Ultra-Wide Input Isolated Low Power Flyback Converter

- **Input**: 19 .. 375V DC / 19 .. 265V AC
- **Output 1**: +12.0V @ 40mA
  **Output 2**: +5.0V @ 15mA
- **Devices**: LM3481, LMV431, LP2980-5.0
- **Free-running switching frequency of 130 kHz**
- **Working in continuous conduction mode at low input voltage and discontinuous conduction mode at high input voltage**
- The converter provides an isolated output with +12.0V / 40mA. A linear regulator generates +5.0V / 15mA out of the +12V rail. The +12V output has large output capacitors to provide sufficient power for the +5V rail, which typically supplies a microcontroller. The microcontroller can detect the falling voltage on the +12V output if the input voltage drops out and act appropriately.
1 Startup

The startup waveform at 19V DC input and no load on the outputs is shown in Figure 1.

Channel C1: 19V DC Input voltage
5V/div, 500ms/div
Channel C2: 12V Output voltage
2V/div, 500ms/div

![Figure 1]

The startup waveform at 375V DC input and no load on the outputs is shown in Figure 13.

Channel C1: 375V DC Input voltage
100V/div, 500ms/div
Channel C2: 12V Output voltage
2V/div, 500ms/div

![Figure 2]
2 Shutdown

The shutdown waveform at 19V DC input and 55mA load on the +12V output is shown in Figure 3.

Channel C1: **19V DC Input voltage**
5V/div, 50ms/div

Channel C2: **12V Output voltage**
2V/div, 50ms/div

![Figure 3](image)

The shutdown waveform at 375V DC input and 55mA load on the +12V output is shown in Figure 4.

Channel C1: **375V DC Input voltage**
100V/div, 500ms/div

Channel C2: **12V Output voltage**
2V/div, 500ms/div

![Figure 4](image)
3 Efficiency and Load Regulation

The efficiency and load regulation of a single converter are shown in Figure 5 and Figure 6.

![Figure 5](image1.png)

![Figure 6](image2.png)
4 Frequency Response

Figure 7 shows the loop response at 19V DC, 100V DC, 200V DC and 300V DC input voltage with a 55mA load on the 12V output.

19V DC input
47 deg phase margin, 1.6 kHz bandwidth, -17 dB gain margin

100V DC input
71 deg phase margin, 1.5 kHz bandwidth, -21 dB gain margin

200V DC input
65 deg phase margin, 1.6 kHz bandwidth, -20 dB gain margin

300V DC input
72 deg phase margin, 0.8 kHz bandwidth, -31 dB gain margin

Figure 7
5 Switching Node

The drain-source voltage on the switching node at 19V DC input is shown in Figure 8. The image was captured with a 55mA load on the 12V output and the converter is working in continuous conduction mode.

Channel C2: **Drain-source voltage**, -2.1V minimum voltage, 71.5V maximum voltage
20V/div, 5us/div

![Figure 8]

The drain-source voltage on the switching node at 200V DC input is shown in Figure 9. The image was captured with a 55mA load on the 12V output and the converter is working in discontinuous conduction mode.

Channel C2: **Drain-source voltage**, -2.0V minimum voltage, 254.0V maximum voltage
50V/div, 5us/div

![Figure 9]
The drain-source voltage on the switching node at 375V DC input is shown in Figure 10. The image was captured with a 55mA load on the 12V output and the converter is working in discontinuous conduction mode. Additionally, pulses are skipped to maintain the output voltage constant.

Channel C2: **Drain-source voltage**, -7.0V minimum voltage, 438.0V maximum voltage 100V/div, 5us/div

![Figure 10](image1.png)

The drain-source voltage on the switching node at 375V DC input is shown in Figure 11. The image was captured with no load on the outputs and the converter is working in pulse skipping / burst mode.

Channel C2: **Drain-source voltage**, -6.0V minimum voltage, 432.0V maximum voltage 100V/div, 100us/div

![Figure 11](image2.png)
6 Output Ripple Voltage

The output ripple voltage of the 12V output at 55mA load for 19V DC, 200V DC and 375V DC input is shown in Figure 12.

Channel M1: **Output voltage @ 19V DC input**, 22mV peak-peak (0.2%)  
20mV/div, 5us/div, AC coupled

Channel M2: **Output voltage @ 200V DC input**, 25mV peak-peak (0.2%)  
20mV/div, 5us/div, AC coupled

Channel M3: **Output voltage @ 375V DC input**, 29mV peak-peak (0.2%)  
20mV/div, 5us/div, AC coupled

![Figure 12](image_url)
7 Thermal Measurement

Figure 13 shows the thermal image at an ambient temperature of 21 °C with an input voltage of 19V DC and a 55mA load on the 12V output.

![Thermal Image](image)

**Markers**

<table>
<thead>
<tr>
<th>Label</th>
<th>Temperature</th>
<th>Emissivity</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>U2</td>
<td>35.6 °C</td>
<td>0.95</td>
<td>21.0 °C</td>
</tr>
<tr>
<td>D1</td>
<td>36.4 °C</td>
<td>0.95</td>
<td>21.0 °C</td>
</tr>
<tr>
<td>Q4</td>
<td>33.2 °C</td>
<td>0.95</td>
<td>21.0 °C</td>
</tr>
<tr>
<td>T1</td>
<td>34.1 °C</td>
<td>0.95</td>
<td>21.0 °C</td>
</tr>
<tr>
<td>D4</td>
<td>32.6 °C</td>
<td>0.95</td>
<td>21.0 °C</td>
</tr>
</tbody>
</table>
Figure 14 shows the thermal image at an ambient temperature of 21 °C with an input voltage of 375V DC and a 55mA load on the 12V output.

![Thermal Image](image_url)

**Figure 14**

<table>
<thead>
<tr>
<th>Markers</th>
<th>Temperature</th>
<th>Emissivity</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>U2</td>
<td>38.1 °C</td>
<td>0.95</td>
<td>21.0 °C</td>
</tr>
<tr>
<td>Q2</td>
<td>39.0 °C</td>
<td>0.95</td>
<td>21.0 °C</td>
</tr>
<tr>
<td>Q4</td>
<td>42.6 °C</td>
<td>0.95</td>
<td>21.0 °C</td>
</tr>
<tr>
<td>T1</td>
<td>38.8 °C</td>
<td>0.95</td>
<td>21.0 °C</td>
</tr>
<tr>
<td>D4</td>
<td>31.6 °C</td>
<td>0.95</td>
<td>21.0 °C</td>
</tr>
</tbody>
</table>
8 EMI Measurement

Figure 15 shows the EMI measurement of the converter connected to an isolation transformer plus a Hameg HM6050-2 LISN. The supply voltage is 230V AC. The 12V output was loaded with 55mA by a resistor. Both converter and resistor have been placed 20cm over the ground plane. The output ground terminal has been left floating.
Texas Instruments Incorporated (“TI”) reference designs are solely intended to assist designers (“Buyers”) who are developing systems that incorporate TI semiconductor products (also referred to herein as “components”). Buyer understands and agrees that Buyer remains responsible for using its independent analysis, evaluation and judgment in designing Buyer’s systems and products.

TI reference designs have been created using standard laboratory conditions and engineering practices. TI has not conducted any testing other than that specifically described in the published documentation for a particular reference design. TI may make corrections, enhancements, improvements and other changes to its reference designs. Buyers are authorized to use TI reference designs with the TI component(s) identified in each particular reference design and to modify the reference design in the development of their end products. HOWEVER, NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY THIRD PARTY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT, IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI REFERENCE DESIGNS ARE PROVIDED “AS IS”. TI MAKES NO WARRANTIES OR REPRESENTATIONS WITH REGARD TO THE REFERENCE DESIGNS OR USE OF THE REFERENCE DESIGNS, EXPRESS, IMPLIED OR STATUTORY, INCLUDING ACCURACY OR COMPLETENESS. TI DISCLAIMS ANY WARRANTY OF TITLE AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, QUIET ENJOYMENT, QUIET POSSESSION, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS WITH REGARD TO TI REFERENCE DESIGNS OR USE THEREOF. TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY BUYERS AGAINST ANY THIRD PARTY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON A COMBINATION OF COMPONENTS PROVIDED IN A TI REFERENCE DESIGN. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, SPECIAL, INCIDENTAL, CONSEQUENTIAL OR INDIRECT DAMAGES, HOWEVER CAUSED, ON ANY THEORY OF LIABILITY AND WHETHER OR NOT TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES, ARISING IN ANY WAY OUT OF TI REFERENCE DESIGNS OR BUYER’S USE OF TI REFERENCE DESIGNS.

TI reserves the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale for semiconductor products. Testing and other quality control techniques for TI components are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

Reproduction of significant portions of TI information in TI data books, data sheets or reference designs is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has the necessary expertise to create and implement safeguards that anticipate dangerous failures, monitor failures and their consequences, lessen the likelihood of dangerous failures and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in Buyer’s safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed an agreement specifically governing such use. Only those TI components that TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components that have not been so designated is solely at Buyer’s risk, and Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.