Application Note

Comparison of TPS629xx-Q1 vs. TPS621x0A-Q1

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ABSTRACT

The TPS6290x-Q1 (TPS62903-Q1, TPS62902-Q1, TPS62901-Q1) and TPS6299x-Q1 (TPS62993-Q1, TPS62992-Q1) are the next generation to the TPS621x0A-Q1 (TPS62130A-Q1, TPS62150A-Q1) family of products. This application note goes through in detail the improvements that were made from the previous version to the new and how those changes benefit the designer. Key concepts discussed further:

- Feature sets contribute to a smaller solution size
- Increased operating junction temperature
- Reduced power losses from a lower quiescent current and improved MOSFET $R_{DS(ON)}$
- Increased flexibility enabling a wider range of applications

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1 Introduction

The technology that drives buck converters is continuously being innovated to provide the best possible system performance. Power is at the heart of every electrical system, so improvements in size, efficiency, and thermal characteristics are beneficial to all applications. The TPS6290x-Q1 family is the next generation of 18V, low Iq, high efficiency, buck converters that improved upon the previous family TPS621x0A-Q1. The new generation also includes the TPS6299x-Q1 set of devices that feature a lower maximum input voltage of 10V. Table 1-1 shows the key features of each product and the improvements on the latest generation family. But what does *improved* really mean? To understand how technology has improved, this application report provides a comparison of the previous version to the new version, as well as an explanation of how the changes benefit the user more than the previous version.

Table 1-1. Feature comparison of TPS621x0A-Q1 and TPS629xx-Q1

Features	TPS621x0A-Q1	TPS6290x-Q1	TPS6299x-Q1	Improvements
VIN	3 V to 17 V	3 V to 18 V	3 V to 10 V	
VOUT	0.9 V to 6 V	0.4 V to 5.5 V		Supports lower Vout down to 0.4 V(1)
FB accuracy (over temperature range)	1.8%	1.25%		31% tighter Vref accuracy
Typical quiescent current (device not switching)	17uA	4uA		Better light load efficiency
Package size	3.0mmx3.0mm QFN	2.2mmx2.0mm QFN		51% smaller package
Smart configuration	No	Yes		Fewer external components needed to configure device
Junction Temperature	-40C to 125C	-40C to 165C		Supports higher Tj up to 165C
Switching Performance	2.5 MHz and 1.25 MHz	2.5 MHz and 1.0 MHz		Wider range in frequency selection
$R_{DS(ON)}$	90mΩ/40mΩ	62mΩ/22mΩ		Less power loss
Efficiency (12Vin, 1.2Vo, 2.2uH, 3 A)(2)	78.9% (1.25 MHz)	83.0% (1MHz)	N/A	Improved efficiency
Efficiency (6Vin, 1.2Vo, 2.2uH, 3A)(2)	80.4% (1.25 MHz)	84.6% (1 MHz)		
Automatic Efficiency Enhancement	No	Yes		High efficiency for varying duty cycles
Output discharge	Using PG	Using VOS		Achieved internally when selected
Selectable VOUT (VSET and internal voltage divider)	No	Yes		This allows for internal divider that has lower BOM count and better overall system accuracy
Wettable flanks	No	Yes		Enables visual inspection of solder joints (AVI)

(1) VREF lowered from 0.8 V to 0.6 V with the 0.4 V output achieved through VSET only.
(2) Efficiency measurements taken on the device's EVM using an XGL4020-222MEC inductor.

2 Achieving a Smaller Solution

2.1 Smaller Package and Fewer External Components

The QFN package of TPS629xx-Q1 is half the size of the previous generation, however the size of the package is not the only thing that has shrunk. The total solution size is reduced by 20% of the TPS621x0A-Q1 when compared on their EVMs, with the reduction limited by larger automotive grade capacitors used on the TPS629xx-Q1 versus the standard TPS6290x. To achieve both of these reductions, TPS629xx-Q1 has decreased the number of pins on the package from 16 to 9, allowing the package to shrink and decreasing the passives needed to configure the device. The result saves precious board space, BOM costs and design time.

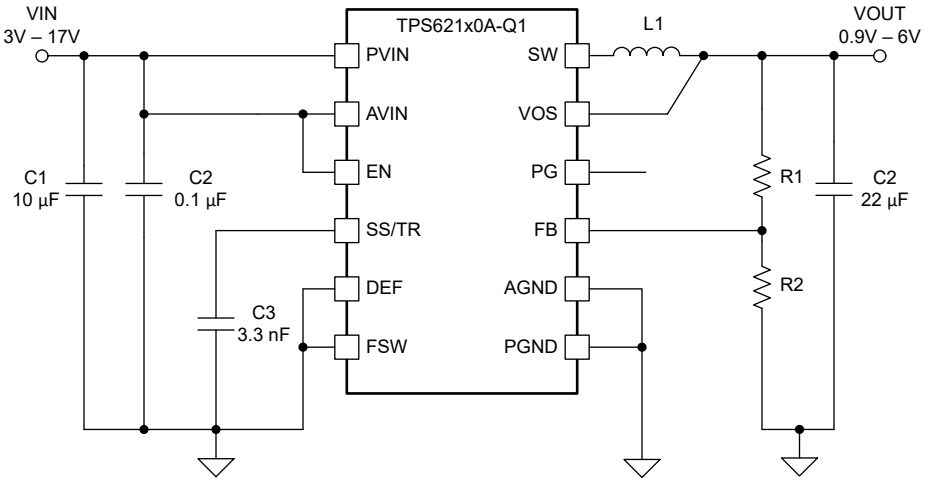

Figure 2-1. Typical Application Schematic of the TPS621x0A-Q1

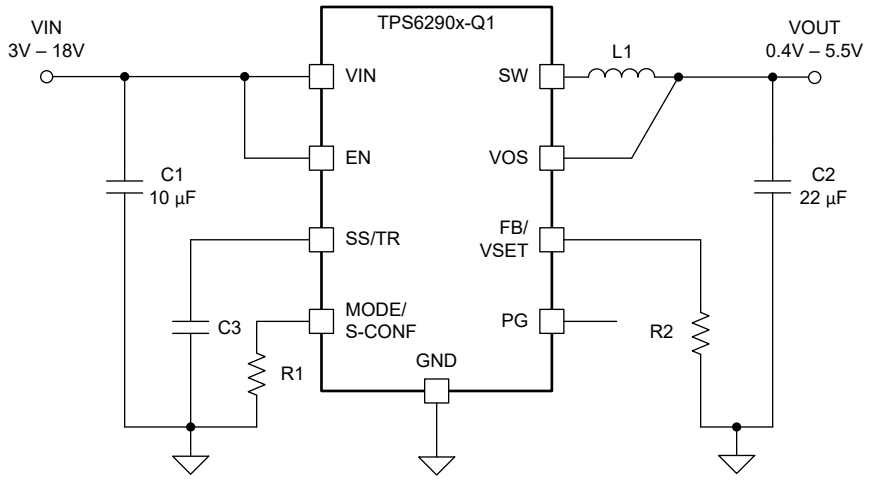

Figure 2-2. Typical Application Schematic of the TPS6290x-Q1

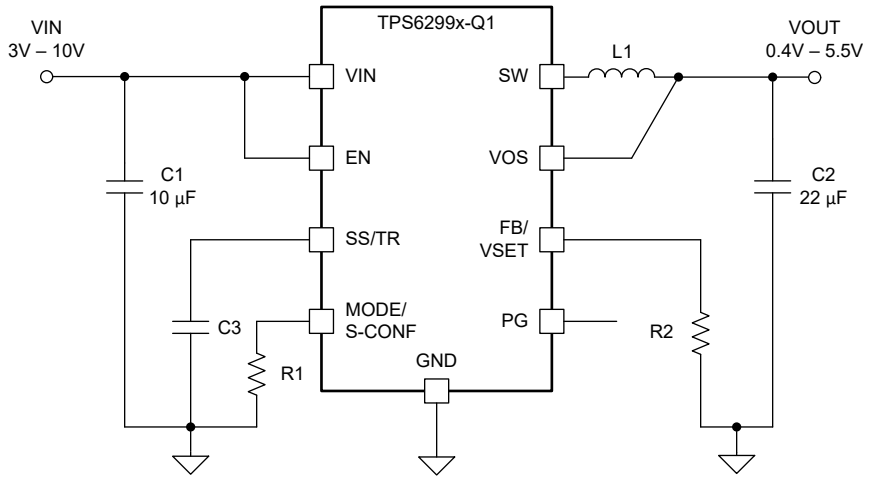

Figure 2-3. Typical Application Schematic of the TPS6299x-Q1

2.2 Smart Configuration Pin

The smart configuration pin is one of the primary contributors to the space savings and a key differentiators between the next generation devices and their predecessors. The MODE/S-CONF pin gives the user flexibility to select the settings of four features (FB/VSET, switching frequency, FPWM/PFM, and output discharge) with only one resistor. In the previous generation, each of these features would have to be configured individually. There are several advantages associated with this pin, too many to discuss in this document. To learn more about smart configuration pins and all of their design benefits, reference the document *Multi-Function Pins for Easy Designing*.

2.3 VSET

The MODE/S-CONF pin along with the FB/VSET pin, can be used to save additional resistors when setting the output voltage. Typically, to set the output voltage, a resistor divider is used on the feedback pin. The advantage of using the resistor divider is you are able to choose any output value in the output voltage range. Both the TPS621x0A-Q1 and TPS629xx-Q1 have the ability to use a resistor divider to configure the output voltage. Standard voltage rails similar to 1.2 V and 3.3 V are often used in point-of-load applications, so TPS629xx-Q1 has added the ability to select an output voltage setting from one of 16 common options through the VSET function. These values vary from 0.4 V to 5.5 V. If one of those preset output voltages is desired for a design, the VSET function can be used to save one or even both resistors (if left floating or tied to GND) when configuring the output voltage, as shown in Figure 2-4.

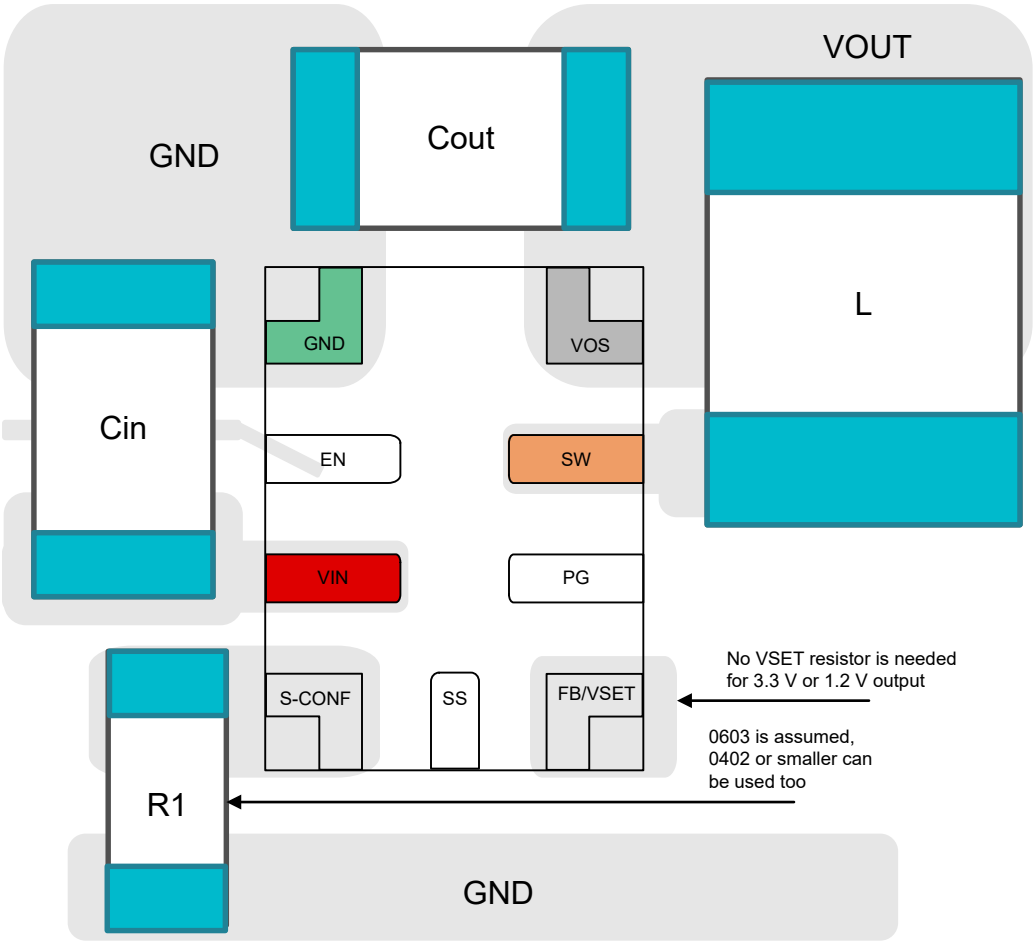

Figure 2-4. Configuration for the Smallest Solution Size Using TPS629xx-Q1

3 Reducing Power Loss

3.1 Junction Temperature

The TPS629xx-Q1 has an extended junction temperature of 165°C versus the 125°C of the TPS621x0A-Q1. This allows the device to operate at a higher output current while still maintaining a junction temperature within the recommended range. The main two factors that play a role in determining junction temperature are efficiency and thermal resistance. Using the TPS6290x-Q1 as an example, the efficiency under a 1 MHz switching frequency, 12-V input, 1.2-V output, and 3-A load current is 83%. After subtracting the inductor power loss, the IC power loss is 468 mW, and multiplying by the junction-to-ambient thermal resistance ($R_{\Theta JA}$) gives a temperature rise of approximately 34°C. With this amount of temperature rise, the ambient temperature can be as high as 130°C while staying within the 165°C recommended operating junction temperature.

In comparison, the TPS621x0A-Q1 has a lower efficiency and lower operating junction temperature. For this device the ambient temperature must stay below 100°C for the junction temperature to remain under the 125°C recommended operating junction temperature.

Note

The efficiency depends on both input and output conditions, thus a recalculation of temperature rise would be needed to evaluate other operating points. In addition, the efficiency measurements were taken from the device's EVM using the XGL4020-222MEC inductor.

3.2 Automatic Efficiency Enhancement (AEE)

The AEE feature in the TPS629xx-Q1 provides highest efficiency over the entire input and output voltage range by automatically adjusting the converter's switching frequency when 2.5 MHz is selected. The efficiency decreases when VOUT decreases and or VIN increases. In order to keep the efficiency high over the entire duty cycle range (VOUT/VIN ratio), the switching frequency is adjusted by changing the t_{on} of the converter as shown in Equation 1. This mode also maintains the current ripple to ensure the current limits of the device aren't exceeded at the maximum output current. Equation 2 shows how setting the calculated t_{on} can keep the inductor current ripple constant and independent of VOUT.

$$t_{on}(ns) = 100 \times \frac{V_{IN}}{V_{IN} - V_{OUT}} \quad (1)$$

$$\Delta I_L(mA) = 0.1 \times \frac{V_{IN}(V)}{L(\mu H)} \quad (2)$$

The AEE feature provides an efficiency enhancement for various duty cycles, especially for lower Vout values, where fixed frequency converters suffer from a significant efficiency drop. Furthermore, this feature compensates for the very small duty cycles of high VIN to low VOUT conversion, which limits the control range in other topologies.

3.3 Quiescent Current

Low Iq is a key parameter for applications where the device is operated in standby or shutdown mode for the majority of the time. For battery powered applications, the quiescent current is critical to extending the life of the battery and improving light load efficiency. The TPS621x0A-Q1 has a low quiescent current of 17 µA. The TPS629xx-Q1 quiescent current is reduced even further to 4 µA. The batteries in these applications are meant to last an extended amount of time without having to be replaced. The reduction of the Iq by 76% will reduce the amount of current being drawn from the battery, therefore extending the battery life significantly. Figure 3-1 shows how a decrease in Iq boosts the efficiency at light loads and a decrease in MOSFET $R_{DS(ON)}$ improves the full load condition.

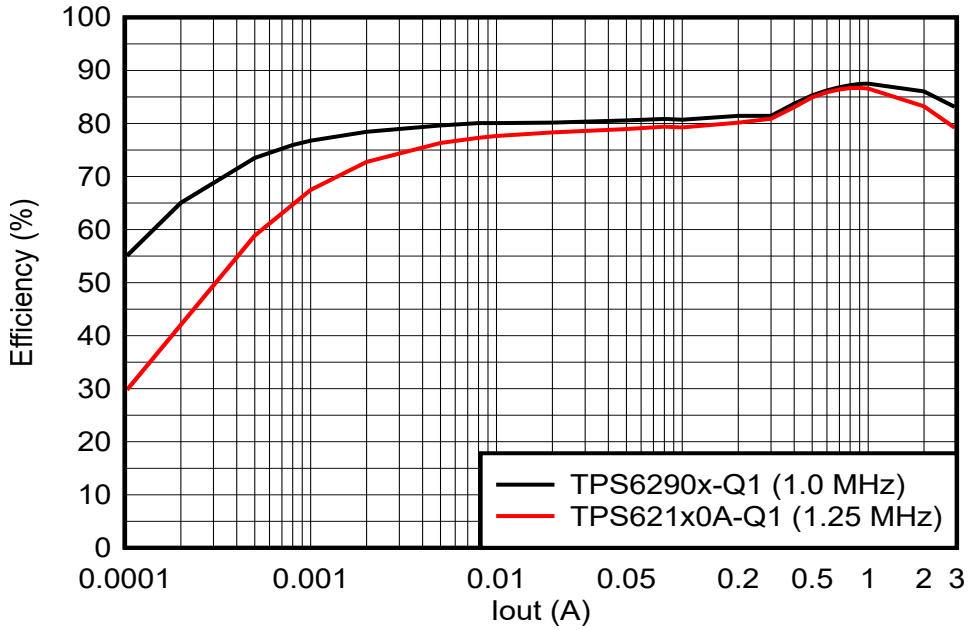

Figure 3-1. Efficiency Comparison of TPS6290x-Q1 vs. TPS621x0A-Q1, VIN=12 V, VO=1.2 V, L=2.2 uH (XGL4020-222MEC)

3.4 Auto PFM/PWM vs. Forced PWM

To receive the best efficiency possible at light loads, the user can select the auto PFM/PWM mode which transitions seamlessly between pulse frequency modulation and forced PWM modes. The device enters PFM at the discontinuous conduction mode (DCM) boundary where the inductor current goes to zero and the switching frequency scales down linearly with load current. Alternately, forced PWM mode enables the device to remain in continuous conduction mode (CCM) through a negative inductor current. This has some efficiency impact at light load but the user can easily predict the operating frequency and set filters as needed. The user can choose between these modes using the MODE/S-CONF pin discussed previously.

4 Application Flexibility

4.1 1.0 MHz and 2.5 MHz Switching Frequencies

The TPS629xx-Q1 switching frequency can be set to 1.0 MHz or 2.5 MHz using the smart configuration pin. This allows the user to flexibly set the switching frequency to suit their application needs. To improve the efficiency and reduce switching losses of the converter, 1.0 MHz can be selected, with the trade-off of using a larger inductor. This selection is ideal for applications that may not have large space constrains, but efficiency or thermals are the main concern. For applications needing a smaller inductor, optimized overall solution size, and can afford a slight drop in efficiency, 2.5 MHz is the ideal choice.

4.2 Lower and More Accurate Output Voltages

TPS621x0A-Q1 supports 0.9 V as a minimum output with a 1.8% Vout accuracy combined with the accuracy of the two feedback resistors used. This covers a lot of use cases, however not all. There are applications that require lower than a 0.9-V output voltage, or a tighter spec for Vout accuracy and have previously been unable to use the TPS621x0A-Q1 because of these requirements. TPS629xx-Q1 opens up the opportunity for these applications to take advantage of its high-performance feature set by supporting as low as 0.4 V output voltage when using VSET and as low as 0.6 V using the feedback resistor option with a 1.25% FB accuracy across full temperature range. If VSET option is selected, the external resistors are not needed and thus the total system accuracy is improved for the fact that the external feedback resistor accuracy is no longer added to the feedback loop.

4.3 Output Voltage Discharge

In some applications, the output voltage needs to get to zero as soon as the device is disabled. For that, an internal discharge circuit is implemented inside the device to bleed off the remaining charge of the output capacitor as soon as the device is disabled. The purpose of the discharge function is to ensure a defined down-ramp of the output voltage when the device is being disabled but also to keep the output voltage close to 0 V when the device is off. The output discharge feature is only active once TPS629xx-Q1 has been enabled at least once since the supply voltage was applied. The internal discharge resistor is connected to the VOS pin. The discharge function is enabled as soon as the device is deactivated, in thermal shutdown or in undervoltage lockout. The user can turn this feature on or off using the smart configuration pin.

In the TPS621x0A-Q1, this feature is implemented using the PG pin. The TPS621x0A-Q1 pulls the PG pin low, when the device is shut down by EN, UVLO or thermal shutdown. Connecting PG to VOUT through a resistor can be used to discharge VOUT in those cases. The discharge rate can be adjusted by the pull up resistor, which is also used to pull up the PG pin in normal operation.

4.4 Wettable Flanks

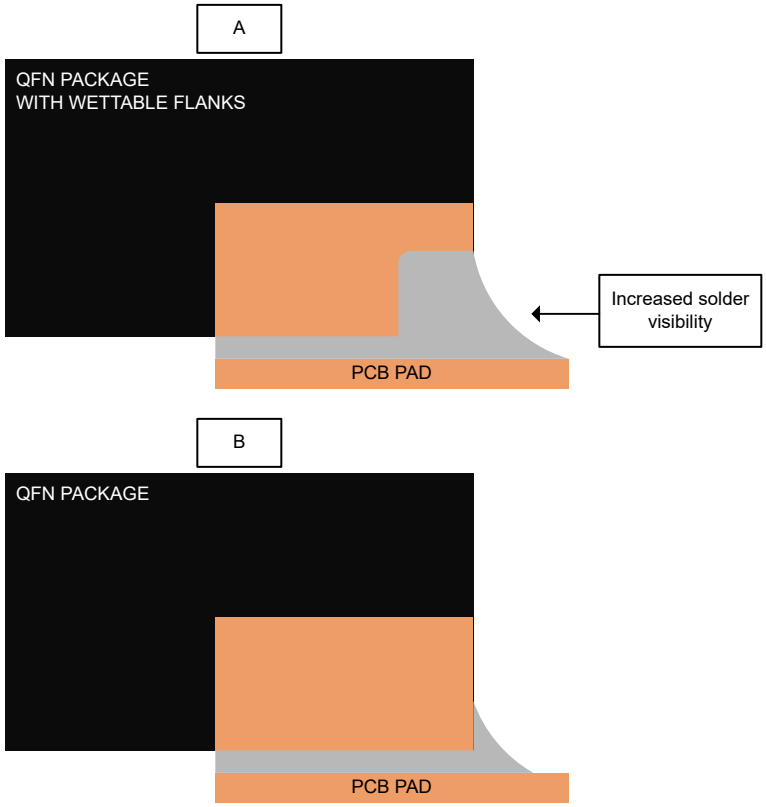

Figure 4-1. QFN Package Cross-Sectional View with (A) and Without (B) Wettable Flanks

Automated visual inspection (AVI) is commonly used in manufacturing to ensure high reliability and robustness of the final product. Automotive manufacturing is no exception where products are held up to strict standards. Standard quad-flat no-lead (QFN) packages have been problematic for AVI in the past because the soldered pins are not exposed, which makes determining the quality of the connections difficult. The wettable-flank process was developed to solve this issue through side-lead wetting that makes the solder connection visible. The TPS629xx-Q1 is assembled using a 9-pin VQFN package with wettable flanks that allows AVI for reduced inspection time and manufacturing costs.

Note

The TPS629xx-Q1 uses a VQFN package with special L-shaped corner pins that help to increase board level reliability (BLR).

5 Summary

The comparison between the TPS621x0A-Q1 and TPS629xx-Q1 family of products has exemplified the improvements in the new generation and how those improvements benefit the user's design. Decreased solution size, increased efficiency, implementation of the MODE/S-CONF pin, and more all combine together to make significant advancements in buck converter applications and the technology of tomorrow.

6 References

- Texas Instruments, *Understanding the Trade-offs and Technologies to Increase Power Density* marketing white paper.
- Texas Instruments, *Multi-Function Pins for Easy Designing* application brief.
- Texas Instruments, *Which Pinout is Best?* article.

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