SMT30E 12Vin Single

Application Note 175

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1. Introduction

This application note describes the features and functions of Artesyn Technologies' 12 V, 30 A series of non-isolated Surface-Mountable, high power density, single output dc-dc converters.

The SMT30E 12V is available with a 8 Vdc t o 14 Vdc operating range and can operate over an ambient temperature range of -40 °C to +85 °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 overtemperature 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 SMT30E series converters are extremely reliable.

2. Models

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

Model	Input Voltage	Output Voltage	Output Current
SMT30E-12W3V3J	8V - 14 Vdc	0.8 3.63 V	30 A

Table 1 - SMT30E Model

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.

2.1 Features

- High efficiency topology, typically 91% at 3.3 Vout @ full load
- Industry standard footprint
- Wide ambient temperature range, -40 °C to +85 °C
- 0.8-3.63 V output voltage adjustability
- No minimum load requirement
- Remote ON/OFF
- Remote sense compensation
- Fixed switching frequency
- Continuous short-circuit protection
- Overtemperature protection (OTP)
- Available RoHS compliant

Note: These devices have a moisture sensitivity level 3 rating in line with IPC/JEDEC J-STD-020C Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State surface mount devices.

3. General Description

3.1 Electrical Description

A block diagram of the 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 optimized for high efficiency power conversion.

The output is adjustable over a range of 0.8 V to 3.63 V by means of an external resistor from trim pin to ground. The output voltage default is 0.8 V, which can be trimmed up to any required set-point 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; a 'Positive Logic' input is supplied as standard. Positive logic implies that the converter is disabled if the remote ON/OFF input is ≤ 0.8 V, and enabled if it is high (≥2.8 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 °C to 120 °C PCB temperature, to protect the unit.

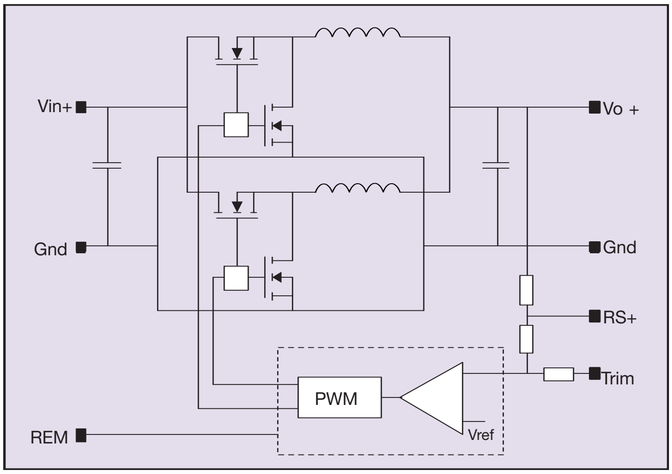

Figure 1 - Electrical Block Diagram

3.2 Physical Construction

The SMT30E 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. System Interface Information

4.1 Input Characteristics
The SMT30E 12 Vin series has an input voltage range of 8 V to 14 V. The wide input voltage range gives designers more flexibility in choosing an Intermediate Bus Converter to operate the Point-of-Load converter.

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 SMT30E series is approx 1.3 A peak to peak at full load, with the output trimmed up to 3.3 V.

4.1.2 Input Source Impedance and Input Capacitance
The SMT30E 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 µF 20 V 1812 or similar.

4.2 Output Characteristics and Output Capacitance
The SMT30E 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 µF 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 µF. 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 SMT30E 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. Sample measurements are shown in Figures 2 and 3. These were taken at nominal input voltage, full output current and Vout set to 1.5 V.

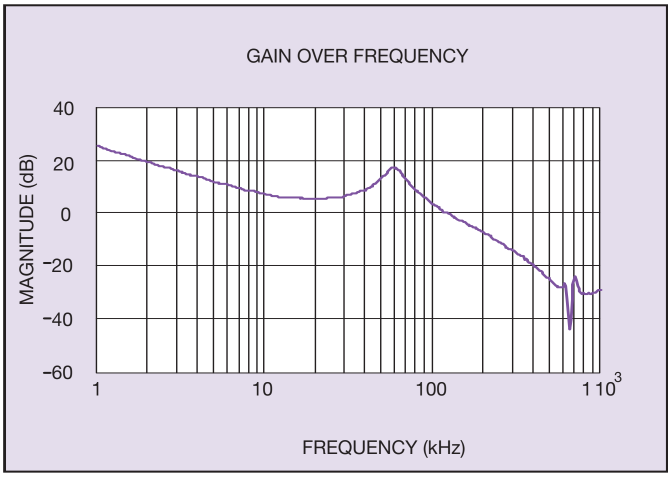

Figure 2 - Converter Stability Plot

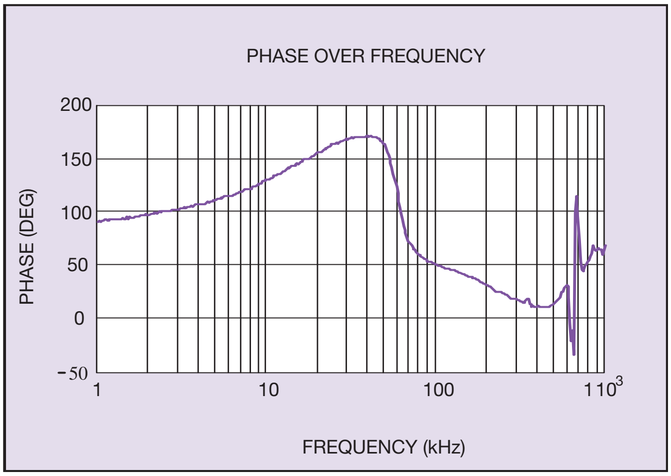

Figure 3 - Converter Stability Plot

Sample measurements of typical transient response are shown in Figures 4 and 5. These were taken at nominal input voltage, and Vout set to 1.5 V.

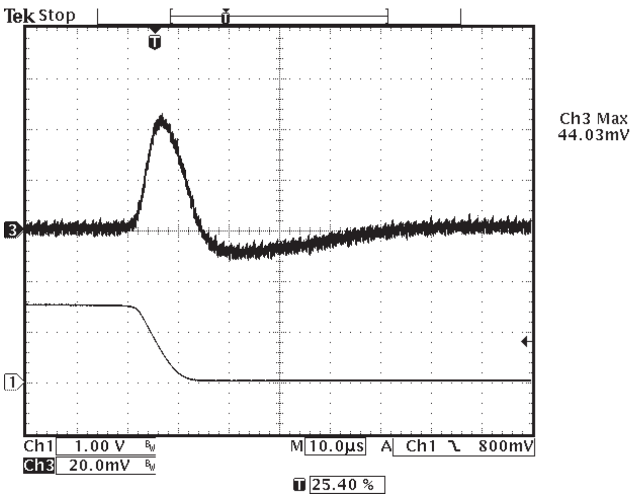

Figure 4 - Typical Transient Response for 75% to 50% (0.5 A/µs) Load Step

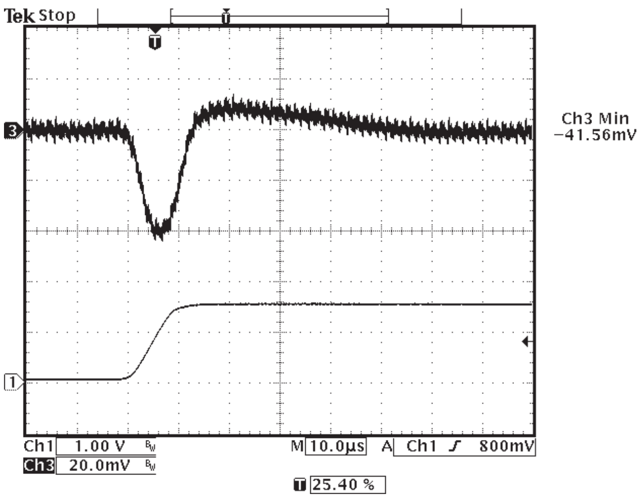

Figure 5 - Typical Transient Response for 5% to 75% (0.5 A/µs) Load Step

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 SMT30E 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.

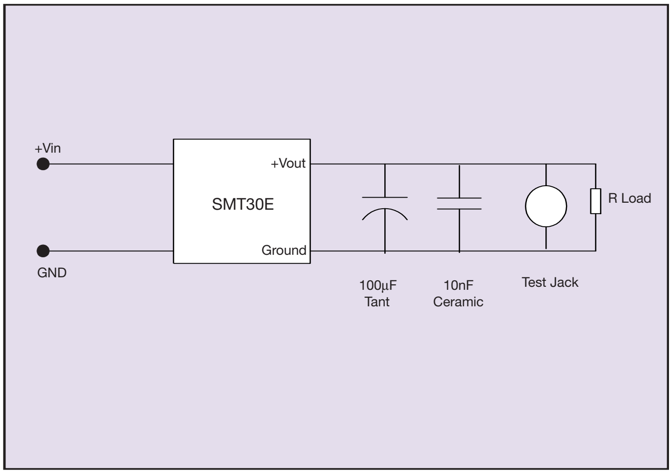

Figure 6 - Ripple and Noise Measurement Set-up

4.3 EMC

The SMT30E series 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

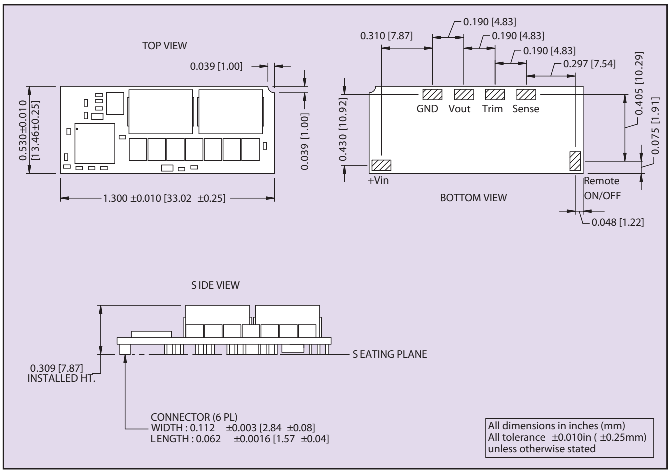

Figure 7 - SMT30E Mechanical Outline

5.2 Pin-out Table

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

Table 2 - SMT30E Pin-Out

5.3 Pin Composition

The surface mount links provide mechanical, electrical and thermal connection between the converter and application. They are constructed from a high conductivity alloy giving superior electrical and thermal connection. The links are plated with a 90/10 tin/lead electroplate over a nickel barrier layer.

5.4 PCB Layout Information

The actual performance of the SMT30E will be dependent on the application environment e.g. ambient temperature, airflow, application substrate etc. It is not possible to recommend specific implementation guidelines to cover all environments but there are a number of best practice guidelines which should be followed in order to optimize the layout for any particular application.

The SMT30E shares a footprint with the SMT15E and other similar non-isolated POL converters. However, the higher output current capability of the SMT30E means that more attention will need to be paid to the electrical and thermal conduction paths. In particular pay attention to the copper pours at the Vin, Gnd and Vout pads that will accommodate nests of paralleled vias to connect to the appropriate internal power planes. These copper pours should be extended in the direction of current flow. Use a number of parallel vias to connect the pads to the appropriate internal power planes. Typical industry practice is to allow 2 A per 0.012" (0.3 mm) via or 3 A per 0.022" (0.56 mm) via. The resistance of these vias can be calculated for any specific PCB application and some typical values are given in Table 3. The layer 1 copper under the converter should be ground plane. Some vias should also be placed close to the capacitor terminations.

No. of Vias	FHS	Plating	Via Length	Resistance
15	0.012"	0.005"	0.060"	0.178 mΩ
10	0.022"	0.005"	0.060"	0.145 mΩ

Table 3 - Approximate DC Resistance of Nests of Parallel Vias at 70 °C with 1/2 oz Plating in the Vias

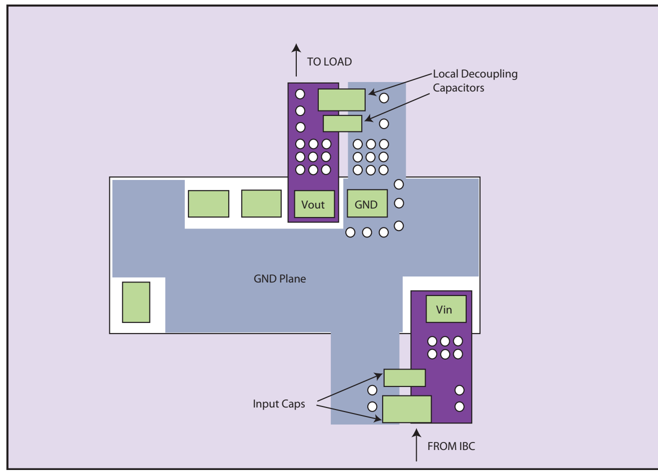

Figure 8 - Copper Pours Elongated in the Direction of Current Flow and Approximate Positions for Parallel Vias

The power distribution planes will also have an additional frequency dependant ac resistance and hence some decoupling MLCCs should be used local to the load. There are a number of approaches to estimating the distribution losses in the power planes.

1 The simplest is an analysis of sheet resistance of a plane. The dc sheet resistance of a 1 oz copper plane is approximately 0.6 mΩ/square. If this is unacceptable then a number of 1 oz planes will need to be connected in parallel with suitable numbers of vias.

2 The second approach uses the following formula which calculates the resistance of a plane of thickness "t" between two vias of diameter "d1 and d2" separated by a distance "x" at temperature "T". While not exactly applicable to a case where nests of parallel

$$R_{plane} = \frac{\rho \cdot \left[1 + \left(T - 20\right) \cdot TCR\right]}{2 \cdot \pi \cdot t} \cdot \left(\ln\left(\frac{2 \cdot x}{d1}\right) + \ln\left(\frac{2 \cdot x}{d2}\right)\right)$$

vias are used, it does yield some insightful results.

r is the resistivity of copper at 20 °C, TCR is the temperature coefficient of resistivity

If the contact points lie near any edge of the plane, the resistance between them may go up by a factor of 2. The resistance near corners may rise even higher.

3 The third and most accurate approach is through the use of finite element methods.

6. Packaging Information

6.1 Packaging

The SMT30E are available in trays of 30 units and tape and reel format in quantities of 250 units per reel. Tray and tape dimensions including pick point are shown in the following diagrams.

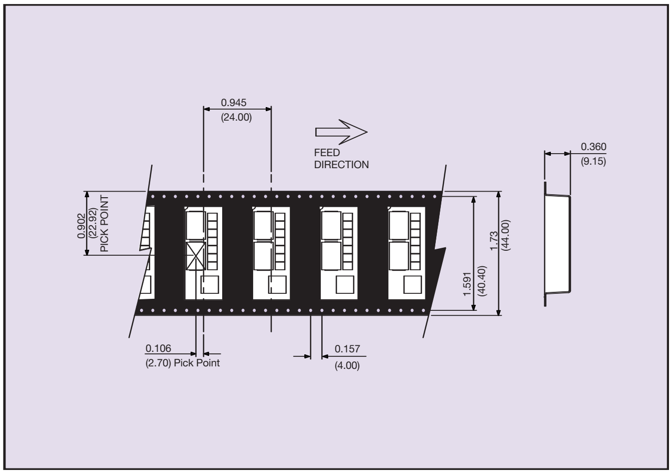

Figure 9 - SMT30E Tape Dimensions

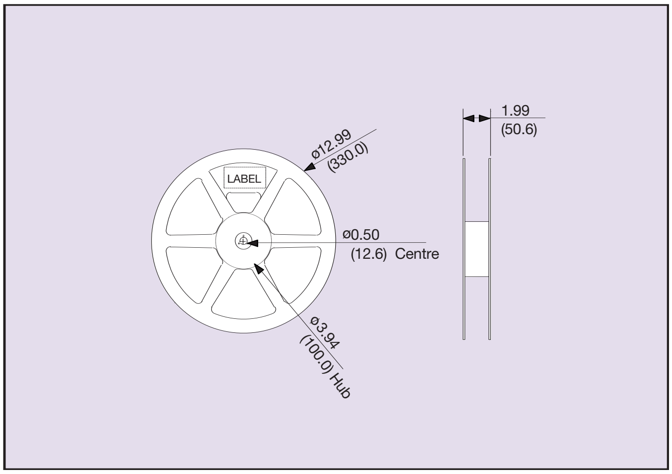

Figure 10 - SMT30E Reel Dimensions

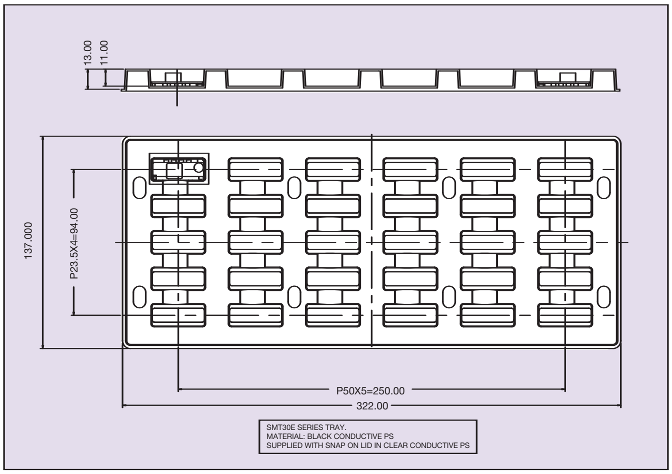

Figure 11 - SMT30E Tray

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 as shown in Figure 12.

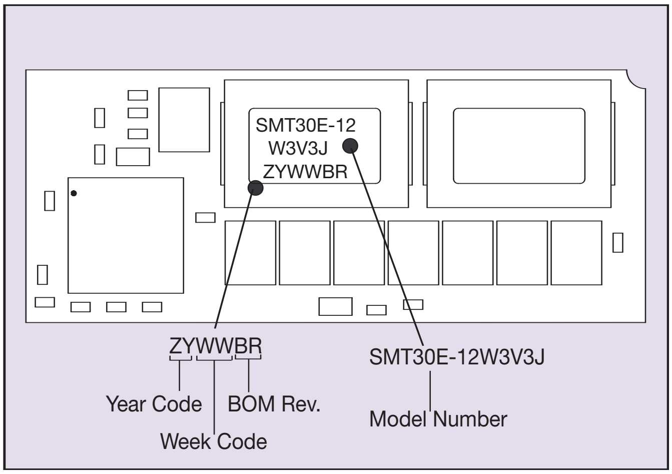

Figure 12 - SMT30E Part Numbering

6.3 MSL Classification Labels

Both the individual trays and inner box carry moisture identification labels as shown in Figures 13 and 14.

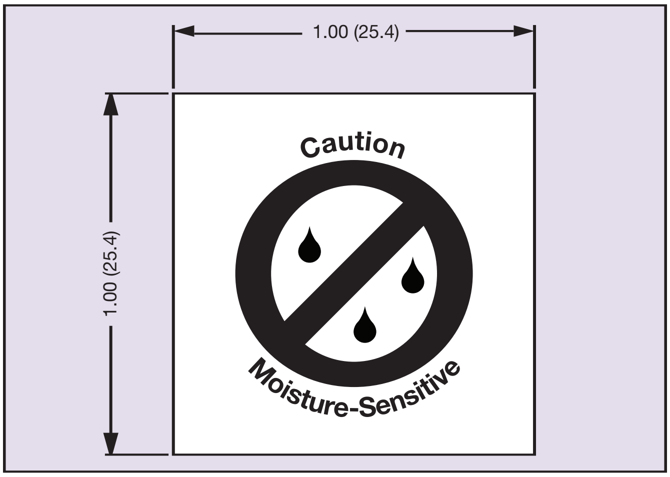

Figure 13 - Moisture Identification Label that goes on the Inner Box

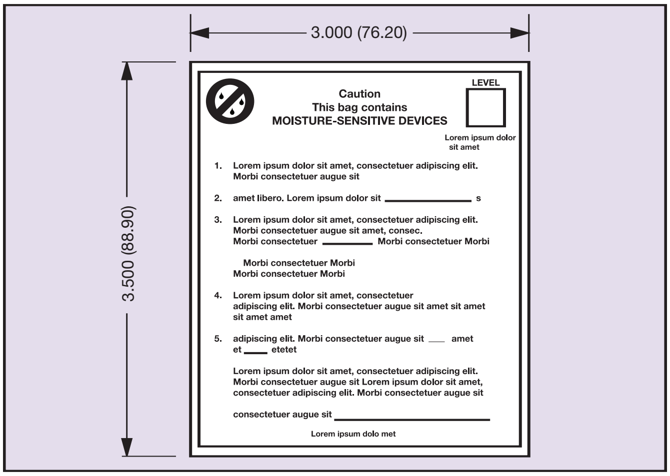

Figure 14 - Caution Label that goes on the Moisture barrier bag for each tray

7. Safety Information

7.1 Safety Standards and Approvals
All models will have full international safety approval including EN60950-1 and UL/cUL60950-1. 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 10 A amp fast blow fuse should be used for all models. Recommended fuse: Bussman ABC-V-10.

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 Overtemperature Protection (OTP)
The 12 V 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 hiccup 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 SMT30E 12V series have an output setpoint default of 0.8 V.

This setpoint can be set by the user to any required voltage of 0.8 V to 3.63 V. When trimmed up by the user, the unit can deliver an output load of 30 A or 99 W, whichever is the lesser of the two.

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

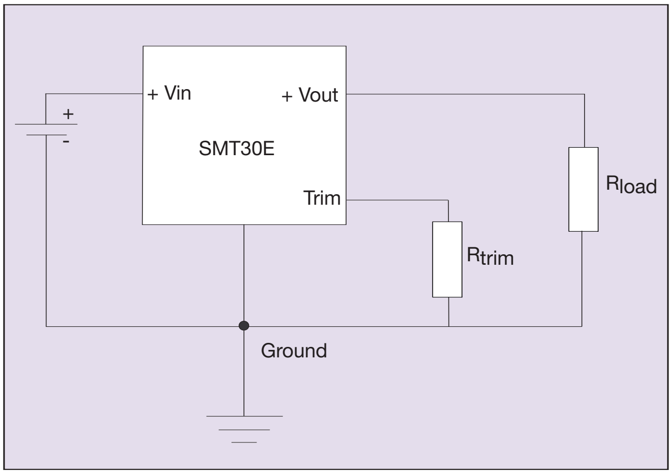

Figure 15 - Output Trim-up Resistor to Ground

The output set-point can be set with an external resistor as governed by the following equation:

$$R_{trim} = \left[\frac{9680}{V_{out} - 0.8} - 715 \right]$$

Where Vout is the required output setpoint
R_{trim} is given in Ohms

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

$$R_{trim} = \left[\frac{9680}{1.8 - 0.8} - 715 \right]$$

$$R_{trim} = 8.965\text{k}\Omega$$

V_O (V)	R_{trim} (KΩ)
0.8	Open
1.2	23.4
1.5	13.2
1.8	8.96
2.0	7.32
2.5	4.99
3.3	3.16

Table 3 - E-192 Value Resistors

Table 3 shows the 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:

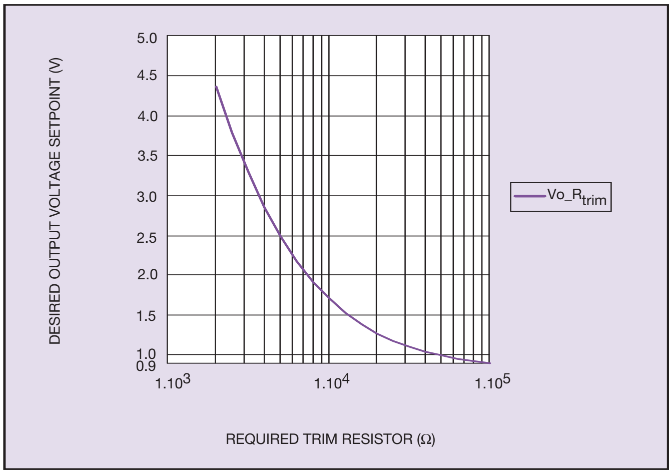

Figure 16 - Trim Up

9.2 Remote ON/OFF

The remote ON/OFF input allows external circuitry to put the SMT30E into a low dissipation sleep mode. Positive logic remote ON/OFF is available as standard.

Positive logic units of the SMT30E series are turned on if the remote ON/OFF pin is high, or leaving it 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 2.8 V. The unit is guaranteed OFF if this voltage level is equal to or less than 0.8 V.

To simplify the design of the external control circuit, logic signal. The remote ON/OFF input can be driven as shown in Figure 17.

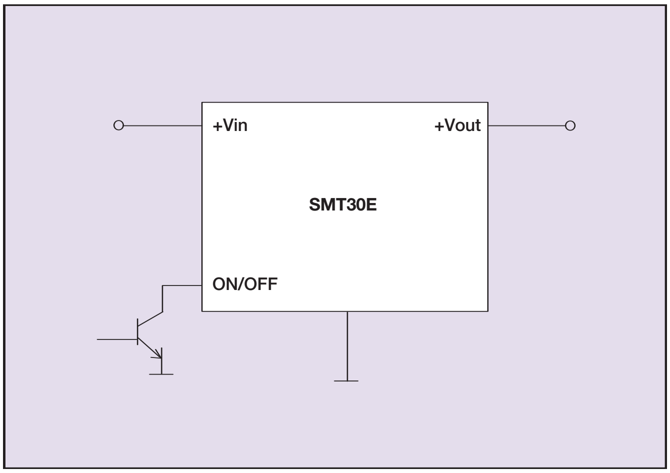

Figure 17 - Remote ON/OFF

9.3 Remote Sense

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 does 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 100 nF 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 if 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.

9.4 Parallel and Series Operation

Parallel operation of multiple converters is not recommended. If unavoidable, some de-coupling techniques 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. The thermal reference point is shown in Figure 18.

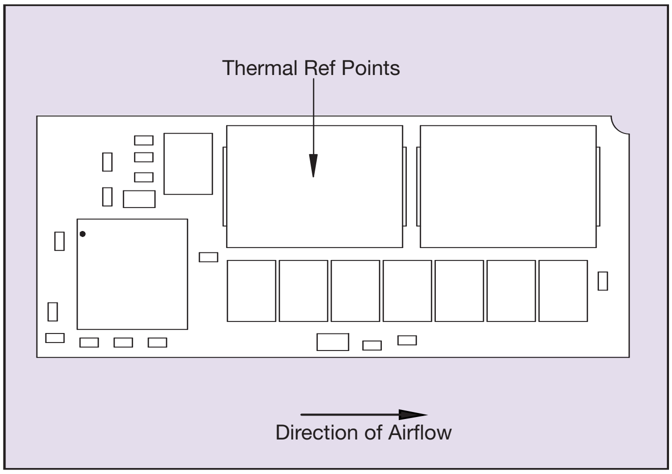

Figure 18 - Thermal Reference Point Locations on SMT30E Converters

10.2 Thermal Derating Curves
Thermal characterization data is presented in the datasheet in a thermal derating graph of which one is repeated here in Figure 19. 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 18.

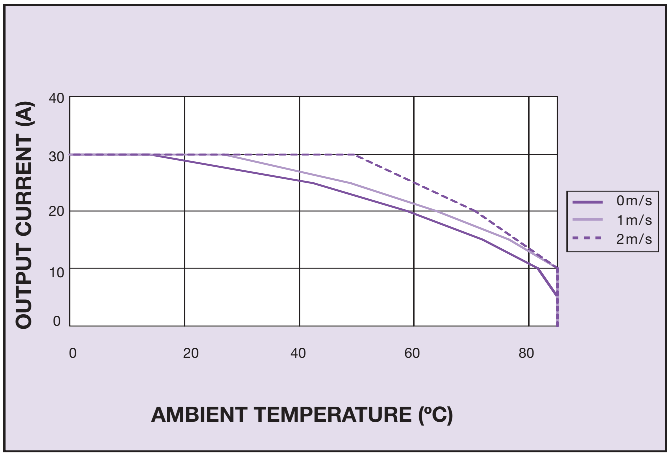

Figure 19 - Thermal Derating Curve Vin = 12 V; Vout = 2.5 V

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, six layer FR4 PCB with the inner layers consisting of 2 oz 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 indicates 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 85 °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 SMT30E 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 90/10.

Due to the fact that components with high thermal capacity such as the SMT30E may be slower to heat up than typical SMT parts, it may be necessary to customize 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 20 shows the recommended temperature of the +Vout pin during a typical reflow profile. The SMT30E is compatible with convection soldering using common solder alloys such as 63/37 and 62/36/02.

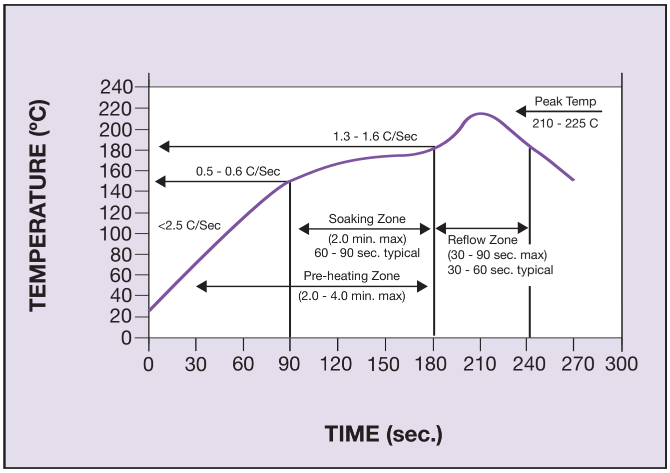

Figure 20 - Solder Reflow Profile per CECC 00802

11.3 Coplanarity

The SMT30E has a maximum co-planarity as defined by JESD22-B108 of better than 100 µm (approximately 0.004inch). Innovative design, interconnect technology, and specialized manufacturing processes ensure product integrity.

11.4 Paste Height/Coverage

Good quality solder joints have been demonstrated using a volume of 1.25mm^3 (77420 mils^3) of solder paste containing 90% metal. This can be achieved by using a 150 µm (0.006 inch) stencil on pads measuring 3.7 x 2.5mm.

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:

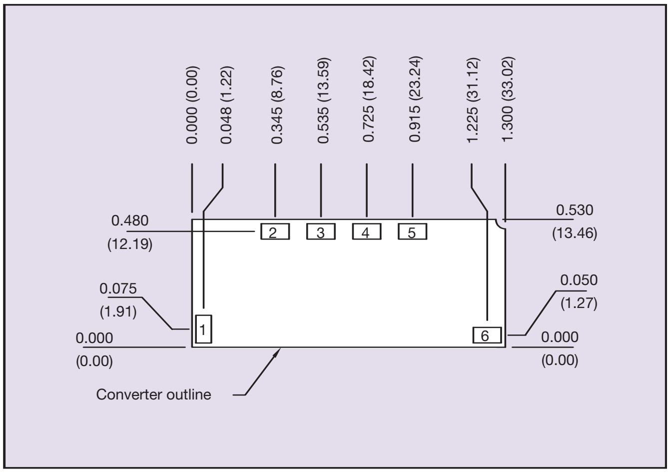

Figure 21 - Recommended Land Pattern for SMT30E

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

See Section 5.4 for PCB layout recommendations.

11.6 Pick and Place Information

The SMT30E 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 7 grams (0.24oz) 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 (0.15in^2) 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 SIL product onto application boards. The SIL 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 SMT30E is facilitated by the following:

- The pins of the SMT30E 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 and MSL Packaging Requirements

These devices have a moisture sensitivity level 3 rating in line with IPC/JEDEC J-STD-020C Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State surface mount devices.

Product is packaged according to IPC/JEDEC J-STD-033A handling, packing, shipping and use of Moistur e/Reflow Sensitive sur face mount devices.