PARTNER CONTENT

Sustainable Design of Power Supply Circuits with Nano Cap™ and QuiCur™ Technology from ROHM

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ROHM Semiconductor's new Nano Cap™ and QuiCur™ technologies increase design flexibility and reduce the resources needed to develop power supply circuits by enabling stable operation with fewer external components.

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Rising awareness of sustainable energy consumption is leading to increased electrification in a wide range of applications. This has led to growing demand for electronic components and design resources, particularly in the automotive sector. In addition, the number of capacitors required to stabilize supply voltages has increased significantly. However, because of the precarious global market situation — not just for semiconductors but for passive components as well — demand is increasing for power supplies that eliminate output capacitors if possible or that require only very small capacitance values. As a result, the number of capacitors used for a wide variety of purposes must be reduced.

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To ensure a stable power supply, a power supply IC constantly monitors the output voltage and stabilizes it to an accurate internal reference voltage by means of an error amplifier in the feedback loop. Faster response times imply that changes in the output voltage caused by fluctuations in the input voltage and/or load current can be quickly regulated. However, responses that are too fast can result in instability, causing oscillation at the output. As the output capacitance also affects the response speed, it has been difficult to achieve the desired performance, until now.

With QuiCur™ (Quick Current), ROHM Semiconductor has developed a new power supply technology that improves the output voltage response speed and stability in DC/DC converter ICs (switching regulators) and low-dropout (LDO) voltage regulators (linear regulators) during transients (load changes).

By integrating QuiCur™ technology, an ideal power supply can be achieved without the error amplifier becoming unstable and potentially taking the entire converter loop with it. Output capacitors with lower capacitance not only reduce the number of external components and their PCB mounting area, but a loss of capacitance as a function of the applied voltage becomes less critical. As a result, stable operation is ensured even when specification changes like aging and biasing increase the capacitance. This significantly reduces power supply circuit design resources by providing stable operation with fewer external components (**Figure 1**).

DETAILS OF QUICUR™ TECHNOLOGY

For optimal transient characteristics, a compromise must be found in conventional switching regulators between the amplification factor (gain) and the 0-dB crossover (frequency) point to ensure stable behavior. In combination, the transfer characteristics of the power stage and of the error amplifier play an important role.

First, let's consider the transfer function of the error amplifier in a conventional switching regulator (**Figure 2**).

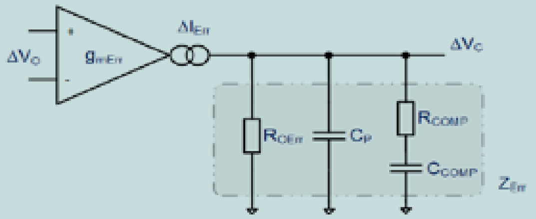


Figure 2: *Block diagram of a conventional error amplifier*

The transfer function can be expressed as:

$$\Delta V_C = -\Delta V_O * g_{mErr} * Z_{Err}$$

$$\frac{\Delta V_C}{\Delta V_O} = -g_{mErr} * Z_{Err}$$

Now let's look at a QuiCur™ error amplifier (**Figure 3**).

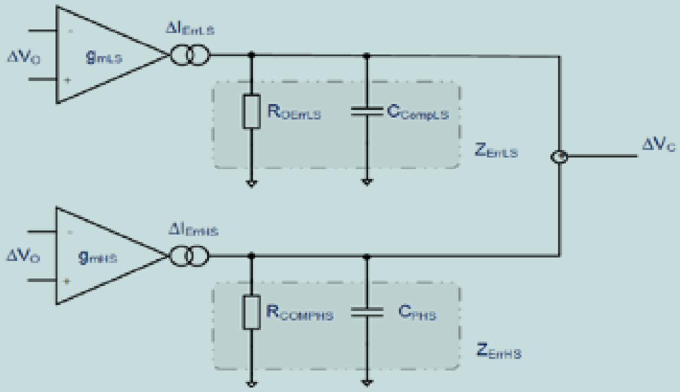


Figure 3: *Block diagram of a QuiCur™ error amplifier*

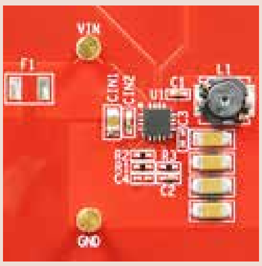
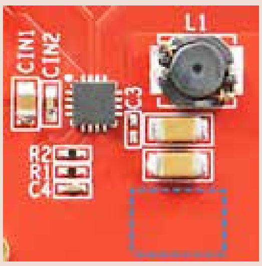
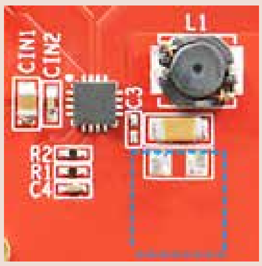
Conventional Switching Regulator	Switching Regulator with QuiCur™ Technology	
BD9S400	BD9S402 Mode = Low	BD9S402 Mode = High
		
C_{OUT} = 4 × 22 µF	C_{OUT} = 2 × 22 µF	C_{OUT} = 1 × 22 µF

Figure 1: *Comparison of space requirements for comparable voltage regulators*

The new error amplifier architecture with separation into two paths results in the following calculation of the control voltage ΔV_C:

$$\Delta V_C = -\Delta V_O * g_{mLS} * Z_{ErrLS} - \Delta V_O * g_{mHS} * Z_{ErrHS}$$

From this equation, we can now calculate the transfer function of the new error amplifier architecture:

$$\frac{\Delta V_C}{\Delta V_O} = -(g_{mLS} * Z_{ErrLS} + g_{mHS} * Z_{ErrHS})$$

As can clearly be seen, there are now two independent paths available for which the gain g_m and filter characteristics can be set independently of each other.

The transient characteristics of a switching regulator are the product of the transfer function of the error amplifier and of the power stage, which we can calculate as a function of the internal resistance ($Ri = 1/g_m$), the load, and the output capacitance:

$$\frac{\Delta V_C}{\Delta V_O} = \frac{g_m * R_L}{1 + jwC_O R_L}$$

Now let's compare the Bode plots of both switching regulators, having comparable characteristics (**Figures 4** and **5**). In the Bode plot with QuiCur™ technology, we see lower overall gain as well as a phase response with an almost constant phase margin up to frequencies well above the 0-dB crossover point.

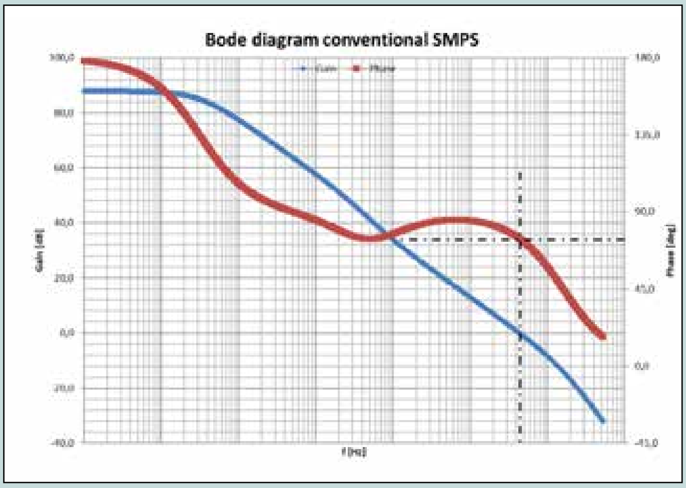


Figure 4: *Conventional switching regulator*

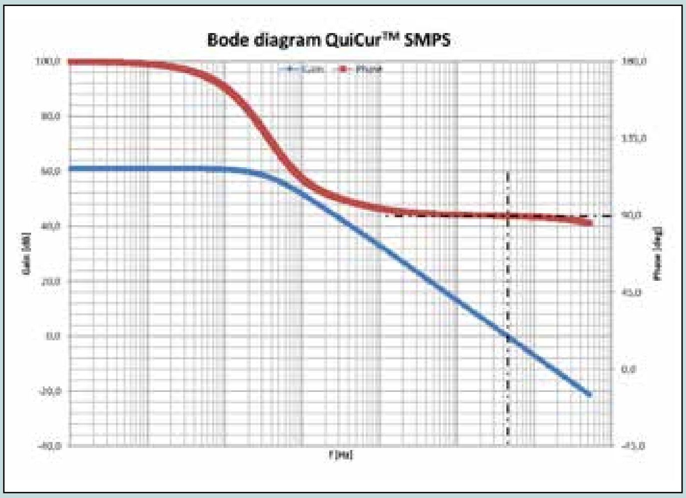


Figure 5: *Switching regulator with QuiCur™ technology*

Next, let's consider the influence of the output capacitance values when these are subject to tolerances. In the example shown in **Figures 6** and **7**, the standard value of 44 µF is halved to 22 µF. As can be seen in the Bode plots, this shifts the frequency of the 0-dB gain crossover point to a higher value. This changes the phase margin, which is the measure of the stability of a voltage regulator. The phase margin can be read from the graphs at the intersections of the vertical of the 0-dB crossover point with the phase curve.

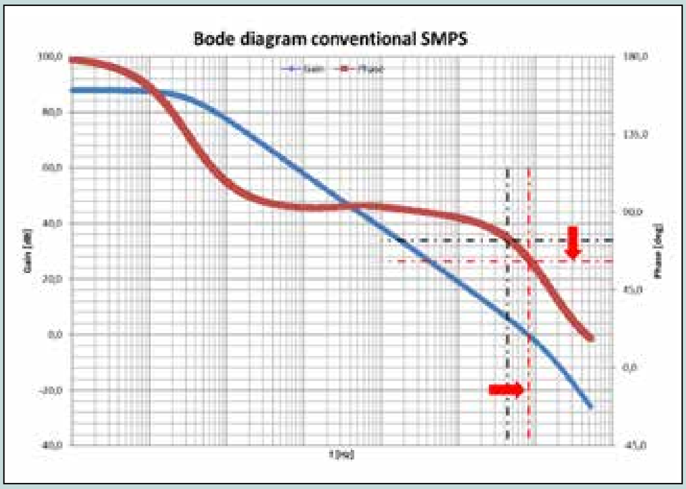


Figure 6: *Conventional switching regulator (22 µF)*

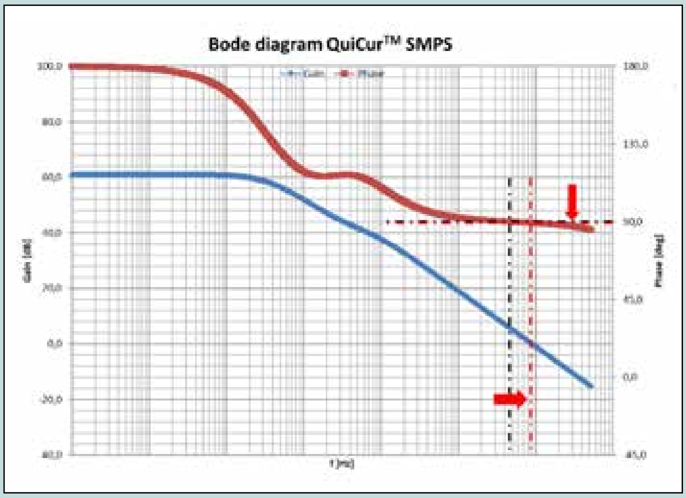


Figure 7: *QuiCur™ switching regulator (22 µF)*

Another advantage of this new technology comes from splitting the error amplifier into a slow and a fast signal path. The slow path ensures output voltage accuracy, and the fast signal path handles output voltage fluctuations caused by transients. As the two signal paths have separate amplifiers, they can be adjusted independently. The Bode plots in **Figures 8** and **9** each show the gain and phase of a switching regulator: standard on the left, and on the right with an approximately double 0-dB crossover frequency. Both plots were recorded with only 22-µF output capacitance.

From the Bode plots, it is easy to see that switching regulators with the new, innovative QuiCur™ technology offer a significantly higher phase margin and therefore better stability. Also, the 0-dB crossover point can be configured separately so that the switching regulator has optimized transient characteristics without becoming unstable.

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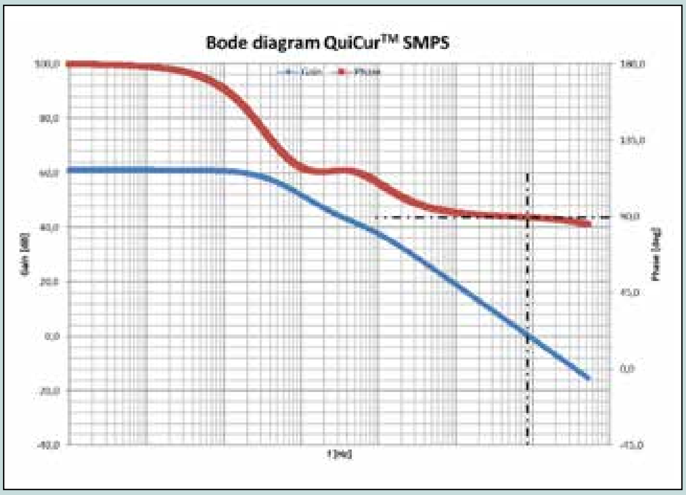

Figure 8: *QuiCur™ (slow)*

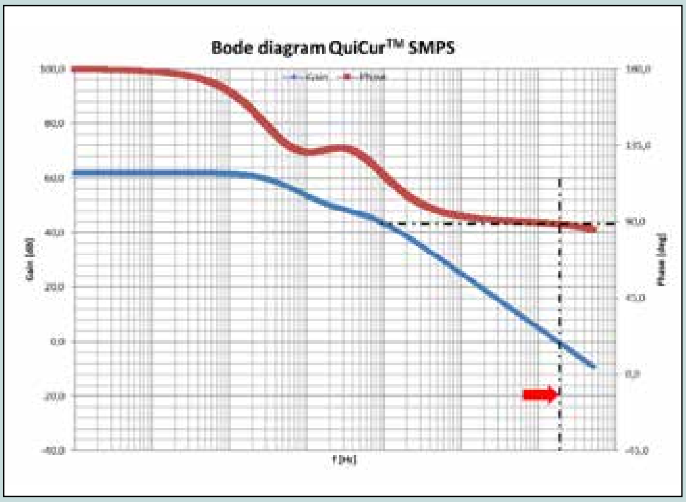

Figure 9: *QuiCur™ (fast)*

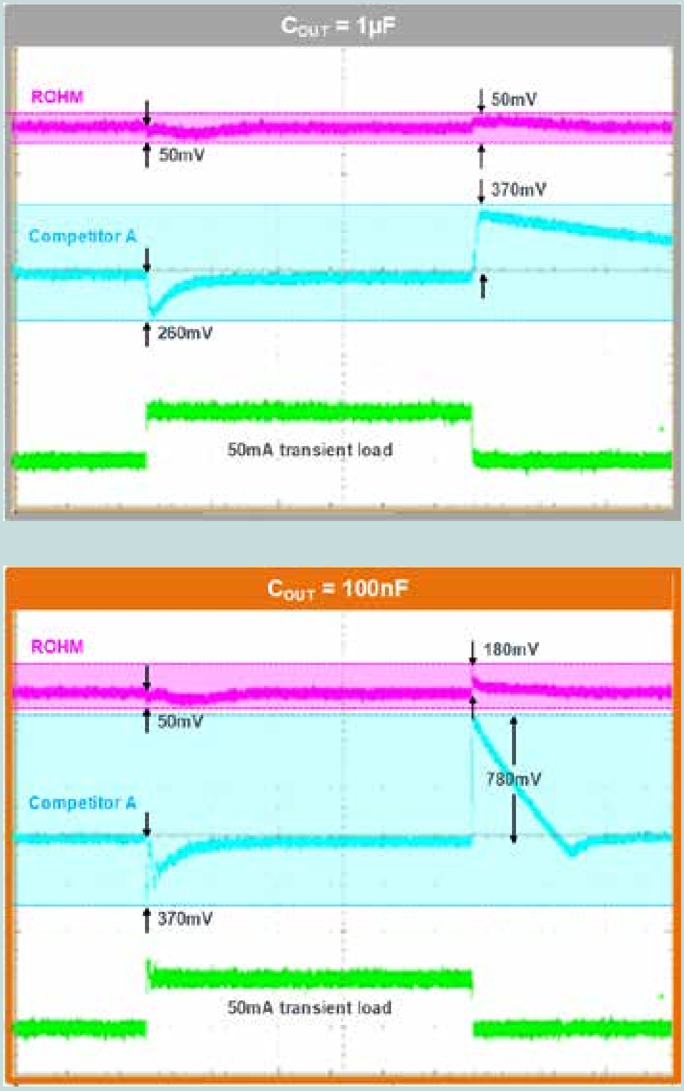

Figure 10: *Comparison of undershoot/overshoot measurements for Nano Cap™ and conventional LDOs*

COMBINATION WITH NANO CAP™ POWER SUPPLY TECHNOLOGY

ROHM developed its ultra-stable Nano Cap™ technology for LDO voltage regulator ICs in 2020. Compared with conventional LDOs, this technology additionally uses current information to precisely regulate the output voltage. The combination of this Nano Cap™ technology together with QuiCur™ technology now allows a substantial reduction in the output capacitor value together with significantly improved transient characteristics. This allows the output capacitance to be reduced to less than 1/10th that of conventional solutions. In the ideal case, it is even possible to omit the output capacitor altogether and instead use the load's input capacitor (typically a 100-nF capacitor) to stabilize the voltage.

Figure 10 provides a comparison of a Nano Cap™ LDO with a conventional comparable LDO under varying loads (transients) based on the output capacitance. As can be seen from the images, the output voltage overshoots and undershoots with the Nano Cap™ LDO are much smaller than with a conventional LDO. At 1-µF output capacitance, we see factors of 5.2 and 7.4, respectively, with identical load steps. If we now replace the output capacitor with a 100-nF type, the undershoot with the Nano Cap™ LDO remains at the same value, and the overshoot increases to 180 mV. With a conventional LDO, the overshoot and undershoot increase significantly, by factors of 7.4 and 4.3, respectively, compared with ROHM's new technology with the same output capacitance. These overshoots and undershoots are usually outside the load's allowed voltage range and often exhibit oscillations during the regulation process that are unacceptable.

The Nano Cap™ together with QuiCur™ technology prevents oscillation, even with small output capacitances; reduces overshoot and undershoot; and helps to save more resources, reduce PCB requirements, simplify designs, and cut costs.

NEW AUTOMOTIVE DC/DC CONVERTER ENSURES STABLE OPERATION

The BD9S402MUF-C is a buck DC/DC converter IC (switching regulator) with integrated MOSFETs for automotive applications like infotainment or advanced driver-assistance systems (ADAS). The new IC supports output voltages from 0.6 V up to (0.8 × V_{IN}) and a maximum output current of 4 A at switching frequencies of typically 2.2 MHz.

The BD9S402MUF-C is compact in size, which is a requirement for increasingly demanding secondary power supply applications for high-performance MCUs and SoCs. Using QuiCur™ technology, it

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enables stable operation at an industry-leading 30-mV over/undervoltages (measurement conditions: 5-V input voltage, 1.2-V output voltage, 44-µF output capacitance, load-current variation 0 to 1 A/1 µs). This represents a 25% reduction in output voltage fluctuations compared with class-leading standard products of equivalent functionality.

The BD9S402MUF-C is also equipped with a transient response selection feature. It exploits the characteristics of QuiCur™ technology and enables the user to switch priority between the lowest "voltage fluctuation" (for smallest transient voltages) and "capacitance reduction" (to ensure stable operation at 22 µF) by setting the gain pins to high/low (**Figure 11**). For example, the user can set the gain pin to high if the power supply is for an SoC, thus supporting the required high accuracy for the supply voltage even with large transients. Or the gain pin can be set to low to achieve a good balance between power and capacitor cost if the power supply is for a load with lower transient voltage accuracy requirements.

the AEC-Q100 standard for reliability in automotive applications. In addition, the primary LDOs are capable of handling large input voltages (greater than 40 V). ROHM's Nano Cap™ power supply technology, together with its QuiCur™ technology, supports an output capacitance of 100 nF. In this way, it ensures stable operation of the applications even when the input voltage and load current fluctuate. This makes it possible to provide high performance with a good balance in terms of output capacitance range and response characteristics.

As well as the usual microfarad-class multilayer ceramic capacitors, the new regulators can operate with a wide range of output capacitances, starting at 100 nF in ultra-compact 0603/0402 package sizes. This was not possible in the past because the circuits were not stable enough. This new option not only helps miniaturize components and boards but also reduces design requirements by supporting a wider range of capacitor conditions.

ROHM will expand the LDO regulator series with integrated Nano Cap™ technology to 22 models with different output voltages and

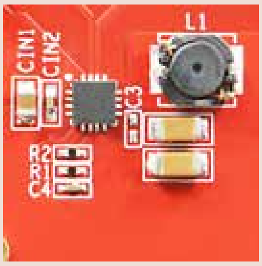
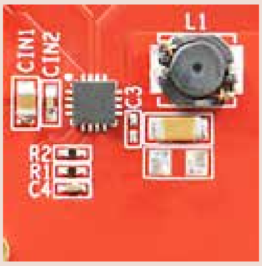
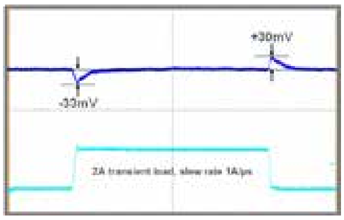
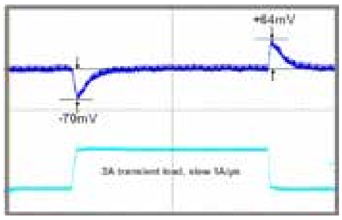
Design Priority	Transient Response	Cost
Gain Setting	High	Low
Output Capacitance	44 µF (2 × 22 µF)	22 µF (1 × 22 µF)
PCB Layout		
Step Response V_{IN} = 5 V V_{OUT} = 1 V I_{OUT} = 0 A → 2 A (1 A/µs) f_{SW} = 2.2 MHz		

Figure 11: *BD9S402MUF-C transient load response*

The end result is that the user can significantly reduce the resources required for power supply circuit design, as stable operation can be achieved not only with the original design but also in the event of specification or model changes.

LDO REGULATORS FOR AUTOMOTIVE APPLICATIONS

With the BD9xxN1 series, ROHM offers a range of primary LDO ICs for automotive applications. The ICs are optimized for the direct 12-V on-board power supply in a wide range of in-vehicle applications — for example, in the powertrain, vehicle body, ADAS, and infotainment.

The BD9xxN1 primary LDOs meet basic automotive product requirements, such as operation above 125˚C and qualification to

packages by the end of 2022. In 2023, 24 models will be added to support output currents of 500 mA. This means a total of 46 products will be available by the end of 2023, covering an even broader range of applications.

CONCLUSION

With Nano Cap™ and QuiCur™, ROHM offers two innovative technologies that increase design flexibility in the development of sustainable power supply circuits while ensuring stable operation. Output capacitors with lower capacitance have not only reduced the number of external components and the mounting area; overall, they also enable significant cost savings in procurement, inventory, design-in, assembly, and testing. ■