EDN
NETWORK

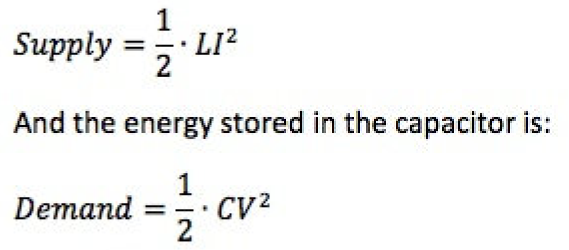
Predictive energy balance control for PDN applications

Steve Sandler - March 05, 2015

Power integrity (PI) and power distribution network (PDN) design are now central elements in the design of all high-speed, high-performance, and low-noise electronic circuits. The first rule in achieving optimum performance is to maintain the power distribution path impedance magnitude below some specific level, often referred to as the target impedance. The second rule is to keep the power distribution impedance as flat as possible over frequency. Semiconductor companies are introducing new voltage regulator architectures incorporating non-linear controls, multiple loops, and hysteretic operation to achieve these goals. One of the more interesting topologies is the patented predictive energy balance (PEB) controller, developed and owned by Cognipower.

What is PEB?

The PEB control algorithm controls the voltage converter performance from a supply vs. demand perspective. As in most switching converters, energy is stored in an inductor and transferred to the output where the voltage is averaged in a capacitor. The energy stored in the inductor is:



$$Supply = \frac{1}{2} \cdot LI^2$$

And the energy stored in the capacitor is:

$$Demand = \frac{1}{2} \cdot CV^2$$

The PEB controller establishes the required supply based on the demand, setting these equations equal during each switching cycle. The result is a “memory-less” control, with every cycle being a “clean slate” resulting in complete dynamic response recovery within a single switch cycle. The output neither overshoots nor undershoots. The controller is inherently stable, since there are no compensating poles added in the control function. The PEB control computational block diagram is shown in Figure 1.

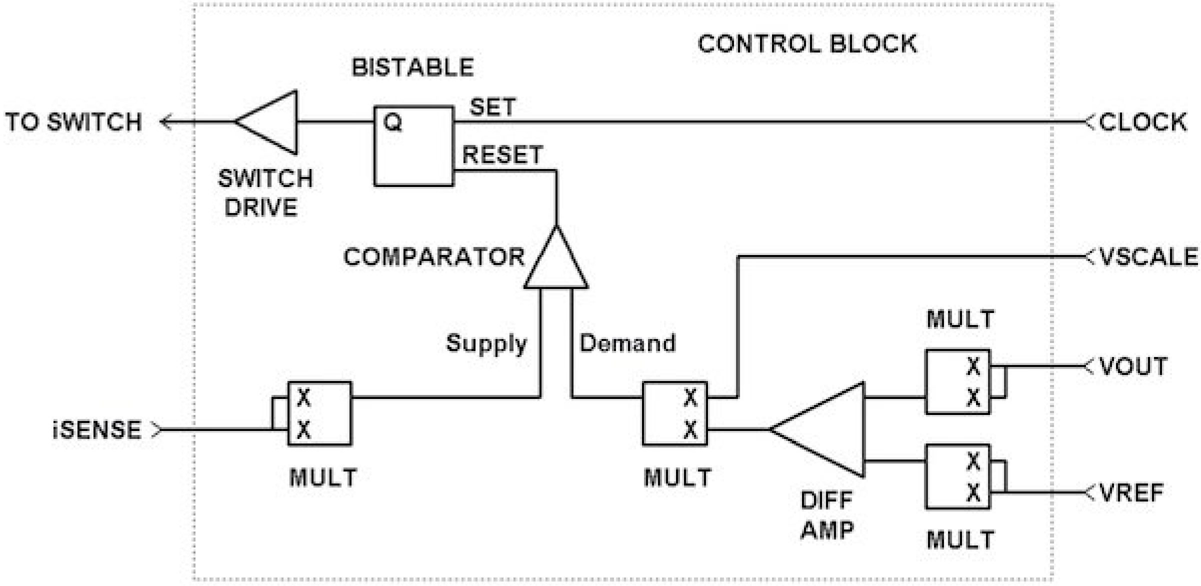


Figure 1 Block diagram of the PEB computational control. Note that the voltage terms and the current terms are squared in order to provide energy comparisons rather than voltage or current comparisons.

PEB control is adaptable to many switching topologies, including buck and flyback, operating in both discontinuous and continuous operating modes.

Why it might be ideal for PDN

The converter output impedance function under PEB control is a near frequency independent resistance, coincident with the goals of PDN applications. The fixed resistance is a function of the inductor and capacitor ratio. The single cycle response results in the fastest possible recovery time, also ideal for PDN applications. The flat impedance profile is illustrated in Figures 2 and 4, using a low power, discontinuous mode PEB demonstration board. (This measurement was provided by Cognipower and was not designed for any particular application.)

Figure 2 The top trace (pink) is the output voltage response while the middle trace (yellow) is the load current and the bottom trace (green) is the inductor current. Note the high frequency spikes have not been filtered in order to provide the unaltered response of the controller.

The demonstration board inductor and capacitor values were modified to set a target impedance of 300mΩ and set in a probing fixture, shown in Figure 3.

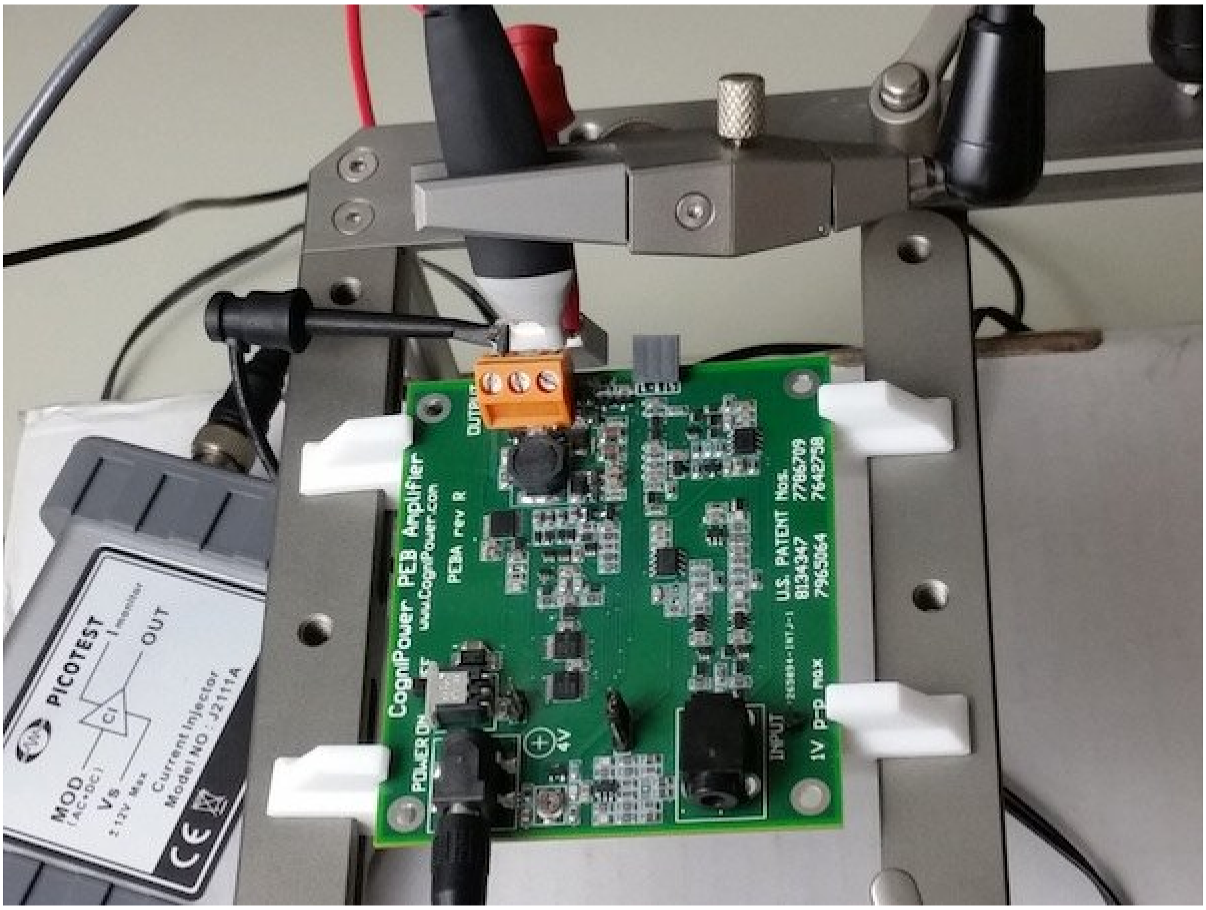
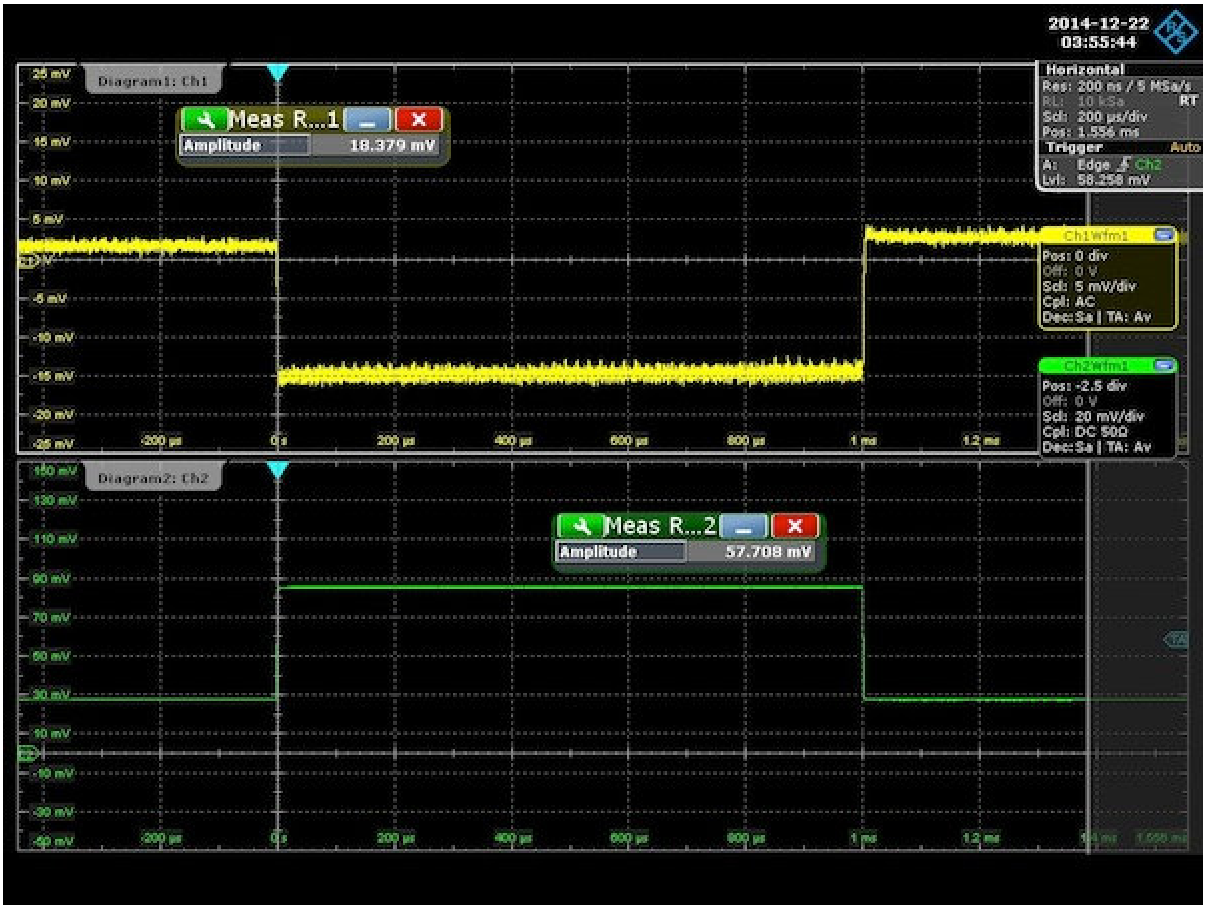


Figure 3 The demonstration board is set in a probe station for measurement. The output voltage is monitored using a P2100A unity gain probe and the load is pulsed using a 20ns J2111A current injector.

The measured converter impedance computed from the 18mV voltage excursion and 58mA current step is approximately 320mΩ. The output ripple voltage is removed by averaging in this measurement for clarity. Note the total absence of overshoot or undershoot in the voltage response as shown in Figure 4.



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Horizontal
Res: 200 ns / 5 MSa/s
RL: 10 kSa RT
Scl: 200 µs/div
Pos: 1.556 ms

Trigger Auto
A: Edge Ch2
Lvl: 58.258 mV

Meas R...1
Amplitude 18.379 mV

Ch1Wfm1
Pos: 0 div
Off: 0 V
Scl: 5 mV/div
Cpl: AC
Dec:Sa | TA: Av

Meas R...2
Amplitude 57.708 mV

Ch2Wfm1
Pos: -2.5 div
Off: 0 V
Scl: 20 mV/div
Cpl: DC 50Ω
Dec:Sa | TA: Av

Figure 4 Load step response of the modified demonstration board adjusted for an output impedance of 300mΩ. Note the lack of overshoot or undershoot. The output voltage is averaged in order to strip the ripple for clarity.

While this example provides a 300mΩ output impedance, representative of a low-power application, the PEB control is scalable to any power level. The computational requirements are minimal allowing either digital or analog implementations. Presumably, the controller could be integrated into a single monolithic chip.

The PEB controller is hardware independent, allowing control of a silicon MOSFET power stage or for much higher frequency operation and optimum efficiency, a GaN power stage. The PEB controller can also be used as an amplifier allowing dynamic voltage programming also with the absence of overshoot or undershoot. When considering the many new switching topologies for PDN applications, the PEB control offers some useful benefits. I hope to explore this topology further in the future.

References

Tom Lawson, *Predictive Energy Balancing for Agile Control of Switched-Mode Power Converters*, **BODOS Power** May 2013 http://www.cognipower.com/pdf/Bodos_May_2013_PEB_Article.pdf

Steve Sandler and Tom Lawson, *Quantifying the Difference: Predictive Energy Balancing Controls for Switched-Mode Power Converters* **PowerViews** Nov. 25 2014 http://m.powerpulse.net/powerViews.php?pv_id=85

Also See:

- SoC power integrity challenges
- Measure PDN on a budget

- PDN design essentials for wideband low impedance