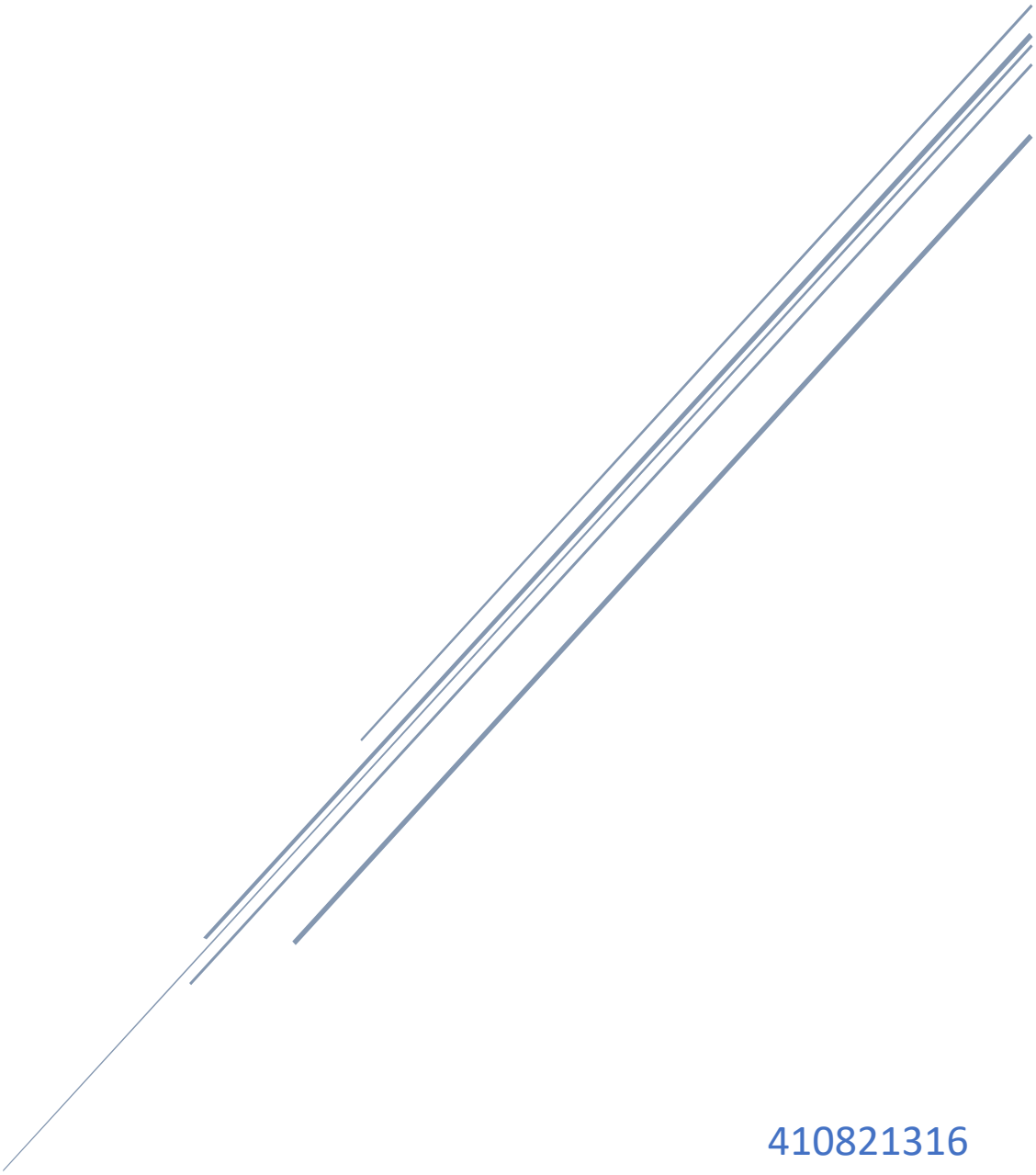
SYSTEM PROGRAMMING

Programming Assignment 1



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Assignment Problem

Write an SIC assembler that reads an SIC assembly program, translates SIC statements into their machine code equivalents, and generates an object file.

Highlight Program

Program Listing

```
import java.io.BufferedReader;
import java.io.FileReader;
import java.io.IOException;
import java.io.PrintWriter;
import java.util.ArrayList;
import java.util.Scanner;

class Data2 {
    private String first = "";
    private String second = "";
    private String third = "";
    private String str = "";

    public Data2(String first, String second, String third, String
str) {
        this.first = first;
        this.second = second;
        this.third = third;
        this.str = str;
    }

    public String getFirst() {
        return first;
    }

    public String getSecond() {
        return second;
    }

    public String getThird() {
        return third;
    }

    public String getStr() {
        return str;
    }
```

```
}

class Pair2 {
    private String symbol = "";
    private String location = "";

    public Pair2(String symbol, String location) {
        this.symbol = symbol;
        this.location = location;
    }

    public String getSymbol() {
        return symbol;
    }

    public String getLocation() {
        return location;
    }

}

public class SICAssembler {
    public static void main(String[] args) throws IOException {
        String[] op_TAB = { "ADD", "ADDF", "ADDR", "AND", "CLEAR",
"COMP", "COMPF", "COMPR", "DIV", "DIVF", "DIVR",
                "FIX", "FLOAT", "HIO", "J", "JEQ", "JGT", "JLT",
"JSUB", "LDA", "LDB", "LDCH", "LDF", "LDL", "LDS",
                "LDT", "LDX", "LPS", "MUL", "MULF", "MULR", "NORM",
"OR", "RD", "RMO", "RSUB", "SHIFTL", "SHIFTR",
                "SIO", "SSK", "STA", "STB", "STCH", "STF", "STI",
"STL", "STS", "STSW", "STT", "STX", "SUB", "SUBF",
                "SUBR", "SVC", "TD", "TIO", "TIX", "TIXR", "WD" };

        String[] opCode = { "18", "58", "90", "40", "B4", "28", "88",
"A0", "24", "64", "9C", "C4", "C0", "F4", "3C",
                "30", "34", "38", "48", "00", "68", "50", "70", "08",
"6C", "74", "04", "E0", "20", "60", "98", "C8",
```

```
            "44", "D8", "AC", "4C", "A4", "A8", "F0", "EC", "0C",
"78", "54", "80", "D4", "14", "7C", "E8", "84",
            "10", "1C", "5C", "94", "B0", "E0", "F8", "2C", "B8",
"DC" };

      ArrayList<Pair2> SYM_TAB = new ArrayList<>();
      ArrayList<String> Location = new ArrayList<>();
      ArrayList<String> Target = new ArrayList<>();
      ArrayList<Data2> Data = new ArrayList<>();

      FileReader fr = new FileReader("src/main/resources/SIC.txt");
      BufferedReader br = new BufferedReader(fr);
      Scanner scn = new Scanner(br);

      int n = 0;
      int num = 0;
      int DecLoc = 0;
      int j;
      int i;

      String HexLoc;
      String str1 = " ";
      String str2 = " ";
      String str3 = " ";

      boolean isOpCode = false;
      boolean isLine = false;

      while (scn.hasNext()) {
         String tempString = scn.next();

         if (tempString.equals("START") || tempString.equals("END")
||
               tempString.equals("WORD") ||
tempString.equals("BYTE") ||
               tempString.equals("RESB") ||
tempString.equals("RESW")) {
            str2 = tempString;
```

```
            isOpCode = true;
        } else {
            for (i = 0; i < op_TAB.length; i++) {
                if (tempString.equals(op_TAB[i])) {
                    str2 = tempString;
                    isOpCode = true;
                    break;
                }
            }
        }

        if (tempString.equals(".")) {
            str1 = ".";
            isLine = true;
        }

        if (str2.equals("RSUB")) {
            isLine = true;
        }

        if (!isOpCode) {
            str1 = tempString;
        } else if (!str2.equals("RSUB")) {
            str3 = scn.next();
            isLine = true;
        }

        if (isLine) {
            Data.add(new Data2(str1,str2,str3,str1+str2+str3));
            str1 = " ";
            str2 = " ";
            str3 = " ";
            isLine = false;
            isOpCode = false;
        }
    }

    fr.close();
```

```
      for (i = 0; i < Data.size(); i++) {
         // Calculate location (address)
         if (Data.get(i).getStr().contains(".")) {
            Location.add("");
            HexLoc = (Integer.toHexString(DecLoc +=
Integer.parseInt(Integer.toString(num),16))).toUpperCase();
         } else {
            if (i != 1) {
               HexLoc = (Integer.toHexString(DecLoc +=
Integer.parseInt(Integer.toString(num),16))).toUpperCase();

               if (i == Data.size() - 1)  {
                  HexLoc = "";
               }
            } else { // Starting point "1"
               HexLoc = Integer.toString(n);
            }
            Location.add(HexLoc);
         }

         if (i == 0) { // Default location (address)
            n = Integer.parseInt(Data.get(i).getThird());
            DecLoc = Integer.parseInt(Integer.toString(n), 16);
            Location.remove(0);
            Location.add(0, Integer.toString(n));
         }

         // Calculate the length
         if (Data.get(i).getStr().contains(".") || i == 0) {
            num = 0;
         } else if (Data.get(i).getSecond().equals("BYTE")) { //
"BYTE" Type C & Type X
            if (Data.get(i).getThird().contains("C")) { // C'EOF'
with length 3
               char[] c = Data.get(i).getThird()
                     .substring(Data.get(i).getThird().indexOf('\'
') + 1,
```

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                                Data.get(i).getThird().length() -
1).toCharArray();
                    num = c.length;
                } else  {
                    num = 1; // X'F1' with length 1
                }
            } else if (Data.get(i).getSecond().contains("RESW")) { //
"RESW" with 3 times
                num = Integer.parseInt(Data.get(i).getThird()) * 3;
            } else if (Data.get(i).getSecond().contains("RESB")) {
                num =
Integer.parseInt(Integer.toHexString(Integer.parseInt(Data.get(i).get
Third())));
            } else { // Leftovers with "WORD"
                num = 3;
            }

            // Create "SYM_TAB"
            if (!Data.get(i).getFirst().contains(" ") && i != 0
&& !Data.get(i).getFirst().contains(".")) {
                SYM_TAB.add(new Pair2(Data.get(i).getFirst(), HexLoc));
            }
        }

        /// Pass 2 create object code
        for (i = 0; i < Data.size(); i++) {
            StringBuilder s = new StringBuilder("");

            for (j = 0; j < op_TAB.length; j++) {
                if (Data.get(i).getSecond().equals(op_TAB[j])) {
                    s.append(opCode[j]);
                    break;
                }
            }

            for (j = 0; j < SYM_TAB.size(); j++) {
                if (Data.get(i).getThird().contains(",X")) {
                    if (SYM_TAB.get(j).getSymbol().equals(Data.get(i)
```

```
                        .getThird().substring(0,Data.get(i).getThird(
).length()-2))) { // Add 8000 for BUFFER with "X"
                    // Hexa to Deci addition, then exchange back to
Hexa

s.append(Integer.toHexString(Integer.parseInt(SYM_TAB.get(j)
                            .getLocation(), 16) +
Integer.parseInt("8000",16)));
                    break;
                }
            } else if
(SYM_TAB.get(j).getSymbol().equals(Data.get(i).getThird())) {
                // "SYM_TAB" table check & fill up digits
                if (s.length() +
SYM_TAB.get(j).getLocation().length() != 6) {
                    int len = s.length() +
SYM_TAB.get(j).getLocation().length();
                    s.append("0".repeat(Math.max(0, 6 - len)));
                    s.append(SYM_TAB.get(j).getLocation());
                } else {
                    s.append(SYM_TAB.get(j).getLocation());
                }

                break;
            }
        }

        switch (Data.get(i).getSecond()) {
            case "BYTE" -> { // Deal with "X" & "C"
                char[] c = Data.get(i).getThird()
                        .substring(Data.get(i).getThird().indexOf('\'
') + 1, Data.get(i).getThird().length() - 1).toCharArray();
                for (char value : c) {
                    if (Data.get(i).getThird().contains("C")) {

s.append(Integer.toHexString(value).toUpperCase()); // ASCII code
from 10 to 16 decimal
                    } else {
```

```
                        s.append(value);
                    }
                }
            }

            case "WORD" -> { // Deal with "Data.get(i).getThird()"
and fill up to six digit object code

s.append(Integer.toHexString(Integer.parseInt(Data.get(i).getThird())
).toUpperCase());

                if (s.length() < 6) {
                    s.reverse();
                    int len = s.length();
                    s.append("0".repeat(Math.max(0, 6 - len)));
                    s.reverse();
                } else if (s.length() > 6) {
                    s = new StringBuilder(s.substring(2, 8));
                }
            }

            case "RSUB" -> // "RSUB" fill up with "Zeros" for six
digit
                    s.append("0000");
          }

          Target.add(s.toString()); // Store the final result to the
object code section

          if(Data.get(i).getFirst().equals(".")){
              Target.remove(i);
              Target.add("");
          }
      }

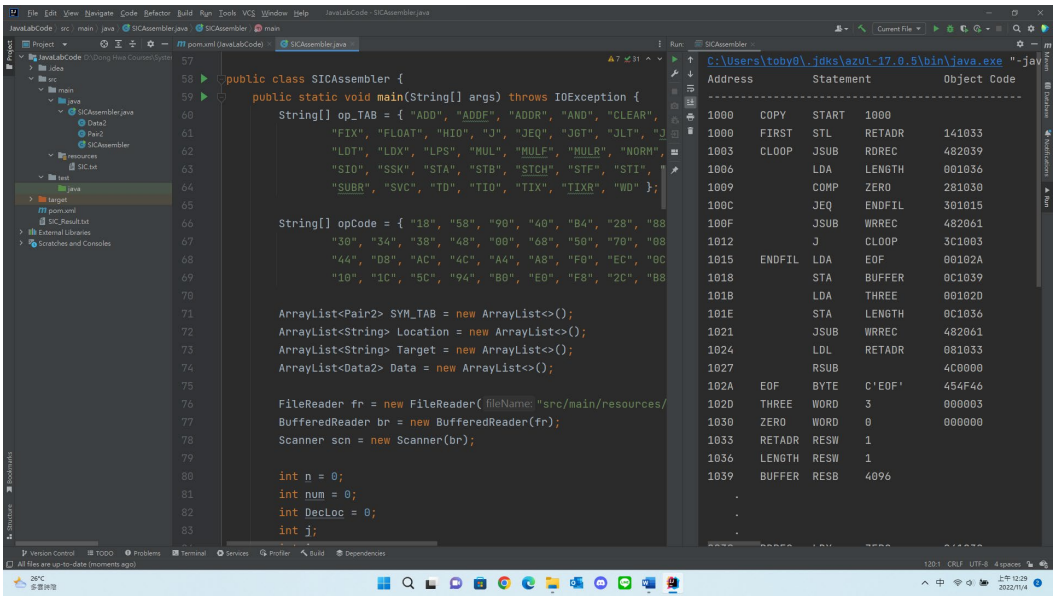
      Target.remove(Target.size() - 1);
      Target.add("");
```

```
        // Result Display & File Output
        PrintWriter Write = new PrintWriter("SIC_Result.txt");
        System.out.printf("%s\t%-6s\t%-6s\t%-5s\t%s\t\r\n", "Address",
" ", "Statement", " ", "Object Code");
        Write.printf("%s\t%-6s\t%-6s\t%-5s\t%s\t\r\n", "Address", " ",
"Statement", " ", "Object Code");
        System.out.println("-----------------------------------------
------");
        Write.println("-----------------------------------------------
-");

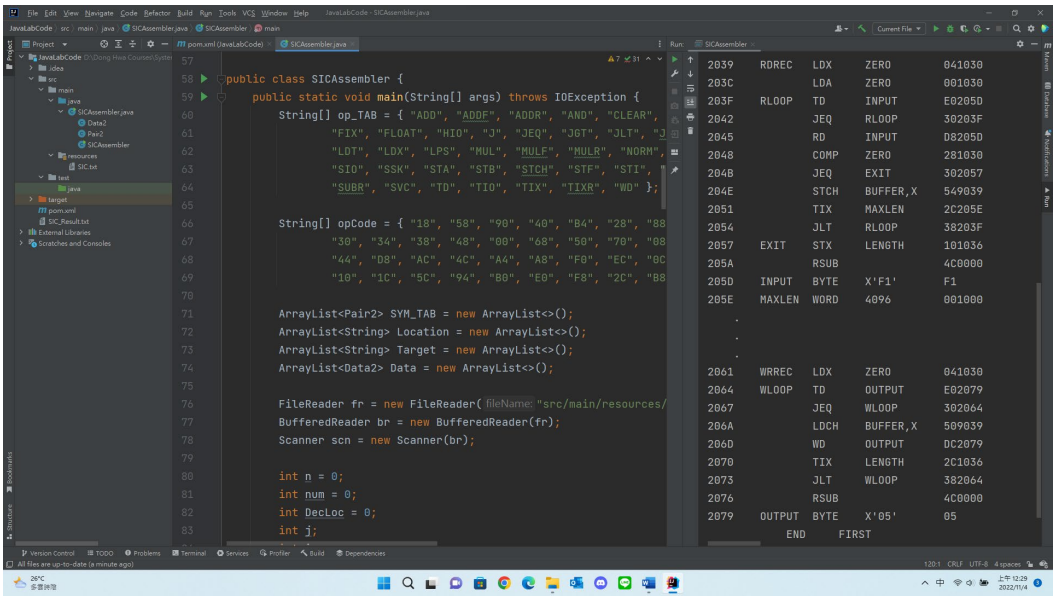
        for (j = 0; j < Data.size(); j++) {
            Write.printf("%s\t%-6s\t%-6s\t%-10s\t%s\t\r\n",
Location.get(j), Data.get(j).getFirst(),
                    Data.get(j).getSecond(), Data.get(j).getThird(),
Target.get(j));
            System.out.printf("%s\t%-6s\t%-6s\t%-10s\t%s\t\r\n",
Location.get(j), Data.get(j).getFirst(),
                    Data.get(j).getSecond(), Data.get(j).getThird(),
Target.get(j));
        }

        Write.close();
    }
}
```

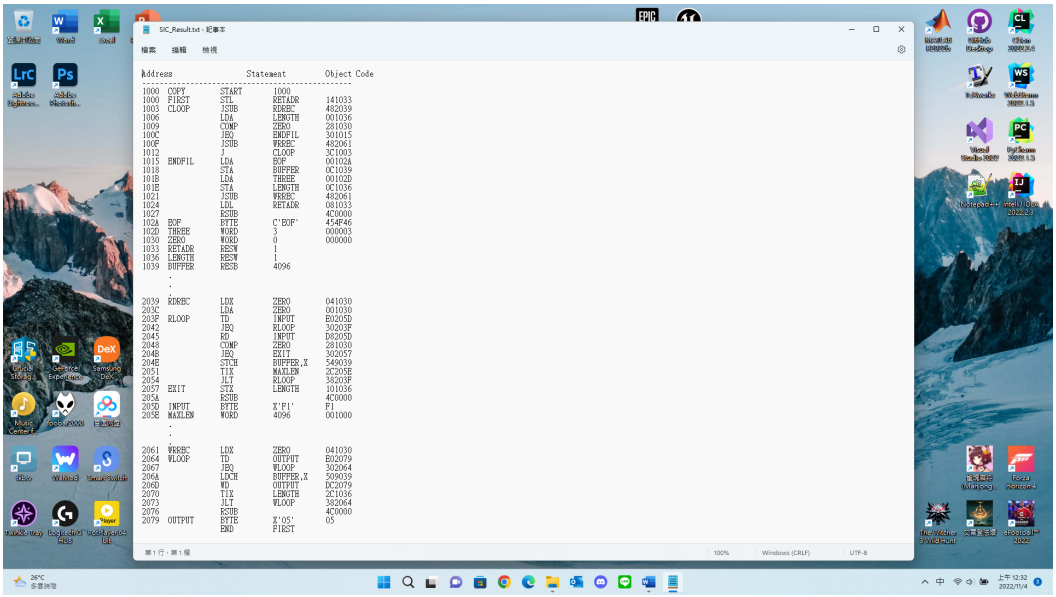
Test Run & File Output



```
C:\Users\toby0\.jdks\azul-17.0.5\bin\java.exe "-jav
Address         Statement           Object Code
-----------------------------------------------
1000    COPY    START   1000
1000    FIRST   STL     RETADR      141033
1003    CLOOP   JSUB    RDREC       482039
1006            LDA     LENGTH      001036
1009            COMP    ZERO        281030
100C            JEQ     ENDFIL      301015
100F            JSUB    WRREC       482061
1012            J       CLOOP       3C1003
1015    ENDFIL  LDA     EOF         00102A
1018            STA     BUFFER      0C1039
101B            LDA     THREE       00102D
101E            STA     LENGTH      0C1036
1021            JSUB    WRREC       482061
1024            LDL     RETADR      081033
1027            RSUB                4C0000
102A    EOF     BYTE    C'EOF'      454F46
102D    THREE   WORD    3           000003
1030    ZERO    WORD    0           000000
1033    RETADR  RESW    1
1036    LENGTH  RESW    1
1039    BUFFER  RESB    4096
```



```
2039    RDREC   LDX     ZERO        041030
203C            LDA     ZERO        001030
203F    RLOOP   TD      INPUT       E0205D
2042            JEQ     RLOOP       30203F
2045            RD      INPUT       D8205D
2048            COMP    ZERO        281030
204B            JEQ     EXIT        302057
204E            STCH    BUFFER,X    549039
2051            TIX     MAXLEN      2C205E
2054            JLT     RLOOP       38203F
2057    EXIT    STX     LENGTH      101036
205A            RSUB                4C0000
205D    INPUT   BYTE    X'F1'       F1
205E    MAXLEN  WORD    4096        001000
2061    WRREC   LDX     ZERO        041030
2064    WLOOP   TD      OUTPUT      E02079
2067            JEQ     WLOOP       302064
206A            LDCH    BUFFER,X    509039
206D            WD      OUTPUT      DC2079
2070            TIX     LENGTH      2C1036
2073            JLT     WLOOP       382064
2076            RSUB                4C0000
2079    OUTPUT  BYTE    X'05'       05
                END     FIRST
```



```
Address         Statement           Object Code
-----------------------------------------------
1000    COPY    START   1000
1000    FIRST   STL     RETADR      141033
1003    CLOOP   JSUB    RDREC       482039
1006            LDA     LENGTH      001036
1009            COMP    ZERO        281030
100C            JEQ     ENDFIL      301015
100F            JSUB    WRREC       482061
1012            J       CLOOP       3C1003
1015    ENDFIL  LDA     EOF         00102A
1018            STA     BUFFER      0C1039
101B            LDA     THREE       00102D
101E            STA     LENGTH      0C1036
1021            JSUB    WRREC       482061
1024            LDL     RETADR      081033
1027            RSUB                4C0000
102A    EOF     BYTE    C'EOF'      454F46
102D    THREE   WORD    3           000003
1030    ZERO    WORD    0           000000
1033    RETADR  RESW    1
1036    LENGTH  RESW    1
1039    BUFFER  RESB    4096
2039    RDREC   LDX     ZERO        041030
203C            LDA     ZERO        001030
203F    RLOOP   TD      INPUT       E0205D
2042            JEQ     RLOOP       30203F
2045            RD      INPUT       D8205D
2048            COMP    ZERO        281030
204B            JEQ     EXIT        302057
204E            STCH    BUFFER,X    549039
2051            TIX     MAXLEN      2C205E
2054            JLT     RLOOP       38203F
2057    EXIT    STX     LENGTH      101036
205A            RSUB                4C0000
205D    INPUT   BYTE    X'F1'       F1
205E    MAXLEN  WORD    4096        001000
2061    WRREC   LDX     ZERO        041030
2064    WLOOP   TD      OUTPUT      E02079
2067            JEQ     WLOOP       302064
206A            LDCH    BUFFER,X    509039
206D            WD      OUTPUT      DC2079
2070            TIX     LENGTH      2C1036
2073            JLT     WLOOP       382064
2076            RSUB                4C0000
2079    OUTPUT  BYTE    X'05'       05
                END     FIRST
```

Discussion