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Design Guide:
Steps to Designing a Miniature Belt and Pulley Drive System

BENEFITS OF BELT DRIVES:

- Little or no maintenance
- Lower cost than chain drives
- Quiet
- Efficient

Today's timing belts are reinforced with various tensile cords, such as polyester, fiberglass or aramid, making them stronger than ever.

TERMS USED WHEN DESCRIBING BELTS AND PULLEYS:

Pitch Diameter: The drive pulley diameter
Center Distance: Distance between two pulleys' centers
Pitch: Distance measured along the pitch line of the timing belt from one tooth center to the adjacent tooth center.
Belt Length: Total length of the belt if cut in half and laid flat.

› Step 1.
Determine the peak torque for your drive. This is usually the motor starting torque, but may also be any unusual momentary or shock load which may occur during normal operation.

› Step 2.
Determine the largest pulley diameters that can be utilized, considering the space limitations and drive ratio of your system. This helps to increase the torque capacity of the drive and extend the service life of the belt.

› Step 3.
Calculate the teeth in mesh (*T.I.M.*) using **Formula 5** in **Table 1**. Consult **Table 2** for the teeth in mesh factor. Divide the peak torque (from **Step 1**) by the *T.I.M.* factor to determine the design torque by using **Formula 7** in **Table 1**.

› Step 4.
Calculate the belt pitch length based on the design center distance of your drive using **Formula 2** in **Table 1**.

› Step 5.
Divide the belt pitch length by the tooth pitch selected and round the result to the nearest whole number. This is the number of teeth on the belt for your application. Adjust the nominal center distance of your drive design to match the belt using **Formula 1** in **Table 1**.

› Step 6.
Using **Formula 6** in **Table 1**, calculate the effective tension (*Te*) on the drive using the pitch radius and design torque of the smallest loaded pulley in the system.

› Step 7.
(a) Select the strength factor for your application from **Table 3**. Divide the effective tension from **Step 6** by the strength factor to determine the required break strength for the belt design. **(b)** Multiply by 2 to represent a double span break. Consult **Table 4** to determine the required reinforcement type and belt width. The value listed in the table must be greater than the design break strength.

› Step 8.
Using the torque capacity graph, select a belt width that is capable of handling the design torque with the selected pulley size. **Note:** This belt width may be different from the width selected in **Step 7**. The belt width required for the system will be the wider of the two.

› Step 9.
Special Note: Limiting torque values must be multiplied by 0.45 for fiberglass reinforced belts.

IMPORTANT NOTE
Always incorporate a means of adjusting center distance to allow for pitch length manufacturing tolerance.

› ENGINEERING FORMULAS • Table 1

No.	Unknown	Where	Formula
1	Center Distance (using unequal size pulleys for driveR and driveN) (approximation formula)	CD = center distance mm (in.) PL = belt pitch length mm (in.) D = large pulley pitch dia. mm (in.) d = small pulley pitch dia. mm (in.)	$CD = \frac{b + \sqrt{b^2 - [8 \times (D - d)^2]}}{8}$ $b = (2 \times PL) - [\pi \times (D + d)]$
2	Belt Pitch Length (approximation formula)	PL = belt pitch length mm (in.) CD = center distance mm (in.) D = large pulley pitch dia. mm (in.) d = small pulley pitch dia. mm (in.)	$PL = (2 \times CD) + [1.57 \times (D + d)] + \frac{(D - d)^2}{(4 \times CD)}$
3	Number of Teeth on Belt	N_B = number of teeth on belt PL = belt pitch length mm (in.) P = tooth pitch mm (in.)	$N_B = \frac{PL}{P}$
4	Belt Speed	V = belt speed mm/sec. (in./sec.) D_r = pitch diameter of driver pulley mm (in.) rpm = speed of driver 1/min.	$V = \frac{D_R \times \pi \times rpm}{60}$
5	Teeth in Mesh	$T.I.M.$ = teeth in mesh N_d = number of teeth on small pulley CD = center distance mm (in.) D = large pulley pitch dia. mm (in.) d = small pulley pitch dia. mm (in.)	$T.I.M. = \left[0.5 - \left(\frac{(D - d)}{(6 \times CD)}\right)\right] N_d$
6	Effective Tension	Te = effective tension N (lbf) T_d = design torque N • mm (lbf • in.) r = pulley radius mm (in.)	$Te = \frac{T_d}{r}$
7	Design Torque	T_d = design torque N • mm (lbf • in.) T_{pk} = peak torque N • mm (lbf • in.)	$T_d = \frac{T_{pk}}{T.I.M.\ factor}$

› ENGINEERING FORMULAS • Table 2 - Teeth in Mesh Factor

Teeth in Mesh on Drive	T.I.M. Factor
6 or more	1.0
5	0.8
4	0.6
3	0.4
2	0.2

› ENGINEERING FORMULAS • Table 3 - Strength Factor

Drive Description	Examples	Strength Factor
Critical Positioning Tolerance and Accuracy	Pen Plotter, Printers and Pick and Place Robots	0.02
High Positioning Tolerance and Accuracy	Medical Equipment, Paper Handling and Security Cameras	0.10
Low Positioning Tolerance and Accuracy	Home Appliances, Currency Equipment and Light Load Unidirectional Drives	0.20

› ENGINEERING FORMULAS • Table 4 - Breaking Strength

Belt Width	Kevlar N (lbf)	Fiberglass N (lbf)
3 mm	905 (205)	485 (110)
6 mm	1865 (420)	995 (225)