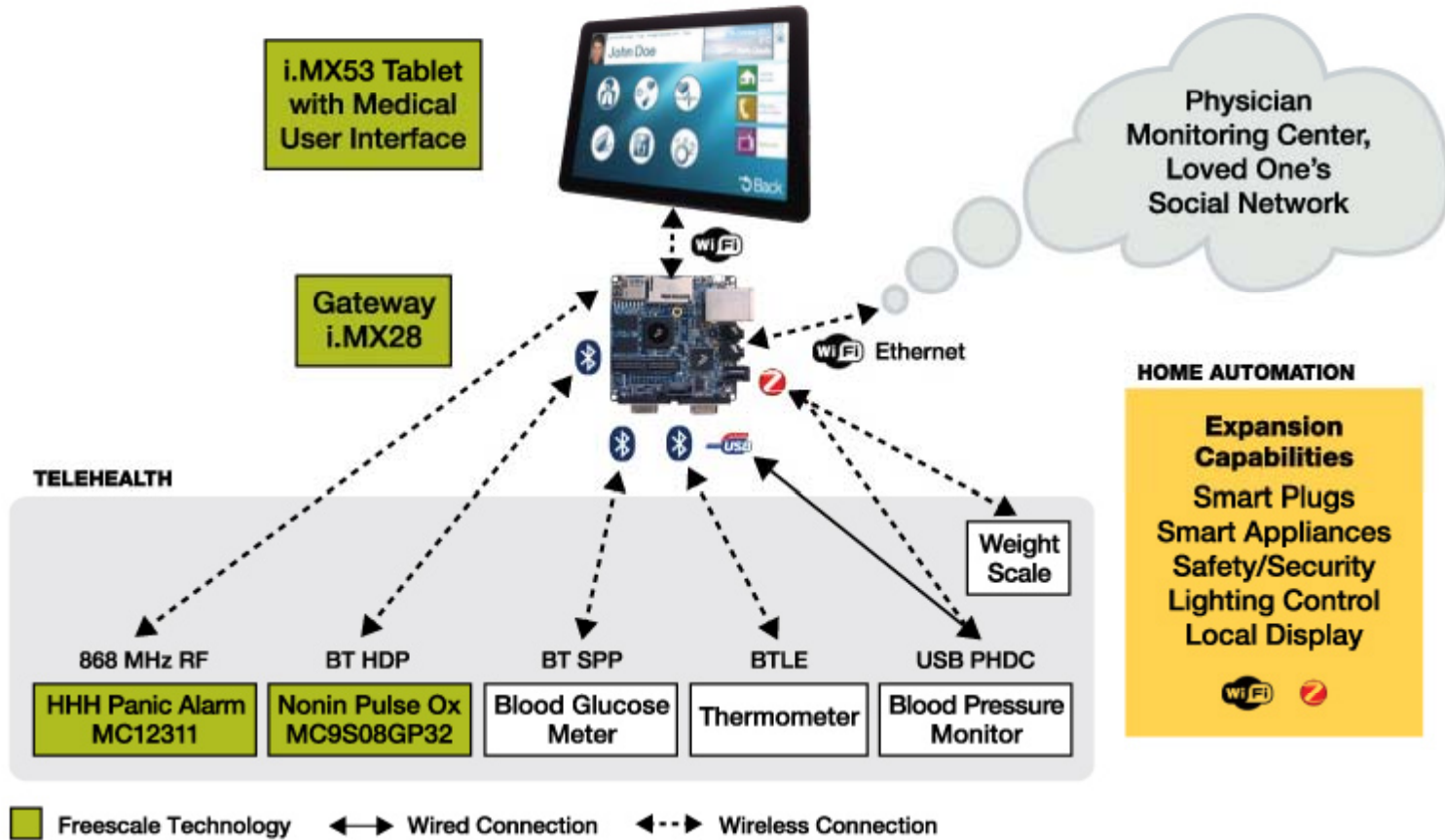
Our Medical Center of Excellence has developed several reference designs essentially creating an Intelligent Hospital featuring a biometric acquisition system that acquires vital signs, performs basic medical tests, and incorporates devices such as:

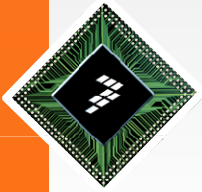




# Platform Demonstration

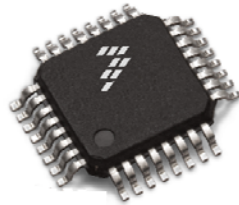
## Home Health Hub Reference Platform Demonstration





# The Microcontroller Systems View of Healthcare Device Trends

SoC



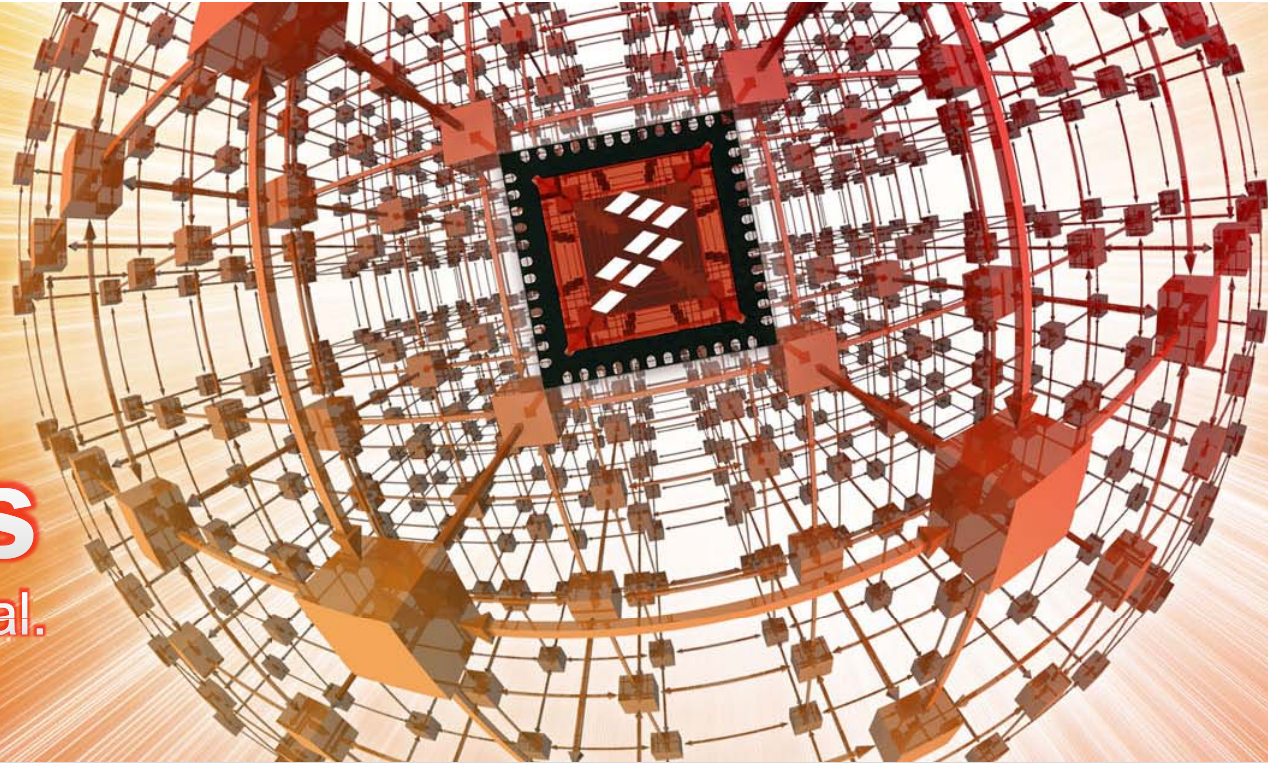
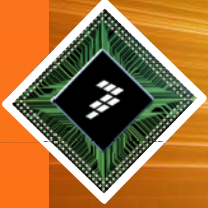
DoC



## ▶ **System Doctor on Chip**

- ▶ *DoC will be able to measure, process and administer*
- ▶ *DoC features*
  - ▶ Measurement unit with analog front end, high accuracy ADC, PDB to control measurement timing and DMA to allow measurement processing
  - ▶ Efficient CPU instructions that process measurement data
  - ▶ Low power operation with Low power CPU and low power time keeping capability
  - ▶ Connectivity through Ethernet, USB and RF
  - ▶ Graphical display interface capabilities
  - ▶ Biosensors generated from special processes that create FETs that react to medical stimuli





# Kinetis

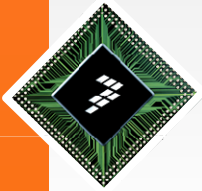
Design Potential.  
Realized.

**Ultra-Scalable** – Market’s most scalable portfolio of low-power ARM® Cortex™-M4 MCUs with over 200 hardware and software compatible devices

**Mixed Signal** – Exceptional integration with fast 16-bit ADCs, DACs, PGAs and more. Powerful, cost-effective signal conversion, conditioning and control

**Innovative Flex Memory** – Low Power 90nm Thin-Film Storage Flash with FlexMemory offers EEPROM capability with unprecedented programming speed and endurance

**Comprehensive Enablement** – Freescale MQX RTOS and Eclipse-based CodeWarrior IDE, as well as IAR, KEIL and other ARM ecosystem providers



# Hello Kinetis K50 Microcontrollers

The Integration Benchmark for Measurement and Monitoring

**NEW**

## Integrated Measurements

Kinetis K50 integrates a measurement engine, allowing reliable processing of analog signals

## Multiple Monitoring Options

Kinetis K50 offers multiple connectivity options to constantly monitor, evaluate and control system variables

## Kinetis K50 Microcontrollers

based on the ARM  
Cortex-M4 core

**ARM**

## Freedom

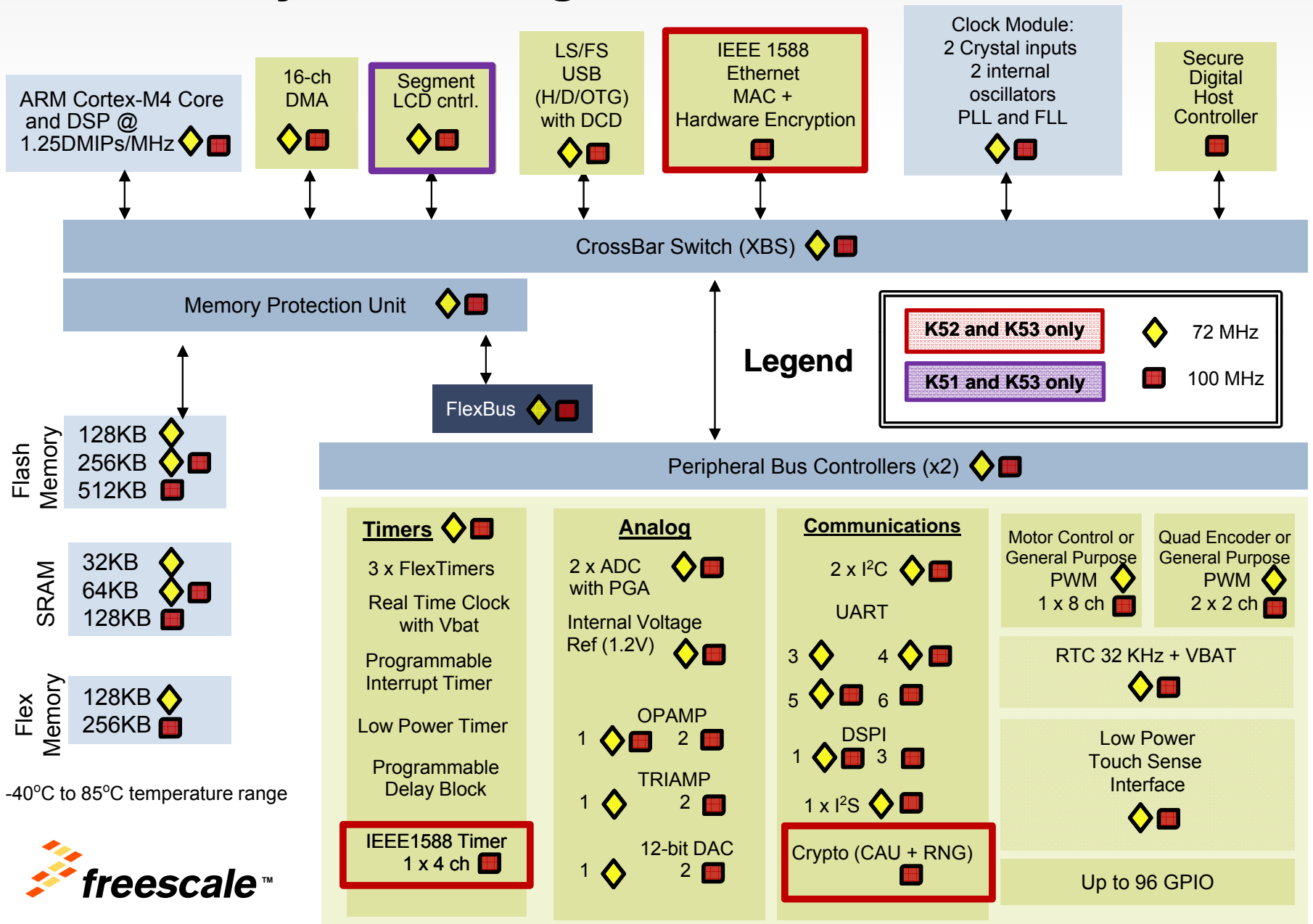
Kinetis K50 delivers exceptional scalability within the Kinetis portfolio

## Design Ease

Kinetis K50 delivers exceptional design ease within the Kinetis portfolio, easy-to-use software and modular hardware development tools



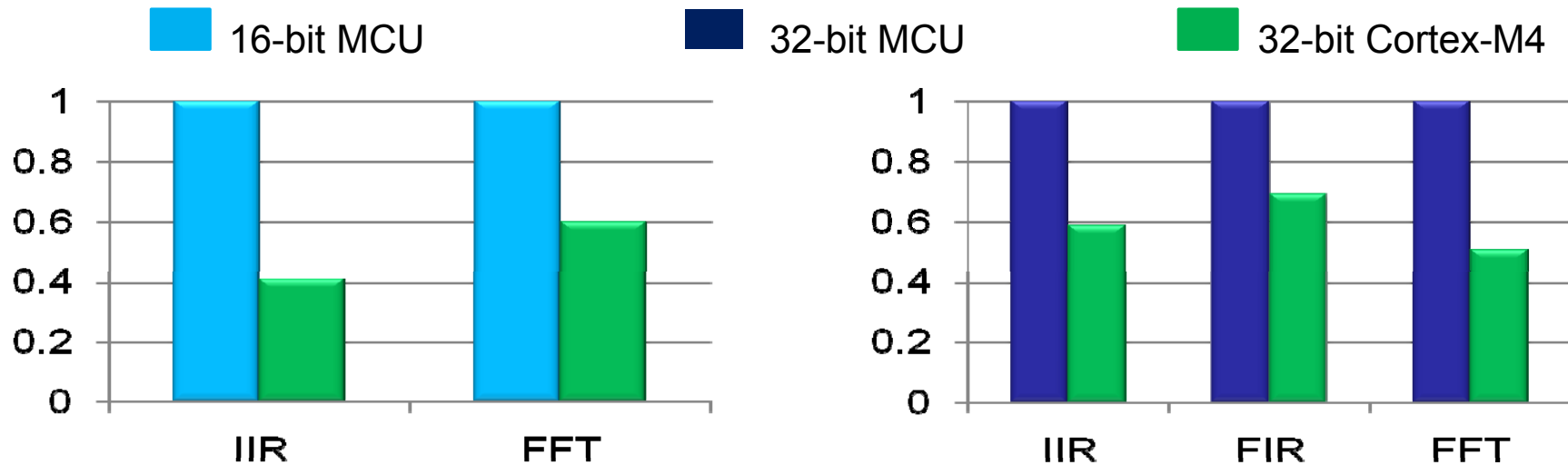
# K50 Family Block Diagram

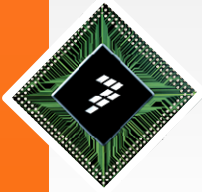


# Cortex-M4: Efficient Blend



The Cortex-M4 is ~2X more efficient on most DSP tasks than leading 16 and 32 bit MCU devices with DSP extensions

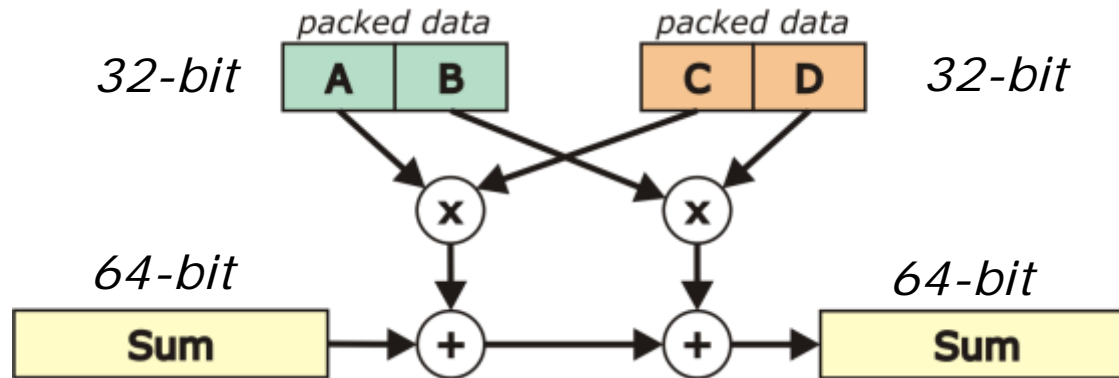




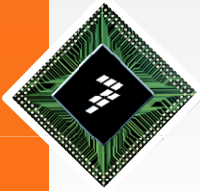
# SIMD Operations

SIMD extensions perform multiple operations in one cycle

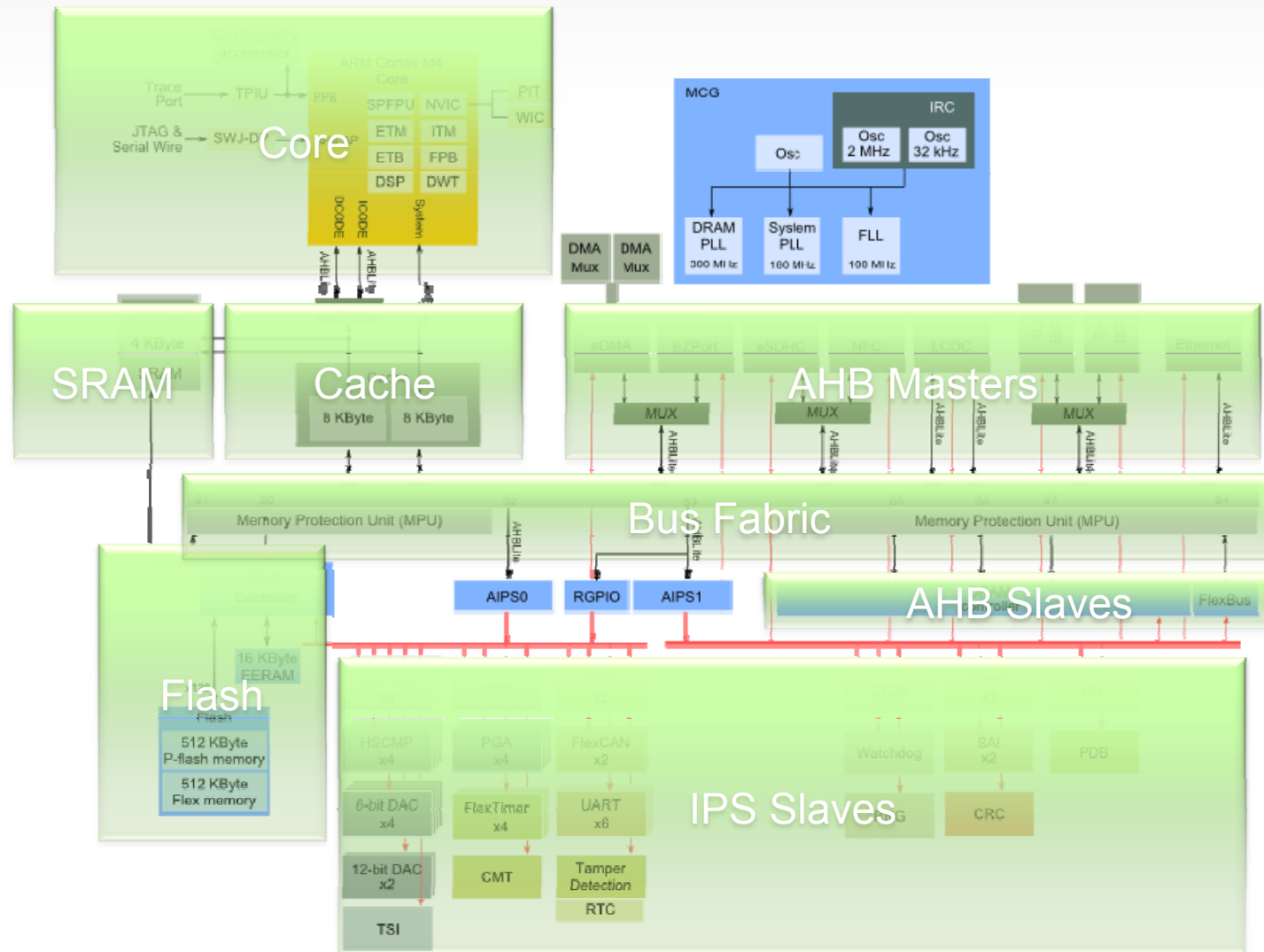
$$Sum = Sum + (A \times C) + (B \times D)$$

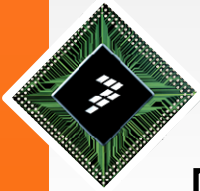


SIMD techniques operate with packed data

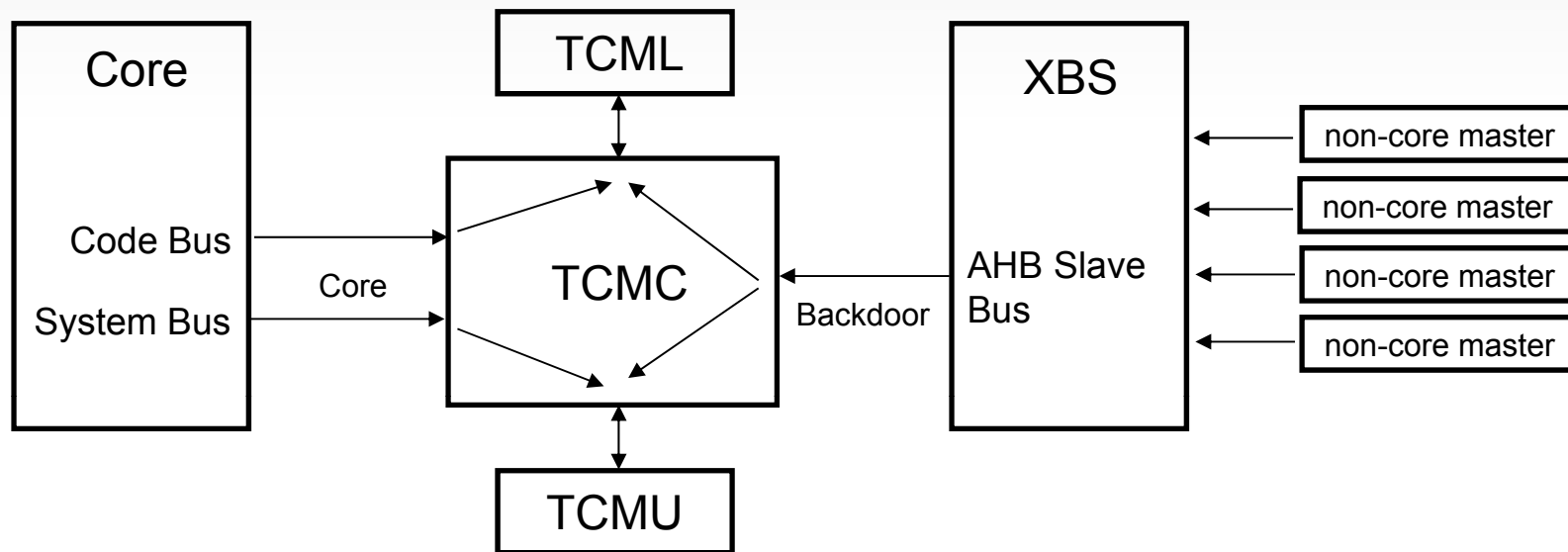


# Kinetis Platform

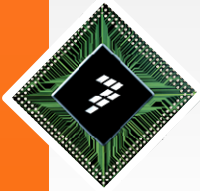




## SRAM Memory Controller (aka TCMC)



- TCMC (Tightly Coupled Memory Controller) manages accesses to TCML/TCMU arrays via configurable arbitration mechanism:
  - Round Robin, Special Round Robin, or Fixed Priority (core or backdoor)
- The following simultaneous accesses can be made to TCML and TCMU SRAM arrays:
  - Core instruction (TCML) and core data (TCMU)
  - Core instruction (TCML) and non-core master (TCMU)
  - Core data (TCMU) and non-core master (TCML)
- Two non-core masters cannot access the same SRAM array simultaneously because of crossbar switch arbitration



# Multi-master Crossbar Features

Excerpt from [Kinetis Reference Manual](#)

## 17.1.1 Features

The crossbar switch includes these distinctive features:

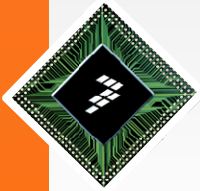
- Symmetric crossbar bus switch implementation
  - Allows concurrent accesses from different masters to different slaves
  - Slave arbitration attributes configured on a slave by slave basis
- 32-bit wide and supports byte, 2 byte, 4 byte, and 16 byte burst transfers
- Operates at a 1-to-1 clock frequency with the bus masters
- Low-power park mode support

Concurrent accesses

Slave by slave arbitration options

Burst transfers (16 byte)





# What is FlexMemory?

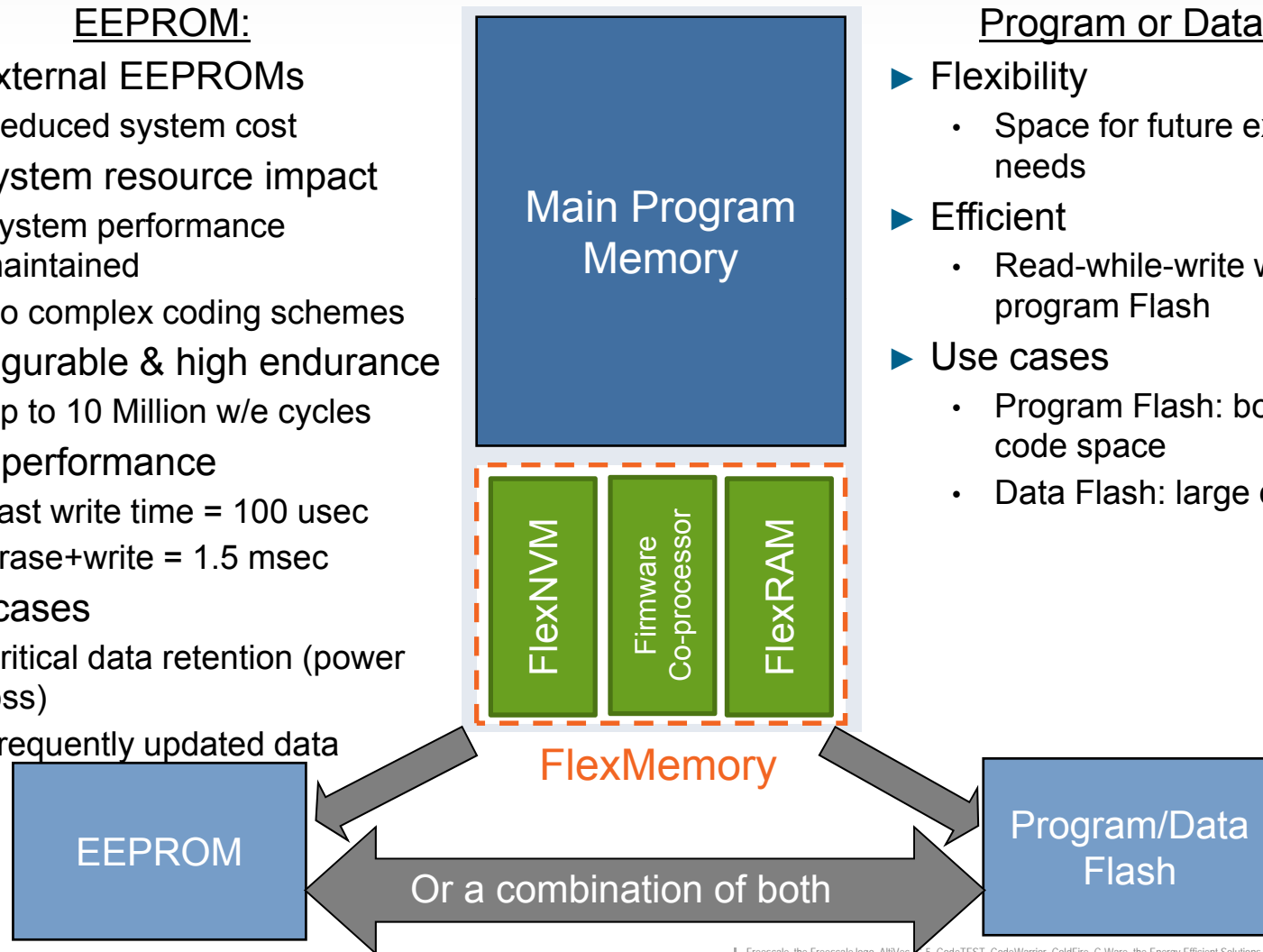
## User Configurable As...

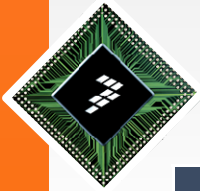
### EEPROM:

- ▶ 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 = 1.5 msec
- ▶ Use cases
  - Critical data retention (power loss)
  - Frequently updated data

### Program or Data Flash:

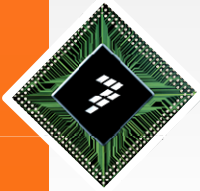
- ▶ Flexibility
  - Space for future expansion needs
- ▶ Efficient
  - Read-while-write with the main program Flash
- ▶ Use cases
  - Program Flash: bootloader code space
  - Data Flash: large data tables





# FlexMemory vs. Traditional EEPROM

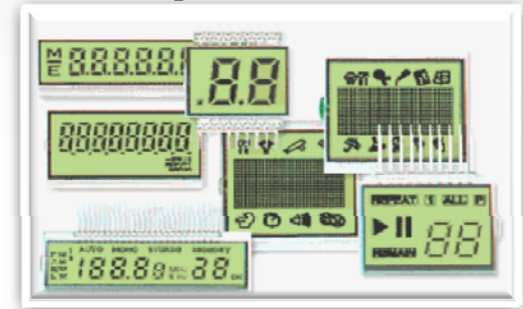
Attribute	Traditional Embedded EEPROM	FlexMemory
Read-while-write with program memory	Yes	Yes
Granularity	Byte write/erase	Byte write/erase
Write time	~1-5 msec (byte write only)	~100 µsec (byte or word program to erased location, brown-outs w/o loss or corruption of data)
Erase + write time	~5-10 msec	~1.5 msec ( byte or word erase and program, erase is automatic by executing write)
Endurance	50-300K cycles (fixed)	SoC implementation and user configurable, can exceed 10M cycles
Minimum write voltage	≥ 2.0V	1.71V
Flexibility	Fixed by part number	Programmable trade-off - quantity vs. endurance



# Key Human to Machine Interface Peripherals

## Segment LCD Controller (K51 and K53 only)

- Segment fault detection capability
- Up to by 8 multiplexing
- Low power blinking mode
- Front and back plane re-assignment
- Internal charge pump



## Hardware Touch-Sensing Interface (TSI)

- Capacitive touch sensing detection across all low power modes
- 16 input capacitive touch sensing pins
- TSI interrupts



## External Bus Interface (FlexBus)

- 8-,16-, and 32-bit port sizes with configuration for multiplexed or non-multiplexed address and data buses
- Connect a QVGA display easily
- Interface with SRAM, PROM, EPROM, EEPROM, flash, and other peripherals

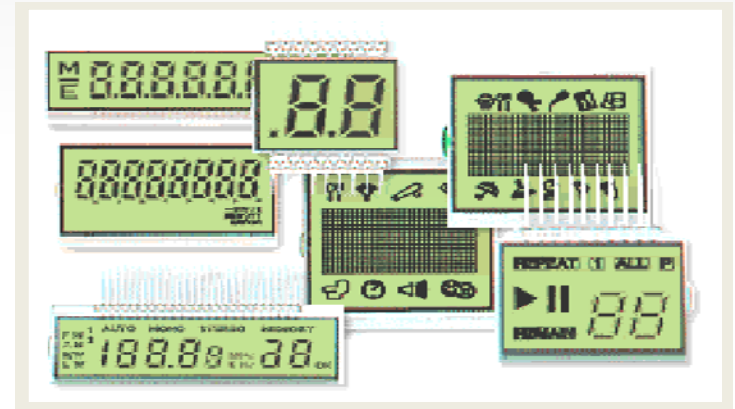


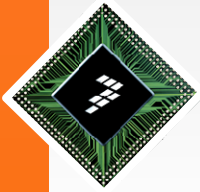
Support for up to 320 segments!!

## Segment LCD Controller



- **Segment fault detection capability**
  - Hardware support for segment LCD display errors
    - Essential when displayed data is safety critical
    - Automates factory test for end product
- **Up to by 8 multiplexing**
  - Fewer pins required to drive LCD segments
    - Kinetis: 48 pins needed to drive 320 segments
    - Competition: 80 pins needed to drive 320 segments
- **Front and back plane re-assignment**
  - Any LCD pin can be a frontplane or backplane pin or GPIO function
  - Assist in vertical scrolling on dot-matrix displays
- **Internal charge pump provides voltage required to power LCD glass**
  - Internally regulated voltage for constant contrast across MCU VDD
  - Trim register for software contrast control
  - Drive for 3V or 5V LCD glass
- **Low power blinking mode**
  - LCD glass blink capability in low power modes
  - Alternate display feature can be activated to display alternate data (i.e. blink temperature and time)

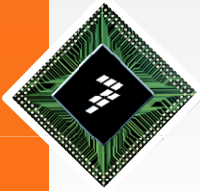




# Low Power Capabilities

- Flexible power modes
  - 11 Run, Wait & STOP modes (2x competition devices)
    - customize power usage to application requirements
- Industry leading 90nm process technology
  - 1/3 dynamic power reduction vs. existing technologies
  - Intelligent power management controller reduces dynamic and leakage currents
- Low power design techniques
  - Clock gating: only leakage currents are incurred
  - Power gating: shuts down unused modules and memories reducing leakage
- Ultra fast wake up times
  - 6 $\mu$ s wake up from low leakage stop (LLS) mode
  - New Low Leakage Wake-up Unit for leakage current reduction

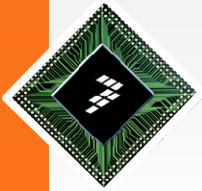




# Kinetis Power Outlook

Typical Power Modes in an embedded system	Cortex-M4 Power Modes	Kinetis Extended Power Modes	Recovery Time	"Typical" Idd Range
Run	Run	Run	-	Starting @ <200uA/MHz
Wait	Sleep	VLPR	-	Starting @ <200uA/MHz
Stop	DeepSleep	Wait	-	
		VLPW	4us	
		Stop	4us	300uA - 400uA
		VLPS	4us	10uA - 30uA
<p>Freescle Adds Low Leakage Wake-up Unit</p> <ul style="list-style-type: none"> <li>▶ Enables complete shut-down of core logic, including WIC, further reducing leakage currents in all low power modes</li> <li>▶ Supports 16 external input pins and 8 internal modules as wakeup sources</li> <li>▶ Wakeup inputs are activated in LLS or VLLS modes</li> </ul>		LLS	6us	4uA - 12uA
		VLLS3	75us	920nA - 8uA
		VLLS2	75us	850nA - 4uA
		VLLS1	120us	840nA - 2uA
		VBAT only (RTC + OSC)		200nA off / 750nA on



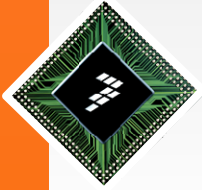


# Module Operation in Low Power Modes

**Table 7-2. Module operation in low power modes**

Modules	Stop	VLPR	VLPW	VLPS	LLS	VLLSx
<b>Core modules</b>						
NVIC	static	FF	FF	static	static	OFF
<b>System modules</b>						
Mode Controller	FF	FF	FF	FF	FF	FF
LLWU <sup>1</sup>	static	static	static	static	FF	FF
Regulator	ON	low power	low power	low power	low power	low power
LVD	ON	disabled	disabled	disabled	disabled	disabled
Brown-out Detection	ON	ON	ON	ON	ON	ON
DMA	static	FF	FF	static	static	OFF
Watchdog	FF	FF	FF	FF	static	OFF
EWM	static	FF	static	static	static	OFF
<b>Analog</b>						
16-bit ADC	ADC internal clock only	FF	FF	ADC internal clock only	static	OFF
CMP <sup>7</sup>	HS or LS compare	FF	FF	HS or LS compare	LS compare	LS compare
6-bit DAC	static	FF	FF	static	static	static
VREF	FF	FF	FF	FF	static	OFF
12-bit DAC	static	FF	FF	static	static	static

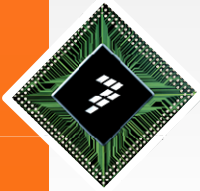
*Table continues on the next page...*



# Polling Operation

- Polling States and Power:
- Test Case 1 >>>VLPS mode Base Current, no Analog modules enabled  
**= 150uA**
- Test Case 2 >>>VLPS mode with ADC continuous conversions  
**= 560uA**
- Test Case 3 >>>VLPS mode with ADC Triggered by Low power timer every 33ms  
**= 160uA**
- Test Case 4 >>>VLPS mode with ADC Triggered by Low power timer, OPAMP and DAC in Low power modes  
**= 310uA**
- Test Case 5 >>>VLPS mode with ADC Triggered by Low power timer, OPAMP and DAC in high performance modes  
**= 745uA**
- Test Case 6 >>>VLPS mode with ADC Triggered by Low power timer, VREF, OPAMP and DAC in Low power modes  
**= 440uA**
- Test Case 7 >>>VLPS mode with ADC Triggered by Low power timer, VREF, OPAMP and DAC in high performance modes  
**= 1250uA**





# Key Connectivity Peripherals

## 10/100-Mbps Ethernet MAC (ENET) (*K52 and K53 only*)

- Implements the full 802.3 specification
- Supports 10/100 Mbps full duplex and configurable half duplex operation
- Supports AMD magic packet detection with interrupt for node remote power management
- Seamless interface to commercial Ethernet PHY device
- Hardware time stamping support for IEEE 1588 provides precision clock synchronization for real-time control

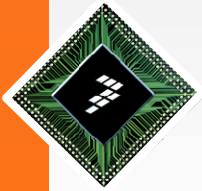
## USB FS/LS OTG Controller

- USB 1.1 and 2.0 compliant host, device and on-the-go (OTG) controller
- 5V regulator sources up to 120 mA in output pin and Eliminates LDO cost
- USB device charger detect

## Other Interfaces

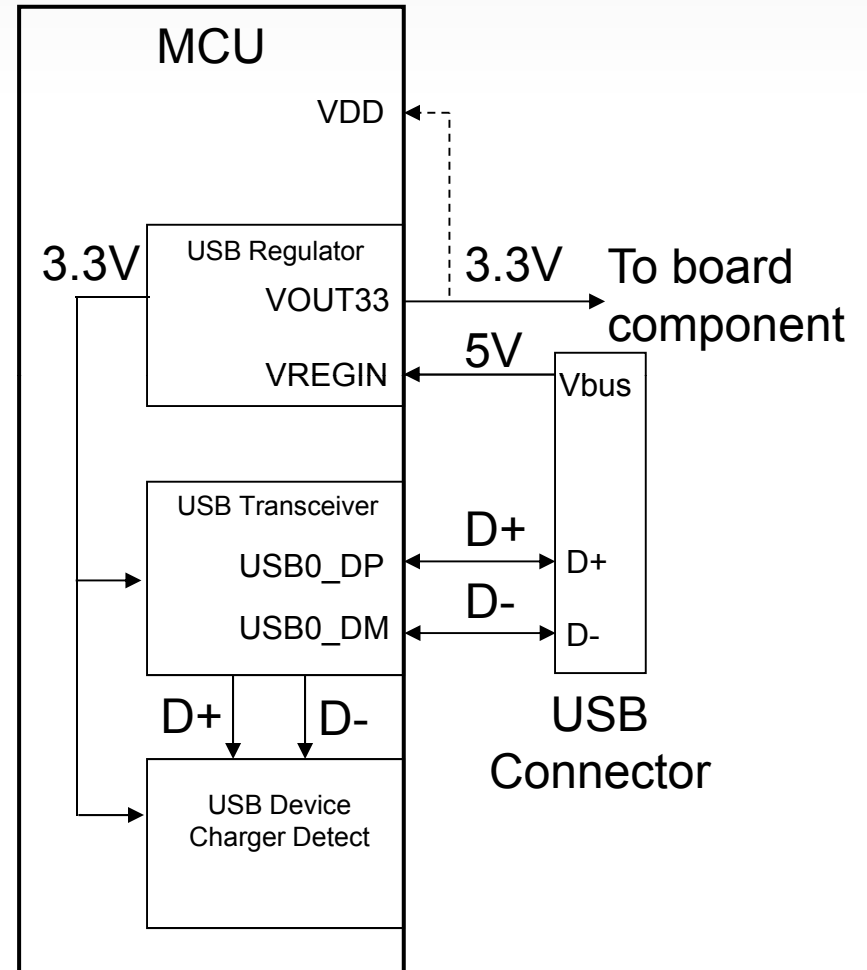
- Up to 3 x DSPI , 6 x UARTS , 2 x I2C
- I2S
- SDHC (*100 MHz devices only*)

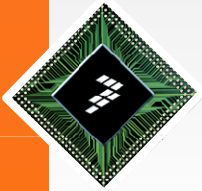




# USB Subsystem - More Than USB Connectivity

- 5V regulator input (VREGIN) typically provided by USB Vbus or Rechargeable Battery power
- 3.3V regulated output powers on-chip USB transceiver and device charger detect
- Output pin (VOUT33) from regulator can be used to power external board components and source up to 120mA
- 120uA quiescent current in run mode
- 1uA quiescent current in standby mode
- Eliminates cost of external LDO
- 3.3V regulated output can power MCU main power supply





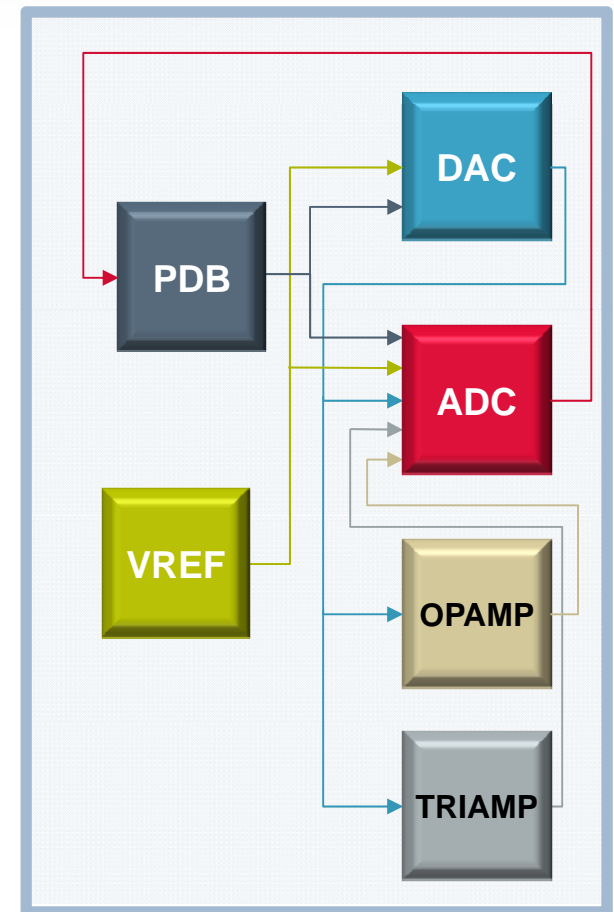
# Measurement Engine IP Specifics

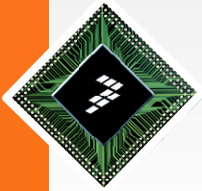
## Measurement Engine Functions

- Static and Dynamic Biasing
- Signal Conditioning
- Accurate Measurements

## Measurement Engine Contains

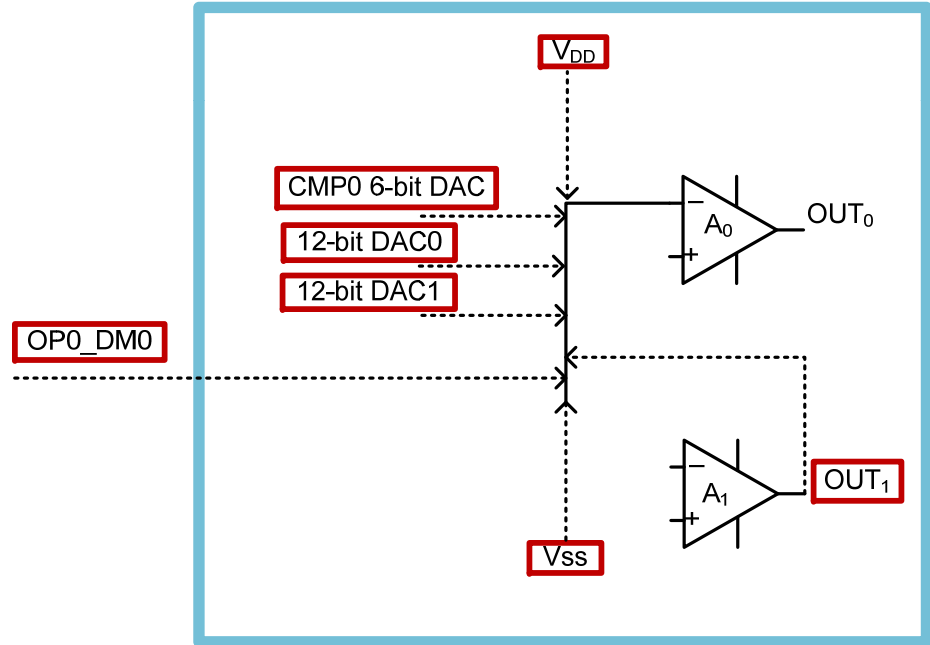
- 16b Analog-Digital Converter
  - SAR type; typical 14b accuracy
- 12b Digital-Analog Converter
  - 1us settling time (min)
- Programmable Delay Block
  - Synchronizes ADC and DAC operations
- 1.2 V Trimmable Voltage Reference
- General Purpose Operational Amplifier
  - Customizable function – filter, PGA
- Trans-Impedance Amplifier
  - 300 pA input bias current operation
- Analog Comparator with Prog. Reference
  - Low power wakeup on analog threshold

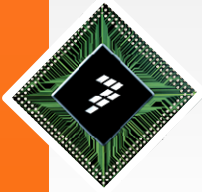




# Operational Amplifier (OPAMP) Input Selector

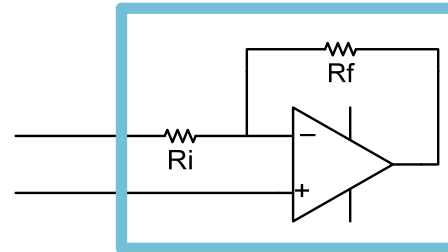
- Selectable input terminal
- Possible sources (OPAMP0 negative input)
  - VDD
  - VSS
  - OPAMP1 output
  - CMP0 6-bit DAC output
  - 12-bit DAC0 output
  - 12-bit DAC1 output
  - PAD



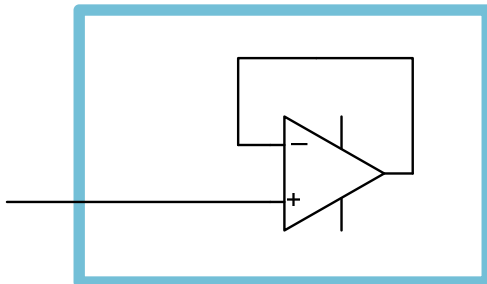


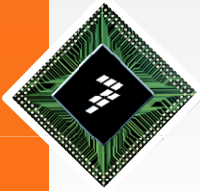
# Operational Amplifier (OPAMP) Modes

- Programmable gain (Inverting or Non Inverting)
  - Possible gains =  $\pm 1, \pm 2, \pm 3, \pm 4, \pm 5, \pm 6, \pm 7, \pm 8, \pm 9, \pm 10, \pm 11, \pm 12, \pm 13, \pm 14, \pm 15, \pm 16, -17$



- Buffer mode



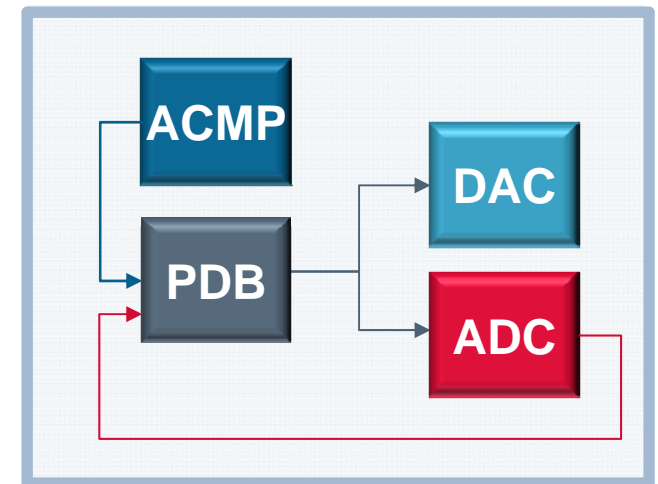
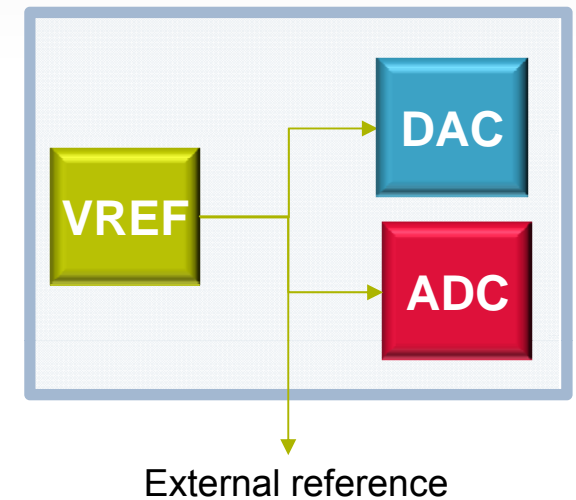


VREF

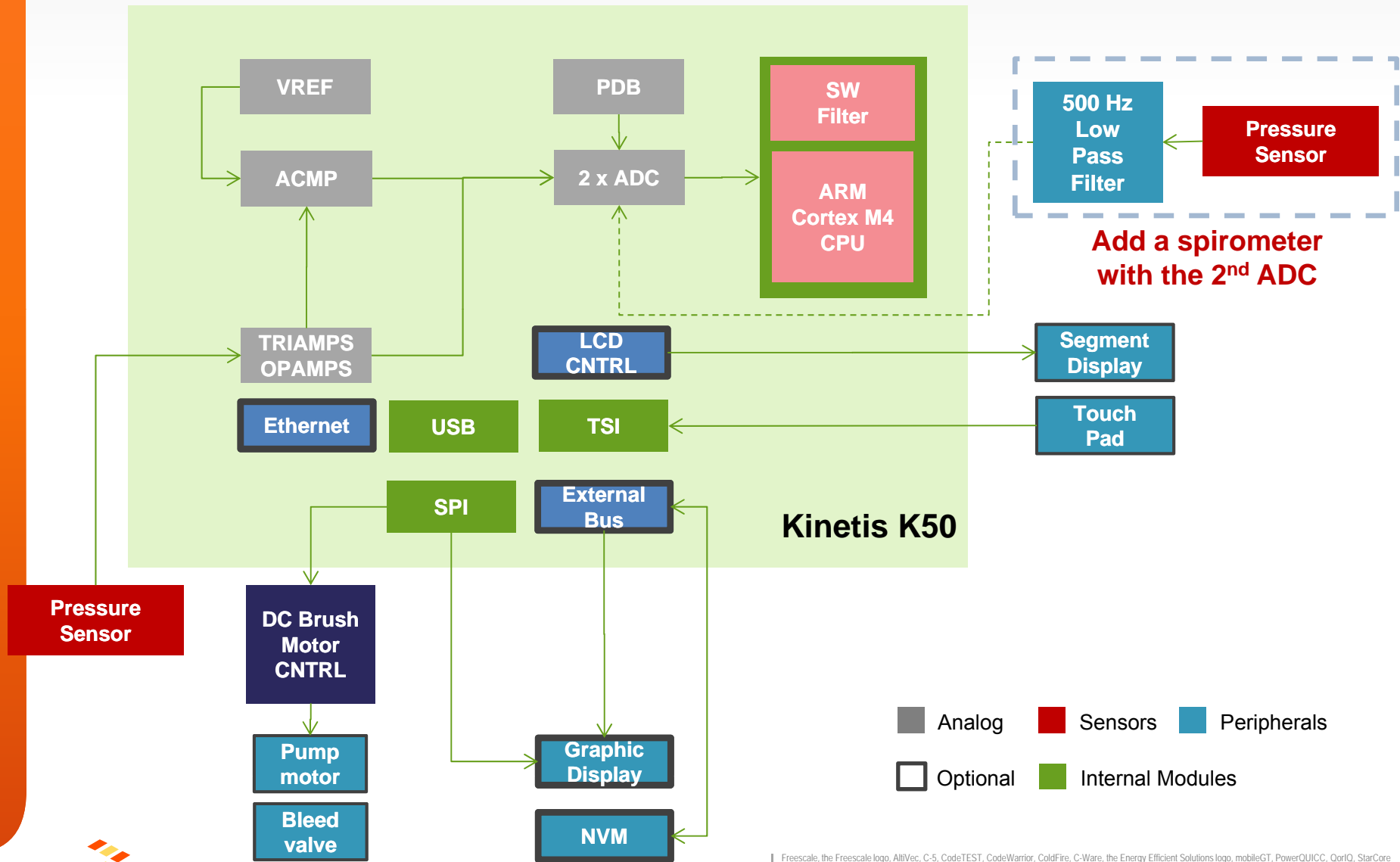
PDB

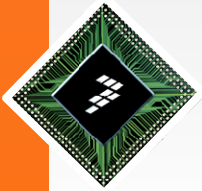
# Voltage Reference Module (VREF) and Programmable Delay Block (PDB)

- Programmable trim register with 0.5 mV steps
- Dedicated output pin (VREFO)
- Programmable mode selection
  - 1.2 V output at room temperature
- Allows timing control over ADC conversions / DAC updates
  - Programmable delay intervals
  - Sample trigger input of one or more ADCs
  - Hardware trigger to the DAC
- Trigger output to advance the DAC buffer pointer
- **4 delay registers to schedule delays with 4 ADC channels**
- Is a timer with Counting register and Modulo register
- Up to eight DAC interval triggers



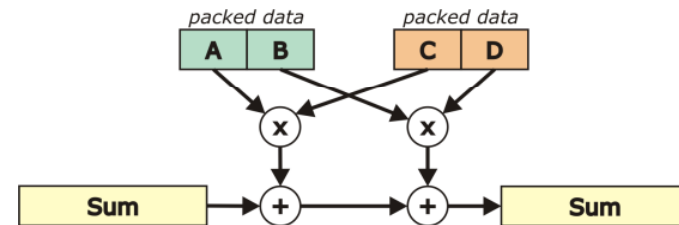
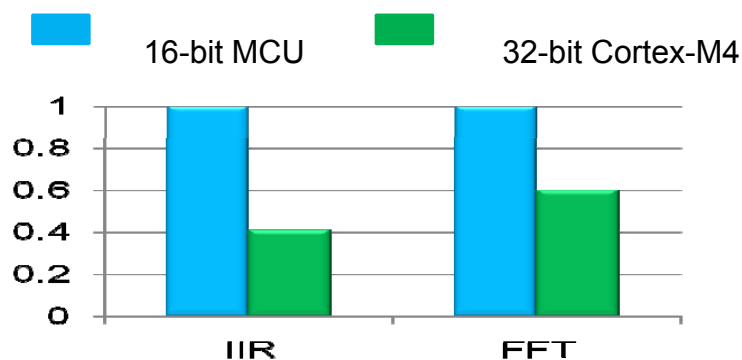
# Blood Pressure Monitor (BPM) + Spirometer



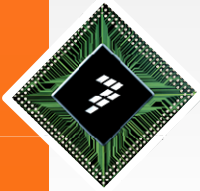


## Hello Kinetis K50. Goodbye Competition.

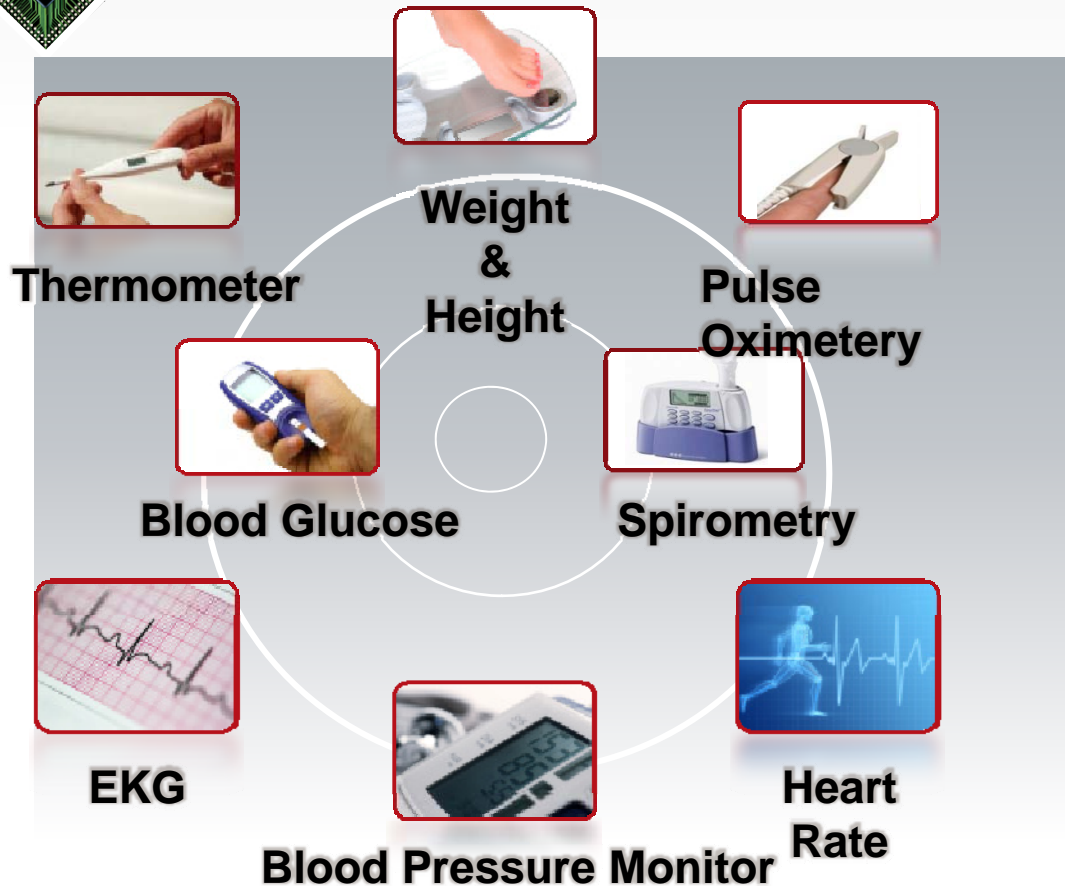
- Kinetis platform performance and efficiency allow improvements to healthcare device diagnostic capabilities that are not achievable with legacy microcontrollers
  - ARM Cortex-M4 core with DSP instructions can improve measurement accuracy with real time software filtering
  - Freescale's platform supports multiple master operations
  - Performance levels up to 100MHz provide the bandwidth needed to make diagnostic calculations



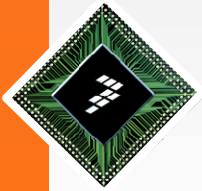




## Kinetis K50 vs. Competition.

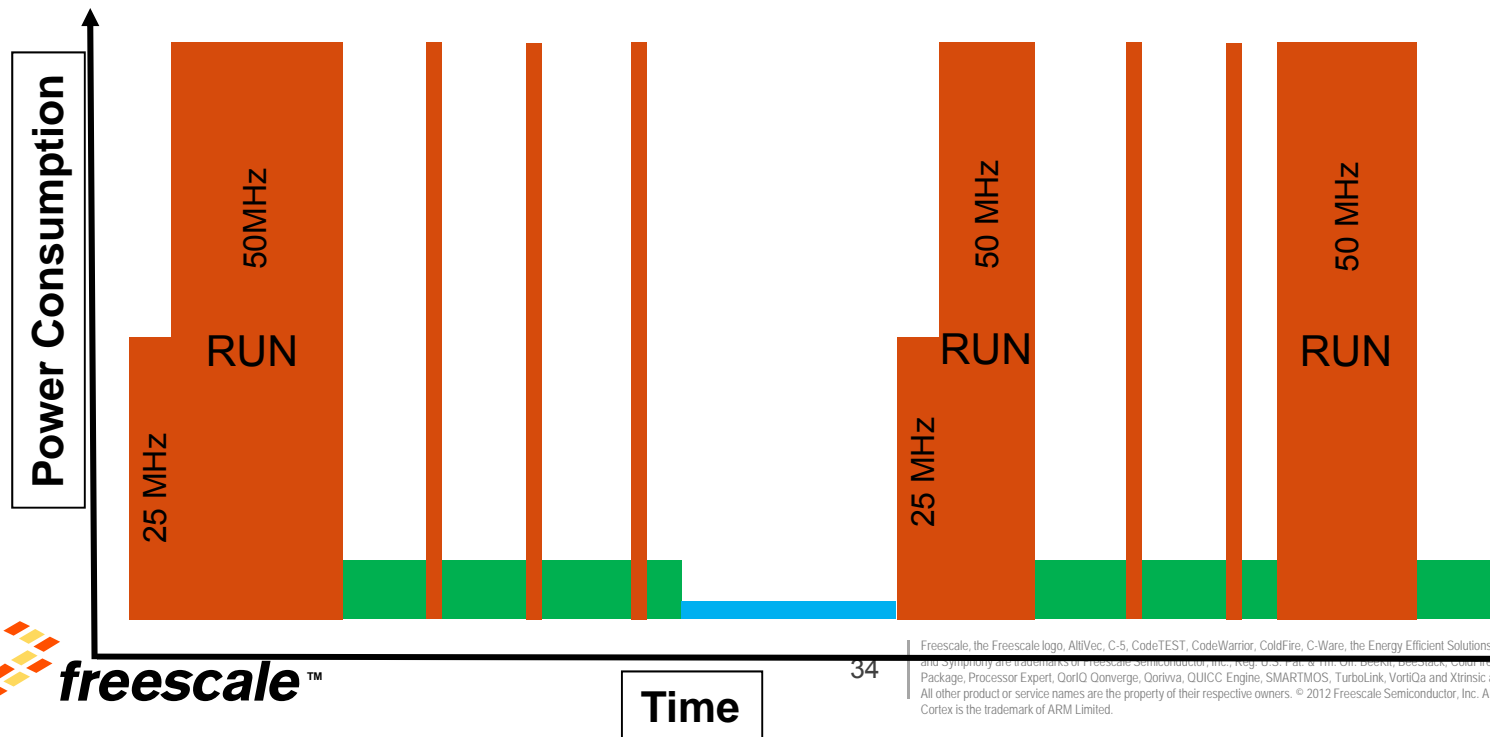


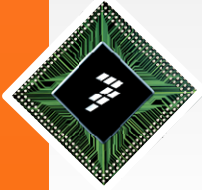
- Unique integration reduces system cost and allows healthcare device manufacturers to provide devices with more functionality
  - Over 40 Kinetis K50 family devices with Flash Memory sizes up to 512KB and up to 128KB of SRAM
  - USB sub-system with integrated LDO regulator and device charge detection capability
  - Integrated Human to Machine Interface peripherals and analog front end



## Kinetis K50 vs. Competition

- Kinetis low power architecture helps ensure that healthcare devices can satisfy battery life requirements
  - LCD blink modes support user feedback during Deep Sleep modes
  - Module functionality in low power modes:
    - Integrated Touch sensor functionality in all modes
    - Analog peripheral functionality in Sleep modes





## Kinetis K50

- Kinetis feature rich serial communications peripherals support a wide range of connectivity options

### 10/100-Mbps Ethernet MAC (ENET) (*K52 and K53 only*)

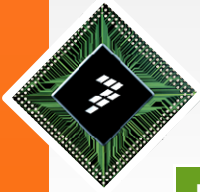
- Supports 10/100 Mbps full duplex and configurable half duplex operation
- Seamless interface to commercial Ethernet PHY device

### USB FS/LS OTG Controller

- USB 1.1 and 2.0 compliant host, device and on-the-go (OTG) controller
- 5V regulator sources up to 120 mA in output pin and Eliminates LDO cost
- USB device charger detect

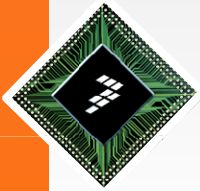
### Other Interfaces

- Up to 3 x DSPI , 6 x UARTS , 2 x I2C
- I2S
- SDHC



## Kinetis K50

Key Feature	Kinetis K50	Competition
Performance	Up to 100Mhz	Up to 20Mhz with limitations at lower Voltage levels
DSP Instructions	Yes	32b Multiply Peripheral
Platform	16ch DMA, Concurrent access crossbar	6-ch DMA, SYS module arbitrates memory accesses
Memory	Up to 512KB Flash Up to 128KB RAM	Limited to 256KB Flash Limited to 16KB RAM
Module operation in low power modes	DAC, VREF, ADC and OPAMPs for low power measurements	No
Connectivity	Ethernet, SDHC	No
HMI	Integrated Touch	No
Misc.	Integrated USB Regulator	No



# Get Started with Modular Development Platform TWR-K53N512-KIT

- Features K53N512CMD100 MAPBGA 144 pins MCU
- Tower compatible processor module
- S08JM60 based Open Source JTAG (JTAG) circuit
- User-controlled status LEDs
- Medical expansion connector
- SD Card Slot
- Connect TWRPI-SLCD board (28 segment LCD) through TWRPI interface
- Capacitive Touch Pad sensors and mechanical push buttons
- Compatible with TWR-SER (Ethernet, USB connectivity)
- MMA7660 Accelerometer



<b>Kit</b>	TWR-K53N512	TWR-ELEV
<b>contains:</b>	TWR-SER	TWRPI-SLCD

<http://www.freescale.com/TWR-K53N512>



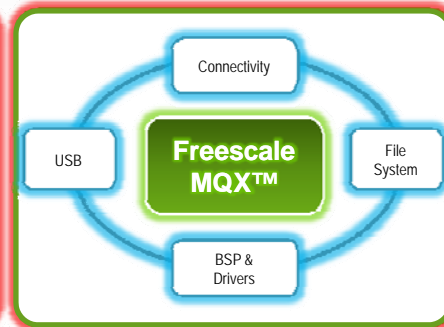
# Easy Enablement – Rapid Prototyping for Quality Software Development



Modular, expandable and cost-effective development platform



Premier suppliers of *IDE: Tools and Compilers.*



Full-featured, scalable, proven RTOS



*HW BDM Debugger/Emulators*



- Security and medical application partners and ready to use software.



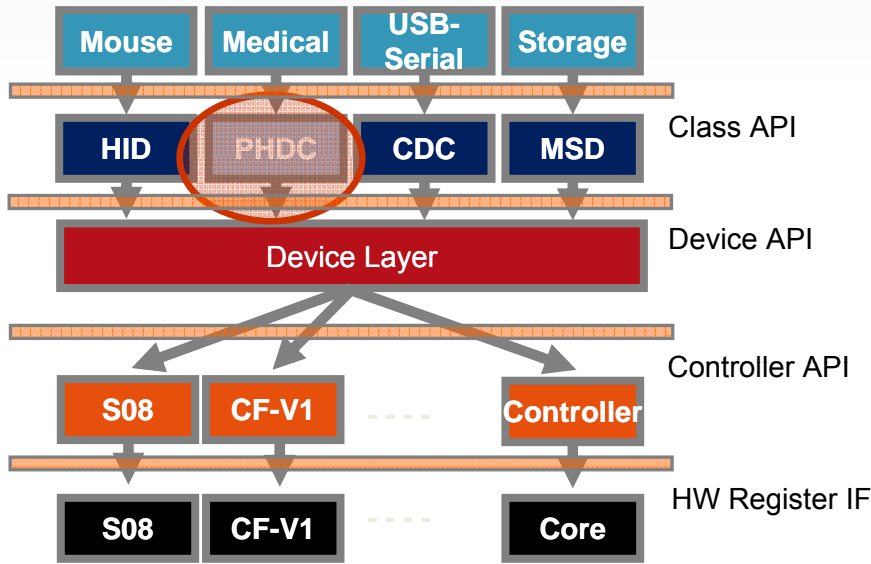
- Initialization Setup
- GUI creation
- Ready to use libraries
- Documentation



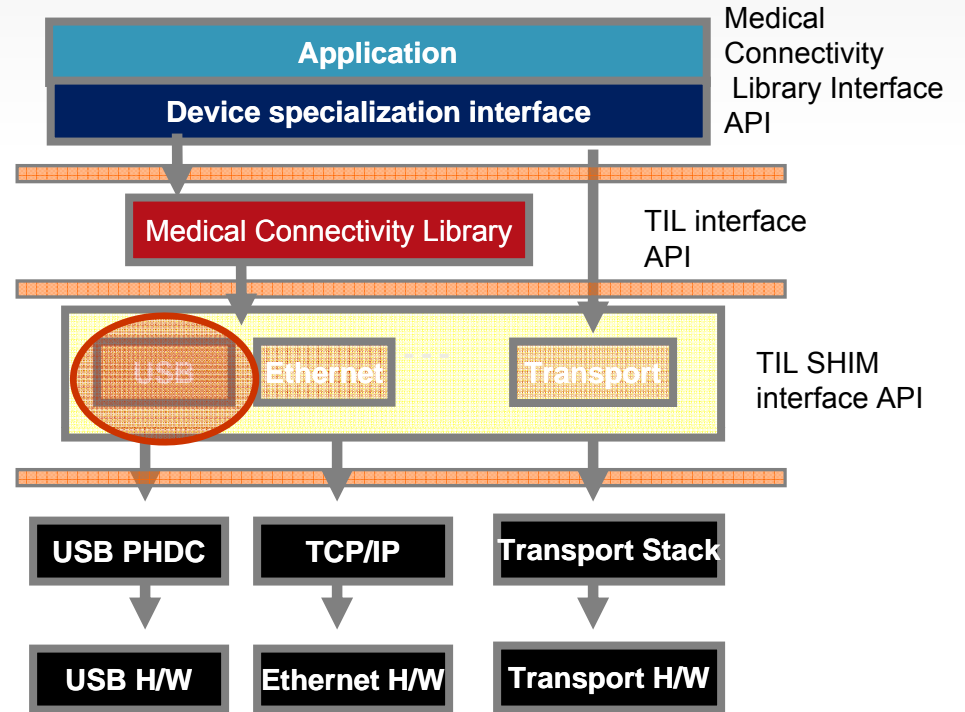
- MQX support
- Design Services



# Medical USB Connectivity



USB Stack with PHDC support



Available  
Functionality

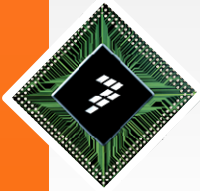
Medical Connectivity Library  
(IEEE 11073)

Use both stacks to enhance Medical USB connectivity!

- Developed under Continua Guidelines
- IEEE 11073
- PHDC support

<http://www.freescale.com/medicalusb>



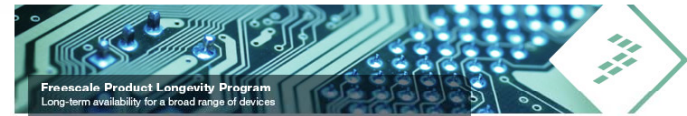


# Product Longevity Program

- The embedded market needs long-term product support
- Freescale has a longstanding track record of providing long-term production support for our products
- Freescale is pleased to introduce a formal product longevity program for the market segments we serve
- For the Automotive and Medical segments, Freescale will make a broad range of program devices available for a minimum of 15 years
- For all other market segments in which Freescale participates, Freescale will make a broad range of devices available for a minimum of 10 years
- Life cycles begin at the time of launch
- For Terms and Conditions and to obtain a list of available products please see:

[www.freescale.com/productlongevity](http://www.freescale.com/productlongevity)

## Product Longevity



### Freescale Product Longevity Statement

Freescale Semiconductor provides a product longevity program for the market segments we serve. For the automotive and medical segments, Freescale will make a broad range of devices available for a minimum period of 15 years. For all other market segments in which Freescale participates, Freescale will make a broad range of devices available for a minimum period of 10 years.

Life cycles for participating Freescale products will begin at the time of product launch and will include the standard Freescale end-of-life notification policy (one-year notice for placement of final orders and an additional year until the last ship date). Freescale will manage the program through our own factories, outside foundries and other manufacturing resources. If it becomes necessary to transfer the production of a participating product to an alternate manufacturing facility, Freescale will re-quality that product. These actions demonstrate our intention to provide supply stability to our customers.

Products included in the Freescale product longevity program:

Search/Filter:

Category	Family	10-Year	15-Year	Product Launch
Industrial MCU	16-bit DSC	MC56F803X	-	2009-07
Industrial MCU	16-bit DSC	MC56F802X	-	2007-08
Industrial MCU	16-bit DSC	MC56F8013/14	-	2005-04
Industrial MCU	16-bit DSC	MC56F8006/2	-	2009-03
Auto MCU	16-bit S12	-	S12HYx	2009-10
Auto MCU	16-bit S12	-	S12Px	2009-07
Auto MCU	16-bit S12	-	S12C	2010-10
Auto MCU	16-bit S12 MagniV	-	S12VR64	2011-12
Auto MCU	16-bit S12X	-	S12XS	2009-09
Auto MCU	16-bit S12X	-	S12XE	2009-09
Auto MCU	16-bit S12X	-	S12XF	2009-03





# Resources

- **Home Health Hub Reference Platform**
  - [www.freescale.com/homehealthhub](http://www.freescale.com/homehealthhub)
- **Freescale Medical Homepage**
  - [www.freescale.com/medical](http://www.freescale.com/medical)
    - Applications, block diagrams, product details
    - Demo videos, reference designs
    - Development tools
- **Medical Applications Guide**
  - [www.freescale.com/medicalappsguide](http://www.freescale.com/medicalappsguide)
    - Complete guide with over 16 chapters of medical applications and 150 diagrams
- **Medical By Design Blog**
  - [blogs.freescale.com/category/medical-by-design](http://blogs.freescale.com/category/medical-by-design)

