Application Note

Integrated FETs vs External FETs: Performance Comparison of Motor Drivers

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ABSTRACT

There are many factors to consider when selecting motor drivers, and one of the most important is deciding between integrated FETs or external FETs for the power stage. Integrated FET drivers reduce solution size and number of external components in the bill of materials, but the thermal performance of gate drivers is generally superior. With recent advances in semiconductor technology, integrated FET drivers from Texas Instruments are now able to support higher power requirements than ever before and can replace external FET gate drivers in many applications. This application report serves as a guide to explain the differences between integrated FET drivers and external FET gate drivers, comparing traditional motor driver solutions for high power against few recently released integrated FET drivers from Texas Instruments in regards to solution size, bill of materials, and thermal performance.

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1 Introduction

1.1 Gate Driver

In this topology, the power stage FETs and the FET controller are in different IC packages. Figure 1-1 shows the block diagram of a brushed-DC motor driver circuit with a controller chip, along with four external FETs. This arrangement allows the designer to select the controller and the FETs independently.

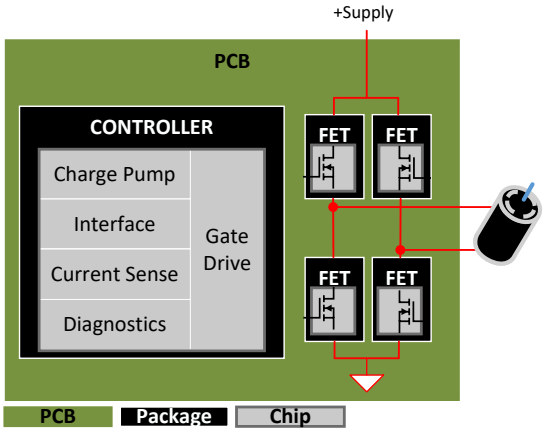


Figure 1-1. Gate Driver With External FETs

Gate drivers generally require more number of passive external components, and gate driver circuit design might involve a number of iterations so that the performance can be optimized.

1.2 Integrated FET Driver

A motor driver with an integrated FET means the power stage FETs are included inside the driver package, as Figure 1-2 shows. Integrated FETs minimize the design effort needed to get started with a motor drive application, as the FET characteristics are already selected to match the requirements of the specified motor current.

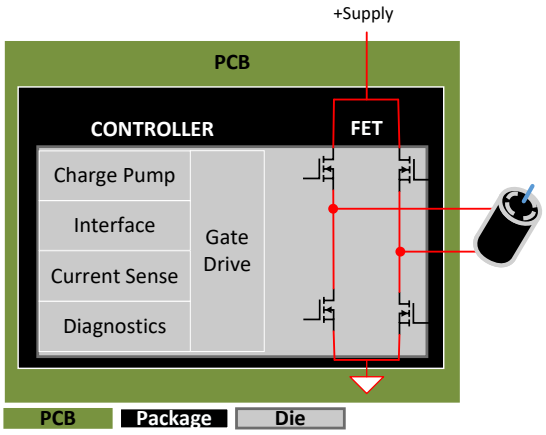


Figure 1-2. Integrated FET Driver

The integrated FET topology has been traditionally used for low to moderate motor current applications - for example, brushed-DC motors up to 10 A peak current and stepper motors up to 3 A full-scale current. The maximum current was primarily limited by the lowest possible on resistance of the FETs that could be integrated in the same monolithic die - it was difficult to integrate on resistance less than 300 mΩ if the voltage rating of the driver was close to 40 V or higher. For applications that needed higher currents, external FET gate drivers were used.

However, with recent innovations in analog process technologies, IC design and packaging technologies, latest integrated FET drivers from Texas Instruments are now capable of driving significantly higher current at a higher supply voltage. This is done by reducing the on resistance of the integrated FETs to 100 mΩ or lower. As shown in Table 1-1, several high-power integrated FET motor drivers for industrial and automotive applications have been introduced. These integrated FET motor drivers can replace external FET gate drivers which were the preferred solution for high power motor driver systems so far.

Table 1-1. High-Power Integrated FET Motor Drivers

Device	Type	Maximum Operating Voltage	Maximum Current	FET On Resistance
DRV8462	Stepper Driver	65 V	10 A	100 mΩ
DRV8452		48 V	5 A	100 mΩ
DRV8262	Brushed-DC Driver	65 V	20 A	50 mΩ
DRV8252		48 V	10 A	50 mΩ
DRV8243-Q1		35 V	12 A	85 mΩ
DRV8244-Q1		35 V	21 A	45 mΩ
DRV8245-Q1		35 V	32 A	30 mΩ
DRV8962	Half-bridge Driver	65 V	10 A	100 mΩ
DRV8952		48 V	5 A	100 mΩ

2 Integrated FET Driver vs. Gate Driver

There are several points to consider when selecting between an integrated FET driver and a gate driver -

- Integrating the FETs can often increase the IC package size. However, without the need of external FETs, the overall solution size decreases. Therefore, integrated FET drivers have significantly higher power density than gate driver solutions.
- With the FETs in the same IC package as the controller, complete testing of the whole driver during production assures the device will perform as expected.
- Another advantage to integrated FET topology is that the board layout and the overall design process can be more simple.
- However, integrated FET driver topology is not optimized for spreading power dissipation. For external FET gate drivers, having the flexibility of selecting FETs and driver independently allows handling of higher current.

Some of these points are explained in greater detail in the following subsections.

2.1 Solution Size

Solution size can play a major role in deciding which motor driver topology is going to be used. Solution size of a motor driver can vary significantly depending on whether it is an integrated FET driver or a gate driver.

Integrated FET drivers typically have smaller solution sizes than gate drivers because of the inclusion of the power FETs within the driver package. Applications for which PCB space is limited or a simple design without much flexibility is required, an integrated FET driver might be the best option. For example, applications such as PLC (programmable logic controller) and factory automation prefers integrated FET motor drivers, because the overall solution box size is decreasing in every generation of system design.

Another factor that needs to be taken into consideration when comparing the solution sizes of integrated FET drivers and gate drivers is the MOSFET drain-source on resistance ($R_{DS(ON)}$). This is where the flexibility of gate drivers can be useful. For same output power level, the external FETs can be selected with lower $R_{DS(ON)}$. Even if this makes the solution size larger for the gate driver, it allows for lower power loss and higher system efficiency.

Table 2-1 compares the PCB solution size of the DRV8262 H-Bridge integrated FET driver against the DRV8701 H-Bridge gate driver, both designed for 10 A peak current.

- The solution size for the DRV8262 is approximately 500 mm^2.
- The solution size for the DRV8701 is approximately 1400 mm^2, **2.8 times** the solution size of the integrated FET solution.
  - In other words, the integrated FET brushed-DC driver solution saves **64% PCB area** compared to the gate driver solution.

Table 2-1. Solution Size Comparison Between DRV8262 and DRV8701

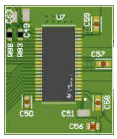
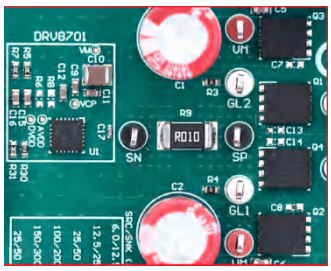
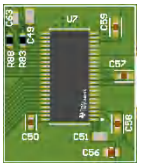
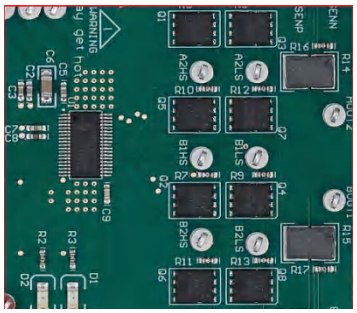
 **Figure 2-1. DRV8262 Solution Size**	 **Figure 2-2. DRV8701 Solution Size**
Solution Size: **20.3 mm x 24.2 mm**	Solution Size: **40.5 mm x 34.5 mm**

Table 2-2 compares the PCB solution size of the DRV8462 integrated FET stepper driver against the DRV8711 stepper gate driver, both designed for 5 A full-scale current.

- The solution size of the DRV8462 is approximately 500 mm^2
- The solution size for the DRV8711 is approximately 2400 mm^2, **4.8 times** the solution size of the integrated FET solution.
  - The integrated FET stepper driver solution saves **80% PCB area**.

Table 2-2. Solution Size Comparison Between DRV8462 and DRV8711

 **Figure 2-3. DRV8462 Solution size**	 **Figure 2-4. DRV8711 Solution size**
Solution size: **20.3 mm x 24.2 mm**	Solution size: **51 mm x 46.7 mm**

This comparison holds good for external FET gate drivers from other motor driver vendors as well.

2.2 External Bill of Materials

Motor drivers require external components like capacitors, resistors, and diodes connected from various pins of the motor driver to FETs, voltage supply, or ground. Regardless of whether it is an integrated FET driver or a gate driver, passive components surrounding the driver are necessary for certain bypassing, protection and control features.

As gate drivers have their FETs located externally, more passive components are expected to be present - leading to an increase in the external bill of materials. The following points must be considered by a system designer:

- An increase in size and external bill of materials comes with an increase in price.
- Too many components outside of the driver package makes the solution less reliable due to the possibility of any component failing.

Table 2-3 shows the comparison between the external BOM of DRV8262 and DRV8701.

Table 2-3. BOM Count Comparison Between DRV8262 and DRV8701

Device	DRV8262	DRV8701
Number of Resistors	2	9
Number of Capacitors	8	13
Number of MOSFETs	0	4
Total number of Components	**10**	**26**

Table 2-4 shows the comparison between the external BOM of DRV8462 and DRV8711.

Table 2-4. BOM count comparison between DRV8462 and DRV8711

Device	DRV8462	DRV8711
Number of Resistors	2	14
Number of Capacitors	8	7
Number of MOSFETs	0	8
Total number of Components	**10**	**29**

As is evident, integrated FET drivers require far lesser number of external components, leading to lower external BOM cost and higher reliability.

2.3 Thermal Performance

Traditionally, thermal performance of integrated FET drivers is difficult to manage for high power requirements. Since the power stage FETs are inside the package, it can be difficult dissipating the heat away. Gate drivers can handle higher current by selecting low $R_{DS(ON)}$ external FETs.

However, with the latest adavances of the monolithic IC design techniques, integrated FET motor drivers from Texas Instruments can now push the boundary of maximum current and deliver output power much higher than was possible few years ago. By doing this, integrated FET drivers can replace external FET gate drivers - thereby delivering significant PCB area savings and external BOM cost reduction to customers.

In addition to using low on resistance of the integrated FETs, latest stepper motor drivers like the DRV8462 and DRV8452 also integrate advanced features to reduce power loss and maximize system efficiency even further. The DRV8462 and DRV8452 have the following features to reduce power loss and temperature rise of the driver:

- **Auto-torque**: Reduces output current when STEP pulses are being applied, but the load torque is lower than peak load.
- **Standstill Power Saving Mode**: Reduces output current when STEP pulses are not being applied.
- **DDV Package**: The DRV8462, DRV8262 and DRV8962 further support a DDV package option. The DDV package allows mounting a heat sink on top of the package, and therefore can reduce the thermal resistance of the package to ultra-low values.

Figure 2-5 to Figure 2-8 show the thermal images of the DRV8462 EVM at room temperature ambient for:

- DDW package at 24V, 5A, 1/16 microstep, 6 kpps speed; with and without auto-torque enabled
- DDV package at 48V, 10A, 1/16 microstep, 6 kpps speed; with and without auto-torque enabled

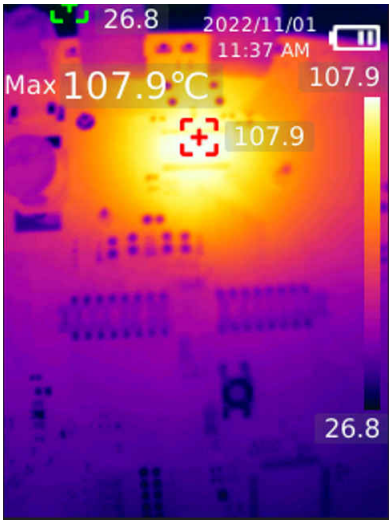


Figure 2-5. DRV8462, DDW Package, Auto-Torque Disabled

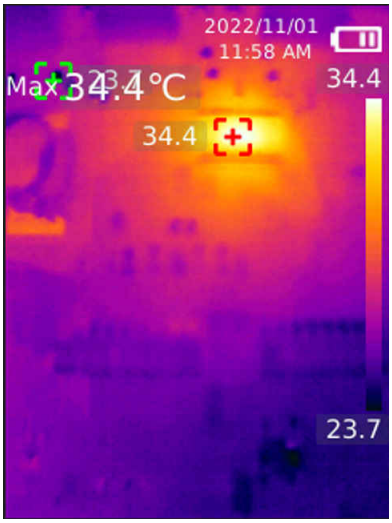


Figure 2-6. DRV8462, DDW Package, Auto-Torque Enabled

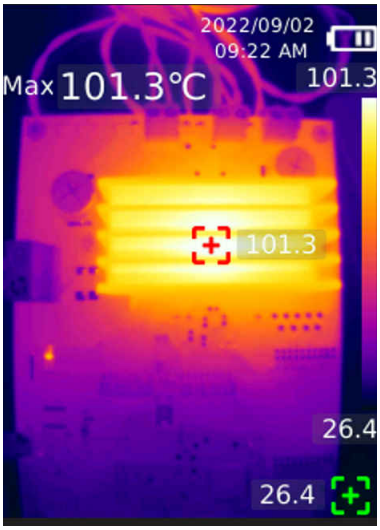


Figure 2-7. DRV8462, DDV Package, Auto-Torque Disabled

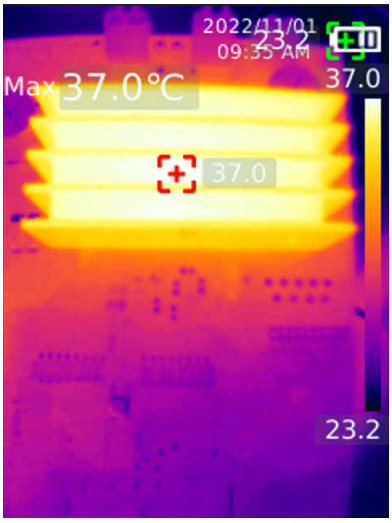


Figure 2-8. DRV8462, DDV Package, Auto-Torque Enabled

As seen in Figure 2-5 and Figure 2-7, without auto-torque, the DRV8462 IC and heat sink temperatures both exceed 100 °C. Moreover, the heat is concentrated in a small portion of the PCB - which makes it challenging to dissipate the heat away by increasing the PCB copper area or any other heat sinking method. With auto-torque enabled though, as seen in Figure 2-6 and Figure 2-8, temperature rise is minimal compared to the ambient temperature.

Figure 2-9 shows the thermal image for a DRV8711 EVM. Clearly the heat is spread out all over the PCB and concentrated over the external FETs, which makes it easier to cool down the solution by simple heat sinking methods.

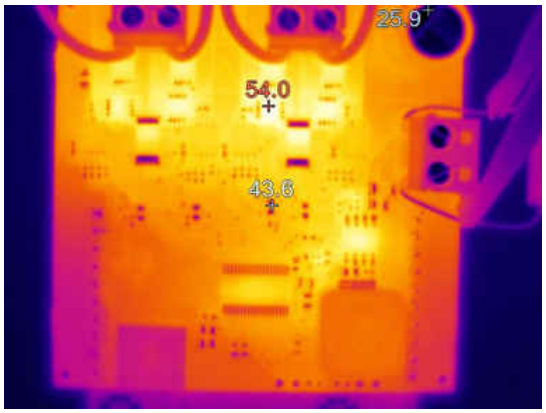


Figure 2-9. DRV8711 Thermal Image at 50 V, 3A, 1/8 Microstep, 1 kpps

3 Summary

In summary, when considering motor driver solutions, it is important to understand the tradeoffs with integrated FET drivers and gate drivers. Integrated FET drivers offer smaller solution size and simplicity in design while gate drivers offer flexibility in design and potentially better thermal performance. Recently launched integrated FET motor drivers from Texas Instruments make it possible to deliver up to 10 A to stepper motors and up to 32 A to brushed-DC motors, thereby making it possible to replace external FET gate drivers with integrated FET drivers in many applications.

4 References

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- Texas Instruments, *DRV8244-Q1 AutomotiveH-BridgeDriver with Integrated Current Sense and Diagnostics Data Sheet*
- Texas Instruments, *DRV8245-Q1 Automotive H-Bridge Driver with Integrated Current Sense and Diagnostics Data Sheet*

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