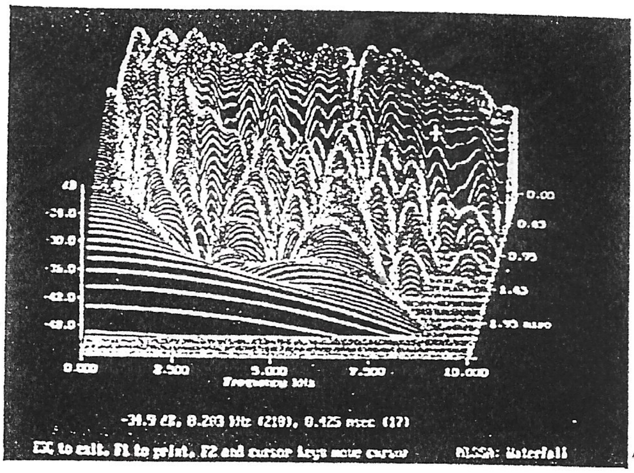
MLSSA

Maximum-Length Sequence System Analyzer

- Advanced MLS Technology.
- Impulse response curves to 32768 points.
- Transfer function via the FFT to 32768 points.
- Spectral decay (waterfall) plots with 3D cursor.



MLS Technology

MLSSA (pronounced "Melissa") is a linear-system analyzer which makes high quality audio and acoustic measurements based on a revolutionary new approach.

The maximum-length sequence or MLS method is a new system identification method with important advantages over conventional swept sinewave and dual channel FFT methods. The MLS method uses a special kind of pseudorandom noise known mathematically as a maximum-length sequence. This test signal has several important properties which allow efficient recovery of the impulse response from the system output. The impulse response is the most fundamental measurement of any linear system and, once captured, many other audio-related curves can be derived from it through computer-aided post-processing.

The MLS approach is very robust. It is highly immune to signal contamination due to both noise and distortion components. But the ability of MLS methods to quickly measure a long-duration impulse response over the full audio bandwidth is a key advantage over conventional swept sinewave and FFT methods. To be practical, conventional measurements must be restricted in one or both domains. Swept sinewave measurements, for instance, can quickly measure the transfer function over the entire audio frequency range but at the expense of limiting the time range of the measured impulse response. And a time-limited impulse response means poor resolution in the frequency domain. Frequency resolution can be improved by lowering the sweep rate but this can lead to very long measurement times. The operator must constantly be aware of these tradeoffs and make decisions involving the sweep-rate, start frequency, stop frequency and other parameters depending upon what types of measurements are desired. And such decisions must be made on-the-fly while the actual measurements are being performed.

The MLS approach overcomes these problems by its ability to measure a long-duration impulse response while simultaneously maintaining a wide measurement bandwidth. With the MLS approach, neither frequency resolution ~~and~~ nor frequency range is compromised and complete system characterization is achieved through a single high-speed measurement. The measured impulse response can be analyzed immediately or archived and analyzed later in a myriad of ways to reveal, for instance, the transfer function, energy-time curve or cumulative spectral decay (waterfall) plots. But because such curves are obtained through post-processing operations, they can be reproduced at any time even long after the actual impulse response measurement was performed.

Of course, a long wideband impulse response can also be measured directly with a narrow pulse test signal. The system output is then an accurate approximation to the true impulse response. But a narrow pulse contains very little energy and many measurements must usually be taken and averaged together to overcome the background noise. And this method cannot reject distortion components generated by imperfect transducers. The MLS method, in contrast, delivers a large amount of energy in a short time interval. In fact, a maximum-length sequence delivers the most energy of any conceivable signal. Its crest-factor is 0 dB, the lowest possible.

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The MLSSA Measurement System

This advanced MLS measurement technology is provided by the *MLSSA* measurement system. *MLSSA* stands for Maximum-Length Sequence System Analyzer and was designed to provide all the theoretical and practical advantages inherent in the MLS method.

Personal Computer based Design

The main design goals for *MLSSA* were to maximize flexibility and minimize cost without compromising quality. To achieve these goals, the instrument is designed around an IBM-PC or compatible personal computer. Proprietary high-speed software performs the required deconvolution and FFT calculations. Typical measurements take only a few seconds on AT class machines while 386 machines provide even faster performance.

In addition to lower cost, a PC-based design means performance improvements automatically follow PC technology improvements. Thus when PCs based on Intel's new 80486 processor become available, for instance, performance will automatically be enhanced. Instrument portability is also possible using a portable host PC.

The hardware portion of the instrument is contained on a single printed-circuit card which plugs into the expansion bus of IBM-PC, IBM-AT or compatible PCs. The hardware is capable of sampling and digitizing analog data at any rate up to 150 kHz. A full 16 bits of effective resolution is achieved though a combination of signal processing and signal dithering techniques.

Programmable MLS Generator

A programmable hardware MLS generator provides 1023, 4095, 16383 and 65535-point maximum-length sequences. Output amplitude is also variable under software control. Narrow pulse and step function stimuli are also provided for performing conventional tests if desired.

Programmable Antialiasing Filter

A high-quality antialiasing filter is a must for error-free MLS measurements. The hardware includes a fully-programmable state-variable 8-pole antialiasing filter. The filter's roll-off characteristic, cut-off frequency and passband gain are all programmable. The programmable gain feature permits autoranging by software means.

MLSSA Software

The *MLSSA* menu driven software performs a wide variety of important loudspeaker and acoustic measurements. Nevertheless, fully custom software can also be written for more specialized applications. Below is a summary of audio related measurements performed by the standard *MLSSA* menu-driven software.

Impulse Response

MLSSA can measure and display impulse response curves up to 32768 points in length. Impulse response measurements can be stored on disk and later retrieved for further post-processing analysis.

Loudspeaker Anechoic Transfer Function

An important application of *MLSSA* is measuring the anechoic transfer function of loudspeakers. Real-time analyzer measurements can be misleading because they cannot separate the loudspeaker sound from the room response. Psychoacoustic research has established that the ear is more sensitive to the direct sound than to the delayed room reflections especially in regards to loudspeaker imaging and the subjective perception of flat response. To measure the direct sound or "anechoic" response of a loudspeaker *MLSSA* uses cursors to select only the initial portion of the impulse response before the arrival of contaminating room reflections. Selection of the anechoic segment of the impulse response using cursors is illustrated in the top figure (see insert). *MLSSA* applies an FFT to this segment to yield the anechoic transfer function of the loudspeaker. The frequency response, phase response and group-delay can all be computed and displayed.

Cumulative Spectral Decay (Waterfall) Plots

A generalization of the anechoic transfer function is the cumulative spectral decay or waterfall plot. This 3D plot is formed by successively applying the FFT to successively time-shifted versions of the anechoic impulse response. The resulting surface often resembles a waterfall and shows how the acoustic energy is dissipated in both time and frequency. The bottom figure shows a waterfall plot for a typical dynamic loudspeaker. The impulse response segment used for this calculation is shown in the top figure bounded by the two vertical cursors. *MLSSA* provides direct cursor readout of any point on the waterfall surface and the cursor automatically changes color when positioned over hidden lines.

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Schroeder Plots and Reverberation Time

A Schroeder plot is formed by reverse integrating the square of the measured impulse response. This curve reveals reverberation decay of the sound field. When a Schroeder plot is graphed on a logarithmic scale its slope is a measure of the room's reverberation time. *MLSSA* not only calculates wideband Schroeder plots and reverberation times but can derive them for any desired frequency band by means of its built-in programmable digital bandpass filter. The bandpass filter permits reverberation measurements to be made over any octave or 1/3 octave band. *MLSSA* computes reverberation time using linear regression techniques. The top figure (reverse insert) shows a Schroeder plot for an octave band centered at 2 kHz.

Energy-Time Curve

The energy-time curve is a broadband display of energy dissipation in the time domain. *MLSSA* also provides this important function. The energy-time curve is useful in locating room reflections and determining the time-alignment of loudspeaker drivers. A typical energy-time curve is shown in the bottom figure.

Step Response

The step response of a loudspeaker can often be used to provide time-alignment information regarding the individual drivers. *MLSSA* computes the step response by numerically integrating the impulse response.

Impedance

MLSSA measures loudspeaker impedance using a known resistor connected in series with the load. *MLSSA* computes the unknown complex impedance of the load based on the known source resistance.

Power Spectral Density for Noise Measurements

MLSSA provides algorithms for measuring the power spectral density or PSD of noise signals. This feature can be used to measure the system noise floor.

Distortion Measurements

With an external sinewave source, *MLSSA* measures true odd harmonic, even harmonic and total harmonic distortion. Intermodulation distortion measurements are also possible.

Arbitrary Size and Large FFTs

MLSSA has many built-in floating-point signal processing algorithms that greatly aid data analysis. *MLSSA* can compute any size FFT ranging from 32 to 4000 points in length. This means that an FFT size can always be chosen which exactly fits the length of the available time-domain data. Above 4000 points, FFT sizes must be a power-of-two either 8192, 16384 or 32768 points. Such large FFTs are required to realize the fine frequency resolution inherent in long-duration impulse response measurements. For example, given a 32768-point impulse response sampled at 33 kHz, a 32768-point FFT provides 1 Hz frequency resolution.

MLSSA's signal processing algorithms are highly optimized for the 8087, 80287 and 80387 coprocessors. With the 80387 coprocessor, a 1024-point FFT requires 150 milliseconds while a 32768-point FFT requires only 5 seconds.

Online Help

The *MLSSA* menu driven software provides extensive online help for all commands and features. You simply press function key F1 at any time to display context sensitive help information.

Color Graphics

MLSSA runs in full color on EGA or VGA displays and in black and white on CGA displays. Signals can be zoomed, panned, scrolled and printed on a many standard printers. The figures in this brochure are actual *MLSSA* printouts from a VGA display printed on an HP LaserJet Series II printer.

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Maximum-Length Sequence System Analyzer — Technical Information

Hardware

Antialiasing Filter: Fully programmable 8-pole lowpass filter. A Chebyshev, Bessel or Butterworth roll-off characteristic can be programmed. Cut-off frequency is variable from 1 to 50 kHz and passband gain is variable from .2 to 500.

Acquisition: Data acquisition to memory via DMA at up to 150 kHz sampling rate at 12-bit resolution.

Stimuli: Maximum-length sequences of 1023, 4095, 16363 and 65535 points. Periodic narrow pulse with programmable repetition period. Square wave with programmable period and duty cycle. Output amplitude of all stimuli is programmable from 0 to ±5.25 volts.

Trigger: Internal trigger from stimulus generator or external trigger source. Hardware also supports pre-trigger mode and trigger delays to ±65535 samples.

Input Ranges: Programmable input full scale range (FSR) from ±10 mv to ±25 volts.

Input Noise: Input noise floor is -72 dB FSR including antialiasing filter.

Distortion: Harmonic distortion of 0.015% or -76 dB FSR including antialiasing filter.

Software

General: *MLSSA* is fully menu-driven and operates in both the time and frequency domains. A DOS Shell command lets you run other programs from inside *MLSSA*.

Time Domain: In the time domain *MLSSA* computes and displays the Impulse Response, Step Response, Energy-Time Curve, Schroeder-Plot reverberant decay, Cumulative-Energy and Input Data (oscilloscope mode). Curves up to 32768 points in length can be displayed.

Digital Filter: Programmable 6-pole Butterworth digital bandpass filter for octave and 1/3 octave analysis.

Frequency Domain: The frequency domain is entered using an optimized FFT routine operating on selected time domain data. Non-power-of-two FFTs are also possible using a built-in chirp-z algorithm. FFT lengths range from 32 to 32768 points. *MLSSA* computes and displays the Real Part, Imaginary Part, Magnitude, 1/3 octave Smoothed Magnitude, Phase (wrapped and unwrapped) and Group Delay of the Transfer Function or Complex Impedance. All phase curves can be delay corrected. *MLSSA* also measures the Power Spectral Density (PSD) of random or asynchronous signals.

Waterfall Plots: *MLSSA* plots 3D cumulative spectral decay curves based on impulse response measurements. Full 3D cursor support is provided.

Statistics: *MLSSA* calculates these statistics on all displayed curves: Mean, RMS, Standard Deviation, Variance, Peak Deviation from Mean, Max, Min, Peak-to-Peak, Crest factor and Slope by linear regression. *MLSSA* also calculates these special values from selected curves: T60 (reverberation time), Reverberant/Direct sound ratio and odd, even and total harmonic distortion (THD).

Online Help: *MLSSA* provides online help screens for all function keys and menu commands. Context-sensitive help is provided for all menu commands.

Setup Files: Setup files store all the options and modes you select. Once *MLSSA* is configured for a specific application, a single command stores the all the details in a setup file. Later, another command reads the setup file and reinstates the configuration.

Graphics: Any displayed curve can be zoomed, compressed or panned. Individual data points can be located with a cursor and read out numerically. Changing from a linear to a logarithmic scale is done by pressing a single function key. Printouts of all graphs can be made using standard dot-matrix or laser printers. Previous measurements can be plotted over a current one for making comparisons. With an overlay present, *MLSSA* automatically reads out the difference between the two curves as the cursor is moved from point to point.

Data Files: *MLSSA* normally saves or loads time-domain or frequency-domain data using binary files which are fully documented so they can be read by other programs. Data files also contain header information to document measurement conditions. Standard ASCII data files are also supported for importing or exporting measurement data.

Equalization: Equalization of measurements is possible based upon a reference measurement.

Units: *MLSSA* features fully programmable units. Acquisition, stimulus, impedance, time and frequency units are all programmable. Phase can be expressed in either radians or degrees.

Personal Computer Requirements

Requires an IBM-PC, XT, AT or compatible personal computer with an 8087, 80287 or 80387 numeric coprocessor. Requires CGA, EGA or VGA color graphics, 640K of memory and a hard disk.

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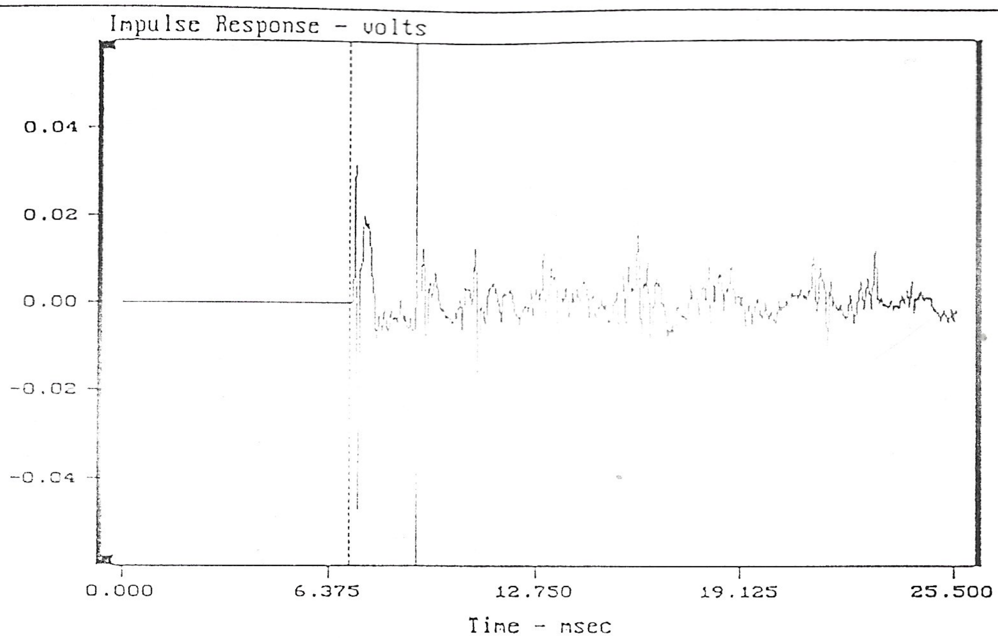
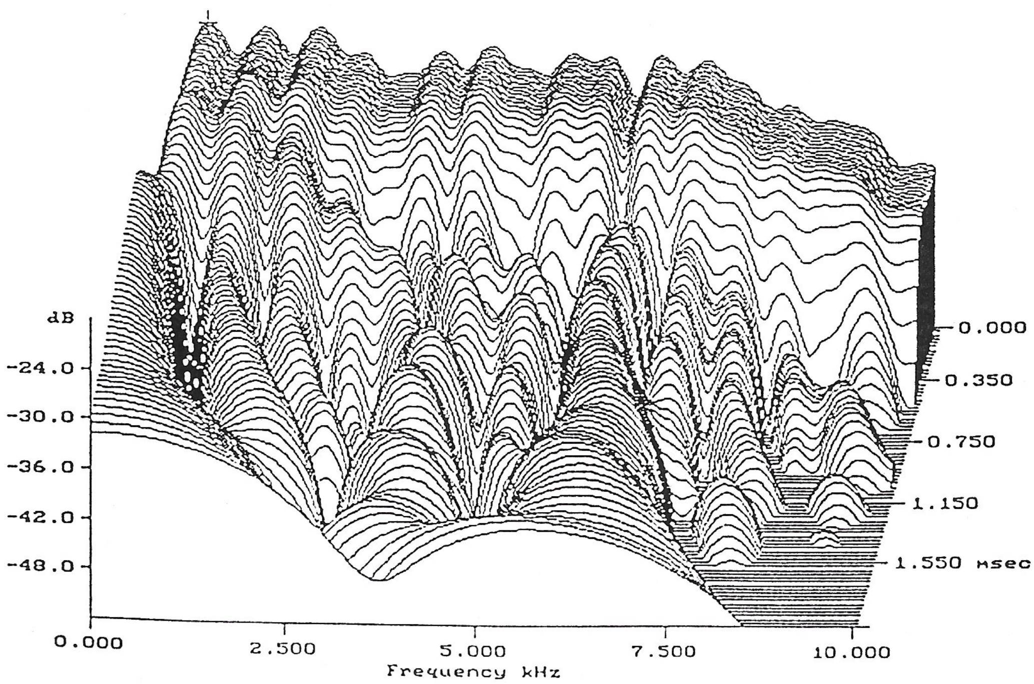


CURSOR: y = 9.28345e-005 x = 9.0500 (362)

Cumulative spectral decay (waterfall) from anechoic impulse response



-18.1 dB, 0.391 kHz (10), 0.000 msec (0)

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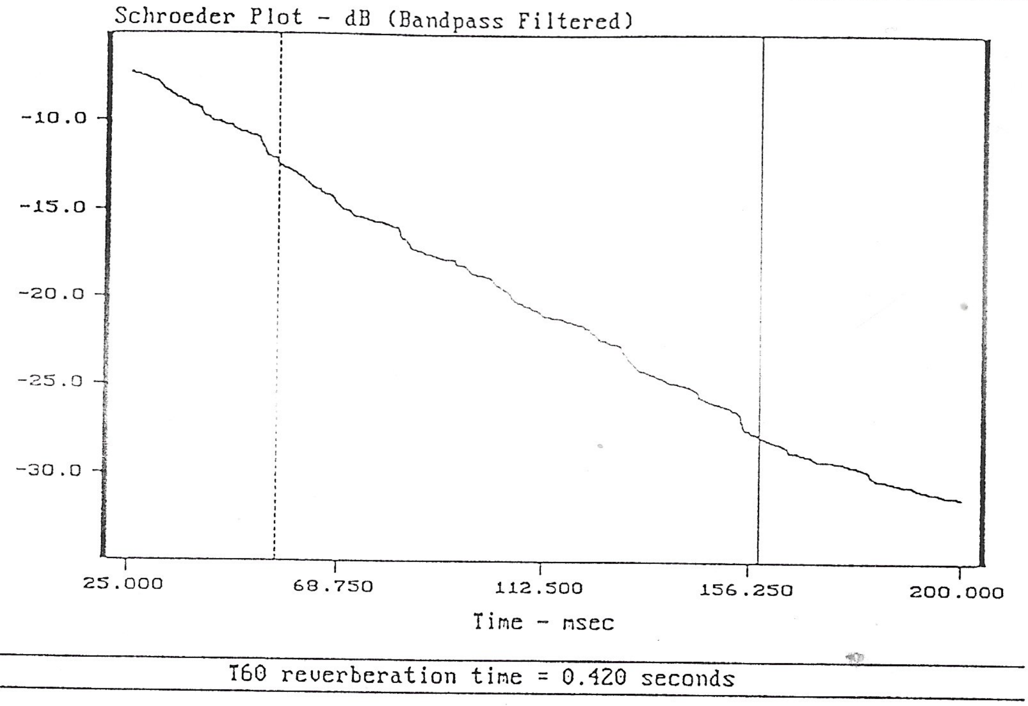
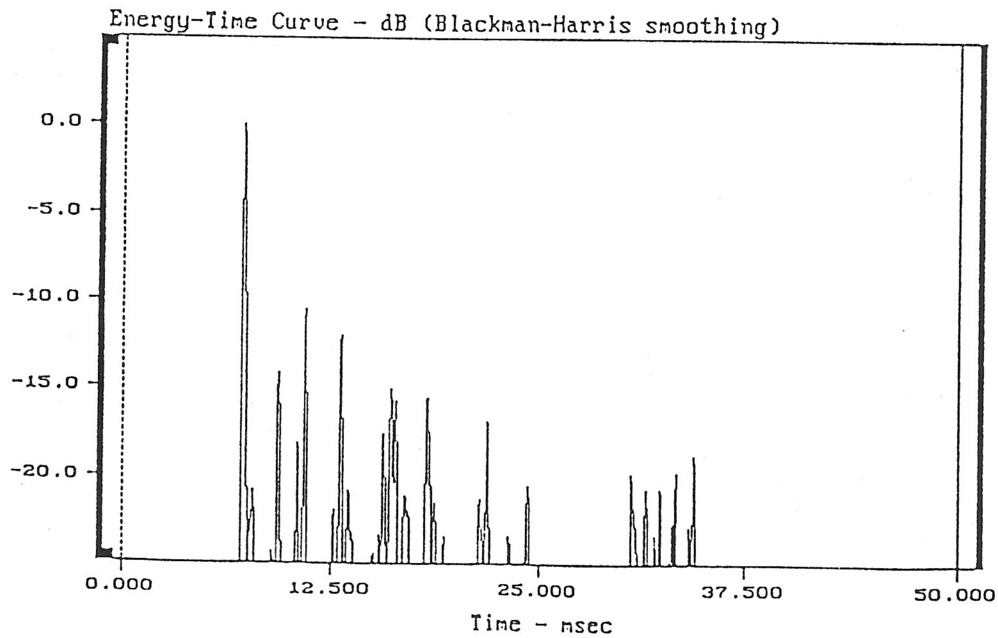


Schroeder plots for reverberation time measurements



Energy-time curve shows room reflections

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