Adaptive Voltage Scaling (AVS)

Ultimate Energy Efficiency

D&R IP SoC Conference
December 5th, 2023

DOLPHIN DESIGN

Efficiency: A Growing Concern

- Demographic boom / Resource scarcity / Global warming
- Geopolitical tensions
  - tougher energy supply → explosion of electricity prices
  - tighter access to raw material → bottleneck for batteries
- Surge demand for High-Performance Computing (HPC)
  - 2% of global electricity consumption → 4% by 2030 (1)
  - heat impacts performances (package limited) and cost-of-use (cooling)
- IoT deployment and maintenance
  - 78 million batteries will be discarded daily by 2025 (2)
  - batteries shall last longer than the devices they power

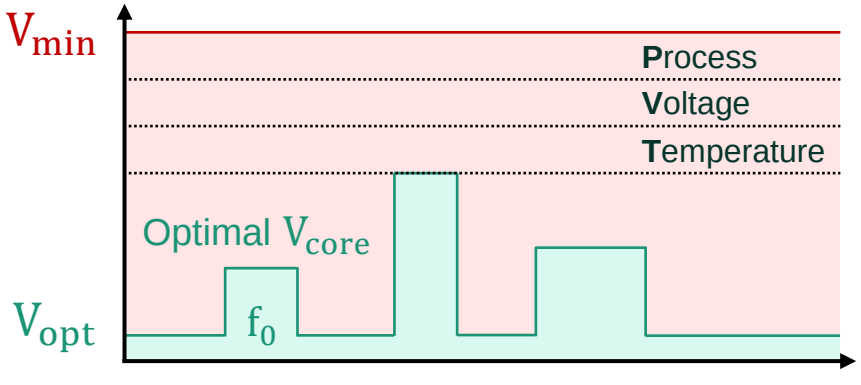
(1) MarketsandMarkets / (2) Fortune Business Insights

Efficiency: Margin Limited

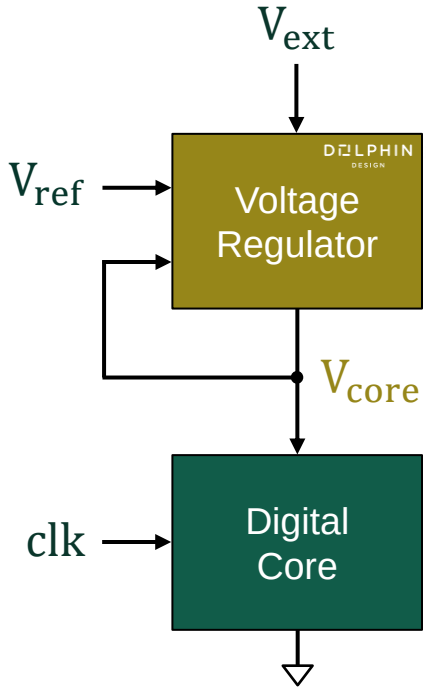
$$P_{core} = P_{leakage} + P_{dynamic}$$
$$= I_{leak}\, V_{core} + \propto f_{clk}\, C\, V_{core}^2$$

⇨ Minimize V_{core}

⇨ $V_{core} > V_{min}(f_{clk})$



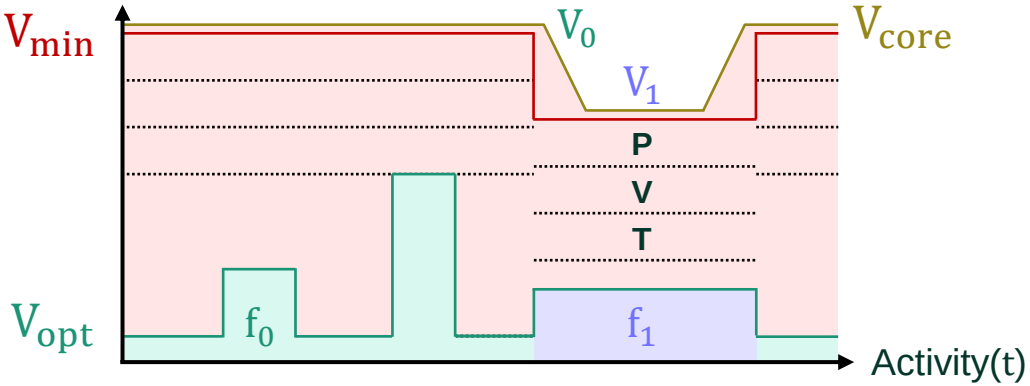
⇨ Wasted energy

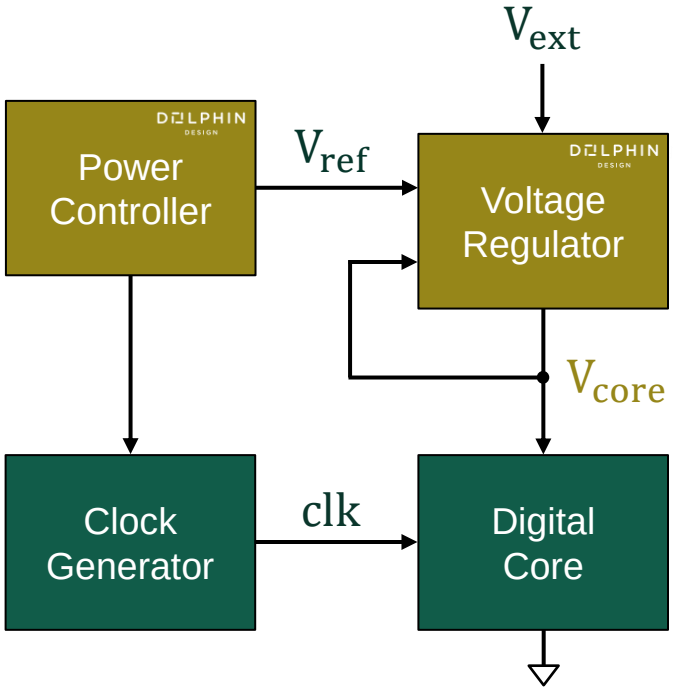


Dynamic Voltage & Frequency Scaling (DVFS)

- Increases the power efficiency of the core
- via a dynamic adjustment of its performances
- based on a predefined set of modes $\{f_{clk}, V_{core}\}$

⇨
- Limited number of modes
- PVT margins not reduced

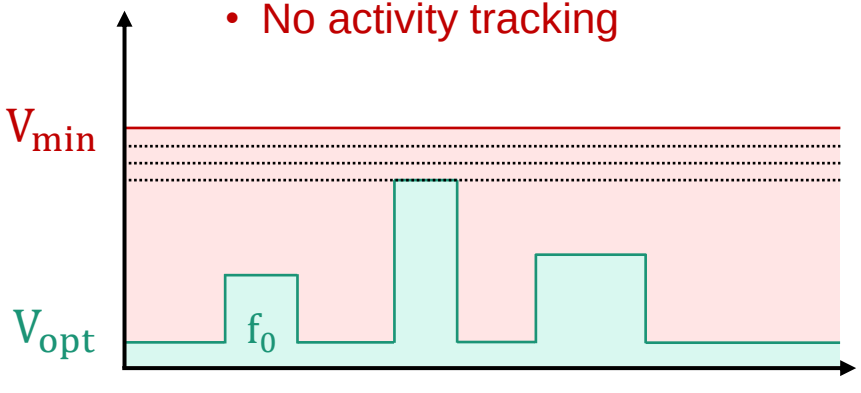


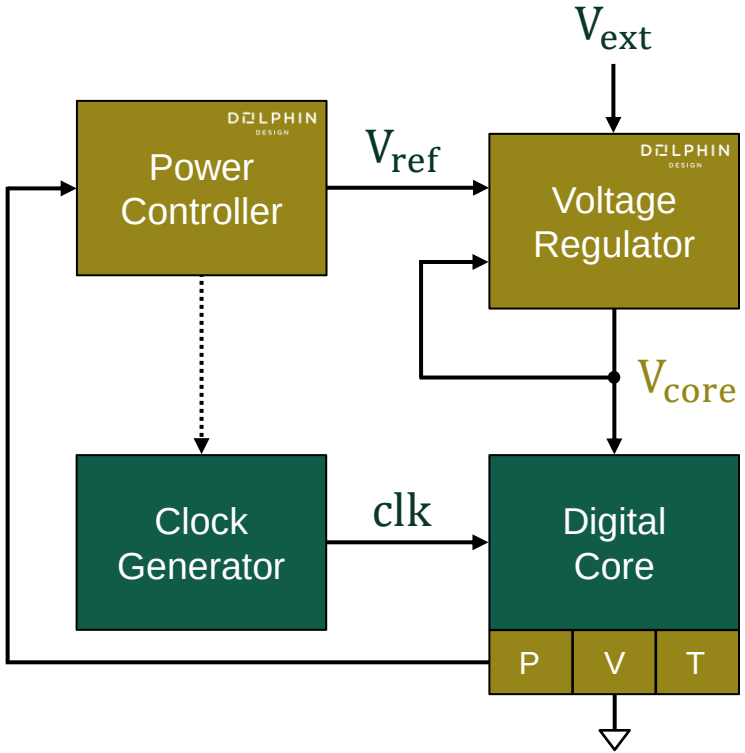


Adaptive Voltage Scaling (AVS)

- Reduces the PVT margins
- via a closed-loop approach
- based on embedded monitors

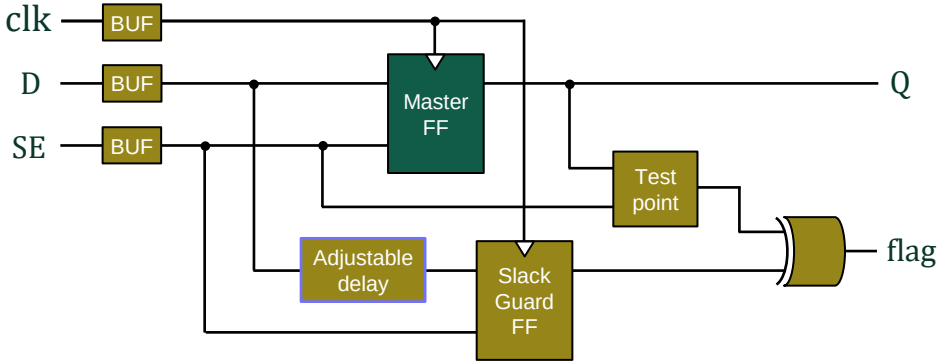
- Actual slack is unknown
- PVT margins still required
- No activity tracking

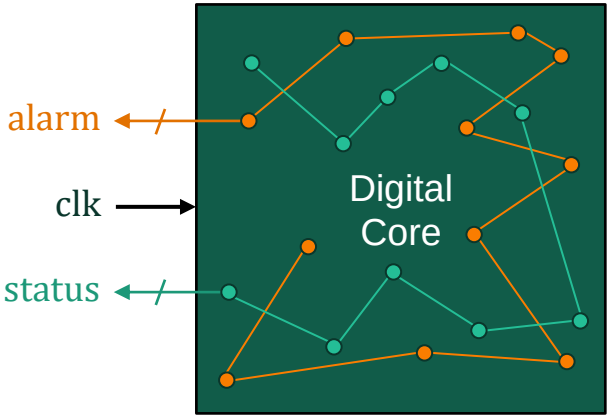


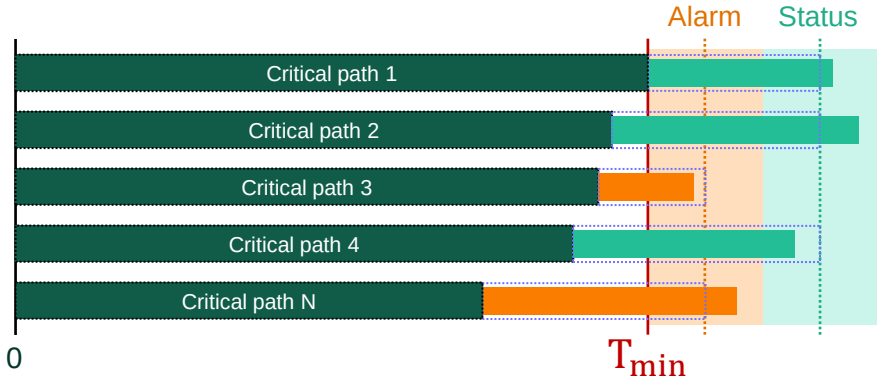


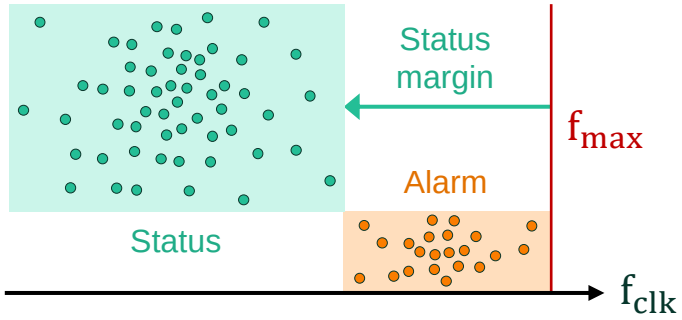
Dolphin's Slack Guard

Patented



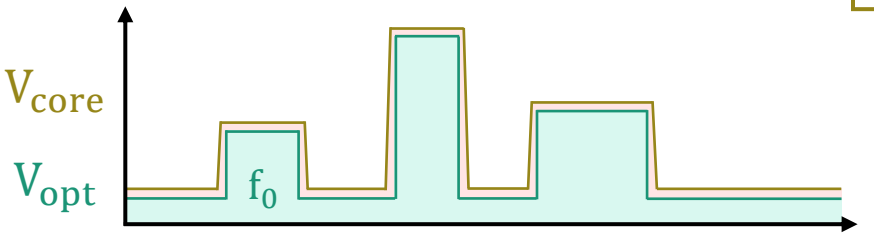






Slack Guard based AVS – Benefits

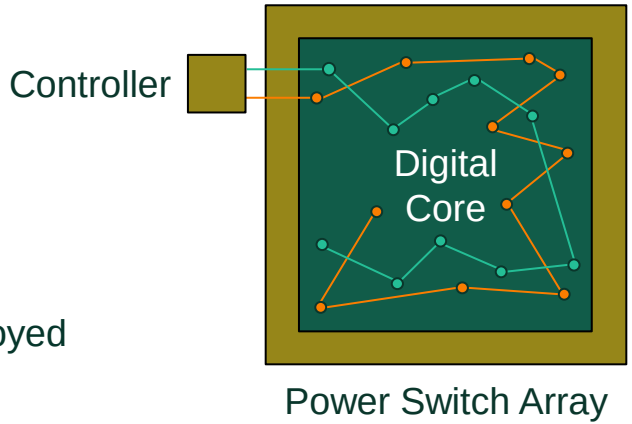
- **Real-time slack regulation** → Minimize voltage margin → **Maximize efficiency**
- Fully digital capless implementation → **Scalable / Small silicon area**
- Standard power switches (PMK) → AVS + **Power gating** → **Optimize $R_{on/off}$**
- Dynamic adaptation of V_{core} to f_{clk} → Fine **thermal budget management**
- Fast regulation → **Voltage droop management**
- Emergency clock division → **Safety mechanism**



⇨ **Perfect solution for HPC**

Slack Guard based AVS – Results (12FF)

- **Slack Guards**
  - High coverage: ~1% endpoints → > 50% logic cones
  - Fully digital solution based on foundry standard cells
  - Compatible with standard DFT flow / AMBA interfaces
  - No area impact – test points inserted in existing floorplan



- **Controller**
  - Leverages Dolphin's ABB control loop – patented & deployed
  - Small silicon area: 0.004 mm²

- **Power Switch Array (5 A)**
  - Based on foundry standard power switches (PMK)
  - Joint management of AVS & power gating
  - Reasonable silicon area: 0.15 mm²

⇨

- **Pwr eff (0.8V, 85°C): +20%**
- **Response time: < 3 ns**
- PSRR: 0 dB @ 10 MHz

Takeaways

Dolphin's AVS solution

- Real-time slack regulation
- Fully-digital capless implementation
- Direct monitoring of the actual critical path endpoints
- Ultimate power efficiency
- Safe operation