

# DESIGN *FAQs*

## Frequently Asked Questions:

### DESIGNING HIGH-VOLTAGE INPUT POWER CONVERTERS

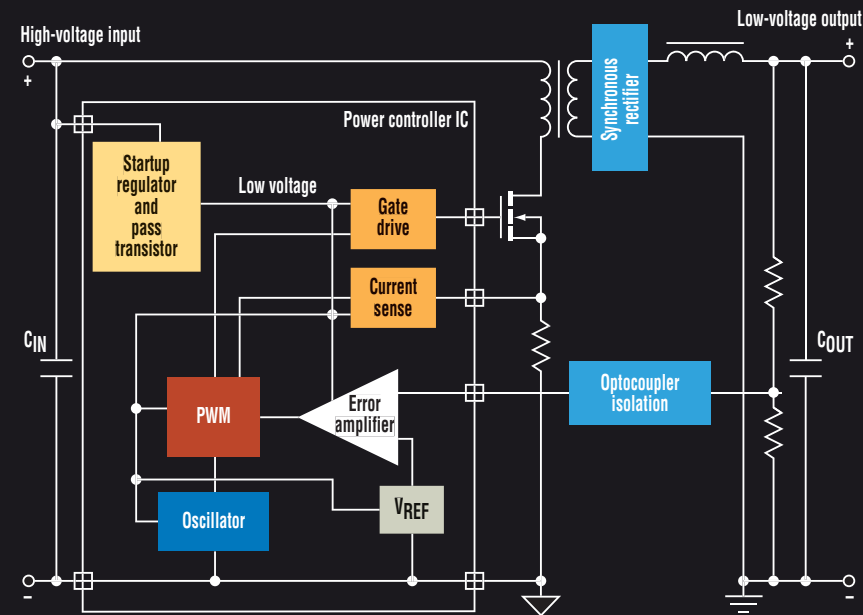
Sam Davis, Contributing Editor

#### How do you define “high-voltage” input for power converter ICs?

For most power-management subsystem ICs, “high-voltage” input is 30 up to 100 V. The 100-V maximum input rating ensures reliable and safe operation of 48-V bus telecommunication power converters, 42-V automotive systems, and other industrial systems that operate at similar voltages. The normal voltage range is lower than 100 V. However, parasitic inductances and peak noise transients can cause voltage spikes that approach 100 V. The higher-voltage rating provides additional reliability insurance.

#### What does the IC manufacturer have to do to obtain a high-voltage input rating?

High-voltage ICs require specialized wafer technologies and device designs that increase the breakdown voltage of certain transistors. Most high-voltage ICs integrate high-voltage devices with low-voltage logic and control circuits. The high-voltage devices use deeper junctions and larger dimensions than the standard low-voltage devices.



This simplified high-voltage input, current-mode controller is employed in a forward converter topology to produce an isolated (no dc path from input to output) low voltage.

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#### How is the lower operating voltage produced in a high-voltage input IC?

Usually, these high-input-voltage ICs have a startup regulator that connects directly to the high-voltage input and provides a bias voltage for the lower-voltage control circuits.

#### What circuit topologies usually require a high-voltage-input rating?

One popular topology is the forward converter in the figure. For a telecom example, the input-voltage range is 36 to 75 V dc, and the output is an isolated low voltage.

#### How does current-mode control function in a forward converter?

Referring to the figure, current-mode control employs inductor (or transformer) current feedback as well as the output voltage error signal to drive the pulse-width modulation (PWM) circuit, which controls the converter’s output voltage. In a typical current-mode controller, the inductor current increases during the on-time of the PWM. A signal proportional to the inductor current is compared with the output voltage error signal by the PWM comparator to determine the duration of the on-time (or pulse width).

#### How does current-mode control provide current limiting?

Current-mode control has inherent cycle-by-cycle current limiting. It requires no additional circuitry to sense the inductor current because it is already in place due to the current feedback loop.

#### How do voltage-mode and current-mode line regulation compare?

Voltage mode and current mode differ in their line regulation, defined as the change in the output voltage caused by a change in the input voltage. The gain control-to-output transfer function in current mode architecture is independent of  $V_{IN}$ , so line regulation is very good. In contrast, voltage-mode line regulation has a  $V_{IN}$  factor in its expression, which implies that the gain is directly proportional to  $V_{IN}$ . Line regulation of voltage-mode con-

troller suffers in comparison to current mode, but techniques such as line voltage feed-forward significantly improve performance.

### How do converters handle continuous and discontinuous conduction modes?

In continuous conduction mode (CCM), inductor current is continuous and does not reach zero. In discontinuous conduction mode (DCM), inductor current is discontinuous and zero for part of the switching period. As the load current decreases, there is a point where the converter transitions from CCM to DCM. In a voltage-mode system, the power stage transitions from a second-order to a first-order system at the boundary of CCM/DCM, which requires very different compensation networks for optimization. However, the current-mode architecture power stage transfer function is very similar in DCM and CCM modes. So for very large load changes, where the converter operates in both DCM and CCM, current-mode dynamic performance does not change drastically.

### How is slope compensation used in a power converter?

At duty cycles greater than 50%, current-mode control circuits are subject to subharmonic oscillation (output oscillation at frequencies less than the switching frequency). Designers can avoid these oscillations by adding a small fixed ramp (slope) to the current sense signal. Most current-mode ICs include provisions for slope compensation.

### How does the skip mode improve operating efficiency in a PWM converter?

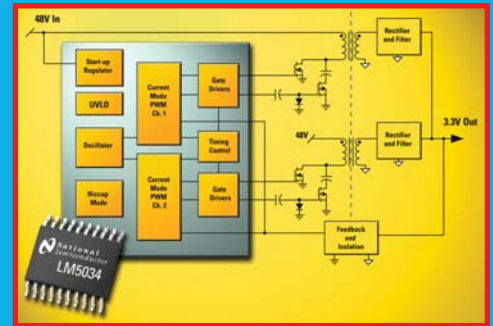
A skip cycle function employs a light load detector that reduces the average switching frequency to reduce switching losses and improve efficiency during light load conditions. With light loads, power-supply efficiency typically drops as switching losses become a significant percentage of load power. Reducing the switching frequency cuts losses because each PWM cycle consumes a finite amount of energy as the MOSFET turns on and off.

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# PRODUCT Q&As

## LM5032/LM5034—High-Voltage Dual Interleaved Current-Mode Controllers

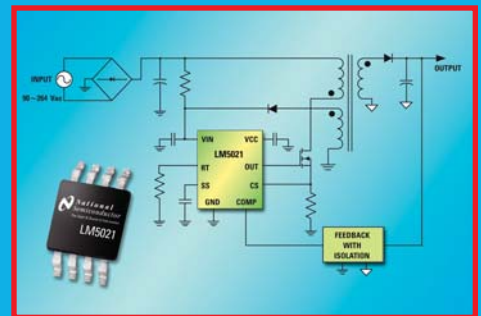
The LM5032 is a dual current-mode pulse-width modulation (PWM) controller, capable of controlling two independent dc-dc converters or a single high-current converter consisting of two interleaved power stages. The two controller channels operate 180° out of phase, which reduces input ripple current. A startup regulator provides low voltage bias, derived from an input voltage of up to 100 V. Compound (bipolar + CMOS) gate drivers provide 2.5-A peak sink current for external power MOSFETs. The IC's adjustable maximum PWM duty cycle reduces stress on the external MOSFET switches.



Additional features include programmable line undervoltage lockout, cycle-by-cycle current limit, hiccup-mode fault operation with adjustable response time, PWM slope compensation, independent soft-start for each regulator, 2-MHz capable oscillator with synchronization capability, maximum duty cycle fold-back at high line voltage, and thermal shutdown.

## LM5021—AC-DC Current-Mode PWM Controller

The LM5021 offline controller can control an efficient single-ended fly-back or forward power converter using current-mode control. The LM5021 features include 25- $\mu$ A startup current, which minimizes power losses in the high-voltage startup network. Its integrated 0.7-A sink gate driver directly drives an external power MOSFET. To enhance standby power, a skip cycle mode reduces switching frequency with light loads.



Additional features include undervoltage lockout, cycle-by-cycle current limit, hiccup-mode overload protection, slope compensation, soft-start, and oscillator synchronization capability. This IC has total propagation delays less than 100 ns and a 1-MHz capable oscillator programmable with a single external resistor. The LM5021 is offered in two versions, with maximum duty cycle limited to 80% for the LM5021-1 or 50% for the LM5021-2. The LM5021 comes in either an eight-pin MSOP or MDIP.



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