

# Application Brief

## Current Sensing in Mobile Robots



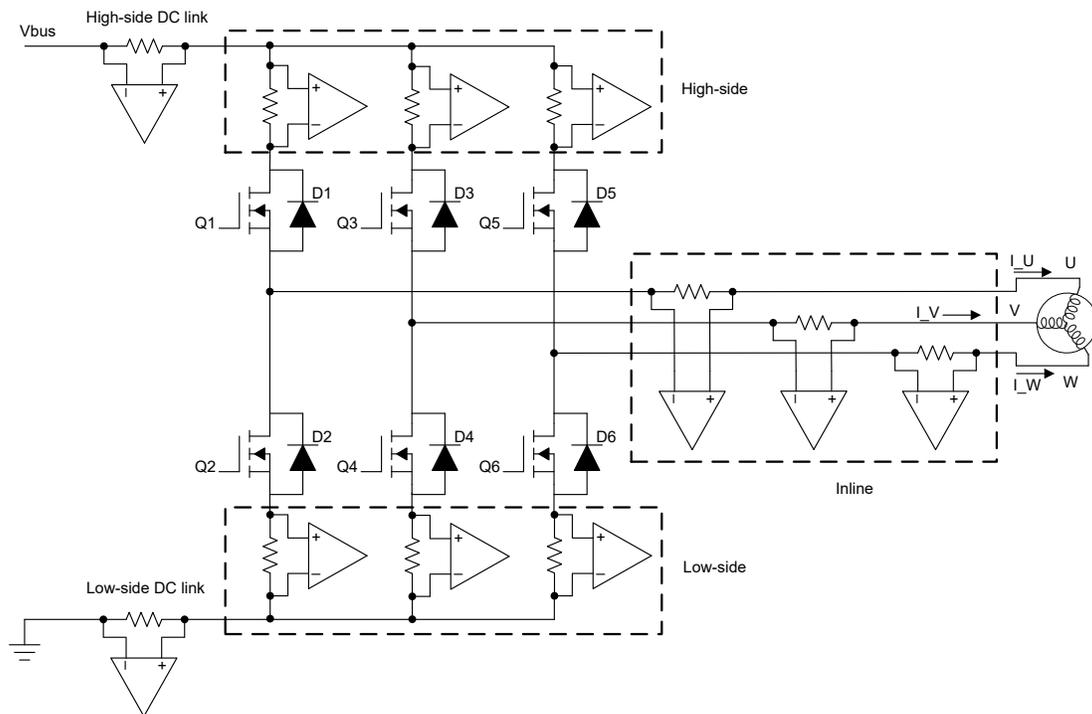
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Current Sensing

### 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 in-line 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.

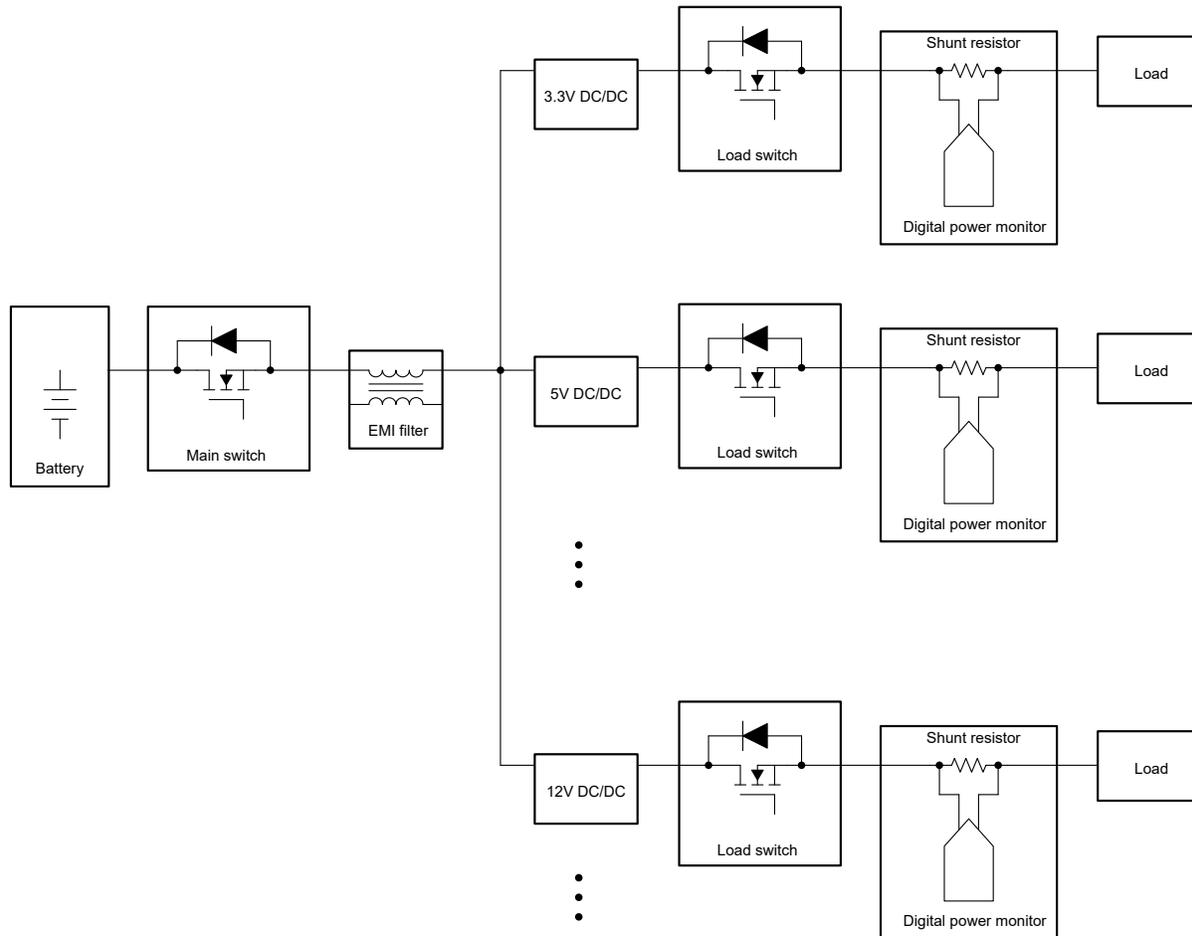
**Table 1. Current Sensing in an H-Bridge**

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-m $\Omega$  shunt with an accuracy of 0.1% and a temperature drift of  $< 15$  ppm/ $^{\circ}$ C. The [INA253](#) is limited to applications that need  $< \pm 15$  A of continuous current at  $T_A = 85^{\circ}$ 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
<a href="#">INA241B</a>	$V_{cm}$ range: -5 V to 110 V Bidirectional	Slightly lower accuracy compared to <a href="#">INA241A</a>
<a href="#">INA281</a>	$V_{cm}$ range: -4 V to 110 V	Unidirectional
<a href="#">INA381</a>	Integrated Comparator	$V_{cm}$ limited to 26 V
<a href="#">INA253</a>	Integrated shunt 2 m $\Omega$ , $V_{CM}$ range: -4 V to 80 V	$\pm 15$ -A maximum continuous current

**Table 3. Related TI Application Briefs**

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

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