- **Writing Assembly Language Programs**
  - Use flow charts to lay out structure of program
  - Use common flow structures
    - If-then
    - If-then-else
    - Do-while
    - While
  - Plan structure of data in memory
  - Top-down design
    - Plan overall structure of program
    - Work down to more detailed program structure
    - Implement structure with instructions
  - Optimize program to make use of instruction efficiencies
  - Do not sacrifice clearly for efficiency or speed

- **Input and Output Ports**
  - How to get data into and out of the MC9S12

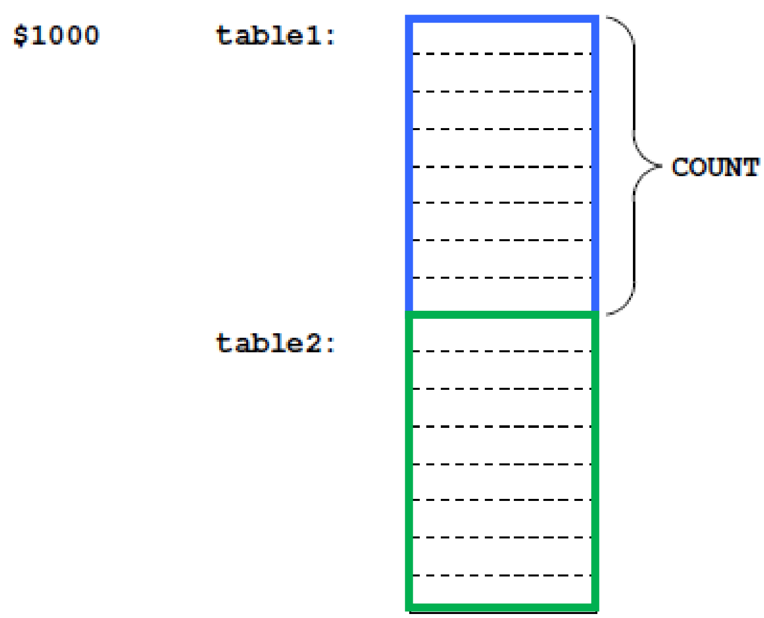
Example Program: Divide a table of data by 2

Problem: Start with a table of data. The table consists of 5 values. Each value is between 0 and 255. Create a new table whose contents are the original table divided by 2.

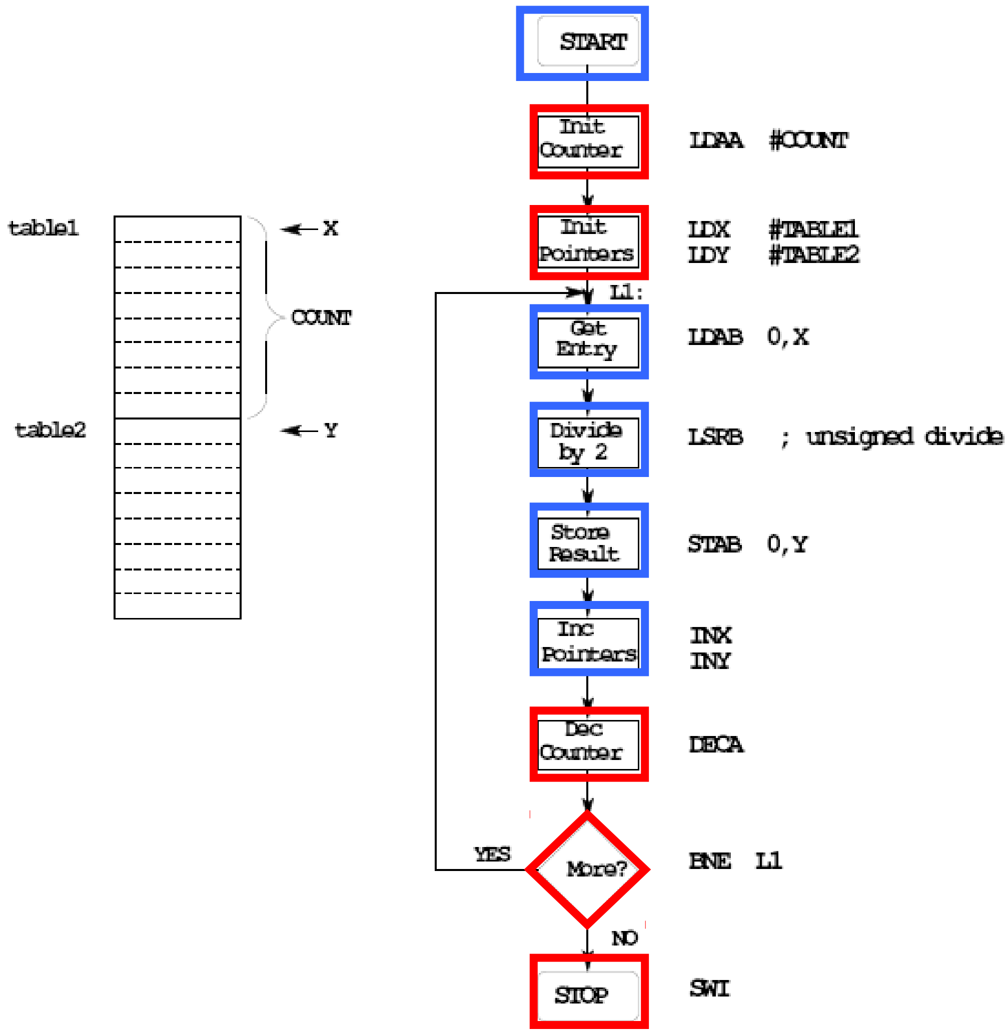
1. Determine where code and data will go in memory.
Code at $2000, data at $1000.

2. Determine type of variables to use.
Because data will be between 0 and 255, can use unsigned 8-bit numbers.

3. Draw a picture of the data structures in memory:



4-7. Add code to implement blocks:



8. Write the program:

```
; Program to divide a table by two
; and store the results in memory

prog:     equu  $2000
data:     equ   $1000

count:    equ   5

          org   prog       ; Set program counter to 0x2000
          ldaa  #count     ; Use A as counter
          ldx   #table1    ; Use X as data pointer to table1
          ldy   #table2    ; Use Y as data pointer to table2
l1:       ldab  0,x        ; Get entry from table1
          lsrb             ; Divide by two (unsigned)
          stab  0,y        ; Save in table2
          inx              ; Increment table1 pointer
          iny              ; Increment table2 pointer
          deca             ; Decrement counter
          bne   l1         ; Counter != 0 => more entries
                           ; to divide
          swi              ; Done


          org   data
table1:   dc.b  $07,$c2,$3a,$68,$f3
table2:   ds.b  count
```

9. Advanced: Optimize program to make use of instructions set efficiencies:

```
; Program to divide a table by two
; and store the results in memory

prog:    equ  $1000
data:    equ  $2000

count:   equ  5

         org   prog      ; Set program counter to 0x1000
         ldaa  #count    ; Use A as counter
         ldx   #table1   ; Use X as data pointer to table1
         ldy   #table2   ; Use Y as data pointer to table2
l1:      ldab  1,x+      ; Get entry from table1; then inc
                         ;  pointer
         lsrb            ; Divide by two (unsigned)
         stab  1,y+      ; Save in table2; then inc potr.
         dbne  a,l1      ; Decrement counter; if not 0,
                         ;  more to do
         swi             ; Done


         org   data
table1:  dc.b  $07,$c2,$3a,$68,$f3
table2:  ds.b  count
```

TOP-DOWN PROGRAM DESIGN

• PLAN DATA STRUCTURES IN MEMORY

• START WITH A LARGE PICTURE OF THE PROGRAM STRUCTURE

• WORK DOWN TO MORE DETAILED STRUCTURE

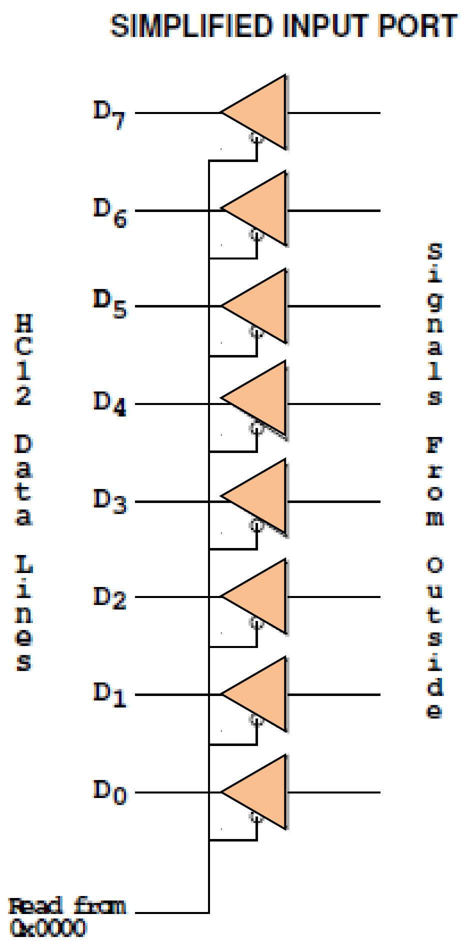
• TRANSLATE STRUCTURE INTO CODE

• OPTIMIZE FOR EFFICIENCY

DO NOT SACRIFICE CLARITY FOR EFFICIENCY

Input and Output Ports

• How do you get data into a computer from the outside?

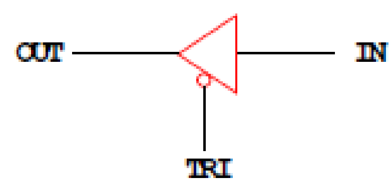


Any read from address $0000 gets signals from outside

LDAA $00

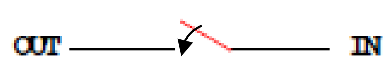
Puts data from outside into accumulator A.

Data from outside looks like a memory location.

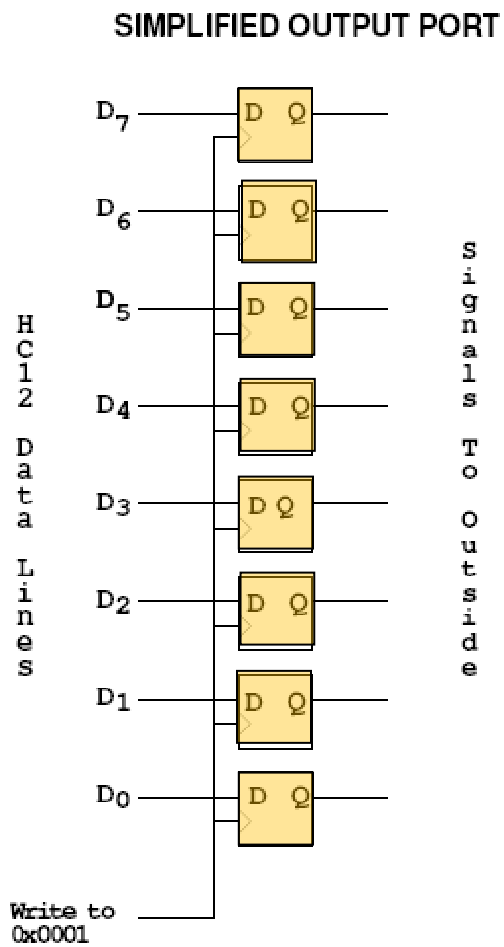


A Tri-State Buffer acts like a switch

If TRI is not active, the switch is open: OUT will not be driven by IN
Some other device can drive OUT



- How do you get data out of computer to the outside?



Any write to address $01 latches data into FF, so data goes to external pins

MOVB #$AA,$01

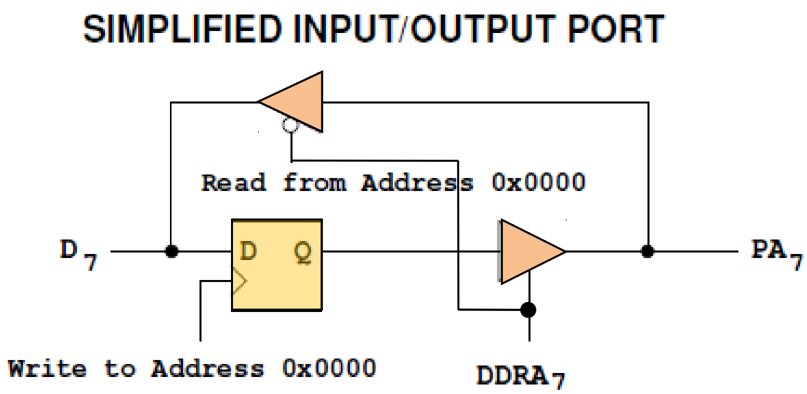
Puts $AA on the external pins

When a port is configured as output and you read from that port, the data you read is the data which was written to that port:

MOVB #$AA, $01
LDAA $01

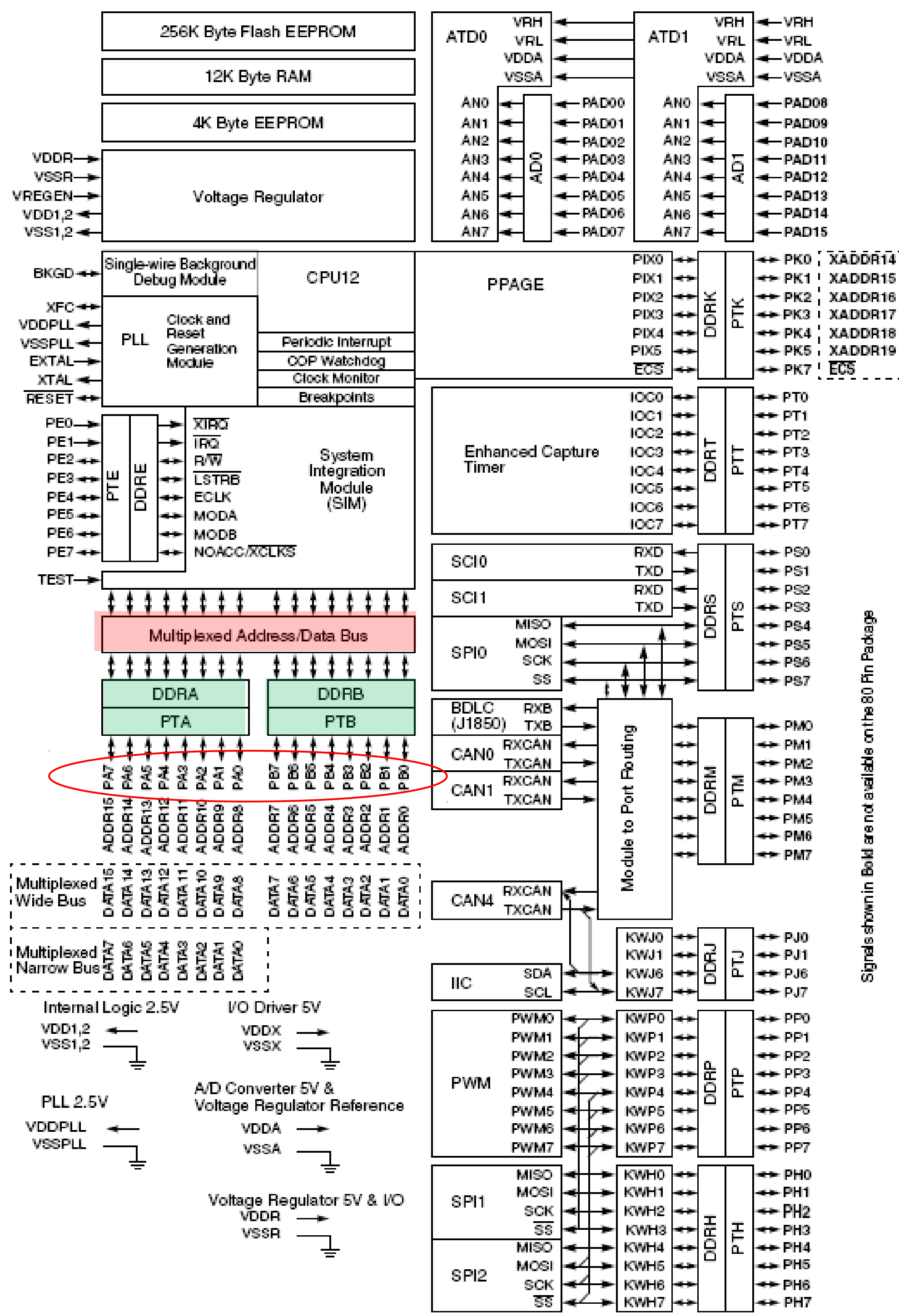
Accumulator A will have $AA after this

• Most I/O ports on MC9S12 can be configured as either input or output



- A write to address 0x0000 writes data to the flip-flop
  A read from address 0x0000 reads data on pin
- If Bit 7 of DDRA is 0, the port is an input port. Data written to flip-flop does not get to pin though tri-state buffer
- If Bit 7 of DDRA is 1, the port is an output port. Data written to flip-flop does get to pin though tri-state buffer
- DDRA (Data Direction Register A) is located at 0x0002

Figure 1-1 MC9S12DT256 Block Diagram



Ports on the HC12

• How do you get data out of computer to the outside?

• A Port on the MC9S12 is a device that the MC9S12 uses to control some hardware.

• Many of the MC9S12 ports are used to communicate with hardware outside of the MC9S12.

• The MC9S12 ports are accessed by the MC9S12 by reading and writing memory locations **$0000** to **$03FF**.

• Some of the ports we will use in this course are **PORTA**, **PORTB, PTJ** and **PTP**:

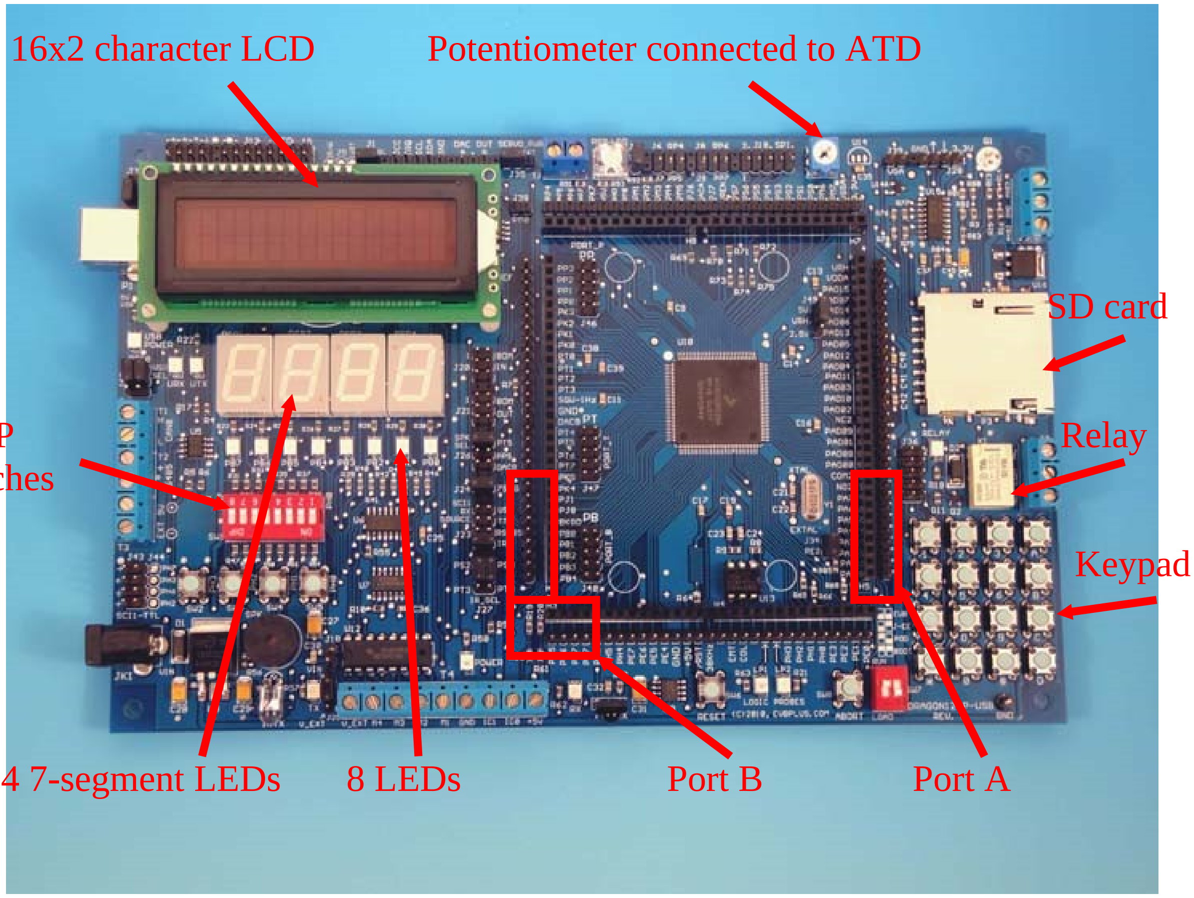
• PORTA is accessed by reading and writing address $0000.
  - DDRA is accessed by reading and writing address $0002.

• PORTB is accessed by reading and writing address $0001.
  - DDRB is accessed by reading and writing address $0003.

• PTJ is accessed by reading and writing address $0268.
  - DDRJ is accessed by reading and writing address $026A.

• PTP is accessed by reading and writing address $0258.
  - DDRP is accessed by reading and writing address $025A.

• On the DRAGON12-Plus EVB, eight LEDs and four seven-segment LEDs are connected to PTB.



-Before you can use the eight individual LEDs or the seven-segment LEDs, you need to enable them:

- <u>Bit 1 of PTJ must be low to enable the eight individual LEDs</u>.

  * To make Bit 1 of PTJ low, you must first make Bit 1 of PTJ an output by writing a 1 to Bit 1 of DDRJ.

  * Next, write a 0 to Bit 1 of PTJ.

- Bits 3-0 of PTP are used to enable the four seven-segment LEDs.

- To use the seven-segment LEDs, first write 1's to Bits 3-0 of DDRP to make Bits 3-0 of PTP outputs.

  * A low PTP0 enables the left-most (Digit 3) seven-segment LED

  * A low PTP1 enables the second from the left (Digit 2) seven-segment LED

  * A low PTP2 enables the third from the left (Digit 1) seven-segment LED

  * A low PTP3 enables the right-most (Digit 0) seven-segment LED

– To use the eight individual LEDs and turn off the seven-segment LEDs, write ones to Bits 3-0 of PTP, and write a 0 to Bit 1 of PTJ:

```
BSET DDRP,#$0F     ; Make PTP3 through PTP0 outputs
BSET PTP,#$0F      ; Turn off seven-segment LEDs
BSET DDRJ,#$02     ; Make PTJ1 output
BSET PTJ,#$02      ; Turn on individual LEDs
```

• On the DRAGON12-Plus EVB, the LCD display is connected to PTK

• When you power up or reset the MC9S12, PORTA, PORTB, PTJ and PTP are input ports(!).

• You can make any or all bits of PORTA, PORTB PTP and PTJ outputs by writing a 1 to the corresponding bits of their *Data Direction Registers (DDRs)*.

– You can use DBug-12 to manipulate the IO ports on the 68HCS12

* To make PTB an output, use MM to change the contents of address $0003 (DDRB) to an $FF.

* You can now use MM to change contents of address $0001 (PORTB), which changes the logic levels on the PORTB pins.

* If the data direction register makes the port an input, you can use MD to display the values on the external pins.

Using Port A of the 68HC12

To make a bit of Port A an **output** port, write a 1 to the corresponding bit of DDRA (address 0x0002).

To make a bit of Port A an **input** port, write a 0 to the corresponding bit of DDRA.

On reset, DDRA is set to $00, so Port A is an input port(!).

	DDRA7	DDRA6	DDRA5	DDRA4	DDRA3	DDRA2	DDRA1	DDRA0	
Reset	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**$0002**

For example, to make bits 3−0 of Port A inputs, and bits 7 – 4 outputs, write a *0xF0* to DDRA.

To send data to the output pins, write to PORTA (address 0x0000). When you read from PORTA input pins will return the value of the signals on them ($0 \Rightarrow 0V$, $1 \Rightarrow 5V$); output pins will return the value written to them.

	PA7	PA6	PA5	PA4	PA3	PA2	PA1	PA0	
Reset	-	-	-	-	-	-	-	-	**$0000**

Port B works the same, except DDRB is at address 0x0003 and PORTB is at address 0x0001.

```
;A simple program to make PORTA output and PORTB
; input, then read the signals on PORTB and write these
; values out to PORTA

prog:       equ  $2000

PORTA:      equ  $00
PORTB:      equ  $01
DDRA:       equ  $02
DDRB:       equ  $03

            org   prog
            movb  #$ff,DDRA ; Make PORTA output
            movb  #$00,DDRB ; Make PORTB input

            ldaa  PORTB
            staa  PORTA
            swi
```

- Because DDRA and DDRB are in consecutive address locations you could make PORTA an output and PORTB and input in one instruction:

```
movw  #$ff00,DDRA ; FF -> DDRA, 00 -> DDRB
```

GOOD PROGRAMMING STYLE

1. Make programs easy to read and understand.

   - Use comments

   - Do not use tricks

2. Make programs easy to modify

   - Top-down design

   - Structured programming – no spaghetti code

   - Self contained subroutines

3. Keep programs short BUT do not sacrifice items 1 and 2 to do so

TIPS FOR WRITING PROGRAMS

1. Think about how data will be stored in memory.

- Draw a picture

2. Think about how to process data

- Draw a flowchart

3. Start with big picture. Break into smaller parts until reduced to individual instructions

- Top-down design

4. Use names instead of numbers

Another Example of an Assembly Language Program

• Find the average of the numbers in an array of data.

• The numbers are 8-bit unsigned numbers.

• The address of the first number is $E000 and the address of the final number is $E01F. There are 32 numbers.

• Save the result in a variable called *answer* at address $1000.

Start by drawing a picture of the data structure in memory:

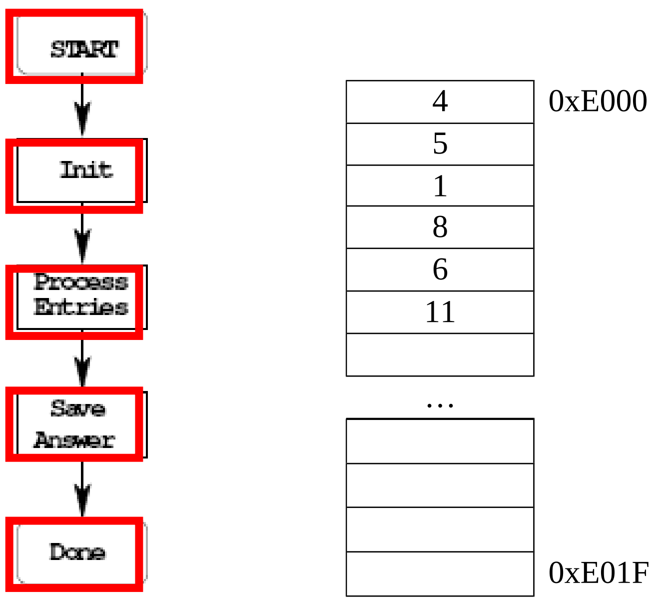
FIND AVERAGE OF NUMBERS IN ARRAY FROM 0XE000 TO 0XE01F

<u>Treat numbers as 8−bit unsigned numbers</u>

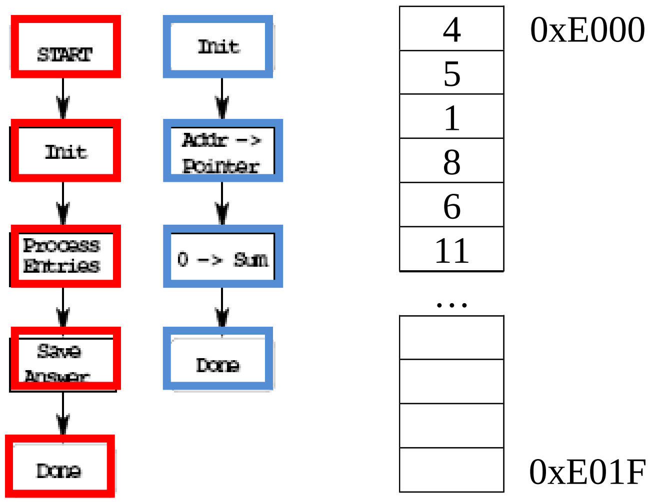
4	0xE000
5	
1	
8	
6	
11	
…	
	0xE01F

Start with the big picture

Find average of 8-bit numbers in array from 0xE000 to 0xE01F



Add details to blocks



Decide on how to use CPU registers for processing data

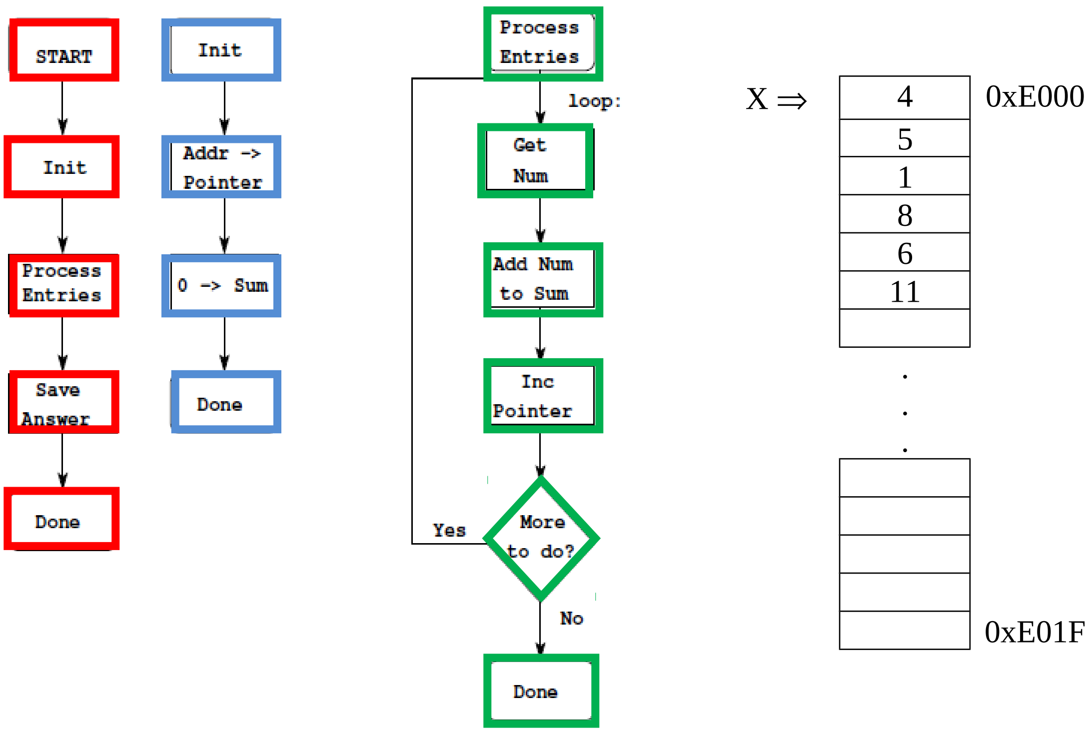
Find average of 8-bit numbers in array from 0xE000 to 0xE01f

Sum: 16−bit register. Can use D or Y

No way to add 8−bit number to D

Can use ABY to add 8−bit number to Y: (B)+(Y) ⇒ Y

Add more details: Expand another block



More details: How to tell when program reaches end of array

How to check if more to do?
If X < 0xE020, more to do.

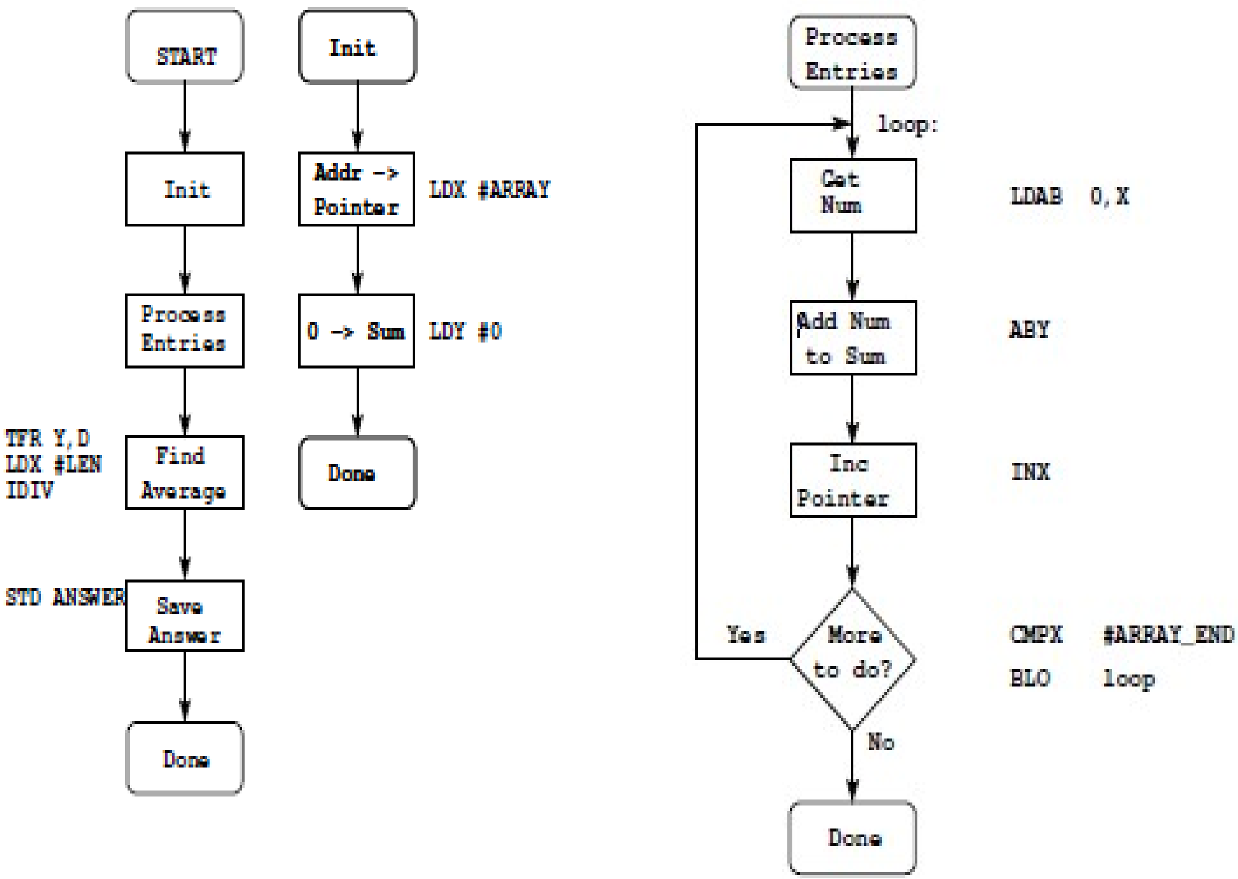
BLT or BLO; Addresses are unsigned, so BLO

How to find average? Divide by LEN

To divide, use IDIV

```
TFR Y,D        ; transfer Y to D
LDX #LEN       ; load divisor in X
IDIV
```

Convert blocks to assembly code



X ⇒	4	0xE000	**ARRAY**
	5		
	1		
	8		
	6		
	11		
	…		
		0xE01F	**ARRAY_END**

Write program

```
;Program to average 32 numbers in a memory array

prog:   equ $2000
data:   equ $1000

array: equ $E000
len:    equ 32

        org  prog
        ldx  #array        ; initialize pointer
        ldy  #0            ; initialize sum to 0
loop:   ldab 0,x           ; get number
        aby                ; add to sum
        inx                ; point to next entry
        cpx  #(array+len)  ; more to process?
        blo  loop          ; if so, process
        tfr  y,d           ; to divide, need dividend in D
        ldx  #len          ; to divide, need divisor in X
        idiv               ; D/X quotient in x, remainder in D
        stx  answer        ; done – save answer
        swi

        org  data
answer: ds.w 1             ; reserve 16-bit word for answer
```

• Important: Comment program so it is easy to understand.

The assembler output for the above program

```
Freescale HC12-Assembler
(c) Copyright Freescale 1987-2009
Abs.   Rel.   Loc      Obj. code     Source line
----   ----   ----------   ---------       -----------
1      1                             ;Program to average 32 numbers in a memory array
2      2
3      3      0000 2000              prog:   equ    $2000
4      4      0000 1000              data:   equ    $1000
5      5
6      6       0000 E000             array:  equ $E000
7      7      0000 0020              len:    equ 32
8       8
9       9                                    org prog
10     10
11     11     a002000 CEE0 00                ldx #array      ; initialize pointer
12     12     a002003 CD00 00                ldy #0           ; initialize sum to 0
13     13     a002006 E600           loop:   ldab 0,x        ; get number
14     14     a002008 19ED                   aby             ; odd - add to sum
15     15     a00200A 08                     inx             ; point to next entry
16     16     a00200B 8EE0 20                cpx #(array+len)        ; more to process?
17     17     a00200E 25F6                   blo loop                ; if so, process
18     18
19     19     a002010 B764                   tfr y,d         ; To divide, need dividend
 20    20     a002012 CE00 20                ldx #len        ; To divide, need divisor
 21    21      a002015 1810                  idiv            ; D/X quotient in X,
remainder
 22    22     a002017 7E10 00                stx answer      ; done -- save answer
23     23     a00201A 3F                     swi
24     24
25     25                                    org data
26     26     a001000                         answer: ds.w 1 ; reserve 16-bit word for 27
27
28     28
```

Here is the .s19 file:

S11E2000CEE000CD0000E60019ED088EE02025F6B764CE002018107E10003FAB
S9030000FC