White Paper WP16

Integrated Digital Power for PoE

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INTRODUCTION

The initial markets for PoE clients are Powered Device (PD) applications such as IP cameras, Wireless Access Points (WAPs) and VoIP Phones. All continue to grow as IP clients continue to expand into the initial enterprise markets and beyond into the industrial and residential markets. As is often the case, competitive market forces are driving the need to deliver more value and features, often within a shrinking circuit-board footprint.

New applications for PoE such as video conferencing, thin clients, and smart office lighting are driving the development of a new standard, IEEE802.3bt, for 60Watt power delivery, double the 30Watt power delivery defined under the 2009 IEEE802.3at standard. These new higher power applications will drive double-digit growth in PDs annually over the next 5 years. At the same time, current enterprise trends seek to reduce power consumption and improve efficiency. PoE platform designers and buyers cannot avoid this growing demand for the "Green" Power initiatives – more efficient use and intelligent allocation of power, and reduction in the overall energy footprint. As end-to-end network power management evolves, the growing PD-client markets will have to be part of the solution, whether at 13W, 25W or 60W.

This emphasis on power efficiency provides opportunities for silicon innovation. With this trend towards green energy, there is an emerging opportunity to introduce advanced power management into the PD function.

The ideal next generation of PoE PD power silicon will include the following attributes:

- Negotiation of power delivery between the PSE and PD to address intermediate power levels between 13W and 60W.
- Highly-efficient power conversion architectures that provide high efficiency from light-load to full-load, minimizing power loss in the system.
- Architecture that seamlessly enables power management on the high-voltage (primary) and low-voltage (secondary) side of the isolation barrier.
- Small solution form factor that utilizes state-of-the-art silicon process technology and minimizes the application footprint on the system PCB.

PLATFORM APPROACH TO PoE PD POWER SILICON

PD POWER SOLUTIONS TODAY

In addition to PD classification functionality, many silicon solutions available today include a DC-DC controller to provide a single isolated voltage from the PoE primary voltage. This primary supply is then used to source additional downstream point-of-load (POL) converters. But unlike server or telco backplane environments, most downstream voltages are physically located on the same PC board as the primary power source. This is due to the typically small size of most PoE appliances. Even when multiple boards or daughter boards are employed, the end-to-end power traces are sufficiently short to be easily served by remote power sensing from a central power source.

The number of required voltage sources in a typical PoE PD platform is very similar to typical embedded microprocessor-based platforms. The architecture includes a processor, DRAM/SRAM, Flash memory and I/O, each having differing voltage and power requirements. For a VoIP phone, there is often a display that may demand a unique voltage, whereas a pan-tilt-zoom (PTZ) camera will have multiple motors as well as low-voltage electronic power needs.

With the ubiquitous usage of CMOS technology, the embedded silicon market has continued a trend

towards ever-lower voltages, (5V, 3.3V, 2.5V, 1.8V, 1.2V and downward). At any point in time, the various silicon components are often one or two generations out of step with each other, requiring a mix of compatible supply voltages. However, the number of unique voltages in a platform is usually very consistent from generation to generation. Typical numbers for PD platforms are two to three unique voltages needed for CMOS technology and one to two voltages needed for any unique analog subsystem, such as a display or motor.

PoE AS AN ENTERPRISE POWER MANAGEMENT TOOL

Overall power management is crudely built into PoE clients today, via PoE power classification, but this is a limited and static solution. It is not aligned with the IT Managers' desire for a dynamic, fine grain, end-to-end power management environment to meet Enterprise energy conservation goals. PDs must become a seamless part of that ecosystem. PCs, servers, and even traditional Ethernet (e.g. IEEE's Energy Efficient Ethernet initiative) are all being unified today under the power management umbrella, so extending similar practices to PoE devices would appear to be a prudent course of action.

Power Management of PD platforms will continue to evolve around requirements that appear to be contrary goals to one another – increase in maximum available PD power with the new 60W PoE standard along with demand for Green Power related design techniques.

So how does a 60W-PoE solution fit into this end-to-end "greening" of the enterprise? One solution is to do dynamic and on-demand allocation of platform power. In the enterprise, VoIP phones don't need the typical 6.5Watts or 13Watts that are allocated to them via initial PSE/PD classification. They can be reduced to a much lower standby power and quickly ramp up to their active power level upon the initiation of a call or other wake-up event. The PSE (Power Sourcing Equipment, usually built in the Ethernet switch) can dynamically reallocate power to the ports that need active power. For example, a PSE supporting 50 VoIP phones does not have to be built to support simultaneous full power usage of all 50 phones. If the PSE can reallocate the power to any port that needs it, it can reduce the power supply by 2x-4x depending on statistical usage pattern of the VoIP phones in that environment. This savings can become significant when considering a PoE lighting system in which each PoE PD luminaire consumes 60W. With the occupancy sensors & daylighting techniques commonly employed to reduce lighting power consumption, the opportunity to reallocate power and manage energy at a network level becomes even more important.

Similarly, IP cameras working in low light, generating high-definition IP video streams of a rapidly-moving object might only require its maximum 60W allocation during a midnight alarm condition, likely when the VoIP phone usage is minimal. So power from VoIP ports can be reallocated to the IP camera ports at night time.

Therefore, what PD platforms need are silicon component functions that allow PoE power management to become truly dynamic end-to-end. Once this mode-dependent level of control is added to the system, the net effect is that PoE clients become active eco-partners in the overall "greening" process, without sacrificing system performance or disallowing innovative functionality.

By employing intelligent power management, Servers and PSEs can now be used to monitor PD status and power usage profiles. This opens up additional enterprise-critical platforms such as PCs, notebooks, UMPCs and thin clients to new PoE usage scenarios. One example is a PoE-based battery backup for a desktop PC in standby mode. Another is the use of PoE as a trickle charger for notebook computers. An additional application could be to use PoE as a primary power source for low-power thin-client computers. All are scenarios that will be more practical with the advent of the new 60Watt PoE standard.

NEW PLATFORM REQUIREMENTS FOR PD CLIENTS

Current PDs are routinely adding new features (802.11n, HD video streaming, etc) as market conditions demand. However, the platform often stays within a fixed, or shrinking, form factor. Costs, customer usage, installation and other factors dominate form-factor design for many PoE platforms, similar to other electronics markets. Therefore, the pressure to innovate pushes silicon vendors towards ever-increasing component integration. For digital logic, this typically adheres to Moore's law. Power subsystems, however, have tended to be discrete designs, and although power electronics is also trending towards denser integration, the high voltage-isolation requirements for PoE have kept integration to a minimum.

Hence the right PD solution for new generation of PoE client platforms must (a) include highly efficient power supply architecture, (b) enable dynamic power management and (c) provide high level of integration to support shrinking and denser platform requirements.

AKROS' INTEGRATED DIGITAL POWER MANAGEMENT PD

Akros' introduction of the AS18xx family of PoE PD controllers brings the advanced functionality required to implement intelligent digital power management. The AS18xx family of products are highly-integrated solutions that can derive their power from the PSE or local power supply and provide up to four (4) managed voltage outputs to meet all the power supply requirements of standard PoE IP appliances. This solution enables Green Power implementations by providing (a) breakthrough improvements in efficiency across the whole load range (light-load to full-load), and (b) primary and secondary side power management capability to assist dynamic power allocation.

The breakthrough innovation provided by the AS18xx family is achieved through integration of the Akros' Digital Edge™ technology (US Patents 7732889, 7864546, 7923710) enabling non-opto based isolation exceeding $1500V_{RMS}$. In addition to digital control of the PWM, the AS18xx family of PDs includes an I^2C interface for Digital Power Management. The devices monitor and control the voltage outputs on both the primary and secondary side of the isolation barrier, allowing the system controller to easily monitor the health of each power supply.

BENEFITS OF INTEGRATED ISOLATION

ISOLATED DIGITAL POWER

Where isolated power is a requirement, such as in PoE PDs, the desire for high efficiency is usually at odds with the need for solution simplicity and/or to ease external component selection. Isolated systems generally require lengthy optimization design cycles before final components are selected. The designs are not usually portable from one PD model to another when slightly different specifications are required – leading to redesigns, revalidation and compliance testing. Therefore the need to fine tune for high efficiency usually has bill-of-material (BOM) cost and time-to-market/time-to-revenue implications.

Primary power supply design objectives with on silicon integration of Akros' Digital Edge™ Isolation technology are:

- Integrated (low external component count) capabilities for power-efficient topologies, such as synchronous flyback and forward.
- Superior power supply efficiency (light load to full load) by minimizing switching losses with digital control of timing edges.
- Automatic adaptation to a broad range of external components in the primary power-control loop, leading to reduction in design times and improving design portability

- Replacing traditional slow, analog-feedback loops employing unreliable opto-couplers with fast isolated, digital-feedback designs.
- Digital speed for fast power-transient response to deal with modern "green" designs that demand fast turn-on and fast turn-off of power supplies based on application needs.

COMMUNICATIONS AND HIGH-VOLTAGE POWER MANAGEMENT

Integrated high-voltage power management provides a unique opportunity for power-control innovation. Digital isolation can accomplish something not easily (or cost-effectively) done with analog isolation techniques based on discrete opto-couplers.

Akros' Digital Edge™ solution provides seamless bi-directional digital communication across the 1500V isolation barrier – enabling monitoring and control of the high-voltage primary from a secondary-side interface, such as a microcontroller bus and via GPIO interfaces. The AS18xx devices feature an embedded bi-directional high-speed communication bus across the isolation barrier.

Primary design objectives of the communication bus across Akros' Digital Edge™ Isolation barrier are:

- Effective primary-side power management (monitoring and control) from the secondary side.
- Automatic and user-transparent channel setup and usage (e.g. for I²C operation).
- Secondary-side control and monitoring of primary-side GPIO pins – for use with external primary side sensors.
- Primary side voltage and current ADC capabilities with secondary side control.
- Elimination of low reliability opto-couplers for communication needs.
- Low impact to the final device cost.

EMI MANAGEMENT

In a PoE platform, any common-mode noise that leaks out onto the Ethernet twisted pair cable (UTP) will show up as conducted or radiated EMI, depending on the frequency. Therefore, controlling the behavior of the DC-DC converter is critical in the management of electromagnetic emissions.

By definition, a PoE PD will have a primary-side Ethernet twisted pair port, but this is not always the only cable-interface connection in the platform. Secondary-side ports such as USB, 1394 and RS232 connections are often present and are necessarily included in the testing of the PD platform for radiated EMI. These secondary ports (that readily become antennas with attached cables) also provide escape paths for system-level noise to leak and radiate. Isolated switching power supplies are a dominant source of ground noise in a system. Therefore, a poorly-designed DC-DC converter can lead to significant EMI problems.

A robust EMI solution should encompass both the primary-side and secondary-side DC-DC converters, ideally with deterministic clock management and power-design techniques that are managed to maximize the ability of the PD platform to attain proper spectral power margin to any FCC test.

In traditional designs, it's difficult and expensive (if not impossible) to provide clock management between down-stream secondary DC-DC converters, the rest of the system, and the isolated primary converter. Akros' Digital Edge™ technology offers the unprecedented ability to transfer timing information across the isolation barrier without added system cost, thus enabling a new level of EMI control.

Primary EMI Management design objectives with integration of Akros' Digital Edge™ Isolation are:

- Integrated primary-side DC-DC converter with reduced EM emission for FCC Class B compliant applications.
- Managed capabilities for primary and secondary system-level clocking with spread-spectrum (US Patent 8400230), randomization and external synchronization capabilities.
- Multi-phase switched-PWM clocking for secondary buck noise reduction.
- IEC 61000-4-2/3/4/5/6, FCC and IEC 60950 requirements for EMC compliance and isolation.

SURGE SUPPRESSION: A PLATFORM OPPORTUNITY FOR SILICON SOLUTIONS

A key requirement for PoE systems is immunity to over-voltage and surge events. These events can be caused by inductive coupling of lightning events creating surge voltages on external power lines. A destructive discharge can also occur during cable connection or disconnection event – with static electricity buildup in the Ethernet cable (Cable Discharge) or when disconnecting a hot DC-current carrying Ethernet cable (Cable Disconnect). These events can be of moderate duration, with very high peak currents and rise-time constants as short as 1ns, as in IEC61000-4-2, or they can be much longer events with less intense peak currents and slower rise times, such as IEC61000-4-5.

Typically, ESD compliance requires expensive and rugged external components, such as sidactors or transient voltage suppressors (TVS). These devices are added to shield sub-micron semiconductor devices from the stress of external surge events that can easily become destructive. The surge-suppression components are often selected by trial and error to achieve the required performance and are very dependent on board parasitics and the CMOS components (e.g. PHYs) that are connected to the cable. In addition, CMOS Ethernet PHY technology is heading towards smaller fabrication geometries (90nm, 65nm) where it is very difficult to develop system-level surge protection.

A better solution is to integrate the protection circuitry into the PoE silicon to provide a much faster response to surge events, substantially improving surge-protection performance and reducing dependence on external-component variability.

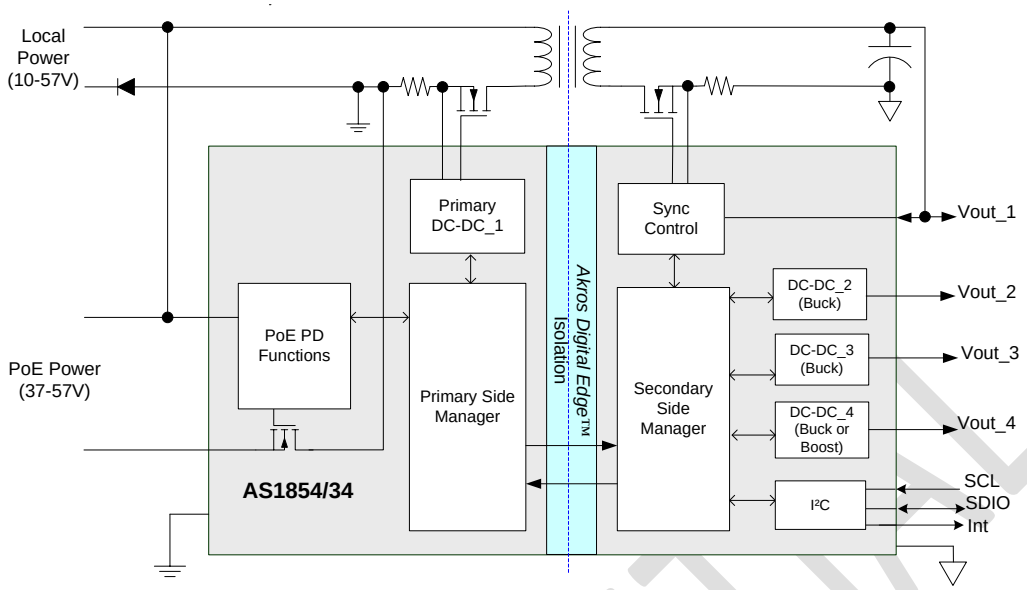
The design goals for surge suppression on the AS18xx family are:

- Cost-effective integrated designs that provide very fast, low-impedance paths for surge events.
- Pre-tested solutions that meets IEC 61000-4-2/3/4/5/6 and IEC 60950 requirements for surge.

AS18XX PRODUCT OVERVIEW

Figure 1 shows the block diagram of the Akros AS1834 PoE PD Controller.

Figure 1 - Block Diagram of AS1834 PoE PD Controller



As described above, the device provides an internal isolation barrier that also allows the transfer of management and control information between the primary and secondary sides of the chip. Four different voltage outputs can be implemented, each configured per the system/application voltage and power requirements. The fourth voltage output (Vout_4) may be configured as either a buck or boost converter, allowing source voltages higher than the primary voltage (Vout_1).

Akros Silicon provides a range of devices within the AS18xx family. Table 1 summarizes their different capabilities:

Table 1 - AS18xx Family of PoE PD Controllers

Device	Power Rating	Number of Outputs	Mode of Operation
AS1824	13W	4	Hardware
AS1834	13W	4	Software
AS1844	25W	4	Hardware
AS1854	25W	4	Software
AS1860	60W	4	Software

AS18XX FEATURES

The following is a list of key features provided by the AS18xx family:

PD AND POWER OUTPUTS

- PoE PD
  - Full 13W/25W 803.3af/at capability
  - 60W capability verified through interoperability testing with Broadcom BCM59111 & BCM59121 PSE controllers
  - Local-power operation from 10-57V
- Power outputs (four total)
  - Highly-efficient PD-based primary-to-secondary (VOUT_1)
  - Two complete bucks with integrated 1.5A power FETs (VOUT_2, VOUT_3)

  - One buck/boost controller (VOUT_4)
  - Total platform power solution capable: 13W to 60W

- Digital power, high-efficiency converters
  - Digitally-isolated primary converter, no opto-couplers needed
  - Synchronous primary-secondary digital loop controller
  - Synchronous buck converters
  - Startup power sequencing, per output

- Low-emission DC-DC converters
  - Slew-rate-controlled power drivers
  - Multi-phase switched outputs
  - Spread-spectrum clocking
  - External SYNC input

- Protection
  - Over-current / over-voltage protection
  - High-temperature warning and shutdown
  - Surge protection, per IEC 61000-5

PROGRAMMABLE POWER MANAGEMENT FUNCTIONS

- Monitoring
  - Individual "power good" monitors
  - Primary voltage and current measurements
  - PoE or local power active
  - Temperature monitoring and over-range warning
- Margining and control
  - Output voltage adjust ±2.5% or ±5%
  - Adjustable system clock modulation control (EMI suppression)
- Supervisory power monitor
  - Reset: power-up, power-down, watchdog
  - Programmable watchdog timer
- Primary-side GPIO control and status
  - General-purpose A/D input
  - General-purpose digital I/Os
- Interrupt based alerts
  - PD alarms
  - DC-DC status alarms (voltage/current)
  - A/D input value vs. predetermined threshold

SUMMARY

With growing penetration of Power over Ethernet in diverse IP connected appliances, there is strong need for these PoE clients to become active eco-partners in the "Greening" of the enterprise. This next generation of PD appliances will demand cost effective solutions for high power supply efficiency and dynamic power management features. Power management will be especially important under the new 60Watt profile of Ethernet-based PSEs in the enterprise. A managed PD power solution is therefore virtually certain to become a new system requirement.

The Akros Silicon AS18xx family of PoE Power Manager offers a highly integrated digital power solution to address the needs of today's energy conscious systems. Integration of Akros' Digital Edge™ Isolation technology on the silicon enables an unprecedented level of performance and features. By taking a platform approach to PoE power delivery, the Akros AS18xx family delivers the performance needed for the next generation of cost-effective PD power silicon.

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