NON-ISOLATED DC-DC Converter

9.0-14Vin, 0.75-5.0Vout, 16A

INSTALLATION / APPLICATION NOTE
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1. Introduction

This application note describes the features and functions of Lambda’s PL16S-12C / PL16SMS-12C series of Non Isolated DC-DC Converters. These are highly efficient, reliable and compact, high power density, single output DC/DC converters. These “Point of Load” modules serve the needs specifically of the fixed and mobile telecommunications and computing market, employing economical distributed Power Architectures. The series provides precisely regulated output voltage range from 0.75V to 5.0Vdc over a wide range of input voltage (9.0 – 14Vdc) and can operate over an ambient temperature range of –40°C to +85°C. Ultra-high efficiency operation is achieved through the use of synchronous rectification and drive control techniques. The modules are fully protected against short circuit and over-temperature conditions.

2. Models

<table>
<thead>
<tr>
<th>Model</th>
<th>Input Voltage</th>
<th>Output Voltage</th>
<th>Output Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL16S-12C</td>
<td>9.0 – 14VDC</td>
<td>0.75 – 5.0VDC</td>
<td>16A</td>
</tr>
<tr>
<td>PL16SMS-12C</td>
<td>9.0 – 14VDC</td>
<td>0.75 – 5.0VDC</td>
<td>16A</td>
</tr>
</tbody>
</table>

Table 1 – Models

<table>
<thead>
<tr>
<th>Output Voltage</th>
<th>Output Current</th>
<th>Input Current (mA)</th>
<th>Efficiency typ.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75V</td>
<td>16A</td>
<td>40</td>
<td>1299mA</td>
</tr>
<tr>
<td>1.2V</td>
<td>16A</td>
<td>50</td>
<td>1928mA</td>
</tr>
<tr>
<td>1.5V</td>
<td>16A</td>
<td>50</td>
<td>2326mA</td>
</tr>
<tr>
<td>1.8V</td>
<td>16A</td>
<td>60</td>
<td>2727mA</td>
</tr>
<tr>
<td>2.0V</td>
<td>16A</td>
<td>60</td>
<td>2996mA</td>
</tr>
<tr>
<td>2.5V</td>
<td>16A</td>
<td>65</td>
<td>3704mA</td>
</tr>
<tr>
<td>3.3V</td>
<td>16A</td>
<td>75</td>
<td>4783mA</td>
</tr>
<tr>
<td>5.0V</td>
<td>16A</td>
<td>75</td>
<td>7092mA</td>
</tr>
</tbody>
</table>

Table 2 – Efficiency and Input Current with 12V input

3. Converter Features

- High efficiency topology, typically 94% at 5.0Vdc
- Industry standard footprint
- Wide ambient temperature range, -40°C to +85°C
- Cost efficient open frame design
- Programmable output voltage via external resistor from 0.75 to 5.0Vdc
- No minimum load requirement (Stable at all loads)
- Remote ON/OFF
- Remote sense compensation
- Fixed switching frequency
- Continuous short-circuit protection and over current protection
- Over-temperature protection (OTP)
- Monotonic Startup with pre-bias at the output.
- UL/IEC/EN60950 Certified.

4. General Description

4.1 Electrical Description

A block diagram of the converter is shown in Figure 1. Extremely high efficiency power conversion is achieved through the use of synchronous rectification and drive techniques. Essentially, the topology is based on a non-isolated synchronous buck converter. The control loop is optimized for unconditional stability, fast transient response and very tight line and load regulation. In a typical pre-bias application the converters do not draw any reverse current at start-up. The output voltage can be adjusted from 0.75 to 5.0vdc, using the TRIM pin with an external resistor. The converter can be shutdown via a remote ON/OFF input that is referenced to ground. This input is compatible with popular logic devices; ‘positive’ logic input is supplied as standard. Positive logic implies that the converter is enabled if the remote ON/OFF input is high (or floating), and disabled if it is low. The converter is also protected against over-temperature conditions. If the converter is overloaded or the ambient temperature is excessive, the converter will shut down.

Figure 1. Electrical Block Diagram
4.2 Thermal Packaging and Physical Design
The converter uses multi-layer FR4 PCB construction. All surface mount power components are placed on one side of the PCB, and all low-power control components are placed on the opposite side. Thus, the heat dissipation of the power components is optimized, ensuring that control components are not thermally stressed. The converter is an open-frame product and has no case or case pin. The open-frame design has several advantages over encapsulated devices. Among these advantages are:

- Efficient Thermal Management: the heat is removed from the heat generating components without affecting other components.
- Environmental: Lead free open-frame converters are easily recycled.
- Cost Efficient: No encapsulation. Cost efficient open-frame construction.
- Reliable: Efficient cooling provided by open frame construction, offers high reliability.

5. Main Features and Functions
5.1 Operating Temperature Range
The converters operate over a wide ambient temperature environment (-40°C to 85°C). Attention must be given to the de-rating curves when determining the maximum power that can be drawn from the converter. The maximum power drawn is influenced by a number of factors, such as:

- Input voltage range.
- Output load current.
- Air velocity (forced or natural convection).
- Mounting orientation of converter PCB with respect to the Airflow.
- Motherboard PCB design, especially ground and power planes. These can be effective heat sinks for the converter.

5.2 Over-Temperature Protection (OTP)
The converters are equipped with non-latching over-temperature protection. A temperature sensor is located at the hottest point within the converter; typically, on top of the switching device. If the temperature exceeds a threshold of 130°C (typical) the converter will shutdown, disabling the output. When the temperature has decreased the converter will automatically start. The over-temperature condition can be caused by external overload condition or a system fan failure.

5.3 Output Voltage Adjustment
Section 7.8 describes in detail as to how to trim the output voltage with respect to its set point. The output voltage on all models is adjustable over range of 0.75 – 5.0Vdc.

5.4 Safe Operating Area (SOA)
Figure 2 provides a graphical representation of the Safe Operating Area (SOA) of the converter. This representation assumes ambient operating conditions such as airflow are met as per thermal guidelines provided in Sections 7.2 and 7.3.
5.7 UVLO (Under-Voltage Lockout)
The voltage on the Vcc pin determines the start of the operation of the
converter. When the input Vcc rises and exceeds about 8.0V the
converter initiates a soft start. The UVLO function in the converter has a
hysteresis (about 300mV) built in to provide noise immunity at start-up.

6. Safety
6.1 Input Fusing and Safety
These products are approved to UL 60950-1:2003, CAN/CSA C22.2
These products are designed to be PCB mounted and for use within
other equipment or enclosures. For safe installation and operation,
carefully follow the instructions below:
Do not install, test, or operate the products near water or spill liquid on
them.
Do not operate these products unless they are securely fastened.
These products must be installed in a restricted access location
accessible to authorized personnel only.
These products must be professionally installed in accordance with the
prevailing electrical wiring regulations and safety standards.
The output power taken from the unit must not exceed the ratings
stated in the catalog datasheet.
Ensure adequate ventilation is provided to allow air to circulate.
This product has functional insulation between input and output and
therefore the DC source to this product must be reinforced or double
insulated to the AC input in accordance with IEC/EN 60950-1 to
achieve SELV output.
Fusing – External ceramic sand-filled fuse, 250V, F20A HBC.

7. Applications
7.1 Layout Design
In optimizing thermal design the PCB is utilized as a heat sink. Also
some heat is transferred from the module to the main board through the
connecting pins. The system designer must ensure that the
components in the vicinity of the converter meet the spacing
requirements to which the system is approved. Low resistance and low
inductance PCB layout traces are the norm and should be used where
possible. Attention must also be given to proper low impedance tracks
between power module, input and output grounds. The recommended
converter footprint is shown in figures 5 and 6.
7.2 Convection Cooling

To predict the approximate cooling needed for the module, refer to the Power De-rating curves in Figures 10 - 13. These de-rating curves are approximations of the ambient temperatures and airflow required to keeping the power module temperature below its maximum rating. Once the module is assembled in the actual system, the module’s temperature should be checked as shown in Figure 7 to ensure it does not exceed 120°C. Proper cooling can be verified by measuring the power module’s temperature at Q1-pin 6 as shown in Figures 8 and 9.

7.3 Thermal Considerations

The power module operates in a variety of thermal environments; however, sufficient cooling should be provided to help ensure reliable operation of the unit. Heat is removed by conduction, convection, and radiation to the surrounding environment. The thermal data presented is based on measurements taken in a set-up as shown in Figure 7. Figures 10 to 13 represent the test data. Note that the airflow is parallel to the long axis of the module as shown in Figure 7 for the converters. The temperature at either location should not exceed 120 °C. The output power of the module should not exceed the rated power for the module (VO, set x IO, max). The thermal data presented is based on measurements taken in a wind tunnel.
7.4 Power De-Rating Curves

Figure 10a. Typical Power De-rating for 12V IN 5.0Vout

Figure 10b. Typical Power De-rating for 12V IN 3.3Vout

Figure 10c. Typical Power De-rating for 12V IN 2.5Vout

Figure 10d. Typical Power De-rating for 12V IN 2.0Vout

Figure 10e. Typical Power De-rating for 12V IN 1.8Vout

Figure 10f. Typical Power De-rating for 12V IN 1.5Vout
PL16S-12C, PL16SMS-12C

Figure 10g. Typical Power De-rating for 12V IN 1.2Vout

Figure 10h. Typical Power De-rating for 12V IN 0.75Vout

Figure 11a. Typical Power De-rating for 12V IN 5.0Vout

Figure 11b. Typical Power De-rating for 12V IN 3.3Vout

Figure 11c. Typical Power De-rating for 12V IN 2.5Vout

Figure 11d. Typical Power De-rating for 12V IN 2.0Vout
PL16S-12C, PL16SMS-12C

Figure 11e. Typical Power De-rating for 12V IN 1.8Vout

Figure 11d. Typical Power De-rating for 12V IN 1.5Vout

Figure 11f. Typical Power De-rating for 12V IN 1.2Vout

Figure 11g. Typical Power De-rating for 12V IN 0.75Vout
7.5 Efficiency vs Load Curves

PL16S-12C Vo=5.0V (Eff Vs Io)

PL16S-12C Vo=3.3V (Eff Vs Io)

PL16S-12C Vo=2.5V (Eff Vs Io)

PL16S-12C Vo=2.0V (Eff Vs Io)

PL16S-12C Vo=1.8V (Eff Vs Io)

PL16S-12C Vo=1.5V (Eff Vs Io)
PL16S-12C, PL16SMS-12C

**PL16S-12C Vo=1.2V (Eff Vs Io)**

- 9.0V
- 12V
- 14V

**PL16S-12C Vo=0.75V (Eff Vs Io)**

- 9.0V
- 12V
- 14V

**PL16SMS-12C Vo=5.0V (Eff Vs Io)**

- 9.0V
- 12V
- 14V

**PL16SMS-12C Vo=3.3V (Eff Vs Io)**

- 9.0V
- 12V
- 14V

**PL16SMS-12C Vo=2.5V (Eff Vs Io)**

- 9.0V
- 12V
- 14V

**PL16SMS-12C Vo=2.0V (Eff Vs Io)**

- 9.0V
- 12V
- 14V
7.6 Input Capacitance

The converters must be connected to a low source impedance to avoid problems with loop stability. The input capacitors should be placed close to the converter’s input pins to reduce distribution inductance. Input capacitors should have a high capacitance and a low ESR (typically <100m ohms) for suitable ripple handling capability. Electrolytic capacitors should be avoided. The circuit as shown in Figure 14 represents typical measurement methods for ripple current. Input reflected-ripple current is measured with a simulated source Inductance of 1uH. Current is measured at the input of the module.

7.7 Test Set-Up

The basic test set-up to measure parameters such as efficiency and load regulation is shown in Figure 15. This converter is non-isolated; therefore, the input and output share a common ground. These grounds should be connected together via low impedance ground plane in the application circuit. When testing a converter on a bench set-up, ensure that -Vin and -Vo are connected together via a low impedance short to ensure proper efficiency and load regulation measurements are being made. When testing the converter under any transient conditions, please ensure that the transient response of the source is sufficient to power the equipment under test.

The value of efficiency is defined as:

$$\eta = \frac{Vo \times Io}{Vin \times Iin} \times 100\%$$

Where:
- Vo is output voltage,
- Io is output current,
- Vin is input voltage,
- Iin is input current.

The value of load regulation is defined as:

$$Load regulate = \frac{V_{FL} - V_{NL}}{V_{NL}} \times 100\%$$

Where:
- V_{FL} is the output voltage at full load,
- V_{NL} is the output voltage at no load.

The value of line regulation is defined as:

$$Line regulate = \frac{V_{HL} - V_{LL}}{V_{LL}} \times 100\%$$

Where:
- V_{HL} is the output voltage of maximum input voltage at full load,
- V_{LL} is the output voltage of minimum input voltage at full load.

7.8 Remote Sense Compensation

Remote Sense regulates the output voltage at the point of load. It minimizes the effects of distribution losses such as drops across the connecting pin and PCB traces (see Figure 16). Please note however, the maximum drop from the output pin to the point of load should not exceed 500mV for remote compensation to work.

The amount of power delivered by the module is defined as the output voltage multiplied by the output current (VO \times IO).

When using TRIM UP, the output voltage of the module will increase which, if the same output current is maintained, increases the power output by the module. Make sure that the maximum output power of the module remains at or below the maximum rated power.

When the Remote Sense feature is not being used, leave sense pin disconnected.

Figure 16. Circuit Configuration for Remote Sense Operation
7.9 Output Voltage Adjustment

The output Voltage can be adjusted in the range 0.75V to 5.0V by connecting a single resistor on the motherboard (shown as Rtrim) in Figure 16. When Trim resistor is not connected the output voltage defaults to 0.75V.

![Diagram of Trim-up Voltage Setup](image)

Figure 16. Trim-up Voltage Setup

The value of Rtrim-up defined as:

\[
R_{trim} = \left( \frac{10500}{V_o - 0.75} - 1000 \right)
\]

Where: \( R_{trim} \) is the external resistor in ohms,
\( V_o \) is the desired output voltage.

To give an example of the above calculation, to set a voltage of 3.3Vdc, \( R_{trim} \) is given by:

\[
R_{trim} = \left( \frac{10500}{3.3 - 0.75} - 1000 \right)
\]

\( R_{trim} = 3117 \) ohms

For various output voltages, the resistance values are provided in Table 3.

<table>
<thead>
<tr>
<th>( V_o, \text{set (V)} )</th>
<th>( R_{trim} ) (Kohm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75</td>
<td>Open</td>
</tr>
<tr>
<td>1.20</td>
<td>22.33</td>
</tr>
<tr>
<td>1.50</td>
<td>13.0</td>
</tr>
<tr>
<td>1.80</td>
<td>9.0</td>
</tr>
<tr>
<td>2.00</td>
<td>7.4</td>
</tr>
<tr>
<td>2.50</td>
<td>5.0</td>
</tr>
<tr>
<td>3.30</td>
<td>3.12</td>
</tr>
<tr>
<td>5.0</td>
<td>1.47</td>
</tr>
</tbody>
</table>

Table 3 – Trim Resistor Values

7.10 Output Ripple and Noise Measurement

The test set-up for noise and ripple measurements is shown in Figure 17. A coaxial cable with a 50 ohm termination was used to prevent impedance mismatches.

![Diagram of Output Voltage Ripple and Noise Measurement Set-Up](image)

Figure 17. Output Voltage Ripple and Noise Measurement Set-Up

7.11 Output Capacitance

Lambda’s converters provide unconditional stability with or without external capacitors. For good transient response low ESR output capacitors should be located close to the point of load. For high current applications point has already been made in layout considerations for low resistance and low inductance traces. Output capacitors with its associated ESR values have an impact on loop stability and bandwidth. The converters are designed to work with load capacitance up to 8,000uF. It is recommended that any additional capacitance, Maximum 8,000uF and low ESR, be connected close to the point of load and outside the remote compensation point.

7.12 PL16SMS12C Reflow Profile

An example of the SMT reflow profile is given in Figure 18.

**Equipment used:** SMD HOT AIR REFLOW HD-350SAR

**Alloy:** AMQ-M293TA or NC-SMQ92 IND-82088 SN63

![Reflow Profile Graph](image)

Figure 18. Reflow Profile
8. Mechanical

8.1 Mechanical Outline Diagrams

Dimensions are in millimeters and inches

Tolerance: x.xx ±0.02 in. (0.5mm) , x.xxx ±0.010 in. (0.25 mm) unless otherwise noted

Figure 19  PL16S –12C Mechanical Outline Diagram

Figure 20  PL16SMS –12C Mechanical Outline Diagram

8.2 PL16SMS–12C Tape and Reel Dimensions

The Tape Reel dimensions for the SMS module is shown in Figure 21.

Figure 21 – PL16SMS –12C Tape and Reel Dimensions