Coupled inductors broaden DC/DC converter usage

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Introduction

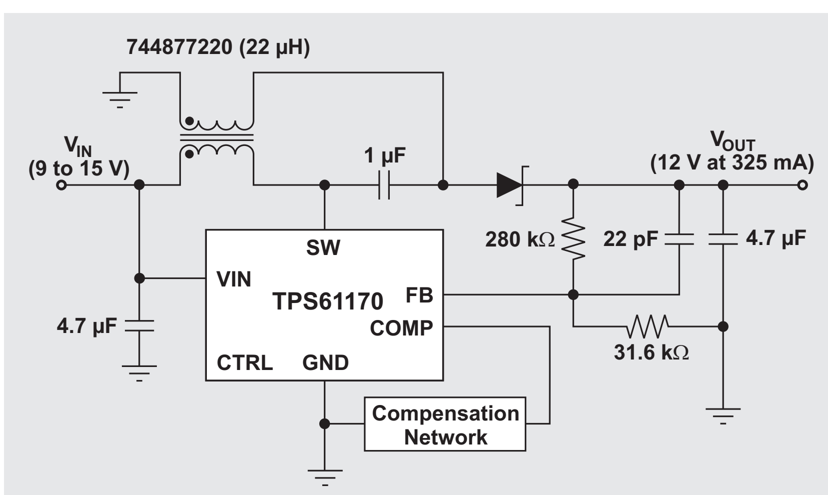
Recently, inductor manufacturers have begun to release off-the-shelf coupled inductors. Consisting of two separate inductors wound on the same core, coupled inductors typically come in a package with the same length and width as that of a single inductor of the same inductance value, only slightly taller. The price of a coupled inductor is also typically much less than the price of two single inductors. The windings of the coupled inductor can be connected in series, in parallel, or as a transformer. This article highlights four DC/DC converter topologies that meet common application needs with coupled inductors.

Clearly understanding the specifications of coupled inductors is essential to using them to their full advantage. Most of these coupled inductors have the same number of turns—i.e., a 1:1 turns ratio—but some newer ones have a higher turns ratio. The coupling coefficient, K, of coupled inductors is typically around 0.95, much lower than a custom transformer's coefficient of greater than 0.99. The mutual inductance of coupled inductors makes them perform somewhat inefficiently in flyback applications and can cause non-ideal (e.g., rounded instead of triangular) inductor waveforms. Also, the current specifications for a coupled inductor are different depending on whether its windings are physically connected in series or in parallel. For example, when the windings are connected in series, the equivalent inductance is more than twice the rated inductance due to the mutual inductance. The saturation and RMS current ratings must be applied to the current flowing simultaneously through both windings, unless otherwise stated in the data sheet. With this understanding of the specifications, some examples of coupled inductors in real applications can now be examined.

More efficient SEPIC with smaller footprint

While not new, the DC/DC single-ended primary inductance converter (SEPIC) topology was not popular until recently, despite the ever-present need for a converter capable of regulating an output voltage that is in-between a higher and lower input voltage (for example, an unregulated wall wart providing 12 V). Any boost converter/controller can be configured as a SEPIC, but this was rarely used until recently. Two factors have contributed to the SEPIC's newfound popularity: (1) IC manufacturers have begun making more boost controllers with current-mode control to simplify compensation, and (2) inductor manufacturers have begun making single-packaged coupled inductors that minimize the converter's overall PCB footprint. Specifically, the power-supply footprint of many applications with two separate inductors can be reduced by a third when a coupled inductor is used instead. Figure 1 shows a SEPIC using the Texas Instruments (TI) TPS61170 and the Wuerth 744877220.

Figure 1. SEPIC using the TI TPS61170 and Wuerth 744877220



Even more appealing, using a SEPIC with a 1:1 coupled inductor forces the inductor ripple current to split between the two windings, allowing the use of half the inductance that two single inductors would require for the same ripple current. Compared to two single inductors at twice the inductance value in a package of the same size, the coupled inductor has lower DC resistance, which helps increase overall converter efficiency. Specifically, with a 15-V input and a 12-V, 325-mA output, the SEPIC in Figure 1 exceeds 91% efficiency. See Reference 1 for more information.

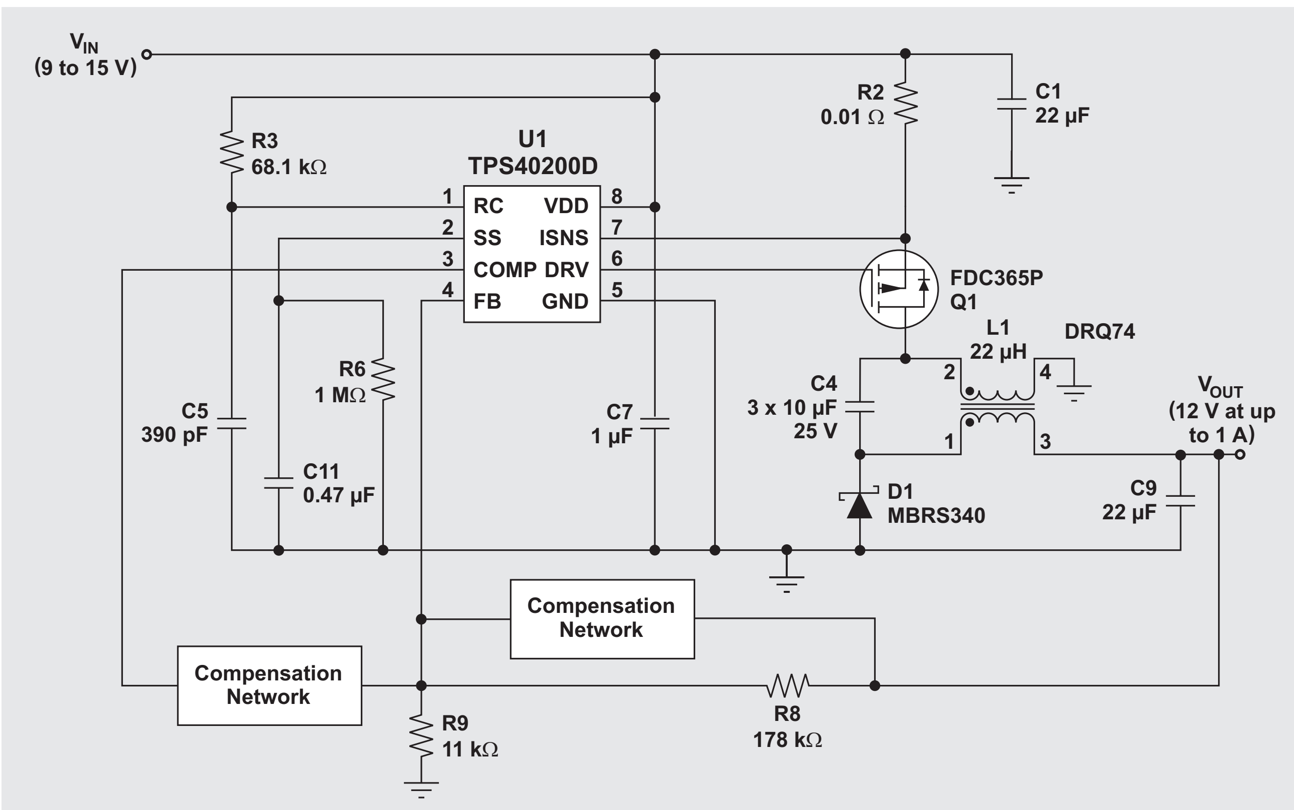
ZETA converter with smaller footprint

A ZETA converter provides the same buck and boost functionality as a SEPIC by using two inductors and a coupling capacitor, but with a buck controller instead of a boost controller. Figure 2 shows the TI TPS40200 and the Coiltronics DRQ74 in a ZETA configuration. Benefiting from the split-inductor ripple current like the SEPIC, this ZETA converter requires half the inductance for the same ripple current. Also like the SEPIC, its overall power-supply footprint is a third smaller than with two separate inductors. Since the output inductor current flows continuously to the output in a ZETA converter, the ZETA converter's output voltage has lower ripple than that of a SEPIC with the same inductance. Therefore, the ZETA may be a better fit for low-noise applications than a SEPIC. See Reference 2 for more information.

Split-rail supply

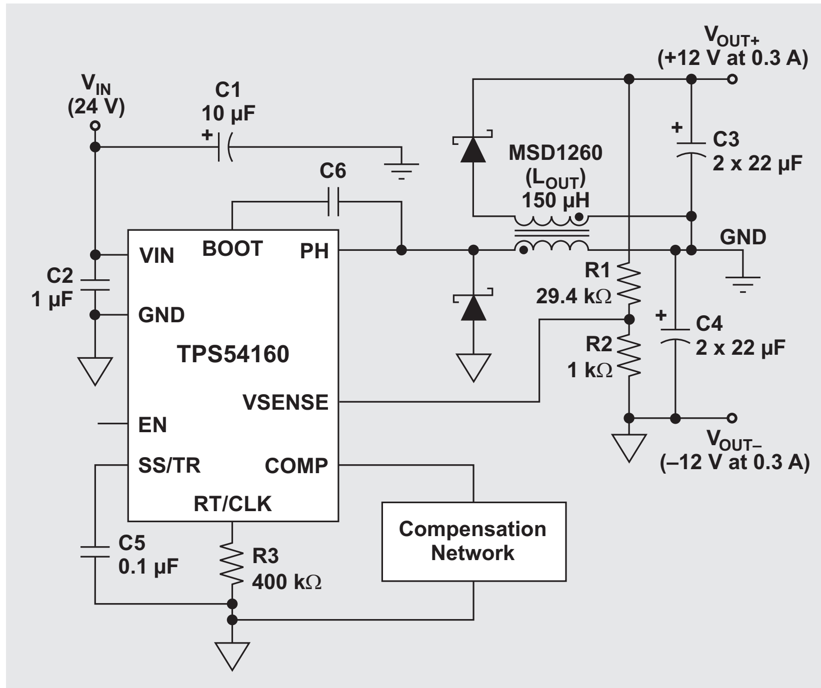
Matching positive and negative power rails are common requirements in industrial applications, especially for amplifiers. A wide-input-range buck converter can be configured to provide a negative output voltage. Replacing the inductor of this inverting buck converter with a coupled inductor and adding a diode and capacitor turns this

Figure 2. ZETA converter with TI TPS40200 and Coiltronics DRQ74



inverting buck converter into one with a dual output. Figure 3 shows the TI TPS54160 and the Coilcraft 150-µH MSD1260 used in this fashion. Even though the difference between each rail is regulated instead of each rail being individually regulated, as long as the loads on each rail are somewhat close together, the coupled inductor assists in providing excellent regulation of each rail. See Reference 3 for more information.

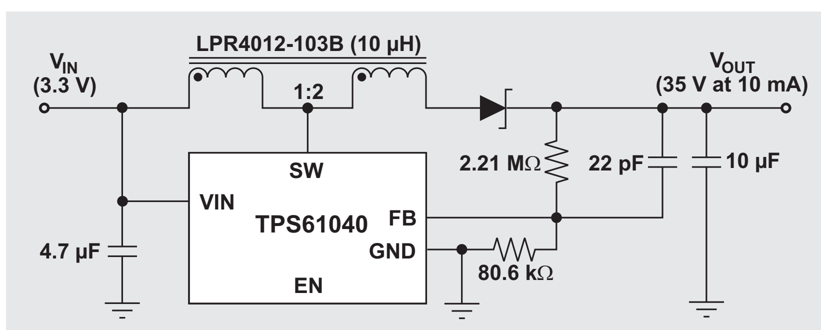
Figure 3. Split-rail buck converter using the TI TPS54160 and Coilcraft MSD1260



Higher output voltage

The output voltage of a DC/DC converter with integrated FETs is limited by the converter's switch current rating. Tying a coupled inductor with a turns ratio greater than 1:1 to the converter's switch (SW) pin can extend the effective output-voltage range of any boost converter. For example, Figure 4 shows the TI TPS61040 boost converter with a 30-V absolute maximum current rating configured to provide 35 V or more, and the Coilcraft LPR4012-103B, which is a 1:2 coupled inductor. When the coupled inductor is configured with the multiple-winding side in series with the diode, the single wound inductor—and therefore the converter's switch FET—has only a third of the output voltage, minus the input voltage, across it.

Figure 4. TI TPS61040 and Coilcraft LPR4012-103B providing extended output voltage



Conclusion

Most inductor manufacturers have a family of coupled inductors with a turns ratio of 1:1 or higher. So, think out of the box! Coupled inductors may expand the application space for a favorite DC/DC converter IC.

References

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Document Title **TI Lit. #**

1. Jeff Falin, "Designing DC/DC converters based on SEPIC topology," *Analog Applications Journal* (4Q 2008) slyt309
2. Jeff Falin, "Designing DC/DC converters based on ZETA topology," *Analog Applications Journal* (2Q 2010) slyt372
3. David G. Daniels, "Creating a split-rail power supply with a wide input voltage buck regulator," Application Report slva369

Related Web sites

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Replace *partnumber* with TPS40200, TPS54160, TPS61040, or TPS61170

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