Steve [illegible]
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digital

pdp12

FAST FOURIER TRANSFORM AND DISPLAY

DEC-12-FQEA-D

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The material in this handbook, including but not limited to instruction times and operating speeds, is for information purposes and is subject to change without notice.

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ACKNOWLEDGMENT

The PDP-12 Fast Fourier Transform + Display program is an adaptation of a program written by James Rothman, of Digital Equipment Corporation. The algorithm is described briefly in Section 7.0 of this manual and in detail in DECUSCOPE, Volume 72, Number 3, available from DECUS Library, Digital Equipment Corporation, Maynard, Massachusetts.

#####

1.0 INTRODUCTION

The FFTD (Fast Fourier Transform + Display) program can perform a Fast Fourier Transform or Inverse Fast Fourier Transform on 4 to 1Ø24 real or complex points which have been stored on a LAP6-DIAL[1] or data LINCtape or disk. The real and imaginary parts of the input or output data and the magnitude of the output data may be displayed on the scope via a moving window. Transformed data may also be stored on a DIAL or data LINCtape or disk. In addition, the scale of the displayed data can be user-modified over twelve different ranges.

2.0 MINIMUM HARDWARE REQUIREMENTS

8K PDP-12B with EAE.

3.0 OPERATING PROCEDURE

3.1 Loading FFTD

FFTD is a "load and go" program and is called from tape or disk by the DIAL command:

```
     →LO FFTD, n↵
```

where n is the tape (Ø-7) or disk (1Ø-17) containing the program. A DIAL system tape must be on unit Ø. (If a non-existent unit is addressed, NO is displayed on the scope. Press RETURN and issue the proper command.)

At any time during program operation, FFTD may be restarted by pressing the console keys; LINC mode, I/O PRESET, and START 2Ø.

3.2 FFTD Displays

The first display is:

```
DISPLAY 1          SINGLE PRECISION FFT
                   INPUT ON DIAL UNIT?  Y/N__
```

[1] LAP6-DIAL is hereafter referred to as DIAL.

Type Y if the data file is on a tape or disk containing DIAL; type N if the file is on a data tape or disk. (A file copied from paper tape via PIP must be referenced as a data tape or disk.)

The final user replies to all the scope displays are terminated by pressing LINE FEED.

If the input is on a DIAL tape or disk, the second display is:

```
DISPLAY 2           UNIT NUMBER__
                    FILE NAME________
```

Specify the unit number, Ø to 7 for tape, and 1Ø to 17 for disk, where the file is located and press RETURN. Then type the file name, which may be 1 to 8 characters long and must begin with a non-numeric character and not contain a ?, /, \ , or > . After typing the file name, press LINE FEED. Note that a file addressed by name on a DIAL tape or disk can not have a header block and must have been placed on the device only by the FFTD program. If a non-existent unit is requested, NO is displayed. To restart the program from LINCtape, press STOP, I/O PRESET, and START 2Ø. The program must be reloaded from an RK8 or RFØ8 disk.

The user is told if the file is not on the specified unit:

```
DISPLAY 3           CANNOT FIND
                    HIT RETURN TO CONT
```

Press RETURN to bring back display 2

If the input is on a data tape or disk, the second display is:

```
DISPLAY 4           UNIT NUMBER__
                    BLOCK NUMBER___
```

The unit may be any number from Ø to 7 for tape and 1Ø to 17 for disk. The block number must be an octal number from Ø to 777. If a data file with a header block is on a DIAL device, it may be accessed by this sequence (instead of the DIAL message). The correct block number is the value in the DIAL index plus one. After the file has been located, the calculation must be specified.

```
DISPLAY 5          HOW MANY PTS____
                     (4-1Ø24 BY POWERS OF 2)
                   REAL OR
                   COMPLEX?  R/C_
```

Powers of 2, from 2 to 1Ø, are acceptable, permitting 4 to 1Ø24 points. Type R if the data is real; type C if it is complex. (Refer to Section 4.0 for a description of data storage format.) If there is not enough room between the starting block number and the end of tape to hold the number of points specified, display 5 will reappear.

The calculation is further specified:

```
DISPLAY 6          FFT OR DISPLAY?  F/D_
                   TRANSFORM OR
                   INVERSE?  T/I_
```

If the data is just to be displayed, type D and press RETURN. Then type T if the data has most recently been transformed or I if it has not been manipulated at all or has been inversely transformed. Continue at display 7.

The next display is:

```
DISPLAY 7          OUTPUT ON DIAL UNIT?  Y/N_
```

Type Y if output is to a DIAL tape or disk; type N if output is to a data tape or disk.

A reply of Y to display 7 (DIAL tape or disk) causes the display:

```
DISPLAY 8          UNIT NUMBER__
                   FILE NAME________
```

These answers have the same restrictions as the input display, display 2. If there is not enough space on the DIAL tape/disk to hold the output data, the next display is:

```
DISPLAY 9          NO SPACE
                   HIT RETURN TO CONT
```

Press RETURN to bring back display 7.

If a file already exists with the specified name, the next display is:

```
DISPLAY 10          REPLACE?  Y/N_
```

Type Y or N to replace or not to replace the file. A reply of N will cause display 8 to reappear. If the file is to be replaced, but the new file is larger than the old file, display 9 will reappear.

If output is to a data tape or disk, the next display is:

```
DISPLAY 11          UNIT NUMBER__
                    BLK NUMBER___
```

The answers have the same restrictions as the input display, display 4. If there is not enough space from the starting block number to the end of the tape to hold the output data, display 9 will reappear.

The program will now read in the data, perform a Fast Fourier Transform or Inverse Fast Fourier Transform, and write the results as complex data pairs onto the specified tape or disk.

When the transform is completed or if just displays are desired, the following message is displayed:

```
DISPLAY 12          WHICH DISPLAY?
                    R(EAL)
                    I(MAGINARY)
                    M(AGNITUDE)
                    S(CALE FACTOR)
                    LINE FEED (RESTART)
```

Type R, I, M, or S and LINE FEED to obtain the desired display. The scale factor is displayed as a decimal number (Ø-12). (Refer to Section 6.0, Data Scaling, for an explanation of the scale factor.) (The magnitude, M, for a+b is M $=\sqrt{a^2+b^2}$.)

If the display is less than 512 points, it will be stationary and centered on the scope. If it contains 512 or more points, the display can be moved in either direction using A/D knob Ø.

A cursor which can be moved by rotating A/D knob 1 will ride along the curve. Associated with the cursor are four octal words displayed in the top left corner of the scope, one beneath the other. The first two words are the absolute 15-bit core address of the cursor point. The third word is the contents of the displayed core address, i.e., the actual 12-bit value in the data buffer of the data word that corresponds to the cursor point. The fourth word is the scope Y coordinate of the cursor point. The fourth word is a relative value and depends upon the Y scale factor and Y offset. Because the data is scaled to nine bits prior to display, the fourth word or Y coordinate will range from ØØØ1 to 1ØØØ$_8$, where ØØØ1 corresponds to the bottom of the scope and 1ØØØ to the top.

The curve can be expanded in the Y direction by typing a 1 or decreased by typing Q. Twelve different ranges are possible. As the display is enlarged, no check is made against losing significant digits of large values because the user may wish to expand small features of the display. Therefore, as the display is enlarged, large values may suddenly decrease in size as significant digits are lost.

The magnitude display is shown at half scale initially. If the values allow, the number 1 can be typed once to show the display at full scale.

Pressing RETURN will cause display 12 to reappear. As many displays as desired may be requested. Subsequent displays will be initially shown at the same range as the preceding display. Pressing LINE FEED without entering a character will cause display 1 to reappear.

4.0 EXAMPLE

This section provides examples of the displays which result from a transform performed on a square wave of 512 points and from an inverse transform performed on the resulting coefficients.

4.1 Input Display

Consider a square wave[1] of 512 real points which has the following format on tape or disk:

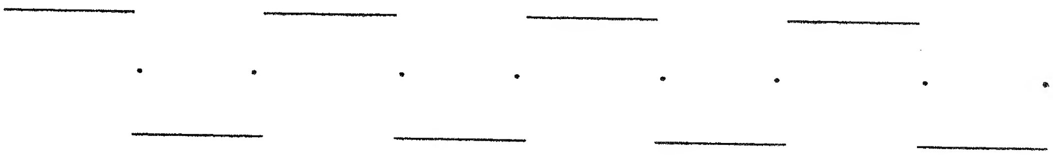
Address	Value	
Ø	2ØØØ	77 points
	⋮	
77	1ØØØ	
1ØØ	ØØØØ	77 points
	⋮	
177	1ØØØ	

[1] The displays shown on the following pages are adaptations and are for demonstration purposes only.

```
Address      Value
  2ØØ        2ØØØ  \
                    >  77 points
  277        1ØØØ  /
  300        ØØØØ  \
                    >  77 points
  377        1ØØØ  /
  4ØØ        2ØØØ  \
                    >  77 points
  477        1ØØØ  /
  5ØØ        ØØØØ  \
                    >  77 points
  577        1ØØØ  /
  6ØØ        2ØØØ  \
                    >  77 points
  677        1ØØØ  /
  7ØØ        ØØØØ  \
                    >  77 points
  777        1ØØØ  /
```

If the input is displayed, there will only be a REAL display. It will look as follows, assuming the cursor is to the extreme left and the display is not moving.

ØØØ1
ØØØØ
2ØØØ
Ø6Ø1

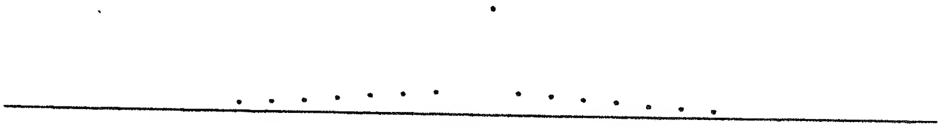


The first two values in the upper left hand corner are the address of the point on which the cursor is resting. When the cursor is at the extreme left, it indicates location ØØØØ of field 1. The third value is the contents of that memory location, in this case, 2ØØØ. The fourth value is the position of the cursor with respect to the bottom of the screen. [1 = bottom, 4Ø1 = X axis (middle), 1ØØØ = top.]

4.2 Transform Displays

4.2.1 Real Display

ØØØ1
2ØØØ
ØØØØ
Ø4Ø1



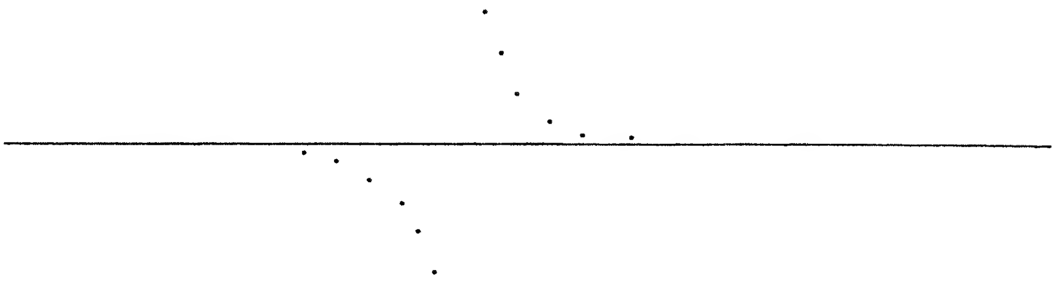
Moving the cursor to the highest point in the display will change the value display to:

```
ØØØ1
24ØØ
2ØØØ
Ø6Ø1
```

This is the DC component of the wave.

4.2.2 Imaginary Display

```
ØØØ1
2ØØØ
ØØØØ
Ø4Ø1
```



Moving the cursor to the lowest point produces the values:

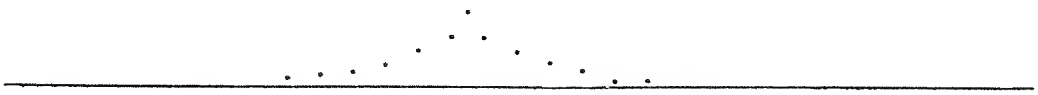
```
ØØØ1
2374
6567
Ø257
```

Moving the cursor to the highest point displays:

```
ØØØ1
24Ø4
1214
Ø522
```

4.2.3 Magnitude Display

```
ØØØ1
2ØØØ
ØØØØ
Ø4Ø1
```



Moving the cursor to the highest point gives the following display:

```
ØØØ1
24ØØ
1ØØØ
Ø5Ø1
```

Because the magnitude of maximum values causes overflow, a factor of 2 is removed during computation. Therefore, the values displayed are half scale; type the key "1" once to display the magnitude at full scale.

4.2.4 Scale Factor Display

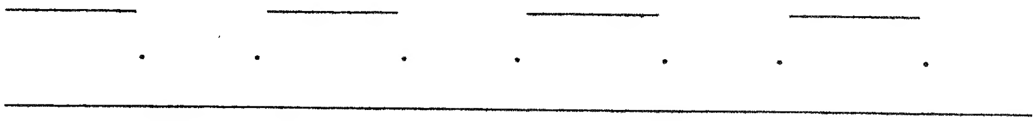
The scale factor has a value of 1. To obtain the actual coefficients, rest the cursor on the desired point and shift right the third value of the corner display the number of bits equal to the scale factor. In this example, the highest value of the real display is 2ØØØ. Shifting it right by the scale factor (=1) yields 1ØØØ, the actual value of the DC component, which in binary is 001 000 000 000. Because the binary point is to the right of the sign bit, the actual value is $+.01_2$.

4.3 Inverse Transform Displays

The output of the transfer was 512 complex points. The inverse yields the following displays:

4.3.1 Real Display

```
ØØØ1
ØØØØ
Ø764
Ø477
```



The third value, Ø764, is a deviation from 1ØØØ, the exact value. At this time there are 2 scale factors involved. The relationship between the computed results and the original data is:

$$\text{results} = [(\text{original data})*2^{\text{sum of scale factors}}]/\#\text{ of points}$$

Reducing the equation for the first point yields:

$$1\emptyset\emptyset\emptyset_8 = [(2\emptyset\emptyset\emptyset_8)*2^8]/1\emptyset\emptyset\emptyset_8$$

$$2^9 = 2^{1\emptyset}*2^8/2^9$$

$$=2^9$$

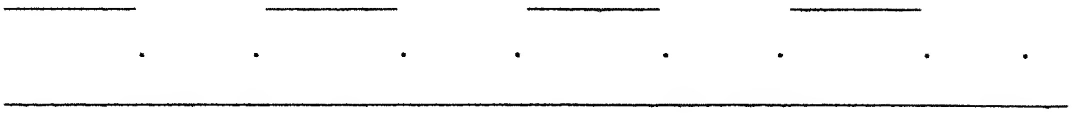
4.3.2 Imaginary Display

```
ØØØ1
1ØØØ
ØØØ7
Ø4Ø1
```

The values are very small and are the result of imprecision in the computations.

4.3.3 Magnitude Display

```
ØØØ1
2ØØØ
Ø372
Ø44Ø
```



As in the magnitude display of the transform, the values displayed are half scale. Because the imaginary components are essentially zero, the magnitude, when doubled, equals the real values.

4.3.4 Scale Factor Display

The scale factor has a value of 7.

5.0 DATA STORAGE

The data must be stored sequentially on tape or disk in a binary file starting at the beginning of a block. If the data is complex, the real parts are grouped together followed by the imaginary parts, if any. If there are none, the program will create imaginary parts of value zero. The input and output data are in the form of binary fractions. For output data, the location following the last imaginary part contains the scale factor (refer to Data Scaling, Section 6.0). A file of complex values are stored in the following format:

Ø	$REAL_1$	
	$REAL_2$	
	↓	
	$REAL_n$	
n	$IMAG_1$	
	$IMAG_2$	
	↓	
	$IMAG_n$	
2n	SCALE FACTOR	-only present if file is generated by the FFTD program.

6.0 DATA SCALING

All calculations in FFTD are done with single precision fixed point signed binary fractions. The binary point is located between bit Ø and bit 1, leaving an 11 bit signed mantissa. Bit Ø is used as a sign bit. Negative numbers are formed by taking the two's complement of the positive binary fraction, so all inputs must be scaled in magnitude to less than one. The outputs are also formatted as above.

In order to preserve precision, it is sometimes necessary to divide by 2 in a computation. As a result, a pseudo floating point format has been adopted in which a variable scale factor (or exponent) is imposed on all the Fourier coefficients. This scale factor or pseudo exponent is found in item SCAL after each transform has been completed. It is also stored after the last imaginary part on tape or disk. The values stored on tape or disk are the Fourier coefficients multiplied by 2^{SCAL}. Because in binary notation shifting a number right one bit is equivalent to dividing by two, to retrieve the coefficients themselves, shift each number right by the number of bits equal to the value of the scale factor. In the case of the inverse transform, the time samples are the values in memory multiplied by 2^{-SCAL}. If, however, the inverse transform was performed on normalized transform data, the results are equal to([(original data)*2^n]/no. of points)where n equals the sum of both scale factors. To retrieve the time samples, shift left each number by the value of the scale factor.

7.0 SUBROUTINES USED

Manipulation of the DIAL and data LINCtapes and disk is done using the program MILDRED (DEC-12-FZDA). The question and answer displays are handled by QANDA (DEC-12-FISA). The data displays are handled by DISPLAY

(DEC-12-FLSA). A modification of FFTS-C (DECUS #8-144) is used to perform the Fourier Transforms.

8.0 ALGORITHM DESCRIPTION

The Fast Fourier Transformation enables computation of the power spectrum of a time series in a minimum of time. Specifically, it permits the discrete Fourier transformation

$$S_j=\frac{1}{N}\left[\sum_{k=\emptyset}^{N-1} x_k e^{-2\pi ijk/N}\right] \qquad \begin{array}{l} j=\emptyset,.,.,\ldots,N-1 \\ i=\sqrt{-1} \end{array}$$

of a series on N equally spaced time samples (where N is a power of 2). The time required is proportional to $N_2\log_2 N$, whereas previous methods required times proportional to N. This gives a reduction in computation time of $1-\log_2 N/N$ or over 99 percent for N=1Ø24. The algorithm makes use of the fact that

$$W^k=W^{(k\bmod N)} \text{ (where } W=e^{-2\pi i/N}\text{)}$$

to reduce the number of manipulations necessary for a transformation.

9.0 CORE CHART

```
     Field Ø

SEGMENT Ø
        PAGE Ø - IFFT
        *4ØØ   - FFT
        *14ØØ  - DISPLAY
SEGMENT 1      - MILDRED
SEGMENT 2      - MONITOR
                 QANDA
SEGMENT 3      - Data display code
                 FDV table
                 RWPARM table
                 Questions
                 Sine Table
     Field 1
        Ø      - Buffer - real parts
        2ØØØ   - Buffer - imaginary parts
```

10.0 PROGRAM REGION DESCRIPTION

10.1 Routines

IFFT - Take the Inverse Fourier Transformation of the data in field 1. The results are in bit inverted order (refer to the SORTX routine).

FFT - Take the Fourier Transformation of the data in field 1. The results are in bit inverted order (refer to the SORTX routine).

SORTX - Sort the data from bit inverted order to sequential order. Bit inversion means simply the process of re-ordering the bits in a binary number. For instance, the binary number 001 bit inverted is just 1ØØ (=4). For example, to locate S_5 in memory for a 16 point transformation (N=16, n=4), write 5 as a binary number of n=4 bits, $5_{1Ø}=Ø1Ø1_2$. Then reverse the order of these bits to $1Ø1Ø_2$. This means S_5 is stored in position 1Ø. Physically, then, S_5 of the real parts is to be found in location XRTAB+9.

MULTIP - Perform a rounded single precision signed multiply using EAE. The CAL+1 contains the address of the multiplicand. The AC contains the multiplier. Exit with the product in the AC.

INVRT - Reverse the bits of the number contained in the AC.

TRIGET - Fetch sine and cosine values. Specifically, if the AC=K on entry, the values of sin $(2\pi K/N)$ and cos $(2\pi K/N)$ are fetched from an internal trig table. K must be $\geq N/2$. A register COSINE contains the cosine value and the AC contains the sine value on exit.

ADDR - Perform a single precision add with rounding.

IDORA - This subroutine generates a moving window display with a cursor riding on the curve. For more information refer to the DISPLAY document, DEC-12-FLSA-D.

IFDIAL - Display the question: FROM DIAL UNIT? Y/N_ If the answer is Y, jump to UNTFIL; if N, jump to DATTAP; if neither, redisplay the question.

UNTFIL - Jump to the subroutine ASK2 to display:

```
UNIT NUMBER__
FILE NAME________
```

If the unit number is illegal, jump to ASK2 again to redisplay the question. If legal, jump to LOOKUP with the address of the File Description Vector (hereafter referred to as FDV) parameter list in the AC. If the file cannot be found, display the message:

```
CANNOT FIND
HIT RETURN TO CONT
```

When RETURN is hit, jump back to UNTFIL. If the file is found, jump to MOVINP.

DATTAP - Jump to the subroutine ASK3 to display:

```
UNIT NUMBER__
BLK NUMBER___
```

If an illegal value is entered, jump back to DATTAP. If all the input is legal, fall through to MOVINP.

MOVINP - Jump to FDV2RW to move the input information from the FDV to the read/write parameter list. Fall through to PTS.

PTS - Display:

```
NUMBER OF PTS____
   (4-1Ø24 BY POWERS OF 2)
REAL OR
COMPLEX?  R/C_
```

Set B1 to the address of the answer buffer, MPLIER to 12 and UPLEGL to -71 (-9) because the number of points is entered as a decimal value. Set the AC to the largest legal value, 2ØØØ, and jump to CONV. If the answer is an illegal value jump back to PTS; store the value in N and store its 1's complement in TEMP1. Since the number of points must be an integral power of 2, only one bit in TEMP1 may be set. Bit 11 is the exception to one bit being a power of 2. Check bit 11 first, then rotate the value adding up the number of bits set. If the total is not 1, jump back to PTS. Otherwise fall through to ROT1.

ROT1 - Compute the power of 2 by rotating right the value in TEMP1 and stepping B2 until the bit that is set is encountered in bit 11. Fall through to STAMU.

STAMU - Store the power of 2 in NU. If the power is less than 2, jump back to PTS. Otherwise load the AC with the number of points*2 and jump to NUMBKS to compute the number of blocks needed to hold the output. Store the value in FDV+7. Store it also in RWPARM+3 since, for complex data, the input and output data consist of the same number of blocks. If the answer to the second question is not R, jump to IFCOM. If it is R, the input consists of half as many words as the output. Load the AC with the value of N and jump to NUMBKS to compute the number of input blocks. Store the value in RWPARM+3. Set REALFG and jump to CKEND.

IFCOM - If the answer is C, clear REALFG and fall through to CKEND. Otherwise jump back to PTS to redisplay the question.

CKEND - If there is not enough room between the starting block number and the end of tape to hold the number of points specified, jump back to PTS. If the number of output words is 4ØØ or greater, another block will be needed to hold the scale factor. Increment FDV+7. Fall through to IFFFT.

IFFFT - Display: FFT OR DISPLAY? F/D_
TRANSFORM OR
INVERSE? T/I_

If the answer to the first question is D, set DISFLG to indicate that the data will only be displayed. If F, clear DISFLG to indicate that a Transform or Inverse Transform will be performed. If the answer to the second question is T, clear FTFLG; if I, set it. If DISFLG is set, jump to DISPLY to display the data. Otherwise, jump to OUTQES.

OUTQES - Display the question: OUTPUT ON DIAL UNIT? Y/N_ If the answer is Y jump to OUTUNT; if N jump to ONDAT; otherwise redisplay the question.

OUTUNT - Jump to the subroutine ASK2 to display:

UNIT NUMBER__
FILE NAME_________

If an illegal value is input, redisplay the question. Otherwise jump to ENTER with the address of the parameter list in the AC. If a file with the specified name already exists, jump to SAMNAM. If there is not enough space to hold the output data, jump to NOSPAC. If it is a new file and there is enough space to hold it, fall through to RDDATA.

RDDATA - Clear 4ØØØ words of field 1 and read in the input data. If REALFG is Ø, the data is complex - move the imaginary parts to start at location 2ØØØ. If it is non-zero, the data is real and nothing need be done. Jump to PROC.

PROC - If IFTFLG is Ø, jump to FT to do a Transform. Otherwise, fall through to do an Inverse Transform.

IFT - Jump to the subroutine IFFT to do an Inverse Transform on the input data. Then jump to the subroutine SORTX to sort the coefficients into sequential order from bit inverted order. Jump to STSCAL to store the scale factor which is equal to NU-SCAL. The data should be shifted by this value.

FT - Jump to the subroutine FFT to transform the input data. Then jump to the subroutine SORTX to sort the coefficients into sequential order from bit inverted order. The scale factor is the value in SCAL and equals the number of bits by which the data should be shifted right. Fall through to STSCAL.

STSCAL - Store the scale factor in the word following the last imaginary part. Move the imaginary parts from 2ØØØ to immediately behind the real parts.

NOWSTR - Jump to the subroutine FDV2RW to move the output parameters from the FDV to the read/write parameter list. Write the data onto the output tape and jump to DISPLY.

NOSPAC - Jump to the subroutine ASK to display the message:

```
NO SPACE
HIT RETURN TO CONT
```

When RETURN is hit, jump to OUTQES.

SAMNAM - Jump to the subroutine ASK to display:

```
ALREADY EXISTS
REPLACE?  Y/N_
```

If the answer is Y, jump to REPL; if it is N, jump to OUTUNT. If it is neither, redisplay the question.

REPL - Try to replace the existing file with the new file. If the new file is longer, jump to NOSPAC. If the replacement is successful, jump to RDDATA.

ONDAT - Jump to the subroutine ASK3 to display:

```
UNIT NUMBER__
BLK NUMBER___
```

If an illegal value is entered, redisplay the question. If there is not enough space between the specified block number and the end of tape to hold the output data, jump to NOSPAC. Otherwise, jump to RDDATA.

10.2 Subroutines

FDV2RW - Transfer the unit number, starting block number, and number of blocks from the FDV parameter list to the READ/WRITE parameter list.

NUMBKS - Enter with the number of words in the AC. Convert this value to blocks by counting the number of times 4ØØ can be subtracted from it before the value becomes negative. Return with the number of blocks in the AC.

ASK2 - Jump to OCTL to set MPLIER to 1Ø and UPLEGL to -67(-7) because the unit number is input as an octal number.

```
Display:  UNIT NUMBER__
          FILE NAME________
```

by jumping to the subroutine ASK with the address of QUES2 in the AC. Set B1 to the address of the answer buffer and jump to the subroutine CONV with the largest legal unit number, 17, in the AC. If the value is illegal, return to CALL+1. If legal, store it and the file name in the FDV parameter list. Fill the file name out to 8 characters with 77's. Return to CALL+2.

ASK3 - Display:

```
UNIT NUMBER__
BLK NUMBER________
```

by jumping to the subroutine ASK with the address of QUES3 in the AC. Set B1 to the address of the answer buffer and jump to OCTL to set MPLIER to 1Ø and UPLEGL to -67(7) because the unit and block numbers are input in octal. Jump to subroutine CONV with the largest legal unit number, 17, in the AC. If the value is illegal, return to CALL+1. Otherwise, store it in word Ø of the FDV parameter list. B1 is now pointing to the block number. Jump to CONV with the largest legal block number, 777, in the AC. If the value is illegal,return to CALL+1. If legal, store it in word 6 of the FDV parameter list. Return to CALL+2.

CONV - CONV is entered with the largest legal value in the AC and B1 pointing to the address - (1 half word) of the first character to be converted. Store the 1's complement of the largest legal value in TEMP2 and clear TEMP1. UPLEGL contains a -71(-9) or -67(-7) and MPLIER contains a 1Ø or 12 depending on whether the number to be converted is in decimal or octal. Extract a character and compare it against an ASCII Ø and the contents of UPLEGL. If it is a legal value, jump to MULPLY which will multiply the value in TEMP1 by the contents of MPLIER and add the digit being converted to it. Repeat the procedure until a character is found which is not between Ø and UPLEGL. If it is not a 34, 74, or Ø, it is an illegal character: return to CALL+1. A 34 or 74 indicates the end of the input field; a Ø indicates the end of the input. Compare the converted value in TEMP1 against the maximum legal value in TEMP2. If the value is legal return to CALL+2; otherwise return to CALL+1.

OCTL - OCTL sets MPLIER to 1Ø and UPLEGL to -67(-7) so that CONV will convert an octal number.

ASK - ASK is entered with the address of the display in the AC. Store it in the parameter list and jump to QAINIT to display the message. Refresh the display until the answer is input. Return to the calling routine.

DISPLY - This region is entered either after the Transform or Inverse Transform is completed or in response to a D in answer to the display: FFT OR DISPLAY? F/D_. Since the data is manipulated in preparation for each display it must be read in before each display. After reading in the data, display:

```
WHICH DISPLAY?
R(EAL)
I(MAGINARY)
M(AGNITUDE)
S(CALE FACTOR)
LINE FEED (RESTART)
```

If the answer buffer contained Ø, just LINE FEED was hit: jump to IFDIAL to restart the program. Otherwise jump to WCHDIS.

WCHDIS - Jump to DPIMAG, DPMAG, DPREAL, or DPSCAL if the answer was I, M, R, or S,respectively. Otherwise redisplay the question.

DPIMAG - If REALFG is non-zero, the input is real and no Transform was performed. Therefore, there are no imaginary parts to display; redisplay the question. If REALFG is zero, check IFTFLG. If it equals zero, either an Inverse Transform was performed or the original data is just being displayed. In either case the data is in the right order. If IFTFLG is non-zero, a transform was performed. The positive half of the curve is first followed by the negative half and the signs are reversed. Swap the halves and reverse signs before jumping to PREPAR.

DPREAL - Check IFTFLG for the same reason as in DPIMAG. The only difference is that the signs of the real parts are not reversed.

PREPAR - If less than 1ØØØ points are to be displayed, the display will not move and the points displayed will be centered on the scope. To achieve this, LEFTX is set to the 1's complement of -1ØØØ+(1ØØØ=# of points)/2,MINPTS to the 2's complement of the number of points, and MVDIS to the instruction CLR. Jump to SHOWIT.

GQ1ØØØ - If 1ØØØ or more points are to be displayed, the display will fill the scope and will move. To achieve this, LEFTX is set to the 1's complement of 1ØØØ, MINPTS to the 2's complement of 1ØØØ and MVDIS to the instruction SCR 4. Fall through to SHOWIT.

SHOWIT - Jump to the subroutine IDORA to display the data. The six parameters following the call to IDORA are in order: the memory field of the lower address, the lower address, the memory field of the higher address, the higher address, the Y offset of the display and the scale factor of the data. Both fields are always 1, the lower address is always Ø. The higher address is set in the region DISPLY. The Y offset is always Ø; therefore the baseline is half way up the scope. The scale factor is the instruction SCR plus the number of bits to scale the data right before displaying it. Since IDORA displays only the right nine bits, if the left three bits are significant, the data must be scaled right three before displaying it.

RFRSH - Jump to RDORA to refresh repeatedly the display until a key on the teletype is hit. If the RETURN is hit, jump to REDPLY which jumps to DISPLY to redisplay the question: WHICH DISPLAY? If a 1 is entered, jump to LARGER to blow up the display. If a Q is hit, jump to SMALLR to decrease its size. If anything else is entered, ignore it.

SMALLR - If the instruction at SIZE contains a shift of 11 bits, a bigger shift would be meaningless. Jump back to RFRSH. Otherwise, increment the value of the shift and jump to SHOWIT.

LARGER - If the instruction at SIZE contains a shift of Ø bits,jump back to RFRSH. Otherwise decrement the value of the shift and jump to SHOWIT.

DPSCAL - If REALFG is non-zero, only real parts are present, meaning this program did not create the file and therefore there is no scale factor. Return to DISPLY to redisplay the question. If REALFG is Ø, the scale factor is stored after the last imaginary part. Convert it to ASCII decimal and display it.

DPMAG - If REALFG is non-zero, the input data is real and no transform was performed; therefore the magnitude is the same as the real points. Redisplay the question: WHICH DISPLAY? Otherwise move the imaginary parts to location 2ØØØ. Set RELPTR and IMGPTR, which contain the effective address of the multipliers, to 6ØØØ since the data begins at location Ø of their respective segments and is fractional. Fall through to NXTMAG.

NXTMAG - Square a real part and store it. Square the imaginary part, add the square of the real part to it, jump to the subroutine SQRT to get the square root of the sum and store it in place of the real part. Repeat the process for each point. Then jump to SHOWIT to display the magnitude.

MOVPTS - The subroutine MOVPTS moves values from one buffer (address -1 in 1Ø) in field 1 to another (address -1 in 11). If CMPFLG equals 1, the values are complemented as they are moved. TEMPR contains the 2's complement of the number of values to move.

MVRLMG - The subroutine MVRLMG is used to swap the first and second halves of the real or magnitude values. In the process they are moved from the buffer starting at location Ø to the one starting at 2ØØØ.

FDV - The File Descriptor Vector parameter list is used by the LOOKUP, ENTER, and REPLACE sections of MILDRED. Word Ø contains the unit number, words 1-4 contain the file name, word 5 contains a 2 indicating the file is binary, word 6 is the starting block number, and word 7 is the number of blocks. Word 6 is filled by LOOKUP, ENTER and REPLACE. Word 7 is filled by LOOKUP but must be supplied for ENTER and REPLACE.

RWPARM - The Read/Write parameter list is used by the READ and WRITE sections of MILDRED. Bits Ø-2 of word Ø contain the field, bits 9-11 contain the unit. Word Ø contains the starting address, word 1 the starting tape block number and word 2 the number of blocks.

SQRT - The subroutine SQRT is entered with a value in the double precision location DPSQ. It returns with the square root in the AC.

10.3 Symbols

N	Number of words in computation
NU	Power of 2 of value of N
L	Index to show what array is being constructed
S	Gives spacing between node pairs in the Lth array
NOVER4	Storage for N/4
MAXNU	Power of 2 of largest table size (13)
MNOVR2	Storage for N/2
QR	Pointer to real part of X(Q)
QI	Pointer to imaginary part of X(Q)
PR	Pointer to real part of X(P)
PI	Pointer to imaginary part of X(P)
Q	Numerical index Q (=Ø,1,...,N-1)
P	Numerical index P (=Ø,.,...,N-1)
K	Number in the node being operated on
C	Interrupts computation of Lth array every S passes
ADD2	Used by subroutine ADDR as data (addend) Used by monitor as a temporary location
TEMPR	Temporary storage register for real parts Used by monitor as a temporary location
SINE	Temporary storage for sin (S*PI*K/N) Used by monitor as a temporary location
COSINE	Temporary storage for cos (2*PI*K/N) Used by monitor as a temporary location
GR	Real part of product (W^k*X(P)) - temporary storage Used by monitor as a temporary location
GI	Imaginary part of product (W^k*X(P)) - temporary storage
SCAL	Pseudo exponent of Fourier coefficients
SHFLAG	If =1, add with shift; if =Ø, add without shift
SHFCHK	Indicates if all X's in an iteration are <.5
DISFLG	If ≠Ø, the data will just be displayed
IFTFLG	If ≠Ø, an Inverse Transform was performed
REALFG	If ≠Ø, the data does not contain imaginary parts
DPSQ	Used to save the double precision squares of the real and imaginary parts during calculation of the magnitude.
CMPFLG	If =1, the subroutine MOVPTS will complement the values as it moves them

10.4 Beta Registers

Beta registers 1, 2, and 3 are used by the monitor in ASK2 and ASK3 as temporary pointers and counters. QANDA and MILDRED make more extensive use of the Beta registers.

11.0 ASSEMBLY INSTRUCTIONS

The FFTD program is assembled in three sections by assembling and saving each, then adding them together. The entire command sequence is:

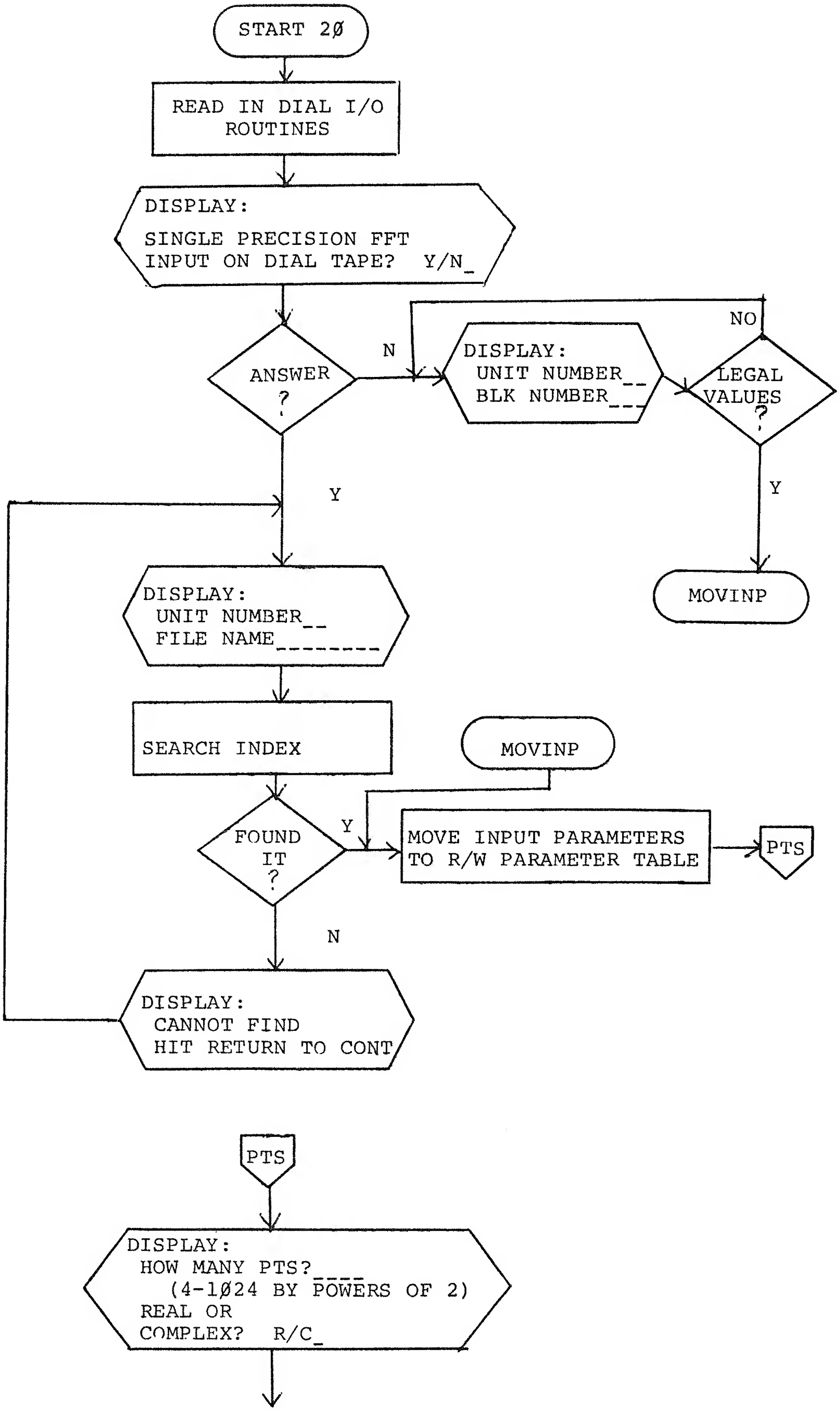
```
→AS MILQAN,n↲          where n is the unit
→SB MILQAN,n↲          containing the program
→AS SIN256,n↲
→SB SIN256,n↲
→AS FFTC-1↲            (FFTC-1 chains to FFTC-2)
→SB FFTC-1↲
→ZE↲
→AB MILQAN,n↲
→AB SIN256,n↲
→AB FFTC-1,n↲
→SB FFTD,n,L↲          (saves the whole program)
```

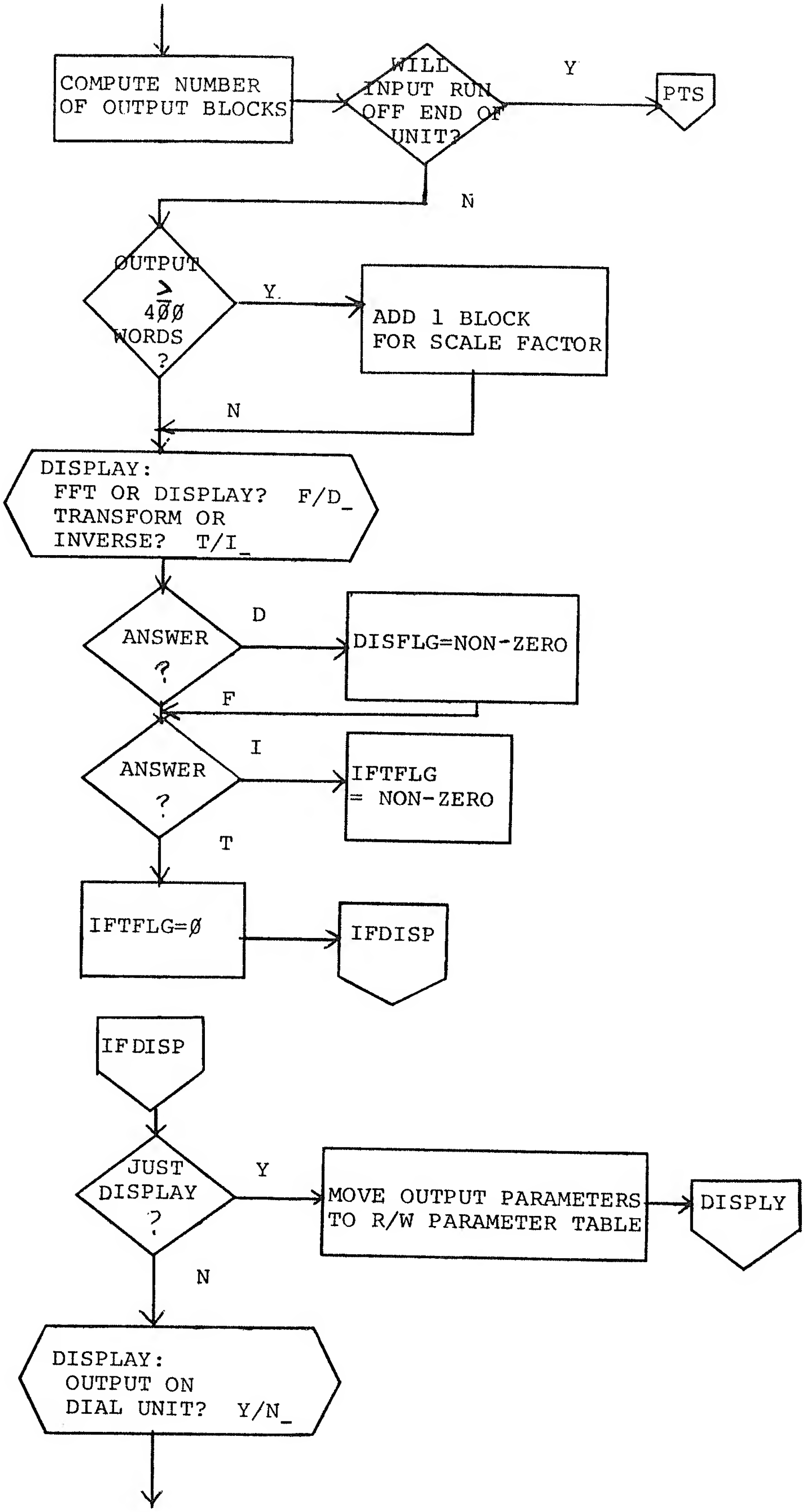
12.0 SYSTEM FLOWCHARTS

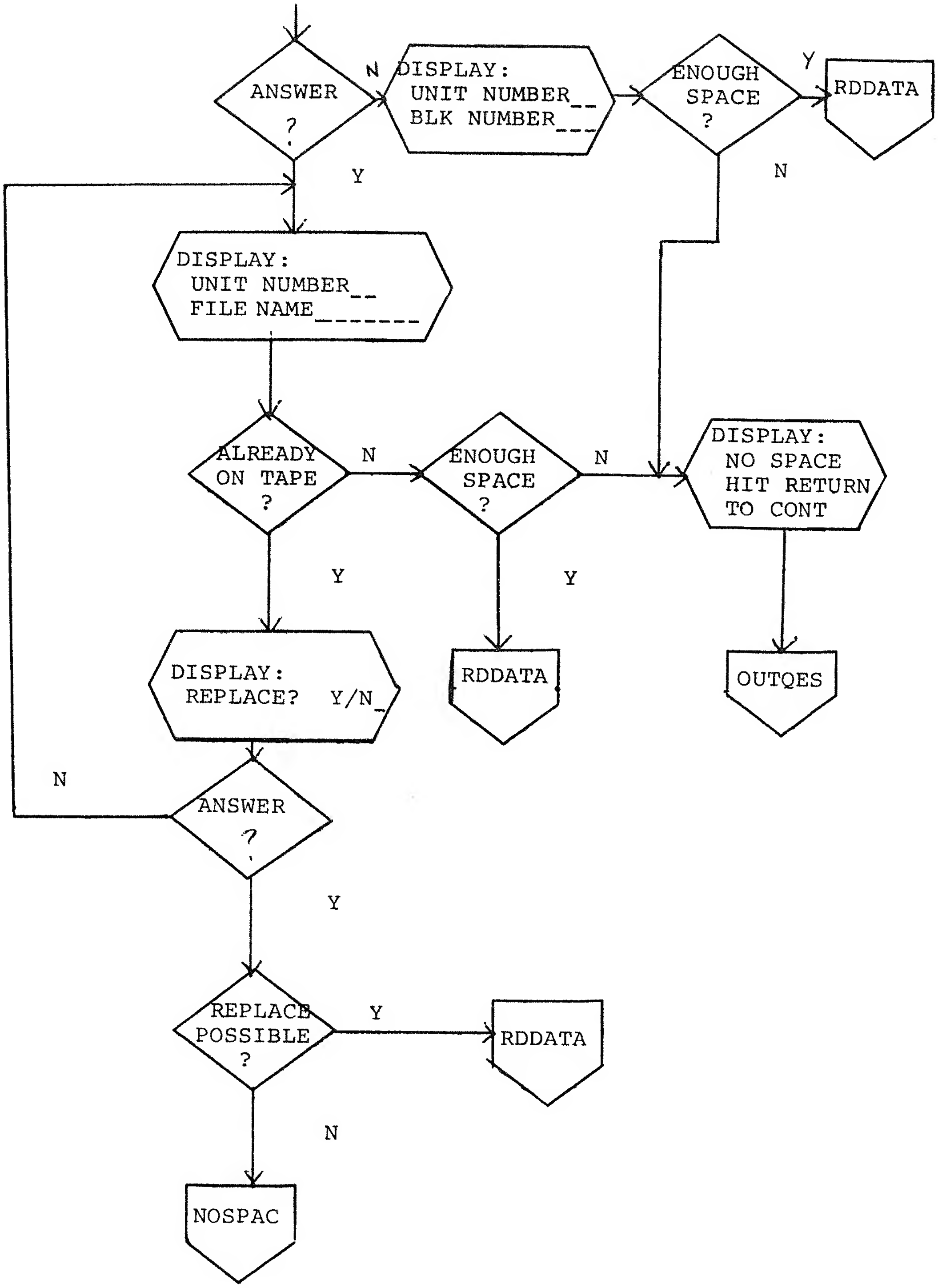
(Attached)

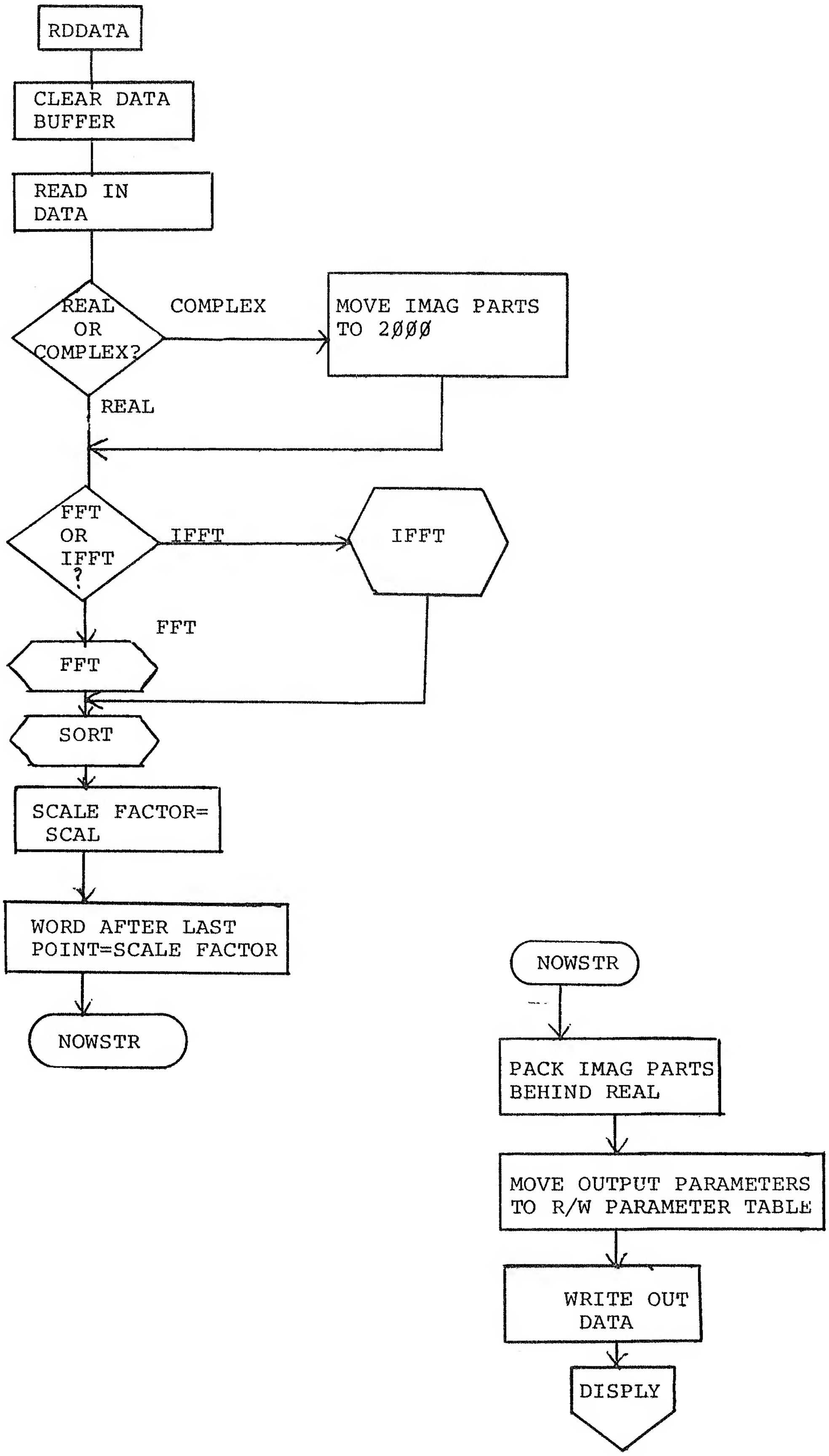
13.0 PROGRAM LISTING

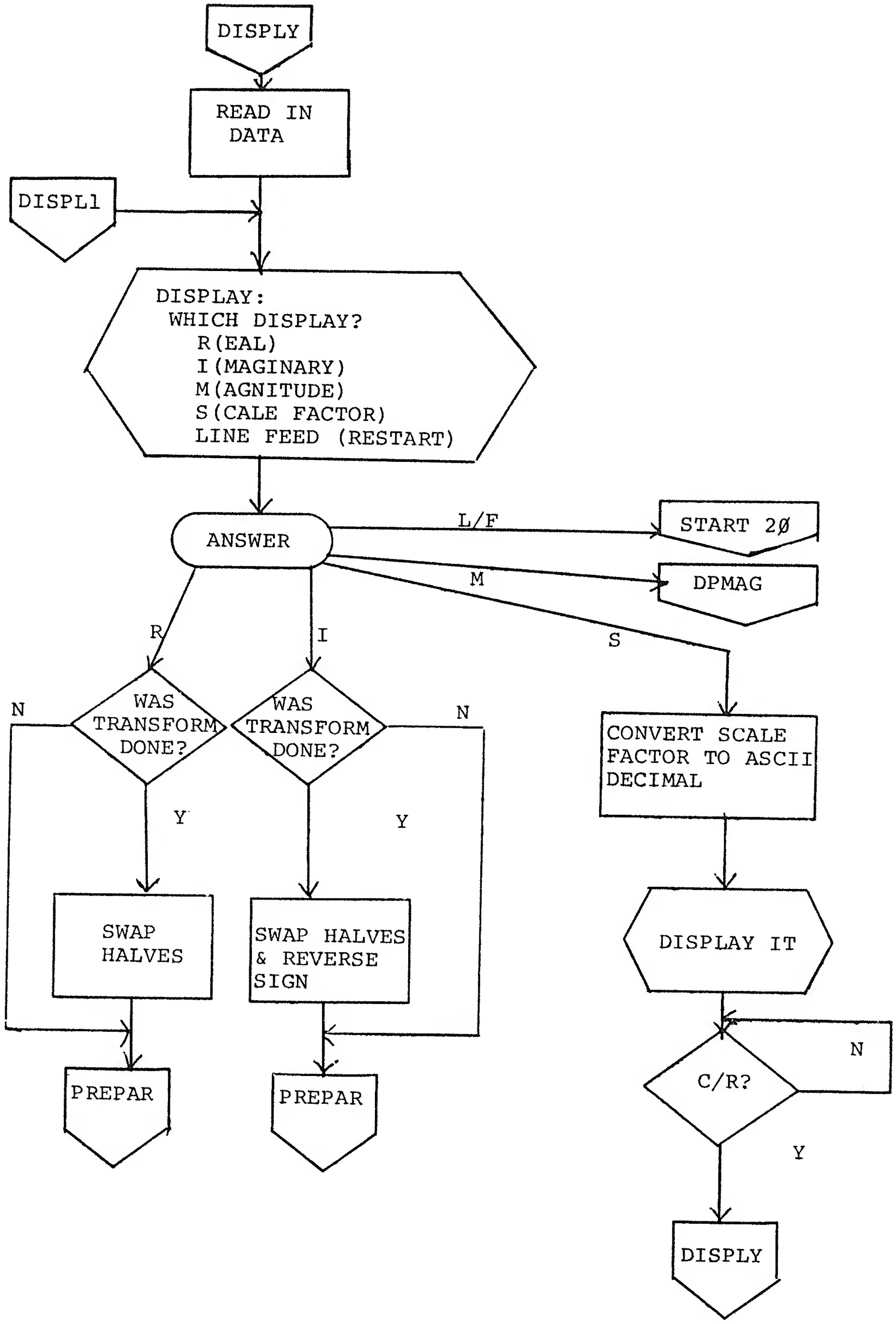
(Attached)

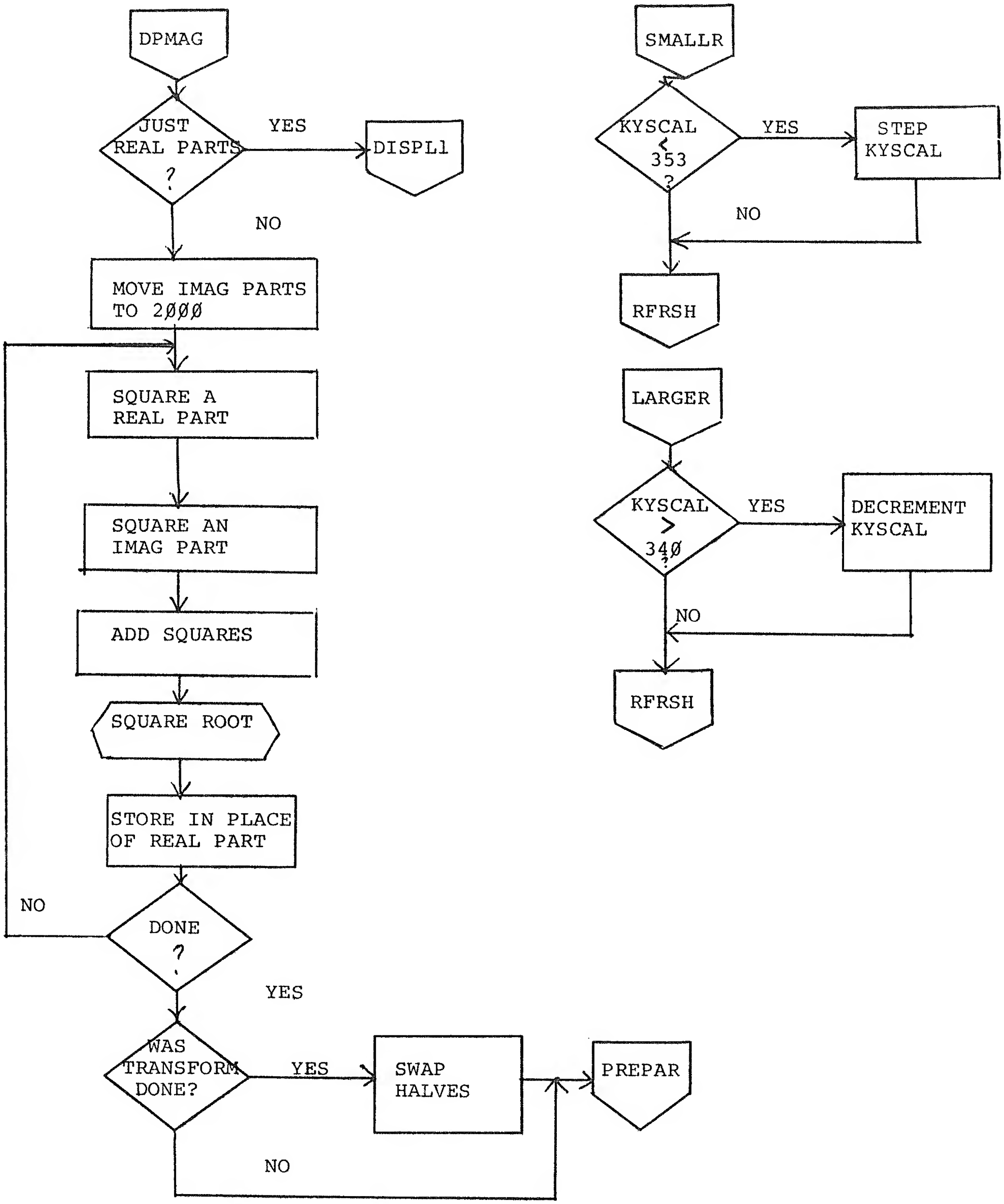

START 2Ø
READ IN DIAL I/O ROUTINES
DISPLAY:
SINGLE PRECISION FFT
INPUT ON DIAL TAPE? Y/N_
ANSWER ?
N
DISPLAY:
UNIT NUMBER__
BLK NUMBER___
LEGAL VALUES ?
NO
Y
MOVINP
Y
DISPLAY:
UNIT NUMBER__
FILE NAME_________
SEARCH INDEX
MOVINP
FOUND IT ?
Y
MOVE INPUT PARAMETERS TO R/W PARAMETER TABLE
PTS
N
DISPLAY:
CANNOT FIND
HIT RETURN TO CONT
PTS
DISPLAY:
HOW MANY PTS?____
(4-1Ø24 BY POWERS OF 2)
REAL OR
COMPLEX? R/C_

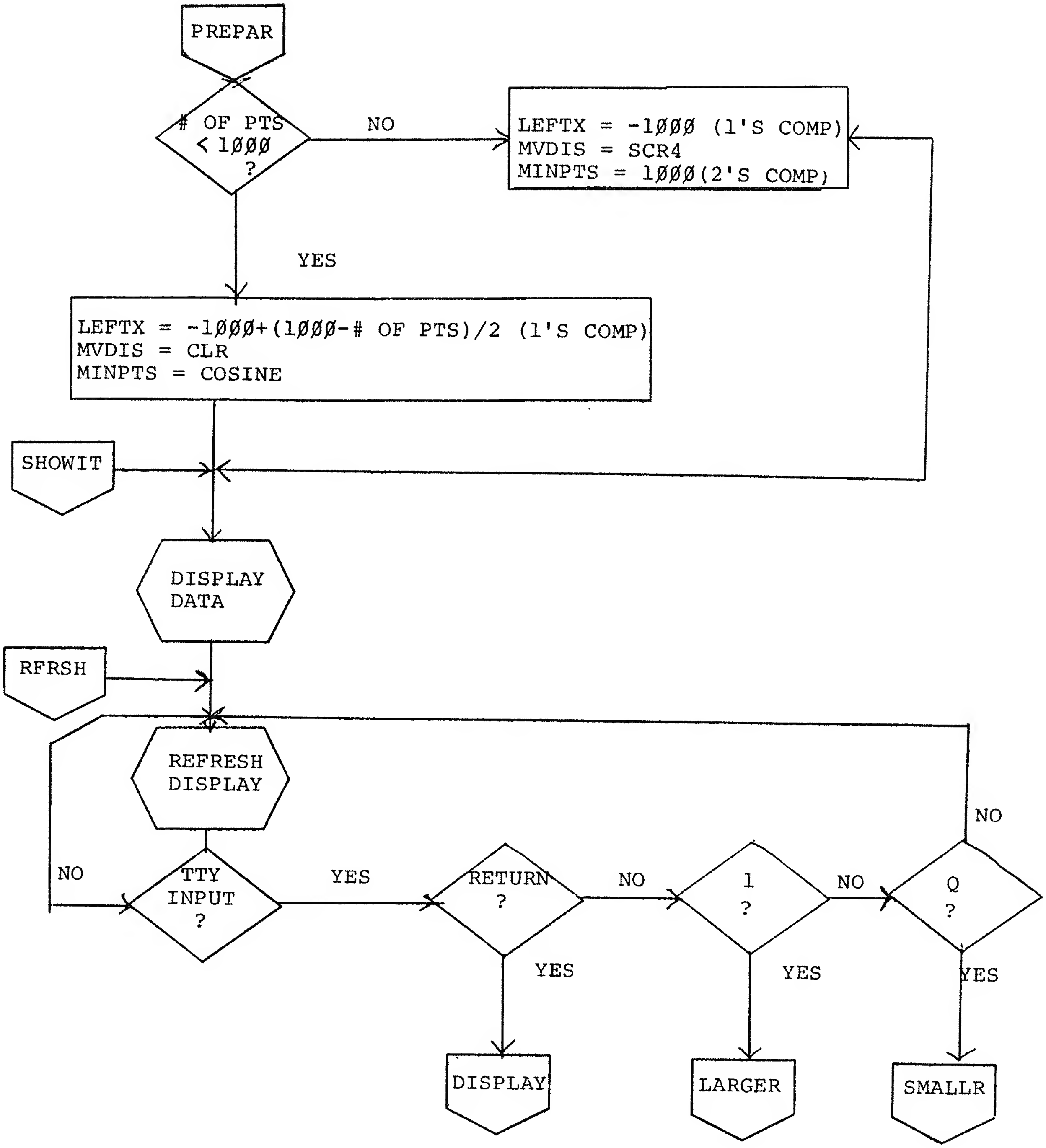

COMPUTE NUMBER OF OUTPUT BLOCKS
WILL INPUT RUN OFF END OF UNIT?
Y
PTS
N
OUTPUT ≥ 4ØØ WORDS ?
Y.
ADD 1 BLOCK FOR SCALE FACTOR
N
DISPLAY:
FFT OR DISPLAY? F/D_
TRANSFORM OR
INVERSE? T/I_
ANSWER ?
D
DISFLG=NON-ZERO
F
ANSWER ?
I
IFTFLG = NON-ZERO
T
IFTFLG=Ø
IFDISP
IFDISP
JUST DISPLAY ?
Y
MOVE OUTPUT PARAMETERS TO R/W PARAMETER TABLE
DISPLY
N
DISPLAY:
OUTPUT ON
DIAL UNIT? Y/N_


ANSWER ?
N
DISPLAY: UNIT NUMBER__ BLK NUMBER___
ENOUGH SPACE ?
Y
RDDATA
N
Y
DISPLAY: UNIT NUMBER__ FILE NAME________
ALREADY ON TAPE ?
N
ENOUGH SPACE ?
N
DISPLAY: NO SPACE HIT RETURN TO CONT
Y
Y
DISPLAY: REPLACE? Y/N_
RDDATA
OUTQES
N
ANSWER ?
Y
REPLACE POSSIBLE ?
Y
RDDATA
N
NOSPAC


RDDATA
CLEAR DATA BUFFER
READ IN DATA
REAL OR COMPLEX?
COMPLEX
MOVE IMAG PARTS TO 2ØØØ
REAL
FFT OR IFFT ?
IFFT
IFFT
FFT
FFT
SORT
SCALE FACTOR= SCAL
WORD AFTER LAST POINT=SCALE FACTOR
NOWSTR
NOWSTR
PACK IMAG PARTS BEHIND REAL
MOVE OUTPUT PARAMETERS TO R/W PARAMETER TABLE
WRITE OUT DATA
DISPLY


DISPLY
READ IN DATA
DISPL1
DISPLAY:
WHICH DISPLAY?
R(EAL)
I(MAGINARY)
M(AGNITUDE)
S(CALE FACTOR)
LINE FEED (RESTART)
ANSWER
L/F
START 2Ø
M
DPMAG
S
R
I
N
WAS TRANSFORM DONE?
WAS TRANSFORM DONE?
N
Y
Y
CONVERT SCALE FACTOR TO ASCII DECIMAL
SWAP HALVES
SWAP HALVES & REVERSE SIGN
DISPLAY IT
N
C/R?
Y
PREPAR
PREPAR
DISPLY


DPMAG
JUST REAL PARTS ?
YES
DISPL1
NO
MOVE IMAG PARTS TO 2ØØØ
SQUARE A REAL PART
SQUARE AN IMAG PART
ADD SQUARES
SQUARE ROOT
STORE IN PLACE OF REAL PART
NO
DONE ?
YES
WAS TRANSFORM DONE?
YES
SWAP HALVES
PREPAR
NO
SMALLR
KYSCAL < 353 ?
YES
STEP KYSCAL
NO
RFRSH
LARGER
KYSCAL > 34Ø ?
YES
DECREMENT KYSCAL
NO
RFRSH


PREPAR
# OF PTS
< 1ØØØ
?
NO
LEFTX = -1ØØØ (1'S COMP)
MVDIS = SCR4
MINPTS = 1ØØØ(2'S COMP)
YES
LEFTX = -1ØØØ+(1ØØØ-# OF PTS)/2 (1'S COMP)
MVDIS = CLR
MINPTS = COSINE
SHOWIT
DISPLAY
DATA
RFRSH
REFRESH
DISPLAY
NO
TTY
INPUT
?
YES
RETURN
?
NO
1
?
NO
Q
?
NO
YES
YES
YES
DISPLAY
LARGER
SMALLR

INDEX

```
                  *20
                  /FFTS-REAL
                  /THIS IS A PROGRAM FOR CALCULATING THE
                  /FAST FOURIER TRANSFORMATION OF N REAL
                  /TIME SAMPLES WHICH ARE STORED ON DIAL
                  /OR DATA TAPE OR DISK
                  /TO BE RUN ON A PDP-12 COMPUTER EQUIPPED/WITH THE FOLLOWING MINIMUM HARDWARE:
                  /  1) ASR 33 OR ASR 35 TELETYPE
                  /  2) 8 K OF CORE MEMORY
                  /  3) VR12 CRT DISPLAY
                  /
                  /COPYRIGHT 1970, DIGITAL EQUIPMENT CORPORATION
                  /         MAYNARD, MASS, 01754
                  /TRANSFORM ALGORITHM
                  /WRITTEN BY JAMES ROTHMAN -- AUGUST, 1968
                          QARFSH=1053
                          QAINIT=1000
                          XRTAB=0
                          XITAB=2000
                          SINTAB=7347
                          CDF1=6211
                          CDF0=6201
                          PMODE
                  /PAGE ZERO
                  *3
                  /TABLE PARAMETERS
      0003  0000  N,      0               /NUMBER OF POINTS IN COMPUTAION DIVIDED BY 2
      0004  0000  NU,     0               /POWER OF TWO OF POINTS IN COMPUTATION (N=2↑NU) MINUS 1
      0005  0000  L,      0               /INDEX TO SHOW WHAT ARRAY IS BEING CONSTRUCTED
      0006  0000  S,      0               /GIVES SPACING BETWEEN NODE PAIRS IN THE LTH ARRAY,
      0007  0000  F,      0               /USED FOR SCALING NODE POSITION TO GET NUMBER IN NODES.

                          *20
      0020  0000  NOVER4, 0               /STORAGE FOR N/4
      0021  0012  MAXNU,  BIGSNU          /LARGEST TABLE SIZE (POWER OF 2)
      0022  0000  MNOVR2, 0               /STORAGE FOR -N/2
                  /INDEXING VARIABLES
      0023  0000  QR,     0               /POINTER TO REAL PART OF X(Q)
      0024  0000  QI,     0               /POINTER TO IMAG, PART OF X(Q)
      0025  0000  PR,     0               /POINTER TO REAL PART OF X(P)
      0026  0000  PI,     0               /POINTER TO IMAG, PART OF X(P)
      0027  0000  Q,      0               /NUMERICAL INDEX Q(=0,1,...N-1)
      0030  0000  P,      0               /NUMBERICAL INDEX P(=0,1,..,N-1)
      0031  0000  K,      0               /NUMBER IN THE NODE BEING OPERATED ON
                  /LOOP DELIMITERS
      0032  0000  C,      0               /INTERRUPTS COMPUTATION OF LTH ARRAY EVERY S PASSES
                  /DATA VARIABLES
      0033  0000  ADD2,   0               /USED BY SUBROUTINE ADDR AS DATA (ADDEND)
      0034  0000  TEMPR,  0               /TEMPORARY STORAGE REGISTER FOR REAL PARTS
      0035  0000  SINE,   0               /TEMP. STORAGE FOR SIN (S*PI*K/N)
      0036  0000  COSINE, 0               /TEMP. STORAGE FOR COS (2*PI*K/N)
      0037  0000  GR,     0               /REAL PART OF PRODUCT (W↑K)*X(P), TEMP STORAGE
      0040  0000  GI,     0               /IMAG. PART OF (W↑K)*X(P), TEMP STORAGE
                  /SUBROUTINE CALL LIST
      0041  1135  ADDER,  ADDR            /ADD C(AC) TO C(ADD2) AND SCALE RIGHT ONE IF NECESSARY.
      0042  0701  SORT,   SORTX           /BIT INVERTED BUFFER SORTED
      0043  1040  INVERT, INVRT           /WORD IN AC OF NU BITS IS BIT INVERTED
      0044  1000  MULT,   MULTIP
      0045  1060  GETRIG, TRIGET          /FETCH SIN AND COS OF 2*PI*C(AC)/N
      0046  0400  DOFFT,  FFT             /DO FFT OF THE INPUT BUFFER
```

```
ØØ5Ø  7547   SINLOC, SINTAB
ØØ51  ØØØØ   XRLOC,  XRTAB              /INPUT BUFFER AND TABLE OF ARRAYS
ØØ52  2ØØØ   XLOCDF, XITAB=XRTAB        /DIFF IN ADDR OF REAL & IMAG PART TABLES
             /PSEUDO FLOATING POINT FORMAT FLAGS
ØØ53  ØØØØ   SCAL,   Ø                  /PSEUDO EXPONENT OF FOURIER COEFFICIENTS
ØØ54  ØØØ1   SHFLAG, 1                  /IF =1, ADD WITH SHIFT; IF=Ø, ADD WITHOUT SHIFT
ØØ55  ØØØØ   SHFCHK, Ø                  /INDICATES IF ALL XS IN AN ITERATION ARE <.5
             /POINTERS TO SINE TABLE LOOK-UP SHIFTS
ØØ56  1Ø77   SHIFT1, SHFT1              /THE NUMBER 1Ø-NU MUST BE PLACED
ØØ57  1114   SHIFT2, SHFT2              /IN EACH OF THESE LOCATIONS
ØØ6Ø  1125   SHIFT3, SHFT3
             /POINTERS TO INSTRUCTION "FLAG" LOCATIONS
ØØ61  ØØØØ   WORD,   Ø
ØØ62  ØØØØ   WORDP,  Ø
ØØ63  ØØØØ   FLIPCT, Ø
             /
ØØ64  Ø544   RBUILD, BUILD
ØØ65  Ø542   RESETC, SETC
ØØ66  Ø515   RECHK,  CHKPT
ØØ67  4ØØØ   M4ØØØ,  -4ØØØ
ØØ7Ø  7777   M1,     -1
ØØ71  7766   M12,    -12
ØØ72  777Ø   M1Ø,    -1Ø
ØØ73  616Ø   GRET1Ø, 616Ø
ØØ74  4Ø6Ø   LESS1Ø, 4Ø6Ø
ØØ75  7774   M4,     -4
ØØ76  627Ø   PDPMAG, DPMAG
ØØ77  7767   M11,    -11
Ø1ØØ  7773   M5,     -5
Ø1Ø1  6ØØØ   C6ØØØ,  6ØØØ
Ø1Ø2  7563   M215,   -215
Ø1Ø3  7457   M321,   -321
Ø1Ø4  7425   M353,   -353
Ø1Ø5  744Ø   M34Ø,   -34Ø
Ø1Ø6  7517   M261,   -261
Ø1Ø7  74ØØ   M4ØØ,   -4ØØ
Ø11Ø  1777   C1777,  1777
Ø111  ØØØØ   YSHFT,  Ø
Ø112  ØØØØ   XCURHI, Ø
Ø113  ØØØØ   XCURLO, Ø
Ø114  ØØØØ   CORVAL, Ø
Ø115  ØØØØ   YCUR,   Ø
Ø116  ØØØØ   COUNT,  Ø
Ø117  12ØØ   KIDORA, IDORA
Ø12Ø  1343   KRDORA, RDORA
Ø121  6162   PSHOWT, SHOWIT
Ø122  6171   PRFRSH, RFRSH
Ø123  64Ø4   PFDV7,  FDV+7
Ø124  1361   PMVDIS, MOVDIS
Ø125  1363   PLEFTX, LEFTX
Ø126  7132   PMRLMG, MVRLMG
Ø127  7116   PMVPTS, MOVPTS
Ø13Ø  ØØØØ   CMPFLG, Ø
Ø131  ØØØØ   MINPTS, Ø
Ø132  6Ø53   PRELFG, REALFG
Ø133  4356   PIFTFG, IFTFLG
Ø134  7774   PREAD,  7774
Ø135  7775   PWRITE, 7775
Ø136  1444   KYSCAL, YSCAL
Ø137  1ØØØ   C1ØØØ,  1ØØØ
Ø14Ø  2ØØØ   C2ØØØ,  2ØØØ
Ø141  6777   M1K,    6777               /-1ØØØ 1,S CC
Ø142  ØØØØ   DPSQ,   Ø                  /D.P. SQUARE
```

```
Ø174      Ø143   ØØØØ            Ø
Ø175                             LMODE
Ø176      Ø144   Ø644   LDF4,    LDF 4
Ø177      Ø145   Ø344   SCR4,    SCR 4
Ø2ØØ      Ø146   ØØ11   CCLR,    CLR
Ø2Ø1                             PMODE
Ø2Ø2                             EJECT
```

```
                 /THIS SUBROUTINE TAKES THE INVERSE FFT (IFFT) OF THE DATA IN THE BUFFER.
                 /IT IS ASSUMED THAT THIS DATA IS STORED SEQUENTIAL ORDER.
                 /THE RESULTS ARE STORED IN BIT INVERTED ORDER.
                 /THE ALGORITHM USED IS AS FOLLOWS:
                 /       THE NORMAL TRANSFORM IS PERFORMED, EXCEPT:
                 /       ON FETCHING THE VALUE FOR IM[W↑K], WHICH IS
                 /       THE SIN(2*PI*K/N), THIS SIN VALUE IS NEGATED.
                 /
                 /THE REASONING FOR THIS IS AS FOLLOWS:
                 /       A WEIGHTING FACTOR OF W↑8-K) IS USED IN THE IFFT
                 /       AND SINCE W↑K AND W↑(-K) ARE THE SAME EXCEPT THAT
                 /       THEIR IMAGINARY PARTS HAVE OPPOSITE SIGNS, IT FOLLOWS
                 /       THAT IM]W↑K] SHOULD BE REPLACED BY -IM[W↑K].
0147  0000       IFFT,   0
0150  7300               CLA CLL
0151  1162               TAD     CCIA    /NEGATE IM[W↑K], GET CIA INSTRUCTION
0152  3561               DCA I   SGNADJ  /AND PUT AT LOCATION ADJSN
0153  4443               JMS I   DOFFT   /DU FFT
0154  6201               CDF0
0155  1163               TAD     CNOP    /RE-INSTATE NOP AT ADJSGN FOR FFT.
0156  3561               DCA I   SGNADJ
0157  6211               CDF1
0160  5547               JMP I   IFFT    /EXIT
0161  0570       SGNADJ, ADJSGN          /POINTER TO SIGN ADJUST INSTRUCTION
0162  7041       CCIA,   CIA
0163  7000       CNOP,   NOP
                         EJECT
```

```
                      *400
                      /COMPUTATION OF FIRST COMPLEX ARRAY   )M INPUT DATA
                      /NUMBER OF INPUT POINTS IN "N" ,LOG2(N)IN"NU", FOR DETAILS OF ALGORITHM, SEE FLOWCHART
0400  0000    FFT,    0
0401  7301            CLA IAC CLL
0402  3005            DCA     L                   /L<=1
0403  3053            DCA     SCAL                /INITIALIZE FLOATING POINT FORMAT
0404  7001            IAC
0405  3054            DCA     SHFLAG
0406  3055            DCA     SHFCHK
0407  1003            TAD     N
0410  7112            CLL RTR                     /INITIALIZE PROGRAM CONSTANTS
0411  3020            DCA     NOVER4
0412  1004            TAD     NU
0413  7041            CIA
0414  1021            TAD     MAXNU
0415  3456            DCA I   SHIFT1
0416  1456            TAD I   SHIFT1
0417  3457            DCA I   SHIFT2
0420  1457            TAD I   SHIFT2
0421  3460            DCA I   SHIFT3
0422  1003            TAD     N
0423  7110            CLL RAR
0424  3006            DCA     S                   /S<=N/2 IS SPACING OF NODE PAIRS IN FIRST ARRAY
0425  1006            TAD     S
0426  7041            CIA
0427  3022            DCA     MNOVR2
0430  7040            CMA                         /AC<=-1
0431  1006            TAD     S                   /AC<=[N/2-1]*2
0432  1051            TAD     XRLOC               /BEGINNING OF TABLE OF REAL PARTS,
0433  3023            DCA     QR                  /Q<=N/2-1, QR POINTS TO WORD IN MEMORY, WHILE Q IS ACTUAL INDEX
0434  1004            TAD     NU
0435  7041            CIA
0436  7001            IAC
0437  3007            DCA     F                   /F<=1-NU (=L-NU SINCE L=1)
0440  1023    LOOP1,  TAD     QR                  /QR=XRLOC+Q AT ALL TIMES.
0441  1006            TAD     S
0442  3025            DCA     PR                  /P<=Q+N/2
0443  1023            TAD     QR                  /XLOCDF=XILOC-XRLOC (XILOC=BEGIN, OF IMAG PARTS TABLE)
0444  1052            TAD     XLOCDF              /QR+XLOCDF=(S+XRLOC)+(XILOC-XRLOC)=XILOC+S=QI
0445  3024            DCA     QI                  /QI=XILOC+Q AT ALL TIMES, QI POINTS TO IMAG. PART OF X(Q)
0446  1025            TAD     PR
0447  1052            TAD     XLOCDF              /COMPUTE COMPLEX OPERATIONS X(P)<=X(Q)-X(P) AND X(Q)<=X(Q)+X(P)
0450  3026            DCA     PI                  /BY REAL AND IMAGINARY PARTS.
0451  6211            CDF1
0452  1424            TAD I   QI                  /IM(X(Q)) (IM () MEANS IMAGINARY PART)
0453  3033            DCA     ADD2                /MAKE IT ADDEND, DO IMAG. PARTS FIRST
0454  1426            TAD I   PI                  /IM(X(P))
0455  4441            JMS I   ADDER               /FORM ADDITION IM[X(P)+X(Q)]=IM[X(P)]+IM[X(Q)] AND SCALE RIGHT
0456  3034            DCA     TEMPR               /FOR SCALING, THEN STORE.
0457  1424            TAD I   QI                  /FORM DIFFERENCE IM[X(Q)-X(P)]=IM[X(Q)]-IM[X(P)]
0460  3033            DCA     ADD2
0461  1426            TAD I   PI
0462  7041            CIA
0463  4441            JMS I   ADDER
0464  3426            DCA I   PI                  /PUT AWAY AT IM[X(P)]
0465  1034            TAD     TEMPR               /GET IM[X(P)+X(Q)]
0466  3424            DCA I   QI                  /PUT AT IM[X(Q)], IMAGINARY PARTS DONE.
0467  1423            TAD I   QR                  /ADD REAL PARTS NEXT
0470  3033            DCA     ADD2
0471  1425            TAD I   PR                  /RE=REAL PART
0472  4441            JMS I   ADDER               /FORM RE[X(P)+X(Q)]=RE[X(P)]+RE[X(Q)]
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0474  1423          TAD I   QR              /GET RE[X(Q)]
0475  3033          DCA     ADD2
0476  1425          TAD I   PR              /RE=REAL PART
0477  7041          CIA
0500  4441          JMS I   ADDER           /FORM RE[X(Q)-(P)] (DIVIDED BY 2)
0501  3425          DCA I   PR              /PUT AT RE[X(P)]
0502  1034          TAD     TEMPR           /GET RE[X(Q)+X(P)]
0503  3423          DCA I   QR              /PUT AT RE[X(Q)],REAL PARTS DONE
0504  1051          TAD XRLOC               /Q=QR-XRLOC
0505  7041          CIA
0506  1023          TAD QR          /AC IS Q
0507  7750          SPA SNA CLA     /IS Q>0? (IE THE WHOLE ARRAY HAS NOT BEEN COVERED)
0510  5315          JMP CHKPT       /NO, Q=0, DONE WITH FIRST ARRAY, MOVE ON TO OTHERS
0511  7040          CMA             /YES, Q<=Q-1, MOVE UP THIS ARRAY
0512  1023          TAD QR          /OR EQUIVALENTLY, QR<=QR-1
0513  3023          DCA QR
0514  5240          JMP LOOP1       /DO NEXT NODE PAIR
0515  1005  CHKPT,  TAD L           /L GIVES THE NUMBER OF THE VERTICAL ARRAY JUST BUILT
0516  7041          CIA
0517  1004          TAD NU          /IS L=NU?  (IE HAS THE LAST ARRAY BEEN COMPUTED?)
0520  7650          SNA CLA
0521  5600          JMP I FFT     /YES, DONE, RESULTS STORED IN BIT REVERSED ORDER
0522  1055          TAD SHFCHK      /GET SCALE FACTOR AND ADJUST FOR PROPER
0523  3054          DCA SHFLAG      /ADDITION ON NEXT ITERATION
0524  1055          TAD     SHFCHK
0525  7650          SNA CLA
0526  2053          ISZ     SCAL
0527  3055          DCA     SHFCHK
0530  2005          ISZ     L               /L<=L+1, MOVE ON TO NEXT ARRAY
0531  1006          TAD     S               /S GIVES SPACING BETWEEN NODE PAIRS, WHICH IS N/2↑L
0532  7110          CLL RAR                 /DIVIDE BY 2 AND PUT BACK, SO THAT ON THE LTH PASS THROUGH
0533  3006          DCA     S               /S WILL=N/2↑L, THE SPACING,
0534  2007          ISZ     F               /F<=F+1, ON LTH PASS, F WILL BE F=L-NU, THE SCALE FACTOR FOR K.
0535  7000          NOP                     /NOP FOR WHEN F=-1 TO PREVENT ERROR DUE TO SKIP
0536  7040          CMA                     /AC<=-1
0537  1003          TAD     N
0540  1051          TAD     XRLOC
0541  3025          DCA     PR              /P<=N-1, PR POINTS TO RE[X(P=N-1)]
0542  7201  SETC,   CLA IAC
0543  3032          DCA     C               /C<=1, C BREAKS BUILD LOOP EVERY S ITERATIONS
0544  1025  BUILD,  TAD     PR      /SO AS TO AVOID RECOMPUTATION
0545  1052          TAD     XLOCDF
0546  3026          DCA     PI
0547  1051          TAD     XRLOC   /PR=XRLOC+P
0550  7041          CIA
0551  1025          TAD     PR
0552  3030          DCA     P       /ACTUAL INDEX IS P:(0,1,,,,N-1)
0553  1007          TAD     F               /BUILD ARRAY, F=L-NU, SHIFT "P"-F PLACES RIGHT (=NU-L)
0554  7450          SNA                     /SHIFT ZERO PLACES?
0555  5364          JMP     NOROT           /YES, LEAVE ALONE
0556  7040          CMA                     /F COMPLEMENTED IS -F-(1)=-(F+1)=PLACES TO BE SHIFTED-1
0557  3362          DCA     SHIFCT          /CONTAINS-F-1
0560  1030          TAD     P               /GET NODE INDEX
0561  7417          LSR                     /SHIFT P RIGHT SHIFCT+1=-F-1+1=-F=NU-L PLACES
0562  7402  SHIFCT, HLT             /STORAGE FOR SHIFT COUNT.
0563  7410          SKP                     /AC<=INTEGER PART [P*2↑F]
0564  1030  NOROT,  TAD     P               /NO ROTATION, JUST GET P=P*2↑0
0565  4443          JMS I   INVERT          /INVERT BIT ORDER AND PUT IN K (NUMBER IN PTH NODE)
0566  1022          TAD     MNOVR2          /SUBTRACT N/2 TO GET NUMBER IN Q (=K) (PS NODE PAIR.)
0567  4445          JMS I   GETRIG          /GET REAL AND IMAGINARY PARTS OF W*K.
0570  7000  ADJSGN, NOP                     /SET     CIA FOR DOING IFFT, NOP FOR FFT.
0571  3035          DCA     SINE            /SIN(2*PI*K/N)=-IM[W↑K], COS IN REGISTER COSINE.
0572  1425          TAD I   PR              /FORM (W↑K)*X(P)-A COMPLEX MULTIPLICATION
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0434   0573  4444        JMS I   MULT              /DO REAL PART FIRST=RE[X(P)]*COSINE+IM[X(P)]*SINE
0435   0574  0036        COSINE                    /AC=RE[X(P)]*COSINE=RE[X(P)]*RE[W+K]
0436   0575  3033        DCA     ADD2              /SAVE FOR ADDITION LATER
0437   0576  1426        TAD I   PI                /GET IM[X(P)]
0440   0577  4444        JMS I   MULT
0441   0600  0035        SINE                      /AC=IM[X(P)]*SINE=-IM[W+K]*IM[X(P)]
0442   0601  1033        TAD     ADD2              /AC=RE[W+K]*RE[X(P)]-IM[W+K]*IM[X(P)]=RE[X(P)=W+K]
0443   0602  3037        DCA     GR                /STORE AT GR
0444               /DO IMAG, PART NEXT=IM[X(P)]*COSINE-RE[X(P)]*SINE=IM[X(P)]*RE[W+K]+RE[X(P)]*IM[W+K]
0445   0603  1426        TAD I   PI
0446   0604  4444        JMS I   MULT              /AC=IM[X(P)]
0447   0605  0036        COSINE                    /AC=IM[X(P)]*COSINE=IM[(P)]*RE[W+K]
0450   0606  3033        DCA ADD2                  /STORE FOR LATER ADDITION
0451   0607  1425        TAD I PR                  /AC=RE[X(P)]
0452   0610  4444        JMS I MULT
0453   0611  0035        SINE            /AC=RE[X(P)]*SINE=-RE[X(P)]*IM[W+K]
0454   0612  7041        CIA             /AC=RE[X(P)]M*IM[W+K]
0455   0613  1033        TAD ADD2        /AC=IM[X(P)]*RE[W+K]+RE[X(P)]*IM[W+K]=IM[X(P)*W+K]
0456   0614  3040        DCA GI          /STORE AT GI, SO GI=IM[X(P)*W+K] AND GR=RE[X(P)*W+K] G=GR+I*GI
0457   0615  1006        TAD S           /LOCATE P NODE PAIR Q, LOCATED S=N/(2+L) UP ARRAY
0460   0616  7041        CIA             /SO SET Q=P-S=INDEX OF NODE PAIR
0461   0617  1025        TAD PR          /LOCATE X(Q) IN MEMORY BY FIXING POINTERS QR AND QI
0462   0620  3023        DCA QR          /TO QS REAL AND IMAG PARTS RESPECTIVELY
0463   0621  1023        TAD     QR
0464   0622  1052        TAD     XLOCDF
0465   0623  3024        DCA     QI
0466   0624  1423        TAD I   QR                /DO THE COMPLEX OPERATIONS:  X(P)<=X(Q)-G;X(Q)<=X(Q)+G
0467   0625  3033        DCA     ADD2              /FIRST DO REAL PART OF X(P), GET RE[X(Q)] AND STORE
0470   0626  1037        TAD     GR                /GET RE[G]
0471   0627  7041        CIA
0472   0630  4441        JMS I   ADDER             /SUBTRACT THEM,
0473   0631  3425        DCA I   PR                /RE[X(P)]<=RE[X(Q)]-RE[G]
0474   0632  1424        TAD I   QI                /COMPUTE IMAG, PART OF X(P), GET IM[X(Q)]
0475   0633  3033        DCA     ADD2              /AND STORE
0476   0634  1040        TAD     GI                /GET IM[G]
0477   0635  7041        CIA
0500   0636  4441        JMS I   ADDER             /AND SUBTRACT THEM.
0501   0637  3426        DCA I   PI                /IM[X(P)]<=IM[X(Q)]-IM[G],X(P) IS NOW DONE.
0502   0640  1423        TAD I   QR                /NEXT COMPUTE X(Q), FIRST REAL PART
0503   0641  3033        DCA     ADD2              /GET RE[G] AND STORE
0504   0642  1037        TAD     GR                /GET RE[G] AND ADD TO FORM
0505   0643  4441        JMS I   ADDER             /RE[X(Q)]+RE[G].
0506   0644  3423        DCA I   QR                /RE[X(Q)]<=RE[X(Q)]+RE[G]
0507   0645  1424        TAD I   QI                /NOW COMPUTE IMAG PART OF X(Q), GET IM[X(Q)]
0510   0646  3033        DCA     ADD2              /AND STORE
0511   0647  1040        TAD     GI                /GET IM[G] AND ADD TO FORM
0512   0650  4441        JMS I   ADDER             /IM[X(Q)]+IM[G]
0513   0651  3424        DCA I   QI                /IM[X(Q)]<=IM[X(Q)]+IM[G], THE NEW NODE PAIR IS COMPUTED.
0514   0652  7040        CMA                       /MOVE UP ARRAY TO NEXT NODE, SET AC=-1
0515   0653  1030        TAD     P                 /TO FORM -1
0516   0654  3030        DCA     P                 /P<=P-1
0517   0655  7040        CMA
0520   0656  1025        TAD     PR      /DO THE SAME FOR POINTER PR
0521   0657  3025        DCA     PR
0522   0660  1032        TAD     C                 /CHECK ON SPACING, IS A NODE WHICH HAS ALREADY BEEN COMPUTED
0523   0661  7041        CIA                       /ABOUT TO BE RE-DONE, OR EQUIVALENTLY,
0524   0662  1006        TAD     S                 /IS C=S?
0525   0663  7640        SZA CLA                   /YES.
0526   0664  5277        JMP     CNOTS             /NO, DO NEXT NODE PAIR
0527   0665  1030        TAD     P                 /YES, BUT ARE WE AT THE TOP OF THE ARRAY?
0530   0666  7040        CMA                       /OR, IS S=P+1?  (P COMPLEMENTED=-P-1=-(P+1)
0671  5466           JMP I   RECHK        /YES, DONE WITH THIS ARRAY, DO NEXT ONE.
0672  1006           TAD     S            /NO, MOVE PAST AREA THAT HAS AREADY BEEN DONE, OR SET P TO P-S.
0673  7041           CIA                  /BY CHANGING THE POINTER TO RE[X(P)]
0674  1025           TAD     PR
0675  3025           DCA     PR
0676  5465           JMP I   RESETC       /REINITIALIZE C TO 1 SINCE AN UNUSED AREA HAS BEEN ENTERED.
0677  2032  CNOTS,   ISZ     C            /C<=C+1, ANOTHER NODE PAIR HAS BEEN HANDLED.
0700  5464           JMP I   RBUILD       /DO NEXT NODE PAIR IN THIS AREA.
0701  0000  SORTX,   0                    /SUBROUTINE THAT
0702  7040           CMA                  /SORTS OUT TRANSFORMS BY
0703  1003           TAD     N            /BIT INVERSION OF ADDRESS.
0704  3027           DCA     Q            /Q<=N-1, START FROM BOTTOM OF BUFFER
0705  1027  REVERS,  TAD     Q            /P<=BIT INVERTED Q
0706  4443           JMS I   INVERT       /BIT INVERSION ROUTINE
0707  3030           DCA     P
0710  1030           TAD     P            /FORM Q-P
0711  7041           CIA
0712  1027           TAD     Q
0713  7750           SPA SNA CLA          /IS P<Q?
0714  5345           JMP     SWAPED       /NO, HAVE ALREADY DONE THIS PAIR
0715  1030           TAD     P            /YES, SWAP ORDER
0716  1051           TAD     XRLOC        /FIRST SET UP SUBSCRIPT POINTERS FOR X(P) AND X(Q).
0717  3025           DCA     PR
0720  1027           TAD     Q
0721  1051           TAD     XRLOC
0722  3023           DCA     QR
0723  1025           TAD     PR
0724  1052           TAD     XLOCDF
0725  3026           DCA     PI
0726  1023           TAD     QR
0727  1052           TAD     XLOCDF
0730  3024           DCA     QI      /EXCHANGE: X(P)<=X(Q) AND X(Q)<=X(P)
0731  1425           TAD I   PR           /EXCHANGE REAL PARTS, GET RE[X(P)]
0732  3034           DCA     TEMPR        /STORE IT.
0733  1423           TAD I   QR           /GET RE[X(Q)]
0734  3425           DCA I   PR           /MAKE IT RE[X(P)]
0735  1034           TAD     TEMPR        /GET RE[X(P)]
0736  3423           DCA I   QR           /MAKE IT RE[X(Q)]
0737  1426           TAD I   PI           /EXCHANGE IMAGINARY PARTS, GET IM[X(P)]
0740  3034           DCA     TEMPR        /STORE IT.
0741  1424           TAD I   QI           /GET IM[X(Q)]
0742  3426           DCA I   PI           /MAKE IT IM[X(P)]
0743  1034           TAD     TEMPR        /GET IM[X(P)]
0744  3424           DCA I   QI           /MAKE IT IM[X(Q)]
0745  1027  SWAPED,  TAD     Q            /IS Q=0?, IE; ARE WE AT THE TOP OF THE ARRAY
0746  7640           SZA CLA
0747  5352           JMP .+3
0750  6201           CDF0
0751  5701           JMP I   SORTX        /YES, DONE EXIT
0752  7040           CMA                  /NO, Q<=Q-1, IE; MOVE UP THE ARRAY
0753  1027           TAD     Q
0754  3027           DCA     Q
0755  5305           JMP     REVERS       /GO BACK AND CONTINUE
                     EJECT
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                       *1ØØØ
                /SIGNED S.P. MULTIPLY, USING THE EAE
                /ENTRY: AC=MULTIPLIER, C(CALL+1)=ADDR OF MULTIPLICAND, EXIT*AC=PRODUCT,
                /AN 11 BIT SIGNED BINARY FRAC
1ØØØ  ØØØØ      MULTIP, Ø                  /AC=ARG1 (MULTIPLIER)
1ØØ1  71ØØ              CLL                /ARG1>Ø?
1ØØ2  751Ø              SPA
1ØØ3  7Ø61              CMA CML IAC        /NO-MAKE POS-SET L=1 TO SHOW IT WAS NEG
1ØØ4  7421              MQL                /LOAD INTO MQ
1ØØ5  62Ø1              CDFØ
1ØØ6  16ØØ              TAD I   MULTIP     /GET ADDR OF MULTIPLICAND
1ØØ7  322Ø              DCA     ARG2                /STORE
1Ø1Ø  162Ø              TAD I   ARG2                /AND RETRIEVE MULTIPLICAND ITSELF.
1Ø11  22ØØ              ISZ     MULTIP              /(FOR EXIT AT CALL+2)

1Ø12  751Ø              SPA                         /ARG2>Ø?
1Ø13  7Ø61              CMA CML IAC                 /NO, MAKE POSITIVE, CHANGE LINK, SINCE-1*-1=1 AND -1*1=-1
1Ø14  322Ø              DCA     ARG2                /PUT AWAY AT ARG2
1Ø15  7Ø1Ø              RAR
                                           /SIGN IN LINK, PUT INTO AC11 AND
1Ø16  3237              DCA     SIGN                /PUT AWAY AT SIGN (=1 IF -; =Ø IF +)
1Ø17  74Ø5              MUY                         /DO MULTIPLICATION
1Ø2Ø  74Ø2      ARG2,   HLT                         /ARGUMENT 2 (MULTIPLICAND)
1Ø21  7413              SHL                         /NORMALIZE BINARY POINT.
1Ø22  ØØØØ              Ø
1Ø23  322Ø              DCA     ARG2                /SAVE HIGH ORDER, NOW ROUND OFF.
1Ø24  1237              TAD     SIGN
1Ø25  7413              SHL                         /SET AC11=MQØ,ACØ-1Ø=Ø
1Ø26  ØØØØ              Ø
1Ø27  122Ø              TAD     ARG2
1Ø3Ø  751Ø              SPA
1Ø31  735Ø              CLA CLL CMA RAR
1Ø32  7ØØØ              NOP
1Ø33  743Ø              SZL                         /POSITIVE SIGN?
1Ø34  7Ø41              CMA IAC                     /NO, NEGATE
1Ø35  6211              CDF1
1Ø36  56ØØ              JMP I   MULTIP              /EXIT, SIGNED RESULT IN AC.
1Ø37  ØØØØ      SIGN,   Ø
                /BIT INVERSION ROUTINE
                /ENTRY:  AC=WORD TO BE INVERTED; EXIT:AC=RESULT
                /NU CONTAINS THE NUME OF BITS IN THE WORD
1Ø4Ø  ØØØØ      INVRT,  Ø
1Ø41  3Ø61              DCA     WORD                /GET WORD TO BE INVERTED
1Ø42  3Ø62              DCA     WORDP               /ZERO OBJECT REGISTER
1Ø43  1ØØ4              TAD     NU                  /GET NUMBER OF BITS TO BE
1Ø44  7Ø41              CIA                         /INVERTED AND USE TO LIMIT THE
1Ø45  3Ø63              DCA     FLIPCT              /EXTENT OF LOOP
1Ø46  1Ø61      FLIP,   TAD     WORD                /PULL OUT RIGHTMOST BIT OF WORD
1Ø47  711Ø              CLL RAR            /RT MOST BIT NOW IN AC
1Ø5Ø  3Ø61              DCA     WORD                /(PUT BACK SO A NEW BIT IS OPERATED ON EACH TIME)
1Ø51  1Ø62              TAD     WORDP               /AND PUSH INTO WORDP FROM LEFT
1Ø52  7ØØ4              RAL
1Ø53  3Ø62              DCA     WORDP
1Ø54  2Ø63              ISZ     FLIPCT              /ALL BITS DONE?
1Ø55  5246              JMP     FLIP                /NO, DO NEXT BIT
1Ø56  1Ø62              TAD     WORDP               /YES, PICK UP RESULT
1Ø57  564Ø              JMP I   INVRT               /AND EXIT
                        EJECT
                /THIS SUBROUTINE FETCHES THE VALUES OF SIN(2*PI*C(AC)/N)
                /AND OF COS(2*PI*C(AC)/N) FOR C(AC) < N/2+1
                /ENTRY:  AC=INDEX OF LOOP UP
                /EXIT :  COS(2*PI*C(AC)/N) STORED AT "COSINE" AND
                /        AC=VALUE OF SIN(2*PI*C(AC)/N).
1060  0000      TRIGET, 0
1061  6201              CDF0
1062  3031              DCA     K                /STORE C(AC) AT K.
1063  7421              MQL                      /CLEAR MQ
1064  1031              TAD     K                /FORM N/4-K,
1065  7141              CLL CIA
1066  1020              TAD     NOVER4
1067  3333              DCA     NO4MIK
1070  7430              SZL                      /IS N/4-K<0?
1071  5310              JMP     QUAD1            /NO, FIRST QUADRANT ANGLE.
1072  1333      QUAD2,  TAD     NO4MIK           /2ND QUADRANT, GET -COS AT K-N/4.
1073  7041              CIA
1074  7417              LSR                      /MAKE CORRECTIVE RIGHT SHIFT ON INDEX.
1075  0000              0
1076  7413              SHL                      /FIND ON SINE TABLE FOR 2*MAXNU BY MULTIPLYING
1077  7402      SHFT1,  HLT                      /INDEX BY 2*(MAXNU-NU), WHICH IS STORED HERE.
1100  1050              TAD     SINLOC           /LOCATE IT IN MEMORY.
1101  3334              DCA     INDEX
1102  1734              TAD I   INDEX
1103  7041              CIA                      /2ND QUADRANT COS IS NEGATIVE.
1104  3036              DCA     COSINE
1105  1333              TAD     NO4MIK           /GET SIN AT N/2-K
1106  1020              TAD     NOVER4
1107  5322              JMP     SINRET
1110  1333      QUAD1,  TAD     NO4MIK           /GET COS AT N/4-K,
1111  7417              LSR
1112  0000              0
1113  7413              SHL
1114  7402      SHFT2,  HLT
1115  1050              TAD     SINLOC
1116  3334              DCA     INDEX
1117  1734              TAD I   INDEX
1120  3036              DCA     COSINE
1121  1031              TAD     K                          /GET SIN AT K.
1122  7417      SINRET, LSR
1123  0000              0
1124  7413              SHL
1125  7402      SHFT3,  HLT
1126  1050              TAD     SINLOC
1127  3334              DCA     INDEX
1130  1734              TAD I   INDEX            /AC=SINVALUE.
1131  6211              CDF1
1132  5660              JMP I   TRIGET
1133  0000      NO4MIK, 0                        /STORAGE FOR N/4-K
1134  0000      INDEX,  0                        /POINTER TO SINE TABLE
                /THIS ROUTINE PERFORMS A SINGLE PRECISION ADD WITH ROUNDING EACH ARGUMENT IS
                /SHIFTED RIGHT ONCE TO PREVENT OVERFLOW OF BINARY POINT (IF NECESSARY)
                /AND THEN CHECKED TO SEE IF IT CAN BE NORMALIZED AFTER ADDITION
                /ENTRY:  AC=ADDEND,C(ADD2)=AUGEND
                /EXIT  :  -AC=RESULT, DIVIDED BY TWO IF NECESSARY.
1135  0000      ADDR,   0
1136  3374              DCA     ADD1
1137  1054              TAD     SHFLAG           /SHOULD ADD BE DONE WITH SHIFT?
1140  7650              SNA CLA
1141  5357              JMP     ADDWOS           /NO, DO ADD WITH OUT SHIFT
1142  1374              TAD     ADD1             /YES GET ADDEND
1143  7415              ASR                      /DO 1 SIGNED RIGHT SHIFT
1144  0000
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1Ø12    1145 3374          DCA    ADD1
1Ø13    1146 1Ø33          TAD    ADD2
1Ø14    1147 7415          ASR                     /MQØ=LO(ADD2)
1Ø15    115Ø ØØØØ          Ø                       /MQ(1)=LO(ADD(1))
1Ø16    1151 3Ø33          DCA    ADD2
1Ø17    1152 75Ø1          MQA                     /GET MQ
1Ø2Ø    1153 7ØØ4          RAL                     /L<=LO(ADD2); ACØ<=LO(ADD1)
1Ø21    1154 7Ø6Ø          CMA CML                 /COMPLEMENT BOTH,
1Ø22
1Ø23    1155 772Ø          SMA SNL CLA             /IF BOTH WERE=1 (NEITHER=Ø), INTRODUCE A CARRY.
1Ø24    1156 7ØØ1          IAC
1Ø25    1157 1374 ADDWOS,  TAD    ADD1             /DO THE ADDITION,
1Ø26    116Ø 1Ø33          TAD    ADD2
1Ø27    1161 3375          DCA    XSUM             /STORE THE RESULT
1Ø3Ø    1162 1375          TAD    XSUM             /CHECK TO SEE IF ALREADY NORMALIZED,
1Ø31    1163 751Ø          SPA                     /IS IT POSITIVE?
1Ø32    1164 7Ø41          CIA                     /MAKE IT POSITIVE,
1Ø33    1165 7ØØ4          RAL                     /GET BIT 1, WAS NORMALIZED IF =1
1Ø34    1166 77ØØ          SMA CLA
1Ø35    1167 5372          JMP    NOTNOR           /NOT NORMALIZED, LEAVE SHFCHK ALONE,
1Ø36    117Ø 7ØØ1          IAC
1Ø37    1171 3Ø55          DCA    SHFCHK           /SET SHFCHK=1
1Ø4Ø    1172 1375 NOTNOR,  TAD    XSUM
1Ø41    1173 5735          JMP I  ADDR             /AND EXIT
1Ø42    1174 ØØØØ ADD1,    Ø                /ADDEND STORAGE
1Ø43    1175 ØØØØ XSUM,    Ø                /TEMP STORAGE FOR SUM
1Ø44                       EJECT
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        /DEFINITIONS FOR EAE
        DVI=7407
        NMI=7411
        SHL=7413
        ASR=7415
        LSR=7417
        MQL=7421
        MUY=7405
        MQA=7501
        CAM=7621
        SCA=7441
        SCL=7403
        /ASSEMBLY PARAMETERS
        BIGSNU=12       /LARGEST TRANSFORMATION HAS DIMENSION 2↑10.
                EJECT
```

```
                  /MOVING WINDOW DISPLAY SUBROUTINE
                          PMODE
                          PAGE
1200  ØØØØ  IDORA,        Ø                   /GET BOUNDS
1201  73ØØ                CLA CLL
1202  62Ø1  ACDFØ,        CDF Ø
1203  16ØØ                TAD I IDORA         /DATA BUFFER
1204  3635                DCA I KMNFLD        /15 BIT
1205  22ØØ                ISZ IDORA           /LOWER BOUND
1206  16ØØ                TAD I IDORA         /AT P+1, P+2
1207  3636                DCA I KMNADR        /MINFLD,MINADR
121Ø  22ØØ                ISZ IDORA
1211  16ØØ                TAD I IDORA         /UPPER BOUND
1212  3637                DCA I KMXFLD        /AT P+3, P+4
1213  22ØØ                ISZ IDORA
1214  7ØØ1                IAC                 /RDORA USES
1215  16ØØ                TAD I IDORA         /MAX+1
1216  364Ø                DCA I KMXADR
1217  7ØØ4                RAL
122Ø  1637                TAD I KMXFLD
1221  3637                DCA I KMXFLD
1222  22ØØ                ISZ IDORA
1223  16ØØ                TAD I IDORA         /Y SHIFT
1224  3111                DCA YSHFT
1225  22ØØ                ISZ IDORA
1226  16ØØ                TAD I IDORA         /Y SCALE
1227  3536                DCA I KYSCAL
123Ø  1635                TAD I KMNFLD        /INITIALIZE
1231  3641                DCA I KBUFHI        /WINDOW
1232  1636                TAD I KMNADR        /STARTING ADDR
1233  3642                DCA I KBUFLO
1234  56ØØ                JMP I IDORA         /RTN TO SCR N
1235  1415  KMNFLD,       MINFLD
1236  1416  KMNADR,       MINADR
1237  1474  KMXFLD,       MAXFLD
124Ø  1475  KMXADR,       MAXADR
1241  1574  KBUFHI,       BUFHI
1242  1575  KBUFLO,       BUFLO
1243  Ø4Ø1  P4Ø1,         4Ø1
1244  1243  DSCLOC,       TAD P4Ø1            /DSC X,Y COORD
1245  3274                DCA VCOORD
1246  1112                TAD XCURHI          /FIELD
1247  4261                JMS DSCWD
125Ø  1113                TAD XCURLO          /ADDRESS
1251  4261                JMS DSCWD
1252  1114                TAD CORVAL          /CONTENTS OF
1253  4261                JMS DSCWD           /CURSR CORE LOC
1254  1115                TAD YCUR            /Y COORD OF
1255  1243                TAD P4Ø1
1256  4261                JMS DSCWD           /CURSOR POINT
1257  ØØØØ  RTNCDF,       Ø                   /RESTORE USER
                                              /DATA FLD
126Ø  5743                JMP I RDORA         /RTN
1261  ØØØØ  DSCWD,        Ø                   /DSC C(AC)
1262  6141                LINC
                          LMODE
1263  5276                STC TEMP            /SAVE VALUE
1264  4ØØ1                STC XCORD           /CHAN 1
1265  ØØ24                SFA                 /VC FOR FULL
1266  Ø265                ROL I 5             /SIZE IS -4Ø
1267  1Ø2Ø                LDA I               /-2Ø FOR HALF
127Ø  7757                -2Ø
```

```
1164     1272  0241            ROL 1           /NO VC+40
1165     1273  1160            ADM I           /UPDATE VC
1166     1274  0000  VCOORD,   0
1167     1275  1020  DSCLOP,   LDA I
1170     1276  0000  TEMP,     0
1171     1277  0243            ROL 3           /1 DIGIT
1172     1300  1040            STA             /AT A TIME
1173     1301  1276            TEMP            /UPDATE
1174     1302  1560            BCL I           /LOW 3 BITS
1175     1303  7770            7770            /ONLY
1176     1304  0241            ROL 1           /*2 AND REL
1177     1305  1120            ADA I           /TO GRID TAB
1200     1306  1323            TAB&1777
1201     1307  4002            STC 2
1202     1310  3274            ADD VCOORD
1203     1311  1742            DSC 2
1204     1312  1762            DSC I 2
1205     1313  0221            XSK I 1         /MAKE GAP
1206     1314  0221            XSK I 1         /BETWEEN CHARS
1207     1315  1520            SRO I           /DSC 4 CHARS ?
1210     1316  3567            3567
1211     1317  7275            JMP DSCLOP      /NO CONT
1212     1320  0002            PDP
1213                           PMODE
1214     1321  7300            CLA CLL
1215     1322  5661            JMP I DSCWD     /RTN
1216     1323  4536  TAB,      4536     /60,0
1217     1324  3651            3651
1220     1325  2101            2101     /61,1
1221     1326  0177            0177
1222     1327  4523            4523     /62,2
1223     1330  2151            2151
1224     1331  4122            4122     /63,3
1225     1332  2651            2651
1226     1333  2414            2414     /64,4
1227     1334  0477            0477
1230     1335  5172            5172     /65,5
1231     1336  0651            0651
1232     1337  1506            1506     /66,6
1233     1340  4225            4225
1234     1341  4443            4443     /67,7
1235     1342  6050            6050
1236     1343  0000  RDORA,    0
1237     1344  7300            CLA CLL         /SAVE USER DF
1240     1345  6214            RDF
1241     1346  1202            TAD ACDF0
1242     1347  3257            DCA RTNCDF
1243     1350  6141            LINC
1244                           LMODE
1245     1351  0101  CSAM,     CURSAM          /CURSOR
1246     1352  0341            SCR 1           /9 BITS COVERS
1247     1353  0002            PDP             /SCOPE
1250                           PMODE           /MAKE RANGE
1251     1354  1243            TAD P401        /-1 TO -1000
1252     1355  7141            CIA CLL
1253     1356  6141            LINC
1254                           LMODE
1255     1357  5573            STC CURCNT&1777
1256     1360  0100  WSAM,     WINSAM          /WINDOW
1257     1361  0000  MOVDIS,   0               /SCR 4 OR CLR
1260     1362  0061            SET I XCORD
1261     1363  0000  LEFTX,    0               /LEFT COORD (    ISPLAY
1262     1364  7400            JMP CONT&1777
```

```
1365  Ø105  FREE,   FRESAM
1366  Ø341          SCR 1
1367  ØØØ2          PDP
                    PMODE
1370  3115          DCA YCUR
1371  1115          TAD YCUR
1372  6141          LINC
1373  6ØØØ          6ØØØ           /JMP Ø
                    PAGE
1400  ØØØ2  CONT,   2
1401  62Ø1  CCDFØ,  CDF Ø
14Ø2  3347          DCA DBLLO      /PUT KNOB VAL
14Ø3  1347          TAD DBLLO      /IN DAC
14Ø4  771Ø          SPA CLA        /PROPAGATE SIGN
14Ø5  7Ø4Ø          CMA            /BIT HI ORD
14Ø6  3341          DCA DBLHI
14Ø7  43Ø4          JMS DADD
141Ø  1347          TAD DBLLO      /UPDATE WIN ADDR
1411  3375          DCA BUFLO
1412  1341          TAD DBLHI
1413  3374          DCA BUFHI
                                   /MUST CHK
                                   /WINDOW SA
                                   /WITH BOUNDS
                                   /TO MAINTAIN
                                   /BUFFER RING
1414  4316          JMS BOUND      /LOWER BOUND
1415  ØØØ1  MINFLD, 1
1416  ØØØØ  MINADR, Ø
1417  77ØØ          SMA CLA        /LOW END WRAP?
142Ø  5273          JMP CHKHI      /NO
1421  1274          TAD MAXFLD     /RESET TO
1422  3374          DCA BUFHI      /UPPER BOUND
1423  1275          TAD MAXADR
1424  3375  WRAP,   DCA BUFLO
1425  43Ø4          JMS DADD       /CORRECT WRAP
1426  1347          TAD DBLLO      /CORRECTED
1427  3375          DCA BUFLO      /WINDOW SA
143Ø  1341          TAD DBLHI
1431  3374          DCA BUFHI
1432  1375  SETFLD, TAD BUFLO      /SET DISPLAY
1433  33Ø4          DCA BUFPTR     /ARGS
1434  1131          TAD MINPTS
1435  3116          DCA COUNT
1436  1374          TAD BUFHI
1437  3316          DCA BOUND
144Ø  4341          JMS SETDF
1441  17Ø4  NXTPNT, TAD I BUFPTR
1442  1111          TAD YSHFT      /OFF SET
1443  6141          LINC
                    LMODE
1444  Ø341  YSCAL,  SCR 1          /SCALE FACTOR
1445  Ø161          DIS I XCORD
1446  ØØØ2          PDP
                    PMODE
1447  2373          ISZ CURCNT     /READY TO DIS
                                   /CURSOR ?
145Ø  761Ø  CURRTN, SKP CLA        /NO
1451  5351          JMP CURDIS
1452  2376          ISZ ENDLO      /CHK FOR HI
1453  5263          JMP OKEND      /END WRAP
```

```
1455  5263            JMP OKEND
1456  1216            TAD MINADR     /RESET TO
1457  3304            DCA BUFPTR     /LOWER BOUND
146Ø  1215            TAD MINFLD
1461  3316            DCA BOUND
1462  5266            JMP NXTDF
1463  23Ø4  OKEND,    ISZ BUFPTR     /CHK FOR FIELD
                                     /BOUNDARY
1464  5267            JMP OKFLD      /ITS OK
1465  2316            ISZ BOUND      /SET NXT FLD
1466  4341  NXTDF,    JMS SETDF
1467  2116  OKFLD,    ISZ COUNT      /512 PNTS ?
147Ø  5241            JMP NXTPNT     /NO
1471  5672            JMP I .+1      /DSC READ OUT
1472  1244            DSCLOC
1473  4316  CHKHI,    JMS BOUND      /CHK UPR BOUND
1474  ØØØ2  MAXFLD,   2
1475  ØØØØ  MAXADR,   Ø
1476  771Ø  M7Ø,      SPA CLA        /HI WRAP ?
1477  5232            JMP SETFLD
15ØØ  1215            TAD MINFLD     /YES
15Ø1  3374            DCA BUFHI      /RESET TO
15Ø2  1216            TAD MINADR     /LOWER BOUND
15Ø3  5224            JMP WRAP
            /DOUBLE PRECISION ADD
            /(DBLHI,DBLLO)+(BUFHI,BUFLO)
            /RESULT IN (DBLHI,DBLLO)
            /(BUFHI,BUFLO)=INITIAL SCOPE ADDRESS

15Ø4  ØØØØ  DADD,     Ø
15Ø5  73ØØ            CLA CLL
15Ø6  1347            TAD DBLLO
15Ø7  1375            TAD BUFLO
151Ø  3347            DCA DBLLO
1511  7ØØ4            RAL
1512  1341            TAD DBLHI
1513  1374            TAD BUFHI
1514  3341            DCA DBLHI
1515  57Ø4            JMP I DADD

            /ADD -UPPER OR -LOWER BOUND
            /TO (BUFHI,BUFLO)
            /BOUND IS AT P+1,P+2 OF CALL

1516  ØØØØ  BOUND,    Ø
1517  1716            TAD I BOUND    /2S COM OF ARG
152Ø  714Ø            CMA CLL        /TO DAC
1521  3341            DCA DBLHI
1522  2316            ISZ BOUND
1523  1716            TAD I BOUND
1524  7Ø41            CIA
1525  743Ø            SZL
1526  2341            ISZ DBLHI
1527  7ØØØ  M1ØØØ,    NOP
153Ø  3347            DCA DBLLO
1531  43Ø4            JMS DADD
1532  1341            TAD DBLHI
1533  3377            DCA ENDHI      /DAC HOLDS -NUM
1534  1347            TAD DBLLO      /TO END OF BUF
1535  3376            DCA ENDLO      /NO MATTER FOP
                                     /LOW END WRA
1536  1341            TAD DBLHI      /TO CHK FOR
1537  2316            ISZ BOUND      /UPON RTN
```

```
1540  5716           JMP I BOUND
1541  0000  SETDF,   0               /SET 8 FIELD
1542  1316           TAD BOUND       /REL TO BOUND
1543  7106           CLL RTL
1544  7004           RAL
1545  1201           TAD CCDF0
1546  3347           DCA .+1
1547  0000  DBLLO,   0
1550  5741           JMP I SETDF
1551  3115  CURDIS,  DCA YCUR        /DISP CURSOR
1552  1316           TAD BOUND       /SAVE X,Y
1553  3112           DCA XCURHI      /COORDINATES
1554  1304           TAD BUFPTR
1555  3113           DCA XCURLO
1556  1704           TAD I BUFPTR
1557  3114           DCA CORVAL
1560  1276           TAD M70
1561  3347           DCA DBLLO
1562  1115           TAD YCUR
1563  6141  CURLOP,  LINC
                     LMODE
1564  0465           SNS I 5
1565  7365           JMP FREE        /FREE CURSOR
1566  0141           DIS XCORD
1567  0002           PDP
                     PMODE
1570  2347           ISZ DBLLO
1571  5363           JMP CURLOP
1572  5250           JMP CURRTN
1573  0000  CURCNT,  0
            /THESE 5 GUYS MAY BE PAGE 0
1574  0001  BUFHI,   1
1575  0000  BUFLO,   0
1576  0000  ENDLO,   0
1577  0000  ENDHI,   0
                     DBLHI=SETDF
                     BUFPTR=DADD
                     XCORD=1
                     LMODE
                     CURSAM=SAM 1    /CURSOR KNOB
                     WINSAM=SAM 0    /WINDOW KNOB
                     FRESAM=SAM 5    /FREE CURSOR
                     SCALE=SCR
                     SC12BU=SCR 3    /SCALE FACTOR
                                     /12 BIT UNSIGNED
                     OF12BU=4000     /Y OFFSET FOR
                                     /12 BIT UNSIGNED
                     CHAIN "FFTC-2"
```

```
0000                  *20
2001                        EJECT
```

```
                        LMODE
                        SEGMNT 2
                        *20
0020  0647              LDF     7    /BOOTSTRAP IN DIAL MS I/O ROUTINES
0021  0700              RDC
0022  6322              6322
0023  0700              RDC
0024  7323              7323
0025  0643              LDF     3
0026  1020     IFDIAL,  LDA I             /INPUT FROM DIAL TAPE?
0027  2411              QUES1+2000
0030  0602              LIF 2
0031  6720              JMP     ASK
0032  1300              LDH
0033  7043              ANSWER+6000
0034  1460              SAE I
0035  0031              31
0036  0456              SKP
0037  6044              JMP     UNTFIL   /DIAL
0040  1460              SAE I
0041  0016              16
0042  5026              JMP     IFDIAL  /ERROR
0043  6061              JMP     DATTAP          /DATA
               /ASK FOR UNIT NO + FILE NAME
0044  6523     UNTFIL,  JMP     ASK2
0045  6044              JMP     .-1             /ASK AGAIN
0046  0601              LIF     1
0047  1020              LDA I
0050  2375              FDV+2000
0051  6020              JMP     20              /SEARCH INDEX
0052  0456              SKP                     /CANT FIND IT
0053  6063              JMP     MOVINP
0054  0602              LIF     2
0055  1020              LDA I                   /DISPLAY ERROR MSG
0056  2760              MSG1+2000
0057  6720              JMP     ASK
0060  6044              JMP     UNTFIL          /ASK AGAIN
0061  6572     DATTAP,  JMP ASK3
0062  6061              JMP     DATTAP          /ERROR-ASK AGAIN
0063  6165     MOVINP,  JMP FDV2RW    /MOVE INPUT PARAMETERS TO R/W LIST
0064  0643     PTS,     LDF     3
0065  0602              LIF     2
0066  1020              LDA I                   /ASK FOR NO OF PTS
0067  2521              QUES4+2000
0070  6720              JMP     ASK
0071  0061              SET I   1
0072  3043              ANSWER+2000
0073  1020              LDA I             /INPUT IS DECIMAL
0074  0012              12
0075  4701              STC MPLIER
0076  1020              LDA I
0077  7706              -71
0100  4045              STC UPLEGL
0101  1020              LDA I                   /1024 PTS MAX
0102  2000              2000
0103  6627              JMP     CONV
0104  6064              JMP     PTS             /ERROR
0105  0640              LDF     0
0106  1040              STA
0107  2003              N+2000
0110  0643              LDF 3
0111  0017              COM
```

```
0102     0114  0000  TEMP1,  0
0103     0115  0456          SKP
0104     0116  6064          JMP PTS          /BIT 11=1 NOT POWER OF 2
0105     0117  0062          SET I 2
0106     0120  7764          -13
0107     0121  1500  ROTAT,  SRO              /COUNT NO OF BITS SET
0110     0122  0114          TEMP1
0111     0123  6126          JMP .+3
0112     0124  1120          ADA I
0113     0125  0001          1
0114     0126  0222          XSK I 2
0115     0127  6121          JMP ROTAT
0116     0130  1120          ADA I
0117     0131  7776          -1
0120     0132  0017          COM
0121     0133  0450          AZE
0122     0134  6064          JMP PTS          />1-NOT POWER OF 2
0123     0135  4002          STC 2            /CLEAR
0124     0136  1500  ROT1,   SRO              /DETERMINE POWER OF 2
0125     0137  0114          TEMP1
0126     0140  0456          SKP
0127     0141  6144          JMP STAMU
0130     0142  0222          XSK I 2
0131     0143  6136          JMP ROT1
0132     0144  1000  STAMU,  LDA
0133     0145  0002          2
0134     0146  0640          LDF     0
0135     0147  1040          STA
0136     0150  2004          NU+2000
0137     0151  1120          ADA I
0140     0152  7776          -1
0141     0153  0451          APO
0142     0154  6064          JMP     PTS      /POWER<2
0143     0155  1000          LDA                   /COMPUTE NO OF OUTPUT BLKS
0144     0156  2003          N+2000           /NO OF PTS
0145     0157  0241          ROL 1            /*2
0146     0160  6503          JMP NUMBKS       /CONVERT TO BLKS
0147     0161  1040          STA
0150     0162  2404          FDV+2007         /NO OF BLKS FOR REAL & IMAG
0151     0163  1040          STA
0152     0164  2410          RWPARM+2003
0153     0165  1300          LDH
0154     0166  3046          ANSWER+2003
0155     0167  1460          SAE I
0156     0170  0022          22
0157     0171  6203          JMP IFCOM
0160     0172  1040          STA              /REAL-SET FLAG
0161     0173  2053          REALFG+2000
0162     0174  0640          LDF 0
0163     0175  1000          LDA
0164     0176  2003          N+2000           /COMPUTE INPUT BLKS
0165     0177  6503          JMP NUMBKS
0166     0200  1040          STA
0167     0201  2410          RWPARM+2003
0170     0202  6211          JMP CKEND
0171     0203  1460  IFCOM,  SAE I
0172     0204  0003          3
0173     0205  6064          JMP PTS /ERROR
0174     0206  0011          CLR              /COMPLEX-CLEAR FLAG
0175     0207  1040          STA
0176     0210  2053          REALFG+2000
0177     0211  1000  CKEND,  LDA              /WILL INPUT RUN OFF END OF TAPE
```

```
Ø212  24Ø7          RWPARM+2ØØ2
Ø213  11ØØ          ADA
Ø214  241Ø          RWPARM+2ØØ3
Ø215  112Ø          ADA I
Ø216  6777          -1ØØØ
Ø217  Ø471          APO I
Ø22Ø  6Ø64          JMP      PTS      /YES
Ø221  ØØØ2          PDP
                    PMODE
4222  72ØØ          CLA
4223  1ØØ3          TAD N  /ADD 1 BLK FOR SCALE FACTOR IF 4ØØ WORDS OR MORE
4224  71Ø4          CLL RAL           /NO OF OUTPUT WRDS = NO OF PTS*2
4225  11Ø7          TAD M4ØØ
4226  77ØØ          SMA CLA
4227  2523          ISZ I PFDV7
423Ø  6141          LINC
                    LMODE
Ø231  1Ø2Ø  IFFFT,  LDA I             /DO FFT OR JUST DISPLAY?
Ø232  2625          QUES11+2ØØØ
Ø233  672Ø          JMP ASK
Ø234  13ØØ          LDH
Ø235  7Ø43          ANSWER+6ØØØ
Ø236  146Ø          SAE I
Ø237  ØØØ4          4
Ø24Ø  6244          JMP .+4
Ø241  1Ø6Ø          STA I             /NOT=Ø JUST DISPLAY
Ø242  ØØØØ  DISFLG, Ø
Ø243  6251          JMP      FIF
Ø244  146Ø          SAE I
Ø245  ØØØ6          6
Ø246  6231          JMP IFFFT         /ERROR
Ø247  ØØ11          CLR
Ø25Ø  4242          STC      DISFLG  /=Ø WILL DO TRANSFORM OR INVERSE
Ø251  13ØØ  FIF,    LDH
Ø252  7Ø44          ANSWER+6ØØ1
Ø253  146Ø          SAE I
Ø254  ØØ24          24
Ø255  6261          JMP IFI
Ø256  ØØ11          CLR
Ø257  4356          STC IFTFLG        /DO FFT
Ø26Ø  6265          JMP IFDISP
Ø261  146Ø  IFI,    SAE I
Ø262  ØØ11          11
Ø263  6231          JMP      IFFFT
Ø264  4356          STC IFTFLG        /DO IFFT
Ø265  2242  IFDISP, ADD      DISFLG
Ø266  Ø47Ø          AZE I
Ø267  6273          JMP      OUTQES
Ø27Ø  6466          JMP      FDV2RW  /MOVE OUTPUT PARAMETERS TO R/W
Ø271  Ø6Ø3          LIF      3       /JUST DISPLAY
Ø272  6ØØ1          JMP      DISPLY
            /GET OUTPUT INFO
Ø273  1Ø2Ø  OUTQES, LDA I
Ø274  2571          QUES5+2ØØØ
Ø275  672Ø          JMP      ASK           /PUT ON DIAL TAPE?
Ø276  13ØØ          LDH
Ø277  7Ø43          ANSWER+6ØØØ
Ø3ØØ  146Ø          SAE I
Ø3Ø1  ØØ31          31
Ø3Ø2  Ø456          SKP
Ø3Ø3  631Ø          JMP      OUTUNT
Ø3Ø4  146Ø          SAE I
```

```
Ø3Ø6  6273            JMP OUTQES
Ø3Ø7  6452            JMP     ONDAT           /NO
Ø31Ø  6523  OUTUNT,   JMP     ASK2    /ASK FOR UNIT NO & FILE NAME
Ø311  631Ø            JMP     OUTUNT  /ERROR
Ø312  Ø6Ø1            LIF     1
Ø313  1Ø2Ø            LDA I                   /ENTER IN INDEX
Ø314  2375            FDV+2ØØØ
Ø315  6Ø22            JMP     22
Ø316  643Ø            JMP     SAMNAM          /NAME ALREADY USED
Ø317  6423            JMP     NOSPAC          /NO SPACE
Ø32Ø  ØØØ2  RDDATA,   PDP     /CLEAR DATA BUFFER
                      PMODE
4321  724Ø            CLA CMA
4322  1Ø51            TAD XRLOC
4323  3Ø1Ø            DCA 1Ø
4324  1Ø67            TAD M4ØØØ
4325  3Ø11            DCA 11
4326  6211            CDF1
4327  341Ø            DCA I 1Ø
433Ø  2Ø11            ISZ 11
4331  5327            JMP .-2
4332  62Ø1            CDFØ
4333  6212            CIF     1Ø      /READ IN DATA
4334  4534            JMS I   PREAD
4335  64Ø5            RWPARM
4336  62Ø1            CDFØ
4337  72ØØ            CLA
434Ø  1532            TAD I PRELFG    /REAL OR COMPLEX
4341  764Ø            SZA CLA
4342  5357            JMP   PROC      /REAL
4343  7Ø4Ø            CMA             /MOVE IMAG PARTS TO 2ØØØ
4344  1ØØ3            TAD     N       /OLD ADDR = NO OF PTS
4345  3Ø1Ø            DCA     1Ø
4346  111Ø            TAD     C1777   /NEW ADDR = 2ØØØ
4347  3Ø11            DCA     11
435Ø  1ØØ3            TAD     N
4351  7Ø41            CIA
4352  3Ø34            DCA     TEMPR   /CTR
4353  313Ø            DCA     CMPFLG  /DONT COMPLEMENT
4354  4527            JMS I   PMVPTS  /MOVE THEM
4355  5357            JMP     PROC

4356  ØØØØ  IFTFLG, Ø                 /Ø=FFT NONØ=IFFT

4357  3532  PROC,     DCA I   PRELFG  /OUTPUT WILL BE COMPLEX REGARDLESS OF INPUT
436Ø  1356            TAD IFTFLG      /DO IFFT?
4361  765Ø            SNA CLA
4362  5365            JMP     FT      /NO
4363  4447  IFT,      JMS I DOIFFT
4364  741Ø            SKP
4365  4446  FT,       JMS I DOFFT
4366  4442            JMS I SORT      /PUT IN SEQUENTIAL ORDER
4367  1Ø53  STSCAL,   TAD SCAL
437Ø  6211            CDF1
4371  3Ø34            DCA     TEMPR    /SAVE
4372  1ØØ3            TAD     N
4373  71Ø4            CLL RAL
4374  3Ø36            DCA     COSINE  /NO OF PTS*2
4375  1Ø34            TAD     TEMPR
4376  3436            DCA I   COSINE    /STORE SCALE FACTOR AFTER DATA
4377  62Ø1  NOWSTR,   CDFØ
44ØØ  111Ø            TAD     C1777   /OLD ADDR = .
44Ø1  3Ø1Ø            DCA     1Ø
```

```
4402  7Ø4Ø            CMA               /NEW ADDR =     OF PTS
4403  1ØØ3            TAD      N
4404  3Ø11            DCA      11
4405  1ØØ3            TAD      N
4406  7Ø41            CIA
4407  3Ø34            DCA      TEMPR    /CTR
441Ø  313Ø            DCA      CMPFLG   /DONT COMPLEMENT
4411  4527            JMS I    PMVPTS   /PACK IMAG PARTS BEHIND REAL
4412  6141            LINC
                      LMODE
Ø413  6466            JMP FDV2RW
Ø414  ØØØ2            PDP
                      PMODE
4415  6212            CIF      1Ø       /WRITE OUT DATA
4416  4535            JMS I    PWRITE
4417  64Ø5            RWPARM
442Ø  6141            LINC
                      LMODE
Ø421  Ø6Ø3            LIF 3
Ø422  6ØØ1            JMP DISPLY
Ø423  Ø6Ø2  NOSPAC,   LIF      2
Ø424  1Ø2Ø            LDA I
Ø425  3Ø13            MSG2+2ØØØ
Ø426  672Ø            JMP      ASK
Ø427  6273            JMP      OUTQES            /ASK OUTPUT QUESTIONS AGAIN
Ø43Ø  Ø6Ø2  SAMNAM,   LIF      2
Ø431  1Ø2Ø            LDA I                      /NAME ALREADY EXISTS
Ø432  2612            QUES6+2ØØØ
                                        /REPLACE WITH NEW FILE?
Ø433  672Ø            JMP      ASK
Ø434  13ØØ            LDH
Ø435  7Ø43            ANSWER+6ØØØ
Ø436  146Ø            SAE I
Ø437  ØØ31            31
Ø44Ø  Ø456            SKP
Ø441  6446            JMP      REPL
Ø442  146Ø            SAE I
Ø443  ØØ16            16
Ø444  643Ø            JMP      SAMNAM
Ø445  631Ø            JMP      OUTUNT   /NO-ASK FOR NAME AGAIN
Ø446  Ø6Ø1  REPL,     LIF 1
Ø447  6Ø24            JMP      24
Ø45Ø  6423            JMP      NOSPAC
Ø451  632Ø            JMP      RDDATA
Ø452  Ø6Ø2  ONDAT,    LIF      2
Ø453  6572            JMP ASK3          /ASK FOR UNIT/BLK NO
Ø454  6452            JMP ONDAT         /ERROR
Ø455  1ØØØ            LDA
Ø456  24Ø3            FDV+2ØØ6          /BLK NO
Ø457  11ØØ            ADA
Ø46Ø  24Ø4            FDV+2ØØ7          /NO OF BLKS
Ø461  112Ø            ADA I
Ø462  6777            -1ØØØ
Ø463  Ø471            APO I
Ø464  6423            JMP NOSPAC        /NOT ENOUGH BLKS LEFT
Ø465  632Ø            JMP      RDDATA
                      /MOVE FDV PARAMETERS TO R-W LIST
Ø466  1ØØØ  FDV2RW,   LDA
Ø467  2375            FDV+2ØØØ
Ø47Ø  1Ø4Ø            STA
Ø471  24Ø5            RWPARM+2ØØØ
Ø472  1ØØØ            LDA
```

```
                          STA
0475  2407                RWPARM+2002
0476  1000                LDA
0477  2404                FDV+2007
0500  1040                STA
0501  2410                RWPARM+2003
0502  6000                JMP 0
                   /CONVERT WORDS TO BLOCKS
0503  4114         NUMBKS, STC TEMP1
0504  2000                ADD 0
0505  4522                STC NUMBKX
0506  2114                ADD TEMP1
0507  0643                LDF     3
0510  0061                SET I   1
0511  0001                1
0512  1120                ADA I
0513  7377                -400
0514  0451                APO
0515  6520                JMP .+3
0516  0221                XSK I   1
0517  6512                JMP     .-5
0520  1000                LDA
0521  0001                1
0522  0000         NUMBKX, 0
                   /ASK FOR UNIT NUMBER & FILE NAME
                   /CONV & STORE UNIT NUMBER
                   /MOVE FILE NAME TO ENTER, LOOKUP PARAMETER LIST
                   /STORE UNIT THRU B3
0523  1000         ASK2,  LDA
0524  0000                0
0525  4571                STC     ASK2X
0526  0602                LIF     2
0527  6711                JMP     OCTL     /CHANGE PARAMETERS TO HANDLE OCTAL NUMBERS
0530  1020                LDA I
0531  2453                QUES2+2000
0532  6720                JMP     ASK      /PT TO UNIT NO-1H
0533  0061                SET I   1
0534  3043                ANSWER+2000
0535  1020                LDA I            /MAX VALUE
0536  0017                17
0537  6627                JMP CONV
0540  6571                JMP     ASK2X    /ERROR
0541  1040                STA              /STORE UNIT
0542  2375                FDV+2000
                   /MOVE FILE NAME FROM ANSWER BUFFER TO LOOKUP, ENTER PARAMETER LIST
0543  0061                SET I 1
0544  7044                ANSWER+6001
0545  0062                SET I   2
0546  6375                FDV+6000                   /LEFT HALF 1ST OF FDV+1
0547  0063                SET I   3
0550  7767                -10              /8 CHARS
0551  1321                LDH I   1        /IF 1ST CHAR OF NAME
0552  0470                AZE I            /=00, NO NAME WAS
0553  6571                JMP     ASK2X    /ENTERED-ERROR
0554  0456                SKP
0555  1321         INFILE, LDH I  1
0556  0450                AZE                        /FILL TO 8 CHARS WITH 77
0557  6562                JMP     .+3
0560  1320                LDH I
0561  7700                7700
0562  1362                STH I   2
0563  0223                XSK I   3
0564  6555                JMP     INFILE
```

```
Ø565  1Ø2Ø          LDA I                       /RETURN CALL+2
Ø566  ØØØ1          1
Ø567  114Ø          ADM
Ø57Ø  Ø571          .+1
Ø571  ØØØØ  ASK2X,  Ø
            /ASK FOR UNIT NUMBER + BLK NO AND CONVERT
            /STORE UNIT THRU B7
            /"  BLK NO " B1Ø
Ø572  1ØØØ  ASK3,   LDA
Ø573  ØØØØ          Ø
Ø574  4626          STC     ASK3X
Ø575  Ø6Ø2          LIF     2
Ø576  1Ø2Ø          LDA I
Ø577  2475          QUES3+2ØØØ
Ø6ØØ  672Ø          JMP     ASK
Ø6Ø1  ØØ61          SET I   1                   /ADDR-1H OF 1ST CHAR - UNIT
Ø6Ø2  3Ø43          ANSWER+2ØØØ
Ø6Ø3  6711          JMP OCTL          /CHANGE PARAMETERS TO HANDLE OCTAL
Ø6Ø4  1Ø2Ø          LDA I                       /MAX VALUE
Ø6Ø5  ØØ17          17
Ø6Ø6  6627          JMP CONV
Ø6Ø7  6626          JMP ASK3X         /ERROR
Ø61Ø  1Ø4Ø          STA
Ø611  2375          FDV+2ØØØ
Ø612  ØØ61          SET I 1
Ø613  7Ø44          ANSWER+6ØØ1
Ø614  1Ø2Ø          LDA I             /MAX VALUE FOR BLK NO
Ø615  Ø777          777
Ø616  6627          JMP     CONV
Ø617  6626          JMP     ASK3X
Ø62Ø  1Ø4Ø          STA
Ø621  24Ø3          FDV+2ØØ6
Ø622  1Ø2Ø          LDA I                       /EXIT CALL+2
Ø623  ØØØ1          1
Ø624  114Ø          ADM
Ø625  Ø626          .+1
Ø626  ØØØØ  ASK3X,  Ø
            /CONVERT NUMBER IN ANSWER BUFFER TO BINARY
            /ENTER WITH MAX LEGAL VALUE IN AC
            /IF LEGAL - EXIT CALL+2 WITH VALUE IN AC
Ø627  ØØ17  CONV,   COM
Ø63Ø  4675          STC     TEMP2 /COMPLEMENT MAX VALUE
Ø631  4114          STC     TEMP1
Ø632  2ØØØ          ADD     Ø                   /RETURN ADDR
Ø633  4674          STC     CONVER
Ø634  1321  NXTCHR, LDH I   1                   /GET A CHAR
Ø635  Ø47Ø          AZE I
Ø636  666Ø          JMP ERRCHK
Ø637  112Ø          ADA I
Ø64Ø  772Ø          772Ø                        /-6Ø -2
            /S  COMP
Ø641  Ø451          APO
Ø642  665Ø          JMP     CHKEND              /<6Ø MAYBE TERMINATING CHAR
Ø643  13Ø1          LDH     1                   /CK UPPER LIMIT
Ø644  112Ø          ADA I
Ø645  771Ø  UPLEGL, -67               /UPPER LIM=7 OR 9
Ø646  Ø451          APO
Ø647  6676          JMP     MULPLY              /Ø-9 -ØK
Ø65Ø  13Ø1  CHKEND, LDH     1                   /<9 MAYBE TERMINATING CHAR
Ø651  146Ø          SAE I
Ø652  ØØ34          34
Ø653  Ø456          SKP
```

```
Ø655  146Ø           SAE I
Ø656  ØØ74           74
Ø657  6674           JMP     CONVER           /ILLEGAL CHAR
Ø66Ø  1ØØØ  ERRCHK,  LDA                      /=34 OR 74 - NUMBER COMPLETED
Ø661  Ø114           TEMP1
Ø662  11ØØ           ADA                      /ERROR CHECK SIZE
Ø663  Ø675           TEMP2
Ø664  Ø471           APO I
Ø665  6674           JMP     CONVER           /TOO LARGE
Ø666  1Ø2Ø           LDA I                    /OK STEP EXIT
Ø667  ØØØ1           1
Ø67Ø  114Ø           ADM
Ø671  Ø674           .+3
Ø672  1ØØØ           LDA                      /EXIT WITH VALUE IN AC
Ø673  Ø114           TEMP1
Ø674  ØØØØ  CONVER,  Ø
Ø675  ØØØØ  TEMP2,   Ø
            /
Ø676  1ØØØ  MULPLY,  LDA             /VALUE SO FAR
Ø677  Ø114           TEMP1
Ø7ØØ  126Ø           MUL I
Ø7Ø1  ØØ1Ø  MPLIER,  1Ø
Ø7Ø2  4114           STC     TEMP1
Ø7Ø3  13Ø1           LDH     1                /+ THIS VALUE
Ø7Ø4  156Ø           BCL I
Ø7Ø5  776Ø           776Ø
Ø7Ø6  114Ø           ADM
Ø7Ø7  Ø114           TEMP1
Ø71Ø  6634           JMP     NXTCHR
            /
                     /CHANGE PARAMETERS SO CONV & MULPLY WILL HANDLE OCTAL NUMBERS
Ø711  1Ø2Ø  OCTL,    LDA I
Ø712  ØØ1Ø           1Ø
Ø713  47Ø1           STC     MPLIER
Ø714  1Ø2Ø           LDA I
Ø715  771Ø           -67
Ø716  4645           STC     UPLEGL
Ø717  6ØØØ           JMP     Ø
            /
            /DISPLAY QUESTIONS
Ø72Ø  4734  ASK,     STC     QUESNO           /ADDR OF TEXT
Ø721  2ØØØ           ADD     Ø
Ø722  474Ø           STC     ASKX
Ø723  Ø5ØØ           IOB
                     PMODE
4724  6234           RIB
                     LMODE
Ø725  Ø343           SCR 3
Ø726  156Ø           BCL I
Ø727  774Ø           774Ø
Ø73Ø  112Ø           ADA I
Ø731  Ø6ØØ           LIF Ø
Ø732  4737           STC ASKX-1
Ø733  7ØØØ           JMP     QAINIT           /DISPLAY
Ø734  ØØØØ  QUESNO,  Ø
Ø735  3Ø43           ANSWER+2ØØØ
Ø736  7Ø53           JMP     QARFSH           /WAIT FOR ANSWERS
Ø737  ØØØØ           Ø
Ø74Ø  ØØØØ  ASKX,    Ø

                     EJECT
```

```
                        SEGMNT 3
                        LMODE
                        *1
ØØØ1  ØØØ2   DISPLY,    PDP
                        PMODE
6ØØ2  72ØØ              CLA
6ØØ3  1ØØ3              TAD      N
6ØØ4  711Ø              CLL RAR
6ØØ5  3Ø37              DCA      GR       /NO OF PTS/2
6ØØ6  1Ø37              TAD      GR
6ØØ7  7Ø41              CIA
6Ø1Ø  3Ø33              DCA      ADD2     /-NO OF PTS/2
6Ø11  114Ø              TAD      C2ØØØ
6Ø12  3364              DCA      LOADDR   /LOWER ADDR OF DISPLAY
6Ø13  111Ø              TAD      C1777
6Ø14  1ØØ3              TAD      N
6Ø15  3366              DCA      UPADDR   /UPPER ADDR OF DISPLAY
6Ø16  6212              CIF      1Ø       /READ IN DATA
6Ø17  4534              JMS I    PREAD
6Ø2Ø  64Ø5              RWPARM
6Ø21  6141              LINC
                        LMODE
ØØ22  1Ø2Ø   DISPL1,    LDA I             /WHICH DISPLAY
ØØ23  2665              QUES13+2ØØØ
ØØ24  Ø6Ø2              LIF 2
ØØ25  672Ø              JMP ASK
ØØ26  13ØØ              LDH
ØØ27  7Ø43              ANSWER+6ØØØ
ØØ3Ø  Ø45Ø              AZE
ØØ31  6Ø34              JMP .+3
ØØ32  Ø6Ø2              LIF 2
ØØ33  6Ø26              JMP IFDIAL        /LINE FEED
ØØ34  ØØØ2              PDP
                        PMODE
6Ø35  1Ø77   WCHDIS,    TAD M11
6Ø36  745Ø              SNA
6Ø37  5255              JMP DPIMAG        /IMAG
6Ø4Ø  1Ø75              TAD M4
6Ø41  745Ø              SNA
6Ø42  5476              JMP I PDPMAG      /MAGNITUDE
6Ø43  11ØØ              TAD M5
6Ø44  745Ø              SNA
6Ø45  5317              JMP DPREAL        /REAL
6Ø46  1Ø7Ø              TAD M1
6Ø47  765Ø              SNA CLA
6Ø5Ø  5654              JMP I PDPSCL      /SCALE FACTOR
6Ø51  6141   DISPER,    LINC              /ERROR
                        LMODE
ØØ52  6Ø22              JMP DISPL1
ØØ53  ØØØØ   REALFG,    Ø
                        PMODE
6Ø54  6226   PDPSCL,    DPSCAL
6Ø55  1253   DPIMAG,    TAD REALFG
6Ø56  764Ø              SZA CLA
6Ø57  5251              JMP DISPER        /NO IMAG PARTS TO DISPLAY
6Ø6Ø  1533              TAD I    PIFTFG   /IF TRANSFORM WAS DONE, SWAP HALVES
6Ø61  764Ø              SZA CLA
6Ø62  531Ø              JMP      NOSWPI   /INVERSE WAS DONE
6Ø63  7Ø4Ø              CMA
6Ø64  1ØØ3              TAD      N
6Ø65  3Ø1Ø              DCA      1Ø       /OLD LOW ADDR OF 1ST 1/2 = NO OF PTS
6Ø66  1Ø37              TAD      GR       /NEW LOW ADDR OF 1ST 1/2 = 2ØØØ + NO OF PTS/2
```

```
6070  3011            DCA     11
6071  1033            TAD     ADD2
6072  3034            DCA     TEMPR    /MOVE 1/2 OF PTS
6073  7201            CLA IAC
6074  3130            DCA     CMPFLG   /COMPLEMENT VALUES
6075  4527            JMS I   PMVPTS   /MOVE THEM
6076  7040            CMA              /OLD ADDR OF 2ND 1/2 = 3/2 NO OF PTS
6077  1037            TAD     GR
6100  1003            TAD     N
6101  3010            DCA     10
6102  1110            TAD     C1777    /NEW ADDR OF 2ND 1/2 = 2000
6103  3011            DCA     11
6104  1033            TAD     ADD2
6105  3034            DCA     TEMPR    /1/2 OF PTS
6106  4527            JMS I   PMVPTS   /MOVE THEM - 1ST 1/2 IS NOW 2ND 1/2; 2ND 1/2 IS NOW 1ST 1/2
6107  5330            JMP     PREPAR
6110  1003  NOSWPI,   TAD     N        /LOW ADDR OF IMAG = NO OF PTS
6111  3364            DCA     LOADDR
6112  7040            CMA              /HIGH ADDR = 2*NO OF PTS-1
6113  1003            TAD     N
6114  1003            TAD     N
6115  3366            DCA     UPADDR
6116  5330            JMP     PREPAR

6117  1533  DPREAL,   TAD I   PIFTFG   /IF TRANSFORM WAS DONE, SWAP HALVES
6120  7640            SZA CLA
6121  5324            JMP     NOSWPR
6122  4526            JMS I   PMRLMG   /SWAP
6123  5330            JMP     PREPAR
6124  3364  NOSWPR,   DCA     LOADDR   /LOW ADDR OF REAL
6125  7040            CMA
6126  1003            TAD     N
6127  3366            DCA     UPADDR   /HIGH ADDR = NO OF PTS-1

6130  1033  PREPAR,   TAD ADD2         /NO OF PTS <1000?
6131  7104            CLL RAL
6132  1137            TAD C1000
6133  7550            SPA SNA
6134  5347            JMP GQ1000
6135  7110            CLL RAR          /YES
6136  7001            IAC              /CENTER DISPLAY
6137  1141            TAD M1K
6140  3525            DCA I PLEFTX     /1000-(1000-NO OF PTS/2) 1,S COMP
6141  1146            TAD CCLR
6142  3524            DCA I PMVDIS
6143  1033            TAD ADD2         /WIDTH OF DISPLAY
6144  7104            CLL RAL          /NO OF PTS
6145  3131            DCA MINPTS
6146  5362            JMP SHOWIT
6147  7200  GQ1000,   CLA
6150  1141            TAD M1K          /LEFT JUSTIFY DISPLAY
6151  3525            DCA I PLEFTX     /-1000 1,S COMP
6152  1525            TAD I PLEFTX     /WIDTH OF DISPLAY
6153  7001            IAC
6154  3131            DCA MINPTS
6155  1145            TAD SCR4         /MOVE DISPLAY
6156  3524            DCA I PMVDIS
6157  5362            JMP SHOWIT
            /DISPLAY DATA
6160  6141  REDPLY,   LINC
                      LMODE
6161  6001            JMP DISPLY
                      PMODE
```

```
6162  4517  SHOWPT, JMS I KIDORA
6163  ØØØ1          1                 /LOW ADDR FIL
6164  ØØØØ  LOADDR, Ø                 / "    "      "
6165  ØØØ1          1                 /HIGH   "     "
6166  ØØØØ  UPADDR, Ø                 / "      "
6167  ØØØØ          Ø                 /Y OFFSET
                    LMODE
Ø17Ø  Ø343  SIZE,   SCR 3             /SCALE
                    PMODE
6171  452Ø  RFRSH,  JMS I KRDORA      /REFRESH UNTIL LF IS HIT
6172  6Ø31          KSF
6173  5371          JMP .-2
6174  6Ø36          KRB
6175  11Ø2          TAD M215
6176  765Ø          SNA CLA
6177  536Ø          JMP REDPLY
62ØØ  6Ø36          KRB
62Ø1  11Ø6          TAD M261
62Ø2  765Ø          SNA CLA
62Ø3  5216          JMP LARGER
62Ø4  6Ø36          KRB
62Ø5  11Ø3          TAD M321
62Ø6  765Ø          SNA CLA
62Ø7  5211          JMP SMALLR
621Ø  5522          JMP I PRFRSH
6211  1536  SMALLR, TAD I KYSCAL
6212  11Ø4          TAD M353
6213  771Ø          SPA CLA
6214  2536          ISZ I KYSCAL
6215  5522          JMP I PRFRSH
6216  1536  LARGER, TAD I KYSCAL
6217  11Ø5          TAD M34Ø
622Ø  775Ø          SPA SNA CLA
6221  5522          JMP I PRFRSH
6222  7Ø4Ø          CMA
6223  1536          TAD I KYSCAL
6224  3536          DCA I KYSCAL
6225  5522          JMP I PRFRSH

            /DISPLAY SCALE FACTOR

6226  1532  DPSCAL, TAD I   PRELFG
6227  764Ø          SZA CLA
623Ø  5772          JMP I   PDSPER  /JUST REAL MEANS I DIDNT MAKE FILE - NO SCALE FACTOR
6231  1ØØ3          TAD     N
6232  71Ø4          CLL RAL
6233  3Ø34          DCA     TEMPR   /ADDR = NO OF PTS*2
6234  6211          CDF1
6235  1434          TAD I   TEMPR
6236  1Ø77          TAD     M11
6237  774Ø          SMA SZA CLA
624Ø  5244          JMP     GR9     />9
6241  1Ø74          TAD     LESS1Ø
6242  1434          TAD I   TEMPR   /SPACE + ASCII SCALE FACTOR
6243  5247          JMP     SHOSCL
6244  1Ø71  GR9,    TAD     M12
6245  1434          TAD I   TEMPR
6246  1Ø73          TAD     GRET1Ø  /1Ø+SCALE FACTOR-1Ø
6247  62Ø1  SHOSCL, CDFØ
625Ø  3266          DCA     DPMAG-2 /STORE IN DISPLAY PARAMETERS
6251  6141          LINC
```

```
Ø252  1Ø2Ø          LDA I
Ø253  2257          SCLFAC+2ØØØ
Ø254  Ø6Ø2          LIF 2
Ø255  672Ø          JMP     ASK      /DISPLAY IT
Ø256  6ØØ1          JMP     DISPLY
              SCLFAC, TEXT Z
Ø257  4347
Ø26Ø  4Ø43
Ø261  4Ø43
Ø262  Ø64Ø
Ø263  4Ø4Ø
Ø264  4Ø4Ø
Ø265  4Ø4Ø
Ø266  4Ø4Ø
Ø267  34ØØ
              F         \Z
                    PMODE

              /COMPUTE MAGNITUDE
627Ø  1532    DPMAG,  TAD I PRELFG
6271  764Ø            SZA CLA
6272  5772            JMP I PDSPER
6273  7Ø4Ø            CMA
6274  1ØØ3            TAD     N
6275  3Ø1Ø            DCA     1Ø       /LOW ADDR OF IMAG = NO OF PTS
6276  111Ø            TAD     C1777
6277  3Ø11            DCA     11       /MOVE TO 2ØØØ
63ØØ  1ØØ3            TAD     N
63Ø1  7Ø41            CIA
63Ø2  3Ø34            DCA     TEMPR    /CTR
63Ø3  313Ø            DCA     CMPFLG   /DONT COMPLEMENT VALUES
63Ø4  4527            JMS I   PMVPTS   /MOVE IMAG TO 2ØØØ
63Ø5  3Ø36            DCA     COSINE   /ADDR OF 1ST REAL
63Ø6  111Ø            TAD     C1777    /ADDR-1 OF IMAG PARTS
63Ø7  3Ø11            DCA     11
631Ø  11Ø1            TAD     C6ØØØ    /FRAC MULT
6311  3324            DCA     RELPTR
6312  11Ø1            TAD     C6ØØØ
6313  3336            DCA     IMGPTR
6314  1Ø33            TAD     ADD2
6315  71Ø4            CLL RAL
6316  3Ø34            DCA     TEMPR    /-NO OF PTS
6317  6211            CDF1
632Ø  1436    NXTMAG, TAD I   COSINE   /REAL PART
6321  6141            LINC
                      LMODE
Ø322  Ø644            LDF     4        /FIELD OF REAL
Ø323  124Ø            MUL              /MULT BY ITSELF
Ø324  ØØØØ    RELPTR, Ø
Ø325  Ø363            SCR I   3        /1 BECAUSE PROD IS SHIFTED LEFT 1, 2 BECAUSE MAX VALUE WILL OVERFLOW - TAKE OUT 2
              SQUARED
Ø326  ØØØ2            PDP
                      PMODE
6327  3143            DCA     DPSQ+1   /SAVE D.P. SQ
633Ø  75Ø1            MQA
6331  3142            DCA     DPSQ
6332  1411            TAD I   11       /IMAG PART
6333  6141            LINC
                      LMODE
Ø334  Ø645            LDF     5        /FIELD OF IMAG
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Ø335  124Ø           MUL
Ø336  ØØØØ  IMGPTR,  Ø
Ø337  Ø363           SCR I    3         /SAME REASON AS REAL
Ø34Ø  ØØØ2           PDP
                     PMODE
6341  3Ø35           DCA      SINE      /SAVE H.O.
6342  71ØØ           CLL
6343  75Ø1           MQA                /L.O. OF IMAG
6344  1142           TAD      DPSQ      /L.O. OF REAL
6345  3142           DCA      DPSQ
6346  7ØØ4           RAL                /OVERFLOW IF ANY
6347  1Ø35           TAD      SINE      /H.O. OF IMAG
635Ø  1143           TAD      DPSQ+1    /H.O. OF REAL
6351  3143           DCA      DPSQ+1
6352  4773           JMS I    PSQRT     /TAKE SQ RT
6353  3436           DCA I    COSINE    /STORE IN PLACE OF REAL
6354  2Ø36           ISZ      COSINE    /STEP REAL PTR
6355  2336           ISZ      IMGPTR    / "   IMAG ADDR - ON LAST PT OF 1Ø24 PTS WILL SKIP
6356  2324           ISZ      RELPTR    /STEP REAL ADDR
6357  2Ø34           ISZ      TEMPR     /STEP CTR
636Ø  532Ø           JMP      NXTMAG
6361  6141           LINC
                     LMODE
Ø362  Ø643           LDF      3
Ø363  ØØØ2           PDP
                     PMODE
6364  1533           TAD I    PIFTFG    /IF TRANSFORM WAS DONE, SWAP HALVES
6365  764Ø           SZA CLA
6366  5774           JMP I    PNSWPR
6367  4526           JMS I    PMRLMG
637Ø  5771           JMP I    PPREPR    /DISPLAY MAG
            /
6371  613Ø  PPREPR,  PREPAR
6372  6Ø51  PDSPER,  DISPER
6373  7Ø52  PSQRT,   SQRT
6374  6124  PNSWPR,  NOSWPR
                     EJECT
```

```
                       LMODE
               /LOOKUP, ENTER PARAMETER LIST
Ø375  ØØØØ     FDV,    Ø              /UNIT Ø
Ø376  ØØØØ             Ø              /FILE NAME - 8 CHAR
Ø377  ØØØØ             Ø
Ø4ØØ  ØØØØ             Ø
Ø4Ø1  ØØØØ             Ø
Ø4Ø2  ØØØ2             2              /BINARY
Ø4Ø3  ØØØØ             Ø              /BLK NO
Ø4Ø4  ØØØØ             Ø              /NO OF BLKS
               /
Ø4Ø5  ØØØØ     RWPARM, ØØØØ           /UNIT
Ø4Ø6  ØØ2Ø             ØØ2Ø           /BUFFER ADDR
Ø4Ø7  ØØØØ             Ø              /BLK NO
Ø41Ø  ØØØØ             Ø              /NO OF BLKS
               /
                       LMODE
               /QUESTIONS
Ø411  4Ø4Ø
Ø412  4Ø4Ø
Ø413  4Ø23
Ø414  1116
Ø415  Ø714
Ø416  Ø54Ø
Ø417  2Ø22
Ø42Ø  Ø5Ø3
Ø421  1123
Ø422  1117
Ø423  164Ø
Ø424  Ø6Ø6
               QUES1,  TEXT Z     SINGLE PRECISION FFT
Ø425  2443

Ø426  474Ø
Ø427  4347

Ø43Ø  4Ø43
Ø431  Ø64Ø
Ø432  4Ø11
Ø433  162Ø
Ø434  2524
Ø435  4Ø17
               F  INPUT ON
Ø436  1643

Ø437  474Ø
Ø44Ø  43Ø6
Ø441  4Ø4Ø
Ø442  Ø411
Ø443  Ø114
Ø444  4Ø25
Ø445  1611
Ø446  2477
Ø447  4Ø31
Ø45Ø  5716
Ø451  7461
Ø452  34ØØ
               F  DIAL UNIT? Y/N<1\Z
               QUES2,  TEXT Z
Ø453  4Ø43
Ø454  Ø625
Ø455  1611
```

```
1450     Ø457  1625
1450     Ø460  1502
1450     Ø461  Ø522
1450                  FUNIT NUMBER<2
1451     Ø462  7462
1451     Ø463  4347
1451
1452     Ø464  4Ø43
1452     Ø465  Ø6Ø6
1452     Ø466  1114
1452     Ø467  Ø54Ø
1452     Ø47Ø  16Ø1
1452     Ø471  15Ø5
1452     Ø472  4Ø4Ø
1452     Ø473  747Ø
1452     Ø474  34ØØ
1452                  FFILE NAME  <8\Z
1453                  QUES3,   TEXT Z
1454     Ø475  4Ø43
1454     Ø476  Ø64Ø
1454     Ø477  4Ø25
1454     Ø5ØØ  1611
1454     Ø5Ø1  244Ø
1454     Ø5Ø2  1625
1454     Ø5Ø3  15Ø2
1454     Ø5Ø4  Ø522
1454                  F  UNIT NUMBER<2
1455     Ø5Ø5  7462
1455     Ø5Ø6  4347
1455
1456     Ø5Ø7  4Ø43
1456     Ø51Ø  Ø64Ø
1456     Ø511  4ØØ2
1456     Ø512  1413
1456     Ø513  4Ø16
1456     Ø514  2515
1456     Ø515  Ø2Ø5
1456     Ø516  224Ø
1456     Ø517  7463
1456     Ø52Ø  34ØØ
1456                  F  BLK NUMBER <3\Z
1457                  QUES4,   TEXT Z
146Ø     Ø521  4Ø43
146Ø     Ø522  Ø61Ø
146Ø     Ø523  1727
146Ø     Ø524  4Ø15
146Ø     Ø525  Ø116
146Ø     Ø526  314Ø
146Ø     Ø527  2Ø24
146Ø     Ø53Ø  2377
146Ø                  FHOW MANY PTS? <4
1461     Ø531  7464
1461     Ø532  4347
1461
1462     Ø533  4Ø43
1462     Ø534  474Ø
1462     Ø535  5Ø64
1462     Ø536  5561
1462     Ø537  6Ø62
1462     Ø54Ø  644Ø
1462     Ø541  Ø231
```

```
1462      Ø545  234Ø
1462      Ø546  17Ø6
1462      Ø547  4Ø62
1462                           (4=1Ø24 BY POWERS OF 2)
1463      Ø55Ø  5143
1463
1464      Ø551  474Ø
1464      Ø552  43Ø6
1464      Ø553  22Ø5
1464      Ø554  Ø114
1464      Ø555  4Ø17
1464                  FREAL OR
1465      Ø556  2243
1465
1466      Ø557  474Ø
1466      Ø56Ø  43Ø6
1466      Ø561  Ø317
1466      Ø562  152Ø
1466      Ø563  14Ø5
1466      Ø564  3Ø77
1466      Ø565  4Ø22
1466      Ø566  57Ø3
1466      Ø567  7461
1466      Ø57Ø  34ØØ
1466                  FCOMPLEX? R/C<1\Z
1467                  QUES5,   TEXT Z
147Ø      Ø571  43Ø6
147Ø      Ø572  4Ø4Ø
147Ø      Ø573  1725
147Ø      Ø574  242Ø
147Ø      Ø575  2524
147Ø      Ø576  4Ø17
147Ø                  F  OUTPUT ON
1471      Ø577  1643
1471      Ø6ØØ  Ø64Ø
1471      Ø6Ø1  4ØØ4
1471      Ø6Ø2  11Ø1
1471      Ø6Ø3  144Ø
1471      Ø6Ø4  2516
1471      Ø6Ø5  1124
1471      Ø6Ø6  774Ø
1471      Ø6Ø7  3157
1471      Ø61Ø  1674
1471      Ø611  6134
1471                  F  DIAL UNIT? Y/N<1\Z
1472                  QUES6,   TEXT Z
1473      Ø612  4Ø43
1473
1474      Ø613  474Ø
1474      Ø614  43Ø6
1474      Ø615  4Ø22
1474      Ø616  Ø52Ø
1474      Ø617  14Ø1
1474      Ø62Ø  Ø3Ø5
1474      Ø621  774Ø
1474      Ø622  3157
1474      Ø623  1674
1474      Ø624  6134
1474                  F REPLACE? Y/N<1\Z
1475                  QUES11, TEXT Z
1476      Ø625  43Ø6
1476      Ø626  Ø6Ø6
```

```
1476     Ø627  244Ø
147'     Ø63Ø  1722
147      Ø631  4ØØ4
1476     Ø632  1123
1476     Ø633  2Ø14
1476     Ø634  Ø131
1476     Ø635  774Ø
1476     Ø636  Ø657
1476     Ø637  Ø474
1476                  FFFT OR DISPLAY? F/D<1
1477     Ø64Ø  6143
1477
15ØØ     Ø641  474Ø
15ØØ     Ø642  4347
15ØØ
15Ø1     Ø643  4Ø43
15Ø1     Ø644  Ø624
15Ø1     Ø645  22Ø1
15Ø1     Ø646  1623
15Ø1     Ø647  Ø617
15Ø1     Ø65Ø  2215
15Ø1     Ø651  4Ø17
15Ø1                  FTRANSFORM OR
15Ø2     Ø652  2243
15Ø2
15Ø3     Ø653  474Ø
15Ø3     Ø654  43Ø6
15Ø3     Ø655  1116
15Ø3     Ø656  26Ø5
15Ø3     Ø657  2223
15Ø3     Ø66Ø  Ø577
15Ø3     Ø661  4Ø24
15Ø3     Ø662  5711
15Ø3     Ø663  7461
15Ø3     Ø664  34ØØ
15Ø3                  FINVERSE? T/I<1\Z
15Ø4                  QUES13, TEXT Z
15Ø5     Ø665  43Ø6
15Ø5     Ø666  271Ø
15Ø5     Ø667  11Ø3
15Ø5     Ø67Ø  1Ø4Ø
15Ø5     Ø671  Ø411
15Ø5     Ø672  232Ø
15Ø5     Ø673  14Ø1
15Ø5     Ø674  3177
15Ø5                  FWHICH DISPLAY?<1
15Ø6     Ø675  7461
15Ø6     Ø676  4347
15Ø6
15Ø7     Ø677  4Ø43
15Ø7     Ø7ØØ  474Ø
15Ø7     Ø7Ø1  4Ø4Ø
15Ø7     Ø7Ø2  4Ø4Ø
15Ø7     Ø7Ø3  225Ø
15Ø7     Ø7Ø4  Ø5Ø1
15Ø7                              R(EAL)
151Ø     Ø7Ø5  1451
151Ø     Ø7Ø6  4347
151Ø     Ø7Ø7  4Ø4Ø
151Ø     Ø71Ø  4Ø4Ø
151Ø     Ø711  4Ø11
151Ø     Ø712  5Ø15
```

```
1510     Ø714  1116
1510     Ø715  Ø122
1510                           I(MAGINARY)
1511     Ø716  3151
1511     Ø717  4347
1511     Ø72Ø  4Ø4Ø
1511     Ø721  4Ø4Ø
1511     Ø722  4Ø15
1511     Ø723  5ØØ1
1511     Ø724  Ø716
1511     Ø725  1124
1511     Ø726  25Ø4
1511                           M(AGNITUDE)
1512     Ø727  Ø551
1512     Ø73Ø  4347
1512     Ø731  4Ø4Ø
1512     Ø732  4Ø4Ø
1512     Ø733  4Ø23
1512     Ø734  5ØØ3
1512     Ø735  Ø114
1512     Ø736  Ø54Ø
1512     Ø737  Ø6Ø1
1512     Ø74Ø  Ø324
1512     Ø741  1722
1512                           S(CALE FACTOR)
1513     Ø742  5143
1513     Ø743  474Ø
1513     Ø744  4Ø4Ø
1513     Ø745  4Ø4Ø
1513     Ø746  1411
1513     Ø747  16Ø5
1513     Ø75Ø  4ØØ6
1513     Ø751  Ø5Ø5
1513     Ø752  Ø45Ø
1513     Ø753  22Ø5
1513     Ø754  2324
1513     Ø755  Ø122
1513     Ø756  2451
1513     Ø757  34ØØ
1513                           LINE FEED(RESTART)\Z
1514                   /MESSAGES
1515                   MSG1,   TEXT Z
1516     Ø76Ø  4347
1516
1517     Ø761  4Ø43
1517     Ø762  Ø64Ø
1517     Ø763  4Ø4Ø
1517     Ø764  4ØØ3
1517     Ø765  Ø116
1517     Ø766  1617
1517     Ø767  244Ø
1517     Ø77Ø  Ø611
1517                   F    CANNOT FIND
152Ø     Ø771  16Ø4
152Ø     Ø772  4347
152Ø
1521     Ø773  4Ø43
1521     Ø774  474Ø
1521     Ø775  4Ø4Ø
1521     Ø776  4Ø4Ø
1521     Ø777  4Ø4Ø
1521     1ØØØ  4Ø4Ø
1521     1ØØ1  4Ø1Ø
```

```
1521      1002  1124
1521      1003  4022
1521      1004  0524
1521      1005  2522
1521      1006  1640
1521      1007  2417
1521      1010  4003
1521      1011  1716
1521      1012  2434
1521                                   HIT RETURN TO CONT\Z
1522                  MSG2,    TEXT Z
1523      1013  4347
1523
1524      1014  4043
1524      1015  0640
1524      1016  4040
1524      1017  4016
1524      1020  1740
1524      1021  2320
1524      1022  0103
1524                  F     NO SPACE
1525      1023  0543
1525
1526      1024  4740
1526      1025  4347
1526      1026  4040
1526      1027  4040
1526      1030  4040
1526      1031  4010
1526      1032  1124
1526      1033  4022
1526      1034  0524
1526      1035  2522
1526      1036  1640
1526      1037  2417
1526      1040  4003
1526      1041  1716
1526      1042  2434
1526                               HIT RETURN TO CONT\Z
1527                  /
1530      1043  0000  ANSWER, 0
1531                          *.+6
1532
1533                          EJECT
-
```

```
                        PMODE
                /SQUARE ROOT
7Ø52   ØØØØ     SQRT,   Ø
7Ø53   3273             DCA      ROOT      /CLR ROOT
7Ø54   1142             TAD      DPSQ      /IF SQ IS Ø, EXIT
7Ø55   764Ø             SZA CLA
7Ø56   5262             JMP      NOTØ
7Ø57   1143             TAD      DPSQ+1
7Ø6Ø   765Ø             SNA CLA
7Ø61   5652             JMP I    SQRT
7Ø62   1143     NOTØ,   TAD      DPSQ+1    /1ST APPROX OF ROOT
7Ø63   711Ø             CLL RAR            /DIVIDE BY 2
7Ø64   114Ø             TAD      C2ØØØ     /+1/2
7Ø65   3273             DCA      ROOT

7Ø66   1142     SQRT2,  TAD      DPSQ      /SUM OF SQUARES
7Ø67   7421             MQL
7Ø7Ø   1143             TAD      DPSQ+1
7Ø71   71ØØ             CLL
7Ø72   74Ø7             DVI                /DIVIDE BY ROOT APPROX
7Ø73   ØØØØ     ROOT,   Ø
7Ø74   743Ø             SZL
7Ø75   5314             JMP      SQRT1     /OVERFLOW
7Ø76   72ØØ             CLA
7Ø77   75Ø1             MQA                /QUOTIENT TO AC
71ØØ   1273             TAD      ROOT      /ADD APPROX TO QUOTIENT
71Ø1   7ØØ1             IAC
71Ø2   711Ø             CLL RAR            /DIVIDE BY 2
71Ø3   3Ø35             DCA      SINE      /SAVE
71Ø4   1273             TAD      ROOT      /SUBTRACT OLD ROOT FROM NEW ONE
71Ø5   7Ø41             CIA
71Ø6   1Ø35             TAD      SINE
71Ø7   765Ø             SNA CLA
711Ø   5314             JMP      SQRT1     /=Ø
7111   1Ø35             TAD      SINE
7112   3273             DCA      ROOT      /NEW ROOT
7113   5266             JMP      SQRT2

7114   1273     SQRT1,  TAD      ROOT
7115   5652             JMP I    SQRT


                        EJECT
                        PMODE
                 /MOVE PTS FROM ONE AREA TO ANOTHER
                 /1Ø = OLD BUFFER
                 /11 = NEW    "
                 /IF CMPFLG=1, COMPLEMENT VALUE
7116  ØØØØ       MOVPTS, Ø
7117  6211               CDF1
712Ø  113Ø       NXTPT,  TAD     CMPFLG
7121  711Ø               CLL RAR         /TO LK
7122  141Ø               TAD I   1Ø
7123  743Ø               SZL
7124  7Ø41               CIA
7125  3411               DCA I   11
7126  2Ø34               ISZ     TEMPR
7127  532Ø               JMP     NXTPT
713Ø  62Ø1               CDFØ
7131  5716               JMP I   MOVPTS

                 /MOVE REAL OR MAGNITUDE VALUES
                 /FROM Ø TO 2ØØØ
                 /AND SWAP HALVES
                 /DO NOT COMPLEMENT
7132  ØØØØ       MVRLMG, Ø
7133  7Ø4Ø               CMA             /OLD ADDR OF 1ST 1/2 = Ø
7134  3Ø1Ø               DCA     1Ø
7135  1Ø37               TAD     GR      /NEW ADDR OF 1ST 1/2 = 2ØØØ + 1/2 NO OF PTS
7136  111Ø               TAD     C1777
7137  3Ø11               DCA     11
714Ø  1Ø33               TAD     ADD2
7141  3Ø34               DCA     TEMPR   /MOVE 1/2 NO OF PTS
7142  313Ø               DCA     CMPFLG  /DONT COMPLEMENT
7143  4527               JMS I   PMVPTS  /MOVE THEM
7144  7Ø4Ø               CMA             /OLD ADDR OF 2ND 1/2 = 1/2 NO OF PTS
7145  1Ø37               TAD     GR
7146  3Ø1Ø               DCA     1Ø
7147  111Ø               TAD     C1777   /NEW ADDR OF 2ND 1/2 = 2ØØØ
715Ø  3Ø11               DCA     11
7151  1Ø33               TAD     ADD2
7152  3Ø34               DCA     TEMPR   /1/2 NO OF PTS
7153  4527               JMS I   PMVPTS  /MOVE THEM
7154  5732               JMP I   MVRLMG

                         EJECT
```

```
ACDFØ  1202
A[illegible]R  ØØ41
[illegible]  1135
ADDWOS 1157
ADD1   1174
ADD2   ØØ33
ADJSGN Ø57Ø
ANSWER 7Ø43
ARG2   1Ø2Ø
ASK    472Ø
ASKX   474Ø
ASK2   4523
ASK2X  4571
ASK3   4572
ASK3X  4626
ASR    7415
BIGSNU ØØ12
BOUND  1516
BUFHI  1574
BUFLO  1575
BUFPTR 15Ø4
BUILD  Ø544
C      ØØ32
CAM    7621
CCDFØ  14Ø1
CCIA   Ø162
CCLR   Ø146
CDFØ   62Ø1
CDF1   6211
CHKEND 465Ø
CHKHI  1473
CHKPT  Ø515
CKEND  4211
CMPFLG Ø13Ø
CNOP   Ø163
CNOTS  Ø677
CONT   14ØØ
CONV   4627
CONVER 4674
CORVAL Ø114
COSINE ØØ36
COUNT  Ø116
CSAM   1351
CURCNT 1573
CURDIS 1551
CURLOP 1563
CURRTN 145Ø
CURSAM Ø1Ø1
C1ØØØ  Ø137
C1777  Ø11Ø
C2ØØØ  Ø14Ø
C6ØØØ  Ø1Ø1
DADD   15Ø4
DATTAP 4Ø61
DBLHI  1541
DBLLO  1547
DISFLG 4242
DISPER 6Ø51
DISPLY 6ØØ1
DISPL1 6Ø22
```

```
DOIFFT 0047
DPIMAG 6055
DPMAG  6270
DPREAL 6117
DPSCAL 6226
DPSQ   0142
DSCLOC 1244
DSCLOP 1275
DSCWD  1261
DVI    7407
ENDHI  1577
ENDLO  1576
ERRCHK 4660
F      0007
FDV    6375
FDV2RW 4466
FFT    0400
FIF    4251
FLIP   1046
FLIPCT 0063
FREE   1365
FRESAM 0105
FT     4365
GETRIG 0045
GI     0040
GQ1000 6147
GR     0037
GRET10 0073
GR9    6244
IDORA  1200
IFCOM  4203
IFDIAL 4026
IFDISP 4265
IFFFT  4231
IFFT   0147
IFI    4261
IFT    4363
IFTFLG 4356
IMGPTR 6336
INDEX  1134
INFILE 4555
INVERT 0043
INVRT  1040
K      0031
KBUFHI 1241
KBUFLO 1242
KIDORA 0117
KMNADR 1236
KMNFLD 1235
KMXADR 1240
KMXFLD 1237
KRDORA 0120
KYSCAL 0136
L      0005
LARGER 6216
LDF4   0144
LEFTX  1363
LESS10 0074
LO     6164
LO     0440
LSR    7417
MAXADR 1475
```

```
MAXFLU 1474
MAXNU  0021
MI[illegible]R 1416
MI[illegible]D 1415
MINPTS 0131
MNOVR2 0022
MOVDIS 1361
MOVINP 4063
MOVPTS 7116
MPLIER 4701
MQA    7501
MQL    7421
MSG1   6760
MSG2   7013
MULPLY 4676
MULT   0044
MULTIP 1000
MUY    7405
MVRLMG 7132
M1     0070
M1K    0141
M10    0072
M1000  1527
M11    0077
M12    0071
M215   0102
M261   0106
M321   0103
M340   0105
M353   0104
M4     0075
M400   0107
M4000  0067
M5     0100
M70    1476
N      0003
NMI    7411
NOROT  0564
NOSPAC 4423
NOSWPI 6110
NOSWPR 6124
NOTNOR 1172
NOT0   7062
NOVER4 0020
NOWSTR 4377
NO4MIK 1133
NU     0004
NUMBKS 4503
NUMBKX 4522
NXTCHR 4634
NXTDF  1466
NXTMAG 6320
NXTPNT 1441
NXTPT  7120
OCTL   4711
OF12BU 4000
OKEND  1463
OKFLD  1467
ONDAT  4452
OUTQES 4273
OUTUNT 4310
P      0030
```

```
PDSPER 6372
PFDV7  Ø123
PI     ØØ26
PIFTFG Ø133
PLEFTX Ø125
PMRLMG Ø126
PMVDIS Ø124
PMVPTS Ø127
PNSWPR 6374
PPREPR 6371
PR     ØØ25
PREAD  Ø134
PRELFG Ø132
PREPAR 613Ø
PRFRSH Ø122
PROC   4357
PSHOWT Ø121
PSQRT  6373
PTS    4Ø64
PWRITE Ø135
P4Ø1   1243
Q      ØØ27
QAINIT 1ØØØ
QARFSH 1Ø53
QI     ØØ24
QR     ØØ23
QUAD1  111Ø
QUAD2  1Ø72
QUESNO 4734
QUES1  6411
QUES11 6625
QUES13 6665
QUES2  6453
QUES3  6475
QUES4  6521
QUES5  6571
QUES6  6612
RBUILD ØØ64
RDDATA 432Ø
RDORA  1343
REALFG 6Ø53
RECHK  ØØ66
REDPLY 616Ø
RELPTR 6324
REPL   4446
RESETC ØØ65
REVERS Ø7Ø5
RFRSH  6171
ROOT   7Ø73
ROTAT  4121
ROT1   4136
RTNCDF 1257
RWPARM 64Ø5
S      ØØØ6
SAMNAM 443Ø
SCA    7441
SCAL   ØØ53
SCALE  Ø34Ø
SCL     4Ø3
SCLFA   257
SCR4   Ø145
SC12BU Ø343
```

```
SETC   05[illegible]
SETDF  1[illegible]
SETFLD 14[illegible]
SGNADJ Ø161
SHFCHK ØØ55
SHFLAG ØØ54
SHFT1  1Ø77
SHFT2  1114
SHFT3  1125
SHIFCT Ø562
SHIFT1 ØØ56
SHIFT2 ØØ57
SHIFT3 ØØ6Ø
SHL    7413
SHOSCL 6247
SHOWIT 6162
SIGN   1Ø37
SINE   ØØ35
SINLOC ØØ5Ø
SINRET 1122
SINTAB 7347
SIZE   617Ø
SMALLR 6211
SORT   ØØ42
SORTX  Ø7Ø1
SQRT   7Ø52
SQRT1  7114
SQRT2  7Ø66
STAMU  4144
STSCAL 4367
SWAPED Ø745
TAB    1323
TEMP   1276
TEMPR  ØØ34
TEMP1  4114
TEMP2  4675
TRIGET 1Ø6Ø
UNTFIL 4Ø44
UPADDR 6166
UPLEGL 4645
VCOORD 1274
WCHDIS 6Ø35
WINSAM Ø1ØØ
WORD   ØØ61
WORDP  ØØ62
WRAP   1424
WSAM   136Ø
XCORD  ØØØ1
XCURHI Ø112
XCURLO Ø113
XITAB  2ØØØ
XLOCDF ØØ52
XRLOC  ØØ51
XRTAB  ØØØØ
XSUM   1175
YCUR   Ø115
YSCAL  1444
YSHFT  Ø111
```

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