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# fortran IV software support manual

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DEC-S8-LFSSA-A-D

# OS/8 FORTRAN IV

# SOFTWARE SUPPORT MANUAL

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CONTENTS

# CHAPTER 1

# THE F4 COMPILER

The OS/8 F4 compiler runs in 8K on either a PDP-8 or a PDP-12. It operates in three passes to transform FORTRAN IV source programs into RALF assembly language. The function of each of the three passes is:

1. Analyze statements, check syntax and convert to a polish notation.
2. Convert output of PASS1 to RALF assembly language making extensive use of code skeleton tables.
3. Produce a listing of the FORTRAN source program and/or chain to the assembler.

The following is a more complete description of each of the three passes.

## PASS1 OPERATION

After opening the source language input file(s) and an intermediate output file, PASS1 processes statements in the following fashion:

1. Assemble a statement into the statement buffer by reading characters from the OS/8 input file. This section eliminates comments and handles continuations so that the statement buffer contains the entire statement as if it had been written on one long line.
2. The statement is first assumed to be an arithmetic assignment and an attempt is made to compile it as such. This is done with a special switch (NOCODE) set so that in the event the statement is not arithmetic, no erroneous output is produced. Thus, with this switch set, the expression analyzer subroutine is used merely as a syntax checker.
3. If the statement is indeed an arithmetic assignment statement (or arithmetic statement function) the switch is set off and the statement is then recompiled, this time producing output.

4. If not an arithmetic assignment, the statement might be one of the keyword defined statements. The compiler now checks the first symbol on the line to see of it is a legal keyword (REAL, GOTO, etc.) and jumps to the appropriate subroutine if so. Any statement that is not now classified is considered to be in error.
5. The compilation of each statement takes place. Some statements produce only symbol table entries (e.g., DIMENSION) which will be processed by PASS2. Others use the arithmetic expression analyzer (EXPR) and also output special purpose operators which will tell PASS2 what to do with the value represented by the arithmetic expression (e.g., IF, DO).
6. After the statement has been processed, control passes to the end-of-statement routine which handles DO-loop terminations and then outputs the end-of-statement code.
7. Statements containing some kind of error cause a special error code to be output.
8. The entire process is now repeated for the next statement.
9. When the END statement is encountered, PASS1 chains to PASS2.

PASS1 SYMBOL TABLE

A significant portion of the PASS1 processing involves the production of symbol table entries. These entries contain all storage related information, i.e., variable name, type, dimensions, etc.

The symbol table is organized as a set of linked lists. The first 26 such lists are for variables, with the first letter of the variable name corresponding to the ordinal number of the list. There are also separate lists for statement numbers and literals (integer, real, complex, double, and Hollerith). In addition to list elements, there are special entries for holding DIMENSION and EQUIVALENCE information.

A detailed description of each type of entry follows. (NOTE: All symbol table entries are in Field 1.)

1. VARIABLE - The first word of each entry is a pointer to the next entry, with a zero pointer signaling end of list. The second word contains type information. The third word points to the dimension and/or equivalence information blocks. The next one to three words contain the remainder of the name (the first character is implied by which list the entry is in) in stripped six-bit ASCII terminated by a zero character. Thus, shorter variables take less symbol table space. The entries are (as for all lists in the symbol table) arranged in order of increasing magnitude, or alphabetically.

| | | |
|---|---|---|
| POINTER | → | |
| TYPE | | |
| DIMENSION/EQUIVALENCE | → | |
| NAME 2-3 | N | A |
| NAME 4-5 | M | E |
| NAME 6 | X | Ø |

TYPE WORD FORMAT

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| COM | DIM | EXT | ASF | EQUIV | EXPLIC | LIT | ARG | T | Y | P | E |

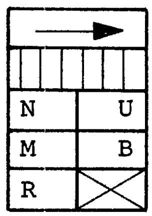
BIT

Ø - Variable is in common.
1 - Variable is dimensioned.
2 - External symbol or subroutine/function name.
3 - Symbol is the name of an arithmetic statement function.
4 - Variable is an equivalence slave.
5 - Variable is explicitly typed.
6 - Entry is a literal.
7 - Variable is a formal parameter.

| | | |
|---|---|---|
| 8-11 Type | 1 | integer |
| | 2 | real |
| | 3 | complex |
| | 4 | double |
| | 5 | logical |
| | 8 | statement number |
| | 9 | common section name |

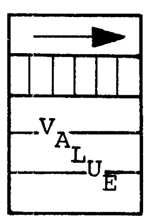
2. STATEMENT NUMBER - The first two words are the standard pointer/type. The next three words are the statement number, with leading zeros deleted, in stripped six-bit ASCII, filled to the right with blanks.

POINTER
TYPE
NUMBER 1-2
NUMBER 3-4
NUMBER 5



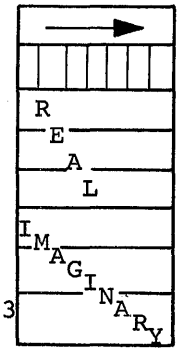

3. INTEGER OR REAL LITERALS - The first two words are the pointer and type. The next three words are the value in standard floating-point format (12-bit exponent, 24-bit signed 2's complement mantissa). Since the type of the literal must be preserved, there are two lists; hence use of 1 and 1.Ø in the same program will cause one entry in each of the integer and real literal lists.

POINTER
TYPE
EXPONENT
MANTISSA 0-11
MANTISSA 12-23



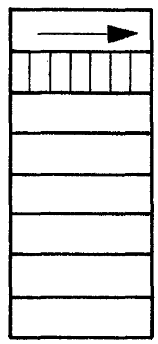

4. COMPLEX LITERALS - The first two words are standard. The next three are the real part in standard floating-point format. The next three are the imaginary part.

POINTER
TYPE
REAL EXPONENT
REAL MANTISSA 0-11
REAL MANTISSA 12-23
IMAGINARY EXPONENT
IMAGINARY MANTISSA 0-11
IMAGINARY MANTISSA 12-23



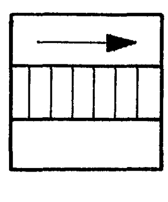

5. DOUBLE PRECISION LITERALS - The first two words are standard. The next six are the literal in FPP extended format (72-bit exponent, 60-bit mantissa).

POINTER
TYPE
EXPONENT
MANTISSA 0-11
MANTISSA 12-23
MANTISSA 24-35
MANTISSA 36-47
MANTISSA 48-59



6. HOLLERITH (quoted) LITERALS - The first two words are standard. The next N words are the characters of the literal in stripped six-bit ASCII, ending in a zero character.

POINTER
TYPE
CHARACTERS 1-2
etc.



7. DIMENSION INFORMATION BLOCK - If a variable is DIMENSIONed, the third word of its symbol table entry will point to its dimension information block (may be indirectly, see section 8 below). The first word of this block is the number of dimensions. The second word is the total size of the array in elements; thus the size in PDP-8 words may be 3 or 6 times

this number. The third word contains the "magic number" which is computed as follows:

$$MN = - 1 + \sum_{i=1}^{n-1} \quad {}^{\;i}_{j=1} \quad d_j$$

where $d_j$ is the $j^{th}$ dimension and n is the number of dimensions.

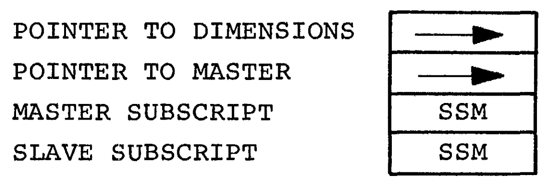
For a 3-dimensional variable this number becomes:

$$MN+ 1+d_1+d_1d_2$$

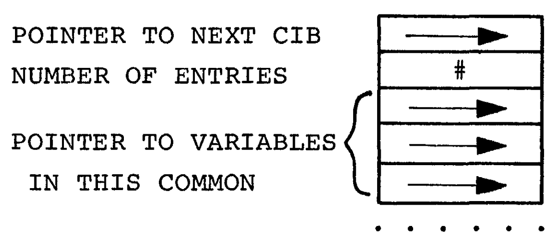
The magic number must be subtracted from any computed index, since indexing starts at one and not zero. The fourth word will (in PASS2) contain the displacement from #LIT of a literal which will contain either the magic number in un-normalized form (for dimensioned variables which are subroutine arguments) or the address of the variable minus the magic number (for local or COMMON dimensioned variables). This literal is necessary for calling subroutines where a subscripted variable is an argument. The next N words are the dimensions of the variable. If the variable is a formal parameter of the subroutine, it may have one or more dimensions which are also formal parameters. In this case, the magic number is zero, and the dimension(s) is a pointer to the symbol table entry for the variable(s) used as a dimension.

| | |
|---|---|
| NUMBER OF DIMENSIONS | # |
| TOTAL NUMBER OF ELEMENTS | SIZE |
| MAGIC NUMBER | MN |
| RESERVED | |
| DIMENSION 1 | $D_1$ |
| DIMENSION 2 | $D_2$ |
| | ....... |
| DIMENSION n | $D_n$ |

8. EQUIVALENCE INFORMATION BLOCK - If a variable is an EQUIVALENCE slave variable, the third word of its symbol table entry points to the equivalence information block. The first word of this block points to the dimension information (if any) of the variable. The second word points to the symbol table entry of the EQUIVALENCE master variable. The third word is the linearized subscript of the master variable from the EQUIVALENCE statement. The fourth word is the linearized subscript of the slave variable.




9. COMMON INFORMATION BLOCK - If a symbol is defined as the name of a COMMON section, the third word of its symbol table entry points to a list of common information blocks. The first word of each such block points to the next block. The second word is the number of entries in the list that follows. The rest of the block is a set of pointers to the symbol table entries of the variables in the COMMON section.




PASS1 OUTPUT

The output of PASS1 is a stream of polish with many special operators. Whenever an operand is to be output, the address of its symbol table entry is used. The following is a list of the output codes (in their mnemonic form, obtain numeric values from listing of PASS1) and the operation they are conveying to PASS2:

| | |
|---|---|
| PUSH | The next word in the output file is an operand (symbol table pointer) to be put onto the stack. |
| ADD | Add the operands represented by the top two stack entries (actually this causes PASS2 to generate the RALF coding which will do the desired add). |
| SUB | Subtract top from next-to-top. |
| MUL | Multiply top two. |
| DIV | Divide top into next-to-top. |
| EXP | Raise next-to-top to power of top. |
| NOT | Logical .NOT. of top of stack. |
| NEG | Negate top of stack. |
| GE | Compare top two for greater than or equal to, this has TRUE value if the next-to-top is .GE. the top. |
| GT | Compare for greater than. |
| LE | Compare for less than or equal. |
| LT | Compare for less than. |
| AND | Logical AND of top two entries. |
| OR | Logical inclusive OR of top two. |
| EQ | Compare top two for equality. |
| NE | Compare top two for inequality. |
| XOR | Exclusive OR of top two. |
| EQV | EQUIVALENCE of top two. |
| PAUSOP | Use top of stack as PAUSE number. |
| DPUSH | The next two words are a symbol table pointer and a displacement; put them onto the stack (used for DATA statements). |
| BINRD1 | Take the top of stack as the unit number and compile an unformatted READ-open. |
| FMTRD1 | The top two stack elements are the unit and format, take them and compile a formatted READ-open. |

| | |
|---|---|
| RCLOSE | Compile a READ-close. |
| DARD1 | Take the top two stack elements as a unit number and a block number and compile a direct access unformatted READ-open. |
| BINWR1<br>FMTWRI<br>WCLOSE<br>DAWR1 | Same as for the corresponding READ case, except substitute the word "WRITE". |
| DEFFIL | Take the top four stack entries as the unit, number of records, record size, and index variable and compile a DEFINE FILE call. |
| ASFDEF | Set the PASS2 switch which says that the following statement is an arithmetic statement function. |
| ARGSOP | The next word is a count, call it n; take the previous n stack entries as subscripts (or arguments) and the N+1st entry from the top as the array (or function) name; now compile this as an array reference (or function/subroutine call). |
| EOLCOD | The current statement is completed, reset stacks and do other housekeeping. |
| ERRCOD | The following word contains an error code, write it on the TTY together with the current line number, and put the error code and line number into the error list for possible PASS3. |
| RETOPR | Compile a subroutine RETURN. |
| REWOPR | Take the top of stack as a unit and compile a rewind. |
| STOROP | Compile a store of the top of stack into the next-to-top. |
| ENDOPR | Compile a RETURN if a function or subroutine or a CALL EXIT if a main program. |
| DEFLBL | The following word is a symbol table pointer to a statement number, compile this as the tag for the current RALF line. |
| DOFINI | The following word is a symbol table pointer for the DO-loop index, compile the corresponding DO-ending code. |
| ARTHIF | The following one, two, or three words are symbol table pointers to statement numbers for the less than zero, zero, and greater than zero conditions with the comparison to be made on the top of stack. |
| LIFBGN | The top of stack is taken as a logical expression PASS 2 should compile a jump-around-on-false; this implies that some statement is to follow. |

| | |
|---|---|
| DOBEGN | The top two stack entries represent the final value and increment of the DO-loop, process them in hopes pf finding a matching DOFINI. |
| ENDFOP | The top of stack is a unit, compile an END FILE. |
| STOPOP | Compile a CALL EXIT. |
| ASNOPR | The next word is the address of the symbol table entry for a statement number; compile an ASSIGN of this statement number to the variable represented by the top of stack. |
| BAKOPR | Take the top of stack as the unit and compile a BACKSPACE. |
| FMTOPR | The following word is a count N; the next N words after that are the image of the FORMAT statement. |
| GO2OPR | The following word is the symbol table entry for the statement number which is to be executed next. |
| CGO2OP | The following word is a count N; the next N words are symbol table pointers for the statement numbers of a computed GO TO list; use the value represented by the top of stack to compile a computed GO TO into this list. |
| AGO2OP | Compile an assigned GO TO with the top of stack. |
| IOLMNT | Take the top of stack as a list element for an I/O statement and compile read or write; PASS2 knows if it is a READ or WRITE by remembering previous FMTRD1, FMTWR1, etc. |
| DATELM | The next word is a count N; the next N words are a data element. |
| DREPTC | The next word is a repetition count for the set of DATELMs up until the next ENDELM. |
| ENDELM | Signals the end of a data element group. |
| PRGSTK | Tells PASS2 to purge the top stack entry. |
| DOSTOR | Performs the same function as STOROP after checking the top two stack elements for legal DO-parameter type (integer or real). |

PASS 1 SUBROUTINES

The following is a brief description of the function of each of the major PASS1 subroutines:

| | |
|---|---|
| RDWR | Compiles everything in a READ or WRITE statement starting at the first left parenthesis. |

| | |
|---|---|
| RESTCP | Restore character pointer and count for the statement buffer from the stack. |
| OUTWRD | Output a word (the AC on entering) to the PASS1 output file. |
| COMARP | Test for comma or right parenthesis; skip one instruction if a comma, two if a right parenthesis, and none if neither. |
| BACK1 | Backup the statement buffer character pointer. |
| GETSS | Scans a variable reference, or subscripted variable reference with numeric subscripts and returns the linearized subscript. |
| MUL12 | Perform a 12-bit unsigned integer multiply. |
| DOSTUF | Handles compilation of DO-loop setup. |
| TYPLST | Process a type declaration, DIMENSION, or COMMON statement; sets up type bits and/or dimension information. |
| LOOKUP | Perform a symbol table search for variables and Hollerith literals. |
| LUKUP2 | Perform a symbol table search for integer, real, complex, and double precision literals or statement numbers. |
| EXPR | Analyze and process an arithmetic expression. |
| LETTER | Get next character from the statement buffer and skip if it is a letter, otherwise put the character back and don't skip. |
| CHECKC | The first word after the JMS is the negative of the ASCII character to test for; if this is the next character, skip. |
| GETCWB | Get the next character from the statement buffer preserving blanks. |
| SAVECP | Save the character pointer and count on the stack. |
| GETC | Get the next character ignoring blanks. |
| ERMSG | Output an error code to PASS1 output file. |
| POP | Pop the stack into the AC. |
| PUSH | Push the AC onto the stack. |
| LEXPR | Analyze and process an arithmetic expression, legal to the left of the equal sign in an assignment statement. |
| GET2C | Get the next two character into one word. |

| | |
|---|---|
| STMNUM | Scan off a statement number and do the symbol table search. |
| DIGIT | Same as letter, except checks for a digit. |
| NUMBER | Scans off an integer, real, or double precision literal. |
| GETNAM | Scan off a variable name. |
| ICHAR | Get the next character from the input file. |

PASS2 OPERATION

The first part of PASS2 generates the storage for variables, arguments, arrays, literals and temporaries by processing the symbol table built by PASS1, which is kept in core. The next step is to generate the code for subroutine entry and exit including argument pickup and restore. After all such prolog code is generated, PASS20 is loaded into core, overlaying most of the prolog-generating functions. The main loop of the compiler is now entered. This consists simply of reading a PASS1 output code from the intermediate file and using this number as an index into a jump table. The sections of code entered in this way then perform the correct generation of RALF code.

Example:

The statement: A=B+C*D
would produce the following PASS1 output:
(assuming A,B,C,D are REAL)

```
1)  PUSH
       →A    (symbol table address of A)
2)  PUSH
       →B
3)  PUSH
       →C
4)  PUSH
       →D
5)  MUL
6)  ADD
7)  STOROP
8)  EOLCOD
```

The corresponding operations performed by PASS2 are:

1) Make a 3-word entry on the stack corresponding to the variable A consisting of a pointer to the symbol table entry, a word containing the type, and one reserved word.

2) Repeat above for B.

3) Repeat above for C.

4) Repeat above for D.

5) The multiply operator is handled like any of the binary operators by the subroutine CODE. This routine is called with the address of the multiply skeleton table. The top two stack entries are taken as the operands, with their types used to index into the skeleton tables. (See description of binary operator skeleton tables below.) The correct skeleton for this combination is chosen based on the where-abouts of each of the operands (AC or memory) at the corresponding point in the code which is being compiled. There are three possible cases: Memory,AC; Memory,Memory; AC,Memory. In this example, both operands are in memory so the code generated would be:

   ```
   FLDA C

   FMUL D
   ```

   The CODE subroutine then makes a new stack entry to replace the entries for C and D. This entry has a Ø in place of the symbol table pointer, signifying that the operand is in the AC. Other special case operand codes are:

   Ø - AC ( Already mentioned)

   1 - 51 Temporaries

   52 - 6Ø Array reference, the subscript of which is in an index register (1-7).

   61 - A variable, the address of which is in base location Ø.

   62 - A variable, the address of which is in base location 3.

   63-6777 - Symbol table entry (can be variable or literal).

   7000 - Special temporary

6) The add operator is handled in the same way as for multiply, except that in this case the add skeleton table is used. When the correct row is found, the memory,AC case is chosen since the result of C*D is now in the AC. This skeleton simply generates:

   ```
   FADD B
   ```

   The new top of stack entry is a Ø, since the result is in the AC.

7) The store operation works in a similar manner using a special skeleton table to determine whether the value to be stored is

already in the AC and whether it must be converted from one type to another. In this case, no conversion need be performed and the code generated is:

```
FSTA A
```

8) The end of statement has been reached and any necessary bookkeeping is performed.

## PASS2 SYMBOL TABLE

PASS2 modifies the symbol table entries corresponding to variables by replacing the first word of the entry with the first character of the name, this character being derived from the list in which the name is located.

## PASS2 ERROR LIST

PASS2 creates a list (in field 1) of error codes and line numbers corresponding to the errors printed on the Teletype during PASS2. This list works downward starting just below the skeleton table area, working towards the symbol table area. PASS3 uses this list to write out extended error messages on the listing.

## PASS2 SKELETON TABLES

All binary operators have associated with them a skeleton table having 24 entries arranged in 8 rows and 3 columns. The rows correspond to the following eight possibilities:

1) Both operands integer or real.
2) Both operands complex.
3) Both operands double precision.
4) First operand integer or real, second complex.
5) First operand integer or real, second double precision.
6) First operand complex, second integer or real.
7) First operand double precision, second integer or real.
8) Both operands logical.

The columns correspond to the following three possibilities:

1) First operand in memory, second in AC.

2) Both operands in memory.

3) First operand in the AC, second in memory.

Each entry of the skeleton tables is either zero (illegal operator-type combination) or points to a code skeleton (minus one). Code skeletons are composed of combinations of the following types of elements:

1) OPCODES - If an element has a non-negative value, it is taken as the address of a text string for the desired opcode. This works since all such text strings are stored below location 4ØØØ (in field Ø). In this case, the next word of the skeleton is taken as a designator for the address field, the possibilities are:

   a. A non-negative values means the address field is a literal text string, with the value being the address of the string. (Same restriction as for opcode text strings.)

   b. A zero indicates that this instruction should have no address field.

   c. A minus one indicates that the address field is the operand defined by the three variables ARG1, TYPE1, and BASE1.

   d. A minus two indicates that the address field is the operand defined by the three variables ARG2, TYPE2, and BASE2.

2) MODE CHANGE - An element value of minus one means generate a STARTF if currently in extended mode. A value of minus two means generate a STARTE if currently in single mode.

3) MACRO - Any other negative value is taken as the address (minus 3) of a sub-skeleton. This sub-skeleton may contain anything except another sub-skeleton reference. When the end of the sub-skeleton is encountered, the main skeleton is re-entered.

4) END-OF-SKELETON - A zero indicates the end of the skeleton.

PASS2 SUBROUTINES

The following is a list of the major PASS 2 subroutines together with a brief functional description.

| | |
|---|---|
| ERMSG | Output a 2-character error code together with the line number on the Teletype; also put the code and line number into the error list for PASS3. |
| UCODE | Generate the code for unary operators,given the skeleton table address. |
| CODE | Generate code for binary operators, given the skeleton table address. |
| INWORD | Read a word from the PASS1 output file. |
| FATAL | Output a fatal error message and exit to OS/8. |
| ONUMBER | Output the AC as a 4-digit octal number. |
| SAVEAC | Generate an FSTA #TMP+XXXX if necessary. |
| GENCOD | Generate the code specified by the given code skeleton. |
| OPCOD | Output a TAB followed by the specified opcode field. |
| OPCODE | Same as OPCOD, except output a second TAB after the opcode field. |
| OADDR | Generate the address field specified by the argument. |
| GENSTF | Generate STARTF if in E mode. |
| GENSTE | Generate STARTE if in F mode. |
| OSNUM | Output a statement number preceded by a "#". |
| CRLF | Output a carriage return/line feed. |
| OTAB | Output a TAB. |
| OUTSYM | Output a text string. |
| GARG | Pop the top entry of the stack into ARG1, TYPE1, and BASE1. |
| GARGS | Pop the top two stack entries into ARG1, TYPE1, BASE1 and ARG2, TYPE2, BASE2. |
| OUTNAM | Output a variable name. |
| OLABEL | Output a generated label. |
| GETSS | Find the address of the dimension information block given the symbol table address. |
| SKPIRL | Skip if integer, real, or logical. |
| GENCAL | Generate the code for a subroutine call from the information contained on the stack. |
| MUL12 | Do a 12-bit unsigned multiply. |

| | |
|---|---|
| OINS | Output a literal opcode and address field. |
| OCHAR | Output a character |
| NUMBRO | Output a 5-digit octal number. |

PASS3 OPERATION

PASS3 first initializes the listing header line with the version number, date, and page number. It then processes lines, much like PASS1, handling continuations and comments and outputs their image to the listing file together with the line number. A constant check is made on the error message list for line numbers that correspond to the current line number, When such a correspondence occurs, the error code is used to find the associated detailed error message, which is then printed out.

# CHAPTER 2

# THE RALF ASSEMBLER

RALF and FLAP are essentially the same program, with differences controlled by the conditional assembly parameter RALF, which must be non-zero to assemble RALF, or zero to assemble FLAP. The source may be assembled by either PAL8 or FLAP; although FLAP flags one error (a US on a FIELD statement), this may safely be ignored. The remainder of this chapter applies to RALF only. The following definitions are prerequisite to discussion of the operation of this assembler.

| | |
|---|---|
| MODULE | The relocatable binary output of an assembly. A module is physically an OS/8 file or sub-file in a library, and is made up of an external symbol dictionary and related text. Logically, it consists of one or more program sections and COMMON sections. |
| LIBRARY | An OS/8 file on a directory device containing a catalog and one or more modules as sub-files. Used solely by the loader, as a source of modules with which to satisfy unresolved symbols in a program being loaded. |
| CATALOG | A list of entry points defined in modules contained in a library, with an indication of the locations of the modules which define them. |
| EXTERNAL SYMBOL DICTIONARY | A list of the global symbols defined in and/or used by a module. Usually called ESD table. |
| TEXT | That part of the assembler's binary output which contains the binary data to be loaded into memory, along with sufficient information for the loader to associate the output with specific memory locations through references to the ESD table. |
| SECTION | A unit of binary data output by the assembler as part of a module to be loaded into a contiguous area of memory. COMMON sections are a special case in that they may be defined with the same name in each of many modules. In this case, all the definitions are combined to create a single section in memory whose size is that of the largest COMMON section with the given name. Program sections, the only other type of section, must have unique names. Sections are listed in the ESD table by name, type and size. |
| ENTRY POINT | An address within a section which is named and defined to be global, so that it may be used for the resolution of external references in other sections. Entry points are listed in the ESD table by name, type and address within the section in which they occur. |

| | |
|---|---|
| EXTERNAL SYMBOL | A symbol which is specified at assembly time to be defined in another module as an entry point. External symbols are listed in the ESD table by name and type. A complete program must include entry point names equivalent to every external symbol defined in every module in the program. There need not, however, be an external symbol for every entry point, nor is there any limit on the number of modules which may contain external symbols referencing one entry point. From a functional viewpoint, entry points correspond to tags within a program and external symbols correspond to references to those tags. Every section is considered to have an entry point at location zero of the section. The name of this entry point is the section name. |

When RALF is called from the monitor, execution begins at the tag BEGIN. Unless entry is via CHAIN, the OS/8 command decoder is called to obtain input and output file designations. If entry is by way of CHAIN, it is assumed that the command decoder area has already been set up by the caller. In either case, it is always assumed that the USR is already in core. A check is made to determine that the first output file is a directory device file and, if no first output file was specified, the default file SYS:FORTRN.RL is set up.

Default output file extensions are defined if none were specified to the command decoder, using .RL for the first output file and .LS for the second output file. The first output file is then opened, and the handler for the first input file is FETCHed. If /L or /G was specified, the loader is looked up on SYS so that chaining will be possible. The symbol table, which is loader above 12000 in order to preserve the USR, is now moved down to 10000. Finally, the system date word is converted to character form and stored in the title buffer. This completes the initialization procedure, and control is passed to NEWLIN to collect the first line in the buffer.

At NEXTST, tests are made to determine whether the line just assembled needs to be listed, and whether there are any remaining significant characters in the line which have not been assembled. If a semicolon terminated the statement, the character pointers are bumped to skip over it, and control passes to ASMBL to process the next statement on the line. If the assembler is currently in a REPEAT line and the count is not exhausted, the current line is re-assembled. Otherwise, a new line is obtained in the line buffer by collecting input characters until a carriage return is found. If the line is longer than 128 characters, all characters after the 128th are ignored and the LT message is printed. The line length is calculated and saved.

At ASMBL, ASMOF is tested to determine whether the assembly is currently inside a conditional. If so, the line is scanned for angle brackets but not assembled. If not, and the first character is not a slash, leading blanks are thrown away and control passes to LUNAME. If there is a name, it is collected. If it is followed by a comma, the symbol is looked up in the user symbol table. If the symbol is undefined, it is defined as a label. If it was already defined, the current location counter is compared with it to check for a possible MD error. Control then returns to ASMBL.

If the symbol found by LUNAME was followed by an equal sign, it is looked up and defined according to the expression to the right of the equal sign. If it was followed by a space, either of the characters ' or #, or the character % and then a space, it is looked up in the op-code table. If it is found, control passes to the appropriate op-code handler. Otherwise, control is dispatched to GETEXP which restores the character pointers saved by LUNAME, processes the rest of the line as a single-word expression, and returns to NEXTST for the next statement.

Expressions are processed on a strict left-to-right basis by the routine EXPR. A symbol is looked up, and its value is stored in WORD1 and WORD2. It is then combined with the accumulated expressions in EXPVAL according to the operator in LASTOP. A new operator (if any) is then located, and the loop begins again. When no operator is found after some symbol, the expression is considered complete and control returns to the calling routine. Undefined symbols appearing in an expression cause output of a US message, and the value zero is used in their place. COMMON and section names in the symbol table have special values (namely their lengths), but they always refer to the starting location of the sections they define, and their values are taken to be zero of the section so named. If GETNAM is not able to find a symbol in the expression, three possibilities are checked before flagging the expression as invalid:

1. It may be a number, rather than a symbol.
2. It may be one of the characters period (representing the current value of the location counter) or double quote (representing the binary value of the next ASCII character).
3. The last operator may have been a plus sign in an indexed FPP instruction.

At the end of expression evaluation, the console keyboard flag is checked to ensure that the user has not typed CTRL/C to stop the assembly.

There are six expression operator routines, one each for the operations add, subtract, AND, OR, multiply and divide. Except for add and subtract, these routines must operate on absolute addresses because the loader does not have facilities for non-additive resolution of address constants.

The symbol table is the sole occupant of field 1, except for the OS/8 field 1 resident. The symbol table is loaded at location 12000 to prevent an unnecessary swap of the USR, but moved down, to start at location 10000, during initialization. Subsequent calls to the USR do require a swap. The symbol table is a set of linked lists, or, more properly, two sets; one for user-defined symbols and one for op-codes and pseudo-ops. Each set contains a list corresponding to every letter of the alphabet, and each list consists of the symbols which start with that same letter. Every time a symbol is encountered in the source, the list corresponding to its first letter is searched until a match is found, or until the end of the list or a symbol of higher alphabetical order is found. In the latter cases, the new symbol is inserted into the user symbol table by changing the list pointers so that the new symbol appears in the list in correct alphabetical order. The pre-defined symbol table is never changed, because the user is not permitted to define op-codes or pseudo-ops.

A RALF output file of relocatable binary data consists of two parts; the ESD table and the text. The ESD table contains all information required by LIBRA or the loader, and is generated between the first and second passes of assembly. It serves as a partial symbol table for the loader (the full symbol table is built up from the ESD tables of all the modules in a program) and provides the name, attributes, and value of every global symbol used by any module, as well as an ESD code by which the symbol may be referred to within the text. Every entry in the ESD table is six words long. The first three words are the symbol itself, packed in stripped ASCII, with two characters per word. The next word contains type information in the following format:

| A VALUE OF | INDICATES |
|---|---|
| 0 | Last entry in the ESD table. |
| 1 | The symbol is defined as external to this module. The value of the symbol must be resolved by a symbol of the same name appearing in the ESD table of another module. The ESD code which follows the type code is the code by which references to this symbol will be identified in the text. |
| 2 | The symbol is defined as an entry point in this module. It is therefore suitable for the resolution of external references in other modules. The ESD code which follows the type word identifies the program section in which this entry point appears, and the value of the symbol is relative to that section. |
| 3 | The symbol is defined as a COMMON section whose size is at least as large as specified by the value of the symbol. If several modules contain ESD entries referring to COMMON sections with the same name, a single COMMON block having the size of the largest symbol is allocated for all of them. A name consisting of blanks is treated in the same manner as any other name. |
| 4 | The symbol is defined as a section of location independent (that is, fully word-relocatable) code of a size equal to the value of the symbol. The ESD code for this section allows text from the module to be included in this section, and relocated with respect to it. |
| 5-17 | Undefined |

The text portion of a relocatable binary file consists of the binary data to be loaded into memory, along with information directing the loader on how to modify that data to correct the addresses for program relocation. The first word of text is a control word, which is made up of a 4-bit type code and an 8-bit indicator. Following the control word, and depending on the type code, are a number of data words to be loaded as directed by the type code and the indicator. The control word type codes are:

| CODE | FUNCTION |
|---|---|
| 0 | End of text, if the indicator is zero, or no operation otherwise. |

| | |
|---|---|
| 1 | Copy the number of words given by the indicator from text directly into memory without modification. |
| 2 | Re-origin to the section identified by the indicator, with a relative location defined by bits 9-23 of the following doubleword. Thus, the next two words define a new origin for the following text, in the program section identified by the indicator. |
| 3 | Relocate the following doubleword bits 9-23 by the value of the symbol whose ESD code is identified by the indicator. The following doubleword is usually a two-word FPP instruction, the low-order 15 bits of which are to be relocated by the value of the symbol identified by the indicator. |

## WRITING PDP-8 CODE UNDER OS/8 FORTRAN IV

RALF contains the normal set of PDP-8 instructions (TAD, DCA, CDF, KSF, etc.), however RALF does not allow literals, the PAGE pseudo-op, or the use of I to specify indirect addressing. PDP-8 code generated by RALF is not relocatable; therefore, operations such as the following are illegal:

```
        EXTERN SWAP      /Illegal
        TAD (SWAP        /Under
        CDF SWAP         /RALF
```

The character % appended to the end of a memory reference instruction indicates indirect addressing, and the character Z indicates a page 0 reference:

| CURRENT PAGE | | PAGE ZERO | |
|---|---|---|---|
| DIRECT | INDIRECT | DIRECT | INDIRECT |
| TAD A | TAD% A | TADZ A | TADZ% A |
| DCA B | DCA% B | DCAZ B | DCAZ% B |

Spaces are not allowed between memory reference instructions and either the Z or the % characters. The Z must precede the % when both are used. I.e., do not write "DCA%Z".

Three pseudo-ops have been added to RALF: SECT8, COMMZ, and FIELD1. All three define sections of code and are handled in the same manner as SECT; however, these new sections have special meaning for the loader. The address pseudo-op (ADDR) which generates a two word relocatable 15 bit address (i.e., JA TAG without use of JA) might prove useful in 8-mode routines. The following example demonstrates a way in which an 8-mode routine in one RALF module calls an 8-mode routine in another module:

```
         EXTERN SUB
         .
         .
         RIF                 /Set DF to current
         TAD  ACDF           /IF for return
         DCA  .+1
         0                   /CDF X
         TAD  KSUB           /Make a CIF from
         RTL  CLL            /Field bits
         RAL
         TAD  ACIF
         DCA  .+1
         0                   /CIF to field
                             /Containing SUB
         JMS%  KSUB+1

KSUB,    ADDR  SUB           /Psuedo-op to
                             /Generate 15 bit
                             /ADDR of subroutine
                             /SUB
ACDF,    CDF
ACIF,    CIF
```

In general the address pseudo-op can be used to supply an 8-mode section with an argument or pointer external to the section.

FPP and 8-mode code may be intermixed in any RALF section. PDP-8 mode routines must be called in FPP mode by either:

```
          TRAP3 SUB
or        TRAP4 SUB
```

A TRAP3 SUB causes FRTS to generate a JMP SUB with interrupts on and the FPP hardware (if any) halted. TRAP4 generates a JMS SUB under the same conditions. The return from TRAP4 is:

```
          CDF CIF 0
          JMP% SUB
```

The return from TRAP3 is:

```
          CDF CIF 0
          JMP% RETURN+1
```

```
        EXTERN  #RETRN
RETURN, ADDR #RETRN
```

Communication between FPP and 8-mode routines is best done at the FPP level because of greater flexibility in both addressing and relocation in FPP mode. The following routine demonstrates how to pass an argument to, and retrieve an argument from, an 8-mode routine:

```
        EXTERN SUB
        EXTERN SUBIN
        EXTERN SUBOUT
        .
        .
        .
        FLDA   X          /Arg for SUB
        FSTA   SUBIN
        TRAP4  SUB        /Call SUB
        FLDA   SUBOUT     /Get result
        FSTA   Y
```

If the 8-mode routine SUB were in the same module as the FPP routine, the externs would not be necessary. In practice it is common for FPP and 8-mode routines that communicate with one another to be in the same section. A number of techniques can be used to pass arguments. For example, an FPP routine could move the index registers to an 8-mode section and pass single precision arguments via ATX.

Because 8-mode routines are commonly used in conjunction with FPP code (generated by the compiler), the 8-mode programmer should be familiar with OS/8 FORTRAN IV subroutine calling conventions. The general code for a subroutine call is a JSR, followed by a JA around a list of arguments, followed by a list of pointers to the arguments. The FPP code for the statement:

```
        CALL SUB (X,Y,Z)
```

would be

```
        EXTERN SUB
        JSR    SUB
        JA     BYARG
        JA     X
```

```
         JA      Y
         JA      Z
BYARG,   .
         .
         .
         .
```

The general format of every subroutine obeys the following scheme:

```
         SECT  SUB
         JA    #ST          /Jump to start of
                            /Routine
         TEXT  +SUB+        /Needed for
                            /Trace back
RTN,     SETX  XSUB         /Reset SUB's index
         SETB  BSUB         /And base page
BSUB,    FNOP               /Start of base page
         JA    .
         .
         .
         ORG   BSUB+30      /Restart for SUB
         FNOP:JA RTN
GOBAK,   FNOP:JA .          /Return to
                            /Calling program
```

Location 00000 of the calling routine's base page points to the list of arguments, if any, and may be used by the called subroutine provided that it is not modified. Location 0003 of the calling routine's base page is free for use by the called subroutine.

Location 0030 of the calling routine's base page contains the address where execution is to continue upon exit from the subroutine, so that a subroutine should not return from a JSR call via location 0 of the calling routine:

```
         CORRECT              INCORRECT

         FLDA 30              FLDA 0
         JAC                  JAC
```

The "non-standard" return allows the calling routine to reset its own index registers and base page before continuing in-line execution. General initialization code for a subroutine would be:

```
         SECT            SUB
         JA              #ST
         .
         .
         .
         BASE            0
```

```
#ST, STARTD             /So only 2 words
                        /Will be picked up
     FLDA     30        /Get return JA
     FSTA     GOBAK     /Save it
     FLDA     0         /Get pointer to list
     SETX     XSUB      /Set SUB's XR
     SETB     BSUB      /Set SUB's Base
     BASE     BSUB
     INDEX    XSUB
     FSTA     BSUBX     /Store pointer
                        /Somewhere on Base
     .
     .
     .
     STARTF             /Set F mode before
     JA       GOBAK     /Return
```

The above code can be optimized for routines that do not require full generality. The JA #ST around the base page code is a convenience which may be omitted. The three words of text are necessary only for error traceback and may also be omitted. If the subroutine is not going to call any general subroutines, the SETX and SETB instructions at location RTN and the JA RTN at location 0030 are not necessary. If the subroutine does not require a base page, the SETB instruction is not necessary in subroutine initialization; similar remarks apply to index registers. If neither base page nor index registers are modified by the subroutine, the return sequence:

```
     FLDA 0
     JAC
```

is also legal. In a subroutine call, the JA around the list of arguments is unnecessary when there are no arguments. A RALF listing of a FORTRAN source will provide a good reference of general FPP coding conventions.

In order to generate good 8-mode code, one must be aware of the manner in which the loader links and relocates RALF code. The loader handles three 8-mode section types: COMMZ, FIELD1, and SECT8. All three types of section are forced to begin and end on page boundaries and to be a part of level MAIN; 8-mode sections never reside in overlays. COMMZ and FIELD1 sections are forced to reside in field 1; SECT sections may be in any field. The first COMMZ section encountered is forced to begin at location 10000, thus enabling a page 0 in field 1. COMMZ sections of the same name are handled like COMMON sections of the same name (i.e., they are combined into one common section). This feature allows 8-mode code in different modules to share page 0, provided that the modules do not destroy each other's page 0 allocations. Suppose two modules were to share page 0, with the first using location 0-17 and the second using locations 20-37:

```
                                /Module A
         COMMZ SHARE
P1,      1
P2,      2
KSUBA1,  SUBA1
KSUBA2,  SUBA2
         .
         .
         .                      /Should not go over
LASTA,   -1                     /20 locations

FIELD1   A

         TADZ P1
         JMSZ% KSUBA1
         .
         .
         .                      /Module B
         COMMZ SHARE
         ORG .+20               /ORG past module A's
                                /Page 0
P3,      3
P4,      4
KSUBB,   SUBB
         .
         .
         .
LASTB    -2
FIELD1   B
         TADZ P3
         .
         .
         .
```

The two COMMZ sections will be put on top of one another, however, because of the ORG .+20 in module B, they will effectively reside back to back. When the image is loaded, the COMMZ sections will look as follows:

```
 LOC      CONTENTS

1 0000      1
  0001      2
     2     SUBA1
     3     SUBA2
     .
     .
     .
1 0017     -1            /LASTA
1 0020      3
    21      4
    22     SUBB
     .
     .
     .
    37     -2            /LASTB
```

If module A is to reference module B's page 0, the procedure is:

```
P3=20
TADZ P3
```

Alternately, a duplicate of the source code for COMMZ SHARE may be included in module B. Modules that are using the same COMMZ section must be aware of how it is divided up. Although COMMZ SHARE takes only 40 locations, the loader allocates a full 200 locations to it. All 8-mode section core allocations are always rounded up so that they terminate on a page boundary. If COMMZ sections of different names exist, they are accepted by the loader and inserted into field 1, but only one COMMZ is the real page 0. In general, it is unwise to have more than 1 COMMZ section name.

FIELD1 sections are identical to COMMZ sections in most respects. Memory allocation for FIELD1 sections is assigned after COMMZ sections, however, and FIELD1 sections are combined with FORTRAN COMMON sections of the same name as well as other FIELD1 sections of the same name. The first difference ensures that COMMZ will be allocated page 0 storage even in the presence of FIELD1 sections. The second allows PDP-8 code to be loaded into COMMON, making it possible to load initialization code into data buffers. Two FIELD1 sections with the same name may be combined in the same manner as two COMMZ, sections.

The primary purpose of COMMZ is to provide a PDP-8 page 0; the primary purpose of FIELD1 is to ensure that 8-mode code will be loaded into field 1 and that generating CIF CDF instructions in-line is not necessary. SECT8 sections may not be combined in the manner of a COMMON and are not ensured of being placed into field 1.

An 8-mode section does not have to be less than a page in length; however, the programmer should be aware that a SECT8 section which exceeds one page may be loaded across a field boundary and could thereby produce disastrous results at execution time. For this reason, it is generally unwise to cross pages in SECT8 code. This situation will never occur on an 8K configuration. If the total amount of COMMZ and FIELD1 code exceeds 4K, the loader generates an OVER CORE message. The loader generates an MS error for any of the following:

1. A COMMZ section name is identical to some entry point or some non-COMMZ section name.
2. A FIELD1 section name is identical to some entry point or a SECT, SECT8 or COMMZ section name.
3. A SECT8 section name is identical to an entry point or some other section name.

COMMZ sections, like FORTRAN COMMONS, are never entered in the library catalog.

For users who intend to write 8-mode code that will execute in conjunction with certain 8-mode library routines, the layout of PDP-8 FIELD1 #PAGE 0 is:

| LOCATION | USE |
|---|---|
| 0-1 | Temps for any non-interrupt time routine. |
| 2-13 | User locations. |
| 14-157 | System locations. |
| 160-177 | User locations. |

1. Do not define any COMMZ sections other than the system COMMZ which is #PAGE0.

2. If the system page 0 is desired, it will be pulled in from the library if EXTERN #DISP appears in the code.

3. Do not use any part of page 0 reserved for the system.

Special purpose PDP-8 mode subroutines may be written to perform idle jobs (refreshing a scope, checking sense lines) or to handle specific interrupts not serviced by FRTS.

The run-time system enters idle loops while waiting for the FPP to complete a task or for an I/O job to complete. It is possible to effect a JMS to a user routine during the idle loop.

RTS contains a set of instructions such as:

```
#IDLE, JMP  .+4
       0
       CDF  CIF
       JMS  I  .-2
```

This sequence of instructions must be revised if an IDLE routine is to be called.

The location #IDLE must be changed to a SKP (7410). #IDLE+1 must be set to the address of the routine to be called. #IDLE+2 must be set to a CDF CIF to the field of the routine. This setup can be done in a routine that is called at the beginning of MAIN. For example:

```
        CALL SETIDL
```

where SETIDL is a routine such as:

```
        SECT8 SETIDL     /Must be an 8-mode section
        JA #RET
        TEXT +SETIDL+    /Traceback information
SXR,    SETX XR
        SETB BP
BP,     0.0
XR,     0.0
         .
         .
         .
        ORG 10*3+BP
```

```
        FNOP                  /For trace back
        JA SXR
         .
        0
RET,    JA .                  /Return address
         .
         .
         .
#RET,   STARTD                /Set up
        FLDA 10*3             /Return address
        FSTA RET
        SETB BP               /Just for traceback
        TRAP4 SET8            /Go to the 8 mode
                              /Routine set 8
        STARTF
        JA RET                /Return to main
SET8,   0
        TAD IDLAD             /Field of idle
        CLL RTL
        RAL                   /Move to
                              /Bits 6-8
        TAD SCDF              /CDF to #IDLE
        DCA .+3
        TAD IDLAD+1           /Address of #IDLE
        DCA IDPTR
        0                     /CDF goes here
        TAD S7410             /SKP
        DCA% IDPTR            /Store at #IDLE
        TAD JOB+1             /Address of IDLE top routine
        ISZ IDPTR
        DCA IDPTR             /Store a #IDLE+1
        TAD JOB               /Field of routine
         CLL RTL
        RAL                   /Position
        TAD SFIELD
        ISZ IDPTR
        DCA% IDPTR            /Store at #IDLE+2
        CDF CIF               /Set to field 0
        JMP% SET8             /Return to instruction
                              /Following "TRAP4 SET8"
        EXTERN #IDLE
IDLAD,  ADDR #IDLE            /15 bit address of IDLE
JOB,    ADDR DOIT             /15 bit address of IDLE
                              /Routine "DOIT"
SCDF,   6201                  /CDF
SFIEL,  6203                  /CDF CIF
IDPTR,  0
S7410,  7410                  /Skip

                              /The following routine performs the
                              /IDLE task
                              /Executed during IDLE loops

DOIT,   0
         .
         .
         .                             /Perform task
         .
        CDF CIF 0             /Back to field 0
        JMP% DOIT             /And back
```

If the subroutine is checking for an illegal argument, an argument error message with traceback can be included in the subroutine by adding two lines somewhere on the base page:

```
          EXTERN #ARGER
EXAMER,   TRAP4 #ARGER
```

When the error is detected in the program, effect a jump to the TRAP4 instruction. For example,

```
FLDA%   EXTMP1
JEQ     EXAMER          /A value of 0 is illegal
```

or

```
FLDA    EXTMP1
FNEG
FADD    EXTMP2
JLT     EXAMER          /The value in EXTMP1 must be
                        /greater than that in EXTMP2
```

Some points to note in the above example

1. Using a # as the first character in the name of the start of the program assumes that the name is not called from the FORTRAN level. This is because # is an illegal FORTRAN keyboard character.
2. If index registers 3-5 are not used by the subroutine, the space from XR3 to the ORG statement can be used for temporary storage, if needed.
3. The arguments passed from the FORTRAN level do not have to be picked up all at once at the start of the calculation (3-word) portion of the program. They can be picked up as required during the program, can be saved in temporary space, or accessed indirectly each time required, as best suits the subroutine.

If a call to this routine such as Z=EXAMPL(A,B,C,D) were encountered by the compiler, it would generate the following call to the routine:

```
JSR EXAMPL      /go to the routine
JA .+10         /jump around arguments
JA A            /pointer to 1st argument
JA B            /pointer to 2nd argument
JA C            /pointer to 3rd argument
JA D            /pointer to 4th argument
```

The AMOD routine is listed below to illustrate an application of the formal calling sequence. It also includes an error condition check and picks up two arguments. When called from FORTRAN, the code is AMOD(X,Y).

```
/
/
/
/       A M O D
/       - - - -
/
/SUBROUTINE     AMOD(X,Y)
        SECT    AMOD                /SECTION NAME(REAL NUMBERS)
        ENTRY   MOD                 /ENTRY POINT NAME(INTEGERS)
        JA      #AMOD               /JUMP TO START OF ROUTINE
        TEXT    +AMOD  +            /FOR ERROR TRACE BACK
AMODXR, SETX    XRAMOD              /SET INDEX REGISTERS
        SETB    BPAMOD              /ASSIGN BASE PAGE
BPAMOD, F 0.0                       /BASE PAGE
XRAMOD, F 0.0                       /INDEX REGS.
AMODX,  F 0.0                       /TEMP STORAGE
        ORG     10*3+BPAMOD         /RETURN SEQUENCE
        FNOP
        JA      AMODXR
        0
AMDRTN, JA      .                   /EXIT
        EXTERN  #ARGER
AMODER, TRAP4   #ARGER              /PRINT AN ERROR MESSAGE
        FCLA                        /EXIT WITH FAC=0
        JA      AMDRTN
        BASE    0                   /STAY ON CALLER'S BASE PG
/LONG ENOUGH TO GET RETURN ADDRESS
MOD,                                /START OF INTEGER ROUTINE SAME AS
#AMOD,  STARTD                      /START OF REAL NUM. ROUTINE
        FLDA    10*3                /GET RETURN JUMP
        FSTA    AMDRTN              /SAVE IN THIS PROGRAM
        FLDA    0                   /GET POINTER TO PASSED ARG
        SETX    XRAMOD              /ASSIGN MOD'S INDEX REGS
        SETB    BPAMOD              /AND ITS BASE PAGE
        BASE    BPAMOD
        LDX     1,1
        FSTA    BPAMOD
        FLDA%   BPAMOD,1            /ADDR OF X
        FSTA    AMODX
        FLDA%   BPAMOD,1+           /ADDR OF Y
        FSTA    BPAMOD
        STARTF
        FLDA%   BPAMOD              /GET Y
        JEQ     AMODER              /Y=0 IS ERROR
        JGT     .+3
        FNEG                        /ABS VALUE
        FSTA    BPAMOD
        FLDA%   AMODX               /GET X
        JGT     .+5
        FNEG                        /ABS VALUE
        LDX     0,1                 /NOTE SIGN
        FSTA    AMODX               /SAV IN A TEMPORARY
        FDIV    BPAMOD              /DIVIDE BY Y
        JAL     AMODER              /TOO BIG.
        ALN     0                   /FIX IT UP NOW.
        FNORM
        FMUL    BPAMOD              /MULITPLY IT.
        FNEG                        /NEGATE IT.
        FADD    AMODX               /AND ADD IN X.
        JXN     AM,1                /CHECK SIGN
        FNEG
AM.     JA      AMDRTN              /DONE
```

RTS has its own interrupt skip chain in which all on-line device flags are checked and serviced. This chain may be extended to handle special interrupts. The external tag #INT marks the first of three locations on RTS which have to be modified to effect a JMS to the user's special interrupt handler. The three locations must be set up in exactly the same manner as that used to set up #IDLE, #IDLE1, #IDLE2 as described above. All the same conventions hold. Refer also to the library subroutines ONQI and ONQB.

Three pseudo-ops have been added to RALF to help the loader determine core allocation. Each is a more definitive case of the SECT pseudo-op and defines a chunk of code, thereby providing more control for the user. They are:

```
SECT8  -  section starts at a page boundary
FIELD1 -  section starts at a page boundary and is in field 1
COMMZ  -  section starts at page 0 of field 1
```

If there is more than one SECT8 section in a module, those sections are not necessarily loaded in contiguous core. The loader considers core to be in two chunks - one block in field 0, and all of field 1 and above.

If there is more than one COMMZ pseudo-op in a module, they are stacked one behind the other, but there is no way of specifying which one starts at absolute location 0 of field 1. COMMZ sections are allocated by the loader before FIELD1 sections.

Modules can share a COMMZ section in the same way that FORTRAN COMMON sections can be shared. FIELD1 sections can also be shared by using the same FIELD1 section name in each module.

The first occurrence of a section name defines that section. For example,

```
SECT8 PARTA
   .
   .
SECT8 PARTB
   .
   .
SECT8 PARTA
```

The second mention of PARTA in the same module continues the source where the first mention of PARTA ended at execution time. (There is a location counter for each section.)

To save core, a RALF FIELD1 section and FORTRAN COMMON section of the same name are mapped on top of each other, being allocated the length of the longer and the same absolute address by the loader. This feature is useful for initialization (once-only) code, which can later be overlayed by a data area. Thus, the occurrence of FIELD1 AREA1 in the RALF module and COMMON AREA1 in the FORTRAN program causes AREA1 to start the same location (in field 1) and have a length of at least 200 locations (depending on the length of the RALF FIELD1 section or of the COMMON section in the FORTRAN).

If the subroutine is longer than one page and values are to be passed across page boundaries, the address pseudo-op, ADDR, is required. The format is:

```
AVAR1, ADDR VAR1
```

This generates a two-word reference to the proper location on another page, here VAR1. For example, to pass a value to VAR1, possible code is:

```
00124  1244        TAD   VAR2         /Value on this page
00125  3757        DCA%  AVAR1+1      /Pass through 12-bit
                     .                /location
00156  0000 AVAR1,ADDR VAR1           /Field and
00157  0322                           /location of VAR1
```

Any reference to an absolute address can be effected by the ADDR pseudo-op.

If it is doubtful that the effective address is in the current data field, it is necessary to create a CDF instruction to the proper field. In the above example, suitable code to add to specify the data field is:

```
TAD  AVAR1                    /Get field bits
RTL                           /Rotate to bits 6-8
RAL
TAD (6201                     /Add a CDF
DCA  .+1                      /Deposit in line
0                             /Execute CDFn
```

If the subroutine includes an off-page reference to another RALF module (e.g., in FORLIB), it can be addressed by using an EXTERN with an ADDR pseudo-op. For example, in the display program, a reference to the non-interrupt task subroutine ONQB is coded as

```
            EXTERN       ONQB
ONQBX,      ADDR         ONQB
```

and is called by

```
            JMS%         ONQBX+1
```

The next instruction in the program is ADDR DISPLY so that DISPLY will be added to the background list. Execution from ONQB returns after the ADDR pseudo-op.

It may be desirable to salvage the first (field) word allocated by ADDR pseudo-ops. If the address requires only twelve bits for proper execution, code such as

```
TMP,                        TMP,ADDR X
ARG,ADDR X           or     ARG= .-1
```

permits TMP to be used for temporary storage because ARG+1 in the left hand example or just ARG in the right hand example defines the 12-bit address.

RALF does not recognize LINC instruction or PDP-8 laboratory device instructions. Such instructions can be included in the subroutine by defining them by equate statements in the program.

For example, adding the statements:

```
PDP = 2
LINC = 6141
DIS = 140
```

takes care of all instructions for coding the PDP-12 display subroutine.

When writing a routine that is going to be longer than a page, it can be useful to have a non-fixed origin in order not to waste core and to facilitate modification of the code. A statement such as

```
IFPOS .-SECNAM&177-K<ORG .-SECNAM&7600+200+SECNAM>
```

will start a new page only if the value [current location less section name] is greater than some K (start of section has a relative value of 0) where K≤177 and is the relative location on the current page before which a new page should be started. The ORG statement includes an AND mask of 7600 to preserve the current page. When added to 200 for the next page and the section name, the new origin is set.

When calculating directly in a module, the following rules apply to relative and absolute values.

```
relative - relative = absolute
absolute + relative = relative
OR (!), AND (&) and ADD (+) of relative symbols
  generate the RALF error message RE.
```

When passing arguments (single precision) from FPP code to PDP code, using the index registers is very efficient. For example,

```
          .
          .
          .
          FLDA%   ARG1          /Get argument in FPP mode
          SETX    MODE8         /Change index registers so XR0 is
                                /At MODE8
          ATX     MODE8         /Save argument
          .
          .
          TRAP4   SUB8          /Go to PDP-8 routine
          .
          .
SUB8,     0                     /PDP-8 routine
          .
          .
          TAD     MODE8         /Get argument
          .
          .
MODE8,    0                     /Index registers set here
          .
          .
```

# CHAPTER 3

## THE FORTRAN IV LOADER

The FORTRAN IV loader accepts a set of (up to 128) RALF modules as input, and links the modules, along with any necessary library components, to form a loader image file that may be read into memory and executed by the run-time system. The main task accomplished by the loader is program relocation, achieved by replacing the relative starting address of every section with an absolute core address. Absolute addresses are also assigned to all entry points, all relocatable binary text, and the externs.

The loader executes in three passes. Pass 0 begins by determining how much memory is available on the running hardware configuration, and then constructs tables from the OS/8 command decoder input for use by pass 1 and pass 2.

Pass 1 reads the relocatable binary input and creates the loader symbol table. The length of each input module is computed and stored, along with the relative values of entry points defined within the input modules. When an undefined symbol is encountered, pass 1 searches the catalog of the FORTRAN IV library specified to pass 0, or FORLIB.RL if no other library was explicitly specified, and loads the library routine corresponding to the undefined symbol.

Pass 1 also allocates absolute core addresses to all modules and, through them, to all symbols. Pass 1 execution concludes by computing the lengths of all overlay levels defined for the current FORTRAN IV job. Trap vectors are also set up at this time, and the tables required for pass 2 loading are initialized.

Pass 2 concludes loader execution by creating a loader image file from the relocated binary input and symbol values processed by pass 1.

LOADER PASS Ø (FILE COLLECTION)

| Address | Contents | Field |
|---|---|---|
| 00000 | OS/8 Command Decoder | FIELD Ø |
| 02000 | Loader Pass 1 and Pass 2 | |
| 04600 | Core measuring routine and scratch area to save 00000-02000 during CD calls | |
| 06600 | Unused | |
| 07600 | OS/8 Field Ø resident | |
| 10000 | OS/8 User Service Routine | FIELD 1 |
| 12000 | Symbol table, loader map titles | |
| 12400 | | |
| 13200 | Pass Ø code | |
| 14000 | Pass 1 initialization | |
| 16000 | Module count and module tables | |
| 17000 | Library catalog header read into this block | |
| 17600 | OS/8 Field 1 resident | |

Pass 2 also produces the loader symbol map, if requested, and chains to the run-time system if /G was specified.

Pass 0 contains very few subroutines. The routine CORDSW checks for the presence of /U, /C or /O option specifications, as supplied to the command decoder, and processes these options if necessary. A routine called UPDMOD is called when input to each overlay has been concluded, to update the module counts in the module count table.

LOADER PASS 1 (SYMBOL RESOLUTION)

| Address | Contents | Field |
|---|---|---|
| 00000 | Pass 1 and Pass 2 utility routines | FIELD Ø |
| 01400 | Symbol map printer | |
| 02000 | Pass 2 | |
| 03200 | Pass 1 symbol collection | |
| 04000 | Inter-pass code allocates storage, builds and writes Loader Image Header Block. | |
| 04600 | Library catalog loads here in 8K. Unused in 12K or more. | |
| 07200 | Input device handlers | |
| 07600 | OS/8 Field Ø resident | |
| 10000 | ESD table | FIELD 1 |
| 11400 | | |
| 12000 | Symbol table | |
| 15400 | Overlay length table | |
| 16000 | Module count and module tables (MCTTBL, MODTBL) | |
| 17200 | Loader header | |
| 17400 | ESD reference page | |
| 17600 | OS/8 Field 1 resident | |
| 20000 | Library catalog loads here in 12K or more. | FIELD 2 |
| 25000 | OS/8 BATCH processor if 12K or more and BATCH is running | |

CORMOV is a general core-moving subroutine, called by the instruction sequence:

```
JMS CORMOV
CDF FROMFIELD
FROMADDR - 1
CDF TOFIELD
TOADDR - 1
- COUNT
```

while ERROR is the local error processing routine, called with a pointer to the appropriate error message in the accumulator.

The major pass 1 and pass 2 subroutines, described below, operate on the loader internal tables, whose format is presented later in this

LOADER PASS 2 (LOADER IMAGE BUILDER)

| Address | Contents | Field |
| --- | --- | --- |
| 00000 | Utility routines: Symbol table look-up, TTY message handler, OS/8 block I/O, MCTTBL processor. | FIELD Ø |
| 01400 | Routine to print symbol map. | |
| 02000 | Pass 2 | |
| 03200 | Binary buffer #1 | |
| 05200 | Binary buffer #2 | |
| 07200 | I/O device handlers | |
| 07600 | OS/8 Field 0 resident | |
| 10000 | RALF module text loads here if 8K. | FIELD 1 |
| 12000 | Symbol table | |
| 15400 | Overlay length table | |
| 16000 | MCTTBL and MODTBL | |
| 17200 | Binary section table and binary buffer (LDBUFS) table | symbol map output buffer |
| 17400 | ESD reference page | |
| 17600 | OS/8 Field 1 resident | |
| 20000 | Binary buffer #3, if >8K | FIELD 2 |
| 22000 | Binary buffer #4, if >8K | |
| 24000 | Binary buffer #5, if >12K | |
| 26000 | Unused | |
| 30000 | RALF module text loads here if >12K | FIELD 3 |

chapter. The subroutines are presented in approximately the order that they occur in the source listing.

SETBPT — Sets words BPTR and BPT2 to contain AC and AC+1, respectively.

TTYHAN — Subroutine to unpack and print a TEXT message on the console terminal. TTYHAN is called by:

```
CDF CURRENT
CIF 0
JMS TTYHAN
CDF MSGFIELD
MSG
```

RTNOS8 — Prints a fatal error message and then returns to the OS/8 monitor. A pointer to the message must follow the JMS RTNOS8.

IOHAN — Used to execute all I/O under OS/8. The calling sequence is:

```
TAD (ACARG      /Optional
CDF CURRENT
CIF 0
JMS IOHAN
ADDR
ARG1
ARG2
ARG3
```

where ARG1, ARG2 and ARG3 are standard OS/8 device handler arguments and ADDR points to a three-word block in field 1 which contains the OS/8 unit number in word 1, the file length in word 2, and the starting block number in word 3.

If ACARG is zero, the indicated I/O operation is executed after the handler has been FETCHed, if necessary. If ACARG=n (greater than zero), the handler for OS/8 unit n is FETCHed, no I/O is done, and the four arguments that conclude the calling sequence are not needed.

ADVOVR — Called to initialize the loader to accept a new input module. ADVOVR determines whether a new overlay or level is being started by accessing the module count table. If so, it sets various pointers and internal counters accordingly, rounds the previous overlay to terminate on a 200 word boundary, and updates the length of the previous level, if necessary, as the maximum of its constituent overlay lengths.

NXTOVR — Called by ADVOVR when the next input module will be the first module in a new overlay.

SETCNT — Initializes the pointers and counters used by ADVOVR. SETCNT is called once at the beginning of each pass.

LOOK — Executes a symbol look-up in the loader symbol table. LOOK is called by:

```
TAD (Pointer to symbol name in
     RALF ESD format
JMS LOOK
RETURN here if not found
RETURN here if found
GPTR points to word following entry name
```

If the symbol is not found, it is inserted into the loader symbol table and GPTR is set to point to the word following the symbol name.

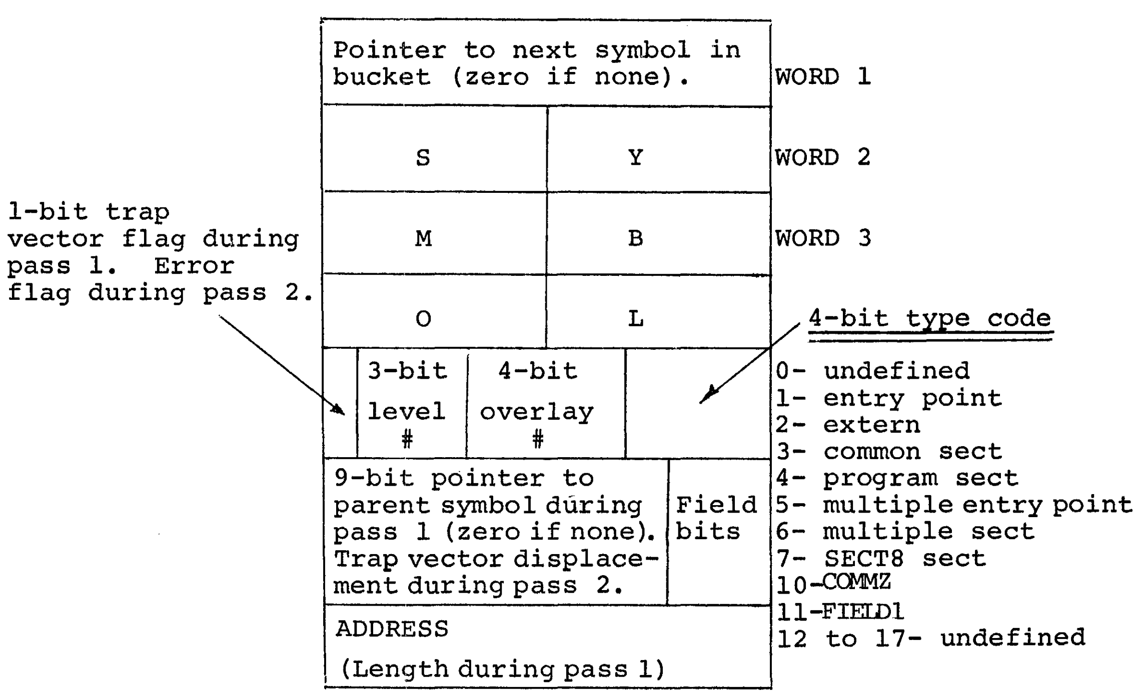
SYMMAP — Produces the symbol map.

| | |
|---|---|
| PUTSYM | Enters an ESD symbol in the loader symbol table. PUTSYM calls LOOK to determine whether the symbol is already present in the symbol table and, if so, verifies that the symbol is not multiply defined. Otherwise, it copies the ESD data words into the symbol table entry, updates the length of the current overlay by the length associated with the symbol, and links the symbol to its parent symbol, if any. |
| FIT | Fits a section into core by subtracting its length from the amount of core still available and substituting its load address for its length in the symbol table. |
| DO8S, FIT8S | Fits an 8-mode section into core by calling FIT and then checking for field 1 overflow. |
| SETREF | Extracts data from the ESD table of the current module and initializes the ESD reference page at 17400. |
| BLDTV | Builds the transfer vector. A transfer vector entry is created for each subroutine in an overlay. This entry provides the information that the run-time system will require in order to load the overlay containing the referenced subroutine. |
| NEWORG | Called whenever an origin is found in an input module, to map the location referenced by the origin into a block of the loader image file and an address within that block. |
| NEWBB | Called whenever a new binary buffer is needed during loader image file construction. NEWBB scans a list of available buffers and dumps the content of the least recently accessed buffer to free up space for new data. |
| MERGE | Relocates an input word pair and outputs it to the loader image file. |
| GETCTL | Gets a control byte from the input module and increments its return address by the content of the control byte. |
| PUTBIN | Inserts words, sequentially, into the current binary buffer. When the buffer is full, PUTBIN calls NEWBB to execute output to the loader image file and supply a new buffer. |
| TXTSCN | Called once for each input module. TXTSCN reads and relocates an entire input module, executing calls to MERGE, PUTBIN and NEWORG as needed. |

SYMBOL TABLE

The loader symbol table begins at location 12000 and contains room for 26 (decimal) permanent system symbol entries and 218 (decimal) user entries. Each entry is 7 words long, and provides the name and definition of a symbol. The table is organized in buckets according to the first character of the symbol, which must be A to Z, #, or blank (for blank COMMON). The table of bucket pointers begins at location 12000 with the pointer to bucket A, and consists of one word per bucket. This word contains a value of zero, if there are no symbols in the corresponding bucket, or else the address of the first symbol in the bucket.

Symbols within a bucket are arranged in alphabetical order, with each symbol entry pointing to the following entry, and the last entry pointing to zero. Thus, the symbol table appears as a set of threaded lists in core. The format of a symbol table entry is:



Several special symbols are created by the loader. The symbol #YLVLn, where n is an octal digit, describes overlay level n. This symbol table entry contains the length of level n during pass 1 and the starting address of level n during pass 2.

The symbol #YTRAP describes the trap vector, a method by which the run-time system controls automatic overlaying of user subroutines. Four words are allocated in the trap vector for each entry point in every overlay except overlay #MAIN. The symbol table entry for #YTRAP contains the accumulated length of the trap vector during pass 1 and the trap vector starting address during pass 2.

ESD CORRESPONDENCE TABLE (ESDPG)

The ESD correspondence table begins at location 17400 and contains 128 (decimal) 1-word entries. This table establishes the correspondence between the local ESD reference numbers used to reference a symbol inside a RALF module, and the address of that symbol in the loader symbol table. The $n^{th}$ entry in the ESD correspondence table points to the address of ESD symbol n.

BINARY BUFFER TABLE (LDBUFS)

The binary buffer table begins at location 17247 and contains from two to ten entries, depending upon the amount of memory available. Each entry is 4 words in length. The binary buffers function as windows into the loader image file, through which the loaded program is written onto mass storage. Each binary buffer is 8 pages (4 OS/8 blocks) in length. The loader tries to minimize the amount of "window turning" necessary to buffer the binary data by keeping a record of the last time each buffer was referenced. In this way, when the content of a binary buffer must be dumped to make room for new data, the loader empties that buffer which was least recently used.

In addition, program loading is overlay oriented such that only one overlay is loaded at a time and while any specific overlay is being loaded, only origins inside that overlay are legal.

The format of a binary buffer table entry is:

| | | | |
|---|---|---|---|
| Pointer to the binary buffer of "next earliest reference", i.e., the youngest buffer older than this buffer. Contains zero if this buffer is oldest. | | | WORD 1 |
| Loader image block #. Contains zero if buffer has not been used. | | | WORD 2 |
| Blocks left in current overlay. If <4, only part of buffer will be dumped. | | | WORD 3 |
| Page address of buffer. | Buffer field bits | Unused | WORD 4 |

The number of binary buffers used varies with the amount of memory available as follows:

| MEMORY AVAIL | NO. OF BUFFERS |
|---|---|
| 8K | 2 |
| 12K | 4 |
| 16K | 5 |
| 20K | 7 |
| 24K | 10 (decimal) |
| 28K | 10 (decimal) |
| 32K | 10 (decimal) |

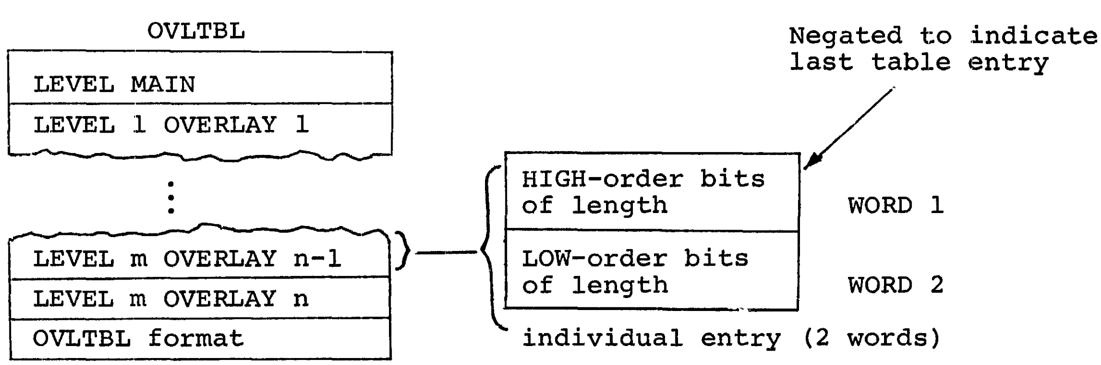
BINARY SECTION TABLE

The binary section table overlays the loader image header block (described under FRTS) after the latter has been written into the loader image file at the beginning of pass 2. Thus, the binary section table begins at location 17200 and contains eight 4-word entries. Each entry relates the core origin of one of the eight overlay levels to that level's position in the loader image file. The format of a binary section table entry is:

| | | |
|---|---|---|
| Unused | Field of level | WORD 1 |
| Address of level | | WORD 2 |
| Relative block # | | WORD 3 |
| Length (in blocks) | | WORD 4 |

OVERLAY TABLE (OVLTBL)

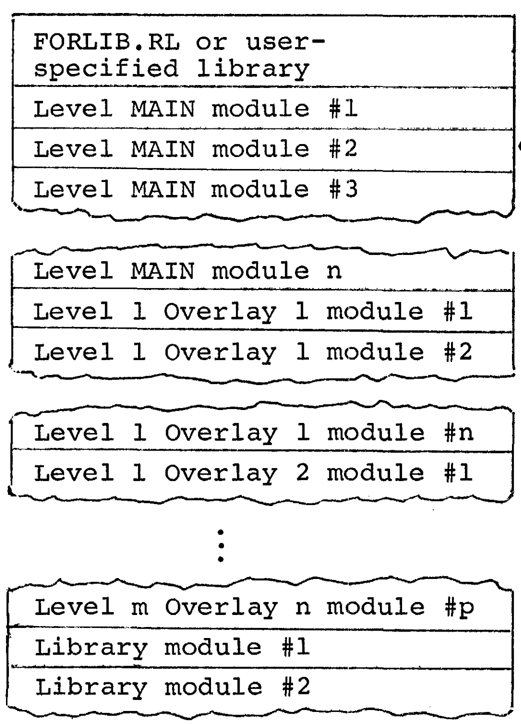
The overlay table begins at location 15435 and contains room for 113 (decimal) 2-word entries. There is one entry for each overlay defined, including overlay MAIN, with each entry designating the length in words, of the corresponding overlay. The format of an overlay table entry is:

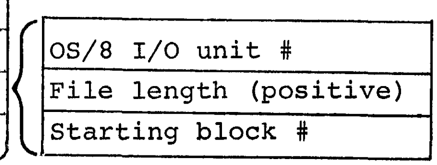


MODULE DESCRIPTOR TABLE (MODTBL)

The module descriptor table begins at location 16172 and contains room for 172 (decimal) 3-word entries. Each entry provides the information needed to locate an input module. The first MODTBL entry corresponds to the library file to be used in building the current loader image. Successive entries correspond to input modules and appear in the order that the modules were specified by the user, (i.e., in ascending order by level, and ascending by overlay within any given level.) At the end of pass 1, entries corresponding to individual library modules are appended to the end of the table, even though the library modules load into level MAIN. The table format is:

MODTBL



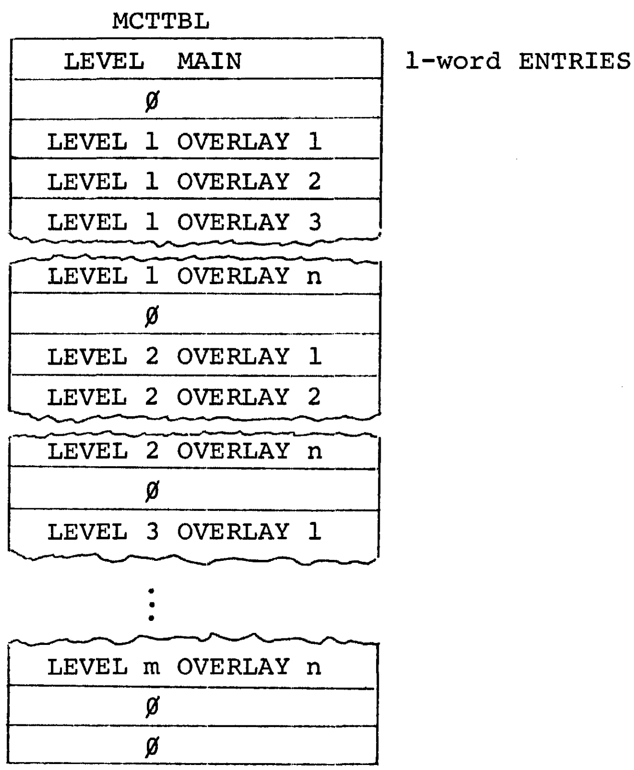




MODTBL format of individual entry (3 words)

MODTBL format

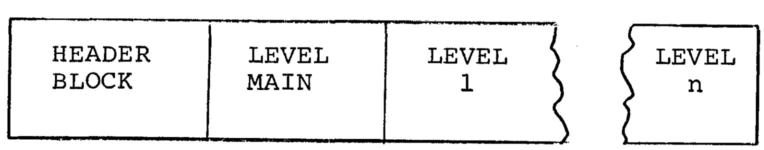
MODULE COUNT TABLE (MCTTBL)

The module count table begins at location 16000 and contains room for 122 (decimal) 1-word entries that give the (two's complement) module count for each overlay level. The table format is:




If an overlay or level is not defined for a specific program, there is no module count table entry corresponding to that overlay or level.

The loader image file, produced by the loader and read as input by the run-time system, consists of a header block followed by a binary image of each level defined in the FORTRAN IV job.



The loader image file header block contains information in the following format:

| LOCATION | CONTENTS |
|---|---|
| 0 | 2 -- Identifies the file as a loader image file. |
| 1-2 | Initial SWAP arguments to load level MAIN. |
| 3-4 | Highest address used by core load, including overlays but not including OS/8 device handlers. |
| 5 | Loader version number. |
| 6 | Double-precision flag. |
| 7-46 | User overlay information table containing one 4-word entry per overlay level (the level MAIN entry is ignored) in the following format: |

| | | | | | |
|---|---|---|---|---|---|
| | Unused until SWAP time. Must be positive or zero. | | | | WORD 1 |
| Load address → | Page bits | Bits 4-5 unused | Field bits | Bits 9-11 unused | WORD 2 |
| | Block number of this level, relative to header block. | | | | WORD 3 |
| | Length of overlays in this level, in blocks. | | | | WORD 4 |

# CHAPTER 4

# THE FORTRAN IV RUN-TIME SYSTEM

The FORTRAN IV run-time system supervises execution of a FORTRAN job and provides an I/O interface between the running program and the OS/8 operating system. FRTS includes its own loader, which should not be confused with LOAD, the system loader. It executes with only one overlay, used to restore the resident monitor and effect program termination. The run-time system was designed to permit convenient modification or enhancement, and it is well documented in the assembly language source, available from the Software Distribution Center, which includes extensive comments.

One of the most valuable modifications to FRTS provides for the inclusion of background (or idle) jobs. When FORTRAN is waiting for I/O operations or the FPP to complete execution, the PDP-8 or PDP-12 processor is sitting in an idle loop. An idle job may be executed by the PDP-8 or PDP-12 CPU during this time, perhaps for the purpose of refreshing a CRT display, for example, or monitoring a controlled process. To indicate such a job, the idle wait loop must be modified to include a reference to the user's PDP-8 routine. The routine #IDLE in FRTS must be changed as part of the user's subroutine from

```
#IDLE,  JMP .+4      to     #IDLE,  SKP
        0                           ADDUSR
        CDF CIF                     FLDUSR
        JMS I .-2                   JMS I .-2
```

Devices issuing interrupts may be added to the interrupt skip chain so that FORTRAN checks the user's device as well as system devices. The original code is:

```
#INT,   JMP .+4
        0
        CDF CIF
        JMS I .-2
```

and must be changed, as above, to:

```
        #INT,   SKP
                ADDUSR
                FLDUSR
                JMS I .-2
```

In both cases, ADDUSR should be the address of the user's routine, and FLDUSR should be the memory field of the user's routine.

The idle job is initiated by the subroutine HANG in the run-time system. Hang should only be called when the FORTRAN program must wait for an I/O device flag. The calling sequence is:

```
        EXTERN #HANG

        IOF                     /Important.
        CDF n                   /Where n is current field.
        CIF 0
        JMS% HANG+1
        ADDRSS
                                /Return here with interrupts OFF
                                /When device flag is raised.

HANG,   ADDR #HANG
```

The word ADDRSS must point to a location in page 400 of the run-time system which must normally contain a JMP DISMIS. Three such locations have been provided for the user at #DISMS, #DISMS+1, and #DISMS+2. The selected location must be the location via which the interrupt caused by the desired flag is dismissed. No two flag routines should use the same dismiss location. The following program example illustrates these calling conventions. This routine may be used to drive a Teletype terminal via the PT08 option.

```
        EXTERN #ONQI
        EXTERN #DISMS
        FIELD1 GETCH        /JMS GETCH GETS A CHAR
        Ø                   /GETCH RUNS IN FIELD 1 ONLY
        ISZ FIRST
        JMP NOTFST
        JMS% ONQI+1
        KSF1
        ADDR KSFSUB
        TAD DISMIS+1        /SET UP TO CALL HANG
        DCA HNGLOC
NOTFST, IOF
        TAD INCHR
        SZA CLA
        JMP GOT1
        CIF Ø
        JMS% HANG+1         /NO CHAR READY: HANG
HNGLOC, Ø
                            /HANG RETURNS W/ IOF
GOT1,   TAD INCHR
        DCA FIRST
        DCA INCHR
        TAD FIRST
        ION
        JMP% GETCH
                            /INTERRUPT ROUTINE
KSFSUB, Ø                   /CALLED AS SUBROUTINE
        KRB1
        DCA INCHR
        CDF CIF Ø
        JMP% DISMIS+1       /RETURN TO SYSTEM LOCATION
                            /CONTAINING "JMP DISMIS"
INCHR,  Ø
ONQI,   ADDR #ONQI
HANG,   ADDR #HANG
DISMIS, ADDR #DISMS
FIRST,  -1
```

In most cases, it is easier to include references to the FORLIB module ONQI for adding a handler to the interrupt skip chain and ONQB for adding a job to the idle chain, instead of trying to modify #IDLE and #INT. ONQB provides slots for up to 9 idle jobs to be executed round-robin, and ONQI provides for up to 9 user flags to be tested on program interrupts.

FRTS entry points are listed, along with the core map, on the following pages. The FRTS calling sequence must be observed in any user subroutine. The formal calling sequence is illustrated below. In general, it can be used exactly as illustrated, changing only the section, entry, base page, index register and return location names.

# FRTS CALLING SEQUENCE

```
        SECT EXAMPL       /Section name.  Your module may
                          /require another section pseudo-op
                          /such as FIELD1 or SECT8.
        JA #EXSRT         /Jump to start of subroutine
                          /Use # for first character
        TEXT +EXAMPL+     /6 character section name for
                          /error traceback (optional)
EXAMXR, SETX XREXAM       /Set up index registers
                          /for this subroutine
        SETB BPEXAM       /and its base page.
BPEXAM, F 0.0             /Base page
XREXAM, F 0.0             /Index registers 0-2
        F 0.0             /Index registers 3-5 (optional)
EXTMP1, F 0.0             /Space between index registers
EXTMP2, F 0.0             /and the ORG for temporary
EXTMP3, F 0.0             /storage (optional)
        ORG 10*3+BPEXAM /Location 30 of base page
        FNOP              /Force a two-word instruction
        JA EXAMXR         /Jump to base page for
                          /return to calling program
        0                 /Force a two-word instruction
EXMRTN, JA .              /Will be replaced by return jump
        BASE 0            /Caller's base page
#EXSRT, STARTD            /Start of subroutine
        FLDA 10*3         /Get return jump from caller's
                          /base page
        FSTA EXMRTN       /Save in return location for
                          /this routine
        FLDA 0            /Location 0 of caller's routine
                          /is a pointer to the argument list
        SETX XREXAM       /Change to EXAMPL's index registers
        SETB BPEXAM       /Change to EXAMPL's base page
        BASE BPEXAM
        FSTA BPEXAM       /Save the pointer
        LDX 1,1           /Set up index register 1
        FLDA% BPEXAM, 1 /Get address of argument list
        FSTA EXTMP1       /Save the addresses
        FLDA% BPEXAM, 1+/of all passed arguments
        FSTA EXTMP2
        FLDA% BPEXAM, 1+
        FSTA EXTMP3       /Continue for all arguments
          .               /to be picked up
          .
          .
        STARTF            /Start three-word instructions
        FLDA% EXTMP1
          .
          .
          .
        FLDA% EXTMP2
          .
          .
          .               /Continue to get arguments
          .               /as required in routine
        JA EXMRTN         /Exit when done
```

| RTS ENTRY POINT | USEAGE AND COMMENTS | |
|---|---|---|
| #UE | TRAP3 #UE | /Produces USER ERROR error message. |
| #ARGER or<br>#ARGERR | TRAP4 #ARGER | /Produces BAD ARG error message. |
| #READO | TRAP3 #READO<br>JA UNITNO<br>JA FORMAT | /Initializes<br>/formatted<br>/read operation. |
| #WRITO | TRAP3 #WRITO<br>JA UNITNO<br>JA FORMAT | /Initializes<br>/formatted<br>/write operation. |
| #RUO | TRAP3 #RUO<br>JA UNITNO | /Initializes unformatted<br>/read operation. |
| #WUO | TRAP3 #WUO<br>JA UNITNO | /Initializes unformatted<br>/write operation. |
| #RDAO | TRAP3 #RDAO<br>JA UNITNO<br>JA RECNO | /Initializes<br>/direct access<br>/read operation. |
| #WDAO | TRAP3 #WDAO<br>JA UNITNO<br>JA RECNO | /Initializes<br>/direct access<br>/write operation. |
| #RFSV | TRAP3 #RFSV | /Passes a variable to or from the read/<br>/write processors via the floating AC. |
| #RENDO | TRAP3 #RENDO | /Terminates a read/write operation. |
| #ENDF<br><br>#REW<br>#BAK | FLDA UNITNO<br>TRAP3 #ENDF<br>or TRAP3 #REW<br>or TRAP3 #BAK | /Executes an<br>/end file,<br>/rewind,<br>/backspace (depending upon the entry used)<br>/on the referenced I/O unit. |
| #DEF | TRAP3 #DEF<br>JA UNITNO<br>JA RECORDS<br>JA FPNPR<br>JA VARIABLE | /Opens a file<br>/for direct access I/O.<br><br>/(FPP numbers per record)<br>/Refer to DEFINE FILE statement |
| #EXIT | JSR #EXIT | /Terminates current FORTRAN* IV job. |
| #SWAP | TRAP3 #SWAP<br>ADDR | /Reads overlay OVLY into level LVL and<br>/jumps to ADR. ADDR is given by:<br>/ADDR=4000000*OVLY+100000*LVL+ADR |
| #8OR12 | /=00000001 if the CPU is a PDP-12. | |
| #IDLE | Address of background job, used by ONQB. Contains: | |

```
JMP I (NULJOB    /Replace by SKP
0                /Replace by addr of background job
CDF CIF 0        /Replace by field of background job
JMS I .-2
JMP .-4
```

CORE LAYOUT OF FRTS

| Address | NON-FPP | FPP (Same as non-FPP unless indicated) |
|---|---|---|
| 0000 | Page zero (0120-0134 free) | |
| 0200 | Most entry points, character I/O handlers, interrupt service, and HANG routine | |
| 0600 | Format decoder; A, H, and ' format processors, and EXIT | |
| 1400 | REWIND, ENDFILE, BACKSPACE and general unit initialization. DATABL table (3 wds/unit) | |
| 2000 | I, E, F and G output | |
| 2400 | I, E, F and G input | |
| 2600 | X, L and T formats and GETHND routine | |
| 3000 | Char in and char out routines including OS/8 packing, editing and forms control | |
| 3400 | Binary and D. A. I/O, and DEFINE FILE processor | |
| 3600 | Overlay loader | |
| 4000 | Input line buffer, overlay and DSRN tables, FORMAT parenth pushdown list, /P processor and init flag clear | |
| 4400 | Floating-point utilities (shift, add, etc.) used even w/FPP | |
| 4600 | Error routine and messages | |
| 5200 | OS/8 handler area and part of FRTS loader initialization | |
| 5600 | FPP simulator | FPP start-up and trap routines |
| 6000 | | B and D format I/O |
| 6600 | Floating-point package and part of LPT ring buffer | Floating-point package (never used) and part of LPT ring buffer |
| 7400 | Most of LPT ring buffer | |
| 7600 | OS/8 handler and field 0 resident | |
| 10000 | OS/8 User Service Routine | |

| Address | Contents | Notes |
|---|---|---|
| 12000 | FRTS loader tables, IONTBL | Locations 12000 to 17400 are overlayed at execution time |
| 12200 | FRTS loader: main flow | |
| 12400 | program start-up[1] | |
| 12600 | initialize and configure system | |
| 13000 | Load OS/8 handlers and assign unit numbers to OS/8 files | |
| 13400 | Utility and error routines, error messages | |
| 14000 | | |
| 15600 | FPP start-up and trap routines | Locations 14000 to 16777 are used to save lower field 0 during loading of device handlers and file specifications |
| 16000 | B and D format I/O | |
| 16600 | EAE Floating-point package | |
| 17400 | Termination routine | Locations 17400 to 17777 are written on SYS block 37 before program load and restored on termination |
| 17600 | OS/8 field 1 resident | |

```
#INT            /Address of user interrupt location, used by ONQI:
                JMP .+4         /Replace with SKP
                0               /Replace with address of interrupt
                                 processor
                CDF CIF 0       /Replace with field of interrupt processor
                JMS I .-2

#DISMS          /Addresses first of three JMP DISMIS instructions for
                 use by specialized I/O routines.

#HANG           /Addresses I/O dismiss routine.

#RETRN          /Provides return from TRAP3.
```

[1]Program start-up moves OS/8 handler to top of core, writes field 1 resident onto SYS, and termination routine goes to FRTS to load program.

DSRN TABLE

The DSRN table controls files and I/O devices used under OS/8 FORTRAN IV ASCII, binary and direct access I/O operations, including BACKSPACE, REWIND, and END FILE operations. The exact meaning of the initials DSRN is one of the great, unanswered questions of FORTRAN IV development and, as such, has considerable historical interest. The DSRN table provides room for 9 entries; each entry is 9 words in length, and contains the following data:

WORD 1: (HAND) Handler entry point. If this value is positive, the I/O device handler is a FORTRAN internal (character-oriented) handler, and the remainder of the DSRN table entry is ignored. If the value is negative, the handler is an OS/8 device handler whose entry point is the two's complement of the value. Entry points always fall in the range [7607, 7777] for resident handlers or [5200, 5377] for non-resident handlers. Space for non-resident handlers is allocated downward from the top of memory, and the handlers are moved into locations 5200 to 5577 before being called.

WORD 2: (HCODEW) Handler code word. Bits 0-4 of this word specify the page into which the device handler was loaded, while bits 6-8 specify the memory field. If all of bits 0-8 are zero, the handler is permanently resident. When any of these bits are non-zero, the data is used to determine which handler, if any, currently occupies locations 5200-5577. This eliminates unnecessarily moving the content of memory. Bit 10 is set if forms control has been inhibited on the I/O unit. Bit 11 is set if the device handler can execute with the interrupt system enabled. The data in bits 10 and 11 is obtained from the IOWTBL table in the FRTS loader.

WORD 3: (BADFLD) Buffer address and field. Bits 0-4 address the memory page at which the I/O buffer for this unit begins, while bits 6-8 specify the memory field. Unlike the FORTRAN internal I/O unit buffers, OS/8 device handler buffers always occupy two full pages of memory. Buffer space is allocated upward from the top of the FORTRAN program.

WORD 4: (CHRPTR) Character pointer.

WORD 5: (CHRCTR) Character counter. Words 4 and 5 of each DSRN table entry define the current character/position in the I/O buffer as follows:

| Value of CHRCTR | Character position | Next value of CHRCTR | Next value of CHRPTR | Special Conditions |
|---|---|---|---|---|
| -3 | Bits 4-11 of word addressed by CHRPTR | -2 | CHRPTR + 1 | Refresh buffer if input operation and CHRPTR mod 256=0 |
| -2 | " | -1 | " | none |
| -1 | Bits 0-3 of words addressed by CHRPTR-2 and CHRPTR-1 | -3 | CHRPTR | Dump buffer if output operation and CHRPTR mod 256=0 |

WORD 6: (STBLK) Starting block of file.

WORD 7: (RELBLIC) Current relative block of file. That is, block to be accessed next.

WORD 8: (TOTBLK) Length of file in blocks.

WORD 9: (FFLAGS) Status flags:

Bit 0 - Has been written flag. Set to 1 if unit has received output since last REWIND.

Bit 1 - Formatted I/O flag. Set to 1 if an ASCII I/O operation has occurred since last REWIND.

Bit 2 - Unformatted I/O flag. Set to 1 if a binary or direct access I/O operation has occurred since last REWIND. Bits 1 and 2 are never set simultaneously.

Bit 11- END FILEd flag. Set to 1 if unit has been END FILEd. Bit 11 is not cleared by a REWIND.

When any active unit is selected for an I/O operation, the DSRN table entry for that unit is moved into 9 words on page 0. These 9 words are tagged with the labels cited above. Upon completion of the I/O operation, the 9 words are moved from page 0 back into the DSRN table.

```
              /PAGE ZERO FOR FORTRAN IV RTS

       0000           *0                /INTERRUPT STUFF
00000  0000           0
00001  5402           JMP I   .+1
00002  0400           INTRPT
00003  5165   LPGET,  LPBUFR            /LINE PRINTER RING BUFFER FETCH
00004  0000   TOCHR,  0                 /TELETYPE STATUS WORD
00005  0000   KBDCHR, 0                 /KEYBOARD INPUT CHARACTER
00006  0000   POCHR,  0                 /P.T. PUNCH COMPLETION FLAG
00007  0000   RDRCHR, 0                 /P.T. READER STATUS
00010  0000   FMTPXR, 0                 /XR USED TO INDEX FORMAT PARENTH
00011  3777   INXR,   INBUFR-1          /XR USED TO GET CHARS FROM INPUT
00012  0000   XR,     0
00013  0000   XR1,    0

       0016   *16
00016  0000   VEOFSW, 0         /USED BY "EOFCHK" TO STORE VARIABLE ADDRESS
00017  0000           0         /*K* MUST BE IN AUTO - XR
00020  0000   T,      0         /TEMPORARY
00021  0000   DFLG,   0         /0 = F.P., 1 = D.P.
00022  0000   INST,   0         /CURRENT INSTRUCTION WORD

              /IOH PAGE ZERO LOCATIONS

00023  0000   RWFLAG, 0                 /READ/WRITE FLAG
00024  0000   FMTTYP, 0                 /TYPE OF CONVERSION BEING DONE
00025  0000   EOLSW,  0                 /EOL SW ON INPUT - CHAR POS ON OUT
00026  0000   N,      0                 /REPEAT FACTOR
00027  0000   W,      0                 /FIELD WIDTH
00030  0000   D,      0                 /NUMBER OF PLACES AFTER DECIMAL

00031  0000   DATCDF, 0                 /SUBROUTINE TO CHANGE DATA FIELD
00032  0000   DATAF,  0                 /CONTAINS VARIOUS CDF'S
00033  5431           JMP I   DATCDF    /RETURN

00034  5013   ERR,    ERROR             /POINTER TO ERROR ROUTINE
00035  0000   FATAL,  0                 /FATAL ERROR FLAG - 0=FATAL
00036  5000   MCDF,   MAKCDF

              /FPP PARAMETER TABLE LOCATIONS:

00037  0000   APT,    0         /VARIOUS FIELD BITS FOR FPP
00040  5313   PC,     DPTEST    /FPP PROGRAM COUNTER
00041  0000   XRBASE, 0         /FPP INDEX REGISTER ARRAY ADDRESS
00042  0000   BASADR, 0         /FPP BASE PAGE ADDRESS
00043  0000   ADR,    0         /ADDRESS TEMPORARY
00044  0000   ACX,    0
00045  0000   ACH,    0                 /*** FLOATING ACCUMULATOR ***
00046  0000   ACL,    0
00047  0000   EAC1,   0
00050  0000   EAC2,   0         /** FOR EXTENDED PRECISION OPTION **
00051  0000   EAC3,   0
```

```
                    /FLOATING POINT PACKAGE LOCATIONS

00052  0000   AC0,     0
00053  0000   AC1,     0                   /FLOATING AC OVERFLOW WORD
00054  0000   AC2,     0                   /OPERAND OVFLOW WORD
00055  0000   OPX,     0
00056  0000   OPH,     0                   /*** FLOATING OPERAND REGISTER ***
00057  0000   OPL,     0

                    /RTS I/O SYSTEM LOCATIONS

00060  0000   FMTBYT,  0                   /FORMAT BYTE POINTER
00061  0000   IFLG,    0                   /I FOEMAT FLAG
00062  0000   GFLG,    0                   /G FORMAT FLAG
00063  0000   EFLG,    0                   /E FORMAT FLAG - SOMETIMES ON FOR
00064  0000   OD,      0
00065  0000   SCALE,   0
00066  0000   PFACT,   0                   /P-SCALE FACTOR
00067  0000   PFACTX,  0                   /TEMP FOR PFACT
00070  0000   INESW,   0                   /EXPONENT SWITCH
00071  0000   CHCH,    0
00072  0000   FMTNUM,  0                   /CONTAINS ACCUMULATED NUMERIC VALUE
00073  0000   CTCINH,  0                   /↑C INHIBIT FLAG
00074  0320   PTTY,    TTY                 /POINTER TO TTY HANDLER - USED BY
00075  0000            0                   / SO FORMS CONTROL WILL WORK ON
00076  6001   FPNXT,   ICYCLE              /USED AS INTERPRETER ADDRESS IF

                    /DSRN IMAGE

00077  0000   HAND,    0                   /HANDLER ENTRY POINT
00100  0000   HCODEW,  0                   /HANDLER LOAD ADDR & FIELD + IOFFL
00101  0000   BADFLD,  0                   /BUFFER ADDRESS AND FIELD
00102  0000   CHRPTR,  0                   /ACTUALLY A WORD POINTER
00103  0000   CHRCTR,  0                   /COUNTER - RANGES FROM -3 TO -1
00104  0000   STBLK,   0                   /STARTING BLOCK OF FILE
00105  0000   RELBLK,  0                   /CURRENT RELATIVE BLOCK NUMBER
00106  0000   TOTBLK,  0                   /LENGTH OF FILE
00107  0000   FFLAGS,  0                   /FILE FLAGS:
                                           /BIT 0 - "HAS BEEN WRITTEN" FLAG
                                           /BITS 1-2 - FORMATTED/UNFORMATTED
                                           /BIT 11 - "END-FILED" FLAG

00110  0000   BUFFLD,  0                   /ROUTINE TO SET DF TO BUFFER FIELD
00111  7402   BUFCDF,  HLT
00112  5510            JMP I   BUFFLD

00113  0000   FGPBF,   0                   /THESE THREE WORDS ARE USED
00114  0000   BIOPTR,  0                   /TO FETCH AND STORE FLOATING POINT
00115  0000            FEXIT               /FROM RANDOM MEMORY
       0200            PAGE
```

```
                /STARTUP CODE

00200  2203  FTEMP2, ISZ     .+3       /ALSO USED AS I/O F.P. TEMPORARY
00201  6213          CDF CIF 10
00202  5603          JMP I   .+1
00203  2200  VDATE,  RTSLDR            /USED TO STORE OS/8 DATE

                /RTS ENTRY POINTS - "VERSION INDEPENDENT"

00204  5777  VUERR,  JMP I   (USRERR /USER ERROR
                                     /** LOADER MUST DEFINE #ARGER AS
00205  4434  VARGER, JMS I   ERR     /LIBRARY ARGUMENT ERROR
00206  2023  VRENDO, ISZ     RWFLAG  /END OF I/O LIST
00207  5634  VRFSV,  JMP I   GETLMN  /I/O LIST ARG ENTRY - COROUTINE
00210  5776  VBAK,   JMP I   (BKSPC  /"BACKSPACE" ROUTINE
00211  5775  VENDF,  JMP I   (ENDFL  /"END FILE" ROUTINE
00212  5774  VREW,   JMP I   (RWIND  /"REWIND" ROUTINE
00213  5773  VDEF,   JMP I   (DFINE  /"DEFINE FILE" ROUTINE
00214  7330  VWUO,   AC4000          /UNFORMATTED WRITE
00215  5772  VRUO,   JMP I   (RWUNF  /UNFORMATTED READ
00216  7330  VWDAO,  AC4000          /DIRECT ACCESS WRITE
00217  5771  VRDAO,  JMP I   (RWDACC /DIRECT ACCESS READ
00220  7330  VWRITO, AC4000          /FORMATTED (ASCII) WRITE
00221  5770  VREADO, JMP I   (RWASCI /FORMATTED (ASCII) READ
00222  5767  VSWAP,  JMP I   (SWAP   /OVERLAY PROCESSOR
00223  3000  VEXIT,  TRAP3;  CALXIT  /"STOP" ROUTINE - ENTERED IN FPP
00224  1317
00225  0000  V8OR12, 0;0             /0;1 IF CPU IS A PDP-12
00226  0000
00227  5766  VBACKG, JMP I   (NULLJB /BACKGROUND JOB DISPATCHER
00230  0000          0
00231  6203          CDF CIF 0       /USED BY ROUTINE "ONQB" IN LIBRARY
00232  4630          JMS I   .-2
00233  5227          JMP     VBACKG

                /IOH GET VARIABLE ROUTINE.
                /THIS ROUTINE MAKES THE FORMATTED I/O PROCESSOR AND THE
                /PROGRAM CO-ROUTINES (DEF(COROUTINE)= 2 ROUTINES EACH
                / IS A SUBROUTINE).  ON ENTRY FAC=INPUT NUMBER
                /IF I/O IS A READ, ON RETURN FAC=OUTPUT NUMBER IF I/O

00234  0000  GETLMN, 0
00235  5577  VRETRN, JMP I   [RETURN
```

All FORTRAN IV mass storage I/O is performed in terms of OS/8 blocks, including direct access I/O. Hence, all FORTRAN IV files conform to OS/8 standard ASCII file format. When a formatted READ or WRITE is requested, the data is converted to or from 8-bit binary representation according to the FORMAT statement associated with the READ or WRITE. Standard OS/8 file format packs three 8-bit characters into two 12-bit words as follows:

MASS STORAGE

| | |
|---|---|
| WORD 3 bits 0-3 | WORD 1 |
| WORD 3 bits 4-7 | WORD 2 |

CORE

| |
|---|
| WORD 1 |
| WORD 2 |
| WORD 3 |

Unformatted (i.e. direct access) READ and WRITE operations also operate on standard OS/8 format files, with each statement causing one FORTRAN IV record to be read or written. A FORTRAN IV record must contain at least one OS/8 block, and always contains an integral number of blocks. The number of variables contained in a 1-block record depends upon the content and format of the I/O list, as follows:

| Format type | Number of 12-bit Words/Variable | Number of Variables/Block |
|---|---|---|
| Integer | 3 | 85 |
| Real | 3 | 85 |
| Double precision | 6 | 42 1/2 |
| Complex | 6 | 42 1/2 |

It is possible to mix any types of data in an I/O list; however, no more than 85 variables may be stored in one OS/8 block. The number of blocks required for a FORTRAN IV record depends, therefore, upon the number of variables in the I/O list, and may be minimized by supplying every direct access WRITE with sufficient data to nearly fill an integral number of blocks without overflowing the last block.

The last word in every file block contains a block count sequence number and is not available for data storage. FRTS assigns block count numbers sequentially, beginning with 1, whenever a file is written. Block count numbers must be maintained by the user when FORTRAN IV files are created outside of an OS/8 FORTRAN IV environment. While reading a binary file, FRTS checks the block count sequence numbers on input blocks and ignores any block whose sequence number is larger than expected. Sequence number checking is disabled during direct access READ operations.

When FRTS is loaded and started, the initialization routines determine what optional hardware, such as FPP-12 Floating Point Processor or KE8E Extended Arithmetic Element, is present in the running hardware configuration. The initialization routines then modify FRTS to use the optional hardware, if available. When an FPP is present in the system and it becomes desirable to disable the FPP under FRTS, this may be accomplished by changing the content of location 12621 from 6555 to 7200. The extended arithmetic element may be disabled in the same manner by changing the content of FRTS location 12623 from 7413 to 7200. These changes must be made before FRTS is started. The OS/8 monitor GET and ODT commands provide an excellent mechanism for changes of this type.

The FRTS internal line printer handler uses a linked ring buffer for maximum I/O buffering efficiency. The buffer consists of several contiguous sections of memory, linked together by pointers. All of these buffer segments are located above 04000, so that the pointers are readily distinguishable from bufferred characters. The entire 07400 page is included in the line printer ring buffer. If it becomes desirable to modify FRTS by patching or reassembly, most of the 07400 page may be reclaimed from the buffer by changing the content of location 07402 from 7577 to 5164. This frees up locations 07403 to 07577 for new code and still leaves about eighty character positions in the LPT ring buffer.

Because FRTS executes with the processor interrupt system enabled, it may hang up on hardware configurations that include equipment capable of generating spurious program interrupts. In addition, any OS/8 I/O device handler that exits without clearing all device flags may cause troublesome interrupts when it is assigned as a FORTRAN I/O unit under FRTS. To counteract these potential problems, FRTS provides certain areas that are reserved for inclusion of user-generated code designed to clear device flags and/or inhibit spurious interrupts.

A string of NOP instructions beginning at location 04020 is executed during FRTS initialization, just before the interrupt system is enabled. When the /H option is specified to FRTS, the system halts after these NOPs have been executed and the interrupt system has been enabled. Another string of NOPs occupying the eight locations from 03746 to 03755 is executed after every call to an OS/8 device handler. Any of these NOP instructions may be replaced by flag-handling or interrupt-servicing code. If additional memory locations are required, they may be obtained by replacing some of the code from locations 04007 to 04017 with flag-handling code. Locations 04007-17 are used to clear flags associated with LAB-8/E peripheral devices.

Due to memory limitations, it is not possible to add internal I/O device handlers to the four internal handlers supplied with the system. However, FORTRAN I/O unit 0, which is not defined by the ANSI standard, may be specified for terminal I/O via the internal console terminal handler. I/O unit 0 is not re-assignable.

```
                 /INTERRUPT DRIVEN I/O HANDLERS

00236  0000  LPT,     0                /RING-BUFFERED - LP08 OR LS8E
00237  0176           AND     [377     /JUST IN CASE
00240  7450  LPTSNA,  SNA
00241  5765           JMP I   (IOERR   /CANNOT BE USED FOR INPUT
00242  6002           IOF
00243  3667           DCA I   LPPUT
00244  1003           TAD     LPGET
00245  7041           CIA
00246  1267           TAD     LPPUT
00247  7640           SZA CLA          /IS LPT QUIET?
00250  5253           JMP     .+3      /NO
00251  1667           TAD I   LPPUT
00252  6666           LLS              /YES - START 'ER UP
00253  7201           CLA IAC
00254  6665           LIE              /ENABLE LPT INTERRUPTS
00255  1267           TAD     LPPUT    /1 IN AC, REMEMBER?
00256  3267           DCA     LPPUT
00257  1667           TAD I   LPPUT
00260  7510           SPA
00261  5256           JMP     .-3      /NEGATIVE NUMBERS ARE BUFFER LINKS
00262  7640           SZA CLA          /ANY ROOM LEFT IN BUFFER?
00263  4764           JMS I   (HANG
00264  0436           LPUHNG           /WAIT FOR LINE PRINTER
00265  6001           ION              /TURN INTERRUPTS BACK ON
00266  5636           JMP I   LPT      /RETURN

00267  5165  LPPUT,   LPBUFR

00270  0000  PTP,     0                /PAPER TAPE PUNCH HANDLER
00271  7450           SNA
00272  5765           JMP I   (IOERR   /INPUT IS ERROR
00273  3236           DCA     LPT      /SAVE CHAR
00274  6002           IOF
00275  1006           TAD     POCHR    /IF PUNCH IS NOT IDLE,
00276  7640           SZA CLA          /WE DISMISS JOB
00277  4764           JMS I   (HANG
00300  0502           PPUHNG  /WAIT FOR PUNCH INTERRUPT
00301  1236           TAD     LPT
00302  6026           PLS              /OUTPUT CHAR
00303  3006           DCA     POCHR    /SET FLAG NON-ZERO
00304  6001           ION
00305  5670           JMP I   PTP

             /*K* THE FOLLOWING ADDRESSES GET FALLEN INTO & MUST BE SMAL

                      IFNZRO  PPUHNG&7000     <←←ERROR←←>
                      IFNZRO  TTUHNG&7000     <←←ERROR←←>
                      IFNZRO  KBUHNG&7000     <←←ERROR←←>
                      IFNZRO  RDUHNG&7000     <←←ERROR←←>
                      IFNZRO  LPUHNG&7000     <←←ERROR←←>
```

```
               /INTERRUPT-DRIVEN PTR AND TELETYPE HANDLER

00306  0000  PTR,    0                     /CRUDE READER HANDLER
00307  7640          SZA CLA
00310  5765          JMP I   (IOERR        /OUTPUT ILLEGAL TO PTR
00311  6002          IOF
00312  6014          RFC                   /START READER
00313  4764          JMS I   (HANG
00314  0510          RDUHNG                /HANG UNTIL COMPLETE
00315  1007          TAD     RDRCHR        /GET CHARACTER
00316  6001          ION
00317  5706          JMP I   PTR           /RETURN

00320  0000  TTY,    0                     /BUFFERS 2 CHARS ON OUTPUT, 1 ON
00321  6002          IOF                   /DELICATE CODE AHEAD
00322  7450          SNA                   /INPUT OR OUTPUT?
00323  5342          JMP     KBD           /INPUT
00324  3236          DCA     LPT           /OUTPUT - SAVE CHAR
00325  1004          TAD     TOCHR         /GET TTY STATUS
00326  7740          SMA SZA CLA           /G.T. 0 MEANS A CHAR IS BACKED UP
00327  4764          JMS I   (HANG
00330  0451          TTUHNG                /WAIT FOR LOG JAM TO CLEAR
00331  1004          TAD     TOCHR         /NO CHAR BACKED UP - SEE IF TTY
00332  7104          CLL RAL               /"BUSY" FLAG IN LINK - INTERRUPTS
00333  7230          CLA CML RAR           /COMPLEMENT OF BUSY IN SIGN
00334  1236          TAD     LPT           /GET CHAR
00335  7510          SPA                   /IF TTY NOT BUSY,
00336  6046          TLS                   /OUTPUT CHAR
00337  3004          DCA     TOCHR         /STORE POS OR NEG, BACKED UP
00340  6001  TTYRET, ION                   /TURN INTERRUPTS BACK ON
00341  5720          JMP I   TTY           /AND LEAVE
```



```
00342  1005  KBD,    TAD     KBDCHR        /HAS A CHARACTER BEEN INPUT?
00343  7650          SNA CLA
00344  4764          JMS I   (HANG
00345  0465          KBUHNG                /NO - RUN BACKGROUND UNTIL ONE IS
00346  1005          TAD     KBDCHR        /GET CHARACTER
00347  3236          DCA     LPT
00350  3005          DCA     KBDCHR        /CHEAR CHARACTER BUFFER
00351  1236          TAD     LPT
00352  5340          JMP     TTYRET        /RETURN WITH INTERRUPTS ON

00353  6554  KILFPP, FPHLT                 /BRING FPP TO A SCREECHING HALT
00354  2353          ISZ     .-1
00355  5354          JMP     .-1           /WAIT FOR IT TO STOP
00356  6552          FPICL                 /CLEAN UP MESS HALT HAS MADE IN FPP
00357  7430          SZL                   /↑C OR ↑B?
00360  5763          JMP I   (7600         /↑C - HIYO SILVER, AWAY!
00361  6032          KCC                   /CLEAR KBD FLAG ON ↑B
00362  4434  CTLBER, JMS I   ERR           /*** THIS MAY BE DANGEROUS! **
```

```
               /INTERRUPT SERVICE ROUTINES

00400  3322   INTRPT, DCA      INTAC
00401  7010           RAR
00402  3323           DCA      INTLNK
00403  5207   VINT,   JMP      .+4      /** MUST BE AT 403 **
                      IFNZRO   VINT-403        <←←← CHANGE LOADER!!!>
00404  0000           0
00405  6203           CDF CIF 0         /USER INTERRUPT ROUTINE GOES HERE
00406  4604           JMS I    .-2

00407  6551           FPINT             /CHECK FOR FPP DONE
00410  5215           JMP      LPTEST
00411  5314   FPUHNG, JMP      DISMIS   /ALWAYS GOES TO RESTRT

00412  5314   VDISMS, JMP      DISMIS   /FOR USE BY USERS
00413  5314           JMP      DISMIS
00414  5314           JMP      DISMIS

00415  6661   LPTEST, LSF
00416  5240           JMP      NOTLPT
00417  6662   LPTLCF, LCF               /CLEAR FLAG
00420  1403           TAD I    LPGET
00421  7650           SNA CLA           /CHECK FOR SPURIOUS INTERRUPT
00422  5314   JMPDIS, JMP      DISMIS   /GO AWAY IF SO
00423  3403           DCA I    LPGET    /ZERO CHAR JUST OUTPUT
00424  2003           ISZ      LPGET
00425  1403           TAD I    LPGET
00426  7510           SPA
00427  3003           DCA      LPGET    /TAKE CARE OF BUFFER LINKS
00430  7450           SNA
00431  1403           TAD I    LPGET    /MAKE SURE CHAR IS IN AC
00432  7440           SZA               /IS THERE A CHARACTER?
00433  6666           LLS               /YES - PRINT IT
00434  7200           CLA
00435  6661           LSF               /CHECK FOR IMMEDIATE FLAG
00436  5314   LPUHNG, JMP      DISMIS   /NO - MAYBE RESTART PROGRAM
00437  5217           JMP      LPTLCF   /YES - LOOP

00440  6041   NOTLPT, TSF               /CHECK TTY
00441  5252           JMP      NOTTTY
00442  6042           TCF               /CLEAR FLAG
00443  1004           TAD      TOCHR    /GET TTY STATUS
00444  7540           SMA SZA           /IF THERE IS A CHARACTER WAITING,
00445  6046           TLS               /OUTPUT IT.
00446  7740           SMA SZA CLA       /CHANGE "WAITING" TO "BUSY",
00447  7130           STL RAR           /"BUSY" TO "IDLE".
00450  3004           DCA      TOCHR
00451  5314   TTUHNG, JMP      DISMIS
```

```
              /KBD AND PTP INTERRUPTS

00452  6031  NOTTTY, KSF
00453  5276          JMP     NOTKBD
00454  1175          TAD     [200
00455  6034          KRS             /USE KRS TO FORCE PARITY BIT
00456  3005          DCA     KBDCHR  /AND ALSO SO THAT ↑C WILL STILL
00457  1005          TAD     KBDCHR
00460  1377          TAD     (-202   /CHECK FOR ↑C OR ↑B
00461  7110          CLL RAR
00462  7650          SNA CLA
00463  5266          JMP     CTCCTB  /YUP - TAKE SOME DRASTIC ACTION
00464  6032          KCC             /DATA CHARACTER - CLEAR FLAG
00465  5314  KBUHNG, JMP     DISMIS

00466  1073  CTCCTB, TAD     CTCINH
00467  7650          SNA CLA         /ARE WE IN A HANDLER?
00470  5366          JMP     NOTINH  /NO
00471  1323          TAD     INTLNK
00472  7104          CLL RAL         /YES - RETURN WITH INTERRUPTS OFF
00473  1322          TAD     INTAC   /TRUST IN GOD AND RTS
00474  6244          RMF
00475  5400          JMP I   0

00476  6021  NOTKBD, PSF
00477  5303          JMP     NOTPTP
00500  6022          PCF             /P.T. PUNCH INTERRUPT - CLEAR FLAG
00501  3006          DCA     POCHR   /CLEAR SOFTWARE FLAG
00502  5314  PPUHNG, JMP     DISMIS

00503  6011  NOTPTP, RSF
00504  5311          JMP     LPTERR
00505  1175          TAD     [200
00506  6012          RRB             /GET RDR CHAR
00507  3007          DCA     RDRCHR
00510  5314  RDUHNG, JMP     DISMIS

00511  6663  LPTERR, LSE             /TEST FOR LP08 ERROR FLAG
00512  7410          SKP
00513  6667          LIF             /DISABLE LP08 INTERRUPTS IF ERROR
00514  1323  DISMIS, TAD     INTLNK
00515  7104          CLL RAL
00516  1322          TAD     INTAC   /RESTORE AC AND LINK
00517  6244          RMF
00520  6001          ION
00521  5400          JMP I   0       /RETURN FROM THE INTERRUPT

00522  0000  INTAC,  0
00523  0000  INTLNK, 0
```

```
                /BACKGROUND INITIATE/TERMINATE ROUTINE

ØØ524  ØØØØ   HANG,    Ø                   /ALWAYS CALLED WITH INTERRUPTS OFF!
ØØ525  1724            TAD I   HANG        /GET POINTER TO UNHANGING LOCATION
ØØ526  3371            DCA     UNHANG
ØØ527  6214            RDF                 /GET FIELD CALLED FROM
ØØ53Ø  1332            TAD     HCIDFØ
ØØ531  3364            DCA     HNGCDF      /SAVE FOR RETURN
ØØ532  62Ø3   HCIDFØ,  CDF CIF Ø
ØØ533  1376            TAD     (JMP RESTRT       /CHANGE THE "JMP DISMIS"
ØØ534  3771            DCA I   UNHANG      /TO A "JMP RESTRT"
ØØ535  1373            TAD     BACKLK
ØØ536  71Ø4            CLL RAL
ØØ537  1372            TAD     BACKAC      /SET UP BACKGROUND AC AND LINK
ØØ54Ø  62Ø2   BAKCIF,  CIF Ø
ØØ541  62Ø1   BAKCDF,  CDF Ø
ØØ542  6ØØ1            ION
ØØ543  5774            JMP I   BACKPC      /INITIATE BACKGROUND

              /        COME HERE WHEN THE HANG CONDITION HAS GONE AWAY

ØØ544  1222   RESTRT,  TAD     JMPDIS      /RESTORE THE UNHANG LOCATION
ØØ545  3771            DCA I   UNHANG
ØØ546  1322            TAD     INTAC       /SUSPEND THE BACKGROUND
ØØ547  3372            DCA     BACKAC
ØØ55Ø  1323            TAD     INTLNK
ØØ551  3373            DCA     BACKLK
ØØ552  1ØØØ            TAD     Ø
ØØ553  3374            DCA     BACKPC
ØØ554  6234            RIB
ØØ555  Ø174            AND     [7Ø
ØØ556  1332            TAD     HCIDFØ
ØØ557  334Ø            DCA     BAKCIF
ØØ56Ø  6234            RIB
ØØ561  4436            JMS I   MCDF        /*K* OK SINCE BACKGROUND DOESN'T
ØØ562  3341            DCA     BAKCDF
ØØ563  2324            ISZ     HANG
ØØ564  74Ø2   HNGCDF,  HLT
ØØ565  5724            JMP I   HANG        /INTERRUPTS ARE OFF - RETURN

ØØ566  1222   NOTINH,  TAD     JMPDIS      /IN CASE WE WERE HUNG, WE DON'T
ØØ567  3771            DCA I   UNHANG      /TO GET "UNHUNG" OUT OF THE ERROR
ØØ57Ø  5775            JMP I   (KILFPP /KILL FPP AND GO TO EXIT OR ERROR

ØØ571  ØØØØ   UNHANG,  Ø
ØØ572  ØØØØ   BACKAC,  Ø
ØØ573  ØØØØ   BACKLK,  Ø
ØØ574  Ø227   BACKPC,  VBACKG
       Ø524   VHANG=   HANG
                       IFNZRO  VHANG-Ø524        <←← CHANGE LOADER!>
ØØ575  Ø353
ØØ576  5344
ØØ577  7576
       Ø6ØØ            PAGE
```

The FRTS /P option provides a mechanism whereby the core image generated from a FORTRAN program may be punched onto paper tape in binary loader format. This permits the loader image to be executed on a hardware configuration that does not include mass-storage devices. To use the /P option, specify /P to FRTS and assign a device or file as FORTRAN I/O unit 9. Assigning the paper tape punch as unit 9 causes the image to be punched out directly; however, it may be desirable to direct the binary output to an intermediate file for later transfer to paper tape via OS/9 PIP. In any event, FRTS returns to the monitor once the core image has been transferred.

The output file is a binary image of memory locations ØØØØØ to Ø7577 and 1ØØØØ up to the highest location used by the FORTRAN load. The content of each field is punched separately with its own checksum and leader/trailer.

With the BIN loader resident in field Ø, load the binary tape produced under the /P option by reading each segment separately and verifying the checksum as each memory field is loaded. When all segments have been read into memory, start execution at location ØØ2ØØ. The following restrictions apply:

1. OS/8 device handlers which have been assigned FORTRAN I/O unit numbers are not necessarily punched out. For this reason, I/O unit assignments other than in the form /n=m should be avoided.

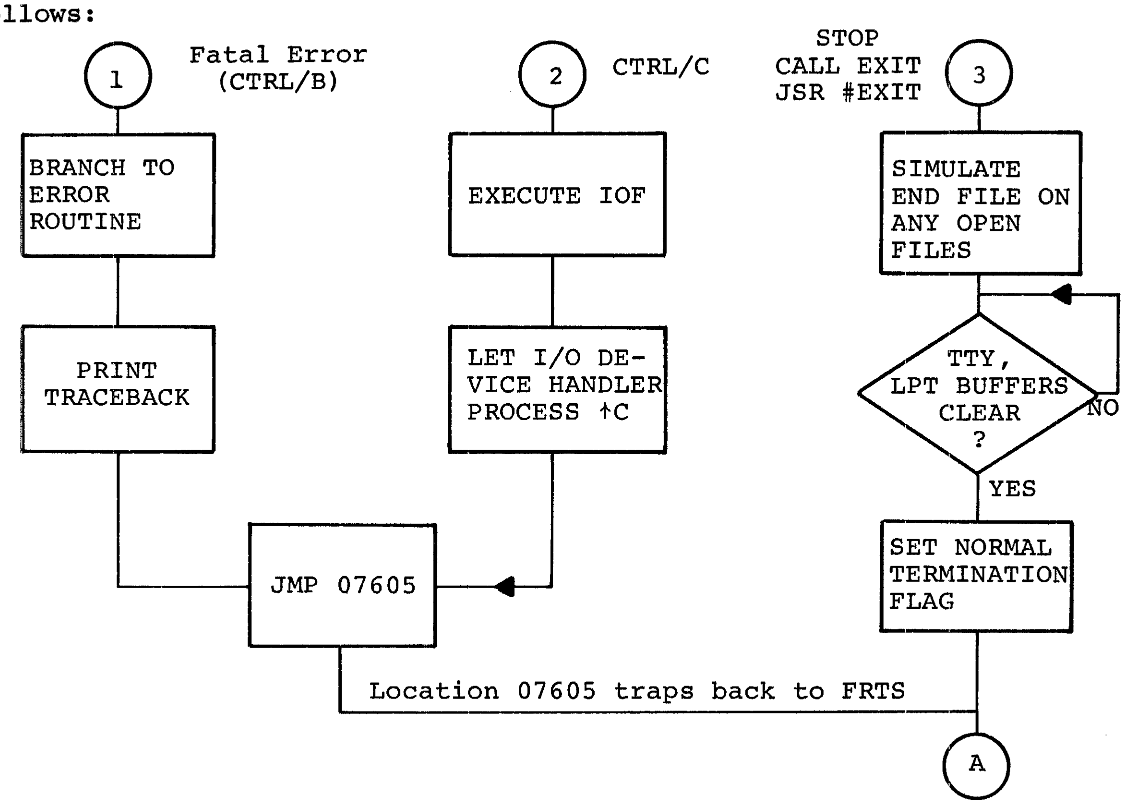
2. With respect to the presence of an FPP and/or EAE, the configuration on which the image is punched must be identical to the configuration on which it is to be run. If the punching configuration contains hardware that is absent from the target configuration, this hardware must be disabled under FRTS. If the target configuration contains hardware that is absent from the punching configuration, the extraneous hardware will not be used.

3. The statements STOP and CALL EXIT cause a core load produced under the /P option to halt. Any fatal error flagged during punching or execution causes error traceback followed by a halt. Do not press CONTinue in response to either of these machine halts.

A FORTRAN IV program is terminated in one of three ways:

1. A fatal error condition is flagged (CTRL/B) is processed as a fatal error.
2. CTRL/C is recognized, or the CPU is halted and re-started in 07600.
3. A STOP, CALL EXIT, or (under RALF) JSR #EXIT statement is executed.

The sequence of events that results in program termination proceeds as follows:




At point A, FRTS executes the following operations.

1. Read termination routine into memory.
2. Read OS/8 field 0 resident from block 37 of SYS.
3. Jump into termination routine at location 17400.
4. Restore normal content of locations 07600 and 07605 (in OS/8 resident).
5. If configuration is an in-core TD8E DECtape system, restore second part of TD8E handler from n7600 to 27600.
6. Wait for TTY to finish all pending I/O. If BATCH is running, print LF on TTY and LPT.
7. If normal termination flag is set, close any output files that were opened by the FRTS loader.
8. Return to OS/8 monitor via location 07605.

```
        6600  FPPKG=   .                   /FOR EAE OVERLAY

              /23-BIT FLOATING PT INTERPRETER
              /W.J. CLOGHER, MODIFIED BY R.LARY FOR FORTRAN

06600   0000  LPBUF2, ZBLOCK  16
06616   7160          LPBUF3

06617   0000  ALIBMP, 0                    /*K* UTILITY SUBROUTINE
06620   7240          STA
06621   1044          TAD     ACX
06622   3044          DCA     ACX
06623   4542          JMS I   [ALI
06624   5617          JMP I   ALIBMP

              /FLOATING MULTIPLY-DOES 2 24X12 BIT MULTIPLIES
06625   4777  DDMPY,  JMS I   (DARGET
06626   7410          SKP
06627   4776  FFMPY,  JMS I   (ARGET   /GET OPERAND
06630   4304          JMS     MDSET    /SET UP FOR MPY-OPX IN AC ON RETN.
06631   1044          TAD     ACX      /DO EXPONENT ADDITION
06632   3044          DCA     ACX      /STORE FINAL EXPONENT
06633   3304          DCA     MDSET    /ZERO TEM STORAGE FOR MPY ROUTINE
06634   3054          DCA     AC2
06635   1045          TAD     ACH      /IS FAC=0?
06636   7650          SNA     CLA
06637   3044          DCA     ACX      /YES-ZERO EXPONENT
06640   4334          JMS     MP24     /NO-MULTIPLY FAC BY LOW ORDER OPR.
06641   1056          TAD     OPH      /NOW MULTIPLY FAC BY HI ORDER MULT
06642   3057          DCA     OPL
06643   4334          JMS     MP24
06644   1054          TAD     AC2      /STORE RESULT BACK IN FAC
06645   3046          DCA     ACL      /LOW ORDER
06646   1304          TAD     MDSET    /HIGH ORDER
06647   3045          DCA     ACH
06650   1045          TAD     ACH      /DO WE NEED TO NORMALIZE?
06651   7004          RAL
06652   7710          SPA     CLA
06653   4217          JMS     ALIBMP   /YES-DO IT FAST
06654   1053          TAD     AC1
06655   7710          SPA CLA          /CHECK OVERFLOW WORD
06656   2046          ISZ     ACL      /HIGH BIT ON - ROUND RESULT
06657   5265          JMP     MDONE
06660   2045          ISZ     ACH      /LOW ORDER OVERFLOWED - INCREMENT
06661   1045          TAD     ACH
06662   7510          SPA              /CHECK FOR OVERFLOW TO 4000 0000
06663   5775          JMP I   (SHR1    /WE HANDLE A SIMILIAR CASE IN
06664   7200          CLA
```

```
06665  3053  MDONE,  DCA      AC1     /ZERO OVERFLOW WD(DO I NEED THIS???
06666  2333          ISZ      MSIGN   /SHOULD RESULT BE NEGATIVE?
06667  7410          SKP              /NO
06670  4543          JMS I    [FFNEG  /YES-NEGATE IT
06671  1045          TAD      ACH
06672  7650          SNA CLA          /A ZERO AC MEANS A ZERO EXPONENT
06673  3044          DCA      ACX
06674  1021          TAD      DFLG
06675  7740          SMA SZA CLA      /D.P. INTEGER MODE?
06676  1044          TAD      ACX     /WITH ACX LESS THAN 0?
06677  7450          SNA
06700  5476          JMP I    FPNXT   /NO - RETURN
06701  7040          CMA
06702  4541          JMS I    [ACSR   /UN-NORMALIZE RESULT
06703  5476          JMP I    FPNXT   /RETURN
```



```
                /MDSET-SETS UP SIGNS FOR MULTIPLY AND DIVIDE
                /ALSO SHIFTS OPERAND ONE BIT TO THE LEFT.
                /EXIT WITH EXPONENT OF OPERAND IN AC FOR EXPONENT
                /CALCULATION-CALLED WITH ADDRESS OF OPERAND IN AC AND
                /DATA FIELD SET PROPERLY FOR OPERAND.

06704  0000  MDSET,  0
06705  7344          CLA CLL CMA RAL /SET SIGN CHECK TO -2
06706  3333          DCA      MSIGN
06707  1056          TAD      OPH     /IS OPERAND NEGATIVE?
06710  7700          SMA      CLA
06711  5314          JMP      .+3     /NO
06712  4774          JMS I    (OPNEG  /YES-NEGATE IT
06713  2333          ISZ      MSIGN   /BUMP SIGN CHECK
06714  1057          TAD      OPL     /AND SHIFT OPERAND LEFT ONE BIT
06715  7104          CLL      RAL
06716  3057          DCA      OPL
06717  1056          TAD      OPH
06720  7004          RAL
06721  3056          DCA      OPH
06722  3053          DCA      AC1     /CLR. OVERFLOW WORF OF FAC
06723  1045          TAD      ACH     /IS FAC NEGATIVE
06724  7700          SMA      CLA
06725  5331          JMP      LEV     /NO-GO ON
06726  4543          JMS I    [FFNEG  /YES-NEGATE IT
06727  2333          ISZ      MSIGN   /BUMP SIGN CHECK
06730  7000          NOP              /MAY SKIP
06731  1055  LEV,    TAD      OPX     /EXIT WITH OPERAND EXPONENT IN AC
06732  5704          JMP I    MDSET
06733  0000  MSIGN,  0
```

```
                /24 BIT BY 12 BIT MULTIPLY.  MULTIPLIER IS IN OPL
                /MULTIPLICAND IS IN ACH AND ACL
                /RESULT LEFT IN MDSET,AC2, AND AC1

06734  0000  MP24,   0
06735  1373          TAD     (-14     /SET UP 12 BIT COUNTER
06736  3055          DCA     OPX
06737  1057          TAD     OPL      /IS MULTIPLIER=0?
06740  7440          SZA
06741  5345          JMP     MPLP1    /NO-GO ON
06742  3053          DCA     AC1      /YES-INSURE RESULT=0
06743  5734          JMP I   MP24     /RETURN
06744  1057  MPLP,   TAD     OPL      /SHIFT A BIT OUT OF LOW ORDER
06745  7010  MPLP1,  RAR              /OF MULTIPLIER AND INTO LINK
06746  3057          DCA     OPL
06747  7420          SNL              /WAS IT A 1?
06750  5356          JMP     MPLP2    /NO - 0 - JUST SHIFT PARTIAL PROD
06751  1054          TAD     AC2      /YES-ADD MULTIPLICAND TO PARTIAL
06752  1046          TAD     ACL      /LOW ORDER
06753  3054          DCA     AC2
06754  7024          CML RAL          /*K* NOTE THE "SNL" 5 WORDS BACK!
06755  1045          TAD     ACH      /HI ORDER
06756  1304  MPLP2,  TAD     MDSET
06757  7010          RAR              /NOW SHIFT PARTIAL PROD. RIGHT 1
06760  3304          DCA     MDSET
06761  1054          TAD     AC2
06762  7010          RAR
06763  3054          DCA     AC2
06764  1053          TAD     AC1
06765  7010          RAR              /OVERFLOW TO AC1
06766  3053          DCA     AC1
06767  2055          ISZ     OPX      /DONE ALL 12 MULTIPLIER BITS?
06770  5344          JMP     MPLP     /NO-GO ON
06771  5734          JMP I   MP24     /YES-RETURN
06773  7764
06774  7203
06775  7110
06776  6514
06777  6460
       7000          PAGE
```



```
                /DIVIDE-BY-ZERO ROUTINE - MUST BE AT BEGINNING OF PAGE

07000  2035  DBAD,   ISZ     FATAL    /DIVIDE BY 0 NON-FATAL
07001  4434          JMS I   ERR      /GIVE ERROR MSG
07002  1200          TAD     DBAD
07003  3044          DCA     ACX      /RETURN A VERY LARGE POSITIVE NUM
07004  7332          AC2000
07005  5325          JMP     FD
```

```
        /FLOATING DIVIDE - USES DIVIDE-AND-CORRECT METHOD

07006 4777 DDDIV,  JMS I  (DARGET
07007 7410         SKP
07010 4776 FFDIV,  JMS I  (ARGET  /GET OPERAND
07011 4775         JMS I  (MDSET  /GO SET UP FOR DIVIDE-OPX IN AC
07012 7041         CMA    IAC     /NEGATE EXP. OF OPERAND
07013 1044         TAD    ACX     /ADD EXP OF FAC
07014 3044         DCA    ACX     /STORE AS FINAL EXPONENT
07015 1056         TAD    OPH     /NEGATE HI ORDER OP. FOR USE
07016 7141         CLL CMA IAC    /AS DIVISOR
07017 3056         DCA    OPH
07020 4231         JMS    DV24    /CALL DIV.--(ACH+ACL)/OPH
07021 1046         TAD    ACL     /SAVE QUOT. FOR LATER
07022 3053         DCA    AC1
07023 1057         TAD    OPL
07024 7650         SNA CLA
07025 5327         JMP    DVL2    /AVOID MULTIPLYING BY Ø
07026 1374         TAD    (-15    /SET COUNTER FOR 12 BIT MULTIPLY
07027 3231         DCA    DV24    /TO MULTIPLY QUOT. OF DIV. BY
07030 5267         JMP    DVLP1   /LOW ORDER OF OPERAND (OPL)

        /DIVIDE ROUTINE - (ACH,ACL)/OPH = ACL REMAINDER REM

07031 0000 DV24,   0
07032 1045         TAD    ACH     /CHECK THAT DIVISOR IS .GT.
07033 1056         TAD    OPH     /DIVISOR IN OPH (NEGATIVE)
07034 7630         SZL    CLA     /IS IT?
07035 5200         JMP    DBAD    /NO-DIVIDE OVERFLOW
07036 1374         TAD    (-15    /YES-SET UP 12 BIT LOOP
07037 3054         DCA    AC2
07040 5251         JMP    DV1     /GO BEGIN DIVIDE
07041 1045 DV2,    TAD    ACH     /CONTINUE SHIFT OF FAC LEFT
07042 7004         RAL
07043 3045         DCA    ACH     /RESTORE HI ORDER
07044 1045         TAD    ACH     /NOW SUBTRACT DIVISOR FROM HI ORDER
07045 1056         TAD    OPH     /DIVIDEND
07046 7430         SZL            /GOOD SUBTRACT?
07047 3045         DCA    ACH     /YES-RESTORE HI DIVIDEND
07050 7200         CLA            /NO-DON'T RESTORE--OPH.GT.ACH
07051 1046 DV1,    TAD    ACL     /SHIFT FAC LEFT 1 BIT-ALSO SHIFT
07052 7004         RAL            /1 BIT OF QUOT. INTO LOW ORD OF ACL
07053 3046         DCA    ACL
07054 2054         ISZ    AC2     /DONE 12 BITS OF QUOT?
07055 5241         JMP    DV2     /NO-GO ON
07056 5631         JMP I  DV24    /YES-RETN W/AC2=Ø
```



```
        /DIVIDE ROUTINE CONTINUED

07057 3057 MP12L,  DCA    OPL     /STORE BACK MULTIPLIET
07060 1054         TAD    AC2     /GET PRODUCT SO FAR
07061 7420         SNL            /WAS MULTIPLIER BIT A 1?
07062 5265         JMP    .+3     /NO-JUST SHIFT THE PARTIAL PRODUCT
07063 7100         CLL            /YES-CLEAR LINK AND ADD MULTIPLICA
07064 1046         TAD    ACL     /TO PARTIAL PRODUCT
07065 7010         RAR            /SHIFT PARTIAL PRODUCT-THIS IS HI
07066 3054         DCA    AC2     /RESULT-STORE BACK
07067 1057 DVLP1,  TAD    OPL     /SHIFT A BIT OUT OF MULTIPLIER
07070 7010         RAR            /AND A BIT OR RESLT. INTO IT (LO
07071 2231         ISZ    DV24    /DONE ALL BITS?
```

```
07072  5257            JMP     MP12L   /NO-LOOP BACK
07073  7141            CLL CIA         /YES-LOW ORDER PROD. OF QUOT. X
07074  3046            DCA     ACL     /NEGATE AND STORE
07075  7024            CML     RAL     /PROPAGATE CARRY
07076  1054            TAD     AC2     /NEGATE HI ORDER PRODUCT
07077  7161            STL CIA
07100  1045            TAD     ACH     /COMPARE WITH REMAINDER OF FIRST
07101  7430            SZL             /WELL?
07102  5331            JMP     DVOPS   /GREATER THAN REM.-ADJUST QUOT OF
07103  3045            DCA     ACH     /OK - DO (REM - (Q*OPL)) / OPH
07104  4231    DVL3,   JMS     DV24    /DIVIDE BY OPH (HI ORDER OPERAND)
07105  1053    DVL1,   TAD     AC1     /GET QUOT. OF FIRST DIV.
07106  7500            SMA             /IF HI ORDER BIT SET-MUST SHIFT 1
07107  5325            JMP     FD      /NO-ITS NORMALIZED-DONE
07110  7100    SHR1,   CLL
07111  2046            ISZ     ACL     /ROUND AND SHIFT RIGHT ONE
07112  7410            SKP
07113  7001            IAC             /DOUBLE PRECISION INCREMENT
07114  7010            RAR
07115  3045            DCA     ACH     /STORE IN FAC
07116  1046            TAD     ACL     /SHIFT LOW ORDER RIGHT
07117  7010            RAR
07120  3046            DCA     ACL     /STORE BACK
07121  2044            ISZ     ACX     /BUMP EXPONENT
07122  7000            NOP
07123  1045            TAD     ACH
07124  5306            JMP     DVL1+1  /IF FRACT WAS 77777777 WE MUST
07125  3045    FD,     DCA     ACH     /STORE HIGH ORDER RESULT
07126  5773            JMP I   (MDONE  /GO LEAVE DIVIDE

07127  3046    DVL2,   DCA     ACL     /COME HERE IF LOW-ORDER QUO=0
07130  5304            JMP     DVL3    /SAVE SOME TIME
```



```
               /ROUTINE TO ADJUST QUOTINET OF FIRST DIVIDE (MAYBE) WHEN
               /REMAINDER OF THE FIRST DIVIDE IS LESS THAN QUOT*OPL

07131  7041    DVOPS,  CMA     IAC     /NEGATE AND STORE REVISED REMAINDER
07132  3045            DCA     ACH
07133  7100            CLL
07134  1056            TAD     OPH
07135  1045            TAD     ACH     /WATCH FOR OVERFLOW
07136  7420            SNL
07137  5344            JMP     DVOP1   /OVERFLOW-DON'T ADJUST QUOT. OF 1
07140  3045            DCA     ACH     /NO OVERFLOW-STORE NEW REM.
07141  7040            CMA             /SUBTRACT 1 FROM QUOT OF
07142  1053            TAD     AC1     /FIRST DIVIDE
07143  3053            DCA     AC1
07144  7300    DVOP1,  CLA     CLL
07145  1045            TAD     ACH     /GET HI ORD OF REMAINDER
07146  7450            SNA             /IS IT ZERO?
07147  3046    DVOP2,  DCA     ACL     /YES-MAKE WHOLE THING ZERO
07150  3045            DCA     ACH
07151  4231            JMS     DV24    /DIVIDE EXTENDED REM. BY HI DIVISOR
07152  1046            TAD     ACL     /NEGATE THE RESULT     /
07153  7141            CLL CMA IAC
07154  3046            DCA     ACL
07155  7420            SNL             /IF QUOT. IS NON-ZERO, SUBTRACT
07156  7040            CMA             /ONE FROM HIGH ORDER QUOT.
07157  5305            JMP     DVL1    /GO TO IT
```

```
07160  0000  LPBUF3, ZBLOCK  12
07172  7316          LPBUF4
07173  6665
07174  7763
07175  6704
07176  6514
07177  6460
       7200          PAGE
```



```
              /"NRMFAC" AND "OPNEG" MUST BE AT 0 AND 3 ON PAGE

07200  3053  NRMFAC, DCA     AC1     /KILL OVERFLOW BIT
07201  4271          JMS     FFNOR
07202  5476          JMP I   FPNXT

07203  0000  OPNEG,  0               /ROUTINE TO NEGATE OPERAND
07204  1057          TAD     OPL     /GET LOW ORDER
07205  7141          CLL CMA IAC     /NEGATE AND STORE BACK
07206  3057          DCA     OPL
07207  7024          CML     RAL     /PROPAGATE CARRY
07210  1056          TAD     OPH     /GET HI ORDER
07211  7141          CLL CMA IAC     /NEGATE AND STORE BACK
07212  3056          DCA     OPH
07213  5603          JMP I   OPNEG
             /
             /FLOATING SUBTRACT AND ADD
             /
07214  4777  FFSUB,  JMS I   (ARGET  /PICK UO THE OP.
07215  4203          JMS     OPNEG   /NEGATE OPERAND
07216  7410          SKP
07217  4777  FFADD,  JMS I   (ARGET  /PICK UP OPERAND
07220  1056          TAD     OPH     /IS OPERAND = 0
07221  7650          SNA     CLA
07222  5476          JMP I   FPNXT   /YES-DONE
07223  1045          TAD     ACH     /NO-IS FAC=0?
07224  7650          SNA     CLA
07225  5236          JMP     DOADD   /YES-DO ADD
07226  1044          TAD     ACX     /NO-DO EXPONENT CALCULATION
07227  7141          CLL CMA IAC
07230  1055          TAD     OPX
07231  7540          SMA     SZA     /WHICH EXP. GREATER?
07232  5243          JMP     FACR    /OPERANDS-SHIFT FAC
07233  7041          CMA     IAC     /FAC'S-SHIFT OPERAND=DIFFRNCE+1
07234  4246          JMS     OPSR
07235  4541          JMS I   [ACSR   /SHIFT FAC ONE PLACE RIGHT
07236  1055  DOADD,  TAD     OPX     /SET EXPONENT OF RESULT
07237  3044          DCA     ACX
07240  4537          JMS I   [OADD   /DO THE ADDITION
07241  4271          JMS     FFNOR   /NORMALIZE RESULT
07242  5476          JMP I   FPNXT   /RETURN
07243  4541  FACR,   JMS  I  [ACSR   /SHIFT FAC = DIFF.+1
07244  4246          JMS     OPSR    /SHIFT OPR. 1 PLACE
07245  5236          JMP     DOADD   /DO ADDITION
```

```
                /OPERAND SHIFT RIGHT-ENTER WITH POSITIVE COUNT-1 IN AC

07246  0000  OPSR,   0
07247  7040          CMA              /- (COUNT+1) TO SHIFT COUNTER
07250  3052          DCA     AC0
07251  1056  LOP2,   TAD     OPH      /GET SIGN BIT
07252  7100          CLL              /TO LINK
07253  7510          SPA
07254  7020          CML              /WITH HI MANTISSA IN AC
07255  7010          RAR              /SHIFT IT RIGHT, PROPAGATING SIGN
07256  3056          DCA     OPH      /STORE BACK
07257  1057          TAD     OPL
07260  7010          RAR
07261  3057          DCA     OPL      /STORE LO ORDER BACK
07262  2055          ISZ     OPX      /INCREMENT EXPONENT
07263  7000          NOP
07264  2052          ISZ     AC0      /DONE ALL SHIFTS?
07265  5251          JMP     LOP2     /NO-LOOP
07266  7010          RAR              /SAVE 1 BIT OF OVERFLOW
07267  3054          DCA     AC2      /IN AC2
07270  5646          JMP I   OPSR     /YES-RETN.

07271  0000  FFNOR,  0                /ROUTINE TO NORMALIZE THE FAC
07272  1045          TAD     ACH      /GET THE HI ORDER MANTISSA
07273  7450          SNA              /ZERO?
07274  1046          TAD     ACL      /YES-HOW ABOUT LOW?
07275  7450          SNA
07276  1053          TAD     AC1      /LOW=0, IS OVRFLO BIT ON?
07277  7650          SNA     CLA
07300  5313          JMP     ZEXP     /#=0-ZERO EXPONENT
07301  7332  NORMLP, CLA CLL CML RTR  /NOT 0-MAKE A 2000 IN AC
07302  1045          TAD     ACH      /ADD HI ORDER MANTISSA
07303  7440          SZA              /HI ORDER = 6000
07304  5307          JMP     .+3      /NO-CHECK LEFT MOST DIGIT
07305  1046          TAD     ACL      /YES-6000 OK IF LOW=0
07306  7640          SZA     CLA
07307  7710          SPA     CLA      /2,3,4,5,ARE LEGAL LEFT MOST DIGS.
07310  5314          JMP     FFNORR   /FOR NORMALIZED #-(+2000=4,5,6,7)
07311  4534          JMS I   [AL1BMP  /SHIFT AC LEFT AND BUMP ACX DOWN
07312  5301          JMP     NORMLP   /GO BACK AND SEE IF NORMALIZED
07313  3044  ZEXP,   DCA     ACX
07314  3053  FFNORR, DCA     AC1      /DONE W/NORMALIZE - CLEAR AC1
07315  5671          JMP I   FFNOR    /RETURN

07316  0000  LPBUF4, ZBLOCK  60
07376  7400          LPBUFE
07377  6514
       7400          PAGE
```

CHAPTER 5

# LIBRA AND FORLIB

The binary output of an assembly under RALF is called a RALF module. Every RALF module consists of an External Symbol Dictionary (or ESD) and associated text. The ESD lists all global symbols defined in the assembly, while the text contains the actual binary output along with relocation data.

There are three major classes of global symbols. Entry points are global symbols defined in a module and referenced by code in other modules. Thus, entry points include the names of all modules and the names of all globally callable subroutines within modules. Externs are global symbols that are referenced in a module but not defined in that module. For example, the entry point of module A would appear as an extern if referenced in module B. The COMMON area comprises a third class of global symbols including all global symbols which define COMMON.

A FORTRAN IV library is a specially formatted file, created with LIBRA, consisting of a library catalog (which lists section names and entry points of library modules) and a set of RALF modules, perhaps interspersed with empty subfiles. The loader uses one such library, specified by the user, to resolve externs while building a loader image file. The general structure of a FORTRAN IV library is:

| | | | | | |
|---|---|---|---|---|---|
| CATALOG | MODULE | FREE AREA | MODULE | MODULE | etc. |

LIBRA is a very simple program, basically a file-to-file copy inside several nested loops. The outer loop begins at START, and calls the command decoder for specification of the library and input files. If no library is specified, the previous library name is used (initially this is SYS:FORLIB.RL). If a new name is given, but no extension is specified, .RL is forced. A check is made to verify that the specified library is on a file-structured device, and the handler is FETCHed.

At ZTEST, the /Z switch is tested. If it was set, control passes to NEWLIB to create a new library. Otherwise, an attempt is made to find an old library of the specified name on the device. If it fails, control passes to NEWLIB. Otherwise, the catalog of the old library is read and scanned to determine the starting block of available space. This is stored at LAVAIL. Control then passes to GETINF to begin reading input files.

If /Z was set, or the specified library isn't found, a new library is entered at NEWLIB, and an empty catalog is written. Control passes to GETINF. There, a check is made to determine whether input is presently coming from another library. If it is, control passes to INLIB to obtain the next module from the library. Otherwise, the next input file is obtained from the command decoder area in field 1, and if one exists, control passes to FTCHIN to load the handler. If there is none, the /C switch is tested. If it is not set, control is passed to LCLOSE to close the library. If it is set, however, the command decoder is recalled to obtain a continuation of the preceding input line, and control returns to NXTINF to look in the command decoder area.

At FTCHIN, the unit, starting block, and length of the next input file are obtained from the command decoder area, the appropriate device handler is fetched, and at LUKMOD, the input file is read to ensure that it is either a module or a library. If a library, control passes to GOTLIB, which sets INLSW and goes to INLIB to obtain the first module from the library. Otherwise, the length is checked against the available length in the library, to ensure that this module can be fit in, and control goes to NXTEBK to read the ESD.

At INLIB, the catalog of the library being input is read, and scanned until a module is found with a starting block greater than the starting block of the last input module (in the case of the first module in a library, MODBLK, which normally contains the starting block of a module, contains the starting block of the library, so this scan yields the starting block of the first module in the library). When the next module has been found, control returns to LUKMOD to check the length of the module against the available length in the library.

At NXTEBK, the end of the input module is scanned for entry point and section names. Whenever one is found, the catalog of the output library is scanned for a matching name. If a match is found, control passes to GOTMAT, which prints the duplicated name, and if the /I switch is set, asks the operator which name to keep. If he types N, for new, control passes to DLETO to delete the old name. Otherwise, control is passed to ESDLND to find the next entry point or section name in the input. If /I is not set, /R is tested. If it is not set, control is passed to ESDLND. If it is, control flows into DELTO, where the old name is cleared, and the rest of the catalog is scanned to find the first available name slot. Control then passes to INSERT.

If no match was found, the /I switch is tested. If it was set, the operator is asked whether to include the name. If he types, N, for no, control is passed to ESDLND. Otherwise, or if /I was not set, a pointer is set up for the new name, and control passes to INSERT, where the new name is added to the catalog.

When the entire ESD has been scanned, INCLUD is tested to determine whether any name has been included in the catalog, and assuming at least one has, the module is copied into the library, and LAVAIL is updated to indicate the next available block in the library. Control returns to GETINF for another module.

LCLOSE receives control whenever the end of the input file string is reached and /C is not set. Here, any remaining changes in the library catalog are written, and if a new library was entered, it is closed. Control passes to CATLST, to create a catalog listing. The second output file, if any was specified, is opened, a title is output to it, and at PRCAT, the entire contents of the catalog are listed. When this process is complete, the output file is closed, and control returns to start for more command decoder input.

User-coded modules may be added to the system library or incorporated in a new library provided that entry points, variable storage allocations, calling sequences, error conditions and the like are handled with care.

Every library module must have a unique section (and entry) name(s). The library supplied by DEC uses the character # before names where duplication in the FORTRAN program may be possible. Note that this character is acceptable to RALF, but is illegal in a FORTRAN source. If more than one entry is required to the routine, they should be listed as such using the pseudo-op ENTRY before they are encountered as tags in the code. Thus, if a double precision tangent routine is being written, it may be helpful to have an entry for a double precision co-tangent calculation also. Appropriate code would be:

```
SECT DTAN
JA #DTAN
ENTRY DCOT
JA #DCOT
:
#DCOT,
:
#DTAN,
```

When routines will handle double precision or complex values, allocate six words for their storage. Such routines can switch between the STARTF (3 word format) and STARTE (6 word format) pseudo-ops as required, being careful to define variables of the proper length to keep track of temporary locations.

All user-written library routines are called by a JSR in STARTF mode. Depending on the type of function, the routine must be coded to exit as follows in order to return the result to the program:

```
Single precision                    Answer in AC in STARTF mode
(integer, real and logical)

          FLDA ANSWER               /In STARTF mode
          JA RETURN                 /3 word result

Double precision:                   Answer in AC in STARTE mode

          FLDA ANSWER               /In STARTE mode
          JA RETURN                 /6 word result

Complex:                            Answer in location #CAC in
                                    STARTE mode

          EXTERN #CAC               /Real part in first 3 words
          STARTE                    /Imaginary in last 3 words
          FLDA ANSWER               /Exit in STARTE mode
          FSTA #CAC                 /6 word result
          JA RETURN
```

Routines should conform to the FPP FORTRAN calling sequence. An example of that sequence follows:

```
          SECT DTAN                 /Sector name
          JA   #DTAN                /Jump to Start of Function
          TEXT +DTAN +              /6 characters for trace
                                    /back feature must be
                                    /immediately before index
                                    /register assignment.
DTANXR,   SETX XRDTAN               /This tag referenced when
                                    /returning to reset base
                                    /page and index registers
          SETB BPDTAN               /if this routine called.

BPDTAN,   F Ø.Ø                     /3 words each
XRDTAN,   F Ø.Ø                     /These locations may be
                                    /used for temporary storage or
          ORG 10*3+BPDTAN           /If this routine is called,
                                    /will set up return to it.
          FNOP
          JA DTANXR
          Ø
DTNRTN,   JA  .                     /Return to calling program
          BASE Ø                    /Still on caller's base page
#DTAN,    STARTD                    /Start of subroutine
          FLDA 10*3                 /Get jump to caller's return jump
          FSTA DTNRTN               /Save for return from this routine
```

```
FLDA Ø                      /Get next location in caller's
                            /routine (pointer to argument list)
SETX XRDTAN                 /Change index registers to this
                            /routine's
SETB BPDTAN                 /Change base page to this routine's
BASE BPDTAN                 /Change base page to this routine's
FSTA TEMP                   /Save pointer
LDX 1,1                     /Set up XRL
FLDA% TEMP,1                /Get address of argument list
FSTA TEMP                   /Save it
STARTE                      /A double precision routine
FLDA% TEMP                  /Get variable
FSTA TEMP                   /Save variable
     .
     .
     .                      /Calculate result
     .
     .
     .
     .
FLDA ANSWER                 /Load answer
JA DTNRTN                   /Exit
```

The following conventions must be observed to return to the calling program at the correct location, to permit the error trace back feature to function properly, and to preserve index registers and base page integrity.

Locations Ø and 3Ø of the called (user-coded) program are determined by a statement in the form ORG 10*3+BPAGE which must be followed by a two-word jump to the index register and base page assignment instructions JA BPXR. In the above example, the code is:

```
ORG 10*3+BPDATN
FNOP
JA DTANXR
```

By saving the contents of location 30 of the calling program (FLDA 10*3,FSTA RETURN) for the return exit, the called program executes (when control is returned to it) a JA BPXR to its base page and index register assignment statement. In the calling program this resets the index registers and base page and then returns to execute the instruction in the calling program. In the tangent example above, the code is:

```
FLDA 10*3
FSTA DTNRTN
```

which creates the instruction

```
JA xxx
```

at the tag DTNRTN, where xxx is the location in the calling routine whose function corresponds to DTANXR in DTAN.

When called, the routine must assign its own base page and index registers (SETX XROWN, SETB BPOWN). If arguments are to be passed to the called routine, a scheme such as illustrated above permits any number of arguments to be passed from the calling program and saved on the base page of the called program, in this case just two arguments.

The corresponding code for the calling program (as created by the compiler) is:

```
EXTERN DTAN
JSR DTAN
JA  .+4                          /Jump past all arguments
JA  A                            /Argument
  .
  .
  .
FSTA Q                           /Save result in some variable
```

The FORTRAN for such code is:

```
Q = DTAN (A)
```

The calling sequence is also discussed in Chapter 2.

To permit the error trace back feature to function properly, a TEXT statement followed by a six alphanumeric character name is required immediately before the index register and base page assignment statements. Thus, if the cotangent routine includes a JSR TAN and an unacceptable argument is passed to the tangent function, the trace back indicates the location of the problem by a sequence such as:

```
DIV0 MAIN
ARGUMENT
7777 SIN
0000 TAN
0000 COT
0007 MAIN
```

(Line numbers are not relevant in RALF modules such as TAN and SIN: they are meaningful only in FORTRAN source programs.)

A new library routine may call other new or existing library routines as part of its function, as well as the error handling function of the run-time system. To invoke the error message program, code such as the following is required:

```
         EXTERN    #ARGER
MERROR,  TRAP4     #ARGER
```

Then any condition encountered in the program that is an error should jump to MERROR. For example, if an argument of ≤Ø is illegal, it could be examined and handled as follows:

```
FLDA%  ARG2
JLE    MERROR      /<Ø error
FSTA   NEXT        / Save non-zero value
```

In this case, the TRAP4 #ARGER at MERROR will produce the message BAD ARG DTAN nnnn followed by traceback and program termination.
If a new library routine would like to use an existing library routine, a JSR to that routine is required. The sequence for passing arguments is:

```
EXTERN    ATAN2
JSR       ATAN2
JA        .+6         /Execute upon exit from
JA        A           /1st arg
JA        B           /2nd arg
FSTA      ANSWER      /Save answer
```

The arguments must be referenced in the order expected by the called routine and must agree in number and type. The following routines can be used in this manner:

| ROUTINE | ARGUMENTS PASSED |
|---|---|
| AMOD | Address of X then Y |
| SQRT | Address of X |
| ALOG10 | Address of X |
| EXP | Address of X |
| SIN | Address of X |
| COS | Address of X |
| TAN | Address of X |
| SIND | Address of X |
| COSD | Address of X |
| TAND | Address of X |
| ASIN | Address of X |
| ACOS | Address of X |
| ATAN | Address of X |
| ATAN2 | Address of X then Y |
| SINH | Address of X |
| COSH | Address of X |
| TANH | Address of X |
| DMOD | Address of X then Y |
| DSIGN | Address of X then Y |
| DSIN | Address of X |
| DLOG | Address of X |
| DSQRT | Address of X |
| DCOS | Address of X |
| DLOG10 | Address of X |
| DATAN2 | Address of X then Y |
| DATAN | Address of X |
| DEXP | Address of X |
| CMPLX | Address of X |
| CSIN | Address of X |
| CCOS | Address of X |
| REAL | Address of X |
| AIMAG | Address of X |
| CONJG | Address of X |
| CEXP | Address of X |
| CLOG | Address of X |
| CABS | Address of X |
| CSQRT | Address of X |

For real and double precision routines, the result is returned via the FAC (3 or 6 words, respectively). For complex routines, the result is returned in #CAC (6 words).

The TAN function from FORLIB is included here as an example of the requirements just discussed. The TAN function calls two external functions, has the standard calling sequence, and contains an error condition exit.

```
/       T A N
/       - - -
/
/SUBROUTINE      TAN(X)
        SECT     TAN              /SECTION NAME
        JA       #TAN             /JUMP AROUND BASE PAGE

        EXTERN   #ARGER
TANER,  TRAP4    #ARGER           /EXIT TO ERROR MESSAGE HANDLER
        TEXT     +TAN   +         /FOR ERROR TRACE BACK
TANXR,  SETX     XRTAN            /START OF FORMAL CALLING SEQUENCE
        SETB     BPTAN
BTAN,   FNOP                      /START OF BASE PAGE
        Ø
        Ø
XRTAN,  F Ø.Ø                     /INDEX REGISTERS
TAN1,   F Ø.Ø                     /LOCATIONS 21-42 OCTAL AVAILABLE
                                  /FOR USER STORAGE
TAN2,   F Ø.Ø
        ORG      1Ø+3+BPTAN       /SET UP FOR A RETURN
                                  /TO THIS ROUTINE
        FNOP
        JA       TANXR            /JUMP TO XR + RP ASSIGNMENT
        Ø
TANRTN, JA       .
        BASE     Ø
#TAN,   STARTD
        FLDA     1Ø*3             /SAVE RETURN JUMP
        FSTA     TANRTN
        FLDA     Ø                /GET NEXT LOCATION
                                  /IN CALLING PROGRAM
        SETX     XRTAN            /SET UP FOR TAN'S INDEX REGS
        SETB     BPTAN            /SET UP FOR TAN'S BP
        BASE     BPTAN
        LDX      1,1
        FSTA     BPTAN
        FLDA%    BPTAN,1          /GET ADDRESS OF X
        FSTA     BPTAN
        STARTF
        FLDA%    BPTAN            /GET X
        JEQ      TANRTN           /IF Ø RETURN NOW
        FSTA     TAN1             /SAVE FOR A SECOND
        EXTERN   COS
        JSR      COS              /TAKE COS(X)
        JA       .+4              /JUMP AROUND ARGUMENT LIST
        JA       TAN1             /REFERENCE TO PASSED ARGUMENT
        JEQ      TANER            /COS=Ø.  A NO-NO
        FSTA     TAN2             /SAVE IT
        EXTERN   SIN
        JSR      SIN              /NOW TAKE SJN(X)
        JA       .+4              /JUMP AROUND ARGUMENT LIST
        JA       TAN1             /REFERENCE TO ARGUMENT
        FDIV     TAN2             /DIV BY COS(X)
        JA       TANRTN           /EXIT
```

The library routine ONQI illustrates many of the same conventions. This listing may also prove valuable as a guide to interfacing with the run-time system.

```
                FIELD1  ONQI            /ROUTINE TO ADD A
/HANDLER TO INTERRUPT SKIP CHAIN
/PUT THIS CODE IN FIELD 1
        0
        JMP     SETINT          /SET UP INT INITIALLY
        ISZ     ONQI            /BUMP ARGUMENT POINTER
        ISZ     INTQ+1          /BUMP INTERRUPT Q POINTER
        DCA%    INTQ+1          /STICK IOT ONTO INT Q
        TAD     XSKP            /FOLLOWED BY A SKIP
        ISZ     INTQ+1
        DCA%    INTQ+1          /ONTO INT Q
        ISZ     ONQI            /SKIP FIRST WORD OF ADDR
        ISZ     INTQ+1
ONQISW, TAD%    ONQI            /GET INT HANDLER ADDRESS
        ISZ     ONQI
        DCA%    INTADR+1        /ONTO ADDRESS STACK
        TAD     INTADR+1        /NOW MAKE JMS%
        AND     L177
        TAD     L4600
        DCA%    INTQ+1          /ONTO INT Q
        ISZ     INTADR+1
        ISZ     IQSIZE          /ROOM FOR MORE?
        JMP%    ONQI            /YES
        TAD     .-1             /NO, CLOSE OUT THE SUBR
        DCA     ONQI+1
        JMP%    ONQI
SETINT, TAD     ONQISW          /DO THIS PART ONLY ONCE
        DCA     ONQI+1
        CDF
        TAD     XSKP            /FIX UP #INT
        DCA%    XINT+1          /PUT SKIP INST. FIRST
        ISZ     XINT+1
        TAD     INTQ+1
        DCA%    XINT+1          /GET ADDR. OF USER'S ROUTINE
        ISZ     XINT+1          /ADD TO INTERRUPT CALL
        TAD     CIFCDF          /GET FIELD INSTRUCTION
/FIELD1 SECTION INSURES ITS IN FIELD 1
        DCA%    XINT+1
CIFCDF, CDF CIF 10
        JMP     ONQI+1          /BACK TO ONQI
        EXTERN  #INT
XINT,   ADDR    #INT            /POINTS TO INT RTN IN COMMON

INTQ,   ADDR    IHANDL          /MUST USE 15 BIT ADDRESS

INTADR, ADDR    IHADRS          /       "

IQSIZE, -5
XSKP,   SKP
L177,   177
L4600,  4600
        CDF CIF
        JMP%    IHANDL
IHANDL, 0
        REPEAT 16
        JMP     IHANDL-2
IHADRS, 0;0;0;0;0               /CAN SET UP 1-5 DEVICES
```

```
        ENTRY   ONQB            /USE "ENTRY" TO PERMIT
/ACCESS FROM OUTSIDE OF SECTION
/ROUTINE TO SET UP AN IDLE JOB
ONQB,   Ø
        JMP     SETBAK          /SETUP #IDLE
        TAD%    ONQB            /GET ADDRESS OF IDLE JOB
ONQBSW, ISZ     ONQB
        DCA%    BAKADR+1        /STORE ONTO BACKGROUND JOB Q
        TAD     BAKADR+1        /MAKE A JMS%
        ISZ     BAKADR+1
        AND     L177
        TAD     L46ØØ
        ISZ     BAKQ+1
        DCA%    BAKQ+1
        ISZ     BQSIZE          /MORE ROOM?
        JMP%    ONQB            /YES
        TAD     .-1             /NO, CLOSE THE DOOR
        DCA     ONQB+1
        JMP%    ONQB
SETBAK, TAD     ONQBSW          /CLOSE OFF #IDLE INITIALIZATION
        DCA     ONQB+1
        CDF
        TAD     XSKP            /FIX UP #IDLE
        DCA%    XIDLE+1         /ADD SKIP TO IDLE CALL
        TAD     BAKQ+1          /GET ADDRESS OF ROUTINE
        ISZ     XIDLE+1
        DCA%    XIDLE+1
        ISZ     XIDLE+1
        TAD     CIFCDF          /GET FIELD INSTR.
        DCA%    XIDLE+1
        CIF CDF 1Ø
        JMP     ONQB+1
        EXTERN  #IDLE           /EXTERNAL REFERENCE
XIDLE,  ADDR    #IDLE

BAKQ,   ADDR    BAKRND

BAKADR, ADDR    BHADRS

BQSIZE, -5
        CDF CIF
        JMP%    BAKRND
BAKRND, Ø
        REPEAT  6
        JMP     BAKRND-2
BHADRS, Ø;Ø;Ø;Ø;Ø               /1-5 JOBS
```

## APPENDIX A

## RALF Assembler Permanent Symbol Table

| Mnemonic | Code |
|---|---|

FPP Memory Reference Instructions

| | |
|---|---|
| FADD | 1000 |
| FADDM | 5000 |
| FDIV | 3000 |
| FLDA | 0000 |
| FMUL | 4000 |
| FMULM | 7000 |
| FSTA | 6000 |
| FSUB | 2000 |

IOT'S

| | |
|---|---|
| FPINT | 6551 |
| FPICL | 6552 |
| FPCOM | 6553 |
| FPHLT | 6554 |
| FPST | 6555 |
| FPRST | 6556 |
| FPIST | 6557 |

8-Mode Memory Reference Instructions

| | |
|---|---|
| AND | 0000 |
| TAD | 1000 |
| ISZ | 2000 |
| DCA | 3000 |
| JMS | 4000 |
| JMP | 5000 |
| IOT | 6000 |
| OPR | 7000 |

FPP Special Format Instructions

| | |
|---|---|
| ADDX | 0110 |
| ALN | 0010 |
| ATX | 0020 |
| FCLA | 0002 |
| FEXIT | 0 |
| FNEG | 0003 |
| FNOP | 0040 |
| FNORM | 0004 |
| FPAUSE | 0001 |
| JA | 1030 |
| JAC | 0007 |
| JAL | 1070 |
| JEQ | 1000 |
| JGE | 1010 |
| JGT | 1060 |
| JLE | 1020 |
| JLT | 1050 |
| JNE | 1040 |
| JSA | 1120 |
| JSR | 1130 |
| JXN | 2000 |
| SETB | 1110 |
| SETX | 1100 |
| STARTD | 0006 |
| STARTE | 0050 |
| STARTF | 0005 |
| TRAP3 | 3000 |
| TRAP4 | 4000 |
| TRAP5 | 5000 |
| TRAP6 | 6000 |
| TRAP7 | 7000 |
| XTA | 0030 |

Pseudo-Operators

ADDR
BASE
COMMON
COMMZ
DECIMAL
DPCHK
E
END
ENTRY
EXTERN
F
FIELD1
IFNDEF
IFNEG
IFNZRO
IFPOS
IFREF
IFZERO
INDEX
LISTOFF
LISTON
OCTAL
ORG
REPEAT
SECT
SECT8
TEXT
ZBLOCK
IFFLAP
IFRALF
IFSW
IFNSW

## APPENDIX B

## ASSEMBLY INSTRUCTIONS

The following sequence of commands may be used to assemble the OS/8 FORTRAN IV system programs. It is assumed that all PAL language sources reside on DSK. In this example, DTA1 is shown as the target device, however any other device could be used via the appropriate ASSIGN command. Note that PASS2O.SV is produced by conditional assembly of PASS2.PA and that the "O" in PASS2O is an oh, not a zero. The initial dot and asterisk characters on every command line shown are printed by the monitor. All other characters (except carriage return, in some cases) are typed by the user. Type CTRL/Z after each of the three system pauses at point (1), to continue assembly of PASS2O. Type ALT MODE to produce the "$" character.

```
.ASSIGN DTA1 DEV
.R PAL8
*F4.BN,LIST.LS<F4$
.R ABSLDR
*F4$
.SAVE DEV F4=0;12200$
.R PAL8
*PASS2.BN,LIST.LS<PASS2$
.R ABSLDR
*PASS2$
.SAVE DEV PASS2=0;5000$
.R PAL8
*PASS2O.BN,LIST.LS<TTY:,DSK:PASS2$OVERLY=1
                                                        (1)
.R ABSLDR
.PASS2O$
.SAVE DEV PASS2O=0;7605$
.R PAL8
*PASS3.BN,LIST.LS<PASS3$
.R ABSLDR
*PASS3$
.SAVE DEV PASS3=0;400$
.R PAL8
*RALF.BN,LIST.LS<RALF$
.R ABSLDR
*RALF$
.SAVE DEV RALF=0;200$
.R PAL8
*LOAD.BN,LIST.LS<LOAD$
.R ABSLDR
*LOAD$
.SAVE DEV LOAD=0;200
.R PAL8
*FRTS.BN,LIST.LS<RTS,RTL$
.R ABSLDR
*FRTS$
.SAVE DEV FRTS=0;200
.R PAL8
*LIBRA.BN,LIST.LS<LIBRA$
.R ABSLDR
*LIBRA$
.SAVE DEV LIBRA=0;200
.
```

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