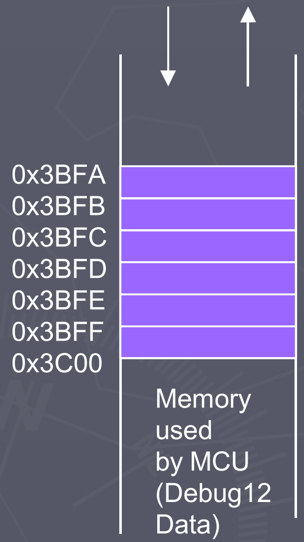
The stack and the stack pointer

If you "google" the word stack, one of the definitions you will get is:

A reserved area of memory used to keep track of a program's internal operations, including functions, return addresses, passed parameters, etc. A stack is usually maintained as a "last in, first out" (LIFO) data structure, so that the last item added to the structure is the first item used.



Sometimes is useful to have a region of memory for temporary storage, which does not have to be allocated as named variables.

When you use subroutines and interrupts it will be essential to have such a storage region.

Such 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 SP 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 LDS (Load Stack Pointer) to initialize the stack pointer.

The stack pointer is initialized only one time in the program.

The stack is an array of memory dedicated to temporary storage

SP points to location last item placed in block

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

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

For the HC12, use 0x3c00 as initial SP

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

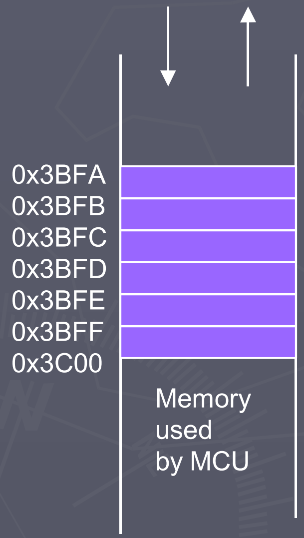
An example of some code which uses the stack

Stack pointer:

Initialize ONCE before the first use (LDS #STACK)

Points to last used storage location

Decreases when you put something on stack, and increases when you take something off stack

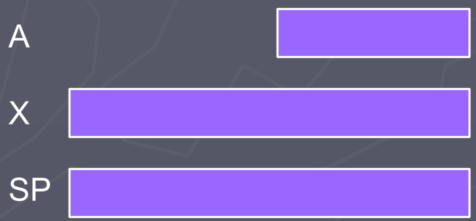



```
STACK:   equu    $3C00

         lds     #STACK
         ldaa    #$2e
         ldx     #$1254
         psha
         pshx
         clra
         ldx     #$ffff

         CODE THAT USES A & X

         pulx
         pula
```



An example of some code which uses the stack

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

PSHX — Push X onto Stack — PSHX

Operation $(SP) - \$0002 \Rightarrow SP$

$(X_H):(X_L) \Rightarrow M_{SP}:M_{SP+1}$

Decrements SP by two and loads the high byte of X into the address to which SP points. Loads the low byte of X into the address to which SP points plus one. After PSHX executes, SP points to the stacked value of the high byte of X.

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 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
PSHX	INH	34	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 the program.

```
        org  $1000

                :
                :
        call sqrt
               :          ??
               :
        call sqrt
               :
               :
        swi

sqrt:   compute square root
               :
               :
        jmp label
```

Example:

-Math functions, such as square root (sqrt)

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 the 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 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 when you return from the subroutine by using RTS (Return from Subroutine) instruction. This instruction pulls the return address off the stack and loads it into the PC.

Subroutines

Caution: The subroutine will probably need to use some HC12 registers to do its work. However, the calling code may be using its registers form 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 certain amount of time

```
; Subroutine to wait for 100 ms

Delay:    ldaa    #250
Loop2:    ldx     #800
Loop1:    dex
          bne     Loop1
          deca
          bne     Loop2
          rts
```

What is the problem with this subroutine?

It changes the values of the registers that are most frequently used: A and X

How can we solve this problem?

Example of a subroutine to delay for certain amount of time

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

```
; Subroutine to wait for 100 ms

Delay:   psha
         pshx
         ldaa    #250
Loop2:   ldx     #800
Loop1:   dex
         bne     Loop1
         deca
         bne     Loop2
         pulx            ; restore registers
         pula
         rts
```

A sample program

```
; Program to make binary counter on LEDS
; The program uses a subroutine to insert a delay between counts

prog:     equu    $1000
STACK:    equ     $3C00
PORTA:    equ     $0000
PORTB:    equ     $0001
DDRA:     equ     $0002
DDRB:     equ     $0003

          org     prog
          lds     #STACK      ; initialize stack
          ldaa    #$ff        ; put all 1s into DDRA
          staa    DDRA        ; to make PORTA output
          clr     PORTA       ; put $00 into PORTA
loop:     jsr     delay       ; wait a bit
          inc     PORTA       ; add 1 to PORTA
          bra     loop        ; repeat forever

; Subroutine to wait for 100 ms

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

```
                      STACK:    equu    $3C00
                                org     $1000
1000 CF 3C 00                   lds     #STACK
1003 16 10 07                   jsr     MY_SUB
1006 7F                         swi
1007 CE 12 34         MY_SUB:   ldx     #$1234
100A 3D                         rts
```

Another example using a subroutine

Using a subroutine to wait for an event to occur then take action

Wait until bit 7 of address $00CC is set.

Write the value of ACCA to address $00CF

```
; This routine waits until the HC12 serial port is ready, then send a byte of data to the serial port

putchar:    brclr    $00CC,#$80,putchar    ; Data Terminal Equip. ready
            staa     $00CF                 ; Send char
            rts

; Program to send the word "hello" to the HC12 serial port

            ldx      #str
loop:       ldaa     1,x+
            beq      done
            jsr      putchar
            bra      loop
done:       swi

str:        fcc      "hello"               ; form constant character
            dc.b     $0a,$0d,0             ; CR-LF
```

Another example using a subroutine

A complete program to write to the screen

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

            org     prog
            lds     #stack              ; initialize stack
            ldx     #str                ; load pointer to “hello”
loop:       ldaa    1,x+
            beq     done                ; is done then end program
            jsr     putchar             ; write character to screen
            bra     loop                ; branch to read next
character
done:       swi


putchar:    brclr   $00CC,$80,putchar   ; check is serial port is
ready
            staa    $00CF               ; and send
            rts

            org     data
str:        fcc     “hello”             ; form constant character
            dc.b    $0a,$0d,0           ; CR-LF
```

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

JSR — Jump to Subroutine — JSR

Operation

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

Subroutine address $\Rightarrow$ PC

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

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

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

Calculates an effective address according to the rules for extended, direct, or indexed addressing.

Jumps to the location determined by the effective address.

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

CCR Effects

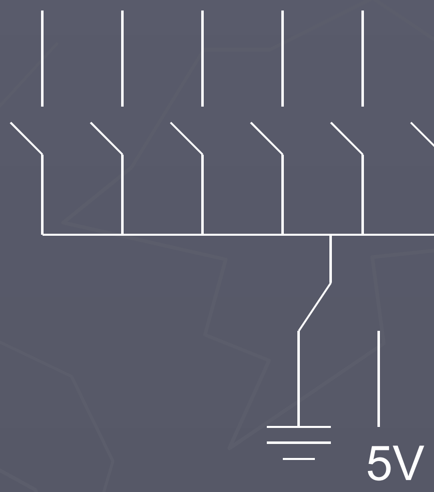
S	X	H	I	N	Z	V	C
–	–	–	–	–	–	–	–

Code and CPU Cycles

Source Form	Address Mode	Machine Code (Hex)	CPU Cycles
JSR *opr8a*	DIR	17 dd	SPPP
JSR *opr16a*	EXT	16 hh ll	SPPP
JSR *oprx0_xysppc*	IDX	15 xb	PPPS
JSR *oprx9,xysppc*	IDX1	15 xb ff	PPPS
JSR *oprx16,xysppc*	IDX2	15 xb ee ff	fPPPS
JSR [D,*xysppc*]	[D,IDX]	15 xb	fIfPPPS
JSR [*oprx16,xysppc*]	[IDX2]	15 xb ee ff	fIfPPPS

Using DIP switches to get data into the HC12

DIP switches make or break a connections (usually to ground)

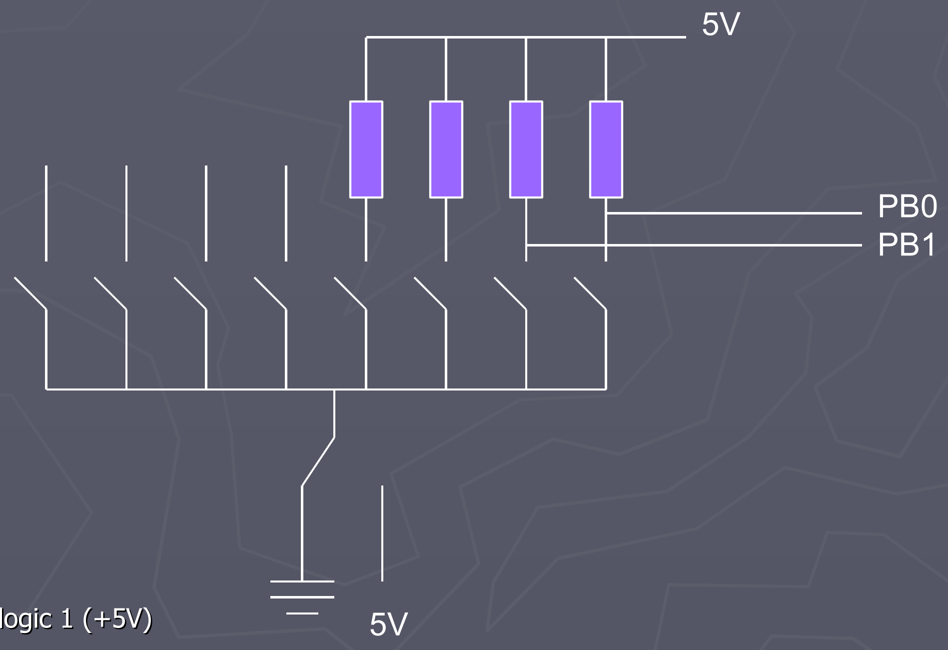


Using DIP switches to get data into the HC12

To use DIP switches, connect one end of each switch to a resistor

Connect the other end of the resistor to +5V

Connect the junction of the DIP switch and the resistor to an input port on the HC12



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

When the switch is closed, the input sees a logic 0 (0V)

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    #b0110
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

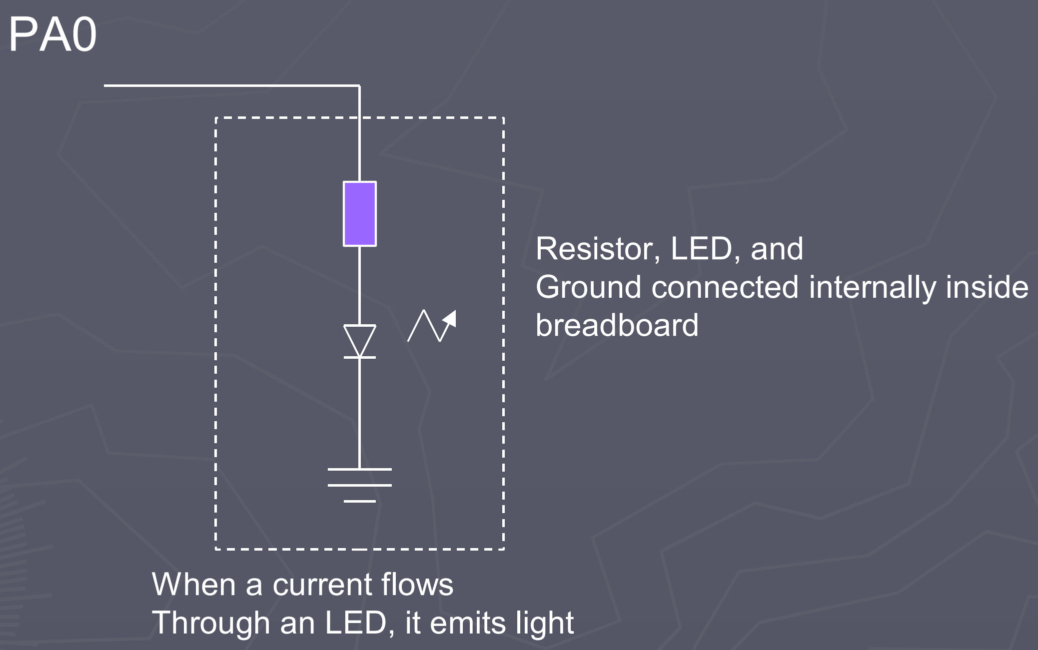
```
ldaa    PORTB
andaa   #b00001111
cmpa    #b00000110
beq     task
```

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.

Using an output port to control an LED



Making a pattern on a 7-segement LED

Want to make a particular pattern on a 7-segmen LED.

Determine a number (hex or binary) that will generate each element of the pattern

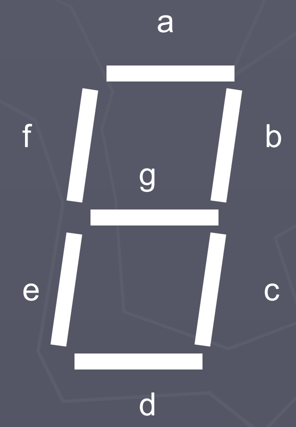
-For example, to display a 0, turn on segments a, b, c, d, e, and f, or bits 0, 1, 2, 3, 4, and 5 of PTH. The binary pattern is 00111111, or $3f

-To display 0, 2, 4, 6, 8, the hex numbers are $3f, $5b, $66, $7d, $7f.

Put the numbers in a table

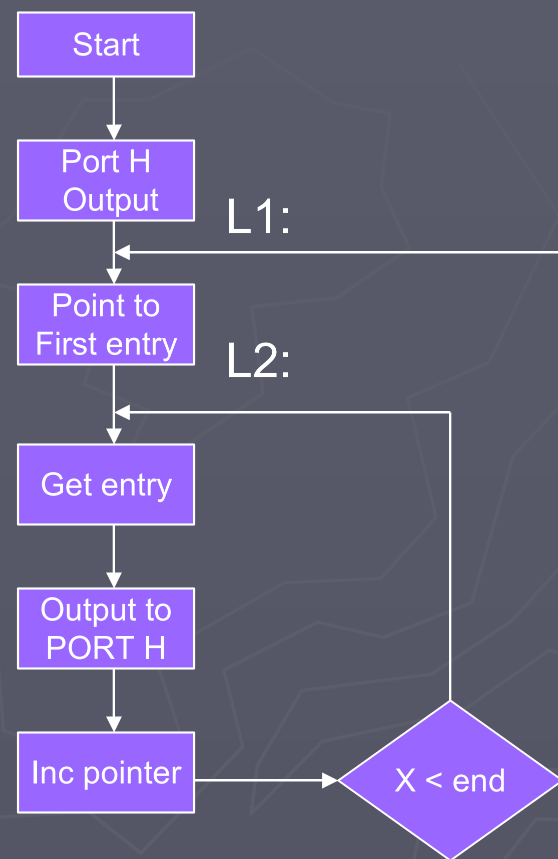
Go through the table one by one to display the pattern

When you get to the last element repeat the loop



Flow chart to display the patterns on a 7-segement LED

table	0x3f	← X
	0x5b	
	0x66	
	0x7d	
table_end	0x7f	




```
ldaa #$ff
staa DDRH

ldx #table

ldaa 0,x

staa PORTH

inx
cpx #end_table
bls L2
bra L1
```

Program to display the patterns on a 7-segement LED

```
; Program to display patterns

prog:       equ     $1000
data:       equ     $2000
stack:      equ     $3C00
PTH:        equ     $0260
DDRH:       equ     $0262
            org     prog
            lds     #stack
            ldaa    #$ff
            staa    DDRH
L1:         ldx     #table
L2:         ldaa    1,x+
            staa    PTH
            jsr     delay
            cpx     #table_end
            bls     L2
            bra     L1

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
```