# Loudspeaker Production Testing Using the Techron TEF System 20 TDS Analyzer and Host PC

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A comprehensive system for doing production testing of loudspeakers and systems is described. Multiple TEF analyzers can be controlled by a single host computer to create elaborate test environments. The software allows the test engineer to orchestrate very complex test sequences while simultaneously minimizing the perceived complexity of the system as viewed by the test operator. Tests that can be incorporated in the test sequence, with pass/fail window parameters, include any or all of the following (in any order): frequency response, phase response (polarity), harmonic tracking, harmonic distortion (of specific harmonics), THD, THD and noise, spectrum analysis (FFT), and impedance. Options include the capability to completely store all the raw data from a test run for after-the-fact review and analysis.

## 0. INTRODUCTION

Non-automated production testing of loudspeakers and/or systems traditionally consists of at minimum, a manual by-the-ear sine-sweep rub-buzz test followed by a possible frequency response test consisting of a visual comparison of the measured curve with an envelope drawn on the face of an analyzer screen. The accuracy and repeatability of these manual tests depends heavily on the skill and condition of the operator. On the other hand, fully computer-based automated testing removes the human judgement factor from the test and greatly improves the testing repeatability.

A hardware/software system is described that allows fully automatic production testing of loudspeakers. The system is based on the use of an IBM compatible personal computer controlling a DSP based test analyzer that uses the technique of Time Delay Spectrometry (TDS) [1, 2, 3]. The system allows complex test setups to be configured, with a minimum of hardware, that allow many different types of production tests to be performed.

## 1. HARDWARE

The system's hardware consists of a general-purpose IBM-compatible desktop computer controlling one or more DSP-based measurement analyzers. Up to 6 separate analyzers can be controlled by one computer and incorporated into a production test setup to increase the measurement capability.

### 1.1. Time Delay Spectrometry Analyzer

The production test system is based on the use of the DSP-based TEF System 20 acoustic analyzer which uses the patented technique of Time Delay Spectrometry pioneered by the late Richard C. Heyser [1]. Analyzers based on the TDS test technique can make accurate measurements in the presence of high background noise, which makes it an ideal test technique for use in noisy production test environments. The TDS technique uses a swept sinewave test signal with an analyzer that has matched tracking bandpass filters that can be offset in time. The process uses a low crest-factor linearly swept sinewave as a test signal which is applied to the test system during the whole measurement/test interval [2]. The test signal characteristics maximize the amount of test energy injected into the system under test for a given peak signal level [3].

The TEF System 20, shown in Fig. 1, utilizes a Motorola 56001 DSP chip for all internal calculations. It communicates with the analog world through a pair of 16-bit, 64-times over-sampled, analog to digital converters (synchronously sampled two-channel); and a 16-bit, 8-times over-sampled, digital to analog converter. All internal calculations are done in 24-bit fixed-point or 4-byte floating point math. All external data communication is in 4-byte floating point format.

Two line level and two phantom-powered microphone inputs are provided. A level control is provided for the single line-level output. TDS swept measurements in the range of 10 Hz to 21 kHz can be performed with a magnitude accuracy of ±0.2 dB, a phase accuracy of ±1°, with a dynamic range of 96 dB. Measurement can be made with sweep times from 0.1 to 1000 seconds (16.7 Minutes). Fig. 2 shows the hardware specifications of the TEF System 20 taken from the specification sheet.

### 1.2. Host Control Computer

The Speaker Test software package runs on an IBM PC or compatible computer which is used to control the TEF System 20. For acceptable performance levels, at least a 20 MHz clock 386 class computer with 1 megabyte memory and math coprocessor is required. A VGA or higher monitor must be used along with at least a 40 megabyte hard drive for storage of test data. For serial communications, an RS-232 serial port is required which is capable of running at 57.6 kilobaud. Higher speed communication capability is available by using the TEF System 20 HI analyzer which includes a built-in high-speed 8-bit parallel I/O port which is used with a supplied parallel-port card that plugs into the host PC.

## 2. SOFTWARE

The production Speaker Test software has the capability of testing many different types of performance parameters including: frequency response, polarity (phase response), harmonic distortion (of specific harmonics), THD, THD and noise, harmonic tracking, spectrum analysis (FFT), and impedance. The extensive distortion testing capability of the software can be used to test for driver rubs and buzzes after a specific driver's rub/buzz distortion signature is identified. This signature can only be determined after exploratory distortion measurements of a batch of drivers exhibiting the specific rub/buzz problems.

A specific production test can contain from one up to 20 of the several the different types of measurements in any order or combination. For example, a specific test can consist of two frequency response measurements (over different response ranges, say high and low), a polarity (phase) measurement, a spectrum analysis of output noise measurement, a THD measurement, and an impedance vs frequency measurement.

Each individual measurement can have limits applied to determine pass/fail criteria for the composite test. These pass/fail limits can be determined in several different ways including:

1. Direct manual entry of limit envelopes,
2. Measurement of a standard loudspeaker and setting envelopes a specific range above and below the standard,
3. Establishment of limits by statistical analysis of the measurements of a batch of loudspeakers utilizing standard deviation or minimum and maximum values, and
4. Setting target limits and rerunning disk-stored batch measurement data to determine the overall pass/fail ratios.

This latter method allows you to rerun a specific batch of speakers off-line using disk stored measurement data of the original batch. In effect you are retesting the same batch of loudspeakers, but without actually running them physically through the test setup again. The pass/fail limits can then be manipulated to check their effect on the overall pass/fail statistics. This allows the test engineer to rapidly see the effect on the pass/fail statistics of tightening or loosening a specific test envelope. For example, a tight window of ±2 dB around a standard might result in a 25% reject rate. Widening the envelope by just 0.5 dB to ±2.5 dB might reduce the reject rate to only 5%. In this case, it might be prudent to go with the slightly wider envelope to reduce the reject rate.

### 2.1. Organization and Menu Structure

The Speaker Test software is organized around two main modes of operation: Operator Mode, and Engineer Mode. These two major operational modes are a direct result of how the system is routinely used. The Operator Mode is utilized by a relatively unskilled operator performing routine production automated testing. The Engineer Mode is used by highly skilled quality assurance personnel that supervise, setup, and define the individual measurements and tests that make up the overall production test.

### 2.1.1. Operator Mode

The Operator Mode is used for all routine day-to-day production testing. In this mode, the system is operated by a relatively unskilled operator that commands tests to be conducted on units coming down the production line. The complex workings of the system are hidden from the operator, and only result information such as individual unit pass/fail indications and overall statistical information is presented.

The Operator Mode appears immediately following startup of the Speaker Test system and is the only mode available without entry of a password. This mode is designed to run production tests only and can be operated from the host computer's keyboard or from a numeric keypad (digits 0 to 9 available only). The available operator options are extremely limited in this mode, and can be further defined by the test engineer in the Engineer Mode.

When the Speaker Test system is first started, and after the operator has entered an ID, the following options appear in the Operator Mode main menu: 1) Select Test , 2) Do Test, 3) Set Delay, 4) Set Amplifier Level, 7) Statistics, 8) Change Com (change serial communications port and analog input), 9) Stop Test, and 0) Quit. The Operator Mode main menu is shown in Fig. 3. Of these eight options, only items 1, 2, 9, and 0 are required for testing. The remaining options can be selectively turned off or on by the test engineer to customize the system. The blank space in the center of the menu screen of Fig. 3 is reserved for future commands and for possible display of information.

The Operator Menu Screen (Fig. 3) contains additional system information around its perimeter. In the center of the top line of the screen in larger letters is the name of the currently selected test, followed by the word "TEST". In the top left corner is the time of day from the PC clock. The top right-hand corner has the date from the PC. The bottom-left corner shows the number of megabytes of free space for the chosen disk drive (hard or floppy). In the lower right-hand corner three information boxes give the following information: trend of failure, or percent failed out of the last ten units tested; percent failure of all units tested; and total number of units tested. The bottom center contains information about the currently selected communications port and currently active analog input. All this information is updated as needed following any operator command.

These Operator Mode main menu commands are briefly described as follows:

#### 2.1.1.1. 1) Select Test

This is the first option selected at startup and allows the operator to select the unit to be tested from a scrolling menu. This option can be selected at any time and allows production tests on a specific unit to be started and stopped with the intermediate test statistics stored and recalled for update.

#### 2.1.1.2. 2) Do Test

This initiates the test cycle on the unit chosen in option 1. The operator may stop the test by pressing 9 (see option described later) to stop the test.

#### 2.1.1.3. 3) Set Delay

This option allows the operator to set the TDS receive delay for all tests. It commands an Energy vs Time test (ETC) to be made, so that the time it takes for the sound to go from the speaker to microphone can be accounted for.

#### 2.1.1.4. 4) Set Amplifier Level

This option allows the operator to set the gain of the external power amplifier (or TEF output level) so that a specific SPL level can be set. A repeated series of sweeps occur with instantaneous dB SPL indicated, so that the operator can adjust levels.

#### 2.1.1.5. 7) Statistics

Displays the current production statistics for the currently chosen unit under test. This allows more in-depth pass/fail information to be displayed than is shown in the lower right of the screen.

#### 2.1.1.6. 8) Change Com

This command allows the temporary change of the communications port (one of six: serial 1, serial 2, HI 1, HI 2, HI 3, or HI 4) and analog input channel (line or mic, and channel A or B).

#### 2.1.1.7. 9) Stop Test

This option allows the operator to stop the currently running test. When the test stops, the partial statistics for the currently tested unit are deleted from the running totals.

#### 2.1.1.8. 0) Quit

Quit saves the necessary statistics and exits Speaker Test.

### 2.1.2. Engineer Mode

The Engineer Mode is used by skilled test personnel to define the separate measurements and pass/fail criteria that make up a specific test sequence. Several pull-down menus are available to help the test engineer accomplish these tasks. The primary purpose of the Engineer Mode is the creation of a series of measurements with associated individual pass/fail criteria that will determine the acceptability (overall pass/fail) of a unit under test.

Creation of test parameters and procedures are accomplished through the use of Standards Files (STN Files) for each individual test employing the "window of acceptability" concept. An individual test includes a single type of measurement, ie frequency response test or distortion test etc, along with associated pass/fail criteria. The tested unit must fall within a designated range in order to pass; otherwise it will fail.

The Standards (STN) Files fall into eight categories: Magnitude vs Frequency Response, Harmonic Tracking, Impedance, Phase, FFT, Harmonic Distortion, THD, and THD + Noise. Each STN file contains information about its specific measurement and pass/fail criteria including: identification and descriptive information, a window of acceptability for one of the eight categories, measurement parameters, display parameters, input/output parameters, response smoothing parameters (available only for magnitude vs frequency and harmonic tracking curves), and fail margin information (this allows the measured data to fall out of the envelope by a certain amount for up to a specific number of data points). A tested unit must pass each individual test in a defined sequence of tests (calls to several STN files stored in a TST File) for a unit to receive an overall pass.

A password is required for entry into the Engineer Mode from the Operator Mode. This minimizes any unauthorized modifications of the loudspeaker test sequences or data. Figures 4 through 8 show various images of menus and entry screens that can be manipulated in the Engineer Mode. The five pull-down menus available in the Engineer Mode are: File, Measure, Parameters, Display, and Input. These menus and their options are briefly described as follows:

#### 2.1.2.1. File Menu

The File Menu includes several commands: for manipulating files (either TDS, ETC, STN, TST, or STAT files): opening files (Open Old), changing drives and directories (Drive and Directory), saving files (Save As), erasing files (Erase), and loading and saving of configuration (setup) files (Configuration); for changing printer information (Printer Settings): resolution, page size, and type; for printing graphs on the screen (Print Screen); for display of version numbers (About TEF), for exiting the Speaker Test system (Quit), and changing the password for entry into the Engineer Mode (Password). The entries in the File Menu are:

Open Old
Drive & Directory
Save As
Erase
Configuration
Printer Settings
Print Screen
About TEF
Quit
Password

#### 2.1.2.2. Measure Menu

The Measure Menu contains commands to do several different types of measurements and to establish this measurement along with entered limits and envelope information to create a Standards File (STN). The parameters for these measurements are set either by commands in the Parameters Menu or set by loading a specific type of file by using the Open Old command in the File menu. A stored test sequence (calls to a series of STN files stored in a TST File) can be initiated by the Do Test Sequence command. The entries in the Measure Menu are:

Do Time Measurement (ETC)
Do Frequency Measurement (TDS)
Do Mag. vs Frequency Measurement and Make Standard
Do Harmonic Tracking Measurement and Make Standard
Do Impedance Measurement and Make Standard
Do Phase Measurement and Make Standard
Do FFT Spectrum Measurement and Make Standard
Do Harmonic Distortion Measurement and Make Standard

Do THD Measurement and Make Standard
Do THD & Noise Measurement and Make Standard
Do Test Sequence

#### 2.1.2.3. Parameters Menu

The Parameters Menu contains commands to set the measurement parameters of all the different types of tests that Speaker Test accomplishes. These parameters include such items such as start and stop frequencies, sweep time, receive delay, resolution, harmonic number, smoothing instructions, and input parameters, etc., as appropriate to the specific chosen measurement. The last entry in this menu allows new production test sequences to be defined. Figure 6 shows the entry screen that results from this command. Up to 20 individual tests can be incorporated into a test sequence. The entries in the Parameters Menu are:

Set Time Response Measurement Parameters (ETC)
Set Frequency Response Measurement Parameters (TDS)
Set Magnitude vs Frequency Test Standard Parameters
Set Harmonic Tracking Test Standard Parameters
Set Impedance Test Standard Parameters
Set Phase Test Standard Parameters
Set FFT Spectrum Test Standard Parameters
Set Harmonic Distortion Test Standard Parameters
Set THD Test Standard Parameters
Set THD & Noise Test Standard Parameters
Define New Production Test Sequence

#### 2.1.2.4. Display Menu

The Display Menu contains commands to set the display parameters for the test that Speaker Test accomplishes. Commands are also included to toggle operation modes on and off, and to change colors that appear on the display screens. The last entry allows changes to be made to the menu items which appear on the Operator menu. The entries in the Display Menu are:

Set Time Response Display Parameters (ETC)
Set Frequency Response Display Parameters (TDS)
Toggle Overlay Mode On or Off
Toggle Difference Mode On or Off
Toggle Cursor On or Off
Adjust Display Colors
Set Choices That Appear on Operator Menu

#### 2.1.2.5. Input Menu

The Input Menu contains commands to change the input configuration, enter microphone and system calibration values, and to change the communications port. The entries in the Input Menu are:

Settings
Calibration
Communication

### 2.2. Setting Production Pass/Fail Limits

Speaker Test has several different ways to set the limits and envelopes for pass/fail determinations. These limit determination methods include: manual entry of limits, limits determined by measurement of a single standard loudspeaker, limits determined by the batch statistics of measurements on several loudspeakers, and limits determined by repeated rerunning of previously measured batch data in a mock production run.

Each Standards File (STN) contains definitions and parameters to accomplish a specific measurement, along with test limits to determine if the results of a specific measurement pass or fail. To create a Standards File (STN), the engineer first should set measurement and display parameters, (by using the Parameters, Display, and Input Menus) and then proceed to the Measure Menu and select the desired measurement to be made a standard. The test engineer must then choose whether he wants to make a single measurement of a standard loudspeaker (one sample unit), or make measurements on a number of loudspeakers (batch sampling of any number of units).

After these measurements are made, the pass/fail limits and envelopes can be set using several different methods outlined as follows:

### 2.2.1. Manual Entry of Limits

The upper and lower limits can be set simply by just entering specific limits as desired without regards to a specific measurement. For example, a rectangular window with lower limit of 84 dB SPL and upper limit of 90 dB SPL between 200 Hz and 10 kHz could be defined for a small wide-range speaker system. This effectively creates a ±3 dB envelope around a nominal sensitivity of 87 dB SPL for a specific input voltage.

### 2.2.2. Limits Determined by Measurement of Standard

The limits can be based on a single measurement of a standard speaker. In this situation, an envelope of arbitrary limits can be formed around the standard's measured response. The envelope shape then rises and falls with increases and decreases in the response of the standard.

### 2.2.3. Limits Determined by Batch Statistics

A batch of loudspeakers can be measured and then a statistical analysis of the results can produce a specific envelope. Various statistical analysis parameters such as mean, standard deviation, and maximum/minimum are available to create the limit envelope. Several tools are available that aid in the creation of these envelopes including, smoothing, offsetting of curves, and direct entry of desired data values.

### 2.2.4. Limits Determined by Rerun of Batch Measurement Data in Mock Production Runs

The final way of creating pass/fail limits and envelopes is much more involved than the previous three methods. It depends on creating a complete target production test (TST File) which consists of several individual measurements with associated pass/fail criteria's (STN Files), and then running a batch of typical (not specially selected) production speakers (say 50 or 100) with the complete raw measurement data for each speaker being stored to disk. The complete production test run can then be rerun (or replayed automatically) offline to determine an overall pass/fail rate. The pass/fail limit envelopes contained in the original test can then be fine tuned to yield an acceptable overall reject rate.

In effect you are repeatedly rerunning the original batch of loudspeakers, without actually physically doing doing it, and then changing the limit envelopes to yield an acceptable reject rate. Sometimes relatively small changes in envelope limits can alter the overall pass/fail statistics dramatically.

## 3. PRODUCTION MEASUREMENTS

In this section a couple of typical production hardware setups are described, and the repeatability of human versus automated testing is discussed along with experimental test results of a batch of loudspeakers repeatedly run through human and automated tests.

### 3.1. Typical Hardware Setups

Figure 9 shows the minimum possible loudspeaker production test setup which utilizes a single TEF System 20 analyzer with control computer, a single-channel power amplifier, and precision test microphone. Figure 10 shows a more complex setup using two analyzers, a power amplifier, and three test microphones. This latter setup allows tests to be made from three separate microphone locations, along with connections which measure the input voltage and input current (and hence impedance) of the loudspeaker.

### 3.2. Repeatability: Humans vs Automated Testing

To compare the repeatability of human-operated (and judged) testing versus computer-operated automated testing, a batch of 100 loudspeakers was repeatedly tested as follows: five different times by the same experienced human tester, once by four different experienced human testers, and six times by a completely computer-operated automated test setup.

The test consisted of only a frequency response measurement with envelope limits and a low-frequency rub-buzz test. The human test consisted of a manually operated response measurement with the curve appearing on an analyzer screen. The operator would then judge the response to see if it fit within limits which were drawn on the face of the analyzer. This was followed by a manual sinewave sweep with the operator listening for rubs and buzzes.

The computer operated test was somewhat similar but both tests were done without human involvement. In the computer operated rub-buzz test, a repetitive fast sweeping low-frequency sinewave was sent to the loudspeaker and its acoustic output was analyzed on a spectrum analyzer to look for higher-frequency extraneous spectral energy.

Figure 11 shows the results of these tests in a bar graph format. The individual testers are listed on the vertical axis and the measured reject rates are shown along the horizontal axis. The top six testers are the automated ones while the remaining are the human judged tests. As can be seen, the automated tests are quite consistent (maximum variation of only 1% in reject rate) while the human judged tests exhibit significantly more variability (variation of 7% in reject rate). Even the tester retesting the same batch of speakers had a variation of 5 percentage points! This implies that with human judged tests, a significant number of bad units will be shipped while a number of good units will be rejected.

## 4. SYSTEM PRICES

As of May 1, 1992, prices for the serial-port version of the TEF System 20 Speaker Test system are $5,850, while the high-speed parallel-port version is $6,500 (FOB Elkhart, Indiana, USA). This price includes hardware (one TEF System 20 or TEF System 20 HI), general purpose measurement software (Sound Lab), and the production test software (Speaker Test). Power amplifiers and test microphones are separately available.

## 5. SUMMARY

This paper has described a relatively low-cost easy-to-operate computer-operated automated loudspeaker production test system that can objectively test many different operational parameters and determine overall pass/fail statistics. The basic system can be expanded to quite complex test setups. It was shown that automated testing can greatly improve the testing consistency, as compared to human-judged tests. This allows bad units to be consistently rejected and good units to be passed.

## 6. REFERENCES

[1] R. C. Heyser, "Acoustical Measurements by Time-Delay Spectrometry," *J. Audio Eng. Soc.*, vol. 15, pp. 370-382 (1967 October).

[2] J. Vanderkooy, "Another Approach to Time-Delay Spectrometry," *J. Audio Eng. Soc.*, vol. 34, pp. 523-538 (1986 July/August).

[3] D. B. Keele Jr., "TDS: Application of Technology," *Sound and Video Contractor*, (1985 September).

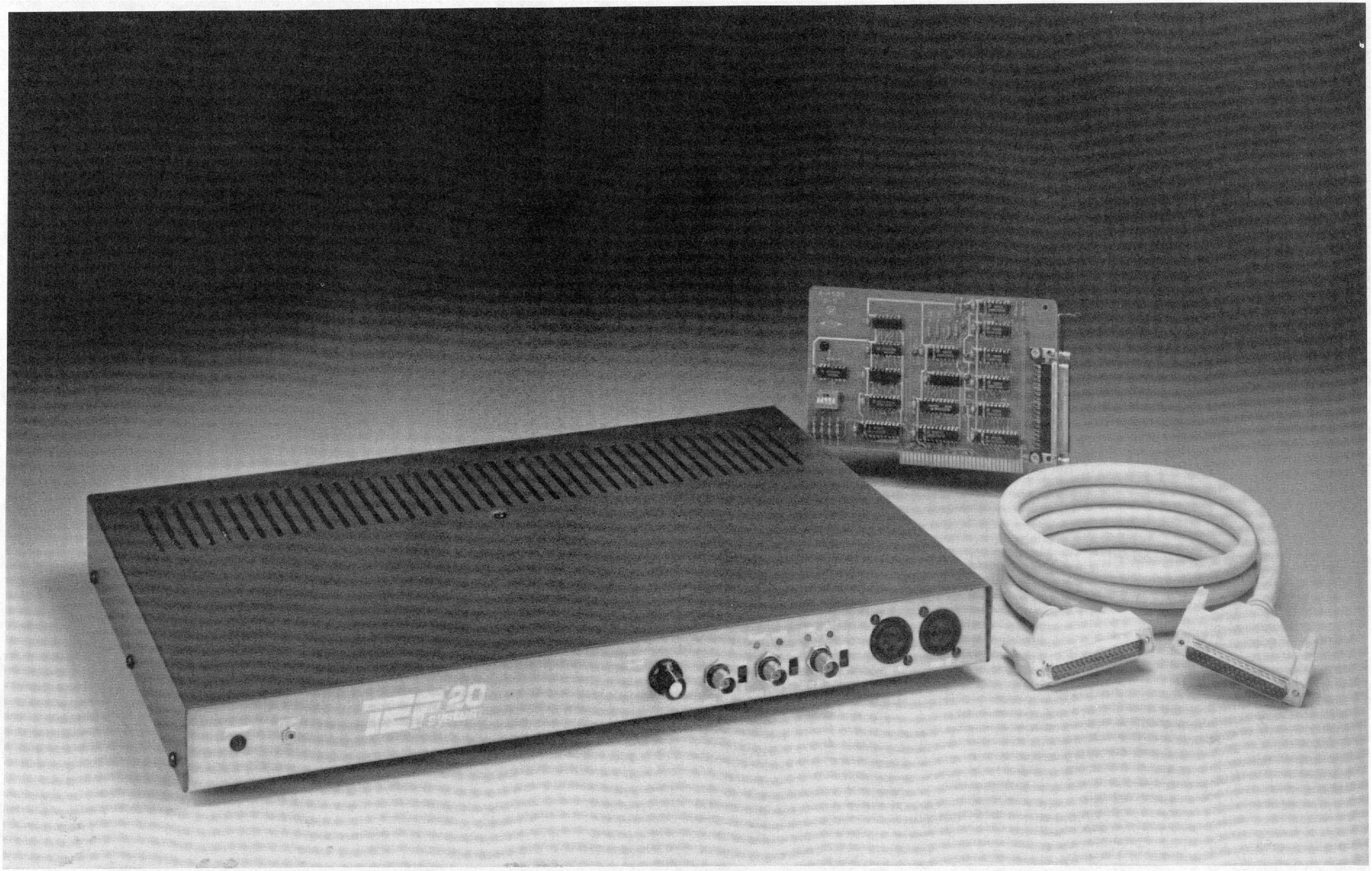


Fig. 1. Photograph of the TEF System 20 HI System. The test analyzer includes a 17-in. x 12 3/8-in. x 1 3/4-in. box which contains the DSP, power supply, A/D and D/A, processing circuitry, and input and output circuitry and connectors. Also shown is the supplied IBM PC compatible parallel interface card with interconnect cable. Up to four interface cards can be used in the PC.

# Hardware specifications.

This section contains specifications and performance data for the TEF System 20 analyzer. Applications software, such as Sound Lab, may not use all the features listed here.

### Processor

| | |
|---|---|
| Memory | RAM 64K x 24<br>Non-programmable ROM, 32K x 24 bits<br>Field programmable ROM, 8K x 24 bits |
| Digital signal processor | Motorola XSP56001ZL27 |
| Digital-to-analog converter | 16 bits, 8 times over-sampled |
| Analog-to-digital converter | 16 bits, 64 times over-sampled (synchronously sampled 2-channel) |
| Data format | IEEE floating point |
| Eight-bit mantissa, 24-bit exponent | |

### Electrical specifications

Frequency and phase response measured at the line-level input, dc coupled.

| | |
|---|---|
| Frequency response | 10 Hz to 21 kHz, ±0.2dB |
| Phase response | 10 Hz to 21 kHz, ±1.0 |
| Dynamic range | 96 dB |
| THD + noise | -85 dB at 1 kHz |

### Trigger connector

| | |
|---|---|
| Connector type | Four-pin DIN, mates with Radio Shack part number 274-007 |
| Voltage level | TTL compatible, 0 and 5 vdc logic |
| Maximum current | Source and sink current no more than 24 mA |

### Microphone input

TEF 20 has two microphone-level inputs on the front panel. Either input can be selected from software.

| | |
|---|---|
| Coupling | Input coupling is ac only |
| Connector | Three-pin XLR, pin 2 "+", pin 3 "-" |
| Gain | 0-60 dB in 4 dB steps, software control |
| Input impedance | 6.81 kΩ |
| Maximum input voltage | 1 volt rms |
| Polarizing voltage | Internal jumper selects 0 or +48 volts |

### Line input

TEF 20 has two line-level inputs on the front panel. Either input can be selected from software.

| | |
|---|---|
| Connector | Front panel BNC |
| Input impedance | DC=2 MΩ<br>AC=1MΩ |
| Coupling | Front panel switch for ac or dc coupling |
| Maximum input voltage | 1 volt rms |

### Test output

| | |
|---|---|
| Connector | BNC |
| Level | 1 volt rms ( ±5 millivolts)<br>Adjustable with front panel control |
| Source impedance | Front panel switch sets source impedance to zero or 50 ohms |

### Indicators and lights

| | |
|---|---|
| Level | Green LED, brightness proportional to input level |
| Overload | Red LED, brightness proportional to overload level |
| Power | Red LED |

### Physical

| | |
|---|---|
| Weight | 10 lbs. 7 oz. (4.73 kg) |
| Dimensions | 17" x 12-3/8" x 1-3/4"<br>(43.2 cm x 31.4 cm x 4.4 cm) |
| Reset switch | Momentary-action, recessed push-button on the front panel |
| Power switch | Rocker switch on the back panel |
| Operating temperature | 32° to 130°F (0° to 55°C) |
| Cooling | Ventilation slots on the top and bottom for convection cooling |
| Communication interface | RS-232 (19.2 and 57.6 kilobaud) |
| AC power | 100, 120, 220 or 240 volts rms<br>48-440 Hz, 30 watts |
| Optional high speed | 8 bit ISA to DSP host interface buss |

### Computer requirements for PCs

The PC version of applications software will run on any MS-DOS-based system, version 3.1 or higher, with EGA or VGA graphics. For systems with acceptable performance levels, we make the following suggestions:

| | |
|---|---|
| Microprocessor | 20 MHz 386 with math coprocessor |
| RAM | Two megabyte recommended,<br>1 megabyte minimum |
| Monitor | VGA high resolution with color recommended, EGA high resolution monitor or VGA medium resolution mimimum |
| Hard disk | 80 megabyte recommended,<br>40 megabyte mimimum |
| Interface | One unassigned RS-232 serial port, capable of 57.6 kilobaud |
| Operating system | Version 3.1 or newer |
| Printers supported | Epson FX, Epson LQ, and HP laser jet |

### Computer requirements for Macintosh

Any Macintosh II family of computers or Macintosh SE 30.

| | |
|---|---|
| Finder and system | 6.0.3 or newer |
| RAM | 2 megabyte (4 megabyte with MultiFinder) |
| Hard disk | 80 megabyte recommended, 40 megabyte minimum |
| Printers supported | All Apple printers including Laserwriter series |

Specific hardware requirements are available from Techron.
*Macintosh is a registered trademark of Apple Computer, Inc.

TEF 20 system

P.O. Box 1000 / Elkhart, IN 46515-1000
219-294-8300 / Fax 219-294-8329
*TEF System Action Line* 1-800-833-8575

**Fig. 2. Hardware specifications of the TEF System 20.**

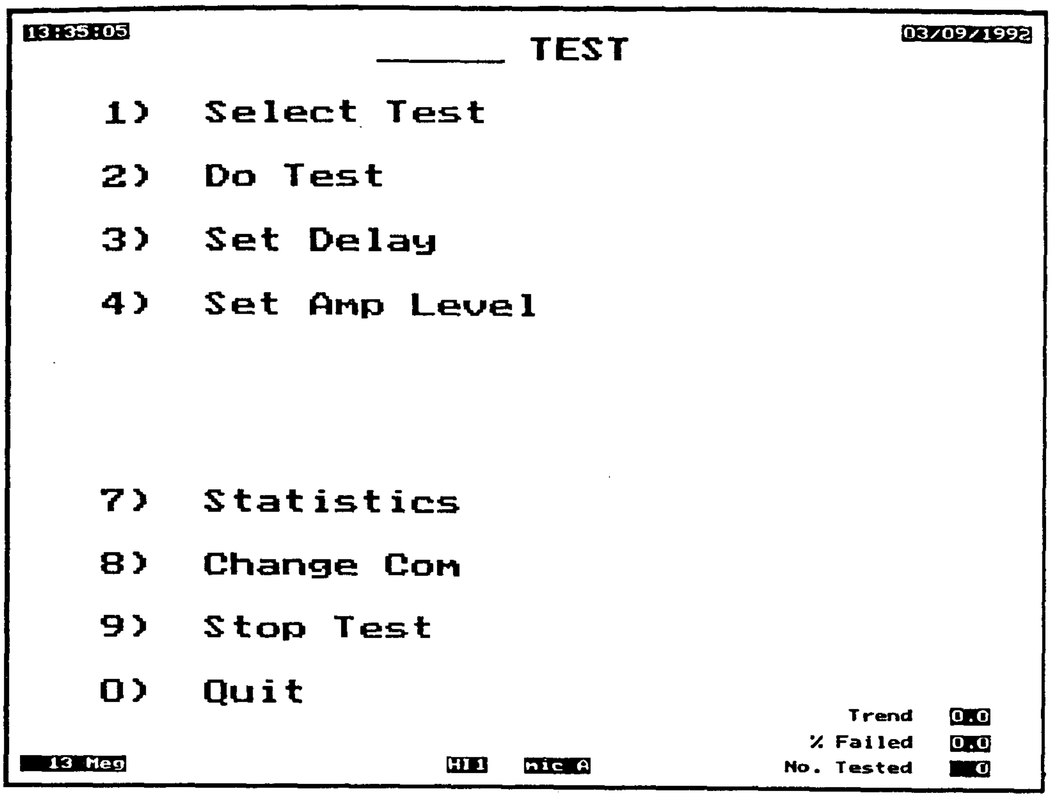


Fig. 3. Startup screen for operator mode.

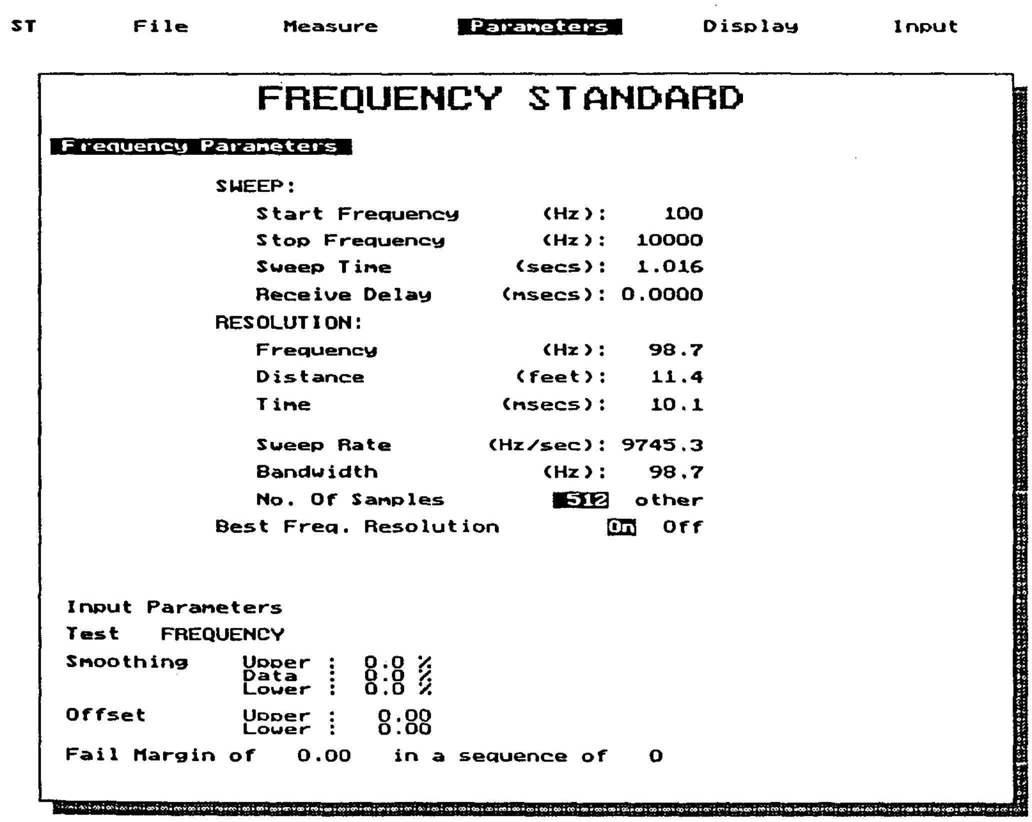


Fig. 4. Data entry screen for the frequency response parameters for doing a magnitude vs frequency test standard.

**Parameters**

| | |
|---|---|
| Time Response | (ETC) |
| Frequency Response | (TDS) |
| **Frequency** | **(STN)** |
| Harmonic Tracking | (STN) |
| Impedance | (STN) |
| Phase | (STN) |
| Do FFT | (STN) |
| Harmonic Distortion | (STN) |
| THD | (STN) |
| THD+N | (STN) |
| Test Sequence | (TST) |

5. Engineer Mode Parameters Menu with Frequency standard entry selected (the results of selecting this entry are shown in the previous Fig. 4).

ST    File    Measure    **Parameters**    Display    Input

## NEW TEST

**File Name :** 1TRY .TST
Creator :
Date/Time : 02/19/1992 17:51:27
DESCRIPTION
Line 1 :
Line 2 :
Test Sequence

| Standard | Output Pass Scr | Dsk | Prn | # | Fail Scr | Dsk | Prn | # | On Fail Quit | Rpt | Pause |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | | | | | | | | | | | |
| 2. | | | | | | | | | | | |
| 3. | | | | | | | | | | | |
| 4. | | | | | | | | | | | |
| 5. | | | | | | | | | | | |
| 6. | | | | | | | | | | | |
| 7. | | | | | | | | | | | |
| 8. | | | | | | | | | | | |
| 9. | | | | | | | | | | | |
| 10. | | | | | | | | | | | |

Recommended Amp Level = 82.5
Sample 1 out of each 0 tested (0 = no samples)
AutoSave Statistics **On** Off
Save (press enter)

Fig. 6. Results of selecting Test Sequence entry in Parameters Menu. This entry screen allows the test engineer to define the sequence of individual measurements that make up a complete production test. Up to 20 different measurements can be incorporated.

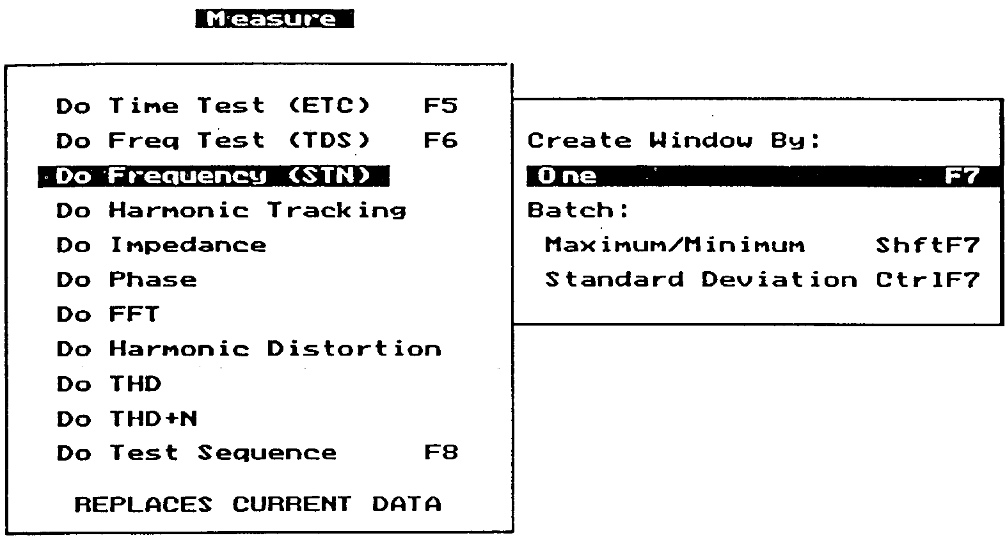


Fig. 7. Pull down of the Engineer Mode Measure Menu with the Do Frequency Test sub menu selected. This entry allows a single or multiple batch test of frequency response magnitude vs frequency. In the batch mode, statistics can be gathered to track maximum/minimum or standard deviation on a batch of speakers to allow easy establishment of upper and lower pass/fail limit envelopes.

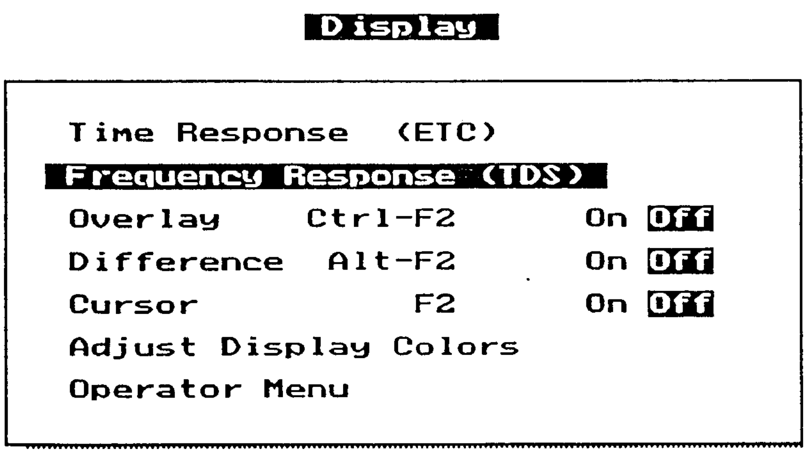


Fig. 8. Engineer Mode Display Menu with Frequency Response entry selected. This entry allows setting of the display parameters of a frequency response test such as minimum and maximum dB ranges and log/linear frequency scale.

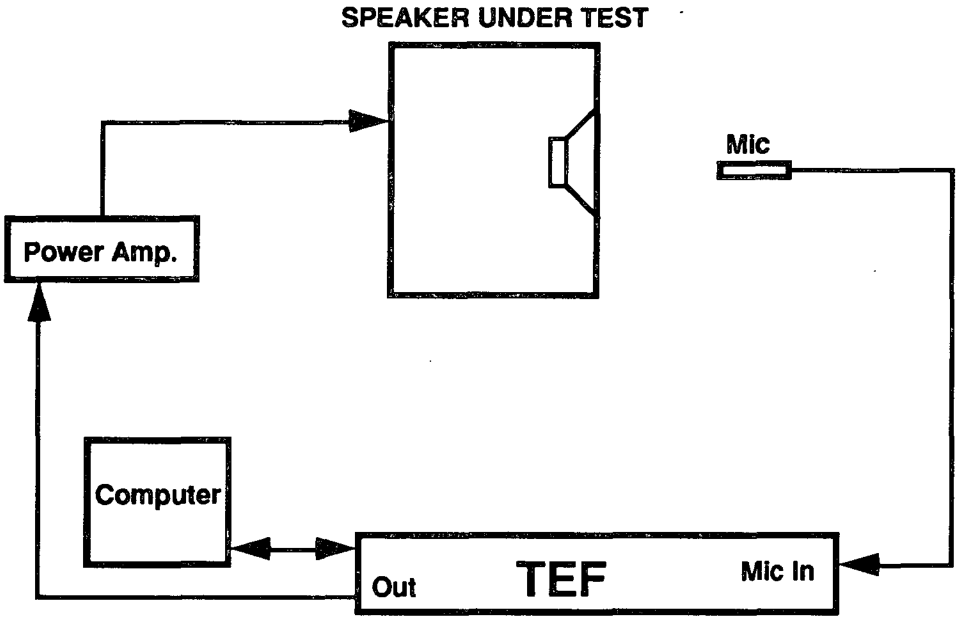


Fig. 9. Block diagram of the simplest loudspeaker production test setup utilizing one TEF System 20 analyzer and control PC, along with power amplifier and test microphone.

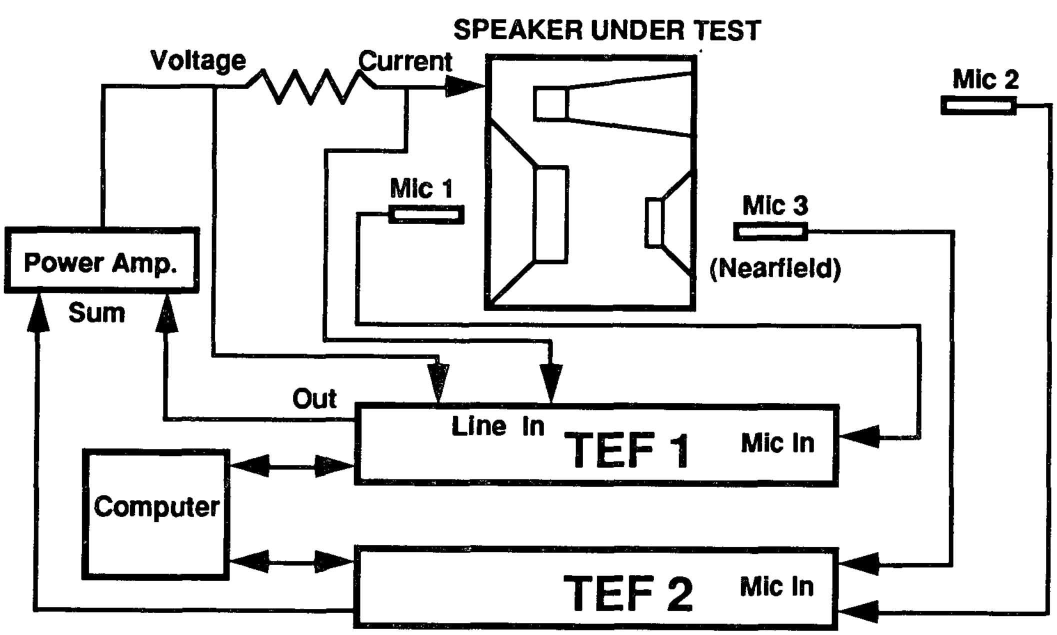


Fig. 10. Block diagram of a loudspeaker production test setup utilizing two TEF System 20 analyzers to check response at three different locations on a speaker and measure impedance.

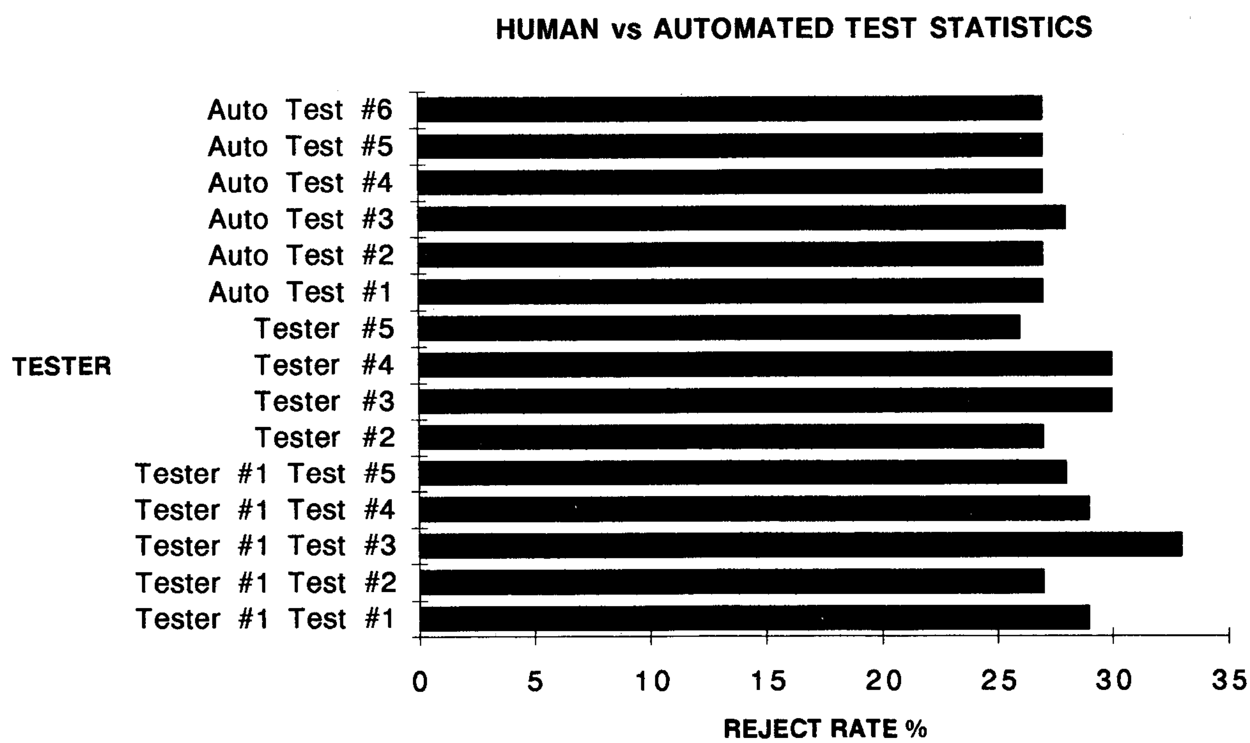


Fig. 11. Bar graph of production test statistics for batch of 100 speakers run several times through the same test operator, several different test operators, and an automated test setup. The operators are listed on the left axis and the percent reject rate is shown along the horizontal axis. Note the fairly wide variation in test results for the human operators and the highly repeatable automated test results (see text).