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VIBRATION MEASUREMENT EQUIPMENT

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ABSTRACT

This paper describes the principles of operation of typical instrumentation used in the measurement of shock and vibration. It deals with the measurement of parameters which characterize the total (broad-band) signal.

1. Introduction

Measurements in mechanical domain, latest use the advantages offered by the special performances of electronic circuits (sensitivity, precision, measurement speed, small dimensions or digitized and stored in a digital memory). That's why I suggest herewith a measurement system of vibrations enhanced the value of these performances, especially the performances of operational amplifies and RC integration network.

2.Vibration measurement equipment

Figure 1 shows a typical measurement system consisting of a preamplifier, a signal conditioner, a detector and an indicating meter. Most or all of these elements often are combined into a single unit called a ***vibration meter***.

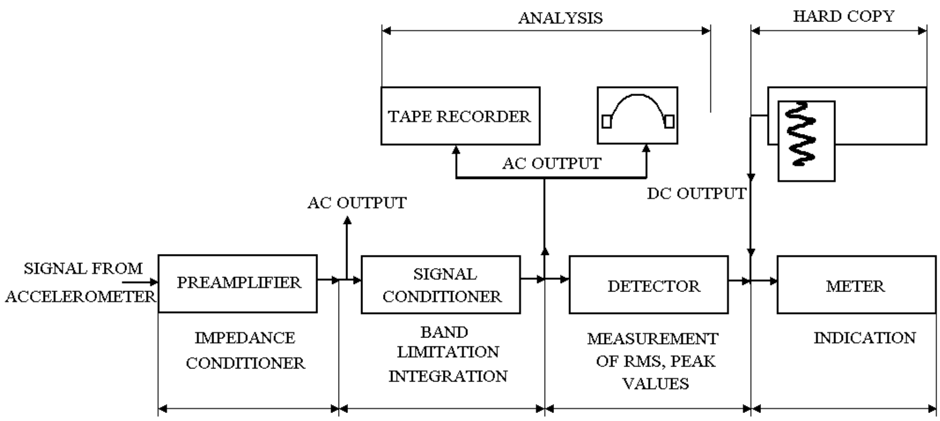

Fig. 1 Typical measurement system

The preamplifier is required to convert the very weak signal at high impedance from a typical piezoelectric transducer into a voltage signal at low impedance, which is less prone to the influence of external effects such as electromagnetic noise pickup. The signal conditioner is used to limit the frequency range of the signal (possibly to integrate it from acceleration to velocity and/or displacement) and to provide extra amplification. The detector is used to extract from the signal, parameters which characterize it, such as rms value, peak values and crest factor. The dc or slowly varying signal from the detector can be viewed on a meter, graphically recorded, or digitized and stored in a digital memory.

2.1 Accelerometer preamplifier

Types of accelerometer preamplifier is charge preamplifier. Figure 2 shows the equivalent circuit of a charge preamplifier with an accelerometer and cable. The charge preamplifier consists of an operational amplifier having amplification A, back-coupled across a condenser C_f; the input voltage to the amplifier is u_i. The output voltage u_0 of this circuit can be expressed as

$$u_0 = Au_i$$
$$u_i = \frac{q_a}{C_e} \qquad (1)$$

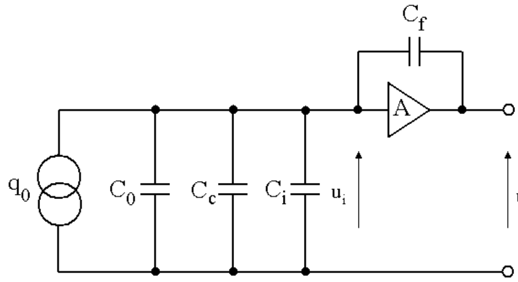

Fig. 2 Equivalent circuit of a charge preamplifier

The equivalent capacitance C_e to the operational amplifier input is

$$C_e = C_a + C_c + C_i - C_f\left(A - 1\right) \qquad (2)$$

and

$$u_i = \frac{q_a A}{C_a + C_c + C_i - C_f\left(A - 1\right)} = f\left(q_a\right) \qquad (3)$$

Which is proportional to the charge q_a generated by the accelerometer. If A is very large, then the capacitances C_a,C_c and C_i become negligible in comparison with AC_f and the expression can be simplified to

$$u_0 \approx -\frac{q_a}{C_f} \qquad (4)$$

which is independent of the cable capacitance. Although with a charge preamplifier the sensitivity is independent of cable length, the noise pickup in the high-impedance circuit increases with cable length and so it is an advantage to have the preamplifier mounted as close to the transducer as is practicable.

2.2 Signal Conditioner

A signal-conditioning section is often required to band-limit the signal, possibly to integrate it (to velocity and/or displacement) and to adjust the gain. High- and low-pass filters normally are required to remove extraneous low-and high-frequency signals and to restrict the measurement to within the frequency range of interest. For broadband measurements the frequency range is often specified, while for tape-recording and/or subsequent analysis the main reason for the restriction in frequency range is to remove extraneous components which may dominate and restrict the available dynamic range of the useful part of the signal.

2.3 Integration

Although an accelerometer, in general, is the best transducer to use, it is often preferable to evaluate vibration in terms of velocity or displacement.

Acceleration signals can be integrated electronically to obtain velocity and/or displacement signals; an accelerometer plus integrator can produce a velocity signal which is valid over a range of three decades (1000:1) in frequency-a capability which generally is not possessed by velocity transducers. Moreover, simply by switching the lower limiting frequency (for valid integration) on the preamplifier, the three decades can be moved by a further decade, without changing the transducer.

A tipical sinusoidal vibration component may be represented by the phasor $Ae^{j\omega t}$. Integrating this once gives $\frac{1}{j\omega}Ae^{j\omega t}$, and thus integration corresponds in the frequency domain to a division by $j\omega$. This is the same as a phase shift of $-\frac{\pi}{2}$ and an amplitude weighting inversely proportional to frequency, and thus electronic integrating circuits must have this property.

One of the simplest integrating circuits is a simple RC circuit, as illustrated in Fig. 3. If u_i represents the input voltage, then the output voltage u_0 is given by

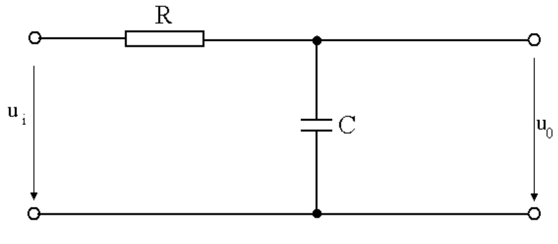

Fig. 3 A simple RC circuit

$$u_0 = \frac{1}{1 + j\omega CR}u_i \qquad (5)$$

which for high frequencies ($\omega CR >> 1$) becomes

$$u_0 = \frac{1}{j\omega CR}u_i \qquad (6)$$

which represents an integration, apart from the scaling constant $1/RC$.

Frequency characteristic of the circuit Fig.3 is shown in figure 4; it is that of a low-pass filter with a slope of -20dB/decade and a cutoff frequency $f_n = 1/2\pi RC$ (corresponding to $\omega RC = 1$).

The limits f_L (below which no integration takes place) and f_T (above which the signal is integrated) can be taken as roughly a factor of 3 on either side of f_n, for normal measurements where amplitude accuracy is most important. Where phase accuracy is important (to measure true peak value), the factor should be somewhat greater. Modern integrators tend to use active filters with a more localized transition between the region of no integration and the region of integration.

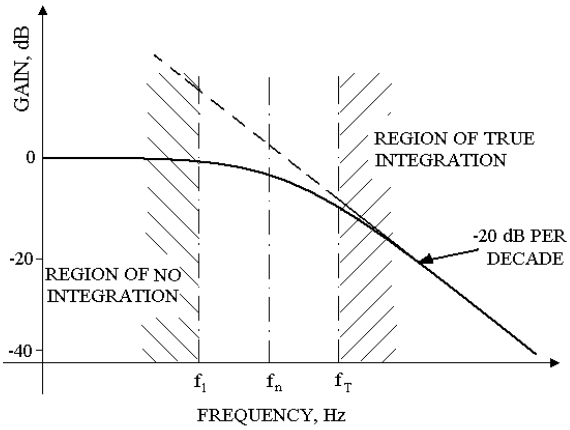

Fig. 4 Frequency characteristic

One situation where the choice of the low-frequency limit is important is in the integration of impulsive signals, for example, in the determination of peak velocity and displacement from an input acceleration pulse.

2.4 Detector

Detectors are used to extract parameters which characterize a signal, such as arithmetic average, mean-square and root-mean-square (rms) values. The arithmetic average value is simplest to measure, using full-wave rectifier to obtain the instantaneous magnitude and a smoothing circuit to obtain the average.

2.5 Vibration meter

Vibration meters are instruments which receive a signal from a vibration transducer and process it so as to give an indication of relevant vibration parameters.

They are sometimes made specifically to meet certain standards, for example, ISO 2372 on "Vibration Severity of Rotating Machines" or ISO 2631 on "Human Vibration"

3. Conclusion

Finally, it is useful if the meter has an ac output, to allow the signal to be fed to an oscilloscope, a tape recorder, or headphones. In the absence of frequency analysis, the human ear can be discern a great deal about the characteristics of a signal, and this setup provides an excellent stethoscope. The ac signal should preferably be of selected parameter (acceleration, velocity, or displacement): the frequency range should be restricted as little as possible.

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