

Feature-Rich Systems Demand Flexible and Configurable, 20 V, High Current PMICs

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Background

The unabated advancement of technology has increased the feature content of all electronic systems, while reducing available space. Cell phones have touch screens, flashlights, power-save modes, and sophisticated cameras. Automotive dashboards once featured only basic AM radio and a few spartan gauges, but now are packed with elaborate instrumentation, satellite radio, Bluetooth®, GPS, and other cell phone-based network connections, multicolored lighting, and a myriad of USB ports. Industrial rugged computers contain barcode readers, large screens, hard drives, and lighted keyboards. Medical electronic devices contain sensors, multi-intensity flashlights, gauges, and power-save modes.

What hasn't changed is the need for power. As portable and system electronics features increase, so do their power requirements, especially when the following sophisticated digital ICs are used:

- ▶ Graphics processing units (GPUs)
- ▶ Field programmable gate arrays (FPGAs)
- ▶ Microcontrollers and microprocessors
- ▶ Programmable logic devices (PLDs)
- ▶ Digital signal processors (DSPs)
- ▶ Application specific integrated circuits (ASICs)
- ▶ Programmable logic devices (PLDs)

These complex digital devices require multirail, high power density power supplies featuring high current, low voltage, and fast transient response. These stringent demands are combined with specific high performance requirements—such as low noise or digital control—placing significant stress on power supply designers to deliver cutting-edge solutions. In all cases, advancements in the above devices demand that power supply designers keep up.

Power System Design Challenges

Modern electronic system designers are challenged to meet restrictive space requirements, limited operating temperature ranges, and noise specifications. Integration levels are high to save PCB space, requiring efficient power components to keep temperatures in check. For example, today's automobile dashboards are packed with electronic systems that operate in a high ambient temperature environment, so temperature monitoring and

reporting is a critical requirement, particularly for power management components. A system controller can respond to overtemperature (OT) alerts with mitigation steps to prevent system overheating, such as turning off less critical functions or throttling back performance of processors, displays, and network communication.

From a power supply perspective, even the most basic dashboard automotive infotainment console requires several low voltage power supply rails (output levels) at several amps of total current; a premium console requires far more. Traditionally, low voltage rails have been produced by a multitude of tiny point of load (POL) discrete power regulator ICs, or large, highly integrated power management integrated circuits (PMICs). Many PMICs often have more rails than are needed, require a large circuit footprint, and can be underpowered for some rails, defeating the purpose of the additional integration.

Another potential design challenge is feature creep, or the slow change of product specifications as development marches forward—such as changes to input and output voltages and output currents. Feature creep can wreak havoc on the selection of ICs and associated discrete components. In the best-case scenario, when a system specification is changed after the board layout is set, a voltage can be tweaked by swapping out a few resistors on an adjustable output converter. In a worst-case situation, several ICs must be replaced with non-pinout-compatible ICs when updated current levels exceed the switch current rating of the incumbent converters. This can require IC-, board-, or system-level requalification, increasing costs and adding schedule delays for even the smallest feature change.

The solution to these problems is a power IC that offers more outputs than purely discrete, single, or dual output ICs, but takes less space, and costs less than a full-featured PMIC. This in-between regulator is a multi-output power IC that can provide a small solution footprint with a configurable number of moderately powered rails. Ideally, such an IC could be configured to output a wide variety of voltages and currents to accommodate changes in power requirements that arise during development, avoiding requalification cycles and reducing product time to market. Furthermore, it could operate at input voltages above 5 V with high efficiency to allow use in a variety of application spaces, such as from 12 V to 18 V wall adapters. Integrated safety and monitoring features, wide temperature range operation, plus innovative package design with high thermal performance are also desirable features.

Flexible and Configurable 20 V Multi-Output Power IC

ADI's Power by Linear™ LTC3376 is a highly integrated, general-purpose power management solution for systems requiring multiple low voltage power supply rails. The device can be configured to provide one to four independent regulated outputs from an input of up to 20 V, with 15 possible output current configurations and a total output current of up to 12 A; see Figure 1 for details. Such flexibility makes the LTC3376 ideally suited to a wide variety of multichannel applications, including telecom, industrial, automotive, and communications systems.

The LTC3376 combines four independent buck regulator channels and eight configurable 1.5 A power stages with flexible sequencing and fault monitoring, for a total available output current of 12 A. The LTC3376 has a peak buck efficiency of 96% with $\pm 1\%$ output voltage accuracy on all channels. Each channel can be powered from an independent 3 V to 20 V input supply and has an output voltage range down to 0.4 V. Adjacent outputs can be combined in parallel with a single shared inductor thus simplifying the circuit. The dc-to-dc converters are assigned to one of 15 power configurations via pin-strappable CFG0 to CFG3 pins. External BST caps are not required since they are integrated into the package.

The LTC3376's switching regulators operate in one of two modes: Burst Mode® operation (power-up default mode) for higher efficiency at light loads and forced continuous pulse-width modulation (PWM) mode for lower noise at light loads. The switching regulators are internally compensated and need only external feedback resistors to set the output voltage. The buck converters have input current limiting, soft start to limit inrush current during startup, differential output sense, and short-circuit protection. The device has a programmable and synchronizable 1 MHz to 3 MHz oscillator with a 2 MHz default switching frequency.

The quiescent current with all four converters enabled is only 42 μ A. Other features include: four power good pins indicating when an enabled dc-to-dc converter is within a specified percentage of its target output, current monitors for external monitoring of each buck's load, an EXT_{V_{CC}} pin for improved efficiency, precision RUN pin thresholds for power-up sequencing, a die temperature monitor output (readable via an analog voltage on the TEMP pin) that indicates internal die temperature, and an overtemperature function that disables the bucks at high die temperatures in case of an overload condition.

The LTC3376 is available in a compact, 64-ball, 7 mm \times 7 mm flip chip ball grid array (BGA) package. E- and I-grades are specified over an operating junction temperature range of -40°C to $+125^{\circ}\text{C}$.

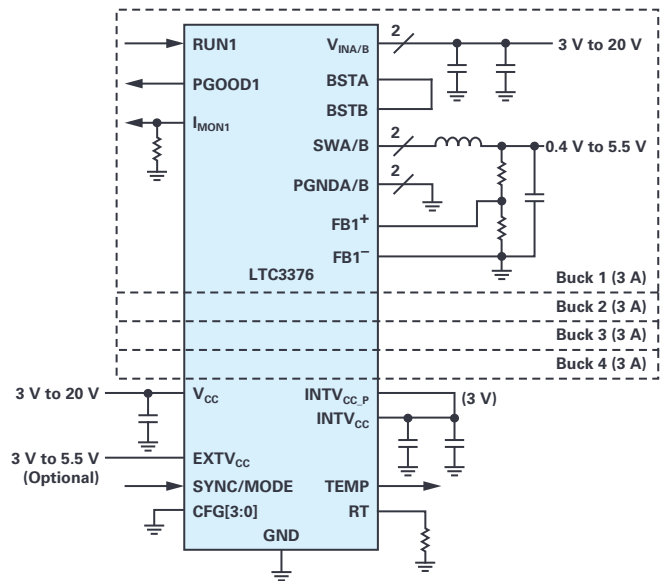


Figure 1. LTC3376 simplified block diagram.

Flexibility and Configurability

The inherent flexibility of the LTC3376 allows it to be set up into 15 different output configurations:

- ▶ Single inductor, single output 12 A buck where all the power stages are internally ganged together to produce maximum current output.
- ▶ Four possible dual-buck combinations with two inductors total with the total output current summing to 12 A.
- ▶ Five triple-buck combinations totaling 12 A each with three total inductors.
- ▶ Five quad-buck configurations of up to 12 A each with four total inductors (see Figure 2).

See Table 1 for a list of the 15 possible output configurations. This flexibility enables easy adjustment when requirements change in the design process—no need to qualify a new IC when the LTC3376 can remain in place.

Table 1. LTC3376: 15 Examples of 12 A Total Current Output Configurations

Topology	Output Current Combinations
5 Quad Bucks	3 A, 3 A, 3 A, 3 A, 4.5 A, 3 A, 3 A, 1.5 A, 4.5 A, 4.5 A, 1.5 A, 1.5 A, 6 A, 1.5 A, 3 A, 1.5 A, 7.5 A, 1.5 A, 1.5 A, 1.5 A
5 Triple Bucks	3 A, 4.5 A, 4.5 A, 6 A, 3 A, 3 A, 4.5 A, 6 A, 1.5 A, 7.5 A, 3 A, 1.5 A, 9 A, 1.5 A, 1.5 A
4 Dual Bucks	6 A, 6 A, 7.5 A, 4.5 A, 9 A, 3 A, 10.5 A, 1.5 A
1 Single Buck	12 A

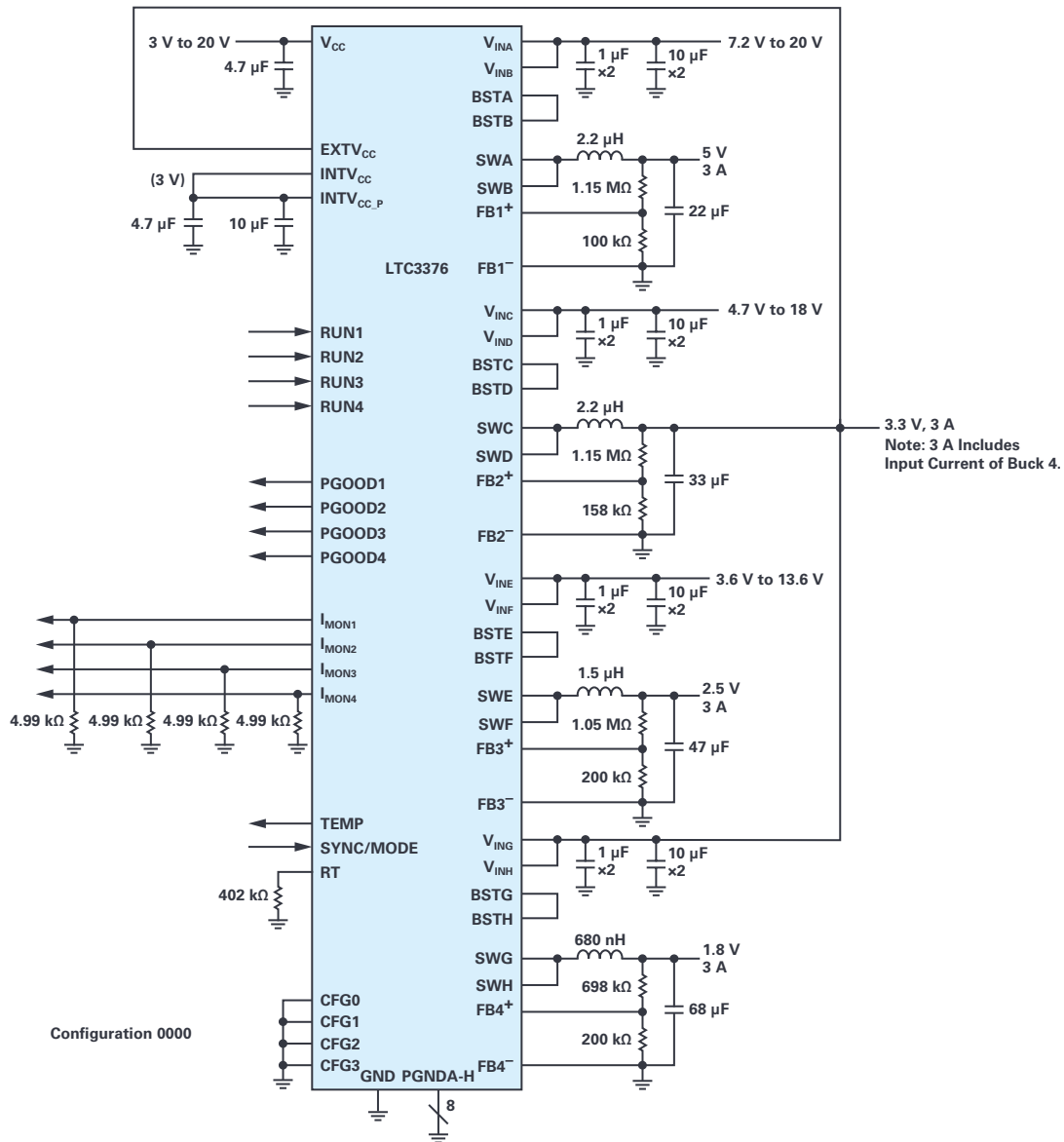


Figure 2. Typical quad-output application circuit.

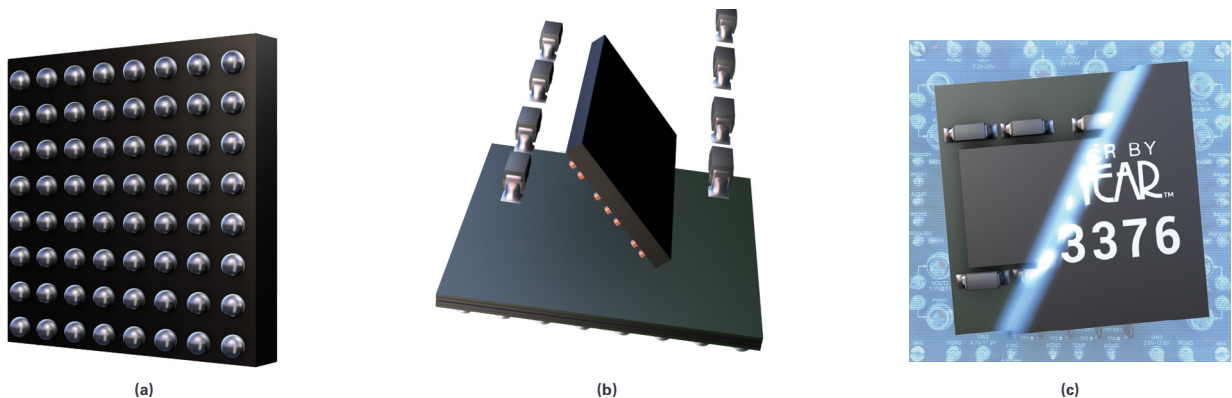


Figure 3. LTC3376 flip chip package with (a) ball grid array, (b) copper pillars under die, and (c) integrated bypass capacitors.

Excellent Thermal Design and Compact Solution

The LTC3376 enables a compact, thermally efficient solution, in part, through a unique combination of packaging techniques in its compact, 64-ball, 7 mm × 7 mm flip chip ball grid array package. The internal package construction uses copper pillars in lieu of bond wires. Internal boost

capacitors and an integrated substrate ground plane further improve EMI—which is less sensitive to PCB layout—simplifying designs and reducing performance risks (see Figure 3 for details). Furthermore, within the die, the power devices are arranged to maximize thermal performance—evenly spreading power dissipation.

Figure 4 shows a complete LTC3376 solution in a quad, 4 × 3 A buck (12 A total output current). Note how compact the total solution size is: the active area is only ~1.5 cm × 2.9 cm ~< 4.4 cm².

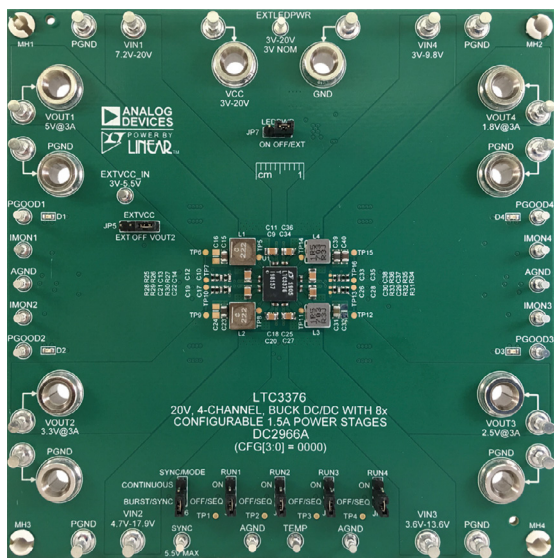


Figure 4. LTC3376 demonstration board for a 4 × 3 A buck solution with 5 V, 3.3 V, 2.5 V, and 1.8 V outputs.

Additional System Monitoring, Safety, and Protection

In addition to its configurability, the LTC3376 includes several safety features to monitor and protect the systems it powers. Power failure conditions are reported by each buck’s associated PGOOD pin. Each buck regulator features a current monitor that produces a current at the IMON pin that is proportional to the average buck load current.

To prevent thermal damage to the LTC3376 and its surrounding components, the LTC3376 incorporates an overtemperature function. When the LTC3376 die temperature reaches 165°C (typical), all enabled buck switching regulators are shut down and remain in a shutdown state until the die temperature falls to 155°C (typical).

Table 2. ADI’s Power by Linear Family of Configurable Quad and Octal Buck Regulators

	ADI/LTC	ADI/LTC	Linear	Linear	Linear	Linear
Parameters	LTC3376	LTC3374A	LTC3374	LTC3375	LTC3371	LTC3370
Topology	Quad buck	Octal buck	Octal buck	Octal buck	Quad buck	Quad buck
Number of Channels	4	8	8	8 + ext HV controller	4	4
Total Output Current	8 × 1.5 A = 12 A	8 × 1 A = 8 A	8 × 1 A = 8 A	8 × 1 A = 8 A	Up to 8 A	Up to 8 A
Output Voltage	V _{OUT} : 0.4 V to 0.83 × V _{IN}	V _{OUT} : 0.8 V to V _{IN}	V _{OUT} : 0.8 V to V _{IN}	V _{OUT} : 0.425 V to V _{IN}	V _{OUT} : 0.8 V to V _{IN}	V _{OUT} : 0.8 V to V _{IN}
Configurations	15	15	15	15	8	8
Parallelable Buck Switchers (Single Inductor)	Yes, up to 4	Yes, up to 4	Yes, up to 4	Yes, up to 4	Yes, up to 4	Yes, up to 4
Input Voltage	3 V to 20 V	2.25 V to 5.5 V	2.25 V to 5.5 V	2.25 V to 5.5 V	2.25 V to 5.5 V dc-to-dc converters 2.7 V to 5.5 V V _{CC}	2.25 V to 5.5 V dc-to-dc converters 2.7 V to 5.5 V V _{CC}
Operating Quiescent Current	28 μA (1 channel)	63 μA (1 channel)	63 μA (1 channel)	68 μA (1 channel)	68 μA (1 channel)	63 μA (1 channel)
Frequency/Sync	1 MHz to 3 MHz	1 MHz to 3 MHz	1 MHz to 3 MHz	1 MHz to 3 MHz	1 MHz to 3 MHz	1 MHz to 3 MHz
I ² C/Simple Interface	Simple	Simple	Simple	I ² C	Simple	Simple
Package (mm)	7 × 7 FC, 64-ball BGA	5 × 7, 38-lead QFN, 38-lead TSSOP-E	5 × 7, 38-lead QFN, 38-lead TSSOP-E	7 × 7, 48-lead QFN	5 × 7, 38-lead QFN, 38-lead TSSOP-E	5 × 5, 32-lead QFN

The LTC3376 also contains a temperature monitor: die temperature may be read by sampling the analog TEMP pin voltage. The temperature, T, indicated by the TEMP pin voltage is given by:

$$T = (V_{TEMP}/10 \text{ mV}) \times 1^\circ\text{C} \tag{1}$$

where V_{TEMP} is the voltage on the TEMP pin.

Configurable Buck Regulator Family

Table 2 shows the entire family of configurable quad and octal buck regulators, of which the LTC3376 is the newest member. The LTC3376 has the highest total output current (up to 12 A) and highest input voltage capability (up to 20 V).

A product video may be found at analog.com/ltc3376.

Conclusion

Technological advances have driven the increase of feature-rich content for automotive infotainment, consumer handhelds, industrial equipment, and medical devices. In many cases, these systems feature input voltages exceeding 5 V and are powered by sophisticated low voltage, high current digital ICs that have their own set of unique power requirements. Traditionally, voltage rails and current levels have been supported by a multitude of discrete power regulator ICs or relatively bulky, overly integrated power management integrated circuits or PMICs. Neither offers both flexibility and compact size.

Replacing these solutions with a single, quad, or octal multi-output power IC is a wise choice. The LTC3376 pin-configurable PMIC is an example of this new generation of multi-output power ICs. It is a 20 V input, digitally programmable, high efficiency multi-output power supply IC containing four synchronous buck converters and eight internal power stages (total I_{OUT} up to 12 A), with low output voltage capability. Since up to 15 different output current configurations are possible, a system designer can utilize its flexibility and mitigate the impact of inevitable power block system changes and feature creep. Costly and untimely board or system level requalifications can be eliminated, reducing product time to market, development costs as well as upgrade time and costs.

About the Author

Steve Knoth is a senior product marketing manager in Analog Devices' Power Group. He is responsible for all power management integrated circuit (PMIC) products, low dropout (LDO) regulators, battery chargers, charge pumps, charge pump-based LED drivers, supercapacitor chargers, low voltage monolithic switching regulators, and ideal diode devices. Prior to joining Analog Devices in 2004, Steve held various marketing and product engineering positions since 1990 at Micro Power Systems and Micrel Semiconductor. He earned his bachelor's degree in electrical engineering in 1988 and a master's degree in physics in 1995, both from San Jose State University. Steve also received an M.B.A. in technology management from the University of Phoenix in 2000. In addition to enjoying time with his kids, Steve is an avid music lover and can be found tinkering with pinball and arcade games or muscle cars, and buying, selling, and collecting vintage toys, movie, sports, and automotive memorabilia. He can be reached at steve.knoth@analog.com.

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