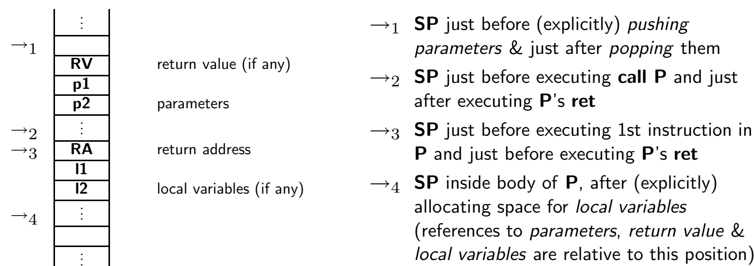
Procedure calls and address parameters in PeANUt

- 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
- Reference:
  - Specification of the PeANUt computer (Section 4)

Procedure calls (1)

- The *procedure call convention* is given by the **stack frame**
  Example C function declaration:

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



Procedure calls (2)

- *Call convention* 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** function
  - Having **SP** 1 beyond the last *parameter* before executing **call**
  - Not *popping* same number of *slots* after the **call** instruction
- For procedures, machine needs **SP**, **!**, **call** and **ret**

Procedure call – Example with two local variables (1)

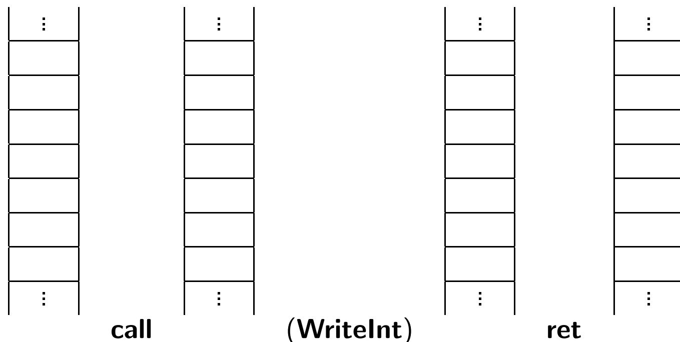
```
                        ;  void WriteInt(
        x       = -4    ;    int x,
        n       = -3    ;    unsigned int n) {
                        ;                      /* what is at !-2? */
        NSp     = -1    ;    int NSp;          /* # of ' 's to print */
        aX      =  0    ;    unsigned 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**

Procedure call – Example with two local variables (2)

```
...
                ;  WriteInt(n, 6);
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 */
```


Procedure call – Example with two local variables (3)



Non-void functions in PeANUt

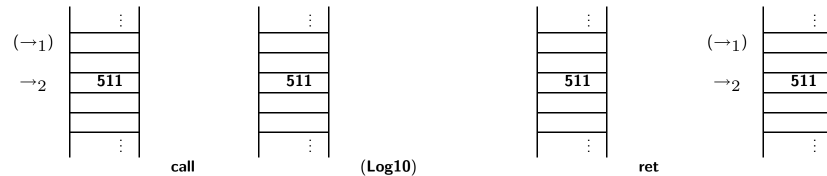
- We implement local variables via the stack
  - Good: Economy, privacy, recursion and sharable
  - Bad: We don't have stack-indirect or stack-indexed addressing modes in PeANUt
- Inside procedures
  - We have to increment the **SP** by number of local variables just after entry (first instruction within procedure)
  - Decrement **SP** by number of local variables just before (each) **ret**
  - Parameters, local variables and return values (**RV**s) 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 */
        ...
```

Non-void function – Example with one return value (2)

```
log:    block  1       ;  int log;
                       ;  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*

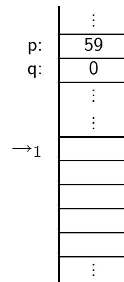
Address parameters – Example (1)

```
                        ;  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-3] */
        add      !b     ;           /* AC=AC+Mem[SP-2] */
        store    *0     ;           /* Mem[XR]=AC */
        ret             ;  } /* Sum() */
        ...
```


Address parameters – Example (2)

```
                        ;  int
p:      block    1      ;    p,
q:      block    1      ;    q;
        ...
                        ;    Sum( 5, p, &q);
        load     #5     ;      /* Push(5); */
        incsp    #1     ;
        store    !0     ;
        load     p      ;      /* Push(p) */
        incsp    #1     ;
        store    !0     ;
        loada    q      ;      /* Push(address q) */
        incsp    #1     ;
        store    !0     ;
        call     Sum    ;
        incsp    #-3    ;      /* Pop(3) */
```

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:

```
                        ;  void WriteString(
        s       = -2    ;    char s[]) { /* same as char *s */
                        ;
        i       = 0     ;    int i;
WriteString:            ;
        incsp   #1      ;
        ...
        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
- Macros
  - Sensibly chosen
  - Well commented when define

More on coding style

- Algorithm
  - Simple is beautiful
  - No unnecessary output (like prompts)
  - Don't bother checking input
  - Own procedures (if any) must not use global variables
- Assembly code
  - Properly indented
  - Keep identifiers as meaningful as possible (in 6 letters)
  - Beware of optimisations
  - No spaghetti code