PKB5000D series Fully Regulated DC-DC Converters
Input 18-60 V, Output up to 20 A / 240 W

Key Features
- Industry standard low profile Eighth-brick 58.4 x 22.7 x 13.2 mm (2.29 x 0.89 x 0.52 in)
- High efficiency, typical 94.6 % at 24 Vin, 12 Vout, half load
- 2250 Vdc baseplate to input isolation
- Pre-bias start up
- Meets safety requirements according to IEC/EN/UL 62368-1
- MTBF 10.6 million hours

General Characteristics
- Input under voltage shutdown
- Monotonic start-up
- Remote control
- Output over voltage protection
- Over temperature protection
- Output short-circuit protection
- Highly automated manufacturing ensures quality
- ISO 9001/14001 certified supplier

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Safety Approvals
UL

Design for Environment
Meets requirements in high-temperature lead-free soldering processes.
PKB5000D series Fully Regulated DC-DC Converters
Input 18-60 V, Output up to 20 A / 240 W

Ordering Information

<table>
<thead>
<tr>
<th>Product program</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>PKB5213D</td>
<td>12 V, 20 A / 240 W</td>
</tr>
</tbody>
</table>

Product number and Packaging

<table>
<thead>
<tr>
<th>PKB5213D Options</th>
<th>n1</th>
<th>n2</th>
<th>n3</th>
<th>n4</th>
<th>n5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mounting</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remote Control logic</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseplate</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead length</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delivery length</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Options Description

- n1: PI Through hole *
- n2: Negative *
- n3: Positive
- n4: Open Frame*
- n5: HS Baseplate
- n6: Lead length, 5.33mm *
- n7: LA Lead length, 3.69 mm
- n8: LB Lead length, 4.57 mm
- n9: LC Lead length, 2.79 mm
- n10: /B Tray

DBP, DIBP and of 0.01% by weight in homogeneous materials for cadmium.

Exemptions in the RoHS directive utilized in Flex Power products are found in the Statement of Compliance document.

Flex Power fulfills and will continuously fulfill all its obligations under regulation (EC) No 1907/2006 concerning the registration, evaluation, authorization and restriction of chemicals (REACH) as they enter into force and is through product materials declarations preparing for the obligations to communicate information on substances in the products.

Quality Statement

The products are designed and manufactured in an industrial environment where quality systems and methods like ISO 9000, Six Sigma, and SPC are intensively used to boost the continuous improvements strategy. Infant mortality or early failures in the products are screened out and they are subjected to an ATE-based final test. Conservative design rules, design reviews and product qualifications, plus the high competence of an engaged work force, contribute to the high quality of the products.

Warranty

Warranty period and conditions are defined in Flex Power Modules General Terms and Conditions of Sale.

Limitation of Liability

Flex Power Modules does not make any other warranties, expressed or implied including any warranty of merchantability or fitness for a particular purpose (including, but not limited to, use in life support applications, where malfunctions of product can cause injury to a person’s health or life).

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General Information

Reliability

The failure rate ($\lambda$) and mean time between failures (MTBF = 1/$\lambda$) is calculated at max output power and an operating ambient temperature ($T_A$) of +40°C. Flex Power Modules uses Telcordia SR-332 Issue 3 Method 1 to calculate the mean steady-state failure rate and standard deviation ($\sigma$).

Telcordia SR-332 Issue 4 also provides techniques to estimate the upper confidence levels of failure rates based on the mean and standard deviation.

<table>
<thead>
<tr>
<th>Mean steady-state failure rate, nFailures/h</th>
<th>Std. deviation, $\sigma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>104</td>
<td>7.9</td>
</tr>
</tbody>
</table>

MTBF (mean value) for the PKB5213D series = 10.6 Mh.
MTBF at 90% confidence level = 9.6 Mh

Compatibility with RoHS requirements

The products are compatible with the relevant clauses and requirements of the RoHS directive 2011/65/EU and 2015/863 and have a maximum concentration value of 0.1% by weight in homogeneous materials for lead, mercury, hexavalent chromium, PBB, PBDE, DEHP, BBP, 

Compatibility with RoHS requirements
PKB5000D series Fully Regulated DC-DC Converters
Input 18-60 V, Output up to 20 A / 240 W

Safety Specification

General information

Flex Power DC/DC converters and DC/DC regulators are designed in accordance with the safety standards IEC 62368-1, EN 62368-1 and UL 62368-1 Audio/video, information and communication technology equipment - Part 1: Safety requirements.

IEC/EN/UL 62368-1 contains requirements to prevent injury or damage due to the following hazards:

- Electrical shock
- Electrically-caused fire
- Injury caused by hazardous substances
- Mechanically-caused injury
- Skin burn
- Radiation-caused injury

On-board DC/DC converters, Power interface modules and DC/DC regulators are defined as component power supplies. As components they cannot fully comply with the provisions of any safety requirements without “conditions of acceptability”. Clearance between conductors and between conductive parts of the component power supply and conductors on the board in the final product must meet the applicable safety requirements. Certain conditions of acceptability apply for component power supplies with limited stand-off (see Mechanical Information for further information). It is the responsibility of the installer to ensure that the final product housing these components complies with the requirements of all applicable safety standards and regulations for the final product.

Component power supplies for general use shall comply with the requirements in IEC/EN/UL 62368-1. Product related standards, e.g. IEEE 802.3af Power over Ethernet, and ETS-300132-2 Power interface at the input to telecom equipment, operated by direct current (dc) are based on IEC/EN/UL 60950-1 with regards to safety.

Flex Power DC/DC converters, Power interface modules and DC/DC regulators are UL 62368-1 recognized and certified in accordance with EN 62368-1. The flammability rating for all construction parts of the products meet requirements for V-0 class material according to IEC 60695-11-10, Fire hazard testing, test flames – 50 W horizontal and vertical flame test methods.

Isolated DC/DC converters & Power interface modules

The product may provide basic or functional insulation between input and output according to IEC/EN/UL 62368-1 (see Safety Certificate), different conditions shall be met if the output of a basic or a functional insulated product shall be considered as ES1 energy source.

For basic insulated products (see Safety Certificate) the output is considered as ES1 energy source if one of the following conditions is met:

- The input source provides supplementary or double or reinforced insulation from the AC mains according to IEC/EN/UL 62368-1.
- The input source provides functional or basic insulation from the AC mains and the product’s output is reliably connected to protective earth according to IEC/EN/UL 62368-1.

For functional insulated products (see Safety Certificate) the output is considered as ES1 energy source if one of the following conditions is met:

- The input source provides double or reinforced insulation from the AC mains according to IEC/EN/UL 62368-1.
- The input source provides basic or supplementary insulation from the AC mains and the product’s output is reliably connected to protective earth according to IEC/EN/UL 62368-1.
- The input source is reliably connected to protective earth and provides basic or supplementary insulation according to IEC/EN/UL 62368-1 and the maximum input source voltage is 60 Vdc.

Galvanic isolation between input and output is verified in an electric strength test and the isolation voltage (Viso) meets the voltage strength requirement for basic insulation according to IEC/EN/UL 62368-1.

It is recommended to use a slow blow fuse at the input of each DC/DC converter. If an input filter is used in the circuit the fuse should be placed in front of the input filter. In the rare event of a component problem that imposes a short circuit on the input source, this fuse will provide the following functions:

- Isolate the fault from the input power source so as not to affect the operation of other parts of the system
- Protect the distribution wiring from excessive current and power loss thus preventing hazardous overheating
### Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>min</th>
<th>typ</th>
<th>max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{P1}$ Operating Temperature (see Thermal Consideration section)</td>
<td>-40</td>
<td>+125</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>$T_{S}$ Storage temperature</td>
<td>-55</td>
<td>+125</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>$V_{I}$ Input voltage</td>
<td>-0.5</td>
<td>+80</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$C_{out}$ Output capacitance</td>
<td>100</td>
<td></td>
<td></td>
<td>µF</td>
</tr>
<tr>
<td>$V_{iso}$ Isolation voltage (input to output test voltage)</td>
<td></td>
<td>2250</td>
<td></td>
<td>Vdc</td>
</tr>
<tr>
<td>$V_{iso}$ Isolation voltage (input to baseplate qualification test voltage)</td>
<td></td>
<td>2250</td>
<td></td>
<td>Vdc</td>
</tr>
<tr>
<td>$V_{iso}$ Isolation voltage (baseplate to output qualification test voltage)</td>
<td></td>
<td>750</td>
<td></td>
<td>Vdc</td>
</tr>
<tr>
<td>$V_{tr}$ Input voltage transient according to ETSI EN 300 132-2 and Telcordia GR-1089-CORE</td>
<td></td>
<td></td>
<td>750</td>
<td>Vdc</td>
</tr>
<tr>
<td>$V_{RC}$ Remote Control pin voltage (see Operating Information section)</td>
<td>Positive logic option</td>
<td>-0.5</td>
<td>6</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>Negative logic option</td>
<td>-0.5</td>
<td>6</td>
<td>V</td>
</tr>
</tbody>
</table>

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the Electrical Specification section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

### Fundamental Circuit Diagram

![Fundamental Circuit Diagram](image)
### Electrical Specification

**PKB5000D series** Fully Regulated DC-DC Converters  
Input 18-60 V, Output up to 20 A / 240 W

#### Input/Output Specifications

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Conditions</th>
<th>min</th>
<th>typ</th>
<th>max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input voltage range</strong></td>
<td></td>
<td>18</td>
<td>60</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td><strong>Turn-off input voltage</strong></td>
<td></td>
<td>12.5</td>
<td>13.5</td>
<td>14.5</td>
<td>V</td>
</tr>
<tr>
<td><strong>Turn-on input voltage</strong></td>
<td></td>
<td>13</td>
<td>14.5</td>
<td>16</td>
<td>V</td>
</tr>
<tr>
<td><strong>Internal input capacitance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>µF</td>
</tr>
<tr>
<td><strong>Output power</strong></td>
<td></td>
<td>0</td>
<td>240</td>
<td></td>
<td>W</td>
</tr>
</tbody>
</table>

#### Efficiency

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Conditions</th>
<th>min</th>
<th>typ</th>
<th>max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td></td>
<td>50% of max I_o V_i = 48 V</td>
<td>94.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>max I_o V_i = 48 V</td>
<td>92.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>50% of max I_o V_i = 24 V</td>
<td>94.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>max I_o V_i = 24 V</td>
<td>92.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Power Dissipation</strong></td>
<td></td>
<td>max I_o</td>
<td>21.0</td>
<td>30</td>
<td>W</td>
</tr>
<tr>
<td><strong>Input idling power</strong></td>
<td>I_o = 0 A, V_i = 48 V</td>
<td>6</td>
<td></td>
<td></td>
<td>W</td>
</tr>
<tr>
<td><strong>Input standby power</strong></td>
<td>V_i = 48 V (turned off with RC)</td>
<td>1</td>
<td></td>
<td></td>
<td>W</td>
</tr>
<tr>
<td><strong>Switching frequency</strong></td>
<td>0-100 % of max I_o</td>
<td>390</td>
<td>415</td>
<td>440</td>
<td>kHz</td>
</tr>
</tbody>
</table>

#### Input voltage initial setting and accuracy

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Conditions</th>
<th>min</th>
<th>typ</th>
<th>max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output voltage tolerance band</strong></td>
<td>0-100% of max I_o, V_i = 19-60 V</td>
<td>11.64</td>
<td>12.36</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td><strong>Idling voltage</strong></td>
<td>I_o = 0 A, V_i = 19-60 V</td>
<td>11.76</td>
<td>12.4</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td><strong>Line regulation</strong></td>
<td>V_i = 19-60 V, max I_o</td>
<td>20</td>
<td>100</td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td><strong>Load regulation</strong></td>
<td>V_i = 48 V, 0-100% of max I_o</td>
<td>2</td>
<td>20</td>
<td></td>
<td>mV</td>
</tr>
</tbody>
</table>

#### Load transient voltage deviation

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Conditions</th>
<th>min</th>
<th>typ</th>
<th>max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Load transient recovery time</strong></td>
<td>V_i = 48 V, Load step 25-75-25% of max I_o, di/dt = 1 A/µs, C_o = 1 mF</td>
<td>±450</td>
<td>600</td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td><strong>Ramp-up time</strong> (from 10-%90 of V_o)</td>
<td></td>
<td>300</td>
<td>500</td>
<td></td>
<td>µs</td>
</tr>
<tr>
<td><strong>Start-up time</strong> (from V_i connection to 90% of V_o)</td>
<td></td>
<td>12</td>
<td>18</td>
<td></td>
<td>ms</td>
</tr>
<tr>
<td><strong>RC start-up time</strong> (from V_o connection to 90% of V_o)</td>
<td>max I_o</td>
<td>17</td>
<td>25</td>
<td></td>
<td>ms</td>
</tr>
</tbody>
</table>

#### RC

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Conditions</th>
<th>min</th>
<th>typ</th>
<th>max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sink current, see Note 1</strong></td>
<td></td>
<td>0.5</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td><strong>Trigger level</strong></td>
<td>Decreasing / Increasing RC-voltage</td>
<td>1.5 / 2.5</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td><strong>Response time</strong></td>
<td></td>
<td>0.1</td>
<td>0.5</td>
<td></td>
<td>ms</td>
</tr>
</tbody>
</table>

#### Output

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Conditions</th>
<th>min</th>
<th>typ</th>
<th>max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current limit threshold</strong></td>
<td></td>
<td>24</td>
<td>33</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td><strong>Short circuit current</strong></td>
<td></td>
<td>7.7</td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td><strong>Recommended Capacitive Load</strong></td>
<td></td>
<td>100</td>
<td>10000</td>
<td>µF</td>
<td></td>
</tr>
<tr>
<td><strong>Output ripple &amp; noise</strong></td>
<td>See ripple &amp; noise section, V_o</td>
<td>150</td>
<td>240</td>
<td></td>
<td>mVp-p</td>
</tr>
<tr>
<td><strong>Over voltage protection</strong></td>
<td></td>
<td>14.6</td>
<td></td>
<td></td>
<td>V</td>
</tr>
</tbody>
</table>

**Note 1:** Sink current drawn by external device connected to the RC pin  
**Note 2:** RMS current at OCP in hiccup mode  
**Note 3:** Low ESR value
Typical Characteristics
12.0 V, 20 A / 240 W

**Efficiency**

- Efficiency vs. load current and input voltage at $T_{P1} = +25^\circ C$.

**Power Dissipation**

- Dissipated power vs. load current and input voltage at $T_{P1} = +25^\circ C$.

**Output Characteristics**

- Output voltage vs. load current at $T_{P1} = +25^\circ C$.

**Current Limit Characteristics**

- Output voltage vs. load current at $I_o > I_o$. $T_{P1} = +25^\circ C$. 
PKB5000D series Fully Regulated DC-DC Converters  
Input 18-60 V, Output up to 20 A / 240 W

Typical Characteristics  
12.0 V, 20 A / 240 W

Start-up

Start-up enabled by connecting \( V_i \) at:  
\( T_{PI} = +25^\circ C, V_i = 48 \text{ V}, \)  
\( I_o = 20 \text{ A resistive load}. \)

Top trace: Output voltage (5 V/div.).  
Bottom trace: Input voltage (50 V/div.).  
Time scale: (10 ms/div.).

Shut-down

Shut-down enabled by disconnecting \( V_i \) at:  
\( T_{PI} = +25^\circ C, V_i = 48 \text{ V}, \)  
\( I_o = 20 \text{ A resistive load}. \)

Top trace: Output voltage (5 V/div.).  
Bottom trace: Input voltage (50 V/div.).  
Time scale: (2 ms/div.).

Output Ripple & Noise

Output voltage ripple at:  
\( T_{PI} = +25^\circ C, V_i = 48 \text{ V}, \)  
\( I_o = 20 \text{ A resistive load}. \)

Trace: output voltage (50 mV/div.).  
Time scale: (2 \mu s/div.).  
20 MHz bandwidth filter 10 \mu F-0.1 \mu F

Output Load Transient Response

Output voltage response to load current step-change (5A– 15A – 5A)  
\( T_{PI} = +25^\circ C, V_i = 48 \text{ V}. \)

Top trace: Output voltage (0.5 V/div.).  
Bottom trace: Output current (10 A/div.).  
Time scale: (0.5 ms/div.).
Typical Characteristics
12 V, 20 A / 240 W

Output Current Derating – Open frame

Available load current vs. ambient air temperature and airflow at \( V_i = 48 \text{ V} \). See Thermal Consideration section.

Output Current Derating – Base plate

Available load current vs. ambient air temperature and airflow at \( V_i = 48 \text{ V} \). See Thermal Consideration section.

Thermal Resistance – Base plate

Thermal resistance vs. airspeed measured at the converter. Tested in wind tunnel with airflow and test conditions as per the Thermal consideration section. \( V_i = 48 \text{ V} \).

Output Current Derating – Cold wall sealed box

Available load current vs. cold wall temperature. \( V_i = 48 \text{ V} \). See Thermal Consideration section.
EMC Specification
Conducted EMI measured according to EN 55022/EN 55032, CISPR 22/CISPR 23 and FCC part 15J (see test set-up). See Design Note 029 for further information. The fundamental switching frequency is 415 kHz for PKB5213D. The EMI characteristics below is measured at \( V_i = 48 \) V and max \( I_o \).

**Conducted EMI** Input terminal value (typ)

EMI without filter, EN55032 Test method and limits are the same as EN55022

Optional external filter for class B
Suggested external input filter in order to meet class B in EN 55022/EN 55032, CISPR 22/CISPR 23 and FCC part 15J.

Filter components:
- \( C1 = 2 \) µF
- \( C2 = 2 \) µF
- \( C3 = 2 \) µF + 220 µF (e-lyt)
- \( C4, C5 = 2 \times 10 \) nF
- \( L1 = 0.63 \) mH
- \( L2 = 2.2 \) µH

Output ripple and noise
Output ripple and noise is measured according to figure below. See Design Note 022 for detailed information.

Layout recommendations
The radiated EMI performance of the product will depend on the PWB layout and ground layer design. It is also important to consider the stand-off of the product. If a ground layer is used, it should be connected to the output of the product and to the equipment ground or chassis.

A ground layer will increase the stray capacitance in the PWB and improve the high frequency EMC performance.
Operating information

Input Voltage
The input voltage range 18 to 60 Vdc meets typical requirements in 48 V DC systems used in communications, industrial and medical equipment.

At input voltages exceeding 60 V, the power loss will be higher than at normal input voltage and $T_{P1}$ must be limited to absolute max +125°C. The absolute maximum continuous input voltage is 80 Vdc.

Short duration transient disturbances can occur on the DC distribution and input of the product when a short circuit fault occurs on the equipment side of a protective device (fuse or circuit breaker). The voltage level, duration and energy of the disturbance are dependent on the particular DC distribution network characteristics and can be sufficient to damage the product unless measures are taken to suppress or absorb this energy. The transient voltage can be limited by capacitors and other energy absorbing devices like Zener diodes connected across the positive and negative input conductors at a number of strategic points in the distribution network. The end-user must ensure that the transient voltage will not exceed the value stated in the Absolute maximum ratings. ETSI TR 100 283 examines the parameters of DC distribution networks and provides guidelines for controlling the transient and reduce its harmful effect.

Turn-off Input Voltage
The products monitor the input voltage and will turn on and turn off at predetermined levels. The minimum hysteresis between turn on and turn off input voltage is 1.3 V.

Remote Control (RC)

The products are fitted with a remote control function referenced to the primary negative input connection (-In), with negative and positive logic options available. The RC function allows the product to be turned on/off by an external device like a semiconductor or mechanical switch.

The RC pin has an internal pull up resistor of 10 kΩ to +5 V. The external device must provide a minimum required sink current to guarantee a voltage not higher than maximum voltage on the RC pin (see Electrical characteristics table). When the RC pin is left open, the voltage generated on the RC pin is 5 V.

The standard product is provided with “negative logic” RC. To turn off the product the RC pin should be left open, or connected to a voltage higher than 4 V referenced to -In. In situations where it is desired to have the product to power up automatically without the need for control signals or a switch, the RC pin can be wired directly to -In. To turn on the product the RC pin should be lower than 1V referenced to -In.

The second option is “positive logic” remote control, which can be ordered by adding the suffix “P” to the end of the part number. When the RC pin is left open, the product starts up automatically when the input voltage is applied. Turn off is achieved by connecting the RC pin to the –In, or a voltage lower than 1 V referenced to -In. The product will restart automatically when this connection is opened.

The RC function incorporates a short delay in order to not trigger on glitches. Typically this filter has a settling time of 0.1-0.5 ms. This setup reduces the risk that the noise may cause the converter to shut down or power up accidently. See Design Note 021 for detailed information.

Input and Output Impedance
The impedance of both the input source and the load will interact with the impedance of the product. It is important that the input source has low characteristic impedance. The products are designed for stable operation with a minimum of 100 µF external capacitors connected to the input. The electrolytic capacitors will be degraded in low temperature and the ESR value may increase. The needed input capacitance in low temperature should be equivalent to 100 µF at 20°C. This means that the input capacitor value may need to be substantially larger to guarantee a stable input at low temperatures. The performance in some applications can be enhanced by addition of external capacitance as described under External Decoupling Capacitors. The minimum required capacitance value depends on the output power and the input voltage. The higher output power the higher input capacitance is needed.

External Decoupling Capacitors
When powering loads with significant dynamic current requirements, the voltage regulation at the load can be improved by addition of decoupling capacitors at the load. The most effective technique is to locate low ESR ceramic and electrolytic capacitors as close to the load as possible, using several parallel capacitors to lower the effective ESR. The ceramic capacitors will handle high-frequency dynamic load changes while the electrolytic capacitors are used to handle low frequency dynamic load changes. It is equally important to use low resistance and low inductance PWB layouts and cabling.

External decoupling capacitors will become part of the product’s control loop. The control loop is optimized for a wide range of external capacitance and the maximum and minimum recommended value that could be used without any additional analysis is found in the Electrical specification. The ESR of the capacitors is a very important parameter. Stable operation is guaranteed with a verified ESR value of >1 mΩ across the output connections.
For further information please contact your local Flex Power Modules representative.

**Parallel Operation**
This product is not designed for paralleling without using external current sharing circuits. See Design Note 006 for detailed information.

**Over Temperature Protection (OTP)**
The products are protected from thermal overload by an internal over temperature shutdown circuit. When $T_{P1}$ as defined in thermal consideration section exceeds 140°C the product will shut down. The product will make continuous attempts to start up (non-latching mode) and resume normal operation automatically when the temperature has dropped >10°C below the temperature threshold.

**Over Voltage Protection (OVP)**
The products have output over voltage protection that will shut down the product in over voltage conditions. The product will make continuous attempts to start up (non-latching mode) and resume normal operation automatically after removal of the over voltage condition. However, at certain conditions the output voltage can be limited to a lower output voltage than the OVP trip point.

**Over Current Protection (OCP)**
The products include current limiting circuitry for protection at continuous overload. The OCP works in a hiccup mode and will make continuous attempts to start up and will resume normal operation automatically after removal of the over current condition. The load distribution should be designed for the specified maximum output short circuit current.

**Pre-bias Start-up**
The product has a Pre-bias start up functionality and will not sink current during start up if a pre-bias load is present at the output terminals.

**Thermal Consideration**

**General**
The products are designed to operate in different thermal environments and sufficient cooling must be provided to ensure reliable operation.

For products mounted on a PWB without a baseplate attached, cooling is achieved mainly by conduction, from the pins to the host board, and convection, which is dependant on the airflow across the product. Increased airflow enhances the cooling of the product. The Output Current Derating graph found in the Output section for each model provides the available output current vs. ambient air temperature and air velocity at $V_{I} = 48$V.

The product is tested on a 254 x 254 mm, 35 µm (1 oz), 16-layer test board mounted vertically in a wind tunnel with a cross-section of 608 x 203 mm.

For products with baseplate used in a sealed box/cold wall application, cooling is achieved mainly by conduction through the cold wall. The Output Current Derating graphs are found in the Output section for each model. The product performance has been tested in a sealed box presented in the figure below. The ambient temperature (inside the box) has been set to 85°C. The cold wall temperature varied. See Design Note 028 for further details.
Definition of product operating temperature
The temperature at the positions (TP1, TP2) should not exceed the maximum temperatures in the table below. The number of measurement points may vary with different thermal design and topology. Temperatures above maximum measured at the reference point P1, P2 are not allowed and may cause permanent damage.

<table>
<thead>
<tr>
<th>Position</th>
<th>Description</th>
<th>Max Temp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Mosfet, Reference point</td>
<td>TP1=125° C</td>
</tr>
<tr>
<td>P2</td>
<td>Controller</td>
<td>TP2=125° C</td>
</tr>
</tbody>
</table>

Ambient Temperature Calculation
For products with base plate the maximum allowed ambient temperature can be calculated by using the thermal resistance.

1. The power loss is calculated by using the formula
   \[
   ((1/\eta) - 1) \times \text{output power} = \text{power losses (Pd)}.
   \]
   \[\eta = \text{efficiency of product. E.g. 92% = 0.92}\]

2. Find the thermal resistance (Rth) in the Thermal Resistance graph found in the Output section for each model. Note that the thermal resistance can be significantly reduced if a heat sink is mounted on the top of the base plate.

Calculate the temperature increase (ΔT).
\[\Delta T = \text{Rth} \times \text{Pd}\]

3. Max allowed ambient temperature is:
\[\text{Max } T_{P1} - \Delta T.\]

E.g. PKB5213D at 1m/s:
1. \[((1/0.92) - 1) \times 240 \text{ W} = 20.8 \text{ W}\]
2. \[20.8 \text{ W} \times 5^\circ\text{C/W} = 90^\circ\text{C}\]
3. \[125^\circ\text{C} - 90^\circ\text{C} = \text{max ambient temperature is 35^\circC}\]

The actual temperature will be dependent on several factors such as the PWB size, number of layers and direction of airflow.
PKB5000D series Fully Regulated DC-DC Converters
Input 18-60 V, Output up to 20 A / 240 W

Connections

<table>
<thead>
<tr>
<th>Pin</th>
<th>Designation</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+In</td>
<td>Positive Input</td>
</tr>
<tr>
<td>2</td>
<td>RC</td>
<td>Remote Control</td>
</tr>
<tr>
<td>3</td>
<td>-In</td>
<td>Negative Input</td>
</tr>
<tr>
<td>4</td>
<td>-Out</td>
<td>Negative Output</td>
</tr>
<tr>
<td>8</td>
<td>+Out</td>
<td>Positive Output</td>
</tr>
</tbody>
</table>
 Mechanical Information - Hole Mount, Open Frame Version

Pin positions according to recommended footprint

Recommended footprint - Top View

Recommended keep away area for user components

All component placements – whether shown as physical components or symbolical outline – are for reference only and are subject to change throughout the product’s life cycle, unless explicitly described and dimensioned in this drawing.
Mechanical Information - Hole Mount, Base Plate Version

All component placements – whether shown as physical components or symbolical outline – are for reference only and are subject to change throughout the product's life cycle, unless explicitly described and dimensioned in this drawing.
Soldering Information - Hole Mounting

The hole mounted product is intended for plated through hole mounting by wave or manual soldering. The pin temperature is specified to maximum to 270°C for maximum 10 seconds.

A maximum preheat rate of 4°C/s and maximum preheat temperature of 150°C is suggested. When soldering by hand, care should be taken to avoid direct contact between the hot soldering iron tip and the pins for more than a few seconds in order to prevent overheating.

A no-clean flux is recommended to avoid entrapment of cleaning fluids in cavities inside the product or between the product and the host board. The cleaning residues may affect long time reliability and isolation voltage.

Delivery Package Information
The products are delivered in antistatic injection molded trays (Jedec design guide 4.10D standard) and in antistatic trays.

<table>
<thead>
<tr>
<th>Tray Specifications – Through hole version</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>PE Foam, dissipative</td>
</tr>
<tr>
<td>Surface resistance</td>
<td>$10^6 &lt; \text{Ohm/square} &lt; 10^{12}$</td>
</tr>
<tr>
<td>Bakability</td>
<td>The trays are not bakable</td>
</tr>
<tr>
<td>Tray thickness</td>
<td>22 mm (0.866 inch)</td>
</tr>
</tbody>
</table>
| Box capacity    | 100 products (4 full trays/box) Open frame  
                         25 products (1 full tray/box) Base plate |
| Tray weight     | Product – Open frame  
                         654 g full tray, 54 g empty tray  
                         Product – Base plate option  
                         1000 g full tray, 54 g empty tray |
## Product Qualification Specification

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>External visual inspection</td>
<td>IPC-A-610</td>
</tr>
<tr>
<td>Change of temperature (Temperature cycling)</td>
<td>IEC 60068-2-14 Na, Temperature range -40 to 100°C, Number of cycles 1000, Dwell/transfer time 15 min/0-1 min</td>
</tr>
<tr>
<td>Cold (in operation)</td>
<td>IEC 60068-2-1 Ad, Temperature T_A, Duration -45°C, 72 h</td>
</tr>
<tr>
<td>Damp heat</td>
<td>IEC 60068-2-67 Cy, Temperature Humidity, Duration 85°C, 85 % RH, 1000 hours</td>
</tr>
<tr>
<td>Dry heat</td>
<td>IEC 60068-2-2 Bd, Temperature Duration -125°C, 1000 h</td>
</tr>
<tr>
<td>Electrostatic discharge susceptibility</td>
<td>IEC 61340-3-1, JESD 22-A114, Human body model (HBM), Class 2, 2000 V, Machine Model (MM), Class 3, 200 V</td>
</tr>
<tr>
<td>Immersion in cleaning solvents</td>
<td>IEC 60068-2-45 XA, method 2, Water, 55°C, Glycol ether, 35°C, Isopropyl alcohol, 35°C</td>
</tr>
<tr>
<td>Mechanical shock</td>
<td>IEC 60068-2-27 Ea, Peak acceleration, 100 g, 6 ms</td>
</tr>
<tr>
<td>Operational life test</td>
<td>MIL-STD-202G, method 108A, Duration 1000 h</td>
</tr>
<tr>
<td>Resistance to soldering heat</td>
<td>IEC 60068-2-20 Tb, method 1A, Solder temperature 270°C, Duration 10-13 s</td>
</tr>
<tr>
<td>Robustness of terminations</td>
<td>IEC 60068-2-21 Test Ua1, Through hole mount products, All leads</td>
</tr>
<tr>
<td></td>
<td>IEC 60068-2-21 Test Ue1, Surface mount products, All leads</td>
</tr>
<tr>
<td>Solderability</td>
<td>IEC 60068-2-20 test Ta, Preconditioning, Temperature, SnPb Eutectic, 235°C, Temperature, Pb-free, 245°C</td>
</tr>
<tr>
<td>Vibration, broad band random</td>
<td>IEC 60068-2-64 Fh, method 1, Frequency 10 to 500 Hz, Spectral density 0.07 g/Hz, Duration 10 min in each direction</td>
</tr>
</tbody>
</table>