



SMT10E Single

Application Note 168



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1. Introduction

This application note describes the features and functions of Artesyn Technologies' SMT10E series of surface-mountable high power density, single DC/DC converters. These Point of Load modules are targeted specifically at the fixed and mobile telecommunications, industrial electronics and distributed power markets.

The SMT10E is available with an output range of 0.8V to 3.63V and can operate over an ambient temperature range of -40°C to $+100^{\circ}\text{C}$. Ultra-high efficiency operation is achieved through the use of synchronous rectification and control techniques. The modules are fully protected against short-circuit and over-temperature conditions. Standard features include remote on/off and remote sense.


The series has been designed primarily for telecommunication applications. Automated manufacturing methods, together with an extensive qualification program, ensure that all SMT10E series converters are extremely reliable.

2. Models

The SMT10E series comprises of 6 models, as listed in Table 1.

Model	Input Voltage	Output Voltage	Output Current
SMT10E-05S1V2J	3.0-5.5 Vdc	1.2 V	10 A
SMT10E-05S1V5J	3.0-5.5 Vdc	1.5 V	10 A
SMT10E-05S1V8J	3.0-5.5 Vdc	1.8 V	10 A
SMT10E-05S2V5J	3.0-5.5 Vdc	2.5 V	10 A
SMT10E-05S3V3J	4.5-5.5 Vdc	3.3 V	10 A
SMT10E-05W3V3J	3.0-5.5 Vdc	3.3 V	10 A

Table 1 - SMT10E Models

RoHS Compliance Ordering Information	
	<p>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.</p>

Features

- Ultra high efficiency: 96% at 5V_{in} and 3.3V_{out}
- Industry standard footprint
- Wide ambient temperature range, -40°C to $+100^{\circ}\text{C}$
- $\pm 10\%$ output voltage adjustability on all output setpoint models or wide trim model available
- No minimum load requirement
- Remote ON/OFF
- Remote sense compensation
- Fixed switching frequency
- Continuous short-circuit protection
- Overtemperature protection (OTP)
- Available RoHS compliant

3. General Description

3.1 Electrical Description

A block diagram of the SMT10E converter is shown in Figure 1. Extremely high efficiency power conversion is achieved through the use of synchronous rectification techniques.

The POL topology is a non-isolated three terminal synchronous buck converter. The control of the synchronous rectifiers are optimised for high efficiency power conversion.

The output is adjustable over a range of -75% to 10% of the nominal output voltage, using the TRIM pin. This is available on the SMT10E-05W3V3J model. All other output setpoints are indicated by 'S' e.g SMT10E-05S3V3J and have a $\pm 10\%$ trim range.

The converter can be shut down via a remote ON/OFF input that is referenced to ground. This input is compatible with popular logic devices; a 'negative' logic input is supplied as standard. Negative logic implies that the converter is enabled if the remote ON/OFF input is low (or floating), and disabled if it is high.

The converter is also protected against over-temperature conditions. If the converter is overloaded or the ambient temperature gets too high, the converter will shut down until the temperature falls below a minimum threshold. There is a thermal hysteresis of typically 120°C to 115°C , to protect the unit.

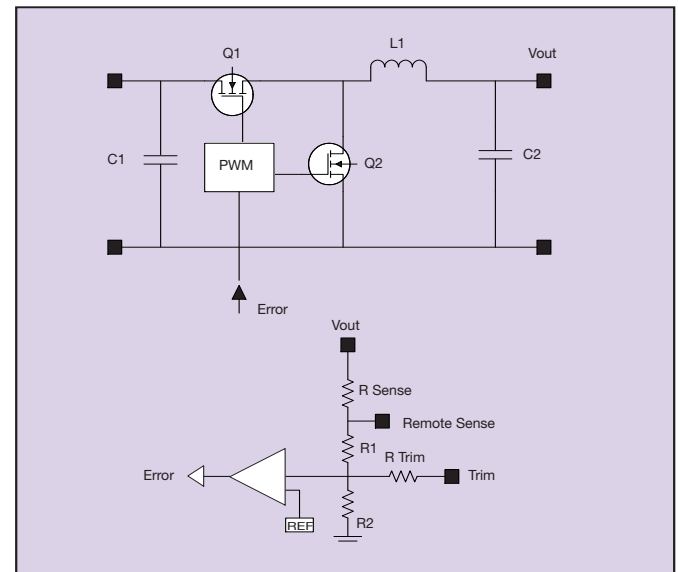


Figure 1 - Electrical Block Diagram

3.2 Physical Construction

The SMT10E 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.

- **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 SMT10E'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
- Target application PCB design, especially ground planes. These can be effective heatsinks for the converter

The SMT10E can be operated from -40°C to a maximum ambient temperature of $+100^{\circ}\text{C}$. A number of design graphs are included in Figures 8, 9 and 10 to simplify the design task and allow the power system designer to determine the maximum output current at which the SMT10E module may be operated for a given ambient temperature and airflow.

4.2 Over-Temperature Protection (OTP)

The SMT10E is equipped with non-latching over-temperature protection. A temperature sensor monitors the temperature of the top switch. If the temperature exceeds a threshold of 120°C (typical) the converter will shut down, disabling the output. When the case temperature has decreased by between 5°C and $+10^{\circ}\text{C}$ the converter will automatically restart.

The SMT10E might experience over-temperature conditions during a persistent overload on the output. Overload conditions can be caused by external faults. OTP might also be entered due to a loss of control of the environmental conditions (e.g. an increase in the converter's ambient temperature due to a failing fan).

4.3 Output Voltage Adjustment

The output voltage on all models is trimmable from -10% to $+10\%$ of the nominal voltage setpoint. Details on how to trim all models are provided in Section 7.3. A wide trim model is also available that allows the user to trim from -75% to $+10\%$ of the output setpoint. This model is the SMT10E-05W3V3J.

4.4 Safe Operating Area

The Safe Operating Area (SOA) of the SMT10E converter is shown in Figure 2. Assuming the converter is operated within its thermal limits it can deliver rated output current I_{rated} .

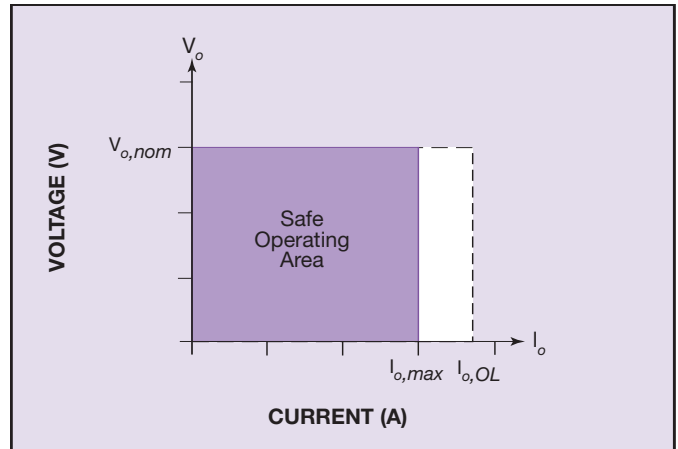


Figure 2 - Maximum Output Current Safe Operating Area

It should be noted that the SOA shown in Figure 2 is valid only if the converter is operated within its thermal specification. See Section 7.1 for more details.

4.5 Short Circuit Protection

All SMT10E models have a full continuous short-circuit protection. The unit will auto recover once the short circuit is removed. The unit is protected only against extreme short circuits.

The unit is protected in an overload condition by the OTP function. However, we do not recommend operating the unit in a heavy overload condition as it results in the converter's lifetime being reduced.

4.6 Remote ON/OFF

The remote ON/OFF input allows external circuitry to put the SMT10E converter into a low dissipation sleep mode.

The SMT10E features a 'Negative Logic' Remote ON/OFF operation. If not using the Remote ON/OFF pin, leave the pin open (the converter will be on). The Remote ON/OFF pin is referenced to ground.

Configuration	Converter Operation
Remote pin open circuit	Unit is ON
Remote pin pulled low	Unit is ON
Remote pin pulled high [$V_{\text{on/off}} > 1.2\text{V}$]	Unit is OFF

A 'Positive Logic' Remote ON/OFF version is also possible with this converter. To order please place the suffix '-R' at the end of the model number, e.g. SMT10E-05W3V3-RJ.

Configuration	Converter Operation
Remote pin open circuit	Unit is ON
Remote pin pulled low	Unit is OFF
Remote pin pulled high [$V_{\text{on/off}} > 1.2\text{V}$]	Unit is ON

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 SMT10E Longform Datasheet. The remote ON/OFF input can be driven as shown in Figure 3.

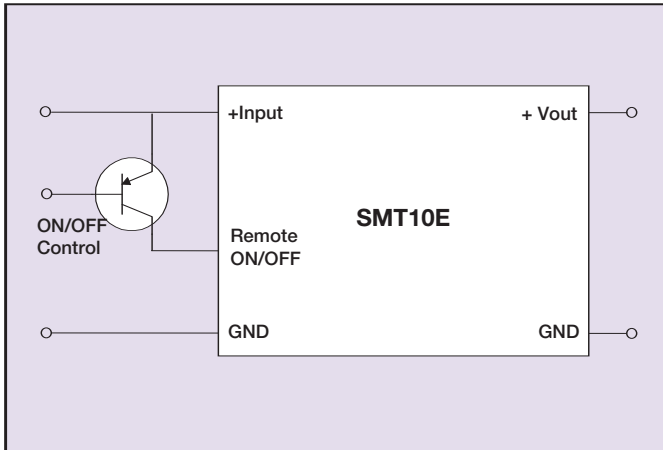


Figure 3 - Remote ON/OFF Input Drive Circuit for Non-Isolated Bipolar

5. Safety

5.1 Input Fusing

In order to comply with safety requirements, the user must provide a fuse in the unearthed input line. The reason for putting the fuse in the unearthed line is to avoid earth being disconnected in the event of a failure.

A 12.5 Amp slow-blow/anti-surge HRC (High Rupture Capacity) fuse should be used for all models.

Recommended Fuse: A - S(T) 1.25 x 0.25 inches
SIBA 70-065/65/12.5ARS.

6. Use in a Manufacturing Environment

6.1 PCB Layout Considerations

It is recommended that the customer uses a solder mask defined land pattern similar to that shown in the following figure.

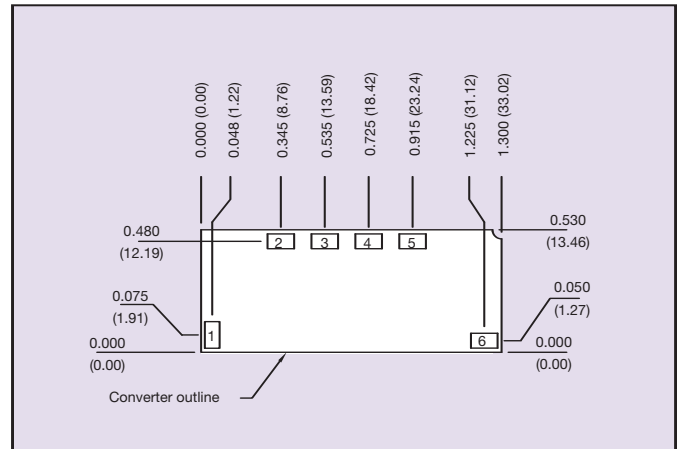


Figure 4 - Recommended Land Pattern for SMT10E

The minimum recommended pad size is 0.140 x 0.095in (3.56 x 2.41mm) and the maximum pad size is 0.165 x 0.110in (4.19 x 2.79mm).

As a surface-mount power component, interconnection to internal power planes will typically be required. This is accomplished by placing a number of vias between the SMT pad and the relevant plane. The number and exact location of these vias should be determined based on electrical resistivity, current flow and thermal requirements. Solder mask should be used to eliminate solder wicking into the vias.

6.2 Soldering Guidelines

The SMT10E is an open-frame power module manufactured with conventional surface mount technology using 62/36/02 with no-clean flux.

The SMT interconnect pins are a copper alloy with a solderable coating to prevent corrosion and ensure good solderability and shelf life. The coating is tin-lead with a nominal alloy composition of 60/40. This near-eutectic solder layer melts close to 183°C. During soldering the lead temperatures must exceed this by approximately 30°C to ensure a reliable solder joint.

Due to the fact that components with high thermal capacity such as the SMT10E may be slower to heat up than typical SMT parts, it may be necessary to customise the solder reflow profile. In doing this, customers need to be cognisant of the process limitations of other relevant components. The temperature of each SMT interconnect lead will vary during reflow due to differences in internal components, PCB lands and connecting paths. +Vout is a good choice for conservative temperature measurement, because it is typically connected to heavy copper paths. Figure 5 shows the recommended temperature of the +Vout pin during a typical reflow profile. The SMT10E is compatible with convection soldering using common solder alloys such as 63/37 and 62/36/02.

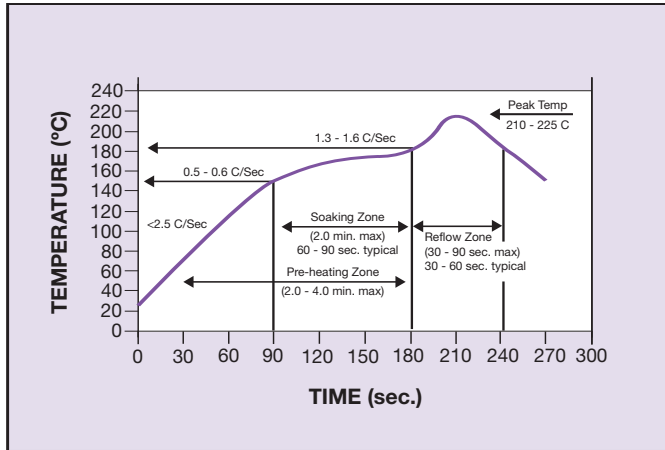


Figure 5 - Solder Reflow Profile per CECC 00802

Good quality solder joints have been demonstrated using a volume of 1.15mm^3 (85260 cubic mils) of solder paste containing 90% metal. This can be achieved by printing solder paste using a $150\mu\text{m}$ (0.006") stencil on pads measuring $3.7 \times 2.5\text{mm}$.

6.2.1 Coplanarity

The SMT10E has a maximum co-planarity as defined by JESD22-B108 of better than $100\mu\text{m}$ (approximately 0.004inch). Innovative design, interconnect technology, and specialised manufacturing processes ensure product integrity.

6.2.2 Pick and Place

The SMT10E is designed with certain features to ensure it is compatible with standard pick and place equipment.

- The product is available in tape and reel.
- The low mass of less than 6.3 grams (0.22oz) is within the capability of standard pick and place equipment. The choice of nozzle size and style and placement speed may need to be optimized
- The centrally placed inductor has a flat area of 100mm^2 (0.15in²) that can be used as a pick-up area.
- The substrate will feature a corner chamfer and bottom side fiducials compatible with many types of machine vision systems.

6.2.3 Inspection/Rework

Inspection and rework of the SMT10E is facilitated by the following:

- The pins of the SMT10E are positioned close to the edge of the unit to facilitate ease of visual inspection and touch-up.
- The unit is assembled with conventional solder and plating finish.
- General SMT repair/rework guidelines apply to these units. In the unlikely event of a unit needing to be removed, this can easily be achieved by heating and removing one pin at a time using either hot air or a conductive iron, however care must be taken not to damage adjacent components. Surface-mount units which have been removed are not suitable for re-use and should be replaced with a suitable new part. Normal warranty criteria will apply to the removed units.

A number of conventional techniques may be employed when replacing a unit in the application. A suitable volume of solder paste (as recommended above in Section 6.2) is applied to the cleaned pads using either a precision dispenser or a suitable mini-stencil. Reflow is achieved using standard SMT rework techniques such as IR or techniques developed for BGA components.

6.3 Water Washing

Where possible, a no-clean solder paste system should be used for solder attaching the SMT product onto application boards. The SMT is suitable for water washing applications, 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.

6.4 ESD Control

SMT10E 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 may affect the lifetime of the converter.

6.5 Storage

All plastic encapsulated semiconductor components are qualified to IPC/JEDEC J-STD-020A level 1 and are classed as 'not moisture sensitive'. No special storage conditions are required.

6.6 Packaging

The SMT10E are available in tape and reel format in quantities of 250 modules per reel. Tape dimensions including pick point are shown in the following diagram.

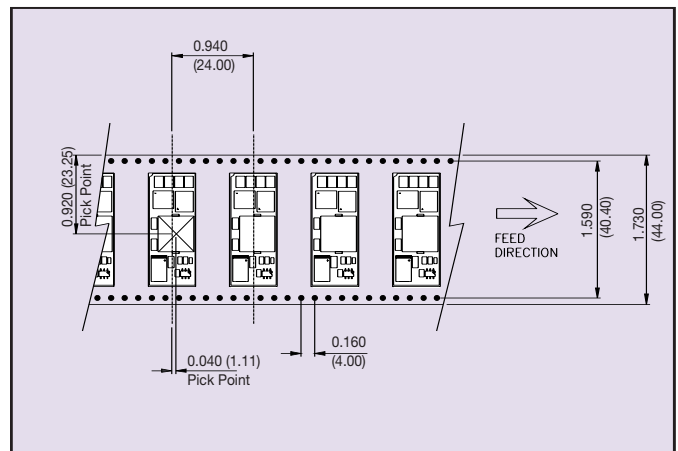


Figure 6 - Tape Dimensions

7. Applications

7.1 Optimum Thermal Performance

The electrical operating conditions of the SMT10E, 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

The maximum acceptable temperature measured at the thermal reference points is 115°C. These thermal reference points are shown in Figure 7.

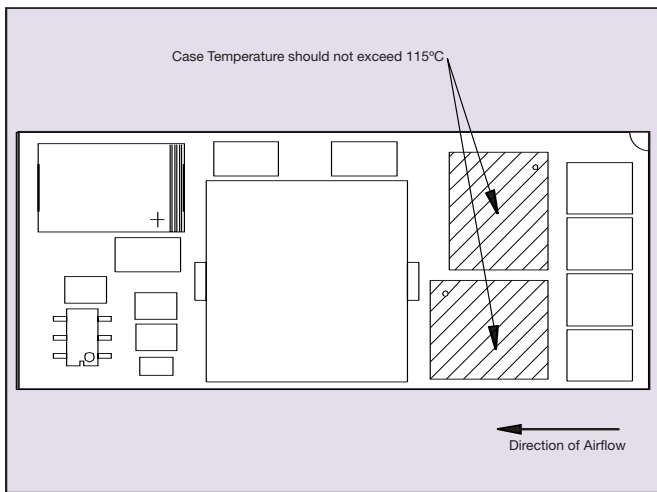


Figure 7 - Thermal Reference Point Locations on SMT10E Converters

Thermal characterization data is presented in the longform datasheet in a number of thermal de-rating graphs of which three are repeated here in figures 8, 9 and 10. These de-rating graphs show the load current of the SMT10E versus the ambient air temperature and velocity. The air velocity is in the direction indicated by the arrow in Figure 7. All of the data was taken with the converter soldered to a test board which closely represents a typical application. The test board is a 1.6 mm, eight layer FR4 PCB with the inner layers consisting of 2oz power and ground planes. The top and bottom layers contain a minimal amount of metalisation. A board to board spacing of 1 inch was used. The data represented by the 0m/s curve indicate a natural convection condition i.e. no forced air. 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 either AWG #36 or #40 gauge thermocouples or an IR camera. In order to comply with stringent Artesyn derating criteria, the ambient temperature should never exceed 100°C. Please contact Artesyn Technologies for further support.

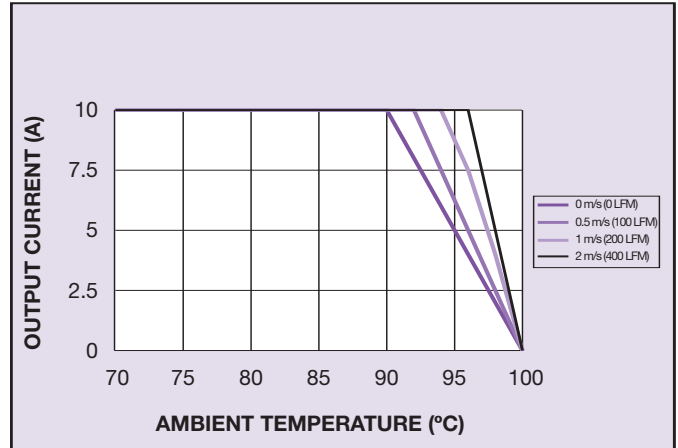


Figure 8 - Maximum Output Current vs. Ambient Temperature and Airflow for SMT10E-05S1V8J, with $V_{in} = 5V$ and No Trim

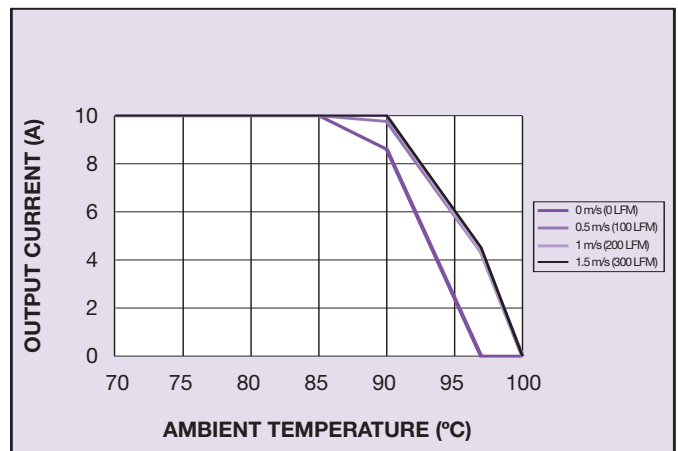


Figure 9 - Maximum Output Current vs. Ambient Temperature and Airflow for SMT10E-05S2V5J, with $V_{in} = 5V$ and no Trim

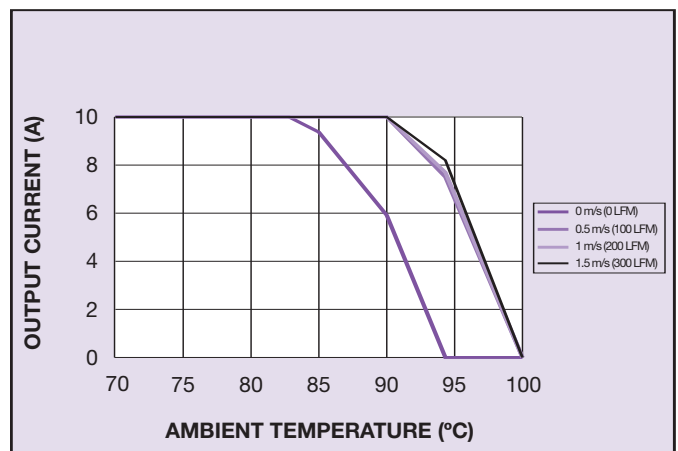


Figure 10 - Maximum Output Current vs. Ambient Temperature and Airflow for SMT10E-05S3V3J, with $V_{in} = 5V$ and no Trim

7.2 Remote Sense Compensation

The remote sense compensation feature minimizes the effect of resistance in the distribution system and facilitates accurate voltage regulation at the load terminals or another selected point. The remote sense line will carry very little current and hence do not require a large cross-sectional area. However, if the sense line is routed on a PCB, it should be located close to a ground plane in order to minimize any noise coupled onto the lines that might impair control loop stability. A small 100nF ceramic capacitor can be connected at the point of load to decouple any noise on the sense wires. The module will compensate for a maximum drop of 10% of the nominal output voltage. However, if the unit is already trimmed up, the available remote sense compensation range will be correspondingly reduced. Remember that when using remote sense compensation all the resistance, parasitic inductance and capacitance of the distribution system are incorporated into the feedback loop of the power module. This can have an effect on the module's compensation capabilities, affecting its stability and dynamic response.

7.3 Output Voltage Adjustment

The output can be externally trimmed by $\pm 10\%$ by connecting an external resistor between the TRIM pin and either the V_{sense+} or Ground pin. With an external resistor between TRIM and ground, R_{TRIM_UP} , the output voltage setpoint increases. Conversely, connecting an external resistor between TRIM and V_{sense+} , R_{TRIM_DOWN} , the output voltage setpoint decreases. This is shown in Figures 11 and 12. A wide trim version allows the user to trim down to 0.8V as shown in Figure 15.

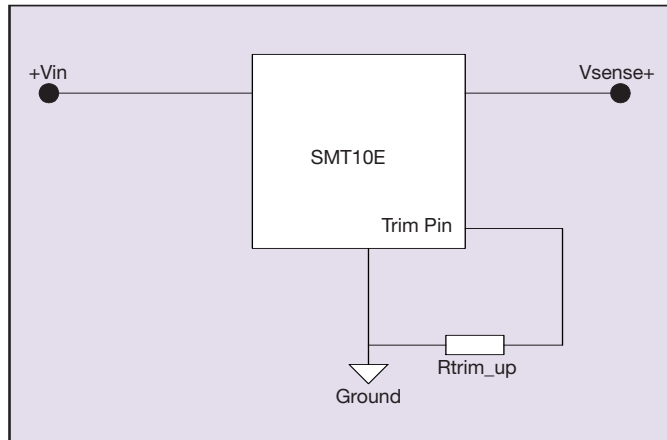


Figure 11 - Trimming Output Voltage - Trim up

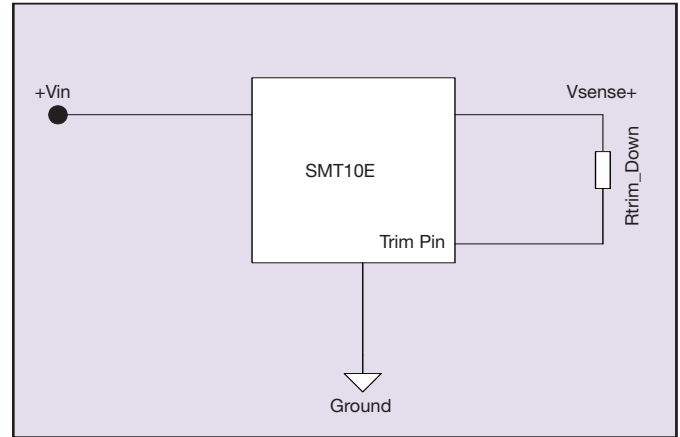


Figure 12 - Trimming Output Voltage - Trim Down

The relevant trim equations (equations hold for any input voltage between 3.0V and 5.5V) to derive the appropriate trim resistance for the SMT10E are as follows:

$$R_{TU} = K \left(\frac{Au - Vout Bu}{Cu Vout - Du} \right)$$

TRIM-UP

Where,

R_{tu} = Trim resistor from trim to GND (Ω)

V_{out} = Desired output trim setpoint

and the following parameters are defined:

	K	Au	Bu	Cu	Du
S1V2J	10^5	4.47	3.02	11.83	14.26
S1V5J	10^5	35.85	20.7	26.8	40.39
S1V8J	10^5	5.17	2.59	2.46	4.43
S2V5J	10^5	11.50	4.11	5.50	13.74
S3V3J	10^5	8.27	2.25	3.92	12.93
W3V3J	10^3	7.7	2.08	1.69	5.575

$$R_{TD} = K \left(\frac{Ad - Vout Bd}{Vout Cd - Dd} \right)$$

TRIM-DOWN

R_{td} = Trim resistor from trim to V_{sense} (Ω)

V_{out} = Desired output trim down setpoint

	K	Ad	Bd	Cd	Dd
S1V2J	10^5	4.47	4.2	11.83	14.26
S1V5J	10^5	35.85	28.0	26.8	40.39
S1V8J	10^5	5.17	3.33	2.46	4.43
S2V5J	10^5	11.50	5.76	5.50	13.74
S3V3J	10^5	8.27	3.44	3.92	12.93
W3V3J	10^3	7.7	9.905	1.69	5.575

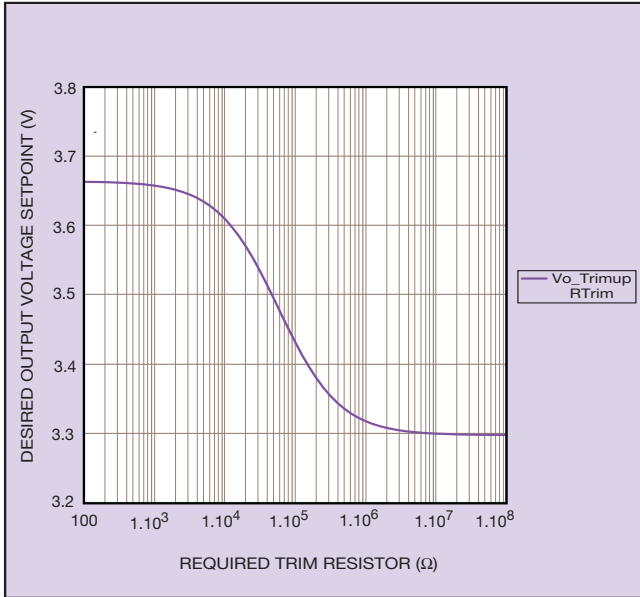


Figure 13 - Typical Trim Up Curve for SMT10E-05S3V3J
(Resistor from Trim to Gnd)

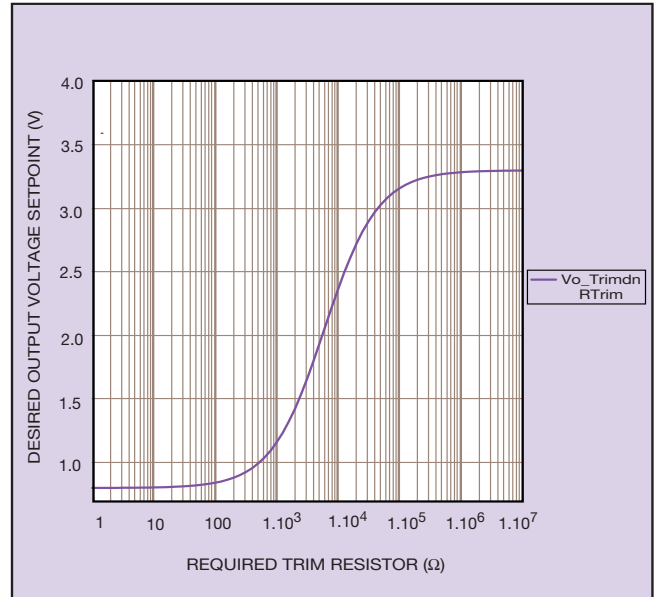


Figure 15 - Typical Trim Down Curve for SMT10E-05W3V3J
(Resistor from TRIM to V_{sense+})

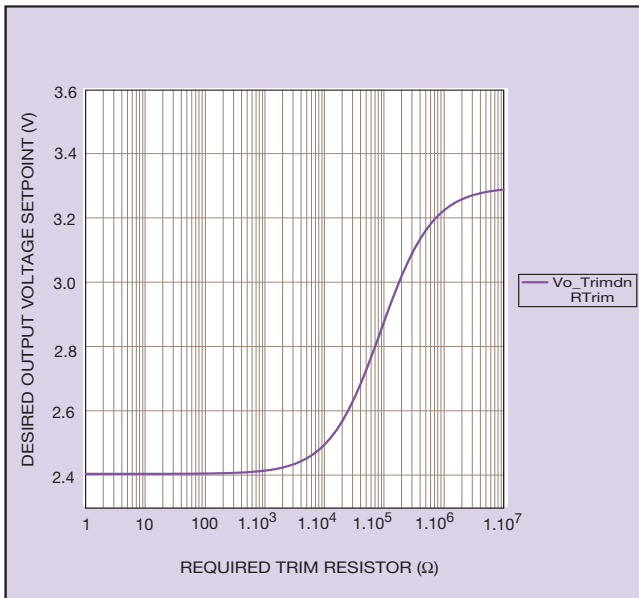


Figure 14 - Typical Trim Down Curve for SMT10E-05S3V3J
(Resistor from TRIM to V_{sense+})

7.4 Output Capacitance

The SMT10E series has been designed for stable operation without the need for external capacitance at the output terminals. 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 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.

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 module's 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. As much of the capacitance as possible should be outside the remote sensing loop and close to the load. Note that the maximum rated value of output capacitance for all models is 10,000 μ F. Contact your local Artesyn Technologies representative for further information if larger output capacitance values are required in the application.

7.5 Output Ripple and Noise Measurement

The measurement set-up outlined in Figure 16 has been used for output voltage ripple and noise measurements on SMT10E series converters. When measuring output ripple and noise, a 50 Ω coaxial cable with a 50 Ω termination should be used to prevent impedance mismatch reflections disturbing the noise readings at higher frequencies.

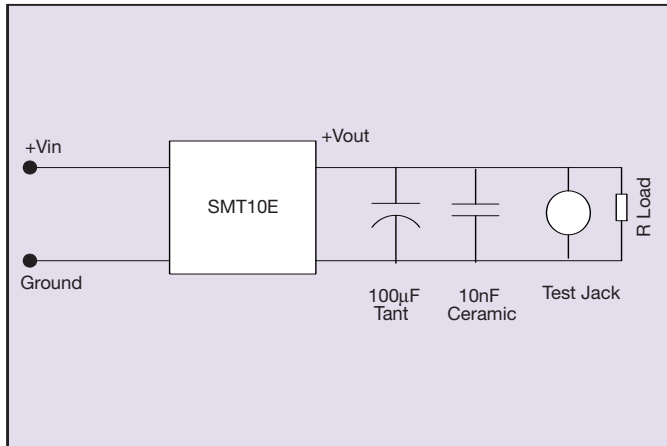


Figure 16 - Output Voltage Ripple and Noise Measurement Set-Up

7.6 Input Capacitance

The SMT10E converter must be connected to a low AC source impedance. High source inductance can affect the loop stability. Input capacitance should be placed close to the converter input pins to decouple distribution inductance. The external input capacitors must be chosen for suitable ripple current rating. Electrolytic capacitors should be avoided. Recommended input capacitors are ceramics such as 10µF 10V 1812 or similar.

7.7 Test Set-up

This converter is non-isolated, that is, the input and output share a common ground. When testing the SMT10E under any transient conditions please ensure that the transient response of the source is sufficient to power the equipment under test. Under some test conditions it may be necessary to power the unit with a half brick such as an Artesyn Technologies EXB250.

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