High Step-Down Ratio Controller Combines Digital Power System Management with Sub-Milliohm DCR Sensing and Accurate PolyPhase Load Sharing

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The increasing complexity of electronics, particularly large computing systems, has exerted pressure on power supplies to improve efficiency, transient response, monitoring and reporting functionality, and digital control. High efficiency is paramount in distributed systems, where high step-down ratios from intermediate voltage busses are used to create local low voltage supplies sourcing high currents. Sensitive low voltage subsystems require accurate output voltage regulation single-cycle load step response. Such needs are frequently met with PolyPhase® designs located in close proximity to their point of load.

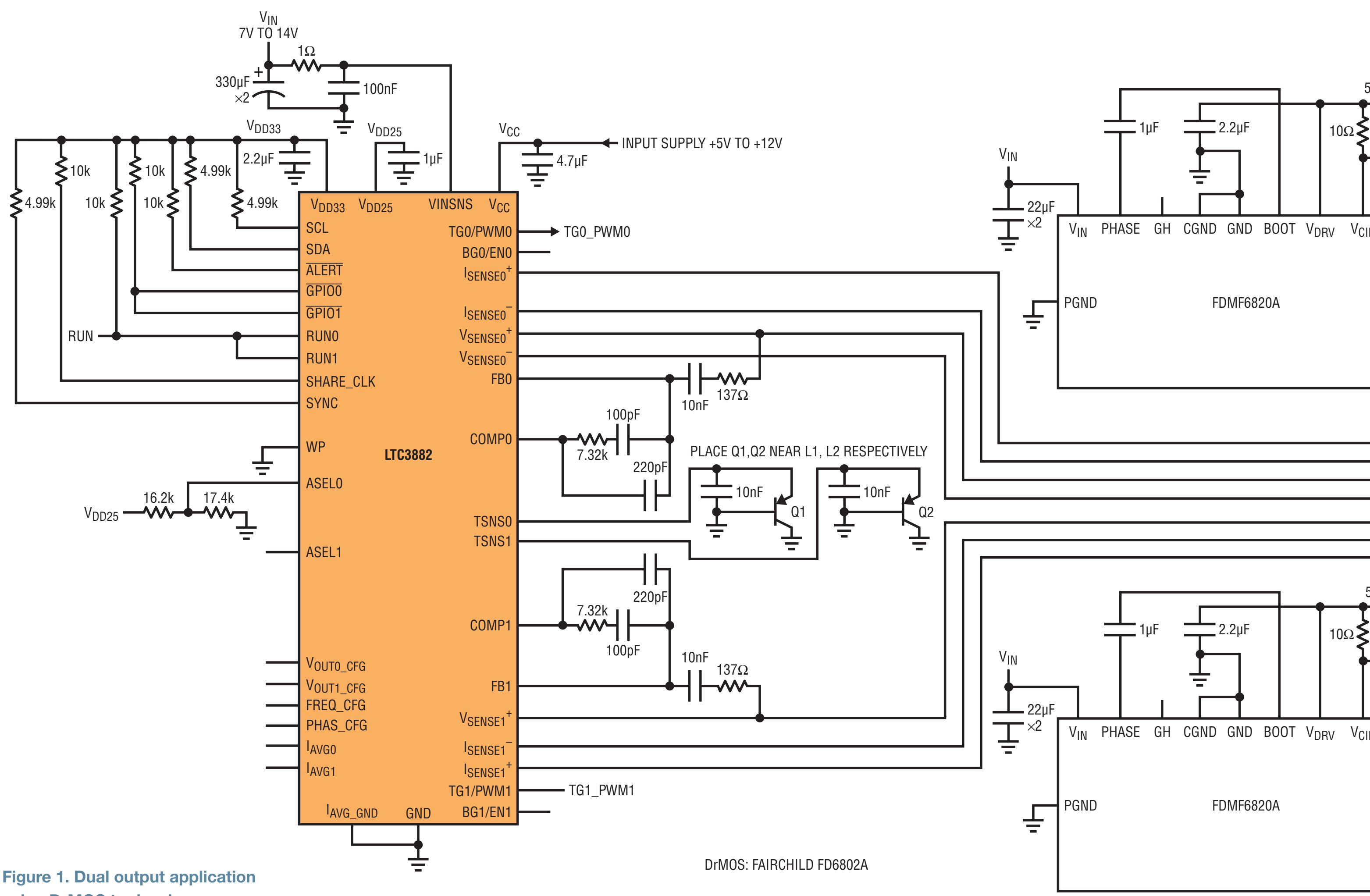

Figure 1. Dual output application using DrMOS to develop over 90W of output power

The LTC3882 satisfies the broad demands placed on the modern power supply. It is a dual channel DC/DC synchronous step-down PWM controller with PMBus-compliant serial interface. Each channel can produce independent output voltages from 0.5V to 5.25V. Up to four LTC3882s can operate interleaved in parallel, creating single-output rails containing up to eight phases.

Higher system complexity translates into demand for nontraditional features from the power subsystem. Host systems can have dozens of local voltage rails delivering a wide range of power levels. The power subsystem must be capable of accurately reporting key operating parameters and providing rapid, autonomous fault response.

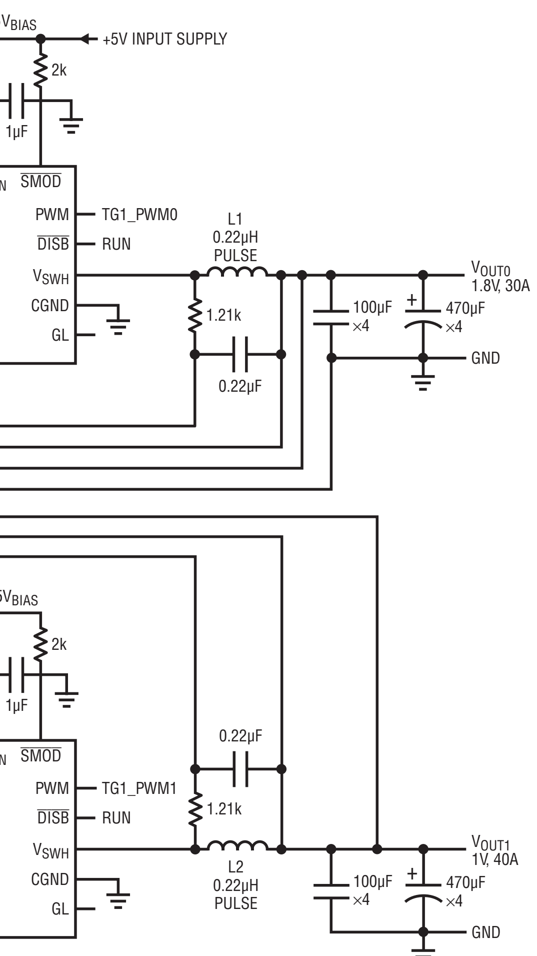

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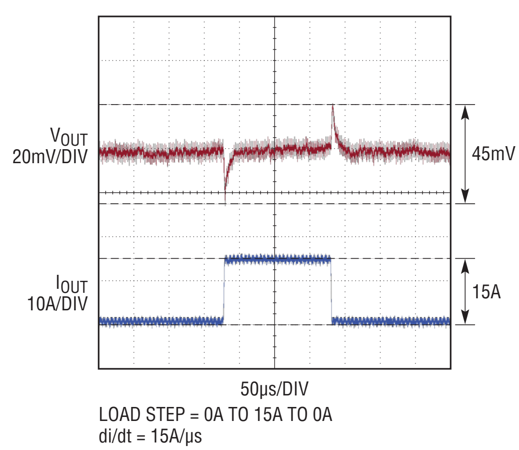
Figure 2. Load step response of Figure 1 circuit



ARCHITECTURE FOR HIGH PERFORMANCE LOAD STEP RESPONSE AND REGULATION

To support high step-down ratios and fast load transient response, the LTC3882 uses a constant frequency, leading-edge modulation voltage mode architecture. This architecture is combined with a very low offset, high bandwidth voltage error amplifier and proprietary internal feedforward compensation. The low output impedance of a true voltage amplifier allows implementation of flexible Type III loop compensation. Internal feedforward compensation instantaneously adjusts duty cycle for changes in input voltage, significantly reducing output overshoot or undershoot. It also creates constant modulator gain independent of input voltage, Each LTC3882 PWM channel provides five selectable PWM control protocols for interfacing to power stage designs that have 3.3V-compatible control inputs. The user can choose the optimum type of power stage for the design requirements: discrete FET drivers, DrMOS devices or power blocks. These can be mixed and matched on a per channel basis.

Figure 3. Transient response with AVP enabled

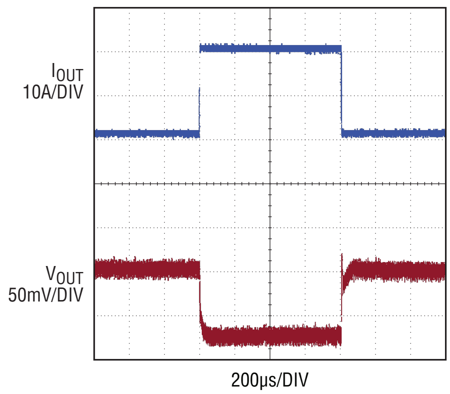
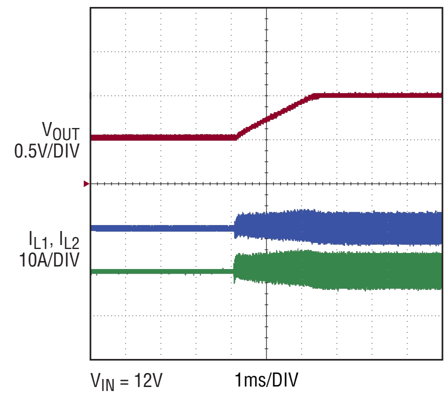


Figure 4. Continuous conduction mode start-up with output prebiased



affording more aggressive loop compensation with improved transient response.

Both channels feature remote output voltage sense. Channel 0 has a corresponding negative sense input for ground offsets. The remote negative sense for channel 1 is the package ground paddle. A separate control loop yields exceptional DC and dynamic PolyPhase load sharing. This high performance architecture can deliver excellent load transient response. Figure 2 shows a typical output transient for an LTC3882 power supply.

Leading-edge modulation affords fast, single-cycle response to output load steps and does not restrict minimum duty cycle. PWM output control pulses can become vanishingly small with this scheme, and minimum on-time is normally limited by the power stage design, not the controller. This, plus feedforward compensation, facilitates robust operation at high step-down ratios. The LTC3882 operates with input power bus voltages from 3V to 38V. Stable operation with no pulse-skipping at step-down ratios approaching 25:1 is possible, even at higher switching frequencies.

For compact solutions, stable operation is possible using only ceramic output capacitors, and the LTC3882 features programmable active voltage positioning (AVP), allowing further optimization of ESR and reduction in output capacitor size. Figure 3 shows a typical example of AVP operation.

Depending on the needs of the application, peak efficiency or solution size can be prioritized by choosing an optimal operating frequency. The LTC3882's 250kHz to 1.25MHz programmable switching frequency supports optimization of inductor size and output current ripple. The LTC3882 can also serve as a shared PWM clock master or accept an external clock input for synchronization to another system time base. For very small magnetic-component footprints, a higher frequency version is available. Contact Linear Technology for details.

As shown in Figure 4, the LTC3882 has the ability to start into a prebiased output without perturbing it, regardless of its soft-start parameter programming or inductor current operating mode (continuous or discontinuous).

LOW DCR SENSING FOR HIGH POWER

At relatively high output currents, conversion efficiency must be maximized to limit heat production and minimize related cooling costs due to conduction losses. Some conduction losses occur in the current sensing element used for detecting output overload and other functions. In a step-down topology, the sense element is key to efficiency because it continuously sees the full DC load current plus additional current ripple.

The LTC3882 monitors critical supply parameters with an internal 16-bit ADC. Digital readback via PMBus is available for input and output voltages, output currents, duty cycles and temperatures. The LTC3882 tracks, maintains and provides peak values for these parameters.

Figure 5. 2-channel efficiency and loss using FDMF5820A DrMOS power stage

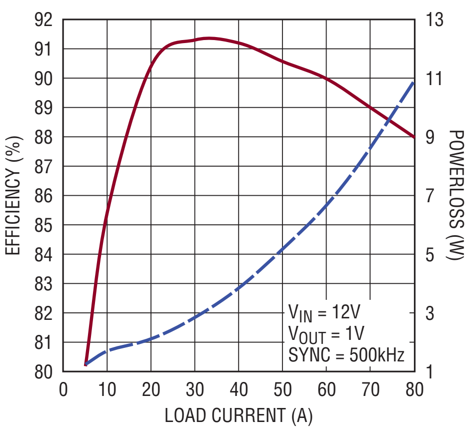
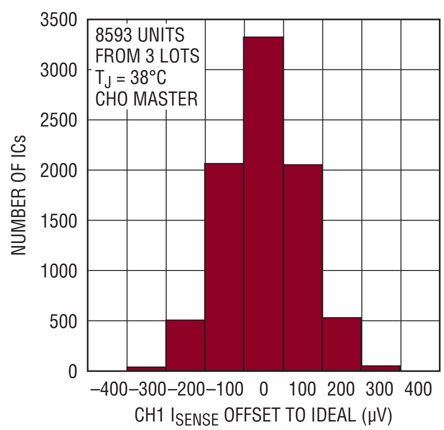


Figure 6. Typical slave I_{SENSE} offset to ideal (master)



The LTC3882 supports conventional sense resistor topologies as well as low DCR sense schemes that can produce a full-scale voltage of only a few tens of millivolts. Trimmed internal auto-zeroed gain amplifiers maintain fast and accurate supervisor detection of output overcurrent conditions. The classical fixed ramp voltage mode PWM architecture allows large signal control of the duty cycle and eliminates noise concerns that could be created by low DCR designs using current-based control schemes. Typical efficiency and loss for a LTC3882 power supply built with Fairchild FDMF5820A DRMOS devices is shown in Figure 5.

DIGITAL ENHANCEMENTS IMPROVE OUTPUT ACCURACY

The LTC3882 contains an optional digital output servo function. When enabled, the 16-bit ADC output for channel voltage is used to servo to the desired average output value. In this case, the converter has an impressive typical output error of only ±0.2% and a worse case error over temperature of ±0.5%. These tolerances are guaranteed over an output voltage range of 600mV to 5V.

ACCURATE LOAD CURRENT SHARING

For PolyPhase operation, the LTC3882 features a separate current sharing loop that provides accurate load balancing, an improvement over conventional voltage mode converters. Channels are designated as control masters or as slaves by pin strapping. The IAVG pin on the master channel provides a voltage analog of its instantaneous output current. A filter capacitor of 100pf to 200pf is added to this line, which is then routed to all slave phases. The slaves use this information and the primary COMP control voltage from the master to match their own output current to that of the master. Figure 6 shows the typical cumulative current sense offset of a slave phase. For low DCR sensing, this translates into typical DC current matching of better than 2% at full output power. Figure 7 shows that this matching is maintained dynamically through high speed load steps.

WIDE SELECTION OF POWER STAGES

Each LTC3882 PWM channel provides five selectable PWM control protocols for interfacing to power stage designs that have 3.3V-compatible control inputs. The user can choose the optimum type of power stage for the design requirements: discrete FET drivers, DRMOS devices or power blocks. These can be mixed and matched on a per channel basis, allowing optimization of power subsystem partitioning, size and cost, according to the power delivery needs of each rail.

There are many reasons to consider use of a power systems management (PSM) controller. PMBus commands can be issued to the LTC3882 to set output voltage, margin voltages, switching frequency, output on/off sequencing and other operating parameters. The LTC3882 supports over 100 PMBus commands, both standard and custom.

ACCURATE OPERATING PARAMETER TELEMETRY

The LTC3882 monitors critical supply parameters with an internal 16-bit ADC. Digital readback via PMBus is available for input and output voltages, output currents, duty cycles and temperatures. The LTC3882 tracks, maintains and provides peak values for these parameters.

Beyond basic supply parameter telemetry, the LTC3882 can report a wide range of internal and external status information to the system host over the PMBus.

FAST, PROGRAMMABLE FAULT RESPONSE

Faults can be detected and communicated using a shared fault bus between LTC3882s as well as other Linear Tehnology PSM family members, such as the LTC3880. The LTC3882 provides a standard open-drain $\overline{ALERT}$ output with compliant ARA response for notification of a wide range of fault conditions to the bus host. The LTC3882 implements high speed, low level hardware responses to critical faults to protect the power stage and downstream system load. PMBus commands can then be used to configure higher-level responses, mask faults to the system, and determine which faults are propagated to the shared fault bus. This provides flexibility in dynamically managing fault handling at the system level, even after hardware has been designed and fabricated.

The LTC3882 includes extensive logging capability that records the state of converter operating conditions immediately prior to a fault. This log can be enabled and stored to internal EEPROM to provide a black box recorder function for in-system diagnosis or subsequent remote debugging of abnormal events.

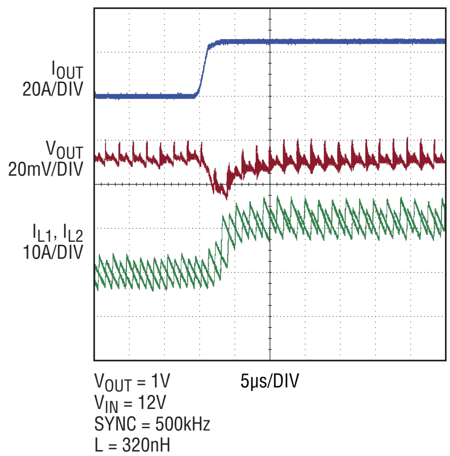


Figure 7. Dynamic load balancing during an output transient

USING DIGITAL PROGRAMMABILITY TO ADVANTAGE

There are many reasons to consider use of a power systems management (PSM) controller. PMBus commands can be issued to the LTC3882 to set output voltage, margin voltages, switching frequency, output on/off sequencing and other operating parameters. In total, the LTC3882 supports over 100 PMBus commands, both standard and custom. A principal benefit of this programmability is reduced design cost and faster time to market.

Once a fundamental hardware macro design is complete, many variations can quickly be created, brought to operation, and verified as needed by simply adjusting digitally programmable parameters inside the LTC3882 controller. Adjustments can continue beyond production release as needed, including fully synchronized resequencing/retiming of power rails. Combined with optional external resistor programming of key supply parameters, this kind of flexibility can avoid risky, costly PCB spins or hand-wired modifications due to last-minute changes in requirements or evolving system use.

Final configurations can be stored to internal EEPROM using a variety of means, including custom factory programming. Once a configuration is stored, the controller powers up autonomously to that state without burdening the host for additional programming. However, even after a final EEPROM configuration is loaded, optional external programming resistors can be used to modify a few key operating parameters: output voltage, frequency, phase and bus address.

Once designed, the multiple addressing schemes supported by the LTC3882 allow the system to communicate with devices globally or selectively at the rail, device or individual channel level, depending on control and monitoring requirements. PMBus then facilitates sophisticated high level system operations, such as energy-efficient application load balancing, local phase shedding, fault containment/redundancy or interactive preventive maintenance. These functions would simply not be cost-effective or even possible with conventional power supply components in large systems.

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DESIGN DEVELOPMENT SUPPORT

Linear Technology offers an array of free software tools to assist with design, development and debug of LTC3882-based power supplies. LTpowerCAD™ provides recommendations for component values and performance estimates specific to the target application. This PC-based tool guides the user through the entire PWM design process, reducing development effort and reducing cycle time. It shows real-time results of feedback loop stability, and the design can be exported to LTspice® for additional design verification. PCB layout examples can also be provided.

LTpowerPlay™ is a PC-based tool with a GUI that supports a wide range and combination of Linear Technology PSM products. The LTC3882 PMBus command and feature set is consistent with other devices in the Linear PSM family. It operates seamlessly with these devices for flexibility and system-level optimization of power management design. LTpowerPlay provides a comprehensive, cohesive PMBus development environment with full configuration, internal EEPROM programming, fault logging and real-time telemetry data/graphing. This can be especially helpful to power supply designers needing to quickly bring up a large, complex power subsystem. The tool can communicate with custom designs and standard demo circuits, such as the DC1936A. Both of these tools and other design reference materials are available at www.linear.com.

Proven firmware examples for use with the LTC3882 are available to qualified customers. Contact Linear Technology for details.

CONCLUSION

The LTC3882 is a high performance PSM voltage mode buck controller capable of very accurate output voltage regulation, supporting up to eight phases with well balanced current sharing. It can be used with discrete FET drivers, DrMOS devices or power blocks. An onboard 16-bit ADC provides accurate telemetry of all critical operating parameters. It features sophisticated fault management, reporting, sharing and storage. With its internal EEPROM for settings and optional external resistor configuration, the LTC3882 can operate independently or under PMBus bus control in complex, managed power subsystems. Applications include high current distributed power systems, servers, network storage, intelligent high efficiency power regulation and industrial systems such as ATE and telecom. ■