An Introduction to Digital Power

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Agenda

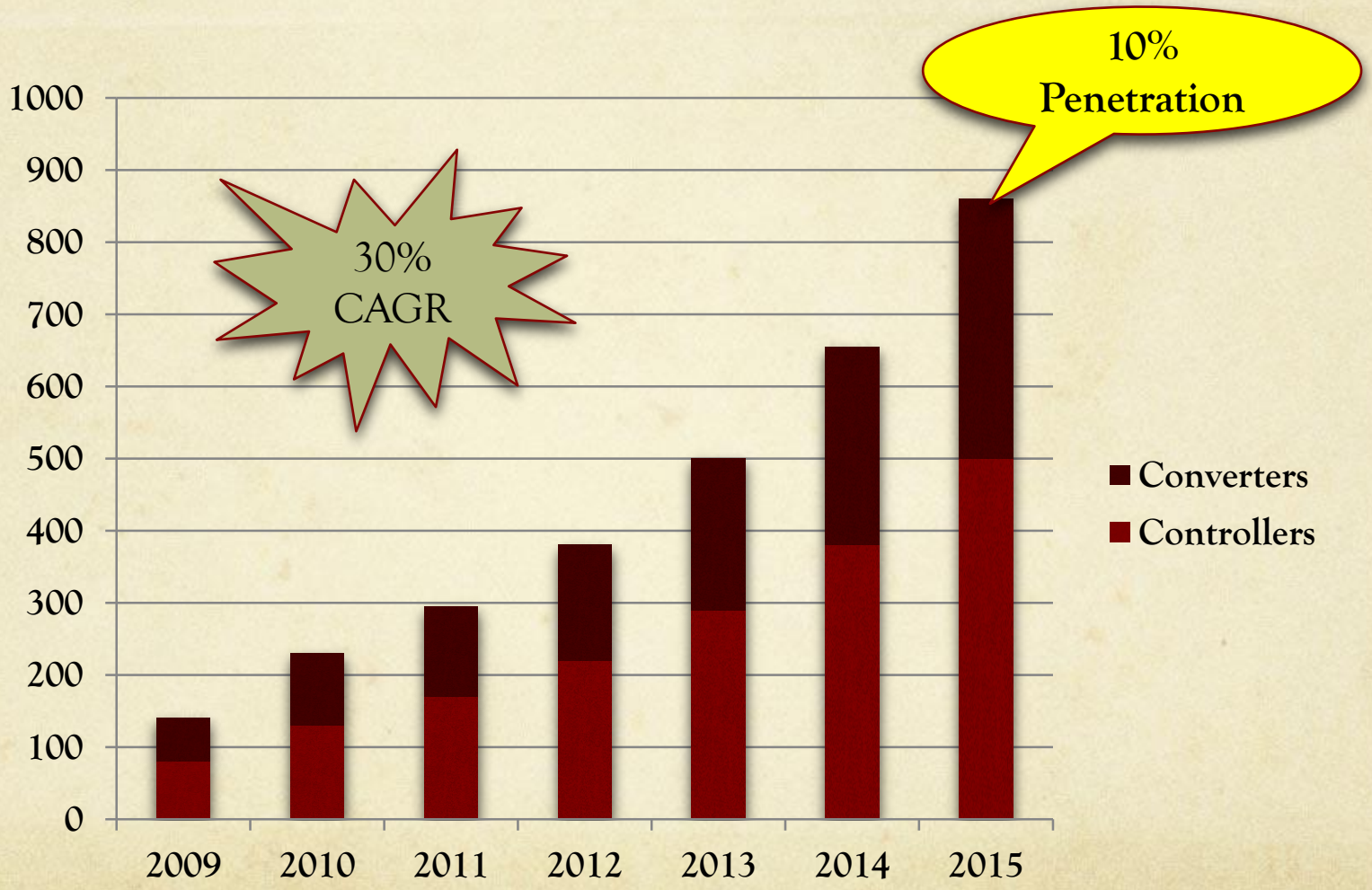
- Definitions – What is Digital Power
- Applications and Markets
- Where is it headed?
- Actions for our Foundry Partners
- Conclusion

What is Digital Power

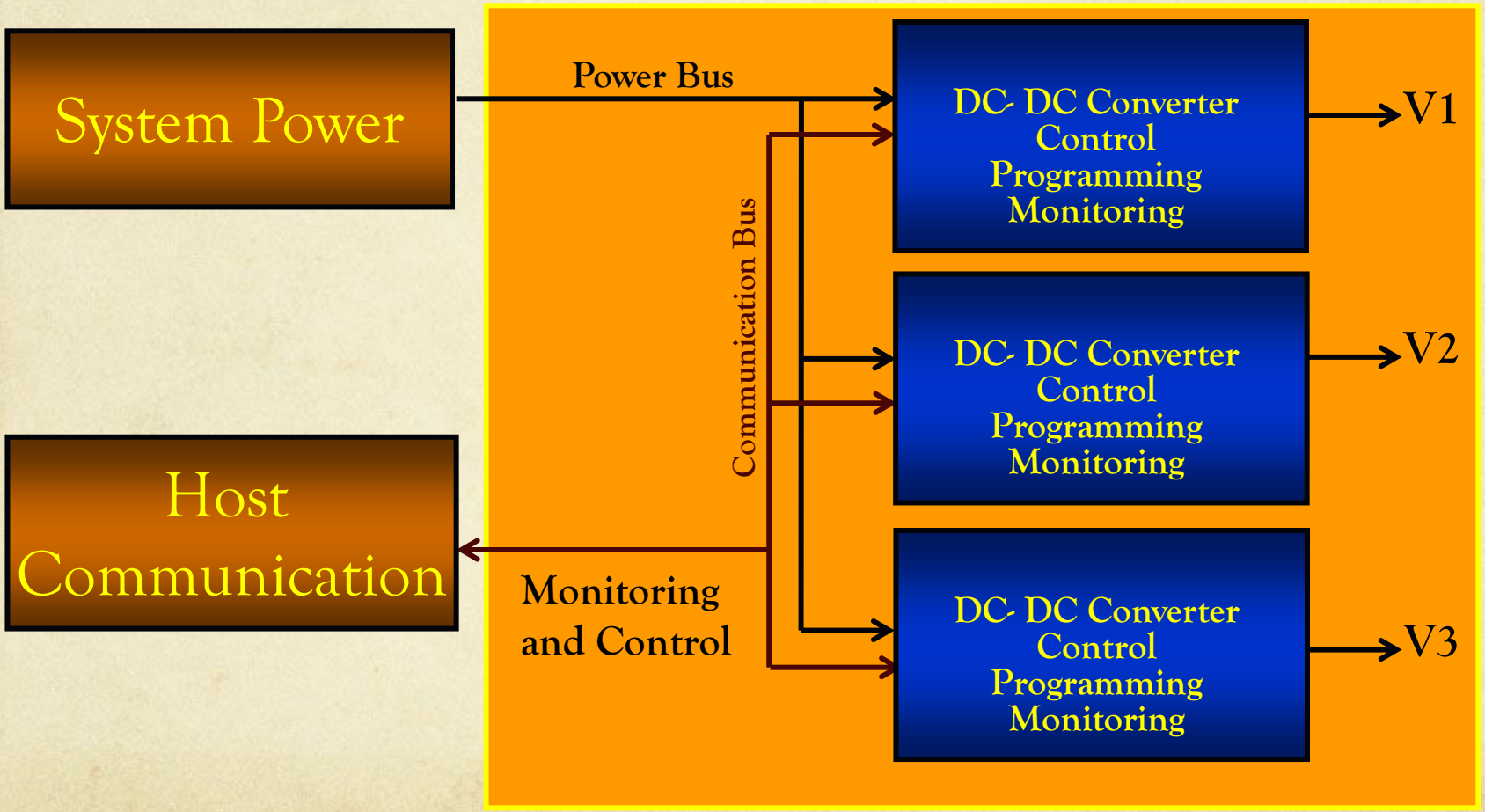
A Power supply with

- Digital programming and configuration through a communication bus.
- Feedback control method (Digital PWM) of the power supply.

Digital DC-DC Converter Revenue Forecast ($M)



Digital Power System Simplified Architecture



Digital Power Uses

- Monitoring
  - Output Voltage, Output Current, Input Current, Temperature
- Programming
  - Output Voltage, Current Limit, System Behavior in response to various system faults.
- Event Driven Sequencing of Various Power Rails.
- Digital Control of the output voltages through DSP techniques. Real time adjustment of DSP loop filter coefficients.

Digital Power Main Applications

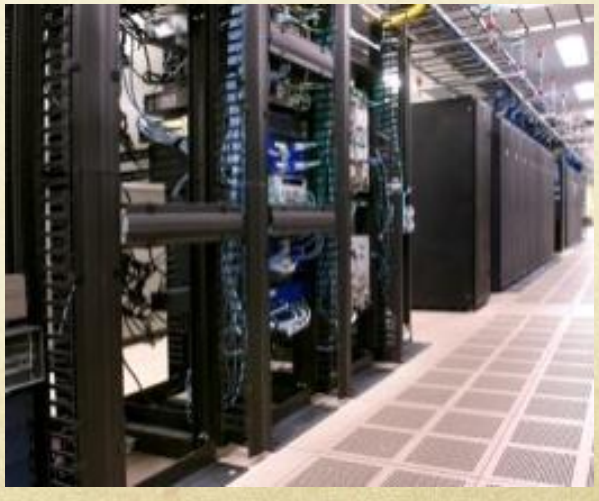
- Portable Devices such as Notebooks were early adopters.
- Servers
- LED Lighting

Digital Power For Mobile Devices

- High Efficiency DC-DC converters increase Battery Life by reducing Power Losses.
- Power Subsystems must communicate through a digital interface to System host to reduce power drain.

Data Center Requirements

- Servers within Data Centers require
  - Energy Efficiency
  - Lowest Downtime
  - Minimum footprint area
- Power monitoring allows optimizing total power demand thus minimizing power usage.



Why Digital Power?

- Cost:
  - Enhanced Performance to Line and Load Transients
  - Allows integration path toward lower system costs by elimination of most Analog components.
- Flexibility:
  - System Parameters (Loop filters parameters) or even PWM architectures can be adapted to system requirements during operation.
  - Reduces Design Time

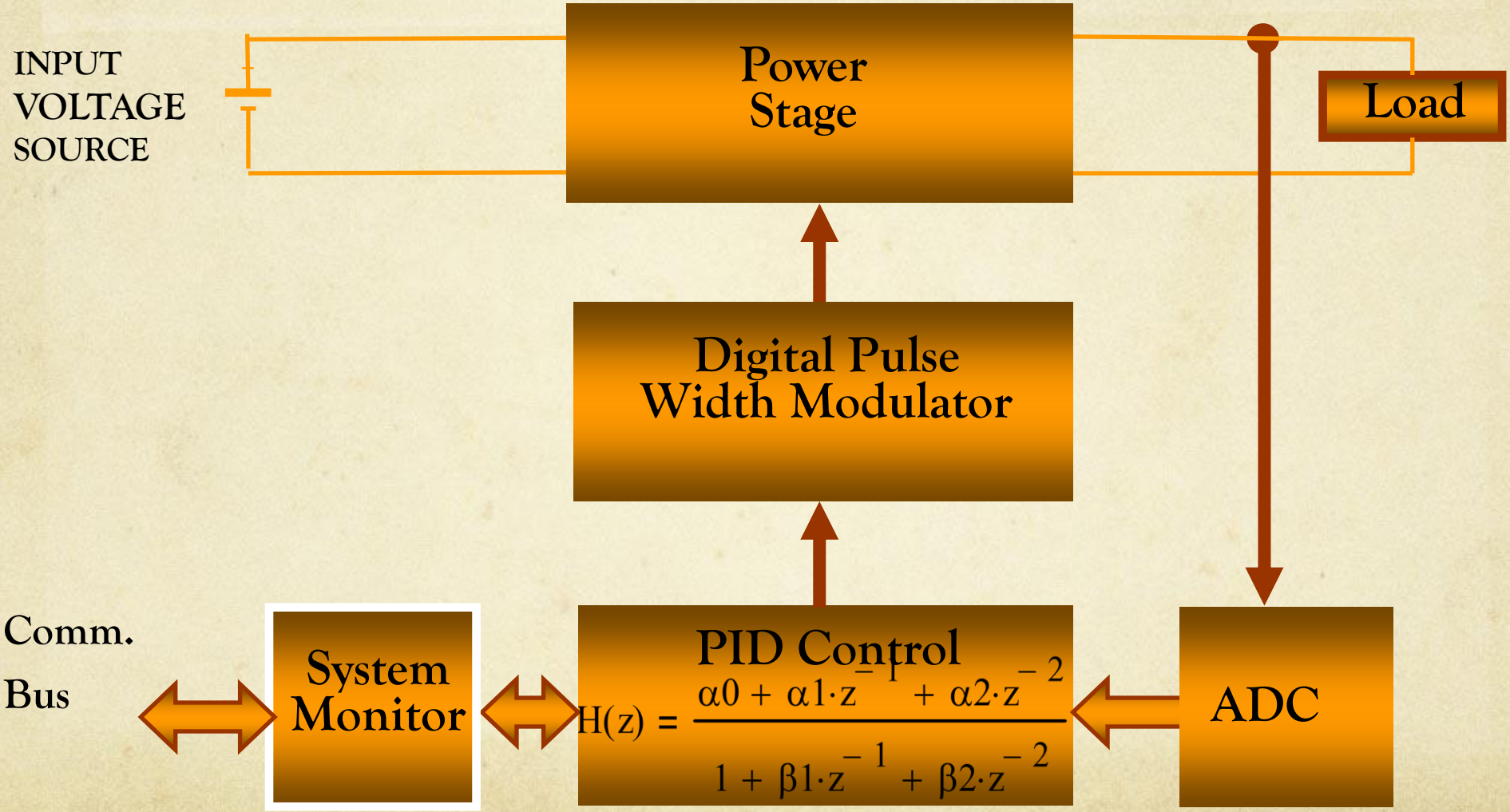
Communication Requirement

- Serial Bus:
  - SMBus – Derived from I2C and only defines the physical layer interface between devices.
  - PMBus - The Power Management Bus (PMBus) is an open standard power-management protocol with a fully defined command language that facilitates communication with power converters and other devices in a power system.

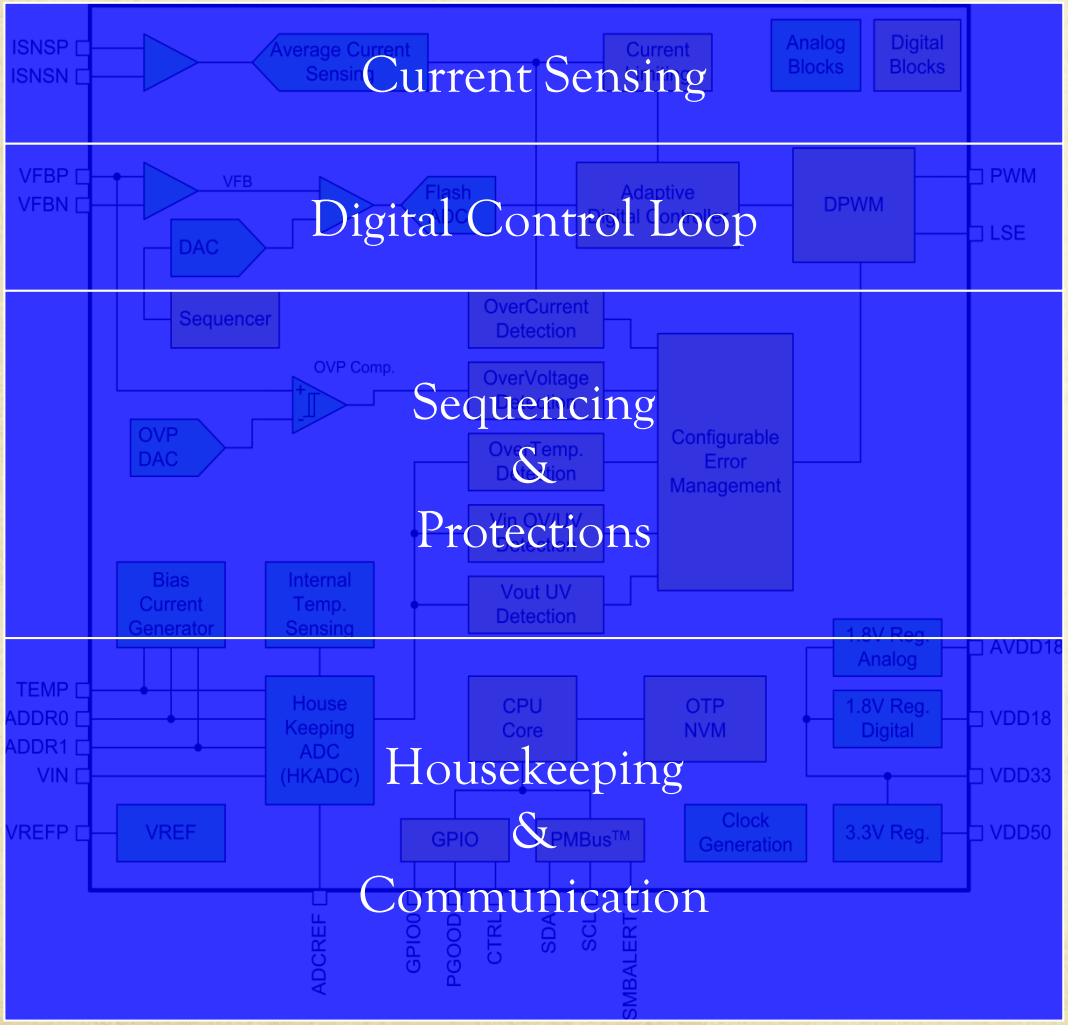
Digital Feedback Control

- **The Pulse Width Modulator incorporates a Discrete Time Control Algorithm.**
- **All control functions are implemented in the digital domain thus being able to get integrated in a fine lithography CMOS process.**

Block Diagram of Digital Control

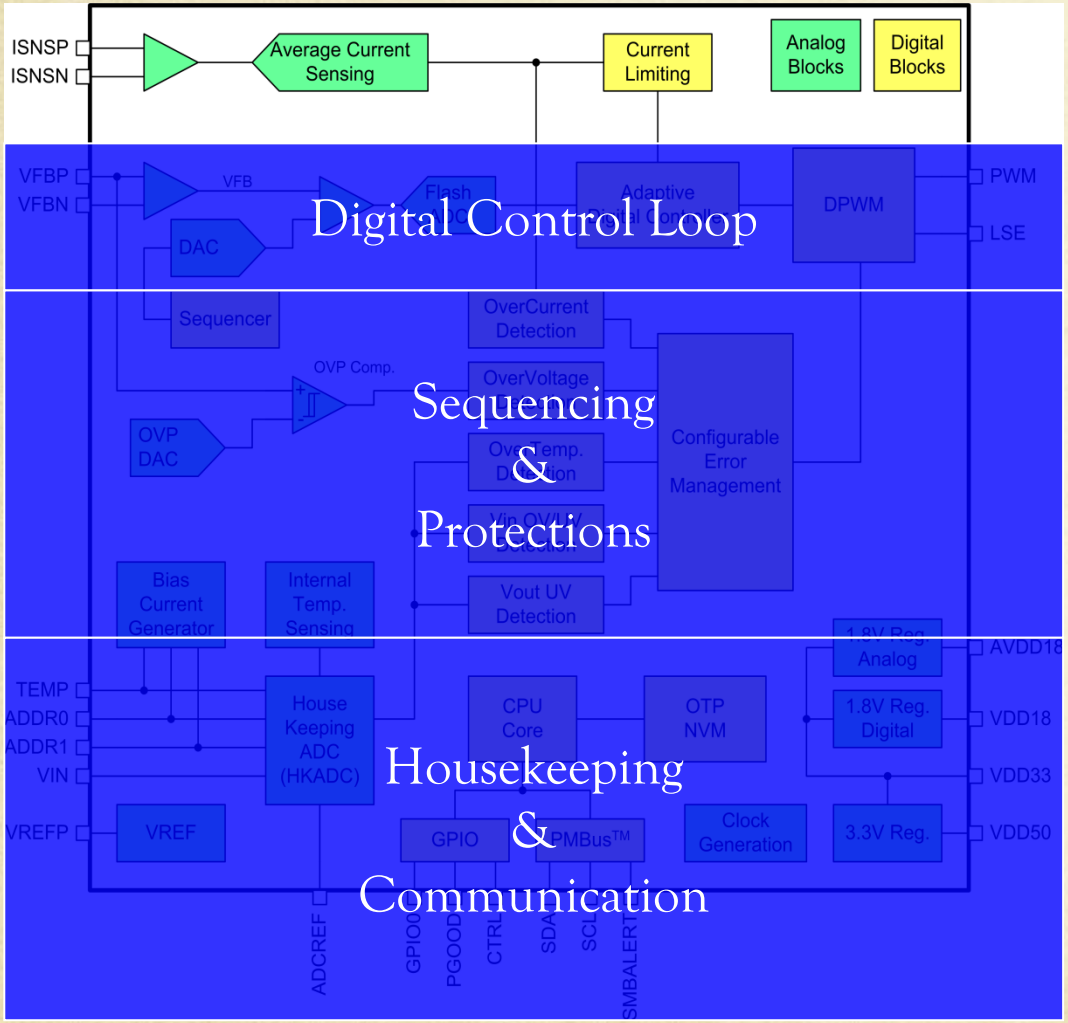


A Typical Chip Architecture
Current Sensing



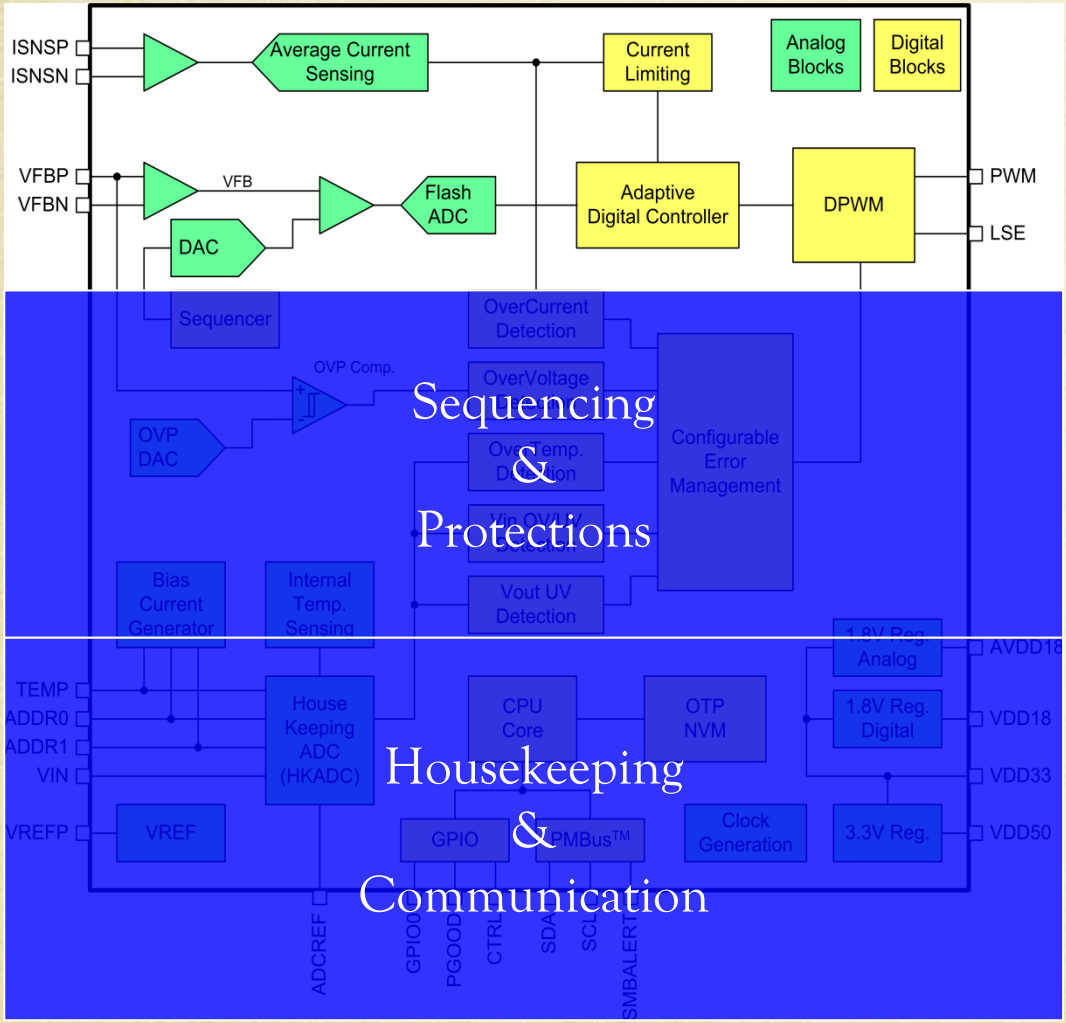
- Current measurement calibration
- Current measurement temperature compensation

A Typical Chip Architecture
Digital Feedback Control



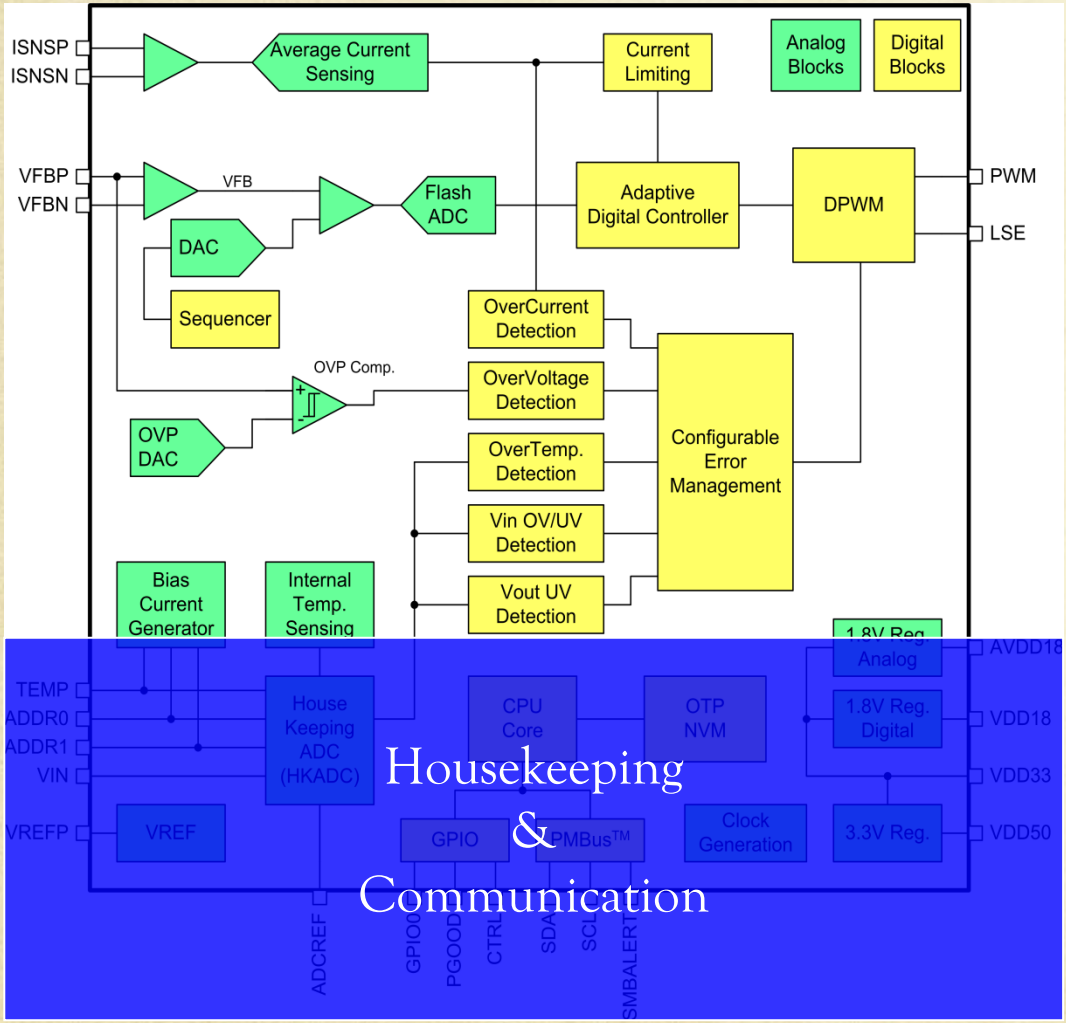
- Adaptive P.I.D. Management with Transient Detection Circuit optimizes coefficients for
  - noise-free steady-state operation
  - faster transient response
- Non-linear PID Gain Control improves settling time under large transients
- User programmable minimum and maximum duty ratio

A Typical Chip Architecture
Sequencing and Protection



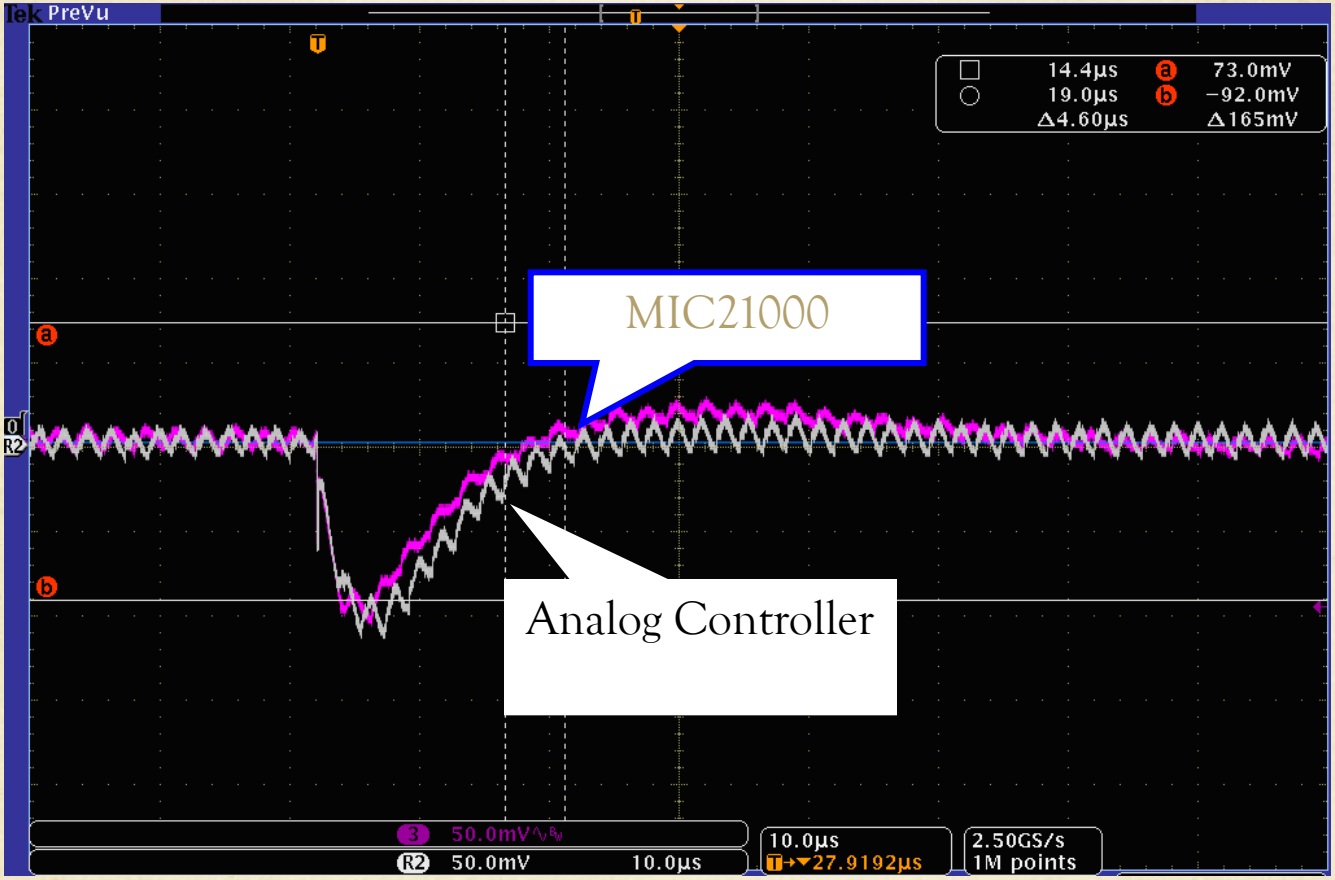
- Direct digital soft-start control
- Reverse current protection (programmable sink level)
- Warning/Fault events manager:
  - Input under voltage
  - Input over voltage
  - Output under voltage
  - Output over voltage
  - Temperature protection (External and Internal)
  - Restart scheduler

A Typical Chip Architecture Communication



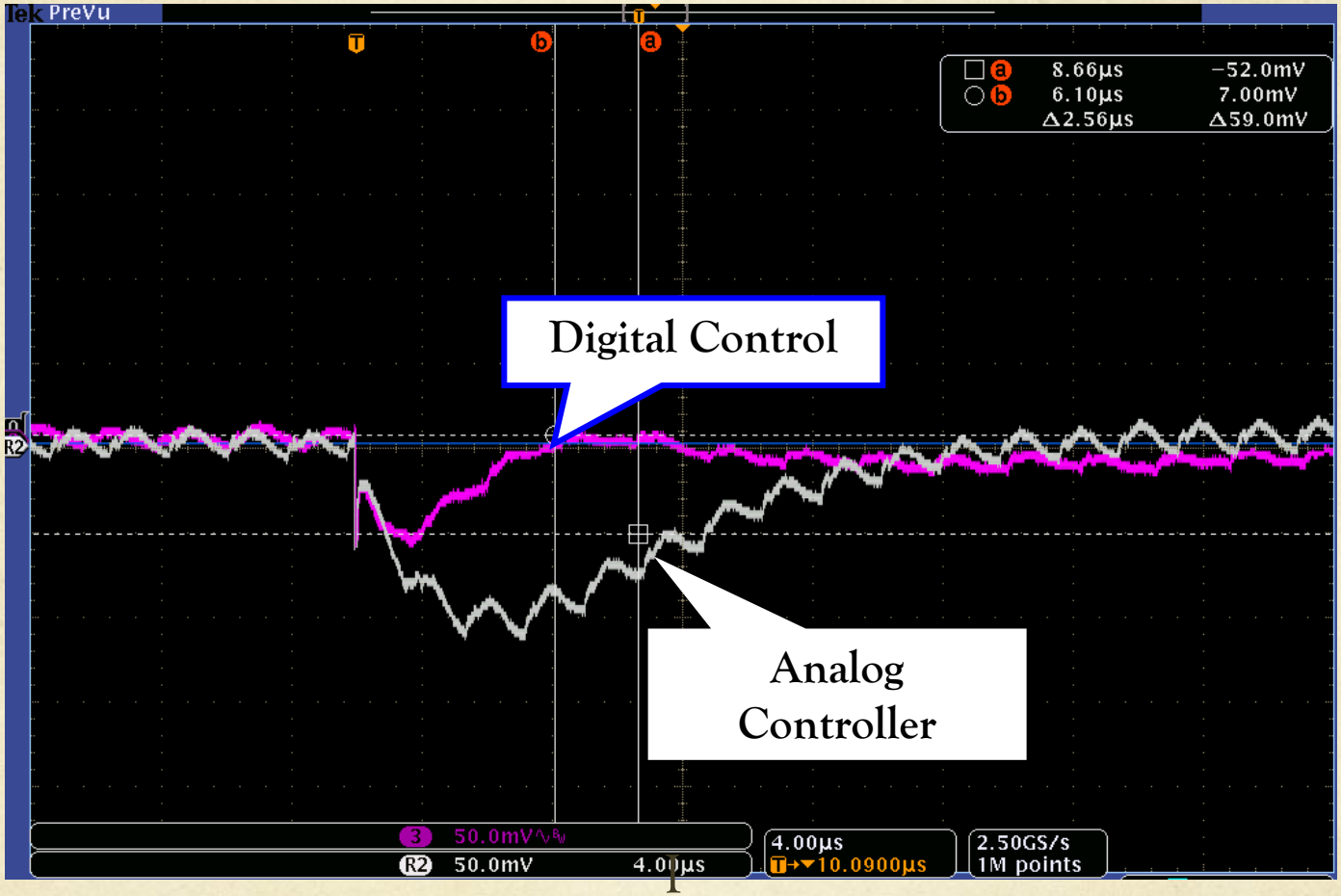
- PMBus interface with SMBALERT and CONTROL pins
- ADDR0; ADDR1 PMBus address programming pins
  - 128 addresses are available using resistor termination
  - 4 addresses by pin-strapping
- Chip internal temperature monitoring
- External temperature sensing (PN junction)
- General purpose ADC with external reference option.
  - Input voltage sensing

Digital Control Allows for Enhanced Transient Response



Ultra-Fast Load Transient Response can be enabled by modifying the Digital Filter Coefficients.

Digital Control Allows Enhanced Transient Response

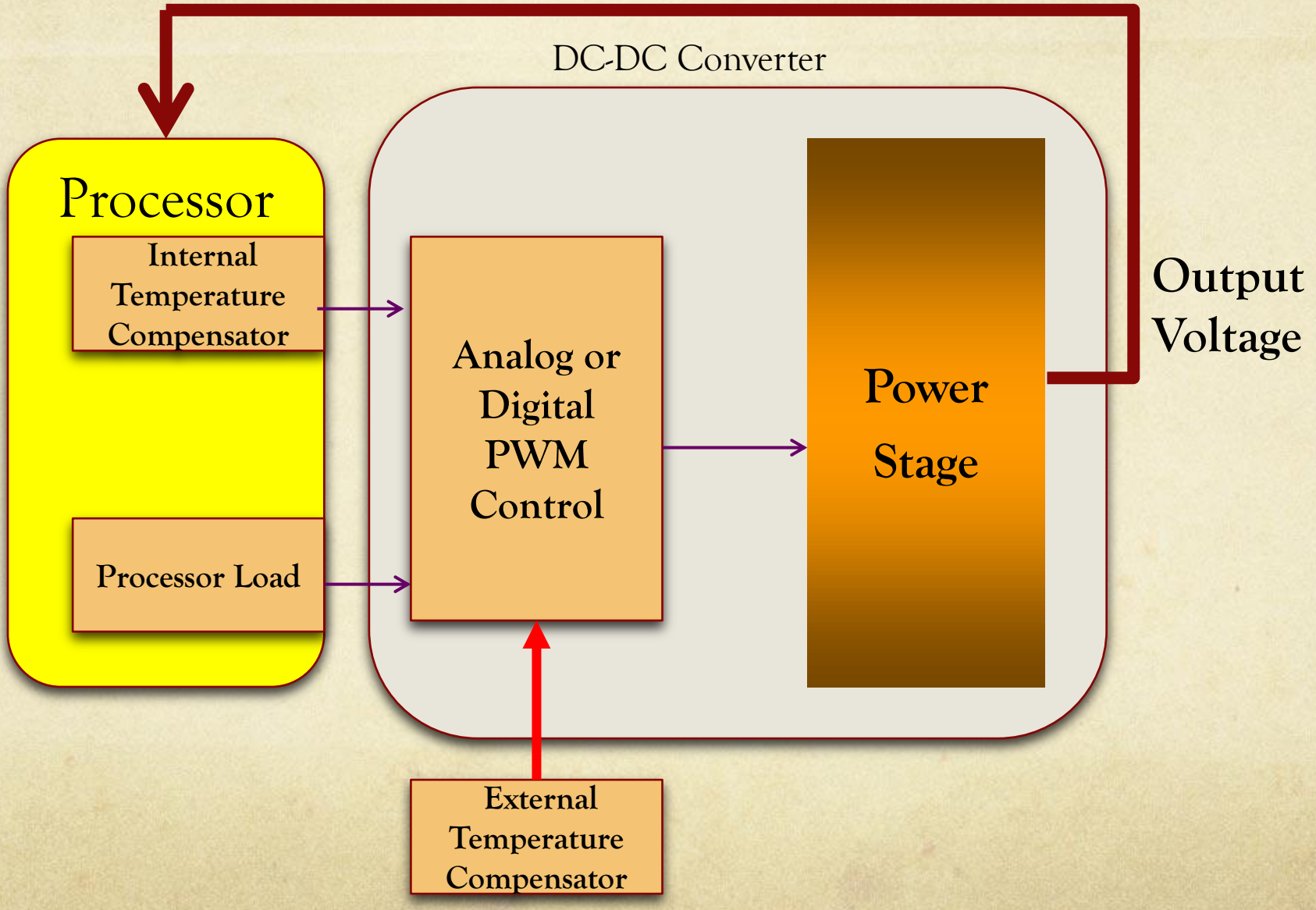


Reduced voltage deviation and faster settling time!
Much smaller output capacitance can be used.

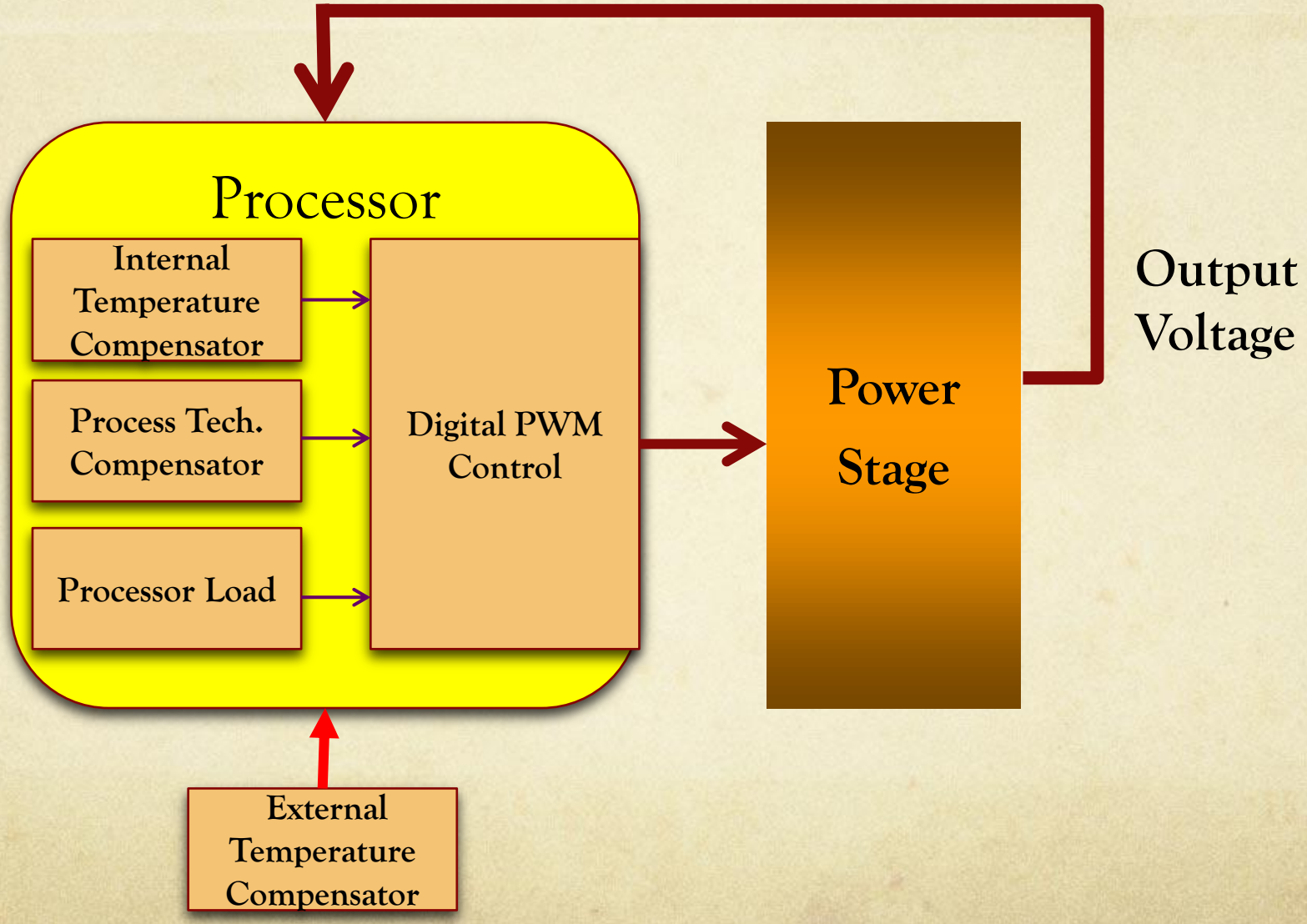
Where are we headed?

- As the need for Powering SOC's with finer geometries grows, Digital Power promises to help optimize power delivery efficiency and cost by:
  1. Monitoring the Power demand of the SOC and adapting the Power controller to the load.
  2. Integration of Digital Power Controller on-board the fine Geometry SOC's.

Where we are now



A Possibility



Integration of Digital Power

- Allows:
  - On-board and off-board **real time** over temperature protection.
  - Setting Output voltage based on **real time** processor load current.
  - Setting output current limit based on **real time** processor load current.
  - Sequencing of various power rails based on **real time** load requirements.

A few Words on Process Technology Requirements

- **Power Stage is the dominant factor setting efficiency of the Power Converter.**
- **Focus on Power Stage Efficiency by minimizing Interconnect losses.**
- **As processor Voltages are reducing, the processor Currents are Increasing. Thus requiring better Interconnect Metallization.**
- **The Industry Needs to Focus on developing power transistors with lower losses at high frequencies.**
  - **Better Ron-Qg.**
- **Power Stage may have to stay Off-Board.**
  - **Optimum Cost vs. Size tradeoffs need to be made.**

Summary

- Digital Power is the critical technology needed for integration of Power Management components.
- Need our foundry partners to develop lower loss power stages to further improve power conversion efficiency.

THANK YOU