Factorized Power Architecture in New Space

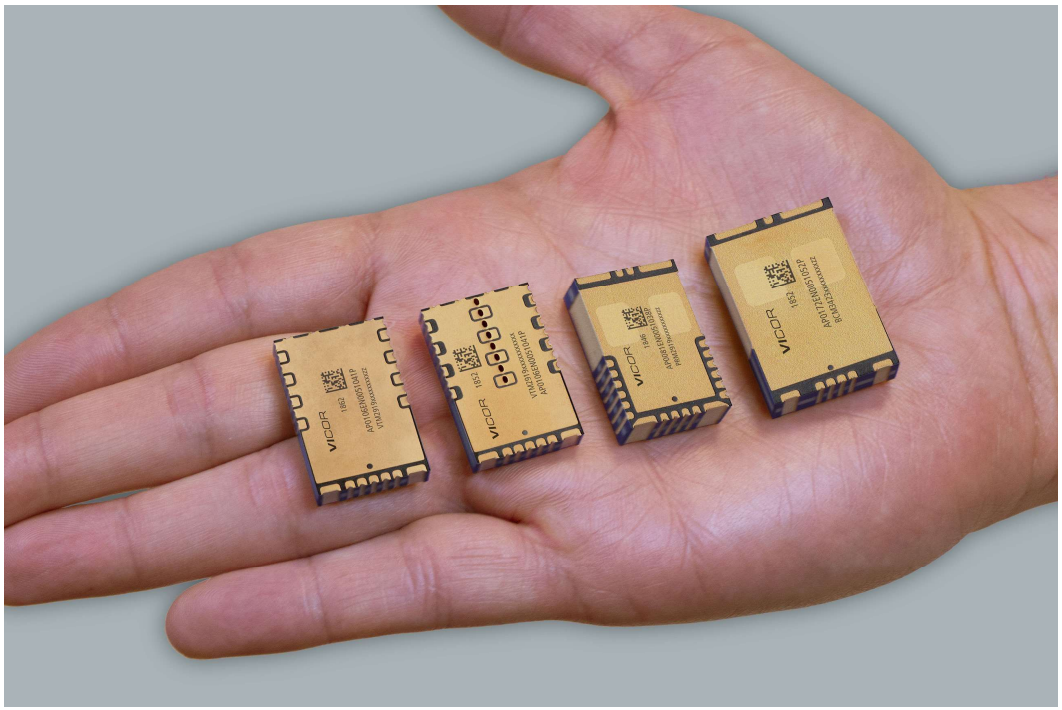
Radiation Tolerant COTS Products and Solutions

For this Presentation, no NDA is Required

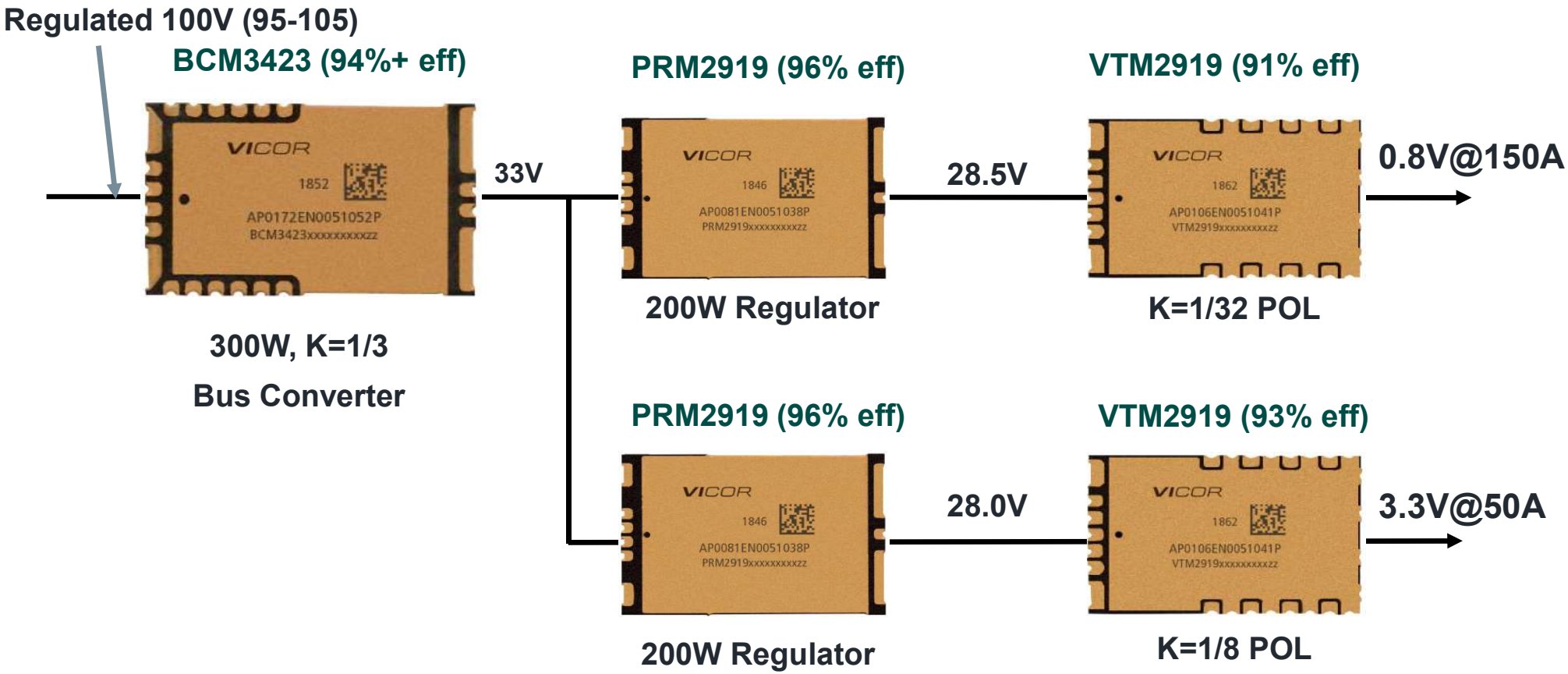
High Density Rad-Tolerant Modules

Vicor currently offers 4 devices for powering High-Performance ASICs.

Modules shown deliver a total of up to 300W to rails of 0.8V @ 150A and 3.3V at 50A from a 100V bus.



Our Current Solution for Powering ASICs



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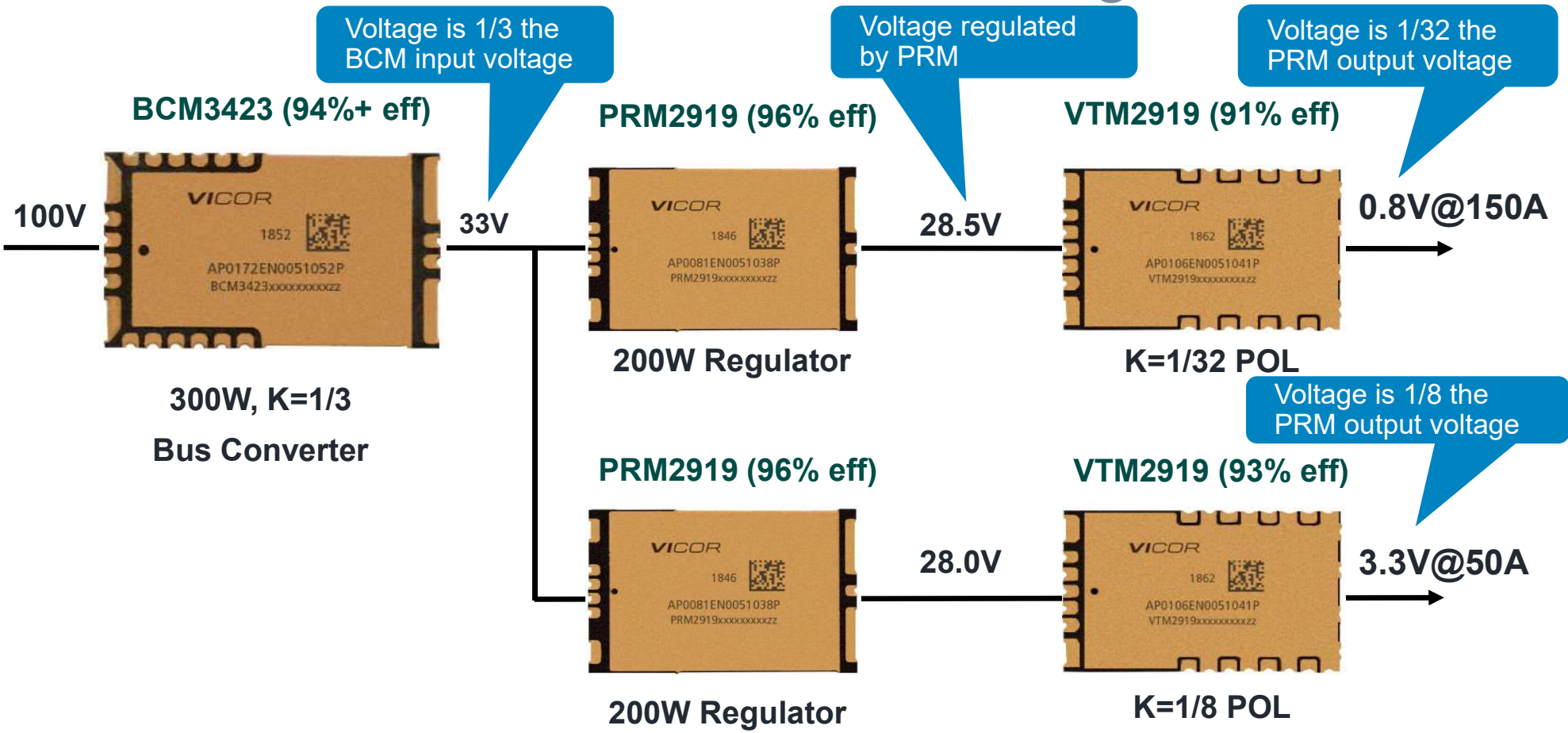

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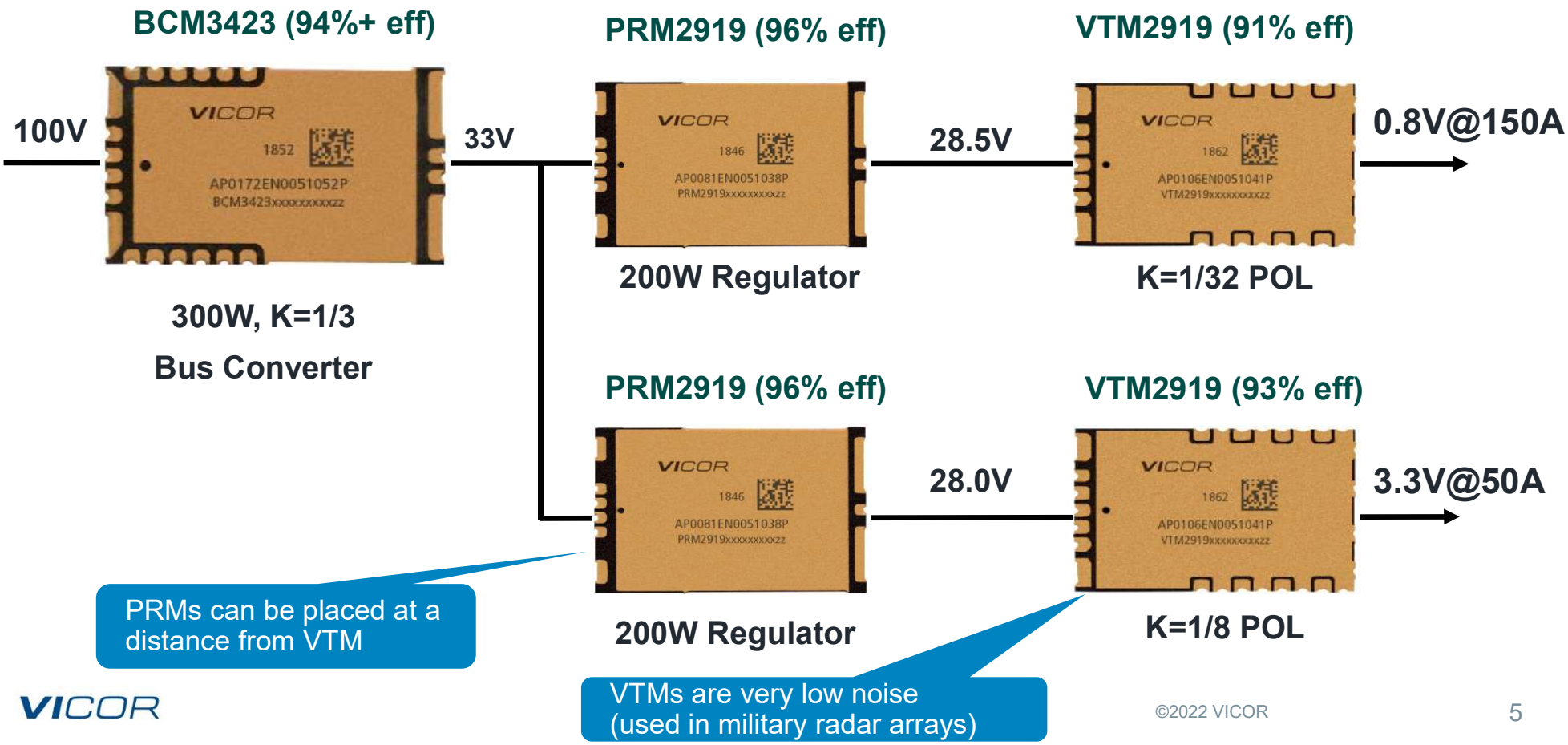
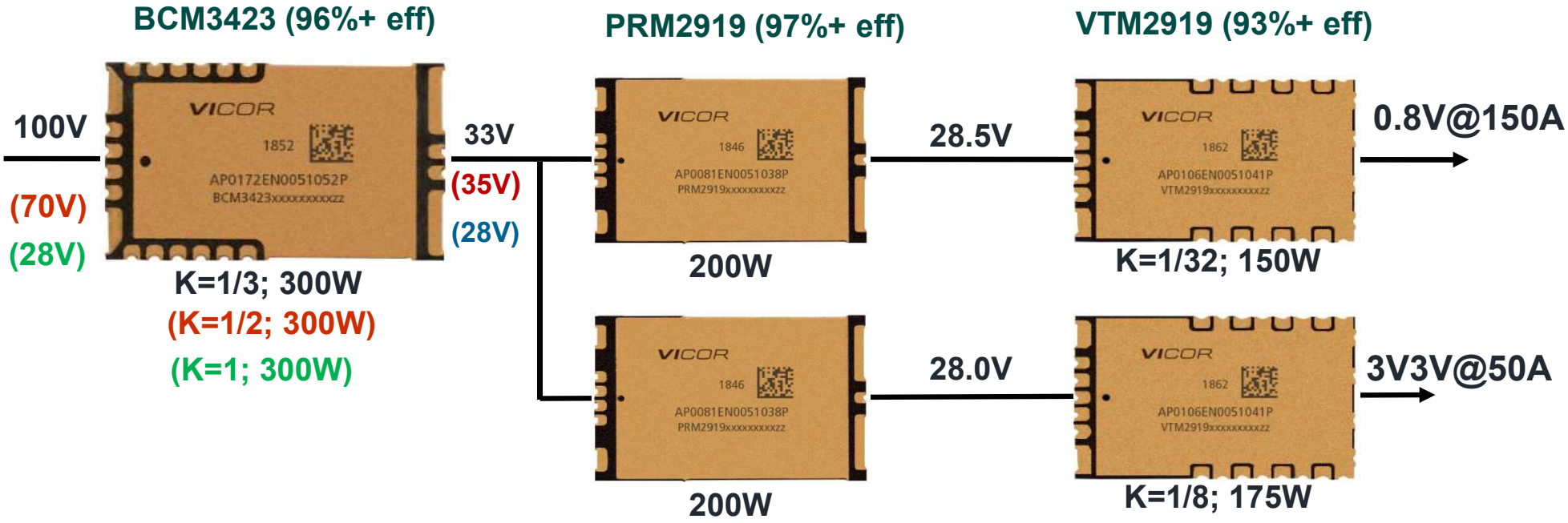


Inherent Internal Design Flexibility

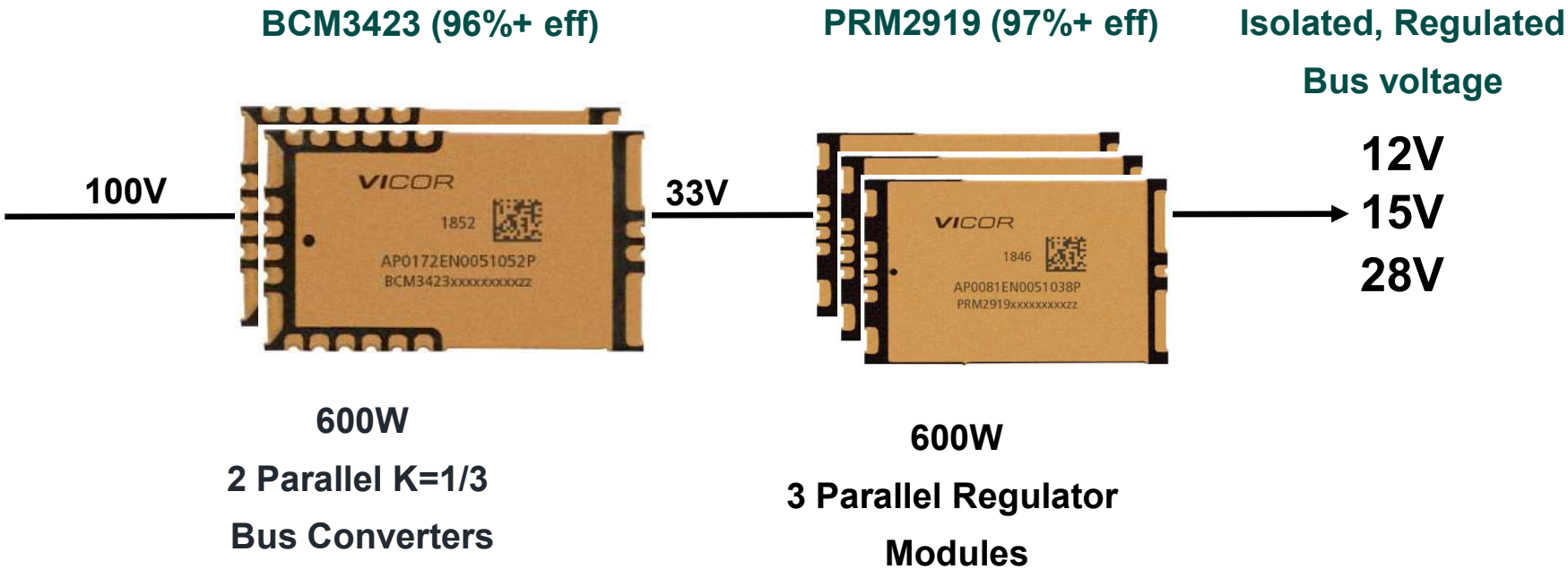
- Different BCM and VTM K factors can be developed to accommodate different bus and load voltages.
- Parallel-Capable BCMs and PRMs can be developed to provide an isolated, high current 12, 15, or 28V nominal bus.
- Higher efficiency through optimized power trains and component selection.

Proposed

28V, 70 V or 100 V BCM (Bus Converter Module) in the 34x23mm package



Proposal to Create High-Current, Isolated and Regulated Nominal Bus Voltages of 12V, 15V, or 28V



Total Ionizing Dose Challenge

- Commercial FETs have been selected and lot screened for TID
  - Suitable power FETs have significant shift in V_{TH} with TID
  - The radiation tolerant modules employ compound FET structures to extend the TID tolerance
- Vicor control IC families are selected for TID tolerance
  - Minor mitigations are added to compensate for some TID shift
- Modules function after 50k TID exposure

SEE Survivability

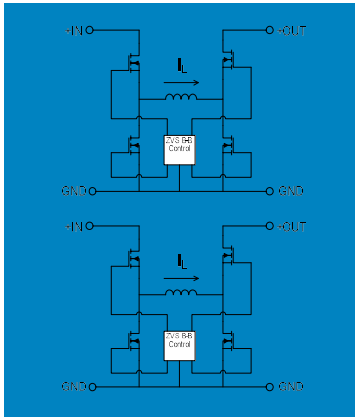
- Commercial MOSFETs were selected and lot-screened for SEB and SEGR
  - Power MOSFETs were selected from robust designs.
  - In addition, power MOSFETs are highly derated VDS for survivability.
- Control ICs have been screened for SEL, SEFI
  - Mitigation circuits are added to detect over currents and reset to ensure survival.

SEFI Mitigation

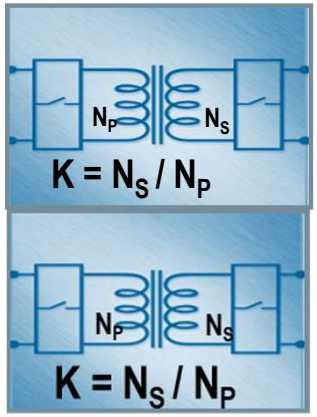
- All radiation tolerant modules include completely redundant power trains operating in parallel.
- If one power train gets upset due to a single event, its protection circuits force a reset.
- During the reset interval the redundant power train carries the full load.
- After the reset, both power trains operate in parallel again.

Rad Tolerant

PRM



VTM

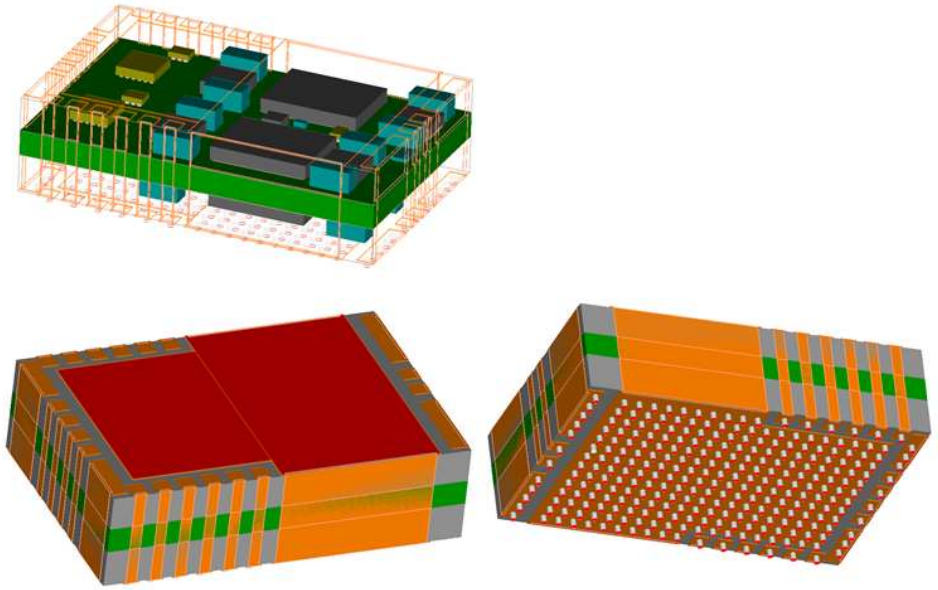


Radiation Tolerant FPA Solution Summary

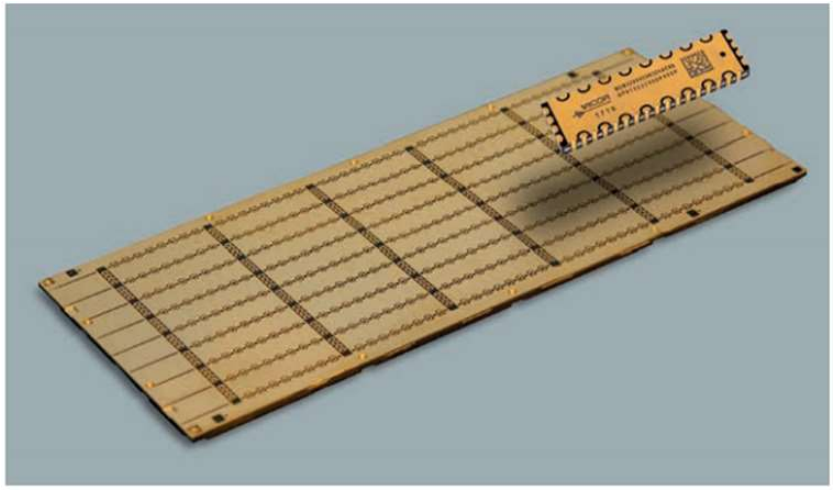
- Radiation Tolerance
  - Single Event Effect Immunity:
    - Robust component selections
    - Extreme derating of MOSFETs
    - Latch detection and reset circuitry
    - Redundant parallel architecture for reliable power delivery
  - Total Ionizing Dose: Components tested to 50k rad
    - All active components separately tested to 50k rad
- The modular approach allows for fast radiation tolerant power solution development.

Module Construction

- Standard dual-sided PCB designed for dual sided cooling. Over-molded with thermally adept mold compound.
- Exterior plating facilitates BGA terminations.



Panel Fabrication Process



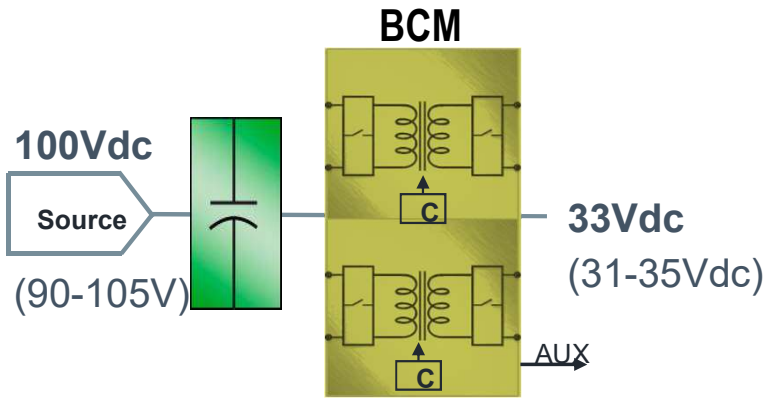
- Vicor developed the CM-ChiP™ common package technology to maximize power module density and thermal performance.
- The CM-ChiP is fabricated within a panel fabrication process, which is similar to a semiconductor wafer fabrication process.
- The CM-ChiP package is a 3D package with an internal mid-plane substrate that enables component placement on both the top and bottom sides and chassis-mount terminations.

Vicor Radiation-Tolerant Modules

- Radiation tolerance
  - Single Event Effect: Modules are designed with redundant powertrains and fault-tolerant control to meet SEE requirements
  - Total Ion Dose: Modules have been tested to 50k rad
- High efficiency, high power density, low weight
- High switching frequency(1Mhz+)
- Added design flexibility with Factorized Power Architecture
- Very low noise at the point-of-load with VTM modules
- Advanced protection features
- Internal operating temperature -40ºC to 125ºC
- Thermally adept, 3D molded packaging with Tin-Lead BGA (ball grid array) connections
- Made in the USA & EAR99

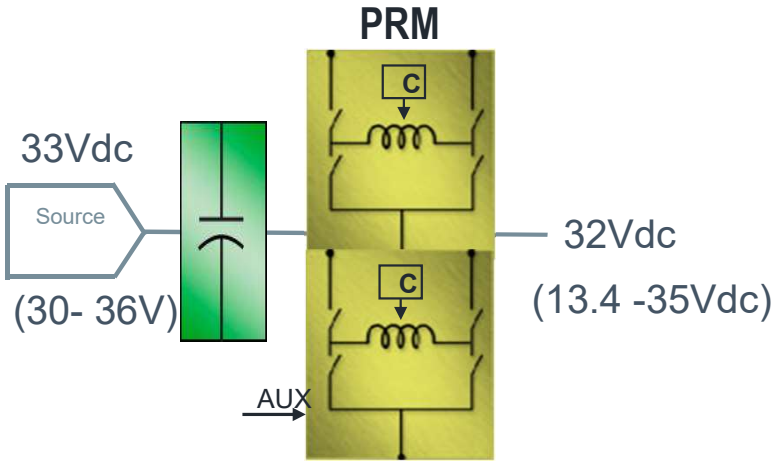
100V Fixed Ratio Converter—BCM3423

- V_{IN} =100VDC (94-105V and 120V transient)
- V_{OUT} = 33V(31-35Vdc, K=1/3)
- P_{OUT} = 300W
- High efficiency (>94%) reduces system power consumption
- High power density, Low Weight
  - 34x23x8mm, 26g
- Contains built-in protection features against:
  - Undervoltage
  - Overvoltage
  - Overcurrent
  - Short Circuit
  - Overtemperature
- Provides enable/disable control
- ZVS/ZCS Resonant Sine Amplitude Converter topology

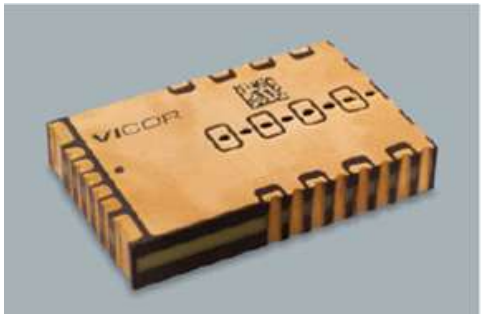


33V Regulator—PRM2919

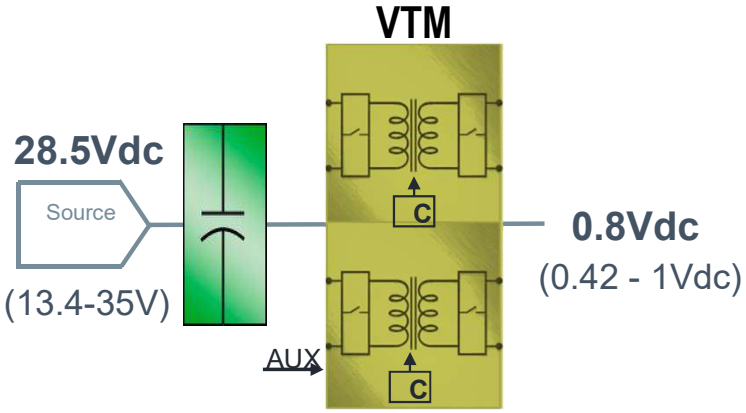
- V_{IN} = 33V (30-36VDC)
- V_{OUT} = 32V (13.4-35VDC)
- P_{OUT} = 200W
- Full Load efficiency (96%), reduces system power consumption
- High power density, Low Weight
  - 29x19x8mm, 16g
- Contains built-in protection features against:
  - Undervoltage
  - Overvoltage
  - Overcurrent
  - Short Circuit
  - Overtemperature
- Non-isolated ZVS buck-boost regulator topology



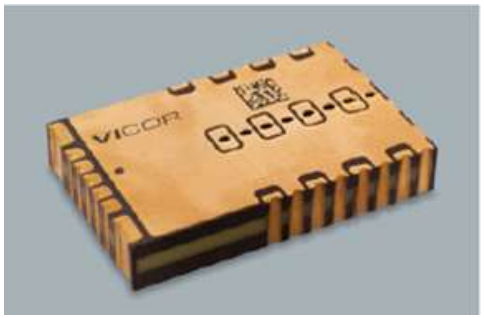
150A Current Multiplier—VTM2919



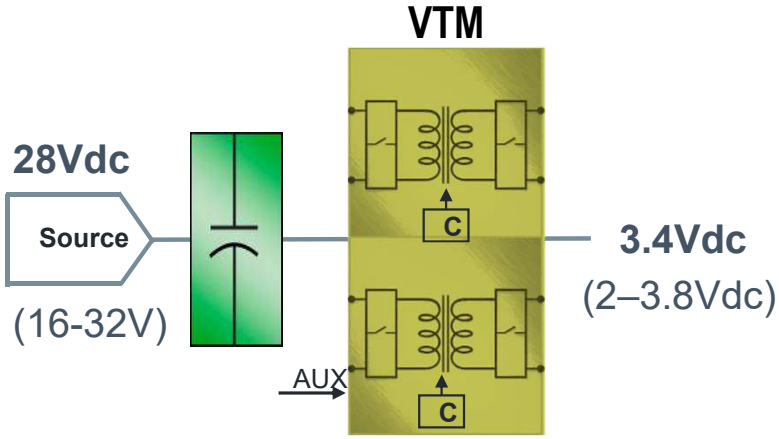
- V_{IN} = 14.4-35VDC
- V_{OUT} = 0.42-1.0V (K=1/32)
- High efficiency (91%), reduces system power consumption
- High power density, Low Weight
  - 29x19x5.5mm, 13g
- Contains built-in protection features against:
  - Overvoltage
  - Overtemperature
- ZVS / ZCS resonant Sine Amplitude Converter topology



50A Current Multiplier—VTM2919



- V_{IN} = 16-32VDC
- V_{OUT} = 2 - 3.8V (K=1/8)
- High efficiency (93%), reduces system power consumption
- High power density, Low Weight
  - 29x19x5.5mm, 10g
- Contains built-in protection features against:
  - Overvoltage
  - Overtemperature
- ZVS / ZCS resonant Sine Amplitude Converter topology



Summary

- Vicor's Solution is a rad-tolerant design suitable for LEO and MEO missions.
- Qualified to 50krad TID.
- Single-Event Latch-up (SEL) with Autonomous latch release hardware is employed. LET ~43 MeV-cm^2/mg (Linear Energy Transfer).
- Vicor will continue to expand our space rad-tolerant power solutions.
- We're looking for partners for next-generation products.