

QE128 Quick Reference User Guide

Devices Supported:

MCF51QE128

MC9S08QE128

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Chapter 1

QE Peripheral Module Quick Reference User Guide

A Compilation of Demonstration Firmware for QE Modules

This document is a brief description of the QE128 microcontroller unit (MCU) in an 8-bit version and 32-bit version. There is also useful information about core differences.

This document is a compilation of code examples and quick reference materials that have been created to help users speed the development of their applications. Each section in this document contains an example that works with an evaluation board (EVB) and Demo board with both 8-bit and 32-bit cores versions. These examples were developed using CodeWarrior™ 6.0 version. Consult the device reference manual for specific part information.

NOTE

- The provided examples were made to be used with the MC9S08QE128 and MCF51QE128 in an 80-pin and 64-bit package, but could be easily migrated to a different QE device, pay attention to the used pins.
- All the example projects were developed in two different boards: EVBQE128 STARTER KIT and DEMO board, no extra hardware is needed except for the ACMP module, SPI, and IIC.

Revision History

Date	Revision Level	Description	Page Number(s)
25-Jun-07	0	Initial public release.	N/A
19-Oct-07	1.0	Changes in template, function names and other minor corrections.	N/A



Chapter 2

QE MCUs 8-bit and 32-bit Comparison

2.1 Overview

This is a brief explanation of MCU architectures. It has helpful information about cores, addressing modes and exception processing. The intention of this section is to provide an overview of the S08 and V1 Core. Further information can be found in reference manuals at www.freescale.com.

2.2 Cores Comparison

2.2.1 V1 core

The MCF51QE128, MCF51QE96, MCF51QE64 are members of the low-cost, low-power, high performance ColdFire[®] V1 core (version 1) family of 32-bit MCUs. [Figure 2-1](#) shows the ColdFire V1 core platform block diagram.

The ColdFire V1 core features are:

- Implements Instruction Set Revision C (ISA_C).
- Supports up to 30 peripheral interrupts and seven software interrupts.
- Built upon lowest-cost ColdFire V2 core microarchitecture.
- Two independent decoupled 2-stage pipelines.
- Debug architecture remapped into S08's single-pin BDM interface.

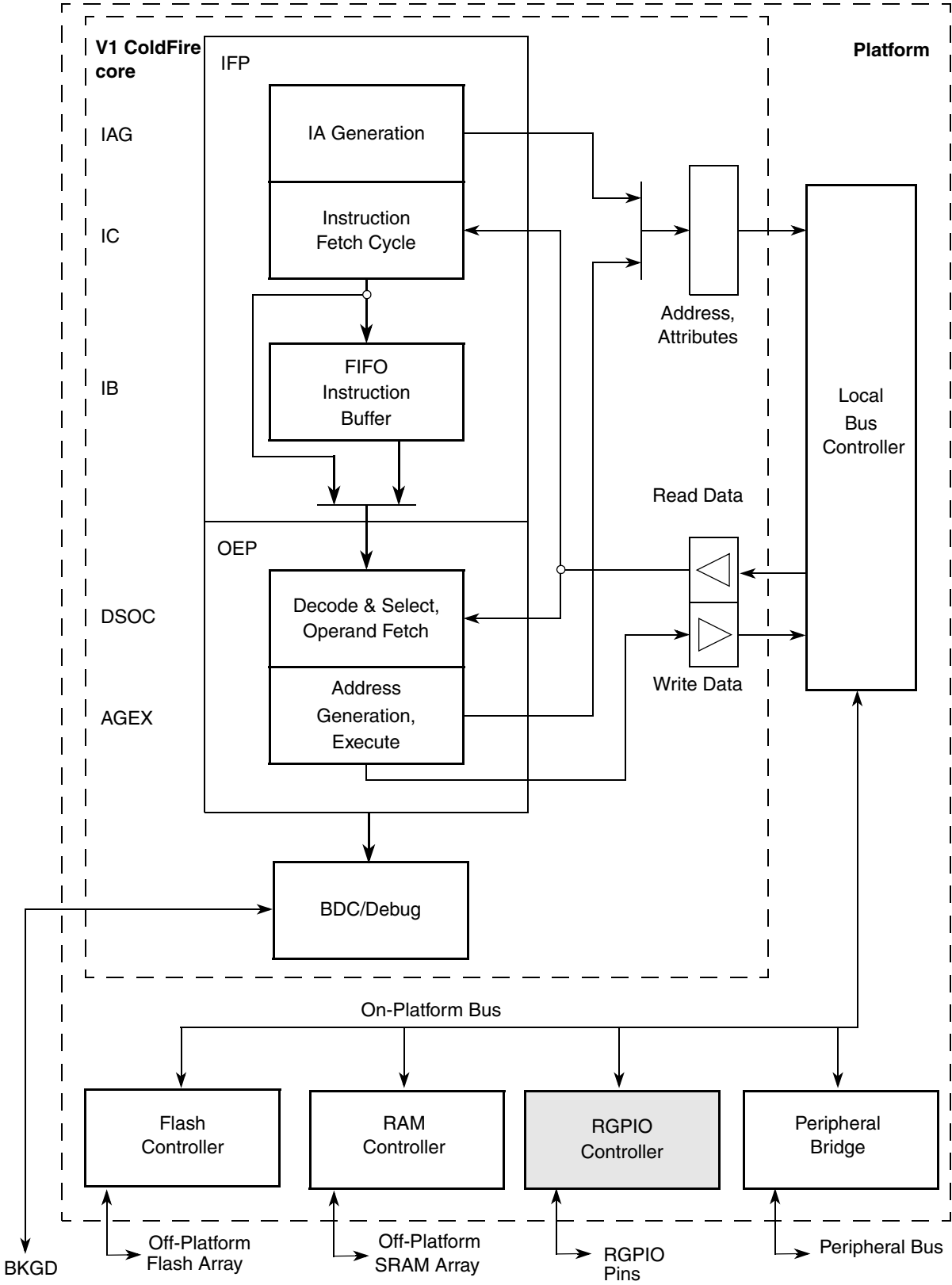


Figure 2-1. ColdFire V1 Core Platform Block Diagram

The ColdFire V1 core has two programming models, the user and supervisor. First, is the user programming model which is the same as the M68000 family microprocessors and consists of the following registers:

- 16 general-purpose 32-bit registers (D0-D7, A0-A7)
- 32-bit program counter (PC)
- 8-bit condition code register (CCR)



Figure 2-2. User Programming Model Registers

Data registers (D0-D7) -- These registers are used for bit, byte, word or longword operations. It can also be used as index registers for effective address (<ea>) calculations.

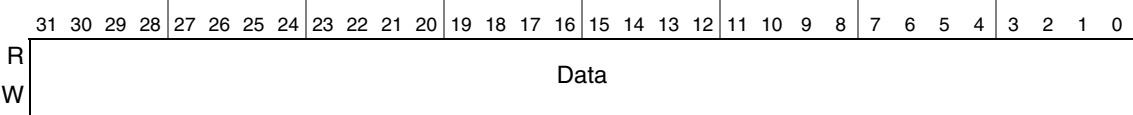


Figure 2-3. Data Registers (D0-D7)

Address registers (A0-A6) -- These registers can be used as software stack pointers, index registers or based address registers. They can also be used as data operation storage, word and longword operations.

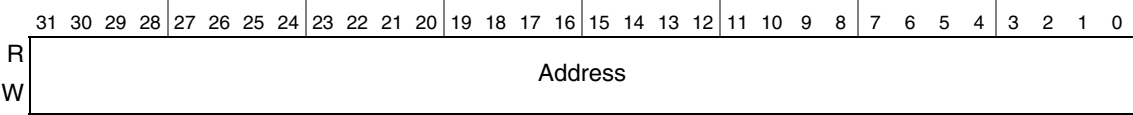


Figure 2-4. Address Registers (A0-A6)

- A7 -- Is a user stack pointer and is treated specifically by CPU.
- Program counter (PC) -- This register contains the address of the currently executing instruction. The PC increments its value or can be loaded with a new one when an instruction is executing or when an exception occurs.

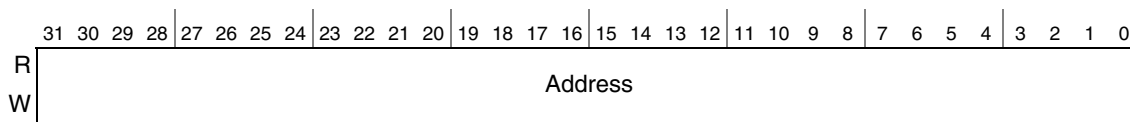


Figure 2-5. Program Counter Register (PC)

Condition code register (CCR) -- This register reflects the result of most instruction flags. It is used to evaluate the instructions of the conditional branches.

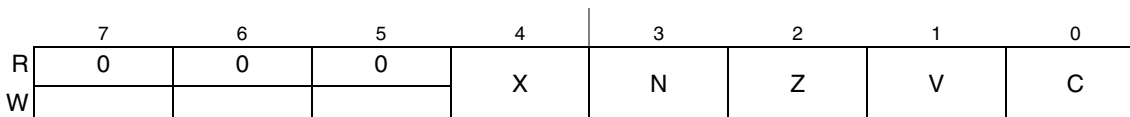


Figure 2-6. Condition Code Register (CCR)

Table 2-1. CCR Field Descriptions

Field	Description
7–5	Reserved, must be cleared.
4 X	Extend condition code bit. Set to the C-bit value for arithmetic operations; otherwise not affected or set to a specified result.
3 N	Negative condition code bit. Set if most significant bit of the result is set; otherwise cleared.
2 Z	Zero condition code bit. Set if result equals zero; otherwise cleared.
1 V	Overflow condition code bit. Set if an arithmetic overflow occurs implying the result cannot be represented in operand size; otherwise cleared.
0 C	Carry condition code bit. Set if a carry out of the operand msb occurs for an addition, or if a borrow occurs in a subtraction; otherwise cleared.

Second, is the supervisor programming model. This is intended to be used only by system control software to implement restricted operating system functions: I/O control, and memory management. In the supervisor programming model all registers and features of the ColdFire processors can be accessed and modified. This consists of registers available in user mode and the following control registers:

- 16-bit status register (SR).
- 32-bit supervisor stack pointer (SSP).
- 32-bit vector base register (VBR).
- 32-bit CPU configuration register (CPUCR).

Status register (SR) — This is a 16-bit register. It stores the processor status and includes the condition code register (CCR). When it is used in user mode only the lower 8-bit can be accessed. When used in supervisor mode the registers can be accessed. If a supervisor instruction is executed in user mode it generates a privilege violation exception. [Figure 2-8](#) shows the SR behavior in a state machine.

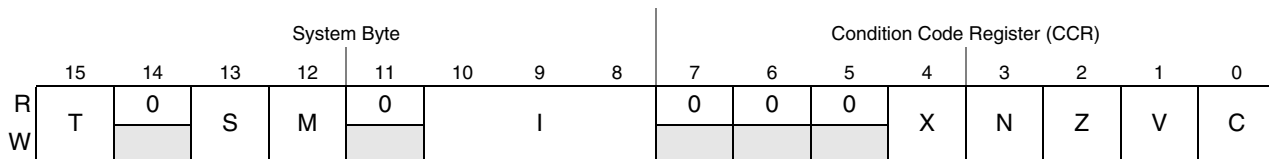


Figure 2-7. Status Register (SR)

Table 2-2. SR Field Descriptions

Field	Description
15 T	Trace enable. When set, the processor performs a trace exception after every instruction.
14	Reserved, must be cleared.
13 S	Supervisor/user state. 0 User mode 1 Supervisor mode
12 M	Master/interrupt state. Bit is cleared by an interrupt exception and software can set it during execution of the RTE or move to SR instructions.
11	Reserved, must be cleared.
10–8 I	Interrupt level mask. Defines current interrupt level. Interrupt requests are inhibited for all priority levels less than or equal to current level, except edge-sensitive level 7 requests, which cannot be masked.
7–0 CCR	Refer to MCF51QE128 Reference Manual.

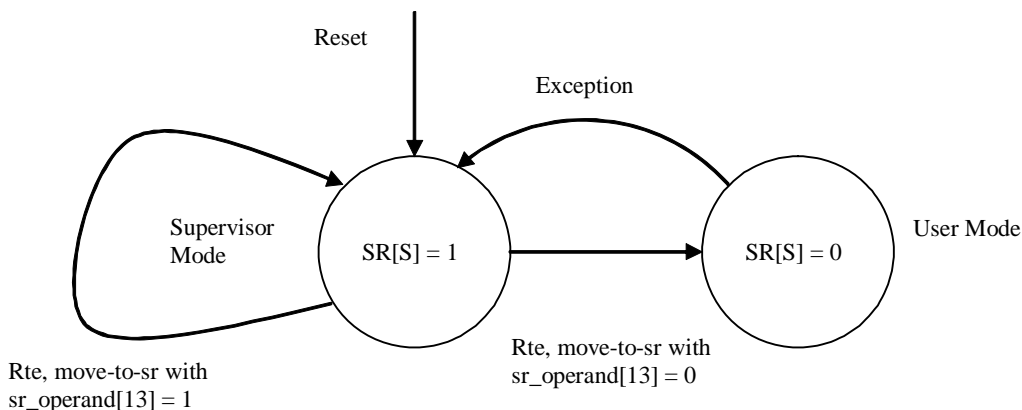


Figure 2-8. Processor Status State Machine

Supervisor stack pointer (SSP) -- This ColdFire architecture supports two independent stack pointers, A7 registers. Each operating mode has its own stack pointer, SSP and user stack pointer (USP). The hardware implementation of these two registers do not identify one as SSP and the other as USP. Instead, the hardware uses one 32-bit register as the active A7 and the other as, OTHER_A7.

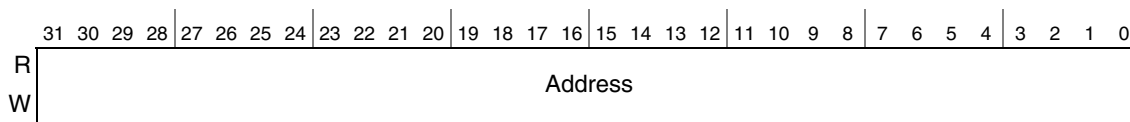


Figure 2-9. Stack Pointer Registers (A7 and OTHER_A7)

Vector base register (VBR) -- This register defines the base address of the exception vector table in the memory. It has two different possible values: 0x(00)00_0000 exception vector table based on the flash, and 0x(00)80_0000 exception vector table based on the RAM. At reset the VBR is cleared. The VBR is located at the base of the exception table at the address 0x(00)00_0000 in the flash.

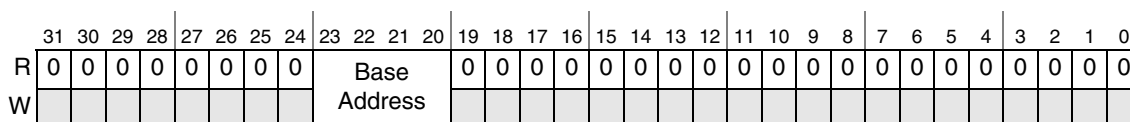


Figure 2-10. Vector Base Register (VBR)

CPU configuration register (CPUCR) -- With this register you can configure some cores into supervisor mode. Certain hardware features can be enabled or disabled based on the state of the CPUCR.

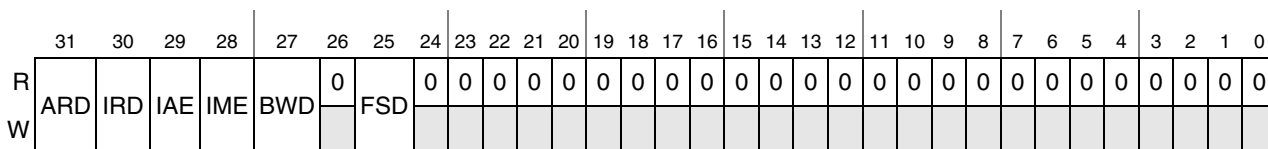


Figure 2-11. CPU Configuration Register

2.2.1.1 Addressing Modes

The ColdFire V1 core counts with 12 different addressing modes. The addressing modes and syntax are shown in [Table 2-3](#):

Table 2-3. Addressing Modes and Syntax

Addressing modes	Syntax
Register Direct.	op.sz ¹ Ry,Rx
Address Register Indirect.	op.sz (Ax),Rx
Address Register Indirect with Post-increment.	op.sz (Ax)+,Rx
Address Register Indirect Pre-decrement.	op.sz -(Ay),Rx
Address Register Indirect with Displacement.	op.sz d16(Ay),Rx
Address Register Indirect with Scaled Index and Displacement.	op.sz d8(Ay,Xi*SF),Rx
Program Counter Indirect with Displacement.	op.sz d16(PC),Rx
Program Counter Indirect with Scaled Index and Displacement.	op.sz d8(PC,Xi*SF),Rx

Table 2-3. Addressing Modes and Syntax

Addressing modes	Syntax
Absolute Short Addressing.	op.sz xxx.w,Rx
Absolute Long Addressing.	op.sz xxx.{l},Rx
Immediate Byte, Word.	op.{b,w} ² #imm,Rx
Immediate Long.	op.l#imm ³ ,Rx

¹ op.sz - operand size(size is 1 for byte, 2 for word, 4 for long).

² op.{b,w} - operand {byte,word}.

³ op.l - operand long.

This is a syntax for a V1 core example:

Source	Destination
#0x55	Rx

2.2.1.2 Exception Processing

Exception processing is defined as processor-detected conditions that force an instruction stream discontinuity because of a program or system error: a system call, a debug, or an I/O interrupt. The ColdFire V1 core uses a reduced version of the interrupt controller from other ColdFire processors. This hardware implementation is available only for a 32-bit MCU.

The processor performs the following operations to process an exception:

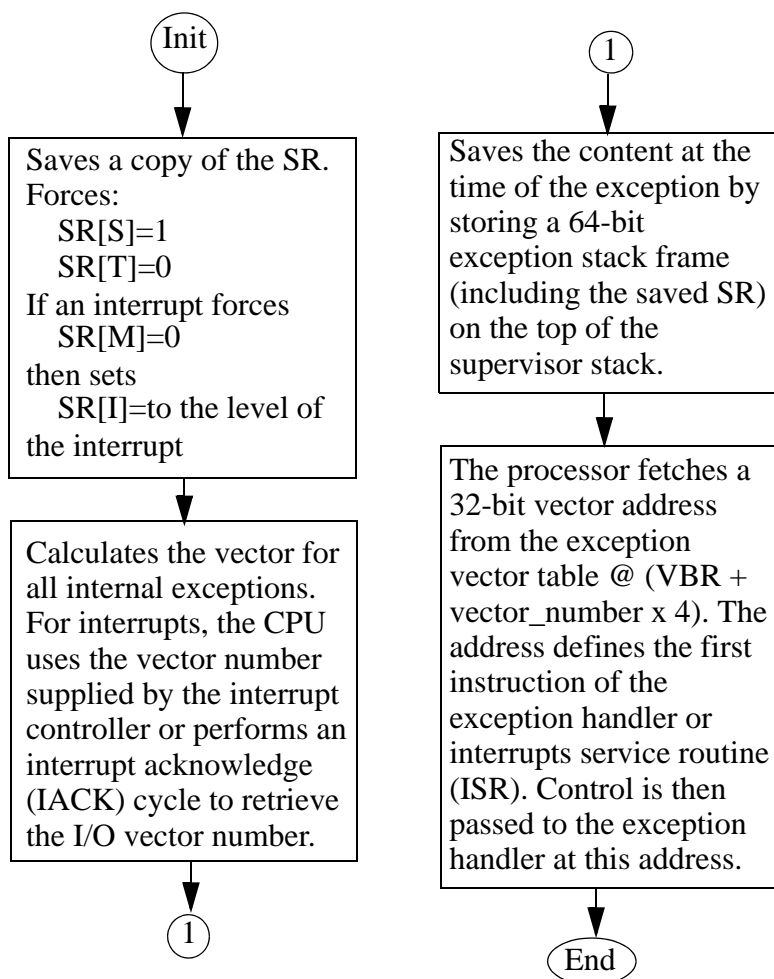


Figure 2-12. Processor Operations Process

Interrupts are treated as lowest-priority exception type. CPU samples for halts and interrupts once per instruction. The first instruction in ISR does not sample. Interrupts are guaranteed to be recoverable exceptions.

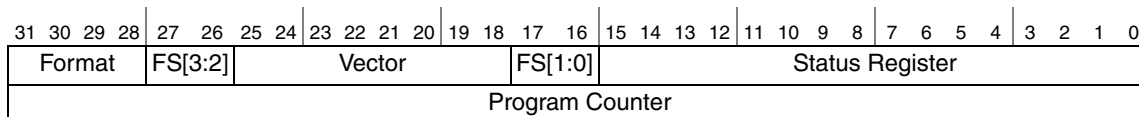


Figure 2-13. Exception Stack Frame Form

ColdFire architecture reserves 64 entries for processor exceptions and the remaining 192 entries for I/O interrupts. The ColdFire V1 core architecture only uses a relatively small number of the I/O interrupt vector. [Table 2-4](#) shows the ColdFire V1 core processor with the exception of the vector table.

Table 2-4. Vector Table

Vector Number(s)	Vector Offset(Hex)	Stacked Program Counter	Assignment
0	0x000	-	Initial supervisor stack pointer
1	0x004	-	Initial program counter
2-63	0x008-0x0FC	-	Reserved for internal CPU Exceptions
64	0x100	Next	IRQ_pin
65	0x104	Next	Low_voltage
66	0x108	Next	TPM1_ch0
67	0x10C	Next	TPM1_ch1
68	0x110	Next	TPM1_ch2
69	0x114	Next	TPM1_ovfl
70	0x118	Next	TPM2_ch0
71	0x11C	Next	TPM2_ch1
72	0x120	Next	TPM2_ch2
73	0x124	Next	TPM2_ovfl
74	0x128	Next	SPI2
75	0x12C	Next	SPI1
76	0x130	Next	SCI1_err
77	0x134	Next	SCI1_rx
78	0x138	Next	SCI1_tx
79	0x13C	Next	IICx
80	0x140	Next	KB1x
81	0x144	Next	ADC
82	0x148	Next	ACMPx
83	0x14C	Next	SCI2_err
84	0x150	Next	SCI2_rx
85	0x154	Next	SCI2_tx
86	0x158	Next	RTC
87	0x15C	Next	TPM3_ch0
88	0x160	Next	TPM3_ch1
89	0x164	Next	TPM3_ch2
90	0x168	Next	TPM3_ch3
91	0x16C	Next	TPM3_ch4
92	0x170	Next	TPM3_ch5
93	0x174	Next	TPM3_ovfl
94-95	0x178-0x17C	-	Reserved; unused for V1
96	0x180	Next	Level 7 Software Interrupt
97	0x184	Next	Level 6 Software Interrupt
98	0x188	Next	Level 5 Software Interrupt
99	0x18C	Next	Level 4 Software Interrupt
100	0x190	Next	Level 3 Software Interrupt
101	0x194	Next	Level 2 Software Interrupt
102	0x198	Next	Level 1 Software Interrupt
103-255	0x19C-0x3FC	-	Reserved; unused for V1

2.2.2 QE S08 core

This section provides summary information about the registers, addressing modes and core features. The generated source and object-code is compatible with the M68HC08 CPU.

The S08 MCU supports only the user programming model. Figure 2-14 shows five CPU registers. These registers are not part of the memory map.

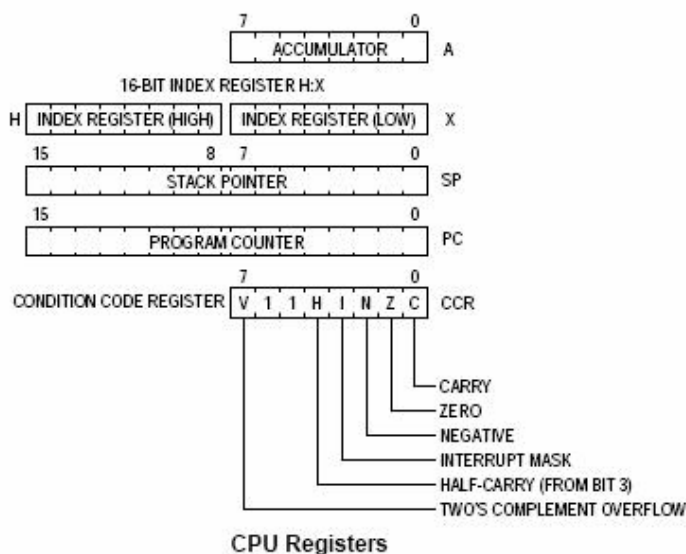


Figure 2-14. CPU Registers

- Accumulator --** The accumulator is a general-purpose 8-bit register. One operand input to the arithmetic logic unit (ALU) is connected to the accumulator and the ALU results are often stored in the accumulator after arithmetic and logical operations.
- Index Register (H:X) --** This is a two separate 8-bit register, which often works together as a 16-bit address pointer where H holds the upper byte of an address and X the lower byte. All the indexing addressing mode instructions use the 16-bit register.
- Stack pointer (SP) --** This 16-bit address pointer register points to the next available location on the automatic last-in-first-out (LIFO). The stack is used to automatically store the return address from subroutine calls or return from interrupts. It stores the context in the interrupt service routine (ISR) and it stores the local variables and parameters in function calls.
- Program counter (PC) --** This register contains the next instruction or operand to be retrieved. This register automatically increments to the next memory location during a normal program execution.
- Condition code register (CCR) --** This 8-bit condition code register contains the interrupt mask (I) and five flags that indicate the results of the instruction just executed. Bits 5 and 6 are permanently set to 1.

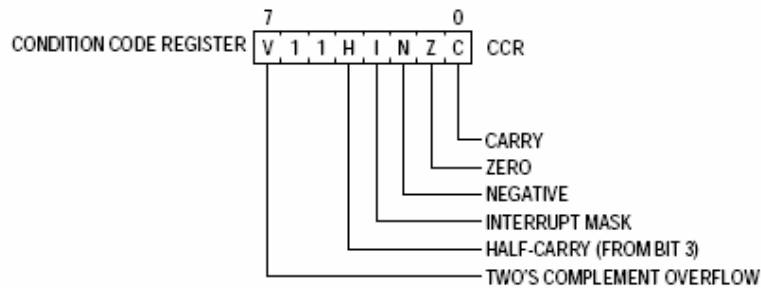


Figure 2-15. Condition Code Register

V - Two's complement Overflow Flag

N - Negative flag

H - Half Carry Flag

Z - Zero Flag

I - Interrupt Mask Bit

C - Carry/Borrow flag

2.2.2.1 Addressing Modes

Addressing modes define the way the CPU accesses operand and data. The S08 core supports seven different addressing modes:

Table 2-5. Addressing Modes and Examples

Addressing Modes	Example
Inherent -- Operands in internal registers.	ASLA – Arithmetic Shift Left A.
Relative -- 8-bit offset to branch destination.	BEQ rel – Branch if equal
Immediate -- Operand in next object code byte.	ADC #opr8i – Add with carry
Direct -- Operand in memory at 0x0000-0x00FF.	ADC opr8a – Add with carry
Extended -- Operand within 64 Kbyte address space.	ADC opr16a – Add with carry
Indexed relative to H:X.	ADC oprx8,X – Add with carry
Indexed relative to SP.	ADC oprx8,SP – Add with carry

n -- Any label or expression that evaluates to a single integer in the range 0-7

opr8i -- Any label or expression that evaluates to an 8-bit immediate value

opr16i -- Any label or expression that evaluates to a 16-bit immediate value

opr8a -- Any label or expression that evaluates to an 8-bit value

opr16a -- Any label or expression that evaluates to a 16-bit value

opr8 -- Any label or expression that evaluates to an unsigned 8-bit value, used for indexed addressing

opr16 -- Any label or expression that evaluates to a 16-bit value

page -- Any label or expression that evaluates to a valid bank number for PPAGE register. Any value between 0 and 7 is valid.

rel -- Any label or expression that refers to an address that is within -128 to +127 locations from the next address after the last byte of object code for the current instruction.

A -- Accumulator

2.2.2.2 Interrupt Sequence

The S08 core interrupt sequence first completes the current instruction then attends the requested interrupt. The CPU responds to an interrupt with the same sequence operation as in a software interrupt (SWI), and it differs from the address used for the vector retrieved.

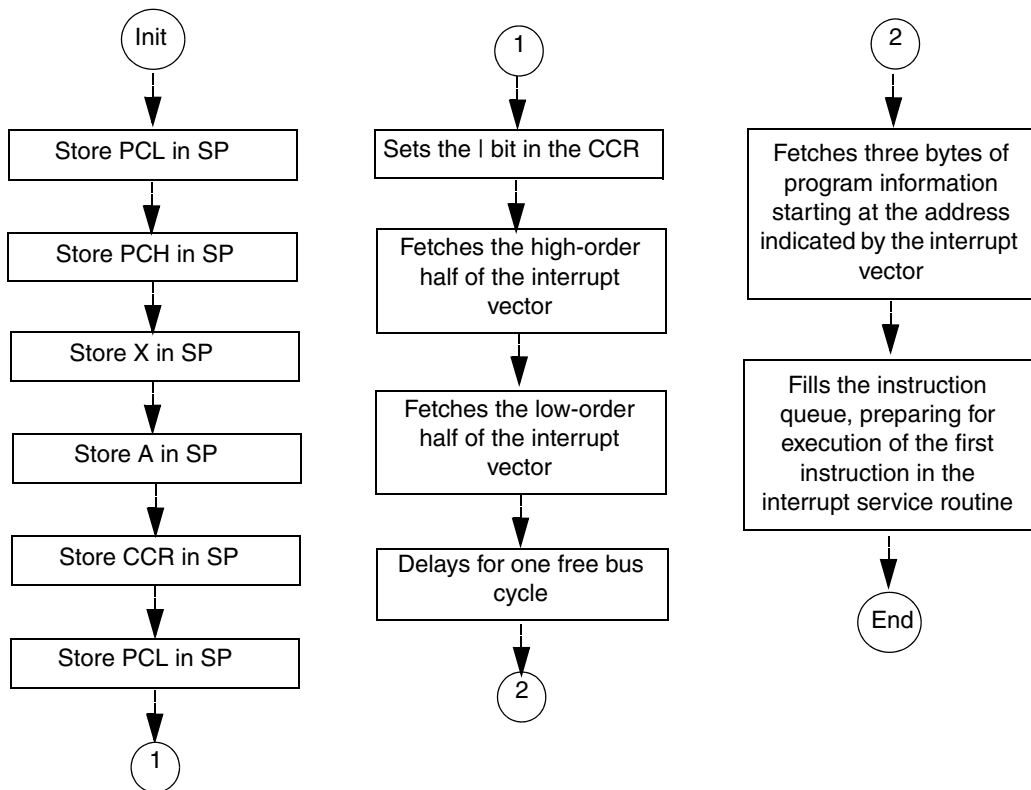


Figure 2-16. The CPU Interrupt Sequence

2.2.3 ColdFire V1 or 9S08QE

The ColdFire V1 and S08 cores have significant differences, even though the 32 bit ColdFire V1 core presents improvements in performance. These differences are highlighted in the following section.

The ColdFire V1 architecture features, staged pipelining allows the core to process multiple instructions at the same time.

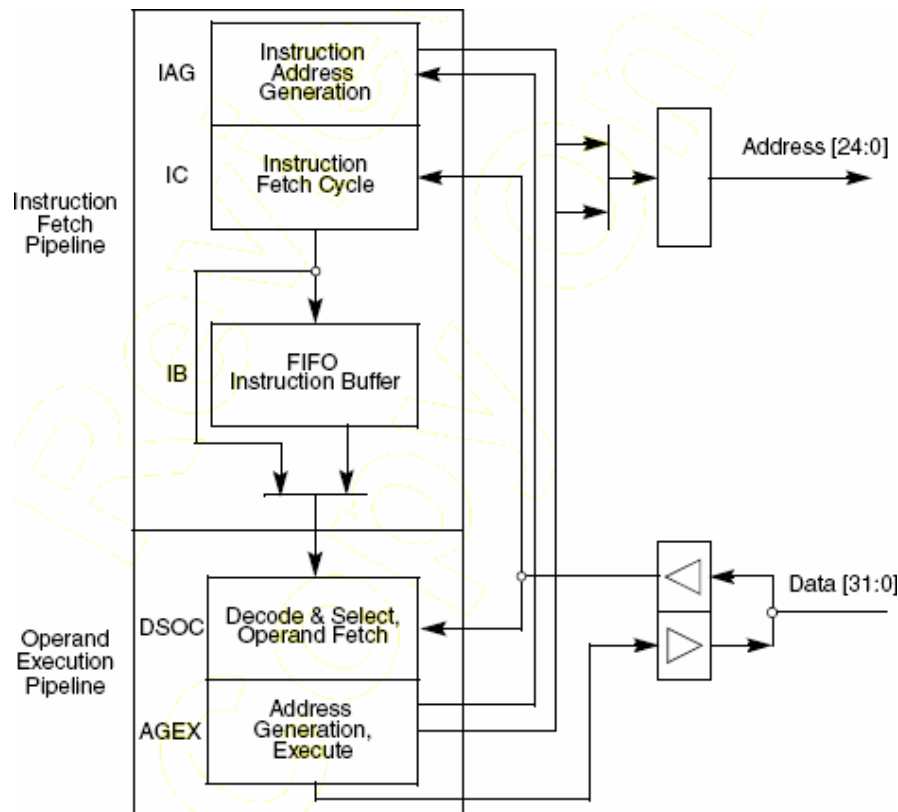


Figure 2-17. V1 Core Pipelines

- The V1 Coldfire core pipeline stages include the following:
 - Two-stage instruction fetch pipeline (IPF) (plus instruction buffer stage)
 - Instruction address generation (IAG) – Calculates the next prefetch address
 - Instruction fetch cycle (IC) – Initiates prefetch on the processor’s local bus
 - Instruction buffer (IB) – Buffer stage minimizes effects of fetch latency using fifo queue
- Two-stage operand execution pipeline (OEP)
 - Decode and select/operand fetch cycle (DSOC) – Decodes instruction and fetches the required components for effective address calculation, or the operand fetch cycle
 - Address generation/execute cycle (AGEX) – Calculates operand address or executes the instruction

ColdFire V1 core architecture -- Is an orthogonal architecture that has an advantage. It has 16 different registers for operation that can be used instead of one. The ColdFire V1 core processes more effectively the 32-bit length operations than the 8-bit core version.

S08 core architecture -- Is accumulator based, almost all arithmetic and logical instructions use the accumulator. The S08 can handle 32-bit length operations but requires more cycles because it executes more instructions, taking more time.

The ColdFire MCU has two programming models with different privileges to control the system. These programming models are similar to the administrator and user in windows. When the MCU is on the

administrator level it can access all the registers and change values. The 8-bit core version does not count with this feature.

Table 2-6 shows a global view of the core differences. Detailed information is explained in the beginning of this chapter. Refer to review Reference Manual MCF51QE128 and MC9S08QE128 at the www.freescale.com site.

Table 2-6. Comparison of Cores

MC9S08QE128	MCF51QE128
Up to 50 MHz CPU from 3.6 V 2.1 V, and 20 MHz CPU from 2.1 V to 1.8 V across temperature ranged of -40°C to 85°C.	
8-bit HCS08 core.	32-bit ColdFire V1 core.
8-bit data bus, 16-bit address bus.	32-bit data bus, 24-bit address bus.
64 Kb memory map, 16 Kb paging window for addressing memory beyond 64 Kb. Linear address pointer for accessing data across entire memory range.	16 Mb memory map, entire memory map addressed directly.
HC08 instruction set with added BGND, CALL and RTC instructions.	ColdFire Instruction Set Revision C (ISA_C), and additional instructions for efficient handling of 8-bit and 16-bit data.
Support for up to 32 interrupt/reset exceptions. Exception priorities are fixed. One level of interrupt grouping. No hardware support for nesting.	Support for up to 256 interrupt/reset exceptions (39 are used on MCF51QE128). Exception priorities are fixed except for two interrupts that can be remapped. Seven levels of interrupt grouping and hardware support for nesting.
Resets: one vector for all reset sources. Vector must point to address within pages 0-3. No illegal address reset. Entire memory map is legal.	Resets: vectors for up to 64 reset sources. Vector can point to any valid address. Illegal address reset is supported.
System reset status (SRS) registers set flags for most recent reset source.	

2.2.3.1 Exception Comparison

Table 2-7 shows the exception differences between 8-bit core and 32-bit core.

Table 2-7. Exception Differences

Attribute	S08	V1 ColdFire
Exception Vector Table.	32, 2-byte entries, fixed location at upper end of memory.	103, 4-byte entries, located at lower end of memory at reset, relocatable with the VBR.
More on Vectors.	2 for CPU + 30 for IRQs (interrupt requests), reset at upper address.	64 for CPU + 39 for IRQs, reset at lowest address.
Exception Stack Frame.	5-byte frame: CCR, A, X, PC.	8-byte frame: F/V, SR, PC; General-purpose registers (An, Dn) must be saved/restored by the ISR.
Interrupt Levels.	1 = f(CCR[I]).	7 = f(SR[I]) with automatic hardware support for nesting.
Non-Maskable IRQ Support.	No	Yes with level 7 interrupts.

Table 2-7. Exception Differences

Core-enforced IRQ Sensitivity.	No	Level 7 is edge sensitive, and others level sensitive.
INTC (interrupt controller) Vectoring.	Fixed priorities and vector assignments.	Fixed priorities and vector assignments, plus any 2 IRQs can be remapped as the highest priority level 6 requests.
Software IACK.	No	Yes
Exit Instruction from ISR.	RTI (real time interrupt).	RTE (real time exception).

2.2.3.2 Code Example Comparison

This example is a code made in C and is compiled and executed for both MCUs, V1 and S08. Both results present a difference in execution time. The generated assembly lines are similar.

There are two four loop cycles that nest within this endless loop. The inner loop cycle counts from 0 to 100 and stores the k variable value in the buffer k array. The outer loop counts from 0 to 60000. The i variable counter increments every time the k variable counter reaches the 101 value.

```
void main(void) {
    unsigned int i,k;
    unsigned int buffer[100];

    SOPT1 = 0x23;          // Watchdog disable. Stop Mode Enable. Background Pin
                          // enable. RESET pin enable

    for(;;) {

        for (i=0; i<=60000; i++) { // This routine is executed 60001
            for (k=0; k<=100; k++) {
                buffer[k] = k;
            }
        }

        } // loop forever
    // please make sure that you never leave main
}
```

Assembly code lines generated for the S08 MCU; observe the difference between this assembly code and the assembly code generated from the ColdFire V1 core.

```
10:    SOPT1 = 0x23; // Watchdog disable. Stop Mode Enable. Background Pin enable. RESET pin
enable
0004 a623    [2]          LDA    #35
0006 c70000 [4]          STA    _SOPT1
0009          L9:
11:    for(;;) {
12:
13:    for (i=0; i<=60000; i++) {
0009 95      [2]          TSX
000a 6f03    [5]          CLR    3,X
000c 6f02    [5]          CLR    2,X
000e          LE:
14:    for (k=0; k<=100; k++) {
000e 95      [2]          TSX
000f 6f01    [5]          CLR    1,X
```

QE MCUs 8-bit and 32-bit Comparison

```

0011 7f      [4]          CLR    ,X
0012                L12:
15:          buffer[k] = k;
0012 95      [2]          TSX
0013 e601    [3]          LDA    1,X
0015 48      [1]          LSLA
0016 af04    [2]          AIX    #4
0018 87      [2]          PSHA
0019 9f      [1]          TXA
001a 8b      [2]          PSHH
001b 95      [2]          TSX
001c eb01    [3]          ADD    1,X
001e e701    [3]          STA    1,X
0020 86      [3]          PULA
0021 a900    [2]          ADC    #0
0023 87      [2]          PSHA
0024 e602    [3]          LDA    2,X
0026 8a      [3]          PULH
0027 88      [3]          PULX
0028 f7      [2]          STA    ,X
0029 9ee602  [4]          LDA    2,SP
002c e701    [3]          STA    1,X
002e 95      [2]          TSX
002f 6c01    [5]          INC    1,X
0031 2601    [3]          BNE   L34 ;abs = 0034
0033 7c      [4]          INC    ,X
0034                L34:
0034 9efe01  [5]          LDHX  1,SP
0037 650064  [3]          CPHX  #100
003a 23d6    [3]          BLS   L12 ;abs = 0012
003c 95      [2]          TSX
003d 6c03    [5]          INC    3,X
003f 2602    [3]          BNE   L43 ;abs = 0043
0041 6c02    [5]          INC    2,X
0043                L43:
0043 9efe03  [5]          LDHX  3,SP
0046 65ea60  [3]          CPHX  #-5536
0049 23c3    [3]          BLS   LE ;abs = 000e
16:          }
17:          }
18:
19:          PTED = 0xFF;
004b 6eff00  [4]          MOV    #-1,_PTED
004e 20b9    [3]          BRA    L9 ;abs = 0009
20:          } // loop forever
21:          // please make sure that you never leave main
22:          }
23:

```

Assembly lines generated for the MCF51QE128 MCU.

```

; 10:  SOPT1 = 0x23;          // Watchdog disable. Stop Mode Enable. Background Pin enable.
RESET pin enable
; 11:  for(;;) {
; 12:
;
0x00000004 0x7023          moveq   #35,d0
0x00000006 0x11C09802     move.b  d0,0xffff9802

```



```

;
; 13:  for (i=0; i<=60000; i++) {
;
0x0000000A 0x4280          clr.l    d0
0x0000000C 0x6016          bra.s   *+24          ; 0x00000024
;
; 14:  for (k=0; k<=100; k++) {
;
0x0000000E 0x4281          clr.l    d1
0x00000010 0x6008          bra.s   *+10         ; 0x0000001a
;
; 15:  buffer[k] = k;
;
0x00000012 0x41D7          lea     (a7),a0
0x00000014 0x21811C00     move.l  d1,(a0,d1.l*4)
;
; 16:  }
;
0x00000018 0x5281          addq.l  #1,d1
0x0000001A 0x0C8100000064     cmpi.l  #100,d1      ; '...d'
0x00000020 0x63F0          bls.s   *-14         ; 0x00000012
;
; 17:  }
; 18:
;
0x00000022 0x5280          addq.l  #1,d0
0x00000024 0x0C800000EA60     cmpi.l  #60000,d0   ; '...'
0x0000002A 0x63E2          bls.s   *-28         ; 0x0000000e
;
; 19:  PTED = 0xFF;
;
0x0000002C 0x103C00FF     move.b  #-1,d0      ; '.'
0x00000030 0x11C08008     move.b  d0,0xffff8008
;
; 20:  } /* loop forever */
;
0x00000034 0x60D4          bra.s   *-42         ; 0x0000000a
0x00000036 0x51FC          trapf

```

Table 2-8 shows the CPU cycles needed and the assembly lines code generated to complete the execution of the program described above. The used compiler for this test was CW 6.0 version and no optimization tool was used.

NOTE

This example is just a particular comparison and the performance between cores is not reflected with this example. The performance is application dependant.

Table 2-8. Comparison of CPU Cycles and Assembly Code Lines

	MCF51QE128	MC9S08QE128
Assembly lines code	18	43
CPU Cycles	49,201,507	407,947,991

2.3 Features Comparison

2.3.1 On-Chip Memory Comparison

Table 2-9. On-Chip Memory Comparison

MC9S08QE128	MCF51QE128
Peripheral register maps maintain relative addresses.	
Up to 8 Kb of random-access memory (RAM).	
FLASH read/program/erase over full operating voltage and temperature.	
Up to 128KB of FLASH, two FLASH arrays of 64Kb x 8-bits arranged in series. Two flash arrays allow for “read while write” programming.	Up to 128 KB of FLASH. Two FLASH arrays of 64 Kb x 8-bits arranged in parallel. FLASH “read while write” not supported.
Security circuitry to prevent unauthorized access to RAM and FLASH contents, default is secured when blank	Security circuitry to prevent unauthorized access to RAM and FLASH contents, default is unsecured when blank

2.3.2 Power-Saving Modes and Power-Saving Features Comparison

Table 2-10. Power-Saving mode Comparison

MC9S08QE128	MCF51QE128
Two very low power stop modes (Stop2 and Stop3).	
Low Power run (LPRun) and wait (LPWait) modes allow for use of peripherals in reduced-current and reduced-speed mode.	
Peripheral clock enable register can disable clocks to unused modules, thereby reducing currents.	
Very low power external oscillator that can be used in stop modes to provide accurate clock source RTC module.	
Very low power real time counter for use in run, wait, and stop modes with internal and external clock sources.	
6μs typical wake up time from stop modes.	
Reduced power wait mode (enabled by WAIT instruction).	Reduced power wait mode (enabled by setting WAIT bit in the SOPT1 register then executing STOP instruction).

2.3.3 Package Comparison

Table 2-11. Package Comparison

MC9S08QE128	MCF51QE128
Pin-to-pin compatible in 80-LQFP and 64-LQFP packages.	
Additional 48-QFN, 44-QFP and 32-LQFP packages.	No additional packages.

2.3.4 Clock Comparison

Table 2-12. Clock Comparison

MC9S08QE128	MCF51QE128
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 a frequency-locked-loop (FLL) controlled by internal or external reference. Precision trimming of internal reference allows 0.2% resolution and 2% deviation over temperature and voltage. Supports CPU frequencies from 2 MHz to 50 MHz	

2.3.5 System Comparison

Table 2-13. System Comparison

MC9S08QE128	MCF51QE128
Watchdog computer operating properly (COP) reset with option to run from dedicated 1 kHz internal clock source or bus clock.	
Low-voltage detection with reset or interrupt. Selectable trip points.	
Illegal opcode detection with reset.	
No illegal address reset, all addresses in maps are legal.	Illegal address detection with reset.
FLASH Block protection: protects in 1k increments. Protects array 0 first (from 0x0FFFF - 0x00000), then array 1 (from 0x1FFFF – 0x10000).	FLASH Block protection: protects in 2 k increments. Protects array from 0x00000 to 0x1FFFF.

2.3.6 Input/Output Comparison

Table 2-14. Input/Output Comparison

MC9S08QE128	MCF51QE128
70 GPIOs (general purpose input/output) and 1 input-only and 1 output-only pin.	
16 KBI (keyboard interrupts) with selectable polarity.	
Hysteresis and configurable pull up device on all input pins, configurable slew rate and drive strength on all output pins.	
SET/CLR registers on 16 pins (PTC and PTE).	
Rapid I/O not featured.	Selectable Rapid I/O supported on PTC and PTE ports.

2.3.7 Development Support Comparison

Table 2-15. Development Support Comparison

MC9S08QE128	MCF51QE128
Single-wire background debug interface. Same hardware Background Debug Mode (BDM) cable supports both devices.	
One version of CodeWarrior integrated development environment (IDE) and debugger supports both devices.	
CodeWarrior stationary, project wizard, initialization wizard and Processor Expert make C-code migration between devices easy.	
SET/CLR registers on 16 pins (PTC and PTE).	
Break point capability to allow single breakpoint setting during in-circuit debugging, plus three more breakpoints in on-chip debug module.	Integrated ColdFire DEBUG_Rev_B+ interface with single wire BDM connection supports the same electrical interface used by the S08 family debug modules.
On-chip in-circuit emulator (ICE) debug module containing three comparators and nine trigger modes. Eight deep FIFO for tracing change-of-flow addresses and event-only data. Debug module supports both tag and force breakpoints.	Classic ColdFire Debug B+ functionality mapped into the single-pin BDM interface. 64 deep FIFO for tracing processor status (PST) and debug data (DDATA). Real time debug support, with 6 hardware breakpoints, four PC, one address and one data, that can be configured into a 1 or 2 level trigger with a programmable response.

2.3.8 Peripherals Comparison

Table 2-16. Peripherals Comparison

MC9S08QE128	MCF51QE128
ADC – 24-Channel, 12-bit resolution, 2.5 μ s conversion time, automatic compare function, 1.7 mV/ $^{\circ}$ C temperature sensor, internal bandgap reference channel, operation in stop3, and fully functional from 3.6 V to 1.8 V.	
ACMPx – Two analog comparators with selectable interrupt on rising, falling, or either edge of comparator output, compare option to fixed internal bandgap reference voltage, and operation in stop3.	
SCIx – Two serial communications interface modules with optional 13-bit break.	
SPIx – Two serial peripheral interfaces with Full-duplex or single-wire bidirectional, double-buffered transmit and receive, Master or Slave mode, MSB-first or LSB-first shifting.	
IICx – Two IICs with up to 100 kbps with maximum bus loading, multi-master operation, programmable slave address, Interrupt driven byte-by-byte data transfer, supports broadcast mode and 10-bit addressing.	
TPMx – One 6-channel (TPM3) and two 3-channel (TPM1 and TPM2), selectable input capture, output compare, or buffered edge- aligned or center-aligned PWM on each channel, and operation in stop3.	
RTC – (Real time counter) 8-bit modules counter with binary or decimal based prescaler; external clock source for precise time base, time-of-day, calendar or task scheduling functions; Free running on-chip low power oscillator (1 kHz) for periodical wake-up without external components; runs in all MCU modes	

Chapter 3

How to Load the QRUG Examples?

3.1 Overview

This section describes the steps needed to download the firmware to flash. This shows the modules working in the hardware.

All the examples described in this document are developed using Code Warrior 6.0 version and can be changed in order to fit the application. To run these examples a Code Warrior version 6.0 and an Evaluation Board or a Demo board are needed in order to run these examples satisfactorily.

3.2 Steps to programming the MCU using Multilink

Follow these simple steps in order to load the QRUG examples and download it to the device. The explanation works for the EVB and Demo board.

1. Open CodeWarrior 6.0.
2. File -> Open, or click on the Open Icon as shown in [Figure 3-1](#).

How to Load the QRUG Examples?

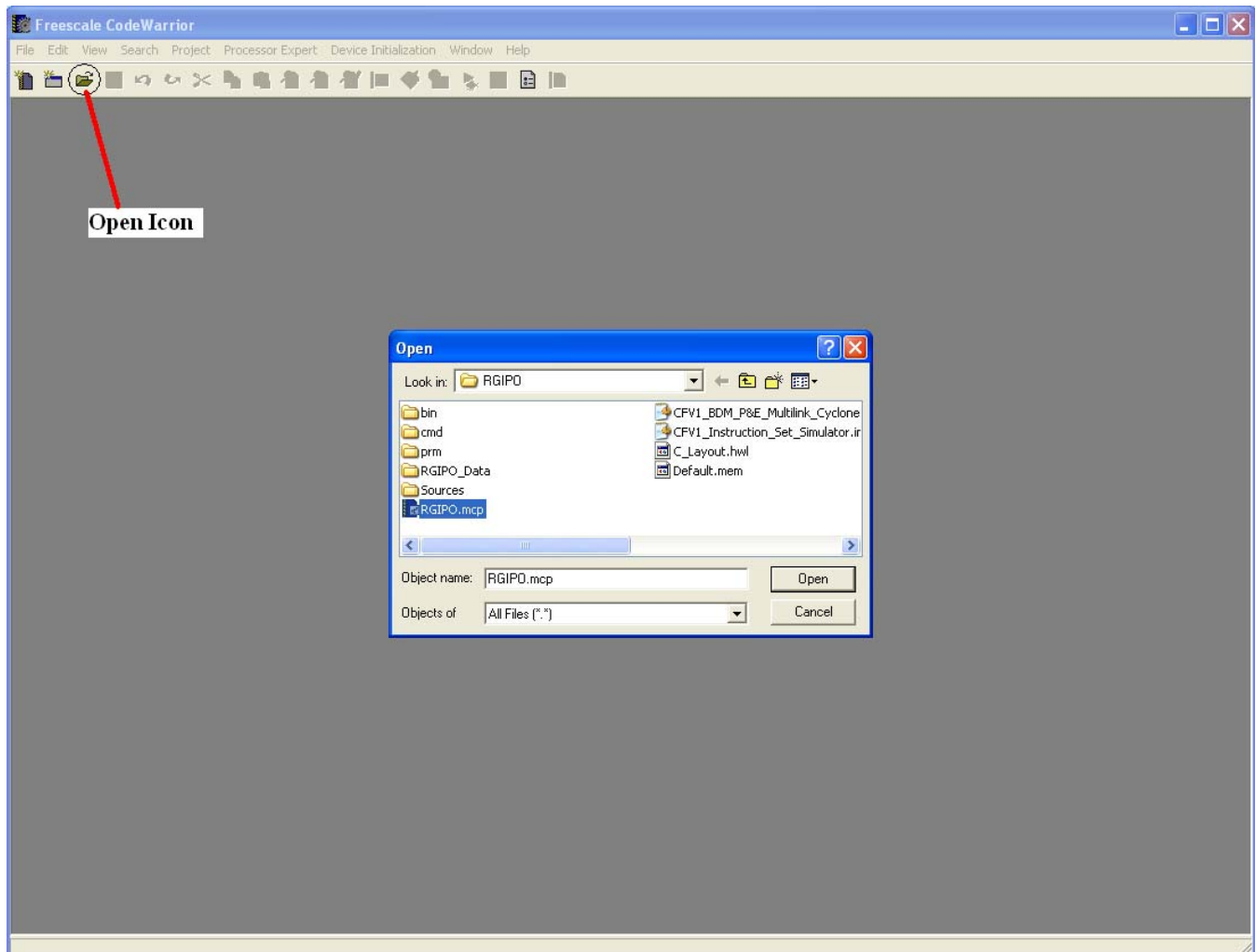


Figure 3-1. Open the Desired Project

3. Browse the desired project.
4. Double click on the .mcp extension file, in this case RGPIO.mcp.
5. To open the file double click on .c extension file (main.c).
6. On the left side of the window is a combo box. Select the P&E Multilink/Cyclone Pro option as shown in [Figure 3-2](#). The BDM multilink hardware for programming the MCU is needed when an EVB is used. This device is developed by PEmicro. If a demo board is used do not buy a multilink.

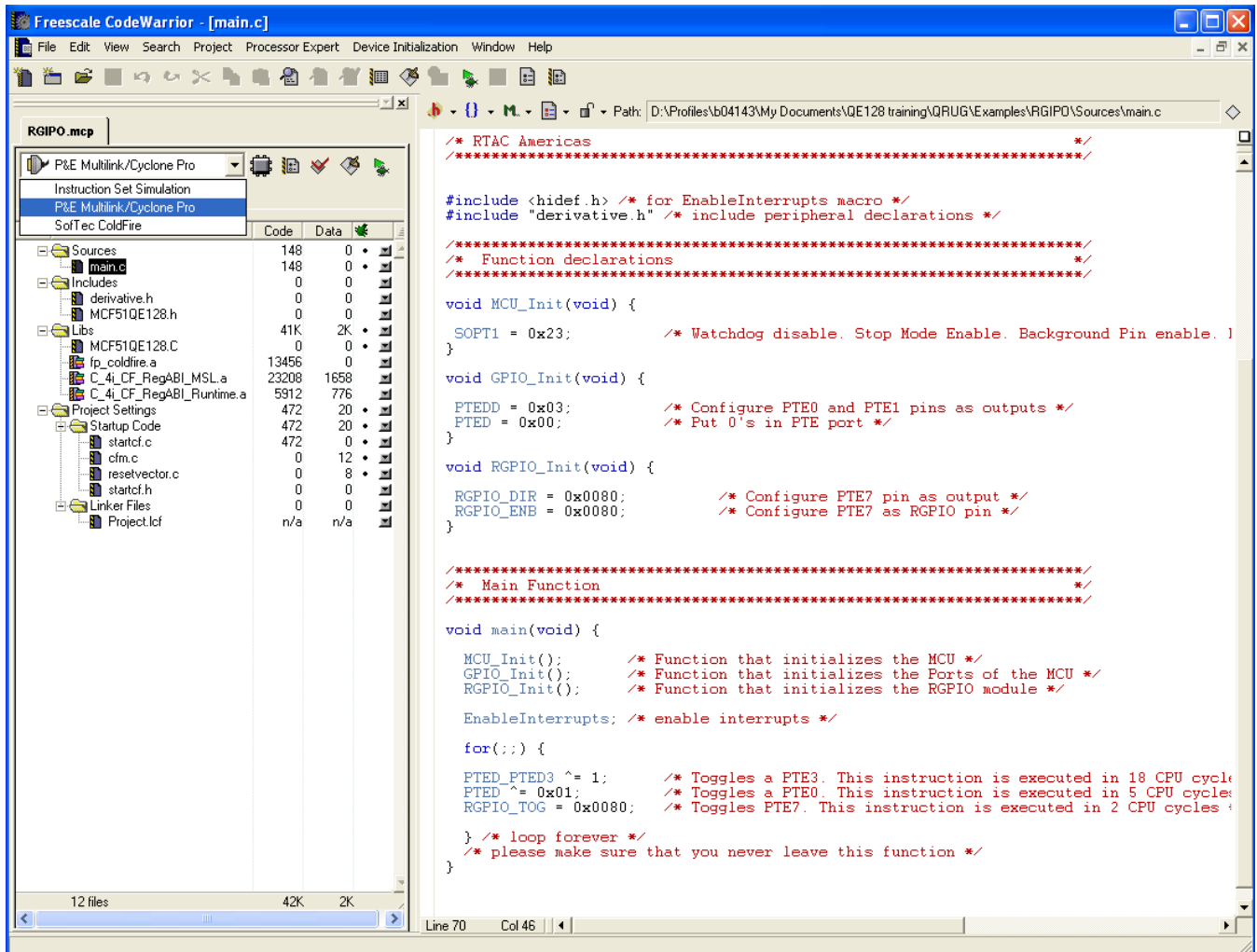


Figure 3-2. Select the Correct Option in the Combo Box

7. There are three different ways to compile the project. Click on the make icon, beside the combo box, as shown in [Figure 3-3](#). The make command can be accessed from the Project menu, -> Make, or just press F7 key on your keyboard.
8. No errors should show up.
9. Project -> Debug. Click on the debug icon beside the make icon, or just press F5 on the keyboard. Doing this launches the debugger and downloads the program to the MCU flash.

How to Load the QRUG Examples?

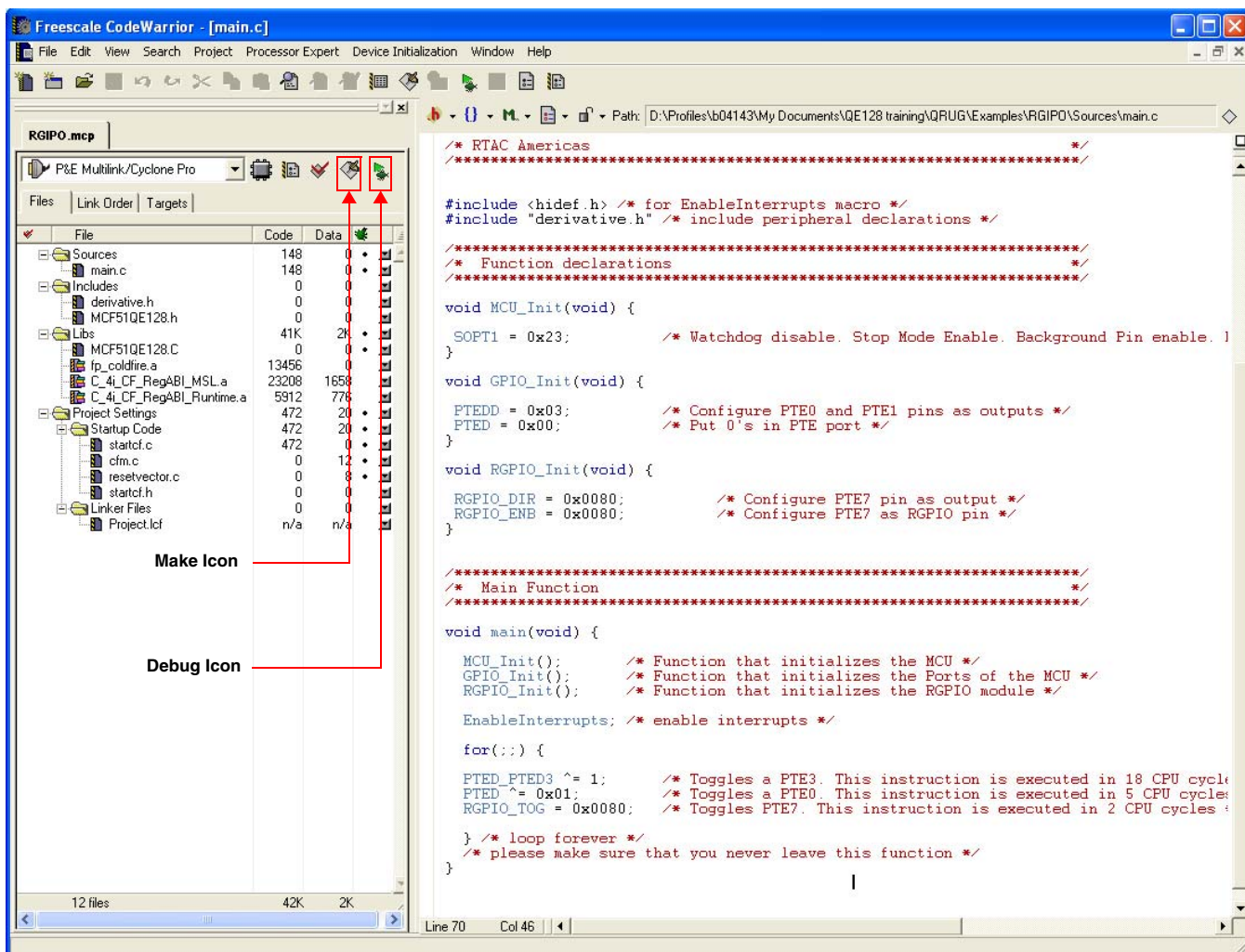


Figure 3-3. Make Icon and Debug Icon

10. After the debug command is executed a window pops up (see Figure 3-4). Click on the Connect option.

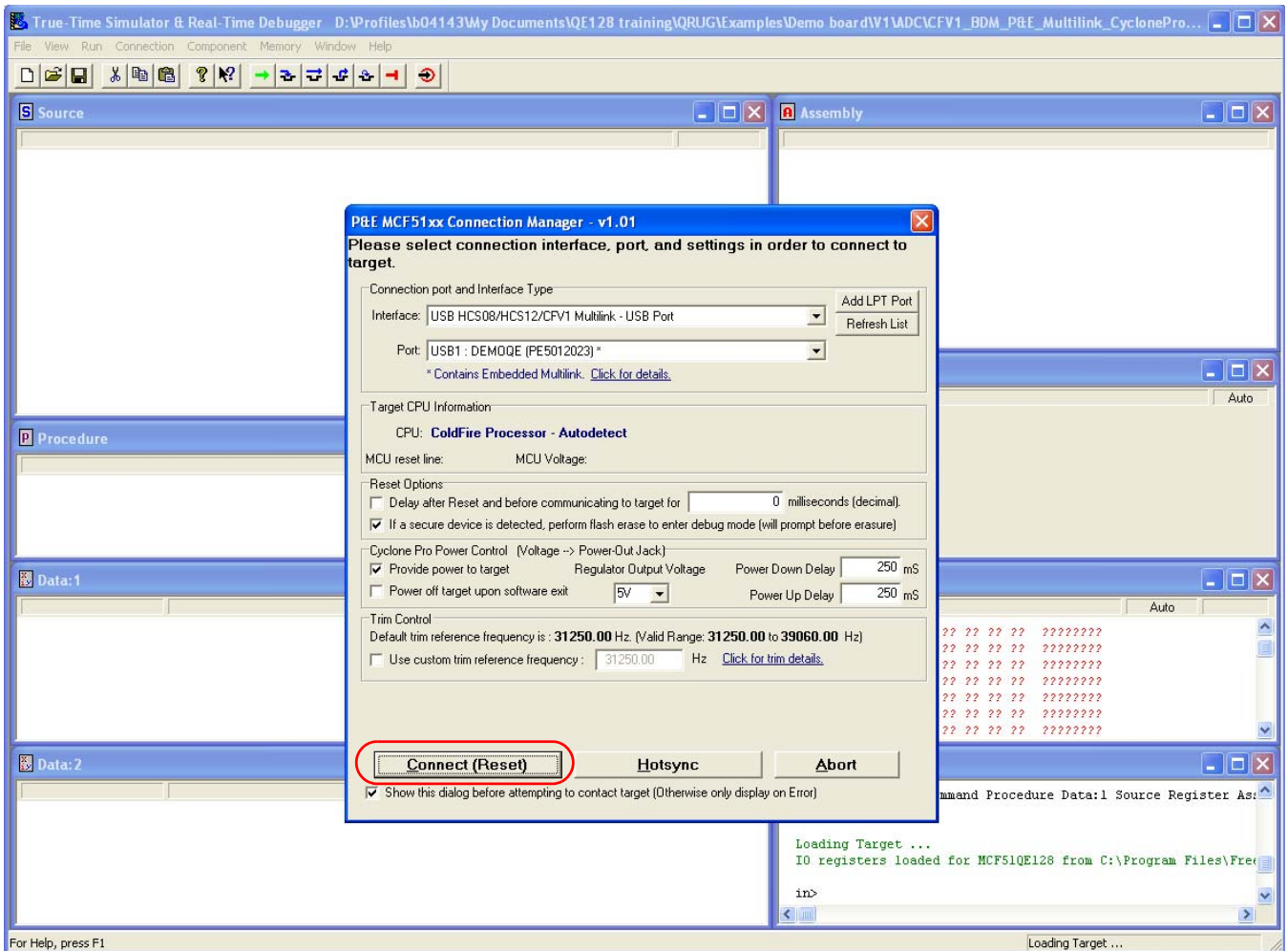


Figure 3-4. Connect Option

11. If a window appears asking to erase and program flash, click Yes.
12. The True-time simulator window appears on your screen. In this window debug the projects, review the registers and memory in real time.
13. Click on the run button as shown in Figure 3-5. This figure shows the true-time simulator window or debugger window. This makes the MCU start to execute the project.

How to Load the QRUG Examples?

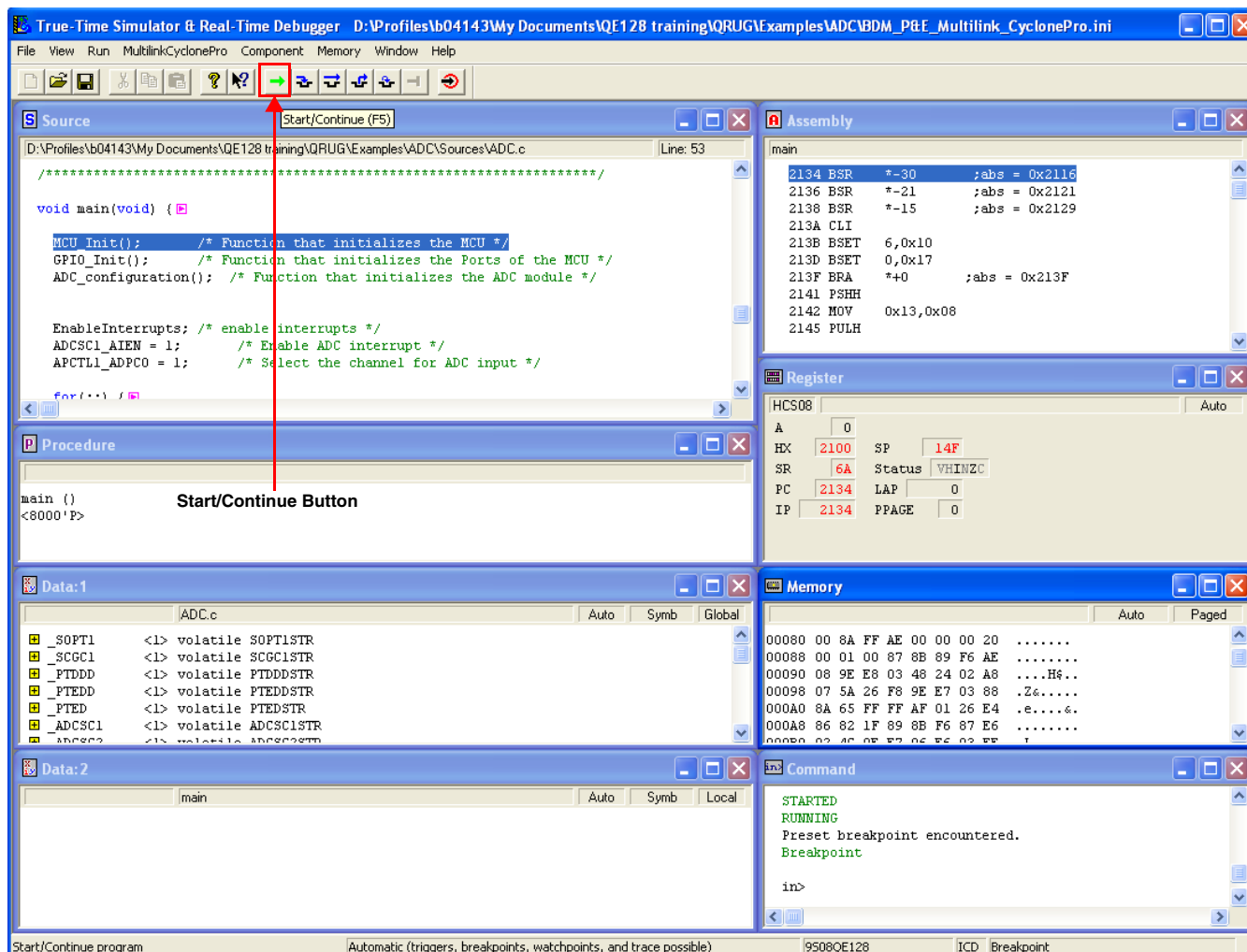


Figure 3-5. Run/Continue Icon

3.3 Steps to programming the MCU Using In-Circuit BDM

Follow these simple steps in order to load the QRUG examples and download it to the device. The explanation works for EVB only.

1. Open CodeWarrior 6.0.
2. File -> Open, or click on the Open Icon as shown in [Figure 3-6](#).

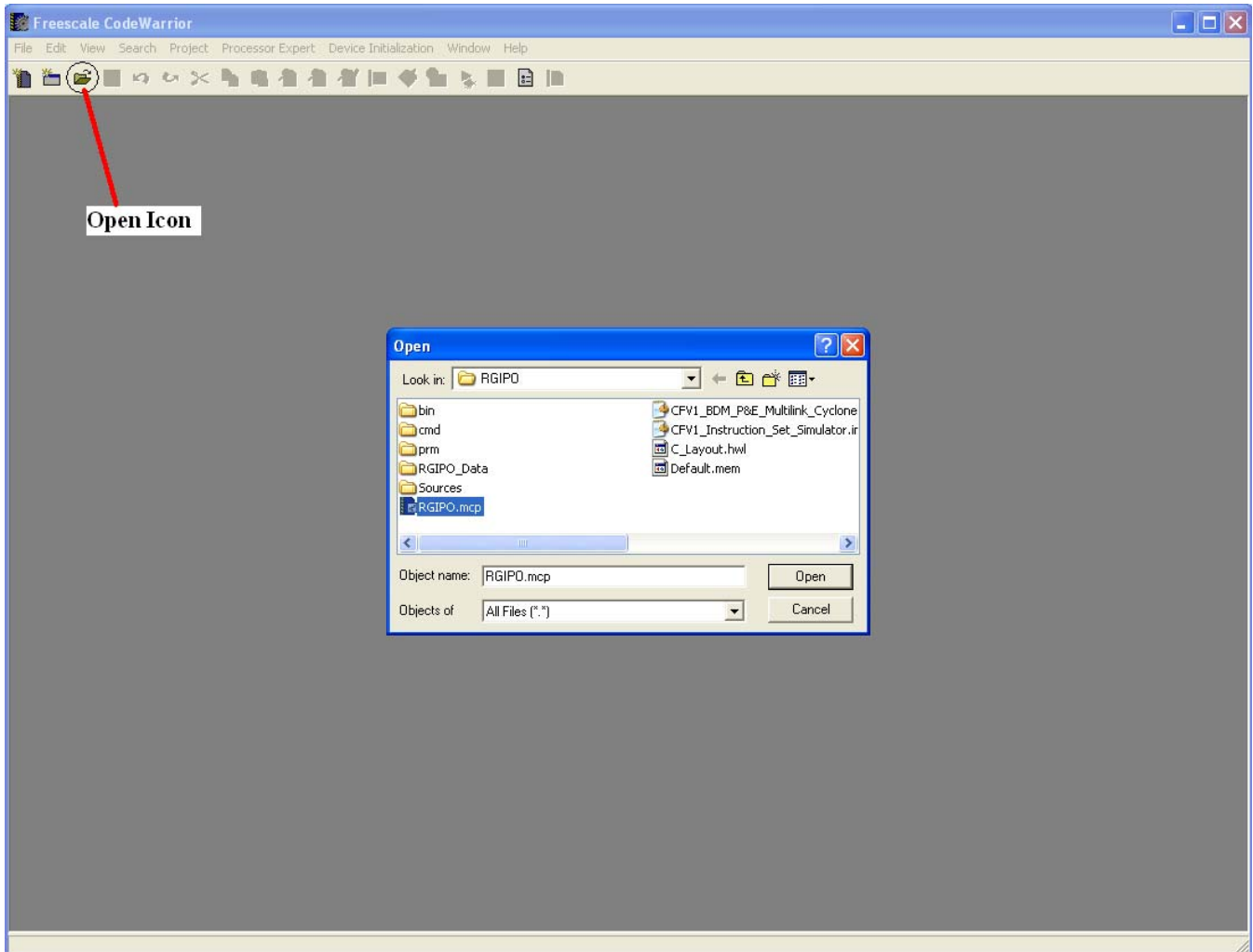


Figure 3-6. Open the Desired Project

3. Browse the desired project.
4. Double click on the .mcp extension file, in this case RGPIO.mcp.
5. To open the file, double click on .c extension file (main.c).
6. On the left side of the window is a combo box. Select the SofTec option as shown in [Figure 3-7](#).

How to Load the QRUG Examples?

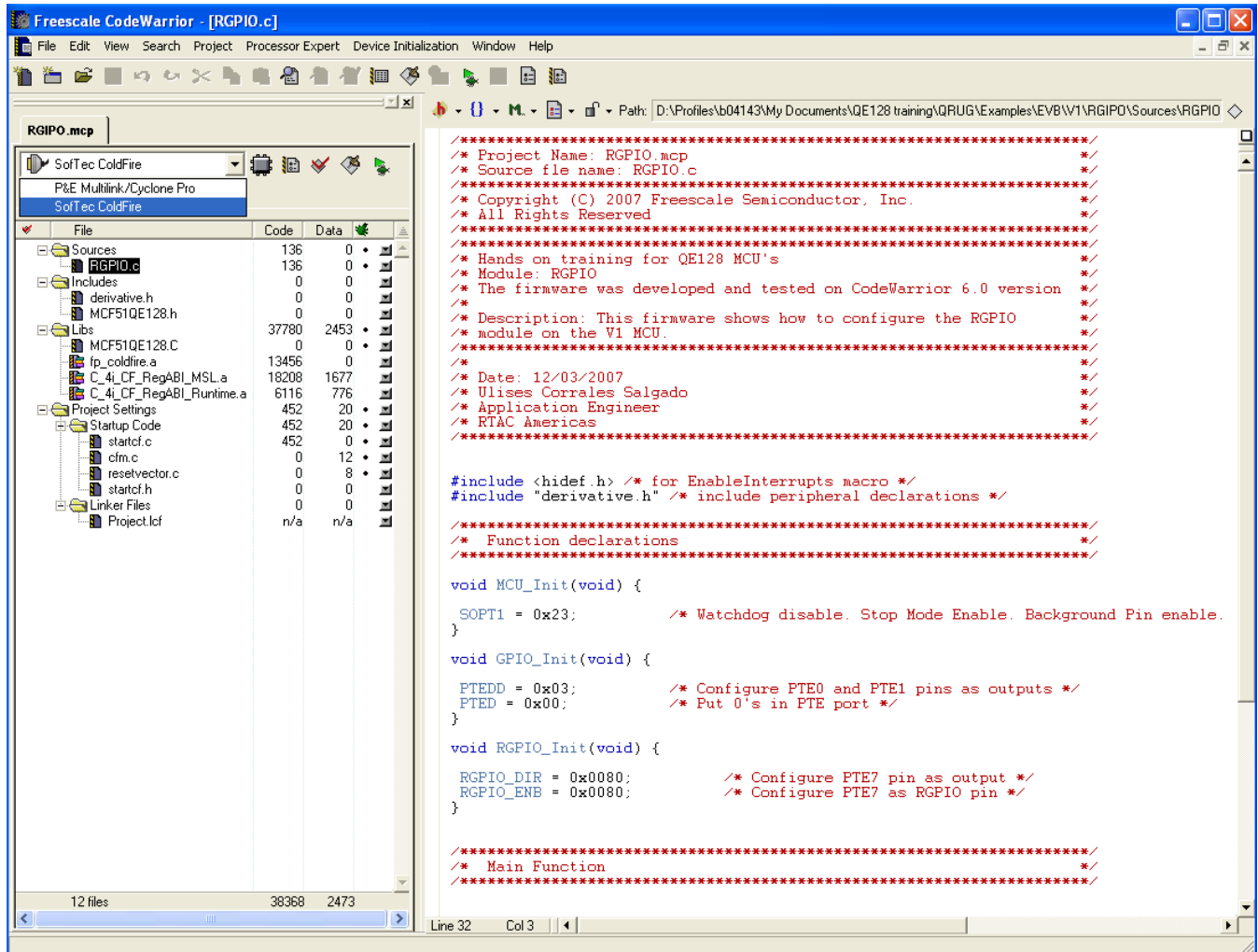


Figure 3-7. Select the Correct Option in the Combo Box

7. There are three different ways to compile the project.
8. Click on the make icon, beside the combo box, as shown in [Figure 3-8](#). The make command can be accessed from the Project menu, -> Make, or just press F7 key on your keyboard.
9. No errors show up.
10. Project -> Debug. Also click on the debug icon beside the make icon, or just press F5 on the keyboard. Doing this launches the debugger and downloads the program to the MCU flash.

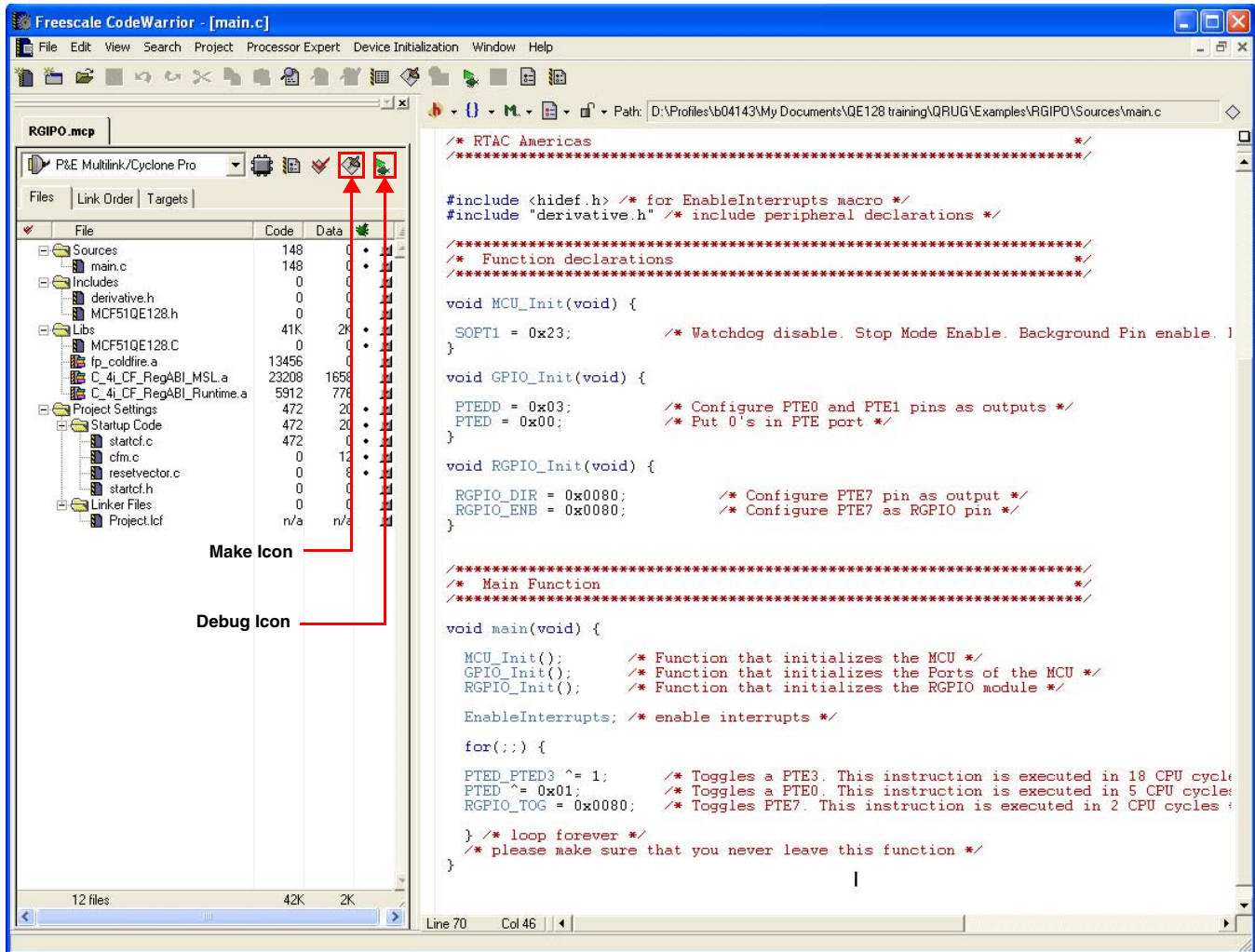


Figure 3-8. Make Icon and Debug Icon

11. After the debug command is executed a window pops up (see Figure 3-9), select the EVBQE128 hardware model and then click on the Connect option.

How to Load the QRUG Examples?

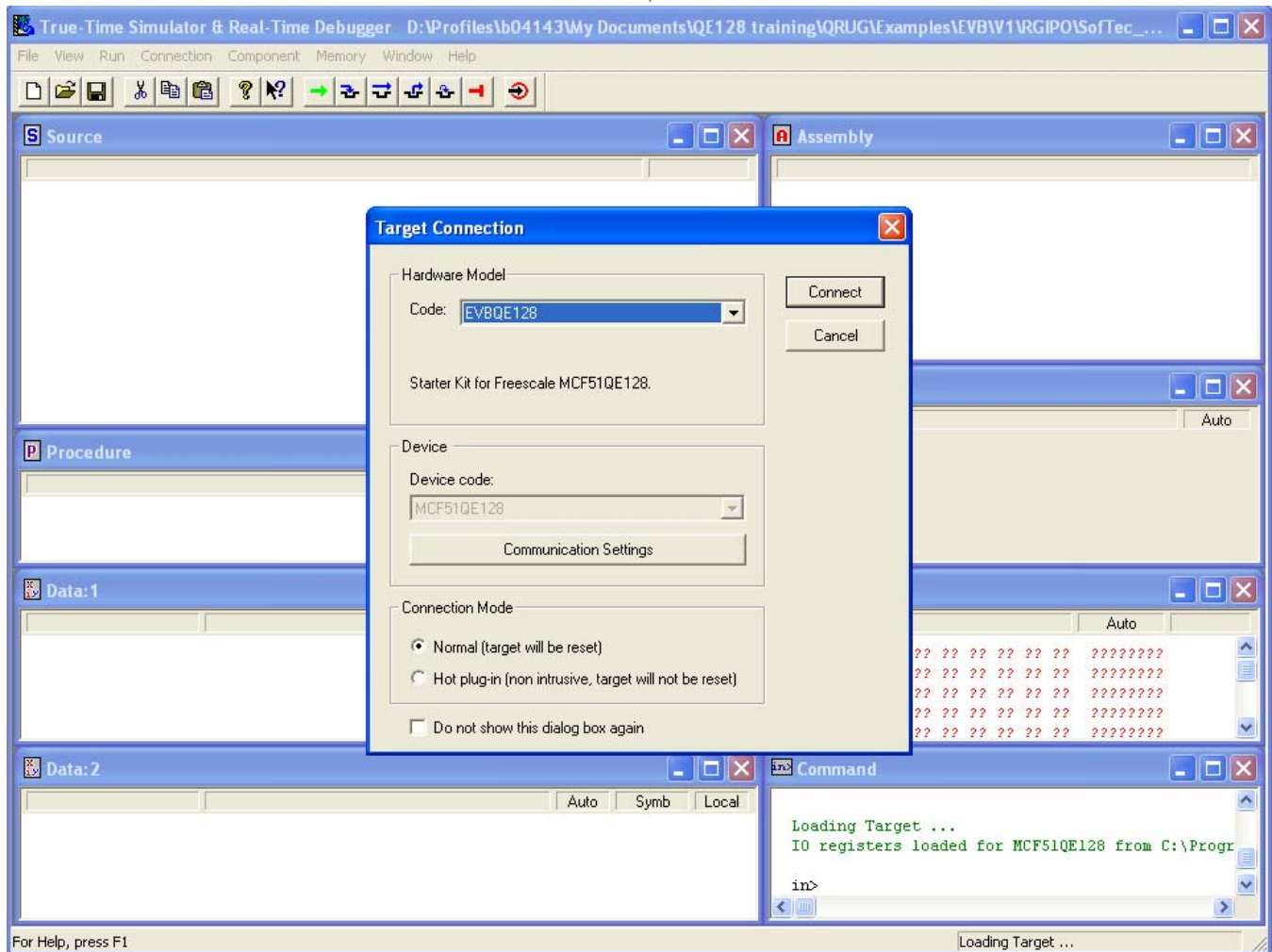


Figure 3-9. Connect Option

12. A new window may appear asking to erase and program flash, click Yes.
13. The True-time simulator window appears on the screen. In this window debug the projects, review the registers and memory in real time.
14. Click on the run button as shown in [Figure 3-10](#). This figure shows the true-time simulator window or debugger window. This makes the MCU start to execute the project.

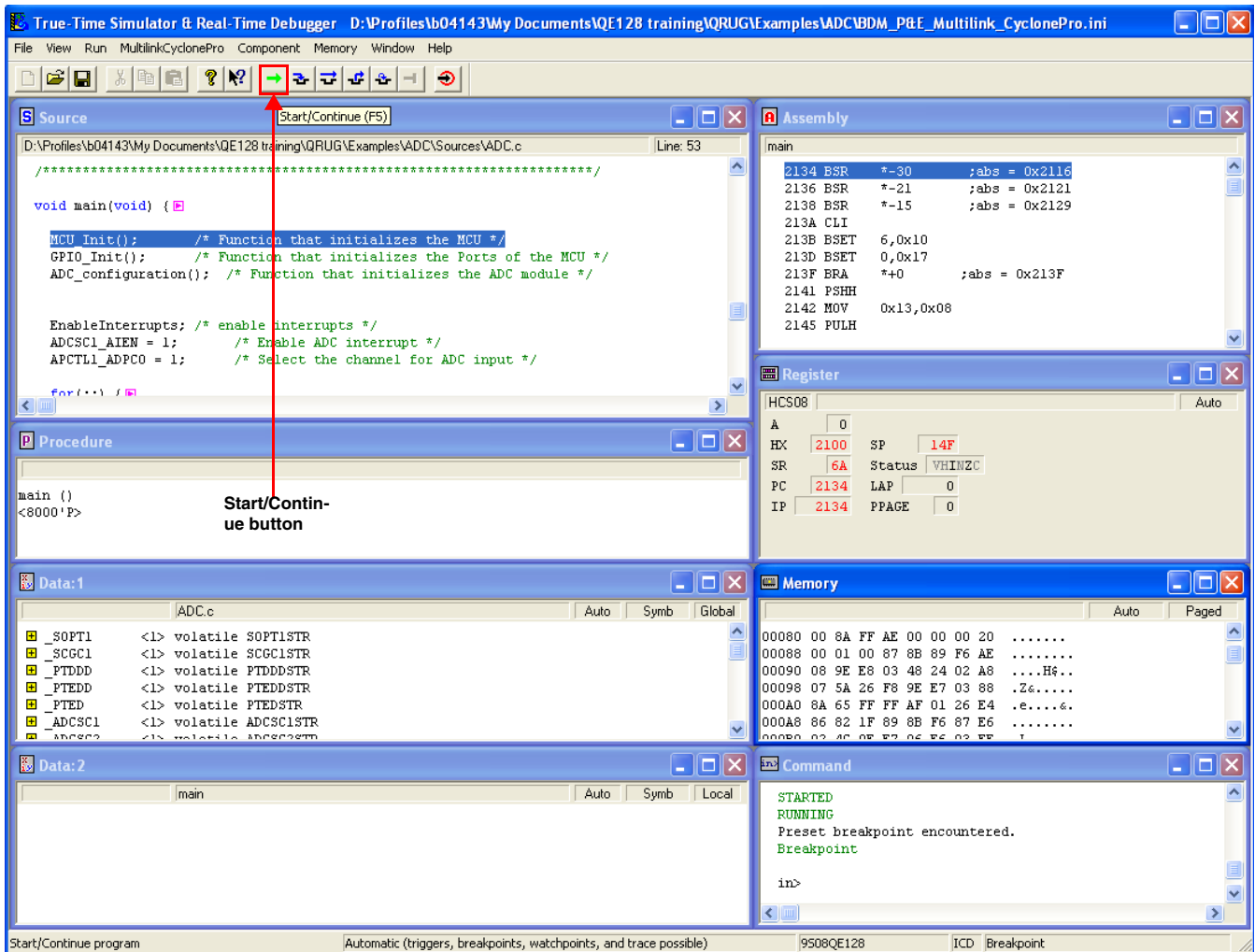


Figure 3-10. Run/Continue Icon

Chapter 4

Using the Keyboard Interrupt (KBI) for the QE Microcontrollers

4.1 Overview

This is a quick reference for using the keyboard interrupt (KBI) module for the QE family microcontrollers (MCUs). Basic information about the functional description and configuration options are provided.

The following example may be modified to suit an application. The KBI project is made for the MC9S08QE128 and MCF51QE128 MCUs.

KBI Quick Reference

Because there is more than one KBI module on this device, there may be more than one full set of registers on your device. In the register name below, where there's a small x, there would be a 1 or a 2 in your software to distinguish the register that is on KBI1 from KBI2.

KBIxSC					KBF	KBACK	KBIE	KBMOD
--------	--	--	--	--	-----	-------	------	-------

Module Configuration

KBF – set when event occurs

KBACK – clears KBF

KBIE – interrupt enable

KBMOD – mode select

KBIxPE	KBIPE7	KBIPE6	KBIPE5	KBIPE4	KBIPE3	KBIPE2	KBIPE1	KBIPE0
--------	--------	--------	--------	--------	--------	--------	--------	--------

KBI Pin Enable

KBIPE[7:0] — enables and disables each port pin to operate as a keyboard interrupt pin.

KBIxES	KBEDG7	KBEDG6	KBEDG5	KBEDG4	KBEDG3	KBEDG2	KBEDG1	KBEDG0
--------	--------	--------	--------	--------	--------	--------	--------	--------

KBI Pin Enable

KBEDG[7:0] – determines the polarity edge that is recognized as a trigger event for the corresponding pin.

4.2 KBI project for EVB

4.2.1 Code example and explanation

This example code is available from the Freescale Web site www.freescale.com

In this application, four of the KBI pins are used to trigger an interrupt routine that toggles an LED every time a keyboard event is detected. The MCU is programmed to:

- Have four KBI pins (PTD4, PTD5, PTD6 and PTD7), as the interrupt trigger.
- Detect falling edges only on the selected pins
- Generate a hardware interrupt where the LED toggle routine is serviced.

The functions for KBI.mcp project are:

- main – Endless loop waiting for a KBI interrupt.
- MCU_Init – MCU initialization, watchdog disable and the KBI clock module enabled.
- GPIO_Init – Configure PTE0 pin as output.
- KBI_Init – KBI module configuration.
- KBI_ISR – routine that toggles an LED every time an interrupt is generated.

The code below executes the instructions to disable the watchdog, enable the Reset option and background pin. The System Option Register 1 (SOPT1) is used to configure the MCU. The SCGC1 and SCGC2 are registers used for power saving consumption, here the bus clock to peripherals can be enabled or disabled. In this example only the bus clock to the KBI module is active. The clocks to the other peripherals are disabled.

```
void MCU_Init(void) {
    SOPT1 = 0x23;           // Watchdog disable. Stop Mode Enable. Background Pin
                          // enable. RESET pin enable
    SCGC1 = 0x00;         // Disable Bus clock to unused peripherals
    SCGC2 = 0x10;         // Bus Clock to the KBI module is enabled
}
```

This is the General Purpose Input/Output configuration. These code lines configure the direction for the PTE port. Eight LEDs from the EVB are connected to the PTE port. The PTE0 is configured as output in order to drive a LED.

```
void GPIO_Init(void) {
    PTEDD = 0x01;         // Configure PTE0 pin as output
    PTED = 0x00;         // Put 0's in PTE port
}
```

This is the initialization code for the keyboard interrupt using the QE128 MCU. For this example, both KBI registers (KBIxSC and KBIxPE) are used to configure the module to detect only falling edges and enable PTD4 to PTD7 as KBI. During the initialization phase the interrupts are masked. It takes time for the internal pull up to reach a '1' logic value. After the false interrupts are cleared, the keyboard interrupt is unmasked.

```
void KBI_Init(void) {
    KBI2SC = 0x06;        // KBI interrupt request enabled. Detects edges only
    KBI2PE = 0xF0;        // PTD4, PTD5, PTD6 and PTD7 enabled as Keyboard interrupts
    KBI2ES = 0x00;        // Pins detects falling edge
}
```

This is the main function, above are the described called functions, and all the interrupts are enabled. After this the keyboard interrupt can be serviced.

```
void main(void) {
    MCU_Init();           // Function that initializes the MCU
}
```

```
GPIO_Init();           // Function that initializes the Ports of the MCU
KBI_Init();           // Function that initializes the KBI module

EnableInterrupts;     // enable interrupts
for(;;) {

}                       // loop forever
                       // please make sure that you never leave this function
}
```

NOTE

This is the KBI service routine. Every time an interrupt is detected this routine toggles a LED. The VectorNumber_Vkeyboard can be replaced by the interrupt vector number. This depends, if the MCU is a 9S08 or V1. Using this example makes the code fully compatible for either MCU.

```
void interrupt VectorNumber_keyboard KBI_ISR(void) {
    // KBI interrupt vector number = 18 (S08)
    // KBI interrupt vector number = 80 (V1)
    KBI2SC_KBACK = 1; // Clear the KBI interrupt flag
    PTED_PTED0 ^= 1; // Toggles PTE0
}
```

4.2.2 Hardware Implementation

This project is developed using the EVBQE128 STARTER KIT and can be downloaded at www.freescale.com. No extra hardware is needed.

If the use of other KBI pins are required, extra hardware is easy to install. A push button, a resistor and a capacitor are used to build the circuit. Figure 4-1 shows the hardware configuration.

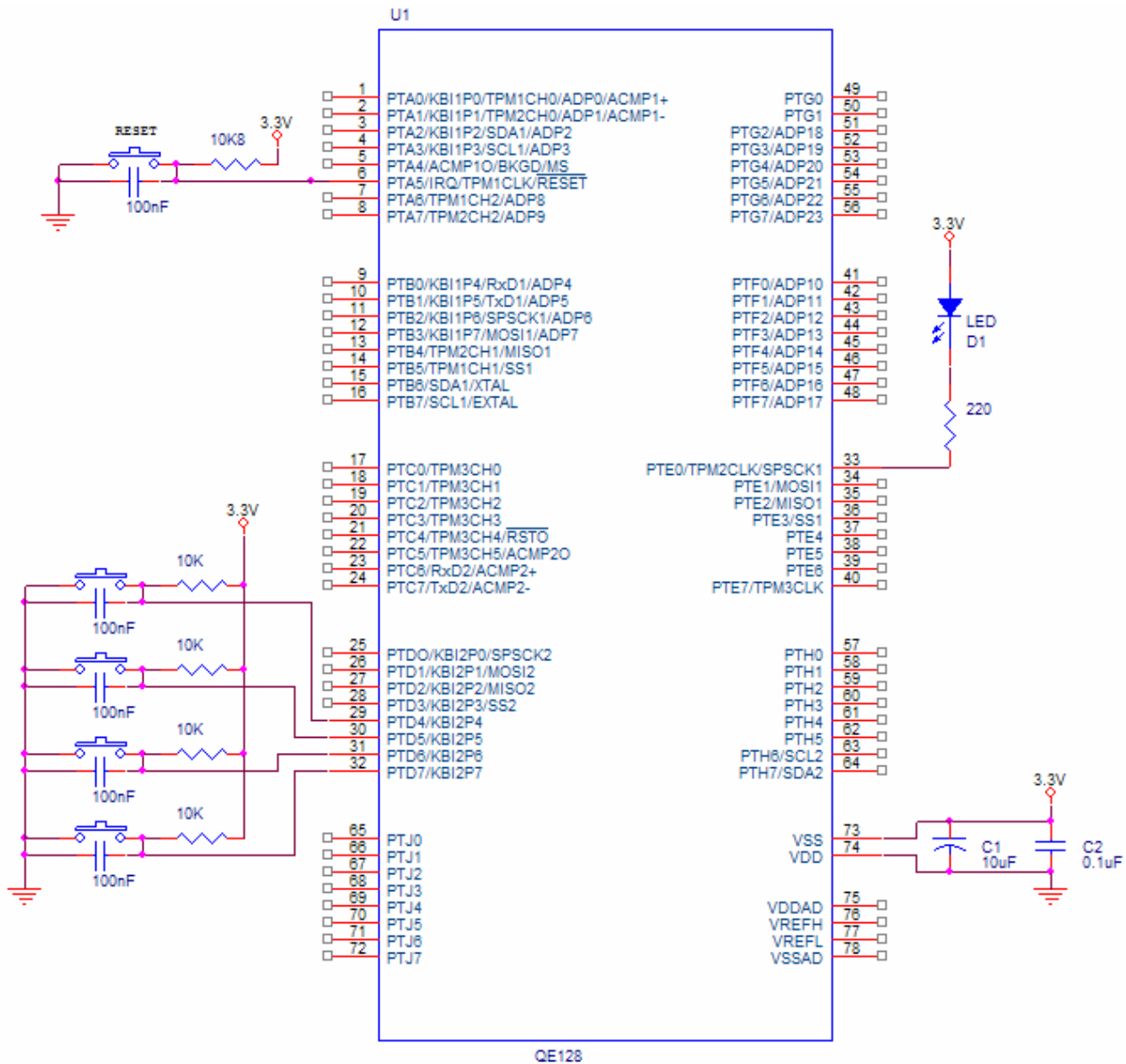


Figure 4-1. EVB KBI Hardware Implementation

NOTE

This example is developed using the CodeWarrior IDE version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (80-pin package). There may be changes needed in the code to initialize another MCU.

Figure 4-1, shows hardware connections used for the KBI project. For detailed information about the MCU supply voltages needed, please refer to the Pins and Connections chapter in the Reference Manual (MC9S08QE128 or MCF51QE128). It can also be found at www.freescale.com.

4.3 KBI project for Demo board

4.3.1 Code example and explanation

This example code is available from the Freescale Web site www.freescale.com.

This section explains the differences of the codes used in EVB and the Demo board. The codes are the same.

The functions for KBI.mcp project are:

- main – Endless loop waiting for a KBI interrupt.
- MCU_Init – MCU initialization, watchdog disable and the KBI clock module enabled.
- GPIO_Init – Enables internal pull-ups. Configures PTC0 pin as output.
- KBI_Init – KBI module configuration.
- KBI_ISR – routine that toggles a LED every time an interrupt is generated.

This is the General Purpose Input/Output configuration. These code lines configure the direction for the PTC port. Only six LEDs from the demo board are connected to the PTC port. The other two LEDs are connected to the E port. In this example only PTC0 is configured as output in order to drive a LED. The demo board does not count with any pull-ups; therefore the internal pull-up is enabled for the PTA2 and PTA3 pins.

```
void GPIO_Init(void) {
    PTAPE = 0x0C;           // Enable PTA2 and PTA3 pins Internal Pullups
    PTCDD = 0x01;           // Configure PTC0 pin as output
    PTC0 = 0x01;           // Put 0's in PTC0 pin
}
```

This is the initialization code for the keyboard interrupt using the QE128 MCU. For this example, both KBI registers (KBIxSC and KBIxPE) are used to configure the module to detect only falling edges and enable PTA2 and PTA3 as KBI. During the initialization phase, the interrupts are masked. It takes time for the internal pull up to reach a '1' logic value. After the false interrupts are cleared, the keyboard interrupt is unmasked.

```
void KBI_Init(void) {
    KBI1SC = 0x06;          // KBI interrupt request enabled. Detects edges only
    KBI1PE = 0x0C;          // PTA2 and PTA3 enabled as Keyboard interrupts
    KBI1ES = 0x00;          // Pins detects falling edge
}
```

NOTE

This is the keyboard interrupt service routine. Every time an interrupt is detected this routine toggles a LED. The VectorNumber_Vkeyboard can be replaced by the interrupt vector number, this depends if the MCU is a 9S08 or V1. Using this example makes the code fully compatible for either MCU.

```
void interrupt VectorNumber_Vkeyboard KBI_ISR(void) {  
KBI1SC_KBACK = 1;           // Clear the KBI interrupt flag  
PTCD_PTC0 ^= 1;           // Toggles PTC0  
}
```

4.3.2 Hardware Implementation

This project was developed using the DEMOQE board. No extra hardware is needed.

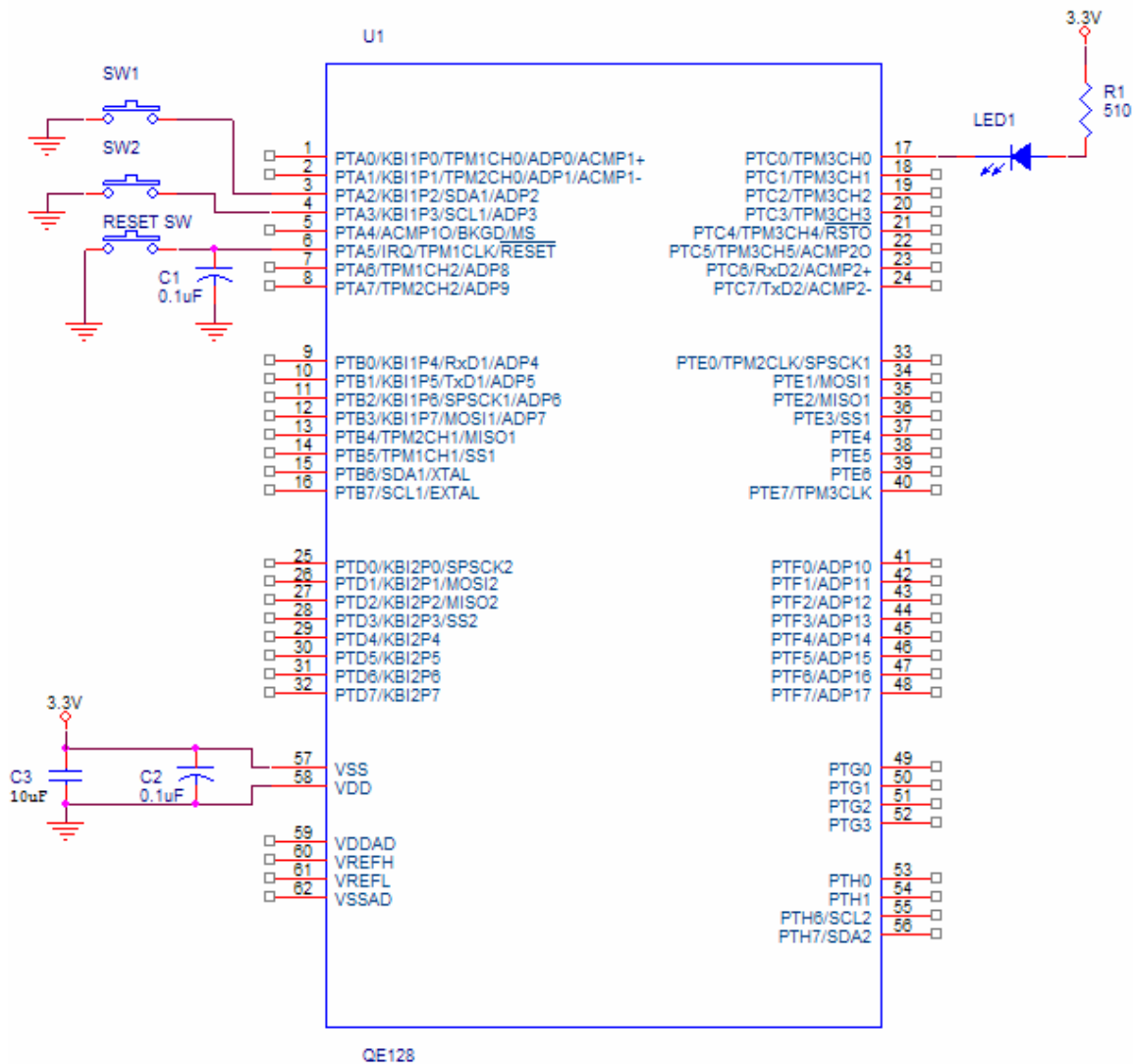


Figure 4-2. Demo Board KBI Hardware Implementation.

NOTE

This example is developed using the CodeWarrior IDE version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (64-pin package). There may be changes needed in the code to initialize another MCU.

Figure 4-2, shows the hardware connections used for the KBI project, for detailed information about the MCU supply voltages needed, please refer to the Pins and Connections chapter in the Reference Manual (MC9S08QE128 or MCF51QE128). It can also be found at www.freescale.com.



Chapter 5

Using the Internal Clock Source (ICS) for the QE Microcontrollers

5.1 Overview

This is a quick reference for using the internal source clock (ICS) module for the QE family microcontrollers (MCUs). Basic information about the functional description and configuration options are provided. The following example may be modified to suit an application. The ICS project is made for the MC9S08QE128 and MCF51QE128 MCUs.

ICS Quick Reference

ICS1	CLKS	RDIV	IREFS	IRCLKEN	IREFSTEN
------	------	------	-------	---------	----------

Module Configuration:

CLKS - Clock Source Select
 RDIV - Reference Divider
 IREFS - Internal Reference Select

IRCLKEN - Internal Reference Clock Enable
 IREFSTEN - Internal Reference Stop Enable

ICS2	BDIV	RANGE	HGO	LP	EREFS	ERCLKEN	EREFSTEN
------	------	-------	-----	----	-------	---------	----------

Module Configuration:

BDIV - Bus Frequency Divider
 RANGE - Frequency Range Select
 HGO - High Gain Oscillator Select
 LP - Low Power Select

EREFS - External Reference Select
 ERCLKEN - External Reference Enable
 EREFSTEN - External Reference Stop Enable

ICSRM	TRIM
-------	------

Internal oscillator trim value: higher value = slower frequency

ICSSC	DRST/DRS	DMX32	IREFST	CLKST	OSCINIT	FTRIM
-------	----------	-------	--------	-------	---------	-------

Module Status:

DRST - DCO Range Status / DRS - DCO Range Select
 DMX32 - DCO Maximum frequency with 32.768 kHz reference
 IREFST - Internal Reference Status

CLKST - Clock Mode Status
 OSCINIT - OSC Initialization
 FTRIM - ICS Fine Trim

5.2 Code Example and Explanation

The project ICS.mcp shows how to configure the ICS module for the QE family MCUs. The main functions are:

- main — Endless loop toggling a LED.
- MCU_Init – MCU initialization, watchdog disable.
- GPIO_Init – Configure PTE0 pin as output.

- ICS_Init – ICS module configuration

This example configures one of six modes of operation for the ICS module.

These are the four definitions used in the ICS code source. You need to uncomment the desired mode and compile the project. This makes the MCU work with the selected clock source. For example to configure the ICS in FEE mode just delete the two slashes at the beginning of the define.

```

//#define FEI // Configure bus clock to run at 25 MHz in FEI mode.
//#define FEE // Configure bus clock to run at 2 MHz in FEE mode.
//#define FBI // Configure bus clock to run at low frequency in FBI mode.
//#define FBE // Configure bus clock to run at low frequency in FBE mode.

```

The code below executes the instructions to disable the watchdog, enable the Reset option and background pin. The System Option Register 1 (SOPT1) is used to configure the MCU. The SCGC1 and SCGC2 are registers used for power saving consumption, here the bus clock to peripherals can be enabled or disabled. The clocks to the other peripherals are disabled.

```

void MCU_Init(void) {
SOPT1 = 0x23;          // Watchdog disabled. Stop Mode Enabled. Background Pin
                        // enabled. RESET pin enabled.
SCGC1 = 0x20;         // Bus to TPM1 peripheral is enabled.
SCGC2 = 0x00;         // All clocks to peripherals are disabled.
}

```

This is the General Purpose Input/Output configuration. These code lines configure the directions for the PTE port. Only one LED is connected to the PTE port; therefore the PTE0 pin is configured as output.

```

void GPIO_Init(void) {
PTEDD = 0x01;         // Configure PTE port as output
PTED = 0x00;         // Put 0's in PTE port
}

```

This is the initialization code for the internal source clock used for the QE MCU. This application configures the MCU in one of six modes of the ICS module.

```

void ICS_Init(void) {
#ifdef FEI
ICSC1 = 0x04; // Output of FLL is selected and Internal Reference Selected
ICSC2 = 0x00; // Bus frequency divided by 1
ICSTRM = *(unsigned char*far)0xFFAF; // Initialize ICSTRM register from a non volatile memory
ICSSC = *(unsigned char*far)0xFFAE | 0xA0; /* Initialize ICSSC register from a non volatile
memory */
#endif
#ifdef FEE
ICSC1 = 0x00; // Output of FLL is selected
ICSC2 = 0x87; // Divides selected clock by 4. External reference is selected
ICSSC = 0x00; // Initialize ICSSC register from a non volatile memory
#endif
#ifdef FBE
ICSC1 = 0xB8; // External reference clock selected. External reference divided by 5
ICSC2 = 0x00; // Bus frequency divided by 1
ICSSC = 0x00; // Initialize ICSSC register from a non volatile memory
#endif
#ifdef FBI
ICSC1 = 0x40; // Internal reference clock is selected
ICSC2 = 0x00; // Divides selected clock by 1

```

```
ICSSC = (*(unsigned char*far)0xFFAE) | 0x00; /* Initialize ICSSC register from a non volatile
memory */
ICSTRM = *(unsigned char*far)0xFFAF; // Initialize ICSTRM register from a non volatile memory
#endif FBI
}
```

This is the main function, above are the described called functions, and the interrupts are all enabled. The ICS_configuration function configures the MCU in the selected clock mode. The clock frequency can be seen on the PTE0 pin.

```
void main(void) {
    MCU_Init();           // Function that initializes the MCU
    GPIO_Init();         // Function that initializes the Ports of the MCU
    ICS_Init();          // Function that initializes the ICS module
    EnableInterrupts;    // interrupts are enabled
    for(;;) {
        PTED_PTED0 ^= 1; // Toggle PTE0
        Delay ();
    }                    // loop forever
                        // please make sure that you never leave this function
}
```

The Bus frequency can be checked in the True-Time Simulator window of CodeWarrior. Once the program is downloaded to the MCU, the simulator window opens, look at the command window and notice the MCU bus frequency change. See [Figure 5-1](#), for detailed information.

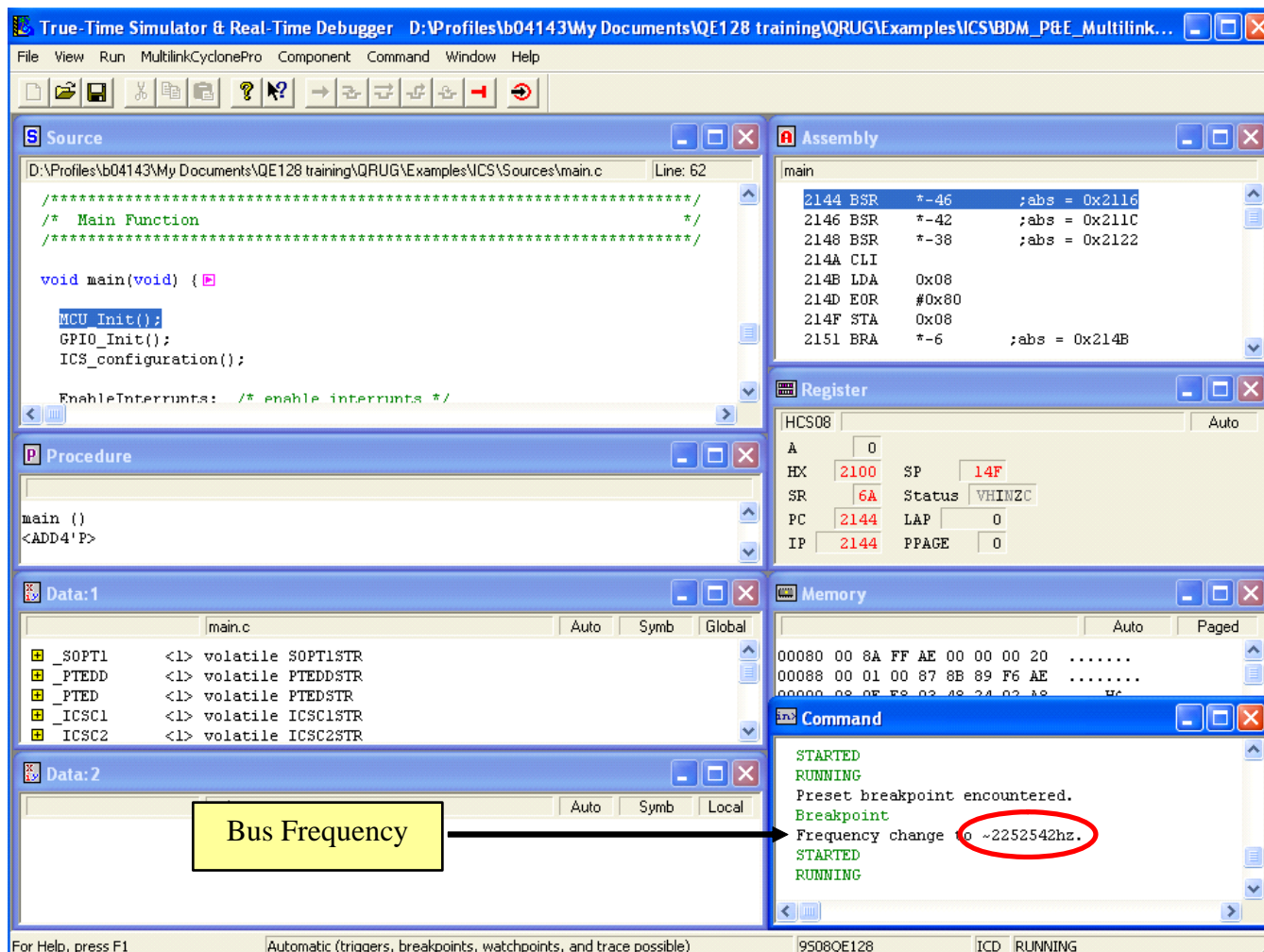


Figure 5-1. Bus Frequency

NOTE

The bus frequency shown in the command window is not always right. The following code is used to check the frequency using an oscilloscope in the TPM1CH0 pin of the MCU. The obtained frequency is the bus frequency divided by 1000.

```
void BUSCLK_DividedBy1000(void) {
    TPM1SC = 0x08;    // TPM1 clock source = Bus clock
    TPM1COSC = 0x28; // PWM is edge-aligned. PWM toggles from high to low
    TPM1MOD = 1000;  // PWM period = bus clock / 1000
    TPM1COV = 500;   // PWM duty cycle = 50%
}
```

5.3 Hardware Implementation

This project is developed using the EVBQE128 STARTER KIT. No extra hardware is needed. Figure 5-2 shows the hardware configuration.

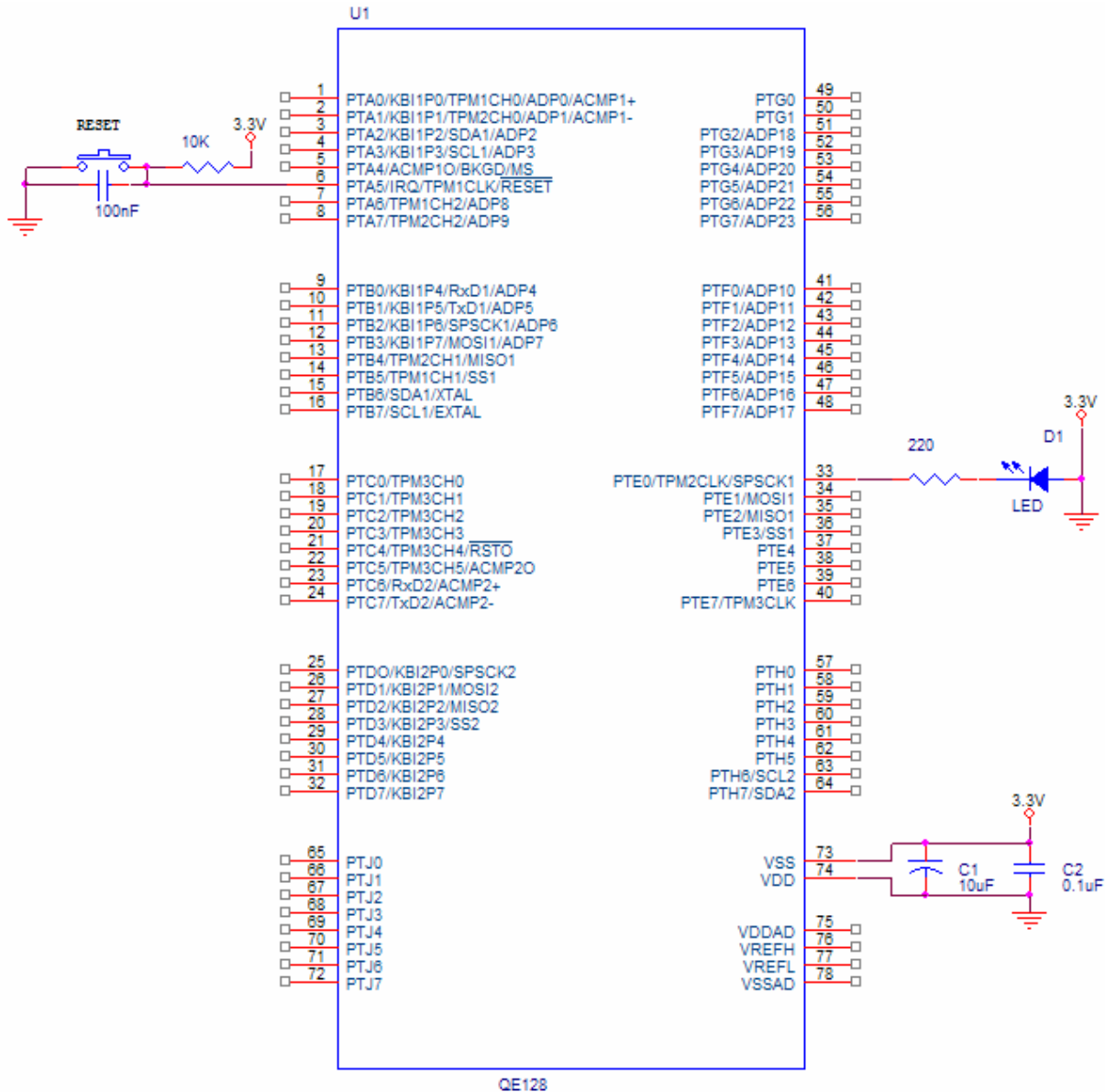


Figure 5-2. ICS Hardware Implementation

NOTE

This example is developed using the CodeWarrior IDE version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (80-pin package). There may be changes needed in the code to initialize another MCU.

Figure 5-2, shows the hardware connections used for the ICS project, for detailed information about the MCU hardware needed, please refer to the Pins and Connections chapter in the Reference Manual. (MC9S08QE128 or MCF51QE128). It can also be found at www.freescale.com.



Chapter 6

Using the Inter-Integrated Circuit (IIC) for the QE Microcontrollers

6.1 Overview

This is a quick reference for using the inter-integrated circuit (IIC) module for the QE family microcontrollers (MCUs). Basic information about the functional description and configuration options are provided.

The following example may be modified to suit an application. The IIC project is made for the MC9S08QE128 and MCF51QE128 MCUs.

IIC Quick Reference

There is more than one IIC modules in this device, there also may be more than one full set of registers on the device. In the register name below, where there's a small x, there would be a 1 or a 2 in the software to distinguish the register that is on IIC1 or IIC2.

IICxA	AD7	AD6	AD5	AD4	AD3	AD2	AD1	
-------	-----	-----	-----	-----	-----	-----	-----	--

This register contains the slave address to be used by the IIC module.

IICxF	MULT	ICR
-------	------	-----

MULT – IIC Multiplier Factor

ICR – IIC Clock Rate

IICxC1	IICEN	IICIE	MST	TX	TXAK	RSTA		
--------	-------	-------	-----	----	------	------	--	--

ModBUSY – Bus Busyule Configuration:

IICEN – IIC Enable

IICIE – IIC Interrupt Enable

MST – Master Mode Select

TX – Transmit Mode Select

TXAK – Transmit Acknowledge Enable

RSTA – Repeat START

IICxS	TCF	IAAS	BUSY	ARBL		SRW	IICIF	RXAK
-------	-----	------	------	------	--	-----	-------	------

TCF – Transfer Complete Flag

IAAS – Addressed as a Slave

BUSY – Bus Busy

ARBL – Arbitration Lost

SRW – Slave Read/Write

IICIF – IIC Interrupt Flag

RXAK – Receive Acknowledge

IICxD	DATA							
-------	------	--	--	--	--	--	--	--

Data Register

IICxC2	GCAEN	ADEXT				AD10	AD9	AD8
--------	-------	-------	--	--	--	------	-----	-----

GCAEN – General Call Address Enable

ADEXT – Address Extension

AD[10:8] – Slave Address

6.2 Code Example and Explanation

This example codes for the Master and Slave project is available from the Freescale Web site www.freescale.com.

6.2.1 IIC Master Project

In this application, two pins are used to work with the protocol. One is the PTH7, this is the Data pin for IIC protocol. The other is the PTH6, the clock pin. For detailed information about the IIC protocol refer to Inter-Integrated Circuit chapter in your reference manual.

The functions for IIC_Master.mcp project are:

- main – Endless loop, sending a byte (counter) and waiting for IIC interrupt to occur.
- MCU_Init – MCU initialization Watchdog disable and the IIC clock module enabled.
- GPIO_Init – Configure PTE port as output, PTH6 and PTH7 pin as output.
- IIC_Init – IIC module configuration.
- IIC_ISR – IIC interrupt service routine.
- Delay – Waste time routine.

The IIC master project configures the MCU to work as master and uses the IIC protocol to send a byte counter to the slave. The counter count displays in eight LEDs.

This part of the code is the MCU initialization. These instructions disable the watchdog, enable the Reset option and background pin. The System Option Register 1 (SOPT1) is used to configure the MCU. The SCGC1 and SCGC2 are registers used to save power consumption, here the bus clock to peripherals can be enabled or disabled. In this example only the bus clock to the IIC module is active. The clocks to other peripherals are disable.

```
void MCU_Init(void) {
    SOPT1 = 0x23;          // Watchdog disable. Stop Mode Enable. Background Pin enable.
                          // RESET pin enable
    SCGC1 = 0x08;        // Bus Clock to the IIC module is enabled
}
```

This is the General Purpose Input/Output configuration. These code lines configure the directions for the PTE and PTH ports. Eight LEDs are connected to the PTE port; therefore the PTE port is configured as output. The PTH6 and PTH7 are configured as output. These two pins are the Serial clock (SCL) and serial data (SDA).

```
void GPIO_Init(void) {
    PTHPE = 0xC0;        // Enable Pull ups on PTH7 and PTH6 pins
    PTEDD = 0xFF;        // Configure PTE as outputs
    PTED = 0x00;        // Put 0's in PTE port
}
```

This is the initialization code for the Inter-Integrated Circuit using the QE MCU. Here, the module is configured to work as master. For example, the MCU runs with a bus speed of 4 MHz the IIC baud rate can be calculated as following:

$$\text{IIC baud rate} = \text{bus speed (Hz)} / (\text{mul} * \text{SCL divider}) \quad \text{Eqn. 6-1}$$

$$\text{IIC baud rate} = 4000000 / (1 * 32)$$

$$\text{IIC baud rate} = 125000$$

The baud rate in this example is 125000 because the ICS module is not configured and the MCU runs at default speed (4 MHz).

```
void IIC_Init (void) {
    IIC2F = 0x09;          // Multiply factor of 1. SCL divider of 32
    IIC2C1 = 0xC0;        // Enable IIC and interrupts
}
```

This is the delay function used before the MCU starts to send the next byte to the slave. This delay function is used only to observe the changes in the LEDs.

```
void Delay (int16 c) {
    int16 i = 0;
    for (i; i<=c; i++) {
    }
}
```

This is the main function, above are the described called functions, all the interrupts are enabled. In the endless loop a byte counter is sent by IIC to the slave. The Delay function is called between byte transfer.

```
void main(void) {
    MCU_Init();           // Function that initializes the MCU
    GPIO_Init();         // Function that initializes the Ports of the MCU
    IIC_Init();          // Function that initializes the IIC module
    EnableInterrupts;    // enable interrupts
    for(;;) {
        Delay(60000);
        PTED = counter;
        counter++;
        if (PTHD_PTHD7 == 0) {
            while (PTHD_PTHD7 == 0); // Wait while pin is low
            while (IIC2C1_MST == 1); // Wait until IIC is stopped
            MasterTransmit(1,1);     // Initialize to Transmit
        }
        else {
        }
        while (IIC2C1_MST == 1);    // Wait until IIC is stopped
        Master_Receive();
    }
    // loop forever
    // please make sure that you never leave this function
}
```

These functions are used when the device is configured as Master.

```
void Master_Read_and_Store(void) {
    if (rec_count == num_to_rec) {
        last_byte_to_rec = 2;
    }
    IIC_Rec_Data[rec_count] = IIC2D;
    rec_count++;
}

void Master_Transmit(uint8 a, uint8 b) {
    // This function starts the transmission of the communication
    last_byte = 0;           // Initialize
    count = 0;
    bytes_to_trans = a;     // Select number of bytes to transfer
    num_to_rec = b;
    IIC2C1_TX = 1;         // Set TX bit for Address cycle
    IIC2C1_MST = 1;        // Set Master Bit to generate a Start
}
```

Using the Inter-Integrated Circuit (IIC) for the QE Microcontrollers

```

    IIC2D = 0xAA;           // Send Address data LSB is R or W for Slave
}
void Master_Receive() {
    rec_count = 0;
    last_byte_to_rec = 0;
    last_byte = 0;
    count = 0;
    num_to_rec = 0;
    IIC2C1_TXAK = 0;
    IIC2C1_TX = 1;         // Set TX bit for Address cycle
    IIC2C1_MST = 1;       // Set Master Bit to generate a Start
    add_cycle = 1;        // This variable sets up a master rec in the ISR
    IIC2D = 0xAB;         // Send Address data LSB is R or W for Slave
}

```

NOTE

This is the Inter-Integrated Circuit service routine. These routines handle the Master and Slave interrupts in both modes, transmit or receive. If the device is working as Master just follow the master logic. If the device is acting as slave follow the slave logic. For a better understanding refer to Typical IIC Interrupt Routine figure from the Reference Manual. The VectorNumber_Viicx can be replaced by the interrupt vector number, this depends if the MCU is S08 or V1. Using this example makes the code fully compatible for either MCU.

```

interrupt VectorNumber_iicx void IIC_ISR(void) {
    // IIC interrupt vector number = 17 (S08)
    // IIC interrupt vector number = 79 (V1)

    IIC2S_IICIF = 1;       // Clear Interrupt Flag
    if (IIC2C1_MST)       // Master or Slave?
    {
        /***** Master *****/
        if (IIC2C1_TX)    // Transmit or Receive?
        {
            /***** Transmit *****/
            if (last_byte) { // Is the Last Byte?
                IIC2C1_MST = 0; // Generate a Stop
            }
            else if (last_byte != 1) {
                if (IIC2S_RXAK) { // Check for ACK
                    IIC2C1_MST = 0; // No ACK Generate a Stop
                }
                else if (!IIC2S_RXAK) {
                    if (add_cycle) { // Is Address Cycle finished? Master done addressing Slave?
                        add_cycle = 0; // Clear Add cycle
                        IIC2C1_TX = 0; // Switch to RX mode
                        IIC2D; // Dummy read from Data Register
                    }
                    else if (add_cycle != 1) {
                        IIC2D = counter; // Transmit Data
                        count++;
                        if (count == bytes_to_trans) {
                            last_byte = 1;
                        }
                    }
                }
            }
        }
    }
}

```



```
count = 0;
bytes_to_trans = a;      // Number of bytes to transfer
num_to_rec = b;         // Number of bytes to store
IIC2C1_TX = 1;          // Set TX bit for Address cycle
IIC2C1_MST = 1;         // Set Master Bit to generate a Start
IIC2D = 0xAA;           // Send Address data LSB is R or W for Slave
}
```

This function is used to read data received from the slave device and stored in the IIC_Rec_Data array. In this example only the first byte is used.

```
void Master_Read_and_Store(void) {
    if (rec_count == num_to_rec) {
        last_byte_to_rec = 2;
    }
    IIC_Rec_Data[rec_count] = IIC2D;
    rec_count++;
}
```

This function is used to initialize the receive and store process in the MCU. Some variables are initialized and the MST bit is set to generate a start.

```
void Master_Receive() {
    rec_count = 0;
    last_byte_to_rec = 0;
    last_byte = 0;
    count = 0;
    num_to_rec = 0;
    IIC2C1_TXAK = 0;
    IIC2C1_TX = 1;          // Set TX bit for Address cycle
    IIC2C1_MST = 1;         // Set Master Bit to generate a Start
    add_cycle = 1;          // This variable sets up a master rec in the ISR
    IIC2D = 0xAB;           // Send Address data LSB is R or W for Slave
}
```

6.2.2 IIC Slave Project

This project is similar to the IIC_Master project. This example shows how to configure the MCU as slave. The ISR is the same and the used functions are the same. For detailed information about the codes visit the web page www.freescale.com.

This function is used when the device is working as slave and is necessary to know if the device does a dummy read or writes data to the master.

```
void SRW(void) {
    if (IIC2S_SRW) {        // Check for Slave Rec or transmit
        IIC2C1_TX = 1;      // Set Tx bit to begin a Transmit
        IIC2D = IIC_TX_Data[count];
        count++;
    }
    else {
        IIC2C1_TX = 0;
        IIC2D;              // Dummy read
    }
}
```

This function reads data from the IIC buffer and stores it in IIC_Rec_Data array. In this example only the first byte of the array is used.

```
void Slave_Read_and_Store(void) {
    if (rec_count == num_to_rec) {
        last_byte_to_rec = 2;
    }
    IIC_Rec_Data[rec_count] = IIC2D;
    rec_count++;
    if (rec_count == num_to_rec) {
        rec_count = 0;
    }
}
```

6.3 Hardware Implementation

This project is developed using the EVBQE128 STARTER KIT. No extra hardware is needed. Two resistors are needed for the protocol to work properly. For this example 2 MCUs are connected. [Figure 6-1](#) shows the hardware configuration.

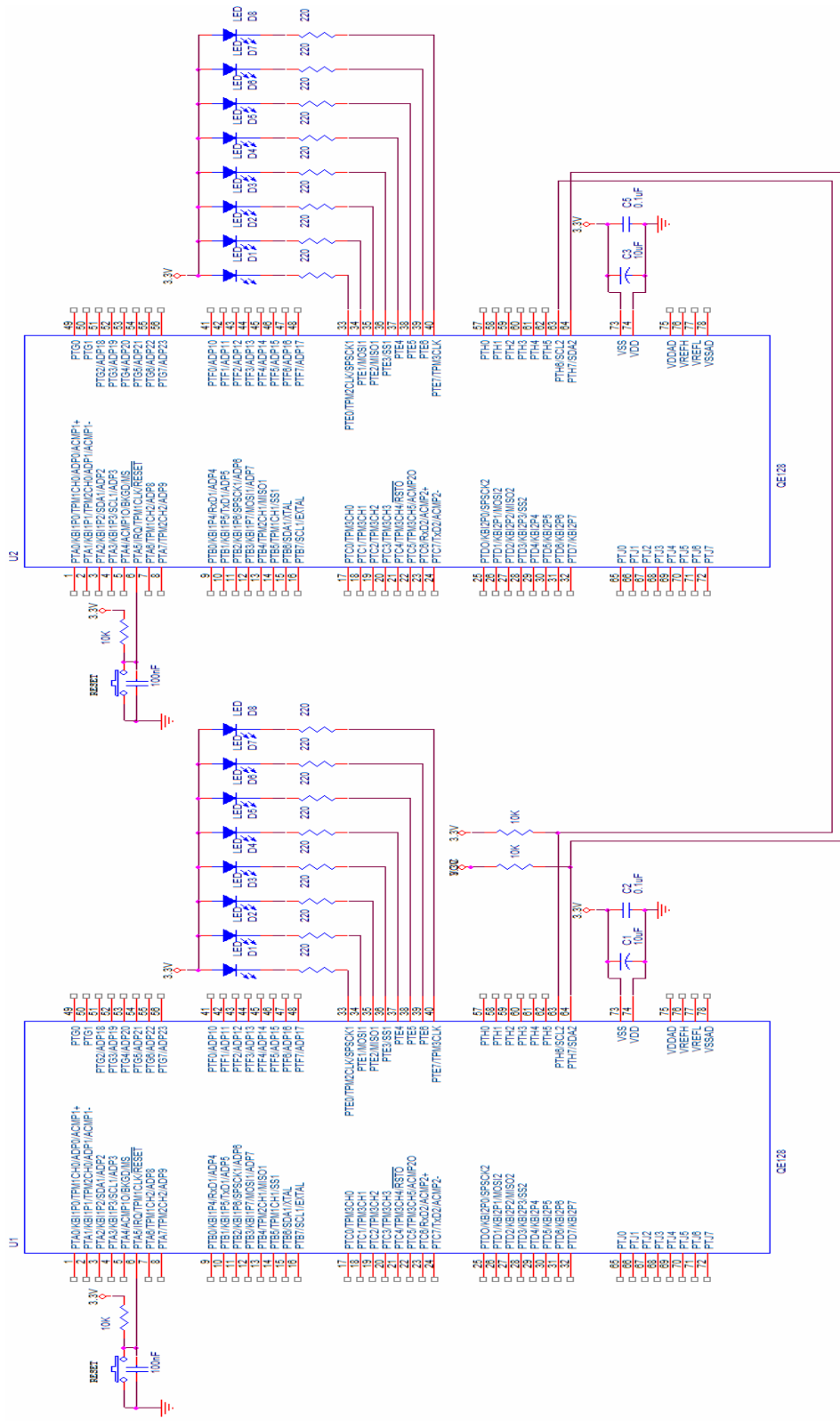


Figure 6-1. IIC Hardware Implementation

NOTE

This example is developed using the CodeWarrior IDE version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (80-pin package). There may be changes needed in the code to initialize another MCU.

[Figure 6-1](#), shows the hardware connections used for the IIC project, for detailed information of the MCU hardware needed, please refer to the Pins and Connections chapter in the Reference Manual.



Chapter 7

Using the Analog Comparator (ACMP) for the QE Microcontrollers

7.1 Overview

This is a quick reference for using the analog-to-digital comparator (ACMP) module for the QE family microcontrollers (MCUs).

Basic information about the functional description and configuration options are provided. The following example may be modified to suit an application. The ACMP project is made for the MC9S08QE128 and MCF51QE128 MCUs.

The ACMP_x module provides a circuit for comparing two analog input voltages for comparing one analog input voltage with an internal reference voltage. Inputs of the ACMP_x module can operate across a full range of supply voltage

ACMP Quick Reference

Because there is more than one ACMP module on this device, there may be more than one ACMP status and control registers on your device. In the register name below, where there's a small x, there would be a 1 or a 2 in the software to distinguish the register that is on an ACMP1 or an ACMP2.

ACMP _x SC	ACME	ACBGS	ACF	ACIE	ACO	ACOPE	ACMOD
----------------------	------	-------	-----	------	-----	-------	-------

Module Configuration:

ACME – enables module	ACO – reads status of output
ACBGS – select bandgap as reference	ACOPE – output pin enable
ACF – set when event occurs	ACMOD[1:0] – sets mode
ACIE – interrupt enable	

The ACMP_x module has two analog inputs named ACMP_{x+} and ACMP_{x-}, and one digital output named ACMP_xO. The ACMP_{x+} serves as a non-inverting analog input and the ACMP_{x-} serves as an inverting analog input. ACMP_xO serves as digital output and can be enabled to drive an external pin. The ACMP1 module can be configured to connect the ACMP1O to the TPM1 input capture channel 0 by setting the ACIC1 in the SOPT2. The TPM with the input capture function captures the time at which an external event occurs. Rising, falling, or any edge may be chosen as the active edge that triggers an input capture. The ACMP2 output can be driven to the TPM2 channel 0 by setting the ACIC2 in the SOPT2.

The ACMP interrupt is generated depending how the ACMOD bits are configured in the ACMPxSC register. Figure 7-1 shows the moment where the ACMP+ signal crosses the ACMP- signal, producing an interrupt.

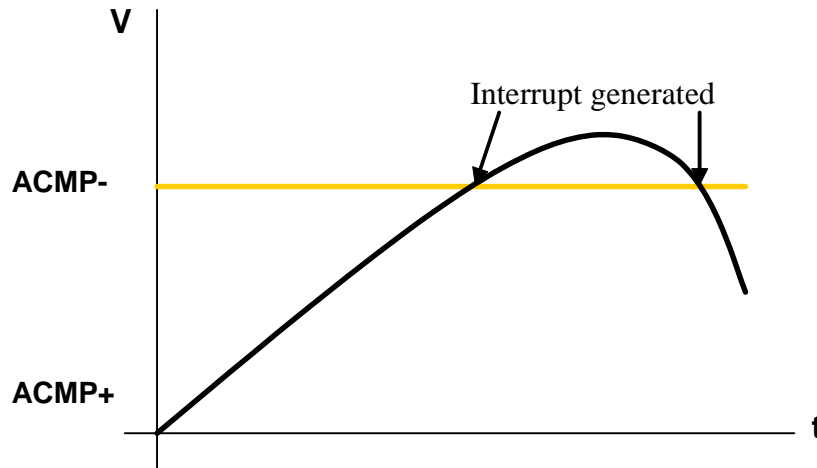


Figure 7-1. ACMP Interrupt Generation

7.2 ACMP project for EVB

7.2.1 Code Example and Explanation

This example code is available from the Freescale Web site www.freescale.com.

The project ACMP.mcp implements the ACMP function selecting a rising- or falling-edge event to trigger hardware interrupts. The main functions are:

main — Endless loop waiting for the ACMP interrupt to occur.

MCU_Init – MCU initialization, watchdog disable and the ACMP clock module enabled.

GPIO_Init – Configure PTE0 pin as output.

ACMP_Init – ACMP module configuration

ACMP_ISR — Toggles a LED after a rising or falling edge event occurs.

This example consists of comparing two different input voltages using the ACMP module. The ACMP- is fed with a static voltage which is an internal bandgap and serves as a reference voltage. For more detailed and specific data about internal reference voltage, please see the QE128 DataSheet. It can be found at www.freescale.com. An ACMP+ is fed with a variable voltage of 0 to 3 V. Every time the ACMP+ voltage crosses the ACMP- reference voltage, a hardware interrupt is triggered toggling the PTE0 pin. This pin is connected to a LED.

The code below executes the instructions to disable the watchdog, enable the Reset option and background pin. The System Option Register 1 (SOPT1). It is used to configure the MCU. The SCGC1 and SCGC2

are registers used for power saving consumption, here the bus clock to peripherals can be enabled or disabled. In this example only the bus clock to the ACMP module is active. The clocks to the other peripherals are disabled.

```
void MCU_Init(void) {
    SOPT1 = 0x23;    // Watchdog disable. Stop Mode Enable. Background Pin enable. RESET pin enable
    SCGC1 = 0x00;    // Disable Bus clock to unused peripherals
    SCGC2 = 0x08;    // Bus Clock to ACMP module is enabled
}
```

This is the General Purpose Input/Output configuration. These code lines configure the direction for the PTE port. The eight LEDs from the EVB are connected to the PTE port, and only the PTE0 is configured as output in order to drive a LED.

```
void GPIO_Init(void) {
    PTEDD = 0x01;    // Configure PTE port as output
    PTED = 0x00;    // Put 0's in PTE port
}
```

This is the initialization code for the analog comparator used for the QE128 MCU. This application uses the ACMP2 module. The internal bandgap is selected and this voltage is compared with the PTC7 pin voltage.

```
void ACMP_Init (void) {
    ACMP2SC = 0xC3;    // ACMP module enable. Internal reference selected. Comparator
                    // output rising or falling edge
}
```

This is the main function, above are the described called functions, and all the interrupts are enabled. After this the analog comparator interrupt can be serviced.

```
void main(void) {
    MCU_Init();        // Function that initializes the MCU
    GPIO_Init();       // Function that initializes the Ports of the MCU
    ACMP_Init()        // Function that initializes the KBI module
    EnableInterrupts;  // enable interrupts
    ACMP2SC_ACIE = 1;  // enable the interrupt from the ACMP
    for(;;) {

    }                  // loop forever
                    // please make sure that you never leave this function
}
```

NOTE

This is the analog comparator interrupt service routine. Every time an interrupt is detected, this routine toggles a LED (PTE0). The VectorNumber_Vacmpx can be replaced by the interrupt vector number, this depends if the MCU is S08 or V1. Using this example makes the code fully compatible for either MCU.

```
void interrupt VectorNumber_Vacmpx ACMP_ISR(void) {
    // ACMP vector address = 20 (S08)
    // ACMP vector address = 82 (V1)
    ACMP2SC_ACF = 1;    // Clear ACMP flag
    PTED_PTED0 ^= 1;    // Toggles PTE0
}
```

7.2.2 Hardware Implementation

This project is developed using the EVBQE128 STARTER KIT. Extra hardware is needed. A variable resistor of 1 kΩ is required. One terminal of the potentiometer (POT) is connected to 3.3 V and the other terminal is connected to the ground. When the POT varies, the voltage in the center pin change. This pin is the input for the PTC7 pin. Figure 7-2 shows the hardware configuration.

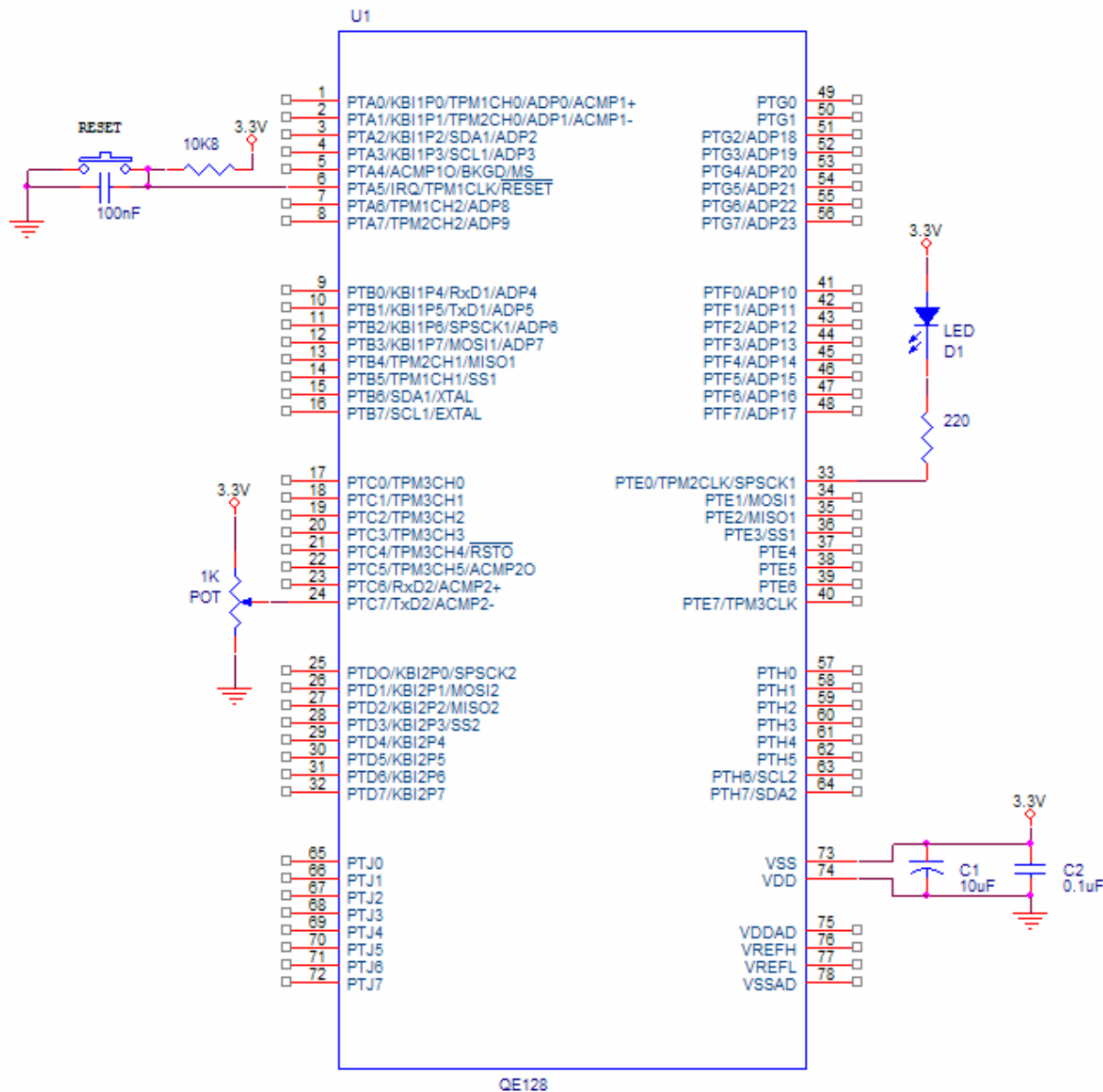


Figure 7-2. ACMP Hardware Implementation

NOTE

This example is developed using the CodeWarrior IDE version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (80-pin package). There may be changes needed in the code to initialize another MCU.

ACMP module can operate with two external inputs. This example code is expressly made to configure the ACMP module to work using the internal reference voltage.

The analog comparator circuit is designed to operate across a full range of supply voltage. Please refer to the data sheet of the device. You can find it at www.freescale.com.

Figure 7-2, shows the hardware connections used for the ACMP project, for detailed information about the MCU supply voltages needed, please refer to the Pins and Connections chapter in the Reference Manual (MC9S08QE128 or MCF51QE128). It can be found at www.freescale.com.

7.3 ACMP project for Demo board

7.3.1 Code Example and Explanation

These example codes are available from the Freescale Web site www.freescale.com.

This section explains the differences of codes using an EVB and Demo board. The codes are the same.

The project ACMP.mcp implements the ACMP function, selecting a rising- or falling-edge event to trigger hardware interrupts. The main functions are:

- main — Endless loop waiting for the ACMP interrupt to occur.
- MCU_Init – MCU initialization, watchdog disable and the ACMP clock module enabled.
- GPIO_Init – Configure PTC0 pin as output.
- ACMP_Init – ACMP module configuration.
- ACMP_ISR — Toggles a LED after a rising or falling edge event occurs.

This is the General Purpose Input/Output configuration. These code lines configure the direction for PTC port. Only six LEDs from the demo board are connected to the PTC port. The other two LEDs are connected to the E port. In this example only the PTC0 is configured as output in order to drive a LED.

```
void GPIO_Init(void) {
    PTCDD = 0x01;      // Configure PTC port as output
    PTC0 = 0x00;      // Put 0's in PTC port
}
```

NOTE

This is the analog comparator interrupt service routine. Every time an interrupt is detected, this routine toggles a LED (PTC0). The VectorNumber_Vacmpx can be replaced by the interrupt vector number, this depends if the MCU is S08 or V1. Using this example makes the code fully compatible for either MCU.

```
void interrupt VectorNumber_Vacmpx ACMP_ISR(void) {
    // ACMP vector address = 20 (S08)
    // ACMP vector address = 82 (V1)
    ACMP2SC_ACF = 1; // Clear ACMP flag */
    PTC0 ^= 1; // Toggles PTC0 */
}
```

}

7.3.2 Hardware Implementation

This project is developed using the demo board. Extra hardware is needed. A variable resistor of 1 kΩ is required. One terminal of the POT is connected to 3.3 V and the other terminal is connected to the ground. In this configuration when POT varies, the voltage in the center pin changes, this pin is the input for PTC7 pin. Figure 7-3 shows the hardware configuration.

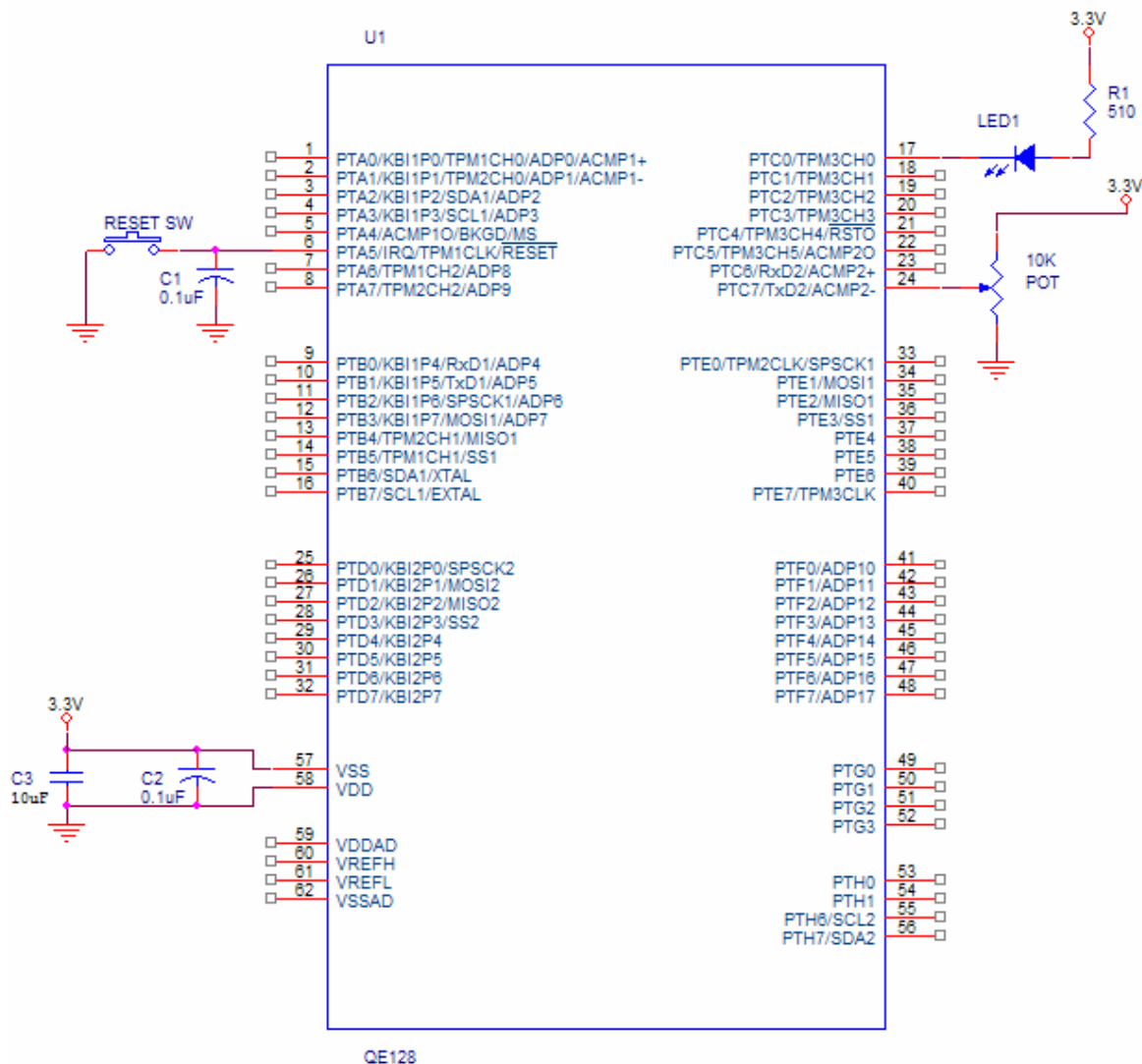


Figure 7-3. ACMP Hardware Implementation

NOTE

This example is developed using the CodeWarrior IDE version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (64-pin package). There may be changes needed in the code to initialize another MCU.

ACMP module can operate with two external inputs. This example code is expressly made to configure the ACMP module to work using the internal reference voltage.

The analog comparator circuit is designed to operate across a full range of supply voltage. Please refer to the data sheet of the device. You can also find it at www.freescale.com.

[Figure 7-3](#), shows the hardware connections used for the ACMP project, for detailed information about the MCU supply voltages needed, please refer to the Pins and Connections chapter the Reference Manual (MC9S08QE128 or MCF51QE128). It can also be found at www.freescale.com.



Chapter 8

Using the Analog to Digital Converter (ADC) for the QE Microcontrollers

8.1 Overview

This is a quick reference for using a 12-bit analog-to-digital converter (ADC) module for the QE family microcontrollers (MCUs). Basic information about the functional description and configuration options are provided. The following example may be modified to suit an application. The ADC project is made for the MC9S08QE128 and MCF51QE128 MCUs.

ADC Quick Reference

For specific pin control registers and bits on the device, please refer to the reference manual (MC9S08QE128 or MCF51QE128). It can be found at www.freescale.com.

ADCSC1	COCO	AIEN	ADCO	ADCH			
--------	------	------	------	------	--	--	--

Module configuration:

ACME – conversion complete flag ADCO – continuous conversion enable
 AIEN – Interrupt enable ADCH– output pin enable.

ADCSC2	ADACT	ADTRG	ACFE	ACFGT				
--------	-------	-------	------	-------	--	--	--	--

Module configuration:

ADACT – conversion active. ADTRG – conversion trigger select
 ACFE – compare function enable. ACFGT– compare function greater than enable

ADCRH					ADR11	ADR10	ADR9	ADR8
-------	--	--	--	--	-------	-------	------	------

Result of ADC conversion:

ADR11-ADR8 – contains the upper four bits of the result of a 12-bit conversion

ADCRL	ADR7	ADR6	ADR5	ADR4	ADR3	ADR2	ADR1	ADR0
-------	------	------	------	------	------	------	------	------

Result of ADC conversion:

ADR7-ADR0 – contains the eight bits of the result of a 12-bit, 10-bit or 8-bit conversion

ADCCVH					ADCV11	ADCV10	ADCV9	ADCV8
--------	--	--	--	--	--------	--------	-------	-------

Compare value:

ADCV11-ADCV8 – contains the upper four bits of the 12-bit compare value.

ADCCVL	ADCV7	ADCV6	ADCV5	ADCV4	ADCV3	ADCV2	ADCV1	ADCV0
--------	-------	-------	-------	-------	-------	-------	-------	-------

Compare value.

ADCV7-ADCV0 – contains the lower eight bits of the 12-bit, 10-bit or 8-bit compare value

ADCCFG	ADLPC	ADIV	ADLSMP	MODE	ADICLK
--------	-------	------	--------	------	--------

ADLPC – Low Power configuration MODE – Conversion mode Selection
 ADIV – Clock divide select ADICLK – Input clock select.
 ADLSMP – Long sample time configuration.

APCTL1	ADPC7	ADPC6	ADPC5	ADPC4	ADPC3	ADPC2	ADPC1	ADPC0
--------	-------	-------	-------	-------	-------	-------	-------	-------

Pin Control: ADC or I/O controlled

ADPC7-ADPC0 – These bits are used to disable the I/O port control of the MCU. For specific information visit www.freescale.com and search for the reference manual MC9S08QE128 or MCF51QE128 MCUs.

APCTL2	ADPC15	ADPC14	ADPC13	ADPC12	ADPC11	ADPC10	ADPC9	ADPC8
--------	--------	--------	--------	--------	--------	--------	-------	-------

Pin Control: ADC or I/O controlled

ADPC15-ADPC8 – These bits are used to disable the I/O port control of the MCU. For specific information visit www.freescale.com and search for the reference manual MC9S08QE128 or MCF51QE128 MCUs.

APCTL3	ADPC23	ADPC22	ADPC21	ADPC20	ADPC19	ADPC18	ADPC17	ADPC16
--------	--------	--------	--------	--------	--------	--------	--------	--------

Pin Control: ADC or I/O controlled

ADPC23-ADPC16 – These bits are used to disable the I/O port control of the MCU. For specific information visit www.freescale.com and search for the reference manual MC9S08QE128 or MCF51QE128 MCUs.

The QE128 MCUs have a 12-bit analog-to-digital successive-approximation converter which is the ADC. It can be configured with a 12-bit, 10-bit or 8-bit resolution. These are some options for the user:

- Three different resolutions: 12-bit, 10-bit and 8-bit.
- Two different types of conversions: single or continuous conversion.
- Selectable ADC clock frequency: include a bus clock prescaler.
- Automatic compare with interrupt for less-than, greater-than or equal-to, programmable value.
- Configurable sample time and conversion speed/power.

8.2 ADC project for EVB

8.2.1 Code Example and Explanation

This example code is available from the Freescale Web site www.freescale.com.

The following examples describe the initialization code for the 12-bit ADC module using the interrupt-based approach, 8-bit resolution, and continuous-sample mode.

The zip file contains the following functions:

- main — Endless loop waiting for the ADC interrupt to occur.

- MCU_Init – MCU initialization, watchdog disable and the ADC clock module enabled.
- GPIO_Init – Configure PTE port as output.
- ADC_Init – ADC module configuration.
- ADC_ISR — The data obtained by ADC module is display on PTE port.

This section consists of varying the potentiometer that also varies the voltage and is connected to the ADC channel 0. The obtained data is displayed in an 8 LEDs array connected to the PTE port. The ADC module is configured in continuous conversion mode. The MCU is interrupted constantly and within the ISR the obtained data is displayed on the PTE port.

The code below executes the instructions to disable the watchdog, enable the Reset option and background pin. The system option register 1 (SOPT1) is used to configure the MCU. The SCGC1 and SCGC2 are registers used for power saving consumption, here the bus clock to peripherals can be enabled or disabled. In this example only the bus clock to the ADC module is active. The clocks to the other peripherals are disabled.

```
void MCU_Init(void) {
SOPT1 = 0x23;          // Watchdog disabled. Stop Mode Enabled. Background Pin
                      // enabled. RESET pin enabled
SCGC1 = 0x10;         // Bus Clock to the ADC module is enabled
SCGC2 = 0x00;         // Disable Bus clock to unused peripherals
}
```

This is the General Purpose Input/Output configuration. These code lines configure the directions for the PTE port. The eight LEDs are connected to the PTE port; therefore the PTE port is configured as output.

```
void GPIO_Init(void) {
    PTEDD = 0xFF;      // Configure PTE port as output
    PTED = 0x00;      // Put 0's in PTE port
}
```

This is the initialization code for the analog-to-digital converter used for the QE MCU. This application uses the ADC module channel 0. The module is configured in continuous conversion mode and an 8-bit resolution.

```
void ADC_Init (void) {
ADCSC1 = 0x20;        // Interrupt disable. Continuous conversion and channel 0
                      // active
    ADCSC2 = 0x00;    // Software trigger selected
    ADCCFG = 0x30;    // Input clock/2. Long Sample time configuration. 8-bit
                      // conversion
    APCTL1 = 0x00;    // ADC0 pin disable
}
```

This is the main function, above are the described called functions, and all the interrupts are enabled. The ADC interrupt can be serviced.

```
void main(void) {
    MCU_Init();        // initializes the MCU
    GPIO_Init();      // initializes GPIO
    ADC_Init();        // Function that initializes the ADC module
    EnableInterrupts; // enable interrupts
    ADCSC1_AIEN = 1;  // Enable ADC interrupt
    APCTL1_ADPC0 = 1; // Select the channel for ADC input
    for(;;) {
        // loop forever
    }
```

```

// please make sure that you never leave this function
}

```

NOTE

This is the analog-to-digital converter interrupt service routine. Every time an interrupt is detected, this routine displays the converted value in PTE port. The VectorNumber_Vadc can be replaced by the interrupt vector number, this depends if the MCU is S08 or V1. Using this example makes the code fully compatible for either MCU.

```

void interrupt VectorNumber_Vadc ADC_ISR(void) {
    // ADC vector address = 19 (S08)
    // ADC vector address = 81 (V1)
    PTED = ADCRL; // Move the acquired ADC value to PTE port
}

```

8.2.2 Hardware Implementation

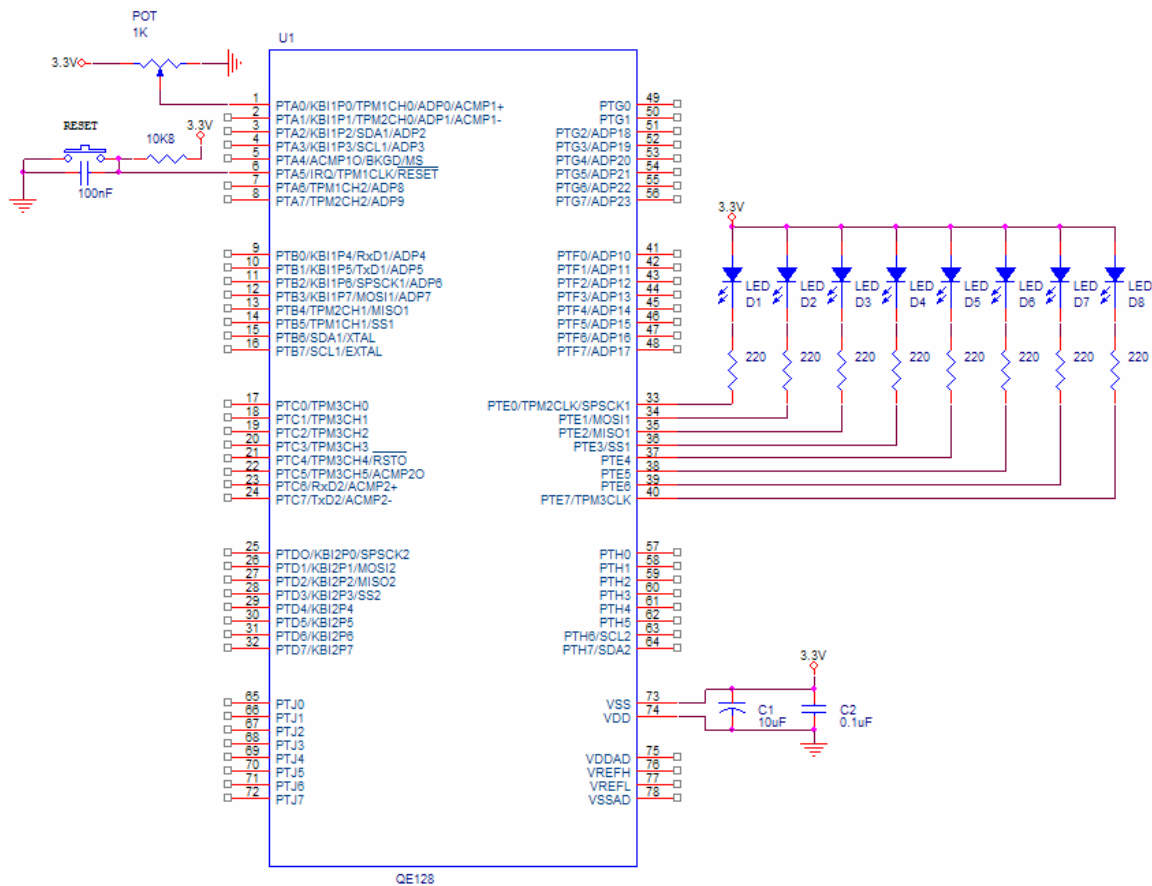


Figure 8-1. ADC Hardware Implementation.

NOTE

This example is developed using the CodeWarrior version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (80-pin package). There may be changes needed in the code to initialize another MCU.

Figure 8-1, shows the hardware connections used for the ADC project, for detailed information about the MCU hardware needed, please refer to the Pins and Connections chapter in the Reference Manual. It can be found at www.freescale.com.

8.3 ADC project for Demo board**8.3.1 Code Example and Explanation**

This example code is available from the Freescale Web site www.freescale.com.

This section explains the differences of codes using an EVB and Demo board. The codes are the same.

The project file contains the following functions:

- Main — Endless loop waiting for the ADC interrupt to occur.
- MCU_Init – MCU initialization, watchdog disable and the ADC clock module enabled.
- GPIO_Init – Configure PTC0 to PTC5, PTE6 and PTE7 as as outputs.
- ADC_Init – ADC module configuration.
- ADC_ISR — The data obtained by the ADC module is displayed on PTC0 to PTC5 pins, PTE6 and PTE7 pins.

This is the General Purpose Input/Output configuration. These code lines configure the direction for the PTC port. Only six LEDs from the demo board are connected to the PTC port. The other two LEDs are connected to port E. In this example the PTC0 to PTC5, and PTE6, PTE7 are configured as outputs in order to drive LEDs.

```
void GPIO_Init(void) {
    PTCDD = (UINT8) (PTCD | 0x3F);    // Configure PTC0-PTC5 as outputs
    PTEDD = (UINT8) (PTED | 0xC0);    // Configure PTE6 and PTE7 pins as outputs
    PTCD = 0x3F;                      // Put 1's in port C in order to turn off the LEDs
    PTED = 0xC0;                      // Put 1's in port E in order to turn off the LEDs
}
```

NOTE

This is the ADC interrupt service routine. Every time an interrupt is detected, this routine displays the converted value in eight LEDs. The VectorNumber_Vadc can be replaced by the interrupt vector number, this depends if the MCU is S08 or V1. Using these example makes the code fully compatible for either MCU.

```
void interrupt VectorNumber_Vadc ADC_ISR(void) {
    // ADC vector address = 19 (S08)
    // ADC vector address = 81 (V1)
```

Using the Analog to Digital Converter (ADC) for the QE Microcontrollers

```

UINT8 temp; // Create a temp variable used for further operations
temp = ~ADCRL; // Negate the ADC converted value because is going to be display
// on the LEDs (The LEDs turn on with 0's)

PTED = (UINT8) (temp & 0xC0); // Move the adquired ADC value to port E
PTCD = (UINT8) (temp & 0x3F); // Move the adquired ADC value to port C
}
    
```

8.3.2 Hardware Implementation

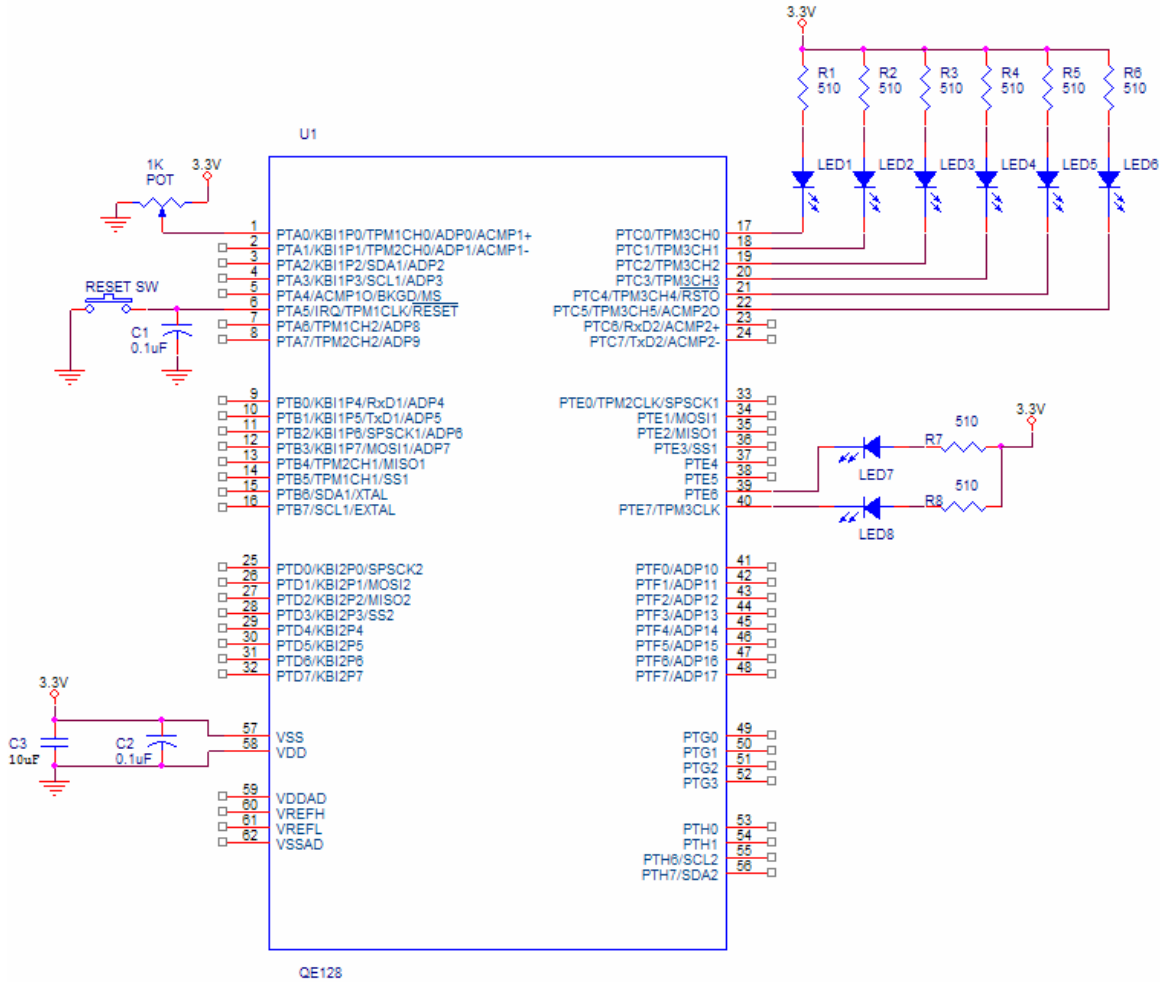


Figure 8-2. ADC Hardware Implementation

NOTE

This example is developed using the CodeWarrior version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (64-pin package). There may be changes needed in the code to initialize another MCU.

Figure 8-2, shows the hardware connections used for the ADC project, for detailed information about the MCU hardware needed, please refer to the Pins and Connections chapter in the Reference Manual. It can be found at www.freescale.com.



Chapter 9

Using the Real Time Counter (RTC) for the QE Microcontrollers

9.1 Overview

This is a quick reference for using the real time counter (RTC) module for the QE family microcontrollers (MCUs). Basic information about the functional description and configuration options are provided. The following example may be modified to suit an application. The RTC project is made for the MC9S08QE128 and MCF51QE128 MCUs.

The RTC module can be used to generate a hardware interrupt at fixed periodic rate. The RTC module in QE MCU has three clock sources, the 1 kHz internal clock, the 32 kHz internal clock and an external clock. There are different periods of time that can be used to interrupt the MCU. Please refer the reference manual for specific times. It can be found at www.freescale.com.

RTC Quick Reference

RTCS	RTIF	RTCLKS	RTIE	RTCPS
------	------	--------	------	-------

Module Configuration:

RTIF - Real-Time Interrupt flag	IRTIE - Real-Time Interrupt Enable
RTCLKS - Real-Time Clock Source Select	RTCPS - Real-Time clock prescaler select

RTCCNT	RTCCNT
--------	--------

RTCCNT - It contains the value of the current RTC count

RTCMOD	RTCMOD
--------	--------

RTCMOD - RTC Modulo

9.2 RTC project for EVB

9.2.1 Code Example and Explanation

This example code is available from the Freescale Web site www.freescale.com.

The zip file contains the following functions:

- main — Endless loop waiting for the RTC interrupt to occur.
- MCU_Init – MCU initialization, watchdog disable and the RTC clock module enabled.
- GPIO_Init – Configure PTE port as output.
- RTC_Init – RTC module configuration.
- RTC_ISR — Toggles PTE port .

The following example describes the initialization code for the RTC module. This example shows how to generate an RTC using 1 kHz of internal reference. Port E toggles every time an interrupt is generated which is every second.

The code below executes the instructions to disable the watchdog, enable the Reset option and background pin. The system option register 1 (SOPT1) is used to configure the MCU. The SCGC1 and SCGC2 are registers used for power saving consumption, here the bus clock to peripherals can be enabled or disabled. In this example only the bus clock to the RTC module is active. The clocks to the other peripherals are disabled.

```
void MCU_Init(void) {
    SOPT1 = 0x23;           // Watchdog disabled. Stop Mode Enable. Background Pin
                          // enable. RESET pin enable
    SCGC1 = 0x00;          // Disable Bus clock to unused peripherals
    SCGC2 = 0x04;          // Bus Clock to the RTC module is enable
}
```

This is the general purpose Input/Output (GPIO) configuration. These code lines configure the directions for the PTE ports. The eight LEDs are connected to the PTE port; therefore the PTE port is configured as output.

```
void GPIO_Init(void) {
    PTEDD = 0xFF;          // Configure PTE port as output
    PTE = 0x00;            // Put 0's in PTE port
}
```

This is the initialization code for the Real-Time clock module used for the QE MCU. This application generates an interrupt every second. Within the interrupt service routine a PTE port is toggled.

```
void RTC_Init (void) {
    RTCSC = 0x0F;          // RTCPS configure prescaler period every 1s
    RTCMOD = 0x00;         // RTCMOD configure to interrupt every 1s
}
```

This is the main function, above are the described called functions, all the interrupts are enabled. The RTC interrupt can be detected.

```
void main(void) {
    MCU_Init();           // Function that initializes the MCU
    GPIO_Init();          // Function that initializes the Ports of the MCU
    RTC_Init();           // Function that initializes the RTC module
    EnableInterrupts;     // enable interrupts
    RTCSC_RTIE = 1;       // Enable RTC interrupt
    }                     // loop forever
                          // please make sure that you never leave this function
}
```

NOTE

This is the RTC interrupt service routine. Every second an interrupt is generated this routine toggles a PTE port. The VectorNumber_Vrtc can be replaced by the interrupt vector number, this depends if the MCU is S08 or V1. Using these example makes the code fully compatible for either MCU.

```
void interrupt VectorNumber_Vrtc RTC_ISR(void) {
```

```

// RTC vector address = 24 (S08)
// RTC vector address = 86 (V1)

RTCSC = RTCSC | 0x80; // Clear the RTC flag
PTED ^= 0xFF; // Toggles Port E
}

```

9.2.2 Hardware Implementation

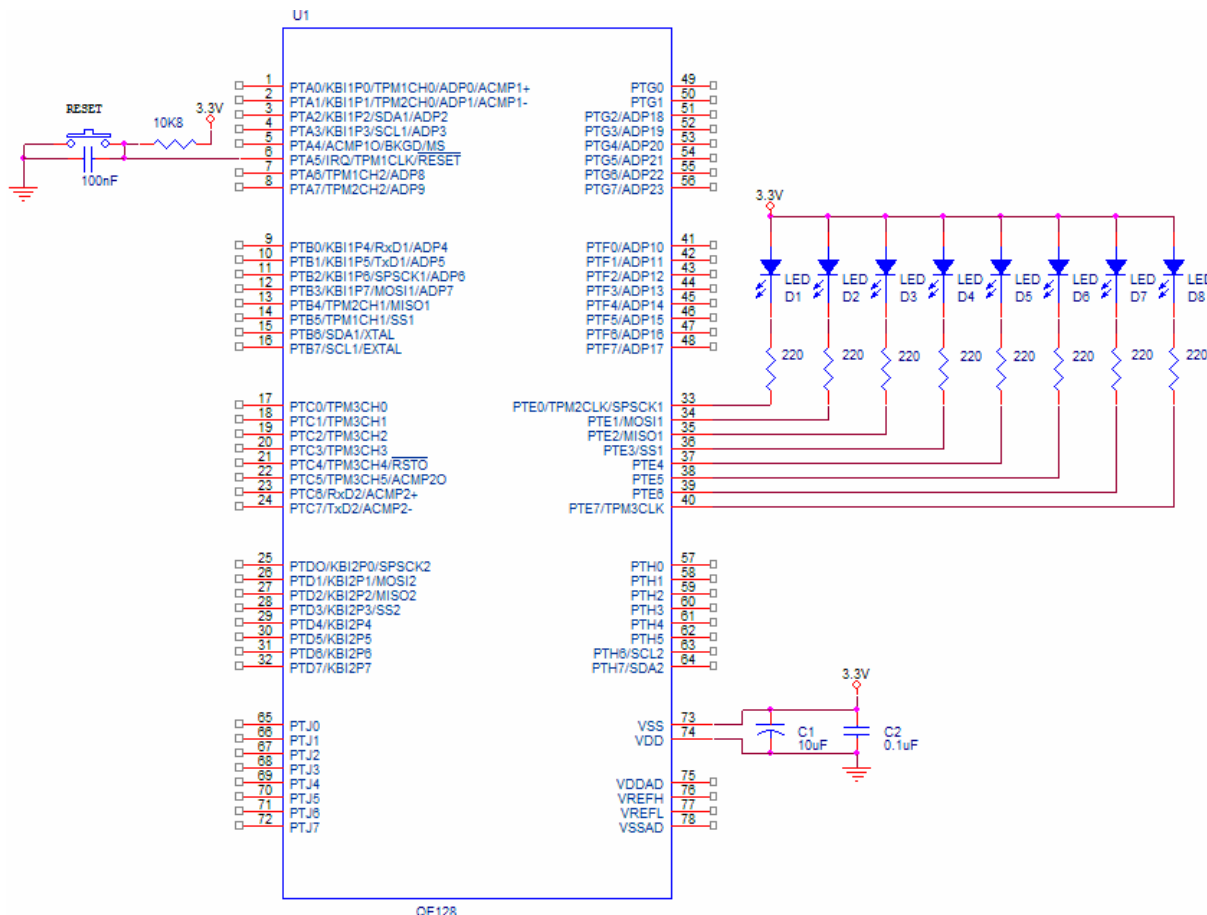


Figure 9-1. RTC Hardware Implementation.

NOTE

This example is developed using the CodeWarrior IDE version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (80-pin package). There may be changes needed in the code to initialize another MCU.

Figure 9-1, shows the hardware connections used for the RTC project, for detailed information about the MCU hardware needed, please refer to the Pins and Connections chapter in the Reference Manual. It can be found at www.freescale.com.

9.3 RTC project for Demo board

9.3.1 Code Example and Explanation

This example code is available from the Freescale Web site www.freescale.com.

This section explains the differences of codes using the EVB and Demo board. The codes are the same.

The project file contains the following functions:

- Main — Endless loop waiting for the RTC interrupt to occur.
- MCU_Init – MCU initialization, watchdog disable and the RTC clock module enabled.
- GPIO_Init – Configure PTC0 pin as output.
- RTC_Init – RTC module configuration.
- RTC_ISR — Toggles PTC0 pin .

This is the general purpose Input/Output (GPIO) configuration. These code lines configure the direction for the PTC port. Only six LEDs from the demo board are connected to the PTC port. The others two LEDs are connected to port E. In this example PTC0 is configured as output in order to drive a LED.

```
void GPIO_Init(void) {
    PTCDD = 0x01;      // Configure PTC0 as output
    PTCDD = 0x01;      // Put 1 in PTC0 to turn off the LED
}
```

NOTE

This is the RTC interrupt service routine. Every second an interrupt is generated this routine toggles a PTE port. The VectorNumber_Vrtc can be replaced by the interrupt vector number, this depends if the MCU is S08 or V1. Using this example makes the code fully compatible for either MCU.

```
void interrupt VectorNumber_Vrtc RTC_ISR(void) {
    // RTC vector address = 24 (S08)
    // RTC vector address = 86 (V1)

    RTCSC = RTCSC | 0x80;      // Clear the RTC flag
    PTCDD_PTCDD0 ^= 1;        // Toggles PTC0 pin
}
```

9.3.2 Hardware Implementation

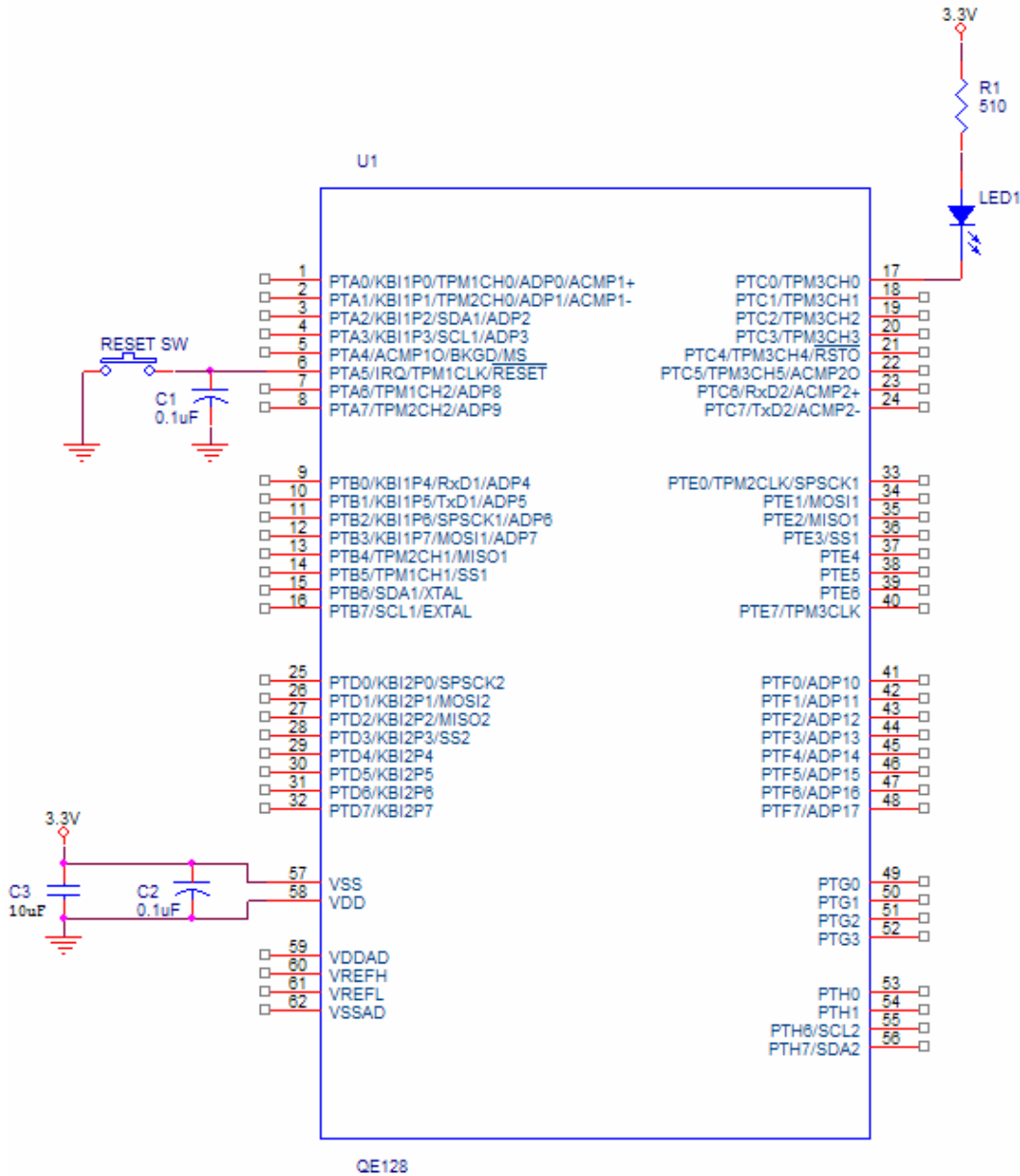


Figure 9-2. RTC Hardware Implementation.

NOTE

This example is developed using the CodeWarrior IDE version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (64-pin package). There may be changes needed in the code to initialize another MCU.

Figure 9-2, shows the hardware connections used for the RTC project, for detailed information about the MCU hardware needed, please refer to the Pins and Connections chapter in the Reference Manual. It can be found at www.freescale.com.

Chapter 10

Using the Serial Communications Interface (SCI) for the QE Microcontrollers

10.1 Overview

This is a quick reference for using the serial communication interface (SCI) module for the QE family microcontrollers (MCUs). Basic information about the functional description and configuration options are provided. The following example may be modified to suit an application. The SCI project is made for the MC9S08QE128 and MCF51QE128 MCUs.

10.2 SCI project for EVB

10.2.1 Code Example and Explanation

This example code is available from the Freescale Web site www.freescale.com.

The zip file contains the following functions:

- main — Endless loop waiting for the SCI interrupt to occur.
- MCU_Init – MCU initialization, watchdog disable and the SCI clock module enabled.
- GPIO_Init – Configure PTE port as output.
- SCI_Init – SCI module configuration.
- SCI_RX_ISR — The data obtained by SCI module is displayed on the PTE port and the character “1” is sent by SCI.

The following example describes the initialization code for the SCI module. This example configures the serial communications interface at 9600bps, in an 8-bit mode. The MCU waits for an interrupt, once an interrupt is detected the received data is displayed on the PTE port and then the character “1” is sent by SCI. The SCI module uses interrupts to handle transmission, reception and errors events, for this example reception interrupt is used.

The code below executes the instructions to disable the watchdog, enable the Reset option and background pin. The System Option Register 1 (SOPT1) is used to configure the MCU. The SCGC1 and SCGC2 are registers used for saving power consumption, here the bus clock to peripherals can be enabled or disabled. In this example only the bus clock to the SCI module is active. The clocks to the other peripherals are disabled.

```
void MCU_Init(void) {
SOPT1 = 0x23;           // Watchdog disabled. Stop Mode Enabled. Background Pin
                        // enable. RESET pin enable
SCGC1 = 0x01;          // Bus Clock to the SCI1 module is enabled
SCGC2 = 0x00;          // Disable Bus clock to unused peripherals
}
```

```
}

```

This is the General Purpose Input/Output configuration. These code lines configure the directions for the PTE ports. The eight LEDs are connected to the PTEport; therefore the PTE port is configured as output.

```
void GPIO_Init(void) {
    PTEDD = 0xFF;           // Configure PTE port as output
    PTED = 0x00;           // Put 0's in PTE port
}

```

This is the initialization code for Serial Communications Interface module used for the QE MCU. This application configures the SCI module in an 8-bit mode, normal operation, and a baud rate of 9600 bps. To reach 9600 bps the Baud Rate Modulo Divisor and the clock source must be configured. For this example the used clock source is at its default of 4 MHz. The Baud Rate Modulo Divisor needs to be at 26 to obtain 9600 bps.

```
void SCI_Init (void) {
    SCI1C1 = 0x00;         // 8-bit mode. Normal operation
    SCI1C2 = 0x2C;         // Receiver interrupt enabled. Transmitter and receiver enabled
    SCI1C3 = 0x00;         // Disable all errors interrupts
    SCI1BDL = 0x1A;        // This register and the SCI1BDH are used to configure the SCI baud rate
    SCI1BDH = 0x00;        //          BUSCLK          4MHz
    // Baud rate = ----- = ----- = 9600bps
    //          [SBR12:SBR0] x 16          26 x 16
}

```

This is the main function, the above described functions are called, and all the interrupts are enabled. The SCI_Rx interrupt can be detected.

```
void main(void) {
    MCU_Init();           // Function that initializes the MCU
    GPIO_Init();          // Function that initializes the Ports of the MCU
    SCI_Init();           // Function that initializes the SCI module
    EnableInterrupts;     // enable interrupts
    for(;;) {
    }                       // loop forever
    // please make sure that you never leave this function
}

```

This is the SCI service routine. Every time a SCI interrupt is detected, the received data is displayed on the PTE port and the character “1” is sent by SCI. The VectorNumber_Vscilrx can be replaced by the interrupt vector number, this depends if the MCU is S08 or V1. Using this example makes the code fully compatible for either MCU.

```
void interrupt VectorNumber_Vscilrx SCI_RX_ISR(void) {
    // SCI vector address = 15 (S08)
    // SCI vector address = 77 (V1)
    SCI1S1_RDRF = 0;      // Receive interrupt disable
    PTED = SCI1D;         // Display on PTE the received data from SCI
    while (SCI1S1_TDRE == 0); // Wait for the transmitter to be empty
    SCI1D = '1';          // Send a character by SCI
}

```


10.2.2 Hardware Implementation

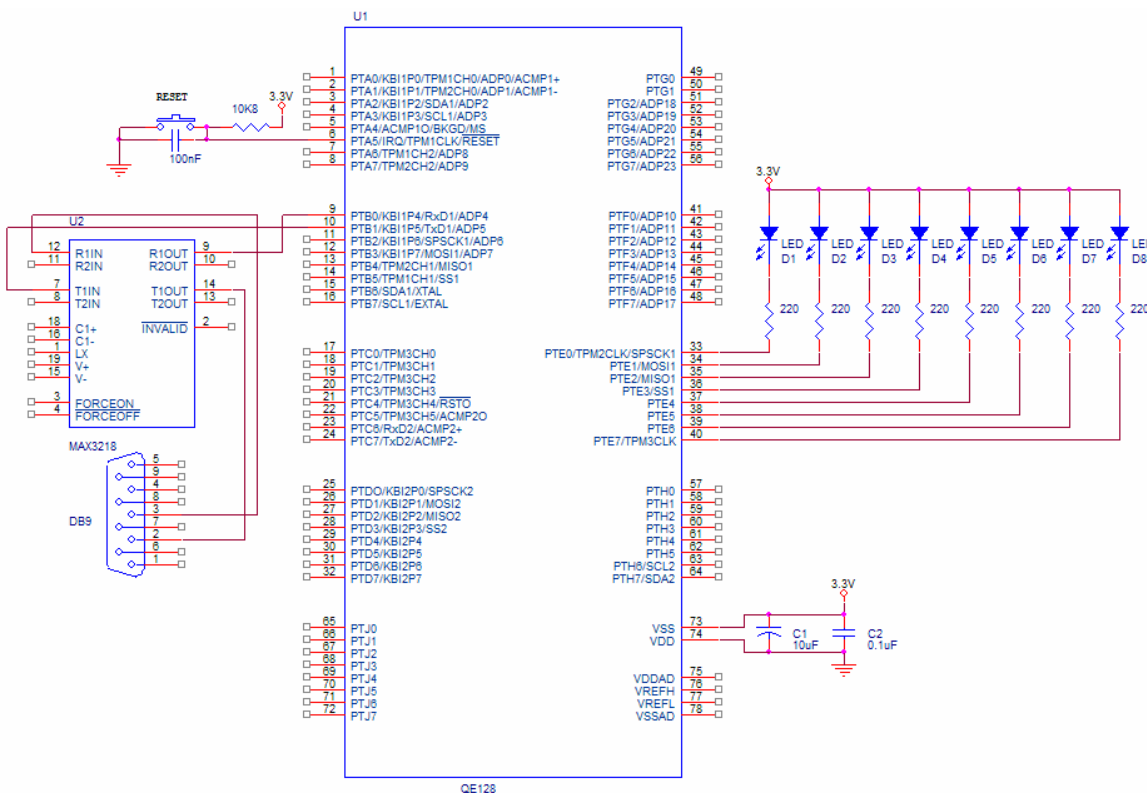


Figure 10-1. SCI Hardware Implementation

NOTE

This example is developed using the CodeWarrior IDE version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (80-pin package). There may be changes needed in the code to initialize another MCU.

Figure 10-1, shows the hardware connections used for the SCI project, for detailed information about the MCU power supply, please refer to the Pins and Connections chapter in the Reference Manual. It can be found at www.freescale.com.

The SCI.mcp project needs to work with the hyperterminal program. The hyperterminal is configured to the following characteristics:

- 9600bps baud rate
- 8-bit mode
- No parity checked
- 1 stop bit
- No flow control

Press any key and the character “1” appears.

10.3 SCI project for Demo board

10.3.1 Code Example and Explanation

This example code is available from the Freescale Web site www.freescale.com.

This section explains the differences of codes used in the EVB and Demo board. The codes are the same.

The project file contains the following functions:

- main — Endless loop waiting for the SCI interrupt to occur.
- MCU_Init – MCU initialization, watchdog disable and the SCI clock module enabled.
- GPIO_Init – Configure PTC0-PTC5, PTE6 and PT7 as outputs.
- SCI_Init – SCI module configuration.
- SCI_RX_ISR — The data obtained by SCI module is display on eight LEDs and the character “1” is send it by SCI.

This is the General Purpose Input/Output configuration. These code lines configure the direction for the PTC port. Only six LEDs from the demo board are connected to the PTC port. The other two LEDs are connected to the E port. In this example PTC0 to PTC5, and PTE6, PTE7 are configured as outputs in order to drive LEDs.

```
void GPIO_Init(void) {
    PTCDD = (UINT8) (PTCD | 0x3F);    // Configure PTC0-PTC5 as outputs
    PTEDD = (UINT8) (PTED | 0xC0);    // Configure PTE6 and PTE7 pins as outputs
    PTCDD = 0x3F;                    // Put 1's in port C in order to turn off the LEDs
    PTEDD = 0xC0;                    // Put 1's in port E port in order to turn off the LEDs
}
```

NOTE

This is the SCI service routine. Every time an SCI interrupt is detected, the received data is displayed on eight LEDs and the character “1” is sent by SCI. The VectorNumber_Vscilrx can be replaced by the interrupt vector number, this depends if the MCU is S08 or V1. Using this example makes the code fully compatible for either MCU.

```
void interrupt VectorNumber_Vscilrx SCI_RX_ISR(void) {
    // SCI vector address = 15 (S08)
    // SCI vector address = 77 (V1)

    UINT8 temp;
    SCI1S1_RDRF = 0;    // Receive interrupt disable
    temp = SCI1D;        // Store the receive value on temp variable
    PTED = (UINT8) (temp & 0xC0);    // Move the received value to port E
    PTCDD = (UINT8) (temp & 0x3F);    // Move the received value to port C

    while (SCI1S1_TDRE == 0);    // Wait for the transmitter to be empty
    SCI1D = '1';                // Send a character by SCI
}
```

10.3.2 Hardware Implementation

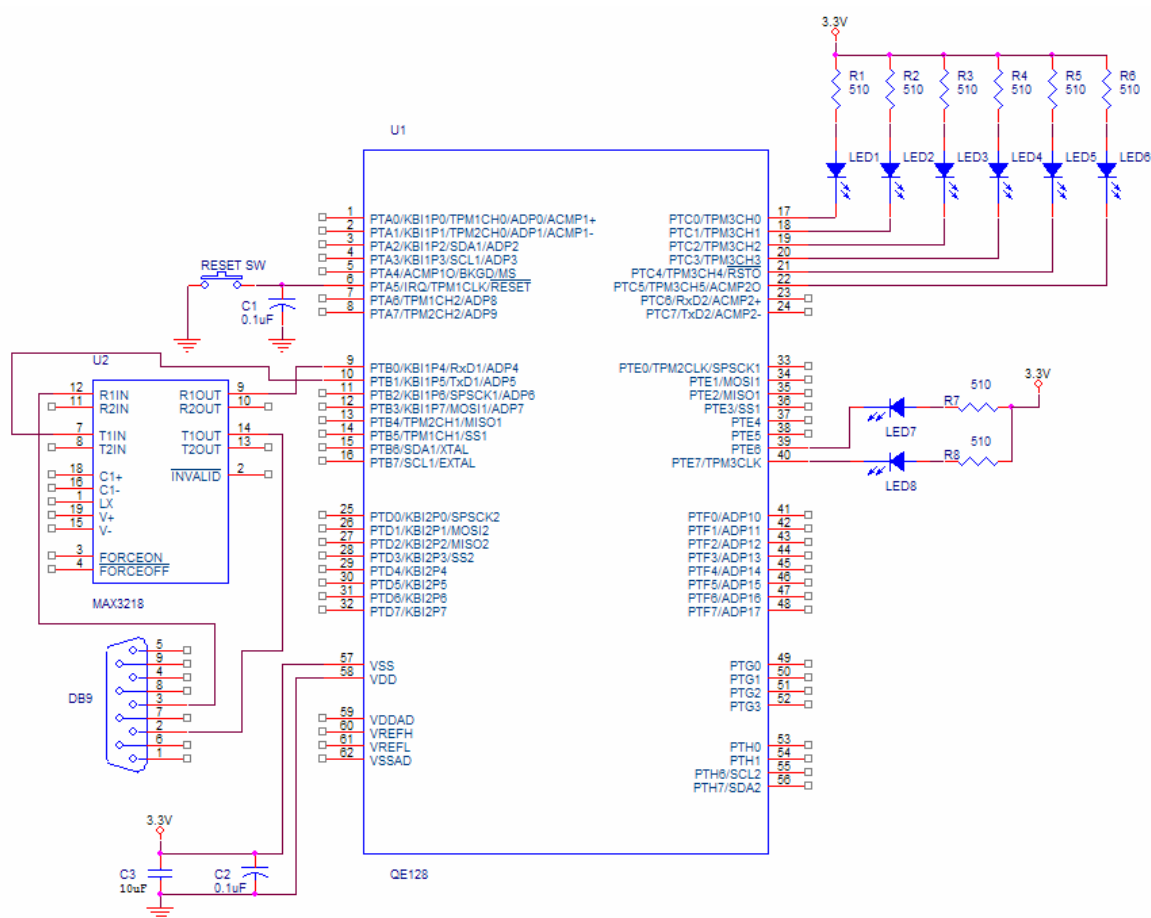


Figure 10-2. SCI Hardware Implementation.

NOTE

This example is developed using the CodeWarrior IDE version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (64-pin package). There may be changes needed in the code to initialize another MCU.

Figure 10-2, shows the hardware connections used for the SCI project, for detailed information about the MCU power supply, please refer to the Pins and Connections chapter in the Reference Manual. It can also be found at www.freescale.com.

The SCI.mcp project needs to work with the hyperterminal program. The hyperterminal is configured to the following characteristics:

- 9600bps baud rate
- 8-bit mode
- No parity checked

Using the Serial Communications Interface (SCI) for the QE Microcontrollers

- 1 stop bit
- No flow control

Press any key and the character “1” appears.

Chapter 11

Using the Serial Peripheral Interface (SPI) for the QE Microcontrollers

11.1 Overview

This is a quick reference for using the serial peripheral interface (SPI) module for the QE family microcontrollers (MCUs). Basic information about the functional description and configuration options are provided. The following example may be modified to suit an application. The SPI project is made for the MC9S08QE128 and MCF51QE128 MCUs.

SPI Quick Reference

Because there are two SPI modules on some devices, there may be two full sets of registers. In the register names below, where there's a small x, there would be a 1 or a 2 in your software to distinguish the registers that are on SPI1 from those on SPI2.

SPIxC1	SPIE	SPE	SPTIE	MSTR	CPOL	CPHA	SSOE	LSBFE
--------	------	-----	-------	------	------	------	------	-------

Module configuration:

SPIE – SPI Interrupt Enable	CPOL – Clock Polarity
SPE – SPI system Enable	CPHA – Clock Phase
SPTIE – SPI transmit Interrupt Enable	SSOE – Slave Select Output Enable
MSTR – Master/Slave Mode Select	LSBFE – LSB First

SPIxC2			MODFEN	BIDIROE		SPISWAI	SPC0
--------	--	--	--------	---------	--	---------	------

Module configuration:

MODFEN – Master Mode-Fault function Enable	SPISWAI – SPI Stop in Wait mode
BIDIROE – Bidirectional mode Output Enable	SPC0 – SPI Pin control 0

SPIxBR		SPPR2	SPPR1	SPPR0		SPR2	SPR1	SPR0
--------	--	-------	-------	-------	--	------	------	------

SPPR[2:0] – SPI Baud Rate Prescaler Divisor	SPR[2:0] – SPI Baud Rate Divisor
---	----------------------------------

SPIxS	SPRF		SPTEF	MODF				
-------	------	--	-------	------	--	--	--	--

SPRF – SPI Read buffer full Flag	MODF – Master Mode Fault Flag
SPTEF – SPI Transmit Buffer Empty Flag	

SPIxD	Bit 7	6	5	4	3	2	1	Bit 0
-------	-------	---	---	---	---	---	---	-------

Data buffer

11.2 SPI project for EVB

11.2.1 Code Example and Explanation

This example code for Master and Slave project is available from the Freescale Web site www.freescale.com.

11.2.1.1 SPI Master Project

The project SPI_Master configures the SPI module in master mode. The main functions are:

- main — A byte is sent by SPI.
- MCU_Init – MCU initialization, watchdog disable and the SPI clock module enabled.
- GPIO_Init – Configure PTE port as output, configure PTD4 as output (\overline{SS} signal).
- SPI_Init – SPI module configuration.
- SPI_ISR — Clear module flags.

The following example describes the initialization code for the SPI module in master mode. Two boards need to be connected. One board is configured as master, the other one works as slave. The firmware configures the MCU as master and sends a count of 0 to 255 to the slave using the SPI module.

The code below executes the instructions to disable the watchdog, enable the Reset option and background pin. The System Option Register 1 (SOPT1) is used to configure the MCU. The SCGC1 and SCGC2 are registers used for power saving consumption, here the bus clock to peripherals can be enabled or disabled. In this example only the bus clock to the SPI2 module is active. The clocks to the other peripherals are disabled.

```
void MCU_Init(void) {
    SOPT1 = 0x23;           // Watchdog disable. Stop Mode Enable. Background Pin
                          // enable. RESET pin enable
    SCGC1 = 0x00;          // Disable Bus clock to unused peripherals
    SCGC2 = 0x02;          // Bus Clock to the SPI2 module is enabled
}
```

This is the General Purpose Input/Output configuration. These code lines configure the pin directions for the PTD port. The SPI protocol can communicate various slaves with one master. To communicate with a specific slave the \overline{SS} signal must be low. The PTD3 pin is configured as output and the \overline{SS} signal must be changed by software using a GPIO.

```
void GPIO_Init(void) {
    PTDDD = 0x04;          // The SS signal must be generated by software using a GPIO
    PTEDD = 0xFF;          // Configure PTE port as output
    PTED = 0x00;           // Put 0's in PTE port
}
```

This is the initialization code for Serial Peripheral Interface module used for the QE MCU. This application configures the SPI module to work in master mode. The different pins are used for data input and data output. To obtain a 15.625KHz bit rate it is necessary to do the following calculations:

$$15.625kHz = \frac{4MHz}{(Prescaler)(Divider)}$$

$$\frac{4MHz}{15.625kHz} = 256$$

$$256 = (Prescaler Divisor) \times (Clock Rate Divider)$$

$$256 = 8 \times 32$$

```

void SPI_Init (void) {
SPI2BR = 0x75;      // Select the highest baud rate prescaler divisor and the
                  // highest baud rate divisor
SPI2C1 = 0xD0;    // SPI Interrupt enable, system enable and master mode selected
SPI2C2 = 0x00;    // Different pins for data input and data output
}
    
```

This is the main function, described above are the called functions, and all the interrupts are enabled. Within the endless loop a byte is sent by SPI and the next byte is sent after a delay. For detailed information about the SPI module, refer to the QE MCU reference manual. It can be found at www.freescale.com.

```

void main(void) {
    UINT8 counter = 0;
    MCU_Init();           // Function that initializes the MCU
    GPIO_Init();         // Function that initializes the Ports of the MCU
    SPI_Init();          // Function that initializes the SPI module
    EnableInterrupts();  // enable interrupts

    for(;;) {
        delay(60000);    // Delay function
        while (!SPI2S_SPTEF && !PTDD_PTDD3); // Wait until transmit buffer is empty
        PTDD_PTDD3 = 0; // Slave Select set in low
        SPI2D = counter; // Put in SPI buffer a data to send
        PTED = counter;  // Display the counter value on LEDs
        counter++;       // Increment counter
    }                    // loop forever
                        // please make sure that you never leave this function
}
    
```

NOTE

This is the SPI interrupt service routine. This routine is used when a byte is sent by the slave to the master.

```

void interrupt VectorNumber_Vspi2 SPI_ISR(void) {
    // SPI interrupt vector number = 12 (S08)
    // SPI interrupt vector number = 74 (V1)

    UINT8 temp;
    while (PTDD_PTDD0); // Wait for clock to return no default
    PTDD_PTDD3 = 1;    // Set Slave Select high
    temp = SPI2S;      // Clear register flag
    temp = SPI2D;      // Read data register to clear receive flag
}
    
```

11.2.1.2 SPI Slave Project

The project SPI_Slave configures the SPI module in slave mode. The main functions are:

- main — Waits for the SPI interrupt to occur.
- MCU_Init – MCU initialization, watchdog disable and the SPI clock module enabled.
- GPIO_Init – Configure PTE port as output.
- SPI_Init – SPI module configuration.
- SPI_ISR — Display the received data in PTE port

The firmware for this project is similar to the SPI_master project. The differences are, the device is configured as slave and only Receives a byte and displays it on the PTE port.

This is the initialization code for the SPI module used for the QE MCU. This application configures the SPI module to work in slave mode.

```
void SPI_Init (void) {
    SPI2BR = 0x75;    // Select the highest baud rate prescaler divisor and the
                    // highest baud rate divisor
    SPI2C1 = 0xC4;    // SPI Interrupt enable, system enable and slave mode selected
    SPI2C2 = 0x00;    // Different pins for data input and data output
}
```

NOTE

This is the SPI interrupt service routine. This routine is used when a byte is sent by the master to the slave.

```
void interrupt VectorNumber_Vspi2 SPI_ISR(void) {
    UINT8 temp, buffer;
    while (PTDD_PTDD0);
    temp = SPI2S;    // Clear register flag
    buffer = SPI2D; // Read data register to clear receive flag
    PTED = buffer;
}
```

For detailed information about the code, refer to the SPI_Slave project from the QRUG examples.

11.2.2 Hardware Implementation

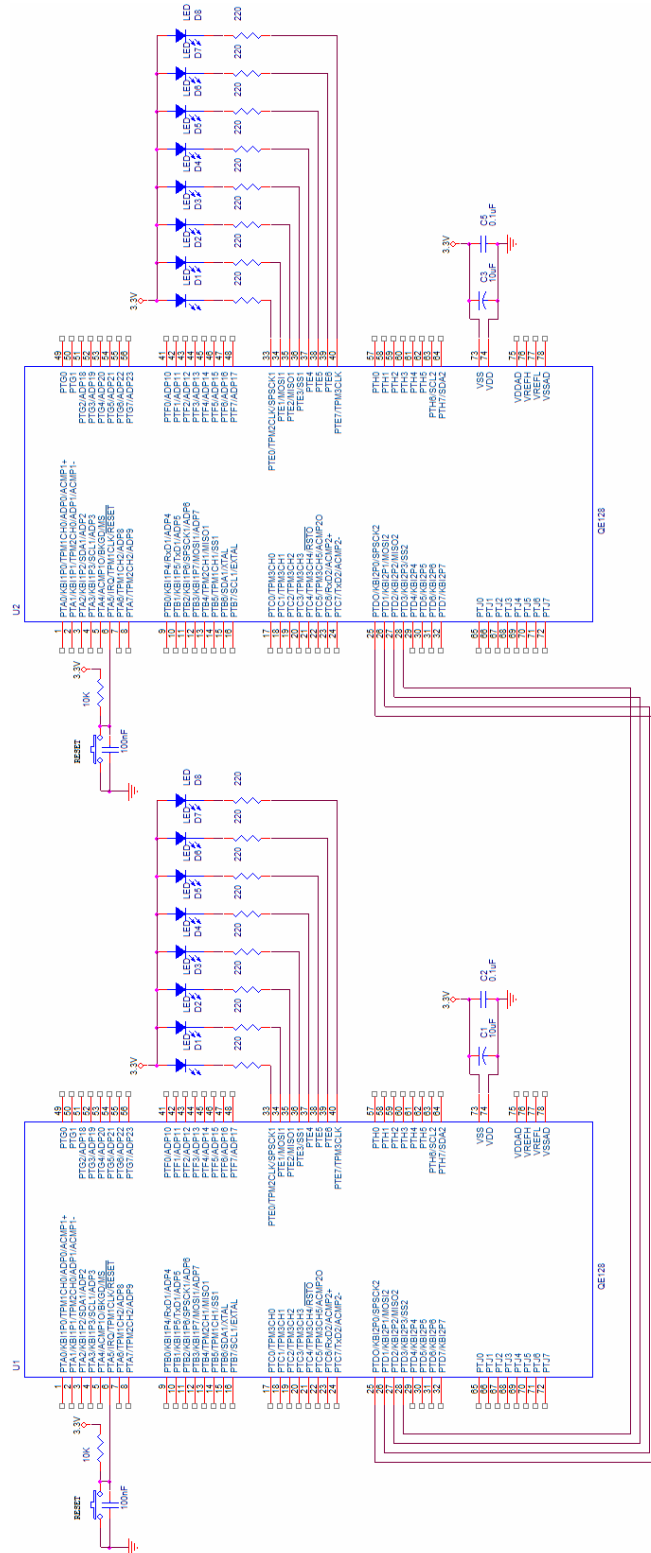


Figure 11-1. SPI Hardware Implementation.

NOTE

This example is developed using the CodeWarrior IDE version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (80-pin package). There may be changes needed in the code to initialize another MCU.

Figure 11-1, shows the hardware connections used for the SPI project, for detailed information about the MCU hardware needed, please refer to the Pins and Connections chapter in the Reference Manual. It can be found at www.freescale.com.

11.3 SPI project for Demo board

11.3.1 Code Example and Explanation

This example code for the Master and Slave project is available from the Freescale Web site www.freescale.com.

This Section explains the differences of codes used in the EVB and Demo board. The codes are the same.

11.3.1.1 SPI Master Project

The project SPI_Master configures the SPI module in master mode. The main functions are:

- main — A byte is sent by the SPI.
- MCU_Init – MCU initialization, watchdog disable and bus clock to the SPI clock module enabled.
- GPIO_Init – Configure PTC-PTC5, PTE6 and PTE7 pins as outputs, configure PTD4 as output (\overline{SS} signal).
- SPI_Init – SPI module configuration.
- SPI_ISR — Clear module flags.

This is the General Purpose Input/Output configuration. These code lines configure the pin directions for the PTD port. The SPI protocol can communicate various slaves with one master. To communicate with a specific slave the \overline{SS} signal must be low. The PTD3 pin is configured as output and the \overline{SS} signal must be changed by software using a GPIO. These code lines configure the direction for the PTC port. Only six LEDs from the demo board are connected to the PTC port. The other two LEDs are connected to the E port. In this example the PTC0 to PTC6, and PTE6, PTE7 are configured as outputs in order to drive LEDs.

```
void GPIO_Init(void) {
    PTDDD = 0x04;                // The SS signal must be generated by software using a GPIO
    PTCDD = (UINT8) (PTCD | 0x3F); // Configure PTC0-PTC6 as outputs
    PTEDD = (UINT8) (PTED | 0xC0); // Configure PTE6 and PTE7 pins as outputs
    PTCD = 0x3F;                 // Put 1's in port C in order to turn off the LEDs
    PTED = 0xC0;                 // Put 1's in port E port in order to turn off the LEDs
}
```

This is the main function, described are the above functions are called, and all the interrupts are enabled. Within the endless loop a byte is sent by SPI and the next byte is sent after a delay. For detailed information about SPI module, refer to the QE MCU reference manual. It can be found at www.freescale.com.

```

void main(void) {
    UINT8 counter = 0;
    MCU_Init();           // Function that initializes the MCU
    GPIO_Init();         // Function that initializes the Ports of the MCU
    SPI_Init();          // Function that initializes the SPI module
    EnableInterrupts;    // enable interrupts

    for(;;) {
        delay(60000);    // Delay function
        while (!SPI2S_SPTEF && !PTDD_PTDD3); // Wait until transmit buffer is empty
        PTDD_PTDD3 = 0; // Slave Select set in low
        SPI2D = counter; // Put in SPI buffer a data to send
        PTED = (UINT8) (counter & 0xC0); // Move the acquired ADC value to port E
        PTCD = (UINT8) (counter & 0x3F); // Move the acquired ADC value to port C
        counter++;      // Increment counter
    }                  // loop forever
                    // please make sure that you never leave this function
}
    
```

11.3.1.2 SPI Slave Project

The project SPI_Slave configures the SPI module in slave mode. The main functions are:

- main — Waits for the SPI interrupt to occur.
- MCU_Init – MCU initialization, watchdog disable and the SPI clock module enabled.
- GPIO_Init – Configure PTE port as output.
- SPI_Init – SPI module configuration.
- SPI_ISR — Display the received data in eight LEDs

The firmware for this project is much similar to SPI_master project. The differences are that the device is configured as slave and only Receives a byte and displays it on the PTE port.

This is the initialization code for Serial Peripheral Interface module used for the QE MCU. This application configures the SPI module to work in slave mode.

```

void SPI_Init (void) {

    SPI2BR = 0x75;       // Select the highest baud rate prescaler divisor and the
                        // highest baud rate divisor
    SPI2C1 = 0xC4;      // SPI Interrupt enable, system enable and slave mode selected
    SPI2C2 = 0x00;      // Different pins for data input and data output
}
    
```

NOTE

This is the SPI interrupt service routine. This routine is used when a byte is sent by the master to the slave.

```

void interrupt VectorNumber_Vspi2 SPI_ISR(void) {
    UINT8 temp, buffer;
    while (PTDD_PTDD0);
    temp = SPI2S;           // Clear register flag
    buffer = ~SPI2D;       // Read data register to clear receive flag
                        // on the LEDs (The LEDs turn on with 0's)
    PTED = (UINT8) (temp & 0xC0); // Move the acquired ADC value to port E
    PTCD = (UINT8) (temp & 0x3F); // Move the acquired ADC value to port C
}
    
```

}

For detailed information about the code, refer to the SPI_Slave project from the QRUG examples.

11.3.2 Hardware Implementation

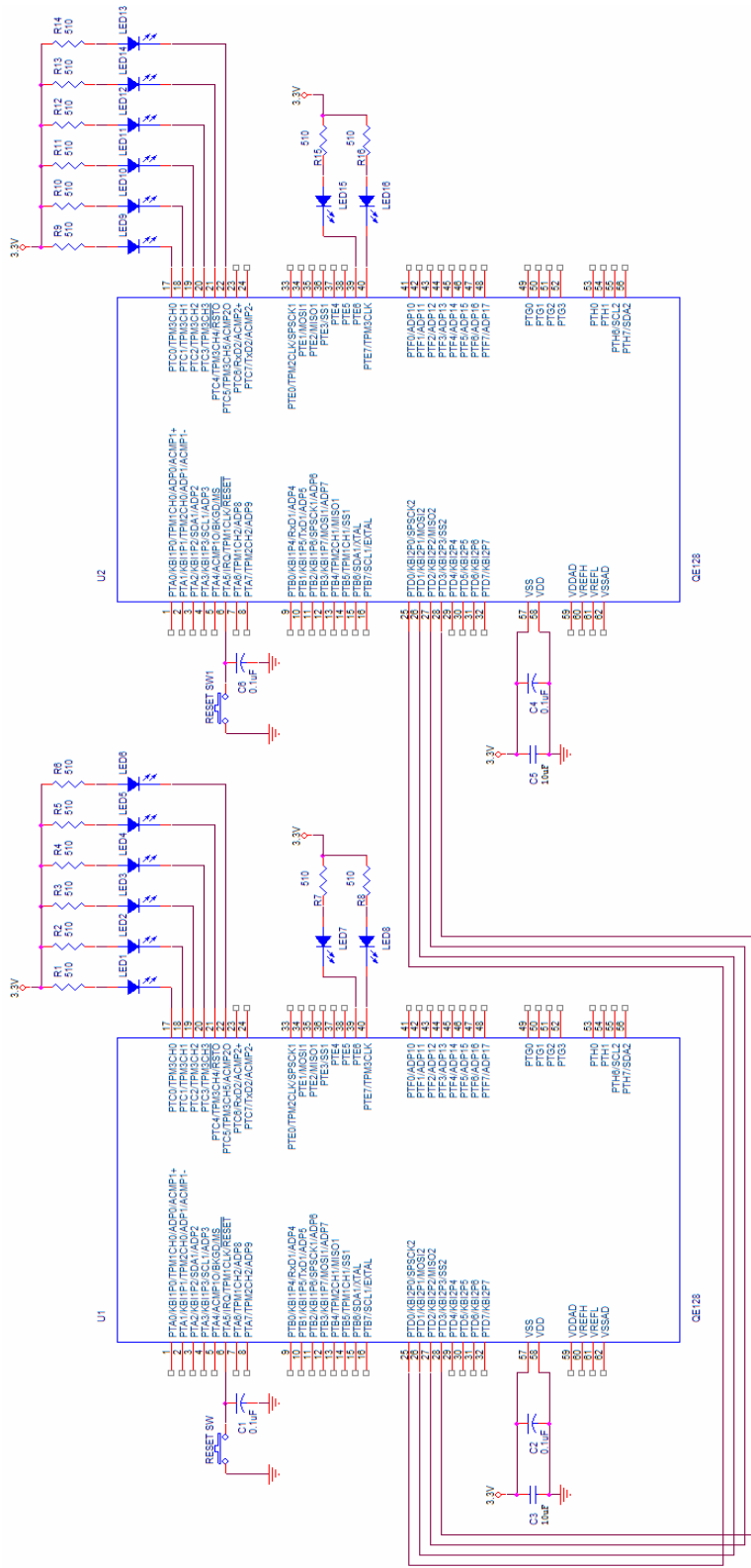


Figure 11-2. SPI Hardware Implementation.

NOTE

This example is developed using the CodeWarrior IDE version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (64-pin package). There may be changes needed in the code to initialize another MCU.

[Figure 11-2](#), shows the hardware connections used for the SPI project, for detailed information about the MCU hardware needed, please refer to the Pins and Connections chapter in the Reference Manual. It can be found at www.freescale.com.

Chapter 12

Generating PWM Signals Using Timer/Pulse-Width Modulator (TPM) Module for the QE Microcontrollers

12.1 Overview

This is a quick reference for enabling the pulse width modulator (PWM) functionality of the timer/pulse-width modulator (TPM) module for the QE family microcontrollers (MCUs). Basic information about the functional description and configuration options are provided. The following example may be modified to suit an application. The PWM project is made for the MC9S08QE128 and MCF51QE128 MCUs.

TPM Quick Reference

Because there is more than one TPM modules on QE MCU, there are three full sets of registers. In the register names below, where there's a small x, there would be a 1, 2 or 3 in your software to distinguish the registers that are on TPM1 from those on TPM2 or from TPM3. A small n in a register name below is a place-holder for the channel number

TPM _x SC	TOF	TOIE	CPWMS	CLKSB	CLKSA	PS2	PS1	PS0
---------------------	-----	------	-------	-------	-------	-----	-----	-----

Module configuration::

TOF – Timer Overflow Flag
 TOIE – Timer Overflow Interrupt Enable
 CPWMS – Center-Aligned PWM Select

CLKS[B:A] – Clock Source Select
 PS[2:0] – Prescale Divisor Select

TPM _x CNTH	Bit 15	14	13	12	11	10	9	Bit 8
TPM _x CNTL	Bit 7	6	5	4	3	2	1	Bit 0

Any write to TPM_xCNTH or TPM_xCNTL clears the 16-bit counter

TPM _x MODH	Bit 15	14	13	12	11	10	9	Bit 8
TPM _x MODL	Bit 7	6	5	4	3	2	1	Bit 0

Modulo value for TPWM module

TPM _x CnSC	CHnF	CHnIE	MSnB	MSnA	ELSnB	ELSnA		
-----------------------	------	-------	------	------	-------	-------	--	--

CHnF – Channel n Flag
 CHnIE – Channel n Interrupt Enable
 MSnB – Mode Select B for TPM Channel n

MSnA – Mode Select A for TPM Channel n
 ELSn[[B:A] – Edge/Level Select Bits

TPM _x CnVH	Bit 15	14	13	12	11	10	9	Bit 8
TPM _x CnVL	Bit 7	6	5	4	3	2	1	Bit 0

Captured TPM counter of input capture function OR output compare value for output compare of PWM function

12.2 PWM project for EVB

12.2.1 Code Example and Explanation

This example code is available from the Freescale Web site www.freescale.com.

The project file contains the following functions:

- main — Endless loop waiting for the TPM interrupt to occur.
- MCU_Init – MCU initialization, watchdog disable and the TPM1 clock module enabled.
- GPIO_Init – Configure PTE0 pin as output.
- TPM_Init – TPM module configuration.
- TPM_ISR — The PWM duty cycle is incremented and the PWM signal is shown in the PTE0 pin.

This example describes the initialization code for the TPM module using the PWM feature. The TPM module uses channel 1 to generate a PWM signal. When Channel 1 interrupt is detected, the PWM duty-cycle is incremented. When the counter reaches a value of 0x00F0, the counter value is reset to 1.

This part of the code is the MCU initialization. These instructions disable the watchdog, enable the Reset option and background pin. The system option register 1 (SOPT1) is used to configure the MCU. The SCGC1 and SCGC2 are registers used for power saving consumption, here the bus clock to peripherals can be enabled or disabled. In this example only the bus clock to the TPM module is active. The other peripheral clocks are disabled.

```
void MCU_Init(void) {
    SOPT1 = 0x23;           // Watchdog disable. Stop Mode Enable. Background Pin enable.
                          // RESET pin enable
    SCGC1 = 0x20;          // Bus Clock to the TPM1 module is enabled
    SCGC2 = 0x00;          // Disable Bus clock to unused peripherals
}
```

This is the General Purpose Input/Output configuration. These code lines configure the pin directions for the PTE port. In this example one LED is connected to the PTE port; therefore the PTE0 pin is configured as output.

```
void GPIO_Init(void) {
    PTEDD = 0x01;          // Configure PTE0 pin as output
    PTED = 0x00;          // Put 0's in PTE port
}
```

These line codes initialize the TPM module for the QE MCU. This application enables the TPM Channel 1 interrupt and configures the TPM module to work in the PWM mode. The MCU bus clock works at 4 MHz. This is the MCU default speed. This clock is divided by 128 and used in the TPM module.

```
void TPM_Init (void) {
    TPM1MOD = 0x00FE;      // Store 0x00FE value
    TPM1C1SC = 0x68;       // Channel 1 interrupt enable. PWM edge aligned
    TPM1C1VH = 0x00;       // TPM1C1V is a 16 bit register, for this example is only
                          // needed to store 0x0001
    TPM1C1VL = 0x01;       // in this register at the beginning because the next value
                          // will be increased by 1 in the ISR
    TPM1SC = 0x0F;         // TPM Clock Source is the bus rate clock. This bus is
                          // divided by 128
}
```


This is the main function, above are the described called functions, and all the interrupts are enabled. The TPM interrupt can then be detected. Within the endless loop the PWM output value is displayed in the PTE0.

```
void main(void) {
    MCU_Init();           // Function that initializes the MCU
    GPIO_Init();         // Function that initializes the Ports of the MCU
    TPM_Init();          // Function that initializes the TPM module
    EnableInterrupts;    // enable interrupts

    for(;;) {
        PTED_PTED0 = PTBD_PTBD5; // PTB5 is the PWM output, so this output is
                                   // display in the PTE0 (This is made only for didactic purposes)
    }                          // loop forever
                                // please make sure that you never leave this function
}
```

NOTE

This is the TPM service routine. Every time a TPM interrupt is detected, the PWM duty cycle is incremented by 1. When the value of the register reaches 0x00F0 the compare value is reset to one.

```
void interrupt VectorNumber_Vtpm1ch1 TPM_ISR(void) {
    // TPM interrupt vector number = 5 (S08)
    // TPM interrupt vector number = 67 (V1)
    TPM1C1SC_CH1F; // Clear TPM flags
    TPM1C1SC_CH1F = 0; // Two-step flag acknowledgement

    if (TPM1C1V <= 0x00F0){ // If the maximum value of the duty cycle is not reached
        TPM1C1V++; // Increment de duty cycle by 1
        PTED_PTED0 = PTBD_PTBD5; // PTB5 is the PWM output, so this output is display in the LED1
    }
    else {
        TPM1C1V = 0x0001; // Reset the value of duty cycle to 1
    }
}
```

12.2.2 Hardware Implementation

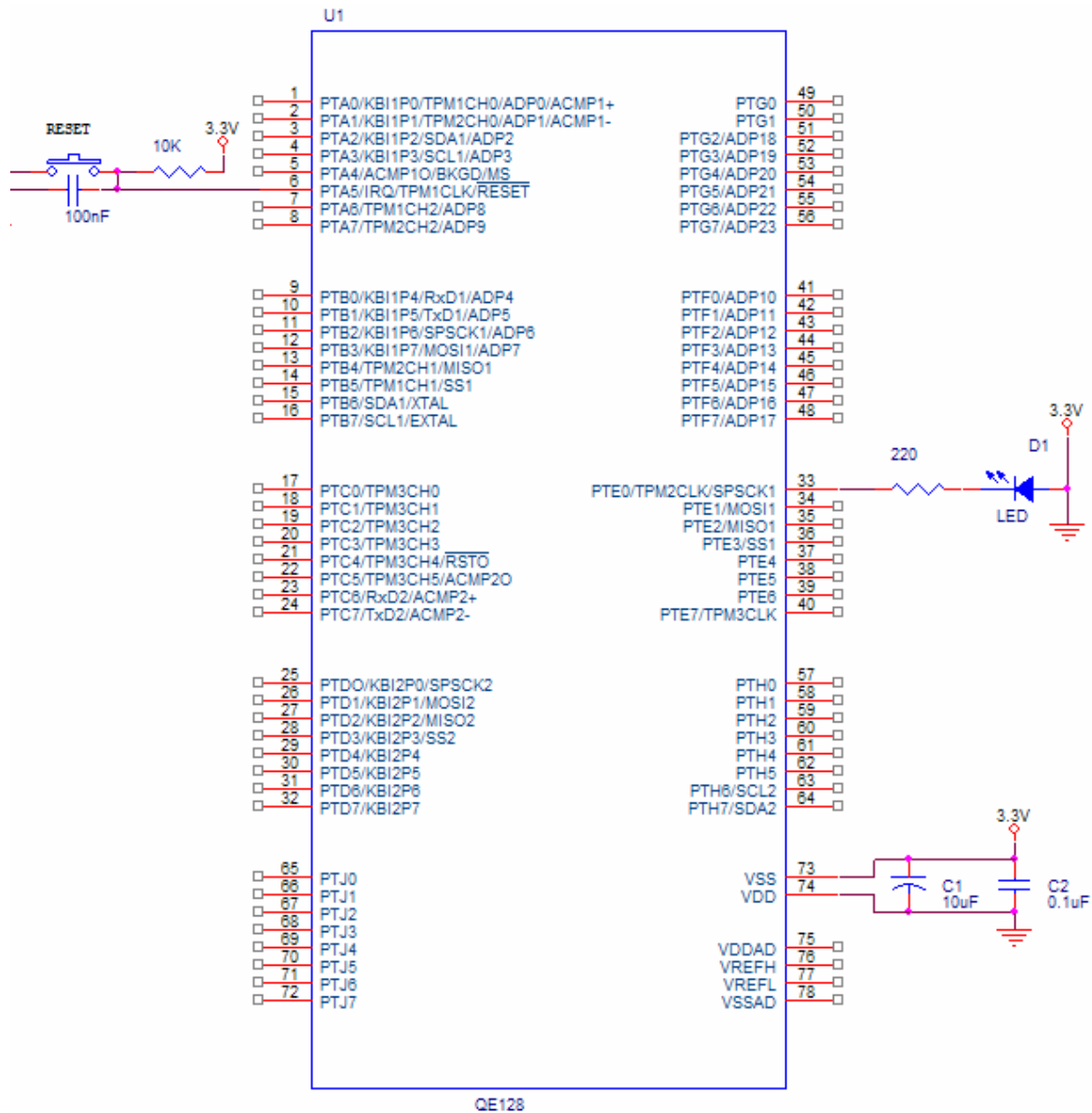


Figure 12-1. PWM Hardware Implementation.

NOTE

This example is developed using the CodeWarrior IDE version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (80-pin package). There may be changes needed in the code to initialize another MCU.

Figure 12-1, shows the hardware connections used for the PWM project, for detailed information about the MCU hardware needed, please refer to the Pins and Connections chapter in the Reference Manual. It can be found at www.freescale.com.

12.3 PWM project for Demo board

12.3.1 Code Example and Explanation

This section explains the differences of codes used in the EVB and Demo board. The codes are the same.

This is the General Purpose Input/Output configuration. These code lines configure the direction for the PTC port. Only six LEDs from the demo board are connected to the PTC port. The other two LEDs are connected to the E port. In this example the PTC0 is configured as output in order to drive a LED.

```
void GPIO_Init(void) {
    PTCDD = 0x01;      // Configure PTC0 as output
    PTC0 = 0x01;      // Put 1 in PTC0 in order to turn off the LED
}
```

This is the main function, above are the described called functions, and all the interrupts are enabled. The TPM interrupt can then be detected. Within the endless loop the PWM output value is displayed which is in the PTE0.

```
void main(void) {
    MCU_Init();        // Function that initializes the MCU
    GPIO_Init();      // Function that initializes the Ports of the MCU
    TPM_Init();       // Function that initializes the TPM module
    EnableInterrupts; // enable interrupts

    for(;;) {
        PTEC_PTC0 = PTBD_PTBD5; // PTB5 is the PWM output, so this output is
                                // display in the LED1 (This is made only for didactic purposes)
    }                          // loop forever
                                // please make sure that you never leave this function
}
```

NOTE

This is the TPM service routine. Every time a TPM interrupt is detected, the PWM duty cycle is incremented by 1. When the value of the register reaches 0x00F0 the compare value is reset to one.

```
void interrupt VectorNumber_Vtpm1ch1 TPM_ISR(void) {
    // TPM interrupt vector number = 5 (S08)
    // TPM interrupt vector number = 67 (V1)

    TPM1C1SC_CH1F; // Clear TPM flags
    TPM1C1SC_CH1F = 0; // Two-step flag acknowledgement

    if (TPM1C1V <= 0x00F0){ // If the maximum value of the duty cycle is not reached
        TPM1C1V++; // Increment de duty cycle by 1
        PTC0_PTC0 = PTBD_PTBD5; // PTB5 is the PWM output, so this output is display in the LED1
    }
    else {
        TPM1C1V = 0x0001; // Reset the value of duty cycle to 1
    }
}
```

}
}

12.3.2 Hardware Implementation

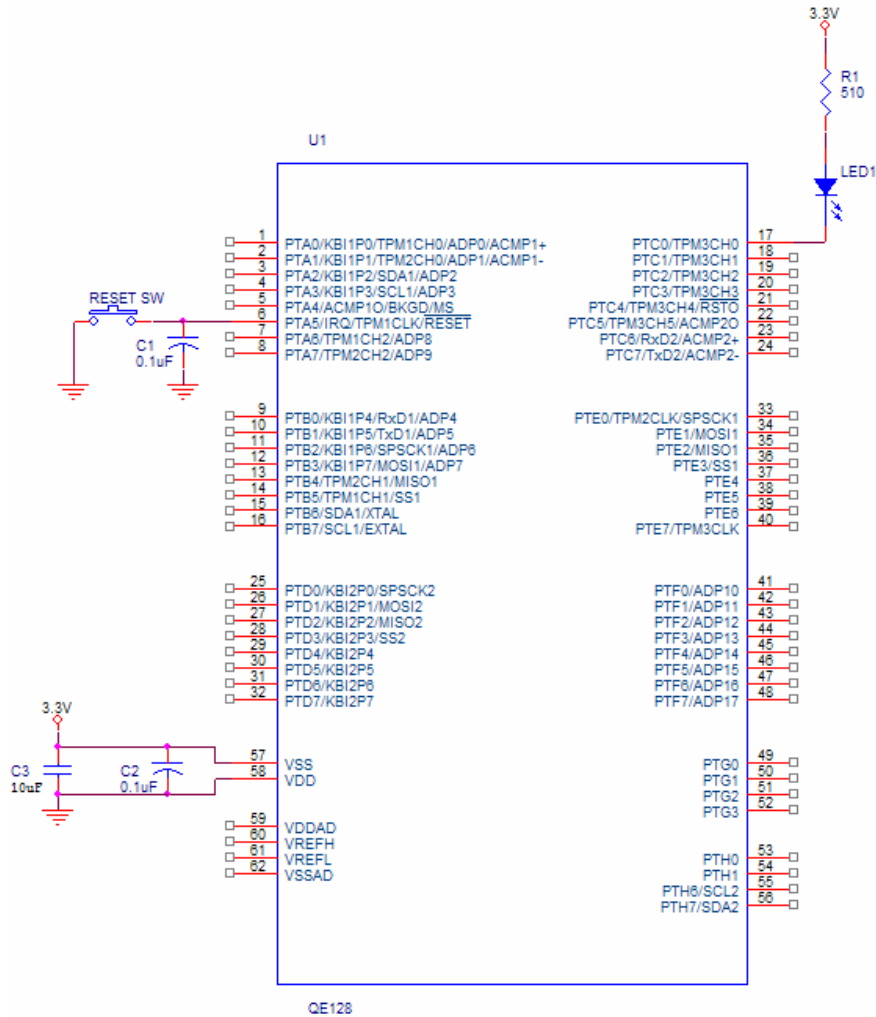


Figure 12-2. PWM Hardware Implementation.

NOTE

This example is developed using the CodeWarrior IDE version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (64-pin package). There may be changes needed in the code to initialize another MCU.

Figure 12-2, shows the hardware connections used for the PWM project, for detailed information about the MCU hardware needed, please refer to the Pins and Connections chapter in the Reference Manual. It can be found at www.freescale.com.

Chapter 13

Using the Output Compare function with the Timer/Pulse-Width Modulator (TPM) module for the QE Microcontrollers

13.1 Overview

This is a quick reference for enabling the PWM functionality of the timer/pulse-width modulator (TPM) module on the QE family microcontrollers (MCUs). Basic information about the functional description and configuration options is provided. The following example may be modified to suit your application. The TPM project was made for the MC9S08QE128 and MCF51QE128 microcontrollers.

TPM Quick Reference

Because there is more than one TPM modules on QE MCU, there are three full sets of registers. In the register names below, where there's a small x, there would be a 1, 2 or 3 in your software to distinguish the registers that are on TPM1 from those on TPM2 or from TPM3. A small n in a register name below is a place-holder for the channel number.

TPM _x SC	TOF	TOIE	CPWMS	CLKSB	CLKSA	PS2	PS1	PS0
---------------------	-----	------	-------	-------	-------	-----	-----	-----

Module configuration:

TOF – Timer Overflow Flag
 TOIE – Timer Overflow Interrupt Enable
 CPWMS – Center-Aligned PWM Select

CLKS[B:A] – Clock Source Select
 PS[2:0] – Prescale Divisor Select

TPM _x CNTH	Bit 15	14	13	12	11	10	9	Bit 8
-----------------------	--------	----	----	----	----	----	---	-------

TPM _x CNTL	Bit 7	6	5	4	3	2	1	Bit 0
-----------------------	-------	---	---	---	---	---	---	-------

Any write to TPM_xCNTH or TPM_xCNTL clears the 16-bit counter

TPM _x MODH	Bit 15	14	13	12	11	10	9	Bit 8
-----------------------	--------	----	----	----	----	----	---	-------

TPM _x MODL	Bit 7	6	5	4	3	2	1	Bit 0
-----------------------	-------	---	---	---	---	---	---	-------

Modulo value for TPM module

TPM _x CnSC	CHnF	CHnIE	MSnB	MSnA	ELSnB	ELSnA		
-----------------------	------	-------	------	------	-------	-------	--	--

CHnF – Channel n Flag
 CHnIE – Channel n Interrupt Enable
 MSnB – Mode Select B for TPM Channel n

MSnA – Mode Select A for TPM Channel n
 ELSn[[B:A] – Edge/Level Select Bits

TPM _x CnVH	Bit 15	14	13	12	11	10	9	Bit 8
-----------------------	--------	----	----	----	----	----	---	-------

TPM _x CnVL	Bit 7	6	5	4	3	2	1	Bit 0
-----------------------	-------	---	---	---	---	---	---	-------

Captured TPM counter of input capture function OR output compare value for output compare of PWM function

13.2 TPM Project for EVB

13.2.1 Code Example and Explanation

This example code is available from the Freescale Web site www.freescale.com

The project file contains the following functions:

- main — Endless loop waiting for the TPM interrupt to occur.
- MCU_Init – MCU initialization, watchdog disable and bus clock to the TPM1 module enabled.
- GPIO_Init – Configure PTE0 pin as output.
- TPM_Init – TPM module configuration.
- TPM_ISR — The ISR instructions will toggle PTE0 pin.

This example describes the initialization code for the Timer-Pulse Width Modulator module using the toggle on output compare feature. The firmware configures TPM module channel 3 to toggle a LED when the counter counts up to 0xFFFF. The toggle instruction is executed within the ISR.

This part of code is the MCU initialization, this instructions disable the watchdog and enable the Reset option and background pin. The SOPT1 register is the System Option Register 1, and is used to configure the MCU. SCGC1 and SCGC2 are registers used for power consumption save, where the bus clock to peripherals can be enable or disable. In this example only the bus clock to the TPM module is active, the others peripheral clocks are disable.

```
void MCU_Init(void) {
    SOPT1 = 0x23;           // Watchdog disable. Stop Mode Enable. Background Pin enable.
                          // RESET pin enable
    SCGC1 = 0x80;          // Bus Clock to the TPM3 module is enabled
    SCGC2 = 0x00;          // Disable Bus clock to unused peripherals
}
```

This is the General Purpose Input/Output configuration, this code lines configure the pin directions for PTE port. In this example only one LED is connected to port PTE, for that reason PTE0 pin is configured as output.

```
void GPIO_Init(void) {
    PTEDD = 0x01;          // Configure PTE0 pin as output
    PTED = 0x00;           // Put 0's in PTE port
}
```

This lines code initializes the Timer-Pulse Width Modulator module for the QE MCU. This application enables TPM Channel 3 interrupt and configures the TPM module to work as toggle output on compare mode. The MCU bus clock will work at 4MHz approximately (default operation), this clock is divided by 128 and used in the Timer-Pulse Width Modulator module.

```
void TPM_Init (void) {
    TPM3MOD = 0xFFFF;      // The counter counts up to 0xFFFF
    TPM3C3V = 0x0000;      // The channel interrupt will happen when counter matches
    TPM3C3SC = 0x54;       // Channel interrupt enabled and configured as toggle output on compare
    TPM3SC = 0x0F;         // TPM clock source is: Bus rate clock divided by 128
}
```

This is the main function, here are called the functions described above and all the interrupts are enable. after this the TPM interrupt can be detected.

```
void main(void) {
    MCU_Init();           // Function that initializes the MCU
    GPIO_Init();         // Function that initializes the Ports of the MCU
    TPM_Init();          // Function that initializes the TPM module
    EnableInterrupts;    // enable interrupts

    for(;;) {

    }                    // loop forever
                        // please make sure that you never leave this function
}

```

NOTE

This is the Timer-Pulse Width Modulator service routine. Every time an TPM interrupt is detected, the PTE0 pin is toggle. The interrupt will be generated when the counter counts up to 0xFFFF, after whis an interrupt will be generated and detected by the MCU.

```
void interrupt VectorNumber_Vtpm3ch3 TPM_ISR(void) {
    // TPM interrupt vector number = 28 (S08)
    // TPM interrupt vector number = 90 (V1)
    TPM3C3SC_CH3F;      // Clears timer flag
    TPM3C3SC_CH3F = 0;
    PTED_PTED0 = ~PTED_PTED0; // Toggle PTE0
}

```

13.2.2 Hardware Implementation

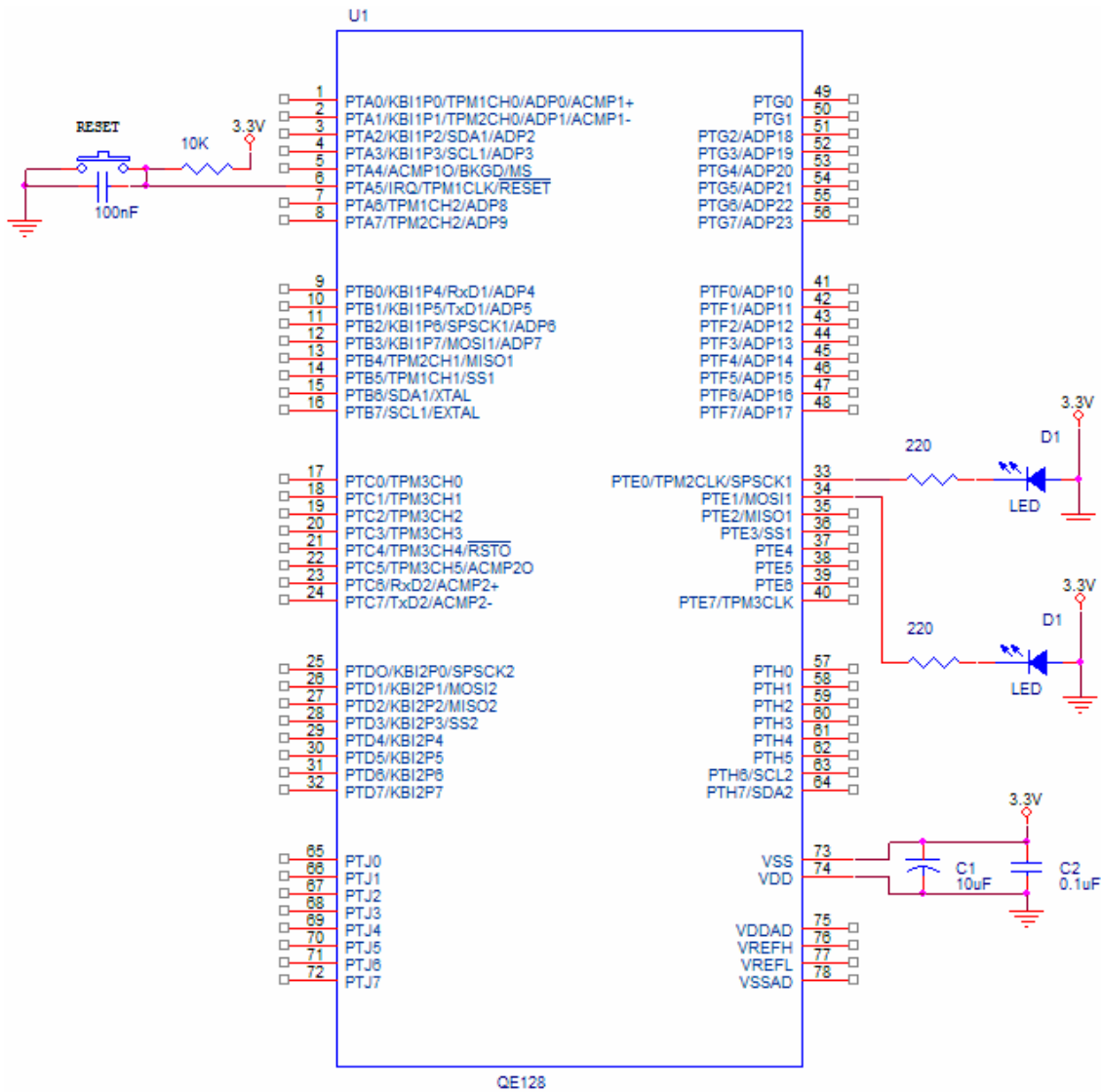


Figure 13-1. TPM Hardware Implementation

NOTE

This example was developed using the CodeWarrior IDE version 6.0 ALPHA 2 for the HCS08 and V1 family, and was expressly made for the MCF51QE128 and MC9S08QE128 (80-pin package). There may be changes needed in the code to initialize another MCU.

The Figure 13-1, shows the hardware connections used for the TPM project, for detailed information about the MCU needed hardware please refer to Pins and Connections chapter on your Reference Manual.

13.3 TPM project for Demo board

13.3.1 Code Example and Explanation

This example code is available from the Freescale Web site www.freescale.com.

The next lines only explains the differences of code using an EVB and the Demo board. The rest of the code are the same.

The project file contains the following functions:

- main — Endless loop waiting for the TPM interrupt to occur.
- MCU_Init – MCU initialization, watchdog disable and bus clock to the TPM1 module enabled.
- GPIO_Init – Configure PTC0 pin as output.
- TPM_Init – TPM module configuration.
- TPM_ISR — The ISR instructions will toggle PTC0 pin.

This is the General Purpose Input/Output configuration, this code lines configure the direction for PTC port. Only six LEDs from demo board are connected to PTC port, the others two LEDs are connected to port E. In this example PTC0 to PTC6, PTE6 and PTE7 are configured as outputs in order to drive LEDs.

```
void GPIO_Init(void) {
    PTCDD = (UINT8) (PTCD | 0x3F);           // Configure PTC0-PTC6 as outputs
    PTEDD = (UINT8) (PTED | 0xC0);         // Configure PTE6 and PTE7 pins as outputs
    PTCDD = 0x3F;                          // Put 1's in port C in order to turn off the LEDs
    PTEDD = 0xC0;                          // Put 1's in port E port in order to turn off the LEDs
}
```

NOTE

This is the Timer-Pulse Width Modulator service routine. Every time an TPM interrupt is detected, the PTE0 pin is toggle. The interrupt will be generated when the counter counts up to 0xFFFF, after whis an interrupt will be generated and detected by the MCU.

```
void interrupt VectorNumber_Vtpm3ch3 TPM_ISR(void) {
    // TPM interrupt vector number = 28 (S08)
    // TPM interrupt vector number = 90 (V1)
    TPM3C3SC_CH3F;                          // Clears timer flag
    TPM3C3SC_CH3F = 0;
    PTED_PTED0 = ~PTED_PTED0;              // Toggle PTE0
}
```

13.3.2 Hardware Implementation

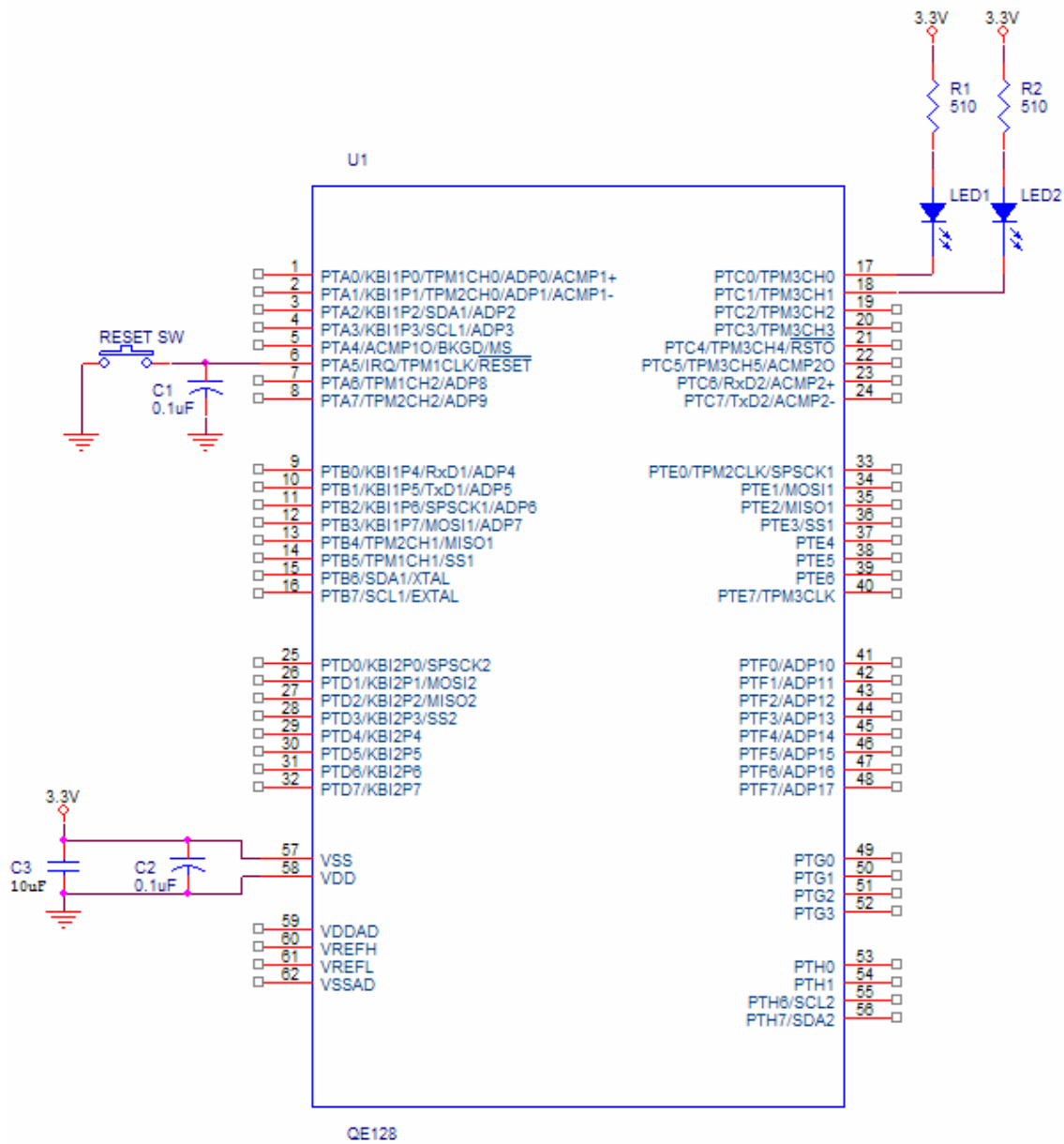


Figure 13-2. TPM Hardware Implementation

NOTE

This example was developed using the CodeWarrior IDE version 6.0 ALPHA 2 for the HCS08 and V1 family, and was expressly made for the MCF51QE128 and MC9S08QE128 (80-pin package). There may be changes needed in the code to initialize another MCU.

The Figure 13-2, shows the hardware connections used for the TPM project, for detailed information about the MCU needed hardware please refer to Pins and Connections chapter on your Reference Manual.

Chapter 14

Using the Rapid General Purpose I/O (RGPIO) for the MCF51QE128 Microcontrollers

14.1 Overview

This is a quick reference for enabling the Rapid GPIO (RGPIO) module for a MCF51QE128 microcontroller (MCU). Basic information about the functional description and configuration options are provided. This example may be modified to suit an application. This module is only available in 32-bit cores (V1).

14.2 Code Example and Explanation

This example code is available from the Freescale Web site www.freescale.com

The project file contains the following functions:

- main — Endless loop. Turn on and off three LEDs.
- MCU_Init – MCU initialization, watchdog disable, RESET pin enabled.
- GPIO_Init – Configure PTE0 and PTE1 pins as outputs.
- RGPIO_Init – RGPIO module configuration.

The following firmware describes the initialization code for the RGPIO module. This example shows the difference using normal GPIO and Rapid GPIO. The differences are shown in the True Time Simulator window and is explained further in this document.

This part of the code is the MCU initialization. These instructions disable the watchdog, enable the Reset option and background pin. The System Option Register 1 (SOPT1) is used to configure the MCU.

```
void MCU_Init(void) {
SOPT1 = 0x23;           // Watchdog disable. Stop Mode Enable. Background Pin
                       // enable. RESET pin enable
}
```

This is the General Purpose Input/Output configuration. These code lines configure the pin directions for the PTE port. In this example two LEDs are connected to the PTE port, therefore the PTE0 and PTE1 pins are configured as outputs.

```
void GPIO_Init(void) {
PTEDD = 0x03;          // Configure PTE0 and PTE1 pins as outputs
PTED = 0x00;          // Put 0's in PTE port
}
```

This is the initialization code for RGPIO module used for the MCF51QE128 MCU. These code lines configure the PTE7 to work as a RGPIO output.

```
void RGPIO_Init(void) {
    RGPIO_DIR = 0x0080;           // Configure PTE7 pin as output
    RGPIO_ENB = 0x0080;         // Configure PTE7 as RGPIO pin
}
```

This is the main function, above are the described called functions. The firmware has an infinite loop and always toggles three different LEDs. These are three different ways of toggling these LEDs. The first one, uses a normal GPIO and the instruction is executed in 20 CPU cycles (18 ASM instructions). The second one, is executed in 6 CPU cycles (6 ASM instructions). The third one, uses the the RGPIO module and the toggle instruction is executed in 2 CPU cycles (2 ASM instructions).

```
void main(void) {
    MCU_Init();                 // Function that initializes the MCU
    GPIO_Init();               // Function that initializes the Ports of the MCU
    RGPIO_Init();              // Function that initializes the RGPIO module
    EnableInterrupts;         // enable interrupts

    for(;;) {
        PTED_PTED3 ^= 1;       // Toggles a PTE3. This C command line is executed in 18 CPU cycles
        PTED ^= 0x01;         // Toggles a PTE0. This instruction is executed in 5 CPU cycles
        RGPIO_TOG = 0x0080;    // Toggles PTE7. This instruction is executed in 2 CPU cycles
    }                           // loop forever
                                // please make sure that you never leave this function
}
```

14.3 Simulation steps

This section describes the necessary steps to observe the differences of using a normal GPIO and RGPIO module in a V1 microcontroller.

1. Once the firmware is downloaded to the MCU, a simulation window is opened like the figure shown below.

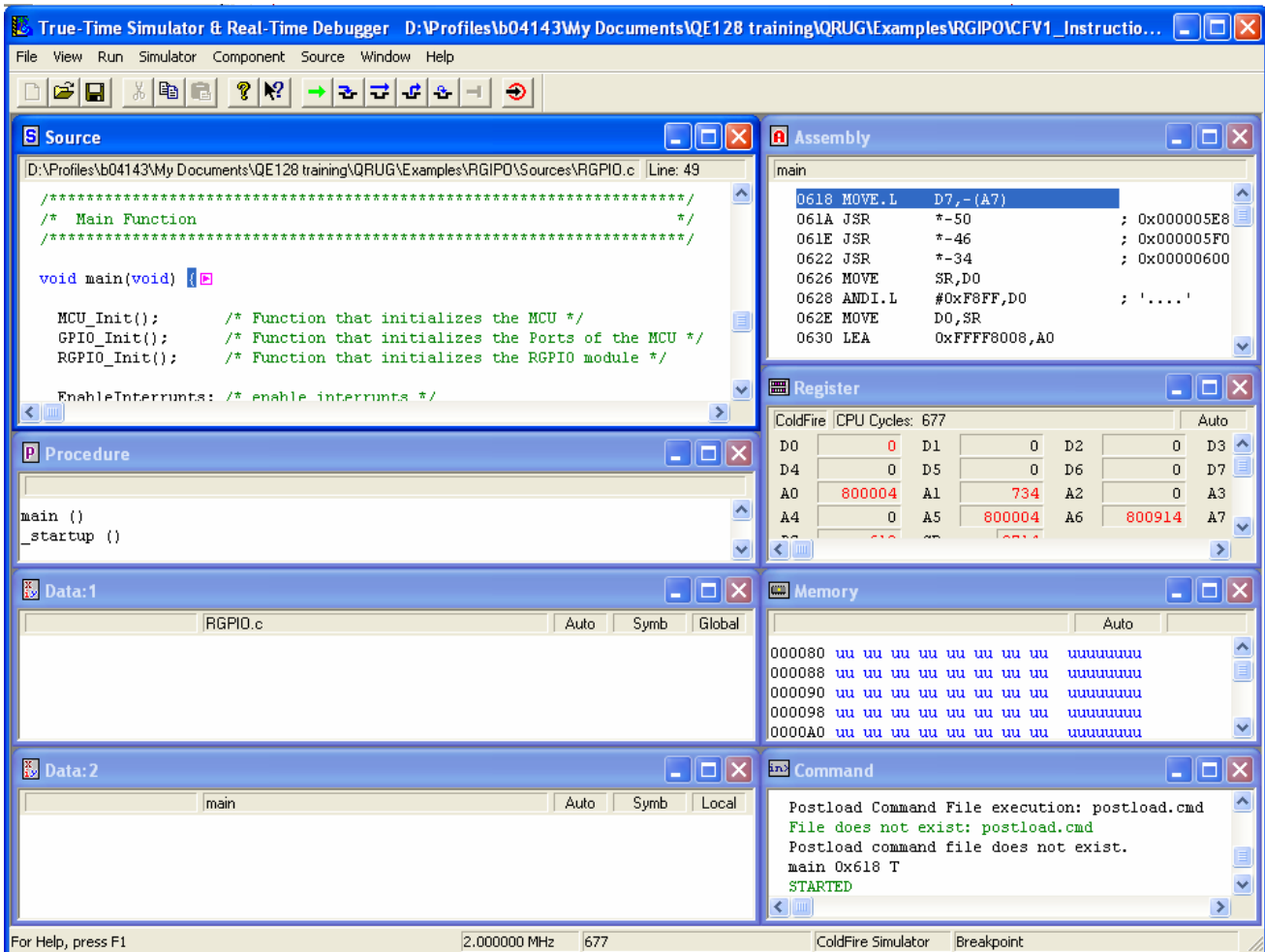


Figure 14-1. Step 1

2. Go to code line `PTED_PTED3 ^= 1`. Right click and select Set Breakpoint option. See next figure.

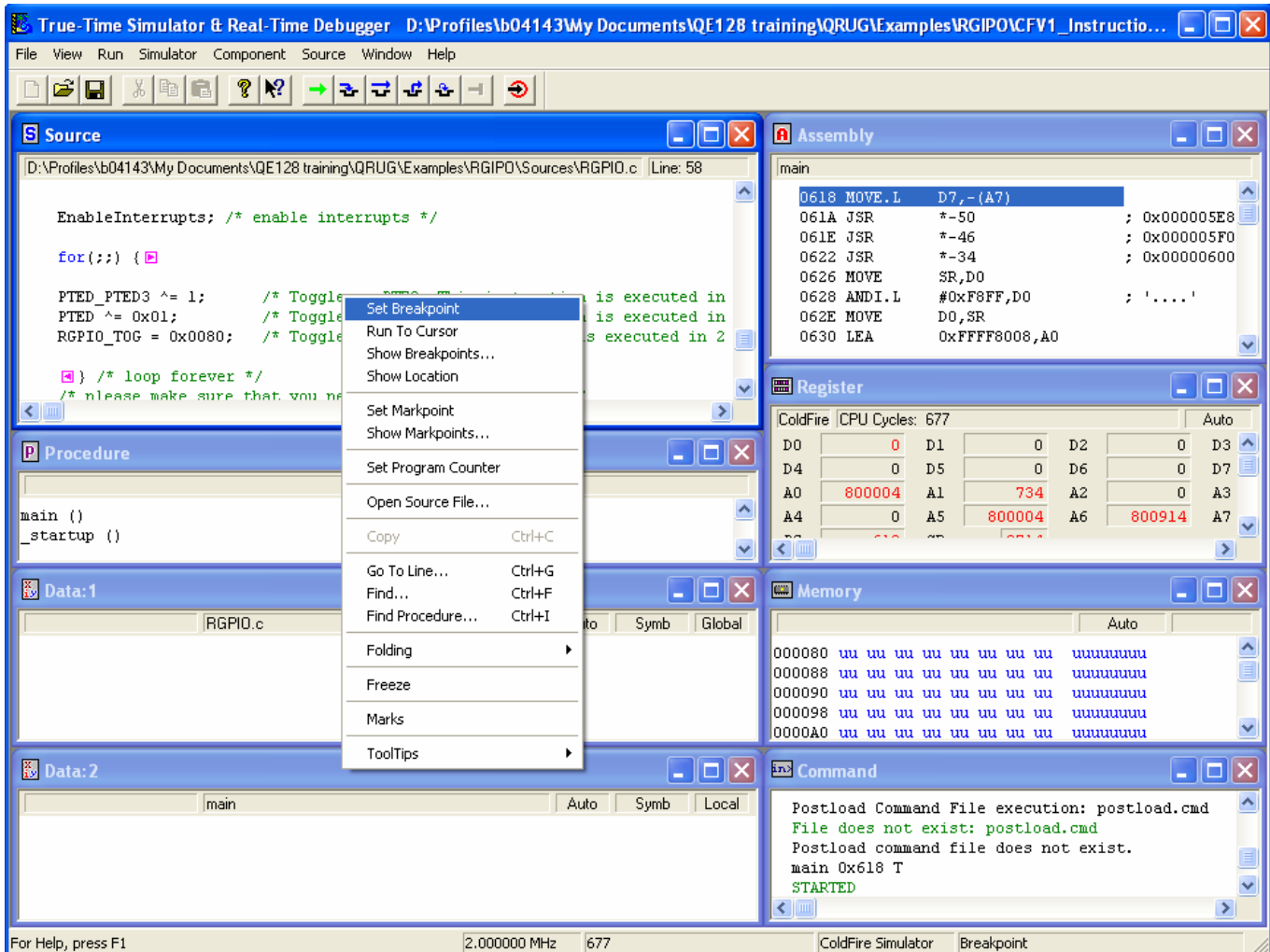


Figure 14-2. Step 2

3. Go to code line PTED ^= 0x01. Right click and select Set Breakpoint option.
4. Put a break point in code line RGPIO_TOG = 0x0080. The break points should be as the figure shows it.

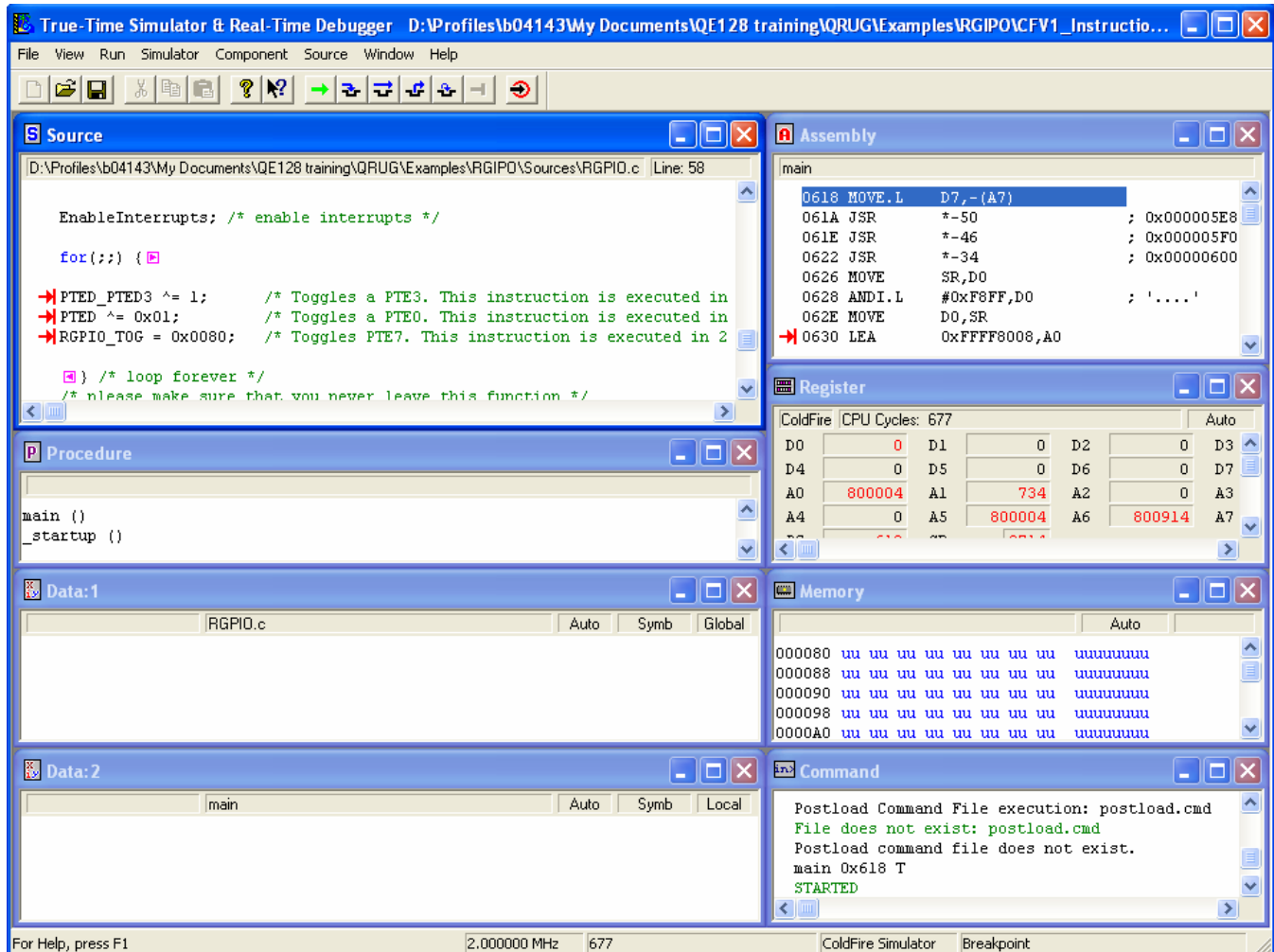


Figure 14-3. Step 4

5. Click on the Start/Continue button, or just press F5 key on the keyboard.
6. In the the assembly window the blue square shows the instruction that has been executed. The first red arrow is a breakpoint from the Source window and corresponds to the first red arrow from the Assembly window. See next figure.

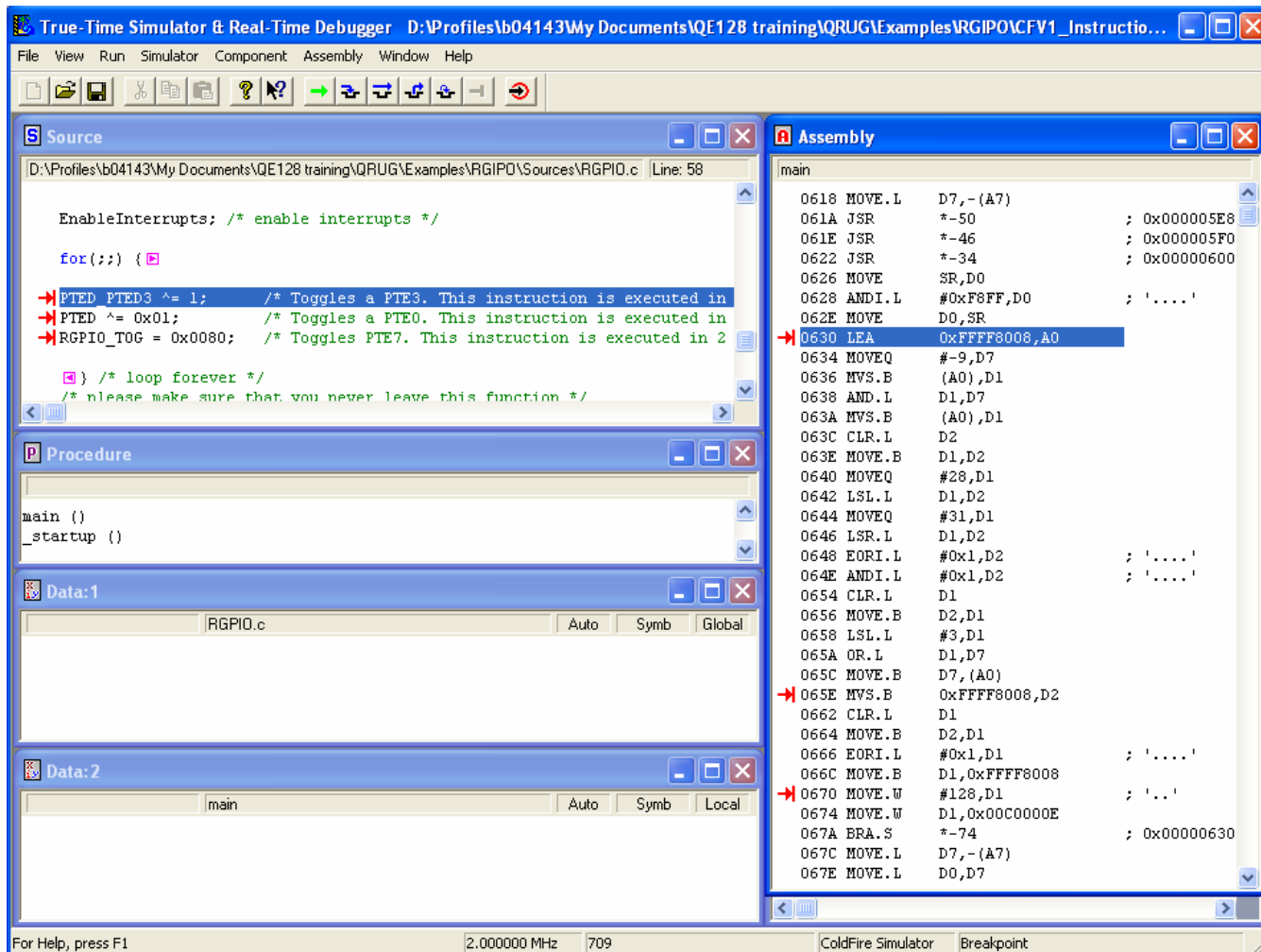


Figure 14-4. Step 6

7. Press Ctrl+F11 on the keyboard or click on assembly step button, and observe the executed assembly instruction from each C command line.

14.4 Hardware Implementation

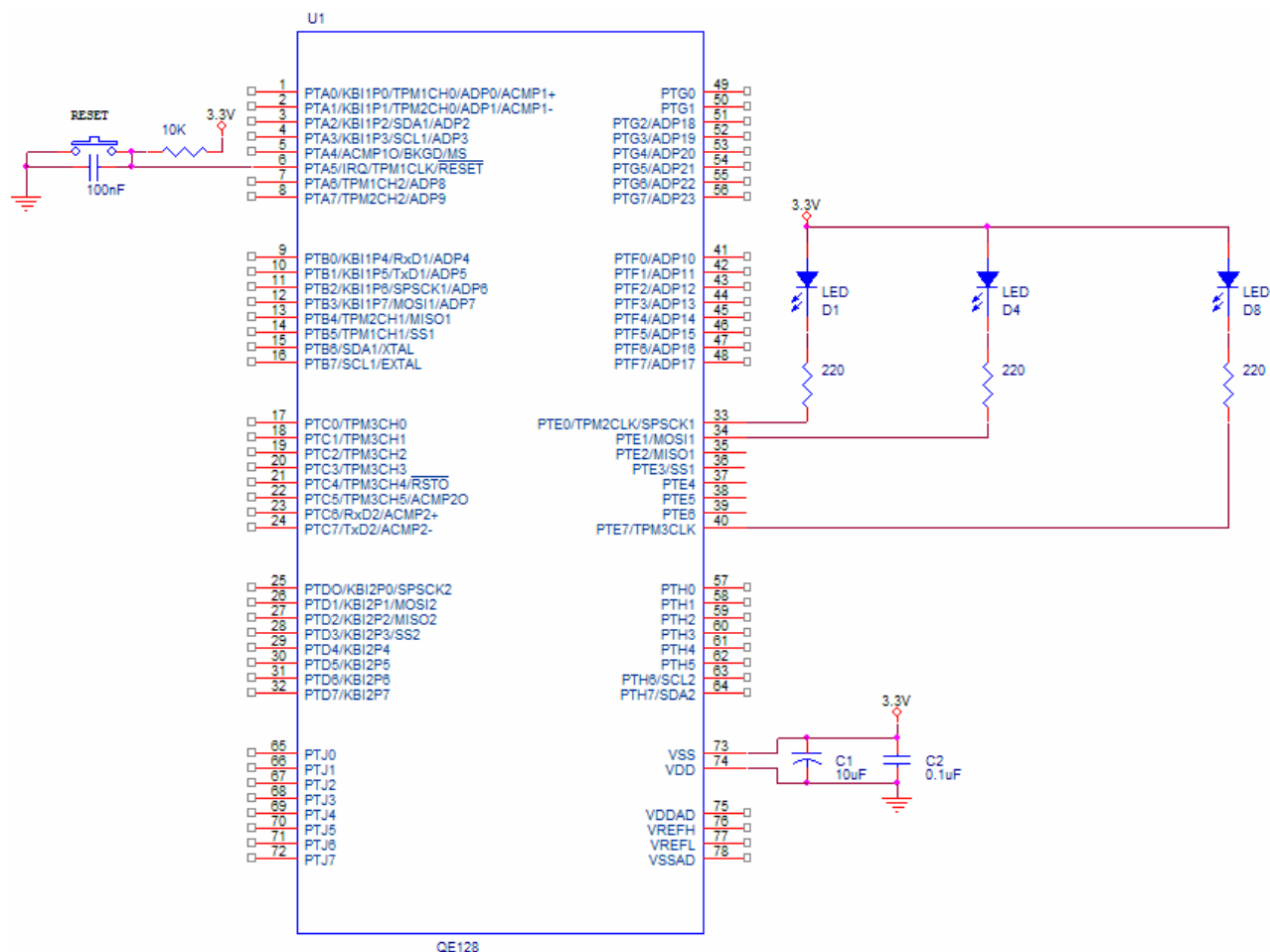


Figure 14-5. RGPIO Hardware Implementation.

NOTE

This example is developed using the CodeWarrior IDE version 6.0 for the HCS08 and V1 families. It is expressly made for the MCF51QE128 and MC9S08QE128 (80-pin package). There may be changes needed in the code to initialize another MCU.

Figure 14-5, shows the hardware connections used for the RGPIO project, for detailed information about the MCU hardware needed, please refer to the Pins and Connections chapter in the Reference Manual. It can be found at www.freescale.com.