BIRZEIT UNIVERSITY

Electrical and Computer Engineering

Computer Design Lab – ENCS4110

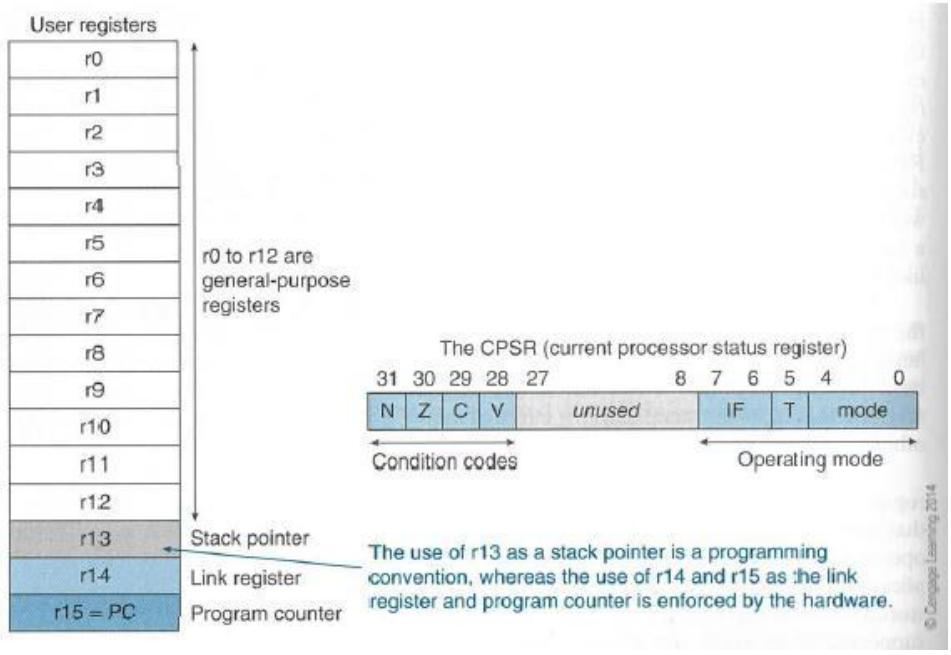
ARM Addressing Modes

Objectives

Explore ARM addressing modes
- Register Addressing Mode
- Register Indirect Addressing Mode
- ARM's Autoindexing Pre-indexed Addressing Mode
- ARM's Autoindexing Post-indexing Addressing Mode
- Program Counter Relative (PC Relative) Addressing Mode
- and so on

Review of ARM Registers Set

As mentioned in the previous lab, ARM has 16 programmer-visiable registers and a *Current Program Status Register*, CPSR.Here is a picture to show the **ARM register set**.



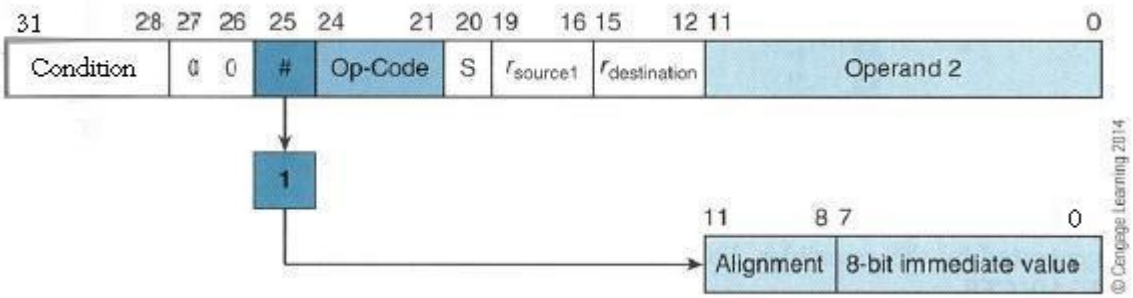
```
R0 to R12 are the general-purpose registers.
R13 is reserved for the programmer to use it as the stack pointer.
R14 is the link register which stores a subroutine return address.
R15 contains the program counter and is accessible by the programmer.



Conditonion code flags in CPSR:
N - Negative or less than flag
Z - Zero flag
C - Carry or bowrrow or extendedflag
V - Overflow flag
The least-significant 8-bit of the CPSR are the control bits of the system.
The other bits are reserved.
```

Summary of ARM addressing Modes

There are different ways to specify the address of the operands for any given operations such as load, add or branch. The different ways of determining the address of the operands are called addressing modes. In this lab, we are going to explore different addressing modes of ARM processor and learn how all instructions can fit into a single word (32 bits).

Name	Alternative Name	ARM Examples
Register to register	Register direct	MOV R0, R1
Absolute	Direct	LDR R0, MEM
Literal	Immediate	MOV R0, #15 ADD R1, R2, #12
Indexed, base	Register indirect	LDR R0, [R1]
Pre-indexed, base with displacement	Register indirect with offset	LDR R0, [R1, #4]
Pre-indexed, autoindexing	Register indirect pre-incrementing	LDR R0, [R1, #4]!
Post-indexing, autoindexed	Register indirect post-increment	LDR R0, [R1], #4
Double Reg indirect	Register indirect Register indexed	LDR R0, [R1, R2]
Double Reg indirect with scaling	Register indirect indexed with scaling	LDR R0, [R1, R2, LSL #2]
Program counter relative		LDR R0, [PC, #offset]

Literal Addressing Mode




```
     Examples                  Meaning
-------------------------------------------------------------------------
     CMP R0, #22
-------------------------------------------------------------------------
     ADD R1, R2, #18
-------------------------------------------------------------------------
     MOV R1, #30
-------------------------------------------------------------------------
     MOV R1, #0xFF
-------------------------------------------------------------------------
     CMN R0, #6400   ; R0 + #6400, update the N, Z, C and V flags
-------------------------------------------------------------------------
     CMPGT SP, R7, LSL #2   ; update the N, Z, C and V flags
-------------------------------------------------------------------------
```

Register Indirect Addressing Mode

Register indirect addressing means that the location of an operand is held in a register. It is also called indexed addressing or base addressing.

Register indirect addressing mode requires three read operations to access an operand. It is very important because the content of the register containing the pointer to the operand can be modified at runtime. Therefore, the address is a variable that allows the access to the data structure like arrays.

- Read the instruction to find the pointer register
- Read the pointer register to find the oprand address
- Read memory at the operand address to find the operand

Some examples of using register indirect addressing mode:

```
     LDR     R2, [R0]        ; Load R2 with the word pointed by R0
-------------------------------------------------------------------------------
     STR     R2, [R3]        ; Store the word in R2 in the location pointed by R3
```

Register Indirect Addressing with an Offset

ARM supports a memory-addressing mode where the effective address of an operand is computed by adding the content of a register and a literal offset coded into load/store instruction. For example,

```
     Instruction            Effective Address
-------------------------------------------------------------------------------
     LDR R0, [R1, #20]      R1 + 20    ; loads R0 with the word pointed at by R1+20
-------------------------------------------------------------------------------
```

ARM's Autoindexing Pre-indexed Addressing Mode

This is used to facilitate the reading of sequential data in structures such as arrays, tables, and vectors. A pointer register is used to hold the base address. An offset can be added to achieve the effective address. For example,

```
     Instruction            Effective Address
-------------------------------------------------------------------------------
     LDR R0, [R1, #4]!       R1 + 4     ; loads R0 with the word pointed at by R1+4
                                       ; then update the pointer by adding 4 to R1
-------------------------------------------------------------------------------
```

ARM's Autoindexing Post-indexing Addressing Mode

This is similar to the above, but it first accesses the operand at the location pointed by the base register, then increments the base register. For example,

```
     Instruction            Effective Address
-------------------------------------------------------------------------------
     LDR R0, [R1], #4        R1         ; loads R0 with the word pointed at by R1
                                       ; then update the pointer by adding 4 to R1
-------------------------------------------------------------------------------
```

Program Counter Relative (PC Relative) Addressing Mode

Register R15 is the program counter. If you use R15 as a pointer register to access operand, the resulting addressing mode is called PC relative addressing. The operand is specified with respect to the current code location. Please look at this example,

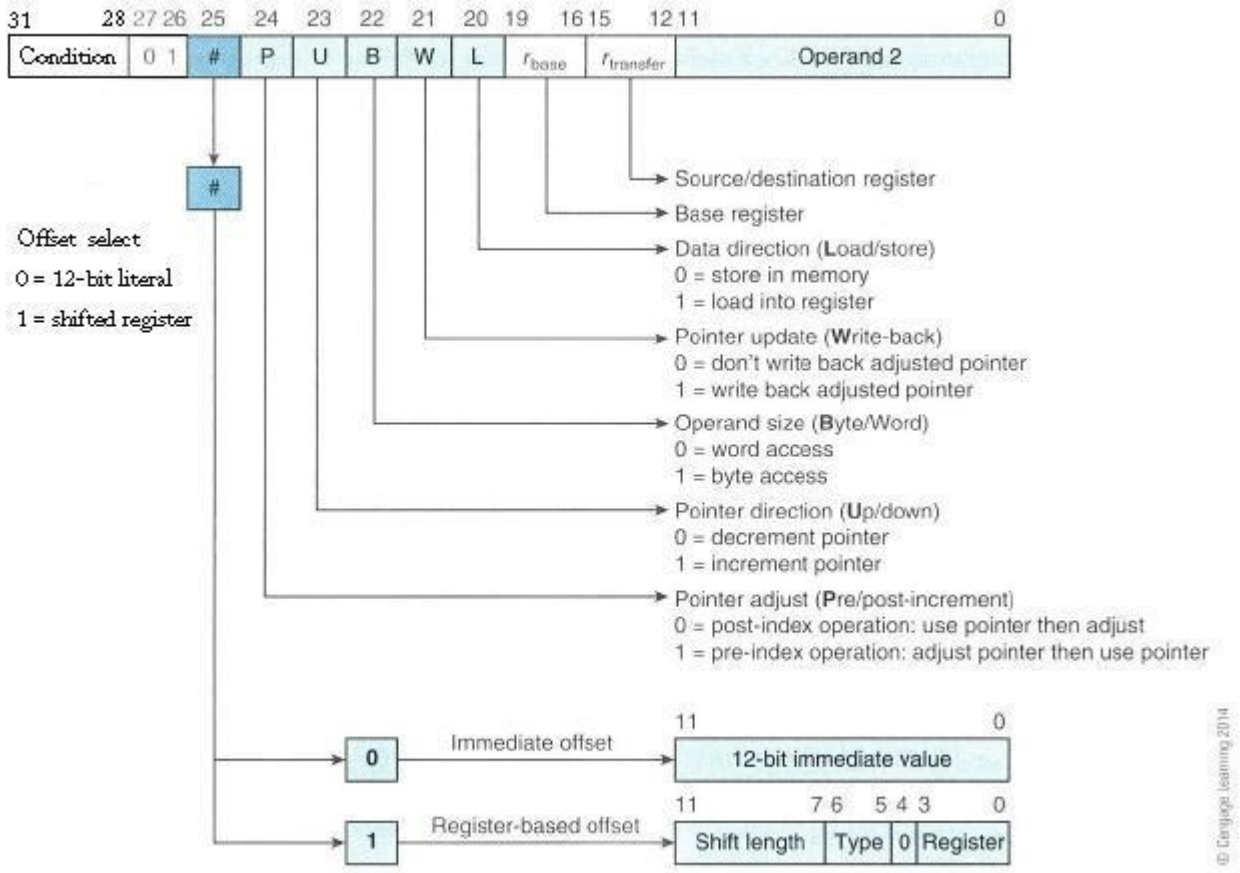
```
     Instruction            Effective Address
-------------------------------------------------------------------------------
     LDR R0, [R15, #24]      R15 + 24  ; loads R0 with the word pointed at by R15+24
-------------------------------------------------------------------------------
```

ARM's Load and Store Encoding Format

The following picture illustrates the encoding format of the ARM's load and store instructions, which is included in the lab material for your reference. Memory access operations have a conditional execution field in bit 31, 03, 29, and 28. The load and store instructions can be conditionally executed depending on a condition specified in the instruction. Now look at the following examples:

```
      CMP     R1, R2
-------------------------------------------------------------------
      LDREQ   R3, [R4]
-------------------------------------------------------------------
      LDRNE   R3, [R5]
```

Encoding Format of ARM's load and store instructions



Summary of ARM's Indexed Addessing Modes

Addressing Mode	Assembly Mnemonic	Effective address	FinalValue in R1
Pre-indexed, base unchanged	LDR R0, [R1, #d]	R1 + d	R1
Pre-indexed, base updated	LDR R0, [R1, #d]!	R1 + d	R1 + d
Post-indexed, base updated	LDR R0, [R1], #d	R1	R1 + d

An Example Program of Using Post-indexing Mode

```
;The semicolon is used to lead an inline documentation
;When you write your program, you could have your info at the top document block
;For Example:  Your Name, Student Number, what the program is for, and what it does
etc.

;       This program will find the sum of an array.


;;; Directives
          PRESERVE8
          THUMB

; Vector Table Mapped to Address 0 at Reset
; Linker requires __Vectors to be exported

          AREA    RESET, DATA, READONLY
          EXPORT  __Vectors

__Vectors
        DCD  0x20001000     ; stack pointer value when stack is empty
          DCD  Reset_Handler  ; reset vector

          ALIGN

;Your Data section
      ;AREA DATA
SUMP    DCD SUM

N     DCD 5
NUM1  DCD 3, -7, 2, -2, 10
POINTER DCD NUM1

      AREA    MYRAM, DATA, READWRITE
SUM   DCD 0

; The program
; Linker requires Reset_Handler
```

```
          AREA    MYCODE, CODE, READONLY

        ENTRY
        EXPORT Reset_Handler


Reset_Handler

;;;;;;;;;;User Code Start from the next line;;;;;;;;;;;;

      LDR R1, N       ; load size of array -
                      ; a counter for how many elements are left to process

      LDR R2, POINTER         ; load base pointer of array

      MOV R0, #0              ; initialize accumulator

LOOP
      LDR R3, [R2], #4        ; load value from array,
                              ; increment array pointer to next word
      ADD R0, R0, R3          ; add value from array to accumulator
      SUBS R1, R1, #1         ; decrement work counter
      BGT LOOP                ; keep looping until counter is zero
      LDR R4, SUMP            ; get memory address to store sum
      STR R0, [R4]            ; store answer

      LDR R6, [R4]            ; Check the value in the SUM

STOP
      B  STOP

      END
```

Another Example

```
;The semicolon is used to lead an inline documentation
;
;When you write your program, you could have your info at the top document block
;For Example: Your Name, Student Number, what the program is for, and what it does
etc.
;
;     This program will count the length of a string.
;

;;; Directives
          PRESERVE8
          THUMB

; Vector Table Mapped to Address 0 at Reset
; Linker requires __Vectors to be exported

          AREA    RESET, DATA, READONLY
          EXPORT  __Vectors

__Vectors
        DCD  0x20001000     ; stack pointer value when stack is empty
          DCD  Reset_Handler  ; reset vector
```

```
          ALIGN

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; Character array - string
; This type of format will construct a C string and null terminate.
; This means you can tell when the string ends
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

string1
      DCB     "Hello world!",0

; The program
; Linker requires Reset_Handler

      AREA    MYCODE, CODE, READONLY

      ENTRY
      EXPORT Reset_Handler


Reset_Handler

;;;;;;;;;;User Code Start from the next line;;;;;;;;;;;;


      LDR     R0, = string1    ; Load the address of string1 into the register R0

      MOV     R1, #0          ; Initialize the counter counting the length of string1

loopCount

      LDRB    R2, [R0], #1    ; Load the character from the address R0 contains
                              ; and update the pointer R0
                              ; using Post-indexed addressing mode

      CBZ     R2, countDone    ; If it is zero...remember null terminated...
                              ; You are done with the string. The length is in R1.

      ;ADD    R0, #1;          ; Otherwise, increment index to the next character

      ADD     R1, #1;          ; increment the counter for length

      B       loopCount


countDone

      B       countDone

      END                     ; End of the program
```

Lab work:

Program#1:

Write an ARM assembly language program **AddGT.s** to add up all the numbers that are great than 5 in the number array NUM1. Look at the following given code for more details and complete it.

```
;The semicolon is used to lead an inline documentation
;When you write your program, you could have your info at the top document lock
;For Example:  Your Name, Student Number, what the program is for, and what it does
etc.

;;; Directives
          PRESERVE8
          THUMB

; Vector Table Mapped to Address 0 at Reset
; Linker requires __Vectors to be exported

          AREA    RESET, DATA, READONLY
          EXPORT    Vectors

__Vectors
        DCD  0x20001000     ; stack pointer value when stack is empty
          DCD  Reset_Handler  ; reset vector

          ALIGN

;Your Data section
      ;AREA DATA
SUM   DCD 0
SUMP    DCD SUM
N     DCD 7
NUM1  DCD 3, -7, 2, -2, 10, 20, 30
POINTER DCD NUM1


; The program
; Linker requires Reset_Handler

          AREA    MYCODE, CODE, READONLY

        ENTRY
        EXPORT Reset_Handler


Reset_Handler

;;;;;;;;;;User Code Start from the next line;;;;;;;;;;;;

;     Please complete the program to add up all the
;     numbers in the array NUM1 that are greater than 5.
;     Put the sum in the register R0.

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
```

Hint: Check the example in the lab notes.

You will hand in the following:

1. The source code in the file **AddGT.s**
2. The screenshot (print screen) to show the program has been successfully built
3. The screenshot showing the sum in R0.

Program#2:

Write an ARM assembly language program **Min-Max.s** to find the maximum value and the minimum value in the number array NUM1. Look at the following given code for more details and complete it.

```
;The semicolon is uded to lead an inline documentation
;When you write your program, you could have your info at the top document lock
;For Example:  Your Name, Student Number, what the program is for, and what it does
etc.

;;; Directives
          PRESERVE8
          THUMB

; Vector Table Mapped to Address 0 at Reset
; Linker requires __Vectors to be exported

          AREA    RESET, DATA, READONLY
          EXPORT  __Vectors

__Vectors
        DCD  0x20001000     ; stack pointer value when stack is empty
          DCD  Reset_Handler  ; reset vector

          ALIGN

;Your Data section
      ;AREA DATA
Max   DCD 0
MaxP  DCD Max
Min   DCD 0
MinP  DCD Min

N     DCD 12
NUM1  DCD 3, -7, 2, -2, 10, 20, 30, 15, 32, 8, 64, 66
POINTER DCD NUM1


; The program
; Linker requires Reset_Handler

          AREA    MYCODE, CODE, READONLY

        ENTRY
        EXPORT Reset_Handler
```

```
Reset_Handler

;;;;;;;;;;User Code Start from the next line;;;;;;;;;;;;;;;;

;     Add code below to find the maximum value and
;     the minimum value in the number array NUM1.
;     You can use the example in the notes as a reference.

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
```

You will hand in the following:

1. The source code in the file **Min-Max.s**
2. The screenshot (print screen) to show the program has been successfully built
3. The screenshot showing the Min in R5 and the Max in R6.