

Choosing the Boost With Bypass or Pass Through

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ABSTRACT

For some applications – smart phones, radio-frequency power amplifiers (RF PA), and USB connectors, for example – the load requires a higher voltage to operate than the minimum voltage. The conventional boost converter outputs greater voltage than the input voltage but cannot handle inputs that swing above the desired output. New topologies combining a boost converter plus a bypass switch or boost with the pass through are introduced to address this issue and extend the operational voltage range. The devices with integrated bypass and pass through can automatically transition between boost and bypass or pass through to prevent the output from falling below the target output voltage. The working scheme of both bypass and pass through are illustrated together with the bench measurements. Also, the pros and cons are shown in this article to help users select the most beneficial solution for the target applications with the tradeoff between the performance and size or cost.

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1 Introduction

The traditional boost converter could not pass the input voltage to output when the input voltage exceeds the desired value. There is usually a minimum on time for switching FET and it could not stop switching, even if the input voltage (V_{IN}) is getting close to the desired boost value (V_{OUT_BOOST}). Two unique modes together with TI's recommended boost converter devices are introduced to achieve the input voltage passing through to the output operation:

1. Bypass mode: There is an additional FET (bypass FET) between the input and the output and this mode turns on the bypass FET when V_{IN} is larger than V_{OUT_BOOST} .
2. Pass-through mode: Fully turns on the high-side FET of the boost converter to make the output voltage follow the input voltage when V_{IN} is larger than V_{OUT_BOOST} .

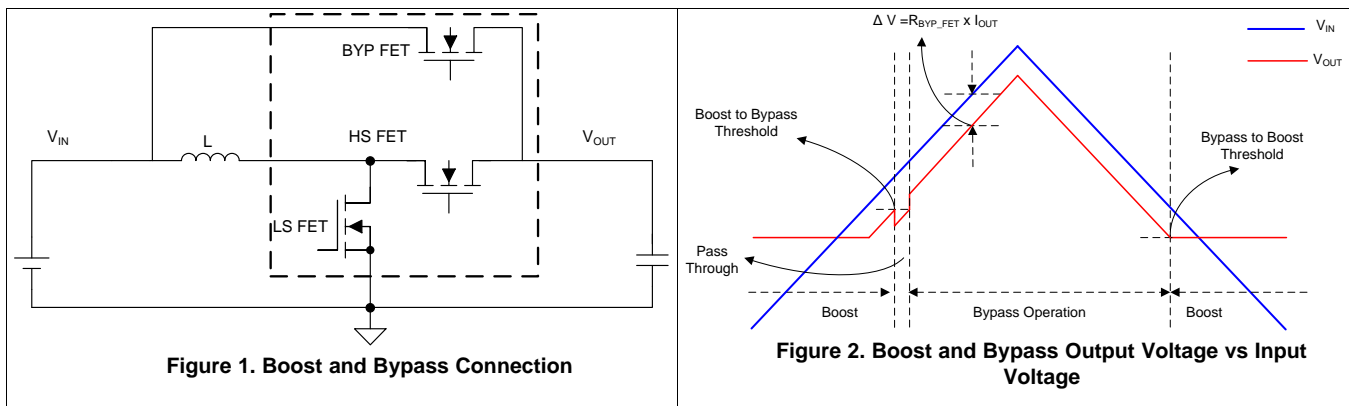
For the application of which the output voltage regulation is not critical, passing the input voltage to the output can make the output voltage be extended to a range of input voltage. During this passing input to output operation, the boost converter works without switching the FET and in return, there is less power loss.

Two devices are introduced to illustrate the boost with bypass and pass through operations: the TPS6128xA has a boost with bypass function and the TPS61253A contains boost with pass through.

2 TPS6128xA Bypass Operation

The TPS6128xA device is a boost converter integrating a low-ohmic bypass FET. It operates in a low-ohmic, high-efficient bypass mode when V_{IN} is larger than V_{OUT_BOOST} . At the bypass mode, the output voltage follows the input voltage closely with a voltage drop of the bypass resistance of the FET. If V_{IN} is lower than V_{OUT_BOOST} , the device works in boost mode, as shown in Figure 1 and Figure 2. When ramping up the input voltage, the bypass mode is triggered when V_{OUT} is 2% larger than V_{OUT_BOOST} and also the switching cycle does not happen during the previous 8 μ s. When sweeping down the input voltage, the device comes back to the boost switching phase if the output voltage reaches 100% of V_{OUT_BOOST} .

For instance, the output voltage of the TPS6128xA at boost mode is 3.4 V. When ramping up the input voltage, the device enters into the bypass mode as long as V_{OUT} exceeds 3.47 V. While ramping down V_{IN} , the TPS6128xA comes back to the boost operation when V_{OUT} is 3.4 V.

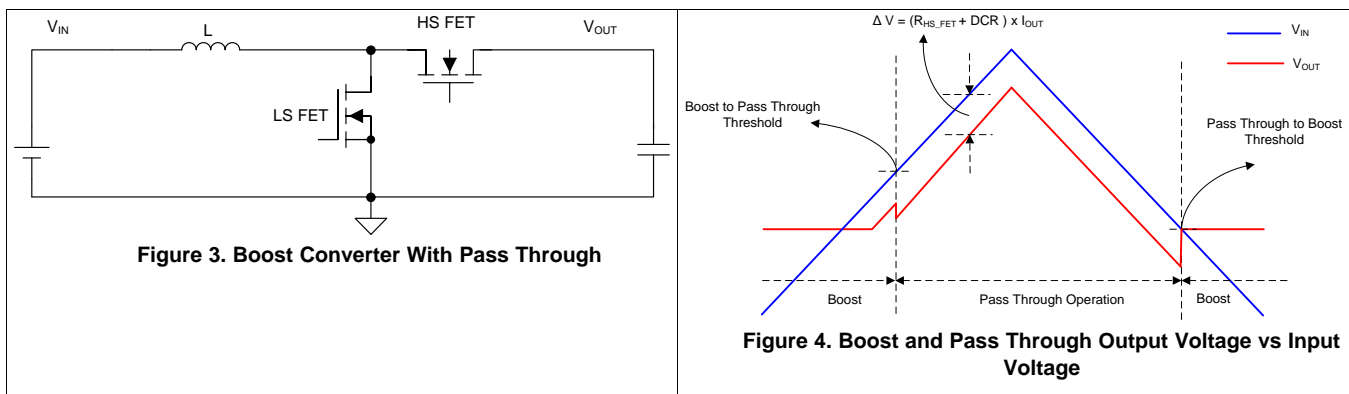


3 TPS61253A Pass-Through Operation

The TPS61253A device, a 5-V output synchronous boost converter supports the pass-through operation. For the pass-through operation, the high-side FET of the boost converter fully turns on (low-side FET fully turns off) when V_{IN} is larger than V_{OUT_BOOST} .

For the TPS61253A device, if the input voltage is 100 mV over the normal boost output voltage, the TPS61253A enters into the pass-through mode when the high-side FET fully turns on. There is a voltage drop caused by the on resistance of the high-side FET plus the DC resistance of the inductor. For sweeping down the input voltage, the device comes back to the boost switching phase when the input voltage reaches the normal output voltage at boost operation. Figure 3 and Figure 4 illustrate the working principle of boost with pass-through operation.

As an example, the output voltage of the TPS61253A at boost is 5.0 V. When ramping up the input voltage, the device enters into the bypass operation as long as the V_{IN} exceeds 5.1 V. While V_{IN} is ramping down, the TPS61253A comes back to the boost operation when V_{IN} reaches 5.0 V.



4 Typical Applications for Boost with Bypass

4.1 Pre-Regulator for PMIC in Smart Phone

For the smart phone application, there is usually a very large current surge by RF PA, and highly loaded application processors, which results into a battery voltage drop. The typical power tree is shown in Figure 5.

Additionally, some new battery chemistries (like silicon anode) allow the cutoff-voltage values that are lower than what the post system needs. Figure 6 shows battery capacity versus the discharge voltage for the traditional Li-Iron chemical and the silicon-anode battery.

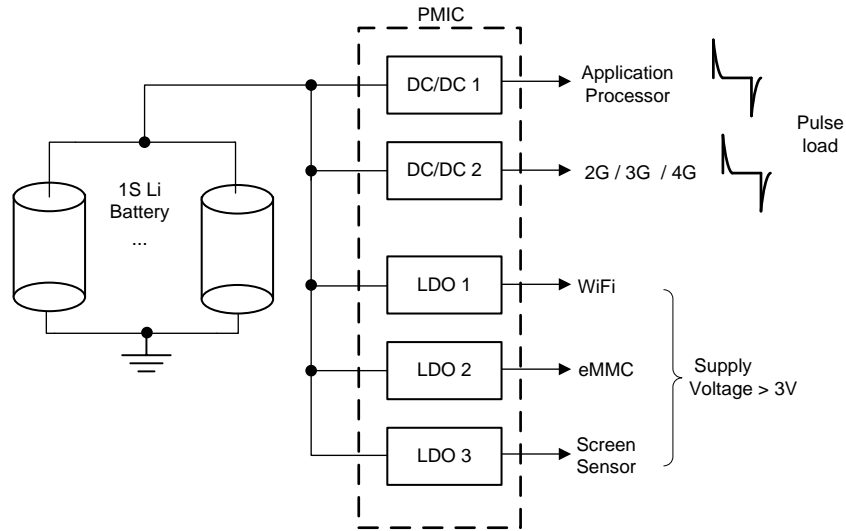


Figure 5. Smart Phone Application Power Tree

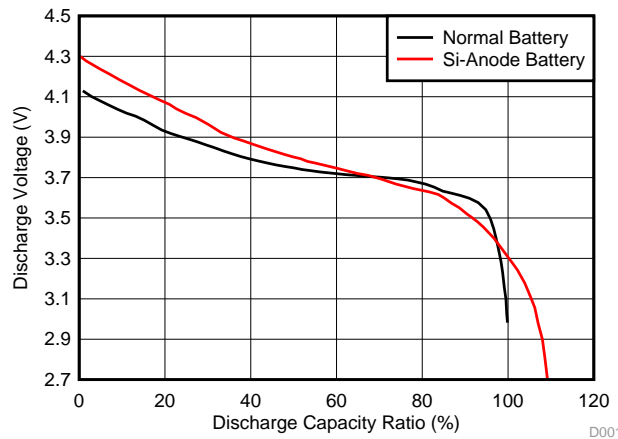


Figure 6. Battery Capacity vs Terminal Voltage

In both situations, the high-voltage LDOs (usually > 3.0 V) in PMIC fall out of regulation and thus cause the load to malfunction, as in WiFi, eMMC, screen sensors, and so forth, due to the insufficient supply voltage.

With the aforementioned challenges, a pre-regulator is recommended between the battery and the PMIC to buffer the battery drop as well as enable the lower battery operating voltage.

The TPS6128xA is a good fit because it operates in a bypass mode when the battery is in a good state of charge, a low-resistance, highly-efficient bypass FET connecting the battery to the system directly. If the battery is in a low state of charge and voltage becomes lower than the required minimum system voltage, the device seamlessly enters into the boost operation.

For this application, the boost with bypass is more competitive versus the boost with pass through due to the lower resistance in the power path since there is an additional FET directly connecting V_{IN} and V_{OUT} (without the DC resistance of the inductor).

Also, as the bypass mode is independent from the boost operation, the TPS6128xA includes a low quiescent bypass mode that supports the system to remain in standby with almost no quiescent current.

4.2 Pre-Regulator for RF PA

Normally, the RF PA supply voltage is quite wide and could cover the single cell Li-Iron battery voltage (3 V to 4.4 V typically). However, for some cases, the supply voltage should be boosted up to support higher RF power and the supply voltage should not be lower than the minimum required voltage for the RF PA. Thus, an additional pre-regulator is required to ensure the supply voltage of the RF PA is not lower than the desired value.

Except for when the lower resistance when V_{IN} is larger than V_{OUT} at the bypass operation, the bypass operation also benefits the application with more stable operation as the inductor is not included in the power path (the inductor causes the oscillation at the transient load).

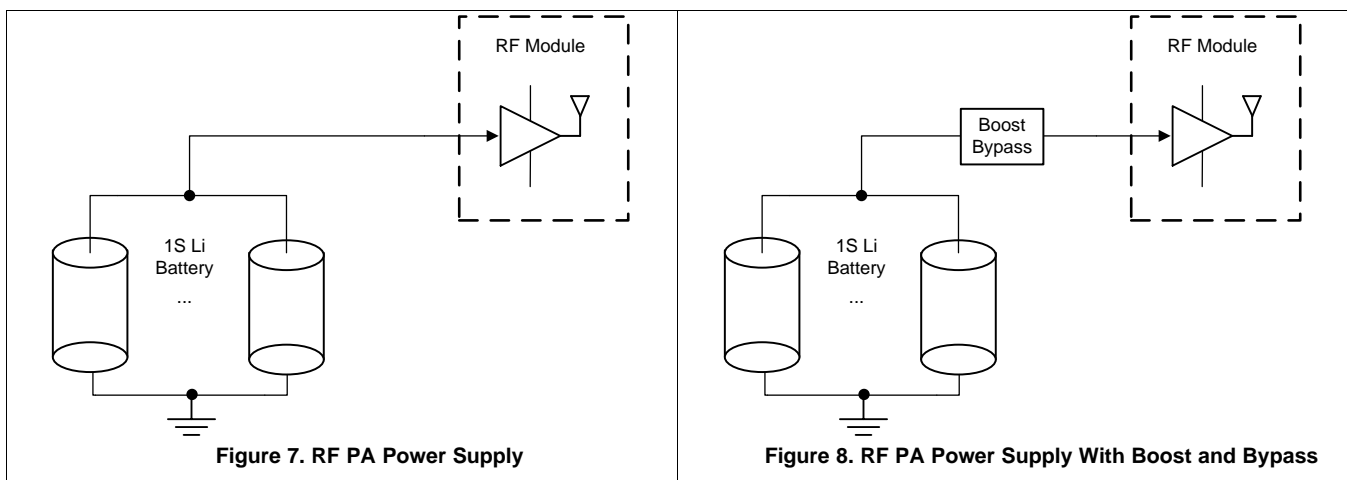


Figure 7. RF PA Power Supply

Figure 8. RF PA Power Supply With Boost and Bypass

4.3 TPS6128xA Bench Measurements

This section contains the bench measurements conducted by TI.

1. Output Voltage vs Input Voltage

Test Condition: $V_{OUT} = 3.4\text{ V}$, $T_A = 25\text{ }^\circ\text{C}$, $L = 0.47\text{ }\mu\text{H}$, $C_{OUT} = 5 \times 15\text{ }\mu\text{F}$ (effective $20\text{ }\mu\text{F}$ at 3.4-V biased), auto PFM mode

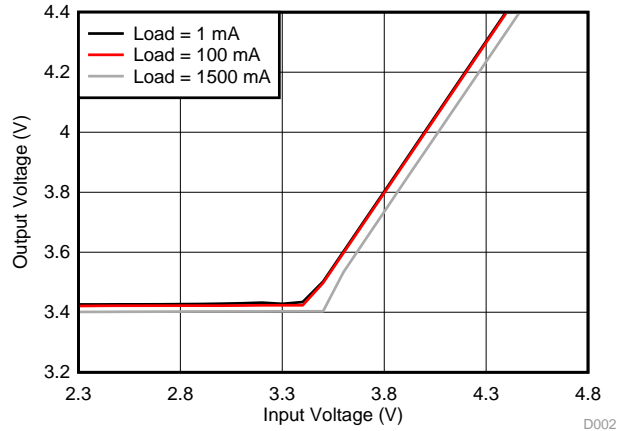


Figure 9. TPS61280A Output Voltage vs Input Voltage

2. Efficiency vs Load

Test Condition: $V_{OUT} = 3.4\text{ V}$, $T_A = 25\text{ }^\circ\text{C}$, $L = 0.47\text{ }\mu\text{H}$, $C_{OUT} = 5 \times 15\text{ }\mu\text{F}$ (effective $20\text{ }\mu\text{F}$ at 3.4-V biased), auto PFM mode

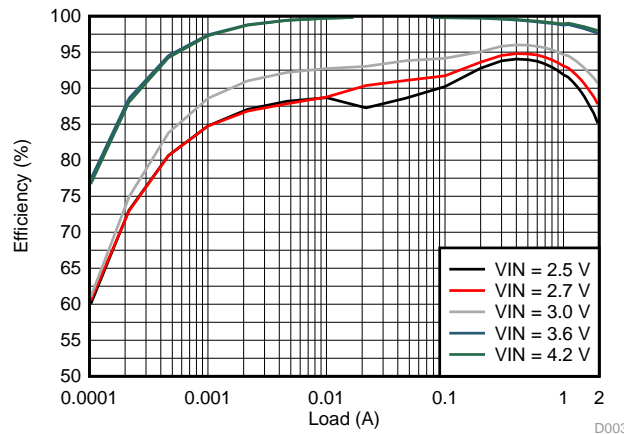
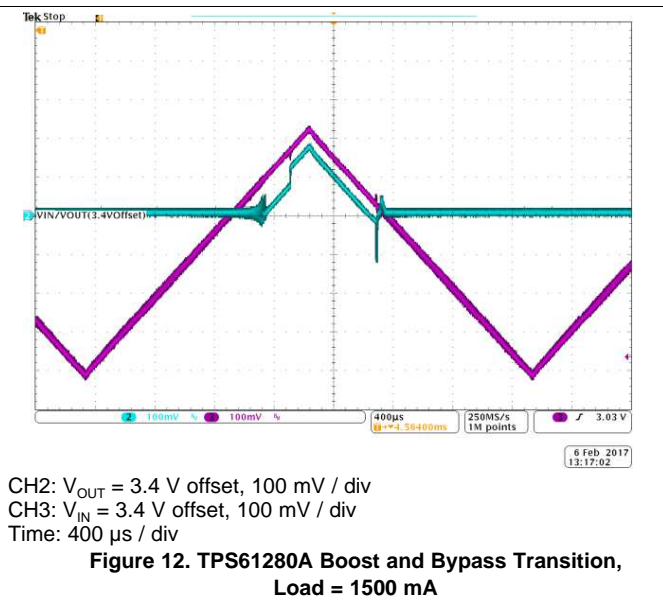
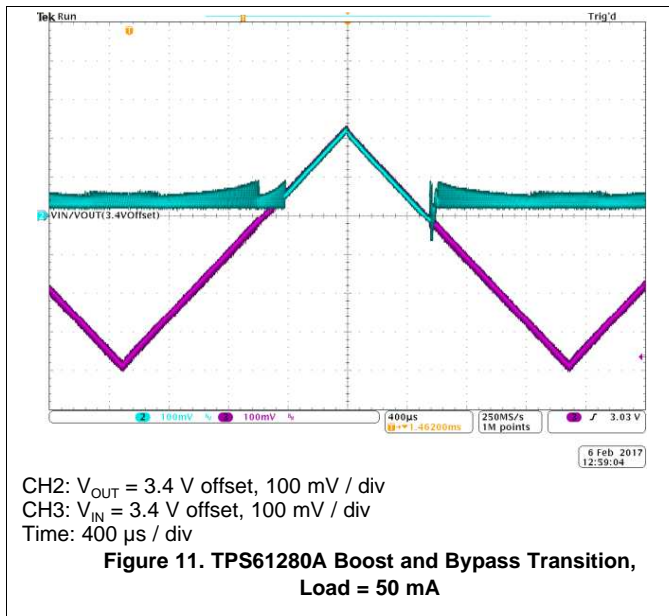


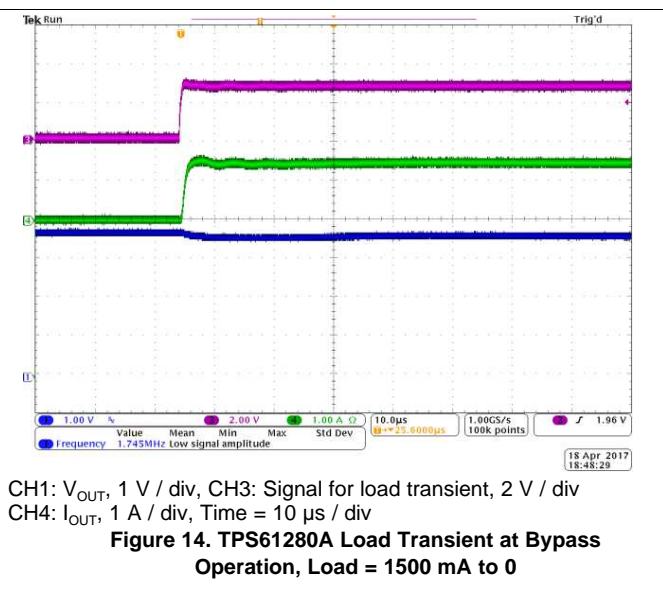
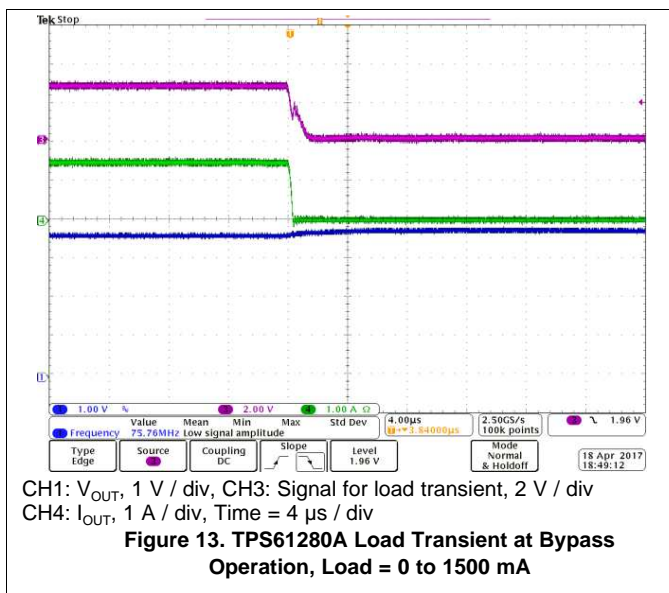
Figure 10. TPS6128xA Efficiency vs Load

3. Boost and Bypass Mode Transition



4. Load Transient at Bypass Operation

Test Condition: $V_{IN} = 3.8 \text{ V}$ (bypass mode), $V_{OUT_BOOST} = 3.4 \text{ V}$, Load Transient = 0–1500 mA



5 Typical Application for Boost with Pass Through

This section discusses using a buffer to avoid the USB port voltage drop and the TPS61253A bench measurement.

5.1 Buffer to Avoid the USB Port Voltage Drop

For applications like USB docking, there is a USB port directly connecting from the input side to the output side to deliver the power for the external devices (like charging the portable device, supply for the storage disk, and so forth). However, there is usually some resistance for the connector, which increases with age or oxidation due to exposure to the air. The resistance erodes the USB port voltage and thus causes the device connecting to the USB port not to function normally or it lowers the charging speed. In this case, adding a buffer regulator is recommended to avoid the voltage drop caused by the resistance of the connector.

The voltage drop is determined by the resistance of the connector and the load flowing through the connector. For instance, a 0.25-Ω resistance and 1.0-A load, the voltage drop is 0.25 V caused by the connector. If the minimum output voltage needs to be larger than 4.75 V at the USB terminals, the output voltage of the boost converter should be 5.0 V (4.75 V + 0.25 V).

The TPS61253A with output voltage 5.0 V at boost is a good candidate to support the pass through function and make the output voltage not lower than 5 SLVUB64.0 V at any condition.

The boost with pass through is a smaller size due to no additional bypass FET and it could be more cost-effective versus the boost bypass solution.

However, there is an inductor in the power path of the power through operation; output voltage ring will be caused for the transient load as shown in Figure 18 and Figure 19. By contrast, the output voltage of the bypass operation is more stable regardless of the transient load.

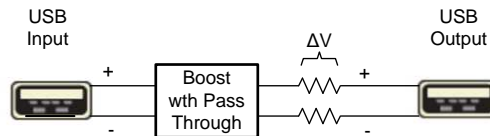


Figure 15. USB Docking Input and Output and Boost With Pass Through

5.2 TPS61253A Bench Measurement

1. Output Voltage vs Input Voltage

$V_{OUT} = 5\text{ V}$, $V_{IN} = 4.3\text{ to }5.5\text{ V}$ Sweep, $T_A = 25\text{ }^\circ\text{C}$, $L = 0.56\text{ }\mu\text{H}$, $C_{OUT} = 14.7\text{ }\mu\text{F}$ (effective 7 μF at 5 V Biased), Auto PFM mode

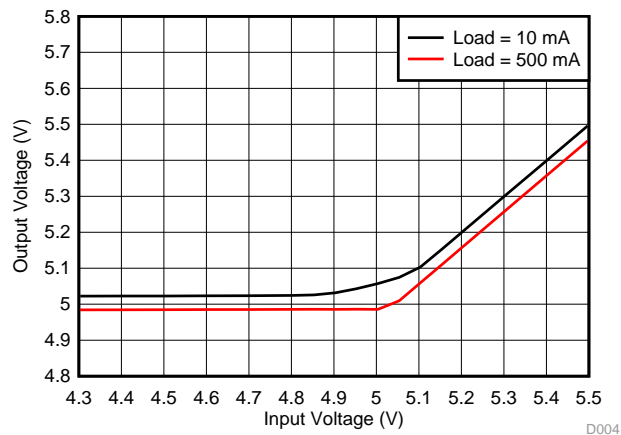


Figure 16. TPS61253A Output Voltage vs Input Voltage

2. Efficiency vs Load

Test Condition: $V_{OUT} = 5\text{ V}$, $T_A = 25\text{ }^\circ\text{C}$, $L = 0.56\text{ }\mu\text{H}$, $C_{OUT} = 14.7\text{ }\mu\text{F}$ (effective $7\text{ }\mu\text{F}$ at 5-V biased), Auto PFM mode

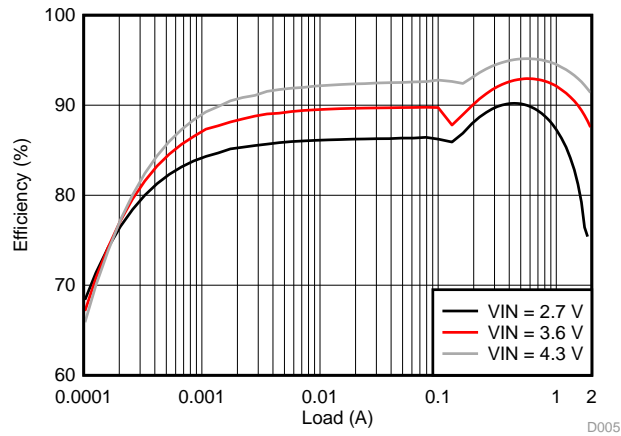
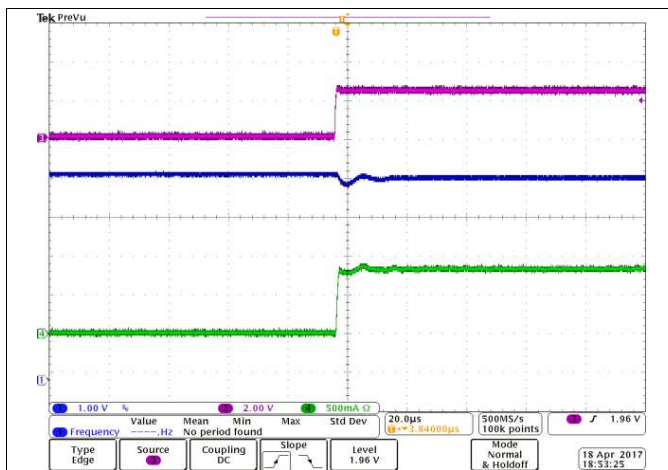


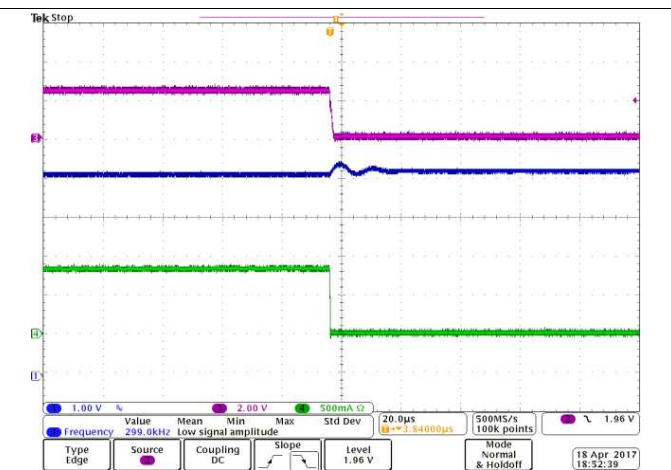
Figure 17. TPS61253A Efficiency vs Load

3. Load Transient at Pass-Through Operation

$V_{OUT} = 5.0\text{ V}$, $V_{IN} = 5.3\text{ V}$, $T_A = 25\text{ }^\circ\text{C}$, $L = 0.56\text{ }\mu\text{H}$, $C_{OUT} = 14.7\text{ }\mu\text{F}$ (effective $7\text{ }\mu\text{F}$ at 5-V biased), Auto PFM mode, Load Transient at pass through mode.



CH2: VOUT_5VBias, CH3: VIN_5V Bias, CH4: IL
Figure 18. TPS61253A Load Transient at Pass-Through Operation, Load = 0 to 1500 mA



CH2: VOUT_5VBias, CH3: VIN_5V Bias, CH4: IL
Figure 19. TPS61253A Load Transient at Pass-Through Operation, Load = 1500 to 0 mA

6 Summary

The boost with bypass or pass through is the optimized control topology to support the input voltage exceeding the desired output voltage. The boost with bypass has an additional FET directly connecting the output to the input without the inductor and high-side FET in the power path. The additional bypass FET can lower the resistance of the power path and provides higher efficiency and ensures the stable output voltage with the transient load at bypass operation. The boost with pass through supports input voltages higher than output by fully turning on the high-side FET, which is more cost-effective and a smaller size.

7 References

- TPS6128xA data sheet ([SLVSDA7](#))
- TPS61253A data sheet ([SLVSDE4](#))

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