Selecting the Optimal PoL Converters for an Automotive SoC Power Tree

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Introduction

Advanced driver assistance systems (ADAS) and infotainment system-on-chips (SoCs) have increasingly higher power demands to meet the need for higher computing power. An SoC can require separate power rails, with currents ranging from hundreds of amperes (A) to a few mA. Building off of optimized pre-regulator design for an automotive SoC, this article will take a deep dive into the intricacies of selecting the optimal point-of-load (PoL) converters to supply the SoC power rails.

System-On-Chip (SoC) Power Requirements

Before discussing component selection, it is important to summarize the power requirements for this case study. Table 1 shows the power requirements for this SoC example.

Table 1: SoC Power Requirements

Rail Name	Voltage (V)	Current (A)	Transient Load (A)	Slew Rate (A/µs)	Voltage Tolerance (1) (%)	Notes
VDD_CORE	0.85	60	40	40	3	
1V8_GPIO	1.8	5	2.5	2.5	5	
3V3_GPIO	3.3	5	2.5	2.5	5	
1V8_analog	1.8	1.5	0.75	0.75	5	From a low-noise DC/DC converter
DDR_VDD	1.05	6	3	3	3	
DDR_VDDQ	0.6	6	3	3	5	
PCIe	0.85	1.5	0.75	0.75	5	
MIPI	0.75	1.5	0.75	0.75	5	

Note:

1) The voltage tolerance includes the converter's DC accuracy, load transient response, and IR drop.

The most important parameter in Table 1 is the maximum current rating, as this determines which IC to select. On one hand, a DC/DC converter must be rated for a nominal output current (I_{OUT}) equal to or greater than the rail's current rating to guarantee the best performance. On the other hand, to get the most cost-effective solution, the engineer should not select a part that provides more than 150% of the current that rail requires. With these considerations in mind, there is a narrow selection of ICs that can match the system requirements. To further optimize IC selection, designers must consider the other requirements.

Both the transient load and voltage tolerance also play an important role when selecting a device. If the transient load magnitude is relatively high (>30% of the rated current) and the voltage tolerance is tight (<5%), the engineer must choose a device that has excellent load transient response. These devices usually implement an advanced control method, such as constant-on-time (COT) or zero-delay PWM (ZDP) (see Figure 1). These controls schemes have very fast load transient response, and minimize the amount of output capacitance needed to meet the tolerance requirement.

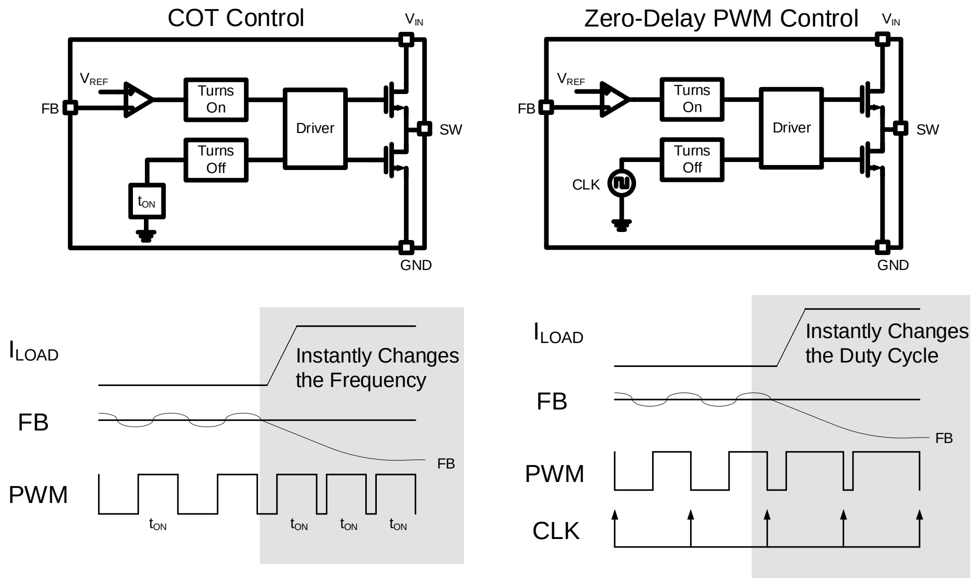

Figure 1: COT Control and ZDP Control

In ADAS systems where cost and scalability are a focus, discrete PoL converters are the best approach for the power supply as they are very flexible. Their counterparts, power management ICs (PMICs), integrate several converters into a single device and can simplify design; however, they are very rigid and may not tailor-fit into the application. PoL devices can be placed nearby the SoC, facilitating a good power delivery network. And since converters dissipate energy in the form of heat, by using discrete ICs the heat sources can be spread out to ease the thermal management.

Choosing the Right Part for Each Rail

VDD_CORE Rail

Starting with the VDD_CORE rail, the maximum current rating is 60A which is quite high. To supply high current and low output voltages, a multi-phase voltage regulator (VR) controller such as the MPQ2967-AEC1 can be used (see Figure 2). To complete the power converter, these VR controllers must be paired with a DrMOS, which are monolithic half-bridges with built-in power MOSFETs and gate drivers.

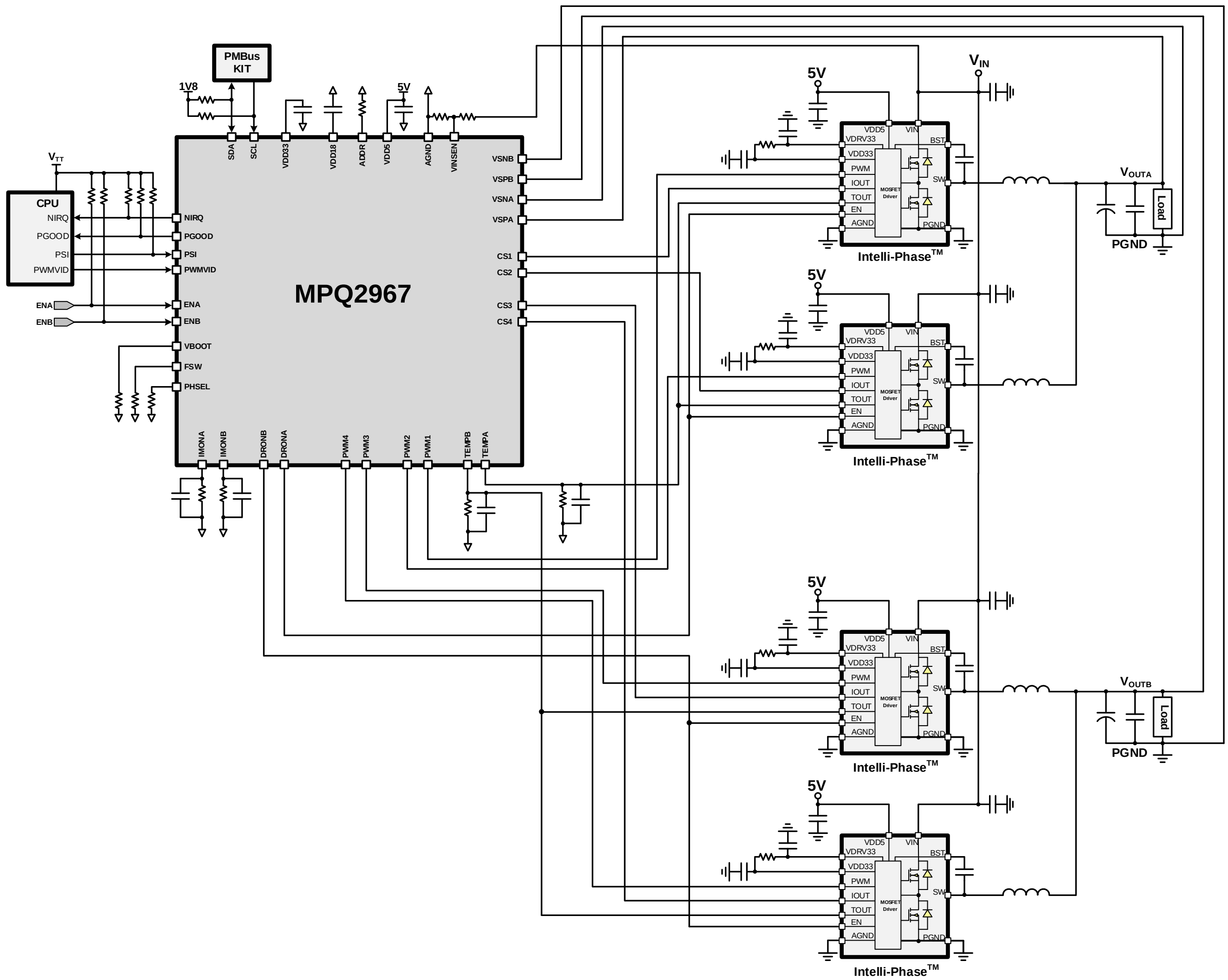

Figure 2: MPQ2967-AEC1 – A Multi-Phase VR Controller with Intelli-Phase™ Architecture

Automotive-grade controllers that use advanced control techniques to minimize disturbances to the power rail achieve excellent transient response performance. In addition, DrMOS are efficient and compact solutions for high loads. For an output current of 60A, it is recommended to pair the MPQ2967-AEC1 controller with two MPQ86960-AEC1 Intelli-Phase™ ICs to create a dual-phase converter capable of supporting such high loads.

The remaining power rails require significantly lower current, so regular monolithic step-down converters can be used to convert the 5V bus voltage to the required voltage for each rail.

1V8_GPIO and 3V3_GPIO Rails

The 1V8_GPIO and 3V3_GPIO rails each require 5A of supply current, but the transient load and voltage tolerance specifications are more relaxed than other rails with stringent specifications. For these rails, selecting an ideal and cost-effective converter is critical, as this helps lower the total solution cost. The MPQ2167A-AEC1 is well-suited for these rails because it can provide up to 6A of output current in a compact 3mmx3mm package. By switching at 2.2MHz, physically smaller and lower-value passive components can be used to save cost and area. With peak current mode (PCM) control and internal compensation, this converter is stable and maintains the required voltage regulation.

1V8_analog, PCIe, and MIPI Rails

The 1V8_analog rail is more challenging, as it supplies power to sensitive analog circuitry in the SoC that require a stable, low-noise source. It also requires a maximum current of 1.5A, which is too high to be supplied from a low-noise and low-dropout (LDO) linear regulator. Such an LDO could overheat in an automotive environment, where the ambient temperature can be 85°C or greater.

A highly efficient step-down converter such as the MPQ2178-AEC1 is well-suited for this power supply, but its output noise must be attenuated to meet the design requirements. To provide the required attenuation for the low-noise supply, a second-stage filter must be added to the converter's output (see Figure 3). The SoC hardware manual should provide guidance on how to design the filter for this supply rail, though there are also articles online that describe how to design the second-stage filter for low-noise power supplies.

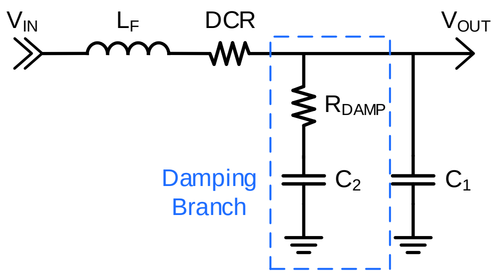

Figure 3: Second-Stage Output Filter with a Damping Branch

The MPQ2178-AEC1 can supply low-current rails. It features advanced COT control and operates at a constant 2.4MHz switching frequency (f_{SW}) during steady state conditions, while also providing an excellent response during transient loads due to COT control.

The MPQ2178-AEC1 can be reused for the PCIe and MIPI supply rails because they have similar requirements to the 1V8_analog rail, but those rails do not require the second-stage output filter.

DDR Memory Supply Rails

Finally, the two DDR memory supply rails require 6A of output current and excellent load transient response. The DDR_VDD rail has a 3% voltage tolerance requirement; with a 1.05V of nominal rail voltage, it only allows for a ±31.5mV deviation.

The DDR_VDDQ rail has a higher voltage tolerance at 5%. However, with a 0.6V nominal voltage, the allowed deviation is also very narrow at 30mV. Furthermore, the DC accuracy of the selected IC must be subtracted from the allowed voltage deviation, leaving even less room for disturbances caused by load transients (Figure 4).

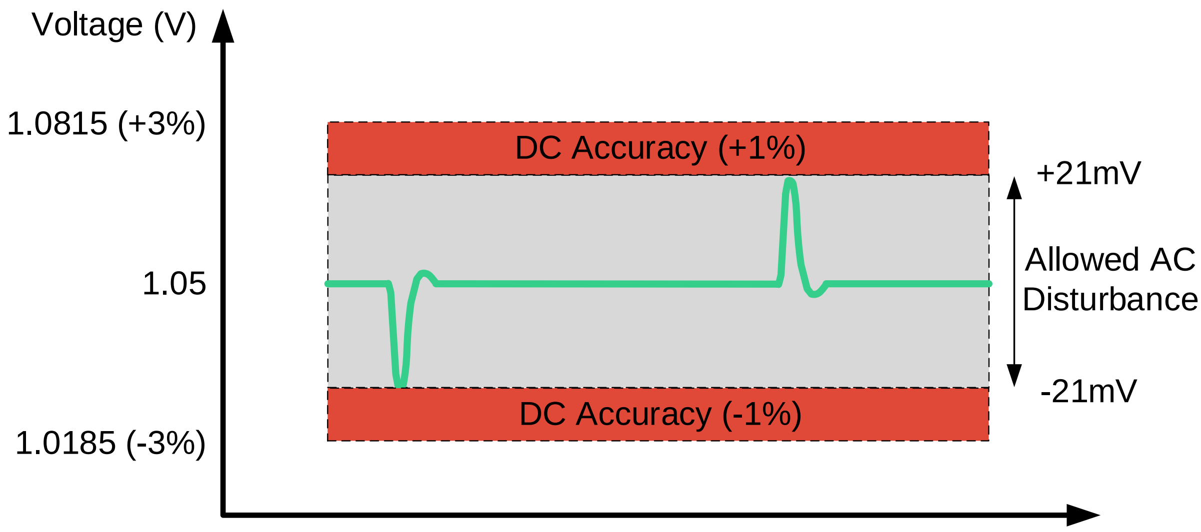

Figure 4: Allowed AC Disturbance

It is vital to select an IC with an excellent accuracy of 1% across the full operating range, as well as a very fast control loop. The MPQ2283-AEC1 was selected for this rail because it is a modern, low-voltage step-down converter designed to tackle these very power requirements. This device implements a ZDP control loop that achieves fast transient response, capable of keeping the voltage disturbance under ±15mV with minimal output capacitance.

Device Selection Summary

Table 2 is a summary of the selected devices for this application.

Table 2: Selected Devices

Rail Name	Voltage (V)	Current (A)	Devices
VDD_CORE	0.85	60	MPQ2967GQKTE-AEC1
			2 x MPQ86960GMJT-AEC1
1V8_GPIO	1.8	5	MPQ2167AGQE-AEC1
3V3_GPIO	3.3	5	MPQ2167AGQE-AEC1
1V8_analog	1.8	1.5	MPQ2178GQHE-AEC1
DDR_VDD	1.05	6	MPQ2283GLE-AEC1
DDR_VDDQ	0.6	6	MPQ2283GLE-AEC1
PCIe	0.85	1.5	MPQ2178GQHE-AEC1
MIPI	0.75	1.5	MPQ2178GQHE-AEC1

Once all of the ICs are selected, the power tree can be updated to reflect the final architecture. Then the hardware engineer can start doing the calculations for the required passive components, such as power inductors and output capacitors. Figure 5 shows the final SoC power tree that has been optimized to meet each rail's specification requirements, including the pre-regulator design.

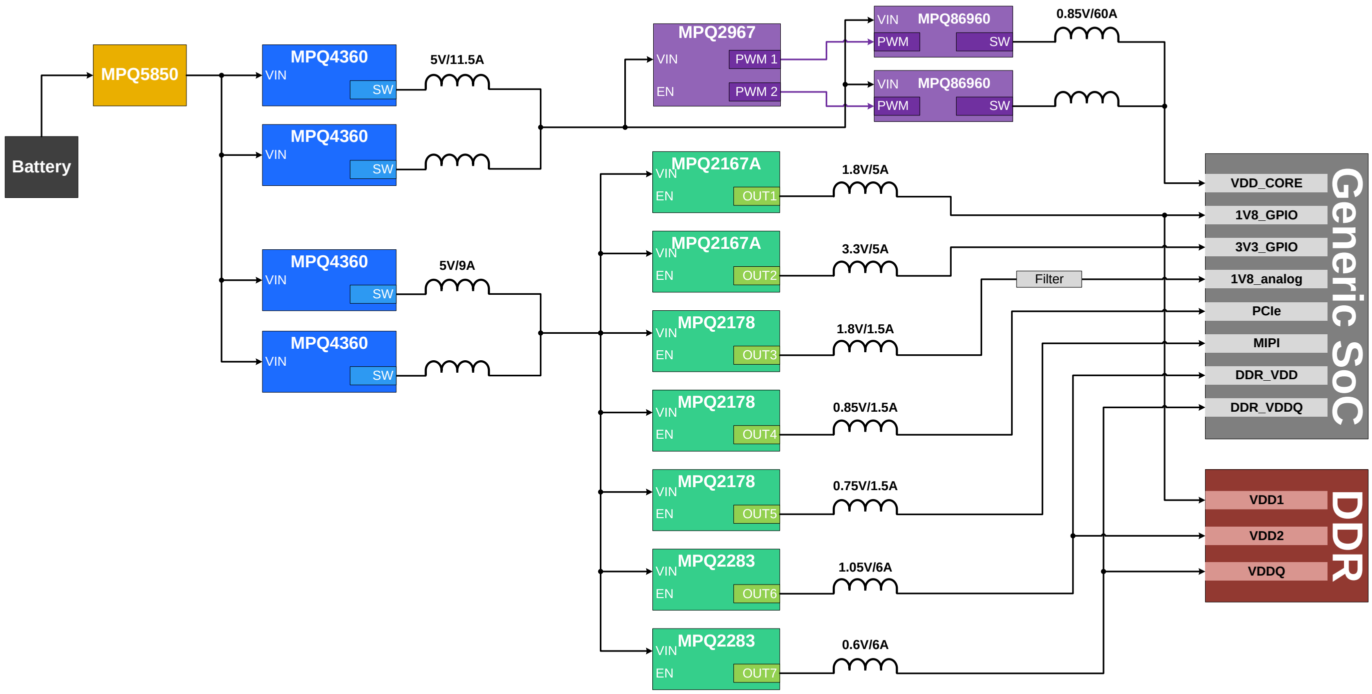

Figure 5: Final SoC Power Tree

Conclusion

This article has explored an automotive SoC power tree design based on PoL converters, and discussed how to select an IC that is optimized for performance and cost, as well as key factors that determine the best component selection for automotive applications. The first step is to identify the key requirement for each rail; be it efficiency, accuracy, noise, or even cost. Then the system architect must identify which device will best match the key requirements. Many suppliers offer an easy way to compare and find the optimal device for each case, such as the available filters on the AEC-Q100 qualified controllers and converters section on the MPS website.