

**Team 04****Haohan Jiang, g3jiangh****Maria Yancheva, c2yanche****Timo Vink, c4vinkti****Chandeep Singh, g2singh****1 Program 2**

As described above, we start with the HALT instruction at address 0, which will be used as our return address for the 'main procedure'.

0     **HALT**

Next we need to put the activation record on the stack and set the display register to point to it. The activation record contains the return address 0, space to save a display register, and space for local variables.

```

        # Set display register
1     PUSHMT
2     SETD           0

        # Create activation record
2     PUSH           0
3     PUSH           UNDEFINED
4     PUSH           UNDEFINED
5     PUSH           UNDEFINED
6     PUSH           10     # 10 words needed for local storage in this scope
7     DUPN

```

The first line that requires generated code is line 2-5. We need to evaluate the expression and then branch based on the output. The addresses of a, b, c, p, q, r, w, x, t, u are 2,3,4,5,6,7,8,9,10,11 from the activation record base respectively.

```

        # Get addr of p and LOAD the value
8     ADDR    0    5
9     LOAD

        # Get addr of q and LOAD the value
10    ADDR    0    6
11    LOAD

        # OR operation
12    OR

        # BF instruction
13    PUSH    17       # beginning of instructions for 2-6
14    BF

```

```

    # Then statement, get addr of a and assign it the value of 3
15  ADDR    0    2
16  PUSH    3
17  STORE

```

For the if statement in line 6, we first need to evaluate the expression:

```

    # Use De Morgan's laws to do the "and" with OR ops and negations
    # since we don't have "not" op, do 1 - bool result to get negation

    PUSH    1          # for later negation

    # Get addr of q, load value, negate, then negate again for deMorgan's law
    PUSH    1          # for later negation
    PUSH    1          # for later negation
18  ADDR    0    6
19  LOAD
20  SUB
21  SUB

    # Get addr of q, load value, negate, then negate again for deMorgan's law
    PUSH    1          # for later negation
    PUSH    1          # for later negation
22  ADDR    0    6
23  LOAD
24  SUB
25  SUB

    # Do an OR instead of AND (since we don't have AND, use deMorgan's law)
    # then negate result (also deMorgan's law)
26  OR
27  SUB

```

Then we need to emit the address for the branch false

```

28  PUSH 33    # beginning of false part
29  BF

```

True part

```

    # get addr of b and assign it the value of 2
30  ADDR    0    3
31  PUSH    2
32  STORE
33  BR      37    # branch to statement after end of if

```

Else part

```
    # get addr of b and assign it the value of 0
34  ADDR    0    3
35  PUSH    0
36  STORE
```

For the while loop on 2-7

```
    # Get the addr of c and load the value
37  ADDR    0    4
38  LOAD
```

```
    # PUSH 7 on the stack and compare
39  PUSH    7
40  LT
```

```
    # Branch to the end if false
41  PUSH    48
42  BF
```

```
    # Do block
43  ADDR    0    4
44  PUSH    8
45  STORE
46  PUSH    37
47  BR
```

For the loop on 2-8

```
    # Get the addr of a and assign it the value of 3
48  PUSH    2
49  PUSH    3
50  STORE
```

```
    # Exit statement
51  PUSH    57
52  BR
```

```
    # Get the addr of b and assign it the value of 7
53  PUSH    3
54  PUSH    7
55  PUSH    48
56  BR
```

For the while loop on 2-9

```
    # Not p
57  PUSH    1
58  ADDR    0    6
59  LOAD
```

```
60    SUB

    # Load r and do the & operation
61    PUSH    1
62    SUB
63    PUSH    1
64    ADDR    0    7
65    LOAD
66    SUB
67    OR
68    PUSH    1
69    SUB

    # Load q and do the | operation
70    ADDR    0    5
71    LOAD
72    OR

    # Branch to the end if false
73    PUSH    85
74    BF

    # Do block
75    PUSH    85
76    ADDR    0    3
77    LOAD
78    PUSH    10
79    EQ
80    PUSH    1
81    SUB
82    BF

    # Branch to beginning of while loop
83    PUSH    57
84    BR
```

For the put statement on 2-10

```
# put "Value is "
PUSH    86 # V
PRINC
PUSH    97 # a
PRINC
PUSH    108 # l
PRINC
PUSH    117 # u
PRINC
PUSH    101 # e
```

```
PRINTC
PUSH    32  # <space>
PRINTC
PUSH    105 # i
PRINTC
PUSH    115 # s
PRINTC
PUSH    32  # <space>
PRINTC

# evaluate a / b and print
ADDR    0   2  # load a
LOAD
ADDR    0   3  # load b
LOAD
DIV
PRINTI

# put " or "
PUSH    32  # <space>
PRINTC
PUSH    111 # o
PRINTC
PUSH    114 # r
PRINTC
PUSH    32  # <space>
PRINTC

# evaluate b * -c and print
ADDR    0   3 # load b
LOAD
ADDR    0   4 # load c
LOAD
NEG          # negate c
MUL
PRINTI

# put skip
PUSH    10  # <newline>
PRINTC
```

For the get statement on line 2-11

```
# get a, c, b
ADDR    0   2  # get a
READI
STORE
ADDR    0   4  # get c
```

```

READI
STORE
ADDR    0    3    # get b
READI
STORE

```

For the nested begin statement, create a new activation record for outer begin/end

```

# save display[1] into main
ADDR    0    2    # main's display_m
ADDR    1    0    # save prev display[1] (there is none, but follow template)
STORE

# start activation record
PUSH    <end of outer begin/ende>    # return addr

ADDR    0    0    # dynamic link
PUSH    undefined # display_m

# update display[1]
PUSHMT
PUSH    3
SUB
SETD    1

# prologue, allocate space for local storage (m, n, c)
PUSH    undefined
PUSH    3
DUPN

```

Then for line 2-14

```

# m is assigned the value of 7 - b + c
ADDR    1    3    # addr of m
PUSH    7
ADDR    0    4    # load b
LOAD
SUB
ADDR    1    5    # load c
LOAD
ADD
STORE

```

For the inner nested begin statement on line 2-15, we must put another activation record on the stack.

```

# save display[2] into outer begin/end activation record
ADDR    1    2    # outer begin/end's display_m

```

```

ADDR    2    0    # save prev display[2] (there is none, but follow template)
STORE

# start activation record
PUSH    <end of inner begin/ende>    # return addr

ADDR    1    0    # dynamic link
PUSH    undefined    # display_m

# update display[2]
PUSHMT
PUSH    3
SUB
SETD    2

# prologue, allocate space for local storage (p, q, r)
PUSH    undefined
PUSH    3
DUPN

```

For the assignment statement on line 2-17, we need to load the address of p and then create another activation record for the anon function.

```

# Load the address of p onto the stack
ADDR    2    3

# save display[3] into inner begin/end activation record
ADDR    2    2    # inner begin/end's display_m
ADDR    3    0    # save prev display[3] (there is none, but follow template)
STORE

# start activation record
PUSH    undefined    # return value
PUSH    <end of anon func>    # return addr

ADDR    2    0    # dynamic link
PUSH    undefined    # display_m

# update display[3]
PUSHMT
PUSH    3
SUB
SETD    3

```

Create another activation record for the begin/end scope inside the anon func

```

# save display[4] into anon func's activation record
ADDR    3    3    # anon func's display_m

```

```

ADDR    4    0    # save prev display[4] (there is none, but follow template)
STORE

```

```

# start activation record
PUSH    <end of this scope>    # return addr

```

```

ADDR    3    0    # dynamic link
PUSH    undefined    # display_m

```

```

# update display[3]
PUSHMT
PUSH    3
SUB
SETD    4

```

Then for p <= a

```

# Assign p the value of a
ADDR    0    2    # addr of p
ADDR    0    5    # load a
LOAD
STORE

```

Epilogue/cleanup for begin/end inside anon func.

```

# no local storage to pop
POP      # pop display_m

# dynamic link is now at top, revert display[4]
PUSH    3    # load caller's display_m
LOAD
SETD    4

# return to return addr
BR

```

Yield statement

```

# yields r - b
ADDR    3    3
LOAD
ADDR    0    4
LOAD
SUB

```

Epilogue/cleanup for anon func.

```

# no local storage to pop
POP      # pop display_m

```



```
# dynamic link is now at top, revert display[3]
PUSH    3      # load caller's display_m
LOAD
SETD    3

# return to return addr
BR
```

Epilogue/cleanup for inner begin/end (starting on line 2-15)

```
# pop local storage
PUSH    3
POPN

POP      # pop display_m

# dynamic link is now at top, revert display[2]
PUSH    3      # load caller's display_m
LOAD
SETD    2

# return to return addr
BR
```

Epilogue/cleanup for our begin/end (starting on line 2-12)

```
# pop local storage
PUSH    3
POPN

POP      # pop display_m

# dynamic link is now at top, revert display[1]
PUSH    3      # load caller's display_m
LOAD
SETD    1

# return to return addr
BR
```

While loop on line 2-20

```
# evaluate expression ! ( p | q )
PUSH    1      # used later to negate with SUB
ADDR    0    5  # load p
LOAD
ADDR    0    6  # load q
LOAD
```

```

OR
SUB          # negate

# branch to end of loop
PUSH <addr>   # addr of end of while loop
BF

# exit when p & r
# evaluate p & r
PUSH 1
ADDR 0 5 # load p
LOAD
ADDR 0 7 # load r
LOAD
SUB

# branch when !(p & r) is false
PUSH <while-loop end addr>
BF

<normal-loop-beginning>

# if w <= a then exit end
# evaluate w <= a
PUSH 1 # for future negation
ADDR 0 8 # load w
LOAD
ADDR 0 2 # load a
LOAD

# perform > op and negate the result
GT
SUB # negate
PUSH <end of normal-loop addr>
BF

PUSH <while-loop end addr>
BR

<end of if>

# t <= { anon function }
ADDR 0 10 # push addr of t

# save display[1] into main's activation record
ADDR 0 3 # main's display_m
ADDR 1 0 # save prev display[1] (there is none, but follow template)
STORE

```

```

# start activation record
PUSH    <end of anon func>    # return addr

ADDR    0    0    # dynamic link
PUSH    undefined    # display_m

# update display[1]
PUSHMT
PUSH    3
SUB
SETD    1

# prologue, allocate local storage (boolean m)
PUSH    undefined
PUSH    1
POPN

# m <= w < t
ADDR    1    3    # addr of m
ADDR    0    8    # load w
LOAD
ADDR    0    10   # load t
LOAD
LT
STORE

# if m then t <= t + c end
ADDR    1    3    # load m
PUSH    <end of if>
BF
ADDR    0    10   # addr of t
ADDR    0    10   # load t
ADDR    0    4    # load c
ADD
STORE           # t <= t + c

<end of if>

# yields t
# set return value to value of t
ADDR    1    0    # return val addr
ADDR    0    10   # load t
LOAD
STORE

# epilogue for anon func

```

```
# pop local storage
PUSH    1
POPN

POP      # pop display_m

# dynamic link is now at top, revert display[1]
PUSH    3      # load caller's display_m
LOAD
SETD    1

# return to return addr
BR

# save return value to t
# top of stack should be return val, followed by addr of t
STORE

# go back to beginning of loop
PUSH    <normal-loop-beginning>
BR

<end of normal-loop>
<while-loop end>
```

We're now at the end of the 'main procedure'. So we need to clean up the activation record and branch to the return address, which is where the `HALT` instruction is.

```
# Clean up activation record (10 vars + display[m] + dynamic link + return addr)
PUSH    13
POPN

# Branch to return address (HALT)
ADDR    0      0
LOAD
BR
```