

FPGA Power System Management

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Introduction

Field-programmable gate arrays (FPGAs) trace their origins back to the 1980s, evolving from programmable logic devices (PLDs). Since then, FPGA resources, speed, and efficiency have improved rapidly, making FPGAs the go-to solution for a wide variety of computing and processing applications, especially when production volume doesn't justify application-specific integrated circuit (ASIC) development costs. FPGAs have advanced to such an extent that they've also found homes in large-scale deployments. For instance, after successfully speeding up the Bing search engine with FPGAs in a 2013 pilot program, Microsoft® expanded FPGA-equipped server usage to its cloud data centers.

FPGA Power System Requirements

FPGAs require a few different low voltage supply rails, each with its own voltage and current specification, to power their internal core logic, I/O circuits, auxiliary logic, transceivers, and memory. These rails may need to turn on and turn off in a specific sequence to avoid damaging the FPGA. Point-of-load (POL) regulators step down the board's higher input supply voltage to the multiple lower rail voltages required by the FPGA. Switching regulators are used as POL regulators when power conversion efficiency is paramount, whereas linear regulators—for example, low dropout (LDO) regulators—are employed for noise-sensitive circuits such as PLLs and transceivers.

Typical board input voltages are 5 V, 12 V, 24 V, and 48 V, while FPGA rail voltages range from below 1 V to around 3 V. For high input voltages (12 V, 24 V, 48 V), an extra step-down may be needed to generate an intermediate voltage bus that feeds the POL regulators (see Figure 1). Among the FPGA rails, the core supply requires the lowest voltage (around or below 1 V) and highest accuracy ($\pm 3\%$ or better), with current levels in the tens of amperes depending on FPGA resource utilization. To prevent logic errors, the supply variation needs to be limited to tens of millivolts, as dictated by the FPGA rail tolerance specification, not just under dc conditions but also during FPGA current transients. The worse the power supply's dc accuracy, the more bypass capacitance is needed to maintain an acceptable supply voltage under transient conditions. For example, assume a $\pm 3\%$ core voltage tolerance specification. Using a $\pm 1\%$ accurate dc supply leaves a good $\pm 2\%$ allowance for transients. On the other hand, a less accurate $\pm 2\%$ dc supply leaves less room ($\pm 1\%$) for transients, requiring more bypass capacitance than the previous case.

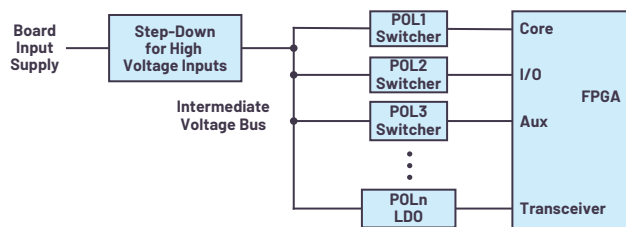


Figure 1. One possible FPGA power tree: a high voltage input supply (for example, 12 V, 24 V, or 48 V) is stepped down to an intermediate voltage bus feeding the POL regulators that power the FPGA.

Tweaking or trimming of the FPGA supply voltage level around the default setpoint is required for last-minute design changes, design reuse in another application, board margin testing, and dynamically optimizing system power consumption during development or field operation. Soldering in different resistors in the supply's feedback network isn't the quickest or most feasible solution for such situations. One method to achieve voltage trimming is with a digital-to-analog converter (DAC) driving the feedback network of a voltage regulator (see Figure 2). Software code needs to be written for the trim routine to obtain supply voltage measurement data from an analog-to-digital converter (ADC), to compute the correct DAC code, and then slowly adjust the DAC output to the computed code for smoothly ramping the supply voltage, without glitches or overshoots, to the target level. This trim routine needs to be repeated over time to ensure that the supply doesn't walk away from the target voltage due to components drifting with time or temperature.

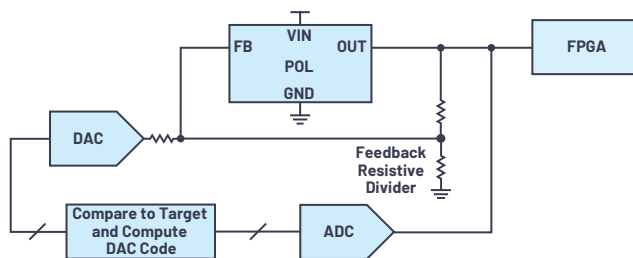


Figure 2. POL supply output voltage trimming to target voltage with DAC and ADC.

Monitoring FPGA supply voltages, currents, and faults is essential to understanding system health and power consumption under different scenarios because the FPGA is the brain of the electronic system. Such an understanding, coupled with trimming capability, avoids designing supplies for the worst case, saving cost and power. Moreover, an upcoming system malfunction could show up as an abnormal trend in FPGA power consumption, alerting the host controller or service staff before the board or system goes down. Voltage monitoring requires ADCs, whereas current monitoring also requires level-shift circuits to translate the high-side current sense voltage to a ground-referenced voltage; for example, with a transconductance amplifier, as shown in Figure 3.

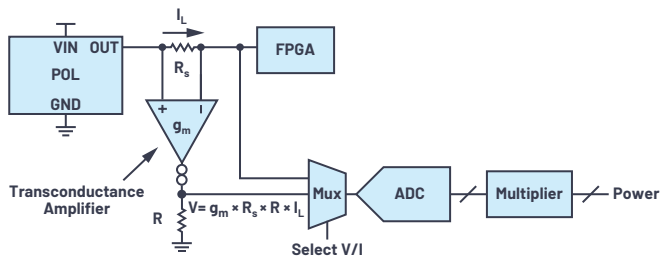


Figure 3. One possible discrete circuit for monitoring POL supply output voltage, current, and power.

One's head may be spinning after reading this long laundry list of requirements although we have not discussed fault management. What should happen when a POL output goes undervoltage or overvoltage—that is, outside the valid voltage window? Should only the faulting supply be turned off, or should other supplies be turned off too? How does one debug a fault that has shut down the board?

As one can see, managing an FPGA's power system can become complicated very quickly, distracting from the essential FPGA application. Remember that the FPGA's power tree is just a portion of the overall power system on a digital processing board. Most of the above requirements also apply to other digital devices such as ASICs, DSPs, GPUs, SoCs, and microprocessors. What is needed is a power system management solution that is simple, scalable, and flexible.

Digital Power System Management

Analog Devices provides a portfolio of digital power system management (DPSM) devices to deal with the complex power systems found on digital processing boards. DPSM devices are available with and without integrated dc-to-dc conversion to either replace POL regulators or work with existing POL regulators. Power system managers—that is, without dc-to-dc conversion—add digital monitoring and control to any existing analog power system, whether made up of switchers or LDO regulators. A single device such as the LTC2980 trims, margins, monitors, sequences, supervises, fault logs, and fault manages 16 POL regulators. Differing channel-count devices (2, 4, 8, or 16 channels) can be mixed and matched to manage hundreds of rails. The 2-channel LTC2972 is the latest addition to this portfolio, providing a simple introductory solution for monitoring and controlling the two most critical rails in such a power system; for example, the FPGA core and auxiliary rails.

2-Channel Power System Manager

The LTC2972 is a 2-channel power system manager, adding comprehensive software-based monitoring, control, and black box fault recording to the power systems of FPGA, ASIC, and processor boards, accelerating time to market, enhancing system reliability, and optimizing board energy consumption (Figure 4). POL supply output voltages are trimmed, margined, and monitored using a best-in-class 16-bit ADC with 0.25% total unadjusted error (TUE), improving board yields and long-term performance. The ability to tighten POL output voltage to $\pm 0.25\%$ accuracy leaves plenty of room for it to move during load transients ($\pm 2.75\%$ for a $\pm 3\%$ FPGA rail specification), significantly reducing needed bypass capacitance and freeing up board space. Supply output currents are measured using a sense resistor, inductor DCR, or the IMON output of a power supply. The voltage and current measurements are multiplied internally to provide a convenient POL power output reading.

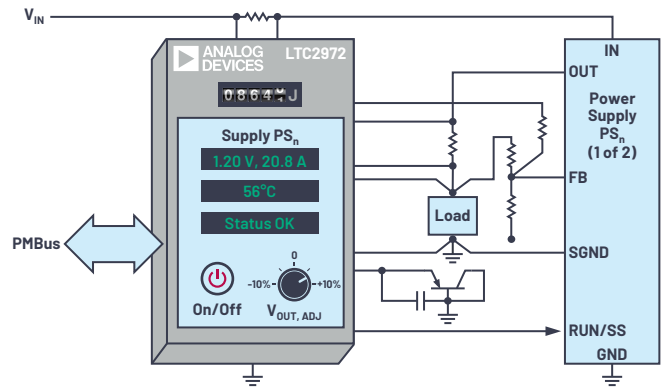


Figure 4. LTC2972, a 2-channel power system manager with intermediate bus energy monitoring and POL output power monitoring.

Supply sequencing, supervision, and EEPROM fault-logging are built into the LTC2972. Sequencing is accomplished with time delays written to an internal register or with cascaded power-good signals. Dedicated fast comparators signal faults when POL input voltage, output voltage, and temperature stray outside digitally settable low and high thresholds. Faults trigger EEPROM black box recording, simplifying failure analysis while providing insight into future system improvements. A first fault command provides additional insight into causes of system failure. Faults can be flexibly propagated to other supplies or other DPSM devices.

The LTC2972 features voltage, current, power, and energy monitoring of the intermediate bus input to POL converters. Monitoring circuit board power and energy use is a prerequisite for managing, optimizing, and reducing their consumption in order to lower server and data center cooling and utility costs. The LTC2972 relieves the host of burdensome polling and computation by conveniently providing the input energy, reported in joules, and the elapsed time through a PMBus interface, the industry standard for communicating with power management and conversion devices. When combined with its digital measurements of POL output voltages, currents, and power, the LTC2972 enables long-term monitoring of a power system's conversion efficiency.

Programmable power-good, or general-purpose input/output (GPIO), pins are available with each channel. The LTC2972 connects with other power system managers to coordinate sequencing and fault management of more than two rails. PMBus-compatible commands over an I²C/SMBus interface are used for flexible programming and data readback of the power system. Configuration is accomplished through the LTpowerPlay[®] development environment, which supports all of Analog Devices' DPSM products (see Figure 5). Once the internal EEPROM is programmed with the needed application-specific configuration, no further software coding is required for autonomous operation.

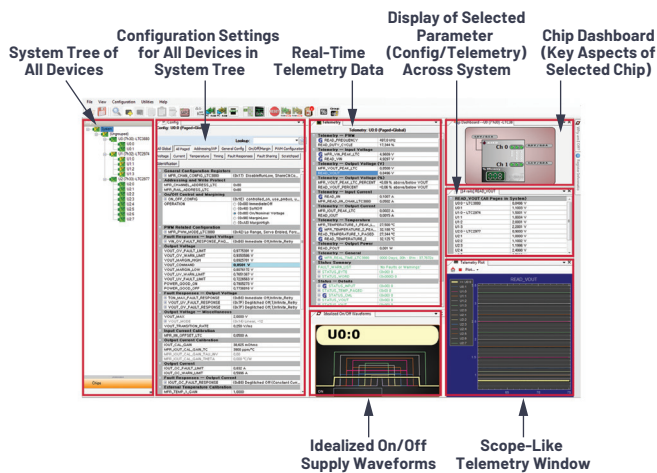


Figure 5. LTpowerPlay development environment for DPSM products: eliminates coding for autonomous operation.

Conclusion

FPGAs are spreading to all kinds of electronic systems, even taking over the job of ASICs, but they come surrounded by a complicated power system. Analog Devices has a wide range of DPSM products to help manage this complexity. If you've never tried DPSM before, the LTC2972 provides an easy introduction to their ability to remove the power system complexity on digital processing boards.

For FPGA reference designs, please visit analog.com/FPGA.

About the Author

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