Exploring Integration of Generalized Predictive Energy Balancing Controls Suitable for Disparate Switched-Mode Power Converters

Presenter:

Thomas Lawson

Founder and President

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Every Power Converter is Different

A popular electronics catalog lists over 172,000 products in the "Power Management IC" category.

That does not include the 227,000 DC/DC converters listed.

You might think, "Who needs one more power controller?" But we see an opportunity here.

There are so many parts, because each needs to be optimized for a narrowly defined task.

That optimization process generally centers on loop compensation.

Loop Compensation is a Rarefied Art

Rigorous loop compensation is time-consuming and mathematically complex.

Adjusting the trade-offs between speed and stability remains an incomplete science.

Compensation is <u>always</u> a compromise, and is only at its best over a small range of conditions.

In an amplifier, poor compensation makes distortion.

In a power converter, poor compensation makes smoke.

CogniPower
power smarter

CogniPower Predictive Energy Balancing

In a Predictive Energy Balancing (PEB) converter the gain is constant – there is no compensation needed.

Each switching decision is based on the predicted outcome of that decision, rather than on the average outcome of some number of previous decisions.

The effect of prediction is to remove the filter delay from the feedback loop.

The math for PEB is simple, and can be done in analog or digital fashion in real time.

The result is what we call intrinsic stability.

Predictive Energy Balancing Benefits

PEB allows each control cycle to be completely self-contained.

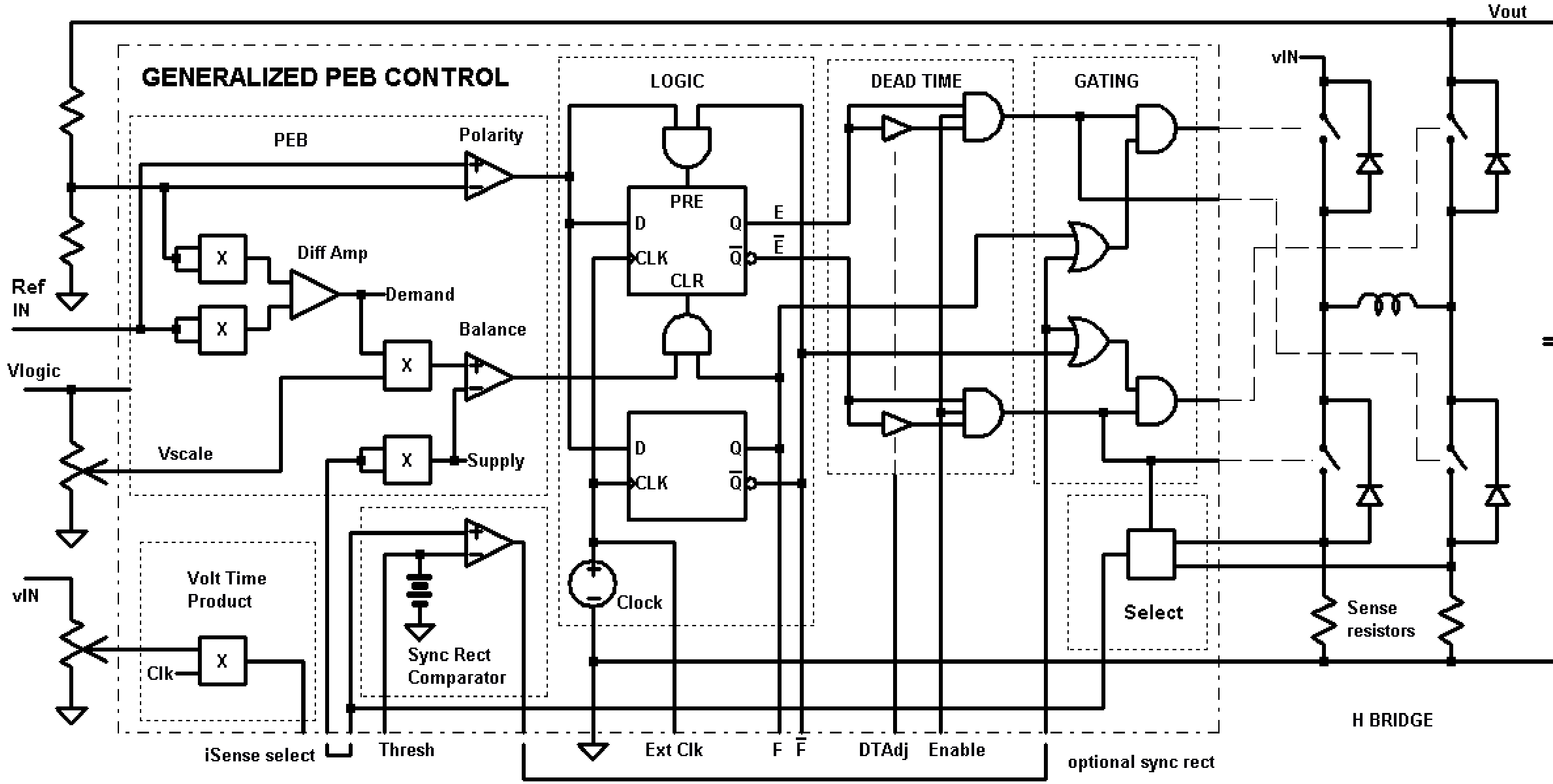
That, in turn, delivers the theoretical best transient response while maintaining stability.

The familiar trade-offs between agility and stability and reliability do not apply when using PEB.

Ordinary power converter structures perform better with PEB, and new structures become practical.

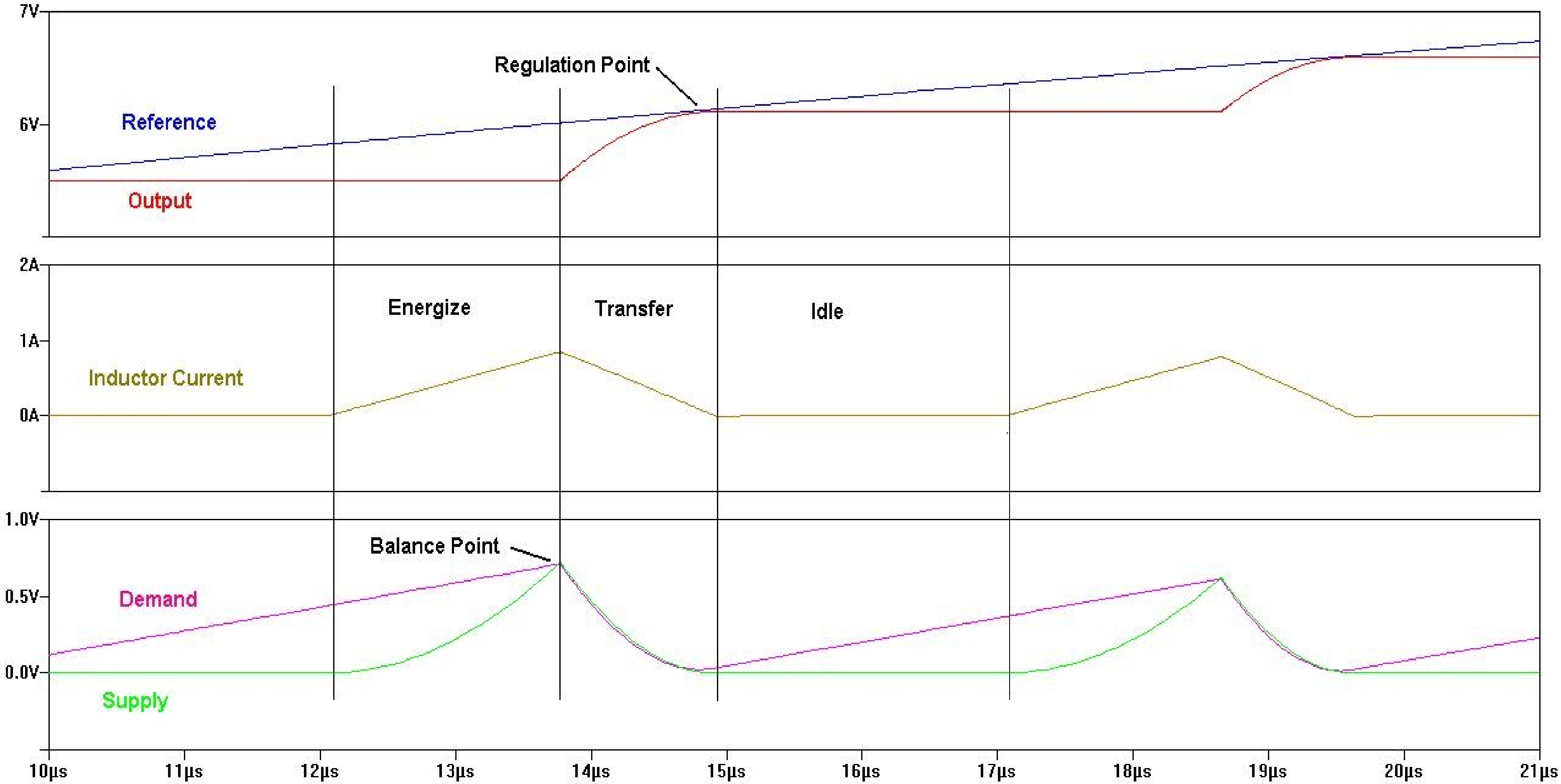
How does it work? PEB is based on the fundamental kinetic energy equations.

PEB Control Block in Generalized Form



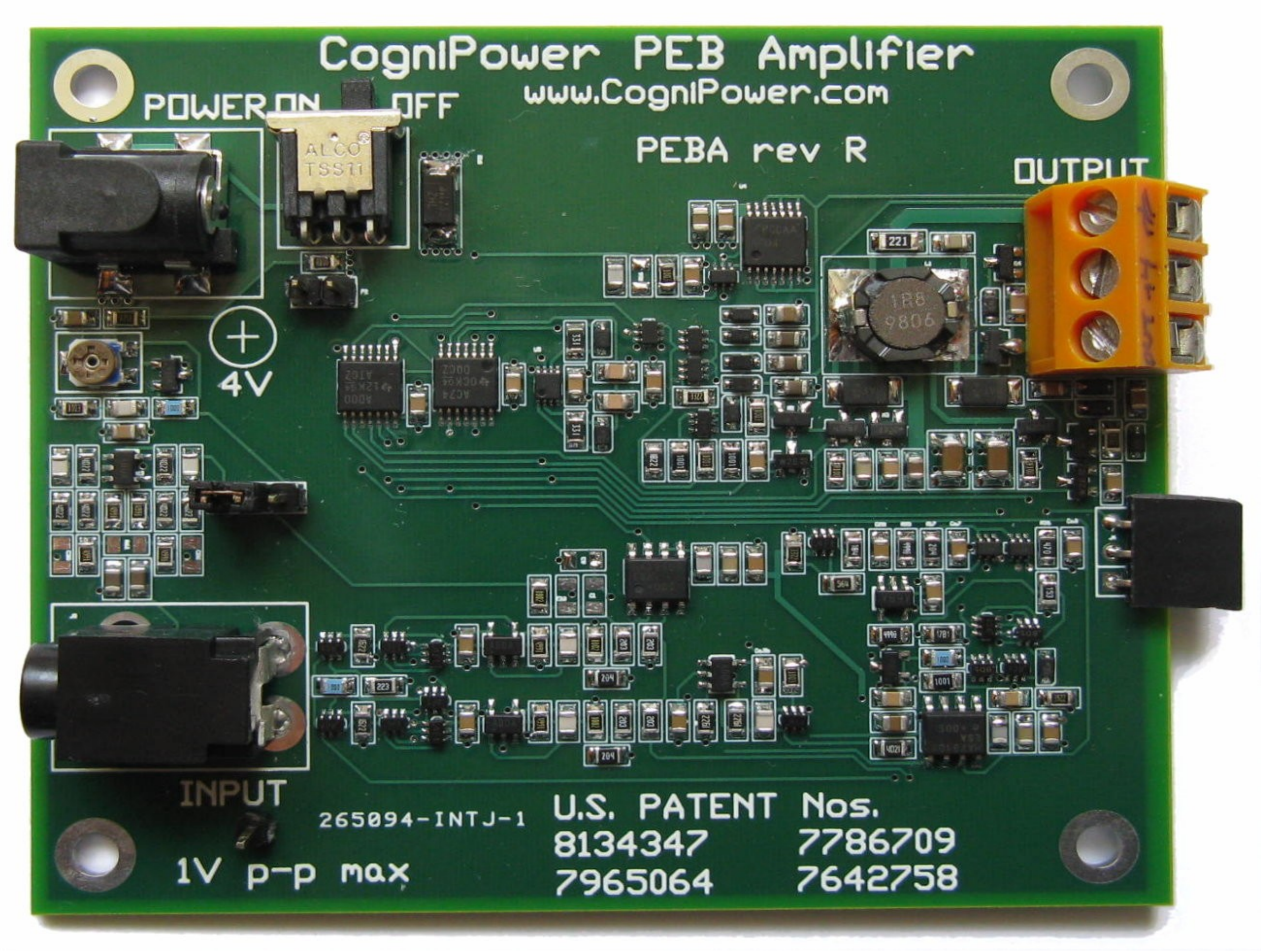
The energy demand at the output is calculated and compared to the energy supply in the switched inductor.

Predictive Energy Balancing Waveforms

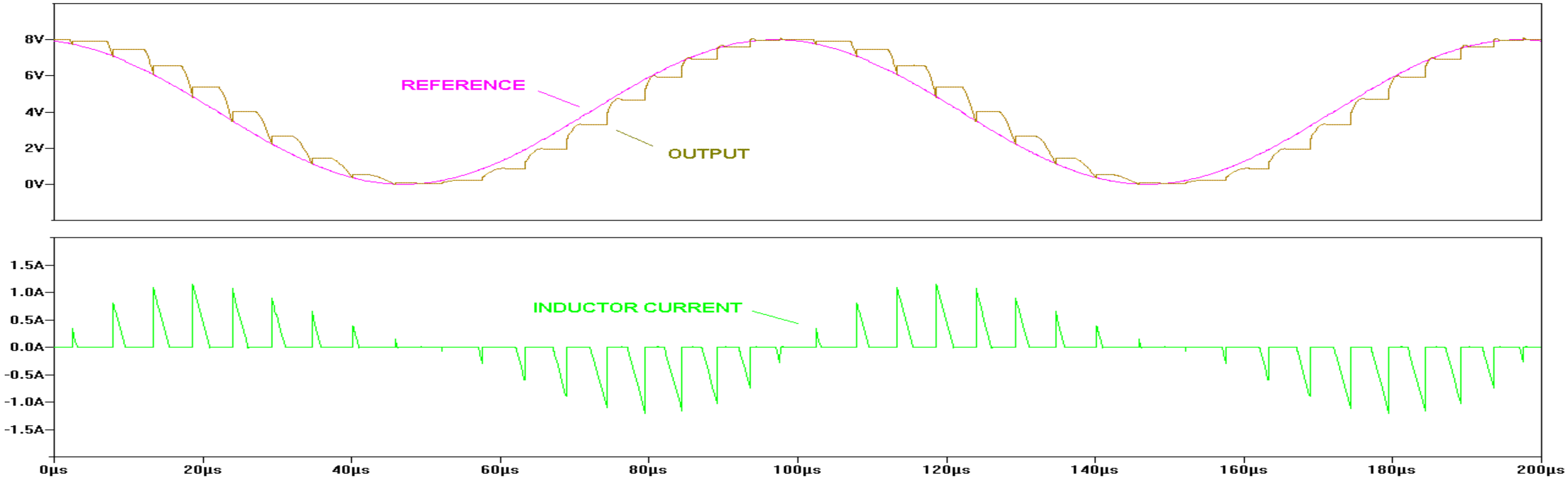


Energize continues until the balance point, when energy supply and energy demand are equal.

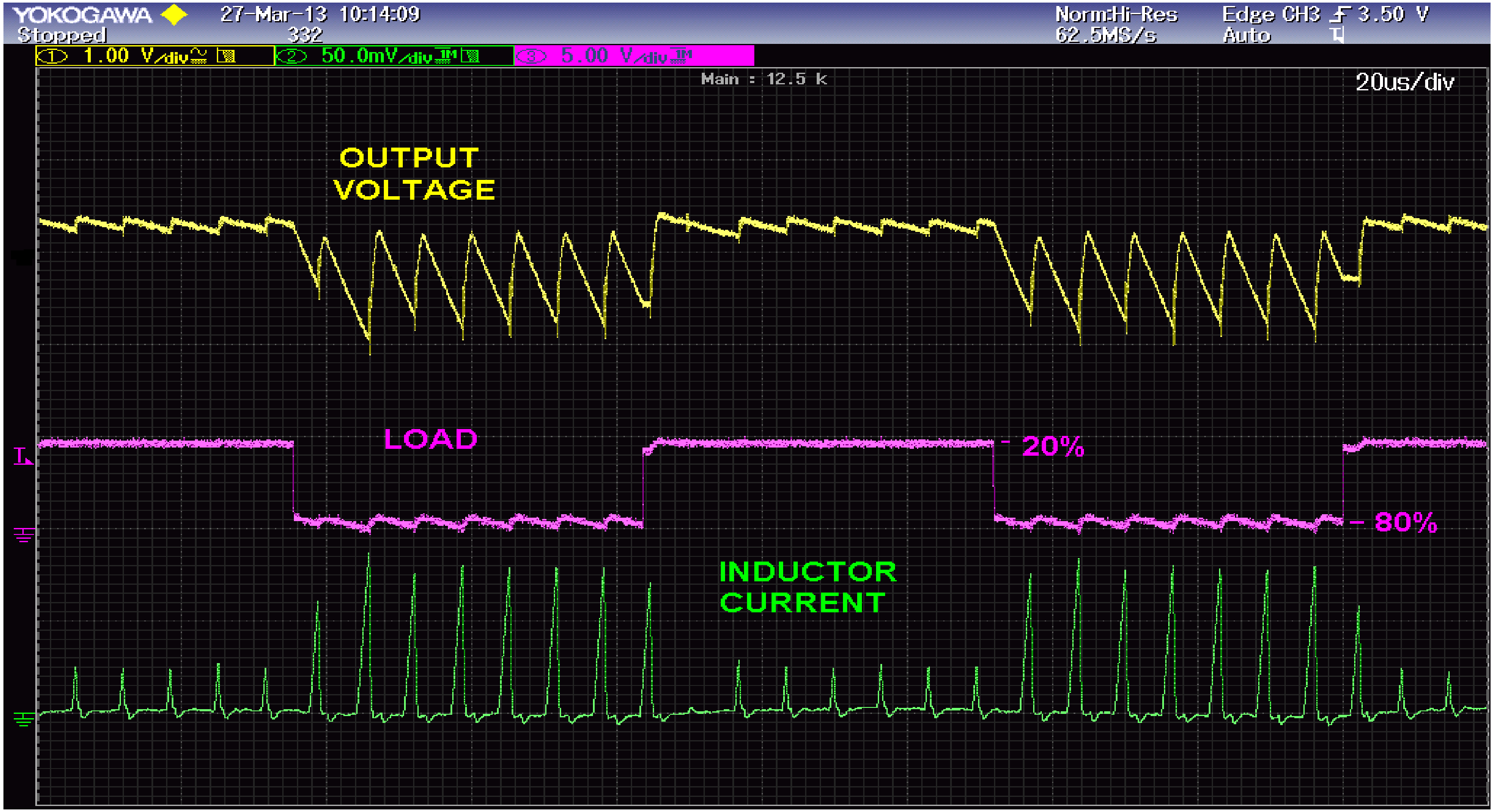
PEB Demonstrated as a Power Amplifier



PEB Amplifier Performance, SPICE vs Bench

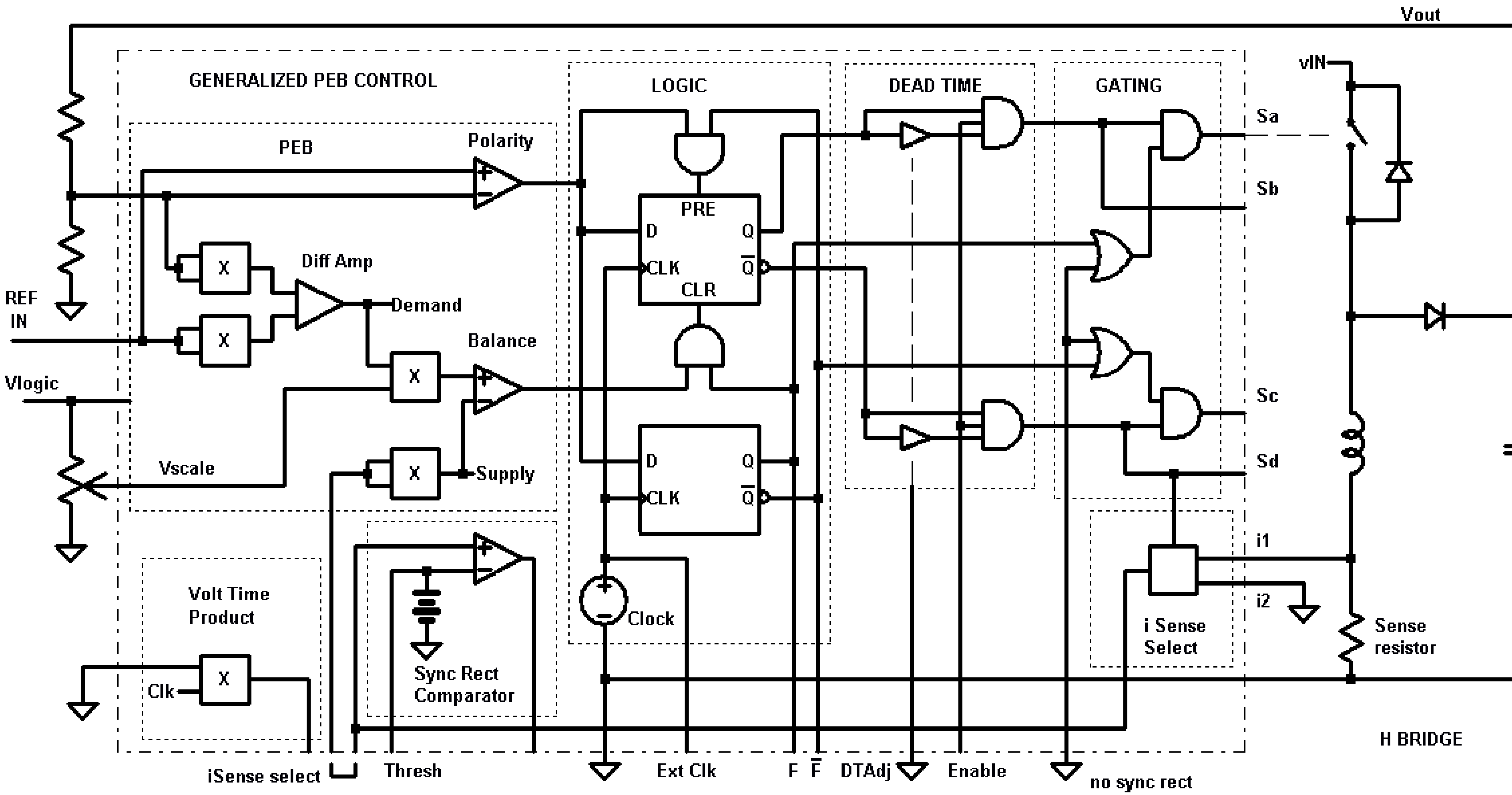


PEB Amplifier Running with a DC Reference



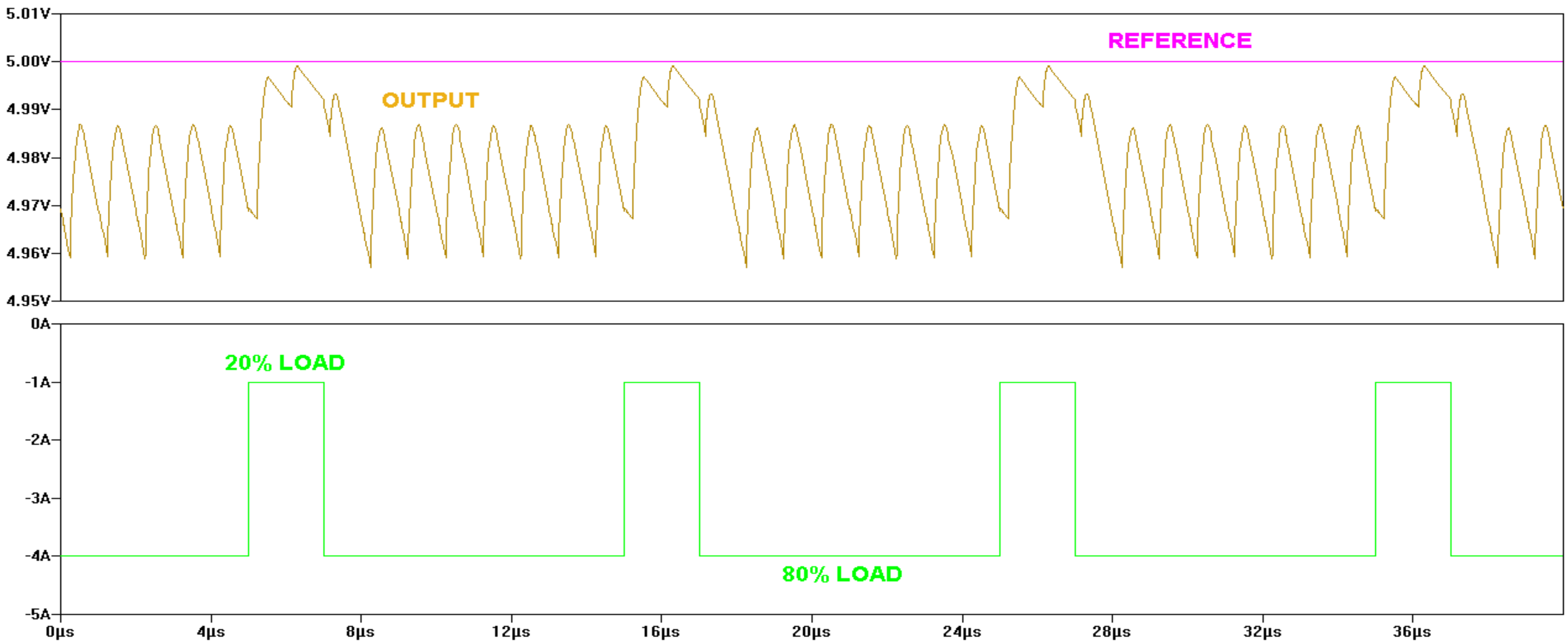
The load is toggling at 10 kHz between 20% and 80%. PEB responds within a single cycle.

The Same Control in a Flyback Converter



The identical PEB controller runs a simple flyback converter. Synchronous rectification is not shown here.

PEB Flyback Performance

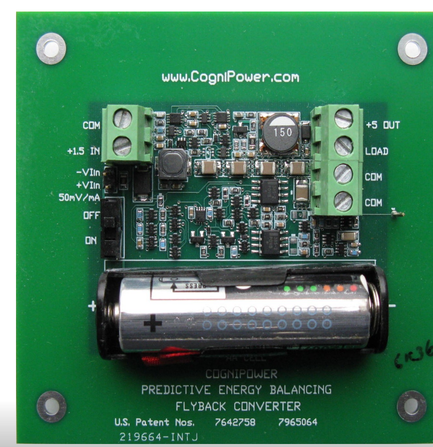


Only one switch is being used here, to illustrate the simplest flyback topology, with a diode for rectification.

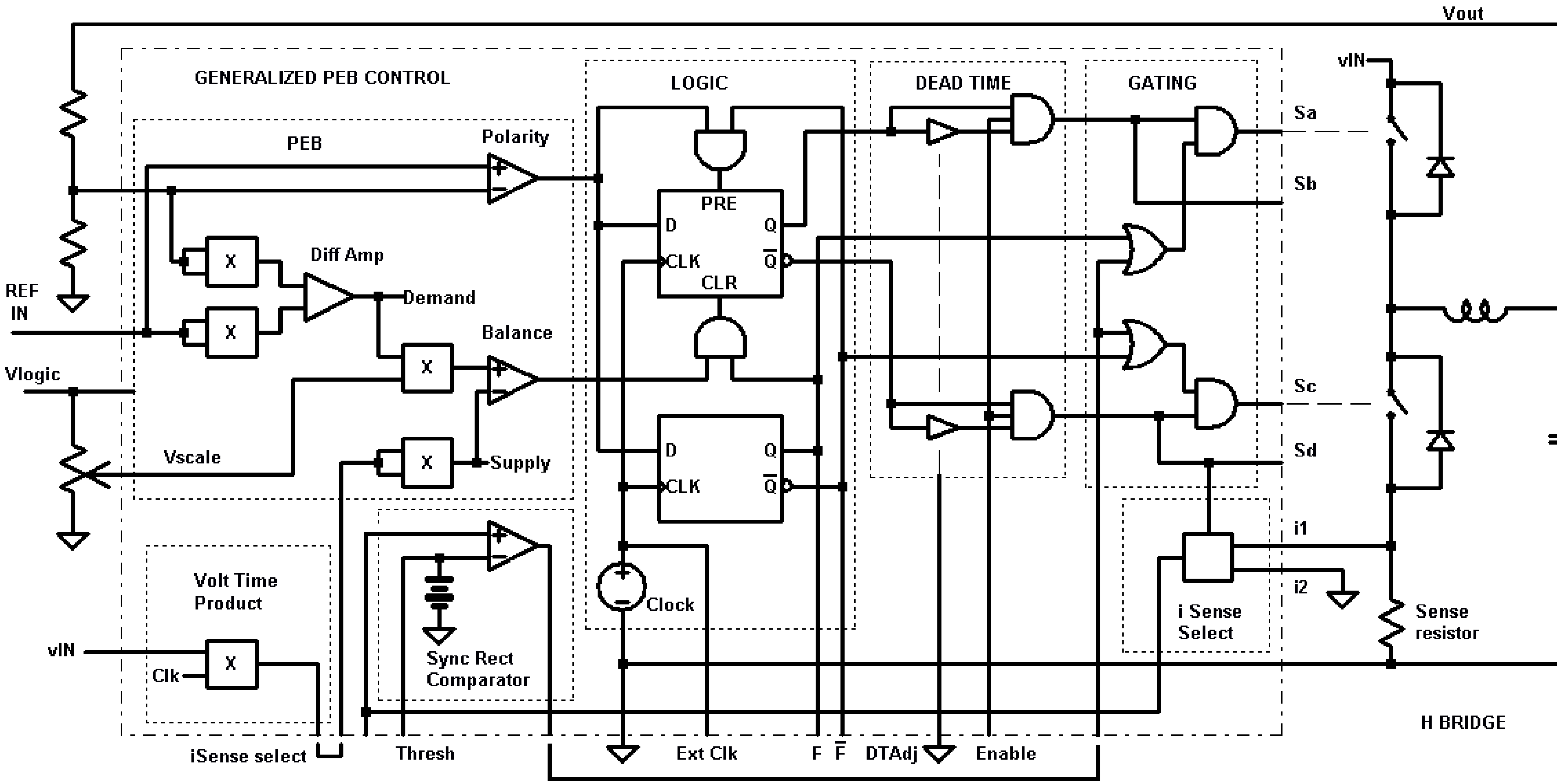
The controller could perform the synchronous rectification, given a second power switch.

PEB Flyback Demonstration Board

The load step, in green, is 20-80%.
The output responds in a single cycle, and regulates to 15 mv out of 5 volts.



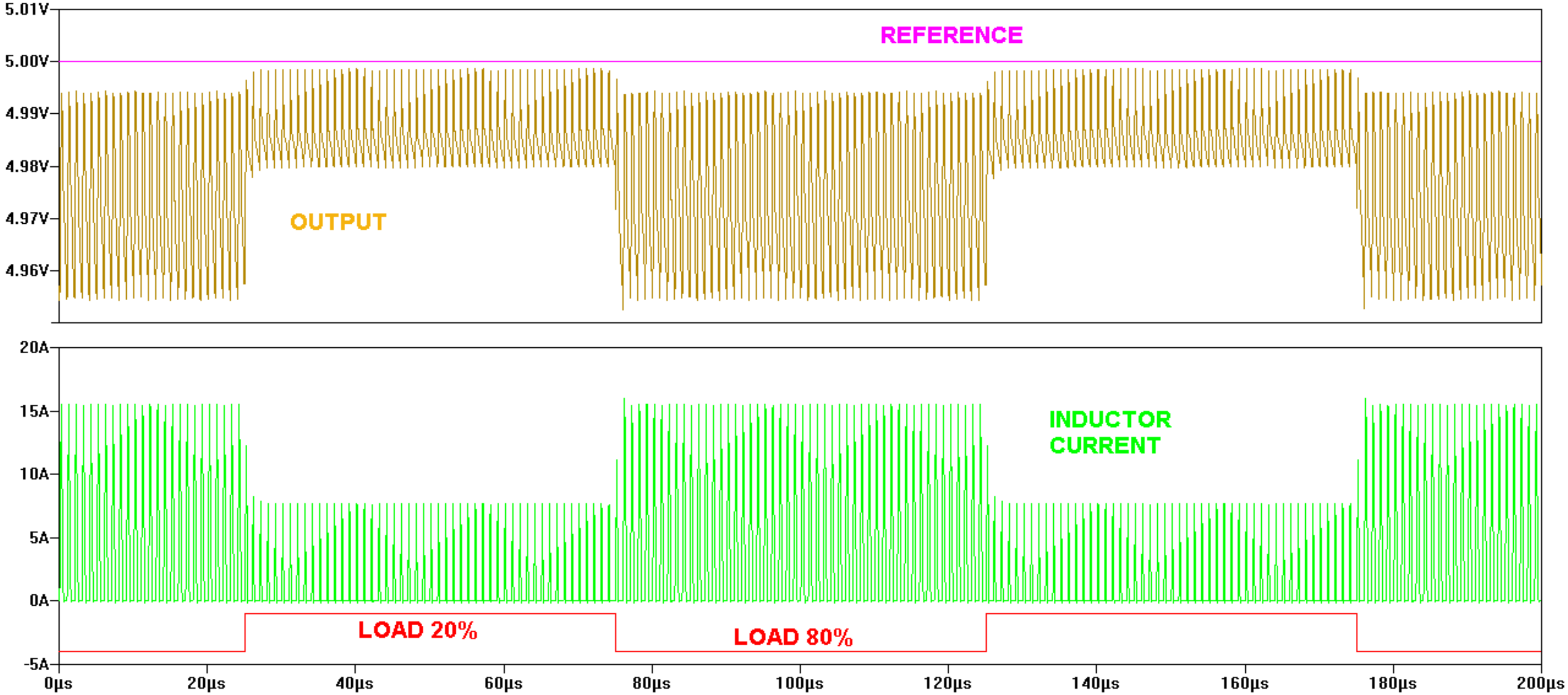
The Same PEB Control for a Buck Converter



An ordinary buck topology with two switches is shown.

This form can do much more than is usually asked of it.

PEB Buck Converter Performance



The same single-cycle control is seen here when running as a discontinuous (DCM) buck converter.

CCM becomes practical with the addition of a load term.

PEB Extends Flexibility and Performance

The buck topology is intrinsically bidirectional.

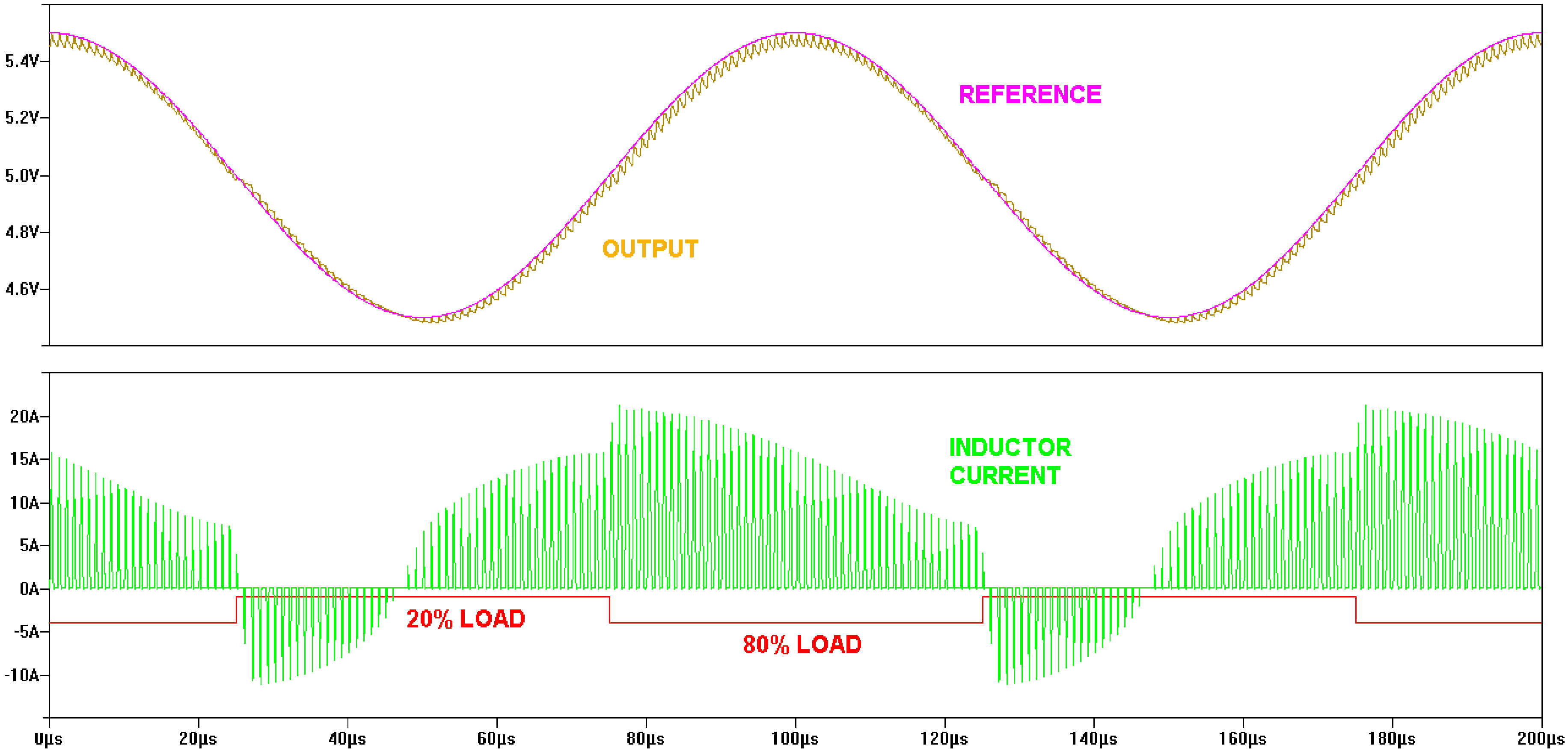
This bidirectional ability can be seen by changing the reference voltage to AC from the example above.

No additional switches or control signals are needed to keep the control loop in good regulation.

The behavior is similar to a Class D amplifier, but the PEB form is 100% fed back while maintaining inherent stability.

Note the reversal of inductor current in the next slide.

PEB Running Bidirectional Buck Converter



Efficiency is excellent because energy is recovered from the load–note the reversal of inductor current polarity.

Same PEB Control Handles SEPIC, & More

The exact same controller will manage a SEPIC converter.

We have investigated more forms of PEB converter than can be covered here.

Those include multi-output, quasi-resonant, and bipolar forms; many are isolated versions.

Also not covered here are improved switch drivers, digital isolators and current sensing techniques.

CogniPower has 7 issued patents covering much of the above, and many more are pending.

Aren't the Old Ways Good Enough?

The simple answer is that PEB offers better transient response without needing compensation, and offers advantages in <u>flexibility</u>, <u>size</u>, <u>efficiency</u>, and <u>cost</u>.

A broader answer requires taking a step back:

When the same controller can handle many sorts of energy transfers, long-standing performance limits drop away, and more function can be obtained from the same topology.

Different operating modes can be chosen on a cycle-by-cycle basis, because the same controls apply.

The loop can be kept closed, even when stressed.

Aren't the Old Ways Good Enough?, cont'd

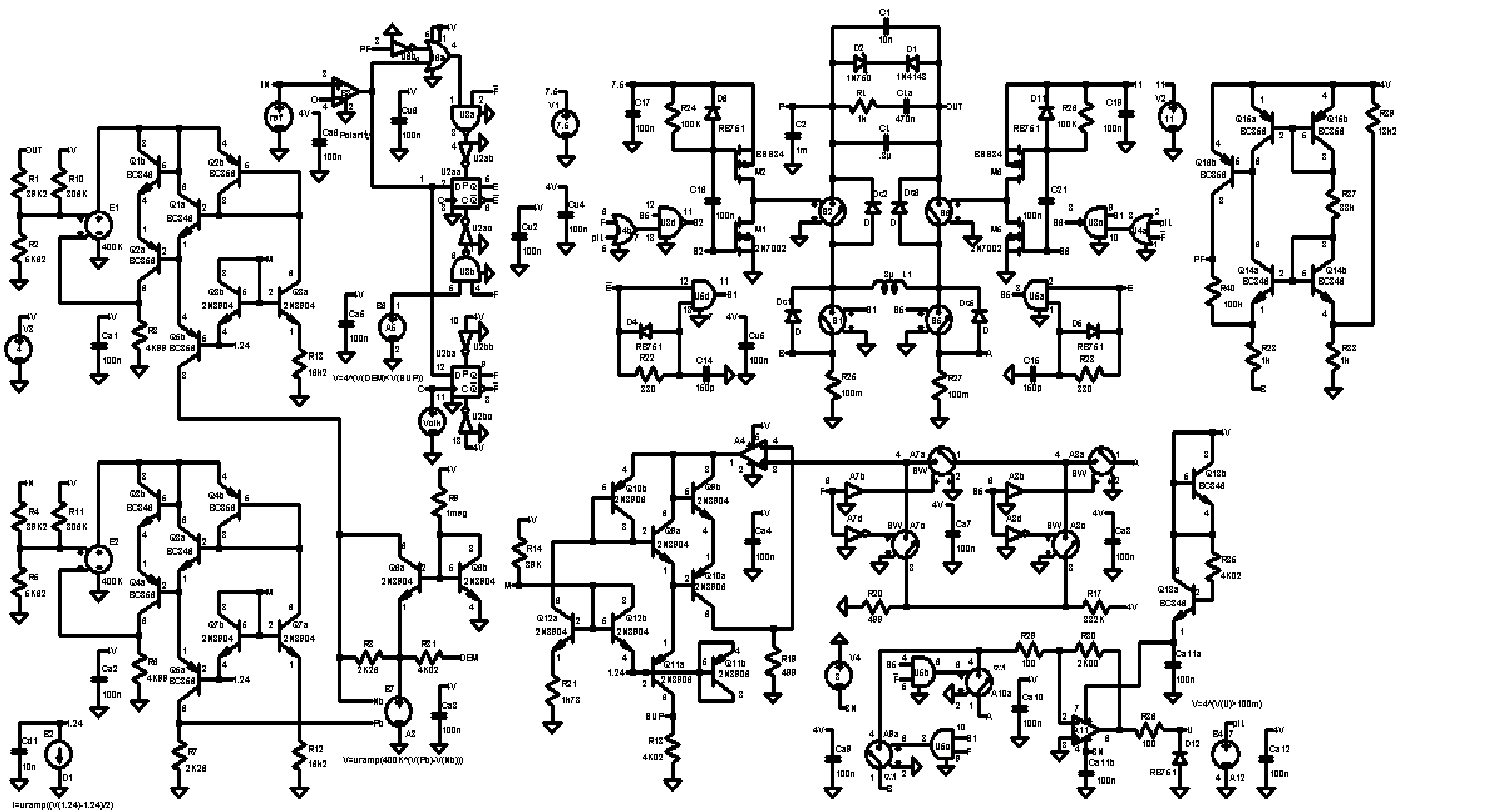
Other power converters can operate in different modes under different circumstances, but extra caution is indicated to insure stability at the transitions.

Such discontinuities are not an issue with PEB control.

Adding an additional power switch to a conventional controller is a lengthy and risky process.

In contrast, the simpler PEB power converters shown here are made by <u>removing</u> switches from a fully implemented PEB amplifier, so, adding switches back in is straightforward.

PEB Power Amplifier Implementation



SPICE schematic of the Cell Phone Audio Amplifier

Integration

We built the PEB engine using bipolar transistors because they are small, run on little power, are inexpensive and are available in discrete form.

An IC would likely be implemented in CMOS.

Standard cells can amplify, add, square, and compare– all faster and with less power consumption.

The PEB engine can be implemented as a generalized controller, or as a series of power converters, or both.

Also, flexibility and controllability allow PEB power converters to be integrated along with the powered device, for increased economy and efficiency.

Application Summary

DC/DC, AC/DC, DC/AC and AC/AC power converters, scalable to any size

Audio amps, from hearing aids to theater systems, including amplifiers for piezo speakers

Envelope-tracking power supplies

Sine wave output motor drives

Re-regulators, i.e. 12v to 12v for automotive use

Medical imaging

LED lighting

Related Ongoing CogniPower Projects

PFC Power Converter

The CogniPower Compound Converter offers independent regulation of input current and output voltage while the majority of power passes through only a single stage of power conversion.

Low-Load Efficient Wall Adapter

Under 10 mw no-load power, and 94% efficient at 25% of full load. More responsive, smaller and less expensive than existing designs. Electrolytic output filter capacitors can be replaced with ceramics.

Conclusions

Power converters can be more controllable, more reliable, and easier to apply.

We have built demonstration CogniPower converters ranging from 50 mW to 1 kW.

Demonstration systems are available, and they exceed expectations.

It is time to integrate Predictive Energy Balancing control so that PEB can be used in cost and size-constrained applications.

Questions?

One more power converter controller chip would be a good idea, after all.

Contact:

Tom Lawson

tlawson@cognipower.com

www.cognipower.com