Monolithic integrated galvanic isolation enabling energy management in Power over Ethernet applications

John Camagna

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Power Management Evolution

- **Bag of chips / Low efficiency**
- **Difficult to design**
- **Component level focus on efficiency**
- **No system view optimization**

- **System level integration**
- **High system efficiency**
- **Network management**

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**Green Power** (components)

- **Bag of chips / Low efficiency**
- **Difficult to design**

**Network Based Energy Management**

- System level integration
- High system efficiency
- Network management

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Energy Efficiency

Savings (Energy, Costs and Space)
Motivation for Network based Energy management

- “Scalar” power management is producing diminishing returns
  - Optimizing Vin/Vout efficiency and light load operation is no longer enough.
  - Communication is necessary between CPU and power supply system for further innovation
  - A system that can turn itself on/off when needed will always beat the best no-load architecture.

- System controllability/observe-ability become much more valuable with energy management
  - DC-DC power supply is usually a black box to the system architect.
  - Power supplies must have the ability to efficiently track the load conditions

- Spatially distributed power supplies require isolation
  - Ground loop: 600V of earth ground variation is possible within 100 meters
  - Safety: Cable cross/cable short to high voltage power cables
  - EMI

  Communication across the isolation barrier is essential to create a network power supply
Power over Ethernet
IEEE 802.3AT
Power over Ethernet

- Power supplied at the switch
- SELV
  - cable does not have to be installed by a licensed electrician
  - Existing cable plant can be used
- 100M cable can act as both a transmit/receive antenna
- 1500Vrms isolation required between Ethernet cable and switch or client circuitry
- Major applications are
  - IP phones
  - IP cameras
  - WLAN
Legacy Approach: “Bag of Chips”
Traditional PD power supply circuit design

- Inefficient power design
  - Multiple power losses in components & interconnections

- Components loosely tied together
  - Limited functionality

- Additional power loss across isolation barrier

- Opto-couplers: reliability concern

- Isolation barrier prevents integration of primary and secondary side circuits
Isolation in Silicon

• Creates ability to communicate over the Isolation Barrier
• Enables end-to-end digital power control by the system architect
• Opens significant integration possibilities
  – Most functions can be implemented in one integrated circuit
• Eliminates significant power loss

No Opto or Pulse Transformer required for feedback
Integrated Galvanic Isolation
Galvanic isolation implementation

- **Requirements**
  - POE: 1500Vrms isolation
  - Offline supplies 3000-5000Vrms
  - Medical > 5000Vrms

- **Dielectric strength of SiO2 ranges from 200-1000V/um**
  - Cost effective capacitors are in the fF range
  - Signaling levels are tiny
Noise Immunity

- Typical POE supplies can switch up to 20A
  - Causes large inductive switching events
  - Large voltage/current surges can be seen across the barrier

- Radiation
  - 100m cable forms a very effective receiving antenna
  - FM/AM/WLAN can and does couple very effectively into isolation circuitry

- Isolation modem must reject these noise sources
  - balanced circuitry
  - Active noise rejection circuitry
  - Error correction
Latency & Fault Protection

- Low latency is required for
  - Fault protection
  - Low phase margin degradation of control loop

- Bit error in the modem can translate into a broken power supply
  - Multiple redundant fault protection circuits
Modem Architecture

- Embedded error correction
- Encoding/decoder
- Driver/reciever
Architectural improvements
Full control of primary/secondary FET’s

Superior Efficiency across varying loads

<table>
<thead>
<tr>
<th></th>
<th>Diode Rectification</th>
<th>Winding-based Sync. Rectification</th>
<th>Sync. Rectification</th>
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</thead>
<tbody>
<tr>
<td><strong>Light Loads Efficiency</strong></td>
<td><strong>Good</strong> performance</td>
<td><strong>Poor</strong> performance due to FET overlap</td>
<td><strong>Good</strong> performance</td>
</tr>
<tr>
<td><strong>Heavy Loads Efficiency</strong></td>
<td><strong>Poor</strong> performance due to diode conduction losses</td>
<td><strong>Good</strong> performance</td>
<td><strong>Good</strong> performance &gt;90%</td>
</tr>
</tbody>
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![Diagram of Diode Rectification, Winding-based Sync. Rectification, and Sync. Rectification](image)

**AS1834 GreenEdge Efficiency Improvement**

Poe 48Vin - 5Vout

- AS1834_GreenEdge
- Diode_Rectification
- Xfrmr_Sync_Rect

>90% Efficiency
EMC & Noise Control

- Selectable Spread-spectrum clocking on all PWMs
  - Primary & Secondary PWM synchronization across Isolation barrier
  - Reduces Power Supply Spectral Noise >15dB
- Deterministic PWM Clock phasing for lower di/dt
- External SYNC clock capability – to all Primary/Secondary PWMs
Monitoring

- Installation & maintenance costs are often more than the total HW cost
- Early replacement is often much cheaper than line down
- Line Voltage monitoring
  - Early brownout detection w/ controlled shutdown
- Line current monitoring
  - Early detection of failing HW
- Temperature sensing
  - Early detection of failing HW
- Monitoring/control also offers remote power throttling, sleep & shutdown
Network based Energy management

- There is a clear industry trend towards system/network wide power management
  - DCDC -> PMIC ->
    - POE
    - Network lighting control
    - Home appliance control

- Galvanic isolation is an enabling technology for full network control

- Much larger gains can be had at the network level than at the component level

- From designer perspective this means that the “little features” enabling power supply control and monitoring can be as important as the architecture of the power supply itself

- It is no longer sufficient for the power supply to be a black-box
  - System architect must have full control

The world is going IP, so must the power supply