1972 B72-10091

NASA TECH BRIEF
NASA Pasadena Office

Control of Acceleration in Sine/Random Vibration Tests

The problem:

Spacecraft vibration qualification test specifications require that accelerations imposed on the test specimen not exceed a prescribed limit. Ordinarily, a single accelerometer is used as a monitor, and it is fastened at the test specimen's point of attachment to the shaker. However, when large specimens are involved, a test fixture is used and it is attached to the shaker at a number of points (usually six), each of which is monitored by an accelerometer. Owing to the composite structure made up of shaker, fixture, and test object, acceleration varies widely with frequency at each test point during a swept-sine test. It is thus difficult to select a single accelerometer output as representative of the shaker force at any instant.

The solution:

Sample the output levels of each accelerometer, then use the largest output or any combination of outputs to control the shaker.

How it's done:

The AC signal from each accelerometer is rectified and filtered to produce a DC value which is proportional to the acceleration level in its particular channel. The outputs of all channels are compared simultaneously by a simple diode OR gate arrangement in which the largest DC value backbiases the other diodes to cut-off. The OR gate output represents the largest momentary acceleration; this signal is processed further and fed back to the amplitude servo for control of shaker force. Whenever the peak acceleration changes from channel to channel, the various DC voltages passing through the OR gate change the DC level of the control signal and hence there is no switching or commutation in the conventional sense; the arrangement is inherently free of switching transients.

Peak acceleration control is useful below 200 Hz, which is the region in which large displacements may damage the spacecraft structure. At higher frequencies, peak control provides an unrealistic under-testing of large structures; signal averaging arrangements are therefore used. However, the accelerometer signals are derived from a common source (the shaker); this precludes direct summation of accelerometer signals because of unacceptable errors caused by vectorial addition of the AC accelerometer signals. Accordingly, summation is performed after phase- and frequency-information have been removed by converting the accelerometer AC values to DC values before averaging.

Depending upon the test specification, either of two types of averaging are utilized. Quadratic-mean averaging is employed when it is desired to restrict the force input from the shaker to the test object to a relatively narrow range and to ensure that the force never exceeds the square root of the sum of the squares of the accelerometer signals. Thus, should there be a loss of signal from one accelerometer in a test in which two accelerometers are used, the maximum acceleration that can be applied by the shaker while under servo-control will never exceed 1.41 times the level of the servo set-point. In the case of a servo-controlled test in which four accelerometers are used, the applied acceleration in the event of loss of signal from three accelerometers will never

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exceed two times the servo set-point level, and in the case of six accelerometers, and loss of five, the force will not exceed 2.45 times the set-point level.

These limitations prevent both undertesting and overtesting of the structure. For example, consider a situation in which there are six points of attachment with six accelerometers, and at each point of attachment the measured acceleration is 1 g and the servo is set to control at that level. If five accelerometers do not produce an output due to structural antiresponse at a particular frequency, the servo will try to force response by increasing gain of the entire system. The use of quadratic mean averaging ensures that the maximum output of the system would never exceed 2.45 g at any of the other attachment points. This effects a conservative test of the spacecraft structure.

Arithmetic mean control is utilized when it is desired to expand the range of test force in a similar situation. Assuming 1 g at each accelerometer and loss of five channels, the acceleration input will never exceed 6 g at the control accelerometer. This effects a more rigorous test of the structure.

Six-channel circuitry for control of peak acceleration has been designed and used for Ranger, Mariner, ATS, and Surveyor test programs. Since each channel utilizes essentially the same circuitry, it is possible to adapt the circuit designs to a larger or smaller number of accelerometers. Briefly, the accelerometer signal is applied to a follower amplifier through a capacitor; this isolates the impedance of the signal source from the input impedance of the full-wave operational rectifier and filter which consists essentially of two operational amplifiers and associated resistors and capacitors.

For control by arithmetic mean, the DC output of each channel is fed to the summing junction of an operational amplifier. For peak acceleration control, the output DC level of all channels are compared by a diode OR gate so that only the largest average DC level (corresponding to the channel with the maximum acceleration) is further amplified, processed, and then used to control the shaker.

Control by quadratic mean involves circuitry by which the filtered DC from the input operational rectifier connected to each accelerometer is fed to a squaring network fabricated of silicon carbide and compensated by suitable resistor networks; the squared inputs from all the accelerometers are then processed at a summing junction.

Note:

Requests for further information may be directed to:

Technology Utilization Officer
NASA Pasadena Office
4800 Oak Grove Drive
Pasadena, California 91103
Reference: TSP72-10091

Patent status:

No patent action is contemplated by NASA.

Source: Raymond C. Woodbury of
Caltech/JPL
under contract to
NASA Pasadena Office

(NPO-11482)