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IN THIS ISSUE

Dual Output DC/DC Controller Combines Digital Power System Management with Analog Control Loop for ±0.5% V_{OUT} Accuracy

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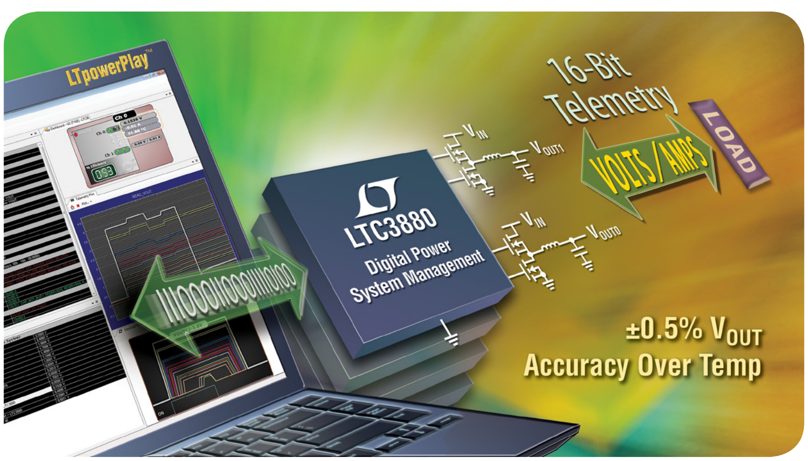
Though power management is critical to the reliable operation of modern electronic systems, voltage regulators are perhaps the last remaining "blind spot" in today's digitally managed systems. Few regulators have the means for direct configuration or monitoring of key power system operating parameters. As a result, power designers who want complete digital control must use a mixed bag of sequencers, microcontrollers and voltage supervisors to program basic regulator start-up and safety functions. Digitally programmable DC/DC converters are available, most notably those with VID output voltage control designed for VRM core power supplies, but these specifically targeted converters do not directly communicate important operating parameters, such as real-time currents.



The LTC3880 in a digitally managed power system.

The LTC®3880/-1 solves the problem of complex power system management by combining a dual output synchronous step-down DC/DC controller with a comprehensive power management feature set accessed via the I²C-based PMBus. PMBus can be used to set the output voltage, margin voltages, switching frequency, sequencing and a number of other operating parameters (see "PMBus Control" below).

(continued on page 4)

A principal benefit of digital power system management is reduced design cost and faster time to market. The LTC3880/-1 greatly simplifies the design of complex multirail systems with the free, downloadable LTpowerPlay™ software, a comprehensive PC-based development environment.

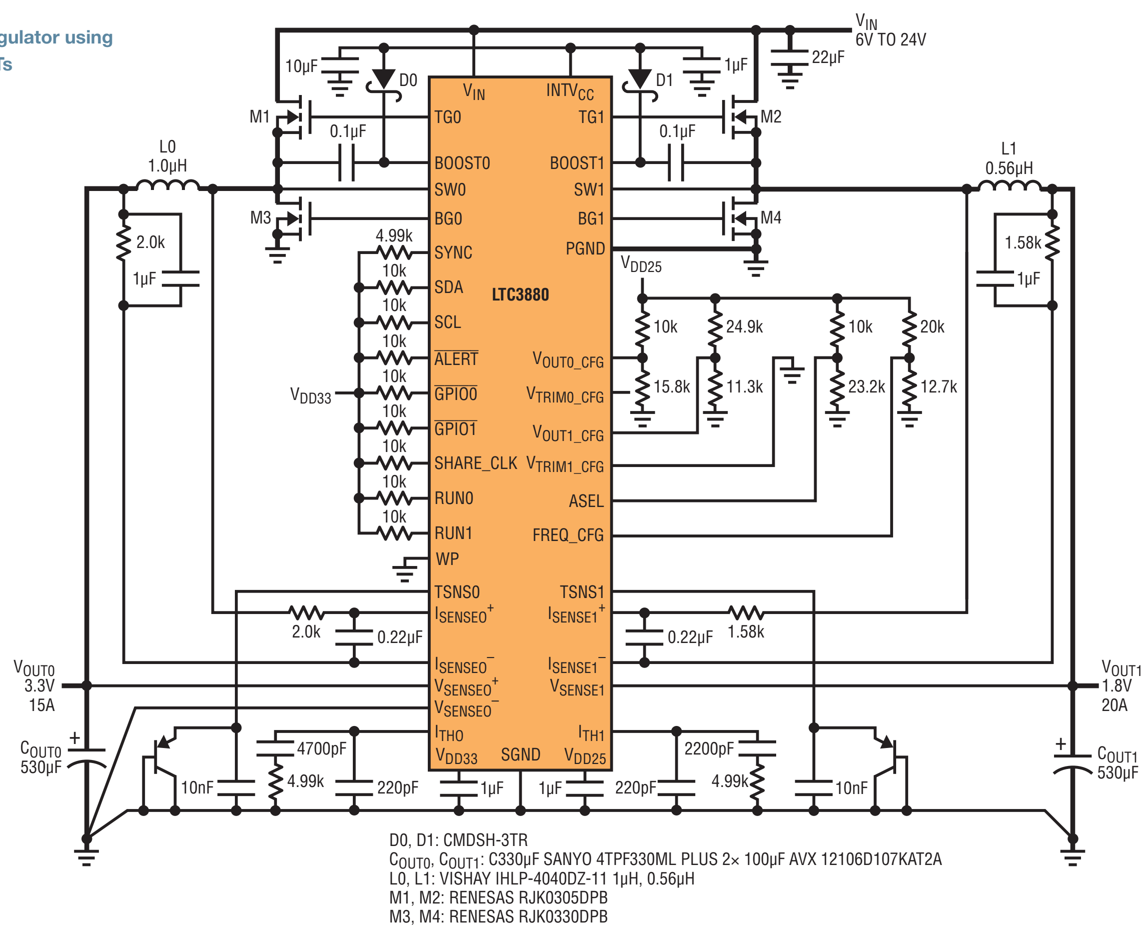
(LTC3880, continued from page 1)

The LTC3880 also allows monitoring of the supplies via a 16-bit data acquisition system, which supplies digital read back of input and output voltages and currents, duty cycle and temperature, including peak values of important parameters. The LTC3880 also includes extensive fault logging capability via an interrupt flag along with a nonvolatile memory, "black box" recorder, which stores the state of the converter's operating conditions immediately prior to a fault.

A principal benefit of digital power system management is reduced design cost and faster time to market. The LTC3880/-1 greatly simplifies the design of complex multirail systems with the free, downloadable LTpowerPlay™ development software, a comprehensive PC-based development environment (see Figure 6). In-circuit testing (ICT) and board debug require only a few clicks of the mouse—no need to solder in "white wire" fixes. The results of your design are immediately accessible, thanks to the availability of real-time telemetry data, making it possible to predict power system failures and immediately implement preventive measures.

Perhaps most significantly, DC/DC converters with digital management functionality allow designers to develop green power systems that optimize energy usage while meeting system performance targets (compute speed, data rate, etc.). Optimization can be implemented at the point of load, at the board, rack and even at installation levels, reducing

Figure 1. Dual output regulator using external power MOSFETs



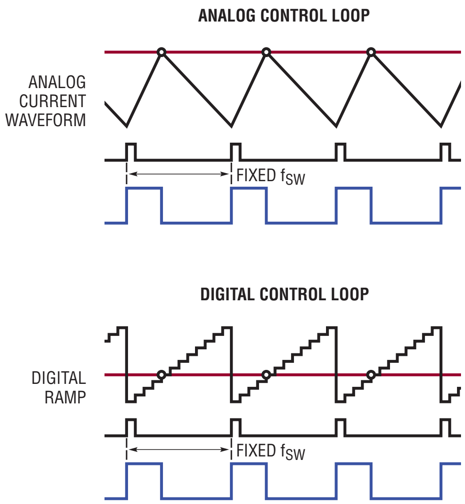


Figure 2. The LTC3880's analog control loop vs a digital control loop

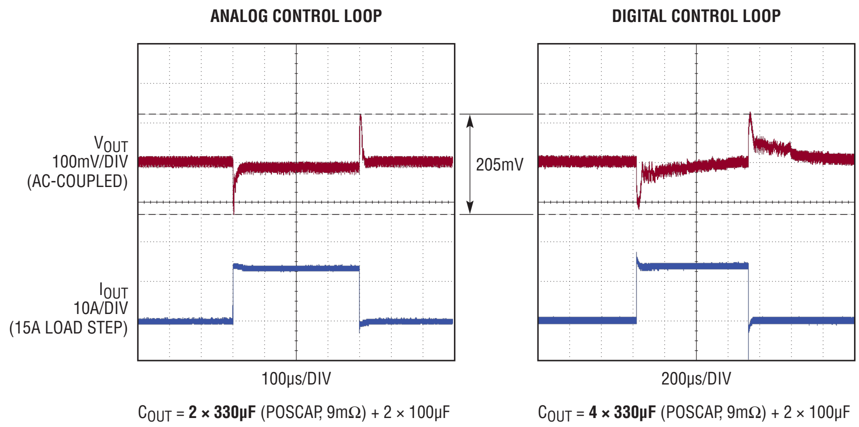


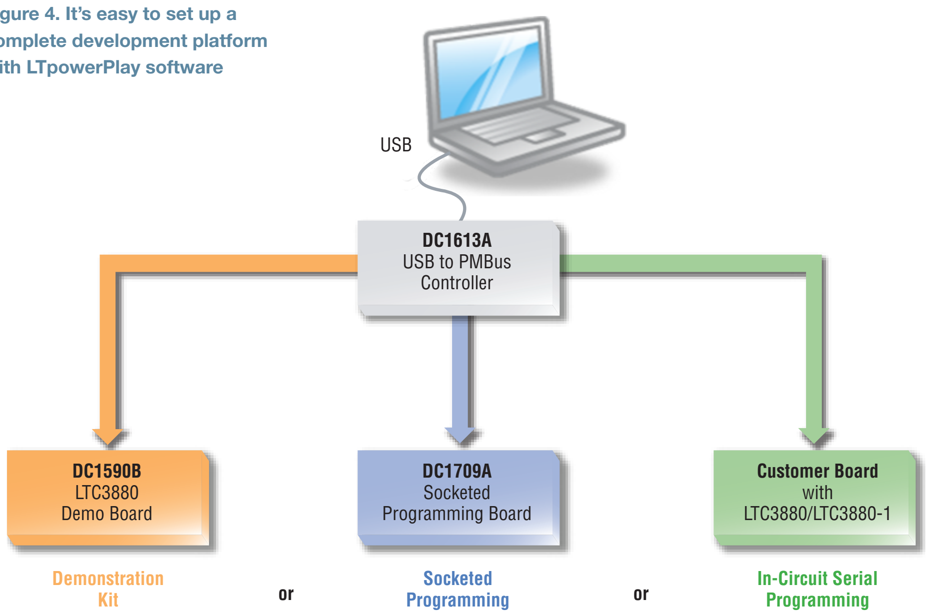
Figure 3. Comparative responses of analog and digital control loops to a 15A transient load step. The analog control loop requires only half the output capacitance of the digital loop while producing far superior settling times.

infrastructure costs and the total cost of ownership over the life of the product.

To provide best performance regulation, the LTC3880 sticks to a precision reference and temperature-compensated *analog* current mode control loop to produce a tight ±0.5% DC output voltage accuracy. The analog control loop makes for easy compensation, which is calibrated to be independent of operating conditions, yields cycle-by-cycle current limit, and produces a fast and accurate response to line and load transients—without any of the ADC quantization-related errors found in products utilizing digital control.

The LTC3880 features an on-chip regulator for increased integration, whereas the LTC3880-1 allows for an external bias voltage for highest efficiency. Both parts are available in a thermally enhanced 6mm × 6mm QFN-40 package with either a –40°C to 105°C operating junction temperature range (E-grade) or a –40°C to 125°C operating junction temperature range (I-grade).

Figure 4. It's easy to set up a complete development platform with LTpowerPlay software



ANALOG CONTROL LOOP ENSURES BEST-IN-CLASS REGULATOR PERFORMANCE

The LTC3880/-1 is digitally programmable for numerous functions including the output voltage, current limit set point, and sequencing. The control loop, though, remains purely analog, which offers the best loop stability and transient response without the quantization effect of a digital control loop. Figure 2 compares the ramp curves of a controller IC with an analog feedback control loop to one with a digital feedback control loop. The analog loop has a smooth ramp, whereas the digital loop has discrete steps that can result in stability problems, slower transient response, more required output capacitance in some applications and higher output ripple and jitter on the PWM control signals due to quantization effects.

In fact, when put up against a comparable IC with a digital control loop, the LTC3880's analog control loop using 50% less output capacitance has better stability with a shorter settling time. Additionally, the digital control transient response has an oscillation prior to settling, due to the quantization effects caused by its finite ADC resolution. Figure 3 shows the transient response of the LTC3880's analog control loop compared to that of

Configurations are downloaded to internal EEPROM via the I²C serial interface supported by Linear Technology's LTpowerPlay PC-based development software. After the configuration file is stored on-chip in nonvolatile memory, the controller powers up autonomously without burdening the host.

a competitor's digital control loop. Note that the LTC3880 yields cleaner results with approximately half the output capacitance of the digital controller.

The LTC3880 is designed so the loop gain does not change when its configuration file is modified. When the output voltage or the current limit is modified, the transient response is unaffected and the compensation loop needs no adjustment.

PMBus CONTROL

The LTC3880/-1 features digital programming and read back for real-time control and monitoring of critical point-of-load converter functions. Configurations are downloaded to internal EEPROM via the I²C serial interface supported by Linear Technology's LTpowerPlay PC-based development software. Figure 4 shows the LTpowerPlay development platform with a USB to I²C/SMBus/PMBus adapter. After the configuration file is stored on-chip in nonvolatile memory, the controller powers up autonomously without burdening the host. Configuring a board is a simple task that requires zero firmware development.

PMBus functions include the ability to program specific power supply management parameters including:

- output voltage and margin voltages
- temperature-compensated current limit threshold based on inductor temperature
- switching frequency
- overvoltage and undervoltage high speed supervisor thresholds
- output voltage on/off time delays
- output voltage rise/fall times
- input voltage on/off thresholds
- output rail on/off
- output rail margin-hi/margin-lo
- responses to internal/external faults
- fault propagation

In addition, PMBus functions allow monitoring of power supply operation including:

- output/input voltage
- output/input current
- internal die temperature
- external inductor temperature
- part status
- fault status
- system status
- peak output current
- peak output voltage
- peak internal/external temperature
- fault log status

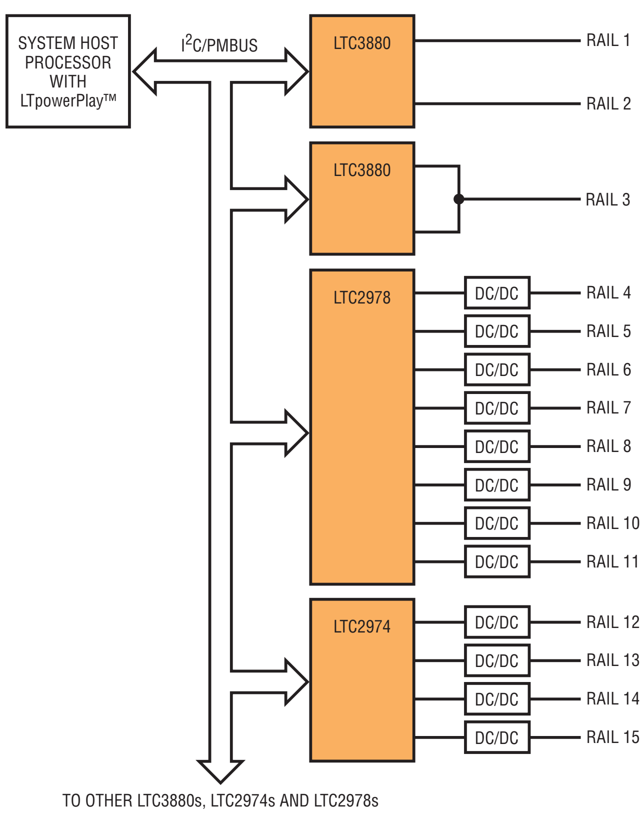


Figure 5. LTpowerPlay and PMBus used to control 15 or more rails.

Linear Technology PMBus controllers such as the LTC3880 and companion ICs such as the LTC2978 make it easy to program power-up and power-down sequencing for any number of supplies. By using a time-based algorithm, users can dynamically sequence rails on and off in any order with simple programmable delays.

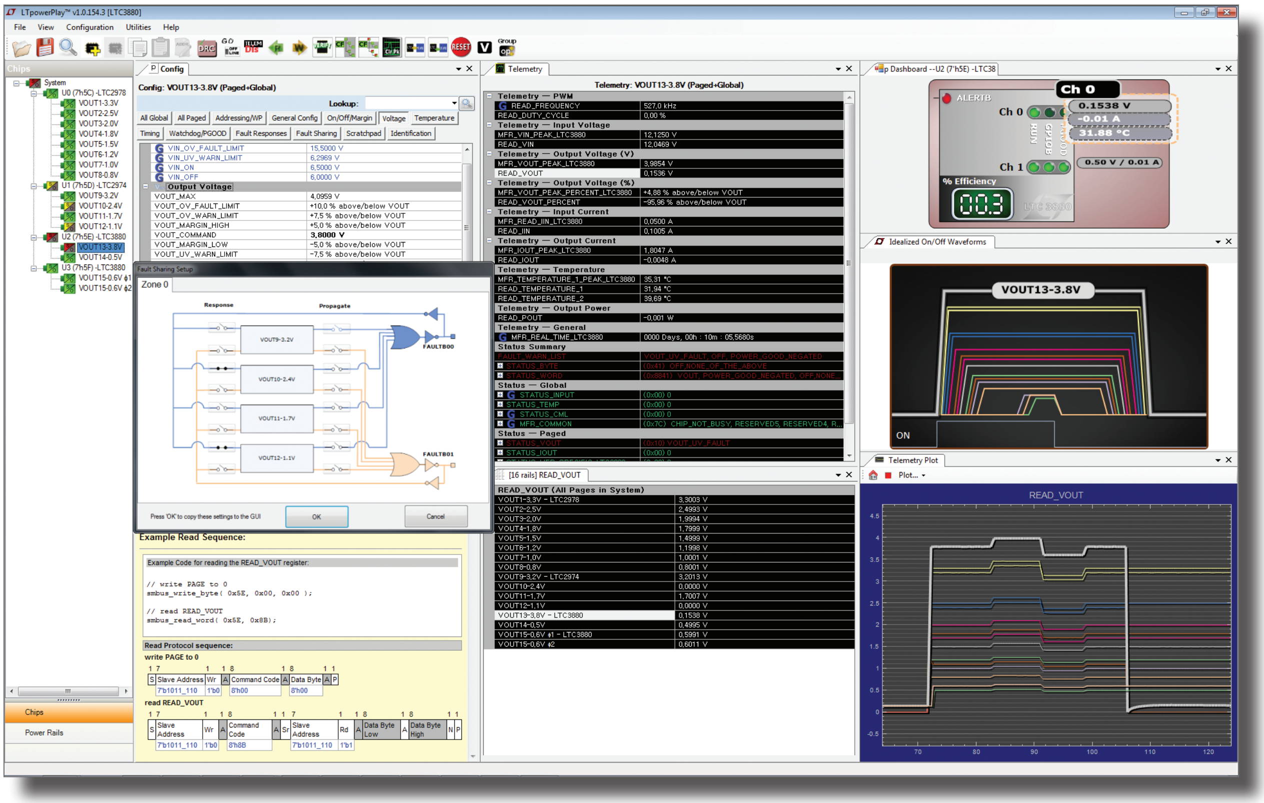


Figure 6. Complex, multirail power systems simplified. LTpowerPlay puts complete power supply control at your fingertips.

PUTTING TOGETHER A MULTIRAIL SYSTEM

A large multirail power board is normally composed of an isolated intermediate bus converter, which converts 48V, 24V or other relatively high voltage from the backplane to a lower intermediate bus voltage (IBV), typically 12V, which is distributed around a PC card.

Individual point-of-load (POL) DC-DC converters step down the IBV to the required rail voltages, which normally range from 0.5V to 5V with output currents ranging from 0.5A to 120A. Figure 5 shows how a multi-rail system can be controlled with various Linear Technology controllers and DC/DC converters PMBus devices. The point of load DC/DC converters can be self-contained modules, monolithic devices or solutions comprising DC/DC controller ICs, associated inductors, capacitors and MOSFETs. These rails normally have strict requirements for sequencing, voltage accuracy, overcurrent and overvoltage limits, margining and supervision.

The sophistication of power management is increasing. It is not uncommon for circuit boards to have over 30 rails. These boards are already densely populated so adding digital power system management circuitry must require minimal board space and external pins. The system must be easily modified by the user or a system host processor. The LTC3880 works seamlessly with other Linear Technology PMBus supervisors, companion ICs and Linear Technology regulators for optimal control of complex boards. These systems operate autonomously after initial configuration or communicate with the host for command, control and to report telemetry.

Linear Technology PMBus controllers such as the LTC3880 and companion ICs such as the LTC2978 make it easy to program power-up and power-down sequencing for any number of supplies. By using a time-based algorithm, users can dynamically sequence rails on and off in any order with simple programmable delays. Sequencing across multiple chips is made possible using the 1-wire SHARE_CLK bus

PMBus chips can be added later without having to worry about system constraints such as a limited number of connector pins. Multiple addresses are supported in PMBus allowing over 100 unique devices on the same I²C bus.

and one or more of the bidirectional general purpose IO ($\overline{\text{GPIO}}$) pins. This greatly simplifies system design because rails can be sequenced in any order. Additional PMBus chips can be added later without having to worry about system constraints such as a limited number of connector pins. Multiple addresses are supported in PMBus allowing over 100 unique devices on the same I²C bus.

Rail sequencing to the on state can be triggered in response to a variety of conditions. For example, the LTC3880 and LTC2978 can auto-sequence when the intermediate bus voltage exceeds a programmed threshold ($V_{IN(ON)}$). Alternatively, rail on sequencing can be initiated in response to the rising edge of the RUN/CONTROL pin. Rail on sequencing can also be initiated by a PMBus command.

The $\overline{\text{GPIO}}$ pins on the LTC3880 can be shared with fault pins from LTC PMBus companion ICs to control fault response dependencies between rails. For example the system can be configured such that a fault on one rail can initiate the shutdown of any number of rails. If the fault response is configured for "immediate off no retry" and a fault occurs, the host must take action for the rails to be restarted. Alternatively, if the fault response is set to "immediate off infinite retry" and a fault occurs, the rail attempts to power up autonomously with a user programmable delays in a hiccup mode. The fault response can also be set to "ignore," where the $\overline{\text{ALERT}}$ pin is pulled low in response to a fault, to alert the host of an issue, but the power supply continues to deliver power to the load. The $\overline{\text{GPIO}}$ pins can also be configured as power good status pins or as the fast UV comparator output for event-based sequencing.

LTpowerPlay DEVELOPMENT SYSTEM

Control of the LTC3880 is fully supported by the LTpowerPlay PC-based software development system, which allows a designer to modify the configuration settings for all Linear Technology PMBus products in real time—no need to manually rewire the board. Figure 6 shows LTpowerPlay in action, controlling a number of functions for multiple devices, such as the output voltage, protection limits and on/off ramps. Some waveforms are displayed including the sequencing of multiple rails and telemetry plots. A fault condition is indicated with the offending rail in red and any affected rails in yellow.

LTpowerPlay is available as a free download at www.linear.com/ltpowerplay. LTpowerPlay works in conjunction with other Linear Technology controller and companion ICs in order to quickly and easily configure multiple rail power systems.

CONCLUSION

The LTC3880/-1 combines best-in-class analog switching regulators with precision data conversion and a flexible digital interface for unsurpassed performance. Multiple LTC3880s can be used with other LTC products to create optimized multi-rail digital power systems. All Linear Technology PMBus products are supported by the easy-to-use LTpowerPlay software development system.

Digital control over analog power supplies enables designers to get their systems up and running quickly providing an easy way to monitor, control and adjust supply voltages, limits and sequencing. Production margin testing is easily performed using a couple of standard PMBus commands. Debug is also simplified because the rail status is communicated over the bus.

Power system data can be sent back to the OEM providing information about the power supplies health and energy consumption. If a board is returned, the fault log can be read to determine which fault occurred, the board temperature and the time of the fault as well as historical data leading up to the fault. This data can be used to quickly determine root cause, whether the system was operated outside of its specified operating limits, or to improve the design of future products. Power consumption data can be used to reduce overall power use in real time.

Digital power is a rapidly growing field driven by customer demand for ever more complex boards. The LTC3880 and other Linear Technology PMBus products work together to give flexible digital control to high performance supplies. Board designers now have the tools to streamline the process of bringing best-in-class performance quickly to market. ■