Intelligent Power Solutions for Next-Generation Robotics Platforms

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Agenda

MPS

- Robotics Market Growth – Key Economic and Technological Drivers
- Robotics SoC Platforms
- Challenges in Powering the High-Performance Compute SoCs in Robotics
- MPS‘s Key Technology Differentiators
- Controller + DrMOS + PoL Solutions for Intelligent Power Management
- Conclusion

Robotics Market Growth

Robotics Market Growth – Key Economic Drivers

- Humanoid robotics market is set to reach ~$3B by 2035
- Increasing demand for industrial automation across manufacturing sectors
- Persistent labor shortages in developed economies
- Rising labor costs make automation more economically viable
- Technological advancements enabling more capable and cost-effective robots
- Growing adoption in non-traditional sectors (e.g. healthcare, retail, and logistics)

Robotics Market Growth – Key Technological Drivers

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AI/Edge Compute
- Vision, perception, on-device decision making

Advanced Sensors
- Cameras, radar, LiDAR, tactile sensing

Electrification
- Battery-powered operation (mobility, efficiency)

Connectivity
- 5G and industrial networks enabling coordination

High-Performance Compute SoCs
- GPU/AI accelerators driving the compute demand

Miniaturization
- More capabilities in smaller form factors

Convergence of AI + Sensing + Compute + Power Efficiency

MPS Solutions for Robotics

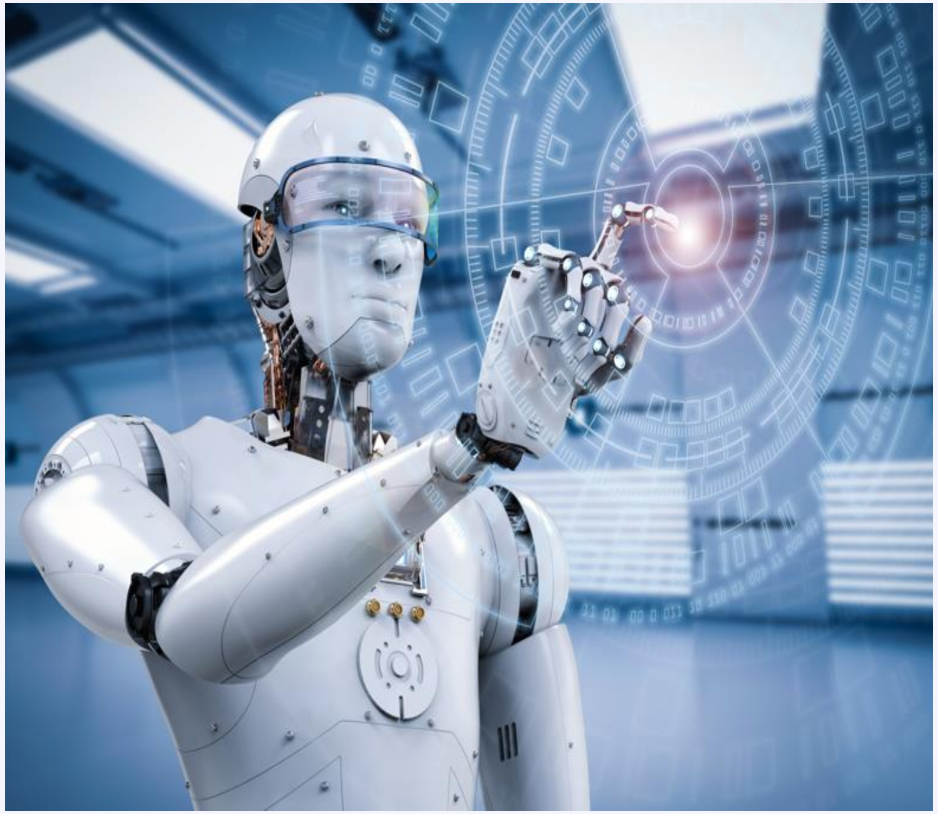
MPS has end-to-end solutions to cater to the power management requirements in robotics solutions.

Actuators

Motors
Motor Drivers
Servo Controllers
Angular Sensors
Power Modules

Drives

Isolated Gate Drivers
Isolated DC/DC Supplies
Digital Isolators
Current Sensors
SiC MOSFETs



Compute

Multi-Phase Controller
Intelli-Phase™ DrMOS
PoL Regulators
Intelli-Modules

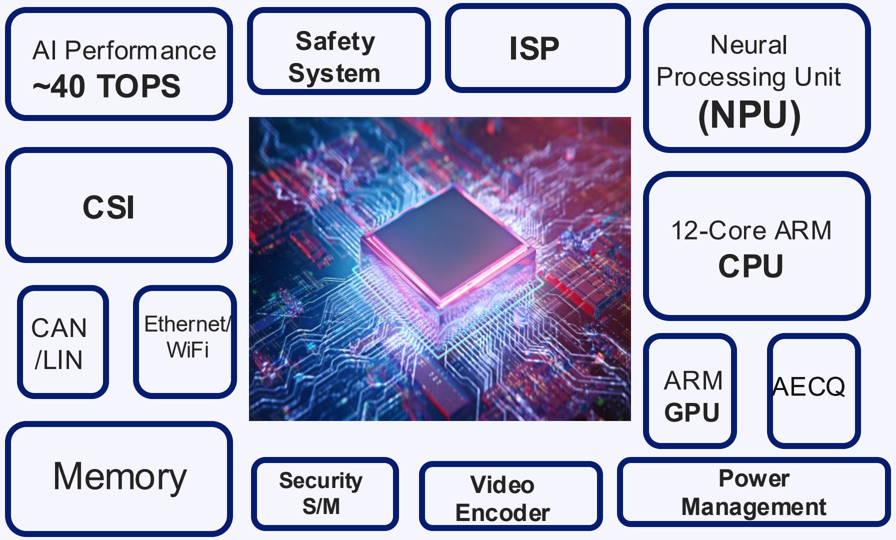
Battery Management

Battery Monitor/Protectors
Fuel Guages
Active Balancers

Robotics SoC Platforms

Why Should We Focus on the SoC Platform?

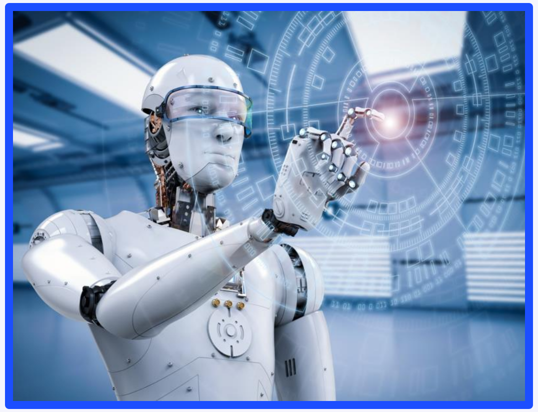
SoC platforms are becoming compute-intensive and power hungry.



These platforms form the brain of the robotics system architecture, so efficient power management is critical!

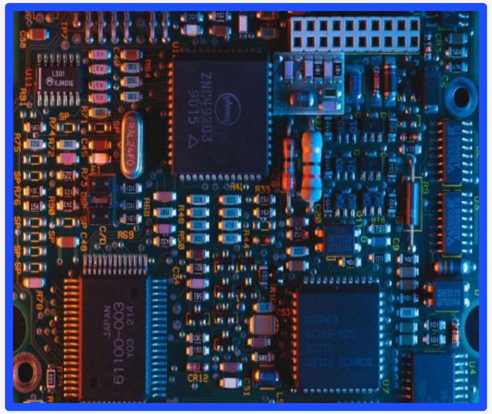
Challenges in Powering Robotics SoCs

Battery-Dominated Systems



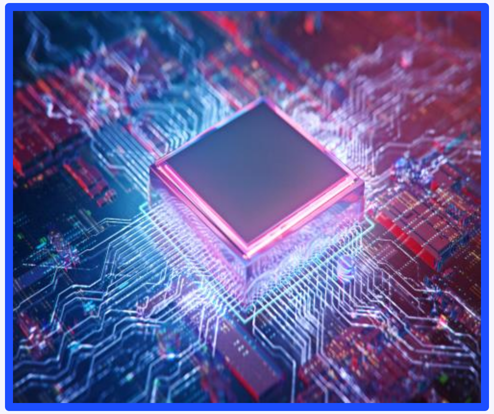
- Limited energy budget and need for longer run time
- **Solution**: sleep mode, low I_Q, and phase-shedding techniques that extend operating times and conserve energy

Smaller Form Factors



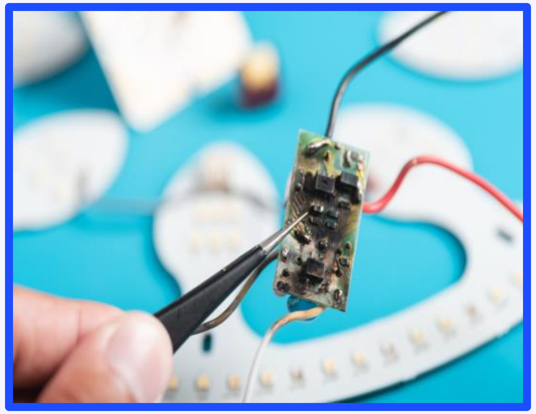
- Systems shrink, but batteries are bulky and more power must be delivered
- **Solution**: advanced packaging and integration technologies

Dynamic Workloads



- AI SoCs switch rapidly between workloads
- **Solution**: VRs that can respond immediately to sudden current spikes – fast transient response

Thermal Management

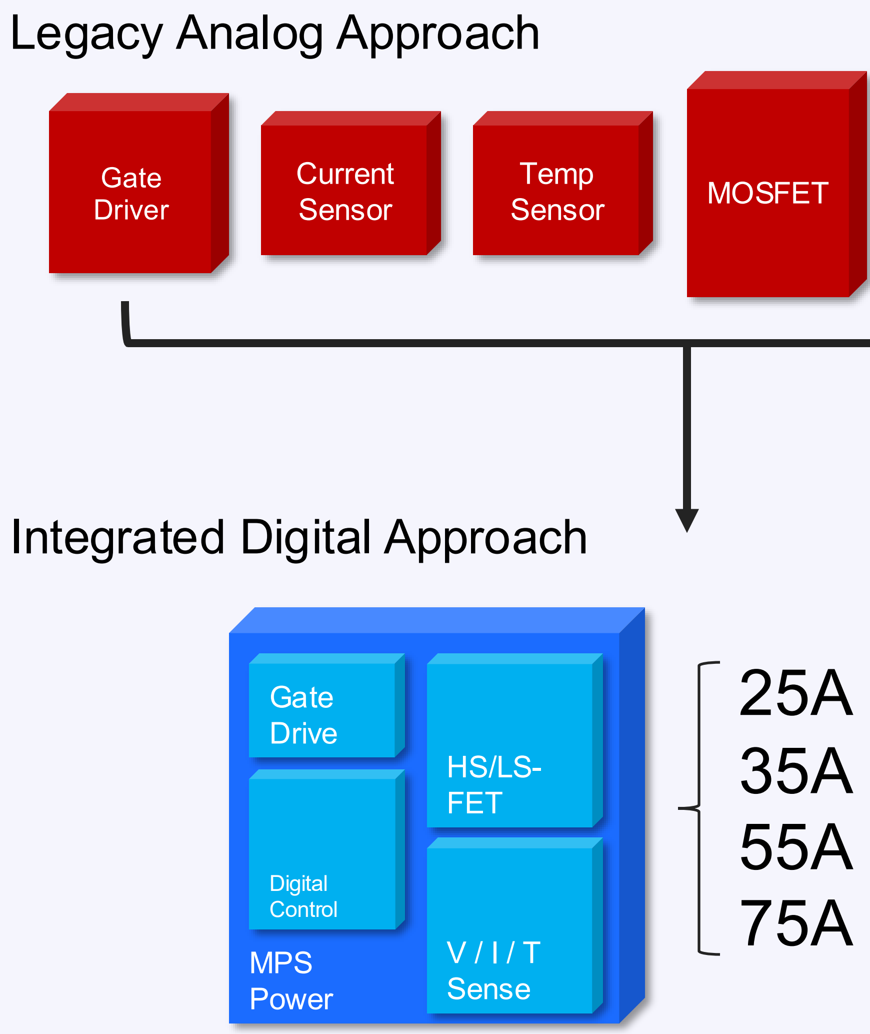


- No heatsinks or fans
- Limited airflow in the head/torso
- **Solution**: deliver high currents with minimal losses without overheating the system

MPS Key Technology Differentiators

1. Advanced Integration Technology for Smaller Form Factors

SoC Power Management Needs High Integration

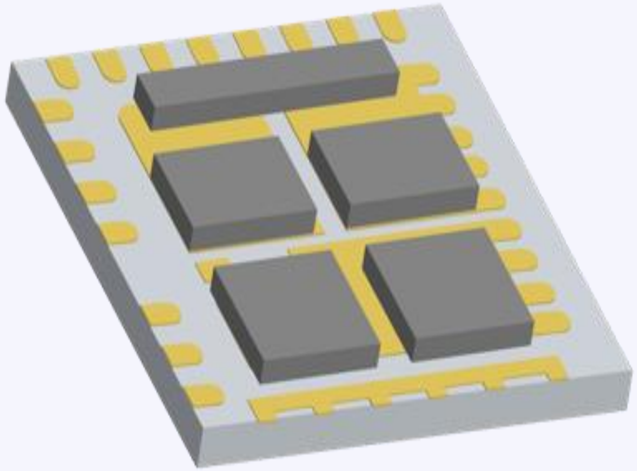


Integration Unlocks Massive Benefits

- High Power Density
- High Efficiency
- High Reliability
- Accurate Current Sensing
- Accurate Temperature Sensing

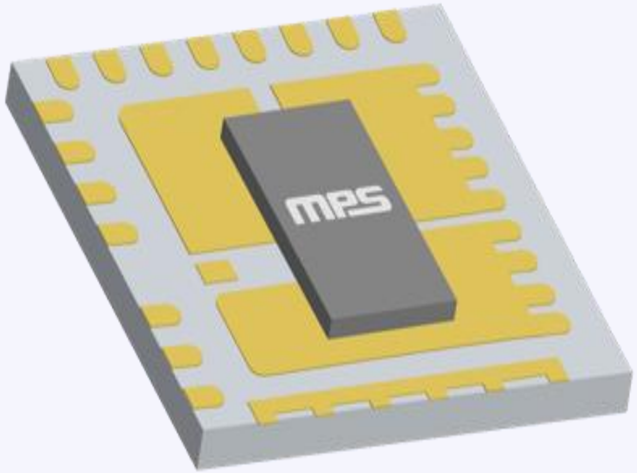
MPS Proprietary Monolithic DrMOS Design

Legacy Five Dice Solution



- Separate driver IC cannot provide simultaneous on/off across the FETs due to gate delay.
- Needs longer dead time to ensure that there is no shoot-through, resulting in lower efficiency.

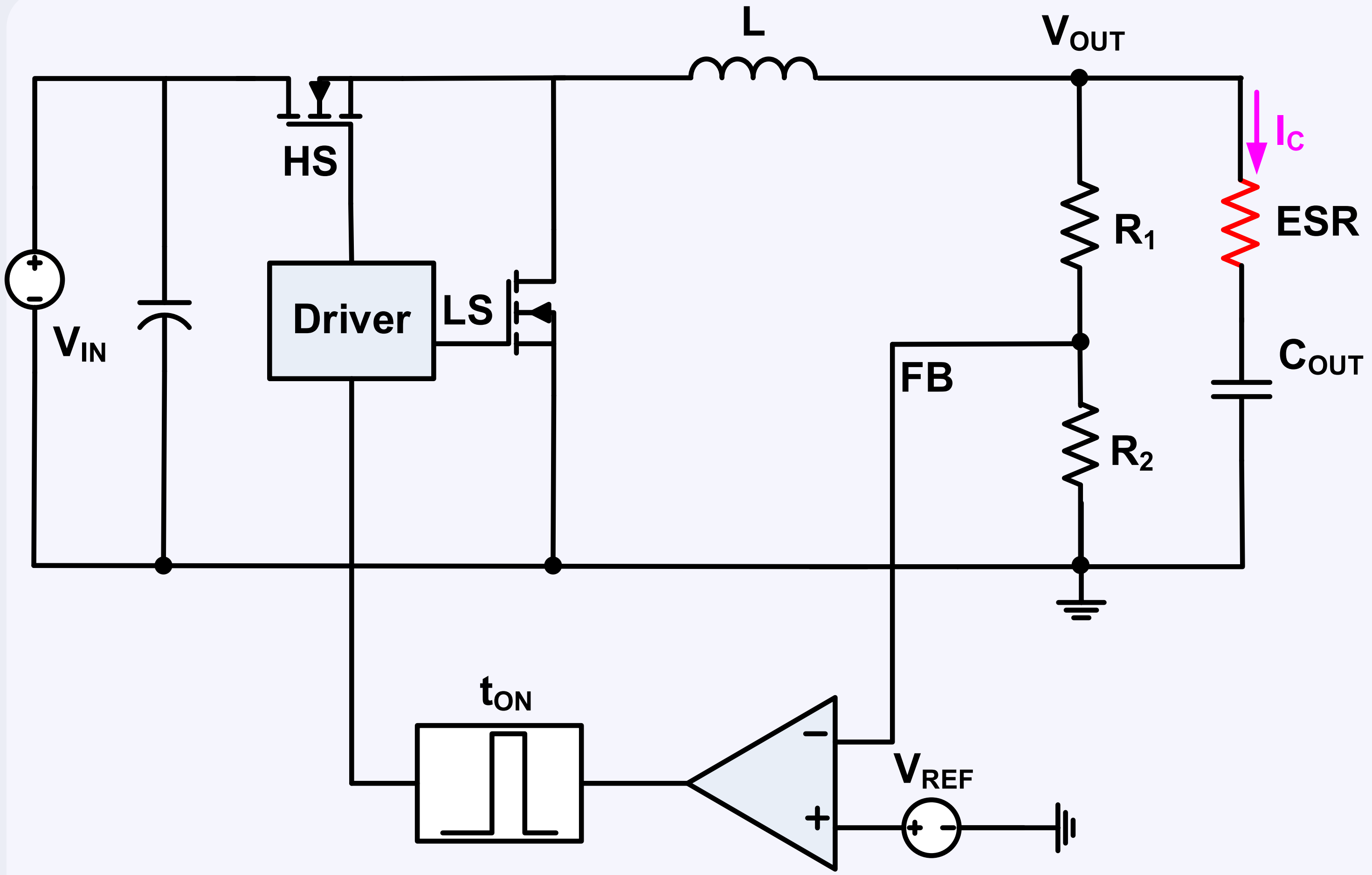
Monolithic One-Die Solution

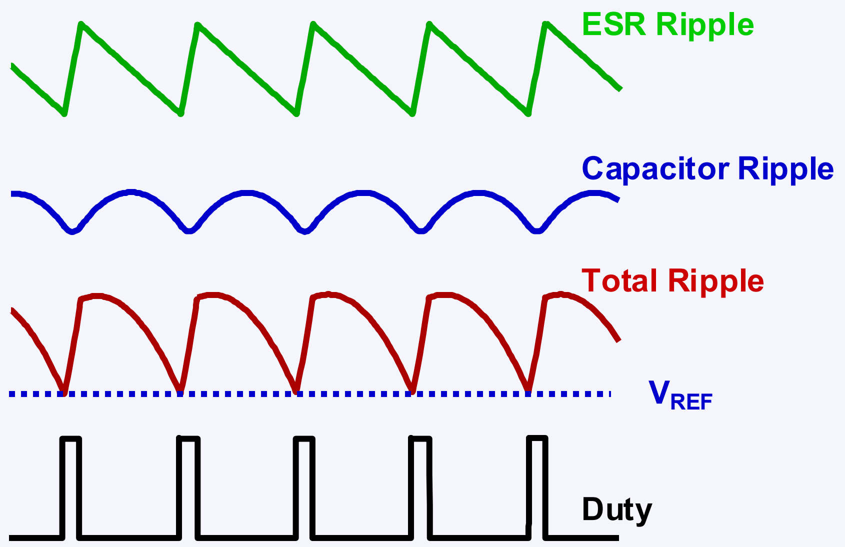


- Distributed gate driver minimizes the gate delay and ensures even current distribution among cells.
- Integrated current and temperature sensing for higher accuracy and efficiency.

2. Advanced PWM Technique for Dynamic Workloads

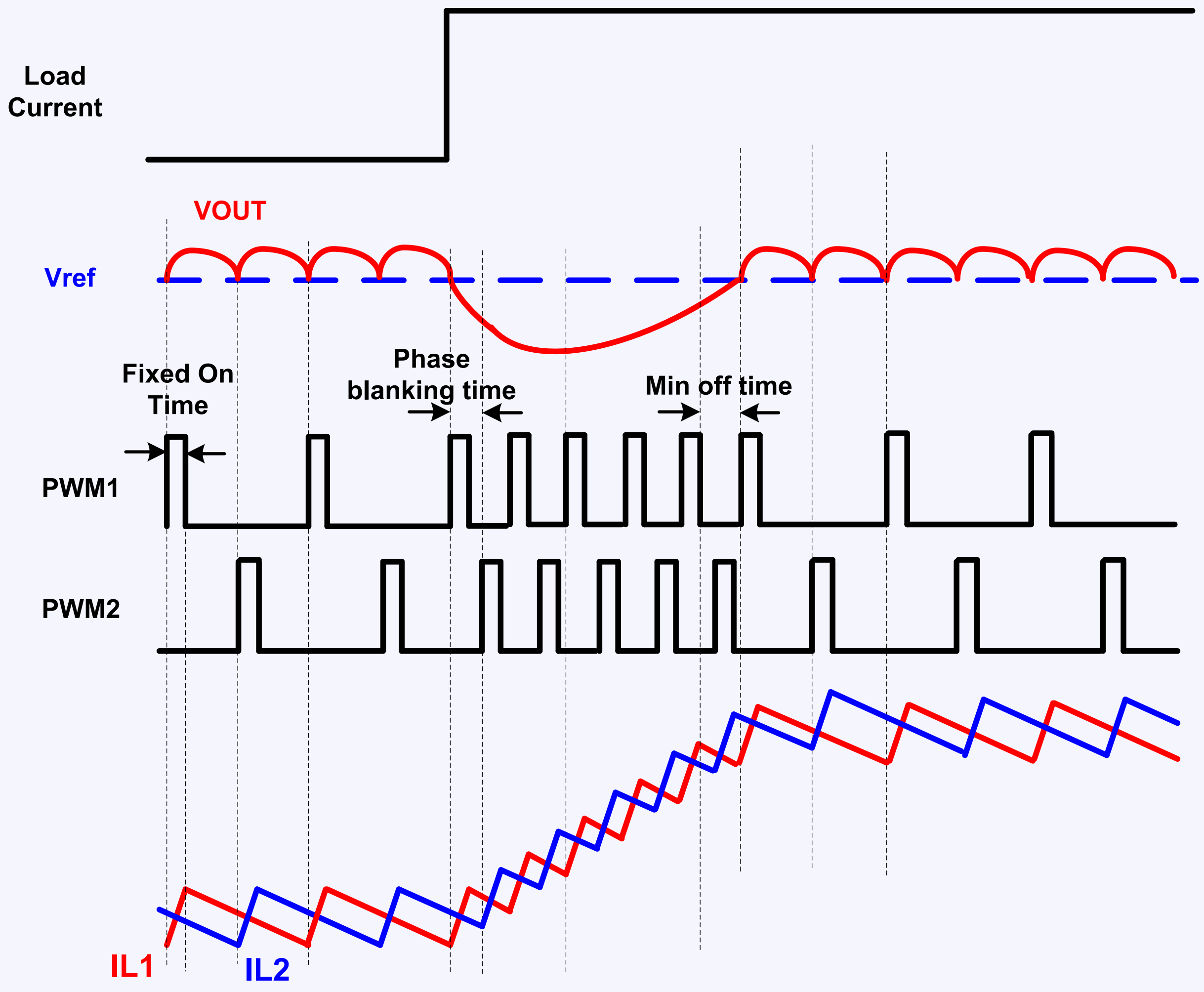
MPS Advanced COT PWM (ACP™) Control





- V_{OUT} ripple is directly compared with V_{REF} to determine the PWM turn-on
- Variable frequency operation
- On-time pulse width is fixed

Advanced COT Improves Dynamic Current Sharing



Reduce the PWM off-time to support transient load, while the PWM on-time stays constant.

PWMs are evenly distributed to each phase.

The inductor current of each phase increases in the pattern of "multiple quick small steps."

- **Inherently better, dynamic current sharing than voltage or current mode control.**

3. Power Management Schemes to Extend Battery Life

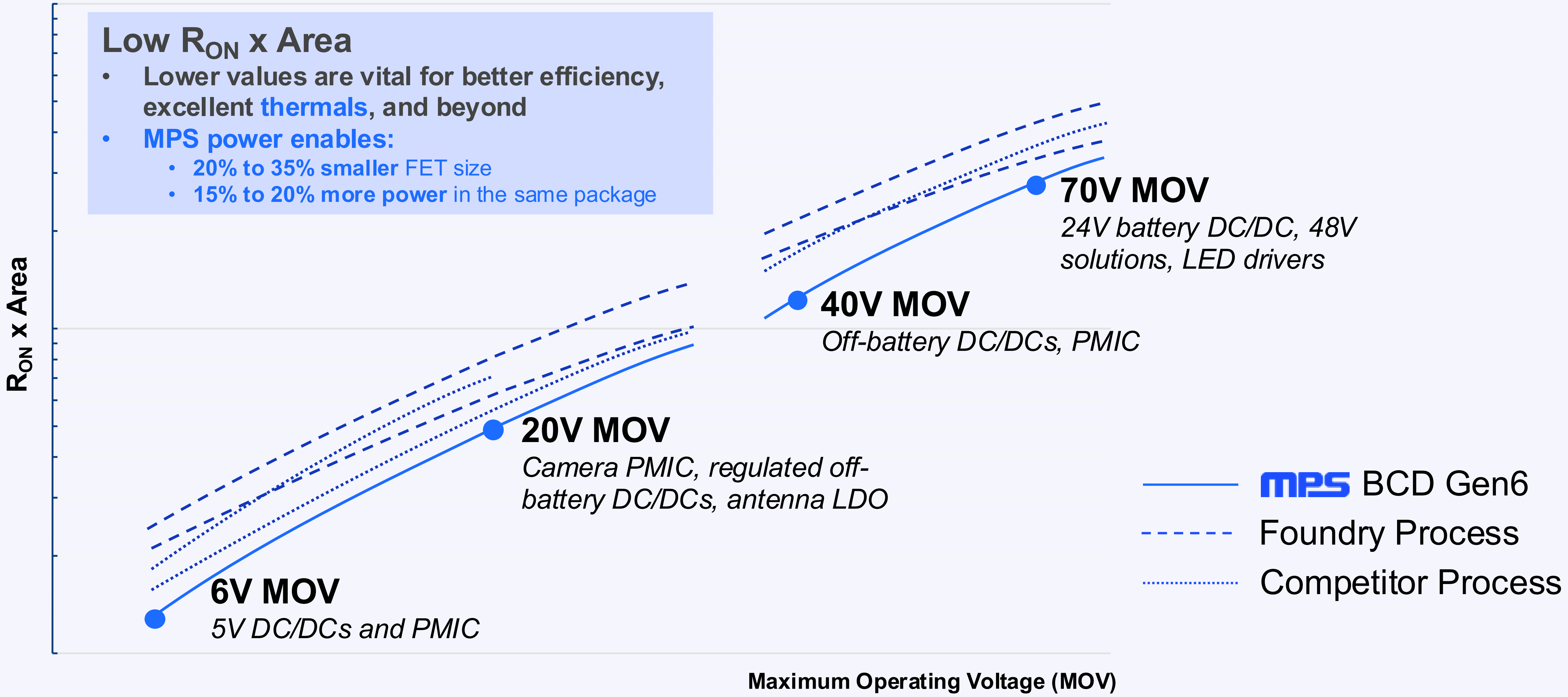
Power Management IC (PMIC) Features

- Low Quiescent Current
  - Lowers the system's current consumption in an idle or sleep state
- Configurable Mode of Operation
  - Discontinuous conduction mode (DCM) under light-load conditions leads to lower switching frequency, which significantly decreases the converter's switching losses
  - Continuous conduction mode (CCM) lowers the RMS current flowing to the converter, which reduces conduction losses
- Supports Adaptive Voltage Scaling (AVS) and Dynamic Voltage Scaling (DVS)
  - AVS is the IC's ability to follow the voltage setting required by each chip due to process variation
  - DVS adjusts the converter's output voltage on the fly to adopt to the SoC or FPGA demand
- Phase-Adding and Phase-Shedding Scheme
  - Automatically adopt the number of phases depending on the output current

4. Process and Package Technologies for Efficient Thermal Management

Why MPS Power : High Power Density Process

Low R_{ON} x Area
- Lower values are vital for better efficiency, excellent **thermals**, and beyond
- **MPS power enables:**
  - **20% to 35% smaller** FET size
  - **15% to 20% more power** in the same package



Approximations shown only

Flip-Chip Packaging Technology

1. Reduced Thermal Resistance ($R_{\theta JA}$)

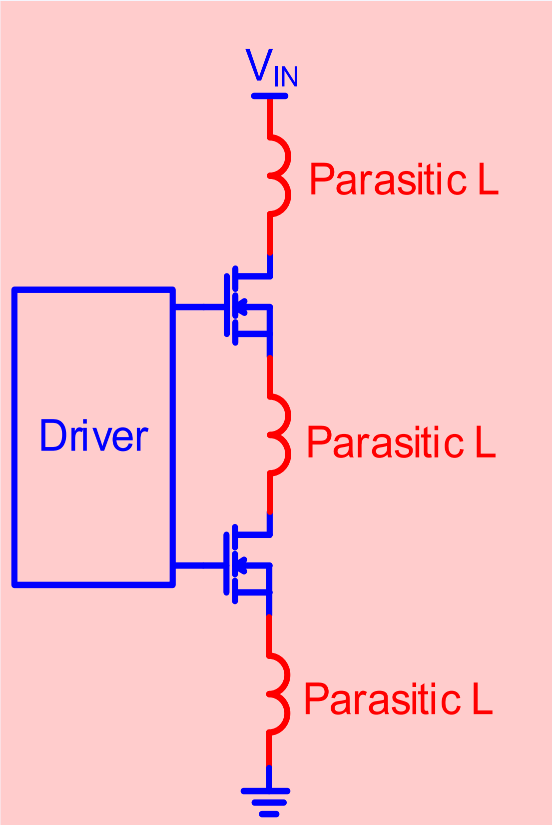
Advanced packages significantly lower the junction-to-ambient thermal resistance, enabling higher power dissipation without oveheating.

2. Improved Electrical Performance

The elimination of wire bonds leads to lower parasitic inductance and better conduction paths.

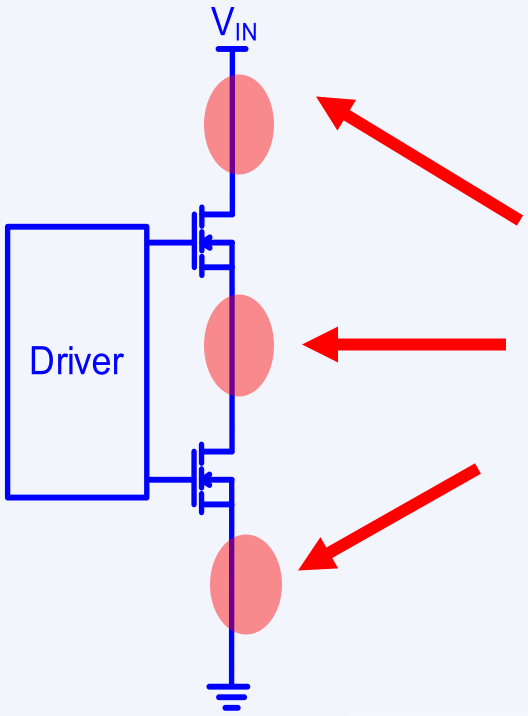
3. Enhanced Heat Flow

The close placement of die, capacitors, and copper paths improves thermal spreading and switching efficiency.



Large parasitic L and R

Traditional Wire-Bond Solution



Smaller L and R

MPS Flip-Chip Solution

MPS's High-Current Core Power Solutions

Controller + DrMOS + PoLs

Digital Controller + DrMOS – Efficient and Compact Solution

Digital Control

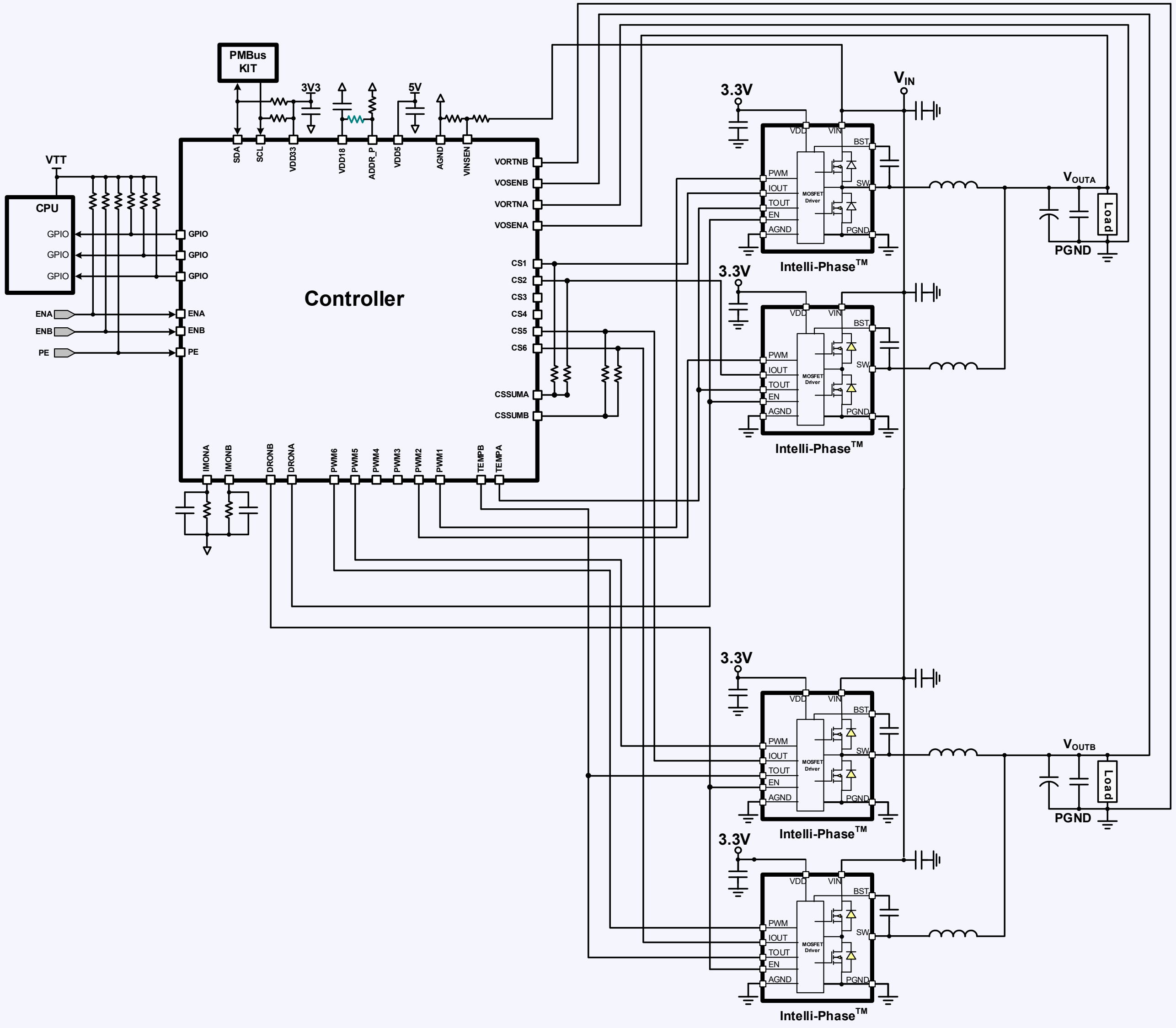
- Easy Compensation
- Fast Transient Response
- Better Current Balancing
- Configurability and Flexibility
- Real-Time Monitoring and Reporting
- Comprehensive Protection

Monolithic DrMOS

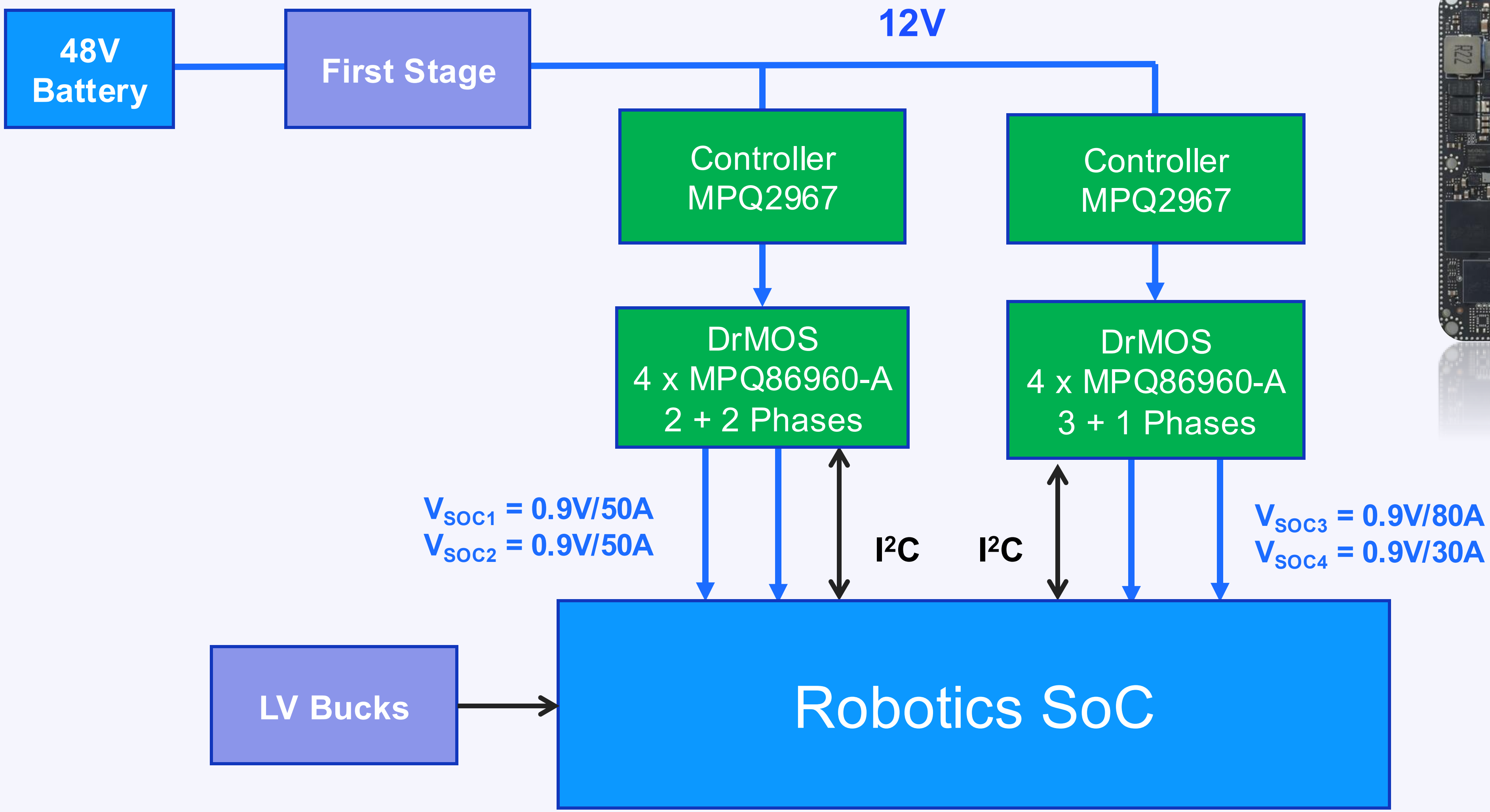
- Monolithic Design — Fewer Components, More Robust
- Switching Loss Reduction — Higher Efficiency
- Superior Current-Sensing Accuracy

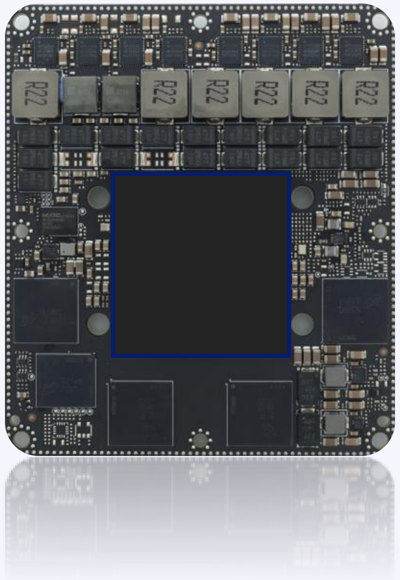
Fewer External Components

- Cost-Effective
- More Compact Design

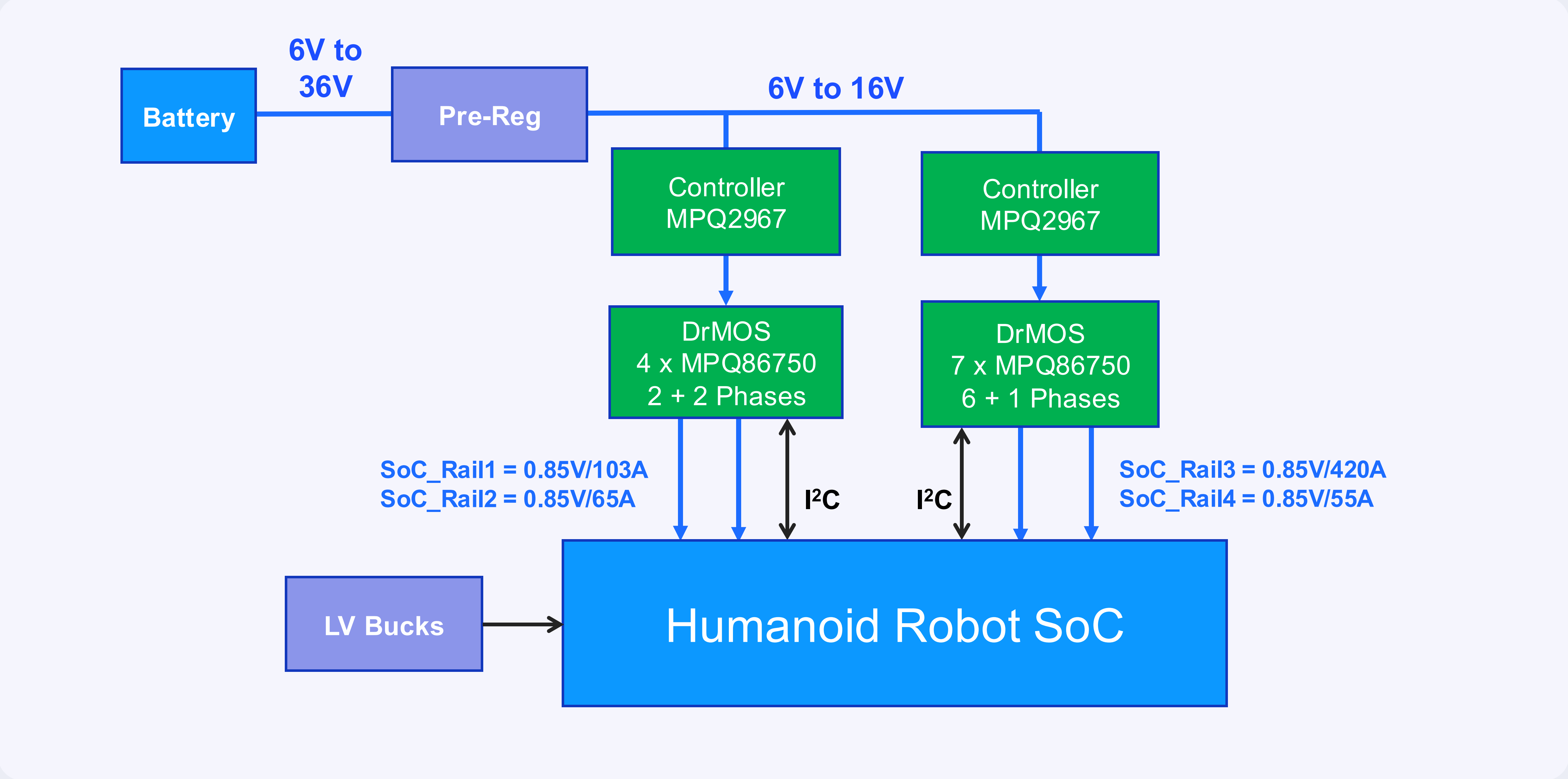


An Example for Robotics SoC Core Power

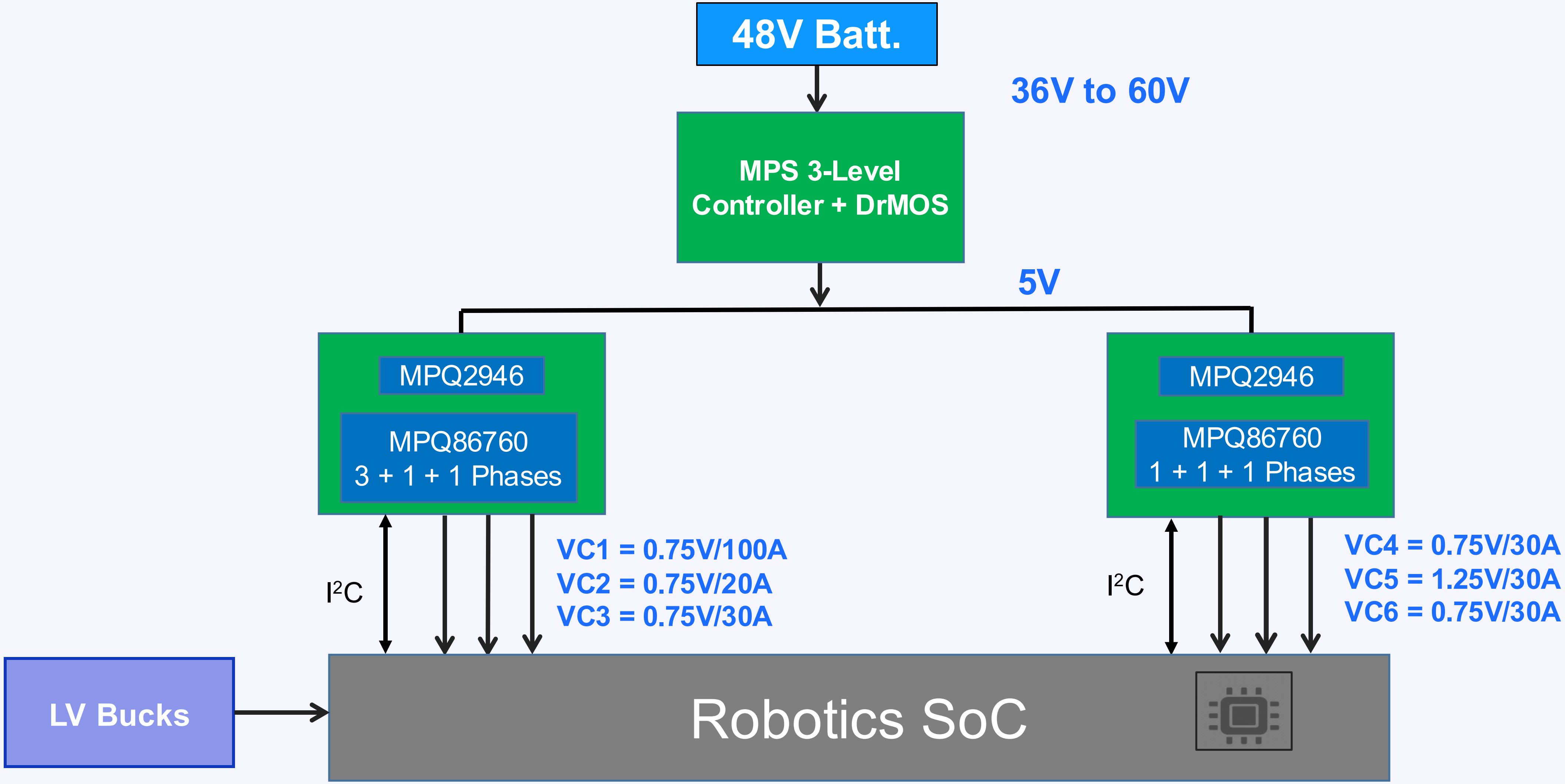




An Example Robotics SoC Core Power Tree

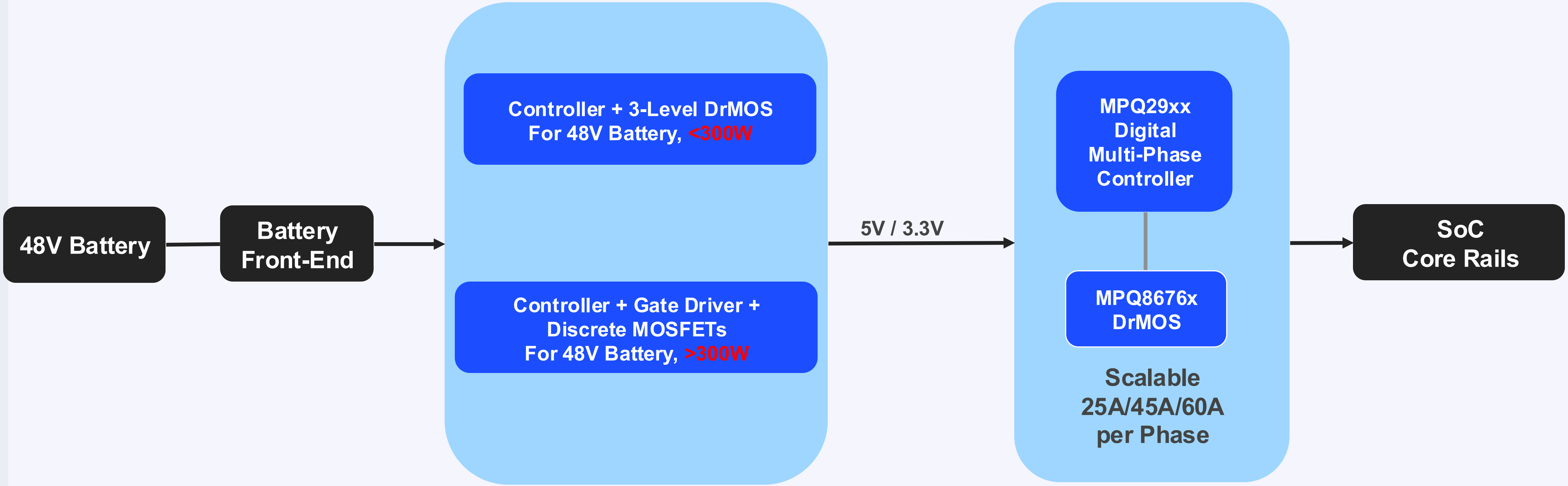


48V Battery with 2-Stage Conversion

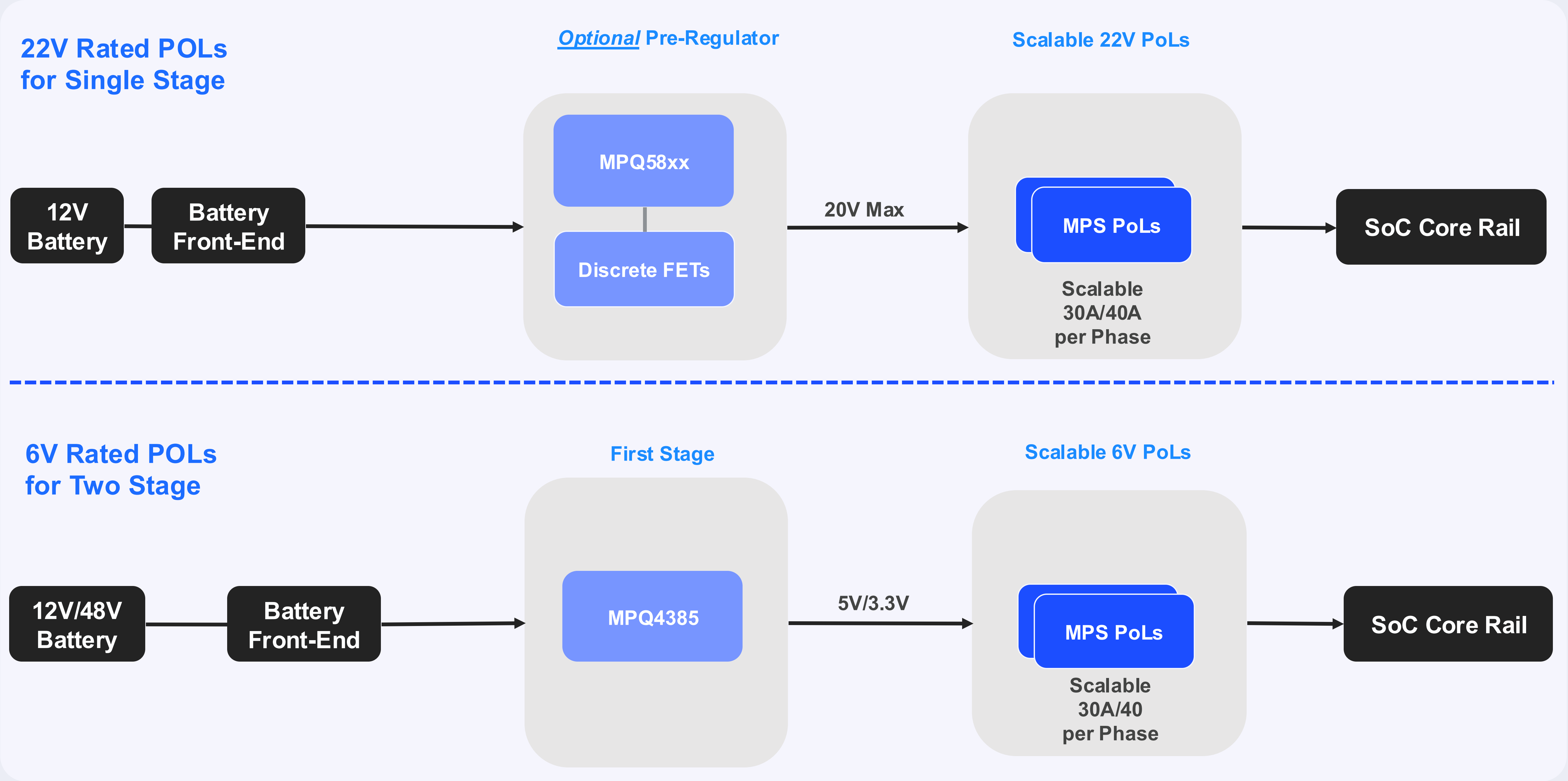


12V/48V Battery – Two-Stage Power Conversion

- Multiple High-Current SoC Rails
- Scalable 5V DrMOS Power Stages



Stackable and Compact High-Current PoLs



Multi-Phase Digital Controllers + DrMOS and PoLs for SoC Power

MPS

Multi-Phase Digital Controllers

MPQ72957FS
4-Rail, 8-Phase, AVSBus/I^2C,
TQFN-48 (7mmx7mm)

MPQ2946
3-Rail, 8-Phase, I^2C,
TQFN-48 (7mmx7mm)

MPQ29125
3-Rail, 8-Phase, SVI3/ I^2C,
TQFN-52 (6mmx6mm)

MPQ2967
2-Rail, 4-Phase, PWMVID/ I^2C,
QFN-40 (6mmx6mm)

MPQ2977
2-Rail, 6-Phase, I^2C,
TQFN-40 (6mmx6mm)

Intelli-Phase™ DrMOS

MPQ86960-A
22V, 50A, LGA-38 (5mmx6mm)

MPQ86970
22V, 50A, TLGA-41 (5mx6mm),

MPQ86940
22V, 40A, TQFN-21 (4mmx5mm)

MPQ86760
6V, 45A, TQFN-21 (4mmx5mm)

MPQ86750
22V, 50A, LGA-38 (5mmx6mm)

High-Current Converters

MPQ29261
22V, 18A, 2-Bit VID, QFN-19
(3mmx4mm)

6V and 22V versions available

MPQ2967 – 2-Rail, 4-Phase Digital Controller

MPSafe™ ASIL-D

Customer Benefits

- Advanced COT PWM (ACP™) for Lower Output Capacitance and Predictable EMI
- Digital Control for Flexibility, Optimized Tuning, and Fast Design Cycles

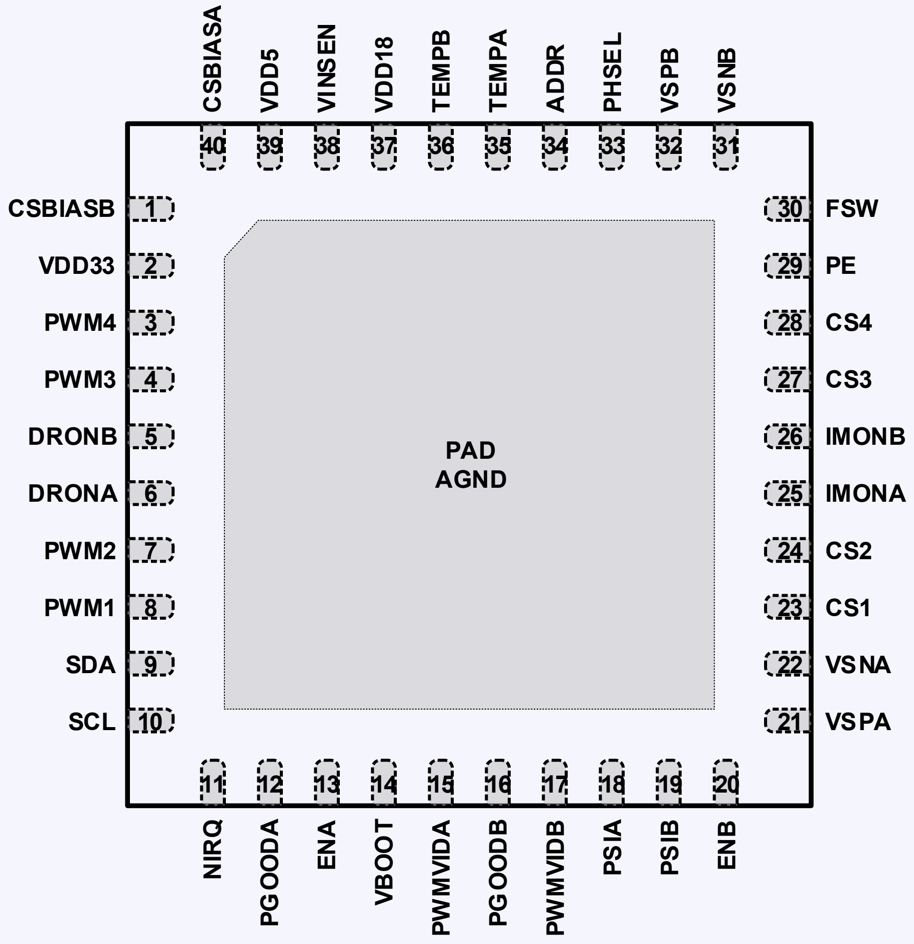
Features

- PMBus for Configuring and Monitoring
- PWM-VID Interface Compliant
- Built-In Multiple-Time Programable (MTP) Memory to Store Custom Configurations
- Protections: Under-Voltage Lockout (UVLO), Over-Voltage Protection (OVP), Under-Voltage Protection (UVP), Over-Current Protection (OCP), and Over-Temperature Protection (OTP) with Register Telemetry Flag
- Input Voltage (V_{IN}), Output Voltage (V_{OUT}), Output Current (I_{OUT}), and Regulator Temperature Monitoring
- Automatic Loop Compensation, Phase-Shedding, and Phase-to-Phase Active Current Balancing
- Runtime Register Cyclic Redundancy Check (CRC) and Packet Error Check (PEC) Mismatch Check
- Separate Enable (EN) for Each Rail

Applications

- Robotics SoC Core Rails

Released



QFN-40 (6mmx6mm with 0.5mm Pitch)

MPQ86960-A – 50A, Intelli-Phase™ DrMOS

MPS

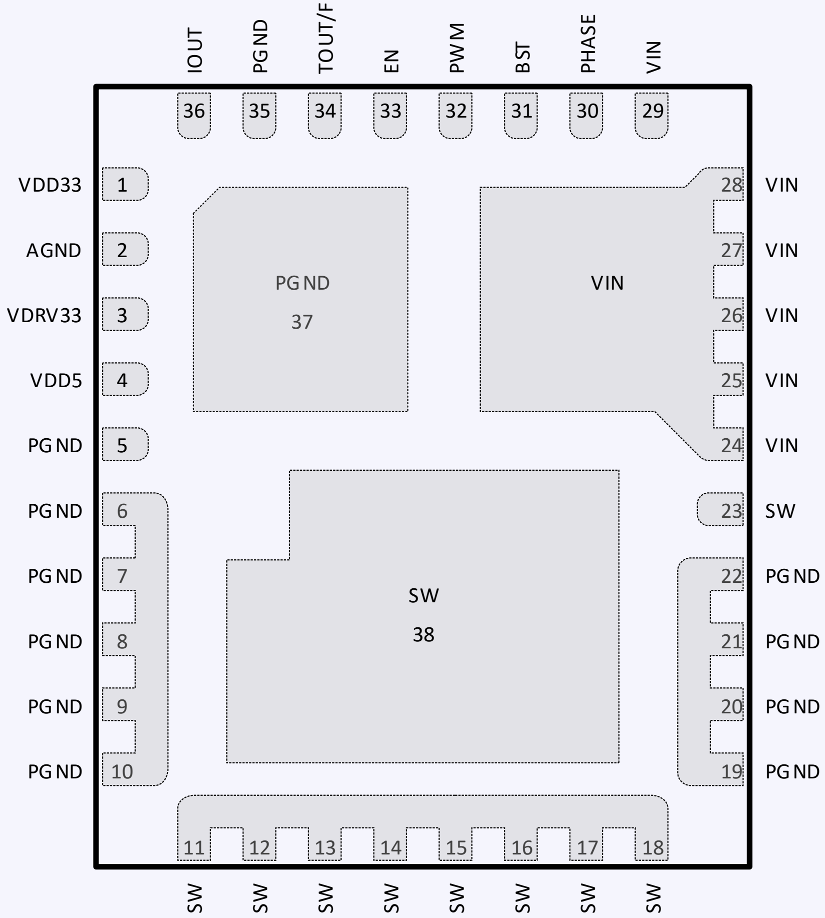
Customer Benefits

- Monolithic Design Offers Higher Switching Frequency (f_{SW}) to Reduce Inductor and Capacitor Size
- Optimized Process Technology for Best Efficiency

Features

- Wide 3V to 22V Operating Input Range
- 5V VDD Input
- VDRV33 and VDD33 Supported by Internal Low-Dropout (LDO) Regulator
- Current Sensing with Accu-Sense™
- Temperature Sensing
- Accepts Tri-State Pulse-Width Modulation (PWM) Input
- Current-Limit Protection
- Over-Temperature Protection (OTP)
- Fault Reporting

Released



LGA (5mmx6mm with 0.5mm Pitch)

Applications

- Robotics Soc Core Rails

MPQ29261 – 18A, 22V, High-Current Power Converter

Customer Benefits

- Advanced COT PWM (ACP™) for Lower Output Capacitance and Predictable EMI
- Digital Control for Flexibility, Optimized Tuning, and Fast Design Cycles

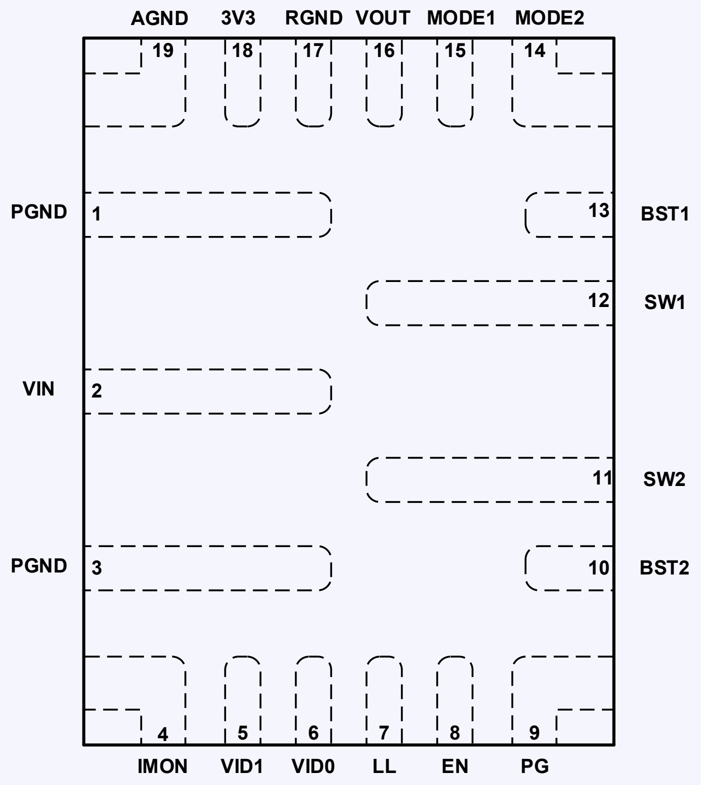
Features

- PMBus for Configuring and Monitoring
- Built-In Multiple-Time Programmable (MTP) Memory to Store Customer Configuration
- Protections: Under-Voltage Lockout (UVLO), Over-Voltage Protection (OVP), Under-Voltage Protection (UVP), Over-Current Protection (OCP), and Over-Temperature Protection (OTP) with Register Telemetry Flag
- Automatic Loop Compensation
- Digital Load-Line Regulation
- Input Voltage (V_{IN}), Output Voltage (V_{OUT}), Output Current (I_{OUT}), and Regulator Temperature Monitoring

Applications

- Robotics SoC Core Rails

Released



QFN-19 (3mmx4mm)

Thank You