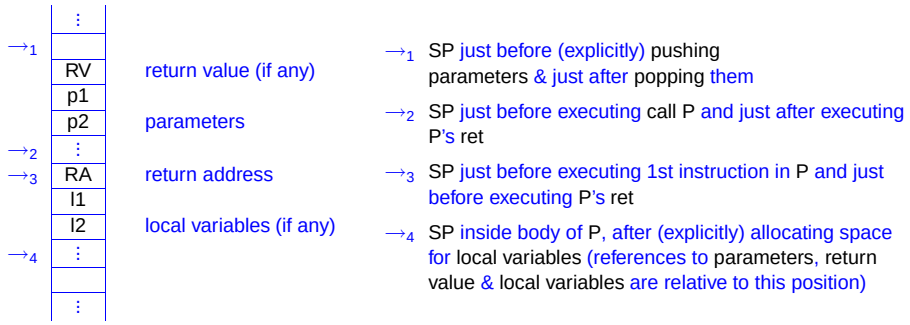
Procedure Calls and Address Parameters in PeANUt

- ref: [PeANUt Spec, sect 4]
- procedure calls
  - with local variables
  - with return values (non-void functions)
- address parameters
  - ability to modify data
  - indirect memory reference via pointers
- assembly coding style
- other issues:
  - Peanut@Home news!

Procedure Calls: Revision

- recall the procedure call convention determines the order of contents of the stack frame
- example C function declaration:

```
int P(int p1, int p2, ...) {
  int l1, l2, ...;
  ...
}
```



Procedure Calls: Key Ideas

- call convention is needed so that caller and procedure can *agree* (on *where* to exchange data)
- role of the stack for RV, parameters & RA
- *symmetric* use of SP
- common errors:
  - using the wrong mode when pushing parameters
  - forgetting to allocate RV slot for non-`void` functions
  - having SP 1 beyond the last parameter before executing call
  - not popping same number of slots after the `call` instruction
- different from macros: procedure definition & calls remain in `.img` file
- for procedures, machine needs SP, `!`, `call` and `ret`

Procedure call – Example with Two Local Variables (1)

```
                        ; /* WriteInt(x,  4) = printf( "%4d", x) */
                        ; /* WriteInt(x, -4) = printf("%-4d", x) */
                        ;  void WriteInt(
        x       = -4    ;    int x,
        n       = -3    ;    unsigned int n) {
                        ;                    /* what is at !-2? */
        NSp     = -1    ;    int NSp;       /* # of ' 's to print */
        aX      =  0    ;    unsigned int aX;/* = |x| */
        Nlocs   =  2    ;
WriteInt:               ;
        incsp   #Nlocs  ;                    /* SP=SP+2 */
        load    !n      ;    Nsp = n - 1;    /* AC=Mem[SP-3] */
        sub     #1      ;                    /* AC=AC-1 */
        store   !Nsp    ;                    /* Mem[SP-1]=AC */
        ...
        incsp   #-Nlocs ;  } /*WriteInt()*//* SP=SP-2 */
        ret             ;                    /* PC=Mem[SP]; SP=SP-1 *
        ...
```

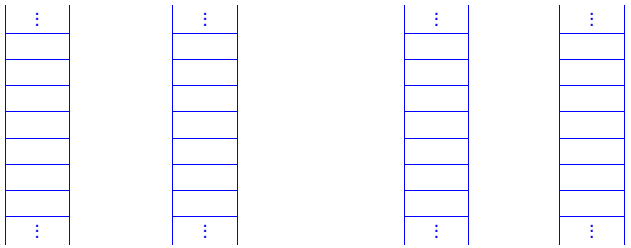
Procedure `WriteInt()` is available in module InOut.ass

(`WriteHex()` can be used similarly to print `x` as an unsigned hex number)

Procedure Call – Example with Two Local Variables (2)

call-writeint.ass:

```
                        ;     WriteInt(n, 6); /*=printf("%6d", n);*/
        load    n       ;     /* Push(n) */   /* AC=Mem[n] */
        incsp   #1      ;                     /* SP=SP+1 */
        store   !0      ;                     /* Mem[SP]=AC */
        load    #6      ;     /* Push(#6) */  /* AC=6 */
        incsp   #1      ;                     /* SP=SP+1 */
        store   !0      ;                     /* Mem[SP]=AC */
        call    WriteInt;                     /* SP=SP+1; Mem[SP]=PC;
                        ;                        PC=WriteInt */
        incsp   #-2     ;     /* Pop(2) */    /* SP=SP-2 */
```



Non-void Functions in PeANUt

- we implement local variables via the stack
  - good: economy, privacy, recursion and sharable, re-entrant code and multithread-safe
  - bad: we don't have stack-indexed (or stack-indirect) addressing modes in PeANUt
- inside procedures:
  - we have to increment the SP by number of local variables just after entry (first instruction within procedure)
  - and decrement SP by number of local variables just before (each) `ret`
  - parameters, local variables and return values (RVs) have stack offsets
- non-void function call is similar, but it must first make (empty) slot for the return value, which gets accessed after call before it is popped

Non-void Function – Example with One Return Value (1)

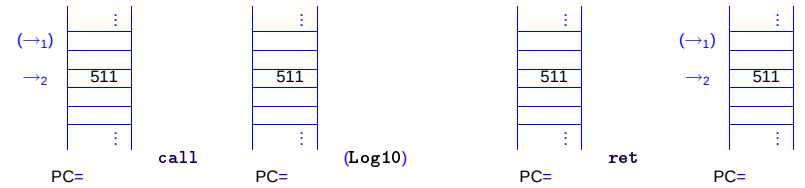
```
        RV      = -3    ;  int Log10(
        x       = -2    ;    unsigned int x) {
                        ;
        Logx    = 0     ;    unsigned int Logx;
        NLocs   = 1     ;
Log10:                  ;
        incsp   #NLocs  ;                      /* SP=SP+1 */
        load    !x      ;    if (x != 0) {     /* AC=Mem[SP-2] */
        cmp     #0      ;                      /* compare AC,0 */
        beq     Lendif  ;
        ...
Lendif:                 ;    } /* if */
        load    !Logx   ;    return Logx;      /* AC=Mem[SP] */
        store   !RV     ;                      /* Mem[SP-3]=AC */
        incsp   #-NLocs ;  } /*Log10()*/       /* SP=SP-1 */
        ret             ;                      /* PC=Mem[SP]; SP=SP-1
        ...
```

Procedure `Log10()` is available in module InOut.ass

Non-void Function – Example with One Return Value (2)

call-log10.ass:

```
                        ;     log = Log10( 511 );
        incsp   #1      ;        /* SP=SP+1 */      /* make RV slot */
        Push    (#511)  ;        /* AC=511; SP=SP+1; Mem[SP]=AC */
        call    Log10   ;        /* SP=SP+1; Mem[SP]=PC; PC=Log10 */
        Pop     (1)     ;        /* SP=SP-1 */
        load    !0      ;        /* AC=Mem[SP] */   /*store RV*/
        store   log     ;        /* Mem[Log]=AC */
        incsp   #-1     ;        /* SP=SP-1 */      /*pop RV slot*/
```



Address Parameters in PeANUt

- in general there are two different types of parameters: value (local copy) and reference (pointers)
- full power of the procedure concept requires the ability to modify data (parameters)
- do via passing address (not value) on stack when calling
- procedures thus reference the *real* memory location indirectly via this pointer

Address Parameters – Example (1)

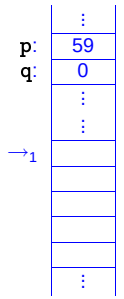
```
                        ;  void Sum(
        a       = -3    ;    int a,
        b       = -2    ;    int b,
        c       = -1    ;    int *c) {
Sum:                    ;
        load    !c      ;    *c = a + b;
        storexr         ;            /* XR=Mem[SP+c] */
        load    !a      ;            /* AC=Mem[SP+a] */
        add     !b      ;            /* AC=AC+Mem[SP+b] */
        store   *0      ;            /* Mem[XR]=AC */
        ret             ;  } /* Sum() */
```

Code is in address-procedure-example.ass

Address Parameters – Example (2)

```
                        ;  int
p:      block   1       ;    p,
q:      block   1       ;    q;
main:                   ;
        load    #59     ;  p = 59;
        store   p       ;
                        ;  Sum(5, p, &q);
        load    #5      ;     /* Push(5); */
        incsp   #1      ;
        store   !0      ;
        load    p       ;     /* Push(p) */
        incsp   #1      ;
        store   !0      ;
        loada   q       ;     /* Pusha(q) */
        incsp   #1      ;
        store   !0      ;
        call    Sum     ;
        incsp   #-3     ;     /* Pop(3) */
        trap    #1      ;  return 0;
```


Address Parameters – Example (3)



- copy address parameter stack slot to XR, then access memory location via *0

Address Parameters – Arrays

- for array parameters, put address *plus* index value in XR
- an address parameter is a pointer to a memory location that the procedure may modify (unfortunately (?), we cannot use @ indirect mode)
- example (from InOut.ass):

```
                            ;  void WriteString(
        s       = -2        ;    char s[]) { /* same as char *s */
                            ;
        i       = 0         ;    int i;
        NumLocs = 1         ;
WriteString:                ;
        incsp   #NumLocs    ;
        ...
        load    !s          ;    printf("%c", s[i]);
        add     !i          ;
        storexr             ;        /* XR = Mem[SP+s]+Mem[SP+i] */
        load    *0          ;
        trap    #3          ;        /* Put */
        ...
```


Coding Style

- use C code to make things clearer
  - often line-by-line correspondence with assembly code
  - short comment for each important variable declaration
  - properly indented (2 spaces)
  - syntactically correct
  - use symbolic constants for both
- macros: sensibly chosen; well commented when defined
- algorithm:
  - simple is beautiful
  - no unnecessary output (like prompts)
  - own procedures (if any) should not use global variables
- assembly code:
  - properly indented
  - keep identifiers as meaningful as possible (in 6 letters)
  - beware of optimisations
  - no spaghetti code!

Appendix: Calling from Procedures with a Single Stack Pointer

- a problem! See printshex.ass. Soln 1: see **`WriteInt()`** from InOut.ass. Alt.:

```
NSp     = -1    ;       /* Q: how does given code ...
aX      = 0     ;          ... in InOut.ass avoid ...
NSpm1   = -2    ;          ... this problem? */
aXm1    = -1    ;
...
incsp   #1      ;    Nsp = Nsp - Log10( aX );
load    !aXm1   ;       /* !aX-1 points to same
incsp   #1      ;          mem location as !aX
store   !0      ;          did before 1st incsp */
call    Log10   ;
incsp   #-1     ;
load    !Nspm1  ;       /* similarly for NSp */
sub     !0      ;       /* RV of Log10 */
store   !Nspm1  ;
incsp   #-1     ;       /* Q: what if this was omitted? */
```

- alt., we can get the required value into AC before moving SP:

```
load    !aX     ;    Nsp = Nsp + -1 * Log10( aX );
incsp   !2      ;       /* works because we only
store   !0      ;          have to push one value */
call    Log10   ;
load    !-1     ;       /* RV */
mul     #-1     ;
incsp   !-2     ;
add     !NSp    ;
store   !NSp    ;
```