MP6540/40A – 35V, 3A, Monolithic Three-Phase Driver Enables Compact Brushless DC Motor Designs

The use of small electric motors to automate basic mechanical functions has proliferated in recent years as consumers come to expect and appreciate "smart functionality" in their everyday appliances. These motorized mechanisms can be grouped into the category of actuators, and are found in a diversity of applications including consumer appliances, home and industrial automation, and vehicle electronics.

From opening a window to operating a door lock or adjusting a headlight beam, motorized actuators are becoming ubiquitous. There is a growing trend to replace older brush style motors with three-phase brushless motors to increase reliability and efficiency.

Simple brush motors can be driven with a half or full MOSFET H-bridge, depending on whether unidirectional or bidirectional rotation is needed (see Figure 1). Their speed can be controlled by using a PWM input to control the current. Brush motors are a mature technology and are often chosen for their low cost and relative ease of control. They suffer from the main disadvantage that the commutator contacts and carbon brushes can wear, limiting the operating life span.

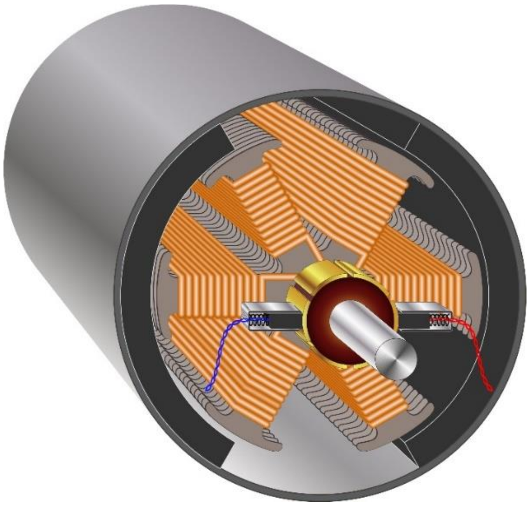

Figure 1: Brushless Motor with Commutator

In contrast, a three-phase brushless motor has greater flexibility when it comes to position control because the current in each of the three phases can be exactly defined to set the motor in a particular position (see Figure 2).

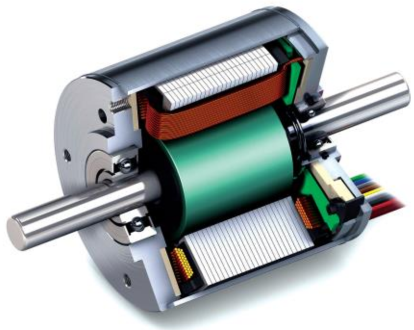

Figure 2: Three-Phase Brushless Motor

The mechanical commutation in the brushed motor is replaced by electronic commutation, giving high reliability since there are no brushes to wear out.

Control can be via simple "six-step" block commutation, in which energy is applied in a rotating, phase-shifted sequence to two of the three phases. Alternately, it can take the more sophisticated form of sinusoidal or field-oriented control, in which the energy is progressively applied to each phase following a profile that allows exact control of the motor position. In order to facilitate this precise control, a three-phase brushless motor driver must have three half-bridges (six MOSFETs) and separate current-sense feedback amplifiers for each phase so that the controlling device can monitor each phase current accurately.

The MP6540 and MP6540A from Monolithic Power Systems (MPS) are new three-phase brushless DC motor driver stages that offer industry-leading power density in a small 5mmx5mm QFN package. The parts can operate from 5.5V to 35V, deliver up to 3A continuous current per phase and up to 10A peak current (with suitable PCB area, and thermal dissipation conditions).

These motor drivers integrate three power stage half-bridges, consisting of 6x 50mΩ N-channel power MOSFETs, along with pre-drivers, gate drive power supplies, and current-sense amplifiers.

An internal charge pump generates the gate drive supply voltage for the high-side MOSFETs, and a trickle-charge circuit maintains sufficient gate drive voltage to operate at 100% duty cycle. The part comes with two input formats: The MP6540 has individual PWM and EN inputs for each phase, whilst the MP6540A has separate high-side and low-side inputs for each phase.

The internal power MOSFET gate pre-drivers include automatic dead time control to prevent shoot-through when switching phases, and automatic synchronous rectification to dissipate freewheeling currents for maximum efficiency. Internal safety features include thermal shutdown, under-voltage lockout, and overcurrent protection (see Figure 3).

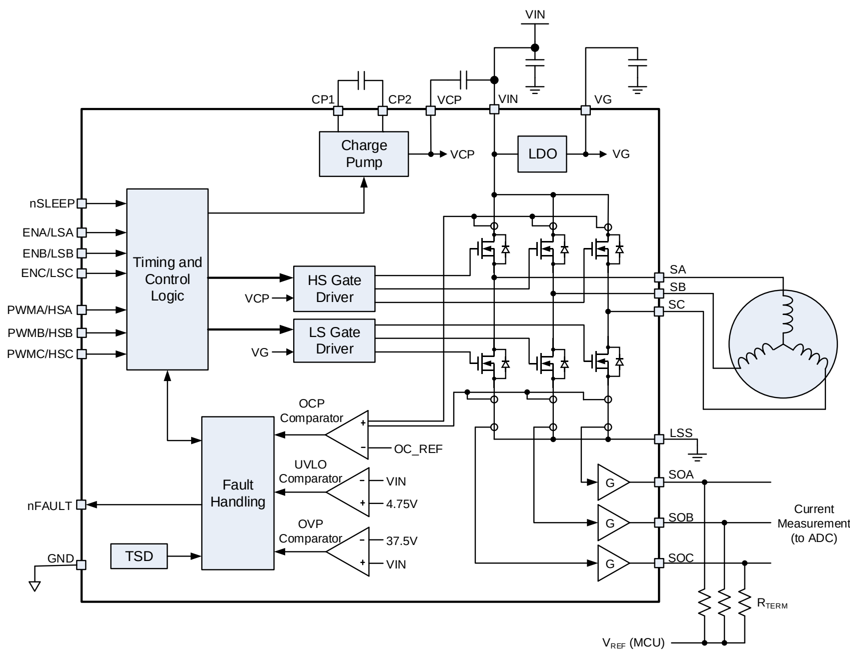

Figure 3: MP6540/MP6540A Brushless Motor Driver Block Diagram

The MP6540 and MP6540A are fully monolithic designs that use MPS's proprietary flip-chip in package technology to dissipate heat directly via the package lead-frame. Long, stripe-shaped pads connect directly to the internal high-side and low-side MOSFETs via copper pillars, providing the lowest thermal resistance path to the PCB copper. Small vias from these pads into the power and ground planes layers of the PCB help to further draw heat away from the motor driver (see Figure 4 and Figure 5).

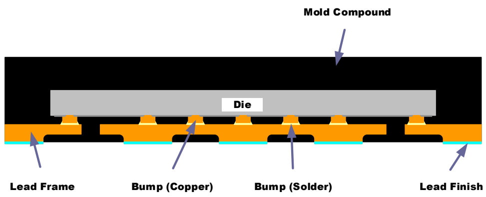

Figure 4: Package Cross-Section Showing Direct Die to Lead Frame Connections

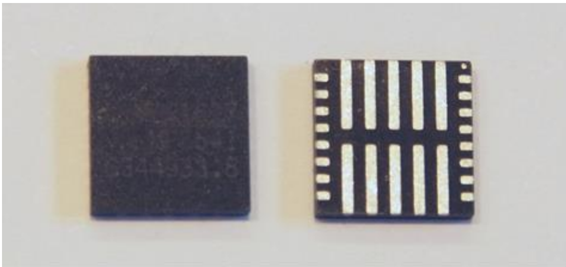

Figure 5: FC-QFN Package Showing Underside Thermal Pads

Figure 6 shows an example of 2-layer PCB, using 1oz copper on a 5cmx5cm FR4 board of 1.6mm thickness.

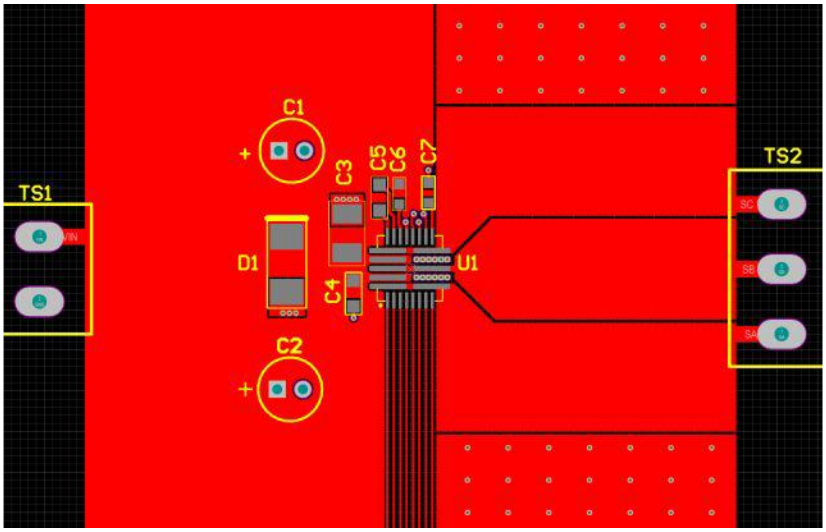

Figure 6: PCB Top Side

A thermal image taken of the MP6540 driving 4A of current into a BLDC motor shows the heat being extracted from the device into the copper areas (see Figure 7). This example uses a 2-layer, 4cmx4cm PCB with standard 1oz copper, and 1.6mm-thick FR-4 PCB material.

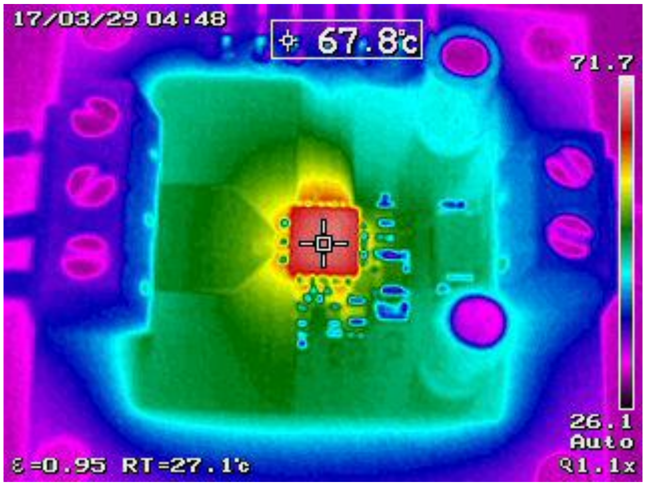

Figure 7: Thermal Image

The small form factor of the MP6540 and MP6540A allows for the creation of very compact brushless motor based actuators, and supports a wide range of control schemes for ease of use. These parts are available now in an -40 to +125°C industrial-qualified temperature range.