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**DUVAS (Derivative UV-Absorption
Spectrometer): Instrument Description
and Operating Manual**

A. R. Hawthorne
J. M. Dougherty
C. E. Metcalfe

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Health and Safety Research Division

**DUVAS (Derivative UV-Absorption Spectrometer):
INSTRUMENT DESCRIPTION AND OPERATING MANUAL**

A. R. Hawthorne
J. M. Dougherty*
C. E. Meccalfe

*Computer Sciences Division

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OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
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UNION CARBIDE CORPORATION
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DEPARTMENT OF ENERGY

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PREFACE

This report is intended to serve as an operating manual and to provide background information and application examples for readers with a general interest in DUVAS. The sections on Instrumentation and Evaluation, along with the Appendices, are of greatest interest to the instrument user. These sections add considerable detail and may be deemphasized by the reader who is only interested in the general subject of derivative spectrometry.

**DUVAS (Derivative UV-Absorption Spectrometer): INSTRUMENT
DESCRIPTION AND OPERATING MANUAL**

A. R. Hawthorne, J. M. Dougherty, and C. E. Metcalfe

ABSTRACT

DUVAS is a real-time, field-portable spectrometer capable of monitoring a variety of aromatic organic vapors and inorganic gases at sub-ppm concentrations. The instrument is a prototype, microcomputer-controlled, derivative ultraviolet (UV) absorption spectrometer (DUVAS) developed primarily for area monitoring at coal conversion facilities, although other important occupational and environmental monitoring applications for compounds such as SO_2 , NO_x , NH_3 , and HCHO are also being pursued.

The first section of this report outlines the theory of derivative spectrometry, discusses various methods of obtaining derivative spectra, and presents the principles on which DUVAS is based. The second section details the instrumentation, both hardware and software, used to implement this prototype DUVAS, while the third section provides details of various evaluation parameters and procedures. Detailed appendices are included showing schematic drawings, parts lists, program listings, and library spectra. The final section gives specific application examples including analysis of real samples in the laboratory and results obtained during field tests.

Further improvements and modifications are under development which will lower the cost, increase the instrument capability, and reduce the size and weight of the instrument. The DUVAS described in this report constitutes a useful addition to the monitoring instruments available to the industrial hygienist and environmental scientist in evaluating the exposure of man and the environment to these potentially hazardous compounds.

INTRODUCTION

Increasing emphasis during the past decade on the adverse health effects on man due to pollutants in both the work and the general environment, and more recently the indoor environment, has necessitated the development of instrumentation suitable for monitoring low levels of many compounds. Several important features must be evaluated in characterizing an instrument for low level pollutant monitoring. Among the more important features are:

- sensitivity,
- selectivity,
- accuracy,
- reproducibility,
- multicomponent capability,
- portability, and
- low cost.

Trade-offs must often be considered among these various parameters.

Ultraviolet (UV) absorption spectrometry is quite sensitive for detecting many important pollutant compounds. However, the technique often suffers from lack of selectivity between compounds. Second-derivative spectrometry offers a method of enhancing the sharp absorption bands of specific pollutants while suppressing the interferences from peaks of broad-band absorption. Second-derivative spectrometry has proven useful both as a method for qualitatively enhancing spectral data and as a means of improving quantitative analysis.¹⁻¹⁹

This report describes a real-time, field-portable spectrometer capable of monitoring a variety of aromatic organic vapors and inorganic gases at sub-ppm concentrations. The instrument is a prototype, microcomputer-controlled, derivative UV-absorption spectrometer (DUVAS) developed primarily for area monitoring at coal conversion facilities, although other important occupational and environmental monitoring applications for compounds such as SO₂, NO_x, O₃, NH₃, and formaldehyde (HCHO) are also being pursued.

Examples of important trace pollutant analysis areas where DUVAS has been evaluated, or shows potential application, include smokeplume monitoring for SO_2 , O_3 , NO_2 , NH_3 , and nitrous acid (HONO).¹⁹ This application requires an instrument that can provide real-time measurement, good selectivity, high sensitivity, and ruggedness. Preliminary evaluation indicates that DUVAS can provide these features. In addition to having promise as a plume monitor, DUVAS should prove a viable alternative to remote station monitoring with multiple instruments for measuring criteria pollutants where a single instrument capable of measuring several pollutants is desirable.

A second area of potential application is indoor air quality measurements. Recent increased awareness as to the potential impact of indoor air quality on human health, coupled with energy conservation measures which tend to increase the levels of indoor pollutants, has highlighted the need for relatively simple and portable instrumentation to measure the levels of various indoor pollutants.²⁰ Among the compounds of interest that DUVAS can measure are NO_x , NH_3 , HCHO (and other aldehydes), plus various organic compounds such as phenolics found in cigarette smoke. Although minimal work has been done in this area to date, future efforts are expected to increase.

A third area, and the prime motivation for the development of DUVAS, is in industrial hygiene monitoring of various aromatic vapors.¹⁸ Although primary emphasis has been placed on coal conversion facilities, many other industrial applications would find need for such an aromatic vapor monitor. A considerable potential hazard exists in the coal conversion industry where a wide range of toxic and carcinogenic materials are found in various product streams.^{21,22} Among the many compounds present are benzene, toluene, phenol, cresols, and naphthalenes. These compounds have sufficient vapor pressures to generate concentrations of several ppm in the work area.²³ Exposure to these and other polynuclear aromatic (PNA) compounds is most likely to occur during maintenance operations or in the event of equipment leaks. A real-time area monitor is needed to provide workers with information on organic concentrations in those areas where concentrations may vary with time. Increased

concentrations of vapors from volatile compounds could also indicate a potential for increased exposure to nonvolatile PNAs.²⁴

A final application of DUVAS is in the analysis of liquid samples, either in extracted solvents or directly in wastewater analysis.¹³ This area has not been emphasized as heavily as gas and vapor analysis but does offer potential as an on-line waste stream analyzer. The insensitivity of derivative spectrometry to sample turbidity is an advantage for this application.

This report is organized into four major sections. The first section outlines the theory of derivative spectrometry, discusses various methods of obtaining derivative spectra, and presents the principles on which DUVAS is based. The second section details the hardware and software instrumentation used to implement this prototype DUVAS, while the third section provides details of various evaluation parameters and procedures. These sections should provide the basic information needed to become familiar with the instrument's operation. The fourth section gives specific application examples including analysis of real samples in the laboratory and results obtained during field tests. References on derivative spectrometry are listed at the end of the text. Finally, appendices are included showing schematic drawings, parts lists, program listings, and library spectra. These should prove useful for instrument repair and modification as well as for a general understanding of the instrument.

THEORY

The lack of selectivity of UV-absorption techniques often prevents their use in the analysis of complex samples without preliminary separation using some form of chemical fractionation such as chromatography. Second-derivative spectrometry offers a method of enhancing narrow absorption peaks while suppressing peaks of broad-band absorption thus improving selectivity. Identification of individual spectra is also easier since for a particular compound the second-derivative spectrum usually contains more detailed structure than the direct spectrum.

Derivative absorption spectrometry has been used to enhance spectral features as well as to improve quantitative analysis of overlapping peaks. The effect of enhancing one peak relative to another is illustrated in Fig. 1, which shows that for peaks that are approximately Gaussian in shape, the peak height ratios are considerably different for the second-derivative spectra than for the direct spectra. In the case of direct spectra, the ratio is 1.0, while the ratio is 2.3 for the second-derivative spectra. Figure 2 illustrates the usefulness of the second-derivative procedure in resolving overlapping peaks. Consider the summation of the peaks in Fig. 1 but with the narrow peak shifted 2 nm and only 10% as intense as the broader peak. In the direct spectrum the small peak is not noticeable, while in the second-derivative spectrum the small peak is clearly visible on the side of the larger peak.

Methods of obtaining second-derivative spectra include numerical differentiation of direct spectra, electronic differentiation of the signal with respect to time, and, for optical systems, wavelength modulation of the source light using vibrating mirrors or oscillating slits followed by synchronous detection.^{3,6,8} Numerical differentiation requires the direct absorption spectra data to be in digital form. A computer program is then used to apply a finite-difference filter, with appropriate coefficients for the second derivative, to the direct spectrum. A trade-off is made between exact representation of the derivative and enhancement of signal-to-noise (S/N) in choosing filter widths. Until recently numerical differentiation was not practical in a low cost, field instrument. Electronic differentiation is performed

Fig. 1. Illustration of second-derivative enhancement of narrow peaks and suppression of broad peaks.

Fig. 2. Superposition of the two peaks shown in Fig. 1 with the narrow peak shifted 2 nm to the right and only 10% as intense as the broad peak to illustrate increased selectivity of second derivative.

by scanning through the spectrum at a constant rate (i.e., $d\lambda/dt = \text{constant}$) and taking the time derivative of the direct analog signal using analog electronic circuits. The fast scanning rates required to give large second-derivative signals utilize short time constants that tend to reduce the S/N ratio, making analysis difficult for low concentrations.¹⁴ Both numerical differentiation and electronic differentiation can be applied to a standard spectrophotometer without modification. A limitation of these techniques is that the second derivative at a specific wavelength can be found only by scanning through that wavelength and not by dwelling at a fixed point. The second derivative of a spectrum can also be obtained by wavelength modulating, by a few nanometers, the wavelength of the light going through the sample and detecting the second harmonic of the modulation frequency, which is proportional to the second derivative. Modulation is achieved by modification of the standard optical components of the spectrometer. Most often this modulation is provided by a vibrating entrance or exit monochromator slit, or an oscillating mirror, to give a wavelength modulation with a frequency that is fast compared to the scanning rate. In contrast to the previously described methods of obtaining the second derivative, this technique will provide the second derivative at a stationary position, thus allowing continuous monitoring at a given wavelength. Also, since the signal of interest is contained in the alternating current (ac) component with a frequency of twice the modulation frequency, the spectrometer can use an automatic-gain-control (AGC) to maintain a constant direct current (dc) signal regardless of the sample absorptivity. This allows the electronic components of the system to operate in their optimum ranges. An example of each of the three methods of obtaining the second derivative of a sample of phenol in water is shown in Fig. 3, along with the direct absorption spectrum.

The DUVAS is based on the technique of wavelength modulation of the incident light beam and detection of the second harmonic of the modulation, which is proportional to the second derivative of the absorption spectrum with respect to wavelength. This relationship can be shown by expanding the intensity distribution in a Taylor's series.⁹

Fig. 3. Spectra of phenol in water (10 µg/mL) showing direct absorption spectrum and second-derivative spectra obtained by various techniques.

$$I(\lambda) = I(\lambda_0) + (\lambda - \lambda_0) \left. \frac{\partial I(\lambda)}{\partial \lambda} \right|_{\lambda_0} + 1/2 (\lambda - \lambda_0)^2 \left. \frac{\partial^2 I(\lambda)}{\partial \lambda^2} \right|_{\lambda_0} + \dots \quad (1)$$

The incident light at wavelength λ_0 is sinusoidally modulated with amplitude $\Delta\lambda$ and angular frequency ω :

$$\lambda = \lambda_0 + \Delta\lambda \sin \omega t \quad (2)$$

Combining Eqs. (1) and (2) yields:

$$I(\lambda) = \sum_{n=0}^{\infty} \frac{\Delta\lambda^n}{n!} \sin^n \omega t \frac{\partial^n I(\lambda)}{\partial \lambda^n} \quad (3)$$

Using some mathematical identities, the first few terms of the series expansion can be written as follows:

$$\begin{aligned}
 I(\lambda) = I(\lambda_0) + 1/4 \Delta\lambda^2 \left. \frac{\partial^2 I(\lambda)}{\partial \lambda^2} \right|_{\lambda_0} + \Delta\lambda \sin \omega t \left. \frac{\partial I(\lambda)}{\partial \lambda} \right|_{\lambda_0} \\
 - 1/4 \Delta\lambda^2 \cos 2 \omega t \left. \frac{\partial^2 I(\lambda)}{\partial \lambda^2} \right|_{\lambda_0} + \dots
 \end{aligned} \quad (4)$$

As seen from Eq. (4), the intensity signal can be considered as composed of a dc term proportional to the direct absorption spectrum (provided $\Delta\lambda^2$ is sufficiently small), an ac term of frequency ω proportional to the first derivative, and an ac term of frequency 2ω proportional to the second derivative. If a complete expansion is performed, there are additional terms that contribute at the various frequencies, but they are usually quite small compared to the leading term.⁹ Demodulation of the 2ω term yields a signal proportional to the second derivative.

The relationship between the measured second-derivative response and the concentration of the analyte can be obtained assuming that Beer's law is applicable for that compound:⁹

$$I(\lambda) = I_0(\lambda) \exp[-bc \mu(\lambda)] , \quad (5)$$

$$\frac{\partial I(\lambda)}{\partial \lambda} / I(\lambda) = \frac{1}{I_0(\lambda)} \frac{\partial I_0(\lambda)}{\partial \lambda} - bc \frac{\partial \mu(\lambda)}{\partial \lambda} , \quad (6)$$

and

$$\begin{aligned}
 \frac{\partial^2 I(\lambda)}{\partial \lambda^2} / I(\lambda) = \frac{1}{I_0(\lambda)} \frac{\partial^2 I_0(\lambda)}{\partial \lambda^2} - bc \left[\frac{\partial^2 \mu(\lambda)}{\partial \lambda^2} \right. \\
 \left. + \frac{2}{I_0(\lambda)} \frac{\partial I_0(\lambda)}{\partial \lambda} \frac{\partial \mu(\lambda)}{\partial \lambda} + bc \frac{\partial \mu(\lambda)}{\partial \lambda}^2 \right] , \quad (7)
 \end{aligned}$$

where $I(\lambda)$ = transmitted intensity as a function of wavelength, $I_0(\lambda)$ = source intensity as a function of wavelength, b = pathlength of light through the sample, c = concentration of analyte in the sample, and $\mu(\lambda)$ = absorption coefficient as a function of wavelength. For small values of bc , the relationship between concentration and the second-derivative, normalized by the direct spectrum response, of Eq. (7) is linear, as previously noted. However, a completely linear response can be obtained by subtracting the square of the first-derivative response given by Eq. (6) from the second-derivative response given by Eq. (7). If this response is then corrected for contributions due to the spectral features of the light source [$\partial I_0(\lambda)/\partial \lambda$ and $\partial^2 I_0(\lambda)/\partial \lambda^2$] by subtracting a blank sample in which bc equals zero, the following relationship is obtained between the concentration and the measured response, $R(bc)$:

$$R(bc) = -bc \frac{\partial^2 \mu(\lambda)}{\partial \lambda^2} . \quad (8)$$

This desirable linear response allows measurement of high concentrations without the use of nonlinear analytical curves. If, instead of true first- and second-derivative responses, one has an infinite series response for the even and odd derivatives, as is the case for a wavelength-modulated derivative spectrometer, the above analysis is not exact and a perfectly linear response is not obtained. However, the response of such an instrument can be improved; the details are presented in ref. 11.

An alternative to performing the division required to normalize the derivative responses in Eq. (6) and Eq. (7) is to use the logarithm of Eq. (5). This procedure yields the following responses:

$$F(\lambda) \equiv \ln I(\lambda) = \ln I_0(\lambda) - bc \mu(\lambda) , \quad (9)$$

$$\frac{\partial F}{\partial \lambda} = \frac{\partial \ln I_0(\lambda)}{\partial \lambda} - bc \frac{\partial \mu(\lambda)}{\partial \lambda} = \frac{1}{I_0(\lambda)} \frac{\partial I_0(\lambda)}{\partial \lambda} - bc \frac{\partial \mu(\lambda)}{\partial \lambda} , \quad (10)$$

and

$$\frac{\partial^2 F}{\partial \lambda^2} = \frac{\partial^2 \ln I_0(\lambda)}{\partial \lambda^2} - bc \frac{\partial^2 \mu(\lambda)}{\partial \lambda^2} = \frac{1}{I_0(\lambda)} \frac{\partial^2 I_0(\lambda)}{\partial \lambda^2} - \frac{\partial I_0(\lambda)}{\partial \lambda} \frac{I_0(\lambda)}{I_0(\lambda)^2} - bc \frac{\partial^2 \mu(\lambda)}{\partial \lambda^2} \quad (11)$$

The prototype DUVAS described in this report utilizes a logarithmic amplifier instead of a divider circuit to provide the desired response.

For applications where $bc \mu(\lambda)$ is small, as often occurs in trace analysis, or when the response is corrected for nonlinearity,¹¹ as just described, the data analysis can be performed using a least-squares method which utilizes standard spectra. This procedure as applied to derivative spectroscopy is discussed in ref. 12.

Another advantage of the normalized second-derivative response is that it is independent of sample opacity, light intensity fluctuations, and source-energy variations. The effect of long-term drift in the light source and detector is greatly reduced. This advantage is particularly useful when no sample preparation to remove particulate matter is performed prior to analysis.

INSTRUMENTATION

Initial motivation for the development of a prototype DUVAS developed from the experimental evaluation of a Lear Siegler SM400 derivative spectrometer (Fig. 4). The prototype DUVAS was designed to be smaller and substantially faster in spectrum scanning compared to the commercially available spectrometer. The SM400 utilizes a 45-Hz oscillating "wobbler" (Fig. 5) to produce the wavelength modulation. Also shown in Fig. 5 are the vapor phase cell and liquid cell modes of operation. The prototype DUVAS utilizes the same type of sampling cells.

ORNL-PHOTO 5699-76

Fig. 4. Photograph of the Lear Siegler SM400 derivative spectrometer. The 1-m multipass sampling cell is behind the electronics module.

Fig. 5. Optical schematic of the SM400 derivative spectrometer showing both the vapor phase cell and liquid cell modes of operation.

A disadvantage of the slow modulation frequency of the SM400 is the long times required to scan a spectrum. There are only two scanning speeds of 2.5 and 10 nm/min. Scanning is provided by unidirectional motors thus necessitating manual repositioning prior to each scan. The SM400 weighs about 60 kg and consists of two units: a control unit 51 x 38 x 61 cm and a sample cell unit 147 x 61 x 23 cm.

Several distinct improvements have been made in the microcomputer-controlled prototype DUVAS constructed at ORNL for field evaluation at various coal conversion facilities. The unit consists of a 32 x 42 x 18 cm box containing the electronics, microcomputer, monochromator, and light source. Attached to this box is a 0.5-m multipass sampling cell. The prototype DUVAS weighs approximately 15 kg. Figure 6 is a photograph of the instrument. Other than power supplies, all controls are implemented through the microcomputer key pad on top of the instrument. Appendices C and D contain circuit schemata and a partial parts list.

ORNL-PHOTO 0398-80

Fig. 6. Photograph of the prototype DUVAS with 0.5-m sampling cell.

Optics

The optical components of DUVAS consist of a light source, monochromator, multipass sampling cell, and a photomultiplier tube (PMT). The light source is a 30-W deuterium lamp providing continuous emission from 190 nm to 400 nm.

The spectrometer monochromator is a small 10-cm holographic grating with a resolution of 8 nm/nm. Wavelength modulation is achieved by replacing one of the mirrors in the monochromator with a commercially available taut-band vibrator that oscillates with a frequency of 400 Hz (Fig. 7). The second harmonic signal at 800 Hz is sufficiently removed from the 120-Hz line voltage to allow good filtering, thus improving the noise characteristics.

ORNL-PHOTO 5226-79

Fig. 7. Inside view of monochromator showing small vibrating mirror.

The multipass "white" cell consists of a 9.5-cm-diam aluminum tube ≈ 0.5 m long with 0.5-m focal length mirrors in each end. The mirrors are coated for optimum reflectance in the UV region. The light beam can be adjusted for multiple reflections through the cell providing a long pathlength through the air sample. The instrument is usually normally operated with a total pathlength of 4 m. The air sample can be either continuously flowed through the cell using a small pump or a volume of air can be trapped within the cell. The cell volume is approximately 3.5 L.

Light detection is accomplished using a high-gain PMT with a quartz window optimized for UV response. For analysis of liquid samples, the multipass cell can be removed and the PMT holder rotated into the light beam directly behind the liquid cell holder.

Electronics

Figure 8 is an interior view of DUVAS showing the electronics, power supplies, stepping motor, monochromator, and lamp. Other than power supplies, all of the electronics are on a single printed circuit (PC) board (top of Fig. 8).

A block diagram of the DUVAS electronics is shown in Fig. 9. The second PC board is a commercially available (Pacific Photometric Instruments, Model 7151) voltage-programmable high-voltage (HV) power supply for the photomultiplier tube. A control voltage input of 0 to 5 V gives a 0 to 1200 V output. The programmable feature allows an automatic-gain-control (AGC) signal to the HV board to control the gain of the PMT by varying the applied voltage. The second-derivative signal is not affected if the time constant of the AGC is slow relative to the 400-Hz modulation frequency because slowly varying the gain is equivalent to slowly changing the light intensity; the second-derivative signal is insensitive to light intensity changes. The AGC feature acts as an automatic iris to ensure that dc signals from the PMT are neither too small nor too large, thus ensuring that the signals fall within the optimum range of the signal processing electronics.

Fig. 8. Inside view of DUVAS showing light source, monochromator, stepping motor, electronics, and power supplies.

Fig. 9. Block diagram of DUVAS electronics.

The signal processing and control circuits are shown in the block diagram of Fig. 10. The AGC circuit can be adjusted for the desired dc signal from the PMT. This AGC circuit then acts as a servo control to adjust the PMT voltage to the desired output. Also, on this PC board is the mirror-driving and sensing circuit.²⁵ This circuit oscillates the mirror and provides a 400-Hz reference signal to a frequency-doubling circuit, which gives an 800-Hz reference signal for use in the synchronous detector circuit. A stepping-motor control circuit takes a direction signal and step pulse from the microcomputer and provides the proper sequence of pulses to the bidirectional four-phase stepping motor. When used with a 2:1 gear reduction, this motor gives a stepping resolution of 0.25 nm/step.

The signal from the PMT, which has an 800-Hz ac component containing the second-derivative information, is input to a logarithmic amplifier circuit. Following the log circuit is a bandpass filter/amplifier with a central frequency of 800 Hz. This circuit filters out both high and low frequencies, including 120-Hz noise from line voltage and some of the 400-Hz signal due to the first-derivative signal. A synchronous detector circuit then selects only signals having an 800-Hz frequency

Fig. 10. Block diagram of DUVAS signal processing and control circuits.

and, with a subsequent filter/amplifier circuit, converts this ac signal into a dc signal proportional to the second derivative of the absorption curve of the measured compound at the measured wavelength. This analog signal is available at the rear panel of the instrument for use with a chart recorder. The final circuit on the board is a voltage-to-frequency (V/F) converter; this provides a frequency signal proportional to the second-derivative signal for the microcomputer to record as digital data.

Microcomputer

DUVAS is controlled by a single-board computer (SBC) that attaches to the top of the instrument box (Fig. 11). Commands are entered via a small keypad with data and status information available to the user on a six digit LED display. The SBC is a 6502 based microprocessor with

ORNL-PHOTO 5229-79

Fig. 11. Photograph of single-board microcomputer that controls DUVAS.

2 kilobytes read-only-memory (ROM) monitor and 4 kilobytes of erasable-programmable read-only-memory (EPROM) containing custom software for DUVAS operations. A detailed computer program listing is given in Appendix B. Also included is 4 kilobytes of random-access-memory (RAM) for storing spectra and temporary machine-language programs.

The microcomputer controls the wavelength positioning and scanning by providing a direction signal and a step pulse to the stepping motor control circuit. A memory register is maintained with the current location of the monochromator wavelength. The monochromator scan speed is selectable.

A train of pulses proportional to the second-derivative signal is input to the microcomputer. A counter on the SBC integrates the pulses for the period of time the monochromator is at a specific wavelength with the integration time being dependent on scan speed and resolution. The integrated signal is stored in the access spectrum buffer at the location corresponding to the current wavelength. The spectrum storage capacity is 256 data points, which corresponds to a wavelength range of 64 nm at a resolution of 0.25 nm/data point and 128 nm at a resolution of 0.5 nm/data point.

The stored spectrum can be saved on an audio cassette recorder or transferred to another computer. DUVAS has a parallel input/output (I/O) port for high speed transfers and a 20-nm current loop for serial communication with a teletype or several other communication devices. Commands can be input to DUVAS via these external interfaces thus allowing remote control of the instrument by an external computer.

The DUVAS has been operated with a Digital Equipment Corporation (DEC) DECLAB 11/03 minicomputer and a Commodore PET 2001 microcomputer. Figure 12 shows a spectrum displayed on the 11/03 system which is interfaced to an early version of DUVAS. For laboratory use the PDP 11/03 provides considerable flexibility, with dual floppy discs for mass data storage and program storage plus a video display for plotting spectra and displaying analyses. For field use the PET 2001 is an inexpensive microcomputer. It provides a 9-in. video display, a communication keyboard, a magnetic-tape cassette data recorder, and a microcomputer programmable in BASIC for data analysis (Fig. 13).

ORNL-PHOTO 4504-78

Fig. 12. DUVAS spectrum displayed on the DECLAB 11/03 system which is interfaced to an early version of DUVAS.

ORNL-PHOTO 4503-78

Fig. 13. DUVAS with liquid sampling compartment attached and interfaced with the PET 2001.

Table 1 is a list of some of the commands available to the user via the SBC keypad. Some of the commands require a list of parameters prior to execution. These parameters are (1) beginning wavelength of the scan, (2) length of the scan, (3) resolution of data storage (nm/data point), and (4) scanning speed (nm/sec). The number of stored data points is the length divided by the resolution; the total scan time required is the length divided by the speed. An "access" command stores

Table 1. DUVAS commands to microcomputer

Command	Parameters ^a (Y/N)	Function	Comment
3	Y	Parameters	Allows user to inspect or change current parameters
4	N	Auto	Calibrates instrument wavelength using a standard sample
5	N	Smooth	Provides a 5-point smooth of the stored data
9	N	Scope	Provides an analog signal of stored data for oscilloscope or recorder
A	Y	Access	Records a spectrum using specified parameters
B	Y	Time	Same as access but monochromator not scanned
C	N	Copy	Copies access spectrum into background spectrum
D	Y	Dwell	Continuously displays voltage at start wavelength
E	N	Exchange	Exchanges access spectrum with background spectrum
F	N	Fix	Allows user to assign wavelength of current monochromator setting to computer
-	N	Subtract	Subtracts the background spectrum from the access spectrum
SAV 2			Stores spectrum on cassette
LD 2			Reads spectrum from cassette

^aParameters input with this command: (1) start wavelength, (2) scan length, (3) resolution (nm/data point), and (4) scan speed.

a spectrum taken with the specified parameters in the access buffer. A "time" command operates like the "access" command except that the monochromator is not scanned. This provides a time spectrum showing the variation in the second-derivative response at the starting wavelength with time, where the total time is length divided by speed and the time per data point is resolution divided by speed. The "dwell" command is similar to the "time" command except the data are not stored in the spectrum buffer but continuously output on the LED display. The "dwell" mode is exited by pressing a key on the SBC keypad. The "parameters" command allows the user to inspect or change current scanning parameters.

In addition to the access spectrum buffer, there is a background spectrum buffer in the microcomputer memory. The "copy" command transfers the spectrum currently in the access buffer to the background buffer. The "exchange" command swaps spectra between the two buffers. A "subtract" command subtracts the background buffer from the access buffer, providing the parameters of the two spectra are the same. The resulted spectrum is stored in the access buffer. Another data manipulation command is the "smooth" command which performs a 5-point smoothing of the data in the access buffer.

When DUVAS is powered-up, the microcomputer does not know at what wavelength the monochromator is positioned. Two commands are available to calibrate the wavelength. One command, "fix" simply assigns the current position to the wavelength that the user provides as input from looking at the monochromator dial. The other, more accurate method, is the "auto" command. The microcomputer scans over a preassigned wavelength region and looks for a peak from a standard calibration sample. The maximum value of this peak is assigned the wavelength value of the standard compound.

Data stored in the access buffer can be output a variety of ways. The "scope" command scales the data in the access buffer and outputs an analog signal from a digital-to-analog converter (DAC) that can be used with an oscilloscope to provide a visual display of the complete spectrum. Also output are the starting wavelength, the ending wavelength, the amplitude of the data, and the position and value of a cursor which can be moved to any data point. These alphanumeric characters are multi-

plexed with the spectral data to provide an informative and convenient display for the user. Another option of the scope command is to output the analog signal at a slow rate suitable for recording on an X-Y plotter or a chart recorder. The alphanumeric information is not output in this mode.

Spectra can also be saved and retrieved using an audio cassette recorder with the "save" and "load" commands. This is a convenient method of keeping spectra for later plotting and data analysis.

EVALUATION

The prototype DUVAS has been tested and evaluated during the past six months in both laboratory and field applications.¹⁸ Additional evaluations are continuing to accumulate a data base of instrument performance under varying conditions. Table 2 lists some of the vapors and gases that can be measured using DUVAS along with their threshold limit values (TLVs) where applicable and an approximate detection limit, based on a S/N of 3, when no interferences are present. Unless otherwise noted, the pathlength of the measurement is 4 m. Appendix A is a library of second-derivative spectra.

Table 2. Approximate detection limits for some aromatic vapors

Compound	TLV ^a (ppm)	Approximate detection limit (ppm)
Benzene	10	0.06 ^b
Cresol	5	0.06 ^b
Phenol	5	0.06 ^b
Naphthalene	10	0.001 ^b
Toluene	200	0.1 ^b
Methylnaphthalene		0.001 ^b
Indane		0.09 ^b
Benzaldehyde		0.05 ^b
Formaldehyde	3	7.5 ^b
Ammonia	50	0.003 ^c
Sulfur dioxide	5	0.003 ^c
Nitric oxide	25	0.02 ^c
Nitrogen dioxide	5	0.04 ^c
Ozone	0.1	0.05 ^c

^aThreshold limit value.

^bObtained using a 0.5-m cell with a total pathlength of 4 m.

^cObtained using a 1-m cell with a total pathlength of 12 m.

A typical calibration curve is shown in Fig. 14. The dynamically generated concentration was produced by vaporizing a known solution of naphthalene in cyclohexane into an air stream. This is accomplished by injecting the solution, using a syringe pump, into the stream of hot air. This procedure is used to calibrate liquid and solid compounds. Gases such as SO_2 , NH_3 , and NO_x are diluted from commercial compressed gas cylinders (usually 50 ppm in N_2). All flow measurements are made using mass flow meters calibrated with a wet test meter. Cross verification of calibration has been performed using a static air sample produced by injecting a small amount of sample directly into the DUVAS multipass sampling cell using a microsyringe with the inlet and exit of the cell closed.

Fig. 14. A typical vapor calibration curve for DUVAS generated using a dynamic flow system.

The system response time is determined primarily by the sample cell volume and the flow rate of air through the cell. Equilibrium response is unaffected by flow rate. The response time (90% of value) to a step change in concentration due to the 0.5 m sampling cell volume (3.5 L) is approximately 25 s for a 10 L/min flow rate. By expressing time as a normalized parameter (t/τ) where τ = cell volume divided by flow rate, the instrument response to a step increase in concentration can be shown independent of flow rate and cell volume. Figure 15 shows the normalized response of DUVAS as well as the expected response assuming either perfect mixing or plug flow in the cell. As expected, the instrument response lies between these two idealized cases. The time required to

Fig. 15. DUVAS response to a step increase in vapor concentration as a function of t/τ where τ equals cell volume divided by flow rate. (Note: t must be in same units as τ .)

reach 90% of equilibrium response is approximately 1.15τ . Figure 16 shows the response time for a cell volume of 7 L and a flow rate of 5 L/min (i.e., $\tau = 1.4$ min). DUVAS was alternately measuring naphthalene and methylnaphthalene vapors above a Synthoil sample. The air flow was shunted around the sample at $t = 3$ min and returned to the original flow path at $t = 6$ min.

Fig. 16. Variation of naphthalene and methylnaphthalene vapor from a synthoil sample illustrating the DUVAS response to a step decrease and increase in concentration.

Care must be exercised in operating the air sampling cell in the static mode with low vapor pressure compounds such as naphthalene since a background response can build up requiring extensive flushing and heating of the cell to reduce the level of background response. This is much less of a problem when air is continuously flowed through the cell and requires attention only when a very low level measurement follows a relatively high level measurement of a low vapor pressure compound (or a particularly absorptive compound such as NH_3).

The precision of the DUVAS response is a function of signal strength and measurement speed. For samples yielding a response not limited by noise, the reproducibility is 2% or less for short-term measurements.¹⁸ For example, 18 measurements of a 0.5 ppm NO sample yielded $\bar{x} = 0.500 \pm 0.010$ ppm for a measurement time of 9 s per measurement. For a longer measurement period of 1 min, 60 measurements of an unknown anthracene liquid sample gave a result of 4.887 ± 0.045 $\mu\text{g/ml}$ (<1% RSD).

Wavelength drift is not a problem with the monochromator being positioned by a stepping motor. Once the initial auto calibration function is exercised after each startup, the wavelength remains locked within one motor step (<0.25 nm). The long-term downward drift of lamp intensity due to aging does not pose a problem since the second-derivative response is independent of source intensity. Calibration curves have remained constant when rechecked up to six months later.

DUVAS is capable of operating in three modes: (1) continuous scanning, (2) monitoring a specific wavelength with time, and (3) sequential multiwavelength measurement. The continuous scanning mode uses the "access" command and associated spectrum parameters such as scanning speed and spectrum length. Figure 17 is a typical spectrum of an aromatic vapor taken using this mode of operation.

Fig. 17. DUVAS spectrum of benzene vapor illustrating a typical aromatic vapor spectrum.

The second mode of operation is implemented using either the "time" or "dwell" commands. Figure 18 is a time spectrum of benzene vapor monitored at the 254-nm peak showing equilibration after injection of a microsyringe of benzene into the closed sampling cell. This mode of operation is useful when a time history of concentration is desired. By utilizing the DUVAS analog signal, a real-time alarm can be implemented when a predetermined level has been exceeded.

Fig. 18. Time spectrum of benzene vapor monitored at the 254-nm peak showing equilibration after injection of a microsyringe of benzene into the closed sampling cell.

The third mode of operation is performed in conjunction with an external computer. In this mode of operation, the DUVAS is instructed to dwell for a short measurement at the wavelength where the minimum voltage occurs for the measured compound followed by a dwell at the wavelength of the maximum voltage (see Fig. 1). The difference of the voltages is multiplied by a calibration constant and displayed on the host computer as a concentration in ppm. Using this mode of operation, DUVAS can rapidly measure several compounds and repeat the series at a

specified time interval. The above discussed example of 18 measurements of a 0.5 ppm NO sample to assess precision was obtained using the PET 2001 and this mode of operation. Interference corrections can be made using an interference matrix that is formed by measuring the response of the various compounds at all of the specified wavelengths.

Another method of interference correction uses the least-squares technique and a complete spectrum in conjunction with a library of spectra. As an illustration of the selectivity of the derivative technique coupled with least-squares analysis, a mixture containing four PNA compounds in cyclohexane was prepared. The sample nominally contained 25 ng/mL each of anthracene, phenanthrene, chrysene, and pyrene. Pure compounds were employed to generate "standard" spectra for use in the least-squares analysis. Spectra of both the pure compounds and the mixture were measured using a 1-cm cuvette containing ~2 mL of solution. Figure 19 shows the spectra obtained for each of the standard solutions. Notice the considerable variation in measured response per concentration for the different compounds, with anthracene providing ~20 times more intense response at the peak near 253 nm than does phenanthrene. Also, note the severe overlapping of absorption peaks between the different compounds, especially for anthracene and phenanthrene near 253 nm, which would make graphical analysis very unreliable.

The measured spectrum and least-squares fit of the mixture are shown in Fig. 20. Table 3 lists the analytical results obtained from the least-squares analysis. Although the concentration determined for the relatively less intense phenanthrene is only 76% of its true value, the least-squares program tells the user that the standard deviation of the phenanthrene result is greater than the others; in fact, the determined value is within 3 σ of the true value. The least-squares analysis of a complete spectrum with library standards is generally restricted to a laboratory-based computer with a fairly fast (relative to cassette tapes) mass storage device. Interference corrections made in the field will likely be confined to a selected number of wavelengths and compounds (10 or less).

ORNL-DWG 77-4689

Fig. 19. Liquid calibration standards for four PNA compounds in cyclohexane used to illustrate selectivity.

ORNL-DWG 77-4638A

Fig. 20. Comparison of least-squares spectral fit to experimental spectrum obtained with DUVAS.

Table 3. Least-squares analysis of a mixture of four PNA compounds in cyclohexane obtained using derivative spectrometry

Compound	Nominal concentration (ng/ml)	Least-squares analysis (ng/ml)
Anthracene	25	25.4 ± 0.2
Chrysene	25	25.0 ± 0.7
Phenanthrene	25	18.9 ± 2.6
Pyrene	25	28.2 ± 0.6

APPLICATIONS

DUVAS should prove valuable in monitoring trace pollutants in a wide range of applications. Specific projects include monitoring wastewater streams of synfuel and other industrial plants, measuring several Environmental Protection Agency criteria pollutants at remote sites, monitoring coal-fired power plant smokestacks, measuring indoor air pollution, and monitoring industrial hygiene for aromatic vapors. Additional, non-health and safety, projects might include such applications as use in real-time process control instrumentation in synfuel plants for optimizing yields of various compounds by varying process operating parameters. A few specific examples will be given in this section to illustrate the type of results that can be obtained using the instrument.

Organic compounds such as phenol and cresols in wastewaters from synfuel and other industrial plants must be cleaned prior to release to the environment. DUVAS should prove feasible as a continuous on-line wastewater monitor for these compounds.¹³ Figure 21 shows a calibration curve for phenol in water. The selectivity obtained with the second-derivative technique is illustrated using a mixture of phenol and *m*-cresol. The main second-derivative peaks for phenol and *m*-cresol are separated by slightly more than 1 nm. When a least-squares spectral analysis computer program was applied to the spectrum, the analysis of the mixture yielded 20.2 $\mu\text{g/mL}$ of phenol and 18.7 $\mu\text{g/mL}$ of *m*-cresol as compared to the expected values of 20.0 $\mu\text{g/mL}$ of each compound. The analysis is especially good considering the high degree of similarity between the two absorption spectra.

A particular advantage of the second-derivative technique applied to environmental and industrial hygiene monitoring problems is the dramatically reduced effect that sample turbidity has on the spectrum. A turbid sample generally produces an absorption which varies slowly with wavelength so that taking the second derivative tends to remove from the spectrum the contribution due to sample turbidity. A direct spectrum obtained for a turbid wastewater sample containing phenol

Fig. 21. Calibration curve generated using DUVAS for phenol in water.

(~25 $\mu\text{g/mL}$) is compared in Fig. 22 with the second-derivative spectrum of the same sample. The second-derivative response looks almost identical to the pure sample response of Fig. 3 while there is a drastic difference between the direct absorption spectra.

Another potential application for DUVAS is coal-fired power plant smokeplume characterization. DUVAS may prove suitable for inclusion in an aircraft instrumentation package traversing the smokeplume and mapping concentration profiles of various gases. Such features as multicomponent capability, sensitivity, real-time response, selectivity, and instrument ruggedness make DUVAS a promising candidate for such a project.

Among the gases found in smokeplumes which DUVAS can detect with sub-ppm sensitivity are NH_3 , SO_2 , NO , O_3 , and NO_2 . Encouraging results have also been obtained in trying to measure HONO , an important species in smokeplume chemistry. Figure 23 shows a calibration curve for NH_3 illustrating that low-ppb concentrations can be measured. These measurements were made with a 1-m sampling cell with a total pathlength of 12 m.

Fig. 22. Normal (bottom) and second-derivative (top) spectra illustrating the effect of sample turbidity on the analysis of phenol in a wastewater sample.

Fig. 23. DUVAS calibration curve (bottom) for low levels of NH_3 using a 1-m sampling cell and 12-m pathlength and a standard spectrum at 100 ppb (top).

A similar project to the smokeplume characterization involves the use of DUVAS as a remote station monitor to measure the same gases found in the smokeplume. Of importance here is the ability of a single multi-component instrument to replace several independent monitors. Further discussions on feasibility and evaluation of this application are expected with the Tennessee Valley Authority.²⁶

Indoor air pollution is an area of health and safety research that is receiving increasing attention as various conservation measures are implemented which tend to increase indoor pollutants. In addition to the above-mentioned gases, DUVAS may prove useful in measuring aldehydes found in the indoor environment. Although the sensitivity for formaldehyde is marginal at best for expected air quality standards, the instrument is quite sensitive to benzaldehyde (low-ppb detection limit). The applicability of DUVAS as an indoor air pollutant monitor will be evaluated as part of a developing program in indoor air pollution characterization.

A final area of application and the primary motivation for the development of DUVAS is as an industrial hygiene monitor for aromatic vapors associated with synfuel facilities. An indication of the aromatic vapors expected from various coal conversion and shale oil products was obtained by flowing an air stream over a sample of the product and diluting the resultant gaseous sample with air for measurement with the DUVAS.¹⁰ The following compounds have been detected in this manner: benzene, toluene, phenol, cresol, indane, naphthalene, and methylnaphthalene. Not all compounds were found in each product, and the relative ratios of compounds varied between products. A variety of parameters such as temperature and age of sample, in addition to the product origin, influence the emission rate from the samples; therefore, a useful comparison between different products is likely to be more qualitative than quantitative. However, results of work currently under way to correlate these parameters are encouraging. As an example of data obtained, Fig. 24 shows a spectrum of vapors sampled above a tar sample from a low-Btu gasifier. The presence of benzene in the sample is clearly evident when compared with Fig. 17.

DUVAS has also been evaluated in field-monitoring applications. Measurements were made at a small benchscale hydrocarbonization unit.

Fig. 24. Spectrum of vapors from a low-Btu gasifier tar sample taken with DUVAS.

Figure 25 shows a spectrum taken before and after a condensate vessel was opened in the experiment area. A dramatic increase is seen in the concentration of methylnaphthalene. Only low levels (<0.1 ppm) of aromatic vapors were observed during normal operation. Additional field monitoring was conducted at a low-Btu gasifier. A particularly striking example of the real-time monitoring capability of DUVAS was obtained while monitoring near a lock-hopper knife valve. Figure 26 is a plot of the benzene concentration versus time taken using the DUVAS "time" command.¹⁹ Each spike in the spectrum corresponds to the opening and closing of the knife valve. Although the mean level of benzene near the valve was relatively low, the rapid response real-time measurement showed significant concentration excursions. This example illustrates the capability of the instrument in providing real-time information on potential worker exposures, as well as in detecting leaks and other sources of aromatic vapors. Further field evaluation studies are under

Fig. 25. Spectrum of room air before and after a condensate vessel is opened taken with DUVAS.

Fig. 26. Plot of benzene concentration versus time near a lock-hopper knife valve as measured by DUVAS.

way with trips planned to the University of Minnesota at Duluth low-Btu gasifier, the H-Coal liquefaction plant at Cattletsburg, Kentucky, and the Holston Ordnance facility at Kingsport, Tennessee.

The preceding examples of DUVAS application illustrate the diversity of projects where the instrument can be utilized. Some of the projects may prove not to be feasible on a routine basis while new projects will likely be recognized. In any event, DUVAS has already proven to be a reliable, highly versatile tool for measuring trace pollutants in a variety of health and safety problem areas.

FUTURE WORK

Several engineering design and evaluation projects are under way to assess the feasibility and desirability of making some rather drastic design modifications. These modifications are aimed primarily toward reducing the cost, improving the reliability, and reducing the size and weight of the DUVAS. Most of the changes considered will utilize more of the capabilities of the instrument microcomputer. In addition to the reduced component count and increase reliability of microprocessor implemented functions, modifications and revisions can easily be made by simply reprogramming the EPROMs containing the DUVAS control program.

The first and most drastic change would be to implement the second-derivative function using the numerical method instead of wavelength modulation. Using current microcomputer systems, a derivative filter can be implemented eliminating the need for an external computer to perform this function. A major advantage of this approach would be the elimination of the vibrating mirror in the monochromator, the required machining work to modify and install the mirror in the monochromator, and the associated mirror drive circuitry. The harmonic detection circuitry would also be eliminated leaving a greatly simplified signal conditioning circuit. A potential disadvantage of this approach is the loss of ability to dwell at a specific wavelength. To maintain this capability, a pseudo "dwell" feature is implemented where the monochromator is scanned a few nanometers about the specified wavelength in order to form the second derivative. This function repeats every few seconds to provide an essentially continuous dwell. A detailed comparison of the performance between the two methods will be made.

The second significant modification being considered is the replacement of the photomultiplier tube and its associated high voltage supply with a solid state photodetector and high-gain, low-noise amplifier. This substitution would eliminate one of the system's power supplies and reduce the size needed for the detector. A potential limitation may be that even with a high-gain amplifier the sensitivity of the photodetector will be insufficient to allow use of the narrow monochromator slits and long pathlengths needed for optimum instrument operation.

A third modification being evaluated is the use of relatively narrow mirrors in the multipass sampling cell with the cell being of narrow rectangular design and folded back forming one side of the instrument. This configuration will significantly reduce the size of the DUVAS. Another feature considered is the addition of heating elements within the cell to facilitate the cleaning of the cell when a low boiling point compound is measured. A final advantage of this cell design would be a fast response time due to reduced cell volume.

Additional features expected to be incorporated in a new design include an autocalibrate on powerup to a sharp emission line of the deuterium lamp. This will eliminate the need for the operator to insert a calibration sample and to initiate manually a wavelength calibration upon startup. Another feature being considered is the incorporation of all functions, including lamp and stepping motor power switches, under microprocessor control. All functions would be controlled by entering commands through the microcomputer keyboard. This allows the instrument to be operated totally by remote control since commands can be entered either through an external computer or through the keypad. This feature may prove to be particularly useful for remote locations where data and commands can be communicated via telephone lines. Another function to be included in the new program is a command to provide direct output of the instrument response in ppm for a limited number of compounds. The appropriate wavelengths and a calibration constant would be entered into the instrument, with concentrations being printed at prescribed intervals. These values could also be compared with a preset value to activate an alarm if the level is exceeded.

More features will likely be implemented as work on these design modifications progresses. A prototype DUVAS incorporating these changes is now under development. The result of the work should be an instrument with lower cost, reduced size, improved reliability, and increased power.

CONCLUSION

The preceding sections have described the theory, the design, the evaluation, and various applications of a derivative UV-absorption spectrometer. A prototype DUVAS has been constructed and evaluated for use in real-time, field-portable monitoring of aromatic vapors at coal conversion facilities. Many of the desired characteristics of an industrial hygiene instrument such as portability, multicomponent capability, selectivity, and sensitivity have been demonstrated. The instrument should prove useful as an industrial hygiene tool both for area monitoring and for locating leaks.

In addition to monitoring for aromatic vapors, the instrument will likely be used to measure low levels of NH_3 , SO_2 , and NO_x , along with other narrow absorption band gases. Future applications will likely involve some monitoring for indoor air pollutants. Measurement of wastewater streams from synfuel plants in an on-line mode of operation is being investigated.

Further improvements and modifications are under development which will lower the cost, increase the instrument capability, and reduce the size and weight. These parameters are particularly important in a field-portable instrument. The DUVAS described in this report helps fill the need for multicomponent real-time monitors of hazardous compounds associated with a variety of energy related technologies. It should prove a useful addition to the monitoring instruments available to the industrial hygienist and environmental scientist in evaluating the exposure of man and the environment to these potentially hazardous compounds.

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Appendix A
LIBRARY OF SECOND-DERIVATE SPECTRA

ACENAPHTHENE

ACENAPHTHYLENE

AMMONIA

BENZALDEHYDE

FORMALDEHYDE

INDAN

ISOQUINOLINE

NAPHTHALENE

1-METHYL NAPHTHALENE

2-METHYL NAPHTHALENE

1,2-DIMETHYL NAPHTHALENE

2,3-DIMETHYL NAPHTHALENE

2,6-DIMETHYL NAPHTHALENE

NITRIC OXIDE

NITROGEN DIOXIDE

OXYGEN

OZONE

PHENOL

3-METHYL PICOLINE

PYRIDINE

Appendix B
DUVAS PROGRAM LISTING

```

DDDD  U  U  V  V  A  SSSS
D  D  U  U  V  V  A  A  S
D  D  U  U  V  V  A  A  S
D  D  U  U  V  V  A  A  SSS
D  D  U  U  V  V  AAAAA  S
D  D  U  U  V  V  A  A  S
DDDD  UUUUU  V  A  A  SSSS

```

DUVAS CONTROL PROGRAM

PROTOTYPE DUVAS MONITOR TO RUN ON THE SYN-1

DUVAS.SYN SUPPORTS THE FOLLOWING DUVAS VERSIONS

VERSION 1: 1 STEP = 2.5 ANGSTROMS
 MINIMUM INTEGRATION PERIOD (HIP) = 1/20 SEC
 MIDPOINT COUNTS FOR HIP = 625

VERSION 2: 1 STEP = 1 ANGSTROM
 MINIMUM INTEGRATION PERIOD (HIP) = 1/50 SEC
 MIDPOINT COUNTS FOR HIP = 250

MAXIMUM SPECTRUM LENGTH IS 256 DATA POINTS - ONE BYTE COUNT

ADDITIONAL PROCESSING POWER MAY BE OBTAINED BY PLUGGING IN
 NEW PROCESSING EPROMS INTO THE EMPTY SYN EPROM SLOTS (2K EACH)

I/O LINES TO EXTERNAL DEVICES

PA0 - PA7 PORT: DATA BUS TO EXTERNAL PERIPHERAL

```

PA0      PIN AA-D
PA1      PIN AA-3
PA2      PIN AA-C
PA3      PIN AA-12
PA4      PIN AA-N
PA5      PIN AA-11
PA6      PIN AA-N
PA7      PIN AA-10

```

PB0 - PB7 CTRL: CONTROL LINES

```

PB0      DIR INDICATOR, 1 => INVERSE OF DEFAULT (PIN AA-L)
PB1      UNUSED (PIN AA-9)
PB2      VERSION INDICATOR, 1 => VERSION 1 (PIN AA-K)
PB3      HANDSHAKE OUTPUT FOR PARALLEL DATA (PIN AA-8)
PB4      HANDSHAKE INPUT FOR PARALLEL DATA (PIN AA-J)
PB5      STEPPING MOTOR PULSE BIT (PIN AA-7)
PB6      VFC INPUT TO 6522 TIMERS (PIN AA-M)
PB7      DIRECTION BIT, 0 => FORWARD (PIN AA-6)

```

MEMORY MAP OF DUVALS

PAGE	FUNCTION
00	ZERO PAGE DATA STORAGE
01	SYN-1 SYSTEM STACK
02	ACCESS SPECTRUM BUFFER (512 BYTES = 256 DATA POINTS)
03	"
04	BACKGROUND SPECTRUM BUFFER (512 BYTES = 256 DATA POINTS)
05	"
06	RAM EXPANSION MODULE (2048 BYTES)
07	"
08	"
09	"
0A	"
0B	"
0C	"
0D	"
0E	OSCILLOSCOPE TEXT BUFFER
0F	OSCILLOSCOPE SPECTRUM BUFFER

C000-C7FF	DUVALS CONTROL PROGRAM
C800-CFFF	RAM EXPANSION MODULE #1
D000-DFFF	RAM EXPANSION MODULE #2

SYN-1 MONITOR ENTRY POINTS

8000	MONITOR-80000	COLD ENTRY INTO MONITOR
8906	SCANPS-80906	DISPLAY FROM RESBUF
88AF	GETKEY-888AF	GET KEY FROM SYN KEYBOARD
8886	SACCRS-88886	ROUTINE TO FREE SYSTEM MEMORY
8306	INSTAT-80306	RETURN STATUS OF KEYBOARD VIA CARRY
8972	BEFP-80972	BEFP ON-BOARD BUZZER AT USER
8A47	OUTCR-80A47	OUTPUT AREG VIA SNAP VECTORS
89A3	RSOCTP-809A3	FOR RESTART/POWER INIT ROUTINE
8923	KEYQ-80923	
A402	PDBA-8A402	
88B7	VECSB-808B7	SNAP VECTORS FOR TTY
8AFF	BAUD-80AFF	SET TTY BAUD RATE
A640	DISBUF-8A640	SYN SEGMENT DISPLAY BUFFER
A645	WDIG-8A645	RIGHT MOST DIGIT
8C29	SEGS-80C29	TABLE OF SEGMENT CODES FOR ASCII
88EF	ASCII-808EF	ASCII CORRESPONDENCE FOR SEGS
8FA0	DEFTBL-80FA0	DEFAULT VALUES FOR SYSTEM RAM (SYN MONITOR)
A620	SRAB-8A620	SYSTEM RAM (SYN MONITOR)

I/O VIA DEFINITIONS

A801	PORT-8A801	DATA PORT TO EXTERNAL COMPUTER/DEVICE
A803	PRDIRB-8A803	DATA PORT DIRECTION ADDRESS
A800	CTRL-8A800	CONTROL LINES PORT
A802	CTDIRB-8A802	CONTROL PORT DIRECTION
A80E	IIR-8A80E	INTERUPT ENABLE REGISTER OF 6522
A80D	ACR-8A80D	AUXILIARY CONTROL REGISTER
A808	T2LL-8A808	TIMER 2 LATCH LOW
A809	T2CH-8A809	TIMER 2 COUNT HIGH
A80A	T1LL-8A80A	TIMER 1 LATCH LOW
A805	T1CH-8A805	TIMER 1 COUNT HIGH
A80C	PCF-8A80C	PCF FOR VIA #1 - FOR CASSETTE INTERFACE
8E20	TIM50-80E20	TIME DELAY FOR 1/50 SEC MIN. INTEGRATION PERIOD
8E20	TIM50L-80E20	
884E	TIM50H-80E4E	
C350	TIM20-8C350	TIME DELAY FOR 1/20 SEC MIN. INTEGRATION PERIOD
8850	TIM20L-80E50	
88C3	TIM20H-80E83	
A67E	IRQLO-8A67E	IRQ RAM VECTOR
A67F	IRQHI-8A67F	
8804	DISABL-80804	SET INTERRUPT DISABLE BIT
8800	DRDY-80800	DATA READY LINE FROM SYN
8810	DRCDV-80810	DATA RECEIVED LINE FROM EXTERNAL PERIPHERAL
887F	DRRDY-8087F	DATA NOT READY MASK

AUTO CALIBRATION DEFINITIONS

5F04	ACBEG=24'00	ASSUMED POSITION FOR AUTO CAL
0004	ACBEG1=3	
0057	ACBEG2=50F	
6204	ACBAY=25300	CALIBRATION PEAK POSITION
0004	ACBAYL=504	
0062	ACBAYH=562	
6704	ACEND=26500	END POINT FOR AUTOCAL SCAN
0004	ACENDL=504	
0067	ACENDH=567	

MODULE DEFINITIONS

0055	EXPFLG=555	FLAG FOR FIRST BYTE OF EXPANSION ROMS (EPROMS)
0000	EXPDL=500	RAN MODULE BEGINING - 5600
0006	EXPDB=505	
C800	CTAB1=5C800	EXTRA EPROM #1 - P1 DEVICE (2K)
D000	CTAB2=5D000	EXTRA EPROM #2 - P2 DEVICE (2K)
0600	CTABH=5600	RAN COMMAND EXPANSION

SPECTRUM BUFFER DEFINITIONS

0000	DSUFL0=500	SPECTRUM DATA BUFFER
0002	DSUFL1=502	
0000	BCKGDL=500	BACKGROUND SPECTRUM BUFFER
0004	BCKGDH=504	

KEY AND DISPLAY CODE DEFINITIONS

0047	GO=547	CODE FOR GO KEY
0000	CR=500	CODE FOR CR KEY
002B	PLUS=52B	CODE FOR + KEY
0044	PERIOD=544	CODE FOR D - DECIMAL POINT
002E	POINT=52E	CODE FOR ASCII DECIMAL POINT
0043	CLEAR=543	CODE FOR C - CLEAR DISPLAY IN FETCH ROUTINE
0000	NOKEY=500	CODE FOR NO KEY DEPRESSED
003E	RIGHT=53E	CODE FOR RIGHT ARROW (-->)
0073	P PROMPT=573	SEGMENT CODE FOR P PROMPT
0040	HYPH=540	SEGMENT CODE FOR HYPHUS
00B9	C PROMPT=5B9	SEGMENT CODE FOR C PROMPT
00D3	QUERY=5D3	SEGMENT CODE FOR ? PROMPT
002D	HYPHUS=52D	CODE FOR - KEY

```

:
:
: PAGE ZERO DEFINITION
:
: *=50000
:
:
:

```

```

0000 00      WASTE .BYTE 0      RESET SETS THIS BYTE TO $6F

```

```

: SPECTRUM PARAMETERS

```

```

PARAM
0001 20 4E    STRT .WORD 20000  START OF SPECTRUM (*10)
0003 E8 03    LEN .WORD 1000   LENGTH OF SPECTRUM
0005 19 00    RESOL .WORD 25   RESOLUTION
0007 64 00    SPED .WORD 100   SPEED OF SPECTROMETER
0009 0A 00    ATEN .WORD 10    ATTENUATION

```

```

C001          SORTL=STRT
0002          STRTH=STRT+1
0003          LENLO=LEN
0004          LENHI=LEN+1
0007          SPEDL=SPED
0008          SPEDE=SPED+1

```

```

: FORMATTED SPECTRUM PARAMETERS

```

```

GCPARM
0008 20 02    GSTRT .WORD 800   STRT (FOR VERSION 1)
0000 28 00    GLEN .WORD 40     LEN
000P 01 00    GRESOL .WORD 1    RESOL
0011 05 00    GSPED .WORD 5     50/SPEED

```

```

0008          GSTRTL=GSTRT
0009          GSTRTH=GSTRT+1
000E          GLENLO=GLEN
000E          GLENHI=GLEN+1
0011          GSPEDL=GSPED
0012          GSPEDH=GSPED+1

```

```

LOC
0013 00      LOCLO .BYTE 0      CURRENT SPECTROMETER SETTING - SET BY CAL
0014 00      LOCHI .BYTE 0

```

```

TPARAM
0015 20 4E    TSTRT .WORD 20000  TEMPORARY PARAMETER STORAGE FOR BACKGROUND
0017 E8 03    TLEN .WORD 1000
0019 19 00    TRESOL .WORD 25
001B 64 00    TSPED .WORD 100
001D 0A 00    TATEN .WORD 10

```

```

TEMP
001F 00      TEMPLO .BYTE 0      FOR INTERMEDIATE RESULTS
0020 00      TEMPHI .BYTE 0
0021 00      TEMPSH .BYTE 0      (FOR TRIPLE PRECISION)
0022 00      SAVE
0023 00      SAVELC .BYTE 0      SECONDARY STORAGE
0024 00      SAVERH .BYTE 0
0024 00      HOLD
0025 00      HOLDL .BYTE 0      USED BY SECNDS
0025 00      HOLDH .BYTE 0
0026 00      INDEX
0027 00      INDEX1 .BYTE 0      ARRAY INDICIES
0027 00      .BYTE 0      (ALSO ADDRESS POINTERS)
0028 00      INDEX2 .BYTE 0
0029 00      .BYTE 0
002A 00      INDEX3 .BYTE 0
002B 00      .BYTE 0

```

```

COUNT
002C 00      COUNT1 .BYTE 0      LOOP COUNTERS
002D 00      COUNT2 .BYTE 0
002E 00      COUNT3 .BYTE 0

```

002F 00	NUMPTS NUMPTL .BYTE	0	NUMBER OF DATA POINTS IN SPECTRUM
0030 00	NUMPTH .BYTE	0	
0031 00	DEST DESTLC .BYTE	0	
0032 00	DESTHI .BYTE	0	
; VERSION DEPENDENT CONSTANTS			
INITC			
0033 00	GEAR GEARLO .BYTE	0	NORMALIZATION FACTOR FOR FORMAT
0034 00	GEARHI .BYTE	0	- MINIMUM RESOLUTION OF THE DUVAS
0035 00	HIDBAS HIDBLC .BYTE	0	HIDPT FOR ONE INTEGRATION PERIOD
0036 00	HIDBHI .BYTE	0	
0037 00	TISELC .BYTE	0	TIME DELAY CONSTANT FOR MIN. INTEGRATION PERIOD
0038 00	TISEHI .BYTE	0	
0039 00	HID HID0 HIDLO .BYTE	0	FREQUENCY COUNT FOR ZERO VOLTAGE
	HID1		
003A 00	HIDHI .BYTE	0	
003B 00	HID2 .BYTE	0	32 BIT EXTENSION FOR SMOOTH
003C 00	HID3 .BYTE	0	
003D 00	MAX MAXLO .BYTE	0	SPECTRUM MAXIMUM VALUE
003E 00	MAXHI .BYTE	0	
003F 00 00	MAXPOS .WORD	0	LOCATION (NORMALIZED) OF SPECTRUM MAXIMUM VALUE + RESOLUTION / GEAR
;			
0041 00	SPECT SPECTL .BYTE	0	POINTER TO SPECTRUM BUFFER
0042 00	SPECTH .BYTE	0	
0043 00	BACK BACKLC .BYTE	0	POINTER TO BACKGROUND BUFFER
0044 00	BACKHI .BYTE	0	
0045 00	TDATA TDATAL .BYTE	0	TEMPORARY SAMPLED DATA POINT
0046 00	TDATAH .BYTE	0	
0047 00	DATA DATA0 .BYTE	0	SAMPLED DATA POINT
	DATA1		
0048 00	DATAH .BYTE	0	
0049 00	DATA2 .BYTE	0	
004A 00	DATA3 .BYTE	0	
004B 00	DIR .BYTE	0	DIRECTION JS BIT 7: 0 => FORWARD
004C 00	TDIR .BYTE	0	TEMPORARY DIRECTION
004D 00	NUMLO .BYTE	0	STORAGE FOR DIVISION ROUTINE
004E 00	NUMHI .BYTE	0	
004F 00	NUMSGN .BYTE	0	(FOR TRIPLE PRECISION)
0050 00	CONLO .BYTE	0	
0051 00	CONHI .BYTE	0	
0052 00	CONSGN .BYTE	0	(FOR TRIPLE PRECISION)
0053 00	DIVCNT .BYTE	0	COUNTER FOR DIVIDE ROUTINE

0054 00	RES0				
	NUMBUF	.BYTE	0		BUFFER FOR DIGITS IN BIN -> BCD
0055 00	RES1				
		.BYTE	0		AND STORAGE FOR MULT ROUTINE
0056 00	RES2				
		.BYTE	0		
0057 00	RES3				
0058 00		.BYTE	0		
		.BYTE	0		
0059 00	CON0				
	CONBPL	.BYTE	0		CONSTANT BUFFER FOR INVERSE DIVISION
005A 00	CON1				
	CONBPH	.BYTE	0		AND FOR MULT ROUTINE
005B 00	CLKPLG	.BYTE	0		0 => STAY IN LOOP; -1 => STOP VFC SAMPLE
005C 00	INPLG	.BYTE	0		IMMEDIATE TRANSFER FLAG ON PARALLEL PORT
005D 00	SPHOVE	.BYTE	0		0 => MOVE CHND; -1 => EXCHANGE CHND
005E 00	EXEC				
	EXECCLC	.BYTE	0		COMMAND EXECUTION ADDRESS
005F 00	EXECCHI	.BYTE	0		
0060 00	CHND	.BYTE	0		SAVE LAST USER COMMAND
0061 00 00	CPOINT	.WORD	0		BASE ADDRESS OF CURRENT ROM COMMAND LIST
0063 00	STIME				
	STIME1	.BYTE	0		DELAY COUNT FOR SECONDS
0064 00	STIMEH	.BYTE	0		
0065 00	TDELAY	.BYTE	0		STORAGE FOR LDELAY
0066 00	TINEPG	.BYTE	0		FLAG FOR TIME SPECTRUM
0067 00	DWLLPG	.BYTE	0		FLAG FOR A DWELL ACCESS
0068 00	DECPLG	.BYTE	0		FLAG FOR DECIMAL POINT IN USER INPUT
0069 00	RHODPG	.BYTE	0		0=> INPUT A RAM MODULE
					-1 => OUTPUT A RAM MODULE
006A 00	AVE	.BYTE	0		NUMBER OF POINTS TO AVERAGE IN AVERAGE MODE
006B 00	AVECHT	.BYTE	0		COUNTER FOR AVERAGE MODE
006C 00	AVEPLG	.BYTE	0		-1 => AVERAGE MODE
006D 00	ACCAVL	.BYTE	0		ACCUMULATE AVERAGE LOW
006E 00	ACCAVE	.BYTE	0		ACCUMULATE AVERAGE HIGH
006F 00	DC				
0070 00	DCLO	.BYTE	0		DWELL WITH CONCENTRATION CONSTANTS
0071 00	DCHI	.BYTE	0		
0072 00	BGLO	.BYTE	0		
	BGHI	.BYTE	0		
0073 00 00	COEFTB	.WORD	0		COEFFICIENT TABLE ADDRESS FOR CONVOLUTION
0075 00	COFPRK	.BYTE	0		COEFFICIENT MASK FOR COMPLIMENT
0076 00 00	SHODAT				
	S1	.WORD	0		TEMPORARY DATA STORAGE FOR SMOOTH
0078 00 00	S2	.WORD	0		
007A 00 00	S3	.WORD	0		
007C 00 00	S4	.WORD	0		
007E 00 00	S5	.WORD	0		
0080 00 00	RESNOL				
	R1	.WORD	0		RESULT OF S(I)*COEF(I)
0082 00 00	R2	.WORD	0		
0084 00 00	R3	.WORD	0		
0086 00 00	R4	.WORD	0		
0088 00 00	R5	.WORD	0		
	RESNO				
008A 00	RESNOL	.BYTE	0		RESULT OF CONVOLUTION
008B 00	RESNOH	.BYTE	0		
008C 00	NVP				
	NVPLO	.BYTE	0		
008D 00	NVPHI	.BYTE	0		
008E 00	SIGNPG	.BYTE	0		

START	LDX	08FF	INITIALIZE 6502 STACK POINTER
	TXS		
INITS	LDA	08CC	FOR AUDIO CASSETTE INTERFACE
	STA	PCN1	
	LCA	0804	SET STATUS, INTERRUPTS DISABLED
	PLA		
	PLP		
	JSR	SACCES	ALLOW ACCESS TO SYS SYSTEM MEMORY
DPTXPR	LDX	085F	INIT SYSTEM RAM FROM DEFAULT BLOCK
DPTXLP	LDA	DPTBLK,X	FETCH SYS SYSTEM DEFAULT
	STA	SRAM,X	PUT IN SYSTEM RAM
	DEX		
	BPL	DPTXLP	
	LDA	07	CHANGE DEVC/BAUD RATE
	JSR	06TCHR	BEEP
HOWENT	CLD		CLEAR DECIMAL MODE
	LDA	0800	CLEAR ZERO PAGE ABOVE SPECTRUM
	LDX	081F	PARAMETERC
INITZF	STA	0,X	
	INX		
	BNE	INITZF	
	JSR	VERSION	SET PROPER VERSION CONSTANTS IN RAM

C02C	A9	00		INITP	LDA	#S00	
C02E	8D	03	A8		STA	PRTDIR	SET PORT TO INPUT
C031	A9	28			LDA	#S28	SET CTRL LINES - HANDSHAKE, STEP HIGH
C033	8D	00	A8		STA	CTRL	
C036	A9	A8			LDA	#SAB	SET CTRL LINES DATA DIRECTION
C038	8D	02	A8		STA	CTDRIR	

C03B 20 0C C5	EXECLE JSR	PROMPT	PROMPT WITH C, CLEAR ARG
C03E 20 05 C4	CHNDIN JSR	KEYIN	WAIT FOR USER INPUT
C041 F0 1D	BEQ	DOCHND	CR - GO DO CONHAND
C043 C9 2B	CHP	OPUS	ARGUMENT TO FOLLOW COMMAND ?
C045 F0 16	BEQ	INARG	YES, PICK IT UP IN TEMP

C047	85	60		STA	CHND	SAVE THIS COMMAND FOR LATER SEARCH
C049	A2	00		LDX	#0	
C04B	DD	EF	8B	LOOKCD	ASCII,X	LOOK FOR ASCII CODE
C04E	F0	03		BEO	GETSEG	FOUND MATCH
C050	E8			INX		NEXT ASCII CODE
C051	D0	F8		BNE	LOOKCD	TRY AGAIN
C053	BD	29	8C	GETSEG	SEG,X	PICK UP CORRESPONDING SEGMENT CODE
C056	09	80		ORA	#80	SET PERIOD FOR COMMAND PROMPT
C058	BD	40	A6	STA	DISBUF	INSERT INTO LEFT CHARACTER
C05B	30	E1		BNI	CHNDIN	(ALWAYS BRANCH)

C05D 20 P1 C2	INARG JSR	PETCHP	GET INPUT PARAMETER
C060 A2 06	DOCHND LDX	\$S06	OFFSET INTO CHND TABLE ADDRESSES
C062 BD 9E C0	CHDADE LDA	CTABLE,X	GET LOW BYTE OF POINTER
C065 85 61	STA	CPOINT	PUT IN COMMAND POINTER
C067 .D 9F C0	LDA	CTABLE+1,X	GET HI BYTE OF POINTER
C06A 85 62	STA	CPOINT+1	
C06C A0 00	LDY	\$S00	INDEX INTO COMMAND LIST
C06E B1 61	ROHTEST LDA	(CPOINT),Y	TEST FOR EXTRA ROH (EPROM)
C070 C9 55	CHP	\$P0HPLG	COMPARE TO PATTERN OF X01010101
C072 D0 0E	BNE	NOCHND	NOT PATTERN => ROH NOT THERE
C074 C8	INY		PATTERN MATCH, POINT TO TABLE
C075 B1 61	TSTCHD LDA	(CPOINT),Y	GET COMMAND CHAR INDIRECT THEN INDEXED
C077 F0 09	BEQ	NOCHND	NOT IN THIS COMMAND LIST
C079 C5 60	CHP	CHND	= TO USER COMMAND ?
C07B F0 0E	BEQ	SETADR	YES, GET ROUTINE ADDRESS
C07D C8	INY		NO, ON TO THE NEXT COMMAND
C07E C8	INY		
C07F C8	INY		
C080 D0 F3	BNE	TSTCHD	FINITE COMMAND LIST !
C082 CA	NOCHND DEX		YES, POINT TO ADDRESS OF COMMAND LIST
C083 CA	DEX		
C084 10 DC	BPL	CHDADE	SEARCH NEW LIST
C086 20 68 C6	CERROR JSR	ERROR	USER COMMAND NOT RECOGNIZED
C089 B0 B0	BCS	EXECLP	
C08B C8	SETADR INY		POINT TO ROUTINE ADDRESS LOW
C08C B1 61	LDA	(CPOINT),Y	
C08E 85 5E	STA	EXECLO	
C090 C8	INY		POINT TO ROUTINE ADDRESS HIGH
C091 B1 61	LDA	(CPOINT),Y	
C093 85 5F	STA	EXECHI	
C095 20 9B C0	JSR	GODOIT	EXECUTE AN INDIRECT JSR
C098 4C 3B C0	JMP	EXECLP	PROCESS THE NEXT COMMAND
C09B 6C 5E 00	GODOIT JMP	(EXEC)	INDIRECT BRANCH TO COMMAND ROUTINE
C09E 00 D0	CTABLE .WORD	CTAB2	EXTRA ROH #2 COMMAND LIST ADDRESS
C0A0 00 C8	.WORD	CTAB1	EXTRA ROH #1 COMMAND LIST ADDRESS
C0A2 00 06	.WORD	CTABR	RAH COMMAND LIST ADDRESS
C0A4 A6 C0	.WORD	CTABO	DUVAS ROH COMMAND LIST

.....

COMMAND TABLE.

GENERAL FORM OF EACH ENTRY

<COMMAND CODE>
<ROUTINE ADDRESS LOW>
<ROUTINE ADDRESS HIGH>

0

COA6 55	CTAB0 .BYTE	\$55	ROB FLAG FOR ROB EXISTENCE TEST
COA7 41	.BYTE	\$41	ACCESS A SPECTRUM - A
COA8 F4 C0	.WORD	ACCESS	
COA9 36	.BYTE	\$36	ACCESS A SPECTRUM WITH IMMEDIATE TRANSFER - 6
COAB F2 C0	.WORD	ACCIN	
COAD 44	.BYTE	\$44	VISUAL DWELL MODE - D
COAE DA C0	.WORD	DWELL	
COB0 37	.BYTE	\$37	DWELL AND TRANSFER ACROSS THE PARALLEL PORT - 7
COB1 D8 C0	.WORD	DULLIN	
COB3 30	.BYTE	\$30	OUTPUT A SPECTRUM - 0
COB4 B9 C1	.WORD	OUTDAT	
COB6 33	.BYTE	\$33	GET ACCESS CONSTANTS FROM USER - 3
COB7 1B C4	.WORD	YILARG	
COB9 2D	.BYTE	\$2D	SUBTRACT BACKGROUND SPECTRUM - "-"
COBA CA C1	.WORD	SUBBAK	
COBC 45	.BYTE	\$45	EXCHANGE BACKGROUND AND ACCESS SPECTRA - E
COBD F5 C1	.WORD	EXCHSP	
COBF 43	.BYTE	\$43	COPY ACCESS SPECTRUM IN BACKGROUND - C
COC0 2F C2	.WORD	SAVSPC	
COC2 32	.BYTE	\$32	SEND ACCESS PARAMETERS BACK TO PET - 2
COC3 B8 C2	.WORD	UPLOAD	
COC5 31	.BYTE	\$31	GET A SPECTRUM FROM THE PARALLEL PORT - 1
COC6 33 C2	.WORD	GETSPT	
COC8 34	.BYTE	\$34	AUTOCALIBRATE THE SPECTROMETER - 4
COC9 4B C2	.WORD	AUTOCL	
COCB 4A	.BYTE	\$4A	JUMP TO MONITOR - J
COCC 00 80	.WORD	MONITE	
COCF 42	.BYTE	\$42	TIME SPECTRUM - B
COD1 E0 C0	.WORD	TINES	
COD2 38	.BYTE	\$38	TIME SPECTRUM WITH IMMEDIATE TRANSFER - 8
COD3 DE C0	.WORD	TINESI	
COD4 46	.BYTE	\$46	FIX THE CALIBRATION TO DISPLAY - F
COD5 A0 C2	.WORD	CALOW	
COD7 00	.BYTE	0	COMMAND TABLE TERMINATOR

GENERALIZED ACCESS LOOP:

- 1) ACCESS - A. (ALL FLAGS = 0)
- 2) ACCESS WITH IMMEDIATE TRANSFER - 6. (INFLG=SPF)
- 3) TIME ACCESS - B. (TIMEPG=SPF)
- 4) TIME ACCESS WITH IMMEDIATE TRANSFER - 8. (TIMEPG=SPF, INFLG=SPF)
- 5) DWELL - D. (DWLLPG=SPF)
- 6) DWELL WITH IMMEDIATE TRANSFER - 7. (DWLLPG=SPF, INFLG=SPF)

```

CODE C6 5C      DWLLIN DEC      INFLG      DWELL IMMEDIATE - 7.

CODE C6 67      DWELL DEC      DWLLPG      DWELL ACCESS - D.
CODE C6 29      BHI      ACCESS2      ENTER GENERAL ACCESS CODE

CODE C6 5C      TIMESI DEC      INFLG      TIME ACCESS IMMEDIATE - 8.
CODE A5 1F      TIMESI LDA      TEMPLO      TIME ACCESS - B.
CODE 05 63      STA      STINEL      MOVE ARGUMENT*10 INTO TIME BUFFER
CODE A5 20      LDA      TEMPNI
CODE 05 64      STA      STINEN
CODE 05 1F      ORA      TEMPLO      NON ZERO ?
CODE D0 Q2      BNE      OKTIME      YES, USER SUPPLIED TIME
CODE E6 63      INC      STINEL      NO, SET TO DEFAULT .1 SEC (1/10)
CODE C6 66      OKTIME DEC      TIMEPG      SET TIME ACCESS FLAG
CODE C6 15      BHI      ACCESS2      ENTER GENERAL ACCESS CODE

CODE C6 5C      ACCIN DEC      INFLG      ACCESS IMMEDIATE - 6.

;
; NORMAL ACCESS ENTRY - A. (ALL FLAGS ZERO)
;
CODE A5 1F      ACCESS LDA      TEMPLO      ARGUMENT FOR AVERAGE NODE ?
CODE 05 20      ORA      TEMPNI
CODE F0 0D      BEQ      ACCESS2      NO, NORMAL ACCESS
CODE A9 0A      LDA      #10      YES, SCALE # OF AVERAGES BY 10
CODE A0 00      LDY      #800      (RKB CONVENTION)
CODE A2 1F      LDX      #TEMP
CODE 20 C9 C4   JSR      DIVIDE
CODE 05 6A      STA      AVE
CODE C6 6C      DEC      AVEFLG      LIMIT OF 255 POINTS FOR AVERAGE NODE
                                      SET AVERAGE NODE FLAG

C107 20 18 C4   ACCESS2 JSR      FILLARG      FILL SPECTRUM PARAMETERS
C10A 20 61 C4   QWKACC JSR      FORMAT      FORMAT SPECTRUM PARAMETERS
C10D 20 2D C5   JSR      CDISPH      CLEAR DISBUF, ACC SET TO ZERO
C110 05 3D      STA      MAXLO      ZERO MAXIMUM BUFFER
C112 05 3E      STA      MAXHI
C114 24 67      BIT      DWLLPG      DWELL NODE ?
C116 30 02      BHI      NOPNT      YES - NO DISPLAY PROMPT
C118 A9 F7      LDA      #SP7      NO - SET A. FOR ACCESS
C11A 8D 80 A6   NOPNT STA      DISBUF      INSERT PROMPT
C11D 20 C3 C2   JSR      SETSPNT      SET SPECTRUM POINTERS, MIDPOINT
C120 20 71 C6   JSR      SETST      MOVE THE DOVAS TO THE BEGINNING
C123 A9 00      LDA      #800      SET TO FORWARD DEFAULT DIRECTION
C125 05 4B      STA      DIR      SET DIR TO FORWARD
C127 A0 F7      LDY      #SP7
C129 20 88 C5   JSR      DELAY      WAIT ABOUT 1/3 SECOND

```



```

:      COMMAND: 0.
:
:      OUTPUT A SPECTRUM ACROSS THE PARALLEL INTERFACE WITH HANDSHAKE

```

```

C1B9 20 B8 C2      OUTDAY JSR   UPLOAD      SEND ACCESS PARAMETERS TO PET
C1BC 20 C3 C2      JSR   SETSPT        SET SPECTRUM POINTERS
C1BF 20 9D C7      OUTDLP JSR   OUTPUT     OUTPUT DATA ASPECT
C1C2 20 BA C2      JSR   INCSPT        INCREMENT POINTERS ONE DATA POINT
C1C5 C6 2F         DEC   NUMPTS       ALL DATA POINTS ?
C1C7 D0 F6         BNE   OUTDLP        NO, DO NEXT POINT
C1C9 60            RTS                YES, NEXT COMMAND

```

```

:      COMMAND: -.
:
:      SUBTRACT THE BACKGROUND SPECTRUM FROM THE ACCESS SPECTRUM

```

```

C1CA 20 C3 C2      SUBBAK JSR   SETSPT        SET SPECTRUM POINTERS
C1CB A0 00          SUBBKL LDY   #000        FORM SPECTRUM - BACKGROUND
C1CF 38            SEC                SUBTRACT LOW ORDER
C1D0 B1 41          LDA   (SPECTL),Y
C1D2 F1 43          SBC   (BACKLO),Y
C1D4 91 41          STA   (SPECTL),Y
C1D6 C8            INY                SUBTRACT HIGH ORDER
C1D7 B1 41          LDA   (SPECTL),Y
C1D9 F1 43          SBC   (BACKLO),Y
C1DB 91 41          STA   (SPECTL),Y
C1DD A0 00          LDY   #000        * MIDPOINT
C1DF 18            CLC
C1E0 B1 41          LDA   (SPECTL),Y
C1E2 65 39          ADC   MIDLO
C1E4 91 41          STA   (SPECTL),Y
C1E6 C8            INY
C1E7 B1 41          LDA   (SPECTL),Y
C1E9 65 3A          ADC   MIDHI
C1EB 91 41          STA   (SPECTL),Y
C1ED 20 DA C2      JSR   INCSPT        INCREMENT POINTERS ONE DATA POINT
C1F0 C6 2F         DEC   NUMPTS       ALL DATA POINTS ?
C1F2 D0 99         BNE   SUBBKL        NO, DO NEXT POINT
C1F4 60            RTS                YES, NEXT COMMAND

```

```

:      COMMAND: 2.
:
:      EXCHANGE THE TWO SPECTRUM BUFFERS

```

```

C1F5 A9 00          EXCHSF LDA   #00          SET SPROVE FLAG TO EXCHANGE CODE

```

```

:      COMMON EXCHANGE / COPY CODE

```

```

C1F7 85 5D          MOVEBT STA   SPROVE
C1F9 20 C3 C2      EXCHLP JSR   SETSPT        SET SPECTRUM POINTERS
C1FC A0 00          LDY   #000        EXCHANGE/MOVE SPECTR <--> BACK
C1FE 20 20 C2      JSR   EXCHBT        EXCHANGE/MOVE LO BYTE
C201 C8            INY
C202 20 20 C2      JSR   EXCHBT        EXCHANGE/MOVE HI BYTE
C205 20 DA C2      JSR   INCSPT        INCREMENT POINTERS ONE DATA POINT
C208 C6 2F         DEC   NUMPTS       ALL DATA POINTS ?
C20A D0 F0         BNE   EXCHLP        NO, DO NEXT POINT

C20C A2 09          EXCHP  LDY   #009        YES, MOVE PARAMETERS
C20E 05 01          LDA   PARAM,X      PICK UP ACCESS PARAMETER
C210 A8            TAY                SAVE COPY

```

C211 24 5D	BIT	SPROVE	COPY ONLY ?
C213 30 04	BHI	NOEXCP	YES
C215 B5 15	LDA	TPARAM, X	NO - MOVE BACKGROUND PARAMETER
C217 95 01	STA	PARAM, X	
C219 98	NOEXCP	TYA	GET SAVED COPY
C21A 95 15	STA	TPARAM, X	COPY PARAM TO TPARAM
C21C CA	DEI		ALL PARAM BYTES ?
C21D 19 EF	BPL	EXCHP	NO
C21F 60	RTS		YES

: EXCHANGE OR MOVE A BYTE FROM SPECT TO BACK

C220 B1 41	EXCHBT	LDA	(SPECTL), Y	
C222 AA		TAX		SAVE FOR EXCHANGE
C223 24 5D		BIT	SPROVE	MOVE OR EXCHANGE
C225 30 04		BHI	NOEXCH	SIMPLY MOVE SPECTL INTO BACK
C227 B1 43		LDA	(BACKLO), Y	MOVE BACK INTO SPECTL
C229 91 41		STA	(SPECTL), Y	
C22B 8A	NOEXCH	TYA		
C22C 91 43		STA	(BACKLO), Y	ALWAYS MOVE SPECTL TO BACK
C22E 60		RTS		

: COMMAND: C.

: SET FLAG FOR COPY ACCESS SPECTRUM INTO BACKGROUND

C22F A9 FF	SAVSPC	LDA	03FF	SET FLAG TO -1
C231 30 C4		BHI	NOVENT	JMP TO MOVE ENTRY

: COMMAND: 1.

: RECEIVE A SPECTRUM FROM THE PARALLEL DEVICE

C233 20 1B C4	GETSPT	JSR	FILARG	INPUT THE SPECTRUM PARAMETERS
C236 20 C3 C2		JSR	SETSPT	SET SPECTRUM POINTERS
C239 20 21 C3	GETSL1	JSR	PARBIN	GET LOW BYTE FROM USER
C23C 85 47		STA	DATAL	
C23E 20 21 C3		JSR	PARBIN	GET HIGH BYTE FROM USER
C241 85 48		STA	DATAN	
C243 20 59 C6		JSR	PUTDAT	PUT DATA INTO SPECTRUM BUFFER
C246 C6 2F		DEC	NURPTS	ALL OF THE DATA POINTS ?
C248 D0 EF		BNE	GETSL1	NO
C24A 60		RTS		

COMMAND: 4.

FORM AN AUTO CALIBRATION BASED UPON A SAMPLE WITH A LARGE
PEAK AT 2530 ANGSTROMS. ASSUME THAT DUVAS IS SET AT 2050
ANGSTROMS.

A DEFAULT ARGUMENT OF ZERO WILL AUTOCALIBRATE THE DUVAS
AT A SPEED OF 10 ANGSTROMS PER SECOND, ELSE THE
ARGUMENT IS THE CALIBRATE SPEED.

NOTE: THE MAXIMUM CALIBRATION SPEED IS 25 ANGSTROMS / SECOND

C240 A5 1P	AUTOCL	LDA	TEMPLO	SAVE USER ARGUMENT
C240 A8		PEA		
C242 A2 09		LDX	0509	
C250 B0 A2 C2	SETCP	LDA	CALPAR,X	
C253 95 01		STA	PARAH,X	
C255 CA		DEI		
C256 10 P0		BPL	SETCP	
C258 60		PLA		GET USER SPEED ARGUMENT (< 25.5)
C259 P0 02		BEQ	ACDEFS	USE AUTOCAL DEFAULT SPEED
C258 05 07		STA	SPEEDL	ELSE INSERT AS AUTOCAL SPEED
C259 A5 33	ACDEFS	LDA	GEARLO	INSERT HIS RESOLUTION FOR VERSION
C25F 05 05		STA	RESOL	
C261 A9 04		LDA	0ACDEGL	SET THE ASSUMED INITIAL POINT
C263 05 1P		STA	TEMPLO	
C265 A9 5P		LDA	0ACDEGH	
C267 05 20		STA	TEMPHI	
C269 20 A0 C2		JSR	CALON	NORMALIZE BY GEAR FOR BOTH VERSIONS
C270 20 0A C1		JSR	QWKACC	DO THE SCAN, GET POSITION OF MAX
C26P A9 04		LDA	0ACNAYL	NORMALIZE EXPECTED PEAK POSITION
C271 05 1P		STA	TEMPLO	
C273 A9 62		LDA	0ACNAYH	
C275 05 20		STA	TEMPHI	
C277 20 A0 C2		JSR	CALON	
C27A 10		CLC		FORM DIFF = (MAXPOS - 1) - ACNAY
C27B A5 3P		LDA	MAXPOS	(THE MAXIMUM LOCATION WAS STEPPED
C27D 25 13		SBC	LOCLO	PRIOR TO THE SAVING OF LOC)
C27F 05 3P		STA	MAXPOS	
C281 A5 40		LDA	MAXPOS+1	
C283 25 14		SBC	LOCNI	
C285 05 40		STA	MAXPOS+1	
C287 A9 04		LDA	0ACENDL	NORMALIZE ASSUMED ENDPOINT
C289 05 1P		STA	TEMPLO	
C28B A9 67		LDA	0ACENDH	
C28D 05 20		STA	TEMPHI	
C28P 20 A0 C2		JSR	CALON	
C292 30		SEC		FORM LOC = ACEND - DIFF
C293 A5 13		LDA	LOCLO	
C295 25 3P		SBC	MAXPOS	
C297 05 13		STA	LOCLO	
C299 A5 14		LDA	LOCNI	
C29B 25 40		SBC	MAXPOS+1	
C29D 05 14		STA	LOCNI	
C29F 60		RTS		

COMMAND: P.

FIX THE CALIBRATION TO THE VALUE IN TEMP

NOTE: THE ARGUMENT OF A USER COMMAND IS CONVERTED TO BINARY IN TEMP

C2A0 A5 33	CALOW	LDA	GEARLO	FORMAT ARG TO LOC BY GEAR
C2A2 A4 34		LDY	GEARHI	
C2A4 A2 1F		LDI	STEMP	POINT TO DIVIDEND
C2A6 20 C9 C4		JSR	DIVIDE	NORMALIZE USER INPUT
C2A9 05 13		STA	LOCLO	STORE NORMALIZED POSITION
C2AB 04 14		STY	LOCHI	
C2AD 60		RTS		

TABLE OF CALIBRATION PARAMETERS FOR VERSION 1

C2AE C0 5D	CALP:R	.WORD	24000	2400.0	START
C2B0 C4 09		.WORD	2500	250.0	LENGTH
C2B2 19 00		.WORD	25	2.5	RESOLUTION
C2B4 32 00		.WORD	50	5.0	SPEED
C2B6 0A 00		.WORD	10	1.0	ATTENUATION

COMMAND: 2.

UPLOAD ROUTINE - P(5) THRU P(4), HIGH BYTE THEN LOW BYTE

C2B8 A2 09	UPLOAD	LDI	0309	
C2BA B5 01	UPDLPL	LDA	PARAH,X	GET THE BYTE
C2BC 20 B3 C7		JSR	PARBYT	SEND ACROSS THE PARALLEL BUS
C2BF CA		DEI		
C2C0 10 F8		BPL	UPDLPL	
C2C2 60		RTS		

SETSPT: INITIALIZE POP SPECTRUM MANIPULATION

- 1) FORMAT THE ACCESS PARAMETERS
- 2) INITIALIZE (SET) SPECTRUM POINTERS:
SPECT <-- DBUFLO,DBUFHI (\$0200)
BACK <-- BCKGDL,BCKGDH (\$0400)
- 3) COMPUTE 32 BIT MIDPOINT

C2C3 20 61 C4	SETSPT	JSR	FORMAT	RE-FORMAT THE ACCESS SPECTRUM PARAMS
C2C6 A9 00		LDA	0DBUFLO	POINT SPECT TO ACCESS SPECTRUM
C2C8 05 41		STA	SPECTL	
C2CA A9 02		LDA	0DBUFHI	
C2CC 05 42		STA	SPECTH	
C2CE A9 00		LDA	0BCKGDL	POINT BACK TO BACKGROUND SPECTRUM
C2D0 05 43		STA	BACKLO	
C2D2 A9 04		LDA	0BCKGDH	
C2D4 05 44		STA	BACKHI	
C2D6 20 0C C6		JSR	MIDPT	COMPUTE THE 32 BIT (1) MIDPOINT
C2D9 60		RTS		

UPDATE THE SPECTRUM POINTERS, SPECT, BACK, TO THE NEXT POINT

- 1) BACK <-- BACK + 2
- 2) SPECT <-- SPECT + 2 (ALTERNATE ENTRY, INCACC)

C2DA 18	INCSPY	CLC		
C2DB A5 43		LDA	BACKLO	UPDATE BACKGROUND POINTER
C2DD 69 02		ADC	0302	(16 BIT DATA POINTS)
C2DF 05 43		STA	BACKLO	
C2E1 90 02		BCC	INCACC	NO CARRY
C2E3 E6 44		INC	BACKHI	CARRY
C2E5 18	INCACC	CLC		
C2E6 A5 41		LDA	SPECTL	UPDATE ACCESS POINTER
C2E8 69 02		ADC	0302	(16 BIT DATA POINTS)
C2EA 05 41		STA	SPECTL	
C2EC 90 02		BCC	INCRET	NO CARRY
C2EE E6 42		INC	SPECTH	CARRY
C2F0 60	INCRET	RTS		

GENERAL PARAMETER INPUT

SPECIAL CHARACTERS:

CR - CONVERT DISPLAY TO NUMBER IN TEMP
 C - CLEAR THE DISPLAY
 -> - SHIFT DISPLAY RIGHT ONE DIGIT
 D - ADD DECIMAL POINT ON RIGHT MOST DIGIT

NOTE1: ALL OTHER KEYS ARE DISPLAYED BY SYM DISPLAY CONVENTIONS. HOWEVER, ARGNUM WILL TREAT NON DIGIT DISPLAY CODES AS ZERO.

NOTE2: A DECIMAL POINT IS ALLOWED IN ONLY THE TWO RIGHT MOST NUMERICAL DIGITS.

C2F1 20 05 C4	FETCHF	JSR	KEYIN	GET A USER INPUT
C2F4 F0 51		BEQ	PNRET	CR - FORM NUMBER AND RETURN
C2F6 C9 43		CHP	CCLEAR	C FOR CLEAR ARGUMENT DISPLAY ?
C2F8 F0 2E		BEQ	CLRPH	YES, CLEAR THE DISPLAY
C2FA C9 3E		CHP	ORAND	--> FOR SHIFT RIGHT ?
C2FC F0 2F		BEQ	DELPH	YES, DELETE RIGHT DIGIT
C2FE C9 44		CHP	OPERIOD	DECIMAL POINT ?
C300 F0 3B		BEQ	GETPER	YES, ADD PERIOD TO RIGHT DIGIT
C302 C9 2E		CHP	OPPOINT	DECIMAL POINT FROM EXTERNAL DEVICE ?
C304 F0 37		BEQ	GETPER	YES, TREAT AS DECIMAL POINT
:				
			NOT A SPECIAL CHARACTER - PUT IN BUFFER	
C306 29 07		AND	080P	ASSUME DIGIT IS : - STRIP ASCII
C308 85 1F		STA	TEMP	SAVE FOR RIGHT
C30A 10 04		LDY	0804	SHIFT DISPLAY UP
C30C A2 00		LDX	0800	
C30E 8D 42 A6	DIGSUP	LDA	DISBUF+2,X	PICK UP SEGMENT CODE
C311 80 03		CPI	0803	SWAPPING ILLEGAL DECIMAL POSITION ?
C313 10 02		BPL	LEVDEC	NO, LEAVE DECIMAL POINT IN DIGIT
C315 29 7F		AND	087F	YES, REMOVE ANY DECIMAL POINT
C317 9D 41 A6	LEVDEC	STA	DISBUF+1,X	PUT DOWN LEFT ONE PLACE
C31A E8		INX		POINT TO NEXT PAIR
C31B 88		DEY		ALL 4 PAIRS ?
C31C D0 F0		BNE	DIGSUP	NO - DO NEXT DIGIT SWAP
C31E A6 1F		LDX	TEMP	PICK UP INPUT DIGIT AS INDEX
C320 8D 29 8C		LDA	SEGS,X	PICK UP SEGMENT CODE
C323 8D 45 A6		STA	RDIG	PUT IN RIGHT MOST DIGIT
C326 D0 C9		BNE	FETCHF	
:				
C328 20 ED C5	CLRPH	JSR	CDISPH	CLEAR DISPLAY ARGUMENT BUFFER
C32B F0 C4		BEQ	FETCHF	
:				
C32D A2 04	DELPH	LDX	0804	SHIFT 4 PAIRS RIGHT
C32F 8D 40 A6	DELPL	LDA	DISBUF,X	
C332 9D 41 A6		STA	DISBUF+1,X	
C335 C1		DEI		
C336 D0 F7		BNE	DELPL	
C338 8E 41 A6		SYX	DISBUF+1	CLEAR HIGH ORDER DIGIT
C33B F0 D4		BEQ	FETCHF	
:				
C33D AD 45 A6	GETPER	LDA	RDIG	INSERT A PERIOD TO THE LAST CHAR
C340 09 80		ORA	0880	TURN ON PERIOD SEGMENT CODE
C342 8D 45 A6		STA	RDIG	
C345 30 AA		DEI	FETCHF	
:				
C347 20 4B C3	PNRET	JSR	ARGNUM	CONVERT DISPLAY TO BINARY IN TEMP
C34A 60		RTS		

CONVERT DISPLAY ARGUMENT BUFFER INTO NUMBER IN TEMP

NOTE: ALL NON NUMERIC DISPLAY CODES ARE TREATED AS ZERO

NOTE: IN ORDER TO ALLOW ONE DECIMAL DIGIT FOR SPECTROM PARAMETERS, THE FINAL RESULT IS MULTIPLIED BY 10 UNLESS THERE IS A FRACTIONAL DIGIT.

E.G. AN ARGUMENT OF 10 BECOMES 100, AN ARGUMENT OF 2.5 BECOMES 25.

C34B A9 00	ARGHUB	LDA	#000	CLR TEMP BUFFER
C34D 05 60		STA	DECPLG	CLEAR DECIMAL FLAG => NO DECIMAL POINT
C34F 05 1F		STA	TEMPLO	
C351 05 20		STA	TEMPHI	
C353 AD 44 A6		LDA	DISBUF,1	VALID DECIMAL POINT ?
C356 10 02		BPL	NOOP	NO IN THIS ENTRY - IGNORE IF WRONG
C358 C6 60		DEC	DECPLG	YES, SET FLAG
C35A A0 01	NOOP	LDY	#001	INDEX TO DISBUF
C35C B9 40 A6	WUHLF	LDA	DISBUF,Y	PICK UP DIGIT SEGMENT CODE
C35F 7F 7F		AND	#07F	STRIP ANY DECIMAL POINT SEGMENT CODE
C361 F0 00		BEQ	SEGHR2	0 => OFF => ZERO VALUE
C363 A2 09		LDX	#009	SEARCH FOR CODE IN NUMBERS
C365 DB 29 9C	DESEG	CMP	SEG5,X	FOUND SEGMENT CODE ?
C368 F0 03		BEQ	SEGHR5	YES, X IS THE VALUE
C36A CA		DEI		NO, POINT TO NEXT
C36B D0 F0		BNE	DESEG	YES, TRY TO MATCH NEXT
C36D 0A	SEGHR5	TXA		GET INDEX AS VALUE
C36E 05 22	SEGHR2	STA	SAVE	TEMP SAVE
C370 20 00 C3		JSR	MUL10	TEMP <-- TEMP * 10
C373 10		CLC		
C374 A5 22		LDA	SAVE	TEMP <-- TEMP * 10 + DIGIT
C376 6E 1F		ADC	TEMPLO	
C378 05 1F		STA	TEMPLO	
C37A 90 02		BCC	ARGHC	NO CARRY TO HIGH ORDER
C37C E6 24		INC	TEMPHI	CARRY OF 1
C37E C0	ARGHC	IFY		POINT TO NEXT DIGIT
C37F C9 06		CPY	#6	ALL DIGITS ?
C381 D0 09		BNE	WUHLF	NOT YET
C383 20 60		BIT	DECPLG	FRACTIONAL NUMBER ?
C385 30 03		BMI	ARGHRT	YES, GOT VALUE
C387 20 00 C3		JSR	MUL10	NO, SCALE UP BY 10
C38A 60	ARGHRT	RTS		

MULTIPLY TEMPLO, TEMPHI BY 10 FOR DECIMAL USER INPUT

C38B A5 1F	MUL10	LDA	TEMPLO	PICK UP 2 BYTE NUMBER
C38D A6 20		LDX	TEMPHI	FOR TEMPORARY STORAGE
C38F 06 1F		ACL	TEMPLO	FORM TEMP*2
C391 26 20		ROL	TEMPHI	
C393 06 1F		ASL	TEMPLO	FORM TEMP*4
C395 26 20		ROL	TEMPHI	
C397 10		CLC		FORM TEMP*4 + TEMP
C398 65 1F		ADC	TEMPLO	
C39A 05 1F		STA	TEMPLO	
C39C 0A		TXA		
C39D 65 20		ADC	TEMPHI	
C39F 05 20		STA	TEMPHI	
C3A1 06 1F		ASL	TEMPLO	FORM TEMP*10
C3A3 26 20		ROL	TEMPHI	
C3A5 60		RTS		

DIVIDE THE INPUT ARGUMENT BY 10

C3A6 A9 0A	DIV10	LDA	#10	INIT DIVISOR
C3A8 A0 00		LDY	#000	
C3AA A2 1F		LDX	TEMPLO	POINT TO ARGUMENT BUFFER
C3AC 20 C9 C4		JSR	DIV10F	PERFORM THE DIVIDE
C3AF 60		RTS		

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:
:      CLEAR THE ARGUMENT BUFFER
:
C380 A9 00      CLRARG   LDA      $000
C382 85 1F      STA      TEMPLO      CLEAR ARGNUM BUFFPP
C384 85 20      STA      TEMPHI
C386 85 5C      STA      IMPLG      CLEAR IMMEDIATE MODE FLAG
C388 85 66      STA      TIMEFG      CLEAR TIME ACCESS FLAG
C38A 85 67      STA      DWLLPG      CLEAR DWELL ACCESS FLAG
C38C 85 6C      STA      AVEPLG      CLEAR AVERAGE MODE FLAG
C38E 60      RTS

:      CLEAR THE DATA BUFFER FOR INTEGRATING THE SPECTRUM POINT
:
C38F A9 00      CLRDAT   LDA      $000
C3C1 85 47      STA      DATAL      CLEAR SAMPLE DATA BUFFER
C3C3 85 4F      STA      DATAH
C3C5 85 6D      STA      ACCAVL      CLEAR AVERAGE MODE DATA BUFFER
C3C7 85 6E      STA      ACCAVH      (ACCUMULATE AVERAGE)
C3C9 60      RTS

:      FETCH A USER RESPONSE FROM KEYBOARD OR PARALLEL INTERFACE
:      IF NO RESPONSE, RETURN WITH AREG SET TO NOKEY
:
C3CA 20 06 89    USER    JSR      SCANDS      REFRESH THE DISPLAY
C3CD F0 04      BEQ      NNOKEY      NO KEY PRESSED
C3CF 20 AF 88      JSR      GETKEY      GET KEY VALUE
C3D2 60      RTS      WITH BEEP, DEBOUNCED, ...
C3D3 A9 10      NNOKEY   LDA      $010      NO, CHECK PARALLEL PORT
C3D5 2C 00 A8      BIT      CTRL      HANDSHAKE GONE LOW ?
C3D8 D0 04      BNE      USRET      NO, GIVE UP FOR NOW !
C3DA 20 E8 C3      JSR      GETBYT      GET PARALLEL BYTE
C3DD 60      RTS
C3DE A9 00      USRET    LDA      $NOKEY      PICK UP FAIL FLAG
C3E0 60      RTS

:      GET A BYTE FROM THE PARALLEL BUS
:
C3E1 A9 10      PARBIN   LDA      $010      CHECK PB4
C3E3 2C 00 A8      BIT      CTRL      DATA ON THE PORT ?
C3E6 D0 F9      BNE      PARBIN      NO, WAIT FOR USER

:      PICK UP PARALLEL DATA - THE HANDSHAKE IS CHECKED PRIOR
:
C3E8 AD 01 A2      GETBYT  LDA      PORT      YES, A USER IS THERE !
C3EB 48      PHA      SAVE TEMPORARY
C3EC AD 00 A8      LDA      CTRL      SIGNAL DATA RECEIVED
C3EF 29 F3      AND      $FF3
C3F1 8D 00 A8      STA      CTRL
C3F4 A9 10      LDA      $010      WAIT FOR ACKNOWLEDGE
C3F6 2C 00 A8      PARWAT  BIT      CTRL
C3F9 F7 FB      BEQ      PARWAT
C3FB A1 00 A8      LDA      CTRL      SIGNAL DATA PORT FREE
C3FE 09 08      ORA      $008
C401 8D 00 A8      STA      CTRL
C403 68      PLA      RESTORE INPUT VALUE
C404 60      RTS

:      GET A KEY FROM THE USER - KEYBOARD OR PARALLEL PORT
:
C405 20 CA C3      KEYIN   JSR      USER      USER INPUT ?
C408 F0 FB      BEQ      KEYIN      NOT YET, WAIT SOME MORE
C40A C9 0D      CNP      $CR      SET FLAGS FOR CARRIAGE RETURN
C40C 60      RTS      AREG HAS VALUE

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:          PROMPT THE USER WITH ? - COMPARE RESULT TO KEY GO
C40D A9 D3      RIGHT LDA    $QUERY      OUTPUT THE PROMPT
C40F 8D 40 A6   STA    DISBUF
C412 20 8D C5   JSR    CDISPM      CLEAR REST OF THE DISPLAY
C415 20 05 C4   JSR    KEYIN      GET INPUT KEY
C418 C9 47      CMP    $GO        EQUAL FLAG IF GO KEY
C41A 60         RTS

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:          COMMAND: 3.

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:          ENTER THE SPECTROMETER PARAMETERS INTO PARAM BUFFER:

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:          1) START OF SPECTRUM IN ANGSTROMS      (STRT)
:          2) LENGTH OF SPECTRUM IN ANGSTROMS     (LEN)
:          3) RESOLUTION OF SPECTRUM IN ANGSTROMS  (RESOL)
:          4) SPEED OF SPECTRUM IN ANGSTROMS / SECOND (SPED)
:          5) ATTENUATION (NOT CURRENTLY USED)     (ATEN)

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C41B A9 00      FILARG LDA    $0      COUNTER AND INDEX TO PARAM BUFFER
C41D 85 2A      STA    INDEX3
C41F A9 01      LDR    $S01      ARGUMENT PROMPT
C421 85 23      STA    SAVEHI
C423 A6 2A      GETP  LDX    INDEX3      MOVE PREVIOUS ARG TO DATA FOR DISPLAY
C425 B5 01      LDA    PARAM,X
C427 85 47      STA    DATA1
C429 B5 02      LDA    PARAM+1,X
C42B 85 48      STA    DATA1
C42D 20 35 C7   JSR    BINBCD      CONVERT TO DECIMAL IN DISPLAY
C430 AD 44 A6   LDA    DISBUF+4     ADD DECIMAL POINT TO NUMBER
C433 09 80      ORA    $80
C435 8D 44 A6   STA    DISBUF+4
C438 A4 23      LDR    SAVEHI
C43A B9 29 8C   LDA    SEGS,Y      GET ARGUMENT NUMBER
C43D 09 80      ORA    $80          INDEX INTO SEGMENT TABLE
C43F 8D 40 A6   STA    DISBUF      ADD PERIOD FOR PROMPT
C442 20 F1 C2   JSR    FETCHP      PUT IN DISPLAY IN PROMPT POSITION
C445 A6 2A      LDX    INDEX3      GET THE ARGUMENT
C447 A5 1F      LDA    TENPLO      STORE VALUE INTO PARAMETER BUFFER
C449 95 01      STA    PARAM,X
C44B A5 20      LDA    TENPHI
C44D 95 02      STA    PARAM+1,X
C44F E6 23      INC    SAVEHI      CHANGE TO NEXT ARGUMENT PROMPT
C451 E6 2A      INC    INDEX3
C453 E6 2A      INC    INDEX3
C455 A5 2A      LDA    INDEX3
C457 C9 0A      CMP    $S0A      ALL FIVE OF THE ARGUMENTS ?
C459 D0 C8      BNE    GETP        NO, GET NEXT PARAMETER
C45B 20 0D C4   JSR    RIGHT      QUERY USER IF CORRECT
C45E D0 8B      BNE    FILARG      NO, DO FILARG AGAIN
C460 60         RTS              YES, RETURN

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:          CONVERT PARAMETERS TO FORMATED FORM IN GOPARM BUFFER:

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:          1) GSTRT = STRT / MINIMUM RESOLUTION (GEAR)
:          2) GLEN = LEN / MINIMUM RESOLUTION (GEAR)
:          3) GRESOL = RESOL / MINIMUM RESOLUTION (GEAR)
:          4) GSPED = 50 / SPED

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:          NOTE: THE PARAMETERS ARE STORED *10

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:          FORM NUMPTS = GLEN / GRESOL

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C461 A9 FD      FORMAT LDA    $-3      CONVERT 1ST 3 ARGUMENTS INTO BUFFER
C463 85 2C      STA    COUNT1
C465 A2 J1      LDX    $PARAM      POINT TO ARGUMENTS

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C467 A5 33	PHTSPT	LDA	GEARLO	VERSION DIVISOR (EITHER 10 OR 25)
C469 A4 34		LDY	SPRPM1	
C46B 20 C9 C4		JSR	DIVIDE	FORMAT PARAMETER
C46E 95 0A		STA	10,I	SAVE IN GO PARAM BUFFER - 10 BYTES ABOVE
C470 94 0B		STY	11,I	
C472 E8		INX		BUMP INDEX UP
C473 E8		INX		
C476 E6 2C		INC	COUNT1	START, LENGTH, RESOLUTION ?
C476 D0 2F		BNE	PHTSPT	YES
C478 A9 74		LDA	0SPA	COMPUTE 500/(SPEED*10) TO GET GSPED
C47A 85 59		STA	CONBPL	MUST USE DIVIDE ROUTINE BACKWARDS
C47C A9 01		LDA	0\$01	
C47E 85 5A		STA	CONBPH	CONSTANT SET UP
C480 A5 07		LDA	SPEDL	DIVISOR SET UP
C482 A4 08		LDY	SPEDH	
C484 A2 59		LDY	0CONBPL	POINT TO DIVIDEND
C486 20 C9 C4		JSR	DIVIDE	
C489 85 11		STA	GSPEDL	STORE RESULT BACK
C48B 84 12		STY	GSPEDH	
C48D A2 0D		LDX	0GLEH	FORM GLEN/GRESOL - POINT TO DIVIDEND
C48F A5 0F		LDA	GRESOL	
C491 A4 10		LDY	GRESOL+1	
C493 20 C9 C4		JSR	DIVIDE	
C496 85 2F		STA	HUMPTL	SAVE AS LOOP COUNTER
C498 84 30		STY	HUMPTH	
C49A 60		RTS		

:			MULTIPLY CON0,CON1 BY DATA0,DATA1,DATA2,DATA3 TO FORM	
:			RES0,RES1,RES2,RES3 AS A 32 BIT RESULT	
:				
:			CON0,CON1 IS TREATED AS A 16 BIT UNSIGNED NUMBER,	
:			DATA0,DATA1,DATA2,DATA3 IS TREATED AS A 32 BIT SIGNED NUMBER	
C49B A9 00	MULT	LDA	00	CLEAR RESULT BUFFER
C49D 85 54		STA	RES0	
C49F 85 55		STA	RES1	
C4A1 85 56		STA	RES2	
C4A3 85 57		STA	RES3	
C4A5 A5 59	MLOOP	LDA	CON0	ANY MORE CONSTANT ?
C4A7 05 5A		ORA	CON1	
C4A9 F0 1D		BEQ	MTHRU	NO, THRU WITH MULTIPLY
C4AB 46 5A		LSR	CON1	YES, PICK UP ADD/NOADD BIT
C4AD 66 59		ROR	CON0	
C4AF 90 0C		BCC	NOADD	NO ADDITION FOR THIS STEP
C4B1 A2 FC		LDX	0-4	FORM RES <-- RES + DATA
C4B3 18		CLC		
C4B4 85 4B	ALOOP	LDA	DATA0+4,X	BYTE BY BYTE
C4B6 75 58		ADC	RES0+4,X	
C4B8 95 58		STA	RES0+4,Y	
C4BA E8		INX		
C4BB D0 F7		BNE	ALOOP	
C4BD 06 47	NOADD	ASL	DATA0	SHIFT UP DATA
C4BF 26 48		ROL	DATA1	
C4C1 26 49		ROL	DATA2	
C4C3 26 4A		ROL	DATA3	
C4C5 4C A5 C4		JMP	MLOOP	
C4C8 60	MTHRU	RTS		

```

:      RETURN RESULT IN A,Y WITH REMAINDER IN TEMP
:      DIVIDE 16 BIT UNSIGNED NUMBER INDEXED BY I BY A,Y

C4C9 85 50      DIVIDE STA CONLO      SAVE DIVISOR
C4CB 84 51      STY CONHI
C4CD 8A          TXA              SAVE IREG ON STACK
C4CE 88          PHA
C4CF 85 00      LDA              0,I      SAVE ARGUMENT
C4D1 85 80      STA WUNLO
C4D3 85 01      LDA              1,I
C4D5 85 8E      STA WUPI
C4D7 A0 00      LDY #000
C4D9 84 52      STY CONSGN      SIGN EXTEND AS POS NUMBERS
C4DB 84 8F      STY WUNSGN      (TRIPLE PRECISION)
C4DD 84 1F      QDIV STY TEMPLO
C4DF 84 20      STY TEMPPI
C4E1 84 21      STY TEMPSP
C4E3 C8          INY
C4E4 84 53      STY DIVCNT      # OF SHIFTS + 1
C4E6 A5 50      LDA CONLO      IS DIVISOR = 0 ?
C4E8 05 51      ORA CONHI
C4EA F0 86      BEQ DIVRET      YES, RETURN ZERO RESULT

C4EC A2 F0      DNOBH LDX 0-3
C4EE 38          SEC
C4EF 85 50      DNRHLP LDA WUNLO+3,I      DIVISOR > DIVIDEND YET ?
C4F1 F5 53      SBC CONLO+3,I
C4F3 E8          INX
C4F4 D0 F9      BNE DNRHLP
C4F6 90 0A      BCC DIVLP      YES, SHIFTED DIVISOR ENOUGH
C4F8 06 50      ASL CONLO      NO, SHIFT DIVISOR LEFT ONE BIT
C4FA 26 51      ROL CONHI
C4FC 26 52      ROL CONSGN
C4FE E6 53      INC DIVCNT      COUNT SHIFT
C500 D0 EA      BNE DNOBH      BR TO DO AGAIN

C502 C6 53      DIVLP DEC DIVCNT      ALL LOOPS ?
C504 F0 2C      BEQ DIVRET      YES, PICK UP ANSWER
C506 46 52      LSR CONSGN      NO, SHIFT DIVISOR RIGHT ONE
C508 66 51      ROR CONHI
C50A 66 50      ROR CONLO
C50C 06 1F      ASL TEMPLO      SHIFT ANSWER LEFT ONE BIT
C50E 26 20      ROL TEMPPI
C510 26 21      ROL TEMPSP
C512 A2 F0      LDX 0-3      DIVIDEND <-- DIVIDEND - DIVISOR
C514 38          SEC
C515 85 50      DIVSUB LDA WUNLO+3,I
C517 F5 53      SBC CONLO+3,I
C519 95 50      STA WUNLO+3,I
C51B E8          INX
C51C D0 F7      BNE DIVSUB
C51E 90 0A      BCC TOOPAR      DIVISOR WILL NOT SUBTRACT
C520 E6 1F      INC TEMPLO      DID SUBTRACT, SET BIT (NOW ZERO)
C522 D0 DE      BNE DIVLP      LOOP ON TO NEXT BIT

C524 A2 F0      TOOPAR LDX 0-3      RESTORE DIVIDEND
C526 18          CLC      DIVIDEND <-- DIVIDEND + DIVISOR
C527 85 50      DIVADD LDA WUNLO+3,I
C529 75 53      ADC CONLO+3,I
C52B 95 50      STA WUNLO+3,I
C52D E8          INX
C52E D0 F7      BNE DIVADD
C530 F0 D0      BEQ DIVLP      BR TO NEXT BIT

C532 68          DIVRET PLA      RESTORE IREG FROM STACK
C533 AA          TAX
C534 A5 1F      LDA TEMPLO      PICK UP 16 BIT RESULT
C536 A4 20      LDY TEMPPI
C538 60          RTS

```

PERFORM THE DUVAS STEP

- 1) SET DIRECTION BIT AND HANDSHAKE BIT ON CONTROL POST
- 2) PULSE STEPPING MOTOR
- 3) UPDATE DUVAS LOCATION

```

C539 A5 4B      STEP  LDA    DIR          SET DIRECTION LOGIC
C53B 2A         B0L    A              ROLL DIRECTION BIT INTO BIT0
C53C 2A         B0L    A
C53D 4D 00 A8   B0R    CTRL          MASK WITH LOGIC FLAG
C540 6A         B0R    A              ROLL BACK INTO SIGN BIT
C541 6A         B0R    A
C542 85 4C      STA    TDIR          SAVE TEMPORARY
C544 AD 00 A8   LDA    CTRL          GET CURRENT DIRECTION
C547 05 4C      ORA    TDIR          INSERT NEW DIRECTION
C549 25 4C      AND    TDIR
C54B 29 80      AND    #80          KEEP ONLY DIR BIT
C54D 09 28      ORA    #828        SET HANDSHAKE, STEPPING MOTOR
C54F 8D 00 A8   STA    CTRL          SIGNAL TO EXTERNAL WORLD
C552 29 DF      AND    #8DF        SET STEPPING MOTOR PULSE LOW
C554 8D 00 A8   STA    CTRL          SEND TO MOTOR
C557 09 20      ORA    #820        RESET MOTOR STEP PULSE
C559 8D 00 A8   STA    CTRL
C55C A5 4B      LDA    DIR          PICK UP DIRECTION BIT AGAIN
C55E 30 07      BEI    BACK1        DIR = 1 => BACKWARD DIRECTION
C560 E6 13      FOR1  INC    LOCLO    DIR = 0 => ADD SINGLE FORWARD STEP
C562 D0 02      BNE    *+4          NO CARRY
C564 E6 14      INC    LOCNI        CARRY
C566 60         RTS
C567 A5 13      BACK1 LDA    LOCLO    SUBTRACT BACKWARD STEP
C569 D0 02      BNE    BNOCRY       THERE WILL BE NO CARRY
C56B C6 14      DEC    LOCNI        THERE WAS A CARRY
C56D C6 13      BNOCRY DEC    LOCLO  DECREMENT
C56F 60         RTS

```

```

;      FORM:  DEST - LOC, BIT 7 => DIR

```

```

C570 38      POSITH  SEC          DO A DOUBLE PRECISION SUBTRACT
C571 A5 31      LDA    DESTLO      DEST - LOC
C573 E5 13      SBC    LOCLO
C575 85 1F      STA    TEMPLO      SAVE FOR EQUAL TEST
C577 A5 32      LDA    DESTNI
C579 E5 14      SBC    LOCNI
C57B 85 20      STA    TEMPNI
C57D 30 08      BEI    POSRET      NEG FLAG SET
C57F A5 1F      LDA    TEMPLO      MUST FORCE THE ZERO/ POS FLAG
C581 05 20      ORA    TEMPNI
C583 F0 02      BEQ    POSRET      DEST = LOC, ZERO FLAG SET
C585 A9 02      LDA    #802        SET POSITIVE, NON-ZERO FLAG
C587 60      POSRET  RTS

```

```

;      DELAY:  (7 + (5*256 - 1)) * YREG + 5 CYCLES =
;              1286 * YREG + 5 CYCLES

```

```

C588 A2 00      DELAY  LDY    #0
C58A CA         DLP
C58B D0 FD      BNE    DLP
C58D 88         DEY

```

```

C58E D0 F8      BNE    DELAY
C590 60         RTS

```

```

;      LONG DELAY:  249502 * YREG + 5 CYCLES (ABOUT 1/4 SECOND)

```

```

C591 84 65      LDELAY STY    TDELAY
C593 A0 C2      LDLP  LDY    #194
C595 20 88 C5   JSR    DELAY
C598 C6 65      DEC    TDELAY
C59A D0 F7      BNE    LDLP
C59C 60         RTS

```

```

;          DELAY FOR STINE/10 SECONDS - USE HOLD BUFFER FOR TIME COUNTDOWN

C59D A5 63      SECNDS LDA    STINEL          SWAP TIME TO HOLD BUFFER
C59F 85 24      STA    HOLDLO
C5A1 A5 64      LDA    STINER
C5A3 85 25      STA    HOLDHI
C5A5 A0 4E      SECLP  LDY    #78
C5A7 20 88 C5   JSR    DELAY          WAIT FOR .1 SECOND
C5AA A5 24      LDA    HOLDLO          DECREMENT SECOND COUNT
C5AC D0 02      BNE    SECNC          WILL BE NO CARRY
C5AE C6 25      DEC    HOLDHI          WAS A CARRY
C5B0 C6 24      SECNC DEC    HOLDLO          ACTUAL DECREMENT
C5B2 A5 24      LDA    HOLDLO          CHECK FOR ZERO
C5B4 05 25      ORA    HOLDHI
C5B6 D0 ED      BNE    SECLP          MORE .1 SECONDS TO COUNT
C5B8 60        RTS                    PROPER DELAY

```

```

;          SET VERSION CONSTANTS ACCORDING TO VERSION BIT

C5B9 A2 05      VERNON LDX    #S05          OFFSET INTO INITC TABLE
C5BB A0 05      LDY    #S05          VERSION 1 OFFSET INTO TINITC TABLE
C5BD A9 04      LDA    #S04          VERSION BIT IS PB2
C5BF 2C 00 A8   BIT    CTRL          CHECK VERSION BIT
C5C2 D0 02      BNE    VER1          1 => VERSION 1 (FLOATING INPUT BIT)
;          0 => VERSION 2 (GROUNDED INPUT LINE)
C5C4 A0 08      VER2  LDY    #S08          VERSION 2 OFFSET INTO TINITC
C5C6 B9 D0 C5   VER1  LDA    TINITC,Y      SWAP BYTES TO ZERO PAGE
C5C9 95 33      STA    INITC,X
C5CB 88        DEY
C5CC CA        DEY
C5CD 10 F7      BPL    VER1          POINT TO NEXT BYTE
C5CF 60        RTS                    ALL BYTES SWAPED ?
;          NO, SWAP REST

```

```

;          TABLE OF VERSION CONSTANTS

C5D0 19 00      TINITC .WORD 25          GEAR - VERSION 1 CONSTANTS
C5D2 71 02      .WORD 625          HIBAS (FOR 12500 HZ)
C5D4 50 C3      .WORD TIME20       TIME (FOR 1/20 SEC HYP)
C5D6 01 00      .WORD 10          GEAR - VERSION 2 CONSTANTS
C5D8 FA 0C      .WORD 250          HIBAS (FOR 12500 HZ)
C5DA 20 4E      .WORD TIME50       TIME (FOR 1/50 SEC HYP)

```

```

;          PROMPT USER FOR A COMMAND

C5DC 20 ED C5   PROMPT JSR    CDISPH          CLEAR THE DISPLAY FOR PARAMETERS
C5DF 85 60      STA    CHND          CLEAR OLD USER COMMAND (A = 0)
C5E1 20 B0 C3   JSR    CLRARG          CLEAR ARGUMENT AND ACCESS FLAGS
C5E4 A9 B9      LDA    #CPHPT        SET PROMPT AS C.
C5E6 8D 40 A6   STA    DISBUF
C5E9 20 72 89   JSR    BEEP          FOR PET USERS
C5EC 60        RTS

```

```

;          CLEAR THE PARAMETER DISPLAY BUFFER
;          EXIT WITH AREG, YREG SET TO ZERO, AND ZERO FLAG SET

C5ED A9 00      CDISPH LDA    #S00
C5EF A0 05      LDY    #S05
C5F1 99 40 A6   CDISPL STA    DISBUF,Y      ZERO PARAMETER DIGIT
C5F4 88        DEY
C5F5 D0 FA      BNE    CDISPL
C5F7 60        RTS

```


; ACCUMULATE THE SPECTRUM POINT FOR ONE INTEGRATION PERIOD

C5P8 A5 11	SAMPLE	LDA	CSPED	
C5P9 85 2D		STA	COUNT2	SET THE INTEGRATION LOOP COUNT
C5PC A9 00	INTEG	LDA	\$S00	
C5PE 85 5B		STA	CLKPLG	ZERO LOOP FLAG
C600 A9 34		LDA	0CLKINT	POINT IRQ VECTOR FOR 6522 TIMER
C602 8D 7E A6		STA	IRQLO	
C605 A9 C6		LDA	0CLKINT/256	
C607 8D 7F A6		STA	IRQHI	
C60A A9 C0		LDA	\$SC0	ENABLE TIMER 1 INTERRUPT
C60C 8D 0E 18		STA	IER	(TIMER 1 INTERRUPT REGISTER)
C60P A9 20		LDA	\$S20	SET TIMER 2 TO COUNT INPUT PULSES
C611 8D 0B A8		STA	ACF	(AUXILIARY CONTROL REGISTER)

C614 A9 FF		LDA	\$SFF	SET TIMER 2 TO MAX COUNT
C616 8D 08 A8		STA	T2LL	(TIMER 2 LATCH LOW)
C619 8D 09 A8		STA	T2CH	(TIMER 2 COUNT HIGH)
C61C A5 37		LDA	TIMEL0	SET BASIC TIMEOUT INTERVAL
C61E 8D 04 A8		STA	TILL	(TIMER 1 LATCH LOW)
C621 A5 38		LDA	TIMER1	
C623 8D 05 A8		STA	T1CH	(TIMER 1 COUNT HIGH) - START TIMER
C626 58		CLI		ENABLE TIMER INTERRUPT
C627 20 06 89	COUNT?	JSR	SCANDS	DISPLAY LAST COUNT
C62A 24 5B		BIT	CLKPLG	VFC TIMED OUT ?
C62C 10 F9		BPL	COUNT?	NO, COUNT MORE VFC PULSES
C62E 78		SEI		YES, DISABLE INTERRUPTS
C62P C6 2D		DEC	COUNT2	ALL TIME INTEGRATIONS ?
C631 8D C9		BNE	INTEG	NO, COUNT
C633 60		RTS		

; CLOCK TIME OUT INTERRUPT - GET PULSE COUNT, ACCUMULATE, SET FLAG

C634 AD 09 A8	CLKINT	LDA	T2CH	COPY HIGH COUNT
C637 AC 08 A8		LDY	T2LL	GET LOW COUNT
C63A C0 FF		CPY	\$SFF	POSSIBLE CARRY ?
C63C D0 03		BNE	NOCRY	NO
C63E AD 09 A8		LDA	T2CH	YES, GET NEW (AND POS. DIFFERENT) HIGH
C641 A9 FF	NOCRY	EOB	\$SFF	FORM ONE'S COMPLEMENT
C643 48		PHA		SAVE TEMP
C644 48		TYA		GET LOW ORDER
C645 A9 FF		EOB	\$SFF	FORM ONE'S COMPLEMENT
C647 18		CLC		ADD TO DATA
C648 65 47		ADC	DATAL	
C64A 85 47		STA	DATAL	
C64C 68		PLA		RESTORE HIGH ORDER
C64D 65 48		ADC	DATAL	
C64P 85 48		STA	DATAL	
C651 A9 40		LDA	\$S40	TURN OFF TIMER INTERRUPT UNTIL RESET
C653 8D 0E A8		STA	IER	
C656 C6 5B		DEC	CLKPLG	SET FLAG TO BREAK LOOP
C658 40		BTI		

; TRANSFER DATA TO MEMORY POINTED TO BY SPECTL, UPDATE SPECTL

C659 A0 00	PUTDAT	LDY	\$0	FOR 6502 INDIRECT
C65B A5 47		LDA	DATAL	
C65D 91 41		STA	(SPECTL),Y	LOW BYTE
C65P C8		INY		
C660 A5 48		LDA	DATAL	
C662 91 41		STA	(SPECTL),Y	HIGH BYTE
C664 20 85 C2		JSR	INCACC	INCREMENT ACCESS POINTER BY 1 DATA POINT
C667 60		RTS		

; BEEP UNTIL A KEY IS PRESSED
; EXIT WITH CARRY SET

C668 20 72 89	ERROR	JSR	BEEP
C66B 20 86 83		JSR	INSTAT
C66E 90 F8		BCC	ERROR
C670 60		RTS	

```

:      MOVE THE SPECTROMETER UNTILL LOC = DEST
C671 A5 08      SETSTL LDA      CSTRTL      MOVE FORMATTED START TO DEST BUFFER
C673 05 31      STA      DESTLO
C675 A5 0C      LDA      CSTRTH
C677 05 32      STA      DESTTH
C679 20 70 C5   SETSTL JSR      POSITH      AT BEGINNING OF SPECTRUM YET ?
C67C F0 00      BEQ      SETRET      YES, RETURN
C67E 05 48      STA      DIR          NO, STORE DIR7 AS THE DIRECTION BIT
C680 20 39 C5   JSR      STEP        OUTPUT DIR, STEP MOTOR, UPDATE POSITION
C683 A0 20      LDY      #32
C685 20 08 C5   JSR      DELAY      DELAY FOR REVIEW
C688 4C 79 C6   JMP      SETSTL
C68B 60      SETRET RTS

```

```

:      COMPUTE THE MIDPOINT FOR THE CURRENT SPECTRUM
C68C A9 00      MIDPT LDA      #0          ZERO CURRENT MIDPOINT
C68E 05 39      STA      MIDLO
C690 05 3A      STA      MIDHI
C692 05 38      STA      MID2          (32 BITS)
C694 05 3C      STA      MID3
C696 A6 11      AND      CSPEDL      FOR EACH SPEED INTEGRATION
C698 A4 0F      MIDLP LDY      CRESOL   FOR EACH RESOLUTION INTEGRATION
C69A 18      ADDBAS CLC
C69B A5 39      LDA      MIDLO
C69D 65 35      ADC      MIDBLO
C69F 05 39      STA      MIDLO
C6A1 A5 3A      LDA      MIDHI
C6A3 65 36      ADC      MIDBHI
C6A5 05 3A      STA      MIDHI
C6A7 88      DEY
C6A8 D0 F0      BNE      ADDBAS
C6AA CA      DEY

```

```

C6AB D0 E8      BNE      MIDLP

```

```

:      MILLIV. FORM THE FRACTIONAL CONSTANT TO FORM MILLIVOLTS
C6AD A9 00      MILLIV LDA      #500      FORM 5130000/MID => 5000*256 / MID
C6AF 05 40      STA      NUMLO
C6B1 A9 08      LDA      #588
C6B3 05 4E      STA      NUMHI
C6B5 A9 13      LDA      #513
C6B7 05 4F      STA      NUMSGN
C6B9 A5 39      LDA      MIDLO
C6BB 05 50      STA      CONLO
C6BD A5 3A      LDA      MIDHI
C6BF 05 51      STA      CONHI
C6C1 A0 00      LDY      #500
C6C3 04 52      STY      CONSGN
C6C5 20 CD C6   JSR      PDIV        (16 BIT CONST), LEAVE YREG = 0
C6C8 05 0C      STA      NUMPLO     FAKE DIVIDE ENTRY
C6CA 04 8D      STY      NUMPHI     SAVE FRACTIONAL CONSTANT
C6CC 60      RTS

```

```

C6CD 48      PDIV FMA
C6CE 4C DD C7 JMP      QDIV      ROM DIVIDE SAVES YREG
                                   USE QUICK ENTRY

```

```

;      VOLT.  CONVERT DATA TO MILLIVOLTS AND OUTPUT TO DISPLAY:  DD.DDD

C6D1 A9 00      VOLT  LDA      #000          ASSUME POSITIVE DATA
C6D3 85 8E      STA      SIGNPG
C6D5 38          SEC                      SUBTRACT MIDPOINT
C6D6 A5 47      LDA      DATAL
C6D8 85 39      SEC      F.LLO
C6DA 85 47      STA      DATAL
C6DC A5 48      LDA      DATAN
C6DE 85 3A      SEC      MIDHI
C6E0 85 48      STA      DATAN
C6E2 D0 15      BCS      VOLTS1          POSITIVE RESULT
C6E4 A9 40      LDA      @BINCODE      SET MINUS FLAG
C6E6 85 8E      STA      SIGNPG
C6E8 A5 47      LDA      DATAL          FORM 16 BIT 2'S COMPLEMENT
C6EA 49 FF      BOR      @SPF          1'S COMPLEMENT
C6EC 38          SEC                      +1
C6ED 69 00      ADC      #000
C6EF 85 47      STA      DATAL
C6F1 A5 48      LDA      DATAN
C6F3 49 FF      BOR      @SPF
C6F5 69 00      ADC      #000
C6F7 85 48      STA      DATAN
C6F9 A5 0C      VOLTS1 LDA      NVFLO          GET MILLIVOLT FRACTION CONSTANT
C6FB 85 59      STA      CON0
C6FD A5 8D      LDA      NVPHI
C6FF 85 51      STA      CON1
C701 A9 00      LDA      #000          ZERO HIGH ORDER OF DATA
C703 85 49      STA      DATA2
C705 85 4A      STA      DATA3
C707 20 9B C4   JSR      BULT          FRACTIONAL MULTIPLY
C70A A5 55      LDA      RES1          SCALE BY 256
C70C 85 47      STA      DATAL
C70E A5 56      LDA      RES2
C710 85 48      STA      DATAN
C712 A5 0E      LDA      SIGNPG          PUT SIGN IN DISPLAY
C714 8D 40 A6   STA      DISBUF
C717 20 35 C7   JSR      BINBCD          PLACE DATA IN DISPLAY
C71A A0 3F      LDY      @SPF          FORMAT FOR DD.DDD
C71C AD 44 A6   LDA      DISBUF+4
C71F D0 03      BNE      NOBLK1
C721 8C 44 A6   STY      DISBUF+4
C724 AD 43 A6   NOBLK1 LDA      DISBUF+3
C727 D0 03      BNE      NOBLK2
C729 8C 43 A6   STY      DISBUF+3
C72C AD 42 A6   NOBLK2 LDA      DISBUF+2
C72F 09 80      ORA      #000          ADD DECIMAL POINT
C731 8D 42 A6   STA      DISBUF+2
C734 60          RTS

```

```

;      CONVERT DATA TO A DECIMAL NUMBER IN THE DISPLAY - BFI !!!

C735 A5 47      BINBCD LDA      DATAL          TRANSFER COPY OF DATA TO TDATA
C737 85 45      STA      TDATA          (BINBCD IS DESTRUCTIVE)
C739 A5 48      LDA      DATAN
C73B 85 46      STA      TDATA
C73D A9 00      TDATA1 LDA      #000
C73F 85 26      STA      INDEX1          TO DIVISOR CONSTANTS IN NUNTAB
C741 85 28      STA      INDEX2          TO RESULT STORAGE IN NUNDOF
C743 A9 05      LDA      #005
C745 85 2C      STA      COUNT1          FIVE DIGITS
C747 A4 26      NEXDIV LDY      INDEX1
C749 89 93 C7   LDA      NUNTAB,Y          LO ORDER CONSTANT
C74C 48          PHA                      TEMP SAVE
C74F 89 94 C7   LDA      NUNTAB+1,Y        HI ORDER CONSTANT
C750 A8          TAY

```

C751 68	PLA		
C752 A2 45	LDX	BTDPATL	POINT TO NUMBER
C754 20 C9 C4	JSR	DIVIDE	
C757 A6 28	LDX	INDEX2	
C759 A5 1F	LDA	TEMPLO	GET DIGIT
C75B 95 54	STA	NUMBUP,X	STORE FOR LATER
C75D E6 28	INC	INDEX2	
C75F A4 26	LDY	INDEX1	
C761 A5 4D	LDA	NUMLO	PETCH REMAINDER
C763 85 45	STA	TDATL	
C765 A5 4E	LDA	NUMHI	
C767 85 46	STA	TDATL	
C769 E6 26	INC	INDEX1	
C76B E6 26	INC	INDEX1	
C76D C6 2C	BEC	CONST1	ALL 5 DIGITS ?
C76F D0 D6	BNE	HEXDIY	NO, DO NEXT
C771 E2 00	LDX	\$800	MOVE TO DISBUP, DO NOT DISTURB PROMPT
C773 B4 54	LDY	NUMBUP,X	PICK UP DIGIT
C775 B9 29 8C	LDA	SEGS,Y	PETCH SEGMENT CODE
C778 9D 41 A6	STA	DISBUP+1,X	PUT IN DISPLAY
C77B E8	INX		POINT TO NEXT DIGIT
C77C E0 05	CPI	\$805	MOVE ONLY 5 DIGITS
C77E D0 F3	BNE	NUMDIS	
C780 A0 00	LDY	\$800	BLANK LEADING DIGITS
C782 A2 FC	LDX	\$-4	
C784 BD 45 A6	LDA	DISBUP+5,X	GET A SEGMENT CODE
C787 C9 3F	CRP	\$83F	IS IT A ZERO ?
C789 D0 07	BNE	BOUT	NO, IGNORE NOLEADING ZEROS
C78B 98	TIA		YES, BLANK IT
C78C 9D 45 A6	STA	DISBUP+5,X	TURN OFF THIS LED
C78F E8	INX		NEXT DIGIT - DO NOT EXAMINE DIGIT
C790 D0 F2	BNE	BLANK	
C792 60	BOUT	RTS	

: DECIMAL CONSTANTS FOR BINBCD

C793 10 27	NUMTAB	.WORD	10000
C795 E8 03		.WORD	1000
C797 64 00		.WORD	100
C799 0A 00		.WORD	10
C79B 01 00		.WORD	1

: OUTPUT DATA POINT POINTED TO BY SPECTL

C79D A0 00	OUTPUT	LDY	\$0	
C79F B1 41		LDA	(SPECTL),Y	MOVE DATA TO DATA
C7A1 85 47		STA	DATAL	
C7A3 C8		INX		
C7A4 B1 41		LDA	(SPECTL),Y	
C7A6 85 48		STA	DATAL	

: SEND DATA ACROSS THE PARALLEL INTERFACE

C7A8 A5 48	PARALL	LDA	DATAL	HIGH ORDER BYTE FIRST
C7AA 20 B3 C7		JSR	PARBYT	
C7AD A5 47		LDA	DATAL	LOW ORDER BYTE SECOND
C7AF 20 B3 C7		JSR	PARBYT	
C7B2 60		RTS		

:		TRANSMIT A SINGLE BYTE ACROSS THE PARALLEL INTERFACE		
C7B3 8D 01 A8	PARB11	STA	PORT	PUT DATA ON PORT
C7B6 A9 FF		LDA	\$5FF	SET FOR OUTPUT
C7B8 8D 03 A8		STA	PRTDIR	
C7BB A9 10	PARB11	LDA	\$S10	WAIT TILL DATA READY SIGNAL
C7BD 2C 00 A8		RIT	CTEL	
C7C0 D0 FB		BNE	PARB11	
C7C2 A9 F7	PARB11	LDA	\$5F7	SIGNAL DATA ON PORT
C7C4 2D 00 A8		AND	CTEL	
C7C7 8D 00 A8		STA	CTEL	
C7CA A9 10	PARB11	LDA	\$S10	WAIT TILL DATA ACCEPTED
C7CC 2C 00 A8		RIT	CTEL	
C7CF F0 FB		BEQ	PARB12	
C7D1 A9 08	PARB12	LDA	\$S08	ACKNOWLEDGE
C7D3 0D 00 A8		ORA	CTEL	
C7D6 8D 00 A8		STA	CTEL	
C7D9 A9 00	PARB12	LDA	\$S00	SET BACK TO INPUT
C7DB 8D 03 A8		STA	PRTDIR	
C7DE 60		RTS		

```

      :  

      :  

      :          CONFIGURE THE SYB-1 TO POWER UP TO THE DUVAS CONTROL PROGRAM.  

      :          THIS REQUIRES A POWER UP VECTOR TO BE PLACED AT $7FC FROM THE  

      :          BEGINING OF THE EPROM, POINTING TO THE START UP ROUTINE.  

      :  

      :  

      *-*START*$7FC               INIT POWER UP VECTOR  

C7FC 00 C0    PWRUP .WORD   START        STARTING POINT OF DUVAS CONTROL PROGRAM  

              .END

```

SYMBOL TABLE

ACBEG	5784	ACBEGH	005F	ACBEGL	0084	ACCAVR	006E
ACCAVL	006D	ACCRS2	C107	ACCESS	C07A	ACCIN	C0F2
ACCRET	C188	ACCRYS	C25D	ACENB	6784	ACENBN	0067
ACPDOL	0084	ACHAK	62D4	ACHAIB	0062	ACHAYL	00D4
ACR	A80B	ADBRAS	C69A	ALDOY	C0BA	ARGHC	C37E
ARGURT	C38A	ARGUWH	C38B	ASCTI	8BEF	ATEH	0009
ASTOCL	C24B	AVE	005A	AVECHT	006B	AVEPLC	006C
AVELP	C137	BACK	0043	BACKI	C567	BACKHI	0044
BACKLO	0043	BAVD	8A7F	BCKGDM	0000	BCKGDI	0000
BERP	8972	BCHY	0072	BGLO	0071	BIBCDI	C735
BLANK	C784	BFOCHY	C56D	BOUT	C792	CALON	C2A0
CALPAR	C24E	CDISPL	C5P1	CDISPH	C5ED	CERROR	C086
CLAR	0043	CLAYLC	005B	CLKINT	C634	CLRANC	C3B0
CLRDAT	C3BF	CLRPH	C32B	CHDADR	C062	CESD	0113
CHNDYH	C03E	COEPHE	0075	COEPTH	0073	COHO	0059
COP1	005A	COHPEH	005A	COHPL	0059	COHPI	0051
COLO	0050	COHSGY	0052	COHWT	002C	COHWT1	002C
COHWT2	002D	COHWT3	002E	COHWT4	C627	CPHPT	00B9
CPOINT	0061	CR	000D	CTABO	C0A6	CTAB1	C000
CTAB2	D000	CTABLE	C09E	CTABR	0600	CTEDIR	A802
CTEL	A800	DATA	0047	DATAO	0047	DATAI	0048
DATA2	0049	DAT3	004A	DATAN	0048	DATAL	0047
DBUFPI	0002	DBUFLO	0000	DC	006F	DCHI	0070
DCLO	006F	DECFLG	0066	DELAY	C588	DELPL	C32F
DELPH	C32D	DESEG	C365	DEST	6031	DESTHI	0032
DESTLO	0031	DFTBLK	8FA0	DFTYPR	C00F	DFTYLP	C011
DIGSUP	C30E	DIE	004B	DISABL	0004	DISBUF	A640
DIV10	C3A6	DIVADD	C527	DIVCHT	0053	DIVIDE	C4C9
DIVLP	C502	DIVRET	C532	DIVSUB	C515	DLP	C58A
DNORH	C4EC	DNRHLP	C4EF	DOCHND	C060	DTBRDY	00F7
DYRCVD	0010	DIRDY	0008	DWELL	C0DA	DWLLPE	0067
DYLLIS	C0D8	ERROR	C668	EXCHBT	C220	EXCHLP	C1FC
EXCHP	C20F	EXCHSP	C1F5	EXEC	005E	EXECHI	005F
EXCLO	005E	EXCHLP	C03B	FDIV	C6CD	FETCHP	C2F1
FILAPC	C41B	FHTSPT	C467	FOR1	C560	FORMAT	C461
GEAR	0033	GEARHI	0034	GEARLO	0033	GETDIT	C3E6
GETKEY	88AF	GETP	C423	GETPER	C33D	GETSEG	C053
GETSL1	C239	GETTPT	C233	GLEN	0C0D	GLENHI	000E
GLENLO	000D	GO	0047	GODOIT	C09B	GOPAH	000D
GRESOL	000F	GSPED	0011	GSPEDH	0012	GSPEDL	0011
GSTRY	000B	GSTRTH	000C	GSTRYL	100B	HEXDIV	C747
HOLD	0024	HOLDHI	0025	HOLDLO	0124	IER	A80E
INPLC	005C	INANC	C05D	INACC	C1E5	INCRET	C2F0
INCSPT	C2DA	INDEXI	0026	INDEX1	0016	INDEX2	0028
INDEX3	002A	INITC	0033	INITP	C0XC	INIT5	C003
INITZP	C024	INSTAT	0386	INTEG	C57C	IRQHI	A67F
IRQLO	A67E	JMPRES	C1B5	KEYIN	C4C5	KEYQ	8923
KSCONT	89A3	LDELAY	C591	LDLP	C593	LEN	0003
LEHHI	0004	LEHLO	0003	LESS	C197	LEVDEC	C317
LOC	0013	LOCHI	0014	LOCLO	0013	LOOKCD	C04B
MAX	003D	MAXHI	003E	MAXLO	003D	MAXPOS	003F
MID	0039	MIDO	0039	MIDI	003A	MID2	0038
MID3	003C	MIDBAS	0035	MIDBHI	0036	MIDBLO	0035
MIDHI	003A	MIDLO	0039	MIDLP	C698	MIDPT	C68C
MILLIV	C6AD	MINCDE	0040	MINOS	002D	NLOOP	C4A5
MONWT	C01F	MONYTH	8000	MOVENT	C1F7	NTHRU	C4C8
MOLLO	C38B	MULT	C49B	NVP	000C	NVPHI	000D
NVFLD	008C	NMOKEY	C3D3	NOADD	C4BD	NOAVE1	C15B
NOAVE2	C17C	NOBLK1	C724	NOBLK2	C72C	NOCHND	C082
NOCHY	C641	NOBELA	C16C	NOOP	C35A	NOEXCH	C22B
NOEXCP	C219	NOINED	C1A8	NOKEY	0000	NOPT	C11A
NOPT	C19E	POSTEP	C169	NOHBY	0054	NUNDIS	C773
NUNHI	000E	NUNLO	004D	NUNLP	C35C	NUNPTH	0030
NUNPTL	002F	NUNPTS	0027	NUNSGH	0047	NUNTAB	C793
OKTINB	C0BE	OUTCHN	8A47	OUTOAT	C1B9	OUTOLP	C1B7
OUTPUT	C74D	PABALL	C7A8	PABAN	0001	PABDIN	C3E1
PABDTT	C7B3	PABGAT	C376	PABWT1	C7BD	PABWT2	C7CC
PBDA	A402	PCR1	A00C	PERIOD	0044	PLUS	002B
PHEET	C347	POINT	002E	PORT	A801	POSITV	C570
POSSET	C587	PPHPT	0073	PHONPT	C5DC	PETDIB	A803

PUTDAT	C659	PL JP	C7FC	QDIV	C4DD	QUERY	00B3
QVRACC	C10A	R1	0080	R2	0082	R3	0084
R4	0086	R5	0088	RAR0	003E	RDIC	A6A5
RES0	0054	RES1	0055	RES2	0056	RES3	0057
RESB0	008A	RESB0H	008B	RESBOL	008A	RESBWL	0080
RESOL	0005	RESOLP	C12C	RIGHT	C40D	RHODPG	0069
RHODH	0006	RHODL	0000	RHPLG	0055	RHSTST	C06E
S1	0076	S2	0078	S3	007A	S4	007C
S5	007F	SACCES	8B86	SAMPLE	C5F8	SAVE	0022
SAVENI	0023	SAVELO	0022	SAVSPC	C22F	SCANDS	8906
SECLP	C5A5	SECNC	C5B0	SECND5	C59D	SEGNH2	C36E
SEGNH1	C36D	SEGS	8C29	SETADR	C08B	SETCP	C250
SETRNT	C60B	SETSPT	C2C3	SETST	C671	SETSTL	C679
SIGNPG	008E	SHODAT	0076	SPECT	0041	SPECTR	0042
SPBCTL	0041	SPECTH	C133	SPED	0007	SPEDH	0006
SPEDL	0007	SPEOVE	005D	SRAN	A620	START	C000
STEP	C539	STINE	0063	STINEH	0064	STINEL	0063
STPT	0001	STTH	0002	STRTL	0001	SUBDAK	C1CA
SUBDEL	C1CD	TICH	A805	TILL	A804	T2CH	A809
T2LL	A808	TATEN	001D	TDATA	0045	TDATAN	0046
TDATAL	9045	TDATST	C73D	TDLAY	0065	TDIR	004C
TEMP	001F	TEMPNI	0020	TEMPLO	001F	TEMPSH	0021
TIN20H	00C3	TIN20L	0050	TIN50H	004E	TIN50L	0020
TINR20	C350	TINR50	4E20	TINRPG	0066	TINRNI	0038
TINRLO	0037	TINR5	C0E0	TINRSI	C0DE	TINITC	C5D0
TLEN	0017	TOOFAR	C524	TPARAN	0015	TRISOL	0019
TSPED	001B	TSTCHD	C075	TSTPT	0015	W/LDLP	C28A
UPLOAD	C280	USER	C3CA	USERET	23DE	VECSW	88B7
VER1	C5C6	VER2	C5C4	VERSON	C5B9	VOLT	C6D1
VOLTS1	C6F9	WASTZ	0000				

EPROS MODULE C800

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SHOOT
SCOPE PLOT
SAVE R3DULE
LOAD R3DULE
HIDPOINT RANGE
SAVE SPECTRUM
LOAD SPECTRUM

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DEFINITIONS FROM SYS-1 MONITOR

0000	MONITE=\$8000	COLD ENTRY INTO MONITOR
0906	SCANDS=\$8906	DISPLAY FROM DISUP
88AF	GETKEY=\$88AF	GET KEY FROM SYS KEYBOARD
8886	SACCS=\$8886	ROUTINE TO FREE SYSTEM MEMORY
8386	INSTAT=\$8386	RETURN STATUS OF KEYBOARD VIA CARRY
8972	BEEP=\$8972	BEEP ON-BOARD BUZZER AT USER
8A87	OUTCHR=\$8A87	OUTPUT AREG VIA SWAP VECTORS
89A3	ESCOMP=\$89A3	FOR RESTART/POWER INIT ROUTINE
8923	KEYQ=\$8923	
A402	PBDA=\$A402	
88B7	VECSB=\$88B7	SWAP VECTORS FOR TTY
8AFF	BAUD=\$8AFF	SET TTY BAUD RATE
8C78	LOADT=\$8C78	LOAD MEMORY FROM CASSETTE
8E87	DUMPT=\$8E87	DUMP MEMORY TO CASSETTE
A68E	ID=\$A68E	TAPE ID
A64C	SAL=\$A64C	STARTING ADDRESS FOR CASSETTE ROUTINES
A64D	SAH=\$A64D	
A64A	EAL=\$A64A	
A64B	EAH=\$A64B	ENDING ADDRESS + 1 FOR CASSETTE ROUTINES
A640	DISUP=\$A640	SYS SEGMENT DISPLAY BUFFER
A645	BDIG=\$A645	RIGHT MOST DIGIT
8C29	SEGS=\$8C29	TABLE OF SEGMENT CODES FOR ASCII
88EF	ASCII=\$88EF	ASCII CORRESPONDENCE FOR SACS
8FA0	DPFULK=\$8FA0	DEFAULT VALUES FOR SYSTEM RAM (SYS MONITOR)
A620	SRAM=\$A620	SYSTEM RAM (SYS MONITOR)
C800	CTAB1=\$C800	EXTRA EPROM #1 - P1 DEVICE (2K)
D000	CTAB2=\$D000	EXTRA EPROM #2 - P2 DEVICE (2K)
0600	CTABR=\$600	RAM COMMAND EXPANSION
0047	GO=\$47	CODE FOR GO KEY
000D	CR=\$0D	CODE FOR CR KEY
002B	PLUS=\$2B	CODE FOR + KEY
0044	PERIOD=\$44	CODE FOR D - DECIMAL POINT
002E	POINT=\$2E	CODE FOR ASCII DECIMAL POINT
0043	CLEAR=\$43	CODE FOR C - CLEAR DISPLAY IN FETCHP ROUTINE
0000	NOKEY=\$00	CODE FOR NO KEY DEPRESSED
003E	RRRO=\$3E	CODE FOR RIGHT ARROW (-->)
003C	LARO=\$3C	CODE FOR LEFT ARROW (<--)
00F3	PPRPT=\$F3	SEGMENT CODE FOR P PROMPT
0040	MINCODE=\$40	SEGMENT CODE FOR -
00B9	CPRPT=\$B9	SEGMENT CODE FOR C PROMPT
00D3	QUERY=\$D3	SEGMENT CODE FOR ? PROMPT
002D	MINUS=\$2D	CODE FOR - KEY
A801	PORT=\$A801	DATA PORT TO EXTERNAL COMPUTER/DEVICE
A803	PRDIR=\$A803	DATA PORT DIRECTION ADDRESS
A800	CTRL=\$A800	CONTROL LINES PORT
A822	CTDIR=\$A822	CONTROL PORT DIRECTION
A80E	IER=\$A80E	INTERUPT ENABLE REGISTER OF 6522
A80B	ACH=\$A80B	AUXILIARY CONTROL REGISTER
A838	T2LL=\$A838	TIMER 2 LATCH LOW
A809	T2CH=\$A809	TIMER 2 COUNT HIGH
A804	T1LL=\$A804	TIMER 1 LATCH LOW
A805	T1CH=\$A805	TIMER 1 COUNT HIGH
0000	DRUFLO=\$00	SPECTRUM DATA BUFFER
0002	DRUFI=\$02	

0000	BCKGDL=\$00	BACKGROUND SPECTRUM BUFFER
0004	BCKGDH=\$04	
A00C	PCRI=\$A00C	PCR FOR VIA #1 - FOR CASSETTE INTERFACE
A001	PORTA2=\$A001	SYSTEM 6522 PORT
A000	PORTB2=\$A000	
A003	DDRA2=\$A003	
A002	DDRB2=\$A002	
4E20	TINE50=\$4E20	TIME DELAY FOR 1/50 SEC MIN. INTEGRATION PERIOD
0020	TIN50L=\$20	
004E	TIN50H=\$4E	
C350	TINE20=\$C350	TIME DELAY FOR 1/20 SEC MIN. INTEGRATION PERIOD
0050	TIN20L=\$50	
00C3	TIN20H=\$C3	
A67E	IRQLO=\$A67E	IRQ RAN VECTOR
A67F	IRQHI=\$A67F	
0004	DISABL=\$04	SET INTERRUPT DISABLE BIT
0008	DTRDY=\$08	DATA READY LINE FROM SYN
0010	DTRCVD=\$10	DATA RECEIVED LINE FROM EXTERNAL PERIPHERAL
00F7	DTRDY=\$F7	DATA NOT READY MASK

0055	RONPLG=\$55	FLAG FOR FIRST BYTE OF EXPANSION ROMS (EPROMS)
5FB4	ACBEG=24500	ASSUMED POSITION FOR AUTOCAL
00B4	ACBEGH=\$B4	
005F	ACDEGH=\$5F	
62D4	ACHAY=25300	CALIBRATION PEAK POSITION
00D4	ACHAYL=\$D4	
0062	ACHAYH=\$62	
6784	ACEND=26500	END POINT FOR AUTOCAL SCAN
0084	ACENDL=\$84	
0067	ACENDH=\$67	
0000	RNODL=\$0C	RAN MODULE BEGINING - \$600
0006	RNODH=\$06	
0E00	TEXT=\$0E00	SCOPE PLOT TEXT BUFFER
0F00	CJTBUF=\$0F00	SCOPE PLOT NORMALIZED SPECTRUM

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;
;
;
ROUTINES REQUIRED FROM RESIDENT DUVAS CONTROL PROGRAM

C2C3	SETSPT=\$C2C3	SET SPECTRUM POINTERS
C2DA	INCSPT=\$C2DA	INCREMENT SPECTRUM I POINTERS
C49B	MULT=\$C49B	32 BIT FRACTIONAL MULTIPLICATION
C59D	SECHDS=\$C59D	DELAY SUBROUTINE
C3CA	USER=\$C3CA	COMMAND INPUT CHECK
C735	BINBCD=\$C735	BINARY TO BCD AND DISPLAY
C4DD	QDIV=\$C4DD	QUICK DIVIDE ENTRY - USE WITH CAUTION !
C6D1	VOLT=\$C6D1	FORMAT VOLTAGE DISPLAY
C6F9	VOLTS1=\$C6F9	SIGNVC SET, DO NOT SUB MID
C3A6	DIV10=\$C3A6	SCALE TEMP BY 10
C7B3	PARBYT=\$C7B3	OUTPUT BYTE ON PARALLEL LINE
C3E1	PARBIN=\$C3E1	INPUT BYTE ON PARALLEL LINE
C5B9	VERSON=\$C5B9	SET VERSION CONSTANTS
C668	ERROR=\$C668	ERROR BEEP
C3A6	DIV10=\$C3A6	FORM TEMP <-- TEMP / 10

```

*-S0000          PAGE ZERO DEFINITION

0000 00          WASTE .BYTE 0          RESET SETS THIS BYTE TO $6F

:              SPECTRUM PARAMETERS

PARAM
0001 20 4E      STRT .WORD 20000      START OF SPECTRUM (*10)
0003 E8 03      LEN .WORD 1000        LENGTH OF SPECTRUM
0005 19 00      RESOL .WORD 25        RESOLUTION
0007 64 00      SPED .WORD 100        SPEED OF SPECTROMETER
0009 0A 00      ATEN .WORD 10         ATTENUATION

0001            STRTL=STRT
0002            STRTH=STRT+1
0003            LENLO=LEN
0004            LENHI=LEN+1
0007            SPEDL=SPED
0008            SPEHH=SPED+1

:              FORMATTED SPECTRUM PARAMETERS

GOPARM
000B 20 03      GSTRT .WORD 800      STRT (FOR VERSION 1)
000D 28 00      GLEN .WORD 40        LEN
000F 01 00      GRESOL .WORD 1       RESOL
0011 05 00      GSPED .WORD 5        50/SPEED

000B            GSTRTL=GSTRT
000C            GSTRTH=GSTRTH+1
000D            GLENLO=GLEN
000E            GLENHI=GLEN+1
0011            GSPEDL=GSPED
0012            GSPEDH=GSPED+1

0013 00          LOC
0014 00          LOCLO .BYTE 0        CURRENT SPECTROMETER SETTING - SET BY CAL
0014 00          LOCHI .BYTE 0

TPARAM
0015 20 4E      TSTRT .WORD 20000    TEMPORARY PARAMETER STORAGE FOR BACKGROUND
0017 E8 03      TLEN .WORD 1000
0019 19 00      TRESOL .WORD 25
001B 64 00      TSPED .WORD 100
001D 0A 00      TATEN .WORD 10

TEMP
001F 00          TEMPLO .BYTE 0        FOR INTERMEDIATE RESULTS
0020 00          TENPHI .BYTE 0
0021 00          TENPSW .BYTE 0        (FOR TRIPLE PRECISION)
0022 00          SAVE
0023 00          SAVELC .BYTE 0        SECONDARY STORAGE
0023 00          SAVENI .BYTE 0
0024 00          HOLD
0024 00          HOLDLC .BYTE 0        USED BY SECNDS
0025 00          HOLDNI .BYTE 0
0026 00          INDEX
0026 00          INDEX1 .BYTE 0        ARRAY INDICES
0027 00          .BYTE 0                (ALSO ADDRESS POINTERS)
0028 00          INDEX2 .BYTE 0
0029 00          .BYTE 0
002A 00          INDEX3 .BYTE 0
002B 00          .BYTE 0

COUNT
002C 00          COUNT1 .BYTE 0        LOOP COUNTERS
002D 00          COUNT2 .BYTE 0
002E 00          COUNT3 .BYTE 0

```

0027 00	NUMPTS			
0030 00	NUMPTL .BYTE	0	NUMBER OF DATA POINTS IN SPECTRUM	
	NUMP E .BYTE	0		
	DRS /			
0031 00	DRPTLO .BYTE	0		
0032 00	DRSTHI .BYTE	0		
: VERSION DEPENDENT CONSTANTS				
INITC				
	GEAR			
0033 00	GEARLO .BYTE	0	NORMALIZATION FACTOR FOR FORMAT	
0034 00	GEARHI .BYTE	0	- MINIMUM RESOLUTION OF THE CURVES	
	HIDBAS			
0035 00	HIDBLO .BYTE	0	HIDPT FOR ONE INTEGRATION PERIOD	
0036 00	HIDBHI .BYTE	0		
	TINEL0			
0037 00	TINEL0 .BYTE	0	TIME DELAY CONSTANT FOR MIN. INTEGRATION PERIOD	
0038 00	TINEL1 .BYTE	0		
	HID			
	HID0			
0039 00	HIDLO .BYTE	0	FREQUENCY CONST FOR ZERO VOLTAGE	
	HID1			
003A 00	HIDHI .BYTE	0		
003B 00	HID2 .BYTE	0	31 BIT EXTENSION FOR SMOOTH	
003C 00	HID3 .BYTE	0		
	HAI			
003D 00	HAILO .BYTE	0	SPECTRUM MAXIMUM VALUE	
003E 00	HAIHI .BYTE	0		
003F 00 00	HAIP05 .WORD	0	LOCATION (NORMALIZED) OF SPECTRUM MAXIMUM VALUE + RESOLUTION / GEAR	
	SPECT			
0041 00	SPECTL .BYTE	0	POINTER TO SPECTRUM BUFFER	
0042 00	SPECTH .BYTE	0		
	BACK			
0043 00	BACKLC .BYTE	0	POINTER TO BACKGROUND BUFFER	
0044 00	BACKHI .BYTE	0		
	TDATA			
0045 00	TDATA0 .BYTE	0	TEMPORARY SAMPLED DATA POINT	
0046 00	TDATA1 .BYTE	0		
	DATA			
	DATA0			
0047 00	DATA1 .BYTE	0	SAMPLED DATA POINT	
	DATA1			
0048 00	DATA2 .BYTE	0		
0049 00	DATA2 .BYTE	0		
004A 00	DATA3 .BYTE	0		
	DIR			
004B 00	DIR .BYTE	0	DIRECTION IS BIT 7: 0 => FORWARD	
004C 00	TDIR .BYTE	0	TEMPORARY DIRECTION	
	HUNLO			
004D 00	HUNLO .BYTE	0	STORAGE FOR DIVISION ROUTINE	
004E 00	HUNHI .BYTE	0		
004F 00	HUNSGH .BYTE	0	(FOR TRIPLE PRECISION)	
0050 00	CONLO .BYTE	0		
0051 00	CONHI .BYTE	0		
0052 00	CONSGH .BYTE	0	(FOR TRIPLE PRECISION)	
0053 00	CONCNT .BYTE	0	COUNTER FOR DIVIDE ROUTINE	

0054 00	RES0				
	NUMBUF	.BYTE	0		BUFFER FOR DIGITS IN BIN -> BCD
0055 00	RES1				
		.BYTE	0		AND STORAGE FOR MULT ROUTINE
0056 00	RES2				
		.BYTE	0		
0057 00	RES3				
0058 00		.BYTE	0		
		.BYTE	0		
0059 00	CON0				
	CONBUF1	.BYTE	0		CONSTANT BUFFER FOR INVERSE DIVISION
005A 00	CON1				
	CONBUFH	.BYTE	0		AND FOR MULT ROUTINE
005B 00	CLKFLG	.BYTE	0		0 => STAY IN LOOP; -1 => STOP VFC SAMPLE
005C 00	INPLG	.BYTE	0		IMMEDIATE TRANSFER FLAG ON PARALLEL PORT
005D 00	SPROVE	.BYTE	0		0 => MOVE CHND; -1 => EXCHANGE CHND
005E 00	EXEC				
	EXECLOC	.BYTE	0		COMMAND EXECUTION ADDRESS
005F 00	EXECCHI	.BYTE	0		
0060 00	CHND	.BYTE	0		SAVE LAST USER COMMAND
0061 00 00	CPOINT	.WORD	0		BASE ADDRESS OF CURRENT ROM COMMAND LIST
0063 00	STIME				
	STIME1	.BYTE	0		DELAY COUNT FOR SECONDS
0064 00	STIMEH	.BYTE	0		
0065 00	TDELAY	.BYTE	0		STORAGE FOR LDELAY
0066 00	TINEPG	.BYTE	0		FLAG FOR TIME SPECTRUM
0067 00	DWLLPG	.BYTE	0		FLAG FOR A DWELL ACCESS
0068 00	DECPG	.BYTE	0		FLAG FOR DECIMAL POINT IN USER INPUT
0069 00	REODPG	.BYTE	0		0=> INPUT A RAM MODULE
					-1 => OUTPUT A RAM MODULE
006A 00	AVE	.BYTE	0		NUMBER OF POINTS TO AVERAGE IN AVERAGE MODE
006B 00	AVECNT	.BYTE	0		COUNTER FOR AVERAGE MODE
006C 00	AVEFLG	.BYTE	0		-1 => AVERAGE MODE
006D 00	ACCAVL	.BYTE	0		ACCUMULATE AVERAGE LOW
006E 00	ACCAVH	.BYTE	0		ACCUMULATE AVERAGE HIGH
006F 00	DC				
	DCLO	.BYTE	0		DWELL WITH CONCENTRATION CONSTANTS
0070 00	DCHI	.BYTE	0		
0071 00	BGLO	.BYTE	0		
0072 00	BGHI	.BYTE	0		
0073 00 00	COEPTB	.WORD	0		COEFFICIENT TABLE ADDRESS FOR CONVOLUTION
0075 00	COEPMH	.BYTE	0		COEFFICIENT MASK FOR COMPLIMENT
	SHODAT				
0076 00 00	S1	.WORD	0		TEMPORARY DATA STORAGE FOR SMOOTH
0078 00 00	S2	.WORD	0		
007A 00 00	S3	.WORD	0		
007C 00 00	S4	.WORD	0		
007E 00 00	S5	.WORD	0		
	RESH01				
0080 00 00	R1	.WORD	0		RESULT OF S(I)*COEF(I)
0082 00 00	R2	.WORD	0		
0084 00 00	R3	.WORD	0		
0086 00 00	R4	.WORD	0		
0088 00 00	R5	.WORD	0		
	RESPO				
009A 00	RESH01	.BYTE	0		RESULT OF CONVOLUTION
009B 00	RESH0B	.BYTE	0		

008C 00	HVP		
008D 00	HVPLO	.BYTE	0
	HVPHI	.BYTE	0
008E 00	SIGWPG	.BYTE	0

009F 00	HIF			
0090 00	HIFLO	.BYTE	0	MINIMUM FOR SCOPE OUTPUT
	HIFHI	.BYTE	C	
0091 00	CURSOR	.BYTE	0	CURSOR FOR SCOPE PLOT
0092 00	WORN	.BYTE	0	NORMALIZATION COUNT FOR SCOPE OUTPUT
0093 00	SCPOUT	.BYTE	0	LENGTH OF SCOPE SCAN
	RANGE			
0094 00	RANGEL	.BYTE	0	RANGE OF DATA
0095 00	RANGEH	.BYTE	0	
0096 00	DISPTR	.BYTE	0	DISPLAY CHARACTER POINTER
0097 00	SCPCHE	.BYTE	0	DISPLAY CODE FOR SCOPE
0098 00	SCPDH	.BYTE	0	SCOPE DECIMAL POINT CODE - \$00 OR \$40
0099 00	SHASK	.BYTE	0	BIT MASK FOR TEXT
009A 00	TITCWT	.BYTE	0	

*SC000

EPRON MODULE C000

```

SHOOTH
SCOPE PLOT
SAVE MODULE
LOAD MODULE
HIDPOINT RANGE
SAVE SPECTRUM
LOAD SPECTRUM

```

COMMAND TABLE.

GENERAL FORM OF EACH ENTRY

```

<COMMAND CODE>
<ROUTINE ADDRESS LOW>
<ROUTINE ADDRESS HIGH>

```

0

C000 55	CTABLE .BYTE	\$55	ROM FLAG FOR ROM EXISTENCE TEST
C001 35	.BYTE	\$35	SHOOTH CURRENT SPECTRUM - 5
C002 17 C0	.WORD	SHOSPC	
C004 39	.BYTE	\$39	OUTPUT SPECTRUM ON SCOPE
C005 43 C9	.WORD	SCOPEP	
C007 52	.BYTE	\$52	SET FREQUENCY RANGE - R
C008 A3 CC	.WORD	HIDRNG	
C00A 11	.BYTE	\$11	HASH CODE FOR <LD P> - LOAD RAM MODULE
C00B 65 CC	.WORD	RHODIN	
C00D 1C	.BYTE	\$1C	HASH CODE FOR <SAV P> - SAVE RAM MODULE
C00E 53 CC	.WORD	RHODOT	
C010 12	.BYTE	\$12	HASH CODE FOR <SAV 2> - SAVE SPECTRUM
C011 B0 CC	.WORD	HYDUMP	
C013 13	.BYTE	\$13	CASH CODE FOR <LD 2> - LOAD SPECTRUM
C014 F2 CC	.WORD	HYLOAD	
C016 00	.BYTE	0	COMMAND TABLE TERMINATOR

COMMAND: 5

SHOOTH CURRENT SPECTRUM WITH 5 POINT SHOOTH

C017 AD 41 C9	SHOSPC LDA	COEFTL	INIT COEF TABLE TO SHOOTH PARAMETERS
C01A 05 73	STA	COEFTB	
C01C AD 42 C9	LDA	COEFTN	
C01F 05 74	STA	COEFTB+1	
C021 AD 40 C9	LDA	SHONSK	PICK UP 2'S COMPLEMENT MASK
C024 05 75	STA	COEFTN	
C026 20 2A C0	JSR	CONVLV	CONVOLUTE SPECTRUM
C029 60	RTS		

```

;          CONVOLUTE THE CURRENT SPECTRUM WITH THE TABLE SCOEPTB

C82A 20 C3 C2      CONVLP JSR      SETSPT      SET SPECTRUM POINTERS
C82D A0 00          LDY      #0              INIT S1,S2,S3 TO FIRST DATA POINT
C82F B1 41          LDA      (SPECTL),Y
C831 85 76          STA      S1
C833 85 78          STA      S2
C835 85 7A          STA      S3
C837 C8            INY
C838 B1 41          LDA      (SPECTL),Y
C83A 85 77          STA      S1+1
C83C 85 79          STA      S2+1
C83E 85 7B          STA      S3+1
C840 C8            INY
C841 A2 04          LDX      #4              INIT S4,S5 TO NEXT TWO DATA POINTS
C843 B1 41          CINIT1 LDA      (SPECTL),Y
C845 99 7A 00       STA      S3,Y
C848 C8            INY
C849 CA            DEY
C84A D0 F7          BNE      CINIT1
C84C A3 2F          LDY      WURPTS
C84E 88            DEY
C84F 88            DEY
C850 84 20          STY      COUNT2
C852 20 0C C8       CONVLP JSR      SETHPT
C855 20 60 C8       JSR      SWAP
C858 20 DA C2       JSR      INCSPT
C85B C6 2F          DEC      WURPTS
C85D D0 F3          BNE      CONVLP
C85F 60            RTS

```

FORM COUNT FOR SWAP FLAG
DO FULL SWAP IF DEC OF COUNT2 <> 0
ELSE, WPD OF SPECTRUM

CONVOLUTE S1,S2,S3,S4,S5
STORE RESULTS, GET NEW CONVOLUTION DATA
INCREMENT POINTERS ONE DATA POINT
ALL DATA POINTS ?
NO, DO NEXT POINT

```

;          GET CONVOLUTION RESULT, UPDATE CONVOLUTION RAW DATA

C860 A0 00          SWAP LDY      #0              MOVE RESULT INTO SPECTRUM
C862 18            CLC
C863 A5 8A          LDA      RESHOL
C865 65 39          ADC      MIDLO
C867 91 41          STA      (SPECTL),Y
C869 C8            INY
C86A A5 8B          LDA      RESHOL
C86C 65 3A          ADC      MIDHI
C86E 91 41          STA      (SPECTL),Y
C870 A2 F8          LDX      #0
C872 B5 80          SWAPLP LDA      S1+10,X
C874 95 7E          STA      S1+8,X
C876 E8            INX
C877 D0 F9          BNE      SWAPLP
C879 C6 20          DEC      COUNT2
C87B F0 0C          BEQ      SPECND
C87D A0 06          LDY      #6
C87F B1 41          LDA      (SPECTL),Y
C881 85 7E          STA      S5
C883 C8            INY
C884 B1 41          LDA      (SPECTL),Y
C886 85 7F          STA      S5+1
C888 60            RTS

C889 B6 20          SPECND INC      COUNT2
C88B 60            RTS

```

SWAP IN NEW SPECTRUM POINT ?
NO, LEAVE COPY OF S5
YES, PICK UP NEW S5 FROM SPECTRUM
PUT DIRECTLY INTO PLACE

RIG COUNT2 TO COUNT OUT NEXT TIME
NO SPECTRUM POINTS TO SWAP TO BUFFER

```

:      CONVOLUTE S1,S2 S3,S4,S5 WITH TABLE #COEFTB TO FORM R1,R2,R3,
:      R4,R5 AND RESHO

C88C A9 05      SHTEPT LDA      #5          FIVE POINT SHOOTR
C88E 05 2C      STA      COUNT1
C890 A9 76      LDA      #SHOOTAT        POINT TO SHOOTR DATA
C892 05 26      STA      INDEX1
C894 A9 80      LDE      #RESHOL        POINT TO RESULT BUFFER
C896 05 2A      STA      INDEX3
C898 A9 00      LDA      #0            ZERO THE HIGH ORDER OF THE ADDRESSES
C89A 05 27      STA      INDEX1+1
C89C 05 2B      STA      INDEX3+1
C89E A5 73      LDA      COEFTB        POINT TO THE COEFFICIENT TABLE
C8A0 05 28      STA      INDEX2
C8A2 A5 7A      LDA      COEFTB+1
C8A4 05 29      STA      INDEX2+1
C8A6 A0 00      SHTEPL LDY      #0            FOR 6502 INDIRECT
C8A8 B1 26      LDA      (INDEX1),Y    FILL DATA, MOVE POINTER
C8AA 05 47      STA      DATA1
C8AC B6 26      INC      INDEX1
C8AE B1 26      LDA      (INDEX1),Y
C8B0 05 48      STA      DATA1
C8B2 10 02      BPL      POSEXT        EXTEND WITH 0 => POSITIVE
C8B4 A0 FF      LDY      #$FF        EXTEND WITH -1 => NEGATIVE
C8B6 04 49      POSEXT STY      DATA2
C8B8 04 4A      STY      DATA3
C8BA E6 26      INC      INDEX1
C8BC A2 FC      LDX      #~4
C8BE 38        SEC
C8BF 05 4B      SUBRID LDA      DATA0+4,X  SUBTRACT THE MIDPOINT
C8C1 75 3D      SBC      MID0+4,X
C8C3 95 4B      STA      DATA0+4,X
C8C5 E8        INX
C8C6 D0 F7      BNE      SUBRID
C8C8 A0 00      LDY      #0
C8CA B1 28      LDA      (INDEX2),Y    MOVE SHOOTR COEF TO CONSTANT
C8CC 05 59      STA      CON0
C8CE E6 28      INC      INDEX2
C8D0 D0 02      BVE      #+4
C8D2 E6 29      INC      INDEX2+1
C8D4 B1 28      LDA      (INDEX2),Y
C8D6 05 5A      STA      CON1
C8D8 E6 28      INC      INDEX2
C8DA D0 02      BNE      #+4
C8DC E6 29      INC      INDEX2+1
C8DE 20 9B C4   JSR      MULT        FORM (DATA - MID) * COEF
C8E1 A0 00      LDY      #0            MOVE RESULT TO BUFFER
C8E3 A5 56      LDA      RES2
C8E5 71 2A      STA      (INDEX3),Y
C8E7 E6 2A      INC      INDEX3
C8E9 A5 57      LDA      RES3
C8EB 91 2A      STA      (INDEX3),Y
C8ED E6 2A      INC      INDEX3
C8EF C6 2C      DEC      COUNT1        ALL 5 DATA POINTS ?
C8F1 D0 B3      BNE      SHTEPL        NO, SUB, MULT NEXT DATA POINT
C8F3 04 8A      STY      RESHOL        YES, ZERO FINAL RESULT
C8F5 04 8B      STY      RESHOR
C8F7 A4 75      LDY      COMPLNK        FORM 2'S COMPLIMENT ACCORDING TO MASK
C8F9 A2 80      LDX      #RESHOL        POINT X TO RESULTS
C8FB 98      CNPL TYA
C8FC F0 0C      BEQ      CNPL2        THRU WITH ALL (IF ANY) COMPLIMENTS
C8FE 4A      LSR          PICK UP BIT FLAG
C8FF A8      TAY
C901 90 03      BCC      #+5        NO COMPLIMENT - SKIP
C902 20 24 C9   JSR      CONP16        COMPLIMENT #X

```


C905 E8	INI	POINT TO TEXT RESULT
C906 E8	INI	
C907 4C FB C8	JMP	CHPL
C90A A9 05	CHPL2 LDA	05
C90C 85 2C	STA	COUNT1
C90E A2 80	LXI	0RESHUL
C910 18	ADDUP CLC	POINT TO PARTIAL PRODUCTS
C911 B5 00	LDA	0,X
C913 65 8A	ADC	RESHOL
C915 85 8A	STA	RESHOL
C917 E8	INI	
C918 B5 00	LDA	0,X
C91A 65 8B	ADC	RESHOL
C91C 85 8B	STA	RESHOL
C91E E8	INI	
C91F C6 2C	DEC	COUNT1
C921 D0 BD	BNE	ADDUP
C923 60	RTS	

; FORM A 2'S COMPLEMENT IN PLACE TO NUMBER 2X

C924 B5 00	COMP16 LDA	0,X	USE EXCLUSIVE OR
C926 49 FF	BOR	0\$FF	
C928 38	SEC		
C929 69 00	ADC	0\$00	
C92B 95 00	STA	0,X	
C92D 65 01	LDA	1,X	
C92F 49 FF	BOR	0\$FF	
C931 69 00	ADC	0\$00	
C933 95 01	STA	1,X	
C935 60	RTS		

; CONVOLUTION TABLES

C936 F1 15	COEFS	.WORD	5617	5 POINT SHOOT
C938 C5 57		.WORD	22469	
C93A 58 7C		.WORD	31832	
C93C C5 57		.WORD	22469	
C93E F1 15		.WORD	5617	
C940 11	SHOESH	.BYTE	\$11	COMPLEMENT R1,15
C941 36 C9	CSHOE	.WORD	COEFS	GENERATE ADDRESS OF SHOOT TABLE
C941	COEFSL=CSHOE			LOW ORDER ADDRESS
C942	COEFSH=CSHOE+1			H1 ORDER ADDRESS

```

:      COMMAND: 9 ARG      WHERE ARG IS NUMBER OF SECONDS BETWEEN
:                          POINT OUTPUT FOR CHART RECORDERS
:
:      OUTPUT THE SPECTRUM TO THE SCOPE VIA A DAC

C943 A5 1F      SCOPEP LDA      TENPLO      TEST FOR SLOW PLOT
C945 05 20      ORA      TENPHI
C947 F0 0A      BEQ      PSTSCP      NO, DO NOT SET FLAG
C949 C6 66      DEC      TIMEPG      YES, PAUSE TENP*10 SECONDS
C94B A5 1F      LDA      TENPLO      SET STINE FOR DELAY IN 1/10 SEC
C94D 85 63      STA      STINEL
C94F A5 20      LDA      TENPHI
C951 85 64      STA      STINER
C953 20 C3 C2   PSTSCP JSR      SETSPT      GET # OF POINTS
C956 A4 2F      LDY      NUPPTS      INIT CURSOR TO FULL SPECTRUM
C958 88          DEY                      (CURSOR IS DATA POINTER)
C959 84 91      STY      CURSOR
C95B 20 00 CA   JSR      NORMSC      NORMALIZE SCOPE BUFFER
C95E 24 6C      SCLOOP BIT      AVEFLG      AUTO CURSOR ON ?
C960 10 03      BPL      NOAUTO      NO
C962 20 BB C9   JSR      INCCUR      YES, ADVANCE CURSOR ONE POINT
C965 A4 2F      LDY      NUPPTS      OUTPUT THE FULL SPECTRUM
C967 20 CB C9   JSR      SCOPOT
C96A 24 66      BIT      TIMEPG      FINISHED A SLOW SCAN ?
C96C 30 4C      BAI      SCOPER      YES, SEND TO RECORDER ONLY ONCE !
C96E A9 02      LDA      $S02      NO, OUTPUT CURSOR SPECTRUM ? TIMES
C970 85 2C      STA      COUNT1
C972 A4 91      CUROUT LDY      CURSOR      POINTER TO CURSOR POSITION
C974 C8          INY                      COUNT OF # OF POINTS TO PLOT
C975 20 CB C9   JSR      SCOPOT      OUTPUT PARTIAL SPECTRUM
C978 20 16 CC   JSR      TITOUT      OUTPUT GRAPH LABELS
C97B C6 2C      DEC      COUNT1
C97D D0 F3      BNE      CUROUT
C97F 20 CA C3   JSR      USER
C982 F0 DA      BEQ      SCLOOP      USEP COMMAND KEY ?
C984 C9 0D      CNP      $CR      NO COMMAND INPUT
C986 F0 32      BEQ      SCOPER      EXIT ROUTINE ?
C988 C9 3E      CNP      $BARO      CURSOR RIGHT ?
C98A F0 28      BEQ      INCUR      CURSOR LEFT ?
C98C C9 3C      CNP      $LARO
C98E F0 0D      BEQ      DECUR
C990 C9 47      CNP      $GO
C992 D0 CA      BNE      SCLOOP      AUTO CURSOR FLIP FLOP ?
C994 A5 6C      TOGCUR LDA      AVEFLG      IGNORE OTHER INPUTS
C996 49 FF      BOR      $SFF      TOGGLE THE AUTO CURSOR FLAG
C998 85 6C      STA      AVEFLG
C99A 4C 5E C9   JNP      SCLOOP
C99D A4 91      DECUR LDY      CURSOR      CURSOR WRAP AROUND ?
C99F F0 08      BEQ      CURWAPU      YES
C9A1 C6 91      DEC      CURSOR      NO, DECREMENT CURSOR POSITION
C9A3 20 08 CB   JSR      SCURSR      PUT NEW CURSOR VALUE IN TEXT
C9A6 4C 5E C9   JNP      SCLOOP
C9A9 A4 2F      CURWAPU LDY      NUPPTS      YES, POINT TO LAST DATA POSITION
C9AB 88          DEY
C9AC 84 91      STY      CURSOR
C9AE 20 08 CB   JSR      SCURSR      PUT NEW CURSOR VALUE IN TEXT
C9B1 4C 5E C9   JNP      SCLOOP
C9B4 20 BB C9   JSR      INCCUR      INCREMENT CURSOR WITH WRAPAROUND
C9B7 4C 5E C9   JNP      SCLOOP
C9BA 60          RTS

C9BB E6 91      INCCUR INC      CURSOR      ADVANCE CURSOR POSITION
C9BD A5 91      LDA      CURSOR      TEST FOR WRAP AROUND
C9BF C5 2F      CNP      NUPPTS      USE AN UNSIGNED TEST
C9C1 90 04      BCC      INCCRT      ACC < NEW
C9C3 A9 00      LDA      $S00      SET TO BEGINNING
C9C5 85 91      STA      CURSOR
C9C7 20 08 CB   JSR      SCURSR      PUT NEW CURSOR VALUE IN TEXT
C9CA 60          RTS

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; OUTPUT YREG VALUES FROM OUTPUT BY DAC

```

C9CB 84 93      SCOP01 STY      SCPOUT      # OF POINTS TO OUTPUT
C9CD A2 FF      LDI      $SP7      SET PORT TO OUTPUT
C9CF 8E 03 A0    STX      DDRA2
C9D2 8E 01 A0    STX      PORTA2      OUTPUT A TRIGGER PULSE
C9D5 EA          NOP                      WAIT TO REACH FULL SCALE FROM ZERO
C9D6 A2 00      LDI      $S00
C9D8 8E 01 A0    STX      PORTA2      TURN OFF TRIGGER PULSE
C9D9 24 93      CPI      SCPOUT      END OF SPECTRUM ?
C9DB B0 06      BCS      SCOP1      YES, OUTPUT ZERO
C9DF BD 00 0F    LDA      OUTBUF, X    NO, GET DATA POINT
C9E2 4C E9 C9    JMP      SCOP2
C9E5 A9 00      SCOP1  LDA      $S90      GET DUMMY POINT
C9E7 EA          NOP                      DELAY SAME AS REAL POINT
C9E8 EA          NOP
C9E9 8D 01 A0    SCOP2  STA      PORTA2      SEND SPECTRUM VALUE TO DAC
C9EC 24 66      BIT      TIMEPG      SPECTRUM GOING TO RECORDER ?
C9EE 10 07      BPL      NOREC      NO
C9F0 86 22      STX      SAVE      YES, SAVE YREG
C9F2 20 9D C5    JSR      SECNDS      WAIT FOR STIME 1/10 SECONDS
C9F5 A6 22      LDI      SAVE
C9F7 E8          NOREC  INX
C9F8 D0 E1      BNE      SPOT
C9FA A9 00      LDA      $S00
C9FC 8D 01 A0    STA      PORTA2
C9FF 60          RTS

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CA00 20 C3 C2    NOHNSC JSR      SETSPT      GET # OF POINTS, SET POINTERS
CA03 A0 00      LDI      $S00      SET MAX,MIN TO FIRST POINT
CA05 B1 41      LDA      (SPECT), Y
CA07 85 3D      STA      MAXLO
CA09 85 0F      STA      MINLO
CA0B C8          INY
CA0C B1 41      LDA      (SPECT), Y
CA0E 85 3E      STA      MAXHI
CA10 85 90      STA      MINHI
CA12 A0 00      LOOP1  LDI      $S00
CA14 38          SEC
CA15 B1 41      LDA      (SPECT), Y      FORM DATA - MAX
CA17 85 3D      SBC      MAXLO
CA19 C8          INY
CA1A B1 41      LDA      (SPECT), Y
CA1C 85 3E      SBC      MAXHI
CA1E 30 09      BHI      L1
CA20 B1 41      LDA      (SPECTL), Y
CA22 85 3E      STA      MAXHI
CA24 88          DEY
CA25 B1 41      LDA      (SPECTL), Y
CA27 85 3D      STA      MAXLO
CA29 A0 00      L1      LEI      $S00
CA2B 38          SEC
CA2C A5 8F      LDA      MINLO      FORM MIN - DATA
CA2E F1 41      SBC      (SPECT), Y
CA30 C8          INY
CA31 A5 90      LDA      MINHI
CA33 F1 41      SBC      (SPECT), Y
CA35 30 09      BHI      L15
CA37 B1 41      LDA      (SPECT), Y
CA39 85 90      STA      MINHI
CA3B 88          DEY
CA3C B1 41      LDA      (SPECT), Y
CA3E 85 8F      STA      MINLO
CA40 20 DA C2    L15   JSR      INCSPT
CA43 C6 2F      DEC      NUMPTS
CA45 D0 C8      BNE      LOOP1
CA47 38          SEC      FIND RANGE

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CA48 A5 3D	LDA	HAXLO	
CA4A E5 8F	SBC	HINLO	
CA4C 85 94	SLI	RANGEL	SAVE RANGE FOR SCOPE OUTPUT
CA4E 85 1F	STA	TEMPLO	
CA50 A5 3E	LDA	HAXHI	
CA52 E5 90	SBC	HINHI	
CA54 85 95	STA	RANGEH	
CA56 85 20	STA	TEMPHI	
CA58 A9 00	LDA	\$500	DIVIDE BY 2 COUNTER
CA5A 85 92	STA	FOR%	
CA5C A5 20	WRNDWN LDA	TEMPHI	SHIFT UNTIL < 256
CA5E P0 09	BEQ	WRNDWN	
CA60 E6 92	INC	WORN	
CA62 46 20	LSR	TEMPHI	
CA64 66 1F	ROR	TEMPLO	
CA66 4C 5C CA	JMP	WRNDWN	
CA69 A5 1F	WRNDWN LDA	TEMPLO	SHIFT UNTIL > 127
CA6B 30 09	BNI	L2	HIGH ORDER BIT IS SET
CA6D C6 92	DEC	ZORN	
CA6F 06 1F	ASL	TEMPLO	
CA71 26 20	ROL	TEMPHI	
CA73 4C 69 CA	JMP	WRNDWN	
CA76 20 C3 C2	L2 JSR	SETSP	RESET NUMPTS AND SPECTRUM POINTERS
CA79 A2 00	L2 LDX	\$500	X AXIS
CA7B A0 00	L3 LDY	\$500	
CA7D 38	SEC		
CA7E B1 41	LDA	(SPECT),Y	
CA80 E5 8F	SBC	HINLO	
CA82 85 47	STA	DATAL	
CA84 C8	INV		
CA85 B1 41	LDA	(SPECT),Y	
CA87 E5 90	SBC	HINHI	
CA89 85 48	STA	DATAN	
CA8B A4 92	LDY	WORN	
CA8D 30 08	BNI	SHPTUP	SCALE DATA UP
CA8F P0 10	BEQ	L4	DATA DOES NOT NEED TO BE SCALED
CA91 46 48	L5 LSR	DATAN	SCALE DATA DOWN
CA93 66 47	ROR	DATAL	
CA95 88	DEY		
CA96 D0 P9	BNE	L5	
CA98 P0 07	BEQ	L4	
CA9A 06 47	SHPTUP ASL	DATAL	
CA9C 26 48	ROL	DATAN	
CA9E C8	INV		
CA9F D0 P9	BNE	SHPTUP	
CAA1 A5 47	L4 LDA	DATAL	
CAA3 9D 00 0F	STA	OUTBUF,X	
CAAE E8	INX		
CAAF 20 DA C2	JSR	INCSPT	
CAAB C6 2F	DEC	NUMPTS	
CAAC D0 CD	BNE	L3	
CAAE A9 00	LDA	\$500	CLEAR TEXT BUFFER
CAB0 AA	TAX		
CAB1 9D 00 0E	CLRTXT STA	TEXT,X	
CAB4 E8	INX		
CAB5 D0 PA	BNE	CLRTXT	
CAB7 8D 40 A6	STA	DISBUF	CLEAR DISPLAY COMMAND
CABA A5 01	LDA	STRTL	OUTPUT START TO TEXT BUFFER
CABC 85 47	STA	DATAL	
CABE A5 02	LDA	STRTH	
CAC0 85 48	STA	DATAN	
CAC2 20 P7 CA	JSR	XNUM	FORMAT DISPLAY AS DDDD.D
CAC5 A2 00	LDX	#0	
CAC7 20 66 CB	JSR	TITNUM	
CACA A5 94	LDA	RANGEL	OUTPUT RANGE
CACC 85 47	STA	DATAL	
CACE A5 95	LDA	RANGEH	
CAD0 85 48	STA	DATAN	
CAD2 A9 00	LDA	\$500	
CAD4 85 8E	STA	SIGNPG	SET TO POSITIVE NUMBER
CAD6 20 P9 C6	JSR	VOLTS1	- VOLT WITH NO MIDPT SUBTRACT
CAD9 A2 31	LDI	949	
CADB 20 66 CB	JSR	TITNUM	
CAD8 20 08 CB	JSR	SCURSR	SET CURSOR CONSTANTS
CAE1 18	CLC		OUTPUT END POINT + RESOL

CAB2	A5	01	LDA	STRTL
CAB4	65	03	ADC	LENL0
CAB6	85	47	STA	DATAL
CAB8	A5	02	LDA	STRTH
CABA	65	04	ADC	LENHI
CAEC	85	48	STA	GATAH
CABE	20	P7 CA	JSR	KNUM
CAP1	12	D2	LDX	#210
CAP3	20	66 CB	JSR	TITNUM
CAP6	60		RTS	

; KNUM. POI DATA INTO DDDD.D

CAP7	20	35 C7	KNUM	JSR	BIN9CD	SET DISPLAY WITH DECIMAL
CAPA	A9	00		LDA	#000	CLEAR PROMPT CHARACTER
CAPC	8D	40 A6		STA	DISBUF	
CAPP	AD	74 A6		LDA	DISBUF+4	INSET PERIOD
CB02	05	90		ORA	#000	
CB04	8D	44 A6		STA	DISBUF+4	
CB07	60			RTS		

; SCURSR. FORMAT CURSOR VALUES IN TEXT

CB08	A2	62	SCURSR	LDX	#98	POSITION IN TEXT
CB0A	A0	41		LDY	#SCPLP-TITTAB	OUTPUT {
CB0C	20	A4 CB		JSR	TITNOV	
CB0P	A5	05		LDA	RESOL	FORM CURSOR * RESOL
CB11	85	47		STA	DATAL	
CB13	A5	9.		LDA	CURSOR	(8 BIT QUANTITIES)
CB15	85	59		STA	CON0	
CB17	A9	00		LDA	#000	ZERO HIGH ORDERS
CB19	85	48		STA	DATAN	
CB1B	85	49		STA	DATA2	
CB1D	85	4A		STA	DATA3	
CB1P	85	5A		STA	CON1	
CB21	20	9B CA		JSR	MULT	
CB24	18			CLC		
CB25	A5	01		LDA	STRTL	START + CURSOR*RESOL
CB27	65	54		ADC	RES0	
CB29	85	47		STA	DATAL	
CB2B	A5	02		LDA	STRTH	
CB2D	65	55		ADC	RES1	
CB2P	85	48		STA	DATAN	
CB31	20	P7 CA		JSR	KNUM	FORMAT POSITION
CB34	A2	69		LDX	#105	
CB36	20	66 CB		JSR	TITNUM	
CB39	A0	3C		LDY	#SCPEP-TITTAB	OUTPUT }
CB3B	20	A4 CB		JSR	TITNOV	
CB3E	A0	46		LDY	#SCPEQ-TITTAB	OUTPUT =
CB40	20	A4 CB		JSR	TITNOV	
CB43	20	C6 C2		JSR	SETSPT+3	RESET POINTERS, DO NOT RE FORMAT
CB46	A5	91				NOTE: SPECTL MUST BE OF FORM \$N00.
CB48	0A			LDA	CURSOR	PICK UP BYTE POINTER
CB49	90	02		ASL	A	CURSOR IN WORDS
CB4B	86	42		BCC	SC1	NOT IN UPPER HALF
CB4D	85	41		INC	SPECTH	POINT INTO UPPER HALF OF SPECTUM
CB4P	A0	00	SC1	STA	SPECTL	CURSOR*2 + \$00
CB51	91	41		LDY	#000	
CB53	85	47		LDA	(SPECT), Y	OUTPUT DATA
CB55	C8			STA	DATAL	
CB56	B1	41		INY		
CB58	85	48		LDA	(SPECT), Y	
CB5A	20	D1 C6		STA	DATAN	
CB5D	A2	A1		JSR	VOLT	CONVERT TO MILLIVOLT FORMAT
CB5P	20	66 CB		LDX	#161	
CB62	20	C3 C2		JSR	TITNUM	
CB65	60			JSR	SETSPT	
				RTS		

; TEXTNUM. MOVE SCOPE CODES FOR DISPLAY TO TEXT,X

CE66 A9 00	TXTNUM	LDA	#S00	INIT DISPLAY INDEX POINTER
CB68 85 96		STA	DISPTR	
CB6A A4 96	TXTNLP	LDY	DISPTR	MOVED ALL 6 CHARACTERS ?
CB6C C0 06		CPY	#S06	
CB6E F0 0A		BEQ	TXTNET	YES
CB70 B9 40 A6		LDA	DISBUF,Y	NO, GET DISPLAY CODE
CB73 20 7B CB		JSR	TXTCHR	SWAP IN PROPER SCOPE CODES
CB76 E6 96		INC	DISPTR	POINT TO NEXT DISP
CB78 D0 F0		BNE	TXTNLP	
CB7A 60	TXTNRT	RTS		

; MOVE CORRESPONDING SCOPE CODES TO TEXT,X FOR DISPLAY CODE IN ACC

CB7B 65 97	TXTCHR	STA	SCPCHR	SAVE DISPLAY CHARACTER
CB7D A0 00		LDY	#S00	ASSUME NO DECIMAL POINT
CB7F A5 97		LDA	SCPCHR	TEXT FOR \$80 DP CODE
CB81 10 02		BPL	NODEC	NO DECIMAL POINT IN CODE
CB83 A0 40		LDY	#S40	SCOPE CODE FOR A DECIMAL POINT
CB85 84 98	NODEC	STY	SCPPDP	SAVE FOR OUTPUT LATER
CB87 A5 97		LDA	SCPCHP	
CB89 29 7F		AND	#S7F	STRIP ANY DECIMAL POINT
CB8B F0 32		BEQ	TBLANK	NULL CHARACTER
CB8D C0 40		CHP	#HINCDE	
CB8F F0 32		BEQ	THINUS	NEGATIVE VOLTAGE
CB91 A0 09		LDY	#S09	MUST BE A DIGIT, LOCK UP VALUE
CB93 D9 29 8C	TDIGLP	CHP	SEGS,Y	SEARCH SYN TABLE OF DISPLAY CODES
CB96 F0 03		BEQ	TSEGOX	FOUND CODE
CB98 88		DEY		LOOK ONLY IN NUMBERS
CB99 D0 F8		BNE	TDIGLP	DEFAULT IS ZERO
CB9B 84 97	TSEGOX	STY	SCPCHR	FORM 5-INDEX Y
CB9D 98		TYA		
CB9E 0A		ACL	A	*2
CB9F 0A		ASL	A	*4
CBA0 18		CLC		
CBA1 65 97		ADC	SCPCHR	*5
CBA3 A8		TAY		
CBA4 A9 05	TITHOV	LDA	#S05	MOVE SCOPE CODES, TITTAB,Y TO TEXT,X
CBA6 85 9A		STA	TITCNT	
CBA8 B9 CB CB	TITSWP	LDA	TITTAB,Y	
CBA9 0D 00 0E		STA	TEXT,X	
CBAE		INX		

CBAP C8		INY		
CB80 C6 9A		DEC	TITCNT	
CB82 D0 F8		BNE	TITSWP	
CB84 A5 98		LDA	SCPPDP	
CB86 9D 5J 0E		STA	TEXT,X	MOVE DECIMAL POINT
CB89 88		INX		
CB8A 9D 00 0E		STA	TEXT,X	
CB8D E8		INX		
CB8E 60		RTS		

CB8F A0 32	TBLANK	LDY	#SCPBLK-TITTAB
CB91 D0 E1		BNE	TITHOV
CB93 A0 37	THINUS	LDY	#SCPWIN-TITTAB
CB95 A0 30	TINLIN	LDA	#S00
CB97 85 98		STA	SCPPDP
CB99 F0 D9		BEQ	TITHOV

: SCOPE CODES FOR DIGITS AND A FEW SPECIAL CHARACTERS

CBCB 3E 51 49 45	TITTAH	SCPZPO .BYTE	\$3E,\$51,\$49,\$45,\$3E	0
CBCF 3E				
CBD0 00 42 7F 40	SCPONE .BYTE	\$00,\$42,\$7F,\$40,\$00	1	
CBD4 00				
CBD5 62 51 49 49	SCPTWO .BYTE	\$62,\$51,\$49,\$49,\$06	2	
CBD9 06				
CBD1 00 49 49 49	SCPTHR .BYTE	\$00,\$49,\$49,\$49,\$36	3	
CBD2 36				
CBDP 18 14 12 7F	SCPPFOU .BYTE	' 18,\$14,\$12,\$7F,\$10	4	
CBE3 10				
CBE4 27 45 45 49	SCPPFIV .BYTE	\$27,\$45,\$45,\$49,\$31	5	
CBE8 31				
CBE9 3C 4A 49 49	SCPSIX .BYTE	\$3C,\$4A,\$49,\$49,\$31	6	
CBED 31				
CBE2 01 61 11 09	SCPSPV .BYTE	\$01,\$61,\$11,\$09,\$07	7	
CBF2 07				
CBF3 36 49 49 49	SCPEIG .BYTE	\$36,\$49,\$49,\$49,\$36	8	
CBF7 36				
CBF8 06 49 49 29	SCPNIN .BYTE	\$06,\$49,\$49,\$29,\$1E	9	
CBFC 1E				
CBFD 00 00 00 00	SCPBLK .BYTE	\$00,\$00,\$00,\$00,\$00	BLANK	
CC01 00				
CC02 08 08 08 08	SCPHIK .BYTE	\$08,\$08,\$08,\$08,\$08	-	
CC06 08				
CC07 00 41 22 1C	SCP RP .BYTE	\$00,\$41,\$22,\$1C,\$00	)	
CC08 00				
CC0C 00 1C 22 41	SCPLP .BYTE	\$00,\$1C,\$22,\$41,\$00	(	
CC10 00				
CC11 24 24 24 24	SCPEQ .BYTE	\$24,\$24,\$24,\$24,\$24	=	
CC15 24				

: TITOUT. OUTPUT TEXT TO SCOPE

CC16 49 FF	TITOUT	LDA	\$FF	SET PORT TO OUTPUT
CC18 8D 03 A0		STA	DDRA2	
CC1B A2 FF		LDX	\$FF	TOP LINE OF TEXT
CC1D A9 01		LDA	\$01	
CC1F 85 99		STA	SHASK	BIT MASK
CC21 A9 FF	VERT	LDA	\$FF	SEND TRIGGER PULSE
CC23 8D 01 A0		STA	PORTA2	
CC26 EA		NOP		WAIT FOR FULL RISE
CC27 A0 00		LDY	\$00	
CC29 8C 01 A0		STY	PORTA2	
CC2C B9 00 02	SWEPP	LDA	TEXT,Y	GET TEXT CODE
CC2F 25 99		AND	SHASK	STRIP BIT
CC31 F0 06		BEQ	SBLANK	NO OUTPUT
CC33 EA		NOP		
CC34 8E 01 A0		STX	PORTA2	OUTPUT LEVEL
CC37 D0 06		BNE	SSKIP	
CC39 A9 F6	SBLANK	LDA	\$F6	ZERO LINE
CC3B 8D 01 A0		STA	PORTA2	
CC3E EA		NOP		SYNCHRONIZE TIME
CC3F C8	SSKIP	INY		
CC40 D0 EA		BNE	SWEPP	
CC42 A9 00		LDA	\$00	
CC44 8D 01 A0		STA	PORTA2	
CC47 CA		DEX		NEXT CHARACTER LEVEL
CC48 85 65		STA	TDELAY	WAIT FOR FULL SWEEP
CC4A C6 65	SCPWAT	DEC	TDELAY	
CC4C D0 FC		BNE	SCPWAT	
CC4E 06 99		ASL	SHASK	
CC50 10 CF		BPL	VERT	DO 7 LEVEL DOT MATRIX
CC52 60		RTS		

```

:      COMMAND: <SAV P> ARG   WHERE ARG IS # OF BYTES IN MODULE
:
:      SEND A RAM MODULE TO THE EXTERNAL COMPUTER
:      (NOTE: ARG IS ASSUMED TO BE SCALED BY 10 FOR THE HKB

```

```

:      CONVENTION)

```

```

CC53 20 A6 C3      RHODOT JSR      DIV10      SCALE INPUT DOWN BY 10 (HKB CONVENTION)
CC56 85 2C          STA      COUNT1      PUT IN Ac BYTE COUNT
CC58 84 2D          STY      COUNT2
CC5A 20 B3 C7      JSR      PARBYT      SEND COUNT TO EXTERNAL COMPUTER
CC5D 98            TTY
CC5E 20 B3 C7      JSR      PARBYT
CC61 A9 FF          LDA      #SFF      SET RAM FLAG TO OUTPUT
CC63 30 0C          BHI      RHOD      SHARE ROUTINE (BRANCH ALWAYS)

```

```

:      COMMAND: <LD P>
:
:      GET A RAM MODULE FROM THE EXTERNAL COMPUTER

```

```

CC65 20 E1 C3      RHODIN JSR      PARBIN      GET COUNT - NOT SCALED BY 10
CC68 85 2C          STA      COUNT1
CC6A 20 E1 C3      JSR      PARBIN
CC6D 85 2D          STA      COUNT2
CC6F A9 00          LDA      #S00      SET RAM FLAG TO INPUT

```

```

CC71 85 69          RHOD   STA      RHODPG      SET RAM FLAG
CC73 A0 00          LDY      #S00      SET FOR INDIRECT USE
CC75 A9 00          LDA      #RHODL      POINT TO RAM MODULE BUFFER
CC77 85 41          STA      SPECTL
CC79 A9 06          LDA      #RHODH
CC7B 85 42          STA      SPECTH
CC7D 24 69          RHODLP BIT      RHODPG      INPUT/OUTPUT ?
CC7F 10 08          BPL      RGET      INPUT
CC81 B1 41          RSEND  LDA      (SPECTL),Y  OUTPUT, PICK UP THE DATA BYTE
CC83 20 B3 C7      JSR      PARBYT      SEND TO EXTERNAL COMPUTER
CC86 4C 8E CC      JBP      ROW      MERGE WITH GET CODE

```

```

CC89 20 E1 C3      RGET   JSR      PARBIN      GET THE DATA BYTE
CC8C 91 41          STA      (SPECTL),Y  PUT IN RAM MODULE

CC8E E6 41          ROW    INC      SPECTL      POINT TO NEXT BYTE
CC90 D0 02          BNE     RSKIP1
CC92 E6 42          INC     SPECTH
CC94 A5 2C          RSKIP1 LDA      COUNT1      DECREMENT BYTE COUNT
CC96 D0 02          BNE     RSKIP2
CC98 C6 2D          JEC     COUNT2
CC9A C6 2C          RSKIP2 DEC      COUNT1
CC9C A5 2C          LDA      COUNT1      CHECK FOR ZERO
CC9E 05 2D          ORA      COUNT2
CCA0 D0 DB          BNE     RHODLP      NO, SEND/GET ANOTHER BYTE
CCA2 60            RTS

```

```

:      COMMAND: <REG> ARG   WHERE ARG = 0,1,2,3
:
:      SCALE THE MIDBAS ACCORDING TO FREQUENCY RANGE

```

```

CCA3 20 B9 C5      MIDREG JSR      VERNON      INIT MIDBAS ACCORDING TO VERSION BIT
CCA5 20 A6 C3      JSR      DIV10      SCALE ARGUMENT BY 10 (HKB CONVENTION)
CCA9 A8            TAY
CCAB D0 01          BNE     MIDSUP      NO DEFAULT
CCAC C8            INY      SET TO DEFAULT = 1
CCAD 88            DEY      MORE SCALLING TO DO ?
CCAE F0 07          BEQ     MIDRET      NO, MIDBAS IS SET
CCB0 06 35          ASI     MIDBLO      YES, SCALE MIDBAS UP BY 2
CCB2 26 36          ROL     MIDBH
CCB4 8C AD CC      JBP      MIDSUP      TRY AGAIN
CCB7 60            MIDRET RTS

```



```

:      COMMAND: <SAV 2> ARG  WHERE ARG IS TAPE ID ($01-$FE)
:
:      DUMP SPECTRUM PARAMETERS AND SPECTRUM TO CASSETTE
:      USING THE SYN-1 CASSETTE ROUTINES.

```

CCB8 20 A6 C2	HYDUMP	JSR	DIV10	SCALE FOR HKB CONVENTION
CCB8 48		PHA		SAVE ID FOR SPECTRUM DUMP
CCBC 8D 4E A6		STA	ID	SET UP SPECTRUM PARAMETER DUMP
CCBF A9 01		LDA	\$001	SAVE \$0001 - \$003A
CCC1 8D 7C A		STA	SAL	STARTING ADDRESS
CCC4 A9 0B		LDA	\$00B	(END ADDRESS + 1)
CCC6 8D 4A A6		STA	EAL	
CCC9 A9 00		LDA	\$000	
CCCB 8D 4D A6		STA	SAH	
CCCE 8D 4B A6		STA	EAH	
CCD1 A0 80		LDY	\$080	USE HIGH SPEED SYN DUMP
CCD3 20 87 8E		JSR	DUMPT	DUMP SPECTRUM PARAMETERS TO TAPE
CCD6 68		PLA		RESTORE ID
CCD7 8D 4E A6		STA	ID	
CCDA A9 02		LDA	\$002	SAVE \$0200 - \$03FF
CCDC 8D 4D A6		STA	SAH	
CCDF A9 04		LDA	\$004	(END ADDRESS + 1)
CCF1 8D 4B A6		STA	EAH	
CCF4 A9 00		LDA	\$000	
CCF6 8D 4C A6		STA	SAL	
CCF9 8D 4A A6		STA	EAL	
CCFC A0 80		LDY	\$080	USE HIGH SPEED SYN DUMP
CCFE 20 87 8E		JSR	DUMPT	DUMP SPECTRUM TO TAPE
CCF' 60		RTS		

```

:      COMMAND: <LD 2> ARG  WHERE ARG IS ID ($01-$FE, ID=$00 =>
:      LOAD NEXT SPECTRUM)
:
:      LOAD THE SPECTRUM PARAMETERS AND SPECTRUM FROM
:      CASSETTE USING SYN ROUTINES.

```

CCF2 20 A6 C3	HYLOAD	JSR	DIV10	SCALE ID BY HKB CONVENTION
CCF5 48		PHA		SAVE ID FOR SPECTRUM LOAD
CCF6 8D 4E A6		STA	ID	SET FOR SPECTRUM PARAMETER LOAD
CCF9 A0 80		LDY	\$080	USE HIGH SPEED SYN FORMAT
CCFB 20 78 9C		JSR	LOADT	SYN LOAD OF SPECTRUM PARAMETERS
CCFE 80 0C		BCC	LDERR1	LOAD ERROR
GD00 68		PLA		RESTORE ID
CD01 8D 4E A6		STA	ID	LOAD SPECTRUM
CD04 A0 80		LDY	\$080	USE HIGH SPEED SYN FORMAT
CD06 20 78 9C		JSR	LOADT	SYN LOAD OF SPECTRUM
CD09 80 02		BCC	LDERR	LOAD ERROR
CD0B 60		RTS		
CD0C 68	LDERR1	PLA		UNSTACK ID
CD0D 20 68 C6	LDERR	JSR	ERROR	BEEP UNTIL USER NOTICES
CD10 60		RTS		

.END

SYMBOL TABLE

ACBEG	5P84	ACBEGH	005P	ACBEGL	00B4	ACCAVH	006E
ACCAVL	006D	ACEWD	6784	ACENDH	0067	ACENDL	0084
ACHAX	62D4	ACHAXH	0062	ACHAXL	00D4	ACH	A80B
ADDDP	C910	ASCII	58EP	ATEN	0009	AVE	006A
AVECST	006B	AVEPLG	006C	BACK	0043	BACKHI	0044
BACKLO	0043	BAUD	84FP	BCRGDH	0004	BCRGDL	0000
BEEP	8972	BGHI	0072	BGLO	0071	BILBCD	C735
CINIT1	C843	CLEAR	0043	CLKPLG	005B	CLRTXT	C481
CEND	0060	CHPL	C8FB	CHPL2	C90A	COEPKH	0075
COEPS	C936	COEPSH	C942	COEPSL	C941	COEPTB	0073
COEP16	C924	COMO	0059	CON1	005A	CONBPH	005A
COEPPL	0059	CONHI	0051	CONLO	0050	CONSGH	0052
CONVLP	C852	CONVLP	C82A	COUNT	002C	COUNT:	002C
COUNT2	002D	COUNT3	002E	CPHPT	00B9	CPOINT	0061
CR	000D	CSHOTB	C941	CTAB1	C800	CTAB2	DJ00
CTABLE	C800	CTABR	7600	CTELIR	A802	CTRL	A800
CURBOT	C972	CURS02	0091	CWRAPU	C9A9	DATA	0047
DATA0	0047	DATA1	0048	DATA2	0049	DATA3	004A
DATAL	0048	DATAL	0047	DBUPH1	0002	DBUPLO	0000
DC	006P	DCHI	0070	DCLO	006P	DDEA2	A003
DDRB2	A002	DECPLG	0068	DECOR	C99D	DEST	0031
DESTHI	0032	DESTLO	0031	DFTBLK	8FA0	DIR	0046
DISABL	0004	DISBOT	A640	DISPTR	0056	DIV10	C3A6
DIVCWT	0053	DTWRDY	00P7	DTRCVD	0010	DTRDY	0008
DUHPT	8E87	DULLPG	0067	EAN	A64B	EAL	A64A
ERROR	C668	EIEC	005E	EIECHI	005P	EIECLO	075E
FSISCP	C953	GEAR	0033	GEARHI	0034	GEARLO	0033
GETKEY	884P	GLEW	000D	GLEWHI	000E	GLEWLO	000D
GO	0047	GOPARN	000B	GRESOL	000P	GSPED	0011
GSPEDH	0012	GSPEDL	0011	GSTRT	000B	GSTRTH	000C
GSTRTL	000B	HOLD	0024	HOLDHI	0025	HOLDLO	0024
ID	A64E	IER	A80E	INPLG	005C	INCCRT	C9C7
INCCUR	C98B	INCSPT	C2DA	INCOR	C9B4	INDEX	0026
INDEX1	0026	INDEX2	0028	INDEX3	702A	INITC	0033
INSTAT	8386	IRQHI	A67P	IRQLO	A67E	KEYQ	8923
KSCOMP	B943	L1	CA29	L15	CA40	L2	CA76
L3	CA78	L4	CAA1	L5	CA91	LARO	003C
LDERR	CD0D	LDERR1	CD0C	LEN	0003	LENHI	0704
LENLO	0003	LOADT	8C78	LOC	0013	LOCHI	0014
LOCLO	0013	LOOP1	CA12	NAX	003D	NAXHI	003E
NAXLO	003D	NAXPOS	003P	NID	0039	NIDO	0039
NID1	003A	NID2	003B	NID3	003C	NIDBAS	0035
NIDBHI	0036	NIDBLO	0035	NIDHI	003A	NIDLO	0039
NIDRET	CCB7	NIDRNG	CCA3	NIDSUP	CCAD	NIN	008P
NINCDE	0040	NINHI	0090	NINLO	009P	NINUS	002D
NOBITR	8000	NULT	C49B	NVP	008C	NVPHI	008D
NVPLC	008C	NYDUMP	CCB8	NYLOAD	CCF2	NOAUTO	C365
NOPEC	C885	NOKEY	0000	NOREC	C9P7	NORN	0092
NOHNSC	CA00	NRHDWT	CA5C	NRHU2	CA69	NUNBUP	0054
NUNHI	004E	NUNLO	004D	NUNPTH	0030	NUNPTL	002P
NUNPTS	002P	NUNSGH	004P	OUTBUP	0P00	OUTCHR	8A47
PARAN	0001	PARBIN	C3E1	PARBYT	C7B3	PBDA	A402
PCR1	A00C	PERIOD	0044	PLUS	002B	POINT	002E
PORT	A801	PORTA2	A001	PORTB2	AC00	POSEXT	C8B6
PPHPT	00P3	PRTDIR	A803	QDIV	C4DD	QUERY	00D3
R1	0080	R2	0082	R3	0084	R4	0086
R5	0088	RANGE	0094	RANGEN	0095	RANGEL	0094
RARO	003E	RDIG	A645	RES0	0054	RES1	0055
RES2	0056	RES3	0057	RESNO	038A	RESNOH	008B
RESHOL	008A	RESHUL	0080	RESOL	0005	RGET	CC89
REOD	CC71	RHODFG	0069	RHODH	0006	RHODIN	CC65
RHODL	0000	RHODLP	CC7D	RHODOT	CC53	RHMYLG	0055
ROW	CC8E	RSEND	CC81	RSKIP1	CC94	RSKIP2	CC9A
S1	0076	S2	0078	S3	007A	S4	007C
S5	007E	SACCES	8B86	SAH	A64D	SAL	A64C
SAVE	0022	SAVENI	0023	SAVELO	0022	SBLANK	CC39
SC1	C84D	SCANDS	8926	SCLOOP	C95E	SCOP1	C9E5
SCOP2	C9E9	SCOPEP	C943	SCOPEP	C9BA	SCOPOT	C9CB
SCPBLK	CB7D	SCPCHE	0097	SCPDF	0098	SCPEIG	CBF3
SCPEQ	CC11	SCPPIV	CB24	SCPP00	CBDF	SCPLP	CC0C

SCPHIN	CC02	SCPHIN	CBF8	SCPHWE	CE00	SCPHWT	0303
SCPRP	CC07	SCPSZY	CBZE	SCPSIX	CBZ9	SCPTNR	CBDA
SCFTWO	CB05	SCPHAT	CC4A	SCPHBO	CBCH	SCVESA	CB08
SECWDS	C590	SEGS	8C29	SETSPT	C2C3	SHFTUP	CA9A
SIGNPG	0382	SHASK	0099	SHODAT	0076	SHONSK	C940
SHOSPC	C817	SHTHLP	CB46	SHTHPT	C88C	SPECUB	C889
SPECT	0041	SPECTH	0042	SPECTL	0041	SPED	0007
SPEDR	0008	SPZOL	0007	SPROVE	005D	SPOT	C9DB
SRAN	A620	SSKIP	CC3F	STINE	0063	STIRER	0064
STINEL	0063	STRT	0001	STRTH	0002	STRTL	0001
SUBRID	CB8F	SWAP	CB60	SWAPLP	C872	SWEEP	CC2C
T1CH	A805	TILL	A804	T2CH	A809	T2LL	A808
TATZB	001D	TBLANK	CB8F	TDATA	0045	TDATAN	0046
TOTAL	0045	TDELAY	0065	TDIGLP	CB93	TDIR	004C
TENP	001F	TENPBL	0020	TENPLO	001F	TENPSW	0021
TEXT	0E00	TIN20H	00C3	TIN20L	0050	TIN50H	034E
TIN50L	0020	TINZ20	C350	TINZ50	4E20	TINZPG	0066
TINZHI	0038	TINZLO	0037	TINLIN	CB05	TLEN	0017
TINUS	CB03	TOGCR	C994	TPARAN	0015	TRZSOL	0019
TSEGOK	CB9B	TSPED	001B	TSRT	0015	TX HR	CB7B
TXCTY	009A	TXNOV	CB44	TXNLPL	CB6A	TXLJRT	CB7A
TXTRUB	CB66	TXTOUT	CC16	TXTSUP	CB48	TXTTAB	CB0B
USER	C3CA	VECSW	88B7	VERSON	C5B9	VERT	CC21
VOLT	C6D1	VOLTS1	C6F9	WASTE	0000	XNOR	CAP7

Appendix C
ELECTRONIC SCHEMATIC FOR DUVAS

Appendix D

PARTIAL PARTS LIST FOR PROTOTYPE DUVAS

Appendix D

PARTIAL PARTS LIST FOR PROTOTYPE DUVAS

Optical scanner, tant-band type, 400 Hz
Bulova Watch Company, Inc., Electronic Division, Type 150 (modified)

Monochromator, 10 cm, holographic grating
J-Y Optical Systems, Model H10 UV-V (modified)

High-voltage supply, plug-in card
Pacific Precision Instruments, Model 7151

Deuterium lamp (Type Di02) and power supply
McKee Pederson, Model MP-1035A (modified)

Stepping motor
Superior Electric Co., SLO-SYN M061FD301

Power supply, 12 Vdc @ 1.7 A
Power-One, Inc., Model B15-1.5

Power supply, 5 Vdc @ 3 A, ± 15 Vdc @ 0.5 A
Lambda Electronics Corp., Model LOT-X-5152

Photomultiplier tube, S-19 spectral response
EMI Corp., Model 9783B

Single board computer with keypad and display, free EPROM sockets,
Synertek Systems Corp., Model SYM-1

Assorted integrated circuits and electrical components - see
drawings Appendix C.