CASCADIA MOTION

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Using Speed Mode

Revision 0.5

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1. Introduction

This document describes how to use the speed mode of the Cascadia Motion controllers.

NOTE: This document describes features that occurred beginning with firmware version 1953.

The controllers can either operate in Torque mode or Speed mode. In torque mode, which is most commonly used, the user provides a torque command and the controller attempts to achieve that operating torque. Torque mode is most analogous to what is experienced in driving a normal car. The accelerator pedal position provides a command that is roughly proportional to torque.

Speed mode can be useful mostly for certain testing scenarios or for specific vehicle type applications (e.g. marine). In some instances speed mode can be useful in multi-speed transmissions.

Certain application might require switching between torque and speed mode while the inverter is actively controlling the motor. The mode switching can be accomplished, but only when using CAN mode.

2. Speed Mode

Speed Mode allows the user to control the speed of the motor. The controller has a method to measure the speed of the motor. The actual speed of the motor is compared to the commanded speed of the motor and the resulting error drives a regulator to increase or decrease the torque as needed to achieve the commanded speed target.

The output of the speed regulator is a torque command. The output torque command is not processed by the Torque Rate Limit function.

Because the speed regulator can drive a motor to the maximum torque it must be used with caution. If for example the resolver is not calibrated a motor may not make any torque even with a large amount of current flowing. Thus the motor could quickly to maximum current without any movement of the motor.

For the purposes of this manual, it is important to define what Forward and Reverse mean. The Forward direction is when a motor spins and the motor feedback speed is positive. The Reverse direction is when a motor spins and the motor feedback speed is negative. The controller does not have a concept of clockwise and counterclockwise. That being said many of the motors that the controller is configured for are setup for counterclockwise as being Forward, but not all.

If the controller is to operate in Speed mode at all times, then the EEPROM variable should be used to set the mode to be Speed Mode. The Run_Mode_EEPROM(Trq=0_Spd=1) parameter should be set to 1 to achieve speed mode.

When operating in speed mode the speed controller will output a torque that is limited to the motor torque limits. The motoring torque (positive torque) is limited to Motor_Torque_Limit_EEPROM_(Nm)_x_10 and the regeneration torque (negative torque) is limited to Regen_Torque_Limit_EEPROM_(Nm)_x_10.

Starting in Gen 3 firmware version 2044 these torque limits may be reduced depending on the configuration of certain de-rating features. These features are the Break Speed setting, the BMS CAN message limits, or Motor Temperature de-rating (Zero/Full Torque Temperatures).

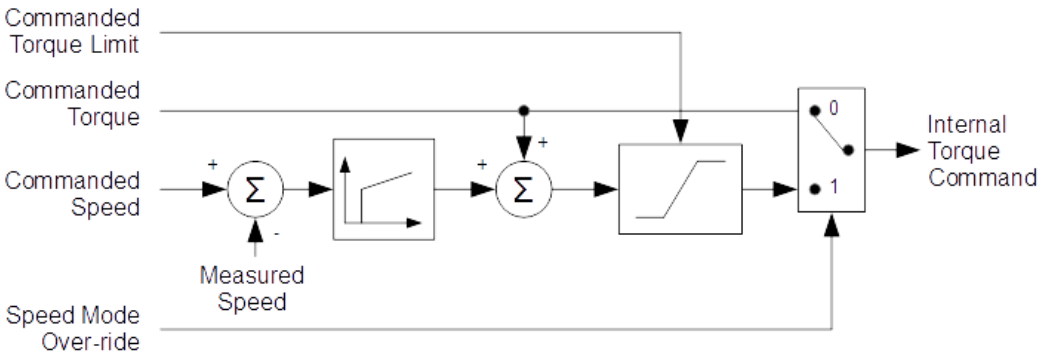
Note: For the Speed Mode to operate properly the two torque limits should be set to values that allow the regulator to work properly. For example, if the Regen torque limit is set to zero and the motor is operated with light load the controller will not be able to regulate the motor speed properly.

Below is a diagram of the speed regulator.

The Commanded Speed as indicated in the diagram is after the Speed Rate Limiter has been applied to the command (whether it be from CAN or VSM mode).

As shown below the Commanded Torque acts as a feedforward to the output of the speed regulator. For many applications the Commanded Torque should be kept at 0.

If it is desirable to have faster response it may be necessary to provide a Commanded Torque feedforward. This type of operation is only recommended for CAN control mode. The CAN Commanded Torque becomes the feedforward value and is NOT constrained by the Torque Rate Limit function. Care must be exercised when applying this feedforward.



Simplified Block Diagram of the Speed Regulator

The PID block of the speed regulator has 4 adjustable gains. The speed regulator PID loop is operated at the PWM frequency. For most applications of the PM Family of inverters the PWM frequency is 12kHz. Thus the speed regulator calculation is done every 83.33 microseconds.

The PID inputs and outputs are done using per-unit calculations. If needed contact technical support for the base units for the particular motor being operated.

The most common set of per unit bases are as follows:

Voltage Base = 200V
Current Base = 300A
Frequency Base = 175 Hz

From these three bases there are several derived bases:

Torque Base = Vbase * Ibase / (2 * PI * Fbase) = 54.57Nm

Speed Base = 120 * Fbase / number of poles

(e.g. for 10 pole motor Fbase = 2100 rpm)

So when attempting simulate or model the PID regulator the inputs and outputs must be first scaled by the per unit bases. For example, if the Commanded Speed was 4100 rpm then the per unit commanded speed would be 4100 / 2100 = 1.952. The output torque from the PID regulator would have to be multiplied by the torque base to get the actual torque command. For example if the torque command was 1.0 in per unit the actual torque commanded would be 1.0 * 54.57 = 54.57 Nm.

For IPM motors the torque command generated from the speed regulator is used by the id/iq look up table every 3ms. IPM motors do not use a torque regulator. The torque command is used directly every 3ms to find a new id/iq current command.

Parameter	Default Value	Descriptions
Kp_Speed_EEPROM_x_100	1600	Proportional gain of the speed regulator PID. For example a setting of 1600 results in a P gain of 16.00
Ki_Speed_EEPROM_x_10000	8	Integral gain of the speed regulator PID. For example a setting of 8 results in an I gain of 8/10000 = 0.0008.
Kd_Speed_EEPROM_x_100	0	Derivative gain of the speed regulator PID. Typically the D gain is not used. However, for example a setting of 1 results in a D gain of 0.01.
Klp_Speed_EEPROM_x_10000	0	Low-pass filter gain of the speed regulator PID. At this time we do not recommend using this feature. Keep this gain as 0.
Max_Speed_EEPROM_(RPM)	n/a	Defines the maximum speed command value when in speed mode. Value is set in RPM.
Speed_Rate_Limit_EEPROM_(RPM/sec)	100	The speed command changes whether from the VSM mode or CAN mode include a rate of change limiter. The limiter will limit how quickly the internal speed command is allowed to change. This EEPROM sets the rate of change limit in rpm / second. If it is necessary to eliminate this feature then set the parameter to 0. Valid range is 10 to 5100 rpm/s.

2.1 Speed Mode when in VSM Mode

VSM Mode allows the control of the motor from the analog and digital inputs.

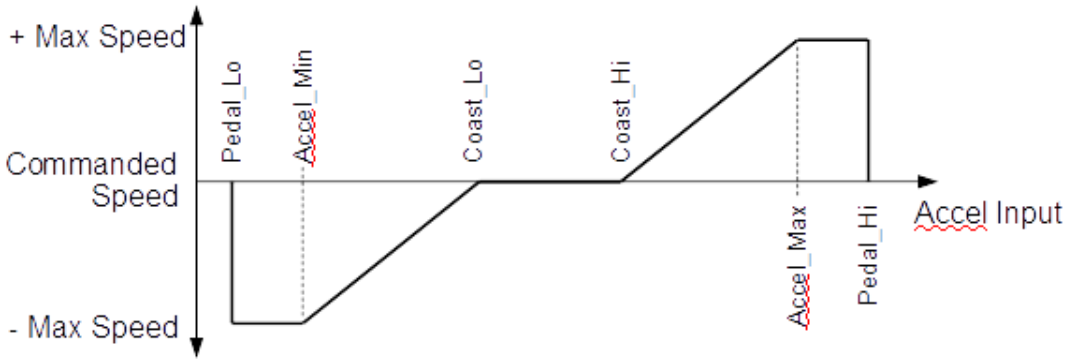
The speed command is derived from the AIN1 input voltage.

The same parameters that are used to define the range of torque from the AIN1 input are also used to define the Commanded Speed.

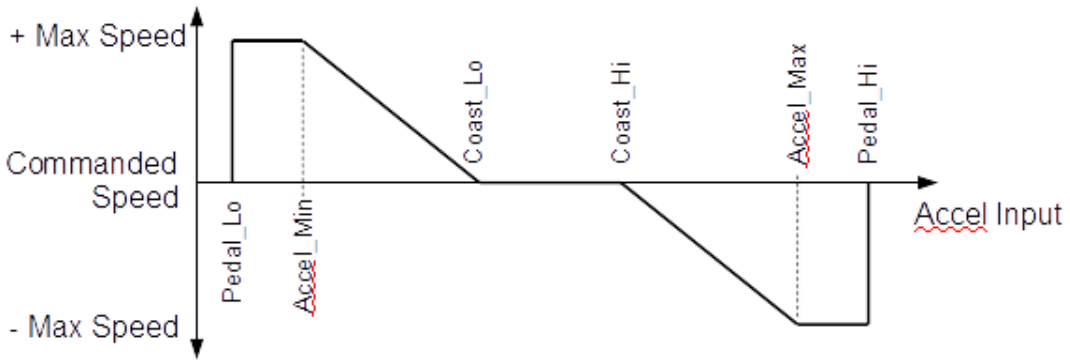
The configuration shown below shows how the commanded speed will allow the motor direction to be completely reversed based on the analog input voltage. This type of configuration can be useful in a marine application.

If movement is only desired in one direction then the Pedal LO, Accel Min, and Coat LO EEPROM parameters should be set to 0. The speed command will be 0 until the speed exceeds the voltage set by Coast Hi.

Unlike in Torque Mode, when in Speed Mode the Brake input does not have to be released before the motor will be spinning to the Commanded Speed. The Brake input must be inserted only to enable the motor.



Commanded Speed when the Forward Direction is selected



Commanded Speed when the Reverse Direction is selected

2.2 Speed Mode when in CAN Mode

CAN Mode allows the control of the motor from the CAN Command message.

The CAN Command message contains the following information:

Byte (s)	Name	Description
0,1	Commanded Torque	If the controller is in Torque Mode then the Commanded Torque is the torque command for the motor. Positive numbers represent motoring torque, negative numbers represent regen torque. If the controller is in Speed Mode then the Commanded Torque is used as a feedforward into the speed regulator.
2,3	Commanded Speed	If the controller is in Speed Mode then the Commanded Speed is the input to motor speed regulator.
4.0	Commanded Direction	If byte 4.0 is set to 1 then the commanded direction is “Forward” where positive torque results in positive speed. If byte 4.0 is set to 0 then the commanded direction is Reverse.
5.0	Inverter Enable	If byte 5.0 is set to 1 then the inverter is enabled, if set to 0 then disabled.
5.1	Active Discharge	Not covered in this manual. See Active Discharge section of Software manual

5.2	Speed Mode Over-ride	If this bit is 1 and the controller EEPROM is set for Torque Mode then it will transition the controller to Speed Mode as long as this bit remains 1. If the bit goes back to zero then the controller will go back to Torque Mode. The bit has no effect if the controller EEPROM is set for Speed Mode.
6,7	Commanded Torque Limit	If the Commanded Torque Limit is set to 0 then the torque limits default to the parameters set in the EEPROM. For non-zero torque limits the motoring and regen torque limit is set to the Commanded Torque Limit.

The Commanded Speed can be a positive or negative number. If the Commanded Direction is Forward then a positive Commanded Speed results in a positive speed, and a negative Commanded Speed results in a negative speed. If the Commanded Direction is Reverse then a positive Commanded Speed results in a negative speed, and a negative Commanded speed results in a positive speed.

When using CAN mode for speed control it is important to send periodic command messages to the controller. The torque limits that are affected by speed (regen fade speed for example) are only updated when a Command Message is received (this is no longer true starting with Gen 3 version 2044).

The controller will allow a negative torque to reverse the direction of the motor ONLY if the Regen Fade Speed EEPROM parameter is set to 0. If this parameter is set to a non-zero value then any negative torque commands (regen) will be set to zero when the speed of the motor reverses from it commanded direction.

The controller can be enabled directly into speed mode without first entering torque mode by using the Speed Mode Over-ride bit. The controller can also transition from torque mode to speed mode and back to torque mode without disabling the controller by using the same bit.

The Commanded Torque is used as a feedforward into the speed regulator. Use of the feedforward may allow a smoother transition or allow for a quicker response when using speed mode.

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Revision History

Version	Description of Versions / Changes	Responsible Party	Date
0.1	Initial version	Chris Brune	7/24/2015
0.2	Added Speed rate of change eeprom parameter description. Added max speed eeprom parameter description.	Chris Brune	11/5/2015
0.3	Added examples of the per unit bases. Added examples of the gain calculations.	Chris Brune	1/4/2017
0.4	Updated to Cascadia Motion. Include new information about torque limits.	Chris Brune	5/5/2021
0.5	Clarification about the torque feedforward. Minor edits	Chris Brune	3/7/2022