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Darnell's Power Forum 2012

Applying CogniPower Predictive Energy Balancing in Switched-Mode Power Products

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Conventional SMPC Control

Pulse Width Modulation (PWM) is the usual means for controlling Switched-Mode Power Converters (SMPCs). The limits of PWM control are well understood.

Stability requires filter capacitance at the output, but that capacitance necessarily adds a pole of filtration to the voltage feedback.

The resulting phase lag causes PWM controls to have a tendency toward oscillation. PWM control necessarily involves a tradeoff between stability and agility.

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PEB Provides Intrinsic Stability

Predictive Energy Balancing effectively removes the output filter pole from the feedback path.

In the process, PEB eliminates the need to compromise between stability and agility.

Eliminating the tendency toward sub-harmonic behavior (and possible destructive runaway) frees the designer to think more creatively.

The math involved is surprisingly simple, and can be done real-time in analog or digital fashion.

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The Underlying Energy Formulas:

The kinetic energy held in an inductor, **L**, is

$$\mathbf{KEL = (I^2 \times L) / 2}$$

where KEL is inductive energy in joules, I is current in amps, and L is inductance in henries.

The kinetic energy held in a capacitor, **C**, is

$$\mathbf{KEC = (V^2 \times C) / 2}$$

where KEC is capacitive energy in joules, V is voltage in volts, and C is capacitance in farads.

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The Energy Balance Equation

At the regulation voltage, **Reg,** the energy in joules held in the output filter capacitor, **C**, will be

$$KEReg = (Reg^2 \times C) / 2$$

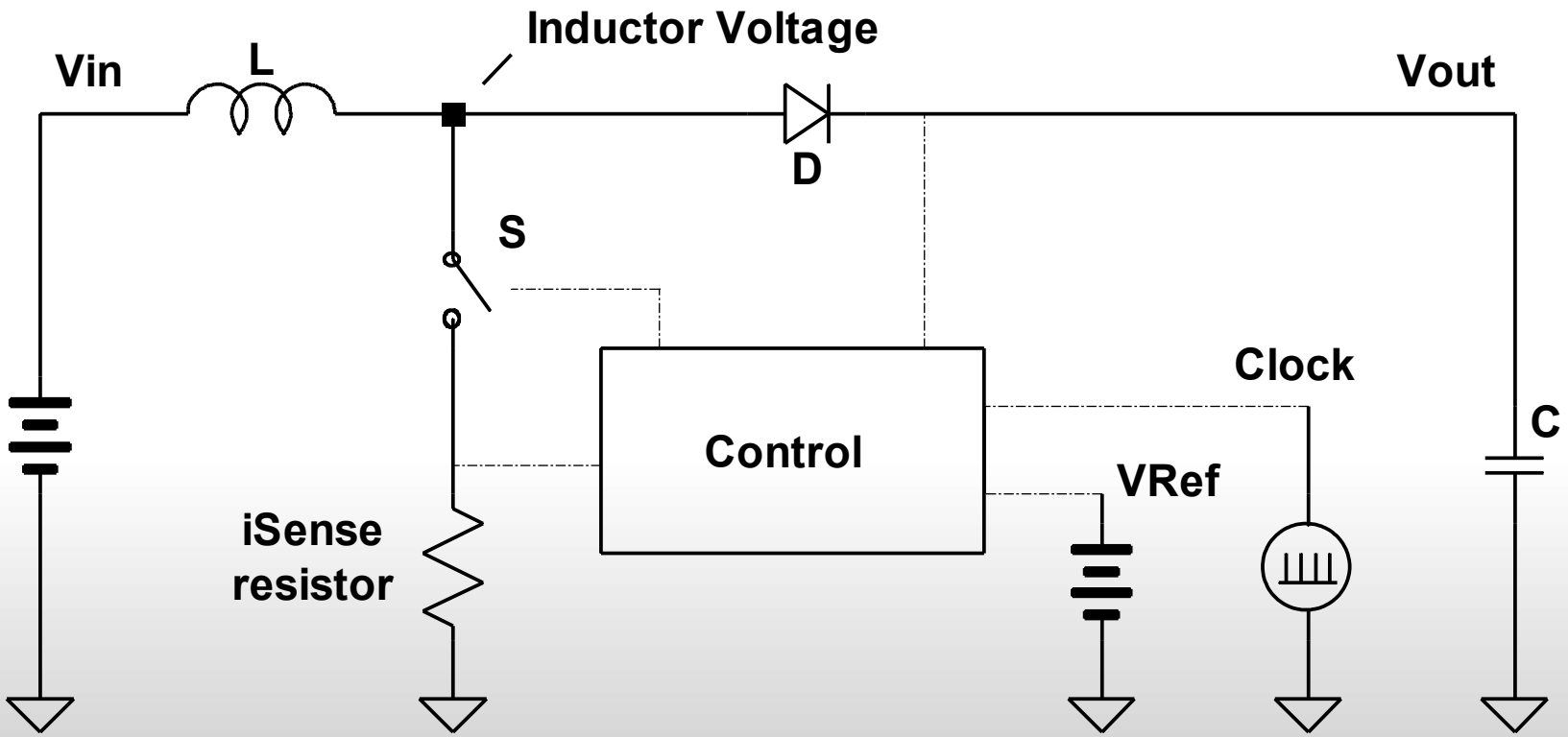
Accordingly, the capacitive energy deficit at the output is

$$KEReg - KEC$$

The energy balance point is the moment when the inductive energy is equal to the capacitive energy deficit

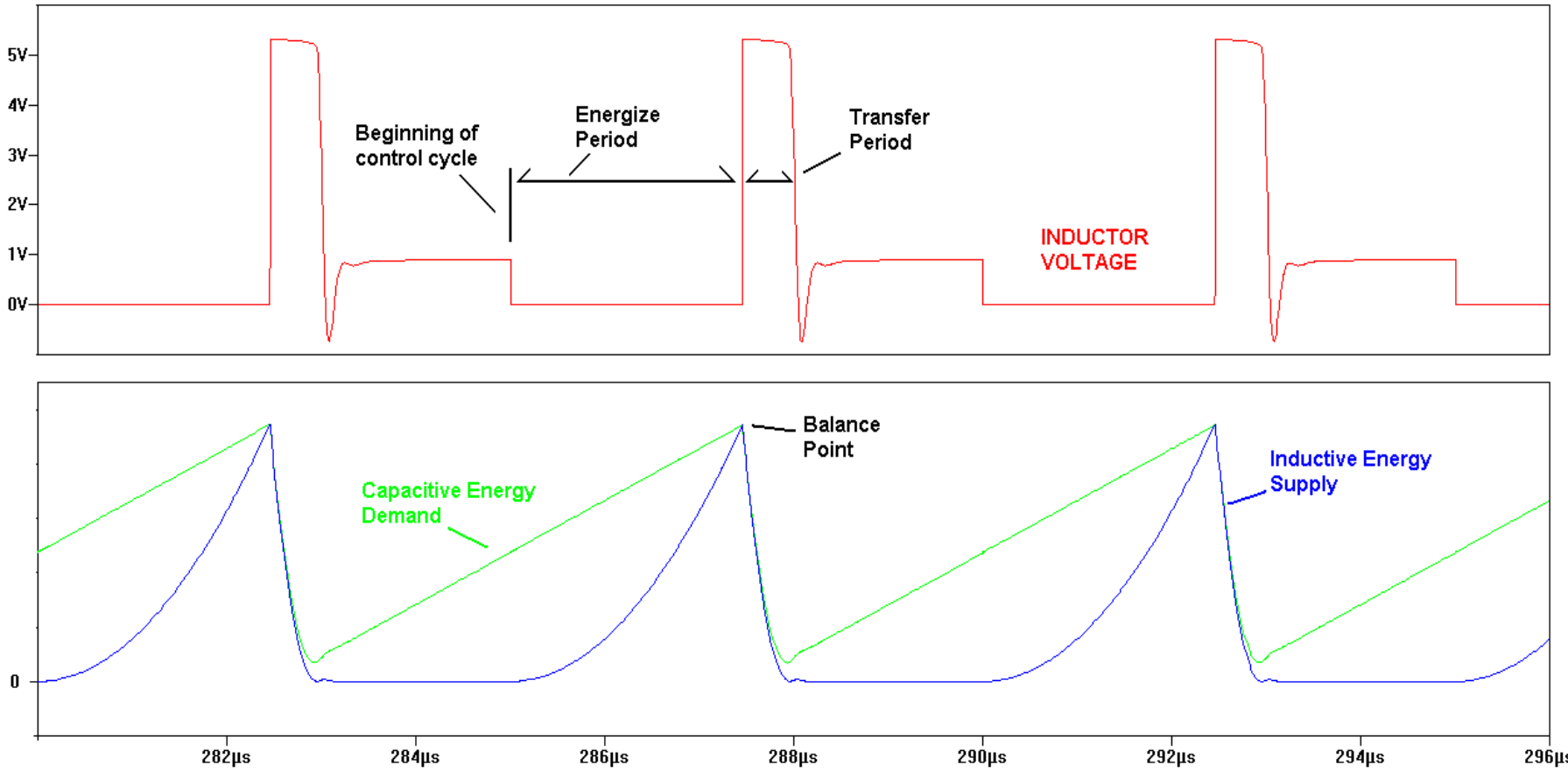
$$KEL = KEReg - KEC$$

A Simple Flyback Converter



When the balance point is reached, Switch S opens, and inductive energy is transferred to the output.

SPICE Waveforms



The balance point is when supply and demand meet.

PEB Control Loops Show Intrinsic Stability

With the balance properly scaled, the voltage on the filter capacitor will equal the regulation voltage after the inductive energy transfer completes.

In this way the predictive calculation removes the output filter pole delay from the feedback loop.

Each control cycle becomes a self-contained operation, not reliant on previous conditions.

Excellent transient response, without sub-harmonic behavior, is the direct result.

PEB allows use of theoretic minimum value filter capacitor.

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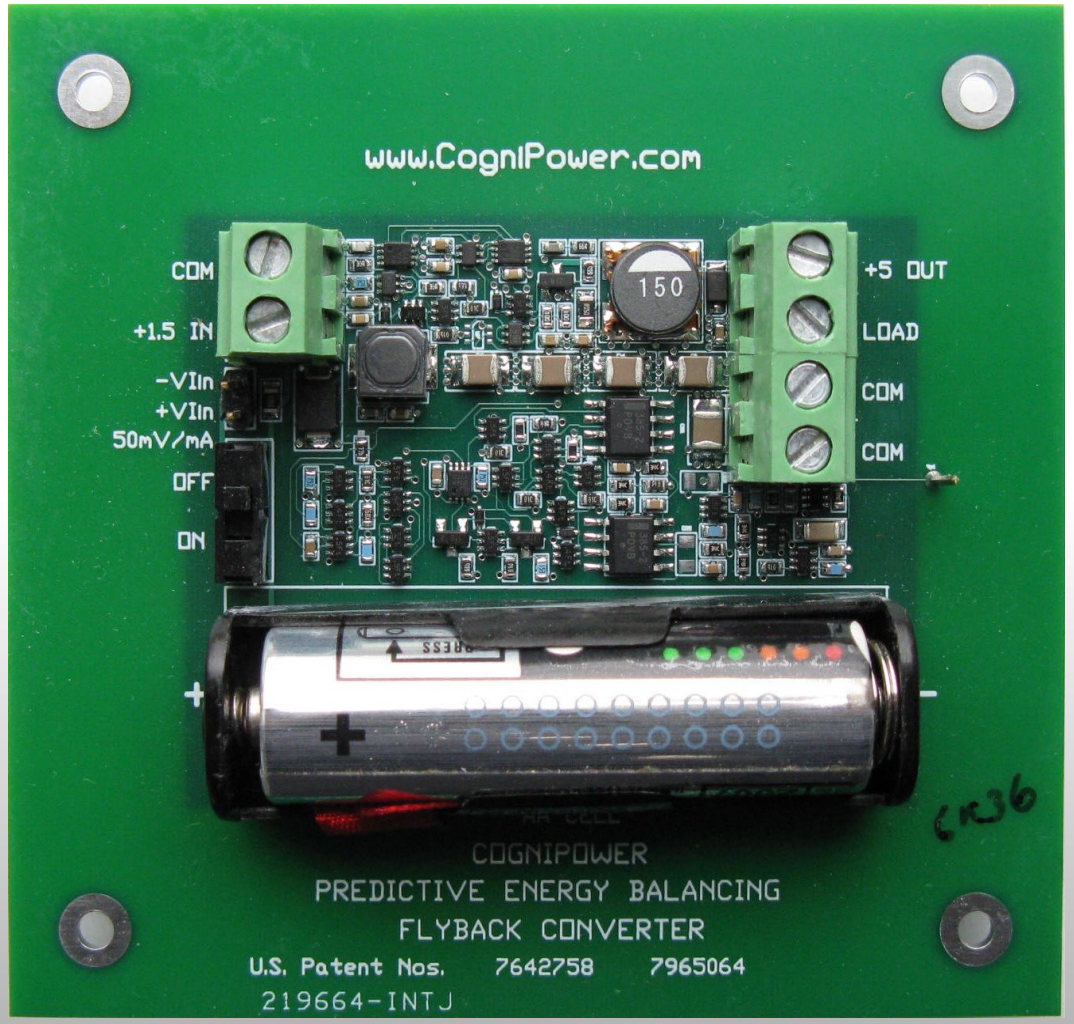
Practical Demonstration

This demonstration board is a simple flyback PEB converter producing 5 volts from a 1.5 volt battery.

The additional circuitry added to implement PEB occupies about 0.2 square inches.



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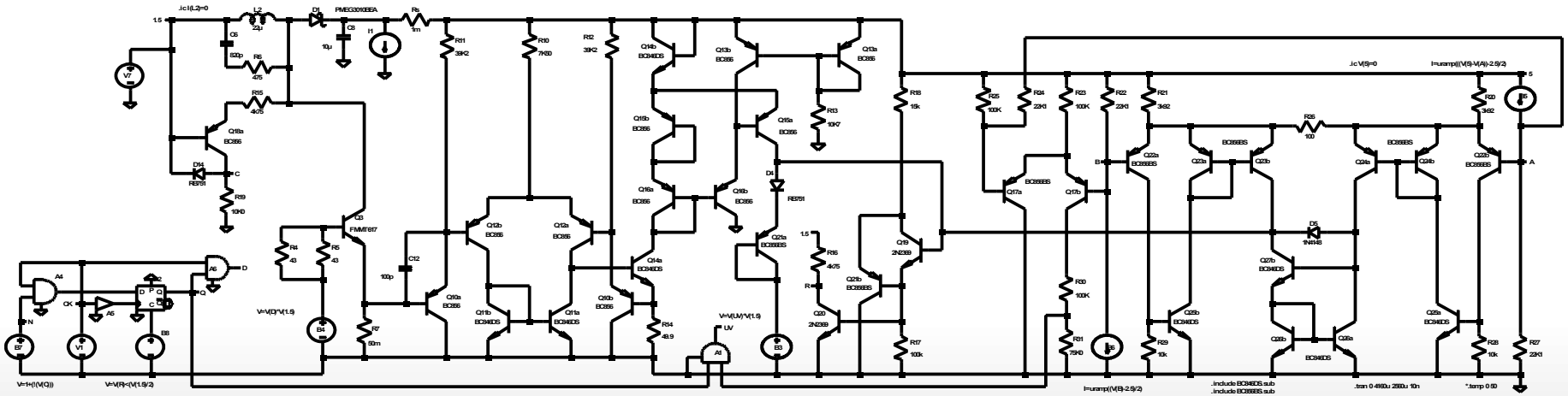
Predictive Energy Balancing Demo Schematic



The converter and calculation circuitry is implemented here using discrete analog components with a very few logic chips. The design is aimed at easy integration.

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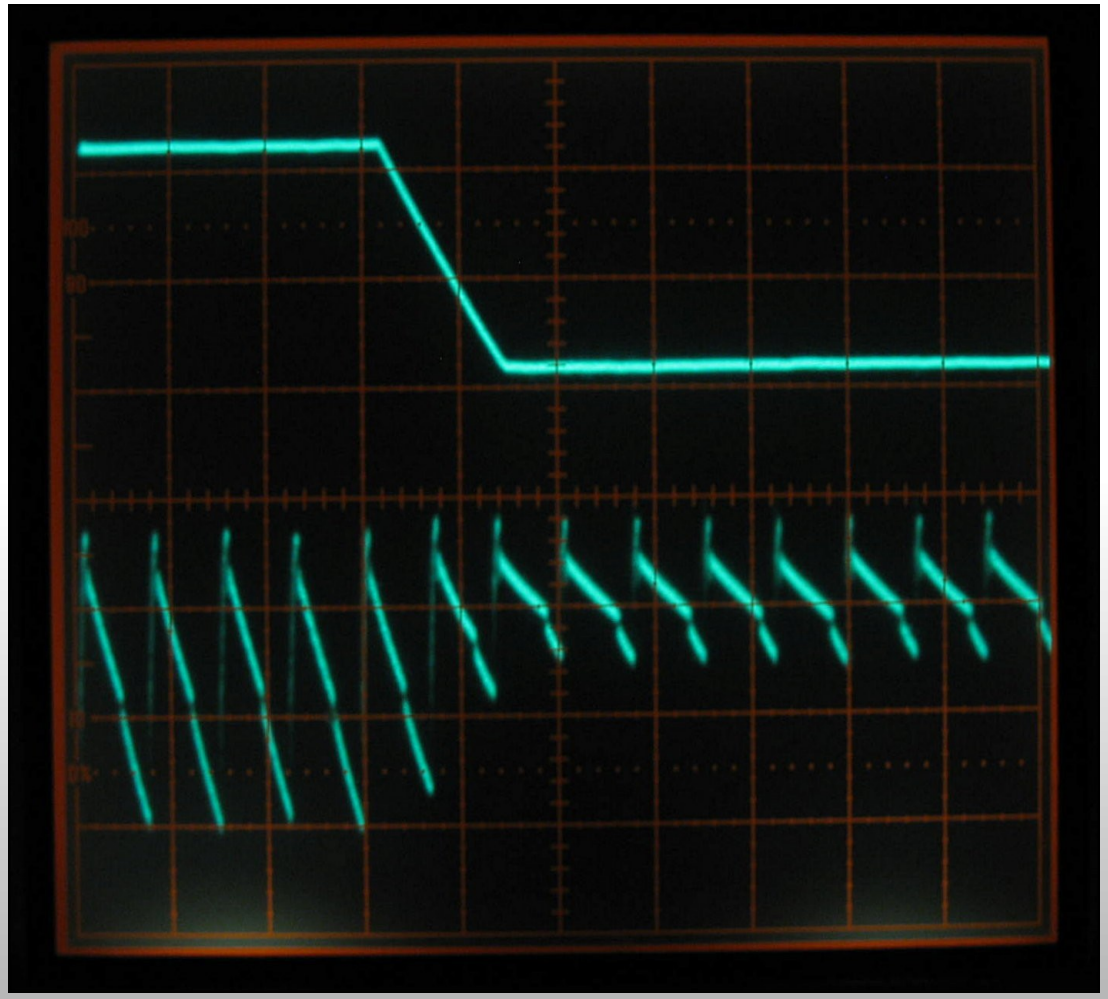
Screen Shot Showing Output Regulation

Upper trace, load current at 10 mA/div

Time scale, 20µs/div

Lower trace, output voltage at 10 mV/div



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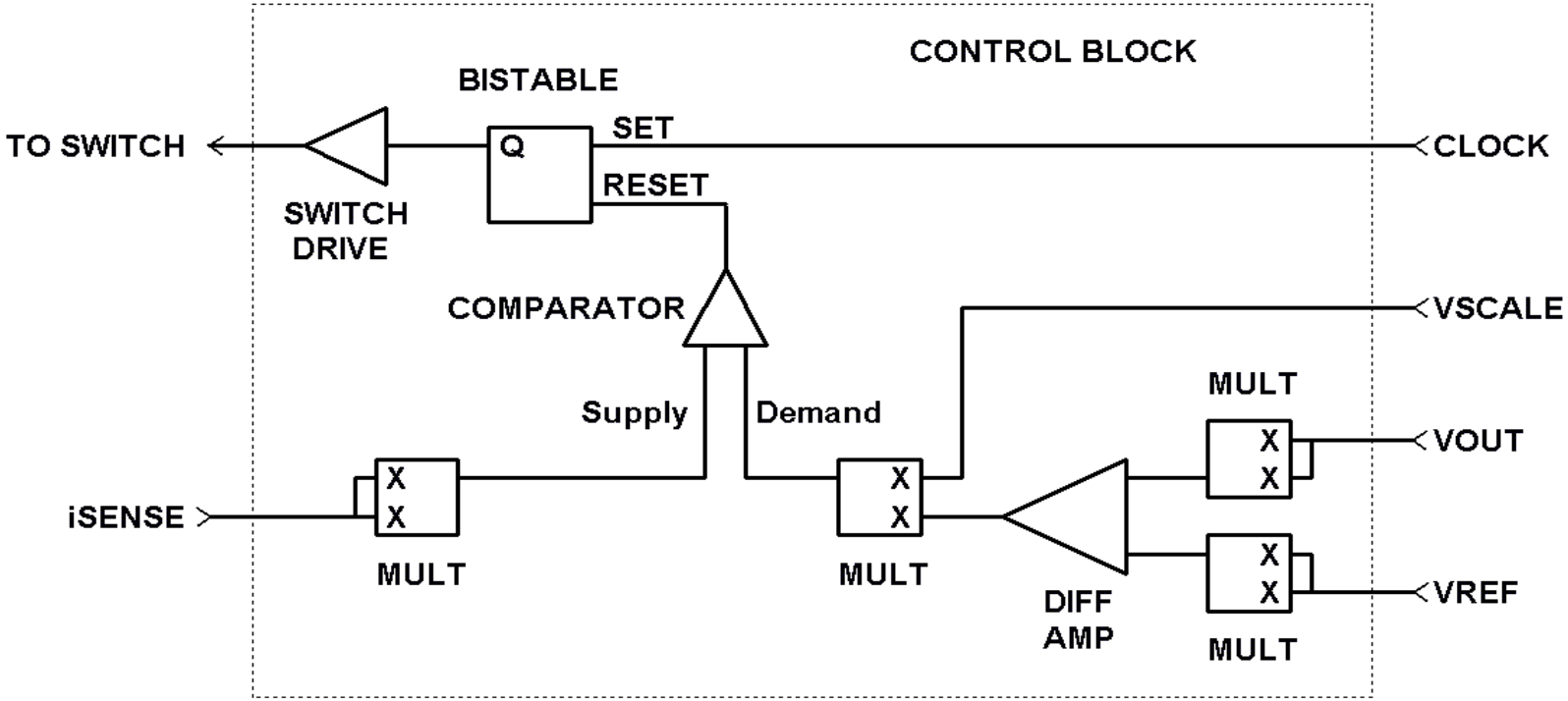
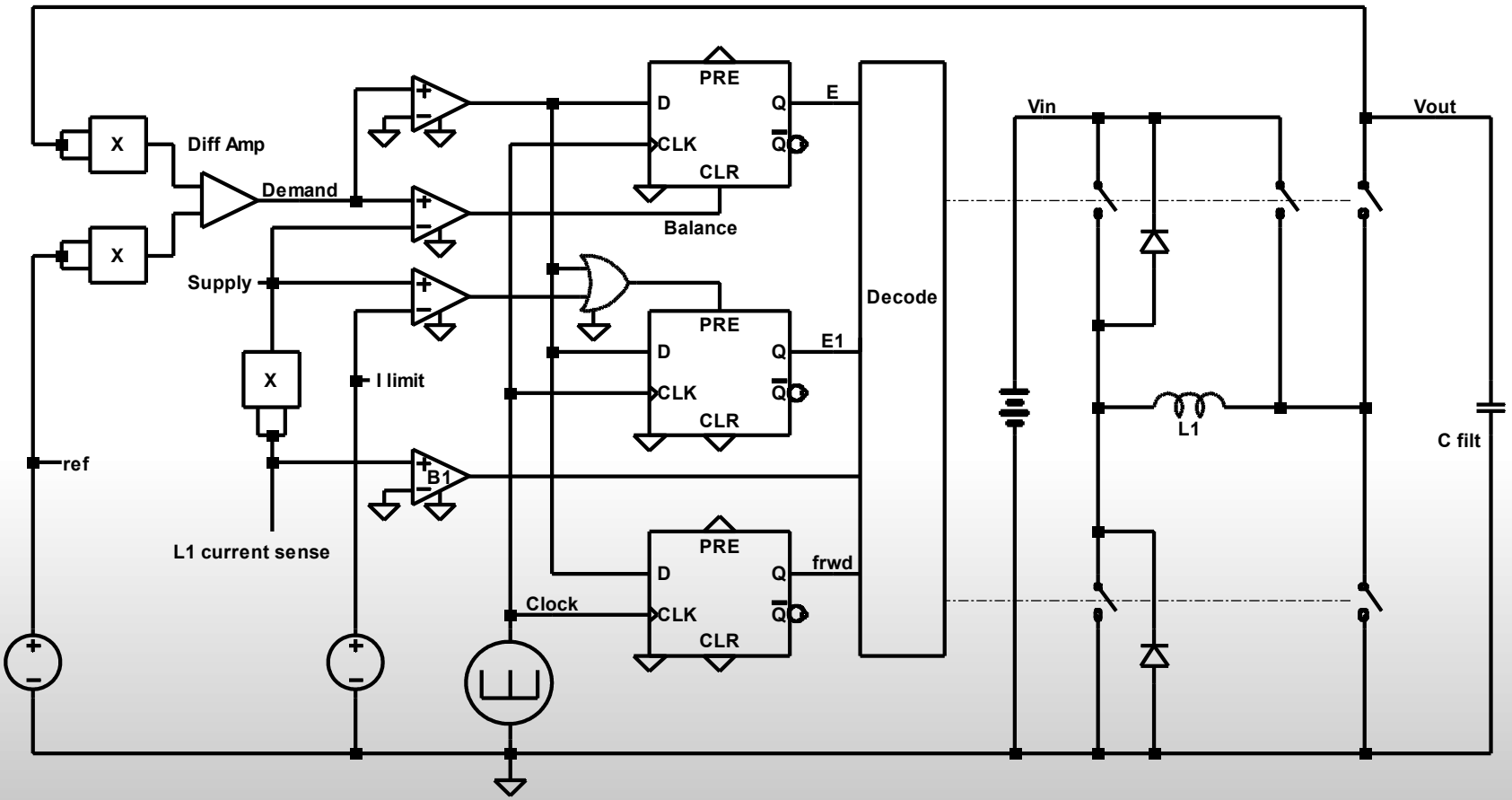
Generalization of PEB Controls



A generalized circuit block can perform the Energy Balancing calculation for a variety of SMPCs.

Bipolar Bidirectional Power Amplifier



An SMPC that can follow a changing reference is a form of amplifier.

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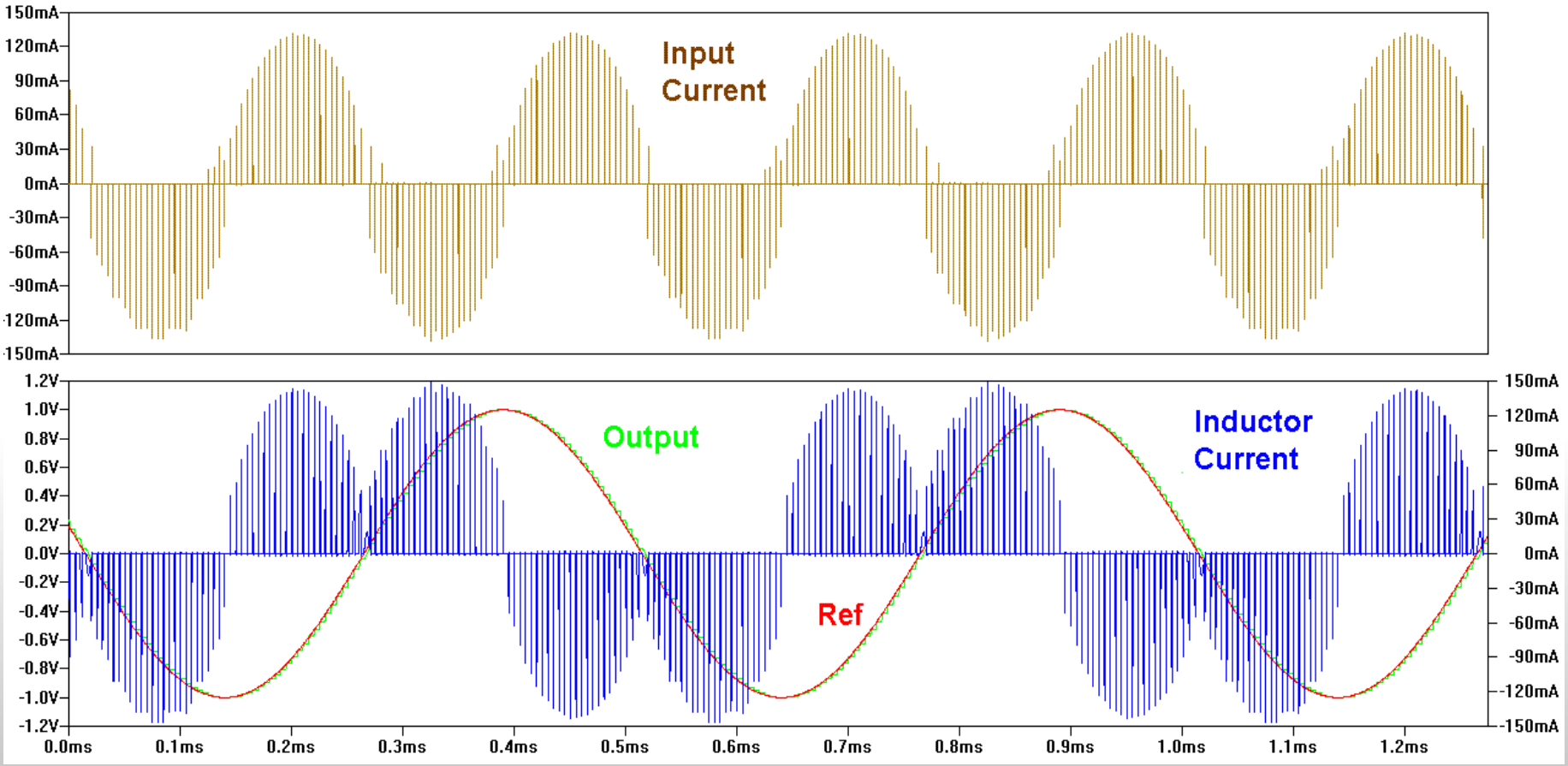
Power Amplifier SPICE Output



A bipolar output is generated from a unipolar input.

Unprecedented Efficiency

Note that the average current at the power input in the previous slide approaches zero when driving a capacitive load.

Energy is alternately moved from input to output, then, from output to input.

If the power converter is 90% efficient in both directions, .9 x .9 = .81, so up to 81% of the power for an AC output cycle could be recovered and reused.

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Why Hasn't This Amp Been Built Before?

To make such an efficient amplifier practical, Predictive Energy Balancing is the essential element.

Without PEB's ability to steer an SMPC output voltage (with a reactive load) to hit a moving target on the first try, such an amplifier would be unmanageable.

This amp is covered by four issued CogniPower Patents.

As a bonus, these amplifiers incorporate active termination, that is, they inherently damp resonances and reflections at their outputs.

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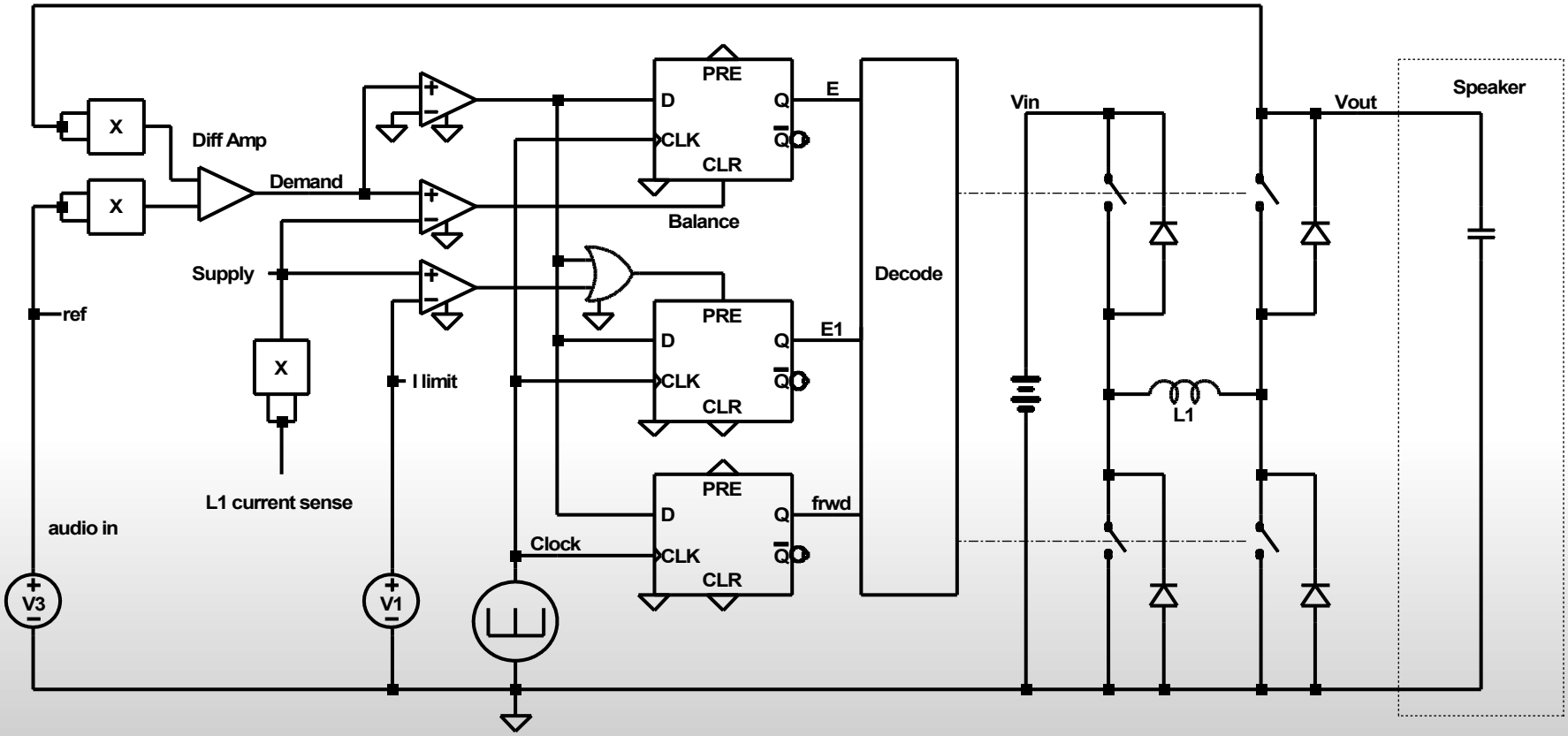
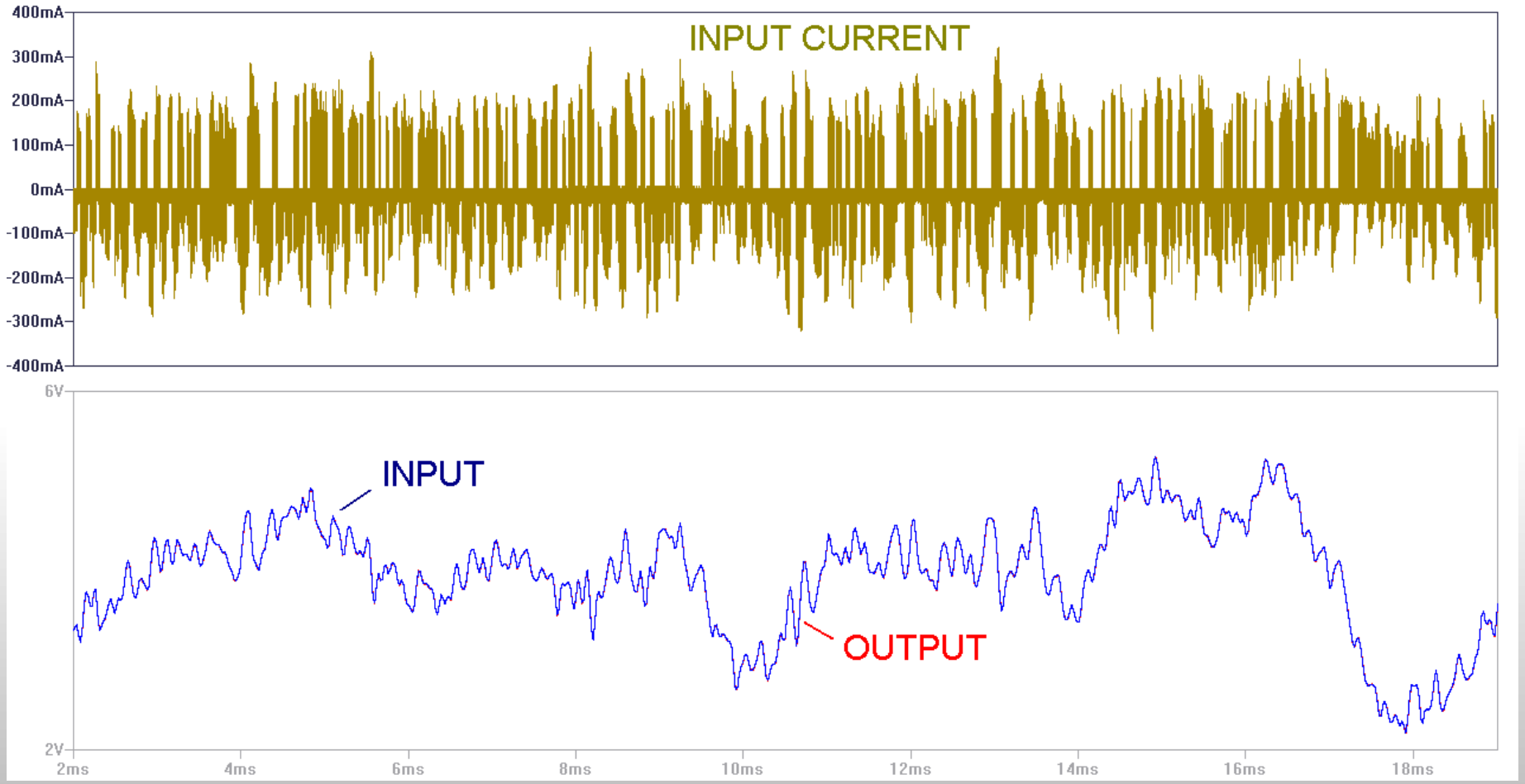
Audio Amplifier, a Related Application



Audio amplifier to drive a cell phone piezo (or dynamic) speaker more efficiently from a 4 volt battery.

Audio Amp SPICE Output



A few ms of music: Output trace hidden by Input trace.

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Cell Phone Audio Amplifier Advantages

The audio amp efficiently produces AC output from a single, unregulated power rail.

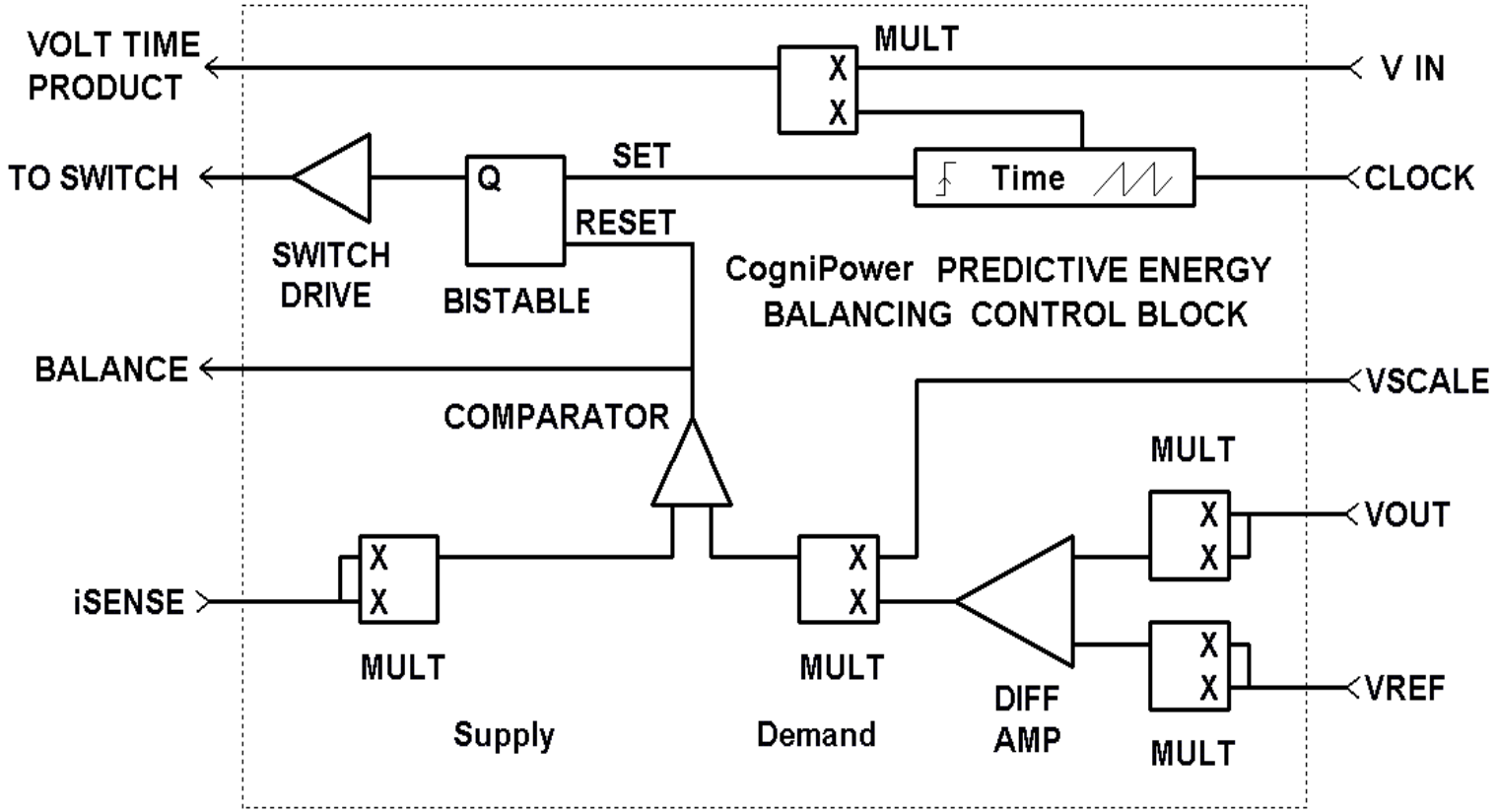
The power input current averages to near zero.

Input and output traces are almost indistinguishable.

Self-termination flattens the response curve, even with a piezo speaker having a strong resonant peak.

This bidirectional amplifier can harvest ambient energy from a piezo speaker for charging the battery.

Control Block for PEB Amplifier or SMPC



A volt time product can replace a sensed inductor current.

Other Applications

Point of Load Converters

LED Lighting

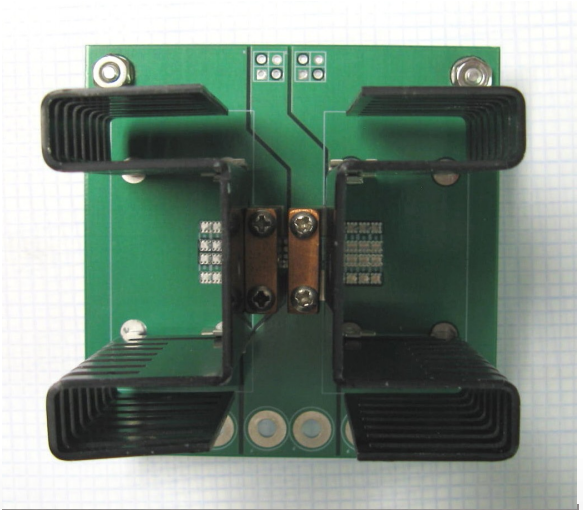
Electric Vehicles

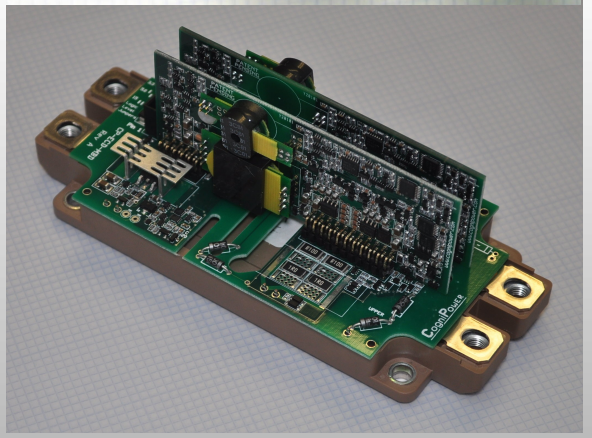
Smart Grid

Computers and File Servers

Solar Inverters

AC-AC Converters





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Related Power Converter Development

CogniPower is developing an AC-DC topology that performs Power Factor Correction and agile output regulation in which the majority of power moves through only a single stage of power conversion. Better efficiency and smaller size result.

A battery charger is also in development. Better regulation allows much smaller filter capacitors, so that small, inexpensive ceramic capacitors can replace larger electrolytic or tantalum parts. Cost and size are reduced while performance and efficiency increase.

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Questions?

CogniPower holds six issued patents, including two fundamental patents covering Predictive Energy Balancing.

Many more patents are in process for SMPC building blocks, controls, and topologies.

Predictive Energy Balancing enables more capable power converters that combine stability, agility and efficiency.

Most SMPCs don't have to make music, but extra responsiveness may provide the crucial margin of safety.

Please visit www.cognipower.com for more information.

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