The TPS22965NEVM evaluation module allows the user to connect power to and control a single channel, 5.7 V, 16-mΩ ON-resistance, 6-A load switch with an adjustable rise time.

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1 Description

The TPS22965N device is a 5.7 V, 16-mΩ ON-resistance ($R_{ON}$), single-channel load switch with an adjustable rise time. The device contains an N-channel MOSFET that can operate over an input voltage range of 0.8 V to 5.7 V and can support a maximum continuous current of up to 6 A. The switch is controlled by an active high on and off input (ON), which is capable of interfacing directly with low-voltage GPIO control signals. The rise time of the device is internally controlled in order to avoid inrush current and can be adjusted using an external ceramic capacitor on the CT pin.

The TPS22965N device is available in a small, space-saving 2-mm × 2-mm 8-pin SON package with integrated thermal pad allowing for high-power dissipation.

Figure 1. 3D Rendering of the TPS22965NEVM
1.1 **Typical Applications**
- Ultrabook™
- Notebooks and Netbooks
- Tablet PC
- Consumer Electronics
- Set-Top Boxes and Residential Gateways
- Telecom Systems
- Solid State Drives (SSD)

1.2 **Features**
- VIN input voltage range: 0.8 V to 5.7 V
- VBIAS input voltage range: 2.5 V to 5.7 V
- High current connection terminals available for 6 A maximum continuous switch current operation
- External capacitor for adjustable rise time control
- Test point connections to VIN, VOUT, VBIAS, and ON pins
- SENSE connections for accurate measurement of VIN and VOUT voltages used for voltage drop and ON-resistance calculations
- SON 8-pin package with thermal pad

2 **Electrical Performance Specifications**
Refer to the datasheet [SLVSBJ0](#) for detailed electrical characteristics of the TPS22965N.

3 **Schematic**

![Figure 2. TPS22965NEVM Schematic](#)
4 EVM Connections

This section describes the connectors, jumpers, and test points on the EVM.

4.1 J1 – VIN Power Connections

This is the high current input connection from the power supply. Connect the positive lead of the power supply to either terminal.

4.2 J2 – VOUT Power Connection

This is the high current output connection for loading the EVM. Connect the positive lead of the load to either terminal.

4.3 JP1 – VBIAS Power

This jumper connects VBIAS to the VIN voltage source. VBIAS must be maintained between 2.5 V – 5.7 V for proper operation on the TPS22965N device. If testing conditions involve taking the VIN voltage below 2.5 V, remove the shunt across JP1 and connect VBIAS voltage at TP4.

4.4 JP2 – ON Control

This three pin jumper connects the ON pin to either VIN or GND, which allows for quickly enabling/disabling the device after power is present.

4.5 TP2 – ON

This test point is used to monitor the EN pin voltage. This test point can also be used to drive the ON pin independently when JP2 is removed.

4.6 TP3 – VIN Sense

This test point provides a low current path to the input pins of the device for accurate voltage measurements. This sense connection should be used when measuring the voltage drop from VIN to VOUT which is used to calculate the ON-resistance. In cases where there is a large load current, it is recommended configure the power supply to use sense connections. Connect the positive sense lead to the VIN sense point to overcome voltage drop in cabling.

4.7 TP5 – VOUT Sense

This test point provides a low current path to the output pins of the device for accurate voltage measurements. This sense connection should be used when measuring the voltage drop from VIN to VOUT which is used to calculate the ON resistance.

4.8 TP7/TP8/TP9/TP10 – GND

These are the GND connection points to the EVM.
# Table 1. Test Point Functions

<table>
<thead>
<tr>
<th>Test Points</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>J1</td>
<td>VIN</td>
<td>DC Input to VIN</td>
</tr>
<tr>
<td>J2</td>
<td>VOUT</td>
<td>VOUT connection</td>
</tr>
<tr>
<td>JP1</td>
<td>VBIAS</td>
<td>Connects VBIAS to VIN</td>
</tr>
<tr>
<td>JP2</td>
<td>ON</td>
<td>Connects ON to VIN or AGND</td>
</tr>
<tr>
<td>JP3</td>
<td>C1</td>
<td>Connects C1 to VIN</td>
</tr>
<tr>
<td>JP4</td>
<td>C5</td>
<td>Connects C5 to VOUT</td>
</tr>
<tr>
<td>JP5</td>
<td>R1</td>
<td>Connects R1 to VOUT</td>
</tr>
<tr>
<td>JP6</td>
<td>R2</td>
<td>Connects R2 to VOUT</td>
</tr>
<tr>
<td>TP1</td>
<td>VIN</td>
<td>VIN of TPS22965N</td>
</tr>
<tr>
<td>TP2</td>
<td>ON</td>
<td>ON of TPS22965N</td>
</tr>
<tr>
<td>TP3</td>
<td>VIN Sense</td>
<td>Sense connect to VIN of TPS22965N</td>
</tr>
<tr>
<td>TP4</td>
<td>VBIAS</td>
<td>VBIAS of TPS22965N</td>
</tr>
<tr>
<td>TP5</td>
<td>VOUT Sense</td>
<td>Sense connect to VOUT of TPS22965N</td>
</tr>
<tr>
<td>TP6</td>
<td>VOUT</td>
<td>VOUT of TPS22965N</td>
</tr>
<tr>
<td>TP7</td>
<td>GND</td>
<td>Ground connection</td>
</tr>
<tr>
<td>TP8</td>
<td>GND</td>
<td>Ground connection</td>
</tr>
<tr>
<td>TP9</td>
<td>GND</td>
<td>Ground connection</td>
</tr>
<tr>
<td>TP10</td>
<td>GND</td>
<td>Ground connection</td>
</tr>
</tbody>
</table>
5 Test Setup

This section will describe how to take key parameter measurements on the EVM.

5.1 $R_{\text{ON}}$ Test Procedure

1. Setup the EVM as shown in Figure 3.
2. Set SOURCE1 level to 5.0V.
3. Place a shunt on JP2 shorting pins 1 to 2. This connects ON to VIN voltage. ON voltage must be between 1.1 V and 5.5 V for a valid ON state.
   (When testing $R_{\text{ON}}$, keep the switch operating in the always ON condition.)
4. Place a load on VOUT.
5. Turn on SOURCE1.
6. Record the voltage reading from METER1. Record the input current reading from SOURCE1.
   Calculate $R_{\text{ON}}$ by dividing METER1 voltage level by the current reading from SOURCE1. The result will be the $R_{\text{ON}}$ value for the switch.
7. Turn off SOURCE1.

![Figure 3. TPS22965EVM-023 Recommended $R_{\text{ON}}$ Test Setup](image)
5.2 **AC Parameter Test Procedure \((t_R, t_{ON}, t_F, t_{OFF}, t_D)\)**

1. A detailed description of \(t_R, t_{ON}, t_F, t_{OFF}, \) and \(t_D\) are listed in the TPS22965N Datasheet (SLVSBJ0) under the Switching Characteristics Section.

2. The rise time \((t_R)\) is selected by the CT capacitor value on each switch channel. The EVM is shipped with a default CT value of 1 nF.

3. Set up the EVM as shown in Figure 4.

4. Set SOURCE1 level to 5.0 V.

5. Remove the shunt from JP2.

6. Place a load on VOUT. (A 10-Ω, 3.25-W resistor is recommended for this test).

7. Set the signal generator output to 0 to 2 Vpp levels, 10 to 100 Hz, and 25% duty cycle. Connect signal generator output to TP2.

8. Turn on SOURCE1.

9. Turn ON the signal generator output.

10. Rise time \((t_R)\), turn-on time \((t_{ON})\), and delay time \((t_D)\) can be observed with an Oscilloscope sync the scope trigger on the rising edge of the ON signal.

11. Fall time \((t_F)\) and turn-off time \((t_{OFF})\) can be observed from the oscilloscope by charging the scope triggering to sync with the falling edge of the ON signal.

12. Turn off SOURCE1 and disable the signal generator output.

---

**Figure 4. TPS22965NEVM Recommended AC Parameter Test Setup**
6  Board Assembly and Layout

Figure 5. TPS22965NEVM Top Assembly

Figure 6. TPS22965NEVM PCB (Top)
Figure 7. TPS22965NEVM PCB (Bottom)
Below is the EVM components list according to the schematic shown in Figure 2.

### Table 2. EVM Component List

<table>
<thead>
<tr>
<th>Count</th>
<th>RefDes</th>
<th>Value</th>
<th>Description</th>
<th>Size</th>
<th>Part Number</th>
<th>MFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>C1, C5</td>
<td>DNP</td>
<td>Capacitor, ceramic, 25 V, X7R, 20%</td>
<td>0603</td>
<td>C1608X5R1C1 05K</td>
<td>Std</td>
</tr>
<tr>
<td>1</td>
<td>C2</td>
<td>1 µF</td>
<td>Capacitor, ceramic, 16 V, X7R, 20%</td>
<td>0603</td>
<td>C1608X5R1C1 05K</td>
<td>Std</td>
</tr>
<tr>
<td>1</td>
<td>C3</td>
<td>1 µF</td>
<td>Capacitor, ceramic, 25 V, X7R, 20%</td>
<td>0603</td>
<td>C0603C102K5 RACTU</td>
<td>Std</td>
</tr>
<tr>
<td>1</td>
<td>C4</td>
<td>0.1 µF</td>
<td>Capacitor, ceramic, 25 V, X7R, 20%</td>
<td>0603</td>
<td>C1608X7R1E1 04K</td>
<td>Std</td>
</tr>
<tr>
<td>2</td>
<td>C6, C7</td>
<td>0.01 µF</td>
<td>Capacitor, ceramic, 16 V, X7R, 20%</td>
<td>0603</td>
<td>C0603C103J5R ACTU</td>
<td>Std</td>
</tr>
<tr>
<td>5</td>
<td>J1, J2</td>
<td>ED120 / 2DS</td>
<td>Terminal block, 2-pin, 15 A, 5.1 mm</td>
<td>0.40 x 0.35 in</td>
<td>ED120/2DS OST</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>JP2</td>
<td>TSW-103-07-G-S</td>
<td>Header, male 3-pin, 100 mil spacing</td>
<td>0.100 in x 3</td>
<td>TSW-103-07-G-S Sullins</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>R1, R2</td>
<td>DNP</td>
<td>Resistor, chip, 1 / 16 W, x%</td>
<td>0805</td>
<td>Std</td>
<td>Std</td>
</tr>
<tr>
<td>5</td>
<td>TP1, TP2, TP3, TP5, TP4, TP6</td>
<td>5005</td>
<td>Test point, red, thru-hole compact style</td>
<td>0.125 x 0.125 in</td>
<td>5005 Keystone</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>TP10, TP11, TP12, TP13</td>
<td>5001</td>
<td>Test point, black, thru-hole compact style</td>
<td>0.125 x 0.125 in</td>
<td>5001 Keystone</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>U1</td>
<td>TPS22965NDS G</td>
<td>IC, 6-A load switch with controlled turn-on</td>
<td>SON-8</td>
<td>TPS22965NDS G TI</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>—</td>
<td>Shunt, black</td>
<td>100 mil</td>
<td>929950-00</td>
<td>3M</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>—</td>
<td>PCB, 2 in x 1.5 in x 0.062 in</td>
<td>HVL023</td>
<td>Any</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. These assemblies are ESD sensitive. Observe ESD precautions.
2. These assemblies must be clean and free from flux and all contaminants. Do not use no clean flux.
3. These assemblies must comply with workmanship standards IPC-A-610 Class 2.
4. Ref designators marked with an asterisk (**) cannot be substituted. All other components can be substituted with equivalent MFR components.
STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

1. **Delivery:** TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.

1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms and conditions that accompany such Software.

1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 **Limited Warranty and Related Remedies/Disclaimers:**

2.1 These terms and conditions do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

2.2 TI warrants that the TI EVM will conform to TI’s published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for any defects that are caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI. Moreover, TI shall not be liable for any defects that result from User’s design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.

2.3 If any EVM fails to conform to the warranty set forth above, TI’s sole liability shall be at its option to repair or replace such EVM, or credit User’s account for such EVM. TI’s liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

3 **Regulatory Notices:**

3.1 **United States**

3.1.1 Notice applicable to EVMs not FCC-Approved:

This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 For EVMs annotated as FCC — FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:

**CAUTION**

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. Changes or modifications not expressly approved by the party responsible for compliance could void the user’s authority to operate the equipment.

**FCC Interference Statement for Class A EVM devices**

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.
FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

3.2 Canada

3.2.1 For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

3.3 Japan

3.3.1 Notice for EVMs delivered in Japan: Please see http://www.tij.co.jp/lads/td/ia/general/eStore/notice_01.page

日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lads/td/ia/general/eStore/notice_01.page

3.3.2 Notice for Users of EVMs Considered “Radio Frequency Products” in Japan: EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry’s Rule for Enforcement of Radio Law of Japan.

2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or

3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.
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開発キットの中には技術基準適合証明を受けていないものがあります。技術基準適合証明を受けていないものご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。日本テキサス・インスツルメンツ株式会社
東京都新宿区西新宿6丁目24番1号
西新宿三菱ビル

3.3.3 Notice for EVMs for Power Line Communication: Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。

http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

4 EVM Use Restrictions and Warnings:
4.1 EVMs ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.
4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.
4.3 Safety-Related Warnings and Restrictions:
4.3.1 User shall operate the EVM within TI’s recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.
4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User’s handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

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