floating point interpretive language manual

GRI Computer Corporation
320 NEEDHAM STREET, NEWTON, MASSACHUSETTS 02164

GRI

FLOATING POINT

INTERPRETIVE LANGUAGE

MANUAL

GRI Computer Corporation, 320 Needham Street, Newton, Massachusetts 02164

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Issued: July 1972
Supercedes: Jan. 1972

74-44-001C
0200 0872

TABLE OF CONTENTS

CHAPTER ONE

FLOATING POINT INTERPRETER

1.1 Introduction:

The GRI Floating Point Intrepreter is a complete system that allows the user to process data in floating point arithmetic. Floating point arithmetic, through the use of multiple precision arithmetic and an exponential concept greatly extends the range of precision available to the user beyond that of fixed point arithmetic. It also, through utility routines, frees the user of the bookkeeping involved with scaling and unscaling of numbers that is necessary in a fixed point system.

GRI computers have an instruction set which is known as machine language. The computer reads instruction words out of its memory and hardware is activated by the interpretation of each instruction word to cause the execution of that instruction. An interpretive software system fetches instructions which we shall call commands from the computer's memory and causes various subroutines to be entered as a result of the interpretation of the command. These commands fetched by the interpreter are also called psuedo-instructions because their format deviates from the machine's instruction format. The standard machine format instruction is

WORD 1	SDA MOD DDA
WORD 2	[ADDRESS] (if a memory reference instruction)

A pseudo-instruction or command such as the ones used in the GRI Floating Point Interpreter looks like this:

WORD 1	OP CODE
WORD 2	[ADDRESS] (if a memory reference pseudo-instruction)

The interpreter actually simulates the process used by the computer's hardware to execute an instruction. The interpreter fetches the OP CODE words and addresses, sets up arguments, flags, and performs a function on the argument(s) as specified by the OP CODE of the pseudo-instruction.

An interpretive approach to floating point arithmetic provides the user with a functionally oriented language that makes usage of floating point arithmetic much easier than if it were done through a series of subroutines called in machine language. The user references floating point numbers with a single address which is the first address of the two word floating point number. The interpreter takes care of the address bookkeeping necessary for two word argument handling. The interpreter also maintains a set of accumulators much the same as an arithmetic unit. Arguments and results are manipulated and left in these accumulators. The interpreter utilizes two such accumulators plus an index register.

There are a set of commands in the interpretive system that are not floating point arithmetic commands. These are program control commands such as conditional jumps and index register manipulators. The index is simply used to keep track of the number of times command loops are executed. These commands, although they could be effected by use of basic machine language, are also provided in the interpretive mode because they can save the user time that would be spent entering and leaving the interpretive mode, and almost always save space in terms of the coding needed.

When the user is ready to execute commands in his program, he first issues a machine language command that causes a jump to the interpreter to take place. The interpreter now assumes control and starts fetching commands which follow the jump that caused interpretive mode entry. If the user wishes to begin executing machine language instructions, he must issue an interpretive command that causes the interpreter to relinquish control. In essence, the machine is running in two different modes; a machine language mode and a psuedo-language mode -- in this case, a floating point language.

The GRI interpretive system offers a novel error trap feature which may be invoked by the user to assist in tracking down places in the program where data values are causing error checks to occur. Errors such as dividing by 0, exceeding the capacity of the psuedo-accumulators in either the mantissa or exponent portions, etc., can all be caused by an unknown data base. All manipulations of data refer to manipulations in and out of the psuedo-accumulator called FAC. This accumulator behaves like the accumulator in an adding machine. It must be loaded to initialize it, stored to save it, and all arithmetic operations leave their results in the accumulator. Commands with two operands are called binary commands and operate on a data word in user memory and the contents of FAC, replacing the result in FAC. Commands with one operand are called unary commands and operate on FAC, leaving their results in FAC. Let us consider a simple example:

Compute R = $\sqrt{X^2 + Y^2}$

```
JU $SFI        ;enter floating mode
FLDA X         ;fetch X to FAC
FMPY X         ;X^2 in FAC
FSTA T1        ;store FAC in temporary loc
FLDA Y         ;fetch Y to FAC
FMPY Y         ;Y^2 in FAC
FADD T1        ;X^2 + Y^2 in FAC
FSQT           ; √(X^2 + Y^2) in FAC
FSTA R         ;store result in R
FEXT           ;exit from floating mode
```

1.2 Basic Package, $SFI:

Floating point arithmetic capabilities are provided through an interpretive package. Associated with the package is an external↔internal format data conversion routine that can be easily tailored to the character set being processed.

The interpretive package is invoked by a normal subroutine call. The call is followed by a string of commands that are established by use of equate statements during the assembly. The last command in the sequence causes a return to the calling program. Operations are performed using a pseudo accumulator maintained locally by the interpretive package. The package also contains a 16 bit pseudo index to allow loops within the command sequence. Without this feature, it would be necessary to exit and re-enter the interpretive package and perform loop counts outside the interpreter. Although the latter procedure is, in most instances, faster in terms of time taken to do the loop, it usually involves considerably more code and, therefore, takes more space.

As an example of a typical problem programmed in the interpreter language, we evaluate the polynomial

$$Y = A_0 + A_1X + A_2X^2 + A_3X^3 + A_4X^4$$

which can iteratively be expressed as $Y = (((A_4X+A_3)X+A_2)X+A_1)X+A_0$

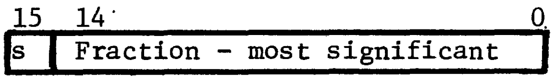
as follows:

```
        JU      $SFI         ;ENTER INTERPRETER

        FLDX    M4           ;LOAD PSEUDO INDEX WITH -4

        FLDA    A4           ;LOAD PSEUDO-ACCUMULATOR

 LOOP:  FMPY    X            ;MULTIPLY IT BY X

        FADDD   CONST        ;DEFERRED ADD A3 (THEN A2, A1, A0)

        FJIX    LOOP         ;COUNT THE LOOP

        FSTA    Y            ;STORE RESULT IN Y

        FEXT                 ;EXIT THE INTERPRETER
        .
        .
        .
    Y:  WRD     0,0          ;STORAGE SPACE FOR ANSWER

CONST:  WRD     A3-1         ;DEFERRED ADDRESS (GETS CHANGED)

    X:  WRD     X1,X2        ;TWO WORD FLOATING POINT VALUE OF X

   A4:  WRD     A41,A42      ;FLOATING A4 VALUE

   A3:  WRD     A31,A32      ;A3

        WRD     A21,A22      ;A2

        WRD     A11,A12      ;A1

        WRD     A01,A02      ;A0

   M4:  WRD     -4           ;ONE WORD INDEX COUNT VALUE
```

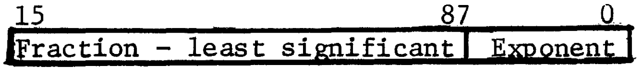
1.3 Floating Point Format:

Internal representation of a floating point number occupies two successive locations in memory and consists of a fixed point fraction (mantissa) with an associated exponent. The mantissa is in two's complement notation with a sign bit followed by 23 bits of significance. The binary point is assumed to be immediately to the right of the sign. The exponent, which is the power of two by which the mantissa is multiplied, has the range -200_8 to $+177_8$ (2^{-128} to 2^{+127}). This exponent is represented in "excess 200_8" notation by adding $+200_8$ to the true exponent. This requires a total of 8 bits and the range of the excess 200_8 notation is 000 to 377_8, where 200_8 represents 2^0. Thus, a floating point number looks like:

Word 1 (16 bits)



Word 2 (16 bits)



This format allows an accuracy of 6+ decimal digits and a range of $\pm 1.469368 \times 10^{-39}$ to $\pm 1.701411 \times 10^{+38}$.

To obtain correct results, all floating point operations (except FLDA, FSTA and FNOR) require the floating point numbers being operated on to be normalized; that is, bit 14 of word 1 must be the most significant bit of the fraction (mantissa). The only exception to this requirement is a floating point zero, which has no significant bits--a normalized floating point zero is two words of all zero (mantissa = 0, excess 200_8 exponent = 0).

Note: The mantissa of a normalized floating point number other than zero has an absolute value in the range $1/2 \leq |\text{mantissa}| < 1$.

Examples:

Decimal	Internal Floating Point (octal)	
	word 1	word 2
1.0	040000	000201
1.25	050000	000201
-1.0	140000	000201
-1.25	130000	000201
100.	062000	000207
-100.	116000	000207
0.5	040000	000200
0.25	040000	000177
π	062207	166602
$\pi/2$	062207	166601
$-\pi$	115570	011602

1.4 Internal Registers:

There are three pseudo-registers contained in the interpreter i) the pseudo-accumulator (FAC), ii) a temporary pseudo-accumulator (FTM), and iii) the pseudo-index register (FINDX).

i) FAC - The floating pseudo-accumulator. This consists of three locations in the interpreter and is used to contain the left-hand argument of a binary floating point command as well as the results of any floating point command. It is organized as follows:

FACHI - contains high order mantissa and sign of value in FAC

FACLO - contains low order mantissa of value in FAC

FACXP - contains excess 200_8 exponent of value in FAC

ii) FTM - temporary pseudo-accumulator. This consists of three locations analogous to FAC. They are named FTMHI, FTMLO, and FTMXP. The temporary accumulator is used to hold an additional floating point value for those commands which require two floating point values in order to operate, e.g. a type II (binary) command (see 2.2.2).

iii) FINDX - pseudo index. This consists of one location of the same name and holds the current value of the index.

Note: FACHI, FACLO and FTMHI, FTMLO are treated as full 31 bit double precision quantities for the basic arithmetic operations add, subtract, multiply, and divide.

CHAPTER TWO

BASIC COMMANDS

2.1 Command Categories:

The commands are of the following categories:

I	load & store	; the command specifies the source or destination of floating point data - the corresponding destination or source is the pseudo accumulator.
II	binary commands	; the command specifies the source of the rightmost operand - the floating accumulator contains the leftmost operand. The result will be in the accumulator.
III	unary commands	; the command merely specifies the function to be performed on the accumulator. The result will be in the accumulator.
IV	index commands	; the command specifies the source or destination of an index value - the corresponding destination or source is the pseudo index.
V	conditionals	; the command specifies an address to which control passes if the test defined by the command is true - the address must contain another floating point command. Tests may be performed on the floating accumulator, certain flags, and the index.
VI	exit	; this command causes a return to the calling program.

The load & store (Type I) and binary (Type II) commands may specify deferred (indirect and auto-indexed) addressing mode. Deferred addressing in floating point commands operates exactly as in machine language.

2.2 Command Descriptions:

2.2.1 TYPE I COMMANDS - LOAD & STORE COMMANDS

LOAD FLOATING ACCUMULATOR (AC)

mnemonic	address	code	no. of words
FLDA	X	01	2

The contents of the location specified by X and X + 1 are treated as a floating point number and are loaded into the floating point pseudo accumulator. The floating point number in locations X and X + 1 is split into three parts i) X, which consists of the high order mantissa, goes into FACHI; ii) bits 8-15 of X + 1, which consists of the low order mantissa, goes into bits 8-15 of FACLO and bits 0-7 of FACLO are set to zero; and iii) bits 0-7 of X + 1, which consists of the excess 200_8 exponent, goes into bits 0-7 of FACXP and bits 8-15 of FACXP is set to zero.

DEFERRED LOAD FLOATING AC

mnemonic	address	code	no. of words
FLDAD	A	101	2

The contents of location A is incremented by one, replaced in A, and the result is used as the effective address X; then the contents of A are incremented and replaced a second time forming the effective address X + 1. The contents of X and X + 1 are then treated as a floating point number and loaded into FAC as explained under FLDA.

STORE FLOATING AC

mnemonic	address	code	no. of words
FSTA	X	02	2

The contents of FAC are rounded into bit 8 of FACLO, bits 0-7 of FACLO are set to zero. Then FACHI, FACLO, and FACXP are packed into a floating point number and stored in X, and X + 1. Note that this operation alters FAC so that it agrees with the value stored in X, and X + 1.

It is also possible for the rounding operation to cause exponent overflow (excess 200_8 exponent exceeds $+377_8$). This can occur only if the number being rounded is very close to the largest possible positive floating point number. The value stored in this case will be X = 077777_8, X + 1 = 177777_8, and FXFLG will be set non-zero. A successful FSTA will set FXFLG to zero.

DEFERRED STORE FLOATING AC

mnemonic	address	code	no. of words
FSTAD	A	102	2

The contents of A are incremented twice as explained under FLDAD, forming effective addresses X and X + 1 into which FAC is stored as explained under FSTA.

2.2.2 TYPE II COMMANDS - BINARY COMMANDS

All Type II commands depend on both FAC and the argument of the command to have normalized mantissas. If unnormalized numbers are used, the results are unpredictable. A FNOR instruction (see 2.2.3) is provided to normalize any quantity if it is necessary to do so. Also, if all inputs are normalized, the results in FAC will be normalized as will the value retrieved from FAC by use of an FSTA instruction.

Type II commands can cause exponent underflow or overflow if the number created in FAC by the command has an excess 200_8 exponent outside the range 0 to $+377_8$ respectively. The occurrence of either condition is indicated by FXFLG being non-zero after the operation has been completed. It may be tested by use of the FJEV command. The successful completion of a Type II command will set FXFLG to zero.

FLOATING ADD

mnemonic	address	code	no. of words
FADD	X	03	2

The floating point number in locations X and X + 1 are added to the contents of FAC, and the result replaces FAC.

DEFERRED FLOATING ADD

mnemonic	address	code	no. of words
FADDD	A	103	2

The contents of A are incremented twice as explained under FLDAD, forming effective addresses X and X + 1, the contents of which are added to FAC, and the result replaces FAC.

FLOATING SUBTRACT

mnemonic	address	code	no. of words
FSUB	X	04	2

The floating point number in locations X and X + 1 are subtracted from the contents of FAC, and the result replaces FAC.

DEFERRED FLOATING SUBTRACT

mnemonic	address	code	no. of words
FSUBD	A	104	2

Effective address is formed from A as in FADDD.

FLOATING MULTIPLY

mnemonic	address	code	no. of words
FMPY	X	05	2

FAC is multiplied by the floating point number in X and X + 1. The result replaces FAC.

DEFERRED FLOATING MULTIPLY

mnemonic	address	code	no. of words
FMPYD	A	105	2

Effective address is formed from A as in FADDD.

FLOATING DIVIDE

mnemonic	address	code	no. of words
FDIV	X	06	2

FAC is divided by the floating point number in X and X + 1. The result replaces FAC. Divide check will occur if X, X + 1 is zero or not normalized. This causes FAC to be set to the largest possible floating point number of the sign which would be the result of the divide if it could take place, and the divide check flag (FDFLG) will be non-zero. A successful divide sets FDFLG to zero.

Note - if both FAC and X are 0, the result will be the largest possible positive floating point number in FAC with FDFLG set non-zero.

DEFERRED FLOATING DIVIDE

mnemonic	address	code	no. of words
FDIVD	A	106	2

Effective address is formed from A as in FADDD.

FLOATING ADD MAGNITUDE

mnemonic	address	code	no. of words
FADM	X	07	2

The absolute magnitude of the floating point number in X and X + 1 is added to FAC. The result replaces FAC.

DEFERRED FLOATING ADD MAGNITUDE

mnemonic	address	code	no. of words
FADMD	A	107	2

Effective address is formed from A as in FADDD.

FLOATING SUBTRACT MAGNITUDE

mnemonic	address	code	no. of words
FSBM	X	10	2

The absolute magnitude of the floating point number in X and X + 1 is subtracted from FAC. The result replaces FAC.

DEFERRED FLOATING SUBTRACT MAGNITUDE

mnemonic	address	code	no. of words
FSBMD	A	110	2

Deferred subtract magnitude. Effective address is formed from A as in FADDD.

2.2.3 TYPE III COMMANDS - UNARY COMMANDS

FLOATING ABSOLUTE VALUE

mnemonic	address	code	no. of words
FABS	none	14	1

The absolute value of the FAC replaces the FAC, i.e. $|FAC|$ replaces FAC.

FLOATING SQUARE

mnemonic	address	code	no. of words
FASQ	none	15	1

The square of FAC is returned in FAC. This instruction requires that the mantissa of FAC be normalized prior to execution as in type II instructions (see 2.2.2).

FLOATING NORMALIZE

mnemonic	address	code	no. of words
FNOR	none	16	1

The contents of FAC are normalized and replace FAC. This instruction can cause exponent overflow or underflow in which case FAC will contain the largest possible negative floating point number or all zeros respectively and FXFLG will be set non-zero. A successful normalize will set FXFLG to zero.

FLOATING NEGATIVE VALUE

mnemonic	address	code	no. of words
FNEG	none	17	1

The contents of FACHI and FACLO are twos complemented, i.e. -FAC replaces FAC.

2.2.4 TYPE IV COMMANDS - INDEX COMMANDS

LOAD INDEX

mnemonic	address	code	no. of words
FLDX	I	27	2

The pseudo-index is loaded with the 16 bit contents of location I.

STORE INDEX

mnemonic	address	code	no. of words
FSTX	I	30	2

The 16 bit pseudo-index is stored into location I.

2.2.5 TYPE V COMMANDS - CONDITIONALS

These commands allow the program to alter the path of control which the interpreter is following based on the results of certain tests. The location to which the interpreter is caused to transfer must contain a valid floating point command. If the interpreter should encounter an invalid command at any time during execution, it will come to a halt with the address of the illegal command displayed in the MB register on the front panel. This is the only halt in the program.

JUMP UNCONDITIONAL

mnemonic	address	code	no. of words
FJMP	C	20	2

Unconditional jump. The interpreter will take the next command from location C and continue from there.

JUMP IF AC POSITIVE

mnemonic	address	code	no. of words
FJAP	C	21	2

If FAC is positive or zero, the interpreter takes the next command from location C. Otherwise, the interpreter continues with the command following the FJAP command.

JUMP IF AC ZERO

mnemonic	address	code	no. of words
FJAZ	C	22	2

If FAC is 0, the interpreter will take the next command from location C. Otherwise, the interpreter continues with the command following the FJAZ command. Note: The interpreter tests only FACHI for zero. FAC may be non-zero and FACHI = 0 only if the number in FAC is not normalized. This condition cannot be created by the interpreter unless the user has introduced unnormalized numbers into his calculations (see 2.2.2).

JUMP IF AC NEGATIVE

mnemonic	address	code	no. of words
FJAN	C	23	2

If FAC is negative, the interpreter will take the next command from location C. Otherwise, the interpreter continues with the command following the FJAN command.

JUMP IF EXPONENT OVERFLOW (OR UNDERFLOW)

mnemonic	address	code	no. of words
FJEV	C	24	2

If FXFLG is non-zero, the interpreter will take the next command from location C and set FXFLG to zero. Otherwise, the interpreter will continue with the command following the FJEV command. The FJEV command is used to detect the occurrence of either exponent overflow or exponent underflow resulting from the execution of the last preceding Type II command or FSTA, FNOR, or FASQ. If desired, the type of overflow may be detected by an FJAZ command at location C, since exponent underflow returns FAC=0, and exponent overflow returns the largest number (+ or -) in FAC.

JUMP IF DIVIDE CHECK

mnemonic	address	code	no. of words
FJDC	C	25	2

If FDFLG is non-zero, the interpreter will take the next command from location C and set FDFLG to zero. Otherwise, the interpreter continues with the command following the FJDC command. The FJDC command is used to detect the occurrence of divide check during execution of the last previous FDIV or FDIVD command. If desired, one may test whether the condition occurred because the divisor was 0 or not normalized by checking the divisor with an FLDA and FJAZ instruction at location C.

JUMP IF INCREMENTED INDEX NOT ZERO

mnemonic	address	code	no. of words
FJIX	C	26	2

The pseudo-index (FINDX) is incremented by one, and if the result is non-zero, the interpreter takes the next command from location C.

If the result is 0, the interpreter continues with the command following the FJIX instruction. The pseudo-index will contain the incremented value whether or not the jump occurs.

2.2.6 TYPE VI COMMAND - EXIT

EXIT FLOATING INTERPRETER

mnemonic	address	code	no. of words
FEXT	none	0	1

This command causes the interpreter to return control to the user at the location immediately following the FEXT. None of the internal registers or flags are altered by either the FEXT or entering the package. The AO is returned in the ADD state.

CHAPTER THREE

DATA CONVERSION

3.1 Introduction:

Two conversion routines are provided; one to convert from floating point to character, the other to convert from character to floating point. Both conversion routines are core to core operations rather than being bound to a particular I/O device (that is, characters are fetched from and stored into memory). For added flexibility, all characters are referenced with an index into a character set table called @FCST, which initially contains 8-bit ASCII codes. Changing the character set for a specific I/O device can easily be accomplished by changing the character codes in @FCST.

External floating point format is expressed as a mantissa or fraction portion and a power of ten by which the mantissa is multiplied. This is written as $\underbrace{\pm n.nnnnnn}_{\text{mantissa}}\ \underbrace{E\ \pm nn}_{\text{exponent}}$, where n is a decimal digit. The number to the right of the E is the power of ten by which the mantissa is multiplied. Thus, -3.527614E+03 is $-3.527614*10^{3}$ or -3527.614. The floating point number +172.100123E-02 is $+172.100123*10^{-2}$ or +1.72100123.

3.2 Floating Point to Character Conversion:

NAME:	@SFC
SUBROUTINES CALLED:	$SFI, @FXC
ALTERED REGISTERS & FLAGS:	FAC, FTM, FXFLG, FDFLG
CALLING SEQUENCE:	JU @SFC WRD e1-1 WRD e2 WRD e3 return
ARGUMENTS:	e1 is the address of the location into which the first output character is to be stored. e2 is the address of the two word floating point argument. The argument need not be normalized but the magnitude must be zero or in the range $(2^{-129}, 2^{+128})$ (in decimal this is 1.469367E-39 to 1.701411E+38) e3 is the address of the error return.
FUNCTION:	Converts a signed two word floating point argument to a string of thirteen characters, stored one character per word, right justified starting in location e1. The character string is of the format $\left\{\begin{matrix}+\\ *\\ -\end{matrix}\right\}$ n.nnnnnn E$\left\{\pm\right\}$nn where n is character representation of a decimal digit.

ERRORS:	If normalization of the floating point argument caused either exponent overflow or underflow, an * is stored rather than a leading + or - sign, and when conversion is completed, control returns to e3. The * can be considered a - sign. An argument resulting in overflow converts to * 1.701411 E + 38. An argument resulting in underflow converts to *0.000000 E + 00.
NOTE:	The magnitude of the three smallest normalized non-zero floating point numbers are converted to one of the character strings ±1.469367E-39 or ±1.469368E-39. These two character strings cannot be converted back to a floating point number. The smallest character string which can successfully be converted to a floating point number is ±1.469369E-39. Therefore, if the user converts any one of these three numbers to a string of characters, he should be aware that he cannot successfully convert the string back to a floating point number.
LENGTH:	306_8 (198_{10}) locations

Description of Algorithm:

The sign of the floating point argument is stored, the argument is then normalized, and the absolute value is taken and used for conversion. If normalization caused either exponent overflow or underflow, the error return is taken when conversion is completed and an asterisk (which may be considered as a '-'), is stored rather than a leading sign.

Since the output character string is of the form$\left\{\begin{matrix}*\\+\\-\end{matrix}\right\}$n.nnnnnnE±nn, the floating point argument is first manipulated to make it greater than or equal to one and less than ten. (If the floating point argument is exactly zero, this portion of the algorithm is bypassed.) Making $1 \leq$ floating point argument < 10 is accomplished by first checking if it is ≥ 1. If it is not, it is multiplied by the largest possible power of ten (10^{38}) and, if necessary, it is multiplied once again by ten to force it ≥ 1. The argument is then checked for < 10. If it is not < 10, it is forced so by dividing by the largest power of ten, which is less than the argument. The powers of ten used in multiplying and dividing the argument to force its value to be between one and ten are used to form the exponent portion of the character string.

With the floating point argument (stored in FAC) now ≥ 1 and < 10, the mantissa portion of the character string can be formed. FACHI, FACLO is treated as a double precision mixed number with FACXP showing the position of the binary point. FACHI, FACLO is left shifted (with overflow bits shifted into a 3rd word) until the binary point immediately precedes bit 15 of FACHI. The overflow word is then converted to character and stored as the first digit of the mantissa, immediately followed by a decimal point. The fraction portion of the mantissa is formed by successively multiplying FACHI, FACLO by 10_{10} and storing the most significant word of the 3 word product. The exponent is then converted and stored, preceded by an E and either a + or - sign.

3.3 Character to Floating Point:

NAME: @SCF

SUBROUTINES CALLED: $SFI, @FXC

ALTERED REGISTERS & FLAGS: FAC, FTM, FXFLG, FDFLG

CALLING SEQUENCE:

```
JU @SCF
WRD e1-1
WRD e2
WRD e3
return
```

ARGUMENTS: e1 is the address of the first character in the string to be converted. The character string should be stored one character per word right justified in the format

$$\begin{bmatrix}+\\-\\*\end{bmatrix}\quad\left\{\begin{matrix}n\,[n\ldots]\,.\,[n\ldots]\\ [.]\,n\,[n\ldots]\end{matrix}\right\}\left[\left\{\begin{matrix}E\ \ [\pm]\\+\\-\end{matrix}\right\}n[n]\right]\quad[\Delta\ldots]\quad[\,\wr\,]$$

The notational conventions are:

1. n is a decimal digit
2. Δ is a space
3. ≀ is a delimiter
4. braces [] contain optional items which may or may not be included.
5. brackets { } contain alternate items where one and only one of the items <u>must</u> be included.
6. ellipses ... denote permissible repetition of the preceding item.

The string is treated as follows:

1. If there is no sign, it is treated as +.

2. If the leading sign is * or -, it is treated as -.
3. If there is no decimal point, it is assumed to follow the last mantissa digit.
4. Characters are processed up to and including the first ↲, or 13_{10} characters have been processed.

e2 is the address where the two word floating point answer is stored.

e3 is the address of the error return.

FUNCTION:

Converts a string of decimal characters to a two word normalized floating point answer. The two word normalized floating point answer is returned in registers AX (MSH), AY (LSH), and is stored in location e2 (MSH) and e2+1 (LSH). The AO is returned in the ADD state.

ERRORS:

A scan error occurs if the character string is illegally formed. Location @SCF+3 is set to zero and control immediately returns to e3.

An overflow error occurs if the character string contains more than 10_{10} mantissa digits (discounting leading zeros) or if the magnitude of the number is outside the range 1.469369E-39 to 1.701411E+38. Location @SCF+3 is set to one and control immediately returns to e3.

Whenever control returns to e3, the AO is in the ADD state.

NOTES:	See NOTES under @SFC.
LENGTH:	406_8 (262_{10}) locations

Description of Algorithm

The mantissa portion of the character string is converted to a double precision integer by multiplying the answer by 10_{10} and adding in the latest digit. This double precision mantissa is then converted to a normalized floating point number. A count of the number of digits to the right of the decimal point is kept and, after the exponent portion of the character string has been converted, this digit count is subtracted from it to obtain the final exponent. The magnitude of the final exponent is used as an index into the positive floating point powers of ten table (see 3.6). The floating point number obtained from the mantissa portion of the character string is then multiplied (if the final exponent was positive) or divided (if the final exponent was negative) by this power of ten to form the final floating point answer. If there was a leading minus sign or asterisk, the floating point answer is two's complemented before return.

3.4 Common Tables & Routines:

The conversion routines @SFC and @SCF reference a common routine called @FXC, which has four entry points. @FXC occupies a total of 213_8 (139_{10}) locations. Since @FXC is common to both @SFC and @SCF, it need appear only once if the conversion routines are used together. In the discussion of @FXC which follows, each of the four entry points is treated separately for the sake of clarity.

3.5 Character Set Table:

NAME: @FCST

FUNCTION: Common external character set table for floating point data conversion routines. The table is ordered as follows:

Location	Contents
@FCST	code for zero
@FCST+1	code for nine
@FCST+2	code for +
@FCST+3	code for -
@FCST+4	code for *
@FCST+5	code for .
@FCST+6	code for E
@FCST+7	code for space
@FCST+10	code for delimiter

NOTES: The standard table is in full 8-bit ASCII. The delimiter character at @FCST+10_8 is a carriage return and may be changed if desired.

The entire table may be replaced with a different character set provided that the numeric codes in the new set are sequential and the code for zero (0) is less than the code for nine. No code may occupy more than <u>15</u> bits.

LENGTH: 12_8 (10_{10}) locations

3.6 Floating Point Powers of Ten Table:

NAME: @FPT

FUNCTION: Common floating point positive powers of 10_{10} table for floating point data conversion routines. Each floating point power occupies two locations in the table. The table is organized as follows:

```
@FPT:   WRD     45473,46777     constant for $10^{38}$
        WRD     74136,160773    constant for $10^{37}$
         .
         .
         .
         .
        WRD     40000,201       constant for $10^{0}$
```

NOTE: @FPT is located at @FCST+12_8

LENGTH: 116_8 (78_{10}) locations

3.7 Left Shift FAC:

NAME:	@LSHF
SUBROUTINES CALLED:	none
ALTERED REGISTERS & FLAGS:	none
CALLING SEQUENCE:	Load AX with the negative shift count JU @LSHF return
ARGUMENTS:	Register AX contains minus the number of places to left shift FACHI, FACLO
FUNCTION:	Performs double precision left shift of FACHI, FACLO. On return, the shifted result is in AX (MSH), AY (LSH). Any carry out of MSH is found in location @DIG+1.
ERRORS:	none detected
NOTES:	@LSHF=@FCST + 170_8 @DIG+1=@LSHF + 14_8
LENGTH:	23_8 (19_{10}) locations

3.8 Multiply FAC by Ten:

NAME: @10X

SUBROUTINES CALLED: @LSHF

ALTERED REGISTERS & FLAGS: FAC

CALLING SEQUENCE: JU @10X

ARGUMENTS: n/a

FUNCTION: Performs unsigned multiplication of FACHI, FACLO by 10_{10}. The most significant word of the three word product is returned in AY. The second and third words of the product are found in FACHI, FACLO respectively.

ERRORS: n/a

NOTES: @10X=@FCST+130_8

LENGTH: 40_8 (32_{10}) locations

CHAPTER FOUR

EXTENDED COMMANDS

4.1 Introduction:

In addition to the basic floating point interpreter, a set of mathematical functions is supplied which can be invoked by a command in the same line with the basic commands. These functions also call the floating interpreter and since the interpreter has already been entered at this point, a push-down scheme is supplied to allow recursive calls such as this. The push-down list will accomodate recursive calls up to seven levels.

It should be noted that all pseudo registers - the floating accumulator, the temporary accumulator and index - and the flags, FDFLG and FXFLG, are common to all levels of the recursion. In other words, if an extended function which calls the interpreter recursively is invoked by a command, these registers and/or flags may be altered. Information detailing such factors is supplied in the documentation accompanying the individual package.

The push-down scheme and command code structure is tailored so that the user may easily add his own functions. The procedure for doing this is described in section 5.3.

The mathematical subroutines which are supplied with the extended package are SINE, COSINE, ARC TANGENT, LOG_e, EXPONENTIAL, and SQUARE ROOT. The commands associated with these are FSIN, FCOS, FATN, FLNE, FEXP, and FSQT (codes 31, 32, 33, 34, 35, and 36) respectively. They each perform the desired function on the contents of the floating pseudo-accumulator and return the results in the same register. Errors which can result, such as attempting to take the square root or log of a negative number, are flagged by the routines in internal locations not accessible in interpretive mode, i.e. cannot be tested with an interpreter command. An error trap routine is available which will handle these and other errors when they occur (see Appendix E).

In the writeups that follow, FAC is the floating pseudo-accumulator, FTM is the temporary floating pseudo-accumulator, FDFLG is the divide check flag, FXFLG is the exponent overflow flag, and FINDX is the pseudo-index.

4.2 Sine, Cosine:

COMMAND: FSIN (code 31), FCOS (code 32)

FUNCTION:

a. FSIN - calculates the SINE of the contents of FAC which is assumed to be a radian argument and replaces FAC with the result.

b. FCOS - calculates the COSINE of the contents of FAC which is assumed to be a radian argument and replaces FAC with the result.

ERRORS: none

ALTERED REGISTERS & FLAGS: FAC, FTM, FXFLG

METHOD:

For FCOS, the absolute value of FAC is subtracted from $\pi/2$ (=1.570796) and the SINE of the result is taken.

For FSIN, the argument (FAC) is first multiplied by $2/\pi$ to convert it into units of a quarter circle, and the result is checked for its absolute magnitude being less than one. If so, it is a first quadrant quantity and the procedure continues with the series calculation described later. If the magnitude of the result is greater than or equal to one, its sign is saved, it is forced positive, and the integer portion is shifted out - leaving a positive fraction (referred to as Y in the following). The last two bits of the integer portion and the sign are used to determine which quadrant the original argument was in and the quantity Y is altered as follows:

sign	last two bits	Y	quadrant
+	00	$Y \rightarrow Y$	I
+	01	$1-Y \rightarrow Y$	II
+	10	$-Y \rightarrow Y$	III
+	11	$-1 + Y \rightarrow Y$	IV
-	00	$-Y \rightarrow Y$	IV
-	01	$-1 + Y \rightarrow Y$	III
-	10	$Y \rightarrow Y$	II
-	11	$1-Y \rightarrow Y$	I

This new value of Y is then treated as a fraction and is normalized.

The series used to calculate the sine is basically a 5 term Chebyshev economized polynomial approximation of a 6 term McLaurin series for sin $\left(\frac{\pi}{2}Y\right)$. The coefficients are further "adapted" to allow the series to be calculated with one less multiplication than would be the case for a standard polynomial evaluation procedure. This results in the sine being calculated as follows:

$$\sin\left(\frac{\pi}{2}Y\right) = ((Z - Y + A_2) * Z + A_3) * A_4 * Y$$

where

$$Z = (Y + A_0) * Y + A_1$$

and

$A_0 = -14.93104811$

$A_1 = -39.74079011$

$A_2 = +367.8139482$

$A_3 = +23410.00773$

$A_4 = +0.0001514440767$

Accuracy is 6 + significant decimal digits for arguments in the first quadrant ($|FAC| \leq \frac{\pi}{2}$). Accuracy loss is about two thirds of a decimal digit for each complete rotation, i.e. if $2\pi n \leq |FAC| < 2\pi(n+1)$, the accuracy is about $6 - \frac{2}{3}n$ decimal digits.

4.3 Arc Tangent:

COMMAND: FATN (code 33)

FUNCTION: The arc tangent of the contents of FAC replace FAC. The result is in radians and lies in the range $(-\frac{\pi}{2}, +\frac{\pi}{2})$.

ERRORS: none

ALTERED REGISTERS & FLAGS: FAC, FTM, FDFLG, FXFLG

METHOD: The argument (FAC) is checked for its absolute magnitude being greater than or equal to one. If so, a flag is set and the reciprocal of the argument is taken and replaces FAC.

The arc tangent of the quantity in FAC is then approximated by

$$Z = \text{ATAN } X = X \cdot \frac{(A_0 + A_1X^2 + A_2X^4)}{(B_0 + B_1X^2 + B_2X^4)}$$

where X is the argument and

$A_0 = 0.6402481953$

$A_1 = 0.4229908144$

$A_2 = 0.0264694361$

$B_0 = 0.6402487022$

$B_1 = 0.6363779373$

$B_2 = 0.1108328778$

If the flag was set by the initial check, the value Z is checked for + or -. If Z is +, $\left(\frac{\pi}{2} - Z\right)$ replaces Z. If Z is -, $\left(-\frac{\pi}{2} + Z\right)$ replaces Z. (This is effected by subtracting Z from + or - $\frac{\pi}{2}$ depending on the sign of Z.)

If the flag was not set by the initial check, the value Z is not altered. Accuracy is 6+ significant decimal digits for all arguments.

4.4 Natural Log:

COMMAND: FLNE (code 34)

FUNCTION: The natural log of the contents of FAC replace FAC.

ERRORS: If FAC is negative, a flag (FNLNF) is set, FAC is forced positive, and the natural log taken.

ALTERED REGISTERS & FLAGS: FAC, FTM, FXFLG, FNLNF (FPLNE+4)

METHOD: The quantity in FAC is

$Z = X \cdot 2^I$ where $.5 \leq X < 1$ and I is an integer.

$$\ln Z = \ln [X \cdot 2^I]$$
$$= \ln X + I \ln 2$$

The quantity ln X is approximated by the polynomial.

$$\ln X = \ln A - Z\ (Y + Y^3/3 + Y^5/5 + Y^7/7)$$

which is a Taylor series evaluated at A

where $A = \frac{1}{\sqrt{2}}$

and $Y = \frac{A - X}{A + X}$

The product [I ln 2] is added to ln X, and the sum is left in FAC.

$A = 0.70710678$

$\ln A = 0.34657359$

$\ln 2 = 0.69314718$

Accuracy is 6+ significant decimal digits except for $.904 \leq Z \leq 1.110$. In the latter range, accuracy decreases as $Z \rightarrow 1$.

4.5 Exponential:

COMMAND: FEXP (code 35)

FUNCTION: The exponential of the contents of FAC replace FAC. ($FAC = e^{FAC}$)

ERRORS: If the result is going to be out of range, i.e. if FAC   88.722, a flag (FEXOF) is set. If FAC was negative, zero is left in FAC. If it was positive, the largest positive number is left.

ALTERED REGISTERS & FLAGS: FAC, FTM, FDFLG, FXFLG, FEXOF (=FPEXP+1)

METHOD:

$$e^X = 2^{X \log_2 e}$$

$$= 2^{I + F} = 2^I \cdot 2^F$$

where I is the integer portion and F is the fractional portion of X $\log_2$ e

2^F is computed by the continued fraction:

$$\frac{A}{B + F + \cfrac{C}{F + \cfrac{D}{F}}} \quad -1$$

where

A = -34.624680982

B = -17.312340491

C = 104.0684491

D = 20.813689813

$\log_2 e = 1.442695041$

Accuracy is 6+ significant decimal digits for $|X| \leq 10$. Accuracy decreases slowly as $|X|$ becomes large until at $|X| \approx 88$, the accuracy is 5+ significant decimal digits.

4.6 Square Root:

COMMAND: FSQT (code 36)

FUNCTION: The square root of $|FAC|$ replaces FAC.

ERRORS: If FAC is negative, it is forced positive, and FSFLG (internal to the square root routine) is set non-zero. If FAC is positive, FSFLG is set to zero.

ALTERED REGISTERS & FLAGS: FAC, FSFLG (=FPSQT + 6)

METHOD: After FAC is forced positive and FSFLG is determined, the exponent of the result is determined by dividing FACXP by two (by shifting right once) and adding 100_8 to preserve the excess 200_8 notation. If the original exponent was odd, the shifted FACXP is increased by one; otherwise, it is left alone. If the original exponent was even, FACHI and FACLO are shifted left once. Since the algorithm treats FACHI and FACLO as a 32 bit positive fraction with the binary point to the left of bit 15 of FACHI, the fact that the left shift will **set** the sign bit (bit 15) of FACHI does not matter.

The algorithm then proceeds to determine a fourteen bit first approximation to the square root by a method based on the fact that N^2 is the sum of the first N odd numbers. This method also leaves as a "remainder" the difference between the square of the approximation and the original number. This remainder and the initial approximation are then used for one Newton-Raphson iteration which completes the square root using the single precision divide entry (FSDVD) of the floating point package.

Accuracy is 6+ significant decimal digits for all input arguments.

CHAPTER FIVE

NON-INTERPRETIVE MODE USAGE

5.1 Introduction:

Certain sections of the floating point interpreter are directly accessible to the user without the need to supply commands. These sections may be invoked by a JU SUBR instruction and, after the operation is completed, will return control to the instruction following the jump. In order to use these routines successfully, it is necessary to know that in addition to the pseudo-accumulator (FACHI, FACLO, and FACXP) there is a "temporary" accumulator (FTMHI, FTMLO, and FTMXP) which is used to contain the floating argument of a Type II command during the execution of the operation (see 1.4). This temporary pseudo-accumulator, referred to as FTM, is loaded in the same manner as FAC (see FLDA instruction in 2.2.1). If the user desires to access the routines described in this section, he may need to load FTM in addition to FAC for those routines that operate on both accumulators.

These sections will be described as subroutines since they are essentially used in this manner when accessed directly. When the floating interpreter resides in memory, all of these subroutines also lie in memory.

5.2 Subroutines:

5.2.1 Double Precision Fixed Point Add

NAME: FDAD

CALLING SEQUENCE: JU FDAD

INPUT: FACHI, FACLO; FTMHI, FTMLO; AO must be in ADD state.

FUNCTION: FACHI, FACLO and FTMHI, FTMLO are treated as signed double precision numbers and added. The result of the addition appears in FACHI, FACLO. FTMHI, FTMLO are left unchanged.

If arithmetic overflow occurred (two numbers of like sign are added and the result has opposite sign), the link will be set to 1. If no arithmetic overflow occurred, the link will be zero.

The AO is in the ADD state upon return.

NOTES: It is possible to generate the maximum negative number (FACHI = 100000_8, FACLO = 000000_8), which is not considered a case of arithmetic overflow; and so the link will not be set.

5.2.2 Double Precision Fixed Point Multiply

NAME:	FDMPY
CALLING SEQUENCE:	JU FDMPY
INPUT:	FACHI, FACLO; FTMHI, FTMLO AX must be set to the value in FTMHI AY must be set to the value in FTMLO The AO must be in the ADD state
FUNCTION:	FACHI, FACLO and FTMHI, FTMLO are treated as signed double precision numbers and are multiplied. The high-order 30 bits of the 62 bit product are returned, right justified, in FACHI, FACLO. The value in FTMHI, FTMLO is unchanged. The AO is in the ADD state upon return.
NOTES:	The 30 bit product is inaccurate in the right-most two bits. If FACHI, FACLO and FTMHI, FTMLO are each considered as a double precision fraction with its binary point immediately to the right of the sign, i.e. between bits 14 and 15 of the high-order word, the binary point of the product will be shifted right once so that it is between bits 13 and 14 of FACHI.

5.2.3 Double Precision Fixed Point Divide

NAME:	FDDIV
CALLING SEQUENCE:	JU FDDIV
INPUT:	FACHI, FACLO; FTMHI, FTMLO AX must be set to the value in FTMHI AY must be set to the value in FTMLO The AO must be in the ADD state
FUNCTION:	FACHI, FACLO and FTMHI, FTMLO are treated as signed double precision numbers, and the former is divided by the latter. The quotient appears in FACHI, FACLO. The value in FTMHI, FTMLO has been destroyed. The quotient will be 30 bits in FACHI, FACLO with the binary point displayed one position to the right in the same way as explained in the note for FDMPY. The absolute magnitude of FTMHI, FTMLO must have bit 14 of FTMHI set for the divide to take place. If this condition is not satisfied, divide check will occur. The AO is in the ADD state upon return.
NOTES:	The rightmost three bits of the quotient are inaccurate. Divide check causes FACHI, FACLO to be set to a large double precision number of the sign which would result if the divide could take place (FACHI, FACLO = 077777, 177400 or 100000, 000400 for + and - respectively); also, FDFLG is set non-zero. A successful divide sets FDFLG to zero.

5.2.4 Single Precision Divide

NAME:	FSDVD
CALLING SEQUENCE:	JU FSDVD
INPUT:	AX = high order dividend FLODV = low order dividend (must be a positive 30 bit double precision number (see below)) AY = negative divisor The AO must be in the ADD state.
FUNCTION:	This is an inner loop which, if used correctly, can be invoked to supply an unsigned single precision divide. The quotient is incomplete in the sense that it is right shifted and truncated upon return. To obtain a <u>complete</u> single precision unsigned divide, the following procedure may be used. First, load AX and the location FLODV with a valid two word positive product (bits 14 and 15 of AX must be zero). Then load AY with the positive single precision divisor and twos complement it. The following code will then perform the divide:

```
                           JU     FSDVD        ;INCOMPLETE QUOTIENT IN TRP
                           RRC    AO,L1,0      ;GET LAST BIT OF QUOTIENT
This code may be         { SFM    NOT LNK      ;UPDATE
eliminated if the        { RR     AO,AX        ;REMAINDER
remainder is to be       {
disregarded.             { NOP                 ;IN AX
                           RR     TRP,L1,AY    ;TRUE QUOTIENT IN AY
```

Note that the incomplete quotient is in the TRP register on return from FSDVD. The AO is in the ADD state upon return.

If either the link is set or AY (the final quotient) is negative following this code, divide check has occurred. This means that the high-order portion of twice the dividend was greater than or equal to the divisor, and the quotient is incorrect.

NOTES:

No flag is set if divide check occurs.

5.2.5 Floating Point Normalize

NAME:	FNORM
CALLING SEQUENCE:	JU FNORM
INPUT:	FACHI, FACLO, FACXP
FUNCTION:	Same as FNOR command (see 2.2.3), including the setting of FAC and FXFLG should exponent overflow or underflow occur. The advantage of the accessibility of this routine lies mainly in the saving of time. For instance, to convert a single precision integer value to floating point, the following two methods could be used. (Assume the integer is in AX, and the floating equivalent is wanted in location X.)

```
1)        RM      AX, FACHI
          ZM      FACLO
          MRI     217, AX
          RM      AX, FACXP
          JU      FNORM
          JU      $SFI
          FSTA    X
          FEXT
           .
           .
           .
or,
2)        RM      AX, FACHI
          ZM      FACLO
          MRI     217, AX
          RM      AX, FACXP
          JU      $SFI
          FNOR
          FSTA    X
          FEXT
```

Version 1) takes one more location in core and saves about 80 machine cycles.

NOTE: The AO may not be in the ADD state upon return.

5.2.6 Negation and Store

NAME: FACMP, FACMA

CALLING SEQUENCE: JU FACMP or JU FACMA

INPUT: FACHI, FACLO or AX, AY

FUNCTION:

a) FACMP - replaces FACHI, FACLO with its two's complement. Result is also returned in AX, AY.

b) FACMA - replaces FACHI, FACLO with the two's complement of the double precision number in AX, AY. Result is also returned in AX, AY.

NAME: FTCMP, FTCMA

CALLING SEQUENCE: JU FTCMP or JU FTCMA

INPUT: FTMHI, FTMLO or AX, AY

FUNCTION:

a) FTCMP - replaces FTMHI, FTMLO with its two's complement. Result is also returned in AX, AY.

b) FTCMA - replaces FTMHI, FTMLO with the two's complement of the double precision number in AX, AY. Result is also returned in AX, AY.

NAME: FASAX

CALLING SEQUENCE: JU FASAX

INPUT: AX,AY

FUNCTION: Stores AX into FACHI and AY into FACLO

NAME: FTSAX

CALLING SEQUENCE: JU FTSAX

INPUT: AX,AY

FUNCTION: Stores AX into FTMHI and AY into FTMLO

5.2.7 Generate Zero or Largest Number

NAME:	F0FAC
CALLING SEQUENCE:	JU F0FAC
INPUT:	none
FUNCTION:	sets FACHI, FACLO and FACXP to zero also returns AX and AY = 0
NAME:	FCMAX
CALLING SEQUENCE:	JU FCMAX
INPUT:	FACHI
FUNCTION:	FACHI, FACLO, FACXP will be set to the maximum possible floating point number of the original sign of FACHI. 1) If $\mathrm{FACHI} < 0$, this routine sets FACHI = 100000 FACLO = 000400 FACXP = 000377 2) If $\mathrm{FACHI} \geq 0$, this routine sets FACHI = 077777 FACLO = 177400 FACXP = 000377 Upon return, AX and AY will be equal to the value stored in FACHI and FACLO respectively.

5.2.8 Floating Arithmetic Right Shift

NAME:	FARSN
CALLING SEQUENCE:	JU FARSN
INPUT:	AX, AY, FARSC
FUNCTION:	This routine arithmetically right shifts the double precision number in AX, AY by the number of places indicated by -FARSC.
NOTES:	FARSC must be set to a negative count before calling FARSN.

5.2.9 Other Notes on Non-Interpretive Usage

1) The pseudo-index is kept in location FINDX and may be set by the user without using an FLDX command (see 2.2.4) by simply storing the desired value via a RM R,FINDX where R is a register containing the index value. This, as with FNORM, is a time saver.

2) The two flags, FXFLG and FDFLG, are in locations defined by their names, and can be checked (or cleared) in non-interpretive mode to save time.

3) The usage of the locations FTBLE, FARGD, FETCH, and FMASK which are entry points to $SFI is described in 5.3.

5.3 User Generated Extended Functions:

If the user desires to add functions of his own to the extended package, the procedure is quite easy as outlined below.

The extended package as delivered uses command codes $00\text{-}36_8$ inclusive and 101_8 through 110_8 inclusive. There are available codes of $37_8\text{-}77_8$ inclusive which the user may assign to his own functions.

User functions may be of two types - invoked by one word commands or invoked by two word commands where the second word is an argument address or value. If deferred mode addressing is desired as an option for the same function, it must be accomplished by user code. Setting bit 6 of the command code to attempt deferred addressing will cause the floating interpreter to take the error halt.

Suppose the command name used to invoke the function is to be FFCN assigned to code 37_8. Assume further that the entry point to the function is to be FPCN.

Step 1) Using the Source Text Editor, substitute the statement WRD FPCN to the Command Table ($SFIC Source - see operating instructions) for the statement WRD FPUNT ;37 which is on the supplied tape.

Step 2) The user code which accomplishes the function <u>must</u> have the following statement at the beginning:

ENTRY FPCN

where FPCN is the location at which the user function begins execution.

Step 3) The last instruction executed by the user function must return control to FGET, usually via a JU FGET. Remember that when the user function is invoked by a command, the interpreter passes control to the user function. The JU FGET returns control to the interpreter.

Step 4) If the function the user is generating needs the floating point capability supplied by the interpreter, the user function may call the interpreter followed by a list of commands to accomplish the task subject to the following restrictions:

a) The command name corresponding to the function itself (in this case, FFCN) may not be used.

b) Commands which cause the interpreter to be called recursively may be used so long as care is taken not to exceed seven levels of recursion in total (see 4.1) (remember that the function being coded is at least at level 1 during its execution, and if it calls the interpreter, all commands in the list are at least at level 2).

c) No function invoked by a command may have in its code a call to the interpreter whose command string contains the command name corresponding to the function itself. This is an indirect violation of restriction a) above.

Step 5) Assemble the function and the new Command Table and load these objects along with the rest of the system.

Notes: If the function being generated is invoked by a two word command whose second word is an argument, one and <u>only</u> one of the following steps <u>must</u> occur during its execution.

a)
```
JU   FARGD
```

This fetches the contents of the location following the command into register AX.

b)
```
JU   FETCH
```

This calls FARGD and uses the contents of the location following the command as an address to fetch a floating point argument which is placed in FTM. Also, AX and AY will be set to the value in FTMHI and FTMLO respectively upon return.

c)
```
ZM   FMASK
JU   FETCH
```

This causes deferred fetching of a floating point argument. The contents of the location following the command is used as an address of another location which is incremented twice to form the addresses of the floating argument which is loaded into FTM and AX, AY as in b).

Examples:

1) FCSX is to be the command name, 1 word, code 37_8. When invoked it is to take the COSINE of the SINE of the value in FAC. Assume Step 1 has been accomplished by adding the statement WRD FCS to a Command

Table tape which already includes the SIN and COSINE routines. This function may be accomplished by the following code:

```
           ENTRY  FCS
           FSIN = 31
           FCOS = 32
           FEXT = Ø
   FCS:    JU $SFI                  ;enter floating interpreter
           FSIN                     ;sin of FAC
           FCOS                     ;cos of FAC
           FEXT                     ;exit interpreter
           JU FGET                  ;return to interpreter
           END
```

When this and the new Command Table are assembled and loaded with $SFI and the SINE, COSINE routine, the user may now call the routine in the floating interpretive mode as follows:

```
FCSX = 37
   .
   .
   .
JU $SFI
   .
   .
   .
FCSX
   .
   .
   .
FEXT
   .
   .
   .
```

2) FMCS is to be the command name, 2 words, assigned to code 40_8. When invoked, it is to take the SIN of the COSINE of the value in FAC and set the sign of the result to the sign of the floating point argument whose address is the second word of the command. Step 1 requires the new command entry (say FMC) to be added to a Command Table tape which includes the SIN and COSINE. This function could be coded as follows:

```
ENTRY  FMC

FCOS = 32

FSIN = 31

FABS = 14

FEXT = 0

FMC:  JU FETCH              ;fetch arg to AX,AY

      RMI AX, 0             ;save MSH arg (sign of arg)

      JU  $SFI              ;enter floating interpreter

      FCOS                  ;cos of FAC

      FSIN                  ;sin FAC

      FABS                  ;abs value of FAC

      FEXT                  ;exit floating interpreter

      MR FMC + 3,AX         ;get sign of arg

      JC AX, GEZ, FGET      ;plus, exit

      JU FACMP              ;minus, comp FAC

      JU FGET               ;return to interpreter

      END
```

When this and the new Command Table are loaded with $SFI, and the SINE, COSINE routine, it may be invoked by another routine via

```
FMCS = 40
    .
    .
    .
JU  $SFI
    .
    .
    .
FMCS  X
    .
    .
    .
FEXT
```

3) FMCSD is to be the command which does the same thing as FMCS, only using deferred mode addressing for the argument. FMCSD must be assigned a different code - say 41_8 in the routine that invokes it. Both FMCSD and FMCS may be coded in the same routine as follows, assuming their corresponding entry names have been added to the Command Table Tape.

```
ENTRY  FMCD,FMC
FCOS = 32
FSIN = 31
FABS = 14
FEXT = 0
FMCD:   ZM FMASK
 FMC:   JU FETCH
        RMI AX, 0
        JU $SFI
        FCOS
        FSIN
        FABS
        FEXT
        MR FMC + 3,AX
        JC AX, GEZ, FGET
        JU FACMP
        JU FGET
        END
```

CHAPTER 6

OPERATING INSTRUCTIONS AND SYSTEM GENERATION

6.1 Using the Package as Supplied:

An equate tape labeled $FCQ is supplied for the package as delivered. This tape is a source tape containing the equates for all the floating point commands. It is intended to be copied via the Source Text Editor (%STE) onto any user written source tape which uses the floating point system in order to define the commands. For convenience, the user may preceed these definitions with an 'NLIST' statement and follow them with an 'LIST' statement to avoid having the lengthy listing of these equates. Of course, commands which are not used in the particular program may be edited out of the source as well to shorten assembly time. A commented listing of this tape is in Appendix B. The supplied tape is not commented.

Also supplied is a source tape labeled $SFIC which consists of a table of addresses of entry points in $SFI corresponding to each floating point command. The package as delivered has two object versions of this tape--one with the basic commands only (labeled also $SFIC) and one with the basic commands and all of the extended functions as well (labeled $SFEC-extended). A listing of the basic $SFIC tape is in Appendix C.

The basic steps for using $SFI as supplied are as follows:

1. Using %STE, construct a source tape consisting of the user program and command definitions (which can be read in from $FCQ). Note that the definitions must come somewhere after any ENTRY statements in the user program.

2. Assemble the user program using %RAS
3. Load the user program, the version of $SFIC desired, then the other components of the floating point system which may be done via a library load using %LLH or via the individual objects using either %RLH or %LLH.
4. Run it!

NOTES:

1. Whenever any component of the floating point system is to be used, some version of $SFIC must be loaded.
2. It is good practice to initialize $SFI when starting up or restarting a program by storing FLIST-1 into FPUSH via, e.g.

```
MRI  FLIST-1,AX
RM   AX,FPUSH
```

This resets the push-down list which may have been left "hanging" by stopping the program in the middle of a floating point operation.

6.2 User Generated Systems

If the user desires a configuration of the floating point system other than that supplied he must edit and assemble the $SFIC tape supplied with the package (see also Chapter 5).

Every command used in an interpretive string following a JU $SFI must have a corresponding entry in the Command Table ($SFIC) loaded with $SFI. This entry defines the address to which the interpreter is to pass control in order to perform the command. It may be an address within $SFI, or in one of the extended functions, or in a user written extended function. All unused commands go to the entry point in $SFI labeled

'FPUNT'. The source tape for $SFIC supplies the appropriate labels for all the basic commands at the proper place in the table (code n is the nth entry - see listing in Appendix C).

The user need only change the 'FPUNT' at the appropriate entry in $SFIC to the desired name (which must be an entry point in some program), reassemble the tape and load the resulting object along with the rest of the system.

Model 40 Floating Point

Conversion of 71-44-001-C (Model 30 Manual)

This package is upward compatible with floating point software written using the Model 30 floating point package. The only differences are 1) the Model 40 floating point is faster and uses less space, 2) FAC, and FTM occupy registers 30-35 and 3) the usage of some of the subroutines in non-interpretive mode is slightly different.

Any changes in going from Model 30 to Model 40 floating point are described in this document by referring to changes that should go into the Floating Point Manual if the Model 40 version is being used.

Pg. 1-7 last 6 lines, change to:

registers in the interpreter and is used to contain the left-hand argument of a binary floating point command as well as the results of any floating point command. It is organized as follows:

reg.	name		
35	FACHI	-	contains high order mantissa and sign of value in FAC
34	FACLO	-	contains low order mantissa of value in FAC
33	FACXP	-	contains excess 200_8 exponent of value in FAC

Pg. 1-8 first three sentences, change to:

> ii) FTM - temporary pseudo- accumulator. This consists of three registers analogous to FAC. They are named FTMHI (reg. 32), FTMLO (reg. 31), and FTMXP (reg. 30).

Pg. 3-2 second line from top, change to:

NAME: @SFC4

Pg. 3-3 seventh line from bottom, change to:

LENGTH: $263_8 (179_{10})$

Pg. 3-5 second line from top, change to:

NAME: @SCF4

Pg. 3-7 second line from top, change to:

LENGTH: $367_8 (247_{10})$

Pg. 3-7 last paragraph, change all references to @SFC to @SFC4, @SCF to @SCF4 and @FXC to @FXC4.

Pg. 3-7 first line, change reference to @SFC to @SFC4.

Pg. 3-7 fifth line from bottom, @FXC4 occupies a total of $175_8 (125_{10})$ locations.

Pg. 3-10, change page to read:

3.7 Left Shift FAC:

NAME: @LSHF

SUBROUTINES CALLED: none

ALTERED REGISTERS & FLAGS: FTMLO,FTMXP

CALLING SEQUENCE: Load FTMXP with negative shift count.
JU @LSHF
return

ARGUMENTS: FTMXP (reg. 30) contains minus the number of places to left shift FACHI,FACLO (regs. 35 and 34).

FUNCTION: Performs double precision left shift of FACHI,FACLO. On return, the shifted result is in AX(MSH),AY(LSH). Any carry out of MSH is found in FTMLO.

ERRORS: None detected

NOTES: @LSHF = @FCST+161_8

LENGTH: $14_8(12_{10})$ locations

Pg. 3-11 fourth line from top, change to:

ALTERED REGISTERS & FLAGS: FAC,FTM

Pg. 3-11 last line, change to:

LENGTH: $31_8(25_{10})$

Pg. 5-3 delete 5th and 6th lines from top (i.e. AX and AY do not need to be set to FTMHI,FTMLO).

Pg. 5-4 same as Pg. 5-3

Pg. 5-5 delete this page entirely, single-precision divide is supplied on the extended arithmetic operator (see EIR Devices Manual).

Pg. 5-6 same as Pg. 5-5

Pg. 5-7 change line 17 through last line to:

```
1)    RR     AX,FACHI
      ZR     FACLO
      MRI    217,FACXP
      JU     FNORM
      JU     $SFI
      FSTA   X
      FEXT
       .
       .
       .

or,
2)    RR     AX,FACHI
      ZR     FACLO
      MRI    217,FACXP
      JU     $SFI
      FNOR
      FSTA   X
      FEXT
```

Pg. 5-8, change "80 machine cycles" to "27 machine cycles".

Pg. 5-9 delete all references to "Result is also returned in AX,AY"

Pg. 5-9 delete last eight lines, i.e. FASAX and FTSAX do not exist.

Pg. 5-10 fourth line from top, change to:

sets FACHI,FACLO,FACXP to zero. No other registers are affected.

Pg. 5-10 delete last three lines, i.e. AX,AY are not affected.

Pg. 5-11 delete this page, arithmetic right shift is supplied on the extended arithmetic operator (see EIR Devices Manual).

Pg. 5-14 last sentence of paragraph b), change to:

AX and AY are destroyed.

Pg. 5-14 last line of paragraph c), change to:

the floating point argument which is loaded into FTM as in b).

Pg. 5-16 after line saying FEXT = 0, insert:

```
FTMHI = 32
```

Pg. 5-16 change line beginning with RMI AX,0 to say:

```
RMI FTMHI,0 ;save MSH arg (sign of arg)
```

Pg. 5-17 same changes as on pg. 5-16

Appendix B - replace with attached Appendix B

Appendix F pg. 3 paragraph 1) b) c) and d), change to:

b) FSPLT is initialized to 06 0010 12

c) FSPLT+1 is initialized to 377

d) FPSTA+3 is initialized to FARGD

APPENDIX B (MODEL 40)

```
*001                         ;$FC04 - COMMENTED
 002                         ;74-43-702L
 003                         ;GRI909/40 COMMAND EQUATE TAPE
 004     0      000030 FTMXP=30        ; FTM EXPONENT
 005     0      000031 FTMLO=31        ; LOW ORDER FTM
 006     0      000032 FTMHI=32        ; HIGH ORDER FTM
 007     0      000033 FACXP=33        ; FAC EXPONENT
 008     0      000034 FACLO=34        ; LOW ORDER FAC
 009     0      000035 FACHI=35        ; HIGH ORDER FAC
 010     0      000000 FEXT=0          ; EXIT COMMAND
 011     0      000001 FLDA=1          ; LOAD FAC COMMAND
 012     0      000101 FLDAD=101       ; LOAD FAC DEFERRED
 013     0      000002 FSTA=2          ; STORE FAC
 014     0      000102 FSTAD=102       ; STORE FAC DEFERRED
 015     0      000003 FADD=3          ; FLOATING ADD
 016     0      000103 FADDD=103       ; FLOATING ADD DEFERRED
 017     0      000004 FSUB=4          ; FLOATING SUBTRACT
 018     0      000104 FSUBD=104       ; FLOATING SUB. DEFERRED
 019     0      000005 FMPY=5          ; FLOATING MULTIPLY
 020     0      000105 FMPYD=105       ; FLOATING MULT. DEFERRED
 021     0      000006 FDIV=6          ; FLOATING DIVIDE
 022     0      000106 FDIVD=106       ; FLOATING DIVIDE DEFERRED
 023     0      000007 FADM=7          ; FLOATING ADD MAGNITUDE
 024     0      000107 FADMD=107       ; FLTNG ADD MAG DEFERRED
 025     0      000010 FSBM=10         ; FLOATING SUB. MAGNITUDE
 026     0      000110 FSBMD=110       ; FLTNG SUB MAG DEFERRED
 027     0      000011 FTRN=11         ; TRACE ON
 028     0      000012 FTRF=12         ; TRACE OFF
 029     0      000013 FSET=13         ; SET ERROR TRAP
 030     0      000014 FABS=14         ; ABSOLUTE MAGNITUDE
 031     0      000015 FASQ=15         ; SQUARE
 032     0      000016 FNOR=16         ; NORMALIZE
 033     0      000017 FNEG=17         ; NEGATE
 034     0      000020 FJMP=20         ; UNCONDITIONAL JUMP
 035     0      000021 FJAP=21         ; JUMP IF FAC > OR = 0
 036     0      000022 FJAZ=22         ; JUMP IF FAC = 0
 037     0      000023 FJAN=23         ; JUMP IF FAC < 0
 038     0      000024 FJEV=24         ; JUMP IF EXFLG NOT 0
 039     0      000025 FJDC=25         ; JUMP IF FDFLG NOT 0
 040     0      000026 FJIX=26         ; BUMP INDEX, JMP IF NOT 0
 041     0      000027 FLDX=27         ; LOAD PSEUDO-INDEX
 042     0      000030 FSTX=30         ; STORE PSEUDO-INDEX
 043     0      000031 FSIN=31         ; SINE
 044     0      000032 FCOS=32         ; COSINE
 045     0      000033 FATN=33         ; ARCTANGENT
 046     0      000034 FLNE=34         ; NATURAL LOGARITHM
 047     0      000035 FEXP=35         ; EXPONENTIAL
 048     0      000036 FSQT=36         ; SQUARE ROOT
```

APPENDIX A

Command Summary - Basic

Definitions:

Y ~ address of floating operand

~ address of location containing address - 1 of floating operand

~ address of another floating command

~ address of index value

[D] ~ optional selection of deferred addressing

I ~ index value of source or destination at address Y

A ~ pseudo-accumulator (FAC)

X ~ pseudo-index register

F ~ floating value of source or destination at effective address formed from Y.

Code (octal)	Basic Commands	Operation	Flags	Registers
00	FEXT	exit	none	none
01 [101]	FLDA [D] Y	$F \rightarrow A$	none	FAC, FTM
02 [102]	FSTA [D] Y	$A \rightarrow F$	FXFLG	FAC
03 [103]	FADD [D] Y	$A+F \rightarrow A$	FXFLG	FAC, FTM
04 [104]	FSUB [D] Y	$A-F \rightarrow A$	FXFLG	FAC, FTM
05 [105]	FMPY [D] Y	$A*F \rightarrow A$	FXFLG	FAC, FTM
06 [106]	FDIV [D] Y	$A/F \rightarrow A$	FXFLG, FDFLG	FAC, FTM
07 [107]	FADM [D] Y	$A+\lvert F\rvert \rightarrow A$	FXFLG	FAC, FTM
10 [110]	FSBM [D] Y	$A-\lvert F\rvert \rightarrow A$	FXFLG	FAC, FTM
14	FABS	$\lvert A\rvert \rightarrow A$	none	FAC
15	FASQ	$A^2 \rightarrow A$	FXFLG	FAC, FTM
16	FNOR	normalized $A \rightarrow A$	FXFLG	FAC
17	FNEG	$-A \rightarrow A$	none	FAC
20	FJMP Y	jump to Y	none	none
21	FJAP Y	jump to Y if $A \geq 0$	none	none
22	FJAZ Y	jump to Y if $A = 0$	none	none

Code (octal)	Basic Commands	Operation	Flags	Registers
23	FJAN Y	jump to Y if $A<0$	none	none
24	FJEV Y	jump to Y if FXFLG set 0	FXFLG (set to zero)	none
25	FJDC Y	jump to Y if FDFLG set 0	FDFLG (set to zero)	none
26	FJIX Y	$X+1 \to X$, jump to Y if X 0	none	FINDX
27	FLDX Y	$I \to X$	none	FINDX
30	FSTX Y	$X \to I$	none	none

Command Summary - Extended Functions

Code (octal)	Extended Command	Operation	Flags	Registers
31	FSIN	$\text{SIN}\ (\text{FAC}) \to \text{FAC}$	FXFLG	FAC,FTM
32	FCOS	$\text{COS}\ (\text{FAC}) \to \text{FAC}$	FXFLG	FAC,FTM
33	FATN	$\text{TAN}^{-1}\ (\text{FAC}) \to \text{FAC}$	FXFLG,FDFLG	FAC,FTM
34	FLNE	$\text{LOG}_e\ (\lvert\text{FAC}\rvert) \to \text{FAC}$	FXFLG(*)	FAC,FTM
35	FEXP	$e^{\text{FAC}} \to \text{FAC}$	FXFLG,FDFLG(1)	FAC,FTM
36	FSQT	$\sqrt{\lvert\text{FAC}\rvert} \to \text{FAC}$	none(+)	FAC

(*) If input argument is negative, FNLNF internal to the FPLNE routine will be set non-zero (see write-up).

(+) If input argument is negative, FSFLG internal to the FPSQT routine will be set non-zero (see write-up).

(1) If input argument is too large, FEXOF internal to the FPEXP routine will be set non-zero (see write-up).

APPENDIX B

$FCQ

```
                     ;$FCQ - COMMENTED
                     ;74-43-402L
                     ;GRI909/30 COMMAND EQUATE TAPE
     0     000000 FEXT=0               ; EXIT COMMAND
     0     000001 FLDA=1               ; LOAD FAC COMMAND
     0     000101 FLDAD=101            ; LOAD FAC DEFERRED
     0     000002 FSTA=2               ; STORE FAC
     0     000102 FSTAD=102            ; STORE FAC DEFERRED
     0     000003 FADD=3               ; FLOATING ADD
     0     000103 FADDD=103            ; FLOATING ADD DEFERRED
     0     000004 FSUB=4               ; FLOATING SUBTRACT
     0     000104 FSUBD=104            ; FLOATING SUB. DEFERRED
     0     000005 FMPY=5               ; FLOATING MULTIPLY
     0     000105 FMPYD=105            ; FLOATING MULT. DEFERRED
     0     000006 FDIV=6               ; FLOATING DIVIDE
     0     000106 FDIVD=106            ; FLOATING DIVIDE DEFERRED
     0     000007 FADM=7               ; FLOATING ADD MAGNITUDE
     0     000107 FADMD=107            ; FLTNG ADD MAG DEFERRED
     0     000010 FSBM=10              ; FLOATING SUB. MAGNITUDE
     0     000110 FSBMD=110            ; FLTNG SUB MAG DEFERRED
     0     000011 FTRN=11              ; TRACE ON
     0     000012 FTRF=12              ; TRACE OFF
     0     000013 FSET=13              ; SET ERROR TRAP
     0     000014 FABS=14              ; ABSOLUTE MAGNITUDE
     0     000015 FASQ=15              ; SQUARE
     0     000016 FNOR=16              ; NORMALIZE
     0     000017 FNEG=17              ; NEGATE
     0     000020 FJMP=20              ; UNCONDITIONAL JUMP
     0     000021 FJAF=21              ; JUMP IF FAC > OR = 0
     0     000022 FJAZ=22              ; JUMP IF FAC = 0
     0     000023 FJAN=23              ; JUMP IF FAC < 0
     0     000024 FJEV=24              ; JUMP IF FXFLG NOT 0
     0     000025 FJOC=25              ; JUMP IF FOFLG NOT 0
     0     000026 FJIX=26              ; BUMP INDEX, JMP IF NOT 0
     0     000027 FLDX=27              ; LOAD PSEUDO-INDEX
     0     000030 FSTX=30              ; STORE PSEUDO-INDEX
     0     000031 FSIN=31              ; SINE
     0     000032 FCOS=32              ; COSINE
     0     000033 FATN=33              ; ARCTANGENT
     0     000034 FLNE=34              ; NATURAL LOGARITHM
     0     000035 FEXP=35              ; EXPONENTIAL
     0     000036 FSQT=36              ; SQUARE ROOT
```

APPENDIX C

$SFIC

```
 *001                            ;$SFIC
  002                            ;74-43-407L
  003                            ;BASIC COMMAND TABLE
  004                                  ENTRY FTBLE
  005          1      177777     FTBLE=.-1
U 006  00000  0 000000                 WRD   FPLDA        ;1
U 007  00001  0 000000                 WRD   FPSTA        ;2
U 008  00002  0 000000                 WRD   FPADD        ;3
U 009  00003  0 000000                 WRD   FPSUB        ;4
U 010  00004  0 000000                 WRD   FPMPY        ;5
U 011  00005  0 000000                 WRD   FPDIV        ;6
U 012  00006  0 000000                 WRD   FPADM        ;7
U 013  00007  0 000000                 WRD   FPSBM        ;10
U 014  00010  0 000000                 WRD   FPUNT        ;11 FPTRN
U 015  00011  0 000000                 WRD   FPUNT        ;12 FPTRF
U 016  00012  0 000000                 WRD   FPUNT        ;13 FPSET
U 017  00013  0 000000                 WRD   FPABS        ;14
U 018  00014  0 000000                 WRD   FPASQ        ;15
U 019  00015  0 000000                 WRD   FPNOR        ;16
U 020  00016  0 000000                 WRD   FPNEG        ;17
U 021  00017  0 000000                 WRD   FPJMP        ;20
U 022  00020  0 000000                 WRD   FPJAP        ;21
U 023  00021  0 000000                 WRD   FPJAZ        ;22
U 024  00022  0 000000                 WRD   FPJAN        ;23
U 025  00023  0 000000                 WRD   FPJEV        ;24
U 026  00024  0 000000                 WRD   FPJDC        ;25
U 027  00025  0 000000                 WRD   FPJIX        ;26
U 028  00026  0 000000                 WRD   FPLDX        ;27
U 029  00027  0 000000                 WRD   FPSTX        ;30
U 030  00030  0 000000                 WRD   FPUNT        ;31 FPSIN
U 031  00031  0 000000                 WRD   FPUNT        ;32 FPCOS
U 032  00032  0 000000                 WRD   FPUNT        ;33 FPATN
U 033  00033  0 000000                 WRD   FPUNT        ;34 FPLNE
U 034  00034  0 000000                 WRD   FPUNT        ;35 FPEXP
U 035  00035  0 000000                 WRD   FPUNT        ;36 FPSQT
U 036  00036  0 000000                 WRD   FPUNT        ;37
  037                                  NLIST              ;40-77 SAME AS 37
  070                                  LIST
U 071  00077  0 000000                 WRD   FPUNT        ;100 (ALWAYS ILLEGAL)
U 072  00100  0 000000                 WRD   FPLDA        ;101 (DEFERRED)
U 073  00101  0 000000                 WRD   FPSTA        ;102 (DEFERRED)
U 074  00102  0 000000                 WRD   FPADD        ;103 (DEFERRED)
U 075  00103  0 000000                 WRD   FPSUB        ;104 (DEFERRED)
U 076  00104  0 000000                 WRD   FPMPY        ;105 (DEFERRED)
U 077  00105  0 000000                 WRD   FPDIV        ;106 (DEFERRED)
U 078  00106  0 000000                 WRD   FPADM        ;107 (DEFERRED)
U 079  00107  0 000000                 WRD   FPSBM        ;110 (DEFERRED)
  080          1      000110           END
```

APPENDIX D

%FCG - Floating Point Constant Generator

%FCG - Floating Point Constant Generator

%FCG is a utility routine which is provided should the user wish to use floating point constants whose octal equivalences are unknown. With %FCG, the user can type in a floating point decimal number and receive the equivalent internal floating point representation.

%FCG occupies locations 0-2660 inclusive.

Operating Instructions

1. Load %FCG by means of %ALH.
2. Turn teletype on-line.
3. Set SC=0.
4. Press START.
5. %FCG responds with a carriage return, line feed.
6. Type a string of up to 13_{10} characters terminated with an equal sign (=). The character string should be in the format described in section 3.3, where the delimiter is an = rather than a carriage return. Typing a back arrow at any point causes the first previous non-back arrow to be ignored. Typing rubout at any point causes %FCG to type a carriage return, line feed, question mark (?) and returns to step 5. Typing more than 13 characters before typing an equal sign has the same effect as typing rubout.
7. When the user terminates the character string with the equal sign, %FCG responds by typing the 2 word floating point equivalent (in octal) and returns to step 5.
8. If the character string did not conform to the format specified in section 3.3, the message SCAN ERROR is typed and %FCG returns to step 5.

9. If the character string resulted in a number whose magnitude was outside the range 1.469369E-39 to 1.701411E+38 or if the character string contained more than 10_{10} mantissa digits, the message ANSWER OUT OF RANGE is typed and %FCG returns to step 5.

APPENDIX E

FPSET - Error Trap Routine

Introduction:

A series of floating point calculations on an unknown data base can generate errors, such as results which exceed the capacity of the machine or dividing by 0, etc. In order to facilitate the localization of the occurrence of such errors, FPSET is provided and serves as an error trap routine. When an error specified by the user is detected, FPSET will interrupt the operation of the interpreter and give control to a user supplied error routine. FPSET supplies the user error routine with the following information, allowing the user to pinpoint the step in his calculations at which the error occurred:

AX = recursion level at which the command at the address in AY was executed.

AY = address of command executed immediately previous to detecting the error.

TRP = error number indicating which flag in the user supplied error list was set non-zero. (TRP = position of address of error flag in user supplied table (see usage)).

The recursive capability of the interpreter somewhat complicates certain usages of FPSET and, for this reason, three modes of operation of FPSET are allowed: "On", "Off", and "Partially On". The latter mode allows FPSET to keep track of commands and recursion levels without examining any error flags. The utility of this mode is described in the examples at the end of this appendix.

Usage:

FPSET is controlled by the use of the FSET (code 13_8) command in the sequence of floating commands being executed by the interpreter. There are three modes of operation of FPSET: 1) ON, 2) OFF, and 3) PARTIALLY ON.

1) To turn FPSET ON, the command is

```
FSET A
```

where A is the address of a table with the following format:

```
A:      WRD     ERR         ;USER ERROR ROUTINE ENTRY
        WRD     FLG1        ;ADDRESSES OF SYSTEM
        WRD     FLG2        ;FLAGS TO BE CHECKED...
         .
         .
         .
        WRD      -1         ;END OF TABLE SIGNAL
```

When this FSET command is encountered with a positive non-zero value for A, FPSET will examine the state of every flag listed in the table at address A after every command executed by the interpreter from the point of the FSET A command onward. Whenever a flag whose address is in the user list has become non-zero (indicating an error), FPSET zeros the flag, and then gives control to the user error routine at the address specified in the first word of the table at A. The information supplied to the user error routine is as stated in the introduction.

The user error routine may use $SFI, but any additional errors which might occur will not be checked by FPSET, and any FSET commands in the command sequence will be ignored. If the user wishes to call $SFI in his error routine, it is up to him to save and restore the states of the interpreter system flags and the floating accumulator (FAC) before and after such $SFI use.

2) To turn FPSET "off", the command is

FSET 0

This completely disconnects FPSET from the interpreter.

3) To turn FPSET "partially on", the command is

FSET N

where N is any negative number.

In this mode, FPSET will keep track of the current command address and recursion level but will not examine any flags. If FPSET is at some later time turned "on" and discovers a flag set non-zero, the level and the command address will be correct within certain limitations (see Notes).

This mode is useful when the user does not wish to enter his error routine for errors which occur during execution of a section of his command sequence. For example, the command sequence may contain an FJEV or similar test for conditions known to the user, and with FPSET "on", these conditions could be altered (cleared) if the corresponding flags are in the user error list at A. In this case, an FSET N (where $N<0$), issued before entering this section, and an FSET A ($A>0$, A=address of table), issued after completion of this section will allow FPSET to retain the necessary information should other errors occur and allow the section itself to operate properly.

User Error Routine:

Basically, the user error routine may do anything. However, the user must remember that his error routine is considered as an extension of the interpreter. At the completion of the error routine, control should be given back to the interpreter via a JU FGET or similar return.

Register AX is used as an argument upon return (via JU FGET) and can turn

FPSET "on", "off", or "partially on" according to $AX>0$, $AX=0$, or $AX<0$ respectively. If $AX>0$, it must be the address of an error table as described above (it need not necessarily be the same one as before).

Notes:

1) It is generally the case that an error flag is set by the command immediately preceding the detection of the flag non-zero. In the case where FPSET was not "on" at that moment, but was turned on later and found the flag non-zero, FPSET will report that it does not know which command caused the error by giving an AY value which points to the FSET "on" command or by AY = -1. The difference in meaning of the two AY values is as follows:

   a) AY = address of FSET "on" command if the flag was non-zero at the time the FSET "on" command was encountered.

   b) AY = -1 if all flags were zero when the FSET "on" was encountered, but a flag was set non-zero later at a point which indicated that the command which caused the error was at a recursion level one less than the level at which the error was detected. This situation is avoided if FPSET is partially on throughout until it is turned on.

2) If the user wishes to restart his entire program or in any other way wishes to use the interpreter without reloading it, he should make sure that FGET+1 is initialized to FARGD and FPUSH is initialized to FLIST-1.

3) A FEXT command does not affect the mode of operation of FPSET, i.e. upon re-entering $SFI, FPSET will operate as per the last FSET command encountered before the FEXT.

Operating Instructions:

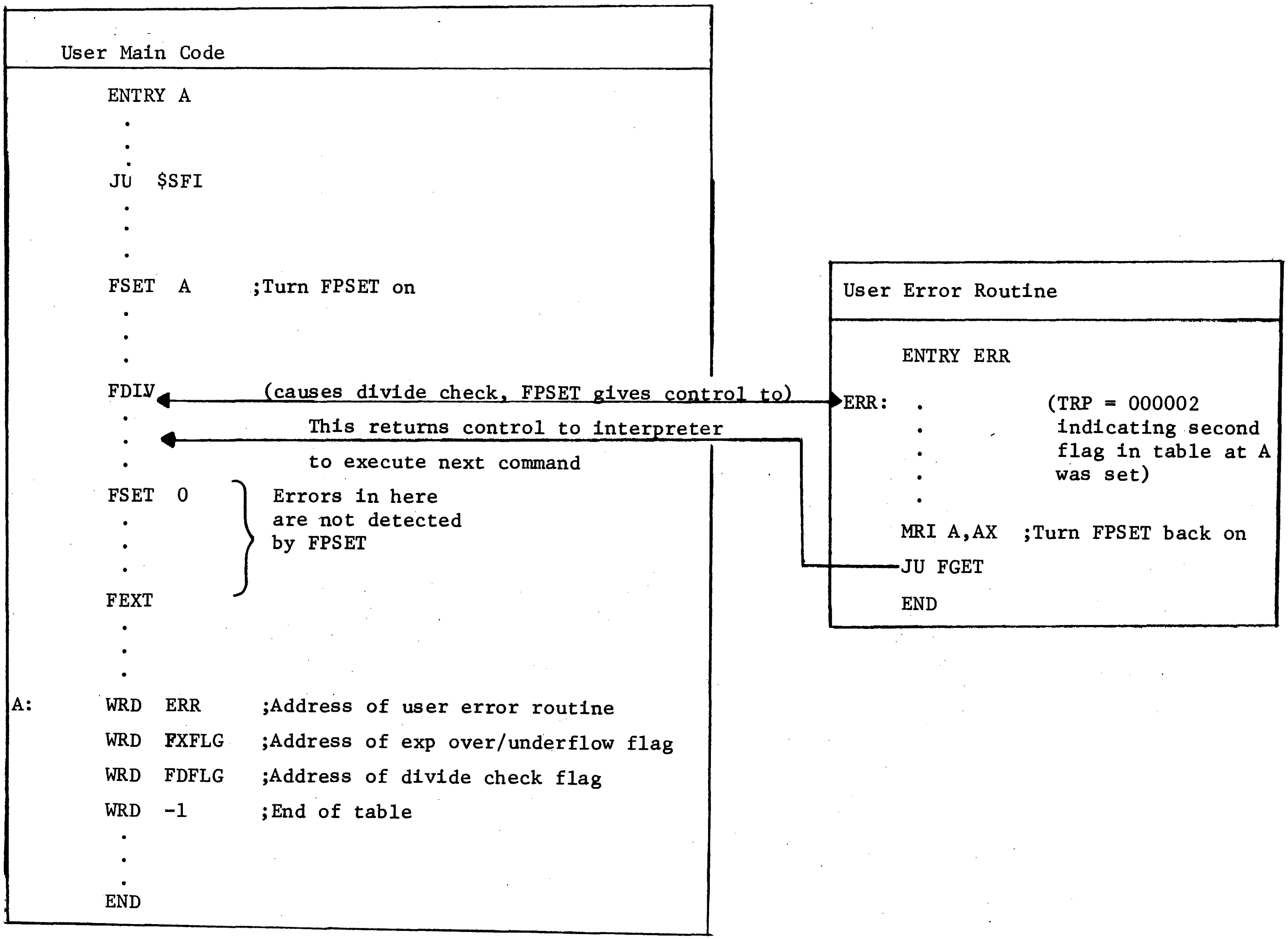
1) Edit the Command Table ($SFIC) source to include WRD FPSET in place of WRD FPUNT;13 which is on the tape as supplied, and assemble it.

2. Load FPSET and the new Command Table with the system.

3. Start user program which has FSET commands in the usual way.

Examples

1. Typical usage of FSET "on" and "off"

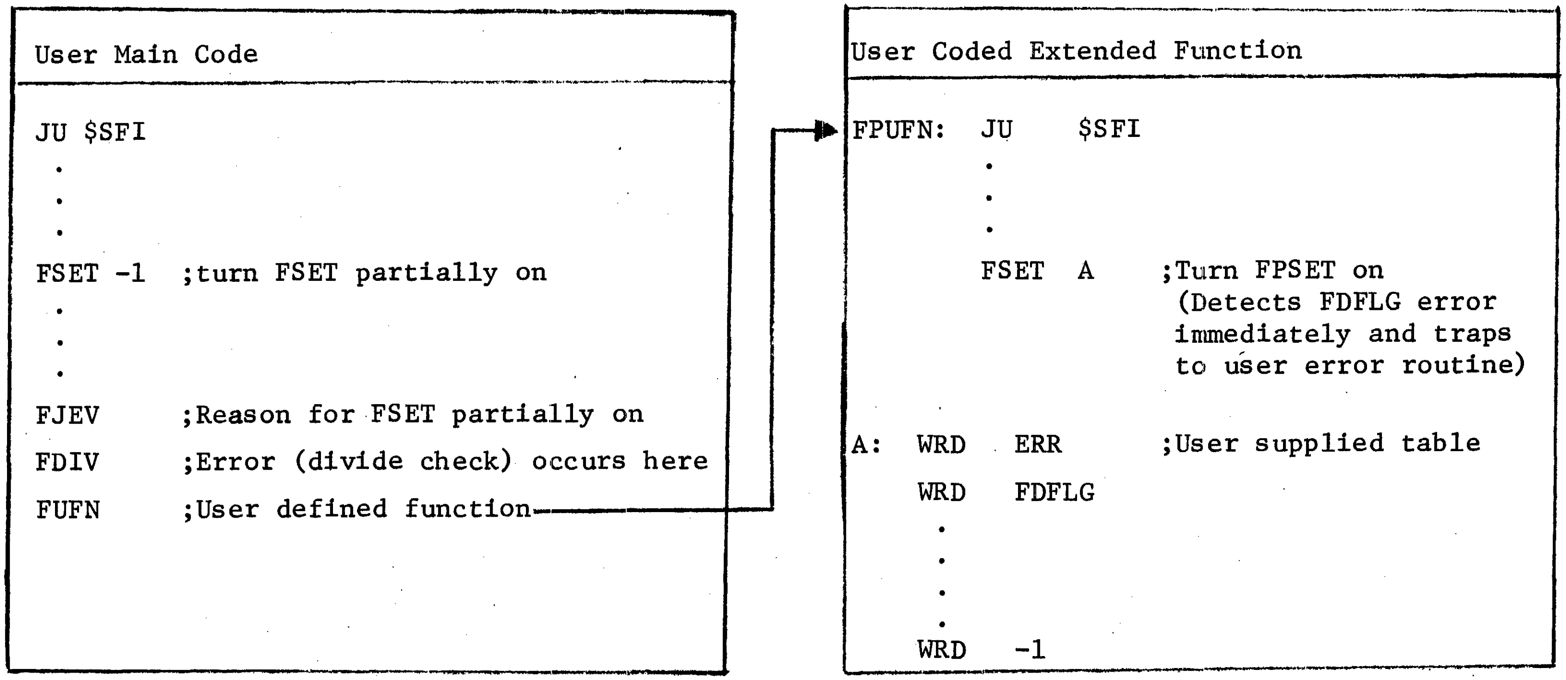


```
User Main Code

        ENTRY A
          .
          .
          .
        JU   $SFI
          .
          .
          .
        FSET  A       ;Turn FPSET on
          .
          .
          .
        FDIV
          .
          .
          .
        FSET  0
          .
          .
          .
        FEXT
          .
          .
          .
A:      WRD  ERR      ;Address of user error routine
        WRD  FXFLG    ;Address of exp over/underflow flag
        WRD  FDFLG    ;Address of divide check flag
        WRD  -1       ;End of table
          .
          .
          .
        END
```

```
User Error Routine

     ENTRY ERR
ERR:   .          (TRP = 000002
       .           indicating second
       .           flag in table at A
       .           was set)
       .
     MRI A,AX  ;Turn FPSET back on
     JU FGET
     END
```

Example

2. Use of FSET "Partially On"



User Main Code

```
JU $SFI
 .
 .
 .
FSET -1  ;turn FSET partially on
 .
 .
 .
FJEV     ;Reason for FSET partially on
FDIV     ;Error (divide check) occurs here
FUFN     ;User defined function
```

User Coded Extended Function

```
FPUFN:  JU    $SFI
        .
        .
        .
        FSET  A     ;Turn FPSET on
                     (Detects FDFLG error
                     immediately and traps
                     to user error routine)

A:   WRD   ERR      ;User supplied table
     WRD   FDFLG
      .
      .
      .
      .
     WRD   -1
```

In this example, because FPSET was only partially on when the error actually occurred, the error trap will indicate that the erring command was FSET. It will, however, indicate that the divide check flag was on (TRP = 000001 since FDFLG is first in table A) and that the error occurred in recursion level 2 since FPSET was turned on in the user function.

Examples

3. Another usage of FPSET "Partially On"

```
User Main Code

JU  $SFI
 .
 .
 .
FSET -1     ;Turn FPSET partially on
 .
 .
 .
FJEV
FUFN        ;User defined function
```

```
User Coded Extended Function

FPUFN:    .
          .
          .
          JU  $SFI
          .
          .
          FSET A             ;Turn FPSET on
          .                   (no errors yet)
          .
          .
          FEXT
          .
          .
          .                  { Input argument cause
          ZM    P1,FUFLG     { user coded function
          .                  { to set error flag
          .
          .
          JU    $SFI
                             error is detected here
          .                  by FPSET
          .
          .
A;  WRD  ERR
    WRD  FXFLG
    WRD  FDFLG
    WRD  FUFLG
     .
     .
     .
    WRD  -1
```

In this example, FPSET indicates an error on recursion level 1, and that the command causing the error was FUFN (i.e. AY will have address of FUFN command). This is as it should be since the arguments given to the user function at the FUFN caused the function to set an error condition.

Note: If the FSET -1 had not been issued in the Main Code, FPSET would have indicated the AY= -1 condition. It would, however, indicate the correct flag and the correct level (i.e. level 1).

APPENDIX F

Trace Routine

The floating point trace is a debugging aid which prints the value of pertinent variables in $SFI and the user's program before the execution of each floating point pseudo command. The variables printed are:

A. current level of $SFI
B. address of the instruction to be executed
C. code for the instruction to be executed
D. FINDX (floating point index)
E. FDFLG (divide check flag)
F. FXFLG (exponent overflow/underflow flag)
G. FAC (floating point pseudo accumulator)
H. effective address of argument, if any
I. value of argument, if any

The user specifies which of the variables are to be printed and the maximum level for which he wants the information printed. This is done through the floating point pseudo commands FTRN and FTRF.

To turn the trace on and specify which of the nine variables are to be printed, the pseudo command is:

```
FTRN  X
```

where bits 0-8 of the integer X correspond to the variables A through I above. For each bit that is on (=1) the corresponding variable will be printed before the execution of each floating point command. The FTRN command sets maximum recursion level to be traced to 7, turns the trace on and prints a heading (A-I), telling which variables are to be printed. The "trace on" causes the specified variables to be printed on one line before each instruction is executed.

The printed value of variables H (argument effective address) and I (argument) need further explanation. If the command to be executed has no argument, columns H and I will be blank. If the argument is floating point, I is printed as a floating point decimal number, otherwise it is octal. If the command is FTRN, FTRF or a JUMP command, then H is the address+1 of the command and I is the contents of H. In the case of the commands FLDX Y, or FSTX Y, H is the address Y and I is the contents of Y. For user coded extended functions, columns H and I will be blank.

To turn the trace off beyond a certain level, the pseudo command is:

```
FTRF  X
```

where the integer value X specifies the maximum recursion level (1-7) for which the specified variables are to be printed. If X is less than or equal to 0, the trace is disabled and no variables will be printed from then on until another FTRN X command is executed.

Notes:

1) When the trace has been turned on, certain locations in $SFI are changed. $SFI is restored to its original state only after the trace is completely disabled by an FTRF 0 command. Therefore, to restart the user program or use $SFI without reloading when the trace has been on, the user should make sure that:

   a) FGET+1 is initialized to FARGD

   b) FSPLT is initialized to 11 0000 06

   c) FSPLT+1 is initialized to FTMHI

   d) FPSTA+1 is initialized to FARGD

2) The trace program cannot run at the same time as FPSET.

```
*001                                ;EXAMPLE 1
 002                                ;THIS EXAMPLE USES TWO FTRN COMMANDS.
 003                                ;THE 1ST FTRN SELECTS VARIABLES A,B,C,D,F,G,H,I
 004                                ;TO BE PRINTED. THIS IS IN EFFECT UNTIL THE
 005                                ;2ND FTRN IS EXECUTED. THE SELECTED VARIABLES
 006                                ;ARE THEN CHANGED TO A,B,C,E,F,G,H. THE
 007                                ;FTRF 0 COMPLETELY DISABLES THE TRACE.
 008                                ;THE $SFIC LISTING WITH THE ADDITION OF
 009                                ;THE FPTRN AND FPTRF ADDED IS NOT SHOWN.
U 010 00000 0 00 0100 03                    JU    $SFI
      00001 0 000000
  011 00002 0 00 0000 11                    FTRN 757         ;PRINT A,B,C,D,F,G,H,I
      00003 0 000757
  012 00004 0 00 0000 27                    FLDX W
      00005 1 000032
  013 00006 0 00 0000 01                    FLDA X           ;Y=X*Y
      00007 1 000033
  014 00010 0 00 0000 05                    FMPY Y
      00011 1 000035
  015 00012 0 00 0000 02                    FSTA Y
      00013 1 000035
  016 00014 0 00 0000 26                    FJIX .-6         ;DONE LOOP 3 TIMES?
      00015 1 000006
  017 00016 0 00 0000 11                    FTRN 367         ;PRINT A,B,C,E,F,G,H
      00017 0 000367
  018 00020 0 00 0000 01                    FLDA X
      00021 1 000033
  019 00022 0 00 0000 06                    FDIV Y
      00023 1 000035
  020 00024 0 00 0000 02                    FSTA Z
      00025 1 000037
  021 00026 0 00 0000 12                    FTRF 0           ;TURN TRACE OFF
      00027 0 000000
  022 00030 0 00 0200 00                    FEXT
  023 00031 0 02 0100 00                    FOM  HLT
  024 00032 0 177775             W:         WRD  -3          ;LOOP COUNT
  025 00033 0 050000             X:         WRD  50000,203   ;5.0
      00034 0 000203
  026 00035 0 040000             Y:         WRD  40000,202   ;2.0
      00036 0 000202
  027 00037 0 000000             Z:         WRD  0,0         ;0.0
      00040 0 000000
  028                                ;EDITED $FCO TAPE FOLLOWS. AN
  029                                ;NLIST WAS ADDED AT THE BEGINNING
  030                                ;TO CUT DOWN ASSEMBLY LISTING TIME
  031                                       NLIST
  041         1      000041                 END
```

PRINTOUT FROM EXAMPLE 1

```
A  B      C      D       F  G              H      I

1  00004  00027  000000  0  +8.320525E-25  00032  177775
1  00006  00001  177775  0  +8.320525E-25  00033  +5.000000E+00
1  00010  00005  177775  0  +5.000000E+00  00035  +2.000000E+00
1  00012  00002  177775  0  +1.000000E+01  00035  +2.000000E+00
1  00014  00026  177775  0  +1.000000E+01  00015  000006
1  00006  00001  177776  0  +1.000000E+01  00033  +5.000000E+00
1  00010  00005  177776  0  +5.000000E+00  00035  +1.000000E+01
1  00012  00002  177776  0  +5.000000E+01  00035  +1.000000E+01
1  00014  00026  177776  0  +5.000000E+01  00015  000006
1  00006  00001  177777  0  +5.000000E+01  00033  +5.000000E+00
1  00010  00005  177777  0  +5.000000E+00  00035  +5.000000E+01
1  00012  00002  177777  0  +2.500000E+02  00035  +5.000000E+01
1  00014  00026  177777  0  +2.500000E+02  00015  000006
1  00016  00011  000000  0  +2.500000E+02  00017  000367

A  B      C      E  F  G              H

1  00020  00001  0  0  +2.500000E+02  00033
1  00022  00006  0  0  +5.000000E+00  00035
1  00024  00002  0  0  +2.000000E-02  00037
1  00026  00012  0  0  +2.000000E-02  00027
```

```
*001                                ;EXAMPLE 2 - THIS EXAMPLE PRINTS ALL 9 VARIABLES
 002                                ;FOR RECURSION LEVELS 1 AND 2. THE USER EXTENDED
 003                                ;FUNCTION IS AT RECURSION LEVEL 2 AND ITS ENTRY
 004                                ;POINT HAS BEEN ADDED TO $SFIC AT CODE 37. THIS
 005                                ;STEP IS NOT SHOWN.
 006                                        ENTRY FPUFN
U 007 00000 0 00 0100 03                JU    $SFI
      00001 0 000000
  008 00002 0 00 0000 11                FTRN 777           ;PRINT A,B,C,D,E,F,G,H,I
      00003 0 000777
  009 00004 0 00 0000 12                FTRF 2             ;MAX TRACE LEVEL=2
      00005 0 000002
  010 00006 0 00 0000 27                FLDX X
      00007 1 000024
  011 00010 0 00 0001 01                FLDAD X+1          ;FETCH ARG DEFERRED
      00011 1 000025
  012 00012 0 00 0000 02                FSTA Y
      00013 1 000027
  013 00014 0 00 0000 37                FUFN Y             ;USER EXTENDED FUNCTION
      00015 1 000027
  014 00016 0 00 0000 26                FJIX .-6           ;DONE?
      00017 1 000010
  015 00020 0 00 0000 12                FTRF 0             ;YES, TRACE OFF
      00021 0 000000
  016 00022 0 00 0000 00                FEXT
  017 00023 0 02 0100 00                FOM   HLT
  018 00024 0 177776          X:        WRD   -2           ;LOOP COUNT
  019 00025 1 000032                    WRD   C50-1        ;FETCH ADR, DEFERRED
  020 00026 1 000032                    WRD   C50-1        ;STORE ADR, DEFERRED
  021 00027 0 000000          Y:        WRD   0,0          ;FUFN ARG.
      00030 0 000000
  022 00031 0 076400          Z:        WRD   76400,211    ;500.0
      00032 0 000211
  023 00033 0 062000          C50:      WRD   62000,206    ;50.0
      00034 0 000206
  024 00035 0 050000                    WRD   50000,204    ;10.0
      00036 0 000204
  025         0      000037 FUFN=37                        ;USER FUNCTION CODE
  026                       ;USER EXTENDED FUNCTION - INCLUDED IN
  027                       ;SAME ASSEMBLY AS CODE WHICH USES IT (ABOVE)
  028                       ;FOR SAKE OF SPACE IN THIS EXAMPLE.
U 029 00037 0 00 0100 03 FPUFN: JU    FARGD
      00040 0 000000
  030 00041 0 11 0000 06                RM    AX,ARG+1
      00042 1 000050
U 031 00043 0 00 0100 03                JU    $SFI         ;ENTER LEVEL 2
      00044 0 000000
  032 00045 0 00 0000 01                FLDA Z             ;500.0/Y
      00046 1 000031
  033 00047 0 00 0000 06 ARG:           FDIV 0
      00050 0 000000
  034 00051 0 00 0001 02                FSTAD X+2
      00052 1 000026
  035 00053 0 00 0000 00                FEXT
U 036 00054 0 00 0100 03                JU    FGET
      00055 0 000000
  037                       ;EDITED $FCC TAPE FOLLOWS WITH NLIST
  038                                   NLIST
  049         1      000056             END
```

PRINTOUT FROM EXAMPLE 2

```
A  B      C      D       E  F  G              H      I

1  00004  00012  000000  0  0  +6.902202E-21  00005  000002
1  00006  00027  000000  0  0  +6.902202E-21  00024  177776
1  00010  00101  177776  0  0  +6.902202E-21  00033  +5.000000E+01
1  00012  00002  177776  0  0  +5.000000E+01  00027  +0.000000E+00
1  00014  00037  177776  0  0  +5.000000E+01
2  00045  00001  177776  0  0  +5.000000E+01  00031  +5.000000E+02
2  00047  00006  177776  0  0  +5.000000E+02  00027  +5.000000E+01
2  00051  00102  177776  0  0  +1.000000E+01  00033  +5.000000E+01
2  00053  00000  177776  0  0  +1.000000E+01
1  00016  00026  177776  0  0  +1.000000E+01  00017  000010
1  00010  00101  177777  0  0  +1.000000E+01  00035  +1.000000E+01
1  00012  00002  177777  0  0  +1.000000E+01  00027  +5.000000E+01
1  00014  00037  177777  0  0  +1.000000E+01
2  00045  00001  177777  0  0  +1.000000E+01  00031  +5.000000E+02
2  00047  00006  177777  0  0  +5.000000E+02  00027  +1.000000E+01
2  00051  00102  177777  0  0  +5.000000E+01  00035  +1.000000E+01
2  00053  00000  177777  0  0  +5.000000E+01
1  00016  00026  177777  0  0  +5.000000E+01  00017  000010
1  00020  00012  000000  0  0  +5.000000E+01  00021  000000
```

```
*001                                 ;EXAMPLE 3
 002                                 ;THIS IS THE SAME AS EXAMPLE 2
 003                                 ;EXCEPT THE MAXIMUM RECURSION
 004                                 ;LEVEL PRINTED IS LEVEL 1 DUE
 005                                 ;TO THE FTRF 1 COMMAND.
 006                                          ENTRY FPUFN
U 007  00000  0 00 0100 03                    JU    $SFI
       00001  0 000000
 008   00002  0 00 0000 11                    FTRN 777            ;PRINT A,B,C,D,E,F,G,H,I
       00003  0 000777
 009   00004  0 00 0000 12                    FTRF 1              ;MAX TRACE LEVEL=1
       00005  0 000001
 010   00006  0 00 0000 27                    FLDX X
       00007  1 000024
 011   00010  0 00 0001 01                    FLDAD  X+1          ;FETCH ARG DEFERRED
       00011  1 000025
 012   00012  0 00 0000 02                    FSTA  Y
       00013  1 000027
 013   00014  0 00 0000 37                    FUFN  Y             ;USER EXTENDED FUNCTION
       00015  1 000027
 014   00016  0 00 0000 26                    FJIX .-6            ;DONE?
       00017  1 000010
 015   00020  0 00 0000 12                    FTRF  0             ;YES, TRACE OFF
       00021  0 000000
 016   00022  0 00 0000 00                    FEXT
 017   00023  0 02 0100 00                    FOM   HLT
 018   00024  0 177776           X:           WRD   -2            ;LOOP COUNT
 019   00025  1 000032                        WRD   C50-1         ;FETCH ADR, DEFERRED
 020   00026  1 000032                        WRD   C50-1         ;STORE ADR, DEFERRED
 021   00027  0 000000           Y:           WRD   0,0           ;FUFN ARG.
       00030  0 000000
 022   00031  0 076400           Z:           WRD   76400,211     ;500.0
       00032  0 000211
 023   00033  0 062000           C50:         WRD   62000,206     ;50.0
       00034  0 000206
 024   00035  0 050000                        WRD   52000,204     ;10.0
       00036  0 000204
 025          0      000037      FUFN=37                          ;USER FUNCTION CODE
 026                             ;USER EXTENDED FUNCTION - INCLUDED IN
 027                             ;SAME ASSEMBLY AS CODE WHICH USES IT (ABOVE)
 028                             ;FOR SAKE OF SPACE IN THIS EXAMPLE.
U 029  00037  0 00 0100 03       FPUFN: JU    FARGD
       00040  0 000000
 030   00041  0 11 0000 06                    RM    AX,ARG+1
       00042  1 000050
U 031  00043  0 00 0100 03                    JU    $SFI          ;ENTER LEVEL 2
       00044  0 000000
 032   00045  0 00 0000 01                    FLDA  Z             ;500.0/Y
       00046  1 000031
 033   00047  0 00 0000 06       ARG:         FDIV 0
       00050  0 000000
 034   00051  0 00 0001 02                    FSTAD  X+2
       00052  1 000026
 035   00053  0 00 0000 00                    FEXT
U 036  00054  0 00 0100 03                    JU    FGET
       00055  0 000000
 037                             ;EDITED $FCC TAPE FOLLOWS WITH NLIST
 038                                          NLIST
 049          1      000056                   END
```

PRINTOUT FROM EXAMPLE 3

```
A  B      C      D       E  F  G               H      I

1  00004  00012  000000  0  0  +6.902202E-21   00005  000001
1  00006  00027  000000  0  0  +6.902202E-21   00024  177776
1  00010  00101  177776  0  0  +6.902202E-21   00033  +5.000000E+01
1  00012  00002  177776  0  0  +5.000000E+01   00027  +0.000000E+00
1  00014  00037  177776  0  0  +5.000000E+01
1  00016  00026  177776  0  0  +1.000000E+01   00017  000010
1  00010  00101  177777  0  0  +1.000000E+01   00035  +1.000000E+01
1  00012  00002  177777  0  0  +1.000000E+01   00027  +5.000000E+01
1  00014  00037  177777  0  0  +1.000000E+01
1  00016  00026  177777  0  0  +5.000000E+01   00017  000010
1  00020  00012  000000  0  0  +5.000000E+01   00021  000000
```

APPENDIX G

System Storage Requirements

Routine	Model 30	Model 40	Description
\$SFI	1360_8 (752_{10})	760_8 (496_{10})	Basic package
\$SFIC	110 (72)	110 (72)	Command table
\$SFEC	110 (72)	110 (72)	Ext. command table
@SCF	406 (262)	367 (247)	char/float pt.
@SFC	306 (198)	263 (179)	float pt./char
@FXC	213 (139)	175 (125)	conversion common
FPSIN	173 (123)	153 (107)	
FPATN	146 (102)	145 (101)	
FPLNE	164 (116)	145 (101)	
FPEXP	201 (129)	150 (104)	
FPSQT	127 (87)	65 (53)	
FPSET	230 (152)	230 (152)	error trap
FPTRC	1020 (528	774 (508)	trace routine

Typical Configuration Storage Requirements

Basic package no conversion	1470 (824)	1070 (568)
Basic package with conversion	2617 (1423)	2137 (1119)
extended Functions	1055 (557)	722 (466)
Total system* (no debug features)	3674 (1980)	3061 (1585)

GRI Computer Corporation

320 NEEDHAM STREET, NEWTON, MASSACHUSETTS 02164

TEL: (617) 969-0800