- **More on programming in assembly language**
- **Introduction to Ports on the HC12**
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    - Tips for writing programs
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        - Simplified Output Port
    - Ports on the HC12
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    - Subroutines and the Stack
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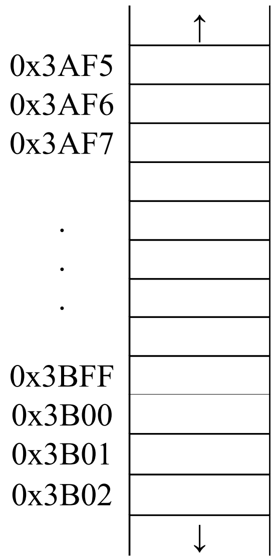
THE STACK AND THE STACK POINTER

• Sometimes it is useful to have a region of memory for temporary storage, which does not have to be allocated as named variables.
• When we use subroutines and interrupts it will be essential to have such a storage region.
• Such a region is called a Stack.
• The Stack Pointer (SP) register is used to indicate the location of the last item put onto the stack.
• When you put something onto the stack (push onto the stack), the SP is decremented before the item is placed on the stack.
• When you take something off of the stack (pull from the stack), the SP is incremented after the item is pulled from the stack.
• Before you can use a stack you have to initialize the Stack Pointer to point to one value higher than the highest memory location in the stack.
• For the HC12 use a block of memory from about $3B00 to $3BFF for the stack.
• For this region of memory, initialize the stack pointer to $3C00.
• Use the LDS (Load Stack Pointer) instruction to initialize the stack point.
• The LDS instruction is usually the first instruction of a program which uses the stack.
• The stack pointer is initialized only one time in the program.
• For microcontrollers such as the HC12, it is up to the programmer to know how much stack his/her program will need, and to make sure enough space is allocated for the stack. If not enough space is allocated the stack can overwrite data and/or code, which will cause the program to malfunction or crash.

The stack is an array of memory dedicated to temporary storage



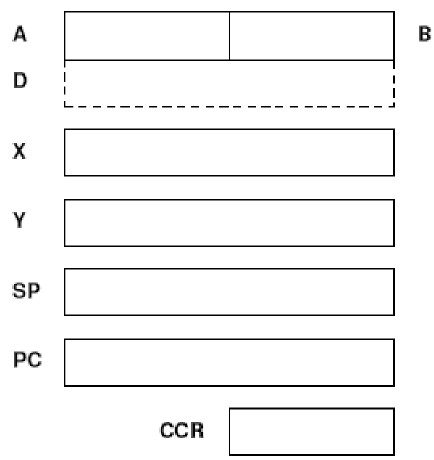
SP points to the location last item placed in block

SP <u>decreases</u> when you put an item on stack

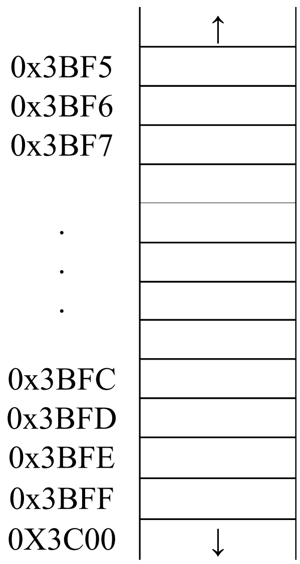
SP <u>increases</u> when you pull item from stack

For HC12 EVBU, use 0x3C00 as initial SP:

```
STACK:   EQU   $3C00
         LDS   #STACK
```



An example of some code which used the stack

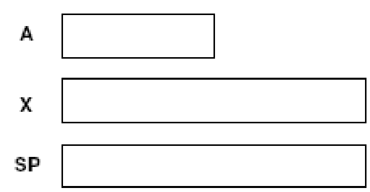


Stack Pointer

Initialize <u>ONCE</u> before first use (LDS #STACK)

Points to last used storage location
Decreases when you put something on stack
Increases when you take something off stack

```
STACK:  EQU   $3C00
        org   0x1000
        lds   #STACK
        ldaa  #$2e
        ldx   #$1254
        psha
        pshx
        clra
        ldx   #$ffff

        CODE THAT USES A & X

        pulx
        pula
```



PSHA — Push A onto Stack — PSHA

Operation

$(SP) - \$0001 \Rightarrow SP$
$(A) \Rightarrow M_{SP}$

Decrements SP by one and loads the value in A into the address to which SP points.

Push instructions are commonly used to save the contents of one or more CPU registers at the start of a subroutine. Complementary pull instructions can be used to restore the saved CPU registers just before returning from the subroutine.

CCR Effects

S	X	H	I	N	Z	V	C
–	–	–	–	–	–	–	–

Code and CPU Cycles

Source Form	Address Mode	Machine Code (Hex)	CPU Cycles
PSHA	INH	36	Os

Subroutines

• A subroutine is a section of code which performs a specific task, usually a task which needs to be executed by different parts of a program.

• Example:

– Math functions, such as square root

• Because a subroutine can be called from different places in a program, you cannot get out of a subroutine with an instruction such as

jmp label

because you would need to jump to different places depending upon which section of code called the subroutine.

• When you want to call the subroutine your code has to save the address where the subroutine should return to. It does this by saving the return address on the stack.

– This is done automatically for you when you get to the subroutine by using the JSR (Jump to Subroutine) or BSR (Branch to Subroutine) instruction. This instruction pushes the address of the instruction following the JSR (BSR) instruction on the stack.

• After the subroutine is done executing its code it needs to return to the address saved on the stack.

– This is done automatically for you when you return from the subroutine by using the RTS (Return from Subroutine) instruction. This instruction pulls the return address off of the stack and loads it into the program counter, so the program resumes execution of the program with the instruction following that which called the subroutine.

The subroutine will probably need to use some HC12 registers to do its work. However, the calling code may be using its registers for some reason — the calling code may not work correctly if the subroutine changes the values of the HC12 registers.

– To avoid this problem, the subroutine should save the HC12 registers before it uses them, and restore the HC12 registers after it is done with them.

BSR Branch to Subroutine BSR

Operation

$(SP) - \$0002 \Rightarrow SP$
$RTN_H:RTN_L \Rightarrow M_{SP}:M_{SP+1}$
$(PC) + \$0002 + rel \Rightarrow PC$

Sets up conditions to return to normal program flow, then transfers control to a subroutine. Uses the address of the instruction after the BSR as a return address.

Decrements the SP by two, to allow the two bytes of the return address to be stacked.

Stacks the return address (the SP points to the high byte of the return address).

Branches to a location determined by the branch offset.

Subroutines are normally terminated with an RTS instruction, which restores the return address from the stack.

CCR Effects

S	X	H	I	N	Z	V	C
–	–	–	–	–	–	–	–

Code and CPU Cycles

Source Form	Address Mode	Machine Code (Hex)	CPU Cycles
BSR *rel8*	REL	07 rr	SPPP

RTS Return from Subroutine RTS

Operation

$(M_{SP}):(M_{SP+1}) \Rightarrow PC_H:PC_L$
$(SP) + \$0002 \Rightarrow SP$

Restores the value of PC from the stack and increments SP by two. Program execution continues at the address restored from the stack.

CCR Effects

S	X	H	I	N	Z	V	C
–	–	–	–	–	–	–	–

Code and CPU Cycles

Source Form	Address Mode	Machine Code (Hex)	CPU Cycles
RTS	INH	3D	UfPPP

Example of a subroutine to delay for a certain amount of time

```
delay:  ldaa    #250
loop2:  ldx     #800
loop1:  dex
        bne     loop1
        deca
        bne     loop2
        rts
```

• Problem: The subroutine changes the values of registers A and X

• To solve, save the values of A and X on the stack before using them, and restore them before returning.

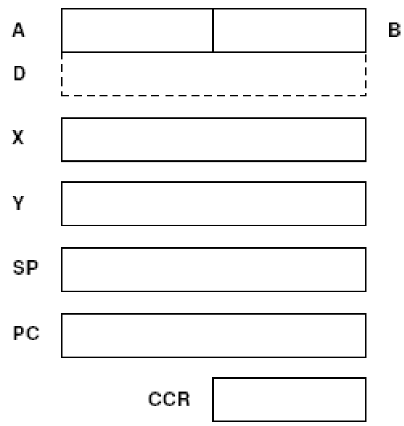
```
delay:  psha                    ; Save regs used by sub on stack
        pshx
        ldaa    #250
loop2:  ldx     #800
loop1: dex
       bne      loop1
       deca
       bne      loop2
       pulx                     ; Restore regs in opposite
       pula                     ; order
       rts
```

; Program to make a binary counter on LEDs

```
;
; The program uses a subroutine to insert a delay
; between counts
prog:       equ   $1000
STACK:      equ   $3C00        ;Stack ends of $3BFF
PORTA:      equ   $0000
PORTB:      equ   $0001
DDRA:       equ   $0002
DDRB:       equ   $0003

            org prog

            lds   #STACK       ; initialize stack pointer
            ldaa  #$ff         ; put all ones into DDRA
            staa  DDRA         ; to make PORTA output
            clr   PORTA        ; put $00 into PORTA
loop:       jsr   delay        ; wait a bit
            inc   PORTA        ; add one to PORTA
            bra   loop         ; repeat forever

; Subroutine to wait for a few milliseconds

delay:      psha
            pshx
            ldaa  #250
loop2:      ldx   #800
loop1:      dex
            bne   loop1
            deca
            bne   loop2
            pulx
            pula
            rts
```

JSR and BSR place return address on stack
RTS returns to instruction after JSR or BSR

```
3c00                     STACK:  EQU     $3C00
1000                             ORG     $1000

1000 cf 3c 00                    LDS     #STACK
1003 16 10 07                    JSR     MY_SUB
1006 3f                          SWI
1007 ce 12 34            MY_SUB: LDX     #$1234
100a 3d                          RTS
```



Another example of using a subroutine

```
; Program fragment to write the word "hello" to the
; HC12 serial port

            ldx $str
loop:       ldaa    1,x+            ; get next char
            beq     done            ; char == 0 => no more
            jsr     putchar
            bra     loop
            swi
str:        dc.b    "hello"
            fc.b    $0A,$0D,0       ; CR LF
```

Here is the complete program to write a line to the screen:

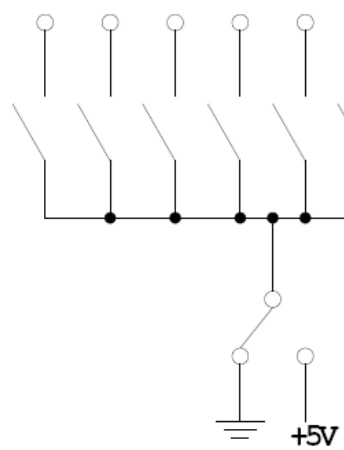
```
prog:        equ    $1000
data:        equ    $2000
stack:       equ    $3c00

            org prog
            lds     #stack
```

```
                ldx     #str
loop:           ldaa    1,x+                    ; get next char
                beq     done                    ; char == 0 => no more
                jsr     putchar
                bra     loop
done:           swi
putchar:        brclr   $00CC,$80,putchar
                staa    $00CF
                rts

                org     data
str:            fcc     "hello"
                dc.b    $0a,$0d,0               ; CR LF
```

Using DIP switches to get data into the HC12

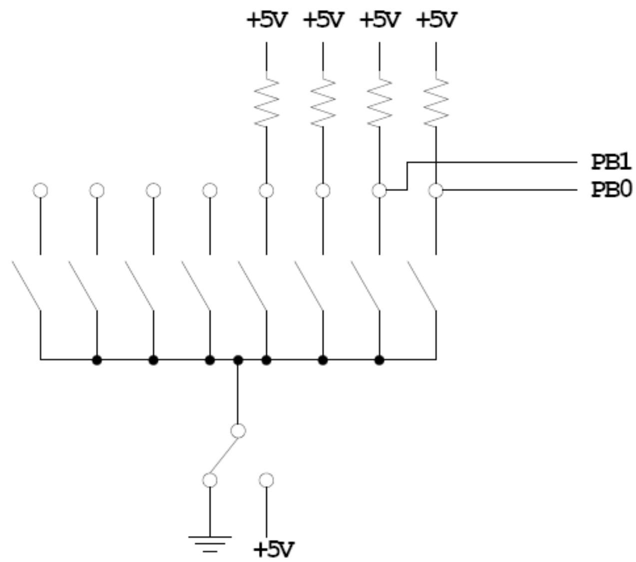
• DIP switches make or break a connection (usually to ground)

DIP Switches on Breadboard



• To use DIP switches, connect one end of each switch to a resistor
• Connect the other end of the resistor to +5 V
• Connect the junction of the DIP switch and the resistor to an input port on the HC12

Using DIP Switches



• When the switch is open, the input port sees a logic 1 (+5 V)
• When the switch is closed, the input sees a logic 0 (0 V)

Looking at the state of a few input pins

• Want to look for a particular pattern on 4 input pins
– For example want to do something if pattern on PB3-PB0 is 0110
• Don't know or care what are on the other 4 pins (PB7-PB4)
• Here is the wrong way to do it:

```
ldaa    PORTB
cmpa    #%0110
beq     task
```

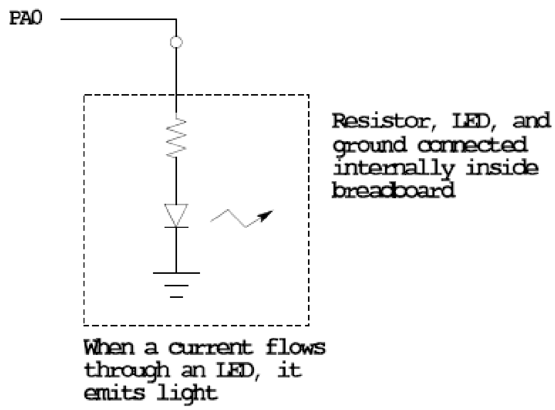
• If PB7-PB4 are anything other than 0000, you will not execute the task.
• You need to mask out the Don't Care bits before checking for the pattern on the bits you are interested in

```
ldaa    PORTB
anda    #%00001111
cmpa    #%00000110
beq     task
```

• Now, whatever pattern appears on PB7-4 is ignored

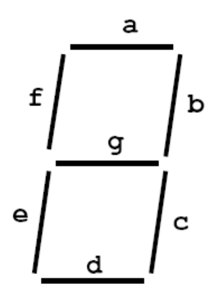
Using an HC12 output port to control an LED

• Connect an output port from the HC12 to an LED.



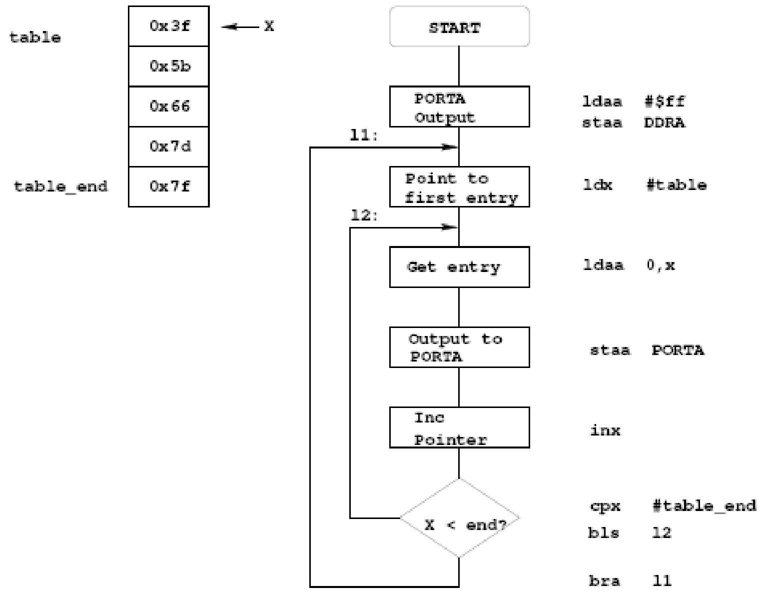
Making a pattern on a seven-segment LED

• Want to generate a particular pattern on a seven-segment LED:



• Determine a number (hex or binary) which will generate each element of the pattern
– For example, to display a 0, turn on segments a, b, c, d, e and f, or bits 0, 1, 2, 3, 4 and 5 of PTH. The binary pattern is 00111111, or $3f.
– To display 0 2 4 6 8, the hex numbers are $3f, $5b, $66, $7d, $7f.
• Put the numbers in a table
• Go through the table one by one to display the pattern
• When you get to the last element, repeat the loop

Flowchart to display a pattern of lights on a set of LEDs




```
; Program using subroutine to make a time delay
prog:       equ     $1000
data:       equ     $2000
stack:      equ     $3C00
PTH:        equ     $0260
DDRH:       equ     $0262

            org prog
            lds     #stack          ; initialize stack pointer
            ldaa    #$ff            ; Make PTH output
            staa    DDRH            ; 0xFF -> DDRH
l1:         ldx     #table          ; Start pointer at table
l2:         ldaa    1,x+            ; Get value; point to next
            staa    PTH             ; Update LEDs
            jsr     delay           ; Wait a bit
            cpx     #table_end      ; More to do?
            bls l2                  ; Yes, keep going through table
            bra l1                  ; At end; reset pointer

delay:      psha
            pshx
            ldaa    #250
loop2:      ldx     #8000
loop1:      dex
            bne     loop1
```

```
                deca
                bne     loop2
                pulx
                pula
                rts

                org     data
table:          dc.b    $3f
                dc.b    $5b
                dc.b    $66
                dc.b    $7d
table_end:      dc.b    $7F
```