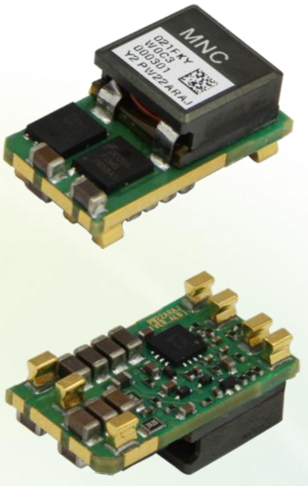
NAK12S20-A
DC-DC Converter Technical Manual V1.6

POL DC-DC Converter	9 - 14 V Input	0.9 - 5.3 V Output	20 A Current	Positive Logic

Description

The NAK12S20-A is a non-isolated DC-DC converter with an input voltage range of 9 V to 14 V and the maximum output current of 20 A. Its output voltage can be adjusted within a range of 0.9 V to 5.3 V.



NAK12S20-A

Operational Features

- Input voltage: 9 - 14 V
- Output current: 0 - 20 A
- Output voltage: 0.9 - 5.3 V
- Efficiency: 95.5% (5 V, 20 A)

Mechanical Features

- SMT pin
- Dimensions: 24 mm x 13.5 mm (0.94 in. x 0.53 in.)
- Height: <12mm (0.47 in.)
- Weight: about 7.4 g

Control Features

- Remote on/off
- Remote sense
- Output voltage trim
- Monotonic start-up into pre-biased outputs

Protection Features

- Input undervoltage protection
- Output overcurrent protection (hiccup mode)
- Output short circuit protection (hiccup mode)
- Output overvoltage protection (self-recovery)
- Overtemperature protection (self-recovery)

Safety Features

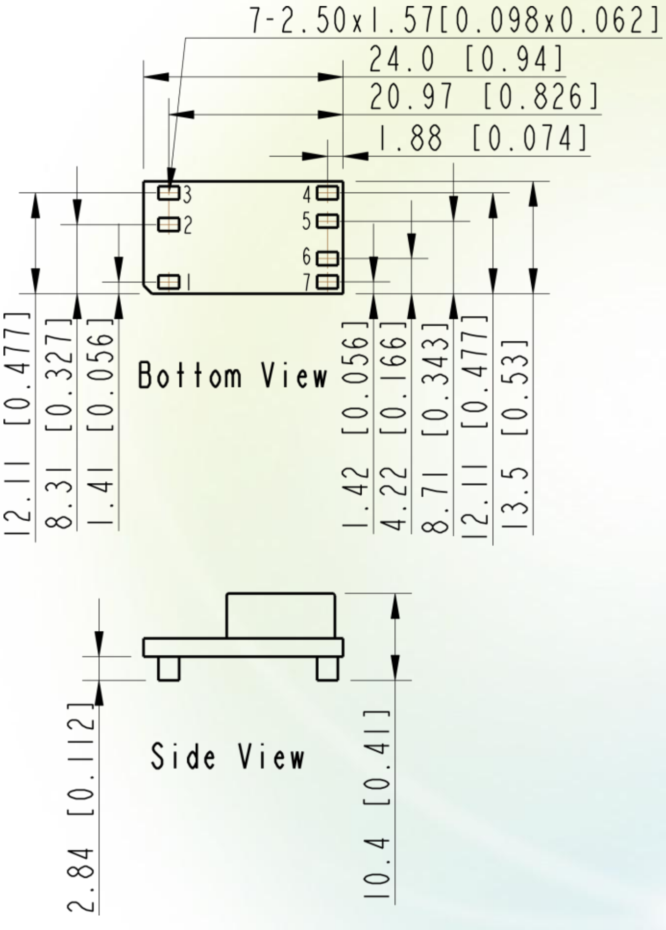
- Meet UL94V-0 flammability requirements
- RoHS6 complaint

Designation Explanation

NAK 12 S 20 -A
1 2 3 4 5

1 — Non-isolated, analog, package type
2 — Input voltage: 12 V
3 — Single output
4 — Output current: 20 A
5 — Extension code

Mechanical Diagram



Pin Description

Pin No.	Function
1	V_{in}
2	GND
3	V_{out}
4	Trim
5	SGND
6	Sense+
7	On/Off

NOTE

1. All dimensions in mm [in.]
   Tolerances: x.x ± 0.5 mm [x.xx ± 0.02 in.]
   x.xx ± 0.25 mm [x.xxx ± 0.010 in.]
2. Tolerances for the lengths, widths, and heights of all pins are x.xx ± 0.05 mm [x.xxx ± 0.002 in.]

Electrical Specifications

Conditions: T_A = -40 - 85°C, V_{in}= 12 V DC, V_{out}= 0.9 - 5.3 V DC, unless otherwise notes.

Parameter	Output	Min.	Typ.	Max.	Units	Notes & Conditions
Absolute maximum ratings						
Input voltage(Continuous)	All	0	-	16	V	-
Operating ambient temperature	All	-40	-	85	ºC	See the thermal derating curve
Storage temperature	All	-55	-	125	ºC	-
Operating humidity	All	5	-	95	% RH	Non-condensing
Input characteristics						
Operating input voltage	All	9	-	14	V	-
Input capacitance	All	40	-	-	µF	Ceramic capacitor(>40 µF); Or a 220 µF aluminum electrolytic capacitor and a ceramic capacitor in parallel
No-load input current	1.2 V	-	25	-	mA	-
No-load loss	1.2 V	-	0.3	-	W	-
Output characteristics						
Output voltage set point	0.9 V	0.89	0.9	0.91	V	V_{in} = 12 V; 50% load
Output voltage Trim range	All	0.9	-	5.3	V	-
Output line regulation	All	-	-	±1	%	V_{in}= 9 - 14 V
Output load regulation	All	-	-	±1	%	I_{out}= 0 - 20 A
Regulated voltage precision	All	-	-	±3	%	The whole range of V_{in} , I_{out} and T_A
Temperature coefficient	All	-	-	±0.02	$\%V_{out}$ /°C	T_A = -40°C to +85°C (-40°F to +185°F)
External capacitance	All	-	-	5000	µF	Aluminum electrolytic capacitor, no include 470 µF output capacitor; ESR>5mΩ
Output current	All	0	-	20	A	-
Output ripple and noise (peak to peak)	All	-	-	150	mV	Oscilloscope bandwidth: 20 MHz
Output voltage overshoot	All	-	-	5	%Vo	-
Output voltage rise time	All	4	6	8	ms	-
Switching frequency	All	-	300	-	kHz	-

Electrical Specifications

Conditions: T_A = -40 - 85°C, V_{in}= 9 - 14 V DC, V_{out}= 0.9 - 5.3 V DC, unless otherwise notes.

Parameter	Output	Min.	Typ.	Max.	Units	Notes & Conditions
Protection characteristics						
Input undervoltage protection Startup threshold Shutdown threshold Hysteresis	All	6.0 5.0 -	6.7 5.7 1.0	7.4 6.4 -	V V V	-
Output overcurrent protection	All	22	30	40	A	Hiccup mode
Output short circuit protection	All	-	-	-	-	Hiccup mode
Output overvoltage protection	All	110	-	120	%	Self-recovery
Overtemperature protection Threshold Hysteresis	All	115 -	125 5	135 -	°C °C	Self-recovery The values are obtained by measuring the temperature of the hottest power component on the top surface of the converter.
Dynamic characteristics						
Overshoot amplitude Recovery time	≤1.2 V	- -	- -	60 200	mV μs	Current change rate: 1 A/μs load : 25% - 50% - 25%; 50% - 75% - 50%
Overshoot amplitude Recovery time	>1.2 V	- -	- -	5 200	% μs	Current change rate: 1 A/μs load : 25% - 50% - 25%; 50% - 75% - 50%
Efficiency						
100% load	0.9 V	83.5	86.0	-	%	V_{in} = 12 V; T_A = 25°C
	1.0 V	85.0	87.5	-	%	V_{in} = 12 V; T_A = 25°C
	1.2 V	86.5	88.5	-	%	V_{in} = 12 V; T_A = 25°C
	1.5 V	88.0	90.5	-	%	V_{in} = 12 V; T_A = 25°C
	1.8 V	89.0	91.5	-	%	V_{in} = 12 V; T_A = 25°C
	2.5 V	90.5	93.0	-	%	V_{in} = 12 V; T_A = 25°C
	3.3 V	91.5	94.0	-	%	V_{in} = 12 V; T_A = 25°C
	5.0 V	93.0	95.5		%	V_{in} = 12 V; T_A = 25°C
Other characteristics						
Remote on/off voltage Low level High level	All All	-0.2 1.5	- -	0.5 5.0	V V	- Pulled high internally (Connecting to an external voltage is not allowed.)
Reliability characteristics						
Mean time between failures (MTBF)	All	-	1.5	-	Million hours	Telcordia SR332; Vin = 12 V; 80% load; Airflow = 1.5 m/s (300 FLM); T_A = 40°C (104°F);

Characteristic Curves

Conditions: T_A = 25°C or 77°F, unless otherwise specified.

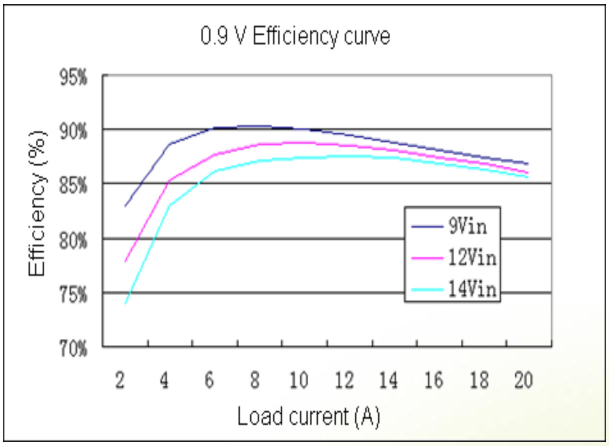


Figure 1: 0.9 V Efficiency

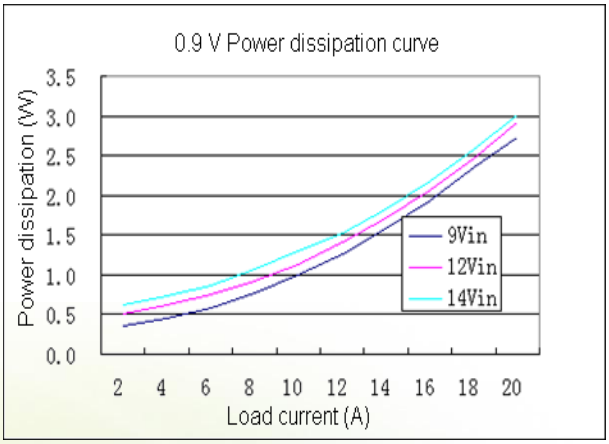


Figure 2: 0.9 V Power dissipation

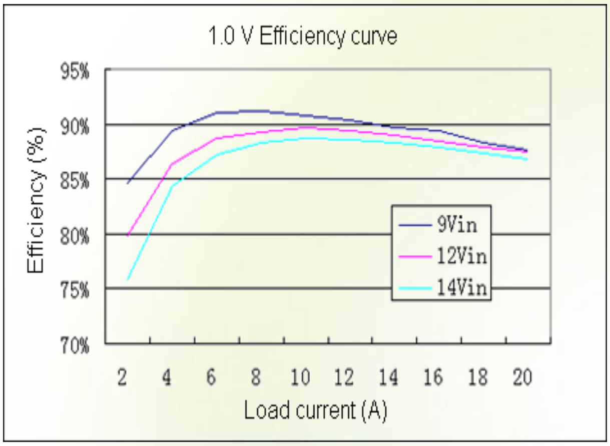


Figure 3: 1.0 V Efficiency

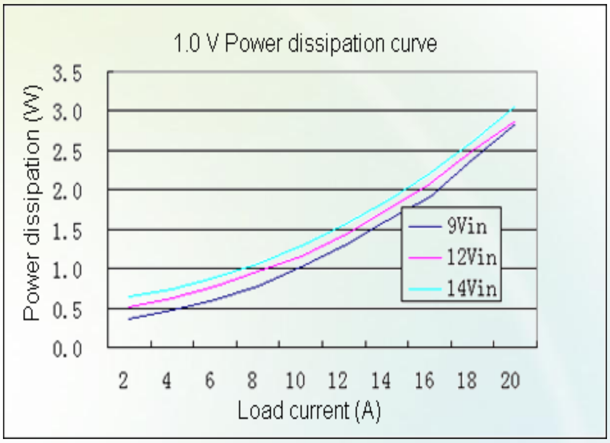


Figure 4: 1.0 V Power dissipation

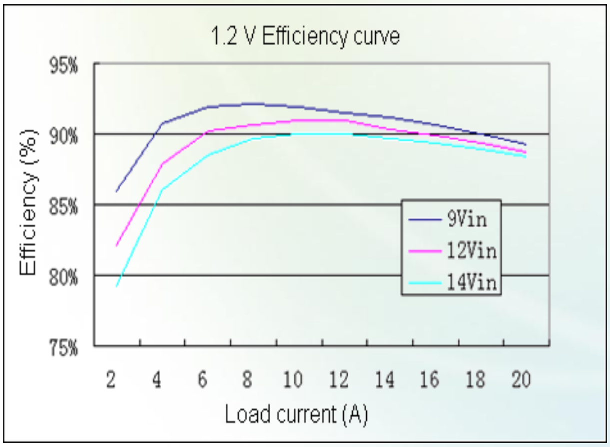


Figure 5: 1.2 V Efficiency

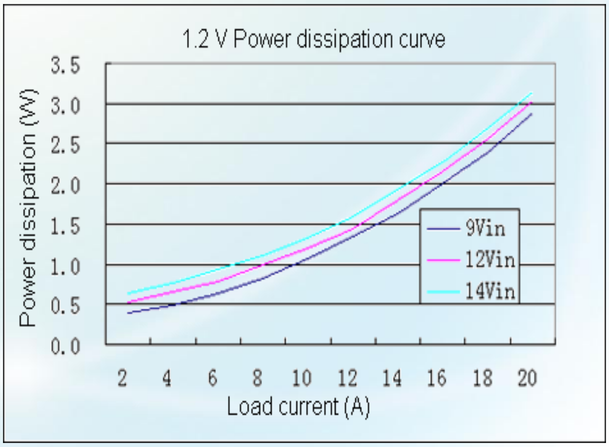


Figure 6: 1.2 V Power dissipation

Characteristic Curves

Conditions: T_A = 25°C or 77°F, unless otherwise specified.

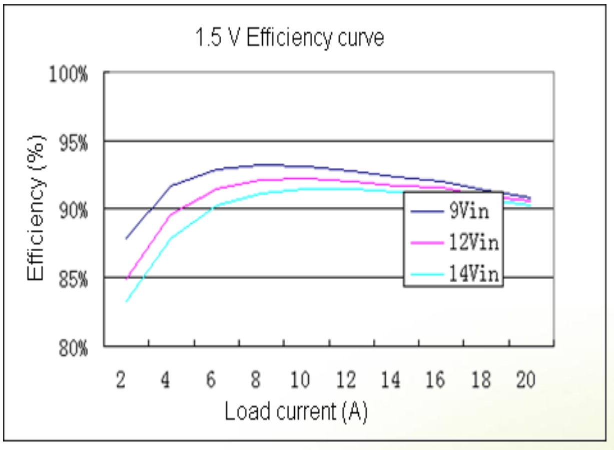


Figure 7: 1.5 V Efficiency

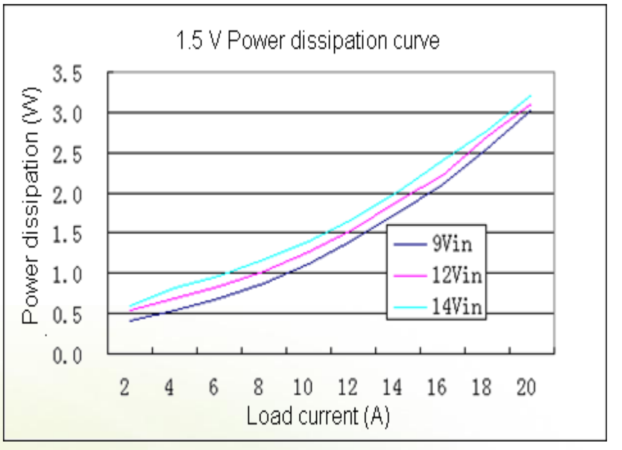


Figure 8: 1.5 V Power dissipation

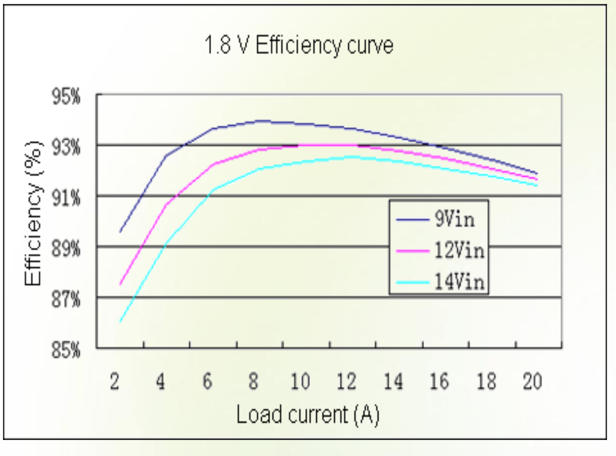


Figure 9: 1.8 V Efficiency

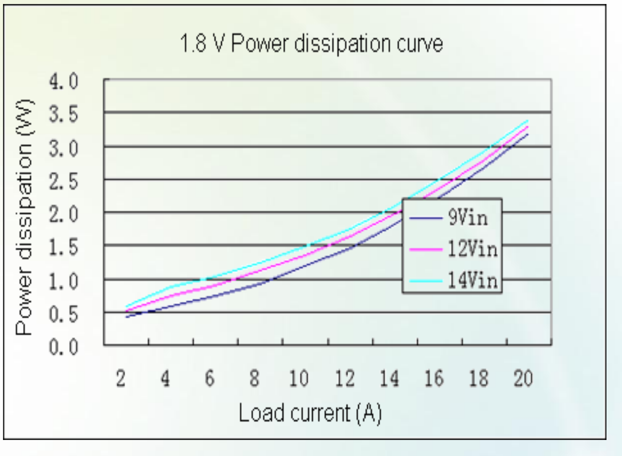


Figure 10: 1.8 V Power dissipation

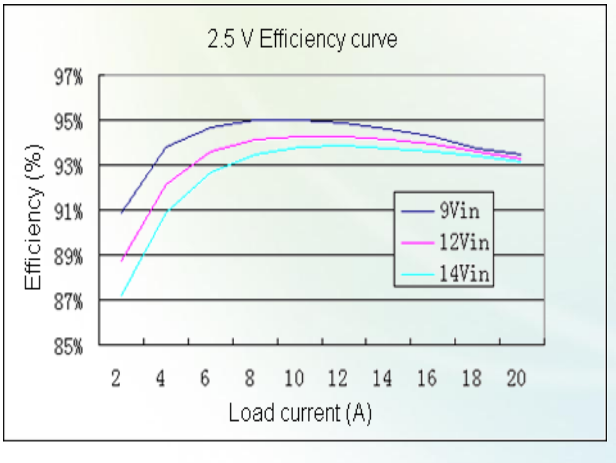


Figure 11: 2.5 V Efficiency

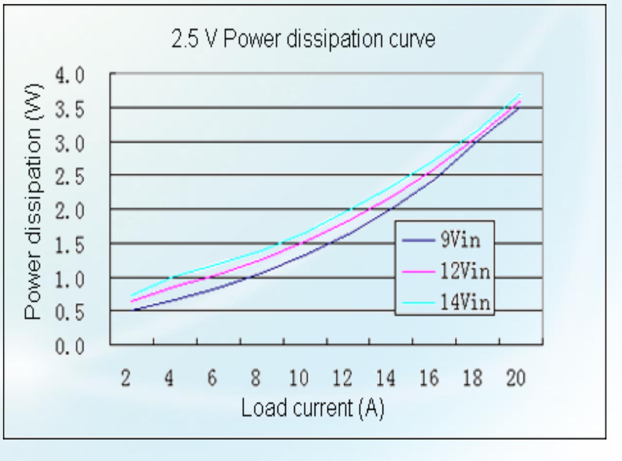


Figure 12: 2.5 V Power dissipation

Characteristic Curves

Conditions: T_A = 25°C or 77°F, unless otherwise specified.

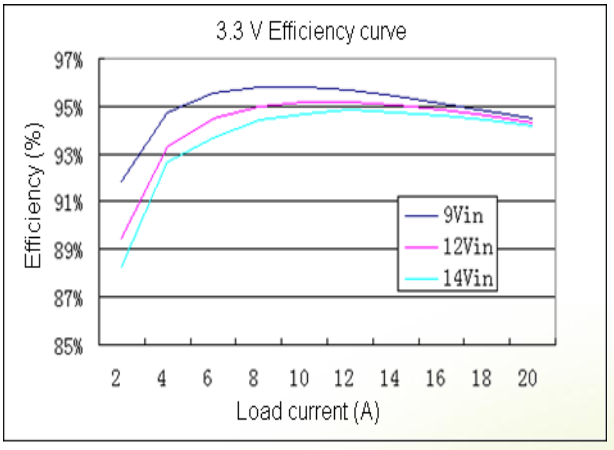


Figure 13: 3.3 V Efficiency

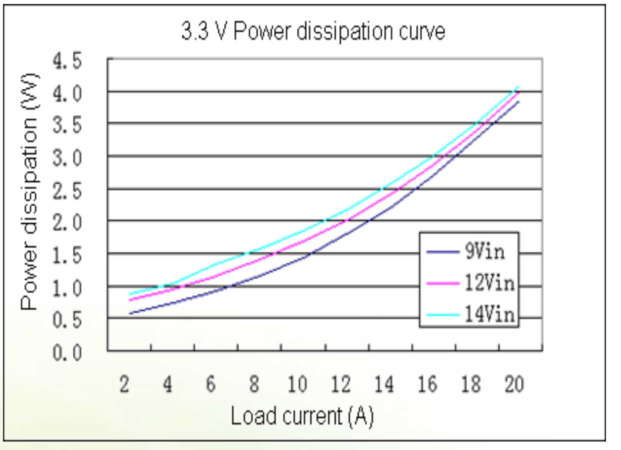


Figure 14: 3.3 V Power dissipation

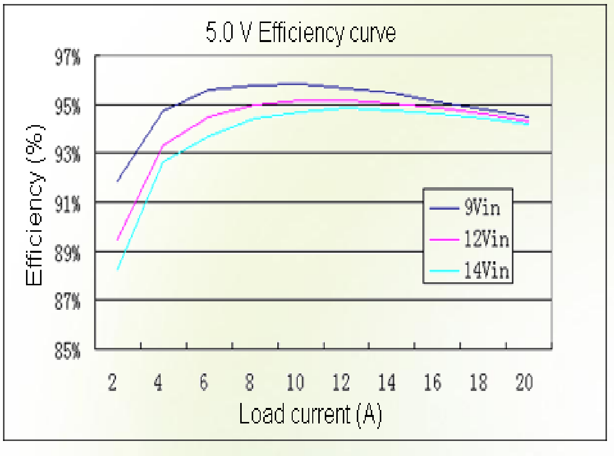


Figure 15: 5.0 V Efficiency

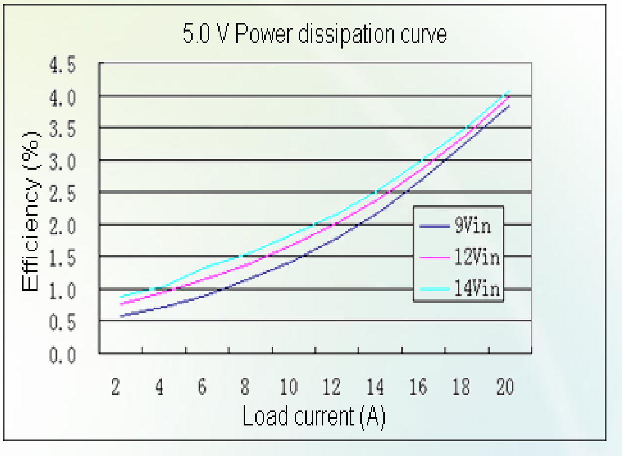


Figure 16: 5.0 V Power dissipation

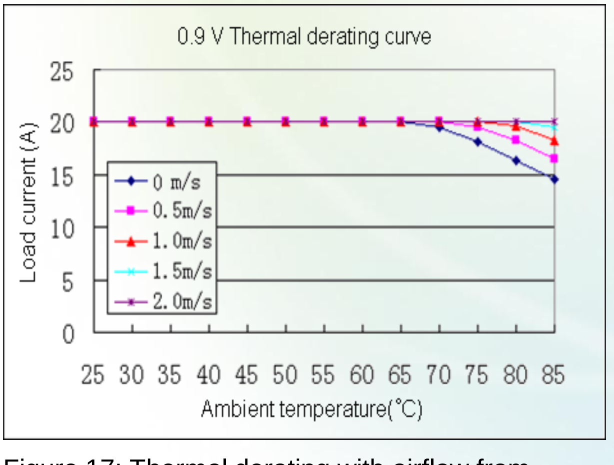


Figure 17: Thermal derating with airflow from Pin1 to Pin6 (V_{in} = 5 V; V_{out} = 0.9 V)

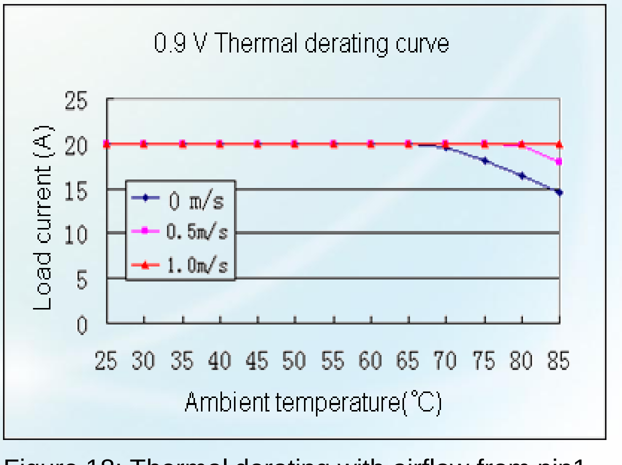


Figure 18: Thermal derating with airflow from pin1 to pin3 (V_{in} = 5 V; V_{out} = 0.9 V)

Characteristic Curves

Conditions: T_A = 25°C or 77°F, unless otherwise specified.

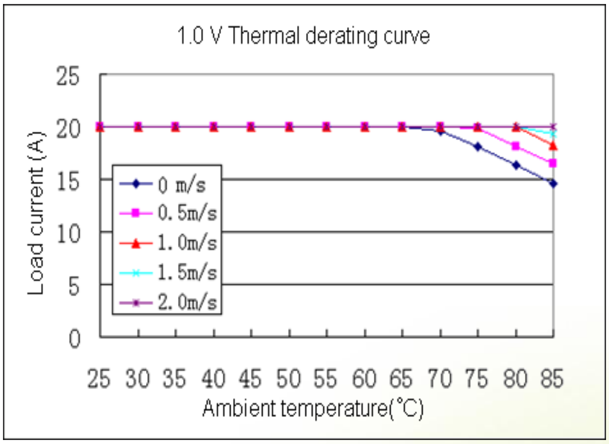


Figure 19: Thermal derating with airflow from pin1 to pin6 (V_{in} = 12 V; V_{out} = 1.0 V)

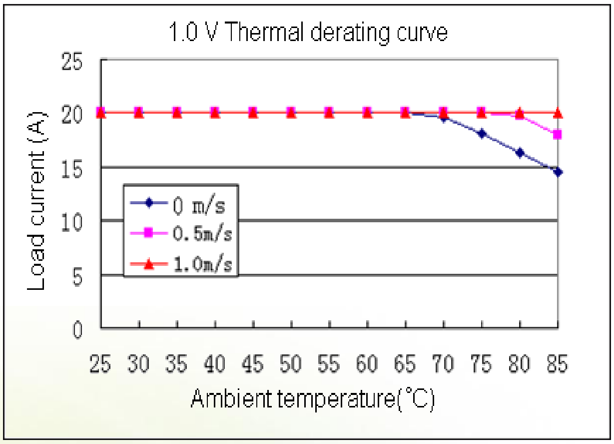


Figure 20: Thermal derating with airflow from pin1 to pin3 (V_{in} = 12 V; V_{out} = 1.0 V)

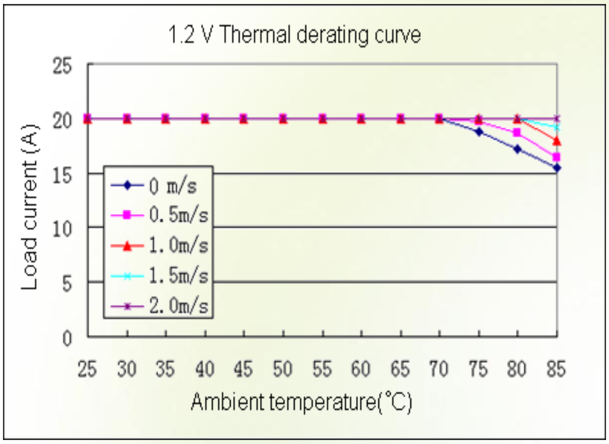


Figure 21: Thermal derating with airflow from pin1 to pin6 (V_{in} = 12 V; V_{out} = 1.2 V)

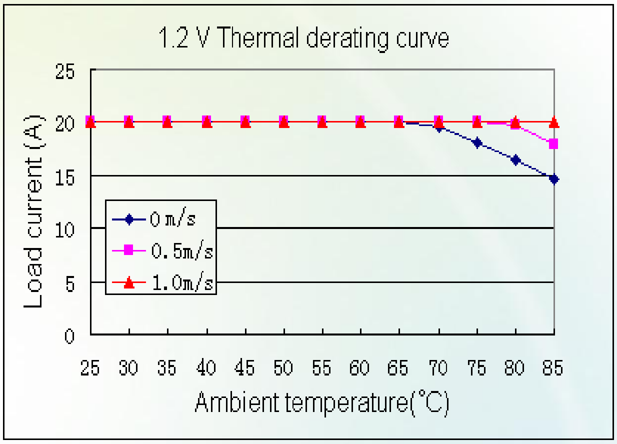


Figure 22: Thermal derating with airflow from pin1 to pin3 (V_{in} = 12 V; V_{out} = 1.2 V)

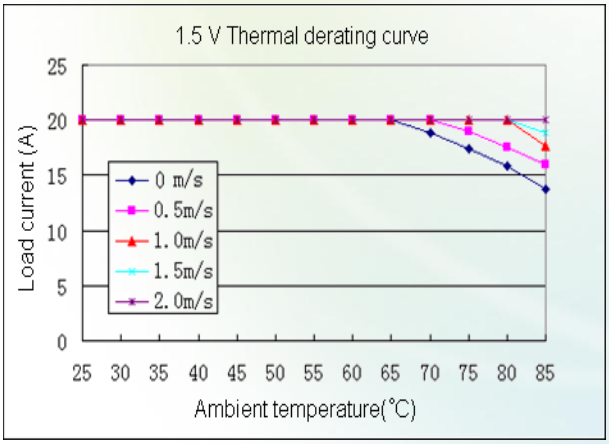


Figure 23: Thermal derating with airflow from pin1 to pin6 (V_{in} = 12 V; V_{out} = 1.5 V)

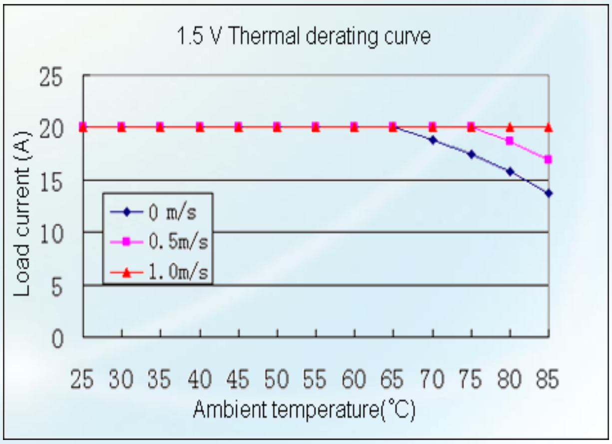


Figure 24: Thermal derating with airflow from pin1 to pin3 (V_{in} = 12 V; V_{out} = 1.5 V)

Characteristic Curves

Conditions: T_A = 25°C or 77°F, unless otherwise specified.

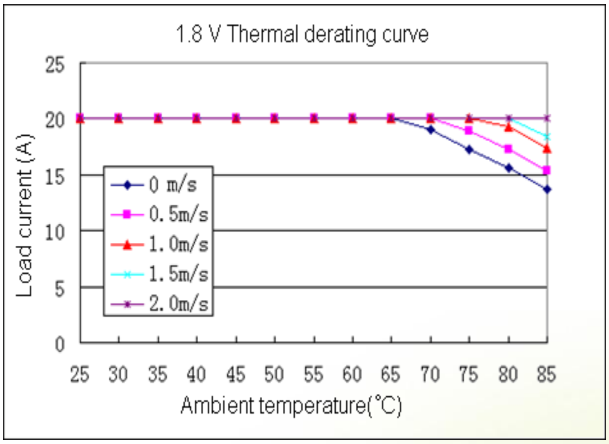


Figure 25: Thermal derating with airflow from pin1 to pin6 (V_{in} = 12 V; V_{out} = 1.8 V)

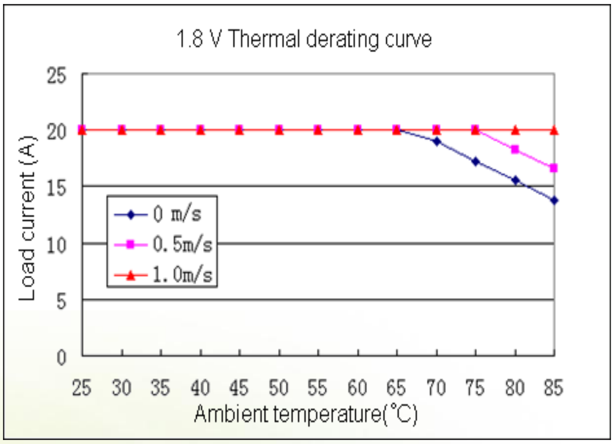


Figure 26: Thermal derating with airflow from pin1 to pin3 (V_{in} = 12 V; V_{out} = 1.8 V)

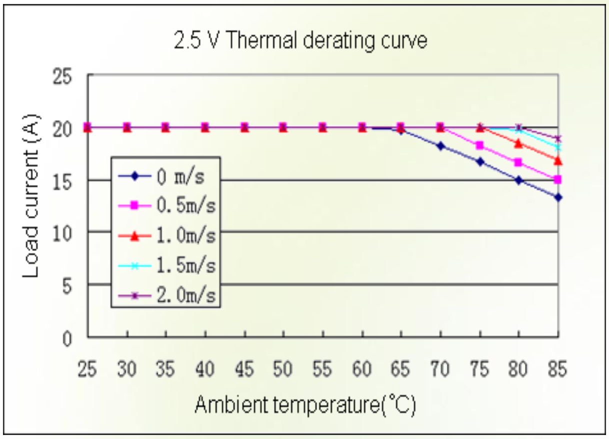


Figure 27: Thermal derating with airflow from pin1 to pin6 (V_{in} = 12 V; V_{out} = 2.5 V)

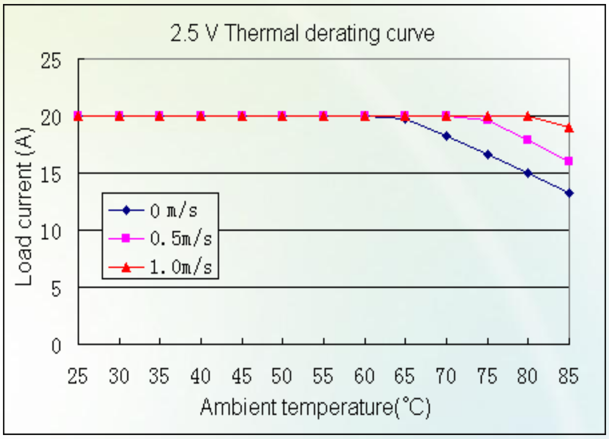


Figure 28: Thermal derating with airflow from pin1 to pin3 (V_{in} = 12 V; V_{out} = 2.5 V)

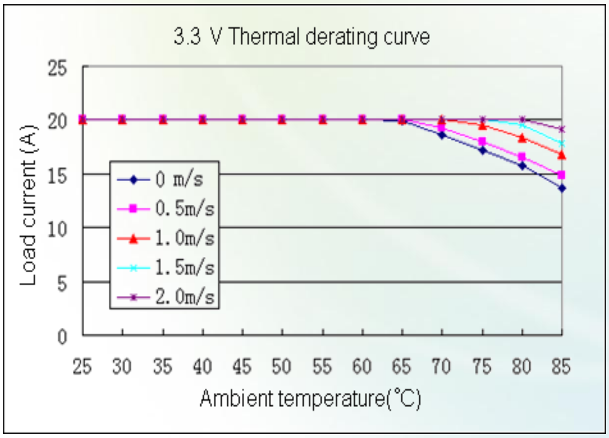


Figure 29: Thermal derating with airflow from pin1 to pin6 (V_{in} = 12 V; V_{out} = 3.3 V)

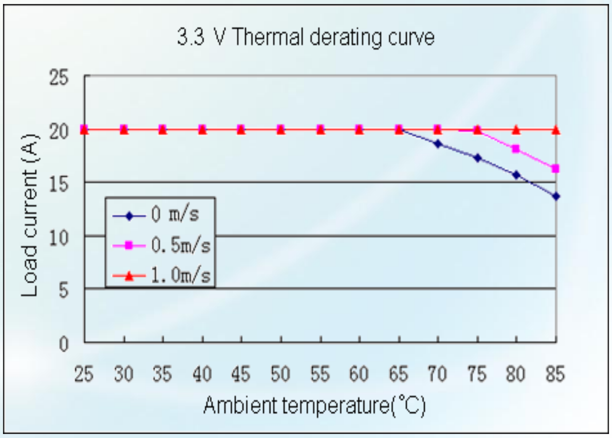


Figure 30: Thermal derating with airflow from pin1 to pin3 (V_{in} = 12 V; V_{out} = 3.3 V)

Characteristic Curves

Conditions: T_A = 25°C or 77°F, unless otherwise specified.

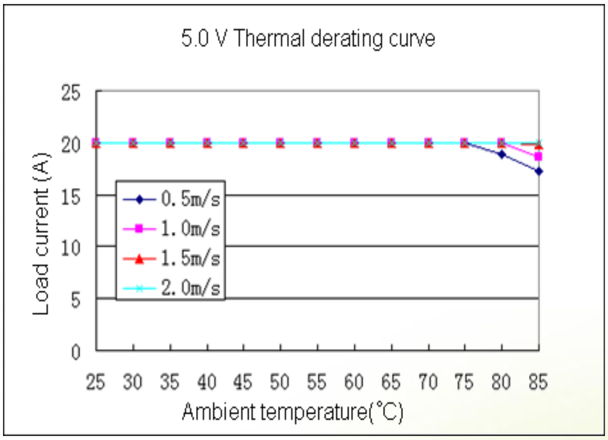


Figure 31: Thermal derating with airflow from pin1 to pin6 (V_{in} = 12 V; V_{out} = 5.0 V)

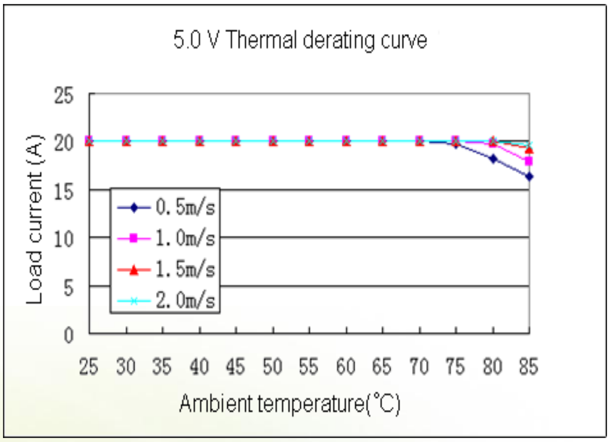


Figure 32: Thermal derating with airflow from pin1 to pin3 (V_{in} = 12 V; V_{out} = 5.0 V)

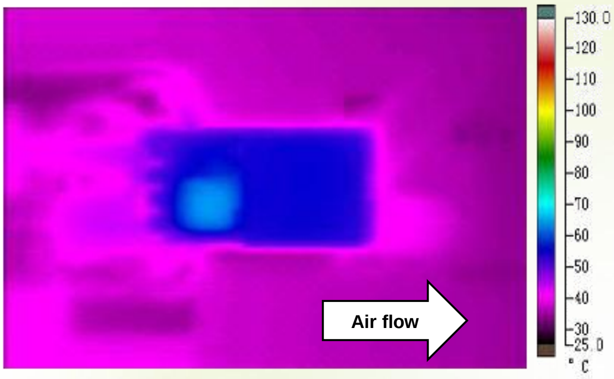


Figure 33: Thermal plot with airflow from pin1 to pin6 (T_A = 25°C (77°F); Airflow = 1 m/s (200 FLM); V_{in} = 12 V; V_{out} = 0.9 V; I_{out} = 20 A)

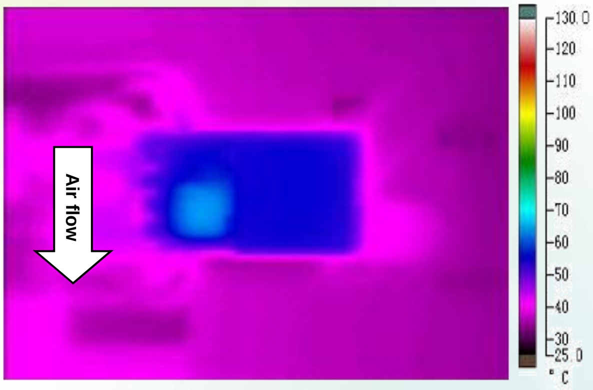


Figure 34: Thermal plot with airflow from pin1 to pin3 (T_A = 25°C (77°F); Airflow = 1 m/s (200 FLM); V_{in} = 12 V; V_{out} = 0.9 V; I_{out} = 20 A)

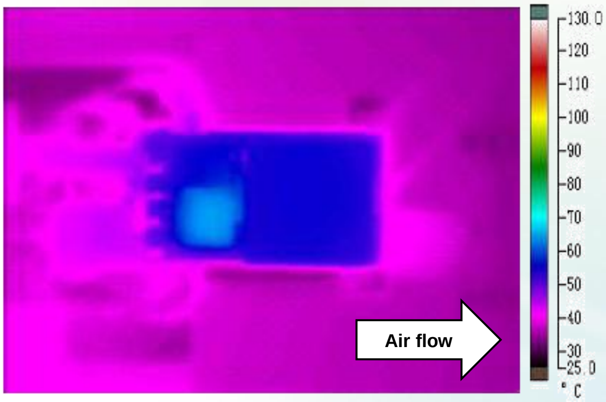


Figure 35: Thermal plot with airflow from pin1 to pin6 (T_A = 25°C (77°F); Airflow = 1 m/s (200 FLM); V_{in} = 12 V; V_{out} = 1.0 V; I_{out} = 20 A)

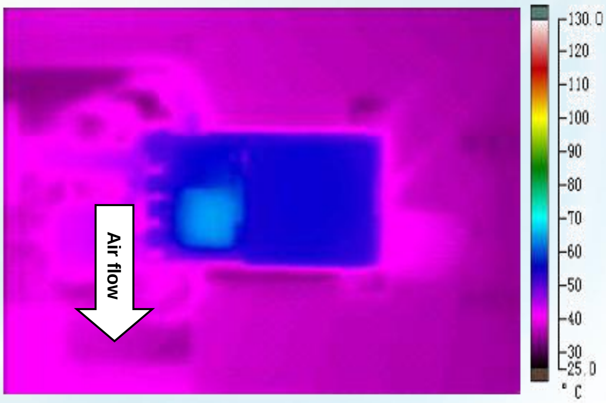


Figure 36: Thermal plot with airflow from pin1 to pin3 (T_A = 25°C (77°F); Airflow = 1 m/s (200 FLM); V_{in} = 12 V; V_{out} = 1.0 V; I_{out} = 20 A)

Characteristic Curves

Conditions: T_A = 25°C or 77°F, unless otherwise specified.

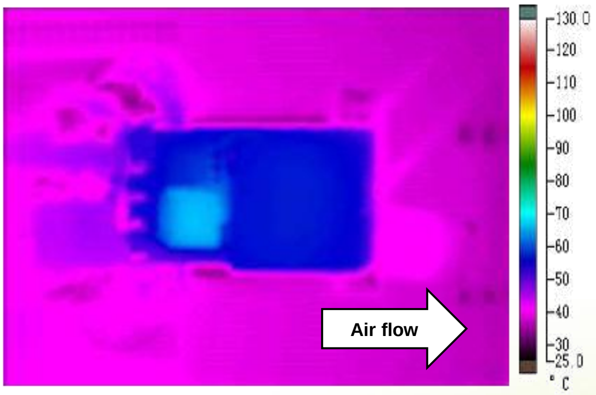


Figure 37: Thermal plot with airflow from pin1 to pin6 (T_A = 25°C (77°F); Airflow = 1 m/s (200 FLM); V_{in} = 12 V; V_{out} = 1.2V; I_{out} = 20 A)

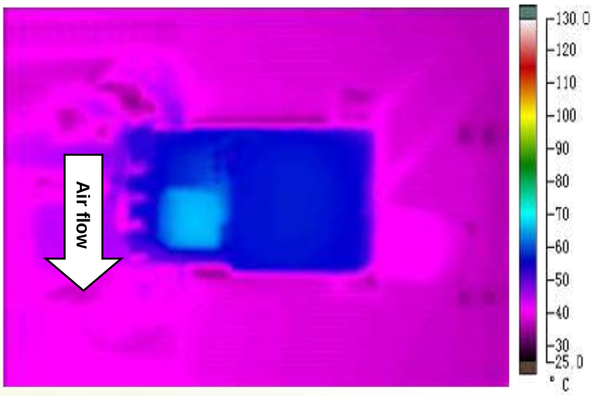


Figure 38: Thermal plot with airflow from pin1 to pin3 (T_A = 25°C (77°F); Airflow = 1 m/s (200 FLM); V_{in} = 12 V; V_{out} = 1.2 V; I_{out} = 20 A)

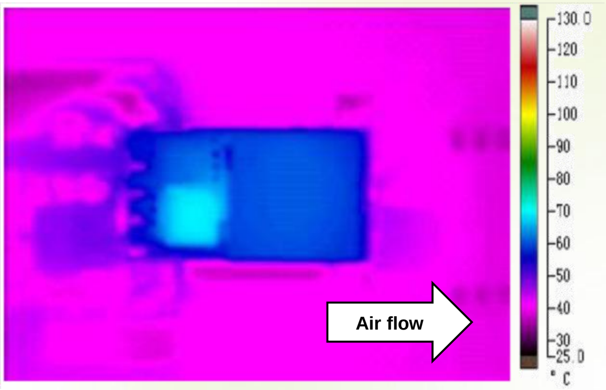


Figure 39: Thermal plot with airflow from pin1 to pin6 (T_A = 25°C (77°F); Airflow = 1 m/s (200 FLM); V_{in} = 12 V; V_{out} = 1.5 V; I_{out} = 20 A)

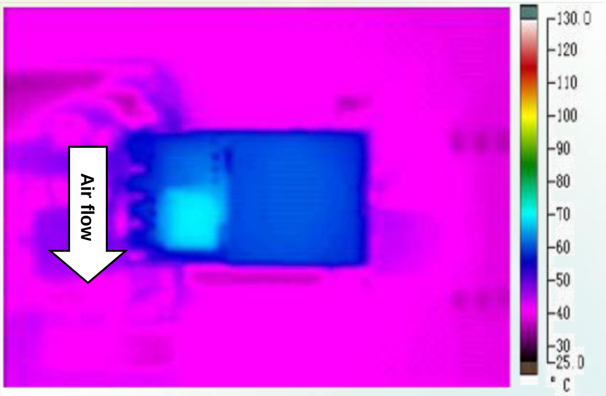


Figure 40: Thermal plot with airflow from pin1 to pin3 (T_A = 25°C (77°F); Airflow = 1 m/s (200 FLM); V_{in} = 12 V; V_{out} = 1.5V; I_{out} = 20 A)

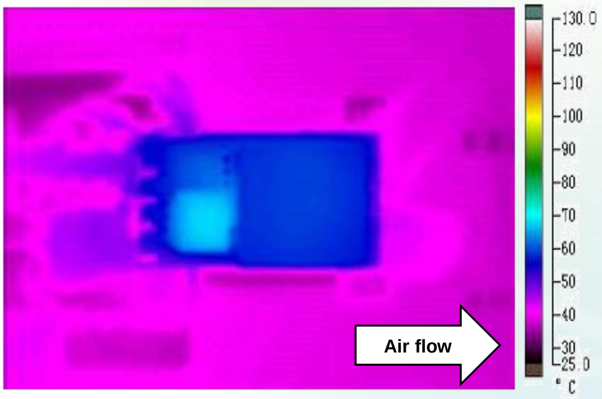


Figure 41: Thermal plot with airflow from pin1 to pin6 (T_A = 25°C (77°F); Airflow = 1 m/s (200 FLM); V_{in} = 12 V; V_{out} = 1.8 V; I_{out} = 20 A)

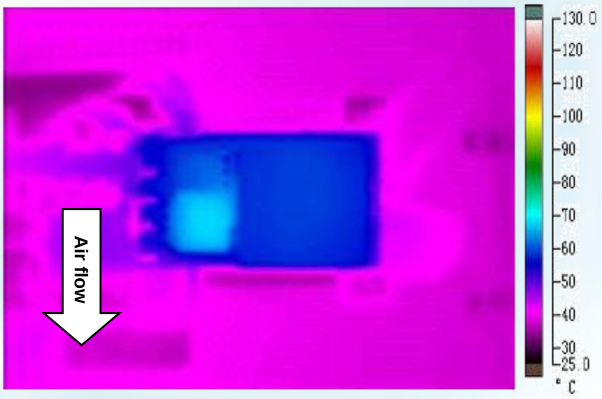


Figure 42: Thermal plot with airflow from pin1 to pin3 (T_A = 25°C (77°F); Airflow = 1 m/s (200 FLM); V_{in} = 12 V; V_{out} = 1.8 V; I_{out} = 20 A)

Characteristic Curves

Conditions: T_A = 25°C or 77°F, unless otherwise specified.

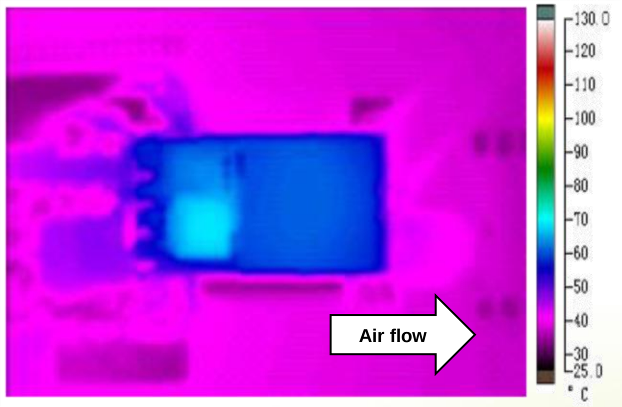


Figure 43: Thermal plot with airflow from pin1 to pin6 (T_A = 25°C (77°F); Airflow = 1 m/s (200 FLM); V_{in} = 12 V; V_{out} = 2.5V; I_{out} = 20 A)

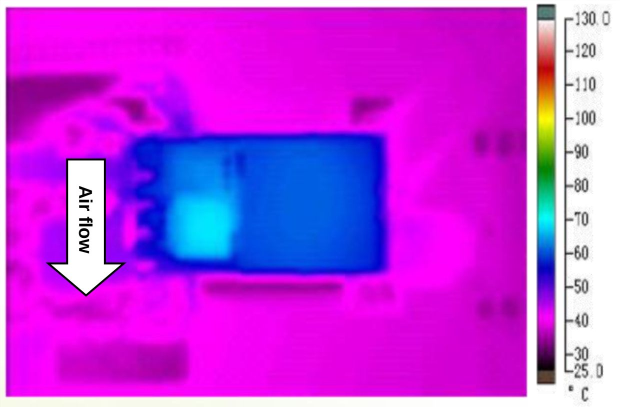


Figure 44: Thermal plot with airflow from pin1 to pin3 (T_A = 25°C (77°F); Airflow = 1 m/s (200 FLM); V_{in} = 12 V; V_{out} = 2.5 V; I_{out} = 20 A)

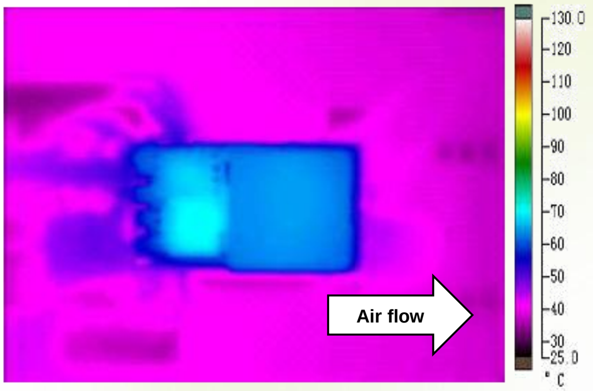


Figure 45: Thermal plot with airflow from pin1 to pin6 (T_A = 25°C (77°F); Airflow = 1 m/s (200 FLM); V_{in} = 12 V; V_{out} = 3.3 V; I_{out} = 20 A)

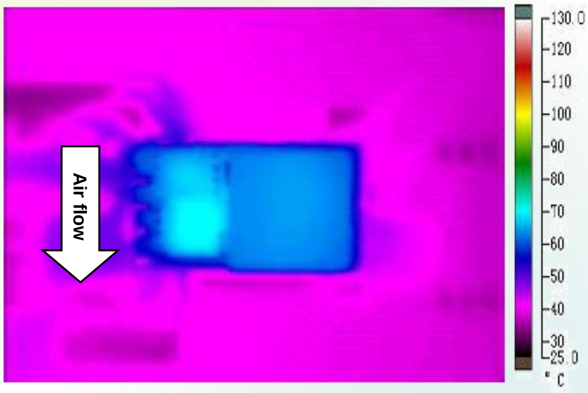


Figure 46: Thermal plot with airflow from pin1 to pin3 (T_A = 25°C (77°F); Airflow = 1 m/s (200 FLM); V_{in} = 12 V; V_{out} = 3.3V; I_{out} = 20 A)

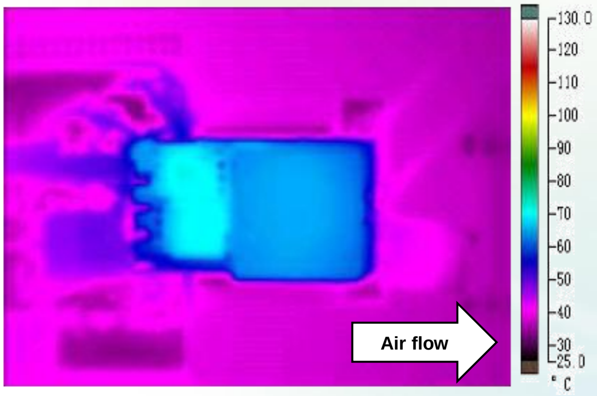


Figure 47: Thermal plot with airflow from pin1 to pin6 (T_A = 25°C (77°F); Airflow = 1 m/s (200 FLM); V_{in} = 12 V; V_{out} = 5.0 V; I_{out} = 20 A)

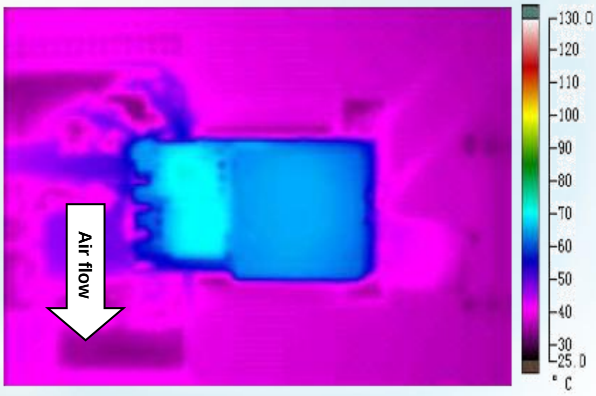


Figure 48: Thermal plot with airflow from pin1 to pin3 (T_A = 25°C (77°F); Airflow = 1 m/s (200 FLM); V_{in} = 12 V; V_{out} = 5.0 V; I_{out} = 20 A)

Typical Waveforms

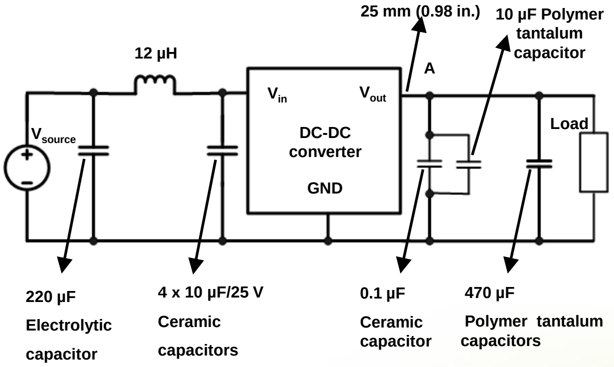


Figure 49: Test set-up diagram

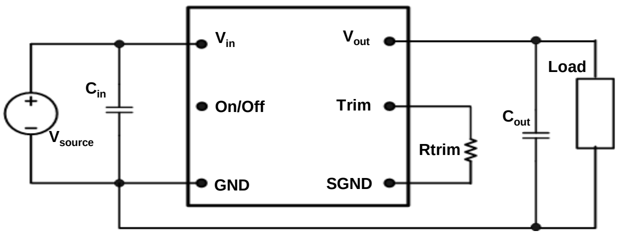


Figure 50: Application guidance

NOTE

1. Measure the output voltage ripple at A respectively shown in Figure 49.
2. During the test of input reflected ripple current, the input terminal must be connected to a 12 µH inductor and a 220 µF electrolytic capacitor.
3. Point A, which is for testing the output voltage ripple, is 25 mm (0.98 in.) away from the V_{out} pin.
4. Test board: D x W = 200 mm x 110 mm, 1oz, 4 layers.

NOTE

Do not connect the GND and SGND pins outside the converter.

To ensure the stable operating of the converter, the proper capacitors must be add to the input and output terminals.

capacitor	Recommend capacitor
C_{in}	4 x 10 µF/25 V ceramic capacitors
C_{out}	470 µF polymer tantalum capacitor

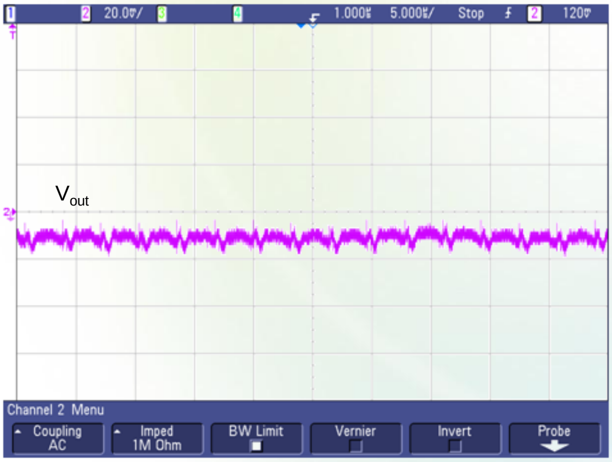


Figure 51: Output voltage ripple
(for point A in the test set-up diagram, V_{in} = 12 V, V_{out} = 1.2 V, I_{out} = 20 A)

Typical Waveforms

Conditions: T_A = 25°C (77°F), V_{in} = 12 V, V_{out} = 1.2 V

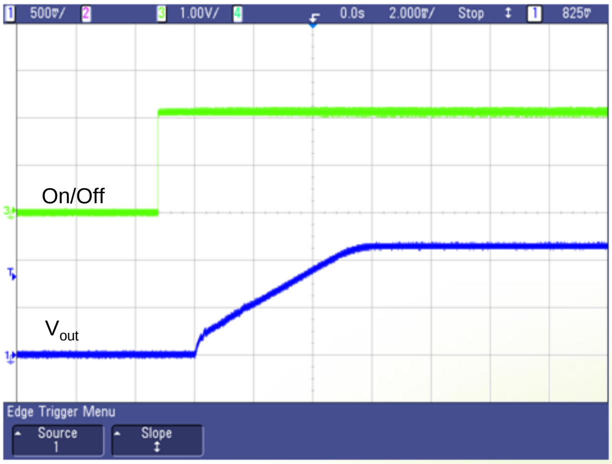


Figure 52: Startup from On/Off

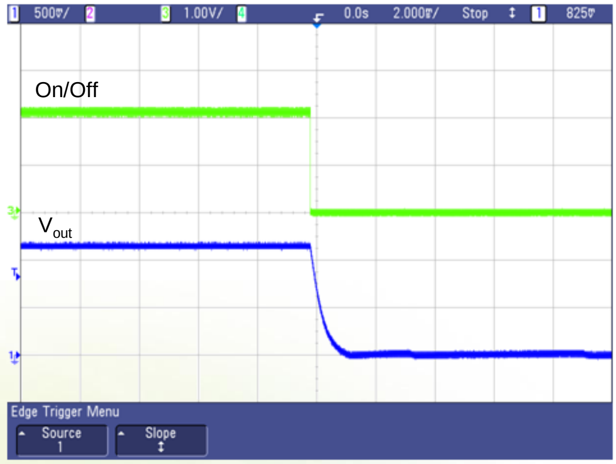


Figure 53: Shutdown from On/Off

Figure 54: Startup by power on

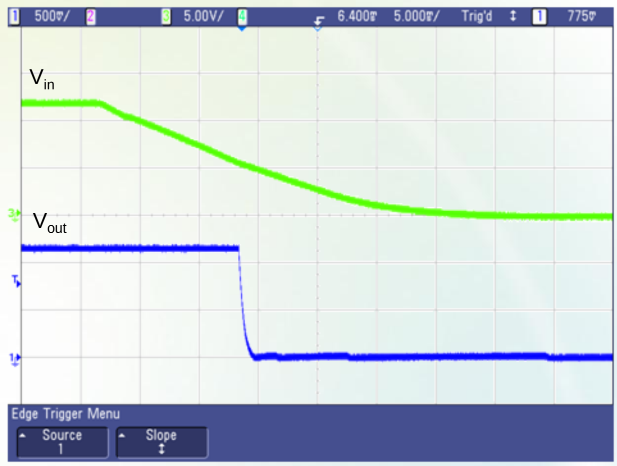


Figure 55: Shutdown by power off

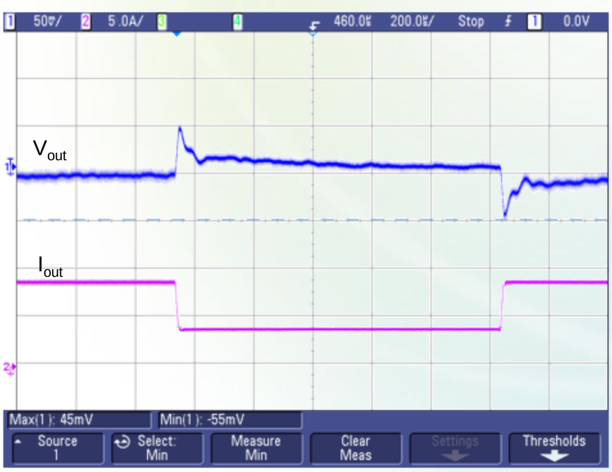


Figure 56: Output voltage dynamic response
(Load : 25% - 50% - 25%, di/dt= 1 A/μs)

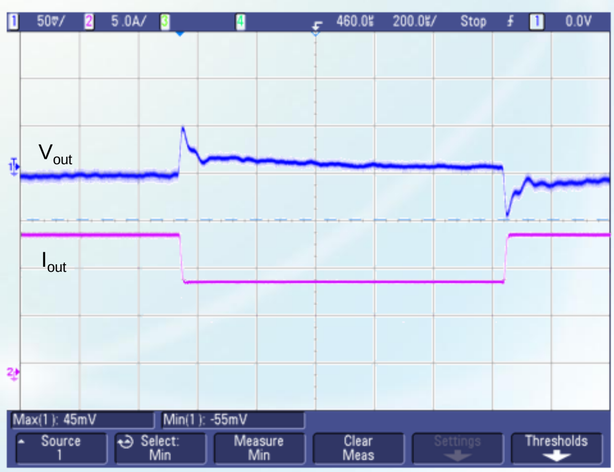


Figure 57: Output voltage dynamic response
(Load : 50% - 75% - 50%, di/dt= 1 A/μs)

Remote On/Off

On/Off Pin Level	Status
Low level	Off
Left open	On

It is recommended to control the On/Off pin with an open collector transistor or similar device.

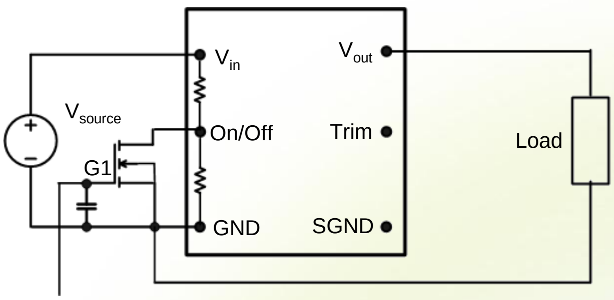


Figure 58: Circuit configuration for On/Off function

Output Voltage Trim

Output voltage can be adjusted by installing an external resistor between the Trim pin and the SGND pin.

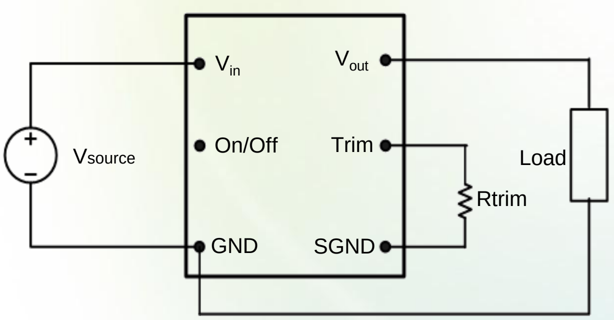


Figure 59: R_{trim} external connections

The relationship between R_{trim} and V_{out}:

$$R_{trim} = \left[\frac{12}{V_{out} - 0.6}\right] \text{K}\Omega$$

The output voltage varies depending on the Rtrim. Note that the trim resistor tolerance directly affects the output voltage accuracy. It is recommended to use ±1% trim resistor.

The following table describes the mapping between the V_{out} and R_{trim}.

Vout (V)	Rtrim (KΩ)
0.9	40
1.0	30
1.2	20
1.5	13.333
1.8	10
2.5	6.315
3.3	4.444
5.0	2.727
5.3	2.553

Remote Sense

The remote sense feature compensates for the voltage drop between the output pins of the converter and the load. The Sense+ should be connected at the load or at the point where regulation is required. The maximum compensation voltage is 0.1 V.

If the remote sense function is disabled, leave the Sense+ open.

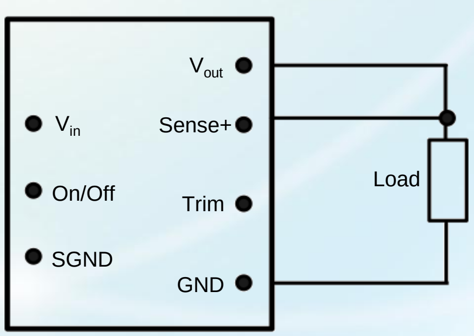


Figure 60: Configuration diagram for remote sense

Input Undervoltage Protection

The converter will shut down after the input voltage drops below the undervoltage protection threshold for shutdown. The converter will start to work again after the input voltage reaches the input undervoltage protection threshold for startup. For the Hysteresis, see the Protection characteristics.

Output Overcurrent Protection

The converter equipped with current limiting circuitry can provide protection from an output overload or short circuit condition. If the output current exceeds the output overcurrent protection threshold, the converter enters hiccup mode. When the fault condition is removed, the converter will automatically restart.

Output Overvoltage Protection

When the voltage directly across the output pins exceeds the output overvoltage protection threshold, the converter will stop working to protect the converter and the load. The converter will automatically resumes normal operation after the over voltage condition is removed.

Overtemperature Protection

A temperature sensor on the converter senses the average temperature of the module. It protects the converter from being damaged at high temperatures. When the temperature exceeds the Overtemperature protection threshold, the output will shut down. It will allow the converter to turn on again when the temperature of the sensed location falls by the value of Overtemperature Protection Hysteresis.

PCB Layout Considerations

To ensure the filtering effects, place the C_{in} and C_{out} symmetrically near the pins. The following figure shows the cable hole layouts at the input and output terminals.

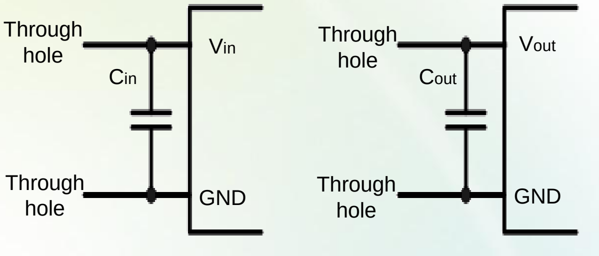


Figure 61: Recommend PCB layout

Qualification Testing

Parameter	Units	Condition
High Accelerated Life Test (HALT)	4	Lowest operating temperature: -60°C (-76°F); highest operating temperature: 120°C (248°F); vibration limit: 40 G
Proof Of Screen (POS)	4	80 temperature cycles; 50% vibration limit stress: 20 G
High Accelerated Stress Audit (HASA)	8	4 temperature cycles; 50% vibration limit stress: 20 G
Thermal Shock	32	500 temperature cycles between -40°C (-40°F) and +125°C (+257°F) with the temperature change rate of 20°C (68°F) per minute Lasting for 30 minutes both at -40°C (-40°F) and +125°C (+257°F)
Temperature Humidity Bias	16	85°C (185°F); 85% RH; 1000 operating hours under lowest load power

Thermal Consideration

Thermal Test Point

Sufficient airflow should be provided to ensure reliable operating of the converter. Therefore, thermal components are mounted on the top surface of the converter to dissipate heat to the surrounding environment by conduction, convection and radiation. Proper airflow can be verified by measuring the temperature at the thermal test point.

Thermal test point

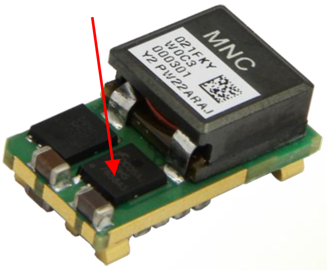


Figure 62: Thermal test point

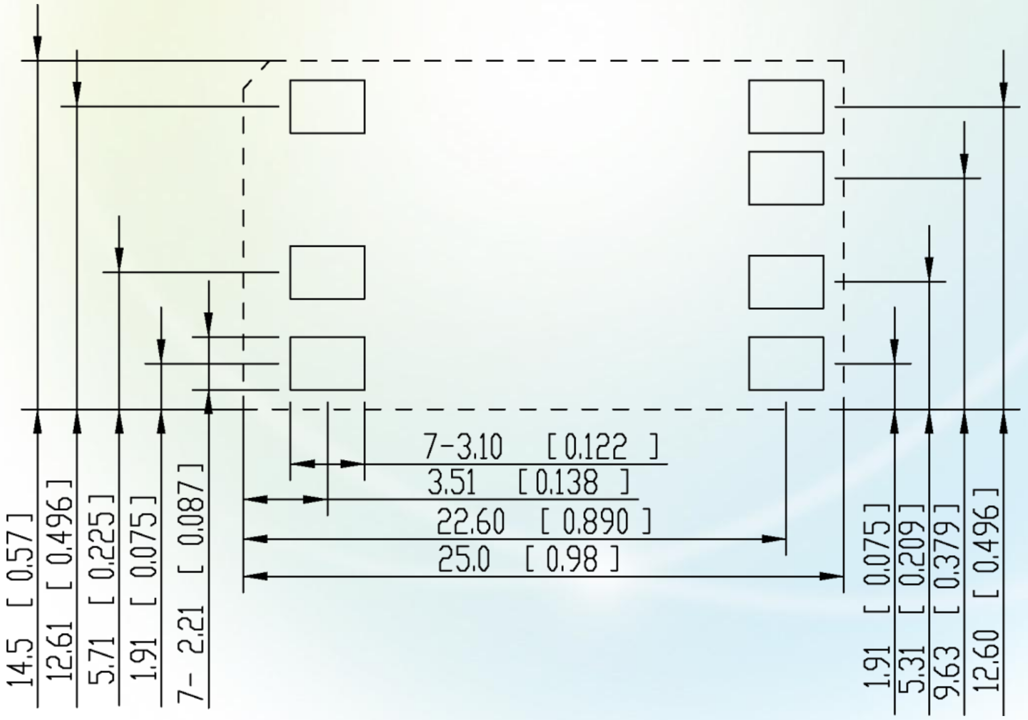
NOTE
The temperature at the thermal test point on the converter cannot exceed 125°C (257°F). Otherwise, the converter will be protected against overtemperature and will not operate properly.

Power Dissipation

The converter power dissipation is calculated based on efficiency. The following formula reflects the relationship between the consumed power (P_d), efficiency (η), and output power (P_o): $Pd= Po(1-\eta)/\eta$

Encapsulation Size Diagram

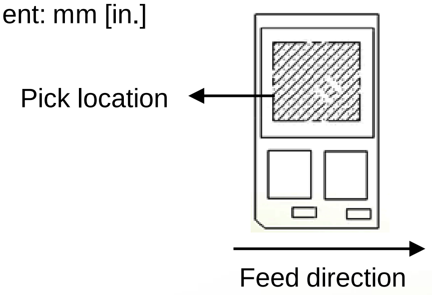
Unit of measurement: mm [in.]

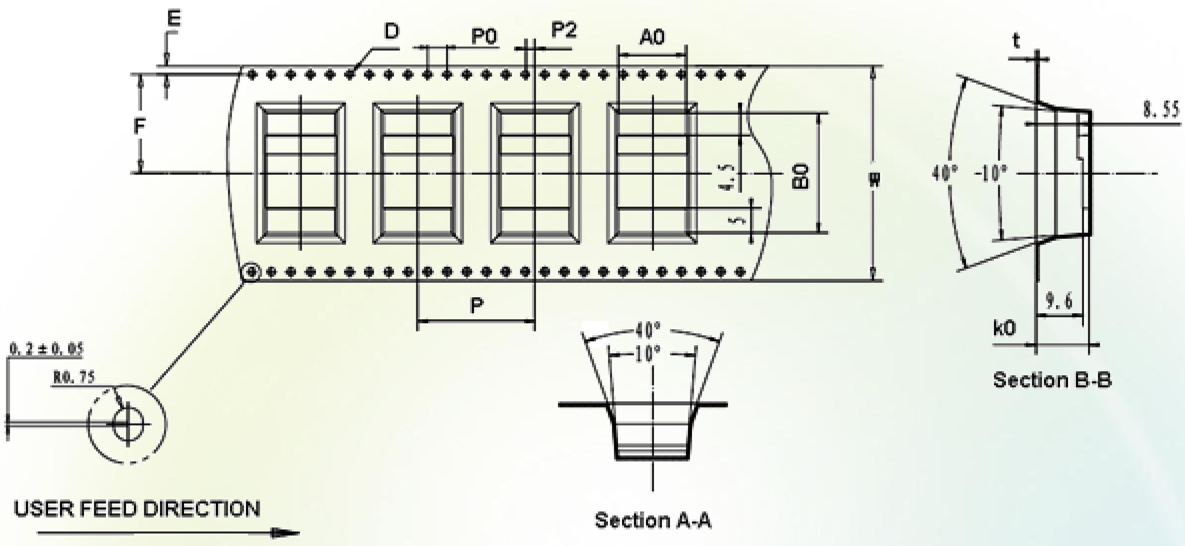


Package Information

The converters are supplied in tape & reel as standard. The following figure shows the tape dimensions.

Unit of measurement: mm [in.]





ITEM	W	A0	B0	K0	P	F	E	D	P0	P2	t	13”	
DIM	44.0	14	24.6	10.9	24	20.2	1.75	1.50	4.00	2.00	0.5	Length /Reel	Number of Components /Reel
TOLE	+0.30 -0.30	+0.10 -0.10	+0.10 -0.10	+0.10 -0.10	+0.10 -0.10	+0.10 -0.10	+0.10 -0.10	+0.10 -0.10	+0.10 -0.10	+0.10 -0.10	+0.05 -0.05	6.2M	220PCS

NOTE

1. The maximum accumulated tolerance for any 10 ratcheting holes is ±0.02 mm.
2. The thickness is measured at the edge of the carrier tape.
3. The maximum tolerance for parallelism of each 100 mm of the carrier tape is 1 mm.
4. The tolerance, if not specified, is ±0.1 mm.
5. A0 and B0 are measured at 0.3 mm above the mould cavity interior. K0 is the internal depth.
6. The chamfer on the exterior of the mould cavity, if not specified, ranges from 0.2 to 0.3.
7. The demould gradient, if not specified, is 3 degrees.
8. After wrapped with coiled tape, the converter is then packaged in a sealed bag together with desiccant.

Mechanical Consideration

Surface Mount Information

The converter uses an open frame structure and is designed for a fully automated assembly process. The flat surface of the label on the large inductor can be the patch mounting surface. The converter weight can be borne by a standard surface mounting device (SMD). For most SMDs, the converter is heavy, and mounting on the capacitor surface will cause deviation. The solution is to optimize the model and size of the suction nozzle and increase the mounting speed and vacuum pressure.
The label meets all the requirements for surface mount processing, as well as safety standards, and is able to withstand reflow temperatures of up to 300°C. The label also carries product information such as product code and manufacturing date.

Recommended Furnace Temperature

The reflow profile should be optimized to avoid excessive heating of the converter. The converter can withstand the temperature of 260°C for 10 seconds. It is recommended that the peak temperature do not exceed 260°C.
It is recommended that the preheat time be long enough to minimize the difference in temperature between the converter and the host PCB.
The converter uses the lead-free technique. The following table lists the recommended values for reflow parameters.

Item	Specifications
Average ramp-up	≤ 2.5°C/s
Preheat time	90 - 120s
Infiltration time	60 - 120s
Reflow time (T_A ≥ 183°C)	60 - 90s
Peak temperature	230 - 260°C
Cooling rate	1°C/s ≤ slope ≤ 4°C/s

The furnace temperature can be adjusted based on the host board conditions.

Moisture Resistance Requirements

Store and transport the converter as required by the MSL rating 2 specified in the IPC/JEDEC J-STD-033A. It is recommended that clean-free solder paste be used to assemble surface mount components. The surface of a soldered converter must be clean and dry. Otherwise the assembly, test, or even reliability of the converter will be negatively affected.

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