

Lecture 7: Subroutines and stack frames

- **Parameter passing through the stack**
 - An example
- **Local variables and the stack frame**
- **LINK and ULNK instructions**
- **Parameter passing through stack frames**
 - An example
- **The need for dynamic allocation**



Parameter passing through the stack

- **The stack can be used to pass parameters to a subroutine**
 - Main function and subroutine must agree on the order in which parameters are pushed on the stack
- **The advantages of passing parameters through the stack are**
 - The stack has no limits other than physical memory bounds
 - Subroutines can be re-entrant and recursive
- **WARNING!!!: Any parameters MANUALLY pushed on the stack must be pushed off the stack MANUALLY afterwards to ensure consistency**



An example: parameter passing through the stack

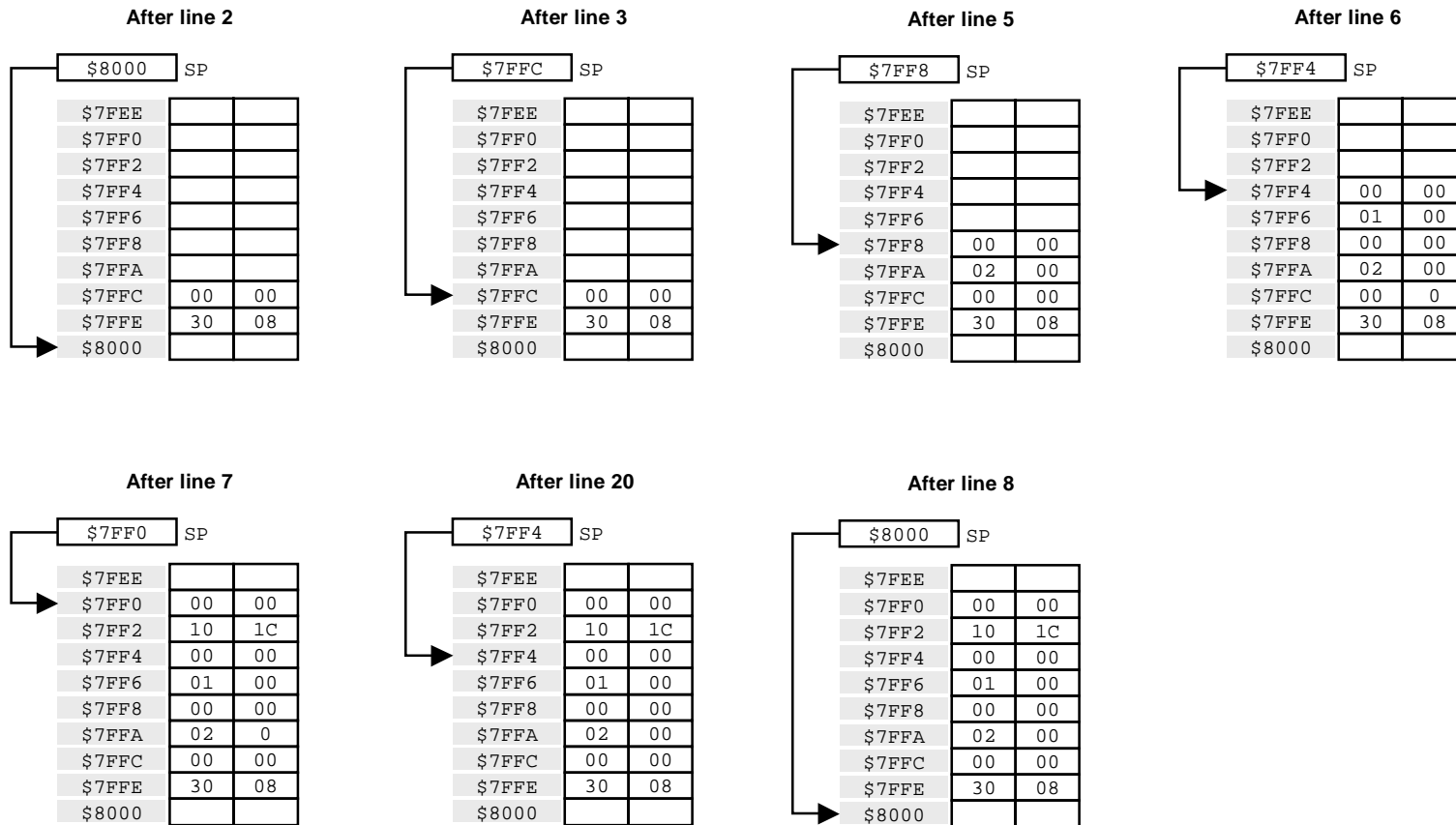
■ Compute the sum of squares of two numbers

$$[M(\text{RESULT})] \leftarrow \text{DATA1}^2 + \text{DATA2}^2$$

```
00001000      1          ORG          $1000          ;Main function section
00001000  2E7C 00008000  2          MOVE.L      #$8000,SP      ;Set up the stack pointer
00001006  4879 00003008  3          PEA          RESULT      ;Pass addr. of RESULT thru stack
                                4          ;Similar to MOVE.L #RESULT,-(SP)
0000100C  2F39 00003000  5          MOVE.L      DATA1,-(SP) ;Pass DATA1 through stack
00001012  2F39 00003004  6          MOVE.L      DATA2,-(SP) ;Pass DATA2 through stack
00001018  6100 0FE6          7          BSR          SUMQSR      ;Call subroutine
0000101C  4FEF 000C          8          LEA          12(SP),SP    ;Restores the stack pointer
00001020  4E75          9          RTS          ;End program execution
                                10
00002000      11          ORG          $2000          ;Subroutine
00002000  43EF 0004          12 SUMQSR    LEA          4(SP),A1    ;Get starting address of params
00002004  4CD9 0103          13          MOVEM.L     (A1)+,D0-D1/A0    ;DATA1 goes to D0
                                14          ;DATA2 goes to D1
                                15          ;address of RESULT goes to A0
00002008  C1C0          16          MULS       D0,D0          ;D0 = D0 * D0
0000200A  C3C1          17          MULS       D1,D1          ;D1 = D1 * D1
0000200C  D280          18          ADD.L      D0,D1          ;D1 = D0 + D1
0000200E  2081          19          MOVE.L     D1,(A0)        ;Save result to RESULT
00002010  4E75          20          RTS
                                21
00003000      22          ORG          $3000          ;Data section
00003000  00000200          23 DATA1    DC.L          $200
00003004  00000100          24 DATA2    DC.L          $100
00003008          25 RESULT    DS.L          1
0000300C          26          END
```



Evolution of the stack



Run on sim68k

MC68000/ECB Simulator.

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Version 2.3

SIM68000 2.3 > LO L7A.S

SIM68000 2.3 > .PC 1000

SIM68000 2.3 > DF

```
PC=00001000 SR=0000=.0..... US=00007000 SS=00007E00
D0=27869CFC D1=85754C53 D2=CC82724D D3=5DB78C66
D4=DBD35416 D5=685193CD D6=C0625BF1 D7=B9F097E4
A0=A1ACCB8F A1=99E39415 A2=B495930D A3=42089F51
A4=36B99A35 A5=585C3485 A6=CAE09383 A7=00007000
-----00001000 2E7C 00008000 MOVE.L #00008000,A7
```

SIM68000 2.3 > T

```
PC=00001006 SR=8000=T.0..... US=00008000 SS=00007E00
D0=27869CFC D1=85754C53 D2=CC82724D D3=5DB78C66
D4=DBD35416 D5=685193CD D6=C0625BF1 D7=B9F097E4
A0=A1ACCB8F A1=99E39415 A2=B495930D A3=42089F51
A4=36B99A35 A5=585C3485 A6=CAE09383 A7=00008000
-----00001006 4879 00003008 PEA $00003008
```

SIM68000 2.3 > MD 7FE0 20

```
007FE0 7D C0 0B 08 56 8B 47 11 F7 D8 F7 06 00 D8 83 DA
007FF0 89 08 46 89 46 8B 06 56 7D C0 0B 0C 56 8B 47 11
```

SIM68000 2.3 > T

```
PC=0000100C SR=8000=T.0..... US=00007FFC SS=00007E00
D0=27869CFC D1=85754C53 D2=CC82724D D3=5DB78C66
D4=DBD35416 D5=685193CD D6=C0625BF1 D7=B9F097E4
A0=A1ACCB8F A1=99E39415 A2=B495930D A3=42089F51
A4=36B99A35 A5=585C3485 A6=CAE09383 A7=00007FFC
-----0000100C 2F39 00003000 MOVE.L $00003000,-(A7)
```

SIM68000 2.3 > MD 7FE0 20

```
007FE0 7D C0 0B 08 56 8B 47 11 F7 D8 F7 06 00 D8 83 DA
007FF0 89 08 46 89 46 8B 06 56 7D C0 0B 0C 00 00 30 08
```

SIM68000 2.3 > T

```
PC=00001012 SR=8000=T.0..... US=00007FF8 SS=00007E00
D0=27869CFC D1=85754C53 D2=CC82724D D3=5DB78C66
D4=DBD35416 D5=685193CD D6=C0625BF1 D7=B9F097E4
A0=A1ACCB8F A1=99E39415 A2=B495930D A3=42089F51
A4=36B99A35 A5=585C3485 A6=CAE09383 A7=00007FF8
-----00001012 2F39 00003004 MOVE.L $00003004,-(A7)
```

SIM68000 2.3 > MD 7FE0 20

```
007FE0 7D C0 0B 08 56 8B 47 11 F7 D8 F7 06 00 D8 83 DA
007FF0 89 08 46 89 46 8B 06 56 00 00 02 00 00 00 30 08
```

SIM68000 2.3 > T

```
PC=00001018 SR=8000=T.0..... US=00007FF4 SS=00007E00
D0=27869CFC D1=85754C53 D2=CC82724D D3=5DB78C66
D4=DBD35416 D5=685193CD D6=C0625BF1 D7=B9F097E4
A0=A1ACCB8F A1=99E39415 A2=B495930D A3=42089F51
A4=36B99A35 A5=585C3485 A6=CAE09383 A7=00007FF4
-----00001018 6100 0FE6 BSR $002000
```

SIM68000 2.3 > MD 7FE0 20

```
007FE0 7D C0 0B 08 56 8B 47 11 F7 D8 F7 06 00 D8 83 DA
007FF0 89 08 46 89 00 00 01 00 00 00 02 00 00 00 30 08
```

SIM68000 2.3 > T

```
PC=00002000 SR=8000=T.0..... US=00007FF0 SS=00007E00
D0=27869CFC D1=85754C53 D2=CC82724D D3=5DB78C66
D4=DBD35416 D5=685193CD D6=C0625BF1 D7=B9F097E4
A0=A1ACCB8F A1=99E39415 A2=B495930D A3=42089F51
A4=36B99A35 A5=585C3485 A6=CAE09383 A7=00007FF0
-----00002000 43EF 0004 LEA $0004(A7),A1
```

SIM68000 2.3 >

```
007FE0 7D C0 0B 08 56 8B 47 11 F7 D8 F7 06 00 D8 83 DA
007FF0 00 00 10 1C 00 00 01 00 00 00 02 00 00 00 30 08
```

SIM68000 2.3 > T

```
PC=00002004 SR=8000=T.0..... US=00007FF0 SS=00007E00
D0=27869CFC D1=85754C53 D2=CC82724D D3=5DB78C66
D4=DBD35416 D5=685193CD D6=C0625BF1 D7=B9F097E4
A0=A1ACCB8F A1=00007FF4 A2=B495930D A3=42089F51
A4=36B99A35 A5=585C3485 A6=CAE09383 A7=00007FF0
-----00002004 4CD9 0103 MOVEM.L (A1)+,D0-D1/A0
```

SIM68000 2.3 > T

```
PC=00002008 SR=8000=T.0..... US=00007FF0 SS=00007E00
D0=00000100 D1=00000200 D2=CC82724D D3=5DB78C66
D4=DBD35416 D5=685193CD D6=C0625BF1 D7=B9F097E4
A0=00003008 A1=00008000 A2=B495930D A3=42089F51
A4=36B99A35 A5=585C3485 A6=CAE09383 A7=00007FF0
-----00002008 C1C0 MULS D0,D0
```

SIM68000 2.3 > T

```
PC=0000200A SR=8000=T.0..... US=00007FF0 SS=00007E00
D0=00010000 D1=00000200 D2=CC82724D D3=5DB78C66
D4=DBD35416 D5=685193CD D6=C0625BF1 D7=B9F097E4
A0=00003008 A1=00008000 A2=B495930D A3=42089F51
A4=36B99A35 A5=585C3485 A6=CAE09383 A7=00007FF0
-----0000200A C3C1 MULS D1,D1
```

SIM68000 2.3 > T

```
PC=0000200C SR=8000=T.0..... US=00007FF0 SS=00007E00
D0=00010000 D1=00040000 D2=CC82724D D3=5DB78C66
D4=DBD35416 D5=685193CD D6=C0625BF1 D7=B9F097E4
A0=00003008 A1=00008000 A2=B495930D A3=42089F51
A4=36B99A35 A5=585C3485 A6=CAE09383 A7=00007FF0
-----0000200C D280 ADD.L D0,D1
```

SIM68000 2.3 >

```
PC=0000200E SR=8000=T.0..... US=00007FF0 SS=00007E00
D0=00010000 D1=00050000 D2=CC82724D D3=5DB78C66
D4=DBD35416 D5=685193CD D6=C0625BF1 D7=B9F097E4
A0=00003008 A1=00008000 A2=B495930D A3=42089F51
A4=36B99A35 A5=585C3485 A6=CAE09383 A7=00007FF0
-----0000200E 2081 MOVE.L D1,(A0)
```

SIM68000 2.3 > T

```
PC=00002010 SR=8000=T.0..... US=00007FF0 SS=00007E00
D0=00010000 D1=00050000 D2=CC82724D D3=5DB78C66
D4=DBD35416 D5=685193CD D6=C0625BF1 D7=B9F097E4
A0=00003008 A1=00008000 A2=B495930D A3=42089F51
A4=36B99A35 A5=585C3485 A6=CAE09383 A7=00007FF0
-----00002010 4E75 RTS
```

SIM68000 2.3 > T

```
PC=0000101C SR=8000=T.0..... US=00007FF4 SS=00007E00
D0=00010000 D1=00050000 D2=CC82724D D3=5DB78C66
D4=DBD35416 D5=685193CD D6=C0625BF1 D7=B9F097E4
A0=00003008 A1=00008000 A2=B495930D A3=42089F51
A4=36B99A35 A5=585C3485 A6=CAE09383 A7=00007FF4
-----0000101C 4FEF 000C LEA $000C(A7),A7
```

SIM68000 2.3 > MD 7FE0 20

```
007FE0 7D C0 0B 08 56 8B 47 11 F7 D8 F7 06 00 D8 83 DA
007FF0 00 00 10 1C 00 00 01 00 00 00 02 00 00 00 30 08
```

SIM68000 2.3 > T

```
PC=00001020 SR=8000=T.0..... US=00008000 SS=00007E00
D0=00010000 D1=00050000 D2=CC82724D D3=5DB78C66
D4=DBD35416 D5=685193CD D6=C0625BF1 D7=B9F097E4
A0=00003008 A1=00008000 A2=B495930D A3=42089F51
A4=36B99A35 A5=585C3485 A6=CAE09383 A7=00008000
-----00001020 4E75 RTS
```



Local variables and stack frames

- A subroutine may need a certain amount of local workspace for its temporary (local) variables
 - Local means that **ONLY** the subroutine has access to them
- Two alternatives: Static and Dynamic Allocation
 - Reserve fixed locations for the subroutine's local variables. This is called Static Allocation.
 - Only satisfactory if the subroutine is not re-entrant or recursive
 - Use the stack. This is called Dynamic Allocation.
 - With the instructions **L**INK and **U**LNK we can create a **STACK FRAME**, a region of temporary memory at the top of the current stack.
 - The stack frame is bound up not only to the subroutine but also to each call to the subroutine.
 - The stack frame locations are indexed through a **FRAME POINTER**, an address register that points to the bottom of the stack frame.



LINK instruction

- LINK is used to create a stack frame
- The instruction **LINK A0, #-16** performs the following four operations
 - Decrement the stack pointer by 4
 - Push the contents of address register A0 onto stack
 - Save the stack pointer in address register A0
 - Move the stack pointer up by 16 locations
- In RTL this is equivalent to

[SP] ← [SP] - 4

[M([SP])] ← [A0]

[A0] ← [SP]

[SP] ← [SP] - 16



ULNK instruction

- **ULNK** is used to collapse a stack frame
- The instruction **ULNK A0** performs the following three operations
 - Move the contents of A0 to stack pointer
 - Move the old value of A0 into A0
 - Move the stack pointer 4 locations down

- In RTL this is equivalent to

$[SP] \leftarrow [A0]$

$[A0] \leftarrow [M(A0)]$

$[SP] \leftarrow [SP] + 4$



An example of local variables and stack frames

■ Perform the operation

$$[M(R)] \leftarrow (P^2+Q^2)/(P^2-Q^2)$$

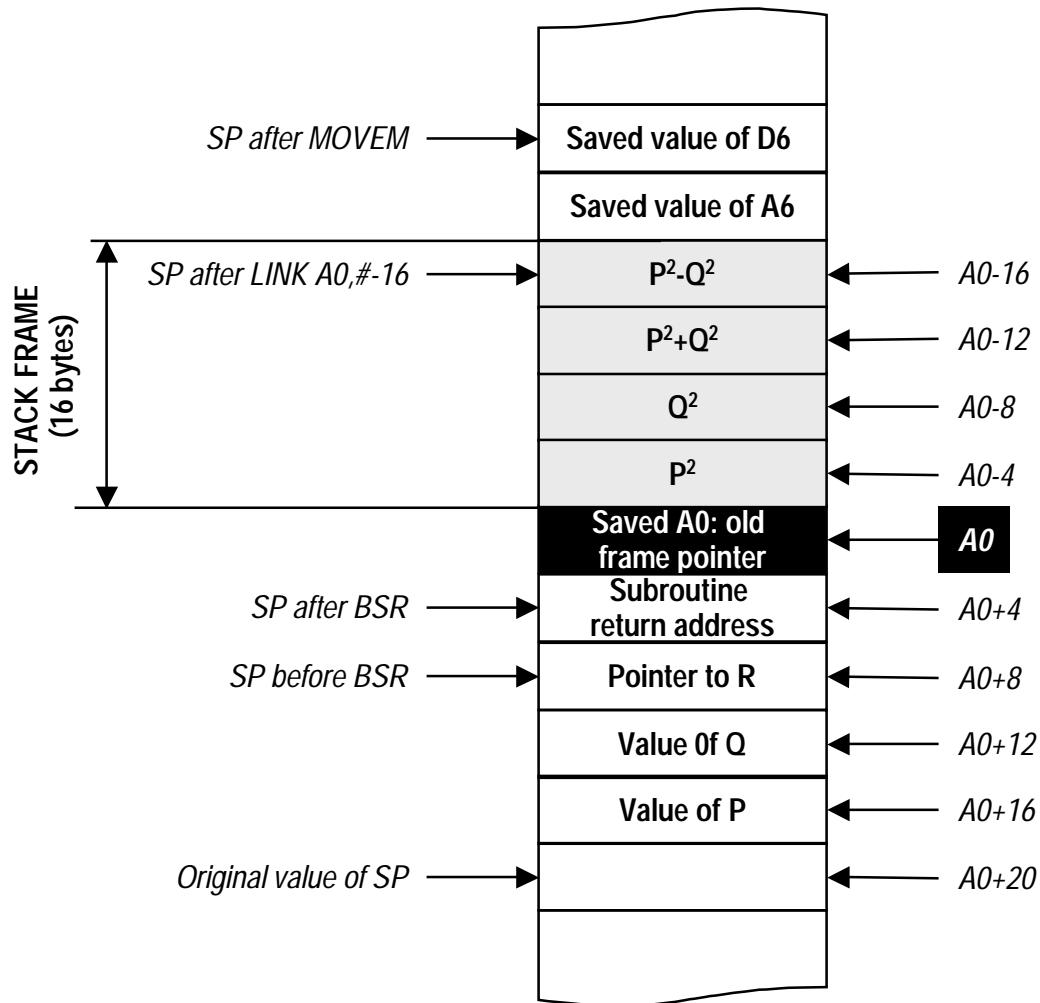
```

00001000          1      ORG          $1000          ;Start of main program
00001000  2E7C 00008000  2      MOVE.L      #$8000,SP          ;Set up the stack pointer
00001006  2C3C D6D6D6D6  3      MOVE.L      #$D6D6D6D6,D6        ;Move data to D6 (for clarity of stack)
0000100C  2C7C A6A6A6A6  4      MOVE.L      #$A6A6A6A6,A6        ;Move data to A6 (for clarity of stack)
00001012  207C A0A0A0A0  5      MOVE.L      #$A0A0A0A0,A0        ;Move data to A0 (for clarity of stack)
00001018  2F39 00003000  6      MOVE.L      P,-(SP)              ;Push value of P to the stack
0000101E  2F39 00003004  7      MOVE.L      Q,-(SP)              ;Push value of Q to the stack
00001024  4879 00003008  8      PEA          R                  ;Push address of R to the stack
0000102A  6100 0FD4      9      BSR          CALC              ;Call the subroutine
0000102E  4FEF 000C     10     LEA          12(SP),SP            ;Clean up the stack by removing P,Q & R
00001032  4E75          11     RTS                          ;Graceful exit
                                12
00002000          13     ORG          $2000          ;Start of subroutine
00002000  4E50 FFF0     14     CALC  LINK  A0,#-16          ;Create a 4 longword stack frame
00002004  48E7 0202     15     MOVEM.L   D6/A6,-(SP)        ;Save working registers on the stack
00002008  2C28 0010     16     MOVE.L    16(A0),D6          ;Get value of P from the stack
0000200C  CCC6          17     MULU     D6,D6                ;Calculate P*P
0000200E  2146 FFFC     18     MOVE.L    D6,-4(A0)          ;Save P*P on the stack frame
00002012  2C28 000C     19     MOVE.L    12(A0),D6          ;Get Q from the stack
00002016  CCC6          20     MULU     D6,D6                ;Calculate Q*Q
00002018  2146 FFF8     21     MOVE.L    D6,-8(A0)          ;Store Q*Q on the stack frame
0000201C  2C28 FFFC     22     MOVE.L    -4(A0),D6          ;Get P*P
00002020  DCA8 FFF8     23     ADD.L     -8(A0),D6          ;Add Q*Q
00002024  2146 FFF4     24     MOVE.L    D6,-12(A0)         ;Store P*P+Q*Q on the stack frame
00002028  2C28 FFFC     25     MOVE.L    -4(A0),D6          ;Get P*P
0000202C  9CA8 FFF8     26     SUB.L     -8(A0),D6          ;Subtract Q*Q
00002030  2146 FFF0     27     MOVE.L    D6,-16(A0)         ;Store P*P-Q*Q on the stack frame
00002034  2C28 FFF4     28     MOVE.L    -12(A0),D6         ;Copy P*P+Q*Q on the stack frame on D6
00002038  8CE8 FFF2     29     DIVU     -14(A0),D6         ;Calculate (P*P+Q*Q) / (P*P-Q*Q)
0000203C  4DE8 0008     30     LEA      8(A0),A6            ;Get pointer to address of R
00002040  2C56          31     MOVEA.L  (A6),A6            ;Get actual address of R
00002042  2C86          32     MOVE.L   D6,(A6)            ;Modify R in the calling routine
00002044  4CDF 4040     33     MOVEM.L  (SP)+,D6/A6        ;Restore working registers
00002048  4E58          34     UNLK     A0                ;Collapse the stack frame
0000204A  4E75          35     RTS                          ;Return from subroutine
                                36
00003000          37     ORG          $3000          ;Data section
00003000  00000004  38 P    DC.L    4                ;Operand number 1
00003004  00000003  39 Q    DC.L    3                ;Operand number 2
00003008  40 R    DS.L    1                ;Storage for the result
0000300C          41     END

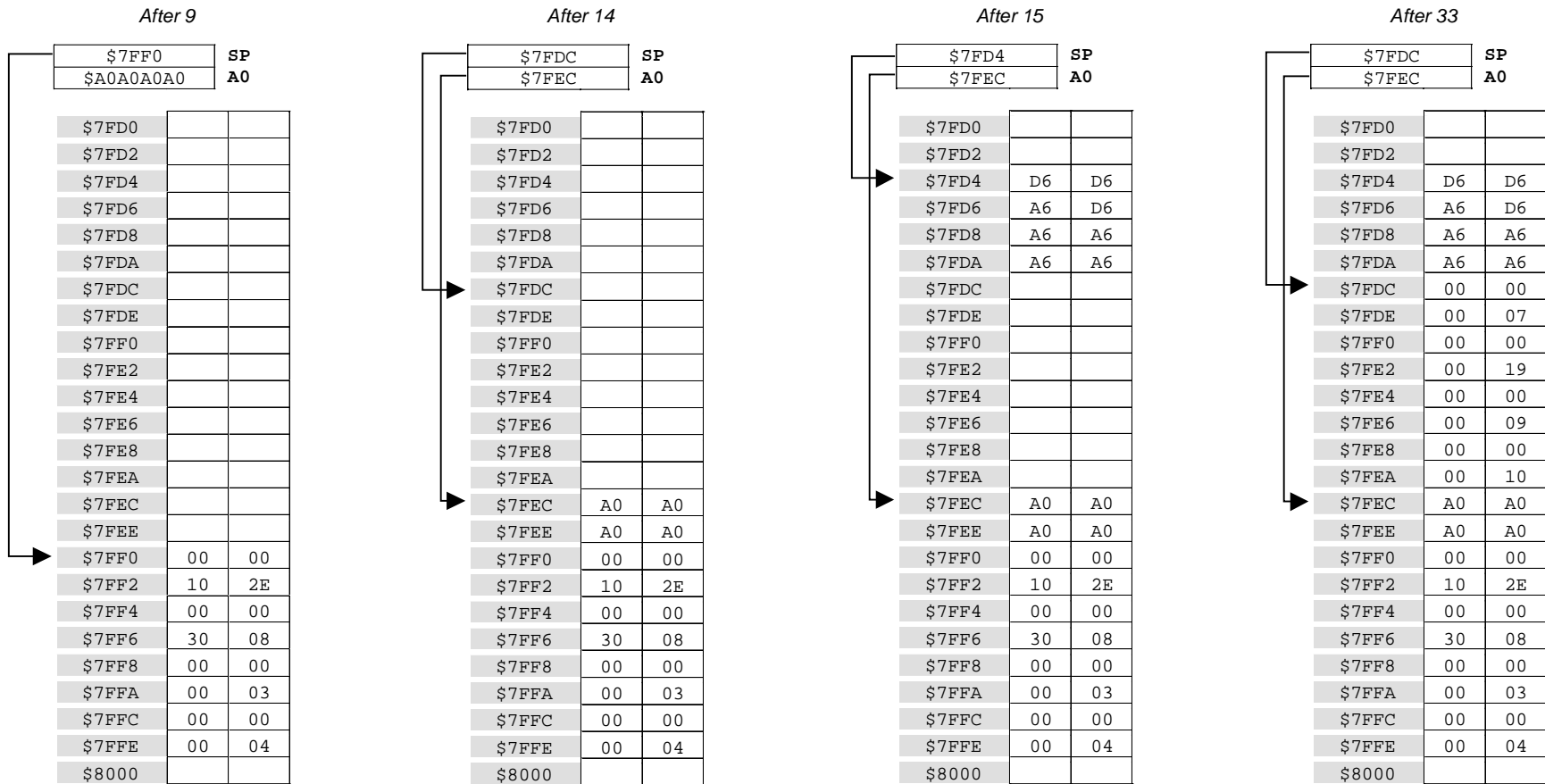
```



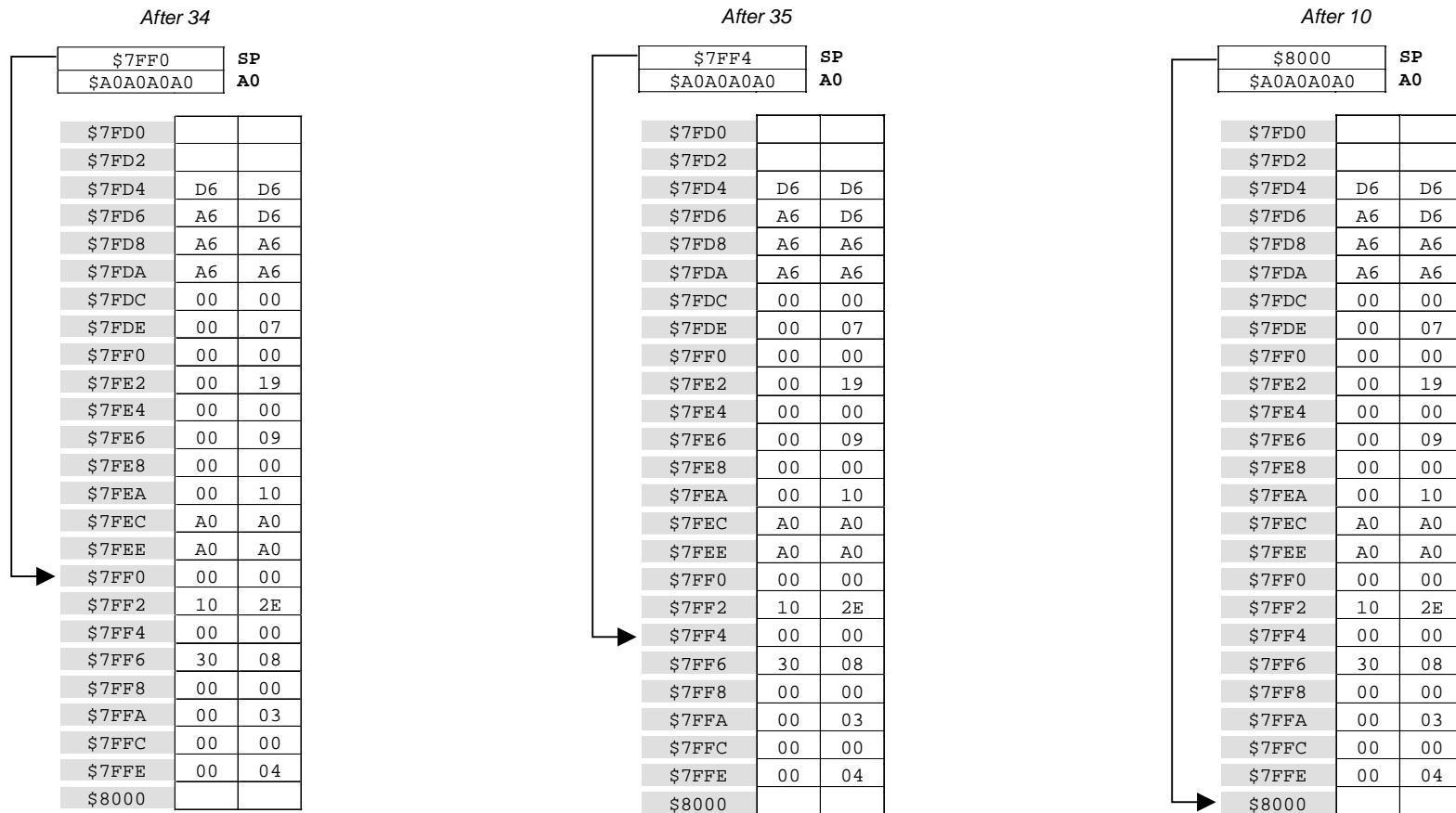
State of the stack during execution of the *CALC* subroutine



State of the stack during execution of the *CALC* subroutine



State of the stack during execution of the *CALC* subroutine



Run on sim68k (part 1)

MC68000/ECB Simulator.
 Copyright (C) Livadas and Ward, 1992. Author Wayne Wolf
 Version 2.3
 SIM68000 2.3 > LO L7B.S
 SIM68000 2.3 > .PC 1000
 SIM68000 2.3 > DF

PC=00001006 SR=8000=T.O. US=00008000 SS=00007E00
 D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
 D4=3D0C963D D5=EE8E6F30 D6=54911844 D7=AC8A69F5
 A0=1AABA47E A1=4D09D05F A2=607663D2 A3=AE679773
 A4=8BC68B91 A5=6DF74536 A6=6FD48B23 A7=00008000
 -----00001006 2C3C D6D6D6D6 MOVE.L #\$D6D6D6D6,D6

SIM68000 2.3 > MD 7FD0 30
 007FD0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
 007FE0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
 007FF0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

SIM68000 2.3 > T
 PC=0000100C SR=8008=T.O.N. US=00008000 SS=00007E00
 D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
 D4=3D0C963D D5=EE8E6F30 D6=D6D6D6D6 D7=AC8A69F5
 A0=1AABA47E A1=4D09D05F A2=607663D2 A3=AE679773
 A4=8BC68B91 A5=6DF74536 A6=6FD48B23 A7=00008000
 -----0000100C 2C7C A6A6A6A6 MOVE.L #\$A6A6A6A6,A6

SIM68000 2.3 >
 PC=00001012 SR=8008=T.O.N. US=00008000 SS=00007E00
 D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
 D4=3D0C963D D5=EE8E6F30 D6=D6D6D6D6 D7=AC8A69F5
 A0=1AABA47E A1=4D09D05F A2=607663D2 A3=AE679773
 A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00008000
 -----00001012 207C A0A0A0A0 MOVE.L #\$A0A0A0A0,A0

PC=00001018 SR=8008=T.O.N. US=00008000 SS=00007E00
 D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
 D4=3D0C963D D5=EE8E6F30 D6=D6D6D6D6 D7=AC8A69F5
 A0=A0A0A0A0 A1=4D09D05F A2=607663D2 A3=AE679773
 A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00008000
 -----00001018 2F39 00003000 MOVE.L \$00003000,-(A7)

PC=0000101E SR=8000=T.O. US=00007FFC SS=00007E00
 D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
 D4=3D0C963D D5=EE8E6F30 D6=D6D6D6D6 D7=AC8A69F5
 A0=A0A0A0A0 A1=4D09D05F A2=607663D2 A3=AE679773
 A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FFC
 -----0000101E 2F39 00003004 MOVE.L \$00003004,-(A7)

007FD0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
 007FE0 00 00 00 00 00 00 00 00 00 00 00 00 00 00
 007FF0 00 00 00 00 00 00 00 00 00 00 00 00 00 04

PC=00001024 SR=8000=T.O. US=00007FF8 SS=00007E00
 D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
 D4=3D0C963D D5=EE8E6F30 D6=D6D6D6D6 D7=AC8A69F5
 A0=A0A0A0A0 A1=4D09D05F A2=607663D2 A3=AE679773
 A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FF8
 -----00001024 4879 00003008 PEA \$00003008

007FD0 00 00 00 00 00 00 00 00 00 00 00 00 00 00
 007FE0 00 00 00 00 00 00 00 00 00 00 00 00 00 00
 007FF0 00 00 00 00 00 00 00 00 00 03 00 00 00 04

PC=0000102A SR=8000=T.O. US=00007FF4 SS=00007E00
 D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
 D4=3D0C963D D5=EE8E6F30 D6=D6D6D6D6 D7=AC8A69F5
 A0=A0A0A0A0 A1=4D09D05F A2=607663D2 A3=AE679773
 A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FF4
 -----0000102A 6100 0FD4 BSR \$002000

007FD0 00 00 00 00 00 00 00 00 00 00 00 00 00 00
 007FE0 00 00 00 00 00 00 00 00 00 00 00 00 00 00
 007FF0 00 00 00 00 00 00 30 08 00 00 03 00 00 04

PC=00002000 SR=8000=T.O. US=00007FF0 SS=00007E00
 D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
 D4=3D0C963D D5=EE8E6F30 D6=D6D6D6D6 D7=AC8A69F5
 A0=A0A0A0A0 A1=4D09D05F A2=607663D2 A3=AE679773
 A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FF0
 -----00002000 4E50 FFF0 LINK A0,#\$FFF0

007FD0 00 00 00 00 00 00 00 00 00 00 00 00 00 00
 007FE0 00 00 00 00 00 00 00 00 00 00 00 00 00 00
 007FF0 00 00 10 2E 00 00 30 08 00 00 03 00 00 04

PC=00002004 SR=8000=T.O. US=00007FDC SS=00007E00
 D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
 D4=3D0C963D D5=EE8E6F30 D6=D6D6D6D6 D7=AC8A69F5
 A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
 A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FDC
 -----00002004 48E7 0202 MOVEM.L D6/A6,-(A7)

007FD0 00 00 00 00 00 00 00 00 00 00 00 00 00 00
 007FE0 00 00 00 00 00 00 00 00 00 00 A0 A0 A0 A0
 007FF0 00 00 10 2E 00 00 30 08 00 00 03 00 00 04

PC=00002008 SR=8000=T.O. US=00007FD4 SS=00007E00
 D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
 D4=3D0C963D D5=EE8E6F30 D6=D6D6D6D6 D7=AC8A69F5
 A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
 A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FD4
 -----00002008 2C28 0010 MOVE.L \$0010(A0),D6

007FD0 00 00 00 00 D6 D6 D6 D6 A6 A6 A6 A6 00 00 00 00
 007FE0 00 00 00 00 00 00 00 00 00 00 00 00 A0 A0 A0 A0
 007FF0 00 00 10 2E 00 00 30 08 00 00 03 00 00 04

PC=0000200C SR=8000=T.O. US=00007FD4 SS=00007E00
 D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
 D4=3D0C963D D5=EE8E6F30 D6=00000004 D7=AC8A69F5
 A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
 A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FD4
 -----0000200C CCC6 MULU D6,D6

SIM68000 2.3 >
 PC=0000200E SR=8000=T.O. US=00007FD4 SS=00007E00
 D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
 D4=3D0C963D D5=EE8E6F30 D6=00000010 D7=AC8A69F5
 A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
 A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FD4
 -----0000200E 2146 FFFC MOVE.L D6,\$FFFC(A0)

PC=00002012 SR=8000=T.O. US=00007FD4 SS=00007E00
 D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
 D4=3D0C963D D5=EE8E6F30 D6=00000010 D7=AC8A69F5
 A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
 A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FD4
 -----00002012 2C28 000C MOVE.L \$000C(A0),D6

007FD0 00 00 00 00 D6 D6 D6 D6 A6 A6 A6 A6 00 00 00 00
 007FE0 00 00 00 00 00 00 00 00 00 00 00 10 A0 A0 A0 A0
 007FF0 00 00 10 2E 00 00 30 08 00 00 03 00 00 04

PC=00002016 SR=8000=T.O. US=00007FD4 SS=00007E00
 D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
 D4=3D0C963D D5=EE8E6F30 D6=00000003 D7=AC8A69F5
 A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
 A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FD4
 -----00002016 CCC6 MULU D6,D6

SIM68000 2.3 >
 PC=00002018 SR=8000=T.O. US=00007FD4 SS=00007E00
 D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
 D4=3D0C963D D5=EE8E6F30 D6=00000009 D7=AC8A69F5
 A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
 A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FD4
 -----00002018 2146 FFF8 MOVE.L D6,\$FF8(A0)



Run on sim68k (part 2)

```
SIM68000 2.3 >
PC=0000201C SR=8000=T.O. US=00007FD4 SS=00007E00
D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
D4=3D0C963D D5=EE8E6F30 D6=00000009 D7=AC8A69F5
A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FD4
-----0000201C 2C28 FFFC MOVE.L $FFFC(A0),D6
```

```
007FD0 00 00 00 00 D6 D6 D6 D6 A6 A6 A6 A6 00 00 00 00
007FE0 00 00 00 00 00 00 09 00 00 00 10 A0 A0 A0 A0
007FF0 00 00 10 2E 00 00 30 08 00 00 00 03 00 00 00 04 .
```

```
SIM68000 2.3 >
PC=00002020 SR=8000=T.O. US=00007FD4 SS=00007E00
D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
D4=3D0C963D D5=EE8E6F30 D6=00000010 D7=AC8A69F5
A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FD4
-----00002020 DCA8 FFF8 ADD.L $FFF8(A0),D6
```

```
PC=00002024 SR=8000=T.O. US=00007FD4 SS=00007E00
D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
D4=3D0C963D D5=EE8E6F30 D6=00000019 D7=AC8A69F5
A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FD4
-----00002024 2146 FFF4 MOVE.L D6,$FFF4(A0)
```

```
PC=00002028 SR=8000=T.O. US=00007FD4 SS=00007E00
D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
D4=3D0C963D D5=EE8E6F30 D6=00000019 D7=AC8A69F5
A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FD4
-----00002028 2C28 FFFC MOVE.L $FFFC(A0),D6
```

```
007FD0 00 00 00 00 D6 D6 D6 D6 A6 A6 A6 A6 00 00 00 00
007FE0 00 00 00 19 00 00 09 00 00 00 10 A0 A0 A0 A0
007FF0 00 00 10 2E 00 00 30 08 00 00 00 03 00 00 00 04 .
```

```
PC=0000202C SR=8000=T.O. US=00007FD4 SS=00007E00
D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
D4=3D0C963D D5=EE8E6F30 D6=00000010 D7=AC8A69F5
A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FD4
-----0000202C 9CA8 FFF8 SUB.L $FFF8(A0),D6
```

```
PC=00002030 SR=8000=T.O. US=00007FD4 SS=00007E00
D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
D4=3D0C963D D5=EE8E6F30 D6=00000007 D7=AC8A69F5
A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FD4
-----00002030 2146 FFF0 MOVE.L D6,$FFF0(A0)
```

```
PC=00002034 SR=8000=T.O. US=00007FD4 SS=00007E00
D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
D4=3D0C963D D5=EE8E6F30 D6=00000007 D7=AC8A69F5
A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FD4
-----00002034 2C28 FFF4 MOVE.L $FFF4(A0),D6
```

```
007FD0 00 00 00 00 D6 D6 D6 D6 A6 A6 A6 A6 00 00 00 07
007FE0 00 00 00 19 00 00 09 00 00 00 10 A0 A0 A0 A0
007FF0 00 00 10 2E 00 00 30 08 00 00 00 03 00 00 00 04 .
```

```
PC=00002038 SR=8000=T.O. US=00007FD4 SS=00007E00
D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
D4=3D0C963D D5=EE8E6F30 D6=00000019 D7=AC8A69F5
A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FD4
-----00002038 8CE8 FFF2 DIVU $FFF2(A0),D6
```

```
PC=0000203C SR=8000=T.O. US=00007FD4 SS=00007E00
D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
D4=3D0C963D D5=EE8E6F30 D6=00040003 D7=AC8A69F5
A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FD4
-----0000203C 4DE8 0008 LEA $0008(A0),A6
```

```
PC=00002040 SR=8000=T.O. US=00007FD4 SS=00007E00
D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
D4=3D0C963D D5=EE8E6F30 D6=00040003 D7=AC8A69F5
A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
A4=8BC68B91 A5=6DF74536 A6=00007FF4 A7=00007FD4
-----00002040 2C56 MOVE.L (A6),A6
```

```
PC=00002042 SR=8000=T.O. US=00007FD4 SS=00007E00
D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
D4=3D0C963D D5=EE8E6F30 D6=00040003 D7=AC8A69F5
A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
A4=8BC68B91 A5=6DF74536 A6=00003008 A7=00007FD4
-----00002042 2C86 MOVE.L D6,(A6)
```

```
PC=00002044 SR=8000=T.O. US=00007FD4 SS=00007E00
D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
D4=3D0C963D D5=EE8E6F30 D6=00040003 D7=AC8A69F5
A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
A4=8BC68B91 A5=6DF74536 A6=00003008 A7=00007FD4
-----00002044 4CDF 4040 MOVEM.L (A7)+,D6/A6
```

```
007FD0 00 00 00 00 D6 D6 D6 D6 A6 A6 A6 A6 00 00 00 07
007FE0 00 00 00 19 00 00 09 00 00 00 10 A0 A0 A0 A0
007FF0 00 00 10 2E 00 00 30 08 00 00 00 03 00 00 00 04 .
```

```
PC=00002048 SR=8000=T.O. US=00007FDC SS=00007E00
D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
D4=3D0C963D D5=EE8E6F30 D6=D6D6D6D6 D7=AC8A69F5
A0=00007FEC A1=4D09D05F A2=607663D2 A3=AE679773
A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FDC
-----00002048 4E58 UNLK A0
```

```
007FD0 00 00 00 00 D6 D6 D6 D6 A6 A6 A6 A6 00 00 00 07
007FE0 00 00 00 19 00 00 09 00 00 00 10 A0 A0 A0 A0
007FF0 00 00 10 2E 00 00 30 08 00 00 00 03 00 00 00 04 .
```

```
SIM68000 2.3 >
PC=0000204A SR=8000=T.O. US=00007FF0 SS=00007E00
D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
D4=3D0C963D D5=EE8E6F30 D6=D6D6D6D6 D7=AC8A69F5
A0=A0A0A0A0 A1=4D09D05F A2=607663D2 A3=AE679773
A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FF0
-----0000204A 4E75 RTS
```

```
007FD0 00 00 00 00 D6 D6 D6 D6 A6 A6 A6 A6 00 00 00 07
007FE0 00 00 00 19 00 00 09 00 00 00 10 A0 A0 A0 A0
007FF0 00 00 10 2E 00 00 30 08 00 00 00 03 00 00 00 04 .
```

```
PC=0000102E SR=8000=T.O. US=00007FF4 SS=00007E00
D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
D4=3D0C963D D5=EE8E6F30 D6=D6D6D6D6 D7=AC8A69F5
A0=A0A0A0A0 A1=4D09D05F A2=607663D2 A3=AE679773
A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00007FF4
-----0000102E 4FEF 000C LEA $000C(A7),A7
```

```
007FD0 00 00 00 00 D6 D6 D6 D6 A6 A6 A6 A6 00 00 00 07
007FE0 00 00 00 19 00 00 09 00 00 00 10 A0 A0 A0 A0
007FF0 00 00 10 2E 00 00 30 08 00 00 00 03 00 00 00 04 .
```

```
PC=00001032 SR=8000=T.O. US=00008000 SS=00007E00
D0=709EAC97 D1=A268A88B D2=38855ADC D3=BE8CD925
D4=3D0C963D D5=EE8E6F30 D6=D6D6D6D6 D7=AC8A69F5
A0=A0A0A0A0 A1=4D09D05F A2=607663D2 A3=AE679773
A4=8BC68B91 A5=6DF74536 A6=A6A6A6A6 A7=00008000
-----00001032 4E75 RTS
```



The need for dynamic allocation

■ Imagine the following situation

- Main program calls subroutine `SUB_A`
- Subroutine `SUB_A` calls subroutine `SUB_B`
- Subroutine `SUB_B` calls subroutine `SUB_A`

■ With static allocation, the second call to `SUB_A` would overwrite the value of the local variable `SUB_A_TMP` calculated in the first call to `SUB_A`

```
MAIN          ...
              BSR          SUB_A
              ...
              ...
SUB_A         ...
              MOVE.L      D0, SUB_A_TMP
              ...
              BSR          SUB_B
              ...
              MOVE.L      SUB_A_TMP, D2
              ...
              RTS
              ...
SUB_B         ...
              MOVE.L      D1, SUB_B_TMP
              ...
              BSR          SUB_A
              ...
              RTS
```



Evolution of the stack with re-entrant code

- The previous problem is solved with the use of stack frames

```

MAIN      ...      BSR      SUBA
          ...
SUBA      ...      LINK     A0, #-96
          ...      BSR      SUBB
          ...      ULNK     A0
          ...      RTS
SUBB      ...      LINK     A0, #-64
          ...      BSR      SUBA
          ...      ULNK     A0
          ...      RTS
    
```

