

Units and Conversions

This unit of the Metrology Fundamentals series was developed by the Mitutoyo Institute of Metrology, the educational department within Mitutoyo America Corporation. The Mitutoyo Institute of Metrology provides educational courses and free on-demand resources across a wide variety of measurement related topics including basic inspection techniques, principles of dimensional metrology, calibration methods, and GD&T. For more information on the educational opportunities available from Mitutoyo America Corporation, visit us at www.mitutoyo.com/education.

This technical bulletin addresses an important aspect of the language of measurement – the units used when reporting or discussing measured values. The dimensioning and tolerancing practices used on engineering drawings and related product specifications use either decimal inch (in) or millimeter (mm) units. Dimensional measurements are therefore usually reported in either of these units, but there are a number of variations and conversions that must be understood. Measurement accuracy, equipment specifications, measured deviations, and errors are typically very small numbers, and therefore a more practical spoken language of units has grown out of manufacturing and precision measurement practice.

Metric System

In the metric system (SI or International System of Units), the fundamental unit of length is the meter (m). Engineering drawings and measurement systems use the millimeter (mm), which is one thousandths of a meter (1 mm = 0.001 m). In general practice, however, the common spoken unit is the “micron”, which is slang for the micrometer (μm), one millionth of a meter (1 μm = 0.001 mm = 0.000001 m). In more rare cases, the nanometer (nm) is used, which is one billionth of a meter. A summary of this language is shown below:

millimeters	Common Language and Conversions
1 mm	1 mm = 0.001 m = one millimeter (don't say one mil)
0.001 mm	1 μm = 0.001 mm = one micrometer = one micron (common spoken slang)
0.000001 mm	1 nm = one nanometer = 0.001 μm

- The word “micron”, while commonly spoken, should not be used in writing or when reporting values.
- The micrometer unit is pronounced with the emphasis on the first syllable and the long “o” (mī'krō-mē'tər); however, the common dimensional measuring tool is pronounced without the emphasis (mī-krōm'ī-tər).

Inch System

In the inch system, the fundamental spoken unit in manufacturing practice is not the inch, but is 0.001 inches or one thousandth of an inch. In spoken practice all other numbers follow from this, and traditional rules from “math” may be broken, e.g. 0.123 inches is pronounced one hundred twenty-three thousandths. This same spoken practice extends to smaller numbers where 0.0001 inches, one tenth-thousandths, is typically called “one tenth”. When numbers get really small, the fundamental unit may switch over to millionths of an inch, 0.000001 inches. This unit is common, for example, in surface roughness or in the calibration of gage blocks. A summary of this language, including the common slang, is shown below:

Inches	Common Spoken Language with Base of One Thousandths of an Inch (0.001 in)
0.100 in	one hundred thousandths
0.010 in	ten thousandths
0.001 in	one thousandths = one thou = one mil (mil is specific to certain industries)
0.0001 in	one ten-thousandths = one tenth
0.00001 in	ten millionths = ten microinches = 10 μinches = 10 μin
0.000001 in	one millionth = one microinch = 1 μinch = 1 μin

- In writing or reporting values, the acceptable inch units are the inch, μinch and mil.
- The μinch and mil are based on the application of metric prefixes to inch units.
- In general, use decimal units, avoid fractions, and don't use feet or yards.
- Avoid using 1” (1 inch) or 1' (1 foot) as those can get confused with angular units of minutes (1') and seconds (1”).
- The inch abbreviation (in) is not well-standardized. Other options include IN (capitalized) and in. (with the period).

Inch - Metric Conversions

All conversions between inch and metric units can be done using the extremely important and officially exact relationship of 1 inch = 25.4 mm. The following approximate conversion factors are useful for quick conversions particularly when talking with others who are not bilingual in both inch and metric units:

$$0.0001 \text{ in} \approx 2.5 \text{ } \mu\text{m}$$

$$0.001 \text{ in} \approx 25 \text{ } \mu\text{m}$$

$$1 \text{ } \mu\text{m} \approx 40 \text{ } \mu\text{in}$$

$$1 \text{ } \mu\text{in} \approx 25 \text{ nm}$$

Metric Prefixes

In manufacturing and dimensional measurement practice, metric use is usually restricted to meters (m), millimeters (mm), micrometers (μm), and in rare cases nanometers (nm). Some industries use centimeters (cm). Metric units are well standardized. The complete list of metric prefixes is shown below:

Prefix	Symbol	Numerical Multiplier	Exponential
yotta	Y	1,000,000,000,000,000,000,000,000	10^{24}
zetta	Z	1,000,000,000,000,000,000,000,000	10^{21}
exa	E	1,000,000,000,000,000,000,000,000	10^{18}
peta	P	1,000,000,000,000,000,000,000,000	10^{15}
tera	T	1,000,000,000,000,000,000,000,000	10^{12}
giga	G	1,000,000,000,000,000,000,000,000	10^9
mega	M	1,000,000,000,000,000,000,000,000	10^6
kilo	k	1,000,000,000,000,000,000,000,000	10^3
hecto	h	100,000,000,000,000,000,000,000	10^2
deka	da	10,000,000,000,000,000,000,000	10^1
Base length unit is the meter (m), defined as distance travelled by light in a vacuum in 1/299,792,458 of a second			
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	μ	0.000 001	10^{-6}
nano	n	0.000 000 001	10^{-9}
pico	p	0.000 000 000 001	10^{-12}
femto	f	0.000 000 000 000 001	10^{-15}
atto	a	0.000 000 000 000 000 001	10^{-18}
zepto	z	0.000 000 000 000 000 000 001	10^{-21}
yocto	y	0.000 000 000 000 000 000 000 001	10^{-24}

Legal Units in the United States

U.S. law first authorized the use of the metric system in 1866. The Metric Conversion Act of 1975 established that the U.S. shall increase the use of the metric system, calling for “a voluntary conversion to the metric system”. The Omnibus Trade and Competitiveness Act of 1988 did “designate the metric system of measurement as the preferred system of weights and measures for United States trade and commerce”; however, both sets of units continue to be widely used in industry.



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