Pspice simulation of Full Bridge LLC converter with resonant current control mode

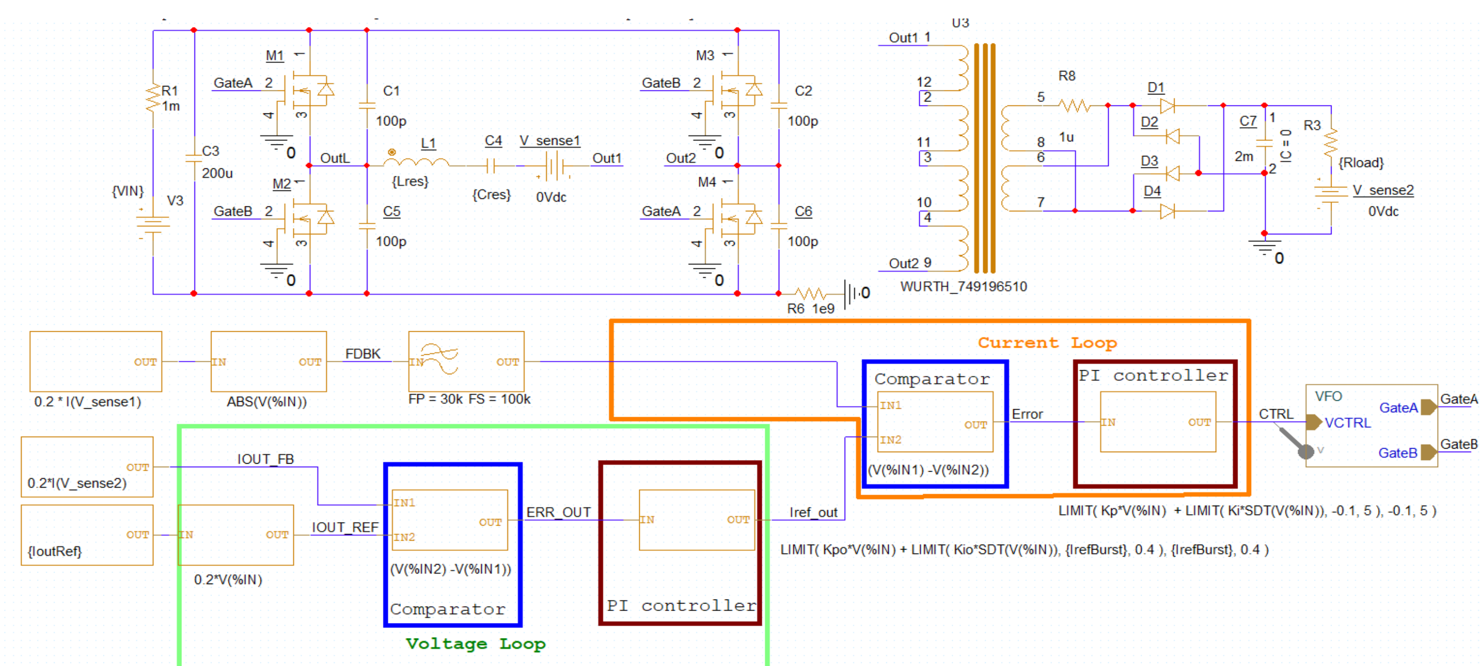
Charge control, as used in commercial half-bridge LLC controllers, depends on a ground-referenced capacitive divider across the resonant capacitor. In a full bridge neither terminal of that capacitor is at a fixed potential, so the method does not transfer, and full-bridge designs at high power fall back to direct frequency control with its load-dependent double pole.

The Full bridge LLC presented here utilizes Resonant Current Magnitude Control by sensing the resonant inductor current directly. The resonant tank current is sensed by a standard galvanically isolated Hall-effect sensor, rectified and averaged to obtain its amplitude, and used as the feedback quantity of an inner current loop. The result is the same first-order plant that charge control produces, but with sensing that does not depend on the topology or the bus voltage.

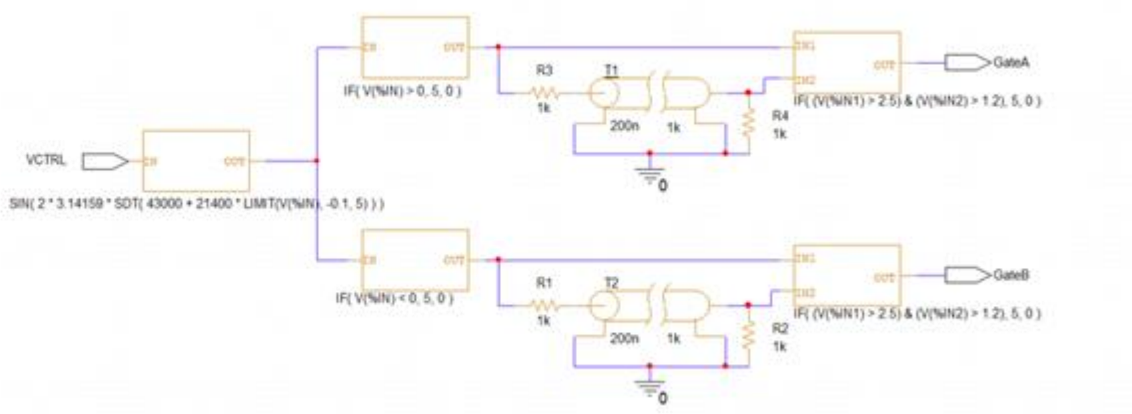
The method is verified in a PSpice model shown below. It is current source, but can be easily converted to voltage source.

Parameters of the simulation model.

Parameter	Value	Note
Tank sensor	0.2 V/A	Hall effect, galvanically isolated, in the Cr branch
Resonant frequency fr	50kHz	
Vin nom	22v	
Load resistance Rload	1 ohm	
Output current range	1.8 to 5.2 A	
Detector	|x| then low-pass	FP 30 kHz, FS 100 kHz
Inner PI	Kp 3.8 / Ki 63 000	clamp −0.1 to 5, nested anti-windup
Outer PI	Kpo 0.2 / Kio 126	clamp to 0.4, nested anti-windup
Oscillator range	43 to 150 kHz	21.4 kHz per volt, linear
Dead time	200 ns	fixed at every frequency



Voltage-controlled oscillator



Simulation results

The reference was stepped from 2 A to 5 A at 22 ms and returned to 2 A at 30 ms, at VIN = 22 V, with a single fixed set of gains. The result is shown in Figure 7.

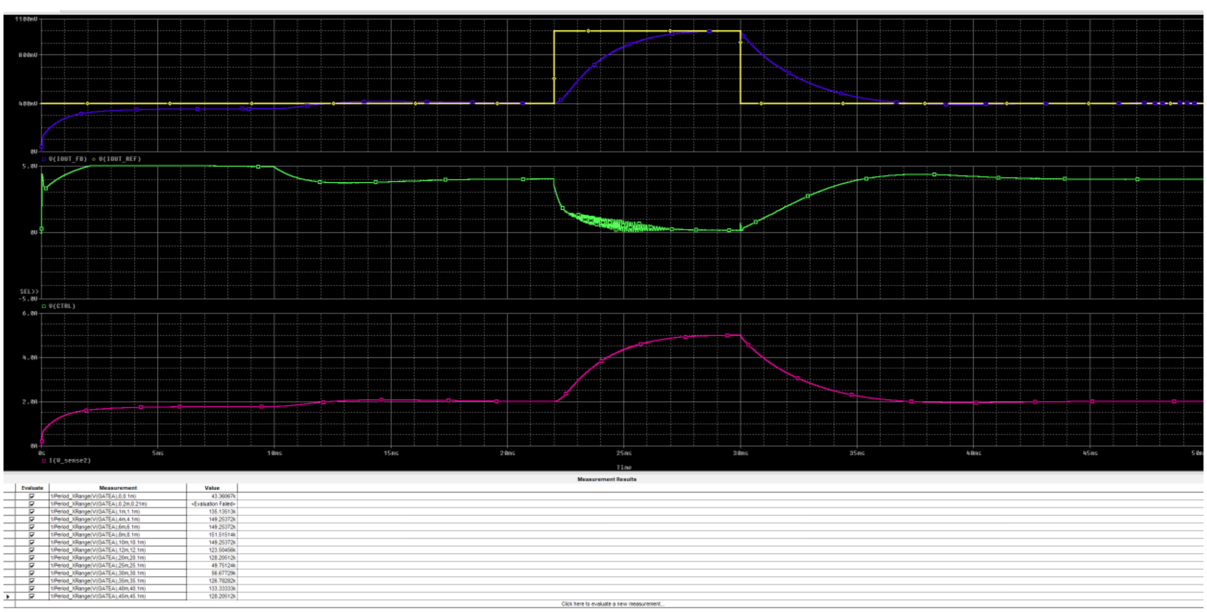


Figure 7. Closed-loop response to both steps.

- Upper trace: feedback following the reference.
- Middle trace: control voltage, varying from 4.0 V at 2 A to a value close to the lower rail at 5 A.
- Lower trace: output current.

Conclusions:

The loop is stable across the full output range. The downward step is slower than the upward step because a reduction in output requires an increase in frequency followed by the discharge of the 2 mF output capacitor into the load.

The proposed method is viable. Isolated sensing of the tank current with an amplitude detector enables Resonant Current Control via a stable cascaded loop. The inner loop acts as a simple first-order system that can be tuned analytically from step measurements. It maintains steady output regulation across a 3:1 range using fixed gains and standard sensors.