**Design Calculations & Nominal Component Selection for Buck Converter Using SiC431**

This buck converter is designed to deliver a stable and efficient 3.3 V power rail suitable for powering Intel® Xeon® processors, which require precise and reliable voltage supplies for optimal operation. The wide input voltage range from 4.5 V to 24 V allows compatibility with various power sources commonly found in server and enterprise environments where Xeon processors are deployed. Supporting a high load current of up to 20 A ensures the converter can meet the substantial power demands of multi-core Xeon CPUs during peak processing loads. The 500 kHz switching frequency balances efficiency and output ripple, aligning with the stringent voltage regulation and noise immunity requirements typical of Intel® Xeon® voltage regulator modules (VRMs), thereby ensuring processor stability, performance, and longevity in demanding applications.

**1. Design Parameters**

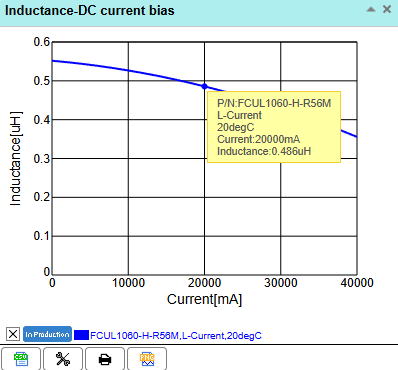
**2. Duty Cycle**

**3. Inductor Value**

**Given:**

* V
* *(used only for % ripple)*
* Duty cycle

**Ripple Current Formula:**

**Ripple Percentage:**

Reducing inductance from **560 nH → 484 nH** causes:

* **Ripple current to increase** from **3.86 A → 4.46 A**
* **% ripple** from **19.3% → 22.3%**

This is still **within acceptable range**, but we will:

* Need slightly **more output capacitance**
* See slightly **higher voltage ripple**
* Benefit from **faster transient response**

|  |  |  |
| --- | --- | --- |
| Inductor | Ripple Current (ΔIL) | % of 20 A |
| 560 nH | 3.86 A | 19.3% |
| 484 nH | 4.46 A | 22.3% |

**Input Capacitor RMS Current**

**Minimum Input Capacitance**

**Peak Inductor Current**

**Output Cap for Load Release (energy-based method)**

**2. Harmonic and LC Filter Analysis**

This section presents a detailed analysis of the harmonic content and output filter design for a 12 V to 1.2 V buck converter supplying 20 A load current. The converter operates at 500 kHz switching frequency with an efficiency of 88%, utilizing a 560 nH inductor optimized for fast transient response in point-of-load applications.

**2.1 Power Calculations**

Output power is calculated as:

Input power, considering efficiency , is:

Power loss in the converter is thus:

**2.2 Switch Node Harmonics**

The switch node waveform is a PWM signal with amplitude 12 V and duty cycle D=0.1. The Fourier series analysis of a rectangular pulse waveform yields harmonic amplitudes as:

Where: is the harmonic number.

Calculated amplitudes for the first three harmonics are approximately:

|  |  |  |
| --- | --- | --- |
| **Harmonic Order** | **Frequency** | **Approximate Amplitude** |
| 1st (Fundamental) | 500 kHz | 2.36 V |
| 2nd | 1.0 MHz | 2.24 V |
| 3rd | 1.5 MHz | 2.06 V |

These harmonics must be attenuated by the output filter to ensure low ripple voltage and electromagnetic interference (EMI) compliance.

**2.3 Output Filter Cutoff Frequency and Attenuation**

The LC output filter cutoff frequency fc​ is determined by:

At the switching frequency , the filter provides an attenuation of:

This attenuation reduces the primary harmonic voltage from approximately 2.36 V down to less than 20 mV at the output.

**2.5 ESR-Induced Voltage Ripple**

Assuming an Equivalent Series Resistance (ESR) of 5 mΩ for the output capacitors, the ESR-related ripple voltage is:

This level of ripple is acceptable for powering digital loads at 1.2 V.

**2.6 Practical Design Guidelines**

* **Capacitors:** Use multiple low-ESR X7R ceramic capacitors in parallel with bulk capacitance (polymer or tantalum) to optimize transient response and stability.
* **Layout:** Minimize high di/dt loop areas to reduce electromagnetic noise and ringing.
* **Snubbers:** Implement snubber or damping circuits if oscillations or ringing are observed at the switching node.
* **Measurement:** Validate harmonic attenuation using FFT analysis on oscilloscope captures of the switch node and output.
* **Thermal Management:** Ensure adequate copper pours and via stitching under heat-generating components to dissipate approximately 3.27 W power loss efficiently.