



# **AC/DC Conversion with PFC**

## **Applying Compound Converter Topologies**

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**Darnell's Power Forum 2014**

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# *PFC is Increasingly Required*

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Power Factor Correction (PFC) is mandated for higher power AC input power converters.

The trend is toward tighter PFC limits on ever smaller power converters.

Existing methods require large reactive components, or else add an additional stage of power conversion.

Neither approach provides a path to smaller, less expensive, more efficient power converters with PFC.

Our answer incorporates an actively managed storage reservoir closely blended with the main power stage.

# *CogniPower Compound Converter*

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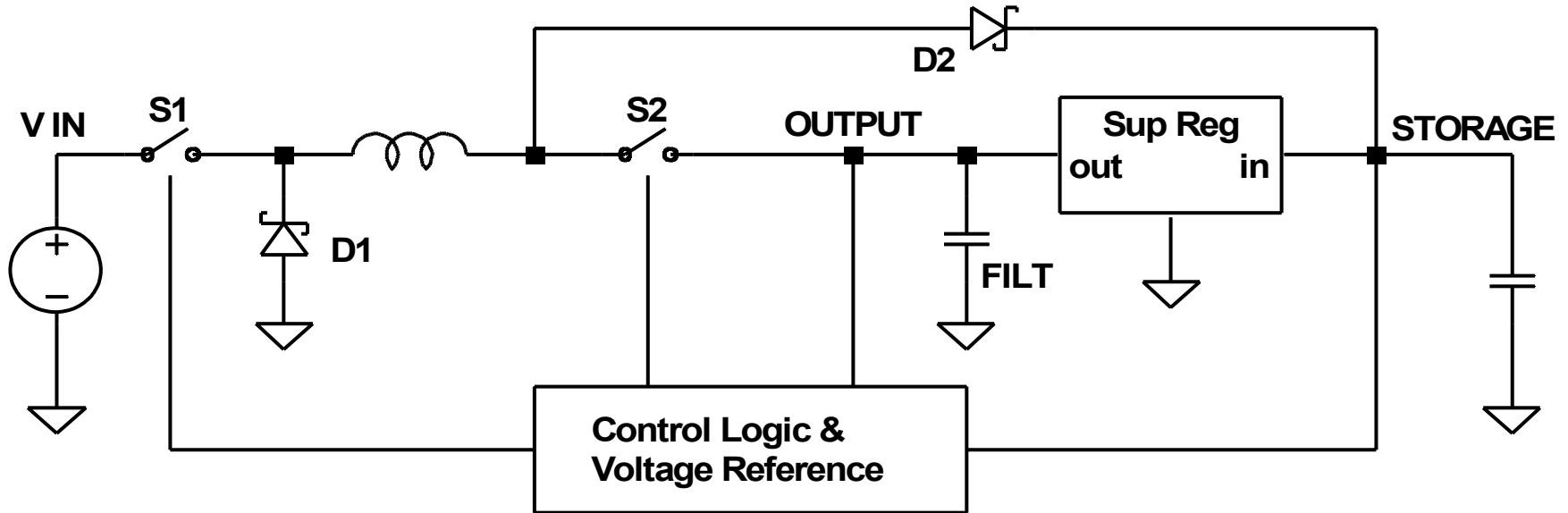
The Compound Converter topology offers agile regulation of both input current and output voltage (or current) while the majority of power passes through only a single stage of power conversion.

Advantages include better PFC, greater efficiency, smaller size, lower cost, and ease of application.

These principles can be applied to almost any AC/DC or AC/AC converter, and even extend to input current shaping for DC input applications.

The circuit requirements for a Compound Converter are surprisingly simple.

# Basic Compound Converter

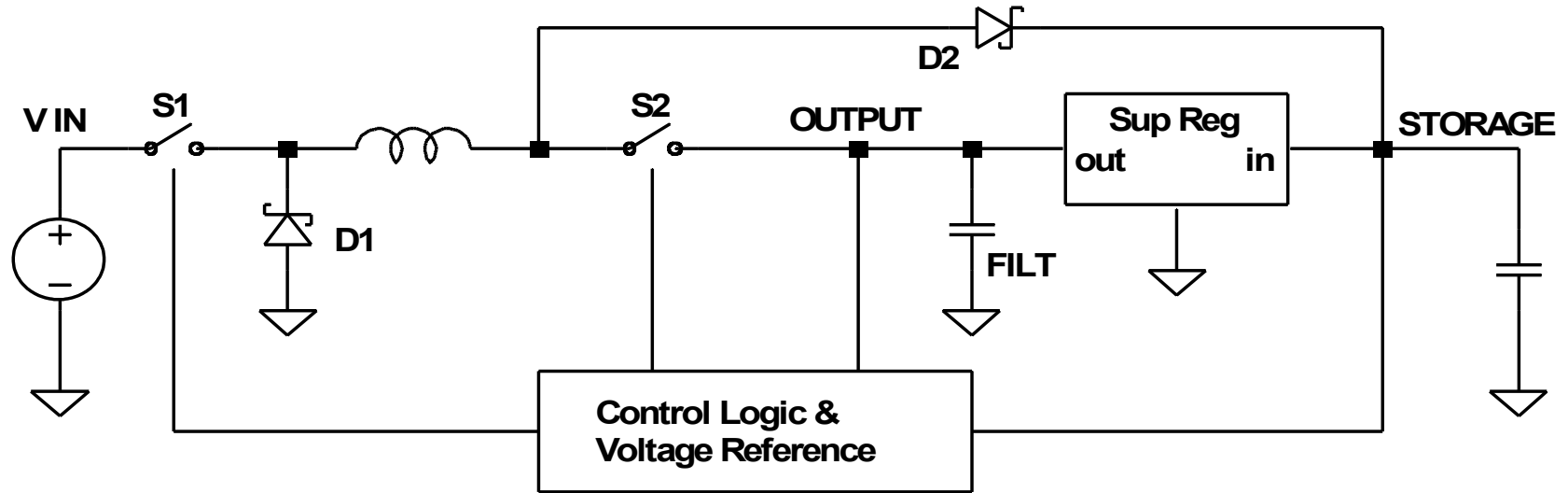


With switch S2 closed, S1 acts as an ordinary buck converter.

When S2 is opened, any inductive energy flows to STORAGE.

The Supplemental Regulator provides additional support for OUTPUT using the STORAGE reservoir as its power source.

# Basic Compound Converter Operation



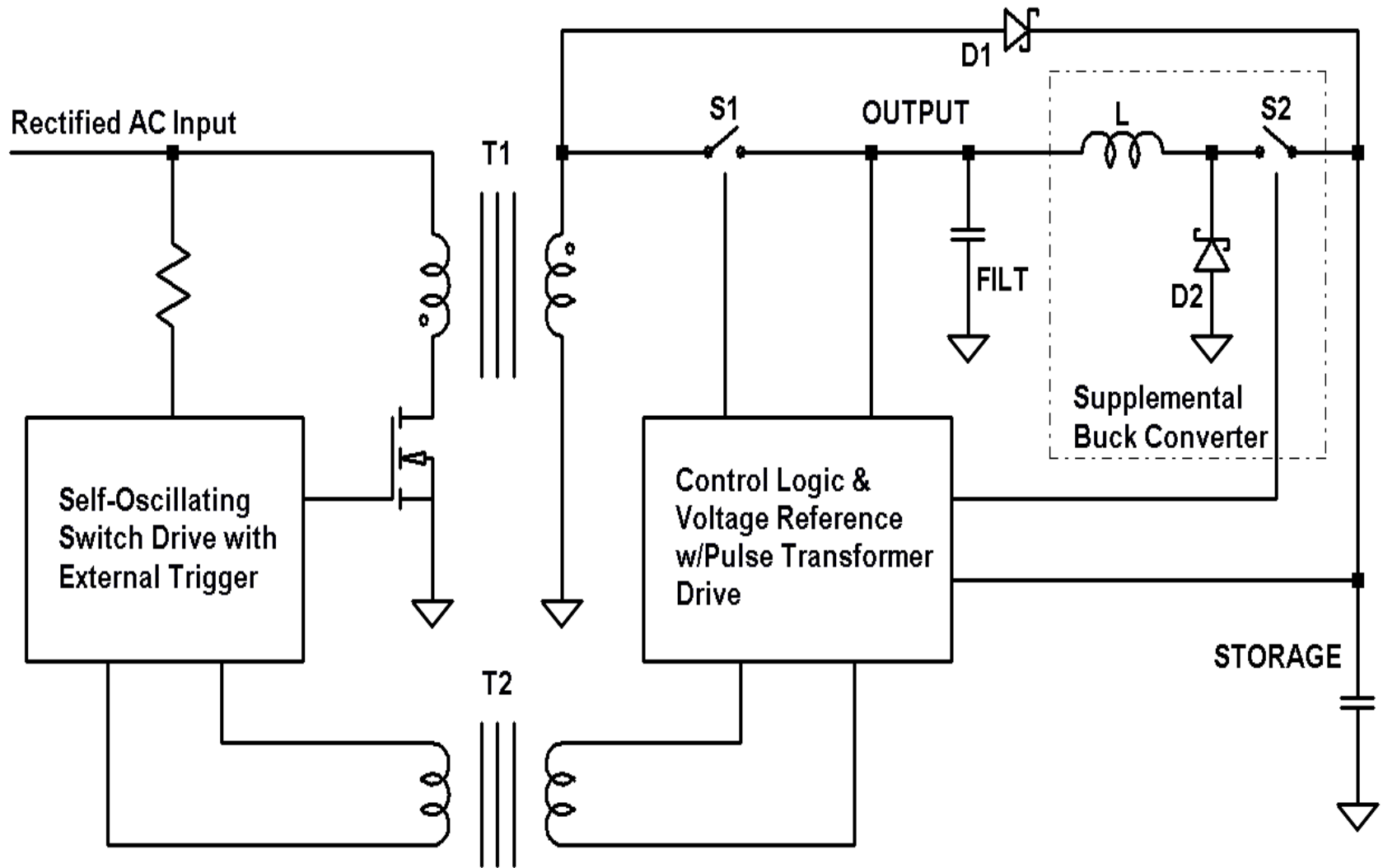
Energy can move directly from  $V_{IN}$  to OUTPUT.

Energy can move directly from  $V_{IN}$  to STORAGE.

Energy can move directly from STORAGE to OUTPUT.

With these 3 capabilities, input current and OUTPUT voltage or current can be independently regulated.

# Simple, Isolated PFC Compound Converter



# *Both PFC and Precise Output Regulation*

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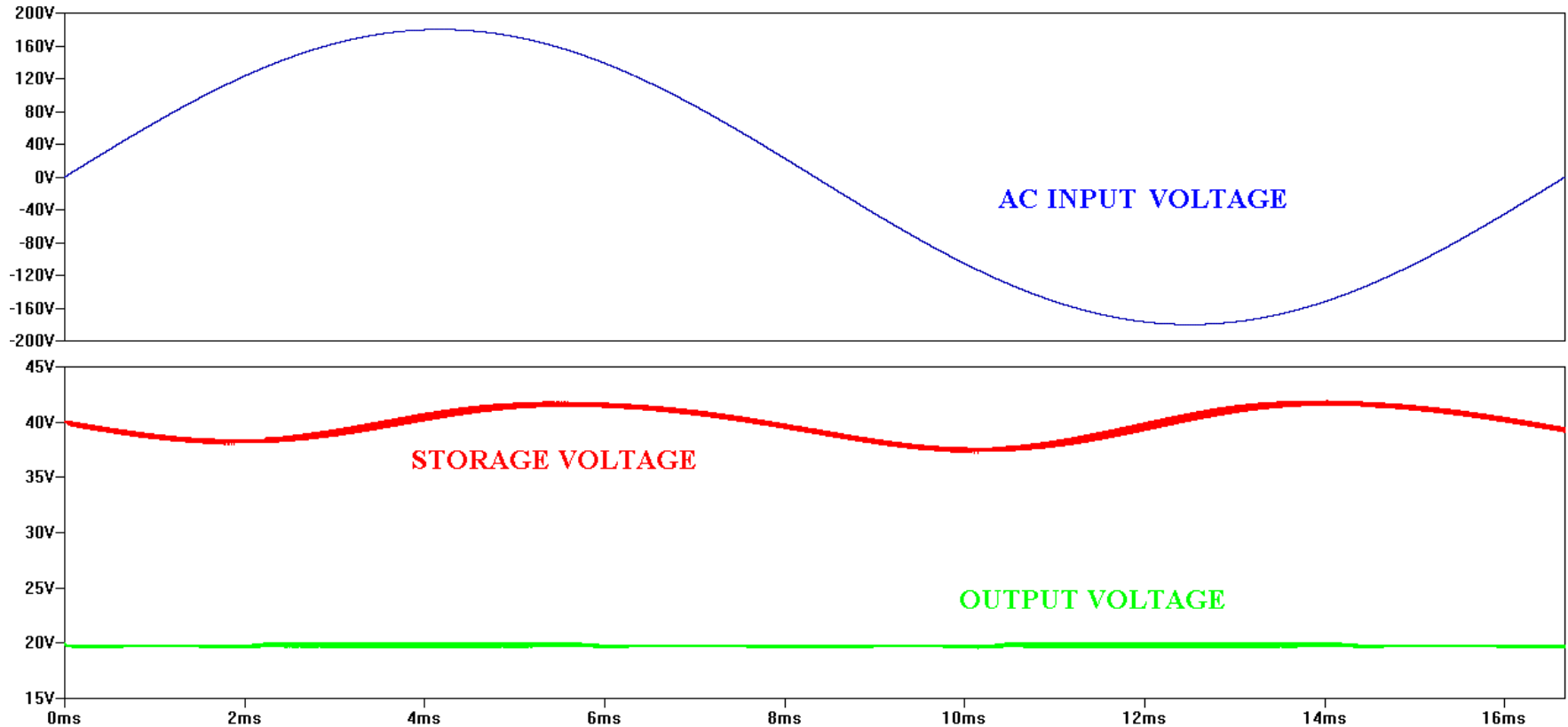
During peaks in the AC waveform, all the load energy moves through the main stage only, and surplus energy is moved to storage.

During zero crossings, the load energy is provided by the supplemental regulator, powered from the storage reservoir.

The AC side switch ON time is essentially constant during any one AC cycle, for near-ideal Power Factor.

The ON time is modulated by a slow, non-critical feedback circuit to keep the storage voltage within preset limits.

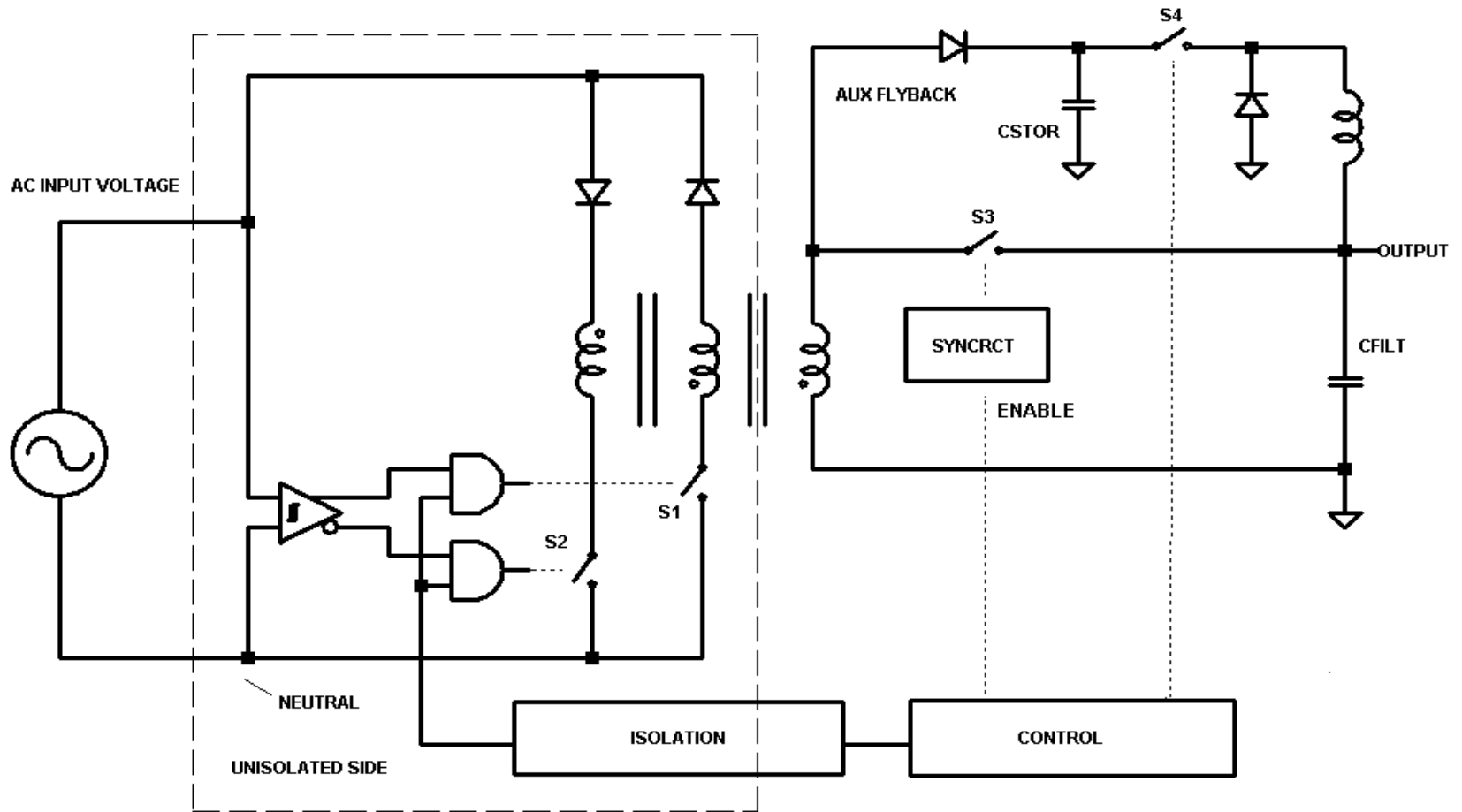
# Compound Converter Waveforms



Power losses are reduced by 25% to 50% compared to 2-stage PFC systems.

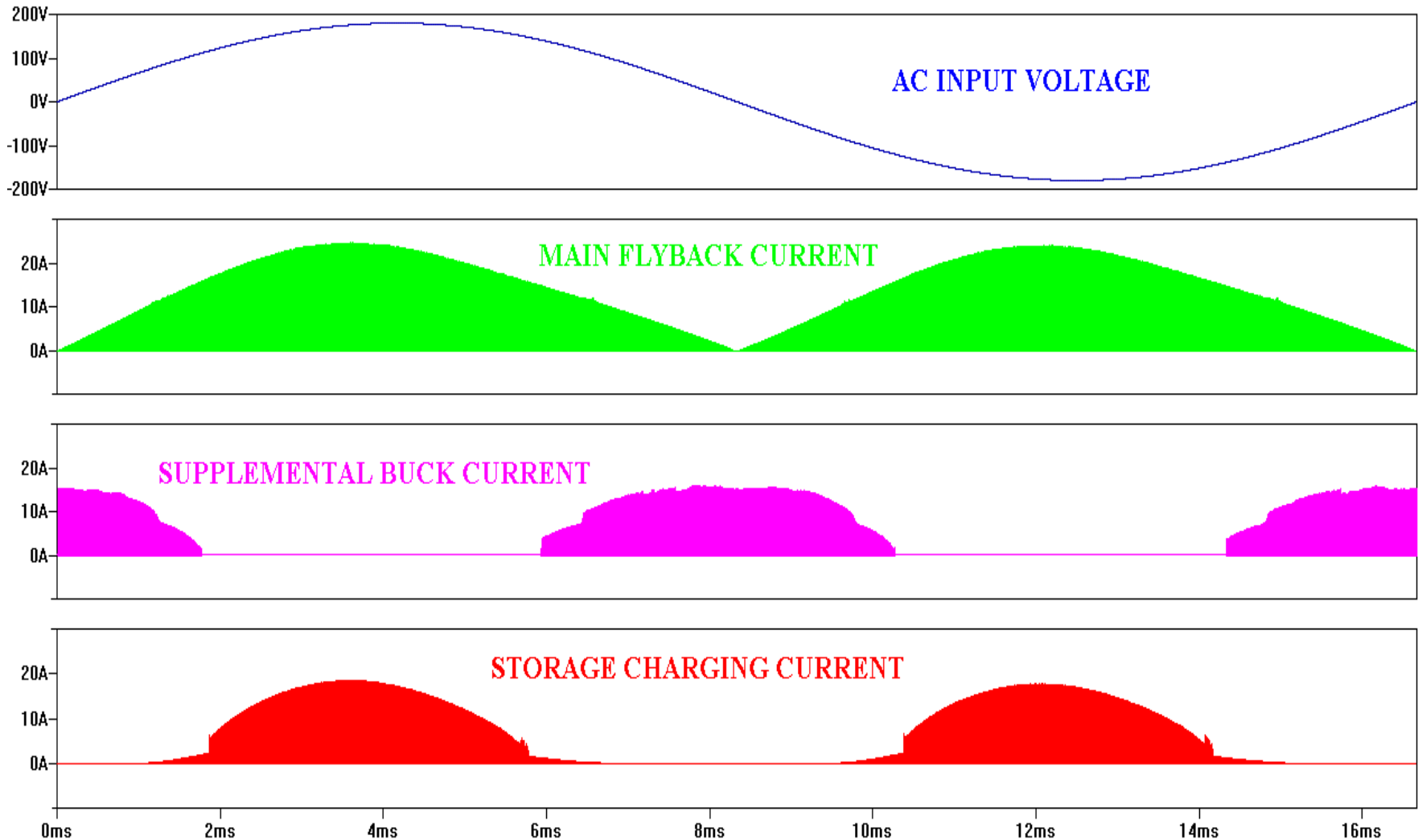


# Split Primary Eliminates Diode Bridge

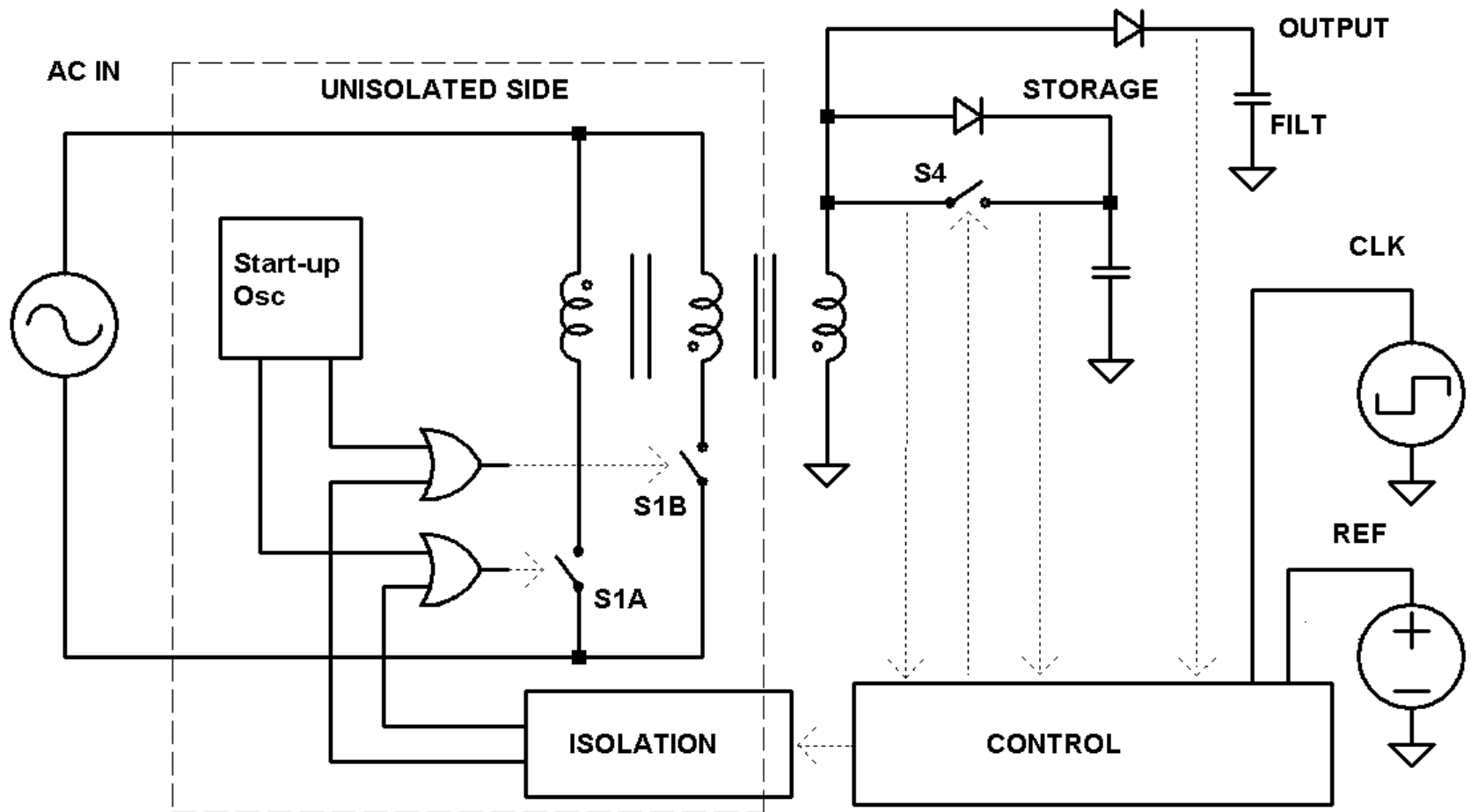


GaN switches could totally eliminate the AC-side diodes.

# Sample Compound Converter Waveforms

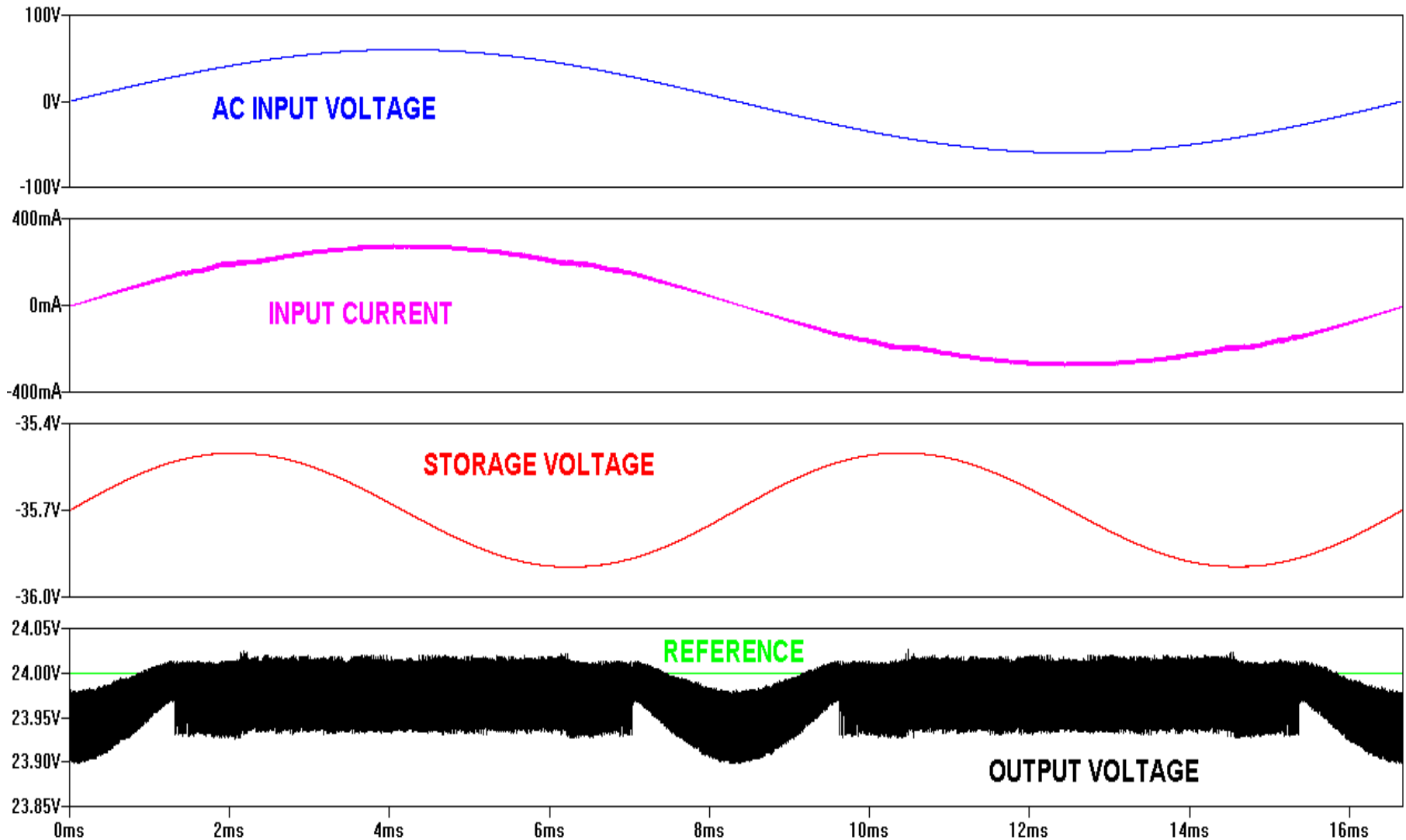


# *An Additional Inductor May Not Be Needed*



Here, a positive OUTPUT pairs with negative STORAGE.

# Waveforms of Preceding Power Converter



# *Waveforms Described*

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The lightly filtered AC input current is seen to be in proportion to the input voltage for best PFC.

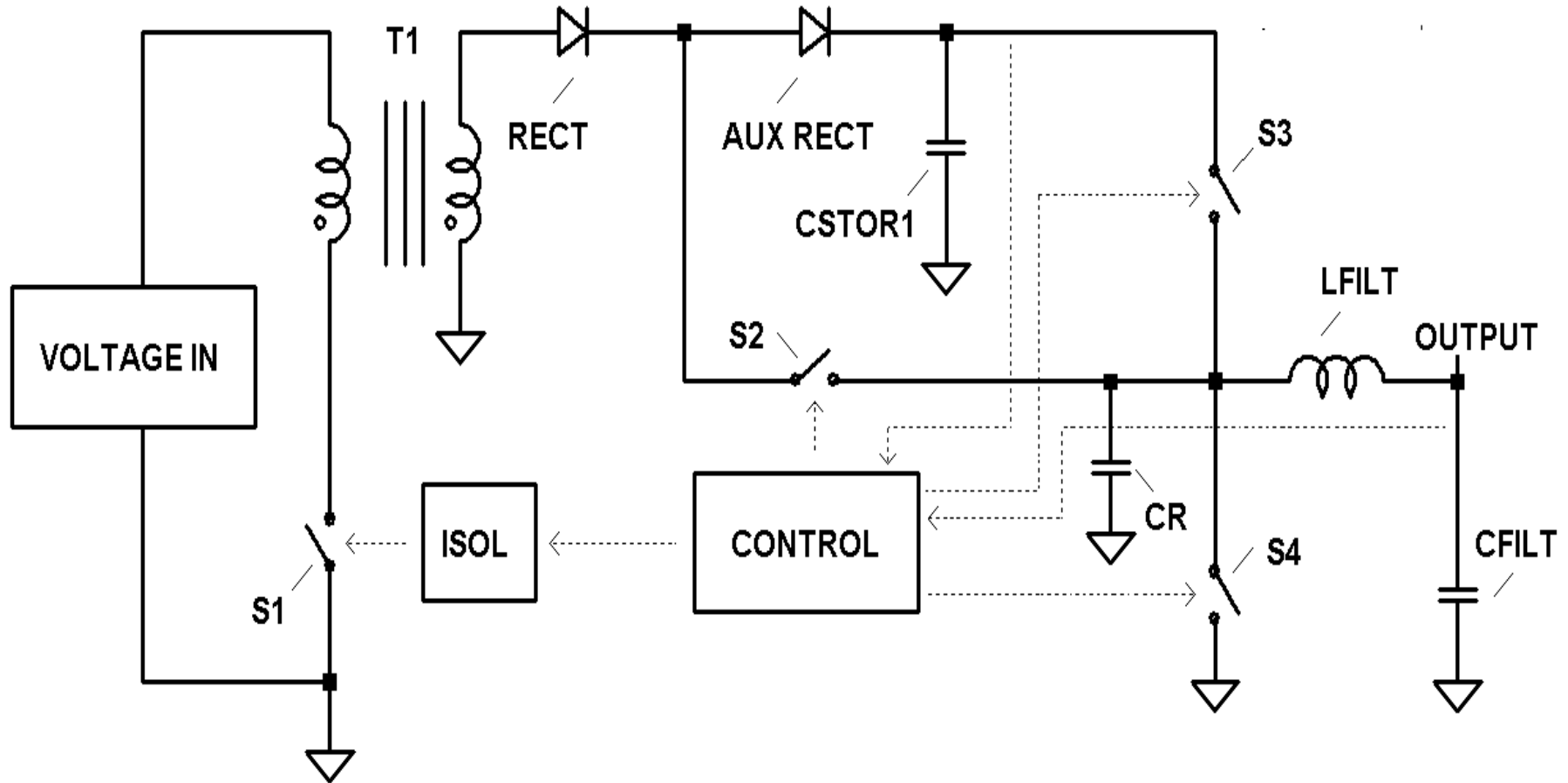
As with other Compound Converters, the storage voltage varies at twice the input frequency.

The supplemental power path here regulates to a slightly lower voltage to maximize efficiency.

This 24 volt converter runs at 200 kHz with only a 20  $\mu$ f filter capacitor, and supporting a 50 ohm load.

The regulation plus ripple envelope is just over 100 mV.

# Quasi-Resonant Compound Converter



# *Other Variations*

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Power amplifier versions offer agile response with excellent PFC, including bipolar, bidirectional options capable of frequency conversion or motor drive.

Multiple regulated outputs can be generated.

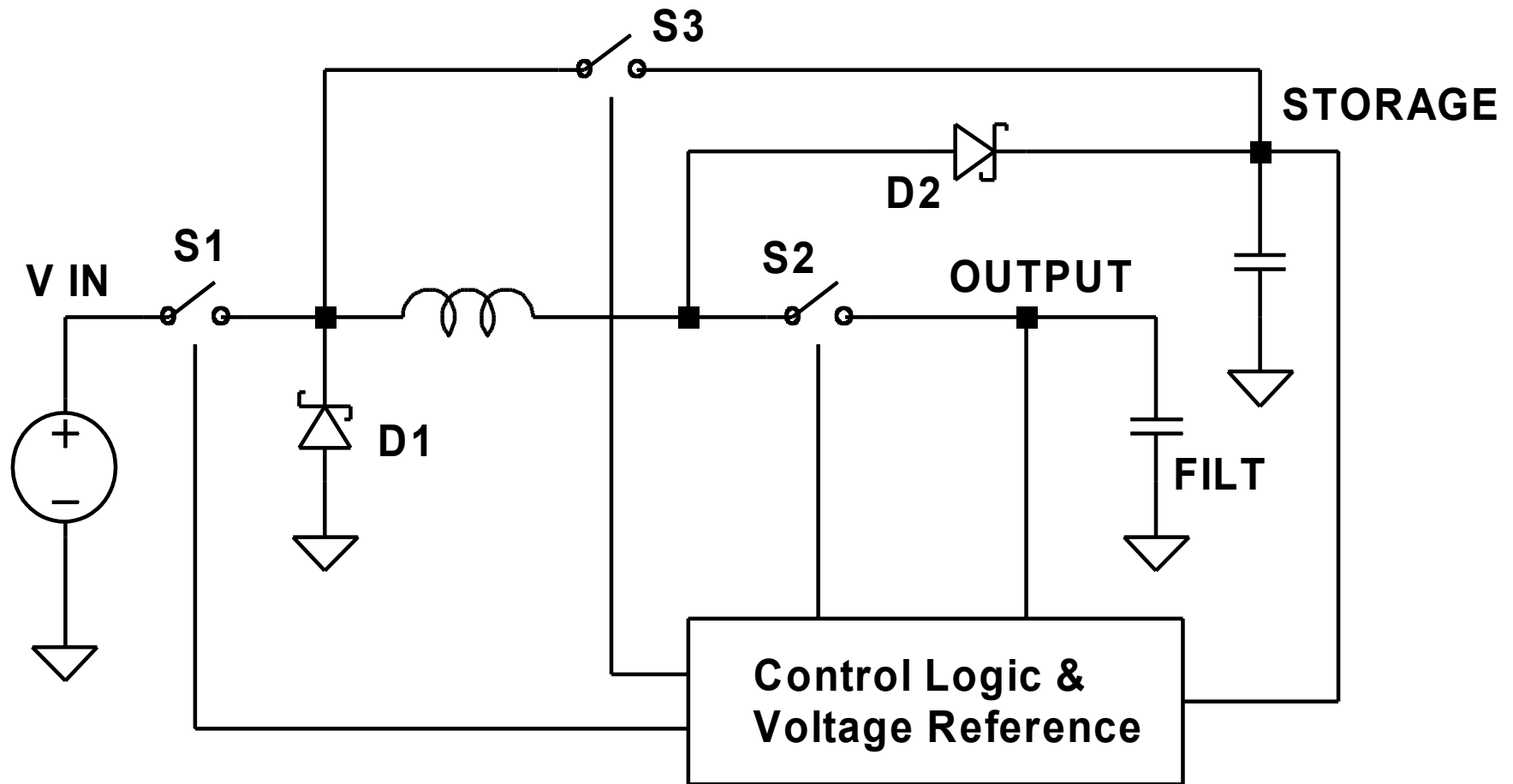
A converter can pass into and out of Continuous Conduction Mode while maintaining excellent PFC.

Transformers can be simple, or with split windings.

Some variations take good advantage of GaN switches.

The same structures also serve for input current shaping in DC input systems.

# *Re-using One Inductor for Two Functions*



This DC input topology has some unusual capabilities.



# *Compound Buck Versatility*

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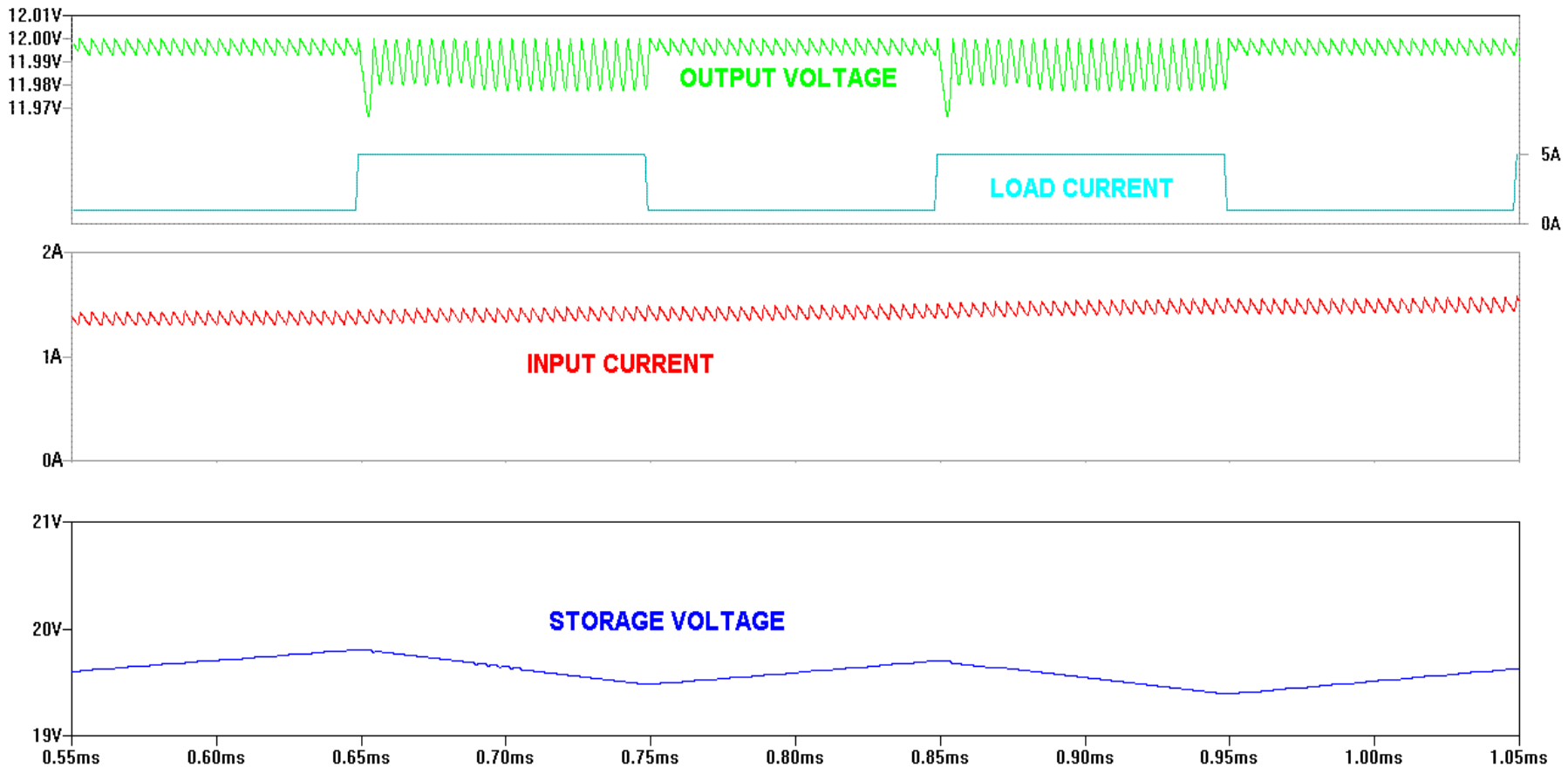
The Compound Buck Converter above can operate as a conventional buck converter with equivalent capabilities and efficiency.

It will also regulate the input current to remove sudden changes due to load variations.

That ability can drastically reduce the demands on a DC power distribution bus, and can greatly reduce the amount of input filter capacitance required.

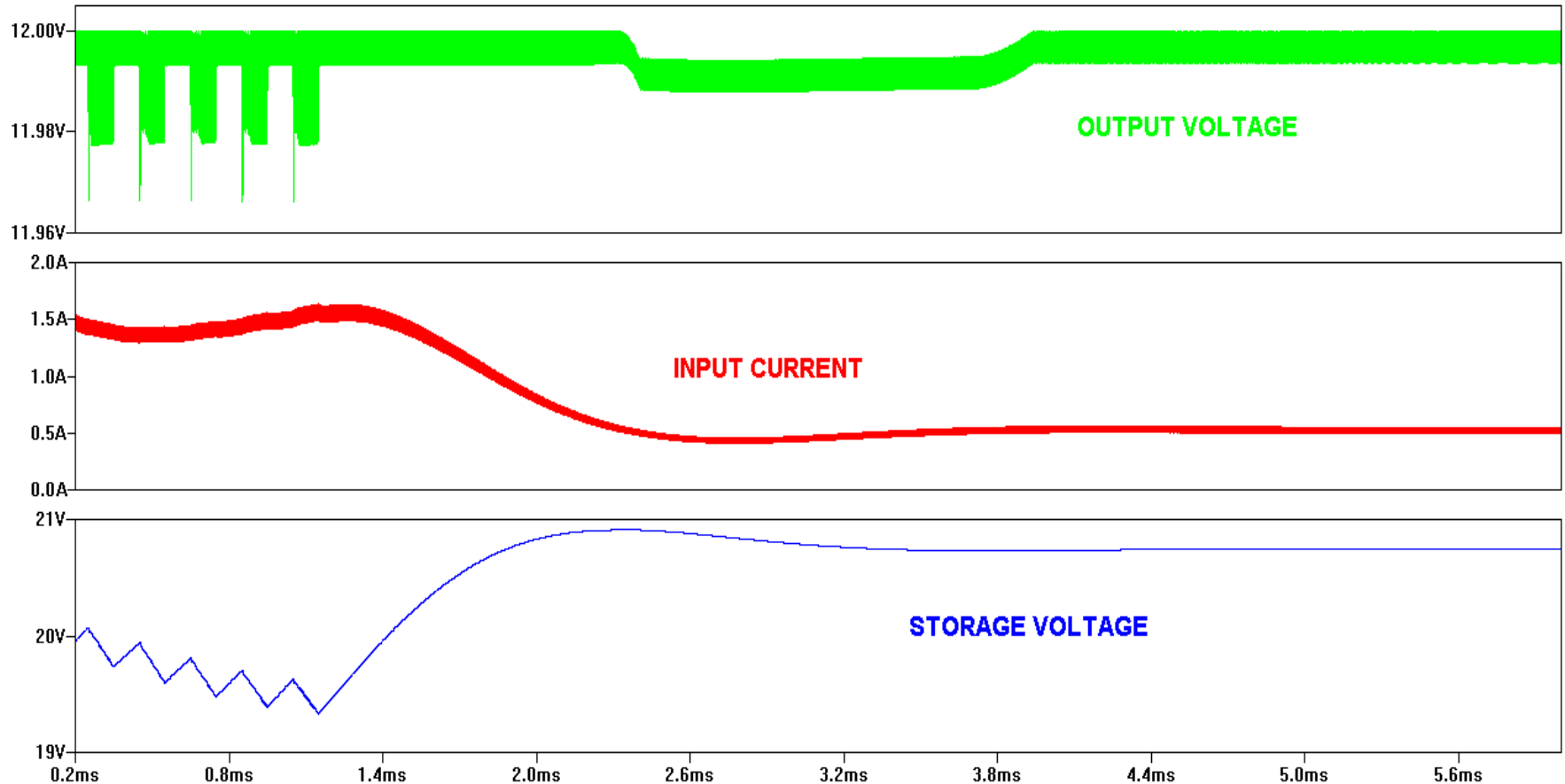
The waveforms to follow show an instantaneous load change from 1 to 5 amps while the input current changes only slowly.

# DC Input Compound Converter Waveforms



The input current changes slowly to obtain the desired average storage voltage—here, the target is 19-21 Volts.

# DC Input, Return to Steady State



Once the load disturbance subsides, the storage voltage stabilizes, and all the power moves through only 1 stage.

# *When to Regulate DC Input Current?*

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One example is in handheld, battery-powered devices, because their batteries have a relatively high source impedance.

Dynamic loads are tamed by re-regulation, decoupling, and through the use of large filter capacitors.

The small, actively managed storage reservoir of a Compound Converter can reduce interactions, improve efficiencies, and reduce size and cost.

Other examples include on-chip power distribution for System on Chip (SoC) applications, and photovoltaics, in general.

# *What Do These Supplies Have in Common?*

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All these power converters can move energy from input to output, from input to storage, and from storage to output.

Bidirectional versions can also move energy from the output to storage.

Less than half the total power converted need pass into and out of storage, providing a 25%-50% reduction in power losses.

Efficiency actually improves at lower loads.

All these power converters can independently regulate input current and output voltage or current.

# *Patent Pending*

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The Compound Converter patent application has been ruled allowable by the European Patent Office, and should issue in due course in both the EU and the US.

It will join CogniPower's 13 issued patents, and 3 more patents in the process of issuing at this writing.

Another, more recent, patent application covers extensions of the fundamental Compound Converter concept.

Including pending patents, the CogniPower portfolio presently stands at 23 patents.

# *Other Patents and Pending Projects*

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**Predictive Energy Balancing** is a superior technique for controlling switched mode power converters. Predictive controls are inherently stable and are so general as to improve almost any power converter.

**Low load efficient wall adapters** use under one milliwatt of no load power. That enables unheard of low load efficiencies, like 85% at 1% of full load. These wall adapters are designed to compete on price with much less efficient products.

**Inductorless, 95% efficient unisolated AC/DC supplies** suitable for bias power and LED lighting.

# *Compound Converter Applications*

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LED Lighting, AC or DC Input

Battery Chargers

Uninterruptible Power Supplies

POL Regulators

Renewable Energy

AC Motor Drive

Computer Power, from Laptops to Servers

*Questions?*

[www.cognipower.com](http://www.cognipower.com)