# Brushed DC motor driver selection

**How to choose a motor driver chip for typical automotive body electronics**

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In this presentation, we will discuss how you can choose a motor driver chip for your automotive body electronics application.

# Abstract

- TI offers different types of devices for driving automotive DC brushed motors
  - Single half-bridge or full-bridge motor drivers with integrated MOSFETs
  - Single half-bridge or full-bridge gate drivers for use with external MOSFETs
  - Multiple half-bridge motor drivers with integrated MOSFETs
  - Multiple half-bridge gate drivers for use with external MOSFETs
- This presentation discusses how to select which type of driver is best for different scenarios based on:
  - Number of motors
  - Motor use-case current profiles
  - Board space constraints
  - Thermal considerations
  - Current sense, diagnostics, etc.

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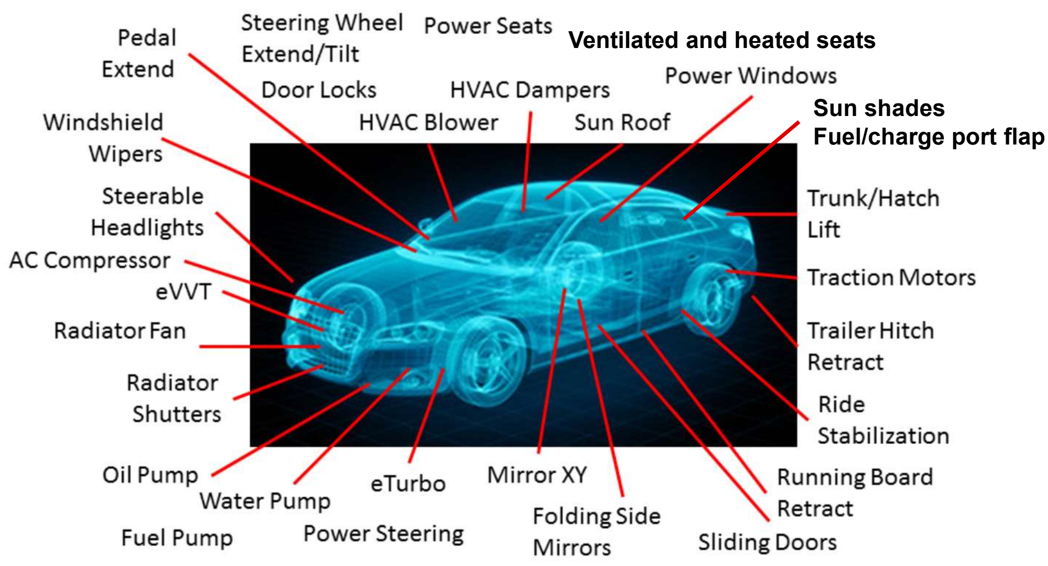
Texas Instruments offers motor driver chips to fit just about every automotive application.

TI offers motor drivers with one half-bridge for a single motor running in only one direction, and multi-channel motor drivers with up to 12 half-bridges in a single chip for multiple bi-directional motors. We also offer motor drivers with integrated MOSFETs as well as gate drivers for use with external MOSFETs, giving almost unlimited range in terms of motor current.

We will briefly discuss some of the selection criteria, such as how many motors or channels are needed, how much current is needed to drive the motor, the size of the motor driver circuit on a printed circuit board, and thermal constraints.

# Many motors in various applications

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Various types and sizes of electric motors are found throughout an automobile. DC brushed motors are commonly used in many automotive body applications due to their simplicity and cost-effectiveness. While every application is different, we can give some general guidance on selecting the right integrated circuit to best match the requirements.

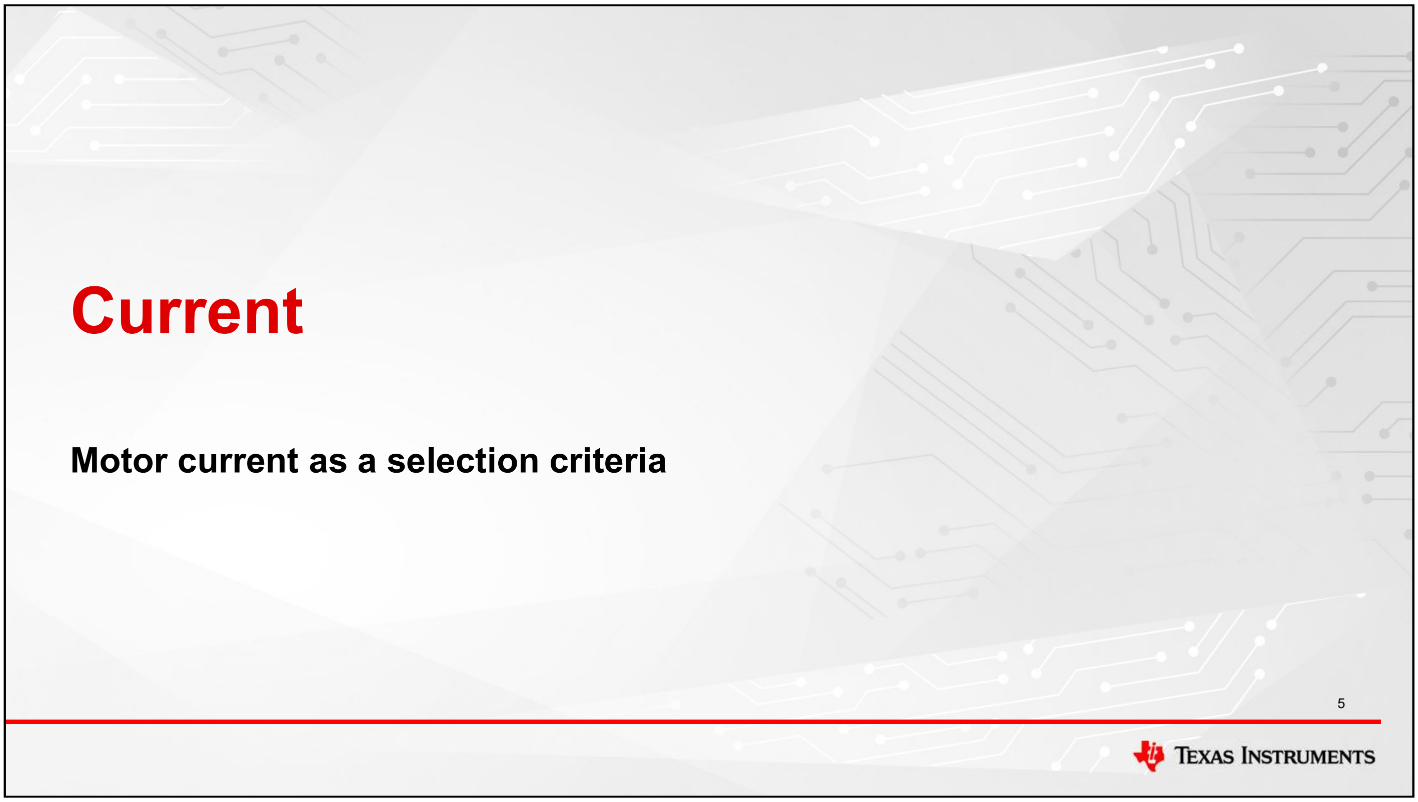
# Typical body motors

| Application | Uni- or bi-directional | Operation time (seconds) | Maximum current | Normal Current |
|---|---|---|---|---|
| Window | bi | 5 | 30A | 5A |
| Lock | bi | 1 | 10A | 2A |
| Seat | bi | 10 | 20A | 4A |
| Back hatch | bi | 10 | 10A | 3A |
| HVAC dampers | bi | 3 | 2A | 0.5A |
| Mirror fold | bi | 3 | 10A | 1A |
| Mirror x/y | bi | 5 | 1A | 0.2A |
| HVAC blower | uni | continuous | 10A | 2A |
| Wiper | uni | continuous | 30A | 10A |





This partial list of typical body motor applications shows the wide variation in requirements. Most applications require the motor to drive in two directions, but a few, such as cabin blower fans or windshield wipers, only need motor rotation in one direction. The operation time, which affects thermal calculations, can range from very short-duration such as door locks, to continuous operation for hours. The normal and maximum current levels can also vary widely, and that can have a strong influence on the selection of motor driver IC.




First let’s look at motor current as one way of deciding which motor driver IC to choose.

# A selection of TI automotive drivers

| Device (DRV_ _ _ _-Q1) | Type | Maximum Current (A) |
|---|---|---|
| 8105, 8106 | 1 half-bridge gate driver | high (external FETs) |
| 8705, 8706 | 2 half-bridge gate driver | high (external FETs) |
| 8714, 8718 | 4 or 8 half-bridge gate driver | high (external FETs) |
| 8145 | 1 half-bridge motor driver | 46 |
| 8144 | 1 half-bridge motor driver | 30 |
| 8143 | 1 half-bridge motor driver | 20 |
| 8245 | 2 half-bridge motor driver | 32 |
| 8244 | 2 half-bridge motor driver | 21 |
| 8243 | 2 half-bridge motor driver | 12 |
| 8873, 8874, 8876 | 2 half-bridge motor driver | 3.5 to 10 |
| 89xx | 4~12 half-bridge motor driver | 1 |



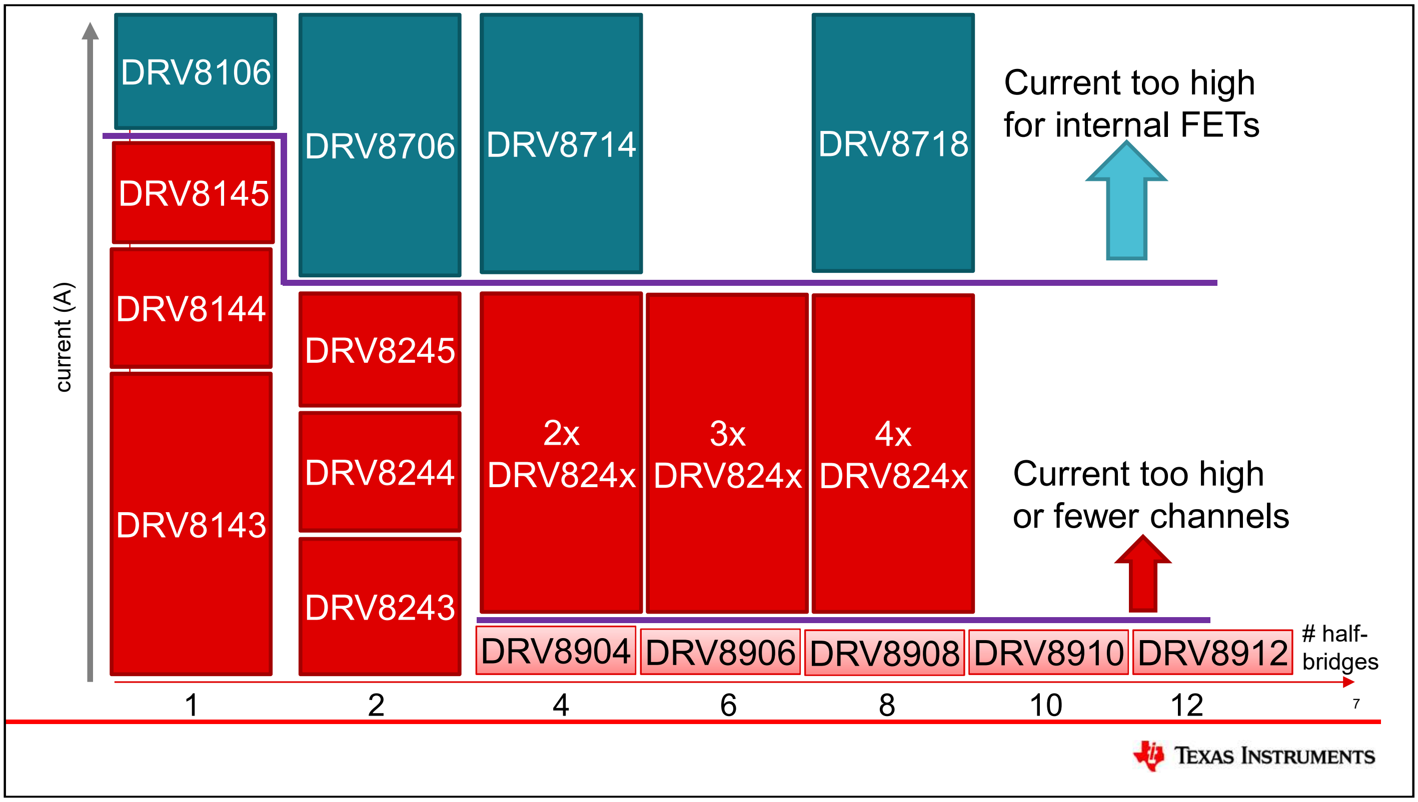


This table summarizes some of the popular automotive drivers for brushed DC motors.

The top blue rows are gate driver devices, which use external MOSFETs but otherwise integrate all the features needed to drive high-current motors. The maximum current they can drive is limited only by the characteristics of the external FETs.

The middle red rows are motor drivers with integrated MOSFETs, with a wide range of maximum current capability. These are offered as either single half-bridges, or full-bridge (two half-bridge) devices.

The bottom pink row is a family of multiple half-bridge drivers with integrated FETs. These devices are well suited for applications where several channels of relatively low current are needed.



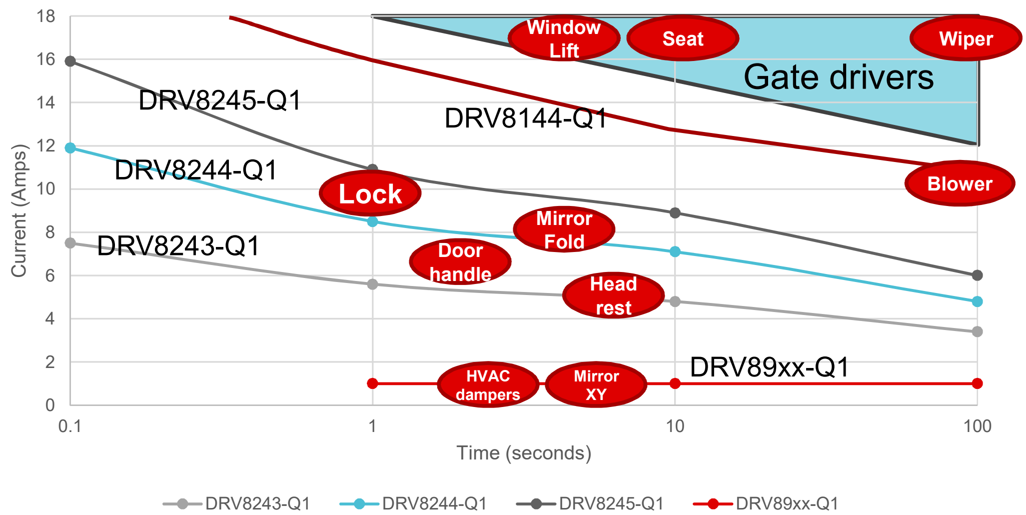

Another way to look at TI's brushed DC motor drivers is by the number of channels as well as current levels.

For low-current applications needing several half-bridges, the DRV8904-Q1 through DRV8912-Q1 are a good fit.

For single and dual half-bridges with medium current, the DRV81xx and DRV82xx-Q1 devices should be the first choice.

For high current applications, gate driver devices with external FETs should be used.

# Example applications plotted on current/time space




Based on initial thermal simulations using **40 mm x 40 mm x 1.6 mm, 4 layer PCB**, for **85 deg C** ambient temperature 8

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Here various applications are plotted with the current-versus-time curves for some of the motor drivers.

Lock motors typically operate for a second or less, and might have maximum currents up to 10 amps. The DRV8245-Q1 might be a good fit.

A power headrest could be adjusted for a few seconds with a current of about 5 amps. A DRV8243-Q1 would be a candidate.

The mirror fold motor could use a DRV8244-Q1 or DRV8245-Q1 to drive up to 10 amps for a few seconds.

Pop-out door handles with a maximum current of about 8 amps could select the DRV8244-Q1.

Lower-current motors for the ventilation dampers and side mirror adjustments could use a DRV89xx-Q1, with up to 12 half-bridges in one package.

Window lift motors can have currents well above 10 amps, so a gate driver with external FETs is a good choice.

There may be several seat motors with high current in each seat, so a multi-channel gate driver like the DRV8714-Q1 or DRV8718-Q1 is a good choice.

So far all of these applications have been bi-directional, but some motors only need to turn in one direction.

Windshield wiper motors are typically uni-directional, and rely on mechanical arrangement to turn the rotary motion into wiper motion. Due to their high current and long-duration operation, a gate driver with external FETis probably needed.

Similarly the cabin ventilation blower runs in one direction, and can run continuously. Depending on the current, a DRV8144-Q1 might be a candidate. Some blowers use brushless motors rather than brushed motors; for these look at TI’s BLDC motor drivers.

# Board size

**Board size as a selection criteria**

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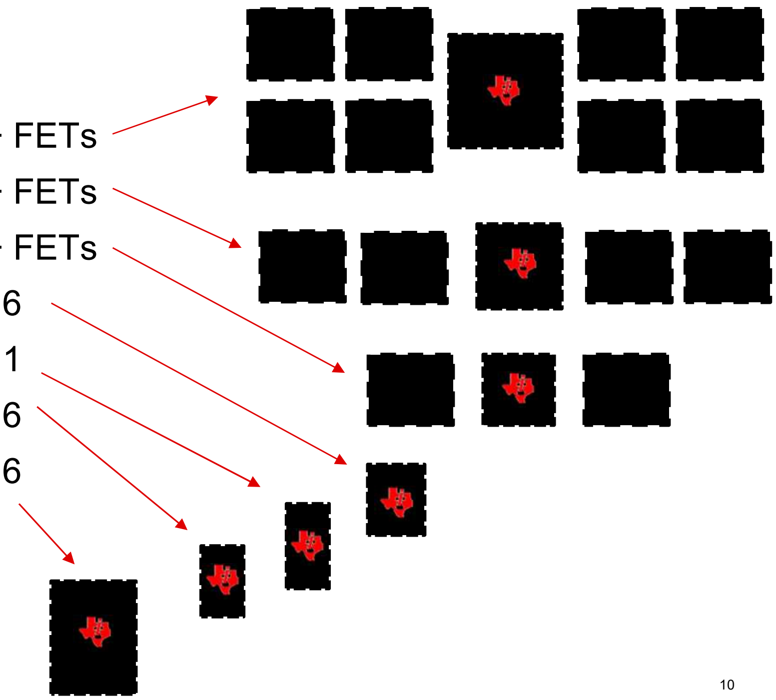
In many applications, board size is a significant constraint. Let's look at how the different choices compare in terms of area on the printed circuit board.

# Package sizes

| | | |
|---|---|---|
| DRV8718 | 66 mm² | 8 x 8 + FETs |
| DRV8714 | 37 mm² | 6 x 6 + FETs |
| DRV8x06 | 27 mm² | 5 x 5 + FETs |
| DRV8245 | 20 mm² | 3.6 x 5.6 |
| DRV8244 | 19 mm² | 3.1 x 6.1 |
| DRV8243 | 15 mm² | 3.1 x 4.6 |
| DRV89xx | 52 mm² | 7.9 x 6.6 |



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The DRV8718-Q1 and external FETs provide eight channels of high-current half-bridge drives. This view shows the relative sizes of the gate driver chip and eight dual-FET packages. This arrangement can drive four independent bi-directional motors, or up to seven motors with some constraints on simultaneous operation.

The DRV8714-Q1 and external FETs provide four channels of high-current half-bridge drives. This can drive two independent motors or up to 4 single-direction motors.

The DRV8706-Q1 with external FETs provides two channels of high-current half-bridge drives. This can drive one bi-directional high-current motor or two uni-directional motors.

The DRV8245-Q1 includes integrated drive FETs to control a bi-directional motor with a maximum current of 32 amps.

The DRV8244-Q1 can drive a bi-directional motor with a maximum of 21 amps.

The DRV8243-Q1 can drive a bi-directional motor with a maximum of 12 amps.

The DRV89xx-Q1 family of devices has 4, 6, 8, 10 or 12 half-bridges to drive multiple motors and loads with current up to 1 amp on each half-bridge output.

# 4 half-bridges with 2 current sense

| | | | | | |
|---|---|---|---|---|---|
| • DRV8714 | 37mm$^2$ | DRV8245 HTSSOP | 65mm$^2$ | in HR 20 mm$^2$ |
| • 8 FETs | 140mm$^2$ | DRV8245 HTSSOP | 65mm$^2$ | in HR 20 mm$^2$ |
| • 2 sense resistors | 62mm$^2$ | | | |
| • Sub-total | 239 mm$^2$ | | 130 mm$^2$ | 40 mm$^2$ |

- This does NOT include passive components or part-to-part spacing

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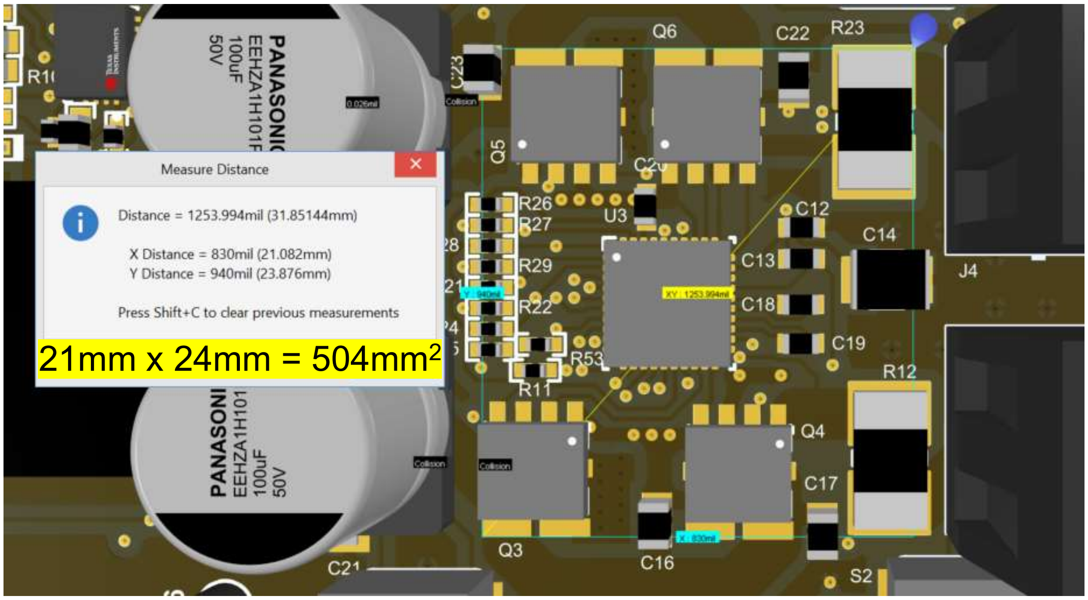
TEXAS INSTRUMENTS

If we consider just the package sizes, we can compare the area for either the gate driver with external FETs, or the integrated FET motor drivers. In the case where four half-bridges are needed, two of the DRV8245-Q1 devices in either the HTSSOP or Hotrod package are significantly smaller than using a gate driver solution. The gate driver with external FETs can be designed for very high currents, but if the current specifications of the integrated FET devices are sufficient, these have a clear size advantage.

# Board size example, 4 half-bridge with DRV8714-Q1

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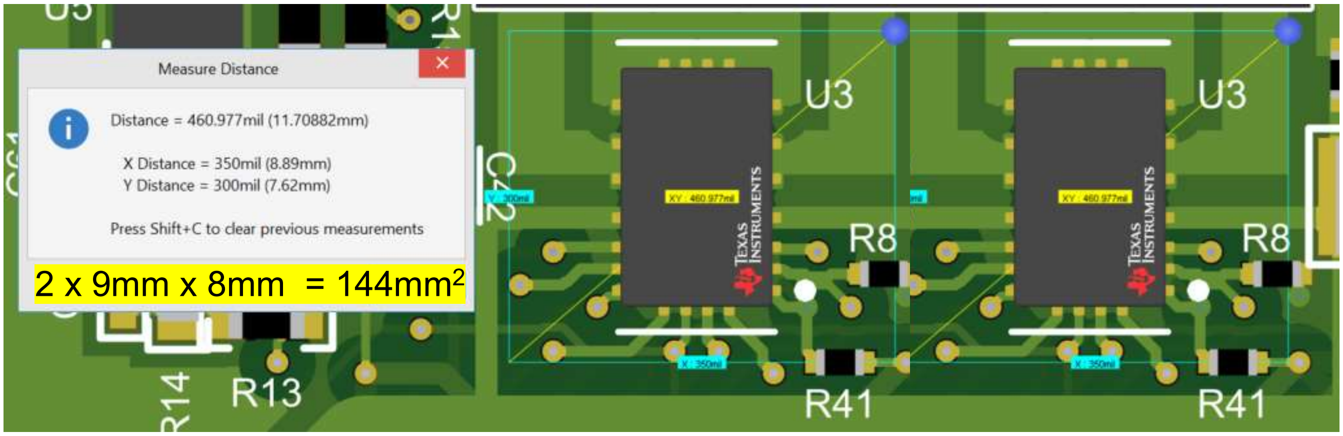
In this example, the DRV8714-Q1 gate driver is shown along with four dual-FET packages, plus two 3 Watt current sense resistors, and all the passive components to implement a four high-current half-bridge design. This could be used to drive two independent window lift motors, or three high-current seat motors with some constraints on their simultaneous motion.

# Board size example, 4 half-bridge with DRV8245-Q1



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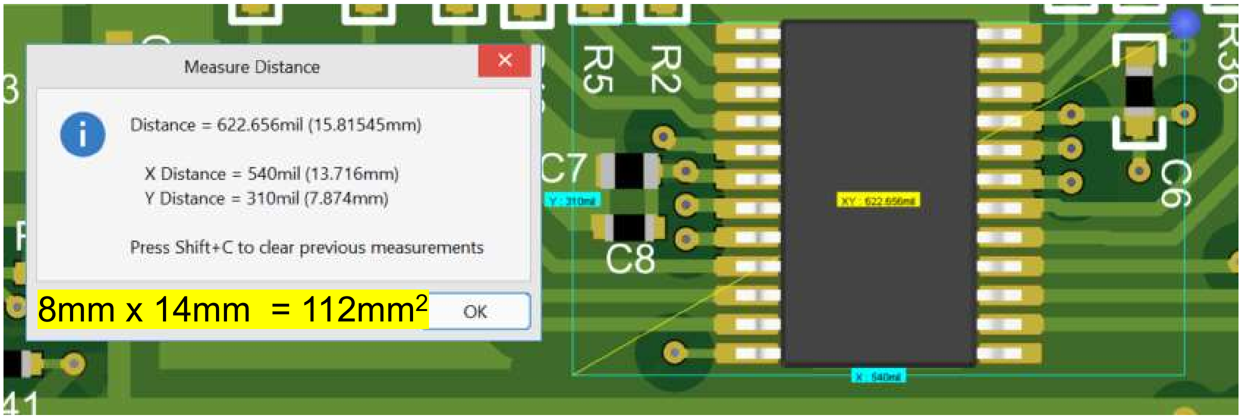
Here we see two DRV8245-Q1 devices next to each other with the associated passive components included. This also implements a four half-bridge design, but for typically lower currents than the gate driver design. For applications where the current matches the specifications for these devices, a very compact solution is achieved.

# Board size example, 4 half-bridge with DRV8904-Q1



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For low-current motors such as mirror XY adjustment and ventilation dampers, the multi-channel DRV8904-Q1 provides an even more compact design. For load currents up to 1 amp per output, as many as 12 half-bridges are available in this same package size.

# Thermal

**Thermal resistance as a selection criteria**

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When driving motor loads, thermal considerations can also be of high importance. Thermal issues are related to package size and current levels, with additional constraints and tradeoffs.

# DRV871x-Q1 – not a significant heat source

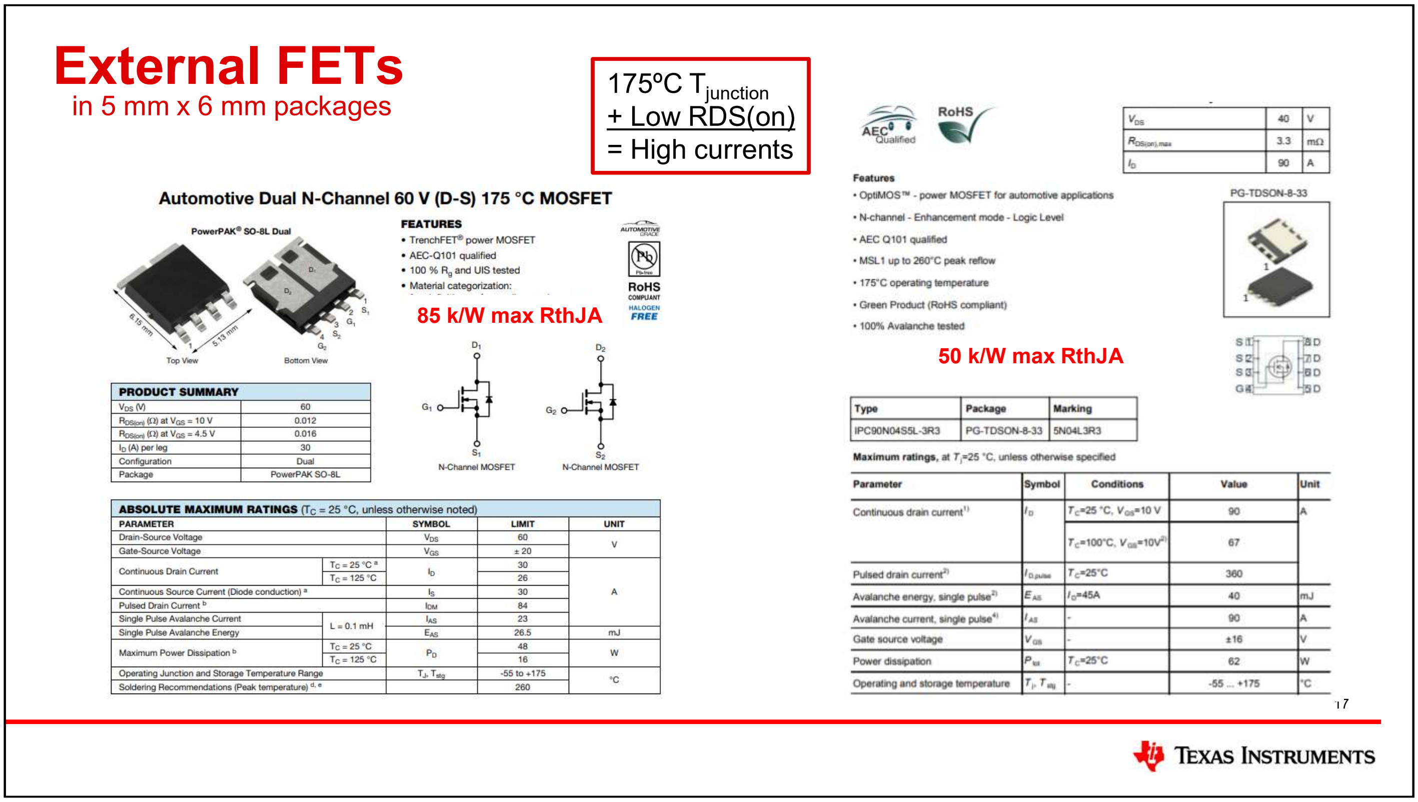
### 7.4 Thermal Information

| THERMAL METRIC[1] | | DRV8718-Q1 RVJ (VQFN) 56 PINS | DRV8714-Q1 RVJ (VQFN) 56 PINs | DRV8714-Q1 RHA (VQFN) 40 PINS | UNIT |
|---|---|---|---|---|---|
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 25.6 | 24.7 | 31 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 15.2 | 14.1 | 20.9 | °C/W |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 10.0 | 9.0 | 12.5 | °C/W |
| $\Psi_{JT}$ | Junction-to-top characterization parameter | 0.2 | 0.2 | 0.2 | °C/W |
| $\Psi_{JB}$ | Junction-to-board characterization parameter | 9.9 | 9.0 | 12.4 | °C/W |
| $R_{\theta JC(bot)}$ | Junction-to-case (bottom) thermal resistance | 3.0 | 2.3 | 2.3 | °C/W |






In general, high-current applications using gate drivers such as the DRV8706-Q1 or DRV8718-Q1 don't have thermal issues with the gate driver device itself.  This is because the high motor current flows through the external FETs rather than the gate driver.




| PRODUCT SUMMARY | |
|---|---|
| $V_{DS}$ (V) | 60 |
| $R_{DS(on)}$ (Ω) at $V_{GS}$ = 10 V | 0.012 |
| $R_{DS(on)}$ (Ω) at $V_{GS}$ = 4.5 V | 0.016 |
| $I_D$ (A) per leg | 30 |
| Configuration | Dual |
| Package | PowerPAK SO-8L |

**ABSOLUTE MAXIMUM RATINGS** ($T_C$ = 25 °C, unless otherwise noted)

| PARAMETER | | SYMBOL | LIMIT | UNIT |
|---|---|---|---|---|
| Drain-Source Voltage | | $V_{DS}$ | 60 | V |
| Gate-Source Voltage | | $V_{GS}$ | ± 20 | |
| Continuous Drain Current | $T_C$ = 25 °C [a] | $I_D$ | 30 | A |
| | $T_C$ = 125 °C | | 26 | |
| Continuous Source Current (Diode conduction) [a] | | $I_S$ | 30 | |
| Pulsed Drain Current [b] | | $I_{DM}$ | 84 | |
| Single Pulse Avalanche Current | L = 0.1 mH | $I_{AS}$ | 23 | |
| Single Pulse Avalanche Energy | | $E_{AS}$ | 26.5 | mJ |
| Maximum Power Dissipation [b] | $T_C$ = 25 °C | $P_D$ | 48 | W |
| | $T_C$ = 125 °C | | 16 | |
| Operating Junction and Storage Temperature Range | | $T_J$, $T_{stg}$ | -55 to +175 | °C |
| Soldering Recommendations (Peak temperature) [d, e] | | | 260 | |

| | | |
|---|---|---|
| $V_{DS}$ | 40 | V |
| $R_{DS(on),max}$ | 3.3 | mΩ |
| $I_D$ | 90 | A |

| Type | Package | Marking |
|---|---|---|
| IPC90N04S5L-3R3 | PG-TDSON-8-33 | 5N04L3R3 |

**Maximum ratings,** at $T_j$=25 °C, unless otherwise specified

| Parameter | Symbol | Conditions | Value | Unit |
|---|---|---|---|---|
| Continuous drain current[1] | $I_D$ | $T_C$=25 °C, $V_{GS}$=10 V | 90 | A |
| | | $T_C$=100°C, $V_{GS}$=10V[2] | 67 | |
| Pulsed drain current[2] | $I_{D,pulse}$ | $T_C$=25°C | 360 | |
| Avalanche energy, single pulse[2] | $E_{AS}$ | $I_D$=45A | 40 | mJ |
| Avalanche current, single pulse[4] | $I_{AS}$ | - | 90 | A |
| Gate source voltage | $V_{GS}$ | - | ±16 | V |
| Power dissipation | $P_{tot}$ | $T_C$=25°C | 62 | W |
| Operating and storage temperature | $T_j$, $T_{stg}$ | - | -55 ... +175 | °C |

The external MOSFETs used with TI's gate drivers are available with a wide range of on resistance, in a variety of packages. Many automotive FETs are rated for operation with junction temperature up to 175 centigrade. In a high-current application, this can be an advantage in terms of thermal performance. The packages typically have large metal heat slugs to aid in transferring heat away from the transistor and into the printed circuit board. This leads to a relatively low thermal resistance from junction to ambient, known as theta JA.

# DRV8245-Q1 thermal specifications

### 7.4 Thermal Information

Refer Transient thermal impedance table for application related use case.

| THERMAL METRIC[1] | | HTSSOP package | VQFN-HR package | UNIT |
|---|---|---|---|---|
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 27.7 | 41.3 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case(top) thermal resistance | 13.8 | 14.4 | °C/W |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 7.1 | 5.5 | °C/W |
| $\Psi_{JT}$ | Junction-to-top characterization parameter | 0.6 | 0.3 | °C/W |
| $\Psi_{JB}$ | Junction-to-board characterization parameter | 7.1 | 5.4 | °C/W |
| $R_{\theta JC(bot)}$ | Junction-to-case(bottom) thermal resistance | 0.9 | N/A | °C/W |

### 7.5.5 Power FET Parameters

*Measured at $V_{VM}$ = 13.5 V*

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $R_{HS\_ON}$ | High-side FET on resistance, HTSSOP package | $I_{OUT}$ = 6 A, $T_J$ = 25°C | | 20 | | mΩ |
| | | $I_{OUT}$ = 6 A, $T_J$ = 150°C | | | 38 | mΩ |
| | High-side FET on resistance, VQFN-HR package | $I_{OUT}$ = 6 A, $T_J$ = 25°C | | 16 | | mΩ |
| | | $I_{OUT}$ = 6 A, $T_J$ = 150°C | | | 30.4 | mΩ |
| $R_{LS\_ON}$ | Low-side FET on resistance, HTSSOP package | $I_{OUT}$ = 6 A, $T_J$ = 25°C | | 20 | | mΩ |
| | | $I_{OUT}$ = 6 A, $T_J$ = 150°C | | | 38 | mΩ |
| | Low-side FET on resistance, VQFN-HR package | $I_{OUT}$ = 6 A, $T_J$ = 25°C | | 16 | | mΩ |
| | | $I_{OUT}$ = 6 A, $T_J$ = 150°C | | | 30.4 | mΩ |

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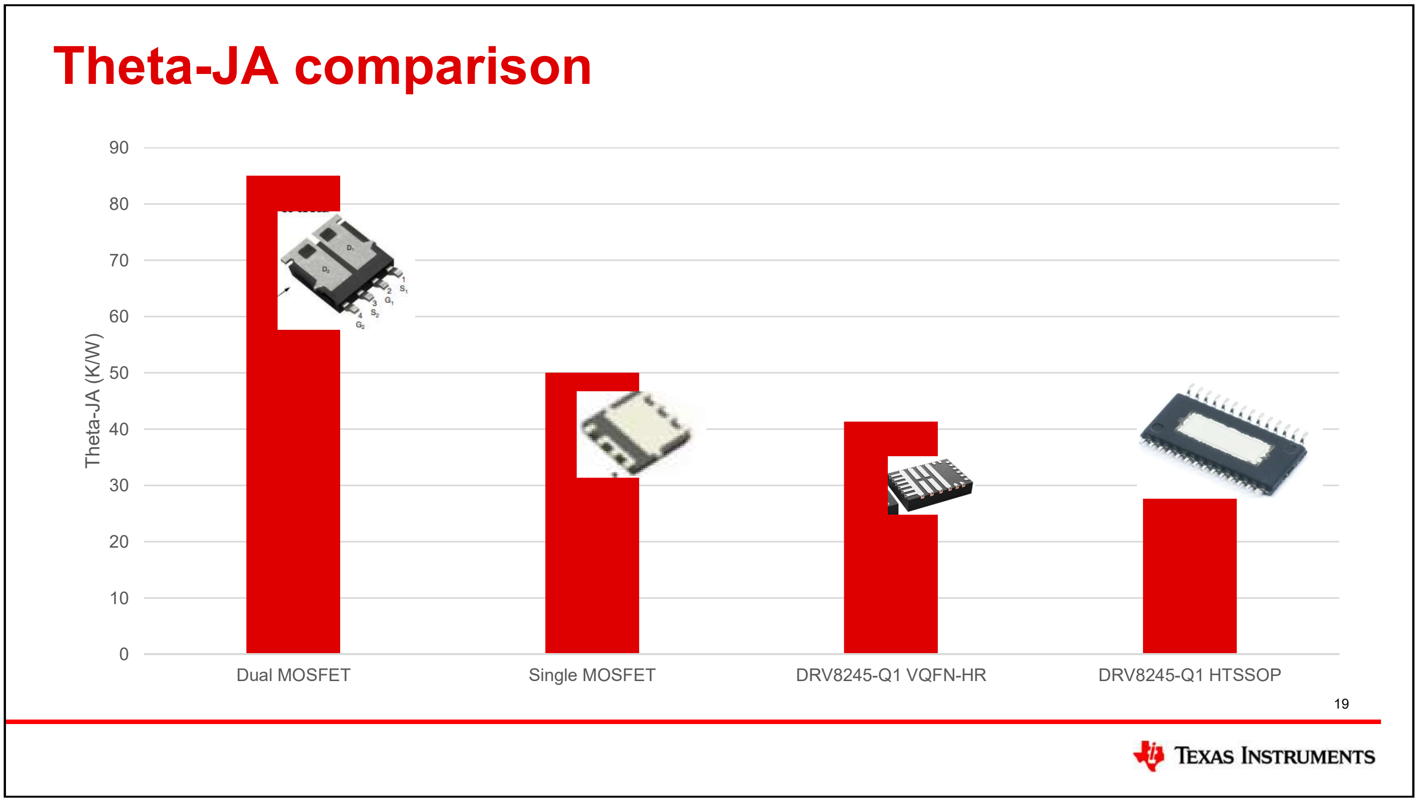
The innovative packaging of the DRV8243, 44, and 45-Q1 devices give them even lower theta JA values than the external FETs, which is a significant advantage in terms of power dissipation in a small package.



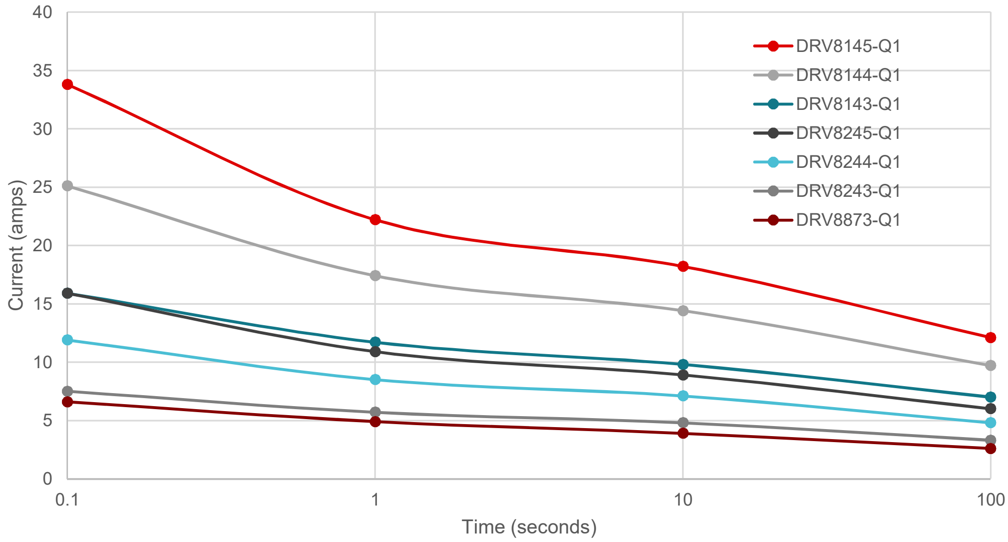

The parameter of thermal resistance from integrated circuit junction to ambient temperature (theta JA) can be used to compare the thermal efficiency of various devices.

The dual MOSFETs in a 5 by 6 mm package have a thermal resistance of 85 degrees per Watt, while the single MOSFETs in a similar package have a lower thermal resistance, due to the larger continuous thermal slug.

The DRV8245-Q1, in a small 3.6 x 5.6 mm package, has lower thermal resistance due to the “hot-rod” flip chip packaging technology.

The DRV8245-Q1 in the HTSSOP package is somewhat larger, but has an even lower thermal resistance than the VQFN hotrod package.

# Transient current capability – integrated FET devices




Based on initial thermal simulations using **40 mm x 40 mm x 1.6 mm, 4 layer PCB**, for **85 deg C** ambient temperature

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The thermal constraints of integrated circuits are based on internal power level and duration. TI motor drivers typically are specified for operation up to 150 degrees centigrade at the integrated circuit junction, and have thermal protection features in case that junction temperature is exceeded due to application fault conditions. External factors such as board design and ambient temperature also affect thermal calculations. In general, high currents are possible for a short duration, and longer durations with lower currents are also fine.

# Thermal calculator for DRV825x-Q1

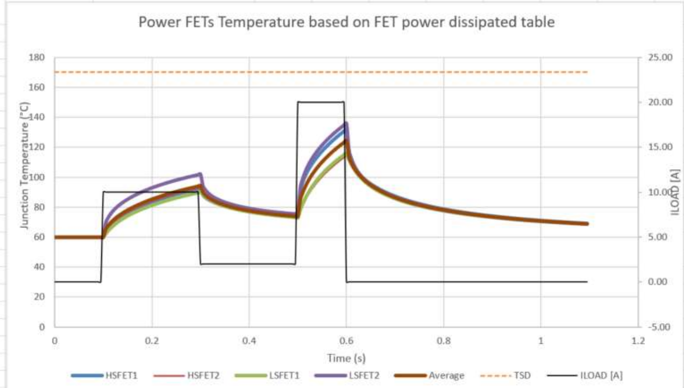
| | | |
|---|---|---|
| User Input # 1 | Ambient Temperature (deg C) | 60 |
| User Input # 2 | Device Choice | 5 |
| User Input # 3 | PCB Choice | 1 |
| User Input # 4 | Input type | 1 |
| User Input # 5 | Model - Typical or WorstCase | Typical |
| User Input # 6 | f(PWM) (KHz) | 20 |
| User Input # 7 | Slew Rate (V/usec) setting | 9.8 |
| User Input # 8 | VM (V) | 12 |

| Choice | Device List | LS + HS typical RDSON (mohm) |
|---|---|---|
| 1 | DRV8243-Q1 VQFN-HR | 84 |
| 2 | DRV8243-Q1 HVSSOP | 98 |
| 3 | DRV8244-Q1 VQFN-HR | 47 |
| 4 | DRV8244-Q1 HVSSOP | 60 |
| 5 | DRV8245-Q1 VQFN-HR | 32 |
| 6 | DRV8245-Q1 HTSSOP | 40 |

| Choice | PCB list - Layers, Size | |
|---|---|---|
| 1 | 4L, 4 cm X 4 cm | 1.6 mm thickness, 2 oz Cu for Top & Bot, 1 oz Cu for internal layers |
| 2 | 4L, 2 cm X 2 cm | |
| 3 | 4L, 8 cm X 4 cm | |

| Choice | Input type |
|---|---|
| 1 | Time vs. Load Current |
| 2 | Time vs. Power Dissipated (25% for each FET - equal spread) |
| 3 | Time vs. Power Dissipated (40% for HS1, 40% for LS2, 20% for HS2) |
| 4 | Time vs. Power Dissipated (40% for HS2, 40% for LS1, 20% for HS1) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| User Input # 9 | Time (s) | 0 | 0.1 | 0.2 | 0.3 | 0.5 | 0.6 | | |
| User Input # 10 | Current (A) [-100 to +100] | 0 | 10 | 10 | 2 | 20 | 0 | | |
| User Input # 11 | PWM [Y/N] | Y | Y | Y | Y | N | N | | |
| User Input # 12 | Duty Cycle [0.01 to 0.99] | 0.01 | 0.5 | 0.5 | 0.1 | | | | |
| User Input # 13 | Total Power Dissipated (W) | | | | | | | | |
| Calculated | HSFET 1 Power Dissipated (W) | 0.00 | 1.95 | 1.95 | 0.08 | 7.81 | 0.00 | 0.00 | 0.0 |
| Calculated | HSFET 2 Power Dissipated (W) | 0.00 | 1.27 | 1.27 | 0.13 | 0.00 | 0.00 | 0.00 | 0.0 |
| Calculated | LSFET 1 Power Dissipated (W) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 |
| Calculated | LSFET 2 Power Dissipated (W) | 0.00 | 3.92 | 3.92 | 0.60 | 7.81 | 0.00 | 0.00 | 0.0 |

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On the product page for the DRV8245-Q1, and other devices in this family, you can find a thermal calculator that estimates the internal junction temperature based on several factors, including the current profile and type and size of printed circuit board. Use this calculator to see which of the devices is the best fit for your specific application.

# Summary

**Brushed DC motor driver selection**





Let's wrap up with a review of what we've discussed.

# Brushed DC motor drivers comparison

| Feature | Single multiple-channel gate driver (+ externalFETs) DRV871x-Q1 | Multiple single-channel motor drivers (internal FETs) DRV824x-Q1 | Multiple-channel motor drivers (with internal FETs) DRV89xx-Q1 |
|---|---|---|---|
| Max current per motor | 50A+ (FET limited) | Up to 32A (DRV824x) | 1A |
| Devices for 2 independent motors | 1 DRV8714 + 8 FETs (or 4 dual FETs) | 2 DRV8245 | 1 DRV8904 |
| Devices for 4 independent motors | 1 DRV8718 + 16 FETs (or 8 dual FETs) | 4 DRV8245 | 1 DRV8908 |
| Board space per motor | Medium | Small | Very small |
| Current sense | 2 integrated CSA, external shunt resistors required | Integrated current mirror per motor | Integrated overcurrent detection |
| Interface | SPI plus parallel for PWM | SPI plus parallel for PWM | SPI |
| Power off braking | Yes | No | No |
| Integrated diagnostic and protection | Yes | Yes | Yes |
| Adjustable slew rate | Yes | Yes | No |
| External CP caps | Yes | No | No |
| PWM | Yes, from external source | Yes, from external source | Yes, internal up to 2 kHz |

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In summary, designers can select from a broad range of motor driver solutions to meet the needs of just about any application. While we have discussed some of the main criteria for choosing between the various devices available from Texas Instruments, there are other reasons why one device or another may be the best fit. For example, the method and precision of current measurement for system feedback, or type of interface between the motor driver and microcontroller may be a key consideration in some designs. Other features such as diagnostic and protection against fault conditions, built-in braking, adjustable voltage slew rate during pulse-width modulation, or availability of a charge pump voltage might be valuable in specific applications.

Overall, motor drivers from Texas Instruments fit the needs of designers for all types of automotive designs.

# Motor drivers

High-voltage gate drivers

Brushless DC motors

DC brushed motors

Isolated gate drivers

Stepper motors