Powering 5G/RFPA
1 Flex Power Modules
2 5G introduction
3 RFPA/5G application overview
4 Product presentation
5 Q&A
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
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 capabilities
• 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
Product & application overview

DC/DC converter solutions that ensure maximum reliability, performance and cost effectiveness for the most demanding applications.
# Evolution of mobile networks

<table>
<thead>
<tr>
<th>Era</th>
<th>1G</th>
<th>2G</th>
<th>3G</th>
<th>4G</th>
<th>5G</th>
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<tr>
<td></td>
<td>1980s</td>
<td>1990s</td>
<td>2000s</td>
<td>2010s</td>
<td>2020s</td>
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<tr>
<td>Services</td>
<td>Analog Voice</td>
<td>Digital Voice</td>
<td>WB Voice Packet Data</td>
<td>Voice, Video Internet, Apps</td>
<td>Everything</td>
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<tr>
<td>Devices</td>
<td><img src="image" alt="1G" /></td>
<td><img src="image" alt="2G" /></td>
<td><img src="image" alt="3G" /></td>
<td><img src="image" alt="4G" /></td>
<td><img src="image" alt="5G" /></td>
</tr>
<tr>
<td>Data Rate</td>
<td>0</td>
<td>100 kbps (GPRS)</td>
<td>10Mbps (HSPA)</td>
<td>100+Mbps (LTE/LTE-A)</td>
<td>10 Gbps (NR)</td>
</tr>
<tr>
<td>Delay</td>
<td>500 ms</td>
<td>100 ms</td>
<td>102 ms</td>
<td>5 ms</td>
<td></td>
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</table>
5G will enable many new use cases
... and the best ones have yet to be imagined

Enhanced Mobile Broadband
- UHD video streaming

Ultra-Reliable & Low Latency
- Autonomous vehicles

Massive IoT
- Smart cities
- Industrial automation
- Wearables / Fitness

Virtual reality
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

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
1. Flex Power Modules
2. 5G Introduction
3. RFPA/5G Application Overview
4. Product Presentation
5. Q&A
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

**Challenges:**

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

**Load at TDD application**
Mounting requirements

Thermal performance plays an important role
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 motherboard by dozens of PCB pads to reduce thermal resistance towards downside

Result: The output power capability is increased when thermal performance improved.
1. Flex Power Modules
2. 5G Introduction
3. RFPA/5G Application Overview
4. Product Presentation
5. Q&A
5G/RFPA DC/DC portfolio

half brick

quarter brick

eighth brick

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}

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

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

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

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

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

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

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

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

100 W 200 W 500 W 700 W 1300 W

PK4516HD Digital / quarter brick
25-55 V_{out} / 500 W

New

New
BMR685

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

Designed for **high power GaN and LDMOS RFPA** applications
Product overview ● BMR685

- Industrial standard half-brick size: 61mm*57.9mm*12.7mm
- Power density: 473W/in³
- Input voltage range: 36V~75V
- Output: 50V/1300W
- Output voltage range: 25V~55V
- Efficiency: 97.2%, 48Vin input half load
- Height dimensional accuracy: 0.2mm
- Excellent thermal derating characteristics
- Input and output isolation voltage: 2250Vdc
- PMBus communication protocol
- Voltage, current, and temperature monitoring
- Output voltage software changeable
- Snapshot (Snapshot) function
## BMR685 1300W vs PKJ4716H 700W 50V

<table>
<thead>
<tr>
<th>产品型号</th>
<th>BMR685</th>
<th>PKJ4716H</th>
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<tbody>
<tr>
<td>外观</td>
<td><img src="image1" alt="BMR685" /></td>
<td><img src="image2" alt="PKJ4716H" /></td>
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<tr>
<td>输出功率</td>
<td>1300W</td>
<td>700W</td>
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<tr>
<td>功率密度 (W/in^3)</td>
<td>475</td>
<td>256</td>
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<tr>
<td>效率曲线</td>
<td><img src="image3" alt="Efficiency" /></td>
<td><img src="image4" alt="Efficiency" /></td>
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</tbody>
</table>
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

**Output Current Derating – Cold wall sealed box**

![Output Current Derating Graph](image)

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
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
快照功能

- **Snapshot** – 记录所有状态和警告信息

- 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

<table>
<thead>
<tr>
<th></th>
<th>BMR685</th>
<th>PKJ4716H</th>
<th>Competitor A</th>
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<tbody>
<tr>
<td><strong>Mechanical</strong></td>
<td></td>
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</tr>
<tr>
<td>Dimensions</td>
<td>Half brick</td>
<td>digital</td>
<td>Half brick</td>
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<tr>
<td><strong>Electrical</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Input voltage range</td>
<td>36-75 V</td>
<td>36-75 V</td>
<td>36-60 V</td>
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<tr>
<td>Output voltage</td>
<td>50 V</td>
<td>50 V</td>
<td>50 V</td>
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<tr>
<td>Output voltage range</td>
<td>25-55 V</td>
<td>25-55 V</td>
<td>50 V</td>
</tr>
<tr>
<td>Output power</td>
<td>1300 W</td>
<td>700 W</td>
<td>1300 W</td>
</tr>
<tr>
<td>Output current</td>
<td>26 A</td>
<td>14 A</td>
<td>26 A</td>
</tr>
<tr>
<td>Efficiency</td>
<td>97.2% half load</td>
<td>95.7% half load</td>
<td>96.4% half load</td>
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<tr>
<td>Switching frequency</td>
<td>120 kHz</td>
<td>200 kHz</td>
<td>140 kHz</td>
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<tr>
<td>Ripple and noise</td>
<td>40 mV&lt;sub&gt;P-P&lt;/sub&gt;</td>
<td>60 mV&lt;sub&gt;P-P&lt;/sub&gt;</td>
<td>200 mV&lt;sub&gt;P-P&lt;/sub&gt;</td>
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<tr>
<td>Isolation</td>
<td>2250 V</td>
<td>1500 V</td>
<td>2250 V</td>
</tr>
</tbody>
</table>
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
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
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
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

<table>
<thead>
<tr>
<th></th>
<th>PKU4116C</th>
<th>PKU-D</th>
<th>PKU4116HD</th>
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<tbody>
<tr>
<td><strong>Mechanical</strong></td>
<td></td>
<td></td>
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<tr>
<td>Dimensions</td>
<td>33 x 22.9 x 9.6 mm</td>
<td>33 x 22.9 x 11.3 mm</td>
<td>33 x 22.9 x 9.8 mm</td>
</tr>
<tr>
<td><strong>Electrical</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Input voltage range</td>
<td>36-60 V</td>
<td>36-75 V</td>
<td>36-60 V</td>
</tr>
<tr>
<td>Output voltage</td>
<td>5-6 V</td>
<td>2.6-13.2 V</td>
<td>55 V</td>
</tr>
<tr>
<td>Output power</td>
<td>60 W</td>
<td>100 – 260 W</td>
<td>110 W</td>
</tr>
<tr>
<td>Output current</td>
<td>12 A</td>
<td>8.3 -33 A</td>
<td>2 A</td>
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<tr>
<td>Efficiency</td>
<td>93%</td>
<td>96%</td>
<td>92.4%</td>
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<tr>
<td>Switching frequency</td>
<td>300 kHz</td>
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<td>Ramp-up time</td>
<td>10 ms</td>
<td>12 ms</td>
<td>19 ms</td>
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<tr>
<td>Isolation</td>
<td>1500 V</td>
<td>2250 V</td>
<td>2250 V</td>
</tr>
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</table>
DC/DC solutions for 5G applications

48V

- Surge protection
- E-cap
- Fuse
- Polarity protection
- EMI filter
- Soft start
- ...
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
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
Q&A

visit our website: flexpowermodules.com