Application Brief

Current Sensing in Mobile Robots

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Current Sensing

Introduction

Mobile robots are widely used in warehouse settings. These mobile robots help to increase efficiency within warehouses by moving quickly around a facility and collecting items that are needed to fulfill orders in a timely manner. By using these mobile robots, warehouse operators can have reduced overhead cost, a continuous faster output, and warehouses can potentially be organized in more efficient configurations, as these mobile robots can reach places humans cannot easily access.

Mobile robots start at their home base where robots are charged and are stored. When the robot is called upon, the robot can move around the warehouse to pick up the requested items, and bring those items to a desired location, where either a human or another robot such as industrial robot can take the items to an assembly line or shipping line. The mobile robot typically uses brushless DC motors to move. An accurate phase current sensing is critical in motor control. A poor current sensing can lead to large torque ripple, audible noise, and inefficiency. Figure 1 illustrates where current sensing plays a role in motor-drive applications.

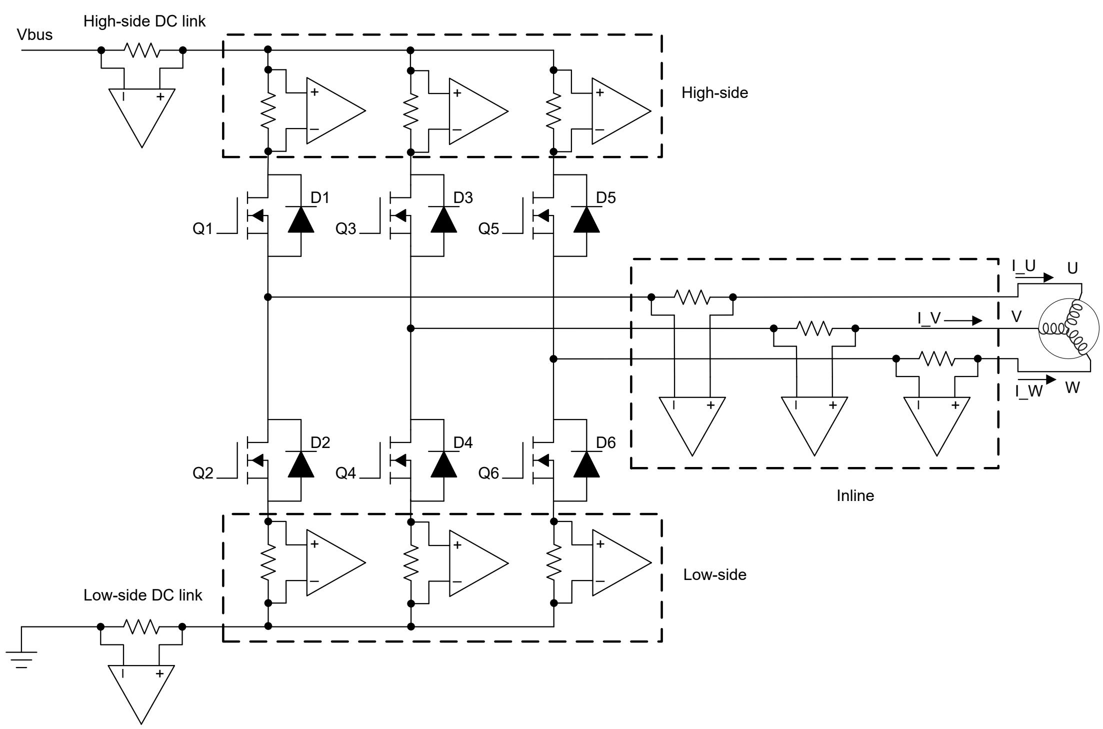

Figure 1. Methods of Motor Current Sensing in Mobile Robots

There are three methods of motor current sensing with their own positives and negatives as shown in Table 1. The best location to measure the motor current is directly inline with each phase due to continuity of signal measurement and direct correlation to the phase currents. In-line current sensing comes with the challenge where each motor phase is subjected to common-mode voltage transitions that can switch between large voltage levels over very short time periods. Current measurement in other locations, such as the low-side of each phase, requires recombination and processing before meaningful data can be utilized by the control algorithm. INA241A is designed for in-line motor current sensing. INA241A offers high CMRR of 166 dB and enhanced PWM rejection allowing for minimal error at the output in switching systems.

Table 1. Current Sensing in an H-Bridge

Current Measurement	Positives	Negatives
High-side	Detect shorted load from battery for diagnostics	High voltage common-mode amplifier
Inline	Direct motor current measurement, low bandwidth amplifier	High dv/dt signals. PWM settling time.
Low-side	Low cost, low common-mode voltage	Unable to detect shorted load.

The mobile robots typically have onboard 48-V lithium-ion batteries, and can be charged wirelessly or wired. Charging currents and discharging currents can be monitored through Texas Instruments' line of digital power monitors such as the INA228 and INA238. The INA228 can monitor current, voltage, power, energy, or charge up to 85-V common-mode input range with 20-bit resolution through an I2C output. This allows for the robot to monitor the battery levels to the onboard computer. INA228 can monitor battery level and when the battery level runs low, the mobile robot can report back to the home base to be re-charged.

There are several other subsystems within the mobile robot, such as DC/DC converters, onboard computers, lighting systems, radars, and so forth, that can use current sensing. DC/DC converters can use current monitors in the system such as the INA296A to monitor the safe level of current and to make the system more efficient. The onboard computer is the brain of the mobile robot, and typically operates on a 5-V rail. The onboard computer can leverage current sensing with a digital power monitor such as the INA219, to monitor current and voltage into the system to report back health or power usage in the system. Current monitors can also be used to monitor various peripherals on the robot such as the lighting and radar systems.

Using current monitors can verify these subsystems are operating correctly for safely preventing an incident with a human or physical structure. Monitoring current through the peripheral systems can enable the system to detect a malfunction and can have the robot return to home base for maintenance. The INA281 or INA296A can be used to monitor the current flow in these peripherals. Figure 2 shows one possible way current sensing can be used in point-of-load (POL) applications where understanding the current going to a specific load in the system is important. This can be used for diagnostics, safety, and protection.

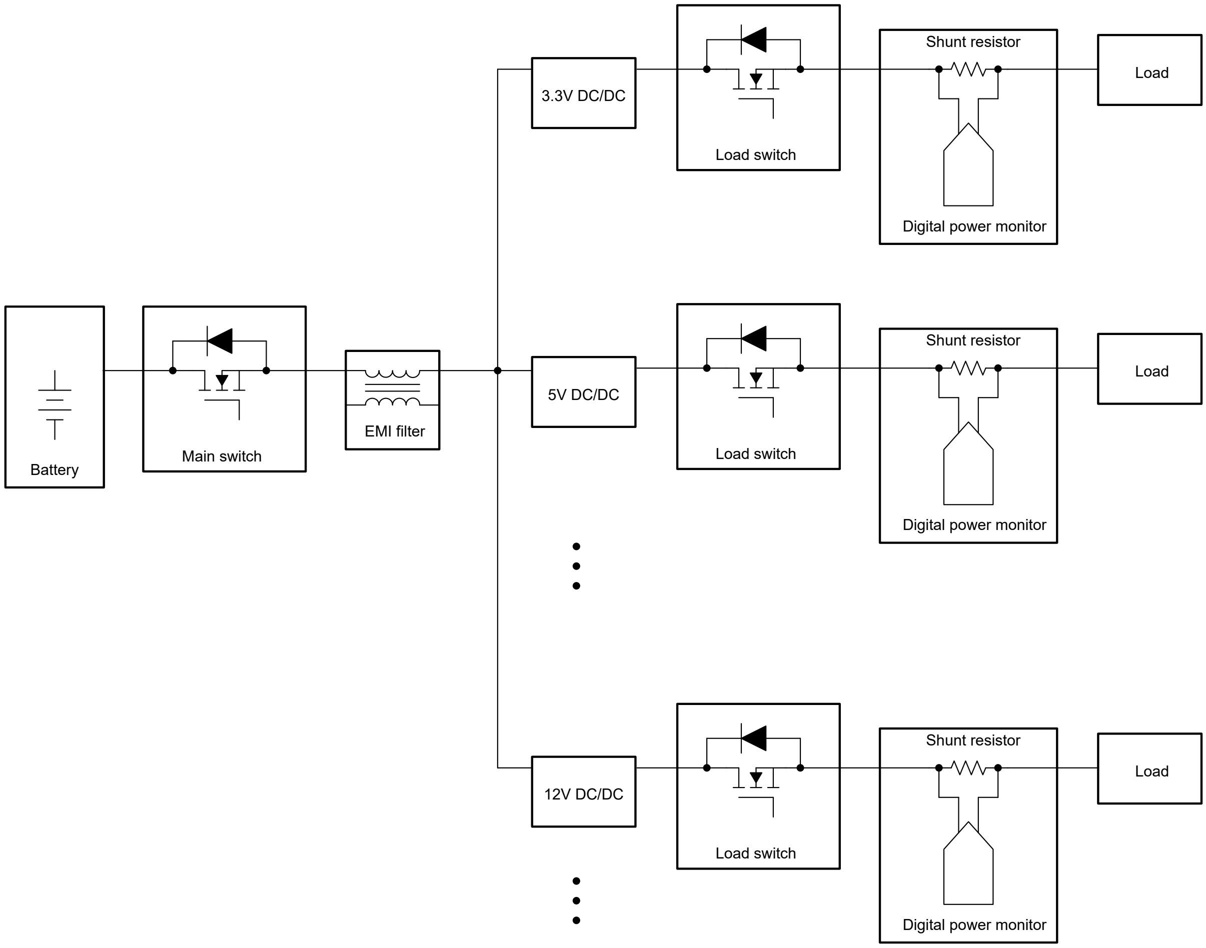

Figure 2. Power Monitoring at POL for Power System in Robotics

Conclusion

In conclusion, mobile robots are generally used in warehousing settings to reduce human involvement and speed up the movement of goods within the facility. Safety and efficiency are critical components of mobile robots. Leveraging various current-sensing techniques within the subsystems in motors, batteries, onboard computers, and peripheral systems can help these robots to operate safely and efficiently.

Alternate Device Recommendations

The INA241B is a high-precision, accurate analog current-sense amplifier. INA241B can be used in high-voltage bidirectional applications paired with 1.1-MHz bandwidth to offer fast response time with precise control for in-line control within H-bridge applications. The INA241B can measure currents at common-mode voltages of –5 V to 110 V and survive voltages between –20 V to 120 V, making the INA241B device an excellent choice for many systems.

The INA253 is an ultra-precise current-sense amplifier with an integrated low-inductive, precision 2-mΩ shunt with an accuracy of 0.1% and a temperature drift of < 15 ppm/°C. The INA253 is limited to applications that need < ±15 A of continuous current at T_A = 85°C. The INA253 integrated shunt is internally Kelvin-connected to the INA240 amplifier. The INA253 provides the performance benefits of the INA240 amplifier with the inclusion of a precision shunt providing a total uncalibrated system gain accuracy of < 0.2%.

The INA281 can be used in high-voltage applications such as high-side current sensing in a motor. The INA281 can measure currents at common-mode voltages of –4 V to 110 V and survive voltages between –20 V to 120 V, making the device versatile for a variety of applications where voltage can swing negative.

An option for low-side sensing is the INA381 which is a cost-optimized current-sense amplifier with an integrated comparator which serves to reduce PCB footprint size and simplifies design.

Table 2. Alternate Device Recommendations

Device	Optimized Parameter	Performance Trade-Off
INA241B	V_{cm} range: –5 V to 110 V Bidirectional	Slightly lower accuracy compared to INA241A
INA281	V_{cm} range: –4 V to 110 V	Unidirectional
INA381	Integrated Comparator	V_{cm} limited to 26 V
INA253	Integrated shunt 2 mΩ, V_{CM} range: –4 V to 80 V	±15-A maximum continuous current

Table 3. Related TI Application Briefs

Literature Number	Description
SBOA160	Low-Drift, Precision, In-Line Motor Current Measurements With PWM Rejection
SBOA176	Switching Power Supply Current Measurements
SBOA163	High-Side Current Overcurrent Protection Monitoring
SBOA555	Current Sensing in Collaborative and Industrial Robotic Arms