



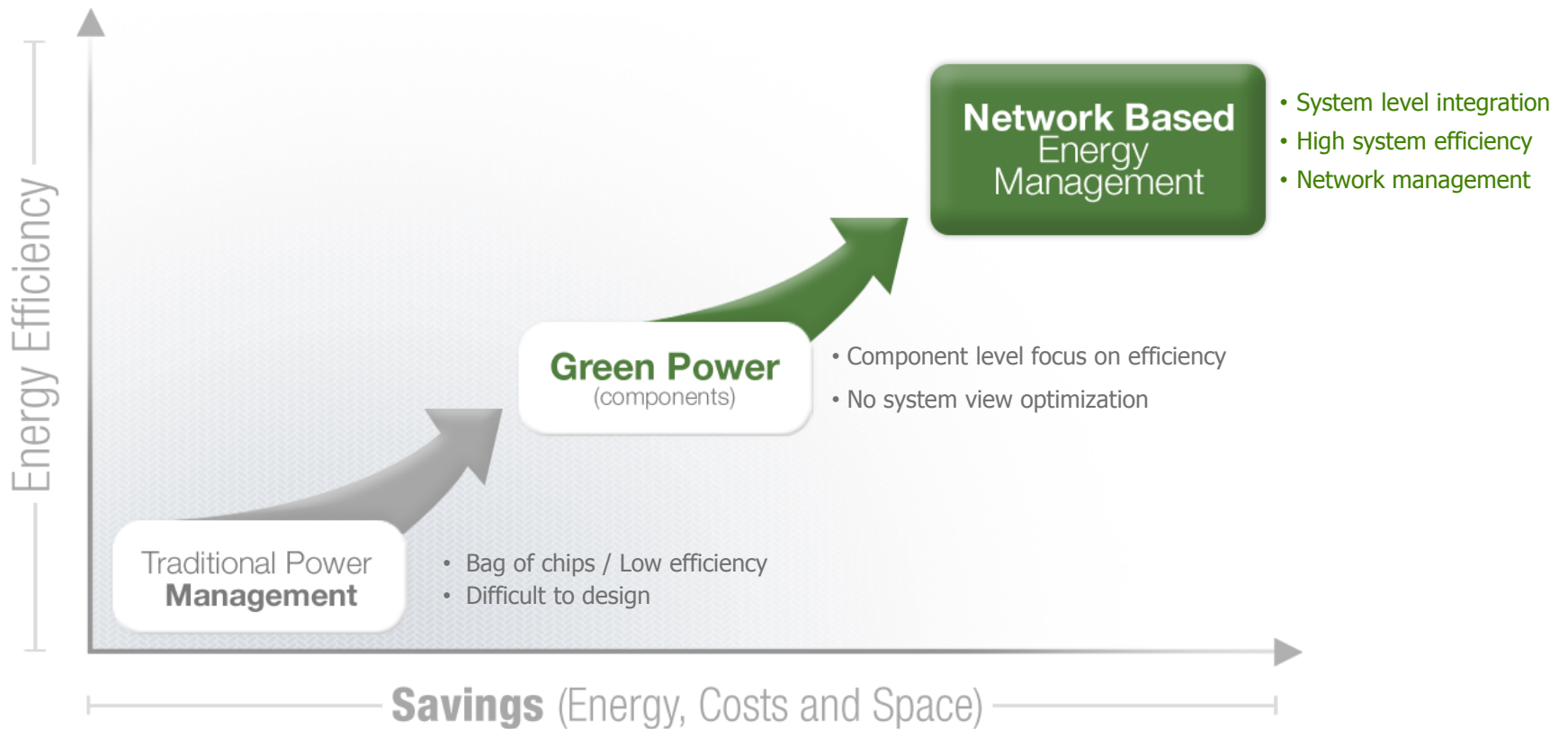
***Monolithic integrated galvanic  
isolation enabling energy  
management in Power over  
Ethernet applications***

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# Power Management Evolution



# 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***



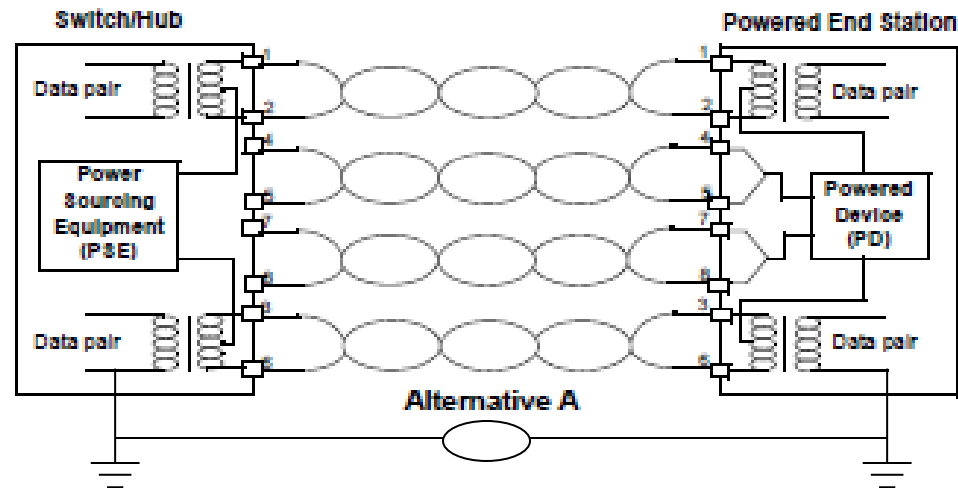
# IEEE 802.3AT Power over Ethernet



IEEE Std 802.3at-2009

AMENDMENT TO IEEE Std 802.3-2008: CSMA/CD

- 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

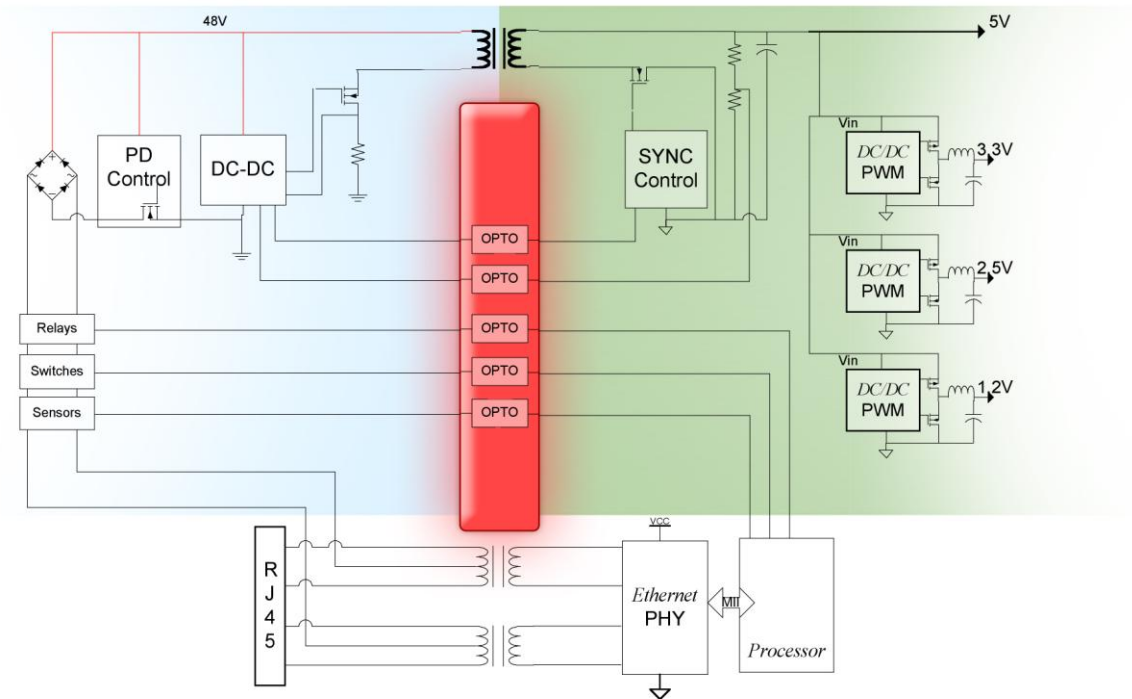


# Legacy Approach: “Bag of Chips”

## 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

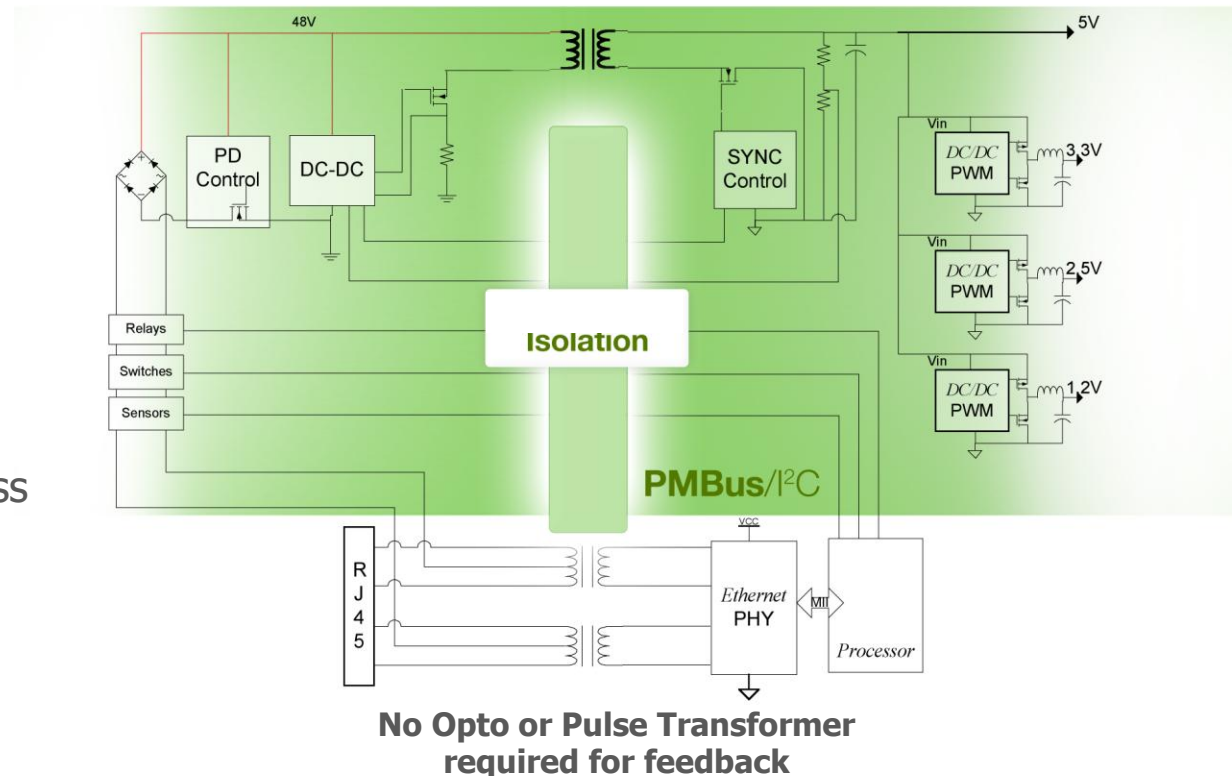
### ISSUE: Isolation Barrier



# PD power supply circuit design using integrated galvanic isolation

## 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





## ***Integrated Galvanic Isolation***





# Galvanic isolation implementation

- Requirements
  - POE: 1500Vrms isolation
  - Offline supplies 3000-5000Vrms
  - Medical > 5000Vrms
- Dielectric strength of SiO<sub>2</sub> ranges from 200-1000V/um
  - Cost effective capacitors are in the fF range
  - Signaling levels are tiny

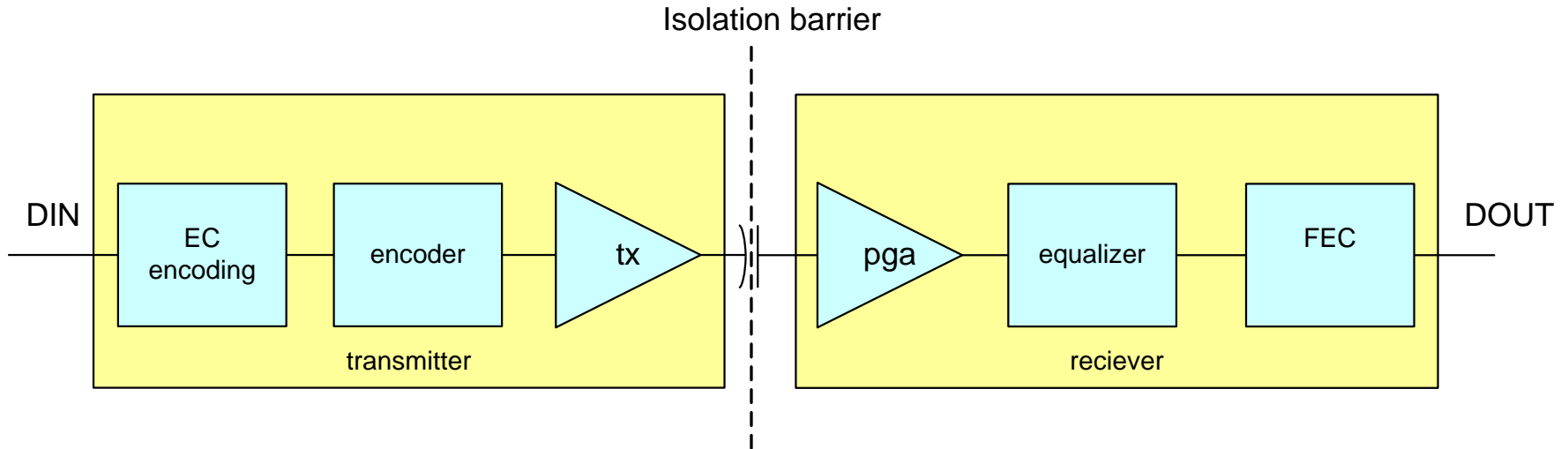
# Noise Immunity

- 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



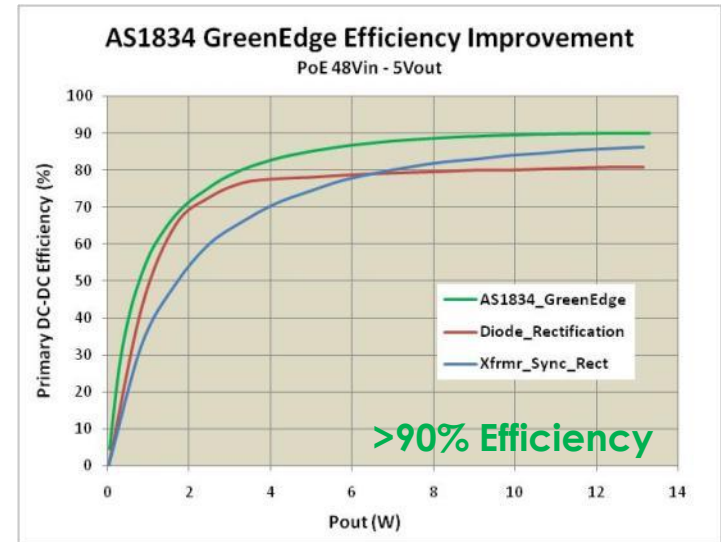
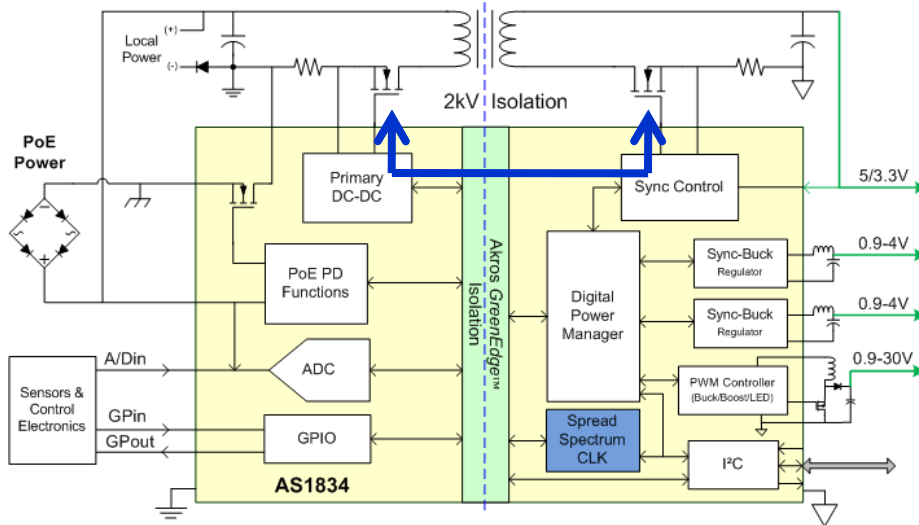
## *Architectural improvements*



# Full control of primary/secondary FET's

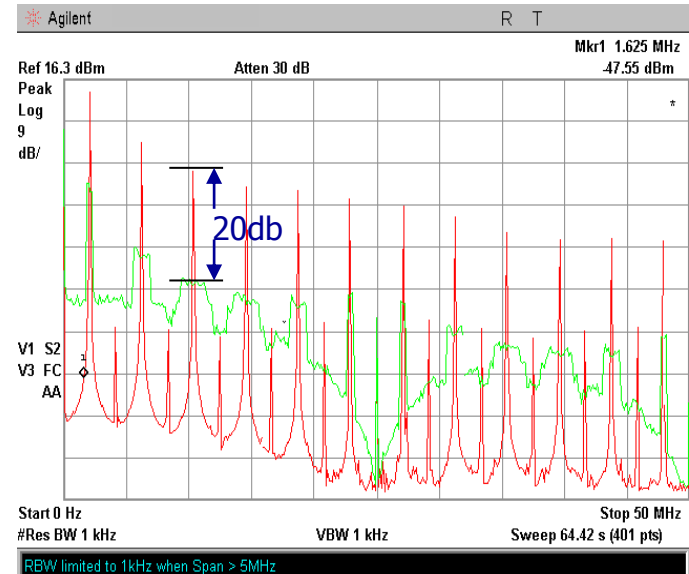
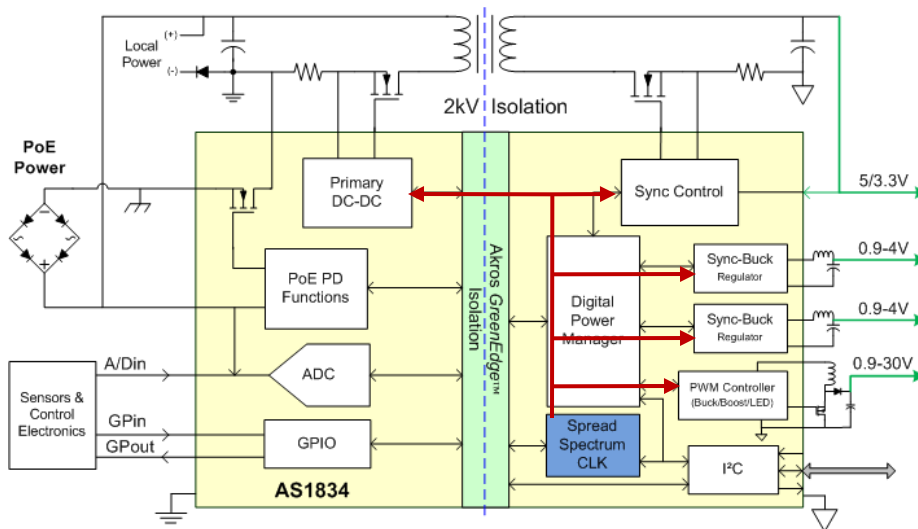
## Superior Efficiency across varying loads

	Diode Rectification	Winding-based Sync. Rectification	Sync. Rectification
Light Loads Efficiency	Good performance	Poor performance due to FET overlap	Good performance
Heavy Loads Efficiency	Poor performance due to diode conduction losses	Good performance	Good performance >90%

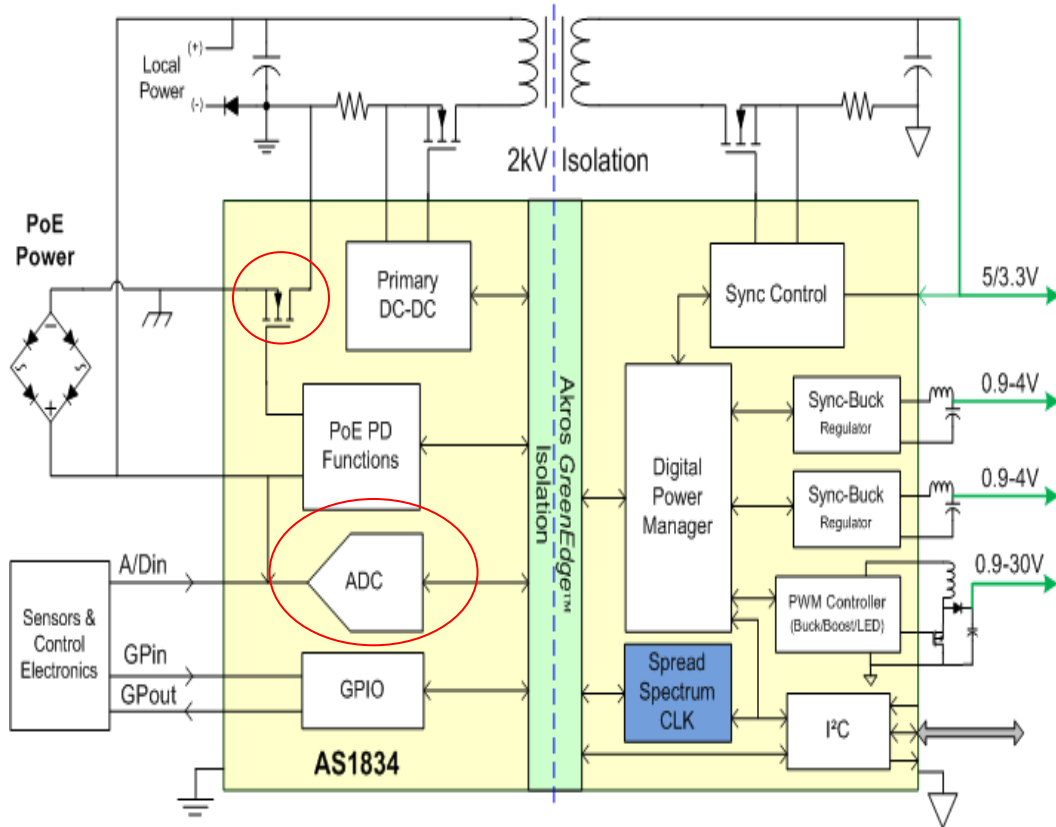


# EMC & Noise Control

- 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