Optimizing High-Side Drivers for Switchmode Supply

By Keith Billings, DKB Power Inc., Ontario, Canada

Switchmode design engineers will be aware of the difficulty of driving the high-side power device in some switchmode topologies. The lower power device shares a common return with the drive circuit, while the high side device does not.

High-side drive methods include specialized ICs and drive transformers. Fig. 1 shows a typical integrated circuit driving FETs in a two transistor forward converter. Notice, in this example, the drive signal is level shifted from the lower part to the high-side driver via a coupling capacitor Cp. The edges of the square wave drive set and reset a latched flip-flop in the high side to provide the drive to Q1. In some applications, there is a tendency for the high side to latch high if triggered by a noise pulse.

However, this type of IC can be used with total confidence in topologies that don't have a silicon path between the high-voltage rail and common, as shown in Fig. 1, where a transformer primary is in the path. Also, various buck-and-boost topologies don't have this silicon path limitation, and the occasional latch-up for a single cycle can be tolerated. However, topologies, such as that shown in Fig. 2 (and the various bridge and half-bridge versions), do provide a direct cross-connected silicon path between the supply rails and a single mistimed event (a latch-up where both power devices turn "on" at the same time), will result in immediate cross-conduction followed by catastrophic failure within microseconds. When using ICs for high-side driving in this type of topology, designers should take care to fully satisfy the IC application recommendations and be sure the chosen IC won't suffer a latch-up problem under any conditions.

Fig. 2 shows a transformer coupled drive applied to a phase-shifted full-bridge (only one-half of the bridge is shown). This type of transformer drive is inherently free of cross-conduction problems. Note from the phasing of the secondary in the drive transformer T1 that when one device is turned "on" the other side drive is reversed biased, ensuring it is fully turned "off" and reversed biased, improving noise immunity. Cross-conduction, as described above, isn't possible with this type of drive, even if the drive circuit misfires.

Drive transformers and drive circuits need careful design. Many application notes give scant attention to the design of the drive circuits. A common error is to omit the essential dc blocking capacitor Cc, shown here in series with the primary of T1. This capacitor is essential to prevent staircase saturation of the drive transformer. Saturation will lead to excessive power loss in the drive circuits and drive transformer, as well as premature termination of the drive pulse with sloppy drive waveforms. A common cause is that the drive waveform (either by design or by error) often won't have exactly equal positive and negative pulse durations. Without Cc, the transformer will easily saturate, because the drive core is normally quite small and will use high-permeability ferrite material or, in some

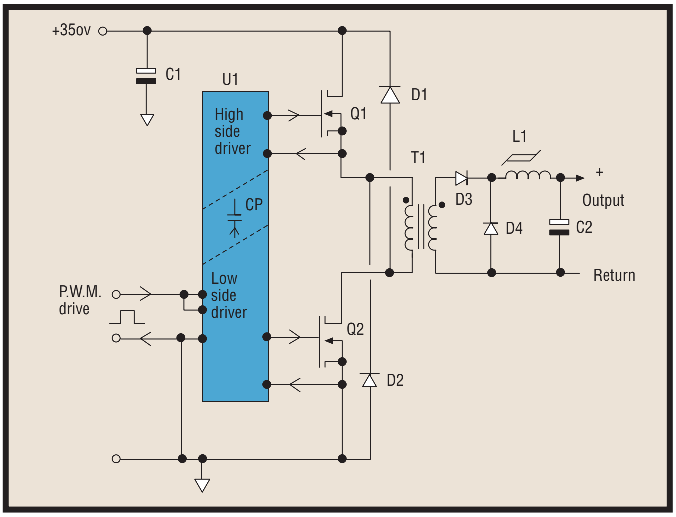

Fig. 1. *Two transistor forward converter.*

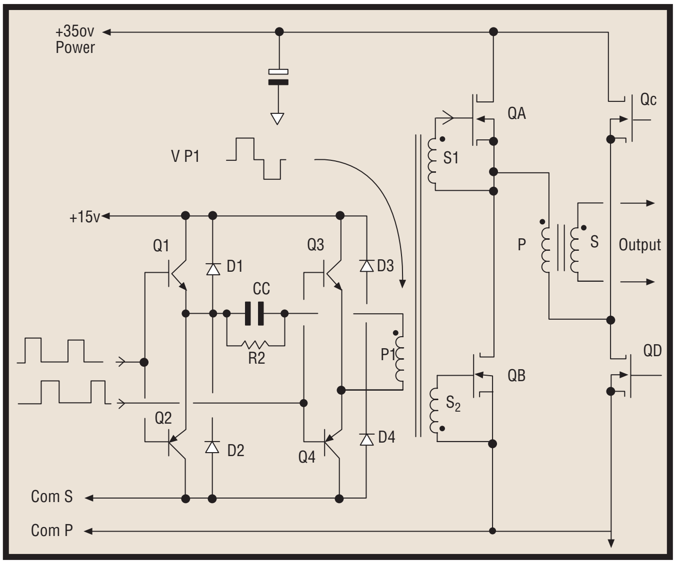

Fig. 2. *Phase-shifted PWM full-bridge converter.*

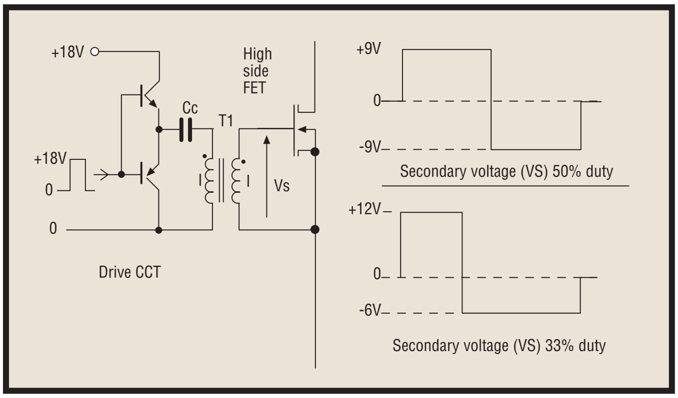

Fig. 3. *Drive transformer waveforms.*

cases, even toroidal ferrite cores with no air gap. In such instances, an effective dc current of only a few milliamps will be sufficient to cause saturation.

The series capacitor Cc blocks dc current flow and allows the drive transformer to automatically adjust its working conditions to ensure equal forward and reverse volt-seconds conditions. Cc does this by automatically taking up a dc bias to satisfy this condition after a few pulses. Fig. 3 shows the waveform expected for the maximum 50% and a smaller 33% duty cycle. This design is for a drive transformer intended for use as a high-side driver (Fig. 1). Notice that although the primary drive is a constant 18-V rectangular drive (with respect to the common line), the primary and secondary windings automatically take up a mean ac working condition, where the forward and reverse volt-seconds equality is satisfied. Consequently, the peak amplitude of the drive voltage reduces with increased duty cycle. This isn't a problem in the example shown, which is limited to 50%, at which point the drive voltage drops from 18-V amplitude for narrow pulses to an adequate 9V at 50% duty. In wide-range duty-cycle applications above 50%, however, the drive voltage can rapidly become too small for efficient FET driving.

Secondary pulse-shaping networks can be used to extend the duty-cycle range, as long as the secondary windings aren't clamped in such a way that the essential dc restoration of the transformer is compromised.

Design the drive transformer with the same care you would apply to the main power transformer. The minimum primary turns and selected flux density must satisfy the maximum pulse width and core loss requirements. Wind the primary and secondary as a trifler winding, pretwisting the three wires to form a tightly coupled flex before winding it on the bobbin or core. This will give a 1-to-1 transformer ratio and minimize the leakage inductance. To meet safety agency requirements, use thin triple-

For more information on this article,
CIRCLE 339 on Reader Service Card

insulated wire, such as TEX-E™, for these windings.

PETech