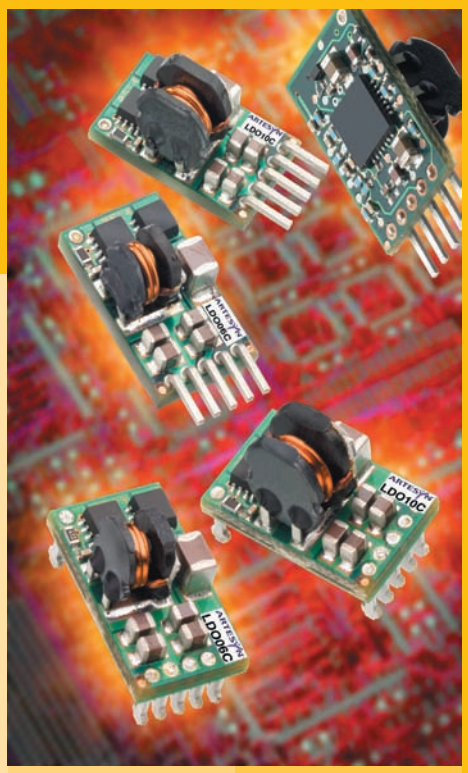
NEW

LDO03C/LDO06C/LDO10C

Application Note 186



RoHS
2002/95/EC

ARTESYN® TECHNOLOGIES

186 Rev. 02 / 15 August 2006

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1. Introduction

This application note describes the features and functions of Artesyn Technologies' LDO03C/06C/10C series of high-power density, adjustable output dc-dc converters. These open-frame, 3 A/6 A/10 A output modules are available in vertical, horizontal, and horizontal surface mount versions, and are designed for use in workstation, computing, industrial, and communications applications. The LDOC series offers great flexibility in board level power distribution by means of its wide output voltage range and small package size.

2. Models

The LDOC series comprises 3 base electrical models, as listed in Table 1.

Model	Input Voltage	Output Voltage	Output Current
LDO03C-005W05-VJ	3-13.8 Vdc	0.59-5.1 V	3 A
LDO06C-005W05-VJ	3-13.8 Vdc	0.59-5.1 V	6 A
LDO10C-005W05-VJ	3-13.8 Vdc	0.59-5.1 V	10 A

To order a unit for horizontal mount use the suffix 'H' on the end, e.g. 'LDO06C-005W05-HJ'. For surface mount use the suffix 'S' on the end. J = Pb-free (RoHS 6/6 compliant).

Table 1 - Available LDO03C/06C/10C Class Models

Features

- 3 A/6 A/10 A current rating
- Input voltage range 3-13.8 V
- Adjustable output voltage 0.59-5.1 V
  - Optional 3-pin model factory set
  - Optional 5-pin model factory set with power good option
- Excellent transient response
- Remote ON/OFF (5-pin model)
- Minimum airflow
- Small package
- Termination voltage capacity
- RoHS compliant

3. General Description

3.1 Electrical Description

The LDO03C/06C/10C is implemented using a voltage-mode single-phase Buck/Boost topology. A block diagram of the converter is shown in Figure 1.

The output is adjustable over a range of 0.59-5.1 V by using a resistor from the trim pin to ground, or by driving the TRIM pin with a voltage.

The converter can be shut down via a remote ON/OFF. This input is run with positive logic that is compatible with popular logic devices. 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 power good signal is an open collector output that is pulled low by the PWM controller when it detects the output is not within ±10% of its set value. Power good is not available if the trim option is chosen.

The output is monitored for overcurrent and short-circuit conditions. The current flow is monitored through each FET, and when the PWM controller detects an overcurrent condition, it forces the module into hiccup mode.

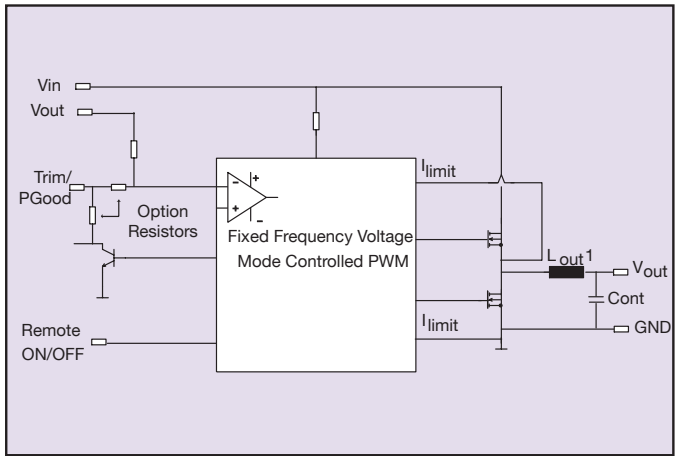


Figure 1 - Electrical Block Diagram

3.2 Physical Construction

The LDO03C/06C/10C is constructed using a multi-layer FR4 PCB. LDOC power components are placed on one side of the PCB, and all low-power control components are placed on the other side. 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 closed devices. Among these advantages are:

- **Cost:** no potting compound, case or associated process costs involved.
- **Thermals:** the heat is removed from the heat generating components without heating more sensitive, less tolerant components such as opto-couplers.
- **Environmental:** some encapsulants are not kind to the environment and create problems in incinerators. Further more open-frame converters are more easily recycled.
- **Reliability:** open-frame modules are more reliable for a number of reasons, including improved thermal performance and reduced TCE stresses.

A separate paper discussing the benefits of open-frame dc-dc converters (Design Note 102) is available at www.artesyn.com.

4. Features and Functions

4.1 Wide Operating Temperature Range

The LDOC's ability to accommodate a wide range of ambient temperatures is the result of its extremely high power conversion efficiency and resultant low power dissipation, combined with the excellent thermal performance of the PCB substrate. The maximum output power that the module can deliver depends on a number of parameters, primarily:

- Input voltage range
- Output load current
- Air velocity (forced or natural convection)
- Mounting orientation of target application PCB, i.e., vertical/horizontal mount, or mechanically tied down (especially important in natural convection conditions).
- Target application PCB design, especially ground planes. These can be effective heatsinks for the converter.

The LDO03C/06C/10C modules have a operating temperature range of 0 °C to 70 °C with suitable derating and/or forced air cooling. A number of derating curves for each model at several output voltage setpoints are included in the Longform Datasheet for each model. Thermal performance is discussed further in Section 7.2.

4.2 Output Voltage Adjustment

The output voltage on all models is adjustable from 0.59-5.1 V. Details on how to trim all models are provided in Section 7.3.

4.3 Undervoltage Lockout

The modules in this line have an adjustable, built-in undervoltage lockout to ensure reliable output power. The lockout prevents the unit from operating when the input voltage is too low. The under-voltage lockout is adjustable by adding a resistor between remote ON/OFF and ground per the following equation:

$$Ren(k\Omega) = 14.81 * \frac{6.81}{6.81Ven - 18.16}$$

Where Ven is the voltage the module turns on at.

4.4 Current Limit and Short-Circuit Protection

The LDO03C/06C/10C models have a built-in non-latching current limit function and full continuous short-circuit protection. The module monitors current through the top and bottom FET. When an overcurrent condition occurs, the module goes into hiccup mode, where it attempts to power up periodically to determine if the problem persists.

The output current level is sensed through the voltage drop across the top and bottom FETs during their on time. This type of sensing is affected by temperature due to the change in Rds_{on} with temperature. So, at higher temperatures, the Rds_{on} increases, which lowers the overcurrent point.

Note that none of the module specifications are guaranteed when the unit is operated in an overcurrent condition.

4.5 Remote ON/OFF

The remote ON/OFF input allows external circuitry to put the LDOC converter into a low dissipation sleep mode. Positive logic remote ON/OFF is available as standard.

The unit is turned on if the remote ON/OFF pin is high (or floating). Pulling the pin low will turn off the unit. To guarantee turn-on, the enable voltage must be above 0.50 V. To turn off the enable voltage, it must be pulled below 0.2 V.

Figures illustrating the response of the unit to switching on and off using the remote ON/OFF feature are included in the Longform Datasheet for this model. Figures 2 and 3 show various circuits for driving the remote ON/OFF feature. The remote ON/OFF input can be driven through a discrete device (e.g. a bipolar signal transistor) or directly from a logic gate output. The output of the logic gate may be an open-collector (or open-drain) device. Please note the remote ON/OFF pin should only be driven in the following range:

If, Vin ≤ 5 V, Von/off (max) = Vin

If, Vin > 5 V, Von/off (max) = 5 V

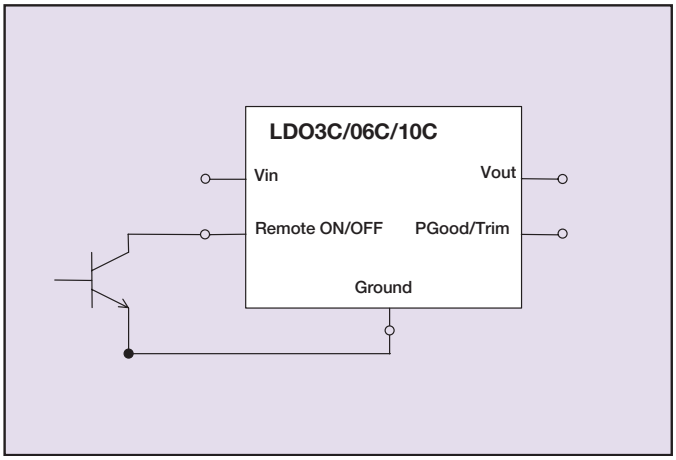


Figure 2 - Remote ON/OFF Input Drive Circuit for Non-Isolated Bipolar

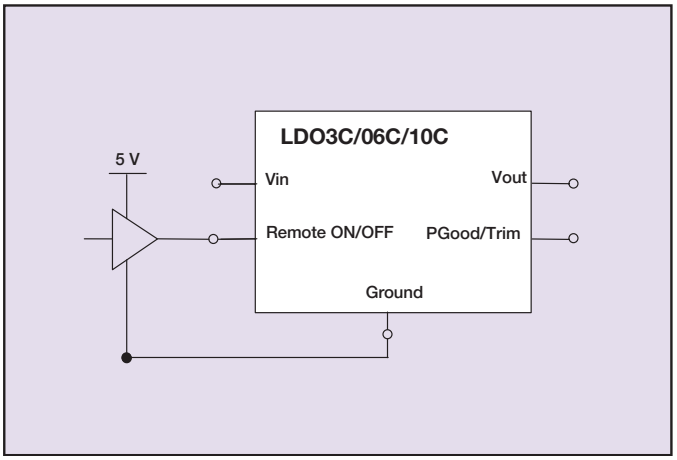


Figure 3 - Remote ON/OFF Input Drive Circuit for Logic Driver

4.6 POWER GOOD Signal

The LDO03C/06C/10C modules have a power good indicator output. This output pin uses positive logic and is open-collector. The Power Good uses the same pin as the trim function and is not available if trim option is used. Also, the power good output is able to sink 10 mA.

When the output of the module is within ±10% of the nominal set point, the power good pin can be pulled high. Note that Power Good should not be pulled higher than the following conditions:

If, Vin ≤ 5 V, Vpgood (max) = Vin

If, Vin > 5 V, Vpgood (max) = 5 V

4.7 Current Sink Capabilities

The LDOC line of dc-dc converters is able to current sink as well as current source. It is able to work the full 3 A/6 A/10 A of current at any output voltage. This feature allows the LDOC to fit into any voltage termination application.

5. Safety

5.1 Safety Standards and Approvals

All models have full international safety approval including EN60950 and UL/cUL60950. Please refer to the shortform datasheet for file numbers.

5.2 Fuse Information

In order to comply with safety requirements, the user must provide a fuse in the unearthed input line. This is to prevent earth being disconnected in the event of a failure.

5.3 Safety Considerations

The converter must be installed as per guidelines outlined by the various safety agency approvals, if safety agency approval is required for the overall system.

6. Use in a Manufacturing Environment

6.1 Resistance to Solder Heat

The LDOC series converters are intended for PCB mounting. Artesyn Technologies has determined how well the product can resist the temperatures associated with soldering of PTH components without affecting its performance or reliability. The method used to verify this is MIL-STD-202 method 210D. Within this method, two test conditions were specified, Soldering Iron condition A and Wave Solder Condition C.

For the soldering iron test, the UUT was placed on a PCB with the recommended PCB layout pattern shown in Section 7. A soldering iron set to 350 ºC ±10 ºC was applied to each terminal for 5 seconds. The UUT was then removed from the test PCB and examined under a microscope for any reflow of the pin solder or physical change to the terminations. None was found.

For the wave solder test, the UUT was again mounted on a test PCB. The unit was wave soldered using the conditions shown in Table 2. The UUT was inspected after soldering and no physical change was found on the pin terminations.

Temperature	Time	Temperature Ramp
260 °C±5 °C	10 sec±1	Preheat 4 °C/sec to 160 °C. 25 mm/sec rate

Table 2 - Wave Solder Test Conditions

6.2 ESD Control

LDOC units are manufactured in an ESD controlled environment and supplied in conductive packaging to prevent ESD damage occurring before or during shipping. It is essential that they are unpacked and handled using approved ESD control procedures. Failure to do so could affect the lifetime of the converter.

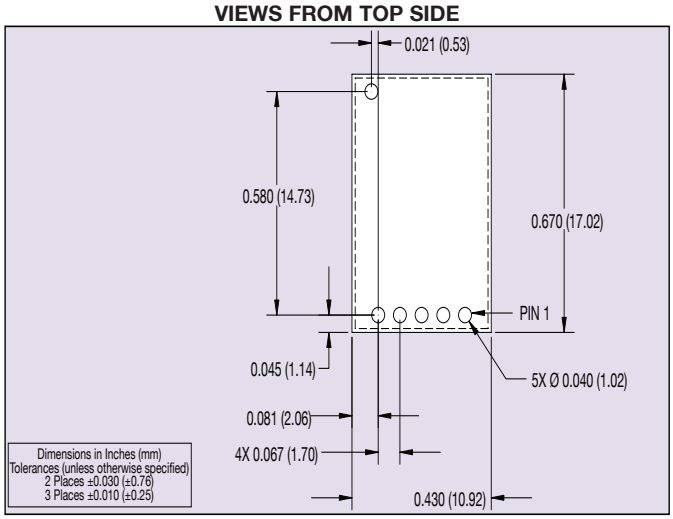
6.3 Coplanarity of Surface Mount Versions

The LDO03C/06C/10C series has a maximum coplanarity as defined by JESD22-B108 of better than 150 µm (approximately 0.006 inches). Innovative design, interconnect technology, and specialised manu-facutring processes ensures product integrity.

7. Applications

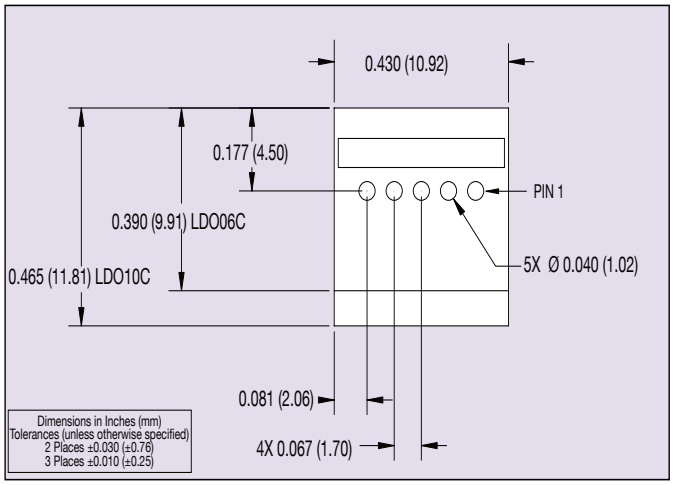
7.1 PCB Layout

The pin diagrams for the LDO06C/10C are detailed in Figures 4A, 4B and 4C. The LDO03C is detailed in Figures 5A, 5B and 5C.



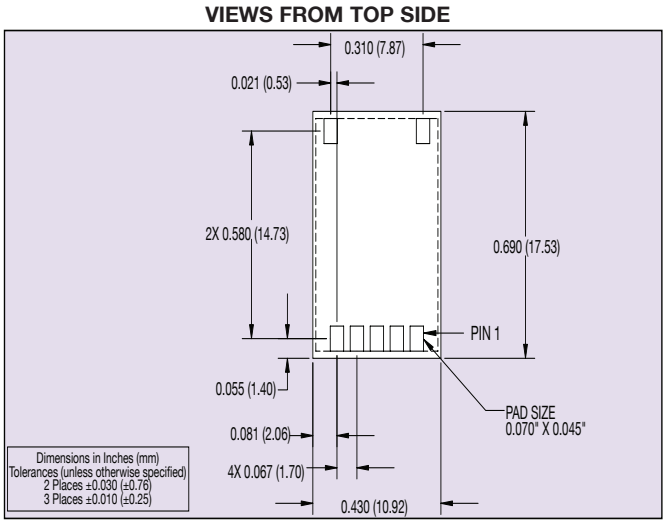
THERMAL RELIEF IN CONDUCTOR PLANES
REFERENCE IPC-D-275 SECTION 5.3.2.3

Figure 4A - LDO06C/10C Horizontal Through-Hole Recommended Footprint



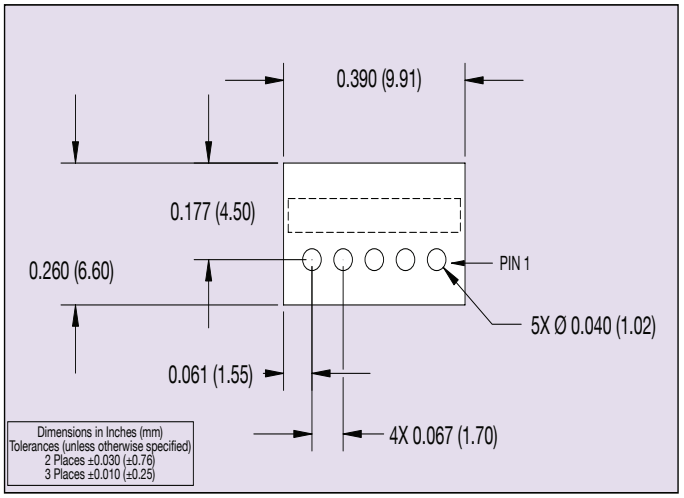
THERMAL RELIEF IN CONDUCTOR PLANES
REFERENCE IPC-D-275 SECTION 5.3.2.3

Figure 4B - LDO06C/10C Vertical Through-Hole Recommended Footprint



THERMAL RELIEF IN CONDUCTOR PLANES
REFERENCE IPC-D-275 SECTION 5.3.2.3

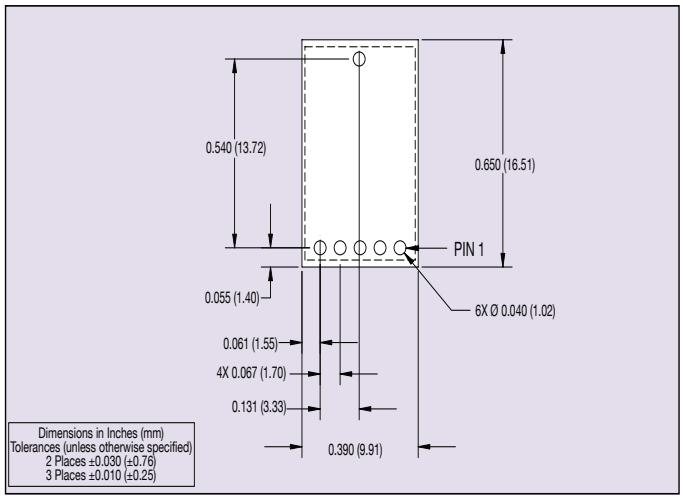
Figure 4C - LDO06C/10C SMT Recommended Footprint



THERMAL RELIEF IN CONDUCTOR PLANES
REFERENCE IPC-D-275 SECTION 5.3.2.3

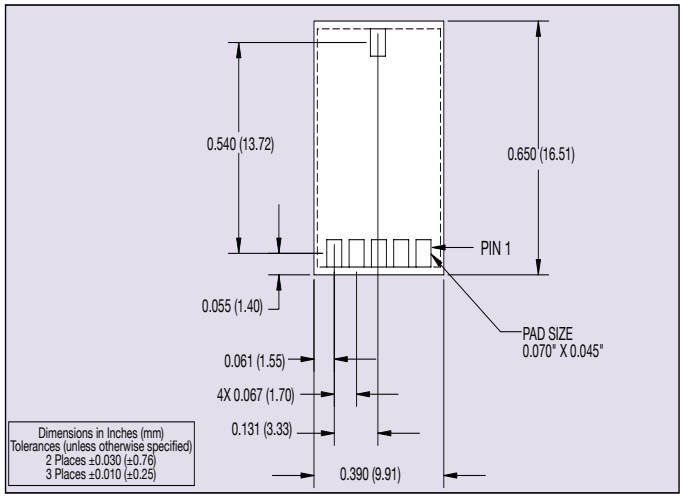
Figure 5A - LDO03C Vertical Through-Hole Recommended Footprint

VIEWS FROM TOP SIDE



THERMAL RELIEF IN CONDUCTOR PLANES
REFERENCE IPC-D-275 SECTION 5.3.2.3

Figure 5B - LDO03C Horizontal Through-Hole Recommended Footprint



THERMAL RELIEF IN CONDUCTOR PLANES
REFERENCE IPC-D-275 SECTION 5.3.2.3

Figure 5C - LDO03C Surface Mount Recommended Footprint

7.2 Thermal Performance

The electrical operating conditions of the LDOC, namely:

- Input voltage, V_{in}
- Output voltage, V_o
- Output current, I_o

Determine how much power is dissipated within the converter. The following parameters further influence the thermal stresses experienced by the converter:

- Ambient temperature
- Air velocity
- Thermal efficiency of the end system application
- Parts mounted on system PCB that may block airflow
- Real airflow characteristics at the converter location

In order to simplify the thermal design, a number of thermal derating plots are provided in the Longform Datasheet. Selected plots are repeated in Figures 6 and 7. These derating graphs show the load current of the LDOC versus the ambient air temperature and forced air velocity. However, since the thermal performance is heavily dependent upon the final system application, the user needs to ensure the thermal reference point temperatures are kept within the recommended temperature rating. It is recommended that the thermal reference point temperatures are measured using a thermocouple or an IR camera. In order to comply with stringent Artesyn derating criteria the ambient temperature should never exceed 70 °C. Please contact Artesyn Technologies for further support.

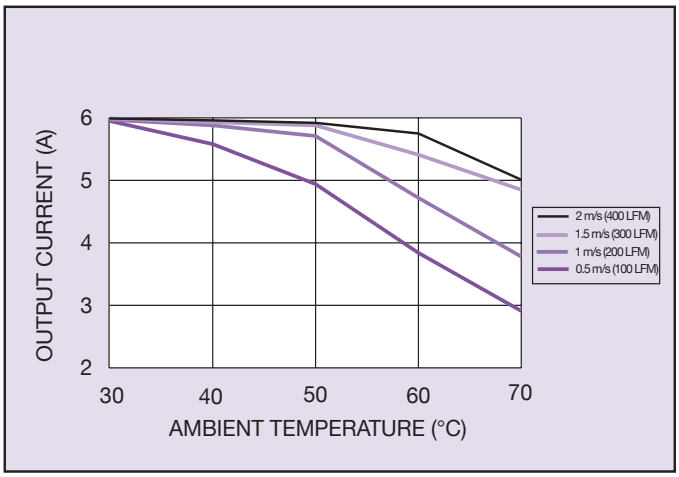


Figure 6 - Maximum Output Current vs. Ambient Temperature and Airflow for LDO06C with Vout Set to 5 V at 12 Vin

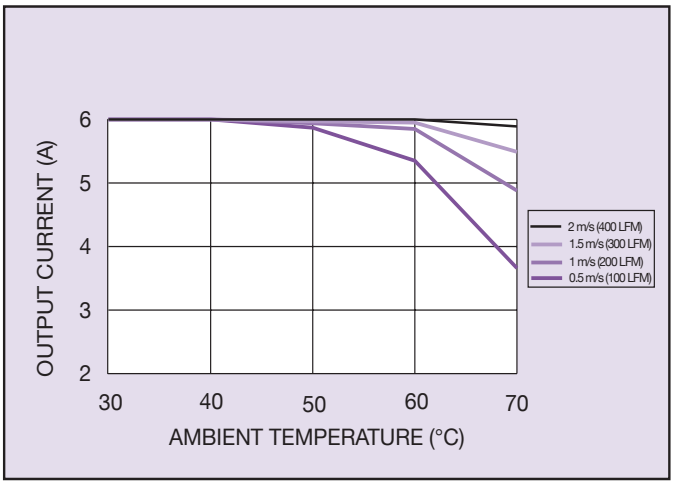


Figure 7 - Maximum Output Current vs. Ambient Temperature and Airflow for LDO06C with Vout Set to 2.5 V at 12 Vin

The maximum acceptable temperature measured at the thermal reference point is 110 ºC. This is shown in Figure 8.

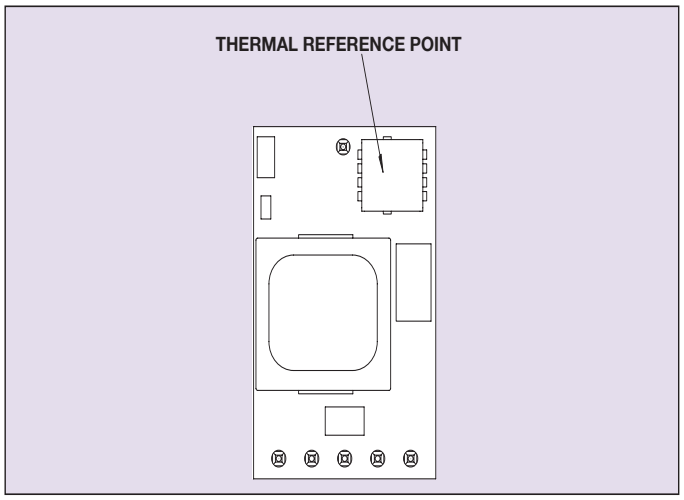


Figure 8 - LDO03C Thermal Reference Point Location Converters

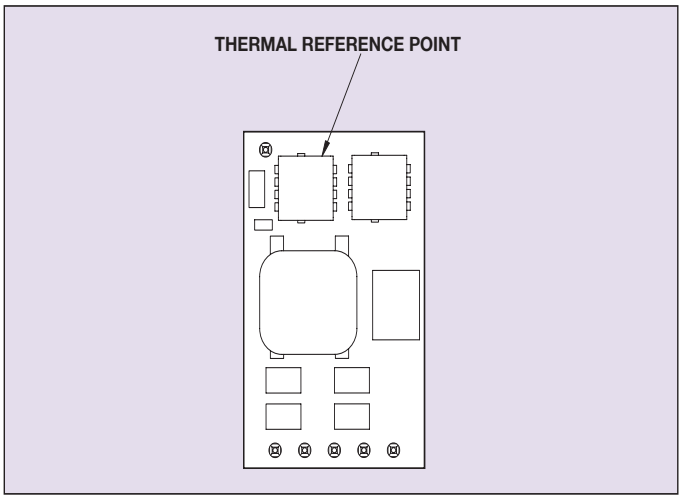


Figure 9 - LDO06C/10C Thermal Reference Point Location Converters

7.3 Output Voltage Adjustment

The output of the module can be adjusted, or trimmed, from 0.59 V to 5.1 V. This is accomplished by connecting an external resistor between the Trim pin and Ground as shown in Figure 9 or by driving the Trim pin with an external voltage as shown in Figure 10. Extremely tight setpoints can be achieved with the use of a potentiometer as shown in Figure 12.

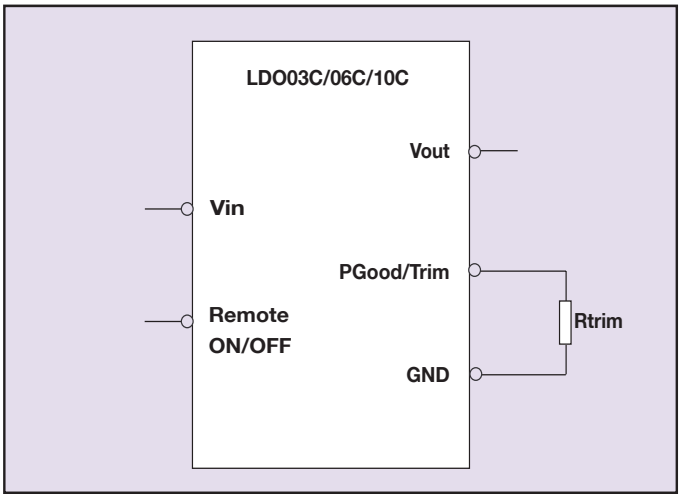


Figure 10 - Output Voltage Trim

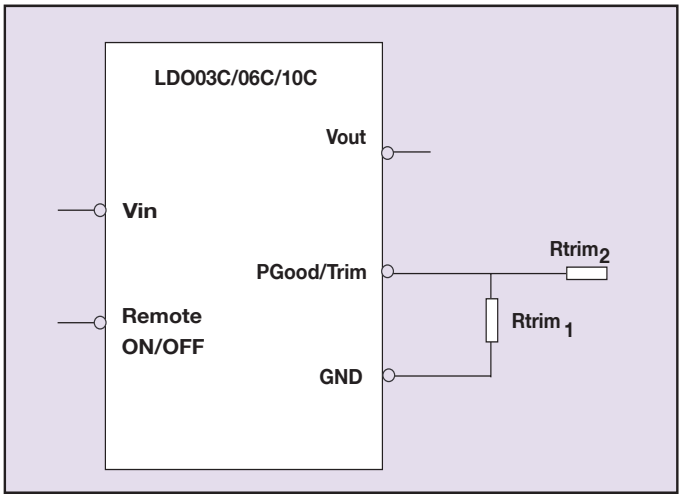


Figure 11 - Output Voltage Trim - with Voltage Source

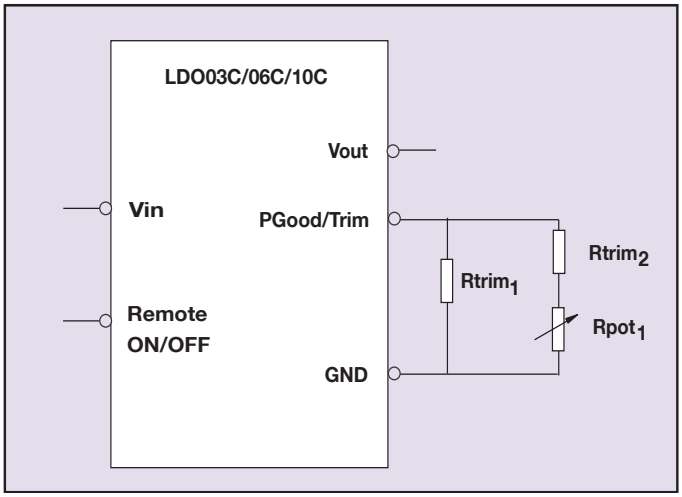


Figure 12 - Output Voltage - with Potentiometer

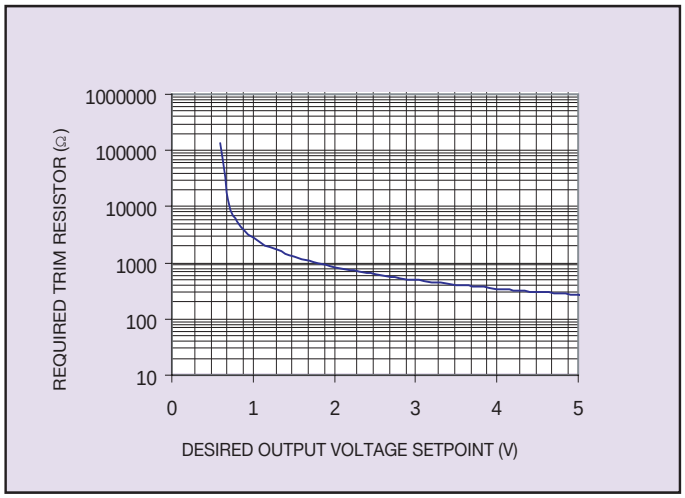


Figure 13 - Typical Trim Curve

The trim equation for the basic configuration shown in Figure 9 is:

$$Rtrim\ (k\Omega) = \frac{1.182}{(Vout - 0.591)}$$

Where Vout is the desired output voltage and Rtrim is the resistance required between the Trim pin and Ground.

The trim equation for the external voltage configuration shown in Figure 10 is:

$$R_{trim2}\ (k\Omega) = \frac{R_{trim1}(1.182 - 2Vt)}{R_{trim1}(Vout - 0.591) - 1.182}$$

Where Vout is the desired ouput voltage, Rtrim1 and Rtrim2 are the resistors in Figure 10 and Vt is the applied external voltage.

The trim equation for the potentiometer configuration show in Figure 11 is:

$$Vout = \frac{0.591}{(R_{trim2} + R_{pot})R_{trim1}} \times$$

$$(2R_{trim2} + 2R_{pot} + R_{trim1}R_{trim2} + R_{trim1}R_{pot} + 2R_{trim1})$$

Where Vout is the desired output voltage, Rtrim 1 and Rtrim2 are the resistors in Figure 11 and Rpot is the resistance of the potentiometer.

7.4 Output Capacitance

The LDOC series has output capacitors on the converter. Therefore, no external output capacitance is required for stable operation. However, when powering loads with large dynamic current requirements, improved voltage regulation can be obtained by inserting capacitors as close as possible to the load. The most effective technique is to place low ESR ceramic capacitors as close to the load as possible, using several capacitors to lower the overall ESR. These ceramic capacitors will handle the short duration high frequency components of the dynamic current requirement. In addition, higher values of electrolytic capacitors should be used to handle the mid-frequency components.

It is equally important to use good design practices when configuring the dc distribution system. Low resistance and low inductance PCB layout traces should be utilized, particularly in the high current output section. Remember that the capacitance of the distribution system and the associated ESR are within the feedback loop of the power capabilities and its resultant stability and dynamic response module. This can have an affect on the modules compensation performance. With large values of capacitance, the stability criteria depend on the magnitude of the ESR with respect to the capacitance. Note that the maximum rated value of output capacitance varies between models and for each output voltage setpoint. The reader is directed to the relevant Longform Datasheet© for details on the maximum rated value of output capacitance. However, these values only guarantee startup, not stability. A stability vs. Load Capacitance calculator, available on www.artesyn.com/powerlab, details how an external load capacitance influences the gain and phase margins of the LDO03C/06C/10C module.

Contact your local Artesyn Technologies representatve if larger output capacitance values are required in the application.

7.5 Output Ripple and Noise Measurement

The measurement set-up outlined in Figure 14 have been used for output voltage ripple and noise measurements on LDOC series converters.

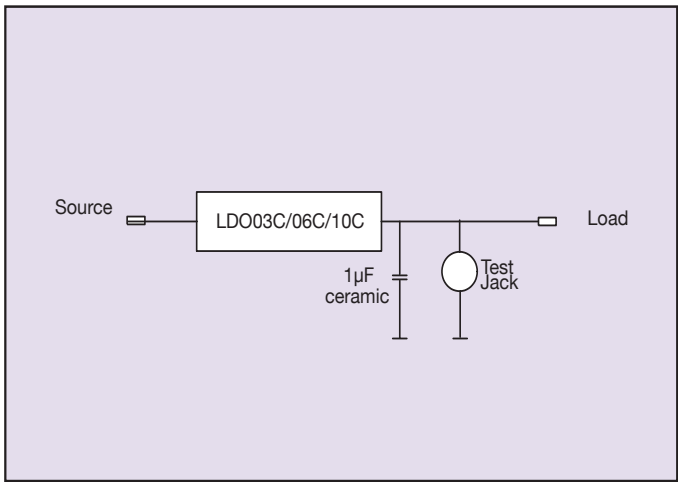


Figure 14 - Input Ripple Current with Output Current