CPE 325: Intro to Embedded Computer System

Lab05

Subroutines, passing parameters, Hardware multiplier

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Report Deadline: 09/30/2020

CPE 325: Embedded Systems Laboratory
Laboratory Assignment #5

Assignment [100 pts]

1. Write an assembly program that passes a base number ***b*** (value should be other than 0 and 1) to a subroutine *calc_power*. This subroutine should populate two arrays in memory with b^1, b^2, b^3, b^4 and b^5. This means your subroutine should compute first 5 powers of a parameter passed into it. *[One of the arrays is populated with results using hardware multiplier and the other using software multiplier.]*

   You must pass ***b*** to *calc_power* using a register of your choice. You may also want to pass the address of your result. Pass these addresses using stack.

   In order to compute the powers, you need multiplication operations. For this you must implement two additional sub routines as defined below in Q2.

2. One of the subroutines that you need to implement is *SW_Mult* that uses Shift-and-Add multiplication algorithm. The algorithm is described in provided pdf file. Another subroutine that you need to implement is *HW_Mult.* It should use Hardware Multiplier to multiply numbers.
   Both of these subroutines should take in input numbers through stack and return the result of multiplication in one of the registers.

   Hints:

   a) *You may want to allocate space for results in main. You can allocate space using .**"bss"** for both results using hardware multiplier and software multiplier.*

   b) *In subroutine calc_power, you can repeatedly call SW multiplier subroutine to populate the memory space allocated for software based result. Then, you can use the similar approach to populate memory space allocated for hardware based result.*

3. Measure the number of clock cycles used by each subroutine for a small range of values. Comment of the efficiency of each subroutine.

4. **Bonus (up to 15pts)** Create a subroutine that converts a string of at least a five-digit number to its numerical value by using the Hardware Multiplier and stores the result in a variable in the memory. The subroutine needs to receive the base address of the string and the address of the variable through the program stack. For full credit you need to use the accumulator. If the accumulator is not used only up to 10pts will be rewarded.

Questions To Be Addressed

Please make sure that you have addressed following questions in your demonstration:

1. How do you pass parameters to a subroutine using stack? Explain how you extract parameters that you pass using this technique.

Topics For Theory

1. Subroutines
2. Passing parameters (3 different ways)
3. Hardware Multiplier

Deliverables

1. Lab report with screenshots of final outputs
2. Commentary on efficiency of each subroutine (in terms of clock cycles taken for operation)
3. Source files (.asm files) or as instructed.

Notes:

1. Try different inputs before you conclude which method is efficient. In your explanation, include the inputs as well.
2. Assume that any of the results does not exceed 16-bits.

Introduction

This lab covers subroutines, passing parameters, and hardware multiplication. We use subroutines to make our code more readable and simpler than writing everything out manually and essentially “hard” coding it in. These subroutines, in different files, makes changes occur much faster and more straight forward, and also helps to eliminate confusion on what you are working on.

Passing parameters is very important in this lab because we do not want to overwrite anything we are doing in our subroutines. Using the stack helps us do this where we push and “pop” (really moving) the values to and from the stack. This is especially important in the hardware multiplication.

Hardware multiplication is using the actual instructions built in to do multiplication instead of implementing and algorithm such as shift add multiply. As you can see, using the specific and general purpose registers makes the code much simpler and faster than doing it with an algorithm.

Theory

Write short notes on each topic discussed in lab.:

Subroutines:

Subroutines help to simplify code and perform specific tasks. They can take in parameters and you go to them with the CALL instruction. You can get out of a subroutine with the RETURN call. Subroutines are very helpful in making your code simpler and more readable.

Passing Parameters (3 different ways):

When passing parameters, you can either add it to the stack and pull it from there later on or you can store the values into registers or in memory locations. Personally, I think the best way to store the data is to put it into specific spots in memory because it allows you to not overwrite any registers or mess with the stack too much. It does require a little more coding but I believe it would be a little more robust.

Hardware Multiplier:

The hardware multiplier, unlike multiplying using software, uses the general-purpose registers to multiply data together. It is simpler than something like the software multiplier that we implemented here in this lab. The run time is also significantly lower. It can be done up to 16-bit multiplication and the register you move it to determines the type of multiplication that will be performed.

Results & Observation

Copy the question from the assignment here:

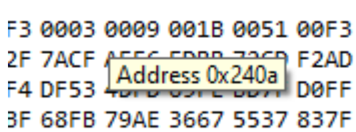
1. How do you pass parameters to a subroutine using stack? Explain how you extract

parameters that you pass using this technique.

- I pushed the values onto the stack using push #swarr etc. and then in the calc_power.asm file, I moved the position on the stack pointer to the register that I wanted to work with.

Results Screenshots/Pictures:

- **Using b = 3**
- **Hardware Multiplier:**



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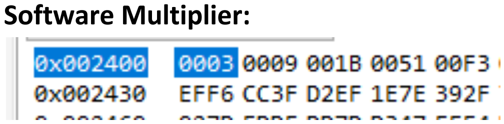
- **Software Multiplier:**



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3. Measure the number of clock cycles used by each subroutine for a small range of values. Comment of the efficiency of each subroutine.

I have inserted images of my calculation for the number of clock cycles each instruction takes. As you can see, the hardware multiplier is over 2 times faster than the software multiplier. Total is the number of clock cycles at the end.

Calc power efficiency:

Subroutine	Instruction	# of cycles	# of times	Execute
calc_power				
	mov 6(SP), R5	3	1	3
	mov 4(SP), R6	3	1	3
	mov 2(SP), R7	3	1	3
	mov #1, R12	2	1	2
	jmp SWLoop	2	1	2
SWLoop				0
	call #SW_Mult	6	5	30
	incd R5	1	5	5
	dec R8	1	5	5
	jnz SWLoop	2	5	10
	mov #5, R8	2	1	2
HWLoop				0
	call #SW_Mult	6	5	30
	incd R6	1	5	5
	dec R8	1	5	5
	jnz HWLoop	2	5	10
lend				0
	reti	5	1	5
		Total:		115

Hardware Multiplication efficiency:

Subroutine	Instruction	# of cycles	# of times	Execute
HW_Mult				
	mov R4, &MPY	4	5	20
	mov R7, &OP2	4	5	20
	mov RESLO, R7	1	5	5
	mov R7, 0(R6)	4	5	20
	ret	5	5	25
			Total:	90

Software Multiplication efficiency:

Subroutine	Instruction	# of cycles	nes for one #SWL	Execute
SW_Mult				
	mov #16, R9	2	1	2
	mov #0, R10	2	1	2
	mov R4, R11	1	1	1
	jmp bitcheck	2	1	2
				0
				0
bitcheck				0
	mov R12, R13	1	16	16
	and #0x01, R13	2	16	32
	cmp #0x01, R13	2	16	32
	jne noadd	2	1	2
	and R11, R10	1	1	1
	jmp noadd	2	1	2
				0
noadd				0
	rrc R12	1	16	16
	rla R11	1	16	16
	dec R9	1	16	16
	jnz bitcheck	2	16	32
	mov r12, R13	1	12	12
	and #0x01, R13	2	12	24
	and #0x01, R13	2	12	24
	jeq neg	2	1	2
	jmp end	2	1	2
				0
neg	sub R11, R10	1	1	1
	jmp end	2	1	2
				0
end	mov R10, 0(R5)	4	1	4
	mov R10, R12	1	1	1
	ret	5	1	5
			Total:	249

Observations:

Hardware implementations are much easier to code and use. I am very interested to see if we keep doing something like hardware multipliers because it is honestly really cool. We do enough software in my opinion and using hardware to our advantage (and to its advantage) seems to be a much better use of our time.

Conclusion

Write your conclusion. (Explain what you have learnt and issues you faced)

Folder Link:

https://drive.google.com/drive/folders/1_Y3ABMDhCUxc9phtQ8JKHCM8LDOK7k7J?usp=sharing

Video link:

https://drive.google.com/file/d/1DmtWEoQLX_pTyNtjfBN_lhFrb2UboLKI/view?usp=sharing

Appendix on the next page

Appendix

Appendix 1 – main.asm

```
;-------------------------------------------------------------------------------
; File       :  main.asm
; Function   :  Push data onto the stack and call a function in another file
; Description:  This file creates an array of 10 bytes for a hardware and software
;                                multiplier
; Input      :  A b value to be multiplied
; Output     :  No output, see registers and memory browser.
; Author     :  N. Anderson  npa0002@uah.edu
; Date       :  09/30/2020
;-------------------------------------------------------------------------------

            .cdecls C,LIST,"msp430.h"       ; Include device header file

;-------------------------------------------------------------------------------
            .def    RESET                   ; Export program entry-point to
                                            ; make it known to linker.
            .ref        calc_power
;-------------------------------------------------------------------------------
;               Allocation for result
                .bss     swarr, 10       ; 10 bytes for software array
                .bss     hwarr, 10       ; 10 bytes for hardware array
                .data
b:              .int     3               ; int variable to intput into the code.
result:         .int                     ; result variable
;-------------------------------------------------------------------------------
            .text                           ; Assemble into program memory.
            .retain                         ; Override ELF conditional linking
                                            ; and retain current section.
            .retainrefs                     ; And retain any sections that have
                                            ; references to current section.
;-------------------------------------------------------------------------------
RESET       mov.w   #__STACK_END,SP         ; Initialize stackpointer
StopWDT     mov.w   #WDTPW|WDTHOLD,&WDTCTL  ; Stop watchdog timer
;-------------------------------------------------------------------------------
; Main loop here
;-------------------------------------------------------------------------------
main:
        push    #swarr                   ; Push the software array address onto the stack.
        push    #hwarr                   ; Push the hardware array onto the stack.
        push    result                   ; Push the result onto the stack.
        mov     b, R4                    ; Mov b into R4.
        mov     #5, R8                   ; Counter for the loops in calc_power.
        call    #calc_power              ; A call to the calc_power.asm file to start the loops.
        jmp     $                        ; jump infinetly.
lend:
        nop
;-------------------------------------------------------------------------------
; Stack Pointer definition
;-------------------------------------------------------------------------------
            .global __STACK_END
            .sect   .stack
;-------------------------------------------------------------------------------
; Interrupt Vectors
;-------------------------------------------------------------------------------
            .sect   ".reset"                ; MSP430 RESET Vector
            .short  RESET
```

Appendix 2 – calc_power.asm

```
;-------------------------------------------------------------------------------
; File      : calc_power.asm
```

```
; Function    :  This file takes the data off of the stack, stores it into registers
;                and uses those register values to perform operations
; Description:  calc_power takes the data off the stack and initializes different data.
; Input       :  Input comes from main.asm which is really just the stack data.
; Output      :  Output is in the memory browser.
; Author      :  N. Anderson  npa0002@uah.edu
; Date        :  09/30/2020
;-------------------------------------------------------------------------------
            .cdecls C,LIST,"msp430.h"   ; Include device header file
            .def calc_power              ; Define the calc_power function.
            .ref SW_Mult                 ; Reference to the Software multiplier file.
            .ref HW_Mult                 ; Reference to the Hardware multiplier file.
            .text

calc_power:
                mov     6(SP), R5        ; Move the Software array address into R5
                mov     4(SP), R6        ; Move the Hardware array address into R6
                mov     2(SP), R7        ; Move the result into R7
                mov     #1, R12          ; R12 will get 1 for the first iteration of the software loop.
                jmp     SWLoop           ; Jump to the SWLoop, it will carry out from there.

SWLoop:         call    #SW_Mult         ; Call the software multiplier.
                incd    R5               ; Increment R5 to the next index.
                dec     R8               ; Decrement R8 (counter).
                jnz     SWLoop           ; Jump not zero back to software loop.
                mov     #5, R8           ; reset power counter

HWLoop:         call    #HW_Mult         ; Call the hardware muliplier.
                incd    R6               ; Increment to the next index.
                dec     R8               ; Decrement the counter.
                jnz     HWLoop           ; Jump not zero back to hardware loop.

lend:
                nop
```

Appendix 3 – SW_Mult.asm

```
;-------------------------------------------------------------------------------
; File        :   SW_Mult.asm
; Function    :  This files function is to perform software multiplication on a value
; Description:  This file takes in R7 and R4 and uses shift - add - multiplication
;                            to find the powers of 4 from 1-5
; Input       :  R4 and R7 from main and calc_power.asm
; Output      :  See memory browser
; Author      :   N. Anderson  npa0002@uah.edu
; Date        :  09/30/2020
;-------------------------------------------------------------------------------
                        .cdecls C,LIST,"msp430.h"      ; Include device header file
                        .def SW_Mult
                        .text
SW_Mult:
        mov     #16, R9          ; Initializing a bit counter.
        mov     #0, R10          ; Initialize the result number to R10.
        mov     R4, R11 ; Move b into R11 so that we can perform operations w/o changing its value
        jmp     bitcheck         ; Jump straight to bitcheck.

bitcheck:
        mov     R12, R13  ; Mov b into R13 so that we can perform operations without changing its value
        and     #0x01, R13       ; bitchecking to see if the LSB is 1
        cmp     #0x01, R13       ; Cmopare operation for previous AND instruction
        jne     noadd            ; If it is not equal (i.e. = 0) then skip the add instruction.
        add     R11, R10         ; Add to the running total
        jmp     noadd            ; Go straight to s
noadd:
        rrc     R12             ; Shift B to right by 1.
```

```
        rla     R11             ; Shift A left by 1.
        dec     R9              ; Decrement the bit counter.
        jnz     bitcheck         ; If bit counter is not zero, go to next bit to add.
        mov     R12, R13        ; If it is 0, move the result into R13.
        and     #0x10, R13       ; Check to see if it is a negative number
        cmp     #0x10, R13       ; If it is negative, jump to subtract from A from result.
        jeq     neg             ; Jump if equal to negative
        jmp     end             ; Unconditionally jump to end
neg:
        sub     R11, R10         ; Sub instruction for negative numbers
        jmp     end              ; Unconditionally jump to end.
end:
        mov     R10, 0(R5)       ; Move the result into the next part of the
        mov     R10, R12         ; Put the result into B for the next power operation.
        ret                      ; Return back to calc_power.asm
```

Appendix 4 – HW_Mult.asm

```
;-------------------------------------------------------------------------------
; File       :  HW_mult.asm
; Function   :  To perform a hardware multiplication on predefined values
; Description:  This file will take in values and use hardware multiplication to
;                                find the powers from 1-5
; Input      :  R4 and R7 from main and calc_power.asm
; Output     :  See memory browser
; Author     :  N. Anderson  npa0002@uah.edu
; Date       :  09/30/2020
;-------------------------------------------------------------------------------
            .cdecls C,LIST,"msp430.h"      ; Include device header file
            .def HW_Mult
            .text
HW_Mult:

        mov     R4, &MPY         ; move R4 into the unsinged 16 bit multiplication register
        mov     R7, &OP2         ; move R4 into the general purpose operator. multiply by...
        nop
        nop
        nop
        mov     RESLO, R7        ; move the result the R7.
        mov     R7, 0(R6)        ; move result  into R6
        ret
```