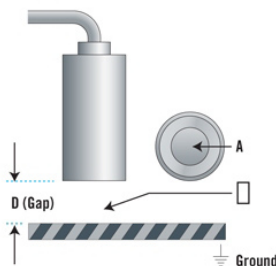


Using Capacitance Sensors to Measure Position, Vibration and Displacement of Small Targets



Capacitance sensors are widely used throughout a variety of industries to provide highly stable, accurate measurements of displacement, vibration, position and runout. Most capacitance probes are passive by design, allowing them to be operated in high shock and vibration environments at temperatures from -270°C to over 500°C . Unfortunately, the measurement range of a capacitive probe is relatively small in proportion to the probe size so measuring tiny targets can be difficult, if not impossible. That is, until MTII introduced the breakthrough Accumeasure 9000 capacitance sensing system.

Capacitance probes can be modeled after a parallel plate capacitor. If two conductive surfaces are separated by a distance and a voltage is applied to one of the surfaces an electric field is created. This occurs due to the different charge stored on each of the surfaces. Capacitance refers to the ability of the surfaces to hold a charge. In a typical capacitive sensor system the probe is one of the plates and the target being measured is the other plate. If a constant current is applied to a capacitive probe the voltage change on the measured target can be monitored and related to the distance between the plates. This distance, or gap, is a function of the area of the capacitance sensor according to the following formula:



$$\text{Capacitance} = \text{Area} \times \text{Dielectric} / \text{Gap.}$$

From this relationship you can see that the greater the area of the capacitance sensor the larger the measurement range or gap. Typical capacitive amplifier systems operate over a specific capacitance range, limiting their ability to measure large motions or operate at comfortable standoff distances. To overcome this problem MTII created a proprietary capacitive circuit that, with minor component modifications, can be adjusted to change the capacitance range and meet a wider variety of customer requirements. This allows MTII's capacitive probes to be used in applications where space is limited or the target being measured is small.

One such example is measuring the runout of small shafts and spindles. MTII was approached by a customer attempting to measure a 2-mm diameter shaft 5-mm's in length. The expected repetitive runout at 20,000 rpm was only about 1 micron so a resolution of 50 nanometers or better was required. Because of the high shaft speed the measurement system needed a frequency response of no less than 5 kHz.

The small shaft diameter dictated the capacitance probe size and shape. A rectangular sensor element was selected because the shaft was longer than the diameter, providing sufficient area for MTII's capacitance probe. By aligning the long axis of the capacitive sensor element with the axis of the shaft, the curvature of the surface did not warp the established electric field. This ensured the required accuracy and linearity would be obtained throughout the complete measurement range. For this application the capacitance probe sensing area was only 125 microns by 1.25 millimeters, an area that equates to a measurement range of approximately 12.5 microns. By adjusting the "push", or capacitance range of the amplifier, the measurement range was increased by a factor of 10X. This provided additional operating distance and reduced the possibility of the capacitance probe hitting the shaft.

There are limits however to how much push can be applied to a capacitance probe. To maintain accuracy and linearity it is essential that the electric flux field at the sensing area be linear and not distorted. To protect this field each capacitive sensor has what is called a guard circuit. This is an additional field created around the probe sensing tip that is driven at the same phase and voltage potential. By being equal, the auxiliary field established protects the capacitance sensing area from becoming warped. For best performance the width of the guard should be at least 2X the measurement range, providing proper protection. With a properly designed capacitance probe the measurement range can be increased by 50 times or more.

In addition to improving linearity and accuracy the guard is also used to reduce noise and external interference. Each capacitance probe is driven by a coaxial cable. The shield of the cable is used to deliver the voltage to the guard, and you may recall at the same potential and phase. This eliminates any stray capacitance that might be created between the center conductor and the shield of the cable, or any other part that may be close to the cable. It is important to note that ordinary coaxial cable usually does not provide adequate protection or shielding and special cable is generally required.

By taking advantage of the unique performance and flexibility of MTII's capacitance probes, customers around the world have adapted these sensors into many applications that previously could not be solved with capacitive sensing technology. The above is only one example of MTII's unique capabilities. Contact MTII's experienced Applications Engineers to learn of others, or for help solving your difficult measurement needs.