Stack and Frame Pointer Usages

Please send corrections (or suggestions) to youngwlim@hotmail.com.

This document was produced by using OpenOffice.

Based on

ARM assembler in Raspberry Pi
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http://thinkingeek.com/

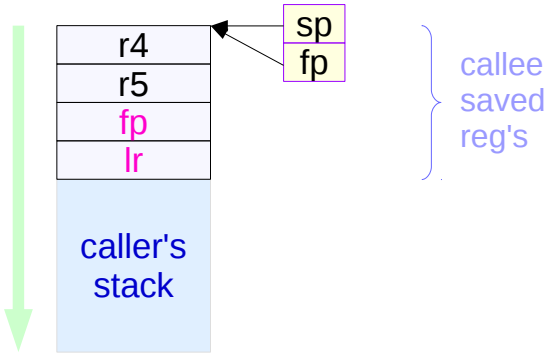
Callee Saved Registers

```
function:

push { r4, lr }    /* Keep the callee saved registers */
    code of the function
pop { r4, lr }             /* Restore the callee saved registers */
bx lr
/* Return from the function */
```

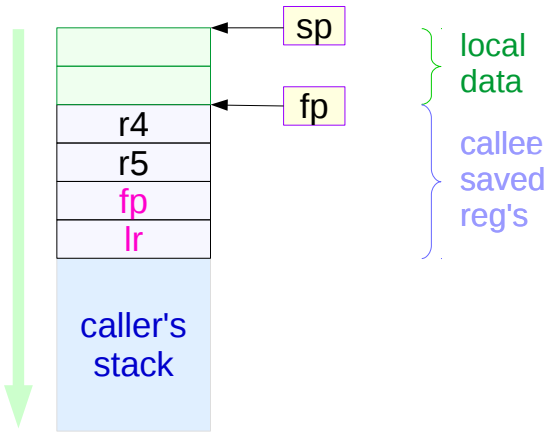
Dynamic Link

```
function:
push { r4, r5, fp, lr }
mov fp, sp                  /* fp ← sp . Keep dynamic link in fp */
    code of the function
mov sp, fp                  /* sp ← fp. Restore dynamic link in fp */
pop { r4, r5, fp, lr }
bx lr
```

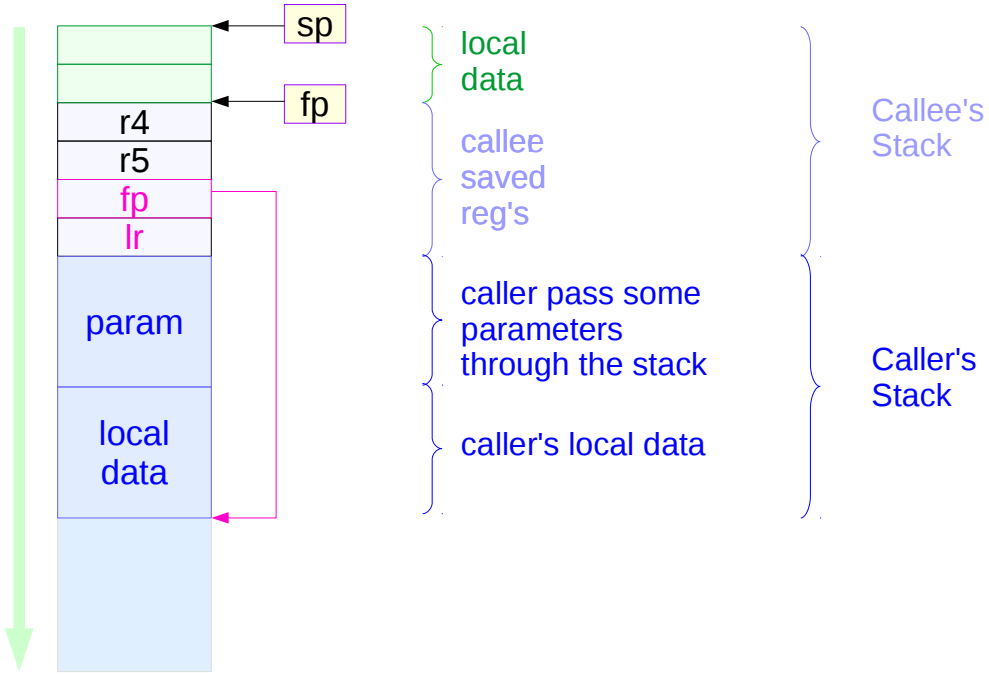


Local Data

```
function:
push { r4, r5, fp, lr }
sub sp, sp, #8          /* 8 bytes local data space */
mov fp, sp
   code of the function
mov sp, fp
pop { r4, r5, fp, lr }
bx lr
```



Local Data and Parameters



Local Data Generating Examples

```
void sq(int *c)
{
        (*c) = (*c) * (*c);
}
```

```
int sq_sum5(int a, int b, int c, int d, int e)
{
        sq(&a);
        sq(&b);
        sq(&c);
        sq(&d);
        sq(&e);
        return a + b + c + d + e;
}
```

callee function

- sq received a reference
- registers do not have an address
- allocate temporary local storage

```
…
    sq_sum5(1, 2, 3, 4, 5);
…
```

caller function

Callee Function Code (1)

```
sq_sum5:
push { fp, lr }
mov fp, sp
sub sp , sp , #16

str r0, [ fp, #-16 ]      *( fp - 16 ) ← r0
str r1, [ fp, #-12 ]      *( fp - 12 ) ← r1
str r2, [ fp, #-8 ]       *( fp -  8 ) ← r2
str r3, [ fp, #-4 ]       *( fp -  4 ) ← r3

mov sp , fp
pop { fp, lr }
bx lr
```

```
sq:
ldr r1, [ r0 ]            r1 ← ( *r0 )
mul r1, r1, r1            r1 ← r1 * r1
str r1, [ r0 ]            ( *r0 ) ← r1
bx lr
```

```
sub r0, fp, #16       r0 ← fp - 16
bl sq                 call sq ( &a )
sub r0, fp, #12       r0 ← fp - 12
bl sq                 call sq ( &b )
sub r0, fp, #8        r0 ← fp - 8
bl sq                 call sq ( &c )
sub r0, fp, #4        r0 ← fp - 4
bl sq                 call sq ( &d )
add r0, fp, #8        r0 ← fp + 8
bl sq                 call sq ( &e )


ldr r0, [ fp, #-16 ]  r0 ← *( fp - 16 ) :a
ldr r1, [ fp, #-12 ]  r1 ← *( fp - 12 ) :b
add r0, r0, r1        r0 ← r0 + r1
ldr r1, [ fp, #-8 ]   r1 ← *( fp - 8 )  :c
add r0, r0, r1        r0 ← r0 + r1
ldr r1, [ fp, #-4 ]   r1 ← *( fp - 4 )  :d
add r0, r0, r1        r0 ← r0 + r1
ldr r1, [ fp, #8 ]    r1 ← *( fp + 8 )  :e
add r0, r0, r1        r0 ← r0 + r1
```

Callee Function Code (2)

```
sq_sum5:
push { fp, lr }
mov fp, sp
sub sp , sp , #16

str r0, [ fp, #-16 ]      *( fp - 16 ) ← r0
str r1, [ fp, #-12 ]      *( fp - 12 ) ← r1
str r2, [ fp, #-8 ]       *( fp -  8 ) ← r2
str r3, [ fp, #-4 ]       *( fp -  4 ) ← r3


mov sp , fp
pop { fp, lr }
bx lr
```

At this point the stack looks like this

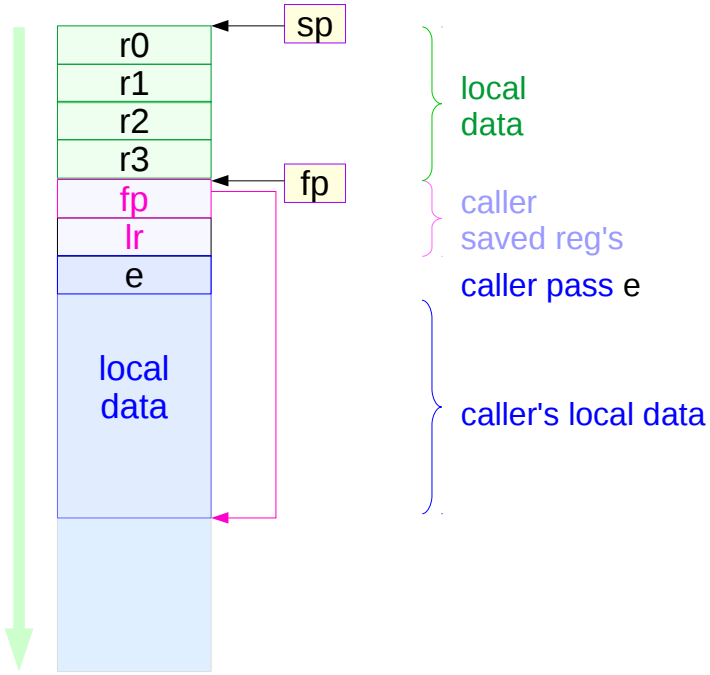
| Value | Address (es)

r0	[fp, #-16] ,	[sp]	local data
r1	[fp, #-12] ,	[sp , #4]	
r2	[fp, #-8] ,	[sp , #8]	
r3	[fp, #-4] ,	[sp , #12]	
fp	[fp] ,	[sp , #16]	callee saved registers
lr	[fp, #4] ,	[sp , #20]	
e	[fp, #8] ,	[sp , #24]	caller pass e parameters

v

Higher addresses

Callee Function Code (3)



At this point the stack looks like this

| Value | Address (es)

```
+--------+-------------------+-------------
|    r0 |   [ fp, #-16 ] ,     [sp]
|    r1 |   [ fp, #-12 ] ,     [sp , #4 ]
|    r2 |   [ fp, #-8 ] ,      [sp , #8 ]
|    r3 |   [ fp, #-4 ] ,      [sp , #12 ]
|    fp |   [ fp ] ,           [sp , #16 ]
|    lr |   [ fp, #4 ] ,       [sp , #20 ]
|     e |   [ fp, #8 ] ,       [sp , #24 ]
v
```

Higher
addresses

local
data

callee saved
registers

caller pass
e parameters

Caller Function Code

```
.data
.align 4

message:
.asciz "Sum of 1^2 + 2^2 + 3^2 + 4^2 +
5^2 is %d\n"

.text

sq: <<defined above>>
sq_sum5: <<defined above>>

.globl main
main:

push { r4, lr }

pop { r4, lr }

bx lr
```

```
mov r0, #1      a ← 1
mov r1, #2      b ← 2
mov r2, #3      c ← 3
mov r3, #4      d ← 4

mov r4, #5      r4 ← 5

sub sp , sp , #8
str r4, [sp]    e ← 5

bl sq_sum5      sq_sum5 ( 1, 2, 3, 4, 5 )

add sp , sp , #8

mov r1, r0
ldr r0, address_of_message

bl printf

address_of_message: . word message
```

APCS Register Use Convention

R11	fp	Frame Pointer
R12	ip	Scratch register / specialist use by linker
R13	sp	Lower end of current stack frame
R14	lr	Link address / scratch register
R15	pc	Program coutner

LR and FP Registers

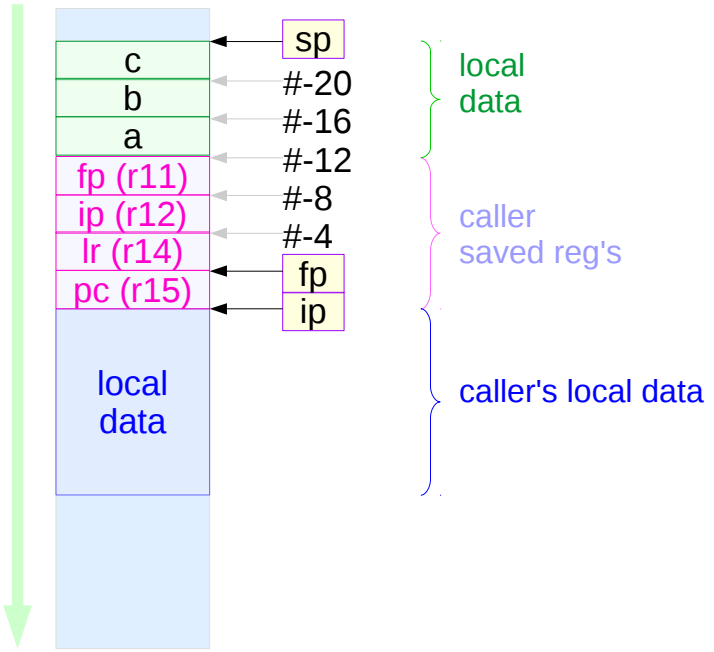
SP where the stack is
FP where the stack was

PC where you are
LR where you were

http://stackoverflow.com/questions/15752188/arm-link-register-and-frame-pointer

-fno-omit-frame-pointer

```
main:
mov     ip, sp
stmfd   sp!, { fp, ip, lr, pc }
sub     fp, ip, #4
sub     sp, sp, #12
ldr     r2, [fp, #-16]
ldr     r3, [fp, #-20]
add     r3, r3, r2
str     r3, [fp, #-24]
sub     sp, fp, #12
ldmfd   sp, {fp, sp, pc}
```

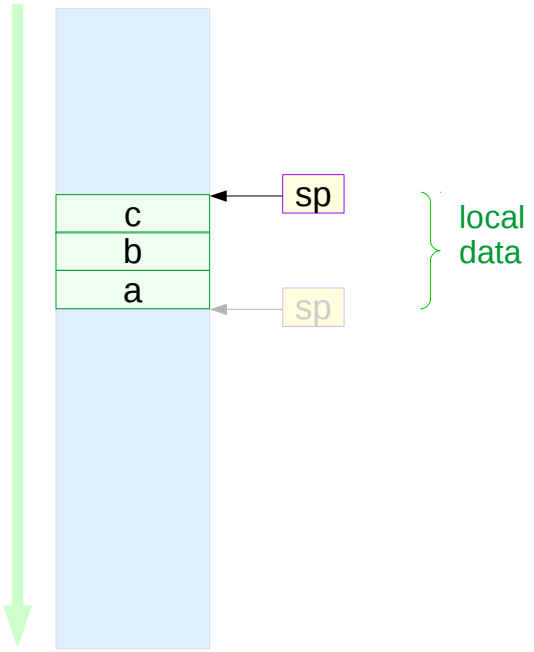



```
main()
{
  volatile int a, b, c;
  c = a + b;
}
```

https://community.arm.com/thread/7092

-fomit-frame-pointer

```
main:
sub     sp, sp, #12
ldr     r2, [sp, #8]
ldr     r3, [fp, #4]
add     r3, r3, r2
str     r3, [sp, #0]
sub     sp, sp, #12
```




```
main()
{
  volatile int a, b, c;
  c = a + b;
}
```

https://community.arm.com/thread/7092

Trigger.c

References

[1] http://wiki.osdev.org/ARM_RaspberryPi_Tutorial_C
[2] http://blog.bobuhiro11.net/2014/01-13-baremetal.html
[3] http://www.valvers.com/open-software/raspberry-pi/
[4] https://www.cl.cam.ac.uk/projects/raspberrypi/tutorials/os/downloads.html