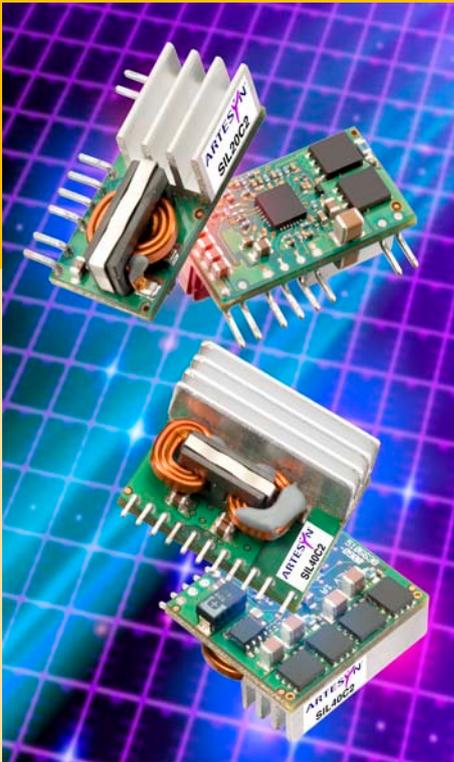


NEW

SIL40C2 Series

Application Note 189



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1. Introduction

This application note describes the features and functions of Artesyn Technologies' SIL40C2 series of high-power density, adjustable output dc-dc converters. These open-frame, 40 A output modules are available in vertical, horizontal, and surface mount versions, and are designed for use in workstation, computing, industrial, and communications applications. The SIL series offers great flexibility in board level power distribution by means of its wide output voltage range and small package size.

2. Models

The SIL40C2 series comprises 3 models, as listed in Table 1.

Model	Input Voltage	Output Voltage	Output Current
SIL40C2-00SADJ-VJ	4.5-13.8 Vdc	0.6-5 V	40 A
SIL40C2-00SADJ-HJ	4.5-13.8 Vdc	0.6-5 V	40 A
SMT40C2-00SADJJ	4.5-13.8 Vdc	0.6-5 V	40 A

Table 1 - Available SIL Models

RoHS Compliance Ordering Information



The 'J' at the end of the part number indicates that the part is Pb-free (RoHS 6/6 compliant). TSE RoHS 5/6 (non Pb-free) compliant versions may be available on special request, please contact your local sales representative for details.

Features

- 40 A current rating
- Input voltage range: 4.5-13.8 V
- Output voltage: 0.6-5 V
- Industry leading value
 - Cost optimized design
- Excellent transient response
- Output enable
- Output voltage adjustability
 - Pathway for future upgrades
 - Supports silicon voltage migration
 - Resulting in reduced design-in and qual time
- Current sink capability
- RoHS compliant

3. General Description

3.1 Electrical Description

The SIL40C2 is implemented using a voltage-mode two-phase Buck topology. A block diagram of the converter is shown in Figure 1.

The output is adjustable over a range of 0.6-5 V by using a resistor from the trim pin to ground, or by driving the TRIM pin with a voltage. Note the maximum duty cycle is 65%.

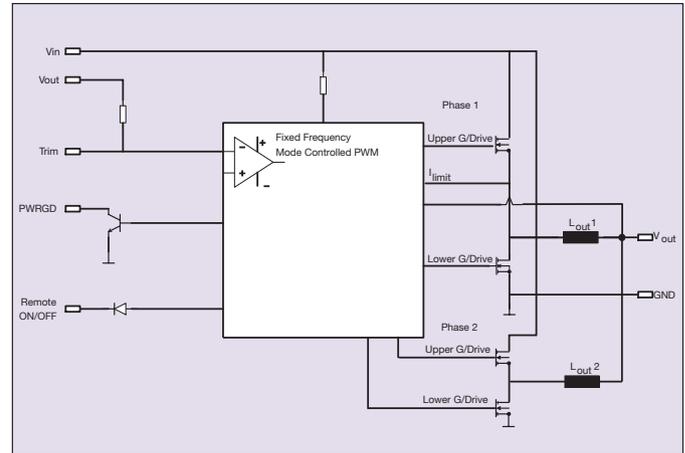


Figure 1 - Electrical Block Diagram

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 $\pm 10\%$ of its set value.

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

3.2 Physical Construction

The SIL40C2 is constructed using a multi-layer FR4 PCB. SIL 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 SIL'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 SIL40C2 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 0.6-5 V. Details on how to trim all models are provided in Section 7.3. Note the maximum duty cycle is 65%

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 undervoltage lockout is adjustable by adding a resistor between remote ON/OFF and ground per the following equation:

$$R_{en}(k\Omega) = \frac{124.8 + V_{en}}{10V_{en} - 42.06}$$

Where V_{en} is the voltage the module turns on at.

4.4 Current Limit and Short-Circuit Protection

The SIL40C2 models have a built-in non-latching current limit function and full continuous short-circuit protection. The module monitors current through the output inductor. When an overcurrent condition occurs, the module goes into hiccup mode, where it attempts to power up periodically to determine if the problem persists.

Determining the overcurrent condition is dependent on the DCR of the output inductor because the voltage drop across the inductor determines the overcurrent trip point. Also, if a high temperature situation occurs, the DCR of the inductor increases which causes the SIL40C2 to hit overcurrent. This acts as an inherent over-temperature protection, helping reduce the potential damage to the module in case of a high temperature situation.

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 SIL 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 1.2 V. To turn off the enable voltage, it must be pulled below 0.7 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, 3, and 4 show various circuits for driving the remote ON/OFF feature. If the remote ON/OFF signal originates on the primary side, 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. If the drive signal originates on the secondary side, the remote ON/OFF input can be isolated and driven through an opto-coupler.

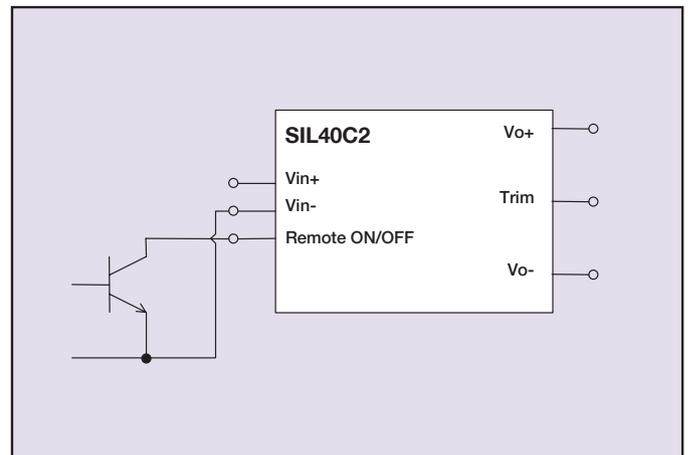


Figure 2 - Remote ON/OFF Input Drive Circuit for Non-Isolated Bipolar

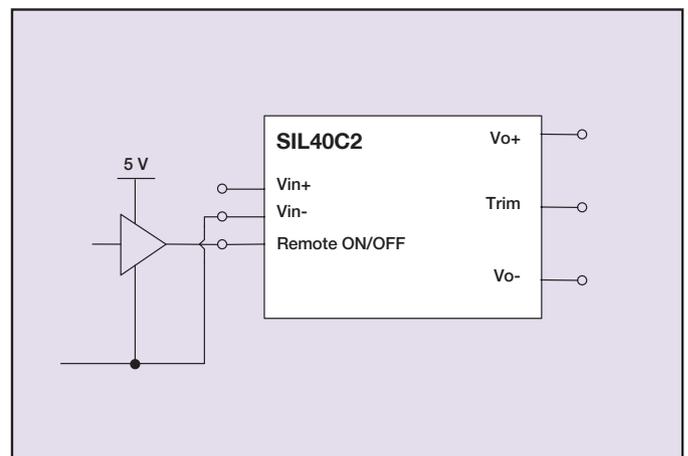


Figure 3 - Remote ON/OFF Input Drive Circuit for Logic Driver

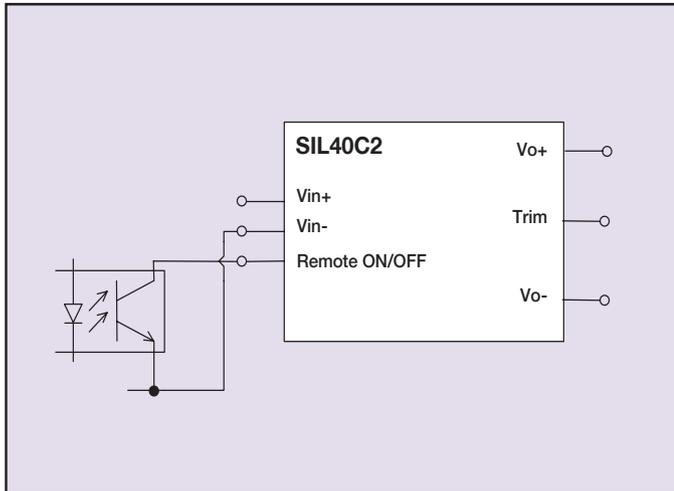


Figure 4 - Remote ON/OFF Input Drive Circuit using an Optocoupler to Maintain the Isolation Barrier from Primary to Secondary

4.6 POWER GOOD Signal

The SIL40C2 modules have a power good indicator output. This output pin uses positive logic and is open-collector. Also, the power good output is able to sink 10 mA.

When the output of the module is within $\pm 10\%$ 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:

$$V_{pgood_max} = V_{in}$$

When,

$$V_{in} < 5 \text{ V} \\ \text{or } V_{pgood_max} = 5 \text{ V}$$

When,

$$V_{in} > 5 \text{ V} \\ \text{Power Good is not available if trim option is used.}$$

5. Safety

5.1 Safety Standards and Approvals

All models have full international safety approval including EN60950 and UL/cUL60950. Please refer to the 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 SIL 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 $350 \text{ }^\circ\text{C} \pm 10 \text{ }^\circ\text{C}$ 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
$260 \text{ }^\circ\text{C} \pm 5 \text{ }^\circ\text{C}$	$10 \text{ sec} \pm 1$	Preheat $4 \text{ }^\circ\text{C}/\text{sec}$ to $160 \text{ }^\circ\text{C}$. $25 \text{ mm}/\text{sec}$ rate

Table 2 - Wave Solder Test Conditions

6.2 ESD Control

SIL 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

The SIL40C2 series has a maximum coplanarity as defined by JESD22-B108 of better than $150 \text{ } \mu\text{m}$ (approximately 0.006 inches). Innovative design, interconnect technology, and specialised manufacturing processes ensure product integrity.

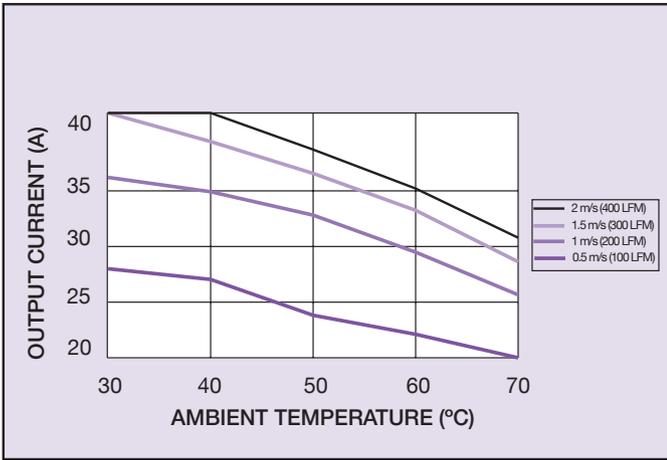


Figure 6 - Maximum Output Current vs. Ambient Temperature and Airflow for SIL40C2 with Vout Set to 5 V at 12 Vin

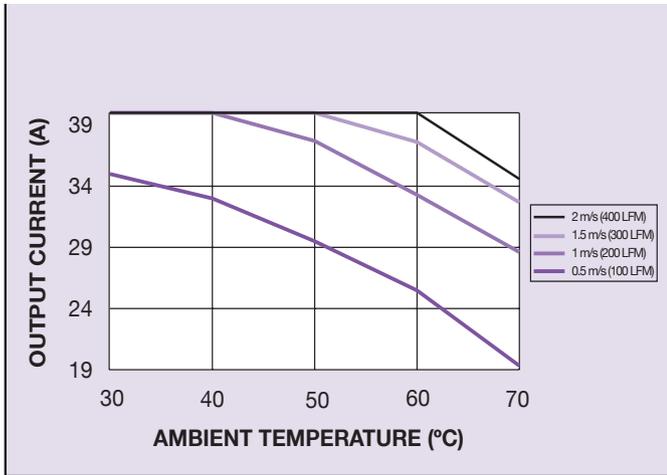


Figure 7 - Maximum Output Current vs. Ambient Temperature and Airflow for SIL40C2 with Vout Set to 0.9 V at 12 Vin

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

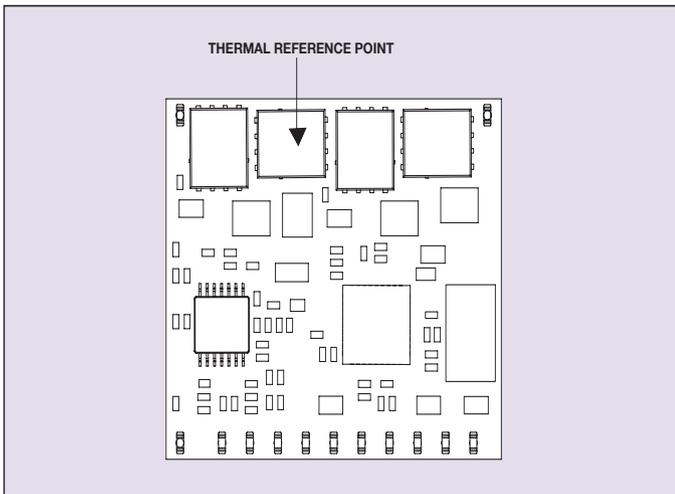


Figure 8 - Thermal Reference Point Location Converters

7.3 Output Voltage Adjustment

The output on the module is trimmable by connecting an external resistor between the TRIM pin and ground as per Figure 9 or by driving the trim pin with a voltage per Figure 11. Extremely tight setpoints can be achieved with a POT as shown in Figure 12.

The SIL40C2 module has a trim range of 0.6-5 V. A plot of trim behaviour is shown in Figure 10. Note the maximum duty cycle is 65%

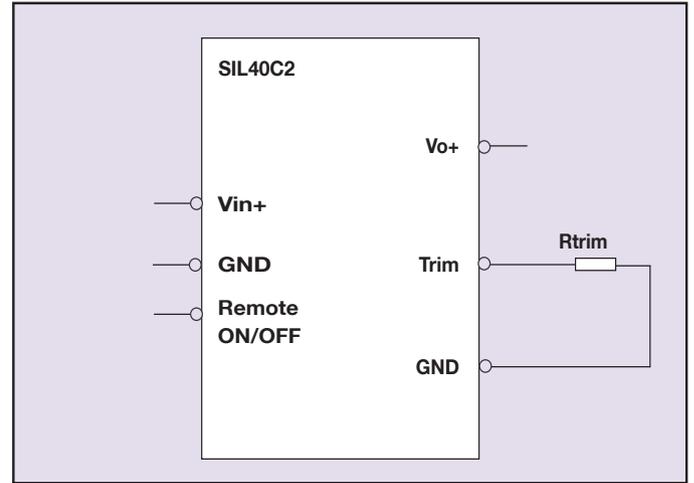


Figure 9 - Trimming Output Voltage

The resistor trim equation (reference Figure 9) for the SIL is as follows:

$$R_{trim} \text{ (k}\Omega\text{)} = \frac{1.2}{(V_{out} - 0.6)}$$

Where,

Vout is the desired voltage setpoint

Rtrim is the resistance required between TRIM and

ground. Rtrim values should not be less than 260 Ω

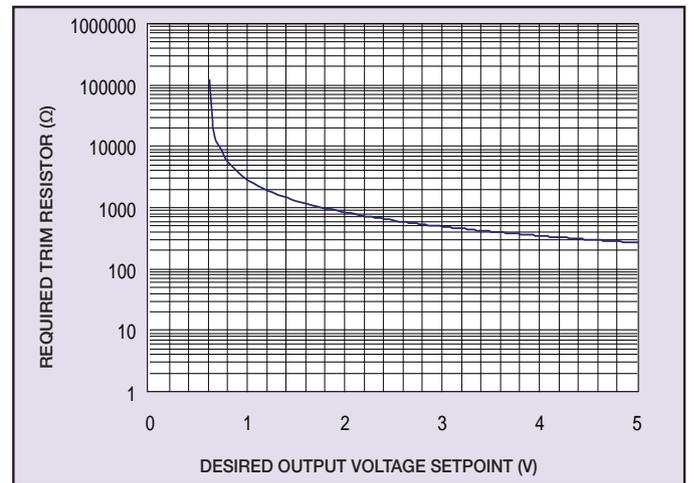


Figure 10 - Typical Trim Curves

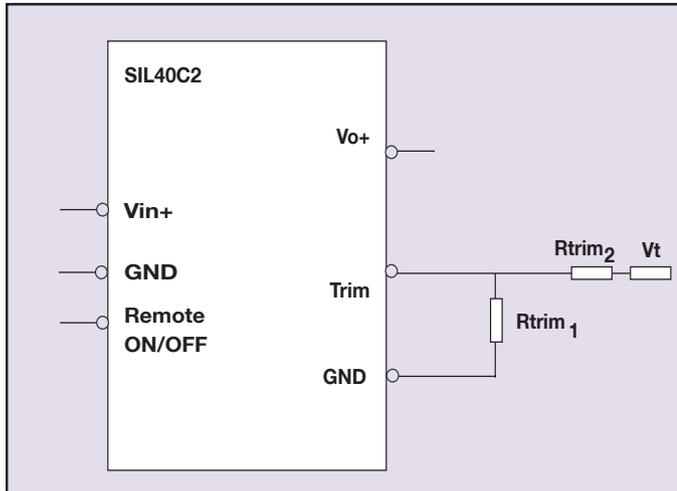


Figure 11 - Trim Output Voltage - with Voltage Source

The resistor trim equation with voltage (Reference Figure 11) for the SIL40C2 is as follows:

$$R_{trim2} \text{ (k}\Omega\text{)} = \frac{R_{trim1}(1.2 - 2V_t)}{R_{trim1}(V_{out} - 0.6) - 1.2}$$

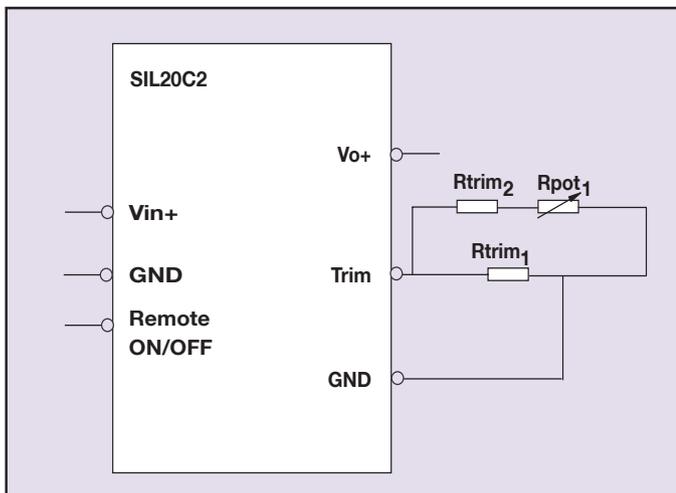


Figure 12 - Trim Output Voltage - with POT

The voltage trim equation using a POT (Reference Figure 12) is as follows:

$$V_{out} = \frac{0.6}{(R_{trim2} + R_{pot})R_{trim1}} \times (2R_{trim2} + 2R_{pot} + R_{trim1}R_{trim2} + R_{trim1}R_{pot} + 2R_{trim1})$$

7.4 Output Capacitance

The SIL series does not have output capacitors on the converter. Therefore, no external output capacitance is required for stable operation. Also, 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 locate 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 effect on the module's 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. 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 allowable load capacitance for each model and setpoint. 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 SIL40C2 module.

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

7.5 Output Ripple and Noise Measurement

The measurement set-up outlined in Figure 13 has been used for output voltage ripple and noise measurements on SIL series converters.

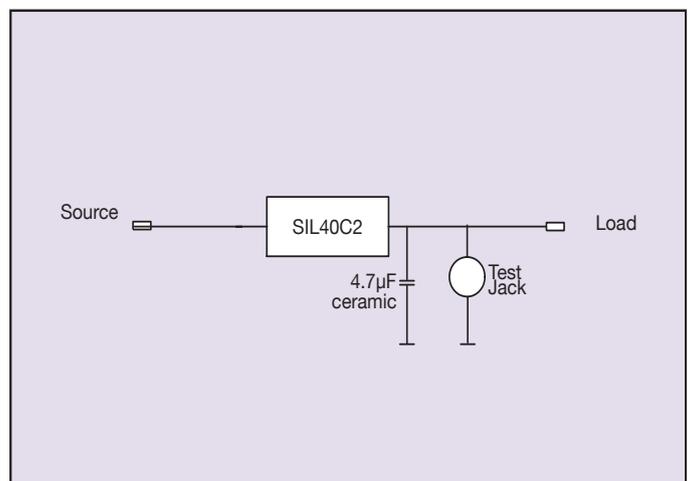


Figure 13 - Input Ripple Current with Output Current