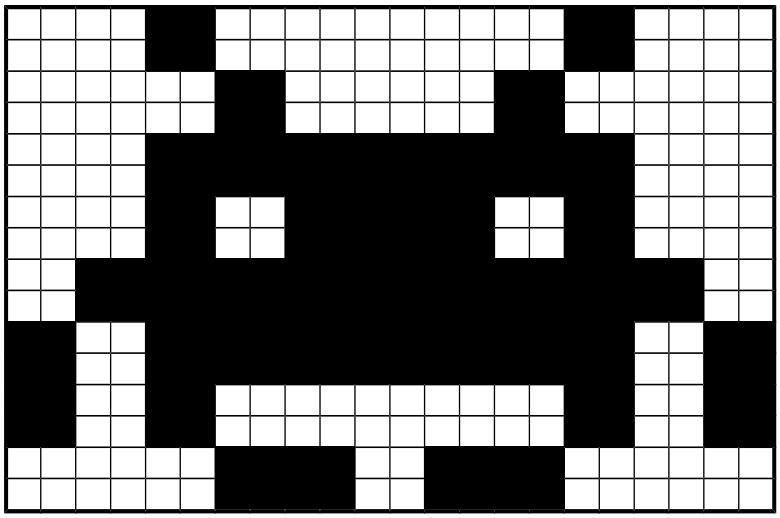
Practical 7
Space Invaders (Part 2)

Approximate duration: 4 hrs.

Step 1

Now that you have familiarized yourselves with the structure of the video memory, we can start to draw our first invader. We are going to reproduce the original graphics as much as possible. Here is the bitmap of the first invader we are going to display:



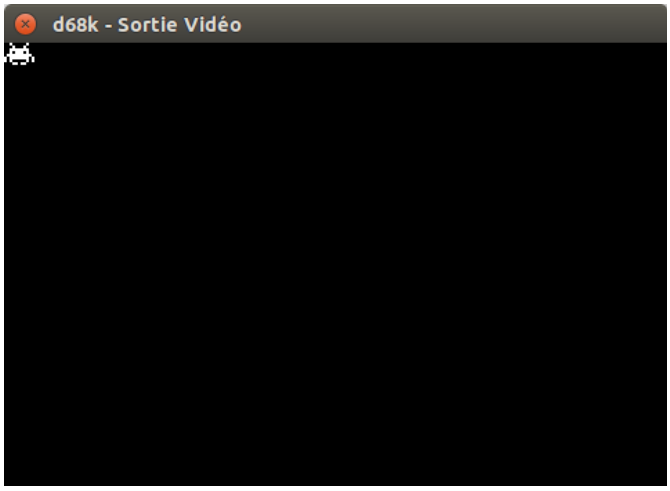
The size of the bitmap is 22 × 16 pixels. Since a memory location holds a single byte, the width of the invader is 3 bytes (3 × 8 = 24).

The dot matrix can be stored in the memory by using the `DC.B` directive (see Chapter 1). Moreover, the prefix "%" can be used to key in data in its binary form. You can find below the instructions to be inserted as data into your source code. If you look carefully, you can make out the shape of the invaders among the 0s and 1s.

```
Invader_Bitmap      dc.b    %00001100,%00000000,%11000000
                    dc.b    %00001100,%00000000,%11000000
                    dc.b    %00000011,%00000011,%00000000
                    dc.b    %00000011,%00000011,%00000000
                    dc.b    %00001111,%11111111,%11000000
                    dc.b    %00001111,%11111111,%11000000
                    dc.b    %00001100,%11111100,%11000000
                    dc.b    %00001100,%11111100,%11000000
                    dc.b    %00111111,%11111111,%11110000
                    dc.b    %00111111,%11111111,%11110000
                    dc.b    %11001111,%11111111,%11001100
                    dc.b    %11001111,%11111111,%11001100
                    dc.b    %11001100,%00000000,%11001100
                    dc.b    %11001100,%00000000,%11001100
                    dc.b    %00000011,%11001111,%00000000
                    dc.b    %00000011,%11001111,%00000000
```

In this step, you simply have to write some instructions in the main program (no subroutine). These instructions must copy the dot matrix into the video memory in order to display the invader on the top left corner of the video output window.

Screenshot of the expected result:



Step 2

Several types of invaders and some other bitmaps are going to be displayed during a game. All of these bitmaps can have different sizes. In order to simplify display handling, the size of a bitmap will be stored in the memory just before the dot matrix. Here is the structure of a bitmap:

- Width of the bitmap in pixels (unsigned 16-bit word).
- Height of the bitmap in pixels (unsigned 16-bit word).
- Dot matrix of the bitmap (variable size).

```
                    ; ==============================
                    ; Data
                    ; ==============================

Invader_Bitmap      dc.w    22,16                           ; Width, Height
                    dc.b    %00001100,%00000000,%11000000   ; Dot matrix
                    dc.b    %00001100,%00000000,%11000000
                    dc.b    %00000011,%00000011,%00000000
                    dc.b    %00000011,%00000011,%00000000
                    dc.b    %00001111,%11111111,%11000000
                    dc.b    %00001111,%11111111,%11000000
                    dc.b    %00001100,%11111100,%11000000
                    dc.b    %00001100,%11111100,%11000000
                    dc.b    %00111111,%11111111,%11110000
                    dc.b    %00111111,%11111111,%11110000
                    dc.b    %11001111,%11111111,%11001100
                    dc.b    %11001111,%11111111,%11001100
                    dc.b    %11001100,%00000000,%11001100
                    dc.b    %11001100,%00000000,%11001100
                    dc.b    %00000011,%11001111,%00000000
                    dc.b    %00000011,%11001111,%00000000
```

Now, let us assume that **A0** holds the `Invader_Bitmap` address. We can deduce that:

- The width of the bitmap is pointed at by **A0**.
- The height of the bitmap is pointed at by **A0 + 2**.
- The dot matrix of the bitmap is pointed at by **A0 + 4.**

Therefore, the address register indirect mode with displacement can be used to access data. For instance, the following instructions copy the width, the height and the address of the dot matrix from the memory into the **D0.W**, **D1.W** and **A1.L** registers:

```
                    move.w  (a0),d0         ; Width                 -> D0.W
                    move.w  2(a0),d1        ; Height                -> D1.W
                    lea     4(a0),a1        ; Address of the matrix -> A1.L
```

However, in order to improve the readability of the code, it is advisable to define three new constants:

```
WIDTH               equ     0
HEIGHT              equ     2
MATRIX              equ     4

                    move.w  WIDTH(a0),d0    ; Width                 -> D0.W
                    move.w  HEIGHT(a0),d1   ; Height                -> D1.W
                    lea     MATRIX(a0),a1   ; Address of the matrix -> A1.L
```

The purpose of this step is to write the **`CopyBitmap`** subroutine, which copies the dot matrix of a bitmap into the video memory. In order to keep the subroutine short and simple, we will break it down and start by writing another two subroutines: **`CopyLine`** and **`PixelToByte`**, which will then be called by **`CopyBitmap`**.

Here is a brief description of the subroutines and their I/O registers:

`CopyBitmap`: Copies the dot matrix of a bitmap into the video memory.
Inputs: **A0.L** = Address of the bitmap.
A1.L = Video address where the dot matrix must be copied.

`CopyLine`: Copies a bitmap line into the video memory with offset handling.
Inputs: **A0.L** = Address of the line.
A1.L = Video address where the line must be copied.
D3.W = Width of the line in bytes.
Output: **A0.L** = Address of the next line.

`PixelToByte`: Convert a size in pixels into a size in bytes:
Input: **D3.W** = Size in pixels to convert (unsigned integer lower than or equal to 480).
Output: **D3.W** = Size in bytes (minimum number of bytes that contains the number of pixels).

Start by writing **PixelToByte**. At first glance, the size in bytes seems to be the size in pixels divided by 8. But be careful! This is right only when the size in pixels is a multiple of 8. For instance, if the size in pixels is 8, 16, 24 or 32, the size in bytes is 1, 2 3 or 4 respectively. On the other hand, if the size in pixels is 10, the size in bytes is 2 (2 bytes are required to store 10 pixels: 8 pixels in the first byte and 2 pixels in the second one).

Test your subroutine with the following values:

```
Main                move.w  #3,d3
                    jsr     PixelToByte     ; D3.W = 1

                    move.w  #8,d3
                    jsr     PixelToByte     ; D3.W = 1

                    move.w  #9,d3
                    jsr     PixelToByte     ; D3.W = 2

                    move.w  #16,d3
                    jsr     PixelToByte     ; D3.W = 2

                    move.w  #20,d3
                    jsr     PixelToByte     ; D3.W = 3

                    move.w  #24,d3
                    jsr     PixelToByte     ; D3.W = 3

                    move.w  #31,d3
                    jsr     PixelToByte     ; D3.W = 4

                    move.w  #32,d3
                    jsr     PixelToByte     ; D3.W = 4

                    illegal
```

Then, write the **CopyLine** subroutine.

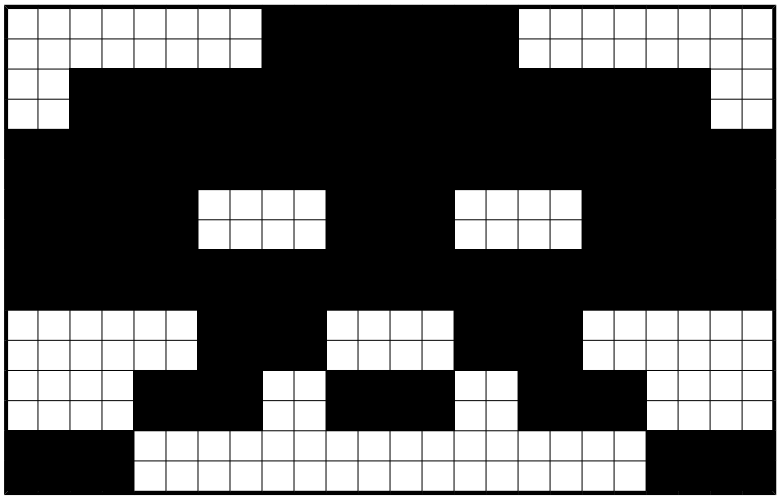
Finally, write the **CopyBitmap** subroutine and use the following structure in order to test it. If everything is fine, the invader should be displayed on the top left corner of the video output window (in the same way as the previous step).

```
                    ; ==============================
                    ; Definitions of Constants
                    ; ==============================

                    ; Video Memory
                    ; ------------------------------

VIDEO_START         equ     $ffb500                     ; Starting address
VIDEO_WIDTH         equ     480                         ; Width in pixels
VIDEO_HEIGHT        equ     320                         ; Height in pixels
VIDEO_SIZE          equ     (VIDEO_WIDTH*VIDEO_HEIGHT/8)    ; Size in bytes
BYTE_PER_LINE       equ     (VIDEO_WIDTH/8)             ; Number of bytes per line

                    ; Bitmaps
                    ; ------------------------------

WIDTH               equ     0                           ; Width in pixels
HEIGHT              equ     2                           ; Height in pixels
MATRIX              equ     4                           ; Dot matrix

                    ; ==============================
                    ; Vector Initialization
                    ; ==============================

                    org     $0

vector_000          dc.l    VIDEO_START                 ; Initial value of A7
vector_001          dc.l    Main                        ; Initial value of the PC

                    ; ==============================
                    ; Main Program
                    ; ==============================

                    org     $500

Main                lea     Invader_Bitmap,a0
                    lea     VIDEO_START,a1
                    jsr     CopyBitmap

                    illegal

                    ; ==============================
                    ; Subroutines
                    ; ==============================

                    ; ...
                    ; ...
                    ; ...

                    ; ==============================
                    ; Data
                    ; ==============================

                    ; ...
                    ; ...
                    ; ...
```

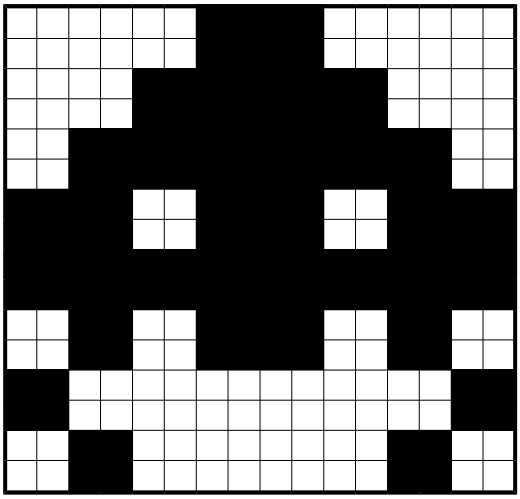
Step 3

In this step, you are going to test the **`CopyBitmap`** subroutine with different types of bitmaps. To do so, we are going to add two invaders and the spaceship of the player. The dot matrices are as follows:

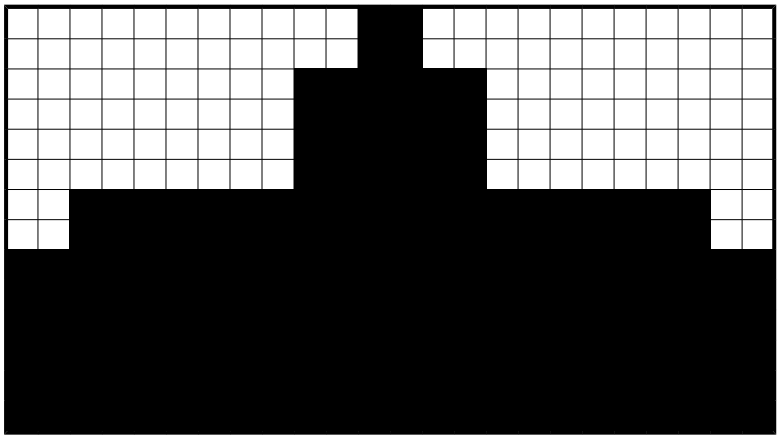
A Invader – (24,16)



C Invader – (16,16)



Spaceship of the player – (24,14)



Let us call the three types of invaders *A*, *B* and *C*. The *B* invader is the one we have already displayed in the previous steps. The *A* and *C* invaders are given above.

Complete the "Data" part in your source file from the above dot matrices and the template below:

```
                    ; ==============================
                    ; Data
                    ; ==============================

InvaderA_Bitmap     dc.w    24,16
                    dc.b    ; ...Insert the binary dot matrix...
                    dc.b    ; ...

InvaderB_Bitmap     dc.w    22,16
                    dc.b    %00001100,%00000000,%11000000
                    dc.b    %00001100,%00000000,%11000000
                    dc.b    %00000011,%00000011,%00000000
                    dc.b    %00000011,%00000011,%00000000
                    dc.b    %00001111,%11111111,%11000000
                    dc.b    %00001111,%11111111,%11000000
                    dc.b    %00001100,%11111100,%11000000
                    dc.b    %00001100,%11111100,%11000000
                    dc.b    %00111111,%11111111,%11110000
                    dc.b    %00111111,%11111111,%11110000
                    dc.b    %11001111,%11111111,%11001100
                    dc.b    %11001111,%11111111,%11001100
                    dc.b    %11001100,%00000000,%11001100
                    dc.b    %11001100,%00000000,%11001100
                    dc.b    %00000011,%11001111,%00000000
                    dc.b    %00000011,%11001111,%00000000

InvaderC_Bitmap     dc.w    16,16
                    dc.b    ; ...Insert the binary dot matrix...
                    dc.b    ; ...

Ship_Bitmap         dc.w    24,14
                    dc.b    ; ...Insert the binary dot matrix...
                    dc.b    ; ...
```

Then, use the following main program in order to test the display of these new bitmaps:

```
Main                lea     InvaderA_Bitmap,a0
                    lea     VIDEO_START+14+100*BYTE_PER_LINE,a1
                    jsr     CopyBitmap

                    lea     InvaderB_Bitmap,a0
                    lea     VIDEO_START+28+100*BYTE_PER_LINE,a1
                    jsr     CopyBitmap

                    lea     InvaderC_Bitmap,a0
                    lea     VIDEO_START+42+100*BYTE_PER_LINE,a1
                    jsr     CopyBitmap

                    lea     Ship_Bitmap,a0
                    lea     VIDEO_START+28+200*BYTE_PER_LINE,a1
                    jsr     CopyBitmap

                    illegal
```

Screenshot of the expected result: