TPD4E004 4-Channel ESD-Protection Array For High-Speed Data Interfaces

1 Features
- IEC 61000-4-2 ESD protection:
  - ±8-kV IEC 61000-4-2 Contact Discharge
  - ±12-kV IEC 61000-4-2 Air-Gap Discharge
- ANSI/ESDA/JEDEC JS-001:
  - ±15-kV Human Body Model (HBM)
- Low 1.6-pF input capacitance
- 0.9-V to 5.5-V supply voltage range
- 4-channel device
- Space-saving SON (DRY) package

2 Applications
- USB
- Ethernet
- FireWire™
- Videos
- Cell phones
- SVGA video connections
- Glucose meters

3 Description
The TPD4E004 is a low-capacitance transient voltage suppression (TVS) device. TPD4E004 is designed to protect sensitive electronics attached to communication lines from electrostatic discharge (ESD). Each of the four channels consists of a pair of diodes that steer ESD current pulses to VCC or GND. The TPD4E004 protects against ESD pulses up to ±15-kV Human-Body Model (HBM) and, as specified in IEC 61000-4-2, ±8-kV contact discharge and ±12-kV air-gap Discharge. This device has 1.6-pF of capacitance per channel, making it ideal for use in high-speed data IO interfaces.

The TPD4E004 is a quad-ESD structure designed for USB, Ethernet™, and other high-speed applications.

Package Information

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PACKAGE(1)</th>
<th>PACKAGE SIZE(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPD4E004</td>
<td>DRY (SON, 6)</td>
<td>1.45 mm × 1 mm</td>
</tr>
</tbody>
</table>

(1) For all available packages, see the orderable addendum at the end of the data sheet.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.

Application Schematic
Table of Contents

1 Features ................................................................. 1
2 Applications ......................................................... 1
3 Description .......................................................... 1
4 Revision History ..................................................... 2
5 Pin Configuration and Functions ......................... 3
6 Specifications ......................................................... 4
   6.1 Absolute Maximum Ratings ......................... 4
   6.2 ESD Ratings .................................................. 4
   6.3 Recommended Operating Conditions ............. 4
   6.4 Thermal Information ..................................... 4
   6.5 Electrical Characteristics .............................. 5
   6.6 Typical Characteristics .................................. 6
7 Detailed Description ............................................... 7
   7.1 Overview ...................................................... 7
   7.2 Functional Block Diagram .............................. 7
   7.3 Feature Description ....................................... 7
   7.4 Device Functional Modes ............................... 7

8 Application and Implementation ....................... 8
   8.1 Application Information ................................. 8
   8.2 Typical Application ..................................... 8
9 Power Supply Recommendations ....................... 9
10 Layout .............................................................. 10
11 Device and Documentation Support ................. 11
   11.1 Documentation Support ............................... 11
   11.2 Receiving Notification of Documentation Updates .. 11
   11.3 Support Resources .................................... 11
   11.4 Trademarks ............................................... 11
   11.5 Electrostatic Discharge Caution .................. 11
   11.6 Glossary .................................................. 11
12 Mechanical, Packaging, and Orderable Information 11

4 Revision History
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision B (March 2016) to Revision C (July 2023) Page
• Updated the Package Information table to include package size ............................................ 1
• Updated the numbering format for tables, figures, and cross-references throughout the document .......................................................... 1
• Updated the Overview section to include IEC 61000-4-2 international standard Level 3 ............... 7

Changes from Revision A (February 2008) to Revision B (March 2016) Page
• Added Device Information table, ESD Ratings table, Feature Description section, Device Functional Modes, Application and Implementation section, Power Supply Recommendations section, Layout section, Device and Documentation Support section, and Mechanical, Packaging, and Orderable Information section. ........ 1
• Deleted the ordering information ................................................................................................................. 1

Submit Document Feedback
5 Pin Configuration and Functions

<table>
<thead>
<tr>
<th>NAME</th>
<th>NO.</th>
<th>TYPE(1)</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>IO1</td>
<td>1</td>
<td>IO</td>
<td>ESD-protected channel</td>
</tr>
<tr>
<td>IO2</td>
<td>2</td>
<td>IO</td>
<td>ESD-protected channel</td>
</tr>
<tr>
<td>GND</td>
<td>3</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>IO3</td>
<td>4</td>
<td>IO</td>
<td>ESD-protected channel</td>
</tr>
<tr>
<td>IO4</td>
<td>5</td>
<td>IO</td>
<td>ESD-protected channel</td>
</tr>
<tr>
<td>VCC</td>
<td>6</td>
<td>PWR</td>
<td>Power-supply input</td>
</tr>
</tbody>
</table>

(1) I = input, O = outputs, GND = ground, PWR = power
6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) (1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{CC}$ Supply voltage</td>
<td>–0.3</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>$V_{IO}$ Input/output voltage</td>
<td>–0.3</td>
<td>$V_{CC} + 0.3$</td>
<td>V</td>
</tr>
<tr>
<td>Bump temperature (soldering)</td>
<td>220</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>Infrared (15 s)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vapor phase (60 s)</td>
<td>215</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead temperature (soldering, 10 s)</td>
<td>300</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>$T_J$ Junction temperature</td>
<td>150</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>$T_{STG}$ Storage temperature</td>
<td>–65</td>
<td>150</td>
<td>°C</td>
</tr>
</tbody>
</table>

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.2 ESD Ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>VALUE</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{(ESD)}$ Electrostatic discharge</td>
<td>Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001</td>
<td>±15000</td>
</tr>
<tr>
<td></td>
<td>IEC 61000-4-2</td>
<td>Contact Discharge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Air-Gap Discharge</td>
</tr>
</tbody>
</table>

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_A$ Operating free-air temperature</td>
<td>–40</td>
<td>85</td>
<td>°C</td>
</tr>
<tr>
<td>$V_{CC}$ Operating voltage for pin $V_{CC}$</td>
<td>0.9</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>$V_{IO}$ Operating voltage for pins IO1, IO2, IO3, and IO4</td>
<td>0</td>
<td>Minimum of: (5.8, $V_{CC}$)</td>
<td>V</td>
</tr>
</tbody>
</table>

6.4 Thermal Information

<table>
<thead>
<tr>
<th>THERMAL METRIC(1)</th>
<th>TPD4E004</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DRY (SON)</td>
</tr>
<tr>
<td>$R_{JA}$ Junction-to-ambient thermal resistance</td>
<td>414.8</td>
</tr>
<tr>
<td>$R_{JC(top)}$ Junction-to-case (top) thermal resistance</td>
<td>258.6</td>
</tr>
<tr>
<td>$R_{JB}$ Junction-to-board thermal resistance</td>
<td>251.6</td>
</tr>
<tr>
<td>$\Psi_{JT}$ Junction-to-top characterization parameter</td>
<td>70.6</td>
</tr>
<tr>
<td>$\Psi_{JB}$ Junction-to-board characterization parameter</td>
<td>248.2</td>
</tr>
<tr>
<td>$R_{JC(bot)}$ Junction-to-case (bottom) thermal resistance</td>
<td>n/a</td>
</tr>
</tbody>
</table>

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report, SPRA953.
## 6.5 Electrical Characteristics

$V_{CC} = 0.9 \text{ V to } 5.5 \text{ V, } T_A = T_{MIN} \text{ to } T_{MAX}$ (unless otherwise noted)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP$^{(1)}$</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{CC}$</td>
<td>Supply voltage</td>
<td>0.9</td>
<td>5.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$I_{CC}$</td>
<td>Supply current</td>
<td></td>
<td>500</td>
<td>nA</td>
<td></td>
</tr>
<tr>
<td>$V_F$</td>
<td>Diode forward voltage $I_F = 1 \text{ mA}$</td>
<td></td>
<td>0.8</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$I_I$</td>
<td>Channel leakage current</td>
<td>±1</td>
<td></td>
<td>nA</td>
<td></td>
</tr>
<tr>
<td>$V_{BR}$</td>
<td>Break-down voltage $I_I = 10 \mu \text{A}$</td>
<td></td>
<td>6</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$C_{I/O}$</td>
<td>Channel input capacitance $V_{CC} = 5 \text{ V, Bias of } V_{CC}/2, f = 10 \text{ MHz}$</td>
<td></td>
<td>1.6</td>
<td>2</td>
<td>pF</td>
</tr>
</tbody>
</table>

$^{(1)}$ Typical values are at $V_{CC} = 5 \text{ V and } T_A = 25^\circ \text{C}$. 
6.6 Typical Characteristics

Figure 6-1. Forward Diode Voltage (Upper Clamp Diode) \((V_{CC} = 0\, V,\, DC\, Sweep\, Across\, the\, IO\, Pin)\)

Figure 6-2. Leakage Current vs Temperature \((V_{IO} = 2.5\, V)\)

Figure 6-3. Reverse Diode Curve Current IO to GND \((V_{CC} =\, Open)\)

Figure 6-4. IO Capacitance vs Input Voltage \((V_{CC} = 5\, V)\)
7 Detailed Description

7.1 Overview

The TPD4E004 is a four-channel TVS protection diode array. The TPD4E004 is rated to dissipate contact ESD strikes of ±8-kV contact and ±12-kV air-gap, meeting Level 3 as specified in the IEC 61000-4-2 international standard. This device has a 1.6-pF IO capacitance per channel, making it ideal for use in high-speed data IO interfaces.

7.2 Functional Block Diagram

7.3 Feature Description

TPD4E004 is a TVS which provides ESD protection for up to four channels, withstanding up to ±8-kV contact and ±12-kV air-gap ESD per IEC 61000-4-2. The monolithic technology yields exceptionally small variations in capacitance between any IO pin of TPD4E004. The small footprint is ideal for applications where space-saving designs are important.

7.4 Device Functional Modes

The TPD4E004 device is a passive integrated circuit that triggers when voltages are above $V_{BR}$ or below the diodes $V_F$ of approximately −0.3 V. During ESD events, voltages as high as ±8-kV contact and ±12-kV air-gap ESD can be directed to ground through the internal diodes. Once the voltages on the protected line fall below the trigger levels of TPD4E004 (usually within 10’s of nano-seconds) the device reverts back to its high-impedance state.
8 Application and Implementation

Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI’s customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

8.1 Application Information

TPD4E004 is a diode array type TVS which is typically used to provide a path to ground for dissipating ESD events on hi-speed signal lines between a human interface connector and a system. As the current from ESD passes through the TVS, only a small voltage drop is present across the diode. This is the voltage presented to the protected IC. The low \( R_{\text{DYN}} \) of the triggered TVS holds this voltage, \( V_{\text{CLAMP}} \), to a tolerable level for the protected IC.

8.2 Typical Application

![Application Schematic](image)

Figure 8-1. Application Schematic

8.2.1 Design Requirements

For this design example, a single TPD4E004 is used to protect all the pins of two USB2.0 connectors. Table 8-1 lists the design parameters for the USB application.

<table>
<thead>
<tr>
<th>DESIGN PARAMETER</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal range on IO1, IO2, IO3, and IO4</td>
<td>0 V to 3.6 V</td>
</tr>
<tr>
<td>Signal voltage range on ( V_{\text{CC}} )</td>
<td>0 V to 5.5 V</td>
</tr>
<tr>
<td>Operating Frequency</td>
<td>240 MHz</td>
</tr>
</tbody>
</table>

8.2.2 Detailed Design Procedure

When placed near the USB connectors, the TPD4E004 ESD solution offers little or no signal distortion during normal operation due to low IO capacitance and ultra-low leakage current specifications. The TPD4E004 is designed so that the core circuitry is protected and the system is functioning properly in the event of an ESD strike. For proper operation, see the following layout and design guidelines should be followed:
1. Place the TPD4E004 solution close to the connectors. This allows the TPD4E004 to take away the energy associated with ESD strike before it reaches the internal circuitry of the system board.

2. Place a 0.1-μF capacitor very close to the V<sub>CC</sub> pin. This limits any momentary voltage surge at the IO pin during the ESD strike event.

3. Ensure that there is enough metallization for the V<sub>CC</sub> and GND loop. During normal operation, the TPD4E004 consumes nA leakage current. But during the ESD event, V<sub>CC</sub> and GND may see 15-A to 30-A of current, depending on the ESD level. Sufficient current path enables safe discharge of all the energy associated with the ESD strike.

4. Leave the unused IO pins floating. In this example of protecting two USB ports, none of the IO pins will be left unused.

5. The V<sub>CC</sub> pin can be connected in two different ways:
   a. If the V<sub>CC</sub> pin is connected to the system power supply, the TPD4E004 works as a transient suppressor for any signal swing above V<sub>CC</sub> + V<sub>F</sub>. A 0.1-μF capacitor on the device V<sub>CC</sub> pin is recommended for ESD bypass.
   b. If the V<sub>CC</sub> pin is not connected to the system power supply, the TPD4E004 can tolerate higher signal swing in the range up to 5.8 V. Please note that a 0.1-μF capacitor is still recommended at the V<sub>CC</sub> pin for ESD bypass.

8.2.3 Application Curves

Figure 8-2 is a capture of the voltage clamping waveform of TPD4E004 during an +8-kV Contact IEC 61000-4-2 ESD strike.

![Figure 8-2. IEC ESD Clamping Waveforms +8-kV Contact](image)

9 Power Supply Recommendations

This device is a passive ESD protection device so there is no need to power it. Make sure that the maximum voltage specifications for each pin are not violated.
10 Layout

10.1 Layout Guidelines

- The optimum placement is as close to the connector as possible.
  - EMI during an ESD event can couple from the trace being struck to other nearby unprotected traces, resulting in early system failures.
  - The PCB designer needs to minimize the possibility of EMI coupling by keeping any unprotected traces away from the protected traces which are between the TVS and the connector.
- Route the protected traces as straight as possible.
- Eliminate any sharp corners on the protected traces between the TVS and the connector by using rounded corners with the largest radii possible.
  - Electric fields tend to build up on corners, increasing EMI coupling.

10.2 Layout Example

![Figure 10-1. TPD4E004 Layout Example](image-url)
11 Device and Documentation Support

11.1 Documentation Support

11.1.1 Related Documentation

For related documentation see the following:

- Texas Instruments, *Reading and Understanding an ESD Protection Data Sheet*
- Texas Instruments, *ESD Protection Layout Guide*

11.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](http://ti.com). Click on *Subscribe to updates* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.3 Support Resources

**TI E2E™ support forums** are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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11.4 Trademarks

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Ethernet™ is a trademark of Xerox Corporation.

TI E2E™ is a trademark of Texas Instruments.

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11.5 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

11.6 Glossary

**TI Glossary** This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.
<table>
<thead>
<tr>
<th>Orderable Device</th>
<th>Status (1)</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>Package Qty</th>
<th>Eco Plan (2)</th>
<th>Lead finish/ Ball material (3)</th>
<th>MSL Peak Temp (3)</th>
<th>Op Temp (°C)</th>
<th>Device Marking (4/5)</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPD4E004DRYR</td>
<td>ACTIVE</td>
<td>SON</td>
<td>DRY</td>
<td>6</td>
<td>5000</td>
<td>RoHS &amp; Green</td>
<td>NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 85</td>
<td>2P</td>
<td>Samples</td>
</tr>
<tr>
<td>TPD4E004DRYRG4</td>
<td>ACTIVE</td>
<td>SON</td>
<td>DRY</td>
<td>6</td>
<td>5000</td>
<td>RoHS &amp; Green</td>
<td>NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 85</td>
<td>2P</td>
<td>Samples</td>
</tr>
</tbody>
</table>

(1) The marketing status values are defined as follows:
- **ACTIVE**: Product device recommended for new designs.
- **LIFEBUY**: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
- **NRND**: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
- **PREVIEW**: Device has been announced but is not in production. Samples may or may not be available.
- **OBSOLETE**: TI has discontinued the production of the device.

(2) **RoHS**: TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
- **RoHS Exempt**: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
- **Green**: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) **MSL, Peak Temp.**: The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) **Lead finish/Ball material**: Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.
**TAPE AND REEL INFORMATION**

**REEL DIMENSIONS**
- Reel Diameter
- Reel Width (W1)

**TAPE DIMENSIONS**
- A0: Dimension designed to accommodate the component width
- B0: Dimension designed to accommodate the component length
- K0: Dimension designed to accommodate the component thickness
- W: Overall width of the carrier tape
- P1: Pitch between successive cavity centers

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**
- Pocket Quadrants
- User Direction of Feed
- Sprocket Holes

*All dimensions are nominal*

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Reel Diameter (mm)</th>
<th>Reel Width W1 (mm)</th>
<th>A0 (mm)</th>
<th>B0 (mm)</th>
<th>K0 (mm)</th>
<th>P1 (mm)</th>
<th>W (mm)</th>
<th>Pin1 Quadrant</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPD4E004DRYR</td>
<td>SON</td>
<td>DRY</td>
<td>6</td>
<td>5000</td>
<td>180.0</td>
<td>9.5</td>
<td>1.2</td>
<td>1.65</td>
<td>0.7</td>
<td>4.0</td>
<td>8.0</td>
<td>Q1</td>
</tr>
</tbody>
</table>
TAPE AND REEL BOX DIMENSIONS

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPD4E004DRYR</td>
<td>SON</td>
<td>DRY</td>
<td>6</td>
<td>5000</td>
<td>189.0</td>
<td>185.0</td>
<td>36.0</td>
</tr>
</tbody>
</table>

*All dimensions are nominal*
NOTES:
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
NOTES: (continued)

3. For more information, see QFN/SON PCB application report in literature No. SLUA271 (www.ti.com/lit/slua271).
NOTES: (continued)

4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
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