Microcomputers I – CE 320

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Announcement

Lecture 15: Subroutines

Today’s Topics

- What is subroutines?
- Learn how to call subroutines from an assembly program.
- Learn the properties of well-written subroutines.
- Learn what are pass-by-reference and pass-by-value.

Introduction

- Good program design is based on the concept of modularity
  - Modularity ➡ partitioning of a large program into subroutines

- Program can be divided into two sections
  - Main program
  - Subroutines

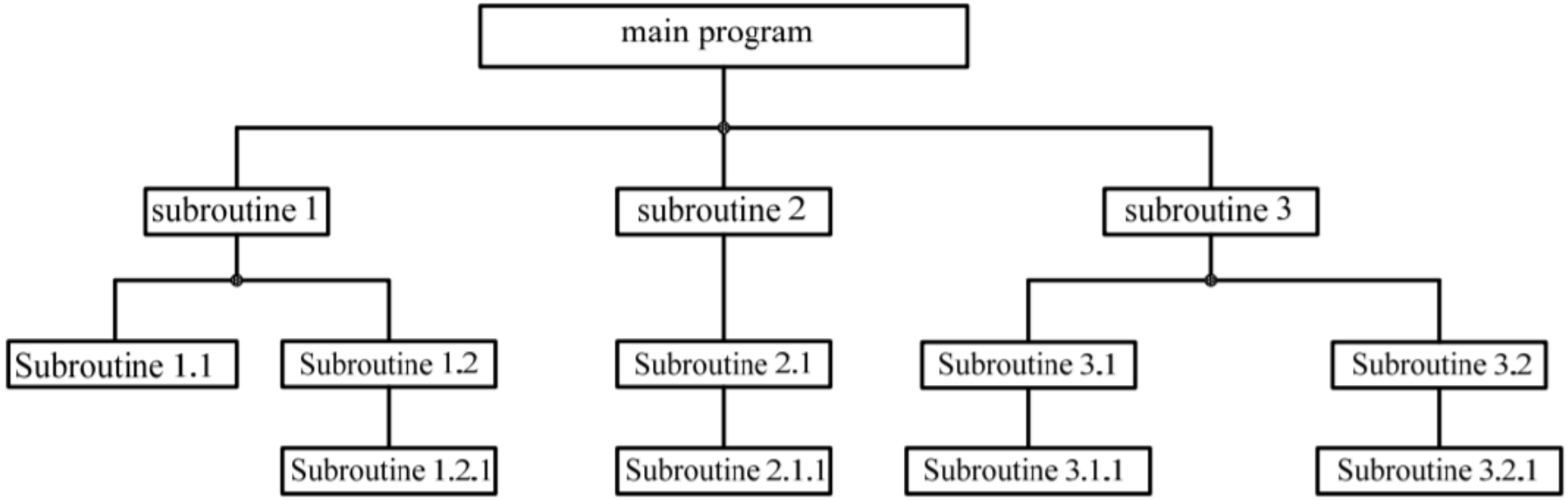
- Main program ➡ contains the logical structure of the algorithm

- Subroutines ➡ execute many of the details involved in the program

Subroutine Hierarchy

- Structure of a modular program can be visualized as shown

- Principles of program design involved in high-level languages can be applied to assembly language programs
  - Subroutine “objects” with calls and returns



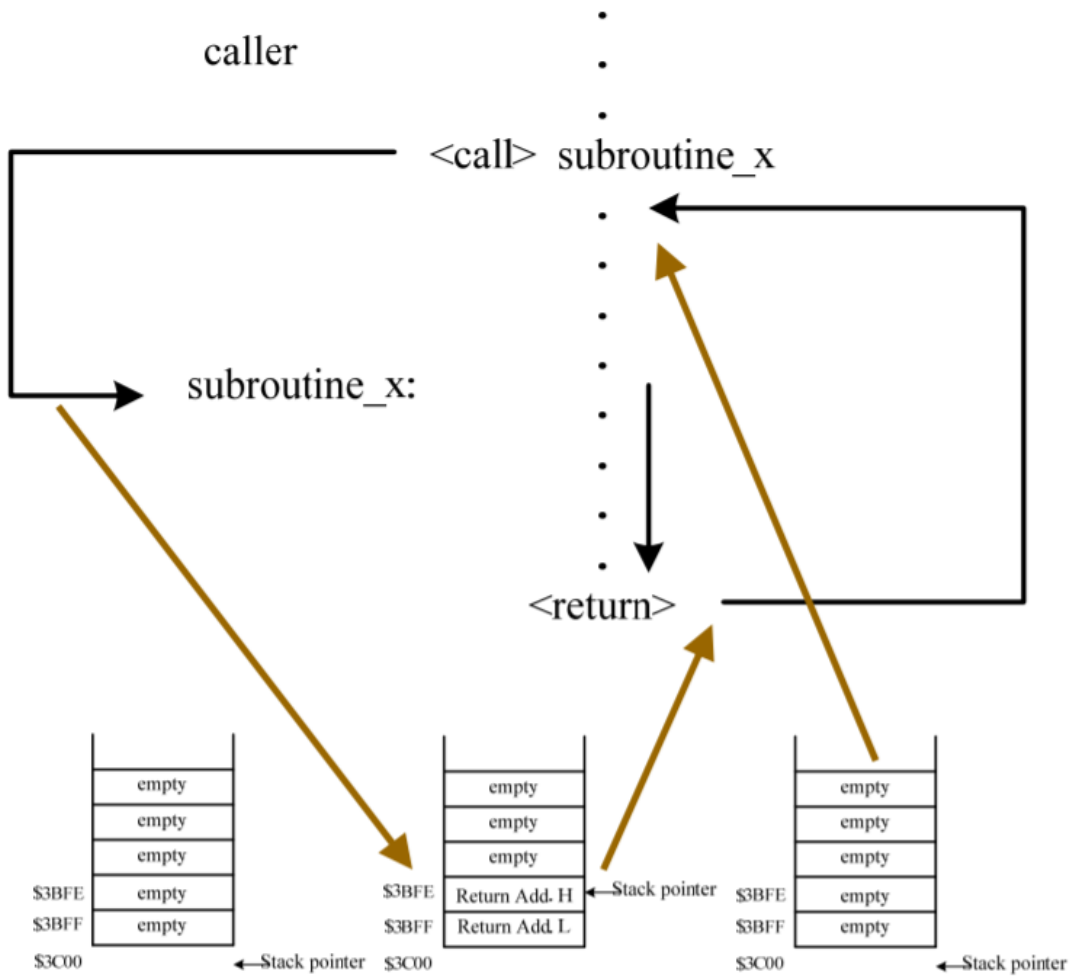
Subroutines

- Subroutine is a sequence of instructions that can be called from many different places in a program
  - One key issue in a subroutine call is to make sure that the program execution returns to the point immediately after the subroutine call when the subroutine completes its computation

- The address for returning to the point immediately after the subroutine completes its computation is known as the **return address**
  - This is normally achieved by saving and retrieving the return address in and from the **stack**

Subroutine Program Flow

- The subroutine call saves the return address, which is the address of the instruction immediately following the subroutine call instruction, in the stack system
- After completing the computation task, the subroutine will return to the instruction immediately following the instruction that makes the subroutine call
- This is achieved by executing a return instruction, which will retrieve the return address from the stack and transfer CPU control to it



Need Something for Subroutine Operation

Let's take a look at this code

- One of the main characteristics that makes a subroutine a subroutine is the ***ability to branch to (or return to) different addresses in the main program***.

- The need for this is demonstrated in the example here.

```
        ORG     $C000
        LDAA    #17         ; C000
        BRA     MagA        ; C002
Ret1    STAA    $1000       ; C004
        LDAA    #-1         ; C007
        BRA     MagA        ; C009
Ret2    STAA    $1001       ; C00B
        SWI                 ; C00E

;  Subroutine MagA
; compute magnitude of a single byte number
; input: byte in register A
; output: magnitude returned in register A

        ORG     $C200
MagA    TSTA
        BPL     return
        NEGA
Return  BRA     ?????
```

Subroutine Instructions

JSR and RTS

- **JSR** (Jump Sub Routine)
  - Pushes two-byte address of the next line of code on the **stack** first.
  - Jump/Branch to the subroutine.
  - Many addressing modes supported, but extended is often the most useful in Micros I.

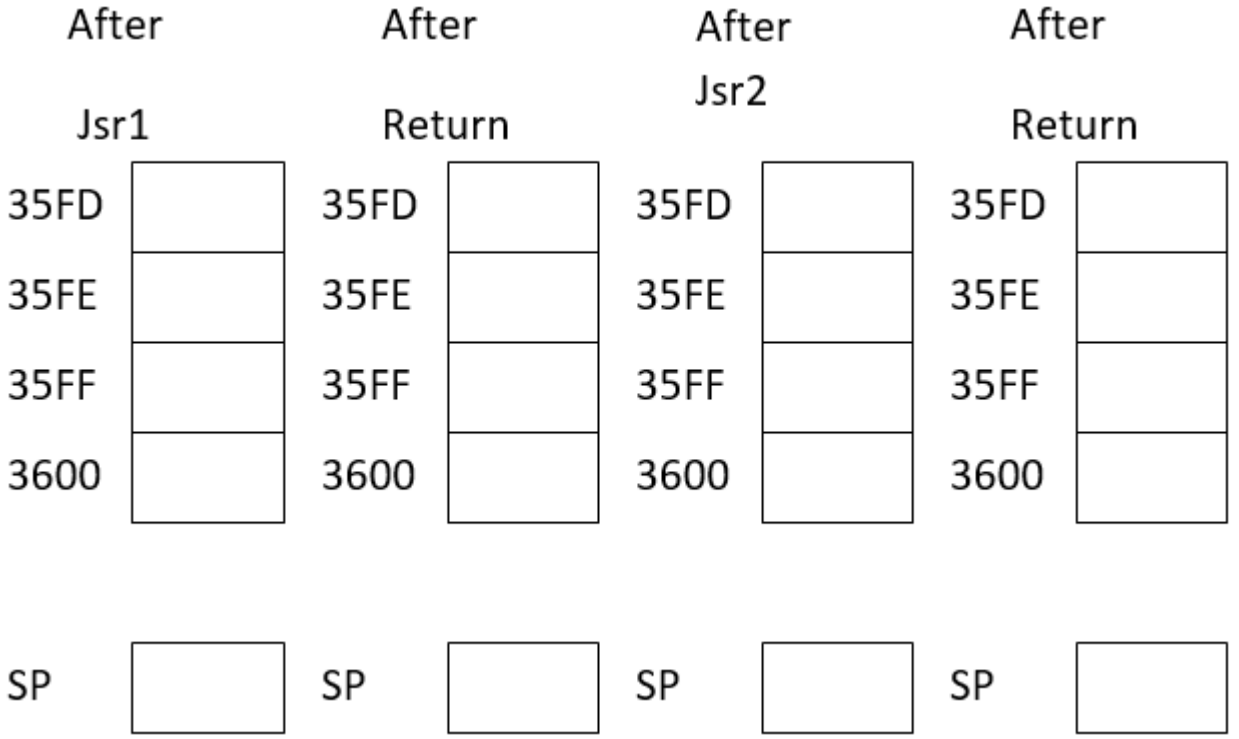
- **RTS** (ReTurn from Subroutine)
  - Pulls two bytes off of the **stack** into the PC and jumps to that address

Example for Subroutines

```
            ORG     $C000
            LDS     #$3600          ; C000
            LDAA    #17             ; C003
Jsr1        JSR     MagA            ; C005
Ret1        STAA    $1000           ; C008
            LDAA    #-1             ; C00B
Jsr2        JSR     MagA            ; C00D
Ret2        STAA    $1001           ; C010
            SWI                     ; C013

; compute magnitude of a single byte number
; input: byte in register A
; output: magnitude returned in register A

 MagA               TSTA
                    BPL     return
                    NEGA
Return              RTS
```



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; compute magnitude of a single byte number
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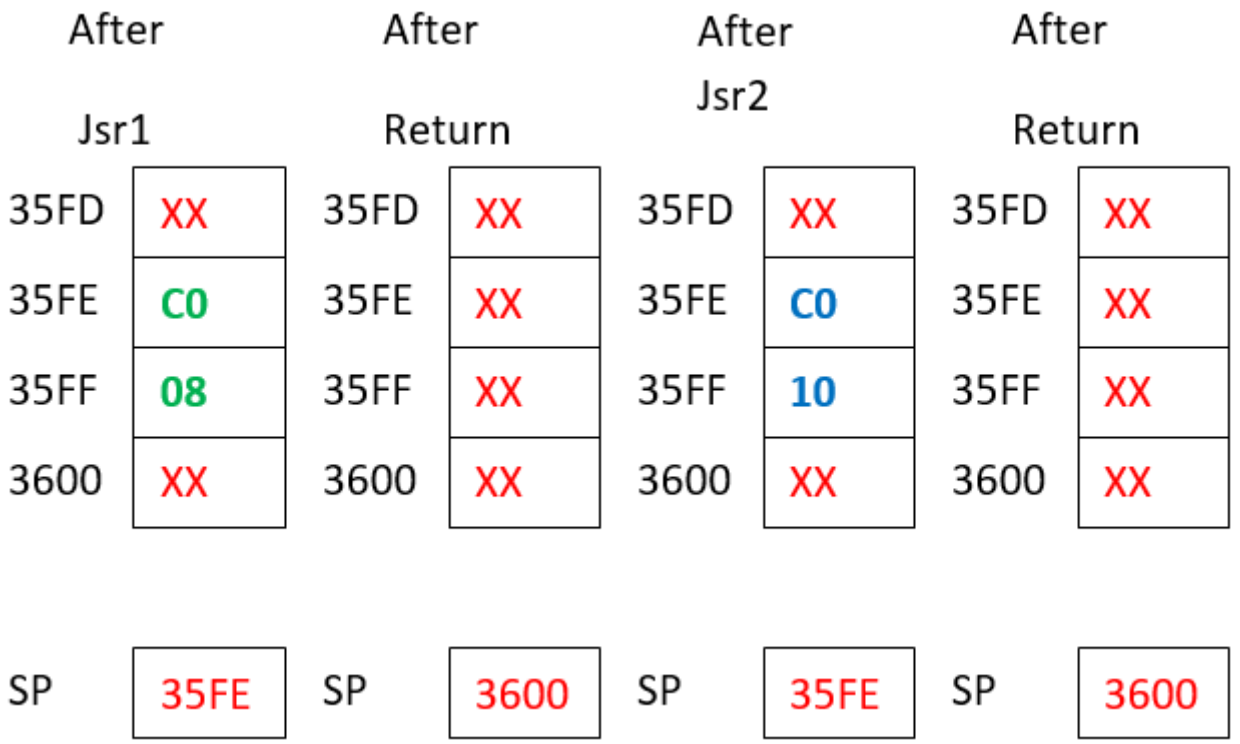
 MagA       TSTA
            BPL     return
            NEGA
Return      RTS
```

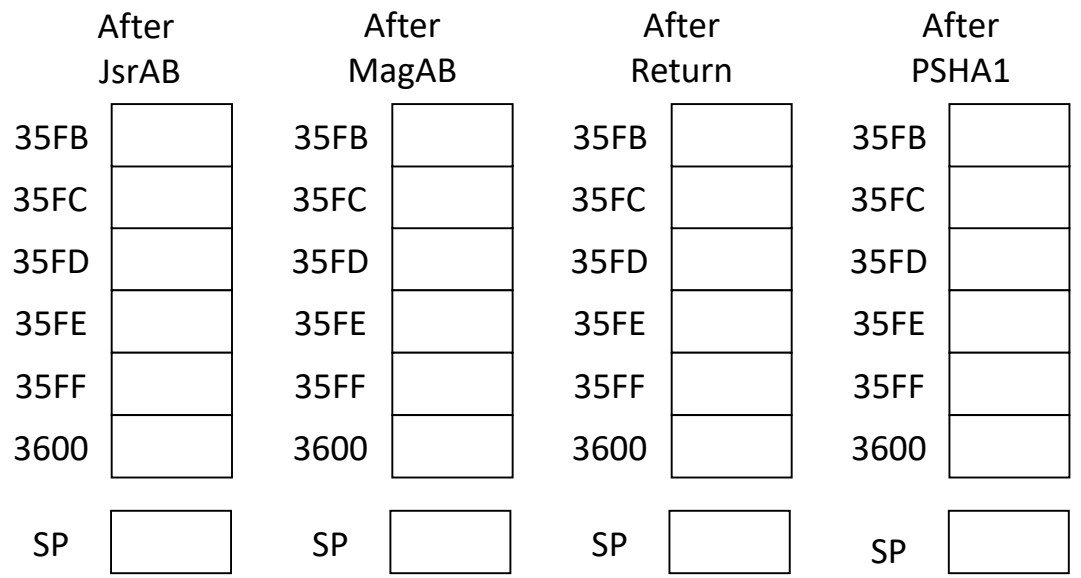


Nesting Subroutines

```
        ORG     $C000
        LDS     #$3600    ; C000
        LDAA    #17       ; C003
        LDAB    #-1       ; C005
JsrAB   JSR     MagAB     ; C007
        SWI               ; C00A

MagAB   JSR     MagA      ; C00B
PSHA1   PSHA              ; C00E
        TFR     B,A       ; C00F
JSR1    JSR     MagA      ; C011
        TFR     A,B       ; C014
PULA1   PULA              ; C016
RTS1    RTS               ; C017

MagA    TSTA              ; C018
        BPL     return    ; C019
        NEGA              ; C01B
Return  RTS               ; C01C
```



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                SWI                     ; C00A

MagAB           JSR     MagA            ; C00B
PSHA1           PSHA                    ; C00E
                TFR     B,A             ; C00F
JSR1            JSR     MagA            ; C011
                TFR     A,B             ; C014
PULA1           PULA                    ; C016
RTS1            RTS                     ; C017

MagA            TSTA                    ; C018
                BPL     return          ; C019
                NEGA                    ; C01B
Return          RTS                     ; C01C
```
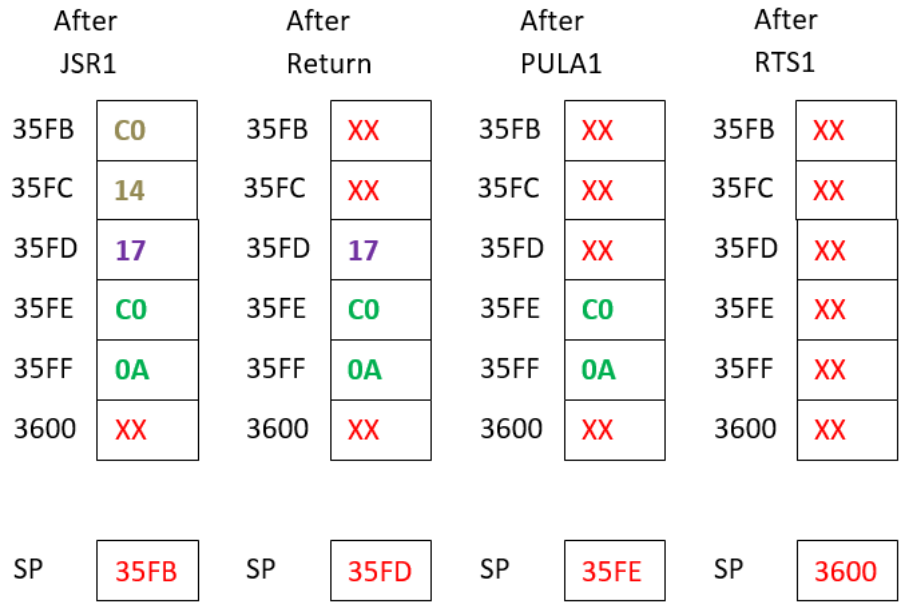
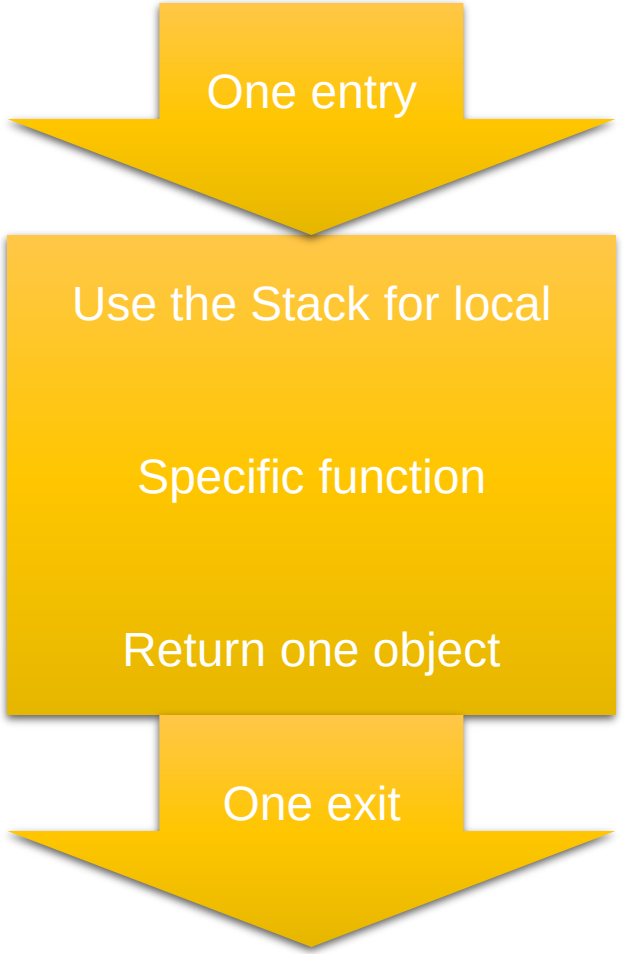



Properties of Well-Written Subroutines

- One Entry Point
- One Exit Point
- One Specific Function
- One Returned Object
- Do NOT store local variables (those used just by your subroutine) at specified memory locations. Use ONLY the stack.



Parameter Passing

- Pass-by-value
  - Much like immediate addressing, the **data itself** is passed.

- Pass-by-reference
  - Much like extended addressing, the **address of the data** is passed.
  - This address must be loaded into an index register to be used by the subroutine.

Questions?

Wrap-up

What we've learned

- Subroutines

- JSR, RTS

What to Come

- Parameter passing