# Design and Digital Control of a Full-Bridge LLC Resonant Converter for a 1kW Off-Grid Solar Microinverter

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The global transition toward decentralised renewable energy requires highly efficient standalone power conversion architectures. In off-grid photovoltaic (PV) microinverter applications, achieving superior DC-DC conversion efficiency and high-power density is a primary engineering challenge. Resonant converter topologies, with their inherent soft-switching characteristics, offer a compelling solution to minimise switching losses. This study presents the design, simulation, and implementation of a 1 kW off-grid solar microinverter using a full-bridge LLC resonant converter and an H-bridge inverter. To establish a complete off-grid application, solar panels charge a 48 V battery system serving as the primary DC source. This feeds the proposed 48 V input full-bridge LLC converter to establish a 400 V DC bus. The DC bus then supplies an H-bridge inverter controlled by an EGS002 module, generating a reliable pure sine wave for continuous AC power delivery. The LLC converter stage is simulated using PLECS and controlled via a Texas Instruments C2000 F28379D microcontroller. The resonant tank comprises a 1.8 µF capacitor and a 6 µH inductor interfaced with a high-frequency transformer. Closed-loop voltage regulation uses a custom-built discrete proportional-integral (PI) controller targeting the 400 V output. The digital control architecture features a soft-start sequence initialised at 500 kHz, decrementing toward a nominal 48 kHz setpoint, using an inverse-frequency gain block ($1/f_{sw}$) to accurately modulate the switching period. Simulation results validate the steady-state performance, demonstrating a stable 404.5 V output across a 160 Ω load (2.5 A, 1 kW). Transient analysis of MOSFET waveforms confirms Zero Voltage Switching (ZVS), substantially mitigating turn-on losses. The PI control loop maintains stable regulation at approximately 56.3 kHz. Furthermore, the 500 kHz soft-start effectively suppresses inrush currents during the power-up transient for safe initialisation. The findings demonstrate that integrating a full-bridge LLC resonant topology with PI-based frequency modulation and an EGS002-driven H-bridge provides a robust, high-efficiency power conversion blueprint for standalone PV applications.

**Keywords:** LLC resonant converter, Zero Voltage Switching (ZVS), off-grid photovoltaic microinverter, digital PI control, soft-start frequency modulation