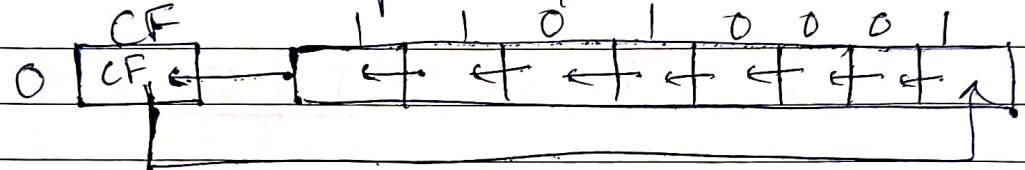
Rotate Left through Carry Instruction (RotateLC) RoLC

The bits of the destination are rotated left. The number of bits rotated is determined by the source operand. The bits rotated out of the most significant bit of the operand go to both the carry bit and the previous carry bit goes to the least significant bit of the operand.



CF ← 1 0 1 0 0 0 1 0 (ANS)

example

Program Control Instructions

Name	mnemonics
Branch	BR
Jump	JMP
Skip	SKP
Call	CALL
Return	RET
Compare (Subtract)	COMPARE
Test	Testbit

Call: It is used to call a subroutine in high level called Function, or assembly language called subroutine.

1000 : Call PL
1004 : Next Instruction.

1. stack(top) ← [PC] // Return address i.e 1004 is stored into the stack and then
2. PC ← Address of the subroutine // here it is represented by PL

Return : It is used to return from a subroutine.

PC ← stack[top] // Return address i.e 1004 is restored from the stack.

Compare : It is used to compare two numbers

Compare Src, dst → It is non destructive compare sub operation.

- performs the operation : [dst] - [src]
- sets the condition code flags based on the result obtained
- Neither of the operands is changed.

Example CMP # 10, R1
BR ≠ 0 L1

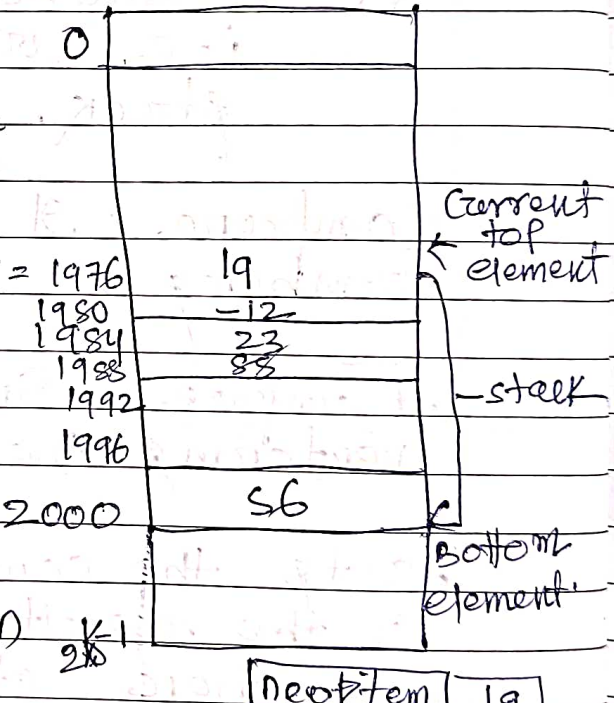
Test : Test instruction is used to check a particular bit Position value of the operand.

Test # bit position, operand.
performs non-destructive AND operation. (Flag, register affected)
Test #2, R1
• Neither of the operands is changed.

(STACK)

Assumption: The machine is byte addresable and each element in the stack occupies 4 Bytes]

Push operation:
• SP always points to the top element, so to push a newitem, first it has to be updated to the location, where a new element can be pushed.



• As stack grows downward in the memory, so first SP is decremented, then the NEWITEM is pushed.

Note: This rule is applicable for pushing any(all) element into the stack.

Subtract #4, SP
Move NEWITEM, (SP)

Pop operation:

- SP always points to the top element, so to pop an element, first, it has to be popped off, then the SP need to be updated to the next top element.
- As stack grows downward in the memory, so SP is incremented, after the top item is popped off.

```
MOV (SP), ITEM
ADD #, SP.
```
→ Move (SP)+, ITEM

Stack [Assumption: the stack is from 2000 to 1500]

Safe Push operation:

```
SAFEPUSH  Compare #1500, SP
          Branch <=0 FULLERROR
          Move NEWITEM, (-SP)
```

On a full stack, Push operation should not be done. So if the value of SP is 1500 or less than 1500, that means already the stack is full. Hence compare operation gives either 0 or a negative value after the operation. If SP is 1500, then next Push operation will be

done at 1496, which is not the part of the stack.

Safepop operation:

SAFEPOP compare #2000, SP
Branch >0 Emptyerror

From a empty stack, no element should be popped out. So, if the value of SP is greater than 2000, that mean already the stack is empty Hence Compare operation gives a +ve value after the operation.

(Subroutines.)

The way in which a computer makes it possible to call and return from subroutines is referred to as subroutine linkage method.

Linkage using Link Register —

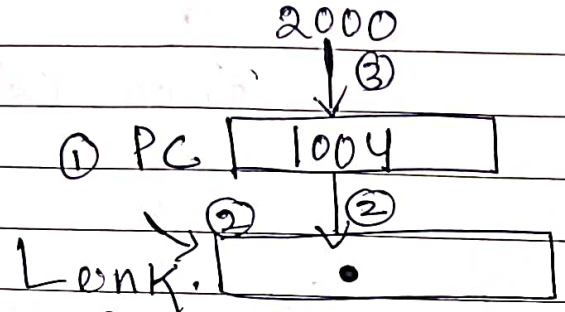
On call

1. Store the contents of the PC in the link register.
2. Branch to the target address specified by the instruction.

On returning from a subroutine

- Branch to the address contained in the link register.

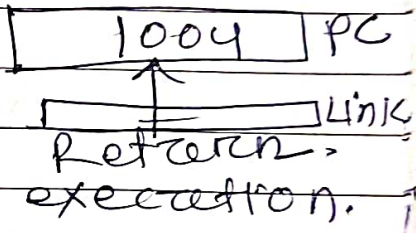
```
1000  CALL Sum.
1004  Next Instruction.
```



(when CALL instruction executed).

Same Eqv. 2000H

```
2000  First
      Instruction
       :
       :
      Return
```



Return execution.

Limitations ??

No support for Nesting of functions.

Limitations of Link Register

```
1020  call p
1024  Next Inst.
```

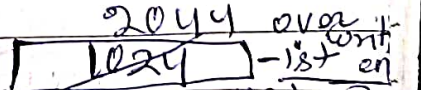
```
p
2000  Inst.
2040  call q
2044  Next Inst.
2070  Return.
```

```
q
3000  1st Inst of
      Inst.
      .
3050  Return
```

Note

There is a single Link register.

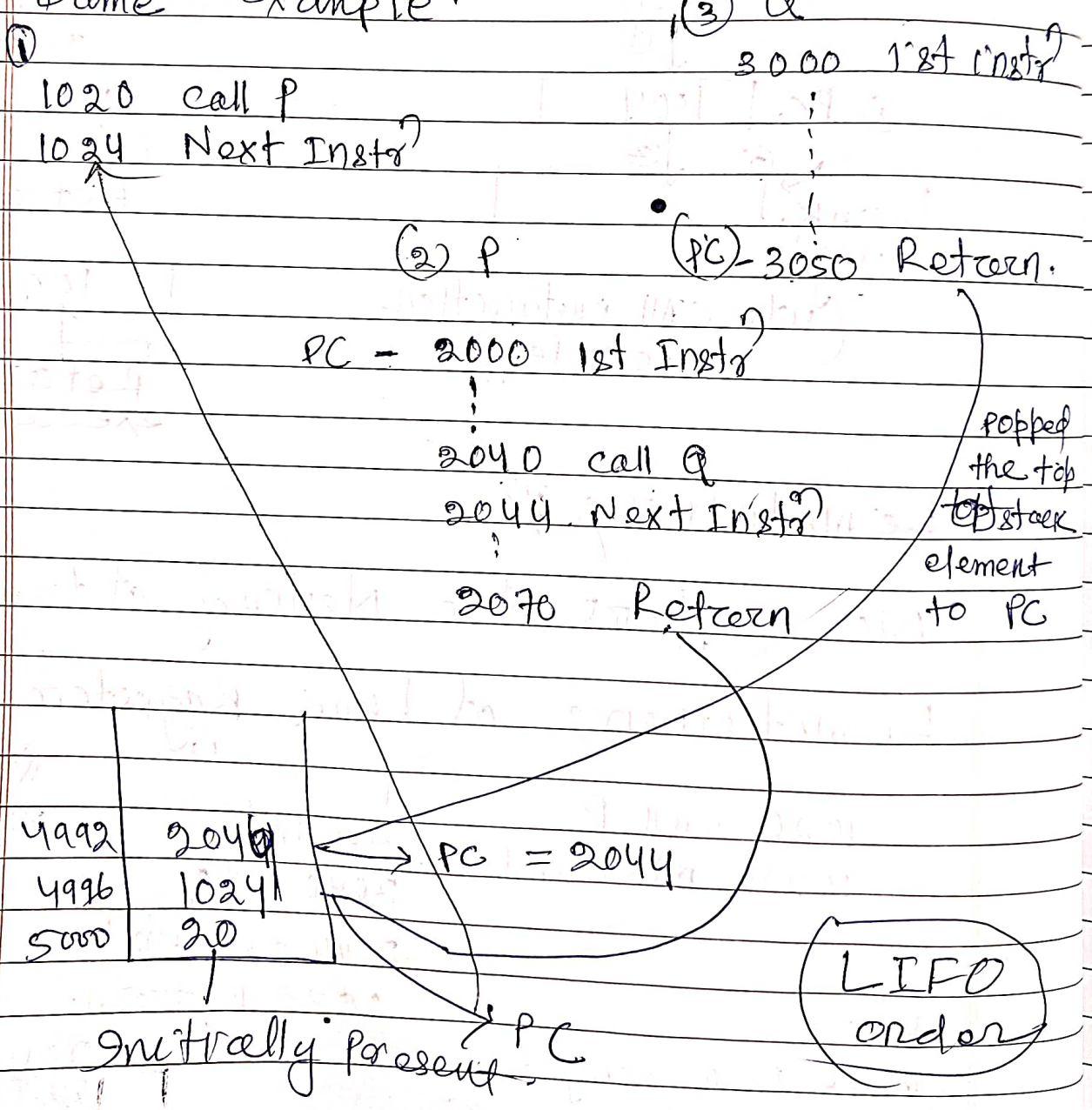
2044 over written in Link register



As a summery we can conclude that using link registers it is not possible to support subroutine nesting.
But calling a single subroutine Link register is OK.

Solution: Using Stack:

Same Example.



Stack as Subroutine Linkage Method.

Using stack: calling a function and returning from it.

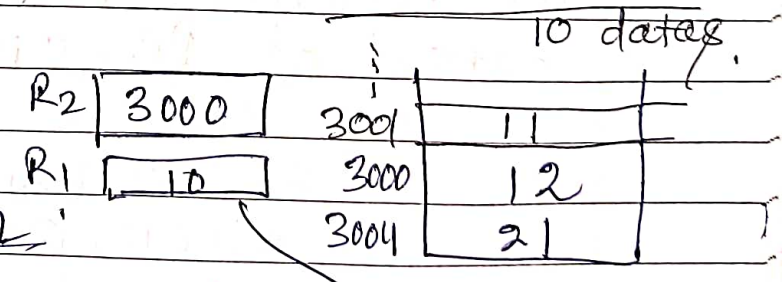
Assumptions.

- Parameters are passed through general purpose registers.
- Returning values through general purpose registers.

Example:

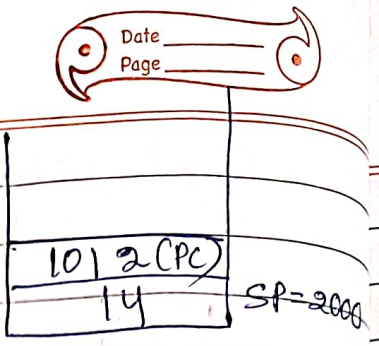
We are going to add N numbers stored in consecutive memory locations starting from the symbolic address NUM1 using a function. The function is going to return the summation result to the caller.

Solution



Calling Program:

```
1000    MOVE N, R1      ; N = counter
1004    MOVE #NUM1, R2.
1008    Call LISTADD
1012    MOVE R0, SUM
```



Subroutine:

LISTADD Clear R0
(PC) → LOOP ADD (R2)+, R0 ; [R0] = 0+12 = 12
Decrement R1
Branch >0 LOOP
Return ; PC ← 1012

The result is at R0.
We are moving here to location [Sum].

Numerical

(1) The content of the top memory stack is 2452. The content of SP is 1258. A two byte call subroutine instruction is located in memory address 1456 followed by address field of 5490 at location 1457. What are the content of PC, SP and top of stack
(1) Before call instruction execution.
(2) After call instruction execution.
(3) After return from subroutine.

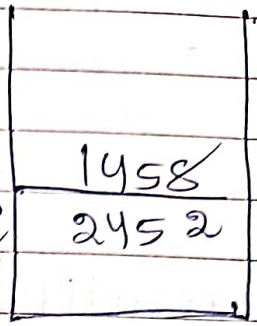
Ans

Given [1456] CALL [1457] Addr = 5490

[1458] Next Instr

Before call instruction execution.

(i) [PC] = 1456
[SP] = 1258
Top of stack (STACK[SP] = 2452.



(ii) After Call instruction execution.

Return address will be pushed onto the stack and PC will be loaded with the value of the address field of the call instr.

[PC] = 5490
[SP] = 1256
STACK [SP] = ~~2452~~ 1458

(iii) After Return from Subroutine.

Top stack content pointed by SP will be popped into PC to return back to the caller

[PC] = 1458
[SP] = 1258
STACK [SP] = 2452

2. How many times a subroutine should be called so that the stack becomes full. Assume that the stack address space ranges from 2000 to 1600 and each stack word consumes 4 bytes and machine is byte addressable. [Note No Parameter return value, registers, local variable are stored in the stack free to sub routine call.]

Solution:

2000 to 1600: no of memory locations = 400

- Each word on the stack occupies 4 Bytes, and the machine is byte addressable, meaning is that each byte will occupy one location.
- Each word in the stack occupies 4 locations.
- So in 400 locations, 400/4 = 100 words can be stored.
- So if we call a subroutine 100 number of times, the stack will become full.

3. Given the following Program fragment.

Main Program:	SUB1	SUB2:
2000 ADD R_1, R_2	3000 MOV R_1, R_2	4000 SUB R_6, R_1
2004 XOR R_3, R_4	3004 ADD R_5, R_1	4008 XOR R_1, R_5
2008 CALL SUB1	3008 CALL SUB2	4012 RETURN.
2012 SUB R_4, R_5	3012 Return.	

Initially the stack Pointer SP contains 5000 what are the content of PC, SP, and the top of the stack?

(i) After the subroutine call instruction is executed in the main Program?
(ii) After the subroutine call instruction is executed in the subroutine SUB1?
(iii) After the return from SUB2 subroutine?

Solution.

(i) After the Subroutine call instr? is executed-

- Given, [2008] CALL SUB1
  Given [2012] Next instr?.
- After call instruction will be pushed into the stack and PC will be loaded with the value of the address field of the call instr?.
  [PC] = 3000
  [SP] = 4996

SP=4992	3012
SP=4996	2012
5000	some value

STACK[SP] = 2012.

(ii) After the subroutine call instruction is executed in the subroutine SUB1?

Given [3008] CALL SUB2
[3012] Next Instr?

After call instruction execution in SUB1 Return address will be pushed onto the stack and PC will be loaded with the value of the address field of the call instr?

[PC] = 4004
[SP] = 4998
STACK[SP] = 3012.

(iii) After the return from SUB2 subroutine?

Given, [4012] RETURN

[PC] - 3012

After the return from SUB2 subroutine Top stack content pointed by SP will be popped into PC to return back to the Caller.

[SP] = 4996
STACK[SP] = 2012

4. The content of the top of the memory stack is 5000. The content of the stack pointer sp is 3000. Assume you want to organize a nested subroutine calls on a computer as follows:
The routine main calls a subroutine SUB1 by executing a two-word call subroutine instruction located in memory at address 1000 followed by the address of 6000 at location 1001. Again subroutine SUB1 calls another subroutine SUB2 by executing a two-word call subroutine instruction located in memory at address 6050 followed by the address field of 8000 at location 6051. What are the content of PC, SP and the top of the stack?

Solution

(i) After the subroutine call instruction is executed in the main routine?

Given the following Program fragment.

Main Program	SUB1 (6000)	SUB2
1000 call SUB1 (6000)	6050 CALL SUB2(8000)	8000 1st instr?
1002 Next instr?	6052 Next instr?	⋮
	6080 Return	8080 Return

Initially the stack Pointer contain 3000

Given [1000] CALL SUB1
[1002] Next instr?

(i) [PC] = 6000
[SP] = 2998
STACK [SP] = 1002.

SP=2996	6052
SP=2998	1002
SP=3000	5000

(ii) After the subroutine call instr? is executed in the subroutine SUB1?
Given [6050] call SUB2
[6052] Next Instr?

[PC] = 8000
[SP] = 2996
STACK [SP] = 6052.

(iii) After the return from SUB2 subroutine.?

Given, [8080] RETURN

[PC] = 6052
[SP] = 2998
STACK [SP] = 1002.

Stack as Subroutine Linkage Method [Parameter Passing and returning Value using stack]

When a large number of parameters are required to pass to a function, we may not have that many general purpose registers.

Solution —

- Parameter are passed onto the task before calling the function.
- Returning values through the stack.

Calling Program

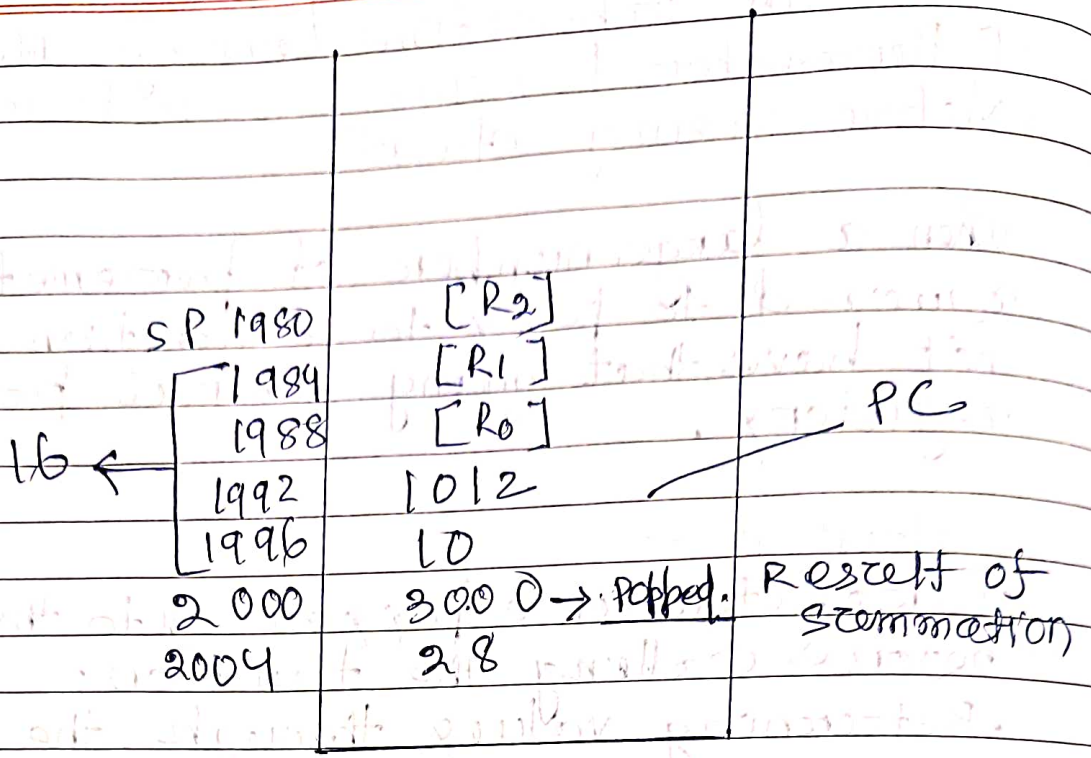
```
1000  MOVE  #NUM1, -(SP)
1004  MOVE  N, -(SP)
1008  Call  Listadd
1012  MOVE  4(SP), SUM
2016  ADD   #8, SP
```

Name of the function.

1992	1012 (Ret. addr)
1996	10 counter (N)
2000	3000 (Base addr) (NUM1)
2004	28

Subroutine:

```
Listadd   MOVE Multiple  R0-R2, -(SP)
          MOVE   16(SP), R1     ← R1 = 10
          MOVE   20(SP), R2     ← R2 = 3000
          CLEAR  R0
Loop      ADD    (R2)+, R0
          Decrement R1
          Branch>0 Loop
          MOVE   R0, 20(SP)
```



MoveMultiple (SP)+, R0-R2
RETURN.

Example-2

When a large number of Parameters are required to pass to a function, we may not have that many general purpose registers.

Q. Register R1 is used in a program to point to the top of a stack. Assume that each stack word consumes 4 bytes and machine is byte addressable. Write a sequence of instructions using the Index, Autoincrement and Autodecrement addressing modes to perform

each of the following tasks:

(a) Pop the top two items off the stack, add them, and the push the result into the task.
(b) copy the Fourth item from the top into the register R_2.
(c) Remove the top five items from the stack.

Solution:-

a) Move $(R_1)+, R_5$
ADD $(R_1)+, R_5$
Move $R_5, -(R_1)$

b) Move $16(R_1), R_2$

c) ADD #20, R_1

Numerical-

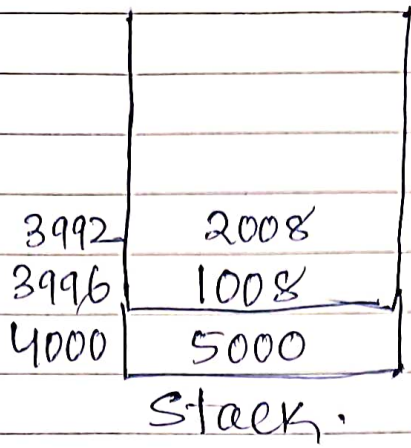
Suppose You want to organize a nested subroutine call for which all the instructions and its corresponding memory addresses are geven below. Here the main program makes a subroutine call named SUB1 and SUB1 makes another subroutine called named 'SUB2'. The content of the stack Pounter (SP) and TOS of memory stack is 4000 & 5000 respectively.

Main Program	SUB1	SUB2
1000 Add R_1, R_2	2000- SUB R_0, R_3	3000 MUL R_4, R_1
1004 Call SUB1	2004 Call SUB2	3004 DIV R_5, R_6
1008 Sub R_3, R_2	2008 MUL R_6, R_3	3008 Return.
1012 Return	2012 Return	

What is the content of PC, SP and TOS for the following.

1. After the subroutine Call instruction is executed in the main Program.
(ii) After the subroutine call instruction is executed in the subroutine SUB1
(iii) After return from the subroutine SUB2

Ans:



Stack.

Ans - After the subroutine call instruction is executed in the main Program.

[PC] = 2000
[SP] = 3996
Stack [SP] = 1008.

(ii) After the subroutine call instruction is executed in the subroutine SUB1.

[PC] = 3000
[SP] = 3992.
Stack [SP] = 2008.

(iii) After Return from the subroutine SUB2

[PC] = 2008.
[SP] = 3996
Stack [SP] = 1008