Filter Senses Current in High-Voltage Motor Drives

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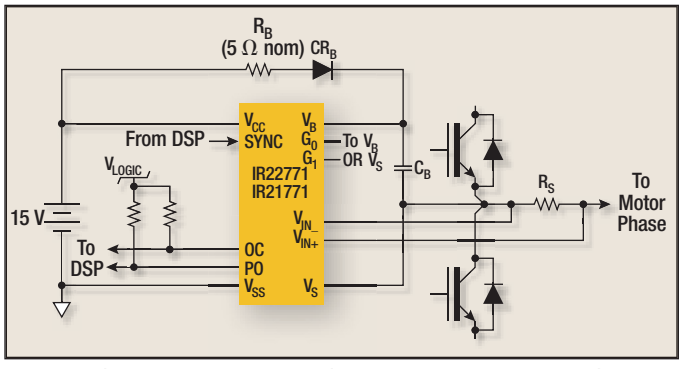
Traditional motor-phase-current sensing methods depend on sensors with signal bandwidths of 100 kHz or greater. Problematically, such bandwidths allow high-frequency noise into the sense path. Topologies that reduce the noise to system-tolerable levels vary from a low-cost RC input filter to more complex and expensive filtering techniques such as analog or digital post-processing. In many cases, the final design embodies a compromise between a large group delay and residual high-frequency harmonics. A novel approach integrates a multistage, adaptive filter in which the tuning and harmonic suppression are functions of the pulse-width modulated (PWM) clock frequency.[1]

A standard current-shunt sense resistor in series with the motor's high-side phase lead maps the motor current onto a ±250-mV full-scale range. An on-chip differential amplifier measures the voltage across the sense resistor and provides the filter's input signal. The filter's first stage is a resettable integrator, which is synchronized with the PWM. The sync pin requires a PWM clock with a 50% duty-cycle square wave.



A motor phase-current sensor IC, the IR22771 (or IR21771) implements a multistage, adaptive filter to suppress noise in the sense-signal path.

The synchronization allows the adaptive filter to precisely place transmission zeros at the input signal's even harmonics. This arrangement results in both high noise attenuation and phase-lag compensation. Moreover, an integrator operating over one-half of the PWM period has a transfer function that is similar to a single-pole system with its corner frequency equal to the PWM frequency, beyond which high-frequency noise is attenuated by the expected -20 dB/decade. The second stage samples the first stage's output at twice the sync frequency. This action removes the odd harmonics from the input signal without adding further delays.

Implementations of this patented adaptive-filter design, which the IR2177, IR2277, IR21771 and IR22771 phase-current sensor ICs embody, include a third stage that provides a PWM output with a duty cycle proportional to the input shunt voltage. A fourth stage on the IR2177 and IR2277 reconstructs a ratiometric analog output that the chip updates twice per PWM cycle. Built on a high-voltage IC process, the devices can accommodate input common-mode voltages as great as 1200 V, operate on a nominal 15-V supply and require only six external components, two of which are pull-up resistors (see the **figure**).

One of the four remaining components, the sense resistor, maps the motor phase current onto a ±250-mV input range. The other three components form a bootstrap supply that floats above the high-voltage common-mode potential. The resistor, 5 Ω nominal, limits the capacitor current at startup. The diode must have a breakdown voltage greater than the IC's high-voltage common-mode voltage—either 600 V or 1200 V depending on the IC model. The diode also needs to have a reverse recovery time less than 100 ns.

Lastly, a simple two-equation procedure determines the bootstrap capacitor's minimum value ($C_{BOOTmin}$) that takes into account a number of application-specific terms such as the PWM's maximum on time (high-side on time, T_{HON}), the bootstrap diode's maximum leakage current ($I_{LKdiode}$) and the capacitor's self-leakage (I_{LKcap}), a term that is dependent upon capacitor construction.

To determine the $C_{BOOTmin}$ value, first calculate the total capacitor charge (Q_{TOT}):

$$Q_{TOT}=Q_{LS}+(I_{QBS}+I_{LK}+I_{LKdiode}+I_{LKcap})\times T_{HON}$$

where Q_{LS} is the charge required by the IC's internal level shifters, typically 20 nC; and I_{QBS} is the floating section quiescent current; I_{LK} is the floating section leakage current. The minimum capacitance can then be calculated as:

$$C_{BOOT\,min}=\frac{Q_{TOT}}{\Delta V_{BS}}$$

where ΔV_{BS} is the maximum admitted voltage drop for V_{BS}, which is the voltage across the capacitor.

Housed in a 16-lead, wide-body SOIC, the IR22771/21771 phase-current sense circuit operates on a maximum quiescent current of 2.8 mA. **PETech**

References

1. IR2277S/IR2177S data sheet, available online at www.irf.com/product-info/datasheets/data/ir2177s.pdf.