threaded fasteners
# Stock Fastener Sizes

## Imperial

<table>
<thead>
<tr>
<th>Thread</th>
<th>Major (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-56</td>
<td>0.086</td>
</tr>
<tr>
<td>4-40</td>
<td>0.112</td>
</tr>
<tr>
<td>6-32</td>
<td>0.138</td>
</tr>
<tr>
<td>8-32</td>
<td>0.164</td>
</tr>
<tr>
<td>10-24</td>
<td>0.190</td>
</tr>
<tr>
<td>10-32</td>
<td>0.190</td>
</tr>
<tr>
<td>1/4-20</td>
<td>0.250</td>
</tr>
</tbody>
</table>

## Metric

<table>
<thead>
<tr>
<th>Thread</th>
<th>Major (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M2-0.4</td>
<td>2.0</td>
</tr>
<tr>
<td>M3-0.5</td>
<td>3.0</td>
</tr>
<tr>
<td>M4-0.7</td>
<td>4.0</td>
</tr>
<tr>
<td>M5-0.8</td>
<td>5.0</td>
</tr>
<tr>
<td>M6-1.0</td>
<td>6.0</td>
</tr>
</tbody>
</table>
NUT

WASHER

SPLIT WASHER

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HEX STANDOFFS

MALE - FEMALE

FEMALE - FEMALE
Actuation
Electric Motors

AC
Magnetic Rotor
Coil Stator
Output speed is a sub-multiple of voltage supply frequency

DC Brushed
Coil Rotor
Magnetic Stator
Brushes carry current to the rotor

DC Brushless
Magnetic Rotor
Coil Stator
Similar in construction to AC, but electrically commutated
Requires a position sensor (commonly built in)

Stepper
Toothed Magnetic Rotor
Multi-Coil Stator
Capable of open-loop positioning
Requires a controller
servo motors
Gears

- **spur**
- **helical**
- **crossed helical**

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Gears

bevel

spiral bevel

hypoid

rack & pinion

worm
Gears

Planetary

Toyota Prius “Power Split Device”
SPROCKETS
SPRINGS
Continuously-Variable Transmissions

the Anderson-CVT
RATCHET WHEELS

RATCHET
Sensors
Potentiometer (position)

\[ V_{out} = \frac{R_1}{R_{total}} V_{in} \]
Optical Encoder (position)

Quadrature Encoding

second ring or sensor
90 degree phase shift
edge triggering

$V_{out}$

1
0
Absolute Encoder (position)

unique combination for each position
high resolution requires many sensors
Tachometer

uses back-EMF “generator” effect
adds load
adds another sensor
Differentiation of Position

use existing position sensor
digitized and quantized
usually requires filtering (which adds time delay)
Infinite horizon (fading-memory) filter

\[ \hat{v}_i = \beta \hat{v}_{i-1} + (1 - \beta) v_i \]

Equivalent analog bandwidth

\[ f = \frac{1}{\tau} = \frac{1 - \beta}{\beta} \Delta t \]
Acceleration

Vision

Force / Torque
A1321LUA
Ratiometric Linear Hall-Effect Transducer

VCC = 4.5 - 5.5V
quiescent voltage = 50% of VCC
sensitivity (@ VCC=5.0V) = 5.000 mV/G