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TITLE	CFFT - Continuous Fast Fourier Transform
AUTHOR	J. R. Mason
COMPANY	U.C.L.A. Brain Research Institute Los Angeles, California
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CFFT - Continuous Fast Fourier Transform

DECUS Program Library Write-up DECUS No. 12-23

PDP-12 SPECTRUM PROGRAM (Using New Cooley-Tukey Fast Fourier Transform Algorithm)

By J. R. MASON, UCLA Brain Research Institute (Data Processing Laboratory)

Equipment = PDP-12 (8K) with KW12 Clock, TU55 LINCtapes.

James Bryan (NIMH) has developed a Cooley-Tukey Fast Fourier Transform (DECUS L-25) for use on the Classic LINC. (It has subsequently been modified by Donald Overton for the PDP-12). (See FFOURIER and FFSAMPLE, included with this write-up).

The version of the program used at the Brain Research Institute utilizes a PDP-12 (8K) with two LINCtape transports, KW12 Clock and CalComp Digital Plotter.

This modified version eliminates the use of LINCtape for intermediate storage, calculation and overlays, but keeps the basic memory block structure of the previous program. All of the program resides in Core. As before, the epoch is fixed at 1792 samples. However, the program samples continuously*, calculates the spectra of the 17.5 second (1792 samples) epochs and writes the CALCULATED SPECTRA values on LINCtape unit 1 in double precision format.

The package consists of the following programs:

CFFS: FFSAMPLE was modified to sample continuously* using the Clock interrupts. When the 1792 word buffer is full, the interrupts are disabled*, the data in the buffer is moved to memory segments 2, 3, and 4 (in the same sequence that FFOURIER dictates), the interrupts are enabled and program control is transferred to the Fast Fourier section.

*Sampling is continuous except for a gap of less than 0.2 second which occurs when the digitized data is being moved out of the buffer.

CFFTW: This is the Spectrum computation program. It is basically the same as the FFOURIER (DECUS L-25) program. However, it is divided into two parts for ease of modification. The modifications consist of changing the Data Fields of the A/D blocks, the Sine table and the working area.

As soon as the Spectra calculations are complete, the two blocks of double precision values are written on LINCtape (2 tape blocks) and the graph of the spectra is displayed on the scope. The display remains until the next full A/D buffer - at which point this sequence is repeated.

While the display is on the scope, it may be scaled as follows:

To scale display up by 2, hit U key; (may be done repeatedly)
To scale display down by 2, hit D key; (may be done repeatedly)
To reset scale to original value, hit S
Sense switch 0 SET produces a bar-chart display

Program is terminated by a SET Sense Switch 5 (program halts after the next

calculated spectra are written out on tape).

This LINCtape is then processed thru the PLOTFFT program which plots the spectra on a CalComp Plotter.

NOTES: (from FFSAMPLE/FFOURIER write-up)

> This particular digitizing timing is intended for EEG work from 0.4 to 40 Hz. It should be used with a low-pass filter which is flat from zero to 40 Hz and at least 40 db down at all frequencies beyond 60 Hz.
> Calibration marks (X-AXIS) on the display are at 5 Hz intervals. The points at 0.0 Hz and 0.2 Hz have been suppressed since the d-c term usually makes these overflow first. Points are at 0.2 Hz intervals.

CCFT - CONTINUOUS FFT - PROGRAM DESCRIPTION

FOR EASE OF PROGRAMMING, CFFT IS DIVIDED INTO FOUR PARTS:

CFFS:	SETS UP SAMPLING ROUTINE SETS UP CLOCK INTERRUPT MOVES A/D DATA FROM 1792 WORD BUFR TO SEG 2, 3, 4	LOC 20 SEG 0 LOC 40
CFFTW:	FFT CALCULATIONS WRITES SPECTRA ON L1 DISPLAYS XY GRID	LOC 20 SEG 5
CDIS:	DISPLAYS SPECTRA	LOC 20 SEG 6
SINTB:	SINE TABLE FOR FFT	LOC 1000 SEG 6

THE BINARIES OF THESE PROGRAMS ARE STORED (COMBINED) UNDER THE NAME: CFFT

CFFS

LOC 20 SEG 0

1. Zero A/D Buffer for clean scope display
2. Disable Teletype Interrupt
3. Initialize TBlock for tape write (TBlock in Seg 5)
4. Type: SB= (for starting Block - Linc 1)
5. Accept 3 octal digits
6. Move Linc 1 to Starting Block
7. Initialize Starting Address of A/D Buffer (Loc 0400 Seg 0)
8. Set up Clock Interrupts
9. Turn on Interrupts
10. SSO NOT SET:

    Display A/D Buffer

    SSO SET after observing A/D scope display:

    Wait for next full Buffer, JMP to FFT program. Prevents JMP to FFT when A/D buffer partially contains data from previous 17 sec. epoch.

LOC 40 SEG 0 LOC 40 INTERRUPT

1. Save PC
2. Save AC
3. Save Loc 0
4. Sample Analog Channel 10
5. If Buffer NOT Full Go To #7
6. When Buffer is full :
   Set Flag = 1
   ReInitialize A/D Start Address
   Move Data → Seg 2, 3, 4
7. Reset clock overflow
   Restore 0, AC, IF
   Turn on Interrupt
8. Return to "Interrupted" Program

CFFT/CDIS

LOC 20 SEG 5

1. Move SINE table into work area
2. Pre-filter set up
3. Calculate FFT
4. Write on Linc tape
   Gets starting block from Seg 0 Loc 21
   Writes 1st blk, Increment MBLK, TBLK
   Writes 2nd blk
   Sets up MBLK, TBLK for next write
   Checks for Blk 777. Halt if = 777
   Checks SS5. Halt if Set

LOC 027 SEG 6
LOC 700 SEG 5 for XY AXIS

5. Display
   ReInitialize Scale to S (No Scale Factor)
   Displays : (SSO Option) Spectra/Bar Graph
6. Before each scope refresh -
   Checks A/D Buffer full flag
   If =0 refresh scope display
   =1, reset to 0 and JMP to start of FFT Program

CFFT - CONTINUOUS FFT - OPERATING INSTRUCTIONS

1. LOAD DIAL SYSTEM UNIT 0 0701 7300

2. LOAD CFFT : LO CFFT,0 (CFFT IS SAVED ON A DIAL SYSTEM TAPE)

3. CONNECT ANALOG SIGNAL TO ANALOG CHANNEL 10 OF ANALOG INPUT PANEL

4. MOUNT A MARKED LINC TAPE ON UNIT 1. (STD. LINC FORMAT)

5. PROGRAM IS STARTED BY: 1/0 PRESET
   LEFT SWITCHES SET TO 0020
   START LEFT SWITCHES

6. PROGRAM REQUESTS SB= FOR STARTING BLOCK TO WRITE ON LINC 1, AND POSITIONS TAPE AT THAT BLOCK. REPLY WITH A 3 DIGIT OCTAL NUMBER.

7. SAMPLING BEGINS IMMEDIATELY

   SS 0 RESET - ALLOWS YOU TO VIEW THE A/D DATA AS IT IS BEING SAMPLED
   SET - WAITS FOR NEXT FULL BUFFER, THEN JMPS TO FFT ROUTINE

8. FFT CALCULATES THE SPECTRA, WRITES IT ON LINC 1, AND THEN DISPLAYS IT. THE DISPLAY IS HELD ON THE SCOPE UNTIL THE NEXT FULL BUFFER (A/D) - STEP 8 IS THEN REPEATED

   SS 0 SET - DISPLAYS A BAR GRAPH
   RESET - DISPLAYS POINTS

9. TO TERMINATE PROGRAM:

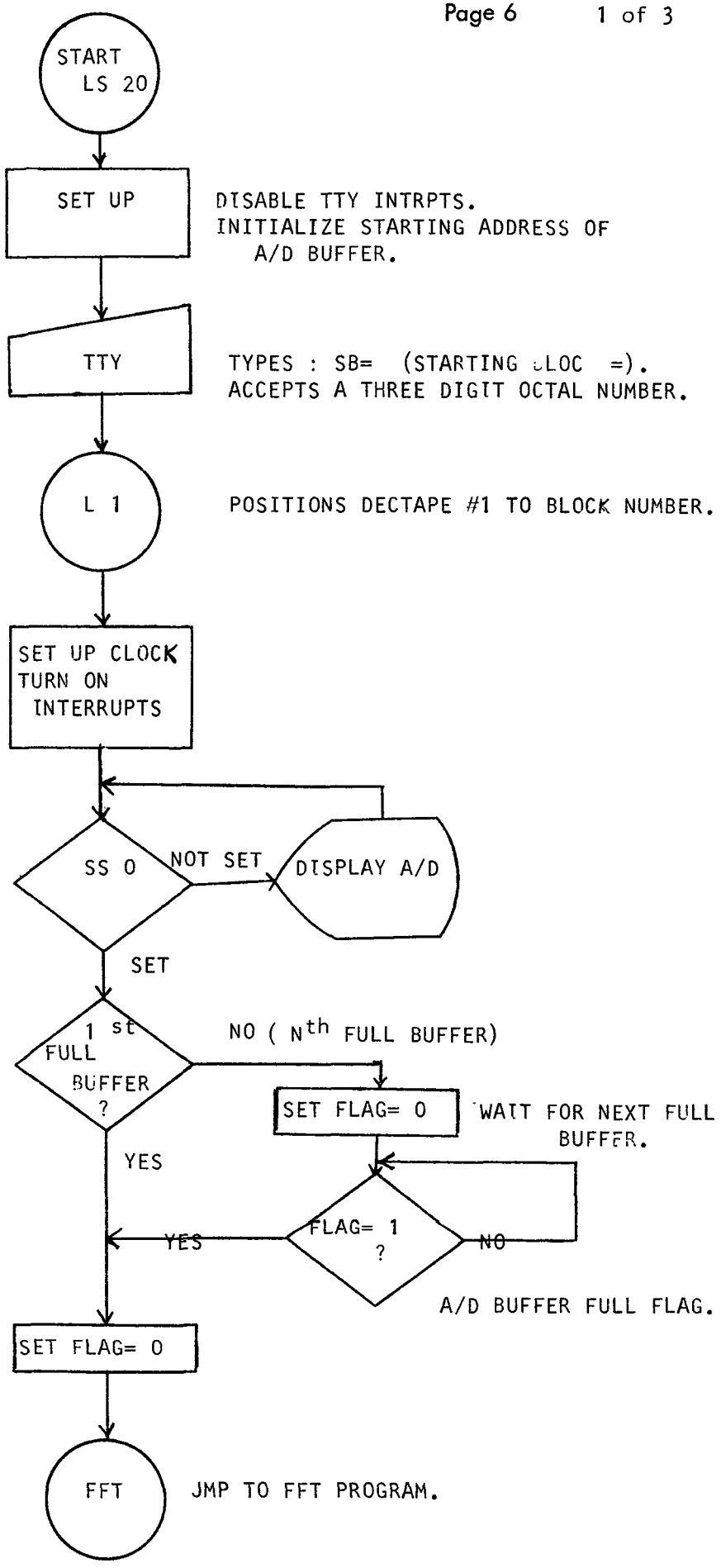
   SS 5 SET - TERMINATES PROGRAM AFTER NEXT CALCULATED SPECTRA ARE WRITTEN ON LINC 1.
   TYPES LB= FOR LAST BLOCK WRITTEN

   PROGRAM WILL AUTOMATICALLY TERMINATE WHEN LINC 1 IS FULL - - BLOCK 777 WRITTEN

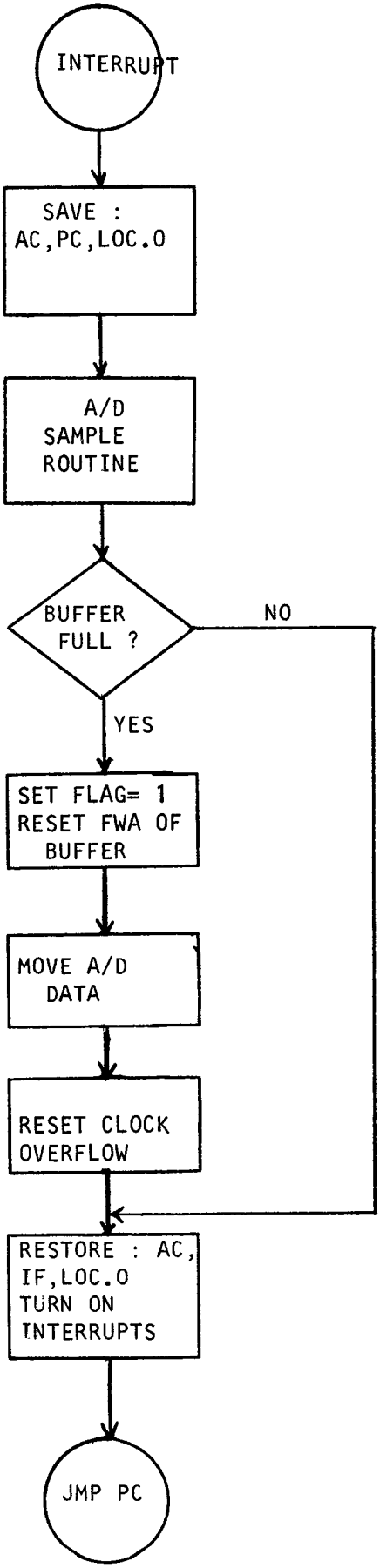
10. WHILE IN THE DISPLAY STATE, HITTING THE FOLLOWING KEYS ON THE TELETYPE WILL SCALE THE GRAPH:

    U = SCALE DATA UP (By 2)
    D = SCALE DOWN (By 2)
    S = RETURN TO ORIGINAL VALUE

CFFS - SAMPLING ROUTINE
SEG.0 LOC. 20



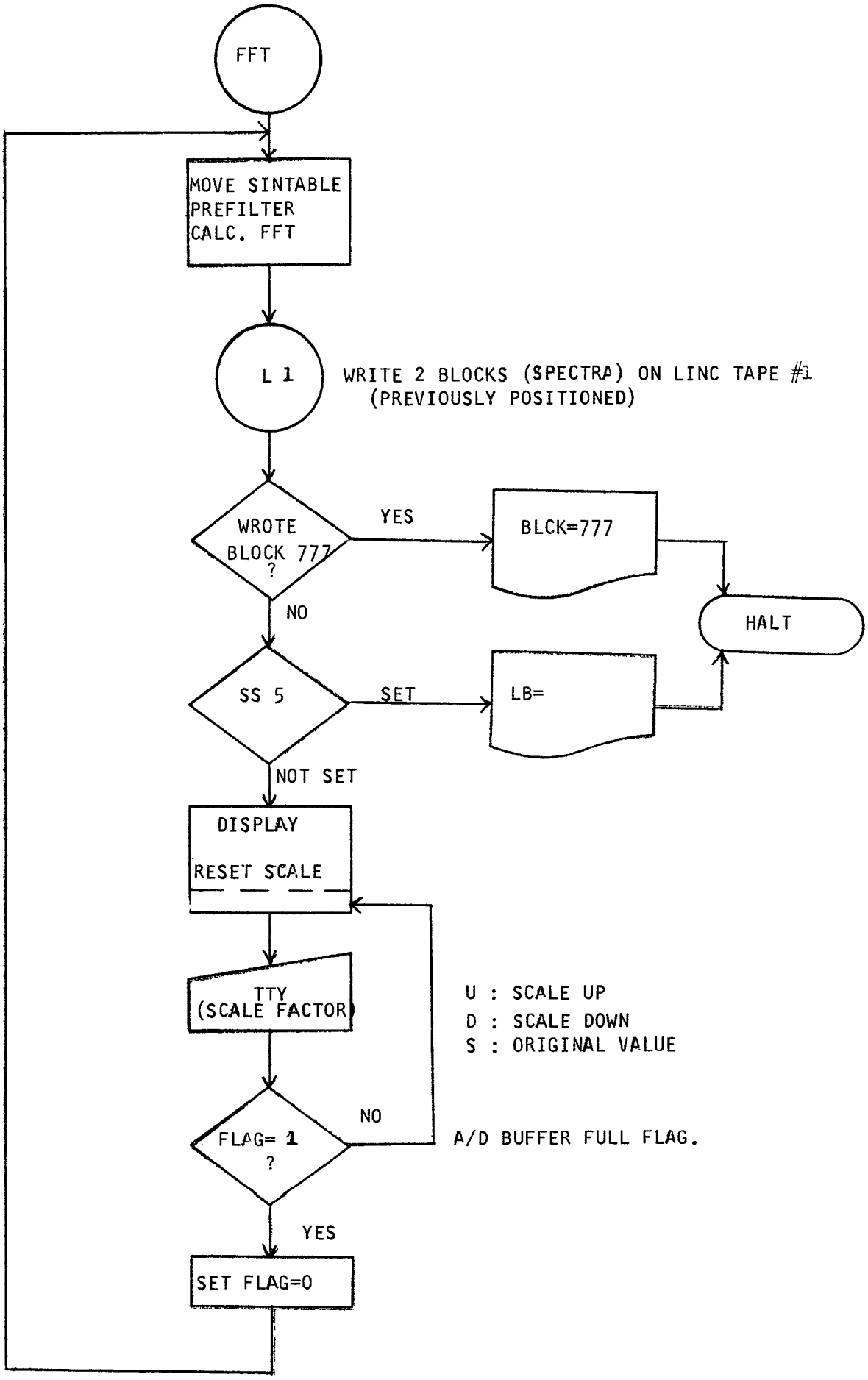
CFFS
CLOCK INTERRUPT CAUSES
A JMP TO LOC. 40



MOVE A/D DATA TO SEG.2,3,4.

CONTINUOUS FFT

FFT ROUTINE IN SEG. 5
LOC. 20



FFOURIER and FFSAMPLE

LINC SPECTRUM PROGRAM (Using New Cooley-Tukey Fast Fourier Transform Algorithm)

By JAMES BRYAN, National Institute of Mental Health
Equipment: PDP-12 with KW12 CLOCK

The version of the program used at the National Institutes of Health utilizes a standard 2000 word LINC III with a Datamec tape deck and a digital plotter. Use of the Datamec permits processing continuous epochs of any length. Since a program to work with this particular input-output equipment would be of use to no one else, a modified version was prepared to share with PDP-12 users.

The modified version uses LINCtape for storage and the oscilloscope display for output. Since the LINC III has unbuffered tape, the longest epoch which this version can handle is 7 quarters long or 1792 samples. PDP-12 users can easily modify the digitizing program for epochs of any length since their tape system is buffered. The LINCtape distributed has been modified for use on the PDP-12. The only restriction is that the number of data blocks in an epoch must be odd.

FFSAMPLE is a data sampling program specifically designed for use with the program FFOURIER. It samples channel 10 for 17.5 sec at 102.4 samples per sec., stores the data in Q1-Q7, and then displays the data. When SS#0 is set to 1, the data is written onto unit 1 at blocks 0, 5, 6, 13, 14, 21 and 22, and the program FFOURIER is read into core from BN60 on unit 0. Certain constants are transferred from FFSAMPLE to FFOURIER, and the FFOURIER program proceeds to completion and displays the resulting autocorrelation.

USAGE: FFSAMPLE may be loaded with DIAL. Alternately, set LS=0700, RS=0XXX and press I/O PRESET and DO. XXX is a block number 1 greater than the starting BN shown for the FFSAMPLE binary in the DIAL index. Data sampling begins immediately after START 20. When sampling is complete and the data is displayed, set SS #0 = 1 to compute the spectrum.

FFOURIER is the spectrum computation program. It is identical to DECUS L-25. The program must reside at BN-65 on unit 0 in order to be properly loaded by FFSAMPLE, and it has been so placed on this DIAL tape (BN57 is a header block - not part of the FFOURIER binary which begins at BN60). During operation FFOURIER writes on all Unit 1 tape blocks 0-22 which were not already written on by FFSAMPLE. Hence a scratch tape should be placed on Unit 1. When the computation is complete the spectrum will be displayed and may be scaled as follows:

To scale display up by 2, hit U key; this may be done repeatedly.
To scale display down by 2, hit D key; this, too, may be repeated.
To rescale scale, hit S key.
Sense switch 0 produces a bar-chart display.

Notes: The location of the program on Unit 0 may be changed. Also, the region of Unit 1 used for storage may be changed. The following notes may help to implement such changes:

FFSAMPLE writes on tape unit 1 at the following blocks:

$$N,\ N+5,\ N+6,\ N+11_{(10)},\ N+17_{(10)},\ N+18_{(10)}$$

where N is the initial block number. N is a program parameter located in memory address 22 of FFSAMPLE and can be changed to any arbitrary block. The unconventional spacing of the data blocks provides working space for the spectrum program with minimum tape shuffling.

This particular digitizing timing is intended for EEG work from 0.4 to 40 Hz. It should be used with a low-pass filter which is flat from zero to 40 Hz and at least 40 db down at all frequencies beyond 60 Hz.

Input data must be scaled in range $\pm$1777 before storage on unit 1.

The Spectrum Program proper resides on blocks 60-65 on Unit 0. Blocks 60-63 contain the program, and blocks 64 and 65 contain a sine table. To compile the program for other locations, equalities 4A and 4C must be changed accordingly. Memory locations 22 and 23 are parameters; 22 determines the initial data block number on unit 1, and 23 determines the number of blocks to be processed in general . . .

$$(23) = \frac{n - 1}{2}$$

where n is the number of blocks and must always be odd.

Calibration marks on the display are at 5 Hz intervals. The points at 0.0 Hz and 0.2 Hz have been suppressed since the d-c term usually makes these overflow first. Points are at 0.2 Hz intervals.

Binary location 52 (block 60) contains a scaling code. Normally it should be 377. It may be changed to 17.7 or 77 at some risk of overflow.