

Dual Input, 42V, 2.5A Synchronous Buck Converter Features Seamless, Automatic Transition Between Two Input Power Sources and Meets Stringent CISPR 25 Class 5 EMI Limits

John Canfield

Many electronic devices must seamlessly transition between a wide variety of input power sources—such as batteries, automotive rails, wall adapters and USB ports. Traditionally, power supply designers rely on Schottky diodes or a prioritized PowerPath (IC controlled MOSFET switches) to combine input sources. Since both methods require additional components in front of the switching power supply, solution size and design complexity increase while overall supply efficiency is reduced. With its ability to operate directly from two different input power sources, the LTC3126 eliminates these disadvantages and enables smaller and higher efficiency multisource power supplies.

The LTC3126 operates directly from two independent power sources, drastically simplifying the design of such systems by minimizing component count and solution size, as shown in Figure 1, while maintaining high overall system efficiency. Ease of use is enhanced by its expansive input voltage range, low total power supply quiescent current of just 2 μ A, and radiated emissions below the stringent CISPR 25 Class 5 automotive limits, as shown in Figure 2.

IDEAL DIODE-OR MODE

The LTC3126 supports two pin selectable PowerPath™ control modes: ideal diode-OR mode (described here) and priority channel mode (described below). In ideal diode-OR mode, as shown in Figure 3, the LTC3126 emulates an ideal diode-OR circuit, where the buck converter automatically operates from the higher voltage of two input power sources. This mode of operation is useful in applications where the two power sources have

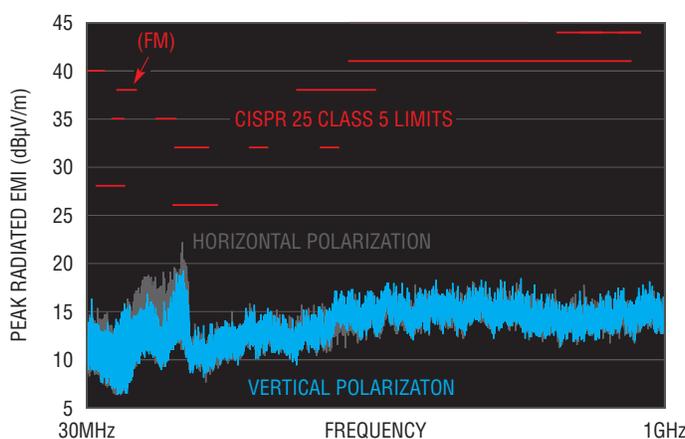


Figure 2. Operating on the standard demo PCB, the LTC3126 passes the CISPR 25 Class 5 radiated emission limits shown in red.

non-overlapping voltage ranges, for example, a rechargeable lithium battery with a voltage range of 3V to 4.2V and a wall adapter with a nominal 12V output.

The LTC3126 contains two internal low resistance, high side switches arranged in the topology shown in Figure 4, allowing the buck converter to operate directly from either input power source with no additional power path components. This has several advantages over the traditional

Schottky-diode approach, where discrete devices are used to accomplish this task:

- A typical 40V, 2A Schottky diode has a forward voltage drop of at least 500mV at full current. This voltage drop increases the required operating headroom, making it impossible to run from input voltage sources that are close to the voltage of the regulated rail, thereby reducing the usable portion of the battery discharge curve. For a 3.3V

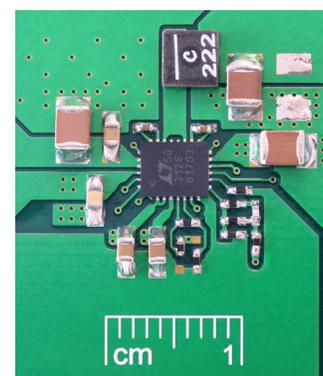
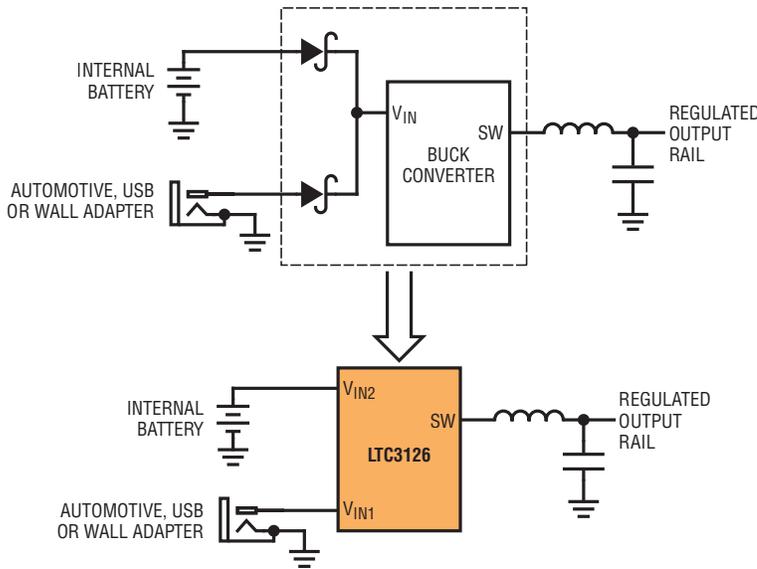


Figure 1. The LTC3126 provides a complete dual input power supply solution in 3.4cm².

The LTC3126's two internal low resistance, high side switches allow it to operate directly from two independent power sources, simplifying the design of such systems by minimizing component count and solution size while maintaining high overall system efficiency. Ease of use is further enhanced by its expansive input voltage range and low total power supply quiescent current of just 2 μ A.

Figure 3. In ideal diode mode, the LTC3126 emulates a discrete diode-OR circuit while eliminating the Schottky's power loss, voltage drop and reverse leakage current.



output, Figure 5 shows the typical extra headroom voltage eliminated by using the LTC3126 rather than a Schottky-OR followed by a buck converter.

- The Schottky forward voltage drop also results in significant efficiency loss. At full load this can account

for 1 watt of additional power loss, representing a 4% to 5% reduction in overall power conversion efficiency, as shown in Figure 6. The LTC3126 eliminates this power loss.

- The discrete Schottky approach suffers from high leakage current into the

Figure 4. The power switch topology of the LTC3126 provides optimal efficiency and minimum solution size, given the buck converter's ability to operate directly from either input, V_{IN1} or V_{IN2} , with no additional power path components.

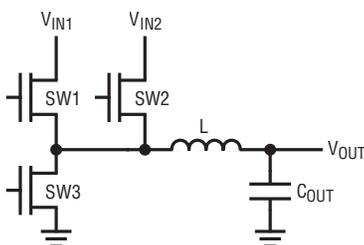
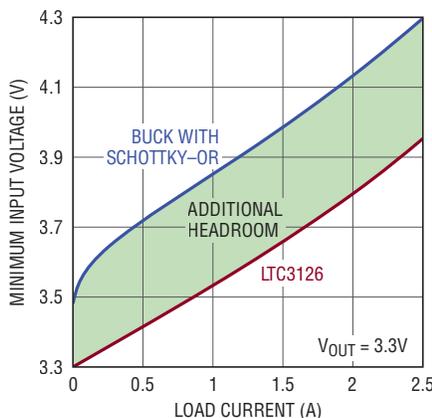


Figure 5. The lossless PowerPath design of the LTC3126 allows operation to lower input voltages while maintaining regulation of a 3.3V output.



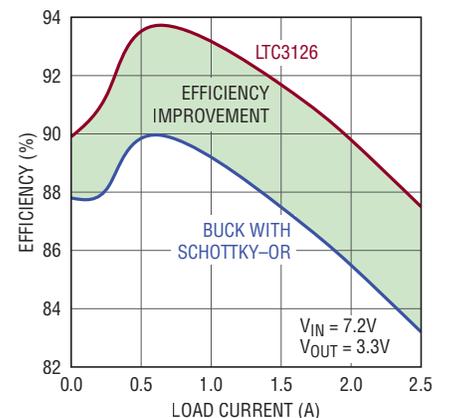
unused input. A typical 40V, 2.5A Schottky may have 500 μ A of leakage current at 25 $^{\circ}$ C, increasing to tens of milliamps at 100 $^{\circ}$ C—significant current into the unused input—which is virtually eliminated by using the LTC3126.

PRIORITY CHANNEL MODE

In many dual power source applications, the two inputs may overlap in functional voltage ranges, with one input required to be preferentially utilized whenever possible, making a diode-OR solution (higher voltage wins) undesirable. For example, a device that operates from both a 12V sealed lead-acid battery and an automotive power rail is usually designed to operate from the automotive input whenever it is present in order to preserve battery life.

This requires a more involved power path solution than can be provided via Schottky diodes, requiring the use of a dedicated PowerPath controller IC and MOSFET switches. Figure 7 shows

Figure 6. The LTC3126's lossless PowerPath design generates a significant improvement in efficiency.



In priority channel mode, each input to the LTC3126 features a user-configurable minimum voltage threshold, above which the channel is considered valid. The internal buck converter operates directly from the priority channel, V_{IN1} , whenever it is valid, regardless of the voltage present at the secondary input. The buck converter only reverts to operation from the secondary channel, V_{IN2} , when the priority channel is invalid.

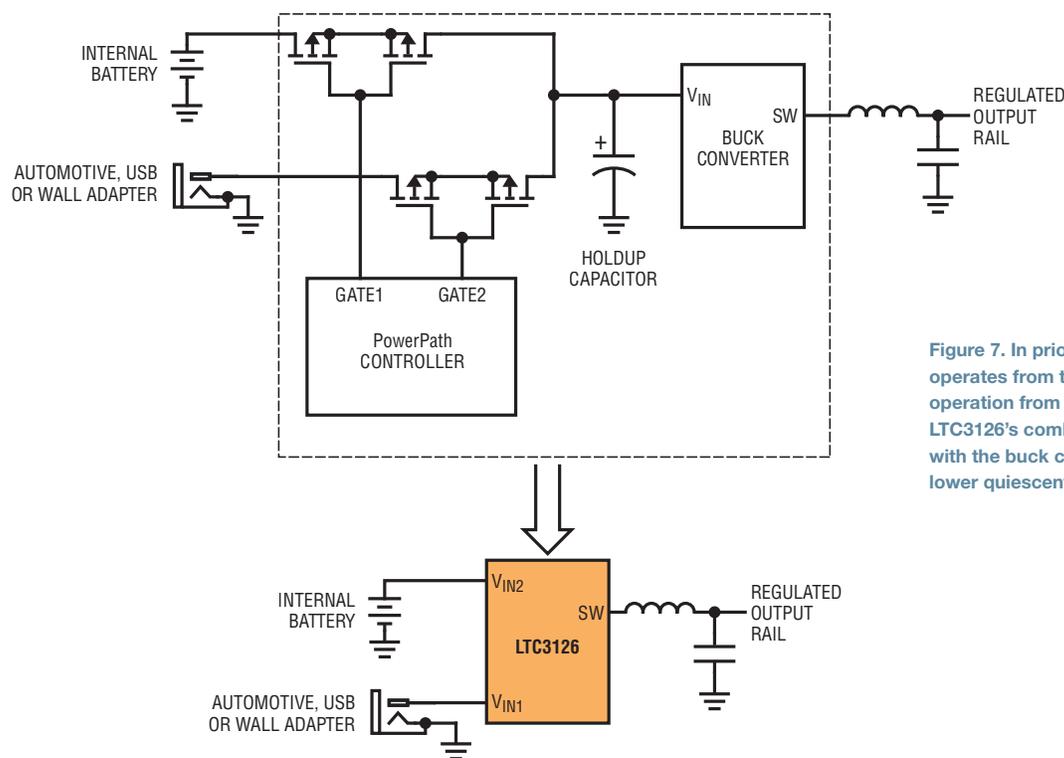


Figure 7. In priority channel mode, the LTC3126 preferentially operates from the V_{IN1} input whenever it is valid and reverts to operation from V_{IN2} only if the voltage on V_{IN1} is invalid. The LTC3126's combination of the PowerPath selection circuitry with the buck converter IC results in higher efficiency and lower quiescent current, as well as a smaller, simpler design.

that the LTC3126 and its pin-selectable priority channel mode integrate this capability with the switching converter, eliminating the need for series MOSFET switches (and a controller) in the power path. This innovation simplifies design, reduces board area requirements, improves efficiency and minimizes the total quiescent current of the power stage.

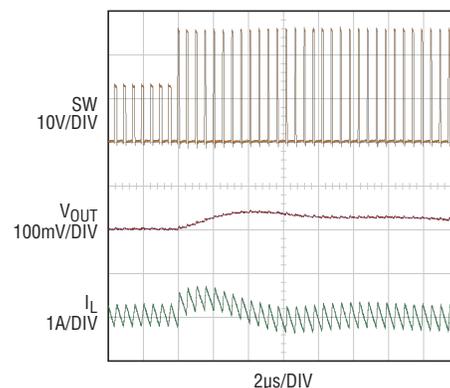
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SINGLE SWITCHING CYCLE TRANSITION BETWEEN INPUTS

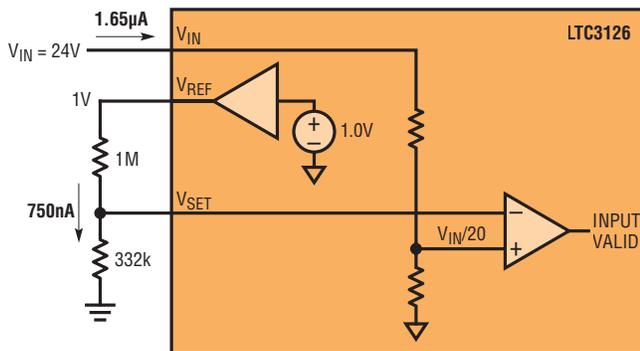
PowerPath controllers that use external MOSFETs typically require substantial time to switch between channels to avoid transients caused by fast switching events. When a channel is switched off, the controller must do so slowly enough to avoid rapidly interrupting the input current flow. Likewise, when a channel is activated, the PowerPath controller must soft-start the external MOSFETs for that channel.

Figure 8. The LTC3126's single cycle transition between input channels reduces holdup capacitance requirements and minimizes output voltage perturbations.



PowerPath controllers that use external MOSFETs typically require substantial time to switch between channels to avoid transients caused by fast switching events. In contrast, the proprietary configuration of switches in the LTC3126 allows it to transition from one input to another in a single switching cycle. This nearly instantaneous switchover minimizes the amount of holdup capacitance required on the channel that is being unplugged and reduces any disturbance in the output voltage.

Figure 9. The LTC3126 utilizes a novel approach for establishing the UVLO thresholds, which minimizes quiescent current by eliminating the need for resistor dividers connected to the input voltage sources.



To avoid power interruption to the load when an input is unplugged, a large holdup or reservoir capacitor must be present to provide enough charge to support the load until the power path has fully transitioned to the alternate input. The large value capacitor required and the fact that it must be rated at the maximum voltage of either input often results in it being the largest component in the system.

In contrast, the proprietary configuration of switches in the LTC3126 allows it to transition from one input to another in a single switching cycle. Figure 8 shows the switch pin, output voltage and inductor current waveforms during the single cycle switchover produced by the LTC3126 when transitioning from a 13.8V input on V_{IN1} to a 24V input on V_{IN2} . This nearly instantaneous switchover minimizes the amount of holdup capacitance required on the channel that is being unplugged and reduces any disturbance in the output voltage. In this case, the output voltage perturbation during

the channel transition is under 40mV, approximately 1% of the 3.3V output.

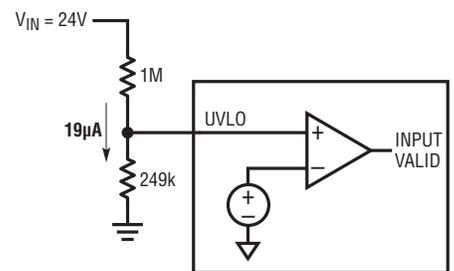
2µA TOTAL QUIESCENT CURRENT

Programmable PowerPath controllers use resistor dividers to set the valid threshold voltages for each input channel, as illustrated in Figure 10. The divider outputs are compared to an internal reference voltage via comparators.

Due to concerns of PCB leakage, the highest usable resistor value in most applications is approximately 1M, resulting in an appreciable current draw from the input rail through the resistor divider, even when the part is in shutdown. For a 24V input, the current could easily be 19µA per input channel.

Furthermore, in many high reliability applications, such as automotive environments, the maximum allowable resistor value is limited to 100k. This can result in over 100µA consumed per input channel by the resistor dividers alone.

Figure 10. The traditional method used to define UVLO thresholds for a PowerPath device utilizes a significant amount of quiescent current in the V_{IN} -connected resistor dividers.



To minimize input current losses in threshold-setting resistor dividers, the LTC3126 uses the novel architecture shown in Figure 9 to establish the minimum input voltage threshold for each channel. The V_{REF} output is internally regulated to a precise, temperature stable 1.00V and is used as a reference for the external resistor dividers used to set the undervoltage lockout threshold for each input channel.

Each UVLO threshold is equal to 20 times the voltage at the respective V_{SET} pin. For example, programming the V_{SET1} pin to 0.5V results in a UVLO threshold of 10V for the V_{IN1} channel. Because the voltage across each divider is only 1V, rather than the full input voltages, quiescent current is reduced by more than an order of magnitude. This feature, in conjunction with low quiescent current Burst Mode® operation, reduces the LTC3126's total quiescent current to ~2µA when operating from a 24V input, while maintaining regulation on the output rail. Even when using sub-100k resistor values, the typical quiescent current remains under 10µA.

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The V_{REF} output can also be used as a temperature stable reference for other comparators or data converters in the system, further reducing IC requirements.

RADIATED EMISSIONS BELOW CISPR 25 CLASS 5 LIMITS

CISPR 25 provides a standardized means of testing electronic devices intended for automotive use to ensure that electrical subsystems don't interfere with common RF receivers including satellite navigation, Bluetooth, cellular telephone and broadcast receivers. Interference in vehicles due to unintentional emissions is an increasing concern for the manufacturers of such systems, given the expanding number of electrical subsystems in vehicles in conjunction with the rising quantity of RF receivers.

Switching power converters can be a particular concern for radiated emissions,

given their high power, fast switching edges and the presence of numerous components carrying switched large amplitude currents, which can all become sources of troublesome emissions. The LTC3126 uses proprietary techniques to minimize radiated emissions without degrading efficiency or reducing operating frequency.

With its low noise fixed frequency operation, the LTC3126's radiated emissions fall well below the CISPR 25 Class 5 limits as shown in Figure 2. The CISPR 25 Class 5 compliance testing shown here was performed at a nationally recognized independent EMI testing laboratory where measurements were taken using the standard LTC3126 demo printed circuit board operating at both 0.5A and 1A loads from a 12V input. The two radiated emission curves shown in Figure 2 are for horizontal and vertical polarization of the

receiver antenna as required by the CISPR 25 specification. Although the CISPR 25 specification governs radiated emissions over the frequency range of 150kHz to 1GHz, the data in Figure 2 is plotted on a linear axis over the range of 30MHz to 1GHz. This is generally the range of most interest, given that the lower frequency emissions below 30MHz lie over 30dB μ V/m below the CISPR limits for that band.

“LAST-GASP” BACKUP POWER SUPPLY

A “last-gasp” backup power capability is becoming a requirement in many systems where functionality must be maintained for a brief duration after power loss in order to perform a controlled shutdown, store vital information to nonvolatile memory or alert other systems of an imminent shutdown. The solid state disk drive, perhaps the highest profile example of this, utilizes a backup power

Table 1. Feature summary of multi-input monolithic converters

	LTC3126	LTC3118
Mode	Buck	Buck-boost
Programmable input UVLO thresholds	✔	✔
Ideal diode or priority V_{IN} select modes	✔	✔
Input range	2.4V to 42V	2.2V to 18V
Output range	0.818V to V_{IN}	2V to 18V
Output current capability	2.5A	5V at 2A for $V_{IN} > 6V$
Operating frequency	200kHz to 2.2MHz	1.2MHz
Quiescent current	2 μ A in Burst Mode operation, 1 μ A in shutdown	50 μ A in Burst Mode operation, 2 μ A in shutdown
Packages	28-lead 4mm \times 5mm QFN and 28-lead TSSOP	4mm \times 5mm 24-lead QFN or 28-lead TSSOP

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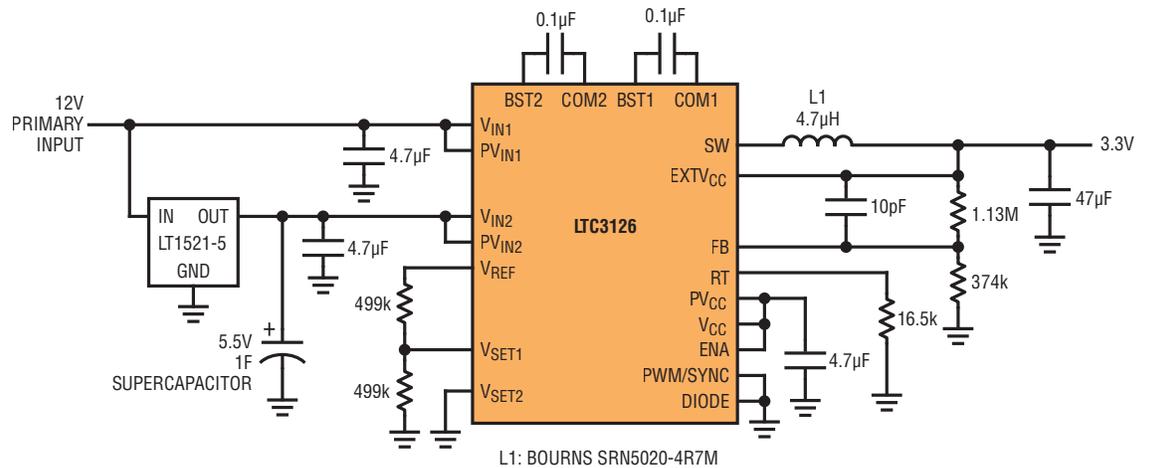


Figure 11. The LTC3126 is used in conjunction with a reverse blocking LDO to provide a complete last-gasp supercapacitor backup supply.

supply to store cached data in SDRAM into nonvolatile flash memory on power failure to prevent data loss. However, this last-gasp capability is now being extended to a wide variety of systems, from industrial controllers to medical devices.

An increasing number of these last-gasp power supplies rely on supercapacitors as the backup power source, given their virtually unlimited cycle life and maintenance-free operation. Figure 11 shows a last-gasp power supply circuit using the LTC3126 to transition glitch-free to backup power when the primary power source is removed. A PNP-based LDO is used to charge the supercapacitor to 5V and provides reverse blocking to ensure there is no discharge path from

the supercapacitor when the primary power source collapses. In this example, the LTC3126 is configured to utilize the primary 12V input down to a UVLO threshold of 10V, at which point the part automatically transitions to the supercapacitor source of the secondary input.

The holdup time of the output rail depends on the charging voltage of the supercapacitor, V_{CAP} , the voltage of the output rail, V_{OUT} , the load current, I_{LOAD} ,

the size of the supercapacitor, C , and the average efficiency of the converter, η . The variable V_{MIN} is the minimum input voltage required to maintain the required output rail voltage. If the output must remain in regulation, then V_{MIN} is equal to the output rail voltage plus the dropout voltage of the buck converter at the required load current.

$$T_{HOLDUP} = \frac{\eta(V_{CAP}^2 - V_{MIN}^2)C}{2V_{OUT} \cdot I_{LOAD}}$$

For a 1A output load on the 3.3V rail, the dropout voltage is approximately 300mV. Therefore, a minimum input voltage of 3.6V is required to maintain regulation of the output rail. Assuming an average efficiency of 90%, the estimated holdup time is 1.6s, which is in close agreement with the measured holdup time of 1.5s shown in Figure 12.

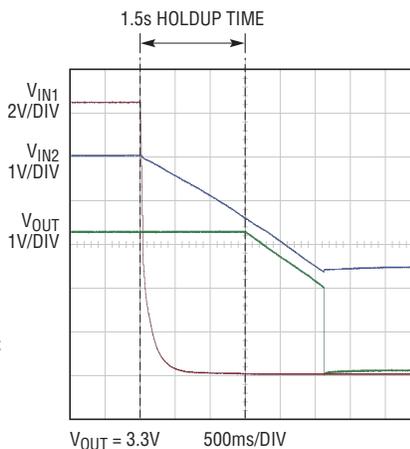


Figure 12. In conjunction with a 1F, 5.5V supercapacitor, the LTC3126 can provide 1.5 seconds of holdup time on power failure for a 3.3V output rail with a 1A load. At that point, the output degrades gracefully as the part enters dropout operation.

$$T_{HOLDUP} = \frac{0.9((5V)^2 - (3.6V)^2)1F}{2(3.3V)(1A)} = 1.6s$$

Its low $1\mu\text{A}$ current in shutdown and $2\mu\text{A}$ current in Burst Mode operation make the LTC3126 ideal for battery powered applications where low current consumption allow it to remain enabled continuously, avoiding the overhead of a supervisory circuit to power up/down the supply.

HIGH EFFICIENCY SYNCHRONOUS OPERATION

The LTC3126 incorporates an internal synchronous rectifier, which reduces power dissipation, improves efficiency and minimizes solution size. Synchronous rectification is particularly beneficial when operating at lower output voltages, where the voltage drop of an external Schottky diode represents a large relative portion of the output voltage. Pin-selectable Burst Mode operation optimizes efficiency at light loads, as shown in Figure 13. The converter maintains over 87% efficiency across the entire range of load currents from 1mA to 2.5A .

High efficiency simplifies thermal management, minimizing component count and easing design concerns. Figure 14 shows that even at a relatively high step-down ratio at full load, the LTC3126 die temperature rises only 36°C .

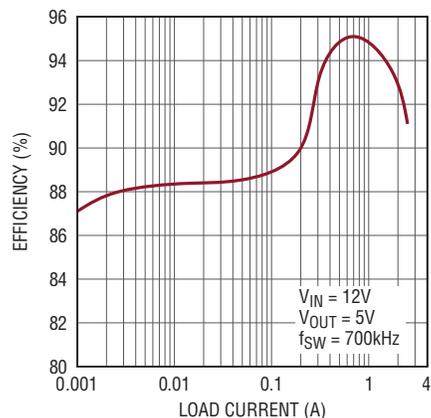


Figure 13. In Burst Mode operation the efficiency exceeds 87% over a wide range of load currents from 1mA to 2.5A .

The switching frequency can be programmed as high as 2.2MHz to eliminate interference within the AM band for noise-sensitive automotive applications, and switching can be synchronized to an externally supplied clock for further noise reduction. As the input voltage decreases to the programmed output voltage, the LTC3126 maintains regulation by keeping the high side switch on for multiple cycles. This produces an effective high side switch duty cycle of over 99%, minimizing dropout voltage to 28mV for a 1A load, thus extending the usable input voltage range to maximize utilization of the battery discharge range.

SUMMARY

The LTC3126 is a dual input, single-IC solution for high efficiency, compact power supplies. Because the lossless PowerPath functionality is integrated into the buck converter, the LTC3126 achieves unrivaled efficiency, application

size and low quiescent current. Its wide 2.4V to 42V input voltage range supports a wide variety of power sources, including automotive, most battery chemistries, multicell battery stacks, USB and poorly regulated wall adapters.

Its low $1\mu\text{A}$ current in shutdown and $2\mu\text{A}$ current in Burst Mode operation make the LTC3126 ideal for battery powered applications where low current consumption allow it to remain enabled continuously, avoiding the overhead of a supervisory circuit to power up/down the supply. The LTC3126 is the perfect match for high performance mobile devices, uninterruptible supplies and industrial test equipment powered from dual input power sources. ■

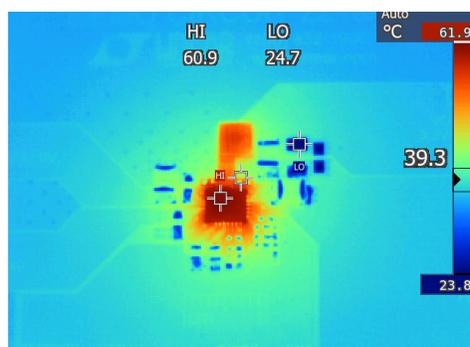


Figure 14. Operating with $V_{\text{IN}} = 12\text{V}$, $V_{\text{OUT}} = 3.3\text{V}$ at a switching frequency of 2MHz , the die temperature rise is only 36°C above ambient at the full rated load current of 2.5A .