

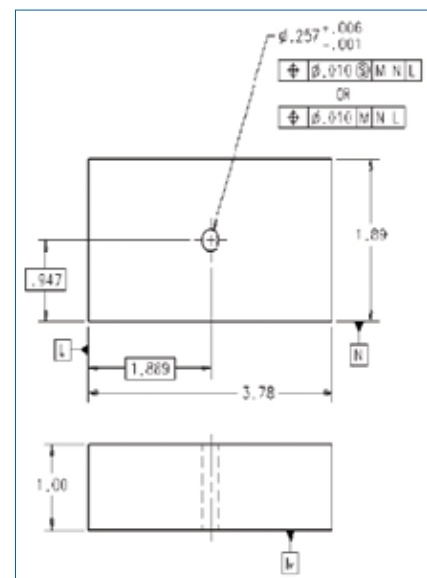
### Executive Summary

Manufacturers today realize that feature location in part design and production is crucial. In order to produce interchangeable parts in a manufacturing environment, care must be taken that the design is sound enough to allow mating parts to work correctly. Furthermore, the industrial process must be robust enough to produce parts called out in design in an efficient and predictable manner. Likewise, measurement of the final parts must be done easily and with confidence in order to verify the in-process or final products. For example, inspection of a bore in an open setup often requires multiple measurement steps and mathematical calculations. Portable CMM technology can alleviate much of this work by allowing the user to fix the part in one spot, take several points to create an alignment of x- and y- axes, and measure the bore. Software is then able to determine the position of the bore and its deviation from the called out position.

### Overview

Traditionally, to find the deviation from true position (sometimes simply called the position) of a feature, the “open setup” is used. This process involves the use of calipers, height gauges, micrometers, and other hand tools used in conjunction with an inspection plate to take measurements and compare the feature’s position to datums. Following the appropriate measurements, the true position diametrical deviation,  $D$ , must then be calculated via the following mathematical formula (equation 1):  $D = 2\{(\Delta x)^2 + (\Delta y)^2\}^{1/2}$  where  $\Delta x$  = the deviation from the true position along the x-axis and  $\Delta y$  = the deviation from the true position along the y-axis.<sup>1</sup>

Consider the following situation (shown in figure 1 below), which is one of the simplest examples using the open setup method. In order to determine the true position of this hole, the block must be fixed in place. At this point, several measurements must be made, perhaps with a pair of calipers. First, the diameter of the hole must be determined. To do this properly, several different measurements should be taken in order to verify the diameter and, at least in a qualitative way, the circularity of the hole. (Little can be said of the actual cylindricity of the hole, however. The diameter’s uncertainty combined with the lack of data on cylindricity often means expensive go/no-go gauges must be used as well.) Next, measurements should be taken of the hole’s closest and farthest points to the x-axis (defined by the datum “L”) and the y-axis (defined by the datum “N”). In this way the position of the centerline of the hole can be calculated in Cartesian coordinates. This (x,y) position can then be compared to the position called out in the drawing (1.889,0.947) and the deviation can be calculated according to equation 1. This cumbersome procedure representing one of the simplest measurement scenarios can take twenty minutes or more and is subject to relatively large amounts of error due to the difficulty of determining the hole’s closest and farthest points from the x- and y- axes. The procedure becomes even more complex when MMC conditions are





applied or when the geometry of the part deviates from the simple part under consideration.

Now consider the use of a portable CMM that records positions of a probe via encoders and translates these positions into a coordinate system useful to the user. First, the user clamps the part in place using simple tools such as toe clamps. Then the operator takes several data points along datum "L" by merely using the device's probe to touch the points in question and pushing a green button each time contact is made to record the data. When all of the appropriate points are taken, the user pulls away from the part and touches the red button to terminate the measurement process. The software then best fits the line and allows the user to define the resulting line as datum "L". The process is then repeated for datum "N" and the hole (cylinder). The user then inputs the nominal values for the cylinder, tells the software to dimension the position of the cylinder, and the result is returned (including cylindricity). The entire process, including setup, is less than five minutes in most cases.

## Conclusion

The advent of portable CMM technology has greatly reduced the difficulty of measuring GD&T properties, including the deviation from true position of features. The combination of hardware and software allows the user to take points easily and quickly and the software uses best fit algorithms to give the user accurate, virtually instantaneous, results. The portable CMM also eliminates other issues associated with the traditional open setup method such as the need for go/no-go gauges and a lack of three dimensional form results. This technology provides manufacturers accurate and convenient measurements where deviations from true position can be found and corrected quickly.



## References

1. James D. Meadows, *Geometric Dimensioning and Tolerancing: Applications and Techniques for Use* (CRC Press, LLC, 1995), p. 441.
2. Robert A. Ochs: *Positional Tolerancing Presentation*  
<http://www.isixsigma.com/offsite.asp?A=Fr&Url=http://faculty-staff.ou.edu/O/Robert.A.Ochs-1/Notes/PositionalTolerancingPres.ppt>

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