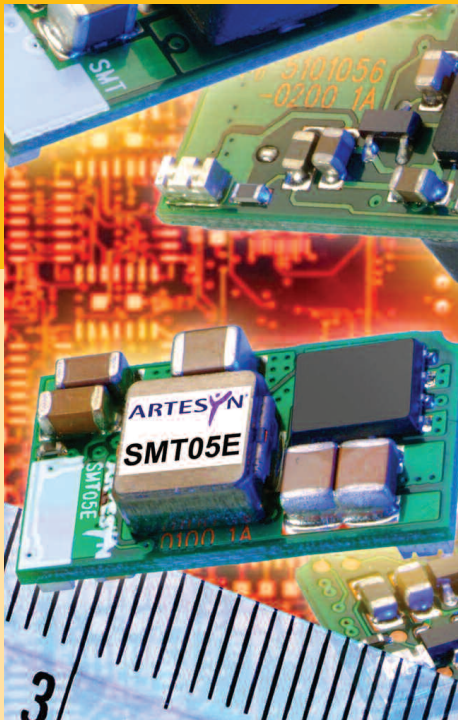




# SMT05E 12Vin Single

## Application Note 144

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## 1. Introduction

This application note describes the features and functions of Artesyn Technologies' 12V, 5A series of non-isolated 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.

Models are available with a 10V to 14VDC operating range and can operate over an ambient temperature range of  $-40^{\circ}\text{C}$  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 SMT05E series converters are extremely reliable.

## 2. Models

The 12V series comprises of 1 model, as listed in Table 1.

Model	Input Voltage	Output Voltage	Output Current
SMT05E-12W3V3J	10.0 - 14.0DC	0.8 - 3.63V	5A

Table 1 - SMT05E 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>

### 2.1 Features

- High efficiency topology, typically 91% at  $3.3\text{V}_{\text{out}}$  @ full load
- Industry standard footprint
- Wide ambient temperature range,  $-40^{\circ}\text{C}$  to  $+100^{\circ}\text{C}$
- 0.8V to 3.63V output voltage adjustability both models
- No minimum load requirement
- Remote ON/OFF
- 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 both 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 0.8V to 3.63V by means of an external resistor from trim pin to ground. The output voltage default is 0.8V, which can be trimmed up to any required setpoint within the range. See Section 9.1 for details.

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; an 'active high' logic input is supplied as standard. Active high implies that the converter is disabled if the remote ON/OFF input is  $\leq 0.8\text{V}$ , and enabled if it is high ( $\geq 1.6\text{V}$ ) or floating.

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  $105^{\circ}\text{C}$  to  $120^{\circ}\text{C}$  PCB temperature, to protect the unit.

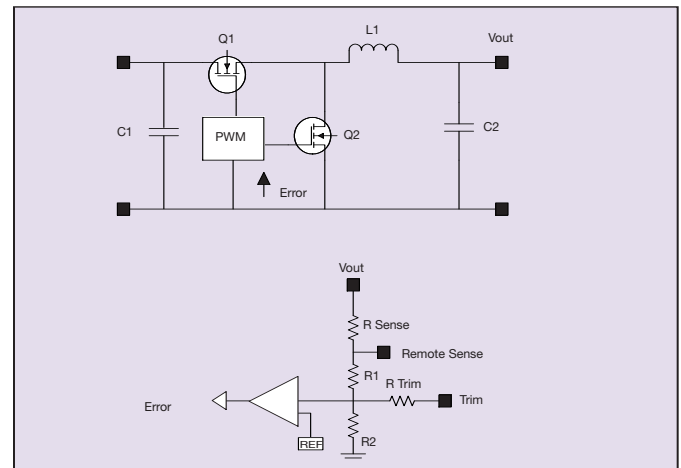


Figure 1 - Electrical Block Diagram

## 3.2 Physical Construction

The SMT05E 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](http://www.artesyn.com)

## 4. System Interface Information

### 4.1 Input Characteristics

The SMT05E 12Volt series has an input voltage range of 10.0 to 14.0 volts. The wide input voltage range gives designers more flexibility in choosing an Intermediate Bus convertor to operate the Point of Load convertor

#### 4.1.1 Reflected Ripple Current

Because of the switching operation of the design, there is an AC current generated at the input of the unit. This is referred to as input reflected ripple current.

The typical ripple current for the SMT05E series is approx 200mA peak to peak at full load, with the output trimmed up to 3.3V.

#### 4.1.2 Input Source Impedance and Input Capacitance

The SMT05E 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 10 $\mu$ F 20V 1812 or similar.

### 4.2 Output Characteristics and Output Capacitance

The SMT05E series has been designed for stable operation without the need for external capacitance at the output terminals. However, when powering loads with 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 (for example 10 $\mu$ F or greater GRM series from Murata or similar) as close to the load as possible. 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 $\mu$ F. Contact your local Artesyn Technologies representative for further information if larger output capacitance values are required in the application.

#### 4.2.1 Converter Stability

The SMT05E series has been designed to meet a minimum criteria of at least 45° at unity gain over all line and load operating conditions. The selection of compensation components ensure the design is unconditionally stable for all operating conditions. Bode plot measurements have been taken to prove out theoretical analysis of the design. Because of the high DC gain, the bode plots were carried out with the unit in closed loop operation. These were taken at nominal input voltage, full output current and Vout set to 3.3V.

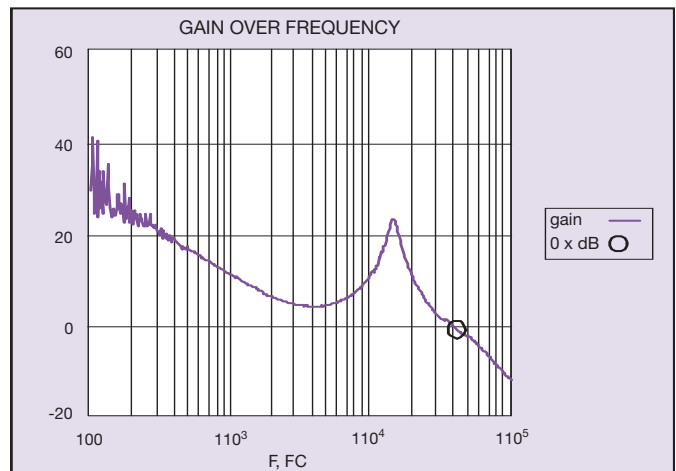


Figure 2 - Converter Stability Plot

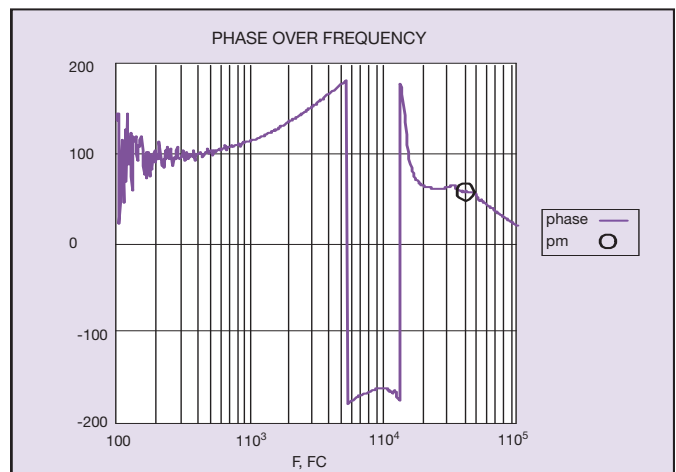
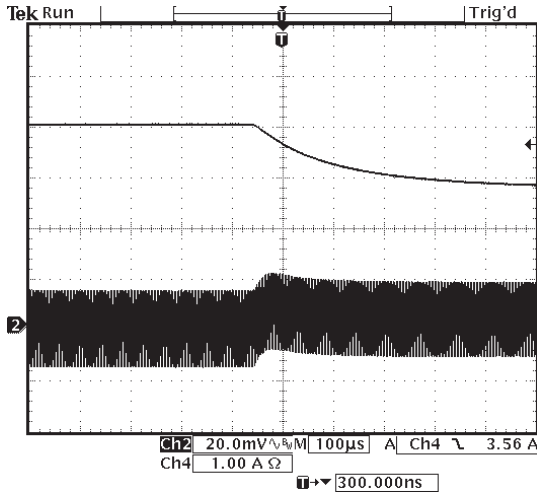
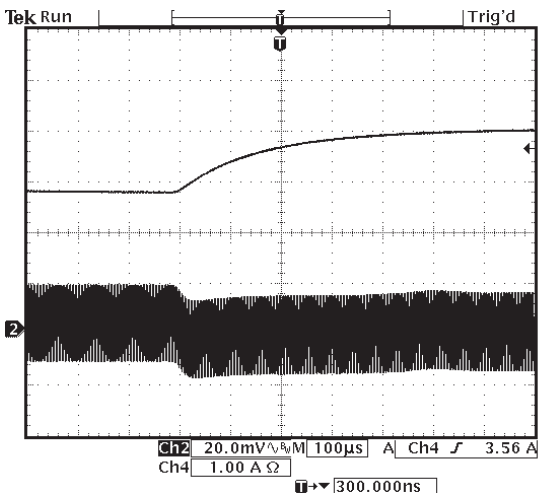


Figure 3 - Converter Stability Plot



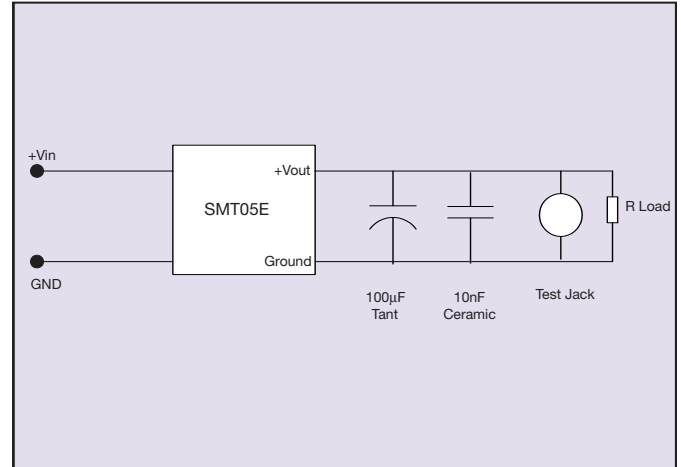
**Figure 4 - Typical Transient Response for 75% to 50% (100mA $\mu$ s) Load Step**



**Figure 5 - Typical Transient Response for 75% to 50% (100mA $\mu$ s) Load Step**

**4.2.2 Ripple and Noise**

The measurement set-up outlined in Figure 6 has been used for output voltage ripple and noise measurements on SMT05E series converters. When measuring output ripple and noise, a 50 $\Omega$  coaxial cable with a 50 $\Omega$  termination should be used to prevent impedance mismatch reflections disturbing the noise readings at higher frequencies.



**Figure 6 - Ripple and Noise Measurement Set-up**

**4.3 EMC**

The SMT05E range has been designed to comply with the EMC requirements of EN61000. It has been tested and has passed radiated noise immunity (EN61000-4-3) and conducted noise immunity (EN61000-4-4) both with normal performance.

## 5. Mechanical Information

### 5.1 Mechanical Outline Drawing

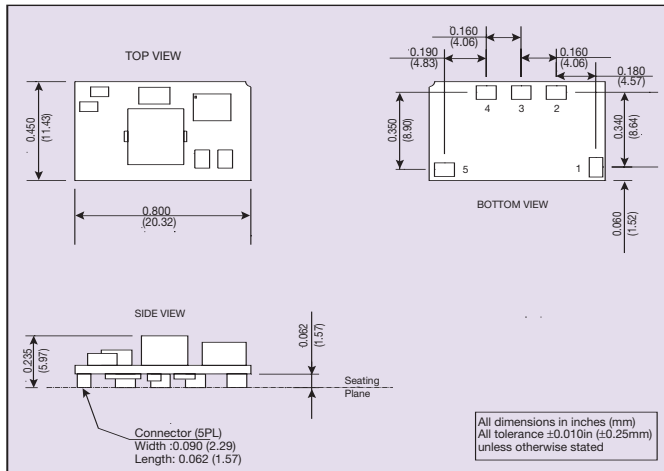


Figure 7 - SMT05E Mechanical Outline

### 5.2 Pin-out Table

PIN CONNECTIONS	
PIN NUMBER	FUNCTION
1	Remote ON/OFF
2	Vout
3	Trim
4	Ground
5	Vin

### 5.3 Pin Composition

The Patent pending surface mount links provide mechanical, electrical and thermal connection between the convertor and application. They are constructed from a high conductivity alloy giving superior electrical and thermal connection. The geometry of the link ensures high shear strength when soldered, while meeting coplanarity specification of ' $<0.004$ ". The links are plated with a 90/10 tin/lead electroplate over a nickel barrier layer

### 5.4 PCB Layout Information

The PCB acts as a heat sink and draws heat from the unit via conduction through the pins and through radiation. The end user must ensure that other components and metal in the vicinity of the SMT05E meet the spacing requirements to which the system is approved. Low resistance and low inductance PCB layout traces should be used where possible, particularly when high currents are flowing (e.g. the output side). A low impedance track should connect input ground and output ground to maximize efficiency of the unit. See section 11.5 for the recommended land patterns.

## 6. Packaging Information

### 6.1 Packaging

The SMT05E are available in trays of 48 units and tape and reel format in quantities of 400 units per reel. Tray and tape dimensions including pick point are shown in the following diagrams.

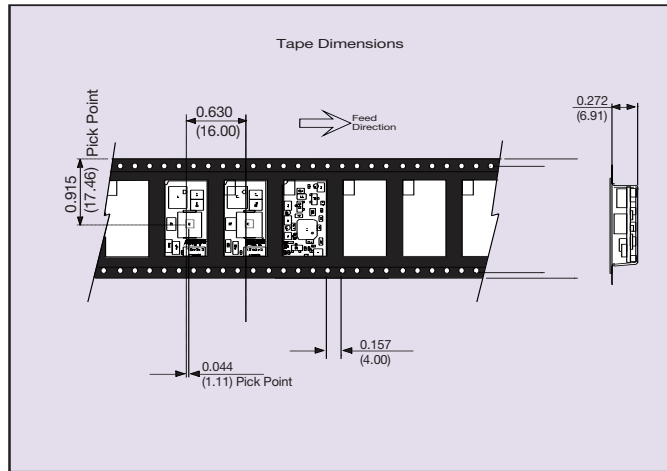


Figure 8 - Tape Dimensions

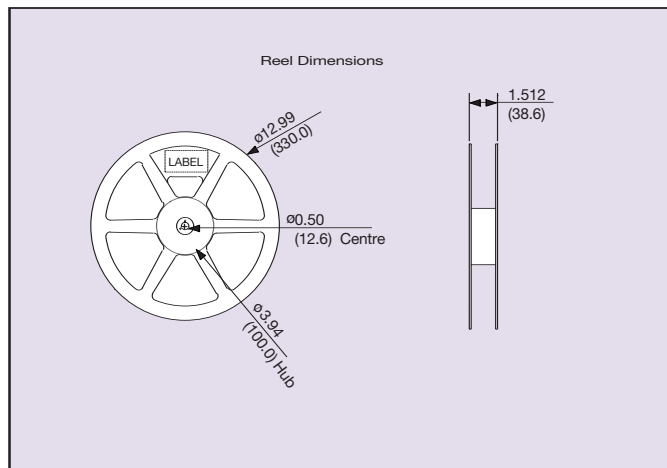


Figure 9 - Reel Dimensions

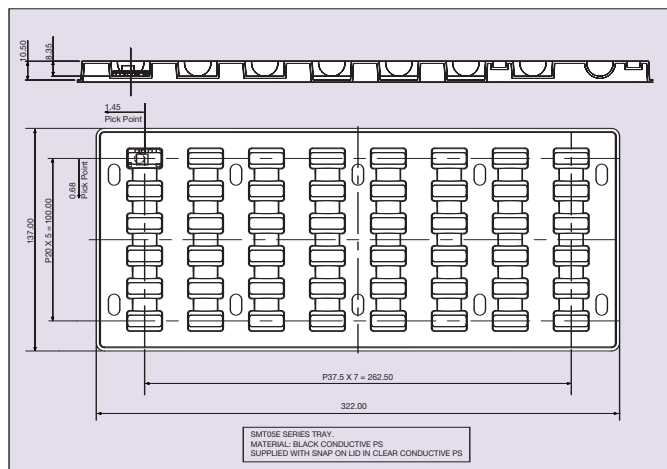


Figure 10 - Tray

### 6.2 Labels and Part Numbering Sequence

All units in the series will be clearly marked to allow ease of identification for the end user. Figure 11 gives details of all the models.

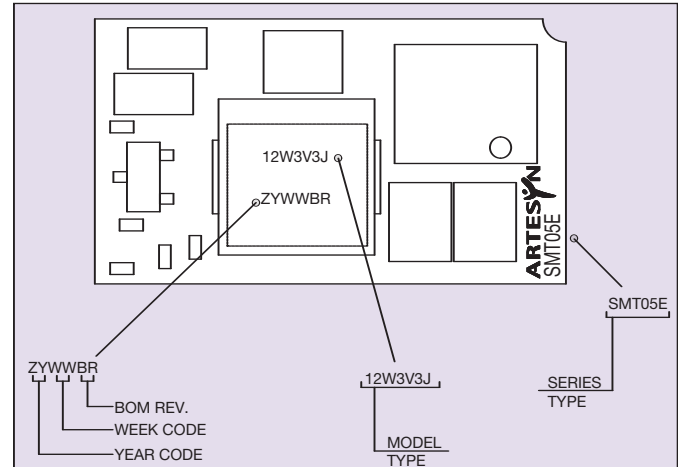


Figure 11 - SMT05E Part Numbering

## 7. Safety Information

### 7.1 Safety Standards and Approvals

All models will have full international safety approval including EN60950 and UL/cUL1950. Models have been submitted to independent safety agencies for approval.

### 7.2 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.

A 3A amp fast blow fuse should be used for all models.  
Recommended fuse: Bussman GMA-3.

### 7.3 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.

## 8. Operating Information

### 8.1 Over-temperature Protection (OTP)

The 12V non-isolated Point of Load range 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 10°C and 15°C the converter will automatically restart.

The unit 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).

### 8.2 Short Circuit Protection

In the event of a short circuit the unit will enter a hic-cup mode, to provide fault protection. Once the source of the short circuit has been removed the unit will auto-recover, and will remain undamaged while in a short circuit mode. This design is protected only against extreme short circuits. The unit is protected in an over-load condition by an over-temperature protection device. We do not recommend operating this unit in a heavy over-load condition as it may reduce the lifetime of the converter.

## 9. Feature Set

### 9.1 Trimming the Output Voltage

The SMT05E 12V series has an output setpoint default of 0.8V.

This setpoint can be set by the user to any required voltage of 0.8V to 3.63V. When trimmed up by the user, the unit can deliver an output load of 5Amps or 16.5Watts whichever is the lesser of the two.

The output can be trimmed up by placing an external resistor between Trim pin and Ground.

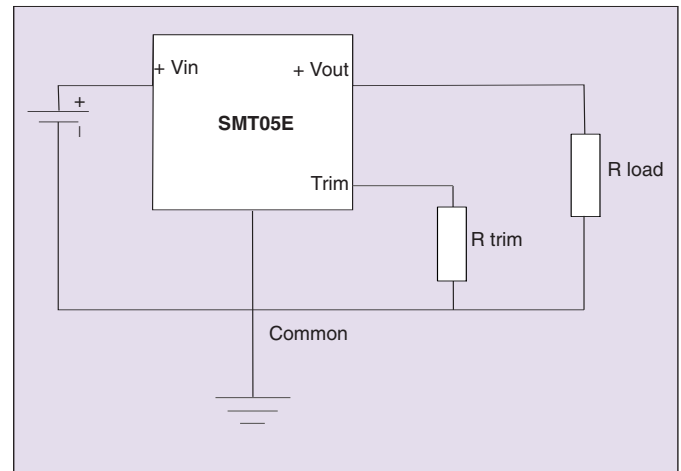


Figure 12 - Output Trim-up Resistor to Ground

The output setpoint can be set with an external resistor as governed by the following equation

$$R_{trim} = \left[ \frac{9605}{V_{out} - 0.8} - 722 \right]$$

Where  $V_{out}$  is the required output setpoint  
 $R_{trim}$  is given in Ohms

For example to set the output voltage to 1.8,  $R_{trim}$  is calculated as follows

$$R_{trim\_up} = \frac{V_{ref}}{\frac{\Delta V_{out2}}{7500}} - 6486$$

$$R_{trim} = 8.87k\Omega$$

$V_o$ (V)	$R_{trim}$ (K $\Omega$ )
0.8	Open
1.2	22.3
1.5	13.0
1.8	8.98
2.0	7.41
2.5	4.99
3.3	3.12

Above is a table of E-192 value resistors that can be used to trim some standard voltage output setpoints.

Care needs to be taken when placing the external trim resistor. Poor grounding on the layout for this resistor may result in an increase of load regulation for the unit. The resistor should be placed directly between the trim pin and ground of the unit.

The trim curve can be graphed as shown below:

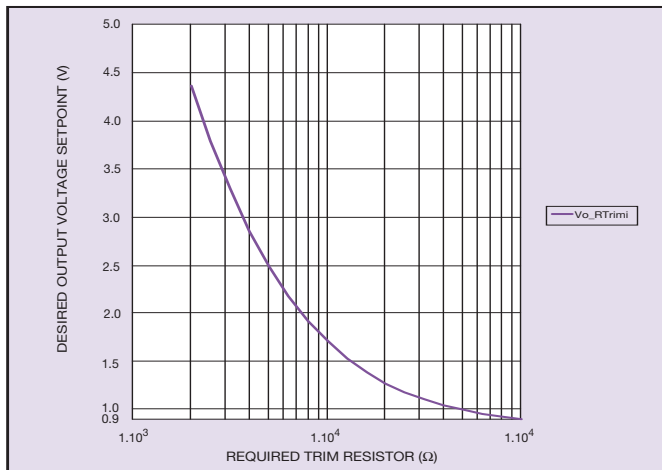


Figure 13 - Trim Up

## 9.2 Remote ON/OFF

The remote ON/OFF input allows external circuitry to put the SMT05E converters into a low dissipation sleep mode. Active-high remote ON/OFF is available as standard.

Active-high units of the SMT05E series are turned on if the remote ON/OFF pin is high, or left floating. Pulling the pin low will turn off the unit. The signal level of the remote on/off input is defined with respect to ground. The unit is guaranteed ON if this voltage level exceeds 1.6V. The unit is guaranteed OFF if this voltage level is equal to or less than 0.8V.

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 Longform Datasheet. The remote ON/OFF input can be driven as described in Figure 14.

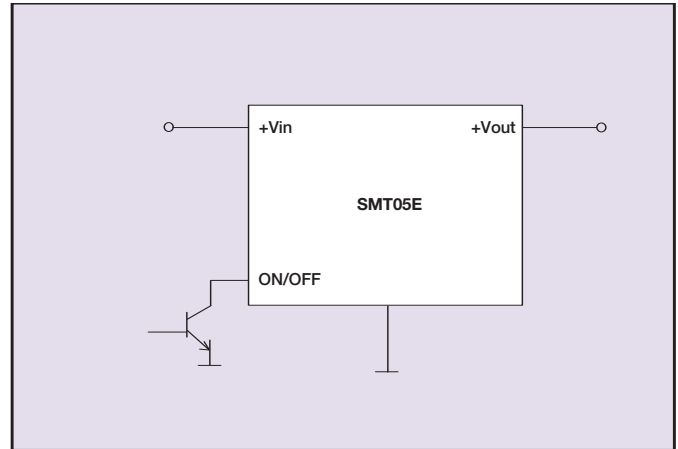


Figure 14 - Remote ON/OFF

## 9.3 Parallel and Series Operation

Parallel operation of multiple converters is not recommended. If unavoidable, some de-coupling technique must be incorporated onto the users design. It should be noted that this measure will adversely effect power conversion efficiency.



## 10. Thermal Information

### 10.1 Thermal Reference Points

The electrical operating conditions 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 15.

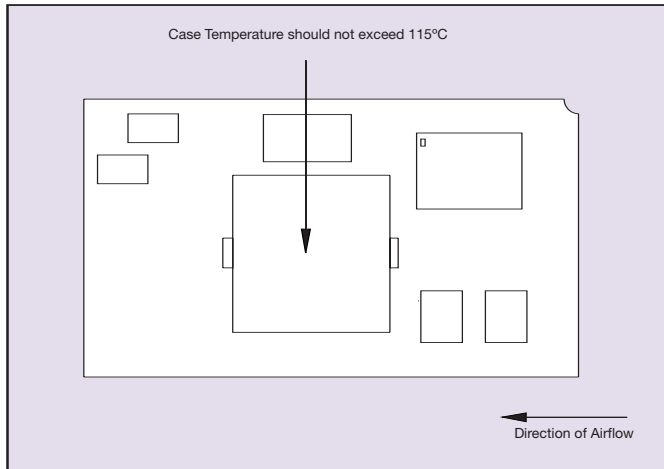


Figure 15 - Thermal Reference Point Locations

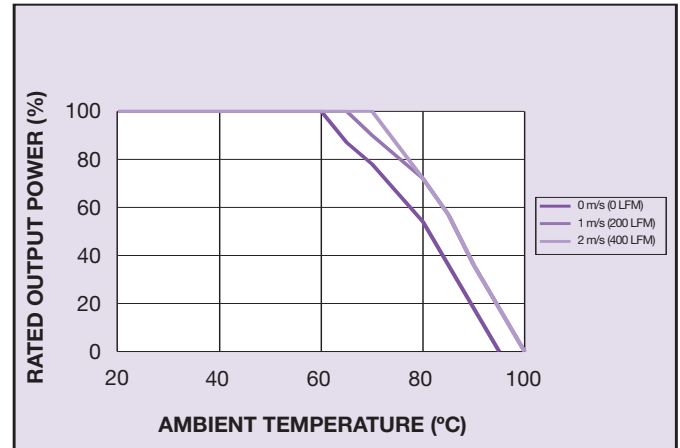


Figure 16 - Thermal Derating Curves SMT05E-12W3V3J Model

### 10.2 Thermal Derating Curves

Thermal characterisation data is presented in the datasheet in a thermal derating graph which is repeated here in Figures 16. This derating graph shows the load current versus the ambient air temperature and velocity. The air velocity is in the direction indicated by the arrow in Figure 15.

### 10.3 Thermal Test Set-up

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 0 m/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.

## 11. Use in a Manufacturing Environment

### 11.1 ESD Requirements

All 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.

### 11.2 Soldering Requirements

The SMT05E 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 SMT05E 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 17 shows the recommended temperature of the +Vout pin during a typical reflow profile. The SMT05E is compatible with convection soldering using common solder alloys such as 63/37 and 62/36/02.

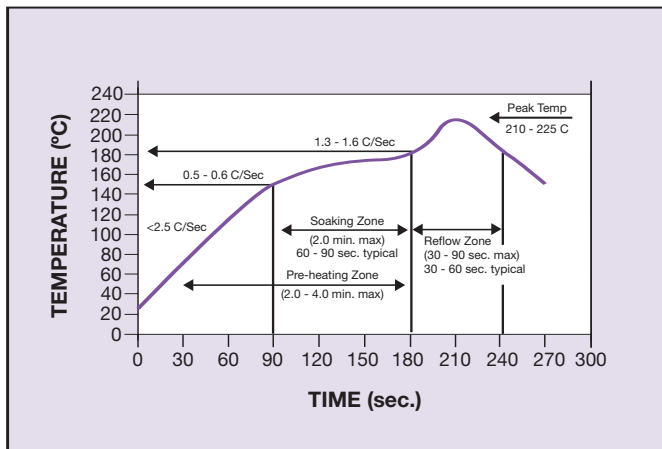


Figure 17 - Solder Reflow Profile per CECC 00802

### 11.3 Coplanarity

The SMT05E 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.

### 11.4 Paste Height/Coverage

Good quality solder joints have been demonstrated using a volume of 0.48mm<sup>3</sup> (29792 cubic mils) of solder paste containing 90% metal. this can be achieved by printing solder paste using a 150 $\mu\text{m}$  (0.006 inches) stencil on apertures measuring 2.15 x 1.49mm.

### 11.5 Recommended Land Pattern

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

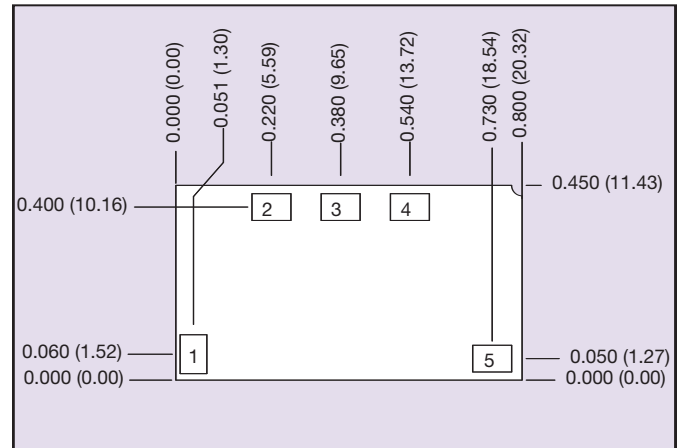


Figure 18 - Recommended Land Pattern

The minimum recommended pad size is 0.115 x 0.095 in (2.92 x 2.41mm) and the maximum pad size is 0.140 x 0.110in (3.56 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.

### 11.6 Pick and Place Information

The SMT05E 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 3 grams (0.10oz) is within the capability of standard pick and place equipment. The choice of nozzle size and style and placement speed may need to be optimised
- The centrally placed inductor has a flat area of 44.4mm<sup>2</sup> (0.69in<sup>2</sup>) 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.

### 11.7 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.

## 11.8 Inspection/Rework

Inspection and rework of the SMT05E is facilitated by the following:

- The pins of the SMT05E 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) 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.

## 11.9 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.

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