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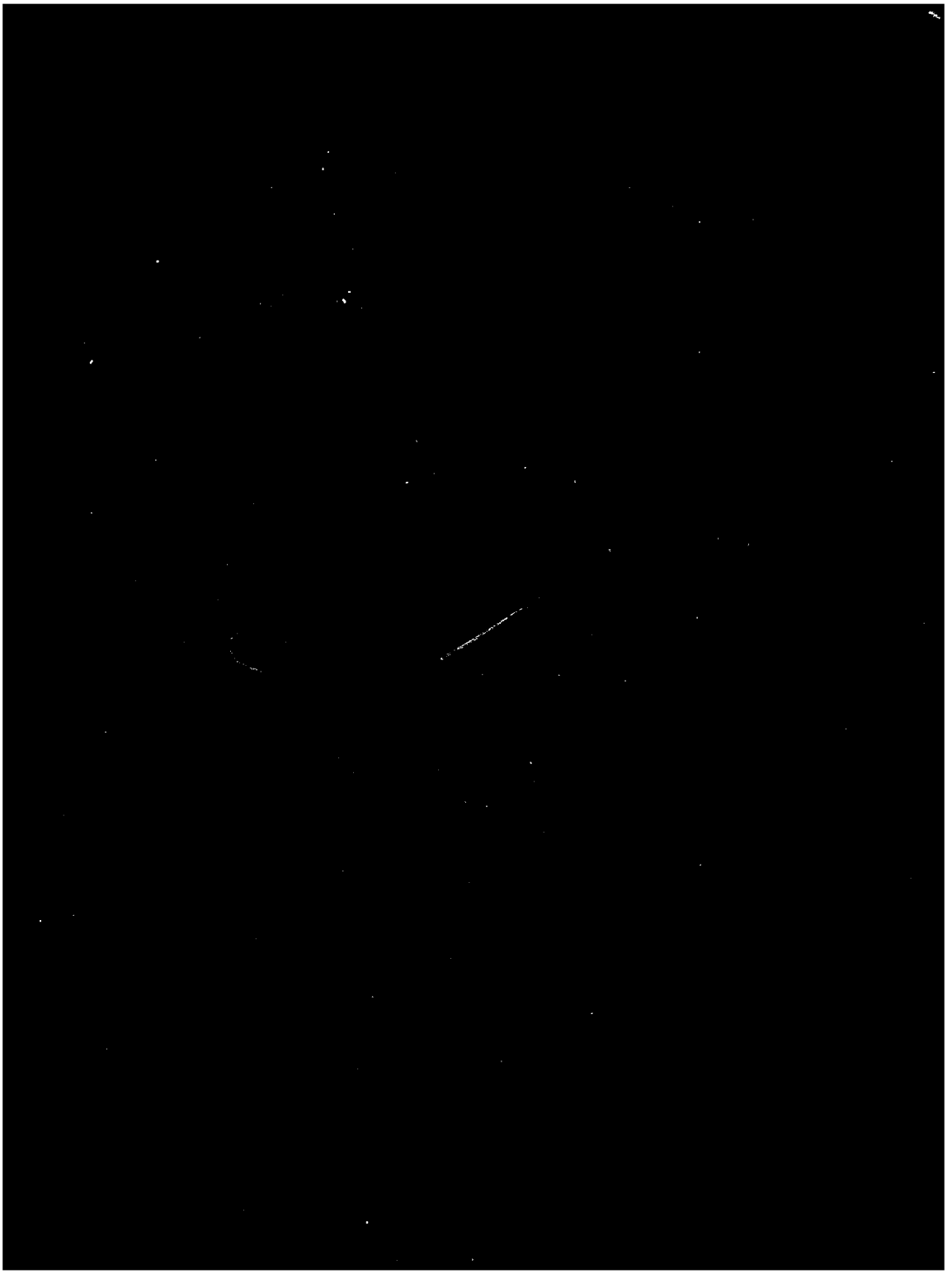

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This report describes CRASS, a two-pass cross-assembler for the TI-9900 microprocessor. The assembler was written in GIRL-FORTRAN to be used on a PDP-11 computer with an RT-11 operating system. It uses the standard TI-9900 mnemonics and allows for most of the same assembly time directives.

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(Block 10)

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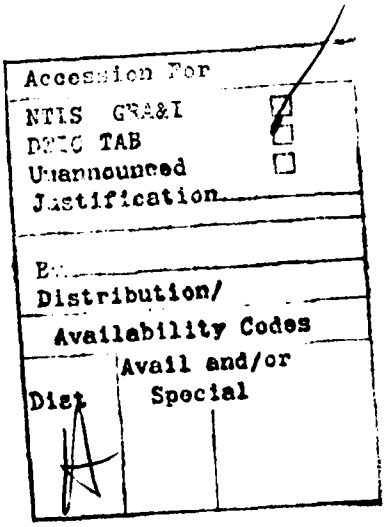
(Block 20 continued)

CRASS has the following features:

- Symbolic memory addressing
- Portability - Since CRASS is written mostly in FORTRAN, it can be easily adapted to any machine having a FORTRAN IV compiler.
- Left to right arithmetic expression handling in binary, decimal, or hexadecimal
- Logical expression handling
- Specified program starting address; however, there is a default value.
- Less program assembly time than with the TI assembler since the code which is created is non-relocatable and therefore does not require a linkage step.



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ABSTRACT

This report describes CRASS, a two-pass cross-assembler for the TI-9900 microprocessor. The assembler was written in GIRL-FORTRAN to be used on a PDP-11 computer with an RT-11 operating system. It uses the standard TI9900 mnemonics and allows for most of the same assembly time directives.

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ADMINISTRATIVE INFORMATION

This work was performed in the Computer Science Division of the Computations, Mathematics, and Logistics Department under the sponsorship of NAVSUP 043C, Task Area TF60531091, Work Unit 1800-008.

INTRODUCTION

This report describes CRASS, a two-pass cross-assembler for the TI9900 microprocessor.[1] The assembler was written in GIRL[2]-FORTRAN to be used on a PDP-11 computer with an RT-11 operating system. It uses the standard TI9900 mnemonics and allows for most of the same assembly-time directives.

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- Portability - Since CRASS is written mostly in FORTRAN, it can be easily adapted to any machine having a FORTRAN IV compiler.
- Left to right arithmetic expression handling in binary, decimal, or hexadecimal

*A complete listing of references is given on page 83.

- Logical expression handling
- Less program assembly time than with the TI assembler since the code which is created is non-relocatable and therefore does not require a linkage step.

Although program debugging would take less assembly time with relocatable code, the time difference is not considered significant for our purposes.

Several uses for the TI9900 microprocessor are envisioned. All these projects will require rapid software development. These projects include use of the TI microprocessor to:

- Control an "intelligent" Logistics Communication Terminal between the SNAP II* and NAVMACS** systems.
- Control the interface between a hardware associative memory and the PDP-11 computer.
- Provide the computing power for an experimental distributed microprocessor.
- Provide the interface for other similar man-machine and machine-machine projects (such as signature verification).

USING CRASS

GENERAL DISCUSSION

An assembly language program may be assembled on the PDP-11 by executing the CRASS.SAV file. If this file is on the system disk, the form is:

R CRASS

The program will respond by asking for the input and output file names:

"PLEASE ENTER FILE NAMES IN COMMAND STRING FORM"

The command string format for CRASS is:

"output file 1 [, output file 2] = input file"

The first output file contains the absolute object code and has a default extension name "ABS." The second output file is optional. It contains the source and identification listing if the "LIST" directive is included in the assembly program. This file has a default extension name "LST." Note that the RK1 disk unit must be turned on, since CRASS places one of its temporary scratch files there.

---

*Shipboard Nontactical ADP Program.

**Naval Modular Automated Communications System.

CONSTANTS AND EXPRESSIONS

Hollerith Constants

Hollerith constants are delineated by either a pair of quotes (') or a pair of dollar signs ($), for example:

```
LABL1  BYTE  'A', 'X', $Y$;
LABL2  DATA  $AB$, 'XY';
LABL3  TEXT  'ABCDE';
LABL4  TEXT  $TODAY'S DATE IS$;
LABL5  TEXT  'COST IS $5.00';
```

The following statements produce identical code:

```
BYTE 'A', 'B', 'C', 'D', 'E', 'F';
DATA 'AB', 'CD', 'EF';
TEST 'ABCDEF';
```

A discussion of the limitations on these directives may be found in the section on limitations and differences with the TI assembler and also in the TI9900 Manual,[1] Section 7, page 10.

Numerical Constants

Numerical constants may be expressed in decimal, binary, or hexadecimal form. Default is decimal; binary numbers are preceded by a percent sign (%) and hexadecimal numbers are preceded by a "greater than" operator (>). The minus sign (-) precedes either "%" or ">" for negative numbers. The following limitations are in effect:

Integer	+32767
Binary	+%111 1111 1111 1111
Hexadecimal	>7FFF, ->7FFF

Identifiers

All identifiers must begin with an alphabetic character. The length of identifiers is limited (solely by the fixed-input format for labels) to six characters.

Logical and Numerical Operators

CRASS allows for the following logical operations:

Operator	Function
.+	Logical OR
.*	Logical AND
.-	Logical NOT (one's complement)
./	Modulo

Arithmetic functions are performed with the four standard operators:

+, *, -, and /.

Logical and Numerical Expressions

All expressions are evaluated strictly on a left to right basis with no parentheses allowed.

For example: X EQU 3+4*5;

X is set to 35, not 23.

Also, expressions must be resolved within two passes.

For example,

```
            DATA  X+3;

      X     MOV   R1,R2;
```

will be correctly evaluated. However,

```
1)    A     EQU   B+C
2)    B     EQU   C+D
3)    C     EQU   10;
4)    D     EQU   5;
```

will not be correctly evaluated since "B" will not be resolved until the second pass examines statement number two.

Logical expressions follow the same structure and are evaluated in the same manner as numerical expressions.

For example:

```
    X  BYTE  F.+%1001.*10;
```

places "0A" into the appropriate byte and

```
    Y  BYTE  F.*%1001.+10;
```

places "0B" into the appropriate byte

INPUT FORMAT

Assembly statements consist of the following four fields:

```
1           8                          13
LABEL       INSTRUCTION OR DIRECTIVE   OPERAND FIELD      COMMENTS
```

The label may be placed anywhere in positions 1-6. Up to six alphanumeric characters are allowed, the first of which must be alphabetic. If an asterisk (*) is placed anywhere in the label field, the entire statement is treated as a comment.

Instructions and assembler directives must begin in position 8. Since the collection of instructions and directives available with CRASS is smaller than that offered by the TI assembler,[1] the reader is referred to Table 2 on page 6 and Table 3 on page 7 for instructions and directives available with CRASS. The reader is also referred to pages 6-18 through 6-60 and pages 7-8 through 7-14 from the TI Manual.[1]

Operands may be placed anywhere from position 13 to position 72. Operand fields are separated by commas and the last field must be terminated by a semicolon (;). Comments may be placed after the semicolon. Instructions and directives which do not use the operand field do not require a semicolon. Arithmetic expressions must not contain any embedded blanks. Operand formats are discussed in the next section.

OPERAND FORMATS

The entire TI9900 instruction set requires twelve formats for the operand field. The format descriptions are listed in Table 1. The formats for the instruction set are summarized in Table 2. The formats for the directives are summarized in Table 3.

TABLE 1 - INSTRUCTION OPERAND FORMAT DESCRIPTIONS

Symbol	Description
S	Modifiable source address
D	Modifiable destination address
W	Unmodified workspace register
DIS	Displacement in bytes (displacement is in words for the TI assembler)
C	Count: integers 0-15
IOP	Immediate operand value
BIT	Integer 0-255

TABLE 1 (Continued)

Operand Format No.	Description
1	S,D
2	DIS
3	S,W
4	S,C
5	W,C
6	S
7	NONE
8	W,IOP
9	S,W (uses W_i and W_{i+1})
A	BIT
B	IOP
C	W

TABLE 2 - INSTRUCTION OPERAND FORMAT NUMBERS

Instr.	Format No.	Instr.	Format No.	Instr.	Format No.
A	1	JGT	2	RTWP	7
AB	1	JH	2	S	1
ABS	6	JHE	2	SB	1
AI	8	JL	2	SBO	A
ANDI	8	JLE	2	SBZ	A
B	6	JLT	2	SETO	6
BL	6	JMP	2	SLA	5
BLWP	6	JNC	2	SOC	1
C	1	JNE	2	SOCB	1
CB	1	JNO	2	SRA	5
CI	8	JOC	2	SRC	5
CLR	6	JOP	2	SRL	5
COC	3	LDCR	4	STCR	4
CZC	3	LI	8	STST	C
DEC	6	LIMI	B	STWP	C
DECT	6	LWPI	B	SWPB	6
DIV	9	MOV	1	SZC	1
IDLE	7	MOVB	1	SZCB	1
IN	6	MPY	9	TB	A
INC	6	NEG	6	X	6
INCT	6	NOP	7	XOP	9
INV	6	ORI	8	XOR	3
JEQ	2	OUT	6		

TABLE 3 - DIRECTIVE OPERAND FORMATS

Directive	Directive Number	Format
AORG	1	expression; (address)
BSS	3	expression;
BYTE	4	$expression_1$, . . . , $expression_N$; N≤19, if PC is odd N≤20, if PC is even
DATA	5	$expression_1$, . . . , $expression_N$; N≤10
DXOP	8	format 6
END	9	none
EQU	10	expression;
EVEN	11	none
LIST	13	none
TEXT	17	Literal-list of N characters N≤19, if PC is odd N≤20, if PC is even
/	20	expression;

NOTES:
1. Slash is equivalent to the AORG directive.
2. Slash must be in column 8.

LIMITATIONS AND DIFFERENCES WITH THE TI ASSEMBLER

The following (known) differences are listed in no particular order.

1) The input format for CRASS is quite rigid

Label - anywhere in columns 1-6

Instructions and Directives - must begin in column 8

Operand Field - anywhere in columns 13-72.

2) The jump instructions accept the value in the operand field as a quantity of bytes, whereas the TI assembler uses the operand value as a word quantity. The operand value must be in the range -256 to +254 bytes.

3) Registers 0 through 15 must be referred to as "R0," "R1," . . . , "R15"

4) Hollerith (literal) data must be bounded by either a pair of dollar signs ($) or a pair of apostrophies (').

5) The current location may be referred to, in CRASS, with an exclamation point (!). The TI assembler uses a dollar sign ($).

6) DXOP. The format for this directive in CRASS is:

```
name DXOP extended operations number;
```

The format used by the TI assembler is:

```
DXOP name, extended operations number;
```

Note that the extended operation name should not be used as an ordinary label.

7) Assembly time constants and other operands must be resolved within two passes of the source program. For example, the following statements will be correctly resolved:

```
A   EQU   B;
B   EQU   2;
```

For the following statements, "A" would not be properly resolved:

```
A   EQU   B;
B   EQU   C;
C   EQU   3;
```

8) To redefine the program counter (PC), both CRASS and the TI assembler will accept:

```
AORG   absolute value;
```

CRASS will also accept a slash (in column 8):

```
/      absolute value;
```

9) Expression evaluation. Both assemblers evaluate expressions from left to right. However, on the TI assembler, a unary minus is performed first. For example,

```
Label1+Value1+(-Value2)
```

is legal with the TI assembler but not with CRASS.

10) Logical operators are legal in CRASS but do not appear to be in the TI assembler.

The operators are:

```
.+     Logical OR
.*     Logical AND
.-     Logical NOT (1's complement)
./     Modulo
```

11) Individual BYTE, DATA, and TEXT statements are limited to a total of 20 characters in the operand field, 19 if the current value of the program counter (PC) is odd. The following statements are examples of the BYTE, DATA, and TEXT directives in which the operands contain the maximum number of allowable characters.

```
BYTE 1, 2, 3, 4, 5, 6, 7, 8, 9,
     0,>A,>B,>C,>D,>E,>F,
     'W','X','Y','Z';

DATA 'AB','CD','EF','GH',1J','KL', 'MN','OP','QR','ST';

TEXT $ABCDEFGHIJKLMNOPQRST$;
```

12) CRASS requires $133,200_8$(46,720) bytes, or

$55,500_8$ ($23,360_{10}$) words plus space for the I/O buffers in order to execute on a PDP-11.
This memory requirement can be reduced should space become a consideration.

ERROR CODES

CRASS separates error conditions into three categories:

1) Multiple label definition
2) Nonexistant instruction name or assembler directive
3) All errors which originate in the operand field, such as:
   a) Undefined memory references
   b) Semantic errors, such as not using a workspace register as the source field operand for input format 5
   c) Exceeding jump displacement limitations
   d) Exceeding 20 characters for the DATA, BYTE, or TEXT directives.

When an error is caught on pass two, a message which describes the line status is sent to the terminal. The line status codes are given in Table 4.

TABLE 4 - LINE STATUS ERROR CODES

Error	Line Status
Label	2
Instruction	4
Operand Field	8

The line status is cumulative for each category of error found in a statement. Thus, a statement with a multiply-defined label and an incorrect instruction name will have a line status of 2 + 4 = 6.

PROGRAM DESCRIPTION

DATA STRUCTURES USED BY CRASS

CRASS employs the Graph Information Retrieval System[3] to create, store, and retrieve its key data structures. Both the Identifier and Op Code-Directives are stored in EPAM tree data structures.

These graphs are composed of source node - link - sink node triples as translated by GIRL.[2] Another way of referring to these triples is to say that the source node is related to the sink node by the link. For example, if the following relationships were to be inserted into a graph, using GIRL, they would appear as follows:

1) A is related to C by B

   G A B C

2) A is related to C and D and E, by B

   G A B (C, D, E)

3) A is related to C by B and C is related to E by D

   G A B C D E

4) A is related to C, D, and E, by B and also D is related to A by F

   G A B (C, D F A, E)

Also discussed in this section are the "label," "token," and "item" (intermediate code) strings which are created in the first pass.

Examples:

1) Instruction-Directive Tree

   This structure is created by a GIRL program called CRSGEN. It is executed before CRASS is run and need be re-executed only if either the instruction set or assembler directive set is changed. The entire program is listed in Appendix A.

As an example, the GIRL statement representing the entire subgraph for directives and op codes beginning with the letter "D" is shown:

```
DATA      DIV
DEC       DORG
DECT      DXOP
DEF
```

(Note that the dollar signs ($) indicate that, although the particular node represents a unique state within the graph, it does not require a unique name.)

```
C
G         START  D  $  (A $ T $ A $ DIRECT "5,"
G         1             E $ (C $ (OPFIN("6,"'//06'),
G         2                      T $ OPFIN("6,"'//06','//40')),
G         3                  F $ DIRECT "6"))
G         4             (I $ V $ OPFIN("9','//3C'),
G         5              0 $ R $ G DIRECT "7",
G         6              X $ 0 $ P $ DIRECT "8")
```

The root node for this graph is called "START." There are two types of terminal nodes. The terminal node for each directive (final link = "DIRECT") contains a unique identifying integer from 1 to 20. For example:

```
DATA  -   5
DEF   -   6
DORG  -   7
DXOP  -   8
```

The terminal node for each op code (final link = "OPFIN") describes:

a) which of the twelve formats the operand field and object code may take, and

b) a skeleton code which forms the basis for the object code. For example, the DIV instruction uses format nine and has a skeleton code of "3C." The statement:

```
DIV   R2, R1;
```

produces "3C42" as the object code.

The nodes which are represented by dollar signs represent uniquely defined random nodes.

2) Identifier Tree

This graph is created largely during the assembler's first pass. When an identifier is first encountered, it is added to the graph, letter by letter. That is, each letter is a potentially new link in the graph.

If the identifier is first encountered in the label field, it is given a value equal to the current location of the program counter (PC) and its status is set to "defined-fullword." If the first encounter is in the operand field, the

identifier is given a value of zero and its status is set to "undefined." The root node for this graph is called "SYMBOL." The following GIRL statements represent a sample subgraph containing a highly correlated set of identifiers:

```
     BLACK          BLOCK4
     BLOCK          BLOCK5
     BLOCK1
G   SYMBOL  B  $ L $ (A $ C $ K $ STOP ("address," "status"),
G  1                  0 $ C $ K $ (STOP ("address," "status"),
G  2                              ONE   STOP  ("address," "status"),
G  3                              FOUR  STOP  ("address," "status"),
G  4                              FIVE  STOP  ("address," "status")))
```

New "label," "token," and "item" strings are created for each statement during the assember's first pass. After each statement is examined during the first pass, the label and token strings are destroyed, but the item string is saved on a file as the intermediate code for that statement.

3) Label string

The label string is composed of a "multivalued list" (MVL) as described by Zaritsky,[3] pages 2-3. The source (root) node is called "STRING" and the link "LABELS." For example, the label "BLOCK1" has the following label string:

```
G   STRING LABELS (B,L,O,C,K,1)
```

4) Token string

The token string is the assembler's first attempt at codifying the operand field. The operand field is broken up into "tokens:" arithmetic operators [+ - * /], numbers, alphanumerics, literals, separators [, ; (] and special characters [! @ % > .]. The token string consists of three separate MVL's:

a) The first MVL consists of a source node/link pair, "TOKEN, STRING," and a set of sink nodes consisting of a sequence of token code numbers representing the operand field. The token codes are listed in Table 5.

TABLE 5 - TOKEN CODES

8	+	16	NUMBER
9	*	17	ALPHANUMERIC
10	-	18	@
11	/	19	%
12	.	20	>
13	!	21	(
14	;	22	.
15	LITERAL		

For example, the operand field:

@TABL->1A(R1),*R2+;

will result in the following token code string:

```
G     TOKEN STRING  (18,  17,  10,  20,  16,  21,  17,  12,  9,  17,  8,  14)
                    [@, TABL,  -,   >,  1A,   (,  R1,   ,   *,  R2,  +,   ;]
```

b) The second MVL describes each token's position in the input buffer. It consists of a source node/link pair, "TOKEN, BUFPOS." For the preceding example, if the at-sign were placed in column 1, the MVL would appear as follows:

```
G     TOKEN BUFPOS ("1","2","6","7","8","10","11","14","15","16","18","19")
```

c) The third MVL describes the length of each token. Although this string could have been eliminated and computed from the second MVL, the time savings warranted its inclusion. For the preceding example, the MVL would appear as follows:

```
G     TOKEN LENID ("1","4","1","1","2","1","2","1","1","2","1","1")
```

5) Item String

The token string is reduced to a string of "items" which include:

•arithmetic operators	[+ - * /]
•logical operators	[.+ .- .* ./]
•literals	
•separators	[, ;]
•numbers	
•identifiers	
•register types	[Ri *Ri @ Ri *Ri+]
•"current PC" operator	[!]
•at-sign	[@]

The item codes are listed in Table 6.

TABLE 6 - ITEM TYPE CODES

0	Reg	10	-
1	*Reg	11	/
2	@Reg	12	,
3	*Reg+	13	!
4	.+ logical OR	14	;
5	.* logical AND	15	literal
6	.- logical NOT	16	number
7	./ modulus	17	identifier
8	+	18	@
9	*		

The item string consists of four separate MVL's:

a) The first MVL consists of a source node, link pair "ITEM, ITMTYP" and the sink nodes consist of a sequence of item codes derived from the token string. The item codes are taken from Table 6.

The token string from the preceding example would result in the following MVL:

```
C     ITEM ITMTYP    ("18", "17", "10", "16", "0", "12", "3", "14")
                        [@   TABL    -    >1A   R1    ,  *R2+    ;]
```

b) The second MVL is the "ITEM,VALUE" pair.

The sink nodes contain the following types of information:

registers	- register number
identifiers	- assigned address or 0 if undefined
numbers	- decimal value
literals	- first two characters in ASCII format
operators	- 0
separators	- 0
exclamation point	- 0

In the example being used, the MVL (during pass two) would appear as follows:

```
G     ITEM VALUE ("0", "address of TABL", "0", "26", "1", "0", "2", "0")
```

c) The third MVL, "ITEM,BUFPOS", is identical to the "TOKEN,BUFPOS" string.

d) The fourth MVL, "ITEM,LENID", is identical to the "TOKEN,LENID" string.

FORMING THE OBJECT CODE WORD

Instruction Code Skeletons

The TI9900 microprocessor instructions take up one 16-bit word (four contiguous hexadecimal integers). Associated with each instruction is an instruction code skeleton, described in the 9900 Family Systems Design Book,[1] pages 6-18 through 6-60. This skeleton may consist of one to four hexadecimal integers which form the heart of each resultant object code word. CRASS takes the skeleton and modifies it as per the operand field to create the object code word. For example: The instruction DIV has a skeleton instruction code "$3C_{16}$" ($0011\ 1100_2$) and an operand format of 9. It will be shown shortly that the operand field "R2,R1;" translates to "042_{16}." Therefore, the statement: DIV R2,R1; translates to "3C42" for the final object code.

Note that an object (data) word is created for immediate operands and also that each memory reference requires an object (data) word.

Object Code Formats

Although there are twelve operand field formats, for the purposes of this assembler there are only eight different object code formats, which are listed in Table 7.

TABLE 7 - MACHINE CODE FORMATS

		Operand Format	Operand Format Number	Machine Code Format
1	a)	S,D	1	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 IC RC_d R_d RC_s R_s
	b)	S,W	3,9	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 IC R_d RC_s R_s
	c)	S,C	4	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 IC C RC_s R_s
2	a)	DIS	2	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 0001 JC DIS
	b)	BIT	A	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 0001 IC BIT
3		W,C	5	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 IC C W
4		S	6	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 IC RC_s R_s
5		none	7	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 IC
6		W,IOP	8	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 IC W
7		IOP	B	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 IC
8		W	C	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 IC W

Explanation of abbreviations:

IC - Instruction Code
JC - Jump Code
W - Workspace register
C - Count
S - Source
D - Destination
R_s, R_d - Register reference, if set to zero, the next word contains a memory reference.
DIS - Displacement
RC - Register Code

Ri = 00_2
*Ri = 01_2
@Ri = 10_2
*Ri+ = 11_2

PROGRAM FLOW

Overview

CRASS requires two passes to create non-relocatable, absolute code. A program listing is given in Appendix B and the variables used are described in Appendix C. The major functions of each pass are:

First pass - Assign address values to labels
Reduce operand field to an item string (intermediate code)
Obtain instruction format and skeleton
Attempt to resolve EQU statements

Second pass - Second attempt to resolve EQU statements
Create and output absolute code
Provide source and identifier listing if desired

Description and Example

To facilitate the program description which follows, the statement:

```
XYZ   MOV   @ABC->23C(R2),*R13+;     (comments)
```

will be converted to object code as an example.

Before CRASS examines any assembly code:

1) User and scratch files are defined
2) The data graph which describes the instructions and directives is read in.
3) The identifiers R0, R1, . . . , R15 are defined as registers.

Begin pass one:

1) Data strings and line statement error flags are re-initialized.
2) The ASCII input line is lexically scanned by subroutine LEXSCN.
   a) The label is converted to a string.
      G STRING LABELS (X,Y,Z)
   b) The instruction is converted to a string.
      G STRING OPCOD (M,O,V)
   c) The operand field is converted to a string (Note that the capitalized names are from labeled common /GIRLCH/).

```
G     TOKEN (STRING (ATSIGN, VARABL, MINUS, GTTHAN, NUMBER, LPAR, VARABL,
G    1                    RPAR,  COMMA,  STAR,  VARABL,  PLUS, SCOLON),
G    2       BUFPOS   ("1",   "2",    "5",   "6",    "7",   "10", "11",
G    3                   "13",  "14",   "15",  "16",   "19",  "20"),
G    4       LENID    ("1",   "3",    "1",   "1",    "3",   "1",  "2",
G    5                   "1",   "1",    "1",   "3",    "1",   "1"))
```

3) If the statement contains a label, Subroutine ADDNAM is called to test for multiple definition and to add the label to the identifier tree if this was the first occurrence of the label. The label is then placed on a special scratch file.

```
G  SYMBOL  X $ Y $ Z $ STOP ("address," "status")
```

where address = the current value of the PC and
status = "defined"

4) Subroutine INSTRU then tries to match the "STRING, OPCOD" list with either a valid instruction or an assembler directive from the Op code - Directive graph. If it is a directive, a unique identifying integer (from 1 to 20) is returned. If it is an instruction, an operand field format and a skeleton code are returned. For the instruction "MOV" these are

format #1
skeleton "$C0_{16}$"

5) Subroutine TOKSCN then converts the token string to an item string. The item string is the intermediate code for transition from pass one to pass two. The item string for this example is:

@, variable, minus, number, register[type 0], comma, register[type 3], semicolon

Note that the values for the ITEM,STRING come from Table 6.

```
G  ITEM (STRING ("18", "17", "10",     "16",     "0",   "12", "13",   "14"),
G        VALUE  (  0, address, 0, decimal value, reg. no., 0, reg. no., 0),
G        BUFPOS ( . . .                                    ),
G        LENID  ( . . .                                    ))
```

TOKSCN also assigns source and destination register codes. For this example,

TOKSCN "sees"

@R2,*R13+

resulting in $R_s = 2 = 0010_2$

$R_d = 13 = 1101_2$

$RC_s = 2 = 10_2$

$RC_d = 3 = 11_2$

6) ITMSCN is then called to create the machine code words for this statement. From Tables 2, 1, and 7, and page 6-19 of the TI 9900 Family Systems,[1] the first machine code word would be:

IC	RC_d	R_d	RC_s	R_s
0123	45	6789	10 11	12 13 14 15
1100	11	1101	1 0	0 0 1 0
C	F	6		2

which equals: "$CF62_{16}$." If the identifier "ABC" has been defined (that is, it occurred in the label field of a statement prior to this one) as, for example, "$23F_{16}$," then the memory reference is computed as $23F_{16} - 23C_{16} = 3$. Therefore, the object code created is:

CF62
0003

If the statement containing "ABC" as a label did not occur until after the present one, the memory reference would have to be resolved in the second pass.

7) The intermediate code is then placed on a scratch file by Subroutine LINOUT.

Before pass two is begun, the read/write pointers of the two scratch files containing the intermediate code and the label names are reset to the beginning. Begin pass two:

1) Data Strings and line statement error flags are re-initialized.

2) Subroutine LINEIN is called to read in the intermediate code for the next statement.

3) Subroutine ITMSCN is called for a second attempt to complete the machine code. If there are no errors, all memory references and "EQU," "DATA," and "BYTE" directives will be resolved at this time.

4) An error checking routine, ERROUT, is then called to determine whether any line statement error flags have been turned on and, if so, to report any errors.

5) If requested by the user (assembler directive "LIST"), Subroutine SRCLST will output a source code listing of the current statement.

6) The object code is then placed on an output file by Subroutine ABSOUT.

After pass two is completed, if "LIST" is requested, the scratch file containing the label names is examined and Subroutine VARLST creates an identifier listing. Otherwise, the program is finished.

BRIEF SUBROUTINE DESCRIPTIONS

The main (driving) program was described in the previous section on program flow. It calls the following subroutines:

ITMSCN	LINEIN
ADDREG	ITMSCN
LEXSCN	ERROUT
ADDNAM	SCRLST
INSTRU	ABSOUT
TOKSCN	VARLST
ASSIGN[RT-11 system library routine]	LINOUT

With a minimum of detail, this section describes the eighteen subroutines and two functions in CRASS.

Subroutine ADDREG

Function:

To add the identifier names R_0, R_1, . . . , R_{15} to the identifier graph and declare them to be workspace registers.

Called By: Main Routine

Subroutine Called: ADDNAM

Subroutine LEXSCN

Function:

To perform a lexical scan of each input statement to create:

1) Label string
2) Instruction string
3) Token string to represent the operand field.

The tokens would consist of arithmetic operators, numbers, alphanumerics, literals, separators, and special characters.

Called By: Main Routine

Subroutine ADDNAM (NODE, IDENT)

Function:

To search the identifier graph for the requested variable from the NODE, IDENT string and add it to the graph if not found. ADDNAM checks for multiple definition of a label and, if the label is new, saves it on a scratch file so that an identifier listing can be created at the end of the program.

Called By: Main Routine
ADDREG
OPFLD
TOKSCN

Subroutine INSTRU

Function:

To search the Opcode - Directive graph for the requested instruction. If it is not found, an error flag is set and a return is made. If an assembler directive is matched, a unique integer identifying that directive is returned. This integer is used later by Subroutine ITMSCN. If an instruction is matched, its machine code skeleton and its operand field format number are returned.

Called By: Main Routine

Subroutine TOKSCN

Function:

To reduce the token string to an item string as described in the sections on data structures and program flow and also to assign values to these items. The items consist of:

Item	Item Value
Identifiers	- Address value or 0 if undefined
Registers	- Register number and code
Numbers	- Decimal value
Literals	- First two ASCII characters
Arithmetic operators	- 0
Logical operators	- 0
Separators	- 0
Exclamation mark	- 0
At-sign	- 0

Called By: Main Routine

Subroutines Called: TMPSTR TWOCMP
ADDNAM LVLFSH

Subroutine ITMSCN

Function:

To scan the item string, left to right, to create the final machine code.

a) First Pass - The number of bytes (halfwords) needed for each instruction is determined and the PC is updated by that amount to assign address values to labels. To update the PC, the following assembler directives are examined:

AORG	EVEN
BSS	TEXT
BYTE	"/"
DATA	

The following directives are also examined on the first pass:

DXOP
END
EQU

b) Second Pass - A second attempt is made to resolve EQU directives. Also, the machine code is constructed and placed on an output file.

Called By: Main Routine

Subroutines Called: FMT1 LVRTSH
OPFLD LVLFSH
DECHEX

Subroutine LINOUT

Function:

To place the intermediate code (item string) onto a scratch file during the first pass.

Called By: Main Routine

Subroutine LINEIN

Function:

To read the intermediate code into core for processing in pass two.

Called By: Main Routine

Subroutine OPFLD (I1)

Function:

To examine a single operand field as delineated by:

beginning to comma
beginning to semicolon
comma to comma
comma to semicolon

where I1 is the location in the operand buffer of the lefthand delineator. For example:

```
                1    1
1   5    0    5
@TABL1(R3),*R2+;
```

To examine the source (left) operand, I1 is set to 0. To examine the destination (right) operand, I1 is set to 11. OPFLD attempts either to extract a register number or to compute a decimal value for the field. The decimal value is converted to hexadecimal and placed into a special array.

OFFLD also determines whether an extra object code word must be allotted for a memory reference.

Called By: ITMSCN

Subroutines Called: DECHEX TMPSTR
COMPUT ADDNAM

Subroutine TMPSTR (ISTLOC, LENGTH)

Function:

To take a sequence of "LENGTH" ASCII characters from the operand field beginning at location ISTLOC, and convert it to a GIRL multivalued list (MVL). For example,

Operand Field:

```
                1    1    2    2
1   5    0    5    0    5
@ABC->123(R1),@TABL1(R2);
```

If ISTLOC = 16,
LENGTH = 5,

the resultant MVL will be:

G STRING STRING (T,A,B,L,ONE)

Called By: TOKSCN
OPFLD

Subroutine VARLST

Function:

If the "LIST" option is requested, to place the status for each identifier and register on the source listing output file.

Called By: Main Routine

Subroutine Called: DECHEX

Subroutine COMPUT (OPRAND, OPRATR)

Function:

To take operands from the two-word array OPRAND () and perform a computation on:

OPRAND(1) OPRATR OPRAND(2)

as determined by the arithmetic or logical operator in OPRATR. The result is placed in OPRAND(1). If this routine is called more than once for a single operand field, the effect is one of left-to-right (no precedence) expression handling. For example, if Subroutine OPFLD is called to handle

,3+5*6

COMPUT will be called twice, first to compute 3+5 and then to compute 8*6.

Called By: OPFLD

Subroutine DECHEX (DECNUM, HEX(1))

Function:

To convert the decimal value in DECNUM to a four-digit hexadecimal number. The four digits are converted to ASCII characters and placed in the four-byte array, HEX().

Called By: ITMSCN ABSOUT
OPFLD SCRLST
VARLST ERROUT

Subroutine called: TWOCMP

Subroutine FMT1 (ADRCOD(1))

Function:

To take the source and destination register values and the source and destination register codes as input and (except for the instruction code) create the machine code for output format number one. This code is placed in the three-byte array, ADRCOD().

Called By: ITMSCN

Subroutine SRCLST (THISPC)

Function:

If the "LIST" directive is requested, to place the following information on an output file:

Input Line number
Address in both decimal and hexadecimal (THISPC)
Line status (non-zero indicates error)
Object Code
Input statement
Comments (if any)

A sample set of instructions and directives is given in Appendix D. The source and identifier listing created by this subroutine from the instructions and directives of Appendix D are given in Appendix E.

Called By: Main Routine

Subroutine Called: DECHEX

Subroutine ABSOUT

Function:

To place the object code on an output file. This routine is called during pass two for each statement which is not a comment. See Appendix F for the format used for generated object code.

Called By: Main Routine

Subroutine Called: DECHEX

Subroutine ERROUT (THISPC)

Function:

To report to the terminal during the second pass any line statement with an error. A single variable, LNSTAT, is used to describe any errors.

```
If error free,          LNSTAT = 0
If label error,         LNSTAT = 2
If instruction error,   LNSTAT = 4
If operand error,       LNSTAT = 8
```

For any combination of errors, the value of LNSTAT is cumulative. For example, if a single line has both an instruction and an operand field error, the line status would be reported as "12."

Called By: Main Routine

Subroutine called: DECHEX

Subroutine TWOCMP (HEX(1))

Function:

To convert a hexadecimal number (from HEX()) of four ASCII digits to its two's complement form and place it, again in ASCII form, back into the four-byte array HEX().

Called By: TOKSCN
DECHEX

Function LVRTSH (WORD, BITS)

Function:

To perform a right logical shift. The content of WORD is moved by the number of bits in BITS.

Called By: ITMSCN

Function LVLFSH (WORD, BITS)

Function:

To perform a left logical shift. The content of WORD is moved by the number of bits in BITS.

Called By: TOKSCN
ITMSCN

UPDATING CRASS

An understanding of GIRL[2] is required to update (or correct any errors in) CRASS.

CRASS consists of two source files:

1) CRASS1.GRL - all routines contain a mixture of GIRL and FORTRAN statements. The first line of code defines the GIRS buffer size.

2) CRASS2.FOR - all routines consist entirely of FORTRAN.

If CRASS1.GRL is modified, it must be converted to all-FORTRAN by the GIRL preprocessor.[2] It must then be compiled with the following switch:

```
.R  FORTRAN
*CRASS1 = CRASS1/N:7
```

No special switches are needed when CRASS2.FOR is compiled:

```
*CRASS2 = CRASS2
```

A copy of the GIRS[3] object file GIRS.OBJ is required to link the files into a "SAV" file:

```
.R LINK
*CRASS=CRASS1,CRASS2,GIRS,SYSLIB/F
```

Note that CRASS1.OBJ must be the first object file in the linking sequence.

If the set of instructions or assembler directives is to be modified, CRSGEN.GRL must be accessed. This program generates the graph which describes the entire legal set of instructions and assembler directives. It is written in GIRL and is listed in Appendix A. Of cource, any change in the generator must be matched in the CRASS1 semantics routine ITMSCN. Also, since the GIRS buffer size is defined here, it must be identical to the first line of code from CRASS1.GRL.

PROPOSED ADDITIONS OR IMPROVEMENTS

1) More precise diagnostics
2) More flexible input format
3) Removal of the limitation for resolving assembly time constants (EQU directives) in two passes.
4) Allow parenthesis precedence in expression evaluation
5) Removal of, or at least improvement on, the 20 character limitation for the BYTE, DATA, and TEXT statements.

ACKNOWLEDGMENTS

The contributions and helpfulness of J. Carlberg, of DTNSRDC Code 1824, are gratefully acknowledged.

APPENDIX A

GIRL-FORTRAN PROGRAM LISTING OF CRSGEN, THE DATA GENERATOR OF THE INSTRUCTION-DIRECTIVE TREE

```
 900            NOSAVE, PRINT, COMMENTS
G         DEFINE EXCLAM, QUOTE, POUND, DOLLAR, PERCNT, AMPERS, APOST,
G         1 LPAR, RPAR, STAR, PLUS, COMMA, MINUS, PERIOD, SLASH,
G         2 ZERO, ONE, TWO, THREE, FOUR, FIVE, SIX, SEVEN, EIGHT,
G         3 NINE, COLON, SCOLON, LSTHAN, EQUALS, GTTHAN, QUEST,
G         4 ATSIGN, A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U,
G         5 V, W, X, Y, Z, START, OPFIN, DIRECT, TOKODE, VARABL, NUMBER, LITRAL
C
G         EXECUTE
          CALL ASSIGN(99, 'SY:CRASS.GRF', 12)
C
C SET TOKEN CODES FOR ALL TOKENS WHICH MAY
C BE THE FIRST CHARACTER OF AN "ITEM"
G         TOKODE PLUS    "8"
G         TOKODE STAR    "9"
G         TOKODE MINUS   "10"
G         TOKODE SLASH   "11"
G         TOKODE COMMA   "12"
G         TOKODE EXCLAM  "13"
G         TOKODE SCOLON  "14"
G         TOKODE LITRAL  "15"
G         TOKODE NUMBER  "16"
G         TOKODE VARABL  "17"
G         TOKODE ATSIGN  "18"
G         TOKODE PERCNT  "19"
G         TOKODE GTTHAN  "20"
G         TOKODE LPAR    "21"
G         TOKODE PERIOD  "22"
C
C STORE DIRECTIVE VALUES AND INSTRUCTION FORMATS AND SKELETON CODES
C
G         START A $'ATEMP (OPFIN("1", '//A0'),
G         1                B $ (OPFIN("1", '//B0'),
G         2                    S $ OPFIN("6", '//07', '//40')))
G         ATEMP     (I $ OPFIN("8", '//02', '//20'),
G         1          N $ D $ I $ OPFIN("8", '//02', '//40'),
G         2          O $ R $ G $ DIRECT "1")
C
G         START B $'BTEMP (OPFIN("6", '//04', '//40'),
G         1                E $ S $ DIRECT "2",
G         2                L $ (OPFIN("6", '//06', '//80'),
G         3                     W $ P $ OPFIN("6", '//04')))
G         BTEMP     (S $ S $ DIRECT "3",
G         1          Y $ T $ E $ DIRECT "4")
C
G         START C $'CTEMP (OPFIN("1", '//80'),
G         1                B $ OPFIN("1", '//90'),
G         2                I $ OPFIN("8", '//02', '//80'))
G         CTEMP     (L $ R $ OPFIN("6", '//04', '//C0'),
G         1          O $ C $ OPFIN("3", '//20'),
G         2          Z $ C $ OPFIN("3", '//24'))
C
G         START D $'DTEMP (A $ T $ A $ DIRECT "5",
G         1                E $ (C $ (OPFIN("6", '//06'),
G         2                          T $ OPFIN("6", '//06', '//40')),
G         3                     F $  DIRECT "6"))
G         DTEMP            (I $ V $ OPFIN("9", '//3C'),
G         1                 O $ R $ G $ DIRECT "7",
G         1                 X $ O $ P $ DIRECT "8")
```

```
C
G       START E $ (N $ D $ DIRECT "9",
G       1           Q $ U $ DIRECT "10",
G       2           V $ E $ N $ DIRECT "11")
C
G       START I $'ITEMP (D $ (L $ E $ OPFIN("7",'//03','//40'),
G       1                     T $ DIRECT "12"))
G       ITEMP N $ (OPFIN("6",'//2C','//40'),
G       1           C $ (OPFIN("6",'//05','//80'),
G       2                T $ OPFIN("6",'//05','//C0')),
G       3           V $  OPFIN("6",'//05','//40'))
C
G       START J $'JTEMP
G       JTEMP (E $ Q $ OPFIN("2",'//13'),
G       1      G $ T $ OPFIN("2",'//15'),
G       2      H $    (OPFIN("2",'//1B'),
G       3              E $ OPFIN("2",'//14')))
G       JTEMP L $ (OPFIN("2",'//1A'),
G       1           E $ OPFIN("2",'//12'),
G       2           T $ OPFIN("2",'//11'),
G       JTEMP M $  P $ OPFIN("2",'//10')
G       JTEMP N $ (C $ OPFIN("2",'//17'),
G       1           E $ OPFIN("2",'//16'),
G       2           O $ OPFIN("2",'//19'))
G       JTEMP O $ (C $ OPFIN("2",'//18'),
G       1           P $ OPFIN("2",'//1C'))
C
G       START L $ (D $  C $ R $ OPFIN("4",'//30'),
G       1           I $ (OPFIN("8",'//02'),
G       2                M $ I $ OPFIN("11",'//03'),
G       3                S $ T $ DIRECT "13"),
G       4           W $  P $ I $ OPFIN("11",'//02','//E0'))
C
G       START M $ (O $ V $ (OPFIN("1",'//C0'),
G       1                   B $ OPFIN("1",'//D0')),
G       2           P $ Y $  OPFIN("9",'//38'))
C
G       START N $ (E $ G $  OPFIN("6",'//05'),
G       1           O $ P $  OPFIN("7",'//10'))
C
G       START O $ (R $ I $  OPFIN("8",'//02','//60'),
G       1           U $ T $  OPFIN("6",'//2C','//80'))
C
G       START P $ A $ G $ E $ DIRECT "14"
C
G       START R $ (E $ F $ DIRECT "15",
G       1           O $ R $ Q $ DIRECT "16",
G       2           T $ (OPFIN("7",'//04','//5B'),
G       3                W $ P $ OPFIN("7",'//03','//80')))
```

```
C
G       START S $'STEMP OPFIN("1", '//60')
G       STEMP B $ (OPFIN("1", '//70'),
G       1           O $ OPFIN("10", '//1D'),
G       2           Z $ OPFIN("10", '//1E'))
G       STEMP E $   T $ O $ OPFIN("6", '//07')
G       STEMP L $   A $ OPFIN("5", '//0A')
G       STEMP O $   C $ (OPFIN("1", '//E0'),
G       1                B $ OPFIN("1", '//F0'))
G       STEMP R $ (A $ OPFIN("5", '//08'),
G       1           C $ OPFIN("5", '//0B'),
G       2           L $ OPFIN("5", '//09'))
G       STEMP T $ (C $ R $ OPFIN("4", '//34'),
G       1           S $ T $ OPFIN("12", '//02', '//C0'),
G       2           W $ P $ OPFIN("12", '//02', '//A0'))
G       STEMP W $   P $ B $ OPFIN( "6", '//06', '//C0')
G       STEMP Z $   C $ (OPFIN("1", '//40'),
G       1                B $ OPFIN("1", '//50'))
C
G       START T $ (B $ OPFIN("10", '//1F'),
G       1           E $ X $ T $ DIRECT "17",
G       2           I $ T $ L $ DIRECT "18")
C
G       START U $ N $ L $ DIRECT "19"
C
G       START X $ (OPFIN("6", '//04', '//80'),
G       1           O $ (P $ OPFIN("4", '//2C'),
G       2                R $ OPFIN("3", '//28')))
C
G       START SLASH $ DIRECT "20"
C
        CALL LVDUMP(0, 0, 99)
C
        WRITE(99) EXCLAM, QUOTE, POUND, DOLLAR, PERCNT, AMPERS, APOST,
        1 LPAR, RPAR, STAR, PLUS, COMMA, MINUS, PERIOD, SLASH,
        2 ZERO, ONE, TWO, THREE, FOUR, FIVE, SIX, SEVEN, EIGHT,
        3 NINE, COLON, SCOLON, LSTHAN, EQUALS, GTTHAN, QUEST,
        4 ATSIGN, A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U,
        5 V, W, X, Y, Z, START, OPFIN, DIRECT, TOKODE, VARABL, NUMBER, LITRAL
C
G       COMPLETE
/       COMPLETE
```

APPENDIX B

GIRL-FORTRAN PROGRAM LISTING OF CRASS

```
 900          *99,NOSAVE COMMENTS
        REAL*4 DEFEXT(2),SCRACH(3)
C
        LOGICAL*1 LABEL,OPCODE,OPRBUF,HEX,HEXCOD,BUF(40),HEXTBL,LINE
        LOGICAL*1 BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ,ASCHAR
        LOGICAL*1 LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY,DUMB
        LOGICAL*1 DEFFLG,REGFLG,MLTFLG,BYTFLG,LABFLG,INSFLG,OPFLG,RESFLG,
        1         DIRFLG,ENDFLG,COMNTS,EXTRA,LSTFLG
C
        COMMON /ASC/     LINE(72),HEX(4),HEXCOD(4,10)
        COMMON /ERRFLG/ LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY
        COMMON /NAMFLG/ DEFFLG,LABFLG,REGFLG,MLTFLG,BYTFLG,DUMB
        COMMON /LINFLG/ INSFLG,OPFLG,RESFLG,DIRFLG,ENDFLG,COMNTS,EXTRA,
        1               LSTFLG
        COMMON /ASSEMB/ PASS,REGSRC,REGDES,REGCOD(2),PC,LINENO,ADDRES,
        1               MAJVAL,COMENT,IDSTAT,LNSTAT,ERRNUM,FMT,DIRNUM,
        2               OPER1,OPER2,ER,ERLABL,WRDNUM,BYTNUM,ERROR
        COMMON /DATUM/  FIRST,SECOND,HEXTBL(16)
        COMMON /GIRLCH/ EXCLAM,QUOTE,POUND,DOLLAR,PERCNT,AMPERS,APOST,
        1               LPAR,RPAR,STAR,PLUS,COMMA,MINUS,PERIOD,SLASH,
        2               ZERO,ONE,TWO,THREE,FOUR,FIVE,SIX,SEVEN,EIGHT,
        3               NINE,COLON,SCOLON,LSTHAN,EQUALS,GTTHAN,QUEST,
        4               ATSIGN,A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,
        5               V,W,X,Y,Z
        COMMON /GIRL/   STRING,TOKEN,ITEM,BUFPOS,LENID,LABELS,OPCOD,STOP,
        1               ITMTYP,VALUE,SYMBOL,REG,REGSTR,REGATS,REGPLS,
        2               VARABL,NUMBER,LITRAL,LOGOR,LOGAND,LOGNOT,MODULO,
        3               OPFIN,DIRECT,START,TOKODE
        COMMON /ASCII/  BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ
C
        DIMENSION LABEL(6),OPCODE(4),OPRBUF(60),FILL(100)
        DIMENSION ASCGRL(58),FILSPC(39)
C
        EQUIVALENCE (LINE(1),LABEL(1))
        EQUIVALENCE (LINE(8),OPCODE(1))
        EQUIVALENCE (LINE(13),OPRBUF(1))
        EQUIVALENCE (ASCGRL(1),EXCLAM),  (HEXCOD(1,1),BUF(1))
C
G       DEFINE STRING,TOKEN,ITEM,BUFPOS,LENID,LABELS,OPCOD,STOP,
G       1 ITMTYP,VALUE,SYMBOL,REG,REGSTR,REGATS,REGPLS,
G       2 LOGOR,LOGAND,LOGNOT,MODULO
C
        DATA LINENO,PC,ERROR,FIRST,SECOND /0,256,0,1,2/
        DATA BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ
        1       /1H ,1H0,1H9,1HA,1HF,1HZ/
        DATA HEXTBL /1H0,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,
        1       1HA,1HB,1HC,1HD,1HE,1HF/
        DATA DEFFLG,REGFLG,MLTFLG,BYTFLG,LABFLG,INSFLG,OPFLG,RESFLG,DIRFLG
        1       /1,    2,     4,     8,     16,    32,    64,    128,    256/
        DATA DEFEXT/6RASSABS,3RLST/
        DATA SCRACH/3RRK1,6RUSER  ,3RTMP/
C
G       EXECUTE
        CALL ASSIGN(99,'SY:CRASS.GRF',12)
        CALL ASSIGN(14,'SY:USER.VAR',11,'SCR')
C
C       CALL ASSIGN(10,'SY:USER.ASS',11)
C       CALL ASSIGN(12,'SY:USER.ABS',11)
C       CALL ASSIGN(13,'SY:USER.LST',11)
```

```
C
        TYPE 2
2       FORMAT( ' PLEASE ENTER FILE NAMES IN COMMAND STRING FORM'/)
        FILSPC(7)=0
        IF(ICSI(FILSPC,DEFEXT,,,0) .NE. 0) STOP 'INVALID COMMAND STRING'
        IF(IASIGN(12,FILSPC(1),FILSPC(2),FILSPC(5),0) .NE. 0) STOP 'INVALID
        1 IASIGN 1'
        IF(FILSPC(7) .EQ. 0) GO TO 5
        IF(IASIGN(13,FILSPC(6),FILSPC(7),FILSPC(10),0) .NE. 0) STOP 'INVALID
        1 IASIGN 2'
5       IF(IASIGN(10,FILSPC(16),FILSPC(17),FILSPC(19),32) .NE. 0) STOP
        1 'INVALID IASIGN 3'
C
        IF(IASIGN(11,SCRACH(1),SCRACH(2),-1,2) .NE. 0) STOP ' BAD SCRATCH
        1 FILE REQUEST'
C
        READ(99) EXCLAM,QUOTE,POUND,DOLLAR,PERCNT,AMPERS,APOST,
        1 LPAR,RPAR,STAR,PLUS,COMMA,MINUS,PERIOD,SLASH,
        2 ZERO,ONE,TWO,THREE,FOUR,FIVE,SIX,SEVEN,EIGHT,
        3 NINE,COLON,SCOLON,LSTHAN,EQUALS,GTTHAN,QUEST,
        4 ATSIGN,A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,
        5 V,W,X,Y,Z,START,OPFIN,DIRECT,TOKODE,VARABL,NUMBER,LITRAL
C
        PASS = FIRST
        LABERR = .FALSE.
        ENDFLG = .FALSE.
        LSTFLG = .FALSE.
C
C BEGIN NAME TABLE BY CREATING REGISTER NAMES: R0, . . . , R15
        CALL ADDREG
C
C READ IN NEXT LINE OF CODE
10      LINENO = LINENO + 1
C
        READ(10,1)LINE
1       FORMAT(72A1)
C
C SET LINE STATUS FLAGS
        TYPERR = .FALSE.
        LABERR = .FALSE.
        DIRERR = .FALSE.
        OPERR  = .FALSE.
        INSTER = .FALSE.
        COMNTS = .FALSE.
        RESOLV = .TRUE.
        WRDNUM = 1
        BYTNUM = 1
        LNSTAT = 0
        DIRNUM = 0
C
C CLEAR ASCII BUFFERS AND GIRL STRINGS
          DO 20 I1=1,40
20        BUF(I1) = BLANK
```

```
C
@       STRING-(LABELS,OPCOD)
@       TOKEN -(STRING,BUFPOS,LENID)
@       ITEM  -(ITMTYP,VALUE,BUFPOS,LENID)
C
C BREAK LINE STATEMENT UP INTO TOKEN STRINGS
        CALL LEXSCN
C
C IS THIS ENTIRE LINE A COMMENT?
22      IF(COMNTS) GO TO 40
C
C DOES THIS STATEMENT CONTAIN A LABEL?
@       STRING+LABELS/30
C
C ADD LABEL TO NAME TREE AND ASSIGN CURRENT PROGRAM COUNTER (PC)
C AS ITS VALUE
        NODE = STRING
        IDENT = LABELS
        CALL ADDNAM(NODE,IDENT)
C
C EXAMINE INSTRUCTION
30      CALL INSTRU
C
C CONVERT OPERAND FIELD FROM A TOKEN STRING TO AN ITEM STRING
C (INTERMEDIATE CODE)
        CALL TOKSCN
C
C DETERMINE CORRECT NUMBER OF TARGET WORDS OF ABSOLUTE CODE NEEDED FOR
C THIS INSTRUCTION AND UPDATE PC BY THAT AMOUNT.  THIS IS NEEDED IN THE
C FIRST PASS IN ORDER TO ASSIGN CORRECT ADDRESSES TO LABELS.
C DO NOT SCAN ITEM STRING IF INSTRUCTION OR DIRECTIVE WAS IN ERROR.
        IF(INSTER .EQ. .TRUE.) GO TO 40
        CALL ITMSCN
C
C OUTPUT INTERMEDIATE CODE TO LUN 11
40      CALL LINOUT
C
C END OF INPUT?
        IF(ENDFLG) GO TO 50
        GO TO 10
C
C BEGIN SECOND PASS
50      PASS = SECOND
        PC = 256
        ENDFLG = .FALSE.
        REWIND 11
        IF(LSTFLG) WRITE(13,100)
100     FORMAT(' LINE NO.    ADDRESS    LINE STATUS  OBJ CODE  LABEL
        1  INSTR.  OP FIELD')
C
C REINITIALLIZE LINE FLAGS
60      TYPERR = .FALSE.
        OPERR  = .FALSE.
        LABERR = .FALSE.
        DIRERR = .FALSE.
        INSTER = .FALSE.
        RESOLV = .TRUE.
```

```
        WRDNUM = 1
        BYTNUM = 1
        LNSTAT = 0
        DIRNUM = 0
C
C SAVE PC FOR PROGRAM LISTING
        THISPC = PC
C
C CLEAR ASCII BUFFERS AND GIRL STRINGS
          DO 120 I1=1,40
120       BUF(I1) = BLANK
C
G       STRING-(LABELS,OPCOD)
G       ITEM  -(ITMTYP,VALUE,BUFPOS,LENID)
C
C READ IN THE INTERMEDIATE CODE, AND CONVERT BACK TO GIRL STRINGS
        CALL LINEIN
        IF(COMNTS) GO TO 140
C
C CREATE TARGET WORDS, UNLESS INSTRUCTION OR DIRECTIVE ERROR
        IF(INSTER .EQ. .TRUE.) GO TO 130
        CALL ITMSCN
C
C CHECK FOR ERRORS
130     CALL ERROUT(THISPC)
C
C GIVE A SOURCE LISTING IF DESIRED
140     IF(LSTFLG) CALL SRCLST(THISPC)
C
C CONVERT TO BYTES AND PLACE ON LUN 12
        IF(.NOT. COMNTS) CALL ABSOUT
C
C END OF PROGRAM ?
        IF(.NOT. ENDFLG) GO TO 60
        REWIND 14
        IF(LSTFLG) CALL VARLST
        STOP
C
G       COMPLETE
C
C
C
*       SUBROUTINE ADDREG
C
        COMMON /ASSEMB/ PASS,REGSRC,REGDES,REGCOD(2),PC,LINENO,ADDRES,
        1               MAJVAL,COMENT,IDSTAT,LNSTAT,ERRNUM,FMT,DIRNUM,
        2               OPER1,OPER2,ER,ERLABL,WRDNUM,BYTNUM,ERROR
        COMMON /GIRLCH/ EXCLAM,QUOTE,POUND,DOLLAR,PERCNT,AMPERS,APOST,
        1               LPAR,RPAR,STAR,PLUS,COMMA,MINUS,PERIOD,SLASH,
        2               ZERO,ONE,TWO,THREE,FOUR,FIVE,SIX,SEVEN,EIGHT,
        3               NINE,COLON,SCOLON,LSTHAN,EQUALS,GTTHAN,QUEST,
        4               ATSIGN,A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,
        5               V,W,X,Y,Z
        COMMON /GIRL/   STRING,TOKEN,ITEM,BUFPOS,LENID,LABELS,OPCOD,STOP,
        1               ITMTYP,VALUE,SYMBOL,REG,REGSTR,REGATS,REGPLS,
        2               VARABL,NUMBER,LITRAL,LOGOR,LOGAND,LOGNOT,MODULO,
        3               OPFIN,DIRECT,START,TOKODE
C
        DIMENSION NUMBUF(10)
C
        EQUIVALENCE(ZERO,NUMBUF(1))
C
C CREATE REGISTER NAME STRINGS R0, ..., R15 AND PLACE INTO NAME TABLE
C TAGGED AS REGISTERS AND GIVEN ADDRESSES EQUAL TO THE REGISTER NUMBER.
C
C R0 - R9
```

```
        NODE = STRING
        IDENT = REG
        ADDRES = -1
G       STRING REG R
          DO 10 I1 = 1,10
          ADDRES = ADDRES + 1
          NUM = NUMBUF(I1)
G         STRING REG - 2 NUM
          CALL ADDNAM(NODE, IDENT)
10        CONTINUE
C
C R10 - R15
G       STRING REG - 2 ONE
          DO 20 I1 = 1,6
          NUM = NUMBUF(I1)
          ADDRES = ADDRES + 1
G         STRING REG - 3 NUM
          CALL ADDNAM(NODE, IDENT)
20        CONTINUE
G       COMPLETE
C
C
C
$       SUBROUTINE LEXSCN
C
        LOGICAL*1 LABEL, OPCODE, OPRBUF, HEX, HEXCOD, BUF(40), HEXTBL, LINE
        LOGICAL*1 BLANK, ASCII0, ASCII9, ASCIIA, ASCIIF, ASCIIZ, ASCHAR
        LOGICAL*1 LABERR, DIRERR, OPERR, TYPERR, INSTER, DUMMY, DUMB
        LOGICAL*1 DEFFLG, REGFLG, MLTFLG, BYTFLG, LABFLG, INSFLG, OPFLG, RESFLG,
        1         DIRFLG, ENDFLG, COMNTS, EXTRA, LSTFLG, HOL1, HOL2
C
        COMMON /ASC/     LINE(72), HEX(4), HEXCOD(4,10)
        COMMON /ERRFLG/  LABERR, DIRERR, OPERR, TYPERR, INSTER, DUMMY
        COMMON /NAMFLG/  DEFFLG, LABFLG, REGFLG, MLTFLG, BYTFLG, DUMB
        COMMON /LINFLG/  INSFLG, OPFLG, RESFLG, DIRFLG, ENDFLG, COMNTS, EXTRA,
        1                LSTFLG
        COMMON /ASSEMB/  PASS, REGSRC, REGDES, REGCOD(2), PC, LINENO, ADDRES,
        1                MAJVAL, COMENT, IDSTAT, LNSTAT, ERRNUM, FMT, DIRNUM,
        2                OPER1, OPER2, ER, ERLABL, WRDNUM, BYTNUM, ERROR
        COMMON /DATUM/   FIRST, SECOND, HEXTBL(16)
        COMMON /GIRLCH/  EXCLAM, QUOTE, POUND, DOLLAR, PERCNT, AMPERS, APOST,
        1                LPAR, RPAR, STAR, PLUS, COMMA, MINUS, PERIOD, SLASH,
        2                ZERO, ONE, TWO, THREE, FOUR, FIVE, SIX, SEVEN, EIGHT,
        3                NINE, COLON, SCOLON, LSTHAN, EQUALS, GTTHAN, QUEST,
        4                ATSIGN, A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U,
        5                V, W, X, Y, Z
        COMMON /GIRL/    STRING, TOKEN, ITEM, BUFPOS, LENID, LABELS, OPCOD, STOP,
        1                ITMTYP, VALUE, SYMBOL, REG, REGSTR, REGATS, REGPLS,
        2                VARABL, NUMBER, LITRAL, LOGOR, LOGAND, LOGNOT, MODULO,
        3                OPFIN, DIRECT, START, TOKODE
        COMMON /ASCII/   BLANK, ASCII0, ASCII9, ASCIIA, ASCIIF, ASCIIZ
C
        DIMENSION LABEL(6), OPCODE(4), OPRBUF(60)
        DIMENSION ASCGRL(58)
C
        EQUIVALENCE (LINE(1), LABEL(1))
        EQUIVALENCE (LINE(8), OPCODE(1))
        EQUIVALENCE (LINE(13), OPRBUF(1))
        EQUIVALENCE (ASCGRL(1), EXCLAM), (HEXCOD(1,1), BUF(1))
C
C THIS ROUTINE IS A LEXICAL SCAN DESIGNED TO CREATE A BASIC TOKEN STRING
C CONSISTING OF OPERATORS, NUMBERS, ALPHANUMERICS, LITERALS, AND SPECIAL
C CHARACTERS.  TWO ASSOCIATED STRINGS RELATE THE TOKEN STRING TO THE
C ORIGINAL ASCII STRING BY INDICATING EACH TOKEN'S STARTING POSITION IN
C ARRAY "OPRBUF" AND ALSO THAT TOKEN'S LENGTH.
C   A LABEL STRING IS CREATED IN ORDER TO PLACE THAT LABEL INTO A NAME
```

```
C TABLE CALLED AN "EPAM" TREE.
C   AN INSTRUCTION STRING IS CREATED IN ORDER TO SEARCH A PREVIOUSLY
C CREATED EPAM TREE WHICH DESCRIBES THE EXISTING INSTRUCTIONS AND
C DIRECTIVES.
C
C $-LITERAL: HOL1
      HOL1 = .FALSE.
C '-LITERAL: HOL2
      HOL2 = .FALSE.
C
C CHECK FOR LABEL AND CREATE LABEL STRING
        DO 10 I1=1,6
        ASCHAR = LABEL(I1)
        IF(ASCHAR .EQ. BLANK) GO TO 20
        GRLCHR = ASCGRL(ASCHAR-BLANK)
C
C IS THE ENTIRE LINE A COMMENT STATEMENT ?
        IF(GRLCHR .EQ. STAR) GO TO 15
G       STRING LABELS GRLCHR
10      CONTINUE
      GO TO 20
15    COMNTS = .TRUE.
      RETURN
C
C CREATE INSTRUCTION STRING
20      DO 30 I1=1,4
        J1 = I1
        ASCHAR = OPCODE(J1)
        IF(ASCHAR .EQ. BLANK) GO TO 35
        GRLCHR = ASCGRL(ASCHAR-BLANK)
G       STRING OPCOD GRLCHR
30      CONTINUE
C
CHECK FOR EXTRANEOUS CHARACTERS IN INSTRUCTION FIELD
35    IF(J1 .EQ. 4) GO TO 40
      J1 = J1 + 1
      ASCHAR = OPCODE(J1)
      IF(ASCHAR .NE. BLANK) INSTER = .TRUE.
      GO TO 35
C
C CREATE TOKEN STRING
40    I1 = 0
      GRLCHR = 0
C
C ELIMINATE INITIAL BLANKS
45    I1 = I1 + 1
      IF(I1 .GT. 60) RETURN
      ASCHAR = OPRBUF(I1)
      IF(ASCHAR .EQ. BLANK) GO TO 45
C
C FIRST CHARACTER FOUND
      LENGTH = 0
      LSTSYM = GRLCHR
      GRLCHR = ASCGRL(ASCHAR-BLANK)
C
C IS IT A LITERAL?
      IF(GRLCHR .EQ. DOLLAR) GO TO 60
      IF(GRLCHR .EQ. APOST) GO TO 70
C
C IS IT A NUMBER?
      IF(LSTSYM .EQ. GTTHAN) GO TO 80
      IF((ASCHAR .GE. ASCII0) .AND. (ASCHAR .LE. ASCII9)) GO TO 80
C
C IS IT AN ALPHANUMERIC?
      IF((ASCHAR .GE. ASCIIA) .AND. (ASCHAR .LE. ASCIIZ)) GO TO 90
C
```

```
C CHARACTER IS EITHER AN OPERATOR OR A SPECIAL SYMBOL
        LENGTH = LENGTH + 1
        ISTLOC = I1
G       TOKEN STRING GRLCHR
G55     TOKEN (BUFPOS "ISTLOC", LENID "LENGTH")
        IF(GRLCHR .NE. SCOLON) GO TO 45
C
C SEMI-COLON ENDS THE STATEMENT ALL FOLLOWING CHARACTERS ARE COMMENTS
        COMENT = I1
        RETURN
C
C $ LITERAL $
60      BOUND = DOLLAR
        GO TO 71
C
C ' LITERAL '
70      BOUND = APOST
G71     TOKEN STRING LITRAL
        ISTLOC = I1 + 1
75      I1 = I1 + 1
        IF(I1 .GT. 60) GO TO 55
        ASCHAR = OPRBUF(I1)
        GRLCHR = ASCGRL(ASCHAR-BLANK)
        IF(GRLCHR .EQ. BOUND) GO TO 55
        LENGTH = LENGTH + 1
        GO TO 75
C
C NUMBER -- (HEX, DECIMAL, OR BINARY)
80      BOUND = ASCIIF
G       TOKEN STRING NUMBER
        GO TO 91
C
C ALPHANUMERIC -- (IDENTIFIER OR REGISTER)
90      BOUND = ASCIIZ
G       TOKEN STRING VARABL
91      ISTLOC = I1
95      I1 = I1 + 1
        LENGTH = LENGTH + 1
        ASCHAR = OPRBUF(I1)
        IF((ASCHAR .GE. ASCII0) .AND. (ASCHAR .LE. ASCII9)) GO TO 95
        IF((ASCHAR .GE. ASCIIA) .AND. (ASCHAR .LE. BOUND )) GO TO 95
        I1 = I1 - 1
        GO TO 55
C
G       COMPLETE
C
C
C
$       SUBROUTINE ADDNAM(NODE,IDENT)
C
        LOGICAL*1 LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY,DUMB
        LOGICAL*1 DEFFLG,REGFLG,MLTFLG,BYTFLG,LABFLG,INSFLG,OPFLG,RESFLG,
        1         DIRFLG,ENDFLG,COMNTS,EXTRA,LSTFLG
C
        COMMON /ERRFLG/ LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY
        COMMON /NAMFLG/ DEFFLG,LABFLG,REGFLG,MLTFLG,BYTFLG,DUMB
        COMMON /LINFLG/ INSFLG,OPFLG,RESFLG,DIRFLG,ENDFLG,COMNTS,EXTRA,
        1               LSTFLG
        COMMON /ASSEMB/ PASS,REGSRC,REGDES,REGCOD(2),PC,LINENO,ADDRES,
        1               MAJVAL,COMENT,IDSTAT,LNSTAT,ERRNUM,FMT,DIRNUM,
        2               OPER1,OPER2,ER,ERLABL,WRDNUM,BYTNUM,ERROR
        COMMON /GIRL/   STRING,TOKEN,ITEM,BUFPOS,LENID,LABELS,OPCOD,STOP,
        1               ITMTYP,VALUE,SYMBOL,REG,REGSTR,REGATS,REGPLS,
        2               VARABL,NUMBER,LITRAL,LOGOR,LOGAND,LOGNOT,MODULO,
        3               OPFIN,DIRECT,START,TOKODE
        COMMON /ASCII/  BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ
```

```
C
        DIMENSION NAME(6)
C
C THIS ROUTINE SEARCHES THE NAME TABLE FOR THE REQUESTED IDENTIFIER
C AND ADDS IT TO THE TABLE IF NOT FOUND   AN ADDRESS IS RETURNED UNLESS
C THE IDENTIFIER IS NOT YET DEFINED (JUMP AHEAD).
C
          DO 10 I1 = 1,6
10        NAME(I1) = 0
        IF(IDENT .NE. REG) ADDRES = 0
        ER = SYMBOL
        IDSTAT = 0
        POS = 0
C
C EXAMINE INPUT STRING
G20     NODE + IDENT."POS=POS+1"/30 'GRLCHR
        NAME(POS) = GRLCHR
G       ER + GRLCHR/65 'ER/20
C
C IF FAILURE, IDENTIFIER IS A SUBSET OF AN EXISTING NAME
C (EG. "VAR" > "VAR1")
G30     ER + STOP(/40 'ADDRES, .2 'IDSTAT)
C
C NAME FOUND
        IF(IDENT .NE. LABELS) RETURN
        ERLABL = ER
C
C TEST FOR MULTIPLE DEFINITIONS
        IF((IDSTAT .AND. DEFFLG) .EQ. 0) GO TO 40
C
C USE MOST RECENT DEFINITION
        ERROR = ERROR + 1
        IDSTAT = IDSTAT .OR. MLTFLG
        LABERR = .TRUE.
C
C UPDATE ADDRESS AND IDENTIFIER STATUS
40      IF(IDENT .EQ. REG) IDSTAT = IDSTAT .OR. REGFLG .OR. DEFFLG
        IF(IDENT .NE. LABELS) GO TO 45
        ADDRES = PC
        ERLABL = ER
        IDSTAT = IDSTAT .OR. DEFFLG
G45     ER STOP(-.1 "ADDRES", -.2 "IDSTAT")
C
C OUTPUT IDENTIFIER TO NAME FILE
        IF( NOT. LABERR) WRITE(14) NAME
        RETURN
C
C NAME MUST BE ADDED TO THE TREE, ADD NEXT CHARACTER
G60     NODE + IDENT."POS=POS+1"/40 'GRLCHR
        NAME(POS) = GRLCHR
G65     ER GRLCHR $'ER
        GO TO 60
G       COMPLETE
C
C
C
$       SUBROUTINE INSTRU
C
        LOGICAL*1 LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY,DUMB
C
        COMMON /ERRFLG/ LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY
        COMMON /ASSEMB/ PASS,REGSRC,REGDES,REGCOD(2),PC,LINENO,ADDRES,
        1               MAJVAL,COMENT,IDSTAT,LNSTAT,ERRNUM,FMT,DIRNUM,
        2               OPER1,OPER2,ER,ERLABL,WRDNUM,BYTNUM,ERROR
        COMMON /GIRL/   STRING,TOKEN,ITEM,BUFPOS,LENID,LABELS,OPCOD,STOP,
        1               ITMTYP,VALUE,SYMBOL,REG,REGSTR,REGATS,REGPLS,
```

```
     2                VARABL, NUMBER, LITRAL, LOGOR, LOGAND, LOGNOT, MODULO,
     3                OPFIN, DIRECT, START, TOKODE
C
      DIRNUM = 0
      FMT = 0
      I1 = 0
      S1 = START
G10   STRING+ OPCOD "I1=I1+1" /20 'GRLCHR
D     TYPE 15, S1, GRLCHR
D15   FORMAT(' S1, GRLCHR', 2X, I4, 2X, I4)
G     S1 + GRLCHR 'S1/40/10
C
C INSTRUCTION NAME OR DIRECTIVE MAY HAVE BEEN FOUND IN TREE
C   TEST FOR INSTRUCTION
G20   S1+OPFIN (1/30 'FMT, 2'OPER1, 3'OPER2//RETURN)
      OPER2 = 0
      RETURN
C
C   TEST FOR DIRECTIVE
G30   S1 + DIRECT 'DIRNUM//RETURN
C
C FAILURE
40    INSTER = TRUE.
      ERROR = ERROR + 1
G     COMPLETE
C
C
C
$     SUBROUTINE TOKSCN
C
      LOGICAL*1 LABEL, OPCODE, OPRBUF, HEX, HEXCOD, BUF(40), HEXTBL, LINE, NEG
      LOGICAL*1 BLANK, ASCII0, ASCII9, ASCIIA, ASCIIF, ASCIIZ, ASCHAR
      LOGICAL*1 LABERR, DIRERR, OPERR, TYPERR, INSTER, DUMMY, DUMB
      LOGICAL*1 DEFFLG, REGFLG, MLTFLG, BYTFLG, LABFLG, INSFLG, OPFLG, RESFLG,
     1          DIRFLG, ENDFLG, COMNTS, EXTRA, LSTFLG
C
      COMMON /ASC/     LINE(72), HEX(4), HEXCOD(4,10)
      COMMON /ERRFLG/  LABERR, DIRERR, OPERR, TYPERR, INSTER, DUMMY
      COMMON /NAMFLG/  DEFFLG, LABFLG, REGFLG, MLTFLG, BYTFLG, DUMB
      COMMON /LINFLG/  INSFLG, OPFLG, RESFLG, DIRFLG, ENDFLG, COMNTS, EXTRA,
     1                 LSTFLG
      COMMON /ASSEMB/  PASS, REGSRC, REGDES, REGCOD(2), PC, LINENO, ADDRES,
     1                 MAJVAL, COMENT, IDSTAT, LNSTAT, ERRNUM, FMT, DIRNUM,
     2                 OPER1, OPER2, ER, ERLABL, WRDNUM, BYTNUM, ERROR
      COMMON /DATUM/   FIRST, SECOND, HEXTBL(16)
      COMMON /GIRLCH/  EXCLAM, QUOTE, POUND, DOLLAR, PERCNT, AMPERS, APOST,
     1                 LPAR, RPAR, STAR, PLUS, COMMA, MINUS, PERIOD, SLASH,
     2                 ZERO, ONE, TWO, THREE, FOUR, FIVE, SIX, SEVEN, EIGHT,
     3                 NINE, COLON, SCOLON, LSTHAN, EQUALS, GTTHAN, QUEST,
     4                 ATSIGN, A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U,
     5                 V, W, X, Y, Z
      COMMON /GIRL/    STRING, TOKEN, ITEM, BUFPOS, LENID, LABELS, OPCOD, STOP,
     1                 ITMTYP, VALUE, SYMBOL, REG, REGSTR, REGATS, REGPLS,
     2                 VARABL, NUMBER, LITRAL, LOGOR, LOGAND, LOGNOT, MODULO,
     3                 OPFIN, DIRECT, START, TOKODE
      COMMON /ASCII/   BLANK, ASCII0, ASCII9, ASCIIA, ASCIIF, ASCIIZ
C
      DIMENSION LABEL(6), OPCODE(4), OPRBUF(60)
C
      EQUIVALENCE (LINE(1), LABEL(1))
      EQUIVALENCE (LINE(8), OPCODE(1))
      EQUIVALENCE (LINE(13), OPRBUF(1))
C
      DATA DEC, BIN, HEXA /1, 2, 3/
C
C THIS ROUTINE
```

```
C  1) COMBINES (REDUCES) THE TOKENS FROM LEXSCN INTO "ITEMS"
C     SUCH AS REGISTER TYPES, LOGICAL AND MATHEMATICAL OPERATORS,
C     VARABLES, NUMBERS, LITERALS, COMMAS, SEMI-COLONS,
C     AND EXCLAMATION MARKS.
C  2) ASSIGNS:   REGISTERS > REGISTER NUMBERS
C                OPERATERS > 0
C                VARIABLES > ADDRESS VALUE OR 0 IF UNDEFINED
C                NUMBERS   > DECIMAL VALUE
C                LITERALS  > FIRST TWO CHARACTERS
C                COMMAS    > 0
C                SEMICOLON > 0
C                EXCLAM MK > 0
C
C-------------------------------------------------------------
C
C ITEM TYPE CODES:  0-18
C TOKEN CODES       8-22
C
C        0   REG           |        12   ,
C        1  *REG           |        13   !
C        2  @REG           |        14   ;
C        3  *REG+          |        15   LITERAL
C        4    +  LOG OR    |        16   NUMBER
C        5    *  LOG AND   |        17   IDENTIFIER
C        6    -  LOG NOT   |        18   @
C        7    /  MODULUS   |        19   %
C        8   +             |        20   >
C        9   *             |        21   (
C        10  -             |        22   .
C        11  /             |
C
C-------------------------------------------------------
C
C INITIALIZE REGISTER CODES AND SOURCE AND DESTINATION REGISTER VALUES
C REGISTER CODES ARE 0 - 3
C
        REGCOD(1) = 0
        REGCOD(2) = 0
        REGSRC    = 0
        REGDES    = 0
C
C EXTRACT TOKEN
        I1 = 0
        COMMAS = 0
C
C DEFAULT:  ASSUME NUMBERS ARE DECIMAL
        NUMTYP = DEC
C
C EXAMINE TOKEN STRING FOR FIRST CHARACTER OF ITEM
G10     TOKEN + STRING "I1=I1+1" /RETURN 'TOKE
G       TOKEN +(BUFPOS I1 'ISTLOC, LENID I1 'LENGTH)
C
C OPERATOR AND DELIMETER VALUES DEFAULT TO 0 IN ORDER TO PAD
C ITEM - VALUE LIST
        VAL = 0
C
C BEGIN ITEM TYPE AND VALUE DEFINITIONS
G       TOKODE + TOKE 'ITMVAL
        INDEX = ITMVAL - 7
C
C                 +     *     -     /     ,     !     ;     LIT  NUM  VAR
        GO TO (2000, 100, 2000, 2000, 200, 2000, 2000, 300, 400, 500,
        1 600, 700, 800, 900, 1000) INDEX
C          @     %     >     (
C
C
```

```
C **** ASTERISK -- (STAR)
C       LOOK AHEAD, IF NOT A REGISTER, TREAT AS ARITHMETIC OPERATOR
C
100     TEMP1 = I1 + 1
G       TOKEN+(STRING(TEMP1)(NEXT), BUFPOS(TEMP1)(NXTLOC), LENID(TEMP1)(NXTLEN))
        IF(NEXT .NE. VARABL) GO TO 2000
C
C NEXT TOKEN IS EITHER A REGISTER OR IDENTIFIER
C PLACE ON TEMPORARY STRING
        CALL TMPSTR(NXTLOC,NXTLEN)
        CALL ADDNAM(STRING,STRING)
        IF((IDSTAT .AND. REGFLG) .EQ. 0) GO TO 2000
C
C VARABLE IS A REGISTER
        LENGTH = LENGTH + NXTLEN
        VAL = ADDRES
        I1 = I1 + 1
C
C ASSIGN SOURCE OR DESTINATION REGISTER VALUE
        IF(COMMAS .GE. 1) GO TO 120
        REGSRC = ADDRES
        GO TO 130
C
120     REGDES = ADDRES
C
C REGISTER MAY HAVE THIS FORM:  *REG+
130     TEMP2 = TEMP1 + 1
G       TOKEN + STRING(TEMP2)(LAST)
C
C SET REGISTER CODE
        ITMVAL = 1
        IF(LAST .NE. PLUS) GO TO 140
C *R+
        ITMVAL = 3
        I1 = I1 + 1
        LENGTH = LENGTH + 1
140     REGCOD(COMMAS + 1) = ITMVAL
        GO TO 2000
C
C **** COMMA
C
200     COMMAS = COMMAS + 1
        GO TO 2000
C
C **** LITERAL  --  PLACE UP TO FIRST TWO CHARACTERS INTO "VAL"
C
300     VAL = OPRBUF(ISTLOC)
        IF(LENGTH .GT. 1) VAL = LVLFSH(VAL,8) .OR. OPRBUF(ISTLOC + 1)
        GO TO 2000
C
C **** NUMBER   --  PLACE DECIMAL VALUE INTO VAL
C
400     GO TO (410, 430, 450) NUMTYP
C
C DECIMAL
410       DO 420 K1 = 1, LENGTH
          M1 = K1 + ISTLOC - 1
          VAL = 10 * VAL + (OPRBUF(M1) - ASCII0)
420       CONTINUE
        GO TO 2000
C
C BINARY
430       DO 440 K1 = 1, LENGTH
          M1 = K1 + ISTLOC - 1
          VAL = 2 * VAL + (OPRBUF(M1) - ASCII0)
440       CONTINUE
```

```
        GO TO 2000
C
C HEXADECIMAL
C   FIRST CHECK FOR VALUES GT 32767
450     NEG = .FALSE.
        IF((LENGTH .NE. 4) .OR. (OPRBUF(ISTLOC) .LE. ASCII0 + 7))
        1  GO TO 453
        NEG = .TRUE.
        CALL TWOCMP(OPRBUF(ISTLOC))
453       DO 460 K1 = 1, LENGTH
          HEXCHR = OPRBUF(K1 + ISTLOC - 1)
                 DO 455 L1 = 1, 16
                 J1 = L1
                 IF(HEXCHR .EQ. HEXTBL(J1)) GO TO 457
455              CONTINUE
457       DECHAR = J1 - 1
          VAL = 16 * VAL + DECHAR
460       CONTINUE
        IF(.NOT. NEG) GO TO 2000
        VAL = -VAL
        CALL TWOCMP(OPRBUF(ISTLOC))
        GO TO 2000
C
C **** IDENTIFIER  --  COULD BE A REGISTER (CODE = 0)
C
C PLACE ON TEMPORARY STRING
500     CONTINUE
        CALL TMPSTR(ISTLOC,LENGTH)
        CALL ADDNAM(STRING,STRING)
        VAL = ADDRES
C
C REGISTER?
        IF((IDSTAT .AND. REGFLG) .EQ. 0) GO TO 2000
        ITMVAL = 0
510     IF(COMMAS .GE. 1) GO TO 520
C
C SOURCE
        REGSRC = ADDRES
        GO TO 530
C
C DESTINATION
520     REGDES = ADDRES
C
C CHECK FOR RIGHT PARENTHESIS
530     TEMP = I1 + 1
G       TOKEN + STRING.TEMP/2000 = RPAR/2000
        I1 = TEMP
        GO TO 2000
C
C **** AT-SIGN  --  @, NEXT ITEM COULD BE A NUMBER, REGISTER, OR VARIABLE
C
600     TEMP = I1 + 1
G       TOKEN+(STRING.TEMP 'NEXT, BUFPOS.TEMP 'NXTLOC, LENID.TEMP'NXTLEN)
        REGCOD(COMMAS + 1) = 2
        IF(NEXT .NE. VARABL) GO TO 2000
C
C CHECK FOR REGISTER
        CALL TMPSTR(NXTLOC,NXTLEN)
        CALL ADDNAM(STRING,STRING)
C
C REGISTER?
        IF((IDSTAT .AND. REGFLG) .EQ. 0) GO TO 2000
        VAL = ADDRES
        I1 = TEMP
        LENGTH = LENGTH + NXTLEN
        ITMVAL = 2
```

```
        GO TO 510
C
C **** PERCENT  --  %, NEXT ITEM IS A BINARY NUMBER
C
700     NUMTYP = BIN
        GO TO 10
C
C **** GTTHAN  --  >, NEXT ITEM IS A HEXADECIMAL NUMBER
C
800     NUMTYP = HEXA
        GO TO 10
C
C **** LEFT PAREN  --  (, NEXT ITEM MUST BE A REGISTER, CODE = 2
C
900     LENGTH = 0
        GO TO 600
C
C **** PERIOD  --  . LOGICAL OPERATOR OR MODULO,
C                    NEXT TOKEN MUST BE + * - /
1000    I1 = I1 + 1
        LENGTH = 2
G       TOKEN + STRING I1 'TOKE
G       TOKODE + TOKE 'ITMVAL
        ITMVAL = ITMVAL - 4
C
C **** PLACE VALUES INTO ITEM LISTS
C
G2000   ITEM (ITMTYP "ITMVAL", VALUE "VAL")
G       ITEM (BUFPOS "ISTLOC", LENID "LENGTH")
C
C DEFAULT  ASSUME NUMBERS ARE DECIMAL
        NUMTYP = DEC
C
C RETURN IF SEMI-COLON
        IF(TOKE  EQ  SCOLON) RETURN
        GO TO 10
C
G       COMPLETE
C
C
C
$       SUBROUTINE ITMSCN
C
        LOGICAL*1 LABEL, OPCODE, OPRBUF, HEX, HEXCOD, HEXTBL, LINE, MASK4
        LOGICAL*1 BLANK, ASCII0, ASCII9, ASCIIA, ASCIIF, ASCIIZ, ASCHAR, TEMP2
        LOGICAL*1 LABERR, DIRERR, OPERR, TYPERR, INSTER, DUMMY, DUMB
        LOGICAL*1 DEFFLG, REGFLG, MLTFLG, BYTFLG, LABFLG, INSFLG, OPFLG, RESFLG,
        1         DIRFLG, ENDFLG, COMNTS, EXTRA, LSTFLG, ADRCOD(3)
C
        COMMON /ASC/     LINE(72), HEX(4), HEXCOD(4,10)
        COMMON /ERRFLG/  LABERR, DIRERR, OPERR, TYPERR, INSTER, DUMMY
        COMMON /NAMFLG/  DEFFLG, LABFLG, REGFLG, MLTFLG, BYTFLG, DUMB
        COMMON /LINFLG/  INSFLG, OPFLG, RESFLG, DIRFLG, ENDFLG, COMNTS, EXTRA,
        1                LSTFLG
        COMMON /ASSEMB/  PASS, REGSRC, REGDES, REGCOD(2), PC, LINENO, ADDRES,
        1                MAJVAL, COMENT, IDSTAT, LNSTAT, ERRNUM, FMT, DIRNUM,
        2                OPER1, OPER2, ER, ERLABL, WRDNUM, BYTNUM, ERROR
        COMMON /DATUM/   FIRST, SECOND, HEXTBL(16)
        COMMON /GIRLCH/  EXCLAM, QUOTE, POUND, DOLLAR, PERCNT, AMPERS, APOST,
        1                LPAR, RPAR, STAR, PLUS, COMMA, MINUS, PERIOD, SLASH,
        2                ZERO, ONE, TWO, THREE, FOUR, FIVE, SIX, SEVEN, EIGHT,
        3                NINE, COLON, SCOLON, LSTHAN, EQUALS, GTTHAN, QUEST,
        4                ATSIGN, A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U
        5                V, W, X, Y, Z
        COMMON /GIRL/    STRING, TOKEN, ITEM, BUFPOS, LENID, LABELS, OPCOD, STOR,
        1                ITMTYP, VALUE, SYMBOL, REG, REGSIR, REGATS, REGPLS,
```

```
     2               VARABL,NUMBER,LITRAL,LOGOR,LOGAND,LOGNOT,MODULO,
     3               OPFIN,DIRECT,START,TOKODE
     COMMON /ASCII/  BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ
C
     DIMENSION LABEL(6),OPCODE(4),OPRBUF(60)
C
     EQUIVALENCE (LINE(1),LABEL(1))
     EQUIVALENCE (LINE(8),OPCODE(1))
     EQUIVALENCE (LINE(13),OPRBUF(1))
C
     DATA EVEN,ODD,SOURCE,DEST,MASK4,MASK8 /0,1,0,1,"17,"377/
     DATA REGIST,ALL,NUM,KOMMA,LITERL /0,-1,16,12,15/
C
C THIS ROUTINE SCANS THE ITEM STRING LEFT TO RIGHT.
C  A) FIRST PASS - THE NUMBER OF TARGET WORDS NEEDED FOR EACH INSTRUCTION
C                  IS COUNTED AND THE PC UPDATED BY THAT AMOUNT SO THAT
C                  LABELS MAY BE GIVEN CORRECT ADDRESS VALUES PRIOR TO THE
C                  SECOND PASS.
C  B) SECOND PASS- THE TARGET MACHINE CODE IS CREATED.
C
C UP TO TEN WORDS MAY BE CREATED BY A DIRECTIVE
C    FOR EXAMPLE:  "DATA" WITH TEN OPERANDS OR "BYTE" WITH TWENTY OPERANDS
C UP TO THREE WORDS MAY BE CREATED BY AN INSTRUCTION.
C
C LEFT TO RIGHT ARITHMETIC WITH NO PARENTHESES IS ALLOWED
C
     BYTNUM = 1
     WRDNUM = 1
     IF(DIRNUM .NE. 0) GO TO 2000
     BYTNUM = 2
     PC = PC + 2
     GO TO (100,200,300,400,500,600,700,800,900,1000,1100,1200) FMT
C
C **** FORMAT 1  S,D
C
100  DESTIN = ALL
C
C FORM FIRST HEX WORD
110  CALL FMT1(ADRCOD(1))
     IF(PASS .EQ. FIRST) GO TO 120
     TEMP1 = LVRTSH(OPER1,8)
     TEMP2 = TEMP1
     HEXCOD(1,1) = TEMP2
     TEMP1 = (OPER1 .AND. MASK8)
     TEMP2 = TEMP1 - ASCII0
     IF(TEMP2 .GT. 9) TEMP2 = TEMP1 - ASCIIA + 10
     HEXCOD(2,1) = HEXTBL(ADRCOD(1) + TEMP2 + 1)
     HEXCOD(3,1) = HEXTBL(ADRCOD(2) + 1)
     HEXCOD(4,1) = HEXTBL(ADRCOD(3) + 1)
C
C COMPUTE SOURCE AND DESTINATION FIELDS
120  IF(FMT .EQ. 4) RETURN
     I1 = 0
     FIELD = SOURCE
125  CALL OPFLD(I1)
C
C DESTINATION FIELD IS RESTRICTED TO SIMPLE REGISTERS FOR FORMATS 3 AND 9
     IF(FIELD .EQ. SOURCE) GO TO 130
     IF(DESTIN .EQ. ALL) GO TO 130
     IF(DESTIN .NE. MAJVAL) OPERR = .TRUE.
C
C WILL EXTRA WORDS BE NEEDED BEYOND THE BASIC INSTRUCTION WORD?
130  IF(.NOT. EXTRA) GO TO 150
     WRDNUM = WRDNUM + 1
     BYTNUM = BYTNUM + 2
     PC = PC + 2
```

```
        IF(PASS .EQ. FIRST) GO TO 150
          DO 140 J1 = 1,4
140       HEXCOD(J1,WRDNUM) = HEX(J1)
150     IF(FIELD .EQ. DEST) RETURN
        FIELD = DEST
        GO TO 125
C
C **** FORMAT 2  DISPLACEMENT  -128 >= DISP >= 127  (JUMP STATEMENTS)
C
200     THSLOC = PC - 2
        IF(PASS .EQ. FIRST) RETURN
C
C COMPUTE ABSOLUTE ADDRESS
        I1 = 0
        CALL OPFLD(I1)
C
C COMPUTE RELATIVE DISPLACEMENT IN WORDS
        DISP = ((ADDRES - THSLOC) - 2) / 2
C
C IF DISPLACEMENT EXCEEDS LIMIT, SET ERROR FLAG
C AND USE DISPLACEMENT MODULO(128)
        IF((DISP .GT. 127) .OR. (DISP .LT. -128)) OPERR = .TRUE.
C
C CONVERT DISPLACEMENT TO HEX
        CALL DECHEX(DISP,HEX(1))
        TEMP1 = LVRTSH(OPER1,8)
        TEMP2 = TEMP1
        HEXCOD(1,1) = TEMP2
        TEMP1 = (OPER1  AND  MASK8)
        TEMP2 = TEMP1
        HEXCOD(2,1) = TEMP2
        HEXCOD(3,1) = HEX(3)
        HEXCOD(4,1) = HEX(4)
        RETURN
C
C **** FORMAT 3  S,W  DESTINATION MUST BE A SIMPLE WORKSPACE REGISTER
C
300     DESTIN = REGIST
        GO TO 110
C
C **** FORMAT 4  S,C  DESTINATION MUST BE AN INTEGER FROM 0 TO 15
C
400     I1 = 0
        FIELD = SOURCE
425     CALL OPFLD(I1)
        IF(FIELD  EQ  SOURCE) GO TO 430
C
C CHECK DESTINATION AGAINST 0-15 VALUE INTEGER
        IF(MAJVAL  NE  NUM) OPERR =  TRUE
        IF((ADDRES .LT  0)  OR  (ADDRES .GT  15)) OPERR =  TRUE
        REGDES = ADDRE
        GO TO 450
C
C EXTRA TARGET WORD NEEDED?
430     IF( NOT  EXTRA) GO TO 450
        BYTNUM = BYTNUM + 2
        WRDNUM = WRDNUM + 1
        PC = PC + 2
        IF(PASS  EQ  FIRST) GO TO 450
          DO 440 J1 = 1,4
440       HEXCOD(J1,WRDNUM) = HEX(J1)
450     IF(FIELD  EQ  DEST) GO TO 110
        FIELD = DEST
        GO TO 425
C
C **** FORMAT 5  W,N
```

```
C
C SOURCE FIELD MUST CONTAIN A SIMPLE WORKSPACE REGISTER
C DESTINATION FIELD MUST CONTAIN AN INTEGER FROM 0 TO 15
500     IF(PASS .EQ. FIRST) RETURN
        I1 = 0
        CALL OPFLD(I1)
C
C SOURCE FIELD -- W
        IF(MAJVAL .NE. REGIST) OPERR = .TRUE.
        TEMP1 = LVRTSH(OPER1,8)
        TEMP2 = TEMP1
        HEXCOD(1,1) = TEMP2
        TEMP1 = (OPER1 .AND. MASK8)
        TEMP2 = TEMP1
        HEXCOD(2,1) = TEMP2
C
        HEXCOD(4,1) = HEX(4)
C
C DESTINATION FIELD --    0 <= N <= 15
        CALL OPFLD(I1)
        IF(MAJVAL .NE. NUM) OPERR = .TRUE.
        HEXCOD(3,1) = HEX(4)
        RETURN
C
C **** FORMAT 6  S
C
600     I1 = 0
        CALL OPFLD(I1)
        IF(EXTRA) PC = PC + 2
        IF(PASS .EQ. FIRST) RETURN
C
        TEMP1 = LVRTSH(OPER1,8)
        TEMP2 = TEMP1
        HEXCOD(1,1) = TEMP2
        TEMP1 = (OPER1 .AND. MASK8)
        TEMP2 = TEMP1
        HEXCOD(2,1) = TEMP2
        TEMP1 = LVRTSH(OPER2,8)
        IF(TEMP1 .EQ. 0) TEMP1 = ASCII0
        TEMP2 = TEMP1 - ASCII0
        IF(TEMP2 .GT. 9) TEMP2 = TEMP1 - ASCIIA + 10
        HEXCOD(3,1) = HEXTBL(REGCOD(1) + TEMP2 + 1)
C
        IF(EXTRA) GO TO 610
C
C NO EXTRA WORD IS NEEDED FOR A SIMPLE REGISTER
        HEXCOD(4,1) = HEX(4)
        RETURN
C
C EXTRA WORD FOR LITERAL, NUMBER, OR MEMORY LOCATION
610     HEXCOD(4,1) = HEXTBL(REGSRC + 1)
        BYTNUM = BYTNUM + 2
        WRDNUM = WRDNUM + 1
          DO 620 J1 = 1,4
620       HEXCOD(J1,WRDNUM) = HEX(J1)
        RETURN
C
C **** FORMAT 7  N/A
C
700     IF(PASS .EQ. FIRST) RETURN
        TEMP1 = LVRTSH(OPER1,8)
        TEMP2 = TEMP1
        HEXCOD(1,1) = TEMP2
        TEMP1 = (OPER1 .AND. MASK8)
        TEMP2 = TEMP1
        HEXCOD(2,1) = TEMP2
```

```
        TEMP1 = LVRTSH(OPER2,8)
        IF(TEMP1 .EQ. 0) TEMP1 = ASCII0
        TEMP2 = TEMP1
        HEXCOD(3,1) = TEMP2
        TEMP1 = (OPER2 .AND. MASK8)
        IF(TEMP1 .EQ. 0) TEMP1 = ASCII0
        TEMP2 = TEMP1
        HEXCOD(4,1) = TEMP2
        RETURN
C
C **** FORMAT 8  W,IOP
C
800     PC = PC + 2
        IF(PASS .EQ. FIRST) RETURN
C
C SOURCE MUST BE A SIMPLE REGISTER
C CONSTRUCT FIRST WORD
        I1 = 0
        CALL OPFLD(I1)
        IF(MAJVAL .NE. REGIST) OPERR = .TRUE.
        TEMP1 = LVRTSH(OPER1,8)
        TEMP2 = TEMP1
        HEXCOD(1,1) = TEMP2
        TEMP1 = (OPER1 .AND. MASK8)
        TEMP2 = TEMP1
        HEXCOD(2,1) = TEMP2
        TEMP1 = LVRTSH(OPER2,8)
        IF(TEMP1 .EQ. 0) TEMP1 = ASCII0
        TEMP2 = TEMP1
        HEXCOD(3,1) = TEMP2
        HEXCOD(4,1) = HEX(4)
C
C CONSTRUCT IMMEDIATE OPERAND   DO NOT RESET ITEM STRING POINTER I1
        CALL OPFLD(I1)
        BYTNUM = BYTNUM + 2
        WRDNUM = WRDNUM + 1
          DO 810 J1 = 1,4
810       HEXCOD(J1,WRDNUM) = HEX(J1)
        RETURN
C
C **** FORMAT 9  S,W  DESTINATION MUST BE A SIMPLE WORKSPACE REGISTER
C
900     DESTIN = REGIST
        GO TO 110
C
C **** FORMAT A  BIT #  --  MUST BE A POSITIVE INTEGER;  VALUE IS
C                              COMPUTED MOD 256
1000    IF(PASS .EQ. 1) RETURN
        I1 = 0
        CALL OPFLD(I1)
        IF(MAJVAL .NE. NUM) OPERR = .TRUE.
        IF(ADDRES .LT. 0)   OPERR = .TRUE.
        TEMP1 = LVRTSH(OPER1,8)
        TEMP2 = TEMP1
        HEXCOD(1,1) = TEMP2
        TEMP1 = (OPER1 .AND. MASK8)
        TEMP2 = TEMP1
        HEXCOD(2,1) = TEMP2
        HEXCOD(3,1) = HEX(3)
        HEXCOD(4,1) = HEX(4)
        RETURN
C
C **** FORMAT B  IOP
C
1100    PC = PC + 2
        IF(PASS .EQ. FIRST) RETURN
```

```
        TEMP1 = LVRTSH(OPER1,8)
        TEMP2 = TEMP1
        HEXCOD(1,1) = TEMP2
        TEMP1 = (OPER1 .AND. MASK8)
        TEMP2 = TEMP1
        HEXCOD(2,1) = TEMP2
        TEMP1 = LVRTSH(OPER2,8)
        IF(TEMP1 .EQ. 0) TEMP1 = ASCII0
        TEMP2 = TEMP1
        HEXCOD(3,1) = TEMP2
        TEMP1 = (OPER2 .AND. MASK8)
        IF(TEMP1 .EQ. 0) TEMP1 = ASCII0
        TEMP2 = TEMP1
        HEXCOD(4,1) = TEMP2
C
C FORM IOP
        I1 = 0
        CALL OPFLD(I1)
        BYTNUM = BYTNUM + 2
        WRDNUM = WRDNUM + 1
          DO 1110 J1 = 1,4
1110      HEXCOD(J1,WRDNUM) = HEX(J1)
        RETURN
C
C **** FORMAT C  W  --  OPERAND FIELD IS RESTRICTED TO SIMPLE REGISTERS
C
1200    IF(PASS .EQ. FIRST) RETURN
        I1 = 0
        CALL OPFLD(I1)
        IF(MAJVAL .NE. REGIST) OPERR = .TRUE.
        TEMP1 = LVRTSH(OPER1,8)
        TEMP2 = TEMP1
        HEXCOD(1,1) = TEMP2
        TEMP1 = (OPER1 .AND. MASK8)
        TEMP2 = TEMP1
        HEXCOD(2,1) = TEMP2
        TEMP1 = LVRTSH(OPER2,8)
        IF(TEMP1 .EQ. 0) TEMP1 = ASCII0
        TEMP2 = TEMP1
        HEXCOD(3,1) = TEMP2
        HEXCOD(4,1) = HEX(4)
        RETURN
C
C_____________________________________________________________________
C
C **** DIRECTIVES ****
C
D2000   TYPE 2001,DIRNUM
D2001   FORMAT(' DIRNUM = ',I5)
2000    GO TO(2100,2200,2300,2400,2500,2600,2700,2800,2900,3000,3100,
        1       3200,3300,3400,3500,3600,3700,3800,3900,4000) DIRNUM
C
C **** AORG
C
2100    COMNTS = .TRUE.
        GO TO 4000
        RETURN
C
C **** BES
C
2200    TYPE 2201
2201    FORMAT(' BES',$)
        TYPE 2205
2205    FORMAT('+',' IS NOT YET IMPLEMENTED')
        COMNTS = .TRUE.
        RETURN
```

```
C
C **** BSS  --  BLOCK STARTING WITH SYMBOL
C
2300    I1 = 0
        CALL OPFLD(I1)
        PC = PC + ADDRES
        RETURN
C
C **** BYTE  --  INITIALIZE BYTE DATA, MUST END WITH SEMI-COLON
C
2400    NUMEXP = 1
        WRDPOS = EVEN
        LIMIT = 20
C       IF((PC .AND. ODD) .EQ. 0) GO TO 2405
C       LIMIT = 19
C       WRDPOS = ODD
2405    PC = PC + 1
C
C COUNT THE COMMAS
        I1 = 0
G2410   ITEM + ITMTYP."I1 = I1 + 1"/2430 =KOMMA/2410/2420
2420    PC = PC + 1
        NUMEXP = NUMEXP + 1
        GO TO 2410
C
C IF THIS DIRECTIVE HAD A LABEL, DECLARE IT AS BTYE
G2430   STRING + LABELS/2450
G       ER + STOP.2 'IDSTAT
        IDSTAT = IDSTAT .OR. BYTFLG
G       ER STOP -.2 "IDSTAT"
C
C BEGIN EVALUATION OF THE EXPRESSIONS;  20 LIMIT IF EVEN, 19 IF ODD
C2450   LIMIT = 20
C       IF(WRDPOS .EQ. ODD) LIMIT = 19
2450    BYTNUM = NUMEXP
        WRDNUM = 1
        I1 = 0
        IF(NUMEXP .GT. LIMIT) OPERR = .TRUE.
          DO 2470 J1 = 1,NUMEXP
          CALL OPFLD(I1)
          IF(WRDPOS .EQ. ODD) GO TO 2460
C PC IS EVEN
          HEXCOD(1,WRDNUM) = HEX(3)
          HEXCOD(2,WRDNUM) = HEX(4)
          WRDPOS = ODD
          GO TO 2470
C PC IS ODD
2460      HEXCOD(3,WRDNUM) = HEX(3)
          HEXCOD(4,WRDNUM) = HEX(4)
          WRDPOS = EVEN
          WRDNUM = WRDNUM + 1
2470      CONTINUE
        IF(WRDPOS .EQ. EVEN) WRDNUM = WRDNUM -1
        RETURN
C
C **** DATA  --  INITIALLIZE WORD DATA
C
2500    NUMEXP = 1
        PC = PC + 2
C
C COUNT THE COMMAS
        I1 = 0
G2510   ITEM + ITMTYP."I1 = I1 + 1"/2530 =KOMMA/2510/2520
2520    PC = PC + 2
        NUMEXP = NUMEXP + 1
        GO TO 2510
```

```
C
C EVALUATE UP TO 10 EXPRESSIONS
2530    LIMIT = 10
        IF(NUMEXP  GT  LIMIT) OPERR =  TRUE
        BYTNUM = 2*NUMEXP
        I1 = 0
        WRDNUM = 0
          DO 2570 J1 = 1,NUMEXP
          CALL OPFLD(I1)
          WRDNUM = WRDNUM + 1
                DO 2560 L1 = 1,4
2560            HEXCOD(L1,WRDNUM) = HEX(L1)
2570      CONTINUE
        RETURN
C
C **** DEF
C
2600    TYPE 2601
2601    FORMAT(' DEF',$)
        TYPE 2205
        COMNTS =  TRUE
        RETURN
C
C **** DORG
C
2700    TYPE 2701
2701    FORMAT(' DORG',$)
        TYPE 2205
        COMNTS =  TRUE
        RETURN
C
C **** DXOP  --  DEFINE EXTENDED OPERATION
C
2800    COMNTS =  TRUE
        IF(PASS  EQ  SECOND) RETURN
C
C REMOVE LABEL FROM IDENTIFIER TREE
G       ERLABL - STOP
C
C ADD LABEL TO "INSTRUCTION - DIRECTIVE" TREE
        S1 = START
        I1 = 0
G20     STRING + LABELS "I1 = I1 + 1"/30 'GRLCHR
G       S1 + GRLCHR 1 /25 'S1 /20
G25     S1 GRLCHR $'S1
        GO TO 20
C
C USE FORMAT "6"
G30     S1 OPFIN "6"
C
C DETERMINE EXTENDED OPERATION NUMBER AND INCORPORATE INTO
C XOP INSTRUCTION SKELETON
        I1 = 0
        CALL OPFLD(I1)
        IF(MAJVAL  NE  NUM) OPERR = .TRUE.
C
C SPLIT XOP NUMBER INTO TWO RIGHT AND TWO LEFT BITS
        RTHALF = ADDRES  AND  3
        LFHALF = LVRTSH(ADDRES,2)
C
C CREATE INSTRUCTION SKELETON
        ISTBYT = HEXTBL(2 + 1)
        SECBYT = HEXTBL(12 + LFHALF + 1)
        ISTWRD = LVLFSH(ISTBYT,8)  OR  SECBYT
        BYTONE = LVLFSH(RTHALF,2)
        BYTONE = HEXTBL(BYTONE + 1)
```

```
        SECWRD = LVLFSH(BYTONE,8)
G       S1 OPFIN (_ISTWRD,_SECWRD)
        RETURN
C
C **** END  --  END OF ASSEMBLY
C
2900    ENDFLG = .TRUE
        RETURN
C
C **** EQU  --  DEFINE ASSEMBLY TIME CONSTANT
C               SET LABEL TO VALUE IN OPERAND FIELD
3000    I1 = 0
        CALL OPFLD(I1)
G       ERLABL STOP - 1 "ADDRES"
        IF(PASS  EQ  SECOND) COMNTS =  TRUE
        RETURN
C
C **** EVEN  --  IF PROGRAM COUNTER IS AN ODD NUMBER, ADD ONE TO EVEN UP
C
3100    IF((PC .AND. ODD)  EQ  0) GO TO 3150
        PC = PC + 1
        HEXCOD(1,WRDNUM) = ASCII0
        HEXCOD(2,WRDNUM) = ASCII0
        RETURN
3150    COMNTS = .TRUE.
        RETURN
C
C **** IDT
C
3200    TYPE 3201
3201    FORMAT(' IDT',$)
        TYPE 2205
        COMNTS = .TRUE.
        RETURN
C
C **** LIST  --  OUTPUT SOURCE LISTING
C
3300    LSTFLG = .TRUE
        COMNTS = .TRUE.
        RETURN
C
C **** PAGE
C
3400    TYPE 3401
3401    FORMAT(' PAGE',$)
        TYPE 2205
        COMNTS = .TRUE.
        RETURN
C
C **** REF
C
3500    TYPE 3501
3501    FORMAT(' REF',$)
        TYPE 2205
        COMNTS = .TRUE.
        RETURN
C
C **** RORG
C
3600    TYPE 3601
3601    FORMAT(' RORG',$)
        TYPE 2205
        COMNTS = .TRUE
        RETURN
C
C **** TEXT  --  INITIALLIZE UP TO 20 CHARACTERS IF PC IS EVEN, 19 IF ODD
```

```
C
3700    LIMIT = 20
        WRDPOS = EVEN
        IF((PC .AND. ODD) .EQ. 0) GO TO 3710
        LIMIT = 19
        WRDPOS = ODD
C
C OBTAIN LOCATION AND LENGTH OF TEXT
G3710   ITEM + (ITMTYP 'ITMVAL, BUFPOS 'ISTLOC, LENID 'LENGTH)
C
C ERROR IF NOT LITERAL OR EXCEEDS 19 OR 20 CHARACTERS
        IF(ITMVAL .NE. LITERL) OPERR = .TRUE.
        IF(LENGTH .GT. LIMIT ) OPERR = .TRUE.
        BYTNUM = LENGTH
        PC = PC + LENGTH
        IF(PASS .EQ. FIRST) RETURN
        WRDNUM = 1
C
C PICK UP NEXT CHARACTER
        NXTLOC = ISTLOC
          DO 3770 J1 = 1, LENGTH
          IF(WRDPOS .EQ. ODD) GO TO 3760
          TEMP2 = OPRBUF(NXTLOC)/16
          HEXCOD(1,WRDNUM) = HEXTBL(TEMP2 + 1)
          TEMP2 = OPRBUF(NXTLOC) .AND. MASK4
          HEXCOD(2,WRDNUM) = HEXTBL(TEMP2 + 1)
          NXTLOC = NXTLOC + 1
          WRDPOS = ODD
          GO TO 3770
C
3760      TEMP2 = OPRBUF(NXTLOC)/16
          HEXCOD(3,WRDNUM) = HEXTBL(TEMP2 + 1)
          TEMP2 = OPRBUF(NXTLOC) .AND. MASK4
          HEXCOD(4,WRDNUM) = HEXTBL(TEMP2 + 1)
          NXTLOC = NXTLOC + 1
          WRDPOS = EVEN
          WRDNUM = WRDNUM + 1
3770      CONTINUE
        RETURN
C
C **** TITL
C
3800    TYPE 3801
3801    FORMAT(' TITL',$)
        TYPE 2205
        COMNTS = .TRUE.
        RETURN
C
C **** UNL
C
3900    LSTFLG = .FALSE.
        COMNTS = .TRUE.
        RETURN
C
C **** SLASH  --  CHANGE PROGRAM COUNTER
C
4000    I1 = 0
        CALL OPFLD(I1)
        PC = ADDRES
        RETURN
G       COMPLETE
```

```
C
C
C
*       SUBROUTINE LINOUT
C
        LOGICAL*1 LABEL,OPCODE,OPRBUF,HEX,HEXCOD,LINE
        LOGICAL*1 LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY,DUMB
        LOGICAL*1 DEFFLG,REGFLG,MLTFLG,BYTFLG,LABFLG,INSFLG,OPFLG,RESFLG,
        1         DIRFLG,ENDFLG,COMNTS,EXTRA,LSTFLG
C
        COMMON /ASC/     LINE(72),HEX(4),HEXCOD(4,10)
        COMMON /ERRFLG/  LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY
        COMMON /NAMFLG/  DEFFLG,LABFLG,REGFLG,MLTFLG,BYTFLG,DUMB
        COMMON /LINFLG/  INSFLG,OPFLG,RESFLG,DIRFLG,ENDFLG,COMNTS,EXTRA,
        1                LSTFLG
        COMMON /ASSEMB/  PASS,REGSRC,REGDES,REGCOD(2),PC,LINENO,ADDRES,
        1                MAJVAL,COMENT,IDSTAT,LNSTAT,ERRNUM,FMT,DIRNUM,
        2                OPER1,OPER2,ER,ERLABL,WRDNUM,BYTNUM,ERROR
        COMMON /GIRL/    STRING,TOKEN,ITEM,BUFPOS,LENID,LABELS,OPCOD,STOP,
        1                ITMTYP,VALUE,SYMBOL,REG,REGSTR,REGATS,REGPLS,
        2                VARABL,NUMBER,LITRAL,LOGOR,LOGAND,LOGNOT,MODULO,
        3                OPFIN,DIRECT,START,TOKODE
        COMMON /TMPARR/  TEMP1(30),TEMP2(30),TEMP3(30),TEMP4(30)
C
        DIMENSION LABEL(6),OPCODE(4),OPRBUF(60)
C
        EQUIVALENCE (LINE(1),LABEL(1))
        EQUIVALENCE (LINE(8),OPCODE(1))
        EQUIVALENCE (LINE(13),OPRBUF(1))
C
C *** OUTPUT INTERMEDIATE CODE (ITEM STRING) FOR A SINGLE LINE
        WRITE(11) REGSRC,REGDES,REGCOD,LINENO,
        1         COMENT,LNSTAT,ERRNUM,FMT,DIRNUM,
        2         OPER1,OPER2,ER,ERLABL,LINE,
        3         INSTER,COMNTS,LABERR,OPERR
C
C EXTRACT INTERMEDIATE CODE FROM THE ITEM STRING UNLESS COMMENT
        IF(COMNTS .EQ. TRUE ) RETURN
        LIMIT = 30
        I1 = 0
G10     ITEM +(ITMTYP,"I1=I1+1" /20 'ITMVAL, VALUE I1 'VAL)
G       ITEM +(BUFPOS,I1 'ISTLOC, LENID I1 'LENGTH)
        TEMP1(I1) = ITMVAL
        TEMP2(I1) = VAL
        TEMP3(I1) = ISTLOC
        TEMP4(I1) = LENGTH
        GO TO 10
20      I1 = I1 - 1
        IF(I1 .GT. LIMIT) GO TO 99
        WRITE(11) TEMP1,TEMP2,TEMP3,TEMP4
        RETURN
C
C ERROR
99      TYPE 100
100     FORMAT(' *** ERROR - TOO MANY ITEMS IN OPERAND FIELD')
        STOP
G       COMPLETE
```

```
$       SUBROUTINE LINEIN
C
        LOGICAL*1 BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ,ASCHAR
        LOGICAL*1 LABEL,OPCODE,OPRBUF,HEX,HEXCOD,BUF(40),LINE
        LOGICAL*1 LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY,DUMB
        LOGICAL*1 DEFFLG,REGFLG,MLTFLG,BYTFLG,LABFLG,INSFLG,OPFLG,RESFLG,
       1          DIRFLG,ENDFLG,COMNTS,EXTRA,LSTFLG,DONE
C
        COMMON /ASC/     LINE(72),HEX(4),HEXCOD(4,10)
        COMMON /ERRFLG/ LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY
        COMMON /NAMFLG/ DEFFLG,LABFLG,REGFLG,MLTFLG,BYTFLG,DUMB
        COMMON /LINFLG/ INSFLG,OPFLG,RESFLG,DIRFLG,ENDFLG,COMNTS,EXTRA,
       1                LSTFLG
        COMMON /ASSEMB/ PASS,REGSRC,REGDES,REGCOD(2),PC,LINENO,ADDRES,
       1                MAJVAL,COMENT,IDSTAT,LNSTAT,ERRNUM,FMT,DIRNUM,
       2                OPER1,OPER2,ER,ERLABL,WRDNUM,BYTNUM,ERROR
        COMMON /GIRLCH/ EXCLAM,QUOTE,POUND,DOLLAR,PERCNT,AMPERS,APOST,
       1                LPAR,RPAR,STAR,PLUS,COMMA,MINUS,PERIOD,SLASH,
       2                ZERO,ONE,TWO,THREE,FOUR,FIVE,SIX,SEVEN,EIGHT,
       3                NINE,COLON,SCOLON,LSTHAN,EQUALS,GTTHAN,QUEST,
       4                ATSIGN,A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,
       5                V,W,X,Y,Z
        COMMON /GIRL/   STRING,TOKEN,ITEM,BUFPOS,LENID,LABELS,OPCOD,STOP,
       1                ITMTYP,VALUE,SYMBOL,REG,REGSTR,REGATS,REGPLS,
       2                VARABL,NUMBER,LITRAL,LOGOR,LOGAND,LOGNOT,MODULO,
       3                OPFIN,DIRECT,START,TOKODE
        COMMON /ASCII/  BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ
        COMMON /TMPARR/ TEMP1(30),TEMP2(30),TEMP3(30),TEMP4(30)
C
        DIMENSION LABEL(6),OPCODE(4),OPRBUF(60)
        DIMENSION ASCGRL(58)
C
        EQUIVALENCE (LINE(1),LABEL(1))
        EQUIVALENCE (LINE(8),OPCODE(1))
        EQUIVALENCE (LINE(13),OPRBUF(1))
        EQUIVALENCE (ASCGRL(1),EXCLAM),  (HEXCOD(1,1),BUF(1))
C
C *** INPUT INTERMEDIATE CODE (ITEM STRING) FOR A SINGLE LINE
        READ(11) REGSRC,REGDES,REGCOD,LINENO,
        1          COMENT,LNSTAT,ERRNUM,FMT,DIRNUM,
        2          OPER1,OPER2,ER,ERLABL,LINE,
        3          INSTER,COMNTS,LABERR,OPERR
C
C IS THE ENTIRE LINE A COMMENT STATEMENT ?
        IF(COMNTS .EQ. .TRUE.) RETURN
C
C RECREATE LABEL AND ITEM STRINGS FROM THE INTERMEDIATE CODE
        DONE = .FALSE.
        READ(11) TEMP1,TEMP2,TEMP3,TEMP4
        DO 10 I1 = 1,30
        IF(DONE) GO TO 20
@       ITEM ITMTYP "TEMP1(I1)"
@       ITEM VALUE  "TEMP2(I1)"
@       ITEM BUFPOS "TEMP3(I1)"
@       ITEM LENID  "TEMP4(I1)"
C
C LOOK FOR SEMICOLON
        IF(TEMP1(I1) .EQ. 14) DONE = .TRUE.
10      CONTINUE
C
C CHECK FOR LABEL AND CREATE LABEL STRING
20        DO 30 I1=1,6
          ASCHAR = LABEL(I1)
          IF(ASCHAR .EQ. BLANK) RETURN
          GRLCHR = ASCGRL(ASCHAR-BLANK)
@         STRING LABELS GRLCHR
```

```
30          CONTINUE
            RETURN
G           COMPLETE
C
C
C
$           SUBROUTINE OPFLD(I1)
            LOGICAL*1 LABEL,OPCODE,OPRBUF,HEX,HEXCOD,HEXTBL,LINE
            LOGICAL*1 BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ,ASCHAR
            LOGICAL*1 LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY,DUMB
            LOGICAL*1 DEFFLG,REGFLG,MLTFLG,BYTFLG,LABFLG,INSFLG,OPFLG,RESFLG,
            1         DIRFLG,ENDFLG,COMNTS,EXTRA,LSTFLG
C
            COMMON /ASC/     LINE(72),HEX(4),HEXCOD(4,10)
            COMMON /ERRFLG/ LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY
            COMMON /NAMFLG/ DEFFLG,LABFLG,REGFLG,MLTFLG,BYTFLG,DUMB
            COMMON /LINFLG/ INSFLG,OPFLG,RESFLG,DIRFLG,ENDFLG,COMNTS,EXTRA,
            1               LSTFLG
            COMMON /ASSEMB/ PASS,REGSRC,REGDES,REGCOD(2),PC,LINENO,ADDRES,
            1               MAJVAL,COMENT,IDSTAT,LNSTAT,ERRNUM,FMT,DIRNUM,
            2               OPER1,OPER2,ER,ERLABL,WRDNUM,BYTNUM,ERROR
            COMMON /DATUM/  FIRST,SECOND,HEXTBL(16)
            COMMON /GIRLCH/ EXCLAM,QUOTE,POUND,DOLLAR,PERCNT,AMPERS,APOST,
            1               LPAR,RPAR,STAR,PLUS,COMMA,MINUS,PERIOD,SLASH,
            2               ZERO,ONE,TWO,THREE,FOUR,FIVE,SIX,SEVEN,EIGHT,
            3               NINE,COLON,SCOLON,LSTHAN,EQUALS,GTTHAN,QUEST,
            4               ATSIGN,A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,
            5               V,W,X,Y,Z
            COMMON /GIRL/   STRING,TOKEN,ITEM,BUFPOS,LENID,LABELS,OPCOD,STOP,
            1               ITMTYP,VALUE,SYMBOL,REG,REGSTR,REGATS,REGPLS,
            2               VARABL,NUMBER,LITRAL,LOGOR,LOGAND,LOGNOT,MODULO,
            3               OPFIN,DIRECT,START,TOKODE
            COMMON /ASCII/  BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ
C
            DIMENSION LABEL(6),OPCODE(4),OPRBUF(60)
C
            EQUIVALENCE (LINE(1),LABEL(1))
            EQUIVALENCE (LINE(8),OPCODE(1))
            EQUIVALENCE (LINE(13),OPRBUF(1))
C
            DIMENSION OPRAND(2)
C
C THE PURPOSE OF THIS ROUTINE IS TO EITHER RETURN THE DECIMAL VALUE OF AN
C OPERAND FIELD (FROM COMMA TO COMMA) OR REGISTER NUMBER IN "ADDRES" AND
C THE HEX VALUE IN "HEX()" AND TO DETERMINE IF AN EXTRA WORD IS NEEDED
C FOR THE TARGET CODE.   IF SO, "EXTRA" =  TRUE.
C
            MAJVAL = 0
            EXTRA =  FALSE
            OPRAND(FIRST)  = 0
            OPRAND(SECOND) = 0
7           OPRAN = FIRST
C
C PICK UP ALL ITEMS UNTIL COMMA OR SEMI-COLON
G10         ITEM + ITMTYP "I1 = I1 + 1"/30 'ITMVAL
G           ITEM + VALUE I1 'ADDRES
C
C IS THIS ITEM A REGISTER?
            IF(ITMVAL  GT  3) GO TO 15
C
C CHECK FOR @VAR(REG) OR @NUM(REG)
            IF(MAJVAL  EQ  17) GO TO 10
            IF(MAJVAL  EQ  16) GO TO 10
            MAJVAL = ITMVAL
            OPRAND(OPRAN) = ADDRES
            GO TO 10
```

```
C
15      ITM = ITMVAL - 3
        IF(ITM .GT. 8) GO TO 20
C
C ITEM IS AN OPERATOR
        OPRATR = ITM
C
C SWITCH TO SECOND OPERAND    __ OP '__'
        OPRAN = SECOND
        GO TO 10
C
C ITEM IS COMMA, EXCLAM MK, SEMI-COLON, LITERAL, NUMBER, IDENTIFIER, OR @
20      ITM = ITM - 8
        IF((ITM .LT. 1) .OR. (ITM .GT. 7)) GO TO 100
C
C               ,    !    ;  LIT  NUM  VAR   @
        GO TO (30, 40, 30,  50,  50,  60, 70) ITM
C
C *** COMMA OR SEMI-COLON
C
C FIELD HAS BEEN COMPLETELY EXAMINED.  NO EXTRA WORDS ARE NEEDED IF FIELD
C CONTAINED AN "UNMODIFIED" REGISTER
30      ADDRES = OPRAND(FIRST)
C
C CONVERT OPERAND FROM DECIMAL TO HEXADECIMAL
        CALL DECHEX(ADDRES,HEX(1))
        RETURN
C
C *** EXCLAMATION MARK
C
40      OPRAND(OPRAN) = PC
        GO TO 55
C
C *** LITERAL OR NUMBER
C
50      OPRAND(OPRAN) = ADDRES
55      EXTRA = .TRUE.
        MAJVAL = ITMVAL
        IF(OPRAN .EQ. FIRST) GO TO 10
C
C AN OPERAND - OPERATOR - OPERAND TRIPLE HAS BEEN FOUND.
C COMPUTE IT AND RETURN RESULT INTO OPERAND NO. 1
        CALL COMPUT(OPRAND(1),OPRATR)
        GO TO 7
C
C *** IDENTIFIER (EXCLUDING REGISTER NAMES)
C
C WAS THE IDENTIFIER DEFINED WHEN THIS STATEMENT OCCURED?
60      IF(ADDRES .GT. 0) GO TO 50
C
C OBTAIN ADDRESS
G       ITEM + BUFPOS.I1  'ISTLOC
G       ITEM + LENID.I1   'LENGTH
        CALL TMPSTR(ISTLOC,LENGTH)
        CALL ADDNAM(STRING,STRING)
        IF(PASS .EQ. FIRST) GO TO 50
C
C STILL UNDEFINED?
        IF(ADDRES .EQ. 0) OPERR = .TRUE.
        GO TO 50
C
C *** AT-SIGN  @  --  NEXT ITEM IS A NUMBER OR VARIABLE
C
C ANTICIPATE SHORTHAND "@(REG)" FOR "@0(REG)"
70      EXTRA = .TRUE.
        ADDRES = 0
```

```
      MAJVAL = 16
      GO TO 10
100   OPERR =  TRUE
G     COMPLETE
C
C
C
*     SUBROUTINE TMPSTR(ISTLOC,LENGTH)
C
      LOGICAL*1 LABEL,OPCODE,OPRBUF,HEX,HEXCOD,BUF(40),LINE
      LOGICAL*1 BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ,ASCHAR
C
      COMMON /ASC/     LINE(72),HEX(4),HEXCOD(4,10)
      COMMON /ASSEMB/ PASS,REGSRC,REGDES,REGCOD(2),PC,LINENO,ADDRES,
     1                MAJVAL,COMENT,IDSTAT,LNSTAT,ERRNUM,FMT,DIRNUM,
     2                OPER1,OPER2,ER,ERLABL,WRDNUM,BYTNUM,ERROR
      COMMON /GIRLCH/ EXCLAM,QUOTE,POUND,DOLLAR,PERCNT,AMPERS,APOST,
     1                LPAR,RPAR,STAR,PLUS,COMMA,MINUS,PERIOD,SLASH,
     2                ZERO,ONE,TWO,THREE,FOUR,FIVE,SIX,SEVEN,EIGHT,
     3                NINE,COLON,SCOLON,LSTHAN,EQUALS,GTTHAN,QUEST,
     4                ATSIGN,A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,
     5                V,W,X,Y,Z
      COMMON /GIRL/    STRING,TOKEN,ITEM,BUFPOS,LENID,LABELS,OPCOD,STOP,
     1                ITMTYP,VALUE,SYMBOL,REG,REGSTR,REGATS,REGPLS,
     2                VARABL,NUMBER,LITRAL,LOGOR,LOGAND,LOGNOT,MODULO,
     3                OPFIN,DIRECT,START,TOKODE
      COMMON /ASCII/   BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ
C
      DIMENSION LABEL(6),OPCODE(4),OPRBUF(60)
      DIMENSION ASCGRL(58)
C
      EQUIVALENCE (LINE(1),LABEL(1))
      EQUIVALENCE (LINE(8),OPCODE(1))
      EQUIVALENCE (LINE(13),OPRBUF(1))
      EQUIVALENCE (ASCGRL(1),EXCLAM),  (HEXCOD(1,1),BUF(1))
C
G     STRING = STRING
      LOC = ISTLOC
        DO 10 K1 = 1, LENGTH
        ASCHAR = OPRBUF(LOC)
        GRLCHR = ASCGRL(ASCHAR - BLANK)
G       STRING STRING GRLCHR
        LOC = LOC + 1
10      CONTINUE
      RETURN
G     COMPLETE
C
C
C
*     SUBROUTINE VARLST
C
      LOGICAL*1 LABEL,OPCODE,OPRBUF,HEX,HEXCOD,LINE
      LOGICAL*1 BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ,ASCHAR
      LOGICAL*1 DEFFLG,LABFLG,REGFLG,MLTFLG,BYTFLG,DUMB,EKS
      LOGICAL*1 IDNTFR(6),STATUS(6)
C
      COMMON /ASC/     LINE(72),HEX(4),HEXCOD(4,10)
      COMMON /ASSEMB/ PASS,REGSRC,REGDES,REGCOD(2),PC,LINENO,ADDRES,
     1                MAJVAL,COMENT,IDSTAT,LNSTAT,ERRNUM,FMT,DIRNUM,
     2                OPER1,OPER2,ER,ERLABL,WRDNUM,BYTNUM,ERROR
      COMMON /GIRLCH/ EXCLAM,QUOTE,POUND,DOLLAR,PERCNT,AMPERS,APOST,
     1                LPAR,RPAR,STAR,PLUS,COMMA,MINUS,PERIOD,SLASH,
     2                ZERO,ONE,TWO,THREE,FOUR,FIVE,SIX,SEVEN,EIGHT,
     3                NINE,COLON,SCOLON,LSTHAN,EQUALS,GTTHAN,QUEST,
     4                ATSIGN,A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,
     5                V,W,X,Y,Z
```

```
      COMMON /GIRL/    STRING, TOKEN, ITEM, BUFPOS, LENID, LABELS, OPCOD, STOP,
      1                ITMTYP, VALUE, SYMBOL, REG, REGSTR, REGATS, REGPLS,
      2                VARABL, NUMBER, LITRAL, LOGOR, LOGAND, LOGNOT, MODULO,
      3                OPFIN, DIRECT, START, TOKODE
      COMMON /ASCII/   BLANK, ASCII0, ASCII9, ASCIIA, ASCIIF, ASCIIZ
      COMMON /NAMFLG/ DEFFLG, LABFLG, REGFLG, MLTFLG, BYTFLG, DUMB
C
      DIMENSION NAME(6), ALPHA(26), NUMBRS(10)
C
      EQUIVALENCE (ALPHA(1), A), (NUMBRS(1), ZERO)
C
      DATA EKS /1HX/
C
C THIS ROUTINE OUTPUTS THE STATUS FOR EACH IDENTIFIER AND REGISTER
C
      WRITE(13, 1)
1     FORMAT(///, ' **** IDENTIFIER LISTING ****', //,
      1 ' NAME        STATUS', /,
      2 12X, 'ADDRESS   REG  UNDEF  MULT DEF  BYTE', /)
C
5     READ(14, END = 200) NAME
      SY = SYMBOL
C
        DO 10 J1 = 1, 6
        IDNTFR(J1) = BLANK
10      STATUS(J1) = BLANK
C
      DO 100 I1 =1, 6
      GRLCHR = NAME(I1)
      IF(GRLCHR .EQ. 0) GO TO 120
C
C OBTAIN ASCII CHAR FROM GIRL VALUE
              DO 20 K1 = 1, 26
              L1 = K1
20            IF(GRLCHR .EQ. ALPHA(L1)) GO TO 50
C
              DO 30 K1 = 1, 10
              L1 = K1
30            IF(GRLCHR .EQ. NUMBRS(L1)) GO TO 40
40    IDNTFR(I1) = ASCII0 + L1 -1
      GO TO 60
50    IDNTFR(I1) = ASCIIA + L1 -1
G60   SY + GRLCHR 'SY
100   CONTINUE
C
G120  SY + STOP(/5 'ADDRES,  2 'IDSTAT)
      REGTST = IDSTAT .AND. REGFLG
      DEFTST = IDSTAT .AND. DEFFLG
      MLTTST = IDSTAT .AND. MLTFLG
      BYTTST = IDSTAT .AND. BYTFLG
      IF(REGTST .GT. 0) STATUS(1) = EKS
      IF(DEFTST .EQ. 0) STATUS(2) = EKS
      IF(MLTTST .GT. 0) STATUS(3) = EKS
      IF(BYTTST .GT. 0) STATUS(4) = EKS
C
      CALL DECHEX(ADDRES, HEX)
      WRITE(13, 150) IDNTFR, ADDRES, HEX, STATUS
150   FORMAT(1X, 6A1, 1X, I6, 1X, 4A1, 4X, A1, 5X, A1, 8X, A1, 6X, 3A1)
      GO TO 5
200   RETURN
G     COMPLETE
/     COMPLETE
```

```
C
C
C
      SUBROUTINE COMPUT(OPRAND,OPRATR)
      IMPLICIT INTEGER (A-Z)
C
      DIMENSION OPRAND(2)
C
C THIS ROUTINE PERFORMS A COMPUTATION ON OPRAND(1) OPRATR OPRAND(2)
C AS DETERMINED BY THE ARITHMETIC OR LOGICAL OPERATOR IN "OPRATR" AND
C PLACES THE RESULT INTO OPRAND(1).
C
C              .+  .*  .-  ./   +   *   -   /
      GO TO ( 10, 20, 30, 40, 50, 60, 70, 80) OPRATR
C
C LOGICAL OR
C
10    OPRAND(1) = OPRAND(1) .OR. OPRAND(2)
      RETURN
C
C LOGICAL AND
C
20    OPRAND(1) = OPRAND(1) .AND. OPRAND(2)
      RETURN
C
C LOGICAL NOT  --  ONE'S COMPLEMENT
C
30    OPRAND(1) = .NOT  OPRAND(2)
      RETURN
C
C MODULO
C
40    OPRAND(1) = MOD(OPRAND(1),OPRAND(2))
      RETURN
C
C ADD
C
50    OPRAND(1) = OPRAND(1) + OPRAND(2)
      RETURN
C
C MULTIPLY
C
60    OPRAND(1) = OPRAND(1) * OPRAND(2)
      RETURN
C
C SUBTRACT
C
70    OPRAND(1) = OPRAND(1) - OPRAND(2)
      RETURN
C
C DIVIDE
C
80    OPRAND(1) = OPRAND(1) / OPRAND(2)
      RETURN
      END
C
C
C
```

```
      SUBROUTINE DECHEX(DECNUM,HEX)
      IMPLICIT INTEGER (A-Z)
C
      LOGICAL*1 HEX(4),HEXTBL,NEG
      LOGICAL*1 BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ,ASCHAR
C
      COMMON /DATUM/  FIRST,SECOND,HEXTBL(16)
      COMMON /ASCII/  BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ
C
C     DIMENSION TEMP(4)
C
C THIS ROUTINE CONVERTS THE DECIMAL VALUE IN "DECNUM" TO HEXADECIMAL
C AND PLACES IT INTO HEX()
C
      NEG =  FALSE
      IF(DECNUM  LT  0) NEG =  TRUE
      NUMBER = IABS(DECNUM)
        DO 5 L1 = 1,4
C       TEMP(L1) = 0
5       HEX(L1) = ASCII0
      HEXPOS = 5
10    HEXPOS = HEXPOS - 1
C
C COMPUTE REMAINDER FROM MODULUS 16
      REM = MOD(NUMBER,16)
C     TEMP(HEXPOS) = REM
      HEX(HEXPOS) = HEXTBL(REM + 1)
      IF(NUMBER  LT  16) GO TO 20
      NUMBER = NUMBER / 16
      GO TO 10
C
C IF NEGATIVE, CONVERT TO TWO'S COMPLEMENT FORM
20    IF( NOT  NEG) RETURN
      CALL TWOCMP(HEX(1))
      RETURN
      END
C
C
C
      SUBROUTINE FMT1(ADRCOD)
      IMPLICIT INTEGER (A-Z)
C
      LOGICAL*1 HEXTBL,ADRCOD(3)
C
      COMMON /DATUM/  FIRST,SECOND,HEXTBL(16)
      COMMON /ASSEMB/ PASS,REGSRC,REGDES,REGCOD(2),PC,LINENO,ADDRES,
      1               MAJVAL,COMENT,IDSTAT,LNSTAT,ERRNUM,FMT,DIRNUM,
      2               OPER1,OPER2,ER,ERLABL,WRDNUM,BYTNUM,ERROR
C
C
      ADRCOD(1) = (REGCOD(2) * 4) + (REGDES/4)
C
      ADRCOD(2) =  REGCOD(1) + (4 * MOD(REGDES,4))
C
      ADRCOD(3) =  REGSRC
      RETURN
      END
C
C
C
      FUNCTION LVLFSH(WORD,BITS)
      IMPLICIT INTEGER(A-Z)
C
C THIS FUNCTION PERFORMS A LEFT LOGICAL SHIFT
C
      IF(BITS  EQ  0) GO TO 10
      IF(BITS  GE  16) GO TO 20
```

```
      LVLFSH = WORD * 2 ** (BITS)
      RETURN
10    LVLFSH = WORD
      RETURN
20    LVLFSH = 0
      RETURN
      END
C
C
C
      FUNCTION LVRTSH(WORD,BITS)
      IMPLICIT INTEGER(A-Z)
C
C THIS FUNCTION PERFORMS A RIGHT LOGICAL SHIFT
C
      IF(BITS  EQ  0) GO TO 10
      IF(BITS  GE  16) GO TO 20
      LVRTSH = WORD / 2 ** (BITS)
      RETURN
10    LVRTSH = WORD
      RETURN
20    LVRTSH = 0
      RETURN
      END
C
C
C
      SUBROUTINE ABSOUT
      IMPLICIT INTEGER (A-Z)
C
      LOGICAL*1 LABEL,OPCODE,OPRBUF,HEX,HEXCOD,HEXTBL,LINE
      LOGICAL*1 BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ,ASCHAR
      LOGICAL*1 LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY
      LOGICAL*1 DEFFLG,REGFLG,BYTFLG,LABFLG,INSFLG,OPFLG,RESFLG,
     1          DIRFLG,ENDFLG,COMNTS,EXTRA,LSTFLG
      LOGICAL*1 HEXBYT(2,20),PGMCTR,DUMMY2,LIN
C
      COMMON /ASC/     LINE(72),HEX(4),HEXCOD(4,10)
      COMMON /ERRFLG/  LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY
      COMMON /NAMFLG/  DEFFLG,LABFLG,REGFLG,BYTFLG
      COMMON /LINFLG/  INSFLG,OPFLG,RESFLG,DIRFLG,ENDFLG,COMNTS,EXTRA,
     1                 LSTFLG
      COMMON /ASSEMB/  PASS,REGSRC,REGDES,REGCOD(2),PC,LINENO,ADDRES,
     1                 MAJVAL,COMENT,IDSTAT,LNSTAT,ERRNUM,FMT,DIRNUM,
     2                 OPER1,OPER2,ER,ERLABL,WRDNUM,BYTNUM,ERROR
      COMMON /DATUM/   FIRST,SECOND,HEXTBL(16)
      COMMON /GIRLCH/  EXCLAM,QUOTE,POUND,DOLLAR,PERCNT,AMPERS,APOST,
     1                 LPAR,RPAR,STAR,PLUS,COMMA,MINUS,PERIOD,SLASH,
     2                 ZERO,ONE,TWO,THREE,FOUR,FIVE,SIX,SEVEN,EIGHT,
     3                 NINE,COLON,SCOLON,LSTHAN,EQUALS,GTTHAN,QUEST,
     4                 ATSIGN,A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,
     5                 V,W,X,Y,Z
      COMMON /GIRL/    STRING,TOKEN,ITEM,BUFPOS,LENID,LABELS,OPCOD,STOP,
     1                 ITMTYP,VALUE,SYMBOL,REG,REGSTR,REGATS,REGPLS,
     2                 VARABL,NUMBER,LITRAL,LOGOR,LOGAND,LOGNOT,MODULO,
     3                 OPFIN,DIRECT,START,TOKODE
      COMMON /ASCII/   BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ
      COMMON /LOCAL/   NUM1,NUM2,NUM3,LINCT1,LINCT2,LINCT3,PGMCTR(5),
     1                 DUMMY2,OLDPC,OLDBYT,LIN(48)
C
      DIMENSION LABEL(6),OPCODE(4),OPRBUF(60)
C
      EQUIVALENCE (LINE(1),LABEL(1))
      EQUIVALENCE (LINE(8),OPCODE(1))
      EQUIVALENCE (LINE(13),OPRBUF(1))
      EQUIVALENCE (HEXCOD(1,1),HEXBYT(1,1))
```

```
C
        DATA PGMCTR /1H0, 1H1, 1H0, 1H0, 1H /
        DATA NUM1, NUM2, NUM3, OLDPC, OLDBYT /0, 1, 0, 256, 0/
        DATA LINCT1, LINCT2, LINCT3 /1, 2, 3/
C
C TEST FOR MODIFICATION OF PC
        IF((DIRNUM .EQ. 3) .OR. (DIRNUM .EQ. 20)) GO TO 500
C
          DO 180 I1 = 1, BYTNUM
          LIN(LINCT1) = BLANK
          LIN(LINCT2) = HEXBYT(1, I1)
          LIN(LINCT3) = HEXBYT(2, I1)
C
C HAS A LINE BEEN FILLED?
          IF(LINCT3 .GE. (16*3)) GO TO 120
C
C IF NOT FILLED, IS THIS THE LAST LINE OF THE PROGRAM?
          IF(ENDFLG) GO TO 200
          LINCT1 = LINCT1 + 3
          LINCT2 = LINCT2 + 3
          LINCT3 = LINCT3 + 3
          GO TO 180
C
C OUTPUT THIS LINE
120       WRITE(12, 101) PGMCTR, LIN
101       FORMAT(53A1)
C
C UPDATE COUNTERS AND THE PROGRAM COUNTER ARRAY
          LINCT1 = 1
          LINCT2 = 2
          LINCT3 = 3
C
          NUM3 = NUM3 + 1
C
C CARRY?
          IF(NUM3 .LE. 15) GO TO 170
          NUM3 = 0
          NUM2 = NUM2 + 1
C
C CARRY?
          IF(NUM2 .LE. 15) GO TO 160
          NUM2 = 0
          NUM1 = NUM1 + 1
          IF(NUM1 .GE. 16) STOP '**** ERROR, PROGRAM EXCEEDS FFFF'
          IF((NUM1 .GE. 8) .AND. (NUM2 .GE. 8))
        1 PAUSE '**** WARNING, PROGRAM EXCEEDS 87FF, (CR) TO CONTINUE'
          PGMCTR(1) = HEXTBL(NUM1 + 1)
160       PGMCTR(2) = HEXTBL(NUM2 + 1)
170       PGMCTR(3) = HEXTBL(NUM3 + 1)
180       CONTINUE
        GO TO 600
C
C BLANK OUT END OF LAST LINE
200     NOMORE = LINCT3 + 1
          DO 250 JJ = NOMORE, 48
250       LIN(JJ) = BLANK
        WRITE(12, 101) PGMCTR, LIN
        GO TO 600
C
C PC MODIFICATION, ZERO FILL TO PC (FROM "BSS" AND "/")
C COMPUTE NEW LINE NUMBER (HEX(1)-HEX(3)) AND COUNTERS
500     PCTEMP = PC
        CALL DECHEX(PCTEMP, HEX)
        NUM1 = HEX(1) - ASCII0
        NUM2 = HEX(2) - ASCII0
        NUM3 = HEX(3) - ASCII0
```

```
        IF(NUM1  GT  9) NUM1 = HEX(1) - ASCIIA + 10
        IF(NUM2  GT  9) NUM2 = HEX(2) - ASCIIA + 10
        IF(NUM3  GT  9) NUM3 = HEX(3) - ASCIIA + 10
C
C CALCULATE DIFFERENCE TO NEW LOCATION
        DIFRNC = PC - OLDPC
C
C SIX POSSIBILITIES
C       A) NO MODIFICATION
C       B) READY TO START NEW LINE
C       C) ZERO FILL TO THE MIDDLE OF THE OUTPUTTED LINE
C       D) ZERO FILL TO THE END OF THE OUTPUTTED LINE
C       E) ZERO FILL TO THE END OF THE OUTPUTTED LINE AND PART OF ANOTHER
C          LINE
C       F) ERROR, PC REQUEST IS LESS THAN CURRENT PC
C
        IF(DIFRNC  LT  0) GO TO 700
        IF(DIFRNC  EQ  0) GO TO 600
        IF(LINCT1  EQ  1) GO TO 570
C
C ZERO FILL OLD LINE
530       DO 550 I1=1,DIFRNC
          LIN(LINCT1) = BLANK
          LIN(LINCT2) = ASCII0
          LIN(LINCT3) = ASCII0
          IF(LINCT3  GE  48) GO TO 560
          LINCT1 = LINCT1 + 3
          LINCT2 = LINCT2 + 3
          LINCT3 = LINCT3 + 3
550       CONTINUE
        GO TO 600
C
D       TYPE 999, NUM1,NUM2,NUM3,OLDPC,OLDBYT,ENDLIN,DIFRNC,PC
D999    FORMAT(1X,8(I6,2X))
C
C OUTPUT OLD LINE AND UPDATE COUNTER
560     WRITE(12,101) PGMCTR,LIN
570       DO 580 I1 = 1,3
580       PGMCTR(I1) = HEX(I1)
C
C ZERO FILL THE BEGINNING OF THE NEW LINE
        LINCT1 = 1
        LINCT2 = 2
        LINCT3 = 3
        DIFRNC = HEX(4) - ASCII0
        IF(DIFRNC  GT  9) DIFRNC = HEX(4) - ASCIIA + 10
        IF(DIFRNC  EQ  0) GO TO 600
          DO 590 I1=1,DIFRNC
          IF(LINCT3  GT  48) GO TO 600
          LIN(LINCT1) = BLANK
          LIN(LINCT2) = ASCII0
          LIN(LINCT3) = ASCII0
          LINCT1 = LINCT1 + 3
          LINCT2 = LINCT2 + 3
590       LINCT3 = LINCT3 + 3
600     OLDPC = PC
        OLDBYT = BYTNUM
        RETURN
700     TYPE 701,PC,OLDPC
701     FORMAT(1X,'*** ERROR ***, PC REQUEST OF',I5,' IS LESS THAN THE
        1 CURRENT PROGRAM COUNTER',I5)
        STOP
        END
C
C
C
```

```
      SUBROUTINE SRCLST(THISPC)
      IMPLICIT INTEGER (A-Z)
C
      LOGICAL*1 LABEL,OPCODE,OPRBUF,HEX,HEXCOD,HEXTBL,LINE
      LOGICAL*1 BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ,ASCHAR
      LOGICAL*1 LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY
      LOGICAL*1 DEFFLG,REGFLG,BYTFLG,LABFLG,INSFLG,OPFLG,RESFLG,
     1          DIRFLG,ENDFLG,COMNTS,EXTRA,LSTFLG
      LOGICAL*1 PGMCTR,DUMMY2,HXCODE(4),LIN
C
      COMMON /ASC/     LINE(72),HEX(4),HEXCOD(4,10)
      COMMON /ERRFLG/  LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY
      COMMON /NAMFLG/  DEFFLG,LABFLG,REGFLG,BYTFLG
      COMMON /LINFLG/  INSFLG,OPFLG,RESFLG,DIRFLG,ENDFLG,COMNTS,EXTRA,
     1                 LSTFLG
      COMMON /ASSEMB/  PASS,REGSRC,REGDES,REGCOD(2),PC,LINENO,ADDRES,
     1                 MAJVAL,COMENT,IDSTAT,LNSTAT,ERRNUM,FMT,DIRNUM,
     2                 OPER1,OPER2,ER,ERLABL,WRDNUM,BYTNUM,ERROR
      COMMON /DATUM/   FIRST,SECOND,HEXTBL(16)
      COMMON /GIRLCH/  EXCLAM,QUOTE,POUND,DOLLAR,PERCNT,AMPERS,APOST,
     1                 LPAR,RPAR,STAR,PLUS,COMMA,MINUS,PERIOD,SLASH,
     2                 ZERO,ONE,TWO,THREE,FOUR,FIVE,SIX,SEVEN,EIGHT,
     3                 NINE,COLON,SCOLON,LSTHAN,EQUALS,GTTHAN,QUEST,
     4                 ATSIGN,A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,
     5                 V,W,X,Y,Z
      COMMON /GIRL/    STRING,TOKEN,ITEM,BUFPOS,LENID,LABELS,OPCOD,STOP,
     1                 ITMTYP,VALUE,SYMBOL,REG,REGSTR,REGATS,REGPLS,
     2                 VARABL,NUMBER,LITRAL,LOGOR,LOGAND,LOGNOT,MODULO,
     3                 OPFIN,DIRECT,START,TOKODE
      COMMON /ASCII/   BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ
      COMMON /LOCAL/   NUM1,NUM2,NUM3,LINCT1,LINCT2,LINCT3,PGMCTR(5),
     1                 DUMMY2,OLDPC,OLDBYT,LIN(48)
C
      DIMENSION LABEL(6),OPCODE(4),OPRBUF(60)
C
      EQUIVALENCE (LINE(1),LABEL(1))
      EQUIVALENCE (LINE(8),OPCODE(1))
      EQUIVALENCE (LINE(13),OPRBUF(1))
C
C IF THE "LIST" DIRECTIVE IS SET, THIS ROUTINE WILL OUTPUT THE INPUT LINE,
C LINE STATUS AND TARGET CODE.
C
C OBTAIN HEX VALUE OF PC
      CALL DECHEX(THISPC,HEX)
C
C IS THIS LINE A COMMENT?
      IF(.NOT. COMNTS) GO TO 5
      WRITE(13,200) LINENO,LINE
200   FORMAT(1X,I5,40X,72A1)
      RETURN
C
5       DO 10 I1 = 1,4
10      HXCODE(I1) = HEXCOD(I1,1)
      N1 = 61
15    N1 = N1 - 1
      IF(N1 .LE. 1) GO TO 20
      IF(OPRBUF(N1) .EQ. BLANK) GO TO 15
20    WRITE(13,100) LINENO,THISPC,HEX,LNSTAT,HXCODE,LABEL,OPCODE,
     1 (OPRBUF(K1),K1=1,N1)
100   FORMAT(1X,I5,3X,I5,2X,4A1,6X,I3,8X,4A1,5X,6A1,1X,4A1,4X,60A1)
      IF(WRDNUM .EQ. 1) RETURN
        DO 30 I1 = 2,WRDNUM
        WRITE(13,25) (HEXCOD(J1,I1),J1 = 1,4)
30      CONTINUE
25    FORMAT(37X,4A1)
      RETURN
      END
```

```
C
C
C
      SUBROUTINE ERROUT(THISPC)
      IMPLICIT INTEGER (A-Z)
C
      LOGICAL*1 LABEL,OPCODE,OPRBUF,HEX,HEXCOD,HEXTBL,LINE
      LOGICAL*1 BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ,ASCHAR
      LOGICAL*1 LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY
      LOGICAL*1 DEFFLG,REGFLG,BYTFLG,LABFLG,INSFLG,OPFLG,RESFLG,
     1          DIRFLG,ENDFLG,COMNTS,EXTRA,LSTFLG
      LOGICAL*1 PGMCTR,DUMMY2,HXCODE(4),LIN
C
      COMMON /ASC/     LINE(72),HEX(4),HEXCOD(4,10)
      COMMON /ERRFLG/ LABERR,DIRERR,OPERR,TYPERR,INSTER,DUMMY
      COMMON /NAMFLG/ DEFFLG,LABFLG,REGFLG,BYTFLG
      COMMON /LINFLG/ INSFLG,OPFLG,RESFLG,DIRFLG,ENDFLG,COMNTS,EXTRA,
     1                LSTFLG
      COMMON /ASSEMB/ PASS,REGSRC,REGDES,REGCOD(2),PC,LINENO,ADDRES,
     1                MAJVAL,COMENT,IDSTAT,LNSTAT,ERRNUM,FMT,DIRNUM,
     2                OPER1,OPER2,ER,ERLABL,WRDNUM,BYTNUM,ERROR
      COMMON /DATUM/   FIRST,SECOND,HEXTBL(16)
      COMMON /GIRLCH/ EXCLAM,QUOTE,POUND,DOLLAR,PERCNT,AMPERS,APOST,
     1                LPAR,RPAR,STAR,PLUS,COMMA,MINUS,PERIOD,SLASH,
     2                ZERO,ONE,TWO,THREE,FOUR,FIVE,SIX,SEVEN,EIGHT,
     3                NINE,COLON,SCOLON,LSTHAN,EQUALS,GTTHAN,QUEST,
     4                ATSIGN,A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,
     5                V,W,X,Y,Z
      COMMON /GIRL/    STRING,TOKEN,ITEM,BUFPOS,LENID,LABELS,OPCOD,STOP,
     1                ITMTYP,VALUE,SYMBOL,REG,REGSTR,REGATS,REGPLS,
     2                VARABL,NUMBER,LITRAL,LOGOR,LOGAND,LOGNOT,MODULO,
     3                OPFIN,DIRECT,START,TOKODE
      COMMON /ASCII/   BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ
      COMMON /LOCAL/   NUM1,NUM2,NUM3,LINCT1,LINCT2,LINCT3,PGMCTR(5),
     1                DUMMY2,OLDPC,OLDBYT,LIN(48)
C
      DIMENSION LABEL(6),OPCODE(4),OPRBUF(60)
C
      EQUIVALENCE (LINE(1),LABEL(1))
      EQUIVALENCE (LINE(8),OPCODE(1))
      EQUIVALENCE (LINE(13),OPRBUF(1))
C
      DATA TEST /0/
C
      LNSTAT = 0
      IF(LABERR) LNSTAT = 2
      IF(INSTER) LNSTAT = LNSTAT + 4
      IF(OPERR)  LNSTAT = LNSTAT + 8
      IF(LNSTAT  EQ  0) RETURN
C
C OBTAIN HEX VALUE OF PC
      CALL DECHEX(THISPC,HEX)
C
        DO 10 I1 = 1,4
10      HXCODE(I1) = HEXCOD(I1,1)
      IF(TEST  EQ.  1) GO TO 70
      TYPE 50
50    FORMAT(/,1X,' **** ERROR ****')
      TYPE 60
60    FORMAT(' LINE NO   ADDRESS      LINE STATUS  OBJ CODE  LABEL
     1  INSTR   OP FIELD')
      TEST = 1
70    TYPE 100, LINENO,THISPC,HEX,LNSTAT,HXCODE,LABEL,OPCODE,OPRBUF
100   FORMAT(1X,I5,3X,I5,2X,4A1,6X,I3,7X,4A1,6X,6A1,1X,4A1,4X,60A1)
      RETURN
      END
```

```
C
C
C
      SUBROUTINE TWOCMP(HEX)
      IMPLICIT INTEGER (A-Z)
C
      LOGICAL*1 HEX(4),HEXTBL,NEG
      LOGICAL*1 BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ,ASCHAR
C
      COMMON /DATUM/  FIRST,SECOND,HEXTBL(16)
      COMMON /ASCII/  BLANK,ASCII0,ASCII9,ASCIIA,ASCIIF,ASCIIZ
C
      DIMENSION TEMP(4)
C
C THIS ROUTINE CONVERTS A HEX NUMBER OF FOUR ASCII DIGITS TO ITS
C 2'S COMPLEMENT FORM IN ASCII CODE
C PLACE INTEGER EQUIVALENT INTO "TEMP"
        DO 30 N1 = 1,4
        VAL = HEX(N1) - ASCII0
        IF(VAL .GT. 9) VAL = HEX(N1) -ASCIIA + 10
        TEMP(N1) = 15 - VAL
30      CONTINUE
      TEMP(4) = TEMP(4) + 1
C
C CHECK FOR OVERFLOW
      N1 = 5
40    N1 = N1 - 1
      IF(TEMP(N1) .LE. 15) GO TO 50
      TEMP(N1) = 0
      IF(N1 .LE. 1) GO TO 50
      TEMP(N1-1) = TEMP(N1-1) + 1
      GO TO 40
C
50      DO 60 N1 = 1,4
        HEX(N1) = HEXTBL(TEMP(N1) + 1)
60      CONTINUE
      RETURN
      END
```

APPENDIX C

VARIABLES IN LABELED COMMON

/ASSEMB/

PASS - Assembler pass number. It is set to either 1 or 2.

REGSRC - Source field workspace register number. Value range 0-15.

REGDES - Destination field workspace register number. Value range 0-15.

REGCOD() - Source (1) and destination (2) register codes. Allowable values:

```
 Ri  = 0
*Ri  = 1
@Ri  = 2
*Ri+ = 3
```

PC - Current value of Program Counter. It is reset at the beginning of pass two and has a default value of 100_{16} (256_{10}). It is user modifiable (see directives AORG, /, BSS).

LINENO - Input line number.

ADDRES - Used by Subroutine ADDNAM to return an address value for a requested identifier. Value is zero if identifier is not yet defined. It is used by Subroutine OPFLD to return the value of a complete operand field.

MAJVAL - Output from Subroutine OPFLD. It is used by Subroutine ITMSCN to check that an operand field is semantically correct. Refer to Tables 1 and 2.

COMENT - Location of the semicolon in the input line. It indicates where comments begin for that line. Value range is 1 to 60.

IDSTAT - Output from Subroutine ADDNAM. It holds the status of the retrieved identifier. Allowable values include various combinations of the following:

1 - Identifier has been defined
2 - Identifier is a register
4 - Identifier is multipli-defined
8 - Identifier is a halfword (byte).

LNSTAT - Status of the input statement. Allowable values include any cumulative combination of the following:

2 - Label error
4 - Instruction or directive error
8 - Operand error

ERRNUM - Reserved for future program enhancement.

FMT - Output from Subroutine INSTRU. At the successful completion of a search of the instruction-directive tree, FMT contains the operand format number for the requested instruction. Refer to Tables 1 and 2.

DIRNUM - Output from Subroutine INSTRU. At the successful completion of a search of the instruction-directive tree, DIRNUM contains the directive number which uniquely defines the directive. Refer to Table 3.

OPER1 and OPER2 - Output from Subroutine INSTRU. At the successful completion of a search of the instruction-directive tree, OPER1 and OPER2 contain the ASCII equivalent of the instruction skeleton.

ER - State pointer for the identifier tree.

ERLABL - State pointer for the identifier tree. It points to the last source node in the string describing the current label. Its link is always "STOP." Refer to discussion on the identifier tree.

WRDNUM - Number of words required by either an instruction or a directive. It is computed during the first (pass) call to Subroutine ITMSCN. Value range is:

Instructions	Directives
1-3	0-10

BYTNUM - Number of bytes required by either an instruction or a directive. It is computed during the first (pass) call to Subroutine ITMSCN and is an input to Subroutine ABSOUT. Value range is:

Instructions	Directives
2-6	0-20

ERROR - Reserved for future program enhancement

/GIRLCH/ - EXCLAM,QUOTE,POUND,DOLLAR,PERCNT,AMPERS,APOST,LPAR,RPAR,STAR, PLUS,COMMA,MINUS,PERIOD,SLASH,ZERO,ONE,TWO,THREE,FOUR,FIVE, SIX,SEVEN,EIGHT,NINE,COLON,SCOLON,LSTHAN,EQUALS,GTTHAN,QUEST, ATSIGN,A,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,V,W,X,Y,Z

These variables are defined within GIRL^2 to represent the particular character as named.

/ERRFLG/ - The following logical*1 variables have the indicated meanings when set to .TRUE.:

LABERR - Label error such as multiple definition.

DIRERR - Not used in present version.

OPERR - Error in operand field.

TYPERR - Reserved for future program enhancement.

INSTER - Instruction name or directive name error.

DUMMY - Filler byte to make this common block contain an even number of bytes.

/NAMFLG/ - The following flags indicate label status. If the status of an identifier includes any of the flags, then that identifier has the following properties:

DEFFLG - Identifier has been defined and given an address by virtue of placement in the label field.

LABFLG - Not used in present version.

REGFLG - Identifier is a register.

MLTFLG - Identifier appears in the label field more than once.

BYTFLG - Identifier is halfword size.

DUMB - Filler byte to make this common block contain an even number of blocks.

/LINFLG/

INSFLG - Not used in present version.

OPFLG - Not used in present version.

RESFLG - Reserved for future program enhancement.

DIRFLG - Not used in present version.

ENDFLG - Set to .TRUE. when END directive is encountered.

COMNTS - Set to .TRUE. if entire input line is a comment statement.

EXTRA - Input to Subroutine ITMSCN from Subroutine OPFLD. It is set to .TRUE. If there is a memory reference in an operand field, thus requiring an extra machine code word on output.

LSTFLG - Set to .TRUE. if LIST directive is encountered.

APPENDIX D

SAMPLE SET OF INSTRUCTIONS AND DIRECTIVES

```
        LIST ;
        A     R1,R2;
JIM     AB    R2,R1;
        ABS   R1;
        AI    R1,>ABC;
        ANDI  R2,>ABC;
        UNL   ;
        ABS   R1;
        AI    R1,>ABC;
        ANDI  R2,>ABC;
        b     R1;
BILL    BL    R2;
        BLWP  R2;
JOE     BSS   >A;
SID     BYTE  >10,128;
        C     R2,R1;
        BYTE  'A';
        BYTE  'B';
        BYTE  'C';
        BYTE  'D';
        CB    R1,R2;
        CI    R1,>7FF;
        CLR   R2;
        COC   R2,R1;
        CZC   R2,R1;
WALTER  DATA  'AB',>23;
        DEC   R1;
        DECT  R2;
        DIV   R2,R1;
        DXOP  ;
JOAN    EQU   3+5*6;
CNTHIA  EQU   JOAN+10+6;
        AI    R1,JOAN;
        AI    R1,RAE;
SHIRA   EVEN  ;
CAROL   BYTE  'A',$B$,>EF;
RAE     EVEN  ;
        IDLE  ;
        IN    R1;
        INC   R2;
        INCT  R2;
        INV   R1;
        JEQ   300;
        JGT   @300;
        JH    300;
        JHE   300;
        JL    300;
        JLE   300;
        JLT   300;
        JMP   300;
        JNC   300;
        JNE   300;
        JNO   300;
        JOC   300;
        JOP   300;
QRTF    LDCR  R1,8;
PLKJ    LI    R1,>ABC;
FHQDJ   LIMI  >ABC;
```

```
PYTRV   LWPI >ABC;
HJFG    MOV  R1,R2;
SFD     MOVB R1,R2;
WR      MPY  R2,R1;
XZC     NEG  R1;
WRQY    NOP       ;
LKUY    ORI  R1,>ABC;
PQTYR   OUT  R1;
        RT   ;
LDFWQ   RTWP   ;
WTUEY   S    R1,R2;
QAZXC   SB   R2,R1;
PLMN    SBO  14;
EFVBG   SBZ  20;
DCFE    SETO R1;
POIJ    SLA  R1,12;
QWER    SOC  R1,R2;
WALT    SOCB R2,R1;
KLEE    SRA  R2,10;
TJUF    SRC  R1,12;
PETW    SRL  R2,8;
SDWER   STCR R2,15;
WDFVE   STST R1;
EVEFR   STWP R1;
        SWPB R1;
PLKJH   SZC  R2,R1;
SKJHY   SZCB R2,R1;
LADWT   TB   18;
        TEXT 'EXAMPLE';
        EVEN ;
        END  ;
WERE    X    R2;
QSPK    XOP  R2;
NVBCW   XOR  R1,R2;
        /    >60A;
        IN   R1;
        INC  R2;
        INCT R2;
        INV  R1;
        JEQ  300;
        JGT  @300;
        JH   300;
        JHE  300;
        JL   300;
        JLE  300;
        JLT  300;
        END  ;
```

APPENDIX E

SOURCE AND IDENTIFIER LISTING GENERATED FROM
APPENDIX A AS INPUT

```
LINE NO.   ADDRESS   LINE STATUS  OBJ CODE  LABEL   INSTR.   OP FIELD
    1                                        LIST ;
    2      256  0100      0       A081              A        R1,R2;
    3      258  0102      0       B042      JIM     AB       R2,R1;
    4      260  0104      0       0741              ABS      R1;
    5      262  0106      0       0221              AI       R1,>ABC;
                                   0ABC
    6      266  010A      0       0242              ANDI     R2,>ABC;
                                   0ABC
    7                                        UNL ;
    8      270  010E      0       0741              ABS      R1;
    9      272  0110      0       0221              AI       R1,>ABC;
                                   0ABC
   10      276  0114      0       0242              ANDI     R2,>ABC;
                                   0ABC
   11      280  0118      0       0441              B        R1;
   12      282  011A      0       0682      BILL    BL       R2;
   13      284  011C      0       0402              BLWP     R2;
   14      286  011E      0               JOE       BSS      >A;
   15      296  0128      0       1080      SID     BYTE     >10,128;
   16      298  012A      0       8042              C        R2,R1;
   17      300  012C      0       41                BYTE     'A';
   18      301  012D      0       42                BYTE     'B';
   19      302  012E      0       43                BYTE     'C';
   20      303  012F      0       44                BYTE     'D';
   21      304  0130      0       9081              CB       R1,R2;
   22      306  0132      0       0281              CI       R1,>7FF;
                                   07FF
   23      310  0136      0       04C2              CLR      R2;
   24      312  0138      0       2042              COC      R2,R1;
   25      314  013A      0       2442              CZC      R2,R1;
   26      316  013C      0       4142      WALTER  DATA     'AB',>23;
                                   0023
   27      320  0140      0       0601              DEC      R1;
   28      322  0142      0       0642              DECT     R2;
   29      324  0144      0       3C42              DIV      R2,R1;
   30                                       DXOP ;
   31                                   JOAN    EQU  3+5*6;
   32                                   CNTHIA  EQU  JOAN+10+6;
   33      326  0146      0       0221              AI       R1,JOAN;
                                   0030
   34      330  014A      0       0221              AI       R1,RAE;
                                   0151
   35                                   SHIRA   EVEN ;
   36      334  014E      0       4142      CAROL   BYTE     'A',$B$,>EF;
                                   EF
   37      337  0151      0       00        RAE     EVEN     ;
   38      338  0152      0       0340              IDLE     ;
   39      340  0154      0       2C41              IN       R1;
   40      342  0156      0       0582              INC      R2;
   41      344  0158      0       05C2              INCT     R2;
   42      346  015A      0       0541              INV      R1;
   43      348  015C      0       13E7              JEQ      300;
   44      350  015E      0       15E6              JGT      @300;
   45      352  0160      0       1BE5              JH       300;
   46      354  0162      0       14E4              JHE      300;
   47      356  0164      0       1AE3              JL       300;
   48      358  0166      0       12E2              JLE      300;
```

```
49    360   0168   0     11E1          JLT     300;
50    362   016A   0     10E0          JMP     300;
51    364   016C   0     17DF          JNC     300;
52    366   016E   0     16DE          JNE     300;
53    368   0170   0     19DD          JNO     300;
54    370   0172   0     18DC          JOC     300;
55    372   0174   0     1CDB          JOP     300;
56    374   0176   0     3201    GRTF  LDCR    R1,8;
57    376   0178   0     0201    PLKJ  LI      R1,>ABC;
                         0ABC
58    380   017C   0     0300    FHGDJ LIMI    >ABC;
                         0ABC
59                                   LIST ;
60    384   0180   0     02E0    PYTRV LWPI    >ABC;
                         0ABC
61    388   0184   0     C081    HJFG  MOV     R1,R2;
62    390   0186   0     D081    SFD   MOVB    R1,R2;
63    392   0188   0     3842    WR    MPY     R2,R1;
64    394   018A   0     0501    XZC   NEG     R1;
65    396   018C   0     1000    WRGY  NOP           ;
66    398   018E   0     0261    LKUY  ORI     R1,>ABC;
                         0ABC
67    402   0192   0     2C81    PGTYR OUT     R1;
68    404   0194   0     045B          RT      ;
69    406   0196   0     0380    LDFWG RTWP        ;
70    408   0198   0     6081    WTUEY S       R1,R2;
71    410   019A   0     7042    GAZXC SB      R2,R1;
72    412   019C   0     1D0E    PLMN  SBO     14;
73    414   019E   0     1E14    EFVBG SBZ     20;
74    416   01A0   0     0701    DCFE  SETO    R1;
75    418   01A2   0     0AC1    POIJ  SLA     R1,12;
76    420   01A4   0     E081    GWER  SOC     R1,R2;
77    422   01A6   0     F042    WALT  SOCB    R2,R1;
78    424   01A8   0     08A2    KLEE  SRA     R2,10;
79    426   01AA   0     0BC1    TJUF  SRC     R1,12;
80    428   01AC   0     0982    PETW  SRL     R2,8;
81    430   01AE   0     37C2    SDWER STCR    R2,15;
82    432   01B0   0     02C1    WDFVE STST    R1;
83    434   01B2   0     02A1    EVEFR STWP    R1;
84    436   01B4   0     06C1          SWPB    R1;
85    438   01B6   0     4042    PLKJH SZC     R2,R1;
86    440   01B8   0     5042    SKJHY SZCB    R2,R1;
87    442   01BA   0     1F12    LADWT TB      18;
88    444   01BC   0     4558          TEXT    'EXAMPLE';
                         414D
                         504C
                         45
89    451   01C3   0     00            EVEN    ;
90    452   01C4   0                   END     ;
```

**** IDENTIFIER LISTING ****

NAME	STATUS ADDRESS	REG	UNDEF	MULT DEF	BYTE
R0	0 0000	X			
R1	1 0001	X			
R2	2 0002	X			
R3	3 0003	X			
R4	4 0004	X			
R5	5 0005	X			
R6	6 0006	X			
R7	7 0007	X			
R8	8 0008	X			
R9	9 0009	X			
R10	10 000A	X			
R11	11 000B	X			
R12	12 000C	X			
R13	13 000D	X			
R14	14 000E	X			
R15	15 000F	X			
JIM	258 0102				
BILL	282 011A				
JOE	286 011E				
SID	296 0128				X
JOAN	48 0030				
CNTHIA	64 0040				
RAE	337 0151				
SHIRA	334 014E				
CAROL	334 014E				X
RAE	337 0151				
GRTF	374 0176				
PLKJ	376 0178				
FHGDJ	380 017C				
PYTRV	384 0180				
HJFG	388 0184				
SFD	390 0186				
WR	392 0188				
XZC	394 018A				
WRQY	396 018C				
LKUY	398 018E				
PQTYR	402 0192				
LDFWQ	406 0196				
WTUEY	408 0198				
QAZXC	410 019A				
PLMN	412 019C				
EFVBG	414 019E				
DCFE	416 01A0				
POIJ	418 01A2				
QWER	420 01A4				
WALT	422 01A6				
KLEE	424 01A8				
TJUF	426 01AA				
PETW	428 01AC				
SDWER	430 01AE				
WDFVE	432 01B0				
EVEFR	434 01B2				
PLKJH	438 01B6				
SKJHY	440 01B8				
LADWT	442 01BA				

APPENDIX F

MACHINE CODE GENERATED FROM APPENDIX A AS INPUT

```
0100:  A0 B1 B0 42 07 41 02 21 0A BC 02 42 0A BC 07 41
0110:  02 21 0A BC 02 42 0A BC 04 41 06 82 04 02 00 41
0120:  00 00 00 00 00 00 00 00 10 80 80 42 41 42 43 44
0130:  90 81 02 81 07 FF 04 C2 20 42 24 42 41 42 00 23
0140:  06 01 06 42 3C 42 02 21 00 30 02 21 01 51 41 42
0150:  EF 00 03 40 2C 41 05 82 05 C2 05 41 13 E7 15 E6
0160:  1B E5 14 E4 1A E3 12 E2 11 E1 10 E0 17 DF 16 DE
0170:  19 DD 18 DC 1C DB 32 01 02 01 0A BC 03 00 0A BC
0180:  02 E0 0A BC C0 81 D0 81 38 42 05 01 10 00 02 61
0190:  0A BC 2C 81 04 5B 03 80 60 81 70 42 1D 0E 1E 14
01A0:  07 01 0A C1 E0 81 F0 42 08 A2 0B C1 09 82 37 C2
01B0:  02 C1 02 A1 06 C1 40 42 50 42 1F 12 45 58 41 4D
01C0:  50 4C 45 00
```

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