Polaris GEM Parameters

Configurable parameters for the Polaris GEM Drive-By-Wire Kit

1 Overview

The parameters described in this document allow configuration of several features of the drive-by-wire system. Parameters can be changed using the DbwConfig.exe Windows application and connecting to modules via USB. See DbwConfig.pdf for details on this process.

Parameters are stored in non-volatile memory, so it is not necessary to set the values each power cycle. The section of non-volatile is not erased by the firmware upgrade process, so values persist between firmware upgrades. If the min/max range changes for a parameter, the value will be sanitized to the new min/max range. It is recommended to visually check the parameter values after a firmware upgrade.

Parameter changes are active immediately, however, it is unwise to change parameters when the vehicle is in motion. Exercise caution when using non-default parameter values, as this will change the way the drive-by-wire system operates.

DISCLAIMER:

This product is intended for research purposes only. Steps have been taken to ensure function on power or communication loss. However, in no event shall Dataspeed Inc. be liable for any direct, indirect, punitive, incidental, special consequential damages, to property or life, whatsoever arising out of or connected with the use or misuse of its products.

2 Throttle Module

2.1 Allow Ignoring Driver Overrides

Name	Default	Min	Max	Unit
AllowIgnore	False	—	—	—

This parameter enables or disables the ability of the user to ignore driver overrides by setting the IGNORE bit in the throttle command message (ID 0x062).

2.2 Driver Override Threshold

Name	Default	Min	Max	Unit
OverrideThresh	0.30	0.15	0.70	%

The override threshold parameter controls how far the user must press the throttle pedal to trigger a driver override. The value of this parameter represents the raw pedal position.

2.3 Driver Override Hysteresis Time

Name	Default	Min	Max	Unit
OverrideHystMs	100	0	250	ms

The driver override hysteresis time parameter controls how many consecutive milliseconds the override threshold must be exceeded before a driver override is triggered.

2.4 Suppress Watchdog Counter Faults

Name	Default	Min	Max	Unit
WdcSuppressDisabled	False	—	—	—

If set, the three fault sources for the Watchdog Counter in the table below are not considered. This allows commands to transition from EN=1 to EN=0 without triggering a Watchdog Counter fault. All modules independently determine these fault conditions, so this value should be the same for all modules in the same vehicle.

Value	Enum	Description
5	BRAKE_DISABLED	Brake module disabled without override when in gear or moving
9	THROTTLE_DISABLED	Throttle module disabled without override when in gear or moving
13	STEERING_DISABLED	Steering module disabled without override when in gear or moving

3 Gateway Module

3.1 Steer Allow Ignoring Driver Overrides

Name	Default	Min	Max	Unit
SteerAllowIgnore	False	—	—	—

This parameter enables or disables the ability of the user to ignore driver overrides by setting the IGNORE bit in the steering command message (ID 0x064).

3.2 Steering Driver Override Threshold

Name	Default	Min	Max	Unit
SteerOverrideThresh	4.50	2.00	8.00	Nm

The override threshold parameter controls how much torque the user must induce on the steering column to trigger a driver override.

3.3 Steering Calibration Status

Name	Default	Min	Max	Unit
SteeringCal	False	—	—	—

If false, steering has not been calibrated. If true, SteeringCalOffset is the steering calibration. This parameter is set automatically.

3.4 Steering Calibration Offset

Name	Default	Min	Max	Unit
SteeringCalOffset	0	-10000	10000	deg

The calibrated offset between steering wheel angle and steering motor angle. Only valid if SteeringCal is true. This parameter is set automatically.

3.5 Unlimited Steering Velocity

Name	Default	Min	Max	Unit
UnlimitedSteering	False	—	—	—

If false, SVEL=0 corresponds to a 500 deg/s steering velocity limit. If true, SVEL=0 corresponds to unlimited steering velocity and the steering acceleration limit above is ignored. Use caution with unlimited steering velocity. Sporadic and jerky steering commands may cause unintended driver overrides that will transition control back to the human driver.

3.6 Steering Acceleration Limit

Name	Default	Min	Max	Unit
SteeringAccelLimit	3600	500	10000	deg/s^2

Limit the amount of angular acceleration on the steering wheel angle command. Zero evaluates to no-limit.

3.7 Unlimited Steering Acceleration

Name	Default	Min	Max	Unit
UnlimitedSteeringAccel	False	—	—	—

If false, the SteeringAccelLimit parameter is observed. If true, the SteeringAccelLimit parameter is ignored. Use caution with unlimited steering acceleration. Sporadic and jerky steering commands may cause unintended driver overrides that will transition control back to the human driver.

3.8 Lateral Acceleration Limit

Name	Default	Min	Max	Unit
LatAccelLimit	6.0	2.0	18.0	m/s^2

This parameter is used to limit the amount of lateral acceleration that can be achieved when commanding steering wheel angle. It does this by limiting the maximum allowed steering wheel angle according to the following relationship:

$$\alpha_{s_{\max}} = \gamma \tan^{-1}\left(\frac{L a_{y_{\max}}}{v^2}\right)$$

where $\alpha_{s_{\max}}$ is the maximum steering wheel angle in radians, $\gamma = 17$ is the ratio between the steering wheel angle and the tire steering angle, $L = 1.75$ is the length of the wheelbase in meters, v is the current speed of the vehicle in m/s, and $a_{y_{\max}}$ is the lateral acceleration limit specified in this parameter.

The maximum value effectively disables this safety feature. For typical driving situations, appropriate values for this parameter range between 4 m/s^2 and 8 m/s^2.

3.9 Angular Acceleration Limit

Name	Default	Min	Max	Unit
AngAccelLimit	4.0	0.5	10.0	rad/s^2

This parameter is used to limit the amount of vehicle angular acceleration that can be achieved when commanding steering wheel angular rate. It does this by limiting the maximum allowed angular rate of the steering wheel according to the following relationship:

$$\dot{\alpha}_{s_{\max}} = \frac{\gamma L}{v} \cos^2\left(\frac{\alpha_s}{\gamma}\right) \ddot{\psi}_{\max}$$

where $\dot{\alpha}_{s_{\max}}$ is the maximum steering wheel rate in rad/s, $\gamma = 17$ is the ratio between the steering wheel angle and the tire steering angle, $L = 1.75$ is the length of the wheelbase in meters, v is the current speed of the vehicle in m/s, α_s is the current steering wheel angle, and $\ddot{\psi}_{\max}$ is the angular acceleration limit specified in this parameter.

The maximum value effectively disables this safety feature. For typical driving situations, appropriate values for this parameter range between 2 rad/s^2 and 4 rad/s^2.

3.10 Brake Allow Ignoring Driver Overrides

Name	Default	Min	Max	Unit
BrakeAllowIgnore	False	—	—	—

This parameter enables or disables the ability of the user to ignore driver overrides by setting the IGNORE bit in the brake command message (ID 0x060).

3.11 Brake Driver Override Threshold

Name	Default	Min	Max	Unit
BrakeOverrideThresh	500	50	2000	Nm

The override threshold parameter controls how far the user must press the brake pedal to trigger a driver override. The value of this parameter represents the torque induced by pressing the brake pedal.

3.12 Brake Driver Override Hysteresis Time

Name	Default	Min	Max	Unit
BrakeOverrideHystMs	250	50	500	ms

The driver override hysteresis time parameter controls how many consecutive milliseconds the override threshold must be exceeded before a driver override is triggered.

3.13 External Brake Input Enable

Name	Default	Min	Max	Unit
ExtBrakeEnable	False	—	—	—

If enabled, a low voltage on digital input 2 will trigger a constant braking value. The external brake input is the highest priority braking command source, and will trigger regardless of the the brake command CAN message and the state of the Watchdog Counter fault. This input is useful as an emergency stop button. The default is a 'large' amount of braking.

3.14 External Brake Input Value

Name	Default	Min	Max	Unit
ExtBrakeValue	3000	0	8000	Nm

This is the value for the constant braking of the external brake input described above.

3.15 Watchdog Counter Brake Value

Name	Default	Min	Max	Unit
WdcBrakeValue	1000	0	5000	Nm

This is the value for the constant braking when the Watchdog Counter fault is triggered. The default is a 'small' amount of braking, just enough to slowly bring the vehicle to a stop.

3.16 Suppress Watchdog Counter Faults

Name	Default	Min	Max	Unit
WdcSuppressDisabled	False	—	—	—

If set, the three fault sources for the Watchdog Counter in the table below are not considered. This allows commands to transition from EN=1 to EN=0 without triggering a Watchdog Counter fault. All modules independently determine these fault conditions, so this value should be the same for all modules in the same vehicle.

Value	Enum	Description
5	BRAKE_DISABLED	Brake module disabled without override when in gear or moving
9	THROTTLE_DISABLED	Throttle module disabled without override when in gear or moving
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3.17 Brake Calibration Clear

Name	Default	Min	Max	Unit
BrakeCalClear	False	—	—	—

Clear the brake calibration table and trigger the calibration procedure. The value resets to False automatically.

3.18 UlcStopTorque

Name	Default	Min	Max	Unit
UlcStopTorque	800	600	1600	Nm

This parameter specifies the constant amount of brake torque used to maintain zero speed.

3.19 UlcDefaultLatAccel

Name	Default	Min	Max	Unit
UlcDefaultLatAccel	4.0	2.0	6.0	m/s^2

When the ULC configuration message is in timeout, or its LAT_ACCEL field is set to zero, this parameter is used to limit the amount of lateral acceleration that can be achieved with the steering component of the ULC. It does this by limiting the maximum allowed steering wheel angle according to the following relationship:

$$\alpha_{s_{\max}} = \gamma \tan^{-1}\left(\frac{L a_{y_{\max}}}{v^2}\right)$$

where $\alpha_{s_{\max}}$ is the maximum steering wheel angle in radians, $\gamma = 17$ is the ratio between the steering wheel angle and the tire steering angle, $L = 1.75$ is the length of the wheelbase in meters, v is the current speed of the vehicle in m/s, and $a_{y_{\max}}$ is the lateral acceleration limit specified in this parameter.

3.20 UlcDefaultAngAccel

Name	Default	Min	Max	Unit
UlcDefaultAngAccel	1.0	0.5	2.0	rad/s^2

When the ULC configuration message is in timeout, or its ANG_ACCEL field is set to zero, this parameter is used to limit the amount of angular acceleration that can be achieved with the steering component of the ULC. It does this by limiting the maximum allowed angular rate of the steering wheel according to the following relationship:

$$\dot{\alpha}_{s_{\max}} = \frac{\gamma L}{v} \cos^2\left(\frac{\alpha_s}{\gamma}\right) \ddot{\psi}_{\max}$$

where $\dot{\alpha}_{s_{\max}}$ is the maximum steering wheel rate in rad/s, $\gamma = 17$ is the ratio between the steering wheel angle and the tire steering angle, $L = 1.75$ is the length of the wheelbase in meters, v is the current speed of the vehicle in m/s, α_s is the current steering wheel angle, and $\ddot{\psi}_{\max}$ is the angular acceleration limit specified in this parameter.

3.21 UlcDefaultLinDecel

Name	Default	Min	Max	Unit
UlcDefaultLinDecel	1.5	0.5	3.0	m/s^2

When the ULC configuration message is in timeout, or its LIN_DECEL field is set to zero, this parameter is used to limit the amount of deceleration used to regulate vehicle speed.

Appendix – Steering Angle and Rate Limit Derivations

This appendix documents the mathematical derivation of the speed-dependent limits on steering wheel angle and steering wheel rate based on the LatAccelLimit calibration parameter (Section 3.8) and the AngAccelLimit calibration parameter (Section 3.9), respectively. These derivations are based on a kinematic bicycle model, illustrated in Figure 1.

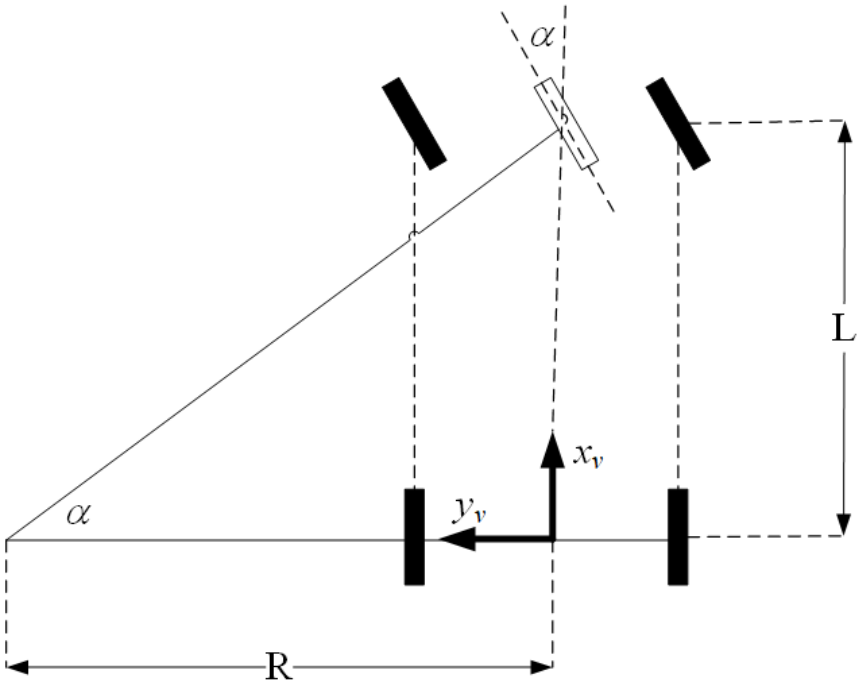

Figure 1: Diagram of a kinematic bicycle model

where α is the equivalent bicycle steering angle of the front wheels, R is the turning radius, $L = 1.75\mathrm{m}$ is the wheelbase of the vehicle, and the vehicle's coordinate frame is defined with x pointing forward, y pointing left, and z pointing up.

Speed-Dependent Angle Limit

The speed-dependent maximum allowed steering wheel angle is computed based on a user-specified maximum allowed lateral acceleration set in the LatAccelLimit calibration parameter. Lateral acceleration is linked to speed and turning radius through the formula for centripital acceleration:

$$a_y = \frac{v^2}{R} \tag{1}$$

Representing turning radius in terms of the steering angle α and substituting into (1) gives:

$$a_y = \frac{v^2 \tan \alpha}{L} \tag{2}$$

Defining the ratio between steering wheel angle and the equivalent bicycle steering angle of the front wheels as the steering ratio, and representing that ratio as $\gamma = 17.0$, (2) can be manipulated to express lateral acceleration in terms of the steering wheel angle:

$$a_y = \frac{v^2 \tan\left(\frac{\alpha_s}{\gamma}\right)}{L} \tag{3}$$

where α_s is the steering wheel angle. Rearranging to represent the maximum steering wheel angle in terms of a lateral acceleration limit setting:

$$\alpha_s = \gamma \tan^{-1}\left(\frac{La_y}{v^2}\right) \tag{4}$$

Speed-Dependent Angle Rate Limit

The speed-dependent maximum allowed steering wheel rate is computed based on a user-specified maximum allowed angular acceleration set in the AngAccelLimit calibration parameter. Angular acceleration is defined as the time derivative of yaw rate, so an expression for the yaw rate in terms of the kinematics parameters and steering wheel angle is required first. This can be constructed using the formula (5) relating arc length, angle, and radius, illustrated in Figure 2.

$$s = R\theta \tag{5}$$

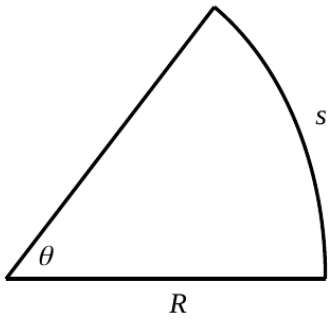

Figure 2: Arc length, angle, and radius

Taking the time derivative of both sides of (5):

$$\frac{ds}{dt} = R\frac{d\theta}{dt} \tag{6}$$

where $ds/dt \equiv v$ is the forward speed of the vehicle, and $d\theta/dt \equiv \dot{\psi}$ is the yaw rate. Substituting into (6) the same expression as before for the vehicle's turning radius, the yaw rate can be expressed in terms of the steering wheel angle:

$$\dot{\psi} = \frac{v \tan\left(\frac{\alpha_s}{\gamma}\right)}{L} \tag{7}$$

Taking the time derivative of (7) gives an expression of the angular acceleration:

$$\frac{d\dot{\psi}}{dt} = \frac{1}{L}\left(\cancel{\frac{dv}{dt}\tan\left(\frac{\alpha_s}{\gamma}\right)}^{0} + v\frac{d\left(\tan\left(\frac{\alpha_s}{\gamma}\right)\right)}{dt}\right) = \frac{v\dot{\alpha}_s}{L\gamma}\sec^2\left(\frac{\alpha_s}{\gamma}\right) \tag{8}$$

where $d\dot{\psi}/dt \equiv \ddot{\psi}$ is the angular acceleration, $\dot{\alpha}_s$ is the steering wheel rate, and it is assumed the vehicle's speed is in steady state with acceleration (dv/dt) equal to zero. Rearranging to represent the maximum steering wheel angle rate in terms of an angular acceleration limit setting:

$$\dot{\alpha}_s = \frac{L\gamma}{v}\cos^2\left(\frac{\alpha_s}{\gamma}\right)\ddot{\psi} \tag{9}$$