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A radiation-tolerant LDO voltage regulator for HEP applications

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We have developed a radiation-tolerant Low Drop-Out (LDO) voltage regulator for applications in High Energy Physics experiments. The regulator outputs a fixed voltage of 2.5V, it provides a maximum current of 300mA with a drop-out as low as 150mV. The circuit incorporates over-current, over-voltage and over-temperature protection, and it can be disabled via a dedicated input pin. Manufactured in a commercial quarter-micron CMOS technology, it is available in a very compact 4.9x6x1.6mm 16L-EPP-SSOP package.

Summary

The distribution of power in the LHC experiments represents a real engineering challenge, given the global requirements in terms of power needs, available cooling capacity and limited material budget. The picture is complicated further by the radiation environment, which dictates that all electronics installed inside the experiments need to be radiation tolerant, and by the intense magnetic field that forbids the use of switched converters in many locations.

One solution that is often used is the distribution of low-voltage from supplies located in areas safe from radiation hazards via cables that can be up to 100m long.

This implies large currents to flow in the cables, determining sometimes large voltage drops across the cables. To regulate the voltage locally, linear regulators are used in proximity of the electronics circuits to be powered. These regulators dissipate power into heat that has to be evacuated by the cooling system, therefore it is mandatory to reduce their power dissipation as much as possible (increasing their efficiency). In this respect, relatively low-current regulators can be more effective than circuits that can provide larger currents because they can operate at much lower drop-out voltages, which effectively increases their efficiency. Such linear LDO regulators, capable of drop-out voltages of 100-200mV, are very common in the marketplace, but no radiation-hard component with these characteristics can be found at affordable cost.

With this in mind, we have started in 2004 the development of a radiation-tolerant LDO regulator using the same commercial quarter micron CMOS technology used by a large fraction of the ASICs for the LHC experiments. Aimed at regulating the voltage required by these circuits, it can provide in its first version a fixed output voltage of 2.5V (and a variable version will be easily derived). The circuit can supply currents between 0 and 300mA, with a drop-out voltage of 150mA for the maximum load. Designed with radiation-tolerant layout approach (Enclosed Layout Transistors and guardrings), it has been developed to stand total dose levels of several Mrad.

The regulator is protected against over-voltage, over-current and over-temperature events by automatic detection mechanisms. It can operate safely with input voltages up to 3.5V, after which the regulator is automatically disabled. In case of over-temperature, the circuit is disabled as well, whilst in case of over-current the output voltage drops while the current is limited to a pre-defined maximum value. The regulator can be disabled via a dedicated input pin in case of need.

Due to its limited current capability and its low drop-out voltage, hence low power dissipation, it can be packaged in a very compact 4.9x6x1.6mm 16L-EPP-SSOP package, which can easily be integrated in close proximity to the circuit(s) it has to power.

For stability, it requires small surface-mount capacitors in the 3-6 F range.
A prototype version of the regulator has been produced, packaged and received for testing in April. The first measurements indicate that the circuit meets the specifications in terms of line and load regulation, and the full characterization, including radiation tests, is now starting.

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