ROS Interface to Lincoln MKZ DBW System

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This document describes the ROS topics that can be used to control the DBW system on the Lincoln MKZ, and receive the sensor data over the private Dataspeed CAN bus.

1 Vehicle Commands

Topic	Type	Rate	Info
/vehicle/brake_cmd	dbw_mkz_msgs/BrakeCmd	50 Hz	pedal position or braking torque, enable, (boo_cmd is automatically set)
/vehicle/throttle_cmd	dbw_mkz_msgs/ThrottleCmd	50 Hz	pedal position, enable
/vehicle/steering_cmd	dbw_mkz_msgs/SteeringCmd	50 Hz	steering wheel angle, enable
/vehicle/gear_cmd	dbw_mkz_msgs/GearCmd	On-Event	none/park/reverse/neutral/drive/low
/vehicle/turn_signal_cmd	dbw_mkz_msgs/TurnSignalCmd	20 Hz	none/left/right
/vehicle/cmd_vel_with_limits	dbw_mkz_msgs/TwistCmd	> 5 Hz	linear/angular velocity, accel/decel limits
/vehicle/cmd_vel_stamped	geometry_msgs/TwistStamped	> 5 Hz	linear/angular velocity
/vehicle/cmd_vel	geometry_msgs/Twist	> 5 Hz	linear/angular velocity

2 Vehicle Data

Topic	Type	Rate	Info
/vehicle/dbw_enabled	std_msgs/Bool	On-Change	enabled
/vehicle/brake_report	dbw_mkz_msgs/BrakeReport	50 Hz	pedal position, braking torque, enable
/vehicle/brake_info_report	dbw_mkz_msgs/BrakeInfoReport	50 Hz	torques, abs/pbrake/hsa statuses
/vehicle/throttle_report	dbw_mkz_msgs/ThrottleReport	50 Hz	pedal position, enable
/vehicle/throttle_info_report	dbw_mkz_msgs/ThrottleInfoReport	100 Hz	engine RPM
/vehicle/steering_report	dbw_mkz_msgs/SteeringReport	50 Hz	steering wheel angle and torque, vehicle speed, enable
/vehicle/gear_report	dbw_mkz_msgs/GearReport	20 Hz	current gear
/vehicle/misc_1_report	dbw_mkz_msgs/Misc1Report	20 Hz	turn signals, buttons, wipers, high beams, ambient light
/vehicle/wheel_speed_report	dbw_mkz_msgs/WheelSpeedReport	100 Hz	wheel speeds, magnitude only
/vehicle/surround_report	dbw_mkz_msgs/SurroundReport	5 Hz	parking sonars, blind spot, cross traffic alert
/vehicle/tire_pressure_report	dbw_mkz_msgs/TirePressureReport	2 Hz	tire pressure (4 wheels)
/vehicle/fuel_level_report	dbw_mkz_msgs/FuelLevelReport	10 Hz	fuel level
/vehicle/imu/data_raw	sensor_msgs/Imu	100 Hz	accel, gyro, missing pitch gyro
/vehicle/gps/fix	sensor_msgs/NavSatFix	1 Hz	latitude, longitude, altitude
/vehicle/gps/vel	geometry_msgs/TwistStamped	1 Hz	velocity in global frame
/vehicle/twist	geometry_msgs/TwistStamped	50 Hz	speed and yaw rate computed from steering report

3 Twist Controller Node

3.1 Subscribed Topics

cmd_vel (geometry_msgs/Twist)

Desired forward speed and yaw rate command. **linear.x** should have the forward speed in m/s, and **angular.z** should have the yaw rate in rad/s. Acceleration limits are set via dynamic reconfigure.

cmd_vel_stamped (geometry_msgs/TwistStamped)

Same as the **cmd_vel** topic. This topic is supported simply for compatibility reasons. As such, the node ignores the time stamp.

cmd_vel_with_limits (dbw_mkz_msgs/TwistCmd)

Same as the **cmd_vel** topic, except the acceleration limits can be set by the **accel_limit** and **decel_limit** fields of the message. The dynamic reconfigure acceleration limits are still used as absolute maximum values, but the **accel_limit** and **decel_limit** values can be used to specify more restrictive acceleration limits.

steering_report (dbw_mkz_msgs/SteeringReport)

Steering report message published from the main drive-by-wire node. Used to extract the vehicle speed measurement, which provides feedback to the outer speed control loop, and is used to derive a filtered acceleration estimate for the inner acceleration control loop.

imu/data_raw (sensor_msgs/Imu)

Built-in vehicle IMU data published from the main drive-by-wire node. Used to obtain yaw rate measurement.

dbw_enabled (std_msgs/Bool)

System-level enable signal published from the main drive-by-wire node. Used to avoid undesirable integrator wind-up.

fuel_level_report (dbw_mkz_msgs/FuelLevelReport)

Current fuel level percentage published from the main drive-by-wire node. Used to account for fuel mass when using vehicle mass for deceleration control.

3.2 Published Topics

throttle_cmd (dbw_mkz_msgs/ThrottleCmd)

Throttle pedal command output to main drive-by-wire node.

brake_cmd (dbw_mkz_msgs/BrakeCmd)

Brake pedal command output to main drive-by-wire node.

steering_cmd (dbw_mkz_msgs/SteeringCmd)
: Steering wheel command output to main drive-by-wire node.

3.3 Parameters

~control_rate (float64, default: 50.0)
: Control loop execution rate in Hz.

3.4 Dynamic Reconfigure Parameters

~pub_pedals (bool, default: True)
: Enable the publishing of the throttle and brake pedal commands.

~pub_steering (bool, default: True)
: Enable the publishing of the steering wheel command.

~speed_kp (float64, default: 2.0)
: Proportional gain for outer speed control loop.

~decel_max (float64, default: 3.0)
: Maximum amount of deceleration output allowed from the inner acceleration control loop (m/s^2).

~accel_max (float64, default: 3.0)
: Maximum amount of acceleration output allowed from the inner acceleration control loop (m/s^2).

~max_lat_accel (float64, default: 8.0)
: Maximum lateral acceleration allowed by the steering controller. Requested yaw rate is ignored to saturate the lateral acceleration to this parameter's value.

~steer_kp (float64, default: 0.0)
: Proportional gain on the closed loop term of the feed-forward steering controller.

~wheel_radius (float64, default: 0.2413)
Effective wheel radius in meters.

~vehicle_mass (float64, default: 1736.35)
Curb weight of vehicle in kg.

~fuel_capacity (float64, default: 13.5)
Fuel tank capacity in gallons.

~accel_kp (float64, default: 0.4)
Proportional gain for the inner acceleration control loop.

~accel_ki (float64, default: 0.1)
Integral gain for the inner acceleration control loop.

~brake_deadband (float64, default: 0.1)
Amount of deceleration that must be requested before braking is applied (m/s^2).

~accel_tau (float64, default: 0.5)
Time constant in seconds for the acceleration feedback measurement filter.

3.5 Controller Structure

3.5.1 Speed Controller

Figure 1 shows a diagram of the speed controller, which inputs a speed command and produces throttle and brake pedal outputs to achieve that speed. The vehicle speed measurement feedback comes from the **steering_report** topic. Acceleration feedback is derived by running the speed measurement through a differentiator and first-order low pass filter, where the time constant τ is set by the **accel_tau** parameter.

The outer speed control loop uses proportional control with gain K_p, whose value is set by the **speed_kp** dynamic_reconfigure parameter. The output of the controller is an acceleration command, whose value is clamped between the maximum acceleration and

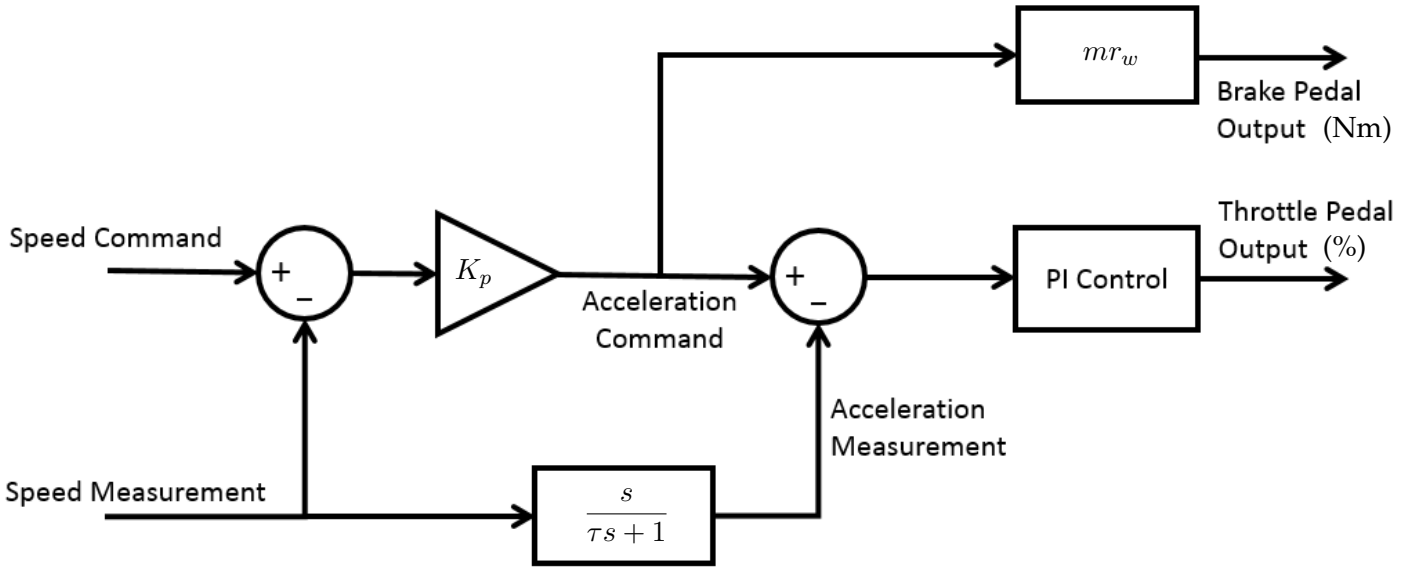

Figure 1: Diagram of the speed controller.

deceleration values set on the **accel_max** and **decel_max** parameters.

Using available vehicle CAN data, a very accurate mapping from brake pedal position to applied braking torque is known. Therefore, for braking, the requested acceleration is multiplied by the vehicle mass and wheel radius to generate a braking torque output. Vehicle mass is determined by the **vehicle_mass** and **fuel_capacity** parameters. Effective wheel radius is set on the **wheel_radius** parameter. The braking torque is only computed and applied when the requested acceleration is negative, and its magnitude is greater than the deadband value set on the **brake_deadband** parameter.

However, there is not a consistent mapping from throttle pedal position to drive force, so an inner PI control loop is used to control the throttle. The filtered acceleration measurement is subtracted from the requested acceleration, the result of which is passed through the PI controller whose gains are set on the **accel_kp** and **accel_ki** parameters. The output of the PI controller is the throttle percentage that is output to the drive-by-wire node. The throttle position is only computed and applied when the requested acceleration is positive.

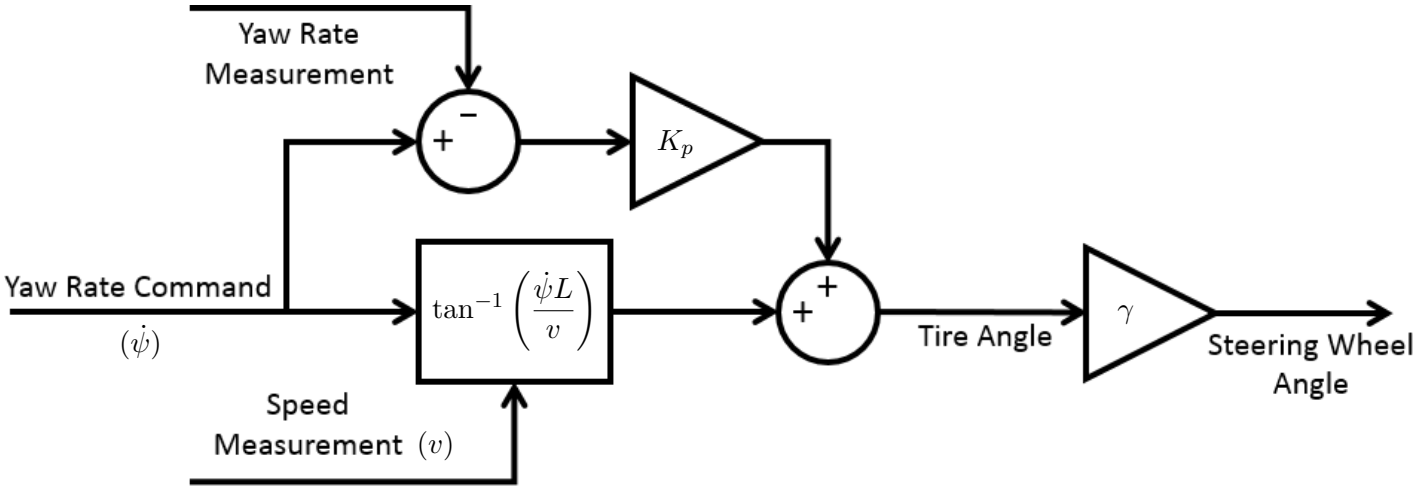

Figure 2: Diagram of the feed-forward steering controller.

3.5.2 Steering Controller

Steering control is implemented with a feed-forward proportional controller, a diagram of which is shown in Figure 2. The requested yaw rate and current speed measurement are used to compute a nominal steering angle based on a simple kinematic bicycle model. The wheelbase length L for the MKZ is 112.2 inches.

A closed loop term is added, where the error between requested and actual yaw rate is multiplied by the gain K_p set on the **steer_kp** parameter. This combined tire angle is then converted to steering wheel angle by multiplying by the steering ratio γ, which is 14.8 : 1.

While turning with significant lateral acceleration, the car body roll affects the accuracy of the yaw rate measurement from the built-in vehicle gyro because the axis of rotation becomes slightly misaligned with the vehicle gyro's sensitive axis. Experiments have shown that the vehicle performs better in tighter turns with just the feed-forward control term because of this effect. Therefore, the proportional gain of the feed-forward steering controller is set to zero by default. If a more sophisticated IMU output is used, such as the Oxford GPS system, a non-zero proportional gain would most likely improve performance.