# RUNTIME ENVIRONMENT



## Introduction

Runtime Environment of a process refers to execution environment provided to the process by the operating system.

A user program in execution is termed as a process. User programs are written in APL, which is a high level language. When an APL program is compiled, it generates XSM machine instructions. These machine instructions are unprivileged instructions and will be run in the USER mode (See Privilege Modes). An operating system capable of supporting multiprogramming can provide this view to more than one process concurrently. We'll learn about the view of a process in detail in the further sections.

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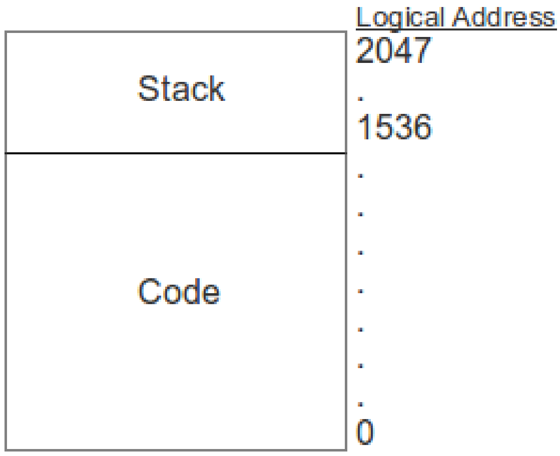
## Machine view of a process

Every user process has a limited view of the machine. Also it accesses only a limited set of registers and memory. It cannot use certain instructions directly. These instructions are called privileged instructions (See Instructions in XSM). The privileged instructions are accessed by the user program through system calls (see System Calls).

### Memory

In XOS, a process views memory as a contiguous block with starting address 0. The size of the block is 2048 words. However, XSM allocates memory as pages. Each page has 512 words. This means that a process can have use at most 4 pages. Although the user process views this as contiguous 4 memory pages, OS may allocate it as non-contiguous pages in the physical memory. The contiguous view that a process gets of the memory is called its Logical address space. When this is mapped to the physical memory, it is called its Physical Address Space. Logical addresses are translated to physical addresses by the machine using the Address translation scheme of XSM. The process is unaware of the existence of a physical address space and the address translation mechanism is hidden from it.




Of the 4 pages that the process uses, the first 3 pages are used for storing the code of the program and the 4th page (address 1536 - 2047) is used as the stack of the process. Stack of a process is a data structure for saving runtime variables and function call arguments of the process. Return value of a function is also passed through the stack. Read about stack in function calls in APL.

## Registers

Although XSM has 34 registers, including program registers, kernel registers, temporary registers and special purpose registers, a particular user process has access to a limited set of registers (See Register Set in XSM). The register set that is visible to a user process includes only the Program Registers (R0 - R7), SP, BP and IP. Out of which, IP cannot be read / modified. The SP or Stack Pointer points to the address of the top of the stack. BP will be used in function calls. Read about stack in function calls in APL.

IP points to the address of the next instruction to be executed within the code.

## Instructions

XSM provides a set of unprivileged instructions. Only these instructions are available to the user program. The user program written in a high level language like APL will compile to only unprivileged instructions. The unprivileged instructions are `MOV`, Arithmetic Instructions, Logic Instructions, Stack Instructions (`PUSH` and `POP`), Sub-routine instructions, input/output instructions, debug instructions, `END` and `INT` (see Instructions in XSM).

NOTE: This limited view is given to the user process by the operating system (XOS). APL is a language which is used to write user programs for XOS. These user programs will run in XOS with a limited machine view allowed for user processes. Hence the translated machine code will use only the limited set of instructions, registers and memory described above. The System Pogrammer's Language (SPL), on the other hand is designed to write system programs and has a complete view of the instructions, registers and memory.

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# Translating APL programs

APL compiler translates an APL program into XSM machine instructions. There are two fundamental aspects about compilers that you must understand. First is how the APL compiler translates a Function Call. Second is how the APL compiler generates instructions for a system call.

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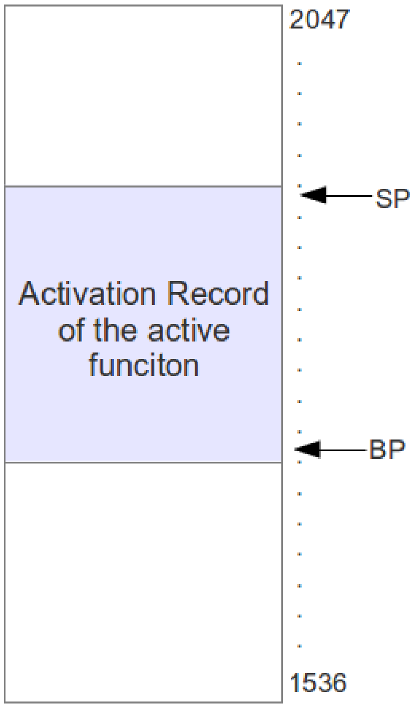
## Function Calls

A function call or a subroutine invocation is done by the machine instruction `CALL` (see subroutine instructions in XSM). The stack is used to pass arguments to the function and get back the return value. Stack is necessary for a programming language that supports recursion. This will be explained in detail, later in this page. Note that APL is a language that supports recursion. The stack of the user process stores information about the active subroutines of the program. An active subroutine is one that has been called but is yet to complete execution. Control should be handed back to the point of call after completing the function execution.

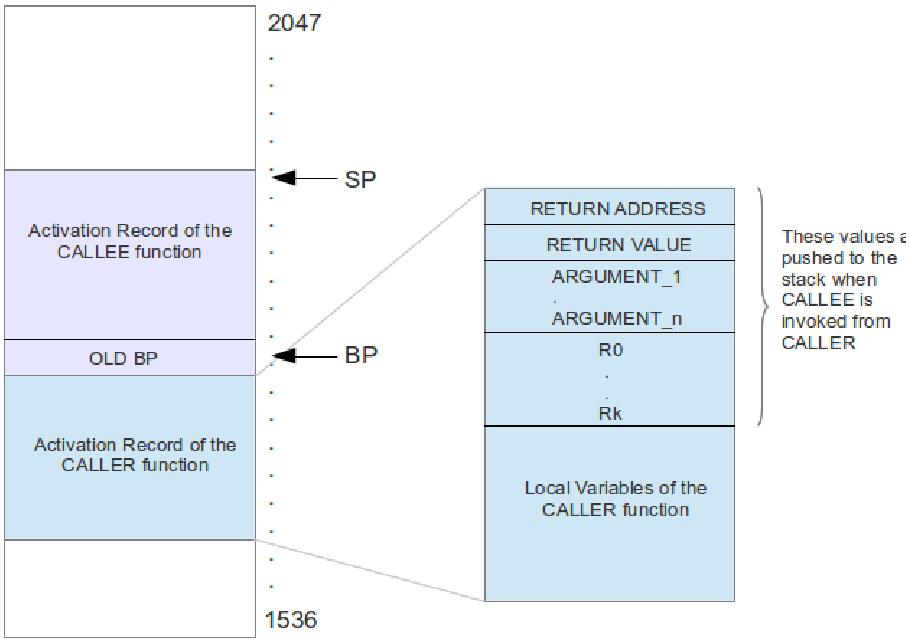
The activation record corresponding to an active subroutine (or the active function) is shown below. The bottom position of the activation record is pointed to by the BP, and the top of the stack is by SP. The region between

BP an SP within the stack is the activation record of the active function. See the figure below.




(NOTE In XOS, stack grows from a lower memory address to a higher memory address. )

The stack contents when a function call is made is shown in the figure below




A: Actions when a CALLER function invokes a CALLEE function

1. The user registers and arguments are pushed into the stack. (See figure). The registers are pushed to backup its values. The CALLEE can now freely use these registers. Arguments are the inputs to the CALLEE function to perform its actions. The arguments become accessible to the CALLEE from the stack.

2. An empty space for the return value is pushed into the stack, specified as RETURN VALUE in the above figure. The CALLEE function will store the return value in this space after it is computed. The CALLER will access this return value from the stack after return from the CALLEE.
3. The `CALL` instruction will push the address of IP into the stack, specified as `RETURN ADDRESS` . This is because the `CALL` instruction changes IP to the address of the CALLEE's starting instruction. After the CALLEE performs its actions it must return back to the point after the function call. Hence the current IP must be backed up

APL generates instructions for doing steps 1 and 2. It also generates the machine instruction `CALL` which does step 3.

B: Actions upon entry into the CALLEE function

The `CALL` instruction passes control to the starting instruction of the CALLEE function. The first few instructions generated by APL compiler for the CALLEE function does the following actions

1. Push the current value of BP to the stack. The base of the activation record of the current function is identified by BP. When the CALLEE function is invoked, BP needs to be changed to the base of activation record of the CALLEE function. Hence, the old value of BP corresponding to the CALLER function must be backed up in the stack so that it can be recovered when control returns back to the CALLER function after completion of CALLEE.

2. BP is changed to the value of SP. This is because, the activation record of the CALLEE starts at this point. The CALLEE is the current function and BP must point to the starting point of its activation record. As long as the CALLEE function does not call another function, or does not return back to the CALLER, BP will not change. The region in the stack above this BP till SP will be its activation record. As SP can change during execution, the activation record also varies during execution of the function.

C: Internal stack operations by the CALLEE function

The local variables declared in the CALLEE program has to be allocated memory. This is done in the stack. Each local variable will be allocated a word in the stack. The Stack Pointer will be updated accordingly. APL compiler will generate machine instructions to do this, when local variables are declared. During runtime of the CALLEE, this space may be modified when local variables are assigned values. The region between SP and BP is known as the activation record of the CALLEE function.

D: Actions in the CALLEE function during return

Upon completion, the CALLEE function must return back to the CALLER. This is done using the APL statement, `return;` which translates to the `RET` machine instruciton. The steps done are given below in detail:

1. The function stores the return value computed in the RETURN VALUE field of the activation record of the CALLER function.
2. All the local variables of the function are popped from the stack as they are no longer required.
3. OLD BP is popped out from the stack. BP is set to OLD BP. .
4. Then the `RET` instruction is generated by the APL. The `RET` instruction sets the IP to the value on top of the stack. Now the top of the stack points to the top of the activation record of the CALLER function. This value, specified as RETURN ADDRESS was pushed by the CALL instruction. When IP is set to this value, it passes control to the instruction after the `CALL` instruction (that invoked the CALLEE) in the CALLER function.

E: Actions in the CALLER function after return

1. The CALLER function obtains the return value from the stack and stores it in a register. It pops out the arguments in its activation record and they are discarded. It also restores the backed up register values, so that the execution of CALLER can resume. Machine instructions to perform the above actions will follow the CALL instruction (which invoked the CALLEE) in the machine code generated by the APL compiler.

An example of translating a recursive program to computing the factorial of the number is shown below

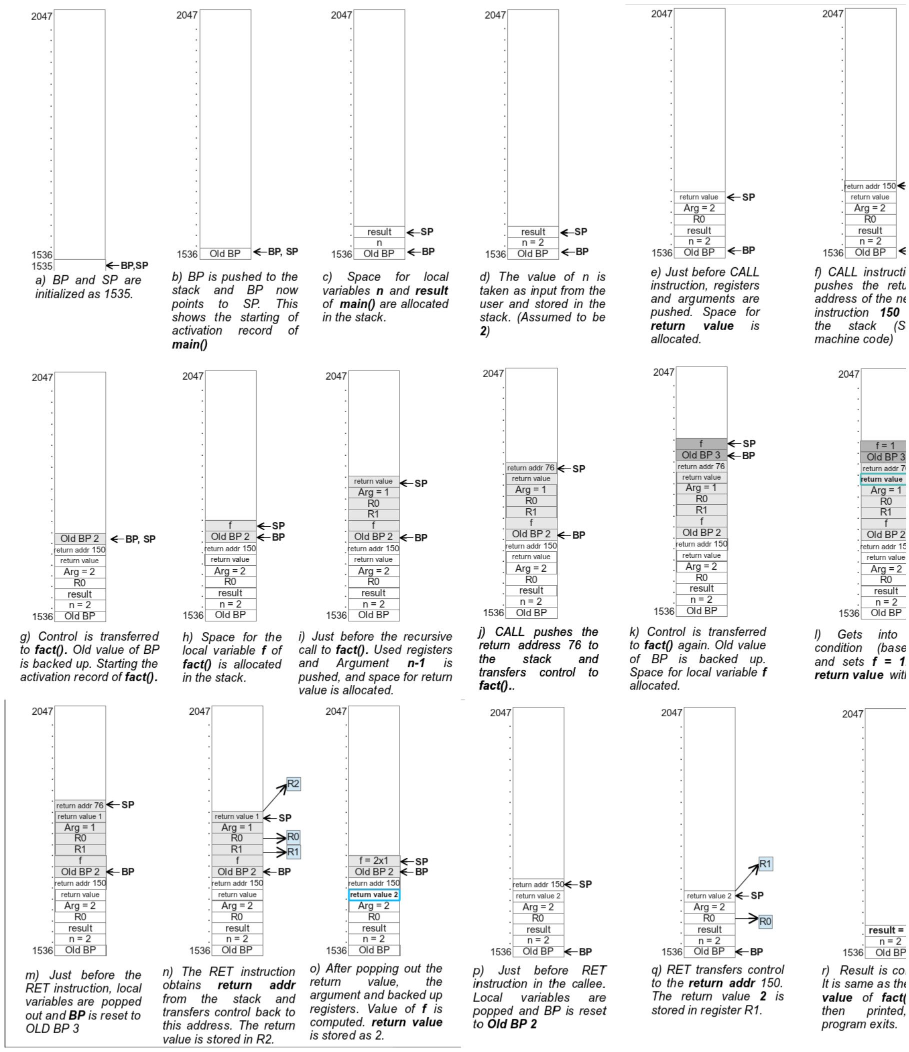
```
decl
        integer fact(integer n);        // Declaration
enddecl
integer fact(integer n)                 // Definition 
{
        integer f;                      // Local varial
        if(n==1) then                   // Checking ba:
                f=1;
        else
                f=n*fact(n-1);          // Recursive ca
        endif;
        return f;                       // Value of f 
}

integer main()
{
        integer n,result;               // Local varial
        read(n);                        // Input is ob
        result=fact(n);                 // Factorial o
        print(result);                  // The value o
        return 0;                       // Return from
}
```

When the above APL program is compiled, the output file generated will contain machine code. The compiled output is shown below (Comments are given for understanding the code. Instruction size in XSM is two words. Word number is shown on the left for each instruction)

```
0:      START
2:      MOV SP, 1535    // Initialize SP to 1535 (Befo
4:      MOV BP, 1535    // Initialize BP to 1535 (Befo
6:      JMP 00110       // Jumps to the main() functio

// fact() function definition starts here

8:      PUSH BP         // Old value of BP is pushed
10:     MOV BP, SP      // BP is changed to SP
12:     PUSH R0         // Allocating space for local
14:     MOV R0, -3      // Argument 1 is obtained at 3
16:     MOV R1, BP      // ... it takes more than one
18:     ADD R0, R1      // ... to achieve an action
20:     MOV R0, [R0]    // ...
22:     MOV R1, 1       // Checking if condition and b
24:     EQ R0, R1       // ...
26:     JZ R0, 00040    // Jumps to 'else' part if con
28:     MOV R0, 1       // 'if' condition actions
30:     MOV R1, BP      // ...
32:     ADD R0, R1      // ...
34:     MOV R1, 1       // ...
36:     MOV [R0], R1    // ...
38:     JMP 00088       // Skip 'else' part
40:     MOV R0, 1       // 'else ' condition actions b
42:     MOV R1, BP      // ...
44:     ADD R0, R1      // ...
46:     MOV R1, -3      // ...
48:     MOV R2, BP      // ...
50:     ADD R1, R2      // ...
52:     MOV R1, [R1]    // ...
54:     PUSH R1         // ... Backing up registers (o
56:     PUSH R0         // ... ...
58:     MOV R0, -3      // ... Calculating argument 'n
60:     MOV R1, BP      // ... ...
62:     ADD R0, R1      // ... ...
64:     MOV R0, [R0]    // ... ...
66:     MOV R1, 1       // ... ...
68:     SUB R0, R1      // ... ...
70:     PUSH R0         // ... Push argument 'n-1' to
72:     PUSH R0         // ... Push a space for return
74:     CALL 8          // ... Recursive call to fact(
        // The following code is executed after return
76:     POP R2          // ... Popping out the RETURN
78:     POP R3          // ... Popping out the argumen
80:     POP R0          // ... Popping out the backed
82:     POP R1          // ... ...
```

```
84:     MUL R1, R2      // ... Computing 'f'
86:     MOV [R0], R1    // ...
88:     MOV R0, 1       // Obtaining the value of 'f'
90:     MOV R1, BP      // ...
92:     ADD R0, R1      // ...
94:     MOV R0, [R0]    // ...
96:     MOV R1, -2      // Storing the return value at
98:     MOV R2, BP      // ...
100:    ADD R1, R2      // ...
102:    MOV [R1], R0    // ...
104:    POP R0          // Popping out local variable
106:    POP BP          // Popping out OLDBP to BP
108:    RET             // Return from the function fa

// main() starts here

110:    PUSH BP         // Old value of BP is pushed
112:    MOV BP,SP       // BP is changed to SP
114:    PUSH R0         // Allocating space for local
116:    PUSH R0         // Allocating space for local
118:    MOV R0, 1       // Computing location of 'n' i
120:    MOV R1, BP      // ...
122:    ADD R0, R1      // ...
124:    IN R1           // Reading 'n' from user
126:    MOV [R0], R1    // Saving the value of 'n' to
128:    MOV R0, 2       // Computing location of 'resu
130:    MOV R1, BP      // ...
132:    ADD R0, R1      // ...
134:    PUSH R0         // Backing up registers for fu
136:    MOV R0, 1       // Computing arguments for fun
138:    MOV R1, BP      // ...
140:    ADD R0, R1      // ...
142:    MOV R0, [R0]    // ...
144:    PUSH R0         // Pushing arguments to stack
146:    PUSH R0         // Allocating space for RETURN
148:    CALL 8          // Function call to fact(), ju
        // The following code is executed after return
150:    POP R1          // Popping out the RETURN VALU
152:    POP R2          // Popping out the arguments f
154:    POP R0          // Popping out backed up regis
156:    MOV [R0], R1    // Saving the return value in
158:    MOV R0, 2       // Getting value of 'result'
160:    MOV R1, BP      // ...
162:    ADD R0, R1      // ...
164:    MOV R0, [R0]    // ...
166:    OUT R0          // Printing 'result'
168:    MOV R0, 10      // Preparing for exiting
170:    PUSH R0         // ...
172:    INT 7           // ...
```

When the above program is run with value of 'n' as 2 taken from input, the following will be the condition of stack



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# System Calls

System calls are like built in functions in APL. When APL translates a system call, it generates an INT instruction, which transfers control to an interrupt service routine that contains the system call implementation. The interrupt routine runs in superuser mode. Read about various system calls available in APL.

(NOTE: This page describes how a system call in a user program is translated by the APL compiler. The actions done by the system call (within the corresponding interrupt routine) is to be programmed in SPL, by the XOS programmer.)

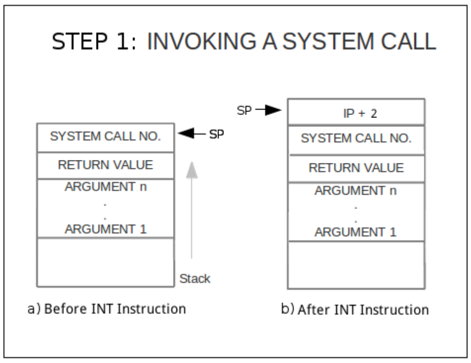
There are three steps in executing a system call. Invoking the system call, performing the system call and returning from the system call. The instructions to do the first and last steps are generated by APL. This page describes how APL does these steps.

## Invoking a system call

An user process invokes a system call by first pushing the arguments and system call number into the stack and then invoking the `INT` machine instruction corresponding to the system call. A system call in APL compiles to the a set of machine instructions like the one shown below.

```
PUSH Argument_1          // Push arguments to the stack
.
.
PUSH Argument_n
PUSH R0                  // Push an empty space for RET
PUSH System_Call_No      // Push system call number
INT number               // Invoke the corresponding IN
```

(NOTE: The machine code above is in the form of pseudo code.)




a) Shows the stack operations performed by the user program before **`INT`** instruction (See machine instructions above) . The arguments are pushed to stack in an order such that last argument comes on top. A push instruction `PUSH R0` is done to put an empty space in the stack for the return value. The system call implementation must ensure that the return value is stored in this space. The system call number is pushed to the stack. The interrupt routine needs this value to identify the system call.

b) Shows the contents of the stack after the **`INT`** instruction is executed. The `INT` instruction will push the value of `IP + 2` on to the stack. This value is the address of the instruction after the `INT` instruction in the user program. Each instruction is 2 words, hence IP is incremented by 2. This IP value will be used by interrupt routine to return back from the system call to the next instruction in the calling program. The `INT` instruction changes mode from USER to KERNEL mode and passes control to the Interrupt Routine corresponding to the system call.

## After return from the system call.

The interrupt routine instruction transfers control back to the user program to the instruction following the `INT` instruction. The following machine instructions are present after the `INT` instruction in the APL compiled machine code given in the previous step.

```
POP System Call Number  // Pop and discard system call
POP RETURN_VALUE// Pop and save the return value
POP Argument_n          // Pop and discard arguments
.
.
POP Argument_1
```

(NOTE: The machine code above is in the form of pseudo code. )

The machine code above pops the values from the stack. The system call number and arguments were inputs to the system call and hence they may be discarded now. The return value which is stored in the stack by the system call is fetched and used by the user program.

## System calls and their translation

In this section, example APL programs invoking a system call and their translated machine code is shown. The code is commented for better understanding.

### Create

*Description:* Creates a file in the XFS disk
*System Call No*: 1
*Interrupt Routine No*: 1
*Arguments*: filename
*Return Value*: 0 (Success) or -1 (Failure)

```
// APL program to invoke Create

integer main()
{
        integer a;
        a = Create("File");
        return 0;
}
```

```
// Compiled XSM machine code

START
MOV SP, 1535    // Initializes
MOV BP, 1535    // Initializes
JMP 00008       // Jump to main

// main() function
//================
PUSH BP
MOV BP,SP
PUSH R0         // Space for 'a
MOV R0, 1
MOV R1, BP
ADD R0, R1      // address of '
// preparing stack for system c
MOV R1, "File"  // Pushing argu
PUSH R1         // ...
PUSH R0         // Pushing spac
MOV R1, 1       // Pushing syst
PUSH R1         // ...
// invoking interrupt routine
INT 1           // Transfers co
// actions after interrupt rout
POP R2          // Pop out syst
POP R1          // Pop out retu
POP R2          // Pop out the
MOV [R0], R1    // Saving the r
MOV R0, 10      // Preparing fo
PUSH R0         // ...
INT 7           // Invoking int
```

## Open

*Description:* The Open system call is used to open a file present in the XFS disk.
*System Call No*: 2
*Interrupt Routine No*: 2
*Arguments*: filename of the file to be opened
*Return Value*: Index of open instance in Per-Process Open File table (Success) or -1 (Failure)

```
// APL program to invoke Open

integer main()
{
        integer a;
        a = Open("File");
        return 0;
}
```

```
// Compiled XSM machine code

START
MOV SP, 1535    // Initializes
MOV BP, 1535    // Initializes
JMP 00008       // Jump to main

// main() function
//================
PUSH BP
MOV BP,SP
PUSH R0         // Space for 'a
MOV R0, 1
MOV R1, BP
ADD R0, R1      // address of '
// preparing stack for system c
MOV R1, "File"  // Pushing argu
PUSH R1         // ...
PUSH R0         // Pushing spac
MOV R1, 2       // Pushing syst
PUSH R1         // ...
// invoking interrupt routine
INT 2           // Transfers co
// actions after interrupt rout
POP R2          // Pop out syst
POP R1          // Pop out retu
POP R2          // Pop out the
MOV [R0], R1    // Saving the r
MOV R0, 10      // Preparing fo
PUSH R0         // ...
INT 7           // Invoking int
```

## Close

*Description*: Closes a file opened

by the process.
*System Call No*: 3
*Interrupt Routine No*: 2
*Arguments*: fileDescriptor
*Return Value*: 0 (Success) or -1 (Failure)

```
// APL program to invoke Close

integer main()
{
        integer a;
        a = Close(0);
        return 0;
}
```

```
//  Compiled XSM machine code

START
MOV SP, 1535    // Initializes
MOV BP, 1535    // Initializes
JMP 00008       // Jump to mai

// main() function
//================
PUSH BP
MOV BP,SP
PUSH R0         // Space for 'a
MOV R0, 1
MOV R1, BP
ADD R0, R1      // address of
// preparing stack for system 
MOV R1, 0       // Pushing arg
PUSH R1         // ...
PUSH R0         // Pushing spa
MOV R1, 3       // Pushing sys
PUSH R1         // ...
// invoking interrupt routine
INT 2           // Transfers c
// actions after interrupt rou
POP R2          // Pop out sys
POP R1          // Pop out ret
POP R2          // Pop out the
MOV [R0], R1    // Saving the
MOV R0, 10      // Preparing f
PUSH R0         // ...
INT 7           // Invoking in
```

## Delete

*Description:* Deletes a file in the disk with the filename given as argument.
*System Call No*: 4
*Interrupt Routine No*: 1
*Arguments*: filename
*Return Value*: 0 (Success) or -1 (Failure)

```
// APL program to invoke Delete

integer main()
{
        integer a;
        a = Delete("File");
        return 0;
}
```

```
//  Compiled XSM machine code

START
MOV SP, 1535    // Initializes
MOV BP, 1535    // Initializes
JMP 00008       // Jump to main

// main() function
//================
PUSH BP
MOV BP,SP
PUSH R0         // Space for 'a
MOV R0, 1
MOV R1, BP
ADD R0, R1      // address of '
// preparing stack for system c
MOV R1, "File"  // Pushing argu
PUSH R1         // ...
PUSH R0         // Pushing spac
MOV R1, 4       // Pushing syst
PUSH R1         // ...
// invoking interrupt routine
INT 1           // Transfers co
// actions after interrupt rout
POP R2          // Pop out syst
POP R1          // Pop out retu
POP R2          // Pop out the
MOV [R0], R1    // Saving the r
MOV R0, 10      // Preparing fo
PUSH R0         // ...
INT 7           // Invoking int
```

Write

*Description:* Used to write a single word to a file opened by the process
*System Call No*: 5
*Interrupt Routine No*: 4
*Arguments*: 1. fileDescriptor, 2. wordToWrite
*Return Value*: 0 (Success) or -1 (Failure)

```
// APL program to invoke Write

integer main()
{
        integer a;
        a = Write(0,a);
        return 0;
}
```

```
//  Compiled XSM machine code

START
MOV SP, 1535    // Initializes
MOV BP, 1535    // Initializes
JMP 00008       // Jump to main

// main() function
//================
PUSH BP
MOV BP,SP
PUSH R0         // Space for 'a
MOV R0, 1
MOV R1, BP
ADD R0, R1      // address of '
// Preparing for system calls
MOV R1, 0       // Pushing argu
PUSH R1         // ...
MOV R1, 1       // Pushing argu
MOV R2, BP      // ...
ADD R1, R2      // ...
MOV R1, [R1]    // ...
PUSH R1         // ...
PUSH R0         // Pushing spac
MOV R1, 5       // Pushing syst
PUSH R1         // ...
// invoking interrupt routine
INT 4           // Transfers co
// actions after interrupt rout
POP R2          // Pop out syst
POP R1          // Pop out retu
POP R2          // Pop out argu
POP R2          // ...
MOV [R0], R1    // Store the re
MOV R0, 10      // Preparing fo
PUSH R0         // ...
INT 7           // Invoking int
```

## Seek

*Description*: Changes the LSEEK position
*System Call No*: 6
*Interrupt Routine No*: 3
*Arguments*: 1. fileDescriptor 2.

newLseek
*Return Value*: 0 (Success) or -1
(Failure)

```
// APL program to invoke Seek

integer main()
{
        integer a;
        a = Seek(0,10);
        return 0;
}
```

```
//  Compiled XSM machine code

START
MOV SP, 1535    // Initializes
MOV BP, 1535    // Initializes
JMP 00008       // Jump to main

// main() function
//================
PUSH BP
MOV BP,SP
PUSH R0         // Space for 'a
MOV R0, 1
MOV R1, BP
ADD R0, R1      // address of '
// Preparing for system calls
MOV R1, 0       // Pushing argu
PUSH R1         // ...
MOV R1, 10      // Pushing argu
PUSH R1         // ...
PUSH R0         // Pushing spac
MOV R1, 6       // Pushing syst
PUSH R1         // ...
// invoking interrupt routine
INT 3           // Transfers co
// actions after interrupt rout
POP R2          // Pop out syst
POP R1          // Pop out retu
POP R2          // Pop out argu
POP R2          // ...
MOV [R0], R1    // Store the re
MOV R0, 10      // Preparing fo
PUSH R0         // ...
INT 7           // Invoking int
```

## Read

*Description*: Reads a word from a file to the variable passed as argument.
*System Call No*: 7
*Interrupt Routine No*: 3
*Arguments*: 1) fileDescriptor 2) wordRead
*Return Value*: 0 (success) and -1

(failure)

```
// APL program to invoke Read

integer main()
{
        integer a;
        string b;
        // Word read will be in b
        // Assume fileDescriptor=0
        a = Read(0,b);
        return 0;
}
```

```
//  Compiled XSM machine code


START
MOV SP, 1535    // Initializes
MOV BP, 1535    // Initializes
JMP 00008       // Jump to main

// main() function
//================
PUSH BP
MOV BP,SP
PUSH R0         // Space for 'a
PUSH R0         // Space for 'b
MOV R0, 1
MOV R1, BP
ADD R0, R1      // address of '
// Preparing for system calls
MOV R1, 0       // Pushing argu
PUSH R1         // ...
MOV R1, 2       // Pushing argu
MOV R2, BP      // ...
ADD R1, R2      // ...
MOV R1, [R1]    // ...
PUSH R1         // ...
PUSH R0         // Pushing spac
MOV R1, 7       // Pushing syst
PUSH R1         // ...
// invoking interrupt routine
INT 3           // Transfers co
// actions after interrupt rout
POP R2          // Pop out syst
MOV R1, 2       // Get the loca
MOV R2, BP      // ...
ADD R1, R2      // ...
POP R2          // Pop out the
// Argument 'b' was passed as r
POP R3          // Pop and save
MOV [R1], R3    // ...
MOV R1, R2      // Move return
POP R2          // Pop out argu
MOV [R0], R1    // Store the re
MOV R0, 10      // Preparing fo
PUSH R0         // ...
INT 7           // Invoking int
```

## Fork

*Description*: Replicates the process which invoked this system call in the memory.
*System Call No*: 8
*Interrupt Routine No*: 5
*Arguments*: None
*Return Value*: In the parent process, PID of the process created (success) or -1 (failure). In the child process, -2

```
// APL program to invoke Fork

integer main()
{
        integer a;
        a = Fork();
        return 0;
}
```

```
//  Compiled XSM machine code

START
MOV SP, 1535    // Initializes
MOV BP, 1535    // Initializes
JMP 00008       // Jump to main

// main() function
//================
PUSH BP
MOV BP,SP
PUSH R0         // Space for 'a
MOV R0, 1
MOV R1, BP
ADD R0, R1      // address of '
// Preparing for system calls
PUSH R0         // Pushing spac
MOV R1, 8       // Pushing syst
PUSH R1         // ...
// invoking interrupt routine
INT 5           // Transfers co
// actions after interrupt rout
POP R2          // Pop out syst
POP R1          // Pop out the
MOV [R0], R1    // Store the re
MOV R0, 10      // Preparing fo
PUSH R0         // ...
INT 7           // Invoking int
```

### Exec

*Description:* used to load and run a new process from a currently running process. The current process is overwritten by new process i.e. the process data structures and memory of the current process is used by the new process.
*System Call No*: 9
*Interrupt Routine No*: 6
*Arguments*: filename
*Return Value*: 0 (success) and -1 (failure)

```
// APL program to invoke Exec

integer main()
{
        integer a;
        a = Exec("File");
        return 0;
}
```

```
//  Compiled XSM machine code

START
MOV SP, 1535    // Initializes
MOV BP, 1535    // Initializes
JMP 00008       // Jump to main

// main() function
//================
PUSH BP
MOV BP,SP
PUSH R0         // Space for 'a
MOV R0, 1
MOV R1, BP
ADD R0, R1      // address of '
// preparing stack for system c
MOV R1, "File"  // Pushing argu
PUSH R1         // ...
PUSH R0         // Pushing spac
MOV R1, 9       // Pushing syst
PUSH R1         // ...
// invoking interrupt routine
INT 6           // Transfers co
// actions after interrupt rout
POP R2          // Pop out syst
POP R1          // Pop out retu
POP R2          // Pop out the
MOV [R0], R1    // Saving the r
MOV R0, 10      // Preparing fo
PUSH R0         // ...
INT 7           // Invoking int
```

## Exit

*Description*:

Terminate the execution of the process which invoked it. Exit removes this process from the memory. If there is only one process, it halts the system.
*System Call No*: 10
*Interrupt Routine No*: 7
*Arguments*: None
*Return Value*:-1 on failure, exits on success

```
// APL program to invoke Exit

integer main()
{
        Exit();
        return 0;
}
```

```
//  Compiled XSM machine code

START
MOV SP, 1535    // Initializes
MOV BP, 1535    // Initializes
JMP 00008       // Jump to main

// main() function
//================
PUSH BP
MOV BP,SP
// preparing stack for the syst
MOV R0, 10      // Pushing syst
PUSH R0         // ...
// invoking interrupt routine
INT 7           // Transfers co
// Ideally, it should exit this
POP R0          // Executed, on
MOV R0, 10      // Default Exit
PUSH R0         // ...
INT 7           // ...
```

## Getpid

*Description*: Gives the ProcessId of the process which invoked this system call.
*System Call No*: 11
*Interrupt Routine No*: 6
*Arguments*: None
*Return Value*: PID of the process which invoked the system call (success) or -1 (failure).

```
// APL program to invoke Getpid

integer main()
{
        integer a;
        a = Getpid();
        return 0;
}
```

```
//  Compiled XSM machine code

START
MOV SP, 1535    // Initializes
MOV BP, 1535    // Initializes
JMP 00008       // Jump to main

// main() function
//================
PUSH BP
MOV BP,SP
PUSH R0         // Space for 'a
MOV R0, 1
MOV R1, BP
ADD R0, R1      // address of '
// Preparing for system calls
PUSH R0         // Pushing spac
MOV R1, 11      // Pushing syst
PUSH R1         // ...
// invoking interrupt routine
INT 6           // Transfers co
// actions after interrupt rout
POP R2          // Pop out syst
POP R1          // Pop out the
MOV [R0], R1    // Store the re
MOV R0, 10      // Preparing fo
PUSH R0         // ...
INT 7           // Invoking int
```

## Getppid

*Description*: Gives the ProcessId of the parent process of the process which invoked this system call.
*System Call No*: 12
*Interrupt Routine No*: 6
*Arguments*: None
*Return Value*: PID of the parent process of the process which invoked the system call (success) or -1 (failure).

```
// APL program to invoke Getppid

integer main()
{
        integer a;
        a = Getppid();
        return 0;
}
```

```
//  Compiled XSM machine code

START
MOV SP, 1535    // Initializes
MOV BP, 1535    // Initializes
JMP 00008       // Jump to main

// main() function
//================
PUSH BP
MOV BP,SP
PUSH R0         // Space for 'a
MOV R0, 1
MOV R1, BP
ADD R0, R1      // address of '
// Preparing for system calls
PUSH R0         // Pushing spac
MOV R1, 12      // Pushing syst
PUSH R1         // ...
// invoking interrupt routine
INT 6           // Transfers co
// actions after interrupt rout
POP R2          // Pop out syst
POP R1          // Pop out the
MOV [R0], R1    // Store the re
MOV R0, 10      // Preparing fo
PUSH R0         // ...
INT 7           // Invoking int
```

## Wait

*Description*: The current process is blocked till the process with PID given as argument signals or

exits.
*System Call No*: 13
*Interrupt Routine No*: 7
*Arguments*: ProcessId
*Return Value*: 0 (Success) or -1 (Failure)

```
// APL program to invoke Wait

integer main()
{
        integer a;
        a = Wait(0);
        return 0;
}
```

```
//  Compiled XSM machine code

START
MOV SP, 1535    // Initializes
MOV BP, 1535    // Initializes
JMP 00008       // Jump to mai

// main() function
//================
PUSH BP
MOV BP,SP
PUSH R0         // Space for '
MOV R0, 1
MOV R1, BP
ADD R0, R1      // address of
// preparing stack for system
MOV R1, 0       // Pushing the
PUSH R1         // ...
PUSH R0         // Pushing spa
MOV R1, 13      // Pushing sys
PUSH R1         // ...
// invoking interrupt routine
INT 7           // Transfers c
// actions after interrupt rou
POP R2          // Pop out sys
POP R1          // Pop out ret
POP R2          // Pop out the
MOV [R0], R1    // Saving the
MOV R0, 10      // Preparing f
PUSH R0         // ...
INT 7           // Invoking in
```

## Signal

*Description*: All processes waiting for the current process are resumed.
*System Call No*: 14
*Interrupt Routine No*: 7
*Arguments*: None
*Return Value*: 0 (Success) or -1 (Failure)

```
// APL program to invoke Signal

integer main()
{
        integer a;
        a = Signal();
        return 0;
}
```

```
//  Compiled XSM machine code

START
MOV SP, 1535    // Initializes
MOV BP, 1535    // Initializes
JMP 00008       // Jump to main

// main() function
//================
PUSH BP
MOV BP,SP
PUSH R0         // Space for 'a
MOV R0, 1
MOV R1, BP
ADD R0, R1      // address of '
// Preparing for system calls
PUSH R0         // Pushing spac
MOV R1, 14      // Pushing syst
PUSH R1         // ...
// invoking interrupt routine
INT 7           // Transfers co
// actions after interrupt rout
POP R2          // Pop out syst
POP R1          // Pop out the
MOV [R0], R1    // Store the re
MOV R0, 10      // Preparing fo
PUSH R0         // ...
INT 7           // Invoking int
```

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