# Shifting From 12-V to 42-V Systems in Automotive Applications

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**Abstract**

This paper will address the shift from a 12-V to a 42-V system voltage in automobiles and its implications for applications using discrete components. The effects of rising voltage levels, such as higher power-handling requirements and side-by-side operation of 12-V and 42-V subsystems during the transition, will be discussed. This paper also will present basic definitions of the two Boardnet voltages, a comparison of the components and electrical characteristics required for each system, an analysis of the types of applications made possible with the higher voltages, and a description and schematics of similarly configured applications. A brief reference to current products that help to address the specific engineering issues accompanying these higher-voltage systems also will be included.

## Introduction

On-board demand for electric power in next-generation automotive applications leaves no choice but to increase system voltages to 42 V from 12 V. This transition will have a number of implications for automotive applications relying on discrete components. With this shift, engineers and manufacturers now will have to address the consequences of rising voltage levels, including the need to handle higher levels of power. Unlike the move 40 years ago from 6-V to 12-V system voltages, the transition from 12-V to 42-V system voltages is intended to be gradual. At first, both 12-V and 42-V subsystems will operate side-by-side in a more complex system architecture, enabling use of proven 12-V designs with implementation of 42-V systems for high-power applications.

The definition of the 42-V Boardnet has been a lively topic at almost every conference on the subject. The emerging set of specifications for maximum battery and system voltages are shown in Table 1 [1]. Compared to the 12-V system, the 42-V Boardnet's much tighter load dump definition is the major difference. The goal is to fit within the maximum voltage rating of available components (60-Vds Power MOSFETs). The advantages of this approach are twofold: (1) it allows for short design cycles, and (2) it eliminates development costs for new power components for most applications.

## Example: Designing a Power Window System in the 42-V Environment

Power window systems in modern automobiles employ single-phase DC motors. Motor ratings range from 60 W to 100 W, with lower actual drive-current requirements. Nevertheless, the design must account for fault conditions such as a locked rotor or even a short circuit on the load.

Temperature-sensing MOSFETs offer a simple solution to this problem by providing protection under the fault conditions that lead to excessive temperatures in the semiconductor device. Current-sensing MOSFETs serve as another alternative, providing protection against over-current and/or short-circuit faults. These two MOSFET types can be incorporated into any of the typical circuit configurations for a power window system, including single-ended high-side (Figure 1), single-ended low-side (Figure 2), and full-bridge (Figure 3) configurations.

The basic schematic remains the same for both a 12-V and 42-V Boardnet, except for a snubber circuit added to the 42-V system to deal with voltage stress arising from the higher voltage level. Ideally, an optimized circuit design can take advantage of the reduced current level and trim the circuit inductance to minimize the voltage stress at its source. The device ratings, however, change considerably as a result.

In the 42-V system, the current level drops to almost one-third of the current level in the 12-V-system. This drop improves thermal performance by reducing the power dissipation in the MOSFET. However, as the die size increases to maintain a constant on-resistance value, the device becomes much more expensive. If a constant thermal level is maintained, the on-resistance value may be allowed to increase by a factor of 3, resulting in a more cost-effective solution.

The number of suitable devices for the system is as unlimited as the range of motors that may be used (Table 2). Devices with higher on-resistance, lower power dissipation, or higher thermal resistance are available or easily manufactured.

Any device, such as the SUM50N04-05LT, can be transformed into a temperature- or current-sensing device to facilitate protection of the device against excessive temperatures or short circuit [2]. In fact, the whole circuit can be built with current and temperature sensing, along with other protection features, into an application-specific MOSFET (ASM). This highly competitive solution reduces board space and component count.

**Implementation of Integrated Starter Generator Using a 42-V Boardnet**

Since the introduction of Permanent Magnet (PM) Technology in motor controls, it has become technically possible to integrate the starter and generator in automotive designs. This allows designers to eliminate field windings, freeing up considerable space. It has been difficult in 12-V systems, however, to accommodate the 10- to 15-kW power demands and the high current levels that are required by an integrated starter generator (ISG). The 42-V Boardnet reduces current levels by two-thirds, simplifying implementation of an ISG as a fully controlled three-phase bridge (Figure 4).

The key to implementing ISGs is to balance the die size and the paralleling of devices while addressing high current-level demand and thermal issues. Furthermore, the load dump scenario requires special attention because the ISG interacts directly with the main battery system in high power exchanges. Careful design eliminates or minimzes parasitic inductances, the key contributor to voltage stress. Adequate avalanche ratings for the power device and passive or active clamping also must be employed.

The power level in ISGs is much higher than in previous motor controls – up to 15 kW, depending on the generator power, with development reaching as high as >50 kW. In this example, the target on-resistance for the power switch is 1 milliohm. As this typically is a module that uses a three-phase bridge, the thermal resistance depends on the customer's method of assembly, which often uses dice instead of packaged parts (Table 3). The customer also dictates the switches' on-resistance, which is determined by the quantity and diameter of the bondwires used. Even innovative bondwireless source connections are attemped in an effort to influence on-resistance values. Input capacitance, another important parameter, rises with the die size and depends on the system's technology.

On-resistance can be reduced further, but an increase in the gate charge also will occur. An issue worth future consideration is the accurate die-level measurment of on-resistance, measured by current level, location, time, etc.

Another critical matter is the die size itself. Naturally, from a semiconductor supplier's point of view, the die should be as small as possible. In terms of actual performance, the die size should not be so small that it will create hot spots, but not so large as to make assembly difficult or to reduce yield significantly.

**Conclusions**

System designs change little with the switch from 12-V to 42-V system voltages, and Vishay offers a wide range of devices to cover both 12-V and 42-V designs. Because effective cost-savings through use of a smaller die requires close monitoring of thermal performance, Vishay Siliconix devices are available with a dice option in addition to standard packaged parts. Temperature- and current-sensing features also are readily available.

**References**


1. 42V Boardnet definition…..
2. Application Note 820 ….

## Table 1: Definition of 42-V Boardnet

| Specification | Voltage | Definition |
|---|---|---|
| $V_{bat}$ | 36 V | Nominal battery voltage (3 x 12-V batteries) |
| $V_{bat\ max.}$ | 42 V | Static battery voltage |
| $V_{eff}$ | 48 V | Effective maximum voltage |
| $V_{max.\ stat.}$ | 52 V | Including Ripple current (8%) |
| $V_{max.\ dyn.}$ | 58 V | Replaces load dump |
| $V_{op.\ min.}$ | 30 V | Minimum operating voltage (maximum 11s) |
| $V_{drop}$ | 16 V | Maximum 100ms |

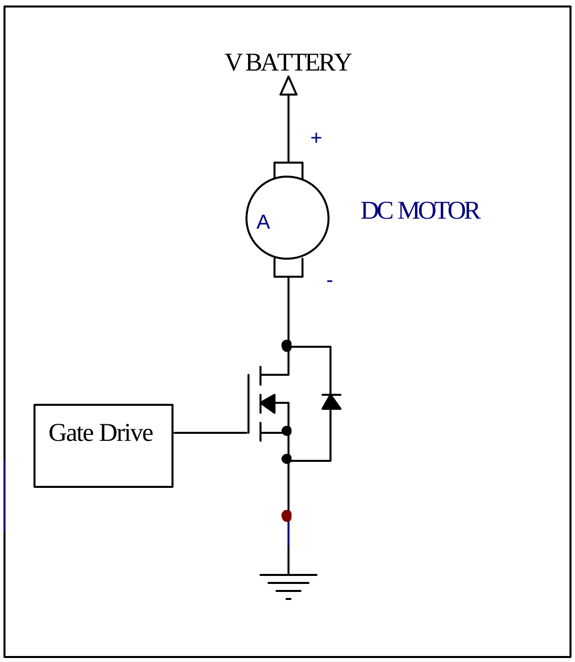
**Table 2: Lowest Available On-resistance Values for Commonly Used Packages**

| Part Number | Package | $r_{DS(ON)}$ (mW) | $I_D$ (W) | $P_D$ (°K/W) | $R_{thJC}$ |
|---|---|---|---|---|---|
| SUM110N04-02L | $D^2$PAK | 2.3 | 110 | 437.5 | 0.4 |
| SUM50N04-05LT | 5L $D^2$PAK | 6 | 50 | 200 | 0.6 |
| SUD50N03-07 | DPAK | 7 | 50 | 83 | 1.8 |
| Si7440DP | PowerPAK TM | 6.5 | 21 | 5.4 | 1.3 |
| Si4404DY | SO-8 [1] | 4 | 23 | 3.5 [2] | 16 [3] |
| Si4888DY | SO-8 | 7 | 16 | 3.5 [2] | 18 [3] |

[1] Power Connect™
[2] 10 seconds
[3] Junction to Foot

**Table 3: Typical Die Sizes Used Today**

| Part Number | Die size ($mm^2$) | $r_{DS(on)}$ (mW) | $U_{DS}$ (V) | $Q_g$ (nF) |
|---|---|---|---|---|
| SUC85N08-04 | 36 | 2.8 | 75 | 6.3 |
| SUC110N08-05 | 25.5 | 4 | 75 | 7.9 |



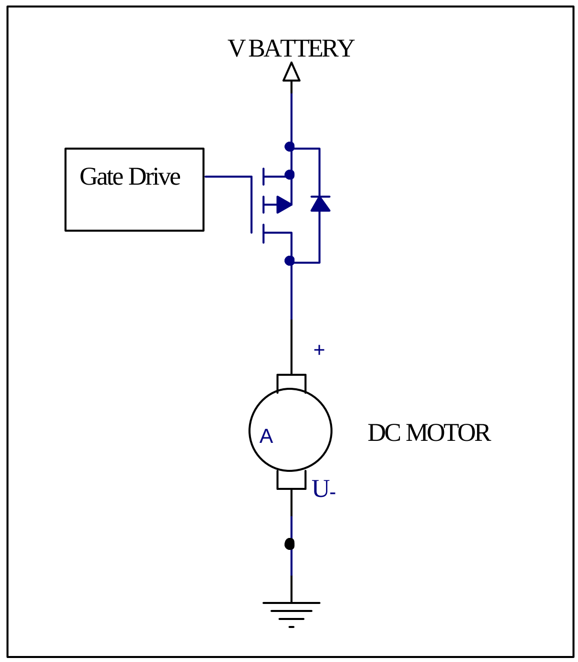




**Figure 1: Single-Ended High-Side Drive Schematic Detail**

**Figure 2: Single-Ended Low-Side Drive Schematic Detail**

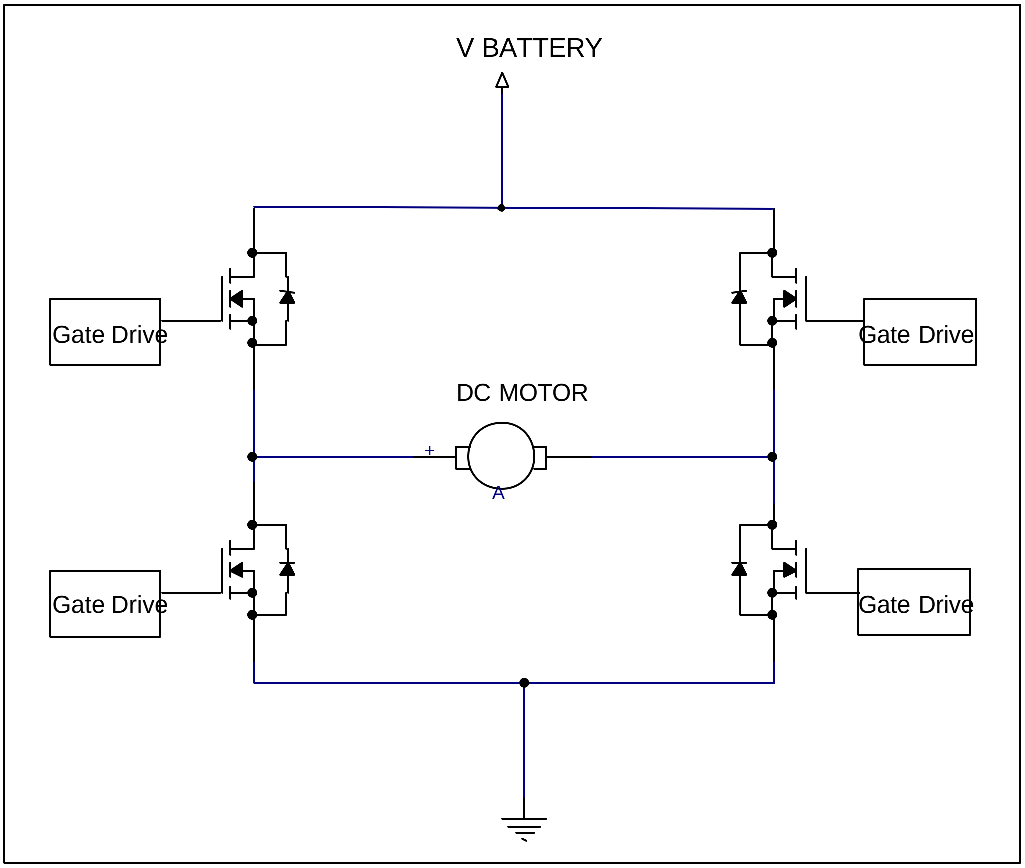



**Figure 3: Full Bridge Configuration Schematic Detail**

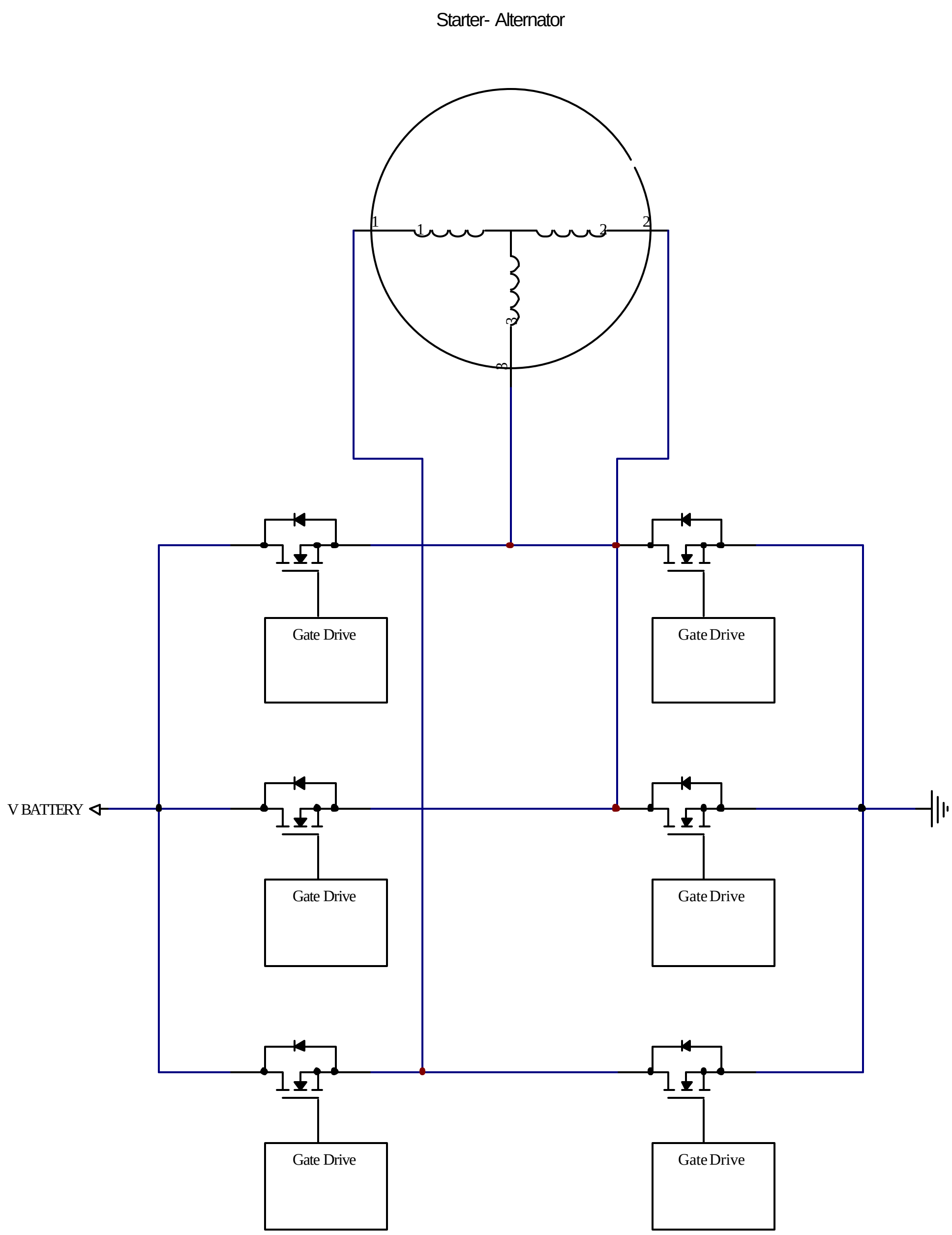

Starter- Alternator
1
1
2
2
3
3
Gate Drive
Gate Drive
Gate Drive
Gate Drive
Gate Drive
Gate Drive
V BATTERY

**Figure 4: Integrated Starter and Alternator in a 3-Phase Bridge Configuration**

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