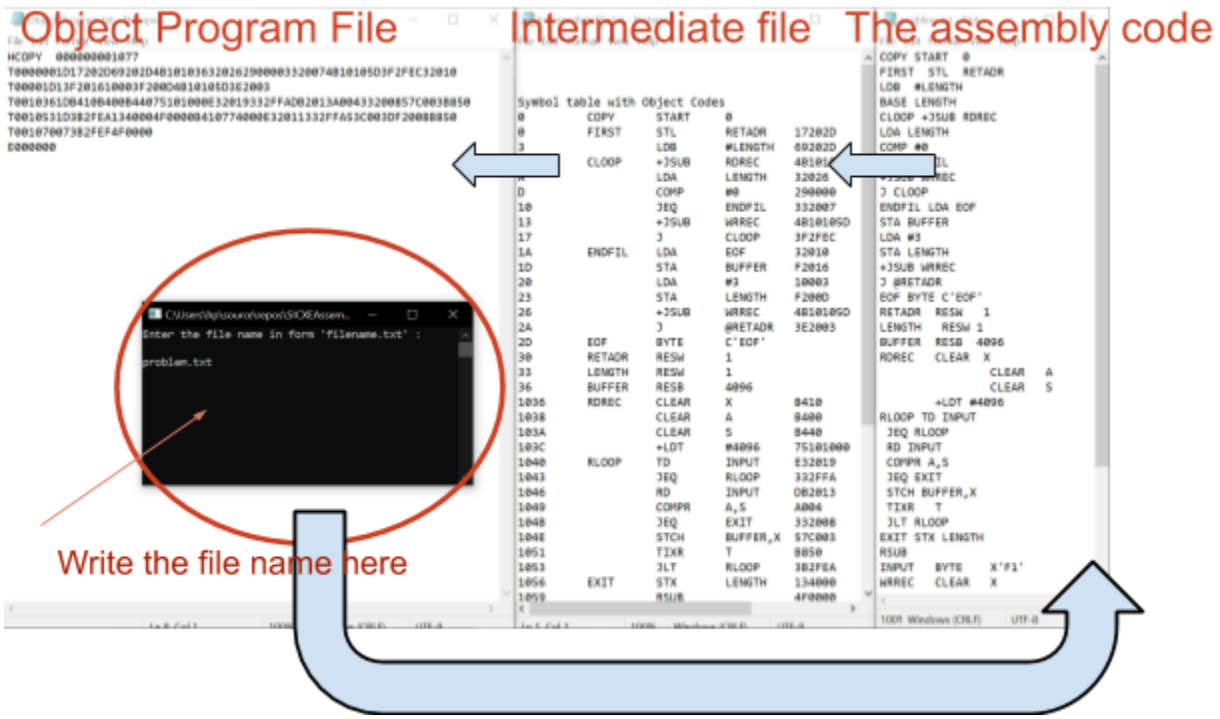

SIC/XE Assembler

Names

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Overview

The SIC machine has basic addressing, storing most memory addresses in hexadecimal integer format. Similar to most modern computing systems, the SIC architecture stores all data in binary and uses the two's complement to represent negative values at the machine level. Memory storage in SIC consists of 8-bit bytes, and all memory addresses in SIC are byte addresses. Any three consecutive bytes form a 24-bit 'word' value, addressed by the location of the lowest numbered byte in the word value. There is also a more complicated machine built on top of SIC called the Simplified Instruction Computer with Extra Equipment (**SIC/XE**). The **XE** expansion of SIC adds a 48-bit floating point data type, an additional memory addressing mode, and extra memory to the original machine. All SIC assembly code is upwards compatible with **SIC/XE**.

Goals

The project is to implement **One Pass SIC/XE Assembler**.assembler, producing code for the absolute loader.

Requirements Specification

1. Reading the source lines from a file.
2. A parser that is capable of handling source lines that are instructions, storage declaration, comments, and assembler directives.
3. The parser is to minimally be capable of decoding 2, 3 and 4-byte instructions.
4. The parser is to handle all storage directives (BYTE, WORD, RESW, and RESB).
5. The assembler should support:
   a- EQU and ORG statements.

   b- Simple expression evaluation. A simple expression includes simple (A B) operand arithmetic, where is one of +, -, *, / and no spaces surround the operation, eg. A+B.

6. The output of the assembler should include (at least):

   a- Intermediate file that contains the symbol table and a definition for any error.

   b- Object-code file.

Design

- ➔ The user inserts the name of the file followed by (.txt) which contain the statements which need to be assembled. then :
  - ◆ The Main class calls the class ReadFromFile to read the statements one by one by for loop, in this loop the Parser is called to check that the statement is valid and doesn't have any syntax error.
    The Parser does that in two parts, first part by calling a function on it, and the second by calling Class DynamicTable which checks that the statement doesn't have any logical error. And if it's valid then it calls class Make Address to generate the Address as location counter of this line, then setting all (Location Counter,Label ,Operation,Operant) in map SymbolMap by call class SymbolTable.
  - ◆ After reading the line and checking if this is a valid one, class ReadFromFile calls class Controller to generate the object code.
- ➔ For the object code generation :
  - ◆ The Controller specifies which format is the instruction then calls the formatchecker that decides which pass to take from the three formats passess whether format 2 or 3 or 4
    - The 3 formats computes the first part of the object code by relatively the same way then for format 2 it finds the hexadecimal corresponding to each register used for format 3 and 4 takes the next step towards "find flags" class.
    - Find flags class specify which addressing mode the instruction uses and gets the corresponding flags combination (NIX) from "legalFlagsCombinationsClass" then performs some calculations to find the proper (BPE) part of the object code and gets it from "legalFlagsCombinationsClass" .
    - After that the "CalculateDisplacement" does its work by calculating the displacement.
    - The controller combines the parts of the object code returned by each class and converts it to hexadecimal and stores the object code in the symbol table.
- ➔ For the forward referencing part :
  - ◆ If the CalculateDisplacement class found an operand symbol that isn't in the symbol table(pre defined) it stores it in the "LocationsTable" singleton class and stores the address of the instruction which is missing this operand.
  - ◆ When the parser finds this symbol it gives it's address to "AddSymbol" class and it automatically completes the computation of the incomplete object codes.

Main data structures

I. Map (Hash map)

- Map to store the definition of data which follow the key word such as(WORD , BYTE ,RESW ,REWB,ORG,EQU).
- Map to store all Register names as key and his object code as parameters which Register are valid to use in Sic/XE .
- Map to store all Operation names as keys and his object code as parameters which Operation are valid to use in Sic/XE .
-

II. Vector

- Vector to store the Operant which is defined as follower reference .
- Vector to split the operand which content of two parts one is Data and other is Register X or operand can be two register the vector store parts to check if the operant is valid .

III. Array One Dimensional

- One dimension array in size seven elements to store the static label such as(WORD , BYTE ,RESW ,REWB,ORG,EQU) as String .
- One dimension array of size three to store the Label,Operation ,Operand.

Algorithms description

- First of all, the assembler reads the source lines from a file line by line and parsing it then sends it to the object code generator.

- Function **CheckWithRegex** in **Parsing** Class checks that the syntax of the line is correct, and splits the line to (Label - Operation - Operand), and then checks that all of them are valid, for example check the the operation belongs to **SIC/XE.**

- Class **DynamicTables** contains function **BuildDataTable** which check that statement don't have any logic error or any sentence error by many conditions such as :
  - Check that the Operand which after the keyword "WORD" the length less than 5 if the Operand is number , the length less than 8 and not contain

white space if Operand is string and in two case must the length be more than zero.

- Check that the Operand which after the keyword "BYTE" the length less than 15 if the Operand is a hexadecimal number ,is even number and contain character "X" and single quote , the length less than 16 and check that contain character "C" and single quote in the first and in the last and in two case must the length be more than zero.
- Check that the Operand which after the keyword "RESB" or "RESW" the length less than 5 number ,must be more than zero.
- Check that the Operand which after the keyword "END" or "RESW" the length be zero or in case "END" label not equal the label in the directive start.
- Check that the Operand which after the keyword "START" the length more than zero and less than 5 and the Operand must be a hexadecimal number .
- If the first character of Operand be '@' ,'#','*' must check that Operation not be any type of which deal with register and the operand size in case of '*' must be one if the Operand after this symbol is word must check if have defined already if not store it to deal on it as forward reference if Operand is number the length must be less than 5 more than zero.

If Operand is two registers or register x and and word define or not must check that the Operation is at the end of character 'R' or is equal "STCH" ,"LDCH",and otherwise which deal on registers.

➢ Class **MakeAddress** contain function **LocationCounter** which return the (LOC) of every line as string of hexadecimal number that make by:

- Define int variable LOC as static the initial value of it is the Operant which became after directive Start .
- Then to calculate the value of location counter two any line take the value of LOC and ADD on it according to every situation :
  - ➢ If Operation is "RESB" then add Loc=Loc+Length of Operand
  - ➢ If Operation is "RESW" then add Loc=Loc+(Length of Operand) *3
  - ➢ If Operation in format 4 then add LOC = 4 + LOC
  - ➢ If Operation is "WORD" then add Loc=Loc+3
  - ➢ If Operation is "BYTE" then add Loc=Loc+(Length of Operand-3) if the Operant is character if is hexadecimal then

    Loc=Loc+(Length of Operand-3)/2 .
  - ➢ Otherwise Loc=Loc+3 and for all that return the string equal the value of LOC at hexadecimal.

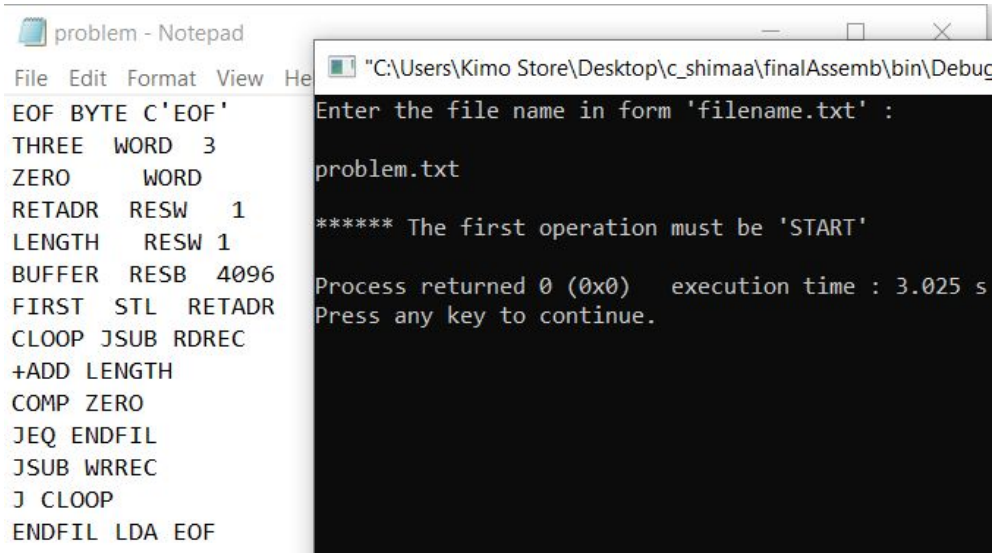
- ➢ If Operation is “ORG”, then the next address will be the address of the operand. And if there is no operand, then it returns the default address.
- ➢ If Operation is “EQU”, then the current address becomes equal to the value in the operand field or the address of the operand.

Assumptions

- ➢ Owr program dealing with forward path technique for all Operand Not only in JSUB instructions but in any Operandand label except the Operand Which comes before Operation (Base) the Operandmust be defined before using it .

Sample runs

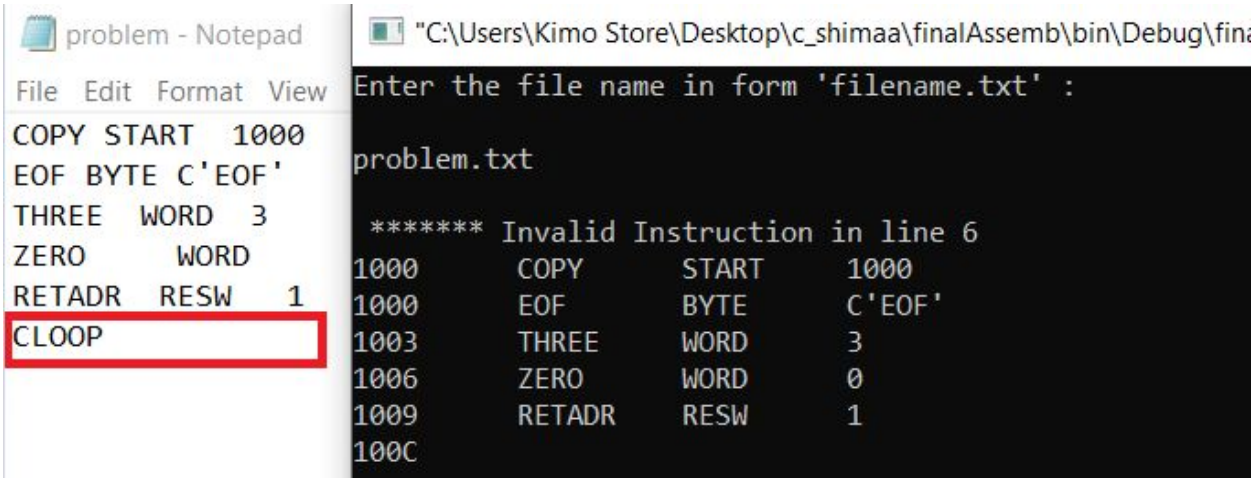
First the parser check that the operation of the first instruction is “START”
Ex.1: The first line operation isn’t “Start”



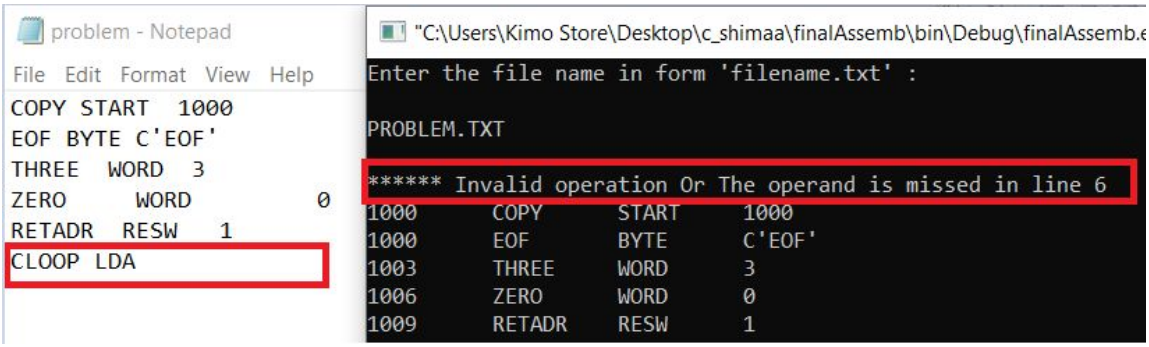
Then the parser checks that the instruction is a valid one with “regex”. We can say the instruction is correct if:

- It contains 3 words, which are label, operation and operand.
- It contains 2 words, operation and operand.
- It contains 1 word, like (RSUB, ORG, END).

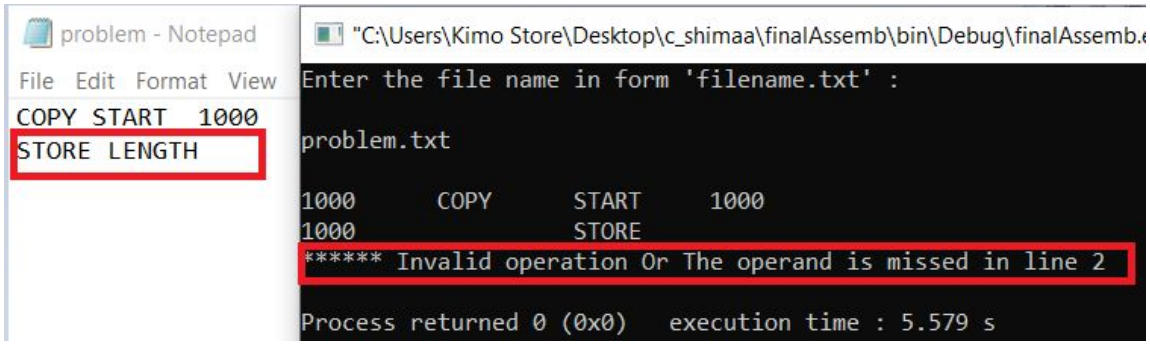
So anything else will be considered as an invalid instruction.
Let's try that.
Ex.2: The instruction is "CLOOP" only:



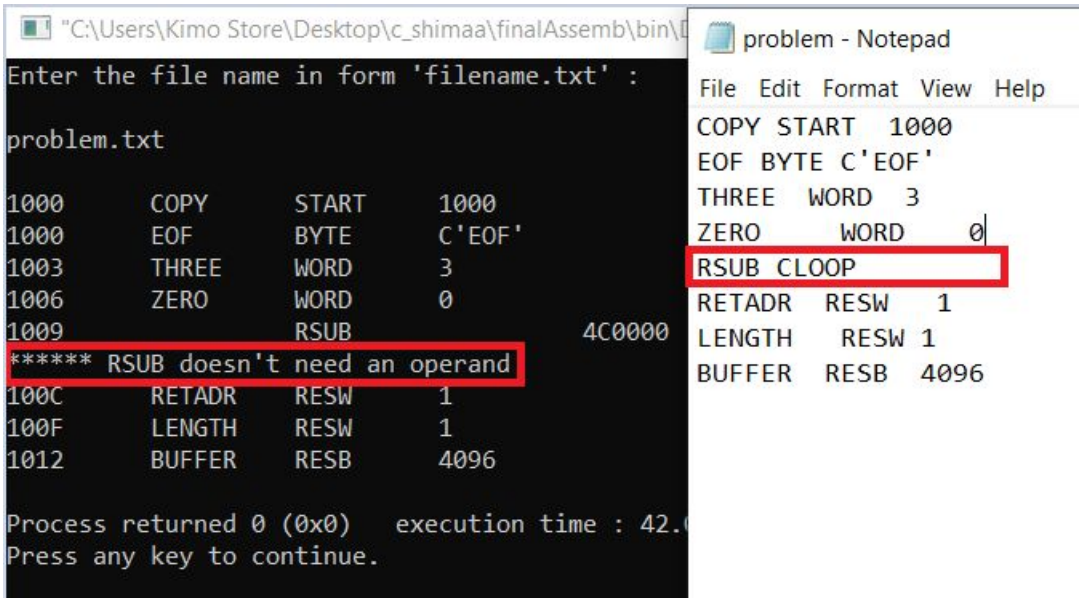
Ex.3: The instruction is only two words but it misses the operand.



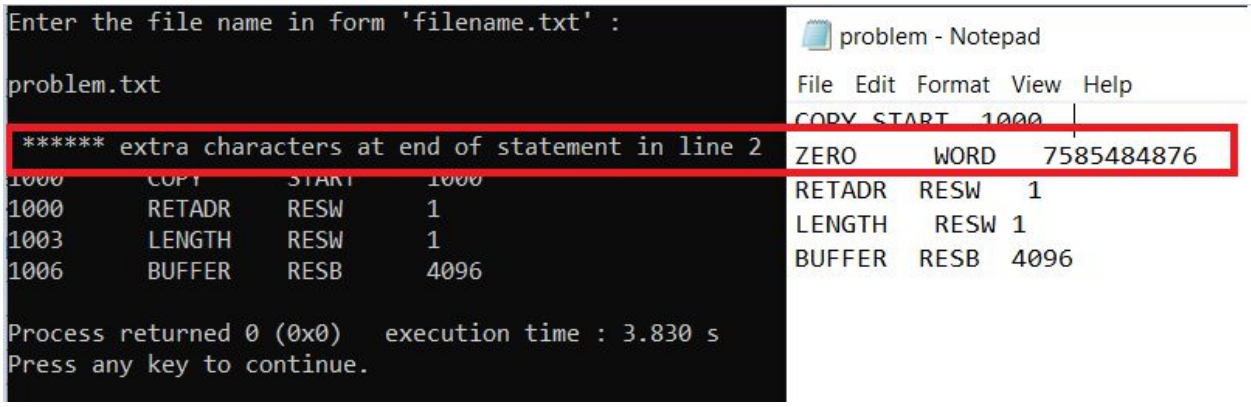
Ex.4: Check that the operation is existing in SIC/XE
"STORE" isn't an operation in SIC/XE



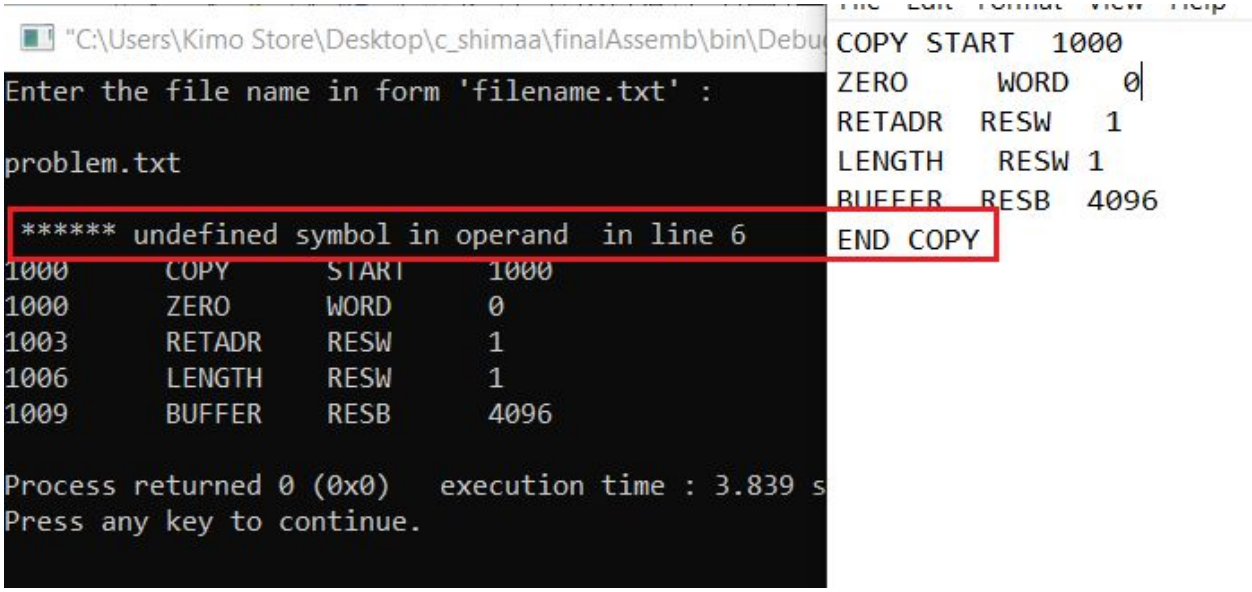
Ex.5: When RSUB has an operand



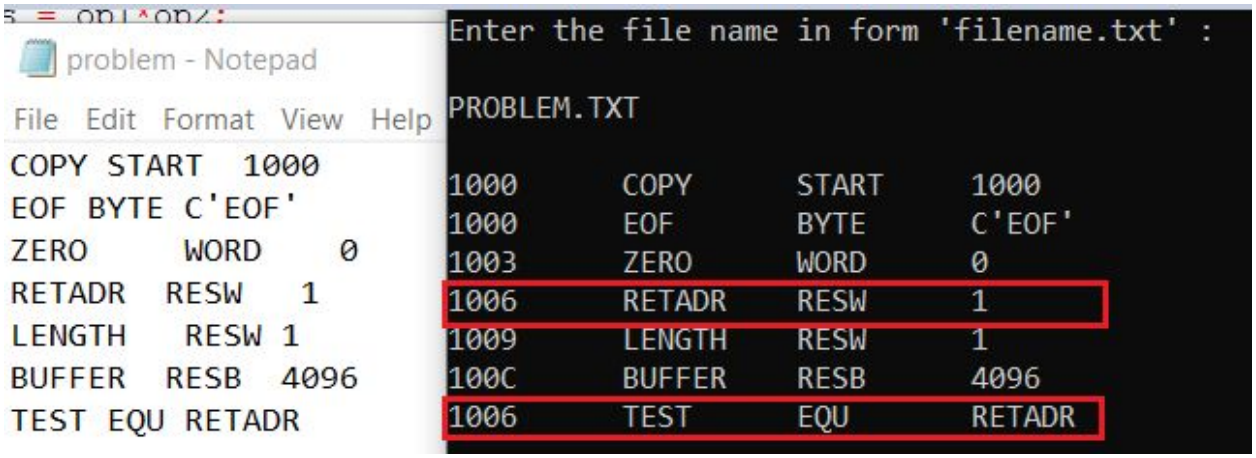
Ex.6 : Extra characters



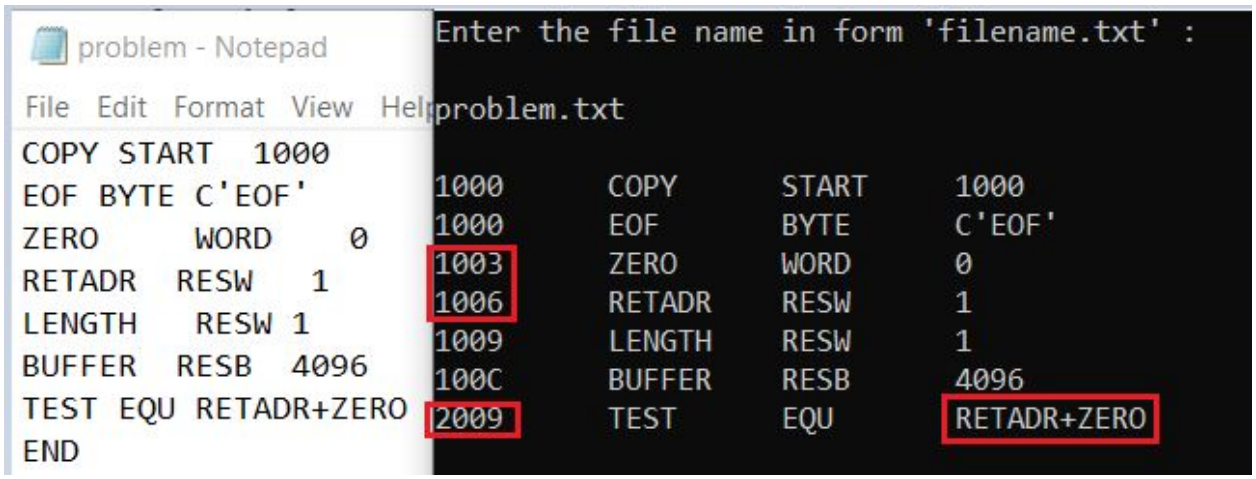
Ex.7 : When **End** has an Operand



Ex.8 : EQU



Ex.9: EQU with Expression



Ex.10: Invalid expression, multiplication is illegal for type relative

problem - Notepad

File Edit Format View Help

```
COPY START  1000
EOF BYTE C'EOF'
ZERO      WORD    0
RETADR  RESW   1
LENGTH   RESW 1
BUFFER  RESB  4096
TEST EQU RETADR*ZERO
END
```

```
Enter the file name in form 'filename.txt' :

problem.txt

****** undefined Expression in operand
1000        COPY        START       1000
1000        EOF         BYTE        C'EOF'
1003        ZERO        WORD        0
1006        RETADR      RESW        1
1009        LENGTH      RESW        1
100C        BUFFER      RESB        4096
ACEE10      TEST        EQU         RETADR*ZERO
```

Ex.11: Test **ORG**

problem - Notepad

File Edit Format View Help

```
COPY START  1000
EOF BYTE C'EOF'
ZERO      WORD    0
RETADR  RESW   1
LENGTH   RESW 1
BUFFER  RESB  4096
TEST ORG RETADR
FIRST  STL  RETADR
CLOOP JSUB RDREC
+ADD LENGTH
J CLOOP
END
```

```
Enter the file name in form 'filename.tx

PROBLEM.TXT

1000        COPY        START       1000
1000        EOF         BYTE        C'EOF'
1003        ZERO        WORD        0
1006        RETADR      RESW        1
1009        LENGTH      RESW        1
100C        BUFFER      RESB        4096
            TEST        ORG         RETADR
1006        FIRST       STL         RETADR
1009        CLOOP       JSUB        RDREC
100C                    +ADD        LENGTH
1010                    J           CLOOP

Process returned 0 (0x0)   execution tim
Press any key to continue.
```

Two **ORG**

problem - Notepad

File Edit Format View He

```
COPY START  1000
EOF BYTE C'EOF'
ZERO      WORD     0
RETADR  RESW   1
LENGTH    RESW 1
BUFFER  RESB  4096
TEST ORG RETADR
FIRST  STL  RETADR
CLOOP JSUB RDREC
ORG
+ADD LENGTH
J CLOOP
END
```

```
Enter the file name in form 'filename

PROBLEM.TXT

1000      COPY      START     1000
1000      EOF       BYTE      C'EOF'
1003      ZERO      WORD      0
1006      RETADR    RESW      1
1009      LENGTH    RESW      1
100C      BUFFER    RESB      4096
          TEST      ORG       RETADR
1006      FIRST     STL       RETADR
1009      CLOOP     JSUB      RDREC
                    ORG
100C                +ADD      LENGTH
1010                J         CLOOP

Process returned 0 (0x0)   execution
Press any key to continue.
```

ORG with undefined Operand

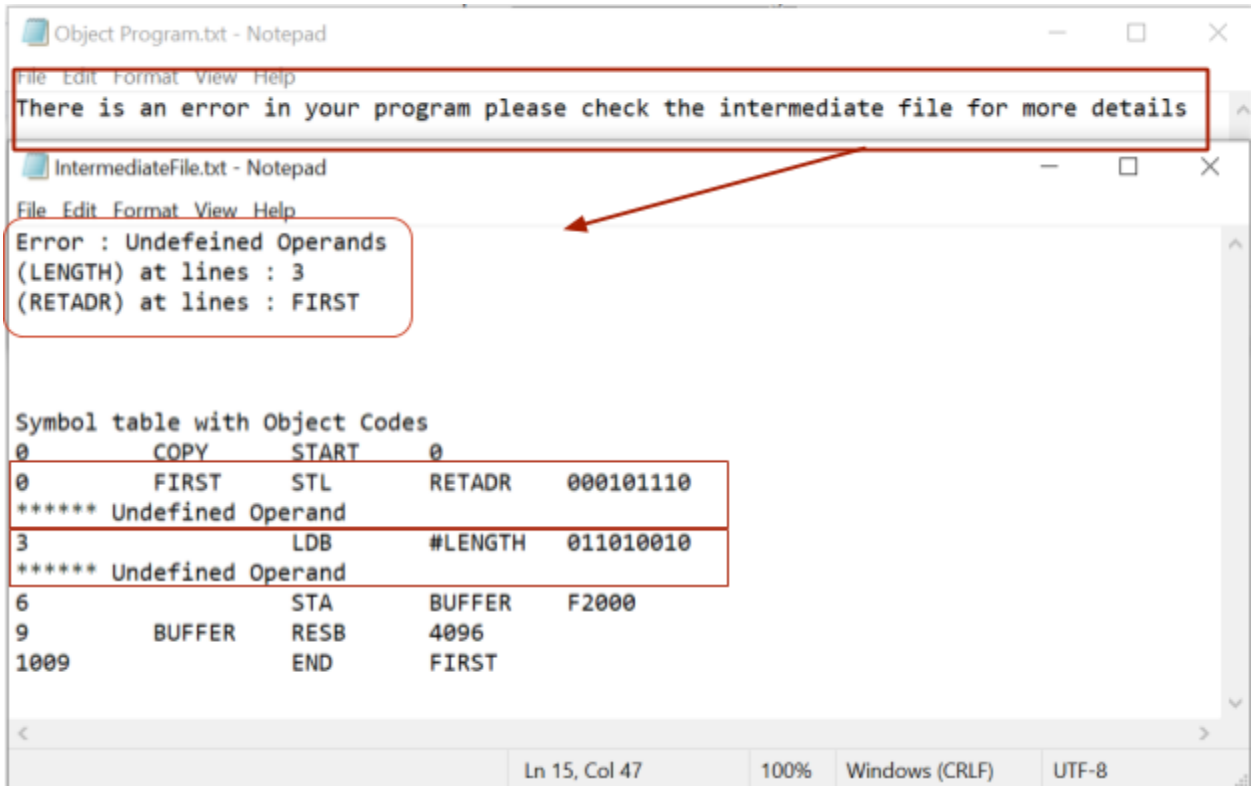
```
Enter the file name in form 'filename.

problem.txt

****** undefined symbol in operand
1000      COPY      START     1000
1000      EOF       BYTE      C'EOF'
1003      ZERO      WORD      0
1006      RETADR    RESW      1
1009      LENGTH    RESW      1
100C      BUFFER    RESB      4096
          TEST      ORG       RDREC
0         FIRST     STL       RETADR
3         CLOOP     JSUB      RDREC
6                   +ADD      LENGTH
A                   J         CLOOP
```

problem - Notepad

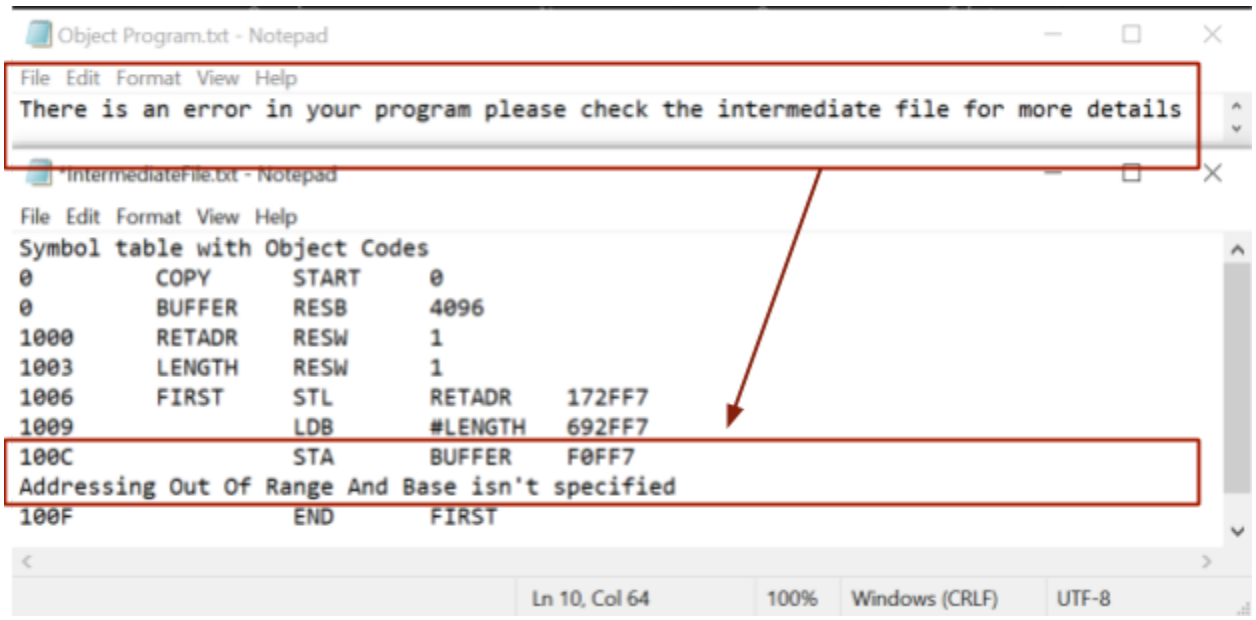
File Edit Format View Help

```
COPY START  1000
EOF BYTE C'EOF'
ZERO      WORD     0
RETADR  RESW   1
LENGTH    RESW 1
BUFFER  RESB  4096
TEST ORG RDREC
FIRST  STL  RETADR
CLOOP JSUB RDREC
+ADD LENGTH
J CLOOP
END
```

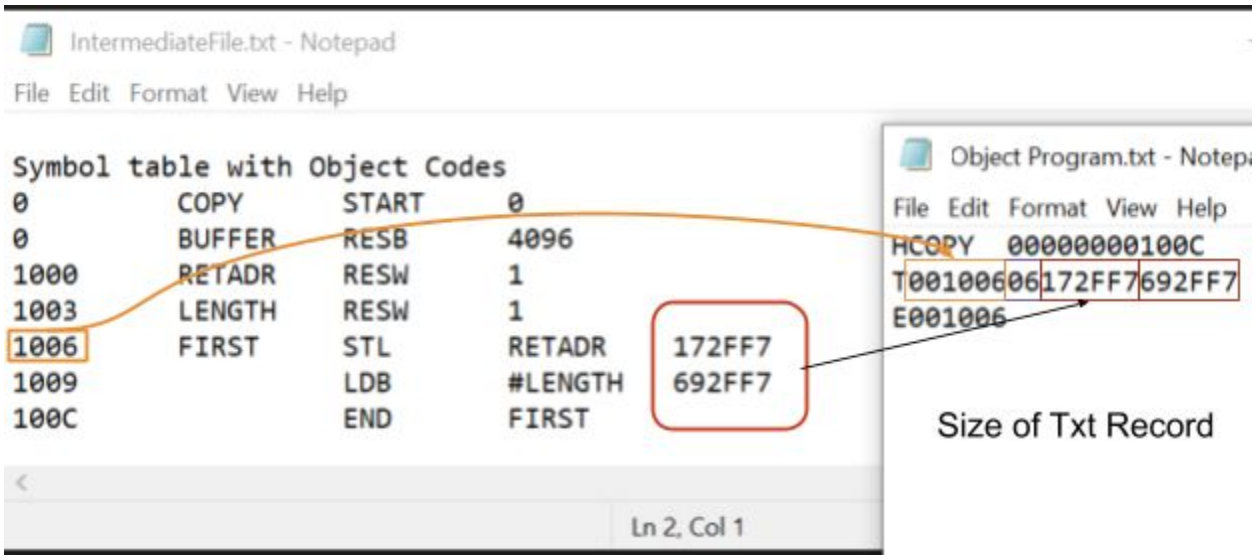
Ex.12: Undefined Operands :



Ex.13: Addressing out of range :

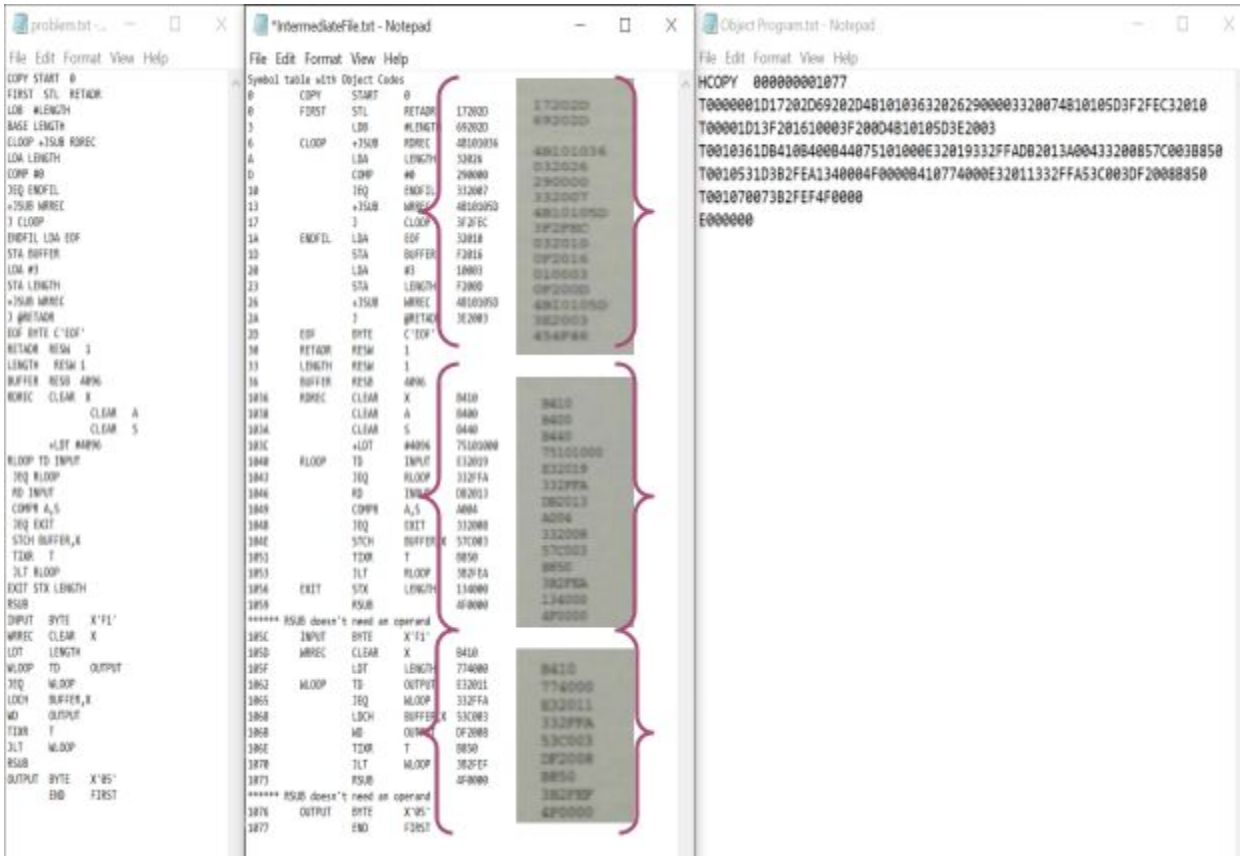


Ex.13: Without forward referencing :



Ex.13: The Book's Example :

```
  5     0000    COPY     START   0
 10     0000    FIRST    STL     RETADR          17202D
 12     0003             LDB     #LENGTH         69202D
 13                      BASE    LENGTH
 15     0006    CLOOP    +JSUB   RDREC           4B101036
 20     000A             LDA     LENGTH          032026
 25     000D             COMP    #0              290000
 30     0010             JEQ     ENDFIL          332007
 35     0013             +JSUB   WRREC           4B10105D
 40     0017             J       CLOOP           3F2FEC
 45     001A    ENDFIL   LDA     EOF             032010
 50     001D             STA     BUFFER          0F2016
 55     0020             LDA     #3              010003
 60     0023             STA     LENGTH          0F200D
 65     0026             +JSUB   WRREC           4B10105D
 70     002A             J       @RETADR         3E2003
 80     002D    EOF      BYTE    C'EOF'          454F46
 95     0030    RETADR   RESW    1
100     0033    LENGTH   RESW    1
105     0036    BUFFER   RESB    4096
110                      .
115                      .       SUBROUTINE TO READ RECORD INTO BUFFER
120                      .
125     1036    RDREC    CLEAR   X               B410
130     1038             CLEAR   A               B400
132     103A             CLEAR   S               B440
133     103C             +LDT    #4096           75101000
135     1040    RLOOP    TD      INPUT           E32019
140     1043             JEQ     RLOOP           332FFA
145     1046             RD      INPUT           DB2013
150     1049             COMPR   A,S             A004
155     104B             JEQ     EXIT            332008
160     104E             STCH    BUFFER,X        57C003
165     1051             TIXR    T               B850
170     1053             JLT     RLOOP           3B2FEA
175     1056    EXIT     STX     LENGTH          134000
180     1059             RSUB                    4F0000
185     105C    INPUT    BYTE    X'F1'           F1
195                      .
200                      .       SUBROUTINE TO WRITE RECORD FROM BUFFER
205                      .
210     105D    WRREC    CLEAR   X               B410
212     105F             LDT     LENGTH          774000
215     1062    WLOOP    TD      OUTPUT          E32011
220     1065             JEQ     WLOOP           332FFA
225     1068             LDCH    BUFFER,X        53C003
230     106B             WD      OUTPUT          DF2008
235     106E             TIXR    T               B850
240     1070             JLT     WLOOP           3B2FEF
245     1073             RSUB                    4F0000
250     1076    OUTPUT   BYTE    X'05'           05
255                      END     FIRST
```



problem.txt - Notepad

File Edit Format View Help

```
COPY START 0
FIRST STL RETADR
LDB #LENGTH
BASE LENGTH
CLOOP +JSUB RDREC
LDA LENGTH
COMP #0
JEQ ENDFIL
+JSUB WRREC
J CLOOP
ENDFIL LDA EOF
STA BUFFER
LDA #3
STA LENGTH
+JSUB WRREC
J @RETADR
EOF BYTE C'EOF'
RETADR RESW 1
LENGTH RESW 1
BUFFER RESB 4096
RDREC CLEAR X
CLEAR A
CLEAR S
+LDT #4096
RLOOP TD INPUT
JEQ RLOOP
RD INPUT
COMPR A,S
JEQ EXIT
STCH BUFFER,X
TIXR T
JLT RLOOP
EXIT STX LENGTH
RSUB
INPUT BYTE X'F1'
WRREC CLEAR X
LDT LENGTH
WLOOP TD OUTPUT
JEQ WLOOP
LDCH BUFFER,X
WD OUTPUT
TIXR T
JLT WLOOP
RSUB
OUTPUT BYTE X'05'
END FIRST
```

*IntermediateFile.txt - Notepad

File Edit Format View Help

```
Symbol table with Object Codes
0       COPY    START   0
0       FIRST   STL     RETADR  172020
3               LDB     #LENGTH 692020
6       CLOOP   +JSUB   RDREC   4B101036
A               LDA     LENGTH  032024
D               COMP    #0      290000
10              JEQ     ENDFIL  332007
13              +JSUB   WRREC   4B103053
17              J       CLOOP   3F2FEC
1A      ENDFIL  LDA     EOF     032010
1D              STA     BUFFER  0F2016
20              LDA     #3      010003
23              STA     LENGTH  0F2000
26              +JSUB   WRREC   4B103053
2A              J       @RETADR 3E2003
2D      EOF     BYTE    C'EOF'  454F46
30      RETADR  RESW    1
33      LENGTH  RESW    1
36      BUFFER  RESB    4096
1036    RDREC   CLEAR   X       B410
1038            CLEAR   A       B400
103A            CLEAR   S       B440
103C            +LDT    #4096   75101000
1040    RLOOP   TD      INPUT   E32019
1043            JEQ     RLOOP   332FFA
1046            RD      INPUT   DB2013
1049            COMPR   A,S     A004
104B            JEQ     EXIT    332008
104E            STCH    BUFFER,X 57C003
1051            TIXR    T       B850
1053            JLT     RLOOP   3B2FEA
1056    EXIT    STX     LENGTH  134000
1059            RSUB            4F0000
****** RSUB doesn't need an operand
105C    INPUT   BYTE    X'F1'
105D    WRREC   CLEAR   X       B410
105F            LDT     LENGTH  774000
1062    WLOOP   TD      OUTPUT  E32011
1065            JEQ     WLOOP   332FFA
1068            LDCH    BUFFER,X 53C003
106B            WD      OUTPUT  DF2008
106E            TIXR    T       B850
1070            JLT     WLOOP   3B2FEF
1073            RSUB            4F0000
****** RSUB doesn't need an operand
1076    OUTPUT  BYTE    X'05'
1077            END     FIRST
```

Object Program.txt - Notepad

File Edit Format View Help

```
HCOPY  000000001077
T0000001D17202D69202D4B10103632026290000332007 4B10105D3F2FEC32010
T00001D13F20161000 3F200D4B10105D3E2003
T0010361DB410B400B4407510100 0E32019332FFADB2013A00433200857C003B850
T0010531D3B2FEA1340004F000004107 74000E32011332FFA53C003DF2008850
T001070073B2FEF4F0000
E000000
```