Technical Article

# *Cobots to humanoids: Driving system efficiency and safety into higher-power robots*

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The robotics market continues to grow as manufacturing becomes more automated and consumers implement these systems into their homes. Companies are beginning to automate manufacturing systems into their factories and warehouses, and adjust to a future where robots interact more with humans.

Design engineers who create robots understand there are hundreds of different types of robotics systems. As shown in Figure 1, robots range from small, helpful cobots that operate with a few watts of power to autonomous mobile robots to humanoid robots to heavy-duty industrial robots that operate up to 4kW and greater.

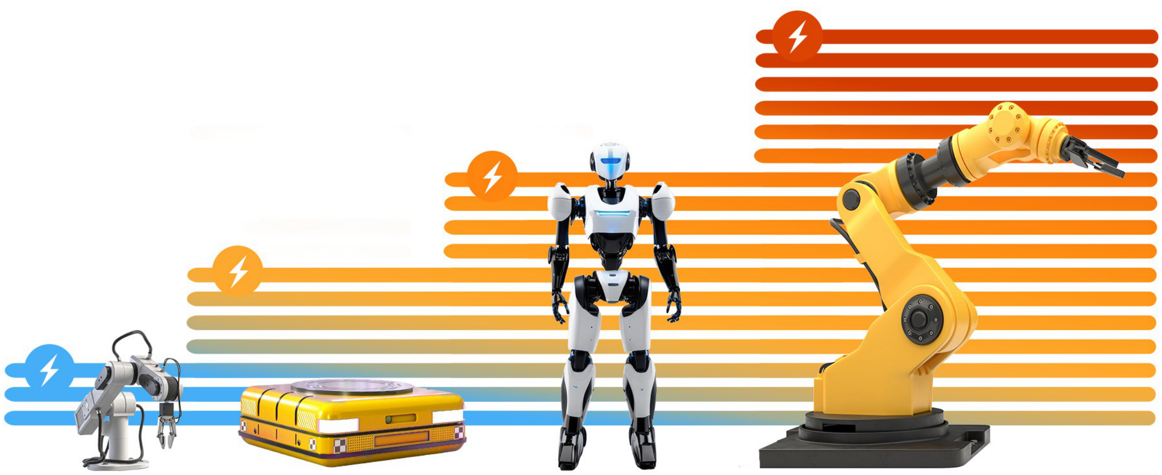

**Figure 1. Cobots, mobile robots, humanoids and industrial robots come in all shapes and sizes, with power levels ranging from 10W to ≥4kW**

Robot manufacturers encounter several design challenges when developing advanced systems. The above robotics applications typically use 48V rail and support payloads from 2kg to 40kg. Engineers designing for higher loads must consider both mechanical and design implications to accommodate higher power levels. Higher currents can result in poor system performance caused by electromagnetic interference (EMI) or high switching losses. Functional safety is also a big factor, since robots are often used in environments with humans. Designing systems that will safely shut down when necessary is extremely important, whether it's on a manufacturing floor or in a consumer's home.

Smart single half-bridge gate drivers such as TI's DRV8162 give you the flexibility to create integrated systems that can withstand large power and voltage ranges while reducing EMI and complying with functional safety standards.

### Designing for a wide range of power levels

Our smart gate drivers feature TI's IDRIVE adjustable gate drive current scheme to control MOSFET slew rates across multiple levels of gate current. The DRV8162 has 16 adjustable granular settings as shown in Figure 2 to control when selecting your MOSFET and end application. For more details about IDRIVE, read Understanding Smart Gate Drive.

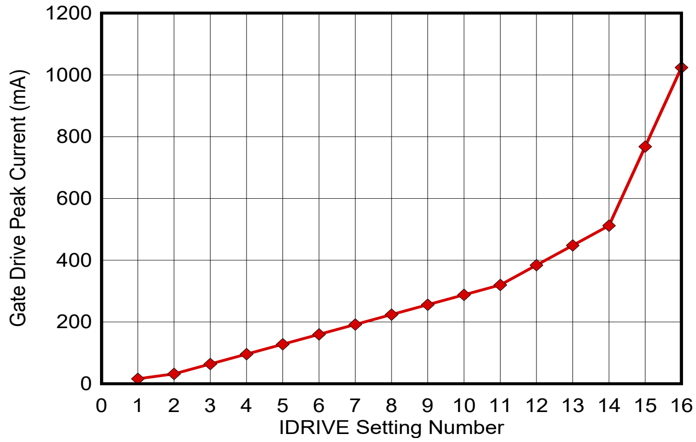


**Figure 2. The DRV8162's 16 IDRIVE settings and programmable sink and source ratio allow you to remove external passive components and simplify your design**

Using Equation 1, you can estimate what IDRIVE setting would be best for your system using the gate-drain charge (Qgd) specification of your MOSFET and the rise and fall time of the MOSFET's maximum voltage between drain and source. These values vary depending on your system performance requirements.

$$\text{IDRIVE}\left(\text{A}\right) = \frac{\text{Qgd (nC)}}{\text{Trise or Tfall (nS)}} \quad (1)$$

If the IDRIVE is not close to a gate drive setting in the device you're using, you will need additional passive components (including gate resistors) to achieve the required gate current. These additional components add to the overall bill-of-materials cost and contribute to added size in the printed circuit board (PCB), which can be worrisome for smaller designs in cobots, mobile robots and humanoid joints.

An external gate resistor is necessary when using competing half-bridge gate drivers, since they only provide a fixed current or two to four discrete settings. The 16 gate-drive settings in the DRV8162 driver and programmable source and sink ratio give you the flexibility to remove external passive components and simplify your design.

The wide Qgd support allows you to use the driver across various low-, mid- and high-power robotics platforms with different MOSFETs without having to change the gate driver design in each system. The source and sink gate currents for DRV8162 can be set as low as 16mA and 32mA respectively, and up to 1024mA and 2048mA. For example, a 1V/ns slew rate in a 48V system can be used to calculate a 48ns Trise/Tfall. This results in a range of 0.77nc/1.54nC to 49.15nC/98.30nC MOSFET Qgd that the device can support.

### Improving system performance

The DRV8162's single half-bridge architecture enables placement closer to the FETs than a three-phase integrated gate driver. Figure 3 shows two circular PCB designs comparing a three-phase to a single-phase half-bridge implementation.

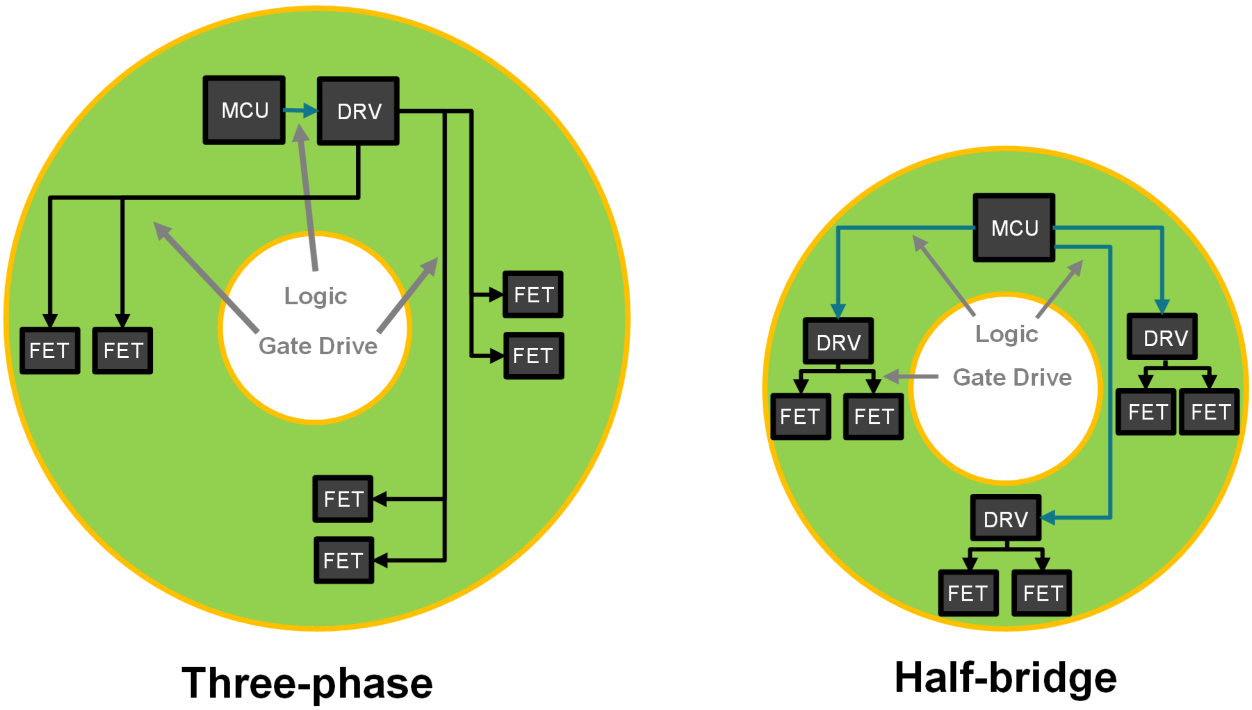


**Figure 3. Circular PCB designs with three-phase gate driver implementation with MCU, driver and FETs on the left and single half-bridge design on the right**

Placing the gate driver closer to the FETs reduces the length of traces, improves signal integrity, and reduces parasitics on the gate and source nodes. Shorter paths also help lower the effects of trace inductance, resulting in lower ringing and lower EMI.

In addition, DRV8162 helps improve system efficiency and acoustics with a 20ns dead time, which also helps enhance the operating pulse-width modulation duty-cycle range and thus the speed range, while increasing the available voltage to the motor. A lower dead time also minimizes diode conduction losses, improving system efficiency, and reduces motor current distortion and thus lowers audible noise. These effects improve overall performance and efficiency of the system.

### STO in robotics

Many robots operate alongside humans, so it's critical to shut down the system in case of a power failing power source, power surge or short-circuit. A failure to a motor-drive application where the torque of the device is unpredictable could result in a dangerous situation. Because some machinery operates in industrial environments that involve heavy loads, it is important to be able to safely shut down, as well as prevent unexpected startup.

The International Electrotechnical Commission (IEC) 61800-5-2 standard defines a safety function called safe torque off (STO) in circuit design, which prevents power to the motor. The DRV8162 and TI's DRV8162L incorporate a split-supply architecture to help you implement STO in your system.

In higher-power designs, engineers can refer to the 48V, 4kW Small Form-Factor Three-Phase Inverter Reference Design for Integrated Motor Drives (TIDA-010956), which features the DRV8162L with a $48V_{DC}$ input and $85A_{RMS}$ output current. As shown in Figure 4, this design includes a proposed STO concept, parallel FETs, high power and a single half-bridge gate driver.

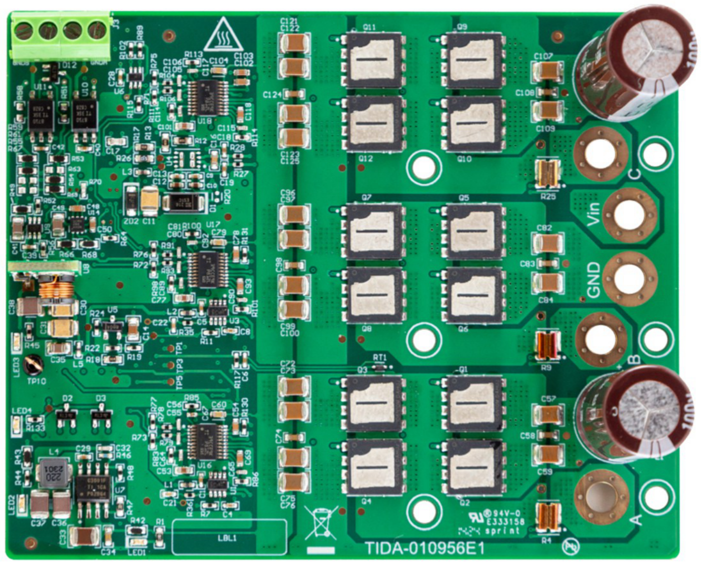


**Figure 4. TI's three-phase inverter reference design (TIDA-010956)**

## Conclusion

Existing motor designs for robots use discrete implementation to meet safety requirements, which increases the board size and bill of materials. Smaller, safer and integrated gate drivers such as the DRV8162 are needed to improve efficiency and safety in robots of all shapes and sizes. New smart single half-bridge gate drivers help designers scale power from 10W to 4kW and greater, while shrinking PCB size, improving performance and safety – and delivering the flexibility to accelerate robot innovation for many years to come.

## Additional resources

- Check out the application brief, Three-Phase Versus Three-Single Half-Bridge Gate Drivers (Literature No. SLVAFZO).
- Learn more about STO with the white paper, Integrating Voltage Monitoring for Safe Power Implementation in Industrial Stationary and Mobile Robots.
- Order the DRV8161EVM evaluation module to get started designing a 30A, three-phase brushless DC drive stage.

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