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1 Introduction
The LM5161PWPFBKEVM evaluation module helps designers evaluate the operation and performance of the LM5161 in the Fly-Buck (isolated buck) configuration. The Fly-Buck topology is derived from the synchronous buck topology by replacing the buck inductor with a transformer (coupled inductor) to produce both primary (non-isolated) and secondary (isolated) outputs. This user's guide highlights the specifications, setup instructions, complete application schematic, bill of materials (BOM), and typical performance curves. The LM5161 device name is used generically throughout this document and represents both the LM5161 and the LM5161-Q1, unless stated otherwise.

2 EVM Description and Performance Specifications
The LM5161PWPFBKEVM is designed to operate from a 48 V nominal bus with the input voltage varying from 36 V to 72 V. It is capable of supplying 12 V at the secondary isolated side with the load rated up to 800 mA. The nominal switching frequency is set at 300 kHz. The EVM is designed to demonstrate a small Fly-Buck solution size with the HTSSOP-14 package (LM5161) for a 10-W isolated bias power supply applications.

<table>
<thead>
<tr>
<th>INPUT</th>
<th>FREQUENCY</th>
<th>V&lt;sub&gt;out&lt;/sub&gt;</th>
<th>V&lt;sub&gt;outiso&lt;/sub&gt;</th>
<th>I&lt;sub&gt;outiso&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIN = 36 V–72 V</td>
<td>300 kHz</td>
<td>12.7 V</td>
<td>12 V</td>
<td>0–800 mA</td>
</tr>
</tbody>
</table>

3 Test Setup and Operation
This section describes the connectors and test-points on the EVM as well as how to correctly connect, setup and use the LM5161PWPFBKEVM with the LM5161 IC for isolated bias power supply applications.

3.1 Recommended Test Setup

3.1.1 Input/Output Connector Description
J1 – Output is the Isolated output voltage terminal of the EVM. The terminal block 12VISO (+) with the isolated ground (-) allows the user to attach the EVM to an isolated load.

J3 – Output is the primary Non-Isolated regulated output voltage terminal of the EVM. The terminal block 12VPRI (+) and ground (-) allows the user to attach the EVM to a non-isolated load.

J2 – Input is the power input terminal of the EVM. The terminal block provides input VIN(+) and the ground (-) allows the user to attach the EVM to a power supply, nominally a 48-V supply.

TP1 – (SW) allows the user to connect a scope probe to measure the primary side switching node of the converter.

J4– (GND) allows the user to connect the ground of the scope probe for the primary side measurements.
3.2 Operation

To power up the Fly-Buck EVM, gradually increase the input voltage, applied across J2. The load on the secondary output (J1), with primary output (J3) unloaded, should not exceed 800 mA, which corresponds to a 15-Ω resistive load. If the primary is loaded, the total load on the two outputs should not exceed 800 mA. The transformer T1 used in the EVM is optimized for a 10 W isolated bias supply application. The transformer T1 care has been carefully selected in order to ensure that it can tolerate any short circuit condition on the isolated secondary side of the EVM, without getting saturated.

When the input voltage exceeds approximately 36 V, the primary and secondary outputs (J3 and J1) power up to approximately 12.7 V and 12 V respectively.

The frequency of operation is set by using the R4 resistor (R\text{ON}) in Equation 1:

\[
F_{\text{SW}} = \frac{V_{\text{OUT}}}{1.008 \times 10^{-10} \times R_4}
\]

The primary output voltage \(V_{\text{OUT}}\) can be set at 12.7 V, with the feedback divider resistors R7 (R\text{FB(Top)}), R10 (R\text{FB(Bottom)}) and the \(V_{\text{REF}} = 2\) V, using the Equation 2:

\[
V_{\text{OUT}} = \left(1 + \frac{R_{\text{FB(Top)}}}{R_{\text{FB(Bottom)}}}\right) \times V_{\text{REF}} = \left(1 + \frac{R_7}{R_10}\right) \times 2\ V
\]

The secondary isolated output (\(V_{\text{OUTISO}}\)) is related to the primary output \(V_{\text{OUT}}\) by the transformer turns ratio and the forward voltage drop of the secondary side diode D1, \(V_{\text{FD1}}\):

\[
V_{\text{OUT}} = \frac{V_{\text{OUTISO}} + V_{\text{FD1}}}{N_2} = \frac{V_{\text{OUTISO}} + 0.7\ V}{1} = 12.7\ V
\]

where \(N_2 : N_1\) is the transformer turns ratio \((N_{\text{SEC}} : N_{\text{PRI}})\) and \(V_{\text{FD1}}\) is the forward voltage drop of the secondary rectifier diode. The Equation 3 above is simplified and does not account for the DCR voltage and the leakage inductances voltage drops across the primary and the secondary windings of the transformer, which have effect on the secondary (isolated) side regulation.
The secondary-side rectifier diode must block the maximum input voltage reflected at the secondary-side. The minimum diode reverse voltage $V_{RD1}$ rating is given in Equation 4.

$$V_{RD1} = V_{IN(\text{max})} \times \frac{N_S}{N_I} + V_{OUTISO} = 72V \times 1 + 12V = 84V$$

(4)

A diode with a 100-V reverse voltage rating is selected here. If the input voltage ($V_{IN}$) has transients above the normal operating maximum input voltage of 72 V, then the worst-case transient input voltage value must be used in Equation 4 when selecting the secondary-side rectifier diode for the LM5161 Fly-Buck EVM.

4 Typical Performance Curves

![Typical Performance Curves](image)

- **Figure 2. Secondary Side ($V_{OUTISO}$) Load Regulation**
- **Figure 3. Secondary Side ($V_{OUTISO}$) Line Regulation**
- **Figure 4. Efficiency vs $I_{OUTISO}$ with Default Board Configuration**
- **Figure 5. Secondary Isolated Output Load Transient at $V_{IN}$ = 48 V and $I_{OUTISO}$ = 250 mA to 750 mA**
Figure 6. Startup Waveforms at \( I_{\text{OUTISO}} = 500 \text{ mA} \) and \( I_{\text{PRI}} = 0 \text{ A} \)

Figure 7. Steady State waveforms at \( V_{\text{IN}} = 48 \text{ V} \) and \( I_{\text{OUTISO}} = 500 \text{ mA} \)

Figure 8. Secondary-side Short applied when \( I_{\text{OUTISO}} = 0 \text{ A} \) and \( I_{\text{PRI}} = 0 \text{ A} \)

Figure 9. Secondary-Side Short Applied when \( I_{\text{OUTISO}} = 0 \text{ A} \) and \( I_{\text{PRI}} = 0 \text{ A} \) (Zoomed After Short is Applied)
Figure 10. Fly-Buck EVM Schematic with the LM5161 IC

Figure 10 shows the Fly-Buck configuration using the LM5161 with VCC externally powered from \( V_{OUT} \) with diode D2 for improved efficiency requirements. Table 2 provides the complete LM5161PWPFBKEVM Bill of Materials.
Table 2. LM5161PWFBKEVM Bill of Materials for 300 kHz Configuration

<table>
<thead>
<tr>
<th>COUNT</th>
<th>REF DES</th>
<th>DESCRIPTION</th>
<th>SIZE</th>
<th>MFR</th>
<th>PART NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>C2, C3, C12, C13</td>
<td>CAP, CERM, 10 µF, 25 V, ± 20%, X7R</td>
<td>1206</td>
<td>TDK</td>
<td>C3216X7R1E106M160AE</td>
</tr>
<tr>
<td>1</td>
<td>C1</td>
<td>CAP, CERM, 2200 pF, 2000 V, ± 10%, X7R</td>
<td>1210</td>
<td>Johanson Technology</td>
<td>202S41W222KV4E</td>
</tr>
<tr>
<td>1</td>
<td>C4</td>
<td>CAP, CERM, 0.01µF, 16 V, ± 10%, X7R</td>
<td>0603</td>
<td>MuRata</td>
<td>GRM188R71C013KA01D</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CAP, CERM, 0.01µF, 16 V, ± 10%, X7R (Alternative Part)</td>
<td></td>
<td>Würth Elektronik</td>
<td>885012206040</td>
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<tr>
<td>1</td>
<td>C5</td>
<td>CAP, CERM, 1000 pF, 100 V, ± 10%, X7R</td>
<td>0603</td>
<td>MuRata</td>
<td>GRM188R72A102KA01D</td>
</tr>
<tr>
<td>2</td>
<td>C8, C9</td>
<td>CAP, CERM, 2.2 µF, 100 V, ± 10%, X7R</td>
<td>1206</td>
<td>MuRata</td>
<td>GRM31CR72A225KA73L</td>
</tr>
<tr>
<td>1</td>
<td>C10</td>
<td>CAP, CERM, 0.1 µF, 100 V, ± 10%, X7R</td>
<td>0603</td>
<td>MuRata</td>
<td>GRM188R72A104KA35D</td>
</tr>
<tr>
<td>1</td>
<td>C11</td>
<td>CAP, CERM, 0.1 µF, 25 V, ± 5%, X7R (Alternative Part)</td>
<td>0603</td>
<td>AVX</td>
<td>06033C104JAT2A</td>
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<td></td>
<td>CAP, CERM 0.1 µF 25 V, ± 10%, X7R (Alternative Part)</td>
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<td>0603</td>
<td>MuRata</td>
<td>GRM188R71H223KA01D</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CAP, CERM 0.022 µF, 50 V, ± 10%, X7R (Alternative Part)</td>
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<td>C15</td>
<td>CAP, CERM, 1 µF, 25 V, ± 10%, X7R (Alternative Part)</td>
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<tr>
<td></td>
<td></td>
<td>CAP, CERM 1 µF 25 V, ± 10%, X7R (Alternative Part)</td>
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<td>C17</td>
<td>CAP, CERM, 2200 pF, 2000 V, ± 10%, X7R</td>
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<td>Johanson Technology</td>
<td>202S41W222KV4E</td>
</tr>
<tr>
<td>3</td>
<td>J1, J2, J3</td>
<td>Terminal Block, 6A, 3.5mm Pitch, 2-Pos, TH 7.0 mm x 8.2 mm x 6.5 mm</td>
<td></td>
<td>On-Shore Technology</td>
<td>ED555/2DS</td>
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<tr>
<td>2</td>
<td>R1, R3</td>
<td>RES, 0 Ω, 5%, 0.125 W</td>
<td>0805</td>
<td>Vishay-Dale</td>
<td>CRCW08050000Z0EA</td>
</tr>
<tr>
<td>1</td>
<td>R2</td>
<td>RES, 2.00 k, 1%, 0.125 W</td>
<td>0805</td>
<td>Vishay-Dale</td>
<td>CRCW08052K00FKEA</td>
</tr>
<tr>
<td>1</td>
<td>R4</td>
<td>RES, 402 k, 1%, 0.1 W, 0603</td>
<td>0603</td>
<td>Vishay-Dale</td>
<td>CRCW0603402KFKEA</td>
</tr>
<tr>
<td>2</td>
<td>R5, R6</td>
<td>RES, 100 k, 1%, 0.1 W, 0603</td>
<td>0603</td>
<td>Vishay-Dale</td>
<td>CRCW0603100KFKEA</td>
</tr>
<tr>
<td>2</td>
<td>R7</td>
<td>RES, 10.7 k, 1%, 0.1 W, 0603</td>
<td>0603</td>
<td>Vishay-Dale</td>
<td>CRCW060310K7FKEA</td>
</tr>
<tr>
<td>1</td>
<td>R9</td>
<td>RES, 3.57 k, 1%, 0.1 W, 0603</td>
<td>0603</td>
<td>Vishay-Dale</td>
<td>CRCW06033K57FKEA</td>
</tr>
<tr>
<td>1</td>
<td>R10</td>
<td>RES, 2.00 k, 1%, 0.1 W, 0603</td>
<td>0603</td>
<td>Vishay-Dale</td>
<td>CRCW06032K00FKEA</td>
</tr>
<tr>
<td>1</td>
<td>T1</td>
<td>Transformer, 60 µH</td>
<td>SMT</td>
<td>Würth Elektronik</td>
<td>750315811</td>
</tr>
<tr>
<td>1</td>
<td>TP1</td>
<td>Test Point, Miniature</td>
<td>SMT</td>
<td>Keystone</td>
<td>5015</td>
</tr>
<tr>
<td>1</td>
<td>U1</td>
<td>Wide Input 65V, 1.5A Synchronous Step-Down DC-DC Converter 4.4 mm x 5 mm HTSSOP-14</td>
<td></td>
<td>Texas Instruments</td>
<td>LM5161PWPR</td>
</tr>
</tbody>
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Figure 11 to Figure 14 below show the top and bottom layers of the LM5161PWPFBKVM. The LM5161PWPFBKEVM is a two layer board.
## Revision History

<table>
<thead>
<tr>
<th>Changes from Original (August 2016) to A Revision</th>
<th>Page</th>
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<tr>
<td>• Changed Orderable name to LM5161PWPR</td>
<td>9</td>
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**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.

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• 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.

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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.

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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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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

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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:

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