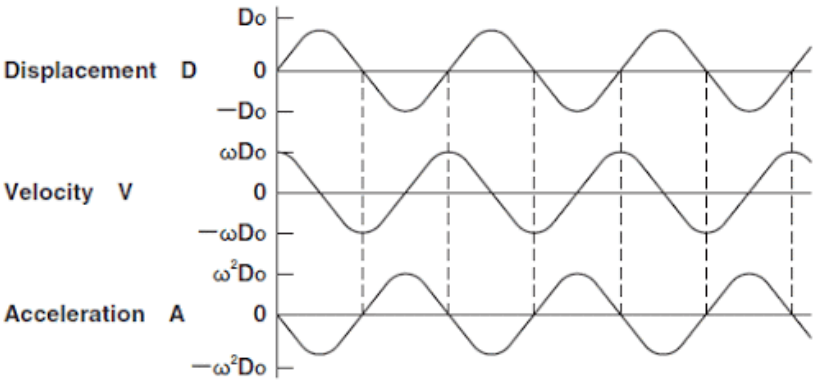
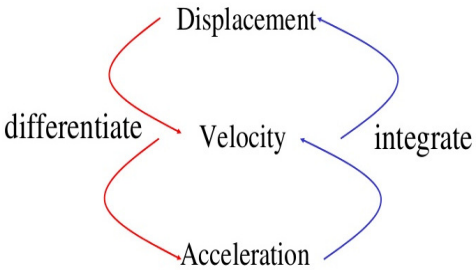
Technical note series:
The Basics of Vibration Measurement – A Very Practical Approach

Relationship between Acceleration, Displacement and Frequency and its impact on Mounting Sensors

There are many 'fundamental' principles that relate to vibration testing and analysis and these are sometimes forgotten in todays' modern world of powerful analysis software which seem to offer the engineer an 'out of the box' solution which takes no set up. This note outlines the relation between Acceleration, displacement and frequency and how this impacts accelerometer use.

Most engineers will hopefully appreciate the mathematical relationship between Acceleration, Velocity and Displacement, not that the maths involved will necessarily be foremost in their memory (I did say appreciate!!), the graphical view is represented below:





The good news is that if you want to calculate these conversions modern software does all the hard work for you, **HOWEVER**, there is an interesting relationship linked to this with a very practical application. The table below shows the displacements required to generate 1g at different frequencies (both imperial and metric options to suit all ages and geographical locations!)

Frequency	Displacement	
1 Hz	19.56 in	496mm
10Hz	0.20 in	4.97mm
150Hz	0.00087 in	0.022mm
350Hz	0.00016 in	0.004mm
750Hz	0.000035 in	0.00088mm
1000Hz	0.00002 in	0.0005mm
1500Hz	0.000009 in	0.0002mm
2000Hz	0.000005 in	0.00012mm
2500Hz	0.000003 in	0.00008mm
3000Hz	0.000002 in	0.00006mm

In the real world this means that at low frequency it takes very high displacement to generate acceleration, these displacements are both easy to see and easy to measure. However, the situation changes quickly as the frequency climbs, at 350Hz the displacement has gone from 496mm to just 0.004mm and it continues to fall, at 3000Hz it is just 0.00006mm to generate the same 1g amplitude. So what!! I hear you say…. Well it is a very big deal to accelerometers when you consider the issue of mounting your accelerometer on to your test item.

In an ideal world the accelerometer should be mounted in such a way that it becomes 'part' of the test item, i.e no risk of any movement between them, the closest way to achieve this is by screwing them together, sadly how often can you drill a hole in your test item? So, in reality the most common method is to glue them down…. now the fun starts!!

Once you introduce a 'foreign' material between the accelerometer and the test item the risk of an error being introduced is increased dramatically particularly at higher frequencies, this can now be appreciated when you realise the displacements required to generate acceleration are incredibly small. Any imperfections in the adhesion, surface finish, soft glue, glue affected by heat etc. etc. can destroy data accuracy because the accelerometer movement independent of the test item creates additional accelerations which are measured by the accelerometer itself.

How many readers of this note are now starting to feel a little concerned? Perhaps even going red with embarrassment? Has anyone ever used tape to 'protect' the surface of their test item before gluing an accelerometer down? come on own up!!! If so how thick is the tape? Compare it to the values in the table above… still feeling OK? This is just one example of how a simple oversight can cause huge issues in the dynamic measurement world of vibration.

Although there are no guaranteed 'right' ways to glue accelerometers down, things to consider include:

- Use as little adhesive as is possible, it doesn't take much so don't use much
- Use an adhesive that goes 'hard', define hard? Not easy, but ask yourself is it as hard as metal when cured? How close to this ideal can I get and keep it practical.
- Is your adhesive suitable at the test temperature or other environmental condition?
- Are you using any other material between accelerometer and test item? How hard or suitable is this?

Common adhesives used include cyanoacrylate, sometimes called superglue, but don't be drawn into using cheap glue sourced from the stationery suppliers, use a quality Loctite® or similar which meets the environmental conditions, then apply to your accel and slide it into position, this will remove the excess leaving a thin layer with good adhesion. Ensure it has time to fully cure before testing commences!!.

Kemo Ltd sales@kemo.com