Conditional Loop Instructions

- LOOPZ and LOOPE
- LOOPNZ and LOOPNE

LOOPZ and LOOPE

- Syntax:
  LOOPE *destination*
  LOOPZ *destination*
- Logic:
  - ECX $\leftarrow$ ECX – 1
  - if ECX > 0 and ZF=1, jump to *destination*
- Useful when scanning an array for the first element that does not match a given value.

LOOPNZ and LOOPNE

- LOOPNZ (LOOPNE) is a conditional loop instruction
- Syntax:

  LOOPNZ *destination*

  LOOPNE *destination*
- Logic:
  - ECX $\leftarrow$ ECX – 1;
  - if ECX > 0 and ZF=0, jump to *destination*
- Useful when scanning an array for the first element that matches a given value.

LOOPNZ Example

The following code finds the first positive value in an array:

```
.data
array SWORD -3,-6,-1,-10,10,30,40,4
sentinel SWORD 0
.code
   mov esi,OFFSET array
   mov ecx,LENGTHOF array
next:
   test WORD PTR [esi],8000h  ; test sign bit
   pushfd                     ; push flags on stack
   add esi,TYPE array
   popfd                      ; pop flags from stack
   loopnz next                ; continue loop
   jnz quit                   ; none found
   sub esi,TYPE array         ; ESI points to value
quit:
```

Your turn . . .

Locate the first nonzero value in the array. If none is found, let ESI point to the sentinel value:

```
.data
array SWORD 50 DUP(?)
sentinel SWORD 0FFFFh
.code
    mov esi,OFFSET array
    mov ecx,LENGTHOF array
L1: cmp WORD PTR [esi],0          ; check for zero


    (fill in your code here)



quit:
```

. . . (solution)

```
.data
array SWORD 50 DUP(?)
sentinel SWORD 0FFFFh
.code
   mov esi,OFFSET array
   mov ecx,LENGTHOF array
L1:cmp WORD PTR [esi],0      ; check for zero
   pushfd                    ; push flags on stack
   add esi,TYPE array
   popfd                     ; pop flags from stack
   loope next                ; continue loop
   jz quit                   ; none found
   sub esi,TYPE array        ; ESI points to value
quit:
```

Conditional Structures

- Block-Structured IF Statements
- Compound Expressions with AND
- Compound Expressions with OR
- WHILE Loops
- Table-Driven Selection

Block-Structured IF Statements

Assembly language programmers can easily translate logical statements written in C++/Java into assembly language. For example:

```
if( op1 == op2 )
  X = 1;
else
  X = 2;
```

```
    mov eax,op1
    cmp eax,op2
    jne L1
    mov X,1
    jmp L2
L1: mov X,2
L2:
```

Your turn . . .

Implement the following pseudocode in assembly language. All values are unsigned:

```
if( ebx <= ecx )
{
  eax = 5;
  edx = 6;
}
```

Your turn . . .

Implement the following pseudocode in assembly language. All values are 32-bit signed integers:

```
if( var1 <= var2 )
  var3 = 10;
else
{
  var3 = 6;
  var4 = 7;
}
```

Compound Expression with AND [1/3]

- When implementing the logical AND operator, consider that HLLs use short-circuit evaluation
- In the following example, if the first expression is false, the second expression is skipped:

```
if (al > bl) AND (bl > cl)
  X = 1;
```

Compound Expression with AND [2/3]

```
if (al > bl) AND (bl > cl)
  X = 1;
```

This is one possible implementation . . .

```
    cmp al,bl              ; first expression...
    ja  L1
    jmp next
L1:
    cmp bl,cl              ; second expression...
    ja  L2
    jmp next
L2:                        ; both are true
    mov X,1                ; set X to 1
next:
```

Compound Expression with AND [3/3]

```
if (al > bl) AND (bl > cl)
  X = 1;
```

But the following implementation uses 29% less code by reversing the first relational operator.

```
    cmp al,bl                 ; first expression...
    jbe next                  ; quit if false
    cmp bl,cl                 ; second expression...
    jbe next                  ; quit if false
    mov X,1                   ; both are true
next:
```

Your turn . . .

Implement the following pseudocode in assembly language. All values are unsigned:

```
if(ebx <= ecx) AND
  (ecx > edx )
{
  eax = 5;
  edx = 6;
}
```

Compound Expression with OR [1/2]

- When implementing the logical OR operator, consider that HLLs use short-circuit evaluation
- In the following example, if the first expression is true, the second expression is skipped:

```
if (al > bl) OR (bl > cl)
  X = 1;
```

Compound Expression with OR [2/2]

```
if (al > bl) OR (bl > cl)
  X = 1;
```

We can use "fall-through" logic to keep the code as short as possible:

```
    cmp al,bl              ; is AL > BL?
    ja  L1                 ; yes
    cmp bl,cl              ; no: is BL > CL?
    jbe next               ; no: skip next statement
L1: mov X,1                ; set X to 1
next:
```

WHILE Loops

A WHILE loop is really an IF statement followed by the body of the loop, followed by an unconditional jump to the top of the loop. Consider the following example:

```
while( eax < ebx)
    eax = eax + 1;
```

This is a possible implementation:

```
top:cmp eax,ebx             ; check loop condition
    jae next                ; false? exit loop
    inc eax                 ; body of loop
    jmp top                 ; repeat the loop
next:
```

Your turn . . .

Implement the following loop, using unsigned 32-bit integers:

```
while( ebx <= val1)
{
   ebx = ebx + 5;
   val1 = val1 - 1
}
```

Table-Driven Selection [1/3]

- Create a table containing lookup values and the offsets of labels or procedures
- Use a loop to search the table

Table-Driven Selection [2/3]

Step 1: Create a table containing lookup values and procedure offsets.

```
.data
CaseTable BYTE 'A'                      ; lookup value
    DWORD Process_A                     ; address of procedure
    EntrySize = ($ - CaseTable)
    BYTE 'B'
    DWORD Process_B
    BYTE 'C'
    DWORD Process_C
    BYTE 'D'
    DWORD Process_D

NumberOfEntries = 4
```

Table-Driven Selection [3/3]

Step 2: Use a loop to search the table. When a match is found, we call the procedure offset stored in the current table entry.

```
    mov ebx,OFFSET CaseTable        ; point EBX to the table
    mov ecx,NumberOfEntries         ; loop counter

L1: cmp al,[ebx]                    ; match found?
    jne L2                          ; no: continue
    call NEAR PTR [ebx + 1]         ; yes: call the procedure
    jmp L3                          ; and exit the loop
L2: add ebx,EntrySize               ; point to next entry
    loop L1                         ; repeat until ECX = 0

L3:
```

required for
procedure pointers

Application: Finite-State Machines

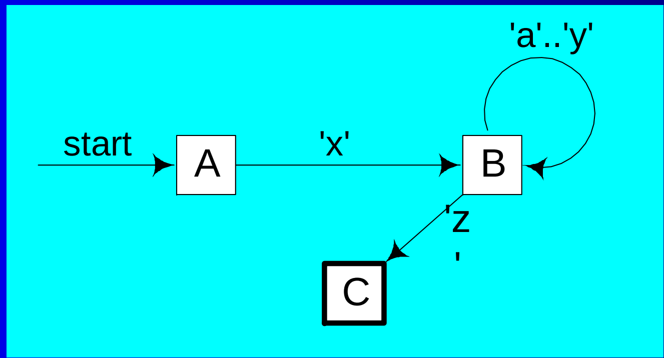
- A finite-state machine (FSM) is a graph structure that changes state based on some input. Also called a state-transition diagram.
- We use a graph to represent an FSM, with squares or circles called nodes, and lines with arrows between the circles called edges (or arcs).
- A FSM is a specific instance of a more general structure called a directed graph (or digraph).
- Three basic states, represented by nodes:
  - Start state
  - Terminal state(s)
  - Nonterminal state(s)

Finite-State Machine

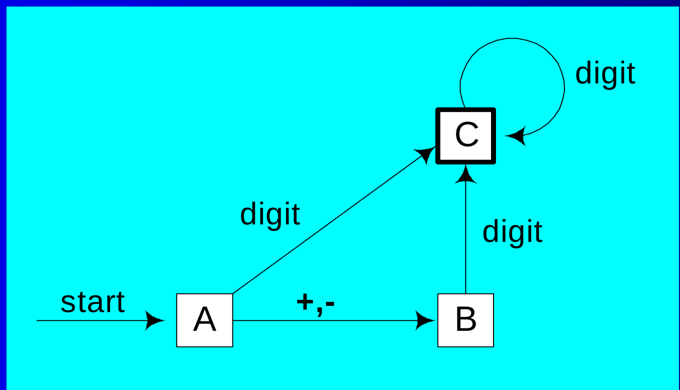
- Accepts any sequence of symbols that puts it into an accepting (final) state
- Can be used to recognize, or validate a sequence of characters that is governed by language rules (called a regular expression)
- Advantages:
  - Provides visual tracking of program's flow of control
  - Easy to modify
  - Easily implemented in assembly language

FSM Examples

- FSM that recognizes strings beginning with 'x', followed by letters 'a'..'y', ending with 'z':

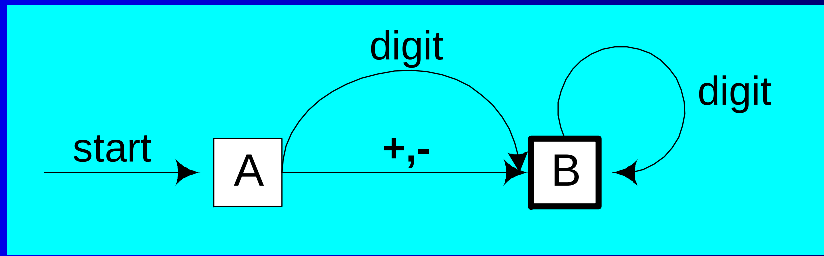


- FSM that recognizes signed integers:



Your turn . . .

- Explain why the following FSM does not work as well for signed integers as the one shown on the previous slide:



Implementing an FSM

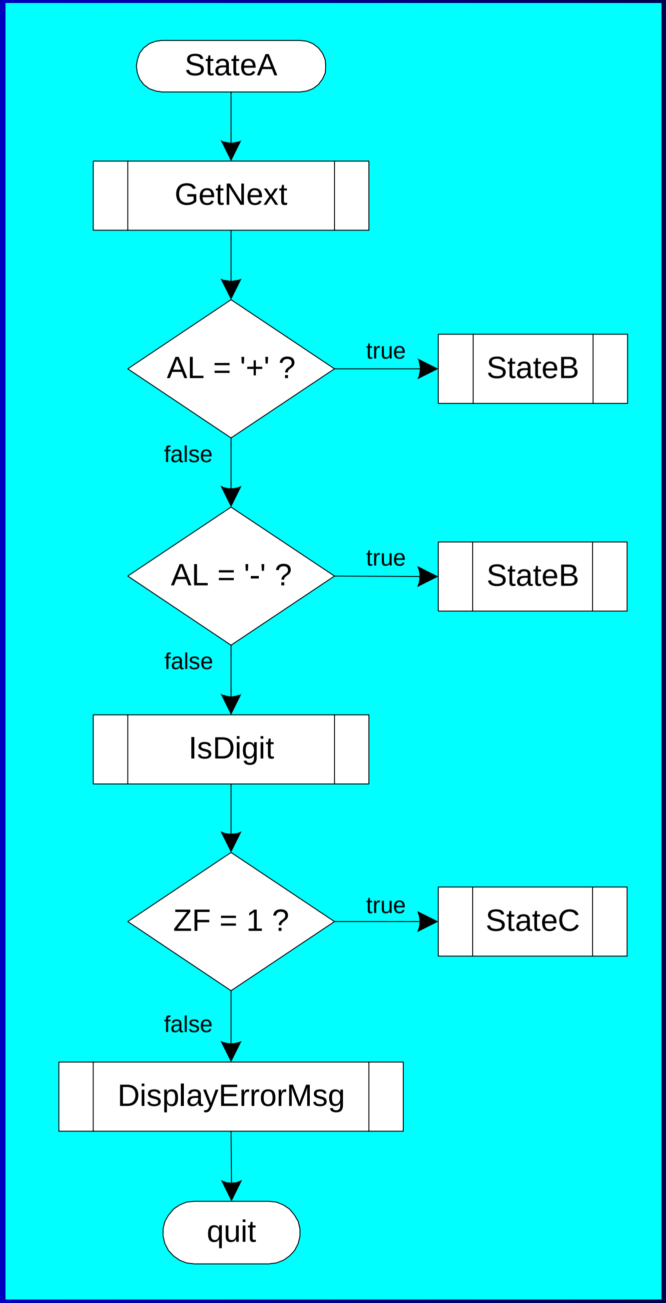
The following is code from State A in the Integer FSM:

```
StateA:
    call Getnext           ; read next char into AL
    cmp al,'+'             ; leading + sign?
    je StateB              ; go to State B
    cmp al,'-'             ; leading - sign?
    je StateB              ; go to State B
    call IsDigit           ; ZF = 1 if AL = digit
    jz StateC              ; go to State C
    call DisplayErrorMsg   ; invalid input found
    jmp Quit
```

View the Finite.asm source code.

Flowchart of State A

State A accepts a plus or minus sign, or a decimal digit.



Runtime Expressions

- .IF, .ELSE, .ELSEIF, and .ENDIF can be used to create block-structured IF statements.
- Examples:

```
.IF eax > ebx
   mov edx,1
.ELSE
   mov edx,2
.ENDIF
```

```
.IF eax > ebx && eax > ecx
   mov edx,1
.ELSE
   mov edx,2
.ENDIF
```

- MASM generates "hidden" code for you, consisting of code labels, CMP and conditional jump instructions.

Relational and Logical Operators

Operator	Description
expr1 == *expr2*	Returns true when *expression1* is equal to *expr2*.
expr1 != *expr2*	Returns true when *expr1* is not equal to *expr2*.
expr1 > *expr2*	Returns true when *expr1* is greater than *expr2*.
expr1 >= *expr2*	Returns true when *expr1* is greater than or equal to *expr2*.
expr1 < *expr2*	Returns true when *expr1* is less than *expr2*.
expr1 <= *expr2*	Returns true when *expr1* is less than or equal to *expr2*.
! *expr*	Returns true when *expr* is false.
expr1 && *expr2*	Performs logical AND between *expr1* and *expr2*.
expr1 || *expr2*	Performs logical OR between *expr1* and *expr2*.
expr1 & *expr2*	Performs bitwise AND between *expr1* and *expr2*.
CARRY?	Returns true if the Carry flag is set.
OVERFLOW?	Returns true if the Overflow flag is set.
PARITY?	Returns true if the Parity flag is set.
SIGN?	Returns true if the Sign flag is set.
ZERO?	Returns true if the Zero flag is set.

MASM-Generated Code

```
.data
val1   DWORD 5
result DWORD ?
.code
mov eax,6
.IF eax > val1
mov result,1
.ENDIF
```

Generated code:

```
    mov eax,6
    cmp eax,val1
    jbe @C0001
    mov result,1
@C0001:
```

MASM automatically generates an unsigned jump (JBE).

MASM-Generated Code

```
.data
val1   SDWORD 5
result SDWORD ?
.code
mov eax,6
.IF eax > val1
mov result,1
.ENDIF
```

Generated code:

```
    mov eax,6
    cmp eax,val1
    jle @C0001
    mov result,1
@C0001:
```

MASM automatically generates a signed jump (JLE).

.REPEAT Directive

Executes the loop body before testing the loop condition associated with the .UNTIL directive.

Example:

```
; Display integers 1 – 10:

mov eax,0
.REPEAT
   inc eax
   call WriteDec
   call Crlf
.UNTIL eax == 10
```

.WHILE Directive

Tests the loop condition before executing the loop body
The .ENDW directive marks the end of the loop.

Example:

```
; Display integers 1 – 10:

mov eax,0
.WHILE eax < 10
   inc eax
   call WriteDec
   call Crlf
.ENDW
```