NEW Product

SIL06C/SIL15C/SIL20C

Application Note 131

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RoHS 2002/95/EC

ARTESYN TECHNOLOGIES

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1. Introduction

This application note describes the features and functions of Artesyn Technologies' SIL06C/SIL15C/SIL20C series of high power density single adjustable output dc-dc converters. These open-frame 6 A, 15 A and 20 A modules are available in both vertical and horizontal 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 when compared to standard brick solutions.

2. Models

The SIL series comprises 4 models, as listed in Table 1 .

Model	Input Voltage	Output Voltage	Output Current
SIL06C-05SADJ-VJ	4.5-5.5 Vdc	0.9-3.3 Vdc	6 A
SIL06C-12SADJ-VJ	10.2-13.8 Vdc	0.9-5.0 Vdc	6 A
SIL15C-05SADJ-VJ	4.5-5.5 Vdc	0.9-3.3 Vdc	15 A
SIL15C-12SADJ-VJ	10.2-13.8 Vdc	0.9-5.0 Vdc	15 A
SIL20C-05SADJ-VJ	4.5-5.5 Vdc	0.9-3.3 Vdc	20 A
SIL20C-12SADJ-VJ	10.2-13.8 Vdc	0.9-5.0 Vdc	20 A

*The standard unit with the suffix '-V' is for vertical mounting. To order a unit with horizontal mounting, please add the suffix '-H' to the model number, e.g. SIL06C-12SADJ-HJ.

Table 1 - Available SIL06C, SIL15C and SIL20C Models

RoHS Compliance Ordering Information

RoHS 2002/95/EC

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

- Wide output voltage trim (0.9 V to 3.3/5.0 V)
- Horizontal and vertical mount versions available
- Power good output signal (open collector)
- Input undervoltage lockout
- Current sink capabilities for termination applications at output voltage settings up to and including 2. V
- Remote ON/OFF
- No minimum load requirement
- Non-latching over current protection
- Compact footprint, vertical and horizontal options
- 5 V and 12 V input options
- Available RoHS compliant

3. General Description

3.1 Electrical Description

The SIL06C/SIL15C/SIL20C is implemented using a voltage-mode controlled Buck/Boost topology. A block diagram is shown in Figure 1. The output is adjustable over a range of 0.9 V to 5.0 V by using a resistor from the trim pin to ground.

The converter can be shut down via a remote ON/OFF input. The input runs with positive logic that is compatible with popular logic devices. Positive logic implies that the converter is enabled if the remote ON/OFF pin is left high (or floating) and is disabled if pulled low.

The power good signal is an open collector output that is pulled low by pwm controller when it detects the output is not within ±10% of its set value. This pin is pulled high when the output voltage is within this range.

The converter is also protected for overcurrent and short circuit conditions on the output. The current in the upper FET is monitored by measuring the voltage drop across the upper FET during the on-time and when the pwm controller detects an overcurrent condition it forces the converter into a hiccup mode.

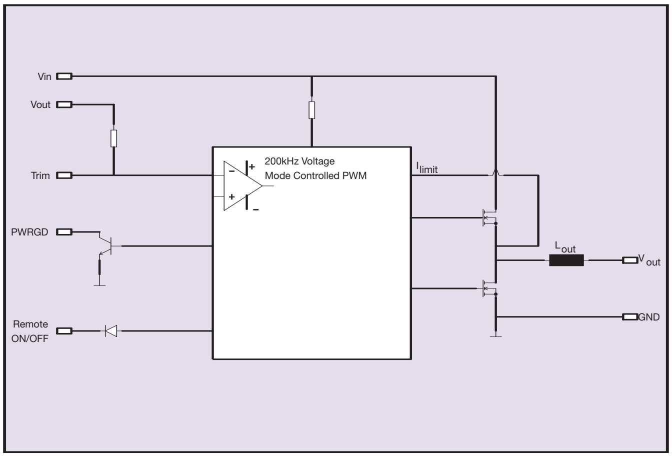


Figure 1 - Electrical Block Diagram

3.2 Physical Construction

The SIL06C/SIL15C/SIL20C is constructed using a multi-layer FR4 PCB. SMT 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 re-cycled
- **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 SIL06C/SIL15C/SIL20C modules have a nominal operating temperature range of 0 °C to 50 °C but this can be extended to 80 °C if suitable derating and/or forced air cooling is used. A number of de-rating curves for each model at several output voltage setpoints are included in the long form data sheet for that model. Thermal performance is discussed further in Section 7.2.

4.2 Output Voltage Adjustment
The output voltage setpoint may be trimmed by connecting an external resistor between TRIM and output ground or by driving TRIM with a voltage. Details on how to trim all models are provided in Section 7.3

4.3 Undervoltage Lockout
The modules in this line have built in undervoltage lockout to ensure reliable output power. The lockout prevents the unit from operating when the input voltage is too low.

The 5 V models have a range of 4.5 V to 5.5 V with UV lockout occurring between 4.2 V to 4.4 V. The 12 V models will operate from 10.2 V to 13.8 V with UV lockout occurring between 7.3 V to 7.7 V. This allows more flexibility in designing and ensures operation on supply lines with large tolerances.

4.4 Current Limit and Short-Circuit Protection
The SIL06C/SIL15C/SIL20C series of converters has built-in non-latching overcurrent and short-circuit protection. The module monitors the current through the top FET on the output of the converter. 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 an overcurrent condition is dependent on the Rdson of the top FET because the voltage drop across the FET determines the overcurrent trip point. Also, if a high temperature situation occurs, the Rdson of the FET increases which causes the SIL06C/SIL15C/SIL20C to hit overcurrent. This acts as an inherent overtemperature protection, helping reduce the potential damage to the module in case of a high temperature situation.

Note that none of the modules specifications is guaranteed when the unit is operated in an over-current 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. The remote ON/OFF function on the 6 A and 15 A modules is active high.

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 2.4 V and to turn off the enable voltage must be pulled below 0.8 V.

Figures illustrating the response of the unit to switching on and off using the remote ON/OFF feature are included in the long form data sheet for that 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 optocoupler.

To simplify the design of the external control circuit, logic signal thresholds are specified over the full temperature range. The maximum remote ON/OFF input open circuit voltage, as well as the acceptable leakage currents, are specified in the relevant Longform Datasheet.

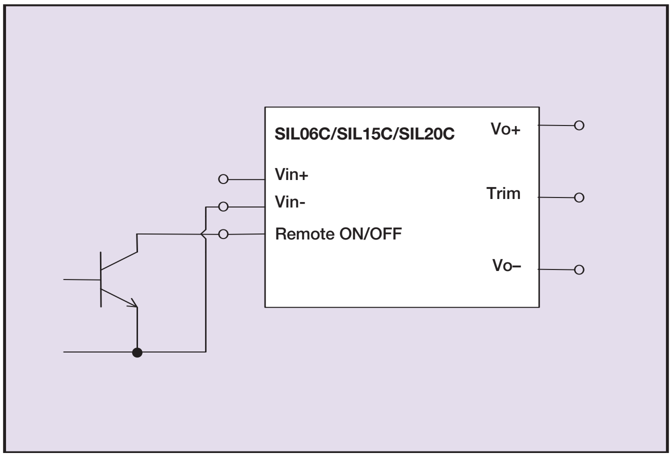


Figure 2 - Remote ON/OFF Input Drive Circuit for Non-Isolated Bipolar

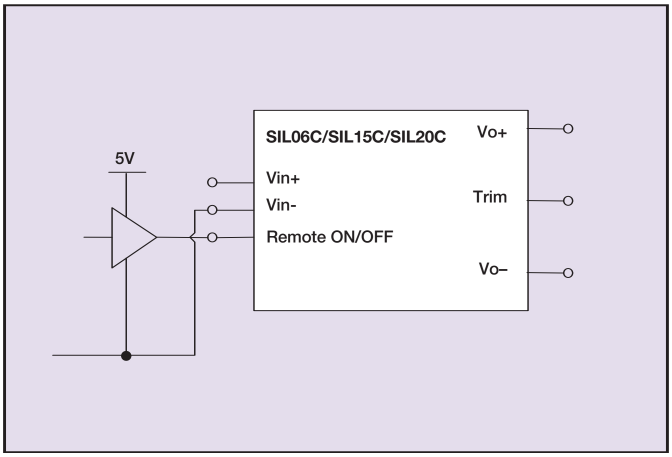


Figure 3 - Remote ON/OFF Input Drive Circuit for Logic Driver

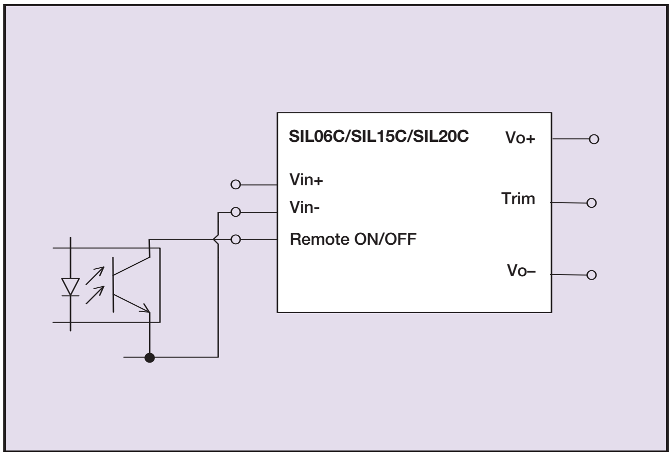


Figure 4 - Remote ON/OFF Input Drive Circuit using an Optocoupler to maintain the isolation barrier from primary to secondary

4.6 Current Sink Capabilities

The SIL06C/SIL15C/SIL20C line of dc-dc converters is able to current sink as well as a current source. It is able to sink the full 6 A/15 A of current at any output voltage up to and including 2.5 V. This feature allows the SIL06C/SIL15C/SIL20C series fit into any voltage termination application.

4.7 POWER GOOD Signal

The SIL06C/SIL15C/SIL20C series 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 5 mA.

When the output of the module is within ±10% of the nominal set point, the power good pin is set high. Plots showing how the power good signal behaves when the remote ON/OFF feature is used to turn the module on and off are included in that models longform datasheet.

5. Safety

5.1 Input Fusing

It is recommended the user provide a fuse in the input line. The amperage rating of the fuse will depend on the output voltage setpoint and the output current in the application. Please consult the factory for details.

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 section 7. A soldering iron set to 350 °C ±10 °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 °C±5 °C	10sec±1	Preheat 4 °C/sec to 160 °C. 25 mm/sec rate

Table 2 - Wave Solder Test Conditions

6.2 Water Washing

Where possible, a no-clean solder paste system should be used for solder attaching the SIL product onto application boards. The SIL is suitable for water washing applications, because it does not have entrapment areas where water and residues may become trapped long term. However, the user must ensure that the drying process is sufficient to remove all water from the converter after washing - never power the converter unless it is fully dried. The user's process must clean the soldered assembly in accordance with ANSI/J-STD-001.

6.3 ESD Control

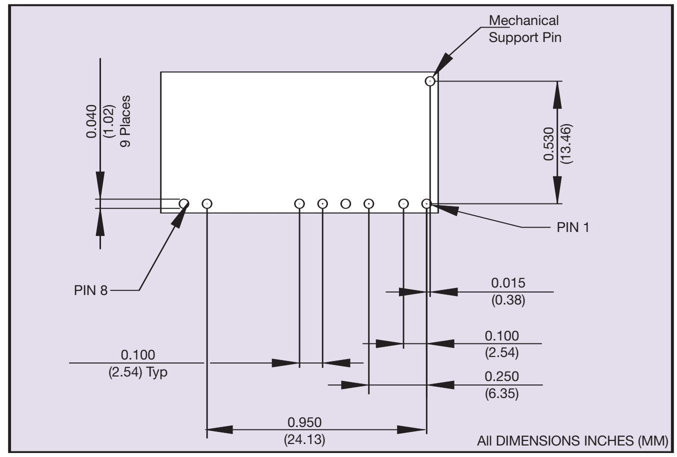
SIL units are manufactured in an ESD controlled environment and supplied in conductive packaging to prevent ESD damage occurring before or during shipping. It is essential that they are unpacked and handled using approved ESD control procedures. Failure to do so could affect the lifetime of the converter.

7. Applications

7.1 PCB Layout

The pin diagrams for the 6 A, 15 A and 20 A models are detailed in Figures 5a, 5b, 5c and 5d.

VIEW IS FROM TOP SIDE

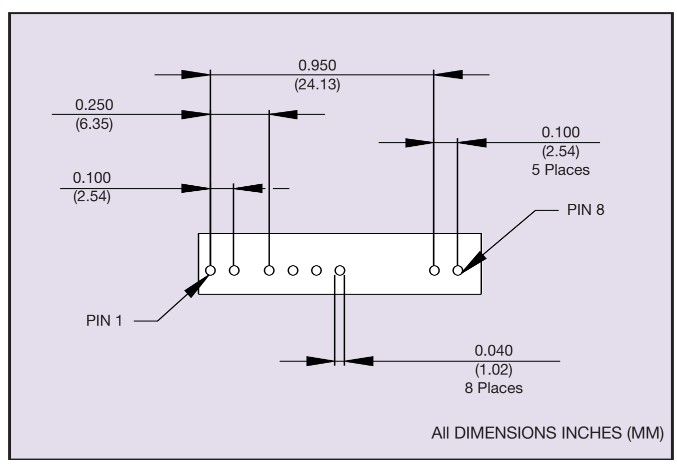


THERMAL RELIEF IN CONDUCTOR PLANES
REFERENCE IPC-D-275 SECTION 5.3.2.3

ALL DIMENSIONS IN INCHES (mm)
ALL TOLERANCES ARE ±0.004 (0.10)

Figure 5a - SIL06C-12SADJ-HJ Recommended Footprints

VIEW IS FROM TOP SIDE

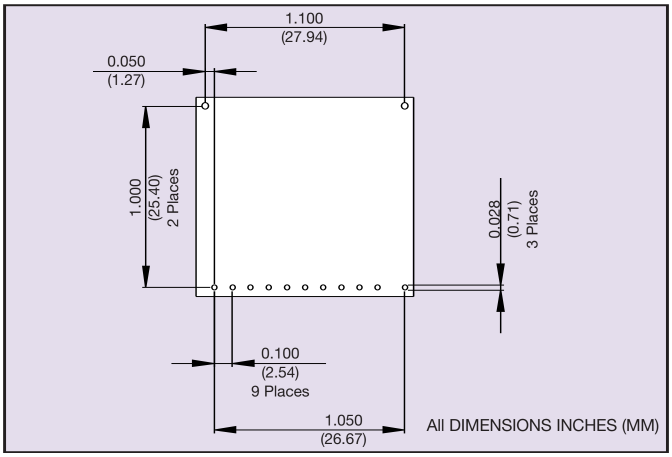


THERMAL RELIEF IN CONDUCTOR PLANES
REFERENCE IPC-D-275 SECTION 5.3.2.3

ALL DIMENSIONS IN INCHES (mm)
ALL TOLERANCES ARE ±0.004 (0.10)

Figure 5b - SIL06C-12SADJ-VJ Recommended Footprints

VIEW IS FROM TOP SIDE

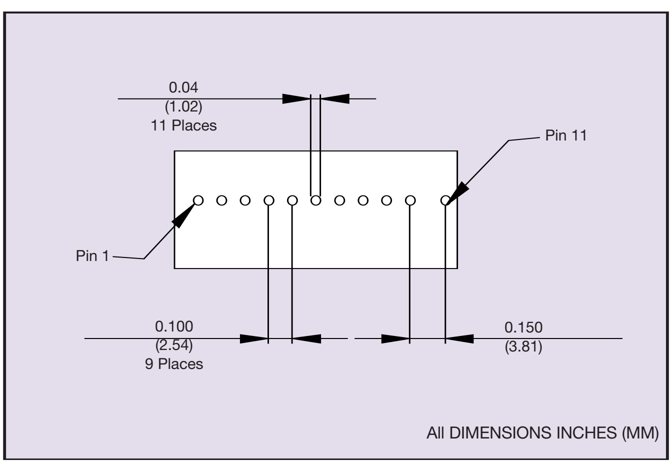


THERMAL RELIEF IN CONDUCTOR PLANES
REFERENCE IPC-D-275 SECTION 5.3.2.3

ALL DIMENSIONS IN INCHES (mm)
ALL TOLERANCES ARE ±0.004 (0.10)

Figure 5c - SIL15C-12SADJ-HJ and SIL20C-12SADJ-HJ Recommended Footprints

VIEW IS FROM TOP SIDE



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

ALL DIMENSIONS IN INCHES (mm)
ALL TOLERANCES ARE ±0.004 (0.10)

Figure 5d - SIL15C-12SADJ-VJ and SIL20C-12SADJ-HJ Recommended Footprints

7.2 Thermal Performance

The electrical operating conditions of the SIL, 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, 7, 8, 9, 10 and 11. These derating graphs show the load current of the SIL 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 80 °C. Please contact Artesyn Technologies for further support.

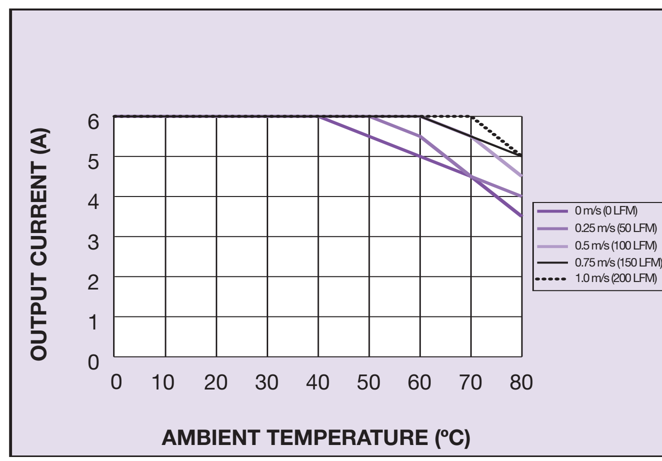


Figure 6 - Maximum Output Current vs. Ambient Temperature and Airflow for SIL06C-12SADJ with Vout set to 0.9 V

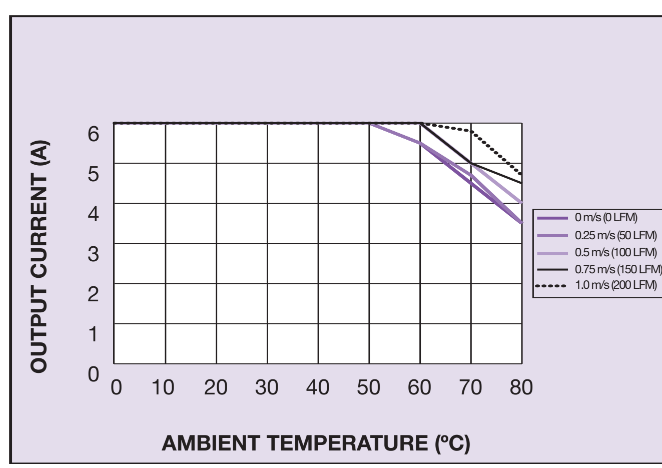


Figure 7 - Maximum Output Current vs. Ambient Temperature and Airflow for SIL06C-12SADJ with Vout set to 5 V

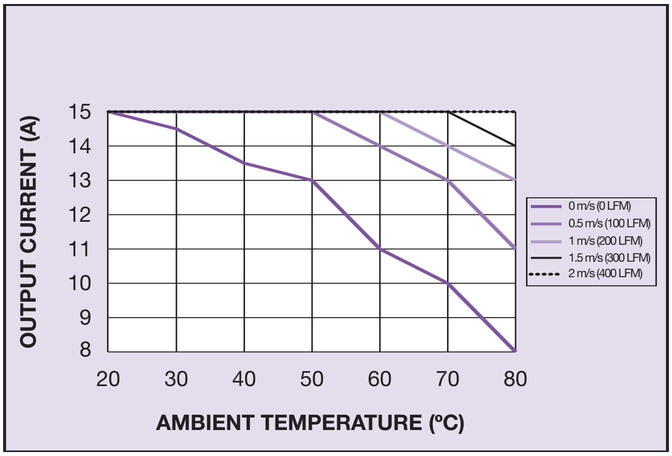


Figure 8 - Maximum Output Current vs. Ambient Temperature and Airflow for SIL15C-12SADJ with Vout set to 0.9 V

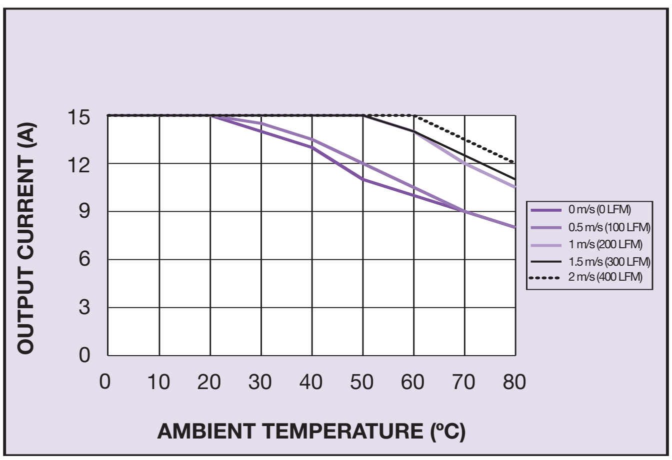


Figure 9 - Maximum Output Current vs. Ambient Temperature and Airflow for SIL15C-12SADJ with Vout set to 5 V

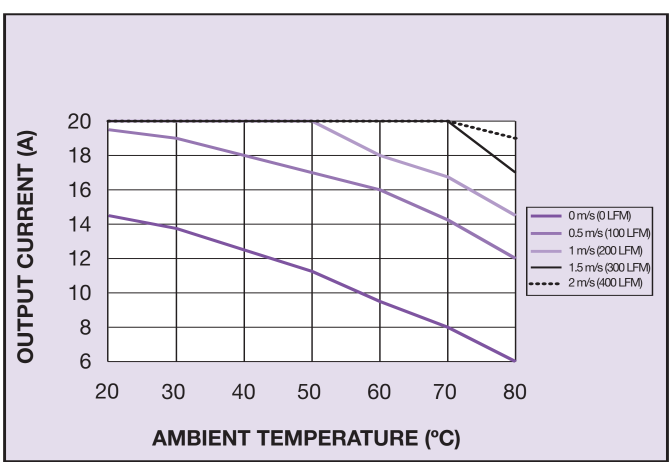


Figure 10 - Maximum Output Current vs. Ambient Temperature and Airflow for SIL20C-12SADJ with Vout set to 0.9 V

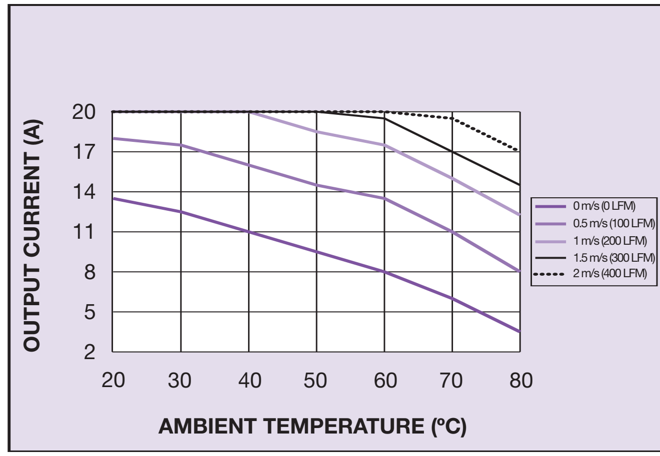


Figure 11 - Maximum Output Current vs. Ambient Temperature and Airflow for SIL20C-12SADJ with Vout set to 5 V

The maximum acceptable temperature measured at the thermal reference point is 100 ºC. This is shown in figures 12a and 12b

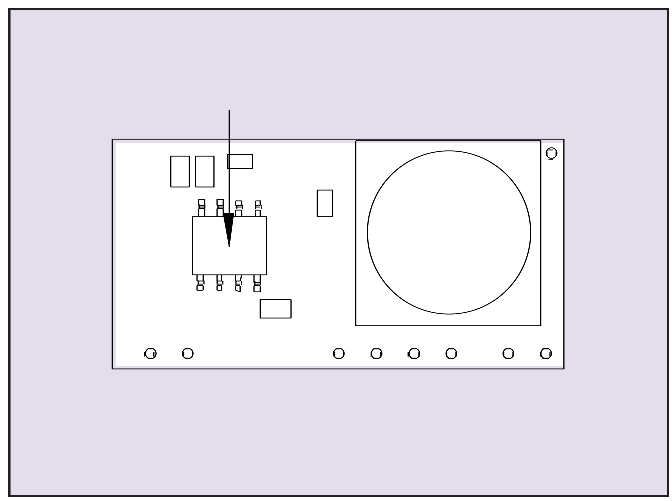


Figure 12a - Thermal Reference Point Location on SIL06C Converters

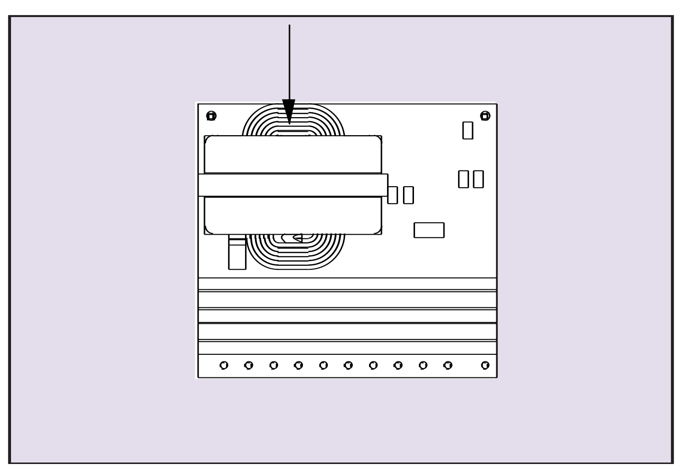


Figure 12b - Thermal Reference Point Location on SIL15C and SIL20C Converters

7.3 Output Voltage Adjustment
The output on all models is trimmable by placing a resistor between the trim pin on the module and ground as per Figure 13 or by driving the trim pin with a voltage as per figure 15.

The 5 V models have an output voltage range of 0.9 V to 3.3 V and the 12 V models have a range of 0.9 V to 5 V. If no trim resistor or voltage is added, then the module output is set to the minimum voltage. A plot of the trim behavior is shown in Figure 14.

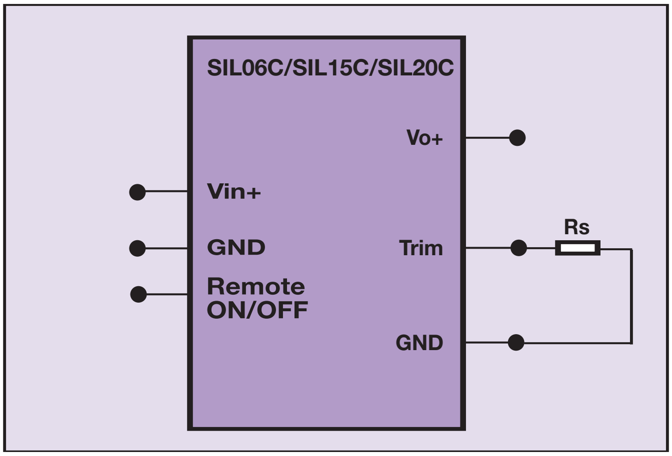


Figure 13 - Trimming Output Voltage using External Resistor

The trim resistor set equation for the SIL is as follows:

$$\text{Rset (k}\Omega\text{)} = \frac{1.17}{Vout - 0.9}$$

Where,

Vout	is the required voltage setpoint
Rset	is the resistance required between TRIM and ground
5 V inputs	Rset values should not be less than 485 Ω
12 V inputs	Rset values should not be less than 280 Ω

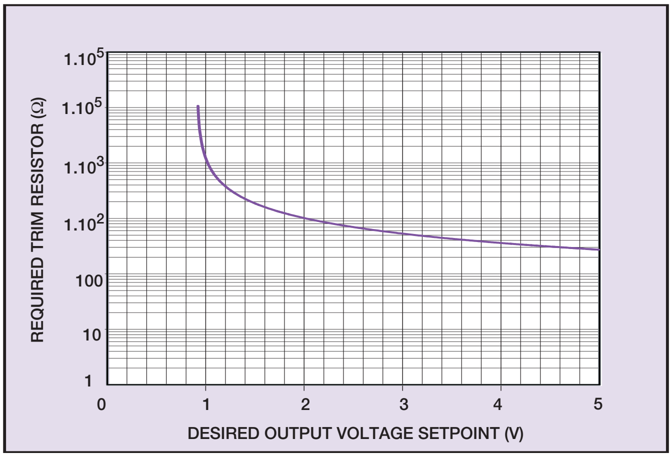


Figure 14 - Typical Trim Curves

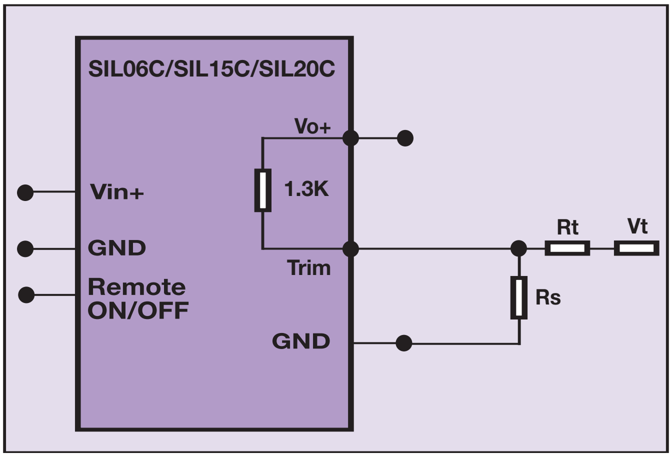


Figure 15 - Trim Output Voltage - with Voltage Source

The voltage trim equation with example for the SIL is as follows:

Example:
Set Vt = 1.25 V

Vt = 1.25 V Vout = 5 V Rs = 0.280 kΩ

$$\text{Rt(k}\Omega\text{):} = \frac{\text{Rs}\,(1.3\text{Vt} - 1.17)}{1.17 - \text{Rs}\,(\text{Vout} - 0.9)}$$

Rt = 5.791 kΩ

7.4 Parallel Operation
Parallel operation of multiple SIL converters is not recommended. If unavoidable, ORing diodes or FETs must be used to decouple the outputs. It should be noted that this measure will adversely affect power conversion efficiency.

7.5 Output Capacitance
The SIL series does not have output capacitors on the converter. Therefore, an external output capacitor 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 module. This can have an effect on the modules compensation capabilities and its resultant stability and dynamic response 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 long form data sheet for details on the maximum allowable load capacitance for each model and setpoint. However, these values only guarantee start-up, 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 SIL module.

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

7.6 Reflected Ripple Current and Output Ripple and Noise Measurement

The measurement set-up outlined in Figure 16 has been used for both input reflected/terminal ripple current and output voltage ripple and noise measurements on SIL06C AND SIL15C series converters. One 270 μF Oscon capacitor is needed for the SIL06C and SIL15C. Two 270 μF Oscon capacitors are needed on the input of the SIL20C as shown in Figure 17

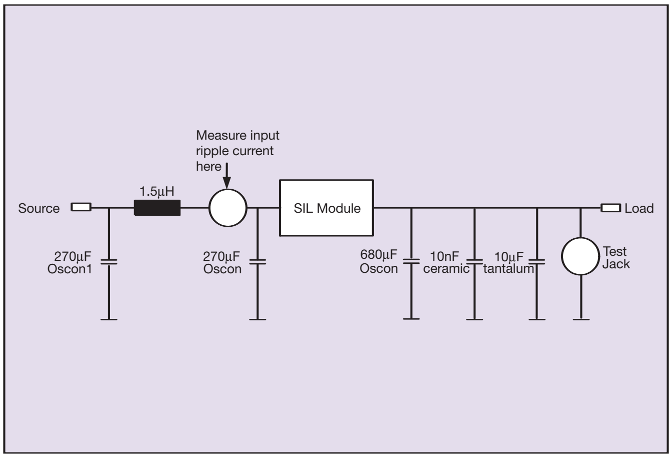


Figure 16 - Input Reflected Ripple/Capacitor Ripple Current and Output Voltage Ripple and Noise Measurement Set-Up for SIL06C and SIL15C

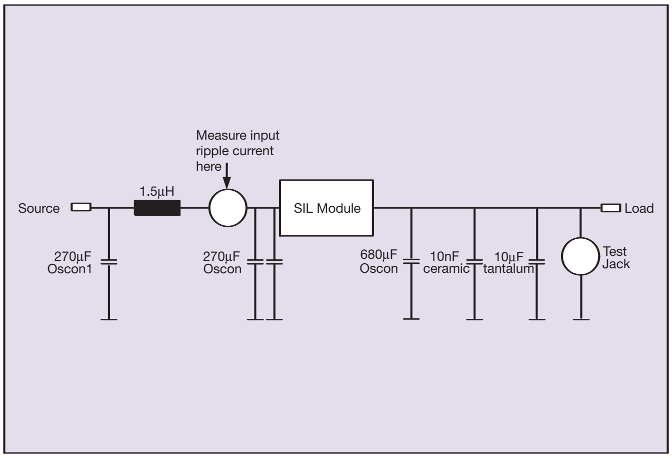


Figure 17 - Input Reflected Ripple/Capacitor Ripple Current and Output Voltage Ripple and Noise Measurement Set-Up for SIL20C

7.7 Input Ripple Current Capacitor Requirements

Care must be taken when selecting the external input capacitor. The equation below calculates the input ripple current for a particular model and output voltage setpoint. The selected input capacitor must be capable of supporting this ripple current. Figure 17 shows the variation of input ripple current with output current.

$$\text{Iripple} = \text{Iout}\sqrt{\frac{D}{\text{Efficiency}} \times \left(1 - \frac{D}{\text{Efficiency}}\right)} \quad \text{where } D = \frac{\text{Vout}}{\text{Vin}}$$

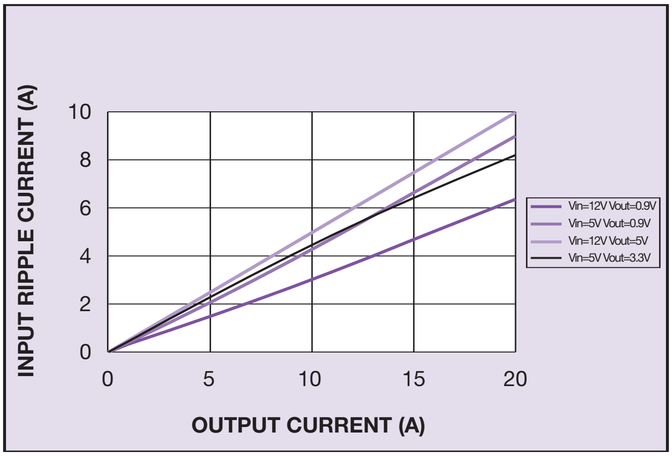


Figure 18 - Input Ripple Current with Output Current