The Case For and Against Integration (of Machinery Vibration Signals)

Vibration is typically measured in engineering units for displacement (mils), velocity (in./sec or ips.) or acceleration (g's). At a given vibration frequency (measured in Hz), there is a specific relationship between displacement, velocity and acceleration. Vibration can be measured in any one of these units. When one converts acceleration units to velocity units (A/V) or velocity units to displacement units (V/D), it is called single integration; when one converts acceleration units to displacement units (A/D), it is called double integration. This term (integration) results from the physical and mathematical relationships between acceleration, velocity and displacement units of measure for vibration.

When single integrating (A/V or V/D), the relationship between the two units is proportional to: 1/f, (where f = frequency, Hz). When double integrating (A/D), the relationship between the two units is proportional to: 1/f2. Integrating amplifiers circuits electronically alter (integrate) the incoming signal ("A" or "V") using these proportional relationships to provide a new signal ("V" or "D") in the desired units of measure. The graphs illustrate these relationships (→ **figs. 1** and **2**).

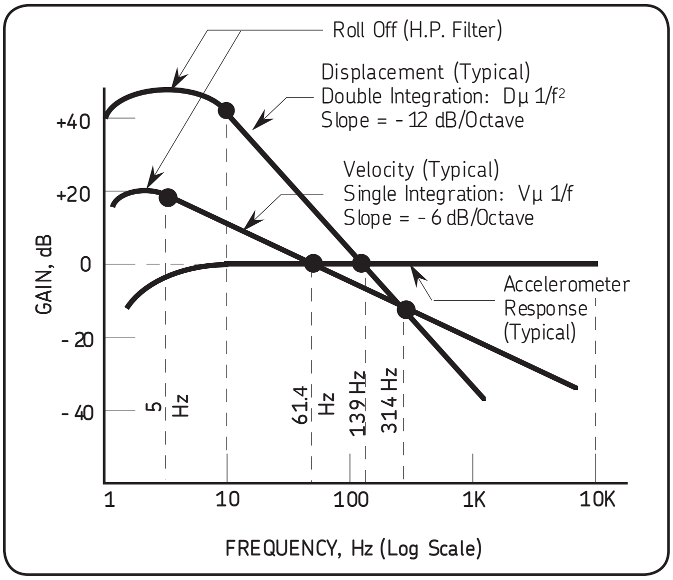

Fig. 1. Integrated accelerometer response.

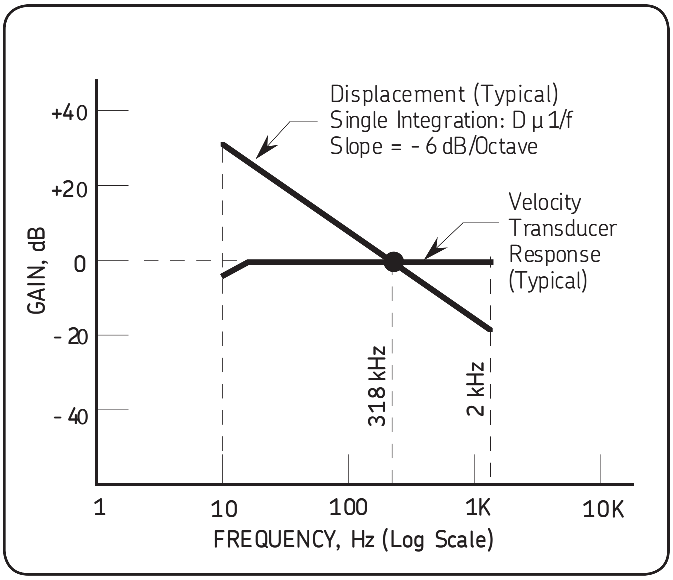

Fig. 2. Integrated velocity response.

For those not familiar with "dB" (or decibel) units of measure, +20 dB indicates (voltage) amplification of 10X, and +40 dB is equivalent to 100X amplification (-20 dB equals attenuation by 0.1X, and –40 dB is equivalent to 0.01X). Thus, we see large (10X to many 100X) amplification of low frequency (around 0 to 20 Hz) signals and some attenuation of high frequency (1 kHz and above). The high frequency signals will be inaccurate.

The significance of this amplification/attenuation in the "real" world is that low frequency vibration signals ***and*** system electrical noise (typically around a millivolt) are amplified and unstable to the extent that they are unusable without further signal conditioning. In other words, the signal-to-noise ratio is too low. Typically, a high pass filter is employed to attenuate (reduce) signal levels in the low frequency region (0 to 20 Hz).

This results in stable signals, but makes the integrated signal inaccurate (attenuated) at low frequency. Virtually all electronic circuits used to integrate vibration signals have a low frequency "roll-off" (attenuation) via a high pass filter or other attenuation technique. Thus, the user of instruments or devices with integration circuits must be aware that the vibration data will be modified (inaccurate) in the low frequency region. If it is necessary to assess the degree of accuracy, you should contact the instrument manufacturer for detailed information and specifications.

By referring to the graph again, we also see that integrated vibration signals at higher frequencies (above 1 kHz) are very small in amplitude. They will be accurate, but may be reduced to voltage levels below those required by the particular indicating instrument used – thus, higher frequency data may be effectively hidden or lost during the vibration signal integrating process. What all this means to the user of equipment containing circuitry that integrates vibration signals is:

- Integration is a very convenient way to "translate" units of measure for vibration (A/V, A/D, V/D).
- Integration can enhance data presentation; for example, displacement values are typically greater at lower frequencies and negligible at high frequencies (whereas acceleration values may be greater at higher frequencies and negligible at lower frequencies).
- Integration will introduce error at very low frequencies; the degree of error (and the frequency region in which it occurs) should be recognized and assessed.
- Integration may mask or reduce high frequency data (signals) to a level that may effectively lose some information that may be of value. The signals will be accurate, but output voltage levels will be too low for practical use with most field instruments.
- Integration is usually safely and accurately employed in the 20 Hz to 1 kHz region; integration can be used at frequencies beyond this region, if the characteristics (degree of alteration and voltage levels) of the integrated signal are not significant at these extended (high and low) frequencies.

This recommended frequency range, 20 Hz to 1 kHz, is only intended as a guideline or rule of thumb. Integration can, at times, be reasonably employed at frequencies slightly beyond this range. In any case, 20 Hz (1 200 r/min) to 1 kHz (60 000 r/min) represents a working region that is very useful for most common turbomachinery vibration applications. Most vibration events of interest on turbomachinery occur within this frequency range.

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