User inputs that affect the motor torque required to drive the OSM.

Enter the desired cycle time. This is the time to move the turret from one position to an adjacent position. The maximum number of cycles for the longest move is 8 cycles.

$t_{cycle} := 3.75sec$ Desired cycle time

Select a desired compression spring for the detent preload force.

The following spring is assumed: Associated Spring Part No. C0360-035-2500-S.

$L_{free} := 25mm$ Free Length of spring $F_{max\_comp\_spr} := 15.12 \cdot 2.97N = 44.906\,N$

$k_{spr} := 2.97 \frac{N}{mm}$

Select a desired preload force for seating the detent into the vee-groove.

$F_{pre} := 15N$ Desired initial preload of compression spring **when the detent is seated** into the vee-groove.

The following two stepper motors are considered for driving the turret.

Motor Parameters for Phytron Steppers

$T_{vss42\_max} := 92N \cdot mm$ VSS42 Stepper motor drive (stall) torque

$T_{vss32\_max} := 32N \cdot mm$ VSS 32.200.1.2-VGPL 32 4-UHVC stepper motor (with 4:1 reduction gear box (stall) torque)

$Ratio_{mot\_gearbox} := 1$

Select a desired gear reduction ratio between the motor and the crank of the geneva mechanism (default ratio is 3:1).

$Ratio_{mitergear} := 3$ Miter gear reduction ratio between stepper and crank

Define crank shaft bearing friction (torque).

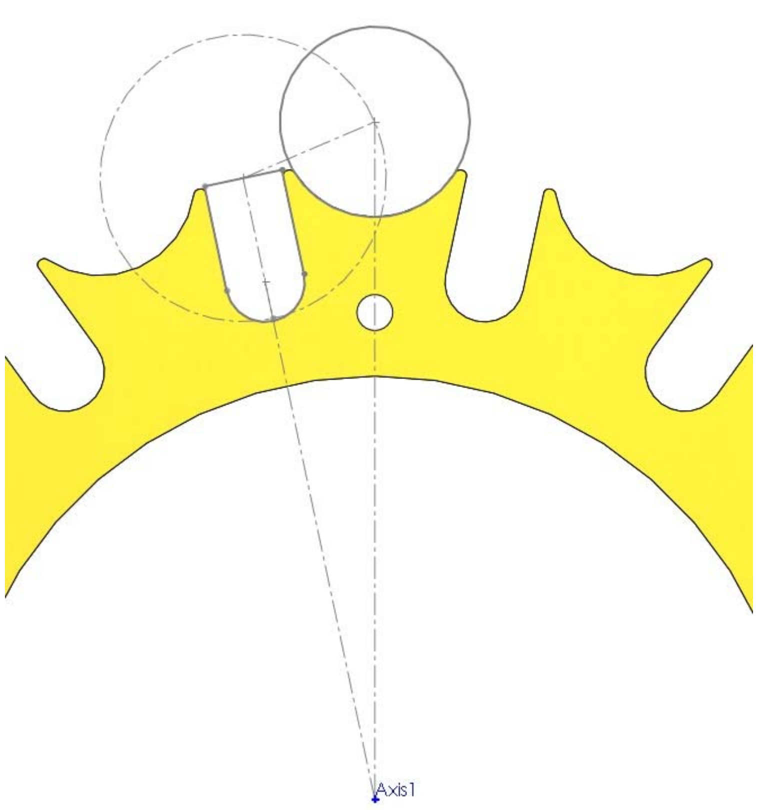
$T_{crank\_friction} := 1N \cdot mm$

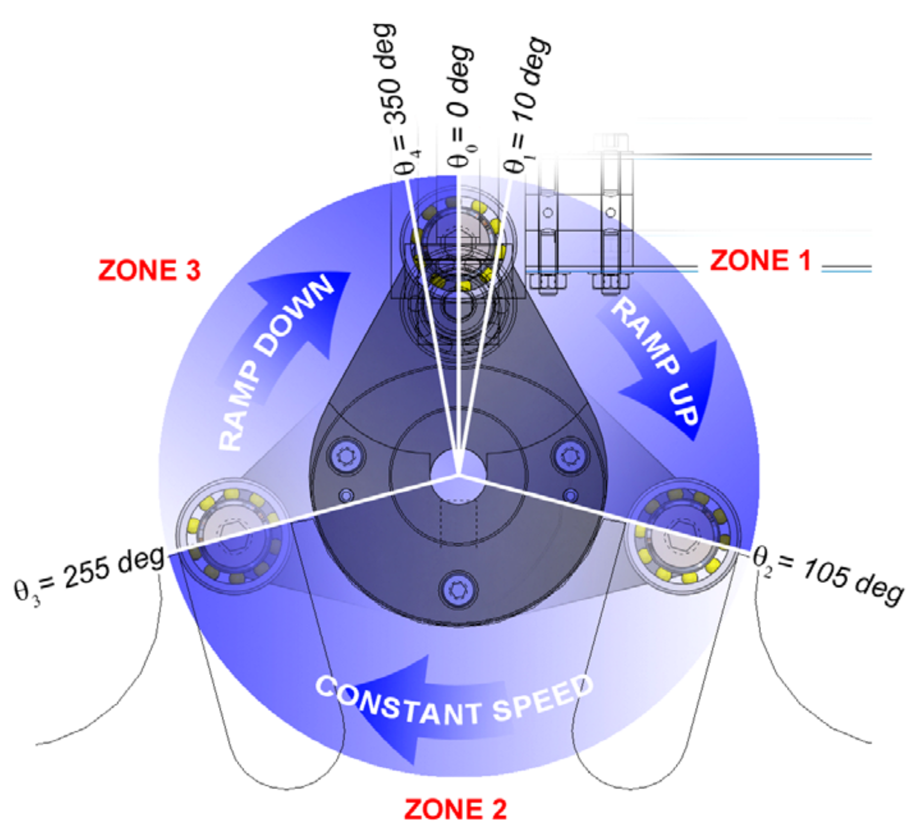
Define motor drive shaft bearing friction (torque).

$T_{fric\_shaft1} := T_{crank\_friction}$

Define OSM hub bearing friction (torque).

$T_{trt\_fric} := 10N \cdot mm$





Part 1. Cam Move Profile Calculations

This calculations assumes a trapezoidal move profile for the Geneva crank. The crank starts at θ_1= 0deg, which corrseponds to the detent mechanism fully seated in the vee-groove. The crank acclerates from θ_1 to θ_2 with constant acceleration. From θ_2 to θ_3, the angular velocity is constant. From θ_3 to θ_4, the crank decelerates back to a stop, completing one cycle of the crank.

The geometry of the Geneva wheel will determine at which angle the cam drive will engage the geneva:

$R_{CG} := 50mm$ Radius of the cam drive axis to the axis of the Geneva wheel

$R_G := 46.5mm$ Radius of the Geneva wheel

$N_S := 10$ Number of discrete positions

$$\theta_{engage} := \frac{\pi}{2} + atan\left[\frac{\left(R_{CG} - R_G \cdot cos\left(\frac{\pi}{N_S}\right)\right)}{R_G \cdot sin\left(\frac{\pi}{N_S}\right)}\right] = 111.898 \cdot deg$$ Angle at which the drive engages the geneva

$$R_{CD} := \sqrt{\left(R_{CG} - R_G \cdot cos\left(\frac{\pi}{N_S}\right)\right)^2 + \left(R_G \cdot sin\left(\frac{\pi}{N_S}\right)\right)^2} = 15.487 \cdot mm$$ Distance from the cam axis to the drive bearing axis

$\theta_0 := 0deg$ Starting position of the crank, which corresponds to the detent mechanism seated in the vee-groove.

$\theta_1 := 10deg$ Cam angle when follower begins to lift detent off of vee-groove.

$\theta_2 := \theta_{engage} = 111.898 \cdot deg$ Position of crank when the detent mechanism completely clears the vee-groove. The crank accelerates to full speed from θ_1 to this position and begin to engage with the geneva wheel to begin cycling the turret to the next position.

$\theta_3 := 360deg - \theta_2 = 248.102 \cdot deg$ Position of crank when the geneva has completed a move of the turret to the next position. The crank rotates at constant speed from this position to θ_4.

$\theta_4 := 360deg - \theta_1 = 350 \cdot deg$ Cam angle when follower finishes seating the detent onto the vee-groove.

$\theta_5 := 360deg$ Ending position of the crank, which corresponds to the detent mechanism seated in the vee-groove.

$\theta := \theta_0, .1 \cdot deg .. \theta_5$ Define range for crank angle.

Calculate the corresponding times for the angular positions above.

$$\omega_{crank\_max} := \frac{1}{t_{cycle}}\left(2\theta_5 - \theta_3 + \theta_2\right) = 25.947 \cdot \frac{rev}{min}$$ Calculated maximum crank velocity for the desired cycle time

$$t_2 := 2 \cdot \frac{(\theta_2)}{\omega_{crank\_max}} = 1.438\,s$$ Calculated time to get to the θ_2 position.

$$t_1 := \sqrt{\frac{2t_2 \cdot \theta_1}{\omega_{crank\_max}}} = 0.43\,s$$

$$t_3 := t_2 + \frac{(\theta_3 - \theta_2)}{\omega_{crank\_max}} = 2.312\,s$$ Calculated time to get to the θ_3 position.

$$t_5 := t_3 + 2 \cdot \left(\frac{\theta_5 - \theta_3}{\omega_{crank\_max}}\right) = 3.75\,s$$ Calculated time to get to the θ_5 position.

$$t_4 := t_5 - t_1 = 3.32\,s$$

Calculate angular position of crank as a function of time.

$t := 0s, .01s .. t_5$ Define time range

$$\theta_x(t) := if\left[t < t_2, \frac{\omega_{crank\_max}}{2t_2} \cdot t^2, \frac{\omega_{crank\_max}}{2} \cdot t_2 + \omega_{crank\_max} \cdot (t - t_2)\right]$$

$$\theta_{crank}(t) := if\left[t < t_3, \theta_x(t), \frac{\omega_{crank\_max}}{t_5 - t_3} \cdot \left(t_5 \cdot t - \frac{1}{2} \cdot t^2\right) + \theta_5 - \frac{\omega_{crank\_max}}{t_5 - t_3} \cdot \frac{t_5^2}{2}\right]$$

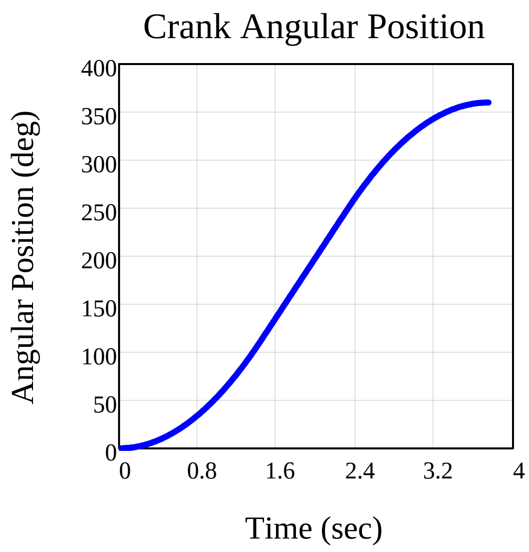
Calculate angular velocity of crank as a function of time.

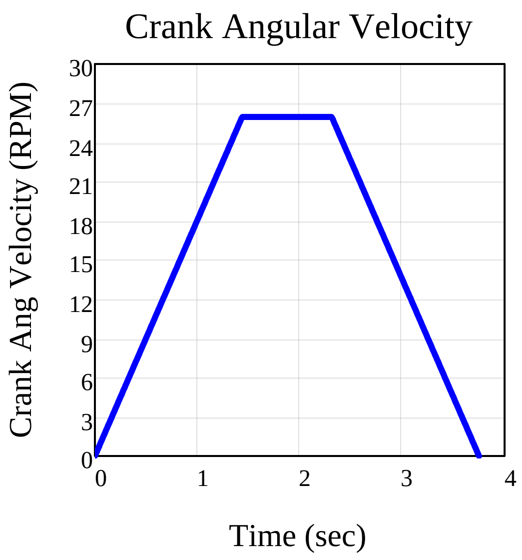
$$\omega_t(t) := if\left[t < t_2, \omega_{crank\_max} \cdot \frac{t}{(t_2)}, \omega_{crank\_max}\right]$$

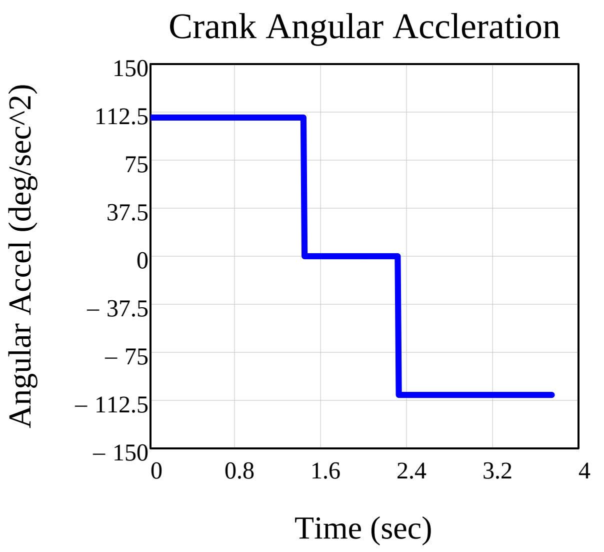
$$\omega_{crank}(t) := if\left[t < t_3, \omega_t(t), \omega_{crank\_max} \cdot \frac{(t_5 - t)}{(t_5 - t_3)}\right]$$

Calculate angular acceleration of crank as a function of time.

$\alpha_{crank}(t) := \frac{d}{dt}\omega_{crank}(t)$ Crank angular acceleration.

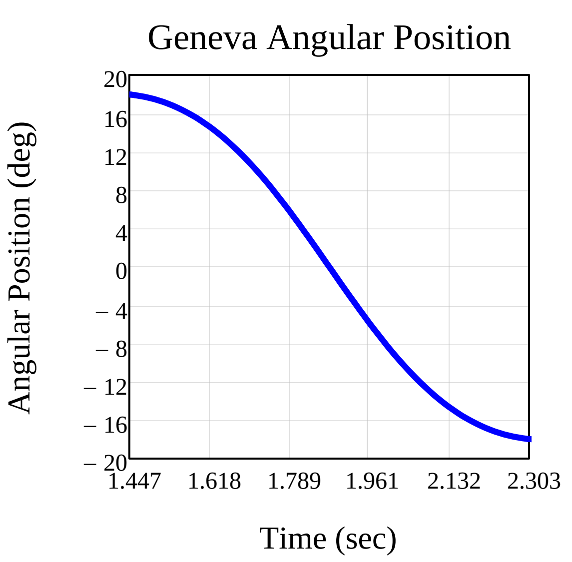






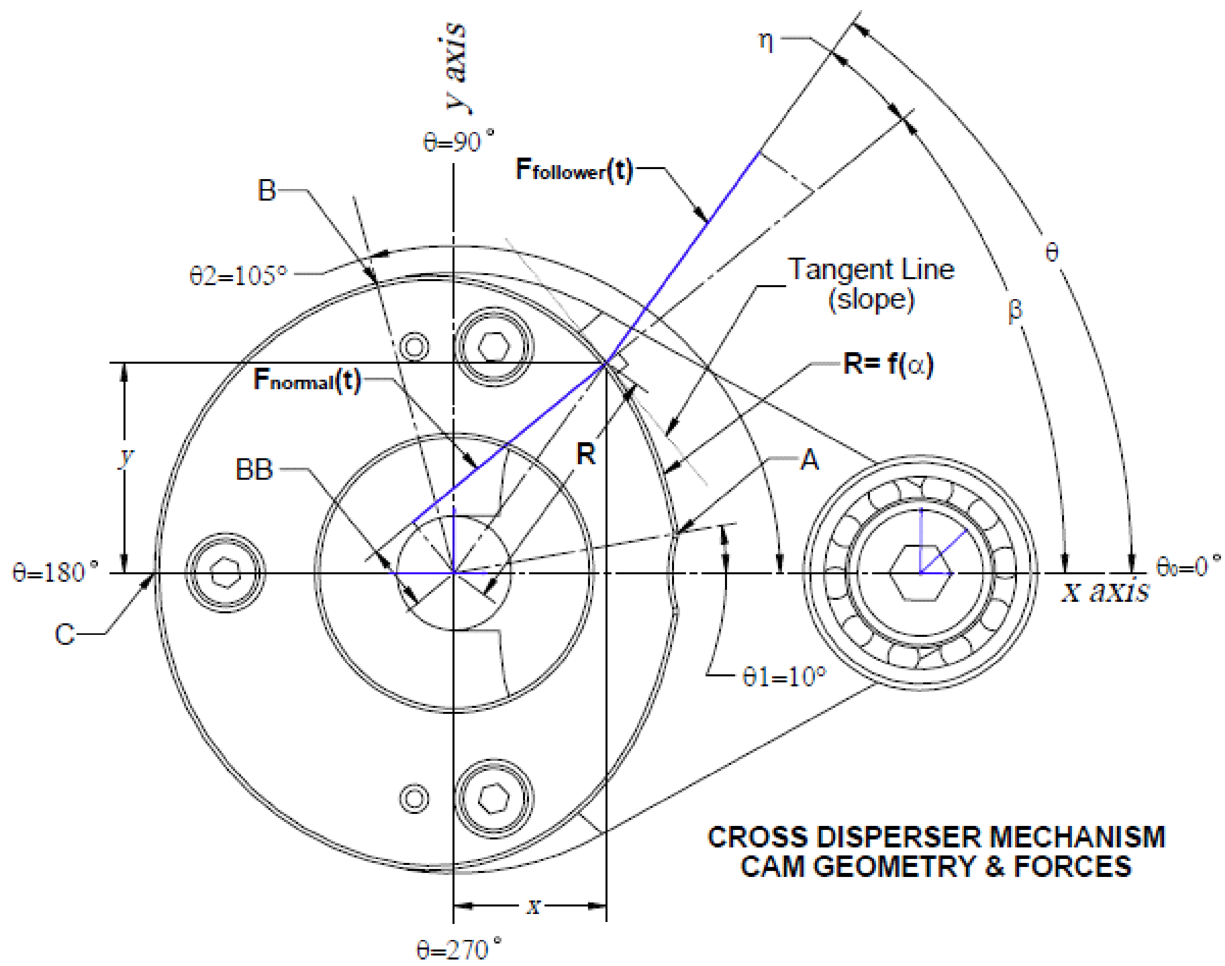
Angle of the geneva in function of the angle of the cam:

$$\gamma_{geneva}(t) := \operatorname{atan}\left(\frac{R_{CD}\cdot\cos\left(\theta_{crank}(t)-\frac{\pi}{2}\right)}{R_{CG}-R_{CD}\cdot\sin\left(\theta_{crank}(t)-\frac{\pi}{2}\right)}\right)$$



t = (s)	$\theta_{crank}(t)$ = (·deg)	$\gamma_{geneva}(t)$ = (·deg)
0.000000	0.000000	0.000000
0.010000	$5.414736\cdot10^{-3}$	$1.280509\cdot10^{-3}$
0.020000	0.021659	$5.122035\cdot10^{-3}$
0.030000	0.048733	0.011525
0.040000	0.086636	0.020488
0.050000	0.135368	0.032013
0.060000	0.194930	0.046098
0.070000	0.265322	0.062745
0.080000	0.346543	0.081952
0.090000	0.438594	0.103721
0.100000	0.541474	0.128050
0.110000	0.655183	0.154940
0.120000	0.779722	0.184391
0.130000	0.915090	0.216402
0.140000	1.061288	0.250974
...	...	...

Cam Follower Path Calculations



This calculation uses a sinusoidal cam follower path for a smooth transition between the seated to unseated positions of the detent mechanism.

$Lift := 7mm$	Cam lift (distance from detent fully seated to fully disengaged).
$R_2 := 15 \cdot mm$	Radius of cam when detent is fully disengaged.
$R_1 := R_2 - Lift$	Radius of cam when detent is seated.

Define cam radius equation for three segments of cam from 0 deg to θ_2, & θ_2 to 180 deg.

$$R_{zone1}(\theta) := if\left[\theta < \theta_1, R_1, R_1 + \left(\frac{R_2 - R_1}{2}\right)\cdot\left[1 + \sin\left[\left(\frac{180deg}{\theta_2 - \theta_1}\right)\cdot\left(\theta - \theta_1\right) - 90deg\right]\right]\right]$$

Radius of cam path in zone 1.

$$R_{zone12}(\theta) := if\left(\theta < \theta_2, R_{zone1}(\theta), R_2\right)$$

Radius of cam path in zones 1 & 2.

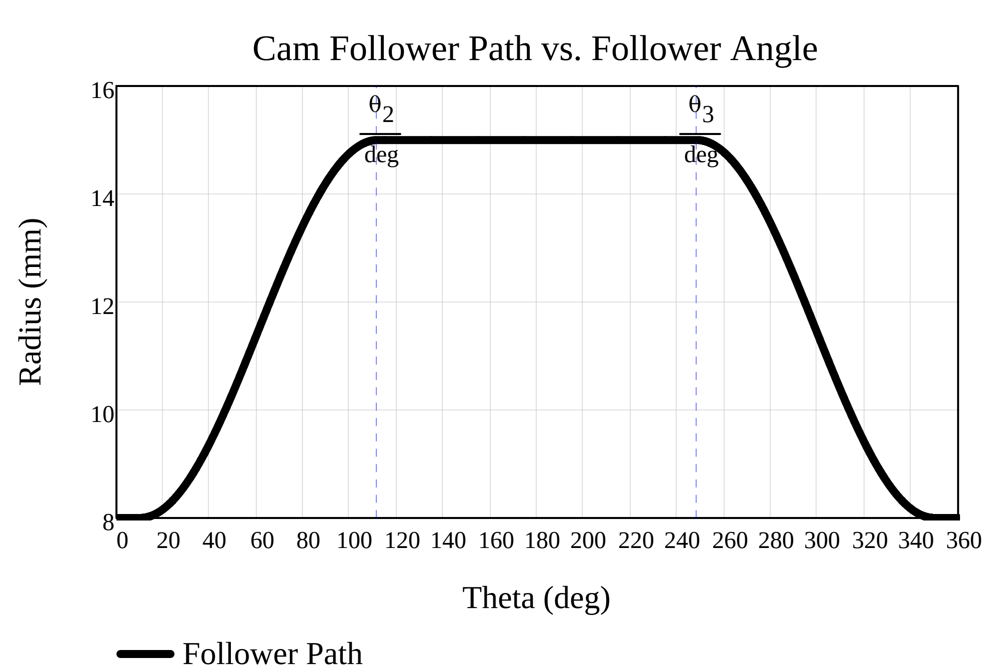
$$R_{zone123}(\theta) := if\left[\theta < \theta_3, R_{zone12}(\theta), R_1 + \left(\frac{R_2 - R_1}{2}\right)\cdot\left[1 + \sin\left[\left(\frac{180deg}{\theta_4 - \theta_3}\right)\cdot\left(\theta - \theta_3\right) + 90deg\right]\right]\right]$$

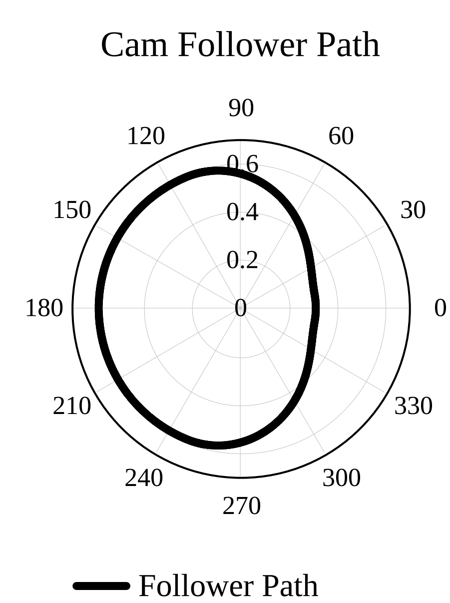
Radius of cam path in zones 1, 2 & 3.

$$R_{zone1234}(\theta) := if\left(\theta < \theta_4, R_{zone123}(\theta), R_1\right)$$

Radius of cam path in zones 1, 2, 3 & 4.

$$R_{cam}(\theta) := R_{zone1234}(\theta)$$



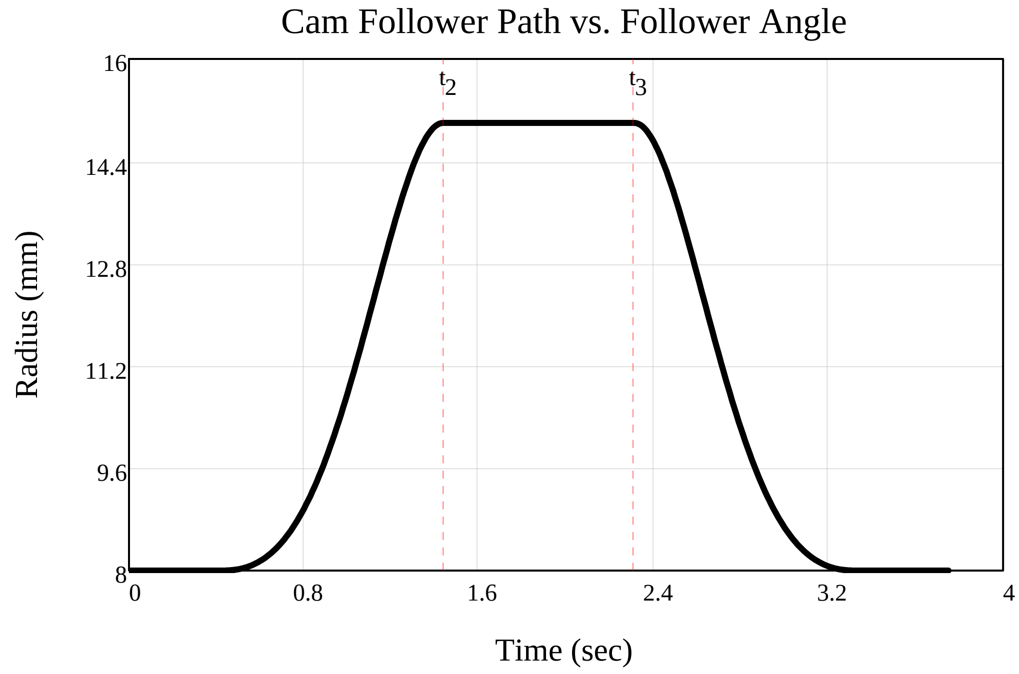


$R_{z1}(t) := \text{if}\left[t < t_1, R_1, R_1 + \left(\frac{R_2 - R_1}{2}\right)\cdot\left[1 + \sin\left[\left(\frac{180\text{deg}}{\theta_2 - \theta_1}\right)\cdot\left(\theta_{crank}(t) - \theta_1\right) - 90\text{deg}\right]\right]\right]$ Radius of cam path in zone 1.

$R_{z12}(t) := \text{if}\left(t < t_2, R_{z1}(t), R_2\right)$ Radius of cam path in zones 1 & 2.

$R_{z123}(t) := \text{if}\left[t < t_3, R_{z12}(t), R_1 + \left(\frac{R_2 - R_1}{2}\right)\cdot\left[1 + \sin\left[\left(\frac{180\text{deg}}{\theta_4 - \theta_3}\right)\cdot\left(\theta_{crank}(t) - \theta_3\right) + 90\text{deg}\right]\right]\right]$ Radius of cam path in zones 1, 2 & 3.

$R_{z1234}(t) := \text{if}\left(t < t_4, R_{z123}(t), R_1\right)$ $R_{cm}(t) := R_{z1234}(t)$ Radius of cam path in zones 1, 2, 3 & 4.



Convert cam follower path to cartesian coordinates

$x(\theta) := R_{cam}(\theta)\cdot\cos(\theta)$ x coordinate

$y(\theta) := R_{cam}(\theta)\cdot\sin(\theta)$ y coordinate

$x_t(t) := R_{cam}\left(\theta_{crank}(t)\right)\cdot\cos\left(\theta_{crank}(t)\right)$ x coordinate

$y_t(t) := R_{cam}\left(\theta_{crank}(t)\right)\cdot\sin\left(\theta_{crank}(t)\right)$ y coordinate

$R_{cam}(\theta) =$ ·in

0.314961
0.314961
0.314961
0.314961
0.314961
...

$x(\theta) =$ ·in

0.314961
0.31496
0.314959
0.314956
0.314953
...

$y(\theta) =$ ·in

0
$5.497097\cdot10^{-4}$
$1.099418\cdot10^{-3}$
$1.649122\cdot10^{-3}$
$2.198822\cdot10^{-3}$
...

Calculate angle beta. See figure of cam geometry above.

$\beta(\theta) := \text{if}\left[\left(\theta < \theta_2\right), 90\text{deg} + \text{atan}\left(\frac{\frac{d}{d\theta}y(\theta)}{\frac{d}{d\theta}x(\theta)}\right), \theta\right]$ $\beta_{1t}(t) := \text{if}\left[\left(t < t_2\right), 90\text{deg} + \text{atan}\left(\frac{\frac{d}{dt}y_t(t)}{\frac{d}{dt}x_t(t)}\right), \theta_{crank}(t)\right]$ $\beta_t(t) := \text{if}\left[\left(t < t_3\right), \beta_{1t}(t), 270\text{deg} + \text{atan}\left(\frac{\frac{d}{dt}y_t(t)}{\frac{d}{dt}x_t(t)}\right)\right]$

Calculate angle η.

$\eta(\theta) := \theta - \beta(\theta)$ $\eta_t(t) := \theta_{crank}(t) - \beta_t(t)$

Calculate moment arm BB

$BB(\theta) := R_{cam}(\theta)\cdot\sin(\eta(\theta))$ $BB_t(t) := R_{cm}(t)\sin\left(\eta_t(t)\right)$ Moment arm length.

Motor & Drive Inertias

$I_{vss32rotor} := 1000\text{gm}\cdot\text{mm}^2$ $I_{shaft1} := 2218\text{gm}\cdot\text{mm}^2$ $I_{crank} := 8763\text{gm}\cdot\text{mm}^2$ $I_{ftw} := 1769112\text{gm}\cdot\text{mm}^2$

$I_{mot\_gearbox} := 0$

Calculate loads on crank in Zone 1 & Zone 3.
(Cam angle from 0 degrees to θ_2 and θ_3 to θ_5).

The crank is subjected to the following loads in zones 1 & 3.
1. Flex Pivot loads from detent mechanism.
2. Preload force from detent mechanism compression spring.
3. Inertial forces caused by accelerating mass of detent mechansim when crank is moving.
4. Inertial force (torque) on crank shaft from accelerating crank (I x α).
5. Frictional forces (torque) from bearings.

1. Calculate Flex Pivot Load.

$L_{arm} := 100.45085\text{mm}$

$\alpha_{detent}(t) := \text{asin}\left[\frac{(R_{cm}(t) - R_1)}{L_{arm}}\right]$ $\quad k_{fp} := 0.0286\text{in}\frac{\text{lbf}}{\text{deg}}$

$F_{fp\_at\_cam}(t) := k_{fp}\cdot\frac{\alpha_{detent}(t)}{L_{arm}}$ Component of detent spring force provided by the parallel spring flexure.

2. Calculate detent mechanism preload compression spring forces.

$L_{arm\_at\_detent} := 60\text{mm}$

$L_{arm\_at\_spring} := 48\text{mm}$

$L_{preload} := L_{free} - \frac{F_{pre}\cdot\frac{L_{arm\_at\_detent}}{L_{arm\_at\_spring}}}{k_{spr}} = 18.687\cdot\text{mm}$ Length at initial preload (seated in vee-groove).

$L_{maxcomp} := L_{preload} - \text{Lift}\cdot\frac{L_{arm\_at\_spring}}{L_{arm}} = 15.342\cdot\text{mm}$ Length at max compression (unseated)

$F_{comp}(t) := F_{pre}\cdot\frac{L_{arm\_at\_detent}}{L_{arm}} + (k_{spr})\cdot(R_{cm}(t) - R_1)\cdot\frac{L_{arm\_at\_spring}}{L_{arm}}$ Component of detent spring force provided by the compression spring.

3. Calculate the inertial forces caused by accelerating mass of detent mechansim when crank is moving.

$v_{detent}(t) := \left(\frac{d}{dt}R_{cm}(t)\right)$ Linear velocity of detent arm when climbing the cam.

$a_{detent}(t) := \left(\frac{d^2}{dt^2}R_{cm}(t)\right)$ Linear acceleration of detent arm when climbing the cam.

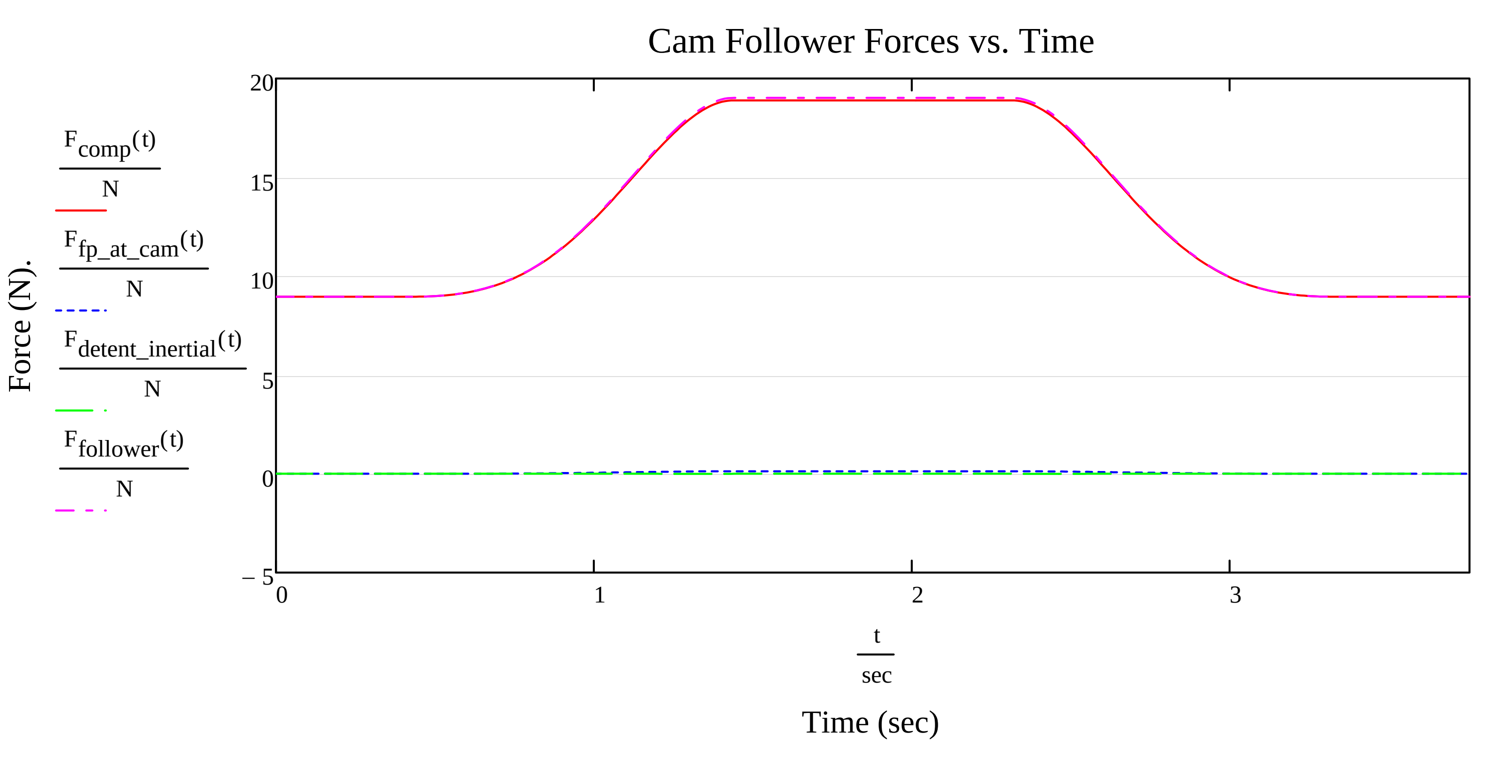
$M_{detent} := 42.75\text{gm}$ Mass of moving portion of detent arm.

$F_{detent\_inertial}(t) := M_{detent}\cdot a_{detent}(t)$ Force component of detent arm due to the acceleration when climbing cam.

Calculate total force on cam from follower loads.

$F_{follower}(t) := F_{comp}(t) + F_{fp\_at\_cam}(t) + F_{detent\_inertial}(t)$ Total detent spring force.

$F_{normal}(t) := \frac{F_{follower}(t)}{\cos(\eta_t(t))}$ Reaction force to the spring in the normal direction

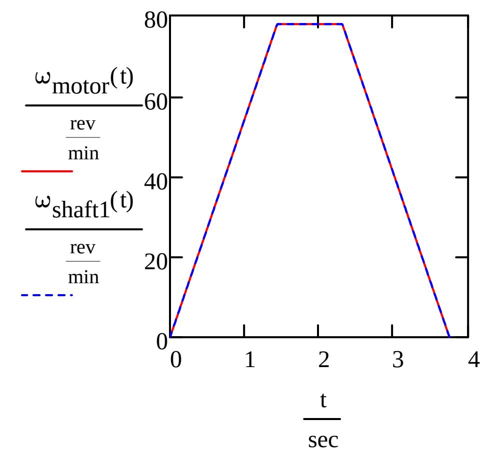


Calculate motor speed and acceleration

$\omega_{shaft1}(t) := \omega_{crank}(t)\cdot\text{Ratio}_{mitergear}$ $\quad \alpha_{shaft1}(t) := \text{Ratio}_{mitergear}\cdot\alpha_{crank}(t)$

$\omega_{motor}(t) := \omega_{shaft1}(t)\cdot\text{Ratio}_{mot\_gearbox}$ $\quad \alpha_{motor}(t) := \alpha_{shaft1}(t)\cdot\text{Ratio}_{mot\_gearbox}$

Calculate loads on crank in Zone 2
(Cam angle from θ_2 to θ_3).



The crank is subjected to the following loads in zone 2..

1. Inertial force (torque) of accelerating turret (I x α) as is cycles from one position to the next.
2. Frictional forces (torque) from turret bearings.

$R_{crank} := 13.55826mm$ Radius of Geneva crank

$D_{ctr} := 64mm$ Distance between centers of Geneva wheel and crank

$$\theta_{gen2}(t) := \text{if}\left(t < t_2, \text{atan}\left(\frac{R_{crank}\cdot\sin(180deg - \theta_2)}{D_{ctr} - R_{crank}\cdot\cos(180deg - \theta_2)}\right), \text{atan}\left(\frac{R_{crank}\cdot\sin(180deg - \theta_{crank}(t))}{D_{ctr} - R_{crank}\cdot\cos(180deg - \theta_{crank}(t))}\right)\right)$$

$$\theta_{geneva}(t) := \text{if}\left(t < t_3, \theta_{gen2}(t), \text{atan}\left(\frac{R_{crank}\cdot\sin(180deg - \theta_3)}{D_{ctr} - R_{crank}\cdot\cos(180deg - \theta_3)}\right)\right)$$

$$R_{geneva}(t) := \frac{R_{crank}\cdot\sin(180deg - \theta_{crank}(t))}{\sin(\theta_{geneva}(t))}$$ Geneva radius as a function of time

$$\omega_{geneva}(t) := \frac{d}{dt}\theta_{geneva}(t) \qquad \alpha_{geneva}(t) := \frac{d^2}{dt^2}\theta_{geneva}(t)$$

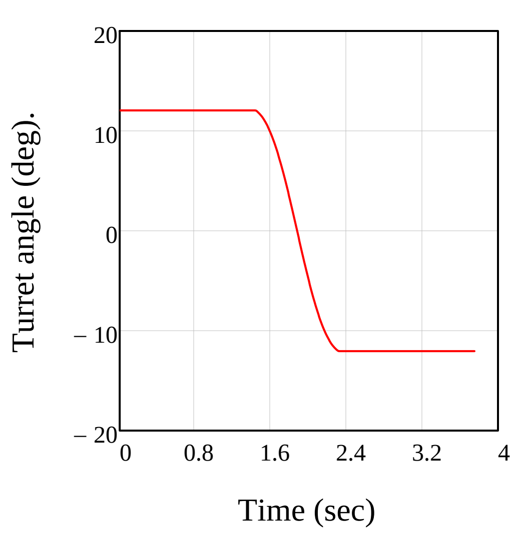
$$T_{ftw}(t) := I_{ftw}\cdot\alpha_{geneva}(t) + T_{trt\_fric}$$

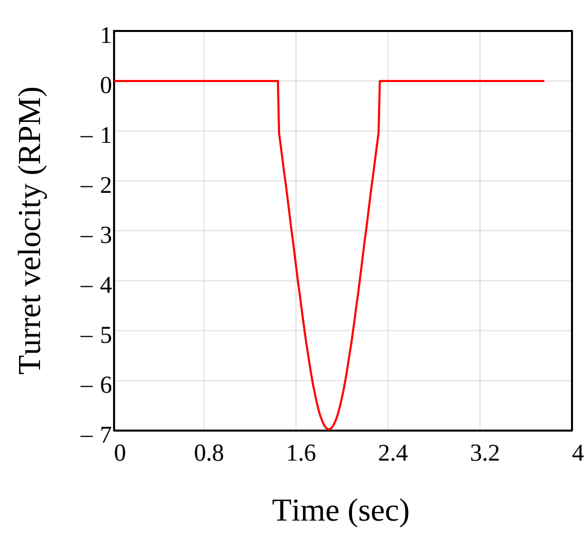
$$F_{tan\_trt\_1}(t) := \text{if}\left(t < t_2, 0lbf, \frac{T_{ftw}(t)}{R_{geneva}(t)}\right)$$

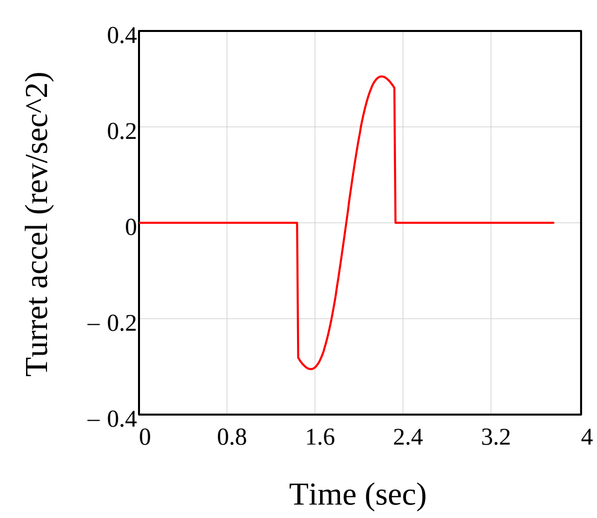
$$F_{tan\_turret}(t) := \text{if}(t < t_3, F_{tan\_trt\_1}(t), 0lbf)$$

$$F_{tan\_crank}(t) := F_{tan\_turret}(t)\cdot\sin(\theta_{crank}(t) - \theta_{geneva}(t) - 90deg)$$

$$T_{crank\_z2}(t) := F_{tan\_crank}(t)\cdot R_{crank}$$





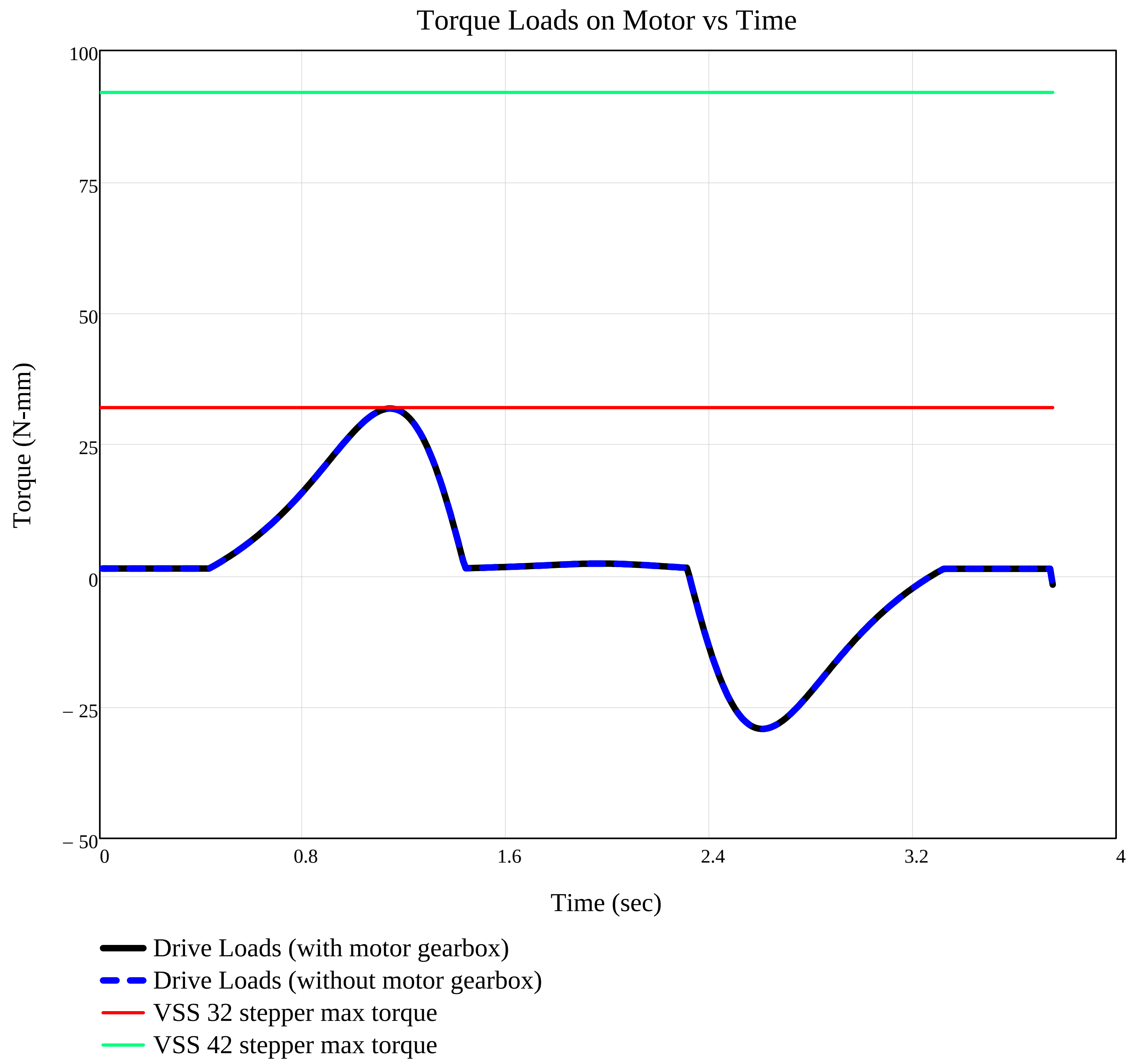


$$T_{crank}(t) := F_{normal}(t)\cdot BB_t(t) + (I_{crank})\cdot\alpha_{crank}(t) + T_{crank\_friction} + F_{tan\_crank}(t)\cdot R_{crank}$$

$$T_{shaft1}(t) := (I_{shaft1} + I_{mot\_gearbox})\cdot\alpha_{shaft1}(t) + \frac{T_{crank}(t)}{Ratio_{mitergear}} + T_{fric\_shaft1}$$

$$T_{mot\_gearbox}(t) := I_{vss32rotor}\cdot\alpha_{motor}(t) + \frac{T_{shaft1}(t)}{Ratio_{mot\_gearbox}}$$

$$T_{mot\_nogrbx}(t) := I_{vss32rotor}\cdot\alpha_{shaft1}(t) + T_{shaft1}(t)$$

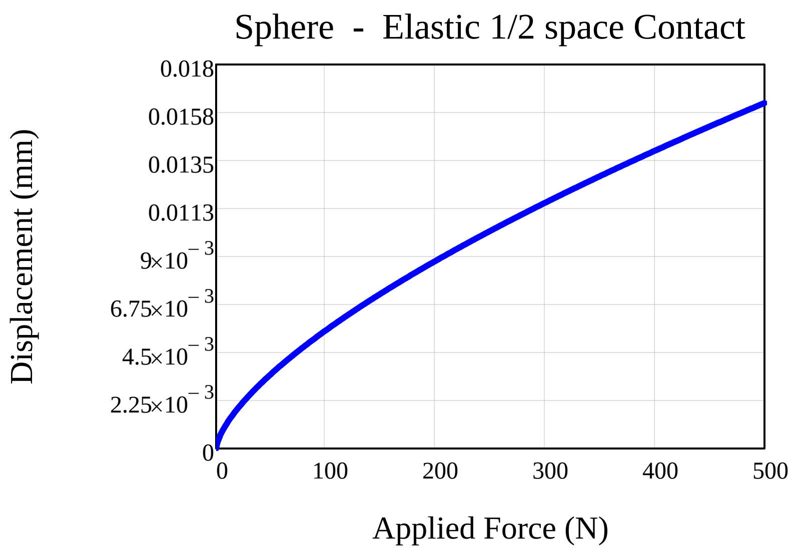

Torque Loads on Motor vs Time
Torque (N-mm)
100
75
50
25
0
− 25
− 50
0
0.8
1.6
2.4
3.2
4
Time (sec)
Drive Loads (with motor gearbox)
Drive Loads (without motor gearbox)
VSS 32 stepper max torque
VSS 42 stepper max torque

Detent Ball Contact, Deformations and Friction:

$F_{detball} := 0.N, 1.N .. 500N$

$R_{ball} := 6mm$	Detent Ball Radius
$E_{ball} := 2\cdot 10^{11} Pa$	Detent Ball Young's Modulus
$\nu_{ball} := 0.3$	Detent Ball Poisson's Coefficient
$E_{vgroove} := 1\cdot 10^{11} Pa$	V-Groove Young's Modulus
$\nu_{vgroove} := 0.33$	V-Groove Poisson's Coefficient

$$d(F_{detball}) := \left[\frac{\frac{3}{4}\cdot\left[\frac{\left(1-\nu_{vgroove}^{2}\right)}{E_{vgroove}}+\frac{\left(1-\nu_{ball}^{2}\right)}{E_{ball}}\right]\cdot F_{detball}}{\left(\sqrt{R_{ball}}\right)}\right]^{\left(\frac{2}{3}\right)}$$



Ball / V-groove friction:

Static Friction Coefficients:

$\mu s_{as} := 0.61$	Aluminum / Steel
$\mu s_{bs} := 0.51$	Brass / Steel
$\mu s_{ss} := 0.8$	Steel / Steel

V-groove angle:

$\alpha_{vgroove} := 45deg$

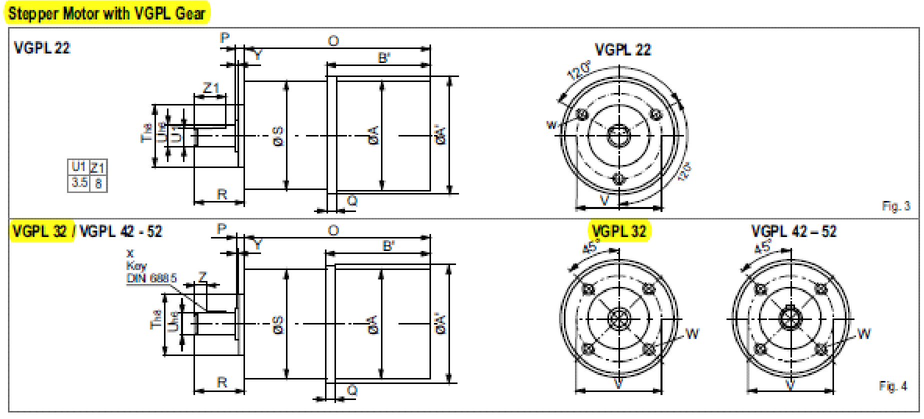
$F_{fas} := 100\cdot\cos\left(\frac{\pi}{2}-\alpha_{vgroove}\right)\cdot\mu s_{as} = 43.134$

Size	Standard Part 200 steps/rev.	Parallel Windings [6] (4 leads) I/Ph [1]	R/Ph [2]	L/Ph [3]	Series Windings (4 leads) I/Ph [1]	R/Ph [2]	L/Ph [3]	Unipolar Connection (5 or 6 leads) I/Ph [1]	R/Ph [2]	L/Ph [3]	Holding Torque [4) 5)]	Detent Torque [5)]	Rotor Inertia	Loads axial	Loads radial	Mass
		A	Ω	mH	A	Ω	mH	A	Ω	mH	mNm	mNm	kg cm²	N	N	kg
19	VSS 19.200.0.3	0.3	6	2.2	0.15	24	8.8	0.21	12	2.2	3.4	0.9	0.0009	3	3	0.05
	VSS 19.200.0.6	**0.6**	**2.1**	**0.55**	0.3	8.4	2.2	0.42	4.2	0.55						
	VSS 19.200.1.2	1.2	0.625	0.15	0.6	2.5	0.6	0.84	1.25	0.15						
25	VSS 25.200.0.3	0.3	12	6	0.15	48	24	0.21	24	6	12	2	0.002	5	5	0.08
	VSS 25.200.0.6	0.6	3.25	1.5	0.3	13	6	0.42	6.5	1.5						
	VSS 25.200.1.2	**1.2**	**0.95**	**0.4**	0.6	3.8	1.6	0.84	1.9	0.4						
32	VSS 32.200.0.6	0.6	4.6	5.3	0.3	18.4	21.2	0.42	9.2	5.3	45	3	0.01	5	15	0.17
	VSS 32.200.1.2	**1.2**	**1.25**	**1.2**	0.6	5.0	4.8	0.84	2.5	1.2						
	VSS 32.200.2.5	2.5	0.3	0.3	1.25	1.2	1.2	1.75	0.6	0.3						
	VSS 33.200.0.6	0.6	7.5	9.3	0.3	30	37.2	0.42	15	9.3	68	3.3	0.018	5	15	0.26
	VSS 33.200.1.2	1.2	1.9	2.2	0.6	7.4	8.8	0.84	3.8	2.2						
	VSS 33.200.2.5	2.5	0.47	0.6	1.25	1.88	2.4	1.75	0.94	0.6						
42	VSS 42.200.0.6	0.6	7.25	11	0.3	29	44	0.42	14.5	11	130	5	0.045	20	40	0.35
	VSS 42.200.1.2	1.2	1.7	3	0.6	6.8	12	0.84	3.4	3						
	VSS 42.200.2.5	**2.5**	**0.34**	**0.7**	1.25	1.36	2.8	1.75	0.68	0.7						
	VSS 43 .200.0.6	0.6	9.5	22.9	0.3	38	91.6	0.42	19	22.9	235	7	0.077	20	40	0.52
	VSS 43.200.1.2	1.2	2.6	5.2	0.6	10.4	20.8	0.84	5.2	5.2						
	VSS 43.200.2.5	2.5	0.5	1.2	1.25	2	4.8	1.75	1	1.2						
52	VSS 52.200.1.2	1.2	2.65	7	0.6	10.6	28	0.84	5.3	7	405	13	0.15	25	70	0.72
	VSS 52.200.2.5	2.5	0.6	1.6	1.25	2.4	6.4	1.75	1.2	1.6						
	VSS 52.200.5	**5**	**0.165**	**0.4**	2.5	0.66	1.6	3.5	0.33	0.4						
56	VSS 57.200.1.2	1.2	3.9	9.5	0.6	15.6	38	0.84	7.8	9.5	630	50	0.24	40	80	0.99
	VSS 57.200.2.5	2.5	0.8	2.4	1.25	3.2	9.6	1.75	1.6	2.4						
	VSS 57.200.5.0	5	0.25	0.8	2.5	1	3.2	3.5	0.5	0.8						

1) I/Ph: Phase current
2) R/Ph: Phase resistance
3) L/Ph: Phase inductance
4) Holding torque in bipolar mode with parallel windings, 2 phases ON at rated current
5) 7 mNm ~ 1 inoz
6) Standard wiring at delivery (if no wiring mode was given in the order)
Design voltage 42 V_{DC} (operation with SELV type supply)
Bold letters = Preferred types

Important:
All values given above were measured at room temperature of 25 °C (77 °F) and atmospheric pressure.

Stepper Motor with VGPL Gear



Gear	Stepper Motor	A	A'	B'	O 1 stage	O 2 stages	O 3 stages	P	Q	R	S	T	U	V	W	X	Y	Z	Mass (motor + gear) 1 stage kg	2 stages kg	3 stages kg
VGPL 22	VSS 19	19	22	29	50	57	64	3	4.5	15	22	12	4	16	M 2.5x4	-	1	-	0.1	0.13	0.15
	VSS 25	25	25.5	33.5	53.5	605	675		5										0.13	0.15	0.18
VGPL 32	VSS 32	32	33	40.5	69.5	785	875	4	5	20	32	20	6	26	M3x5	-	1	-	0.31	0.35	0.42
	VSS 33	32	33	59.5	88.5	97.5	106.5												0.39	0.44	0.51
VGPL 42	VSS 42	42	43	58	93	105.5	118	4	7	22.5	42	25	8	32	M4x8	3x3x14	1	2.25	0.63	07	0.8
	VSS 43	42	43	73	108	120.5	133												0.8	0.85	0.93
VGPL 52	VSS 52	52	53	68.5	109.5	124	138.5	4	6.7	24	52	32	12	40	M5x8	4x4x16	1	2	1.2	14	1.5
	VSS 57	56.4	57	78	119	133.5	148		9										1.4	15	1.6

Mechanical Characteristics

Gear	Stepper Motor	Stages	Gear backlash [1)] arc-min	Max. torque Nm	Gear inertia kg cm²	Radial load [2)] N	Axial load N	Efficiency %	Reduction ratio				
VGPL 22	VSS 19 VSS 25	1	20'	0.1	0.005	30	24	94	4:1	5:1	7:1		
		2	35'	0.5	0.015			85	16:1	20:1	28:1	35:1	49:1
		3	50'	1.5	0.025			80	64:1	80:1	112:1	140:1	196:1
VGPL 32	VSS 32 VSS 33	1	6'	0.4	0.025	80	65	94	4:1	4.5:1	5.2:1	6.25:1	8:1
		2	10'	2	0.04			85	16:1	18:1	25:1	32:1	50:1
		3	15'	6	0.06			80	72:1	100:1	130:1	200:1	256:1
VGPL 42	VSS 42 VSS 43	1	6'	0.7	0.05	150	120	94	4:1	5:1	6:1		
		2	10'	4	0.08			85	14:1	16:1	20:1		
		3	15'	12	0.12			80	56:1	80:1	100:1	120:1	184:1
VGPL 52	VSS 52 VSS 57	1	6'	1.5	0.1	250	200	94	4:1	4.5:1	5.2:1	6.25:1	8:1
		2	10'	10	0.2			85	16:1	25:1	29:1	36:1	50:1
		3	15'	30	0.25			80	72:1	100:1	130:1	200:1	256:1

1) no load   2) center of shaft

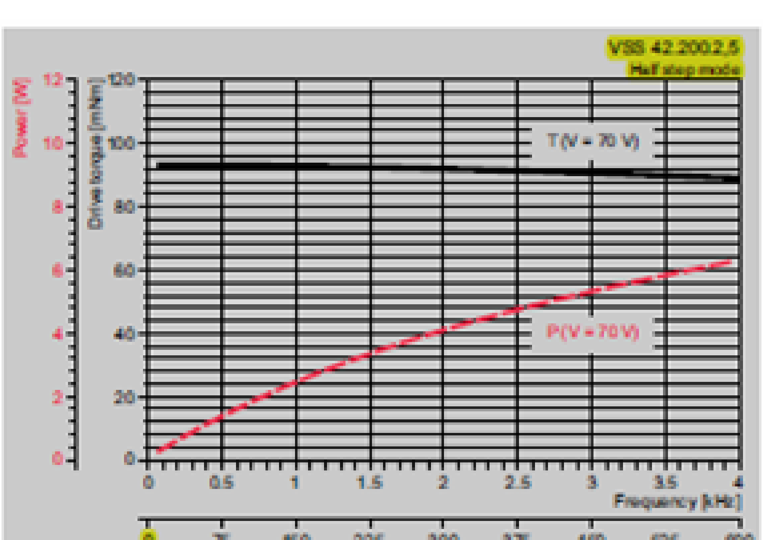


Fig. 10

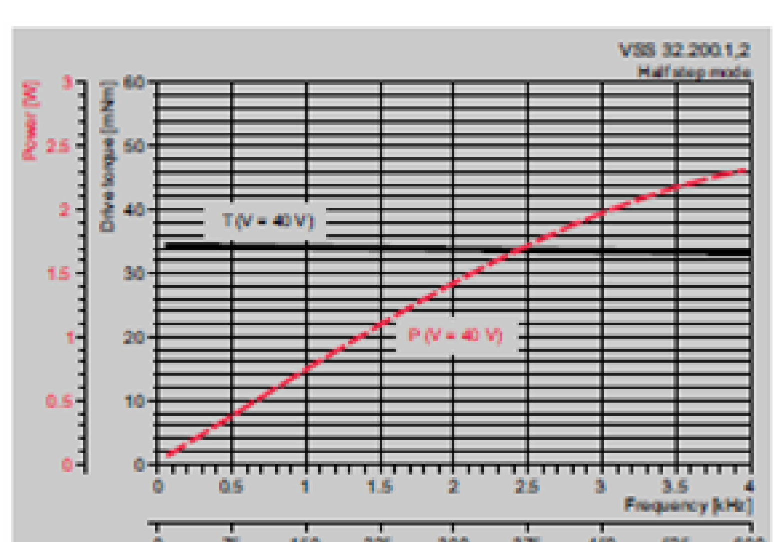


Fig. 9