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A high frequency radiation hardened DC/DC-converter with low volume air core inductor

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The hfrh-buck (high frequency radiation hardened-buck) is a radiation hardened DC/DC-converter operating at a high switching frequency of 100MHz with a small air core inductor of 22nH. To ensure a high radiation dose, the circuit is designed with core transistors of a 65nm TSMC technology. By stacking the transistors of the power stage, the converter can be supplied with a voltage of up to 4.8V. Stable operation can be achieved at an output voltage of 1.2V with a maximum load current of 1A. The prototype demonstrates the ability to power parallel connected hybrid-pixel modules in the innermost layers.

Summary (500 words)

The increasing demand for reliable power management systems due to higher luminosity, higher power consumption and higher radiation doses, requires innovative power supply concepts for future applications. Since the detector systems are designed to be as light as possible, the voltage regulators are designed in the same technology as the readout electronics to enable on-chip integration. In a parallel supply approach, the hybrid pixel modules are connected in parallel and supplied by a DC/DC-converter that converts the supply voltage to the desired module voltage.

Low-inductance switching converters are required to meet the strict space requirements and to ensure the operation in high magnetic fields. In addition, the circuit must be able to withstand a high radiation dose of up to 1 Grad. Low-voltage core transistors can withstand a high radiation because their thin gate oxide makes them less susceptible to radiation damage. Since thick gate oxide transistors are used for higher input voltages, the power stage is stacked with four NMOS and four PMOS core devices each. A driver network is required to ensure that the transistors operate within their voltage limits. The chosen driver network monitors the drain potential of the stacked transistors and ensures that the required gate voltage is applied to the devices, depending on the switching state. The presented prototype was designed in a 65nm TSMC technology, while the entire circuit is built using only core transistors. With the selected switching frequency of 100MHz, a small air core inductor of 22nH can be used. The converter can regulate a supply voltage of 4.8V to 1.2V and drive a maximum load of 1A. A voltage controlled PWM regulator is used to control the output voltage. To ensure a safe operation with fast switching edges and a wide duty cycle range, a sawtooth oscillator based on two triangular waveforms that becomes active alternately was chosen. Further features are implemented to ensure a safe operation at high frequencies and to reduce the effects of crosstalk and kickback for the comparators used. The power transistors have to carry high currents with very fast switching edges. In order to sufficiently damp the oscillations at the supply terminals and to prevent the circuit from malfunctions and faulty switching behavior, a careful decoupling of the critical voltages is required. The functionality of the DC/DC-converter is demonstrated by various measurements that confirm stable operation over the entire load range.

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