Printer: Belt Tension

There is very little good information on what correct belt tension is, and virtually nothing on empirically setting belt tension.

Gates, the creator of the GT2 belt, recommends a tension of 6 to 8 pounds of tension when using a GT2 belt for registration like in a printer. A NEMA 17 stepper motor can handle 6.7 pounds (30N) of radial force centered at 17mm from the motor's face (something to bear in mind if you're using dampers).

Because the belt wraps around the motor's shaft, the radial force on the stepper is double the belt tension, at the minimum of 6 pounds tension recommended by Gates, there's 12 pounds of radial force on the shaft. However, the allowed radial force increases linearly inversely proportional to the pulley center to motor's face distance. For example, if the pulley is centered at 8.5mm from the motor's face (half of 17mm), then the maximum allowed tension doubles to 13.4 pounds.

NOTE: Moon's bearing life charts indicate the radial limit can go as high as 8 pounds, though with reduced bearing life.

Given this, we want a belt tension of 6 pounds with the pulley centered 9.5mm or less from the motor's face. If the pulley center is further out, then the belt must either be tensioned lower or reduced bearing life must be accepted.

NOTE: The Ender 3 pulleys are centered 10mm from the motor's face. In practice I've found tensioning the belts at 6 pounds doesn't appreciably decrease the stepper bearing life

From the Moons' catalog (see link below).

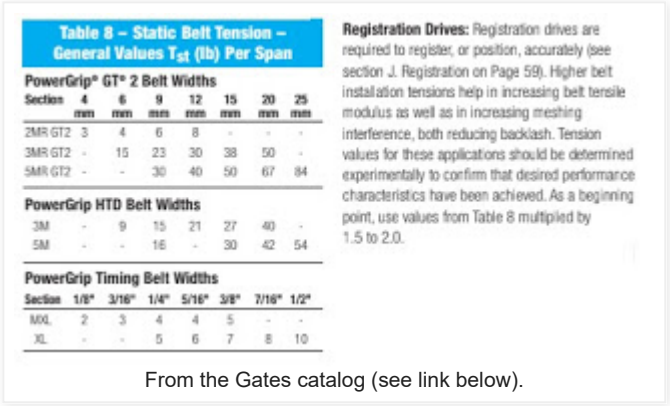


Table 8 – Static Belt Tension – General Values T_{st} (lb) Per Span

PowerGrip® GT® 2 Belt Widths

Section	4 mm	6 mm	9 mm	12 mm	15 mm	20 mm	25 mm
2MR GT2	3	4	6	8	-	-	-
3MR GT2	-	15	23	30	38	50	-
5MR GT2	-	-	30	40	50	67	84

PowerGrip HTD Belt Widths

3M	-	9	15	21	27	40	-
5M	-	-	16	-	30	42	54

PowerGrip Timing Belt Widths

Section	1/8"	3/16"	1/4"	5/16"	3/8"	7/16"	1/2"
MXL	2	3	4	4	5	-	-
XL	-	-	5	6	7	8	10

Registration Drives: Registration drives are required to register, or position, accurately (see section J. Registration on Page 59). Higher belt installation tensions help in increasing belt tensile modulus as well as in increasing meshing interference, both reducing backlash. Tension values for these applications should be determined experimentally to confirm that desired performance characteristics have been achieved. As a beginning point, use values from Table 8 multiplied by 1.5 to 2.0.

From the Gates catalog (see link below).

To actually measure the tension the easiest and most precise way is via its vibration frequency. To calculate our target frequency we use Mersenne's equation 22:

$$f_0 = \frac{1}{2L}\sqrt{\frac{F}{\mu}}$$

Where *f* is the frequency, *L* is the length of the belt between contact points in meters, *μ* is the belt density in kilograms per meter, and *F* is the tension in Newtons (1 pound equals 4.44822 N). The density of a 6mm GT2 belt is 0.0083 kg/m (both stock and genuine Gates).

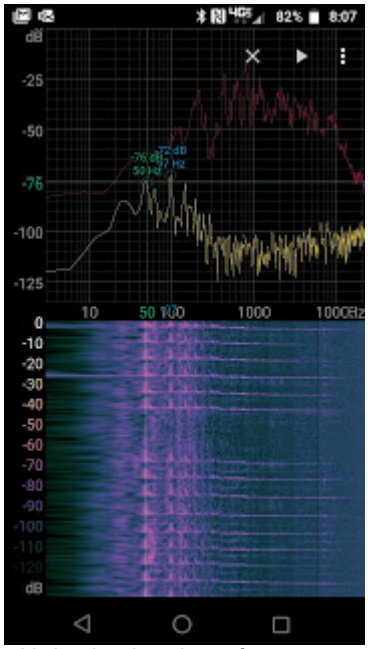
Simplified, for 6 pounds force with a GT2 belt, the formula is:

Hertz = 28.531 / meters

On the Ender 3 specifically, with the hotend carriage against the limit switch, the belt between the carriage and idler is 0.302 meters (302mm) long, so the target frequency is 94 Hz.

Again on the Ender 3, with the bed pushed all the way back, the exposed belt is 0.253 meters (253mm) long, so the target frequency is 112 Hz.

I found the best way to measure the frequency is the Spectroid app for Android. It produces a waterfall display of the frequency, so it's easy to see what the belt frequency actually is. Pluck the belt like a guitar string and look for the biggest spike. Just tap the waterfall display and it'll give you the frequency selected. The belt will naturally have multiple harmonics, but those will be significantly smaller on the waterfall display and can be ignored. From there just adjust the belt tension until you hit the target frequency.



Spectroid showing the primary frequency at 50 Hz.

GT2 design manual

NEMA stepper specs