'A Microcomputer Based Time Domain Spectrometer'

by

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Ottawa, Ontario, 1979

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ABSTRACT

Time domain spectroscopy, like other complex measurements, can be enhanced by the use of microprocessors in two main areas. One is to provide the required data processing, and the other is to simplify the man-machine interface.

This thesis describes a spectrometer in which a single microprocessor performs both of the above mentioned tasks. A high speed floating point mathematical unit operates as a slave to the microprocessor, thus enabling it to perform various processing functions necessary for spectroscopic measurements. The relative complexity of the measurement is also softened through utilization of the microprocessor as a controller.

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Chapter I

INTRODUCTION

The primary objective of this work has been to design, implement, and evaluate a microcomputer based, time domain spectrometer. Without getting into the details of the measurement itself as this point, a few words about the nature of the measurement should suffice to introduce the subject.

The main objective of the measurement is to determine the dielectric properties of a given substance from the spectrum of the scattering parameters of a sample holder containing the test substance. There are two basic techniques used to acquire these parameters, namely the frequency domain methods and the time domain methods, which have been discussed and compared in [1,2]. The work discussed herein is concerned with the time domain techniques for making spectroscopic measurements.

1.1 APPLICATIONS OF SPECTROSCOPIC MEASUREMENTS

The many and diverse applications of spectroscopic measurements range from cancer treatment to evaluation of microwave radiation hazards. Dielectric methods have been used to investigate the quantity and nature of bound water present in biological tissues [3,4]. Other areas of application include anesthesia effects, relationship of heart disease to bound water in lipoprotein solutions, relationship of senile dementia to dielectric properties of spinal fluid, freshness of fish, as well as water content of many other substances [4].

Of more direct medical significance is the use of radiowaves and microwaves in the treatment of cancer. Previous techniques involved the raising of the temperature of the entire body using wax baths, the additional heat causing the tumor to regress. Dielectric techniques could be used to determine if there is a frequency range over which the cancerous tissue absorbs more energy than the surrounding normal tissue. This would facilitate the localization of the heating effect caused by microwave hypothermia treatments. A thorough discussion of biomedical applications of dielectric spectroscopy appears in [4].

1.2 TIME VERSUS FREQUENCY DOMAIN TECHNIQUES

Although both approaches have their advantages and disadvantages, there are two major incentives for using time domain techniques rather than frequency domain methods.

One of the points in favour of time domain measurements is the lower source and receiver cost. A fast rising step function contains frequency components from D.C. to an upper limit imposed by the risetime of the step, thereby requiring a single step generator as a broad-band source. A sampling oscilloscope would satisfy the receiver requirements.

Frequency domain measurements for the same frequency range require a number of programmable swept frequency generators as well as a complex amplitude and phase measuring microwave network analyser as sources and receiver. The frequency domain components are relatively more expensive than their time domain counterparts.

A second advantage for a time domain measurement is that the response can be windowed in time so that only the desired part of the signal is analysed. This feature facilitates the removal of unwanted reflections which are due to impedance mismatches, etc. by simply delaying the perturbation out of the time window of interest.

Another relevant point is that the time domain spectrometer (TDS) described herein uses a time domain reflectometer (TDR) on its front end, and therefore can also be used for TDR type measurements.

1.3 A MICROPROCESSOR CONTROLLED SYSTEM

Time domain techniques for spectroscopic measurements inherently require some form of data processing, which implies the use of a computer. Existing systems which will be discussed in the next chapter, use large central or time shared computers or dedicated minicomputers to do the processing. Ordinarily a microprocessor might be employed to look after the data acquisition, formatting and transfer processes, and possibly even to soften the human interface. However, with the advent of sophisticated microprocessor system compatible single board slave processors, such as the SBC-310 high speed mathematical unit, the use of the microprocessor can now be extended to complex data processing.

The independent stand alone TDS is now a reality although possibly at the expense of over-utilizing a single microprocessor. Alternatives to this are presented in the final chapter of this thesis. This potential over-utilization was not of concern during the course of this work since part of the objective was to evaluate such a system. The recommendations which come from this excercise will certainly be of use in the development of the second generation of stand alone microprocessor based TDS's.

Although applications of microprocessors in instrumentation are widely known, (Refs. 18-24), direct use of microprocessors in time domain spectroscopy has not been widely reported.

1.4 Organization of the Thesis

Chapter two reviews time domain systems presented in the literature. The references discussed in that chapter deal directly with the time domain measurements dealt with in this thesis.

The third chapter gives the theoretical basis and mathematical relationships used in the measurements. Chapter four discusses the hardware aspects of the system, dwelling more on the non-standard or custom components, and shortcomings of the hardware. Also, presented there is an improved procedure which eliminates calibration required in other systems, minimizes the effects of unwanted reflections, simplifies domain conversions, and reduces the measurement time.

Chapter five begins with a flowchart of the overall software implementation of the procedure discussed in chapter four. This implementation is semi-automatic with a friendly human interface which requires a minimum operator intervention. A sample output listing is also given to illustrate the function of the various blocks of the flowchart. The remainder of the chapter discusses the details of the software under three main headings. These headings are data acquisition, human interface, and data processing respectively. The software can be partitioned and distributed among several processors in an integrated system as suggested in chapter six.

The sixth and final chapter is a critical evaluation of the system, followed by recommendations for improvements and future work.

The main contributions of this work, therefore, lie in the procedural improvements resulting in the advantages as stated previously, automation of the procedure through implementation in the software, the human interface, and the evaluation and suggestions for future work. The tangible result is the software, much of which can be carried over into the implementation of the recommendations given in chapter six.

Chapter II

A REVIEW OF THE LITERATURE

In the first part of this chapter, a brief account of the history of time domain methods is reviewed. The second section contains a discussion of some aspects of existing TDS systems which are suitable for implementation using microprocessors.

2.1 A BRIEF HISTORY OF TDS

The study of molecular behaviour in polar systems has been done by experimental means using dielectric spectroscopy since the turn of the century, according to [5]. Due to the wide range of frequencies being studied, for frequency domain measurements a number of different techniques are required, all of which operate in a point by point fashion. In other words, a new measurement is required for each frequency point of interest. The transient or time domain method seemed to represent a more attractive approach since basically only one measurement is required to acquire the response to a time domain signal. Some additional data processing is needed to transform both stimulus and response signals to the frequency domain, and from that point on, the processing is similar to that required for the frequency domain method.

In 1969, time domain reflectometry (TDR) techniques were beginning to be used for spectroscopic measurements at microwave frequencies. At first a time domain measurement involved photographing the oscilloscope CRT display, and reading the points by eye based on the calibration of the vertical axis of the oscilloscope. The data then had to be transferred manually to paper tape or punched cards for processing by a central time shared computer. This kind of procedure was obviously time consuming and inaccurate.

Since that time various work has been done to enhance this method and extend its capabilities. Newer systems use digital voltmeters (DVM's) to facilitate automatic acquisition of the digitized data, and a computer for signal averaging as well as for transforming time domain data. Subsequent systems employed computerized monitoring and correcting techniques to compensate for additive voltage drift and timing jitter. Efforts are still being made to improve measurement accuracy, investigate different sample holder configurations, introduce more automation, and to extend both upper and lower frequency bounds of the technique.

2.2 SOME REPORTED TDS SYSTEMS

Each of the following subsections concerns an aspect of the TDS measurement which lends itself to automation using microprocessor techniques. Some of the systems discussed have already adopted automation of some or all of these particular characteristics, while others are relatively primitive. This is due in part to a relatively large time span between some of these contributions, and also the fact that most of the work done has been concerned with the electromagnetic part of the measurement.

2.2.1 Data acquisition

As has been mentioned in the last section, methods of data acquisition were quite laborious at first. Van Gemert [5] used a Hewlett Packard time domain reflectometer (TDR) system similar to the one described in chapter 4, together with an X-Y plotter from which data was sampled manually and punched on cards. Faber [2] describes in detail a device which he refers to as a "control unit" which was custom designed and built to interface the sampling oscilloscope to a scanning digital multi-meter (DMM) for analog to digital (A/D) conversion. The same author cites the addition of a paper tape punch as a possible improvement to the system, since it would reduce the number of manual operations necessary to process the data using a digital computer. A similar technique using a DMM and a paper tape punch is described in [6], and [7] mentioned using magnetic tape for data storage. Only Gans and Andrews [1] reported the use of a dedicated 14 bit A/D converter which interfaced directly with a minicomputer.

2.2.2 Control

Aside from some automated data acquisition, none of the systems described had automatic measurement procedure control with the exception of [1,7]. Nicolson et al [7] used a programmable hardware sequencer which had lighted push buttons designating various breakpoints in the sequence. Such breakpoints signify when to install a new sample, or take a reference point, etc.. The system has a facility to automatically initialize itself at power on. The sequence is programmable and is stored in one half of the available core memory, the remaining 2048 bytes being reserved for data. Thus the system maintains the stored program even after the power has been turned off. The only circumstances under which the control sequence has to be restored are when sequence modifications are made, or in the event that the control area of the memory should become damaged or overwritten.

The system described in [1] uses a minicomputer for acquisition and storage of data, and also for measurement procedural control (human interface). This system provides another interesting feature which the others did not, and that is computer control of the time base. The advantages of this modification will be discussed in a later chapter under potential improvements for our system.

2.2.3 Data processing

All of the TDS systems thus far discussed use a time shared central computer or a minicomputer. The common factor is that all of the systems use a high level programming language to do the data processing. Various transformation algorithms were used including the fast Fourier transform (FFT), discrete Fourier transform (DFT) with continuous Fourier transform (FT) interpolation and smoothing [6], and Samulon's DFT.

A summary of the various systems discussed is depicted in Table 1.

TABLE 1

A comparison of TDS systems

Reference	[1]	[2]	[5]	[6]	[7]
Data Acquisition	-A/D converter to mini-computer -automatic	-"controller" to interface oscilloscope to DMM.	-XY recorder. -data sampled manually and punched on cards.	-raw data digitized via DVM and punched on paper tape.	-raw data digitized via DVM and stored on magnetic tape.
Control	-entirely computer controlled (including time base)	-manual with exception of data acquisition. -reference points manually recorded.	-manual		-automatic via push button programmable sequencer. -auto-initialization at power on.
Data Processing	-BASIC/FORTRAN for processing, I/O control, & man-machine interface -assembler for control, data acquisition, and some math operations (eg. FFT, binary averaging, etc.)	-FORTRAN on remote computer.	-FORTRAN on remote computer.	-IBM 360 or G.E. deskside time shared service.	-FORTRAN on remote computer. -preliminary scaling and normalization done on controller. -4 reference waveforms necessary.
Frequency Range	d.c.-18GHz	-up to 2GHz	up to 2GHz	3.35GHz $\pm$500MHz	0.1 - 10GHz
Measurement Time/Sample	~2 min.			3-10 min.	~ 10 min.
Number of Data Points	usually 1024	500	300	1,000	256 or 1024
Time Window		~ 2ns			2.5 or 10ns
Other distinguishing characteristics		-lumped capacitive sample holder	-time domain synchronization using maximum slope method (manually).	-uses FFT with continuous F.T. interpolation	-sample holder temperature controlled up to 1,000°F

Chapter III

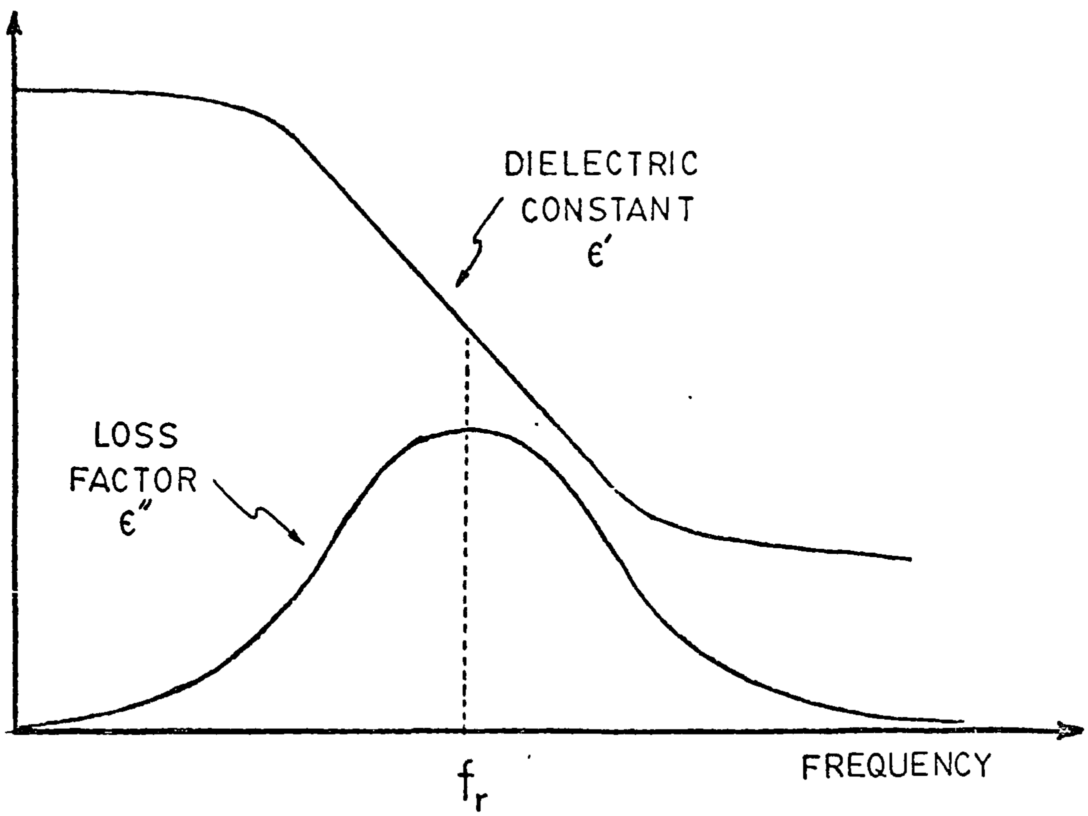
THEORETICAL BASIS FOR THE MEASUREMENT

This chapter discusses the physical nature of the measured and calculated quantities as well as their mathematical relationships.

3.1 PHYSICAL SIGNIFICANCE OF EPSILON

Before getting involved in the mathematical relationships between the input data and the output parameters, first let us take a look at the physical significance of the measurement results. There are basically four distinct forms of dielectric polarization, each of which are apparent in a different frequency range [2]. The polarization which is of concern in this work is dipole polarization, which for the majority of substances of interest occurs at high frequency (radio and microwave region).

It is well known that in the presence of an external electric field, electric dipoles align themselves in the direction of the field. If the field oscillates, the dipoles follow the field up to the point at which the frequency of the changing electric field becomes too high for the dipoles to remain in phase with it. As the frequency increases further, more and more dipoles tend to lag behind in phase, or relax, and energy is absorbed by the dielectric material as a consequence of this relaxation.



The curves shown represent characteristics typical of a pure substance. A mixture depending on its composition, could demonstrate two or more peaks for the loss factor, and the corresponding drops in the dielectric constant.

The declining dielectric constant illustrates the increasing phase lag of the dipole oscillation with respect to the electric field, with increasing frequency.

Figure 1: Typical complex permittivity characteristics

The phase lag of the dipoles with respect to the electric field is illustrated by the declining dielectric constant as shown in Fig. 1. The energy absorbed by the dielectric in the vicinity of the frequency of relaxation is shown by the loss factor curve.

This relaxation frequency may vary within a given sample as well as with time and temperature. It is this characteristic of the complex permittivity versus frequency which is the end product of the data processing in the system described herein.

3.2 REFLECTION COEFFICIENT AND COMPLEX PERMITTIVITY

The dielectric properties of a test substance are measured in this system by using a sample of the substance as a dielectric in a capacitive sample holder. From the reflection coefficient (gamma) of the sample holder, the dielectric constant and loss factor can be obtained using the relationships derived below.

From the fundamental properties of transmission lines, it is known that:

$$\Gamma = \frac{Z_L - Z_O}{Z_L + Z_O} \qquad (3.1)$$

where Γ is the reflection coefficient, Z_L is the termination impedance (in this case, it is the capacitive impedance of the sample holder), and Z_O is the characteristic impedance of the transmission line ($50\,\Omega$ in this case).

Since the sample holder is a lumped capacitance, the load impedance can be expressed as follows:

$$Z_L = \frac{1}{j\omega C} = \frac{1}{j\omega C_O \varepsilon^*} \qquad (3.2)$$

where C_O is the capacitance of the sample holder for a free space dielectric (close to air) and ε^* is the complex permittivity.

Substitution of (3.2) in (3.1) yields:

$$\Gamma = \frac{1 - j\omega\varepsilon^* C_O Z_O}{1 + j\omega\varepsilon^* C_O Z_O} \qquad (3.3)$$

Recall that by definition:

$$\varepsilon^* = \varepsilon' - j\varepsilon''$$

Therefore:

$$\Gamma = \frac{1 - j\omega(\varepsilon' - j\varepsilon'')C_O Z_O}{1 + j\omega(\varepsilon' - j\varepsilon'')C_O Z_O}$$

Transposing yields:

$$j\omega C_O Z_O(\varepsilon' - j\varepsilon'') = \frac{1-\Gamma}{1+\Gamma} \qquad (3.4)$$

Recalling that Γ is a complex quantity having both magnitude and phase:

$$\omega C_O Z_O \varepsilon'' + j\omega C_O Z_O \varepsilon' = \frac{1-|\Gamma|(\cos\theta - j\sin\theta)}{1+|\Gamma|(\cos\theta - j\sin\theta)}$$

Separating the right hand side into real and imaginary parts:

$$\omega C_O Z_O \varepsilon'' + j\omega C_O Z_O \varepsilon' = \frac{1-|\Gamma|^2 + j2|\Gamma|\sin\theta}{|\Gamma|^2 + 2|\Gamma|\cos\theta + 1}$$

Therefore:

$$\varepsilon' = \frac{2|\Gamma|\sin\theta}{\omega C_O Z_O(|\Gamma|^2 + 2|\Gamma|\cos\theta + 1)} \qquad (3.5)$$

$$\varepsilon'' = \frac{1-|\Gamma|^2}{\omega C_O Z_O(|\Gamma|^2 + 2|\Gamma|\cos\theta + 1)} \qquad (3.6)$$

Hence if C_O and Z_O are known and both magnitude and phase of Γ can be measured, ε' and ε'' can be found using equations (3.5) and (3.6) above.

The uncertainty of the complex permittivity is dependent on the uncertainties of the quantities from which the permittivity is calculated. (ie. $|\Gamma|$, θ, C_o, Z_o). These uncertainties have been extensively analysed, for the same HP TDR used in the system herein described, in[2], [5], [13] and [16].

From [16], it is known that:

$$\Delta|\Gamma| / |\Gamma| \approx \Delta\theta \approx 0.014 , \qquad \Delta C_o / C_o \approx 0.01 , \qquad \Delta Z_o / Z_o \approx 0.005$$

3.3 MEASUREMENT OF GAMMA

As has been mentioned above Γ is a complex quantity and can therefore be expressed as:

$$\Gamma = |\Gamma| \, e^{-j\theta}$$

As the term implies, Γ or reflection coefficient is a relationship between an incident stimulus and the reflected response to that stimulus. The relationship can be expressed as follows:

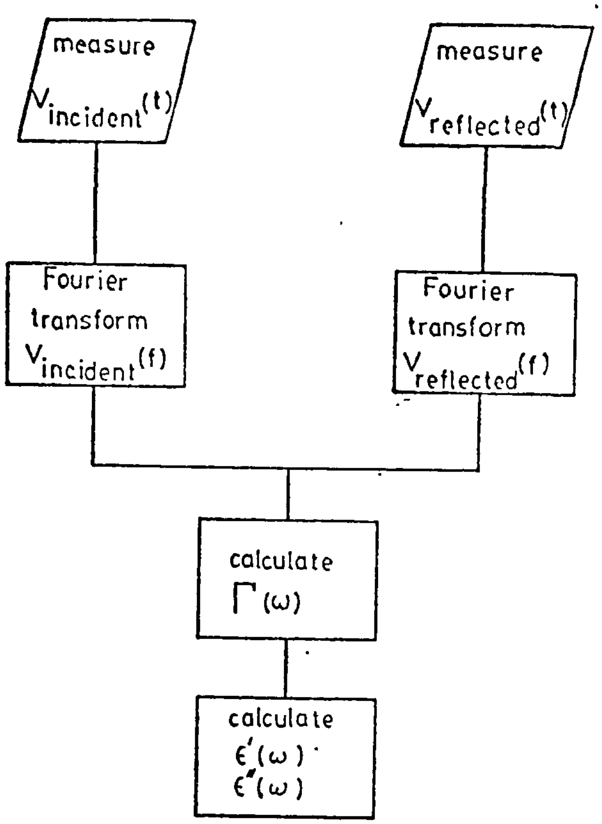
$$|\Gamma|(f) = \frac{|V_{response}(f)|}{|V_{stimulus}(f)|} \quad , \; \theta_{\Gamma}(f) = \theta_{response}(f) - \theta_{stimulus}(f)$$

The measurement of Γ therefore involves the measurement of two characteristics. This is where the similarity between frequency domain and time domain techniques ends. For frequency domain measurements, swept frequency generators provide the stimulus and a network analyser measures the response directly at a given frequency, thereby requiring many measurement points over a range of frequencies.

The time domain measurement uses a fast-rising step voltage generator to stimulate the sample with a range of frequency components simultaneously. The sampling oscilloscope is used to first record the stimulus, and then the response of the sample holder. Both characteristics are transformed to the frequency domain using a modified DFT and then the above relations are used to compute gamma. Only one measurement of each characteristic is required to calculate frequency components of Γ, which are limited primarily by the risetime of the step, noise, and the sampling rate at which the input characteristics are acquired.

At this point, Γ having been computed, Z_o known, and C_o having been calculated and measured (see sections 4.2.1, 4.2.2), the dielectric constant and loss factor can be computed using the relationships expressed in equations (3.5), and (3.6). A summary for the experimental procedure is given in Fig. 2.

The causes of uncertainty stem mainly from the hardware but are also dependent on the data processing algorithms. The uncertainty in $|\Gamma|$ are due to amplitude jitter in the TDR and the timebase instability is the source of the phase uncertainty.



The measurement and Fourier transformation of the stimulus and response characteristics are not performed concurrently as the diagram might seem to suggest. These two branches are rather executed independently, and the results from both are used in subsequent processing.

Figure 2: A summary of the experimental procedure

Chapter IV

EXPERIMENTAL APPARATUS AND PROCEDURE

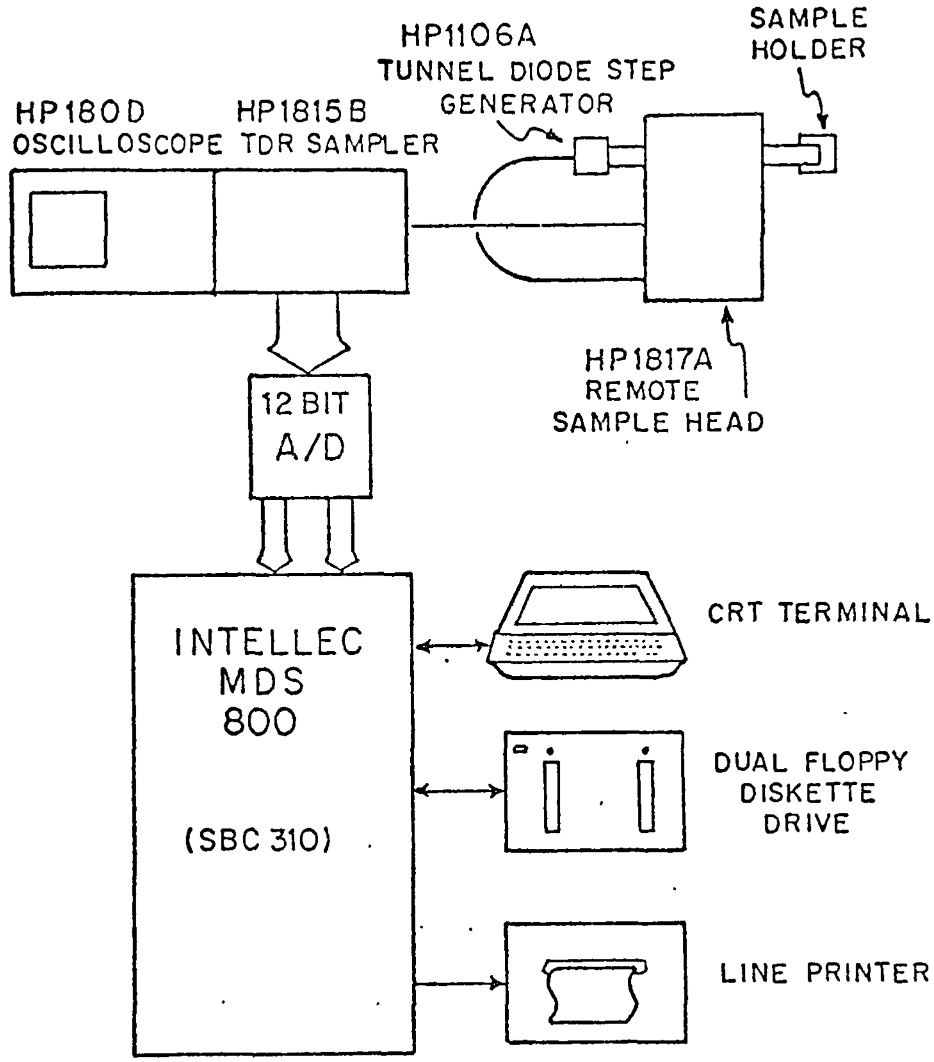
In this chapter the system hardware is described and the measurement procedure is explained.

4.1 SYSTEM HARDWARE

This section is concerned mainly with the hardware portions of the system. Before going into the details of each block, an overall block diagram puts each into perspective with respect to the entire system.

Looking at Fig. 3, it can be seen that the front end of the system is basically a commercially available Hewlett Packard time domain reflectometer consisting of a HP 180D oscilloscope, a HP 1815B plug in sampler unit, a HP 1817A remote sampling head, and a HP 1106A tunnel diode step generator.

The 1815B sampler and 180D oscilloscope effectively stretch an event in time by repeating the event and sampling successive time points each iteration. Once the entire characteristic has been swept in this manner, the whole



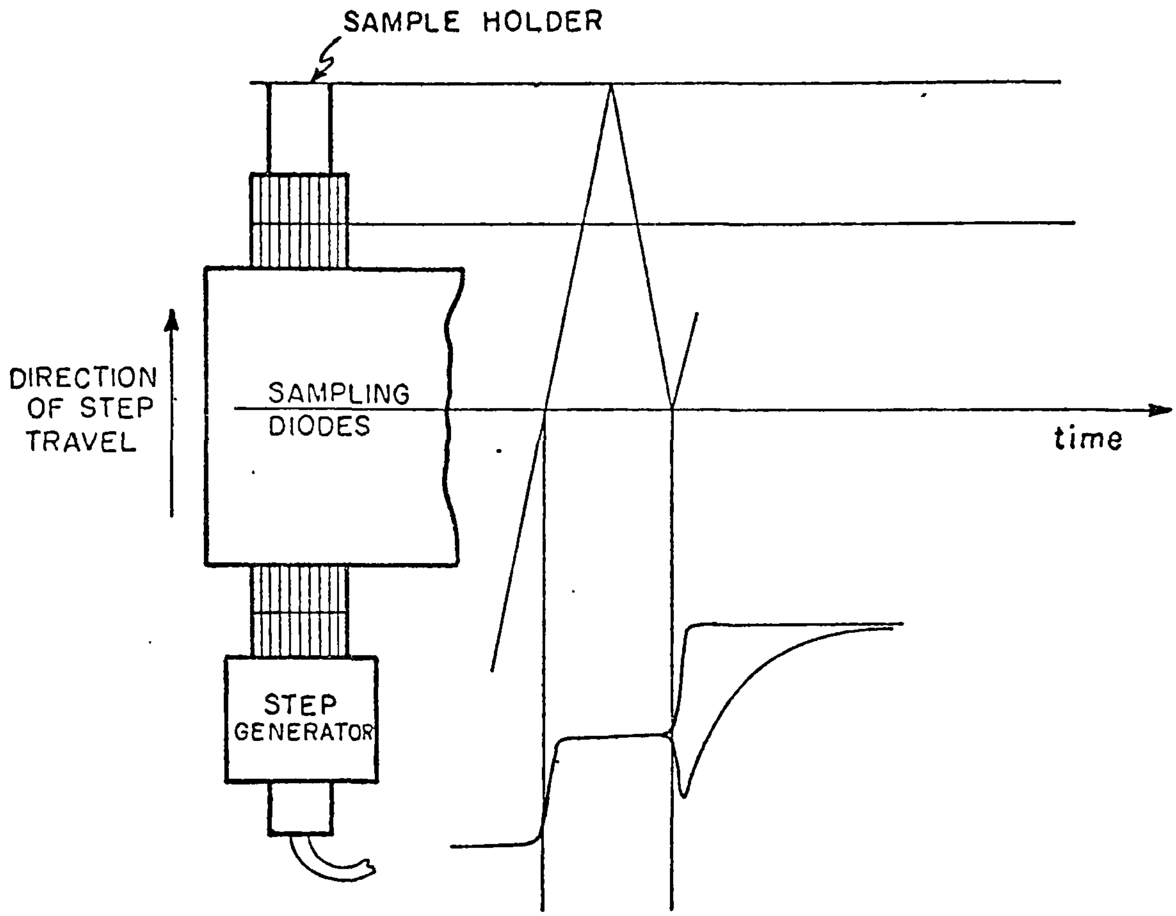
This diagram shows a HP time domain reflectometer system interfaced to an Intel MDS 800 microcomputer via an A/D converter. Data is acquired by the MDS 800 from the TDR through the A/D converter. All processing, output, and operator interface is performed by the microcomputer.

Figure 3: TDS Hardware block diagram

procedure starts over again to maintain a visible display on the screen. Each time the sampler repeats the event, it does so by sending a signal to the 1817A remote sampling head, which in turn triggers the HP 1106A tunnel diode step generator. The step propagates along the transmission line as shown in Fig. 4 and passes through the sample head. The step continues on along the transmission line toward the sample holder, where a small portion of the signal is absorbed. The rest of the signal is reflected back along the same line to where this reflected response again crosses the sampling diodes. In this manner, the sampler has access to both the stimulus and response portions of the characteristic. The secondary reflections caused by the sampling diodes and the output connector of the remote sampling head assembly are discussed in a later section.

The sampled signals which appear on the screen are digitized by an A/D converter and are fed to the microcomputer as two 8-bit inputs (IN1, and IN2). Consideration of the data format and timing signal scheme is given in the next chapter.

The microcomputer must use these signals to acquire the appropriate data, and then perform the rest of the functions necessary to complete the experimental procedure. The partitioning of these functions and their descriptions also appear in chapter 5. A line printer is the output facility for the processed data and a console (keyboard/CRT display) is used for the operator-system interface. A dual floppy



This space-time representation of the signal propagation in the transmission line illustrates both the stimulus and the reflected response portions of the signal from the point of view of the sampler.

Figure 4: Signal propagation in sampling assembly

disk drive is used only to load the operating system program into the microcomputer memory.

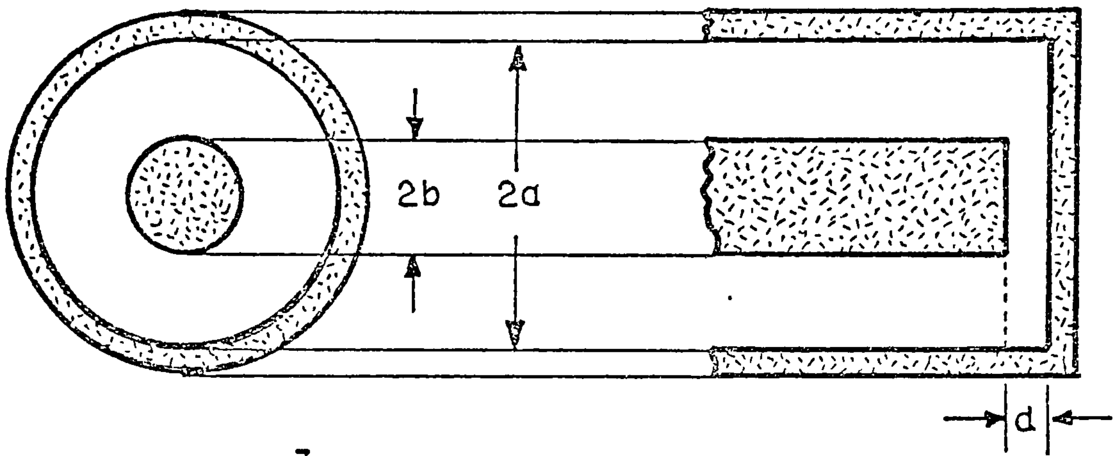
4.2 HARDWARE MODIFICATIONS

A second cursor is of course used together with the existing one to define the time window during which the measurement is to be taken. Since the original cursor shifts the display one way as it shifts the reference point in the other direction, · it should be used to define the leftmost point in the window only. The second (added) cursor can therefore be used to set the reference points and the right most point in the window without disturbing the characteristic. This modification was made using high input impedance components to minimize loading of the already delicately tuned system.

The A/D converter used (Analog Devices ADC-12QM) has a 12 bit BCD output (digits from 000 to 999) and is the successive approximation type. The maximum conversion time is 25 μs.

The sample holder is more of an addition than a modification to the system, but it is a hardware component and therefore its description is best suited to the context of this section. The mechanical characteristics of the sample holder are as shown in Fig. 5.

Recall from chapter 3 that two constants were required in (3.5), and (3.6). These are the characteristic impedance of the transmission line and sample holder, which is known to be 50 ohms, and the free space capacitance of the sample holder. From the dimensions given in Fig. 5, it is possible to calculate the capacitance C_o directly using a formula [9] which accounts for both the parallel plate capacitance and



$2a = 6.998 \times 10^{-3}$ m

$2b = 3.043 \times 10^{-3}$ m

$d = 0.269 \quad 10^{-3}$ m

The sample holder is a coaxial transmission line with the center conductor recessed slightly from a closed end thus creating a capacitance.

Figure 5: Sample holder mechanical dimensions

the fringing capacitance. This method, along with two other methods herein described, has been carried out and all were found to be in good agreement.

4.2.1 Calculation of C_T from mechanical dimensions

The calculation of the capacitance of the sample holder from its dimensions is a straight forward application of some formulae found in [9]. The dimensions shown in Fig. 5 were measured using a micrometer.

From Marcuvitz [9]:

$$\frac{B}{Y_o} = \frac{4b}{\lambda} \ln\left(\frac{a}{b}\right) \left[\frac{\pi b}{4d} + \ln \frac{a-b}{d}\right]$$

Since:

$$jB = j\omega C_T \text{ and } Y_O = \frac{1}{Z_O} = \frac{1}{60\ \ln(\frac{a}{b})}$$

and:
$$\omega\lambda = 2\pi f\lambda = 2\pi\nu$$

where
$$\nu = 2.9979 \times 10^8 \text{ m/s}$$

Substitution and simplification yields:

$$C_T = \frac{b}{30\pi\nu}\left[\frac{\pi b}{4d} + \ln\frac{a-b}{d}\right] = 0.347 \text{ pF}$$

This then is a theoretical value of the capacitance of the sample holder accounting for both parallel plate and fringing capacitance.

4.2.2 Measurement of C_T using resonant cavity

The resonant circuit technique [10] consists basically of measuring a resonant frequency (f_O) of a given resonator, then adding the capacitance of the sample holder at the end of the resonator and measuring a new resonant frequency (f_C). With a few modifications to (4.2), the phase change (ϕ) due to the additional capacitance of the sample holder can be computed. The phase change (ϕ), and the resonant frequency of the resonator with the sample holder (f_C) is substituted into (4.4) to calculate the capacitance of the sample holder.

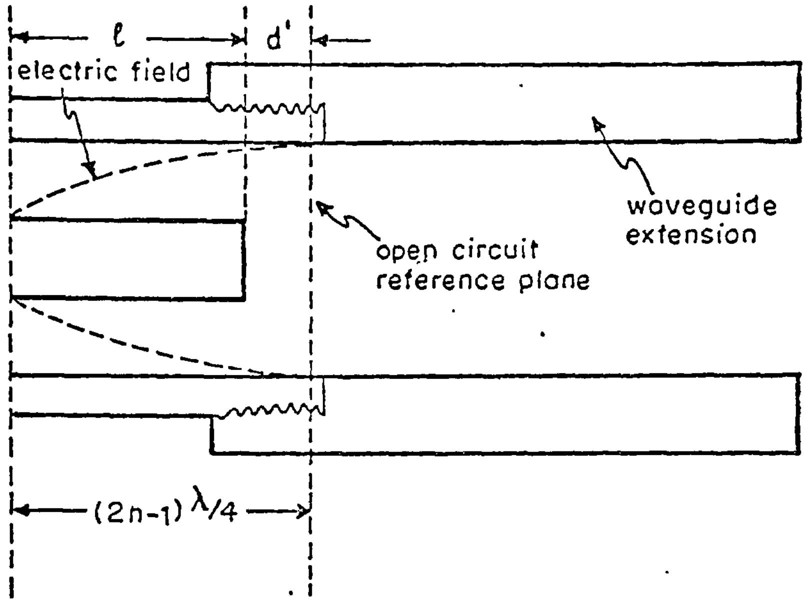
Before this technique can be applied however, it is necessary to account for different reference planes. If the sample holder could be accurately short circuited then the equations could be applied directly. This not being the case, it was decided to open circuit the sample holder by extending the outer conductor with a cut-off waveguide. The waveguide extension, however, shifts the open circuit reference plane away from the inner conductor and towards the open end of the wave guide by a distance d', as shown in Fig. 6.

From reference [8], the displacement d' can be found using:

$$d' = R(R_b - R_a) \qquad (4.1)$$

where R_b is the inner radius of the outer conductor, and R_a is the outer radius of the inner conductor, and R is as defined in [8]. From a table given in the same reference, R was obtained for a few values of Rb/λ, where λ is the wavelength corresponding to the resonant frequency of the system. It was found that over the frequency range of interest in this work, R is practically constant at a dimensionless value of 0.6034 for a 50 ohm line. Substituting in (4.1) yields a displacement of :

$$d' = 1.193 \times 10^{-3} \text{ m}$$



$$\ell + d' = (2n-1)\lambda/4 = \frac{(2n-1)\upsilon}{4f_o} \quad , \quad \ell = \frac{(2n-1)\upsilon}{4f_o} - d'$$

The waveguide extension is used to minimize the fringing effect between the inner conductor and the face of the outer conductor, thus creating an effective open circuit.

Figure 6: Open circuited wave guide extension

Since the sample holder is open circuited, it should resonate at odd integer multiples of $\lambda/4$. That is to say that the electric field should be a maximum at the open circuit reference plane as shown in Fig. 6.

Substituting ℓ in:

$$\phi = 2\,\frac{2\pi f_c}{\nu}\,\ell - (2n-1)\pi \qquad (4.2)$$

yields:

$$\phi = -(2n-1)\,\pi\,(1-\frac{f_c}{f_o}) - \frac{4\pi f_c d'}{\nu} \tag{4.3}$$

where f_o = open circuit resonant frequency

and f_c = empty sample holder resonant frequency

C_T can be obtained from:

$$C_T\ (pF) = \frac{10}{\pi f_c\,(GHz)}\ \tan\left|\frac{\phi}{2}\right| \tag{4.4}$$

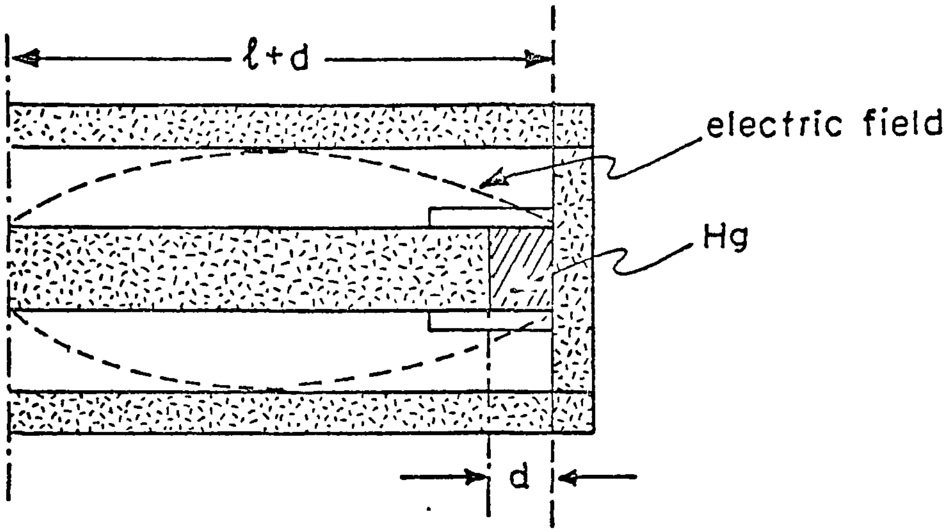
The results of measurements of f_c and f_o for n=2,3,4 and calculation of ϕ and C_T appear in Table 2.

TABLE 2

Results of open circuit resonance measurement

n	f_c (GHz)	f_o (GHz)	ϕ (Rad)	C_T (pF)
2	1.52145	1.56081	-.3138	0.331
3	2.54177	2.60638	-.5165	0.331
4	3.55470	3.64336	-.7129	0.333

As a check, it was decided to measure C_T for the sample holder short circuited (mercury sample) at the end of the sample cavity (Fig. 7). Note that this does not give coincident reference planes, nor is the short circuit completely trustworthy. This was merely intended as a check of the above measurements.



A mercury sample was used to short circuit the sample holder.

Figure 7: Short circuit reference plane displacement

d is known to be 0.269×10^{-3} m

$$\ell + d = \frac{n\lambda}{2} \text{ (short circuit)}$$

$$\ell = \frac{n\nu}{2f_o} - d$$

substitution of ℓ in (4.2) yeilds:

$$\phi = -2n\pi\left(1-\frac{f_c}{f_o}\right) + \pi - \frac{4\pi f_c d}{\nu} \qquad (4.5)$$

Equation (4.4) can still be used to calculate C_T from ϕ. Note that only f_O had to be remeasured since all of the values of f_C should remain the same.

The results for this are summarized in Table 3, and can be seen to agree quite well with the open circuit values for C_T.

The capacitance due to fringing is known to be greater for an ideally sharp edge on the central conductor of the sample holder. One would therefore expect the measured values of capacitance to be less than the value calculated in section 4.2.1, simply because in practice the edges are slightly rounded off. Out of the two measured values for the capacitance, the open circuit results are more reliable. Therefore, for the frequency range of 25 MHz to 2 GHz, a value for the free space capacitance of the sample holder of 0.331 pF has been used.

TABLE 3

Results of short circuit resonance measurement

n	f_C (GHz)	f_O (GHz)	ϕ (Rad)	C_T (pF)
2	1.52145	2.09331	-.3085	0.325
3	2.54177	3.14564	-.5056	0.324

4.2.3 Linear phase increment compensation

When the stimulus measurement is being taken, what is actually being recorded is the stimulus reflected from an open circuit, for reasons discussed in section 4.3. Recall that due to fringing capacitance effects, it is advisable to extend the outer conductor as a cut-off waveguide, thereby acheiving a better open circuit, and thus a more accurate representation of the stimulus characteristic. Recall also that this waveguide extension shifts the open circuit reference plane, thereby adding a time delay to the stimulus which results in an incremental phase error in the frequency domain stimulus characteristic.

The relationship between a delayed time domain signal and its frequency domain characteristic can be expressed as :

$$f(t-t_o) \xrightarrow{\mathcal{F}} e^{-j\omega t_o} F(\omega)$$

The corresponding incremental phase error is :

$$\Delta\phi_i = \omega t_o = 2\pi \Delta f_i t_o$$

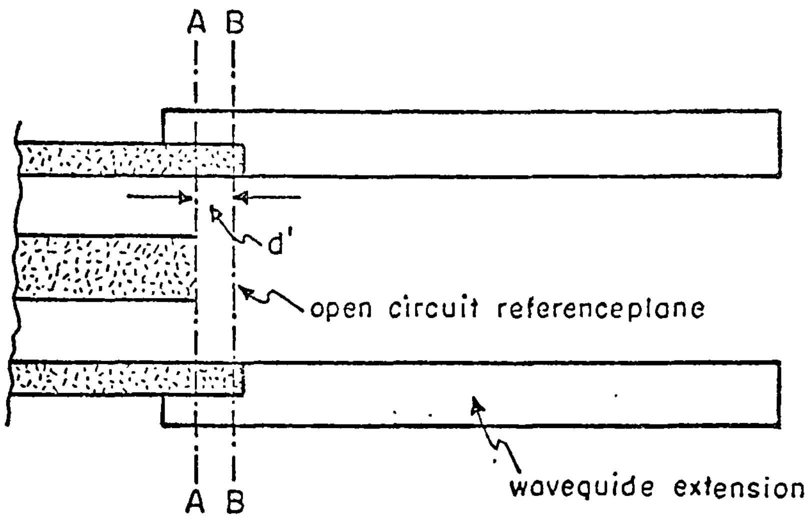
Therefore when evaluating the Fourier transtorm of the stimulus characteristic (sample holder with the open circuited waveguide) the time delay due to the shifted open circuit reference plane will have to be accounted for as follows :

$$\phi_{A-A}(f_i) = \phi_{B-B}(f_i) - \Delta\phi_i$$

where:

$$t_o = \frac{2d'}{v}$$

and: $\Delta f_i = f_i - f_{i-1}$ (discrete frequency increment)



The open circuit reference plane is shifted by the waveguide extension of the outer conductor towards the open end of the line. This causes an additional time delay for the response of an open circuit (reflected stimulus) which should be accounted for in the phase calculations.

Figure 8: Open circuit reference plane

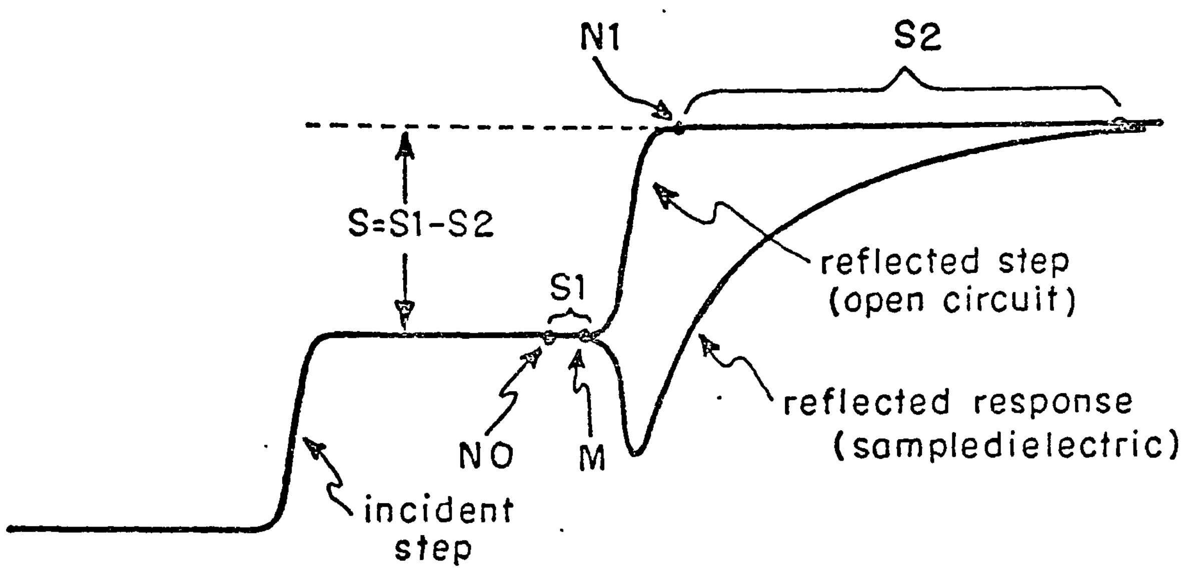
The 2d in the numerator accounts for the time delay for the incident signal and the time delay for the reflected signal. Figure 8 illustrates the relationship between $\phi_{A\text{-}A}$ and $\phi_{B\text{-}B}$. From Fig. 8 it can easily be seen that the first $\Delta\phi_i$ will be proportional to the first f_i since $f_{i-1}=0$. Each subsequent $\Delta\phi_i$ will be proportional to the frequency increment Δf_i.

So that the open circuit phase compensation algorithm will be compatible for any phase increment, it must remember the previous frequency point, and, knowing the present frequency point, compute Δf. For the first frequency point in the characteristic, the previous frequency point must be zero so that $\Delta f_i = f_i$ for the first point.

4.3 EXPERIMENTAL PROCEDURE

Recall from the first chapter,that the objective of the measurement is to obtain the dielectric permittivity from time domain measurements. In chapter 3, it was noted that at least two time domain characteristics are required, as well as Z_O which is known, and C_O which has been considered in this chapter.

The first set of data is the stimulus characteristic or incident step. Along with this data set, two reference points must be taken for normalization purposes as shown in Fig 9. The reference points are established by setting the second cursor described in chapter 4, and signalling to the system via the keyboard to record the location of that point. The number of low level points taken should be kept small so as to minimize the incremental phase offset due to the time delayed step. This has nothing to do with the waveguide, it is a property of the Fourier transform. The number of low level points will vary depending on the time-base setting. Best results are achieved for a time-base setting of 0.2 ns/div. and M=3 or 4.



The response to an open circuited sample holder is taken to be the stimulus. The response to a dielectric sample illustrates the capacitive nature of the sample holder. i.e. The response shows a temporarily low impedance followed by an exponential charging of the capacitance. The reference points are designated as: NO for the first point in the time window, M for the last low level point, N1 for the first high level point, and NP for the last point.

Figure 9: Typical stimulus and response curves

Note that since the stimulus portion of the waveform need not be taken so frequently, it is possible to use the response to an empty, open circuited sample holder as the stimulus. This is illustrated as the reflected step portion of the curve shown in Fig. 9. The only extra consideration involves compensation for the phase shift due to the waveguide as discussed in the previous section. Since precision APC-7 air coaxial lines are being used, attenuation of the stimulus is negligible. The advantages of using the reflected stimulus are :

1. No additional reference points required for each response if the same time base is used and the cursors are not moved.

2. No complicated start pointer finding algorithm is required for the Fourier transform [5].

3. Minimal phase error in reflection coefficient since stimulus and responses are from the exact same time window.

4. No redundant data is acquired.

5. Simplification of the operators task.

6. Any perturbations in the stimulus also show up in the response.

The second data set is the response characteristic. The sample is placed in the holder and a keyboard signal initiates response data acquisition. No reference points are entered, the cursors are not moved. The response characteristic is normalized using information from the first data set (S,S1) and the Fourier transtorm for the same frequency points as for the stimulus is tabulated, plotted, and stored.

The frequency domain representations of the normalized response and stimulus are then used to determine the reflection coefficient as a function of frequency. The dielectric constant and loss factor, also as functions of frequency, are tabulated and plotted and a plot of loss factor versus dielectric constant is also included.

At this point, one sample or network has been as completely processed as this TDS has been programmed to do. Now a second measurement can be made, but this time, the overhead of taking reference points and the measurement of the stimulus are not necessary, if one can assume negligible change of these quantities within the time period in question. (ie. within the time required to process one stimulus and one response). The operator can now make this decision and, if it is decided not to repeat the entire procedure, only the response characteristics of subsequent measurements need be acquired. The same output as before will be given for each new response acquired.

After some time, the operator may decide that a fresh set of reference points and stimulus are required, and may then go back and obtain that information and continue as described before.

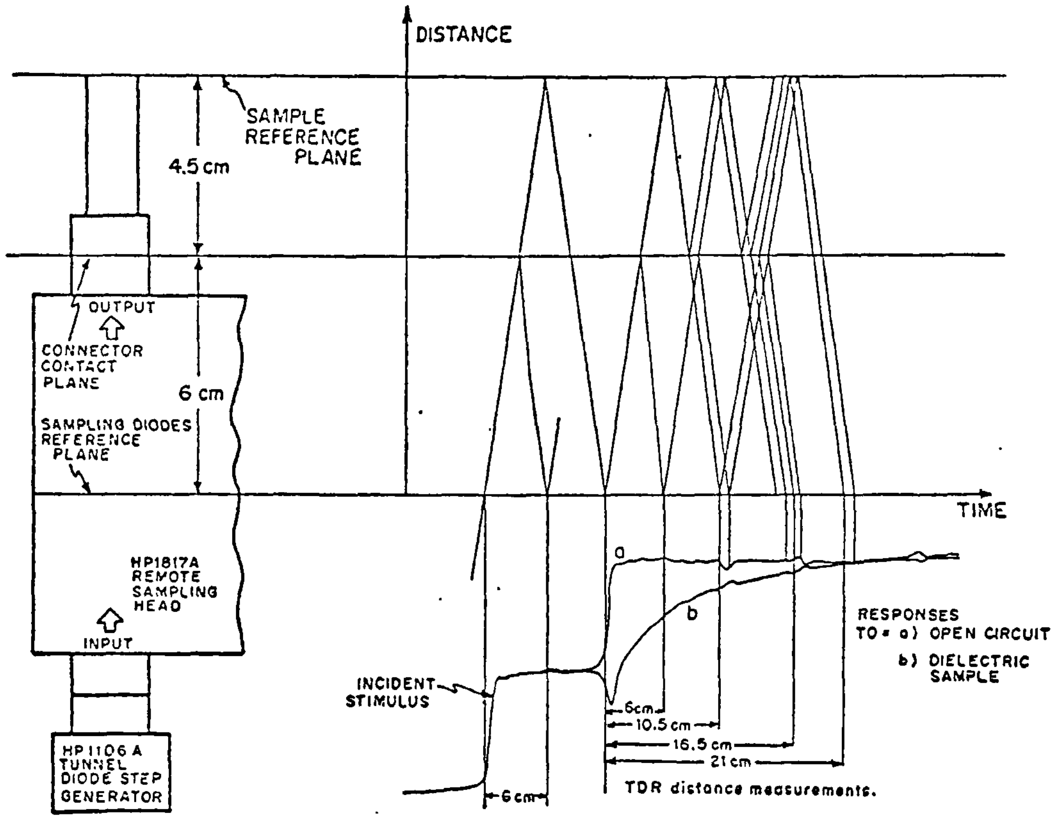
4.4 LIMITATIONS OF EXISTING HARDWARE

The most salient limitations of the TDS hardware are the time and amplitude jitter. When used in the TDR mode (as opposed to the CW mode), the time jitter at the leading edge of the step should be less than 15 ps. (1815B operating and service manual, sect. 5-17). For a 1.8 ns time window with 105 points, which is the minimum number of points possible for 9 divisions at 0.2 ns/div., the 15 ps time jitter is less than the sampling period. (0.875 x sampling period). This jitter, combined with cursor instability, may cause the loss of one point at the beginning of the time window. These are compensated for during data acquisition with signal averaging and alignment, as is described in the next chapter.

Another fairly evident hardware problem is related to unwanted reflections caused by impedance mismatches in the remote sampling head, tunnel diode and sample holder subsystem. This effect stems partially from the connectors and also from the sampling diodes themselves. It is extremely difficult to eliminate or even minimize this undesirable characteristic, therefore the simplest solution seems to be to try and compensate for it. The effects of these perturbations are most noticeable when a time window is used for the response which is different from that used by the stimulus. In this case the perturbation may be shifted in time and cause a phase error, or it might not be present at all in one of the data sets, thereby causing it to seem as though it were a characteristic of the sample. Even when maintaining exactly the same time window for the stimulus as for the response, the capacitive nature of the sample holder may still cause a slight time shift of the perturbations in the response data set.

An analysis of the reflections present in this system is shown in Fig. 10. In this diagram, the space-time relationship of the reflections illustrates the sampling diodes and output connector of the remote sampling head as the principle causes of the aberrations. Even in some Hewlett Packard literature, photographs of the display showed the inevitable sampling diode reflection. In an attempt to reduce the reflection at the connector, the element of the connector was replaced, but the reflection persists.

Other weaknesses include trigger pulse feed through. A video coaxial cable from the sampling head to the back of the tunnel diode step generator (HP 1106A) supplies a d.c. bias for the tunnel diode as well as a trigger pulse to initiate step generation. The problem occurs when the trigger pulse propagates through the tunnel diode network, thus distorting the generated step. A solution was



This diagram illustrates the perturbations in the time domain characteristics as being caused by multiple reflections between the sampling diodes and the output connector of the remote sampling head. These secondary reflections rapidly become complicated as they are damped out, thus only the first few reflections are useful for determining the locations of the discontinuities.

Figure 10: Space-time reflection analysis

suggested by Andrews [11], which involved triggering of the tunnel diode assembly from its output port through a directional coupler. The output impedance of the HP 1106A should be well enough matched so that any reflection would be considerably smaller than the feed through trigger pulse. The HP 1106A still had to be biased from the other port as before unless an external bias supply such as is described in [12] is used.

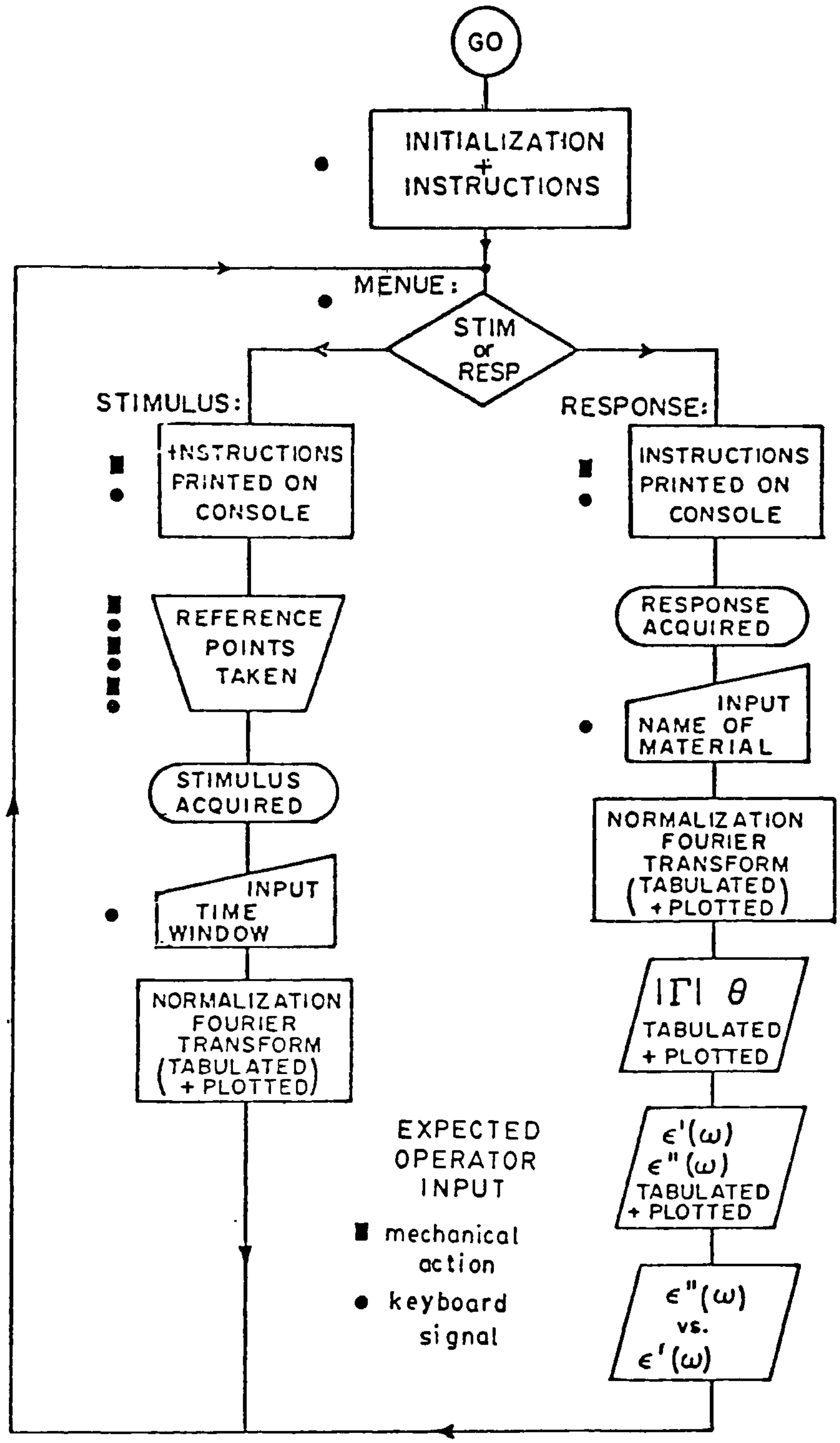
Chapter V

TDS SOFTWARE

As in chapter 2, the software is discussed in this chapter under three basic headings. These are human interface, data acquisition, and data processing respectively. A fourth category, data output, is recognized here, although the software used to carry out this function is also imbedded in the human interface and data processing blocks.

The main purpose of this chapter is to provide an aid for the continuation of this work. For this reason, the flowcharts and program listings in the appendices will no doubt have to be referred to extensively in order to derive a complete understanding of some of the details.

As an aid to the understanding of the contents of this chapter, a flowchart illustrating the overall software structure is given in Fig. 11. This figure closely parallels the description of the experimental procedure given in section 4.3. Also shown in the flowchart are the points in the procedure at which the system expects operator interaction. This operator input to the system falls under two categories. The first category consists of inputs by the operator which are expected by the system at specific points throughout the procedure. Such inputs include selection of branch (STIMULUS or RESPONSE), reference point



The points at which the system expects operator interaction are illustrated as shown. Mechanical action includes such functions as setting the timebase, installing the sample, etc.. Keyboard signals select from options presented by the system and confirm completion of mechanical actions.

Figure 11: Software implementation of the measurement procedure

entry, time window input, name of material input, etc.. The second category of operator interaction is unexpected input. As of this writing, the only input under this classification is the interrupt driven abort command which is described in this chapter.

Upon commencement of execution, the program described in Fig. 11 initializes interrupt handling routines and storage buffer pointers. The system then prompts the operator to opt for or skip the introductory instructions. The operator is then asked to select either the STIMULUS or RESPONSE branch of the procedure. Since some of the computations in the RESPONSE branch require results from the STIMULUS branch, the system will not allow the RESPONSE part of the procedure to be taken until the STIMULUS branch has been successfully completed at least once.

Once the STIMULUS branch has been selected, instructions appear on the console requesting the operator to install the open circuit waveguide, set up the time window and cursors to select the first reference point M. This is followed by instructions for the acquisition of a second reference point M1, and then automatic acquisition of the entire time window containing the stimulus characteristic. The system then prompts the operator to enter the time window in floating point decimal. The normalization and Fourier transform of the stimulus is then carried out and the results are output for each frequency point of interest as it becomes available (see Fig. 12 : Fourier transform of the stimulus, as an example).

Control is then returned to MENU where the operator is again asked which branch should be executed next. If for some reason the stimulus is unsatisfactory (eg. cursor was moved during acquisition, etc.), it may be retaken. If all is well, then the RESPONSE branch may be executed. As before, instructions appear on the screen requesting the operator to insert the sample in the sample holder. The response characteristic is then automatically acquired and the operator is asked to input the name of the test material for later identification of the output. From this point on, the system automatically computes and outputs the Fourier transform of the response characteristic, the magnitude and phase of the reflection coefficient, ε' and ε'' as well as ε'' versus ε', all as functions of frequency. Refer to Figs. 13,14,15, and 16 respectively for samples of these outputs.

Control is again returned to MENU and another response may now be processed using the same stimulus data, as discussed in section 4.3.

5.1 <u>OPERATOR INTERFACE</u>

This block must instruct the human operator in a step by step fashion through the entire measurement procedure. It must also receive signals from the operator telling the system that a certain external action has been performed, as well as which phase of the measurement procedure is to be

The following five figures (Figs. 12 to 16 inclusive) represent a typical set of output listings for one complete measurement. They represent the Fourier transform of the stimulus characteristic, the Fourier transform of the response characteristic, the reflection coefficient (gamma), the complex permittivity (epsilon), and ε'' versus ε', respectively.

In each of Figs. 12, 13, and 14, the three columns of data represent magnitude, phase, and frequency, respectively. The corresponding graphs are plots of the magnitude and phase (denoted as * and +, respectively) with respect to frequency in Hz. The frequency axis begins at the top left hand side of the graph at 25 MHz and increases from top to bottom in 25 MHz increments until it reaches 1 GHz, after which the increments are 50 MHz until the interval of interest terminates at 2 GHz. The magnitude (*) is scaled between 0 at the extreme left hand side of the graph (frequency axis), and the maximum value attained in that frequency interval at the extreme right hand side of the graph. Thus the actual magnitude at each frequency increment can be read from the magnitude column and the shape of the magnitude as a function of frequency, normalized to full scale over the frequency interval of interest, can be observed from the graph. The phase plot (+) is scaled between -180 degrees at the extreme left hand side of the graph, and +180 degrees at the extreme right hand side of the graph. As before, the actual phase (in degrees) at each frequency increment can be read from the phase column.

In Fig. 15, the first two columns represent ε' and ε'' denoted * and + respeectively on the graph. Both of these functions of frequency have been expanded to full scale on the graph. (ie. graph pt. = $(\varepsilon - \varepsilon_{min})/(\varepsilon_{max} - \varepsilon_{min})$). The frequency increments in the third column and the frequency axis are as in Figs. 12, 13, and 14.

Figure 16 shows a graph of ε'' (scaled minimum to maximum from left to right) versus ε' (scaled maximum to minimum from top to bottom).

Figure 12: 48

FOURIER TRANSFORM [illegible] TIME [illegible]

MAG(+)	PHASE(+)	FREQ
+5 2527 E-09	-2 [illegible]55 E+01	+2 5000 E+07
+2 1279 E-09	-5 [illegible] E+01	+5 [illegible] E-07
+1 0541 E-09	-2 6547 E+01	+7 5000 E-07
+1 5656 E-09	-1 5275 E+01	+1 00[illegible] E-0[illegible]
+1 2551 E-09	-1 4155 E+01	-1 [illegible] E-0[illegible]
+1 0495 E-09	-9 [illegible] E+01	+1 5000 E-0[illegible]
+9 0145 E-10	-1 1745 E+01	+1 7500 E-0[illegible]
+7 9131 E-10	-9 0455 E-01	+2 0000 E-0[illegible]
+7 0553 E-10	-7 9155 E-01	+2 2500 E-0[illegible]
+6 [illegible]752 E-10	-7 [illegible] E+01	+2 5000 E-0[illegible]
+5 5165 E-10	-7 6455 E+01	+2 7500 E-0[illegible]
+5 1535 E-10	-7 5051 E+01	+3 0000 E-0[illegible]
+4 9555 E-10	-7 [illegible] E+01	-3 2500 E-0[illegible]
-4 [illegible]155 E-10	-7 [illegible]145 E+01	-3 5000 E-0[illegible]
+4 [illegible] E-10	-7 0[illegible] E+01	+3 7500 E-0[illegible]
-4 0580 E-10	-6 8105 E+01	+4 0000 E-0[illegible]
+3 5151 E-10	-6 [illegible]541 E+01	+4 2500 E-0[illegible]
+3 6159 E-10	-6 5455 E+01	+4 5000 E+0[illegible]
+3 4263 E-10	-6 4[illegible] E+01	+4 7500 E-0[illegible]
+3 2527 E-10	-6 2792 E+01	+5 0000 E+02
+3 0935 E-10	-6 1131 E+01	+5 2500 E-0[illegible]
+2 9457 E-10	-5 9514 E+01	+5 5000 E-0[illegible]
+2 9095 E-10	-5 9055 E+01	+5 7500 E+02
+2 6571 E-10	-5 6525 E+01	-6 0000 E+02
+2 5250 E-10	-5 5035 E-01	+6 2500 E-0[illegible]
+2 4547 E-10	-5 [illegible] E-01	+6 5000 E+02
+2 2517 E-10	-5 2191 E+01	-6 7500 E+02
+2 2559 E-10	-5 0259 E+01	+7 0000 E+0[illegible]
-2 1[illegible] E-10	-4 9502 E-01	-7 2500 E-0[illegible]
+2 09[illegible] E-10	-4 [illegible]	[illegible]
-2 0071 E-10	-4 [illegible] E-01	[illegible]
+1 [illegible] E-10	-4 [illegible] E+01	-8 0000 E-0[illegible]
-1 [illegible] E-10	-4 [illegible] E-01	+8 [illegible] E-0[illegible]
-1 [illegible] E-10	-4 [illegible] E+01	-8 [illegible] E-0[illegible]
-1 7[illegible] E-10	-4 [illegible] E-01	-8 [illegible] E-0[illegible]
+1 7[illegible] E-10	-4 1[illegible] E-01	-9 [illegible] E-0[illegible]
[illegible] E-10	-4 1[illegible] E-01	-9 [illegible] E-0[illegible]
+1 [illegible] E-10	-3 9[illegible] E-01	+9 [illegible] E-0[illegible]
+1 5901 E-10	-3 [illegible] E+01	-9 7500 E-0[illegible]
+1 5551 E-10	-3 7[illegible] E-01	+1 0000 E-0[illegible]
+1 [illegible] E-10	-3 [illegible] E-01	-1 [illegible] E-0[illegible]
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+1 [illegible] E-10	-3 [illegible]10 E-01	+1 [illegible] E-0[illegible]
+1 [illegible] E-10	-1 [illegible] E-01	-1 [illegible] E-0[illegible]
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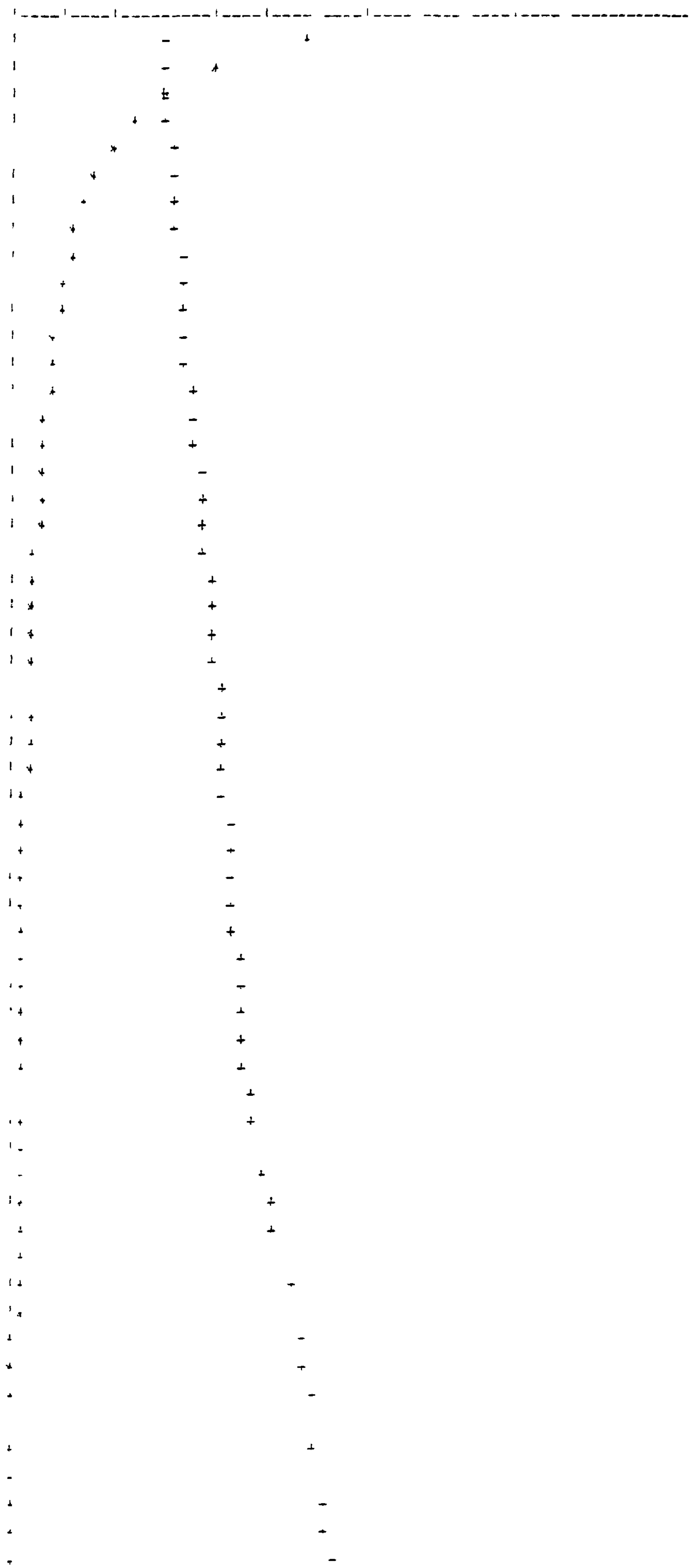
-1 [illegible] E-10	-1 [illegible] E-01	-1 [illegible] E-0[illegible]
-1 [illegible] E-11	-[illegible] E-0[illegible]	-1 [illegible] E-0[illegible]
-1 [illegible] E-10	-[illegible] E-0[illegible]	+1 [illegible] E-0[illegible]
+9 [illegible]11 E-11	-[illegible] E-0[illegible]	+1 [illegible] E+0[illegible]
-9 [illegible] E-11	-[illegible] E-0[illegible]	-1 [illegible] E-0[illegible]
-9 [illegible] E-11	-[illegible] E-0[illegible]	+1 [illegible] E-0[illegible]
-9 [illegible] E-11	-2 [illegible] E-0[illegible]	-1 [illegible] E-0[illegible]
-9 [illegible] E-11	-2 [illegible] E-0[illegible]	+1 [illegible] E-0[illegible]
-8 0[illegible] E-11	-2 1045 E-0[illegible]	+1 [illegible] E-0[illegible]
-7 [illegible] E-11	-1 2041 E-01	-1 [illegible] E-0[illegible]
-7 [illegible] E-11	-1 [illegible] E-01	-1 [illegible] E-0[illegible]



MAG(+)	PHASE(+)	FREQ
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[illegible]	[illegible]	[illegible]
+2 0451 E-0?	[illegible]	[illegible]
+1 51?? E-0?	[illegible]	[illegible]
+1 2001 E-0?	[illegible]	+1 2500 E-0?
+9 9517 E-10	-? 2111 E-01	+1 5000 E+0?
+8 2971 E-10	-5 [illegible] E-01	+1 7500 E+0?
+7 1161 E-10	-5 [illegible]	+2 0000 E+0?
+6 1??? E-10	-4 [illegible] E-01	+2 2500 E+0?
+5 4710 E-10	-4 1451 E+01	+2 5000 E-0?
-4 [illegible] E-10	-3 7125 E+01	+2 7500 E+0?
+4 [illegible] E-10	-3 ?101 E+01	+3 0000 E+0?
[illegible] E-10	[illegible] E+01	[illegible]
+? 4493 E-10	-? 5?54 E-01	-? 5000 E-0?
[illegible]	[illegible]	[illegible]
+? 9?6? E-10	-1 ?146 E+01	+4 0000 E+0?
[illegible] E-10	-1 5945 E-01	-4 2500 E+0?
+2 ?511 E-10	-1 1053 E-01	-4 5000 E+0?
+? 1571 E-10	[illegible] E-00	-4 7500 E+0?
+1 3976 E-10	[illegible] E+00	-5 0000 E-0?
+1 [illegible] E-10	[illegible] E+03	[illegible]
+1 7140 E-10	-? 1715 E-0?	+5 5000 E+0?
+1 5990 E-10	+0 0032 E+00	+5 7500 E+0?
+1 5005 E-10	+1 9217 E-0?	+? 0000 E+0?
+1 41?? E-10	[illegible] E-00	[illegible]
+1 [illegible] E-10	[illegible] E+0?	-? 5000 E-0?
+1 [illegible]	[illegible]	[illegible]
+1 2?04 E-10	+? 5711 E-00	+7 0000 E-0?
+1 1301 E-10	-1 15?? E+01	[illegible] E+0?
+1 1171 E-10	[illegible] E-04	[illegible]
[illegible]	[illegible]	[illegible]
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+1 [illegible] E-1?	[illegible]	[illegible]
+? [illegible] E-11	[illegible]	[illegible]
+5 [illegible] E-11	[illegible] E-01	[illegible]
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[illegible]	[illegible]	[illegible]
+? [illegible] E-11	[illegible] E-01	[illegible]
+? 5??1 E-11	-? [illegible] E+01	+? 7500 E-0?
-? ?071 E-11	[illegible] E-01	-1 0000 E-0?
+7 [illegible] E-11	[illegible]	[illegible]
[illegible] E-11	[illegible]	[illegible]
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[illegible] E-11	[illegible]	[illegible]
-4 [illegible] E-11	[illegible] E-01	[illegible]
-4 [illegible] E-11	[illegible] E-01	[illegible]
-4 [illegible] E-11	[illegible] E-01	[illegible]
[illegible] E-11	[illegible]	[illegible]
[illegible] E-11	[illegible]	[illegible]
+? [illegible] E-11	[illegible]	[illegible]
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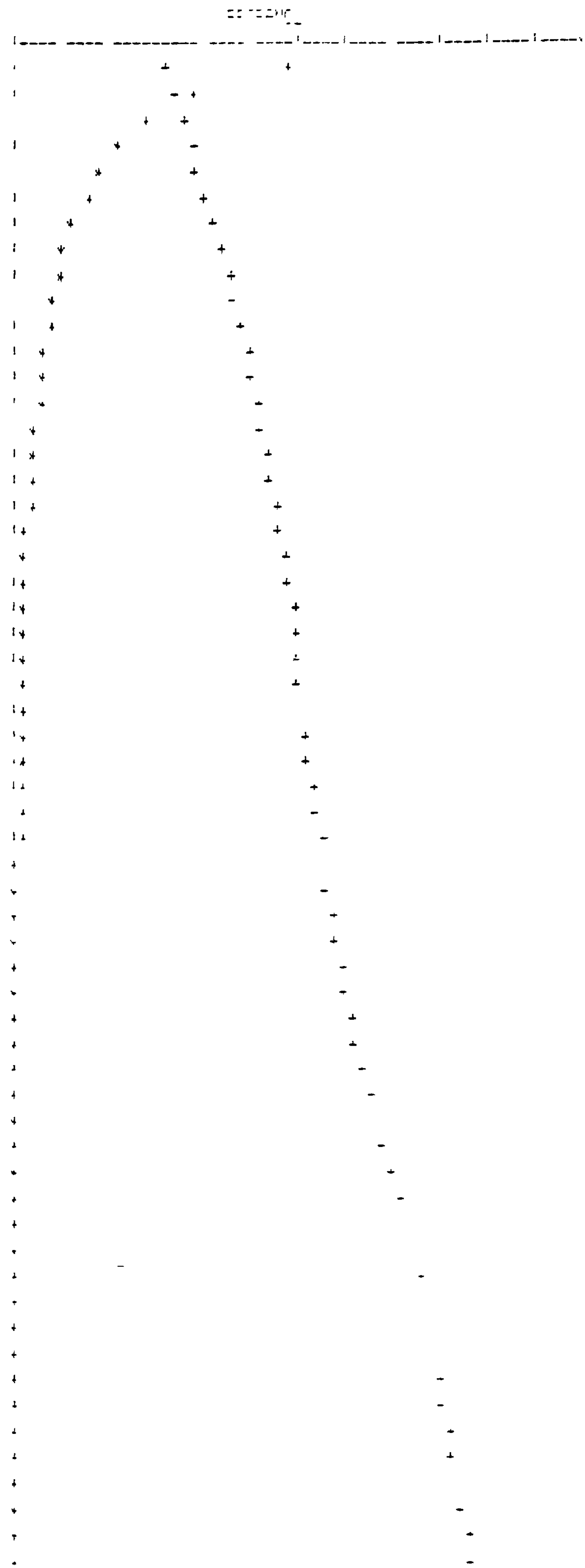

FOURIER TRANSFORM

MAG(*)	PHASE(+)	FREQ
+9 9424 E-01	+2 3115 E-00	-1 [illegible] E+07
+9 9975 E-01	+7 9057 E+00	+5 [illegible] E+07
+9 8129 E-01	+1 1565 E+01	-7 5000 E+07
+9 7116 E-01	+1 5477 E+01	+1 [illegible] E+3[illegible]
+9 5515 E-01	+1 9311 E+01	+1 [illegible] E+3[illegible]
+9 2950 E-01	-2 [illegible] E+01	+1 [illegible] E+3[illegible]
+9 2043 E-01	+2 [illegible] E-01	+1 7500 E+0[illegible]
+8 9926 E-01	-2 3395 E-01	+1 [illegible] E+3[illegible]
+8 7623 E-01	+2 [illegible] E-01	+2 [illegible] E+0[illegible]
+8 5190 E-01	+3 [illegible] E+01	+2 5770 E+0[illegible]
+8 2643 E-01	+3 9101 E+01	-2 [illegible] E+0[illegible]
+8 0027 E-01	+4 1953 E+01	+2 0000 E+09
+7 7380 E-01	-4 4513 E-01	+2 [illegible] E+0[illegible]
+7 4744 E-01	+4 2951 E+01	+3 [illegible] E+3[illegible]
+7 2154 E-01	+4 3375 E+01	+3 7500 E+3[illegible]
+6 9647 E-01	+5 0655 E+01	-4 [illegible] E+0[illegible]
+6 7260 E-01	+5 2439 E+01	+4 [illegible] E+0[illegible]
+6 5022 E-01	+5 3306 E+01	+4 5000 E+09
+6 2923 E-01	+5 5399 E-01	+4 7500 E+09
+6 1106 E-01	+5 6052 E+01	+5 0000 E+09
+5 9472 E-01	+5 6949 E+01	+5 [illegible] E+3[illegible]
+5 8072 E-01	+5 7491 E+01	+5 5000 E+3[illegible]
+5 6916 E-01	+5 9055 E+01	+5 7500 E+09
+5 5997 E-01	+5 9447 E+01	+6 0000 E+09
+5 5310 E-01	+5 [illegible] E+01	+6 [illegible] E+0[illegible]
+5 4944 E-01	+5 9314 E+01	+6 [illegible] E+0[illegible]
+5 4567 E-01	+5 9915 E+01	-6 [illegible] E+0[illegible]
+5 4452 E-01	+6 0478 E+01	+7 [illegible] E+3[illegible]
+5 4465 E-01	+6 1133 E-01	+7 [illegible] E+0[illegible]
+5 4527 E-01	+6 2175 E+01	+7 [illegible] E+3[illegible]
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+5 4934 E-01	-6 [illegible] E+01	-8 [illegible] E+3[illegible]
+5 5022 E-01	+6 4155 E-01	+8 [illegible] E+0[illegible]
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-4 [illegible] E-01	-8 [illegible] E-01	-1 [illegible] E+0[illegible]
+4 [illegible] E-01	+8 [illegible] E+01	-1 [illegible] E+0[illegible]
+4 4415 E-01	+8 [illegible] E-01	+1 [illegible] E+0[illegible]
-4 [illegible] E-01	-8 [illegible] E-01	+1 [illegible] E+0[illegible]
-4 [illegible] E-01	+8 [illegible] E-01	-1 [illegible] E+0[illegible]
+4 [illegible] E-01	-8 [illegible] E-01	+1 [illegible] E+0[illegible]
-4 [illegible] E-01	+8 [illegible] E-01	-1 [illegible] E+0[illegible]
+4 [illegible] E-01	+9 [illegible] E-01	-1 [illegible] E+0[illegible]
+4 [illegible] E-01	-9 [illegible] E-01	+1 [illegible] E+0[illegible]
+4 4115 E-01	-9 [illegible] E-01	-1 [illegible] E+[illegible]
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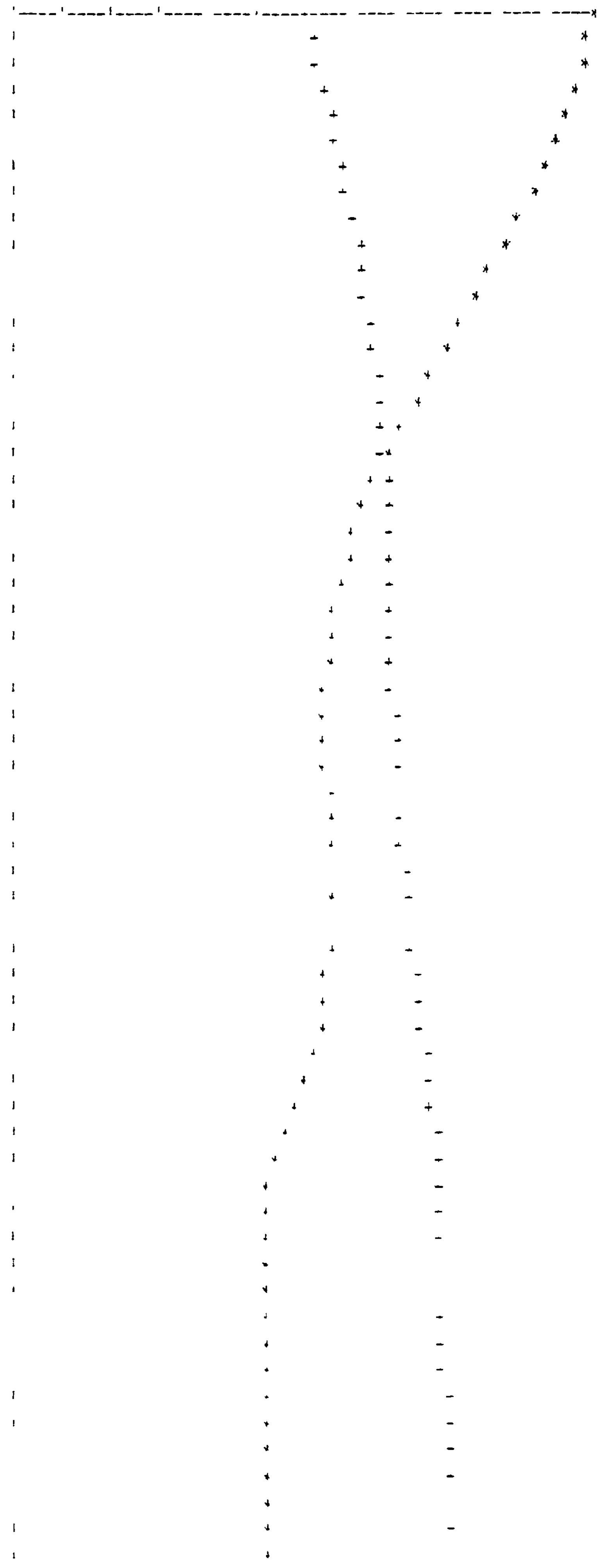
-4 [illegible] E-01	-9 [illegible] E-01	-1 [illegible] E+[illegible]
-4 [illegible] E-01	-9 [illegible] E-01	-1 [illegible] E+0[illegible]
+4 [illegible] E-01	-9 [illegible] E-01	-1 [illegible] E+[illegible]
-4 4154 E-01	+9 [illegible] E-01	+1 [illegible] E+[illegible]
-4 [illegible] E-01	+9 4141 E-01	-1 [illegible] E+[illegible]
+4 [illegible] E-01	-9 [illegible] E-01	-1 [illegible] E+[illegible]



EPSILON' (+)	[illegible] (-)	FEED
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+1 6729 E+01	[illegible]	[illegible]
+1 [illegible] E+01	[illegible]	[illegible]
+1 6254 E+01	[illegible]	+1 [illegible]
+1 6194 E+01	[illegible]	+1 [illegible] E+03
+1 6115 E+01	[illegible] E+00	+1 5030 E+02
+1 6014 E+01	+2 [illegible] E+00	+1 7500 E+02
+1 [illegible] E+01	[illegible] E+00	+1 0000 E+02
+1 [illegible] E+01	[illegible] E+00	+1 2500 E+0?
+1 5714 E+01	+4 [illegible] E+00	[illegible] E+03
+1 [illegible] E+01	-4 [illegible]	[illegible]
+1 5030 E+01	+5 [illegible] E-00	[illegible] E+03
+1 4735 E+01	+5 [illegible] E+00	[illegible] E+03
+1 4451 E+01	+5 [illegible]	[illegible] E+02
+1 407? E-01	[illegible]	[illegible] E+02
-1 [illegible] E-01	[illegible] E+00	+4 0000 E+05
+1 [illegible] E+01	+6 [illegible]	+4 2500 E-05
+1 27?? E+01	+7 0[illegible] E+00	+4 5000 E+03
+1 2288 E+01	+7 1522 E+00	+4 7500 E-03
+1 1904 E+01	+7 [illegible] E+03	+5 0000 E+09
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[illegible] E+00	+5 [illegible]	+1 [illegible] E+09
[illegible]	[illegible]	[illegible]
[illegible] E-00	[illegible] E+03	+1 1607 [illegible]
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[illegible]	[illegible]	+1 1500 [illegible]
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-5 5?10 E+[illegible]	+5 [illegible] E+03	-1 [illegible]
[illegible]	[illegible]	+1 [illegible]
[illegible]	[illegible]	-1 [illegible]
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[illegible]	[illegible]	+1 [illegible]
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+4 [illegible]	[illegible] E+0?	-1 [illegible]
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[illegible]	[illegible]	[illegible]

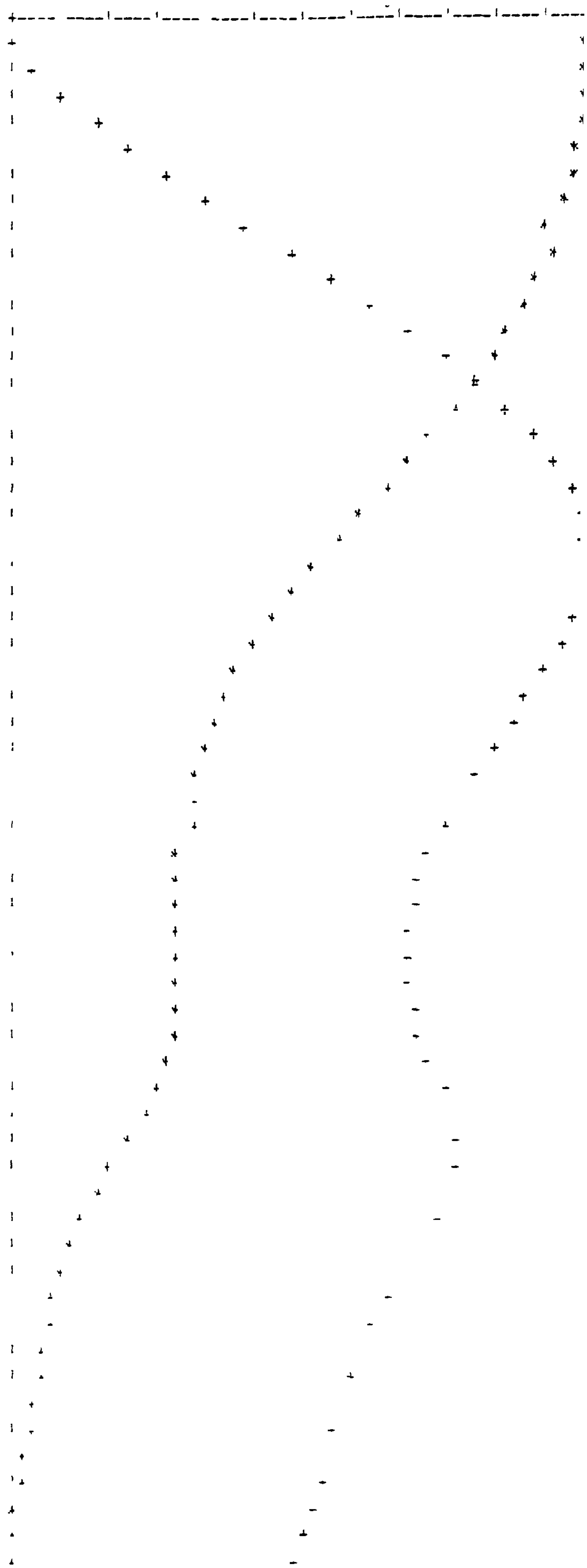
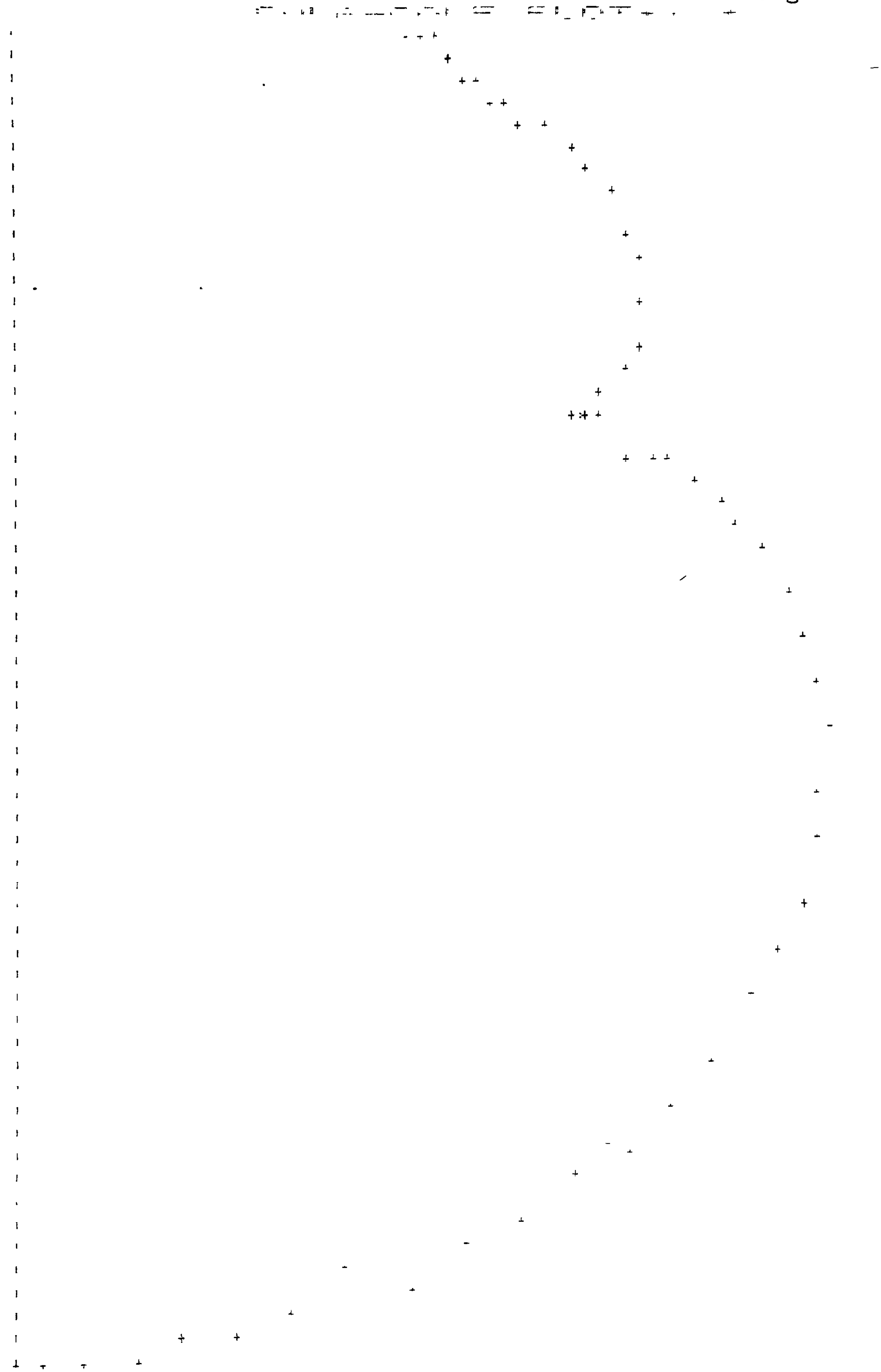


Figure 16: 52



performed next. The capability of manually entering numerical and alphabetical parameters would also be useful. In the event of some malfunction or procedural error, an abort facility should be provided which can place the system in a known state with a minimal loss ot data. Due to the modularity of the procedure, only the data acquired or calculated during the aborted block need be lost. This data is useless anyway because it would only be a partial data set.

Since the system upon which the software was developed has a CRT terminal as well as a line printer, the user instructions appear on the CRT only and the required output is sent to the line printer only. This is accomplished using certain built in monitor subroutines imbedded in a buffer loading routine. Therefore to output a given message, (eg. an instruction), the address of the buffer which contains that message is first loaded into the designated register pair, (HL), and the appropriate buffer loading and output routine is called. These routines are known as PRINT and XPRINT, depending upon whether the message is to go to the CRT or line printer, respectively.

To enable the system to receive signals from the operator, an interrupt routine, KEYIN, which is sensitive to keyboard inputs, was devised. This routine stores the received ASCII character (minus the parity bit) in a single byte buffer called KEYSIG. The point in the main system program which is expecting such a signal simply scans repetitively the contents of KEYSIG until the required signal has been received before proceeding with the appropriate activity.

The same keyboard activated interrupt routine checks the input signal to see if it corresponds to the abort (CTRL A) command. If so, the stack pointer is reset to its initial value and control is returned to MENUE.

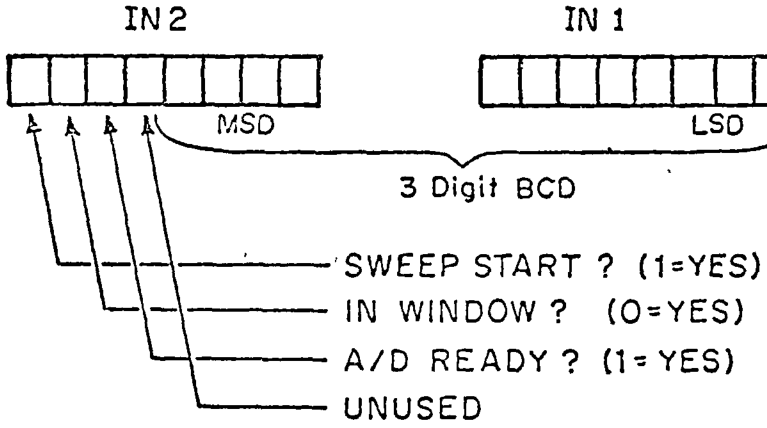
From MENUE the operator has the option of selecting either one of the two main branches of the procedure. These are S for stimulus characteristic input and processing, and R for response characteristic input and processing. The latter branch requires data from the former branch, and therefore the main program will not allow this path to be taken until the stimulus branch has been executed at least once.

Alphabetical and numerical parameters can be input from the keyboard only when the program is expecting such an input. The operator is signalled with an appropriate instruction and a prompt character. The program therefore knows whether the information is floating point decimal (time window) or alphabetic (name of material) and transfers the data to the appropriate buffer. The end of the keyboard entered character string is signalled by the operator with a carriage return, and the program appends the appropriate termination to the buffer (ETX or 03H for alphabetic and 00H for numerical parameters). The alphabetic parameter is saved until the headings for the response characteristic are printed, at which time the buffer contents are dumped out to the line printer along with the heading. The numerical parameter is converted immediately upon having been input to the 32 bit floating point format using the FDECBI routine. The time interval per sample point is then calculated and stored. The buffer containing the time window, being in ASCII form, is also printed on the output heading for both the stimulus and the response.

5.2 DATA ACQUISITION

Although data acquisition, in the strict sense of the term, involves no more than reading and storage of raw data, the nature of the measurement makes it convenient to include a little preprocessing during acquisition. The extent of this preprocessing is limited to the point by point averaging of the characteristic in the time window (designated by two cursors) over 100 sweeps. This is designed to reduce the effect of amplitude jitter on the outcome of the later processing. Also to be acquired are the reference points M and N1, the subscripts of the last low level point and first high level point respectively. These points are used during the normalization procedure described in the next section.

Actually, the acquisition portion of this block is the software part of the sampling scope-microcomputer interface, and must therefore be designed around the hardware provided. From the microcomputers (and programmers) point of view, the A/D converter looks like the two input ports to which it is connected. Each of the ports (IN1 and IN2) are 8 bits wide, and each are partitioned into two 4 bit fields. If these two bytes are concatenated as shown Fig. 11, they form, from left to right, a 4 bit timing field and three 4 bit BCD numbers. The timing field is the key to the acquisition process, and of the 4 bits in the field, only 3 are used. The first bit is a SWEEP START indicator which strobes the start of a new sweep of the characteristic on the screen of the oscilloscope. The second bit indicates whether the point currently being sampled is or is not in the time window of interest. The time window is the set of points between and including the two cursors. The third bit simply signifies validity of the BCD data from the A/D converter. A flow chart illustrating the usage of these signal lines appears in appendix B under the name TDR.



The format of the unidirectional interface shows 3 timing bits and a 3 BCD digit data field.

Figure 17: A/D converter interface format

Acquisition of the reference points is achieved simply by setting the right hand cursor to the desired point and tapping the space bar. The reference point acquisition routine (REFACQ) calls the TDP data acquisition routine, in which there is a counter which counts the number of points in the window. After one sweep, the contents of this counter is stored as the subscript of the reference point. The output of the same counter is displayed on the screen of the terminal during data and reference point acquisition.

The preprocessing mentioned at the beginning of this section involves alignment of the contents of NEWVEC (the newly acquired sweep) with the contents of ACCVEC (the accumulated point by point sum of sweeps), then a format conversion and summation of each point. Alignment is necessary because of the cursor jitter at high sampling densities, and is done with respect to the sweep start location. That is, the number of points before the window is counted for each sweep, but this number for the first sweep is stored as a reference (DREF). Each subsequent sweep is then aligned with ACCVEC depending on the difference between the number of points before the window (DNEW) and DREF. As each new sweep is taken, the maximum DNEW (DMAX) and the minimum number of points in the window (HMIN) are checked and updated. After 100 sweeps have been acquired, aligned, converted to 32 bit floating point format, and summed, a certain number of points on each end of ACCVEC are truncated. This is due to the fact that they have not been summed 100 times because of the shifting during alignment. This is where DMAX and HNEW, the maximum first point subscript and minimum last point subscript respectively are used. The points between DMAX and HNEW inclusive are all valid averaged points, and the others are truncated. The number of truncated points usually varies from 0 to 2 points.

The format conversion is a two step process. The incoming data is in BCD and the required format for data processing is the 32 bit floating point binary format. The first step is to convert the BCD data to binary, and the second step converts the binary data to the 32 bit format using the SBC-310 FLTDS opcode.

The question which arises is when is the best time to do the conversion? Recall that the A/D has a 3 digit BCD output. This gives a maximum magnitude for any given point of 999 units. If 100 sweeps of a given characteristic are taken, the sum total of any given point could possibly reach 99900. The fixed point to floating point conversion in the SBC-310 requires an unsigned 16 bit binary input. The maximum magnitude of such a number would have a decimal equivalent of 65,536, which is considerably short of the potential 99900. This leaves two alternatives. One is to cut the averaging down to 50 sweeps, and convert after summing, and the other is to convert the numbers before they get too large. Again, two possibilities emerge from the second alternative. The first one is to compound two iterative procedures by acquiring 50 sweeps, converting, then acquiring 50 more sweeps, converting again, and then summing the results. The second is to simply convert each sweep as it is acquired and sum it with ACCVEC. The latter option was selected for reasons of simpler programming, at the expense of execution time.

Since each characteristic to be transformed is normalized between -1 and +1, it is unnecessary to divide each point magnitude by the number of sweeps taken. A simplified flow chart for the data acquisition and preprocessing is shown in appendix B under the name DATACQ.

5.3 DATA PROCESSING

This block can be partitioned into several functional sub-blocks, some of which have been discussed earlier as preprocessing in the data acquisition section. Some of these functional sub-blocks are composed of sub-sub-blocks which may be subroutines, others may be spread out over several levels of programming. The partitioning of the components of this section will conform as much as is possible to the actual software implementation, to facilitate future modification and improvements.

These components include normalization, preprocessing for the F.T. algorithm, and the Fourier transform itself. There are a few utility routines which service the SBC-310 related operations and also some which sweep the frequency range of interest for the frequency domain conversion. Also used in the transformation routine are two trigonometric subroutines for computing sine, cosine, and arctangent, as well as two format conversion routines.

5.3.1 Normalization

The data normalization is a two stage process. The first part of the process (HILOAV) is a calibration procedure. This involves scanning the entire stimulus data set, averaging all of the low level points (S1), averaging all of the high level points (S2), and taking the difference (S=S1-S2) as shown in Fig. 9. Only S and S1 are used in the second part of the process (NORM) which is the normalization itself. This routine is used for both stimulus and response normalization. Again the entire data set is scanned taking each point, subtracting it from S1, and dividing by S.

$$|\text{point}| = \frac{S1 - |\text{point}|}{S}$$

Note that S1>S2 due to the manner in which the A/D was installed, but the above normalization process puts the characteristic in the correct perspective. Note also that it is possible to have some magnitudes greater than 1, due to the fact that S is the difference between averages. There is a built in limiting facility which replaces magnitudes which are greater than 1 by the 32 bit floating point equivalent of 1. This introduces a slight clipping error which should be negligible considering the number of sweeps over which the signal has been averaged.

HILOAV makes use of the reference points M (last low level point) and N1 (first high level point), but NORM sweeps over the entire characteristic. Flowcharts for these routines can be found in appendix B .

5.3.2 F.T. processing

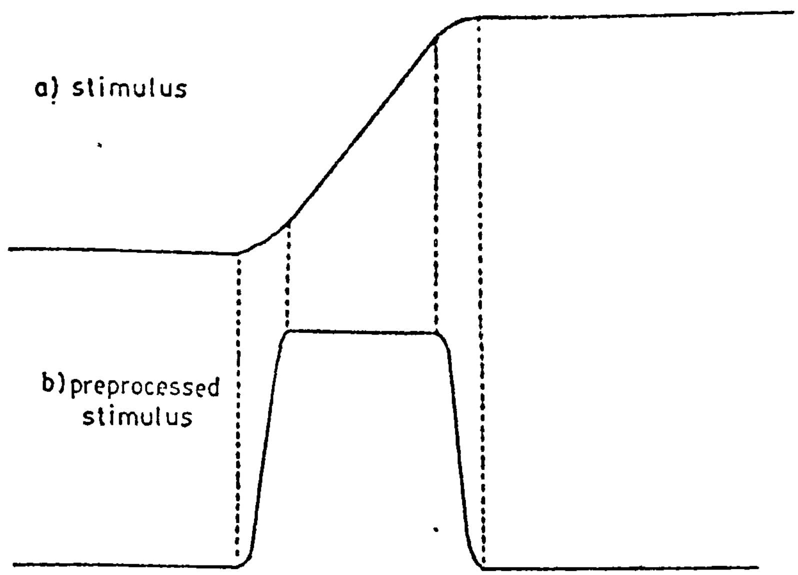
The algorithm used to do the Fourier transform requires, as input, the difference between consecutive normalized points, and the time span between samples. The latter quantity is calculated immediately upon input of the total time window from the keyboard. The former is an array of points P(m), in which the normalized magnitudes have been replaced by the difference between itself and the point before. (ie. P(m)=R(m)-R(m-1)). This is another relatively simple routine which has been imbedded in the same loop as, and immediately following, the normalization mentioned above.

The Fourier transform is done using Samulon's formula which is particularly useful for this application. It is well known that sampling in the time domain causes a periodicity of the spectrum in the frequency domain, and vice versa. Conventional DFT algorithms require a periodic repetition of the time window thereby causing a sampling effect in the frequency domain. In other words, the Fourier transform is valid only at those discrete intervals of 1/T

Hz, where T is the time window in seconds. This means that the resolution in the frequency domain is determined by the width of the time window. For example, a 25 MHz resolution in the frequency domain would require a 40 ns time window. If the event being measured has a 2 ns duration, it would have to be compressed into a prohibitively small sample space in order to **accommodate** the entire 40 ns time window on the screen. In addition, the bulk of the data set would contain relatively little information since the event of interest is practically over in 2 ns. Samulon's formula enables the event to be stretched into a more convenient sample space, and since the functions being measured are well behaved, the remainder of these characteristics can be predicted.

Take for example the stimulus function shown in Fig. 12(a). Sampling this signal and taking the difference between consecutive samples is, roughly speaking, analogous to differentiation. This would yield a signal similar to that in Fig. 12 (b).

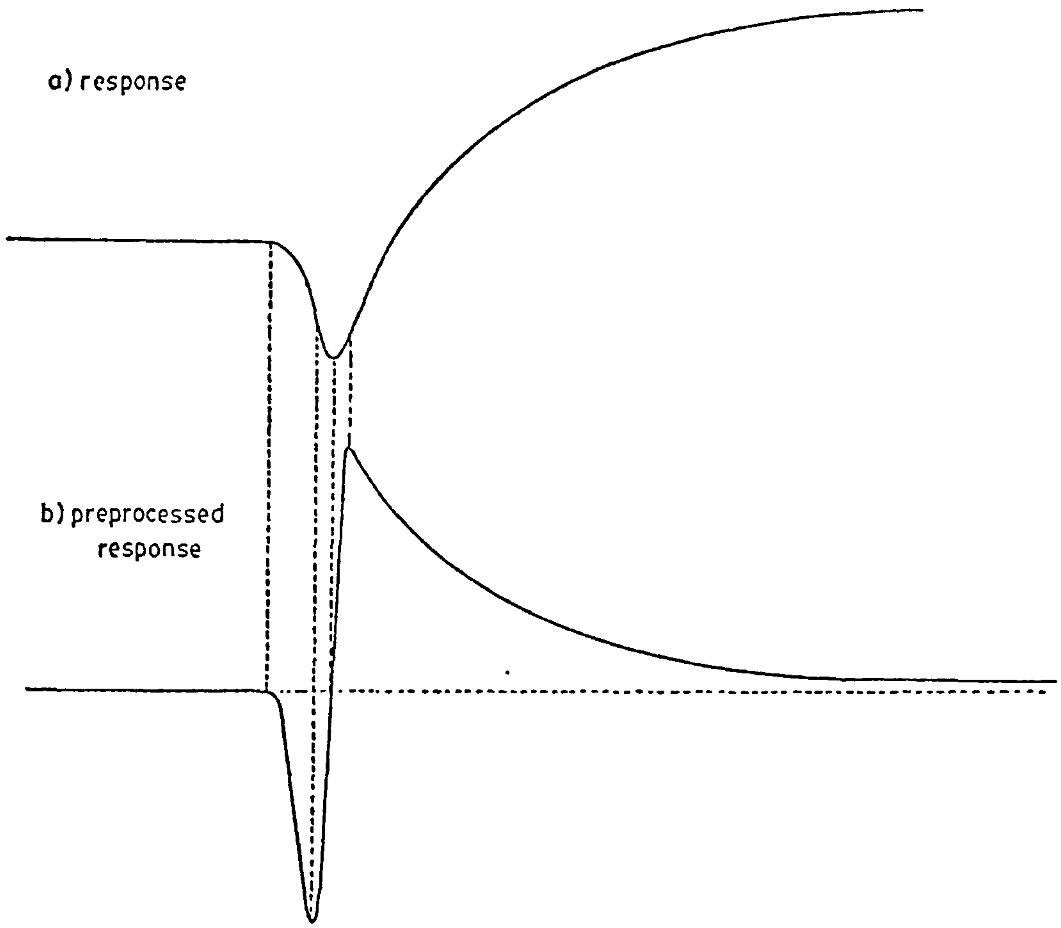
If it could be assumed that the step continues on to infinity, it could also be assumed that the signal in Fig. 12 (b) continues to infinity in similar fashion. That is to say, adding an infinite tail of zeros to the second signal would be a valid assumption and it would also serve to extend the time window to infinity. In practice of course,



The preprocessing of the stimulus consists of normalization followed by the replacement of each point by the difference between that point and the preceding one. The resulting characteristic resembles the derivative of the stimulus, and it is this data which is processed by Samulons F.T. algorithm.

Figure 18: Stimulus normalization and preprocessing

only the finite number of points in the time window would be acquired, but the artificial extension of the time window to infinity serves to give infinitessimal resolution in the frequency domain. Taking the difference between consecutive points enables the signal to be truncated with minimal loss of information content as soon as it reaches a steady state level. This applies to the response as well as the stimulus (see Fig. 13)



As for the stimulus, the response is first normalized and then replaced by the difference between consecutive points before being processed by Samulons F.T. algorithm.

Figure 19: Response normalization and preprocessing

5.3.3 Trigonometric and conversion routines

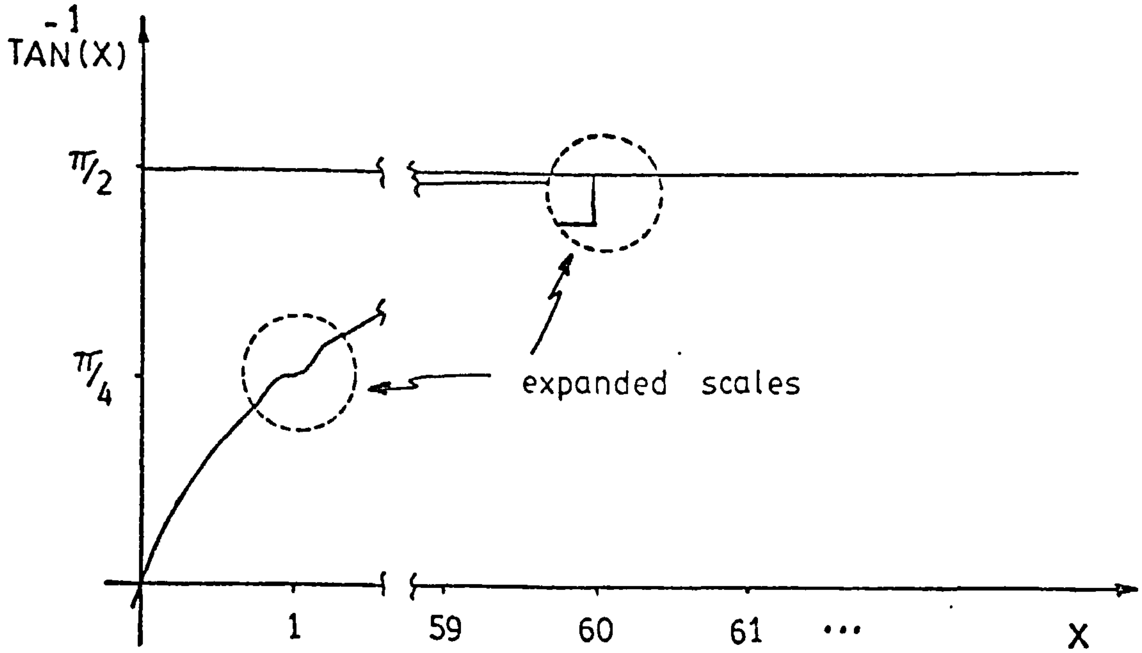
The trigonometric functions were implemented using Taylor's series expansions and are fairly straight forward. The sine function has been implemented using the identity $\sin(x)=\cos(x-\pi/2)$. In other words, the argument is phase shifted and the cosine algorithm is used.

The cosine algorithm, in order to keep the terms in the series small, is only evaluated from 0 to π. From π to 2π, the expression $\cos(\pi + \Delta x)=\cos(\pi - \Delta x)$ is used. For $x= 2\pi$ or greater, x is normalized to within the limits 0 to 2π. The cosine function is symmetric with respect to x=0, so all arguments are taken to be positive.

The arctangent algorithm is a two part expression which uses a different series depending upon whether or not $|x| < 1$. The function itself is inverse symmetrical about x=0. Thus only positive arguments were used and the sign of the input was passed on to the output. Truncation of the series leads to a slight perturbation around x=1. The more terms evaluated, the lesser is the perturbation. Too many iterations causes overflow for large values of x, since each consecutive term in the series has an odd power of x which increases by 2. Since for $x > 1$, the function asymptotically approaches $+\pi/2$, there can be a maximum value of x set so that for:

$$x \geq xmax \ , \ \tan^{-1}(x) = \frac{\pi}{2}$$

This introduces an error which is greatest at x=xmax and decreases with increasing x.



The arctangent algorithm suffers from an aberration around X=1 due to truncation of the two series expression. A second irregularity around X=60 is due to a clipping error which was introduced to relieve an overflow problem for large values of X.

Figure 20: Perturbations in the arctangent algorithm

This error can be reduced with some linear extrapolation at x=xmax. This xmax limitation has been incorporated in SAMULO near the end of TRNSFM. This is the only place where ATAN is used in the entire system. If a linear extrapolation is to be implemented, then it should be done in the ATAN routine itself, and the xmax limitation could be moved there at the same time.

FBIDEC is a routine which actually could be used for base conversion, but it is being used in this system to convert the 32 bit floating point binary to floating point decimal format. The mathematical basis is as follows:

It is desired to convert a quantity from the form $F_B \times 2^{E_B}$ to $F_D \times 10^{E_D}$. It is well known that:

$$\log_a N = \frac{\log_b N}{\log_b a} \qquad (5.1)$$

For a=2, b=10, (5.1) becomes:

$$\log_2 N = \frac{\log_{10} N}{\log_{10} 2}$$

If $N = 2^{E_B}$, then $\log_2 N = E_B$

Therefore:

$$E_B \log_{10} 2 = \log_{10} N.$$

$$\text{let } \log_{10} N = E_D' \quad \text{where } E_D' = E_D + E_{DF} \qquad (5.2)$$

where E_D is a decimal integer and E_{DF} is a decimal fraction. (E_{DF} should be > 0 for the following series to be valid. eg. for $E_D' = -4.3$, $E_D = -5$ and $E_{DF} = +0.7$)

From (5.2):

$$2^{E_B} = 10^{E_D'}$$

$$\Longrightarrow \quad F_B \times 2^{E_B} = F_B \times 10^{E_D'} = F_B \times 10^{E_{DF}} \times 10^{E_D} \qquad (5.3)$$

From (5.3) and (5.2), the decimal exponent E_D can be taken directly as the integer part of: $E_D = E_B \log_{10} 2$ (5.4)

F_D can be found from : $F_B \times 10^{E_{DF}}$

where:

$$10^{E_{DF}} = (1+L.E_{DF}(1+L.\frac{E_{DF}}{2}(1+L.\frac{E_{DF}}{3}(\ldots 1+L.\frac{E_{DF}}{n}))))$$

where L = ln10

This is evaluated in the loop designated as SERIES in FBIDEC.

FDECBI takes an ASCII character string in memory representing a floating point decimal quantity in the general form:

$$\pm\, d_1 d_2 \ldots d_n . f_1 f_2 \ldots f_n \text{ E } \pm\, e_1 e_2 \ldots e_n$$

and converts it to its 32 bit floating point binary equivalent. In practice, there is usually one digit to the left of the decimal point and only two digits in the exponent. The principle of operation is as follows.

The algorithm first sums up all of the significant digits keeping track of the number of digits to the right of the decimal point. This is accomplished by converting each digit from ASCII to binary, floating that value, and summing it with a floating point accumulated value. Before each new digit is summed, the floating point accumulated value is multiplied by 10, thus resulting in an integer valued representation which is greater or lesser than the actual value by a factor which is a power of 10. This quantity is then successively multiplied or divided by 10, depending on the sign of the exponent, each time incrementing or decrementing the exponent, until it becomes zero. At this point, the result is the 32 bit floating point binary representation of the decimal quantity represented by the ASCII string in memory.

The FDFCBI routine is used to convert the numerical value for the time window, which is keyboard entered in floating point decimal, to the format required by the SBC-310.

The routines for calculation of gamma magnitude and phase, as well as dielectric constant and loss factor are straight forward requiring no special explanation other than the discussion of memory usage below.

UTLITY is a collection of routines associated with the use of the SBC-310. Such programs include WAIT, the various LOAD routines, and CLEAR and FILL.

The WAIT routine is used after an opcode has been sent to the SBC-310, to ensure that the operation has been completed before the result is sought, or the operands modified. After the operation is completed, WAIT checks for errors. If there is no error, WAIT simply returns. If there is an error, WAIT checks to see if the error is an underflow, and if so, the result of the operation is replaced by zero and WAIT returns. If the error is not an underflow, WAIT outputs the error code and the top three stack entries, and then stops the system. This of course should never happen during the normal operation of the system, but it is a useful diagnostic tool for tracing the source of bugs when modifications are being made.

The LOAD routines are all based on LOADY, which simply takes the contents of (HL) and the subsequent four bytes, and moves it to the starting address specified by (DE). LOADX calls wait before going into LOADY. LOP2 assigns OP2 as the destination address (DE) and then goes into LOADX. Finally, OP210 assigns the address of a constant, 10, to the source address (HL) and goes into LOP2, thus effectively moving 10 to OP2.

The CLEAR and FILL routines require no explanation and listings are given in appendix C under UTLITY.

5.4 MEMORY USAGE

This section is a summary of the use of the data buffers and an explanation of how one pair of buffers in particular (RESMAG, and RFPHAS) is used for different data sets throughout the response processing phase.

From the memory map shown in Fig. 15, it can be seen that there are two large data buffers, and four smaller ones of equal length. The largest buffer (A000H - A800H) consists of 800H bytes (2048 D) and is for storage of the accumulated sum of the data during signal averaging. The information in this buffer is in the 32 bit floating point format thus limiting the capacity to 512 points.

The next largest buffer is 400H bytes (1024 D) long and is for storage of NEWVEC, or the most recently acquired sweep of data. This data is in a 3 digit BCD format which requires 2 bytes per point thus also having a capacity of 512 points.

The next four groups are for frequency domain data, as opposed to the time domain data stored in NEWVEC, and ACCVEC. Since only 60 frequency points are called for (as the system is programmed as of this writing), only 240 bytes are required to store the data in 32 bit format. The space actually alotted for each group is 256 D bytes, for reasons of conveniently round hexadecimal addresses.

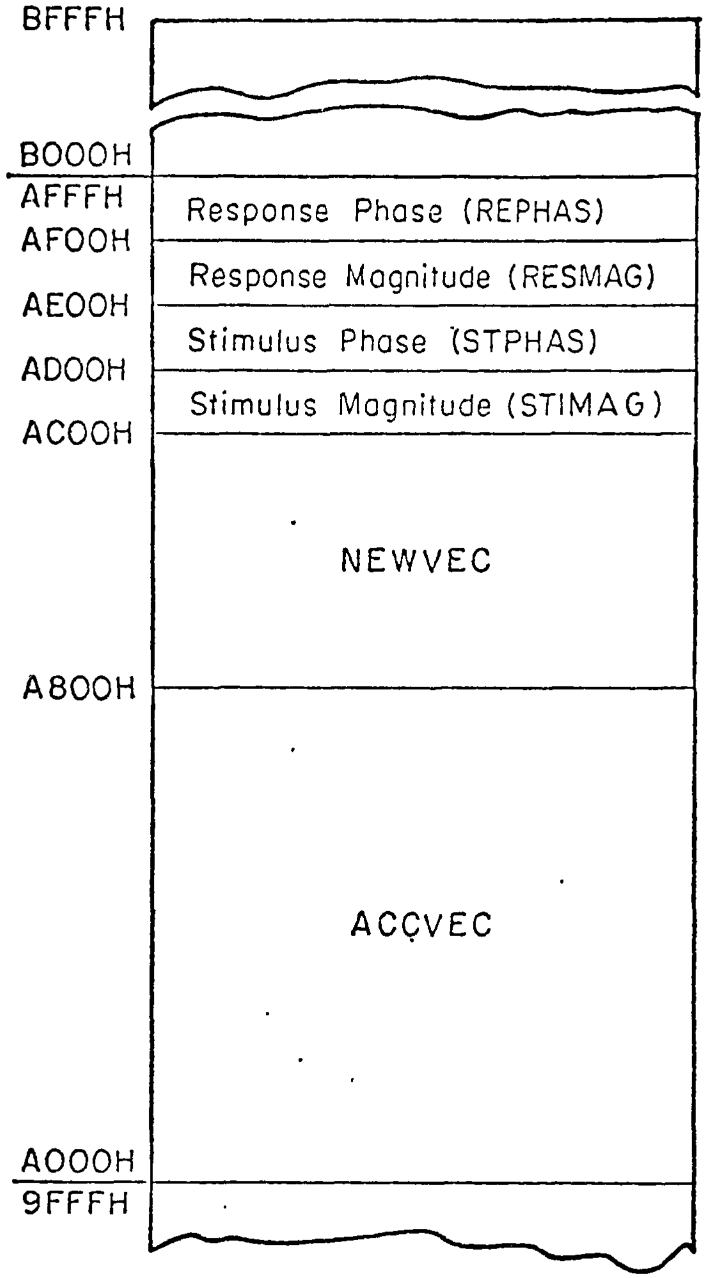
These four areas are grouped into two buffer pairs. The first pair (STIMAG,STPHAS) represents the magnitude and phase of the stimulus respectively, the second pair (RESMAG, REPHAS) being the magnitude and phase of the response respectively.

The total area alotted for bulk data storage (ie. not including time window, name of material, S, S1, etc.) is 1000H, or in decimal 4096 bytes.

NEWVEC and ACCVEC are used for each new signal aquisition. STIMAG and STPHAS are altered only when a fresh stimulus characteristic is being processed, and must be preserved during the remainder of the course of the procedure. The contents of RESMAG and REPHAS are altered during every phase of the response characteristic processing.

Immediately upon receiving the name of the material from the keyboard, SPECTRE II begins to compute the Fourier transform of the response in a point by point fashion, filling RESMAG and REPHAS as it does so. After this portion of the response processing is concluded, SPECTRE II begins to compute the magnitude and phase of gamma, overwriting the corresponding locations of RESMAG and REPHAS with the results as it does so. This is permissible since the response is only being stored for use in calculating gamma. This being done, SPECTRE II then goes on to the next step and overwrites (RESMAG) and (REPHAS) with ε' and ε'' respectively, again in a point by point fashion. Each step of the procedure, as (RESMAG) and (REPHAS) are being overwritten, the same values are being printed on the line printer, and the data is never saved longer than it has to be available for the next computation.

Two more small data buffers (E0STO, and E2STO) are maintained for plotting the Cole-Cole relationship. These areas occupy from B000H to B03CH and B040H to B070H respectively. These buffers store the sixty one-byte scaled plotting integer subscripts for (E0) and (E2) respectively, and range in value from 00H to 3CH. The routine for using these integers to form the Cole-Cole plot is called COLPLT and is described in appendices B and C.



This figure shows the various data buffers and their relative sizes and locations.

Figure 21: Data buffer memory map

Chapter VI

CONCLUSIONS

This chapter is actually a conglomerate of three sections, each of which must be at the end of this writing, and none of which justifies a chapter on its own. The first section presents some experimental results and an overall performance evaluation. In the second section, some recommendations for future work are given, and the last section summarizes this work.

6.1 RESULTS AND SYSTEM PERFORMANCE

The experimental results available for polar liquids are primarily for normal alcohols, and vary considerably from author to author. Reference [13] quotes values for the relaxation frequency of propanol varying from 413 MHz to 722 MHz. Some of these measurements have been made using frequency domain, and some using time domain techniques. The range in the measured values of relaxation frequency can be attributed to many causes including temperature variation, purity of the chemical, measurement technique employed, etc. Van Gemert [5] made mention of having the chemicals dried in $CaSO_4$ for 24 hr and then distilled just prior to making the measurement.

A chemist colleague suggested using spectro-grade chemicals for the measurement to ensure purity. Chemical purity grades are numerous and the percentage of purity for a given grade varies depending on the chemical. Some of these grades, in order of increasing purity, are practical, reagent, spectro, ultrex, and HPLC (high pressure liquid chromatograph).

Results obtained with our TDS for a reagent grade propanol showed a relaxation frequency of 525 MHz. Other liquids for which results were given in the references were not readily available. Measurements were however made on various other chemicals which were available, including methanol, ethanol, and glycerol. In each case, with the exception of glycerol (which exhibits a relatively low relaxation frequency), a second peak was present which centered in the range of 900 MHz to 1.25 GHz. The reasons for these additional peaks can only be speculated at this time, however they are worth mentioning at least for the sake of discussion.

A first possibility is that the chemicals, being of inferior grade, contain contaminants which are responsible for the higher relaxation frequencies. The slight variations in the magnitude of this peak from sample to sample of the same chemical could easily be due to a nonhomogenous mixture, temperature differences, and evapouration. These chemicals are generally supplied in bulk and are often stored in metal containers, thus increasing the likelihood of the presence of corrosion, sediment, oils etc..

The second potential problem is slightly more difficult to verify and solve. It involves time-base instability, which was also encountered by Gans and Andrews [14]. This instability manifests itself as high frequency distortion (above 1 GHz).

Another possible source of error is the cleansing of the sample holder between measurements. The sample holder itself is made of brass and there is always the possibility of residue or oxide being present. A small teflon sleeve around the central conductor has been removed to facilitate cleaning, and reduce the amount of lint, etc. accumulated by the sample holder. The cleaning between samples involves simply drying the end of the central conductor, then rinsing it with the next sample to be used, drying again, and finally insertion of the next sample. Even the slightest contamination is significant considering the small sample size (approximately 7.8 microliters).

Sample outputs for a normal alcohol, 3 dB and 10 dB attenuators appear in appendix D. The gamma curves for the two attenuators for a 0.9 ns time window are within 5% of nominal value up to approximately 1.3 GHz. When a 1.8 ns time window is used, gamma for the 3 dB pad begins to differ from the nominal value by 10% between the frequencies of 850 MHz to 875 MHz, and gamma for the 10 dB pad is practically useless. Note that cutting the time window in half while keeping the same number of points between the cursors effectively doubles the sampling rate. The measurement was therefore repeated for the larger time window, but with double the number of data points, yielding the same results as with only half of the points in the same time window.

The problem then, would seem to be more a function of the time window itself, and not the number of points in the window. This would suggest a high sensitivity to time base jitter. The smaller the time window is, the smaller is the relative timebase jitter. This would agree with previous experimental results using overly large time windows, where the distortion was too great for the measurement to be of any value. The higher distortion for the 10 dB pad would seem to indicate the amplitude jitter as another error contributing factor. Therefore for weak signals and large time windows (low relaxation frequencies), the system does not perform well. Potential solutions to these problems are presented in the next section.

Regarding system performance, there are two main sources of delay in the procedure. The first occurs during data acquisition where the time required to input a characteristic is approximately 1 s for every 10 points in the characteristic. This is a result of the selection of acquisition procedure as discussed in section 5.2. The second delay appears during the Fourier transform portion of the data processing, and can be attributed to two causes.

The first F.T. delay is again proportional to the number of points in the time window, since the entire time window is swept by the F.T. algorithm for each frequency domain point. The second cause is the iterative trigonometric algorithms used by the F.T.. The delay per frequency domain point is approximately 3s for just over 100 points, up to 12s for about 500 points in the time window. A third factor, although it does not contribute to the delay per frequency point, is the number of frequency domain points calculated.

This TDS can fully process one sample of a test substance in under 10 minutes for approximately 100 points in the time window, and each subsequent sample can be processed in less than 6 minutes, providing the first stimulus is maintained. Comparison with the systems summarized in Table 1 is favourable. A comparison of the results of one measurement of a given substance in which 105 points were in the time window, with those of a second measurement of the same sample using 443 points, showed no significant difference. The sampling rates in both cases were well above that required by Nyquiste's sampling criterion, and the slight difference in results was similar to that experienced for two consecutive measurements of the same sample and sampling rate. This can be attributed to temperature change and evaporation of the sample. The sample holder temperature was found to increase fairly steadily during the time the system was in use.

6.2 RECOMMENDATIONS FOR FUTURE WORK

After having done the groundwork and built a foundation for the developement of a microprocessor based stand alone TDS, a number of ideas come to mind which could solve many of the problems still present in the existing system. Most of these improvements involve both hardware and software modifications, and as such, provide an interesting challenge to anyone interested in microprocessor applications to digital signal processing and instrumentation. These ideas are presented here in no particular order.

Perhaps the most radical modification recommended is not a modification at all but a new design altogether. The suggestion involves distribution of the various tasks among two or even three microprocessors to achieve better accuracy, reliability, and shorter measurement time. A partition of duties would be to use one processor for human interface and data acquisition, and a second processor for data processing and output. In this manner, the stimulus data could be processed while the other processor is acquiring one or more response characteristics. This overlapping of the time consuming tasks should shorten the measurement time considerably. The reduction in time between stimulus and response acquisitions should minimize the effects of certain instabilities in the TDR hardware, thus improving the accuracy of the measurement. The improved reliability stems from the possibility of having firmware shared between the two processors, so that in the event of a processor failure, the remaining processor could perform both tasks. This would give a softly degrading system thus improving the reliability.

Digital control of the sampler time-base via a D/A converter would improve the time-base stability, facilitate automatic calibration, and simplify signal averaging during acquisition. With this modification, it would be possible to sample the same point several times before proceeding to the next point. This would enable immediate rejection of spurious points. It also requires only one sweep of the time window thereby elimination the necessity to align consecutive sweeps before summing.

The implementation of this modification would involve both hardware and software. A standard oscilloscope uses a ramp as a horizontal sweeper for the time-base. The sampler in the sampling scope uses a staircase waveform and a ramp with a comparator to trigger the sample and hold (S/H) network when the ramp reaches the level of the staircase. The staircase is incremented, the event retriggered, and the ramp reset so that there is a slightly longer time elapsed before the ramp again reaches the level of the staircase, thus sampling the next time point of the characteristic (see [15], section 4-12 to 4-24). This staircase could be provided by a D/A converter driven from an output port of the microprocessor system. The software would involve the incrementing and outputting of the contents of a counter when the next time point is required. This would require major modification of the entire SYSRTN file, and in particular, the DATACQ routine.

Also the number of times each point is averaged could be reduced to 50 thus postponing the necessary conversion to the 32 bit format until after the averaging. This would require only one format conversion per data point and it should speed up the data acquisition considerably. This modification could be done as the system stands as of this writing, with a few modifications to the DATACQ routine. This would involve a simple loop counter change and some modification to the summation routine in DATACQ.

There is another possibility for dealing with the time-base instability. The idea is to compensate for the problem rather than to improve the stability and as such, it has a few drawbacks. One such disadvantage is the increased processing required for this compensation. Another is the necessity of an additional calibration phase in the procedure. Advantages of this method are that no additional hardware is required (with the exception of one 3 dB attenuator) and the modifications necessary could be made straight away. The suggestion is as follows.

It was observed that the distortions due to time base instabilities were rather consistent for a given sample or component, and time window. The additional calibration phase in the procedure would then be to measure the reflection coefficient of a known component (eg. a 3 dB attenuator). Then subtract from each frequency point the known reflection coefficient for that component. For a 3 dB pad, 0.501 would be subtracted from each magnitude point thus leaving only the contribution to the reflection coefficient of the systematic distortion. This characteristic could then be subtracted from the reflection coefficient of each sample just prior to the computation of epsilon. Implementation of this suggestion would involve three main modifications to the existing system. First of all, an additional data buffer would have to be created for the storage of the magnitude of the reflection coefficient of the distortion. This is rather simple and involves no more than defining a storage space as is done for the other buffers (see DSFG section of SPECTP).

Secondly, a third path would have to be built into SPECTR to allow for the input of this calibration data. As before, at least one stimulus acquisition and processing phase would have to be successfully completed before the calibration could be done. The new calibration path would have to instruct the operator to install a 3 dB pad and tap the space bar when ready. The system would have to acquire the data in the usual fashion, normalize, and Fourier transform the data, and then calculate gamma as in the response branch. The difference occurs at this point and involves calling a new routine which will subtract the constant expected reflection coefficient from the measured gamma, and store the result in the new buffer as described above.

The third modification is simply the addition of a routine called from the response processing branch of SPECTP just after gamma has been calculated, but before it has been plotted. This routine would simply subtract point by point the contents of the new buffer from the magnitude of gamma for the response currently being processed. Then gamma could be plotted and the system could continue as before.

Automatic vertical calibration of the system could be achieved with a computer controlled voltage source. The base line of the trace could be positioned and the time-base selected. A set of predetermined voltages could then be supplied to the remote sample head and compensation made for non linearities in the A/D converter. This would require a separate calibration branch in SPECTR which would average the window to establish a value for the input voltage. Also the corresponding scaling of each new set of measurement data would have to be done before normalization.

Another hardware improvement that could be made to the system would be to implement the auxiliary tunnel diode bias supply presented in [12]. This would result in better temperature stability due to the differential amplifier used in the supply. Also it would facilitate the triggering of the tunnel diode step generator from the output side as discussed in section 4.4 and in reference [11].

The delay during data processing could be considerably reduced by improvement of the trigonometric subroutines. Such improvements can be achieved by optimization of the existing algorithms, using other fast algorithms, or implementing a look-up table scheme with interpolation between the discrete points. An alternative to this would be to use a recently announced monolithic mathematical unit

(Am 9511). This unit already has the necessary trigonometric functions (sine, cosine, arctangent) built in. It also uses the same 32 bit floating point binary format as the SBC-310 but the operand transfer routine (LOADY) will have to be modified to interface with the stack oriented operand storage used by the Am 9511.

A facility for automatic sample holder temperature recording could prove useful for comparison with other experimental results. Other helpful solutions would include removal or reduction of the undesireable reflections, also discussed in section 4.4, as well as some other measurement capabilities such as the ability to measure transmission coefficient, etc..

6.3 SUMMARY AND CONCLUSIONS

Time domain techniques for making spectroscopic measurements have been reviewed. Some existing systems have been investigated and compared. A measurement procedure which is suitable for microprocessor based implementation has been developed, and the realization of this procedure is described in terms of both hardware and software.

This design has been implemented and all of the software required to perform the human interface, data acquisition, data processing and output has been developed and documented. Some measurements and tests have been made and the results and system performance have been analysed.

Recommendations for future work based on these results and performance evaluations have been made. It has been verified that the microprocessor is indeed suitable for each of the tasks required of it as a TDS system element for a stand alone TDS. When one microprocessor is burdened with all of these tasks however, some weaknesses of a single processor system become apparent. These problems could be alleviated somewhat through distribution of the time consuming tasks among two or more microprocessors. This would also serve to reduce the effects of hardware instability.

Certain difficulties which were encountered were also mentioned in some of the references, and are hardware oriented. Some of the solutions proposed by these references should be implemented in order to minimize these problems. An alternative software method of partially compensating for one of these hardware instabilities in particular (time-base jitter) has been presented.

Sophisticated mathematical slave processors make complex processing practical in a microprocessor based environment. The SBC-310 has been extensively used throughout the entire software design. However, a more powerful monolithic unit (Am 9511) would eliminate the trigonometric routines and improve the efficiency of the data processing.

Now that the feasibility of a practical microprocessor based TDS has been demonstrated, implementation of the proposed recommendations could prove to yield better efficiency in terms of space, cost, speed, accuracy, and versitility than many of the systems published. The main features of such a system would include task distribution among at least two microprocessors, computer control of the sampler time-base, the above mentioned monolithic math unit, and the hardware modifications suggested in the previous section.

Appendix A

NOTES ON THE USE OF THE SBC-310

From a users point of view, the SBC-310 (once initialized) appears as special memory addresses and input/output (I/O) ports. The base address (IOBAS=40H) has been set via a DIP switch on the SBC-310 card. It is with respect to this base address that the unit is initialized and operated.

Initialization consists of assigning a location for the two 4 byte (32 bit) operands. The low order byte of the operand address is sent to output port IOBAS+1 and the high order byte of the same address is sent to IOBAS+2. For SPECTRE II, this location has been chosen to be 0C100H since the MDS 800 only has memory up to 0BFFFH. This operand base address should be reinitialized each time the RESET switch is pressed on the MDS 800 CPU. This routine is as shown in fig. 16 below.

This puts the lowest order fraction byte of operand 1 at 0C100H followed by the others in order of increasing significance, then the lowest order byte of operand 2, followed by the others in order of increasing significance.

```
6000 3E00      MVI   A,0      ;LOW ORDER BYTE OF 0C100H
6002 D341      OUT   41H      ;IOBAS+1
6004 3EC1      MVI   A,0C1H   ;HIGH ORDER BYTE OF 0C100H
6006 D342      OUT   42H      ;IOBAS+2
```

Figure 22: SBC-310 operand initialization

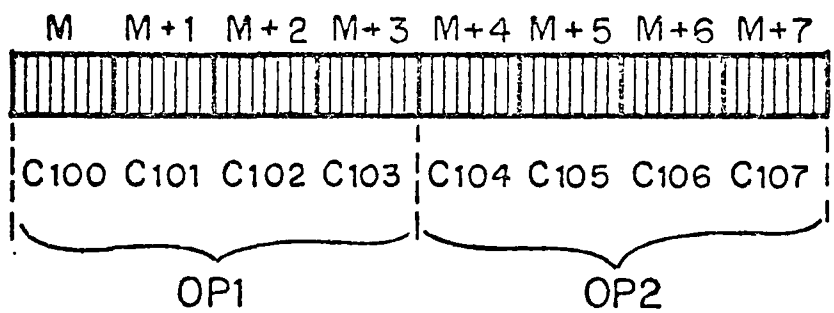


Figure 23: Operand location in memory

The 32 bit floating point binary format is as shown in fig. 18.

where: e7.....e1 is the exponent, offset by 7FH to give powers of 2 from -127 to +127, and f23...f21 is the 23 bit fraction normalized so that the bit immediately left of the binary point is 1. s=0 for positive, and s=1 for negative operands.

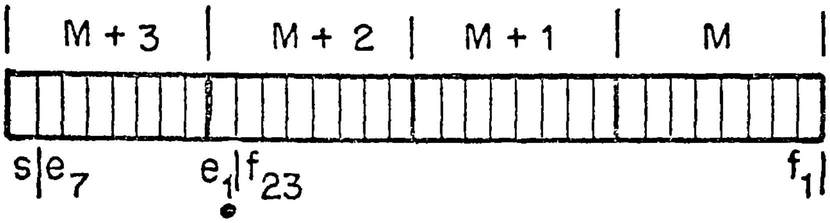


Figure 24 : The 32 bit floating point format

The floating point argument is therefore:

$$(OP1) = (-1)^{s} \cdot 2^{(e-7FH)} \cdot (1.f) \qquad [A.1]$$

Therefore the 32 bit floating point expression for 06H can be derived as follows:

0000 0110 = 06H

Normalize to the form in A.1:

s = 0

f = .100....

e = 7FH + 02H = 81H

therefore: $06H = (-1)^{0} \cdot 2^{2} \cdot 1.1$

or:

M+3	M+2	M+1	M
0100 0000	1100 0000	0000 0000	0000 0000
4 0	C 0	0 0	0 0

Now putting this quantity into OP1 in ascending address order:

C100	C101	C102	C103
00	00	C0	40

The SBC-310 has both single operand and double operand instructions (opcodes), the results of which are placed in OP1 (M,M+1,M+2,M+3) for arithmetic operations, or in the status byte for FCMPP and FZTST. The only exception is EXCH which exchanges the contents of OP1 and OP2. All single operand instructions consider OP1 as the operand.

To use the SBC-310 to perform an operation designated by one of the opcodes, it is necessary to load the operand locations with the appropriate values and format, and then output the opcode to IOBAS. The MDS 800 is then free to do other tasks while the SBC-310 is executing the opcode. MDS may not however tamper with the operands or IOBAS until the SBC-310 has completed its execution of the current opcode. If the result is required immediately of if the next operand in a chain type calculation is ready to be loaded, MDS 800 must first check to ensure that the previous operation has been successfully completed. This is accomplished via the flag byte, which is input from IOBAS+7 (see tables 3-1, 3-5 and 3-6 in the SBC-310 reference manual). This waiting for completion of the previous operation is performed in WAIT.

The loading of the operands is done by putting the address corresponding to byte M of the source quantity in HL, and the address corresponding to byte M of the destination quantity in DE, then calling LOADY.

eg.

```
                  23 .     LXI    H,SIXTY ;SIXTY IS THE ADDR  OF BYTE M OF SOURCE
6008 110001       24       LXI    D,OP1   ;OP1=BYTE M OF OPERAND 1 (0C100H)
600B CD0000   E   25       CALL   LOADY
```

If it is necessary to wait before proceeding with the load, then routine LOADX, which calls WAIT before proceeding with LOADY, should be used. (see section 5.3)

eg.

```
                                 ;ASSUME OPERANDS PRELOADED
600E 3E09         MVI    A,FMUL  ;OPCODE FOR MULTIPLICATION
6010 D340         OUT    IOBAS   ;OPCODE SENT TO SBC-310
6012 210001       LXI    H,OP1   ;RESULT WILL BE IN OP1
6015 110000   E   LXI    D,BUFFER;DESTINATION OF RESULT
6018 CD0000   E   CALL   LOADX   ;CALLS WAIT, THEN PERFORMS LOADY
```

For a listing of WAIT, LOADX, LOADY, and other SBC-310 utility routines, see the file called UTLITY in appendix C.

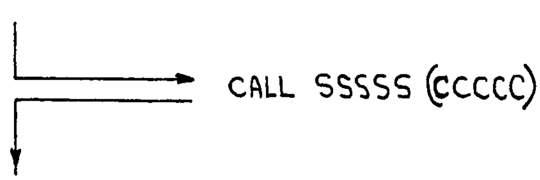
Appendix B

FLOWCHARTS AND PROGRAM DESCRIPTIONS

This section consists of the flowcharts of the various routines in the order in which they appear in the program listing section. Some routines may be too simple to to warrant a space consuming flowchart so a verbal description for these cases is given instead. Some of these flowcharts may appear to be unduly complicated, but bear in mind that many are shared routines which may have been compromised to facilitate direct application from multiple call points.

There are basically five files composing SPECTRE II. These are, in sequence of linkage; SPECTR , SYSRTN, FRQDOM, SAMULO, and SPEC.LIB. The last file is in turn composed of UTLITY, FBIDEC, FDECBI, SINCOS, ATAN, and PLOT. The flowcharts and verbal descriptions in this appendix follow this order for easy reference.

The following symbol:



denotes a call to a subroutine named SSSSS which is briefly explained by (CCCCC).

The following symbol:

$\longrightarrow$ To LLLLL

denotes a jump to the location specified by LLLLL.

Throughout the comments in the listings section and the boxes in the flowcharts, round brackets around a capitalized (upper case letters) parameter designates "contents of". For example (HL) means "the contents of register pair HL". This is to adhere to the convention used in the definition of the Intel 8080 instruction set.

Hardware (HW) and software (SW) required reflect only that which is not normally supplied with the MDS 800 system.

Name: SPECTR

Function: Main program

Subroutine nesting level: 6

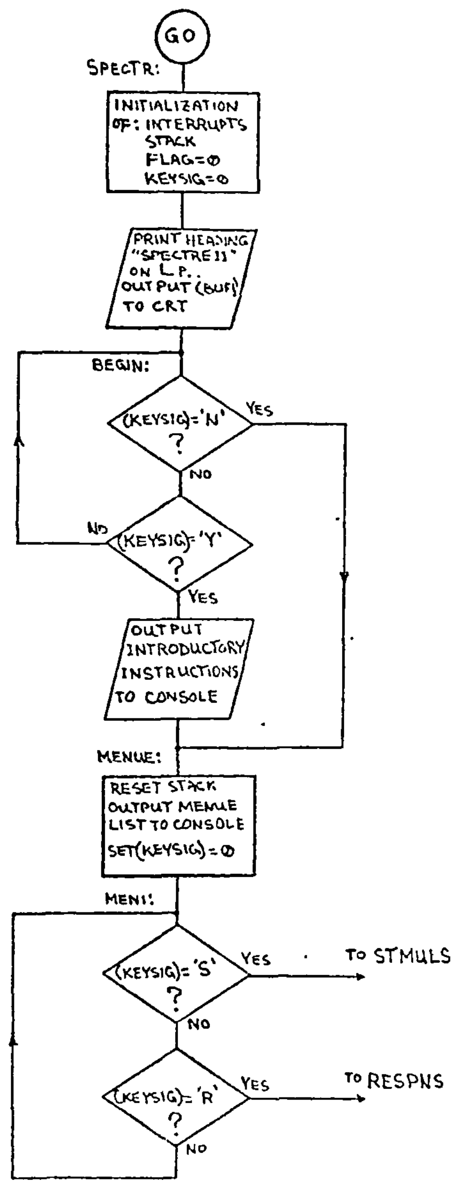
Registers modified: all

Input parameters: as requested on CRT

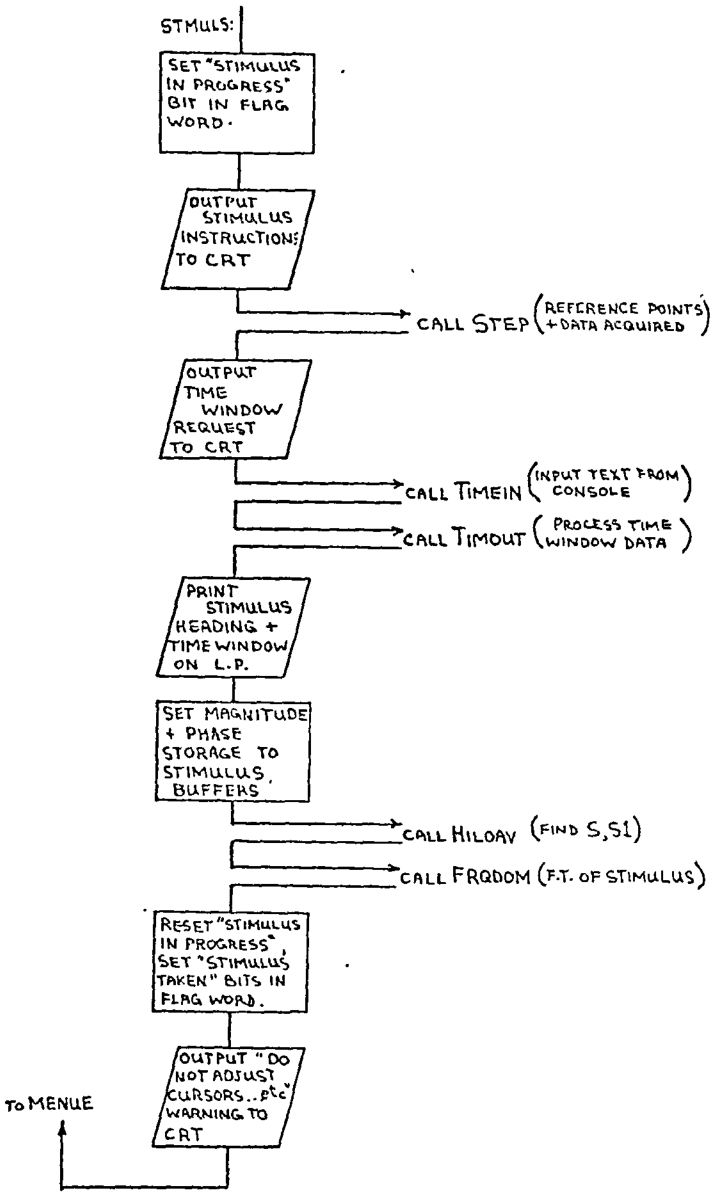
Output parameters: system output as described.

HW required: entire TDS system

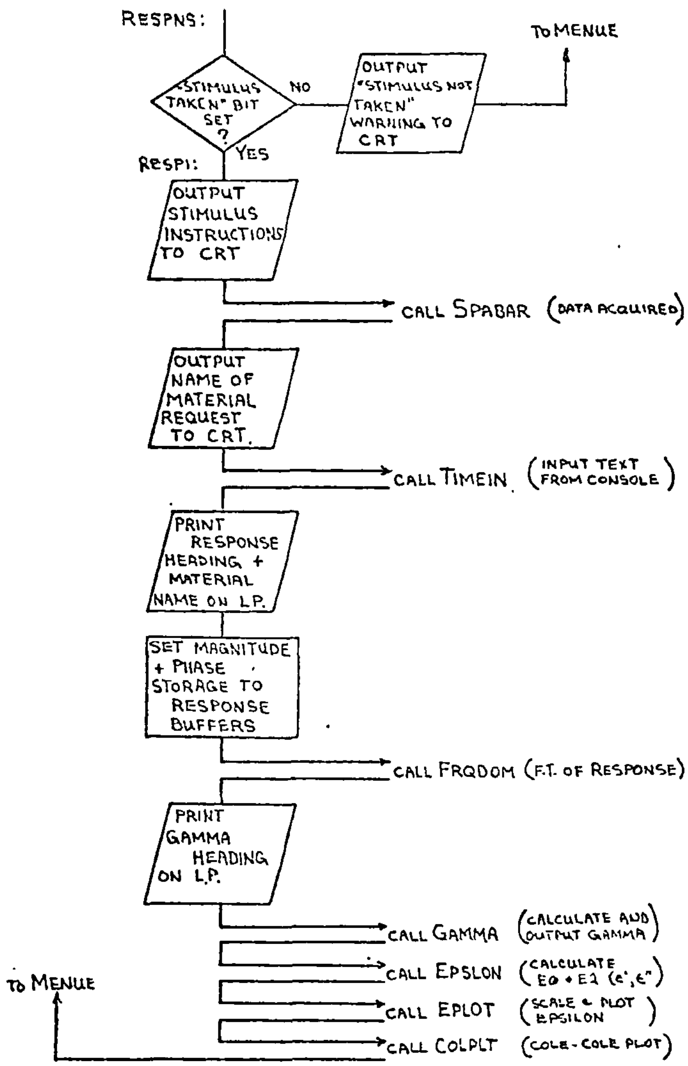
SW required: all programs in app. B,C.



Name: SPECTR


STMULS:
SET "STIMULUS IN PROGRESS" BIT IN FLAG WORD.
OUTPUT STIMULUS INSTRUCTIONS TO CRT
CALL STEP (REFERENCE POINTS + DATA ACQUIRED)
OUTPUT TIME WINDOW REQUEST TO CRT
CALL TIMEIN (INPUT TEXT FROM CONSOLE)
CALL TIMOUT (PROCESS TIME WINDOW DATA)
PRINT STIMULUS HEADING + TIME WINDOW ON L.P.
SET MAGNITUDE + PHASE STORAGE TO STIMULUS BUFFERS
CALL HILOAV (FIND S,S1)
CALL FRQDOM (F.T. OF STIMULUS)
RESET "STIMULUS IN PROGRESS", SET "STIMULUS TAKEN" BITS IN FLAG WORD.
OUTPUT "DO NOT ADJUST CURSORS..etc" WARNING TO CRT
TO MENUE

Name: SPECTR


RESPNS:
"STIMULUS TAKEN" BIT SET ?
NO
OUTPUT "STIMULUS NOT TAKEN" WARNING TO CRT
TO MENUE
YES
RESP1:
OUTPUT STIMULUS INSTRUCTIONS TO CRT
CALL SPABAR (DATA ACQUIRED)
OUTPUT NAME OF MATERIAL REQUEST TO CRT.
CALL TIMEIN (INPUT TEXT FROM CONSOLE)
PRINT RESPONSE HEADING + MATERIAL NAME ON L.P.
SET MAGNITUDE + PHASE STORAGE TO RESPONSE BUFFERS
CALL FRQDOM (F.T. OF RESPONSE)
PRINT GAMMA HEADING ON L.P.
CALL GAMMA (CALCULATE AND OUTPUT GAMMA)
CALL EPSLON
CALL EPLOT (SCALE & PLOT EPSILON)
CALL COLPLT (COLE-COLE PLOT)
TO MENUE

Name: TIMEIN

Function: storage of ASCII string input from console

Subroutine nesting level: 2

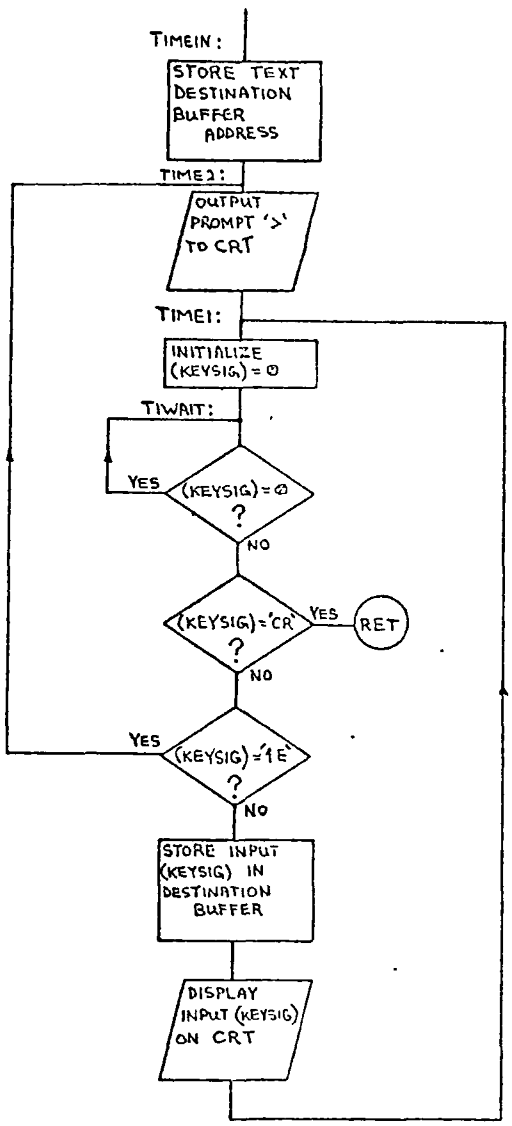
Registers modified: A,C,H,L

Input parameters: storage buffer address

Output parameters: prompt character to CRT

HW required: none

SW required: KEYIN



Name: TIMOUT

Function: see below

Subroutine nesting level: 4

Registers modified: all

Input parameters: time window buffer, NPSTO

Output parameters: DIST, time window to CRT

HW required: SBC-310

SW required: FDECBI, UTLITY

This routine sets up the contents (ASCII) of the time window buffer for printout and conversion to 32 bit floating point binary format. The conversion routine FDECBI is called and the result is divided by the number of points in the window and stored as (DIST).

Name: STEP

Function: to acquire ref. pts. and data

Subroutine nesting level: 4

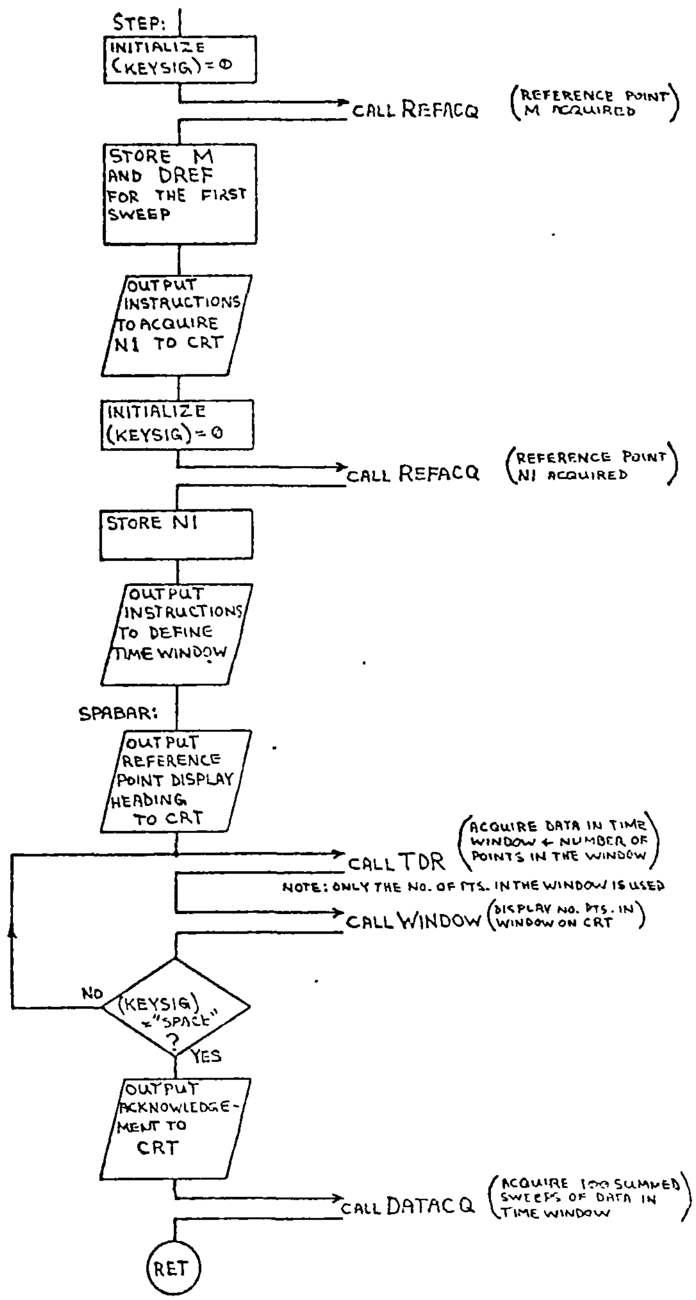
Registers modified: all

Input parameters: raw data (from A/D)

Output parameters: stored data

HW required: TDS system

SW required: as shown



Name: JITTER

Function: see below

Subroutine nesting level: 2

Registers modified: A,C,H,L

Input parameters: hollerith address

Output parameters: hollerith string

HW required: none

SW required: PRINT

This routine prints the warning :"TOO FEW LOW LEVEL POINTS" and returns control to MENUE.

Name: XPRINT
or PRINT

Function: see below

Subroutine nesting level: 1

Registers modified: A,C,H,L

Input parameters: hollerith address

Output parameters: hollerith string

HW required: none

SW required: LPT or CRTOUT, respectively

These two routines take the contents of the buffer location specified in (HL) and compare it to the ETX (end of text 03H) character. If it is ETX, the routine returns. If not it outputs the character to the line printer if XPPINT was called, or to the CRT if PRINT was called. The buffer pointer (HL) is incremented and the next character is compared to ETX, and so on until the end of the buffer, designated by ETX, is reached.

Name: KEYIN

Function: interrupt driven keyboard input

Subroutine nesting level: 0

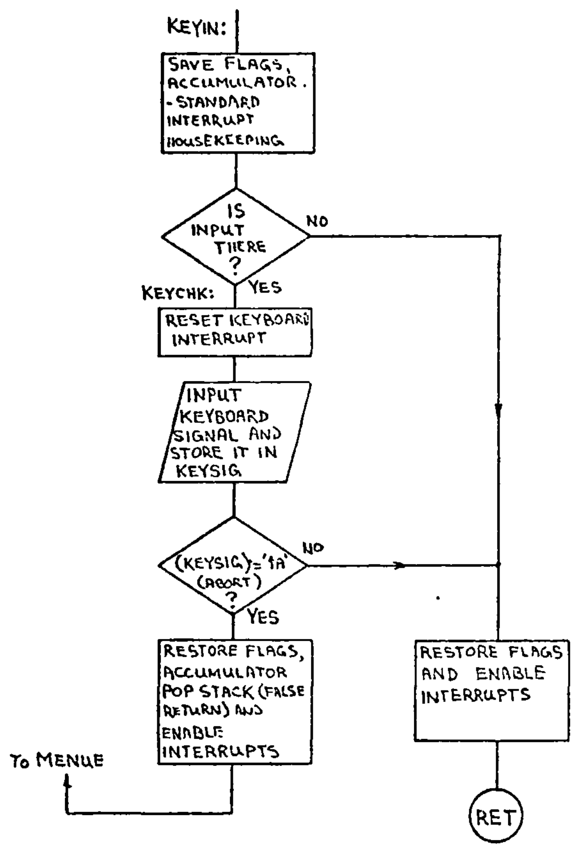
Registers modified: none (except H,L during abort)

Input parameters: keyboard status and signal

Output parameters: interrupt housekeeping

HW required: none

SW required: SPECTR



Name: DATACQ

Function: data acquisition, alignment, and averaging

Subroutine nesting level: 2

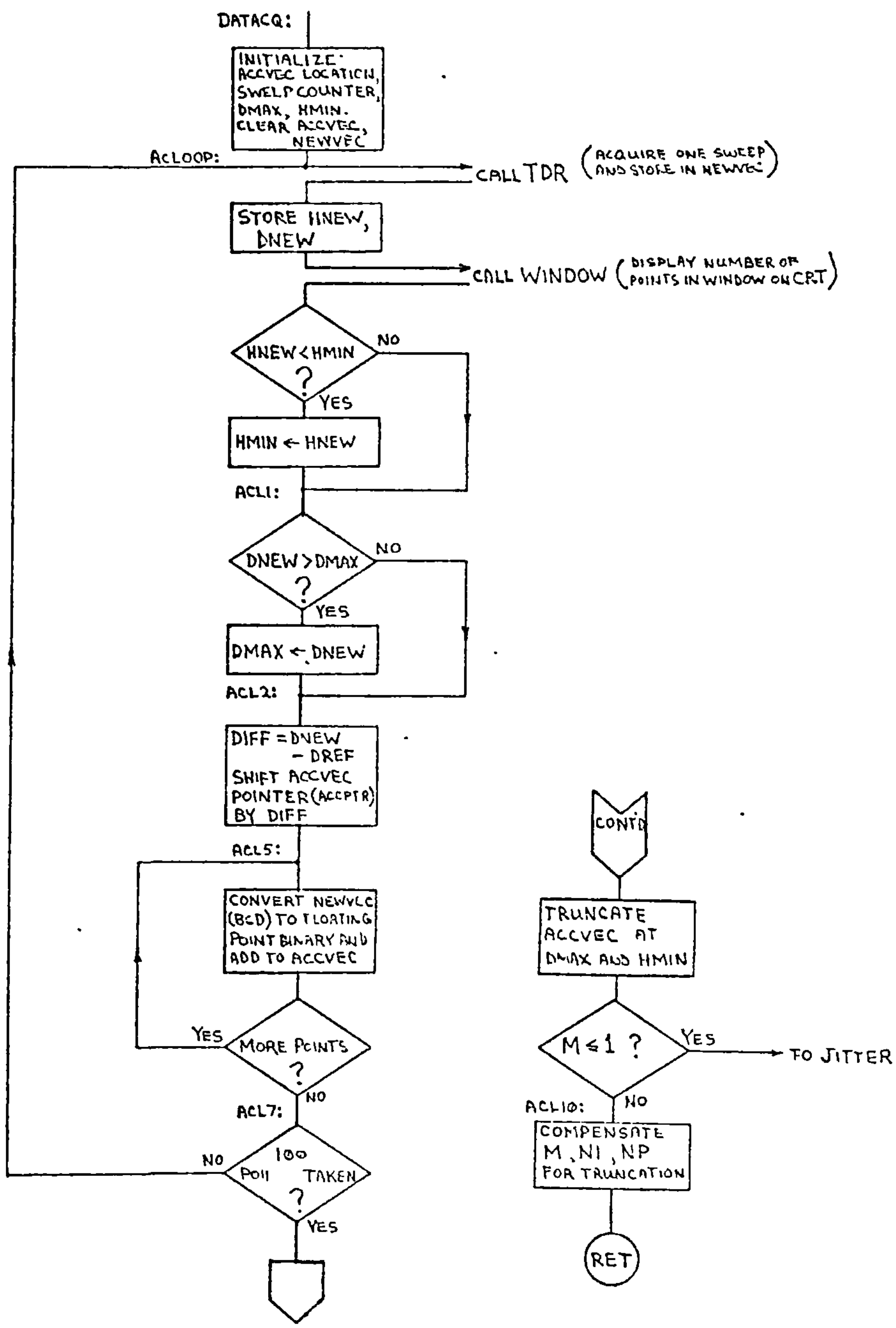
Registers modified: all

Input parameters: from A/D

Output parameters: averaged data stored

HW required: TDS system

SW required: as shown



Name: .TDP

Function: acquisition of one sweep

Subroutine nesting level: 0

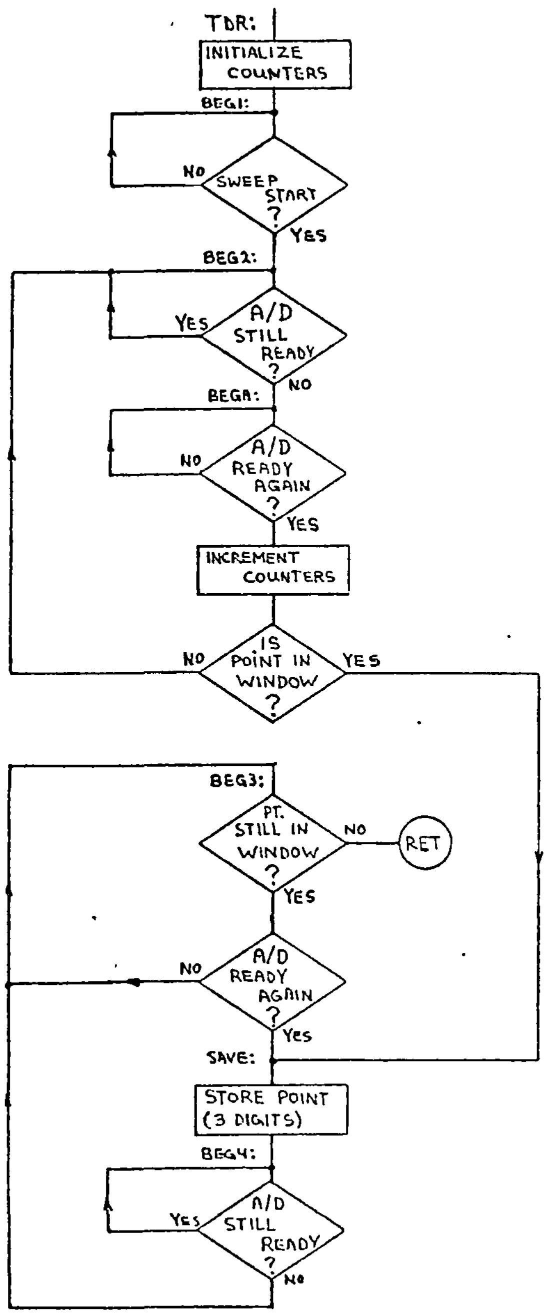
Registers modified: A,C,D,E,H,L

Input parameters: from A/D

Output parameters: data points, no. pts. in/before window

HW required: TDS system

SW required: none



Name: HILOAV

Function: feeds appropriate data to VECSUM.

Subroutine nesting level: 3

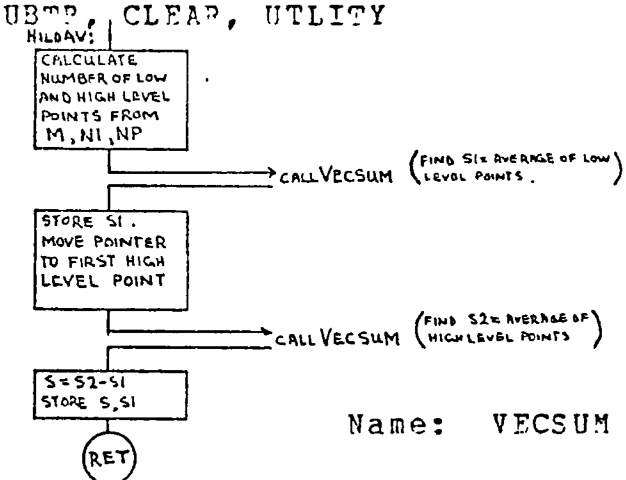
Registers modified: all

Input parameters: reference pts., averaged data

Output parameters: S1, S

HW required: none

SW required: VECSUM, SUBTR, CLEAR, UTLITY



Name: VECSUM

Function: average data between ref. pts.

Subroutine nesting level: 2

Registers modified: all

Input parameters: no. pts. on level

Output parameters: average of pts. on level (S1 or S2)

HW required: none

SW required: UTLITY

This routine sums all of the points on the given level (low or high) as designated by the reference points. The result is divided by the number of points on the level to give the average magnitude of the points on that level.

Name: REFACQ

Function: see below

Subroutine nesting level: 2

Registers modified: A,C,D,E,H,L

Input parameters: no. pts. in window

Output parameters: stored reference point

HW required: TDS system

SW required: TDR, WINDOW

This routine displays the number of points between the cursors. After calling TDR, (HL) is the address of the point after the last point acquired in that sweep. WINDOW uses this information, together with the starting address of NEWVEC, to calculate the number of points in the window. This number of points in the window is stored as the reference point in REFPT and subsequently moved to its designated storage location.

Name: SUBTR

Function: see below

Subroutine nesting level: 0

Registers modified: A,H,L

Input parameters: (HL),(DE)

Output parameters: (HL)

HW required: none

SW required: none

This short routine subtracts the contents of DE from the contents of HL and puts the result in HL. ie.(HL)=(HL)-(DE)

Name: BLANK

Function: see below

Subroutine nesting level: 0

Registers modified: A,D,E,H,L

Input parameters: bounds of area to be cleared

Output parameters: none

HW required: none

SW required: none

This routine clears memory locations from location (HL) to location (DE)

Name: WINDOW

Function: see below

Subroutine nesting level: 1

Registers modified: A

Input parameters: upper bound of NEWVEC

Output parameters: no. pts. in window

HW required: none

SW required: PRTHL

This routine subtracts from the address of the last point in the window A800H (lower bound of NEWVEC area) and divides the result by 2 and adds 1 to get the number of points between the cursors inclusive. (There are two bytes required to store each point, hence division of the difference in addresses by 2). This result is stored in REFPT and also converted to decimal and displayed on the CRT.

Name: BCDBIN

Function: see below

Subroutine nesting level: 0

Registers modified: all

Input parameters: 3 digit BCD no. in HL

Output parameters: binary equivalent of above

HW required: none

SW required: none

This is a fast conversion routine from BCD to binary. It can take up to a 3 digit BCD number in HL and convert it to its binary value and put the result back in HL. The short listing is heavily documented thus making a flowchart superfluous.

Name: FRQDOM

Function: see below

Subroutine nesting level: 6

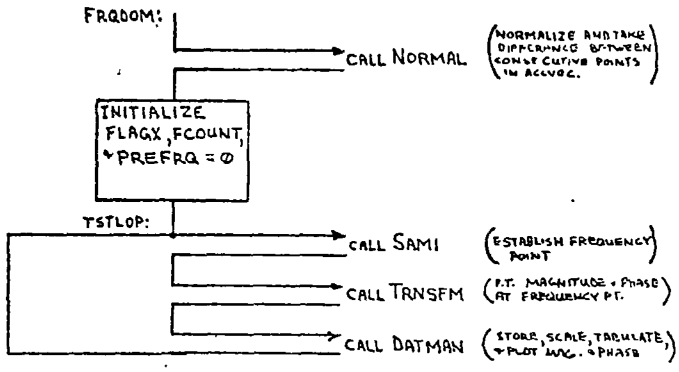
Registers modified: all

Input parameters: averaged data, S, S1, DIST

Output parameters: FT of input data

HW required: SBC-310

SW required: as shown



This routine supervises normalization and Fourier transformation of the contents of ACCVEC.

Name: DATMAN

Function: plot, output, and store FT of input data

Subroutine nesting level: 3

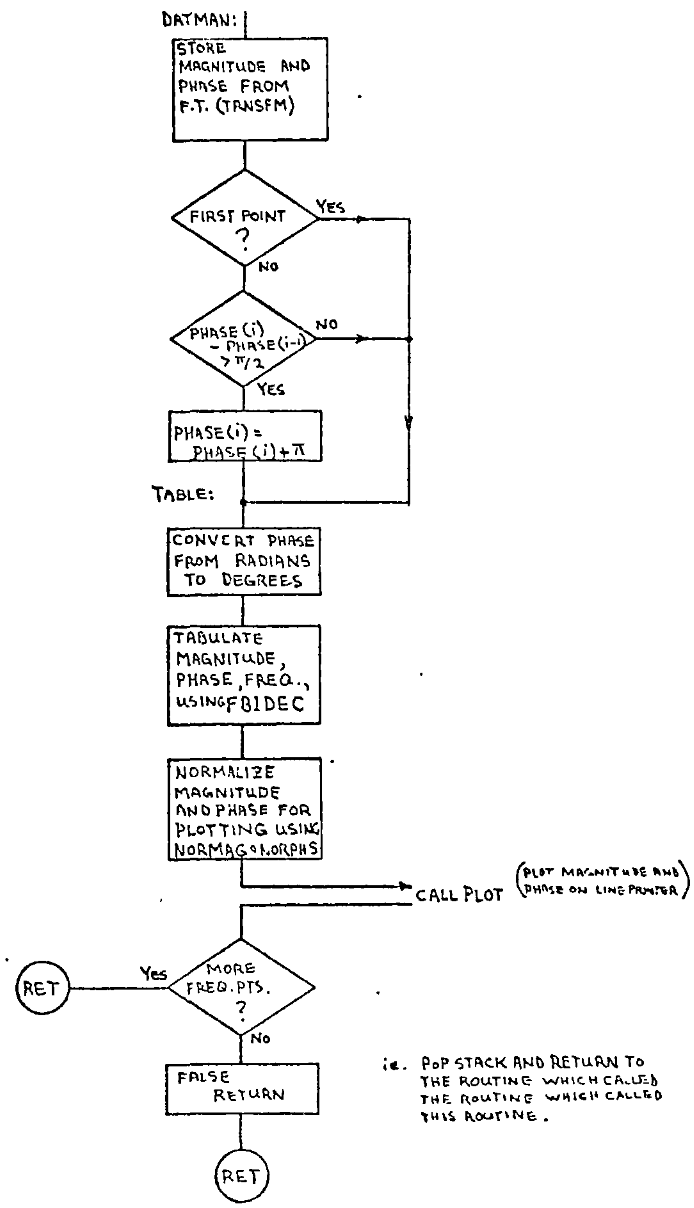
Registers modified: all

Input parameters: storage buffer addresses, MAG, PHASE

Output parameters: magnitude & phase of FT

HW required: SBC-310

SW required: NORMAG, NORPHS, FBIDEC, PLOT, UTLITY



Name: NORMAG

Function: see below

Subroutine nesting level: 2

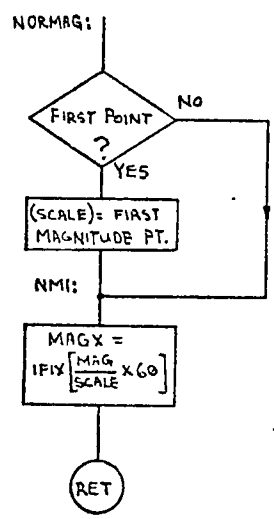
Registers modified: A,D,E,H,L

Input parameters: MAG, FLAGX

Output parameters: MAGX (scaled magnitude)

HW required: SBC-310

SW required: UTLITY



The first point is assumed to be the greatest in magnitude. This assumption is valid for our purposes, but for general purpose spectrum analysis, it would have to be changed. By assuming the first point to be the greatest in magnitude, each subsequent point can be scaled and plotted as it is calculated. Since the frequency domain points are stored anyway, they could be scanned later and scaled with respect to the maximum. (Use EPSLOP and PLTNRM). This would leave a pause of between 3 to 12 minutes before MDS 800 begins to output data.

Name: NORPHS

Function: see below

Subroutine nesting level: 2

Registers modified: A,D,E,H,L

Input parameters: PHASE

Output parameters: PHASX

HW required: SBC-310

SW required: UTLITY

PHASX= IFIX ((PHASE+180)/6)

The quantity PHASE from TRNSFM should lie between -180 degrees and 0 degrees. The scale of the plot routine is from 0 to 60 inclusive, and, for the phase plot, maps onto the range from -180 to +180 degrees. The 360 degree range in a 60 space scale yields 6 degrees per space, hence the 6 in the denominator. The + 180 degrees in the numerator simply shifts the value of the phase (PHASE) so that it is a positive integer for the plot scale.

Name: GAMMA

Function: calculate reflection coefficient

Subroutine nesting level: 4

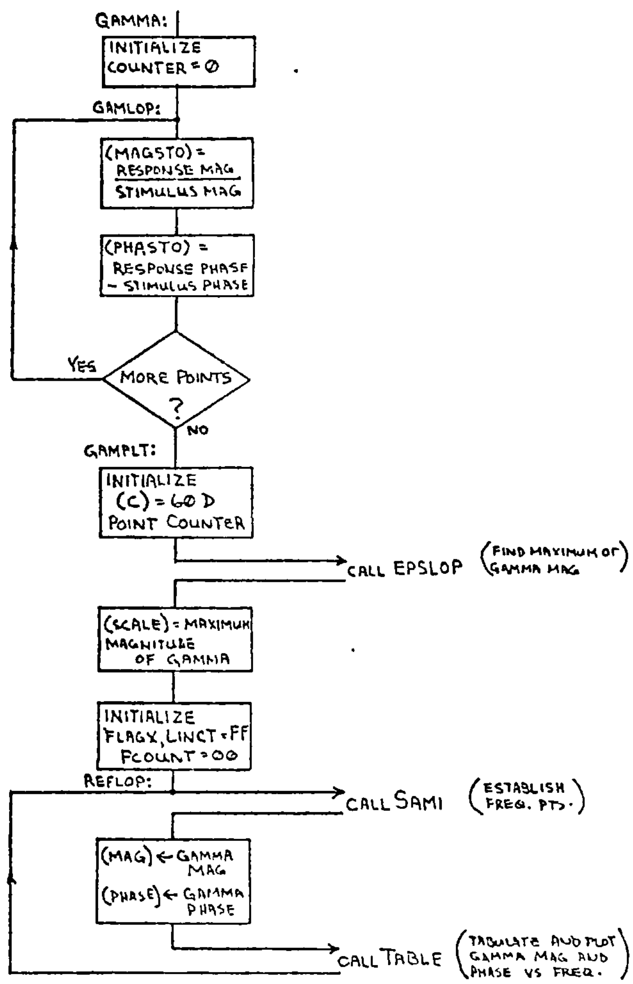
Registers modified: all

Input parameters: stimulus & response buffer addrs.

Output parameters: magnitude & phase ot gamma

HW required: SBC-310

SW required: as shown, UTLITY



Name: EPSLON

Function: calculate epsilon

Subroutine nesting level: 3

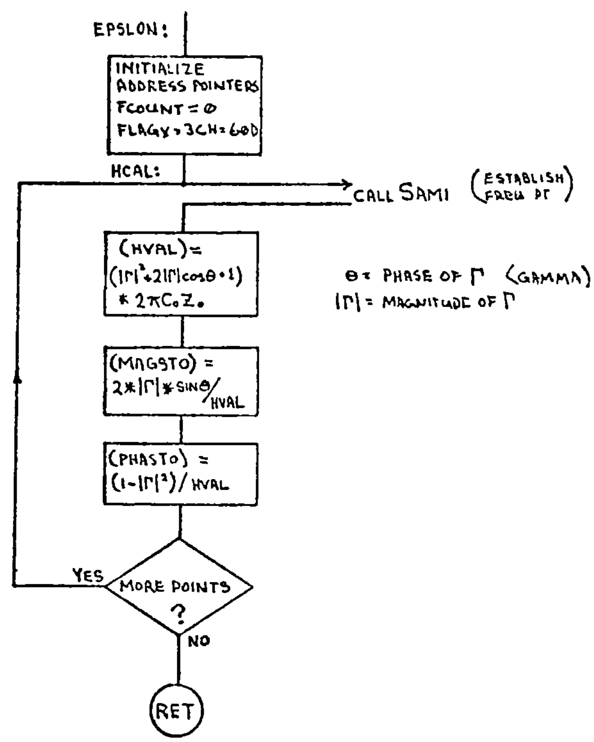
Registers modified: all

Input parameters: gamma buffer addresses

Output parameters: ε', ε''

HW required: SBC-310

SW required: as shown, UTLITY



Name: AMBIG

Function: set 0.LE.PHASE.LE.180

Subroutine nesting level: 1

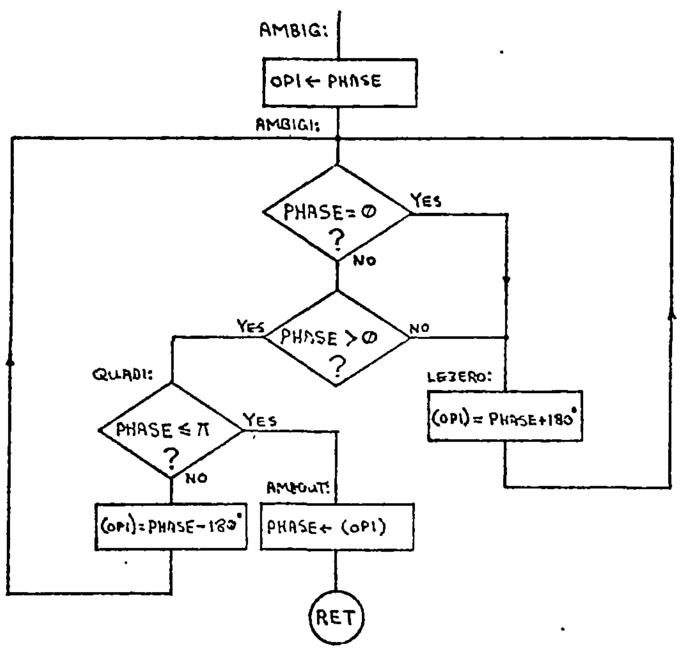
Registers modified: all

Input parameters: PHASE

Output parameters: corrected PHASE

HW required: SBC-310

SW required: UTLITY



Name: EPLOT

Function: plot & print epsilon

Subroutine nesting level: 3

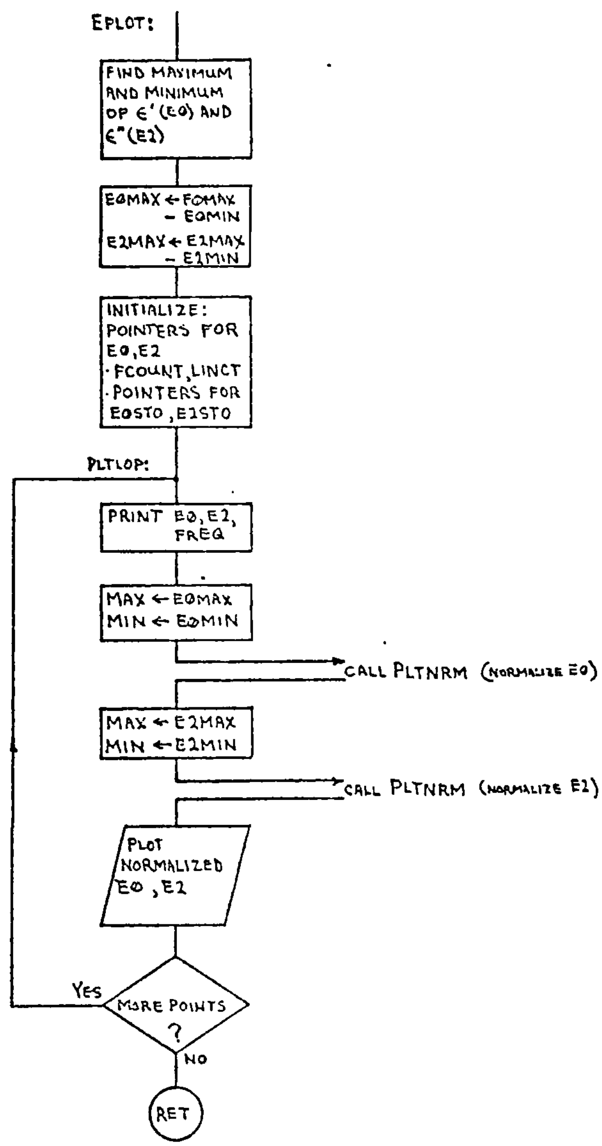
Registers modified: all

Input parameters: epsilon buffer addresses

Output parameters: epsilon

HW required: SBC-310

SW required: EPSLOP, UTLITY, PLTNRM, FBIDEC, SPACE9



Name: PLTNPM

Function: see below

Subroutine nesting level: 2

Registers modified: A,D,E,H,L

Input parameters: operand in OP1

Output parameters: normalized operand

HW required: SBC-310

SW required: UTLITY

This is a routine which updates the given address pointer and saves it in (FUNCTY), then normalizes the magnitude of the given point with respect to the maximum and minimum values of its set. ie. point=IFIX((pt.-MIN)/(MAX-MIN)*60)

Name: EPSLOP

Function: find maximum & minimum of data set

Subroutine nesting level: 2

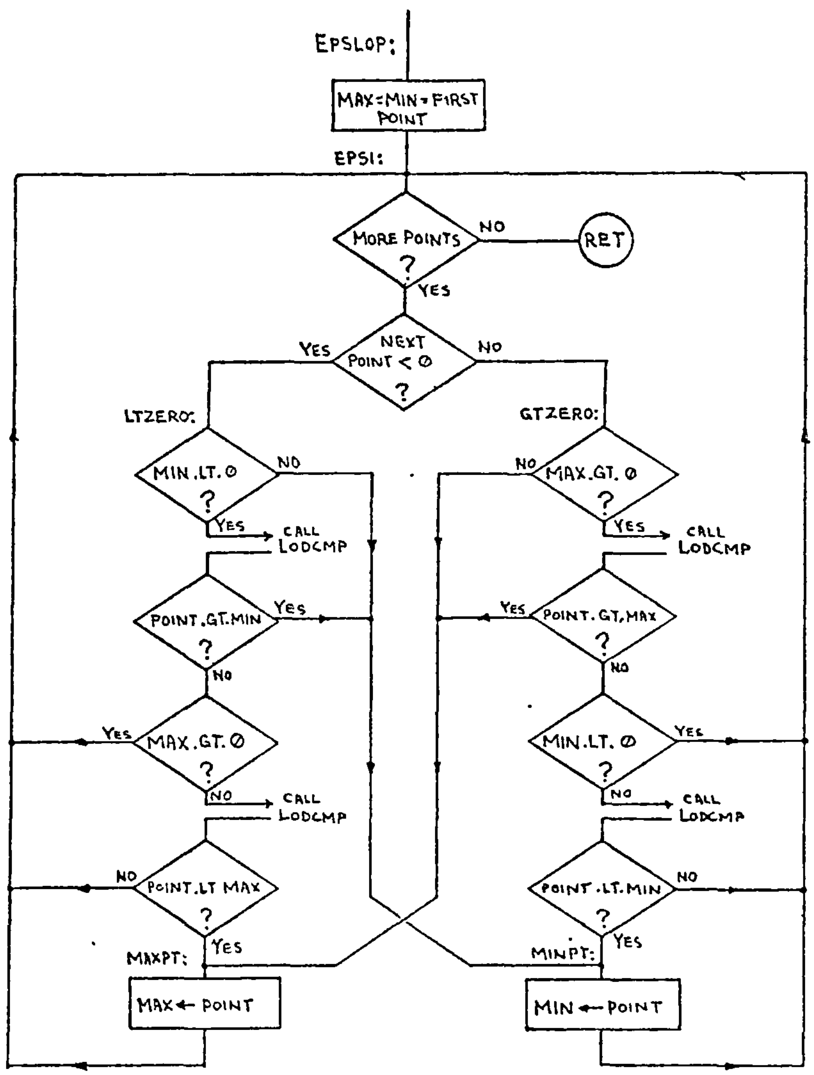
Registers modified: all

Input parameters: data set address

Output parameters: MAX, MIN

HW required: SPC-310

SW required: UTLITY, LODCMP



EPSLOP simply scans a 60 point buffer to locate the maximum and minimum points, which it stores in (MAX) and (MIN) respectively. This routine could have been much simpler had it not been for an annoying discrepancy in the hardware math unit (SBC-310). The problem is that although the FCMPR function works well for values of OP1 and OP2 being (+,+),(+,-), or (-,+), it does not work for (-,-). That is to say, the FCMPR actually compares the absolute values of the two operands when both are negative. This gives rise to the relatively cumbersome routine necessary for finding the maximum and minimum of a set of points which can have both positive and negative elements, or all positive or all negative elements.

Actually, ε' and ε'' should never be negative theoretically speaking. However, the normalization being the way it is, (average low and high level points) it is possible for the response to be greater than the stimulus for some of the lower frequencies where the magnitudes are very close. This implies a "gain" and thus a negative loss factor. Therefore these irregularities being a possibility, the algorithm had to account for data sets with both positive and negative numbers. For data sets guaranteed to have both positive and negative elements, the algorithm EPSLOP can be somewhat simplified. However, it was decided to implement the given algorithm in the event that for some future requirement, such a routine would satisfy all of the possibilities.

Name: COLPLT

Function: see below

Subroutine nesting level: 2

Registers modified: all

Input parameters: E0STO, E2STO buffers

Output parameters: Cole-Cole plot

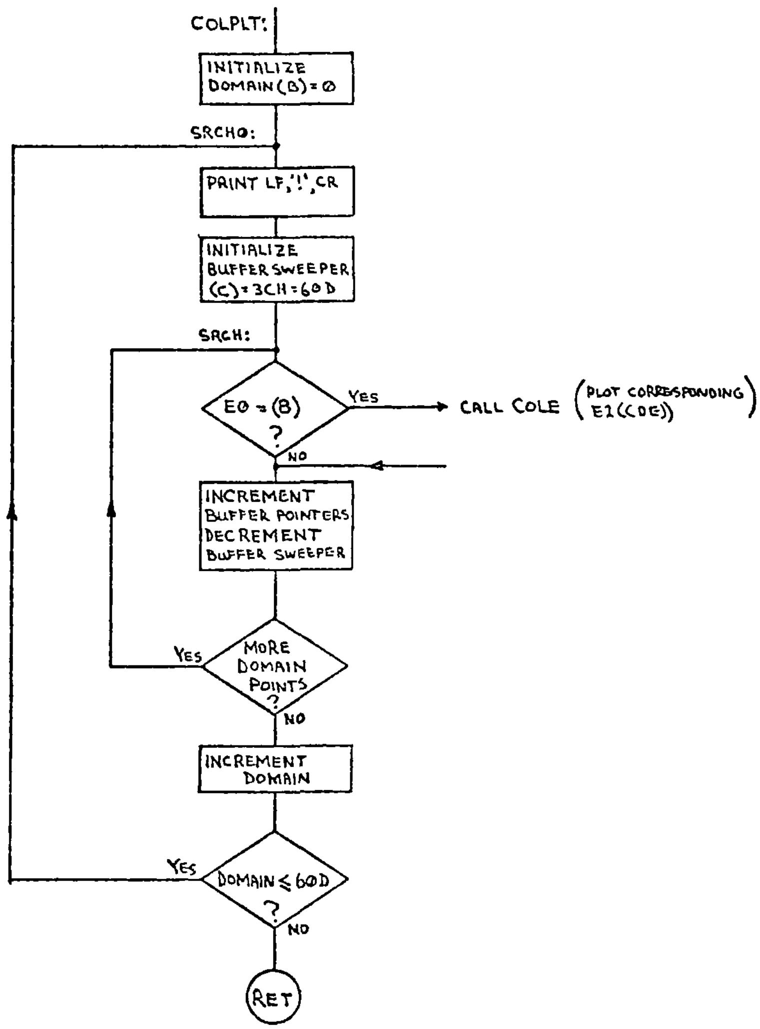
HW required: none

SW required: COLE, F80FH ((C) to LP)

This routine does not use the SBC-310 and is not a data processing algorithm. It is simply a character array plotting routine which does a job which is most easily done using a two dimensional array when using FORTRAN. ε'' is not necessarily a single valued function of ε' nor is ε' linear, thus ruling out the use of the function plotting routines (PLOT, or GRAPH).

Since this algorithm tends to be very register oriented, a more detailed flowchart is given.

Name: COLPLT


COLPLT:
INITIALIZE DOMAIN(B)=Ø
SRCHØ:
PRINT LF,'!',CR
INITIALIZE BUFFER SWEEPER (C)=3CH=60D
SRCH:
EØ=(B) ?
YES
CALL COLE (PLOT CORRESPONDING E1((DE)))
NO
INCREMENT BUFFER POINTERS DECREMENT BUFFER SWEEPER
MORE DOMAIN POINTS ?
YES
NO
INCREMENT DOMAIN
DOMAIN ≤ 6ØD ?
YES
NO
RET

Name: COLE

Function: plot one point (ε' , ε'')

Subroutine nesting level: 1

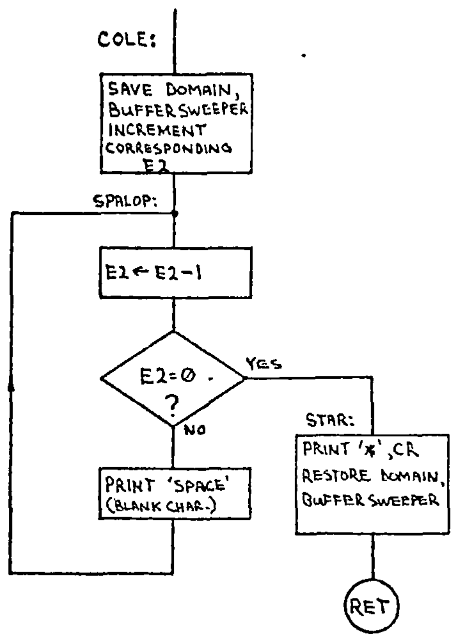
Registers modified: A,D

Input parameters: ((DE))

Output parameters: plotted point

HW required: none

SW required: F80FH ((C) to LP)



Name: SPACE9

or SPACE

Function: output space to LP

Subroutine nesting level: 1

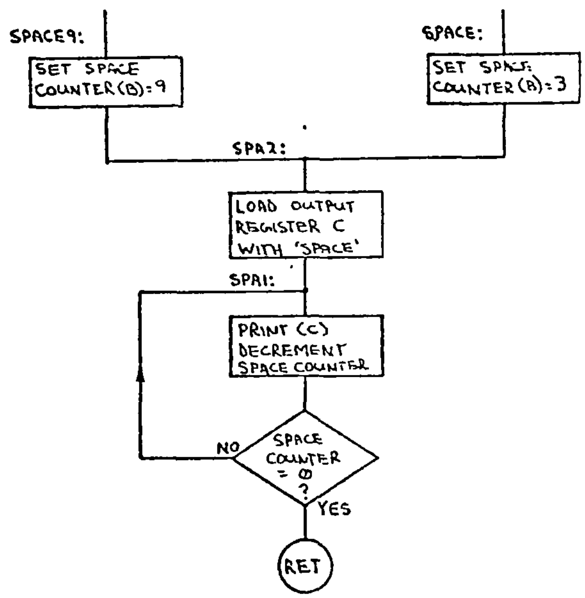
Registers modified: B,C

Input parameters: none

Output parameters: space character (20H) to LP

HW required: none

SW required: F80FH ((C) to LP)



Name: NORMAL

Function: see below

Subroutine nesting level: 3

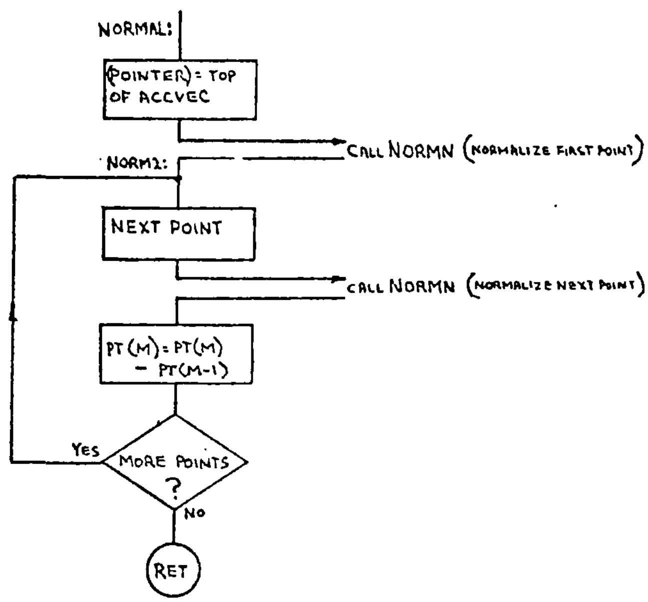
Registers modified: all

Input parameters: S, S1, buffer address

Output parameters: normalized data

HW required: SBC-310

SW required: NORMN, UTLITY



This routine takes the contents of ACCVEC and normalizes it point by point, beginning with the last point, using the routine NOPMN and quantities S and S1 from HILOAV. As each new point is normalized, the difference between normalized consecutive points is substituted for each normalized point in the fashion: P(m)=P(m)-P(m-1). This will cause the very first point in the buffer to be lost since there is no consecutive point to subtract from it. The resulting data is ready for the F.T. algorithm.

Name: NOPMN

Function: normalize one point

Subroutine nesting level: 2

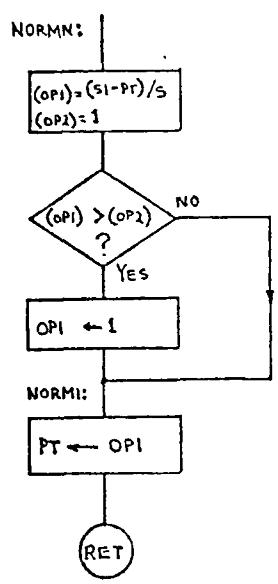
Registers modified: A,D,E,H,L

Input parameters: S, S1, raw data

Output parameters: normalized data

HW required: SBC-310

SW required: UTLITY



Name: SAM1

Function: see below

Subroutine nesting level: 2

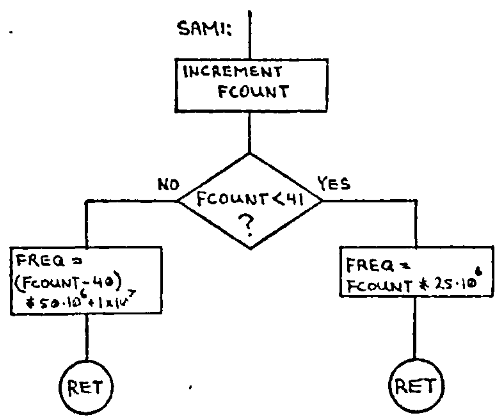
Registers modified: A,B,D,E,H,L

Input parameters: FCOUNT

Output parameters: FREQ

HW required: SBC-310

SW required: UTILITY



This routine establishes the frequency points at which the F.T. algorithm will be evaluated. It is also used simply to sweep the frequency range used, to provide a frequency scale for other parameters (eg. gamma, epsilon). The sixty point frequency scale is non linear. That is to say, the incremental frequency is 25 MHz from 25 MHz to 1.0 GHz, and 50 MHz from 1.0 GHz to 2.0 GHz.

Name: TRNSFM

Function: FT of data set for one freq. pt.

Subroutine nesting level: 4

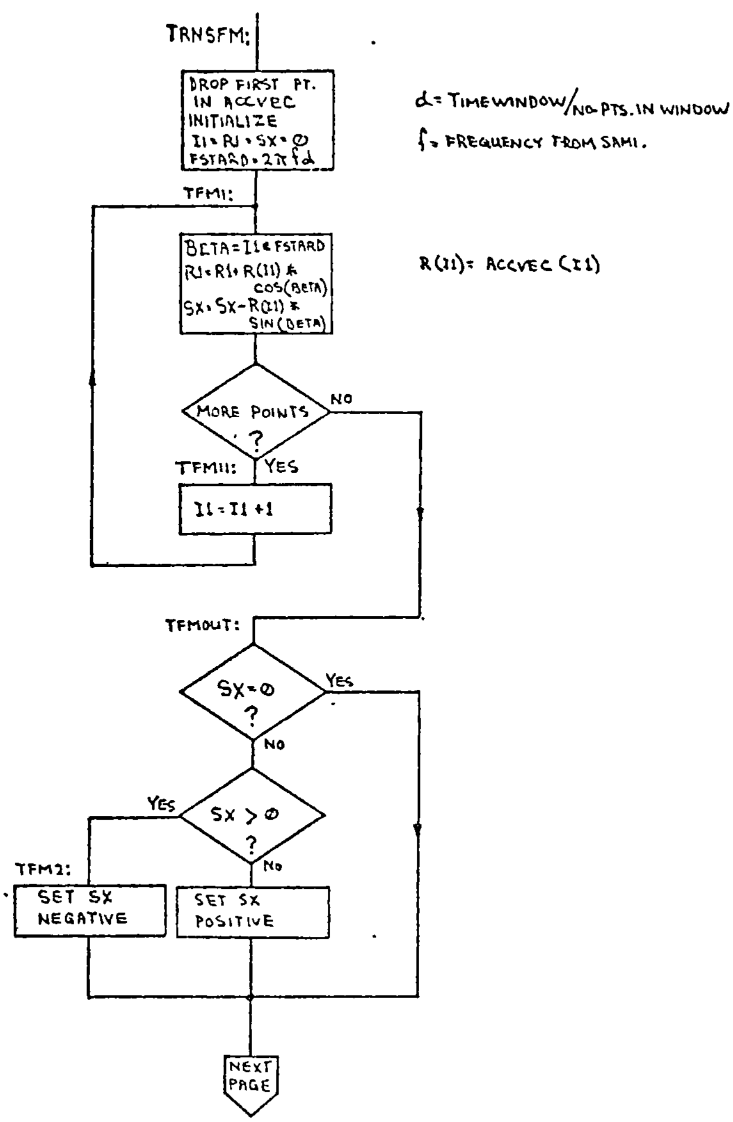
Registers modified: all

Input parameters: FREQ, DIST, data set

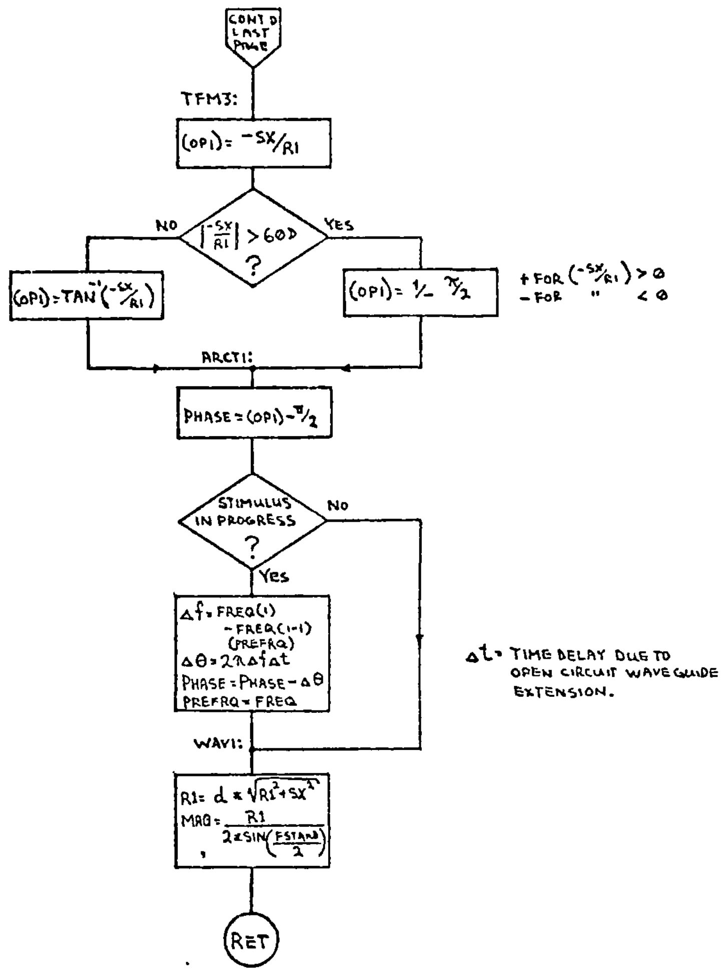
Output parameters: FT magnitude and phase

HW required: SBC-310

SW required: UTLITY, SINCOS, ATAN



Name: TRNSFM


CONT'D LAST PAGE
TFM3:
(OPI) = -SX/R1
|-SX/R1| > 60D ?
NO
YES
(OPI) = TAN⁻¹(-SX/R1)
(OPI) = +/- π/2
+ FOR (-SX/R1) > 0
- FOR " < 0
ARCT1:
PHASE = (OPI) - π/2
STIMULUS IN PROGRESS ?
NO
YES
Δf = FREQ(I) - FREQ(I-1) (PREFRQ)
Δθ = 2πΔfΔt
PHASE = PHASE - Δθ
PREFRQ = FREQ
Δt = TIME DELAY DUE TO OPEN CIRCUIT WAVEGUIDE EXTENSION.
WAV1:
R1 = d * √(R1² + SX²)
MAG = R1 / (2*SIN(FSTAN/2))
RET

Name: FBIDEC

Function: format conversion

Subroutine nesting level: 2

Registers modified: all

Input parameters: address of 32 bit binary number

Output parameters: floating point decimal equivalent to LP

HW required: SBC-310

SW required: UTLITY

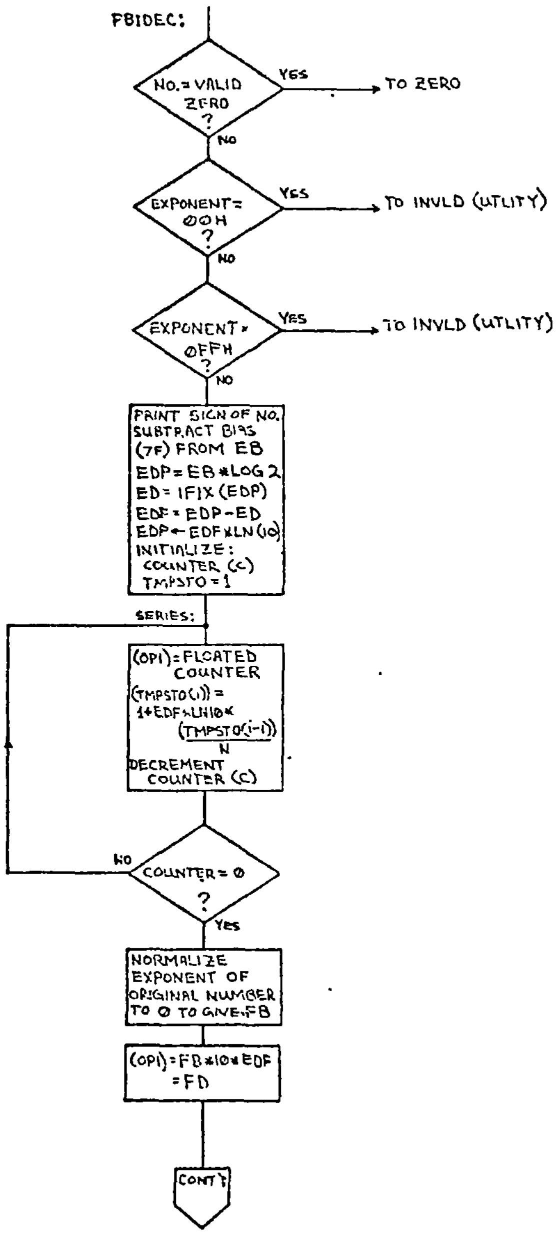
The only "trick" in this program is in the use of the SBC-310 FIXSD operation. The manual is very poor so far as proper description of the operations is concerned, thus it neglects to mention a very useful feature of this particular operation. When a mixed number, consisting of an integer component and a fraction, are expressed in the 32 bit floating point format and then converted using the FIXSD opcode, the integer portion of the quantity is found in OP1, but the remaining fraction is in OP2. The resulting format is as shown in Fig. 19. This important feature is used in FBIDEC between CONT4 and CONT6.

eg. Setting (OP1) = 2.75 (D) and executing FIXSD yeilds :

OP1+3	OP1+2	OP1+1	OP1		OP2+3	OP2+2	OP2+1	OP2
00	00	00	02	.	C0	00	00	00

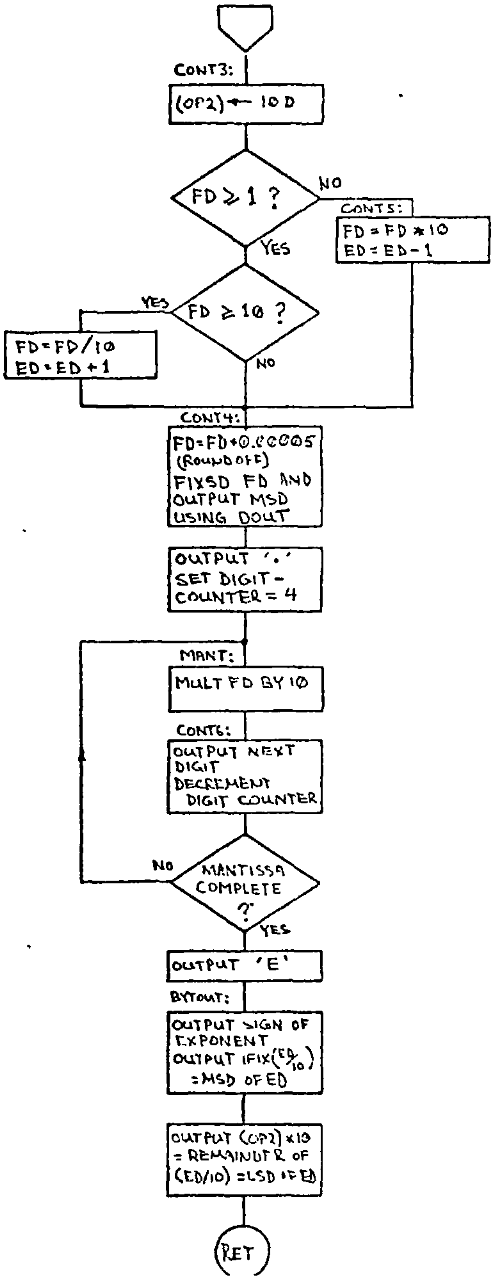
The equivalent binary fraction is 0010.1100

Figure 25 : FIXSD opcode result format



FBIDEC:
NO.= VALID ZERO ?
YES
TO ZERO
NO
EXPONENT= ØØH ?
YES
TO INVLD (UTLITY)
NO
EXPONENT= ØFFH ?
YES
TO INVLD (UTLITY)
NO
PRINT SIGN OF NO.
SUBTRACT BIAS (7F) FROM EB
EDP = EB*LOG 2
ED = IFIX (EDP)
EDF = EDP-ED
EDP ← EDF*LN(10)
INITIALIZE:
COUNTER (C)
TMPSTO = 1
SERIES:
(OP1) = FLOATED COUNTER
(TMPSTO(i)) = 1+EDF*LN10*(TMPSTO(i-1))/N
DECREMENT COUNTER (C)
NO
COUNTER = Ø ?
YES
NORMALIZE EXPONENT OF ORIGINAL NUMBER TO Ø TO GIVE FB
(OP1) = FB*10*EDF = FD
CONT'D

Name: FBIDEC


CONT3:
(OP2) ← 10 D
FD ≥ 1 ?
NO
YES
CONT5:
FD = FD * 10
ED = ED - 1
FD ≥ 10 ?
YES
NO
FD = FD/10
ED = ED + 1
CONT4:
FD = FD + 0.00005
(ROUND OFF)
FIXSD FD AND
OUTPUT MSD
USING DOUT
OUTPUT '.'
SET DIGIT-
COUNTER = 4
MANT:
MULT FD BY 10
CONT6:
OUTPUT NEXT
DIGIT
DECREMENT
DIGIT COUNTER
MANTISSA
COMPLETE
?
NO
YES
OUTPUT 'E'
BYTOUT:
OUTPUT SIGN OF
EXPONENT
OUTPUT IFIX(ED/10)
= MSD OF ED
OUTPUT (OP2) x 10
= REMAINDER OF
(ED/10) = LSD OF ED
RET

Name: FDFCBI

Function: format conversion

Subroutine nesting level: 3

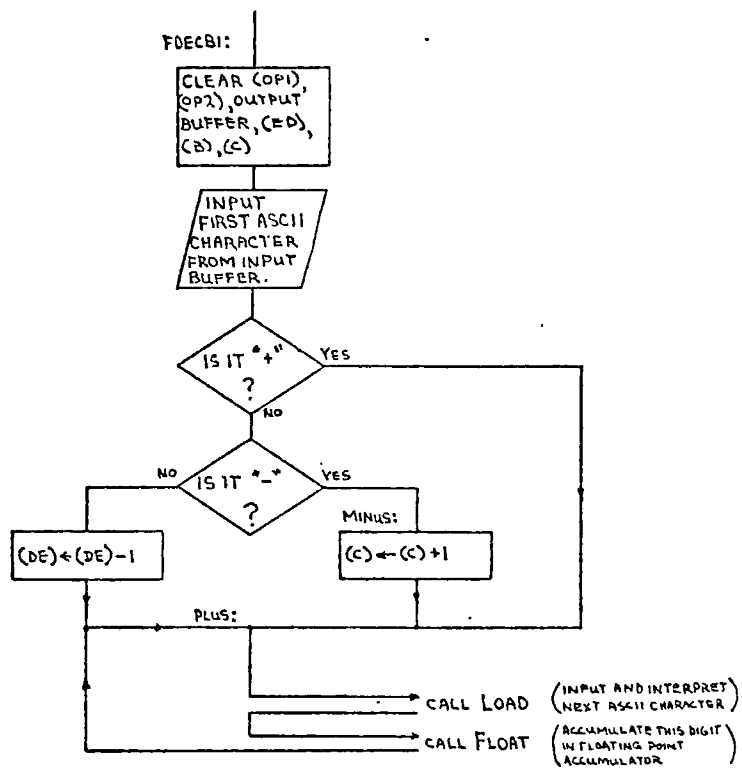
Registers modified: all

Input parameters: address of ASCII data buffer

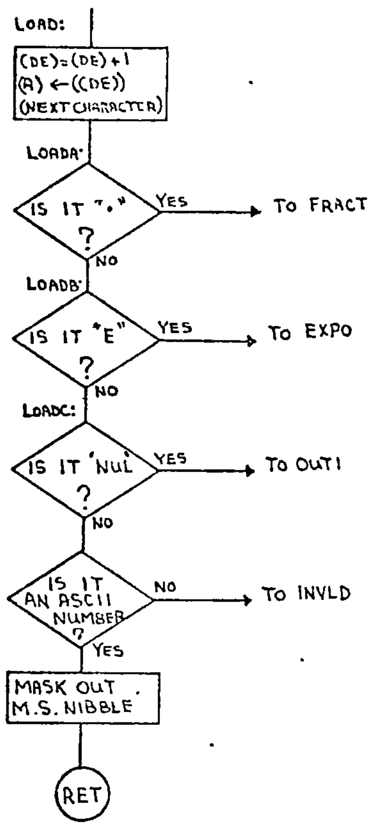
Output parameters: 32 bit floating pt. binary equivalent

HW required: SBC-310

SW required: UTLITY



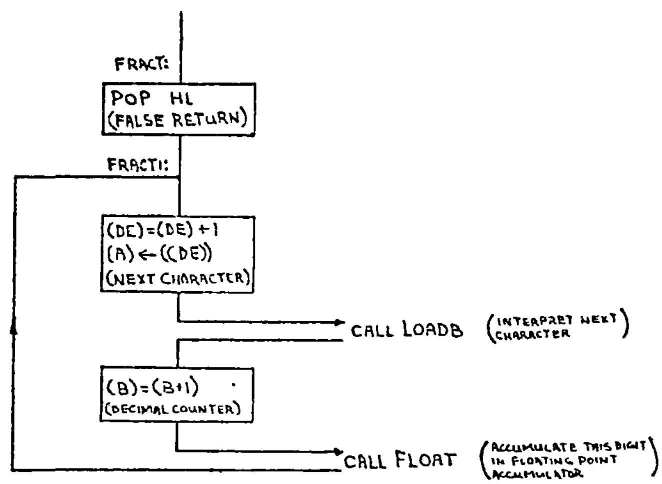
Name: FDFCBI

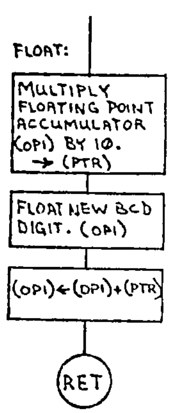

LOAD:
(DE)=(DE)+1
(A) ←((DE))
(NEXT CHARACTER)
LOADA:
IS IT "."
?
YES
To FRACT
NO
LOADB:
IS IT "E"
?
YES
To EXPO
NO
LOADC:
IS IT 'NUL'
?
YES
To OUT1
NO
IS IT AN ASCII NUMBER ?
NO
To INVLD
YES
MASK OUT M.S. NIBBLE
RET

Name: FDECBI

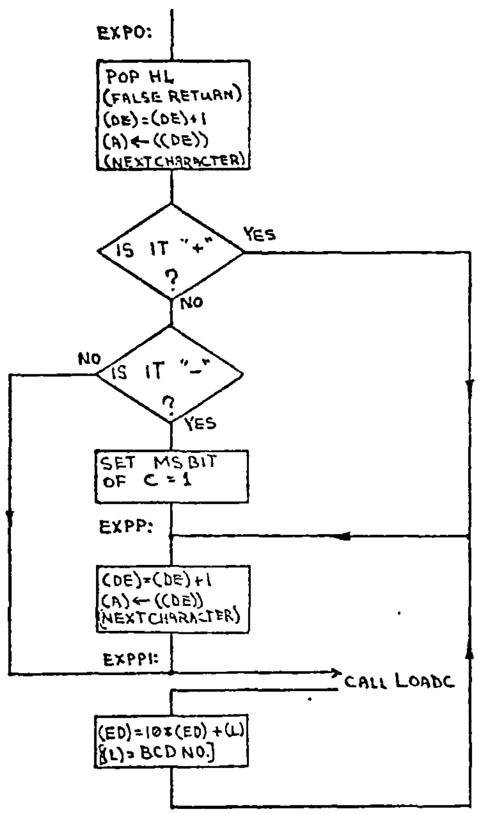
FRACT continues building up the decimal mantissa value using the significant digits given by successive calls to FLOAT. (-uses LOADP since only one "." can exist)

FLOAT simply takes each digit and accumulates a base 10 sum in 32 bit floating point format. ie. The previous sum is multiplied by 10 before the next digit is added.



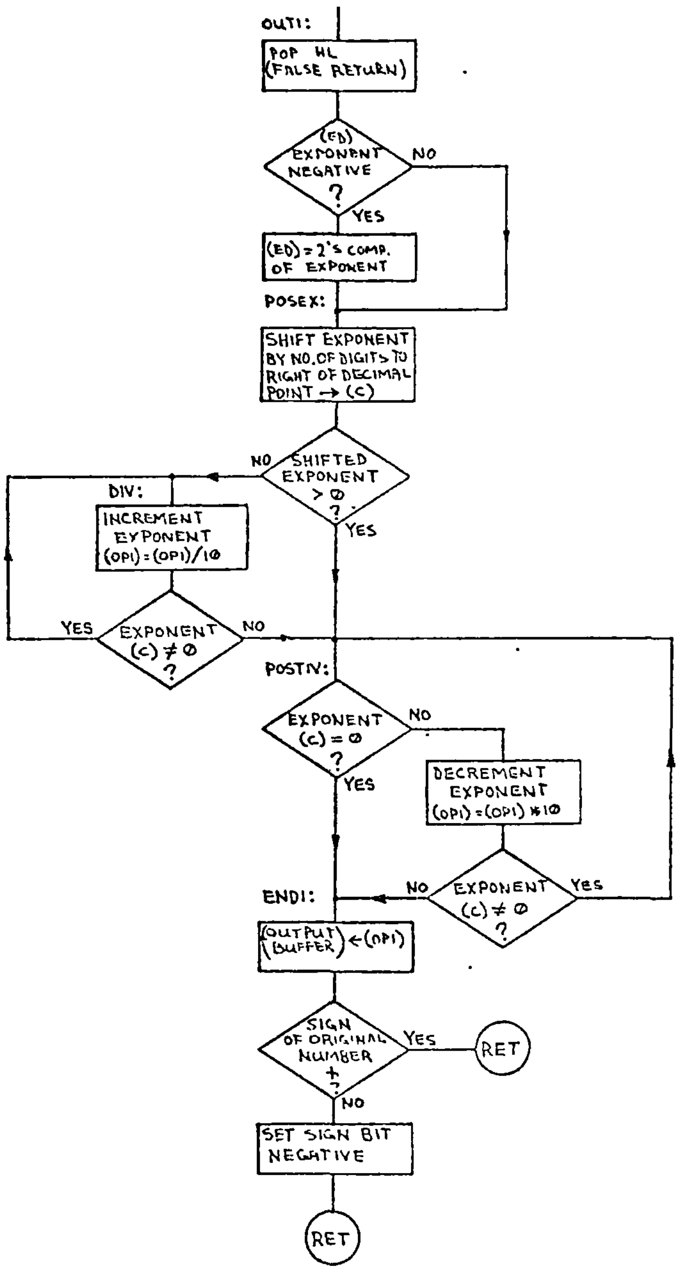


EXPO simply sums the exponent digits each time multiplying the current sum by 10 before adding the next significant digit. It is similar in principle to FLOAT, except the magnitude in this case is at most a two digit integer, thus not requiring the SBC-310.



Name: FDECBI

OUT1 checks the sign of the exponent (2's compliment if negative), shifts the decimal exponent by successive multiplications or divisions until the decimal exponent is zero, and checks the sign of the original number and sets the sign of the result accordingly.



Name: SINCOS

Function: sine, cosine of (OP1)

Subroutine nesting level: 2

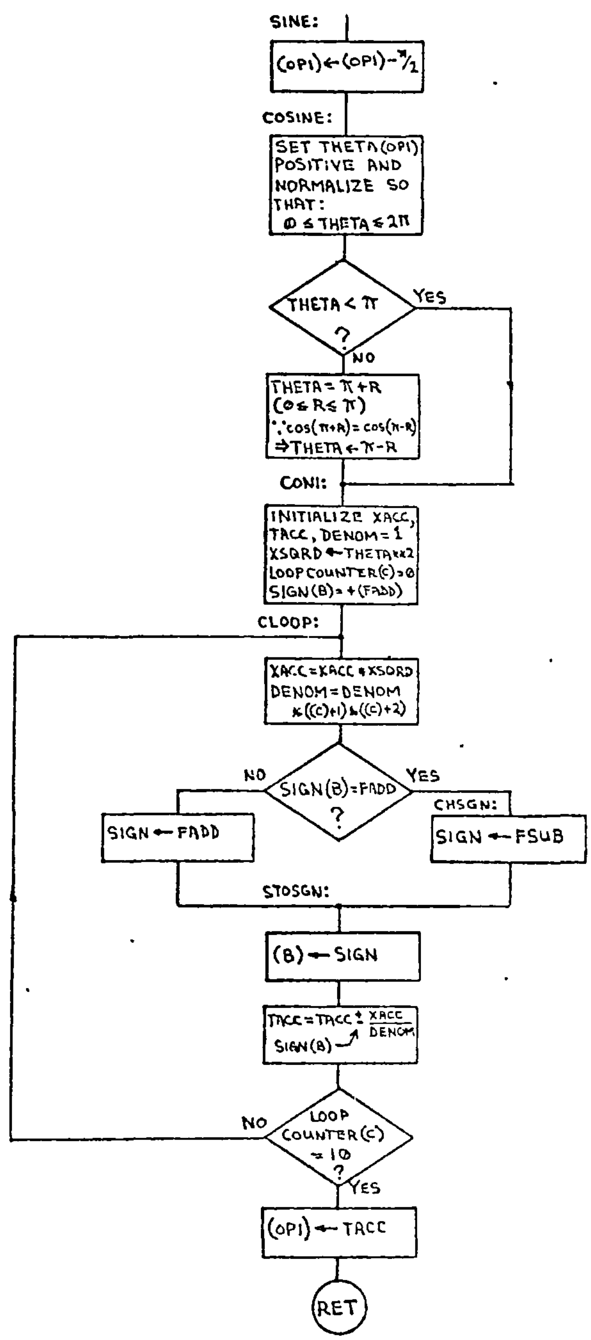
Registers modified: all

Input parameters: (OP1) in radians

Output parameters: (OP1) =sine or cosine of (OP1)

HW required: SBC-310

SW required: UTLITY



Name: ATAN

Function: arctangent of (OP1)

Subroutine nesting level: 3

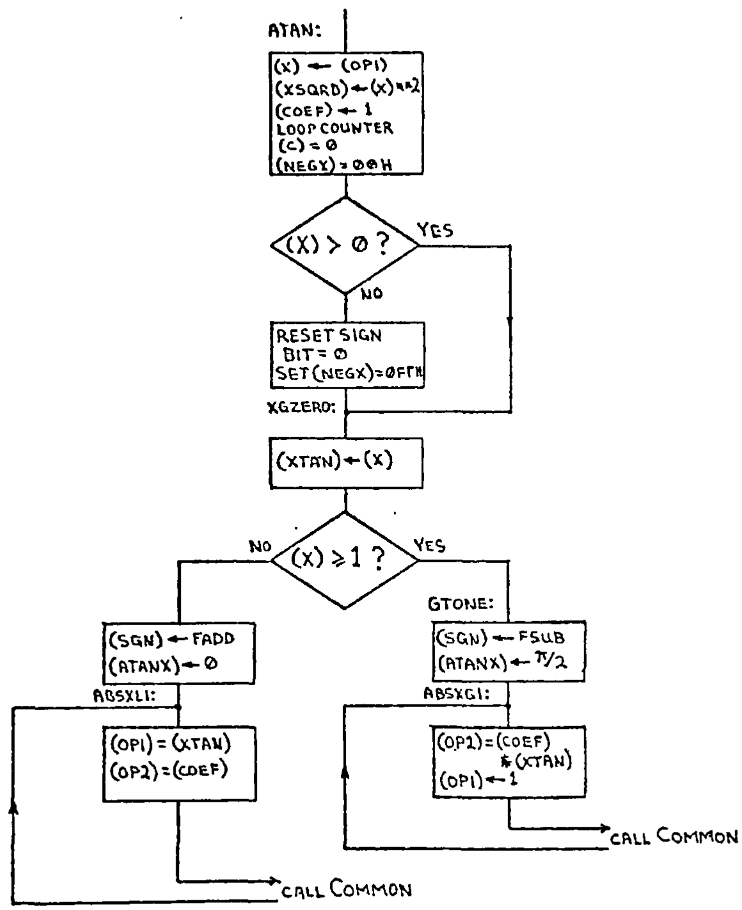
Registers modified: all

Input parameters: (OP1)

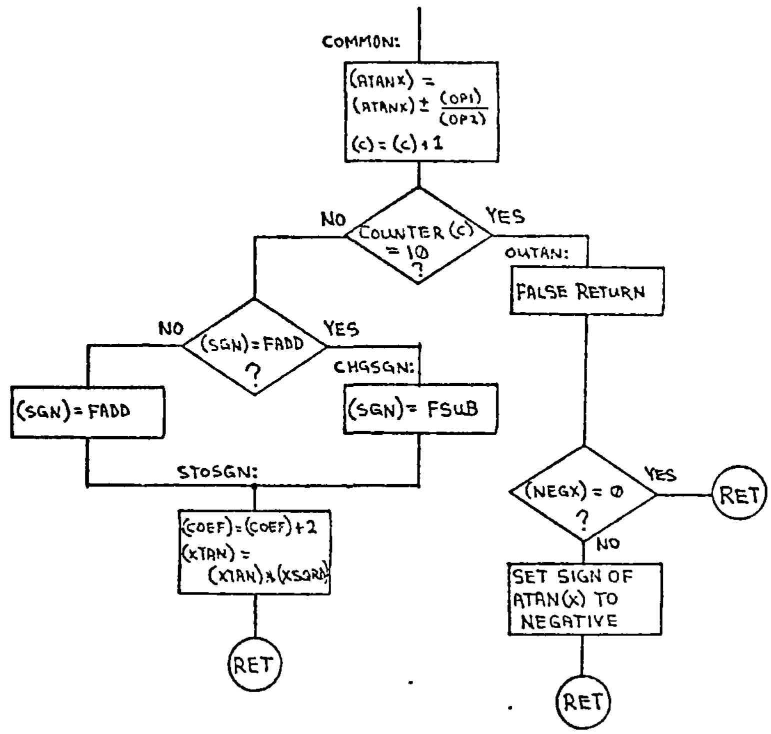
Output parameters: (OP1)= arctan(OP1) (in radians)

HW required: SBC-310

SW required: UTLITY



Name: ATAN


COMMON:
(ATANX) = (ATANX) ± (OP1)/(OP2)
(C) = (C) + 1
NO
COUNTER (C) = 10 ?
YES
OUTAN:
FALSE RETURN
NO
(SGN) = FADD ?
YES
CHGSGN:
(SGN) = FADD
(SGN) = FSUB
STOSGN:
(COEF) = (COEF) + 2
(XTAN) = (XTAN) * (XSQR)
RET
(NEGX) = 0 ?
YES
RET
NO
SET SIGN OF ATAN(X) TO NEGATIVE
RET

Name: PLOT

Function: plot 2 functions on same axes

Subroutine nesting level: 1

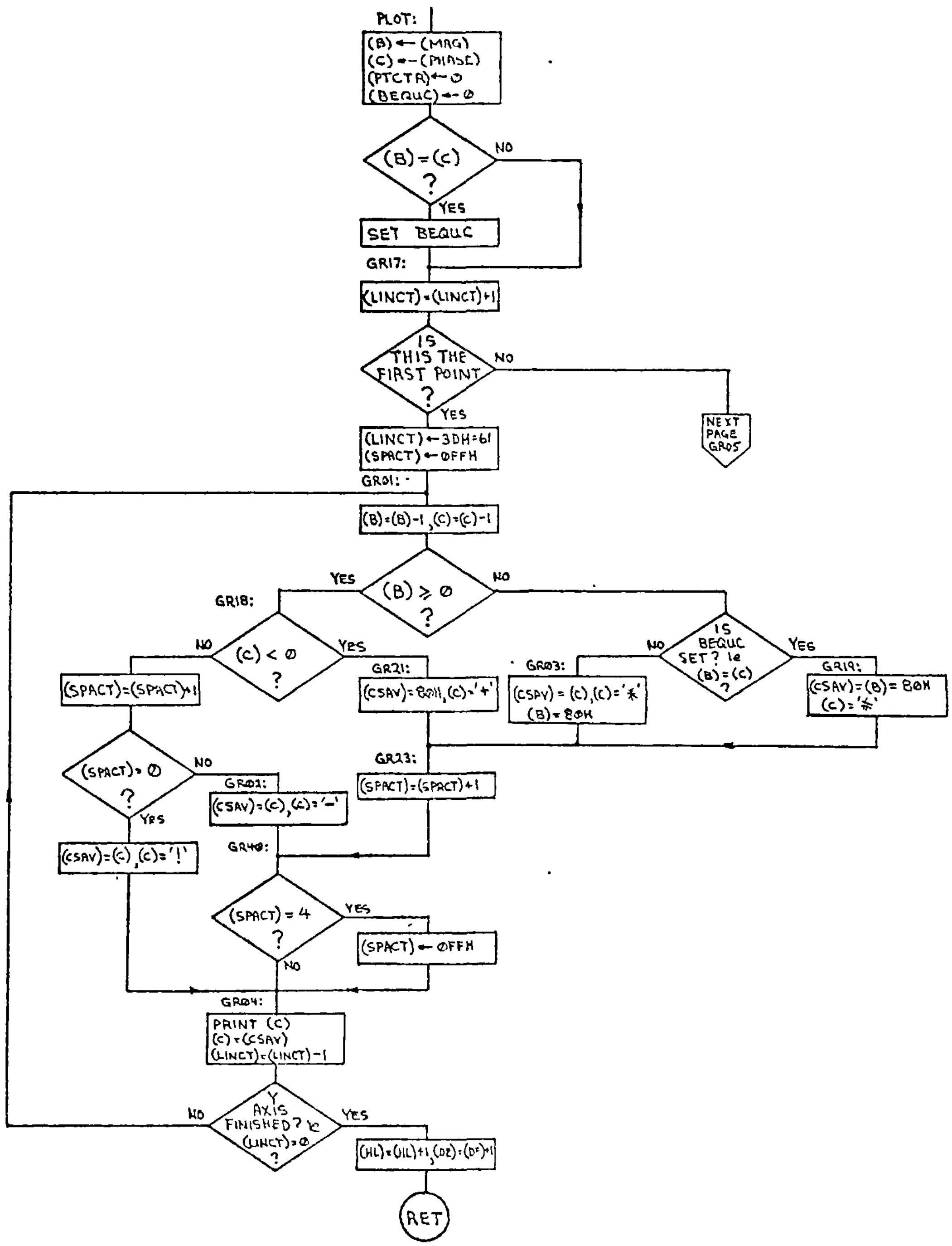
Registers modified: all

Input parameters: (HL),(DE) contain buffer addresses

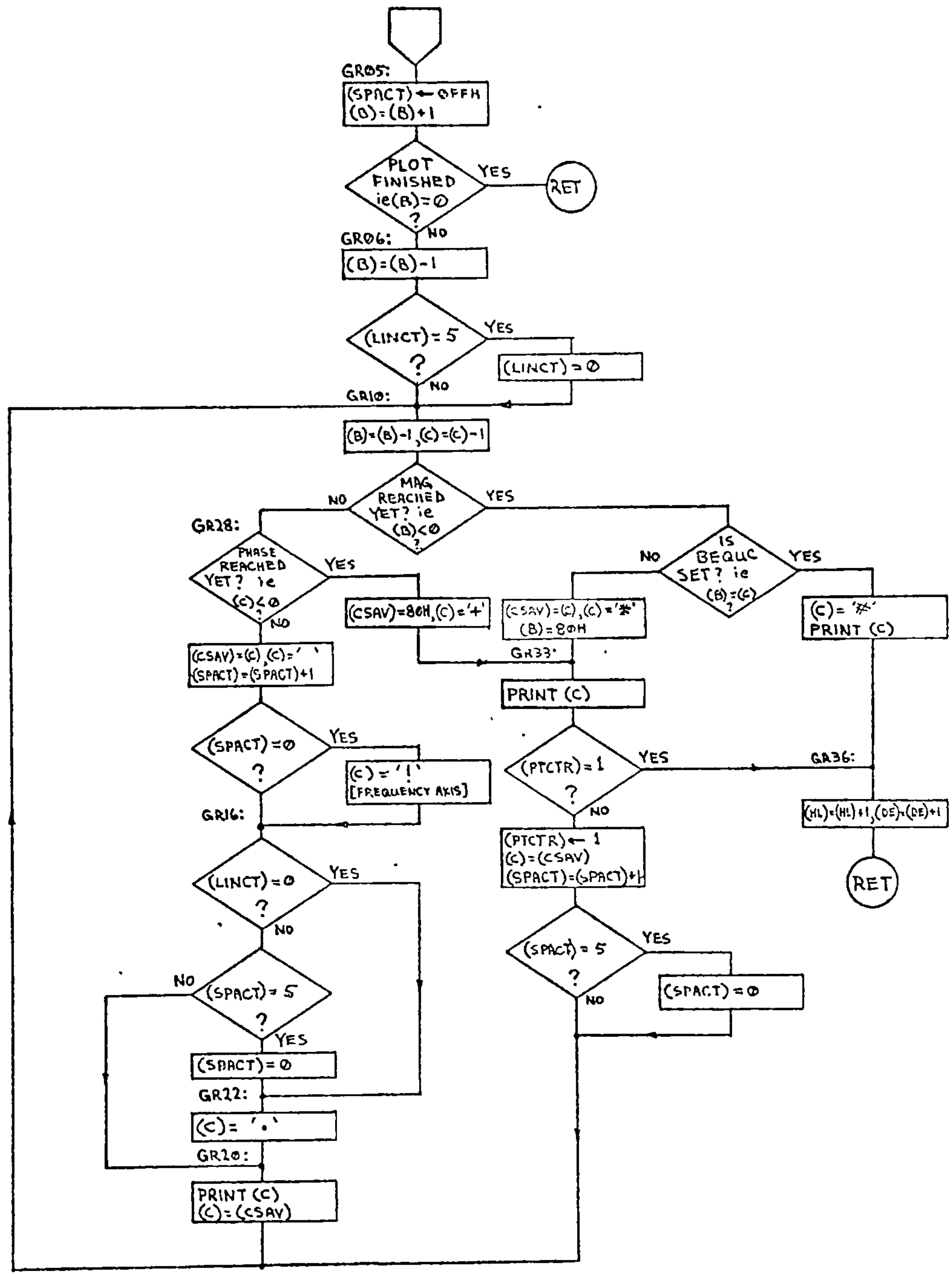
Output parameters: a 2 function plot on LP

HW required: none

SW required: F80FH ((C) to LP)



Name: PLOT


GR05:
(SPACT) ← 0FFH
(B) = (B)+1
PLOT FINISHED ie (B) = 0 ?
YES
NO
RET
GR06:
(B) = (B)-1
(LINCT) = 5 ?
YES
(LINCT) = 0
NO
GR10:
(B) = (B)-1, (C) = (C)-1
MAG REACHED YET? ie (B)<0 ?
NO
YES
GR28:
PHASE REACHED YET? ie (C)<0 ?
YES
NO
(CSAV) = 80H, (C) = '+'
IS BEQUC SET? ie (B) = (C) ?
NO
YES
(CSAV) = (C), (C) = '*'
(B) = 80H
(C) = '#'
PRINT (C)
(CSAV) = (C), (C) = ' '
(SPACT) = (SPACT)+1
GR33:
PRINT (C)
(SPACT) = 0 ?
YES
(C) = '!'
[FREQUENCY AXIS]
(PTCTR) = 1 ?
YES
GR36:
NO
(HL) = (HL)+1, (DE) = (DE)+1
GR16:
(PTCTR) ← 1
(C) = (CSAV)
(SPACT) = (SPACT)+1
RET
(LINCT) = 0 ?
YES
NO
(SPACT) = 5 ?
YES
NO
(SPACT) = 0
(SPACT) = 5 ?
NO
YES
(SPACT) = 0
GR22:
(C) = '.'
GR20:
PRINT (C)
(C) = (CSAV)

Appendix C

PROGRAM LISTINGS

```
ISIS-II 8080/8085 MACRO ASSEMBLER, V2.0        MODULE   PAGE   1

 LOC  OBJ         SEQ        SOURCE STATEMENT

                    1 ;NAME  SPECTR
                    2 ;THIS IS THE MAIN SYSTEM PROGRAM WHICH
                    3 ;CALLS FILES IN SPECTR LIB
 0002               4 FMUL    EQU     2
 0003               5 FDIV    EQU     3
 0004               6 FADD    EQU     4
 0005               7 FSUB    EQU     5
 0006               8 FSQR    EQU     6
 0007               9 FSQRT   EQU     7
 0008              10 FLTDS   EQU     8H
 0009              11 FIXSD   EQU     9H
 000A              12 FCHSP   EQU     0AH
 000B              13 FZTST   EQU     0BH
 000F              14 ECH     EQU     0FH
 C100              15 OP1     EQU     0C100H
 C104              16 OP2     EQU     OP1+4
 0040              17 IOBAS   EQU     40H
 0003              18 ETX     EQU     3
 FD13              19 CPTOUT  EQU     0FD13H
 FE7A              20 FPTHL   EQU     0FE7AH
 FE21              21 DBYTE   EQU     0FE21H  ;(HL)TO ASCII ON LIST DEV
 FD93              22 LPT     EQU     0FD93H
 F90C              23 CI      EQU     0F90CH   CONSOLE INPUT
                   24
                   25 ASEG
 0018              26         ORG     18H
 0018 F3           27         DI
 0019 C30022   C   28         JMP     KEYIN   ;KEYBOARD INPUT ROUTINE
                   29
                   30 CSEG
                   31 STKLN   100     ;MAXIMUM STACK DEPTH
                   32 EXTRN   COLFLT,GAMMA,EPSLON,EPLOT
                   33 EXTRN   TEP,WAIT,ACCLOC,ACCFTR
                   34 EXTRN   LOPI,CLEAR,FDECBI,LOADX,LOADY
                   35 EXTRN   PEPAIR,WINDOW,MSTO,M1STO,DATACO
                   36 EXTRN   HILOAV,FRDOUT,DREF,MPSTO
                   37 PUBLIC  KEYIN,DIST,PHASTO,MAGSTO,KEYBIG
                   38 PUBLIC  FLAG,ETIMAG,STPHAS,REEMAG,REPHAS
                   39 PUBLIC  JITTER
                   40 .
 0000 3E12         41         MVI     A,12H   ;-------------------------
 0002 D3FD         42         OUT     0FDH    ;INTERRUPT INITIALIZATION BLOCK
 0004 AF           43         XRA     A
 0005 D3FC         44         OUT     0FCH    ;INTERRUPT MASK (ENABLE ALL)
 0007 3EF0         45         MVI     A,0F0H  ;MASK OUT INT  LEV  7,6,5,4.
 0009 D3FC         46         OUT     0FCH
 000B 3EFF         47         MVI     A,0FFH  ;CLEAR  PREVIOUS INTERRUPTS
 000D D3FD         48         OUT     0FDH    ;----------------------------
 000F 310000   S   49         LXI     SP,STACK;INITIALIZE SP (STACK ASSIGNED
 0012 21E602   C   50         LXI     H,BEESUF BY LOCATE)
 0015 CD5501   C   51         CALL    XPRINT
 0018 21E902   C   52         LXI     H,BUF1
```

```
LOC  OBJ          SEQ        SOURCE STATEMENT

001B CD0101   C    53         CALL   PRINT
001E AF            54         XRA    A
001F 320100   D    55         STA    FLAG    ,INITIALIZE FLAG
0022 320000   D    56         STA    KEYSIG  ,INITIALIZE KEYSIG
0025 3A0000   D    57 BEGIN   LDA    KEYSIG
0028 FE4E          58         CPI    'N'     ,IS IT N ? (4EH)
002A CA3B00   C    59         JZ     MENUE   ,YES GO TO MENUE
002D FE59          60         CPI    'Y'     ,IS IT Y ? (59H)
002F C22500   C    61         JNZ    BEGIN   ,NO, GO TO BEGIN
0032 219007   C    62         LXI    H,INSTR ,YES, IT IS Y
0035 CD0101   C    63         CALL   PRINT   ,PRINT INSTRUCTIONS ON CONSOLE
                   64
003B 310000   S    65 MENUE   LXI    SP,STACK         ,CLEAN UP STACK FOR EACH PHASE
003E 21F505   C    66         LXI    H,MENBUF
003E CD0101   C    67         CALL   PRINT   ,MENUE LIST
0041 AF            68         XRA    A
0042 320000   D    69         STA    KEYSIG  ,CLEAR KEYSIG BUFFER
0045 3A0000   D    70 MEN1    LDA    KEYSIG
0048 FE53          71         CPI    'S'     ,STIMULUS ?
004A CA5500   C    72         JZ     STMULS  ,YES, GO TO STMULS
004D FE52          73 MEN2    CPI    'R'     ;RESPONSE ?
004F C24500   C    74         JNZ    MEN1    ,NO, GO TO MEN1
0052 C3E1??   C    75         JMP    RESPNS  ,YES, GO TO RESPNS
                   76
0055 3A0100   D    77 STMULS  LDA    FLAG
0058 F604          78         ORI    4       ,SET 'STIM IN PROGRESS' BIT
005A 320100   D    79         STA    FLAG
005D 2167??   C    80         LXI    H,STBUF1
0060 CD0101   C    81         CALL   PRINT   ,PRINT STIMULUS MESSAGE
0063 CDA?01   C    82         CALL   STEP    ,ACQUIRE REF POINTS AND NEWREC
0066 21??0?   C    83         LXI    H,STBUF5,TIME WINDOW REQUEST ON CONSOLE
0069 CD0101   C    84         CALL   PRINT
006C 210000   D    85         LXI    H,TIMWIN,SPECIFY BUFFER FOR TIMEIN
006F CDA?01   C    86         CALL   TIMEIN  ,INPUT TEXT FROM CONSOLE
0072 CD??01   C    87         CALL   TIMOUT  ,TIME WINDOW DATA PROCESSED
0075 21??06   C    88         LXI    H,STBUF6
0078 CDF501   C    89         CALL   XPRINT
007B 210000   D    90         LXI    H,TIMWIN,TIME WINDOW PRINTED ON PLOT
007E CDF501   C    91         CALL   XPRINT
0081 215?0?   C    92         LXI    H,PTHEAD
0084 CDF501   C    93         CALL   XPRINT
0087 21??0?   C    94         LXI    H,TERM  ,TERMINATION OF TEXT LINE FOR LP
008A CDF501   C    95         CALL   XPRINT
008D 21??F?        96         LXI    H,STIMAG,------------------------------
0090 22??1?   D    97         SHLD   MAGSTO  ,SET MAG & PHASE STORAGE IN
0093 21????        98         LXI    H,STPHAS STIMULUS AREA
0096 22??00   D    99         SHLD   PHASTO  ,------------------------------
0099 CD0000   E   100         CALL   MILCAM
009C CD0000   E   101         CALL   FRADIM
009F 3A0100   D   102         LDA    FLAG
00A2 E6FB         103         ANI    0FBH    ,RESET 'STIM IN PROGRESS' BIT
00A4 F602         104         ORI    2       ,SET 'STIMULUS TAKEN' FLAG
00A6 320100   D   105         STA    FLAG
00A9 21?10?   C   106         LXI    H,WARN1
00AC CD0101   C   107         CALL   PRINT   ,DO NOT ADJUST       WARNING
```

```
LOC  OBJ          SEQ        SOURCE STATEMENT

00AF C32600   C   108        JMP   MENUE
                  109
00B2 3A0120   D   110 RESPNS LDA   FLAG
00B5 E602         111        ANI   2       ;STIM BIT SET ?
00B7 C2C000   C   112        JNZ   RESP1   ;YES  CONTINUE
00BA 21A209   C   113 STOP   LXI   H,WARN2 ;STIM NOT TAKEN
00BD CD0100   C   114        CALL  PRINT   ;PRINT WARNING
00C0 C32600   C   115        JMP   MENUE
00C3 219F05   C   116 RESP1  LXI   H,RESUF1 PRINT INSTRUCTIONS
00C6 CD0100   C   117        CALL  PRINT
00C9 21E305   C   118        LXI   H,RESUF' HIT SPACE BAR TO INITIATE     '
00CC CD0100   C   119        CALL  PRINT
00CF CD7301   C   120        CALL  SPREAD  ;DATA ACQUIRED
00D2 211005   C   121        LXI   H,LABEL ;NAME OF MATERIAL REQUEST ON CONSOLE
00D5 CD0100   C   122        CALL  PRINT
00D8 210000   D   123        LXI   H,LASBUF SPECIFY BUFFER FOR TIMEIN
00DB CD3901   C   124        CALL  TIMEIN  ;INPUT TEXT FROM CONSOLE
00DE 3603         125        MVI   M,ETX   ;PRINT ROUTINES TERMINATION REQUIREMENT
00E0 21197D   C   126        LXI   H,RESUF2
00E3 CDF501   C   127        CALL  XPRINT  ;RESPONSE HEADING
00E6 21017A   D   128        LXI   H,TIMWIN,TIME WINDOW PRINTED ON PLOT
00E9 CDF501   C   129        CALL  XPRINT
00EC 21500F   C   130        LXI   H,PTHEAD
00EF CDF501   C   131        CALL  XPRINT
00F2 210000   D   132        LXI   H,LASBUF NAME OF MATERIAL TO LP
00F5 CDF501   C   133        CALL  XPRINT
00F8 210005   C   134        LXI   H,TERM  ;TERMINATION OF TEXT LINE FOR LP
00FB CDF501   C   135        CALL  XPRINT
00FE 2100FE       136        LXI   H,RESMAG,---------------------------
0101 220500   D   137        SHLD  MAGSTO  SET MAG + PHASE STORAGE IN
0104 2100FF       138        LXI   H,RESPHS RESPONSE AREA
0107 220400   D   139        SHLD  PHASTO  ;---------------------------
010A CD0000   E   140        CALL  FFTOUT  ;TRANSFORM AND OUTPUT
010D 21E509   C   141        LXI   H,GAMBUF,GAMMA HEADING
0110 CDF501   C   142        CALL  XPRINT
0113 21500F   C   143        LXI   H,PTHEAD
0116 CDF501   C   144        CALL  XPRINT
0119 210005   C   145        LXI   H,TERM  ;LINE TERMINATION FOR LP
011C CDF501   C   146        CALL  XPRINT
011F CD0000   E   147        CALL  GAMMA   ;CALCULATE + PLOT GAMMA
0122 CD0000   E   148        CALL  EPSILON ;EPSILON CALCULATED (EQ.E2)
0125 2100A0   C   149        LXI   H,EPSBUF
0128 CDF501   C   150        CALL  XPRINT
012B CD0000   E   151        CALL  EPLOT   ;EPSILON SCALED & PLOTTED
012E 21600F   C   152        LXI   H,COLBUF,COLE-COLE PLOT HEADING
0131 CDF501   C   153        CALL  XPRINT
0134 CD0000   E   154        CALL  COLPLT  ;COLE-COLE PLOT
0137 C32600   C   155        JMP   MENUE
                  156
013A 220000   D   157 TIMEIN SHLD  BUFBUF  ;STORE SPEC'D BUF IN BUFFER POINTER
013D 21CE0F   C   158 TIMEL  LXI   H,RETRN
0140 CD0100   C   159        CALL  PRINT
0143 2A0100   D   160        LHLD  BUFBUF  ;(H&L)=SPEC'D BUFFER BEGINNING
0146 AF           161 TIME1  XRA   A
0147 320000   D   162        STA   KEYSIG  ;KEYSIG=0
```

```
LOC  OBJ          SEQ        SOURCE STATEMENT

014A 3A0000   D   163 TIWAIT  LDA     KEYSIG  ;CHECK KEYSIG=0 ?
014D FE00         164         CPI     0       ;KEYSIG LOADED BY INTERRUPT
014F CA4A01   C   165         JZ      TIWAIT
0152 FE0D         166         CPI     0DH     ;CARRIAGE RETURN ?
0154 C8           167         RZ              ;YES, RETURN
0155 FE05         168         CPI     5       ;CTRL E ?
0157 CA1D01   C   169         JZ      TIME2   ;YES START OVER (INPUT ERROR)
015A 77           170         MOV     M,A
015B 4F           171         MOV     C,A
015C CD1CF0       172         CALL    CRTOUT  ;TO DISPLAY INPUT KEY ON CRT
015F 23           173         INX     H       ;STORE ASCII CHAR   INX MAP
0160 C34E01   C   174         JMP     TIME1
0163 AF           175 TIMOUT  XRA     A       ;CR  TIME WINDOW IS ENTERED
0164 77           176         MOV     M,A     ;STOP CRITERION FOR FDECBI
0165 23           177         INX     H
0166 EB           178         XCHG
0167 213E02   C   179         LXI     H,SECOND
016A CD0000   E   180         CALL    LOADY   ;APPEND ' SEC' 13H,0AH,0DH,ETX
016D CD0000   E   181         CALL    LOADY   ;TO TIMWIN FOR OUTPUT ON PLOT
0170 110000   D   182         LXI     D,TIMWIN
0173 210000   D   183         LXI     H,DIST  ;DESTINATION OF 32BIT OUTPUT
0176 CD0000   E   184         CALL    FDECBI
0179 210001       185         LXI     H,OP1
017C CD0000   E   186         CALL    CLEAR   ;CLEAR OP1 TO FLOAT NP
017F 2A0000   E   187         LHLD    NPSTO
0182 220001       188         SHLD    OP1
0185 3E0E         189         MVI     A,FLTDS
0187 D340         190         OUT     IO8A5   ;OP1=NO  PTS  IN CHARACTERISTIC
0189 210000   D   191         LXI     H,DIST
018C CD0000   E   192         CALL    LOP2    ;OP2=TIME WINDOW
018F 3E0F         193         MVI     A,E'CH
0191 D340         194         OUT     IO8A5
0193 CD0000   E   195         CALL    WAIT
0196 3E0C         196         MVI     A,FDIV
0198 D340         197         OUT     IO8A5
019A 210001       198         LXI     H,OP1
019D 110000   D   199         LXI     D,DIST
01A0 CD0000   E   200         CALL    LOADX   ;DIST=TIME WINDOW/NO  PTS  IN WINDOW
01A3 C9           201         RET
                  202
01A4 AF           203 STEP    XRA     A
01A5 320000   D   204         STA     KEYSIG
01A8 CD0000   E   205         CALL    REPACQ  ;ACQUIRE M
01AB 220000   E   206         SHLD    MSTO    ;STORE M(SUBSCRIPT)
01AE EB           207         XCHG
01AF 220000   E   208         SHLD    DREF    ;STORE DREF (FIRST SWEEP)
01B2 21EE04   C   209         LXI     H,STEUF2
01B5 CD0100   C   210         CALL    PRINT   ;PRINT MESSAGE
01B8 AF           211         XRA     A
01B9 320000   D   212         STA     KEYSIG
01BC CD0000   E   213         CALL    REPACQ  ;ACQUIRE M1
01BF 220000   E   214         SHLD    M1STO   ;STORE M1
01C2 21E004   C   215         LXI     H,STEUF3
01C5 CD0100   C   216         CALL    PRINT
01C8 AF           217 SPREAD  XRA     A
```

```
LOC  OBJ          SEQ         SOURCE STATEMENT

0119 320000   D   21-         STA     KEYSIG
011C 21 F05   C   219         LXI     H STELF7
011F CD1000   C   220         CALL    PRINT
0122 CD  00   E   221 STIM1   CALL    TOP      ,TO DISPLAY NO  PTS  IN WINDOW
0125 2B           222         DCX     H        ,HL =ADDR OF PT ABOVE LAST PT
0126 2B           223         DCX     H        ,IN NEW EC
0127 CD0000   E   224         CALL    WINDOW   WHILE SETTING LAST HIGH LEV  PT
012A 3A0000   D   225         LDA     KEYSIG
012D FE20         226         CPI     20H       IS IT SPACE BAR ?
012F C20101   C   227         JNZ     STIM1     NO. WAIT FOR SPACE BAR
01E2 21F00F   C   22-         LXI     H,STEUP4
01E5 CD0000   C   22-         CALL    PRINT
01E8 CD0000   E   230         CALL    DATACQ   ,ACQUIRE NEW EC
01EB C9           231         RET
                  232
01EC 210F05   C   233 JITTER  LXI     H JITEJF
01EF CD1000   C   234         CALL    PRINT
01F2 C30000   C   235         JMP     MENUE
                  236
01F5 7E           237 YPRINT  MOV     A,M
01F6 FE00         238         CPI     EOT
01F8 C8           239         RZ
01F9 4E           240         MOV     C,M
01FA CD00FD       241         CALL    LPT
01FD 23           242         INX     H
01FE C3F501   C   243         JMP     YPRINT
0201 7E           244 PRINT   MOV     A,M
0202 FE00         245         CPI     EOT
0204 C8           246         RZ
0205 4E           247         MOV     C M
0206 CD00F0       24-         CALL    CRTOUT
0209 23           24-         INX     H
020A C30102   C   250         JMP     PRINT
                  251
020D F5           252 KEYIN   PUSH    PSW
020E 3EFD         253         MVI     A 0FDH    RESET ALL BUT KEYBOARD INT
0210 D3FD         254         OUT     0FDH
0212 3E00         255         MVI     A 20H
0214 D3FD         256         OUT     0FDH     ,COMPULSARY RESTORATION OF UP LEV
0216 DBF5         257         IN      0F5H      CHECK  CONSOLE INPUT
0218 E602         25-         ANI     2        ,IS INPUT THERE ?
021A CA0000   C   25-         JZ      XIT       NO. GO TO XIT
021D 3EFF         260 KEY 4   MVI     A 0FFH
021F D3FD         2-1         OUT     0FDH      RESET ENTIRE INTERRUPT STATUS
0221 DBF4         262         IN      0F4H     ,INPUT SIGNAL FROM KEYBOARD
0223 E67F         263         ANI     7FH       MASK OUT PARITY
0225 320000   D   264         STA     KEYSIG
0228 FE01         265         CPI     1         IS IT CTRL A ?
022A C20000   C   266         JNZ     XIT       NO  GO TO  IT
022D F1           267         POP     PSW
022E E1           26-         POP     H        ,FALSE RET
022F FB           26-         EI
0230 C30000   C   270         JMP     MENUE
0233 F1           271 XIT     POP     PSW
0234 FB           272         EI
```

```
LOC  OBJ          SEQ        SOURCE STATEMENT

0235 C9           273        RET
                  274
0236 0A           275 BEGBUF: DB     0AH,0AH,0AH,0AH,0AH,0AH,0AH,0AH
0237 0A
0238 0A
0239 0A
023A 0A
023B 0A
023C 0A
023D 0A
023E 0A           276        DB     0AH,0AH,0AH,0AH,0AH,0AH,0AH,0AH
023F 0A
0240 0A
0241 0A
0242 0A
0243 0A
0244 0A
0245 0A
0246 20202020     277        DB     '              SPECTRE II',12H,0EH,09H,0AH,07H,0DH
024A 20202020
024E 20202020
0252 20205350
0256 45435452
025A 45204949
025E 12
025F 0E
0260 09
0261 0A
0262 07
0263 0D
0264 20202020     278        DB     '                 AUTOMATIC TIME DOMAIN SPECTROMETER',12H,0AH,0DH
0268 20202020
026C 20202020
0270 20202020
0274 20204155
0278 544F4D41
027C 54494320
0280 54494D45
0284 20444F4D
0288 41494E20
028C 53504543
0290 54524F4D
0294 45544552
0298 12
0299 0A
029A 0D
029B 0A           279        DB     0AH,0AH,'       DEVELOPED AT UNIVERSITY OF OTTAWA',12H,0DH
029C 0A
029D 20202020
02A1 20202044
02A5 4556454C
02A9 4F504544
02AD 20415420
02B1 554E4956
02B5 45525349
```

```
LOC  OBJ          SEQ       SOURCE STATEMENT

02B9 5459204F
02BD 46204F54
02C1 54415741
02C5 12
02C6 0D
02C7 20202020     200       DB      '       /DEVELOPPE A L UNIVERSITE D OTTAWA',12H,0AH,0DH
02CB 2020202F
02CF 44455645
02D3 4C4F5050
02D7 45204120
02DB 4C20554E
02DF 49564552
02E3 53495445
02E7 2044204F
02EB 54544157
02EF 41
02F0 12
02F1 0A
02F2 0D
02F3 20202020     201       DB      '       PAR/BY:  BRIAN PARISIEN',12H,0AH,0DH
02F7 20202050
02FB 41522F42
02FF 593A2020
0303 42524941
0307 4E205041
030B 52495349
030F 454E
0311 12
0312 0A
0313 0D
0314 20202020     202       DB      '       FOR/POUR    DR.S.S.STUCHLY',12H,0AH,0DH,ETX
0318 20202046
031C 4F522F50
0320 4F555220
0324 20202044
0328 522E532E
032C 532E5354
0330 5543484C
0334 59
0335 12
0336 0A
0337 0D
0338 03
0339 0A           203 BUF1  DB    0AH,0AH,'WOULD YOU LIKE THE INSTRUCTIONS ?  (Y/N)',0AH,07H,0DH,ETX
033A 0A
033B 574F554C
033F 4420594F
0343 55204C49
0347 4B452054
034B 48452049
034F 4E535452
0353 55435449
0357 4F4E5320
035B 3F202028
035F 592F4E29
```

```
LOC  OBJ          SEQ         SOURCE STATEMENT

0CED 0A
0CE1 07
0CE5 0D
0CE? 0D
0CE? 0A               234 STSLP1  DB      0AH,0AH,'STIMULUS ACQUISITION & PROCESSING',0AH,0DH
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
0C?? 47
0C?? 0A
0C?? 0D
0C?? 0A               235         DB      0AH,'1) INSTALL WAVEGUIDE ON VOID SAMPLE HOLDER ',0AH,0AH,0DH
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
0C?? 0D
0C?? 0A
0C?? 0D
0C?? 0D
0C?? [illegible]      236         DB      '-SET APPROPRIATE TIME BASE',0AH,0DH
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
0C?? [illegible]
0C?? 0A
0C?? 0D
0C?? [illegible]      237         DB      '-SET LEFT HAND CURSOR TO LEFT EXTREMITY OF SCALE',0AH,0DH
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
0?A? 0A
```

```
LOC  OBJ         SEQ        SOURCE STATEMENT

040A 0D
040E 2D534554     287        DB     '-SET RIGHT HAND CURSOR TO SUITABLE LAST LINE LEVEL POINT(N) ',0AH,0AH,0DH
0412 20524947
0416 48542048
041A 414E4420
041E 43555253
0422 4F522054
0426 4F205355
042A 49544142
042E 4C45204C
0432 41535420
0436 4C455645
043A 4C20504F
043E 494E5428
0442 4E29
0445 0A
0446 0A
0447 0D
0448 2D484954     288        DB     '-HIT SPACE BAR TO ENTER N ',0AH,07H,0DH
044C 20535041
0450 43452042
0454 41522054
0458 4F20454E
045C 54455220
0460 4E20
0462 0A
0463 07
0464 0D
0465 2D2D4E      289        DB     ' N',0AH,0DH,ETX
0468 0A
0469 0D
046A 03
046B 0A          291 STBUF2 DB     0AH,0AH,0DH  N IS RECORDED  0AH,0DH
046C 0A
046D 0D
046E 4E204953
0472 20524543
0476 4F52445E
047A 44
047B 0A
047C 0D
047D 2D534554     292        DB     '-SET RIGHT HAND CURSOR TO SUITABLE FIRST HIGH LEVEL POINT(NL) ',0AH,0AH,0DH
0481 20524947
0485 48542048
0489 414E4420
048D 43555253
0491 4F522054
0495 4F205355
0499 49544142
049D 4C452046
04A1 49525354
04A5 20484947
04A9 48204C45
04AD 56454C20
```

```
LOC  OBJ         SEQ        SOURCE STATEMENT

0451 5041434E
0455 5420454E
0459 13
045A 0A
045B 0A
045C 0D
045D 2D484954     292         DB     '-HIT SPACE BAR TO ENTER N1',0AH,0DH,0DH
0461 20535041
0465 43452042
0469 41522054
046D 4F20454E
0471 54455220
0475 4E31
0477 0A
0478 0D
0479 0D
047A 204E31      294         DB     ' N1',0AH,0DH,ETX
047D 0A
047E 0D
047F 03
0480 0A          295 STBUF1  DB     0AH,0AH,0DH,'N1 IS RECORDED',0AH,0DH
0481 0A
0482 0D
0483 4E312049
0487 53205245
048B 434F5244
048F 4544
0491 0A
0492 0D
0493 0A          296         DB     0AH,'-SET RIGHT HAND CURSOR TO RIGHT EXTREMITY',0AH,0DH
0494 2D534554
0498 20524947
049C 48542048
04A0 414E4420
04A4 43555253
04A8 4F522054
04AC 4F205249
04B0 47485420
04B4 45585452
04B8 454D4954
04BC 59
04BD 0A
04BE 0D
04BF 204F4620     297         DB     ' OF DESIRED CHARACTERISTIC',0AH,0DH
04C3 44455349
04C7 52454420
04CB 43484152
04CF 41435445
04D3 52495354
04D7 4943
04D9 0A
04DA 0D
04DB 2D484954     298 REBUF1  DB     '-HIT SPACE BAR TO INITIATE DATA ACQUISITION',0AH,0DH,0DH,ETX
04DF 20535041
04E3 43452042
```

```
LOC  OBJ          SEQ        SOURCE STATEMENT

0547 [illegible]
054B [illegible]
054F [illegible]
0553 [illegible]
0557 [illegible]
055B [illegible]
055F [illegible]
0563 [illegible]
0566 [illegible]
0567 [illegible]
0568 [illegible]
0569 [illegible]
056A [illegible]     199 STEUF4  DB      0AH,0AH,0DH,'ACCUMULATION COMMENCED',0AH,0DH
056B [illegible]
056C [illegible]
056D [illegible]
0571 [illegible]
0575 [illegible]
0579 [illegible]
057D [illegible]
0581 4544
0583 [illegible]
0584 [illegible]
0585 0A              200 STEUF7  DB      0AH,0AH,'NO  PTS ',0AH,0DH
0586 [illegible]
0587 [illegible]
058B [illegible]
058F [illegible]
0590 [illegible]
0591 [illegible]     201         DB      'IN WINDOW',0AH,0AH,07H,0DH,ETX
0595 [illegible]
0599 [illegible]
059A [illegible]
059B [illegible]
059C [illegible]
059D [illegible]
059E [illegible]
059F 0A              202 STEUF5  DB      0AH,0DH,'ENTER TIME WINDOW (E TYPE FORMAT,IN SECONDS)',ETX
05A0 [illegible]
05A1 [illegible]
05A5 [illegible]
05A9 [illegible]
05AD [illegible]
05B1 [illegible]
05B5 [illegible]
05B9 [illegible]
05BD [illegible]
05C1 [illegible]
05C5 [illegible]
05C9 [illegible]
05CD [illegible]
05CE [illegible]     203 RETRY   DB      0AH,0AH,07H,'EH',ETX
05CF [illegible]
05D3 [illegible]
05D4 [illegible]
```

```
LOC  OBJ         SEQ        SOURCE STATEMENT

0FD2 0D
0FD3 0A          204 LABEL1   DB      0AH,0DH,'ENTER NAME OF MATERIAL (MAX 30 CHARACTERS)',ETX
0FD4 0D
0FD5 454E5445
0FD9 [illegible]
0FDD [illegible]
0FE1 [illegible]
0FE5 [illegible]
0FE9 [illegible]
0FED [illegible]
0FF1 [illegible]
0FF5 [illegible]
0FF9 [illegible]
0FFD [illegible]
0FFF 0C
0A00 0A          205 TERM     DB      0AH,0DH,ETX
0A01 0D
0A02 0C
0A03 0D          206 STELAB   DB      0DH,10H      '++++ STIMULUS ++++',0DH,0AH,00H
0A04 10
0A05 [illegible]
0A09 [illegible]
0A0D [illegible]
0A11 [illegible]
0A15 [illegible]
0A19 [illegible]
0A1D 0D
0A1E 0A
0A1F [illegible]
0A20 [illegible]  207         DB                 ' FOURIER  TRANSFORM          TIME WINDOW =  ',ETX
0A24 [illegible]
0A28 [illegible]
0A2C [illegible]
0A30 [illegible]
0A34 [illegible]
0A38 [illegible]
0A3C [illegible]
0A40 [illegible]
0A44 [illegible]
0A48 [illegible]
0A4C [illegible]
0A50 [illegible]
0A52 0C
0A53 [illegible]  208 STHEAD  DB                       MAG(+)        PHASE(+)        FREQ'
0A57 [illegible]
0A5B [illegible]
0A5F [illegible]
0A63 [illegible]
0A67 [illegible]
0A6B [illegible]
0A6F [illegible]
0A73 [illegible]
0A77 [illegible]
0A7B [illegible]
0A7F [illegible]
```

```
LOC  OBJ            SEQ       SOURCE STATEMENT

[illegible]         [illegible]  [illegible]                                   ,ETX
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]         [illegible]  0AH  [illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible] 47
[illegible] 0A
[illegible]
[illegible]         I11       DB   'DO NOT CHANGE TIME [illegible] 0AH [illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]         [illegible]  DB   'DO NOT MOVE CURSOR [illegible] 0AH,0DH
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]         I13       DB   0AH [illegible] INSTALL SAMPLE IN HOLDER [illegible] 0AH,0DH,ETX
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
0711 [illegible]
[illegible]
[illegible]
[illegible]
[illegible]         [illegible]  DB   0AH [illegible] ***** [illegible] ***** [illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
```

```
LOC  OBJ        SEQ       SOURCE STATEMENT

[illegible]
          315        DB    '       FOURIER  TRANSFORM'          TIME  IN[illegible] = [illegible]ET
[illegible]
          316 COLPBL  DB    0CH 12H '    +++++COLE-COLE PLOT+++++',0EH 0AH 0CH,ET[illegible]
[illegible]
          317 [illegible]   DB    SEC [illegible]12H,0AH 0CH ET
[illegible]
          3[illegible]   DB    0AH,0AH  +++ COMMAND [illegible] +++  0AH 0AH 0CH
[illegible]
          [illegible]          DB    CTRL A = [illegible] CURRENT [illegible] 0AH 0DH
[illegible]
```

```
LOC  OBJ          SEQ        SOURCE STATEMENT

[illegible]
0EE1 [illegible]   [illegible]   EE     ;CTRL E = RE-ENTER TIME [illegible] MATERIAL [illegible] 0AH,0AH,00H
[illegible]
[illegible]        [illegible]   DB     ;THERE ARE 2 BASIC CHARACTERISTICS TO BE MEASURED ,0AH,00H
[illegible]
[illegible]        [illegible]   DB     THE STIMULUS IS AN AUTONORMALIZING CHARACTERISTIC ,0AH,00H
[illegible]
[illegible]        [illegible]   DB     THE RESPONSE(S) ARE NOT ALIGNED AT THE STIMULUS ,0AH,0AH
```

```
LOC  OBJ          SEQ         SOURCE STATEMENT

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible] 0A
[illegible] 0D
[illegible] 0A         114         DB      0AH,'NOTE: ONE SET OF STIMULUS DATA MUST BE  PROCESSED',0AH,0DH
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible] 0A
[illegible] 0D
[illegible]            115         DB      '      BEFORE ANY RESPONSE CHARACTERISTICS CAN BE PROCESSED',0AH,0DH,0AH,ETX
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible] 0A
[illegible]
[illegible]
[illegible]
[illegible] 0A         116 ITEM5: DB      0AH,0AH,0AH,'----- TOO FEW [illegible] POINTS -----',0AH,0DH
[illegible] 0A
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
```

163

```
LOC  OBJ          SEQ        SOURCE STATEMENT

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]           [illegible]   DB     '     'TRY INCREASING [illegible]' 0AH 07H 0DH ET[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
0AEE 07
[illegible]
[illegible]
[illegible]           [illegible]   DB     0DH 0AH 07H '*** DO NOT ADJUST CURSORS OR TIMEBASE ***',07H 0AH 0DH,ETX
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]           [illegible]   DB     0AH 'STIMULUS CHARACTERISTIC NOT YET PROCESSED',0AH,0DH 07H ET[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]           [illegible]   DB     0AH 0AH '***** [illegible] *****' [illegible]
[illegible]
```

```
LOC  OBJ          SEQ        SOURCE STATEMENT

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]               331        DB      'ENTER    S     FOR STIMULUS CHARACTERISTIC',0AH,0DH
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]               332        DB      '         R     FOR RESPONSE CHARACTERISTIC',0AH,0DH,07H,ETX
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]               333 GRSUP  DB      0CH,13H,'  ***** GRAPH *****',13H,0AH,0CH
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]               334        DB      '      FOURIER  TRANSFORM',13H,0AH,13H,ETX
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
```

```
  LOC  OBJ         SEQ        SOURCE STATEMENT

 0A74 0D
 0A75 03
 0A76 0C           335 EPSSLP  DB      0CH,12H,      ***** EPSILON ----*',0EH,0FH,0AH,0DH
 0A77 12
 0A78 2020202A
 0A7C 2A2A2A2A
 0A80 2A2D4550
 0A84 53494C4F
 0A88 4E2D2D2D
 0A8C 2D2A2A
 0A8F 0E
 0A90 0F
 0A91 0A
 0A92 0D
 0A93 20202020     336         DB      '          EPSILON' 27H,  (+)   EPSILON',22H,  (+)        FREQ',0AH,0DH,ETX
 0A97 20202020
 0A9B 20455053
 0A9F 494C4F4E
 0AA3 27
 0AA4 20282B29
 0AA8 20202045
 0AAC 5053494C
 0AB0 4F4E
 0AB2 22
 0AB3 20282B29
 0AB7 20202020
 0ABB 20202046
 0ABF 524551
 0AC2 0A
 0AC3 0D
 0AC4 03
                   337
                   338 DSEG
 0001              339 KBSIG   DS      1        ;STORED KEYBOARD SIGNAL DURING KEYIN
 0001              340 FLAG    DS      1        ;ENSURES CORRECT SEQUENCING OF PROGRAM
 0002              341 BUFPNT  DS      2        ;TEXT BUFFER POINTER
 0002              342 PHASTO  DS      2         STORAGE OF F.T. PHASE
 0002              343 MAGSTO  DS      2        ;STORAGE OF F.T. MAG
 0004              344 DIST    DS      4         TIME WINDOW FOR FTS (USED IN PRTION)
 A000              345 STIMAG  EQU     0A000H   ;STORAGE LOCATION OF STIMULUS MAGNITUDE
 A000              346 STPHAS  EQU     0A0004   ;STORAGE LOCATION OF STIMULUS PHASE
 A500              347 REFMAG  EQU     0A500H   ;STORAGE LOCATION OF REFERENCE MAGNITUDE
 AF00              348 REFPHS  EQU     0AF00H   ;STORAGE LOCATION OF REFERENCE PHASE
 0010              349 TINDIG  DS      10H       STORAGE LOCATION OF ASCII DECIMAL STRING
 0010              350 CASEN   DS      10H      ;STORAGE OF MATERIAL NAME
                   351
                   352 END

PUBLIC SYMBOLS
DIST   D 0008    FLAG   D 0001    JITTER C 015C    KEYIN  C 0000    KBSIG  D 0000    MAGSTO D 0005    PHASTO D 0004
STPHAS A A000    REFMAG A A500    STIMAG A A000    STPHAS A A000

EXTERNAL SYMBOLS
ACTLCT E 0000    ADIATP E 0000    CLEAR  E 0000    COLFLT E 0000    DATPOI E 0000    DPEP   E 0000    EPLOT  E 0000
EPSLON E 0000    FDEIEI E 0000    FRMCOM E 0000    GAMMA  E 0000    HILDAT E 0000    LOADI  E 0000    LOADY  E 0000
```

```
LOFI   E [illegible]  MSTO   E [illegible]  M1STO  E 0000  NFSTO  E 0000  REFACQ E 0000  TOF    E 0000  WAIT   E 0000
UNEOM1 E [illegible]

USER SYMBOLS
ADCLOC E [illegible]  ASTATR E [illegible]  BEGBUF C 011E  BEGIN  C 0115  BUF1   C [illegible]  BUFBUF D 0002  CI     A F80C
CLEAR  E [illegible]  COLREL C 07EE  COLRLT E 0000  CRTOUT A F80C  CATAIN E [illegible]  CBYTE  A FE11  DIST   D [illegible]
DREF   E [illegible]  ERLIN  E [illegible]  ERSBUF C [illegible]  EPSLON E 0000  ET     A [illegible]  E?H    A 000F  FADD   A 2034
FBYTE  A [illegible]  FIETEI E [illegible]  FDIV   A [illegible]  FIXSD  A 0003  FLAG   D 0001  FLTDS  A 0002  FMUL   A 0002
[illegible] E [illegible]  [illegible] A [illegible]  FSQRT  A 0037  FSUB   A 0005  FTHERD C [illegible]  FZTST  A [illegible]  GAMBUF C 0A3E
[illegible] E [illegible]  [illegible] E [illegible]  INSTR  C 0730  IOERS  A 0040  JITBUF C [illegible]  JITTER C 01EC  KEYCH  C 021D
[illegible] C [illegible]  KEYSIG D [illegible]  LASBUF D [illegible]  LABEL  C [illegible]  LIAN   E 0000  LOADY  E [illegible]  LOFI   E [illegible]
LST    A [illegible]  MASTO  D [illegible]  [illegible] C 0045  MENI   C [illegible]  MEMBUF C 05CF  MEN E  C [illegible]  MSTO   E [illegible]
M1STO  E [illegible]  NFSTO  E [illegible]  OF1    A C100  OF2    A C104  PHASTO D [illegible]  PRINT  C [illegible]  RATHL  A [illegible]
[illegible] C [illegible]  [illegible] C 0715  [illegible] C 050E  REFACQ E [illegible]  [illegible] A [illegible]  [illegible] A [illegible]  REST1  C [illegible]
[illegible] C [illegible]  [illegible] C [illegible]  [illegible] C [illegible]  [illegible] C [illegible]  STBUF1 C [illegible]  STBUF2 C [illegible]  STBUF3 C 04E0
[illegible] C [illegible]  [illegible] C 05?F  [illegible] C [illegible]  STBUF7 C [illegible]  [illegible] C [illegible]  STEP   C 01A4  STIM1  C [illegible]
[illegible] A [illegible]  [illegible] C 0055  [illegible] A [illegible]  TOF    E 0000  TERM   C [illegible]  TIME1  C 014E  TIME2  C 01CD
TIMEIN C 01CA  TIMOUT C 01E?  TIMWIN D 000C  TIWAIT C 014A  WAIT   E 0000  WARN1  C 0571  WARN2  C 05A1
[illegible] E 0000  IT     C 0232  XPRINT C 01F5

ASSEMBLY COMPLETE,   NO ERRORS
```

REMAP F1 SYSPTN

ISIS-II 8080/8085 MACRO ASSEMBLER, V2.0   MODULE   PAGE   1

```
 LOC  OBJ         SEQ   -     SOURCE STATEMENT

                     1 ;NAME  SYSPTN
                     2 ;THIS FILE IS A CONGLOMERATION OF ROUTINES
                     3 ;USED BY THE MAIN SPECTRA SYSTEM PROGRAM
                     4 ;IT SHOULD BE ADDED TO THE SPECTR LIB FILE
                     5 ;AND LINKED TO THE MAIN SYSTEM PROGRAM
 0002                6 FMUL     EQU     2
 0003                7 FDIV     EQU     3
 0004                8 FADD     EQU     4
 0005                9 FSUB     EQU     5
 0006               10 FSQR     EQU     6
 0007               11 FSQRT    EQU     7
 0008               12 FLTDS    EQU     8H
 0009               13 FIXSD    EQU     9H
 000A               14 FCHS     EQU     0AH
 000B               15 FZTST    EQU     0BH
 000F               16 ENCH     EQU     0FH
 C100               17 OP1      EQU     0C100H
 C104               18 OP2      EQU     OP1+4
 0040               19 IOBAS    EQU     40H
 FE7A               20 PRTHL    EQU     0FE7AH
 FD1D               21 COUT     EQU     0FD1DH  ;CONSOLE OUTPUT
 A300               22 NEWLOC   EQU     0A300H  ;STARTING ADDRESS OF NEWVEC
                    23 CSEG
                    24 PUBLIC   NSTO,N1STO,NPSTO,TOP,ACCPTR
                    25 PUBLIC   FILTOP,WINDOW,ACCLOC,IPEP
                    26 PUBLIC   DATACQ,HILOW,PEPACQ,E1
                    27 EXTRN    FENSIG,PRNDCM,CLEAR,LOAD,LOADX
                    28 EXTRN    LOADX,FLAG,WAIT,JITTER
                    29
                    30
 0000 2100A2        31 DATACQ   LXI     H,0A000H
 0003 220000   D    32          SHLD    ACCLOC  ;INITIALIZE ACCVEC LOCATION
 0006 21003F        33          LXI     H,03F00H;DATA ACQUISITION AND ACCUMULATION
 0009 11FFAE        34          LXI     D,0AEFFH
 000C CD7F02   C    35          CALL    BLANK
 000F 3E64          36          MVI     A,64H   ;100=LOOP COUNTER
 0011 320000   D    37          STA     SWPCTR  ;IE 100 SUMMED SWEEPS
 0014 210000        38          LXI     H,0     ;--------------------------------
 0017 220500   D    39          SHLD    DMAX    ;INITIALIZE DMAX=0000,HMIN=FFFF
 001A 21FFFF        40          LXI     H,0FFFFH
 001D 220300   D    41          SHLD    HMIN    ;--------------------------------
 0020 CD5C01   C    42 ACLOOP   CALL    TOP     ;NEWVEC ACQUIRED
 0023 2B            43          DCX     H       ;FROM TOP,HL =ADDR OF PT BEYOND
 0024 2B            44          DCX     H       ;LAST PT IN NEWVEC
 0025 220500   D    45          SHLD    HNEW    ;HNEW=ADDR OF LAST PT IN NEWVEC
 0028 EB            46          XCHG
 0029 220700   D    47          SHLD    DNEW    ;DNEW=ADDR BEFORE WINDOW
 002C EB            48          XCHG
 002D CD0000   C    49          CALL    WINDOW  ;HL =HNEW  DE=DNEW
 0030 EB            50          XCHG
 0031 2A0300   D    51          LHLD    HMIN    ;DE=HNEW
 0034 7D            52          MOV     A,L     ;HMIN-HNEW
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LOC  OBJ         SEQ        SOURCE STATEMENT

0035 93           53        SUB   E
0036 7C           54        MOV   A,H
0037 9A           55        SBB   D
0038 DA3F00   C   56        JC    ACL1    ;HMIN LT HNEW ? YES, GO TO ACL1
003B EB           57        XCHG          ;(HL)=HNEW
003C 220100   D   58        SHLD  HMIN    ;NO  STORE HMIN=HNEW
003F 2A0500   D   59 ACL1   LHLD  DMAX
0042 EB           60        XCHG
0043 2A0300   D   61        LHLD  DNEW    ;(DE)=DMAX .
0046 7B           62        MOV   A,E
0047 95           63        SUB   L
0048 7A           64        MOV   A,D
0049 9C           65        SBB   H       ;DMAX-DNEW GT 0 ?
004A D25000   C   66        JNC   ACL2    ;YES, GO TO ACL2
004D 220500   D   67        SHLD  DMAX    ;NO, DMAX=DNEW
0050 2A0300   D   68 ACL2   LHLD  DNEW    ;------------------------
0053 EB           69        XCHG
0054 2A0700   D   70        LHLD  DREF
0057 7B           71        MOV   A,E
0058 95           72        SUB   L
0059 6F           73        MOV   L,A
005A 7A           74        MOV   A,D
005B 9C           75        SBB   H
005C 67           76        MOV   H,A     ;(HL)=DIFF=DNEW-DREF
005D B5           77        ORA   L       ;CHECK IF DIFF=0
005E EB           78        XCHG          ;CY=0 IF DIFF IS POSITIVE
005F 2A1D00   D   79        LHLD  ACCLOC  ;DNEW IS NO LONGER NEEDED
0062 CA7B00   C   80        JZ    ACL4    ;DIFF=0, DO NOT SHIFT ACCPTR
0065 D27300   C   81        JNC   POSHFT  ;(DE)=DIFF
0068 2B           82 NGSHFT DCX   H       ;SHIFT ACCPTR=ACCLOC-4*DIFF
0069 2B           83        DCX   H
006A 2B           84        DCX   H
006B 2B           85        DCX   H
006C 1D           86        DCR   E       ;ASSUMING DIFF LT 16
006D C26800   C   87        JNZ   NGSHFT
0070 C37B00   C   88        JMP   ACL4
0073 23           89 POSHFT INX   H       ;SHIFT ACCPTR=ACCLOC+4*DIFF
0074 23           90        INX   H
0075 23           91        INX   H
0076 23           92        INX   H
0077 1D           93        DCR   E       ;ASSUMING DIFF LT 16
0078 C27300   C   94        JNZ   POSHFT  ;------------------------
007B 220000   D   95 ACL4   SHLD  ACCPTR  ;ACCPTR=ACCLOC +/- 4*DIFF
007E 210000       96        LXI   H,NEWLOC ;(HL)=ADDR
0081 220000   D   97        SHLD  NEWPTR  ;NEWPTR=NEWLOC
0084 210000       98 ACL5   LXI   H,OP1   ;CLEAR OP1 FOR FLTDS
0087 CD0000   E   99        CALL  CLEAR
008A 2A0000   D  100        LHLD  NEWPTR  ;(HL)=ADDR OF NEWMED(NEWPTR)
008D 7E          101        MOV   A,M
008E 2F          102        CMA           ;AND GIVES COMPLIMENT OF ECD
008F 5F          103        MOV   E,A     ;PUT COMPLIMENTED INPUT IN (DE)
0090 23          104        INX   H
0091 7E          105        MOV   A,M
0092 E60F        106        ANI   0FH     ;MS NIBBLE ELIMINATED,LS NIBBLE
0094 57          107        MOV   D,A     ;COMPLIMENTED
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LOC  OBJ          SEQ       SOURCE STATEMENT

0095 EB           108       XCHG              ;(HL)=COMPLEMENTED INPUT
0096 CD0000   C   109       CALL    BCDBIN  ;(HL)=BINARY VERSION OF INPUT
0099 220000       110       SHLD    OP1
009C 3E00         111       MVI     A,FLTDS          .
009E D300         112       OUT     ICEF3   ;OP1=NEW EC (FLOAT)
00A0 2A0000   D   113       LHLD    ACCPTR  ;(HL)=(ACCPTR)
00A3 CD0000   E   114       CALL    LOP2    ;OP2=ACCVEC(ACCPTR)
00A6 3E00         115       MVI     A,FADD
00A8 D300         116       OUT     ICEF3              .
00AA 2A0000   D   117       LHLD    ACCPTR
00AD EB           118       XCHG
00AE 210000       119       LXI     H,OP1
00B1 CD0000   E   120       CALL    LOP0,   ;ACCVEC(ACCPTR)+NEWVEC(FLT)
00B4 2A0000   D   121       LHLD    HNEW    ;------------------------
00B7 3A0000   D   122       LDA     NEWPTR+1
00BA BC           123       CMP     H       ;MSB NEWPTR LT MSB HNEW ?
00BB DA0000   C   124       JC      ACL6    ;YES, GO TO ACL6
00BE 3A0000   D   125       LDA     NEWPTR  ;NO, CHECK LSB OF EACH
00C1 BD           126       CMP     L       ;IE. IF NEWPTR LT HNEW, CONTINUE
00C2 D20000   C   127       JNC     ACL7    ;OTHERWISE GO TO ACL7
00C5 2A0000   D   128 ACL6  LHLD    NEWPTR  ;------------------------
00C8 23           129       INX     H       ;NEWPTR=NEWPTR+2
00C9 23           130       INX     H
00CA 220000   D   131       SHLD    NEWPTR
00CD 2A0000   D   132       LHLD    ACCPTR
00D0 23           133       INX     H
00D1 23           134       INX     H
00D2 23           135       INX     H
00D3 23           136       INX     H                   .
00D4 220000   D   137       SHLD    ACCPTR  ACCPTR=ACCPTR+4
00D7 C30000   C   138       JMP     ACL5    ;------------------------
                  139
00DA 3A0000   D   140 ACL7  LDA     SUFCTR  ;SUFCTR=SUFCTR-1
00DD 3D           141       DCR     A
00DE 320000   D   142       STA     SUFCTR  ;SUFCTR=0 ?
00E1 C20000   C   143       JNZ     ACLOOP  ;NO, CONTINUE ACQUIRING AND SUMMING
00E4 2A0000   D   144       LHLD    OFEF    ;YES, FIND DIFFMAX=DMAX-OFEF
00E7 EB           145       XCHG
00E8 2A0000   D   146       LHLD    DMAX    DMAX MUST BE GE OFEF
00EB CD0000   C   147       CALL    SUBTR   ;(HL)=(HL)-(DE)
00EE 54           148       MOV     D,H
00EF 5D           149       MOV     E,L     ;COPY DIFMAX INTO (DE)
00F0 4D           150       MOV     C,L     ;DIFMAX SHOULD BE LESS THAN 1 BYTE
00F1 2A0000   D   151       LHLD    ACCLOC
00F4 79           152       MOV     A,C
00F5 B7           153       ORA     A       ;DIFMAX=0 ?
00F6 CA0000   C   154       JZ      ACL9    ;YES, GO TO ACL9
00F9 23           155 ACL8  INX     H       ;------------------------
00FA 23           156       INX     H       ACCLOC=ACCLOC+DIFMAX*4
00FB 23           157       INX     H
00FC 23           158       INX     H
00FD 0D           159       DCR     C
00FE C20000   C   160       JNZ     ACL8    ;------------------------
0101 220000   D   161 ACL9  SHLD    ACCLOC
0104 2A0000   D   162       LHLD    MSTV    ;(DE)=DIFMAX
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 LOC  OBJ          SEQ         SOURCE STATEMENT

0107 CD0000   C   163          CALL   SUBTR   ;SUBTR > HL=HL-DE
010A 3A0000   E   164          LDA    FLAG
010D E604         165          ANI    4       ;STIM IN PROGRESS ?
010F CA0000   C   166          JZ     ACL10   ;NO, SKIP M C-SC?
0112 FA0000   E   167          JM     JITTER   M LT 0, GO TO JITTER
0115 7C           168          MOV    A,H
0116 A7           169          ANA    A
0117 C20000   C   170          JNZ    ACL10   ;H NE 0, GO TO ACL10
011A 7D           171          MOV    A,L
011B FE01         172          CPI    1        IF H EQ 0 AND
011D DA0000   E   173          JC     JITTER  ;L LT 1 (IE=0), GO TO JITTER
0120 CA0000   E   174          JZ     JITTER  ;L EQ 1         GO TO JITTER
0123 220000   D   175 ACL10    SHLD   MSTO
0126 2A0000   D   176          LHLD   N1STO
0129 CD0000   C   177          CALL   SUBTR
012C 221500   D   178          SHLD   N1STO
012F 42           179          MOV    B,D     ;SAVE DIFMAX
0130 4B           180          MOV    C,E
0131 2A0000   D   181          LHLD   HMIN
0134 1100A8       182          LXI    D,0A800H
0137 CD0000   C   183          CALL   SUBTR   ;HL=HMIN-A800H
013A 7C           184          MOV    A,H     ;CY=0 SINCE HMIN GT A800H
013B 1F           185          RAR
013C 67           186          MOV    H,A
013D 7D           187          MOV    A,L
013E 1F           188          RAR
013F 6F           189          MOV    L,A     ;HL=NP=((HMIN-A800H)/2)+1
0140 23           190          INX    H
0141 50           191          MOV    D,B
0142 59           192          MOV    E,C     ;(DE)=DIFMAX
0143 CD0000   C   193          CALL   SUBTR   ;(HL)=((HMIN-A800H)/2)+1-DIFMAX
0146 220000   D   194          SHLD   NFSTO   ;NFSTO=# LEGITIMATE PTS IN ACC SC
0149 EB           195          XCHG           ;(DE)=NFSTO
014A 2A1D00   D   196          LHLD   ACCLOC  ;----------------------------
014D 1B           197          DCX    D
014E 23           198 GETOP    INX    H
014F 23           199          INX    H
0150 23           200          INX    H
0151 23           201          INX    H
0152 1B           202          DCX    D
0153 7A           203          MOV    A,D
0154 B3           204          ORA    E
0155 C24E01   C   205          JNZ    GETOP   ;----------------------------
0158 221F00   D   206          SHLD   ACCTOP  ;ACCTOP=ACCLOC+4*NF
015B C9           207          RET
                  208
015C 110000       209 TOP      LXI    D,0     ;TOP IS THE DATA ACQUISITION ROUTINE
015F 2100A8       210 BEG      LXI    H,0A800H;NEW SC STARTING ADDRESS
0162 DB02         211 BEG1     IN     2       ;SWEEP START ?
0164 17           212          RAL
0165 D26201   C   213          JNC    BEG1     NO, GO TO BEG1
0168 DB02         214 BEG2     IN     2        YES, A/D STILL READY (FROM LAST PT) ?
016A E6C0         215          ANI    C0H
016C C26801   C   216          JNZ    BEG2    ;YES, GO TO BEG2
016F 13           217          INX    D       ;NO, INCREMENT POINT COUNTER
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LOC  OBJ         SEQ        SOURCE STATEMENT

0170 DB02          218 BEGA    IN      2        ;A/D READY AGAIN ?
0172 4F            219         MOV     C,A      ;(PREVENTS READING SAME PT. TWICE)
0173 E620          220         ANI     20H
0175 CA7001    C   221         JZ      BEGA     ;NO, GO TO BEGA
0178 79            222         MOV     A,C      ;YES, BUT IS PT. IN WINDOW ?
0179 E640          223         ANI     40H
017B CA9D01    C   224         JZ      SAVE     ;YES, GO TO SAVE
017E C3??01    C   225         JMP     BEG2     ;NO, GO BACK TO BEG2
0181 DB02          226 BEG3    IN      2
0183 4F            227         MOV     C,A
0184 E640          228         ANI     40H      ;STILL IN WINDOW ?
0186 C8            229         RZ               ;NO, RETURN
0187 79            230         MOV     A,C
0188 E620          231         ANI     20H      ;YES, A/D READY AGAIN ?
018A CA8101    C   232         JZ      BEG3     ;NO, GO TO BEG3
018D DB01          233 SAVE    IN      1        ;YES, STORE PT. IN MEMORY
018F 77            234         MOV     M,A      ;  (TWO LOCATIONS REQUIRED)
0190 23            235         INX     H
0191 71            236         MOV     M,C
0192 23            237         INX     H
0193 DB02          238 BEG4    IN      2
0195 E620          239         ANI     20H      ;A/D STILL READY ?
0197 C29301    C   240         JNZ     BEG4     ;YES, THEN WAIT IN LOOP
019A C38101    C   241         JMP     BEG3     ;NO, GO TO BEG3 FOR NEXT PT
                   242
019D 2A1C00    D   243 HILOAV  LHLD    ACCLOC
01A0 22??00    D   244         SHLD    ACCPTR   ;INITIALIZE ACCPTR
01A3 2A1500    D   245         LHLD    N1STO    ;AVG LO AND HI LEVEL PTS
01A6 EB            246         XCHG
01A7 2A1700    D   247         LHLD    NPSTO    ;(NPSTO)=NO PTS IN ACC'ED
01AA CD??01    C   248         CALL    SUBTR    ;(HL)=NPSTO-N1STO
01AD 23            249         INX     H
01AE 221100    D   250         SHLD    NPCTR    ;(DE)=N1,NPCTR=NP-N1+1
01B1 2A1?00    D   251         LHLD    MSTO     ;IE NPCTR=# HI LEVEL PTS
01B4 EB            252         XCHG             ;(HL)=N1, DE=M
01B5 CD??01    C   253         CALL    SUBTR
01B8 221500    D   254         SHLD    N1STO    ;(DE)=MSTO,N1STO=N1-M
01BB D5            255         PUSH    D        ;-----------------------
01BC 21??01        256         LXI     H,OP1
01BF CD??00    E   257         CALL    CLEAR
01C2 D1            258         POP     D        ;D=MSTO=# OF LOW LEV. PTS
01C3 EB            259         XCHG
01C4 22??01        260         SHLD    OP1
01C7 3E??          261         MVI     A,FLTDE
01C9 D3??          262         OUT     IOBAS
01CB 21??01        263         LXI     H,OP1
01CE 11????    D   264         LXI     D,DENSAV ;DENSAV=M+1 (# LOW LEV. PTS)
01D1 CD??00    E   265         CALL    LOADN    ;------------------------
01D4 2A1?00    D   266         LHLD    MSTO     ;RECLOP COUNTER
01D7 CD??01    C   267         CALL    RECSUM
01DA 11??00    D   268         LXI     D,E1
01DD CD??00    E   269         CALL    LOADN    ;E1=AVG LOW LEV PTS
01E0 2A1500    D   270         LHLD    N1STO    ;N1STO=N1-M
01E3 2B            271         DCX     H        ;N1=N1-1 SINCE ACCPTR ALREADY
01E4 4D            272         MOV     C,L      ;INCREMENTED IN LOOP (RECSUM)
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LOC  OBJ          SEQ        SOURCE STATEMENT

01E5 44            273         MOV   B,H      ED)=N1
01E6 2A0000   D    274         LHLD  ACCPTR
01E9 23            275 HLA1    IN    H        ;-----------------------------
01EA 23            276         IN    H
01EB 23            277         INX   H
01EC 23            278         INX   H
01ED 05            279         DCR   B
01EE 78            280         MOV   A,B
01EF B1            281         ORA   C         SHIF TO N1
01F0 C2E901   C    282         JNZ   HLA1     ;-----------------------------
01F3 220000   D    283         SHLD  ACCPTR   ;ACCPTR HAS BEEN SHIFTED TO N1
01F6 210001        284         LXI   H,OP1
01F9 CD0000   E    285         CALL  CLEAR
01FC 2A0000   D    286         LHLD  NPCTR     GENERATE (FLOATED)
01FF 220001        287         SHLD  OP1
0202 3E00          288         MVI   A,FLTDS
0204 D300          289         OUT   IOBASE
0206 210001        290         LXI   H,OP1
0209 110000   D    291         LXI   D,DENEAV
020C CD0000   E    292         CALL  LOAD     -----------------------------
020F 2A0000   D    293         LHLD  NPCTR     VECLOP COUNTER
0212 CD0000   C    294         CALL  VECSUM
0215 CD0000   E    295         CALL  WAIT     ;OPERATION PENDING IN VECSUM
0218 3E00          296         MVI   A,ECH    ;OP1=S2=A FS HI LEV  PTS
021A D300          297         OUT   IOBASE   ;OP2=S2
021C 210000   D    298         LXI   H,S1
021F 110001        299         LXI   D,OP1
0222 CD0000   E    300         CALL  LOAD     ;OP1=S1
0225 3E00          301         MVI   A,FS S
0227 D300          302         OUT   IOBASE
0229 210001        303         LXI   H,OP1
022C 110000   D    304         LXI   D,S
022F CD0000   E    305         CALL  LOAD      S=S1-S2 (S1 GT S2 FROM P D)
0232 C9            306         RET            ;---------------------------
                   307
0233 4D            308 VECSUM  MOV   C,L
0234 44            309         MOV   B,H      (BC)= NO  PTS  ON LEVEL
0235 0B            310         DCX   B
0236 2A0000   D    311         LHLD  ACCPTR   ---------------------------
0239 110001        312         LXI   D,OP1     ACCPTR=ACC(0) ALREADY MODIFIED)
023C CD0000   E    313         CALL  LOAD+     (HL)=ACCPTR+4
023F CD0000   E    314         CALL  LOAD+     TO AVOID CALL NO  AIT IN
0242 C34500   C    315         JMP   VECL      LOAD SEE LOCAL)
0245 CD0000   E    316 VECLOP  CALL  LOAD     (HL)=ACCPTR+4 IN LOAD
0248 3E00          317 VECL    MVI   A,FADD
024A D300          318         OUT   IOBAS
024C 0B            319         DCX   B
024D 78            320         MOV   A,B
024E B1            321         ORA   C
024F C24502   C    322         JNZ   VECLOP   ---------------------------
0252 220000   D    323         SHLD  ACCPTR    ACCPTR POINTS TO FIRST LOCATION
0255 210000   D    324         LXI   H,ECD     SEE NO POINTS ALONG SI  ATION
0258 CD0000   E    325         CALL  LOAD
025B 3E00          326         MVI   A,FTI
025D D300          327         OUT   IOBASE
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 LOC  OBJ         SEQ        SOURCE STATEMENT

02EF 2100F1       328        LXI   H,0F1
02F2 C9           329        RET
                  330
02F3 CD5C01   C   331 REFADR: CALL  TOP     ;HL=LAST PT ADDR, DE=# PTS  IN NEWREC
02F6 1B           332        DCX   D       ;FROM TOP, HL=# OF PT ADDR E
02F7 2B           333        DCX   H       ;LAST PT IN NEWREC
02F8 CD8C02   C   334        CALL  WINDOW  ;DISPLAY NO PTS  IN NEWREC
02FB 3A0000   E   335        LDA   KEYSIG
02FE FE20         336        CPI   20H     ;IS IT SPACE ?
0300 C2F302   C   337        JNZ   REFADR
0303 2A1A03   C   338        LHLD  REFPT   ;REFPT=ELEMENT OF PT, NOT ADDRESS
0306 C9           339        RET
                  340
0307 7D           341 SUBTR: MOV   A,L     ;SUBTR DOES HL=HL-DE
0308 93           342        SUB   E
0309 6F           343        MOV   L,A
030A 7C           344        MOV   A,H
030B 9A           345        SBB   D
030C 67           346        MOV   H,A
030D C9           347        RET
                  348
030E 23           349 BLKIN: INX   H       ;---------------------------
030F 3600         350 BLANK: MVI   M,0     ;THIS ROUTINE CLEARS A MEMORY
0311 7C           351        MOV   A,H     ;BLOCK WHOSE LOWER BOUND IS IN
0312 BA           352        CMP   D       ;HL AND UPPER BOUND IS IN DE
0313 C20E03   C   353        JNZ   BLKIN
0316 7D           354        MOV   A,L
0317 BB           355        CMP   E
0318 C20E03   C   356        JNZ   BLKIN
031B C9           357        RET           ;---------------------------
                  358
031C E5           359 WINDOW: PUSH H       ;(HNEW-ADDR) TO END & DISPLAY
031D D5           360        PUSH  D
031E C5           361        PUSH  B
031F 7C           362        MOV   A,H     ;NEWREC OCCUPIES 9300-9FFF (A)
0320 D693         363        SUI   093H
0322 1F           364        RAR
0323 67           365        MOV   H,A
0324 7D           366        MOV   A,L     ;NO PTS IN WIND=(HL-9300)/2
0325 1F           367        RAR
0326 6F           368        MOV   L,A     ;HL=NO PTS IN WINDOW-1
0327 23           369        INX   H
0328 221A03   D   370        SHLD  REFPT   ;REFPT=NO OF PTS IN NEWREC
032B 019CFF       371        LXI   B,-100
032E CDE303   C   372        CALL  DECNO
0331 57           373        MOV   D,A
0332 01F6FF       374        LXI   B,-10
0335 CDE303   C   375        CALL  DECNO
0338 07           376        RLC
0339 07           377        RLC
033A 07           378        RLC
033B 07           379        RLC
033C B5           380        ORA   L       ;LSB IN L
033D 5F           381        MOV   E,A
033E EB           382        XCHG
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LOC  OBJ         SEQ         SOURCE STATEMENT

01AF CD7A0E      383         CALL    PRTHL   ;OUTPUT CONTENTS OF HL ON CONSOLE
01B2 0E0D        384         MVI     C,0DH
01B4 CD0F0D      385         CALL    COUT
01B7 C1          386         POP     B
01B8 D1          387         POP     D
01B9 E1          388         POP     H
01BA C9          389         RET
01BB AF          390 DECNO   XRA     A       ;(USE 30H IF ASCII)
01BC D5          391         PUSH    D
01BD 5D          392 DECN2   MOV     E,L     ;REPETITIVE SUBTRACTION OF E
01BE 54          393         MOV     D,H
01BF 3C          394         INR     A
01C0 19          395         DAD     D       ADD 2'S COMP OF DECIMAL PLACE
01C1 DABD01      396         JC      DECN2
01C4 3D          397         DCR     A
01C5 6B          398         MOV     L,E     ;RESTORE REMAINDER TO (HL)
01C6 62          399         MOV     H,D     ;FOR NEXT ITERATION
01C7 D1          400         POP     D
01C8 C9          401         RET
                 402
                 403
                 404  THIS ROUTINE CONVERTS A 3 DIGIT BCD NO. IN HL
                 405  TO ITS BINARY EQUIVALENT AND PUTS THE RESULT
                 406  IN HL
01C9 C5          407 BCDBIN  PUSH    B
01CA D5          408         PUSH    D
01CB 7D          409         MOV     A,L
01CC 4F          410         MOV     C,A     ;COPY LS 2 DIGITS IN C
01CD E60F        411         ANI     0FH     ;MASK OUT LS DIGIT
01CF 5F          412         MOV     E,A     ;SAVE LS DIGIT
01D0 79          413         MOV     A,C     ;REINSTATE LS 2 DIGITS
01D1 E6F0        414         ANI     0F0H    ;MASK OUT 2ND SIG. DIGIT D(10)
01D3 0F          415         RRC
01D4 0F          416         RRC             ;SAME AS D(10)*4
01D5 4F          417         MOV     C,A     ;SAVE   D(10)*4
01D6 0F          418         RRC
01D7 0F          419         RRC             ;SAME AS D(10)*1
01D8 81          420         ADD     C       ;A=D(10)*1+D(10)*4=D(10)*5
01D9 07          421         RLC             ;A=D(10)*5*2
01DA 83          422         ADD     E
01DB 5F          423         MOV     E,A     ;E=LS DIGIT + 2ND SIG. DIGIT *10
01DC 1600        424         MVI     D,0     CLEAR MS REG. OF PR DE
01DE 0600        425         MVI     B,0     ;CLEAR MS REG. OF PR BC
01E0 D5          426         PUSH    D       SAVE LS 2 DIGITS IN E
01E1 7C          427         MOV     A,H     ;MS DIGIT
01E2 E60F        428         ANI     0FH     MASK OUT MS DIGIT
01E4 07          429         RLC
01E5 07          430         RLC             ;MSD*4
01E6 4F          431         MOV     C,A     BC=MSD*4
01E7 07          432         RLC
01E8 07          433         RLC             MSD*16
01E9 2600        434         MVI     H,0     CLEAR MS REG. OF PR HL
01EB 6F          435         MOV     L,A     HL= MSD*16
01EC 29          436         DAD     H       MSD*32
01ED E5          437         PUSH    H       ;SAVE MSD*32
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 LOC  OBJ        SEQ        SOURCE STATEMENT

 01EE 29          438        DAD    H        ;MSD*64
 01EF D1          439        POP    D        ;DE=MSD*32
 01F0 19          440        DAD    D        ;HL=MSD*96
 01F1 09          441        DAD    B        ;HL=MSD*96+MSD*4=MSD*100
 01F2 D1          442        POP    D        ;DE=LS 2 DIGITS
 01F3 19          443        DAD    D        ;HL=LS 2 DIGITS+MSD*100
 01F4 D1          444        POP    D
 01F5 C1          445        POP    B
 01F6 C9          446        RET
                  447
                  448 DSEG
 0001             449 SHPCTR  DS     1        ;NO. OF SWEEPS OF CHARACTERISTIC
 0002             450 RCPPT   DS     2        ;POSITION OF RIGHT HAND CURSOR
 0002             451 AMIN    DS     2        ;MINIMUM UPPER ADDRESS OF ACVEC
 0002             452 DMAX    DS     2        ;MAXIMUM LOWER POINT SUBSCRIPT
 0002             453 DREF    DS     2        ;FIRST LOWER POINT SUBSCRIPT
 0002             454 DNEW    DS     2        ;NEW LOWER POINT SUBSCRIPT
 0002             455 ANEW    DS     2        ;NEW UPPER ADDRESS OF NEWVEC
 0002             456 ACCPTR  DS     2        ;ACCVEC ADDRESS POINTER
 0002             457 NEWPTR  DS     2        ;NEWVEC ADDRESS POINTER
 0002             458 NPCTR   DS     2        ;=NP-N1 COUNTER IN HILOAV
 0002             459 MSTO    DS     2        ;LAST LOW LEVEL POINT
 0002             460 N1STO   DS     2        ;FIRST HI LEVEL POINT
 0002             461 NPSTO   DS     2        ;LAST PT. IN CHARACTERISTIC
 0004             462 ACCTOP  DS     4        ;ADDRESS OF LAST PT. IN ACCVEC
 0004             463 ACCLOC  DS     4        ;ADDRESS OF FIRST PT. IN ACCVEC
 0004             464 DSNEAV  DS     4        ;NO. OF PTS. ON EACH LEVEL(HILOAV)
 0004             465 S       DS     4        ;S=S1-S2
 0004             466 S1      DS     4        ;S1=AVERAGE OF LOW LEVEL POINTS
                  467
                  468        END

PUBLIC SYMBOLS
ACCLOC D 001D   ACCPTR D 000D   ACCTOP D 0019   DATPCO C 0000   DREF   D 0007   HILOAV C 013D   MSTO   D 0011
N1STO  D 0015   NPSTO  D 0017   PEPACO C 0263   S      D 0025   S1     D 0029   TOP    C 015C   WINDOW C 013C

EXTERNAL SYMBOLS
CLEAR  E 0000   FLAG   E 0000   FRODOM E 0000   JITTER E 0000   LEVSIG E 0000   LOADV  E 0000   LOPDV  E 0000
LOP2   E 0000   WAIT   E 0000

USER SYMBOLS
ACCLOC D 001D   ACCPTR D 000D   ACCTOP D 0019   ACL1   C 00CF   ACL10  C 0111   ACL2   C 00ED   ACL4   C 007E
ACL5   C 00A4   ACL6   C 00C5   ACL7   C 00DA   ACL8   C 00F9   ACL9   C 0131   ACLOOP C 0102   BISEIN C 0113
BSG    C 015F   BSG1   C 015C   BSG2   C 0155   BSG3   C 0181   BSG4   C 0192   BSGA   C 0170   BLANK  C 0172
BLINK  C 017E   BOUT   A FD1D   CLEAR  E 0000   DATACO C 0000   DECMD  C 01E1   DEMO   C 01E6   DENSA  D 0011
DMAX   D 0005   DNEW   D 0009   DREF   D 0007   ESCH   A 000F   FADD   A 0004   FCMPR  A 0004   FDIV   A 0001
FINSD  A 0002   FLAG   E 0000   FLTDS  A 0003   FMUL   A 0011   FRODOM E 0000   FSUB   A 0005   FSTST  A 0017
FSUS   A 000E   FSTST  A 000E   GETLR  C 0145   HILOAV C 0130   HLS1   C 015A   HMIN   D 0000   HNEW   D 000B
HIEAR  A 0140   JITTER E 0000   LEVSIG E 0000   LOADV  E 0000   LOADV  E 0000   LOP2   E 0000   LSTO   D 0011
N1STO  D 0015   NEWLOT A F810   NEWPTR D 000F   NGSHFT C 0055   NPCTR  D 0011   NPSTO  D 0017   OPL    A 0120
PEI    A 0104   PISHFT C 0001   PPTHL  A FE7A   PEPACO C 0063   RCPPT  D 0001   S      D 0025   S1     D 0029
SAVE   C 0101   SHSTR  C 0100   SHPCTR D 0000   TOP    C 015C   WEELOP C 0045   WECLY  C 0043   ZLEVM  C 0000
WAIT   E 0000   WINDOW C 013C

ASSEMBLY COMPLETE,  NO ERRORS
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LOC  OBJ        SEQ        SOURCE STATEMENT

                     1 ;NAME PROGM
                     2  THIS IS A TEMPORARY ROUTINE TO
                     3  TEST THE F.T. ROUTINES IE FILE
                     4 ;ED   LD
0002                 5 FMIL    EQU     2
0003                 6 FDIV    EQU     3
0004                 7 FADD    EQU     4
0005                 8 FSUB    EQU     5
0006                 9 FSUB    EQU     6
                    10 FI EI   EQU     ?H
                    11 FC FF   EQU     0AH
C100                12 CF1     EQU     0C100H
C104                13 CF2     EQU     CF1+4
0040                14 IOEFE   EQU     40H
E000                15 EGSTO   EQU     0E000H  ;STORAGE FOR 60 1BYTE PTS
E040                16 ECSTO   EQU     0E040H  ;SAME AS ABOVE BUT FOR E2
                    17 CSEG
                    18 PUBLIC  FLAGS
                    19 PUBLIC  FROCUM LAMDA EPSLON EPLOT,COLPLT
                    20 EXTRN   LOHL  STINAG,STPHAS RESMAG,REPHAS
                    21 EXTRN   ?? NE SINE
                    22 EXTRN   LPL LOADY WAIT FREQ LIMIT,CLEAR
                    23 EXTRN   FCOUNT E E1,STACCR TRNSFM FREERR
                    24 EXTRN   MTR HL,FADDEG SP 1 PICTOR PHASTO
                    25 EXTRN   FEIDEC,PLOT MAG PHASE MAGSTO
0000 CD0000   E     26 FROC01  CALL    NORMAL
0003 AF             27         XRA     A
0004 320000   D     28         STA     FLAGS   ;INITIALIZE FLAG  LIMIT ETC )
0007 320000   E     29         STA     FCOUNT  ;INITIALIZE FCOUNT
000A 210000   E     30         LXI     H,FREERR OPEN CCT  PHASE COMPENSATION
000D CD0000   E     31         CALL    CLEAR    INITIALIZE F(I-1)=0
0010 CD0000   E     32 TSTLOP  CALL    ES01
0013 CD0000   E     33         CALL    TRNSFM
0016 CD1000   C     34         CALL    DATMAN
0019 C31000   C     35         JMP     TSTLOP
                    36
001C 2A0000   E     37 DATMAN  LHLD    MAGSTO  -------------------------
001F EB             38         XCHG            MAG & PHASE ARE STORED IN APPROPRIATE
0020 210000   E     39         LXI     H,MAG   ;E FREFS  (STOP OF FEES)
0023 CD0000   E     40         CALL    LOADY    ((MAGSTO))=(MAG)
0026 EB             41         XCHG
0027 220000   E     42         SHLD    MAGSTO   (MAGSTO) INCRE ENTED BY 4 IN L
002A 2A0000   E     43         LHLD    PHASTO
002D EB             44         XCHG
002E 210000   E     45         LXI     H,PHASE
0031 CD0000   E     46         CALL    LOADY   ;((PHASTO))=(PHASE ETC)
0034 3A0000   D     47         LDA     FLAGS   -------------------------
0037 E7             48         ANA     A        E OF THIS BLOCK ARE FIRST ET
0038 CA0000   C     49         JZ      DATMN1
003B 210000   E     50         LXI     H,PHASE
003E 110000         51         LXI     D,CF1
0041 CD0000   E     52         CALL    LOADY
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LOC  OBJ        SEQ         SOURCE STATEMENT

0944 110471          53          LXI    D,OF2    ;THIS BLOCK COMPARES DIFFERENCE
0947 2A0000     E    54          LHLD   PHASTO   ;BETWEEN CONSECUTIVE PHASE. IF IT
094A 2B              55          DCX    H        IS GREATER THAN PIBY2, PHASE=PHASE+PI/2
094B 2B              56          DCX    H
094C 2B              57          DCX    H
094D 2B              58          DCX    H
094E CD0000     E    59          CALL   LOADY    ;OF2=GAMMA PHASE(I-1)
0951 3E15            60          MVI    A,FSUB   ;OF1=GAMMA PHASE(I)
0953 D340            61          OUT    IOBAS
0955 210000     D    62          LXI    H,PIBY2
0958 CD0000     E    63          CALL   LOAD
095B 3A0001          64          LDA    OF1+2
095E E67F            65          ANI    7FH      STRIP OFF SIGN BIT
0960 320001          66          STA    OF1+2
0963 3E1A            67          MVI    A,FCMP
0965 D340            68          OUT    IOBAS
0967 CD0000     E    69          CALL   WAIT     ;DIFF GT PIBY2 ?
096A 210000     E    70          LXI    H,PHASE  ;BEFORE CHECKING, DO THIS TO
096D 110001          71          LXI    D,OF1    ;FACILITATE UPDATING OF PHASTO
0970 CD0000     E    72          CALL   LOADY
0973 DB41            73          IN     41H      STATUS BYTE
0975 E640            74          ANI    40H      ;NOW CHECK, DIFF GT PIBY2 ?
0977 CA0000     C    75          JZ     DATMN1   ;NO  (PHASTO<=PHASE)
097A 210000     D    76          LXI    H,PI
097D 110001          77          LXI    D,OF2
0980 CD0000     E    78          CALL   LOADY
0983 3E10            79          MVI    A,FADD   ;YES  PHASE=PHASE+PI
0985 D340            80          OUT    IOBAS
0987 210001          81          LXI    H,OF1
098A 110000     E    82          LXI    D,PHASE
098D CD0000     E    83          CALL   LOADY    REPLACE (PHASE) WITH PHASE+PI
0990 2A0000     E    84 DATMN2   LHLD   PHASTO
0993 110001          85          LXI    D,OF1
0996 EB              86          XCHG
0997 CD0000     E    87          CALL   LOADY    ;(PHASTO)=PHASE+PI
099A EB              88 DATMN1   XCHG
099B 220000     E    89          SHLD   PHASTO   (PHASTO) INCREMENTED BY 4 IN LOADY
099E 210000     E    90 TABLE    LXI    H,PHASE  -------------------------
09A1 110001          91          LXI    D,OF1    PHASE(RAD)=PHASE(DEG) FOR PLOT
09A4 CD0000     E    92          CALL   LOADY
09A7 210000     E    93          LXI    H,RADDEG
09AA 110401          94          LXI    D,OF2
09AD CD0000     E    95          CALL   LOADY
09B0 3E12            96          MVI    A,FMUL
09B2 D340            97          OUT    IOBAS
09B4 210001          98          LXI    H,OF1
09B7 110000     E    99          LXI    D,PHASE
09BA CD0000     E   100          CALL   LOADY    --------------------------
09BD CD0000     E   101          CALL   SPACES   LEFT MARGIN
09C0 210000     E   102          LXI    H,MAG    ;------------------------
09C3 CD0000     E   103          CALL   FETCH    ;TABULATE MAG  PT
09C6 CD0000     E   104          CALL   SPACE
09C9 210000     E   105          LXI    H,PHASE
09CC CD0000     E   106          CALL   FETCH    TABULATE PHASE PT
09CF CD0000     E   107          CALL   SPACE
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LOC  OBJ        SEQ      SOURCE STATEMENT

00D2 21????  E  107          LXI   H,FREQ
00D5 CD????  E  108          CALL  FEIDEC  ;TABULATE FREQ PT
00D8 CD????  C  110          CALL  SPACE
00DB CD????  C  111          CALL  NMFLAG  ;NORMALIZE MAG FOR PLOT
00DE CD????  C  112          CALL  NMFPHS  ;NORMALIZE PHASE FOR PLOT
00E1 21????  D  113          LXI   H,MAGX
00E4 11????  D  114          LXI   D,PHASEX
00E7 CD????  E  115          CALL  PLOT    ;PLOT MAG & PHASE PTS @ FREQ
00EA 0E0A       116          MVI   C,0AH   ;LINE FEED
00EC CD????     117          CALL  0F809H  ;LO
00EF 0E0D       118          MVI   C,0DH   ;CARRIAGE RETURN
00F1 CD????     119          CALL  0F809H
00F4 3A????  E  120          LDA   FCOUNT  ;FREQ PT COUNTER
00F7 FE??       121          CPI   3CH     ;IS FCOUNT =60 ?
00F9 C?         122          RNZ
00FA E1         123          POP   H       ;FALSE RETURN
00FB C9         124          RET
00FC 21????  E  125 NMFLAG:  LXI   H,MAG
00FF 11????     126          LXI   D,OF1
0102 CD????  E  127          CALL  LOADY
0105 3A????  D  128          LDA   FLAGX
0108 FEFF       129          CPI   0FFH    ;FIRST POINT ?
010A ?A1E01  C  130          JZ    NM1     ;NO GO TO NM1
010D 21????     131          LXI   H,OF1   ;THIS LINE ONLY USED FOR FIRST PT
0110 11????  D  132          LXI   D,SCALE ;ASSUME FIRST MAG IS GREATEST
0113 CD????  E  133          CALL  LOADY
0116 3EFF       134          MVI   A,0FFH
0118 32????  E  135          STA   LINCT   ;INITIATE LINCT
011B 32????  D  136          STA   FLAGX
011E 21????  D  137 NM1:     LXI   H,SCALE ;---------------------------
0121 11????     138          LXI   D,OF2   ;THIS BLOCK TAKES EACH MAG PT
0124 CD????  E  139          CALL  LOADY   ;AND DIVIDES IT BY (SCALE), THEN
0127 3E??       140          MVI   A,FDIV  ;MULTIPLIES BY 60 WHICH IS THE
0129 D3??       141          OUT   IOESS   ;MAXIMUM SCALE OF THE PLOT FTN
012B 21????  D  142          LXI   H,SIXTY
012E CD????  E  143          CALL  LOAD?
0131 3E??       144          MVI   A,FMUL  ;IE MAG=SIXTY*(MAG/SCALE)*60)
0133 D3??       145          OUT   IOESS
0135 CD????  E  146          CALL  WAIT
0138 3E??       147          MVI   A,FIXED
013A D3??       148          OUT   IOESS
013C CD????  E  149          CALL  WAIT
013F 3A????     150          LDA   OF1
0142 32????  D  151          STA   MAG     ;---------------------------
0145 C9         152          RET
                153
0146 21????  E  154 NMFPHS:  LXI   H,PHASE ;THIS BLOCK SCALES THE PHASE
0149 11????     155          LXI   D,OF1   ;SO THAT IT LIES BETWEEN -1 &
014C CD????  E  156          CALL  LOADY   ;AND +1 ...
014F 21????  D  157          LXI   H,SPEED ;PLOT SCALE
0152 11????     158          LXI   D,OF2
0155 CD????  E  159          CALL  LOADY
0158 3E??       160          MVI   A,FADD
015A D3??       161          OUT   IOESS
015C 21????  D  162          LXI   H,SI
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 LOC  OBJ          SEQ        SOURCE STATEMENT

 015E CD0000   E   163            CALL    LOP2
 0161 3E3C         164            MVI     A,FDIV
 0163 D340         165            OUT     IOSAS
 0165 CD0000   E   166            CALL    WAIT
 0168 3E9A         167            MVI     A,FIXSD
 016A D340         168            OUT     IOSAS
 016C CD0000   E   169            CALL    WAIT
 016F 3A0001       170            LDA     OP1
 0172 325100   D   171            STA     PHASX    PHASE=IFIX((PHASE+180)/5)
 0175 C9           172            RET              ;----------------------------
                   173
 0176 210000   E   174 GAMUP      LXI     H,REFMAG
 0179 220000   E   175            SHLD    MAGSTO
 017C 210000   E   176            LXI     H,REFPAS
 017F 220000   E   177            SHLD    PHASTO   MAGSTO PHASTO ARE ADDR  POINTERS
 0182 210000   E   178            LXI     H,STIMAG
 0185 220F00   D   179            SHLD    MAGSS
 0188 210000   E   180            LXI     H,STPHAS
 018B 221100   D   181            SHLD    PHASS    MAGSS PHASS ARE ALSO ADDR  POINTERS
 018E AF           182            XRA     A
 018F 321300   D   183            STA     FLAGX
 0192 2A0000   E   184 GAMLOP     LHLD    MAGSTO
 0195 110001       185            LXI     D,OP1
 0198 CD0000   E   186            CALL    LOADY
 019B 2A0F00   D   187            LHLD    MAGSS
 019E 110401       188            LXI     D,OP2
 01A1 CD0000   E   189            CALL    LOADY
 01A4 220F00   D   190            SHLD    MAGSS    NEXT STIM MAG PT
 01A7 3E3C         191            MVI     A,FDIV
 01A9 D340         192            OUT     IOSAS    OP1=MAG(REF)/MAG(STIM)
 01AB 110001       193            LXI     D,OP1
 01AE 2A0000   E   194            LHLD    MAGSTO
 01B1 EB           195            XCHG
 01B2 CD0000   E   196            CALL    LOADX    (MAGSTO)=REFMAG/STIMAG)
 01B5 EB           197            XCHG
 01B6 220000   E   198            SHLD    MAGSTO   ;NEXT MAG(REF) PT
 01B9 2A0000   E   199            LHLD    PHASTO   ;----------------------------
 01BC 110001       200            LXI     D,OP1
 01BF CD0000   E   201            CALL    LOADY    ;OP1=REFERENCE PHASE
 01C2 2A1100   D   202            LHLD    PHASS
 01C5 110401       203            LXI     D,OP2
 01C8 CD0000   E   204            CALL    LOADY    OP2=STIMULUS PHASE
 01CB 221100   D   205            SHLD    PHASS    ;NEXT STIM PHASE PT
 01CE 3E3D         206            MVI     A,FSUB
 01D0 D340         207            OUT     IOSAS    OP1=PHASE(REF)-PHASE(STIM)
 01D2 110001       208            LXI     D,OP1
 01D5 2A0000   E   209            LHLD    PHASTO
 01D8 EB           210            XCHG
 01D9 CD0000   E   211            CALL    LOADX    ;(PHASTO)=(REFPHS)-(STPHAS)
 01DC EB           212            XCHG
 01DD 220000   E   213            SHLD    PHASTO   UPDATE PHASTO
 01E0 3A1300   D   214            LDA     FLAGX
 01E3 3C           215            INR     A        ;INCREMENT COUNTER
 01E4 FE0C         216            CPI     0CH      COUNTER=END ?
 01E6 CA0000   C   217            JZ      GAMFLT
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LOC  OBJ          SEQ         SOURCE STATEMENT

01EA [illegible]  D   218            STA    FLAGY   ;NO, STORE COUNTER
01ED C3[illegible] C  219            JMP    GAMLOP
                      220
01F0 0E[illegible]    221 GAMPLT     MVI    C,3CH   ;END FREQ COUNTER
01F2 [illegible]  E   222            LXI    H,RESMAG
01F5 [illegible]  C   223            CALL   SRSLOP  ;FIND MAX OF (RESMAG)
01F8 [illegible]  D   224            LXI    H,MAX
01FB [illegible]  D   225            LXI    D,SCALE
01FE [illegible]  E   226            CALL   LOADY   ;(SCALE)= GAMMA MAGNITUDE [illegible]
0201 [illegible]  E   227            LXI    H,RESMAG ---------------------------
0204 [illegible]  E   228            SHLD   MAGSTO  RESET [illegible] MAG & PHASE
0207 [illegible]  E   229            LXI    H,RESPHASE ADDRESS POINTERS
020A [illegible]  E   230            SHLD   PHASTO  ---------------------------
020D 3EFF             231            MVI    A,0FFH  INITIALIZE FLAGX LINCT FCOUNT
020F [illegible]  D   232            STA    FLAGX
0212 [illegible]  E   233            STA    LINCT
0215 AF               234            XRA    A
0216 [illegible]  E   235            STA    FCOUNT  ;FOR SAM1
0219 [illegible]  E   236 RSFLOP     CALL   SAM1    ;ESTABLISH FREQ
021C [illegible]  E   237            LHLD   MAGSTO
021F [illegible]  E   238            LXI    D,MAG
0222 [illegible]  E   239            CALL   LOADY   ;(MAG)=((MAGSTO))
0225 [illegible]  E   240            SHLD   MAGSTO  UPDATE MAGSTO
0228 [illegible]  E   241            LHLD   PHASTO
022B [illegible]  E   242            LXI    D,PHASE
022E [illegible]  E   243            CALL   LOADY   ;(PHASE)=((PHASTO))
0231 [illegible]  E   244            SHLD   PHASTO  ;UPDATE PHASTO
0234 CD[illegible] C  245            CALL   TABLE   ;TABULATE & PLOT GAMMA
0237 [illegible]  C   246            JMP    RSFLOP  AUTO RET IN TABLE
                      247
023A [illegible]  E   248 EPSLON     LXI    H,RESMAG
023D [illegible]  E   249            SHLD   MAGSTO
0240 [illegible]  E   250            LXI    H,RESPHASE
0243 [illegible]  E   251            SHLD   PHASTO  MAGSTO PHASTO ARE ADDR POINTERS
0246 AF               252            XRA    A
0247 [illegible]  E   253            STA    FCOUNT
024A 3E[illegible]    254            MVI    A,3CH   60D=FREQ DOMAIN COUNTER
024C [illegible]  D   255            STA    FLAGX   ;FLAG NO LONGER REQUIRED FOR NORMAG
024F [illegible]  E   256 NORL       CALL   SAM1    TO ESTABLISH FREQ
0252 [illegible]  E   257            LHLD   MAGSTO  GAMMA MAGNITUDE
0255 [illegible]      258            LXI    D,OP1
0258 [illegible]  E   259            CALL   LOADY
025B 3E[illegible]    260            MVI    A,F3DF
025D [illegible]      261            OUT    IOSSS
025F [illegible]      262            LXI    H,OP1
0262 [illegible]      263            LXI    D,GAMSTR GAMSTR=GAMMAG+2
0265 [illegible]  E   264            CALL   LOAD
0268 [illegible]  E   265            LHLD   PHASTO
026B [illegible]      266            LXI    D,OP1   OP1=GAMMA PHASE
026E [illegible]  E   267            CALL   LOADY
0271 [illegible]  C   268            CALL   [illegible]  SET 0 [illegible] PHASE [illegible]
0274 [illegible]  E   269            CALL   [illegible]  [illegible]
0277 [illegible]  E   270            LHLD   PHASTO  [illegible]
027A [illegible]      271            LXI    D,OP1
027D [illegible]  E   272            CALL   LOADY
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 LOC  OBJ          SEQ        SOURCE STATEMENT

0180 3E02          273         MVI     A,FMUL
0182 D340          274         OUT     IOEAS   ;OP1=GAMMAG*COS(GAMPHAS)
0184 210F00   D    275         LXI     H,TWO
0187 CD0000   E    276         CALL    LOF2
018A 3E02          277         MVI     A,FMUL
018C D340          278         OUT     IOEAS   ;OP1=2*GAMMAG*COS(GAMPHAS)
018E 110700   D    279         LXI     H,GAMSQR
0191 CD0000   E    280         CALL    LOF2
0194 3E04          281         MVI     A,FADD
0196 D340          282         OUT     IOEAS   ;OP1=GAMMAG**2+2*GAMMAG*COS(GAMPHAS)
0198 210B00   D    283         LXI     H,ONE
019B CD0000   E    284         CALL    LOF2
019E 3E04          285         MVI     A,FADD
01A0 D340          286         OUT     IOEAS
01A2 210001        287         LXI     H,OP1
01A5 110500   D    288         LXI     D,HVAL
01A8 CD0000   E    289         CALL    LOADY   ;HVAL=GAMMAG**2+2*GAMMAG*COS(GAMPHAS)+1
01AB 210000   E    290         LXI     H,FREQ
01AE 110001        291         LXI     D,OP1
01B1 CD0000   E    292         CALL    LOADY
01B4 211600   D    293         LXI     H,PI2C2D;PI2C2D=2*PI-C0*Z0
01B7 110401        294         LXI     D,OP2
01BA CD0000   E    295         CALL    LOADY
01BD 3E02          296         MVI     A,FMUL
01BF D340          297         OUT     IOEAS   ;OP1=2*PI-F*C0*Z0
01C1 210500   D    298         LXI     H,HVAL
01C4 CD0000   E    299         CALL    LOF2
01C7 3E02          300         MVI     A,FMUL
01C9 D340          301         OUT     IOEAS
01CB 210001        302         LXI     H,OP1
01CE 110500   D    303         LXI     D,HVAL
01D1 CD0000   E    304         CALL    LOADY   ;HVAL=(G**2+2*G*COS(P)+1)*2*PI-F*C0-Z0
                   305
01D4 2A0000   E    306         LHLD    PHASTO
01D7 110001        307         LXI     D,OP1
01DA CD0000   E    308         CALL    LOADY
01DD CD0000   E    309         CALL    SINE
01E0 2A0000   E    310         LHLD    MAGSTO  ;OP1=SIN(GAMPHAS)
01E3 110401        311         LXI     D,OP2
01E6 CD0000   E    312         CALL    LOADY
01E9 3E02          313         MVI     A,FMUL
01EB D340          314         OUT     IOEAS   ;OP1=GAMMAG*SIN(GAMPHAS)
01ED 210F00   D    315         LXI     H,TWO
01F0 CD0000   E    316         CALL    LOF2
01F3 3E02          317         MVI     A,FMUL
01F5 D340          318         OUT     IOEAS   ;OP1=2*GAMMAG*SIN(GAMPHAS)
01F7 210500   D    319         LXI     H,HVAL
01FA CD0000   E    320         CALL    LOF2
01FD 3E03          321         MVI     A,FDIV
01FF D340          322         OUT     IOEAS   ;OP1=2*GAMMAG*SIN(GAMPHAS)/HVAL
0201 110001        323         LXI     D,OP1
0204 2A0000   E    324         LHLD    MAGSTO
0207 EB            325         XCHG
0208 CD0000   E    326         CALL    LOAD    ;REG(MAG)=FED
020B EB            327         XCHG
```

```
LOC  OBJ              SOURCE STATEMENT

020C 220000   E        SHLD   MAGSTO  ;NEXT MAG PT

020F 210000   D        LXI    H,GAMSQR
0212 112401            LXI    D,OP2
0215 CD0000   E        CALL   LOADY
0218 210000   D        LXI    H,ONE
021B 110001            LXI    D,OP1
021E CD0000   E        CALL   LOADY
0221 3E05              MVI    A,FSUB
0223 D3 A0             OUT    IOEAS   ;OP1=1-GAMSQR
0225 210000   D        LXI    H,HVAL
0228 CD0000   E        CALL   LOP2
022B 3E02              MVI    A,FDIV
022D D3A0              OUT    IOEAS   ;OP1=(1-GAMSQR)/HVAL
022F 110001            LXI    D,OP1
0232 2A0000   E        LHLD   PHASTO
0235 EB                XCHG
0236 CD0000   E        CALL   LOADY   ;(PERPHSE)=E2
0239 EB                XCHG
023A 220000   E        SHLD   PHASTO  ;NEXT PHASE PT
023D 3A0000   D        LDA    FLAGY
0240 3D                DCR    A
0241 C8                RZ
0242 320000   D        STA    FLAGY
0245 C30000   C        JMP    HCAL

0248 2A0000   E  AMBIG LHLD   PHASTO  ;ELIMINATION OF PHASE AMBIGUITIES
024B 110001            LXI    D,OP1
024E CD0000   E        CALL   LOADY   ;OP1=PHASE
0251 210001     AMBIG1 LXI    H,OP1   ;CHECK FOR VALID ZERO
0254 7E                MOV    A,M
0255 23                INX    H
0256 B6                ORA    M
0257 23                INX    H
0258 B6                ORA    M
0259 23                INX    H
025A B6                ORA    M
025B CA0000   C        JZ     LEZERO  ;PHASE = 0, GO TO LEZERO
025E 3A0301            LDA    OP1+3
0261 E680              ANI    80H     ;PHASE GT 0 ?
0263 CA0000   C        JZ     CLAD1   ;YES, CHECK IF IN CLAD1
0266 210000   D LEZERO LXI    H,ONE20
0269 110001            LXI    D,OP2
026C CD0000   E        CALL   LOADY
026F 3E01              MVI    A,FADD
0271 D3A0              OUT    IOEAS
0273 CD0000   E        CALL   WAIT
0276 C30000   C        JMP    AMBIG1
0279 210000   D  CLAD1 LXI    H,ONE20 ;OP1=PHASE GT 0
027C 110001            LXI    D,OP2
027F CD0000   E        CALL   LOADY
0282 3E0A              MVI    A,FCLR  ;OP1-ONE20
0284 D3A0              OUT    IOEAS
0286 CD0000   E        CALL   WAIT
0289 DBA1              IN     A1H     ;STATUS BYTE
```

```
LOC  OBJ         SEQ        SOURCE STATEMENT

0195 E680         383        ANI    40H      ;PHASE LE 180 ?
0197 CA9A01   C   384        JZ     AMBOUT   ;YES
019A 3E0F         385        MVI    A,FEUB   ;NO. PHASE=PHASE-180
019C D3..         386        OUT    IOEPS
019E CD0000   E   387        CALL   WAIT
01A1 C3..01   C   388        JMP    AMSIG1
01A4 210001       389 AMSOUT LXI    H,OF1
01A7 110000   E   390        LXI    D,PHASE
01AA CD0000   E   391        CALL   LOADY
01AD C9           392        RET
                  393
01AE 0E..         394 EPLOT  MVI    C,3CH    ;600 (FREQ AT 10 STEP)
01B0 2100..   E   395        LXI    H,REEMAG
01B3 CD....   C   396        CALL   EPELOP   ;FIND MAX AND MIN OF REEMAG BUFFER
01B6 210000   D   397        LXI    H,MAX
01B9 111500   D   398        LXI    D,E0MAX
01BC CD0000   E   399        CALL   LOADY
01BF 211700   D   400        LXI    H,MIN
01C2 111F00   D   401        LXI    D,E0MIN
01C5 CD0000   E   402        CALL   LOADY    ;E0MAX E0MIN ESTABLISHED
                  403
01C8 0E3C         404        MVI    C,3CH
01CA 210000   E   405        LXI    H,REPHAS
01CD CD....   C   406        CALL   EPELOP   ;FIND MAX, MIN OF REPHAS BUFFER
01D0 211100   D   407        LXI    H,MAX
01D3 112300   D   408        LXI    D,E2MAX
01D6 CD0000   E   409        CALL   LOADY
01D9 211700   D   410        LXI    H,MIN
01DC 112700   D   411        LXI    D,E2MIN
01DF CD0000   E   412        CALL   LOADY    ;E2MAX E2MIN ESTABLISHED
                  413
01E2 211500   D   414        LXI    H,E0MAX
01E5 110001       415        LXI    D,OF1
01E8 CD0000   E   416        CALL   LOADY
01EB 211F00   D   417        LXI    H,E0MIN
01EE 110101       418        LXI    D,OF2
01F1 CD0000   E   419        CALL   LOADY
01F4 3E05         420        MVI    A,FEUB
01F6 D3..         421        OUT    IOEPS
01F8 210001       422        LXI    H,OF1
01FB 111500   D   423        LXI    D,E0MAX
01FE CD0000   E   424        CALL   LOADY    ;E0MA=E0MA-E0MIN
0201 212300   D   425        LXI    H,E2MAX
0204 110001       426        LXI    D,OF1
0207 CD0000   E   427        CALL   LOADY
020A 212700   D   428        LXI    H,E2MIN
020D 110401       429        LXI    D,OF2
0210 CD0000   E   430        CALL   LOADY
0213 3E05         431        MVI    A,FEUB
0215 D3..         432        OUT    IOEPS
0217 210001       433        LXI    H,OF1
021A 110000   E   434        LXI    D,E2MA
021D CD0000   E   435        CALL   LOADY    ;E2MA=E2MA-E2MIN
                  436
0220 210000   E   437        LXI    H,REEMAG
```

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LOC  OBJ         SEQ       SOURCE STATEMENT

0419 220000  E   438        SHLD   MAGSTO  ;E0 ADDR POINTER
041C 210000  E   439        LXI    H,FEPHAS
041F 220000  E   440        SHLD   PHASTO  ;E2 ADDR POINTER
0422 AF          441        XRA    A
0423 320000  E   442        STA    FCOUNT  ;FOR SAM1 FRED
0426 210000      443        LXI    H,E0STO
0429 220000  E   444        SHLD   PTADDR
042C 2140E0      445        LXI    H,E2STO
042F 220000  D   446        SHLD   EPSPTR
0432 3EFF        447        MVI    A,0FFH
0434 320000  E   448        STA    LINCT   ;FOR PLOT
0437 CD0000  E   449 PLTLOP CALL   SAM1    ;-------------------------
043A CD0000  C   450        CALL   SPACE9  ;MARGIN
043D 2A0000  E   451        LHLD   MAGSTO
0440 CD0000  E   452        CALL   FBIDEC  ;E0 PRINTED
0443 CDF505  C   453        CALL   SPACE
0446 2A0000  E   454        LHLD   PHASTO
0449 CD0000  E   455        CALL   FBIDEC  ;E2 PRINTED
044C CDF505  C   456        CALL   SPACE
044F 210000  E   457        LXI    H,FRED
0452 CD0000  E   458        CALL   FBIDEC  ;FRED PRINTED
0455 CDF505  C   459        CALL   SPACE   ;------------------------
0458 211E00  D   460        LXI    H,E0MAX
045B 111C00  D   461        LXI    D,MAX
045E CD0000  E   462        CALL   LOADY
0461 211F00  D   463        LXI    H,E0MIN
0464 111D00  D   464        LXI    D,MIN
0467 CD0000  E   465        CALL   LOADY
046A 2A0000  E   466        LHLD   MAGSTO
046D CDFA04  C   467        CALL   PLTNRM
0470 325100  D   468        STA    MAGY    ;MAGY=NORMALIZED E0
0473 2A4E00  D   469        LHLD   FUNCTY  ;UPDATED ADDR  PTR  STORED IN PLTNRM
0476 220000  E   470        SHLD   MAGSTO  ;UPDATED MAGSTO FOR NEXT PT
0479 2A0000  E   471        LHLD   PTADDR
047C 77          472        MOV    M,A     ;STORE FOR COLE-COLE PLOT
047D 23          473        INX    H
047E 220000  E   474        SHLD   PTADDR
0481 212000  D   475        LXI    H,E2MAX
0484 111C00  D   476        LXI    D,MAX
0487 CD0000  E   477        CALL   LOADY
048A 212100  D   478        LXI    H,E2MIN
048D 111D00  D   479        LXI    D,MIN
0490 CD0000  E   480        CALL   LOADY
0493 2A0000  E   481        LHLD   PHASTO
0496 CDFA04  C   482        CALL   PLTNRM
0499 325200  D   483        STA    PHASY   ;PHASY=NORMALIZED E2 FOR PLOT
049C 2A4E00  D   484        LHLD   FUNCTY  ;UPDATED ADDR  PTR  STORED IN PLTNRM
049F 220000  E   485        SHLD   PHASTO  ;UPDATED PHASTO FOR NEXT PT
04A2 2A0000  D   486        LHLD   EPSPTR
04A5 77          487        MOV    M,A     ;STORE FOR COLE-COLE
04A6 23          488        INX    H
04A7 220000  D   489        SHLD   EPSPTR
04AA 215100  D   490        LXI    H,MAGY
04AD 115200  D   491        LXI    D,PHASY
04B0 CD0000  E   492        CALL   PLOT
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LOC  OBJ         SEQ        SOURCE STATEMENT

04E3 0E0A         493        MVI    C,0AH
04E5 CD[illegible]         494        CALL   0F809H
04E8 0E0D         495        MVI    C,0DH
04EA CD09F8       496        CALL   0F809H
04ED 3A[illegible]    E    497        LDA    PCOUNT
04F0 FE0C         498        CPI    0CH
04F2 C2[illegible]    C    499        JNZ    PLTLOP
04F5 C9           500        RET
                  501
04F6 11[illegible]         502 PLTAPM LXI    D,OP1
04F9 CD[illegible]    E    503        CALL   LOADY    ;LOAD OPERAND
04FC 22[illegible]    D    504        SHLD   PNCTY    ;STORE UPDATED ADDR POINTER
04FF 21[illegible]    D    505        LXI    H,MIN
0502 11[illegible]         506        LXI    D,OP2
0505 CD[illegible]    E    507        CALL   LOADY
0508 3E05         508        MVI    A,FSUB
050A D340         509        OUT    IOBAS    ;OP1=EPSILON(P)-EPSILON(MIN)
050C 21[illegible]    D    510        LXI    H,NA     ;RECALL E RANGE MAX-E MIN
050F CD[illegible]    E    511        CALL   LOP2
0512 3E0D         512        MVI    A,FDIV
0514 D340         513        OUT    IOBAS    ;OP1=(E(P)-EMIN)/(E MAX-E MIN) LE 1
0516 21[illegible]    D    514        LXI    H,SIXTY
0519 CD[illegible]    E    515        CALL   LOP2
051C 3E0C         516        MVI    A,FMUL
051E D340         517        OUT    IOBAS
0520 CD[illegible]    E    518        CALL   WAIT
0523 3E[illegible]         519        MVI    A,FIXSD
0525 D340         520        OUT    IOBAS
0527 CD[illegible]    E    521        CALL   WAIT
052A 3A[illegible]         522        LDA    OP1
052D C9           523        RET
                  524
052E 22[illegible]    E    525 EPSLOP SHLD   PTADDR
0531 11[illegible]    D    526        LXI    D,MAX
0534 CD[illegible]    E    527        CALL   LOADY
0537 2A[illegible]    E    528        LHLD   PTADDR
053A 11[illegible]    D    529        LXI    D,MIN
053D CD[illegible]    E    530        CALL   LOADY    ;MAX=MIN=FIRST POINT
0540 22[illegible]    E    531        SHLD   PTADDR   ;SECOND POINT
0543 0D           532 EPS1   DCR    C
0544 C8           533        RZ
0545 2A[illegible]    E    534        LHLD   PTADDR
0548 11[illegible]         535        LXI    D,OP1
054B CD[illegible]    E    536        CALL   LOADY
054E 22[illegible]    E    537        SHLD   PTADDR   ;NEXT POINT
0551 3A[illegible]         538        LDA    OP1+3    ;CHECK SIGN BIT
0554 E6[illegible]         539        ANI    80H      ;FORMER USES ADD AL FOR OP1 OP2
0556 C2[illegible]    C    540        JNZ    LTZERO   ;BOTH LT ZERO
0559 3A[illegible]    D    541 GTZERO LDA    MAX+3
055C E6[illegible]         542        ANI    80H
055E C2[illegible]    C    543        JNZ    MAXPT    ;IF MAX IS NEG, GO TO MAXPT
0561 21[illegible]    D    544        LXI    H,[illegible]
0564 CD[illegible]    C    545        CALL   LDCMP    ;LOAD AND COMPARE
0567 E6[illegible]         546        ANI    40H      ;PT GT MAX
0569 C2[illegible]    C    547        JNZ    MAXPT    ;YES, GO TO MAXPT
```

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LOC  OBJ          STMT         SOURCE STATEMENT

0E3D 3A1E0F   D   548          LDA     MIN+3    NO, MIN LT 0 ?
0E3F E680         549          ANI     80H
0E41 C2110F   C   550          JNZ     EPE1     YES, GO TO EPE1
0E44 21170D   D   551          LXI     H,MIN    NO
0E47 CD2C0E   C   552          CALL    LODCMP
0E4A E610         553          ANI     10H      ,PT LT MIN ?
0E4C CA110F   C   554          JZ      EPE1     NO, GO TO EPE1
0E4F 210C01       555 MINPT    LXI     H,OP1
0E52 111700   D   556          LXI     D,MIN
0E55 CD0000   E   557          CALL    LOADY    YES, MIN=PT
0E58 C3110F   C   558          JMP     EPE1
                  559
0E5B 3A1A0D   D   560 LTZERO   LDA     MIN+3
0E5E E680         561          ANI     80H
0E60 CA4F0E   C   562          JZ      MINPT    MIN IS POS, GO TO MINPT
0E63 21170D   D   563          LXI     H,MIN
0E66 CD2C0E   C   564          CALL    LODCMP
0E69 E640         565          ANI     40H      PT GT MIN ? (ABS PT GT ABS MIN)
0E6B C24F0E   C   566          JNZ     MINPT    ,YES, GO TO MINPT
0E6E 3A1A0D   D   567          LDA     MAX+3    NO, MAX GT 0 ?
0E71 E680         568          ANI     80H
0E73 CA110F   C   569          JZ      EPE1     YES, GO TO EPE1
0E76 211300   D   570          LXI     H,MAX    ,NO
0E79 CD2C0E   C   571          CALL    LODCMP
0E7C E610         572          ANI     10H      ,PT LT MAX ?
0E7E CA110F   C   573          JZ      EPE1     ,NO, GO TO EPE1
0E81 210C01       574 MAXPT    LXI     H,OP1
0E84 111300   D   575          LXI     D,MAX
0E87 CD0000   E   576          CALL    LOADY    YES, MAX=PT
0E8A C3110F   C   577          JMP     EPE1
                  578
0E8D 110A01       579 LODCMP   LXI     D,OP2    ,LOAD (HL) INTO OP2 AND
0E90 CD0000   E   580          CALL    LOADY    ,COMPARE WITH (OP1
0E93 3E0A         581          MVI     A,FCMPR
0E95 D3C0         582          OUT     IOBAS
0E97 CD0000   E   583          CALL    WAIT
0E9A DB41         584          IN      41H      ,STATUS
0E9C C9           585          RET
                  586
0E9D 0600         587 COLPLT   MVI     B,0      ,DOMAIN
0E9F 0E84         588 SPCHG    MVI     C,84H
0EA1 CD0EFE       589          CALL    0FE0EH   0FE0EH IS THE STARTING ADDR OF
0EA4 0E11         590          MVI     C,11     A ROUTINE WHICH SENDS (C) REG
0EA6 CD0EFE       591          CALL    0FE0EH   TO THE LP
0EA9 0E12         592          MVI     C,12H    ,CHAR DENSITY TO 12
0EAB CD0EFE       593          CALL    0FE0EH
0EAE 0E04         594          MVI     C,04H    TO 4? IN STEP FOR LF
0EB0 CD0EFE       595          CALL    0FE0EH   ,(INTERLEAVED CH CODE ARE SEPARATED
0EB3 0E0C         596          MVI     C,0CH     BY LF, FF)
0EB5 1100E0       597          LXI     D,E0STO  (DE)=ADDR OF E0
0EB8 2100E1       598          LXI     H,E0STO  HL=ADDR OF E1
0EBB 7E           599 SPCH     MOV     A,M
0EBC BB           600          CMP     E        ,FOR EACH E, SEE IF IT IS PRESENT IN E1
0EBD CCE90F   C   601          CZ      COLE
0EC0 23           602          INX     H
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LOC  OBJ          SEQ         SOURCE STATEMENT

05C1 13           603         INX     D
05C2 0D           604         DCR     C        ;BUFFER CHECKER
05C3 C2C505  C    605         JNZ     SPCH     ;MORE DOMAIN ETC. CONTINUE
05C6 04           606         INR     B        ;DOMAIN INCREMENT
05C7 3E1C         607         MVI     A,1CH    ;E10
05C9 B8           608         CMP     B        ;DOMAIN OUT OF RANGE ?
05CA C8           609         RZ               ;YES
05CB C3C505  C    610         JMP     SPCH0
05CE C5           611 CODE    PUSH    B
05CF 1A           612         LDAX    D
05D0 3C           613         INR     A
05D1 3D           614 SPALOP  DCR     A
05D2 CADE05  C    615         JZ      STAR
05D5 0E10         616         MVI     C,10H
05D7 F5           617         PUSH    PSW
05D8 CD0FF8       618         CALL    0F80FH
05DB F1           619         POP     PSW
05DC C3D105  C    620         JMP     SPALOP
05DF 0E2A         621 STAR    MVI     C,'*'
05E1 CD0FF8       622         CALL    0F80FH
05E4 0E12         623         MVI     C,12H    ;CHAR. DENSITY TOGGLE
05E6 CD0FF8       624         CALL    0F80FH
05E9 0E0D         625         MVI     C,0DH
05EB CD0FF8       626         CALL    0F80FH
05EE C1           627         POP     B
05EF C9           628         RET
                  629
05F0 0605         630 SPACER  MVI     B,05H    ;LEFT MARGIN 5 SPACES
05F2 C3F705  C    631         JMP     SPA1
05F5 0602         632 SPACE   MVI     B,2      ;OUTPUT 2 SPACES TO LIST DEV
05F7 0E20         633 SPA1    MVI     C,20H    ;SPACE
05F9 CD0FF8       634 SPA2    CALL    0F80FH   LO
05FC 05           635         DCR     B
05FD C2F905  C    636         JNZ     SPA1
0600 C9           637         RET
                  638
                  639 DSEG
0002              640 ERSETR  DS      2
0001              641 FLAG    DS      1
0004              642 SCALE   DS      4
0004              643 CAMERA  DS      4        ;CAMERA=GA  AAAL
0004              644 HVAL    DS      4        ;HVAL  USED IN EPLOT
0002              645 VALUES  DS      2        ;ADDR  PTR FOR GAMMA
0002              646 PHASES  DS      2        ;ADDR  PTR FOR GAMMA
0004              647 YA      DS      4        ;FOR EPLOT
0004              648 MIN     DS      4        ;FOR EPLOT
0004              649 EDIM    DS      4        ;FOR EPLOT
0004              650 EDMAX   DS      4        ;FOR EPLOT
0004              651 ELMAX   DS      4        ;FOR EPLOT
0004              652 ELMIN   DS      4        ;FOR EPLOT
0015 00           653 EL      DB      0,0,20H,40H
0016 00
0017 20
0018 40
0019 00           654 EL TP   DB      0,0,20H,41H
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LOC  OBJ         SEQ        SOURCE STATEMENT

0030 83
0031 70
0032 42
0033 00          655 ONESQ.  DB      0,0,304,42H
0034 00
0035 34
0036 42
0037 00          656 THIRTY  DB      0,0,0F0H,41H
0038 00
0039 F0
003A 41
003B 00          657 ONE     DB      0,0,304,3FH
003C 00
003D 00
003E 3F
003F 00          658 TWO     DB      0,0,0,40H
0040 00
0041 00
0042 40
0043 DA          659 PIB2    DB      0DAH,0FH,0C9H,3FH
0044 0F
0045 C9
0046 3F
0047 DA          660 PI      DB      0DAH,0FH,49H,40H      ;SO BELOW = 3.1 FF
0048 0F
0049 49
004A 40
004B 7B          661 PIDCD0  DB      7BH,0A5H,0E4H,3EH     ;2*PI*C0*C0
004C A5
004D E1
004E 3E
0001             662 PMCTY   DS      2
0001             663 MAG     DS      1
0001             664 PHASE   DS      1
                 665 END

PUBLIC SYMBOLS
COLPLT C 0590   EPLOT  C 0CA4   EPSLON C 02DA   FLAGX  D 0002   FREDOM C 0020   GAMMA  D 0177

EXTERNAL SYMBOLS
ACTOR  E 0000   CLEAR  E 0000   COSINE E 0000   FEIDEI E 0000   FIDUNT E 0000   FRED   E 0000   LIMIT  E 0000
LOFT   E 0000   LIFT   E 0000   LOPE   E 0000   MAG    E 0000   MAGSTO E 0000   NORMAL E 0000   PHASE  E 0000
PHASTC E 0000   PLOT   E 0000   PREPRO E 0000   PTADDR E 0000   PRTIES E 0000   REPHAE E 0000   RESTAS E 0000
S      E 0000   S1     E 0000   SAM1   E 0000   SINE   E 0000   STINAS E 0000   STAAAS E 0000   TRNSFN E 0000
WAIT   E 0000

USER SYMBOLS
ACTOR  E 0000   ASIG   C [illegible]   AMBIG1 C 0CF1   A EDLT C [illegible]   CLEAR  E [illegible]   COLE   C [illegible]   COLPLT C 0590
COSINE E 0000   [illegible]   [illegible]   [illegible]   [illegible]   [illegible]   [illegible]
[illegible]   [illegible]   [illegible]   EPLOT  C 0CA4   EPS1   C 0510   EPSLON C 02DA   EPSLON [illegible]
[illegible]   [illegible]   [illegible]   [illegible]   [illegible]   [illegible]   [illegible]
[illegible]   [illegible]   [illegible]   [illegible]   [illegible]   [illegible]   PMCTY  D [illegible]
[illegible]   GAMMA  D 0177   [illegible]   [illegible]   [illegible]   [illegible]   [illegible]
[illegible]   [illegible]   LIMIT  E [illegible]   LOAD   E [illegible]   [illegible]   [illegible]   LOPE   E [illegible]
LTTERC C 0588   MAG    E [illegible]   MAGSS  D [illegible]   MAGSTO E 0000   MAG    D 0051   [illegible]   [illegible] C 0561
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MIN    D 0017   MINAT  C 059F   NM1    C 011E   NORMAG C 00FC   NORMAL E 0000   NORPHS C 0146   ONE    D 0026
OVERFL D 0022   OP1    A C100   OP2    A C104   PHASE  E 0000   PHASES D 0011   PHASTO E 0000   PHAS   D 0052
PI     D 0047   PI2    D 0045   PIBY2  D 0043   PLOT   E 0000   PLTLOP C 0427   PLTMAN C 04C5   PREFRQ E 0000
PTR    E 0000   QUAD   C 0073   RADIES E 0000   REFLCP C 0119   REPHAS E 0000   RESPHS E 0000   S      E 0000
S1     E 0000   SA1    E 0000   SCALE  D 004C   SINE   E 0000   SIN    D 001E   SINTW  D 001F   SPA1   C 05F9
SPAD   C 05E7   SPACE  C 05F5   SPACES C 05F0   SPALTF C 05D1   SPC4   C 05EE   SPCH3  C 059F   STAR   C 05DF
STMAG  E 0000   STPHS  E 0000   TABLE  C 003E   THIRTY D 0037   TRNSFM E 0000   TSTLOP C 0018   TWO    D 002F
WAIT   E 0000
```

ASSEMBLY COMPLETE, NO ERRORS

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LOC  OBJ          SEQ        SOURCE STATEMENT

                             ;NAME  SAMULO
                             ;THIS FILE CONTAINS ALL NORMALIZATION ROUTINES
                             ;AND PREPARATORY ROUTINES FOR THE FOURIER
                             ;TRANSFORM, ALSO IN THIS FILE
0002                         FMUL    EQU     2
0003                         FDIV    EQU     3
0004                         FADD    EQU     4
0005                         FSUB    EQU     5
0006                         FSQR    EQU     6
0007                         FSTAT   EQU     7
0008                         FLTDS   EQU     8H
0009                         FIXSD   EQU     9H
000A                         FCLPR   EQU     0AH
000E                         FITST   EQU     0EH
000F                         FXCH    EQU     0FH
C100                         OP1     EQU     0C100H
C104                         OP2     EQU     OP1+4
0040                         IOBASE  EQU     40H      ;MEM  BASE ADDR
                             CSEG
                             EXTRN   S,S1,FLAGN,FLAG
                             PUBLIC  FREQ TRNSFM FRIDEC PREPRO
                             PUBLIC  MAG,PHASE,PTCNT
                             PUBLIC  NORMAL,SAM1,PTADDR
                             EXTRN   SINE COSINE,ATAN POCTOR,ACCLOC
                             EXTRN   LOADY,LOAD  LOAD WAIT,CLEAR DCET
0000 2A0000    E             NORMAL  LHLD    ACCTOR
0003 CD0000    E                     CALL    NORMN   ;PT=NORMALIZED PT
0006 2A0000    D                     LHLD    PTADDR  ;PTADDR=M
0009 2B                      NORML   DCX     H
000A 2B                              DCX     H
000B 2B                              DCX     H
000C 2B                              DCX     H       ;PTADDR=M-1 .
000D CD0000    C                     CALL    NORMN
0010 2A0000    D                     LHLD    PTADDR
0013 1104C1                          LXI     D,OP2
0016 CD0000    E                     CALL    LOADY   ;OP2=PT(M-1)
0019 1100C1                          LXI     D,OP1
001C CD0000    E                     CALL    LOADY   ;OP1=PT(M)
001F 3E05                            MVI     A,FSUB
0021 D340                            OUT     IOBASE
0023 2B                              DCX     H
0024 2B                              DCX     H
0025 2B                              DCX     H
0026 2B                              DCX     H
0027 1100C1                          LXI     D,OP1
002A EB                              XCHG
002B CD0000    E                     CALL    LOADY   ;PT(M)=PT(M)-PT(M-1)
002E 2A0000    E                     LHLD    ACCLOC
0031 EB                              XCHG
0032 2A0000    D                     LHLD    PTADDR  ;THIS BLOCK COMPARES PTADDR TO
0035 7C                              MOV     A,H     ;ACCLOC TO SEE IF THERE ARE MORE
0036 BA                              CMP     D        POINTS
```

```
LOC  OBJ          SEQ        SOURCE STATEMENT

0037 C20000   C    53          JNZ    NORM2
003A 7D            54          MOV    A,L
003B 5B            55          CMP    E
003C C20000   C    56          JNZ    NORM2
003F C9            57          RET
                   58
0040 2A0000   D    59 NORMN    LHLD   PTADDR
0043 110001        60          LXI    D,OP2
0046 CD0000   E    61          CALL   LOADY   ;OP2=(PTADDR)
0049 210000   E    62          LXI    H,S1
004C 110001        63          LXI    D,OP1
004F CD0000   E    64          CALL   LOADY   ;OP1=S1
0052 3E1D          65          MVI    A,FSUB
0054 D340          66          OUT    IOEA5
0056 210000   E    67          LXI    H,S
0059 CD0000   E    68          CALL   LOF2    ;OP1=S1-PT, OP2=S
005C 3E1C          69          MVI    A,FDIV
005E D340          70          OUT    IOEAS
0060 214E00   D    71          LXI    H,ONE   ;REINSTATE ONE TO OP2
0063 CD0000   E    72          CALL   LOF2    ;OP1=(S1-PT)/S, OP2=1
0066 3E0F          73          MVI    A,FCMPR ;(S1-PT)/S GT ONE ?
0068 D340          74          OUT    IOEAS
006A CD0000   E    75          CALL   WAIT
006D 2A0000   D    76          LHLD   PTADDR
0070 110001        77          LXI    D,OP1
0073 EB            78          XCHG           ;SET UP TO REPLACE OLD PT WITH
0074 DB41          79          IN     41H     ;(STATUS BYTE)  NORMALIZED PT
0076 E640          80          ANI    40H     ;PT GT 1 (FROM FCMPR RSD BIT)?
0078 DA7E00   C    81          JC     NORM1   ;NO, GO TO NORM1
007B 214E00   D    82          LXI    H,ONE   ;YES, REPLACE PT WITH 1
007E CD0000   E    83 NORM1    CALL   LOADY
0081 C9            84          RET
                   85
0082 210001        86 SPM1     LXI    H,OP1
0085 CD0000   E    87          CALL   CLEAR   ;CLEAR OP1 FOR FLTDS OF FCOUNT
0088 3A0000   D    88          LDA    FCOUNT  ;INCREMENT FREQ AND CALL TRNSFM
008B 3C            89          INR    A       ;CALCULATE F.T. FOR ONE PT PER CALL
008C 320000   D    90          STA    FCOUNT
008F 47            91          MOV    B,A     ;SAVE FCOUNT FOR TEST
0090 320001        92          STA    OP1     ;OP1=FCOUNT(BIN)
0093 3E02          93          MVI    A,FLTDS
0095 D340          94          OUT    IOEAS   ;OP1=FCOUNT(FLT. PT. FMT.)
0097 78            95          MOV    A,B     ;RESTORE FCOUNT FOR TEST
0098 FE29          96          CPI    29H     ;FCOUNT LT 41 ?
009A DA0000   C    97          JC     LT41    ;YES, GO TO LT41
009D 215000   D    98          LXI    H,FORTY ;FCOUNT(FLT) GE 41
00A0 CD0000   E    99          CALL   LOF2    ;OP1=FCOUNT(FLT)
00A3 3E05         100          MVI    A,FSUB  ;OP2=40
00A5 D340         101          OUT    IOEAS
00A7 210000   D   102          LXI    H,NEG50 ;OP1=FCOUNT-40
00AA CD0000   E   103          CALL   LOF2    ;OP2=50 OR 0.5
00AD 3E1D         104          MVI    A,FMUL
00AF D340         105          OUT    IOEAS   ;OP1=(FCOUNT-40)*5.0 E-03
00B1 210000   D   106          LXI    H,DIG1
00B4 CD0000   E   107          CALL   LOF2
```

```
LOC  OBJ          SEQ        SOURCE STATEMENT

0067 3E04          108         MVI    A,FADD  ,OP1=(FCOUNT-40)*5 E07+1'E03
0069 D340          109         OUT    IOEAS
006B 210001        110         LXI    H,OP1
006E 110000   D    111         LXI    D,FREQ  ,FREQ=(FCNT-40)*5E07-1E03
0071 CD0000   E    112         CALL   LOADX   ;FREQUENCY HAS BEEN ESTABLISHED
0074 C9            113         RET
                   114
0075 210000   D    115 LT41    LXI    H,MEG25 ,DIFFERENT FREQ FOR I LT 41
0078 CD0000   E    116         CALL   LOP2    ,FCOUNT*FLT) LT 41
007B 3E02          117         MVI    A,FMUL  ,OP1=FCOUNT*2 5E 07
007D D340          118         OUT    IOEAS
007F 210001        119         LXI    H,OP1
0082 110000   D    120         LXI    D,FREQ  ,FREQUENCY HAS BEEN ESTABLISHED
0085 CD0000   E    121         CALL   LOADX   ,------------------------------
0088 C9            122         RET
                   123
0089 2A0000   E    124 TFNSFM  LHLD   ACCLOC
008C 23            125         INX    H       ,---------------------------
008D 23            126         INX    H       ,FIRST PT  OF RXMX1 IS INVALID
008E 23            127         INX    H       ,THIS ALSO COVERS FOR ANY VERT
008F 23            128         INX    H       ,TRANSLATION FROM STIM TO RESP
0090 220000   D    129         SHLD   PTADDR  ,(PTADDR)=(ACCLOC)
0093 210000   D    130         LXI    H,I1
0096 CD0000   E    131         CALL   CLEAR   ,I1=0 INITIALLY
0099 211700   D    132         LXI    H,R1
009C CD0000   E    133         CALL   CLEAR   ,R1=0 INITIALLY
009F 211B00   D    134         LXI    H,SY
00A2 CD0000   E    135         CALL   CLEAR   ,SY=0 INITIALLY
00A5 212E00   D    136         LXI    H,TWOPI ,OP1=FREQ
00A8 110401        137         LXI    D,OP2   ,OP2=TWOPI
00AB CD0000   E    138         CALL   LOADY
00AE 3E02          139         MVI    A,FMUL
0100 D340          140         OUT    IOEAS
0102 210000   E    141         LXI    H,DIST
0105 CD0000   E    142         CALL   LOP2
0108 3E02          143         MVI    A,FMUL
010A D340          144         OUT    IOEAS
010C 210001        145         LXI    H,OP1
010F 111300   D    146         LXI    D,FSTARD,FSTARD=2*PI*F*D
0112 CD0000   E    147         CALL   LOADX   ,OP1=2*PI*FREQ*DIST
0115 210B00   D    148         LXI    H,I1
0118 110401        149         LXI    D,OP2
011B CD0000   E    150         CALL   LOADY
011E 3E02          151 TFM1    MVI    A,FMUL  ,LOOP TO CALCULATE R1 AND SY
0120 D340          152         OUT    IOEAS   ,OP2=I1 OP1=FSTARD
0122 210001        153         LXI    H,OP1
0125 110000   D    154         LXI    D,BETA
0128 CD0000   E    155         CALL   LOADX
012B CD0000   E    156         CALL   COSINE  ,OP1=COSINE(BETA)
012E 2A0000   D    157         LHLD   PTADDR
0131 110401        158         LXI    D,OP2
0134 CD0000   E    159         CALL   LOADY   ,OP2=R(PTADDR)
0137 3E02          160         MVI    A,FMUL
0139 D340          161         OUT    IOEAS
013B 211700   D    162         LXI    H,R1
```

```
LOC  OBJ          SEQ         SOURCE STATEMENT

013E CD0000   E   163          CALL    LOF2
0141 3E34         164          MVI     A,FADD
0143 D340         165          OUT     IOEAS
0145 210701       166          LXI     H,OP1
0148 111700   D   167          LXI     D,P1
014B CD0000   E   168          CALL    LOADY   ;P1=P1-F(I1)*COS(BETA)
014E 210900   D   169          LXI     H,BETA
0151 110701       170          LXI     D,OP1
0154 CD0000   E   171          CALL    LOADY
0157 CD0000   E   172          CALL    SINE    ;OP1=SINE(BETA)
015A 2A0300   D   173          LHLD    PTADDR
015D 110B01       174          LXI     D,OP2
0160 CD0000   E   175          CALL    LOADY   ;OP2=F(I1)
0163 3E32         176          MVI     A,FMUL
0165 D340         177          OUT     IOEAS
0167 211300   D   178          LXI     H,SX
016A CD0000   E   179          CALL    LOF2
016D 3E0F         180          MVI     A,EXCH
016F D340         181          OUT     IOEAS
0171 CD0000   E   182          CALL    WAIT
0174 3E35         183          MVI     A,FSUB
0176 D340         184          OUT     IOEAS
0178 210701       185          LXI     H,OP1
017B 111300   D   186          LXI     D,SX
017E CD0000   E   187          CALL    LOADY   ;SX=SX-F(I1)*SINE(BETA)
0181 2A0000   E   188          LHLD    ACCTOP
0184 EB           189          XCHG
0185 2A0300   D   190          LHLD    PTADDR
0188 7C           191          MOV     A,H
0189 BA           192          CMP     D
018A C29101   C   193          JNZ     TEM11
018D 7D           194          MOV     A,L
018E BB           195          CMP     E       ;PTADDR=ACCTOP ?
018F CA1401   C   196          JZ      TEMOUT  ;YES, GO TO TEMOUT
0192 23           197 TEM11    INX     H
0193 23           198          INX     H
0194 23           199          INX     H
0195 23           200          INX     H
0196 220300   D   201          SHLD    PTADDR  ;PTADDR=PTADDR+4
0199 210F00   D   202          LXI     H,I1
019C 110701       203          LXI     D,OP1
019F CD0000   E   204          CALL    LOADY
01A2 21FE00   D   205          LXI     H,ONE
01A5 110B01       206          LXI     D,OP2
01A8 CD0000   E   207          CALL    LOADY
01AB 3E34         208          MVI     A,FADD
01AD D340         209          OUT     IOEAS   ;OP1=I1+1
01AF 210701       210          LXI     H,OP1
01B2 110F00   D   211          LXI     D,I1
01B5 CD0000   E   212          CALL    LOADY   ;I1=I1+1
01B8 211100   D   213          LXI     H,FSTADD
01BB 110B01       214          LXI     D,OP2
01BE CD0000   E   215          CALL    LOADY
01C1 C31501   C   216          JMP     TEM1
                  217
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LOC  OBJ          SEQ         SOURCE STATEMENT

01C7 21153A   D   218 TRMOUT  LXI     H,S%
01CA 11 01        219         LXI     D,OP1
01CD CD0000   E   220         CALL    LOADY
01D0 21 01        221         LXI     H,OP1    ;-----------------------
01D3 7E           222         MOV     A,M      ;CHECK FOR VALID ZERO
01D4 23           223         INX     H
01D5 B6           224         ORA     M
01D6 23           225         INX     H
01D7 B6           226         ORA     M
01D8 23           227         INX     H
01D9 B6           228         ORA     M        -----------------------
01DA CAE201   C   229         JZ      TRM3     IF VALID ZERO  GO TO TRM3
01DD 3A0001       230         LDA     OP1+3    CHECK SIGN OF S
01E0 17           231         RAL
01E1 D2E701   C   232         JNC     TRM2     ;POSITIVE  GO TO TRM2
01E4 1F           233         RAR
01E5 E67F         234         ANI     7FH      NEGATIVE  SET POSITIVE
01E7 C3EA01   C   235         JMP     TRM3
01EA 1F           236 TRM2    RAR
01EB F680         237         ORI     80H      ;POSITIVE  SET NEGATIVE
01ED 320001       238 TRM3    STA     OP1+3    ;S=-S
01F0 21         D 239         LXI     H,P1
01F3 110401       240         LXI     D,OP2
01F6 CD0000   E   241         CALL    LOADY
01F9 3E           242         MVI     A,FDIV
01FB D3           243         OUT     IOBAS    OP1=-S/P1
01FD 21         D 244         LXI     H,S/TY   ;-----------------------
0200 CD0000   E   245         CALL    LOFI     ;THIS BLOCK SUBSTITUTES P1 2
0203 3A           246         LDA     OP1+3    FOR ATAN(-S/P1) IF ABS(S/P1) GT 10
0206 E6           247         ANI     80H      (PRESERVE SIGN)
0208 5F           248         MOV     E,A      ;THIS IS TO PREVENT A ERROR IN ATAN
0209 3A           249         LDA     OP1+3    THE ERROR IS APPROX  ..64 %  ...
020C E67F         250         ANI     7FH      SET POSITIVE
020E 320001       251         STA     OP1+3
0211 3E           252         MVI     A,FCMPR
0213 D3           253         OUT     IOBAS
0215 CD0000   E   254         CALL    WAIT
0218 DB41         255         IN      41H
021A E640         256         ANI     40H      -S/P1 GT 100 ?
021C CA           257         JZ      ARCT     NO  CALL ATAN
021F 21       D   258         LXI     H,PIBY2  ;YES  ATAN(-S/P1) = ... PIBY2
0222 11 01        259         LXI     D,OP1
0225 CD0000   E   260         CALL    LOADY
0228 3A0001       261         LDA     OP1+3
022B B3           262         ORA     E        RESTORE SIGN
022C 32   1       263         STA     OP1+3
022F C3       C   264         JMP     ARCT1    SKIP CALLING ATAN
0232 3A0001       265 ARCT    LDA     OP1+3
0235 B3           266         ORA     E        RESTORE SIGN
0236 320001       267         STA     OP1+3
0239 CD0000   E   268         CALL    ATAN     OP1=ATAN(OP1)
```

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LOC  OBJ          SEQ        SOURCE STATEMENT

0244 D340          273        OUT   IOBAS
0246 210001        274        LXI   H,P1      ,PHASE=PHASE-PIBY2
0249 110000   D    275        LXI   D,PHASE   IE  -1=0 LE PHASE LE 0
024C CD0000   E    276        CALL  LOADY     ,PHASE CALCULATION COMPLETE
024F 3A0000   E    277        LDA   FLAG      ------------------------
0252 E604          278        ANI   4         OPEN CKT  PHASE COMPENSATION
0254 CA0000   C    279        JZ    WAV1      ,STIM NOT IN PROGRESS  GO TO WAV1
0257 210000   D    280        LXI   H,PREFRQ ,PREFRQ =F(I-1)=PREVIOUS FREQ
025A CD0000   E    281        CALL  LOP2
025D 210000   D    282        LXI   H,FREQ
0260 110001        283        LXI   D,OP1
0263 CD0000   E    284        CALL  LOADY
0266 3E0F          285        MVI   A,FELB
0268 D340          286        OUT   IOBAS
026A 210000   D    287        LXI   H,DELCON,OP1=DELTA FREQ=F(I)-F(I-1)
026D CD0000   E    288        CALL  LOP2      ,OP2=2*PI*TIME DELAY
0270 3E0C          289        MVI   A,FMUL
0272 D340          290        OUT   IOBAS
0274 110000   D    291        LXI   H,PHASE ,OP1=DELTA PHASE
0277 CD0000   E    292        CALL  LOP2
027A 3E0F          293        MVI   A,EXCH   ,OP2=DELTA PHASE
027C D340          294        OUT   IOBAS    ,OP1=PHASE
027E CD0000   E    295        CALL  WAIT
0281 3E05          296        MVI   A,FSUB
0283 D340          297        OUT   IOBAS    ,OP1=PHASE-2*PI*TIME DELAY*DELTA FREQ
0285 210001        298        LXI   H,OP1
0288 110000   D    299        LXI   D,PHASE
028B CD0000   E    300        CALL  LOADY    ,PHASE=PHASE-DELTA PHASE
028E 210000   D    301        LXI   H,FREQ   UPDATE PREFRQ
0291 110000   D    302        LXI   D,PREFRQ F(I-1)=F(I)
0294 CD0000   E    303        CALL  LOADY    ,--------------------------------
0297 210000   D    304 WAV1   LXI   H,P1
029A 110001        305        LXI   D,OP1
029D CD0000   E    306        CALL  LOADY
02A0 3E0F          307        MVI   A,FADD
02A2 D340          308        OUT   IOBAS    ,OP1=F1+P1
02A4 210001        309        LXI   H,OP1
02A7 110000   D    310        LXI   D,P1
02AA CD0000   E    311        CALL  LOADY    ,F1=F1+P1
02AD 210000   D    312        LXI   H,E
02B0 110001        313        LXI   D,OP1
02B3 CD0000   E    314        CALL  LOADY
02B6 3E0F          315        MVI   A,FSUB
02B8 D340          316        OUT   IOBAS
02BA 210000   D    317        LXI   H,P1
02BD CD0000   E    318        CALL  LOP2
02C0 3E0C          319        MVI   A,FSUB   OP1=E+EN
02C2 D340          320        OUT   IOBAS    ,OP2=F1-P1
02C4 CD0000   E    321        CALL  WAIT
02C7 3E0F          322        MVI   A,FSQRT
02C9 D340          323        OUT   IOBAS
02CB 210000   E    324        LXI   H,DIST   ,OP1=SQRT((F1-P1)+(E+EN))
02CE CD0000   E    325        CALL  LOP2     ,OP2=DIST
02D1 3E0C          326        MVI   A,FMUL
02D3 D340          327        OUT   IOBAS
```

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LOC  OBJ          SEQ         SOURCE STATEMENT

0CD5 2100C1            228          LXI    H,OP1
0CD8 111700    D       229          LXI    D,R1     ;R1=NUMERATOR=DIST*SQRT(R1*R1+I1*I1)
0CDB CD0000    E       230          CALL   LOADX    ;---------------------------
0CDE 211300    D       231          LXI    H,RETARD
0CE1 1100C1            232          LXI    D,OP1
0CE4 CD0000    E       233          CALL   LOADY
0CE7 214700    D       234          LXI    H,TWO
0CEA 1104C1            235          LXI    D,OP2
0CED CD0000    E       236          CALL   LOADY
0CF0 3E03              237          MVI    A,FDIV
0CF2 D340              238          OUT    IOBAS    ;OP1=F*D/2
0CF4 CD0000    E       239          CALL   WAIT
0CF7 CD0000    E       240          CALL   SINE
0CFA 214700    D       241          LXI    H,TWO
0CFD 1104C1            242          LXI    D,OP2
0D00 CD0000    E       243          CALL   LOADY
0D03 3E02              244          MVI    A,FMUL
0D05 D340              245          OUT    IOBAS    ;OP1=2*SIN(F*D/2)
0D07 211700    D       246          LXI    H,R1
0D0A CD0000    E       247          CALL   LOAD
0D0D 3E0F              248          MVI    A,EXCH
0D0F D340              249          OUT    IOBAS
0D11 CD0000    E       250          CALL   WAIT
0D14 3E03              251          MVI    A,FDIV
0D16 D340              252          OUT    IOBAS    ;OP1=NUMERATOR/(2*SIN(F*D/2))
0D18 2100C1            253          LXI    H,OP1
0D1B 111F00    D       254          LXI    D,MAG
0D1E CD0000    E       255          CALL   LOADX
0D21 C9                256          RET
                       257
                       258 DSEG
0002                   259 STACKP   DS     2        ;POINT POINTER OF CURRENT OPERAND
0004                   260 OMEGA    DS     4        ;OMEGA=2*PI*F
0004                   261 BETA     DS     4        ;=B IN TANEFM
0004                   262 FREQ     DS     4        ;F=FREQ. PT. AT WHICH R,I IS TAKEN
0001                   263 FCOUNT   DS     1        ;WHICH OUT OF 50 FREQ. PTS
0004                   264 I1       DS     4        ;IN TANEFM
0004                   265 RETARD   DS     4        ;F*D
0004                   266 R1       DS     4        ;REAL PART
0004                   267 IM       DS     4        ;IMAGINARY PART
0004                   268 MAG      DS     4
0004                   269 PHASE    DS     4
                       270
0004                   271 PREPRO   DS     4        ;OPEN LOOP PHASE (L  F     F(I-1))
002B DA                272 TWOPI    DB     0DAH,0FH,0C9H,40H
002C 0F
002D C9
002E 40
002F 00                273 FORTY    DB     0,0,20H,42H
0030 00
0031 20
0032 42
0033 FF                274 BIG1     DB     0FFH,0FFH,0FEH,4EH
0034 FF
0035 FE
```

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 LOC  OBJ         SEQ          SOURCE STATEMENT

 0036 4E
 0037 20           375 MEG50    DB      20H,0ECH,2EH,40H
 0038 EC
 0039 2E
 003A 40
 003B 20           376 MEG25    DB      20H,0BCH,0BEH,4EH
 003C BC
 003D BE
 003E 4E
 003F 0B           377 RADDEG   DB      0B5H,02EH,65H,42H
 0040 2E
 0041 65
 0042 42
 0043 00           378 NINETY   DB      0,0,0B4H,42H
 0044 00
 0045 B4
 0046 42
 0047 00           379 TWO      DB      0,0,0,40H
 0048 00
 0049 00
 004A 40
 004B 00           380 ONE      DB      0,0,80H,3FH
 004C 00
 004D 80
 004E 3F
 004F 00           381 SIXTY    DB      0,0,70H,42H
 0050 00
 0051 70
 0052 42
 0053 C5           382 DELCON   DB      0C5H,0EEH,5EH,2EH       ;2*PI-TIME DELAY=5.0007IE-11)
 0054 EE
 0055 5E
 0056 2E
 0057 DA           383 FIEYE    DB      0DAH,0FH,0C9H,3FH
 0058 0F
 0059 C9
 005A 3F
                   384 END

PUBLIC SYMBOLS
FCOUNT D 0035   FRED   D 0005   MAG    D 001F   NORMAL C 0003   PHASE  D 0022   PREPRO D 0027   RTADDR D 0000
RADDEG D 003F   SP 1   C 0032   TANGRN C 0009

EXTERNAL SYMBOLS
ACCLOC E 0000   ACCTOP E 0000   ATAN   E 0000   CLEAR  E 0000   COSINE E 0000   DIST   E 0000   FLAG   E 0000
FLASH  E 0000   LTACT  E 0000   LOADY  E 0000   LOP2   E 0000   S      E 0000   S1     E 0000   SINE   E 0000
WAIT   E 0000

USER SYMBOLS
ACCLOC E 0000   ACCTOP E 0000   ASIT   C 003F   ASCT1  C 0003   ATAN   E 0000   BETA   D 0005   CLEAR  E 0000
COSINE E 0000   DELCON D 0053   DIST   E 0000   E CH   A 0 F    ...    A 0004  .FOMFR  A 0 0A   FCOUNT D 0035
[illegible]     [illegible]     FLAG   E 0000   FLAS   E 0000   FLTOS  A 0 0F   F    A 0 0    FIFTY  D 00 0
FRED   D 0005   FE F   A 0005   FETAT  A 0 0    FETARD D 0000   FE E   A 0005   FITET  A 0 0E   GETL   D 0 00
I1     D 000F   ICSAE  A 0040   LIAD   E 0000   LOADY  E 0000   LPFC   E 0000   LT41   C 0005   MAG    D 001F
MEG25  D 003B   MEG50  D 0037   NINETY D 0043   NORM1  C 00CE   NORM2  C 000A   NORMAL C 0003   NORMN  C 0000
```

OMEGA	D [illegible]	ONE	D 004E	OP1	A C100	OP2	A C101	PHASE	D 00[illegible]	PIEYC	D 00[illegible]	PREPRN	D 0027
[illegible]	[illegible]	S1	D 0017	S-DEG	D 003F	S	E 00[illegible]	S1	E 0000	SPIN	C 00[illegible]	SINE	E [illegible]
[illegible]	[illegible]	S[illegible]	D 001E	TRM1	C 011E	TRM11	C 01[illegible]	TRMC	C 01E7	TR[illegible]C	C 01EA	TRMOUT	C 0104
TRMERM	C 00D3	TWO	D 0047	TWOPI	D 00CB	WAIT	E 0000	WAV1	C 01[illegible]				

ASSEMBLY COMPLETE, NO ERRORS

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ISIS-II 8080/8085 MACRO ASSEMBLER, V2.0        MODULE   PAGE    1


  LOC  OBJ         SEQ         SOURCE STATEMENT

                    1 ;AM9511 UTILITY
                    2 ;THIS FILE CONTAINS ROUTINES USED FOR 9511 IN VARIOUS
                    3 ;OTHER MODULES OF THE TURTLE SYSTEM
  FE13              4 DBYTE   EQU      0FE13H
  FE14              5 DADR    EQU      0FE14H
  0040              6 IOBAS   EQU      40H
  FE0F              7 LO      EQU      0FE0FH
  0002              8 FMUL    EQU      2
  0003              9 FDIV    EQU      3
  0004             10 FADD    EQU      4
  0005             11 FSUB    EQU      5
  000E             12 FLTDS   EQU      0EH
  000F             13 FIXSD   EQU      0FH
  00[illegible]    14 FCHSF   EQU      0[illegible]H
  00[illegible]    15 EXCH    EQU      0[illegible]H
  [illegible]      16 OP1     EQU      0C100H
  C104             17 OP2     EQU      OP1+4
                   18
                   19 CSEG
                   20         PUBLIC  WAIT,[illegible] LOAD [illegible] MESG
                   21         PUBLIC  ERROR[illegible] CLEAR [illegible]
  0000 DB41        22 WAIT    IN      IOBAS+1 ;FLAG BYTE
  0002 E601        23         ANI     1        ;COMPLETED ?
  0004 C20000  C   24         JNZ     WAIT     ;NO, JUMP TO WAIT
  0007 DB41        25         IN      IOBAS+1 ;YES, INPUT STATUS BYTE
  0009 E61E        26         ANI     [illegible]        ;CHECK FOR ERROR
  000B C8          27         RZ               ;NO ERROR, RETURN
  000C FE[illegible]  28         CPI     [illegible]        ;CHECK ERROR CODE = RESERVED?
  000E C8          29         RZ               ;YES, RETURN
  000F FE04        30         CPI     4        ;CHECK ERROR CODE=UNDERFLOW ?
  0011 C2[illegible] C   31      JNZ     CONT1    ;NO, CONTINUE
  0014 E5          32         PUSH    H
  0015 [illegible]       33         LXI     H,OP1
  0018 [illegible]  C    34         CALL    CLEAR    ;OP1 IS SET TO A VALID ZERO
  001B E1          35         POP     H
  001C C9          36         RET
  001D [illegible]  C    37 CONT1   LXI     H,ERRORM
  [illegible]      38         MOV     E,A      ;SAVE ACCUMULATOR
  [illegible]      39         CALL    MESG     ;OUTPUT ERROR MESSAGE
  [illegible]      40         MOV     A,E
  [illegible]      41         CALL    DBYTE    ;OUTPUT STATUS BYTE
  [illegible]      42         MVI     D,[illegible]      ;SET NESTING DEPTH
  [illegible]      43 SEND    MVI     C,[illegible]
  [illegible]      44         CALL    LO       ;OUTPUT SPACE
  [illegible] E1   45         POP     H
  [illegible]      46         CALL    DADR     ;OUTPUT LAST CALL ADDR
  [illegible]      47         DCR     D        ;DECREASE DEPTH [illegible]
  [illegible]  C   48         JNZ     SEND
  [illegible]      49         RST     0
  [illegible]  C   50 OP[illegible]  LXI     H,TEN     ;[illegible] TEN TO OP[illegible]
  [illegible]      51 [illegible]    LXI     D,OP2     ;[illegible] TO [illegible]
  [illegible]  C   52 LOAD    CALL    WAIT     ;WAIT FOR [illegible] COMPLETE
```

```
 LOC  OBJ         SEQ         SOURCE STATEMENT

 0041 C5              53 LOADY   PUSH    B        ;SAVE (BC)
 0042 0604            54         MVI     B,4      ;BYTE COUNTER
 0044 7E              55 LOAD    MOV     A,M      ;MOVE NEXT 4 LOCATIONS IN (HL)
 0045 12              56         STAX    D        ;TO NEXT FOUR LOCATIONS IN (DE)
 0046 23              57         INX     H
 0047 13              58         INX     D
 0048 05              59         DCR     B
 0049 C24400    C     60         JNZ     LOAD
 004C C1              61         POP     B
 004D C9              62         RET
 004E 216D00    C     63 INVLD   LXI     H,INVLDM ;LOAD 'INVALID' MESSAGE
 0051 4E              64 MESG    MOV     C,M      ;OUTPUT MESSAGE
 0052 AF              65 RPT     XRA     A
 0053 B1              66         ORA     C        ;CHECK, END OF STRING (0)?
 0054 C8              67         RZ               ;YES, RETURN
 0055 CD0FF8          68         CALL    LO       ;NO, OUTPUT CHARACTER
 0058 23              69         INX     H
 0059 C35100    C     70         JMP     MESG
 005C AF              71 CLEAR   XRA     A
 005D 77              72         MOV     M,A
 005E 23              73 FILL    INX     H
 005F 77              74         MOV     M,A
 0060 23              75         INX     H
 0061 77              76         MOV     M,A
 0062 23              77         INX     H
 0063 77              78         MOV     M,A
 0064 C9              79         RET
 0065 4552524F        80 ERRORM  DB      'ERROR= ',0
 0069 523D20
 006C 00
 006D 494E5641        81 INVLDM  DB      'INVALID NUMBER ',0
 0071 4C494420
 0075 4E554D42
 0079 455220
 007C 00
 007D                 82 PTR     DS      2
 007F                 83 ED      DS      1
 0080 00              84 TEN     DB      0,0,10H,41H
 0081 00
 0082 10
 0083 41
                      85         END

PUBLIC SYMBOLS
CLEAR  C 005C    ED     C 007F    ERRORM C 0065    FILL   C 005E    INVLD  C 004E    LOAD   C 00CE    LOADY  C 0041
LOAD   C 00CE    MESG   C 0051    CP210  C 00C3    PTR    C 007D    TEN    C 0080    WAIT   C 0090

EXTERNAL SYMBOLS


USER SYMBOLS
CLEAR  C 005C    CONT1  C [illegible]  CRLF  A FE21   DBYTE  A FE1A    ED     C 007F    ERRORM C 0065    E L-   A [illegible]
FAT    A [illegible]  FD [illegible] A [illegible]  FJ[illegible] A [illegible]  FILL  C 005E    FI ED  A 00[illegible]    FLTFE  A [illegible]    FULL   A [illegible]
FSUB   A [illegible]  INVLD  C 004E    INVLDM C 006D    ICEAS  A [illegible]    LO     A F80F    LOAD   C 0044    LOAD   C 00CE
LOADY  C 0041    LOAD   C 00CE    MESG   C 0051    OR1    A C1[illegible]    ORL    A C1[illegible]    CP210  C 00C3    RPT    C 0052
```

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PTR   C 0070   SEND  C 0025   TEN   C 0050   WAIT  C 0000

ASSEMBLY COMPLETE, NO ERRORS
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ISIS-II 8080/8085 MACRO ASSEMBLER, V2.0        MODULE   PAGE    1

  LOC  OBJ          SEQ          SOURCE STATEMENT

                      1 NAME FEIDEC
                      2 ;THIS ROUTINE TAKES A DIGIT FLT PT FMT NO AND
                      3 ;CONVERTS IT TO FLOATING POINT DECIMAL FORMAT AND
                      4 ;DISPLAYS IT ON THE LIST DEVICE   THE LOCATION OF
                      5 ;THE NO MUST FIRST BE PLACED IN (HL)
FE13                  6 CENTE   EQU     0FE13H
FE11                  7 DALF    EQU     0FE21H
0040                  8 ILEAS   EQU     40H
F50F                  9 LO      EQU     0F50FH
0002                 10 FMUL    EQU     2
0003                 11 FDIV    EQU     3
0004                 12 FADD    EQU     4
0005                 13 FSUB    EQU     5
0008                 14 FLTDS   EQU     8H
0009                 15 FIXSD   EQU     9H
000A                 16 FCHSR   EQU     0AH
000F                 17 ENCH    EQU     0FH
C100                 18 OP1     EQU     0C100H
C104                 19 OP2     EQU     OP1+4
                     20
                     21 CSEG
                     22         PUBLIC  FEIDEC
                     23         EXTRN   WAIT,OP210,LOP2,LOAD,LOADY,INVLD,MESG
                     24         EXTRN   ERRIP1,STR,EXTEN,CLEAR,FILL
0000 220000   E      25 FEIDEC  SHLD    PTR     ;(HL)=ADDR  LS BYTE FLT PT NO
0003 0E2F            26         MVI     C,'+'
0005 7E              27         MOV     A,M     ;------------------------------
0006 23              28         INX     H       ;CHECK FOR VALID ZERO
0007 B6              29         ORA     M       ;IE  ALL BITS =0
0008 23              30         INX     H
0009 B6              31         ORA     M
000A 23              32         INX     H
000B B6              33         ORA     M
000C CA0000   C      34         JZ      ZERO    ;------------------------------
000F 2B              35         DCX     H       ;GET 8 BIT E.F  IN A
0010 7E              36         MOV     A,M     ;GET SIGN BIT IN CY
0011 17              37         RAL
0012 23              38         INX     H
0013 7E              39         MOV     A,M
0014 17              40         RAL
0015 D21A00   C      41         JNC     POSTIV
0018 0E2D            42         MVI     C,'-'   ;CHANGE SIGN IF NEGATIVE
001A 47              43 POSTIV  MOV     B,A
001B A7              44         ANA     A
001C CA0000   E      45         JZ      INVLD   ;INVALID NUMBER IF E.F =00
001F FEFF            46         CPI     0FFH    ;UNLESS ALL BITS  0)
0021 CA0000   E      47         JZ      INVLD   ;INVALID NUMBER IF E.F =0FF
0024 CDFFFF          48         CALL    LO      ;PRINT SIGN
0027 2101C1          49         LXI     H,OP1
002A 70              50         MOV     M,B     ;STORE E.F (BIASED)
002B C6F1            51         ADI     0F1H    ;A=EB+2 E.F ... OF OP
002D 77              52         MOV     M,A     ;OP1=EB (2 E.F) ... IF NEGATIVE)
```

```
LOC  OBJ         SEQ          SOURCE STATEMENT

002E 3E00         53          MVI     A,0       ;XRA WOULD DESTROY CY
0030 DA3400   C   54          JC      POSEX     ;IE. IF CY=1 NO. IS POSITIVE
0033 2F           55          CMA
0034 CD0000   E   56 POSEX    CALL    FILL      ;OP1 WITH 00 OR FF DEPENDING (+,-)
0037 3E09         57          MVI     A,FLTDS   ;FLOAT ED (IE. FLOAT 2'S COMP. FMT.)
0039 D340         58          OUT     IOSAS
003B 210001   C   59          LXI     H,LOG2
003E CD0000   E   60          CALL    LOP2
0041 3E02         61          MVI     A,FMUL
0043 D340         62          OUT     IOSAS
0045 210001       63          LXI     H,OP1     ;OP1=ED'=ED*LOG2
0048 110001   C   64          LXI     D,EDP
004B CD0000   E   65          CALL    LOADY     ;EDP=ED'
004E 3E0F         66          MVI     A,FIXED
0050 D340         67          OUT     IOSAS
0052 CD0000   E   68          CALL    WAIT      ;OP1=FIX(ED')=ED
0055 3A0001       69          LDA     OP1       ;(ED)=ED IN FIXED PT. FMT
0058 320000   E   70          STA     ED        ;SAVE DEC. EXP
005B 3E09         71          MVI     A,FLTDS
005D D340         72          OUT  *  IOSAS
005F 110001   C   73          LXI     H,EDP
0062 CD0000   E   74          CALL    LOP2
0065 3E0F         75          MVI     A,ECH
0067 D340         76          OUT     IOSAS
0069 CD0000   E   77          CALL    WAIT      ;OP1=EDP
006C 3E05         78          MVI     A,FSUS    ;OP1=ED (FLOAT PT. FMT.)
006E D340         79          OUT     IOSAS     ;FRACTION EXP. IN OP1
0070 210001   C   80          LXI     H,LN10    ;OP1=EDP-ED=EDF
0073 CD0000   E   81          CALL    LOP2
0076 3E02         82          MVI     A,FMUL
0078 D340         83          OUT     IOSAS     ;OP1=EDF*LN10
007A 0E19         84          MVI     C,25      ;LOOP COUNTER FOR SERIES
007C 210001   C   85          LXI     H,ONE
007F 110001   C   86          LXI     D,TMPSTO           ;TMPSTO=ONE
0082 CD0000   E   87          CALL    LOADY     ;LOADY=LOADY WITHOUT WAIT
0085 210001       88          LXI     H,OP1
0088 110001   C   89          LXI     D,EDP     ;EDP=EDF*LN10
008B CD0000   E   90          CALL    LOADY     ;EDP = LN10*FRACTION EXP
008E 210001       91 SERIES   LXI     H,OP1     ;-------------------------------
0091 71           92          MOV     M,C       ;THIS LOOP CALCULATES 10**EDF
0092 AF           93          XRA     A
0093 CD0000   E   94          CALL    FILL      ;OP1=N=COUNTER (IN C)
0096 3E09         95          MVI     A,FLTDS   ;OP1=FLOATED COUNTER (IN C)
0098 D340         96          OUT     IOSAS
009A 210001   C   97          LXI     H,TMPSTO
009D CD0000   E   98          CALL    LOP2      ;OP2=TMPSTO
00A0 3E0F         99          MVI     A,ECH     ;OP1=TMPSTO
00A2 D340        100          OUT     IOSAS     ;OP2=N (=25 FIRST TIME
00A4 CD0000   E  101          CALL    WAIT
00A7 3E03        102          MVI     A,FDIV
00A9 D340        103          OUT     IOSAS     ;OP1=TMPSTO/N
00AB 110001   C  104          LXI     H,EDP     ;OP2=EDP=LN10
00AE CD0000   E  105          CALL    LOP2
00B1 3E02        106          MVI     A,FMUL
00B3 D340        107          OUT     IOSAS     ;OP1=EDP*LN10*TMPSTO/N
```

```
LOC  OBJ         SEQ        SOURCE STATEMENT

08DE 210001  C   108        LXI    H,ONE
08E1 CD0000  E   109        CALL   LOP2
08E4 3E04        110        MVI    A,FADD
08E6 D341        111        OUT    IOSAS    ;OP1=1+EDF*LN10+TMPSTO N
08E8 210001      112        LXI    H,OP1
08EB 110001  C   113        LXI    D,TMPSTO
08EE CD0000  E   114        CALL   LOPIY    ;TMPSTO=1+EDF+LN10*TMPSTO N
08F1 0D          115        DCR    C
08F2 C2E308  C   116        JNZ    SERIES
08F5 2A0000  E   117        LHLD   PTR      ;(HL)=ADDR OF 8 BYTE OPRND
08F8 CD0000  E   118        CALL   LOP2     ;OP2 = (PL+2)=SIG FLT PT NO
08FB 1B          119        DCX    D        ;DE=OP2+2
08FC 3E2F        120        MVI    A,2FH
08FE 12          121        STAX   D        ;(OP2-1)=2F
08FF 1B          122        DCX    D
0900 1A          123        LDAX   D        ;A=(OP1+2)
0901 FE30        124        CPI    30H
0903 12          125        STAX   D        ;(OP2+2)=1
0904 3E0D        126        MVI    A,FMUL   ;OP2 = OP2+2 =FE (EXP=7F)
0906 D341        127        OUT    IOSAS    ;OP1=F6-10--EDF=FD
0908 210001  C   128 CONT3  LXI    H,ONE
090B CD0000  E   129        CALL   LOP2
090E 3E0A        130        MVI    A,FCMPR  ;COMPARE FD TO ONE
0910 D340        131        OUT    IOSAS
0912 CD0000  E   132        CALL   OP210    ;OP2=10
0915 DB41        133        IN     IOSAS+1
0917 E6C0        134        ANI    0C0H     ;CHECK FD GE ONE ?
0919 CA2301      135        JZ     CONT5    ;NO  JUMP TO CONT5
091C 3E0A        136        MVI    A,FCMPR  ;YES  COMPARE FD TO TEN
091E D340        137        OUT    IOSAS
0920 CD0000  E   138        CALL   WAIT
0923 DB41        139        IN     IOSAS+1
0925 E6C0        140        ANI    0C0H     ;CHECK FD GE TEN ?
0927 CA4401  C   141        JZ     CONT4    ;NO  JUMP TO CONT4
0101 3A0000  E   142        LDA    ED       ;YES
0104 3C          143        INR    A
0105 320000  E   144        STA    ED       ;ED=ED+1
0108 3E0C        145        MVI    A,FDIV   ;OP1=FD/10
010A D340        146        OUT    IOSAS
010C C30801  C   147        JMP    CONT4
010F 3E0D        148 CONT5  MVI    A,FMUL
0111 D340        149        OUT    IOSAS    ;OP1=FD*10
0113 3A0000  E   150        LDA    ED
0116 3D          151        DCR    A
0117 320000  E   152        STA    ED       ;ED=ED-1
011A 210001  C   153 CONT4  LXI    H,ROUND  ;ROUND= 00005 (E)
011D CD0000  E   154        CALL   LOP2     ;OP1=FD
0120 3E0C        155        MVI    A,FADD
0122 D340        156        OUT    IOSAS
0124 CD0000  E   157        CALL   WAIT
0127 3E0A        158        MVI    A,FC..   ;FD=FD+ROUND
0129 D340        159        OUT    IOSAS
012B CD0000  E   160        CALL   WAIT
012E 2A0001      161        LHLD   OP1      ;OP1=FIELD OF FD
0131 CDE001  C   162        CALL   LOUT
```

```
LOC  OBJ          SEQ         SOURCE STATEMENT

0134 0E20         163         MVI     C,' '
0136 CD3FF3       164         CALL    LO        ;OUTPUT ' '
0139 2A9411       165         LHLD    OP2
013C EB           166         XCHG              ;(DE)=OP2,OP2+1
013D 210A00       167         LXI     H,0AH
0140 229411       168         SHLD    OP2       ;OP2,OP2+1=0A,00
0143 2A9611       169         LHLD    OP1+2     ;(HL)=(OP1+2,OP1+3)
0146 0604         170         MVI     B,4       ;DECIMAL PLACE COUNTER
0148 EB           171 MANT    XCHG              ;(HL)=OP2,OP2+1  (FRC)/(DE)
0149 229011       172         SHLD    OP1       ;OP1=OP2,OP2+1 00,MED,ED
014C AF           173         XRA     A         ;SAME AS MVI A,MUL(OP2,OP2+1=0A,00)
014D D3E5         174         OUT     ICBASE
014F CD0000   E   175         CALL    WAIT      ;MULTIPLY BY 10
0152 3A9211       176         LDA     OP1+2
0155 4F           177         MOV     C,A       ;(C)=MSB OF LOWER 2 BYTES
0156 2A9011       178         LHLD    OP1
0159 AF           179         XRA     A         ;SAME AS MVI A,MUL
015A EB           180         XCHG
015B 229011       181         SHLD    OP1       ;(OP2+2,OP2+3)MD,ED TO OP1
015E D3E5         182         OUT     ICBASE    ;MULT BY 10
0160 CD0000   E   183         CALL    WAIT
0163 2A9011       184         LHLD    OP1
0166 79           185         MOV     A,C
0167 85           186         ADD     L         ;ADD WITH FRACTION * 10
0168 6F           187         MOV     L,A
0169 3A9211       188         LDA     OP1+2
016C D27401   C   189         JNC     CONTE
016F 24           190         INR     H         ;IF CARRY, (H)=(H)+1
0170 D27401   C   191         JNC     CONTE
0173 3C           192         INR     A         ;STILL A CARRY, INCREMENT # TO BE OUTPUT
0174 CD3C01   C   193 CONTE   CALL    DOUT
0177 05           194         DCR     B         ;DCR DECIMAL PLACE COUNTER
0178 C24801   C   195         JNZ     MANT      ;MANTISSA COMPLETE? NO-GO MANT
017B 0E20         196         MVI     C,' '     ;YES,OUTPUT ' E
017D CD3FF3       197         CALL    LO
0180 0E45         198         MVI     C,'E'
0182 CD3FF3       199         CALL    LO
0185 3A0000   E   200         LDA     ED        ;ACCUMULATOR = ED
0188 A7           201 EXPOUT  ANA     A         ;SET P IF POSITIVE
0189 0E2B         202         MVI     C,'+'
018B F29201   C   203         JP      PLS
018E 0E2D         204         MVI     C,'-'
0190 2F           205         CMA               ;2'S COMPLIMENT IF NEGATIVE
0191 C601         206         ADI     1
0193 47           207 PLS     MOV     B,A       ;SAVE ACCUMULATOR
0194 CD3FF3       208         CALL    LO        ;OUTPUT SIGN
0197 AF           209         XRA     A
0198 219011       210         LXI     H,OP1
019B 70           211         MOV     M,B       ;MOVE ED TO OP1
019C 23           212         INX     H
019D 77           213         MOV     M,A       ;OP1+1=00
019E 23           214         INX     H
019F 23           215         INX     H
01A0 23           216         INX     H
01A1 360A         217         MVI     M,0AH     ;OP2=0AH
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```
 LOC  OBJ         SEQ        SOURCE STATEMENT

 0193 23          218        INX    H
 0194 77          219        MOV    M,A      ;OP2+1=00
 0195 3C          220        INR    A        ;MVI    A,DIV (FIXED PT.)
 0196 D340        221        OUT    IOEAS     OP1=ED/10 (FIXED PT.)
 0198 CD0000   E  222        CALL   WAIT
 019B 3A0001      223        LDA    OP1
 019E CDB401   C  224        CALL   DOUT     ;OUTPUT=ED/10=MSD OF ED
 01A1 3A0401      225        LDA    OP2      ;OP2=REMAINDER=LSD OF ED
 01A4 F630        226 DOUT   ORI    30H      ;CONVERT TO ASCII
 01A6 4F          227        MOV    C,A       OUTPUT ASCII DIGIT
 01A7 C30000      228        JMP    LO        AUTOMATIC RETURN IN LO ROUTINE
 01AA 320000   E  229 ZERO   STA    ED       ;ED=0 (INPUT NO. =0 )
 01AD CD0000      230        CALL   LO        OUTPUT 00
 01B0 2A0000   E  231        LHLD   PTR
 01B3 110001      232        LXI    D,OP1
 01B6 CD0000   E  233        CALL   LOADY     OP1=00 00 00 00
 01B9 C31A01   C  234        JMP    CONT4    ;(OUTPUT 0 0000 E 00)
 0004             235 TMPSTO DS     4
 01C0 9C          236 LOG2   DB     9CH,20H,9AH,3EH
 01C1 20
 01C2 9A
 01C3 3E
 01C4 3D          237 LN10   DB     8DH,5DH,13H,40H
 01C5 5D
 01C6 13
 01C7 40
 0004             238 EDP    DS     4
 01CC 00          239 ONE    DB     0,0,80H,3FH
 01CD 00
 01CE 80
 01CF 3F
 01E0 20          243 ROUND  DB     20H,0B7H,51H,33H
 01E1 B7
 01E2 51
 01E3 33
                  244 END

PUBLIC SYMBOLS
FBIDEC C 0000

EXTERNAL SYMBOLS
CLEAR  E 0000   ED     E 0000   ERRORM E 0000   FILL   E 0000   INVLD  E 0000   LOADX  E 0000   LOADY  E 0000
LOCS   E 0000   SIG    E 0000   SP210  E 0000   PTR    E 0000   TEN    E 0000   WAIT   E 0000

USER SYMBOLS
BYTOUT C 0133   CLEAR  E 0000   CONT3  C 00DF   CONT4  C 011A   CONT5  C 01CF   CONT6  C 0174   DACR   A FE11
DBYTE  A FE10   DOUT   C 01A4   ED     E 0000   EDP    C 01C8   ERRORM E 0000   E CH   A 00CF   FADD   A 0034
FBIDEC C 0000   FCHPR  A 0000   FDIV   A 0000   FILL   E 0000   FIXED  A 0000   FLTDS  A 0000   FMUL   A 0000
FSUB   A 0005   INVLD  E 0000   IOEAS  A 0040   LN10   C 01C4   LO     A FE1F   LOADX  E 0000   LOADY  E 0000
LOG2   C 01C0   LOCS   E 0000   MANT   C 0143   NEG    E 0000   ONE    C 01CC   OP1    A 0100   OP2    A 0104
SP210  E 0000   PLS    C 0150   PLSS   C 0104   POSTIV C 011A   PTR    E 0000   ROUND  C 01E0   SERIES C 00E8
TEN    E 0000   TMPSTO C 01BC   WAIT   E 0000   ZERO   C 01AA

ASSEMBLY COMPLETE   NO ERRORS
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ISIS-II 8080/8085 MACRO ASSEMBLER, V2.0   MODULE   PAGE   1

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 LOC  OBJ         SEQ         SOURCE STATEMENT

                    1 ;NAME FDECBI
                    2 ;THIS ROUTINE CONVERTS A FLOATING PT. DECIMAL
                    3 ;STRING TO A 32BIT FLOATING PT. BINARY STRING
 FE29               4 DBYTE    EQU     0FE29H
 FE21               5 DADR     EQU     0FE21H
 0040               6 IOBAS    EQU     40H
 FE0F               7 LO       EQU     0FE0FH
 0002               8 FMUL     EQU     2
 0003               9 FDIV     EQU     3
 0004              10 FADD     EQU     4
 0005              11 FSUB     EQU     5
 0009              12 FLTDS    EQU     9H
 0009              13 FIXSD    EQU     9H
 000A              14 FCHSR    EQU     0AH
 000F              15 EXCH     EQU     0FH
 C100              16 OP1      EQU     0C100H
 C104              17 OP2      EQU     OP1+4
                   18
                   19          CSEG
                   20          PUBLIC FDECBI
                   21          EXTRN   WAIT,OPC10,LOFC,LOADY,LOADX,INVLD,MESG
                   22          EXTRN   ERROR,PTR,ED,TEN,CLEAR,FILL
 0000 2A0000   E   23 FDECBI   SHLD    PTR
 0003 CD0000   E   24          CALL    CLEAR   ;CLEAR DESTINATION LOCATION
 0006 2100C1       25          LXI     H,OP1
 0009 CD0000   E   26          CALL    CLEAR   ;CLEAR OP1
 000C D340         27          OUT     IOBAS   ;(F)=00, CLEAR OP2
 000E 320000   E   28          STA     ED      ;(ED)=0
 0011 47           29          MOV     B,A
 0012 4F           30          MOV     C,A     ;CLEAR B,C
 0013 1A           31          LDAX    D       ;(DE)=SIGN OF ASCII SOURCE STRING
 0014 FE2B         32          CPI     '+'     ;SIGN = + ?
 0016 CA2300   C   33          JZ      PLUS    ;YES, GO TO PLUS
 0019 FE2D         34          CPI     '-'     ;NO, SIGN = - ?
 001B CA2200   C   35          JZ      MINUS   ;YES, GO TO MINUS
 001E 1B           36          DCX     D       ;NO, (DE) INCREMENTED IN LOAD
 001F C32300   C   37          JMP     PLUS    ;NO SIGN, ASSUME POSITIVE
 0022 0C           38 MINUS    INR     C
 0023 CD2C00   C   39 PLUS     CALL    LOAD    ;INTERNAL LOAD (IS IN THIS FILE)
 0026 CD4F00   C   40          CALL    FLOAT
 0029 C32300   C   41          JMP     PLUS
 002C 13           42 LOAD     INX     D       ;NEXT CHARACTER IN STRING
 002D 1A           43          LDAX    D       ;(A)=(DE)
 002E FE2E         44 LOADA    CPI     '.'     ;IS IT . ?
 0030 CA7300   C   45          JZ      FRACT   ;YES, JUMP TO FRACT
 0033 FE45         46 LOADE    CPI     'E'     ;NO, IS IT E
 0035 CA8E00   C   47          JZ      EXPO    ;YES, GO TO EXPO
 0038 FE00         48 LOADC    CPI     0       ;NO, IS IT NULL ?
 003A CA0C01   C   49          JZ      OUT1    ;YES, GO TO OUT1
 003D FE30         50          CPI     30H     ;NO, # GT LOWER 1ST ASCII DIGIT ?
 003F FA0000   E   51          JM      INVLD   ;NO, INVALID
 0042 FE3A         52          CPI     3AH     ;YES, # GT UPPER LAST ASCII START ?
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LOC  OBJ         SEQ        SOURCE STATEMENT

0044 F20000   E   53             JP      INVLD   ;YES, INVALID
0047 E60F         54             ANI     0FH     ;IF IT GETS THIS FAR, # MUST BE A NUMBER,
0049 C9           55             RET             ;SO, MASK OUT MS NIBBLE
                  56
004A C5           57 FLOAT       PUSH    B       ;(B)=0 FIRST TIME
004B D5           58             PUSH    D       ;(DE)=ADDR OF CURRENT ASCII CHAR
004C 4F           59             MOV     C,A     ;(C)=BCD DIGIT
004D CD0000   E   60             CALL    OP210   ;(OP2)=10D IN FLT PT FMT
0050 3E02         61             MVI     A,FMUL  ;(OP1)=10*(OP1) (=0 FIRST TIME)
0052 D340         62             OUT     IOEA5
0054 2A0000   E   63             LHLD    PTR
0057 EB           64             XCHG            ;(DE)=(PTR)
0058 210001       65             LXI     H,OP1   ;((PTR))=(OP1)
005B CD0000   E   66             CALL    LOADN
005E 210001       67             LXI     H,OP1
0061 CD0000   E   68             CALL    CLEAR   ;CLEAR OP1
0064 79           69             MOV     A,C
0065 320001       70             STA     OP1     ;(OP1)=(C)=BCD DIGIT
0068 3E03         71             MVI     A,FLTDS
006A D340         72             OUT     IOEA5   ;(OP1)=(C) FLOATED
006C 2A0000   E   73             LHLD    PTR     ;(HL)=(PTR)
006F CD0000   E   74             CALL    LOP2    ;(OP2)=(PTR)
0072 3E04         75             MVI     A,FADD
0074 D340         76             OUT     IOEA5   ;(OP1)=(C)FLOATED+(PTR)
0076 D1           77             POP     D
0077 C1           78             POP     B
0078 C9           79             RET
0079 E1           80 FRACT       POP     H
007A 13           81 FRACT1      INX     D       ;NEXT ASCII CHARACTER
007B 1A           82             LDAX    D       ;(A)=((DE))
007C CD0000   C   83             CALL    LOADB   ;CONVERT NO. TO BCD
007F 04           84             INR     B       ;INCREMENT # DIGITS AFTER DEC. PT
0080 CD4A00   C   85             CALL    FLOAT   ;ADD NEW DIGIT TO ACCUMULATED SUM
0083 C37A00   C   86             JMP     FRACT1
0086 E1           87 EXPO        POP     H
0087 13           88             INX     D       ;NEXT ASCII CHARACTER
0088 1A           89             LDAX    D       ;(A)=((DE))
0089 FE2B         90             CPI     '+'     ;IS IT + ?
008B CA9700   C   91             JZ      EXPR    ;YES, GO TO EXPR
008E FE2D         92             CPI     '-'     ;NO, IS IT - ?
0090 C29900   C   93             JNZ     EXPR1   ;NO, GO TO EXPR1
0093 3E80         94             MVI     A,80H   ;YES, # IS NEG
0095 B1           95             ORA     C
0096 4F           96             MOV     C,A     ;(C)=1XXX ' '
0097 13           97 EXPR        INX     D       ;NEXT ASCII CHARACTER
0098 1A           98             LDAX    D       ;(A)=((DE))
0099 CD0000   C   99 EXPR1       CALL    LOADC   ;CONVERT NO. TO BCD (MS 4 BITS =0)
009C 6F          100             MOV     L,A
009D 3A0000   E  101             LDA     ED      ;(ED)=0 FIRST TIME
00A0 07          102             RLC
00A1 67          103             MOV     H,A     ;(H)=(ED)*2
00A2 07          104             RLC
00A3 07          105             RLC
00A4 84          106             ADD     H       ;(A)=(ED)*8+(ED)*2=(ED)*10
00A5 85          107             ADD     L       ;(A)=10*(ED)+(L)
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 LOC  OBJ          SEQ         SOURCE STATEMENT

 0948 320000   E   107         STA    ED       ;(ED)=10*(ED)+(L)
 0949 C30000   C   108         JMP    EXPP     ;((L)=ECD NO )
 094C E1           110 OUT1    POP    H
 094D 79           111         MOV    A,C      ;FLAG BYTE
 094E E680         112         ANI    80H
 0950 3A0000   E   113         LDA    ED       ;(A)=((ED))
 0953 CA0000   C   114         JZ     POSEX    ;EXPONENT NEGATIVE - YES, GO TO POSEX
 0956 2F           115         CMA
 0957 3C           116         INR    A        ;NO, 2'S COMPLIMENT  ED, IN ACC
 0958 93           117 POSEX   SUB    E        ;(E)=# OF DIGITS TO RIGHT OF DECIMAL PT
 0959 C5           118         PUSH   B
 095A 4F           119         MOV    C,A      ;(C)=(A)-(B)=SHIFTED EXPONENT
 095B F20000   C   120         JP     POSTIV
 095E CD0000   E   121 DI      CALL   OP210    ;(OP1)=MANTISSA FROM FLOAT=INTEGER
 0961 3E03         122         MVI    A,FDIV   ;SUCCESSIVE DIVISION BY 10
 0963 D340         123         OUT    IOEAS
 0965 0C           124         INR    C        ;INCREMENT SHIFTED EXPONENT
 0966 C20000   C   125         JNZ    DIV      ;IF EXPONENT - 0, GO TO END1
 0969 CA0000   C   126 POSTIV  JZ     END1
 096C CD0000   E   127         CALL   OP210    ;(OP2)=10 TO FLT  PT  FMT
 096F 3E02         128         MVI    A,FMUL   ;SUCCESSIVE MULT  BY 10
 0971 D340         129         OUT    IOEAS    ;(OP1)=10*(OP1)
 0973 0D           130         DCR    C        ;DECREMENT SHIFTED EXPONENT
 0974 C20000   C   131         JNZ    POSTIV
 0977 2A0000   E   132 END1    LHLD   PTR      ;DECIMAL EXPONENT = 0
 097A EB           133         XCHG
 097B 210000       134         LXI    H,OP1
 097E CD0000   E   135         CALL   LOADX    ;(PTR)=(OP1)
 0981 C1           136         POP    B        ;CHECK SIGN OF ORIGINAL NUMBER
 0982 79           137         MOV    A,C
 0983 E601         138         ANI    1        ;LSB=0 ? (IE  SIGN = + ?)
 0985 C8           139         RZ              ;YES  RETURN
 0986 1B           140         DCX    D        ;NO, (DE)=OP1+4-1=OP1+3
 0987 1A           141         LDAX   D        ;(A)=((DE))=(OP1+3)
 0988 F680         142         ORI    80H      ;SET MSB=1  (IE  SET SIGN BIT NEGATIVE)
 098A 12           143         STAX   D
 098B C9           144         RET
                   145         END

PUBLIC SYMBOLS
FREIBI C 0000

EXTERNAL SYMBOLS
CLEAR  E 0000   ED     E 0000   ERRORH E 0000   FILL   E 0000   INTLD  E 0000   LDFL   E 0000   LOADY  E 0000
LOP2   E 0000   NEGG   E 0000   OP210  E 0000   PTR    E 0000   TEN    E 0000   WAIT   E 0000

USER SYMBOLS
CLEAR  E 0000   DADR   A FE01   DBYTE  A FE03   DIV    C 0955   ED     E 0000   ENDI   C 0007   ERROR1 E 0000
ENCH   A 0018   E PO   C 0935   E PP   C 0937   E PP1  C 0939   FADD   A 0004   FCHS   A 0004   FIECDI C 0000
FDIV   A 0003   FILL   E 0000   FIXED  A 0008   FLOAT  C 004A   FLTDS  A 0005   FMUL   A 0002   FRACT  C 0072
FRACT1 C 0078   FSUB   A 0005   INTLD  E 0000   IOEAS  A 0040   LD     A FE0F   LDBD   C 0000   LOADA  C 0000
LOADB  C 0000   LTHIS  C 0000   LDFL   E 0000   LOADY  E 0000   LDFL   E 0000   NEGG   E 0000   NLOVE  C 0000
OP1    A 0130   OP2    A 0134   OP210  E 0000   OUT1   C 094C   PLUS   C 0000   POSEX  C 0958   POSTIV C 0969
PTR    E 0000   TEN    E 0000   WAIT   E 0000

ASSEMBLY COMPLETE,   NO ERRORS
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ISIS-II 8080/8085 MACRO ASSEMBLER, V2.0        MODULE   PAGE    1


 LOC  OBJ          SEQ         SOURCE STATEMENT

                    1 ;NAME SINCOS
                    2 ;THIS ROUTINE TAKES A 32 BIT FLT. PT. NO. IN
                    3 ;OP1 (IN RADIANS) AND CALCULATES EITHER SINE OR
                    4 ;COSINE OF THAT ANGLE.  THE RESULT IS PLACED IN
                    5 ;OP1.  NEGATIVE ANGLES ARE TREATED AS POSITIVE
                    6 ;ANGLES SINCE SINE IS A SHIFTED COSINE AND
                    7 ;COSINE IS SYMMETRIC
                    8
 0040               9 IOSAS   EQU     40H
 0002              10 FMUL    EQU     2
 0003              11 FDI     EQU     3
 0004              12 FADD    EQU     4
 0005              13 FSUB    EQU     5
 0006              14 FSQR    EQU     6
 0008              15 FLTDS   EQU     8H
 0009              16 FIXSD   EQU     9H
 000A              17 FCMPR   EQU     0AH
 000B              18 FCTST   EQU     0BH
 000F              19 EXCH    EQU     0FH
 C100              20 OP1     EQU     0C100H
 C104              21 OP2     EQU     OP1+4
                   22
                   23 CSEG
                   24 PUBLIC  COSINE,SINE
                   25 EXTRN   LOADM,LOADV,WAIT,CLEAR
 0000 210000   D   26 SINE    LXI     H,PIBY2
 0003 1104C1       27         LXI     D,OP2
 0006 CD0000   E   28         CALL    LOADV
 0009 3E05         29         MVI     A,FSUB
 000B D340         30         OUT     IOSAS
 000D CD0000   E   31         CALL    WAIT
 0010 3A03C1       32 COSINE  LDA     OP1+3    ;RESET SIGN BIT TO POSITIVE
 0013 E67F         33         ANI     7FH
 0015 3203C1       34         STA     OP1+3    ;-----------------------
 0018 210000   D   35         LXI     H,TWOPI  THIS BLOCK NORMALIZES THETA
 001B 1104C1       36         LXI     D,OP2    ;TO   0 LE THETA LE 2*PI
 001E CD0000   E   37         CALL    LOADV
 0021 3E03         38         MVI     A,FDI
 0023 D340         39         OUT     IOSAS
 0025 2100C1       40         LXI     H,OP1
 0028 110000   D   41         LXI     D,THETA
 002B CD0000   E   42         CALL    LOADV    ;THETA=(RAD)/(2*PI)=IP+FP
 002E 3E09         43         MVI     A,FIXSD
 0030 D340         44         OUT     IOSAS
 0032 CD0000   E   45         CALL    WAIT
 0035 3E08         46         MVI     A,FLTDS
 0037 D340         47         OUT     IOSAS
 0039 CD0000   E   48         CALL    WAIT
 003C 3E0F         49         MVI     A,EXCH
 003E D340         50         OUT     IOSAS    ;OP2=INTEGER PART OF THETA (IP)
 0040 210000   D   51         LXI     H,THETA
 0043 1100C1       52         LXI     D,OP1
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LOC  OBJ          SEQ       SOURCE STATEMENT

0048 CD0000   E    53        CALL    LOADX   ,OP1=THETA (IF PP)
004B 3E05          54        MVI     A,FSUB
004D D340          55        OUT     IOEAS   ,OP1=PP
004F 210400   D    56        LXI     H,TWOPI
0052 110401        57        LXI     D,OP2
0055 CD0000   E    58        CALL    LOADX
0058 3E02          59        MVI     A,FMUL
005A D340          60        OUT     IOEAS   ,OP1=PP*2*PI
005C 210001        61        LXI     H,OP1
005F 110000   D    62        LXI     D,THETA
0062 CD0000   E    63        CALL    LOADY   ,0 LE THETA LE 2*PI
0065 210800   D    64        LXI     H,PI    ----------------------------
0068 110401        65        LXI     D,OP2   ,THIS BLOCK CHECKS TO SEE IF
006B CD0000   E    66        CALL    LOADX   ,THETA LT PI
006E 3E0F          67        MVI     A,ECMP
0070 D340          68        OUT     IOEAS
0072 CD0000   E    69        CALL    WAIT
0075 3E09          70        MVI     A,FCMPR ,(OP2)=THETA
0077 D340          71        OUT     IOEAS
0079 CD0000   E    72        CALL    WAIT
007C DB41          73        IN      41H     ,STATUS BYTE
007E E6C0          74        ANI     0C0H    ,PI GE THETA ?
0080 C2A500   C    75        JNZ     CON1     YES, GO TO CON1
0083 3E05          76        MVI     A,FSUB
0085 D340          77        OUT     IOEAS   ,OP1=-P
0087 210800   D    78        LXI     H,PI
008A 110401        79        LXI     D,OP2
008D CD0000   E    80        CALL    LOADX
0090 3E04          81        MVI     A,FADD
0092 D340          82        OUT     IOEAS   ,OP1=PI-P
0094 210001        83        LXI     H,OP1
0097 110000   D    84        LXI     D,THETA
009A CD0000   E    85        CALL    LOADX
009D 210001        86 CON1   LXI     H,OP1   ,------------------------------
00A0 CD0000   E    87        CALL    CLEAR   ,INITIALIZE XACC,DENOM,TACC=1
00A3 3E01          88        MVI     A,1
00A5 320001        89        STA     OP1
00A8 3E02          90        MVI     A,FLTDS
00AA D340          91        OUT     IOEAS
00AC 210001        92        LXI     H,OP1
00AF 111000   D    93        LXI     D,XACC
00B2 CD0000   E    94        CALL    LOADX
00B5 210001        95        LXI     H,OP1
00B8 111800   D    96        LXI     D,DENOM
00BB CD0000   E    97        CALL    LOADY
00BE 210001        98        LXI     H,OP1
00C1 111C00   D    99        LXI     D,TACC
00C4 CD0000   E   100        CALL    LOADY   ,------------------------------
00C7 210000   D   101        LXI     H,THETA ,THIS BLOCK CALCULATES
00CA 110001       102        LXI     D,OP1   ,XSQRD=X*X
00CD CD0000   E   103        CALL    LOADY
00D0 3E03         104        MVI     A,FMUL
00D2 D340         105        OUT     IOEAS
00D4 210001       106        LXI     H,OP1
00D7 111C00   D   107        LXI     D,XSQRD
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LOC  OBJ          SEQ         SOURCE STATEMENT

0062 CD0000   E   108         CALL    LOADX   ;------------------------------
0068 0E00         109         MVI     C,0     ;INITIALIZE LOOP COUNTER=0
00DD 06D4         110         MVI     B,FADD  ;INITIALIZE SIGN=+
00DF 210000   D   111 CLOOP   LXI     H,XSCRD
00E2 110001       112         LXI     D,OP1
00E5 CD0000   E   113         CALL    LOADY
00E8 210000   D   114         LXI     H,YACC
00EB 110401       115         LXI     D,OP2
00EE CD0000   E   116         CALL    LOADY
00F1 3E00         117         MVI     A,FMUL
00F3 D340         118         OUT     IOEAS
00F5 210001       119         LXI     H,OP1
00F8 110000   D   120         LXI     D,YACC
00FB CD0000   E   121         CALL    LOADY   ;YACC=YACC*SCRD
00FE 210001       122         LXI     H,OP1   ;------------------------------
0101 CD0000   E   123         CALL    CLEAR
0104 210401       124         LXI     H,OP2
0107 CD0000   E   125         CALL    CLEAR
010A 79           126         MOV     A,C
010B 3C           127         INR     A
010C 320001       128         STA     OP1
010F 3C           129         INR     A
0110 320401       130         STA     OP2     ;OP1=C+1 (FIXED PT  2 BYTE)
0113 4F           131         MOV     C,A     ;OP2=C+2 (FIXED PT  2 BYTE)
0114 AF           132         XRA     A       ;MVI    A,MUL (FIXED PT )
0115 D340         133         OUT     IOEAS
0117 CD0000   E   134         CALL    WAIT    ;OP1=(C+1)*(C+2)
011A 3E00         135         MVI     A,FLTDS
011C D340         136         OUT     IOEAS
011E 210000   D   137         LXI     H,DENOM
0121 110401       138         LXI     D,OP2
0124 CD0000   E   139         CALL    LOADY   ;OP2=DENOM,OP1=(C+1)*(C+2) (FLOAT)
0127 3E00         140         MVI     A,FMUL
0129 D340         141         OUT     IOEAS
012B 210001       142         LXI     H,OP1
012E 110000   D   143         LXI     D,DENOM
0131 CD0000   E   144         CALL    LOADY   ;DENOM=DENOM*(C+1)*(C+2)
0134 210000   D   145         LXI     H,YACC
0137 110401       146         LXI     D,OP2
013A CD0000   E   147         CALL    LOADY
013D 3E0F         148         MVI     A,EXCH
013F D340         149         OUT     IOEAS
0141 CD0000   E   150         CALL    WAIT
0144 3E00         151         MVI     A,FDIV
0146 D340         152         OUT     IOEAS
0149 210000   D   153         LXI     H,TACC  ;OP1= ACC/DENOM
014B 110401       154         LXI     D,OP2
014E CD0000   E   155         CALL    LOAD
0151 3E0F         156         MVI     A,EXCH  ;------------------------------
0153 D340         157         OUT     IOEAS   ;OP1=TACC,OP2=YACC/DENOM
0155 78           158         MOV     A,B     ;A=SIGN OF TERM (+ OR -)
0156 FED4         159         CPI     FADD    ;SIGN=+?
0158 CAF501   C   160         JZ      CHSIGN  ;YES  TIME TO CHANGE SIGN
015B 3D           161         DCR     A       ;NO, DECREMENT SIGN = FADD
015C C36101   C   162         JMP     STOSGN
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 LOC  OBJ         SEQ         SOURCE STATEMENT

 015F 3C           163 CHGSGN  INR     A        ;CHANGE FADD TO FSUB
 0160 47           164 STOSGN  MOV     B,A      ;STORE SIGN
 0161 CD0000   E   165         CALL    WAIT
 0164 78           166         MOV     A,B
 0165 D340         167         OUT     IOEAS
 0167 210001       168         LXI     H,OP1
 016A 111400   D   169         LXI     D,TACC
 016D CD0000   E   170         CALL    LOADX    ;TACC NEW=TACC(OLD) +/- NACC/DENOM
 0170 79           171         MOV     A,C      ;-------------------------------
 0171 FE09         172         CPI     09H      ;CHECK LOOP COUNTER
 0173 C2CF00   C   173         JNZ     CLOOP    ;IF DENOM = 10!, STOP
 0176 110001       174         LXI     D,OP1
 0179 211400   D   175         LXI     H,TACC
 017C CD0000   E   176         CALL    LOADY
 017F C9           177         RET
                   178
                   179
                   180 DSEG
 0000 FA           181 PIBY2   DB      0FAH,0FH,0C9H,3FH
 0001 0F
 0002 C9
 0003 3F
 0004 FA           182 TWOPI   DB      0FAH,0FH,0C9H,40H
 0005 0F
 0006 C9
 0007 40
 0008 FA           183 PI      DB      0FAH,0FH,49H,40H
 0009 0F
 000A 49
 000B 40
 0004              184 THETA   DS      4        ;ANGULAR OPERAND (IN RADIANS)
 0004              185 NACC    DS      4        ;NUMERATOR ACCUMULATOR
 0004              186 TACC    DS      4        ;SERIES ACCUMULATOR
 0004              187 DENOM   DS      4        ;DENOMINATOR ACCUMULATOR
 0004              188 XSQRD   DS      4        ;X**2
                   189
                   190 END

PUBLIC SYMBOLS
COSINE C 0010    SINE   C 0000

EXTERNAL SYMBOLS
CLEAR  E 0000    LOADX  E 0000    LOADY  E 0000    WAIT   E 0000

USER SYMBOLS
CHGSGN C 015F    CLEAR  E 0000    CLOOP  C 00CF    CON1   C 00[illegible]  COSINE C 0010    DENOM  D 0018    ENCH   A 000F
FADD   A 00[illegible] FCHS   A 000A    FDIV   A 0003    FIXED  A 00[illegible]  FLTDS  A 000E    FMUL   A 0002    FSTR   A 0009
FSUB   A 0005    FXTST  A 000E    IOEAS  A 0040    LOADX  E 0000    LOADY  E 0000    OP1    A 0100    OP2    A 0104
PI     D 0008    PIBY2  D 0000    SINE   C 0000    STOSGN C 0160    TACC   D 0014    THETA  D 000C    TWOPI  D 0004
WAIT   E 0000    NACC   D 0010    XSQRD  D 001C

ASSEMBLY COMPLETE,   NO ERRORS
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LOC  OBJ          SEQ         SOURCE STATEMENT

                    1 ;NAME  ATAN
                    2 ;THIS ROUTINE CALCULATES ARCTANGENT
                    3 ; OF THE CONTENTS OF OP1 AND PUTS THE
                    4 ; RESULT IN OP1
0002                5 FMUL   EQU    2
0003                6 FDIV   EQU    3
0004                7 FADD   EQU    4
0005                8 FSUB   EQU    5
0006                9 FSQR   EQU    6
0009               10 FCOFF  EQU    09H
000F               11 E.IN   EQU    0FH
0100               12 OP1    EQU    0100H
0104               13 OP2    EQU    OP1+4
0040               14 IOBAS  EQU    40H     ;MEM  BASE ADDR
                   15 CSEG
                   16 PUBLIC  ATAN
                   17 EXTRN   WAIT,LOADY,LOADX,CLEAR,LOP2
0000 210001        18 ATAN   LXI    H,OP1
0003 110000   D    19        LXI    D,X
0006 CD0000   E    20        CALL   LOADY   ;SAVE OPERAND
0009 3E06          21        MVI    A,FSQR
000B D340          22        OUT    IOBAS
000D 210001        23        LXI    H,OP1
0010 110000   D    24        LXI    D,XSQRD
0013 CD0000   E    25        CALL   LOADY   ;XSQRD=X**2
0016 210000   D    26        LXI    H,ONE
0019 110000   D    27        LXI    D,COEF
001C CD0000   E    28        CALL   LOADY   ;INITIALIZE COEF  1
001F AF            29        XRA    A
0020 4F            30        MOV    C,A     ;INITIALIZE LOOP COUNTER
0021 320000   D    31        STA    NEGX    ;INITIALIZE NEGX FLAG
0024 3A0500   D    32        LDA    X+3     ;----------------------------
0027 17            33        RAL            ;X GT 0 ?
0028 D23500   C    34        JNC    XGZERO  ;YES, GO TO XGZERO
002B 3F            35        CMC
002C 1F            36        RAR
002D 320000   D    37        STA    X+3     ;NO  RESET SIGN BIT
0030 3EFF          38        MVI    A,0FFH
0032 320000   D    39        STA    NEGX    ;SET NEGATIVE FLAG
0035 210000   D    40 XGZERO LXI    H,ONE    ----------------------------
0038 110001        41        LXI    D,OP2
003B CD0000   E    42        CALL   LOADY
003E 210000   D    43        LXI    H,X
0041 110001        44        LXI    D,OP1
0044 CD0000   E    45        CALL   LOADY
0047 210001        46        LXI    H,OP1
004A 110000   D    47        LXI    D,XTAN   ;XTAN=+X
004D CD0000   E    48        CALL   LOADY
0050 3E09          49        MVI    A,FCOFF
0052 D340          50        OUT    IOBAS
0054 CD0000   E    51        CALL   WAIT
0057 DB41          52        IN     41H      STATUS BYTE
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LOC  OBJ          SEQ         SOURCE STATEMENT

0059 E6C0          53          ANI    0C04    ,Y GE ONE ?
005B C27300   C    54          JNZ    GTONE   ,-------------------------
005E 210500   D    55          LXI    H ATANX ,FESX X LT 1
0061 CD0000   E    56          CALL   CLEAR   ,ATANX=0 INITIALLY
0064 3E00          57          MVI    A FADD
0066 322100   D    58          STA    SGN     ,INITIALIZE SIGN OF TERM
0069 211100   D    59 RESUL1   LXI    H,COEF  ,OP1=XTAN
006C 110401        60          LXI    D,OP2
006F CD0000   E    61          CALL   LOADY
0072 CDA400   C    62          CALL   COMMON
0075 C36900   C    63          JMP    RESUL1
                   64
0078 3E05          65 GTONE    MVI    A FSUB
007A 322100   D    66          STA    SGN     ,INITIALIZE SIGN OF TERM
007D 211E00   D    67          LXI    H,PIBY2
0080 110500   D    68          LXI    D ATANX
0083 CD0000   E    69          CALL   LOADY   ,ATANX=PI/2 INITIALLY
0086 211100   D    70 RESUL1   LXI    H,COEF
0089 110401        71          LXI    D,OP2   ,OP1=XTAN
008C CD0000   E    72          CALL   LOADY   ,OP2=COEF
008F 3E02          73          MVI    A FMUL
0091 D340          74          OUT    IOBAS
0093 211600   D    75          LXI    H,ONE
0096 CD0000   E    76          CALL   LOP2     OP1=COEF*XTAN
0099 3E0F          77          MVI    A SXCH
009B D340          78          OUT    IOBAS   ,OP1=1
009D CD0000   E    79          CALL   WAIT    ,OP2=COEF*XTAN
00A0 CDA400   C    80          CALL   COMMON
00A3 C38600   C    81          JMP    RESUL1
                   82
00A6 3E03          83 COMMON   MVI    A FDIV
00A8 D340          84          OUT    IOBAS   ,OP1=OP1/OP2
00AA 210500   D    85          LXI    H,ATANX
00AD CD0000   E    86          CALL   LOP2
00B0 3E0F          87          MVI    A,SXCH
00B2 D340          88          OUT    IOBAS
00B4 CD0000   E    89          CALL   WAIT    ,OP1=ATANX
00B7 3A2100   D    90          LDA    SGN
00BA D340          91          OUT    IOBAS
00BC 210401        92          LXI    H OP1
00BF 110500   D    93          LXI    D,ATANX
00C2 CD0000   E    94          CALL   LOADX   ,ATANX=ATANX +- NEW TERM
00C5 0C            95          INR    C       ,-----------------------
00C6 79            96          MOV    A C     ,UPDATE AND CHECK COUNTER
00C7 FE09          97          CPI    09H
00C9 CAE500   C    98          JZ     OUTAN
00CC 3A2100   D    99          LDA    SGN     ,------------- ------------
00CF FE04         100          CPI    FADD     CHANGE SIGN
00D1 CAD900   C   101          JZ     CHGSGN
00D4 3D           102          DCR    A
00D5 C3DA00   C   103          JMP    STOSGN
00D8 3C           104 CHGSGN   INR    A
00D9 322100   D   105 STOSGN   STA    SGN      --------------------------
00DC 211100   D   106          LXI    H,COEF  ,COEF=COEF+2
00DF 110401       107          LXI    D,OP1
```

```
 LOC  OBJ          SEQ        SOURCE STATEMENT

00E2 CD0000   E   108          CALL    LOADY
00E5 210A00   D   109          LXI     H,TWO
00E8 110401       110          LXI     D,OP2
00EB CD0000   E   111          CALL    LOADY
00EE 3E04         112          MVI     A,FADD
00F0 D340         113          OUT     IOEAS
00F2 210001       114          LXI     H,OP1
00F5 111100   D   115          LXI     D,CCEF
00F8 CD0000   E   116          CALL    LOADY      ;-------------------------
00FB 210A00   D   117          LXI     H,XTAN     ;XTAN=XTAN/XSQRD
00FE 110001       118          LXI     D,OP1
0101 CD0000   E   119          CALL    LOADY
0104 210600   D   120          LXI     H,XSQRD
0107 110401       121          LXI     D,OP2
010A CD0000   E   122          CALL    LOADY
010D 3E02         123          MVI     A,FMUL
010F D340         124          OUT     IOEAS
0111 210001       125          LXI     H,OP1
0114 110A00   D   126          LXI     D,XTAN
0117 CD0000   E   127          CALL    LOADY      ;-------------------------
011A C9           128          RET
                  129
011B E1           130 OUTAN    POP     H          ;FALSE RETURN
011C 3A0000   D   131          LDA     NEGX
011F A7           132          ANA     A
0120 C8           133          RZ
0121 3A0301       134          LDA     OP1+3
0124 EE80         135          XRI     80H        ;ATAN(-X)=-ATAN(X)
0126 320301       136          STA     OP1+3
0129 C9           137          RET
                  138
                  139 DSEG
0001              140 NEG      DS      1          ;NEGATIVE OPERAND FLAG
0001              141 SGN      DS      1          ;ALTERNATING SIGN IN SERIES
0004              142 X        DS      4          ;SAVE OPERAND
0004              143 XSQRD    DS      4          ;XSQRD=X**2
0004              144 XTAN     DS      4          ;POWERS OF X IN SERIES
0004              145 ATAN     DS      4          ;ACCUMULATOR OF TERMS OF SERIES
0004              146 CCEF     DS      4          ;ACCUMULATOR OF COEFFICIENTS
0016 00           147 ONE      DB      0,0,80H,3FH
0017 00
0018 80
0019 3F
001A 00           148 TWO      DB      0,0,0,40H
001B 00
001C 00
001D 40
001E DA           149 PIE2     DB      0DAH,0FH,0C9H,3FH
001F 0F
0020 C9
0021 3F
                  150
                  151 END

PUBLIC SYMBOLS
```

```
ATAN    C 0030

EXTERNAL SYMBOLS
CLEAR  E 0000    LOADX  E 0000    LOADY  E 0000    LOP2   E 0000    WAIT   E 0000

USER SYMBOLS
ADDSG1 C [illegible]    ADDSL1 C [illegible]    ATAN   C 0000    ATANX  D 000E    CHGSGN C 0003    CLEAR  E 0000    COEF   D 0012
COMMON C [illegible]    ECH    A 000F    FADD   A 0004    FCMPR  A 000A    FDIV   A 000C    FMUL   A 0002    FSUB   A 0006
FOUR   A [illegible]    GTONE  C [illegible]    IDEAS  A 2040    LOADX  E 0000    LOADY  E 0000    LOP2   E 0000    NEGX   D 0000
ONE    D 001E    OP1    A C100    OP2    A C104    OUTAN  C 011B    PI2?2  D 001E    SGN    D 0001    STOSGN C 00D9
TWO    D 001A    WAIT   E 0000    X      D 0002    XGZERO C 00C5    YZERO  D 0006    YTAN   D 000A

ASSEMBLY COMPLETE,  NO ERRORS
```

ISIS-II 8080/8085 MACRO ASSEMBLER, V2.0   MODULE   PAGE   1

```
LOC  OBJ         SEQ         SOURCE STATEMENT

                     ;SUBROUTINE PLOT

                             PUBLIC  PLOT,LINCT,SPACT

                             CSEG
F30F                     CO  EQU     0F30FH
0000 46                  PLOT MOV    B,M     ,LOAD MAG INTO B
0001 EB                      XCHG
0002 4E                      MOV     C,M      LOAD PHASE INTO C
0003 EB                      XCHG
0004 AF                      XRA     A       ,CLEAR ACC
0005 320000   D              STA     EEQUC   ,INITIALIZE EEQUC FLAG
0008 320000   D              STA     PTCTR   ,INITIALIZE PTCTR FLAG
000B 78                      MOV     A,B
000C B9                      CMP     C       ,B=C ?
000D C21500   C              JNZ     GR17    ,NO - JUMP
0010 3EFF                    MVI     A,0FFH  ,YES - SET EEQUC
0012 320000   D              STA     EEQUC    STORE EEQUC

0015 3A0000   D          GR17 LDA    LINCT    LOAD LINE COUNTER
0018 3C                      INR     A        FIRST POINT ?
0019 320000   D              STA     LINCT
001C C23E00   C              JNZ     GR05    ,NO - JUMP
001F 3E3D                    MVI     A,3DH
0021 320000   D              STA     LINCT   ,INITIATE LINE COUNTER
0024 3EFF                    MVI     A,0FFH
0026 320100   D              STA     SPACT   ,INITIATE SPACE COUNTER

0029 0D                  GR01 DCR    C
002A 05                      DCR     B       ,CHECK - REACHED MAG YET ?
002B F22900   C              JP      GR19    ,NO - JUMP
002E 3A0000   D              LDA     EEQUC
0031 A7                      ANA     A       ,CHECK - EEQUC SET?
0032 C25100   C              JNZ     GR19    ,YES - JUMP AND OUTPUT #
0035 C3E200   C              JMP     GR03    ,NO - JUMP AND OUTPUT +

0038 79                  GR18 MOV    A,C
0039 A7                      ANA     A
003A FA5E00   C              JM      GR21    ,YES - OUTPUT +
003D 3A0100   D              LDA     SPACT   ,NO
0040 3C                      INR     A        INCREMENT SPACE COUNTER
0041 320100   D              STA     SPACT
0044 C27700   C              JNZ     GR02    ,NOT A SPACE MULTIPLE OF 5
0047 79                      MOV     A,C
0048 323400   D              STA     CSAV
004B 0E21                    MVI     C,'!'   ,SPACE   MULTIPLE OF 5
004D C3A700   C              JMP     GR04

0050 3E23                L 19 MVI    A,23H   ,INSURE C NEVER GETS -VE
0052 323400   D              STA     CSAV
0055 0E23                    MVI     C,'#'   ,B=C ? OUTPUT #
0057 0693                    MVI     E,93H   ,INSURE E NEVER GETS -VE
```

```
LOC  OBJ         SEQ         SOURCE STATEMENT

                  53
0059 3A0100   D   54 GP23    LDA     SPACT   ,LOAD SPACE COUNTER
005C 3C           55         INR     A
005D 320100   D   56         STA     SPACT   ,STORE INCREMENTED SPACE COUNTER
0060 C37E00   C   57         JMP     GP40    ,TO PRESERVE Y AXIS GRADUATION
                  58
0063 0630         59 GP03    MVI     B,30H   ,INSURE B NEVER GETS -VE
0065 79           60         MOV     A,C
0066 320400   D   61         STA     CSAV    ,STORE C
0069 0E2A         62         MVI     C,'*'   ,REACHED MAX  OUTPUT *
006B C35900   C   63         JMP     GP23
                  64
006E 3E09         65 GP21    MVI     A,60H   ,INSURE C NEVER GETS -VE
0070 320400   D   66         STA     CSAV    ,STORE C
0073 0E2B         67         MVI     C,'+'   ,REACHED PHASE  OUTPUT +
0075 C35900   C   68         JMP     GP23
                  69
0078 79           70 GP02    MOV     A,C
0079 320400   D   71         STA     CSAV    ,SAVE C
007C 0E2D         72         MVI     C,'-'
007E 3A0100   D   73 GP40    LDA     SPACT   ,EVAL D MODULO 5
0081 D604         74         SUI     04H
0083 C28900   C   75         JNZ     GP04
0086 2F           76         CMA             ,PUT -1 INTO D
0087 320100   D   77         STA     SPACT
                  78
008A CD0000       79 GP04    CALL    CO
008D 3A0400   D   80         LDA     CSAV    ,REINSTATE C
0090 4F           81         MOV     C,A
0091 3A0200   D   82         LDA     LINCT
0094 3D           83         DCR     A       ,FINISHED Y AXIS?
0095 320200   D   84         STA     LINCT
0098 C20000   C   85         JNZ     GP01    ,NO- JUMP
009B 23           86         INX     H
009C 13           87         INX     D       ,INCREMENT BUFFER POINTERS
009D C9           88         RET             ,RETURN FROM 1ST CALL
                  89
009E 3EFF         90 GP05    MVI     A,0FFH  ,SPACT=-1 INDICATES NON Y AXIS
00A0 320100   D   91         STA     SPACT
00A3 04           92         INR     B       ,CHECK FINISHED GRAPH
00A4 C2A900   C   93         JNZ     GP06    ,NO- JUMP
00A7 37           94         STC             ,YES- SET CARRY
00A8 C9           95         RET
                  96
00A9 05           97 GP06    DCR     B       ,RESTORE DATA
00AA 3A0200   D   98         LDA     LINCT   ,EVAL  LINE NO  MODULO 5
00AD D605         99         SUI     05H
00AF C2B500   C  100         JNZ     GP10
00B2 320200   D  101         STA     LINCT
                 102
00B5 0D          103 GP10    DCR     C
00B6 05          104         DCR     B       CHECK - REACHED MAX YET?
00B7 F2[illegible]   C  105         JP      GP[illegible]   ,NO - [illegible]
00BA 3A[illegible]   D  106         LDA     [illegible]   ,YES
00BD A7          107         ANA     A       ,SEQUC SET ?
```

```
LOC  OBJ          SEQ          SOURCE STATEMENT

00EE D2[illegible]     C    108          JNC     GR29    ,YES - JUMP AND OUTPUT #
00C1 0[illegible]              109          MVI     B,30H   ,NO - INSURE B NEVER GETS -VE
00C3 79                110          MOV     A,C
00C4 32[illegible]     D    111          STA     CSAV    ,SAVE C
00C7 0E2A              112          MVI     C,'*'    OUTPUT *
00C9 C35000      C    113          JMP     GR22
                       114
00CC 0E23              115 GR13     MVI     C,'#'   ,B=C > OUTPUT #
00CE CD[illegible]          116          CALL    CO
00D1 C3[illegible]     C    117          JMP     GR26
                       118
00D4 79                119 GR23     MOV     A,C
00D5 A7                120          ANA     A        CHECK - FETCHED PHASE SET?
00D6 F2[illegible]     C    121          JP      GR25    ,NO - JUMP
00D9 0E30              122          MVI     C,30H   ,YES - INSURE C NEVER GETS -VE
00DB 32[illegible]     D    123          STA     CSAV    ,STORE C
00DE 0E2B              124          MVI     C,'+'
                       125
00E0 CD[illegible]          126 GR32     CALL    CO       OUTPUT CHARACTER IN C REG
00E3 3A[illegible]     D    127          LDA     PTCTR   ,LOAD POINT COUNTER (NO PTS. OUTPUT)
00E6 FE01              128          CPI     01H     ,PTCTR =1?
00E8 CA[illegible]     C    129          JZ      GR35    ,YES JUMP
00EB 3E01              130          MVI     A,01H   ,NO - SET PTCTR
00ED 32[illegible]     D    131          STA     PTCTR
00F0 3A0400      D    132          LDA     CSAV    ,TO INSURE CSAV NE ASCII CHAR
00F3 4F                133          MOV     C,A
00F4 3A0100      D    134          LDA     SPACT   ,INCREMENT SPACE COUNTER
00F7 3C                135          INR     A
00F8 32[illegible]     D    136          STA     SPACT
00FB D605              137          SUI     05H     ,CHECK SPACT MOD 5
00FD C2[illegible]     C    138          JNZ     GR10
0100 32[illegible]     D    139          STA     SPACT
0103 C3[illegible]     C    140          JMP     GR10
                       141
0106 79                142 GR25     MOV     A,C
0107 32[illegible]     D    143          STA     CSAV    ,SAVE C
010A 0E20              144          MVI     C,' '   ,NO- TYPE SPACE
010C 3A0100      D    145          LDA     SPACT
010F 3C                146          INR     A       ,CHECK - ON AXIS?
0110 320100      D    147          STA     SPACT
0113 C2[illegible]     C    148          JNZ     GR16     NO- JUMP
0116 0E[illegible]              149          MVI     C,'!'    YES
                       150
0118 3A[illegible]     D    151 GR16     LDA     LINCT   ,LOAD LINE COUNTER
011B A7                152          ANA     A       ,LINE MOD 5 = 0 ?
011C CA[illegible]     C    153          JZ      GR22     YES - JUMP
011F 3A[illegible]     D    154          LDA     SPACT   ,EVAL SPACES MODULO 5
0122 D605              155          SUI     05H
0124 C2[illegible]     C    156          JNZ     GR22
0127 32[illegible]     D    157          STA     SPACT
0129 0E[illegible]              158 GR22     MVI     C,'-'   ,EVERY FIFTH Y
                       159
012B CD[illegible]          160 GR22     CALL    CO      ,OUTPUT SPACE - OR +
012E 3A[illegible]     D    161          LDA     CSAV     REINSTATE C
0131 4F                162          MOV     C,A
```

```
 LOC  OBJ         SEQ         SOURCE STATEMENT

 0123 C39503   C   163          JMP     GP10
                   164
 0126 23           165 GP26     INX     H
 0127 12           166          INX     D       ;INCREMENT BUFFER POINTERS
 0128 C9           167          RET
                   168
                   169          DSEG
 0005              170 FLAG     DS      5       ;THIS RESERVES 5 LOCATIONS FOR FLAGS ETC
 0000          D   171 LINCT    EQU     FLAG    ;LINE COUNTER
 0001          D   172 SPACT    EQU     FLAG+1  ;SPACE COUNTER
 0002          D   173 PTCTR    EQU     FLAG+2  ;POINT COUNTER  NO. OF POINTS PLOTTED
 0003          D   174 BEDLC    EQU     FLAG+3   FLAG=FF IF (B)=(C)
 0004          D   175 CSR      EQU     FLAG+4   TO STORE (C) WHEN USING CO ROUTINE
                   176
                   177
                   178          END

PUBLIC SYMBOLS
LINCT  D 0000    PLOT   C 0000    SPACT  D 0001

EXTERNAL SYMBOLS


USER SYMBOLS
BRDUC  D 0003    CO     A F80F    CSAW   D 0004    FLAG   D 0000    GP01   C 0029    GP02   C 007E    GP03   C 00E3
GP04   C 00A5    GP05   C 00BE    GP06   C 00A9    GP13   C 0055    GP16   C 0112    GP17   C 0015    GP18   C 0026
GP19   C 00E3    GP20   C 011C    GP21   C 00EE    GP22   C 011A    GP23   C 0059    GP25   C 00D4    GP29   C 00CC
GP33   C 00E0    GP25   C 010E    GP26   C 0126    GP40   C 007E    LINCT  D 0000    PLOT   C 0000    PTCTR  D 0002
SPACT  D 0001

ASSEMBLY COMPLETE,  NO ERRORS
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Appendix D

SAMPLE RESULTS

This appendix contains a typical output for a completely processed normal alcohol, as well as the results of reflection coefficient measurements for 10 dB and 3 dB attenuators.

The first set of listings is a complete output. The remaining listings are only partial since only the reflection coefficients as functions of frequency are of interest here. The second set is for both attenuators for a 1.8 nsec time window and uses the same stimulus for both responses. The third and fourth sets are for a 0.9 nsec time window for 10 dB and 3 dB pads respectively, and each has its own stimulus measurement.

A discussion of these results appears in section 6.1.

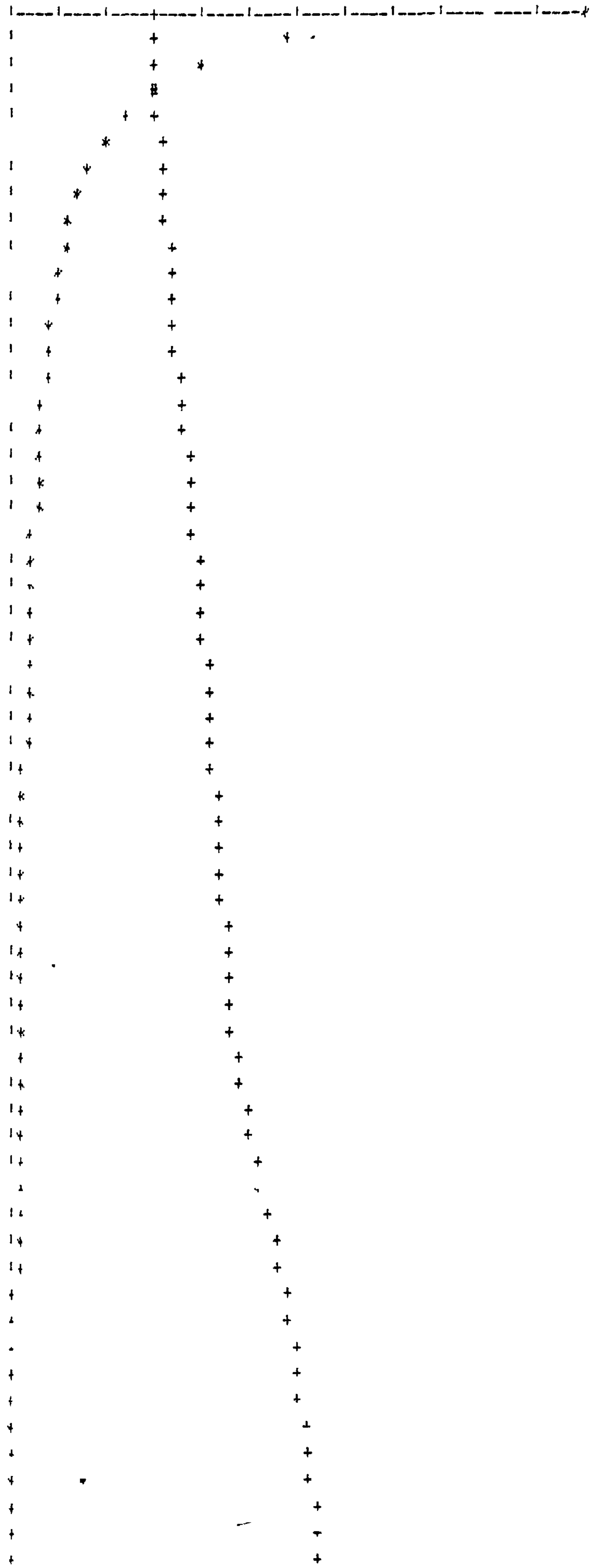
SPECTRE II

AUTOMATIC TIME DOMAIN SPECTROMETER

DEVELOPED AT UNIVERSITY OF OTTAWA
'DEVELOPPE A L UNIVERSITE D OTTAWA
PAR/BY BRIAN PARISIEN
FOR/POUR DR S S STUCHLY

FOURIER TRANSFORM TIME WINDOW = 1 [illegible] SEC

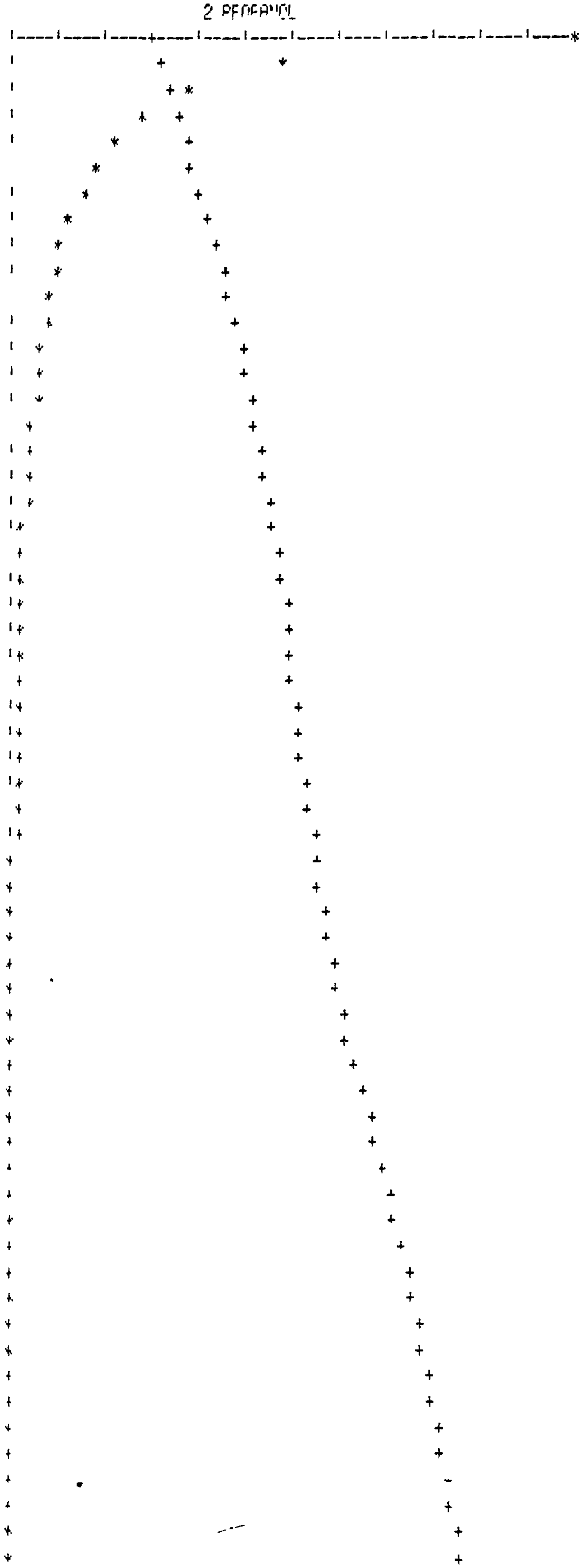
MAG(+)	PHASE(+)	FREQ
+6 2527 E-09	-8 5255 E+01	+2 5000 E+07
+3 1579 E-09	-[illegible] 7706 E+01	+5 0000 E+07
+2 0943 E-09	-8 6547 E+01	+7 5000 E+07
+1 5656 E-09	-8 5275 E+01	+1 0000 E+08
+1 2551 E-09	-8 4155 E+01	+1 2500 E+08
+1 0496 E-09	-8 2971 E+01	+1 5000 E+08
+9 0145 E-10	-8 1745 E+01	+1 7500 E+08
+7 9133 E-10	-8 0453 E+01	+2 0000 E+08
+7 0533 E-10	-7 9169 E+01	+2 2500 E+08
+6 3752 E-10	-7 7935 E+01	+2 5000 E+08
+5 5165 E-10	-7 6466 E+01	+2 7500 E+08
+5 2505 E-10	-7 5061 E+01	+3 0000 E+08
+4 9555 E-10	-7 3610 E+01	+3 2500 E+08
+4 6155 E-10	-7 2145 E+01	+3 5000 E+08
+4 31 2 E-10	-7 0533 E+01	+3 7500 E+08
+4 0550 E-10	-6 9103 E+01	+4 0000 E+08
+3 8251 E-10	-6 7543 E+01	+4 2500 E+08
+3 6159 E-10	-6 5966 E+01	+4 5000 E+08
+3 4260 E-10	-6 4376 E+01	+4 7500 E+08
+3 2527 E-10	-6 2752 E+01	+5 0000 E+08
+3 0935 E-10	-6 1132 E+01	+5 2500 E+08
+2 9453 E-10	-5 9614 E+01	+5 5000 E+08
+2 9039 E-10	-5 7055 E+01	+5 7500 E+08
+2 6931 E-10	-5 6525 E+01	+6 0000 E+08
+2 5650 E-10	-5 5025 E+01	+6 2500 E+08
+2 4547 E-10	-5 3529 E+01	+6 5000 E+08
+2 3517 E-10	-5 2191 E+01	+6 7500 E+08
+2 2559 E-10	-5 0555 E+01	+7 0000 E+08
+2 1666 E-10	-4 9503 E+01	+7 2500 E+08
+2 0829 E-10	-4 7449 E+01	+7 5000 E+08
+2 0074 E-10	-4 7443 E+01	+7 7500 E+08
+1 9369 E-10	-4 6765 E+01	+8 0000 E+08
+1 8723 E-10	-4 3565 E+01	+8 2500 E+08
+1 8122 E-10	-4 3303 E+01	+8 5000 E+08
+1 7594 E-10	-4 3455 E+01	+8 7500 E+08
+1 7107 E-10	-4 1601 E+01	+9 0000 E+08
+1 6666 E-10	-4 1653 E+01	+9 2500 E+08
+1 6266 E-10	-3 9523 E+01	+9 5000 E+08
+1 5901 E-10	-3 8573 E+01	+9 7500 E+08
+1 5551 E-10	-3 7295 E+01	+1 0000 E+09
+1 4997 E-10	-3 4514 E+01	+1 0500 E+09
+1 4472 E-10	-3 2145 E+01	+1 1000 E+09
+1 3991 E-10	-3 3091 E+01	+1 1500 E+09
+1 3516 E-10	-3 5731 E+01	+1 2000 E+09
+1 3027 E-10	-3 2210 E+01	+1 2500 E+09
+1 2516 E-10	-1 9735 E+01	+1 3000 E+09
+1 1953 E-10	-1 5175 E+01	+1 3500 E+09
+1 1434 E-10	-1 1711 E+01	+1 4000 E+09
+1 0952 E-10	-9 4739 E+00	+1 4500 E+09
+1 0340 E-10	-5 4015 E+00	+1 5000 E+09
+9 7311 E-11	-2 6455 E+00	+1 5500 E+09
+9 3621 E-11	+0 0021 E+00	+1 6000 E+09
+9 0447 E-11	+2 0547 E+00	+1 6500 E+09
+9 5314 E-11	+4 1531 E+00	+1 7000 E+09
+8 2733 E-11	+6 1513 E+00	+1 7500 E+09
+8 0121 E-11	+9 1745 E+00	+1 8000 E+09
+7 7553 E-11	+1 0741 E+01	+1 8500 E+09
+7 5303 E-11	+1 2293 E+01	+1 9000 E+09
+7 4292 E-11	+1 4643 E+01	+1 9500 E+09
+7 1519 E-11	+1 6950 E+01	+2 0003 E+09



RESPONSE

FOURIER TRANSFORM TIME WINDOW = 1 [illegible] SEC

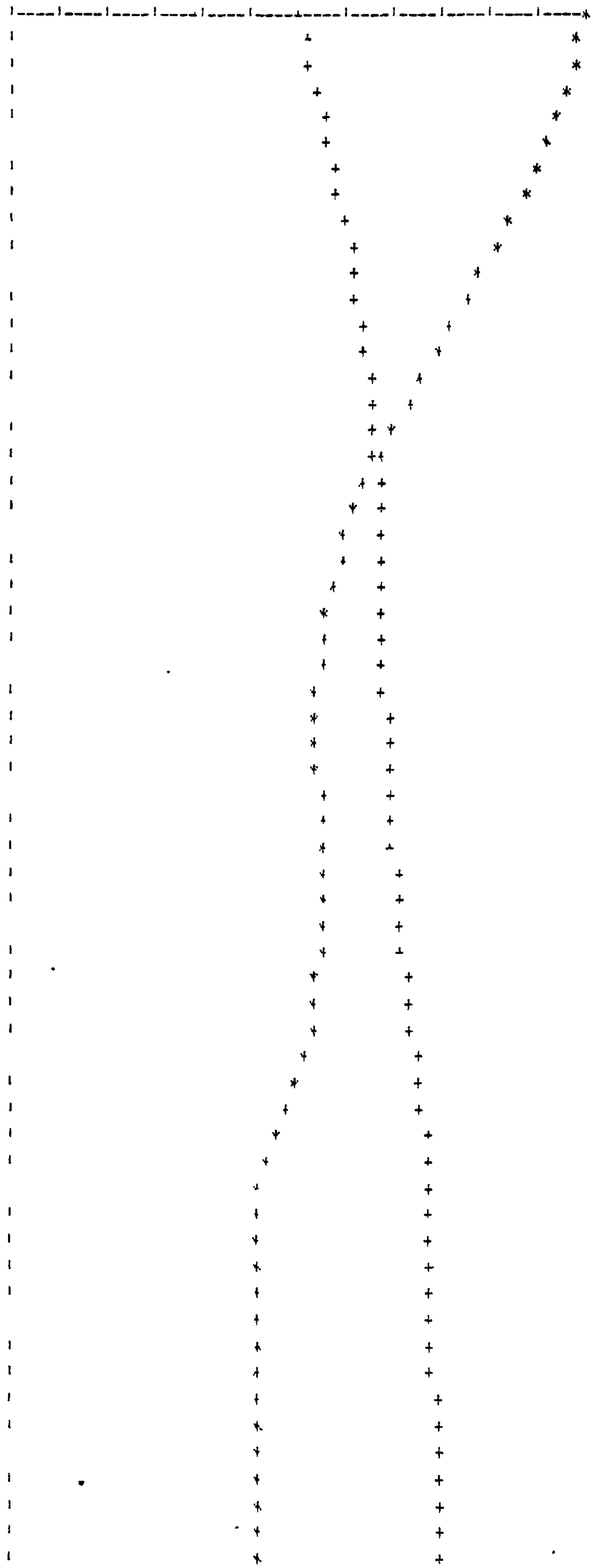
MAG(K)	PHASE(+)	FREQ
+6 2167 E-09	-3 4944 E+01	+2 5000 E+07
+3 0906 E-09	-7 9500 E+01	+5 0000 E+07
+2 0452 E-09	-7 4392 E+01	+7 5000 E+07
+1 5153 E-09	-6 9303 E+01	+1 0000 E+08
+1 2001 E-09	-6 4474 E+01	+1 2500 E+08
+9 9517 E-10	-6 0111 E+01	+1 5000 E+08
+8 2973 E-10	-5 5227 E+01	+1 7500 E+08
+7 1161 E-10	-5 0672 E+01	+2 0000 E+08
+6 1353 E-10	-4 6726 E+01	+2 2500 E+08
+5 4310 E-10	-4 1452 E+01	+2 5000 E+08
+4 2069 E-10	-3 7265 E+01	+2 7500 E+08
+4 2919 E-10	-3 3101 E+01	+3 0000 E+08
+3 5146 E-10	-2 9102 E+01	+3 2500 E+08
+3 4493 E-10	-2 5294 E+01	+3 5000 E+08
+3 1165 E-10	-2 1662 E+01	+3 7500 E+08
+2 9263 E-10	-1 9246 E+01	+4 0000 E+08
+2 5729 E-10	-1 5045 E+01	+4 2500 E+08
+2 3511 E-10	-1 2060 E+01	+4 5000 E+08
+2 1571 E-10	-9 2273 E+00	+4 7500 E+08
+1 9976 E-10	-6 7209 E+00	+5 0000 E+08
+1 8297 E-10	-4 3420 E+00	+5 2500 E+08
+1 7110 E-10	-2 1215 E+00	+5 5000 E+08
+1 5993 E-10	+0 0032 E+00	+5 7500 E+08
+1 5025 E-10	+1 9317 E+00	+6 0000 E+08
+1 4187 E-10	+3 9231 E+00	+6 2500 E+08
+1 3462 E-10	+5 7159 E+00	+6 5000 E+08
+1 2933 E-10	+7 6262 E+00	+6 7500 E+08
+1 2294 E-10	+9 5712 E+00	+7 0000 E+08
+1 1901 E-10	+1 1536 E+01	+7 2500 E+08
+1 1371 E-10	+1 3657 E+01	+7 5000 E+08
+1 0994 E-10	+1 5337 E+01	+7 7500 E+08
+1 0620 E-10	+1 9192 E+01	+8 0000 E+08
+1 0202 E-10	+2 0533 E+01	+8 2500 E+08
+9 9917 E-11	+2 2073 E+01	+8 5000 E+08
+9 6947 E-11	+2 5646 E+01	+8 7500 E+08
+9 4051 E-11	+2 3194 E+01	+9 0000 E+08
+9 1244 E-11	+2 0972 E+01	+9 2500 E+08
+8 9427 E-11	+2 3650 E+01	+9 5000 E+08
+8 5761 E-11	+3 6419 E+01	+9 7500 E+08
+8 3071 E-11	+3 9121 E+01	+1 0000 E+09
+7 7797 E-11	+4 3505 E+01	+1 0500 E+09
+7 2695 E-11	+4 9799 E+01	+1 1000 E+09
+6 7545 E-11	+5 4633 E+01	+1 1500 E+09
+6 3149 E-11	+5 9213 E-01	+1 2000 E+09
+5 9052 E-11	+6 3614 E+01	+1 2500 E+09
+5 5532 E-11	+6 7613 E+01	+1 3000 E+09
+5 2269 E-11	+7 1270 E+01	+1 3500 E+09
+4 9545 E-11	+7 4255 E+01	+1 4000 E+09
+4 7155 E-11	-7 9427 E+01	+1 4500 E+09
+4 4270 E-11	+8 1519 E+01	+1 5000 E+09
+4 2796 E-11	+8 5157 E+01	+1 5500 E+09
+4 1102 E-11	+8 3425 E+01	+1 6000 E+09
+3 9460 E-11	+9 1607 E+01	+1 6500 E+09
+3 7951 E-11	+9 4622 E-01	+1 7000 E+09
+3 6614 E-11	+9 7629 E+01	+1 7500 E+09
+3 5412 E-11	+1 0049 E+02	+1 8000 E+09
+3 4419 E-11	+1 0326 E+02	+1 8500 E+09
+3 3560 E-11	+1 0603 E+02	+1 9010 E+09
+3 2744 E-11	+1 0879 E+02	+1 9500 E+09
+3 2250 E-11	+1 1165 E+02	+2 0000 E+09



[illegible]

FOURIER TRANSFORM

MAG(*)	PHASE(+)	FREQ
+9 9424 E-01	+2 9115 E+00	+2 5000 E+07
+9 9935 E-01	+7 9057 E+00	+5 0000 E+07
+9 9128 E-01	+1 1665 E+01	+7 5000 E+07
+9 7116 E-01	+1 5473 E+01	+1 0000 E+08
+9 5616 E-01	+1 9211 E+01	+1 2500 E+08
+9 3950 E-01	+2 2762 E+01	+1 5000 E+08
+9 2043 E-01	+2 6405 E+01	+1 7500 E+08
+8 9926 E-01	+2 9906 E+01	+2 0000 E+08
+8 7629 E-01	+3 2433 E+01	+2 2500 E+08
+8 5190 E-01	+3 6372 E+01	+2 5000 E+08
+8 2643 E-01	+3 9001 E+01	+2 7500 E+08
+8 0027 E-01	+4 1953 E+01	+3 0000 E+08
+7 7550 E-01	+4 4619 E+01	+3 2500 E+08
+7 4744 E-01	+4 6661 E+01	+3 5000 E+08
+7 2154 E-01	+4 9375 E+01	+3 7500 E+08
+6 9547 E-01	+5 0956 E+01	+4 0000 E+08
+6 7260 E-01	+5 2433 E+01	+4 2500 E+08
+6 5023 E-01	+5 3906 E+01	+4 5000 E+08
+6 2562 E-01	+5 5032 E+01	+4 7500 E+08
+6 1106 E-01	+5 6052 E+01	+5 0000 E+08
+5 9472 E-01	+5 6549 E+01	+5 2500 E+08
+5 8072 E-01	+5 7492 E+01	+5 5000 E+08
+5 6916 E-01	+5 9055 E+01	+5 7500 E+08
+5 5997 E-01	+5 8447 E+01	+6 0000 E+08
+5 5310 E-01	+5 8955 E+01	+6 2500 E+08
+5 4944 E-01	+5 9314 E+01	+6 5000 E+08
+5 4667 E-01	+5 9219 E+01	+6 7500 E+08
+5 4452 E-01	+6 0430 E+01	+7 0000 E+08
+5 4465 E-01	+6 1133 E+01	+7 2500 E+08
+5 4557 E-01	+6 2135 E+01	+7 5000 E+08
+5 4719 E-01	+6 2325 E+01	+7 7500 E+08
+5 4924 E-01	+6 4324 E+01	+8 0000 E+08
+5 5022 E-01	+6 4155 E+01	+8 2500 E+08
+5 5102 E-01	+6 6597 E+01	+8 5000 E+08
+5 5100 E-01	+6 9146 E+01	+8 7500 E+08
+5 4925 E-01	+6 9905 E+01	+9 0000 E+08
+5 4750 E-01	+7 1624 E+01	+9 2500 E+08
+5 4233 E-01	+7 3212 E+01	+9 5000 E+08
+5 2909 E-01	+7 4355 E+01	+9 7500 E+08
+5 2348 E-01	+7 6525 E+01	+1 0000 E+09
+5 1904 E-01	+7 8419 E+01	+1 0500 E+09
+5 0026 E-01	+8 1944 E+01	+1 1000 E+09
+4 8452 E-01	+8 2750 E+01	+1 1500 E+09
+4 6570 E-01	+8 5105 E+01	+1 2000 E+09
+4 5452 E-01	+8 5902 E+01	+1 2500 E+09
+4 4115 E-01	+8 6252 E+01	+1 3000 E+09
+4 3704 E-01	+8 6555 E+01	+1 3500 E+09
+4 3331 E-01	+8 6667 E+01	+1 4000 E+09
+4 3252 E-01	+8 6961 E+01	+1 4500 E+09
+4 3336 E-01	+8 7221 E+01	+1 5000 E+09
+4 3634 E-01	+8 7304 E+01	+1 5500 E+09
+4 4932 E-01	+8 8425 E+01	+1 6000 E+09
+4 4115 E-01	+8 8502 E+01	+1 6500 E+09
+4 4232 E-01	+9 0593 E+01	+1 7000 E+09
+4 4252 E-01	+9 1459 E+01	+1 7500 E+09
+4 4232 E-01	+9 2301 E+01	+1 8000 E+09
+4 4152 E-01	+9 3017 E+01	+1 8500 E+09
+4 4194 E-01	+9 3610 E+01	+1 9010 E+09
+4 4263 E-01	+9 4141 E+01	+1 9500 E+09
+4 4409 E-01	+9 4763 E+01	+2 0000 E+09



[illegible]

EPSILON' (+)	EPSILON" (-)	FREQ
+1 6344 E+01	+1 [illegible]42 E+00	+2 5000 E+07
+1 6329 E+01	+1 2575 E+00	+5 0000 E+07
+1 6337 E+01	+1 5233 E+00	+7 5000 E+07
+1 6254 E+01	+1 9459 E+00	+1 0000 E+08
+1 6194 E+01	+2 1063 E+00	+1 2500 E+08
+1 6115 E+01	+2 5903 E+00	+1 5000 E+08
+1 6014 E+01	+2 9255 E+00	+1 7500 E+08
+1 5276 E+01	+3 2973 E+00	+2 0000 E+08
+1 5235 E+01	+3 3017 E+00	+2 2500 E+08
+1 5714 E+01	+4 2253 E+00	+2 5000 E+08
+1 5223 E+01	+4 6544 E+00	+2 7500 E+08
+1 5050 E+01	+5 0653 E+00	+3 0000 E+08
+1 4765 E+01	+5 4670 E+00	+3 2500 E+08
+1 4451 E+01	+5 9457 E+00	+3 5000 E+08
+1 4079 E+01	+6 1956 E+00	+3 7500 E+08
+1 3669 E+01	+6 5153 E+00	+4 0000 E+08
+1 3229 E+01	+6 7554 E+00	+4 2500 E+08
+1 2766 E+01	+7 0123 E+00	+4 5000 E+08
+1 2255 E+01	+7 1522 E+00	+4 7500 E+08
+1 1504 E+01	+7 2951 E+00	+5 0000 E+08
+1 1326 E+01	+7 3503 E+00	+5 2500 E+08
+1 0362 E+01	+7 3511 E+00	+5 5000 E+08
+1 0436 E+01	+7 3043 E+00	+5 7500 E+08
+1 0020 E+01	+7 2069 E+00	+6 0000 E+08
+9 6556 E+00	+7 0773 E+00	+6 2500 E+08
+9 3216 E+00	+6 [illegible]13[illegible] E+00	+6 5000 E+08
+9 0575 E+00	+6 7426 E+00	+6 7500 E+08
+8 9233 E+00	+6 5577 E+00	+7 0000 E+08
+8 6451 E+00	+6 2731 E+00	+7 2500 E+08
+8 5150 E+00	+6 1573 E+00	+7 5000 E+08
+8 4336 E+00	+6 0415 E+00	+7 7500 E+08
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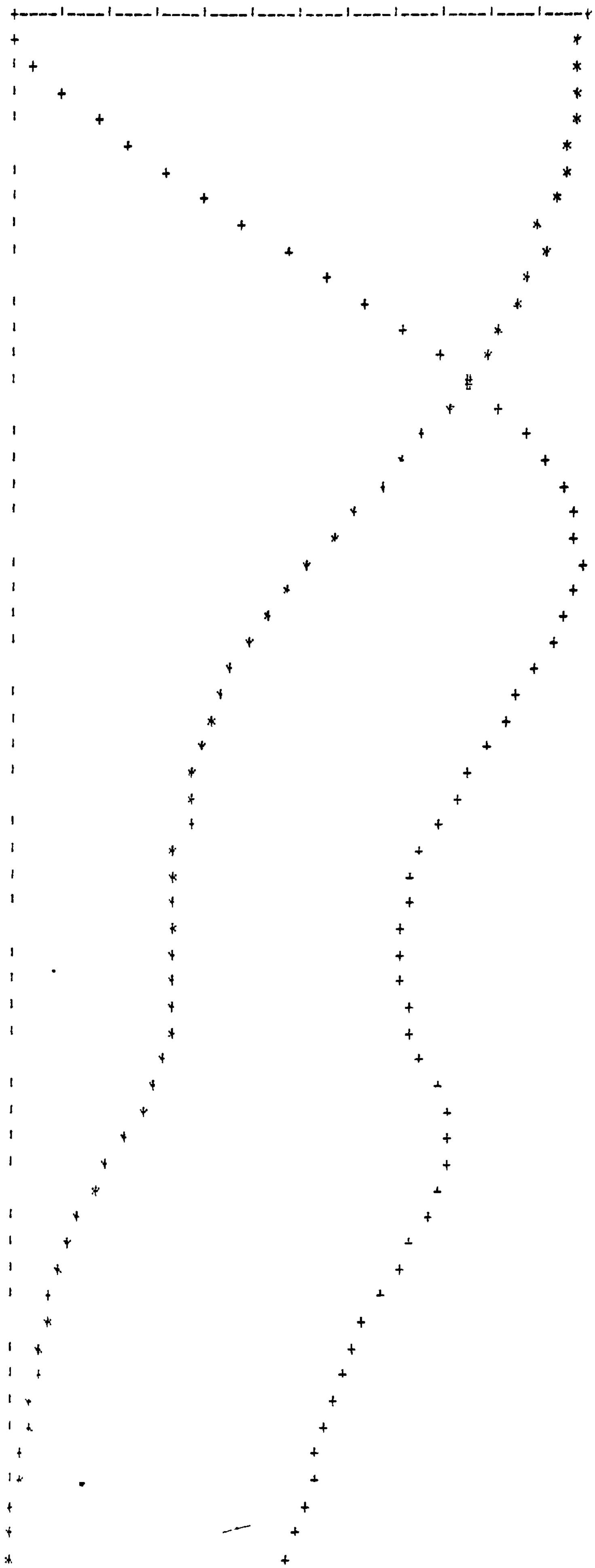
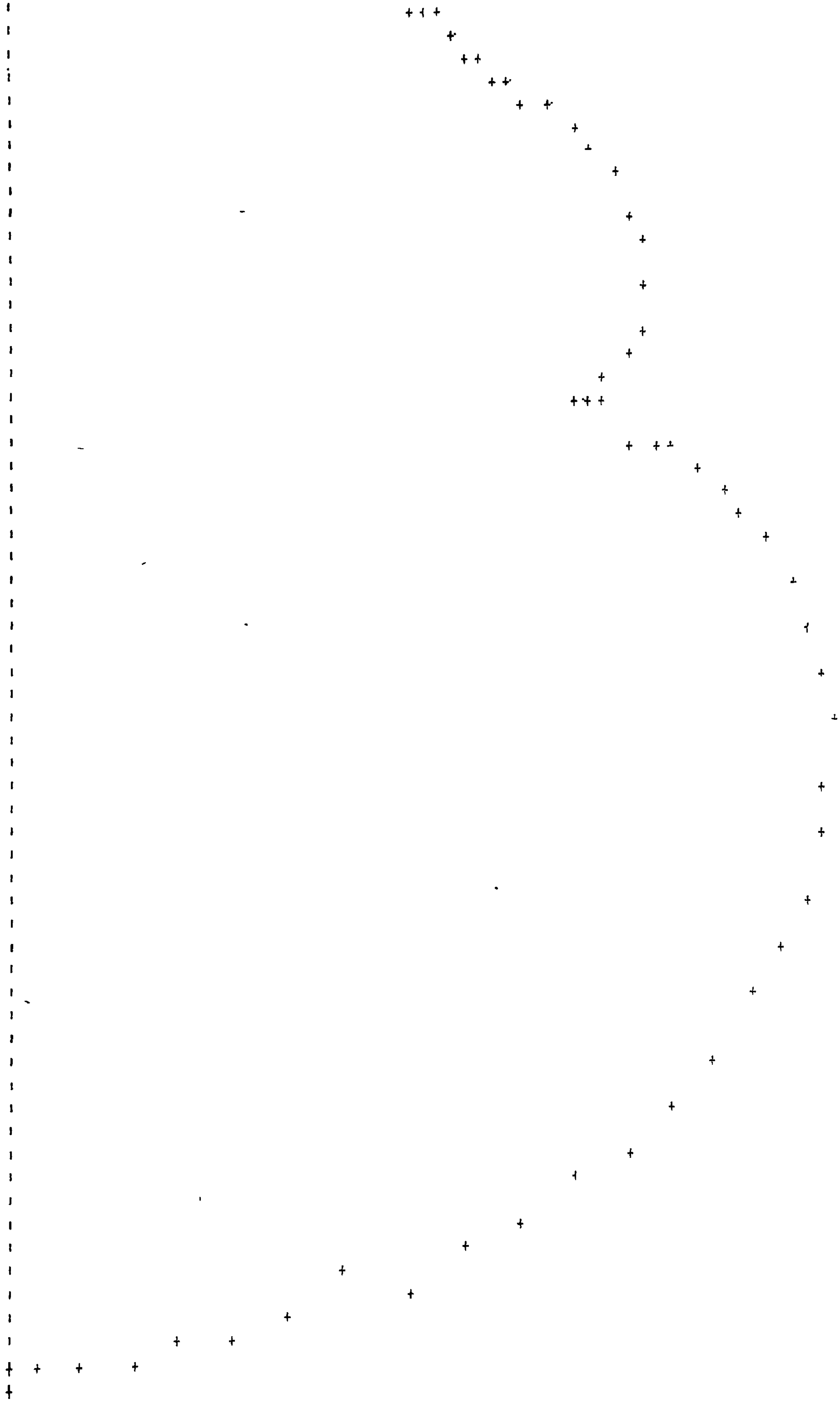
+8 0594 E+00	+5 6741 E+00	+8 2500 E+08
+8 1319 E+00	+5 6100 E+00	+8 5000 E+08
+8 1613 E+00	+5 5572 E+00	+8 7500 E+08
+8 1729 E+00	+5 5010 E+00	+9 0000 E+08
+8 1725 E+00	+5 5071 E+00	+9 2500 E+08
+8 1651 E+00	+5 5142 E+00	+9 5000 E+08
+8 1359 E+00	+5 5412 E+00	+9 7500 E+08
+8 0953 E+00	+5 5926 E+00	+1 0000 E+09
+7 9426 E+00	+5 6143 E+00	+1 0500 E+09
+7 7672 E+00	+5 9293 E+00	+1 1000 E+09
+7 4357 E+00	+5 9354 E+00	+1 1500 E+09
+7 1651 E+00	+5 9572 E+00	+1 2000 E+09
+6 8314 E+00	+5 9714 E+00	+1 2500 E+09
+6 5055 E+00	+5 9514 E+00	+1 3000 E+09
+6 2155 E+00	+5 7660 E+00	+1 3500 E+09
+5 9726 E+00	+5 6072 E+00	+1 4000 E+09
+5 7745 E+00	+5 4145 E+00	+1 4500 E+09
+5 6199 E+00	+5 2732 E+00	+1 5000 E+09
+5 5010 E+00	+5 1072 E+00	-1 5500 E+09
+5 3245 E+00	+4 9515 E+00	+1 6000 E+09
+5 2225 E+00	+4 7545 E+00	+1 6500 E+09
+5 2423 E+00	+4 7[illegible] E+00	+1 7000 E+09
+5 15-4 E+00	-4 [illegible] E+00	+1 7500 E+09
+5 0646 E+00	+4 6101 E+00	+1 8000 E+09
+4 9537 E+00	+4 5211 E+00	+1 8500 E+09
+4 8750 E+00	+4 4470 E+00	+1 9010 E+09
+4 7366 E+00	+4 3590 E+00	+1 9500 E+09
+4 7051 E+00	+4 2695 E+00	+2 0000 E+09

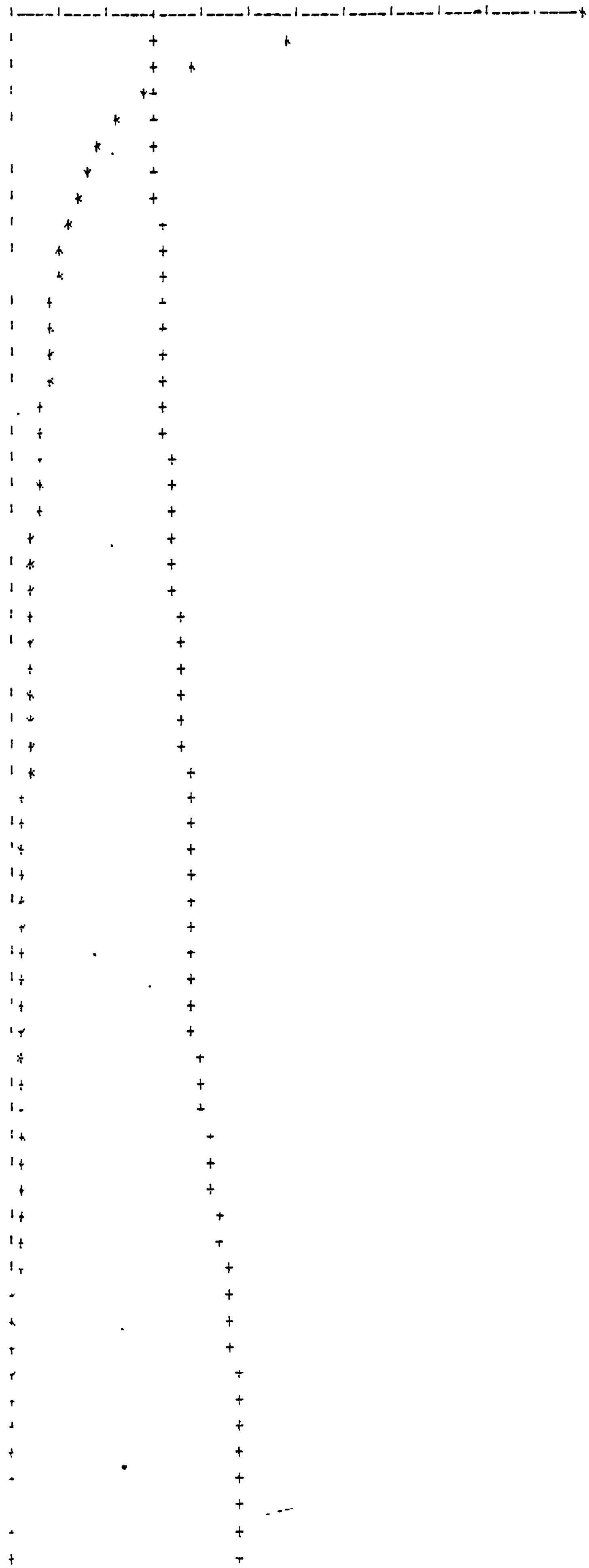


*******COLE-COLE PLOT*******



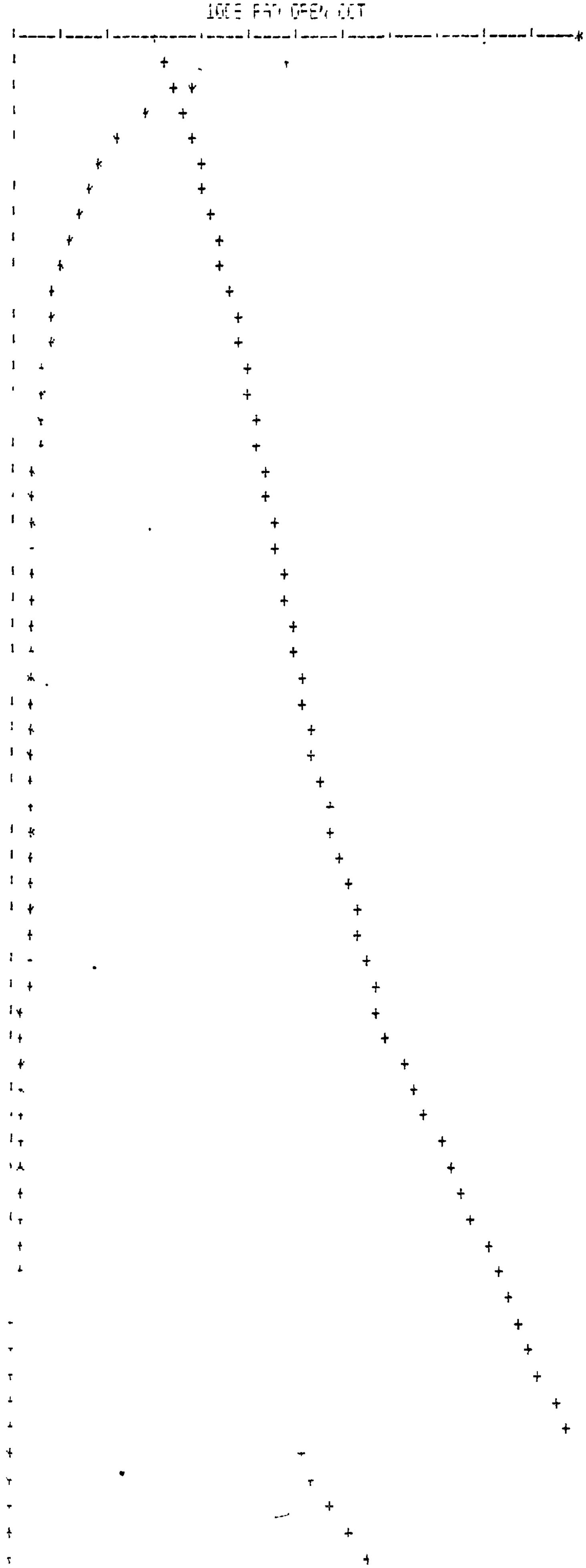
FOURIER TRANSFORM TIME WINDOW - L AE-09 SEC

MAG(*)	PHASE(+)	FREQ
+2 2497 E-09	-3 3299 E+01	+2 5000 E+07
+2 1677 E-09	-2 3524 E+01	+5 0000 E+07
+2 10 4 E-09	-8 7732 E+01	+7 5000 E+07
+1 5202 E-09	-3 7042 E-01	+1 0000 E+08
+1 2620 E-09	-2 6227 E+01	+1 2500 E+08
+1 0515 E-09	-5 5549 E+01	+1 5000 E+08
+5 0??? E-10	-5 4434 E+01	+1 7500 E+08
+7 9312 E-10	-3 4313 E+01	+2 0000 E+08
+7 0051 E-10	-3 2705 E-01	+2 [illegible] E+08
+6 2103 E-10	-3 2075 E-01	+2 5000 E+08
+5 7487 E-10	-3 2442 E+01	+2 7500 E+08
+5 2215 E-10	-3 1304 E+01	+3 0000 E+08
+4 3990 E-10	-6 1117 E+01	+3 2500 E+08
+4 5556 E-10	-3 1415 E+01	+3 5000 E+08
+4 1650 E-10	-7 3630 E-01	+3 7500 E+08
+4 0177 E-10	-7 3304 E+01	+4 0000 E+08
+3 7361 E-10	-7 3064 E+01	+4 2500 E+08
+3 5933 E-10	-7 7171 E+01	+4 5000 E+08
+3 4111 E-10	-7 6220 E+01	+4 7500 E+08
+3 2531 E-10	-7 5544 E+01	+5 0000 E+08
+3 1101 E-10	-7 4222 E+01	+5 2500 E+08
+2 9713 E-10	-7 2172 E-01	+5 5000 E+08
+2 8427 E-10	-7 2103 E+01	+5 7500 E+08
+2 7213 E-10	-7 1044 E+01	+6 0000 E+08
+2 6??5 E-10	-6 3330 E+01	+6 2500 E+08
+2 4936 E-10	-6 3363 E+01	+6 5000 E+08
+2 3551 E-10	-6 7333 E+01	+6 7500 E+08
+2 2929 E-10	-6 7253 E+01	+7 0000 E+08
+2 2071 E-10	-6 6195 E+01	+7 2500 E+08
+2 1109 E-10	-6 5404 E-01	+7 5000 E+08
+2 0401 E-10	-5 4552 E+01	+7 7500 E+08
+1 9651 E-10	-5 4061 E+01	+8 0000 E+08
+1 8659 E-10	-6 2595 E+01	+8 2500 E+08
+1 8325 E-10	-6 3015 E+01	+8 5000 E+08
+1 7749 E-10	-6 2597 E+01	+8 7500 E+08
+1 7230 E-10	-6 2195 E+01	+9 0000 E+08
+1 5767 E-10	-5 1521 E+01	+9 2500 E+08
+1 6256 E-10	-6 1441 E+01	+9 5000 E+08
+1 5953 E-10	-6 1010 E+01	+9 7500 E+08
+1 5672 E-10	-5 0574 E+01	+1 0000 E+09
+1 5120 E-10	-5 5519 E+01	+1 0500 E+09
+1 4651 E-10	-5 5013 E+01	+1 1000 E+09
+1 4171 E-10	-5 [illegible] E-01	+1 1500 E+09
+1 3555 E-10	-5 [illegible] E+01	+1 2000 E-09
+1 3412 E-10	-5 1302 E+01	+1 2500 E-09
+1 2316 E-10	-4 5700 E+01	+1 3000 E+09
+1 2270 E-10	-4 6713 E-01	+1 3500 E+09
+1 1761 E-10	-4 2350 E-01	+1 4000 E+09
+1 1171 E-10	-4 [illegible] E+01	+1 4500 E+09
+1 0561 E-10	-3 [illegible] E+01	+1 5000 E+09
+9 [illegible] E-11	-2 7256 E+01	+1 5500 E-09
+9 44[illegible] E-11	-2 [illegible] E+01	+1 6000 E+09
+[illegible] E-11	-2 [illegible] E+01	+1 6500 E+09
+[illegible] E-11	-2 4737 E+01	+1 7000 E+09
+8 2765 E-11	-2 4440 E-01	+1 7500 E+09
+8 0255 E-11	-2 4101 E-01	+1 [illegible] E+09
+7 [illegible] E-11	-2 2555 E-01	+1 [illegible] E+09
+7 7157 E-11	-2 [illegible] E+01	+1 9310 E+09
+7 [illegible] E-11	-2 2151 E-01	+1 9500 E+09
+7 5227 E-11	-2 1114 E+01	+[illegible] E+09



FOURIER TRANSFORM TIME WINDOW - 1 7E-08 SEC

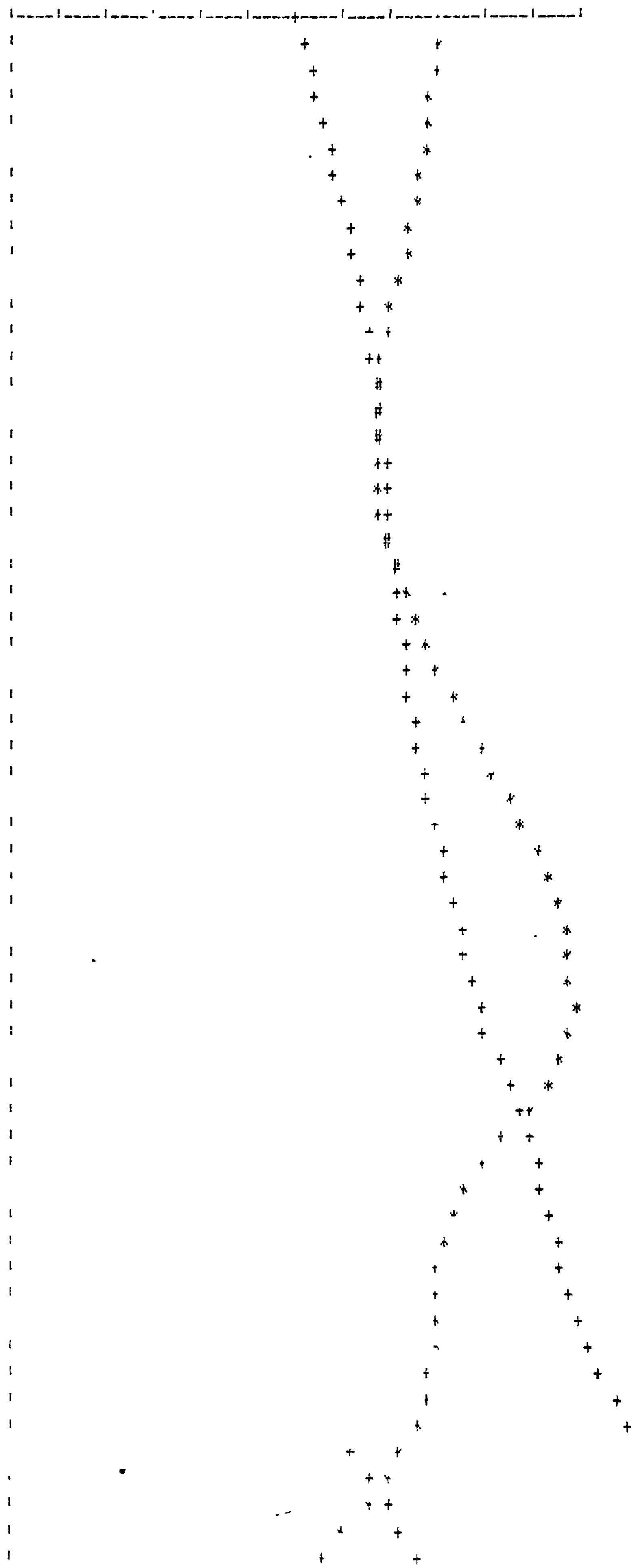
MAG(+)	PHASE(+)	FREQ
+6.0223 E-10	-8 4352 E-01	+2 5000 E+07
+2 9990 E-10	-7 3727 E+01	+5 0000 E+07
+1 9835 E-10	-7 4645 E+01	+7 5000 E+07
+1 4915 E-10	-6 3641 E+01	+1 0000 E+03
+1 1756 E-10	-6 4726 E+01	+1 2500 E+08
+9 7033 E-11	-5 3523 E+01	+1 5000 E+08
+8 2261 E-11	-5 5265 E+01	+1 7500 E+08
+7 1156 E-11	-5 6731 E-01	+2 0000 E+05
+6 2485 E-11	-4 6 64 E-01	+2 2500 E+08
+5 6523 E-11	-4 2101 E+01	+2 5000 E+08
+4 9555 E-11	-3 5265 E-01	+2 7500 E+08
+4 5171 E-11	-3 4630 E+01	+3 0000 E+08
+4 1263 E-11	-3 1101 E+01	+3 2500 E+08
+3 3901 E-11	-2 7323 E-01	+3 5000 E+08
+3 5155 E-11	-2 4350 E+01	+3 7500 E-08
+3 2371 E-11	-2 1540 E+01	+4 0000 E-03
+3 1059 E-11	-1 5123 E+01	+4 2500 E+03
+2 9471 E-11	-1 6435 E+01	+4 5000 E+03
+2 8164 E-11	-1 3263 E+01	+4 7500 E+08
+2 7100 E-11	-1 1246 E-01	+5 0000 E+05
+2 6223 E-11	-3 5813 E+00	+5 2500 E-05
+2 5545 E-11	-5 6274 E+00	+5 5000 E-08
+2 4550 E-11	-2 3737 E+00	+5 7500 E+08
+2 4545 E-11	+0 0032 E+00	+6 0000 E+03
+2 4157 E-11	+1 1325 E-00	+6 2500 E+08
+2 2391 E-11	+5 4325 E+00	+6 5000 E+06
+2 3627 E-11	+5 3463 E+00	+6 7500 E+08
+2 2411 E-11	+1 2534 E+01	+7 0000 E+06
+2 2155 E-11	+1 7261 E+01	+7 2500 E+38
+2 2951 E-11	+1 1261 E+01	+7 5000 E+08
+2 2757 E-11	+2 5231 E+01	+7 7500 E+08
+2 2515 E-11	+2 9405 E+01	+8 0000 E+05
+2 2254 F-11	+3 2625 E+01	+5 2500 E-09
+2 1555 E-11	+3 7835 E+01	+8 5000 E+08
+2 1647 E-11	+4 2041 E+01	+8 7500 E+08
+2 1292 E-11	+4 7235 E-01	+9 0000 E+08
+2 0513 E-11	+5 1057 E+01	+9 2500 E-08
+2 0503 E-11	+5 5463 E-01	+9 5000 E+08
+2 0074 E-11	+5 2150 E+01	+9 7500 E+08
-1 9511 E-11	+5 4075 E+01	+1 0000 E+09
+1 9610 E-11	+7 2935 E-01	+1 0500 E-09
+1 7575 E-11	-3 1514 E-01	+1 1000 E-09
+1 6471 E-11	+3 5764 E-01	+1 1500 E+09
+1 5209 E-11	+5 7707 E+01	+1 2000 E+09
+1 4023 E-11	+1 0531 E+01	+1 2500 E+09
+1 7205 E-11	-1 1056 E+02	+1 3000 E+09
+1 2257 E-11	+1 1351 E+01	+1 3500 E+09
+1 1402 E-11	+1 2614 E-01	+1 4000 E+09
+1 0276 E-11	+1 2259 E-01	-1 4500 E+09
+1 0709 E-11	-1 2362 E+02	+1 5000 E+09
+3 4403 E-12	-1 4547 E+02	+1 5500 E-09
+7 3167 E-12	+1 5263 E+02	-1 6000 E+09
+5 4055 E-12	+1 6126 E+01	+1 6500 E+09
+7 3623 E-12	+1 7357 E+02	-1 7000 E+09
+7 5045 E-12	-1 7525 E-02	+1 7500 E+09
+7 0523 E-12	+7 7145 E+00	+1 8000 E+09
+6 2563 E-12	-1 7467 E-01	-1 8500 E+09
+6 1606 E-11	-1 3155 E+01	-1 9000 E+09
+5 7277 E-11	-2 5250 E+01	+1 9500 E+09
+5 2475 E-12	-3 0510 E+01	+2 0000 E+09



GAMMA

FOURIER TRANSFORM

MAG(*)	PHASE(+)	FREQ
+9 4756 E-02	+4 4476 E+00	+2 5000 E+07
+9 4641 E-02	+5 5071 E-00	+5 0000 E+07
+9 4233 E-02	+1 1130 E+01	+7 5000 E+07
+9 3746 E-02	+1 7405 E+01	+1 0000 E+08
+9 3079 E-02	+2 1611 E+01	+1 2500 E+08
+9 2272 E-02	+2 5721 E+01	+1 5000 E+08
+9 1336 E-02	+2 9715 E+01	+1 7500 E+08
+9 0235 E-02	+3 3547 E+01	+2 0000 E+08
+8 9146 E-02	+3 6742 E+01	+2 2500 E+08
+8 7946 E-02	+4 0375 E+01	+2 5000 E+08
+8 6724 E-02	+4 4160 E+01	+2 7500 E+08
+8 5513 E-02	+4 7111 E+01	+3 0000 E+08
+8 4425 E-02	+4 9324 E+01	+3 2500 E+08
+8 3421 E-02	+5 2507 E+01	+3 5000 E+08
+8 2626 E-02	+5 4344 E+01	+3 7500 E+08
+8 2074 E-02	+5 6324 E+01	+4 0000 E+08
+8 1916 E-02	+5 8394 E+01	+4 2500 E+08
+8 1935 E-02	+5 9577 E+01	+4 5000 E+08
+8 2331 E-02	+6 2260 E+01	+4 7500 E+08
+8 3152 E-02	+6 3397 E+01	+5 0000 E+08
+8 4152 E-02	+6 5640 E+01	+5 2500 E+08
+8 5355 E-02	+6 7235 E+01	+5 5000 E+08
+8 7508 E-02	+6 9123 E+01	+5 7500 E+08
+9 0135 E-02	+7 1044 E+01	+6 0000 E+08
+9 2753 E-02	+7 3162 E+01	+6 2500 E+08
+9 5615 E-02	+7 5452 E+01	+6 5000 E+08
+9 8651 E-02	+7 7927 E+01	+6 7500 E+08
+1 0174 E-01	+8 0642 E+01	+7 0000 E+08
+1 0510 E-01	+8 3556 E+01	+7 2500 E+08
+1 0833 E-01	+8 6665 E+01	+7 5000 E+08
+1 1154 E-01	+8 9274 E+01	+7 7500 E+08
+1 1455 E-01	+9 3463 E+01	+8 0000 E+08
+1 1733 E-01	+9 7129 E+01	+8 2500 E+08
+1 1957 E-01	+1 0090 E+02	+8 5000 E+08
+1 2136 E-01	+1 0463 E+02	+8 7500 E+08
+1 2261 E-01	+1 0825 E+02	+9 0000 E+08
+1 2476 E-01	+1 1232 E+02	+9 2500 E+08
+1 2523 E-01	+1 1630 E+02	+9 5000 E+08
+1 2551 E-01	+1 2052 E+02	+9 7500 E+08
+1 2513 E-01	+1 2435 E+02	+1 0000 E+09
+1 2300 E-01	+1 3251 E+02	+1 0500 E+09
+1 1944 E-01	+1 3950 E+02	+1 1000 E+09
+1 1513 E-01	+1 4533 E+02	+1 1500 E+09
+1 1017 E-01	+1 5155 E+02	+1 2000 E+09
+1 0633 E-01	+1 5551 E+02	+1 2500 E+09
+1 0225 E-01	+1 6126 E+02	+1 3000 E+09
+9 9171 E-02	-1 6524 E+02	+1 3500 E+09
+9 6950 E-02	-1 6907 E+02	+1 4000 E+09
+9 5530 E-02	-1 7316 E+02	+1 4500 E+09
+9 4973 E-02	-1 7747 E+02	+1 5000 E+09
+9 4510 E-02	+1 4773 E-02	+1 5500 E+09
+9 4414 E-02	+1 5377 E+02	+1 6000 E+09
+9 3350 E-02	+1 2557 E+02	+1 6500 E+09
+9 2715 E-02	+1 0406 E+02	+1 7000 E+09
+8 2711 E-02	+2 1273 E-02	+1 7500 E+09
+8 7322 E-02	+4 1915 E+01	+1 8000 E+09
+8 4122 E-02	+5 1022 E-01	+1 8500 E+09
+7 9946 E-02	+6 1023 E+01	+1 9000 E+09
+7 5254 E-02	+7 1451 E+01	+1 9500 E+09
+7 0891 E-02	+8 2654 E+01	+2 0000 E+09

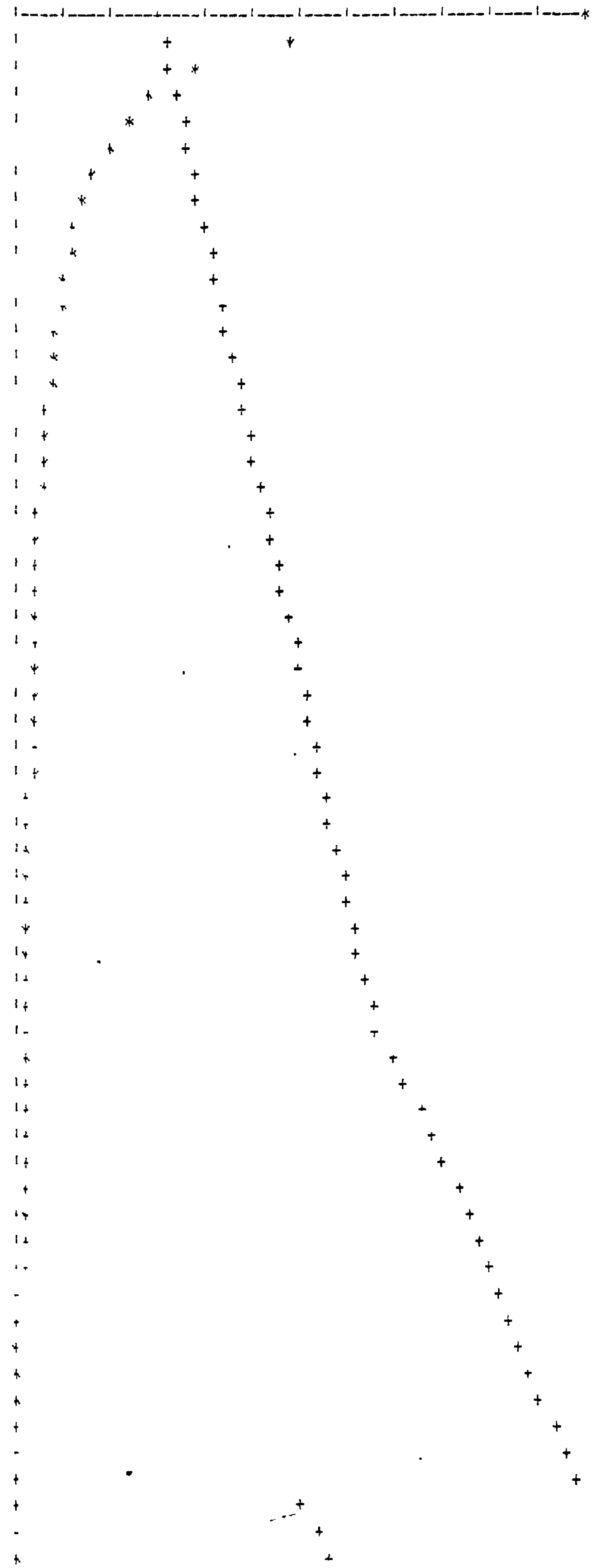


**** RESPONSE ****

FOURIER TRANSFORM   TIME WINDOW = 1 [illegible]E-09 SEC

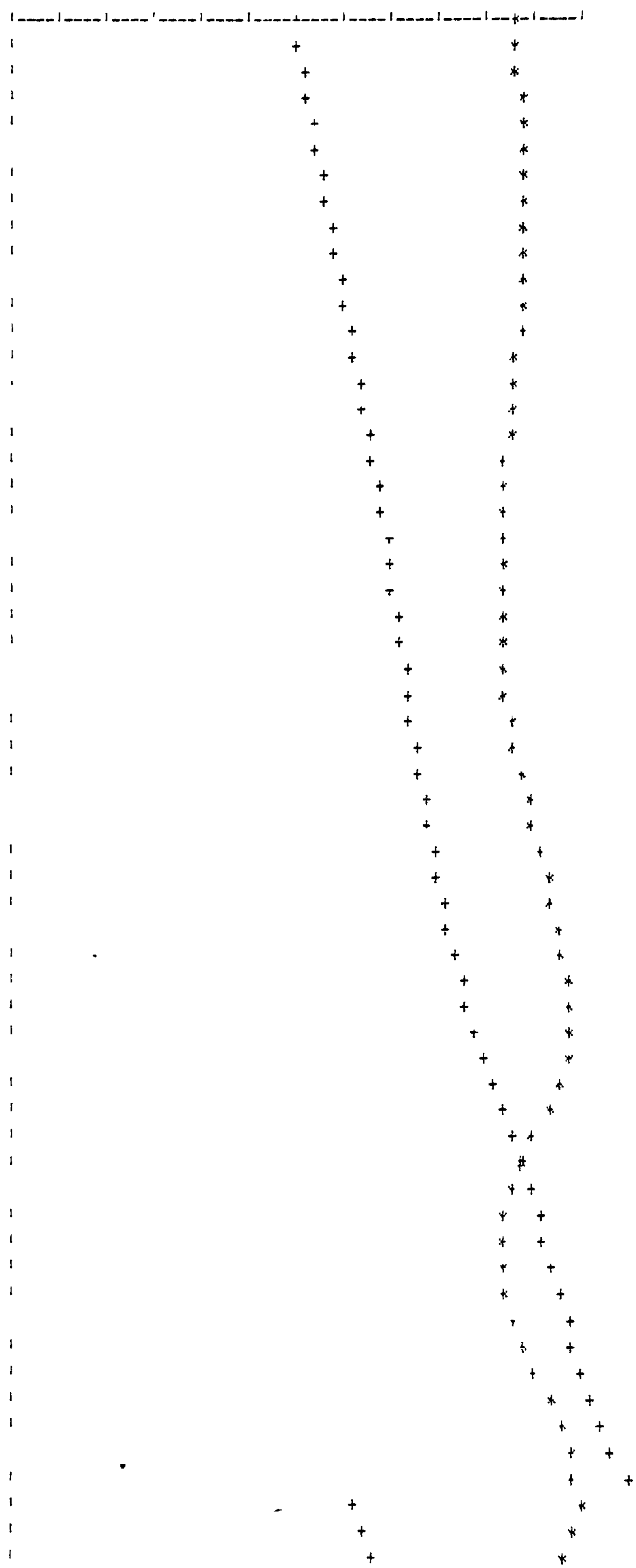
305 RAD OPEN CCT

MAG(+)	PHASE(+)	FREQ
+[illegible] 2701 E-09	-3 5413 E+01	+2 5000 E+07
+1 6410 E-09	-[illegible] E+01	+5 0000 E+07
+1 0333 E-09	-7 3225 E-01	+7 5000 E-07
+5 1713 E-10	-7 5613 E+01	+1 0000 E+08
+5 5415 E-10	-7 1333 E+01	+1 2500 E-09
+5 4574 E-10	-6 3165 E+01	+1 5000 E+08
+4 6325 E-10	-6 4718 E+01	+1 7500 E+08
+4 1313 E-10	-6 1058 E+01	+2 0000 E+09
+3 6155 E-10	-5 7335 E+01	+2 2500 E+08
+3 2871 E-10	-5 3703 E+01	+2 5000 E+06
+2 9937 E-10	-5 0360 E+01	+2 7500 E+08
+2 7401 E-10	-4 6534 E-01	+3 0000 E-09
+2 5133 E-10	-4 2274 E+01	+3 2500 E+0[illegible]
+2 3471 E-10	-3 8951 E-01	+3 5000 E+08
+2 1890 E-10	-3 5103 E+01	+3 7500 E-09
+2 0521 E-10	-3 1672 E+01	+4 0000 E+09
+1 9277 E-10	-2 8054 E+01	-4 2500 E-06
+1 8173 E-10	-2 4467 E+01	+4 5000 E+05
+1. 7200 E-10	-2 0811 E+01	+4 7500 E-06
+1 6313 E-10	-1 7223 E+01	+5 0000 E+08
+1 5527 E-10	-1 3501 E+01	+5 2500 E+09
+1 4312 E-10	-1 0445 E+01	+5 5000 E+09
+1 4167 E-10	-7 0305 E-00	+5 7500 E+08
+1 3581 E-10	-3 6119 E+00	+6 0000 E+09
+1 3055 E-10	+0 0012 E+00	+6 2500 E-08
+1 2573 E-10	+3 1271 E+00	+6 5000 E-09
+1 2143 E-10	+6 4970 E+00	+6 7500 E+08
+1 1760 E-10	+9 5715 E+00	+7 0000 E+08
+1 1405 E-10	+1 3066 E+01	+7 2500 E+08
+1 1063 E-10	+1 6533 E+01	+7 5000 E-08
+1 0755 E-10	+2 0151 E+01	+7 7500 E+09
+1 0534 E-10	+2 3662 E+01	+8 0000 E+06
+1 0253 E-10	+2 7227 E+01	+8 2500 E+09
+1 0064 E-10	+3 0851 E+01	-8 5000 E-05
+9 8510 E-11	+3 4526 E+01	+8 7500 E+09
+9 6515 E-11	+3 8222 E+01	+9 0000 E-09
+9 4526 E-11	+4 1510 E+01	-9 2500 E+06
+9 2772 E-11	+4 5710 E-01	+9 5300 E-09
+9 0953 E-11	+4 9981 E-01	+9 7500 E+09
+8 9163 E-11	+5 2952 E+01	+1 0000 E+09
+8 5572 E-11	+6 [illegible] E+01	+1 0500 E+05
+8 1510 E-11	+7 3014 E-01	+1 [illegible] E-09
+7 7153 E-11	+7 2530 E+01	+1 1500 E+09
+7 4157 E-11	+8 5731 E+01	+1 1000 E+09
+7 0034 E-11	-9 4511 E+01	+1 1500 E-09
+6 6751 E-11	+1 0160 E+02	+1 2000 E+09
+6 2545 E-11	+1 1036 E+02	+1 2500 E+08
+5 9000 E-11	+1 1714 E+02	+1 4000 E-09
+5 5115 E-11	+1 2135 E+02	+1 4500 E-09
+5 2109 E-11	+1 3119 E+02	-1 5000 E+09
+5 0333 E-11	+1 3551 E+02	+1 5500 E+09
+4 9133 E-11	+1 4151 E-02	+1 6000 E+09
+4 7542 E-11	-1 4475 E+02	+1 6500 E-09
+4 7048 E-11	+1 5571 E+02	+1 7000 E+09
+4 6151 E-11	+1 5115 E+02	+1 7500 E-09
+4 5754 E-11	+1 5351 E-02	+1 8000 E+09
+4 5111 E-11	-1 7742 E-02	+1 8500 E-09
+4 4127 E-11	-5 5558 E+00	+1 9000 E+09
+4 3343 E-11	+1 3337 E-01	+1 9500 E+09
+4 2124 E-11	-2 1510 E+01	+2 0000 E+09



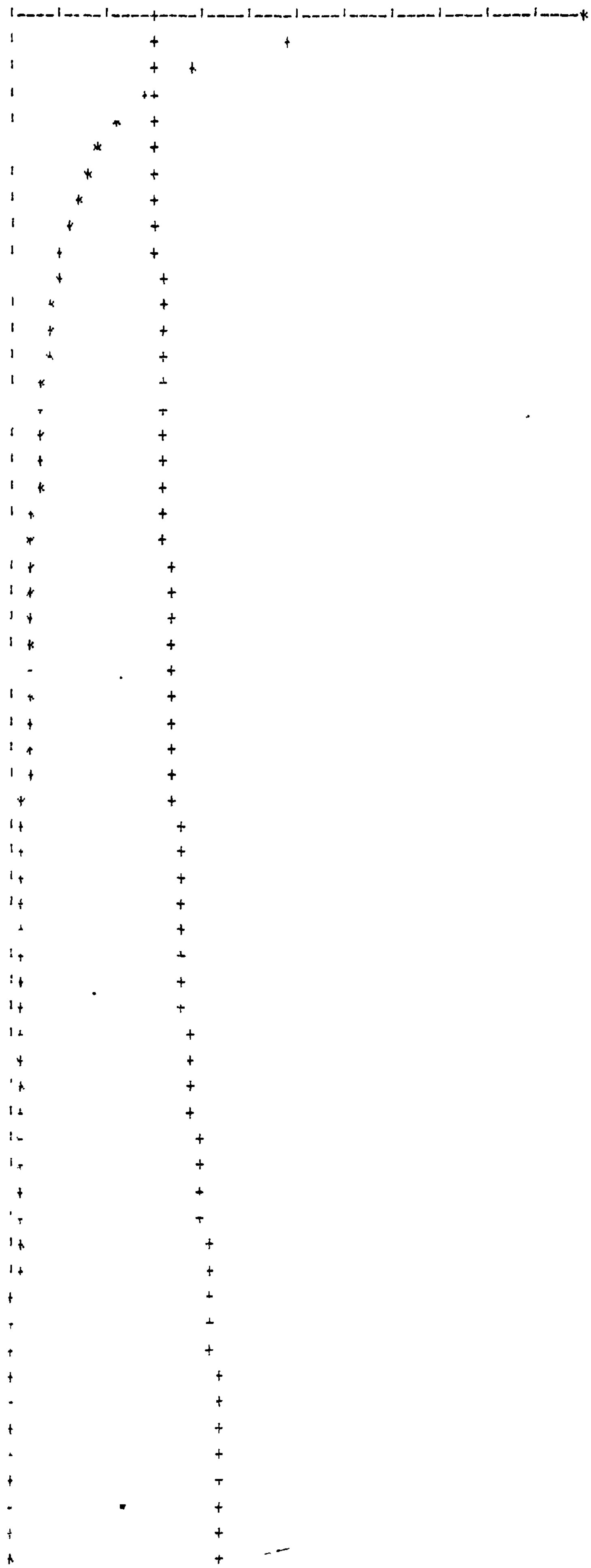
FOURIER TRANSFORM

MAG(*)	PHASE(+)	FREQ
+5 1503 E-01	+2 3161 E+00	+2 5000 E+07
+5 1552 E-01	+5 7111 E+00	+5 0000 E+07
+5 1611 E-01	+5 5567 E-00	+7 5000 E+07
+5 1707 E-01	+1 1411 E-01	+1 0000 E+08
+5 1901 E-01	+1 4119 E+01	+1 2500 E+08
+5 1997 E-01	+1 7124 E-01	+1 5000 E+08
+5 1979 E-01	+1 0256 E+01	+1 7500 E+08
+5 2013 E-01	-1 3230 E+01	+2 0000 E+08
+5 2065 E-01	+1 6219 E+01	+2 2500 E+08
+5 2050 E-01	+1 9171 E-01	+2 5000 E+08
+5 1950 E-01	-1 2155 E-01	+2 7500 E+08
+5 1921 E-01	+1 4910 E+01	+3 0000 E+08
+5 1724 E-01	+1 4762 E+01	+3 2500 E+08
+5 1512 E-01	+4 1435 E-01	+3 5000 E+08
+5 1233 E-01	+4 4325 E-01	+3 7500 E+08
+5 1015 E-01	+4 7222 E+01	+4 0000 E+08
+5 0770 E-01	+5 0009 E+01	+4 2500 E+08
+5 0513 E-01	+5 2705 E+01	+4 5000 E+08
+5 1277 E-01	+5 5013 E+01	+4 7500 E+08
+5 0073 E-01	+5 7354 E-01	+5 0000 E+08
+4 9954 E-01	+6 0321 E+01	+5 2500 E+08
+4 9913 E-01	+6 2717 E+01	+5 5000 E+08
+4 9924 E-01	+6 5055 E-01	+5 7500 E+08
+4 9914 E-01	+6 7412 E+01	+6 0000 E+08
+5 0094 E-01	+6 9950 E+01	+6 2500 E+08
+5 0245 E-01	+7 2397 E+01	+6 5000 E+08
+5 0704 E-01	+7 4425 E+01	+6 7500 E+08
+5 1159 E-01	+7 6912 E-01	+7 0000 E+08
+5 1676 E-01	+7 9461 E+01	+7 2500 E+08
+5 2234 E-01	+8 1392 E+01	+7 5000 E+08
+5 2901 E-01	+8 4340 E+01	+7 7500 E+08
+5 3604 E-01	+8 7712 E-01	+8 0000 E+08
+5 4177 E-01	+8 7712 E+01	+8 2500 E+08
+5 4922 E-01	+9 1359 E+01	+8 5000 E+08
+5 5514 E-01	+9 7126 E-01	+8 7500 E+08
+5 6015 E-01	+1 3345 E+02	+9 0000 E+08
+5 6419 E-01	+1 0275 E+01	+9 2500 E+08
+5 6712 E-01	+1 0315 E+01	+9 5000 E+08
+5 6574 E-01	+1 1101 E+02	+9 7500 E+08
+5 6397 E-01	-1 1450 E+01	+1 0000 E+09
+5 6557 E-01	+1 1150 E+02	+1 0500 E+09
+5 5501 E-01	+1 1214 E+02	+1 1000 E+09
+5 4767 E-01	+1 1470 E-01	+1 1500 E+09
+5 3505 E-01	-1 4363 E+02	+1 2000 E+09
+5 2411 E-01	-1 4512 E+01	+1 2500 E+09
+5 1171 E-01	-1 5140 E+01	+1 3000 E+09
+5 0564 E-01	+1 5572 E+01	+1 3500 E+09
+5 0079 E-01	+1 6003 E+01	+1 4000 E+09
+4 9972 E-01	+1 6465 E+02	+1 4500 E+09
+5 0157 E-01	-1 6901 E+01	+1 5000 E+09
+5 1012 E-01	-1 7415 E-01	+1 5500 E+09
+5 2002 E-01	+1 7471 E-01	+1 6000 E+09
+5 3401 E-01	+1 [illegible] E-01	+1 6500 E+09
+5 4772 E-01	-1 3012 E-01	+1 7000 E+09
+5 6315 E-01	+1 9570 E-01	-1 7500 E+09
+5 6903 E-01	+1 0170 E+01	+1 8000 E+09
+5 7412 E-01	+1 1175 E+01	+1 8500 E+09
+5 7451 E-01	+1 3507 E+01	+1 9010 E+09
+5 6954 E-01	+4 6167 E+01	+1 9500 E+09
+5 [illegible] E-01	+5 1724 E+01	+2 0000 E+09



FOURIER TRANSFORM TIME WINDOW = 0 9E-09 SEC

MAG(+)	PHASE(+)	FREQ
+6 2592 E-09	-6 9455 E+01	+2 5000 E-07
+3 1696 E-09	-3 3300 E+01	+5 0000 E+07
+2 1106 E-09	-9 9115 E+01	+7 5000 E+07
+1 5319 E-09	-3 7733 E+01	+1 0000 E+08
+1 2649 E-09	-3 7154 E+01	+1 2500 E+08
+1 0537 E-09	-3 6579 E+01	+1 5000 E+08
+9 0194 E-10	-3 6007 E+01	+1 7500 E+08
+7 9377 E-10	-3 5440 E+01	+2 0000 E+08
+7 0135 E-10	-9 4577 E+01	+2 2500 E+08
+6 3156 E-10	-3 4319 E+01	+2 5000 E+08
+5 7410 E-10	-3 3765 E+01	+2 7500 E+08
+5 2626 E-10	-3 3216 E+01	+3 0000 E+08
+4 8593 E-10	-3 2670 E+01	+3 2500 E+08
+4 5122 E-10	-3 2129 E+01	+3 5000 E+08
+4 2129 E-10	-3 1555 E+01	-3 7500 E+08
+3 9516 E-10	-3 0050 E+01	+4 0000 E+08
+3 7216 E-10	-3 0513 E+01	+4 2500 E+08
+3 5177 E-10	-7 3975 E+01	+4 5000 E+08
+3 3359 E-10	-7 9435 E+01	+4 7500 E+08
+3 1723 E-10	-7 8833 E+01	+5 0000 E+08
+3 0257 E-10	-7 8255 E+01	+5 2500 E+08
+2 8915 E-10	-7 7732 E+01	+5 5000 E+08
+2 7714 E-10	-7 7221 E+01	+5 7500 E+08
+2 6597 E-10	-7 6662 E+01	+6 0000 E+08
+2 5594 E-10	-7 7082 E+01	+6 2500 E+08
+2 4662 E-10	-7 5432 E+01	+6 5000 E+08
+2 3803 E-10	-7 4889 E+01	+6 7500 E+08
+2 3005 E-10	-7 4271 E+01	+7 0000 E+08
+2 2254 E-10	-7 3633 E-01	+7 2500 E+08
+2 1572 E-10	-7 2990 E+01	+7 5000 E+08
+2 0906 E-10	-7 2326 E+01	+7 7500 E+08
+2 0312 E-10	-7 1646 E+01	+8 0000 E+08
+1 9750 E-10	-7 0949 E+01	+8 2500 E+08
+1 9211 E-10	-7 0225 E+01	+8 5000 E+08
+1 8703 E-10	-6 9505 E+01	+8 7500 E+08
+1 8215 E-10	-6 8751 E+01	+9 0000 E+08
+1 7752 E-10	-6 8030 E+01	+9 2500 E+08
+1 7312 E-10	-6 7225 E+01	+9 5000 E+08
+1 6889 E-10	-6 6432 E+01	+9 7500 E+08
+1 6483 E-10	-6 5627 E+01	+1 0000 E+09
+1 5712 E-10	-6 4067 E+01	+1 0500 E-09
+1 4331 E-10	-6 2410 E+01	+1 1000 E-09
+1 4218 E-10	-6 0772 E+01	+1 1500 E+09
+1 3960 E-10	-5 9372 E-01	+1 2000 E+09
+1 3047 E-10	-5 7433 E+01	+1 2500 E+09
+1 2459 E-10	-5 5203 E+01	+1 3000 E+09
+1 1337 E-10	-5 4022 E+01	+1 3500 E+09
+1 1062 E-10	-5 3375 E+01	+1 4000 E+09
+1 0355 E-10	-5 1546 E-01	+1 4500 E+09
+1 0077 E-10	-5 0245 E+01	+1 5000 E+09
+9 3237 E-11	-4 9209 E-01	+1 5500 E+09
+9 5155 E-11	-4 3420 E+01	+1 6000 E+09
+9 1764 E-11	-4 7713 E+01	+1 6500 E+09
+8 7973 E-11	-4 7132 E-01	+1 7000 E+09
+8 4380 E-11	-4 6522 E+01	+1 7500 E+09
-8 2015 E-11	-4 6612 E+01	+1 8000 E+09
+7 9805 E-11	-4 2771 E+01	-1 8500 E+09
+7 7347 E-11	-4 1594 E+01	+1 8910 E+09
+7 6112 E-11	-4 3373 E-01	+1 9500 E+09
+7 4452 E-11	-4 1442 E+01	+2 0000 E+09

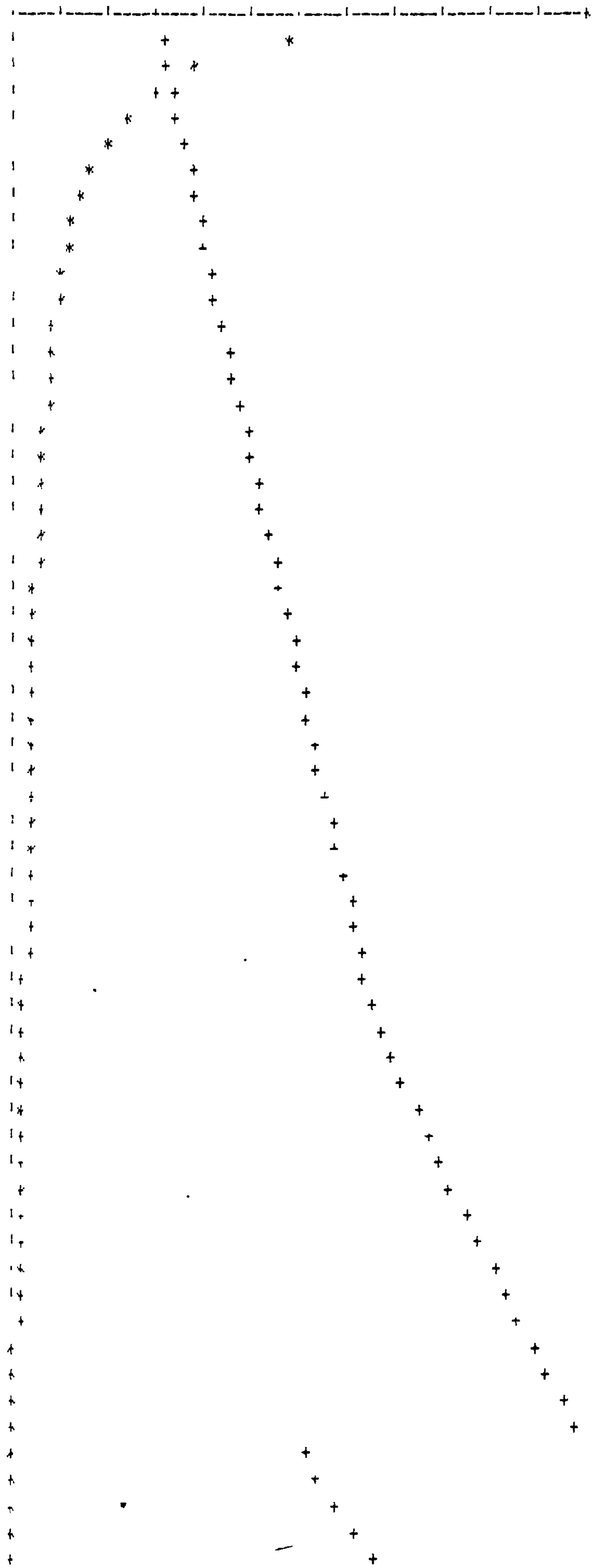


FFT POWER

FOURIER TRANSFORM TIME WINDOW = [illegible] SEC

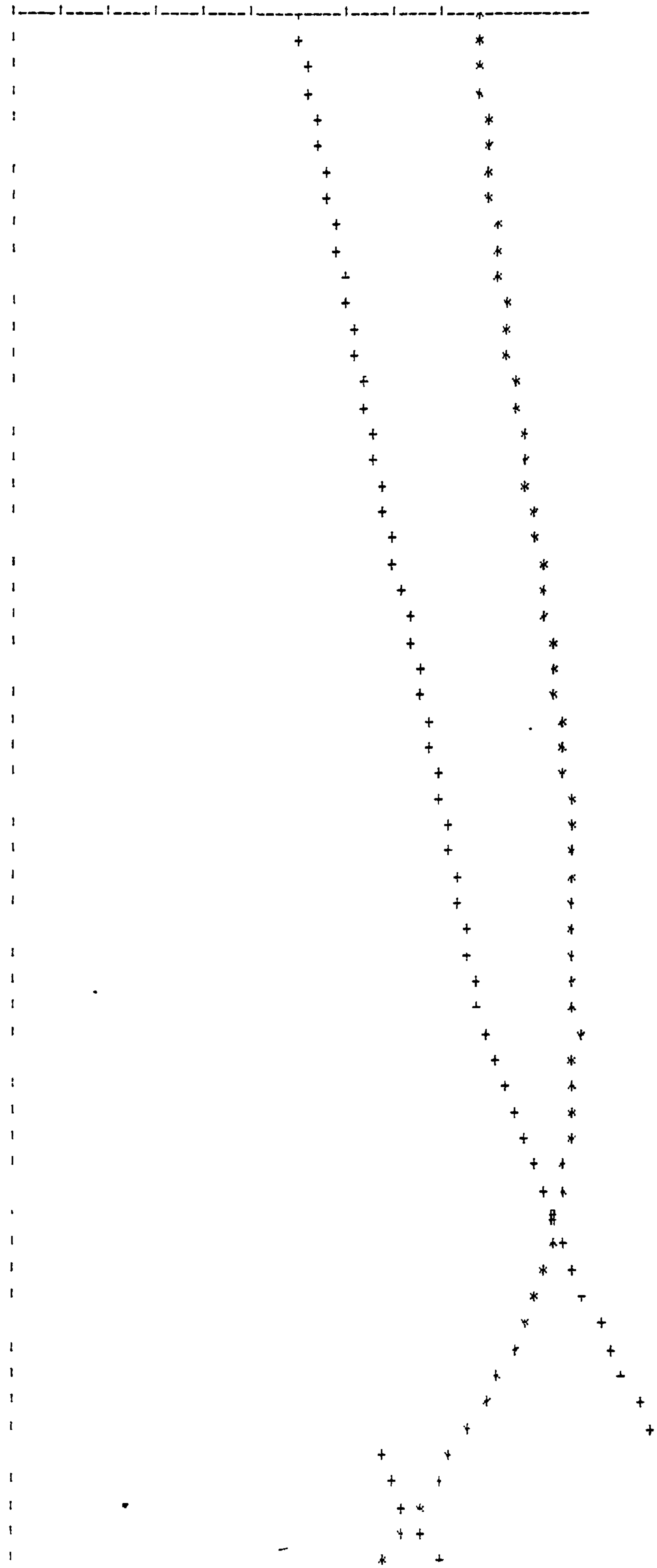
10 06 FAD OPEN CCT

MAG(*)	PHASE(+)	FREQ
+5 5577 E-10	-9 6507 E+01	+2 5000 E+07
+2 7732 E-10	-8 3013 E+01	+5 0000 E+07
+1 9535 E-10	-7 3517 E-01	+7 5000 E-07
+1 3315 E-10	-7 5013 E+01	+1 0000 E+08
+1 1174 E-10	-7 2516 E+01	+1 2500 E+08
+9 3460 E-11	-6 5375 E+01	+1 5000 E+08
+8 0454 E-11	-5 5496 E+01	+1 7500 E+08
+7 0747 E-11	-5 1577 E+01	+2 0000 E+08
+6 3225 E-11	-5 3451 E+01	+2 2500 E+08
+5 7253 E-11	-5 4320 E-01	+2 5000 E+08
+5 2296 E-11	-5 1193 E+01	+2 7500 E+08
+4 9352 E-11	-4 8024 E+01	+3 0000 E+08
+4 4950 E-11	-4 3415 E+01	+3 2500 E+08
+4 2092 E-11	-4 0533 E+01	+3 5000 E+08
+3 9504 E-11	-3 7120 E+01	+3 7500 E+08
+3 7413 E-11	-3 3519 E+01	+4 0000 E+08
+3 5507 E-11	-3 3343 E-01	+4 2500 E+08
+3 3254 E-11	-2 6323 E+01	+4 5000 E+08
+3 2453 E-11	-2 2722 E+01	+4 7500 E+08
+3 1006 E-11	-1 3037 E-01	+5 0000 E+08
+2 9730 E-11	-1 5452 E+01	+5 2500 E+08
+2 8635 E-11	-1 1820 E+01	+5 5000 E+08
+2 7575 E-11	-8 1675 E+00	+5 7500 E+08
+2 6747 E-11	-4 5019 E+00	+6 0000 E+08
+2 5833 E-11	-0 0022 E+00	+6 2500 E+08
+2 5034 E-11	+2 2544 E+00	+6 5000 E+08
+2 4252 E-11	+6 5373 E+00	+6 7500 E+08
+2 3657 E-11	+1 0244 E+01	+7 0000 E+08
+2 3004 E-11	+1 3961 E+01	+7 2500 E+08
+2 2336 E-11	+1 7675 E+01	+7 5000 E+08
+2 1753 E-11	+2 1138 E+01	+7 7500 E+08
+2 1240 E-11	+2 5121 E-01	+8 0000 E+08
+2 1787 E-11	+2 8373 E+01	+8 2500 E+08
+2 0195 E-11	+3 2631 E+01	+8 5000 E+08
+1 9701 E-11	+3 6150 E-01	+8 7500 E+08
+1 9225 E-11	+4 0117 E+01	+9 0000 E+08
+1 8762 E-11	+4 3164 E+01	+9 2500 E+08
+1 8314 E-11	+4 7343 E-01	+9 5000 E-08
+1 7373 E-11	+5 1554 E+01	+9 7500 E+08
+1 7456 E-11	+5 5047 E-01	+1 0000 E+09
+1 6676 E-11	-7 2353 E-01	+1 0500 E+09
+1 5913 E-11	-7 1557 E+01	+1 1000 E+09
+1 5051 E-11	+7 3155 E+01	+1 1500 E+09
+1 4204 E-11	-8 6165 E-01	+1 2000 E+09
+1 3567 E-11	+9 4006 E+01	+1 2500 E+09
+1 2950 E-11	-1 0131 E+02	+1 3000 E+09
-1 2143 E-11	+1 0535 E-02	+1 3500 E+09
+1 1457 E-11	+1 1735 E+02	+1 4000 E+09
+1 0814 E-11	+1 2612 E-02	+1 4500 E+09
+1 0151 E-11	+1 3347 E+02	+1 5000 E+09
+9 5405 E-12	-1 4235 E+02	+1 5500 E+09
+8 9413 E-12	+1 5142 E+02	+1 6000 E+09
+8 2273 E-12	+1 6314 E-02	+1 6500 E-09
+7 3134 E-12	+1 6507 E+02	+1 7000 E+09
+7 3001 E-12	+1 7322 E+02	+1 7500 E-09
+6 5164 E-12	-7 6229 E-00	+1 8000 E-09
+6 3701 E-12	+1 7075 E-01	+1 8500 E+09
+5 3633 E-12	-2 7226 E+01	+1 9010 E+09
+5 6005 E-12	+3 7471 E+01	+1 9500 E-09
+5 2234 E-12	+4 3152 E+01	+2 0000 E+09



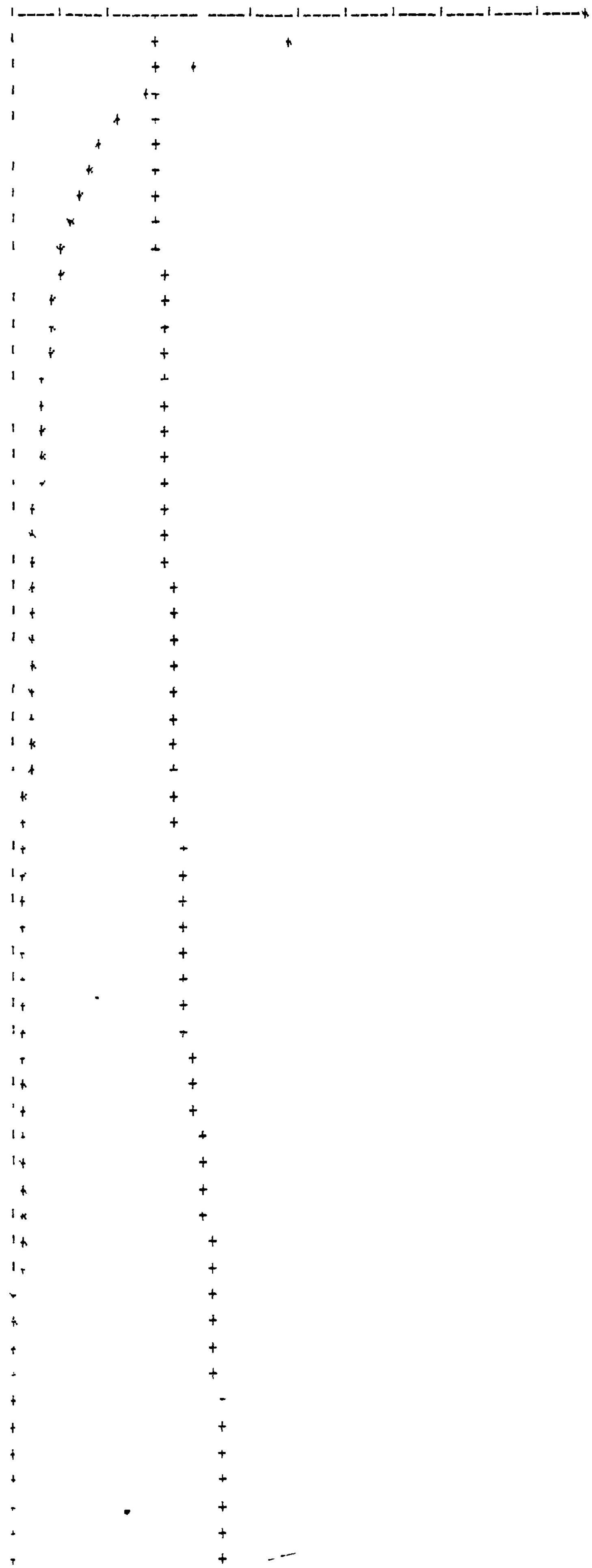
FOURIER TRANSFORM

MAG(*)	PHASE(+)	FREQ
+8 7552 E-02	+2 9782 E+00	+2 5000 E+07
+9 7652 E-02	+5 3365 E+00	+5 0000 E+07
+9 7319 E-02	+5 7492 E+00	+7 5000 E+07
+8 5050 E-02	+1 1715 E+01	+1 0000 E+08
+8 8245 E-02	+1 4623 E+01	+1 2500 E+08
+8 9700 E-02	+1 7570 E+01	+1 5000 E+08
+9 9112 E-02	+2 0511 E+01	+1 7500 E+08
+9 9579 E-02	+2 3462 E+01	+2 0000 E+08
+9 0337 E-02	+2 6426 E+01	+2 2500 E+08
+9 0550 E-02	+2 9393 E+01	+2 5000 E+08
+9 1266 E-02	+2 2272 E+01	+2 7500 E+08
+9 1339 E-02	+3 5192 E+01	+3 0000 E+08
+9 2532 E-02	-3 9257 E+01	+3 2500 E+08
+9 3234 E-02	+4 1435 E+01	+3 5000 E+08
+9 4005 E-02	+4 4463 E+01	+3 7500 E+08
+9 4742 E-02	+4 7511 E+01	+4 0000 E+08
+9 5439 E-02	+5 3570 E+01	+4 2500 E+08
+9 6023 E-02	+5 2537 E+01	+4 5000 E+08
+9 6937 E-02	+5 6313 E+01	+4 7500 E+08
+9 7729 E-02	+5 9725 E+01	+5 0000 E+08
+9 8457 E-02	+6 2292 E+01	+5 2500 E+08
+9 9163 E-02	+6 5374 E+01	+5 5000 E+08
+9 9953 E-02	-6 3064 E+01	+5 7500 E+08
+1 0052 E-01	+7 2153 E+01	+6 0000 E+08
+1 0116 E-01	+7 7352 E+01	+6 2500 E+08
+1 0175 E-01	+7 9145 E+01	+6 5000 E+08
+1 0231 E-01	-8 1427 E+01	+6 7500 E+08
+1 0252 E-01	+8 4515 E+01	+7 0000 E+08
+1 0322 E-01	+8 7600 E+01	+7 2500 E+08
+1 0377 E-01	-9 0566 E+01	+7 5000 E+08
+1 0417 E-01	-9 3724 E+01	+7 7500 E+08
+1 1452 E-01	+9 6777 E+01	+8 0000 E+08
+1 0495 E-01	-9 9326 E+01	+8 2500 E+08
+1 0512 E-01	-1 0237 E+02	+8 5000 E+08
+1 0525 E-01	+1 0539 E+02	+8 7500 E+08
+1 0554 E-01	+1 0333 E+02	+9 0000 E+08
+1 0563 E-01	+1 1127 E+02	+9 2500 E+08
+1 0573 E-01	+1 1517 E+02	+9 5000 E+08
+1 0585 E-01	+1 1735 E+02	+9 7500 E+08
+1 0591 E-01	+1 2097 E+02	+1 0000 E+09
+1 0557 E-01	+1 2737 E+02	+1 0500 E+09
+1 0565 E-01	+1 3310 E+02	+1 1000 E+09
+1 0525 E-01	+1 3312 E+02	-1 1500 E+09
+1 0455 E-01	+1 4524 E+02	+1 2000 E+09
+1 0353 E-01	+1 5144 E+02	+1 2500 E+09
+1 0214 E-01	+1 5775 E+02	+1 3000 E+09
+1 0212 E-01	-1 6413 E+02	-1 3500 E+09
+1 0032 E-01	-1 7032 E+02	-1 4000 E+09
+9 8527 E-02	+1 7767 E+02	+1 4500 E+09
+9 7921 E-02	-1 5232 E+02	+1 5000 E+09
+9 6935 E-02	+1 3215 E+02	-1 5500 E+09
+9 3911 E-02	+1 3382 E+02	+1 6000 E+09
+9 1593 E-02	+2 0746 E-02	+1 6500 E+09
+9 [illegible] E-02	-2 16[illegible] E+0	-1 7000 E+09
+8 5955 E-02	-2 [illegible] E+02	-1 7500 E+09
+8 [illegible] E-	-5 4[illegible] E-01	+1 [illegible] E+
+7 [illegible] E-02	-5 0335 E+01	-1 8500 E+09
+7 6511 E-02	+7 [illegible] E+01	+1 9010 E+09
+7 2730 E-02	-- 0739 E+01	-1 9500 E+09
+7 0451 E-02	+5 1050 E+01	+2 0000 E+09



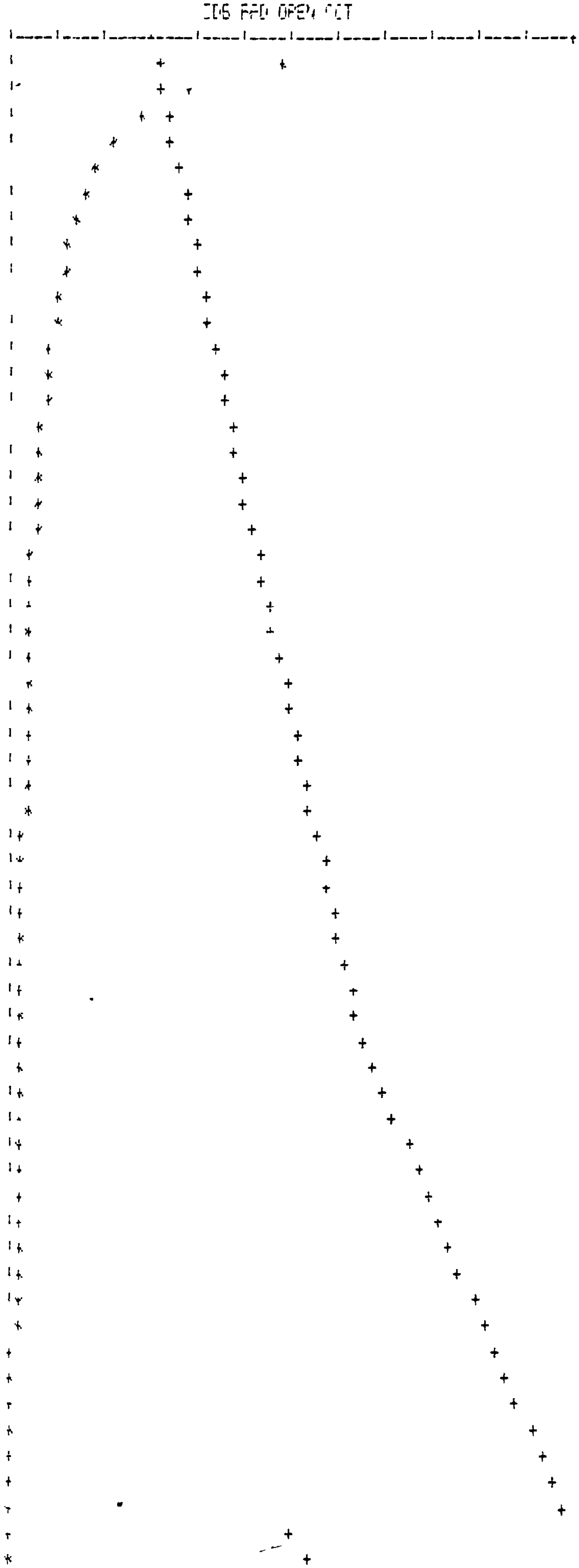
FOURIER TRANSFORM TIME WINDOW = 0 [illegible]E-09 SEC

MAG(+)	PHASE(+)	FREQ
+6 2505 E-09	-2 3456 E+01	+2 5000 E+07
+3 1702 E-09	-3 2301 E+01	+5 0000 E+07
+2 1103 E-09	-6 5243 E+01	+7 5000 E+07
+1 5510 E-09	-2 7777 E+01	+1 0000 E+08
+1 2650 E-09	-3 7209 E+01	+1 2500 E+08
+1 0522 E-09	-5 6644 E+01	+1 5000 E+08
+9 0230 E-10	-2 6034 E+01	+1 7500 E+08
+7 9379 E-10	-6 5322 E+01	+2 0000 E+08
+7 0134 E-10	-3 4 73 E+01	+2 2500 E+08
+6 2152 E-10	-3 4422 E+01	+2 5000 E+08
+5 7402 E-10	-3 3331 E+01	+2 7500 E+08
+5 2617 E-10	-3 2254 E+01	+3 0000 E+08
+4 8572 E-10	-3 2222 E+01	+3 2500 E+08
+4 5110 E-10	-3 2232 E+01	+3 5000 E+08
+4 2115 E-10	-3 1757 E+01	+3 7500 E+08
+3 9501 E-10	-3 1242 E+01	+4 0000 E+08
+3 7209 E-10	-3 0721 E+01	+4 2500 E+08
+3 5153 E-10	-2 0133 E+01	+4 5000 E+08
+3 3441 E-10	-7 3673 E+01	+4 7500 E+08
+3 1703 E-10	-7 9145 E+01	+5 0000 E+08
+3 0229 E-10	-7 3515 E+01	+5 2500 E+08
+2 8507 E-10	-7 3073 E+01	+5 5000 E+08
+2 7525 E-10	-7 7533 E+01	+5 7500 E+08
+2 6539 E-10	-7 7350 E+01	+6 0000 E+08
+2 5574 E-10	-7 6417 E+01	+6 2500 E+08
+2 4644 E-10	-7 5342 E+01	+6 5000 E+08
+2 3755 E-10	-7 5153 E+01	+6 7500 E+08
+2 2938 E-10	-7 4557 E+01	+7 0000 E+08
+2 2247 E-10	-7 4041 E+01	+7 2500 E+08
+2 1557 E-10	-7 3409 E+01	+7 5000 E+08
+2 0512 E-10	-7 2762 E+01	+7 7500 E+08
+2 0305 E-10	-7 2093 E+01	+8 0000 E+08
+1 9733 E-10	-7 1413 E+01	+8 2500 E+08
+1 9199 E-10	-7 0721 E+01	+8 5000 E+08
+1 8633 E-10	-7 0027 E+01	+8 7500 E+08
+1 8165 E-10	-6 9273 E+01	+9 0000 E+08
+1 7744 E-10	-6 8575 E+01	+9 2500 E+08
+1 7202 E-10	-6 7775 E+01	+9 5000 E+08
+1 6832 E-10	-6 6837 E+01	+9 7500 E+08
+1 6477 E-10	-6 5207 E+01	+1 0000 E+09
+1 5723 E-10	-6 4676 E+01	+1 0500 E+09
+1 4933 E-10	-6 3047 E+01	+1 1000 E+09
+1 4209 E-10	-6 1402 E+01	+1 1500 E+09
+1 3554 E-10	-5 9762 E+01	+1 2000 E+09
+1 2943 E-10	-5 8147 E+01	+1 2500 E+09
+1 2441 E-10	-5 6573 E+01	+1 3000 E+09
+1 1901 E-10	-5 5074 E+01	+1 3500 E+09
+1 1744 E-10	-5 3655 E+01	+1 4000 E+09
+1 0553 E-10	-5 2246 E+01	+1 4500 E+09
+1 0121 E-10	-5 1150 E+01	+1 5000 E+09
+9 8221 E-11	-5 0115 E+01	+1 5500 E+09
+9 5334 E-11	-4 9211 E+01	+1 6000 E+09
+9 1735 E-11	-4 8451 E+01	+1 6500 E+09
+8 7552 E-11	-4 7[illegible] E+01	+1 7000 E+09
+8 4355 E-11	-4 7423 E+01	+1 7500 E+09
+8 2112 E-11	-4 7271 E+01	+1 8000 E+09
+7 9834 E-11	-4 [illegible] E+01	+1 8500 E+09
+7 7323 E-11	-4 6524 E+01	+1 9013 E+09
+7 6136 E-11	-4 5709 E+01	+1 9501 E+09
+7 4321 E-11	-4 2546 E+01	+2 0002 E+09



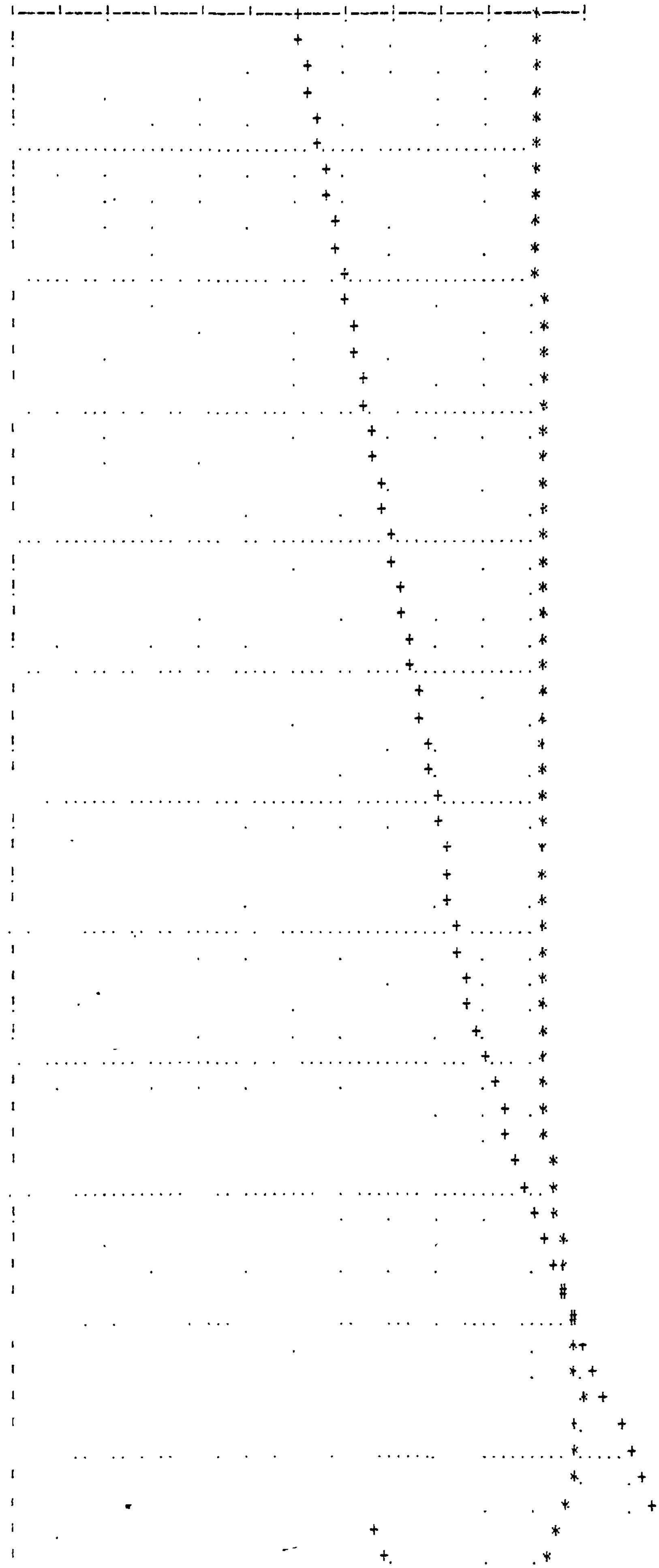
FOURIER TRANSFORM TIME WINDOW - [illegible] 9E-09 SEC

MAG(+)	PHASE(+)	FREQ
+2 2075 E-09	-9 6550 E+01	+2 5000 E+07
+1 6175 E-09	-[illegible] E+01	+5 0000 E+07
+1 0743 E-09	-7 3543 E+01	+7 5000 E-07
+2 0514 E-10	-7 6155 E+01	+1 0000 E+08
+6 4501 E-10	-7 2745 E+01	+1 2500 E-08
+5 3777 E-10	-6 3150 E-01	+1 5000 E-08
+4 6115 E-10	-6 5325 E+01	+1 7500 E+08
+4 0190 E-10	-6 2273 E+01	+2 0000 E-08
+3 5917 E-10	-5 9321 E-01	+2 2500 E-09
+3 2272 E-10	-5 5453 E+01	+2 5000 E+08
+2 9459 E-10	-5 2010 E-01	+2 7500 E-08
+2 7045 E-10	-4 3555 E+01	+3 0002 E+08
+2 5391 E-10	-4 5411 E-01	+3 2500 E-08
+2 3151 E-10	-4 1471 E+01	+3 5000 E+08
+2 1775 E-10	-3 3122 E+01	+3 7500 E+08
+2 0410 E-10	-2 4560 E+01	+4 0000 E+08
+1 9241 E-10	-2 1125 E+01	+4 2500 E+08
+1 8105 E-10	-2 7776 E-01	+4 5000 E+08
+1 7273 E-10	-2 4225 E-01	+4 7500 E+08
+1 6445 E-10	-2 0740 E+01	+5 0000 E+08
+1 5930 E-10	-1 7252 E+01	+5 2500 E+08
+1 5003 E-10	-1 3762 E+01	+5 5000 E+08
+1 4354 E-10	-1 0272 E+01	+5 7500 E-08
+1 3312 E-10	-6 7716 E+00	+6 0000 E+08
+1 3255 E-10	-3 2727 E+00	+6 2500 E+08
+1 2300 E-10	+0 0522 E+00	+6 5000 E+08
+1 2250 E-10	+3 7415 E-00	+6 7500 E+08
+1 1932 E-10	+7 2540 E-00	+7 0000 E-08
+1 1542 E-10	+1 0765 E-01	+7 2500 E+08
+1 1179 E-10	+1 4232 E+01	+7 5000 E+08
+1 0933 E-10	+1 7234 E+01	+7 7500 E-08
+1 0513 E-10	+2 1221 E-01	+8 0000 E+08
+1 0217 E-10	+2 4550 E+01	+8 2500 E-08
+9 3770 E-11	+2 [illegible] 0 E+01	+8 5000 E+08
+9 5644 E-11	+3 1904 E+01	+8 7500 E+08
+9 4101 E-11	+3 5450 E+01	+9 0000 E-08
+9 1833 E-11	+3 8972 E+01	+9 2500 E-08
+5 9325 E-11	+4 2292 E-01	+9 5000 E+08
+5 7203 E-11	+4 6755 E+01	+9 7500 E-08
+9 5111 E-11	+4 9701 E+01	+1 0000 E+09
+9 1214 E-11	+5 2755 E+01	+1 0500 E+09
+7 7732 E-11	+5 2677 E+01	+1 1000 E-09
+7 4223 E-11	+7 1097 E-01	+1 1500 E+09
-7 1171 E-11	+7 2147 E+01	+1 2000 E+09
+6 [illegible] E-11	+3 5134 E+01	+1 2500 E+09
+6 5555 E-11	+3 [illegible]25 E-01	+1 3000 E+09
+6 2051 E-11	-3 3577 E+01	+1 3500 E+09
+6 0554 E-11	+1 0574 E-02	+1 4000 E-09
+5 [illegible] E-11	+1 1221 E-02	+1 4500 E+09
+5 6134 E-11	+1 2135 E+01	+1 5000 E+09
+5 4123 E-11	-1 [illegible] E-[illegible]	+1 5500 E+09
+5 [illegible] E-11	+1 [illegible] E+0[illegible]	+1 6000 E+09
+5 0223 E-11	+1 4253 E-02	+1 6500 E-09
+4 3441 E-11	+1 4975 E+[illegible]	+1 7000 E+09
+4 6725 E-11	-1 [illegible] E-0[illegible]	+1 7500 E+09
+4 5377 E-11	-1 [illegible] E-[illegible]	+1 [illegible] E+09
-4 3[illegible] E-11	+1 7122 E+0[illegible]	+1 8500 E+09
+4 1571 E-11	+1 7223 E-[illegible]	+1 9010 E+09
-4 0510 E-11	-5 5155 E-10	+1 9500 E+09
+3 9112 E-11	+1 2254 E+01	+2 0000 E+09



FOURIER TRANSFORM

MAG(+)	PHASE(+)	FREQ
+5.0534 E-01	+2.9464 E+00	+2.5000 E+07
+5.0597 E-01	-5.8221 E+00	+5.0000 E+07
+5.0919 E-01	+8.6339 E+00	+7.5000 E+07
+5.0950 E-01	+1.1581 E+01	+1.0000 E+08
+5.0958 E-01	+1.4465 E+01	+1.2500 E+08
+5.1003 E-01	+1.7354 E+01	+1.5000 E+08
+5.1035 E-01	+2.0245 E+01	+1.7500 E+08
+5.1143 E-01	+2.3150 E+01	+2.0000 E+08
+5.1204 E-01	+2.6056 E+01	+2.2500 E+08
+5.1271 E-01	+2.6 69 E+01	+2.5000 E+08
+5.1337 E-01	+3.1830 E+01	+2.7500 E+08
+5.1406 E-01	+3.4298 E+01	+3.0000 E+08
+5.1475 E-01	+3.6391 E+01	+3.2500 E+08
+5.1543 E-01	+4.0820 E+01	+3.5000 E+08
+5.1607 E-01	+4.3644 E+01	+3.7500 E+05
+5.1669 E-01	+4.6584 E+01	+4.0000 E+08
+5.1726 E-01	-4.9516 E+01	+4.2500 E+08
+5.1778 E-01	+5.2451 E+01	+4.5000 E+08
+5.1824 E-01	+5.5449 E+01	+4.7500 E+08
+5.1863 E-01	+5.8406 E+01	+5.0000 E+08
+5.1895 E-01	+6.1352 E+01	+5.2500 E+08
+5.1919 E-01	+6.4316 E+01	+5.5000 E+08
+5.1936 E-01	+6.7265 E+01	+5.7500 E+08
+5.1946 E-01	+7.0208 E+01	+6.0000 E+08
+5.2949 E-01	+7.3144 E+01	+6.2500 E+08
+5.1939 E-01	+7.5843 E+01	+6.5000 E+08
+5.1922 E-01	+7.8959 E+01	+6.7500 E+08
+5.1905 E-01	+8.1511 E+01	+7.0000 E+08
+5.1865 E-01	+8.4308 E+01	+7.2500 E+08
+5.1857 E-01	+8.7693 E+01	+7.5000 E+08
+5.1828 E-01	+9.0566 E+01	+7.7500 E+08
+5.1796 E-01	+9.3429 E+01	+8.0000 E+08
+5.1769 E-01	-9.6278 E+01	+8.2500 E+08
+5.1735 E-01	+9.9111 E+01	+8.5000 E+08
+5.1712 E-01	+1.0193 E+02	+8.7500 E+08
+5.1720 E-01	+1.0474 E+02	+9.0000 E+08
+5.1674 E-01	+1.0752 E+02	+9.2500 E+08
+5.1554 E-01	+1.1007 E+02	+9.5000 E+08
+5.1658 E-01	+1.1276 E+02	+9.7500 E+08
+5.1661 E-01	+1.1591 E+02	+1.0000 E+09
+5.1701 E-01	-1.2143 E+02	+1.0500 E+09
+5.1795 E-01	+1.2692 E+02	+1.1000 E+09
+5.1953 E-01	+1.3141 E+02	+1.1500 E+09
+5.2161 E-01	+1.3731 E+02	+1.2000 E+09
+5.2409 E-01	+1.4340 E+02	+1.2500 E+09
+5.2694 E-01	+1.4939 E+02	+1.3000 E+09
+5.3017 E-01	+1.5455 E+02	+1.3500 E+09
+5.3373 E-01	+1.6040 E+02	-1.4000 E+09
+5.3748 E-01	+1.6525 E+02	+1.4500 E+09
+5.4124 E-01	-1.7214 E+02	+1.5000 E+09
+5.4472 E-01	+1.7815 E+02	+1.5500 E+09
+5.4765 E-01	+1.8570 E+02	+1.6000 E+09
+5.4574 E-01	+1.9107 E+02	+1.6500 E+09
+5.5076 E-01	+1.9774 E+02	-1.7000 E+09
+5.5303 E-01	+2.0425 E+02	+1.7500 E+09
+5.4801 E-01	+2.1115 E+02	+1.8000 E+09
+5.4402 E-01	+2.1804 E+02	+1.8500 E+09
+5.3558 E-01	+2.2500 E+02	+1.9010 E+09
+5.3103 E-01	-4.3227 E+01	+1.9500 E+09
+5.3106 E-01	+5.6200 E-01	+2.0000 E+09



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