Balancing Design Challenges in Portable Products
Design With Freescale Low Power Seminars
www.freescale.com/lowpowerseminars

Low Power Product *Design* Seminars

A new approach to low power training

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

What will I learn?

Your Goal:

- To develop a scalable handheld battery operated product

Our Objectives:

- To provide you with an understanding of Freescale’s low power solutions
- To educate you on the benefits of designing products based on Freescale devices
- To provide you with the techniques required to design a low power, scaleable handheld product with a rich human-machine interface

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Seminar Agenda

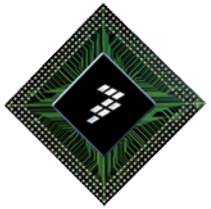
- Defining low power
- Defining your power management strategy
- Selecting your low power MCU
- Other Low Power solutions from Freescale
- Introduction to CodeWarrior & Processor Expert
- Digital Multi-Meter Design
  - Labs: S08QE8, S08QE32, S08QE128, CF51QE128

    8-bit S08 32-bit ColdFire
- Low Power Resources & Wrap-up

After the seminar each attendee will be sent an email voucher with instructions on how to get their free development tool.

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Defining low power



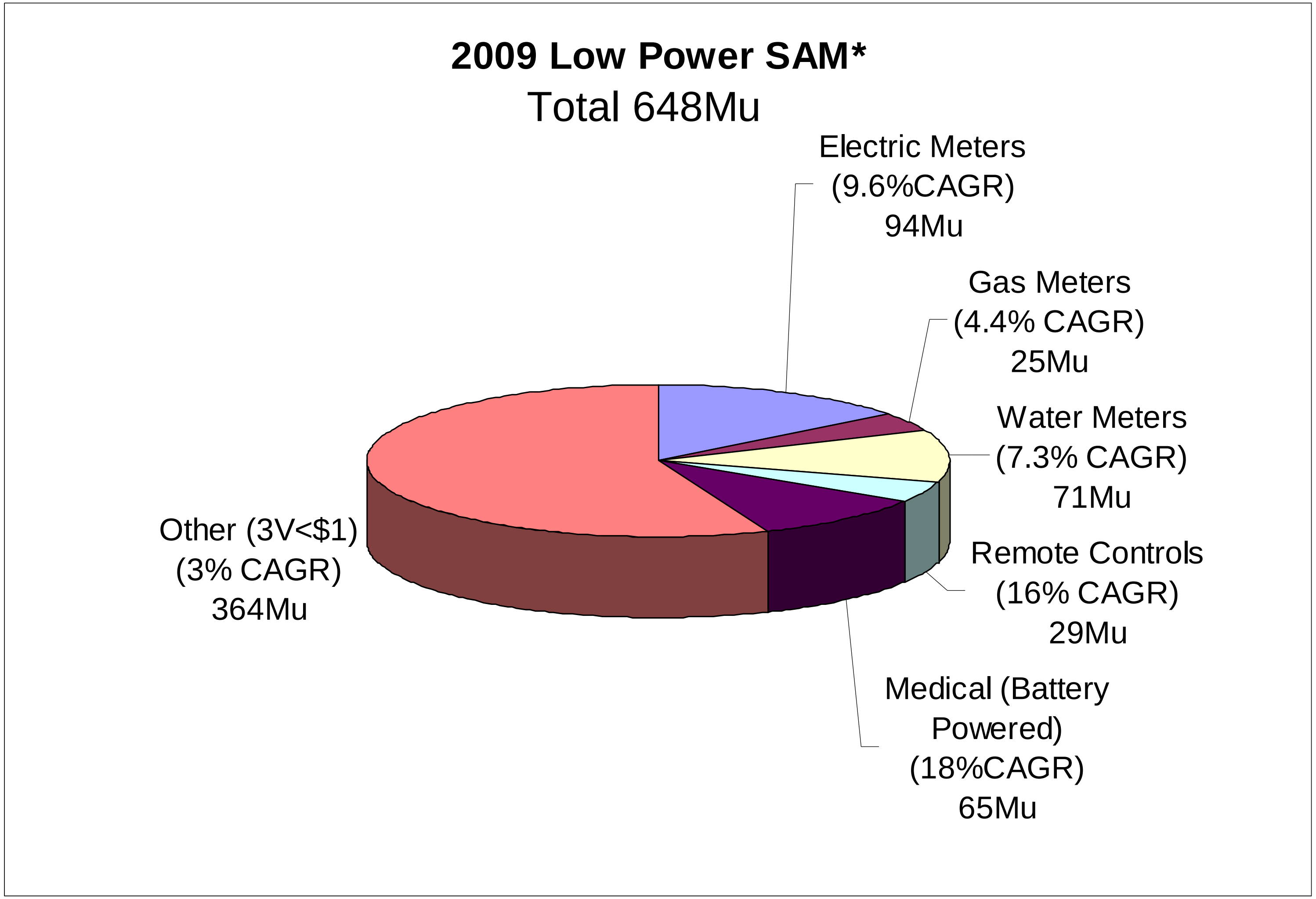
Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

The Importance of Low Power

Longer battery life	Reduced operating costs / end product differentiation
Reduced heat dissipation	Removes cost of heat sinks / fans
Reduced system complexity	Faster development / time-to-market
Ability to meet more low power standards	Larger target market
Increased reliability for battery back-up critical applications	End product differentiation
Increased board density	Increased system performance

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Low Power Market Overview - SAM



Source: iSuppli, IMM Marketing

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Freescale's Low Power Strategy

•Develop industry leading low power technology that delivers enhanced battery life performance for embedded applications

•Embed low power IP across the 8-bit S08, 16-bit Digital Signal Controller, & 32-bit ColdFire architectures offering performance & price scalability for low power applications

•Develop a broad portfolio of general purpose & market specific product families that combine low power IP with LCD, Ethernet, USB, and Motor Control functionality

•Provide an extensive development ecosystem including reference designs, application notes, and training resources (like this seminar!) to promote the awareness of low power design techniques and reduce product time to market

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Defining Low Power

How semiconductor manufacturers specify low power?

Measured in Run Current (mA or mA/MHz)

Does high Run Current mean high power consumption?

Measured in Lowest Sleep Current (nA or uA)

Low Power is Defined as Lowest Power Mode. Is it practical? Is it useful in real applications?

Measured in performance per Watt (MIPS/Watt)

Does it make more sense?

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Defining Low Power

How customers ask for low power?

Measured in Battery Life (Years)

Customer preferred method

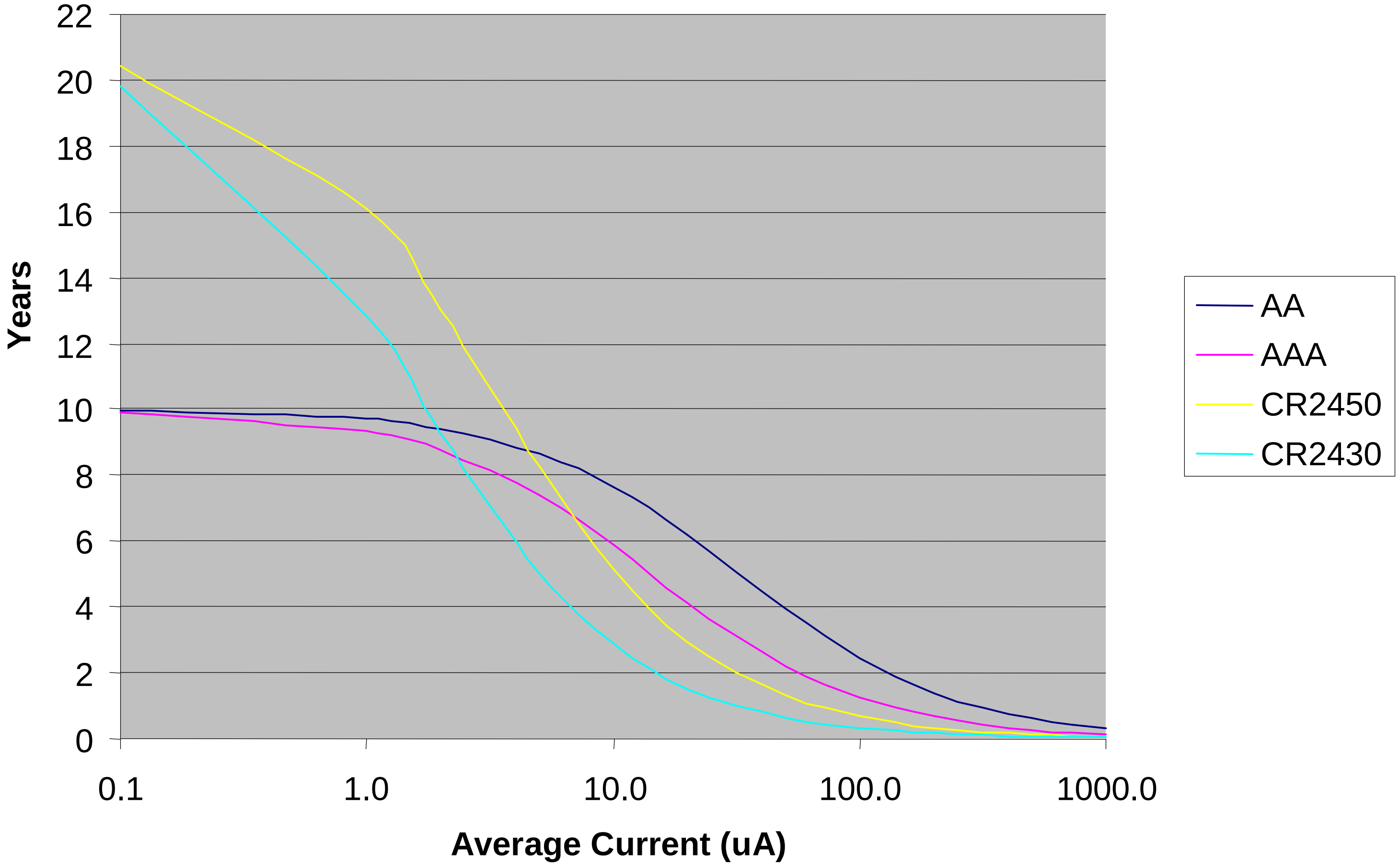
Measured in Average Power (Watt/Hour)

Influences battery life. See the figure on following slide

Measured in Peak Current? (mA)

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Battery Life vs. Average Current



Defining Low Power

Low Power means different things for different applications

Every low power design is different and will have its own interesting set of problems to solve. You have to think through every element of the design, not only hardware but software if you want to operate at very low power levels.

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Defining your power management strategy

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Factors affecting power consumption

- MCU Low Power modes
- MCU Speed
- MCU Peripheral Power Consumption
- Low Power I/O
- Periodic Wake-Up from Low Power mode

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Low Power Modes

How many MCU operating modes are there and what are they?

- Does the MCU have one of more low power modes?

What are the features of each operating mode?

- What is the maximum speed?
- What is the regulator status?

Is the Low Power mode practical for your application?

- How long will the MCU take to recover from the Low power mode? Too long for the application?
- What functions can be supported by the MCU in the Low-Power mode? How to wake up the MCU from the Low-Power mode?

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

MCU Speed

Speed kills !

- Power consumed by modern CMOS devices is almost always dominated by how fast the device is being clocked.
- As a general rule, if you double the speed, you double the power consumption.
- We often forget, if you double the bus width, you may also double the power consumption.
- Try to architect your system to run as slowly as practical.

Can the clock speed be changed on the fly?

- Allow the processor to dynamically change the speed of operation based on instantaneous demand for computing power

Run at the full speed across the whole voltage range?

- How fast can the part run at lower voltages?
- Typically Low Power Competitors Have 1MHz Bus Speed

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Peripheral Power Consumption

Do the peripherals consume power when unused?

- Try to reduce the power consumption of the peripherals unused

Is it pratical to turn off all functions in the Low Power mode?

- The functions may be critical to your application in the LP mode. For example, the low power mode won’t do much good if it turns off the on-chip UART and you have to wake up based on receiving characters on the serial port.

Are the peripherals fully functional when the voltage is low?

- Can the flash be programmed at lower voltages? Typically Low Power Competitors need > 2V
- Can the ADC work at lower voltages?

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Low-power I/O

What pull-up values are really needed?

- The days of using 4.7K pull-up resistors are gone.
- Start thinking of pull-ups with values in the 1MW range.

Are all of the pull-up resistors required all of the time?

- Consider removing power from pull-ups.

Should you use a pull-down instead?

- Look at the state you expect an input to be in most of the time. If it will be reliably low most of the time, consider using a pull-down resistor rather than a pull-up.

Do not float the I/O unused!

- Current is consumed at the point where the transistor switches.
- Applying a mid-rail voltage and allowing an input pin to float will cause a current to flow from VDD to VSS.
- Ensure that input voltages are held to VDD or VSS.

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Periodic Wake-Up

Reducing the power consumption by sleeping and waking up periodically provided your applif your application can

Many embedded applications spend most of their time waiting for something to happen: receiving data on a serial port, watching an I/O pin change state, or waiting for a time delay to expire. If the processor is still running at full speed when it is just waiting for something to happen, we are burning up battery life while accomplishing little.

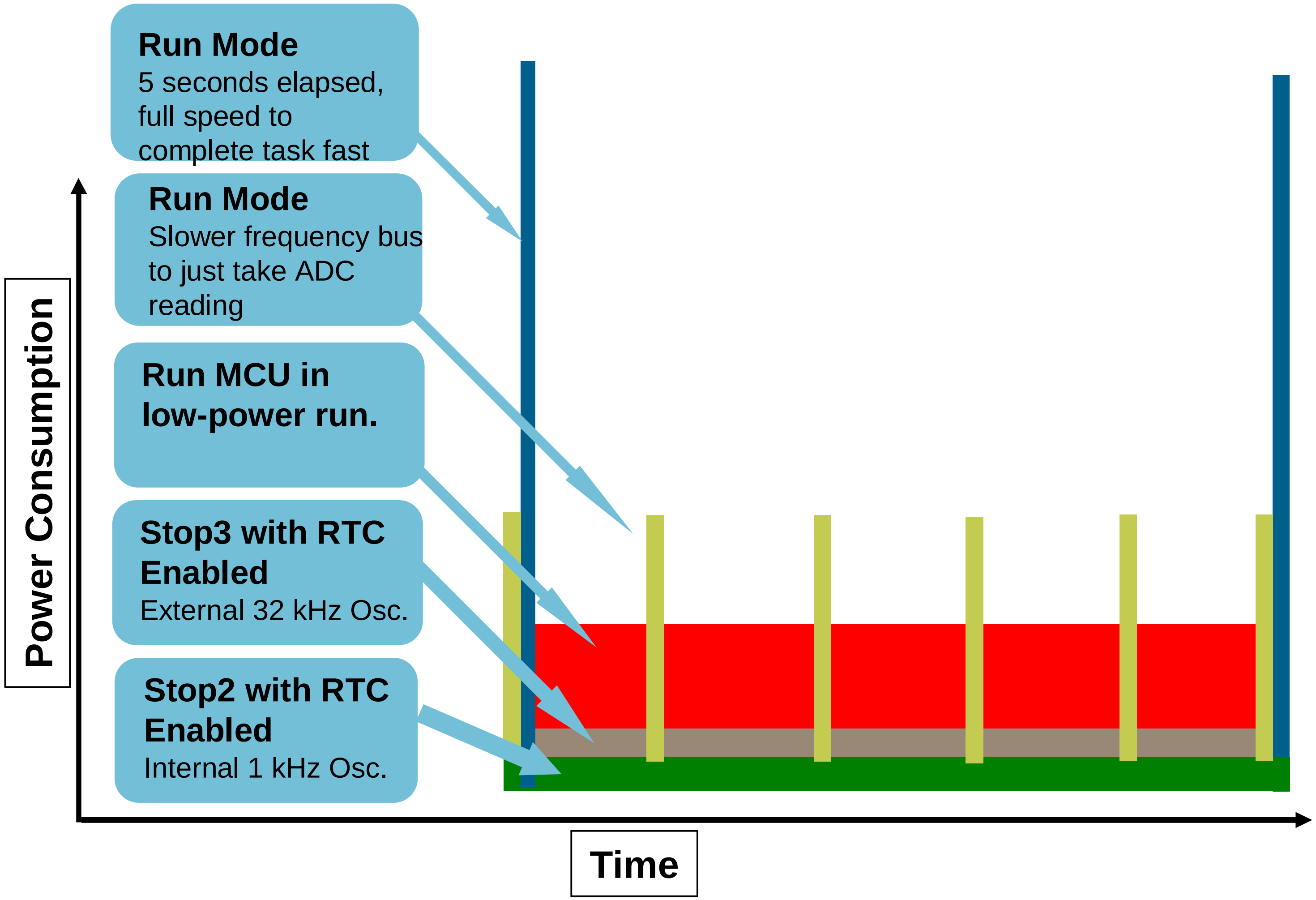
Example:
Need to wake every second and read sensor. Every 5 seconds, process data.

Which approach uses less power?

1. Run MCU in low-power run the entire time
2. Use MCU’s RTC with a crystal to provide accurate clock during Stop3 mode
3. Use MCU’s RTC with internal LPO reference during Stop2 mode

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

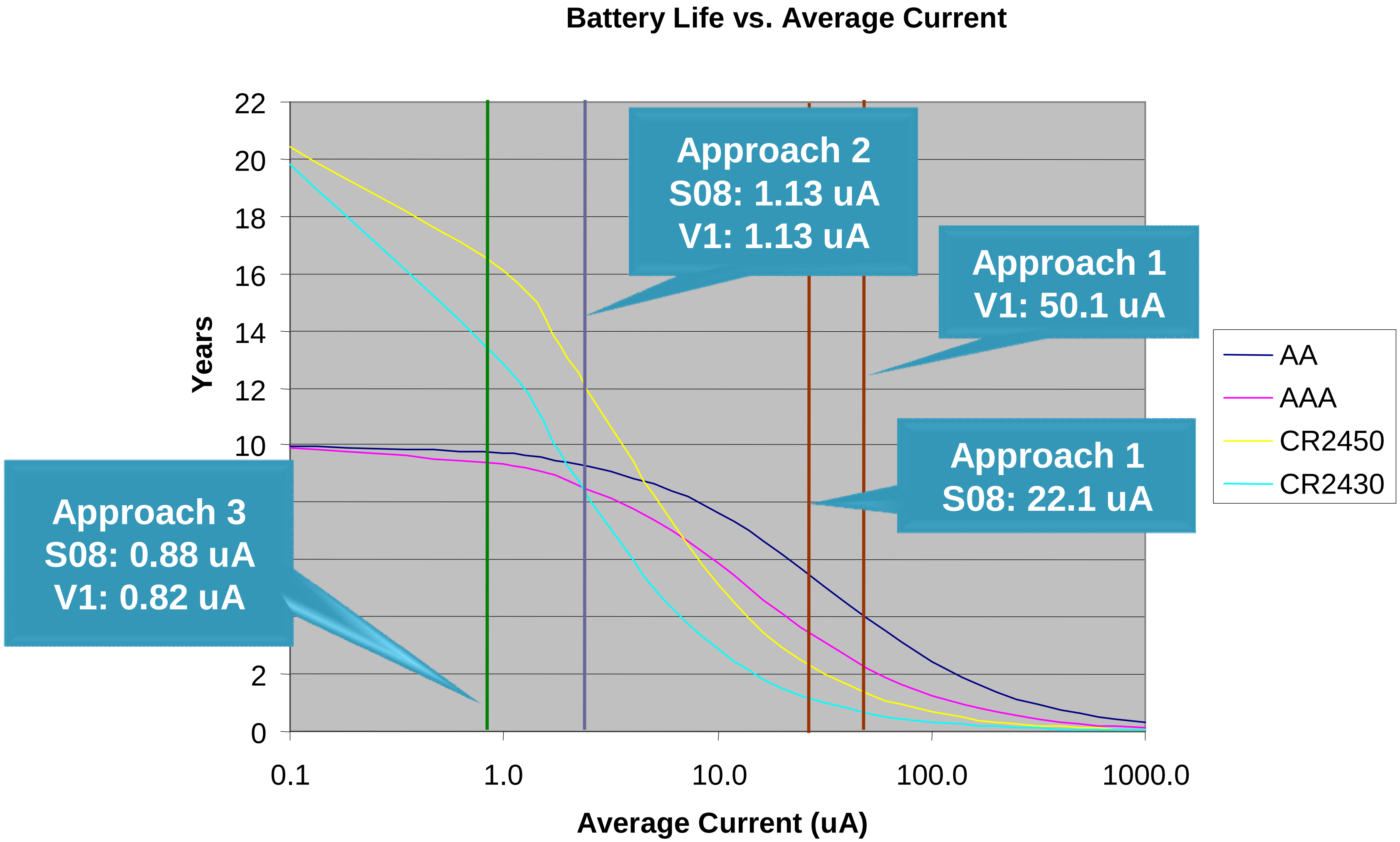
Example



Run Mode
5 seconds elapsed, full speed to complete task fast
Run Mode
Slower frequency bus to just take ADC reading
Run MCU in low-power run.
Stop3 with RTC Enabled
External 32 kHz Osc.
Stop2 with RTC Enabled
Internal 1 kHz Osc.
Power Consumption
Time

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Battery Life vs. Average Current



Approach 2
S08: 1.13 uA
V1: 1.13 uA

Approach 1
V1: 50.1 uA

Approach 1
S08: 22.1 uA

Approach 3
S08: 0.88 uA
V1: 0.82 uA

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

The Product: Digital Multi-Meter

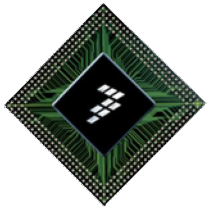
- ►In the following labs you will design a portable Digital Multi-Meter (DMM)

- ►Why was a Digital Multi-meter chosen?
  - The DMM was selected as the end product for reasons of design simplicity. The low power design principles used in this seminar can be applied to <u>any portable battery-operated product</u>

- ►Typical DMM application requirements
  - Easy development to provide shorter time to market
  - Time keeping in low power mode
  - Ability to turn peripherals on and off in order to reduce power consumption
  - Ability to change System clock speeds
  - Flash programming at low voltages
    - Data capture and display
  - Operation across Battery voltage range 1.8V-3.6V
  - Scalability for a Family of Multi Meter devices
    - Low end DMM to Oscilloscope DMM with Data logger

- ►In the next section we will map product requirements to MCU device features

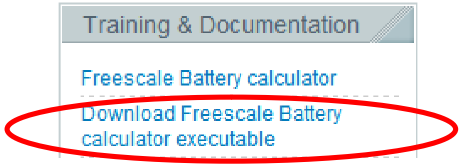
Selecting your Low Power MCU



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Freescale Battery Life Calculator

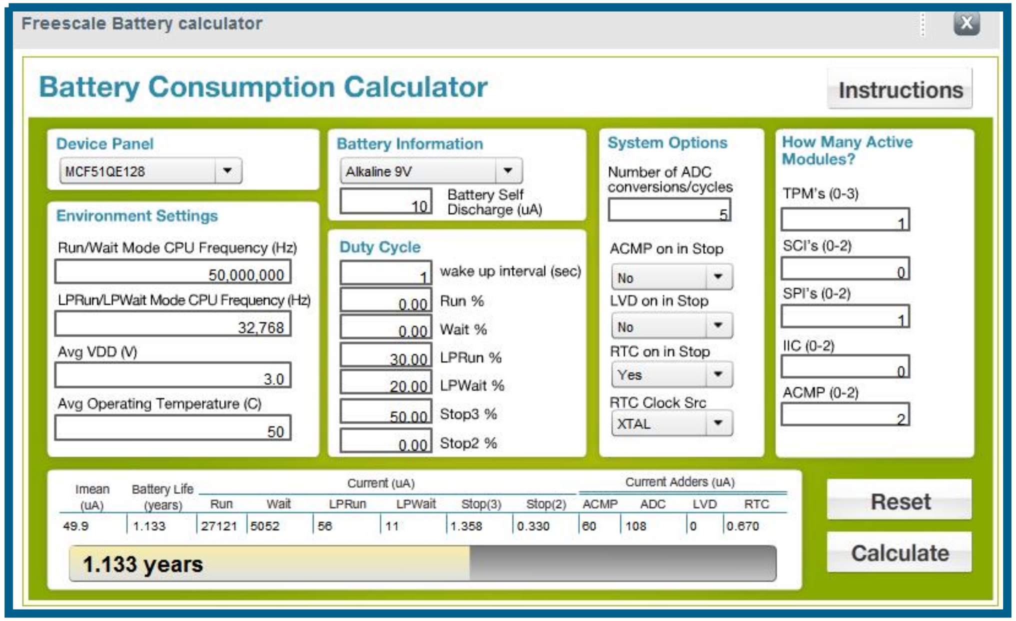
- www.freescale.com/lowpower
- Determines the average current the MCU is consuming and estimate the resulting battery life
- Based on application system variables: V, Hz, °C, % of time in in MCU modes (run, wait, stop3, stop2 and stop1), periodic wakeup interval
- User can select from a variety of standard battery sizes and types or enter battery characteristics directly



Training & Documentation

Freescale Battery calculator

Download Freescale Battery calculator executable



Freescale Battery calculator

Battery Consumption Calculator

Device Panel

MCF51QE128

Environment Settings

Run/Wait Mode CPU Frequency (Hz): 50,000,000

LPRun/LPWait Mode CPU Frequency (Hz): 32,768

Avg VDD (V): 3.0

Avg Operating Temperature (C): 50

Battery Information

Alkaline 9V

Battery Self Discharge (uA): 10

Duty Cycle

wake up interval (sec): 1

Run %: 0.00

Wait %: 0.00

LPRun %: 30.00

LPWait %: 20.00

Stop3 %: 50.00

Stop2 %: 0.00

System Options

Number of ADC conversions/cycles: 5

ACMP on in Stop: No

LVD on in Stop: No

RTC on in Stop: Yes

RTC Clock Src: XTAL

How Many Active Modules?

TPM's (0-3): 1

SCI's (0-2): 0

SPI's (0-2): 1

IIC (0-2): 0

ACMP (0-2): 2

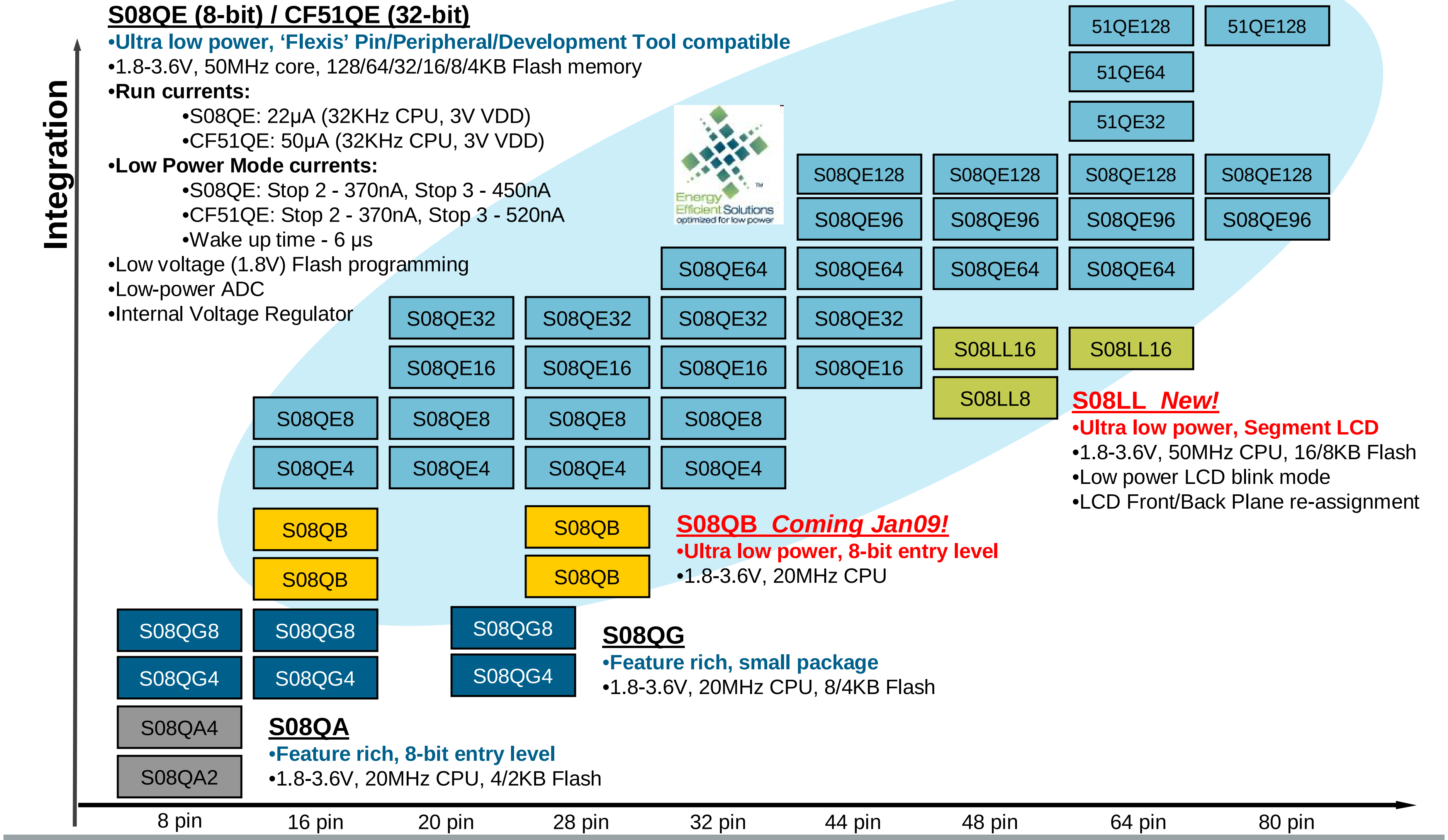
Imean (uA)	Battery Life (years)	Current (uA)						Current Adders (uA)			
		Run	Wait	LPRun	LPWait	Stop(3)	Stop(2)	ACMP	ADC	LVD	RTC
49.9	1.133	27121	5052	56	11	1.358	0.330	60	108	0	0.670

1.133 years

- Devices currently supported: S08QE128/96/64, MCF51QE128/64/32, S08QE8
- Additional devices will be added as they are introduced to market

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Freescale 3V MCU Solutions



S08QE (8-bit) / CF51QE (32-bit)

- **Ultra low power, 'Flexis' Pin/Peripheral/Development Tool compatible**
- 1.8-3.6V, 50MHz core, 128/64/32/16/8/4KB Flash memory
- **Run currents:**
  - S08QE: 22µA (32KHz CPU, 3V VDD)
  - CF51QE: 50µA (32KHz CPU, 3V VDD)
- **Low Power Mode currents:**
  - S08QE: Stop 2 - 370nA, Stop 3 - 450nA
  - CF51QE: Stop 2 - 370nA, Stop 3 - 520nA
  - Wake up time - 6 µs
- Low voltage (1.8V) Flash programming
- Low-power ADC
- Internal Voltage Regulator

S08LL *New!*

- **Ultra low power, Segment LCD**
- 1.8-3.6V, 50MHz CPU, 16/8KB Flash
- Low power LCD blink mode
- LCD Front/Back Plane re-assignment

S08QB *Coming Jan09!*

- **Ultra low power, 8-bit entry level**
- 1.8-3.6V, 20MHz CPU

S08QG

- **Feature rich, small package**
- 1.8-3.6V, 20MHz CPU, 8/4KB Flash

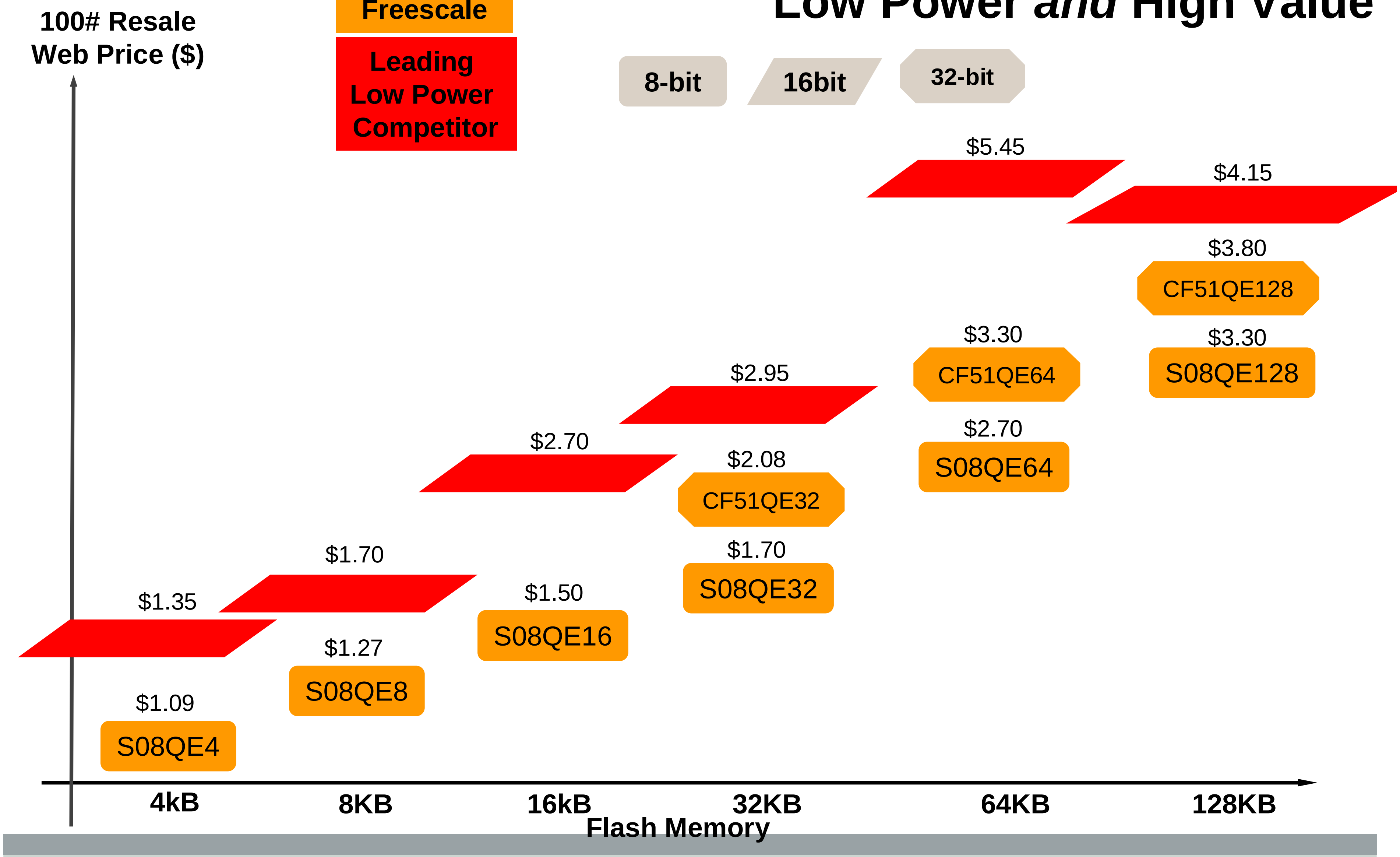
S08QA

- **Feature rich, 8-bit entry level**
- 1.8-3.6V, 20MHz CPU, 4/2KB Flash

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

freescale™ semiconductor

Low Power *and* High Value



NOTE: Pricing valid Nov08

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Flexis™ QE Device Overview

	S08	ColdFire V1
CPU Mode	Only one mode	User Mode/Supervisor Mode
Program Model	A(8-bit), HX(16-bit), SP(16-bit), PC(16-bit), CCR(8-bit)	User Mode D0-7(32-bit), A0-7(32-bit), PC(32-bit), CCR(32-bit) Supervisor Mode OTHER_A7, VBR, CPUCR, SR(16-bit)
Bus	8-bit Data bus, 16-bit Address bus	32-bit Data bus, 24-bit Address bus
Instruction	HC08 instruction set with added BGND, CALL, RTC instructions	ColdFire Instruction Set Revision C (ISA_C)
Memory Map	64K-byte Memory Map, Memory Management unit (MMU) for S08, 16K paging window for addressing memory beyond 64K, Linear address pointer for addressing data across entire memory,	16M-byte Memory Map, entire memory map addressed directly
Exception/Interrupt	Support up to 32 interrupt/reset vectors, priorities are fixed, One level interrupt grouping, No hardware support for nesting	Support up to 32 interrupt/exception vectors, interrupt/exception priorities are fixed except two interrupts can be remapped, seven levels interrupt grouping, hardware support for nesting
Reset	One vector for reset sources	Vectors for up to 64 reset sources

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Flexis™ QE Device Overview (Continued)

	MC9S08QE128	MCF51QE128
Development Support	Single-wire background debug interface, Same hardware/BDM cable for both devices, One version of CodeWarrior IDE and debugger support both devices,	
Operation Range	Up to 50MHz CPU from 3.6V ~ 2.1V, 20MHz CPU from 2.1V ~ 1.8V, across temperature range -40C ~ 85C	
On-chip memory	8K-byte RAM, 128K-byte Flash	
Operation Mode	Run, Low Power Run, Wait, Low Power Wait, STOP3, STOP2	
	-	STOP4
Peripherals	24-ch 12-bit ADC, 2 TPM (3-ch) 1 TPM (6-ch), 2 SPI, 2 SCI, 2 IIC, 16-ch KBI, RTC, GPIO	
	-	Interrupt controller, Rapid GPIO,
Packages	Pin to pin compatible in 80-pin LQFP and 64-pin LQFP	
	48-pin QFN, 44-pin QFP, 32-pin LQFP	-

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

QE Low Power Family Device Overview

	QE8	QE32	S08QE128	51QE128
CPU	S08 Up to 20 MHz	S08 Up to 50MHz	S08 Up to 50 MHz	ColdFire V1 Up to 50 MHz
FLASH	8K Bytes	32K Bytes	128K Bytes	128K Bytes
RAM	512 Bytes	2K Bytes	8K Bytes	8K Bytes
ADC	10-ch 12-bit ADC	10-ch 12-bit ADC	24-ch 12-bit ADC	24-ch 12-bit ADC
TPM	2 TPM (3-ch)	2 TPM (3-ch) 1 TPM (6-ch)	2 TPM (3-ch) 1 TPM (6-ch)	2 TPM (3-ch) 1 TPM (6-ch)
SPI	1 SPI	1 SPI	2 SPI	2 SPI
SCI	1 SCI	2 SCI	2 SCI	2 SCI
IIC	1 IIC	1 IIC	2 IIC	2 IIC
KBI	8-ch KBI	16-ch KBI	16-ch KBI	16-ch KBI
Rapid GPIO	NA	NA	NA	Yes
Others	ICS, RTC, GPIO, BDM			

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Ultra-Low Power Overview

- **Ultra-low-power run and wait modes**
- CPU and peripherals run with voltage regulator in low power mode
- Allows full functionality at reduced frequency for lower power operation

- **Clock gating**
- Turn clocks off to unused peripherals
- Reduces overall run and wait mode current

- **Ultra-low-power internal regulator & oscillator**
- Fast Start Up from stop modes, typically 6-7 usec
- New low power external oscillator consumes less than 1 uA

- **Ultra-low-power internal clock source & oscillator**
- Eliminates need for external clock source
- Supports low frequency operations which lowers power in system

- **Ultra-low-power real-time counter**
- Use in run, wait and stop modes
- Use with low power oscillator, internal or external clock sources

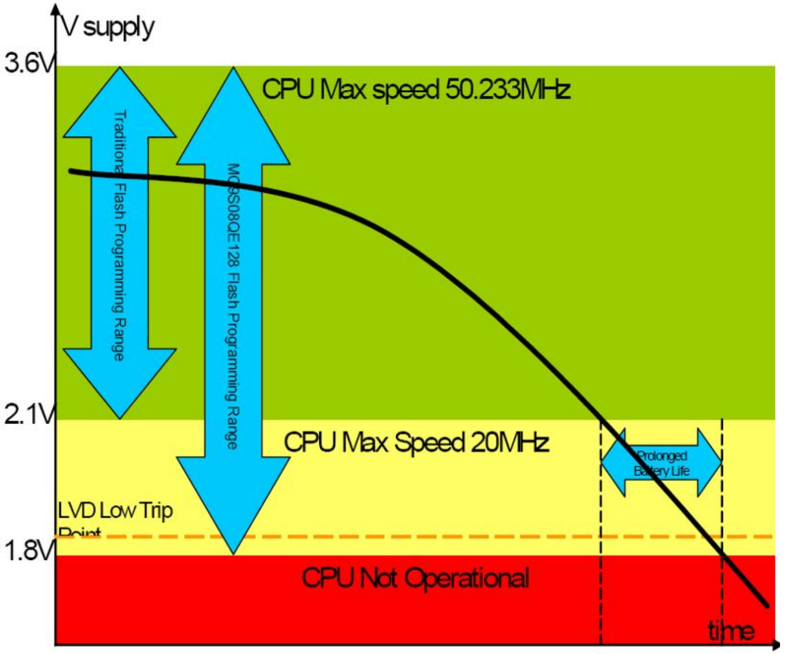
	MCF51QE128	MC9S08QE128
Run Mode @ 2 MHz CPU / 1 MHz bus	2 mA	1 mA
Run Mode @ 50 MHz CPU / 25 MHz bus	27 mA	11 mA
Lower Power Run Mode @ 32 kHz CPU/16 kHz bus	50 uA	22 uA
Stop 2 – Lowest power mode; partial power down of circuits	370 nA	370 nA
Stop 3 - Int. circuits loosely regulated; clocks at low frequency	520nA	450 nA
Stop 3 - Wake Up Time	6 us	6 us

Preliminary typical measurements, Vdd = 3V, Temp = 25C

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

High Performance *and* Low Power

- ► QE128 devices can run at 50 MHz CPU frequency down to 2.4V, 40MHz from 2.4V to 2.1V
  - Configure peripherals in microseconds
  - Copy/search large data tables rapidly
  - Perform complex calculations faster
- ► Below 2.1V, QE128's can still run at 20 MHz CPU frequency
  - Flexis devices are designed to run at high frequency across all voltages
- ► Flash programming at 1.8V while typical competitors' lowest is 2.2V
  - If working off batteries, with FSL part customer can re-program flash
  - Ability to update variables/constants and provides greater flexibility
    - ▪ Can save variables to flash before batteries die and are replaced
    - ▪ Can perform field s/w upgrades at any time, doesn't require fresh batteries



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

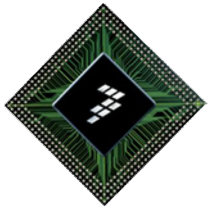
Internal Positioning

	S08QE8	S08QE32	S08QE128	MCF51QE128
Stop2 @ 3V	**750 nA**	**950 nA**	**2000 nA**	**11 uA**
Stop2 @ 2V	**600 nA**	**850 nA**	**1900 nA**	**10 uA**
Stop3 @ 3V	**1800 nA**	**2300 nA**	**4200 nA**	**18 uA**
Stop3 @ 2V	**1500 nA**	**2000 nA**	**3900 nA**	**16 uA**

FSL spec max @70C

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Freescale Product Specifications



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

New Product Specifications: S08QE8 & S08QE32

S08QE8						
		V	typ	max		temp
P	Stop 2	3	0.3	0.65	uA	-40 to 25
C			0.5	0.8		70
P			1	2.5		85
C		2	0.25	0.5	uA	-40 to 25
C			0.3	0.6		70
C			0.7	2		85

S08QE32						
		V	typ	max		temp
P	Stop 2	3	0.35	0.65	uA	-40 to 25
C			0.8	1		70
P			2	4.5		85
C		2	0.25	0.5	uA	-40 to 25
C			0.75	0.85		70
C			1.5	3.5		85

P	Stop 3	3	0.4	0.8	uA	-40 to 25
C			1	1.8		70
P			3	6		85
C		2	0.35	0.6	uA	-40 to 25
C			0.8	1.5		70
C			2.5	5.5		85

P	Stop 3	3	0.45	1	uA	-40 to 25
C			1.5	2.3		70
P			4	8		85
C		2	0.35	0.7	uA	-40 to 25
C			1	2		70
C			3.5	6		85

- Changes have been made to the Flexis QE family product specifications to include power consumption ratings @ 70°C
- Stop Idd grows exponentially with temperature - 70°C rating is significantly lower than 85°C rating – good for applications that don’t require 85C
- Parameters are characterized by design [C] and production tested [P]. Parameters that are production tested are checked on every device before it is shipped
- Typical values: the value that most parts will achieve
- Maximum values: the Limit (usually set in production testing) that parts will achieve

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

New Product Specifications: S08QE128 & MCF51QE128

S08QE128						
		V	typ	max		temp
P	Stop 2	3	0.35	0.6	uA	-40 to 25
C			0.98	2		70
P			2.5	7.5		85
C		2	0.25	0.5	uA	-40 to 25
C			1.4	1.9		70
C			1.91	6.5		85

51QE128 - O'Douls						
		V	typ	max		temp
P	Stop 2	3	0.6	0.8	uA	-40 to 25
C		3	3.0	11		70
P		3	8.0	20		85
C		2	0.6	0.8	uA	-40 to 25
C		2	2.5	10		70
C		2	6.0	12		85

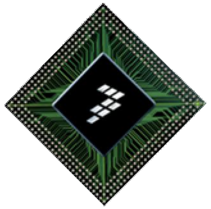
P	Stop 3	3	0.45	1	uA	-40 to 25
C			1.99	4.2		70
P			5	15		85
C		2	0.35	0.7	uA	-40 to 25
C			2.9	3.9		70
C			3.77	13.2		85

P	Stop 3	3	0.8	1.3	uA	-40 to 25
C		3	6.0	18		70
P		3	18.0	28		85
C		2	0.8	1.3	uA	-40 to 25
C		2	5.0	16		70
C		2	12.0	20		85

- Changes have been made to the Flexis QE family product specifications to include power consumption ratings @ 70°C
- Stop Idd grows exponentially with temperature - 70°C rating is significantly lower than 85°C rating – good for applications that don’t require 85C
- Parameters are characterized by design [C] and production tested [P]. Parameters that are production tested are checked on every device before it is shipped
- Typical values: the value that most parts will achieve
- Maximum values: the Limit (usually set in production testing) that parts will achieve

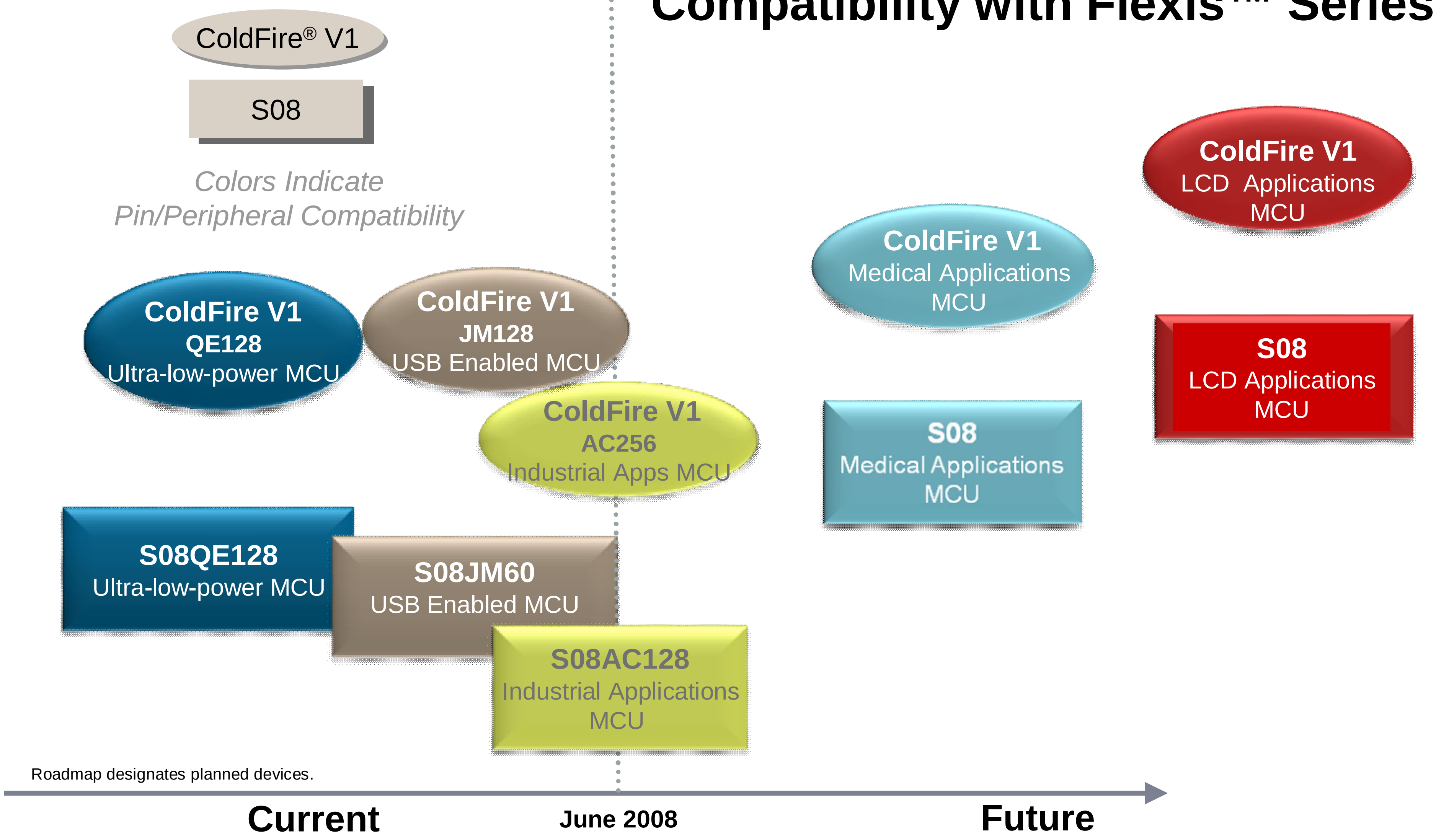
Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Other Low Power Solutions from Freescale



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Compatibility with Flexis™ Series

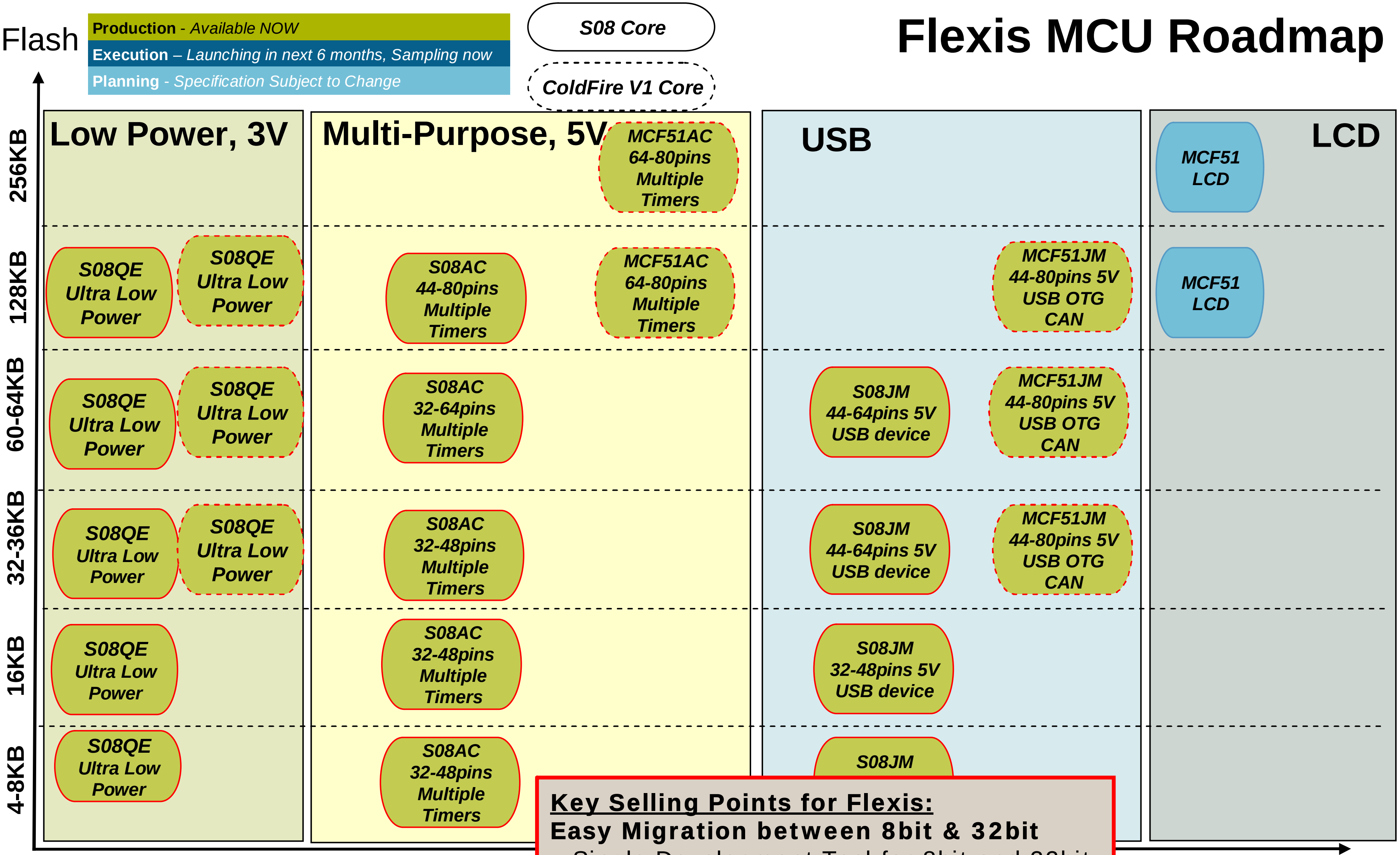


ColdFire® V1
S08
Colors Indicate Pin/Peripheral Compatibility
ColdFire V1 QE128 Ultra-low-power MCU
ColdFire V1 JM128 USB Enabled MCU
ColdFire V1 AC256 Industrial Apps MCU
S08QE128 Ultra-low-power MCU
S08JM60 USB Enabled MCU
S08AC128 Industrial Applications MCU
ColdFire V1 Medical Applications MCU
S08 Medical Applications MCU
ColdFire V1 LCD Applications MCU
S08 LCD Applications MCU
Roadmap designates planned devices.
Current
June 2008
Future

Learn more at www.freescale.com/flexis101

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Flexis MCU Roadmap



Flash

Production - *Available NOW*

Execution – *Launching in next 6 months, Sampling now*

Planning - *Specification Subject to Change*

S08 Core

ColdFire V1 Core

Flash	Low Power, 3V	Multi-Purpose, 5V	USB	LCD
256KB		MCF51AC 64-80pins Multiple Timers		MCF51 LCD
128KB	S08QE Ultra Low Power S08QE Ultra Low Power	S08AC 44-80pins Multiple Timers MCF51AC 64-80pins Multiple Timers	MCF51JM 44-80pins 5V USB OTG CAN	MCF51 LCD
60-64KB	S08QE Ultra Low Power S08QE Ultra Low Power	S08AC 32-64pins Multiple Timers	S08JM 44-64pins 5V USB device MCF51JM 44-80pins 5V USB OTG CAN	
32-36KB	S08QE Ultra Low Power S08QE Ultra Low Power	S08AC 32-48pins Multiple Timers	S08JM 44-64pins 5V USB device MCF51JM 44-80pins 5V USB OTG CAN	
16KB	S08QE Ultra Low Power	S08AC 32-48pins Multiple Timers	S08JM 32-48pins 5V USB device	
4-8KB	S08QE Ultra Low Power	S08AC 32-48pins Multiple Timers	S08JM	

Key Selling Points for Flexis:

Easy Migration between 8bit & 32bit

- Single Development Tool for 8bit and 32bit
- Common Peripheral Set – allows software re-use between 8bit & 32bit
- Pin-to-Pin Compatability – maximises hardware re-use between 8bit and 32bit designs

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freesc
of Freescale Semiconductor, Inc. All other product or service names are the property of their res

Introducing new 8-bit MCUs with LCD capability: S08LL16/8, RS08LA8, RS08LE4

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Introducing the L Family

Introducing a trio of 8-bit MCU families (S08LL, RS08LA, RS08LE) with industry-leading LCD capabilities, including the ability to drive more segments with fewer pins (up to 8x mode). In addition, the S08LL family offers best-in-class, ultra-low-power performance.

Integrated LCD Driver

- High segment on-chip LCD driver module is software-configurable and eliminates the need for separate display driver chip, reducing board space and total system cost.

Flexible Pin Functionality

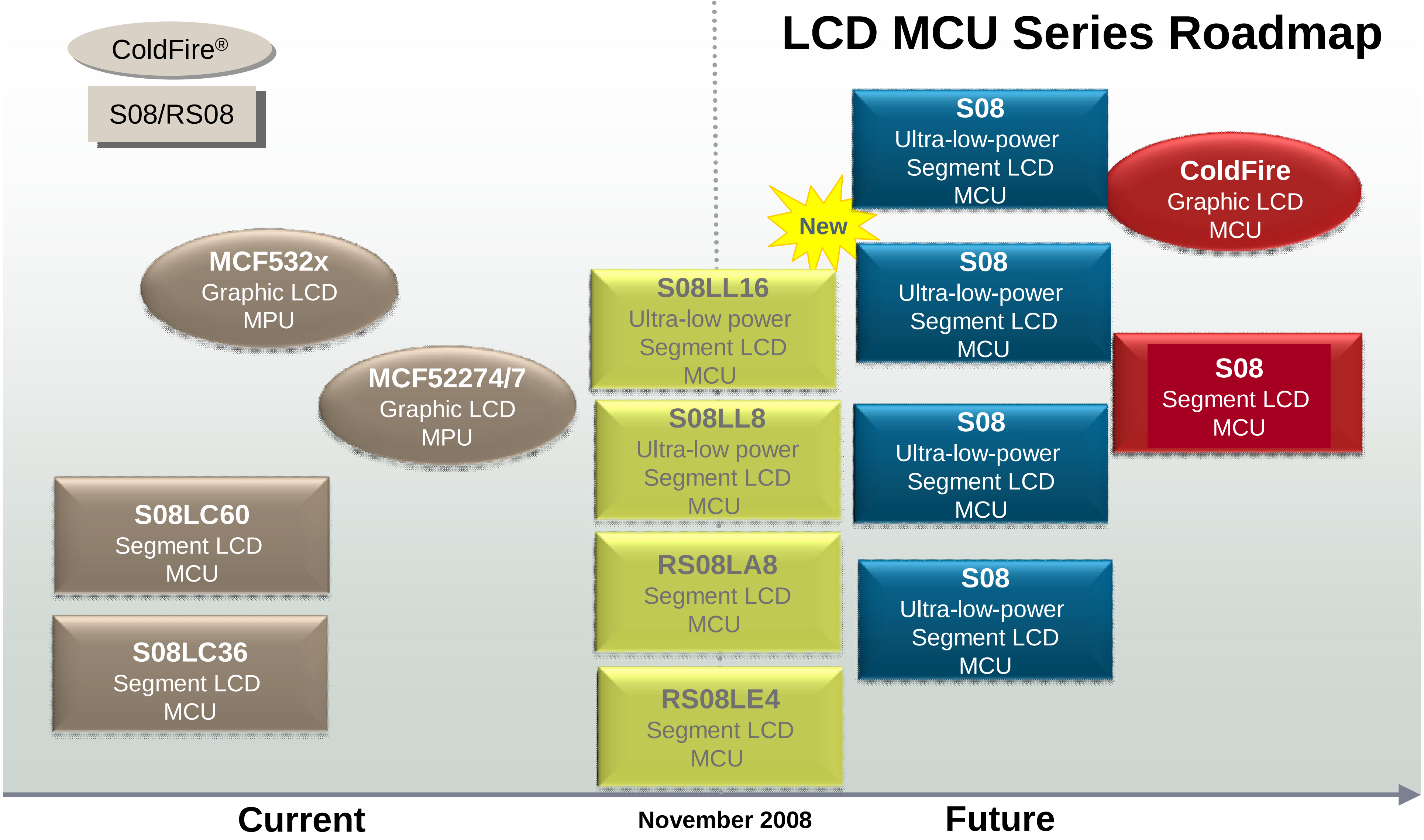
- With L family MCUs, developers can drive more segments with fewer pins, enabling smaller connectors and smaller footprint. Different functionality can be assigned to pins, enhancing design flexibility

Ultra-Low Power

- Developers can choose from a wide range of products within the family to optimize their designs for power-conscious, cost-sensitive applications.

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

LCD MCU Series Roadmap



ColdFire®

S08/RS08

MCF532x Graphic LCD MPU

MCF52274/7 Graphic LCD MPU

S08LC60 Segment LCD MCU

S08LC36 Segment LCD MCU

S08LL16 Ultra-low power Segment LCD MCU

S08LL8 Ultra-low power Segment LCD MCU

RS08LA8 Segment LCD MCU

RS08LE4 Segment LCD MCU

New

S08 Ultra-low-power Segment LCD MCU

S08 Ultra-low-power Segment LCD MCU

S08 Ultra-low-power Segment LCD MCU

S08 Ultra-low-power Segment LCD MCU

ColdFire Graphic LCD MCU

S08 Segment LCD MCU

Current **November 2008** **Future**

Roadmap designates planned devices.

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

New Segment LCD Solutions

Segment LCD Solutions	Key Features & Benefits
S08LL16/8	• The LL16/8 offers Freescale’s ultra-low-power technology at 1.8V with winning features, such as 20MHz CPU, flash reprogramming and ADC accuracy. Intended for low-power and portable applications, such as thermostats and blood glucose meters.
9RS08LA8	• The LA8 is a cost-effective MCU that features 6-channel 10-bit ADC, analog comparator, internal charge pump and internal oscillator.
9RS08LE4	• The LE4 has the RS08 core, which provides 8-channel 10-bit ADC in 28-pin SOIC package options for small appliances and meters.
Common Features	• LCD features can drive large segment (8x mode) LCDs with fewer pins. FP or BP reassignment simplifies PCB layout and provides the opportunity to optimize designs for EMI performance.

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

New

MC9S08LL16 – Ultra Low Power with Segment LCD

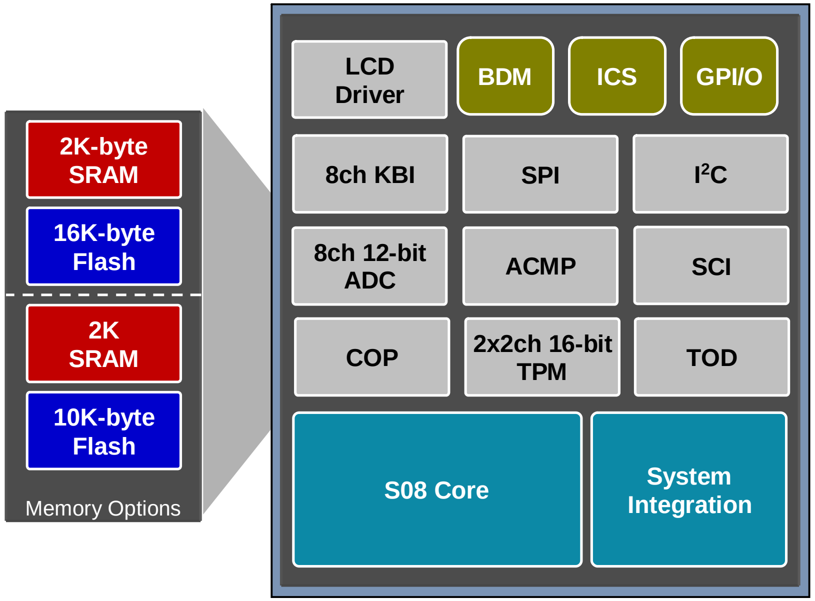
Introducing the 8-bit MCU LL family with industry-leading LCD capabilities, including the ability to drive more segments with fewer pins (up to 8x mode). In addition, it offers best-in-class, ultra-low-power performance.

S08 Core

- Up to 20M CPU
- Temperature range of -40°C to 85°C, 1.8-3.6V Op Range
- **On-Chip Memory**
  - FLASH read/program/erase over full operating voltage and temperature
  - 2K Random-access memory (RAM)
  - Flash size

    LL16: 16K-byte, 8K in Flash A, 8K in Flash B

    LL8: 10K-byte, 8K in Flash A, 2K in Flash B
- **Clock Source Options**
  - Oscillator (XOSC) — Loop-control Pierce oscillator; Crystal or ceramic resonator range of 31.25 kHz to 38.4 kHz or 1 MHz to 16 MHz
  - Internal Clock Source (ICS) — Internal clock source module containing an FLL controlled by internal or external reference; supports bus frequencies up to 10 MHz
- **System Protection**
  - Watchdog computer operating properly (COP) reset
  - Low-voltage detection with reset or interrupt
  - Illegal opcode detection with reset
  - FLASH block protect
- **Single Wire Background Debug Interface**



- **Power-Saving Modes**
  - 2 very low power stop modes
  - Reduced power wait mode
  - Low power run and wait modes allow peripherals to run while voltage regulator is in standby
  - Very low power external oscillator that can be used in stop2 or stop3 modes to provide accurate clock source
  - 6 usec typical wake up time
  - Peripheral clock gating

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

MC9S08LL16: Low Power Features

Power Saving modes

- 2 very low power stop modes
- Reduced power wait mode
- Low power run and wait modes allow peripherals to run while voltage regulator is in standby
- 6 usec typical wake up time

Low Power LCD Module

- Low power LCD waveform
- Multi LCD power supply configuration
- Efficient internal charge pump to produce LCD bias voltages
- LCD display and blink in Low Power mode

Low Power Oscillator

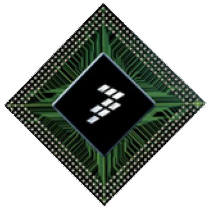
- Very low power external oscillator that can be used in stop2 or stop3 modes to provide accurate clock source in LP mode

Others

- TOD for low power time keeping
- Clock gating

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Freescale Battery Charging Solutions



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

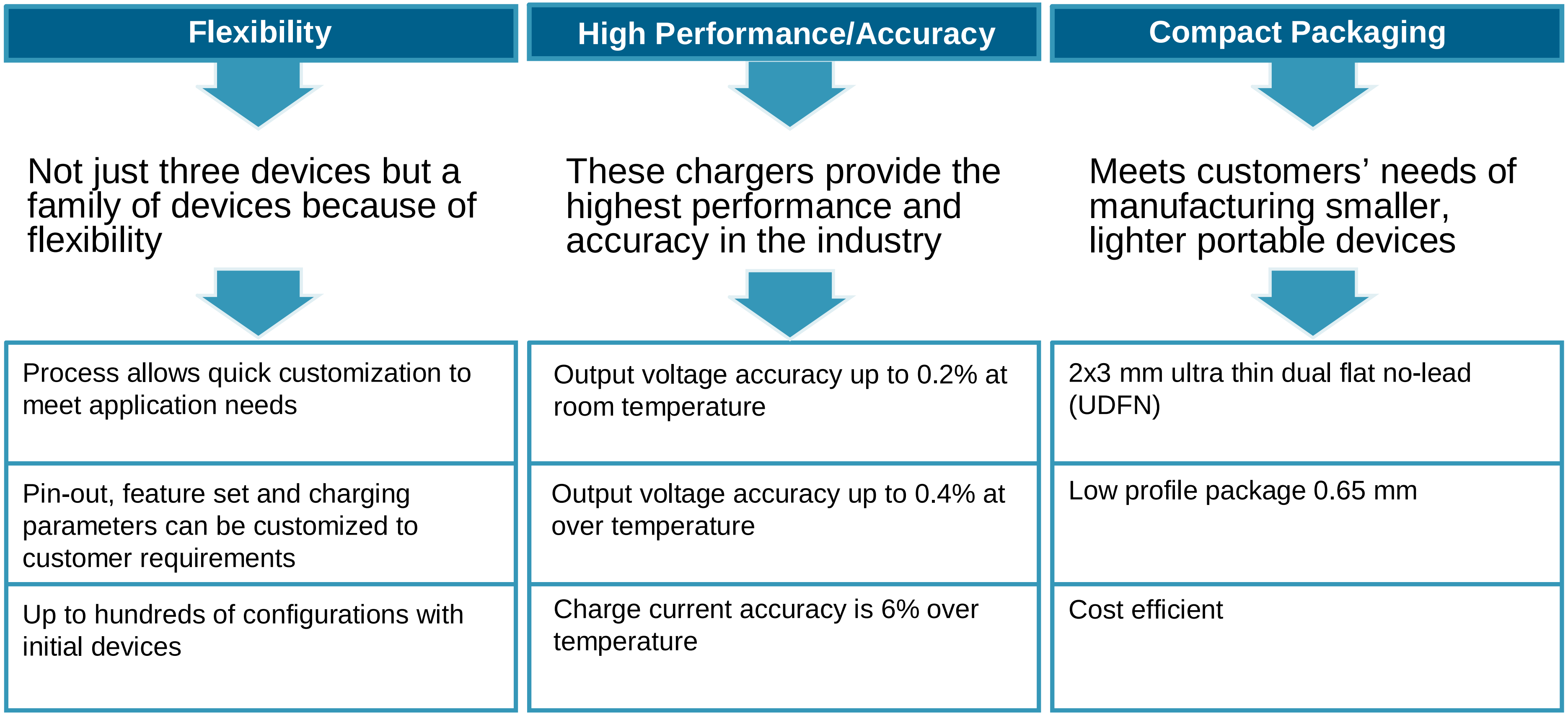
Target Applications for Battery Chargers

Single-cell Li-Ion/Polymer battery powered devices or their accessories

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Freescale Battery Charger Benefits

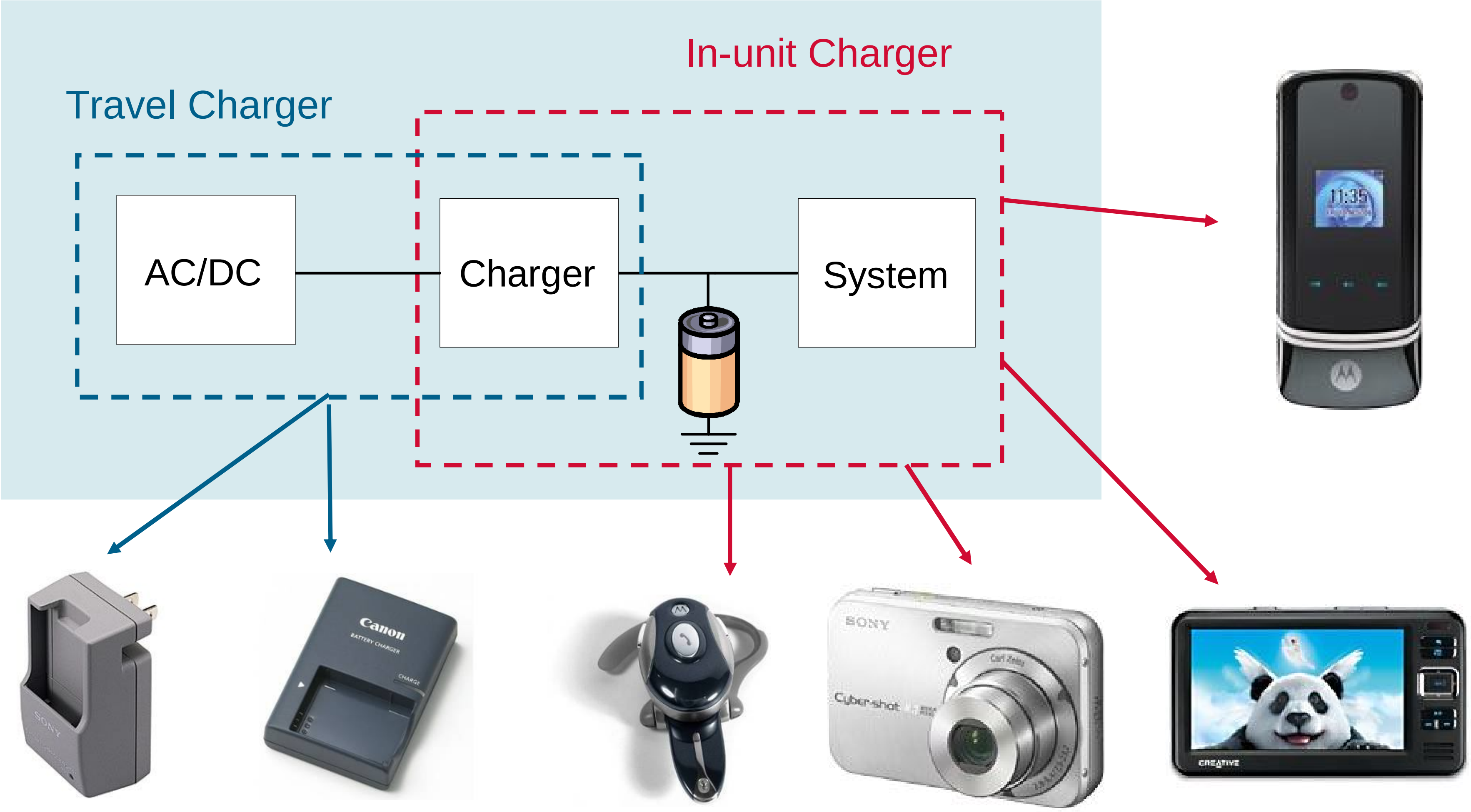
The industry’s most flexible battery charger ICs that can be customized for a wide variety of applications during the final test phase of the manufacturing process



Flexibility	High Performance/Accuracy	Compact Packaging
Not just three devices but a family of devices because of flexibility	These chargers provide the highest performance and accuracy in the industry	Meets customers’ needs of manufacturing smaller, lighter portable devices
Process allows quick customization to meet application needs	Output voltage accuracy up to 0.2% at room temperature	2x3 mm ultra thin dual flat no-lead (UDFN)
Pin-out, feature set and charging parameters can be customized to customer requirements	Output voltage accuracy up to 0.4% at over temperature	Low profile package 0.65 mm
Up to hundreds of configurations with initial devices	Charge current accuracy is 6% over temperature	Cost efficient

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Where Does It Fit in System?



Travel Charger

In-unit Charger

AC/DC

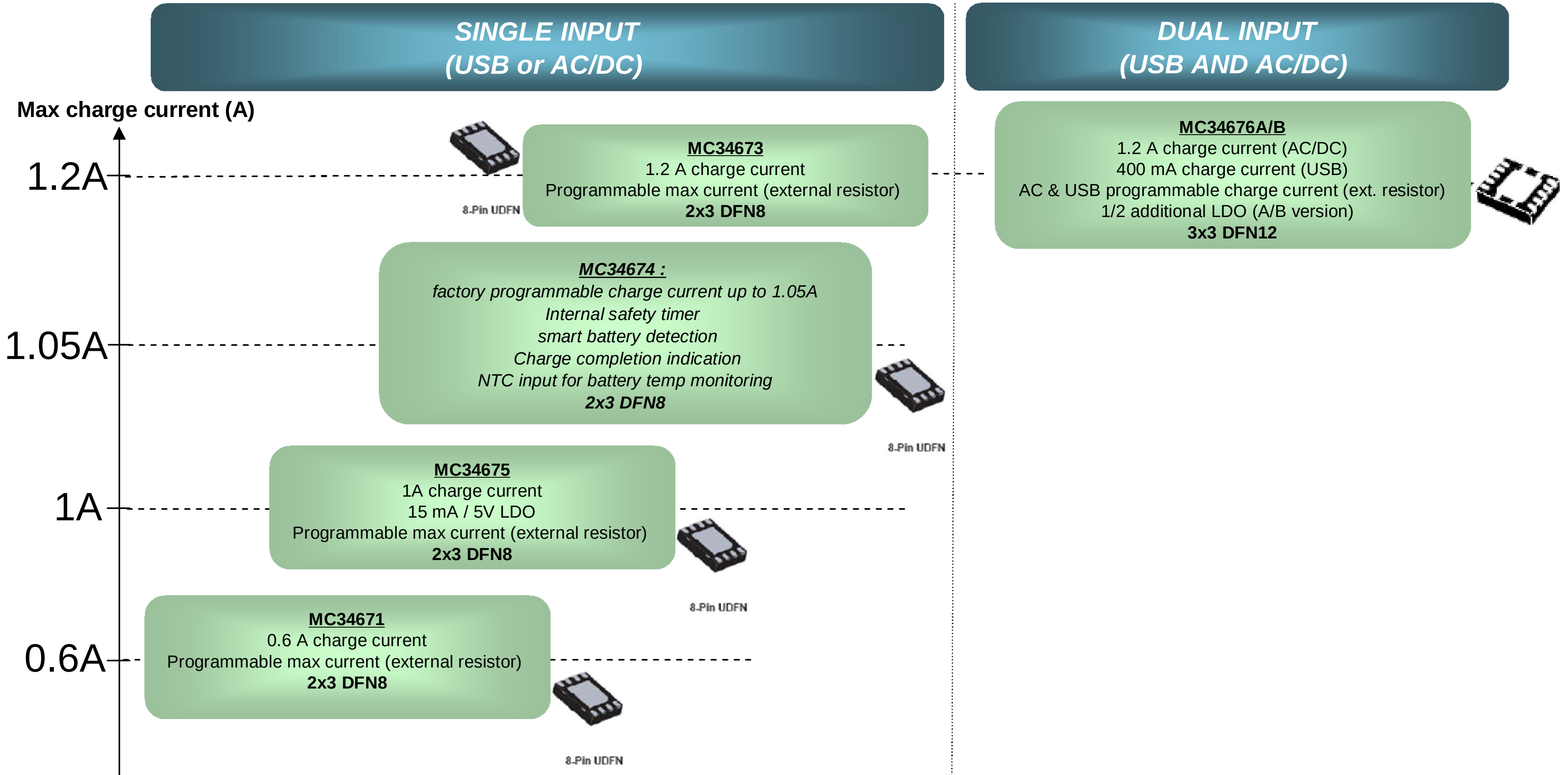
Charger

System

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

MC3467x Product Roadmap

A complete family from the low end to the high end….



SINGLE INPUT (USB or AC/DC)

MC34673
1.2 A charge current
Programmable max current (external resistor)
2x3 DFN8

MC34674 :
factory programmable charge current up to 1.05A
Internal safety timer
smart battery detection
Charge completion indication
NTC input for battery temp monitoring
2x3 DFN8

MC34675
1A charge current
15 mA / 5V LDO
Programmable max current (external resistor)
2x3 DFN8

MC34671
0.6 A charge current
Programmable max current (external resistor)
2x3 DFN8

DUAL INPUT (USB AND AC/DC)

MC34676A/B
1.2 A charge current (AC/DC)
400 mA charge current (USB)
AC & USB programmable charge current (ext. resistor)
1/2 additional LDO (A/B version)
3x3 DFN12

***Applications** : PC peripherals, cell phone, blue-tooth headset, MP3, gaming, PMP, portable Medical, POS, bar code scanners*

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Battery Charger Solutions: Product Overview

MC34671	• 600mA charge current
MC34673	• 1200mA charge current
MC34674	• Travel Charger • 1050mA charge current
MC34675	• 1000mA charge current • 4.8V@10mA LDO
MC34676	• 1200mA charge current (AC) • 400mA charge current (USB) • 4.8V@10mA LDO or BATT detect

Highest Performance Chargers in Industry

- **0.4% output voltage accuracy over temperature**
- **5% current accuracy**

Up to 28V input voltage

Factory-Programmable Parameters for Increased Device Flexibility

- Output voltage
- Input over-voltage protection
- CC current
- Trickle charge current
- Trickle charge voltage threshold
- EOC current
- Recharge threshold
- Thermal fold back threshold
- Timeout
- Verification filter timing

Factory-Reconfigurable Features

- Indicator pin functions are programmable
- ISET pin
- Negative Temperature Coefficient (NTC) thermistor interface
- Battery connection verification
- EOC flow
- Remote sense

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Battery Charger Solutions: Competitive Overview

Vendor	Part Number	Max Input voltage (V)	Max CC (A)	Safety Timer? (Y/N)	Thermal Reg? (Y/N)	Pwr Path mgmt (Y/N)	CC Accuracy (+/- %)	Voltage Accuracy (+/- %)	Status Indication (# of bits)	OVP (V)	Package
TI	bq24061/2/3/4/5/6	18	1	Y	Y	N		0.5	3	6.5V/10.5	3x3DFN-10
TI	bq24030/2/5/8	18	1.5	Y	Y	Y	17	1	4	-	3.5x4.5QFN-20
TI	bq24020/2/3/4/5/6/7	7	1	Y	N	N		1	2	-	3x3DFN-10
Intersil	ISL6294	28	0.9	N	Y	N	10	1	2	6.5	2x3DFN-8
Intersil	ISL6299A	28/7	1	N	Y	N	10	1	2	-	3x3DFN-10
Intersil	ISL6292/B/C/D	7	2	Y	Y	N	10	1	2	-	3x3DFN-10/4x4/5x5
Intersil	ISL6297	7	1.5	Y	Y	N	10	0.7	2	-	4x4QFN-16
Maxim	MAX8808X/Y/Z	16	1	N	Y	N	10	1	2	7	2x2TDFN-8
Maxim	MAX8606	16	1	Y	Y	N		0.5	2	5.8	3x3TDFN-14
Maxim	MAX1551/5	7	0.28	N	Y	N	20	0.5	1	-	SOT23-5
LTC	LTC4055	5.5	1.25	Y	Y	Y	5	1	2	-	4x4QFN-16
LTC	LTC4065	5.5	0.75	Y	Y	N	5	1	1	-	2x2DFN-6
LTC	LTC4059A	10	0.9	N	Y	N	6	1	1	-	2x2DFN-6
LTC	LTC4075	10	0.95	Y	Y	N	5	1	2	-	3x3DFN-10
National	LM3658	6.5	1	Y	Y	N	15	1.5	2	-	3x3DFN-10
Freescale	MC34xxxx	28	1.2	Y	Y	N	5	0.5	3	5.5/6.8/11	2x3DFN-8/2x2DFN-8

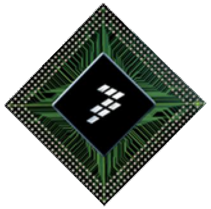
Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Battery Charger Solutions: Summary

- ✓• Industry’s most flexible Li-ion and Li-polymer battery charger solution
- ✓• Complete charger for single-cell Li-ion and Li-polymer batteries
- ✓• Feature-rich and easily modified to meet the needs of a wide variety of applications
  - ✓ • +/-0.7% output voltage accuracy over -20°C to +70°C (+/-0.4% at room temperature)
  - ✓ • +/-0.7% output voltage accuracy over -40°C to +85°C (MC34675)
  - ✓ • +/-5% charge current accuracy over -40°C to +85°C (+/-6% for MC34673
  - ✓ and MC34675)
- ✓• Factory-configurable parameters for faster time to market and lower system cost
- ✓• Meets AC/DC adapter standard YD/T 1591-2006 in the Chinese cell phone market
- ✓• Low external component count

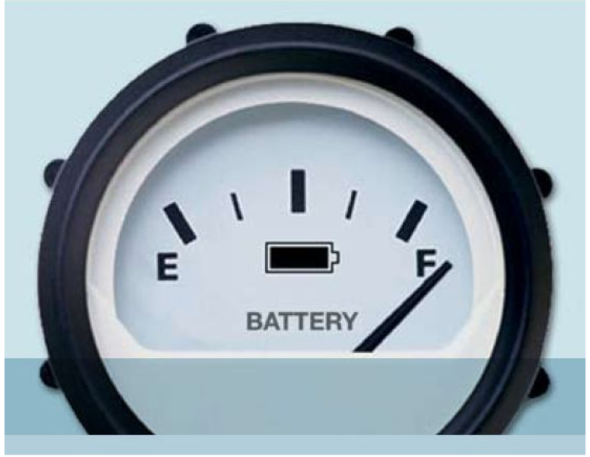
Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Freescale Low Power Features



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

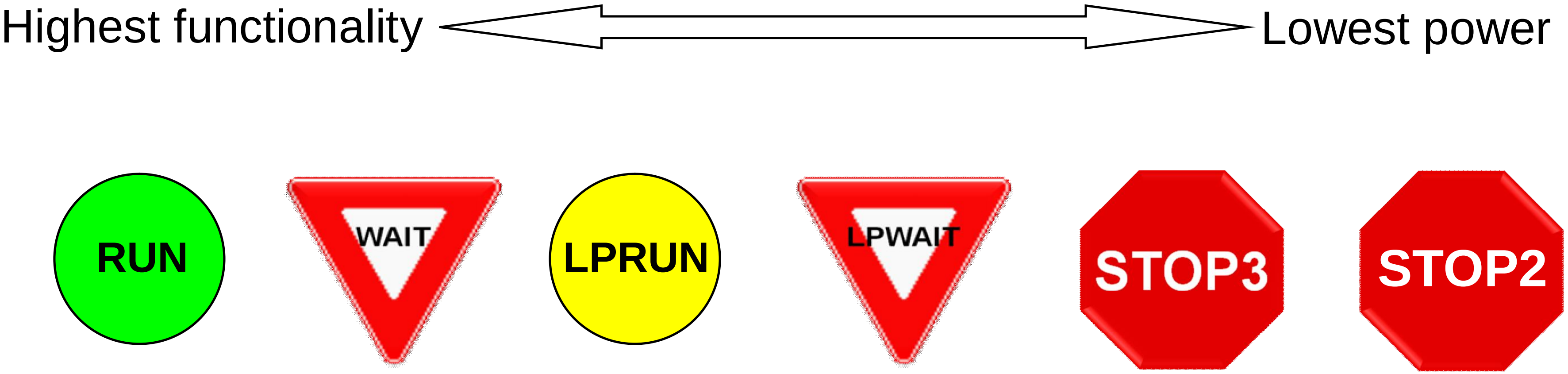
Freescale Low Power Features



1. Multiple power-saving modes
   - 6 modes totally
   - Low-power run and wait modes New
2. Clock gating for the periphrals
3. Internal Clock Source (ICS) module allows to generate clock signals from a variety of sources
4. Ultra-low-power (ULP) 32kHz oscillator
5. New voltage regulator
   - Faster wake up times 6uS
6. Low power Peripherals Real Time Counter
   - Ultra-low power Real Time Counter (RTC)
   - Low power ADC

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Operation Modes



Highest functionality

Lowest power

RUN

WAIT

LPRUN

LPWAIT

STOP3

STOP2

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

QE8 – Run Mode

▶ Run Mode

- Standard user mode – default mode out of any reset
  - Clocks are enabled to CPU and all peripherals
  - All peripherals disabled out of reset.
- The voltage regulator is in active mode
- Typical IDD as low as **5.6 mA** at 10 MHz Bus and 3V with all modules enabled.

▶ Advantages

- All peripherals can be used without limitations
- Interrupts can be serviced without changing modes
- Flash can be reprogrammed across all VDDs and temperature

▶ Limitations

- Consumes more current than other modes

RUN

QE8-S08
POWER
LIMIT
5.6
mA

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

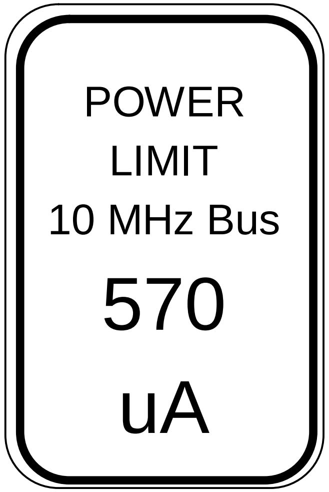
QE8- Wait Mode

▶ Wait Mode

- The bus clock source remains active
- Clocks are disabled to CPU but peripherals can be clocked
- Typical IDD as low as 0.57 mA at 10 MHz CPU and 3V

▶ Advantages

- Reduces power consumption versus run mode
- No stop recovery time; the interrupt is serviced immediately
- Reduces noise while taking A-to-D readings



POWER
LIMIT
10 MHz Bus
570
uA

▶ Limitations

- The voltage regulator remains active, consuming more current than stop or LP modes

▶ Exit times :

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

New

QE8 Low-power Modes : LPRun

▶ Low-power Run (LPRun) Mode

- The bus clock source is limited to FBELP
- Typical IDD as low as 7.3 µA at 32 kHz CPU and 3V when executing from RAM
- Typical IDD as low as 21 uA at 32 kHz CPU and 3V when executing from Flash
- The voltage regulator is in low-power mode

LPRUN

S08
POWER
LIMIT
7.3/21
µA

▶ Advantages

- All peripherals can be used
- Reduces power consumption versus Run mode when high performance is not required
- Interrupts can be serviced without changing modes

▶ Limitations

- Maximum frequency is limited (see reference manual)
- Flash cannot be programmed or erased

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Low-power Modes—LPWait

New

►Low-power Wait (LPWait) Mode

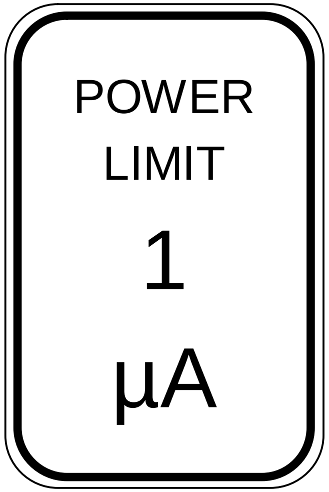
- The bus clock source is limited to FBELP
- Clocks are disabled to CPU but peripherals can be clocked
- Typical IDD as low as 1 µA at 32 kHz CPU and 3V
- The voltage regulator is in low-power mode

►Advantages

- Reduces power consumption versus LPRun mode
- No stop recovery time; the interrupt stacking begins immediately
- Reduces noise while taking A-to-D readings

►Limitations

- Consumes more current than stop modes
- Maximum frequency is limited
- Due to slower frequencies, may take longer to react to wake-up trigger than stop2 or stop3 modes



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

QE8-Low-power Modes: Stop3

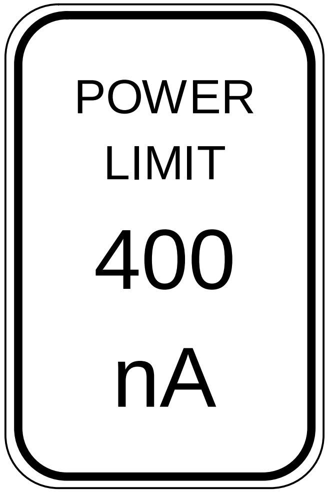
▶ Stop3 Mode

- Bus and CPU clocks halted
- Voltage regulator in standby
- Typical IDD of 400 nA at 3V
- Exit with any active interrupt: ADC, ACMP, IRQ, KBI, LVD, RTC, SCI or reset

▶ Exit times : 6 uS

▶ Advantages

- Still has very low-current consumption
- RAM and register retain their values
  - **Does not require reinitializing peripherals**
- Latency from interrupt event to code execution is only 5 us + 38 ICSOUT cycles



▶ Limitations

- Not quite as low current as stop2

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

QE8- Low-power Modes: Stop2

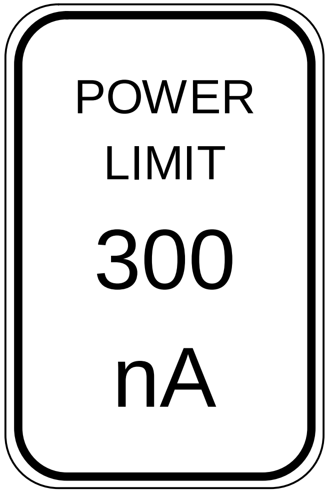
► Stop2 Mode

- Partial power down mode with typical IDD as low as 300 nA at 3V
- Exit with wake-up pin (IRQ/RESET pin) or RTC
  - **Stop2 recovery is always through a system reset**

► Advantages

- Lowest-power consumption mode for these devices
- RAM contents are maintained, I/O pin states are latched.

► Exit times : 29 uS



► Limitations

- Register values are reset, but values can be saved to and restored from RAM
- Wake up latency from reset to code execution is ~5 us + 162 ICSOUT cycles.

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

CPU Mode Comparison Chart

	Features	Exit Sources	Wake-up Time
Run	**CPU clocks can be run at full speed** **Internal supply is fully regulated**	n/a	n/a
Wait	**CPU not clocked** **System clocks are running** **Full regulation is maintained**	Any interrupt	Instantly
LP Run	**Bus frequency is restricted to 125 kHz maximum** **Voltage regulator standby**	Clear LP bit or interrupt with LPWUI set	n/a
LP Wait	**CPU not clocked** **Bus frequency is restricted to 125 kHz maximum** **Full regulation is maintained**	Any interrupt	Instantly
Stop 3	**CPU not clocked** **Voltage regulator stand by** **Peripherals not clocked but powered for fast recovery**	RTC, LVD/LVW, ADC, ACMP, IRQ, SCI, KBI or RESET	6 µs
Stop 2	**CPU and peripherals not clocked** **Voltage regulator partial power down** **RAM content is retained**	RTC, IRQ or RESET	29 µs

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

New Voltage Regulator

- Voltage Regulator is always on when MCU is in Run or Wait modes
  - Also on when in stop3 with LVI or ADC enabled
  - Runs internal logic at lower voltage, therefore lower power

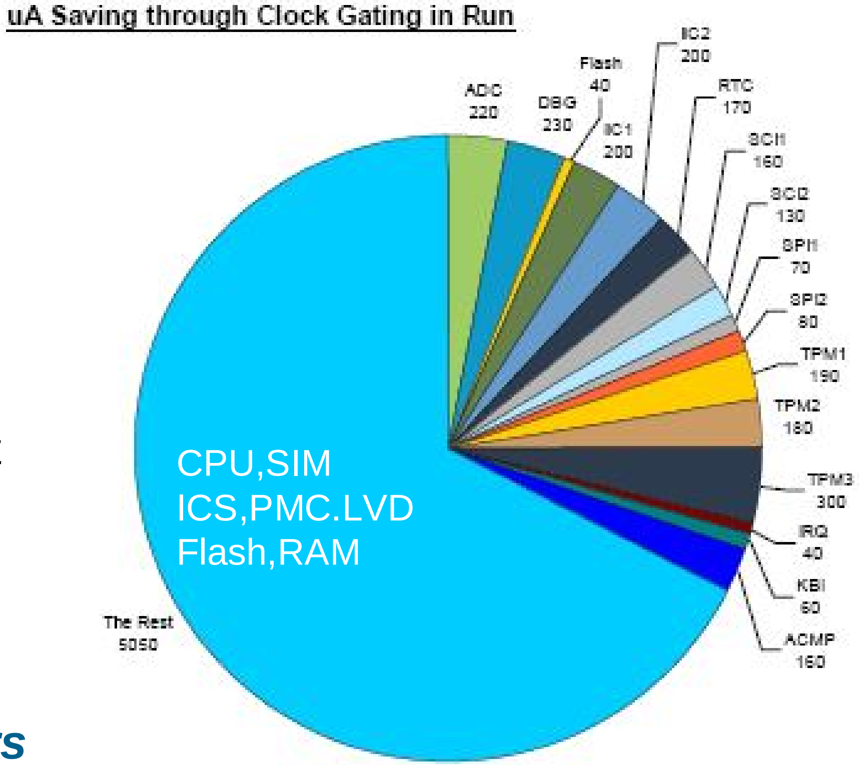
- Modified stand-by mode to allow execution in low power modes
  - New LPRun and LPWait modes allow peripherals to run while regulator is in stand-by
  - Condition for this is to have ICS configured in a special low power modes where bus frequency is restricted (125 KHz max)
  - *New faster regulator start-up time!* ***6 uS***
  - Allows more applications to use Stop modes

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Periphrals Clock Gating
µA Saved Through Clock Gating @ 20MHz CPU in FEE Mode

- ► Clock gating is the mechanism used to disable the clock tree to any unused peripheral
- ► Bus or peripheral clock runs to all modules
  - Regardless if they are enabled or not
- ► Saves power by not clocking unused gates

Using the system clock gating registers RUN IDD can be reduced by up to ~33%



Total Run Current with all module clocks disabled = 5050uA
Total Run IDD with all module clocks enabled = 7480uA

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

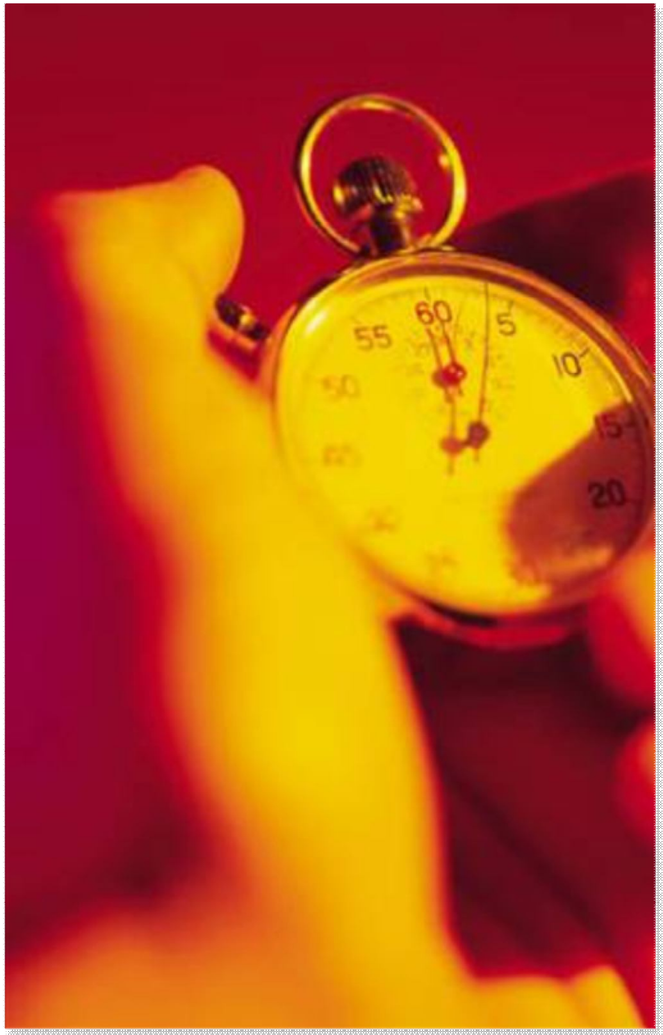
How does power relate to ICS?

- Software-selectable bus frequency divider (BDIV)
  - Available in all clock modes
  - Allows frequency changes without losing FLL Lock in FEI and FEE
  - Run fast only when needed
- Low-power or high-gain oscillator options
  - Low-power limits voltage swing on oscillator pins to minimize power consumption
- The external reference can be left enabled in stop mode
  - 32 kHz crystal in low-power mode only adds 800nA to stop mode currents!
- Stop mode currents are affected only by the references enabled in stop mode, not the ICS mode before entering
  - Ex: if running FEE mode with ext oscillator enabled in stop mode, only the ext oscillator will be enabled when stop is entered, the FLL will be disabled automatically

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Ultra-low Power Real-time Counter (RTC)

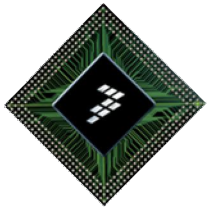
- Enhancement from Real-Time Interrupt Module
- 1 kHz internal low-power oscillator (LPO)
  - 300 nA typical power consumption
  - No crystal required
  - Independent of internal bus clock source
- External clock option for greater accuracy
  - 550 nA typical power consumption with 32 kHz low power oscillator
- Programmable wake-up intervals
  - 8-bit counter
  - 15 selectable input clock prescalers
  - 8-bit user programmable modulo value
- Can be enabled in any mode



TIP

The internal LPO oscillator can be measured against the bus clock. User software can adjust RTC timeout to compensate for inaccurate LPO clock.

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.



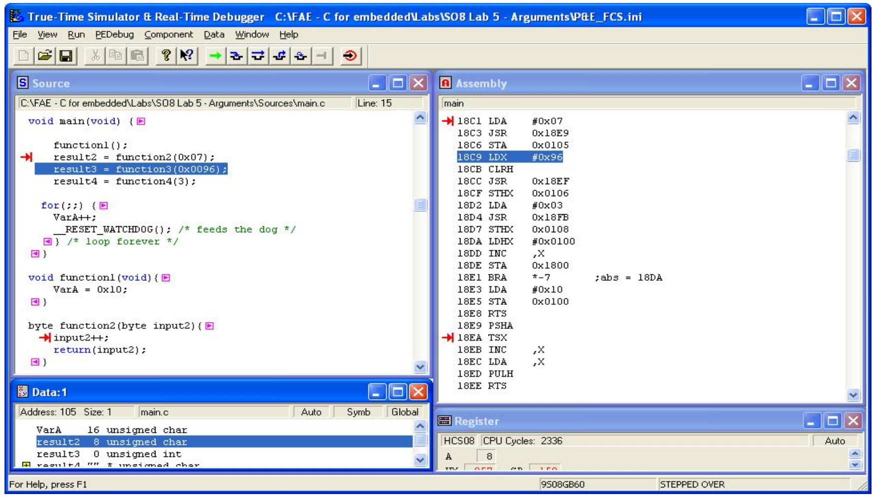
Introduction to CodeWarrior & Processor Expert

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

CodeWarrior IDE (Integrated Development Environment)

Fully featured and class leading IDE

- Full-chip simulation and flash programming
- Assembler, linker, and source level debugger supports all MCUs
- Highly optimized ANSI C compiler and C (code limitations)
- Automatic C code generation for on-chip peripherals with Processor Expert
- Special edition for S08 free up to 32k code
  - CodeWarrior for Microcontrollers
- Special edition for MCF51 free up to 64k code
  - CodeWarrior for Microcontrollers


True-Time Simulator & Real-Time Debugger   C:\FAE - C for embedded\Labs\SO8 Lab 5 - Arguments\P&E_FCS.ini
File View Run PEDebug Component Data Window Help
Source
Assembly
Data:1
Register

C:\FAE - C for embedded\Labs\SO8 Lab 5 - Arguments\Sources\main.c   Line: 15

```
void main(void) {

    function1();
    result2 = function2(0x07);
    result3 = function3(0x0096);
    result4 = function4(3);

  for(;;) {
    VarA++;
    __RESET_WATCHDOG(); /* feeds the dog */
  } /* loop forever */
}

void function1(void){
    VarA = 0x10;
}

byte function2(byte input2){
    input2++;
    return(input2);
}
```

main

```
18C1 LDA    #0x07
18C3 JSR    0x18E9
18C6 STA    0x0105
18C9 LDX    #0x96
18CB CLRH
18CC JSR    0x18EF
18CF STHX   0x0106
18D2 LDA    #0x03
18D4 JSR    0x18FB
18D7 STHX   0x0108
18DA LDHX   #0x0100
18DD INC    ,X
18DE STA    0x1800
18E1 BRA    *-7        ;abs = 18DA
18E3 LDA    #0x10
18E5 STA    0x0100
18E8 RTS
18E9 PSHA
18EA TSX
18EB INC    ,X
18EC LDA    ,X
18ED PULH
18EE RTS
```

Address: 105   Size: 1   main.c   Auto   Symb   Global

```
VarA     16 unsigned char
result2   8 unsigned char
result3   0 unsigned int
```

HCS08   CPU Cycles: 2336   Auto

A   8

For Help, press F1   9S08GB60   STEPPED OVER

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

What is Processor Expert?

A rapid application design tool with …

- **Graphical User Interface** which allows an application to be specified by the functionality needed
- **Automatic code generator** which creates tested, optimized C code tuned to the application needs and selected Freescale MCU
- **Built-in knowledgebase**, which immediately flags resource conflicts and incorrect settings in the beginning phase

Creating…

- **Hardware Abstraction Layer (HAL)** – hardware-dependent, low-level drivers with a known application programming interface (API)

Benefits

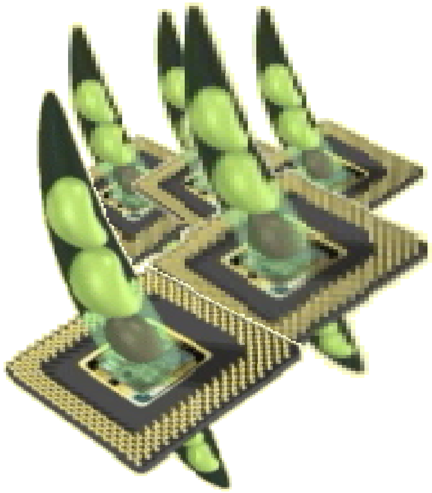
- Eases migration between Freescale devices
- Designers don’t have to be intimately familiar with every page of a specification
- Errors are caught early in design cycle; therefore, designers get to market faster with higher quality product

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

What is an Embedded Bean?

►Embedded Beans are software components, which encapsulate the initialization and functionality of an embedded system’s basic elements

- CPU core
- CPU on-chip peripherals
- FPGAs
- Stand-alone peripherals
- Virtual devices
- Pure software algorithms



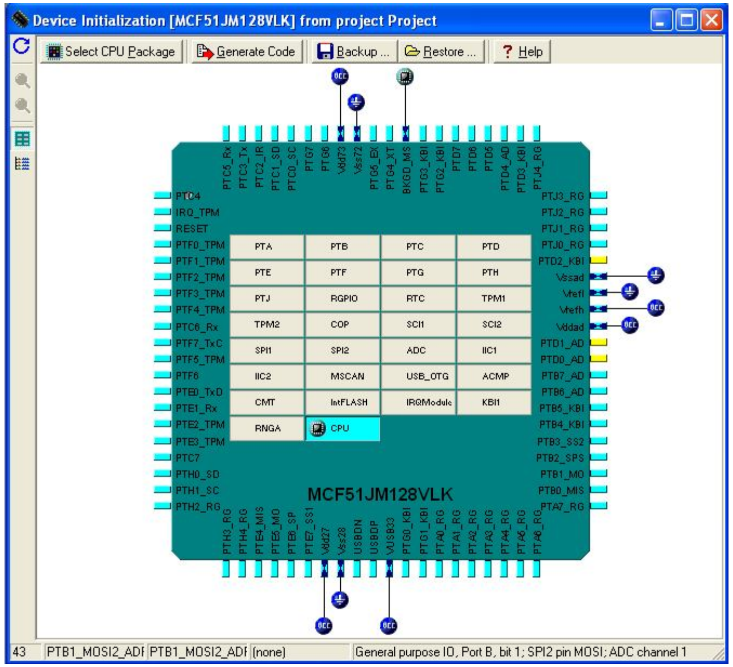
►Embedded Beans provide a hardware abstraction layer (HAL), which eases migration between devices

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

What’s Device Initialization

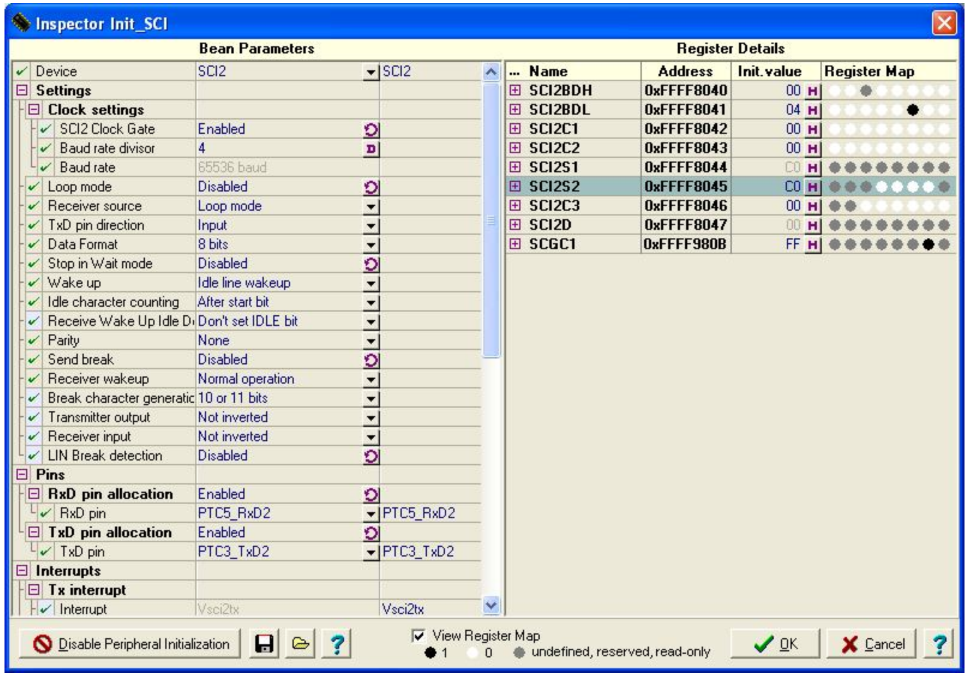
► Device Initialization is…

- A **Graphical User Interface** with CPU, peripherals and pins, which allows registers to be setup via individual bits or parameters
- An **automatic code generator** which creates **initialization code** in C or assembly



PTA	PTB	PTC	PTD
PTE	PTF	PTG	PTH
PTJ	RGPIO	RTC	TPM1
TPM2	COP	SCI1	SCI2
SPI1	SPI2	ADC	IIC1
IIC2	MSCAN	USB_OTG	ACMP
CMT	IntFLASH	IRQModule	KBI1
RNGA	CPU		

43 | PTB1_MOSI2_ADI | PTB1_MOSI2_ADI | (none) | General purpose IO, Port B, bit 1; SPI2 pin MOSI; ADC channel 1



Bean Parameters

✓ Device	SCI2	SCI2
⊟ **Settings**		
⊟ **Clock settings**		
✓ SCI2 Clock Gate	Enabled	
✓ Baud rate divisor	4	
✓ Baud rate	65536 baud	
✓ Loop mode	Disabled	
✓ Receiver source	Loop mode	
✓ TxD pin direction	Input	
✓ Data Format	8 bits	
✓ Stop in Wait mode	Disabled	
✓ Wake up	Idle line wakeup	
✓ Idle character counting	After start bit	
✓ Receive Wake Up Idle D	Don't set IDLE bit	
✓ Parity	None	
✓ Send break	Disabled	
✓ Receiver wakeup	Normal operation	
✓ Break character generatic	10 or 11 bits	
✓ Transmitter output	Not inverted	
✓ Receiver input	Not inverted	
✓ LIN Break detection	Disabled	
⊟ **Pins**		
⊟ **RxD pin allocation**	Enabled	
✓ RxD pin	PTC5_RxD2	PTC5_RxD2
⊟ **TxD pin allocation**	Enabled	
✓ TxD pin	PTC3_TxD2	PTC3_TxD2
⊟ **Interrupts**		
⊟ **Tx interrupt**		
✓ Interrupt	Vsci2tx	Vsci2tx

Register Details

... Name	Address	Init.value	Register Map
⊞ SCI2BDH	0xFFFF8040	00 H	○○◐○○○○○
⊞ SCI2BDL	0xFFFF8041	04 H	○○○○○●○○
⊞ SCI2C1	0xFFFF8042	00 H	○○○○○○○○
⊞ SCI2C2	0xFFFF8043	00 H	○○○○○○○○
⊞ SCI2S1	0xFFFF8044	C0 H	◐◐◐◐◐◐◐◐
⊞ SCI2S2	0xFFFF8045	C0 H	◐◐◐○○○○◐
⊞ SCI2C3	0xFFFF8046	00 H	◐◐○○○○○○
⊞ SCI2D	0xFFFF8047	00 H	◐◐◐◐◐◐◐◐
⊞ SCGC1	0xFFFF980B	FF H	◐◐◐◐◐◐●◐

☑ View Register Map
● 1 ○ 0 ◐ undefined, reserved, read-only

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Migration Aids

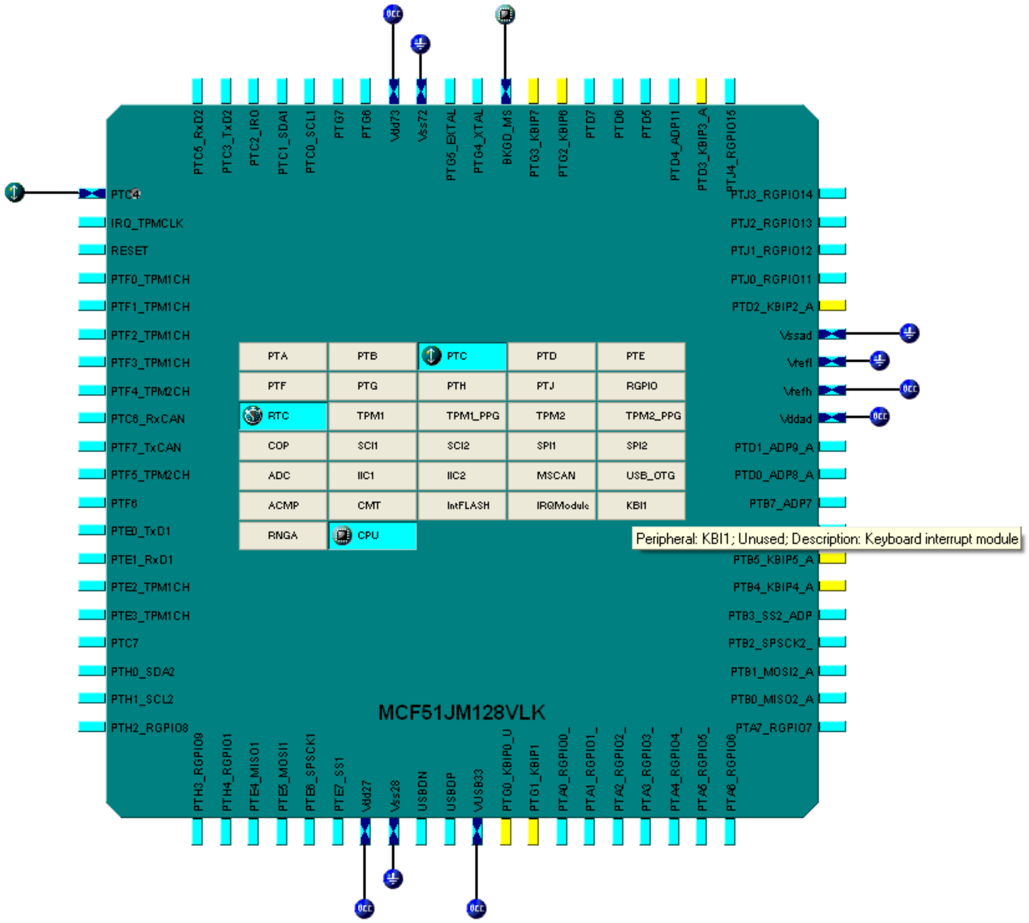
- ►Porting initialization code/low level drivers with Processor Expert
  - Use GUI to map software components to resources on new silicon
  - Regenerate initialization code and low-level drivers
  - Limitations
    - Only code generated by Processor Expert can be reconfigured and re-generated.
- ►Porting initialization code with Device Initialization
  - Use GUI to select, configure and generate initialization code for new silicon
  - Replace initialization code in project

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Evaluate Silicon

►CPU Package and Peripherals

- Displays selected targeted MCU with its peripherals and pins
- Pins associated with a peripheral are highlighted when mouse hovers over the peripheral
- Help is available for pins and peripherals by moving the mouse over the item



PTA	PTB	PTC	PTD	PTE
PTF	PTG	PTH	PTJ	RGPIO
RTC	TPM1	TPM1_PPG	TPM2	TPM2_PPG
COP	SCI1	SCI2	SPI1	SPI2
ADC	IIC1	IIC2	MSCAN	USB_OTG
ACMP	CMT	IntFLASH	IRQModule	KBI1
RNGA	CPU			

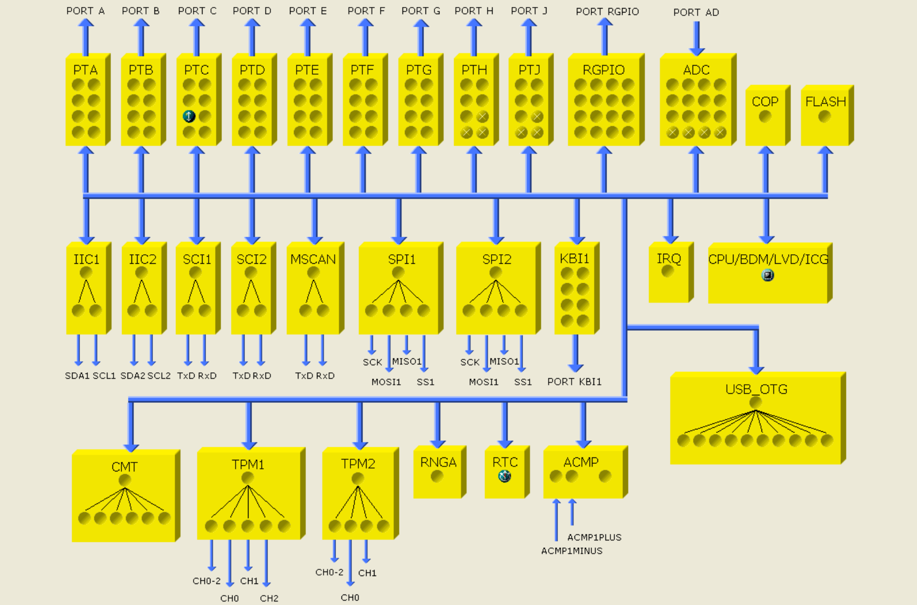
Peripheral: KBI1; Unused; Description: Keyboard interrupt module

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Evaluate Silicon

►CPU Block Diagram

- Every peripheral is represented by a block.
- Every block contains slots for every resource that can be allocated (e.g. pin or channel).
- If the resource is allocated, the slot contains the icon of the allocating component.



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Unique in the Market

► Processor Expert delivers functionality that is unique in the market.

	CodeWarrior - Processor Expert	RealView Tools Suite	Green Hills	IAR (VisualSTATE 6.1)	HITEX (startEasy)	Keil
Graphical Interface	Yes	Yes	Yes	Yes	Yes	Yes
Configurable Application Notes	Yes	No	No	Yes	Yes	No
Integrated Knowledgebase	Yes	No	No	No	No	No
Generates Initialization Code	Yes	No	No	Yes	Yes	No
Generates Low Level Drivers	Yes	No	No	Yes	No	No
Tools to Add Higher Level Drivers	Yes	No	No	No	No	No
Integration with UML Modeling Tools	Yes	Yes	Yes	Yes	No	Yes

* Software support for ARM competitors

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Digital Multimeter Design

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

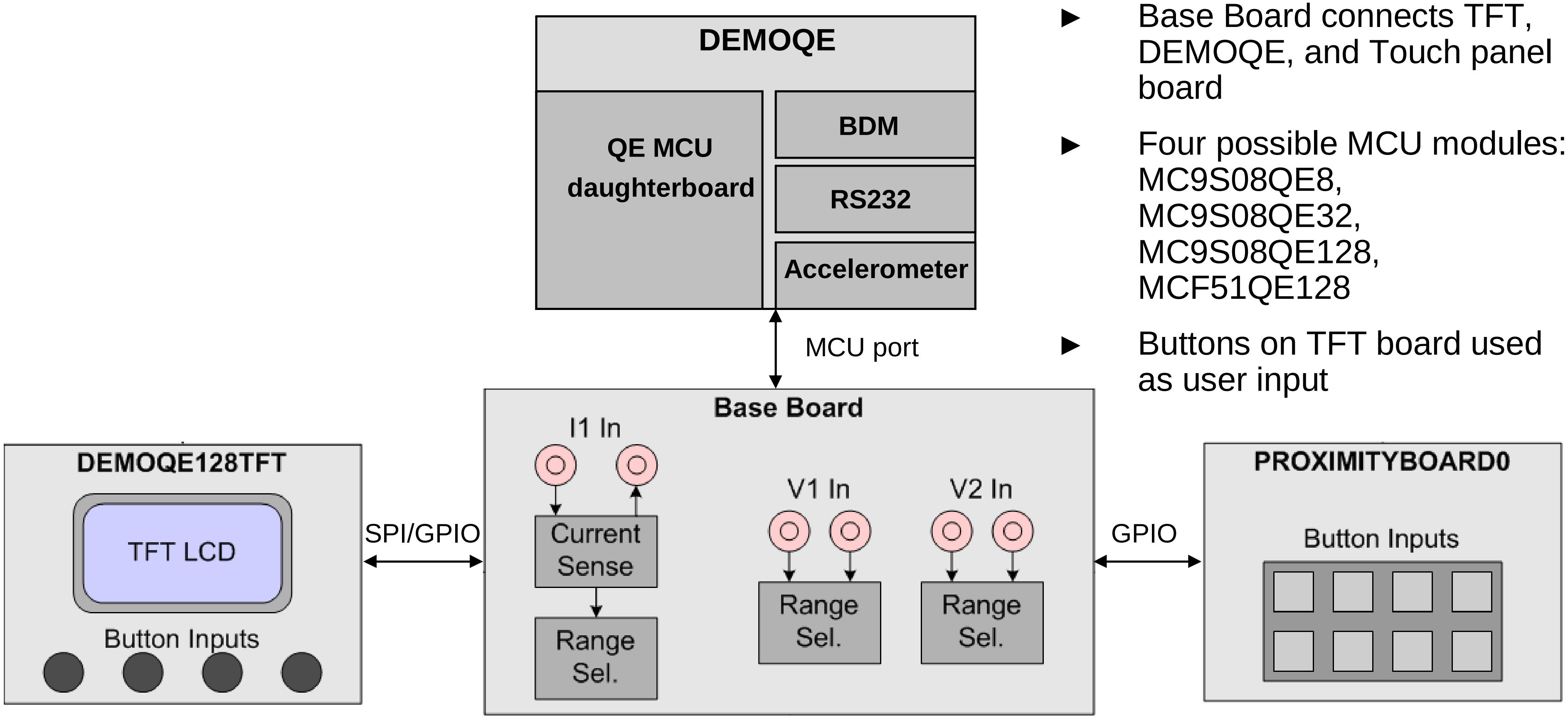
Agenda

- **Introductory information**
  - System design
  - Software Overview
- CodeWarrior, Processor Expert, and Beans
- Lab1: QE8
- Lab2: QE32
- Lab3: QE128 (HCS08)
- Lab4: QE128 (Coldfire V1)

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Digital Multimeter System Design

Hardware Overview



- ► Base Board connects TFT, DEMOQE, and Touch panel board
- ► Four possible MCU modules: MC9S08QE8, MC9S08QE32, MC9S08QE128, MCF51QE128
- ► Buttons on TFT board used as user input

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Hardware Block Connection:

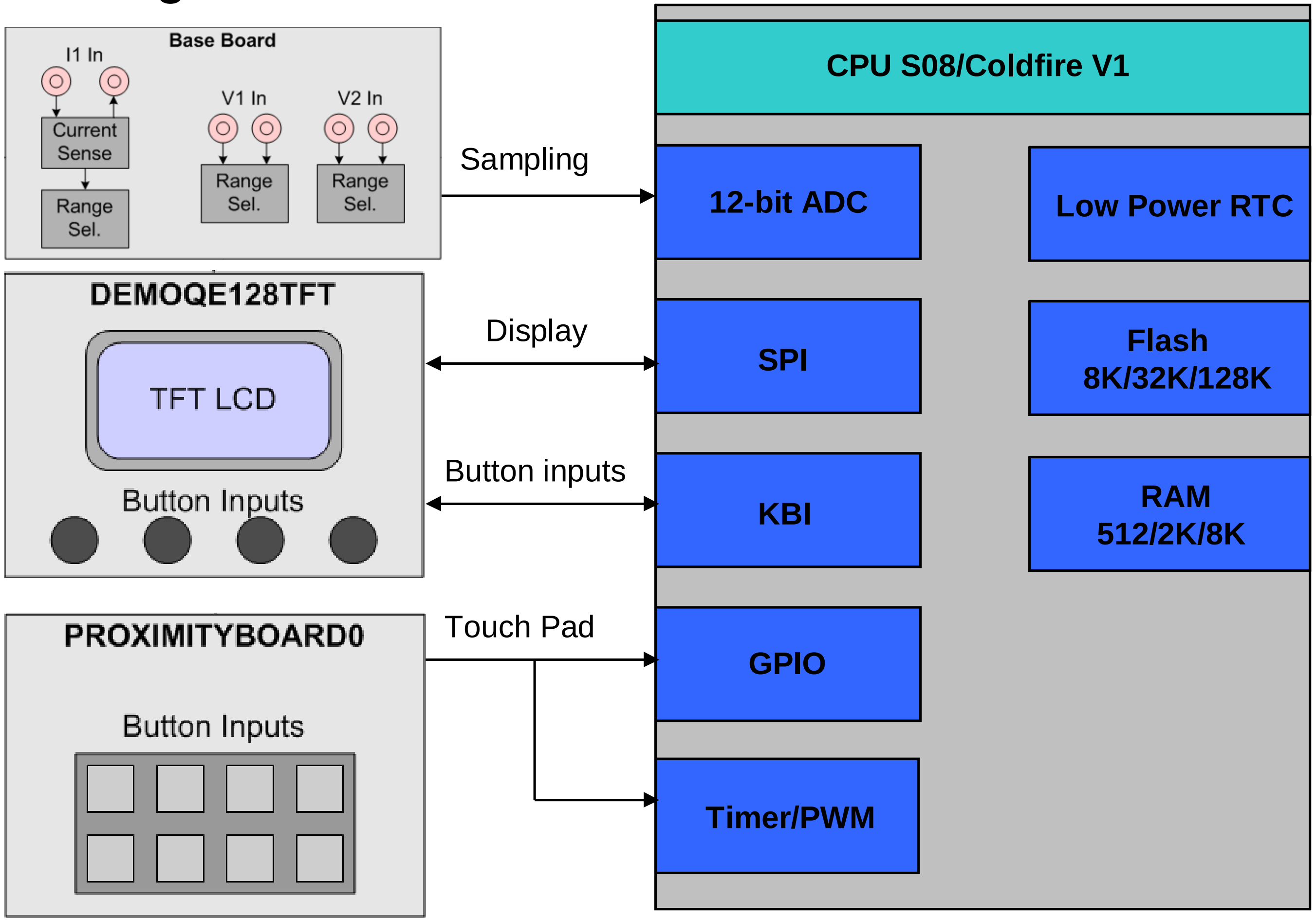
- ► Base Board (J1) connects DEMOQE (J1)
- ► Base Board (J2) connects TFT
- ► Base Board (J5) connects Touch panel board (J1)
- ► Four possible MCU daughter boards connect to DEMOQE:
  - MC9S08QE8
  - MC9S08QE32
  - MC9S08QE128
  - MCF51QE128

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Digital Multimeter System Design

Hardware Overview

Functional Diagram:



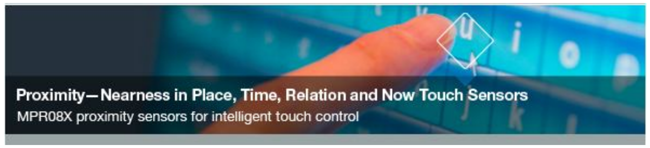
Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Hardware & Software Re-use

To meet the time-to-market requirements of the DMM project, the re-use of Freescale reference h/ware & s/ware was essential -

- DEMOQE128 board & associated daughter cards — [Freescale]
  - www.freescale.com/flexis
- DMM Connector/Expansion board — [Freescale 3rd party vendor]
- DMM Software — NUVATION
- DEMOQE128TFT LCD board & display driver software — DISPLAY 3000
  - S/ware is included with purchase of any DEMOQETFT LCD board
  - www.shop-en.display3000.com/pi19/pi18/pd38.html

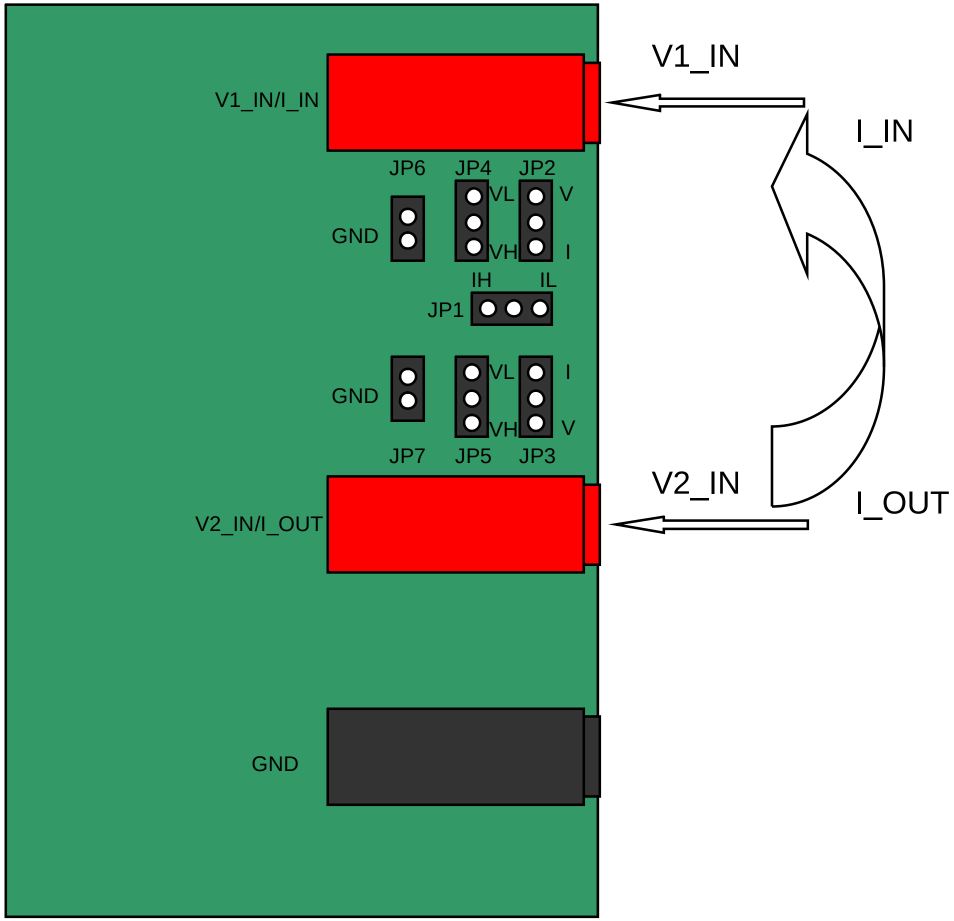
- Capacitive touch software — [Freescale]
  - www.freescale.com/proximity


Proximity—Nearness in Place, Time, Relation and Now Touch Sensors
MPR08X proximity sensors for intelligent touch control

- Application notes were referenced in order to illustrate migrating across the QE family

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

DMM System Design
Base Board Configuration



- Jumper JP2 and JP3 Select Voltage or Current measurement of input 1 and 2
- Jumper JP4 and JP5 control input range for Voltage input 1 and 2

High Voltage input range: 0 – 15V

Low Voltage input range: 0 – 7.5V

- Jumper JP1 controls input range for Current input

High Current input range: 100 uA~100 mA

Low Current input range: 500 nA~500 uA

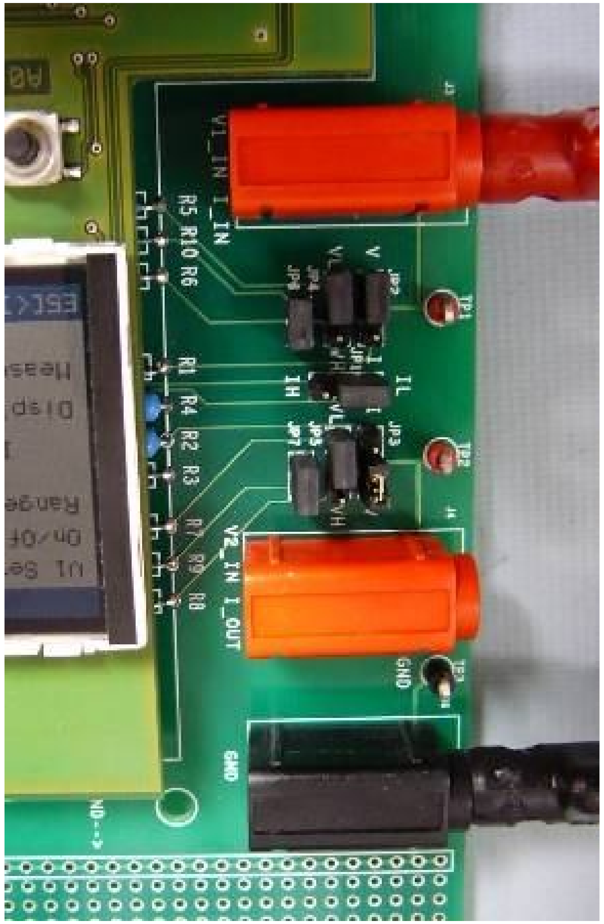
Default Jumper Settings	
Jumper	**Setting**
JP1	500nA – 500uA (IL)
JP2	(V)
JP3	(V)
JP4	0 – 7.5V (VL)
JP5	0 – 7.5V (VL)
JP6	Installed
JP7	Installed

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

DMM System Design
Operational Overview

Using the DMM Base Board:

- Jumper JP4 controls input range for Voltage input 1
  - JP4 VL selects 0 ~ 15V
  - JP4 VH selects 0 ~ 7.5V
- Jumper JP5 controls input range for Voltage input 2
  - JP5 VL selects 0 ~ 15V
  - JP5 VH selects 0 ~ 7.5V
- Jumper JP1 controls input range for Current input 1
  - JP1 IL selects 500 nA – 500 uA
  - JP1 IH selects 100 uA – 100 mA



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

DEMOQE Board Jumper Settings:

Accelerometer	
Jumper	**Pins**
J13	2&3
J14	2&3
J15	2&3
J16	None

Inputs	
Jumper	**Pins**
J12	None
J18	1&2, 3&4
J11	1&2, 3&4

System Power	
Jumper	**Pins**
J3	2&3
J4	3&4
J5	3&4, 5&6

RS232	
Jumper	**Pins**
J6	1&2
J7	1&2
J8	2&3

External Clock	
Jumper	**Pins**
J17	1&2, 3&4

Buzzer	
Jumper	**Pins**
J19	1&2

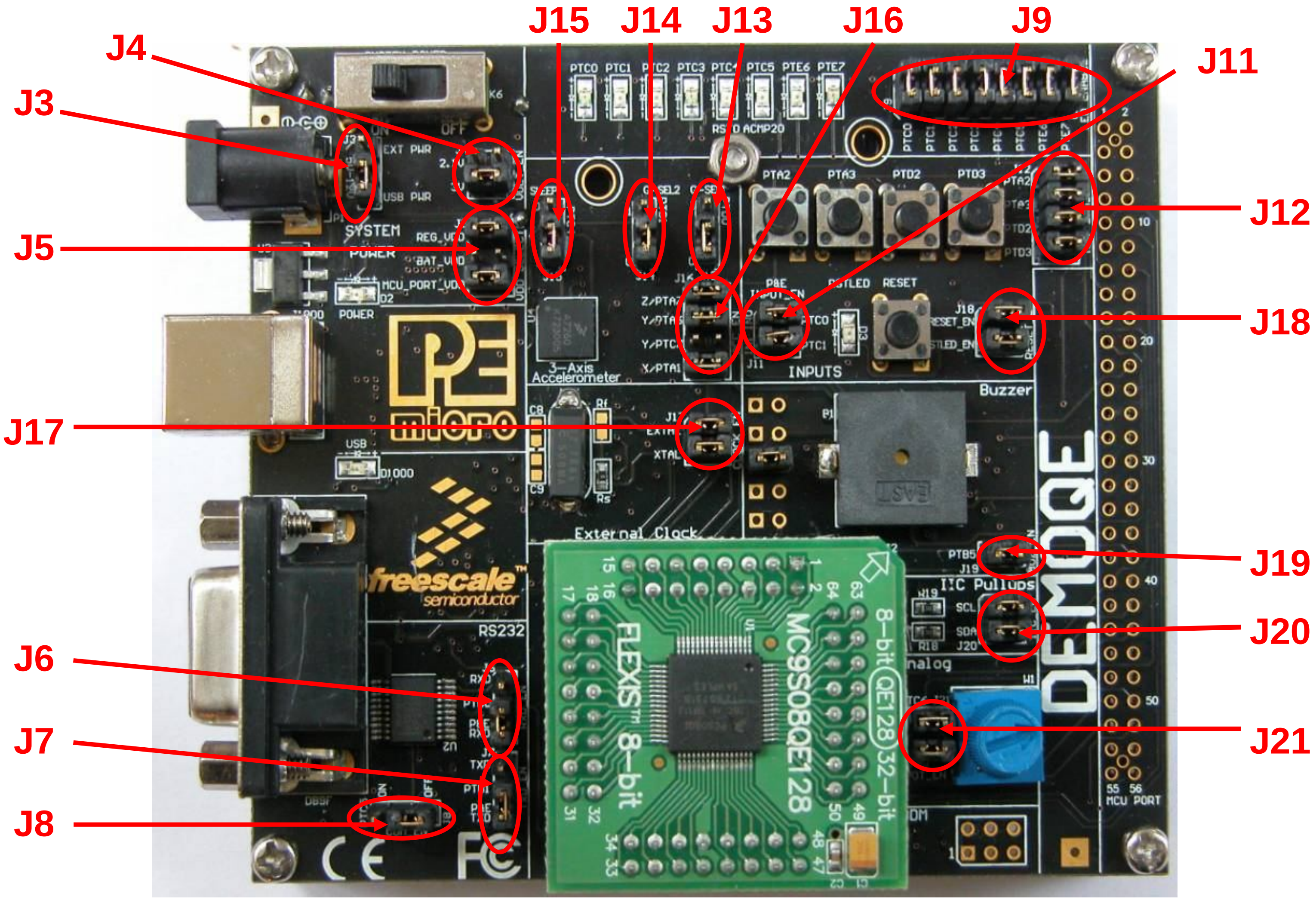
IIC Pullups	
Jumper	**Pins**
J20	None

Analog	
Jumper	**Pins**
J21	None

LEDs	
Jumper	**Pins**
J9	None

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

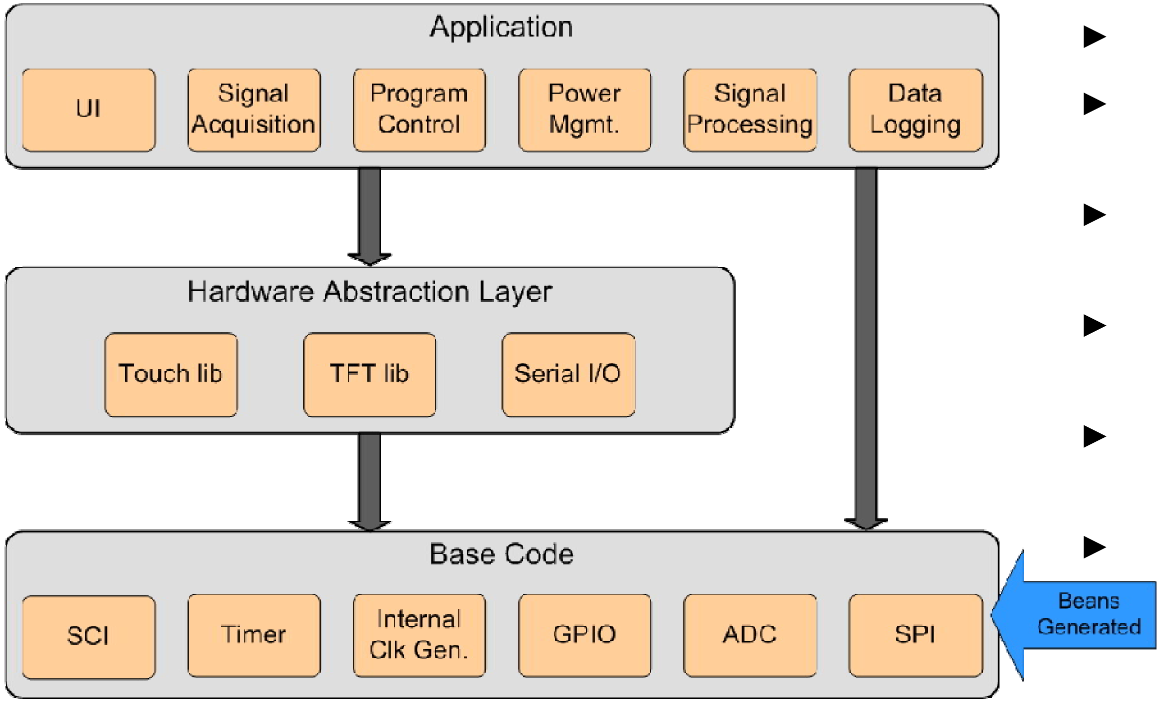
DEMOQE Board Jumper Locations



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Software Overview

Architecture

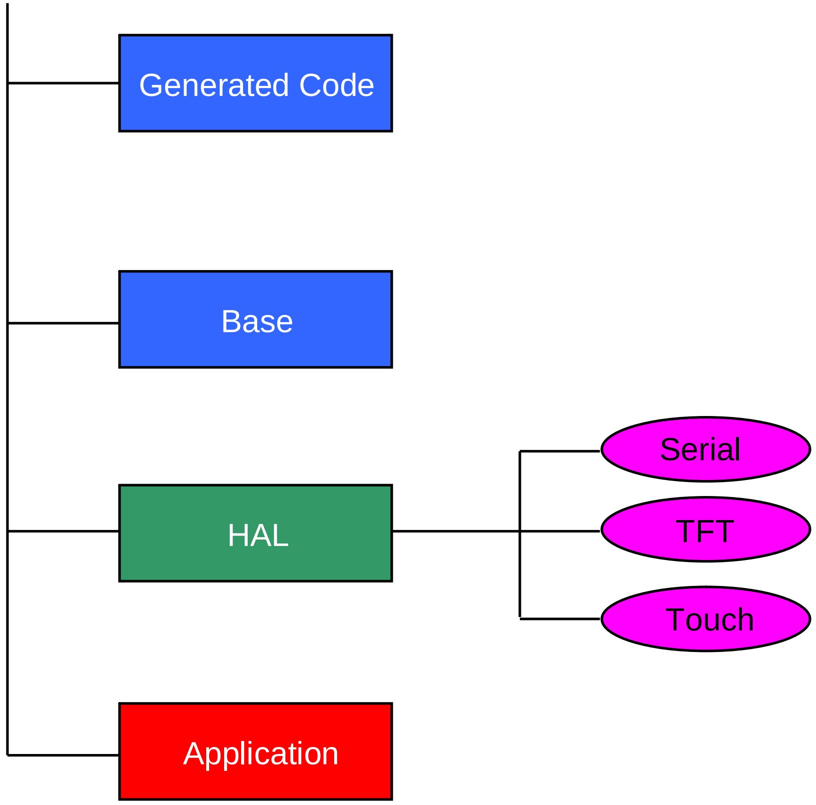


- Three functional layers
- Each functional layer is unaware of the layer(s) above it
- Base code generated exclusively by Processor Expert Beans
- HAL layer generalizes hardware-specific functionality
- Application layer implements demo application functionality
- Object oriented module-based approach

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Software Overview

Project Structure



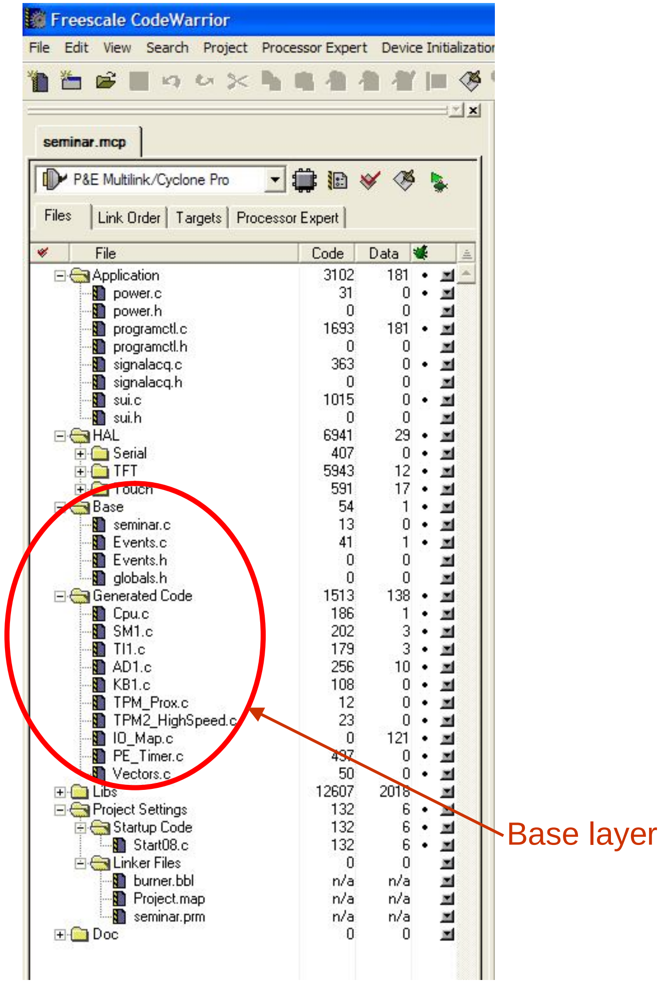
- "Generated Code" source group contains all Beans-generated code
- "Base" source group contains Beans code that is tied to user modules through Processor Expert
- Sub-group for serial I/O utilizing Beans-generated functions
- Sub-groups for off-the-shelf TFT display library and touchpad interface library
- HAL code is common for all targets
- Application modules are included in the application group

🟦	Base Code Layer	🟩	Hardware Abstraction Layer	🟥	Application Layer	⬭	Sub-group

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Software Overview

Project Structure


Freescale CodeWarrior
File Edit View Search Project Processor Expert Device Initializatior
seminar.mcp
P&E Multilink/Cyclone Pro
Files
Link Order
Targets
Processor Expert

File	Code	Data	
Application	3102	181	•
power.c	31	0	•
power.h	0	0	
programctl.c	1693	181	•
programctl.h	0	0	
signalacq.c	363	0	•
signalacq.h	0	0	
sui.c	1015	0	•
sui.h	0	0	
HAL	6941	29	•
Serial	407	0	•
TFT	5943	12	•
Touch	591	17	•
Base	54	1	•
seminar.c	13	0	•
Events.c	41	1	•
Events.h	0	0	
globals.h	0	0	
Generated Code	1513	138	•
Cpu.c	186	1	•
SM1.c	202	3	•
TI1.c	179	3	•
AD1.c	256	10	•
KB1.c	108	0	•
TPM_Prox.c	12	0	•
TPM2_HighSpeed.c	23	0	•
IO_Map.c	0	121	•
PE_Timer.c	497	0	•
Vectors.c	50	0	•
Libs	12607	2018	
Project Settings	132	6	•
Startup Code	132	6	•
Start08.c	132	6	•
Linker Files	0	0	
burner.bbl	n/a	n/a	
Project.map	n/a	n/a	
seminar.prm	n/a	n/a	
Doc	0	0	

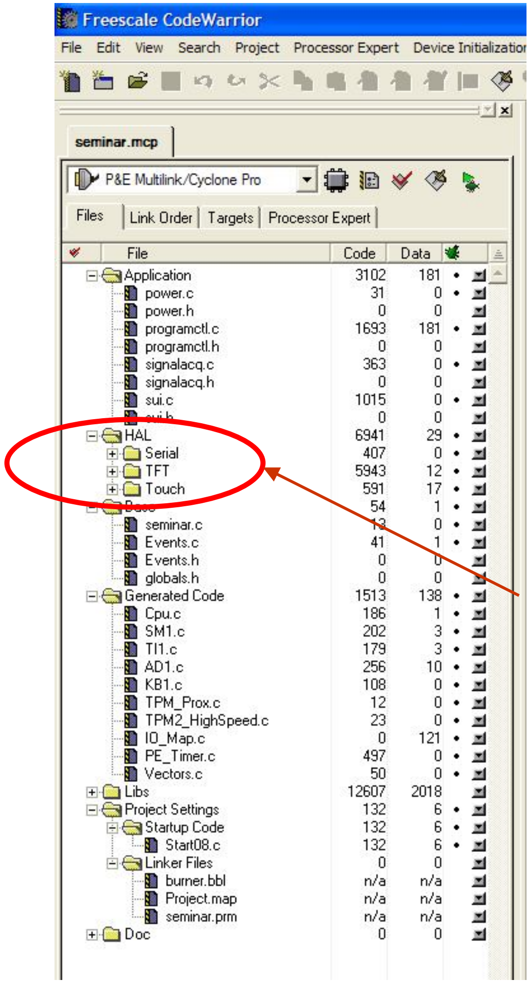
Base layer

- ► Base layer sources contained in “Base” and “Generated Code” source groups
- ► “Generated Code” source group contains all Beans-generated code
- ► “Base” source group contains Beans code that is tied to user modules through Processor Expert

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Software Overview

Project Structure


Freescale CodeWarrior
File Edit View Search Project Processor Expert Device Initializatio
seminar.mcp
P&E Multilink/Cyclone Pro
Files
Link Order
Targets
Processor Expert

File	Code	Data	
Application	3102	181	•
power.c	31	0	•
power.h	0	0	
programctl.c	1693	181	•
programctl.h	0	0	
signalacq.c	363	0	•
signalacq.h	0	0	
sui.c	1015	0	•
sui.h	0	0	
HAL	6941	29	•
Serial	407	0	•
TFT	5943	12	•
Touch	591	17	•
Base	54	1	•
seminar.c	13	0	•
Events.c	41	1	•
Events.h	0	0	
globals.h	0	0	
Generated Code	1513	138	•
Cpu.c	186	1	•
SM1.c	202	3	•
TI1.c	179	3	•
AD1.c	256	10	•
KB1.c	108	0	•
TPM_Prox.c	12	0	•
TPM2_HighSpeed.c	23	0	•
IO_Map.c	0	121	•
PE_Timer.c	497	0	•
Vectors.c	50	0	•
Libs	12607	2018	
Project Settings	132	6	•
Startup Code	132	6	•
Start08.c	132	6	•
Linker Files	0	0	
burner.bbl	n/a	n/a	
Project.map	n/a	n/a	
seminar.prm	n/a	n/a	
Doc	0	0	

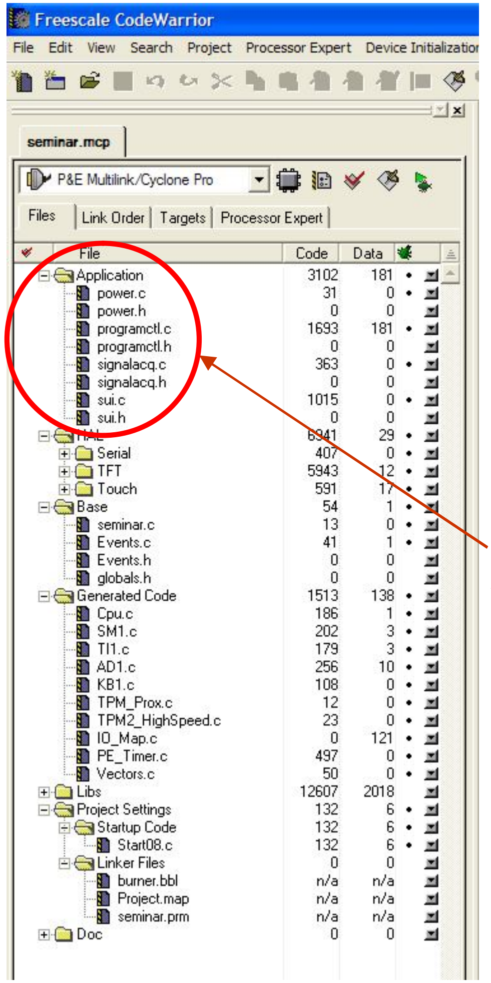
HAL layer

- ► Hardware Abstraction Layer is contained in the “HAL” source group
- ► Contains sub-group for serial I/O utilizing Beans-generated functions
- ► Contains sub-groups for off-the-shelf TFT display and touchpad interface libraries
- ► HAL code is common for all targets

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Software Overview

Project Structure


Freescale CodeWarrior
File Edit View Search Project Processor Expert Device Initializatio
seminar.mcp
P&E Multilink/Cyclone Pro
Files
Link Order
Targets
Processor Expert

File	Code	Data	
Application	3102	181	•
power.c	31	0	•
power.h	0	0	
programctl.c	1693	181	•
programctl.h	0	0	
signalacq.c	363	0	•
signalacq.h	0	0	
sui.c	1015	0	•
sui.h	0	0	
HAL	6941	29	•
Serial	407	0	•
TFT	5943	12	•
Touch	591	17	•
Base	54	1	•
seminar.c	13	0	•
Events.c	41	1	•
Events.h	0	0	
globals.h	0	0	
Generated Code	1513	138	•
Cpu.c	186	1	•
SM1.c	202	3	•
TI1.c	179	3	•
AD1.c	256	10	•
KB1.c	108	0	•
TPM_Prox.c	12	0	•
TPM2_HighSpeed.c	23	0	•
IO_Map.c	0	121	•
PE_Timer.c	497	0	•
Vectors.c	50	0	•
Libs	12607	2018	
Project Settings	132	6	•
Startup Code	132	6	•
Start08.c	132	6	•
Linker Files	0	0	
burner.bbl	n/a	n/a	
Project.map	n/a	n/a	
seminar.prm	n/a	n/a	
Doc	0	0	

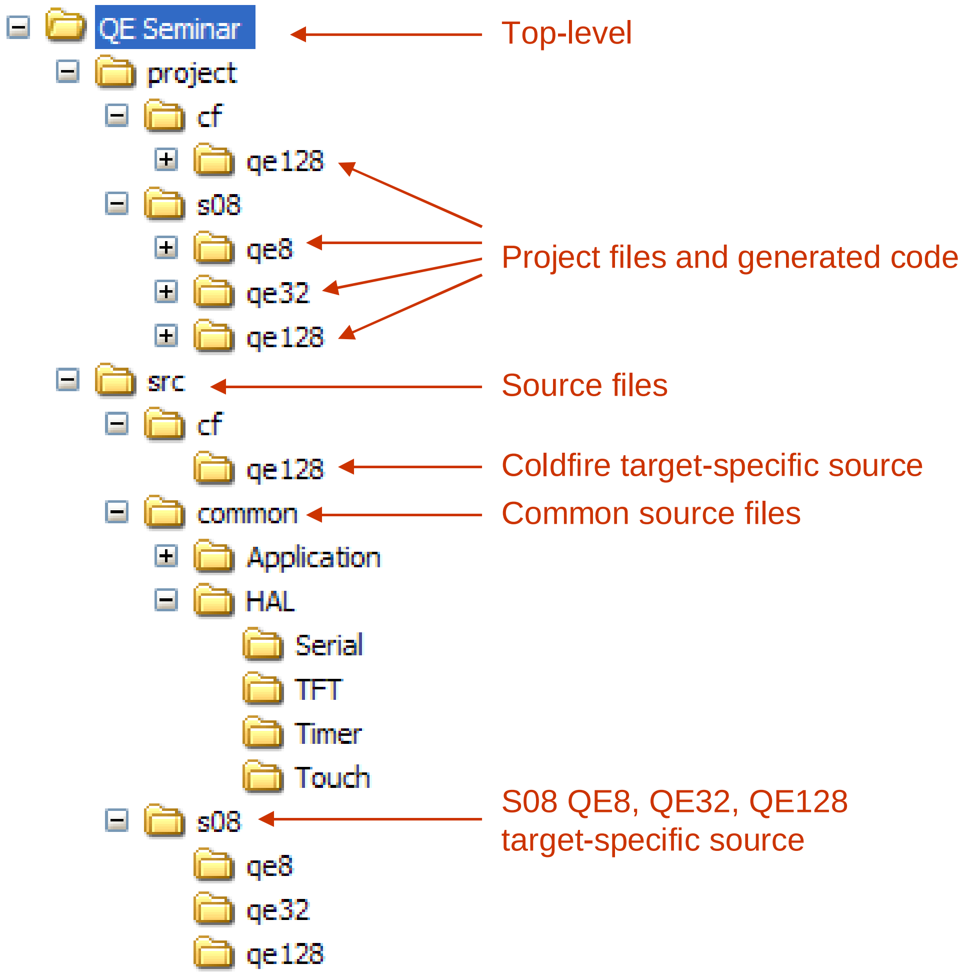
Application layer

- ► Application modules are contained in the "Application" source group
- ► Each module implemented as one source and one header file
- ► The list of included application modules will change/increase as program complexity increases

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Software Overview

Directory Structure



Top-level

Project files and generated code

Source files

Coldfire target-specific source

Common source files

S08 QE8, QE32, QE128 target-specific source

- We will start with QE8 project and modify this project for migration to other targets
- Target-specific projects allow seminar labs to continue should something go wrong
- The majority of the source is common amongst all targets
- Only programctl modules differ from target to target

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Agenda

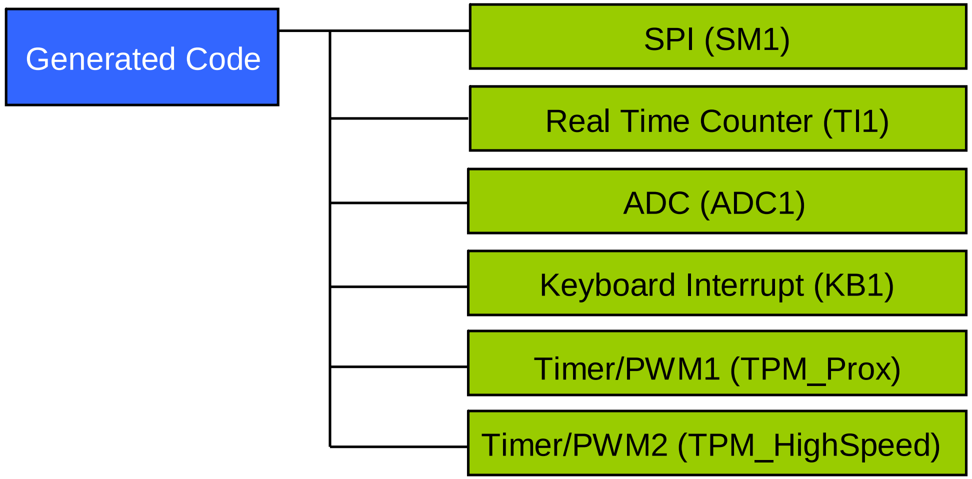
- Introductory information
  - System design
  - Software Overview
- **CodeWarrior, Processor Expert, and Beans**
- Lab1: QE8
- Lab2: QE32
- Lab3: QE128 (HCS08)
- Lab4: QE128 (Coldfire V1)

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Processor Expert, and Beans

- Beans are self contained configuration modules that automatically generate peripheral driver code
- Beans provide a high-level interface to low-level hardware functions
- Modifying Beans settings has little to no impact on the code using it; code is refactored on-the-fly
- CPU Beans allow the changing of target MCUs on-the-fly within the same project

Peripheral driver Beans in this project include:



Generated Code

SPI (SM1)

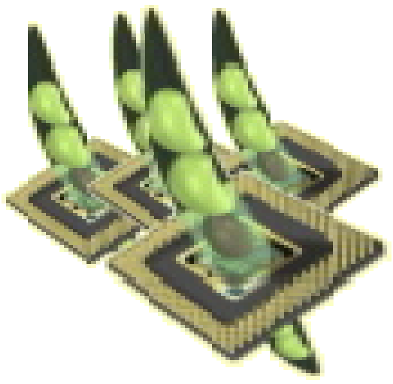
Real Time Counter (TI1)

ADC (ADC1)

Keyboard Interrupt (KB1)

Timer/PWM1 (TPM_Prox)

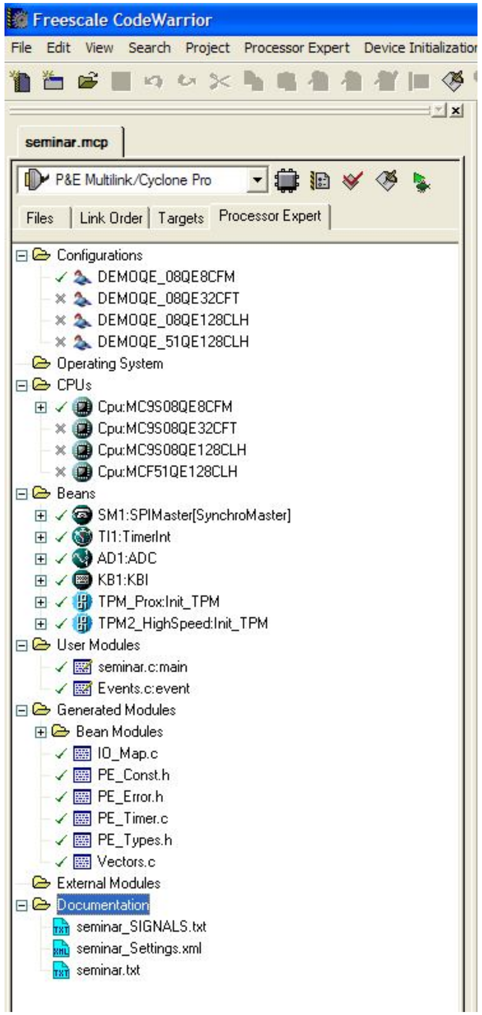
Timer/PWM2 (TPM_HighSpeed)



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

CodeWarrior, Processor Expert, and Beans

Beans Configuration


Freescale CodeWarrior
File Edit View Search Project Processor Expert Device Initializatio
seminar.mcp
P&E Multilink/Cyclone Pro
Files | Link Order | Targets | Processor Expert

- Configurations
  - ✓ DEMOQE_08QE8CFM
  - ✗ DEMOQE_08QE32CFT
  - ✗ DEMOQE_08QE128CLH
  - ✗ DEMOQE_51QE128CLH
- Operating System
- CPUs
  - ✓ Cpu:MC9S08QE8CFM
  - ✗ Cpu:MC9S08QE32CFT
  - ✗ Cpu:MC9S08QE128CLH
  - ✗ Cpu:MCF51QE128CLH
- Beans
  - ✓ SM1:SPIMaster[SynchroMaster]
  - ✓ TI1:TimerInt
  - ✓ AD1:ADC
  - ✓ KB1:KBI
  - ✓ TPM_Prox:Init_TPM
  - ✓ TPM2_HighSpeed:Init_TPM
- User Modules
  - ✓ seminar.c:main
  - ✓ Events.c:event
- Generated Modules
  - Bean Modules
  - ✓ IO_Map.c
  - ✓ PE_Const.h
  - ✓ PE_Error.h
  - ✓ PE_Timer.c
  - ✓ PE_Types.h
  - ✓ Vectors.c
- External Modules
- Documentation
  - seminar_SIGNALS.txt
  - seminar_Settings.xml
  - seminar.txt

- ► CPU Beans allow the changing of target MCUs on-the-fly within the same project
- ► Peripheral driver Beans in this project include:
  - SPI (SM1)
  - Real Time Counter (TI1)
  - ADC (ADC1)
  - Keyboard Interrupt (KB1)
  - Timer/PWM1 (TPM_Prox)
  - Timer/PWM2 (TPM_HighSpeed)
- ► User code that uses Beans is mapped to “User Modules” allowing on-the-fly refactoring when Beans settings or naming changes

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

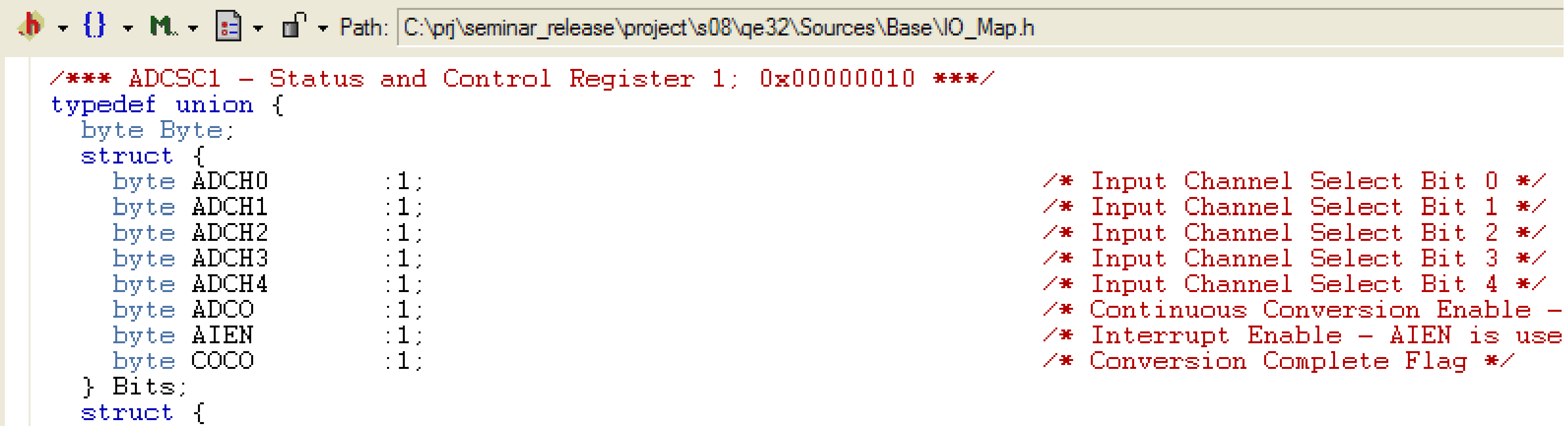
Technique 1: Using Processor Expert

- Processor Expert generates the underlying driver code
- If the target changes, the driver code will be re-generated automatically since driver function definitions are specific to a given Bean, and not the target MCU

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Technique 2: Using the provided register map

- Freescale provides a standard header file containing the entire register map for all Flexis MCUs
- Contains named interrupt vector definitions
- This header file can be accessed directly, or through Beans
- Easy to use Word, Byte, or bit access to registers
- Flexis MCUs with compatible peripheral sets can be targeted easily; naming conventions are consistent


Path: C:\prj\seminar_release\project\s08\qe32\Sources\Base\IO_Map.h

```
/*** ADCSC1 - Status and Control Register 1; 0x00000010 ***/
typedef union {
  byte Byte;
  struct {
    byte ADCH0       :1;                                       /* Input Channel Select Bit 0 */
    byte ADCH1       :1;                                       /* Input Channel Select Bit 1 */
    byte ADCH2       :1;                                       /* Input Channel Select Bit 2 */
    byte ADCH3       :1;                                       /* Input Channel Select Bit 3 */
    byte ADCH4       :1;                                       /* Input Channel Select Bit 4 */
    byte ADCO        :1;                                       /* Continuous Conversion Enable -
    byte AIEN        :1;                                       /* Interrupt Enable - AIEN is use
    byte COCO        :1;                                       /* Conversion Complete Flag */
  } Bits;
  struct {
```

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

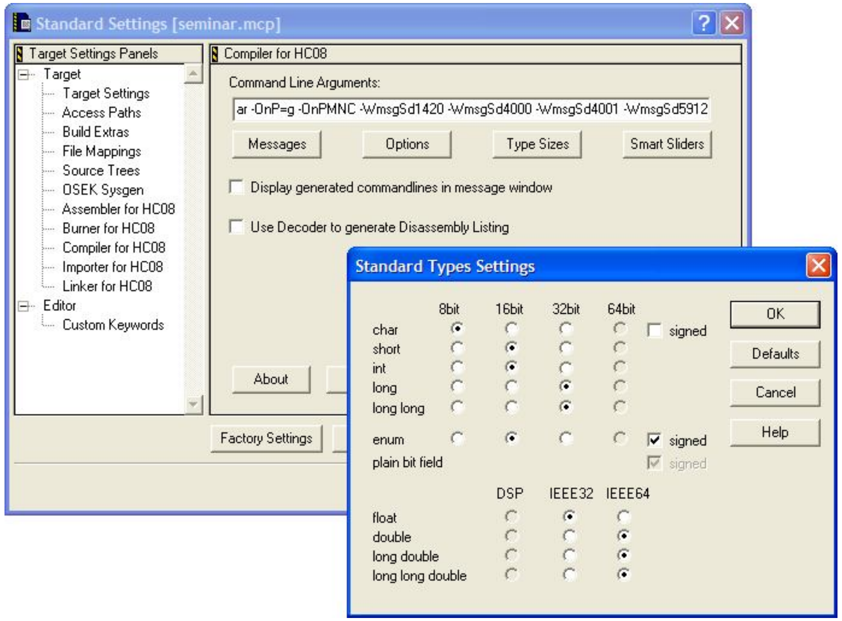
Technique 3: Defining standard primitive types

- ► Primitive type sizes can be different from one compiler to another
- ► Defining a fixed set of standard primitives will allow seamless migration between CPU targets and compilers

Example:

```
typedef unsigned char  uint8;
typedef unsigned short uint16;
typedef unsigned long  uint32;

typedef char  int8;
typedef short int16;
typedef long  int32;
```

Compiler Setup:



Command Line Arguments:

```
ar -OnP=g -OnPMNC -WmsgSd1420 -WmsgSd4000 -WmsgSd4001 -WmsgSd5912
```

☐ Display generated commandlines in message window

☐ Use Decoder to generate Disassembly Listing

	8bit	16bit	32bit	64bit	
char	●	○	○	○	☐ signed
short	○	●	○	○	
int	○	●	○	○	
long	○	○	●	○	
long long	○	○	●	○	
enum	○	●	○	○	☑ signed
plain bit field					☑ signed

	DSP	IEEE32	IEEE64
float	○	●	○
double	○	○	●
long double	○	○	●
long long double	○	○	●

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

CodeWarrior, Processor Expert, and Beans

Designing for Portability

Things to avoid:

- Avoid using assembly code wherever possible
- Absolute memory declarations for memory access, peripheral addressing, and interrupt vectors

Things to be cautious of:

- Timing routines
  - blocking cpu timers will not necessarily execute at the same rate
  - clocking may not be the same between targets
- Entering low power modes

More information:

Migrating from 8-bit S08 to 32-bit ColdFire V1 using CodeWarrior for Microcontrollers V6.x Application Note

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Low Power Considerations: Software

- ►Properly set the system options and configurations registers
    - The stop instruction must be enabled
    - Low voltage detect in stop mode must be disabled
    - The internal bandgap signal must be disabled
    - Enable/disable the IRQ and Reset pins as necessary

- ►Routines to enter low power modes should disable all un-necessary internal and external peripherals
    - SCI/SPI should be disable so that pin control is handled by GPIO
    - All unused GPIO should be configured
    - TFT display should be placed into low power mode

- ►Routines to recover from low power modes must handle re-initializing the TFT display

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

LAB1: QE8

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

QE8 Overview

	QE8	QE32	S08QE128	51QE128
CPU	**S08 Up to 20 MHz**	S08 Up to 50MHz	S08 Up to 50 MHz	ColdFire V1 Up to 50 MHz
FLASH	**8K Bytes**	32K Bytes	128K Bytes	128K Bytes
RAM	**512 Bytes**	2K Bytes	8K Bytes	8K Bytes
ADC	**10-ch 12-bit ADC**	10-ch 12-bit ADC	24-ch 12-bit ADC	24-ch 12-bit ADC
TPM	**2 TPM (3-ch)**	2 TPM (3-ch) 1 TPM (6-ch)	2 TPM (3-ch) 1 TPM (6-ch)	2 TPM (3-ch) 1 TPM (6-ch)
SPI	**1 SPI**	1 SPI	2 SPI	2 SPI
SCI	**1 SCI**	2 SCI	2 SCI	2 SCI
IIC	**1 IIC**	1 IIC	2 IIC	2 IIC
KBI	**8-ch KBI**	16-ch KBI	16-ch KBI	16-ch KBI
Rapid GPIO	**NA**	NA	NA	Yes
Others	**ICS, RTC, GPIO, BDM**			

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 1: QE8
Device Overview

MCU: MC9S08QE8

Specs	
CPU	HCS08
RAM	512 Bytes
Flash	8192 Bytes
Max Bus Clock	10 MHz
Max CPU Clock	20 MHz

Peripherals:

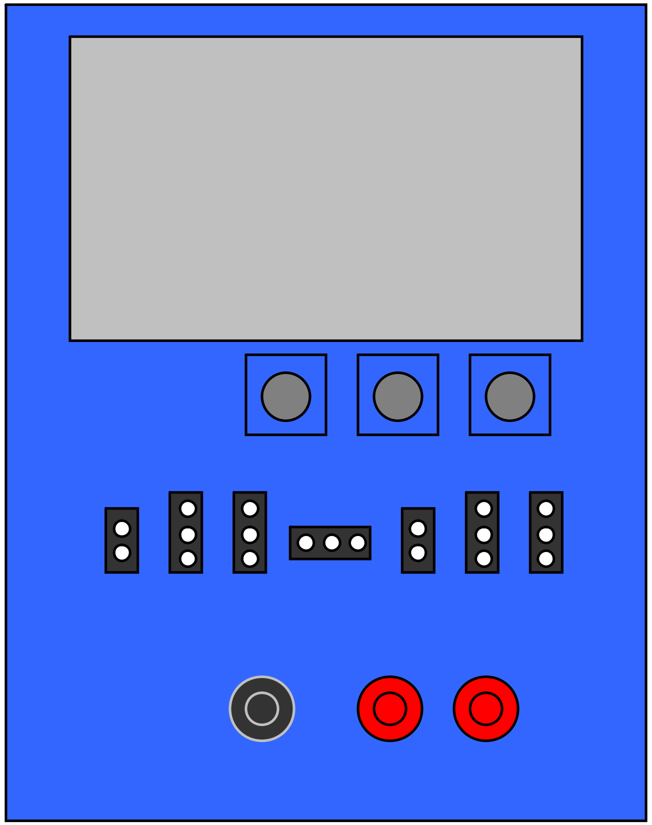
- ►ADC (10-ch, 12-bit)
- ►Comparators (2)
- ►SCI
- ►SPI
- ►I2C
- ►TPM (2x 3-ch)
- ►RTC
- ►KBI (8-ch)

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 1: QE8

Software Overview

Program Mode: Digital Multimeter



- readings on two voltage inputs and one current input
- Can select input range with jumpers
- Readings displayed on the TFT LCD
- Can enable/disable voltage inputs
- User input is done through push buttons on LCD board
- Enters low power “sleep” mode after a user configurable timeout interval
- Measurements taken upon “wakeup” from sleep mode
- Wakeup sources – RTC and KBI

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

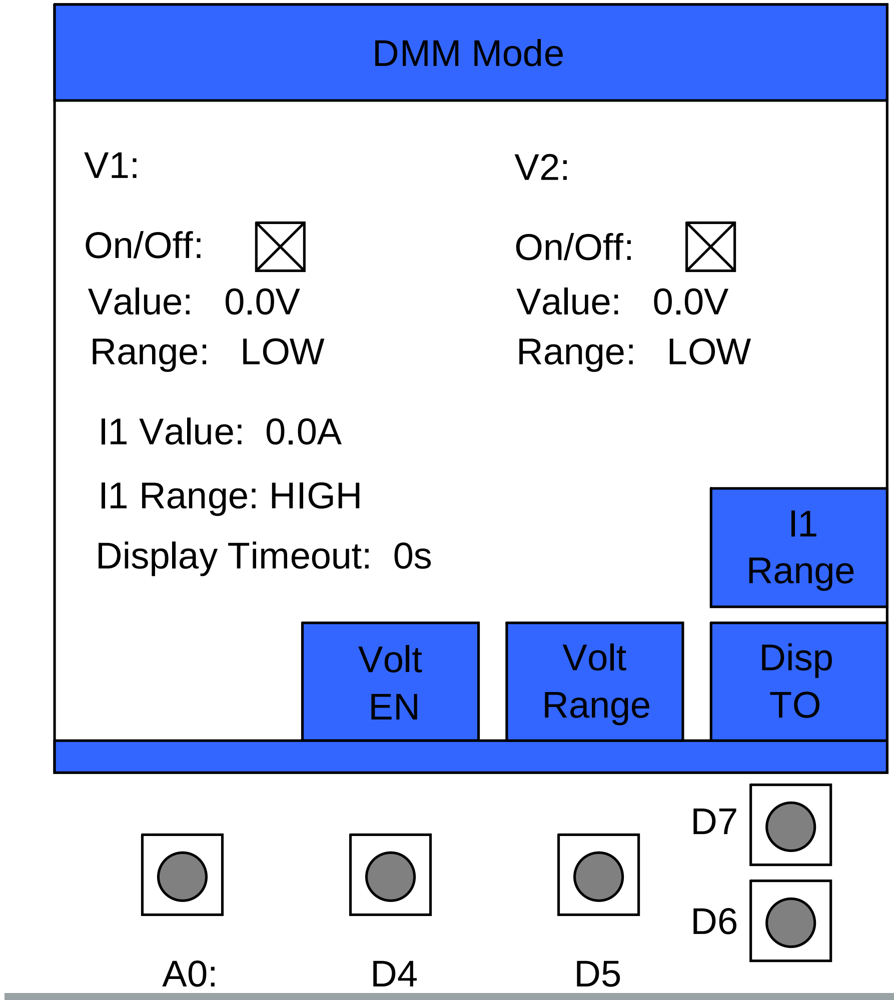
Program Mode: Digital Multimeter

- Implements a Digital Multimeter
  - Performs readings on two voltage inputs and one current input
  - Can select input range with jumpers
  - Readings displayed on the TFT LCD
  - Can enable/disable voltage inputs
- User input is done through push buttons on LCD board
- Enters low power “sleep” mode after a user configurable timeout interval
- Measurements taken upon “wakeup” from sleep mode
- Wakeup sources – RTC and KBI

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 1: QE8

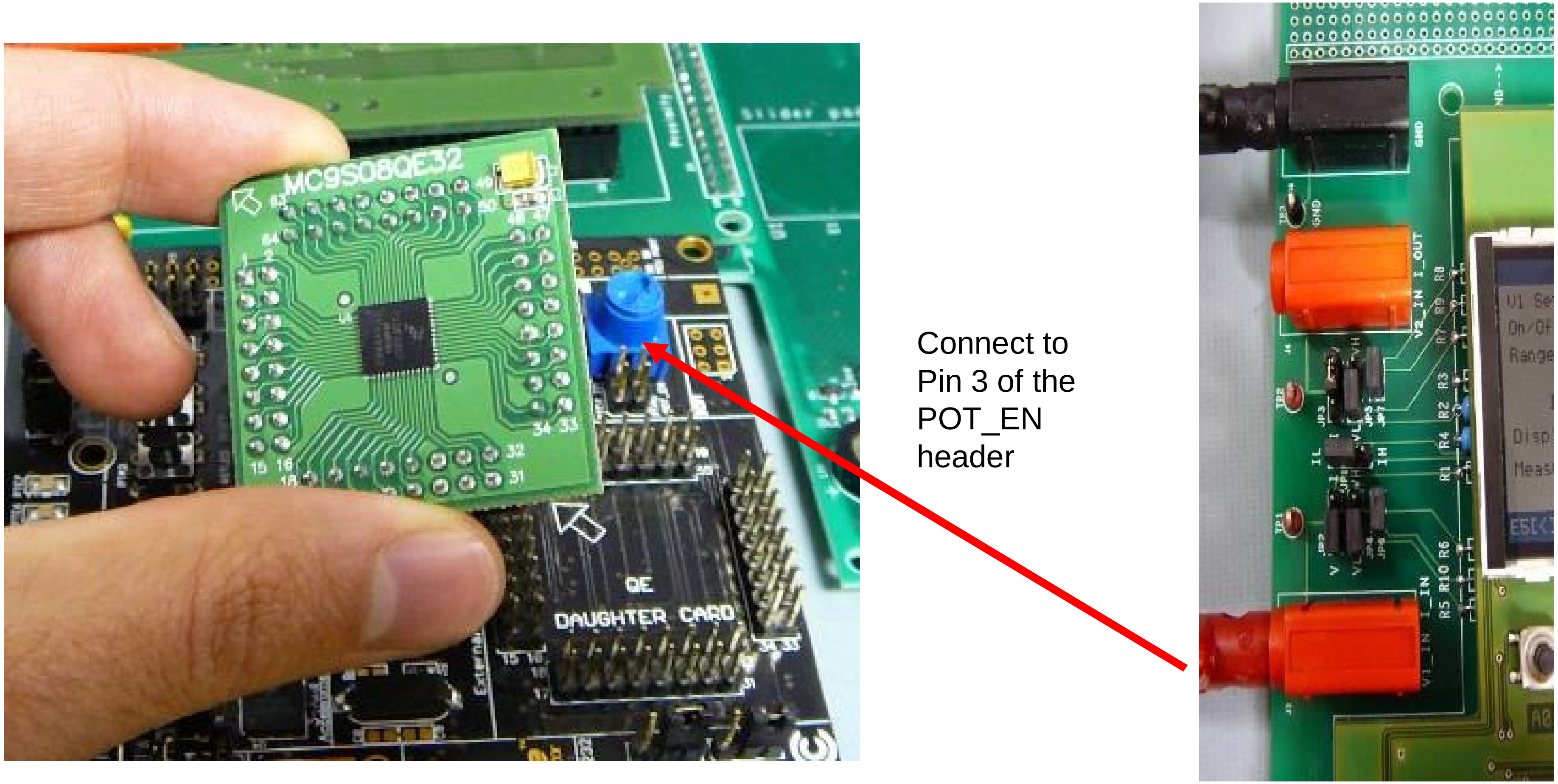
Graphical User Interface



- Single UI screen – no program mode switching
- Very simple UI element definitions
- Mapping button functions one-to-one
  - Push button D4 to enable/disable voltage inputs
  - Push button D5 to select voltage range
  - Push button D7 to select current range
  - Push button D6 to select display timeout
- The active UI element is not highlighted

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Using POT to measure voltage



Connect to Pin 3 of the POT_EN header

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 1: QE8

Application Features

Non-blocking push-button polling:

- ► One channel of one TPM module used as a debounce timer
- ► A change in button values starts the debounce timer and disables further polling
- ► In the *configure_debounce_timer* function,
  - The TPM counter is read
  - Compare register is set such that a compare event happens 10 ms in the future
- ► Compare ISR sets debounce flag in programctl module and keys are polled again when this is detected by the program loop
- ► Generated ISR function and timer Bean used to accomplish this

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 1: QE8

Application Features

Graphical User Interface

- Custom UI written on top of off-the-shelf LCD drawing library
  - Drawing library allows for lines, shapes, text
- 8k code size is the primary constraint
- Code was kept small through:
  - Simplified implementation of UI module used in QE32 and QE128 code
  - Mapping button functions one-to-one (no dynamic UI element highlighting)
  - Very simple UI element definitions – cannot re-paint an element
  - Single UI screen – no program mode switching
  - Minimized use of program modules external to programctl

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 1: QE8

Code Highlights

Program control structure

- This is the heart of the application; ties all module functionality together
- Program modes implemented by individual functions with program loops
- Program mode functions called from top-level switch statement in `set_next_program_mode(void)`
- The QE8 currently has one program mode
- No blocking calls in any of the program modes
- Program modes are determined by the `mode` variable (static to programctl)
    - If this is changed anywhere, the current program mode function will drop out of its program loop and return
    - The next program mode will be called from the `set_next_program_mode` function

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 1: QE8
Code Highlights

Sleep/Wakeup

- In power.c, stop mode functions are defined
  - `Cpu_SetStopMode()` function generated by the CPU bean
- In programctl, when the `power_set_mode_stop3()` function is called, code stops executing
- When a wakeup source (RTC, KBI, etc.) generates a wakeup condition, code resumes executing within the `power_set_mode_stop3()` function and returns

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Low Power Design Challenge

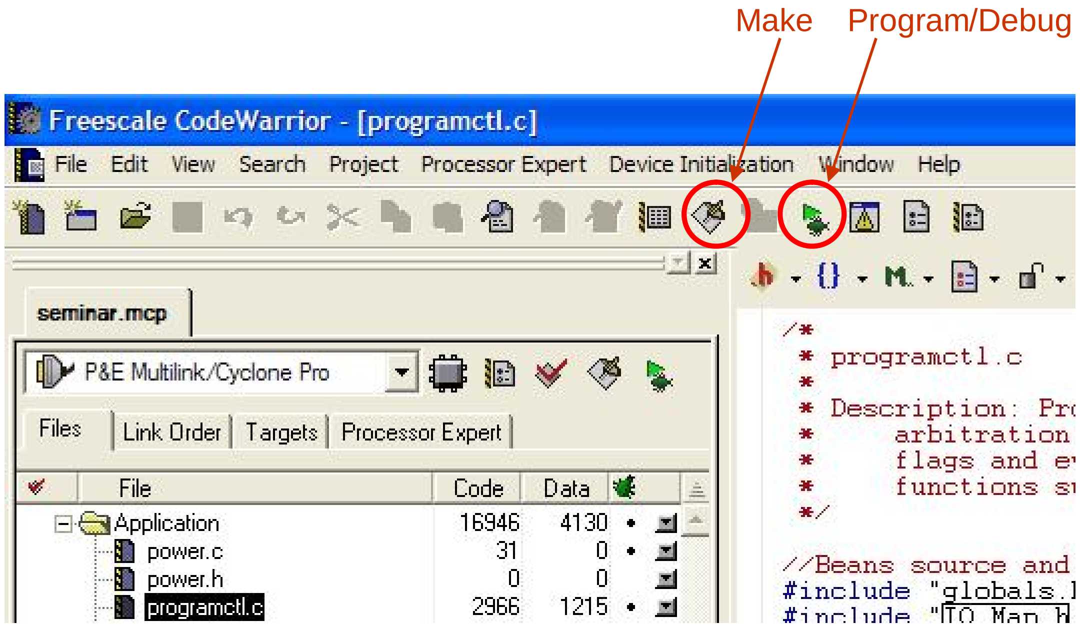
- ►For the QE8 application the main Low power design challenge was configuring the TFT Display for low power
  - The TFT display interface involves several GPIO and SPI lines
  - In order to enter low power modes several steps were necessary
    - The SPI was disable in order to allow the SPI pins to be configured as GPIO
    - The CS and D/C lines were driven low
    - The RESET line Was driven low

- ►Upon wake up the display has to be re-initialized in order to recover from the low power configuration

- ►NOTE: Low power designs should always place internal and external peripherals in a low power state, and handle recovery within the software routines

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Compile, Run, and Test!


Make
Program/Debug
Freescale CodeWarrior - [programctl.c]
File Edit View Search Project Processor Expert Device Initialization Window Help
seminar.mcp
P&E Multilink/Cyclone Pro
Files
Link Order
Targets
Processor Expert

File	Code	Data	
Application	16946	4130	•
power.c	31	0	•
power.h	0	0	
programctl.c	2966	1215	•

```
/*
 * programctl.c
 *
 * Description: Pr
 *     arbitration
 *     flags and e
 *     functions s
 */

//Beans source and
#include "globals.
#include "IO_Map.h
```

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

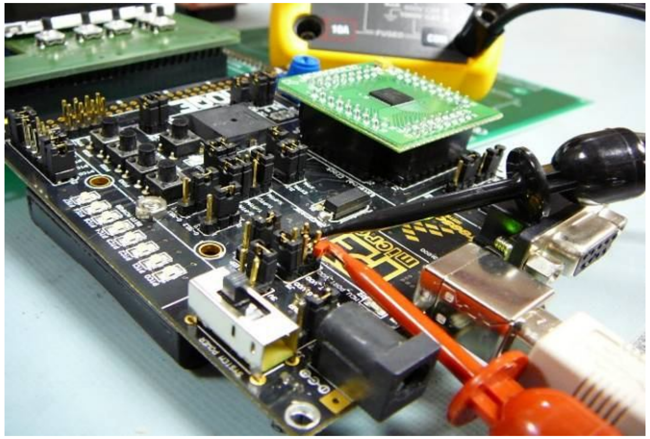
Lab 1: QE8
Testing

Stop Current		
SIDD(nA)	Condition	Note
400	Stop3, 3V	External Crystal disabled
300	Stop2, 3V	
1350	Stop3, 3V	External Crystal enabled
1300	Stop2, 3V	

Test Point:

►Test on Jumper J5.5 and J5.6 Near DC Power jack.

►Test on Jumper J24 (next to buzzer).



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 1: QE8

Self-Study Project Enhancement

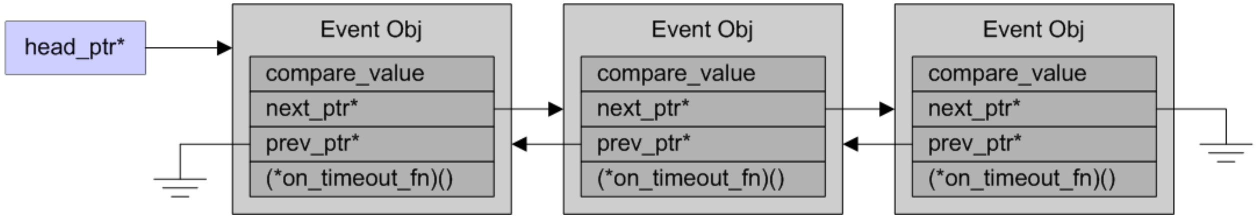
Enhancement: Event Scheduler

- Channels in a given TPM module are a finite resource
- Can maximize the use of TPM peripherals by scheduling events through dynamically configuring a TPM channel’s compare interrupt
- Events objects are queued in a doubly linked list sorted by timer compare value
- Insertion sort algorithm used to add new elements to the list
- Compare ISR calls event callback (on_timeout_ptr in diagram)

Functions to be written:

```
int8 schedule_event(uint16 ticks_from_now, on_timeout_fn callback);
void ch_n_compare_isr(void);
```

Event queue:



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

LAB2: QE32

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

QE32 Overview

	QE8	QE32	S08QE128	51QE128
CPU	S08 Up to 20 MHz	**S08** **Up to 50MHz**	S08 Up to 50 MHz	ColdFire V1 Up to 50 MHz
FLASH	8K Bytes	**32K Bytes**	128K Bytes	128K Bytes
RAM	512 Bytes	**2K Bytes**	8K Bytes	8K Bytes
ADC	10-ch 12-bit ADC	**10-ch 12-bit ADC**	24-ch 12-bit ADC	24-ch 12-bit ADC
TPM	2 TPM (3-ch)	**2 TPM (3-ch) 1 TPM (6-ch)**	2 TPM (3-ch) 1 TPM (6-ch)	2 TPM (3-ch) 1 TPM (6-ch)
SPI	1 SPI	**1 SPI**	2 SPI	2 SPI
SCI	1 SCI	**2 SCI**	2 SCI	2 SCI
IIC	1 IIC	**1 IIC**	2 IIC	2 IIC
KBI	8-ch KBI	**16-ch KBI**	16-ch KBI	16-ch KBI
Rapid GPIO	NA	**NA**	NA	Yes
Others	**ICS, RTC, GPIO, BDM**			

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 2: QE32
Device Overview

MCU: MC9S08QE32

Specs	
CPU	HCS08
RAM	2k Bytes
Flash	32k Bytes
Max Bus Clock	25 MHz
Max CPU Clock	50 MHz

Peripherals:

- ►ADC (10-ch, 12-bit)
- ►Comparators (2)
- ►SCI (2)
- ►SPI
- ►I2C
- ►TPM (2x 3-ch, 1x6-ch)
- ►RTC
- ►KBI (16-ch)

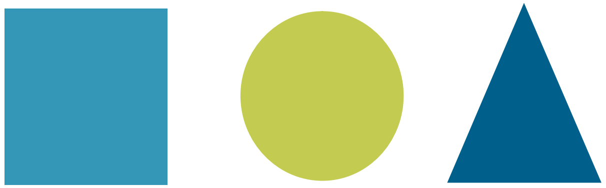
Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Proximity/Capacitive Sensing: Overview

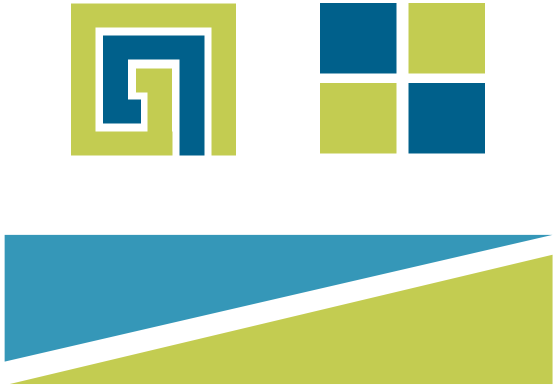
- The S08QE32 based DMM design will include a proximity/capacitive touch sensing user interface implemented using Freescale’s off-the-shelf capacitive touch software library

- **What is capacitance sensing?**
  - Technology that enables detection of touch by measuring capacitance
  - Responds to a change in physical stimulus
  - Used in many areas of consumer, industrial and automotive applications
  - Can be used to measure liquid level and detect frost
  - One of the most popular applications today is touch sensing

- **Single Electrode**



- **Multiplexed Electrodes**



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Proximity/Capacitive Sensing: Benefits

User interface flexibility & product differentiation

- Enables more intuitive user interfaces such as rotary wheels and linear sliders.
- Enables an evolution in user interfaces in a wide range of applications
  - Ability to hide buttons underneath the surface and illuminate them when needed
  - Ability to “morph” touchpad patterns depending on mode of device
- Gives greater flexibility for product designers
- Enhances reliability by eliminating mechanical button/switch wear & tear

Reduced system power consumption

- Enables battery-powered applications
- Satisfies the market need for “green” products

Reduced cost and time-to-market

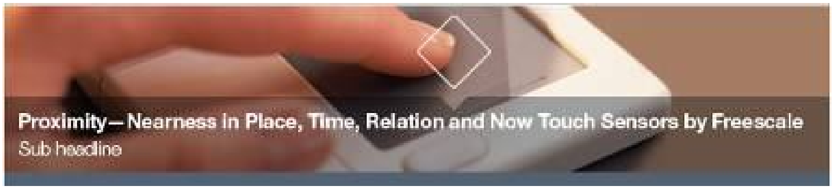
- Enables current MCU users to “just add touch”
- Additional integration lowers component cost
- Providing complimentary enablement software lowers development cost and speeds time to market

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Proximity/Capacitive Sensing: New Products

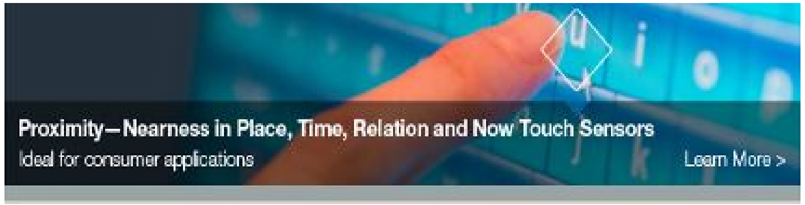
MPR083 – Rotary Capacitive Touch Sensor Controller

- ▶ **Sensitive touch panel control**
  - 8-positon rotary
  - Button and switch replacement
  - Multiple electrode configurations
  - Low 1.8 - 3.6 voltage operation
  - I^{2}C interface


Proximity—Nearness in Place, Time, Relation and Now Touch Sensors by Freescale
Sub headline

MPR084 – Touchpad Capacitive Touch Sensor Controller

- ▶ **Sensitive touch panel control**
  - 8 touch pads
  - Button and switch replacement
  - Multiple electrode configurations
  - Low 1.8 - 3.6 voltage operation
  - I^{2}C interface


Proximity—Nearness in Place, Time, Relation and Now Touch Sensors
Ideal for consumer applications
Learn More >

Proximity Sensing Software Solution for Freescale S08 and ColdFire® V1 MCUs

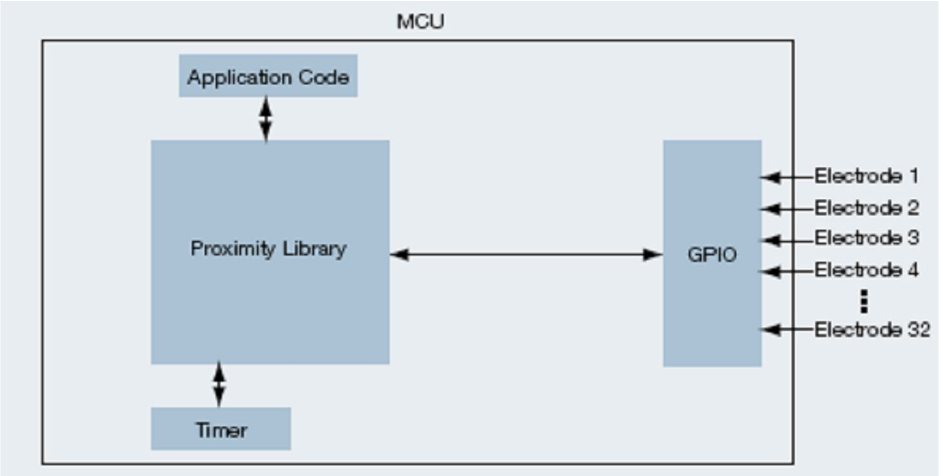
- ▶ **Available on all S08/V1 MCUs (hundreds of MCUs)**
  - Complimentary (royalty/NRE free)
  - Downloadable from freescale.com
  - Development kits available as a plug-in module to the MCU development kits
  - Allows customer to perform both control and UI functions.

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Proximity/Capacitive Sensing Software Solution

Features

- ►NRE/royalty-free solution
- ►Supports up to 32 electrodes
- ►Wide variety of hardware options
    - Compatible with HC9S08 and ColdFire V1 products
    - 1.8V–5.0V operation (MCU dependent)
    - Numerous package options (MCU dependent)
    - -40°C to +85°C operating temperature
- ►Programmable sampling period
- ►Simple averaging function as basic low pass filter
- ►Adjustable touch threshold setting
- ►Source code built on Codewarrior Suite
- ►Electrode touch buzzer sound feedback



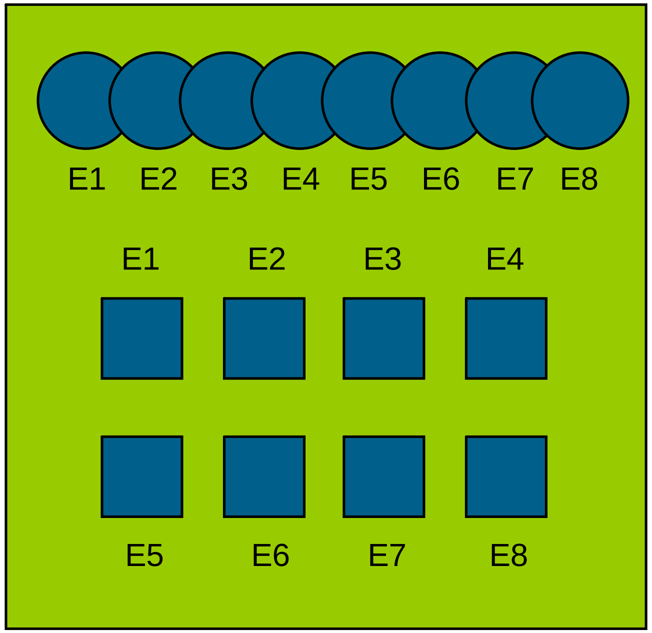
Applications

- ►General Consumer
    - Remote controls / Cell phone / Appliances
- ► General Industrial
    - Building control panels / Machine user interface

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 2: QE32

Touch Pad



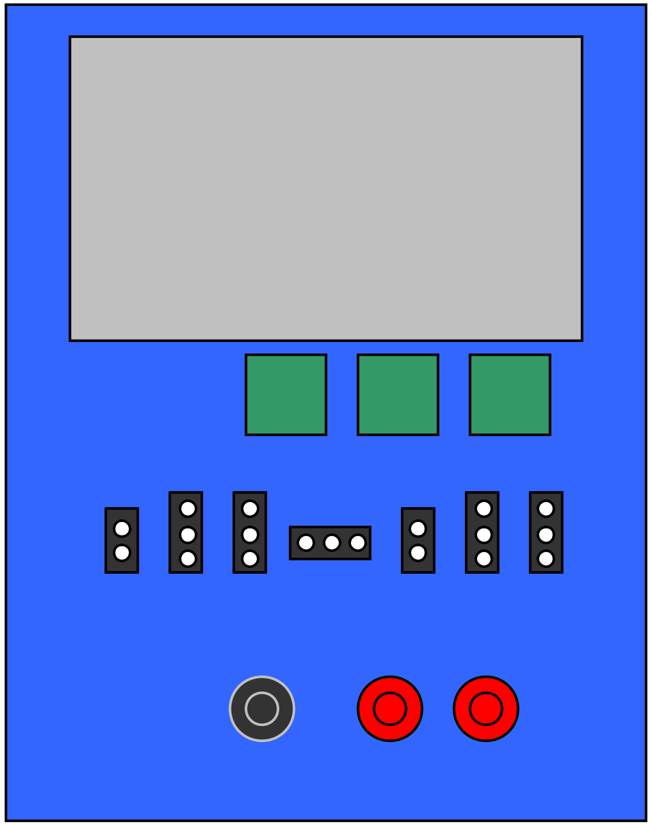
- ► E8 – Switch between Configuration Mode and Display Mode
- ► E7 – Scroll Right through the UI elements
- ► E6 – Select UI element
- ► E5 – Scroll left through the UI elements
- ► E1 ~ E4 are implemented as a slider

- ►Freescale's off-the-shelf capacitive touch library is used
- ►KBI with capacitive touchpad can not wake the system up from the LP mode
- ►Only remaining wakeup source is the RTC
- ►Use the RTC to wakeup and poll the touchpad once every 250 ms in sleep mode

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 2: QE32
Software Overview

Program Mode: Enhanced Digital Multimeter



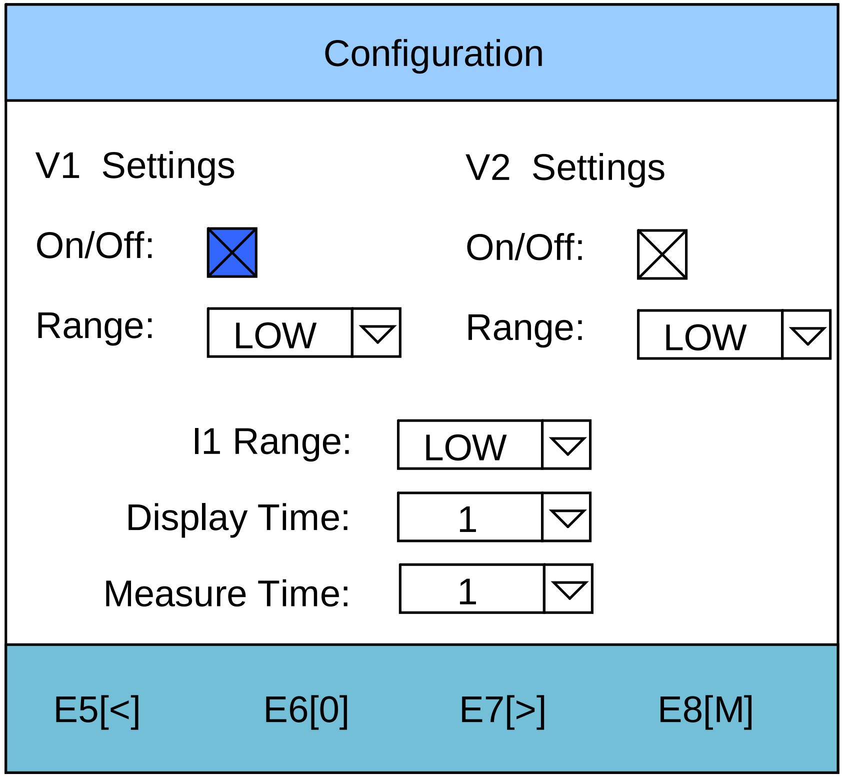
- readings on two voltage inputs and one current input
- Can select input range with jumpers
- Readings displayed on the TFT LCD
- Can enable/disable voltage inputs
- Implements an enhanced UI
- Separate screens for DMM configuration and display
- User input is done through capacitive touch pad
- Enters low power “sleep” mode after a user configurable timeout interval that can wake the system up
- Measurements now taken at user configurable intervals

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 2: QE32

Graphic User Interface

Configuration Mode



Configuration

V1 Settings

On/Off: ☒

Range: LOW

V2 Settings

On/Off: ☒

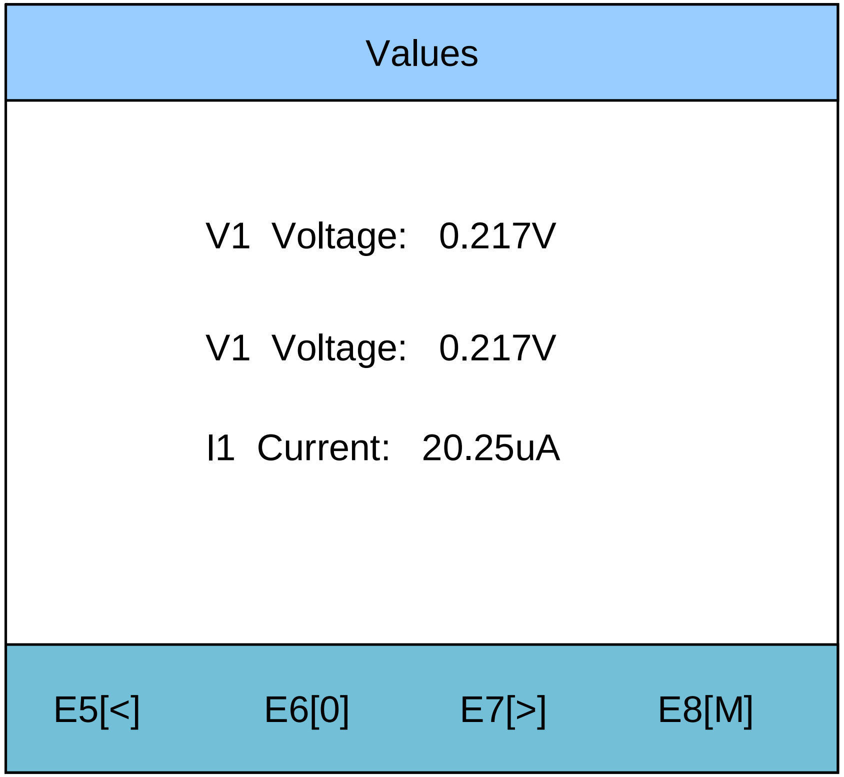
Range: LOW

I1 Range: LOW

Display Time: 1

Measure Time: 1

Display Mode



Values

V1 Voltage: 0.217V

V1 Voltage: 0.217V

I1 Current: 20.25uA

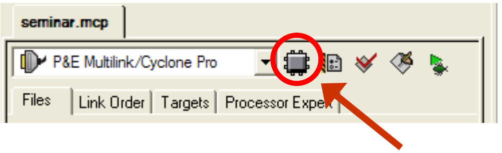
Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 2: QE32

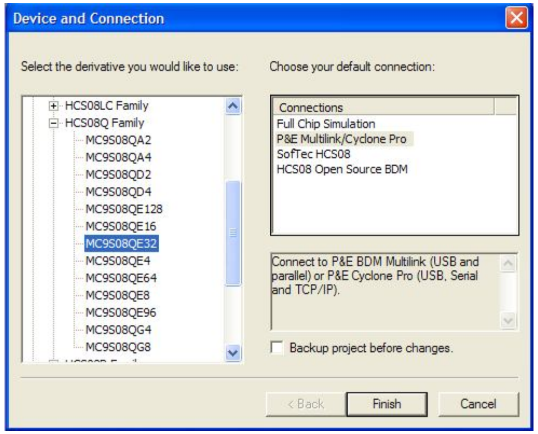
Migration Process

Changes in Processor Expert

1. Click on *Change MCU/Connection*



2. Select MC9S08QE32 from the list
   - ▶ Ensure that *P&E Multilink Cyclone Pro* is selected
   - ▶ Ensure that the *Backup project before changes* box is unchecked


Device and Connection

Select the derivative you would like to use:

- HCS08LC Family
- HCS08Q Family
  - MC9S08QA2
  - MC9S08QA4
  - MC9S08QD2
  - MC9S08QD4
  - MC9S08QE128
  - MC9S08QE16
  - MC9S08QE32
  - MC9S08QE4
  - MC9S08QE64
  - MC9S08QE8
  - MC9S08QE96
  - MC9S08QG4
  - MC9S08QG8

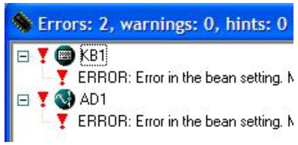
Choose your default connection:

Connections
- Full Chip Simulation
- P&E Multilink/Cyclone Pro
- SofTec HCS08
- HCS08 Open Source BDM

Connect to P&E BDM Multilink (USB and parallel) or P&E Cyclone Pro (USB, Serial and TCP/IP).

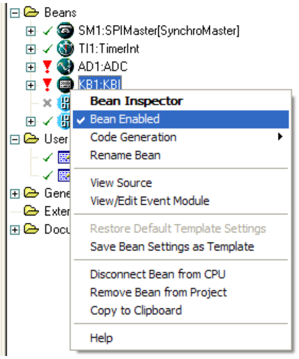
☐ Backup project before changes.

3. Note the Processor Expert errors


Errors: 2, warnings: 0, hints: 0

- KB1
  - ERROR: Error in the bean setting. N
- AD1
  - ERROR: Error in the bean setting. N

4. Click the Processor Expert tab in left panel
5. Right click the KBI Bean's icon and click the *Bean Enabled* menu item to disable it; it is not needed
6. Right click the *TPM_Prox:Init_TPM* bean's icon and click the *Bean Enabled* menu item to enable it

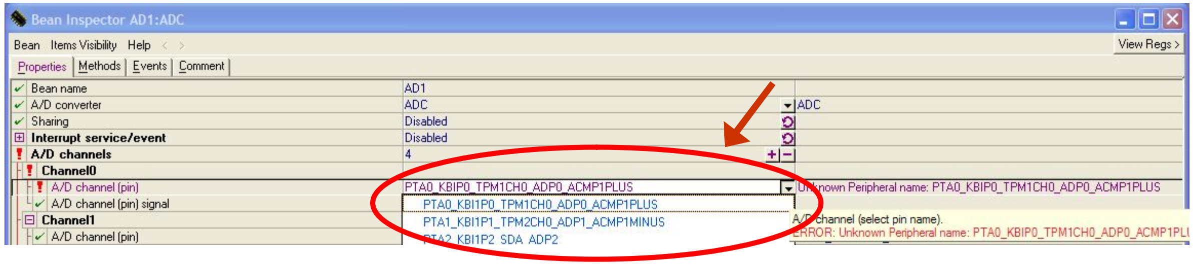


Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 2: QE32
Migration Process

Changes in Processor Expert

7. Double click *AD1:ADC* icon to bring up Bean Inspector for this bean
   - ► in *Channel0,* click dropdown for PTA0 to remove error
   - ► in *Channel2,* click dropdown for PTA1 to remove error

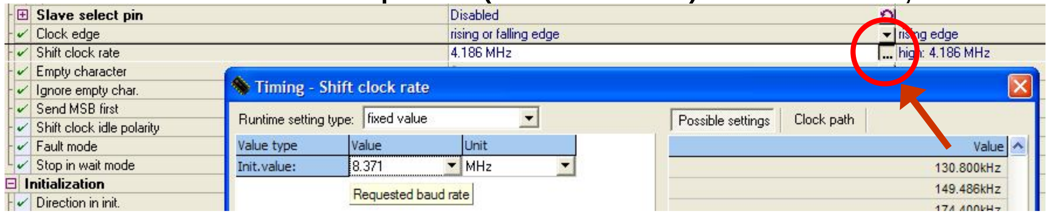


Bean name	AD1	
A/D converter	ADC	ADC
Sharing	Disabled	
Interrupt service/event	Disabled	
A/D channels	4	
Channel0		
A/D channel (pin)	PTA0_KBIP0_TPM1CH0_ADP0_ACMP1PLUS	Unknown Peripheral name: PTA0_KBIP0_TPM1CH0_ADP0_ACMP1PLUS
A/D channel (pin) signal		
Channel1		
A/D channel (pin)		

PTA0_KBI1P0_TPM1CH0_ADP0_ACMP1PLUS
PTA1_KBI1P1_TPM2CH0_ADP1_ACMP1MINUS
PTA2_KBI1P2_SDA_ADP2

A/D channel (select pin name).
ERROR: Unknown Peripheral name: PTA0_KBIP0_TPM1CH0_ADP0_ACMP1PL

8. Close the bean inspector (saves changes)
9. Double click *SM1:SPIMaster* icon to bring up Bean Inspector for this bean
   - ► Under *Settings > Shift clock rate*, expand this option by clicking the ellipsis
   - ► Scroll down to the max speed (8.371 MHz) and click it; click OK to save



Slave select pin	Disabled	
Clock edge	rising or falling edge	rising edge
Shift clock rate	4.186 MHz	high: 4.186 MHz
Empty character		
Ignore empty char.		
Send MSB first		
Shift clock idle polarity		
Fault mode		
Stop in wait mode		
Initialization		
Direction in init.		

Runtime setting type: fixed value

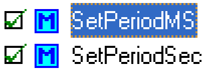
Value type	Value	Unit
Init.value:	8.371	MHz

Value
130.800kHz
149.486kHz
174.400kHz

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

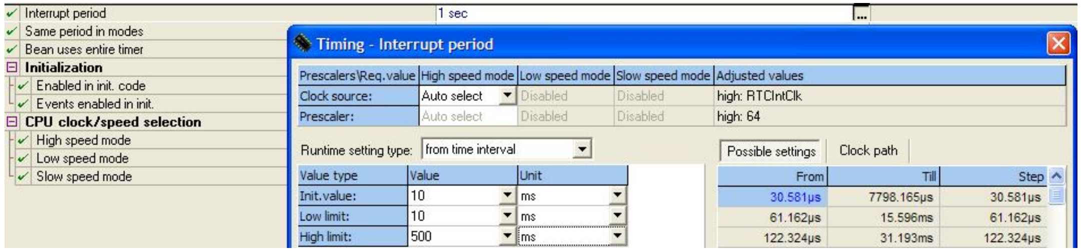
Changes in Processor Expert

10. Expand the *TI1:TimerInt* bean
11. Double click the red X beside *SetPeriodMS* function to enable it to be generated. This should turn into a green check mark



☑ M SetPeriodMS
☑ M SetPeriodSec

12. Double click *TI1:TimerInt* bean icon
13. Click the ellipsis next to the *Interrupt period* setting
    - ▶ Change *Init value* to 10 ms
    - ▶ Change *Low limit* to 10 ms
    - ▶ Change *High limit* to 500 ms



✓ Interrupt period	1 sec ...
✓ Same period in modes	
✓ Bean uses entire timer	
⊟ **Initialization**	
✓ Enabled in init. code	
✓ Events enabled in init.	
⊟ **CPU clock/speed selection**	
✓ High speed mode	
✓ Low speed mode	
✓ Slow speed mode	

Timing - Interrupt period

Prescalers\Req.value	High speed mode	Low speed mode	Slow speed mode	Adjusted values
Clock source:	Auto select	Disabled	Disabled	high: RTCIntClk
Prescaler:	Auto select	Disabled	Disabled	high: 64

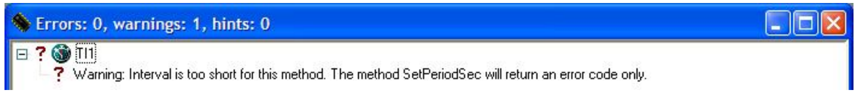
Runtime setting type: from time interval

Value type	Value	Unit
Init.value:	10	ms
Low limit:	10	ms
High limit:	500	ms

Possible settings | Clock path

From	Till	Step
30.581µs	7798.165µs	30.581µs
61.162µs	15.596ms	61.162µs
122.324µs	31.193ms	122.324µs

14. Note the warning generated by PE



Errors: 0, warnings: 1, hints: 0

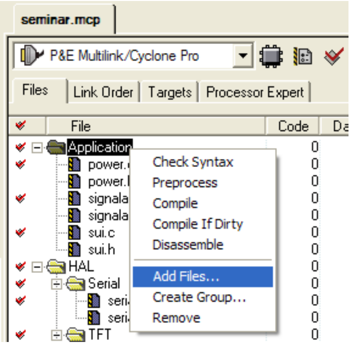
⊟ ? TI1
? Warning: Interval is too short for this method. The method SetPeriodSec will return an error code only.

15. Double click check beside *SetPeriodSec* to disable it; warning should disappear

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 2: QE32
Migration Process

Changes in the CodeWarrior Project



1. Click the *Files* tab on the left panel
2. Remove both *programctl* files by right clicking them and selecting *Remove*
3. Remove both *sui* files – the old simplified UI from the QE8
4. Right click on the *Application* source group and click *Add Files…*
5. Browse from the top-level directory to: `<top_level>\src\common\Application` and select the ui and ui_screens source files
   - ► These are the source files for the enhanced UI
6. Browse from the top-level directory to: `<top_level>\src\s08\qe32` and select the programctl files
   - ► These implement the target-specific program control structure

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Changes in the CodeWarrior Project

7. Click the *Edit > Standard Settings* menu
8. Click on the *Access Paths* on the left pane
9. Click on the old QE8 directory and press the *Remove* button
10. Press OK on the Standard Settings dialog
11. Open seminar.c from the file browser on the left panel
12. Modify the *start_program_ctrl* function to take the *PROGRAM_MODE_NORMAL_DMM_CONFIG* setting as an argument
    - ► Starts the program off in normal DMM mode instead of the old QE8 DMM mode
    - ► Can see program mode definitions in programctl.h
    - ► Browse the code to see how program modes are switched

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

What have we just accomplished?

- We now have:
  - More RAM
  - More Flash
  - More peripherals
  - Pin-compatibility
  - Identical tool chain, development environment, design flow
- We are running on a completely different processor target
- Switching processors typically involves lengthy redesigns
- Demonstrated the ability to enhance our product with minimal impact on:
  - The original HW/SW design
  - The existing design flow

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

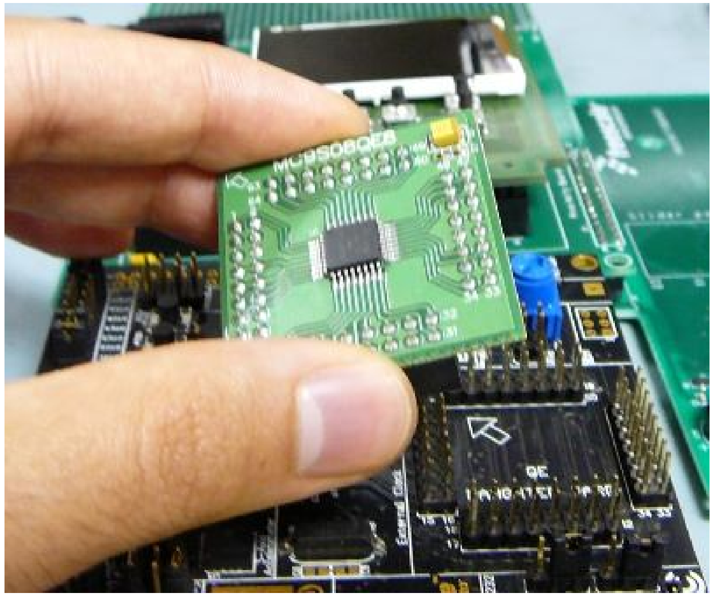
Program Mode: Enhanced Digital Multimeter

- ► Implements a Digital Multimeter
  - Performs readings on two voltage inputs and one current input
  - Can select input range with jumpers
  - Readings displayed on the TFT LCD
  - Can enable/disable voltage inputs
- ► Implements an enhanced UI
- ► Separate screens for DMM configuration and display
- ► User input is done through capacitive touch pad – Freescale’s off-the-shelf capacitive touch library is used
- ► Enters low power “sleep” mode after a user configurable timeout interval that can wake the system up
- ► Measurements now taken at user configurable intervals
- ► Press E8 to scroll through program modes

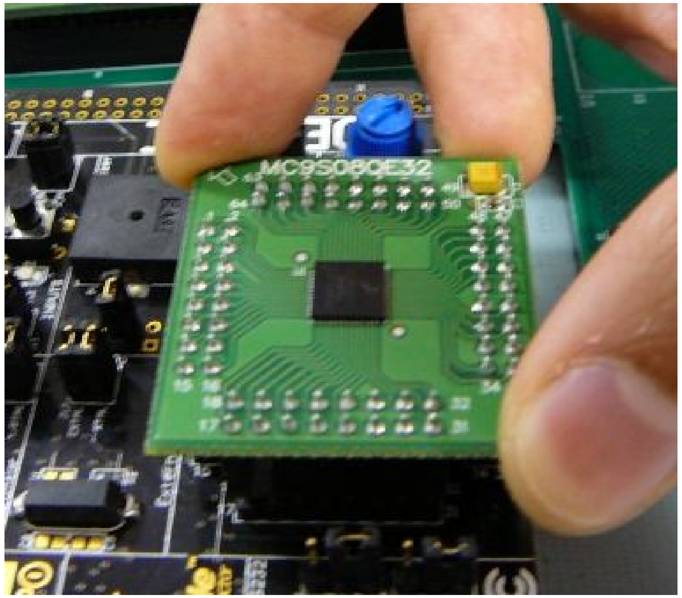
Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Compile, Run, and Test!

Remove QE8 module



Insert QE32 module



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 2: QE32

Application Features

Enhanced Graphical User Interface

- Code size limitation no longer a major issue
- Instead of fixed one-to-one mappings for button functions, can now intelligently highlight UI elements and select them
  - UI elements each have an “on_select” callback in addition to the many new dynamically modifiable attributes
- Widgets now contain basic color attributes
- UI widget definitions and drawing functions contained in *ui* module
- Screen configurations and widget declarations contained in *ui_screens* module
- Can implement basic object model allowing inheritance and generalized widget actions
  - Recursive painter – A top-level redraw function that traverses the list of on-screen to find “dirty” widgets that need to be re-drawn
  - *on_select* callbacks for widgets allow actions to be mapped

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 2: QE32

Application Features

Low power touchpad polling and display:

- Cannot use KBI with capacitive touchpad to wake the system up
- Only remaining wakeup source is the RTC
- Cannot tight poll on touchpad in sleep mode due to power concerns

Solution:

- Use the RTC to wakeup and poll the touchpad once every 250 ms in sleep mode
- No need to debounce anymore

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Low Power Design Challenge

►With the addition of the capacitive touch pad interface, the low power design strategy had to change slightly in order to handle this new interface

Low power touchpad polling and display:

- ► Cannot use KBI with capacitive touchpad to wake the system up
- ► Only remaining wakeup source is the RTC
- ► Cannot tight poll on touchpad in sleep mode due to power concerns

Solution:

- ► Use the RTC to wakeup and poll the touchpad once every 250 ms in sleep mode
- ► No need to debounce anymore

NOTE: Implement timed polling schemes to lower overall average power consumption

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 2: QE32
Code Highlights

UI navigation through button callbacks

- All program modes have the same user input interface
  - [E5:SCROLL LEFT] [E6:SELECT] [E7:SCROLL RIGHT] [E8:MODE SWITCH]
- Scrolling through UI elements with E5 andE7:
  - Every UI screen has a linked-list of UI elements; pressing E5 or E7 traverses to the next or previous (respectively) element in this list
  - The current element is de-highlighted, and the next is highlighted
- Selecting a UI element with E6:
  - UI widgets all inherit from the `UIElement` type
  - This `UIElement` type defines an element that is a function pointer to functions with a `uint8 select_function(void)` signature
  - Pressing the select button, E6, calls this callback
- Switching program modes with E8:
  - The main program loop for each program mode is conditional on the mode variable
  - When E8 is polled and active, the polling function changes the mode variable

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

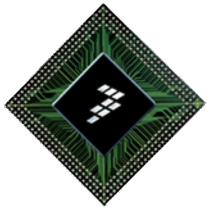
Enhancement: Touchpad slider widget

- Use the enhanced UI to create a slider widget that can represent one value in a continuous range
- Use the remaining four capacitive touch pads E1 to E4 to implement the slider
- Use the touchpad library in the HAL code to read adjacent pad values and interpolate between the two highest ones to determine slider position

Design challenges:

- How will this widget be integrated into the current polling scheme?
- How will the widget's *on_select* callback be called?

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.



LAB2: QE128

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

S08QE128 Overview

	QE8	QE32	S08QE128	51QE128
CPU	S08 Up to 20 MHz	S08 Up to 50MHz	**S08 Up to 50 MHz**	ColdFire V1 Up to 50 MHz
FLASH	8K Bytes	32K Bytes	**128K Bytes**	128K Bytes
RAM	512 Bytes	2K Bytes	**8K Bytes**	8K Bytes
ADC	10-ch 12-bit ADC	10-ch 12-bit ADC	**24-ch 12-bit ADC**	24-ch 12-bit ADC
TPM	2 TPM (3-ch)	2 TPM (3-ch) 1 TPM (6-ch)	**2 TPM (3-ch) 1 TPM (6-ch)**	2 TPM (3-ch) 1 TPM (6-ch)
SPI	1 SPI	1 SPI	**2 SPI**	2 SPI
SCI	1 SCI	2 SCI	**2 SCI**	2 SCI
IIC	1 IIC	1 IIC	**2 IIC**	2 IIC
KBI	8-ch KBI	16-ch KBI	**16-ch KBI**	16-ch KBI
Rapid GPIO	NA	NA	**NA**	Yes
Others	**ICS, RTC, GPIO, BDM**			

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 3: QE128 (HCS08)

Device Overview

MCU: MC9S08QE128

Specs	
CPU	HCS08
RAM	8k Bytes
Flash	128k Bytes
Max Bus Clock	25 MHz
Max CPU Clock	50 MHz

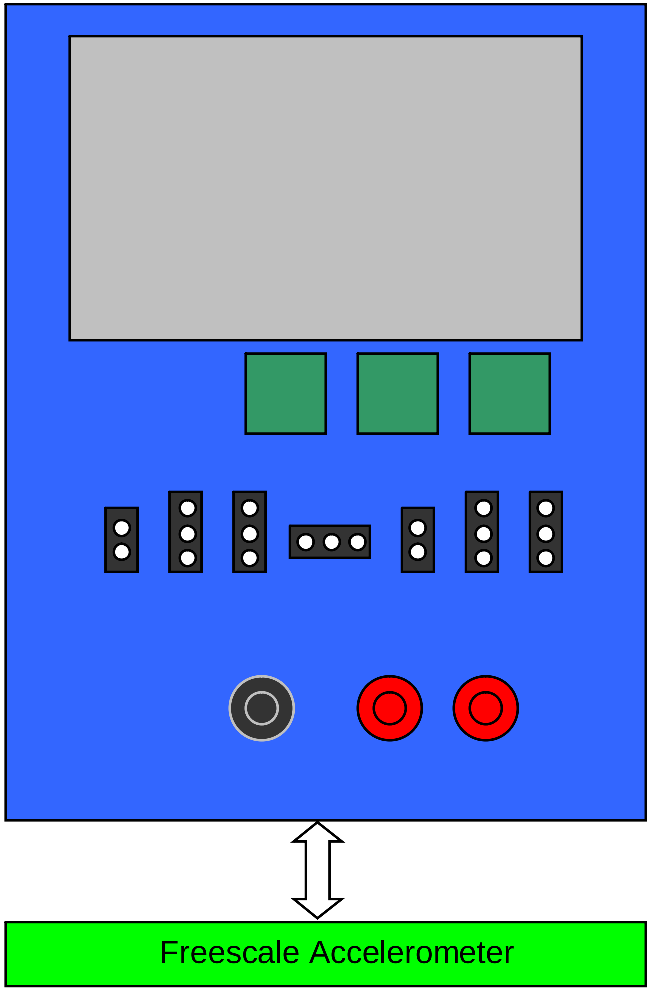
Peripherals:

- ►ADC (24-ch, 12-bit)
- ►Comparators (2)
- ►SCI (2)
- ►SPI (2)
- ►I2C (2)
- ►TPM (1x 6-ch, 2x 3-ch)
- ►RTC
- ►KBI (16-ch)

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 3: QE128 (HCS08)

Software Overview



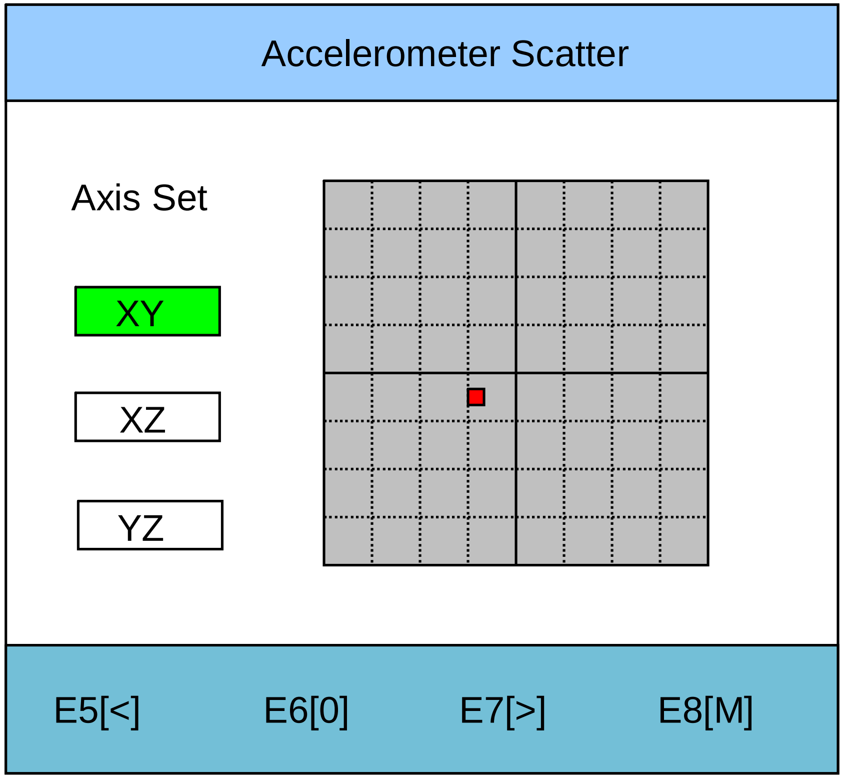
New Program Mode

- 5 Modes (screens) for: DMM configuration, Display, Scatter plot, Data logger for Accelerometer and DMM inputs
- Scatter plot
  - Shows the accelerometer’s output on a two-axis display
  - Can select which two axes of the accelerometer are displayed
- Data logger for Accelerometer and DMM inputs
  - Can capture data from both inputs
  - Scroll through captured data in a display window
  - Send captured data out to a serial port (use PE Micro USB scope utility)

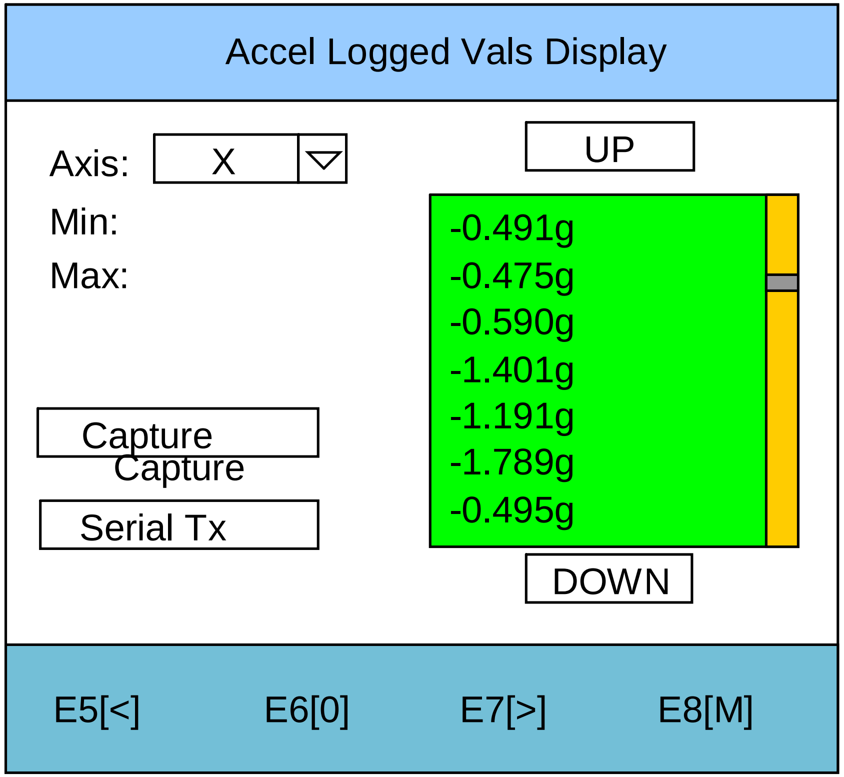
Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 3: QE128 (HCS08)
New Graphic User Interface

Scatter Plot Mode



Data logger for Accelerometer Mode



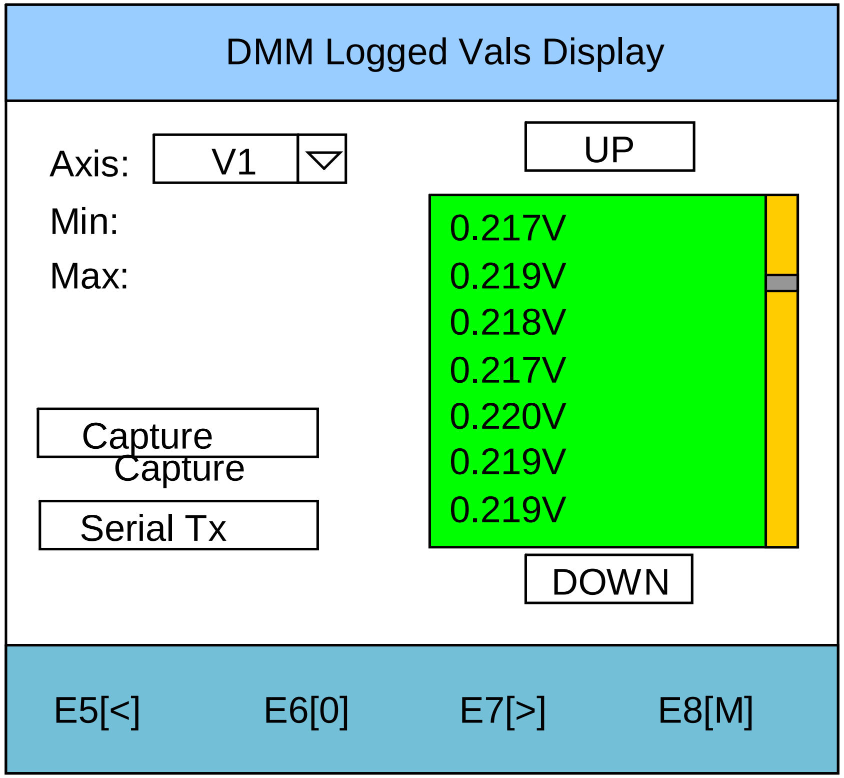
-0.491g
-0.475g
-0.590g
-1.401g
-1.191g
-1.789g
-0.495g

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 3: QE128 (HCS08)

New Graphic User Interface

Data logger for DMM inputs Mode



DMM Logged Vals Display

Axis: V1

Min:

Max:

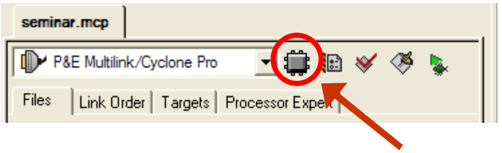
```
0.217V
0.219V
0.218V
0.217V
0.220V
0.219V
0.219V
```

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

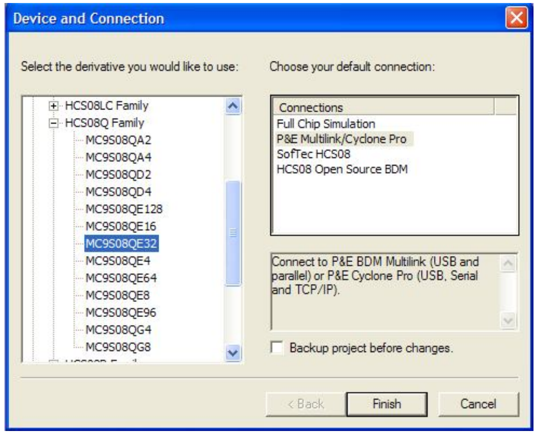
Lab 3: QE128 (HCS08)

Migration Process

Changes in the CodeWarrior Project



1. Click on *Change MCU/Connection*
2. Select MC9S08QE128 from the list
   - ▶ Ensure that *P&E Multilink Cyclone Pro* is selected
   - ▶ Ensure that the *Backup project before changes* box is unchecked



Select the derivative you would like to use:

- HCS08LC Family
- HCS08Q Family
  - MC9S08QA2
  - MC9S08QA4
  - MC9S08QD2
  - MC9S08QD4
  - MC9S08QE128
  - MC9S08QE16
  - MC9S08QE32
  - MC9S08QE4
  - MC9S08QE64
  - MC9S08QE8
  - MC9S08QE96
  - MC9S08QG4
  - MC9S08QG8

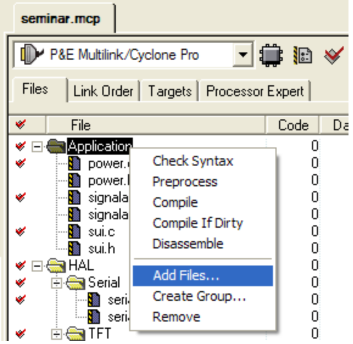
Choose your default connection:

Connections
- Full Chip Simulation
- P&E Multilink/Cyclone Pro
- SofTec HCS08
- HCS08 Open Source BDM

Connect to P&E BDM Multilink (USB and parallel) or P&E Cyclone Pro (USB, Serial and TCP/IP).

□ Backup project before changes.

3. Click the *Files* tab on the left panel
4. Remove both *programctl* files by right clicking them and selecting *Remove*
5. Right click on the *Application* source group and click *Add Files…*



6. Browse from the top-level directory to: `<top_level>\src\s08\qe128` and select the programctl files
   - ▶ These implement the target-specific program control structure

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 3: QE128 (HCS08)

Migration Process

Changes in the CodeWarrior Project

7. Browse from the top-level directory to: `<top_level>\src\common\Application` and select logging.c/logging.h, and bitmap_screens.c
   - The “logging” files implement the datalogger functionality
   - The bitmap_screens contains the bitmap arrays for the accelerometer scatter-plot background graphic
8. Right click the *HAL/Serial* source group and select *Add Files…*
9. Browse from the top-level directory to: `<top_level>\src\common\HAL\Serial` and select serialio.c/serialio.h files
   - These file implement the higher level RS232 functionality and utilize the SERIAL bean we will add
10. Open serialio.c and add `#include “SERIAL.h”` at the top of the file to the list of included header files.

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 3: QE128 (HCS08)

Migration Process

Changes in the CodeWarrior Project

11. Under the *Libs* source group remove the ansiis.lib file

12. Right click the *Libs* source group and click *Add Files…*

13. Browse to the CodeWarrior HCS08 library file directory, typically

    `C:\Program Files\Freescale\CodeWarrior for Microcontrollers 6.2\lib\hcs08\lib`

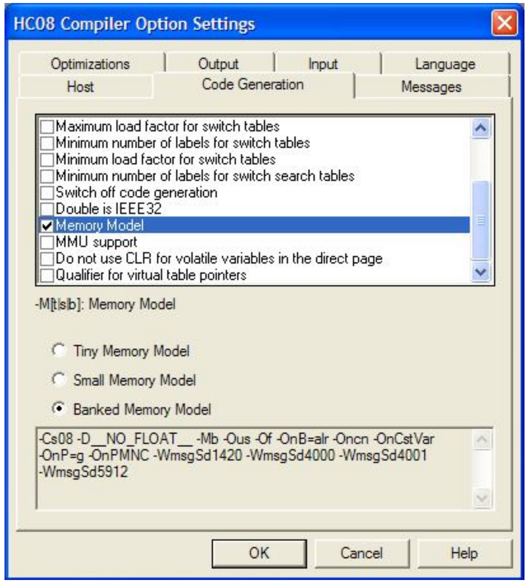
12. Select the ansibim.lib file.

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 3: QE128 (HCS08)
Migration Process

Changes in the CodeWarrior Project

9. Click the *Edit > Standard Settings* menu
10. Click on the *Access Paths* on the left pane
11. Click on the old QE32 directory and press the *Remove* button
12. On the left pane, click the *Compiler for HC08* option
13. Click the *Options* button
14. Select the *Code Generation* tab.
15. Scroll down and uncheck, then check the *Memory Model* checkbox
16. On the radio buttons that appear, select *Banked Memory Model*. Press OK to exit this dialog.
17. Press OK on the Standard Settings dialog.



□ Maximum load factor for switch tables
□ Minimum number of labels for switch tables
□ Minimum load factor for switch tables
□ Minimum number of labels for switch search tables
□ Switch off code generation
□ Double is IEEE32
☑ Memory Model
□ MMU support
□ Do not use CLR for volatile variables in the direct page
□ Qualifier for virtual table pointers

-M[t|s|b]: Memory Model

○ Tiny Memory Model
○ Small Memory Model
● Banked Memory Model

```
-Cs08 -D__NO_FLOAT__ -Mb -Ous -Of -OnB=alr -Oncn -OnCstVar
-OnP=g -OnPMNC -WmsgSd1420 -WmsgSd4000 -WmsgSd4001
-WmsgSd5912
```

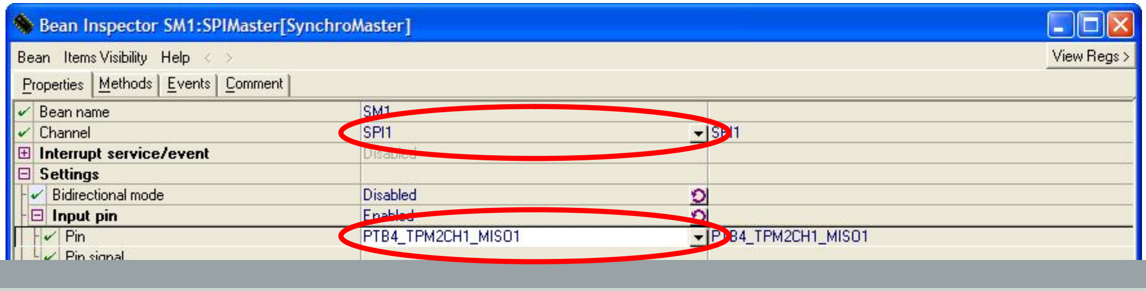
Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 3: QE128 (HCS08)

Migration Process

Changes in Processor Expert

1. Click the Processor Expert tab in left panel
2. Right click the KBI Bean’s icon and click the *Bean Enabled* menu item to disable it; it is not needed
3. Right click the *TPM_Prox:Init_TPM* bean’s icon and click the *Bean Enabled* menu item to enable it
6. Double click *SM1:SPIMaster* icon to bring up Bean Inspector for this bean
   - ► Click the dropdown at the top for “Channel” and select SPI1 to resolve the naming conflict
   - ► Click the dropdown for the input pin and select the option for PTB4 to resolve the naming conflict
7. Close the bean inspector (saves changes)



✓ Bean name	SM1	
✓ Channel	SPI1	SPI1
⊞ Interrupt service/event	Disabled	
⊟ Settings		
✓ Bidirectional mode	Disabled	
⊟ Input pin	Enabled	
✓ Pin	PTB4_TPM2CH1_MISO1	PTB4_TPM2CH1_MISO1
✓ Pin signal		

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 3: QE128 (HCS08)

Migration Process

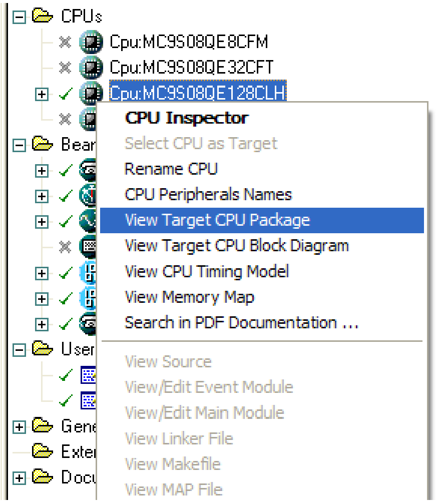
Changes in Processor Expert

8. Under the *CPUs* category, right click the QE128 CPU icon and select *View Target CPU Package.*

9. Right click the *SCI1* peripheral.

10. Select *Add Bean/Template.* Click yes to add to the other configurations.

11. From the resulting menu, select *Asynchro Master*. This generates the bean with RS232/UART functionality.

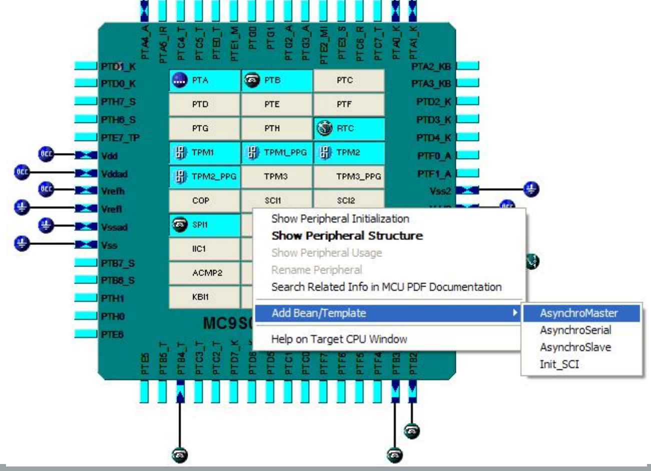


10. Double click the bean icon to open the bean inspector

11. Change the name of the bean from *AM1* to *SERIAL*

12. Click the ellipsis next to the *Baud Rate* category.

13. Set the baud rate to 57600.



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 3: QE128 (HCS08)

Migration Process

Changes in Processor Expert

14. Open the function list for the SERIAL bean and ensure that the GetTxComplete is enabled.

16. Under the *CPUs* category, right click the QE128 CPU icon and select *CPU Inspector.*

17. Select the *Build Options* tab.

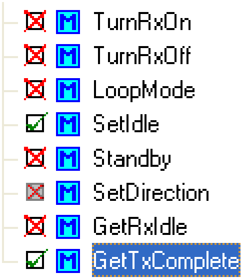
18. Select *Banked* for the memory model.

19. Ensure that the stack size is 256 bytes or higher.

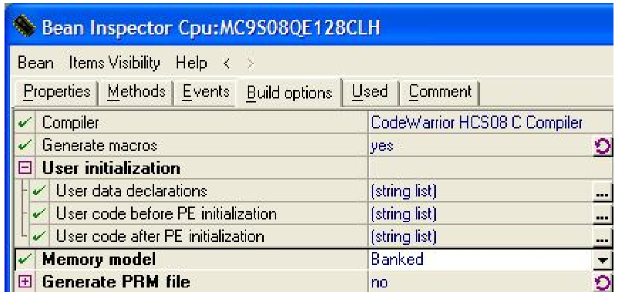
20. Build the project.

21. The linker will report an error about running out of allocation space.

22. Go back to the CPU inspector and click the circular arrow beside *Generate PRM File* to disable PRM file generation.



☒ M TurnRxOn
☒ M TurnRxOff
☒ M LoopMode
☑ M SetIdle
☒ M Standby
☒ M SetDirection
☒ M GetRxIdle
☑ M GetTxComplete



✓ Compiler	CodeWarrior HCS08 C Compiler
✓ Generate macros	yes
⊟ User initialization	
✓ User data declarations	(string list)
✓ User code before PE initialization	(string list)
✓ User code after PE initialization	(string list)
✓ **Memory model**	Banked
⊞ **Generate PRM file**	no

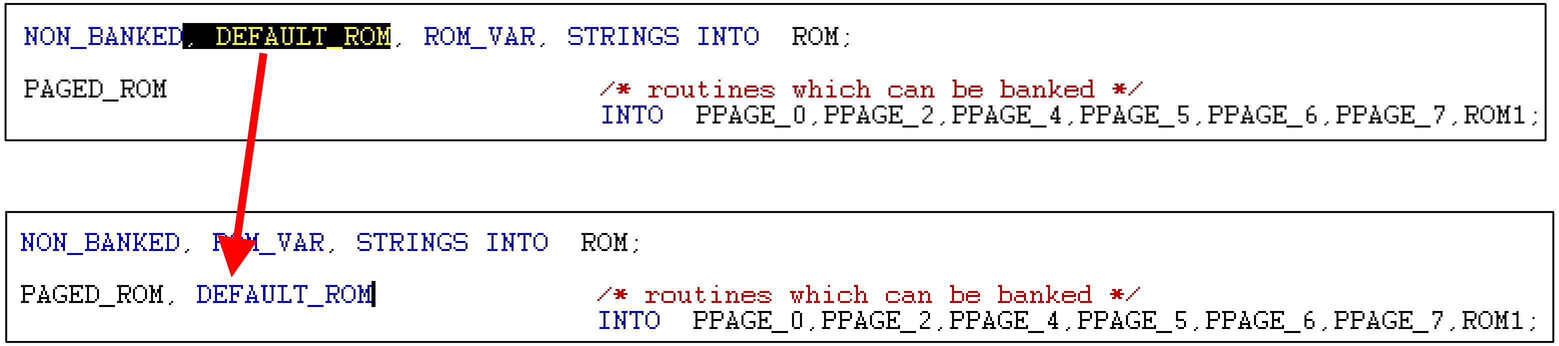
Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 3: QE128 (HCS08)

Migration Process

Changes to the Linker Settings

1. Click the *Files* tab on the left panel to return to the source browser.
2. Under the *Project Settings/Linker Files* source group, double click the *seminar.prm* file to bring up the linker configuration file for this project.
   - ► We will need to ensure that the banked memory is set up properly for the extra flash on the S08 QE128
3. Move the *DEFAULT_ROM* value to after *PAGED_ROM* on the line below
4. Save the PRM file and re-bulid the project.



```
NON_BANKED, DEFAULT_ROM, ROM_VAR, STRINGS INTO  ROM;

PAGED_ROM                                /* routines which can be banked */
                                         INTO  PPAGE_0,PPAGE_2,PPAGE_4,PPAGE_5,PPAGE_6,PPAGE_7,ROM1;
```

```
NON_BANKED, ROM_VAR, STRINGS INTO  ROM;

PAGED_ROM, DEFAULT_ROM                   /* routines which can be banked */
                                         INTO  PPAGE_0,PPAGE_2,PPAGE_4,PPAGE_5,PPAGE_6,PPAGE_7,ROM1;
```

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 3: QE128 (HCS08)

Software Overview

New Program Modes:

- Scatter plot
  - Shows the accelerometer’s output on a two-axis display
  - Can select which two axes of the accelerometer are displayed
- Data logger for Accelerometer and DMM inputs
  - Can capture data from both inputs
  - Scroll through captured data in a display window
  - Send captured data out to a serial port (use PE Micro USB scope utility)
- DMM modes from QE32 are preserved as-is

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 3: QE128 (HCS08)

Testing

DEMOQE Board Jumper Settings:

Accelerometer	
Jumper	**Pins**
J13	2&3
J14	2&3
J15	2&3
J16	None

Inputs	
Jumper	**Pins**
J12	None
J18	1&2, 3&4
J11	1&2, 3&4

System Power	
Jumper	**Pins**
J3	2&3
J4	3&4
J5	3&4, 5&6

RS232	
Jumper	**Pins**
J6	2&3
J7	2&3
J8	2&3

External Clock	
Jumper	**Pins**
J17	1&2, 3&4

Buzzer	
Jumper	**Pins**
J19	1&2

IIC Pullups	
Jumper	**Pins**
J20	None

Analog	
Jumper	**Pins**
J21	None

LEDs	
Jumper	**Pins**
J9	None

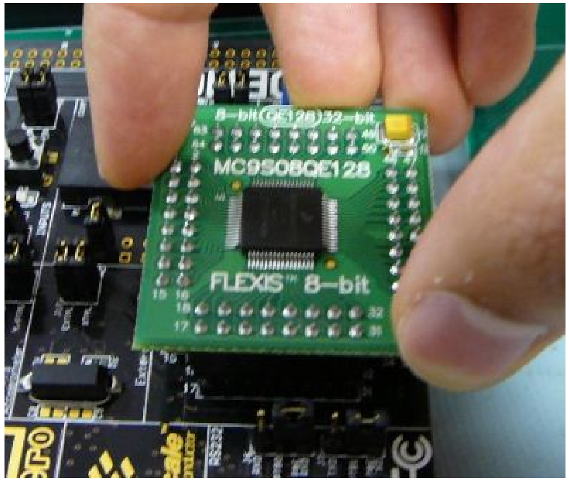
Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

freescale™ semiconductor

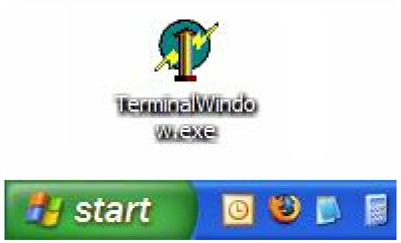
Compile, Run, and Test!

Remove QE32 module

Insert QE128 module



Open PE Micro USB Terminal utility



Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 3: QE128 (HCS08)

Application Features

Scatter Plot

- Increased flash space allows a richer UI experience
- Large bitmap is used to store the scatter plot background image
- Bitmap utilizes paged memory on S08
- Must put accelerometer jumpers J16 on when using accelerometer modes, such as the scatter plot
    - Jumpers on pins 1&2, 3&4, and 7&8

Datalogger

- Increased RAM allows for storage of DMM/Accelerometer data
- Serial bean functions used in *serialio* HAL module to perform Tx routines

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 3: QE128 (HCS08)

Code Highlights

Serial transmit routines

- Note the use of PE bean-generated code in the custom HAL code
- The function, `int8 serialio_write_string(uint8_t* str)` provides an example of this
- Open the *Processor Expert* tab and open the function list for the *SERIAL* bean to see which of the available functions were used in serialio.c

Bitmap allocation and display

- The bitmap representing the scatter plot background image was generated using a bitmap to array converter utility provided by the TFT vendor
- This array is contained in the *Application/bitmap_screens.c* source file
- When the red cursor representing the accelerometer deflection needs to be updated, the previous cursor is erased, the bitmap is redrawn in this location only, and the new cursor is written
  - See the `uint8 UI_PaintScatterPlot(…)` function in ui.c

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 3: QE128 (HCS08)

Flash Programmability

Flash can be programmed at a wide rage of voltages

- ► Range of voltages: 1.8V to 3.6V
- ► Can test this out on the DEMOQE board
  - Turn off power to the board
  - Ensure that the *REG_VDD* jumper is in place on J5
  - Remove the jumper on J4 from the *3V* position (pins 3&4) and place it onto the *2.1V* position (pins 1&2)
  - Plug the USB cable into the board
  - Turn on the board
  - Program the device in CodeWarrior and observe that it programs successfully
  - Turn off the board
  - Place the jumper on J4 back onto the *3V* position
  - Turn on the board and observe that the demo application still runs

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

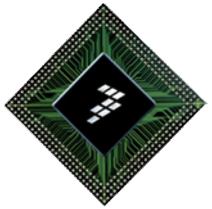
Lab 3: QE128 (HCS08)

Self-Study Project Enhancement

Enhancement: Flash Datalogger

- Modify the datalogger program mode so that it transfers logged values into flash once the RAM is full
- Will use the IntFLASH peripheral on the MCU
- Utilize the flash programming bean based on the IntFLASH peripheral in Processor Expert to:
  - Set up the flash paging and space allocation in the MCU memory map
  - Enable read/write functions to manipulate flash segments

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.



LAB4: MCF51QE128

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

51QE128 Overview

	QE8	QE32	S08QE128	51QE128
CPU	S08 Up to 20 MHz	S08 Up to 50MHz	S08 Up to 50 MHz	**ColdFire V1 Up to 50 MHz**
FLASH	8K Bytes	32K Bytes	128K Bytes	**128K Bytes**
RAM	512 Bytes	2K Bytes	8K Bytes	**8K Bytes**
ADC	10-ch 12-bit ADC	10-ch 12-bit ADC	24-ch 12-bit ADC	**24-ch 12-bit ADC**
TPM	2 TPM (3-ch)	2 TPM (3-ch) 1 TPM (6-ch)	2 TPM (3-ch) 1 TPM (6-ch)	**2 TPM (3-ch) 1 TPM (6-ch)**
SPI	1 SPI	1 SPI	2 SPI	**2 SPI**
SCI	1 SCI	2 SCI	2 SCI	**2 SCI**
IIC	1 IIC	1 IIC	2 IIC	**2 IIC**
KBI	8-ch KBI	16-ch KBI	16-ch KBI	**16-ch KBI**
Rapid GPIO	NA	NA	NA	**Yes**
Others	**ICS, RTC, GPIO, BDM**			

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 4: QE128 (Coldfire V1)

Device Overview

MCU: MCF51QE128

Specs	
CPU	Coldfire V1
RAM	8k Bytes
Flash	32k Bytes
Max Bus Clock	25 MHz
Max CPU Clock	50 MHz

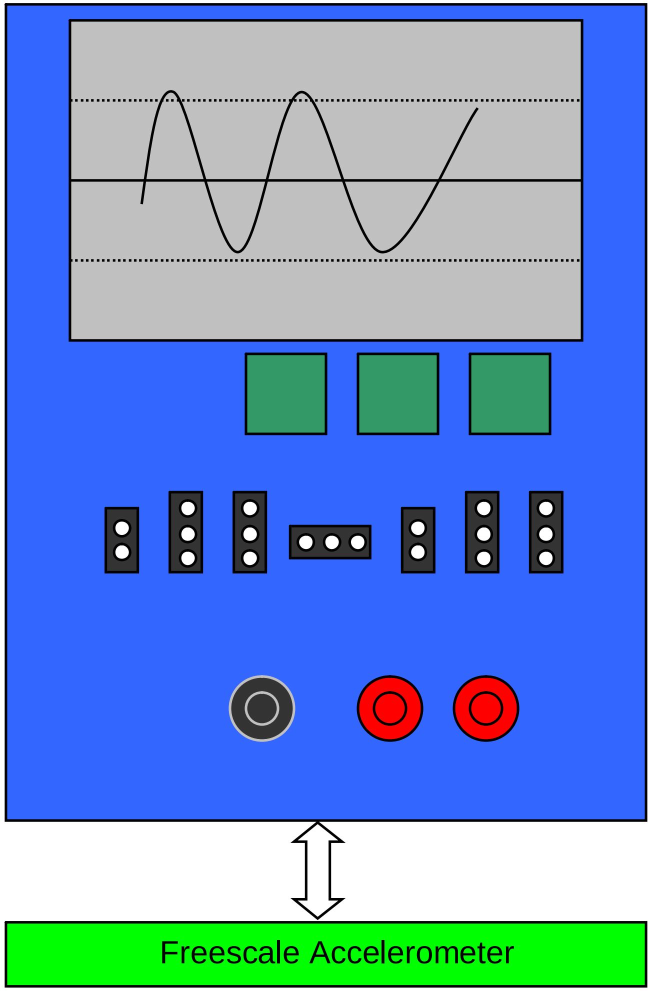
Peripherals:

- ►ADC (24-ch, 12-bit)
- ►Comparators (2)
- ►SCI (2)
- ►SPI (2)
- ►I2C (2)
- ►TPM (1x 6-ch, 2x 3-ch)
- ►RTC
- ►KBI (16-ch)

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 4: QE128 (Coldfire V1)

Software Overview



New Program Mode

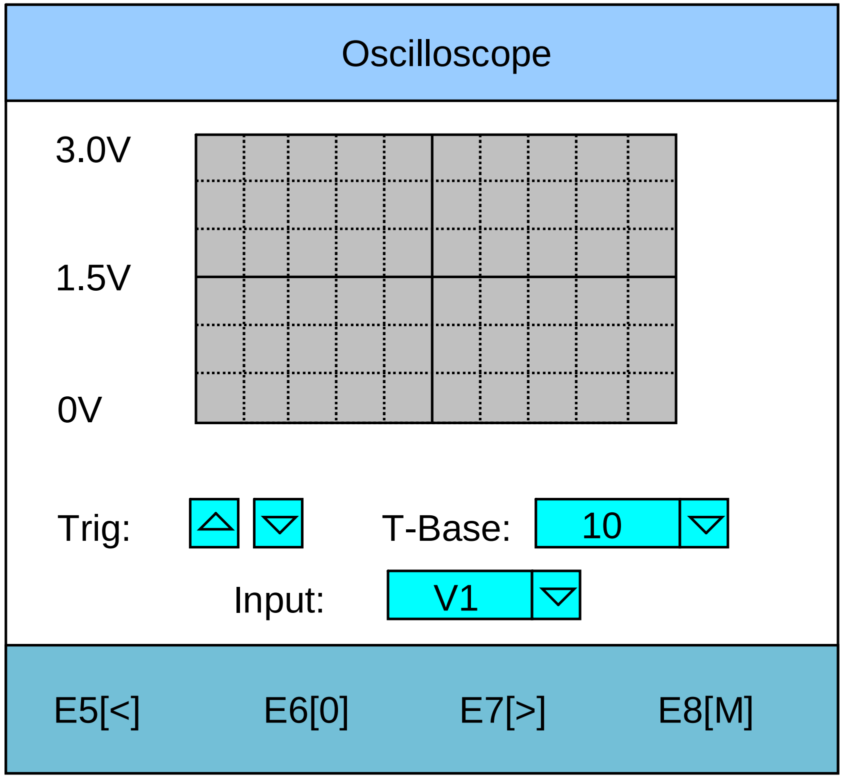
- Real-time graph
  - Plots the input signal from the DMM inputs or accelerometer axes in real-time
  - Utilizes the added processing power of the Coldfire to erase and re-draw all points on the screen as fast as data comes in
  - Can capture one screen of data at a time at the push of a button
- Oscilloscope
  - Implements an oscilloscope function that can operate on DMM inputs or accelerometer axes
  - Triggers on the rising edge of a signal throughout the input voltage range, configurable by the user
  - User can set the timebase in terms of sampling rate in milliseconds

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 4: QE128 (Coldfire V1)

New Graphic User Interface

Oscilloscope Mode

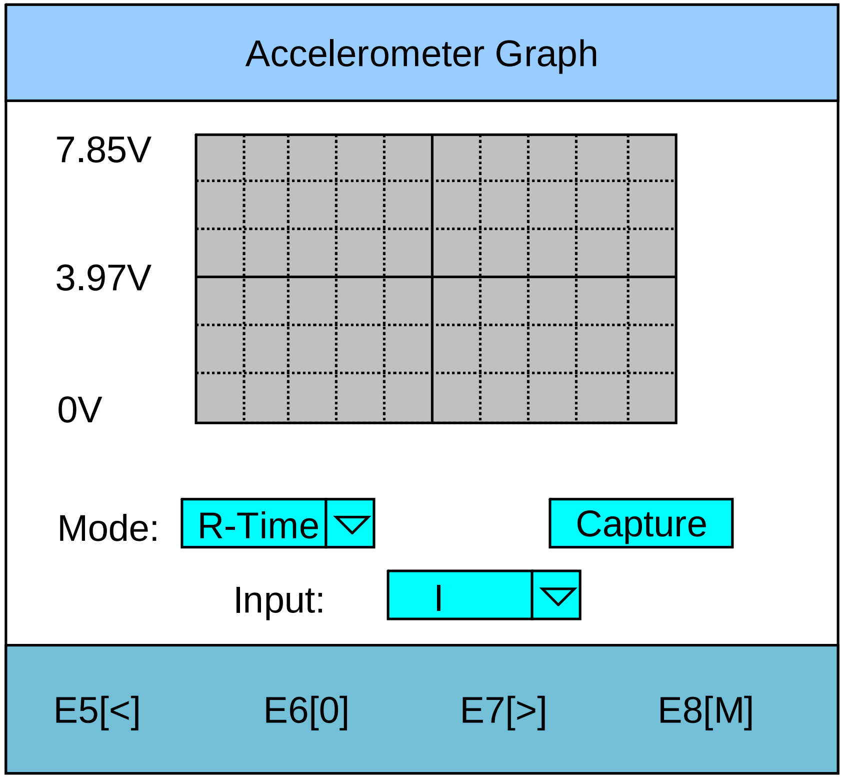


Trig: △ ▽

T-Base: 10 ▽

Input: V1 ▽

Accelerometer Graph Mode



Mode: R-Time ▽

Input: I ▽

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 4: QE128 (Coldfire V1)

CPU Comparison

MC9S08QE128	
CPU	HCS08 (8-bit)
Address Bus	16-bit
Data Bus	8-bit
Instruction Set	HCS08
Interrupt Support	32 interrupts, no nesting

MCF51QE128	
CPU	Coldfire V1 (32-bit)
Address Bus	24-bit
Data Bus	32-bit core, 8-bit peripheral
Instruction Set	Coldfire V1 Rev. C
Interrupt Support	256 interrupts, nesting supported

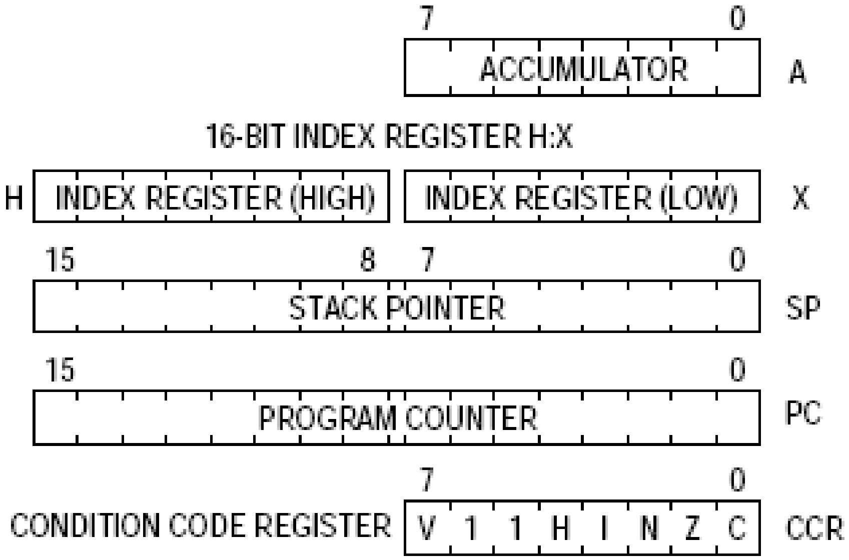
Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 4: QE128 (Coldfire V1)

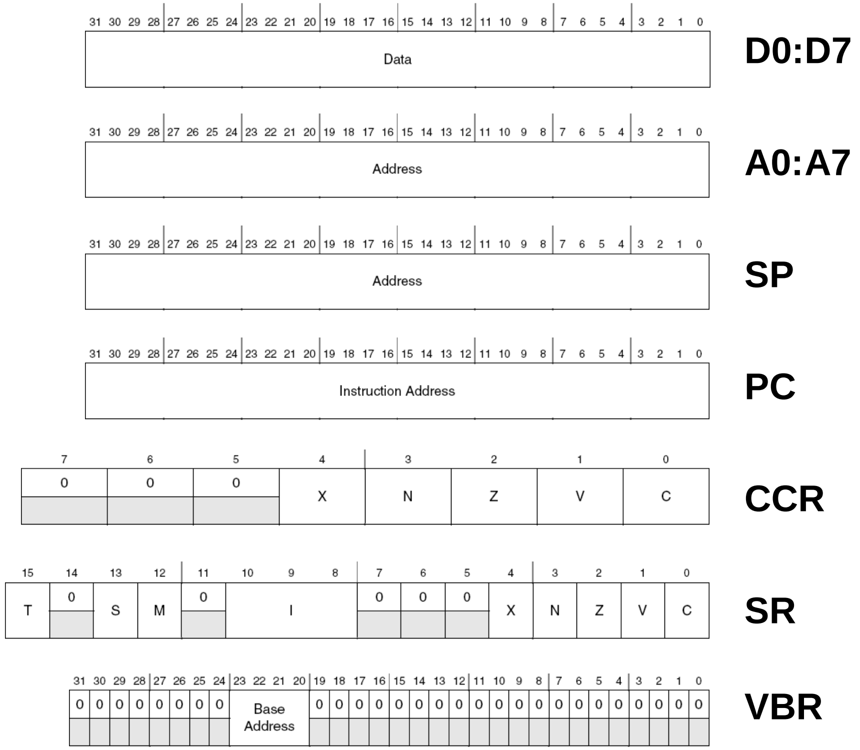
CPU Comparison

CPU Registers:

HCS08



Coldfire V1

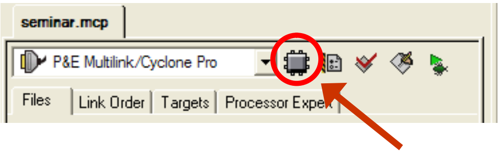


Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

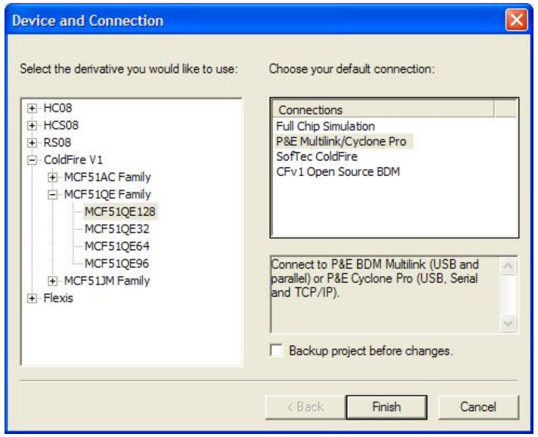
Lab 4: QE128 (Coldfire V1)

Migration Process

Changes in Processor Expert



1. Click on *Change MCU/Connection*
2. Select MCF51QE128 from the list
   - ► Ensure that *P&E Multilink Cyclone Pro* is selected
   - ► Ensure that the *Backup project before changes* box is unchecked
3. Click the Processor Expert tab in left panel
4. Right click the CPU bean’s icon and select the *CPU Inspector* option
5. Select the properties tab
6. Set the *Internal Oscillator Frequency* to 39 (kHz)
7. Set the *Internal Bus Clock* to 19.968 (MHz)


Device and Connection

Select the derivative you would like to use:

- HC08
- HCS08
- RS08
- ColdFire V1
  - MCF51AC Family
  - MCF51QE Family
    - MCF51QE128
    - MCF51QE32
    - MCF51QE64
    - MCF51QE96
  - MCF51JM Family
- Flexis

Choose your default connection:

Connections
Full Chip Simulation
P&E Multilink/Cyclone Pro
SofTec ColdFire
CFv1 Open Source BDM

Connect to P&E BDM Multilink (USB and parallel) or P&E Cyclone Pro (USB, Serial and TCP/IP).

☐ Backup project before changes.

Lab 4: QE128 (Coldfire V1)

Migration Process

Changes in Processor Expert

8. Right click the KBI Bean’s icon and click the *Bean Enabled* menu item to disable it; it is not needed
9. Right click the *TPM_Prox:Init_TPM* bean’s icon and click the *Bean Enabled* menu item to enable it
10. Right click the *TPM2_HighSpeed:Init_TPM* bean’s icon and click the *Bean Enabled* menu item to enable it
11. Double click the TPM2_HighSpeed bean to open the Bean Inspector
12. Press the plus sign (+) beside the *Channels* heading to add a second TPM channel
13. Set the *Capture/Compare Device* to TPM21 and the *Mode* to *Output compare*
14. Set interrupt priorities for all of the TPM channels to remove the errors
15. Enable the interrupt for this channel and name it `TPM2_CompareISR_1`
16. Since the Coldfire core supports interrupt priorities, these need to be set for all interrupts in the TPM bean

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 4: QE128 (Coldfire V1)

Migration Process

Changes in Processor Expert

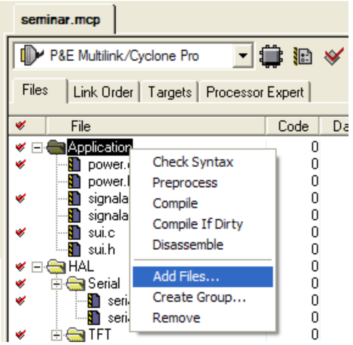
17. Double click the SERIAL bean to open the Bean Inspector
18. Click the ellipsis beside the *Baud Rate* option to open the baud rate dialog
19. Change the tolerance to 2% to remove the error.
    - The resultant baud rate is only 0.01% over the original tolerance for the S08 QE128, which is marginal
20. Double click the SPI bean to open the Bean Inspector
21. Click the ellipsis to set a new shift clock rate.
22. Set the new shift clock rate to 9.984 MHz, the last option in the dropdown list.

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 4: QE128 (Coldfire V1)

Migration Process

Changes in the CodeWarrior Project



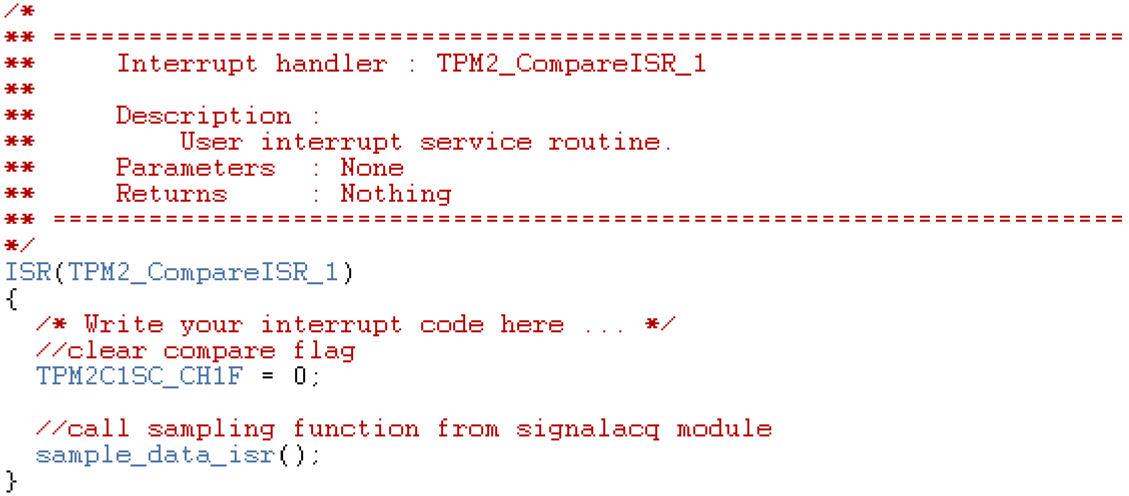
1. Click the *Files* tab on the left panel
2. Remove both *programctl* files by right clicking them and selecting *Remove*
3. Right click on the *Application* source group and click *Add Files…*
4. Browse from the top-level directory to: `<top_level>\src\cf\qe128` and select the programctl files
5. Click the *Edit > Standard Settings* menu
6. Click on the *Access Paths* on the left pane
7. Click on the old s08\qe128 directory and press the *Remove* button
8. Press OK on the Standard Settings dialog
9. Open up the *Libs* source group and remove the ansibim.lib file

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 4: QE128 (Coldfire V1)
Migration Process

Changes in the CodeWarrior Project

10. Open Events.c. This file contains all Beans-generated interrupt service routines.
11. Insert the following lines into the `TPM2_CompareISR_1` at the bottom of the file:
    - ► This allows the compare interrupt to sample data as part of the fixed frequency sampling code in the signal acqusition module (signalacq)



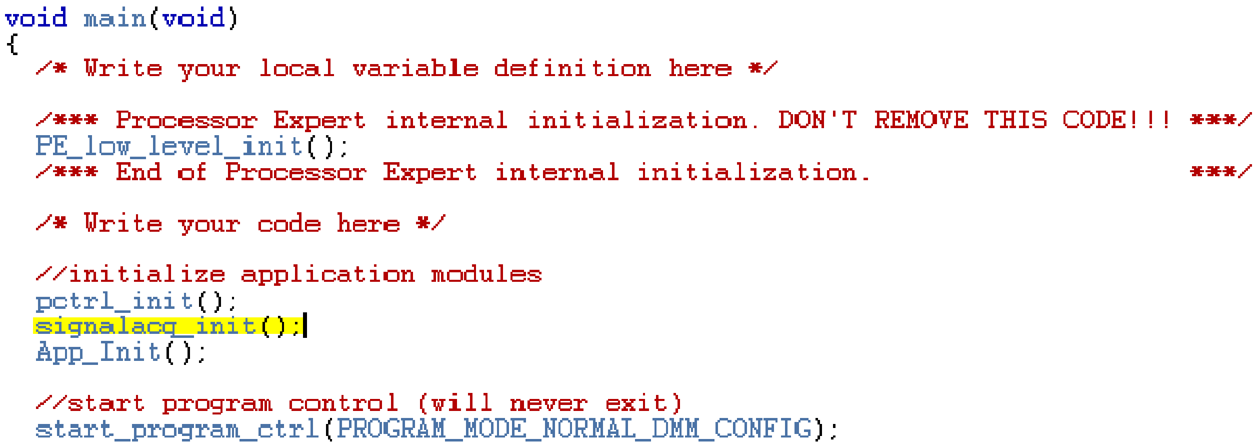
```
/*
** ===================================================================
**     Interrupt handler : TPM2_CompareISR_1
**
**     Description :
**         User interrupt service routine.
**     Parameters  : None
**     Returns     : Nothing
** ===================================================================
*/
ISR(TPM2_CompareISR_1)
{
  /* Write your interrupt code here ... */
  //clear compare flag
  TPM2C1SC_CH1F = 0;

  //call sampling function from signalacq module
  sample_data_isr();
}
```

Lab 4: QE128 (Coldfire V1)

Migration Process

Changes in the CodeWarrior Project

10. Open seminar.c. This file contains the main function and all initialization code.
11. Insert the highlighted line into `main()` :
    - ► We now need to initialize the signal acqusition module for use with the fixed frequency sampling code.



```
void main(void)
{
  /* Write your local variable definition here */

  /*** Processor Expert internal initialization. DON'T REMOVE THIS CODE!!! ***/
  PE_low_level_init();
  /*** End of Processor Expert internal initialization.                    ***/

  /* Write your code here */

  //initialize application modules
  pctrl_init();
  signalacq_init();
  App_Init();

  //start program control (will never exit)
  start_program_ctrl(PROGRAM_MODE_NORMAL_DMM_CONFIG);
```

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 4: QE128 (Coldfire V1)

Software Overview

New Program Modes:

- Real-time graph
  - Plots the input signal from the DMM inputs or accelerometer axes in real-time
  - Utilizes the added processing power of the ColdFire to erase and re-draw all points on the screen as fast as data comes in
  - Can capture one screen of data at a time at the push of a button
- Oscilloscope
  - Implements an oscilloscope function that can operate on DMM inputs or accelerometer axes
  - Triggers on the rising edge of a signal throughout the input voltage range, configurable by the user
  - User can set the sampling interval in milliseconds
- All previous program modes are preserved as-is

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

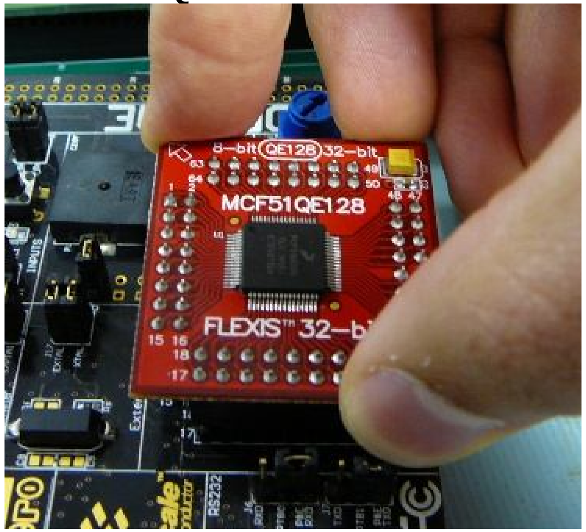
Lab 4: QE128 (Coldfire V1)

Testing

Compile, Run, and Test!

Insert QE128 CF module

Insert QE128 CF module



Open PE Micro USB Terminal utility

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 4: QE128 (Coldfire V1)

Code Highlights

Fixed Frequency Sampling (Signal Acquisition Module)

- ► All sampling functions have the same signature – one function pointer stores the currently active sampling function
  - Pointer definition: `uint16 (*sample_fn)(void);`
- ► Sampling function externally set with enumerated input types using the function, `int8 assign_sampling_input(sampling_input_t sample_input)`
- ► Sampling function called from the ISR for TPM2's Ch. 1 compare ISR generated by the TPM2_HighSpeed bean
  - ISR contained in Events.c, browse to: `ISR(TPM2_CompareISR_1)`
  - Main processing in ISR done in `sample_data_isr()`
- ► Cannot modify signal acqusition module's parameters while a transfer is in progress
  - `sampling_in_progress` flag implements this functionality

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 4: QE128 (Coldfire V1)

Code Highlights

Graphing UI Widgets (User Interface Module)

- ► Operate on buffered ADC data
- ► Can draw an arbitrary number of points on-screen
- ► Can operate in free-running mode (single point updates) or buffered mode
  - This can be seen in the graph and oscilloscope functions
- ► Axis labels and tigger level indicator are also part of this widget; can be set and re-drawn independent of the graph portion of the widget

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 4: QE128 (Coldfire V1)

Power Consumption Comparison

32-bit Can be lower power than 8-bit

- It’s not simply about processor speed or instruction size, but execution efficiency of those instructions
- Compare:
  - HCS08 core has one 8-bit accumulator and one 16-bit index register
  - Coldfire V1 core has eight dedicated 32-bit address and data registers
- **Example 1**: Compare the disassembly of highlighted line of code, below

C code from sample_data_isr function in signalacq.c

```
void sample_data_isr(void)
{
  //sample data with sampling function
  sample_buffer[sample_count] = sample_fn();

  …
}
```

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 4: QE128 (Coldfire V1)

Power Consumption Comparison

32-bit Can be lower power than 8-bit

Coldfire V1 disassembly of signalacq.c

```
;  586: void sample_data_isr(void)
;  587: {
;  588:   //sample data with sampling function
;  589:   sample_buffer[sample_count] = sample_fn();
;
0x00000000                    _sample_data_isr:
;                             sample_data_isr:
0x00000000  0x206D0000               movea.l  _sample_fn(a5),a0
0x00000004  0x4E90                   jsr      (a0)
0x00000006  0x73AD0000               mvz.b    _sample_count(a5),d1
0x0000000A  0x41ED0000               lea      _sample_buffer(a5),a0
0x0000000E  0x31801A00               move.w   d0,(a0,d1.l*2)
```

Summary:

- ► 3 move instructions
- ► 1 jump instruction
- ► 1 load instruction

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 4: QE128 (Coldfire V1)

Power Consumption Comparison

32-bit Can be lower power than 8-bit

HCS08 disassembly of signalacq.c

```
589:    sample_buffer[sample_count] = sample_fn();
0000 ce0000   [4]             LDX   sample_count
0003 58       [1]             LSLX
0004 89       [2]             PSHX
0005 320001   [5]             LDHX  sample_fn:1
0008 c60000   [4]             LDA   sample_fn
000b 8b       [2]             PSHH
000c 8b       [2]             PSHH
000d 8b       [2]             PSHH
000e ac000000 [8]             CALL  _CALL_STAR08_FAR
0012 8b       [2]             PSHH
0013 8c       [1]             CLRH
0014 9f       [1]             TXA
0015 9eee02   [4]             LDX   2,SP
0018 d70001   [4]             STA   @sample_buffer:1,X
001b 86       [3]             PULA
001c d70000   [4]             STA   @sample_buffer,X
```

Summary:

- ► 1 shift instruction
- ► 1 jump instruction
- ► 4 load instructions
- ► 5 push (stack) instructions
- ► 1 pull (stack) instruction
- ► 1 clear instructions
- ► 1 transfer instruction

Three times as many instructions as the CFV1

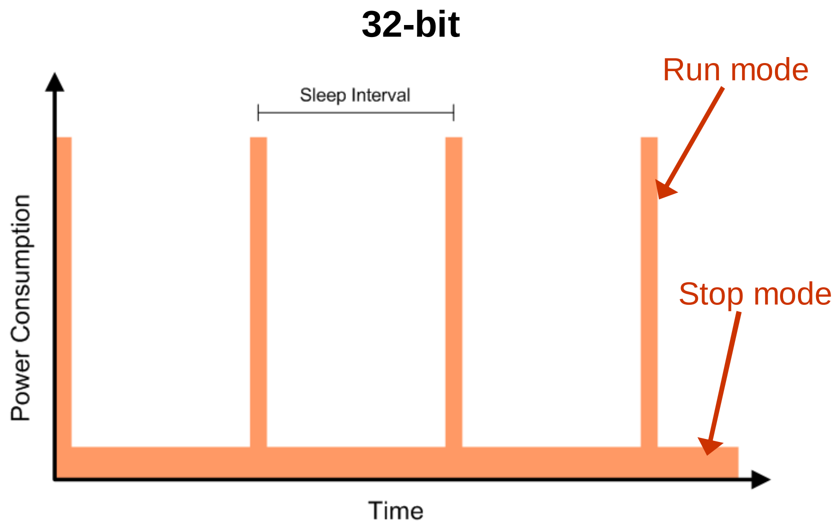
Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

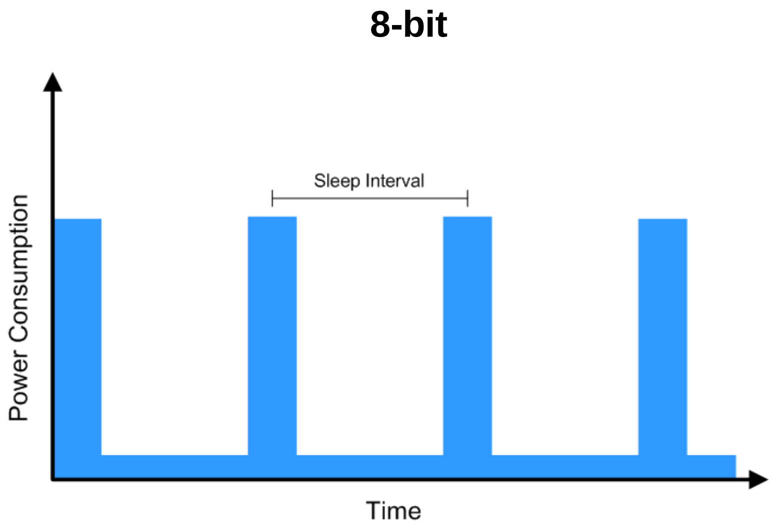
Lab 4: QE128 (Coldfire V1)

Power Consumption Comparison

32-bit Can be lower power than 8-bit

- **Example 2**: Faster execution time does not necessarily mean more power
  - Less time in run-mode means less total power consumption
  - E.g., Doing the same operation in half the time on a fast CPU is equivalent to taking twice as long despite using half the wattage on the slow CPU
  - Area under the power curve represents total power consumed





Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Lab 4: QE128 (Coldfire V1)

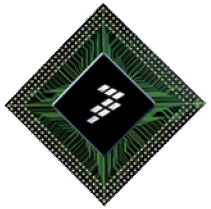
Self-Study Project Enhancement

Enhancement: Spectrum Analyzer

- Both the oscilloscope and the real-time graph program modes operate on buffered data
- Write code that captures data at a fixed sampling interval by using the fixed frequency sampling functions in the signal acquisition module
- Run an FFT algorithm on this data to generate the frequency spectrum data
- Plot this processed data on-screen in a similar way to how it has been done with the oscilloscope and real-time graph program modes
    - Can modify the graph widget to interpolate points using lines instead of drawing single dots

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Low Power Resources



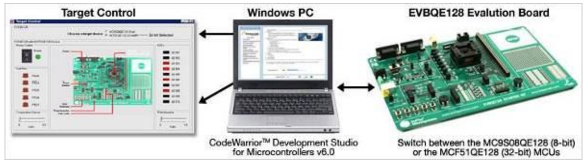
Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Low Power Application Notes & Training

•Application Notes

- •AN3460 Low Power Design enabled by MC9S08QE128 & MCF51QE128 MCUs
- •AN3629: Migrating from the 9S08QE32 to the MCF51QE32
- •AN3502: Differences between the TI MSP430 and QE128
- •AN3506: Migrating from TI's MSP430 to the 9S08QE128 or MCF51QE128
- •AN3467: Using Processor Expert with Flexis MCUs
- •AN3464: Migrating code between ColdFire V1 and V2
- •AN3466: Differences Between a Cortex M3 Processor and the MCF51QE128
- •QRUG QE128 (QE128 Peripheral Module Quick Reference Guide)

•Flexis QE Virtual Lab @ http://www.techonline.com/product/virtualab/202200251


Target Control
Windows PC
EVBQE128 Evalution Board
CodeWarrior™ Development Studio for Microcontrollers v6.0
Switch between the MC9S08QE128 (8-bit) or the MCF51QE128 (32-bit) MCUs

•Online training presentations @ www.freescale.com/flexis

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Flexis QE Family Development Tools

Tool	Resale Price ($)	MCUs Supported	Comments
EVBQE128	325	**MC9S08QE128/96/64/32** **MCF51QE128/64/32**	Evaluation board for in-depth application development. Contains socket to allow evaluation of MC9S08QE or MCF51QE devices
DEMOQE128	99	**MC9S08QE128/96/64/32** **MCF51QE128/64/32**	DEMOQE128 board + MC9S08QE128 daughter card + MCF51QE128 daughter card
DEMO9S08QE32	69	**MC9S08QE32/16**	DEMOQE32 board + MC9S08QE32 daughter card
DEMO9S08QE8	69	**MC9S08QE8/4**	DEMOQE8 board + MC9S08QE8 daughter card
DC51QE128	10	**MCF51QE128/64/32**	MCF51QE128 daughter card. Use with DEMOQE128
DC9S08QE128	10	**MC9S08QE128/96/64**	MC9S08QE128 daughter card. Use with DEMOQE128
DC9S08QE32	10	**MC9S08QE32/16**	MC9S08QE32 daughter card. Can be used with DEMO9S08QE8, DEMO9S08QE32, & DEMOQE128 boards
DC9S08QE8	10	**MC9S08QE8/4**	MC9S08QE8 daughter card. Can be used with DEMO9S08QE8, DEMO9S08QE32, & DEMOQE128 boards

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

MC9S08LL16 Development Tools

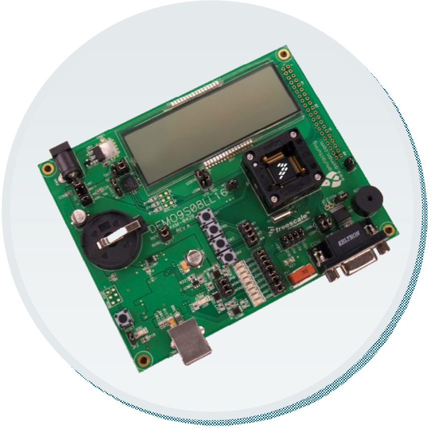
► Cost-effective development kits

DEMO9S08LL16	$69	MSRP
DEMO9RS08LA8	$59	MSRP
DEMO9RS08LE4	$59	MSRP

- Integrated USB-to-BDM interface
  - No USBMULTILINKBDME required - $99 savings!

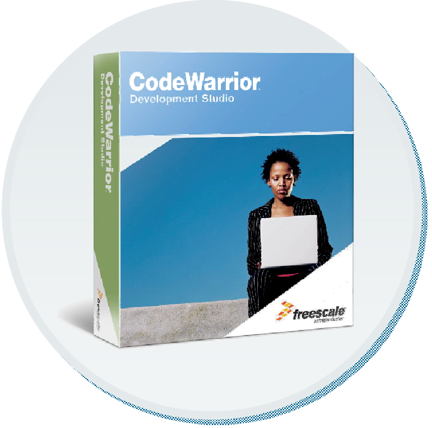
- Integrated USB-to-BDM circuit
  - In-circuit debugging & Flash programming
  - Without emulation requirements of serial monitors or other debugging techniques in the industry.

- Demo board can be powered by the USB circuit
  - No need for external power supply.



► CodeWarrior Development Studio for Microcontrollers v6.2

- Complimentary Special Edition with compiler sizes of 32K
- Single tool suite that supports software development for future migration opportunities for both 8-bit or 32-bit and includes rapid application development tool, Processor Expert



► Online training, webcast, technical documentation and application notes available at www.freescale.com/lcd

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

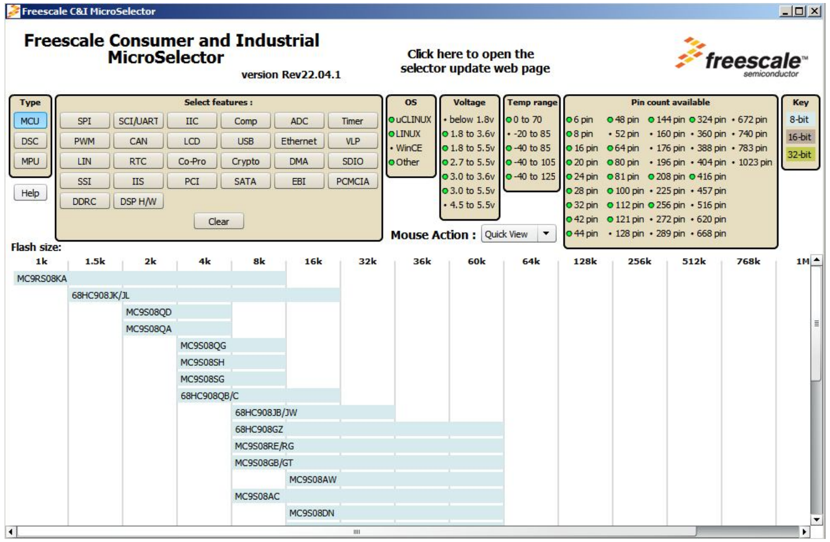
Freescale MicroSelector

Finding the right Freescale MCU for your design

http://www.freescale.com/microselector

Enables you to:

- Find the best fit - filter by features in our wide variety of controller solutions:
  - 8-bit products (RS08, HC08 and HCS08 families)
  - 16-bit products (DSC and S12X families)
  - 32-bit products (ColdFire, i.MX and Power)
- Find package and temperature range offerings.
- Documentation - read collateral for each family.
- Visit the Product Page



Using MicroSelector:

1) Download Freescale MicroSelector Installer.

2) Unzip and execute the file.

3) Open Freescale MicroSelector.

4) Choose Product Type: Microcontroller / Digital Signal Controller / Microprocessor

5) Navigate to find information

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

LCD Hardware www.display3000.com

►The LCD board used in the DMM design is DEMOQE128TFT

- Price $78
- Available from www.display3000.com
- 176x132 64k colour plug-in LCD module
- Kit includes
  - Free license of E-S030 graphics converter software
  - Board schematics
  - CD with heavily commented C (CodeWarrior) software showing you everything you can do with the display
  - Detailed documentation about how to use/program and details on sample s/ware routines (more than 50 pages)

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

What did I learn?

Goal:

- I developed a scalable handheld battery operated product

Objectives:

- I was provided with an understanding of Freescale's low power solutions
- I was educated on the benefits of designing products based on Freescale devices
- I was provided with the techniques required to design a low power, scaleable handheld product with a rich human-machine interface

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

Thank you

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.

freescale™

semiconductor

Freescale Semiconductor Confidential and Proprietary Information. Freescale™ and the Freescale logo are trademarks
of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2006.