Why Automotive ECUs Need a High-Performance POL Converter

Introduction

Modern, high-end cars require almost one hundred electronic control units (ECUs). Each ECU (Figure 1) is powered from the car battery through a front-end buck converter. Back-end point-of-load (POL) buck converters, in turn power the ECU's smart loads (MCU, CAN, I/Os) with the low voltages required by each. These back-end voltage regulators must be small, adhere to tight safety standards, operate with low input voltages across a wide range of temperatures, and minimize radio frequency interference (RFI) while exhibiting high accuracy, high efficiency, and high reliability. This article reviews the challenges of designing an ECU POL buck converter and introduces a new family of buck converters that stand up to the challenge.

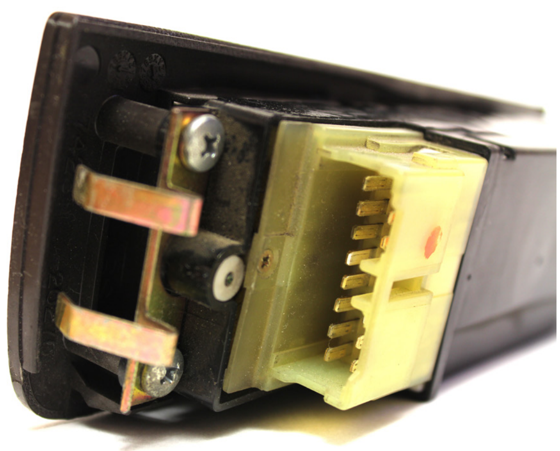

Figure 1. Electric Window Control Unit

ECUs in the Car

ECUs are small computing modules that control most of the systems in a modern car. Accordingly, the on-board power electronics need to take minimum space. ECUs are connected via a controller area network (CAN) to control the car's engine, power windows, brakes, airbags, lights, entertainment system, steering functions, and more.

Powering the ECU

The block diagram of a typical ECU is shown in Figure 2. A front-end high-voltage buck converter (HV BUCK) interfaces directly to the car battery to power the MCU. Its output voltage is then distributed to the other ECU's electronic loads via dedicated low-voltage point-of-load buck converters (LV BUCK). ECUs pack a lot of electronics in a small space.

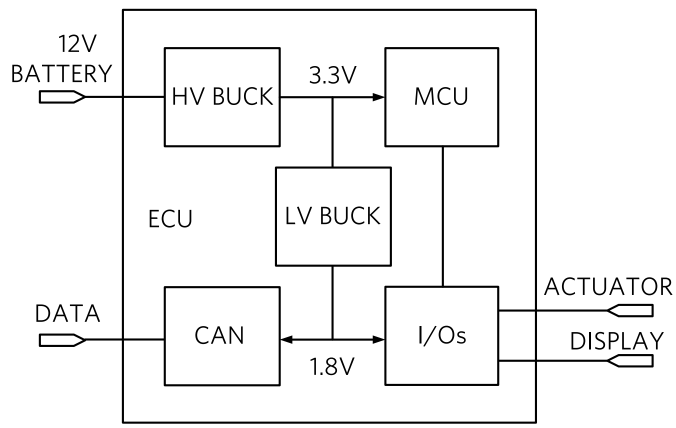

Figure 2. ECU Block Diagram

The Automotive Environment

The LV BUCK regulators must operate with low-input and low-output voltages. They must switch with a high and well-controlled PWM frequency, above the AM band, to reduce RFI. They require PWM clock spread-spectrum modulation to meet electromagnetic interference (EMI) standards. They must be able to report fault conditions for use in safety critical applications (ASIL). Finally, high efficiency across the full operating range is needed to reduce ECU heat generation, improving reliability.

Low Input and Output Voltage

The electronic loads in automobiles are designed with dense, submicron process technologies that require very accurate and very low voltages for operation. Depending on the process utilized, the ICs require diverse input voltages, from sub-1V up to a few Volts. Accordingly, the LV BUCK feeding these loads must operate with low input voltages while delivering a regulated output that while low, covers a wide range of values.

Meet Automotive Standards

It can be difficult to find a single voltage regulator that meets all the stringent requirements of automotive ECUs. The MAX20073/MAX20074 family of buck converters is designed from the ground up to perform in an automotive environment. A low-input supply voltage poses the first challenge, as the LV buck internal circuitry must operate with little headroom. This challenge is addressed with special low-voltage IC design techniques. High-frequency switching avoids AM-band RFI. Spread-spectrum modulation can further reduce EMI to help designs comply with stringent EMI standards such as CISPR25. Digital outputs report fault conditions to the supervisor systems to maximize system reliability.

The MAX20073/MAX20074 family of ICs is manufactured and quality-tested beyond the level of consumer devices to meet automotive reliability requirements. Devices are characterized across the full automotive operating temperature range. Source dies are tracked and go through sorting to ensure the highest quality. ASIL-rated variants are also available.

The MAX20073/MAX20074 high-efficiency switching regulator family delivers 2A/3A load current from 0.5V to 3.8V. The devices operate from a 2.7V to 5.5V input voltage range. All the devices are designed to operate over the -40°C to +125°C operating temperature range. Figure 3 shows the MAX20073 application diagram.

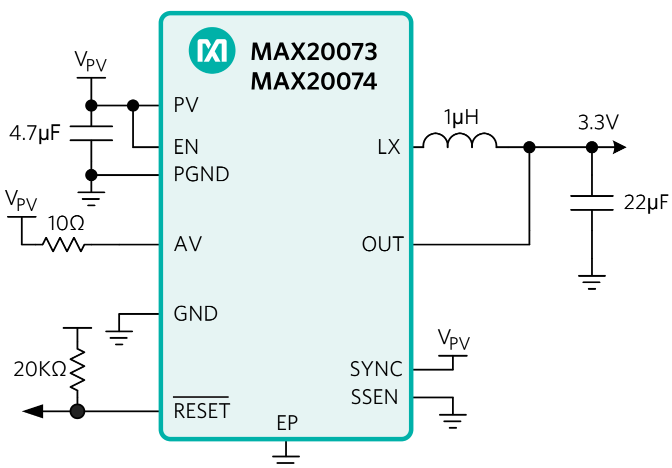

Figure 3. MAX20073 Application Circuit

Fixed-Frequency Operation

The MAX20073/MAX20074 family offers a fixed-frequency PWM mode of operation with a 2.2MHz switching frequency (above the AM band) to reduce RFI. Optional spread-spectrum mode is available to meet EMI requirements.

Skip Mode Operation

A highly efficient pulse-frequency modulation mode (skip mode) greatly improves efficiency at light loads. Skip mode reduces the switching frequency to the minimum required to maintain the output voltage. Skip mode can be activated/deactivated through a digital input on the IC.

Output Voltage Accuracy

The output voltage can be preset at the factory to allow ±1.5% output-voltage accuracy without the need for expensive 0.1% external resistors. Factory trimming supports fixed output voltage values between 0.5V and 3.8V in 25mV increments. Alternatively, the device can be configured to regulate to a voltage set by an external resistor-divider.

High-Efficiency Solution

The family's low R_{DSON} and integrated synchronous rectification MOSFETs contribute to high-efficiency operation. The efficiency remains high over a wide range of currents thanks to skip mode at light load and constant-frequency PWM operation at heavy load. The 2A MAX20073 efficiency curve, with 3.3V input, 1.8V output, is shown in Figure 4 (teal curve).

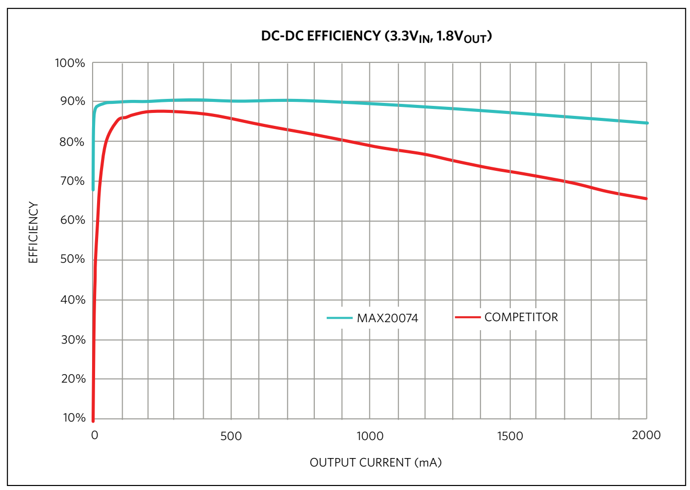

Figure 4. The Efficiency Advantage

The IC exhibits superior efficiency across the entire operating range compared to a competitive device (red curve). At full load (constant-frequency PWM operation) the 20 points of efficiency advantage is at a maximum.

Small Size

The MAX20073/MAX20074 are available in a small (3mm × 3mm) 10-pin TDFN package with an exposed pad (Figure 5). They use very few external components. A complete fixed-output MAX20074 circuit can fit into a small 65mm² area on a PCB.

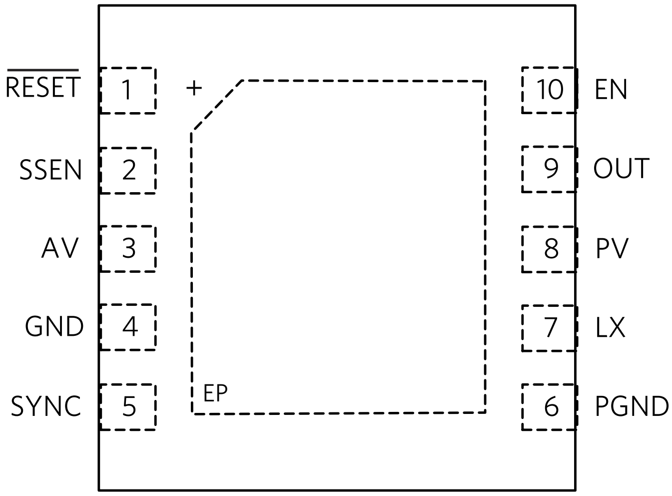

Figure 5. MAX20073/MAX20074 TDFN-10 Package (3mm × 3mm)

Conclusion

We have discussed the challenge of reliability, low-voltage input and output operation, small size, low noise, and high efficiency in automotive ECUs. We introduced the MAX20073/MAX20074 family of 2A/3A POL buck converters. The devices feature fixed-frequency PWM operation, with a 2.2MHz switching frequency to reduce RFI, and spread-spectrum operation to meet EMI standards. Small packages and very few external components result in minimal PCB area occupancy. Factory trimming supports fixed-output voltage values between 0.5V and 3.8V in 25mV increments. Alternatively, the devices can be configured to regulate to a voltage set by an external resistive divider. These devices' features meet the most stringent electrical and mechanical automotive requirements, enabling the design of compact, high-performance ECUs.

Glossary

ASIL: Automotive Safety Integrity Level. A risk classification scheme defined by the ISO 26262.

CAN: Controller area network

CISPR25: International Special Committee on Radio Interference. Limits and methods of measurement of radio disturbance characteristics for the protection of receivers used on board vehicles.

ECU: Electronic control unit

EMI: Electromagnetic interference

MCU: Microcontroller unit

POL: Point-of-load

RFI: Radio frequency interference

Learn more:

MAX20073 2A 2.2MHz Low-Voltage Step-down DC-DC Converter

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