Exercise 2: Keyboard Interrupt

EG-252 Group Design Exercise – Microcontroller Laboratory

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For this exercise you are provided sample keyboard interrupt programs in both C and Assembly in the appendices; make sure that you have downloaded electronic versions of the program from the [GitHub repository](https://github.com/cpjobling/EG-252-Resources/tree/master/Microcontroller-Interfacing/Exercises/Exercise2) before the exercise. The program uses the interrupt generated by push buttons to switch on/off the LEDs on the MC9S08AW60 evaluation board.

You are to carry out the following three tasks with this exercise:

* Use the sample program to practice using interrupt mechanism to interface peripheral devices with the evaluation board.
* Answer the questions related to the CPU interrupt procedure (3 marks given on the final report).
* Adjust the sample program to use the onboard switches to control the display of your student number (7 marks, with 4 marks given on demonstration and 3 marks given on the final report).

The demonstration of your program on the board needs to be done no later than *Monday, 10 November 2014*.

You can view this document as a web page [HTML](exercise2.html), [PDF](exercise2.pdf) or as a Word Document [.docx](exercise2.docx)

## I. Experiment with the Sample Program

The sample program, “[kbi\_interrupt.c](https://github.com/cpjobling/EG-252-Resources/blob/master/Microcontroller-Interfacing/Exercises/Exercise2/kbi_interrupt.c)” and “[kbi\_interrupt.asm](https://github.com/cpjobling/EG-252-Resources/blob/master/Microcontroller-Interfacing/Exercises/Exercise2/kbi_interrupt.asm)”, flashes onboard LEDs upon the interrupt requests generated by the keyboard inputs, which are SW3 and SW4 used as keyboard inputs 6 and 5, respectively. The flowchart of the program is shown in Figure 1. Enter it or copy the electronic file onto your CodeWarrior project, which is created targeting on HCS08 CPU family and MC9S08AW60 MCU.

Start  
Port initialization:  
PTFDD=$FF  
PTDPE=$FF  
LED\_on=$0F  
KBI initialization:  
KBI1PE=$60;  
Set KBI1SC bits 1 and 2  
Unmask CPU interrupts:  
CLI  
Read LED\_on  
Mainloop  
Main Program  
Start  
Clear KBI flag:  
Set bit 2 of KBI1SC  
Toggle bits of LED\_on:  
LED\_on=LED\_on XOR $FF  
Output to light LEDs:  
PTFD = LED\_on  
Interrupt service routine  
RTI

Figure 1. Flowchart of keyboard interrupt program

After you create your own keyboard interrupt project, you can use the evaluation board to debug the sample keyboard interrupt program. Next we will introduce how to use evaluation board to configure peripheral device inputs and generate interrupts.

### A. Interrupt Generation with the Evaluation Board

The evaluation board includes four pushbutton switches (SW1-SW4) which can provide momentary active low input for user applications. SW3 and SW4 are connected to MCU Port PTD3 and PTD2 respectively. If the pins of PTD3 and PTD2 are configured as KBI inputs, they will be read with “1” if the corresponding pushbutton is not pressed and “0” if pressed. Edge events and edge/level events can be easily generated by pressing SW3 and SW4. The KBI inputs can detect the selected events as configured by the programmer and generate interrupt requests if keyboard interrupt for the inputs is enabled.

### B. Experiment with the Interrupt Mechanism

Once we know how to generate keyboard interrupt events, we can use the sample program and evaluation board kits to experiment with interrupt mechanism.

According to the interrupt procedure, CPU will leave the main program and run the interrupt service routine (ISR) if interrupt for the keyboard module is enabled. You can use “Single step” or set breakpoint(s) to observe how the CPU responds to interrupt requests. After the CPU finishes the ISR, it returns to the main program. You can generate as many keyboard interrupts as you like by pushing down the switches.

You can also experiment with detection of rising edge and rising edge/high level events and correspondingly generating keyboard interrupt events by configuring the keyboard interrupt status and control register.

## II. Questions

By doing experiments with either slightly modified sample C or assembly program, you are required to answer the following questions.

1. Upon the generation of keyboard interrupt requests, the ISR will be run by the CPU. Experiment with evaluation board, record and compare the content in the stack just before and after the CPU enter the ISR, just before and after the CPU leaves the ISR corresponding to a keyboard interrupt. You can get stack pointer value from register panel in real-time debugger window.
2. Explain why the stack content may change as you have observed.

## III. Adjust the Sample Program to Display your Student Numbers

All the eight KBI inputs share the KBI source. In this task you are required to adjust the ISR shown in the Appendix, in order to determine which of the two pushbuttons SW3 and SW4 triggered a KBI interrupt and correspondingly display a student number of a member in your team.

Suppose the student numbers for your team are 43210 and 12345, respectively. On reset, if pushbutton SW3 is pressed down, in your ISR you should light up the leftmost nonzero digit 4 in the first student number over LEDs (i.e., in a binary format using four LEDs). Then the CPU should leave the ISR and return to the main program. If SW3 is released and then pressed down again, the next digit 3 in the first student should be displayed over LED in your ISR. With more pressing of SW3, the following digits in the first student number are displayed sequentially. Note that after the rightmost digit 0 was displayed over LEDs upon the last pressing of SW3, the leftmost digit 4 will be displayed over LEDs upon new SW3 pressing. Similar operations are performed for the second student number 12345 if pushbutton SW4 is pressed.

You are required to design and debug the ISR program (using either Assembly or C language), and demonstrate the application to Dr Chris Jobling or Dr Tim Davies.

## Appendix A

### Sample Program in C

/\* kbi\_interrupt.c \*/  
  
#include <hidef.h> /\* for EnableInterrupts macro \*/  
#include "derivative.h" /\* include peripheral declarations \*/  
  
typedef unsigned char muint8;  
typedef unsigned short muint16;  
typedef unsigned long muint32;  
  
typedef char mint8;  
typedef short mint16;  
typedef long mint32;  
  
/\* to clear or set single bits in a byte variable \*/  
#define b\_SetBit(bit\_ID, varID) (varID |= (muint8)(1<<bit\_ID))  
#define b\_ClearBit(bit\_ID, varID) (varID &= ~(muint8)(1<<bit\_ID))  
#define b\_XorBit(bit\_ID, varID) (varID ^= (muint8)(1<<bit\_ID))  
  
muint8 LED\_onseq;  
  
void main(void) {  
 EnableInterrupts; /\* enable interrupts \*/  
 SOPT = 0x00; /\* disable COP \*/  
  
 /\* begin LED/switch test \*/  
  
 PTDPE = 0xFF; /\* enable port D pullups for push button switch interrupt \*/  
  
 /\* Init\_GPIO init code \*/  
 PTFDD = 0xFF; /\* set port F as outputs for LED operation \*/  
 LED\_onseq = 0x0F; /\* initialize LED\_onseq \*/  
  
 /\* enable interrupt for keyboard input \*/  
 b\_ClearBit(1, KBI1SC); /\* KBI1SC: KBIE=0, disable KBI interrupt request \*/  
 KBI1PE = 0x60; /\* KBI1PE: KBIPE7=1, enable KBI function for pins 5 and 6 only \*/  
 b\_ClearBit(0, KBI1SC); /\* KBI1SC: KBIMOD=0, select edge-only detection \*/  
   
 /\* in defaut only falling edge events to be detected \*/  
 b\_SetBit(2, KBI1SC); /\* KBI1SC: KBACK=1, to clear KBI flag \*/  
 b\_SetBit(1, KBI1SC); /\* KBI1SC: KBIE=1, enable KBI \*/  
  
 for(;;) {  
 \_\_RESET\_WATCHDOG(); /\* feeds the dog \*/  
 } /\* loop forever \*/  
 /\* please make sure that you never leave main \*/  
}  
  
interrupt 22 void intKBI\_SW(){  
 KBI1SC\_KBACK = 1; /\*acknowledge interrupt\*/  
 PTFD = LED\_onseq;  
 LED\_onseq ^= 0xFF; /\* toggle LED\_onseq bits \*/  
}

View on [GitHub](https://github.com/cpjobling/EG-252-Resources/blob/master/Microcontroller-Interfacing/Exercises/Exercise2/kbi_interrupt.c)

## Appendix B

### Sample Program in Assembly

;\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*  
;\* kbi\_interrupt.asm \*  
;\* \*  
;\* MC9S08AW60 Evaluation board keyboard interrupt example \*  
;\* - Switch SW3 onboard connected to Port D pin 3, KBI pin6; \*  
;\* - Switch SW4 onboard connected to Port D pin 2, KBI pin5 \*  
;\* \*  
;\* Function: \*  
;\* on reset all LEDs will light on. If SW3 or SW4 pressed, \*  
;\* an interrupt is generated, which set LEDs 0:3 to light on. \*  
;\* More interrupts are genereated if SW3 or SW4 are pressed. \*  
;\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*  
  
; Include derivative-specific definitions  
 INCLUDE 'derivative.inc'  
  
FLASH EQU $2000  
RAM EQU $0070  
WATCH EQU $1802  
  
 ORG RAM  
LED\_on DS.B 1 ; Define a variable VAR\_D with a size of 1 byte  
  
;Start program after reset  
 ORG FLASH  
START\_UP  
 LDA #$00  
 STA WATCH ; Turn off the watchdog timer  
   
;Init\_GPIO init code   
 LDA #$FF  
 STA PTFDD  
 MOV #$0F, LED\_on ; Initialize VAR\_D, used to control the LEDs  
 LDA #$FF  
 STA PTDPE ; Port D is enabled with pull-up  
 RSP ; Reset stack pointer  
   
;Enable interrupt for Keyboard input  
 LDA #$60  
 STA KBI1PE ; KBI1PE: KBIPE7=1, enable KBI function for pins 5 and 6 only  
 BSET $02, KBI1SC ; KBI1SC: KBACK=1, to clear KBI flag   
 BSET $01, KBI1SC ; KBI1SC: KBIE=1, enable KBI   
   
 CLI ; Enable interrupt  
  
MAINLOOP  
 LDA LED\_on ; Simple routine   
 BRA MAINLOOP  
  
;Interrupt service routine for a keyboard interrupt generated upon the press of a pushbutton  
;with a falling edge (transition from high logic level "1" to low logic level "0")   
LED\_SWITCH  
 BSET $02, KBI1SC ; clear KBI flag   
 LDA LED\_on   
 EOR #$FF ; Toggle bits in VAR\_D  
 STA PTFD ; Output to light LEDs (port F)  
 STA LED\_on ; Store the new value to VAR\_D   
 RTI   
  
;INT\_VECTOR   
 ORG $FFD2  
 DC.W LED\_SWITCH  
  
 ORG $FFFE  
 DC.W START\_UP

View on [GitHub](https://github.com/cpjobling/EG-252-Resources/blob/master/Microcontroller-Interfacing/Exercises/Exercise2/kbi_interrupt.asm)