The process capability index $C_p$ is gaining acceptance as a measure of product design for manufacturing, especially in the process-intensive industries such as IC and PCB fabrication. Historically, it has been one of the earliest methods of measuring design for manufacture by forecasting the reject rates in production of new components, assemblies, and products. Its unique blend of the production variability versus design specification makes it a natural method for setting, communicating, and comparing new product specifications and manufacturing quality levels for competitive manufacturing plants.

By focusing on the process capability index, there is a commitment up-front to measuring and controlling manufacturing variability through statistical process control (SPC) tools and methods such as control charts. In addition, it is an excellent tool for negotiating and communication with suppliers to set the appropriate quality level and expectations.

The process capability index focuses on communication between the design, development, and manufacturing parts of the organization. By managing the relationship of design tolerance to manufacturing specifications, it shifts attention away from a possible adversarial relationship between design and manufacturing to a more constructive one, where the common goal of achieving a particular index level facilitates negotiations and cooperation in new product development.

4.1 THE DEFINITIONS OF TOLERANCE LIMITS AND PROCESS CAPABILITY

Electronic products are manufactured through materials and processes that are inherently variable. Design engineers specify materials and process
characteristics to a nominal value, which is the ideal level for use in the product. The maximum range of variation of the product characteristic that will still work in the product determines the tolerance about that nominal value. This range is expressed as upper and lower specifications limits (USL and LSL)—see Figure 4.1.

The manufacturing process variability is usually approximated by a normal probability distribution, with mean of \( \mu \) and a standard deviation of \( \sigma \). The process capability is defined as the full range of normal manufacturing process variation measured for a chosen characteristic. Assuming normal distribution, 99.74% of the process output lies between \(-3\sigma\) and \(+3\sigma\).

A properly controlled manufacturing process should make products whose output mean characteristic or target are set to the nominal value of the specification. This is easily achieved through control charts. If the process mean is not equal to the product nominal value, it can be shifted by recalibrating production machinery or inspecting incoming raw material, characteristics.

The variation of the manufacturing processes (process capability) should be well within the product tolerance limits. The intersection of the process capability and the specification limits determines the reject level (Figure 4.2). Process capability can be monitored using control charts. The manufacturing process variability can be reduced by using optimized equipment calibration and maintenance schedules, increased material inspection and testing, and by using design of experiments to determine the best set of process parameters to reduce variability.

The classical design for manufacturing conflict of interests between design and manufacturing engineers is usually about controlling product quality and cost. The design engineers would prefer the narrowest possible process capability, so that they can specify the maximum tolerance specifications to ensure the proper functioning of their product. In contrast, the manufacturing engineers would prefer the widest possible tolerance specification, so that they can continue to operate the largest possible manufacturing capability.

![Figure 4.1. Process capability index.](image-url)