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| **Course Number** | COE 718 |
| **Course Title** | Embedded Systems Design |
| **Semester/Year** | F2020 |
| **Lab No** | 2 |
| **Instructor Name** | Saber Amini |
| **Section No** | 03 |

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| **Submission Date** | 10/13/2020 |
| **Due Date** | 10/13/2020 |

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| **Name** | **Student ID** | **Signature\*** |
| Vatsal Shreekant | 500771363 |  |

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*www.ryerson.ca/senate/current/pol60.pdf*

**Introduction**

When implementing applications for embedded systems, there is often a need to clear and set individual bits within peripheral and SRAM registers. For instance, to check when an A/D conversion is complete, it is necessary to check the status flag for completion, obtain the value, and then reset the flag to obtain a new conversion.

The bitwise AND and OR masks are needed to check, set and clear the flags. The Cortex-M processors provide a more efficient implementation to perform these frequent actions, known as Bit Banding.

Bit Banding is a technique which allows individual bits in the SRAM and peripheral registers to be read or written to, as opposed to reading a whole register and making the desired bits. These registers are bit addressable.

Table 1: Address Allocation of SRAM and Peripheral Regions

|  |  |
| --- | --- |
| 0x43FFFFFF |  |
| 0x42000000 | 32 MB Bit band alias |
| 0x41FFFFFF |  |
| 0x40100000 | 31 MB |
| 0x40000000 | 1 MB Bit band region |

|  |  |
| --- | --- |
| 0x23FFFFFF |  |
| 0x22000000 | 32 MB Bit band alias |
| 0x21FFFFFF |  |
| 0x20100000 | 31 MB |
| 0x20000000 | 1 MB Bit band region |

The Cortex-M3 memory map includes two bit-band regions. These occupy the lowest 1MB of the SRAM and peripheral memory regions respectively.

SRAM: Bit-band region: 0x20000000 - 0x20100000 Bit-band alias: 0x22000000 - 0x23FFFFFF

PERI: Bit-band region: 0x40000000 - 0x40100000 Bit-band alias: 0x42000000 - 0x43FFFFFF

The mapping formula is:

bit\_word\_offset = (byte\_offset \* 32) + (bit\_number \* 4)

bit\_word\_address = bit\_band\_base + bit\_word\_offset

Table 2: Calculations:

|  |  |
| --- | --- |
| SRAM Bit-band Base alias Base is | 0x22000000 |
| FIOPIN Base address is | 0x2009C034 |
| P1.28 LED Bit Number In Hex | 0x1C |
| P1.29 LED Bit Number In Hex | 0x1D |
| P1.31 LED Bit Number In Hex | 0x1F |
| LPC\_GPIO Base Word offset | 0x0009C034 |

LPC\_GPIO\_BASE\_word\_offset = 0x2009C034 - 0x20000000 = 0x0009C034

**byte\_offset \* 32 0x01380680**

LPC\_GPIO\_Base\_Word\_offset \* 0x20 = 0x0009C034 \* 0x20 = 0x01380680

**bit\_band\_base+(byte\_offset \* 32) is shared for LED 0-2 and is equal to 0x23380680**

0x22000000 + (0x0009C034 \* 0x20) = 0x22000000 + 0x01380680 = 0x23380680

**bit word address for led P1.28 is 0x233806F4**

0x23380680 + (0x1C \* 0x4) = 0x23380680 + 0x00000074 = 0x233806F4

**bit word address for led P1.29 is 0x233806FC**

0x23380680 + (0x1D \* 0x4) = 0x23380680 + 0x0000007C = 0x233806FC

**bit word address for led P1.31 is 0x233806F0**

0x23380680 + (0x1F \* 0x4) = 0x23380680 + 0x00000070 = 0x233806F0

Table 3: Performance of the 3 methods (Masking, Bit Band & Direct Bit Banding)

|  |  |  |  |
| --- | --- | --- | --- |
| **Method** | **Execution Time (-**  **O0)[Microsecond]** | **Execution Time (-**  **O3)[Microsecond]** | **Performance**  **Improvement[Microsecond]** |
| Masking | 0.09 | 0.07 | 0.02 |
| BitBand()  Function | 0.11 | 0.08 | 0.03 |
| Direct Bit  Banding | 0.04 | 0.02 | 0.02 |

**Procedure**

1. Load cond\_ex example project and complete the instructions in the lab manual.
2. Select the following packages under ‘Manage Run-Time Environment’ window and select OK button:

Board Support>LEDb.

CMSIS>CORE

Compiler>Event Recorderd

Device > Startup,GPIO, PIN

1. Modify the ‘cond\_ex.c’ file to include the following functions: Masking, BitBand, Direct Bit Banding and Barrel Shifter.

\* Name: cond\_ex.c

\* Purpose: LED Flasher for MCB1700

\*----------------------------------------------------------------------------\*/

//barrel shifter code

#include "LPC17xx.h"

#define ADDRESS(x) (\*((volatile unsigned long \*)(x)))

#define BitBand(x, y) ADDRESS(((unsigned long)(x) & 0xF0000000) | 0x02000000 |(((unsigned long)(x) & 0x000FFFFF) << 5) | ((y) << 2))

#define GPIO1\_LED31 (\*((volatile unsigned long\*)0x233806FC))

#define GPIO2\_LED2 (\*((volatile unsigned long \*) 0x23380A88))

#include <string.h>

#include <stdio.h>

int main(void){

char text[10];

int r1 = 1, r2 = 1, r3 = 2;

sprintf(text, "Hello");

volatile unsigned long \* GPIO1\_LED28 ;

volatile unsigned long \* GPIO1\_LED29 ;

volatile unsigned long \* GPIO2\_LED4 ;

GPIO1\_LED28 = &BitBand(&LPC\_GPIO1->FIOPIN1, 28);

GPIO2\_LED4 = &BitBand(&LPC\_GPIO2->FIOPIN0, 4);

while(1){

if((r1 - r2) < r3){

printf("bit banding\n");

GPIO2\_LED2 = 1;//LED P2.2 ON using BB

GPIO1\_LED31 = 1;//LED P1.31 ON using BB

//bit banding

r1 += 1; //math for conditional execution

}else if((r1 - r2) > r3){

printf("function mode\n");

\*GPIO2\_LED4 = 1;//LED P1.29 ON using function

\*GPIO1\_LED28 = 1;//LED P1.28 ON using function

//function mode

r1 = 2;

}else{

printf("mask mode\n");

LPC\_GPIO1->FIOPIN |= ( 1 << 29);

LPC\_GPIO2->FIOPIN |= ( 1 << 3);

//mask mode

r1 += 3;

}

int i, j;

for(i = 0; i < 2000; i++){

for(j = 0; j < 2000; j++);

}

LPC\_GPIO2->FIOPIN &= ~( 1 << 3);

LPC\_GPIO2->FIOPIN &= ~( 1 << 29);

\*GPIO1\_LED28 = 0;

\*GPIO1\_LED29 = 0;

GPIO2\_LED2 = 0;

GPIO1\_LED31 = 0;

}

/\*

//bit band mode

GPIO1\_LED31 = 1 ; // on

GPIO1\_LED31 = 0 ; // o f f

//function mode

GPIO1\_LED28 = &BitBand(&LPC\_GPIO1->FIOPIN1, 28);

GPIO1\_LED28 = &BitBand(&LPC\_GPIO1->FIOPIN1, 28);

\*GPIO1\_LED28 = 1 ; // on

\*GPIO1\_LED28 = 2 ;

\*/

//masking mode

// LPC\_GPIO1->FIOPIN &= ~( 1 << 29);

// LPC\_GPIO2->FIOPIN &= ~( 1 << 3);

}

1. Compile project using the build button and start the simulation by selecting the debug button.
2. Select Peripherals🡪GPIO Fast Interface🡪Port 1 and Port 2 from toolbar and run.

**Conclusion**

When comparing and analyzing the results under debug mode, it is evident that directly accessing and switching the bit has the lowest time and this was the initial assumption before implementing the code. The BitBand() function has the most inferior performance in comparison to the other two and is close to masking due to the time it takes to calculate the address to target. The masking method is somewhat more efficient than BitBand() simply because it doesn't need to run calculations to access the bits.

**References**

1. NXP User Manual, https://www.nxp.com/docs/en/user-guide/UM10360.pdf, 2020
2. ARM Keil User Guide, https://www.keil.com/support/man/docs/mcb1700/mcb1700\_intro.htm, 2020