

White Paper

How to Efficiently Boost Power in High Voltage Automotive Applications

Introduction

While the 12-volt lead acid battery is still the dominant power source in automobiles, there are new automotive applications that require higher voltages such as trunk audio power amplifiers and in-glass window defrosters. To address these high voltage applications, a new generation of AEC-Q100-qualified synchronous boost controllers has emerged. The controllers are designed to boost the 12-volt battery voltage, withstand voltage spikes as high as 60 volts and deliver the robust reliability required in new car models.

This white paper examines a pair of easy-to-use 2-phase 55V synchronous boost controllers that efficiently generate power rails of 24V, 36V or 48V in an automotive environment where only a 12V supply is available. We'll explore some of their key integrated features, including the extensive protection functions that enable an optimized solution to reduce cost and improve efficiency, safety and reliability. We'll also discuss an integrated PMBus interface that provides advanced control, telemetry and diagnostics, and simplifies the task of attaining ISO 26262 compliance.

Boosting the 12V Battery

A constant challenge for system designers is how to achieve higher power efficiency while minimizing circuit board space. The ISL78227 and ISL78229 55V synchronous boost controllers address this issue by integrating advanced FET drivers that adaptively adjust switching times to prevent cross conduction while simplifying power-stage design. The controllers operate in a 2-phase configuration that reduces ripple current allowing the use of smaller input and output capacitors, which reduces circuit board footprint area. Two controllers can be used in parallel to expand the number of phases to four to support higher power output levels.

The ISL78227 and ISL78229 with PMBus interface operate over a wide range of frequencies, as low as 50kHz or as high as 1.1MHz, and can be configured to optimize the operating frequency for either efficiency or minimum board space by using smaller external components. They include many features aimed at maximizing efficiency, which is important since a 400-watt load will be pulling peak currents of more than 30 amperes from the 12V battery.

Synchronous FETs for Output Rectification

It's common for buck converters to use a FET in place of a diode for the output rectifier function because most buck converters deliver low output voltages. In this configuration, the voltage drop across the rectifying element represents a high proportion of the power lost to produce the output voltage. Replacing the output rectifier diode with a sync FET that switches on and off at the right time greatly enhances efficiency. This is because the FET losses are typically a fraction of the loss in the rectifier diode. In the buck converter, the sync FET is ground referenced and therefore the drive circuitry is relatively simple.

The sync FET brings several benefits to the boost configuration. In a boost converter application, the output voltage is usually several times greater than the input voltage so the losses in the output rectifier element are not as high of a percentage of the total output power. While the boost converter benefits from the sync FET efficiency improvements, the sync FET provides bidirectional current flow, which allows continuous mode operation, even at light loads – a key benefit for applications that require low electromagnetic interference (EMI). Bidirectional current flow is also a key capability required to implement an effective envelope tracking function, which we'll address later. Additionally, the use of a sync FET does not preclude operation in discontinuous mode. The boost controllers can detect negative current flow and can optionally disable the sync FET to emulate the function of the synchronous rectifier diode.

Diode Emulation for Light Load Efficiency

It is common for audio signals to change over a wide magnitude in very short periods of time. One moment the amplifier may need a burst of high power, the next moment it may be very low. The audio may even go silent between audio sessions. When this occurs, the amount of power used in the amplifier drops significantly, and because of this, the power demand on the boost regulator will also drop to a low value. In fact, under light loads the boost inductor current can go to zero. When this occurs, the voltage across the inductor has a higher voltage on its output (the boost voltage) than on its input (the battery voltage). If the sync FET remains on under this condition, current can start flowing backward through the inductor taking charge from the output capacitor.

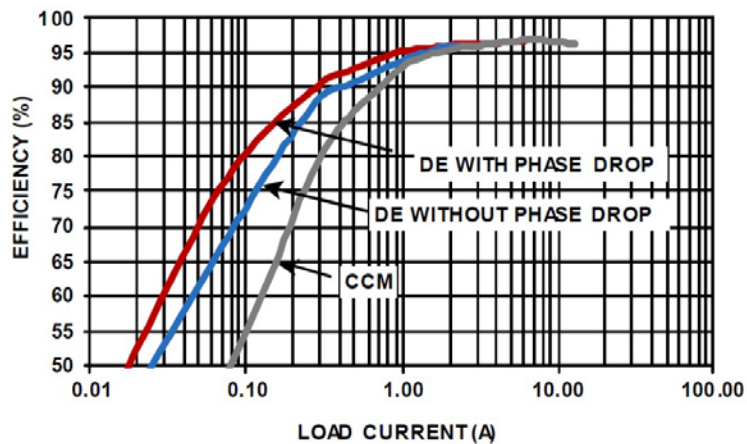


Figure 1. Efficiency vs. load, 2-phase boost, three modes operation, $f_{sw}=200kHz$, $V_{IN}=12V$, $V_{OUT}=36V$, $T_A=+25^{\circ}C$

The 55V boost controllers include circuitry that can optionally avoid this reverse conduction loss by making the sync FET emulate the current-blocking behavior of a real diode. This smart-diode operation is called diode emulation mode (DEM) and functions to turn the sync FET off when the circuitry senses that the inductor current is starting to flow in the wrong direction. If the controller enters into the diode emulation mode and the load is still reducing, the controller will enter into a pulse skipping mode to reduce the number of switching cycles to improve efficiency under extreme light loads on its output.

While DEM can improve efficiency at light loads, it can also present some EMI challenges due to the changing switching characteristics. To avoid EMI issues, it's often desirable to maintain continuous-conduction mode (CCM) operation. But of course, we would then sacrifice the efficiency improvement brought by diode emulation, as shown in Figure 1. However, in applications like audio amplifiers, an alternative method of attaining light-load efficiency improvements is to have the power supply to the amplifier track the demands of the input with an envelope tracking capability.

Forced PWM Operation

Many power system applications require the converter's switching frequency to be held constant to minimize the likelihood of interference. Because of this requirement, the ISL78227 and ISL78229 also operate in PWM mode (no pulse skipping). However, in forced PWM mode there are conditions when reverse currents may flow, such as when starting up into a pre-biased output, or anytime the output voltage is boosted to a higher voltage than expected. In a typical system, there is no means to limit the reverse current and this can damage the sync FET. The ISL78227 and ISL78229 overcome this issue by including a reverse current limiting feature. Limiting the negative current reduces output voltage transients and enhances system reliability. Therefore, the designer can configure the boost controllers in forced PWM mode and not worry about reverse currents getting out of control.

Phase Shedding Improves Light Load Efficiency

The ISL78227/29 sync boost controllers support 2-phase boost operation, enabling two devices to be connected together to achieve four-phase operation (see Figure 2). At heavy loads, the main system losses are due to conduction losses and switching losses, but at lighter loads, the switching losses begin to dominate. To improve efficiency, both controllers can be configured to monitor the magnitude of the system current. If the load drops below a certain threshold, the controller can drop a phase. This reduces switching losses under light load conditions. The phase shedding process is done over 15 switching cycles to prevent a load transient. If the load then increases back above the threshold, the phase is added instantly to manage the increased load.

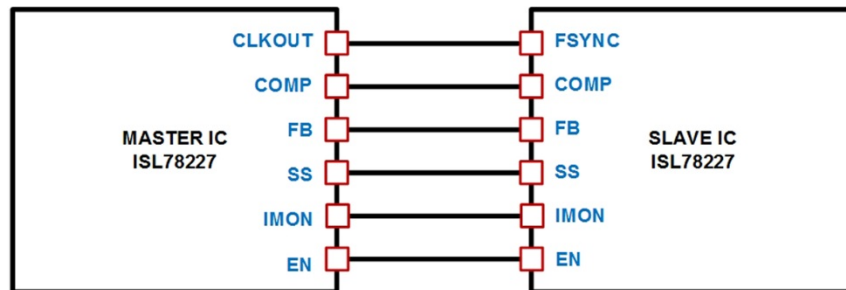


Figure 2. Two devices wired to support 4-phase operation for higher-power applications

Reference Voltage Control and Audio Envelope Tracking

The boost controllers' output voltage can be scaled using the 1.6-volt on-chip voltage reference, or they can be scaled to an external tracking voltage, which drives the control loop. The ISL78227 and ISL78229 controllers are unique in that the external signal used to drive the tracking function is configurable as either an analog voltage or a PWM signal. These TRACK features support the varying of the output boost voltage dynamically. The controllers include negative current limiting and protection, which is useful when the envelope tracking is slewing from a higher voltage to a lower voltage.

The output boost voltage is supposed to track the control signal, but, when going from a higher voltage to a lower voltage, the output capacitor must be discharged for the voltage to fall. If the load itself is not consuming enough current, the sync FET can help discharge the output capacitor, without any concern for FET damage due to excess currents. This is because both controllers include negative current limiting and protection circuitry for these types of conditions.

The ability to support envelope tracking without concern for excess reverse currents can be particularly helpful in audio applications where the supply voltage can quickly vary over a wide range. In an audio application, the TRACK signal can be used to control the boosted output voltage so that it tracks the audio amplifier's signal magnitude as the signal changes. This smooths out the power supply to prevent glitches with changing loads, which prevents pops from the audio power amplifier.

Remember, the power delivered to the speaker is a function of the peak voltage output of the amplifier as shown in the following equation:

$$P_{avg} = V_{rms} \cdot I_{rms} = V_{rms}^2/R = V_{peak}^2/2R$$

Boosting the 12-volt battery to higher voltages is common in automotive audio power amplifier applications. The controllers can boost the battery voltage up to 48V or whatever voltage is needed to support the wattage level of the audio power amplifiers. It is very common for the audio amplifier to be 100-800 watts. Some premium audio systems can have 30-40 watt amplifiers in a multi-channel system with a much higher power amplifier to drive a sub-woofer.

In an analog type audio amplifier, efficiency is improved if the supply voltage is only large enough to support the audio signal. Efficiency benefits in digital type audio amplifiers will depend upon the digital amplifier architecture.

PMBus Control

The ISL78229 boost controller shown in Figure 3 includes a PMBus interface that helps the designer's system achieve ISO 26262 compliance and an Automotive Safety Integrity Level (ASIL) rating. The PMBus interface is useful in systems that require real-time telemetry, fault reporting to the microcontroller, and system control. It provides a means to remotely enable or disable the boost controller and to monitor and report variables such as input voltage, input current, and output voltage. In addition, the boost controller includes a pin to support the measurement of an external negative temperature coefficient (NTC) resistor to monitor temperature. It then digitizes this signal and the reading can be reported over the PMBus. An over temperature fault limit can be set for the external temperature monitoring.

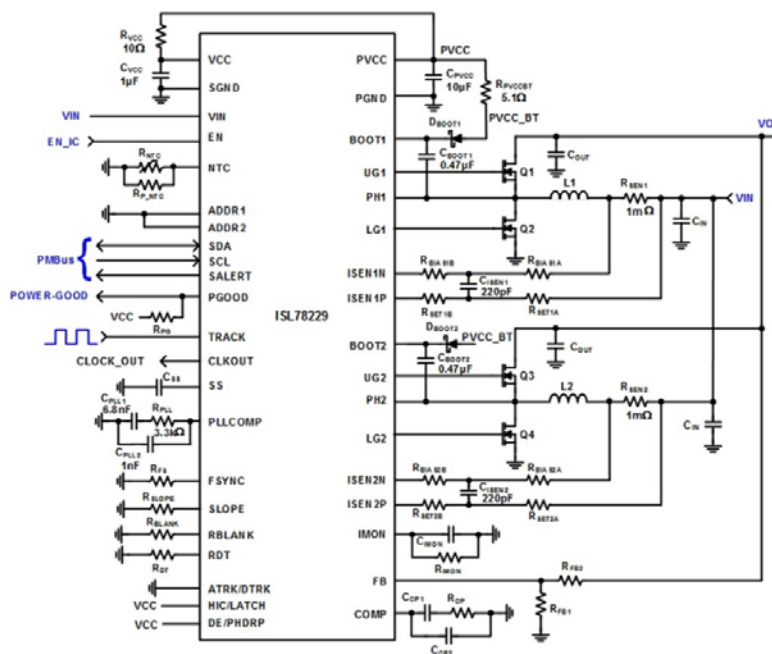


Figure 3. Typical application of the ISL78229 with PMBus control

The boost controller also has fault reporting functions such as input over-voltage, output over-voltage or output under-voltage, over-current faults, and over-temperature. Each function can be monitored via the PMBus. The addition of the PMBus interface eliminates the need for dedicated telemetry circuitry.

Conclusion

The ISL78227/29 multi-phase 55V synchronous boost controllers offer a combination of features that accommodate many different power system requirements. Individually, the capabilities may seem trivial, but when put together, the whole exceeds the value of the sum of the parts. Voltage quality modules for start-stop systems, trunk audio amplifiers, and in-glass window defrosters are just a few of the high voltage applications that require a robust boost controller solution.

Next Steps

- [Learn more about the ISL78227/29](#)
- [Get the datasheets](#)
- [Watch a demo video](#)

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