

Motion Control Module for Liftgate, Sliding Door, Sunroof, and Similar Applications



Cars have several closure applications where multiple motors are managed by a single electronics control unit (ECU). Examples include power liftgates, power trunk lifts, and front-trunks (“frunks”), power sliding doors, and sunroofs. While each of these applications have their own specific functions and requirements, there are common characteristics that are shared.

This design from Texas Instruments provides a full-featured, cost-effective, flexible, and robust design for driving multiple motors in these applications. [Figure 1](#) and [Figure 2](#) show two versions of a typical liftgate block diagram.

The first version connects to a CAN-FD network, and implements the features to independently control the bi-directional motion of four brushed DC motors, as well as inputs for a user button and pinch sensor, and outputs for LED illumination and a warning beeper.

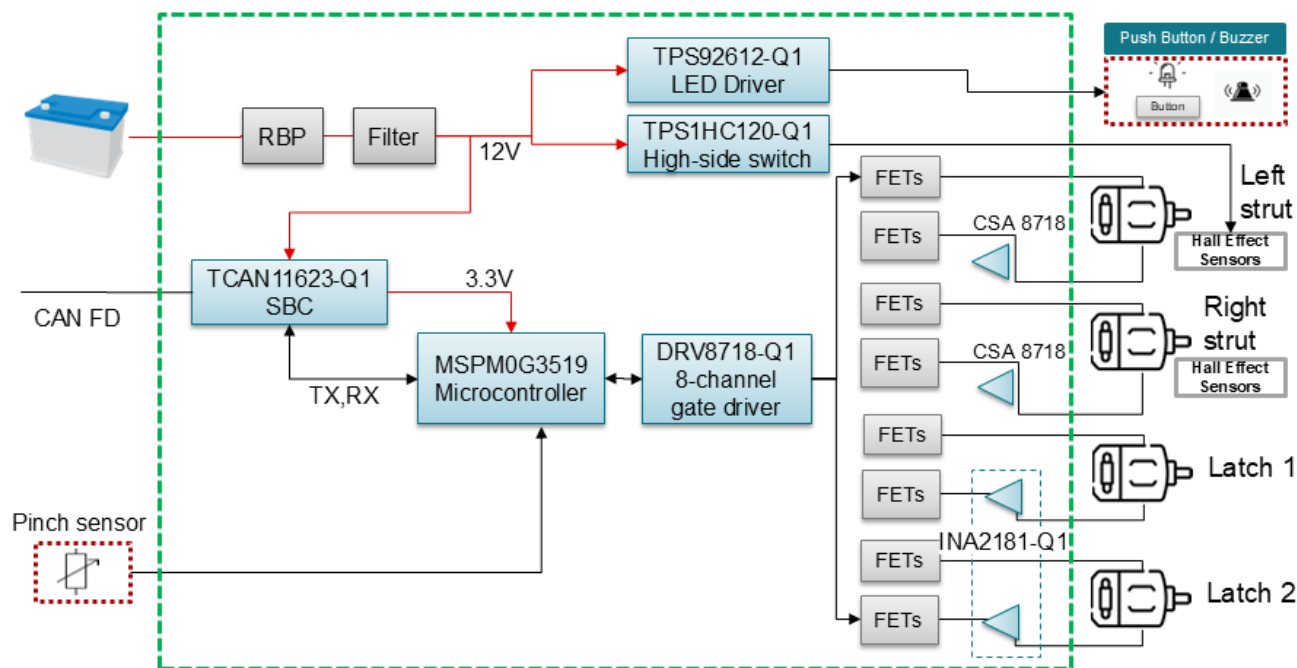


Figure 1. Block Diagram of a Typical Liftgate Design With CAN-FD SBC

The second version has similar functions, but replaces the CAN-FD with Ethernet 10 Base-T1S connectivity. This allows Ethernet messaging to be used throughout the vehicle.

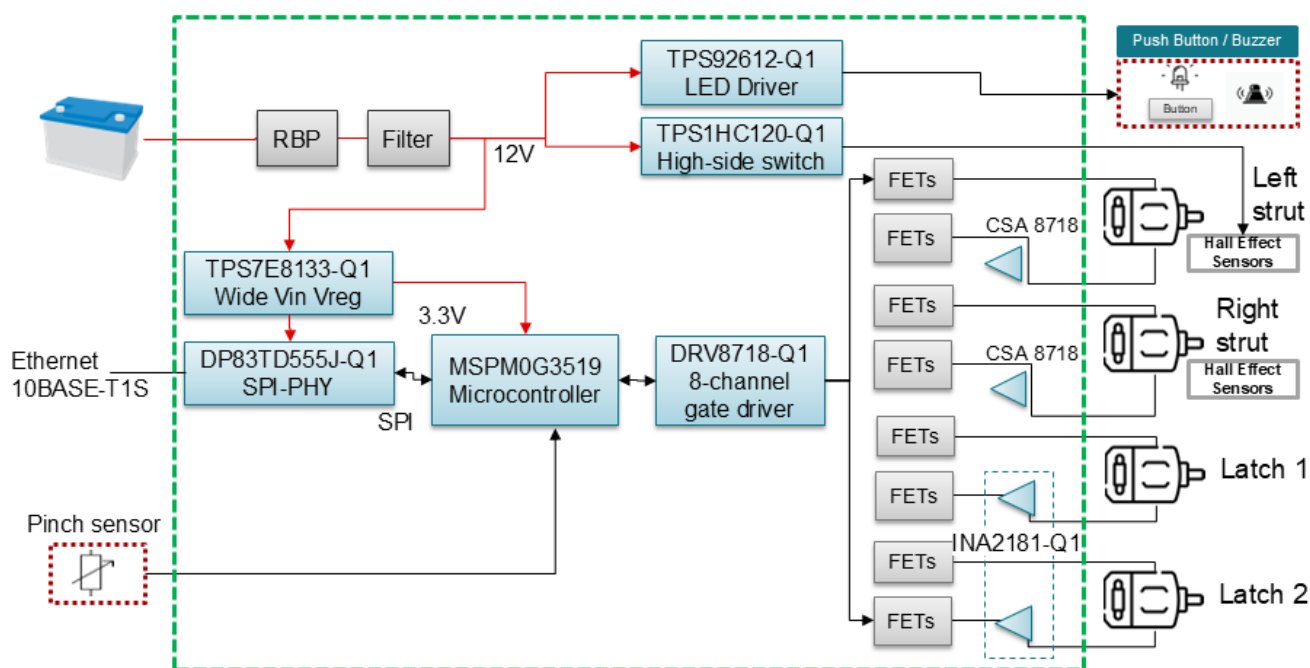


Figure 2. Block Diagram of a Typical Liftgate Design With Ethernet 10 Base-T1S PHY

In this design, either version (CAN-FD or Ethernet 10 Base-T1S) can be implemented by populating different components on the circuit board.

Although initially designed for liftgates, similar applications share many of these components and common features.

Features and Specifications

This design incorporates several features that are common to liftgates and similar multi-function applications:

- Coordinated motion of multiple brushed DC motors
- Control of motors with end-of-travel detection using current or switch feedback
- Hall-effect sensors providing motion feedback
- CAN or Ethernet connection to the vehicle network
- Button inputs for manual control
- Low sleep current with wake from network messages or in response to button changes
- Analog anti-pinch sensor input with high accuracy
- Control of LED current for user button backlighting
- Beeper to alert users of moving mechanism

Table 1 lists some of the specifications for the design performance.

Table 1. Specifications for Performance

Specification	Nominal	Limiting
Input voltage range	8V to 16V	Reverse voltage protected, transients up to 40V
Motors	4 brushed DC motors with independent bi-directional motion	Up to 7 brushed DC motors with some restrictions on simultaneous motion direction
Motor current	20A	Limited by choice of MOSFETs and connector
Sleep current	< 50uA	< 100uA
Pinch sensor accuracy	±1%	Limited by resistor tolerance
LED current	10mA	150mA
Hall effect supply current		1.5A total (thermally limited)

Coordinated Motion of Multiple Brushed DC Motors

Liftgates can use one or two strut motors to raise and lower the back hatch. The motion of these motors must be synchronized to avoid uneven motion that can stress the mechanical components. Latches secure the hatch in place when closed; this also requires coordination between the strut motors and the latch motors. Other multi-motor applications like sunroofs or sliding doors can have similar requirements for coordinated motor control.

The DRV8718-Q1 controls eight half bridges to drive up to seven bi-directional brushed DC motors. With proper selection of external MOSFETs, the motor current can be as high as needed. For completely independent control of four motors, each pair of half bridges can be assigned to a single motor. If fewer motors are needed, the DRV8714-Q1 is a similar part with four half-bridge gate drivers.

Table 2 lists typical motor current levels, assuming a 12V system, for various applications.

Table 2. Typical Motor Currents

Liftgate struts	Liftgate latch	Sliding door	Sunroof
Up to 20A	Up to 10A	Up to 30A	Up to 20A

The MSPM0G3519-Q1 microcontroller works in concert with the gate driver and position feedback to keep the various motors coordinated. The microcontroller interprets messages from the vehicle network, controls the motors, and monitors the overall operation to diagnose fault conditions.

The microcontroller can be programmed using a standard 10-pin JTAG connector for customizing the design to a variety of applications.

Control of Motors With End-of-Travel Detection Using Current or Switch Feedback

To avoid mechanical binding, it is important to stop driving a mechanism when it reaches an end-of-travel point. This design has features to detect this condition as soon as the limit is reached. One method is to monitor the motor current, which is proportional to the torque. Current sense amplifier (CSA) components integrated in the DRV8718-Q1 provide feedback of the motor current through an in-line shunt resistor for two of the motors, and an INA2181-Q1 does the same for the other two motors.

Figure 3 shows example motor current measurements during a lift operation. The current during upward motion is approximately 5A with significant ripple, and then increases to over 10A as the mechanism encounters either an obstacle (color trace) or the end-of-travel (grey trace).

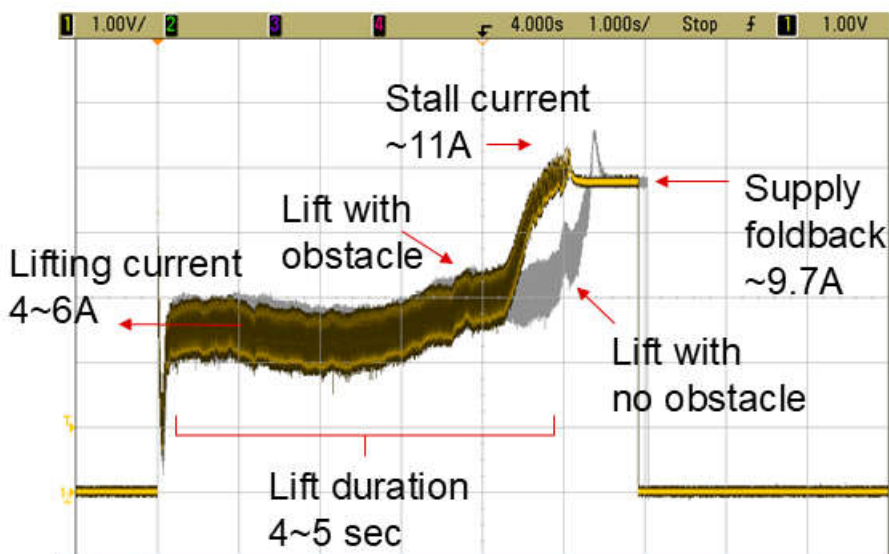


Figure 3. Motor Current Profiles - Lift With Obstacle Compared to Lift Without Obstacle

In addition to monitoring the motor current to detect a stall torque condition, this design also can use position feedback from Hall-effect sensors, detecting any slow-down in the rate of signal transitions, which can indicate end-of-travel. The design also has inputs for limit switches as another method of detecting that the mechanism has reached a stopping point.

Motion Feedback With Hall-Effect Sensors, or Sensorless

For accurate feedback of the mechanical position this design uses Hall-effect sensors which detect the rotation of a magnet mounted on the motor shaft. With a high gear ratio typical of these applications, the position can be determined with precise resolution and accuracy. This enables features such as soft closing and setting personalized maximum height for the lift gate.

Ripple counting is another method for detecting motor motion, using measurement of the motor current variation to detect rotation. The motor current for all four motors is sensed independently and provided to ADC inputs on the MSPM0, so designers can sample the current and use their own algorithms for ripple counting for motion feedback. Find more information about ripple counting see the [Solving Sensorless Brushed DC Motor Speed and Position Control Using Ripple Counting](#) application note.

Connection to the Vehicle Network

Liftgate modules and similar closure applications need to communicate with other components in the car, such as security systems and control consoles. A CAN serial bus is common for communication with the rest of the vehicle. This design has a TCAN11623-Q1 system basis chip (SBC) which includes not only a CAN transceiver and voltage regulator but also remote wake up through a pattern on the bus lines and a local wake input to allow a low-power state when the module is not active.

Ethernet 10BASE-T1S is a vehicle network that is increasingly being used in new designs. As high bit rate Ethernet is finding more utility in the automotive space, using 10BASE-T1S enables Ethernet protocol all the way to edge nodes, reducing the need for reformatting data packets.

This design includes an option to connect to a T1S network using a DP83TD555-Q1 Ethernet SPI-PHY with integrated MAC. For this configuration, the CAN SBC is depopulated, and a wide input voltage linear regulator, the TPS7E8133-Q1 supplies the 3.3V supply needed by the logic circuits. All Ethernet packets are translated to SPI messages by the SPI-PHY.

Button Inputs for Manual Control

Typically these applications can be controlled either remotely through the vehicle network or locally by buttons. This design includes circuitry for several button inputs, with level shifting and filtering on each signal. In addition to application for user inputs, the button inputs can be used during development for testing, and for diagnostic functions.

Low Sleep Current With Wake From CAN or Button Changes

When parked for long periods, the ECU must have very low current from the battery. The TCAN11623-Q1 system basis chip (SBC) supports an ultra low-power standby mode where the high-speed transmitter and normal receiver are switched off and a low-power wake-up receiver enables remote wakeup through the wakeup pattern (WUP) defined by ISO 11898-2:2016. A separate WAKE input pin allows local wakeup in response to a user button signal.

For the Ethernet version, the DP83TD555-Q1 has a similar low-power mode and a remote wake feature by which the ECU can be awakened by a remote wakeup event over the Ethernet data lines.

A TPS1HC120C-Q1 high-side switch, under control of the MCU, disconnects the battery voltage from the Hall-effect sensors and some on-board components when the module is in low-power sleep mode.

Figure 4 shows an oscilloscope measurement of the current to the board from a 12V supply as the board transitions from a low-current sleep state to an active state and then back to sleep. The current in sleep is less than 1mA and the current during the active state is approximately 28.5mA when none of the high-current loads (motors, beeper, and so forth) are active.

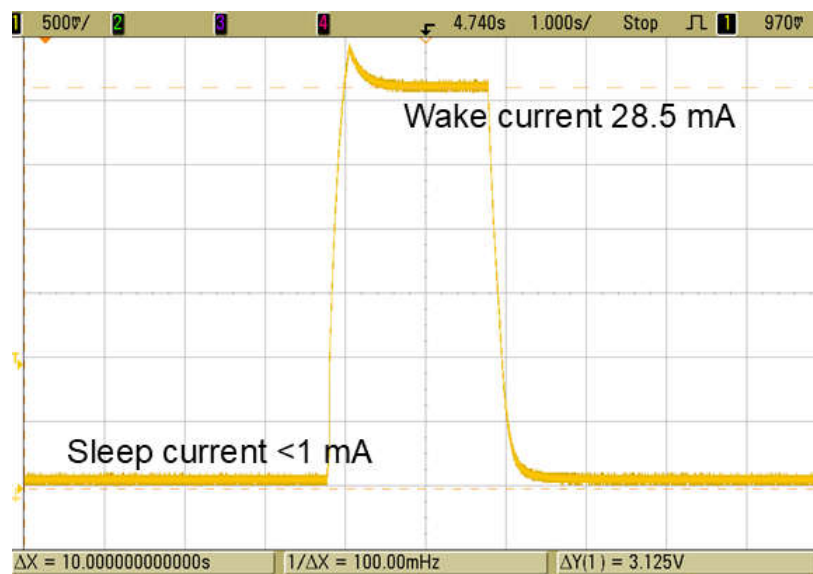


Figure 4. Current Profile Transitions During Sleep and Wake States

Analog Anti-Pinch Sensor Input With High Accuracy

To sense a pinch event, many closure applications include a pressure-sensitive strip along the edge of the closure surface. This design uses the analog-to-digital converter (ADC) integrated in the MSPM0 microcontroller together with a biasing circuit to detect changes in the resistance of such a pressure-sensitive sensor.

This approach provides flexibility in setting the threshold for detection of a pinch event, allowing end-of-line calibration and adaptation of the threshold to sensor wear or environmental changes.

Figure 5 shows ADC readings for several values of pinch detection sensor resistance, with tight accuracy to the ideal theoretical readings.

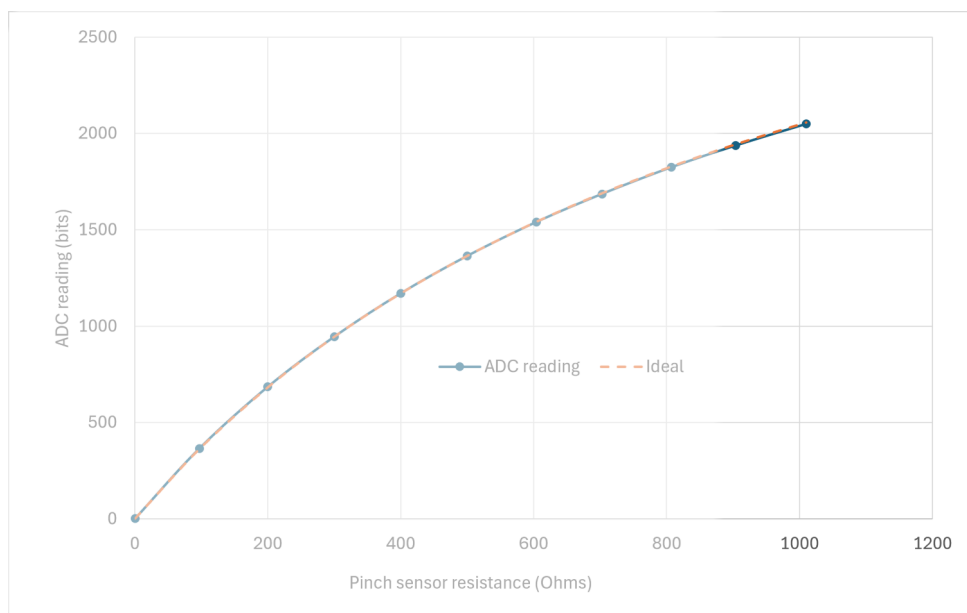


Figure 5. Pinch Sensor Accuracy Measurements

Control of LED Current for User Button Backlighting

LED backlighting on a user button, driven by the TPS92612-Q1 constant current LED driver, illuminates the button for operation in dark environments. It can also be used to signal a warning by flashing if a fault condition is encountered. Different sequences of flashing can be used to indicate various fault conditions, such as encountering an obstacle or overheating.

Beeper to Alert Users of Moving Mechanism

To alert people that the mechanism is being activated, an on-board beeper is controlled by the MCU and sounds before motion begins. While not required in all closure applications, the beeper is available as an option. Like the button illumination, this audible beeper can also be used to indicate fault conditions or to signal diagnostic information with coded sequences of beeps.

Conclusion

This design, shown in [Figure 6](#), implements the common features found in modules which drive liftgates, sliding doors, sunroofs and similar applications. Options for either CAN or Ethernet connection to the vehicle network are included. Designers can use this design as a starting point to accelerate new product development.

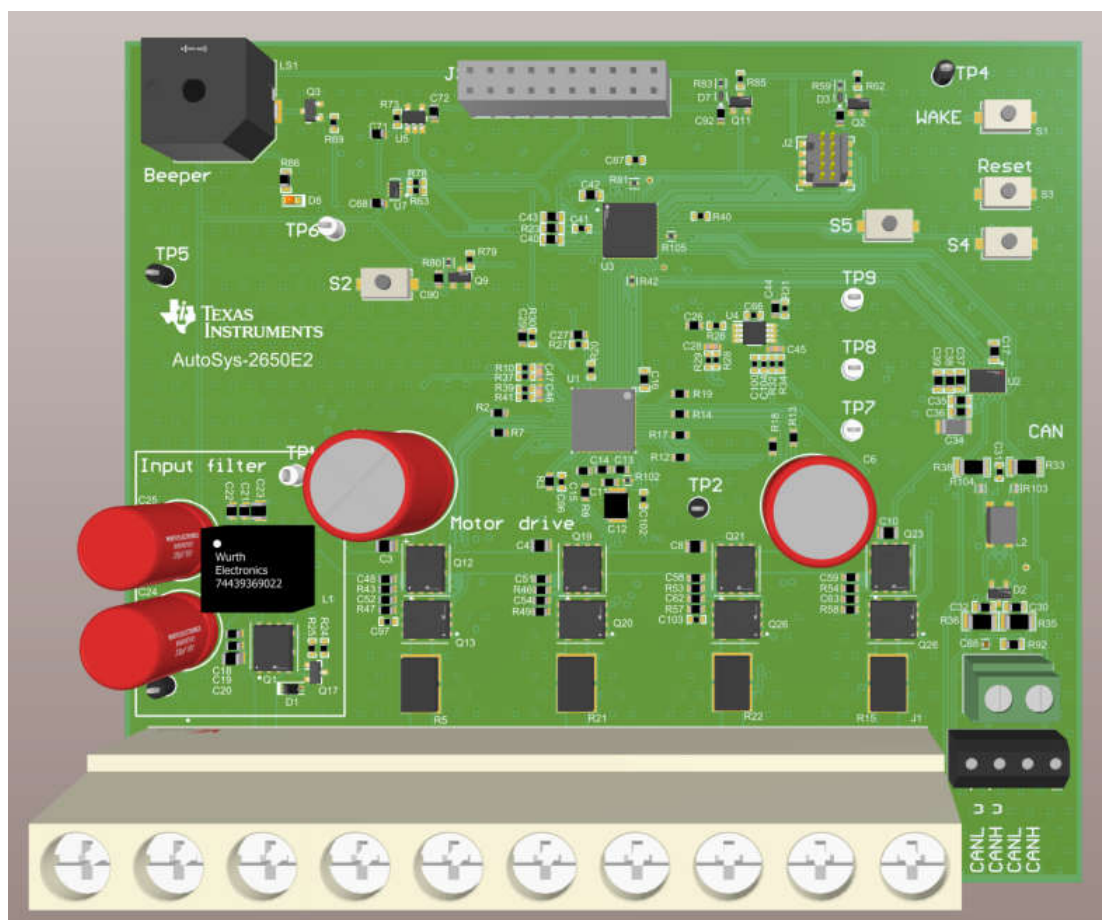


Figure 6. Board Layout

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