Power Technology Roadmap Trends 2014 – 2019

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Outline

• **Power Technology Roadmap**
  - What/Why (Purpose)
  - When/How (Methodology)
  - Retrospective Analysis

• **2015 Results**
  - Structure
  - Product Technology Trends
  - Components Trends
  - Application Trends and Emerging Technologies
• **Power Sources Manufacturers Association**
  ► Multi-national non-profit organization with 160+ members
  ► One of the sponsors of APEC providing industry voice

• **1st Workshop Generated Roadmap in 1994**
  ► Workshop was led by Bob Freund, AT&T Bell Laboratories

• Subsequent Roadmap efforts have evolved by learning from doing and by improved participation

• **Purpose of Technology Roadmap is** Communication

Capture Trends Driving New Technology in Power Conversion
PTR Methodology

• Gather Data (Presentations & Survey)
  ▶ Users
  ▶ Component Suppliers
  ▶ Market Research
  ▶ Technology
  ▶ Survey

  Weightage shift in presentation topics is a good leading indicator of Technology Evolution

• Analyze Data
  ▶ Breakout groups
  ▶ Compile trends into tables

  Y-o-Y consistency helps pick out subtle shifts or throw away outliers; New participants inject new perspectives

• Summarize
  ▶ Presentation Summaries
  ▶ Product Trend Tables Summaries
  ▶ Application Summaries

  Articulation of the results is very important – final result counts!!
Report Tables

General Requirements

Design and Components

Packaging, Thermal Management
Report Structure
Can best be summarized by
PTR: A Retrospective Review

- Data from past 5 roadmaps were analyzed
  - For internal learning and course correction
  - For “gloating” when predictions were right

- Analysis scope limited to quantitative data
  - Easy to track and visualize/report

- Data from 2015 report also included in the analyses

- Generalized learnings
  - Frequencies rarely match projected values
  - Efficiencies have outpaced projections in recent years
  - Usage of digital control lagged projections till very recently

- Many more learnings are available from a qualitative review – exercise to the reader
Ac-Dc Front End Efficiency

Efficiency @ 48 V Output

- Actual is above or at projected in both
- Gap between high-end and low-end smaller in 48V
- Consistency in projected numbers (2010/15)
- 12 V high-end projections catching up to 48 V

Efficiency @ 12 V Output
Ac-Dc Front End Control

- Significant jump to digital 2008-10
- Gradual growth after that

### 2008-Actual

- Analog: 80%
- Digital: 15%
- Mixed Analog/Digital: 5%

### 2010-Projected in 2006

- Analog: 40%
- Digital: 40%
- Mixed Analog/Digital: 20%

### 2010-Actual

- Analog: 40%
- Digital: 40%
- Mixed Analog/Digital: 20%

2017

- Analog: 55%
- Digital: 35%
- Mixed Analog/Digital: 10%
Ac-Dc External

- High-end efficiency - significant jump from 2010-15
- No load power had great decline from 06 to 08. Trend continues…
- Digital/Mixed control adaption at faster rate than predicted in 2011

**Peak Efficiency < 30 W Models**

**No Load Power**
Dc-Dc Isolated

- Greater split in o/p voltages (not predicted)
- Frequency – transition to > 500 kHz (slow)
- Faster transition to digital control
Non-Isolated Dc-Dc

- Projected efficiency not monotonic
- Frequency – 2010 higher than projected; after that more aligned
- Control – Digital takeover too optimistic, aligned from 2012 onwards
2015 Results
Report Content

Application Trends
- Automotive
- Computing
- Consumer
- Industrial
- Lighting
- Medical
- Military/Aerospace
- Motor Control
- Portable Charging
- Renewables

Emerging Technologies
- Power SoC
- Server Power
- 3D Power Packaging
- Additive Manufacturing
- Magnetics
- High Power Wireless Transfer
- Smart Grid
- Energy Storage
- Smart Building

2017 - 2019 Trend Tables
- Ac-Dc front-end
- Ac-Dc external
- Isolated Dc-Dc
- Non-Isolated Dc-Dc power supply in a package (PSiP)
Report Content: Webinars

- **Power Architectures (4)**
  - Datacenter HVDC (Stephen Oliver, Vicor)
  - Automotive Motor Drives (Babak Fahimi, UT Dallas)
  - 400 VDC Distribution (Brian Davies – Andean Power Products, David Greary - StarLine DC Solutions, BJ Sonnenberg - Emerson)
  - Topology Trends (Steve Mappus, Fairchild)

- **Technology and Market Forces (5)**
  - Technology Convergence (Alix Paultre, PSD)
  - 3-D Packaging (Brian Narveson, PSMA)
  - Mission-Critical Power (Dusty Becker, Emerson)
  - Trends in CSC Automotive App’s (Pierric Gueguen, Yole)
  - Digital Power (Dave Freeman, TI)

- **Components (4)**
  - GaN New Life… (Alex Lidow, EPC)
  - SiC BJT (Ranbir Singh, GeneSiC)
  - GaN Power Supply Trends (Eric Persson, IR)
  - HV SiC FETs (Jeffrey Casady, Cree)
2015 Survey Demographics

- About 50-50 split between power supply designers and component providers
- 1-45 years experience in the industry
- 60% in design function (25% marketing)
• Impact of the shift towards DC Distribution Architecture
  ► Very slow adoption rate till now

• PFC Stage
  ► Limited magnetic material choices and EMI concerns are drivers for low fsw (generally < 150 kHz)
  ► Slower adoption of WBG devices due to low switching frequencies
  ► Increasing digital control proliferation

• Additional data captured in trend tables:
  ► Power Management interface, communication protocol, physical layer, communication bus speed,..
  ► Input voltage range, topology, frequency, control implementation, switch/rectifier technology, hold-up time…
Report Highlights
Ac-Dc Front-End Power Supplies

- Incremental increase in efficiencies – plateau effect

- Some applications prefer coverage to 277/480 Vac

- Dc-Dc Conversion
  - A trend towards alternate half-bridge topologies
  - Higher frequencies benefit from WBG devices
  - Increasing digital/mixed control usage

- Additional data captured in trend tables:
  - Topology, frequency, control implementation, switch technology, transformer technology, inductor technology, rectifier technology, ORing device, output capacitor technology,
  - Thermal management technology, Heat removal…
Report Highlights
Ac-Dc External Power Supplies

• Advances are fueled by
  ► Demands for smaller, more efficient and reliable products, and
  ► Regulatory agencies worldwide
• Reduced power requirements in some consumer categories (Laptops, Displays), higher power in Tablets
• Significant R&D on smaller sizes (WBG devices enable higher fsw)
• Universal input voltage and Flyback/QR Flyback are common
• BOM and Component Count Reduction is facilitated by
  ► Primary side regulation (PSR), higher control and HVFET integration
• Continued downward trend in no-load power consumption
• New regulations DoE Level VI, CoC of Energy Efficiency (Jan ‘16) and EPS (Feb ’16) coming soon – significantly raise the efficiency bar
• Additional data captured in trend tables:
  ► Voltage/power ranges, density, architecture/topology, switch/rectifier/capacitor technologies, mounting/heat-removal/packaging technologies,..
Report Highlights
Isolated Dc-Dc Converters

• Major **transition** in demand dominance **from communication segment to computing segment**
  - Focus on efficiency and configurability
  - More voltage variations (including intermediate bus)
  - Increased digital interface

• **Increasing use of 1/8 and 1/16 brick for 100 W power**

• **Regulated or semi-regulated outputs dominate over unregulated**
  - Trend towards adaptable intermediate bus

• **Switching devices – trend away from Silicon predicted**

• **Additional data captured in trend tables:**
  - Form-factor, Output regulation, Efficiency, Topology
  - Power management Interface, Protection, Interface requirements
  - Input voltage range, output voltages and currents, switching frequency
  - Switch, capacitor and magnetics technologies
  - Mounting Technique and Substrate Material
Report Highlights
Non-Isolated Dc-Dc Converters

• Output voltages continue diving into Sub 1-volt region
  ▶ Tighter voltage set point windows
  ▶ Lower output voltage ripple
  ▶ Faster transient response, and
  ▶ Reduced noise generation

• Wide input range (flexibility) requirement conflicts with the need for high power density and high efficiency

• Digital control or interface increasingly expected
  ▶ Analog control with PMBus communication interface popular

• Perceived threat from PSiP or PwrSoC

• Additional data captured in trend tables:
  ▶ Number of outputs, current ratings
  ▶ Topologies, Switching devices, frequency, filter technology
  ▶ Power Management interface, control type and implementation
  ▶ Substrate type and packaging integration technologies
Report Highlights
Non-Isolated PSiP and PwrSOC

- PSiP defined as smaller than a 1” cube
- Faster rise in max current ratings (40 A available now)
  - 2013 max was 15 A with projection of 25 A in 2017
- More configurations becoming available
- Faster adoption of digital control than predicted (30%)

- Modular PwrSOC predicted to take low-end PSiP market
- Huge impact of granular PwrSOC on overall POL market

- Additional data captured in trend tables:
  - Voltage and current ranges, efficiency
  - Topologies, Switching devices, frequency, filter technology
  - Power Management interface, control type and implementation
  - Substrate type and packaging integration technologies
Components
Power Semiconductors

• Low and mid-voltage Silicon (20-200 V)
  ➤ Continued steady improvement in FOM for DC-DC and synchronous rectification applications

• Mid-voltage GaN (40-200 V)
  ➤ Dominated by enhancement-mode transistors
  ➤ Adoption rate is much slower than previous analyst and PSMA predictions
  ➤ Application focus more on high frequency (MHz) and wireless power transfer
  ➤ Manufacturing cost is becoming competitive with Silicon equivalent devices

• HV Silicon (600 V class)
  ➤ Superjunction devices becoming higher performance and increasingly application-specific
  ➤ Optimized for hard-switching unipolar
  ➤ Optimized for lowest loss in ZVS and resonant topologies
  ➤ Optimized for improved diode ruggedness in inverters with hard-switching
Components

High Voltage Wide Band Gap (600-1200 V)

- **600 V GaN cascode devices sampling** to alpha customers from multiple vendors
  - No standards in SMT packages yet
  - Cascode compatible with standard gate drivers
  - Reverse conduction via high performance body diode
  - Performance benefit primarily in bridge derived circuits, hard-switched and ZVT
  - Need for controller ICs to address this application space

- **450-650 V GaN enhancement-mode transistors available and sampling** from multiple vendors
  - Some traditional TO packages and some SMT packages, but nonstandard footprints
  - Gate drive for enhancement mode requires dedicated IC or more complex circuit
  - Reverse conduction characteristic higher Vf than cascode
  - Simpler monolithic device compared to cascode

- **600-1200 V SiC transistors**
  - Very few 600 V class devices released
  - Traditional TO packages
  - Excellent thermal conductivity
  - Excellent ruggedness
  - **1200 V - more device options and more module package options available**
  - Compatible with IGBT class gate drivers
Application Trends & Emerging Technologies: Structure

• Introduction
  ► A high-level introduction and an overview of the application segment/technology

• Market Drivers
  ► Identification of two to three key application areas that are having largest impact on the market and its implications to power electronics

• Key Metrics
  ► Identification of key power electronics metrics or specifications and how they are driving power electronics evolution for the segment/technology

• Trends
  ► Identification of end use trends or disruptive forces that impact the application segment or the core/support technology

• Challenges
  ► The biggest challenges for power electronics industry and its component suppliers in this applications segment/technology
Participate and Benefit

- All participants learned by doing
- Contact PSMA for future participation
- If you give and share, you gain more than you gave
- Participate in the survey to enrich the data
Summary/Takeaway

• Value of the PSMA Technology Roadmap depends on your perspective

Image Courtesy: Getty Images
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Thank You