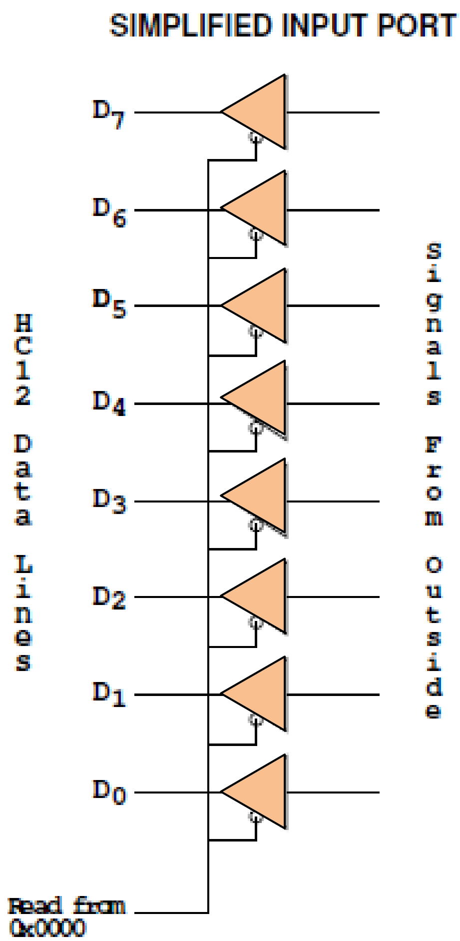
- **More on programming in assembly language**
- **Introduction to Ports on the HC12**
  - Input and Output Ports
    - Simplified input port
    - Simplified output port
    - Simplified input/output port
    - PORTA, PORTB, DDRA, DDRB
    - A simple program to use PORTA and PORTB
  - Good programming style
  - Tips for writing programs
  - A program to average the numbers in a memory array
  - Flow charts
  - Assembly language program
  - Assembly listing file

Input and Output Ports

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

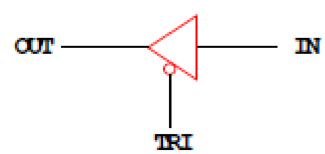


Any read from address $0000 gets signals from outside

LDAA $00

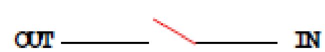
Puts data from outside into accumulator A.

Data from outside looks like a memory location.

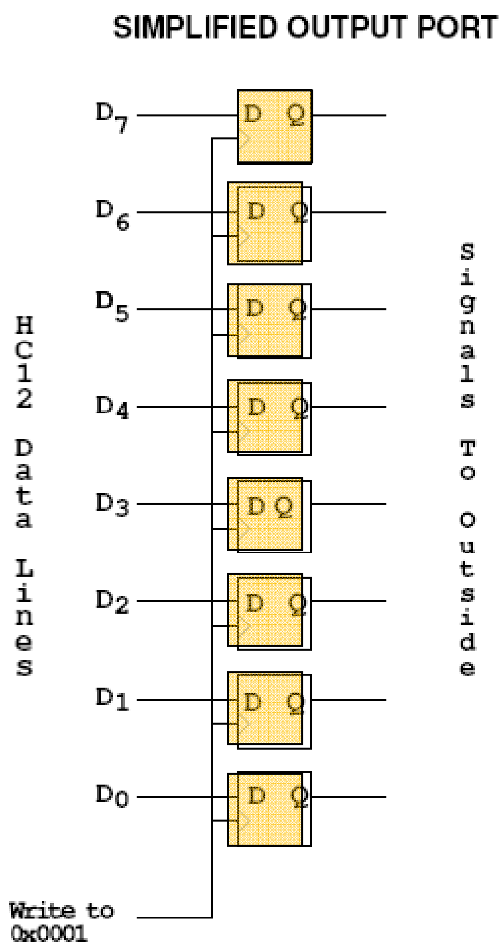


A Tri-State Buffer acts like a switch

If TRI is not active, the switch is open: OUT will not be drived 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

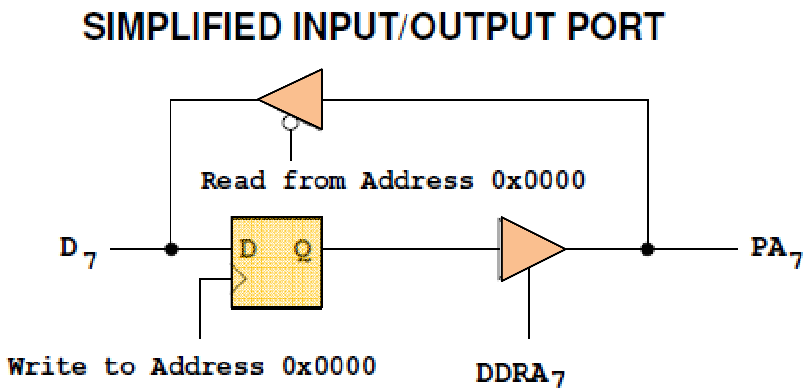
Puts $AA on the external pins

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



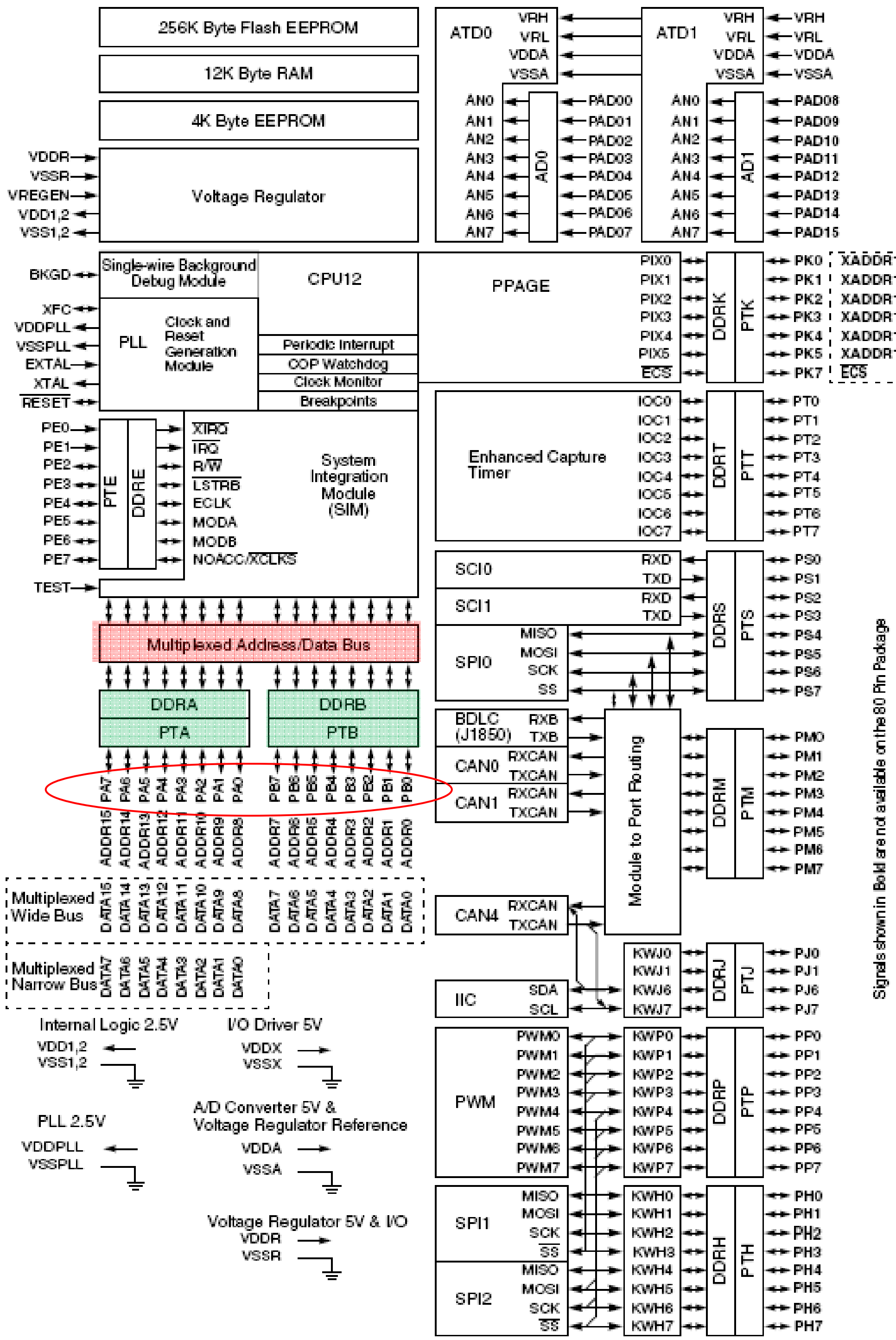
- A write to address 0x0000 writes data to the flip-flop
  A read from address 0x0000 reads data on pin

- If Bit 7 of DDRA is 0, the port is an input port. Data written to FF 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 HC12 is a device that the HC12 uses to control some hardware.

• Many of the HC12 ports are used to communicate with hardware outside of the HC12.

• The HC12 ports are accessed by the HC12 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.

- Bit 1 of PTJ must be low to enable the eight individual LEDs

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

```
BSET #$0F,DDRP    ; Make PTP3 through PTP0 outputs
BSET #$0F,PTP     ; Turn off seven-segment LEDs
```

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

• When you power up or reset the HC12, 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*.

– 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 7–4 output and bits 3–0 of Port A input, 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 ⇒ 0V, 1 ⇒ 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     $1000

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 and 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.

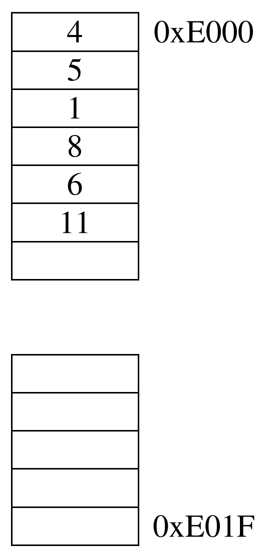
• The numbers are 8-bit unsigned numbers.

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

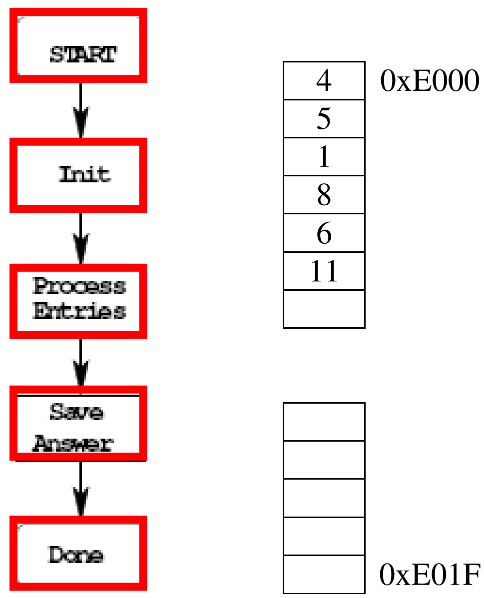
• Save the result in a variable called answer at address $2000.

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

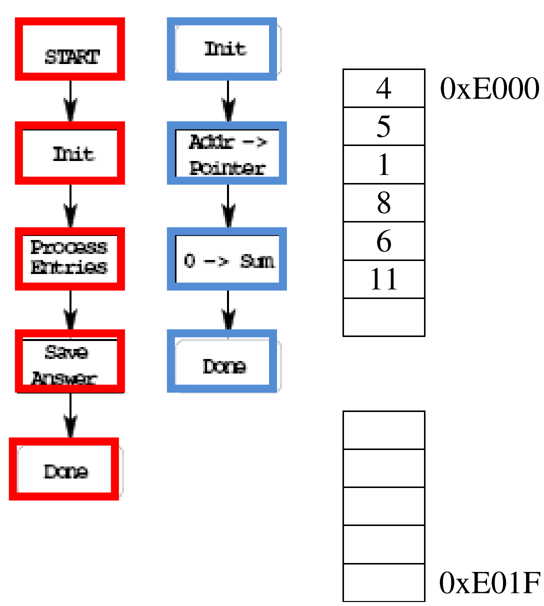
FIND AVERAGE OF NUMBERS IN ARRAY FROM 0XE000 TO 0XE01F
<u>Treat numbers as 8–bit unsigned numbers</u>



Start with the big picture



Add details to blocks



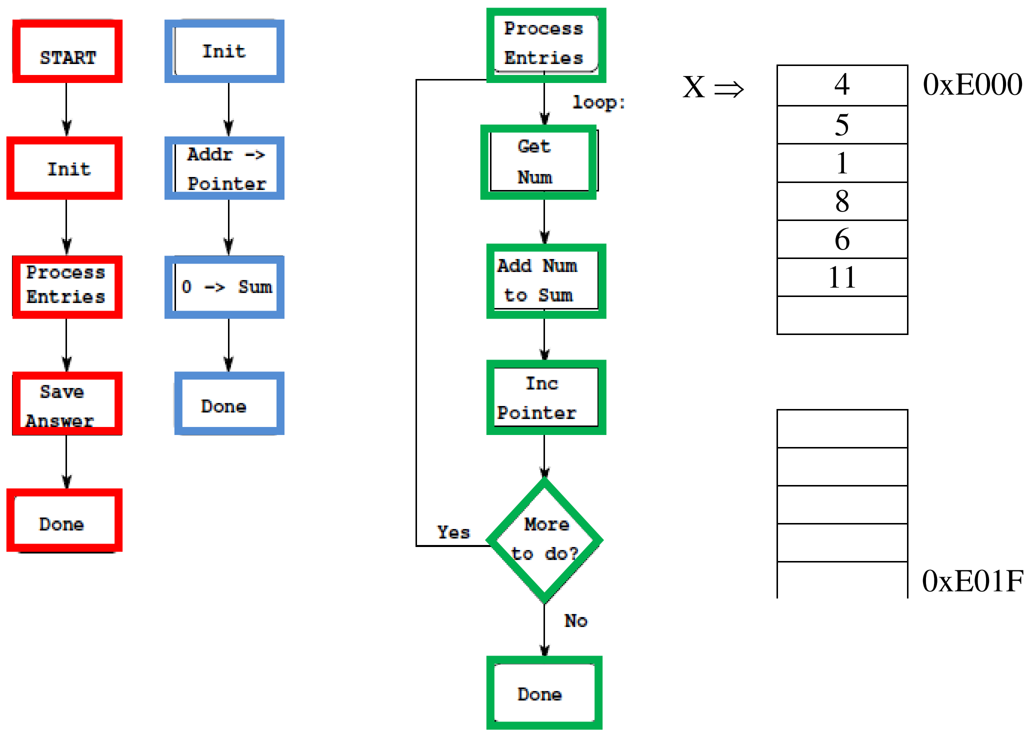
Decide on how to use CPU registers for processing data

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

Add more details: Expand another block



More details: How to tell if number is odd, how to tell when done

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

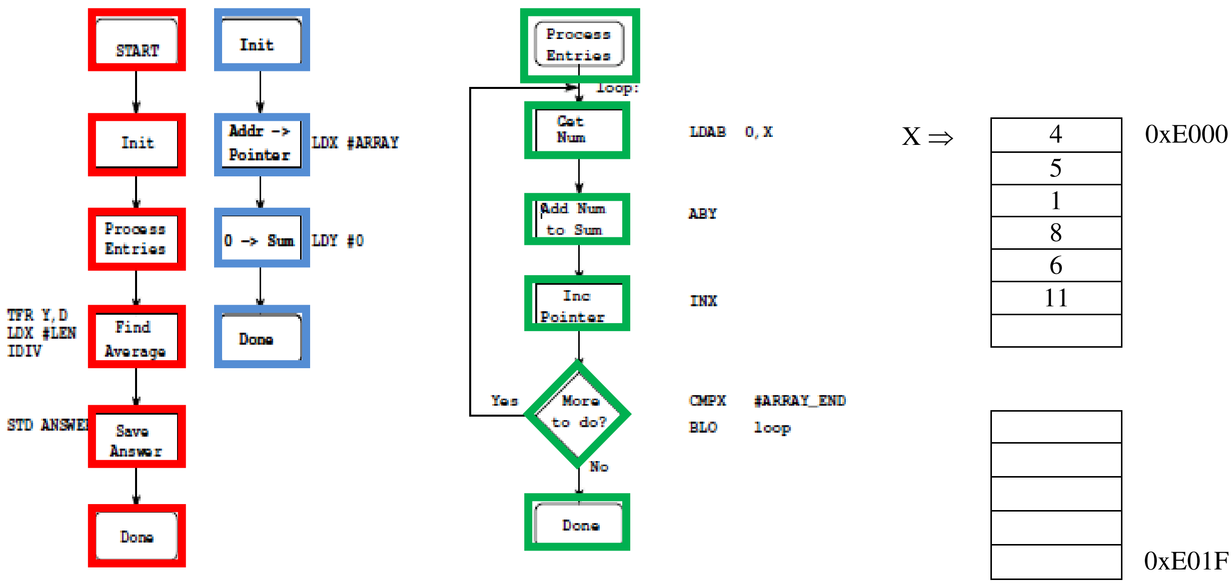
BLT or BLO?

Addresses are unsigned, so BLO

How to find average? Divide by LEN
To divide, use IDIV

```
TFR Y,D      ; divide in D
LDX #LEN     ; divisor in X
IDIV
```

Convert blocks to assembly code



Write program

;Program to average 32 numbers in a memory array

```
prog:   equu    $1000
data:   equ     $2000

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                     ; odd - 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
        idx     #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
```