

Errata

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HP References in this Application Note

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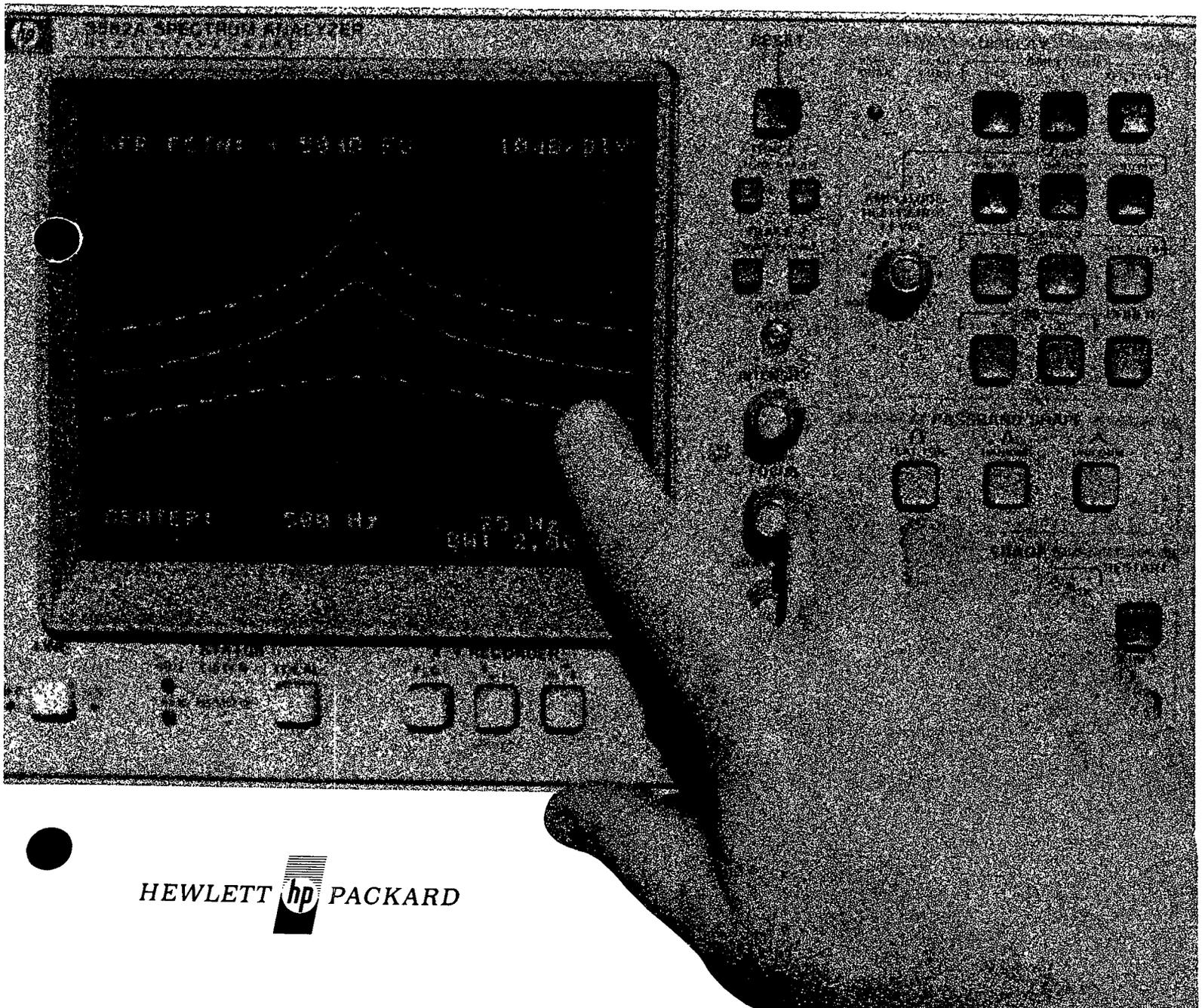
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ACCESSING THE 3582A MEMORY WITH HP-IB



Fast Fourier Transform (FFT) analyzers like the HP 3582A are truly *fast*. The 3582A can analyze a time domain signal up to 200 times faster than a comparable swept frequency analyzer. This is one of the reasons that it is being increasingly used in automatic test systems and other applications where speed is essential.

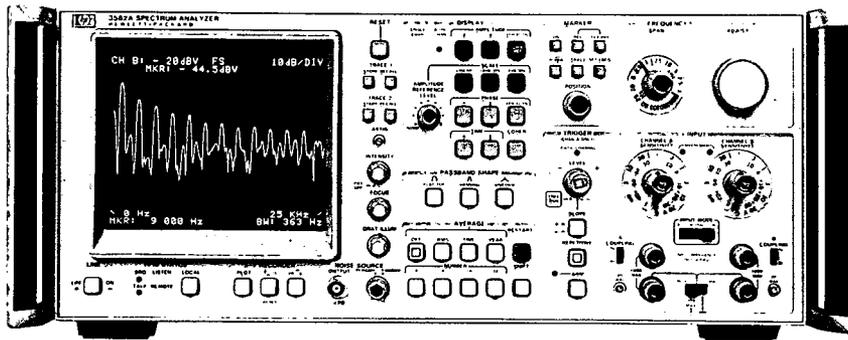
In addition, the 3582A generates some interesting intermediate results which are not available through operating the front panel controls. An example is the cross-power spectrum, which is one of the terms required for calculating the averaged transfer function.

Considerations like these prompted the writing of this application note, whose primary purpose is to spell out clearly the internal memory structure of the 3582A and the various kinds of data to be found there. Equipped

with this information and an HP-IB* controller like the 9835A Desktop Computer, a user may speed up data transfers, obtain normally inaccessible data, modify some routines, and do many other special tasks.

Included with the explanations are listings of several small programs written in BASIC, the language of the 9835A. Our hope is that you will examine the text, the memory maps, and the programs, and then try your own hand at this level of instrument control. You may then wonder how you ever got along before the age of "intelligent instruments"!

*HP-IB is Hewlett-Packard's implementation of IEEE Standard 488 and identical ANSI Standard MC1.1 "Digital Interface for Programmable Instrumentation."



The HP 3582A is a spectrum analyzer covering the frequency range of DC to 25 kHz. Although it is a FFT-based, digital instrument, a special design effort has made it as straightforward to use as a conventional swept analyzer. With dual measurement channels it is possible to measure transfer function gain and phase, as well as the coherence function. A built-in random or pseudo-ran-

dom noise source, whose spectrum tracks the analysis range, is a useful measurement stimulus. Band Selectable Analysis enables narrowband, high resolution analysis to be applied to any portion of the frequency range. The instrument comes equipped with a flexible HP-IB interface for control and two-way data transfers.

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Section 1: Scope of this application note

The 3582A belongs to a group of programmable instruments sometimes referred to as "third level" HP-IB instruments. These are the levels of remote programmability, in order of complexity:

1. Front panel controls may be remotely set
2. Bi-directional data transfer over the bus is possible
3. The internal controller and/or its memory may be remotely accessed and modified

Third level (we could say "third generation") instruments date from about 1978, the year of the introduction of the 3582A. Hence, not many users have had a chance to explore the programming flexibility made possible by access to an instrument's controller and memory.

READ/WRITE MEMORY. *This application note is intended to provide the information needed to work with the read/write part of the 3582A's internal memory.* There is also a fixed part of the memory containing instructions for all the instrument's routines. However, processed results of measurements, in-process results, and raw data are found in the read/write memory, and a primary purpose of this note is to help the user to locate, access, and modify this data.

Another purpose is to help a user who wants to speed up data transfer, such as is needed for automatic testing. For example, the HP-IB command "LDS" will cause the 3582A to list out all the numeric data appearing on the display. The listing is in ASCII format, complete with decimals, signs, commas, etc. It is ready for output to a

printer, typewriter, or display. But it is lengthy, and perhaps too slow for some applications. By contrast, if you need just a few display points, or a faster "dump," and you are willing to do a little more programming, you can directly access the binary data the internal hardware uses to produce the display. True, the data isn't in a form ready to drive a line printer, but it is probably well suited for an automatic test system.

PROGRAM EXAMPLES. Several program listings are given to illustrate some ways of working with the various memory blocks. The program language is BASIC, as used by the 9835A and 9845A controllers. Similar programs can be written in HPL for the 9825A, FORTRAN for the System 1000, or in other languages. It is important that the reader be familiar with input/output statements, especially those used for binary data transfers. It is also helpful to know how to perform conventional binary operations (OR, AND, SHIFT, etc.) on the data.

OTHER LITERATURE. This application note is an extension of some material in the 3582A User's Guide, "Understanding the HP 3582A Spectrum Analyzer." A copy of this guide is recommended for a comprehensive explanation of the operation of the 3582A. It is available through HP field sales offices under part number 5952-8773.

For an additional programming example of memory access, see Application Note 245-3, "Third Octave Analysis with the 3582A Spectrum Analyzer."

Section 2: Definitions of concepts and terms

The subject matter of this application note is strongly rooted in computers and digital signal processing. Because of this, certain terms and concepts peculiar to these subjects are frequently used. Some of these may be confusing, or worse, opaque to the non-specialist.

The following glossary may be helpful:

RAM. "Random-Access Memory," the type of read/write binary data storage used by the 3582A controller.

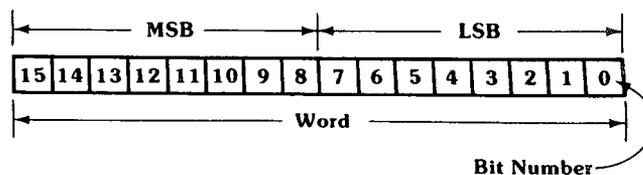
WRITE. To insert new binary data into a location in the 3582A RAM, destroying what was stored there.

READ. To withdraw a duplicate of the binary data stored at a RAM location without destroying what was stored there.

WORD. 16 ordered bits of data; the contents of one RAM address.

ADDRESS. An orderly means of designating word locations in RAM. In this note, octal numbers are used for addresses.

BYTE. One half word. "Least significant byte" (LSB) refers to bits 0-7, and "most significant byte" (MSB) refers to bits 8-15:



2's COMPLEMENT. A means of representing both positive and negative integers with binary numbers. In the 3582A, fundamental processing and storage occurs with 16 bit, 2's complement words, spanning a numeric range of -32768 to +32767. See page 43 of "Understanding the HP 3582A Spectrum Analyzer."

CRT. "Cathode ray tube." a shorthand expression for the type of electronic display used in many instruments, including the 3582A.

BIN. This is used in two separate but related senses. First, it refers to any of the individual "filters" (or their signal content) generated by the FFT algorithm. In the 3582A there are 256 of these in single channel mode (numbered 0-255) and 128 in dual channel (0-127). For instance, in the single channel, 0-25 KHz span, BIN #125 is 12.5 KHz.

Secondly, BIN refers to the left-to-right position on the 3582A display corresponding to a particular FFT filter.

Section 2

HP-IB commands for memory operations in the 3582A

Four 3582A HP-IB instructions are defined for the purpose of accessing internal memory data: LFM, WTM, HLT, and RUN. Programming examples in Section 5 will help to clarify how to use these instructions efficiently to accomplish your objectives. Here are the important features of each:

LFM. The mnemonic refers to "list from memory." This is the instruction used to read any number of words (in consecutive addresses) from the 3582A RAM. The following ASCII sequence must be sent by the controller:

```
LFM,XXXXX,YYYY[linefeed]
```

XXXXX is the *octal* address of the first binary word, and YYYY is the total *decimal* number of consecutive words to be read. On the HP-IB, data transmission takes place in bytes; a 16 bit word is sent in two bytes, the MSB first. Normally, the programmer doesn't have to be concerned with this, since both analyzer and controller automatically take care of "packing" two bytes into one word and vice-versa. (For a counter example where such packing is not wanted, see line 170 of Figure 7. Also note that the 9825A Calculator does not have the packing feature.)

Consider the following 9835A program line:

```
100 OUTPUT 711; "LFM,76077,3"
```

"711" indicates that the HP-IB interface card is set to select code #7 and the 3582A is set to bus address 11. When activated, this line will command the 3582A to prepare to send back the words contained in octal addresses 76077, 76100, and 76101.

Important: This only *prepares* the 3582A to send the data; actual transfer doesn't take place until the controller

addresses the 3582A to talk, itself to listen (for binary, not ASCII, data) and begins the HP-IB handshake. A line like

```
110 ENTER 711 USING "#,3(Y)"; A,B,C
```

will do all this for the 9835A. "#" cancels the need for a linefeed terminator, and "3(Y)" combines the six transmitted bytes into the three variables A, B, and C.

WTM. This instruction is the counterpart to LFM and stands for "write to memory." The syntax to be used by the controller is similar:

```
WTM,XXXXX,YYYY[linefeed]
```

This sequence prepares the 3582A to interpret the subsequent HP-IB data as bytes to be written into RAM.

For this reason, both the instruction sequence and the data can be combined into one program line, if desired:

```
120 OUTPUT 711 USING  
"11A/3(Y)"; "WTM,76077,3", A,B,C
```

"11A" allows the WTM sequence to be output as an ASCII string, while "3(Y)" separates each 16 bit variable into 2 bytes for transmission on the bus. "/" transmits a linefeed after the WTM string, as required by the 3582A syntax.

Both LFM and WTM operations abort "graciously," that is, if they are interrupted by the controller in the midst of data transfer, whatever new operation is commanded will begin. Or, if un-addressed, data transfer will recommence where it was interrupted when the 3582A is again addressed.

HLT. This means "halt" and refers to the 3582A internal processor operation. It does not actually stop processing; rather, it traps the processor at a location in its round of jobs where it is servicing the HP-IB. If this command were not used, data transfers via the bus would be interleaved with other processor tasks, such as performing the FFT. This would result in taking considerably longer time for the data transfer, whereas after sending "HLT" we have the full attention of the processor to perform our job.

After "HLT," bus instructions other than "WTM" and "LFM" can also be sent, such as front panel setups. But the processor will not respond the *momentary* front panel operations like "restart" or "trace store."

RUN. If "HLT" was used, this instruction should be sent at the end of the instruction sequence to allow the processor to continue on its appointed rounds. After receiving "RUN," normal operation will resume, although the 3582A will still remain under remote control. From the "halt" condition, you can return both to normal operation and to local control by sending the "return-to-local" sequence. In the 9835A, this would be

130 LOCAL 711

(assuming 11 is the bus address of the 3582A).

Section 4: Individual memory blocks

In this section we will describe five kinds of information resident in the 3582A during the course of its operation:

- (A) CRT DISPLAY BUFFER
- (B) STORED TRACES
- (C) RAW (UNPROCESSED) SPECTRUM
- (D) RMS AVERAGED SPECTRA
- (E) TIME RECORD

Each of these is described in terms of where it is located in RAM, the form of the data, and additional information needed to properly access and process the information.

(A) CRT DISPLAY BUFFER

Control of the visual output of the 3582A depends on the contents of 512 words beginning at location 74000. This section is continuously accessed by the display hardware such that the screen is refreshed about 50 times per second; this direct memory access continues regardless of whether the data is being changed by the processor. In fact, this is the means by which the dynamic RAM data is kept alive.

The data packed into the 512 words contains:

- the vertical position of the points which make up the trace(s)
- the code to generate four lines of annotation
- whether a trace point is to be intensified
- whether a trace point is to be blanked

The display buffer organization depends on whether the instrument is in single or two channel mode. In addition, commanding a display of a time record momentarily changes the format. Figure 1 is a memory map of the display buffer, showing both one and two channel modes. (Time record displays are described in a paragraph below.) The different buffer size is related to the fact that single channel displays contain 256 points per trace, while dual channel traces have 128. Additional facts about the buffer are:

WORD CONTENT. Bits 0-9 form a binary number which locates the corresponding display point linearly from the bottom (0) to the top (1023) of the graphic area of the CRT. If bit 14 is set, the point is intensified, as in the marker operation. Bit 15 blanks the point; the words of all non-displayed traces have bit 15 set.

There are 128 possible positions for annotation, 32 characters to a line. The code for each character spans 4 words, using bits 10-13 in each word. Because of this complexity, we recommend that you use the "WTA" (i.e., "write alpha") instruction to annotate the display, and the necessary bit juggling will be done automatically.

WORD ORDER. In the conventional sense, the words are in reverse sequence: lowest addresses correspond to the *right* side of the screen, and highest addresses to the *left* side. The same is true for the annotation: addresses 74774 to 74777 contain the code for the character in the lower left corner of the display, while the upper right character is found in 74000 to 74003.

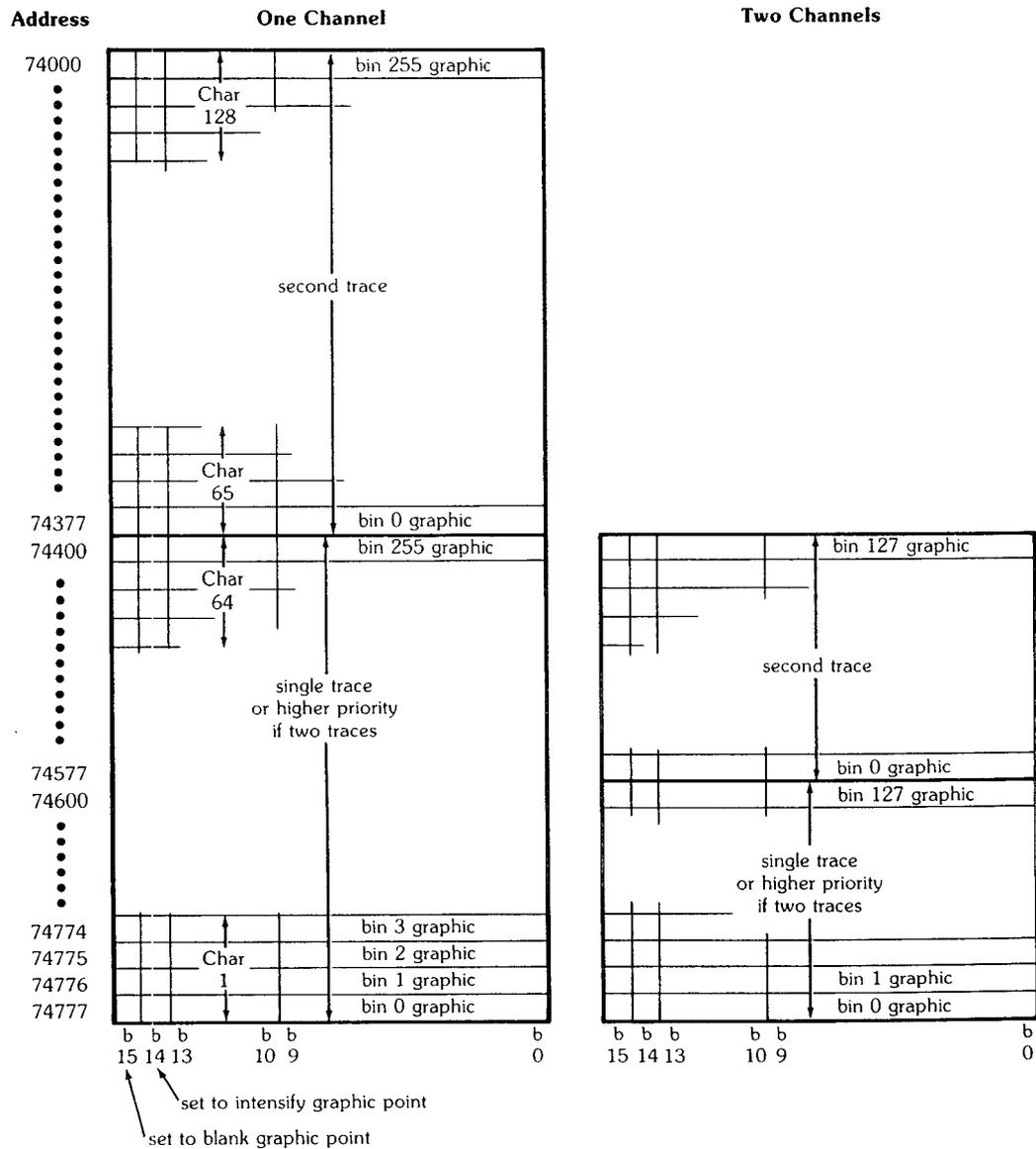
TRACE BLOCKS. The 128 or 256 consecutively addressed words which contain all the graphic data for one trace are placed as high in the buffer address space as possible. For example, in single channel mode, Amplitude A will be located from 74400 to 74777. Then, if Phase A is called up, it is placed from 74000 to 74377. If Amplitude A is removed, leaving only the phase display, the phase data will be moved to the higher address block. The priority followed in determining which of two displays occupies the higher address block is (in descending order) Amplitude A, Amplitude B, Amplitude Transfer Function, Phase A, Phase B, Phase Transfer Function, Coherence, Stored Trace 1, Stored Trace 2.

DISPLAYING A TIME RECORD. The time buffer consists of 1024 words starting at address 7000 (see paragraph (E) of this section). When the front panel TIME button for either channel is pressed (or, equivalently, "TA" or "TB" commands are sent over the HP-IB), one-half the stored time record is scaled to 10 bits and displayed as follows:

One channel — 512 points, consisting of the data in the even numbered addresses of the time buffer (70000, 70002, etc., to 71776).

Two channels — 256 points. In dual channel mode, the time buffer data is interleaved, with channel A occupying even addresses, and channel B odd. Therefore, the display shows data in addresses ending in 0 and 4 for channel A, and addresses ending in 1 and 5 for channel B.

CRT Display Buffer
(for all displays except time records;
for these, see Section 4A)



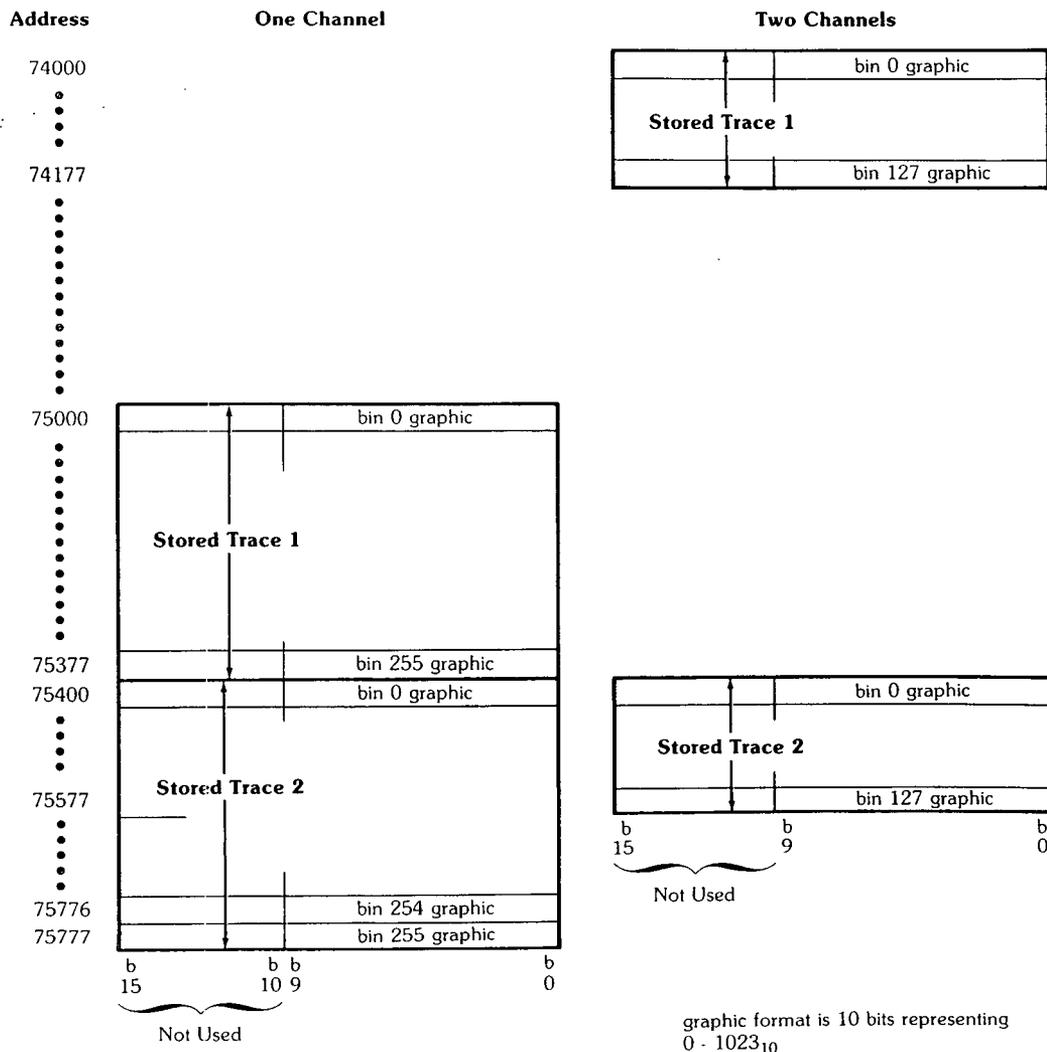
SAVING A DISPLAY IN MASS STORAGE. Often one wants to store away data and examine it at some future time. A convenient way to do this with the 3582A is to save the entire display buffer and then restore it to the CRT when desired. Figure 6 lists a program to do this job, using a string variable to hold the binary data. It is important to obtain and save information about the display state of the 3582A; that is, whether it is in single channel, dual channel, or time display modes when the display is recorded. This information could be recorded manually and the analyzer adjusted to that state before displaying the saved data. However, the same result can be achieved automatically by saving the contents of address 77455, one of the five switch register words in which the state of the front panel controls is stored. (This is part of the "learn mode" routine on page 46 of "Understanding the 3582A Spectrum Analyzer.")

(B) STORED TRACES

There are four switches whose function is to store and recall one or two traces from the display. 512 words of RAM are allocated for this storage. The principle difference between the data stored in this buffer and that stored in the display buffer is that the stored trace words contain only the 10 bits of graphic information — no intensity, blanking, or alpha character codes. Figure 2 shows the memory location and format of the stored traces buffer for single and dual channel modes.

If one does not use the stored trace function very often, its buffer could be a convenient place to store other data temporarily. Two minor words of caution if you do this: don't operate the STORE switches, or your data will be overwritten; and don't switch from single trace to dual trace modes, or vice-versa, as the processor may set bit 15 when moving around the data.

Figure 2.
Stored Traces



(D) RMS AVERAGED SPECTRA

After the 3582A performs from 4 to 256 "RMS" averages, there are two types of results available in memory:

- Auto (or self) power spectra* for one or both channels, depending on the input mode
- The cross power spectrum*, when in dual channel mode

Figures 4 and 5 show the memory organization for these two types of buffers. During averaging, the buffers are used as accumulators. Therefore, at the end of averaging, the numbers therein are the sum of N individual power spectra, where N is the number of averages (4 to 256) chosen. *To get the true average, you must divide the data in the buffers by N.*

Both types of spectrum contain the passband ripple errors mentioned in (C) above, except that the cross spectrum has twice the error (in dB), since it is obtained through multiplying data from two identical channels.

Phase errors don't apply to either spectrum for these reasons:

- 1) Auto spectra are phaseless. (The phase data available in the 3582A with auto spectra is obtained by a simple linear averaging process.)
- 2) Cross spectra are obtained by conjugate multiplication, and the phase errors cancel.

The comments in Section 5, Figure 12, indicate how you can determine the magnitude errors in order to remove the intrinsic ripple from the data before you use it.

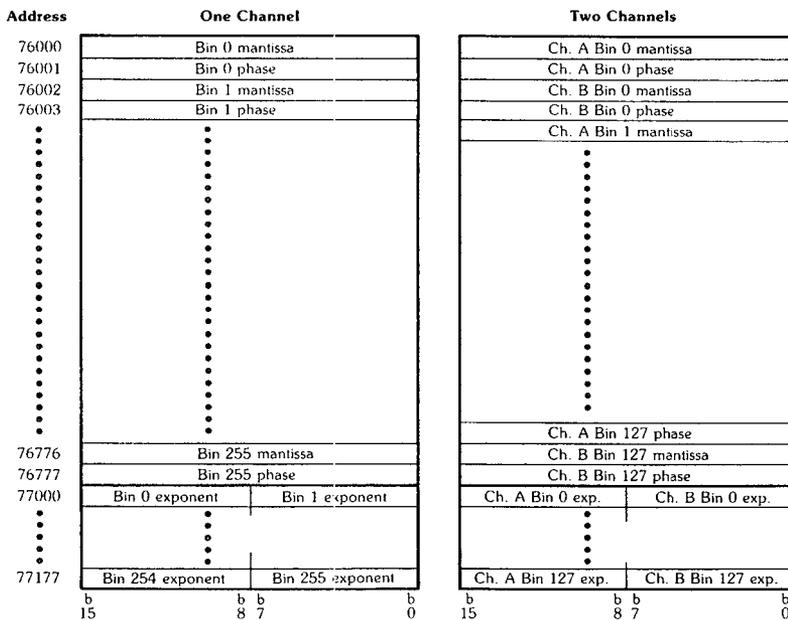
*For an explanation of these spectra and their usefulness, see Application Note 245-1, "Signal Averaging With the HP 3582A Spectrum Analyzer," Sections 3, 5, and 6; also Application Note 245-2, "Measuring the Coherence Function With the HP 3582A Spectrum Analyzer," Appendix.

(E) TIME RECORD

After the input signal is conditioned, its sample values are written into a 1024-word buffer from address 70000 to address 71777. The data is 2's complement binary. When using the dual channel mode, Channel A data is written into even-numbered addresses, and Channel B into odd-numbered addresses. In REPETITIVE operation, new data is written into this buffer whenever the FFT can accept it. For this reason, if you want to preserve the time record (you may have written in your own record over the HP-IB, for instance), you should turn REPETITIVE off. When this is done, the processor will continue to read the time record into the FFT buffer 2-3 times per second, but it will be reading the same time data.

FIGURE 4
Auto (Self) Power Spectra
(RMS Averaging)

NOTE: Read Section 4(D) before using this data



Data Formats:

[Amplitude]²: binary floating point number, evaluated as follows

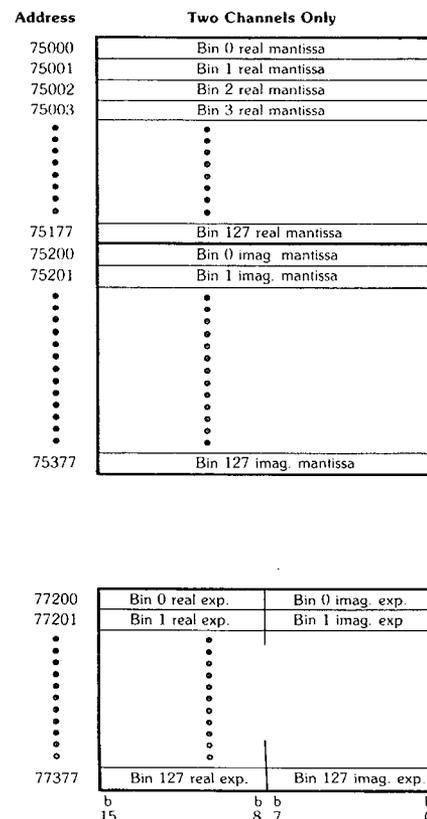
$$[\text{mantissa}] \times 2^{[\text{exponent} - 15]}$$

16 bit 2's complement 8 bit positive binary

Phase: 2's complement, in which $\pm 2^{15}$ corresponds to $\pm 200^\circ$

FIGURE 5
Cross Power Spectra
(RMS Averaging)

NOTE: Read Section 4(D) before using this data



data formats are the same as those of auto power spectra

WINDOW FUNCTIONS. Some measurements could benefit from the use of other window functions than those provided with the 3582A. Exponential windows are useful with transients, for instance. Here is a way to implement your own choice of window function: with REPETITIVE off, enter one time record using the UNIFORM PASSBAND SHAPE (the rectangular win-

dow). Then read the time buffer into the controller, multiply the data by the desired window, and write the modified data back to the time buffer. If a gain correction is desirable, the spectrum data can be multiplied by the appropriate factor; this will avoid possible overload of the time buffer.

Section 5: Illustrative programs

In this section you will find some annotated programs, along with explanatory comments for each. This is not meant to be a comprehensive "library" of software. Rather, the programs are included both for their usefulness, and also as illustrations of BASIC statements needed to work with the 3582A memory.

The following programs are included:

- Fig. 6: STORING THE DISPLAY ON A TAPE CARTRIDGE**
- Fig. 7: CALCULATING PHASE FROM THE CROSS-POWER SPECTRUM**
- Fig. 8: GENERATING AND LOADING AN EXTERNAL TIME RECORD**
- Fig. 9: INTENSIFIED MARKER FOR TIME RECORDS, STORED DISPLAYS, ETC.**
- Fig. 10: SUBTRACTING TRACES**
- Fig. 11: MODIFYING THE NUMBER OF RMS AVERAGES**
- Fig. 12: INTERNAL FILTER RESPONSE CORRECTION**

STORING THE DISPLAY (Fig. 6). Many applications require semi-permanent storage of spectrum information produced by the 3582A. (A common example is monitoring bearing vibration; a series of records is kept to reveal any adverse trends in a bearing's "health.") This program allows any type of display to be saved in its entirety: one or two traces, marker dot, and annotation. This is because it saves the full 512 word display buffer. Before writing the stored data back on the CRT, the 3582A is forced back to the display state it was in when the data was recorded, and "HLT" is transmitted to prevent over-writing the stored data with current data.

Although this is the easiest and fastest method for display storage, it has the disadvantage that the stored display is static; the marker can't be used, nor can the display format (like SCALE) be changed. There are a couple of ways to overcome this: either store the time record, or (in the case of RMS averaging) store the spectrum buffer. If you do the latter, you should get the 3582A to the same state it was — that is, restore the INPUT and FREQUENCY controls, and execute the same number of averages before loading in the stored data.

Figure 6

```

10  ! PROGRAM TO SAVE AND RETRIEVE 3582A DISPLAY
20  ! "Save" SAVES DISPLAY BUFFER (A#) AND DISPLAY STATE (B#);
30  ! "Retrieve" REMOTES 3582A AND LOADS STORED DISPLAY STATE AND DISPLAY.
40  ! STORAGE MEDIUM FOR THIS PROGRAM IS BUILT-IN TAPE CARTRIDGE.
50  OPTION BASE 1
60  DIM A#[1024],B#[2]           ! initialize variables.
70  Analyzer=711
80  CREATE "SAVDSP",1,1100       ! establish data buffer on tape.
90  ASSIGN #1 TO "SAVDSP"
100 PAUSE
110 Save: OUTPUT 711;"HLTLFM,77455,1" ! set switch register word
120   ENTER Analyzer USING "#,2A";B# ! containing display state.
130   OUTPUT Analyzer;"LFM,74000,512" ! set entire display buffer;
140   ENTER Analyzer USING "#,1024A";A# ! 512 16-bit words.
150   LOCAL Analyzer
160   PRINT #1;A#,B#           ! save display data and switch state on tape.
170 PAUSE
180 Retrieve: READ #1,1         ! reposition file data pointer.
190   READ #1;A#,B#           ! load display and switch data from tape.
200   OUTPUT Analyzer USING "11A/2A";"WTM,77455,1",B# ! set display state.
210   OUTPUT Analyzer USING "16A/1024A";"HLTWTM,74000,512",A# ! load buffer.
220 PAUSE

```

CROSS-POWER SPECTRUM PHASE (Fig. 7).

Marker readout of phase has only one degree resolution, largely because of the phase accuracy specification of the 3582A. This, in turn, comes from the imperfect characteristics of the analog input filters, especially over the environmental operating range. However, for restricted environmental change and frequencies much lower than 25 KHz, these filters have less effect on the phase accuracy. In addition, transfer function measurements increase phase accuracy by first-order tracking of the two channels.

These considerations make it attractive to increase the

resolution of the measured phase, and the program is intended for this purpose. The principle is to perform an RMS average of the transfer function, and then to calculate and display the phase, using the stored real and imaginary components of the cross-power spectrum.

The program asks for which bin (of the 128 available) the phase is wanted. It then extracts the spectrum components for that bin, calculates the phase in degrees, and displays it to 0.1 degree resolution. Given the data for the frequency setup of the 3582A, the program could be easily modified to request frequency rather than bin number.

```
10 ! PROGRAM TO COMPUTE AND DISPLAY CROSS-POWER (AND THUS TRANSFER
20 ! FUNCTION) PHASE. MUST BE USED AFTER RMS AVERAGING.
30 Analyzer=711 ! initialize.
40 DEG
50 INPUT "Bin number (0-127)?";Dec
60 Dec_bin=Dec
70 Oct_bin=0 ! convert bin number to octal; this routine
80 FOR I=0 TO 2 ! required for 9845A.
90 Oct_bin=Oct_bin+Dec_bin MOD 8*10^I
100 Dec_bin=INT(Dec_bin/8)
110 NEXT I ! "Oct_bin" is bin number in octal.
120 OUTPUT Analyzer USING "7A;5D;2A";"HLT LFM,";75000+Oct_bin;"1"
130 ENTER Analyzer USING "#;Y";Re_mant ! get the real spectrum mantissa.
140 OUTPUT Analyzer USING "4A;5D;2A";"L FM,";75200+Oct_bin;"1"
150 ENTER Analyzer USING "#;Y";Im_mant ! get the imag spectrum mantissa.
160 OUTPUT Analyzer USING "4A;5D;2A";"L FM,";77200+Oct_bin;"1"
170 ENTER Analyzer USING "#;B;B";Re_Exp;Im_Exp ! get real and imag exponents.
180 Arg=Im_mant/Re_mant*2^(Im_Exp-Re_Exp) ! calculate IMAG/REAL.
190 Phase=ATN(Arg)+(SGN(Re_mant)=-1)*SGN(Im_mant)*180
200 PRINT USING "6A;3D;8A;DDDD.D;4A";"BIN # ";Dec;" PHASE=";Phase;" DEG"
210 LOCAL Analyzer
220 GOTO 50
```

EXTERNAL TIME RECORD (Fig. 8). In "Understanding the HP 3582A Spectrum Analyzer," page 45, there is an explanation and an example of writing external data into the time buffer so that it may be examined

and analyzed just as if it had originated as an input signal. The program given here is much the same, except that it is written in BASIC.

```
10 ! PROGRAM TO GENERATE A SAMPLED SINUSOID AND WRITE IT INTO THE
20 ! 3582A TIME BUFFER.
30 RAD ! set calculator in radian mode.
40 INTEGER T(1023) ! initialize integer variable to store samples.
50 Analyzer=711
60 INPUT "FREQUENCY (CYCLES PER RECORD)?";F ! ask for frequency wanted.
70 Const=2*PI*F/1024 ! compute this once rather than 1024 times.
80 FOR I=0 TO 1023 ! computing loop.
90 T(I)=20000*COS(Const*I) ! values are rounded to integers
100 NEXT I ! through using integer variable.
110 OUTPUT Analyzer;"RP0IM1TA1HLT" ! REPETITIVE off, one chan., disp TIME.
120 OUTPUT Analyzer USING "14A/1024(Y);3A";"WTM;70000;1024";T(*);"RUN"
130 GOTO 60 ! return for another pass.
```

INTENSIFIED MARKER (Fig. 9). In normal operation of the 3582A there is no provision for using the marker on either time record displays or stored trace displays. This program provides a generalized means for moving around an intensified dot on any type of display, and for reading out the magnitude of the graphic data at each point.

The technique is the same as that used by the pro-

cessor: setting and resetting bit 14 of the data buffer word. However, using the HP-IB, this means withdrawing the entire word, changing the bit, and writing the modified word back into RAM. This action is carried out by a subroutine ("Dot"), while the user controls the marker position with the special function keys of the 9835A.

Fig. 9

```

10  ! PROGRAM ALLOWS MANUAL CONTROL OF AN INTENSIFIED DOT BY SPECIAL
20  ! FUNCTION KEYS 0-3.  STARTS AT ADDRESS 74777 (LEFT EDGE OF DISPLAY)
30  ! AND MOVES DOT ACCORDING TO KEY PRESSED, BY EXTINGUISHING PREVIOUS
40  ! DOT AND TURNING ON NEXT DOT.  ADDRESS FIELD LIMITED TO DISPLAY
50  ! BUFFER (77000-74777) BUT NO FURTHER LIMITS CORRESPONDING TO
60  ! DISPLAY MODE; I.E., DOTS OF BLANKED DISPLAY CAN BE TURNED ON.
70  ! BOTH THE ADDRESS OF THE INTENSIFIED BIN AND THE MAGNITUDE OF THE
80  ! GRAPHIC DATA THEREIN ARE WRITTEN ON THE SCREEN.
90  INTEGER Disp_data,I,Dec_addr      ! initialize variables & constants.
100  Prev_addr=Oct_addr=74777
110  Dec_addr=31231
120  GOSUB Dot                        ! turn on the dot at the left side of display.
130  ON KEY #0 GOTO Step_up1         ! move one bin to the left.
140  ON KEY #1 GOTO Step_up10       ! move ten bins to the left.
150  ON KEY #2 GOTO Step_down10     ! move ten bins to the right.
160  ON KEY #3 GOTO Step_down1     ! move one bin to the right.
170  !                               ! these two lines are the waiting
180  GOTO 170                        ! loop required by "ON KEY" lines.
190 Step_up1: Dec_addr=Dec_addr+1
200  GOTO 220
210 Step_up10: Dec_addr=Dec_addr+10
220  IF Dec_addr>31231 THEN Dec_addr=31231 ! upper address bound.
230  GOSUB Dec_to_Octal
240  GOSUB Dot
250  GOTO 170
260 Step_down1: Dec_addr=Dec_addr-1
270  GOTO 290
280 Step_down10: Dec_addr=Dec_addr-10
290  IF Dec_addr<30720 THEN Dec_addr=30720 ! lower address bound.
300  GOSUB Dec_to_Octal
310  GOSUB Dot
320  GOTO 170
330  ! "Dot" IS THE INTENSIFY SUBROUTINE. IT RETURNS THE LAST INTENSIFIED
340  ! WORD TO NORMAL, MOVES TO THE NEXT ADDRESS, AND INTENSIFIES THAT WORD.
350 Dot: OUTPUT 711 USING "7A,5D,2A";"HLTLFM,";Prev_addr,";1"
360  ENTER 711 USING "#,Y";Disp_data      ! get last intensified word.
370  Disp_data=BINAND(Disp_data,16383)    ! de-intensify it.
380  OUTPUT 711 USING "4A,5D,2A/Y";"WTM,";Prev_addr,";1";Disp_data
390  Prev_addr=Oct_addr                  ! save the new address.
400  OUTPUT 711 USING "4A,5D,2A";"LFM,";Oct_addr,";1"
410  ENTER 711 USING "#,Y";Disp_data      ! get the new word.
420  Disp_data=BINIOR(Disp_data,16384)    ! intensify it.
430  OUTPUT 711 USING "4A,5D,2A/Y";"WTM,";Oct_addr,";1";Disp_data
440  Graphic=BINAND(Disp_data,1023)      ! get the magnitude (0-1023) of display.
450  Graphic=Graphic#8/1023              ! scale it to 0 to 8 (8 divisions on CRT)
460  OUTPUT 711 USING "16A,5D,12A,B.DD";"WTA3,ADDRESS IS ";Oct_addr,"  MAG.
IS ",Graphic                          ! write bin number and magnitude on line 3 of display.
470  RETURN
480 Dec_to_Octal:  Oct_addr=0             ! decimal to octal conversion subroutine;
490  Dec=Dec_addr                        ! required by 9845A - 9835A could use
500  FOR I=0 TO 5                          ! "OCTAL" instruction.
510  Oct_addr=Oct_addr+Dec MOD 8*10^I
520  Dec=INT(Dec/8)
530  NEXT I
540  RETURN

```

SUBTRACTING TRACES (Fig. 10). Sometimes it is helpful to be able to perform "trace arithmetic;" this term means not only adding or subtracting trace data, but multiplication, division, and time domain integration or differentiation. The latter two operations are equivalent to applying 6 dB/octave gain decreases or increases in the frequency domain and are a convenient way, for instance, to convert accelerometer data to velocity or displacement.

As an example of this type of data manipulation, the program requests the user to set up two successive traces on the CRT. It inputs the data from each trace, blanks off all but the graphic information, and writes back the difference into the display buffer.

Although the program subtracts the traces, other operations are easily accomplished by changing the contents of the FOR/NEXT loop, lines 140 to 170.

Figure 10

```

10  ! PROGRAM TO INPUT TWO SUCCESSIVE SINGLE CHANNEL AMPLITUDE
20  ! TRACES, AND TO DISPLAY THEIR DIFFERENCE.
30  Analyzer=711                                ! initialize variables.
40  INTEGER First(255),Second(255),Diff(255)
50  DISP "DISPLAY FIRST TRACE, THEN PRESS 'CONTINUE'"
60  PAUSE                                       ! ask for first trace.
70  OUTPUT Analyzer;"HLTLM,74400,256"
80  ENTER Analyzer USING "#,256(Y)";First(*) ! input first trace.
90  LOCAL Analyzer
100 DISP "DISPLAY SECOND TRACE, THEN PRESS 'CONTINUE'"
110 PAUSE                                       ! ask for second trace.
120 OUTPUT Analyzer;"HLTLM,74400,256"
130 ENTER Analyzer USING "#,256(Y)";Second(*) ! input second trace.
140 FOR I=0 TO 255
150 Diff(I)=BINAND(First(I),1023)-BINAND(Second(I),1023) ! blank all but
160 IF Diff(I)<0 THEN Diff(I)=0                ! graphics, subtract, set any
170 NEXT I                                     ! negative values to zero.
180 OUTPUT Analyzer USING "13A/256(Y)";"WTM,74400,256",Diff(*) ! send data.
190 OUTPUT Analyzer;"WTA3, FIRST TRACE MINUS SECOND TRACE "
200 OUTPUT Analyzer;"WTA4, "
210 END

```

ARBITRARY NUMBER OF RMS AVERAGES (Fig. 11). Occasionally there is a need to perform a specific number of RMS averages outside the range of choice available in the 3582A. Within certain constraints, this is possible by using the listed program. The program takes advantage of the fact that one word of RAM (location 77465) is used as a cycle counter by the processor during RMS averaging. This word is loaded with the number of averages, decremented during each cycle, and tested for zero content to stop the averaging. The program merely writes a user-supplied value into this

location before allowing averaging to start.

The following constraints apply to averages performed this way:

- 1) Above approximately 1500 averages, roundoff errors will start to degrade the accuracy of the spectrum data.
- 2) Phase information is largely useless, as it will not be properly scaled.
- 3) The average counter on the display will recycle after 999; therefore, the current average count is shown modulo 1000.

Figure 11

```

10  ! PROGRAM TO SET ARBITRARY NUMBER OF RMS AVERAGES.
20  ! THIS ROUTINE OVERRIDES THE AVERAGE COUNTER IN THE 3582A,
30  ! ALLOWING ANY NUMBER OF AVERAGES <32767. HOWEVER,
40  ! ARITHMETIC CONSIDERATIONS LIMIT THE NUMBER TO
50  ! 1500 OR SO; OTHERWISE INACCURACIES WILL RESULT.
60  ! START PROGRAM WITH 3582A IN RMS AVERAGING.
70  Analyzer=711
80  INPUT "HOW MANY AVES?";N                    ! Get number of averages wanted
90  OUTPUT Analyzer USING "16A/Y,3A";"RP0REWTM,77465,1";N,"RP1"
100  GOTO 80

```

INTERNAL FILTER RESPONSE CORRECTION

(Fig. 12). In Section 4C and 4D we mentioned that the various forms of stored spectrum information contain errors resulting from the passband ripple of the digital filters used to process the time signal(s) before applying the FFT. The magnitude errors are removed by the display algorithms before the spectrum data is shown on the CRT. The actual correction depends on the frequency span and whether band analysis is being used.

A practical way to determine the corrections to be applied for any measurement setup is to observe what the 3582A does. That is, you apply a broad-band signal and compare the computed spectrum with the display. The ratio of these contains the correction information.

The program accomplishes this for the case of single channel, non-averaged data. A convenient broad-band source is the internal periodic noise source, which excites each bin at approximately the same level. Both the spectrum data (real and imaginary components) and the linear display data are retrieved. Then a power ratio is obtained by dividing the spectrum power by the display "power" (the square of the linear display data). Since the units of this ratio are obscure at this point, the ratio is nor-

malized so that the largest of the 256 numbers is set to unity. The result is the "Norm" array.

To use the data, follow these rules:

- divide linear components (real and imaginary, non-averaged) by the square root of "Norm"
- divide auto-power spectra by "Norm"
- divide cross-power spectra by the square of "Norm"

Naturally, for two channel operation, and this includes cross-power spectra, you will need to modify the program to work with 128 data bins rather than 256.

One word of caution: there are some small gain corrections which are not included in "Norm." These come from the fact that the digital filter gain varies somewhat, depending on its configuration. If you need absolute magnitude information, and not just flatness correction, you should make an additional calibration measurement. Use a calibrated sinusoidal source set to the bin where "Norm" has its maximum value (unity), and determine the spectrum value there. Of course, the 3582A marker can be used to measure the amplitude of the source, and thus provide the calibration factor.

Fig. 12

```
10  ! PROGRAM TO DETERMINE THE CORRECTION FACTORS USED BY THE 3582A TO
20  ! OBTAIN A FLAT RESPONSE IN ANY SPAN, NON AVERAGING.  AN ARRAY "Norm"
30  ! IS COMPUTED GIVING THE NORMALIZED FREQUENCY RESPONSE ON THE BASIS OF
40  ! POWER FOR EACH OF THE 256 BINS.  TO OPERATE, USE PERIODIC NOISE SIGNAL,
50  ! UNIFORM PASSBAND, SINGLE CHANNEL AND ADJUST LINEAR AMPLITUDE DISPLAY
60  ! NEAR TOP OF SCREEN.  TO USE RESULTS, DIVIDE AUTO POWER SPECTRUM DATA
70  ! BY "Norm" OR LINEAR SPECTRUM DATA BY THE SQUARE ROOT OF "Norm".
80  Analyzer=711
90  INTEGER Re(255),Im(255),Dsp(255)      ! declare REAL, IMAGINARY, DISPLAY
100 DIM Norm(255)                        ! and NORMALIZE variables.
110  OUTPUT Analyzer;"HLTLFM,76000,512"  ! set real and imaginary parts
120  FOR I=0 TO 255                        ! of power spectrum.
130    ENTER Analyzer USING "#,Y,Y";Re(I),Im(I)
140  NEXT I
150  OUTPUT Analyzer;"LFM,74400,256"    ! set display data.
160  ENTER Analyzer USING "#,256(Y)";Dsp(*)
170  FOR I=0 TO 255                        ! compute magnitude squared from real
180    Norm(I)=Re(I)*Re(I)+Im(I)*Im(I)  ! and imaginary components.
190    Dsp(I)=BINAND(Dsp(I),1023)       ! mask off extraneous display data.
200  NEXT I
210  FOR I=0 TO 255                        ! compute ratio of magnitude squared
220    Norm(I)=Norm(I)/Dsp(255-I)^2     ! to display magnitude squared; save
230  NEXT I                                ! in NORMALIZE array.
240  Max=Norm(0)                           ! determine largest number.
250  FOR I=1 TO 255
260    IF Norm(I)>Max THEN Max=Norm(I)  ! save it in Max
270  NEXT I
280  MAT Norm=Norm/(Max)                  ! largest value in Norm is now 1.
290  LOCAL Analyzer
300  END
```

Summary:

The 3582A is an instrument with an advanced level of remote programming capability. Specifically, it allows direct access to the internal memory used by the instrument's microprocessor. This opens the door to many kinds of programming possibilities, from speeding up data transfers to modifying certain routines. However, to

use this potential effectively, the user must know more about the internal workings and structure of the instrument.

This application note is intended to provide the necessary documentation and explanation to make this level of programming both possible and attractive.



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