2) Terms and Definitions for Linear Motion Systems

There are many terms that are commonly used in industry that are not always understood by designers, end users, and other technical persons. Although some of the terms take on obvious meanings, others may not. This section is provided so that such people can use these terms in proper context, to relieve the possibility of design criteria and specifications being too tightly constrained due to lack of effective communication. Having the following terms explained and understood allows for a more efficient design process, and a more cost-effective solution.

Point to point accuracy or accuracy is defined as the difference between the statistical mean of a series of measurements and the theoretically correct position. Another way of stating this is to say that point to point accuracy is the ability to travel to a desired point or series of points with respect to some known reference.

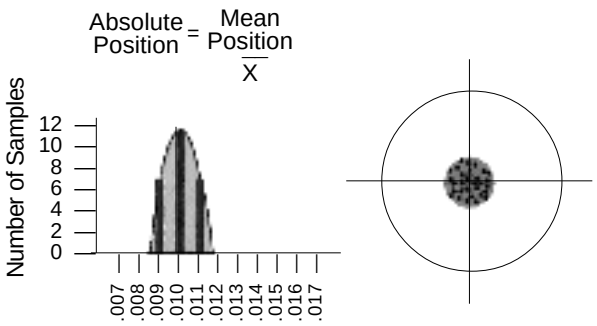
Straight line accuracy is the ability of a machine to accurately travel in a straight line with respect to a known reference plane, and the specification refers to the maximum possible deviation from the desired straight line path.

Accuracy affects how closely parts are made to specifications. There are many factors that contribute to the accuracy of a system, but the most significant ones are the accuracy of the drive mechanism, the accuracy of the motor, and the presence of play, or backlash. Accuracy may also be referred to as “system error”.

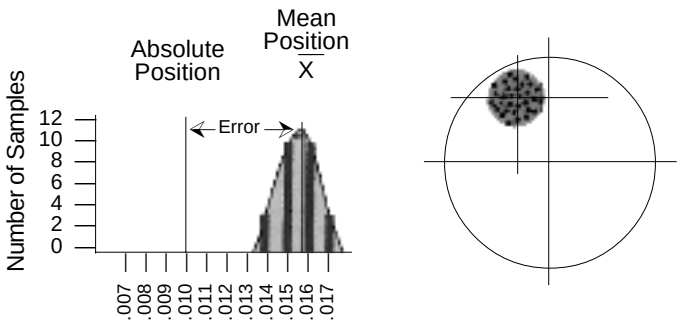
Repeatability is defined as the degree to which repetitive measurements on a single system are in agreement. Another way of stating this definition is to say that repeatability is how close a system returns to a desired location or locations time after time under repeated cycling. Major contributing factors to repeatability are the precision of the bearing ways and the amount of play, or backlash in the system. Repeatability affects how identical parts may differ slightly.

There is a direct relationship between system cost, accuracy and repeatability*; therefore it is essential that the terms are understood. If an application involves a motion stopped by an operator, a position sensor, or a mechanical stop, then the application requires only repeatability. Similarly, if an application requires that the same location be found time after time as with assembly applications, then only repeatability is needed. If an application involves cycled point to point motion or exact length motion as with high-precision parts machining, then both accuracy and repeatability are required. The following diagrams provide a good visual representation of these two terms.*

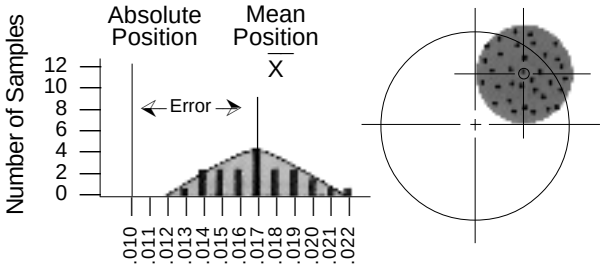
Case 1: Accurate and Repeatable
(Mean = Absolute Position, σ small)



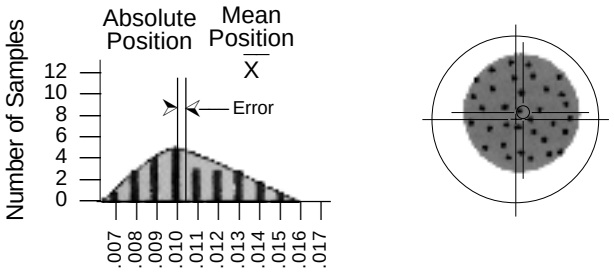
Case 2: Not Accurate but Repeatable
(Mean ≠ Absolute Position, σ small)



Case 3: Not Accurate and not Repeatable
(Mean ≠ Absolute Position, σ large)



Case 4: Accurate but not Repeatable
(Mean ≅ Absolute Position, σ large)



Backlash is defined as the "dead band" experienced when changing directions. This phenomenon is caused by a clearance between interactive elements in a drive train and/or bearing system. Backlash is typically found between gears or between a nut and screw. A common and less technical description of backlash is defined to be the amount of "play" or "slop" in a system. The largest contributing factors to backlash stem from the drive train and bearings being imprecise or worn. Preloading the drive train and bearings will remove excess play in a system, and this type of system is generally referred to as "anti-backlash".

Resolution is defined as the smallest attainable increment of adjustment or positioning. The minimum amount that a positioning system can be moved is referred to as the system resolution. Among the factors that determine resolution are the type of motor and control used, and mechanical advantages found within the drive train.

Lifetime is defined as the cumulative number of linear inches of travel guaranteed by the manufacturer of a linear motion system. This specification varies greatly with load and speed so care should be taken to confirm operating conditions.

Friction is defined as a nonconservative force that acts in the opposing direction of a motion. By means of heat dissipation, friction results in the loss of useful energy and contributes to system wear. As a result of friction, systems become inefficient, inaccurate, and expensive to maintain. Friction due to rolling contact is far less than that due to sliding contact. This should be considered when selecting load bearings and drive trains. For example, lead screws and plain bearings have higher friction forces than ball screws and ball and roller bearings.

Static analysis is defined as force and torque analysis of a body or system of bodies when they are at rest (or when they are at "equilibrium"). Although acceleration forces are present in all gravitational fields, they are counteracted by equal and opposite forces in a static system and motion is constrained. A **static load** is a load acting on a body or system of bodies that is supported by an equal and opposite force. This type of system is analyzed using Newton's 2nd Law in the case where the accelerations acting on all bodies are equal to zero.

Dynamic analysis is defined as force, torque and motion analysis of a body or system of bodies when they are not at rest (or when they are not at "equilibrium"). A dynamic system will have force and torque acting that are not counteracted, resulting in motion of the body or bodies. A **dynamic load** is a load that is not supported by an equal and opposite force and results in a dynamic, or changing system with respect to motion. This type of system is analyzed using Newton's 2nd Law in the case where the accelerations acting on all bodies may be nonzero. Note that dynamic conditions complicate load and life calculations because of shock loads and vibrations.