Powering 5G/RFPA

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1. **Flex Power Modules**
2. 5G introduction
3. RFPA/5G application overview
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Our key figures

REVENUE
10% CAGR

RANKING
Top 5*

EMPLOYEES
> 400

DESIGNERS AND ENGINEERS
45

CUSTOMERS
300

UNITS SOLD
> 100 million

PATENTS REGISTERED
> 150

DESIGN CENTERS
2

* For power supplies manufacturers/ Source: MTC 2020

Flex Power Modules Shanghai, China

" Our goal is to deliver products with **high quality** and on time. We support our customers during the whole journey from product design, development, production and through to maintenance.

Rachel Wang
General Manager, Flex Power Modules China

Site overview

Legal company: Flex Electronics Shanghai
Established: 1996
Headcount: >300
Footprint: 69750 sft

Multi-disciplinary site

- E2E Supply Chain - Order desk, Planning, Sourcing
- Manufacturing, NPI, Test Development
- R&D, Product Management, Sales
- Quality Management and Customer Service

Special capabilites

- Supply of 50 families -1500 variances of Board Mounted Products DC/DC and RF Modules
- R&D and Manufacturing of 7.5x7.5 mm analog PoL to 1500 W digital brick and PSB
- Long experience of building technologies including heavy copper PCB and customized burn-in and test

Certifications

- IEC/EN/UL 60950-1
- IEC/EN/UL 62368-1

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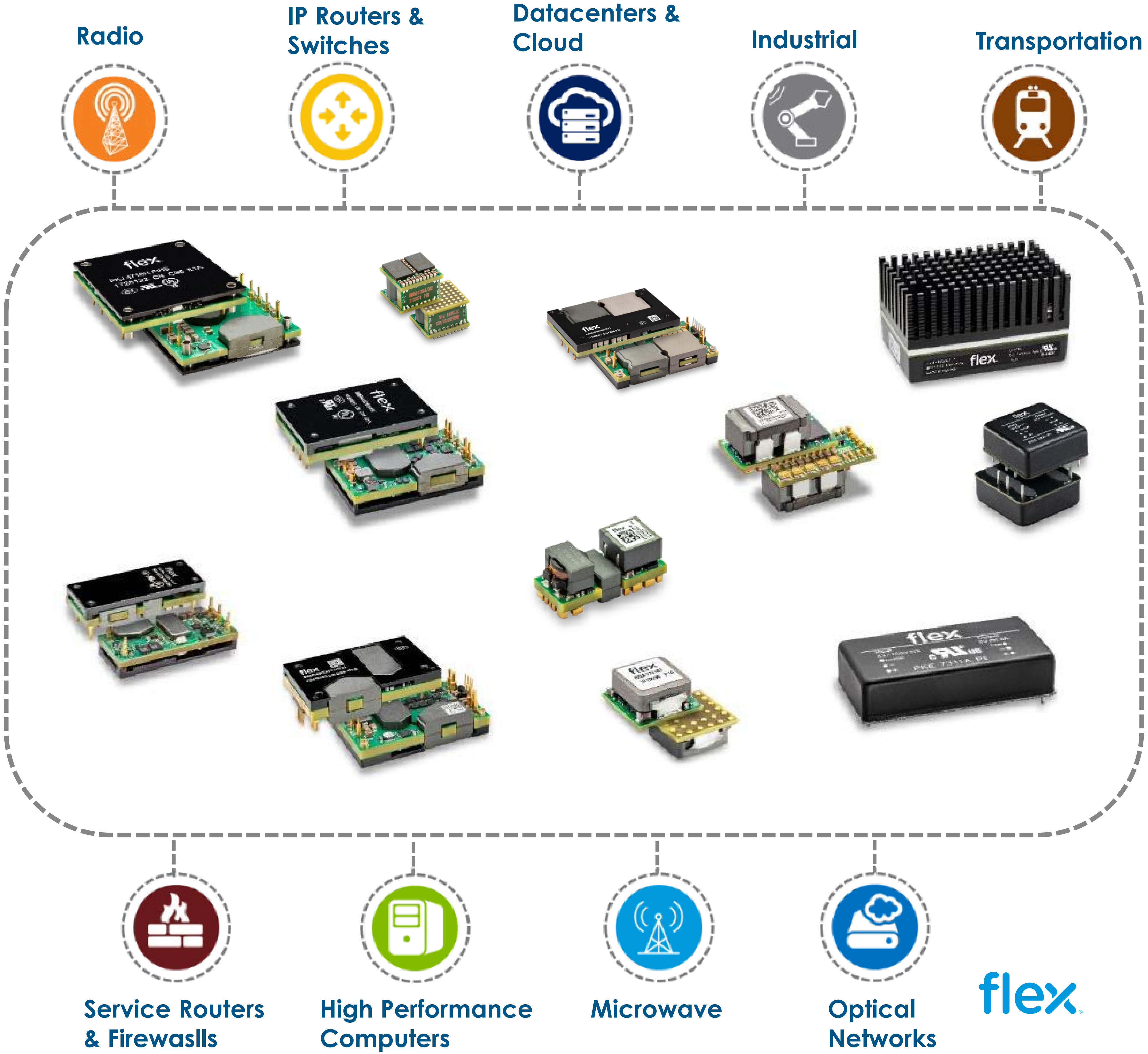
Product & application overview

DC/DC converter solutions that ensure maximum reliability, performance and cost effectiveness for the most demanding applications.



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Evolution of mobile networks

	1G	2G	3G	4G	5G
Era	1980s	1990s	2000s	2010s	2020s
Services	Analog Voice	Digital Voice	WB Voice Packet Data	Voice, Video Internet, Apps	Everything
Devices					
Data Rate	0	100 kbps (GPRS)	10Mbps (HSPA)	100+Mbps (LTE/LTE-A)	10 Gbps (NR)
Delay		500 ms	100 ms	102 ms	5 ms

5G will enable many new use cases

… and the best ones have yet to be imagined

Enhanced Mobile Broadband

UHD video streaming

Virtual reality

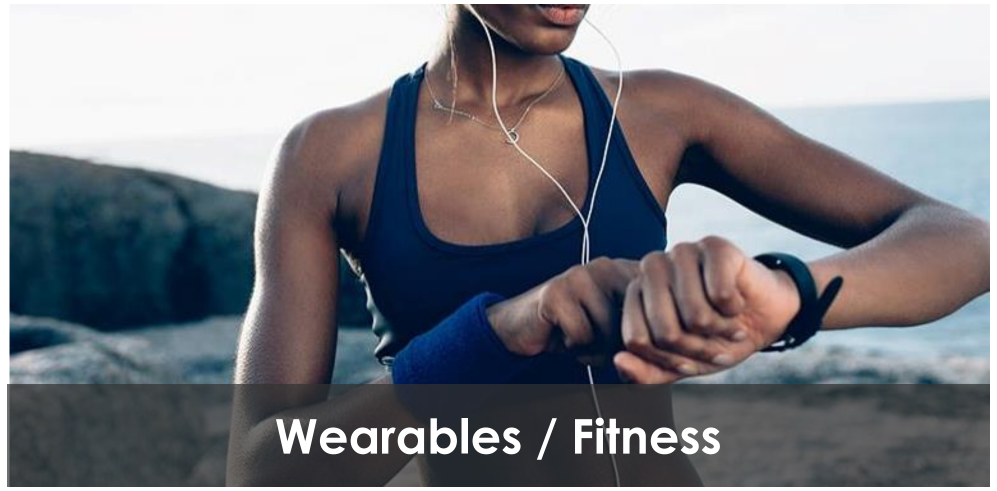
Ultra-Reliable & Low Latency

Autonomous vehicles

Industrial automation

Massive IoT

Smart cities



Wearables / Fitness

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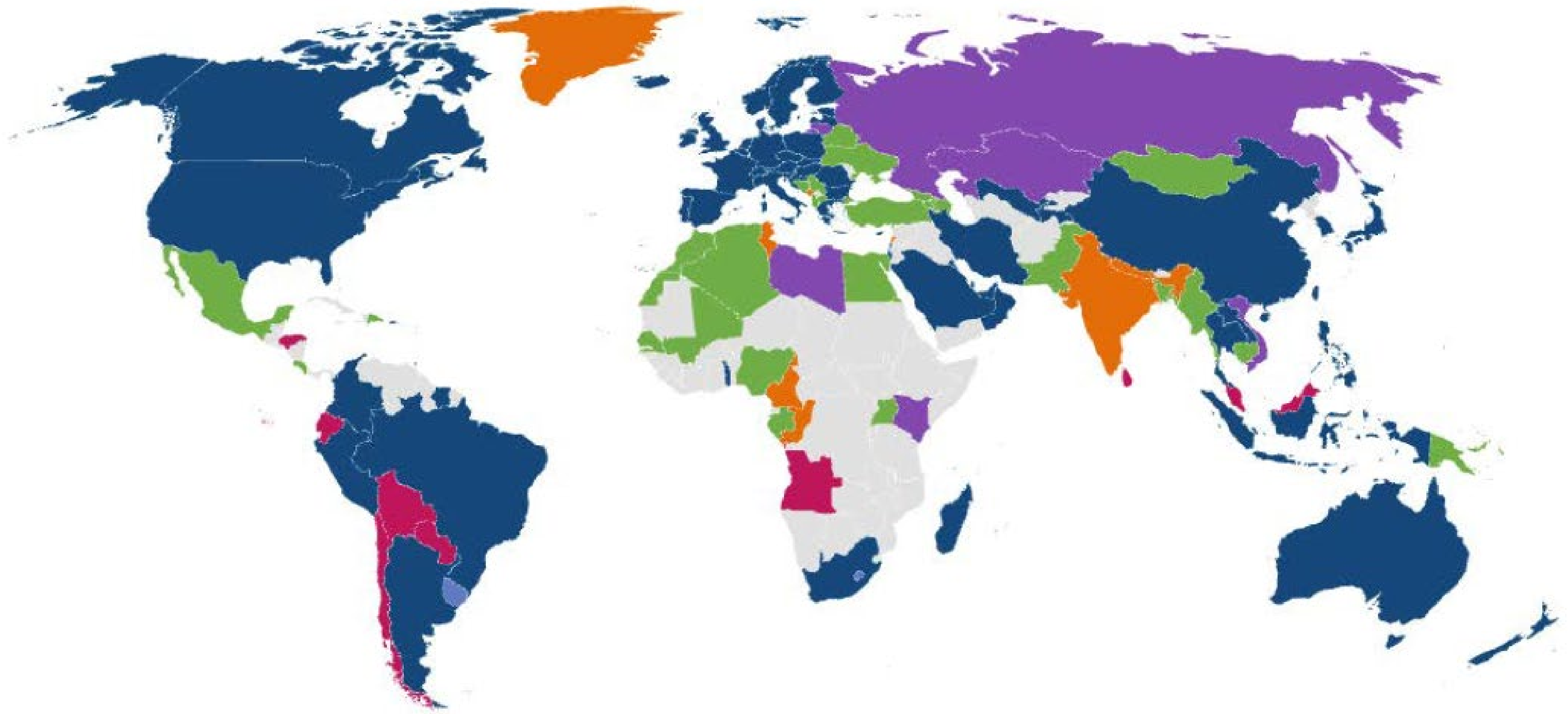
5G Deployment Status

- **465 operators in 139 countries are investing in 5G**
- **180+ operators have commercially launched 5G**
- **600+ commercially available 5G devices**
- **580M 5G subscribers by end of 2021**
- **3.5B 5G subscribers by end of 2026**

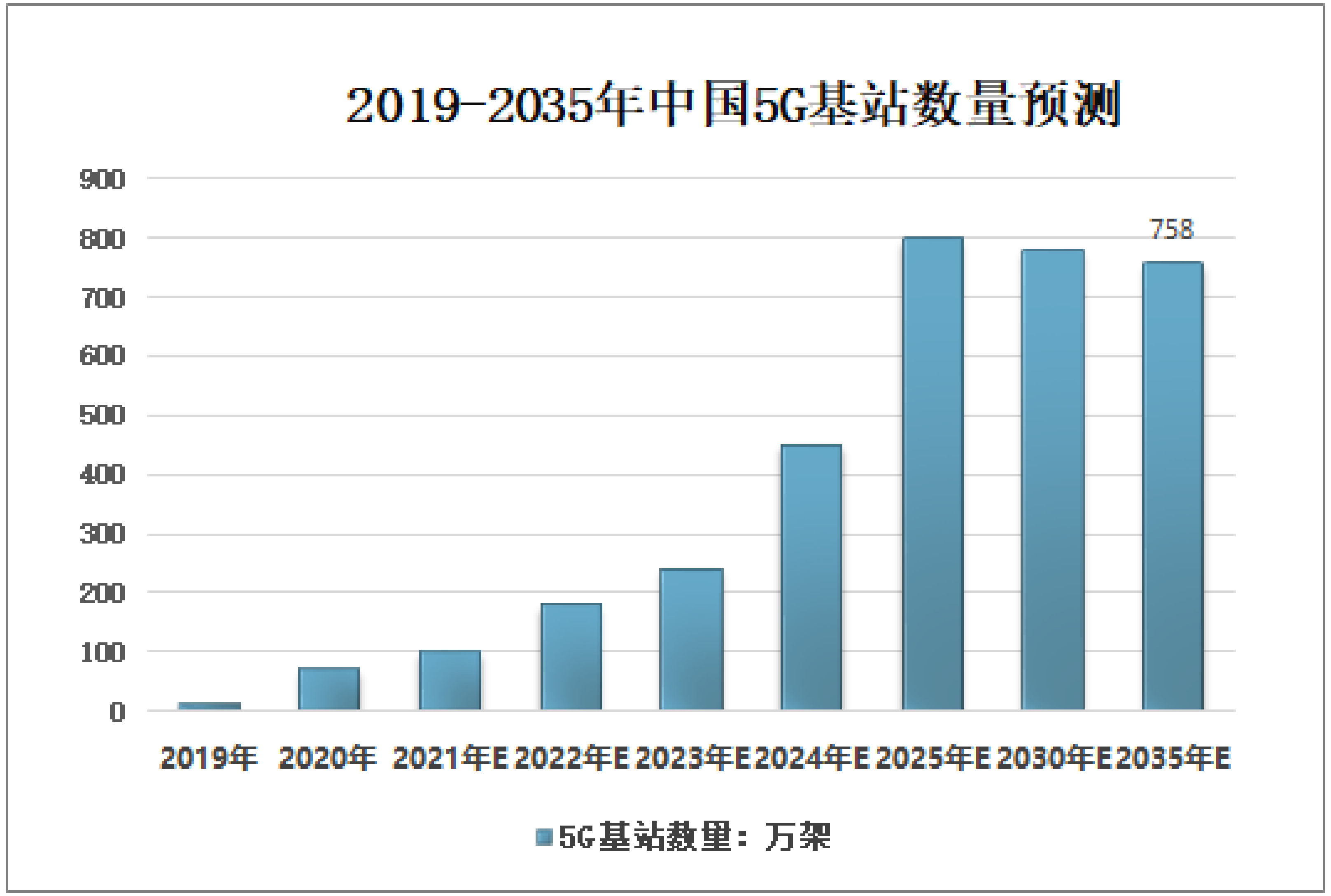


- 5G deployed in network, services launched
- 5G deployed in network, soft launch
- 5G deployed in network, precommercial
- Deploying
- Planning
- Evaluating/testing/trialing

Source: GSA (Sept 2021)

5G deployment in China

- During pandemic, mobile data traffic increased by 40 % (comparing March 2019 with March 2020)
- In 2019 & 2020 operators invested a sum of $78 billion USD (equals 1/5 of revenue) in network rollouts
  - Aggressive 5G rollout
  - 200 million new 5G connections
  - 600 000 new 5G base stations
- Mobile operators play a key role in achieving sustainability development goals by
  - Delivering connectivity and access to life-enhancing services
  - Sustainable development with focus on energy saving solutions and reduce emission supporting transition to zero-carbon economy



Source: 前瞻产业研究院整理

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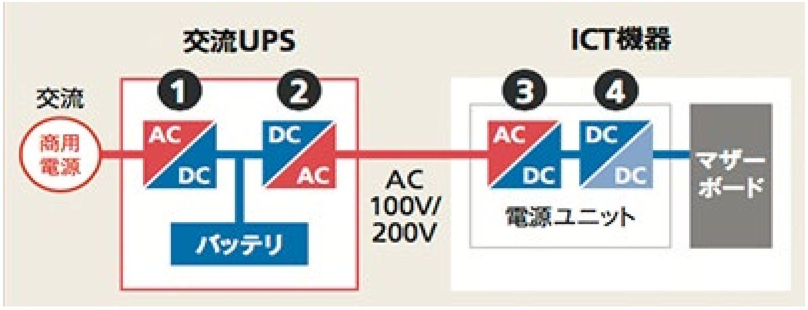
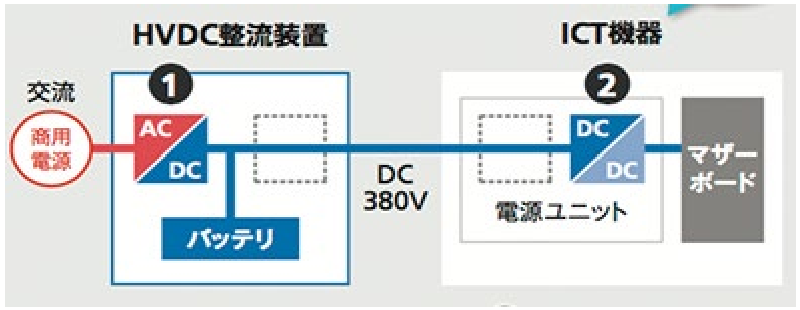
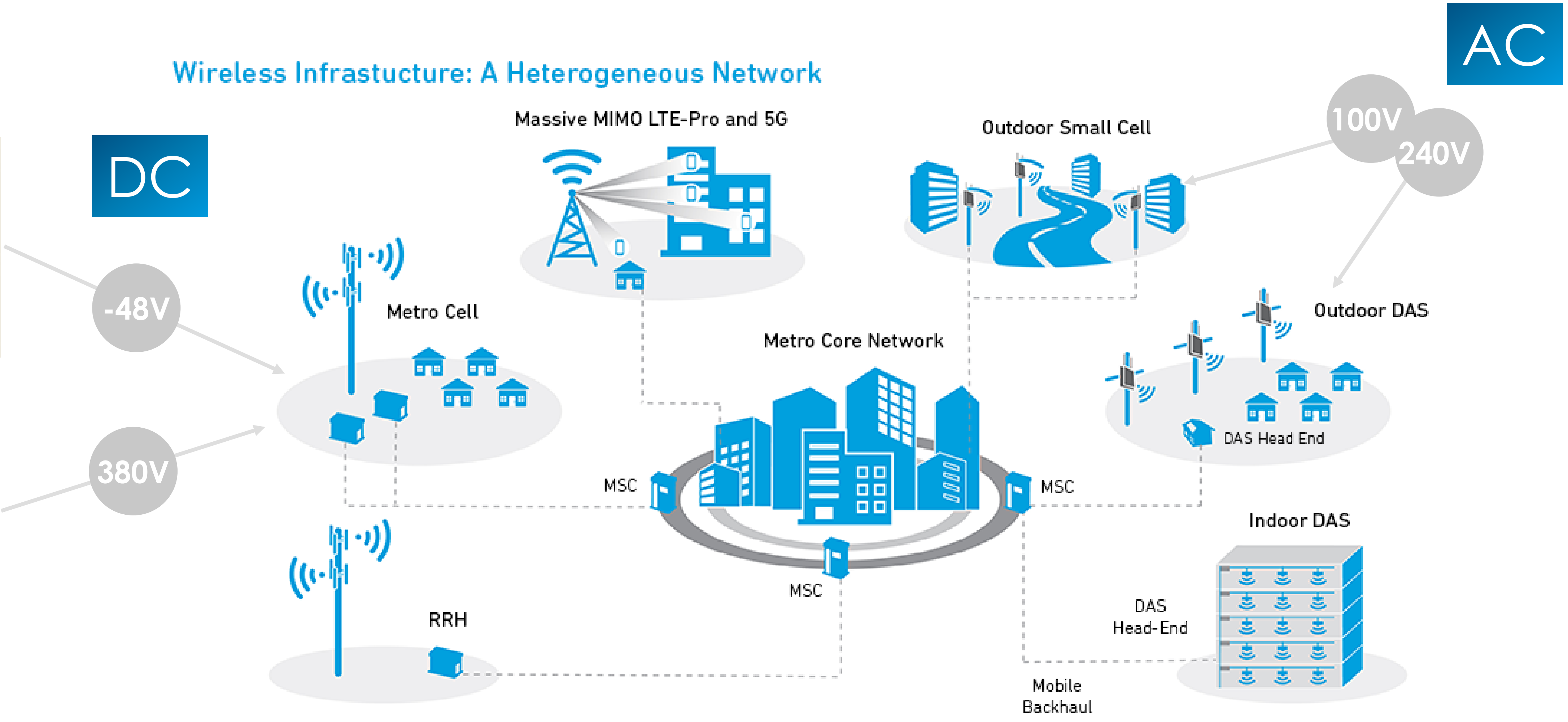
Powering 5G radio network applications

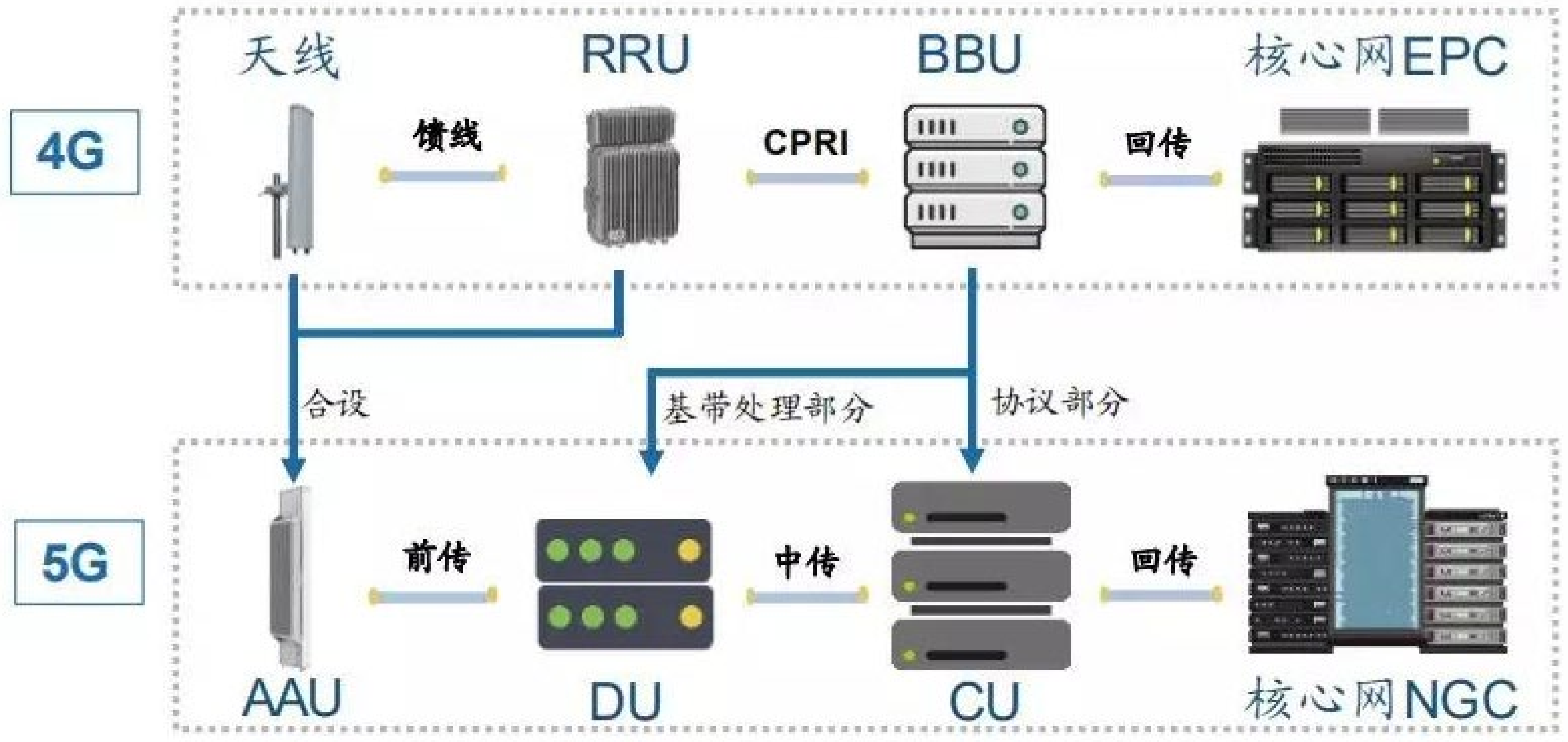


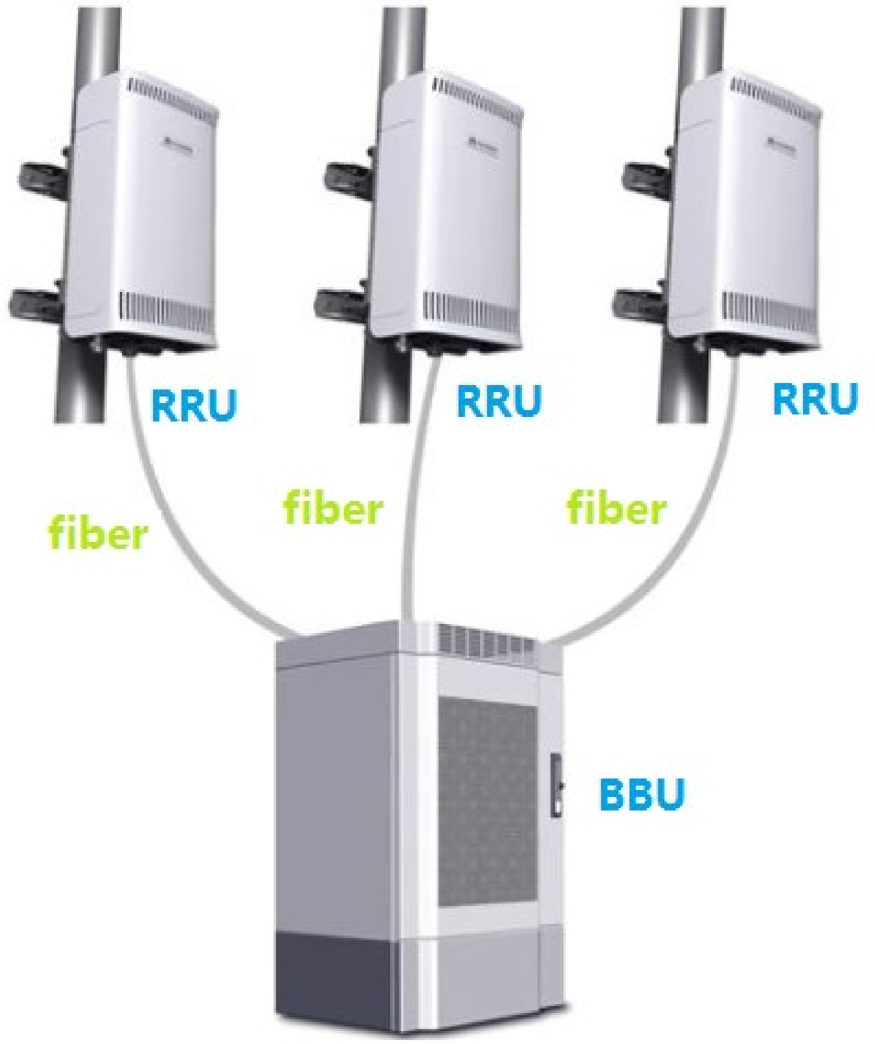




Traditional -48V from battery
or high voltage DC (HVDC)

Macro-base stations





Marco-base stations ● BBU & RRU applications

Requirements from operators and equipment vendors

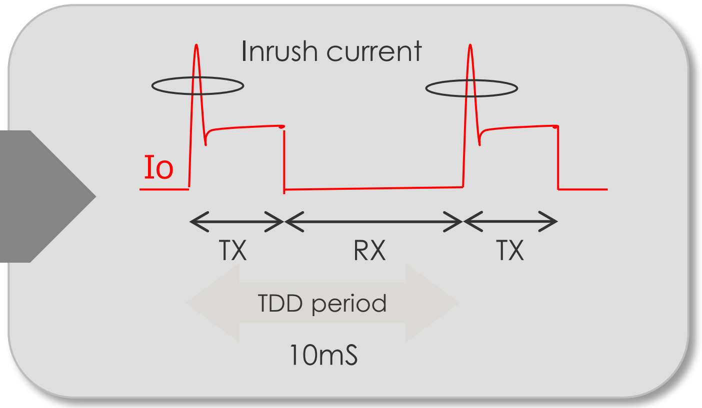
- The maximum power consumption increase 68% vs 4G (single station).
- Overall high efficiency including base station, air-conditioning energy consumption etc.
- RFPA designers are increasingly moving from LDMOS to Gallium Nitride, (GaN), transistors
- Envelope Tracking/Restoration (ET/ER) has emerged as a key RFPA design technique
  - very efficient DC/DC converter required
- DC/DC converter needs to handle broadband RFPA output bias voltage in synchronization with the amplitude variation of the modulated RF input signal
- Operators vs equipment vendors, Open-RAN.

RFPA ● technical requirements & challenges

REQUIREMENTS:

- TDD mode load: better transient response and higher OCP setpoint(<10ms time slot)
- Height tolerance < 0.5mm
- Baseplate OTP on all kinds of conductions >100°C, perhaps increase to 110 °C in future
- -40 °C to 100° C operating temperature
- Power density
- Digital function

Load at TDD application

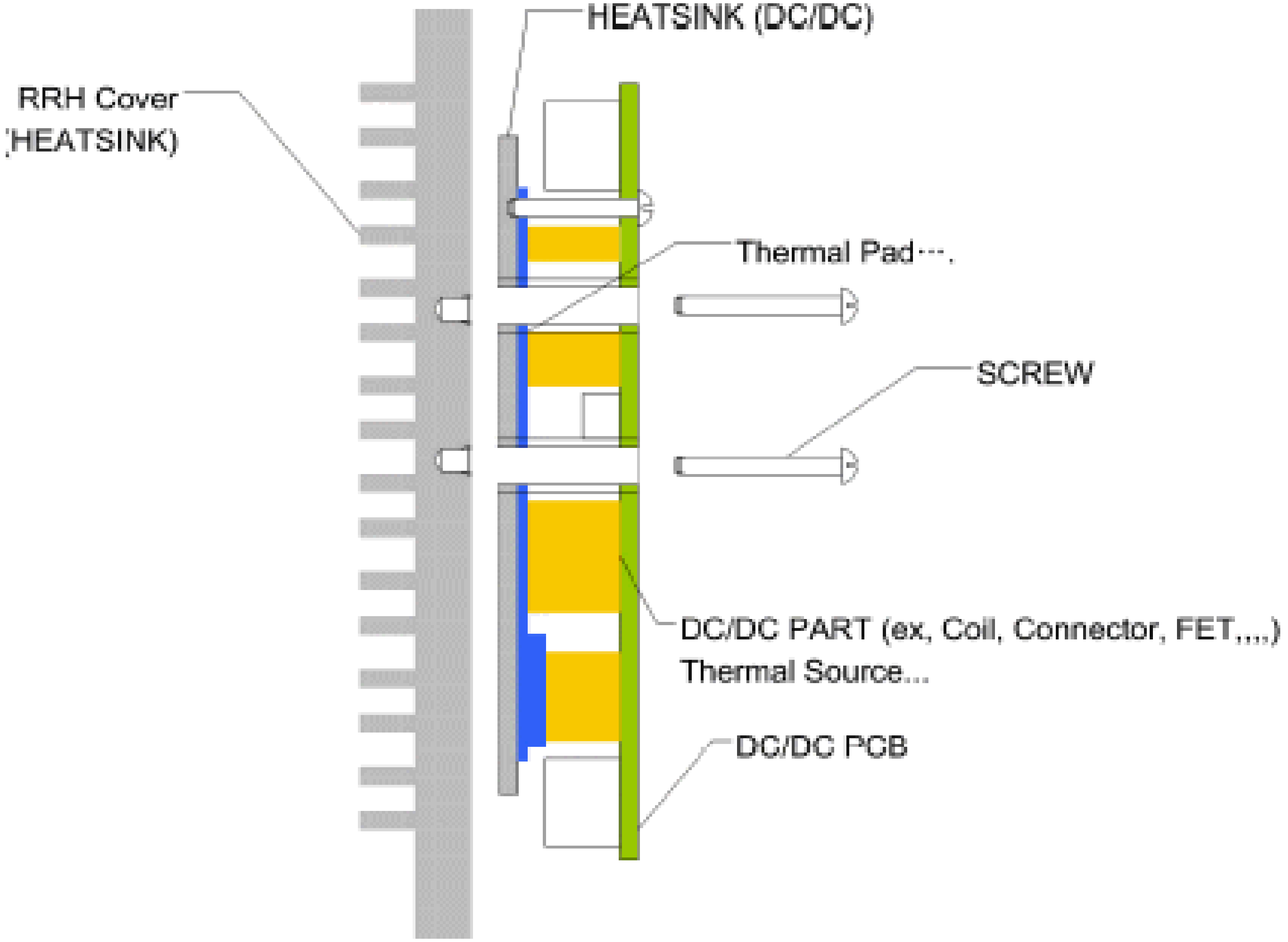


CHALLENGES:

- TDD load
- Time to market (TTM)
- Efficiency
- Cost
- Reliability
- Cold/high temperature performance

Mounting requirements

Thermal performance plays an important role



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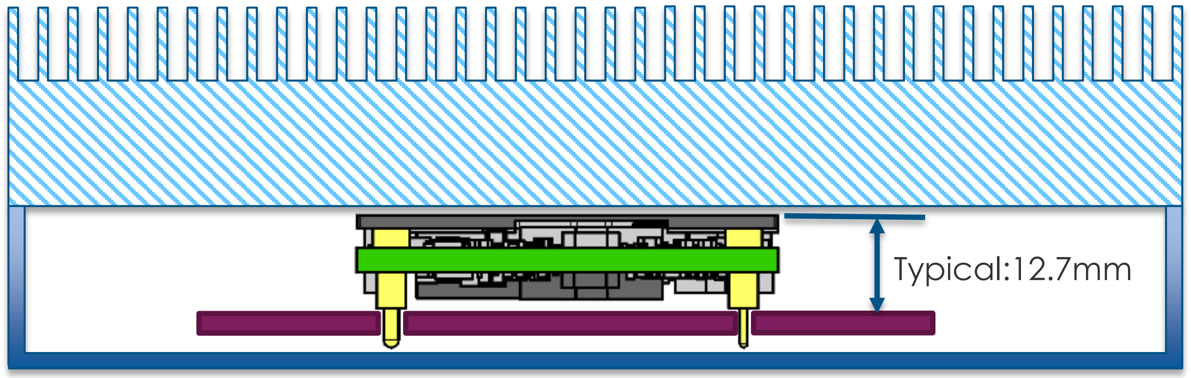
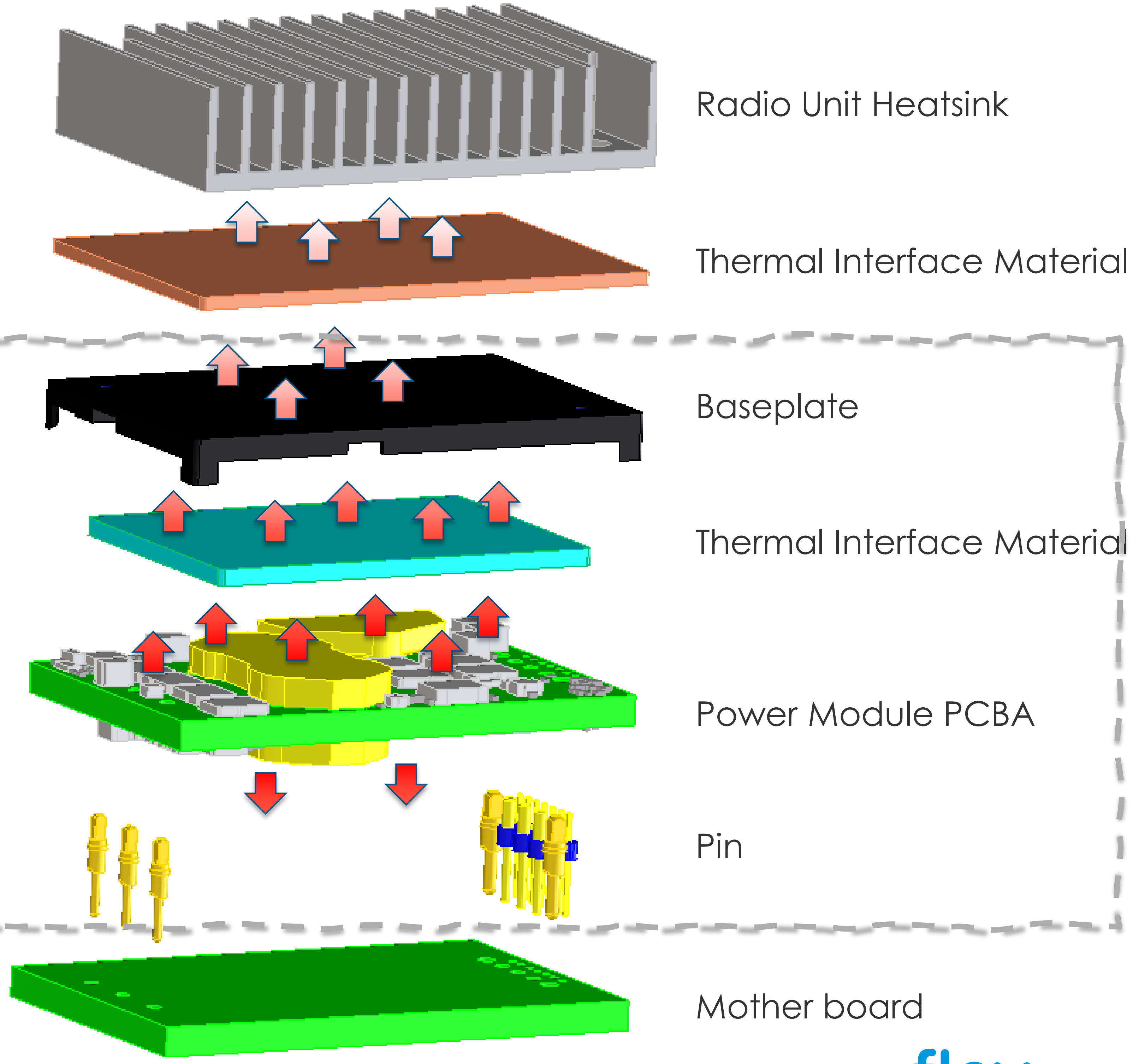
Typical thermal solution

Normally, there is no airflow inside radio units



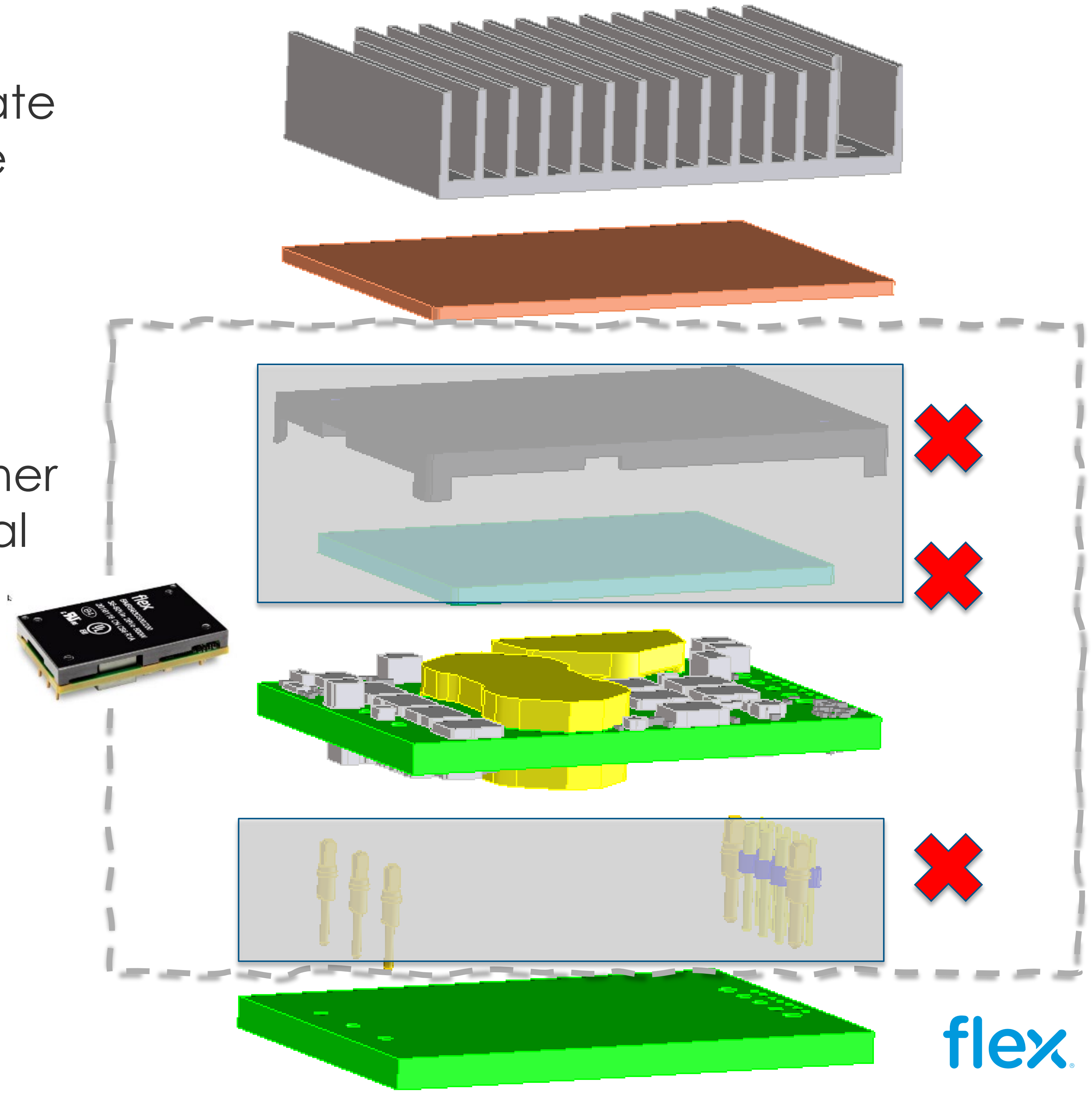
Radio unit diagrammatic sketch



Thermal: ideas for thermal resistance reduction

- Baseplate and TIM between PCBA and baseplate are removed to reduce total thermal resistance
  - attach power module to RRU heatsink through TIM directly
- Dual cool MOSFET is selected to increase heat dissipation capability towards upside
- Pin is removed, connect power module to mother board by dozens of PCB pads to reduce thermal resistance towards downside

<u>Result: </u>The **output power** capability is increased when thermal performance improved.



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5G/RFPA DC/DC portfolio

half brick

New

PKJ4716A
half brick
14-35 V_{out} / 700 W

PKJ4716H
half brick
25-55 V_{out} / 700 W

BMR685
Digital / half brick
25-55 V_{out} / 1300 W

quarter brick

PKM4516AD
quarter brick
14-35 V_{out} / 500 W

PKM4516HD
quarter brick
25-55 V_{out} / 500 W

BMR683
Digital /quarter brick
28 V_{out} / 500 W

eighth brick

New

PKB4216C
eighth brick
15-33 V_{out} / 200 W

PKB4216HD
eighth brick
40-55 V_{out} / 250 W

sixteenth brick

PKU-D 100W
36-75 V_{in}
12 V_{out}

PKU4116C 100W
36-75 V_{in}
10-33 V_{out}

PKU4116HD 110W
36-60 V_{in}
55 V_{out}

100 W 200 W 500 W 700 W 1300 W

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BMR685

First **digital** half brick for RFPA up to 1300 W P_{out}

Designed for **high power GaN and LDMOS RFPA** applications

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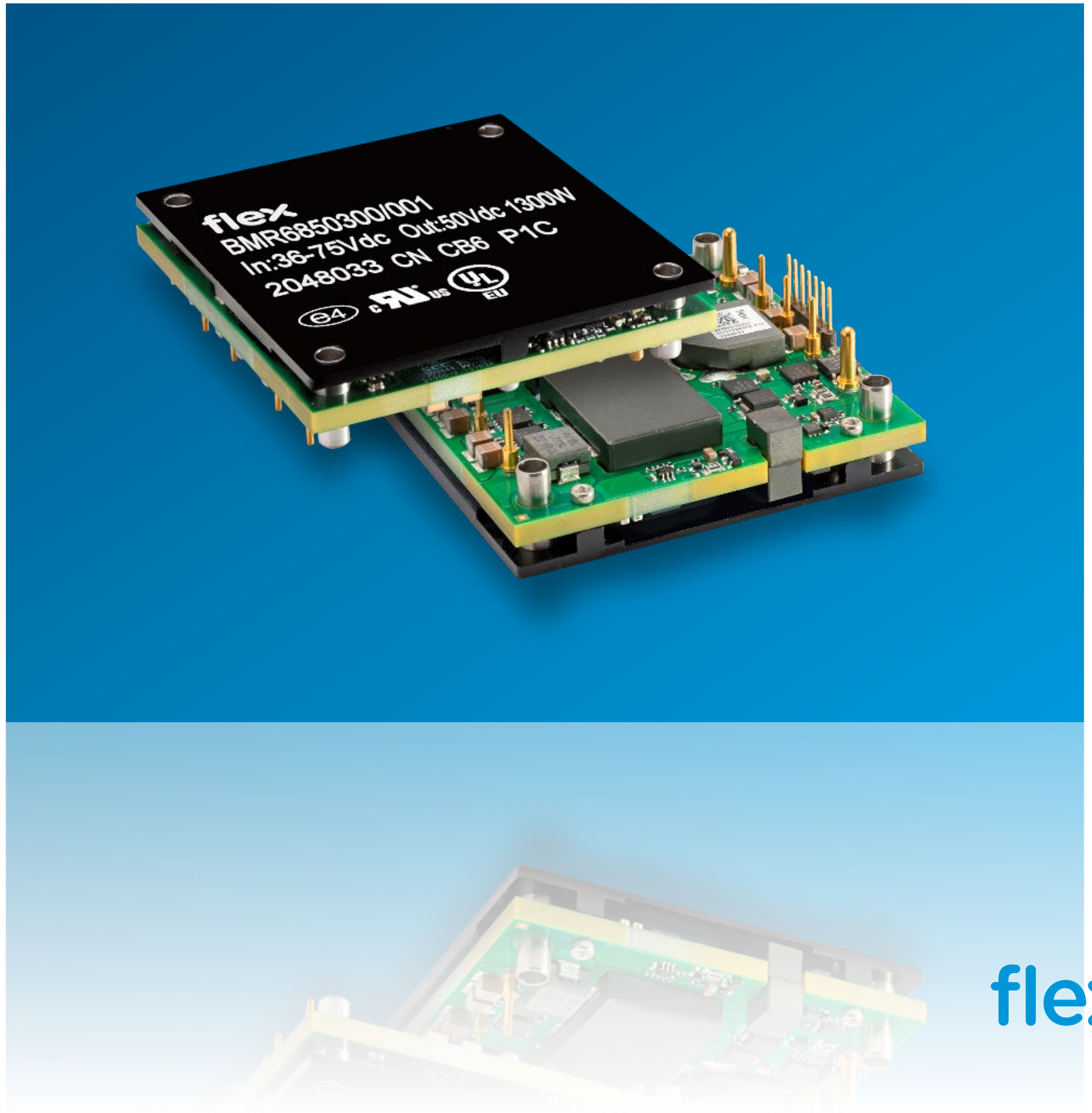
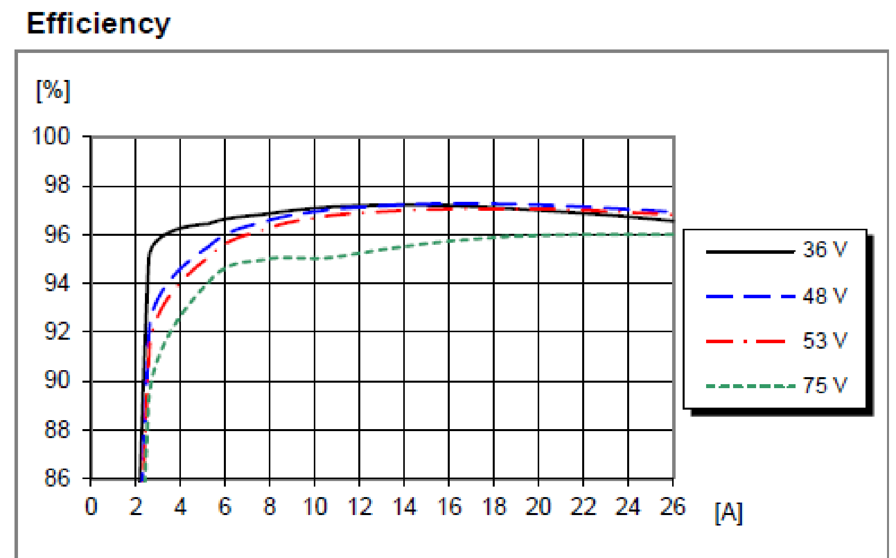
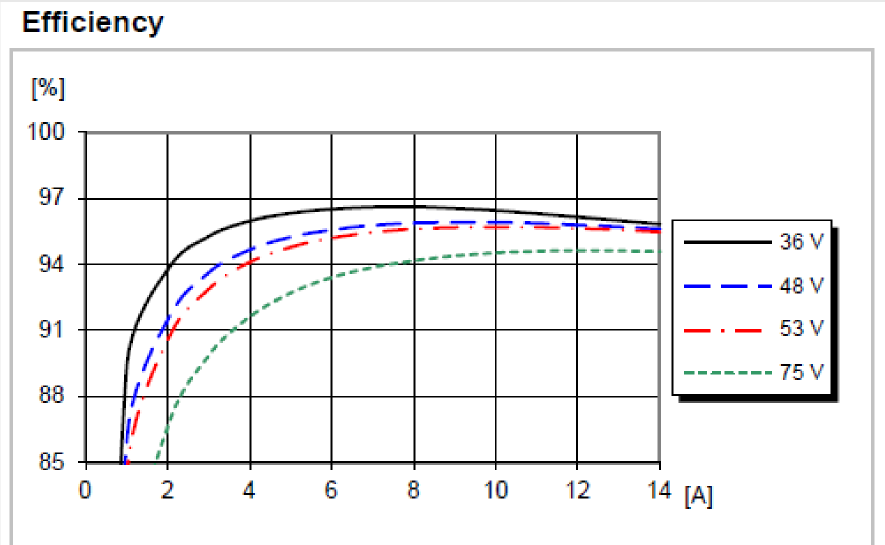
Product overview ● BMR685

- 工业标准半砖尺寸：61mm*57.9mm*12.7mm
- 功率密度：473W/in³
- 输入电压范围: 36V~75V
- 输出: 50V/1300W
- 输出电压范围: 25V~55V
- 效率：97.2%， 48Vin输入半载
- 高度尺寸精度：0.2mm
- 优秀的热降额特性
- 输入和输出隔离电压：2250Vdc
- 兼容PMBus通讯协议
- 电压，电流和温度监控
- 输出电压可软件更改
- 快照（Snapshot）功能

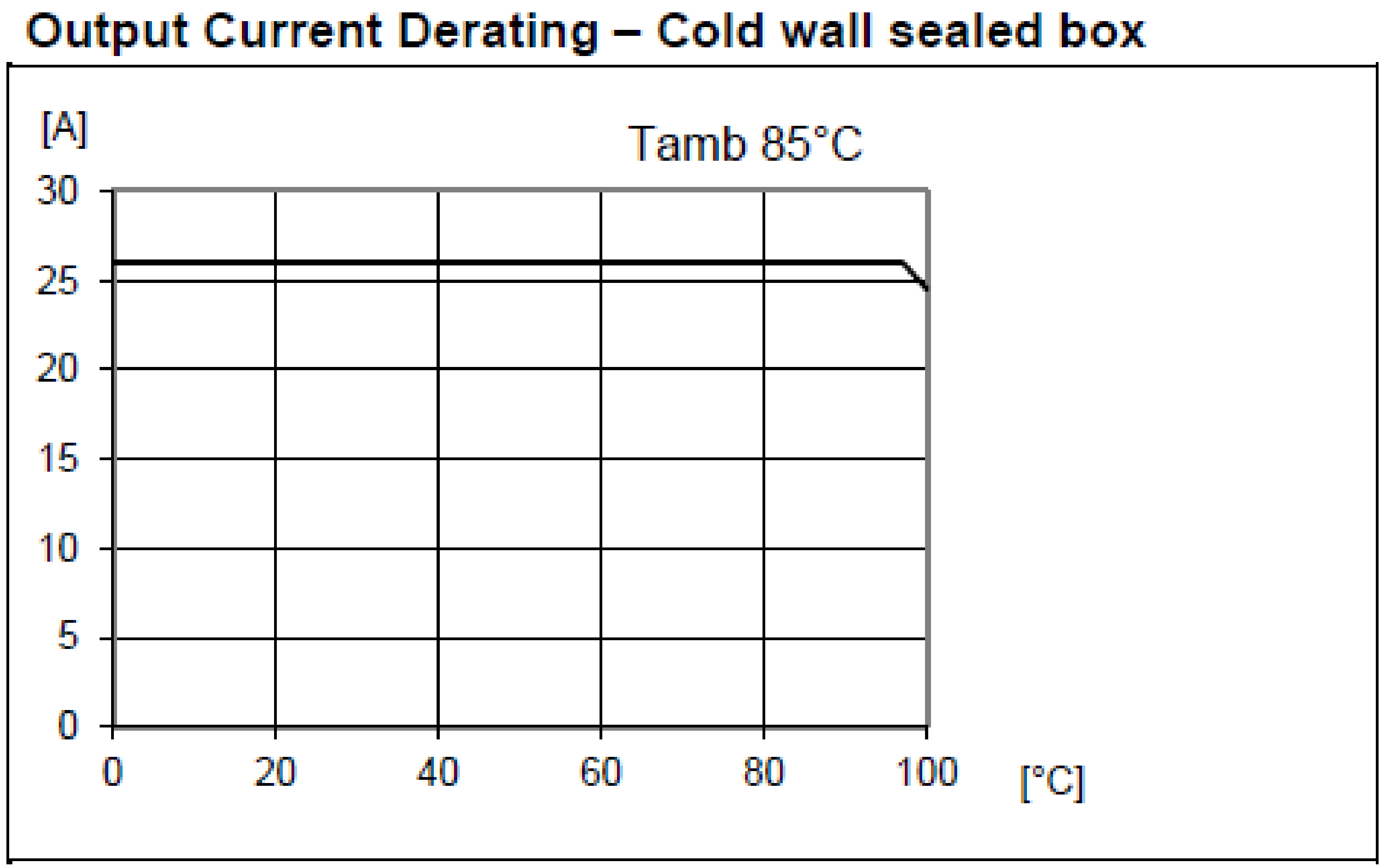


BMR685 1300W vs PKJ4716H 700W 50V

产品型号	BMR685 NEW	PKJ4716H
外观		
输出功率	1300W	700W
功率密度 (W/in^3)	475	256
效率曲线	 Efficiency vs. load current and input voltage at T_{P1} = +25°C	 Efficiency vs. load current and input voltage at T_{P1} = +25°C.

优秀的热降额特性，满足密闭环境的应用

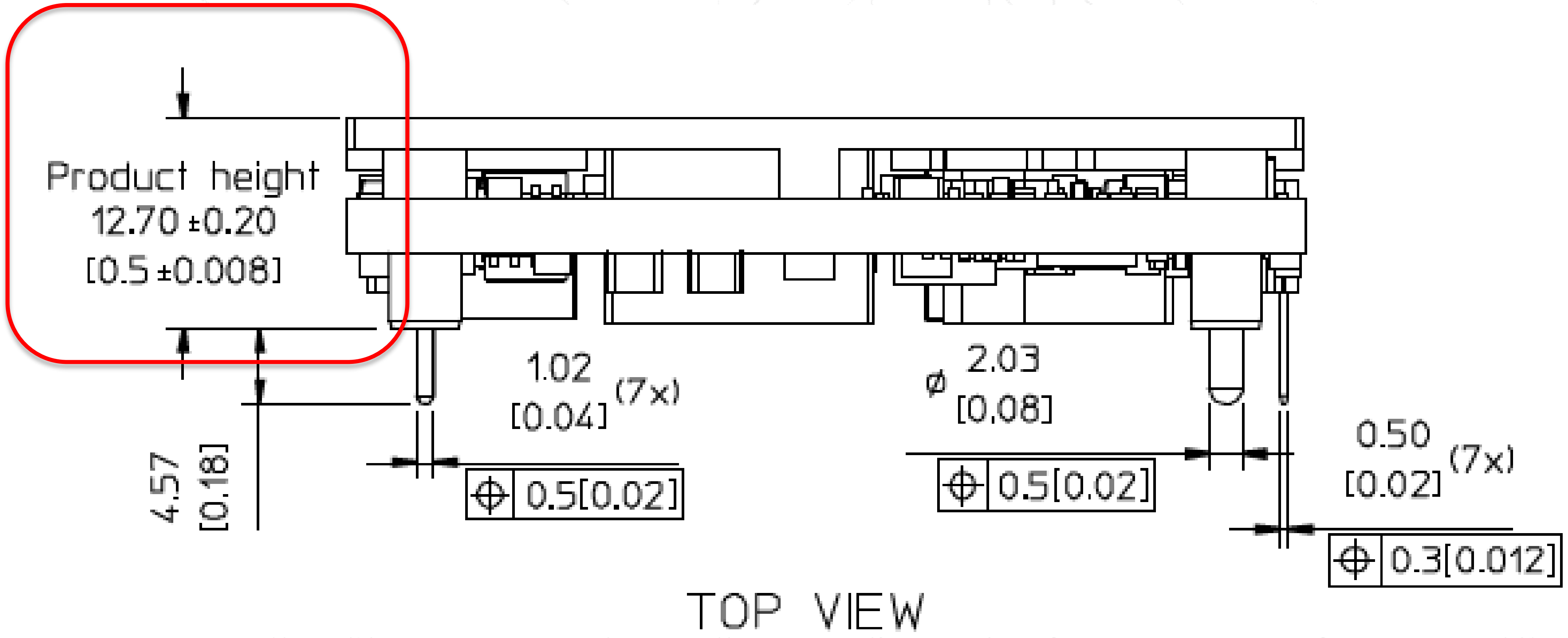
- ➢ 环境温度85度，基板温度100度时，支持满载输出



Available load current vs Base plate temperature.
V_I = 48 V. See Thermal Consideration section.

较小的高度尺寸公差

➢ 高度尺寸公差为±0.2mm，方便客户的结构和热设计



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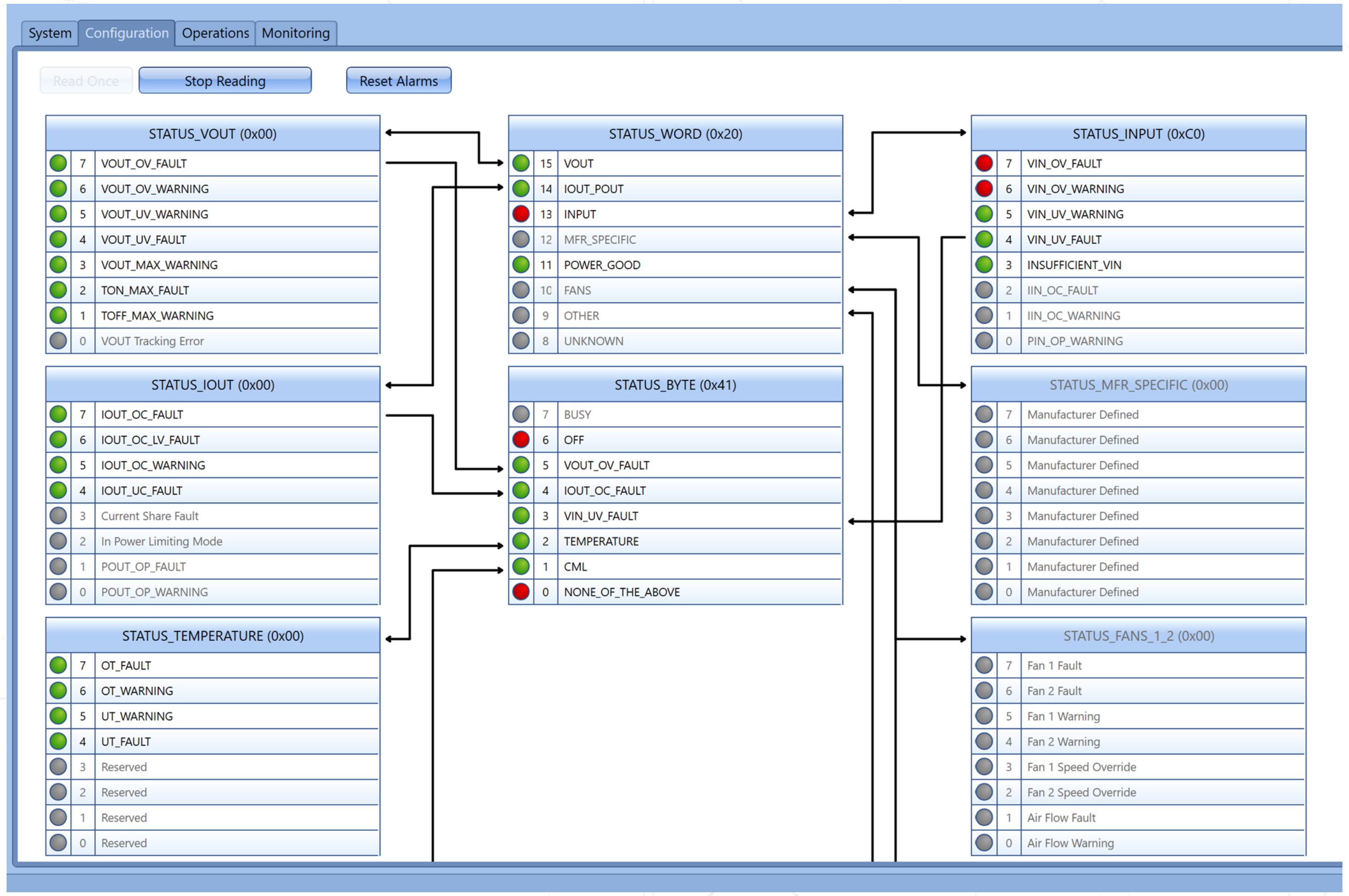
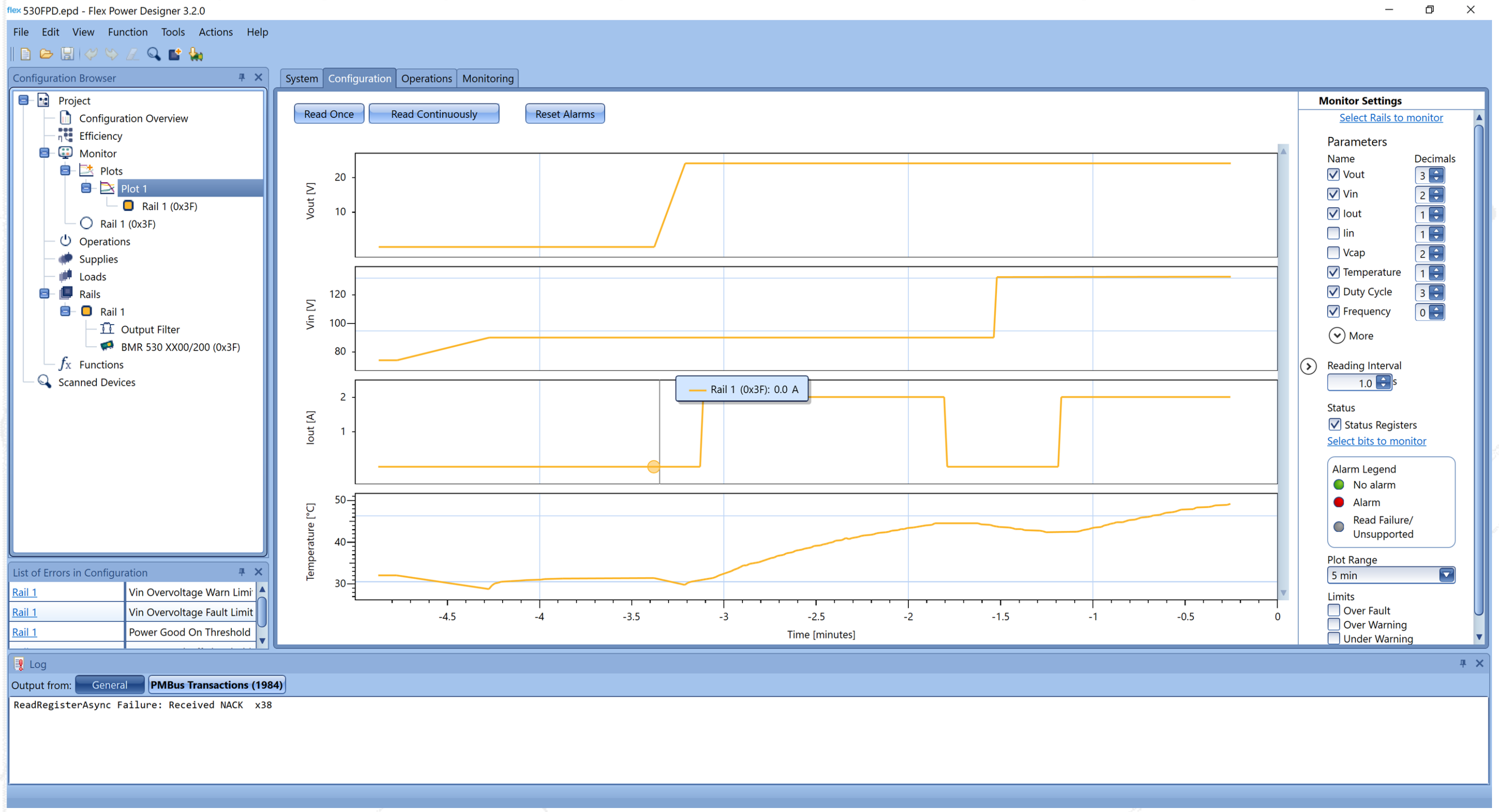
数字功能

- 标准DOSA数字电源封装（可提供兼容模拟产品管脚封装无数字管脚的产品）
- 使用标准PMBus通讯协议
- 提供可软件配置的输入欠压，过压保护；输出过压，过流和过温保护
- Flex Power Designer（FPD）软件可支持BMR685的配置和状态监控
- FPD的画图功能-通过PMBus接口读取模块工作状态信息形成图形化数据
- 监控功能-实时状态信息读取，方便故障现象的诊断
- 快照功能-模块下电时，自动记录失效状态信息到模块内部的闪存存储器里，方便客户后期故障分析





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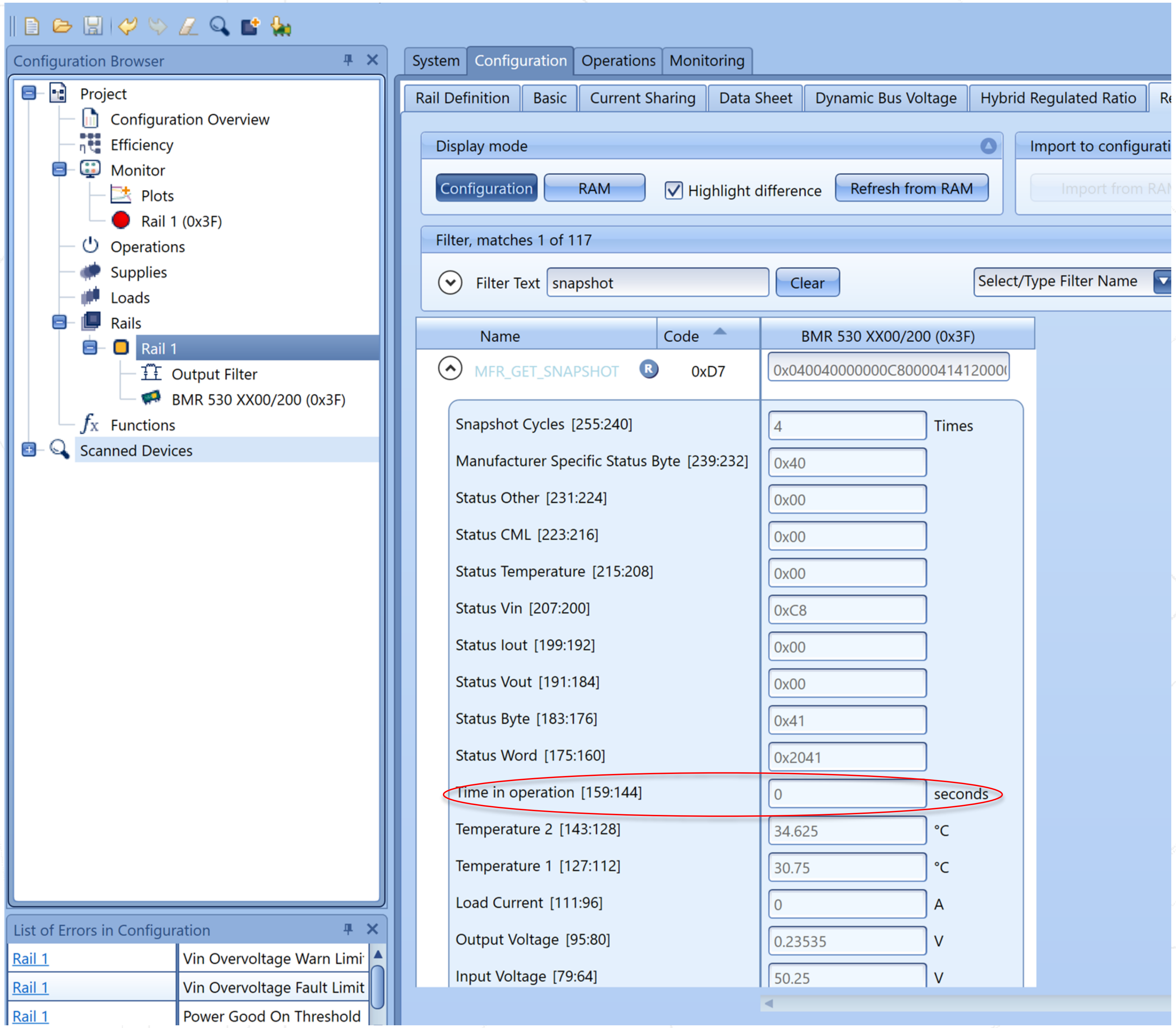
快照功能

- **Snapshot** – 记录所有状态和告警信息

- 当输入跌落到输入关机点，Vin_off(可配置)，模块记录所有状态信息和最后的工作时间信息



Comparison • key features

	BMR685	PKJ4716H	Competitor A
Mechanical			
Dimensions	Half brick | **digital**	Half brick | analog	Half brick | **digital**
Electrical			
Input voltage range	36-75 V	36-75 V	36-60 V
Output voltage	50 V	50 V	50 V
Output voltage range	25-55 V	25-55 V	50 V
Output power	1300 W	700 W	1300 W
Output current	26 A	14 A	26 A
Efficiency	97.2% half load	95.7 % half load	96.4% half load
Switching frequency	120 kHz	200 kHz	140 kHz
Ripple and noise	40 mV_{p-p}	60 mV_{p-p}	200 mV_{p-p}
Isolation	2250 V	1500 V	2250 V

PKU-D & PKU-C

DC/DC converter in sixteenth brick format

Designed for **low power radio applications** such as microwave, small cells and indoor wireless coverage

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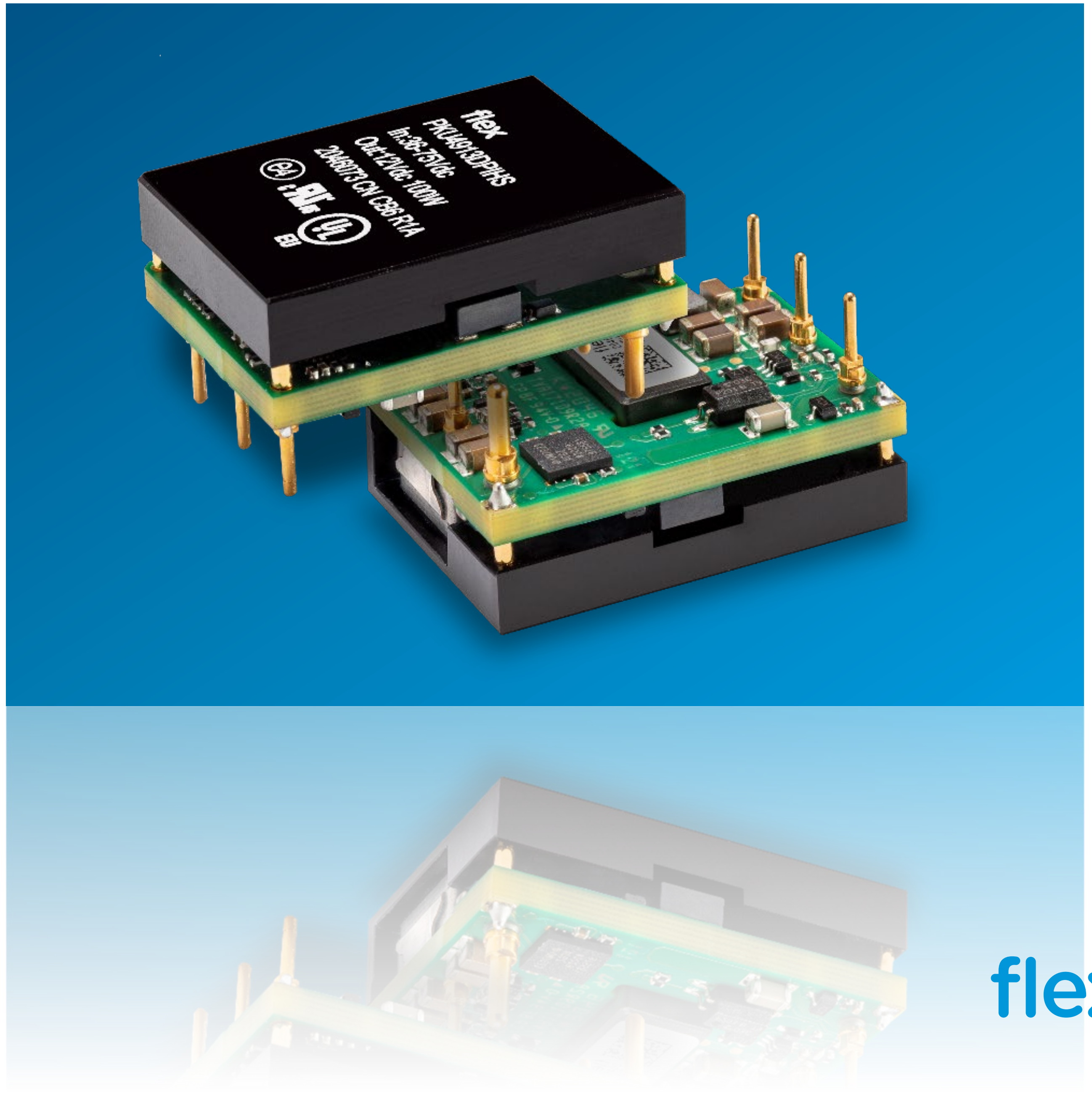
Product overview • PKU-D

- Low profile sixteenth brick – available with baseplate
- Wide output trim range for low-power radio designs
- Excellent price/performance ratio
- Efficiency up to 95% half load
- Extremely good thermal performance
- Output power: 100-260 W
- Input: 36-75 V
- Output: 2.6 – 13.2 V



Dimensions:
33 x 22.9 x 11.3 mm
1.3 x 0.9 x 0.44 in

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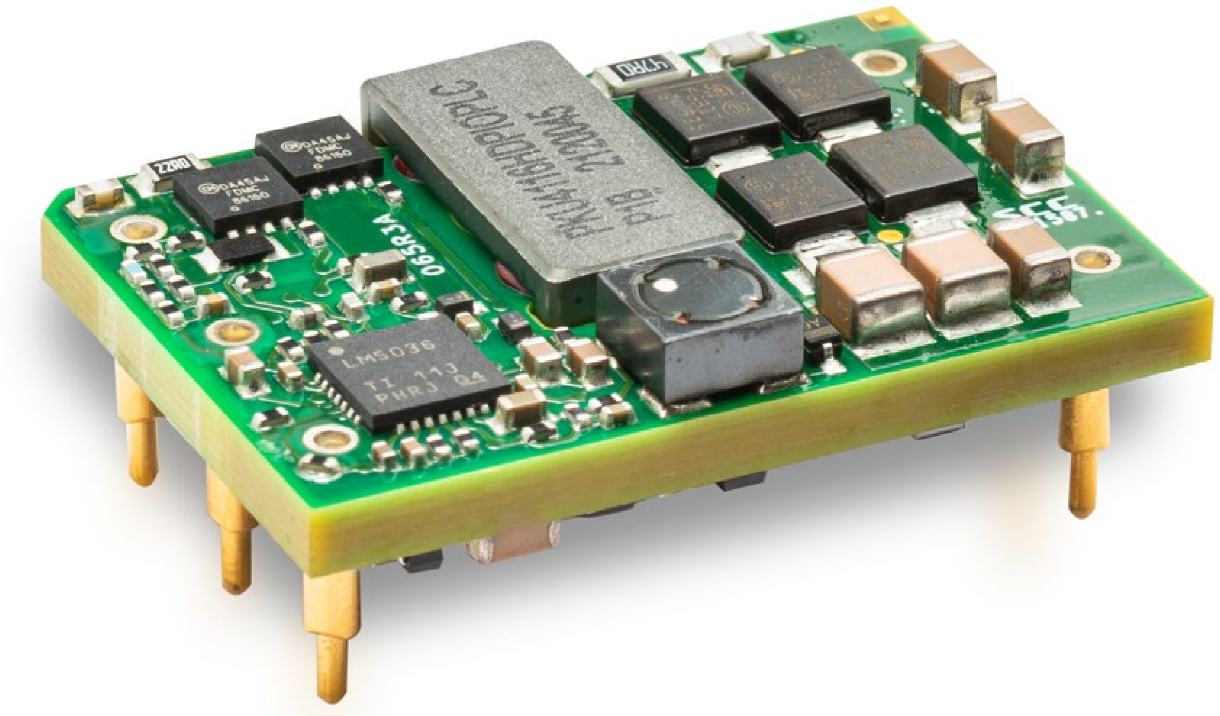
Product overview ● PKU4116HD

- Isolated DC/DC
- Output power: up to 110 W
- Input: 36-60 V
- Output: 55 V
- Isolation 2250Vdc



Dimensions:
33 x 22.9 x 9.8 mm
1.3 x 0.9 x 0.38 in

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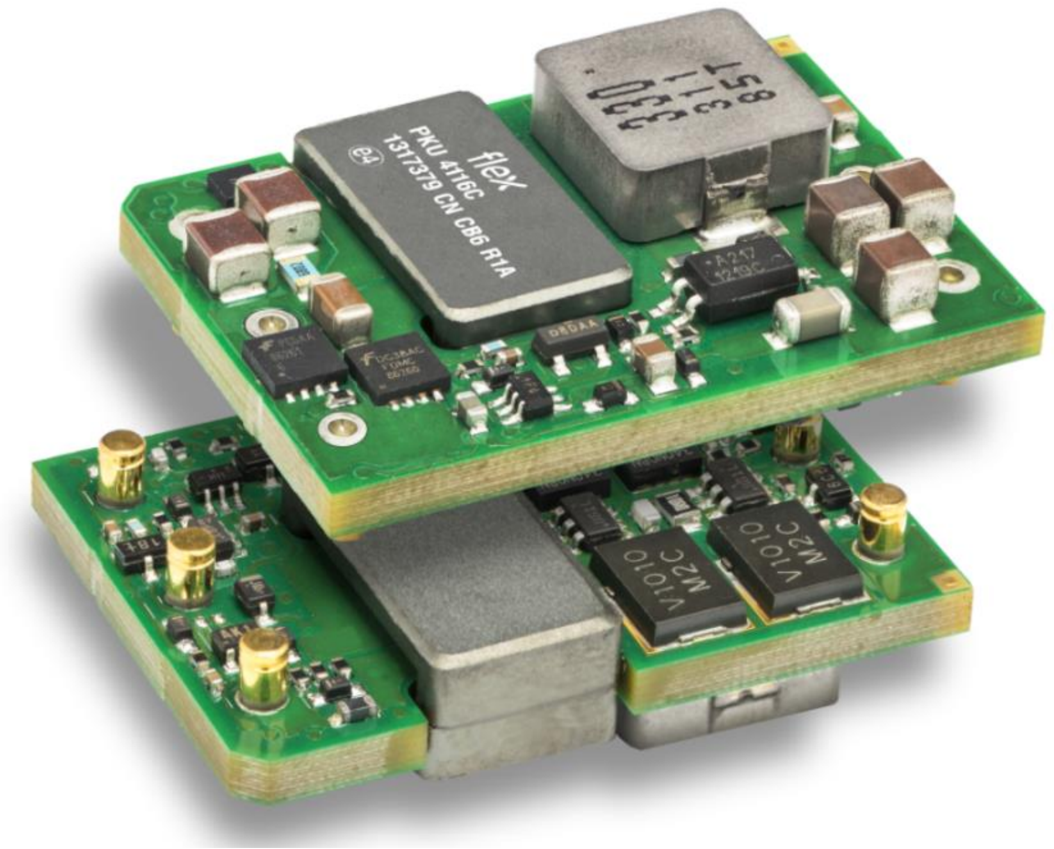
Product overview • PKU4116C

- Low profile sixteenth brick
- Isolated DC/DC
- Output power: up to 100 W
- Input: 36-75 V
- Output: 10 - 33 V
- Isolation 1500 V



Dimensions:
33 x 22.9 x 9.6 mm
1.3 x 0.9 x 0.38 in

Key features

	PKU4116C	PKU-D	PKU4116HD
Mechanical			
Dimensions	33 x 22.9 x 9.6 mm	33 x 22.9 x 11.3 mm	33 x 22.9 x 9.8 mm
Electrical			
Input voltage range	36-60 V	36-75 V	36-60 V
Output voltage	5-6 V	2.6-13.2 V	55 V
Output power	60 W	100 – 260 W	110 W
Output current	12 A	8.3 -33 A	2 A
Efficiency	93%	96%	92.4%
Switching frequency	300 kHz	500 kHz	500 kHz
Ramp-up time	10 ms	12 ms	19 ms
Isolation	1500 V	2250 V	2250 V

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DC/DC solutions for 5G applications

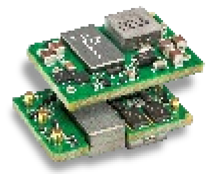
原边: 输入滤波和保护

48V

Surge protection	E-cap
Fuse	Polarity protection
EMI filter	Soft start
	…

副边: 允许不同输出电压选择

30 V



100 W (PKU-C)
- Antenna

12 V

260 W (PKB-D/PKU-D)
- Board control

12 V

300 W (PKB-D), 400 W (PKB-D)
600 W (PKM-NH)
- BBU & DU

32/50 V

500 W (PKM4516) 700 W (PKJ4716)
1300 W (BMR685)
- RF amplifier

Case Study 1

- Customer – a new player in the O-RAN Alliance HW infrastructure development
- Project – Massive MIMO 5G 32T32R reference design using ADI & Marvell
- Design consists of 2 sections:
  - Power Amplifier
  - Baseband
- Power Amplifier DC/DC requirements
  - 28 V with trim capability at up to 1000W. Needed digital interface for monitoring
- Baseband DC/DC requirements
  - 12 V at up to 200 W. Needed digital interface for monitoring
- Thermal – sealed box conduction cooling. Max case temperature of +100°C.

- **Power Amplifier**
  - BMR6830300/200 – 500 W 18-32 V Digital Quarter Brick
- **Radio**
  - BMR4560104/001 – 420 W 12 V Digital Quarter Brick

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Case Study 2

- Customer – a key player in the O-RAN Alliance
- Design consists of 2 sections:
  - Power Amplifier
  - Radio
- Power Amplifier DC/DC requirements
  - 50 V with trim capability at up to 700 W * 2pcs
- Radio DC/DC requirements
  - 12 V at up to 450W
  - 30W up to 60W
- Thermal – sealed box conduction cooling. Max ambient temperature of +95°C.

- **Power Amplifier**
  - PKJ4716HD – 700 W 50 V Half Brick with 25-55 V trim range
- **Radio**
  - PKB4413D – 450 W 12 V Eighth Brick
  - PKU4116C – 100 W 10~30V Sixteenth Brick

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Q&A

visit our website:
flexpowermodules.com