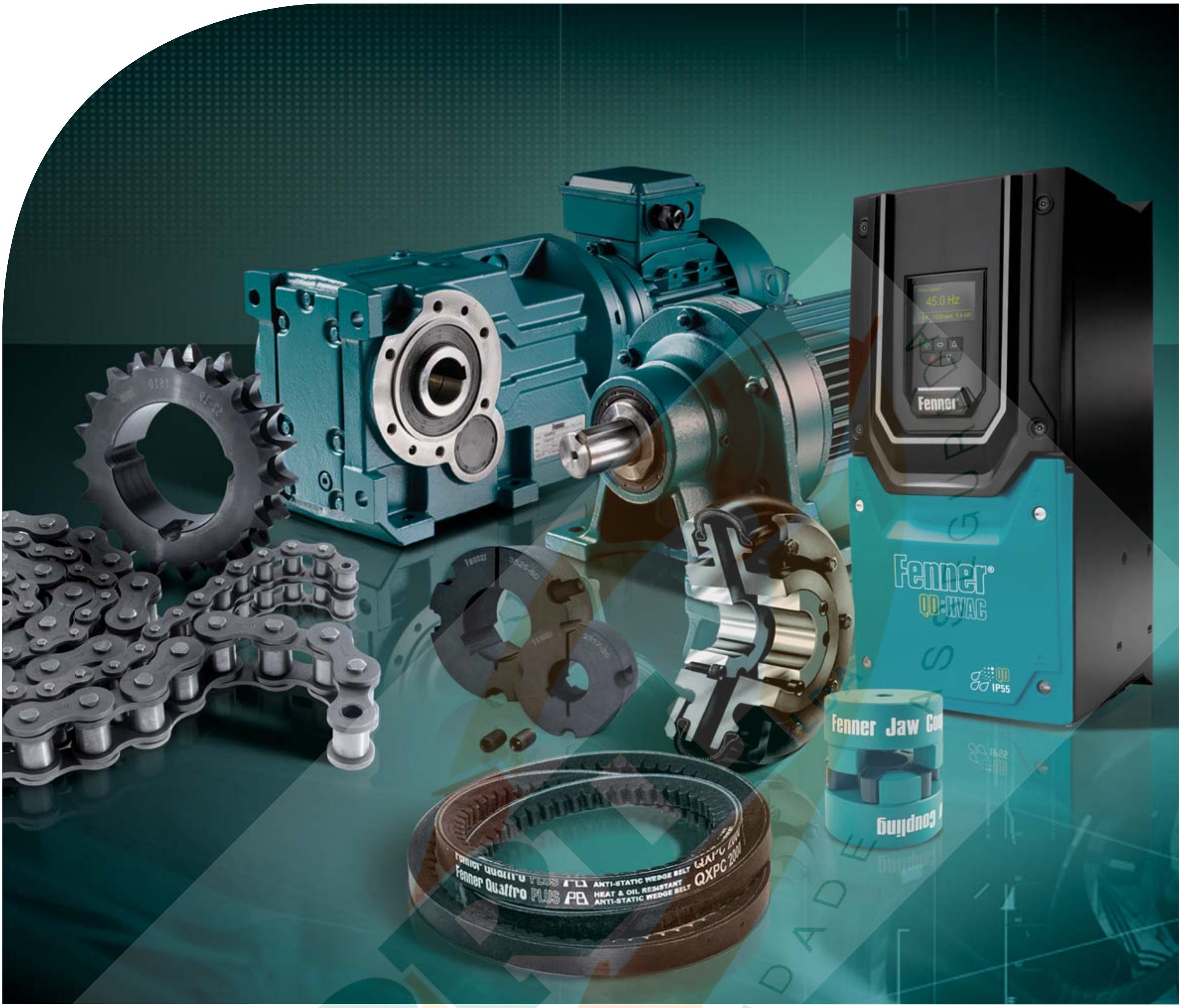


One range, one result

The complete drive solution from initial electrical input through to the final driven machine in one range with one result...

driven performance

Fenner® power transmission products are world renowned for delivering the ultimate combination of rugged construction, reliable & efficient performance and value for money - proven in the harshest environments, guaranteed to perform in yours!

All Fenner power transmission products are manufactured to exacting specifications in line with UK and International standards, and are backed up by a product development programme designed to keep them at the cutting edge.

Fenner®

THE MARK OF ENGINEERING EXCELLENCE

One Range, One Result, One Name

ENGINEERING UNITS, CONVERSIONS & FORMULAE

SI (Systeme Internationale) Basic Units - from which all other units can be derived:

Quantity	Unit	Symbol	Imperial Unit
Length	metre	m	inch
Mass	kilogram	kg	pound
Time	second	s	(same)
Electric current	Ampere	A	(same)
Temperature	Kelvin	K	Fahrenheit

Other units of measurement, and their relationship to basic SI units.

Quantity	Unit	Symbol	Relationship	Imperial Unit
Angle	radian degree	rad °	1 rad = 1m/m 1° = 1 rad x π/180	
Area	square metre	m^2	1 m^2 = 1m.m	square foot square inch
Frequency	Hertz	Hz	1 Hz = 1 s^{-1}	cycle/sec (c/s)
Force	Newton tonne kilogramforce	N t kgf	1 N = 1kg.m/sec^2 1 t = 1000 kgf 1 kgf = 9.81 N	 ton poundforce (lbf)
Pressure	Pascal Bar	Pa bar	1 Pa = 1 N/m^2 1 bar = 10^5 Pa	 lbf/$inch^2$ (psi)
Energy	Joule	J	1 J = 1 N.m	
Power	Watt kilowatt	W kW	1 W = 1 J/s 1 kW = 1000W	horsepower
Electrical Potential Electrical Resistance Electrical Capacity	Volt Ohm Farad	V Ω F	1 V = 1 kg.m^2/A^2.s^3 1 W = 1 V/A 1 F = 1 A.s/V	
Temperature	degree. Celsius	°C	1° C = 1°K	Fahrenheit
Note: the kelvin scale starts at absolute zero i.e. 0°K the Celsius scale starts at 273°K i.e. 0°C (freezing point of water) K and C dgree intervals are the same				
Speed Linear Angular	metre/second radian/second revolution/minute	m/sec rad/s rev/min	 1 rad/s = 1 m/m.s 1 rev/min = π/30 rad/s	mile per hour foot/sec
Torque	Newton metre	Nm	1 Nm = 1 kg.m^2/sec	foot.pound pound.inch
Volume	Cubic metre Litre	m^3 l	1 m^3 = 1m.m.m 1l = 1m^3/1000	cubic inch Imperial Gallon
Acceleration Linear Angular	 metre/second squared radian/second squared	 m/sec^2 rad/sec^2	 1m/sec^2 = 1m/s/s 1 rad/sec^2 = 1m/m.s.s	 ft/sec^2
Inertia	MR^2	kg.m^2	1kg.m^2 = 1 kg.m.m	pound.$inch^2$
Viscosity	centiStoke	cSt	1 cSt = 1mm^2/s	

Some common units are multiples or submultiples of the above.

They use 'preferred' prefixes which indicate multiple or submultiples of basic units and make the resultant unit more relevant to the engineering business.

Prefix	Symbol	Factor
mega	M	x 1,000,000
kilo	k	x 1,000
milli	m	1,000
micro	µ	1,000,000

e.g. the Watt is a small amount of power (an average light bulb consumes 60 Watts) so the kilowatt, i.e. 1000 Watts, is more commonly used in power transmission.

Megawatts i.e. 1,000,000 Watts, are a useful unit of measure for power station capacity.

CONVERSIONS & FORMULAE

CONVERSION FACTORS

Some of the more common Imperial units are mentioned above.
The following table gives a comprehensive range of metric units and factors for their conversion to appropriate Imperial units.

Length

Millimetres x 0.0394 = inches	Inches x 25.4 = millimetres
Metres x 39.37 = inches	Inches x 0.0254 = metres
Metres x 3.281 = feet	Feet x 0.305 = metres
Metres x 1.094 = yards	Yards x 0.914 = metres
Kilometres x 0.6213 = miles	Miles x 1.61 = kilometres

Force

Newtons x 0.225 = lbf	lbf x 4.45 = newtons
kgf x 2.205 = lbf	lbf x 0.454 = kgf
Metric ton x 0.984 = ton (1000kgf) (2240lbf)	Ton x 1.02 = metric ton (2240 lbf) (1000kgf)
kgf x 9.81 = Newtons	Newtons x 0.102 = kgf

Note: kgf = kilogram force and lbf = pounds force

Area

Sq millimetres x 0.0026 = sq inches	Sq inches x 645.2 = sq millimetres
Sq metres x 10.764 = sq feet	Sq feet x 0.093 = sq metres
Sq metres x 1.196 = sq yards	Sq yards x 0.836 = sq metres

Inertia

Kilogram metre squared (kg m^2) x 23.73 = Pound feet squared (lbf ft^2)

Temperature

$°C = \frac{5}{9}(°F - 32)$ $°F = \frac{9}{5}(°C) + 32$

Volume

Cubic metres x 35.317 = cubic feet	Cubic feet x 0.02831 = cubic metres
Cubic metres x 1.308 = cubic yards	Cubic yards x 0.7645 = cubic metres

Fluid Volume & Pressure

Litres x 0.22 = imp. gallons	Imp. gallons x 4.546 = litres
Litres x 0.035 = cubic feet	Cubic feet x 28.32 = litres
Bar x 14.5 = pounds per sq inch (lbf/in2 or psi)	Pounds per sq inch x 0.069 = bar

Torque

Newton metre (Nm) x 0.735	=	Pounds feet (lbf ft)
Newton metre (Nm) x 8.85	=	Pounds inches (lbf in)
Kilogram force metre (kgf m) x 9.81	=	Newton metre (Nm)

Power

Kilowatt (kW) x 1.34 = horse power (hp)

Horse power (hp) x 0.746 = kilowatt (kW)

The German Pferdestarke (PS) and French Cheval-vapeur (CV) are similar to the UK/US horse power.

Pi (π)

The mathematical ratio π (pi) = 3.14159

FORMULAE

Formulae regularly used in power transmission and general engineering.

Power, Torque and Speed

These are the basic parameters of rotational power transmission, related by the following formulae

$$\textbf{Power}\ (kW) = \frac{\textbf{Torque}\ (Nm) \times \textbf{rotational speed}\ (rev/min)}{9550}$$

$$\textbf{Torque}\ (Nm) = \frac{\textbf{Power}\ (kW) \times 9550}{\textbf{Rotational speed}\ (rev/min)}$$

Torque, Inertia and Acceleration

The above power / torque formulae are used for applications at their normal running speed.

If the inertia of an application is known, the higher torque necessary to accelerate the load from rest to running speed can be calculated.

Torque (Nm) = **Inertia** (kg.m^2) **x acceleration** (rad/sec^2)

For linear motion, a similar formula gives the force required to accelerate a mass in a straight line.

Force (N) = **Mass** (kg) **x acceleration** (m/sec^2)

The above formulae can be applied using deceleration, to calculate braking torque or force.

Hydraulic Pumps, Motors & Cylinders

$$\textbf{Shaft Torque}\ (Nm) = \frac{\textbf{Displacement}\ (cm^3/rev) \times \textbf{pressure}\ (bar)}{20\,\pi}$$

Cylinder force (N) = **Pressure** (bar) x **area** (m^2) x **10^5**

Speed Ratio

Speed ratio is a feature of many transmission drives.

Ratio is usually described by a number > 1.0, followed by ":1".

Speed reduction (usually), or increasing, must be specified.

$$\textbf{Ratio} = \frac{\textbf{Faster machine speed}\ (rev/min)}{\textbf{Slower machine speed}\ (rev/min)}$$

E.g. Belt drive from a 1000 rev/min motor to a blower at 500 rev/min has a 2:1 reduction ratio. Same motor driving a fan at 1500 rev/min needs a 1.5:1 increase ratio.

Gearmotor with a 6-pole (960 rev/min) motor, having a 48 rev/min output speed has a 20:1 reduction ratio.

Chain drive using two 23 tooth sprockets has a 1:1 ratio.

Centre Distance Calculation

Belt length, given pulley diameters and centre distance:

$$\textbf{Length}\ (L) = 2C + \frac{(D-d)^2}{4C} + 1{,}57\,(D+d)$$

where

L	=	Pitch length of belt in millimetres.
C	=	Centre distance in millimetres.
D	=	Pitch diam. of large pulley in millimetres.
d	=	Pitch diam. of small pulley in millimetres.

Centre distance, given pulley diameters and belt length:

$$\textbf{Centre Distance}\ (C) = A + \sqrt{A^2 - B}$$ where

$$A = \frac{L}{4} - 0{,}3925\,(D + d) \quad \text{and} \quad B = \frac{(D - d)^2}{8}$$

The above formulae can also be used for chain lengths, using sprocket pitch diameters.

Pulley/Sprocket Pitch Diameters

For pitch diameter of a synchronous belt drive pulley or chain sprocket:

$$\textbf{Pitch dia (mm)} = \frac{\textbf{Chain/belt pitch} \times \textbf{no. of sprocket/pulley teeth}}{\pi}$$

(mm or inch x 25.4)

Indirect Drive End Loads

For vee and wedge belt drives, the following formulae give a good approximation of loads sensed by shafts and bearings.

Static tension

To determine the static tension, Ts, in the belt(s), measure the force, P, required to depress a belt 16 mm per metre of span, by means of a Belt Tension Indicator or use setting forces recommended in the belt installation instructions.

The static tension, Ts, is given by

$Ts = 2(16P) \times B$ (N)

where B = the number of belts
P = Setting force in Newtons, for the belt in question.

Centrifugal tension

The centrifugal tension, Tc, developed in a belt is a function of its weight and the square of its belt speed.

$Tc = M \times S^2$ (N)

The belt speed, S, is given by:

$S = \dfrac{d \times n}{19100}$ (m/s)

where d = pitch diameter of either pulley - mm
n = rotational speed of same pulley - rev/min.
M = mass per unit length for the belt section in question.
See pages 35 to 37 for vee and wedge belt mass values

Dynamic tension

To determine the approximate dynamic tension, T_D, imposed by a drive when running, the centrifugal tension per span, Tc, must be subtracted from the static tension, Ts, hence:

$T_D = 2(16P - Tc) \times B$ (N)

Synchronous Belt Drives

A different rationale applies – consult your Authorised Distributor.

Chain Drives

Approximate end loads can be calculated from the torque being transmitted:

$$\textbf{End load}\ (N) = \frac{\textbf{Torque}\ (Nm)}{\textbf{Sprocket pitch radius}\ (m)\ (= \tfrac{1}{2}\ \textbf{pitch diameter})}$$

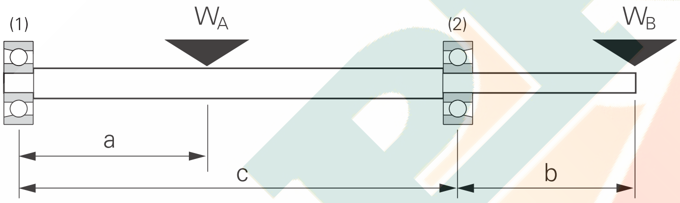
Note that this calculation can be done on either sprocket.

Low torque/small radius (high speed shaft) or high torque/large radius (low speed shaft), give the same answer.

Bearing Loads

The radial load on simple bearing arrangements due to belt/chain drive end loads, gear separating forces, the weight of pulleys or motor rotors etc. can be calculated using "moments" as shown below for two such loads applied to an arrangement of two bearings supporting a horizontal shaft.

Bearing reactions are determined by taking moments about each support.



Taking moments about bearing (2)

$$\textbf{Radial load on (1)} = \left(W_A \cdot \frac{(c-a)}{c} - W_B \cdot \frac{b}{c} \right)$$

Taking moments about bearing (1)

$$\textbf{Radial load on (2)} = \left(W_A \cdot \frac{a}{c} + W_B \cdot \frac{(b-c)}{c} \right)$$

The units of radial bearing load will be the same as for the applied loads.

In the above example both applied loads act vertically downward. Bearing reactions will also be vertical but may be upward or downward, depending on the relative values of the applied loads.

Note: The above is a simple example. Comprehensive calculations involving many other factors must be carried out to determine bearing life

Electrical Engineering and Motors

Ohm's Law gives the relationship between Voltage (V), current (A) and resistance (Ω) for "simple" electric circuits (direct current, DC or 'resistive' circuits)

Voltage (Volts) **= current** (Amps) **x resistance** (Ω)

Electrical power is also related to voltage and current, but as all machinery is less than 100% efficient, an efficiency, designated η must be applied to calculations

Power (Watts) **= voltage** (Volts) **x current** (Amps) **x** η (effy.)

AC, or alternating current, electric motors have relatively complex electric circuits.

The above formulae apply, but need modifying by a 'power factor',

Power Factor = cosine of the circuit phase angle, designated **cos** σ

For single phase AC electric motors:

Power (Watts)
= voltage (Volts) **x current** (Amps) **x cos** σ (PF) **x** η (effy.)

In 3 phase AC electric motors, the applied voltage reaches the windings at a different value depending on whether the supply is connected in star (Y) or delta (Δ) configuration, hence 3Φ electric motor power is usually equal to the above x $\sqrt{3}$

AC electric motor speed is a function of supply frequency (Hz) and the number of pairs of poles, in the stator winding.

$$\textbf{'Synchronous' speed (rev/min)} = \frac{\textbf{supply frequency}\ (Hz) \times \textbf{60}}{\textbf{pairs of poles}}$$

Most everyday electric motors are 'asynchronous', meaning they 'slip' below synchronous speed, to run at around 95-97% synchronous speed when on load.

e.g. A 6-pole (= 3 pairs), motor connected to the European standard 50 Hz supply will run at:

$$\frac{\textbf{50}\ (Hz) \times \textbf{60} \times \textbf{96\%}\ (\text{average slip})}{\textbf{3}\ (\text{pairs of poles})} = \textbf{960}\ \text{rev/min}$$