

# Valuing wide $V_{IN}$ , low EMI synchronous buck circuits for cost-driven, demanding applications

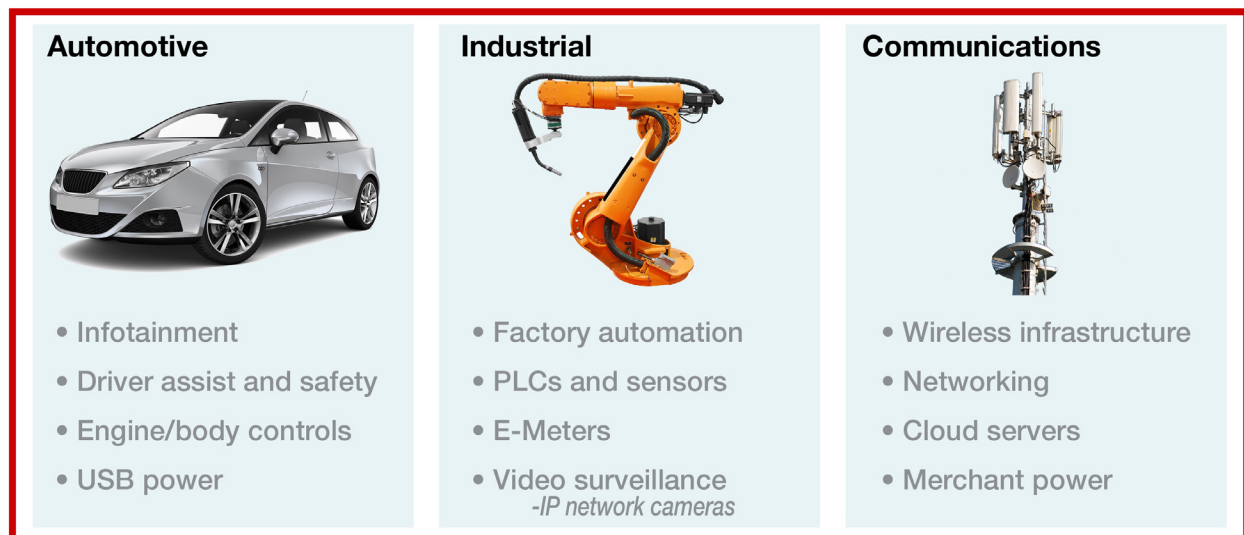


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# Synchronous buck converters with a wide $V_{IN}$ range, proven EMI performance, and multi-output flexibility are indispensable features to reduce total solution cost and time-to-market.

At the epicenter of most power converter implementations is an inevitable trade-off of efficiency versus solution size [1]. However, new applications are coming to fruition that have unique power solution requirements tied to a number of performance features. For the cost-driven industrial, automotive and communications applications shown in **Figure 1**, three particularly desirable features pertinent to synchronous buck converter circuits are required: 1) wide input voltage operating range or wide  $V_{IN}$ ; 2) multiple outputs, both non-isolated and isolated, leveraging dual-channel and Fly-Buck™ solutions; and 3) low noise and electromagnetic interference (EMI).

Referencing Texas Instruments portfolio of easy-to-use, wide  $V_{IN}$  buck converters and controllers, this white paper takes a close look at the value proposition of each listed feature as it relates to a product development environment where bill-of-materials (BOM) cost optimization, reliability, and time-to-market are the overarching constraints.

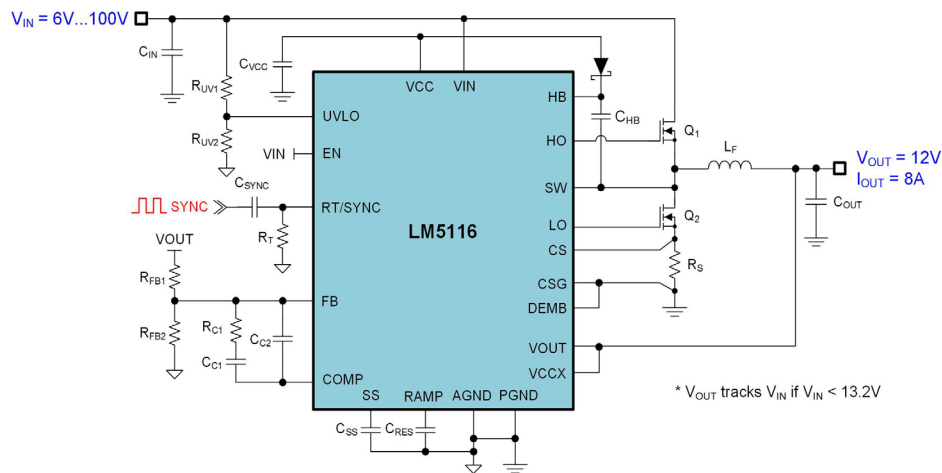


*Figure 1: Cost-driven, demanding applications within automotive, industrial and communications segments.*

## Wide $V_{IN}$ operating range

Power converters specifically with wide  $V_{IN}$  range [2] provide an operating margin to quell input rail transient voltage disturbances. This type of transient immunity performance is critical in applications where high reliability or an extended product life cycle is required.

For example, industrial automation and process control equipment often must operate from largely unregulated 8 V-to-36 V rails that also support high current and inductive load switching of electromechanical (EM) devices. Examples include motors, relays and circuit breakers. When such



**Figure 2:** Robust synchronous buck converter with 6 V to 100 V input voltage range.

devices switch on and off, the combination of series parasitic inductance and high slew rate currents contribute to momentary power surges, causing voltage fluctuations and large overvoltage spikes on the supply rail. Furthermore, IEC 61000-4, a common transient immunity specification for industrial applications [3], describes low- and high-frequency input disturbances (ESD, burst, lightning/surge, and conducted and radiated immunity). Such high slew rates and high-voltage line transients often expose the fragility or marginality of a particular design, resulting in electrical overstress (EOS) or even catastrophic failure. A passive protection network, typically consisting of a low-pass LC filter and transient voltage suppression (TVS) array, is used as a first line of defense to clamp the peak-voltage excursions. However, the circuits located downstream from the protection network must survive up to a 100-V

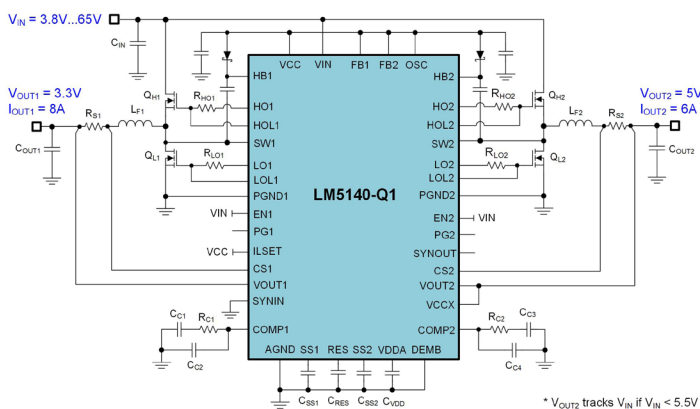
peak transient voltage without damage, as well as function seamlessly through these types of transients without interruption.

Using a DC/DC converter that produces a tightly-regulated output even in volatile voltage environments with a wide range of dynamic disturbances, **Figure 2** shows an example of a high-efficiency solution using an emulated current-mode (ECM) control technique specifically intended for large step-down conversion ratios. Operating over a 16:1 wide  $V_{IN}$  range and capable of sustaining repetitive 100-V surges, the converter maintains uninterrupted regulation and the output voltage is immune to large and noisy voltage swings at the input. The wide  $V_{IN}$  range capability reduces the cost of ancillary passive components for transient protection, and renders designs with minimal component derating unnecessary.

## Multiple outputs

### Dual output synchronous buck converter

The proliferation of electronic subsystems in automobiles has created demand for small size, low cost and highly reliable power supplies that can operate under the stringent conditions presented by the automotive environment. **Figure 3** shows a dual-channel synchronous buck automotive supply [4] that can be used in engine control units (ECU) and other critical functions. These critical functions include braking, fuel system and drive train subsystems where processors must remain



**Figure 3:** Wide  $V_{IN}$ , low  $I_O$  dual-channel synchronous buck controller for automotive applications.

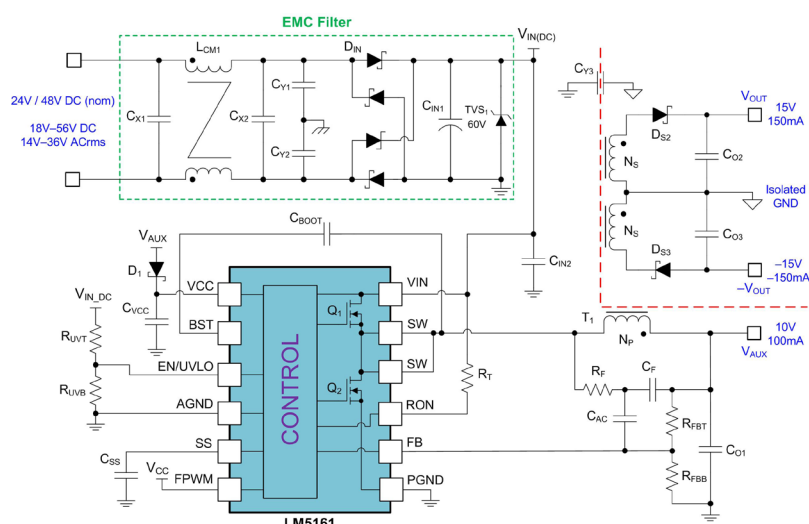
powered without glitches during even the most severe battery voltage transients.

You can select a fixed switching frequency at either 2.2 MHz or 440 kHz to operate above or below the AM broadcast band, respectively, with the option to synchronize to an external clock if needed. The dual-channel controller pushes cost and size boundaries by minimizing the solution footprint. The two channels are interleaved 180 degrees out-of-phase for lower input ripple current with respect to two independent single-phase converters.

Dual-gate drive outputs allow you to adjust the switch (SW) voltage and current slew rate, which helps to reduce high-frequency noise and EMI filter size. At the same time, an IC package with wettable flank terminations allow you to visually inspect the printed circuit board (PCB) for solder joint integrity, reducing production cost and increasing reliability.

## Fly-Buck converter

Recently gaining prominence as a sub-20 W isolated power solution is the Fly-Buck converter [5]. As an extension of the synchronous buck regulator, the Fly-Buck circuit lowers the solution cost by eschewing loop compensation and feedback optocoupler components. A compensated error amplifier is not needed, and an adaptive constant on-time (COT) control approach gives a nearly-instantaneous response for excellent transient dynamics. For maximum flexibility, both isolated and non-isolated outputs are available. The Fly-Buck can be used for low-current auxiliary and bias rails, floating gate supplies that drive power MOSFETs and IGBTs, and bipolar supplies for powering high-precision amplifiers and data converters.



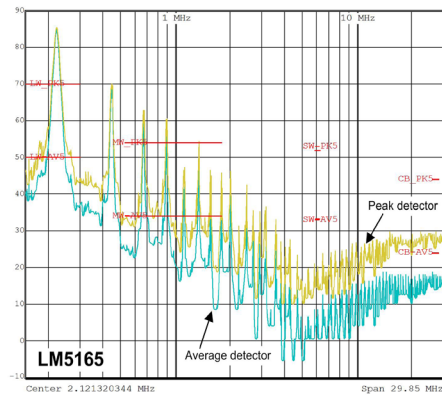
**Figure 4:** AC- or DC-powered Fly-Buck solution supplying  $\pm 15$  V isolated rails.

**Figure 4** shows a Fly-Buck power solution for cost-constrained industrial applications that delivers  $\pm 15$  V isolated rails from a center-tapped secondary winding. The feedback regulation is from the primary side, which uses a standard resistor divider. Output voltages are scaled based on the turns ratio  $N_P/N_S$  of transformer  $T_1$ . A 10-V primary-side regulated auxiliary rail sends bias power to the  $V_{CC}$  to reduce quiescent power loss at high  $V_{IN}$ . To cost-effectively customize a Fly-Buck converter design for additional outputs, simply add a transformer secondary winding (with the appropriate turns ratio), a rectifier diode, and an output capacitor.

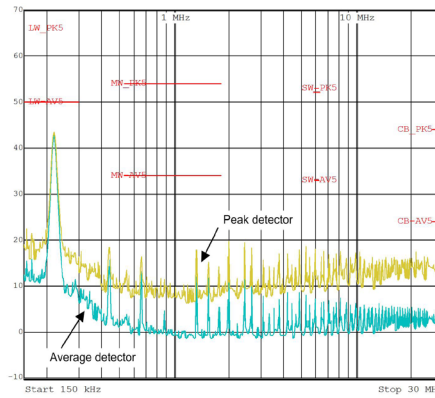
## Low noise and EMI

Electromagnetic susceptibility (EMS), electromagnetic compatibility (EMC) and all environmental effects (E3) are relevant considerations in any electronics product development – and critical for systems integration. Moreover, system-level conformance to EMI regulatory specifications is an increasingly important power solution benchmark and a key milestone in a product's design cycle.

Red Lines Class 5 Limits (peak & average detection)  
 Yellow Peak detection result  
 Blue Average detection result



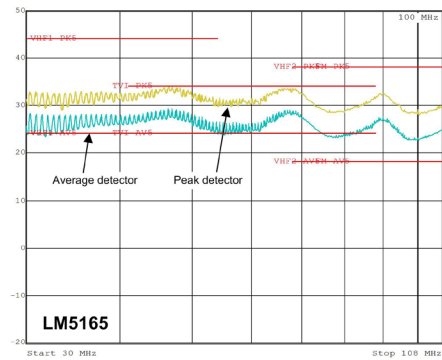
(a)



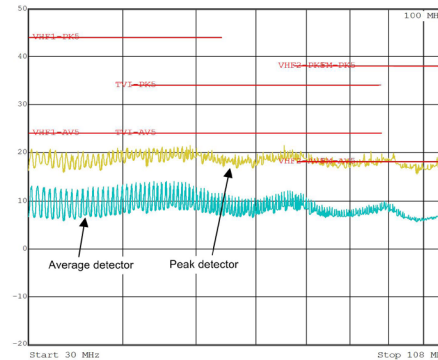
(b)

**Figure 5:** Synchronous buck converter CISPR 25 Class 5 EMI performance from 150 kHz to 30 MHz.  $V_{IN} = 24\text{ V}$ ,  $V_{OUT} = 5\text{ V}$ ,  $I_{OUT} = 100\text{ mA}$ : unfiltered (a); filtered emissions (b).

Red Lines Class 5 Limits (peak & average detection)  
 Yellow Peak detection result  
 Blue Average detection result



(a)



(b)

**Figure 6:** Synchronous buck converter CISPR 25 Class 5 EMI performance from 30 MHz to 108 MHz.  $V_{IN} = 24\text{ V}$ ,  $V_{OUT} = 5\text{ V}$ ,  $I_{OUT} = 100\text{ mA}$ : unfiltered (a); filtered emissions (b).

Such strict regulatory standards have spurred demand for proven “out-of-the-box” compliant solutions using recommended EMI filtering components and PCB layout techniques. Typically, a high-density design has little space available for EMI filtering. Fortunately, a tight layout improves radiated emissions as well as immunity to incoming disturbances. Essential steps to take are to minimize loop areas containing high  $di/dt$  currents and reduce surface areas with high  $dv/dt$  voltages (such as switch node copper polygon areas) [6-8].

Many power converter ICs are specifically designed to minimize their EMI signature. For example, the [LM5088-Q1](#), a current-mode buck controller from TI, has an optional spread-spectrum feature that reduces peak emission levels, particularly at the fundamental frequency and lower harmonics. The [LM5140-Q1](#) controller presented in **Figure 3** has high-side and low-side gate drivers with adjustable

slew rate control to mitigate higher-frequency conducted and radiated emissions. The [LM5165](#) is an example of a synchronous buck converter [9] that uses an integrated active slew rate control of the switch-node voltage transition to reduce EMI filtering requirements, especially in the more troublesome frequency band above 30 MHz. Using an LC input filter of 22  $\mu\text{H}$  and 10  $\mu\text{F}$ , conducted emissions plots for the LM5165 synchronous buck converter shown in **Figure 5** and **Figure 6** meet the CISPR 25 Class 5 automotive EMI standard.

## Conclusion

Synchronous buck converters with a wide input voltage range, multiple outputs (with or without galvanic isolation), and verified EMI performance are indispensable when total solution cost and time-to-market are predominant concerns for the system designer.

Key Market	Features			Solution
	Wide $V_{IN}$ Range	Multiple Outputs	Low EMI/EMC	
Rugged industrial equipment	60 V+ for 24-V backplanes with superimposed voltage spikes and transients	Multi-output fly-buck or fly-back produces isolated bias and IGBT floating gate drive supplies	Smaller input transient protection for space-constrained designs	LM5145, LMR36015, LM5160, LM5180
Advanced automotive electronics	42 V / 60 V to survive battery harness load dump overvoltage	Dual-channel for high-density 5-V and 3.3-V rails	Fixed 2.2-MHz switching frequency avoids AM band	LM5143-Q1, LMR33630-Q1
	3.V $V_{IN}$ manages battery cold crank and start-stop events	Wide adjustable output voltage range for USB Type-C™ power	Spread-spectrum cuts peak emissions	
Sensitive communications systems	75 V+ for 48-V server backplanes, smaller passive component protection network	Fly-buck or fly-back derives $\pm 12$ -V / $\pm 15$ -V bipolar rails for op amps, ADCs and RF circuits	Active slew-rate control of SW node voltage lowers radiated emissions	LM5145, LM5180

**Table 1:** A compelling value proposition with system-level benefits of a wide  $V_{IN}$  range, multiple outputs and low EMI solution.

Conversely, converter designs lacking the requisite performance and reliability can wreak havoc on a design. Against this backdrop, many designers are choosing to capitalize on easy-to-use IC solutions that combine value, performance and reliability. Recounted in this white paper and summarized

in **Table 1**, a cohesive feature set and innovative product advantages play an outsized role in maximizing value and reliability to address a variety of power solution application requirements and end equipment.

## References

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10. Download these data sheets: [LM5088-Q1](#), [LM5140-Q1](#), [LM5161](#), [LM5165](#).

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