HEWLETT
PACKARD

Product Note
8903A-1

Operating the 8903A Audio Analyzer Below 20 Hz

Introduction

The HP 8903A Audio Analyzer is a versatile audio measurement system covering the frequency range of 20 Hz to 100 kHz. Automatic operation does not allow operation below 20 Hz. However, with allowance for somewhat reduced performance, useful measurements can be made below 20 Hz. This product note describes how to operate the analyzer below 20 Hz and what precautions must be observed to obtain valid measurements.

Because the range below 20 Hz is outside that specified for the Analyzer, performance degrades, especially for frequencies less than 10 Hz. When using the procedure for out-of-band operation, it is important to be aware of the performance limitations summarized in Table 1.

Basically the 8903A is composed of an audio oscillator, a tunable notch filter, variable gain amplifiers and an rms voltmeter. Operating the Analyzer involves controlling these elements to obtain a desired result. In the normal operating range, the elements are controlled by the microprocessor, making operation as simple as pushing front panel keys. Outside the normal range, however, all control is by special functions.

Table 1. Performance Summary

	Lowest Operational Frequency	Comment
Source	10 Hz	Distortion increases rapidly below 10 Hz. Level flatness degrades rapidly below 5 Hz. Output not continuous below 9 Hz, available to 0.8 Hz.
Notch (Distortion)	5 Hz	Tuning much slower below 10 Hz (about 5 seconds). Stability marginal below 10 Hz.
Voltmeter	12 Hz	Readings fluctuate below 12 Hz. Slight accuracy rolloff between 12 Hz and 9 Hz. Measurements not possible below 5 Hz.
Frequency counter	8 Hz	Sensitivity remains good down to 8 Hz. No operation below 8 Hz.

Input Circuitry and Voltmeter Considerations

The combined responses of the input and voltmeter circuits fall off rapidly below 9 Hz, and voltmeter readings can fluctuate ±0.1 dB at frequencies below 12 Hz. A typical frequency response curve for the input and voltmeter is shown in Figure 1.

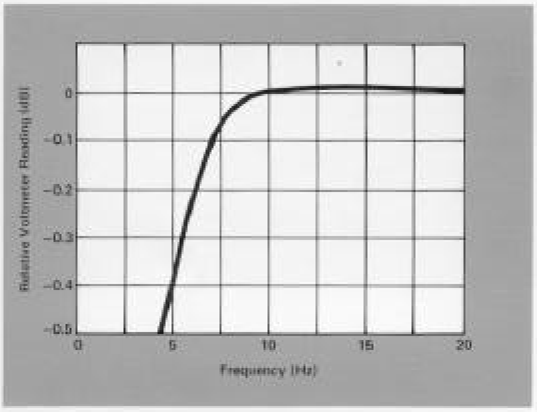

Figure 1. Frequency Response of the Input and Voltmeter Circuits Below 20 Hz.

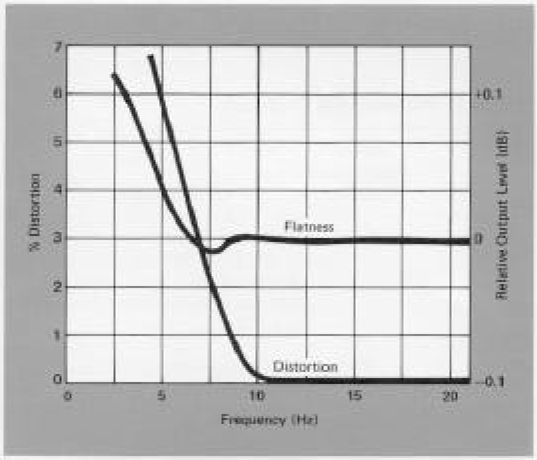

Figure 2. 8903A Source Level Flatness and Distortion* Characteristics Below 20 Hz.

Source Considerations

Level accuracy of the audio source remains excellent down to about 8 Hz but degrades rapidly below 5 Hz, as shown in Figure 2.

Source distortion also remains low (typically 0.003%, -90 dBc) to below 10 Hz but rises rapidly as shown in Figure 2. The distortion is typically dominated by 2nd order effects because the waveform is disturbed unsymmetrically once every cycle by the oscillator start-up circuitry that comes into action around 5 Hz.

Notch Filter Considerations

Distortion measurements can also be made below 20 Hz with certain limitations. Because the auto-ranging gain circuitry responds rapidly when the Analyzer first encounters a signal, large step and pulse signals are generated at the input to the notch. At low frequencies these pulses can cause the notch circuit to oscillate. However, reducing gain in the signal path to the notch prevents the oscillations. The actual amount of gain reduction is discussed in the next section. Below 5 Hz the notch circuit is not stable at any gain setting, and distortion measurements cannot be made.

Source Frequency Control

Frequency coverage for the source is shown in Figures 3 and 4. In Figure 3, each bar represents one of the Analyzer's four bands, and the length of the bar represents the tuning range of that band. In Figure 4, the length of each bar represents the fine tune range of the coarse tune setting shown inside each bar. Figure 4 shows that tuning is not continuous below about 8 Hz. To control the source frequency, special functions are used to program the range, coarse-tune, and fine-tune digital-to-analog converters (DAC). These DACs switch resistors in the oscillator circuitry. The fine tune and coarse tune DACs have 8-bit resolution and therefore 256 different output states. The state of each DAC is programmed by making special function entries via the keyboard or over HP-IB with the necessary prefix and suffix. The source control special functions are represented as follows.

***Note: Distortion was confirmed using a Hewlett-Packard 3582A Spectrum Analyzer measuring the Analyzer's monitor output. Relative output level was measured with a Hewlett-Packard 3403C RMS Voltmeter.**

Coarse Source Tune Special Function

Special prefix	decimal point	suffix
56	.	XXX

Fine Source Tune Special Function

Special prefix	decimal point	suffix
57	.	YYY

For both the fine-tune and coarse-tune special functions, the XXX and YYY suffixes are any integer between 0 and 255. Frequency is proportional to output state for each DAC.

The fine tune covers a range somewhat greater than one step of the coarse tune such that fine tune full coverage (57.0 to 57.255) always overlaps coarse tune minimum coverage (e.g., between 56.125 and 56.126). Within the specified operating range of the analyzer (20 Hz to 100 kHz), the fine tune always provides continuous fine resolution, but, as shown in Figure 3, overlap does not exist below 9 Hz.

Due to manufacturing tolerances, the DACs and resistor arrays within each 8903A have slightly different values. Therefore, the expression governing frequency of oscillation is determined iteratively.

The procedures and related calculations that follow result in the Analyzer's audio source being set to the desired frequency.

Notch Filter Control

Like the source, notch circuitry is also tuned with a combination of range, coarse tune, and fine tune controls. The 4 notch ranges, similar to the source ranges, are controlled with special function 53. The coarse tune is controlled with special function 54, and each tuning step has a range of about 8%. The notch fine tune is an analog circuit that is continuously operating to track frequency fluctuations of the input signal. It therefore has no special function control. The notch fine tune has approximately a 15% range.

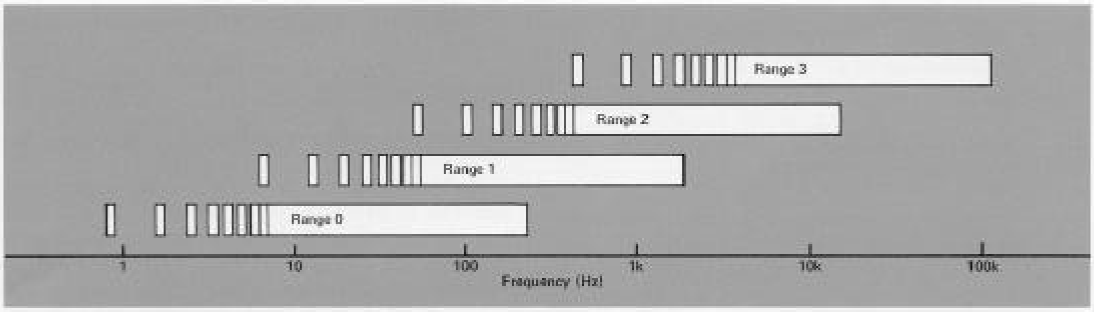

Figure 3. Typical Source Frequency Coverage by Range.

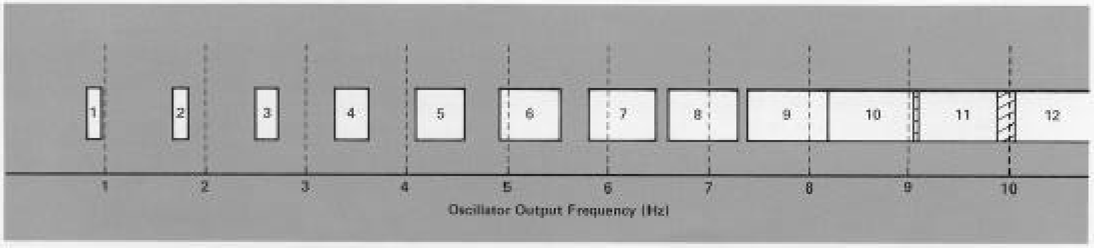

Figure 4. Typical Source Frequency Coverage on Range 0 Below 10 Hz. 56.XX Special Function Frequency Control Codes Show Inside Bars.

Procedure for Operation Below 20 Hz

Frequencies below 20 Hz are obtained using the 8903's special functions. The tune settings for the coarse and fine tune special functions are found by first characterizing the relationship between frequency and tune settings on range 0. Then, knowing the desired source frequency, the tune settings are calculated.

To obtain a frequency below 20 Hz:

(1) Determine the source characteristics on range 0:

Analyzer Entry	**Analyzer Response**
a. 55.0SP	Sets source to lowest range (0).
b. 56.255SP	Sets coarse tune to top of range.
c. 57.128SP	Centers fine tune.
d. 46.0SP	Counts and displays source frequency. (Record as r_1 for later use.)
e. 57.0SP	Sets fine tune to its low end.
f. 46.0SP	Counts source frequency. (Record as r_2 for later use.)
g. 57.255SP	Sets fine tune to high end.
h. 46.0SP	Counts source frequency. (Record as r_3 for later use.)

(2) Determine the coarse-tune setting:

i. $(255*F)/r_1 \rightarrow S$ where F is the desired frequency (r_1 from step d).
j. Integer part of $S \rightarrow D$.
k. Fractional part of $S \rightarrow T$.
l. If $T > 0.5$ then add 1 to D. D is the coarse tune setting (suffix of the 56. special function).

(3) Determine the fine-tune setting:

m. $128.5+255*[\ln(S/D)/\ln(r_3/r_2)] \rightarrow M$.
n. Integer part of $M \rightarrow M$.
o. If $M < 0$ then assign 0 to M.
p. If $M > 255$ then assign 255 to M.
M is the fine tune setting (suffix of the 57. special function).

(4) Set the source frequency:

Analyzer Entry	**Analyzer Response**
q. 56.D SP	Sets coarse tune to D.
r. 57.M SP	Sets fine tune to M.
s. 46.0 SP	Counts and displays source frequency. An auxiliary counter is needed for frequencies less than 8 Hz.

Notch Frequency Control

Programming the notch and making distortion measurements below the normal operating range of the instrumen is done as follows:

(1) Apply the signal to be analyzed to the Analyzer input.
(2) Press **DISTN.**
(3) Press **SPECIAL** twice to display instrument status.
(4) Read the first two digits of the left display. This is the gain code for the input amplifier. It is referred to as N_R in steps 5 and 6.
(5) For frequencies between 10 and 20 Hz, enter 1. (N_R-1) SP: to reduce input gain by 4.0 dB and stabilize the notch.
(6) For frequencies below 10 Hz, enter 1. (N_R-2) SP to reduce input gain by 8.0 dB for extra notch stability.
(7) Enter 53.0 SP to place notch in lowest of 4 ranges.
(8) Enter 54.D SP where D is the integer calculated in steps 1 and 2 at left. The notch has approximately 15% automatic fine tuning range so no operator fine tuning is necessary.
(9) Read the right display after it has stabilized. It may take up to 5 seconds for low distortion signals below 10 Hz to stabilize.

This procedure can be automated. Programs for both the HP 9825 and the HP 85F controllers are listed starting on page 5.

Summary

The Hewlett-Packard 8903A Audio Analyzer typically performs as well at 10 Hz as it does at 20 Hz. Slight accuracy rolloff in the ac level measurement mode is noticed from 12 to 10 Hz. Below 10 Hz, voltage and distortion measurements can be slightly erratic (±0.1 dB typically). The counter stops operating below 8 Hz, and no measurements can be made below 5 Hz.

The source also performs well below 20 Hz. Distortion increases rapidly below 10 Hz, and flatness degrades rapidly below 5 Hz. Coverage is not continuous below 9 Hz, but periodic waveforms with frequencies as low as 850 mHz can be obtained.

Since the typical performance described in this note was determined at standard room temperature (25° C), care should be exercised at higher temperature. Performance of the 8903A is not specified below 20 Hz in the technical data sheet mainly because temperature and component variations cause each unit to perform differently. The biggest effect of these variations is the automatic fine tuning range of the notch.

Program for Setting Source and Measuring Distortion Using HP 9825 Controller

```
0: "8903 FREQUENCY TUNE ROUTINE  JR from JF 7-17-80":
1:
2: cll ´PROG´
3:
4: "PROG":
5: cll ´DEFINE´
6: cll ´INIT´
7: "progloop":
8: cll ´INP´                                   Main Program.  Remainder of program is subroutines
9: cll ´CALC´
10: cll ´OUTOSC´
11: cll ´OUTNOTCH´
12: gto "progloop"
13:
14: "DEFINE":
15: dev "8903",728                             Assigns name "8903" for 8903A HP-IB address
16: ret
17:
18: "INIT":
19: fmt
20: wrt "8903","55.0sp56.255sp57.128spt346.0sp"   Steps a-d in Procedure 1
21: red "8903",r1                                  Step d
22: wrt "8903","57.0spt346.0sp"                    Steps e and f
23: red "8903",r2                                  Step f
24: wrt "8903","57.255spt346.0sp"                  Step g and h
25: red "8903",r3                                  Step h
26: wrt "8903","t0auml"                  Returns instrument to local control in free run trigger mode.
27: lcl "8903"                            This is a convenience and not really necessary
28: ret
29:
30: "INP":
31: 0}F;ent "Frequ?",F                    Operator enters frequency in Hz
32: if F=0;gto "inpend"
33: if F>100000;1e5}F                     Checks to make sure F is a valid number
34: if F<8;8}F                            8 Hz ≤F≤105 kHz
35: "inpend":
36: ret
37:
38: "CALC":                               Calculates D and M as in Procedures 2 and 3
39: if F>200;gto "calcend"
40: if F=0;gto "calcend"
41: 255*F/r1}S                            Equivalent to step i
42: int(S)}D;frc(S)}T                     Equivalent to steps j and k
43: if T>.5;T-1}T;D+1}D                   Equivalent to step l
44: int(ln(S/D)/ln(r3/r2)*255+128.5)}M    Equivalent to steps m and n
45: if M<0;0}M                            Safety check for invalid M values
46: if M>255;255}M
47: "calcend":
48: ret
49:
50: "OUTOSC":                             Oscillator output control
51: if F>=20;fmt "fr",e.4,"hzmlau";wrt "8903",F;lcl "8903";gto "outend"   Writes out frequency normally
                                                                          if F is in normal range
52: if F=0;gto "outend"
53: fmt "au55.0sp56.",f3.0,"sp57.",f3.0,"spml"
54: wrt "8903",D,M                        Outputs D and M to 56 and 57 special functions per format0 on line 53
55: lcl "8903"
56: "outend":
57: ret
58:
59: "OUTNOTCH":                           Notch frequency control
60: if F#0;gto "outnotchend"
61: fmt ;wrt "8903","1.0spml t3t0rl"
62: fmt ;red "8903",F
63: if F>19.9;wrt "8903","1.0sp6.0spm3";lcl "8903";gto "outnotchend"
64: wrt "8903","ss"
65: fmt ;red "8903",G
66: int(G/1000)-1}G
67: fmt "1.",f2.0,"sprr"
68: wrt "8903",G
69: fmt "54.",f3.0,"sp53.0spm3";beep
70: wrt "8903",D
71: lcl "8903"
72: "outnotchend":
73: ret
```

Lines 59 through 73 cause the 8903A to measure distortion. This section of the program is entered by entering 0 in response to the question, "Frequ?".

Program for Setting Source and Measuring Distortion Using HP 85F Controller

```
 10 ! 8903 FREQUENCY SET ROUTINE
 20 ! JR FROM JF 7/17/80
 30 ! CONV. TO 85 BASIC 3/13/81
 40 !
 50 ! VARIABLES USED IN THIS PRO
    GRAM-R1,R2,R3,D,F,G,M,S,T
 60 !
 70 GOSUB 170
 80 !
 90 ! *****PROG LOOP*************
100 !
110 GOSUB 290
120 GOSUB 400
130 GOSUB 570
140 GOSUB 720
150 GOTO 90
160 !
170 ! *****INIT*****************
180 !
190 OUTPUT 728 ;"55.0SP56.255SP5
    7.128SPT346.0SP"
200 ENTER 728 ; R1
210 OUTPUT 728 ;"57.0SPT346.0SP"
220 ENTER 728 ; R2
230 OUTPUT 728 ;"57.255SPT346.0S
    P"
240 ENTER 728 ; R3
250 OUTPUT 728 ;"T0AUM1"
260 LOCAL 728
270 RETURN
280 !


290 ! *****INP******************
300 !
310 F=0
320 DISP "FREQUENCY"
330 INPUT F
340 IF F=0 THEN 370
350 IF F>100000 THEN F=100000
360 IF F<9 THEN F=9
370 ! INPEND
380 RETURN
390 !
400 ! *****CALC*****************
410 !
420 IF F>200 THEN 530
430 IF F=0 THEN 530
440 S=255*F/R1
450 D=INT(S)
460 T=S-D
470 IF T>.5 THEN 500
480 T=T-1
490 D=D+1
500 M=INT(LOG(S/D)/LOG(R3/R2)*25
    5+128.5)
510 IF M<0 THEN M=0
520 IF M>255 THEN M=255
530 ! CALCEND
540 RETURN
550 !
560 !
```

```
570 ! *****OUTSC****************
580 !
590 IF F>=20 THEN 610
600 GOTO 650
610 IMAGE "FR",K,"HZM1AU"
620 OUTPUT 728 USING 610 ; F
630 LOCAL 728
640 GOTO 690
650 IF F=0 THEN 690
660 IMAGE "AU55.0SP56.",K,"SP57.
    "K,"SPM1"
670 OUTPUT 728 USING 660 ; D;M
680 LOCAL 728
690 ! OUTEND
700 RETURN
710 !
720 ! *****OUTNOTCH************
730 !
740 IF F#0 THEN 920
750 OUTPUT 728 "1.0SPM1T3T0R1RL"
760 ENTER 728 ; F
770 ! IF F>19.9 THEN 790
780 GOTO 820
790 ! OUTPUT 728 "1.0SP6.0SPM3"
800 LOCAL 728
810 GOTO 920
820 OUTPUT 728 "SS"
830 ENTER 728 ; G
840 G=INT(G/1000)-1
850 IMAGE "1.",K,"SPRR"
860 OUTPUT 728 USING 850 ; G
870 OUTPUT 728 USING 880 ; D
880 IMAGE "54.",K,"SP53.0SPM3"
890 BEEP
900 OUTPUT 728 USING 880 ; D
910 LOCAL 728
920 ! OUTNOTCHEND
930 RETURN
940 END
```

HEWLETT
PACKARD

5952-8246
Printed in U.S.A.
June 1981