NASA TECH BRIEF
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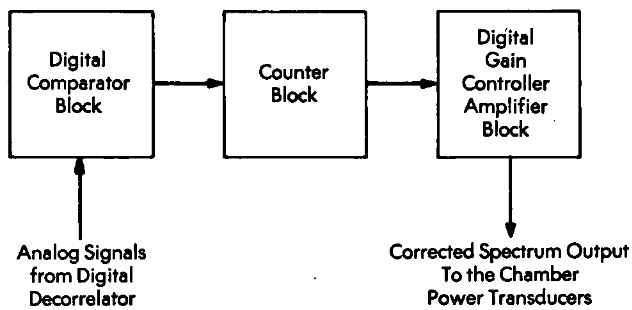
Digital Servo Control of Random Sound Fields

Qualification testing often requires that the test object be subjected to high-intensity random acoustical energy in a reverberant chamber. The high-energy sound field is produced in the chamber by a powerful source in accordance with a specified program of sound levels, but since the chamber is reverberant, the sound field varies with frequency and is of different intensities throughout the volume of the chamber. It is therefore necessary to place a number of sensors (microphones) at different positions in the sound field to determine the actual sound intensities to which the test object is subjected. By monitoring the output of each of the sensors, it is possible to determine whether the specification is being met adequately or exceeded. Because of the variations in intensity, it is necessary to express the average value of the sound field as the quad mean (the square root of the sum of the squares). However, since the excitation is of a random nature, the signals sensed by each of the microphones are essentially coherent and, for statistical reasons, it is impossible to obtain a true average.

Ideally, it is desirable to control the acoustic energy emitted by the source in the chamber so as to assure that test specifications are fully realized. Prior attempts to utilize analog techniques for controlling random sound field excitation of acoustic chambers have been ineffective because in high-energy reverberant test chambers there is an appreciable delay in energy buildup and decay. The delay does not permit use of an instantaneous servo locking arrangement to control sound levels because the sensor signals used to effect control are indeterminate during buildup and decay; if an instantaneous locking arrangement were to be used, there would result an overall oscillatory condition in which the chamber energy source never locks securely on the servo error signal.

A system has been developed to control the random sound energy fields by utilizing digital techniques to



operate automatic gain control systems in discrete acoustic energy bands. In this system, the total sound energy spectrum as perceived by the microphones is subdivided by means of ⅓-octave narrowband filters into 13 channels of varying bandwidth. The level of each narrowband filter is compared with a set level, the latter being that prescribed by the test specification. Following comparison, energy is added to each particular band at a rate which is slower than the natural reverberant buildup in the chamber. Comparisons and energy additions (or subtractions) are repeated until the desired level for each band is reached. After the desired band levels are reached, the system automatically "hunts" at a rate slower than the natural decay and buildup characteristics of the test chamber. Clearly, the arrangement is capable of effecting reasonably stable control of the random sound field throughout the period of the test.

(continued overleaf)

Conventional portions of an acoustic test system into which the digital control arrangement has been incorporated include a noise generator, a bank of ⅓-octave filters (equalizers), a preamplifier, a power amplifier, and transducers. The transducers introduce a spectrum of noise energy into the acoustic chamber. Microphones are disposed in various positions within the sound field to monitor intensities. The practice has been to record the various microphone outputs either graphically or magnetically for subsequent analysis (see Note 1) to determine whether the test complied with the test specifications.

The direct, digital control system (indicated in block diagram form) introduced into this basic system is made up of three main sections or subsystems. The digital comparator block performs the following functions: 1) Spectrum division by means of ⅓-octave filters; 2) AC/DC conversion; 3) Analog switching (multiplex of 13 channels); 4) A/D conversion; 5) Digital buffering (using driver stages); 6) Setting of "Set Point" memory registers; 7) "Set Memory" multiplexing; 8) Equality detection; 9) Determination of relative magnitudes. The counter block includes four elements: 1) an Up/Down counter; 2) Up/Down counter buffer (drivers); 3) "Spectrum Hold" registers; 4) digital feedback control logic. The digital-gain-control amplifier block contains resistor ladders, operational amplifiers connected to the ladders, and analog multipliers; the combination of these three components provides the digital-gain-controlled amplifiers whose outputs are summed in an analog summing amplifier. Simple summation is permissible because the individual channels are all independent.

The system control corrected spectrum is thus reconstructed by the summing amplifier and can be routed to the chamber via the preamplifier, power amplifier, and transducers. Thus, energy can be released into the chamber at a digitally-controlled rate. For example, if microphone acoustic energy in a particular channel is lower than the desired energy level in that particular ⅓-octave band, the Up/Down counter will be directed by the comparator to count upward to release more energy into the chamber in that specific band. The converse is effected if microphone energy is above the desired level which was set in memory. The clock rate of the counter determines the rate at which energy is admitted into the chamber. Each step of the counter therefore involves a fixed amount of drive from the gain amplifiers. Hence, if the test is started at an extremely low level in each ⅓-octave band, energy will build up at a controlled rate which will make it virtually impossible to exceed the test specification.

Notes:

1. A technique for the simultaneous processing of test data is described in NASA Tech Brief B73-10139.
2. Requests for further information may be directed to:

   Technology Utilization Officer
   NASA Pasadena Office
   4800 Oak Grove Drive
   Pasadena, California 91103
   Reference: TSP 73-10297

Patent status:

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

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