Display Memory

Chapter 6 – Textbook

Display Memory

- The debugger gives a very close vision of the processor.
- That is why every program written till now was executed inside the debugger.
- Also the debugger is a very useful tool in assembly language program development, since many bugs only become visible when each instruction is independently monitored the way the debugger allows us to do.
- We will now be using the display screen in character mode, the way DOS uses this screen.
- The way we will access this screen is specific to the IBM PC.

ASCII Codes

- The computer listens, sees, and speaks in binary numbers.
- For example the keyboard is labeled with characters however when we press ‘A’, a specific number is transferred from the keyboard to the computer.
- Our program interprets that number as the character ‘A’.
- When the same number comes on display, the Video Graphics Adapter (VGA) in our computer shows the shape of ‘A’.
- Even the shape is stored in binary numbers with a one bit representing a pixel on the screen that is turned on and a zero bit representing a pixel that is not glowing.
    - This example is considering a white on black display and no colors.
- The interpretation of ‘A’ is performed by the VGA card, while the monitor or CRT (cathode ray tube) only glows the pixels on and turns them off.
- The keyboard has a key labeled ‘A’ and pressing it the screen shows ‘A’ but all that happened inside was in numbers.

ASCII Codes

- A standard numeric representation of all commonly used characters has been developed.
- This is called the ASCII code, (American Standard Code for Information Interchange).
    - This is a code that allows the interchange of information; ‘A’ written on one computer will remain an ‘A’ on another.
- The ASCII table lists all defined characters and symbols and their standardized numbers.
- It has become the standard for global communication.
- The *character mode displays* of our computer use the ASCII standard.
- Newer operating systems use the superset Unicode, but it is not relevant to us in the current discussion.

Extended ASCII

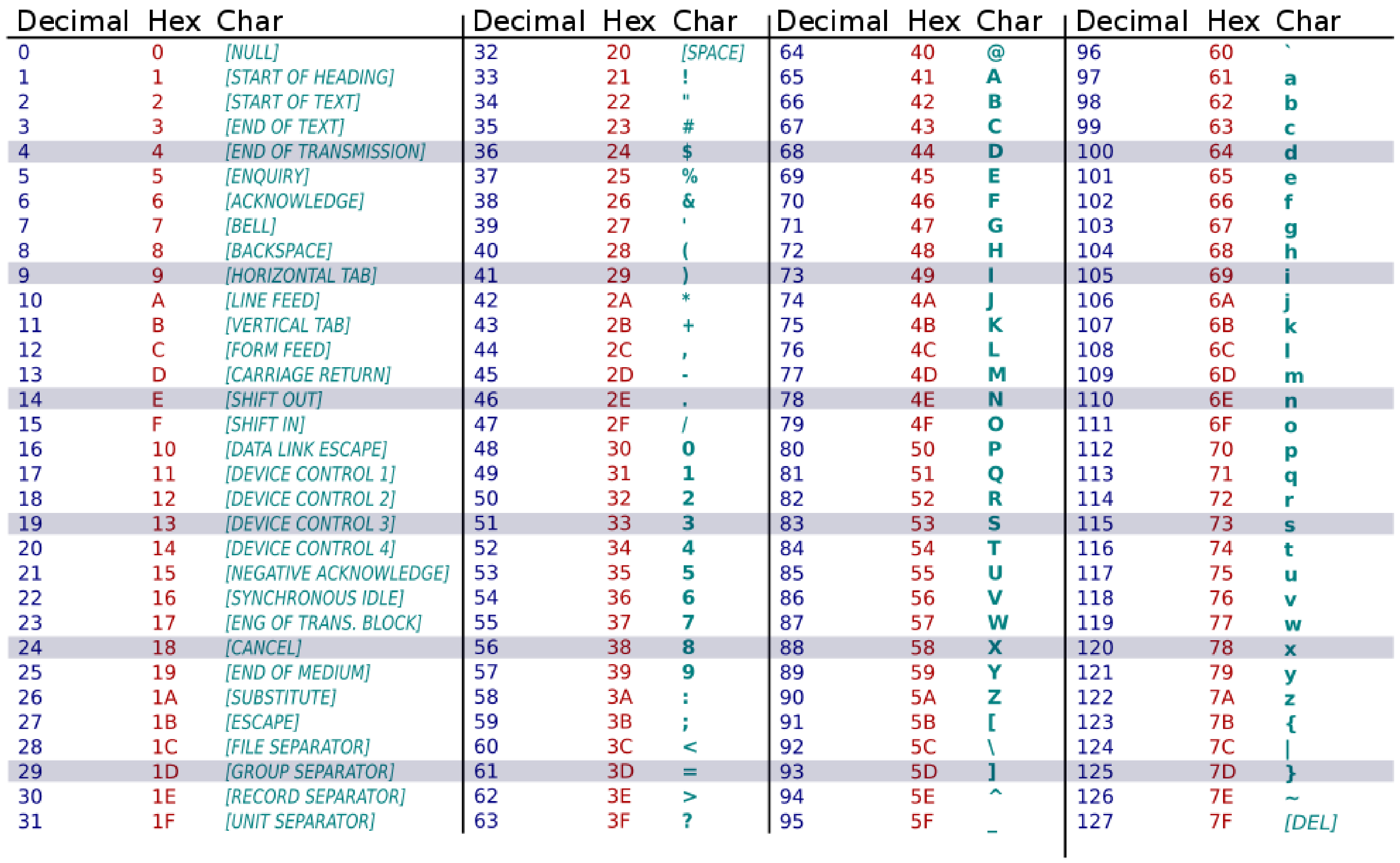
- Standard ASCII has 128 characters with numbers assigned from 0 to 127.
- When IBM PC was introduced, they extended the standard ASCII and defined 128 more characters.
- Thus extending the total number of symbols from 128 to 256 numbered from 0 to 255 fitting in an 8-bit byte.
- The newer characters were used for line drawing, window corners, and some non-English characters.
- The extended ASCII code is just a de facto industry standard but it is not defined by an organization like the standard ASCII.

See Code Page 437 on Wikipedia

ASCII Table

- The important thing to observe in the ASCII table is the contiguous arrangement of the uppercase alphabets (41-5A), the lowercase alphabets (61-7A), and the numbers (30-39).
- This helps in certain operations with ASCII, for example converting the case of characters by adding or subtracting 0x20 from it. It also helps in converting a digit into its ASCII representation by adding 0x30 to it.

ASCII Table



Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char
0	0	[NULL]	32	20	[SPACE]	64	40	@	96	60	`
1	1	[START OF HEADING]	33	21	!	65	41	A	97	61	a
2	2	[START OF TEXT]	34	22	"	66	42	B	98	62	b
3	3	[END OF TEXT]	35	23	#	67	43	C	99	63	c
4	4	[END OF TRANSMISSION]	36	24	$	68	44	D	100	64	d
5	5	[ENQUIRY]	37	25	%	69	45	E	101	65	e
6	6	[ACKNOWLEDGE]	38	26	&	70	46	F	102	66	f
7	7	[BELL]	39	27	'	71	47	G	103	67	g
8	8	[BACKSPACE]	40	28	(	72	48	H	104	68	h
9	9	[HORIZONTAL TAB]	41	29	)	73	49	I	105	69	i
10	A	[LINE FEED]	42	2A	*	74	4A	J	106	6A	j
11	B	[VERTICAL TAB]	43	2B	+	75	4B	K	107	6B	k
12	C	[FORM FEED]	44	2C	,	76	4C	L	108	6C	l
13	D	[CARRIAGE RETURN]	45	2D	-	77	4D	M	109	6D	m
14	E	[SHIFT OUT]	46	2E	.	78	4E	N	110	6E	n
15	F	[SHIFT IN]	47	2F	/	79	4F	O	111	6F	o
16	10	[DATA LINK ESCAPE]	48	30	0	80	50	P	112	70	p
17	11	[DEVICE CONTROL 1]	49	31	1	81	51	Q	113	71	q
18	12	[DEVICE CONTROL 2]	50	32	2	82	52	R	114	72	r
19	13	[DEVICE CONTROL 3]	51	33	3	83	53	S	115	73	s
20	14	[DEVICE CONTROL 4]	52	34	4	84	54	T	116	74	t
21	15	[NEGATIVE ACKNOWLEDGE]	53	35	5	85	55	U	117	75	u
22	16	[SYNCHRONOUS IDLE]	54	36	6	86	56	V	118	76	v
23	17	[ENG OF TRANS. BLOCK]	55	37	7	87	57	W	119	77	w
24	18	[CANCEL]	56	38	8	88	58	X	120	78	x
25	19	[END OF MEDIUM]	57	39	9	89	59	Y	121	79	y
26	1A	[SUBSTITUTE]	58	3A	:	90	5A	Z	122	7A	z
27	1B	[ESCAPE]	59	3B	;	91	5B	[	123	7B	{
28	1C	[FILE SEPARATOR]	60	3C	<	92	5C	\	124	7C	|
29	1D	[GROUP SEPARATOR]	61	3D	=	93	5D	]	125	7D	}
30	1E	[RECORD SEPARATOR]	62	3E	>	94	5E	^	126	7E	~
31	1F	[UNIT SEPARATOR]	63	3F	?	95	5F	_	127	7F	[DEL]

Display Memory Formation

- We will explore the working of the display with ASCII codes, since it is our immediately accessible hardware.
- When 0x41 is sent to the VGA card, it will turn pixels on and off in such a way that a visual representation of ‘A’ appears on the screen. It has no reality, just an interpretation.
- The video device is seen by the computer as a memory area containing the ASCII codes that are currently displayed on the screen and a set of I/O ports controlling things like the resolution, the cursor height, and the cursor position.
- The VGA memory is seen by the computer just like its own memory. There is no difference; rather the computer doesn’t differentiate, as it is accessible on the same bus as the system memory.
- Therefore if that appropriate block of the memory is cleared, the screen will be cleared.
- If the ASCII of ‘A’ is placed somewhere in that block, the shape of ‘A’ will appear on the screen at a corresponding place.

Display Memory Formation

- The screen is two dimensional having 80 rows and 25 columns.
- But memory is a single dimensional space. It should be linearly mapped to 2D screen space
- There is one word per character in which a byte is needed for the ASCII code and the other byte is used for the character's attributes discussed later. Now the first 80 words will correspond to the first row of the screen and the next 80 words will correspond to the next row.
- By making the memory on the video controller accessible to the processor via the system bus, the processor is now in control of what is displayed on the screen.
- The three important things that we discussed are
  - One screen location corresponds to a word in the video memory
  - The video controller memory is accessible to the processor like its own memory.
  - ASCII code of a character placed at a cell in the VGA memory will cause the corresponding ASCII shape to be displayed on the corresponding screen location.

Display Memory Base Address

- The memory at which the video controller's memory is mapped must be a standard, so that the program can be written in a video card independent manner.
- The IBM PC text mode color display is fixed so that system software can work uniformly. It was fixed at the physical memory location of B8000.
- The first byte at this location contains the ASCII for the character displayed at the top left of the video screen.
- Dropping the zero we can load the rest (B800) in a segment register to access the video memory.
- If we do something in this memory, the effect can be seen on the screen. For example we can write a virus that makes any character we write drop to the bottom of the screen.

Display Memory

← 80 Columns →

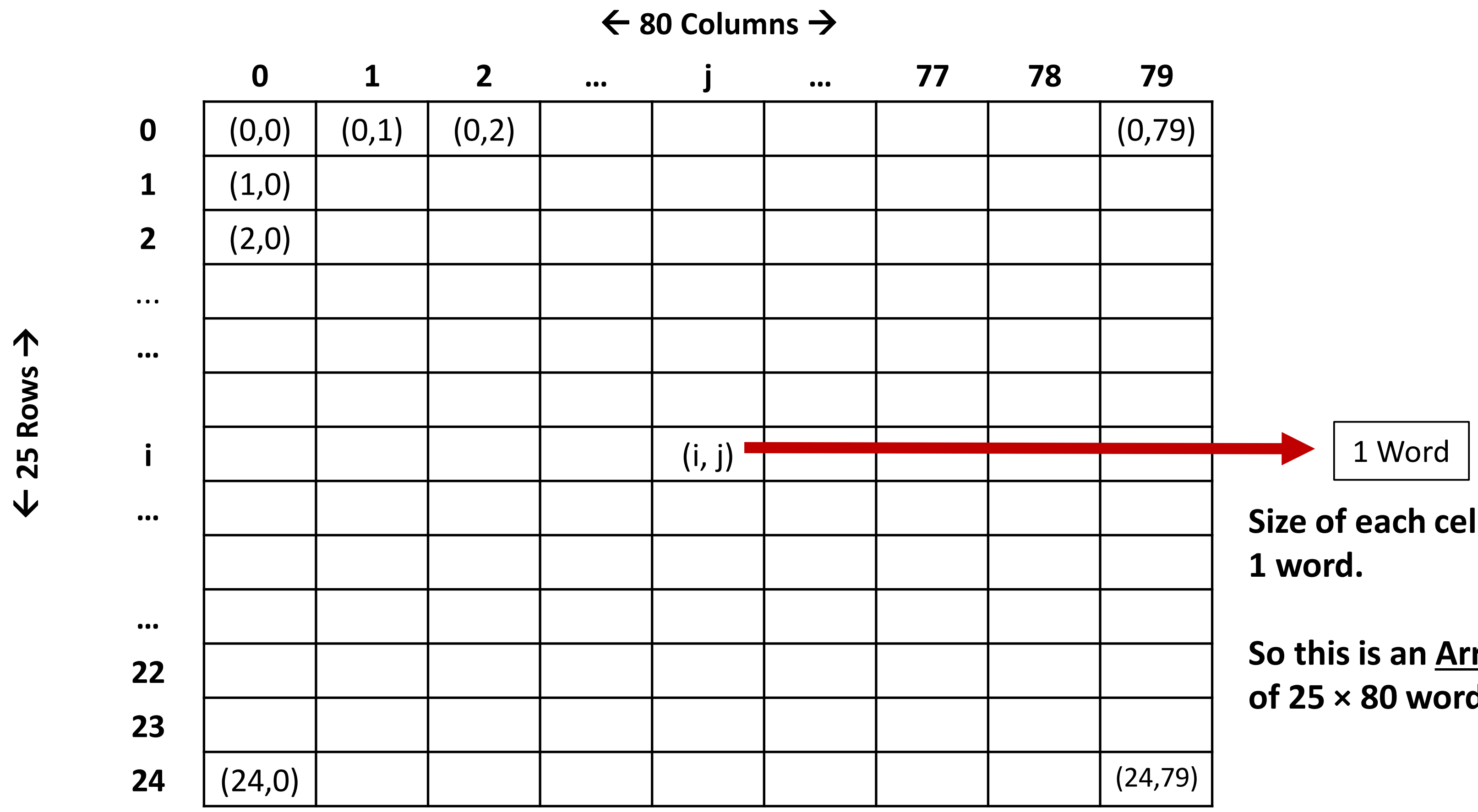
← 25 Rows →

	0	**1**	**2**	**…**	**j**	**…**	**77**	**78**	**79**
0	(0,0)	(0,1)	(0,2)						(0,79)
1	(1,0)								
2	(2,0)								
…									
…									
i					(i, j)				
…									
…									
22									
23									
24	(24,0)								(24,79)

Display Memory is a 2-D array of 25×80 Cells.

We can write one character in each cell.

Display Memory

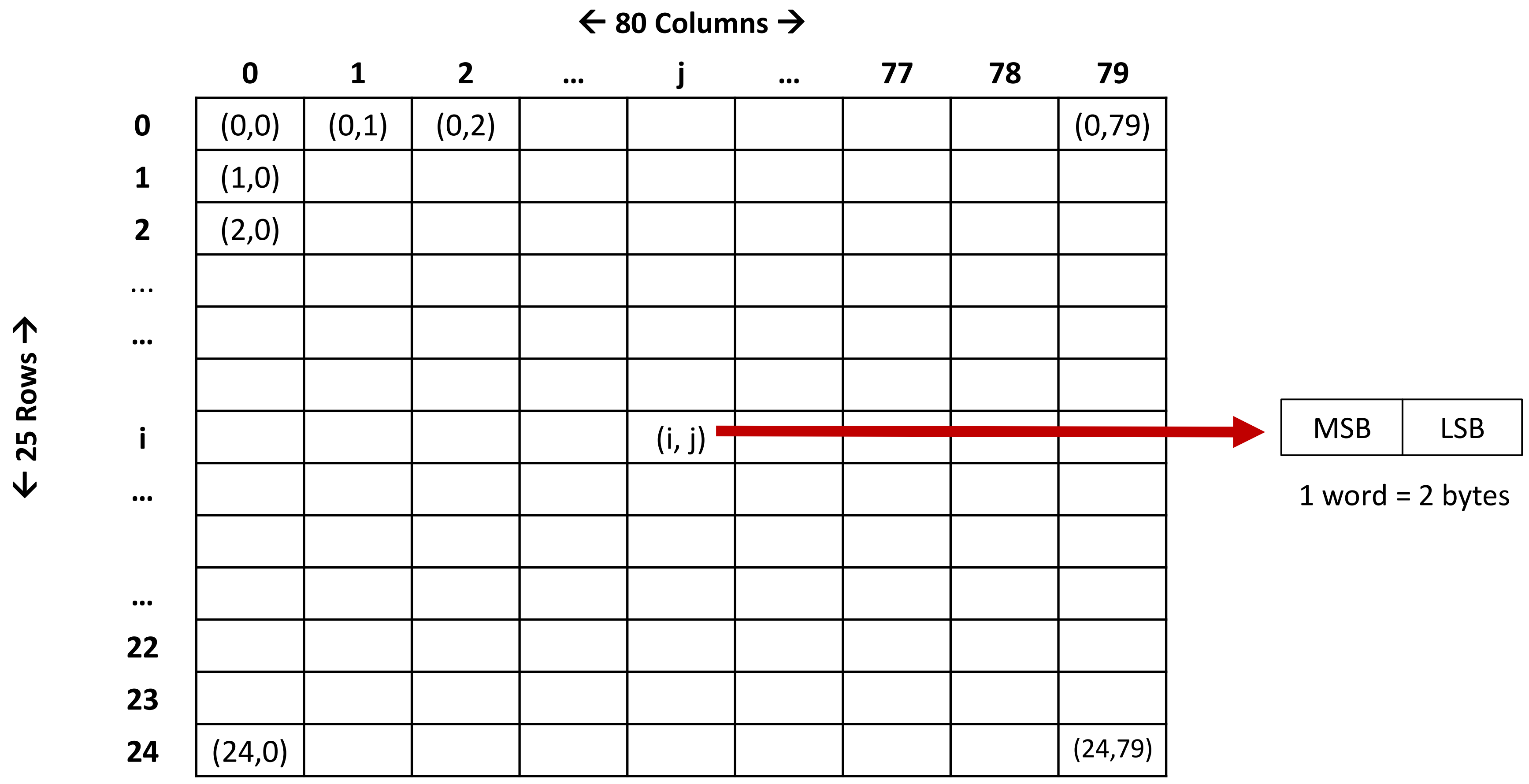


Size of each cell is 1 word.

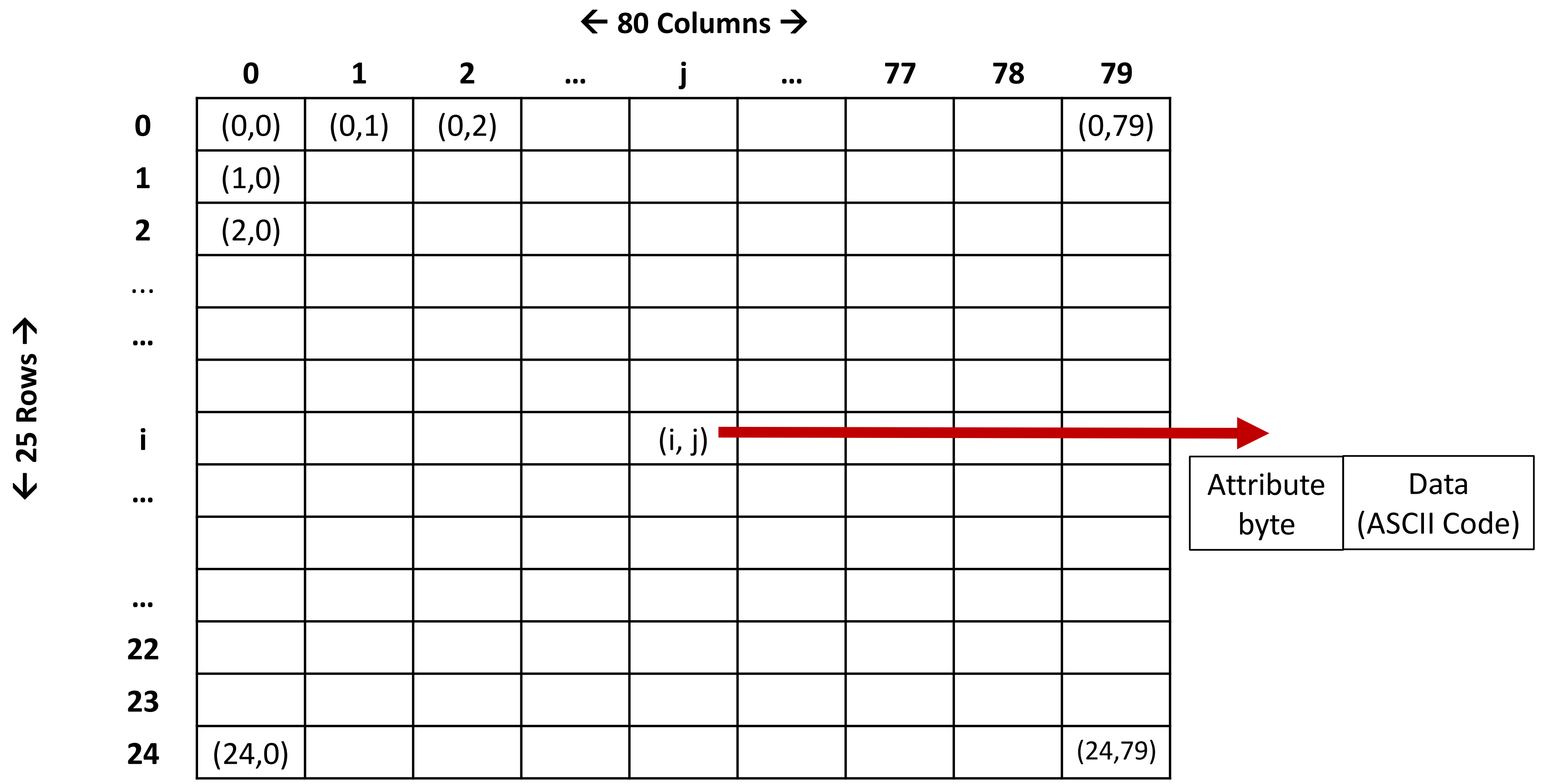
So this is an <u>Array</u> of 25 × 80 words

How much maximum space we need to save a character?

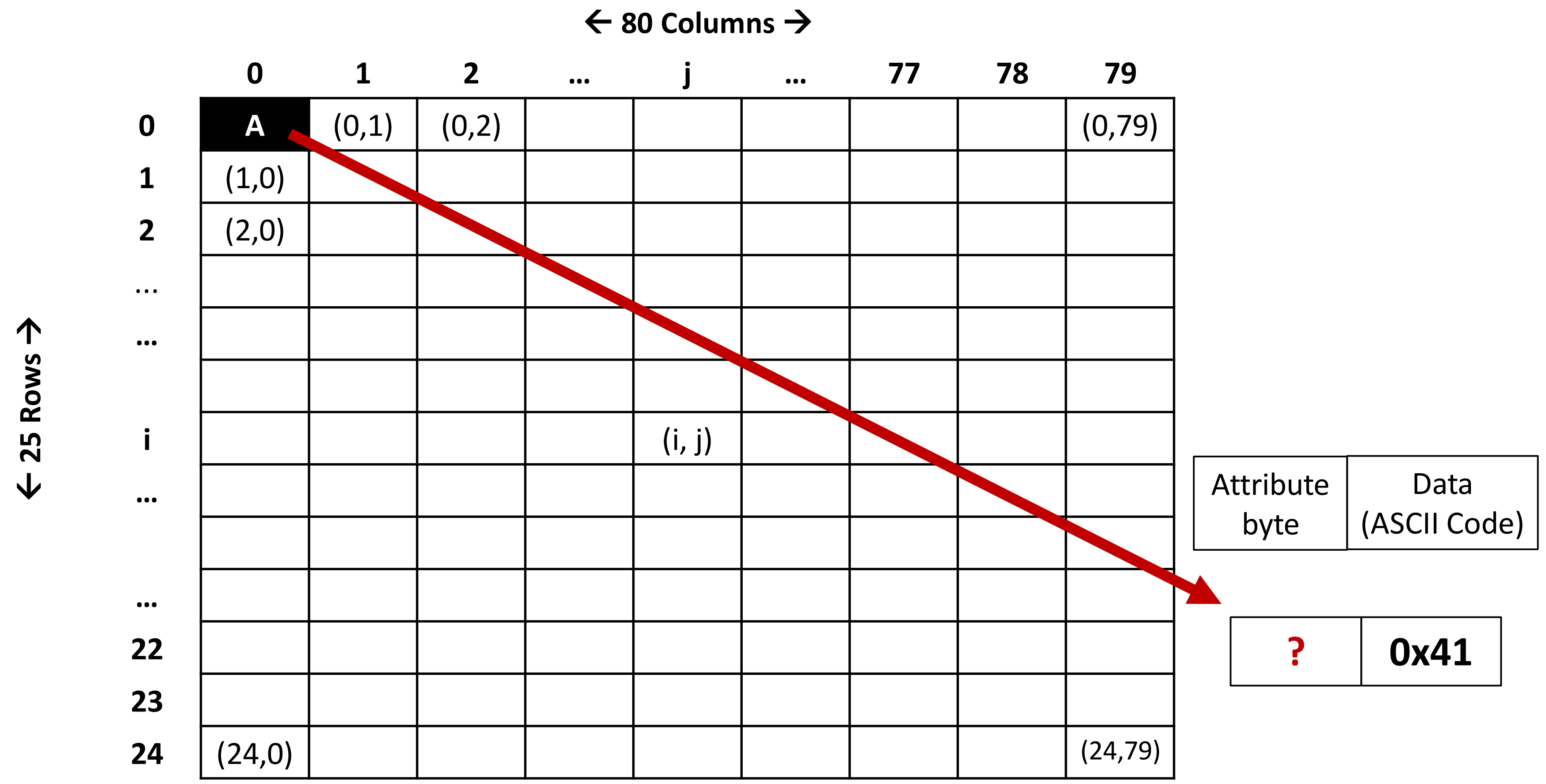
Display Memory



Display Memory



Display Memory



Display Memory

← 80 Columns →

← 25 Rows →

	0	1	2	…	j	…	77	78	79
0	B8000	B8002	B8004						X
1	X+2	X+4	X+6						X+160
2									
…									
…									
i									
…									
…									
22									
23									
24	(24,0)								(24,79)

Display Memory region starts at Physical Address 0xB8000.

Everything that you write at this memory will be visible on screen.

Display Memory

Note the last zero digit dropped. Why?

← 80 Columns →

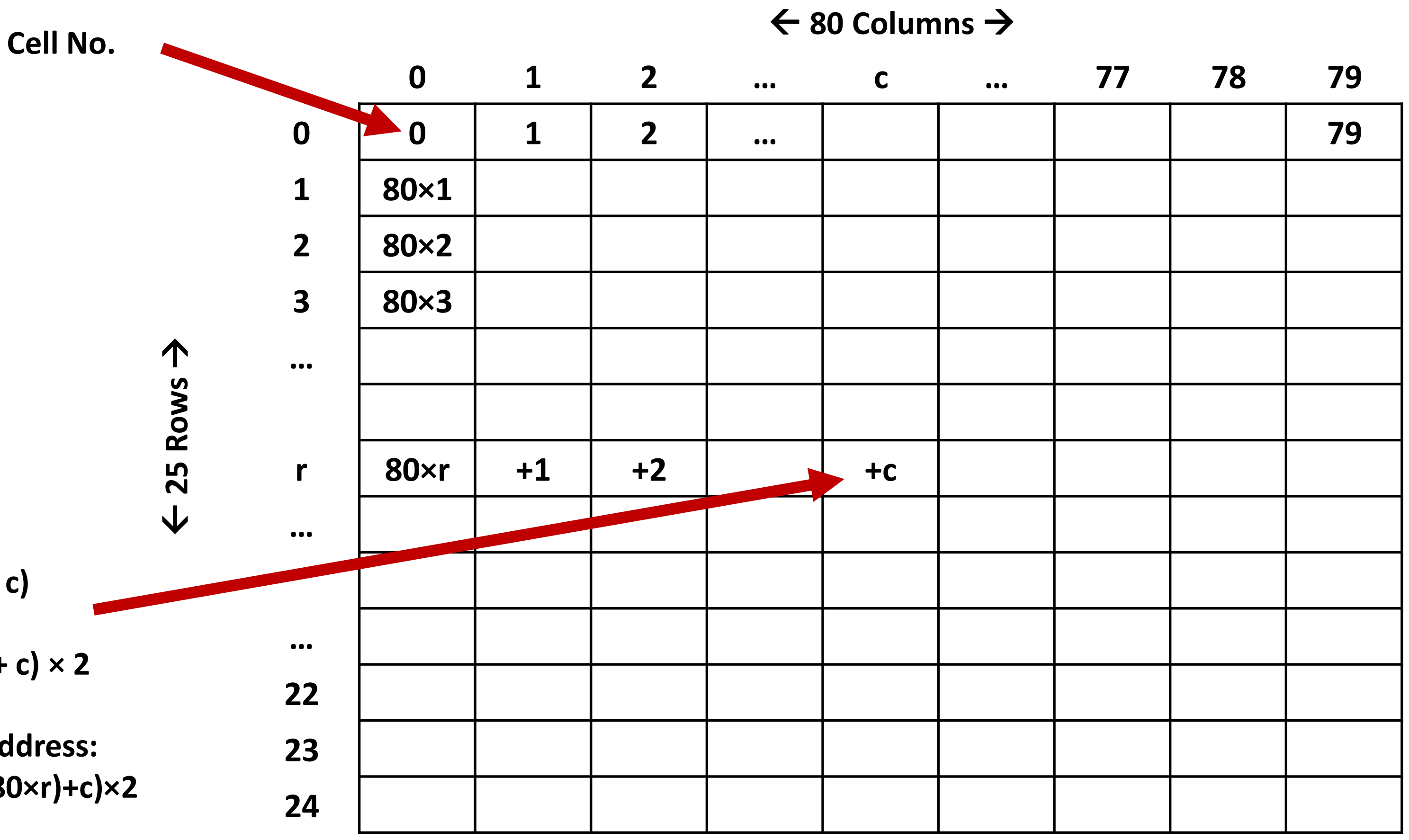
← 25 Rows →

	0	1	2	…	j	…	77	78	79
0	0	2	4						158
1	160	162	164						318
2	320								
…									
…									
i									
…									
…									
22									
23									
24									3998

Note: offsets are written in decimal (not hex) for ease of understanding

Put 0xB800 into a segment register, and we can refer to each cell by just an offset.

Desired Screen Location (row, column)



Cell no.
(80 × r) + c)
Byte no.
((80 × r) + c) × 2

Logical Address:
B800 : ((80×r)+c)×2

Attribute Byte

The second byte in the word designated for one screen location holds the foreground and background colors for the character. This is called its video attribute. So the pair of the ASCII code in one byte and the attribute in the second byte makes the word that corresponds to one location on the screen. The lower address contains the code while the higher one contains the attribute. The attribute byte as detailed below has the RGB for the foreground and the background. It has an intensity bit for the foreground color as well thus making 16 possible colors of the foreground and 8 possible colors for the background. When bit 7 is set the character keeps on blinking on the screen. This bit has some more interpretations like background intensity that has to be activated in the video controller through its I/O ports.

7	6	5	4	3	2	1	0

7 – Blinking of foreground character
6 – Red component of background color
5 – Green component of background color
4 – Blue component of background color
3 – Intensity component of foreground color
2 – Red component of foreground color
1 – Green component of foreground color
0 – Blue component of foreground color

Attribute Byte

	Background			Foreground			
Blink	**R**	**G**	**B**	**Intensity**	**R**	**G**	**B**

A

	Background			Foreground			
Blink	**R**	**G**	**B**	**Intensity**	**R**	**G**	**B**
0	**0**	**0**	**0**	**0**	**1**	**1**	**1**

Possible Colors

Foreground

0000	Black	1000	Grey
0001	Blue	1001	Light Blue
0010	Green	1010	Light Green
0100	Red	1100	Light Red
0011	Cyan	1011	Light Cyan
0101	Magenta	1101	Light Magenta
0110	Brown	1110	Yellow
0111	White	1111	"Bright" White

Background

000	Black
001	Blue
010	Green
100	Red
011	Cyan
101	Magenta
110	Brown
111	Grey

Display Examples

Both DS and ES can be used to access the video memory. However we commonly keep DS for accessing our data, and load ES with the segment of video memory. Loading a segment register with an immediate operand is not allowed in the 8088 architecture. We therefore load the segment register via a general purpose register. Other methods are loading from a memory location and a combination of push and pop.

```
        mov  ax, 0xb800
        mov  es, ax
```

This operation has opened a window to the video memory. Now the following instruction will print an 'A' on the top left of the screen in white color on black background.

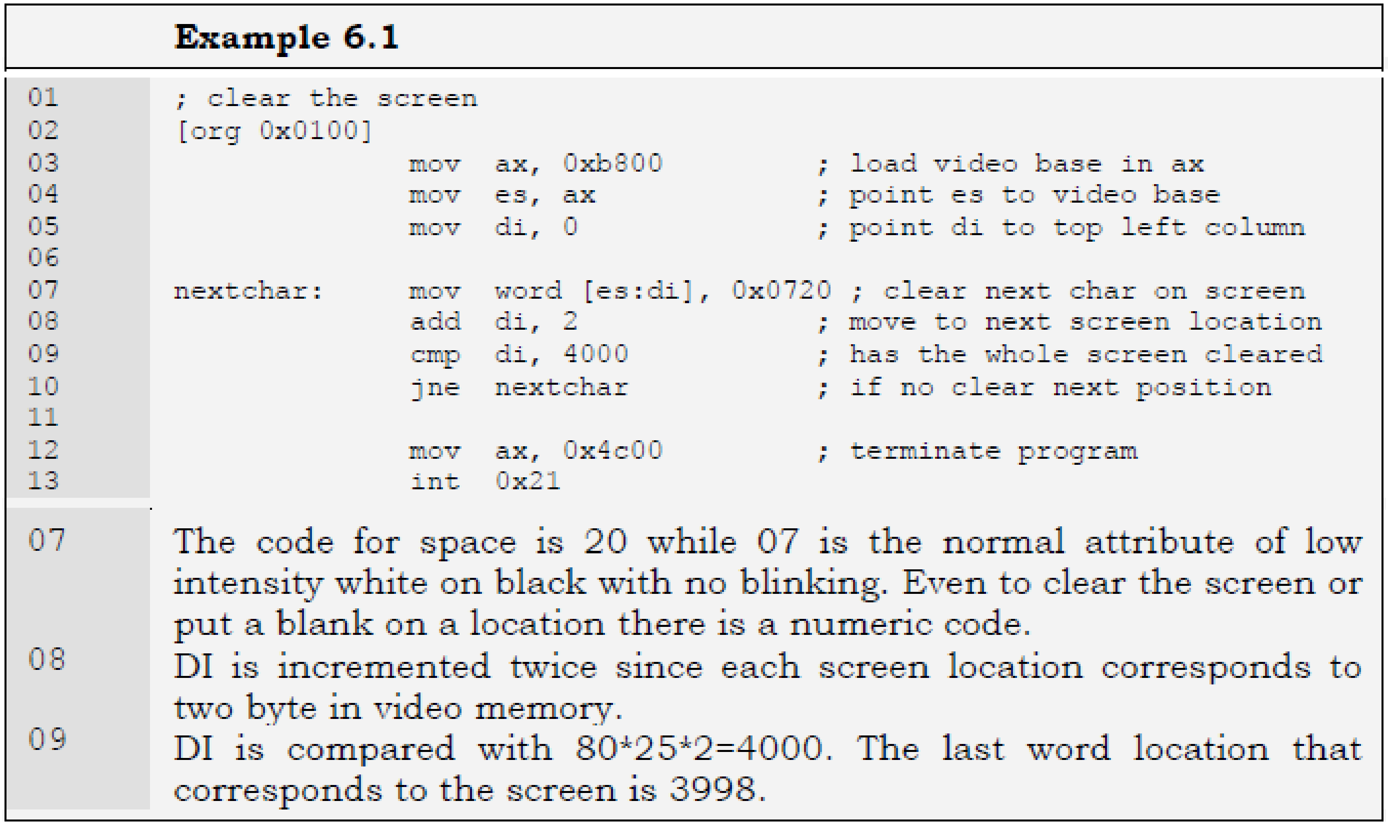
```
        mov  word [es:0], 0x0741
```

The segment override is used since ES is pointing to the video memory. Since the first word is written to, the character will appear at the top left of the screen. The 41 that goes in the lower byte is the ASCII code for 'A'. The 07 that goes in the higher byte is the attribute with I=0, R=1, G=1, B=1 for the foreground, meaning white color in low intensity and R=0, G=0, B=0 for the background meaning black color and the most significant bit cleared so that there is no blinking. Now consider the following instruction.

```
        mov  word [es:160], 0x1230
```

This is displayed 80 words after the start and there are 80 characters in one screen row. Therefore this is displayed on the first column of the second line. The ASCII code used is 30, which represents a '0' while the attribute byte is 12 meaning green color on blue background.

Clear the whole screen



Example 6.1

```
01  ; clear the screen
02  [org 0x0100]
03                mov  ax, 0xb800         ; load video base in ax
04                mov  es, ax             ; point es to video base
05                mov  di, 0              ; point di to top left column
06
07  nextchar:     mov  word [es:di], 0x0720 ; clear next char on screen
08                add  di, 2              ; move to next screen location
09                cmp  di, 4000           ; has the whole screen cleared
10                jne  nextchar           ; if no clear next position
11
12                mov  ax, 0x4c00         ; terminate program
13                int  0x21
```

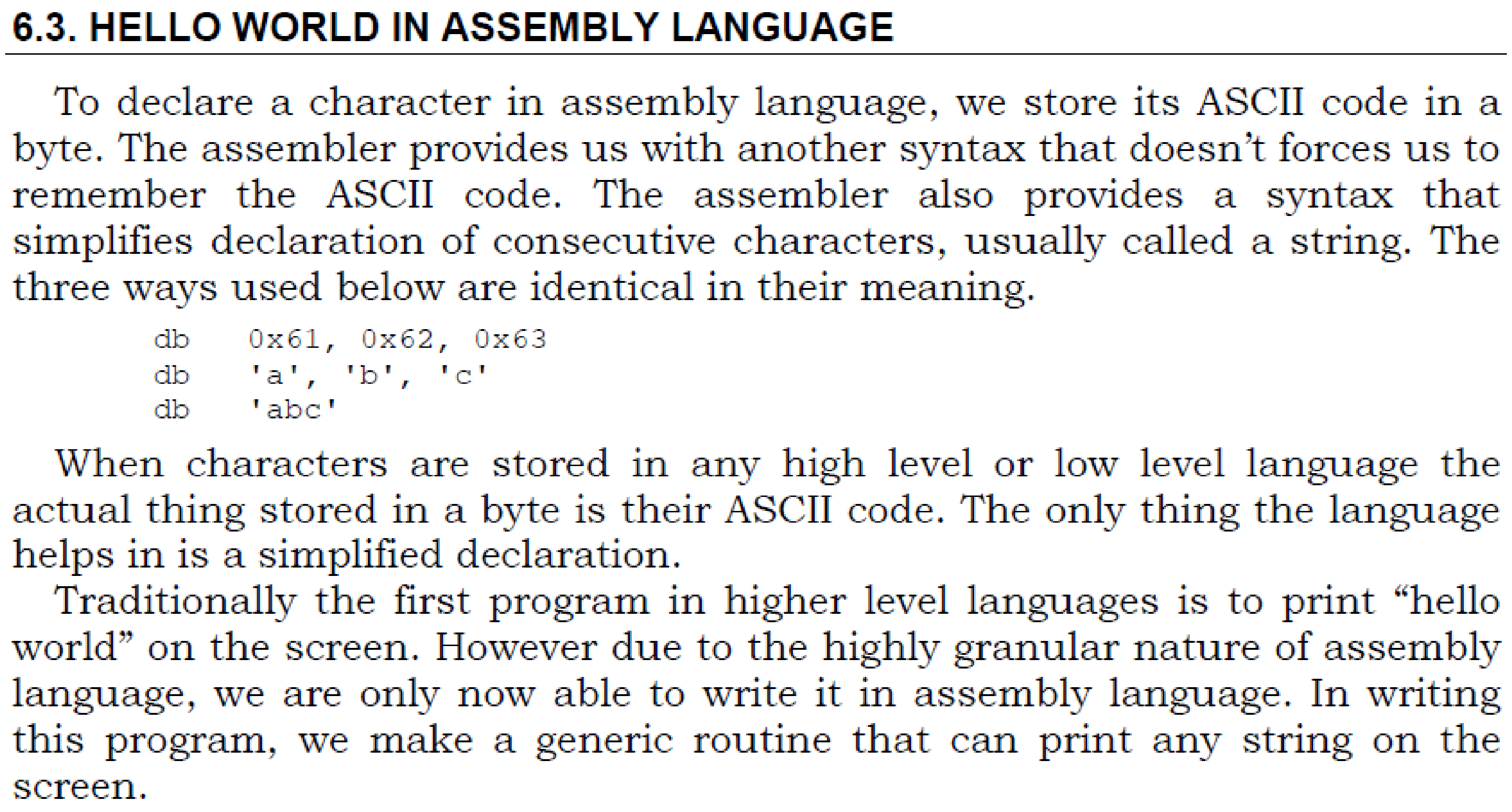
07 The code for space is 20 while 07 is the normal attribute of low intensity white on black with no blinking. Even to clear the screen or put a blank on a location there is a numeric code.

08 DI is incremented twice since each screen location corresponds to two byte in video memory.

09 DI is compared with 80*25*2=4000. The last word location that corresponds to the screen is 3998.

Inside the debugger the operation of clearing the screen cannot be observed since the debugger overwrites whatever is displayed on the screen. Directly executing the COM file from the command prompt*, we can see that the screen is cleared. The command prompt that reappeared is printed after the termination of our application. This is the first application that can be directly executed to see some output on the screen.

Hello World



6.3. HELLO WORLD IN ASSEMBLY LANGUAGE

To declare a character in assembly language, we store its ASCII code in a byte. The assembler provides us with another syntax that doesn't forces us to remember the ASCII code. The assembler also provides a syntax that simplifies declaration of consecutive characters, usually called a string. The three ways used below are identical in their meaning.

```
db    0x61, 0x62, 0x63
db    'a', 'b', 'c'
db    'abc'
```

When characters are stored in any high level or low level language the actual thing stored in a byte is their ASCII code. The only thing the language helps in is a simplified declaration.

Traditionally the first program in higher level languages is to print “hello world” on the screen. However due to the highly granular nature of assembly language, we are only now able to write it in assembly language. In writing this program, we make a generic routine that can print any string on the screen.

Example 6.2

```
; hello world in assembly
[org 0x0100]
              jmp  start

message:      db   'hello world'       ; string to be printed
length:       dw   11                  ; length of the string

; subroutine to clear the screen
clrscr:       push es
              push ax
              push di

              mov  ax, 0xb800
              mov  es, ax              ; point es to video base
              mov  di, 0               ; point di to top left column

nextloc:      mov  word [es:di], 0x0720 ; clear next char on screen
              add  di, 2               ; move to next screen location
              cmp  di, 4000            ; has the whole screen cleared
              jne  nextloc             ; if no clear next position

              pop  di
              pop  ax
              pop  es
              ret

```

```
; subroutine to print a string at top left of screen
; takes address of string and its length as parameters
printstr:      push bp
               mov  bp, sp
               push es
               push ax
               push cx
               push si
               push di

               mov  ax, 0xb800
               mov  es, ax              ; point es to video base
               mov  di, 0               ; point di to top left column
               mov  si, [bp+6]          ; point si to string
               mov  cx, [bp+4]          ; load length of string in cx
               mov  ah, 0x07            ; normal attribute fixed in al

nextchar:      mov  al, [si]            ; load next char of string
               mov  [es:di], ax         ; show this char on screen
               add  di, 2               ; move to next screen location
               add  si, 1               ; move to next char in string
               loop nextchar            ; repeat the operation cx times

               pop  di
               pop  si
               pop  cx
               pop  ax
               pop  es
               pop  bp
               ret  4

start:         call clrscr              ; call the clrscr subroutine

               mov  ax, message
               push ax                  ; push address of message
               push word [length]       ; push message length
               call printstr            ; call the printstr subroutine

               mov  ax, 0x4c00          ; terminate program
               int  0x21
```

05-06	The string definition syntax discussed above is used to declare a string “hello world” of 11 bytes and the length is stored in a separate variable.
09-25	The code to clear the screen from the last example is written in the form of a subroutine. Since the subroutine had no parameters, only modified registers are saved and restored from the stack.
29-35	The standard subroutine format with parameters received via stack and all registers saved and restored is used.
37-42	ES is initialized to point to the video memory via the AX register. Two pointer registers are used; SI to point to the string and DI to point to the top left location of the screen. CX is loaded with the length of the string. Normal attribute of low intensity white on black with no blinking is loaded in the AH register.
44-45	The next character from the string is loaded into AL. Now AH holds the attribute and AL the ASCII code of the character. This pair is written on the video memory using DI with the segment override prefix for ES to access the video memory segment.
46-47	The string pointer is incremented by one while the video memory pointer is incremented by two since one char corresponds to a word on the screen.
48	The loop instruction used is equivalent to a combination of “dec cx” and “jnz nextchar.” The loop is executed CX times.
50-56	The registers pushed on the stack are recovered in opposite order and the “ret 4” instruction removes the two parameters placed on the stack.
62	Memory can be directly pushed on the stack.

Number Printing in Assembly

- Another problem related to the display is printing numbers.
- Every high level language allows some simple way to print numbers on the screen.
- As we have seen, everything on the screen is a pair of ASCII code and its attribute and a number is a raw binary number and not a collection of ASCII codes.
- For example a 10 is stored as a 10 (hex A, binary 1010) and not as the ASCII code of 1 followed by the ASCII code of 0.
- If this 10 is stored in a screen location, the output will be meaningless, as the character associate to ASCII code 10 will be shown on the screen.
- So there is a process that converts a number in its ASCII representation.
- This process works for any number in any base!

Number Printing Algorithm

- The key idea is to divide the number by the base number, 10 in the case of decimal. The remainder can be from 0-9 and is the right most digit of the original number. The remaining digits fall in the quotient. The remainder can be easily converted into its ASCII equivalent and printed on the screen. The other digits can be printed in a similar manner by dividing the quotient again by 10 to separate the next digit and so on.

Number Printing Algorithm

- However, the problem with this approach is that the first digit printed is the rightmost one e.g., 253 will be printed as 352. The remainder after first division was 3, after second division was 5 and after the third division was 2. We have to somehow correct the order so that the actual number 253 is displayed
- The trick is to use the stack since the stack is a Last In First Out structure so if 3, 5, and 2 are pushed on it, 2, 5, and 3 will come out in this order.

Number Printing Algorithm

The steps of our algorithm are outlined below.

- Divide* the number by base (10 in case of decimal)
- The remainder is its right most digit
- Convert the digit to its ASCII representation (Add 0x30 to the remainder in case of decimal)
- Save this digit on stack
- If the quotient is non-zero, repeat the whole process to get the next digit, otherwise stop
- Pop digits one by one and print on screen left to right

*The division used in the process is not floating point division, but integer division that produces an integer quotient and an integer remainder.

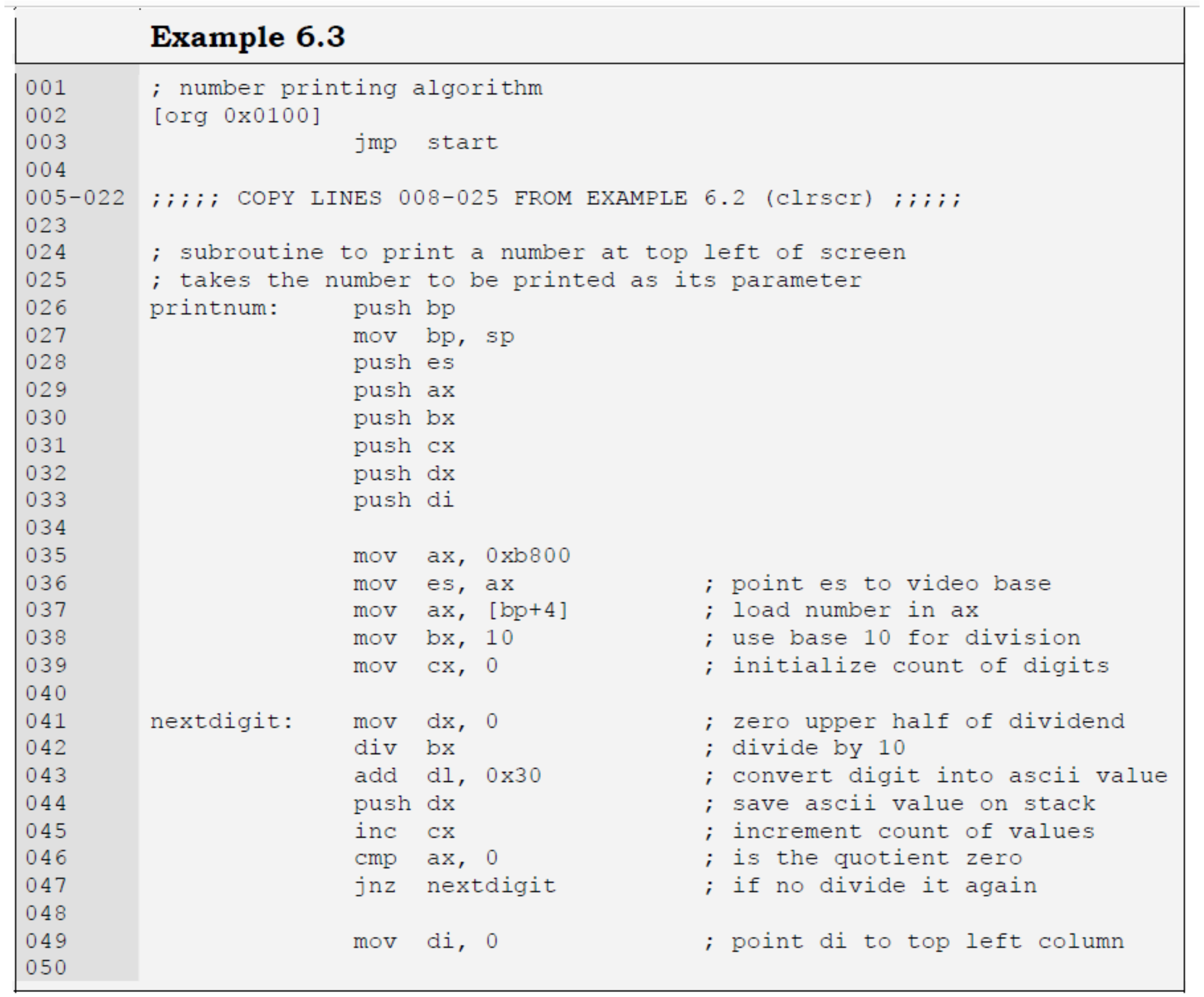
DIV Instruction

- There is a DIV instruction available in the 8088 processor.
- There are two forms of the DIV instruction.
- First form: `DIV BX or DIV word [address]`.
  - when operand is 16 bits, the dividend is implied to be 32 bits, pre-stored in concatenation of DX:AX
  - divides a 32 bit number in DX:AX by its 16 bit operand (e.g. BX) and stores the 16 bit quotient in AX and the 16 bit remainder in DX.

DIV Instruction

- Second form: `DIV BL or DIV byte [address]`
  - when operand is 8 bits, the dividend is implied to be 16 bits, pre-stored in AX
  - divides a 16 bit number in AX by its 8 bit operand (e.g. BL) and stores the 8 bit quotient in AL and the 8 bit remainder in AH.
- DIV performs an unsigned division.
- If the quotient exceeds the capacity of its destination register (FF for byte source, FFFF for word source), as when division by zero is attempted, a type 0 interrupt is generated, and the quotient and remainder are undefined.

Number Printing Example



Example 6.3

```
; number printing algorithm
[org 0x0100]
                jmp  start

;;;;; COPY LINES 008-025 FROM EXAMPLE 6.2 (clrscr) ;;;;;

; subroutine to print a number at top left of screen
; takes the number to be printed as its parameter
printnum:       push bp
                mov  bp, sp
                push es
                push ax
                push bx
                push cx
                push dx
                push di

                mov  ax, 0xb800
                mov  es, ax                 ; point es to video base
                mov  ax, [bp+4]             ; load number in ax
                mov  bx, 10                 ; use base 10 for division
                mov  cx, 0                  ; initialize count of digits

nextdigit:      mov  dx, 0                  ; zero upper half of dividend
                div  bx                     ; divide by 10
                add  dl, 0x30               ; convert digit into ascii value
                push dx                     ; save ascii value on stack
                inc  cx                     ; increment count of values
                cmp  ax, 0                  ; is the quotient zero
                jnz  nextdigit              ; if no divide it again

                mov  di, 0                  ; point di to top left column

```

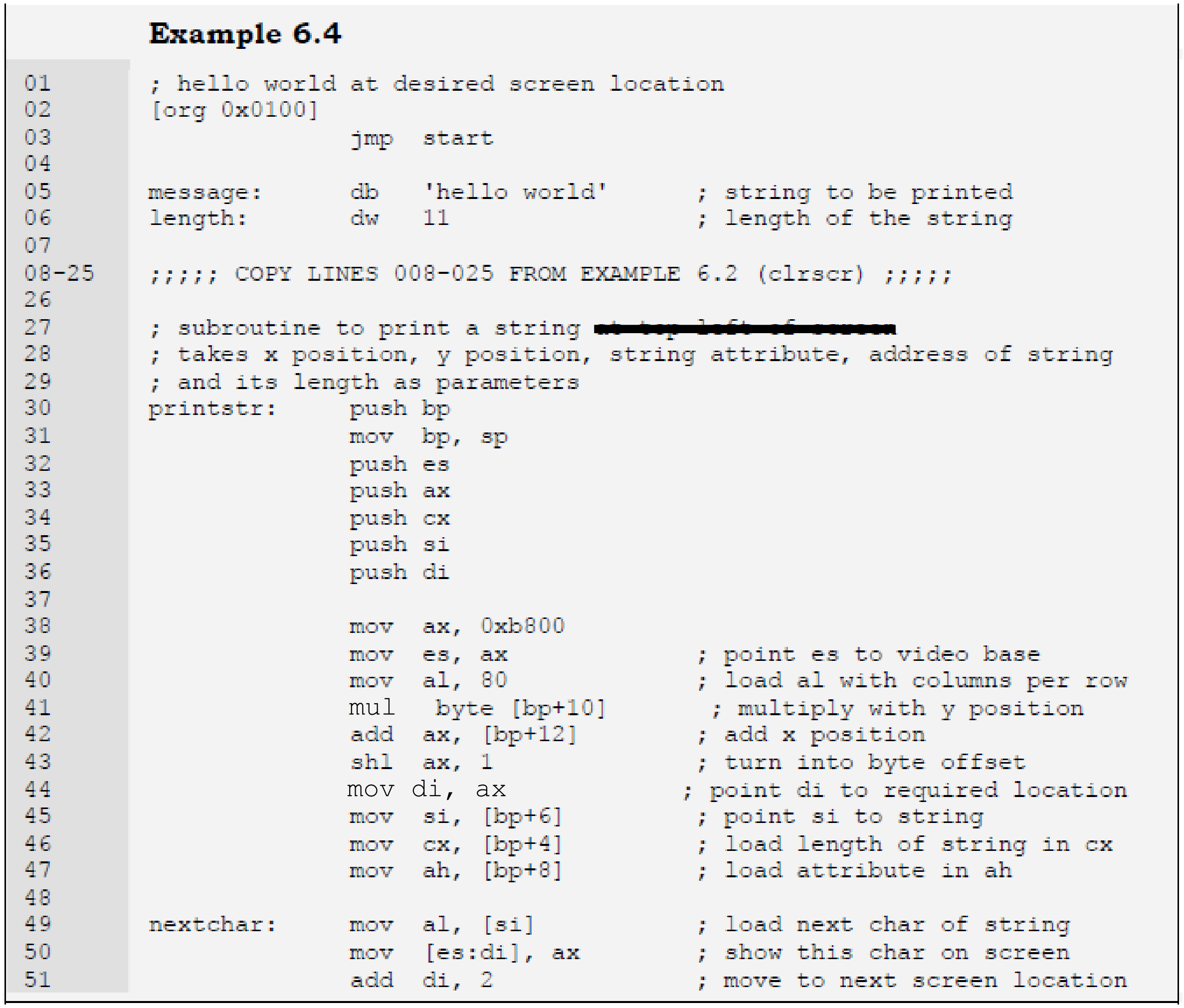
```
nextpos:      pop  dx                  ; remove a digit from the stack
              mov  dh, 0x07            ; use normal attribute
              mov [es:di], dx          ; print char on screen
              add  di, 2               ; move to next screen location
              loop nextpos             ; repeat for all digits on stack

              pop  di
              pop  dx
              pop  cx
              pop  bx
              pop  ax
              pop  es
              pop  bp
              ret  2

start:        call  clrscr             ; call the clrscr subroutine

              mov ax, 4529
              push ax                  ; place number on stack
              call printnum            ; call the printnum subroutine

              mov ax, 0x4c00           ; terminate program
              int 0x21
```

026-033	The registers are saved as an essential practice. The only parameter received is the number to be printed.
035-039	ES is initialized to video memory. AX holds the number to be printed. BX is the desired base, and can be loaded from a parameter. CX holds the number of digits pushed on the stack. This count is initialized to zero, incremented with every digit pushed and is used when the digits are popped one by one.
041-042	DX must be zeroed as our dividend is in AX and we want a 32bit division. After the division AX holds the quotient and DX holds the remainder. Actually the remainder is only in DL since the remainder can be from 0 to 9.
043-045	The remainder is converted into its ASCII representation and saved on the stack. The count of digits on the stack is incremented as well.
046-047	If the quotient is zero, all digits have been saved on the stack and if it is non-zero, we have to repeat the process to print the next digit.
049	DI is initialized to point to the top left of the screen, called the cursor home. If the screen location is to become a parameter, the value loaded in DI will change.
051-053	A digit is popped off the stack, the attribute byte is appended to it and it is displayed on the screen.
054-055	The next screen location is two bytes ahead so DI is incremented by two. The process is repeated CX times which holds the number of digits pushed on the stack.
057-064	We pop the registers pushed and "ret 2" to discard the only parameter on the stack.
066-070	The main program clears the screen and calls the printnum subroutine to print 4529 on the top left of the screen.

Number Printing in other bases

- This algorithm is versatile in that the base number can be changed and the printing will be in the desired base.
- For example if “mov bx, 10” is changed to “mov bx, 2” the output will be in binary as 0010000110110001.
- Similarly changing it to “mov bx, 8” outputs the number in octal as 10661.
- Printing it in hexadecimal is a bit tricky, as the ASCII codes for A-F do not consecutively start after the codes for 0-9.

Printing string at arbitrary location



Example 6.4

```
; hello world at desired screen location
[org 0x0100]
              jmp  start

message:      db   'hello world'      ; string to be printed
length:       dw   11                 ; length of the string

;;;;; COPY LINES 008-025 FROM EXAMPLE 6.2 (clrscr) ;;;;;

; subroutine to print a string ~~at top left of screen~~
; takes x position, y position, string attribute, address of string
; and its length as parameters
printstr:     push bp
              mov  bp, sp
              push es
              push ax
              push cx
              push si
              push di

              mov  ax, 0xb800
              mov  es, ax             ; point es to video base
              mov  al, 80             ; load al with columns per row
              mul  byte [bp+10]       ; multiply with y position
              add  ax, [bp+12]        ; add x position
              shl  ax, 1              ; turn into byte offset
              mov  di, ax             ; point di to required location
              mov  si, [bp+6]         ; point si to string
              mov  cx, [bp+4]         ; load length of string in cx
              mov  ah, [bp+8]         ; load attribute in ah

nextchar:     mov  al, [si]           ; load next char of string
              mov  [es:di], ax        ; show this char on screen
              add  di, 2              ; move to next screen location
```

Recall byte offset formula
((80 × r) + c) × 2

r = y-position (row)
c = x-position (column)

```
52                  add  si, 1                ; move to next char in string
53                  loop nextchar             ; repeat the operation cx times
54
55                  pop  di
56                  pop  si
57                  pop  cx
58                  pop  ax
59                  pop  es
60                  pop  bp
61                  ret  10
62
63  start:          call clrscr               ; call the clrscr subroutine
64
65                  mov  ax, 30
66                  push ax                   ; push x position
67                  mov  ax, 20
68                  push ax                   ; push y position
69                  mov  ax, 1                ; blue on black attribute
70                  push ax                   ; push attribute
71                  mov  ax, message
72                  push ax                   ; push address of message
73                  push word [length]        ; push message length
74                  call printstr             ; call the printstr subroutine
75
76                  mov  ax, 0x4c00           ; terminate program
77                  int  0x21
```

41	Push and pop operations always operate on words; however data can be read as a word or as a byte. For example we read the lower byte of the parameter y-position in this case.
43	Shifting is used for multiplication by two, which should always be the case when multiplication or division by a power of two is desired.
61	The subroutine had 5 parameters so “ret 10” is used.
65-74	The main program pushes 30 as x-position, 20 as y-position meaning 30th column on 20th row. It pushes 1 as the attribute meaning low intensity blue on black with no blinking.

Printing string at arbitrary location

- When the program is executed hello world is displayed at the desired screen location in the desired color.
- The x-position, y-position, and attribute parameters can be changed and their effect be seen on the screen.
- The important difference in this example is the use of MUL instruction and the calculation of screen location given the x and y positions.