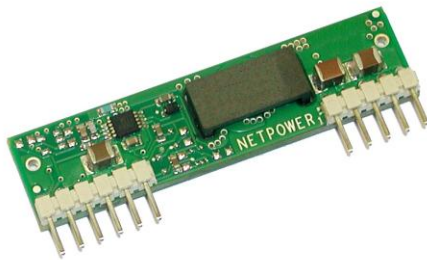




## 10A Through-hole Point-of Load Converter



### Features

- High efficiency, 88% (24Vin, 3.3/10A)
- Excellent thermal performance
- Over-voltage, over-current, short-circuit, and over temperature protection
- Monotonic start-up into pre-biased load
- Output trim, Remote sense
- Switching frequency synchronization
- Remote enable control
- UL 60950-1 2nd edition recognized†

### Options

- Baseplate
- Negative/Positive enable logic
- Output over-voltage protection
- Output voltage tracking/Sequence

### Part Numbering System

NAT	2	□□□	□	10	□	□	□
Series Name:	Input Voltage:	Output Voltage:	Enabling Logic:	Rated Output Current:	Pin Length Options:	Electrical Options:	Mechanical Options
NAT	2: 9 – 36V	Example 000: variable*	P: positive N: negative	Unit: A 10:10A	Regular R: 0.2"	0: None 1: Voltage Tracking 2: OVP 3: Both VT&OVP 4: Synchronization 5: Both Sync&OVP	Lead-free, (ROHS-6 Compliant) 5: Open frame 6: Baseplate

\* Consult the factory for semi-custom codes with the output voltage set to a specific value without using an external programming resistor.

† UL is a registered trademark of Underwriters Laboratory Inc.

## Absolute Maximum Ratings

Excessive stresses over these absolute maximum ratings can cause permanent damage to the converter. Operation should be limited to the conditions outlined under the Electrical Specification Section.

Parameter	Symbol	Min	Max	Unit
Input Voltage (continuous)	$V_i$	-0.5	38.5	Vdc
Operating Ambient Temperature (See Thermal Consideration section)	$T_o$	-40	85*	°C
Storage Temperature	$T_{stg}$	-55	125	°C

\* Derating curves provided in this datasheet end at 85°C ambient temperature. Operation above 85°C ambient temperature is allowed provided the temperatures of the key components or the baseplate do not exceed the limit stated in the Thermal Considerations section.

## Electrical Specifications

These specifications are valid over the converter's full range of input voltage, resistive load, and temperature unless noted otherwise.

### Input Specifications

Parameter	Symbol	Min	Typ	Max	Unit
Input Voltage	$V_i$	9	24	36	Vdc
Input Current	$i_{i,max}$	-	-	6.5	A
Quiescent Input Current ( $V_{in} = 24$ , $V_o = 3.3V$ )	$i_{i,Qsnt}$	-	50	70	mA
Standby Input Current	$i_{i,stdby}$	-	2	-	mA
Input Reflected-ripple Current, Peak-to-peak (5 Hz to 20 MHz, 1 $\mu$ H source impedance)	-	-	20	-	mA <sub>p-p</sub>
Input Ripple Rejection (120 Hz)	-	-	30	-	dB
Input Turn-on Voltage Threshold	-	-	9.5	-	V

### Output Specifications

Parameter	Symbol	Min	Typ	Max	Unit
Output Voltage Set Point Tolerance ( $V_i = 24$ V; $I_o = I_{o,max}$ ; $T_a = 25^\circ$ C)	-	-2.0	-	2.0	%
Output Voltage Set Point Tolerance (over all conditions)	-	-2.5	-	3.50	%
Output Regulator:					
Line Regulation ( $V_i = 9V$ to $36V$ , $I_o = 1/2$ of load)	-	-	0.2	-	% $V_o$
Load Regulation ( $I_o = I_{o,min}$ to $I_{o,max}$ , $V_i = 24V$ )	-	-	0.3	-	% $V_o$
Temperature ( $T_a = -40^\circ$ C to $85^\circ$ C)	-	-	0.2	-	% $V_o$
Output Ripple and Noise Voltage (5 Hz to 20 MHz bandwidth, $V_{in} = 24V$ )	Peak-to-peak -	-	2	-	% $V_o$
	RMS	-	-	1	% $V_o$
External Load Capacitance	-	-	-	2,000	$\mu$ F
Output Current	$I_o$	0	-	10	A
Output Power	$P_o$	0	-	45	W
Output Current-limit Trip Point	$I_{o,cli}$	-	170	-	% $I_{o,max}$
Output Short-circuit Current, hiccup mode			2	-	A
Switching frequency	-	270	300	330	kHz
Output Over Voltage trip point (optional, hiccup mode)		115	125	135	% $V_o$
Voltage Tracking/Sequencing Slew Rate – Power UP				2	V/ms
Voltage Tracking/Sequencing Slew Rate – Power down				1	V/ms



### Output Specifications (continued)

Parameter	Symbol	Min	Typ	Max	Unit
Efficiency (Vi = 24V; TA = 25°C)	Vo = 3.3V, Io = 10A	η	88		%
	Vo = 5V, Io = 9A	η	90		%
Dynamic Response (Vi = 12V; TA = 25°C; Load transient 0.1A/μs)					
Load step from 75% to 100% of full load:					
Peak deviation			50		mV
Settling time (to 10% band of Vo deviation)			80		μs
Load step from 100% to 75% of full load:					
Peak deviation			50		mV
Settling time (to 10% band of Vo deviation)			80		μs

### General Specifications

Parameter	Symbol	Min	Typ	Max	Unit
Remote Enable					
Logic Low:					
ION/OFF = 1.0mA	VON/OFF	0	-	1.2	V
VON/OFF = 0.0V	ION/OFF	-	-	1.0	mA
Logic High:					
ION/OFF = 0.0μA	VON/OFF	-	-	15	V
Leakage Current	ION/OFF	-	-	50	μA
Turn-on Time (Io = full load, Vo within 1% of setpoint)	-	-	6	-	ms
Calculated MTBF (Bellcore TR-332, 40°C, full load)			12.9		10 <sup>6</sup> -hour

### Characteristic Curves

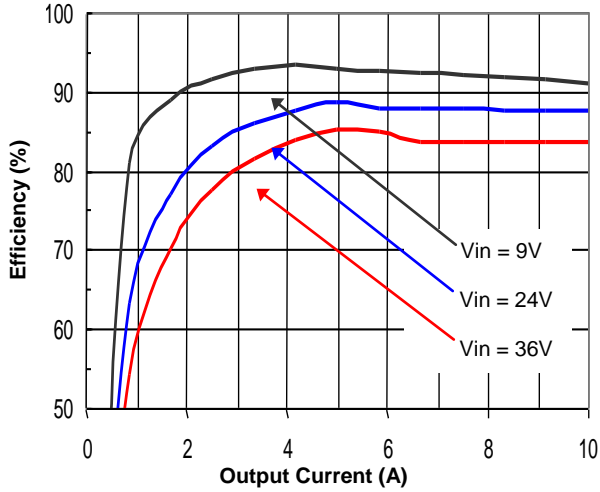


Figure 1(g). Efficiency vs. Load Current (25°C, 3.3V output)

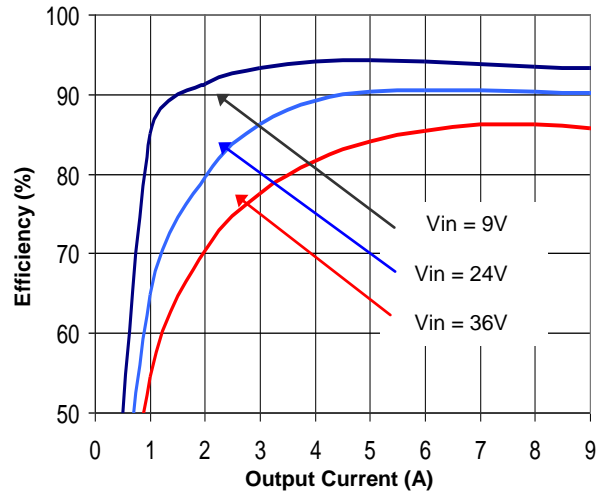


Figure 1(h). Efficiency vs. Load Current (25°C, 5V output)

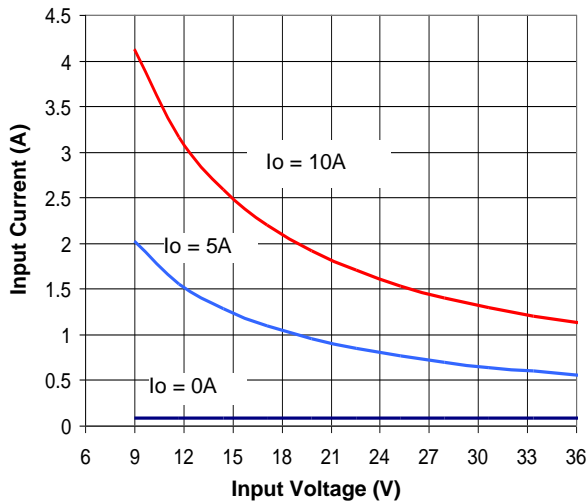


Figure 2. Input Characteristic (3.3V output)

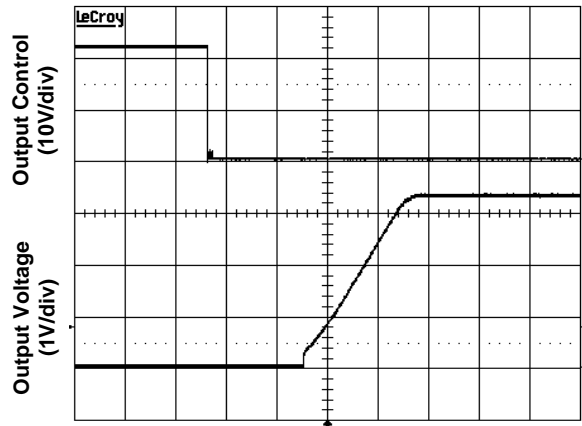


Figure 3. Start-Up from Enable Control  
(Input voltage 24V, Output current 0A 3.3V)

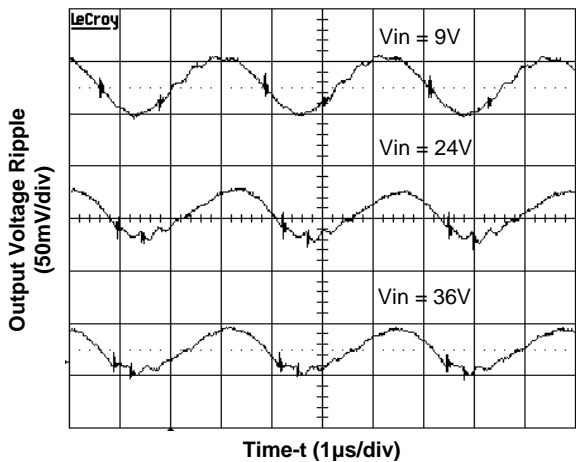


Figure 4. Output Ripple Voltage at 3.3V, 10A Output

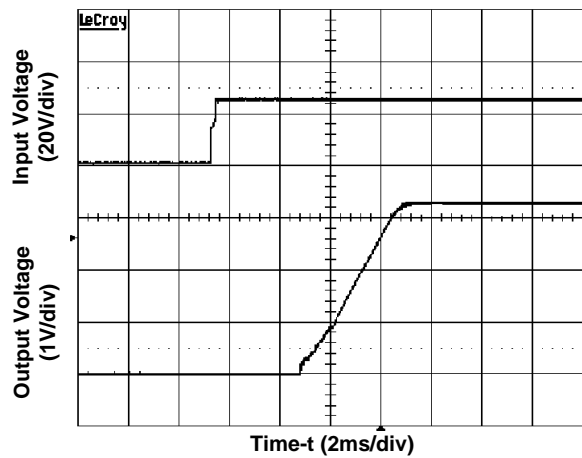


Figure 5. Start-Up from Application of Input Voltage  
(Input voltage 24V, Output current 10A (resistive load) 3.3V)

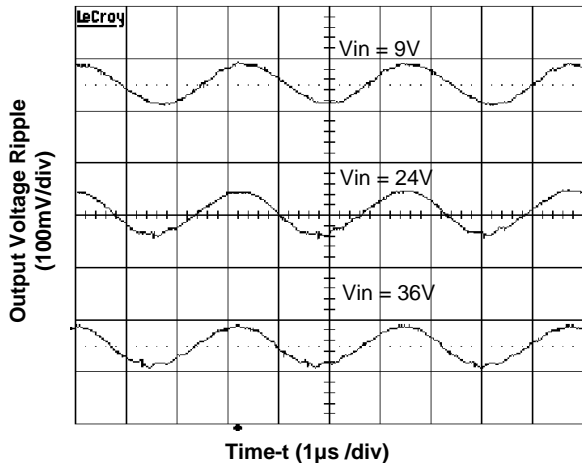


Figure 6. Output Ripple Voltage at 5V, 9A

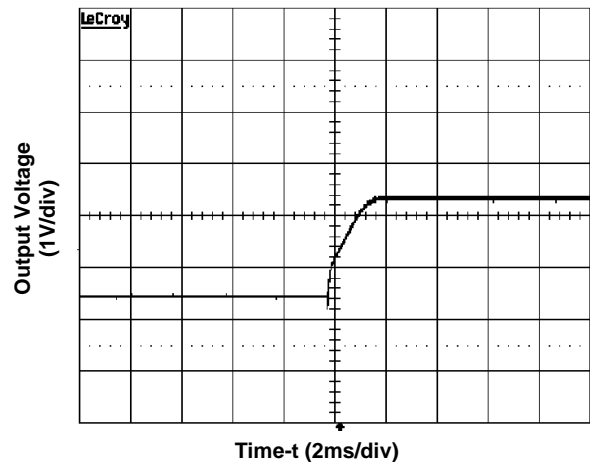


Figure 7. Start-Up with Prebias  
(Input voltage 24V, Output current 0A, Output voltage 3.3V, Prebias 1.5V)

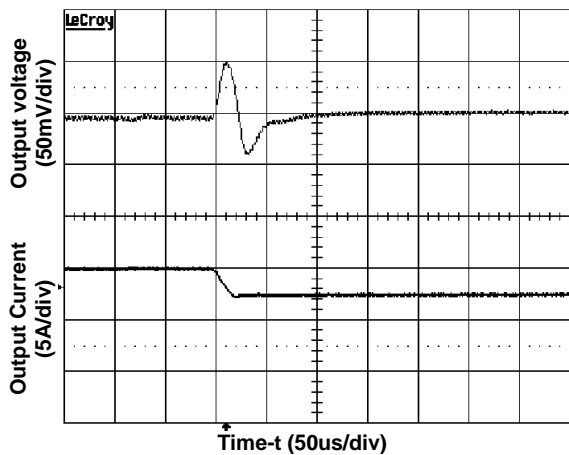


Figure 8. Transient Load Response  
(Input/output voltage 24/3.3V, Output current 10A->7.5A, Slew rate 0.1A/µs.)

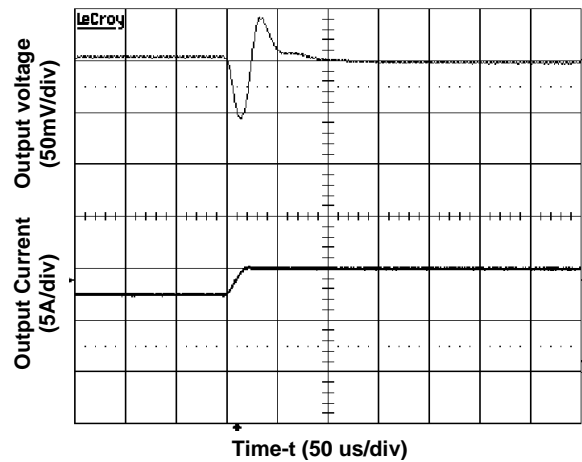


Figure 9. Transient Load Response  
(Input/output voltage 24/3.3V, Output current 7.5A->10A, Slew rate 0.1A/µs.)

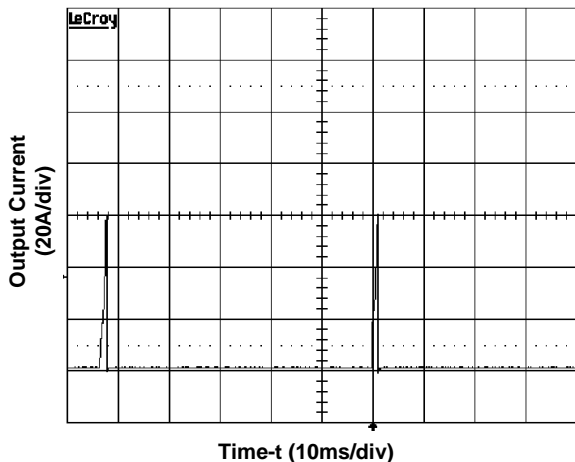


Figure 10. Short Circuit Current. (Vin = 24V)

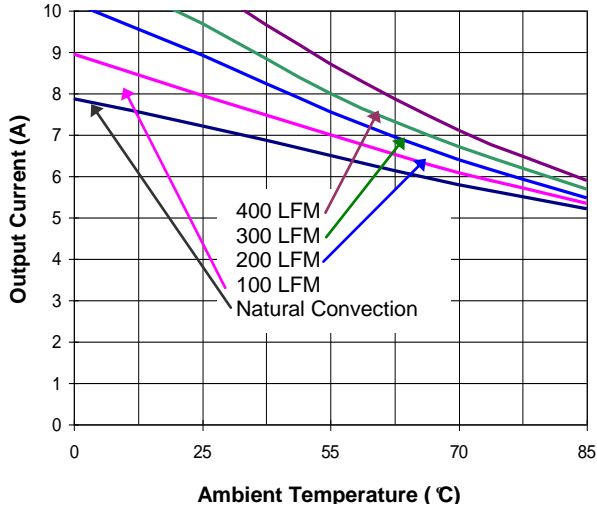


Figure 11(a). Current Derating Curve for 3.3V Output (Vin = 24V open frame)

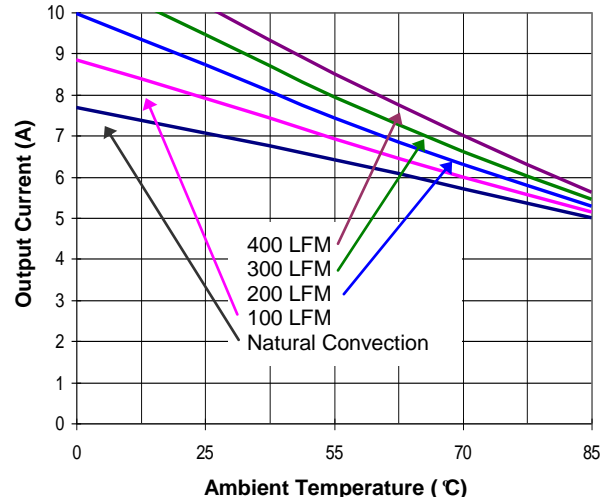


Figure 11(b). Current Derating Curve for 5V Output (Vin = 24V open frame)

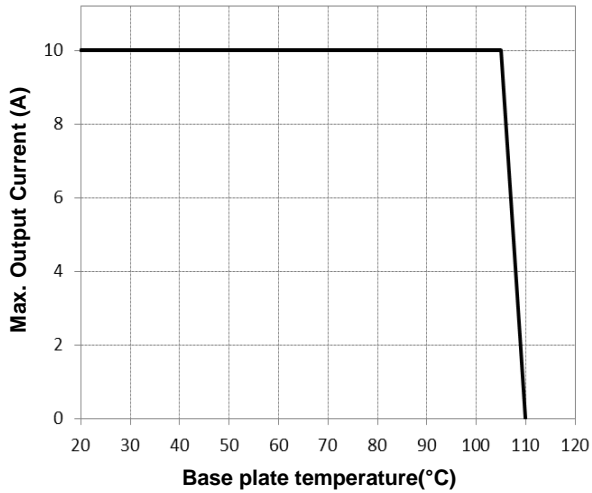


Figure 12. Current Derating Curve for Base plate (typical vin with Base plate; solder interface)

## Feature Descriptions

### Remote ON/OFF

The converter can be turned on and off by changing the voltage or resistance between the ON/OFF pin and GND. The NAT2 converters can be ordered with factory selectable positive logic or negative enabling logic.

For the negative control logic, the converter is ON when the ON/OFF pin is at a logic low level, and OFF when the ON/OFF pin is at a logic high level. With positive control logic, the converter is ON when the ON/OFF pin is at a logic high level and OFF when the ON/OFF pin is at a logic low level.

With the internal pull-up circuitry, a simple external switch between the ON/OFF pin and GND can control the converter. A few example circuits for controlling the ON/OFF pin are shown in Figs. 13, 14 and 15.

The logic-low level is from 0V to 1.2V, and the maximum switch current during logic low is 1mA. The external switch must be capable of maintaining a logic-low level while sinking this current. The maximum ON/OFF pin voltage, generated by the converter internal circuitry for logic-high level, is less than 10V. The maximum allowable leakage current from this pin at logic-high level is 50 $\mu$ A.

When the ON/OFF pin is left unconnected (floating), the converter is enabled.

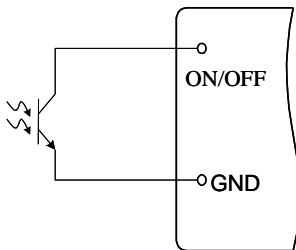


Figure 13. Opto Coupler Enable Circuit

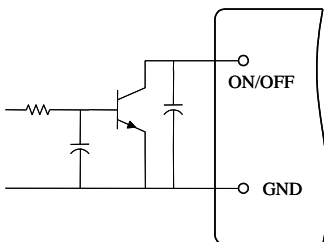


Figure 14. Open Collector Enable Circuit

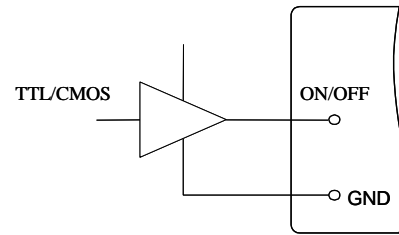


Figure 15. Direct Logic Drive

### Remote SENSE

The remote SENSE pin is used to sense voltage at the load point to accurately regulate the load voltage and eliminate the impact of the voltage drop in the power distribution path.

The SENSE pin should be connected to the point where regulation is desired. The voltage difference between the output pins must not exceed the operating range of this converter shown in the specification table.

When remote sense is not used, the SENSE pin can be connected to the positive output terminals. If the SENSE pins are left floating, the converter will deliver an output voltage slightly higher than its specified typical output voltage.

Because the converter does not have remote sense connection for the return path, it is important to make sure that the connection resistance and voltage drop between GND pin and the load is small.

### Output Voltage Programming and Adjustment

This series of converters are available with variable output voltages. The output voltage is preset to 3.018V, and can be programmed up to 6V using an external trim resistor connected between the Trim pin and GND pin as shown in Figure 16.

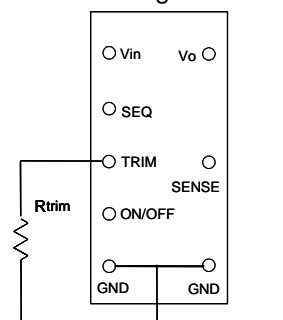


Figure 16. Circuit to Trim Output Voltage



The resistance of the external resistor for trimming up the output voltage can be calculated using the equation below:

$$R_{trim} = \left( \frac{10.5}{\Delta} - 3.48 \right) (k\Omega)$$

Where

$$\Delta = V_o - V_{onom}$$

For variable output,  $V_{onom} = 3.018$ .

Because this converter uses GND as the reference for control, Rtrim should be placed as close to GND pin as possible, and the trace connecting GND pin and Rtrim should not carry significant current, to reduce the effect of voltage drop on the GND trace/plain affecting the output voltage accuracy.

When remote sense and trim functions are used simultaneously, please do not allow the output voltage at the converter output terminals to be outside the operating range.

## Input Under-Voltage Lockout

This feature prevents the converter from turning on until the input voltage reaches 8.5V. However, for converters to output higher than 5.5V, the input under-voltage lockout setpoint is higher and the user should contact the factory for further assistance.

## Output Over-Current Protection

As a standard feature, the converter turns off when the load current exceeds the current limit. If the over current or short circuit condition persist, the converter will operate in a hiccup mode (repeatedly trying to restart) until the over-current condition is cleared.

## Thermal Shutdown

As a standard feature, the converter will shut down if an over-temperature condition is detected. The converter has a temperature sensor, which detects the thermal condition of key components of the converter.

The thermal shutdown circuit is designed to turn the converter off when the temperature at the sensor reaches 120°C. The converter will resume operation after the converter cools down.

## Output Over-Voltage Protection

As an optional feature, if the voltage across the output pins exceeds the output voltage protection threshold as shown in the Specifications Table, the converter will clamp the output voltage to protect the converter and the load. The converter automatically resumes normal operation after the over voltage condition is removed.

The over-voltage protection setpoint is 6.25V for the adjustable output model

## Voltage Tracking/Sequencing

An optional voltage tracking/sequencing feature is available with these converters. This feature is compatible with the “Voltage Sequencing” feature (DOSA) or the “Voltage Tracking” feature (POLA) seen in industry standards.

This feature forces the output of the converter to follow (track) the voltage at the SEQ pin on a 1:1 basis. When the voltage at the SEQ pin rises above the set point, the output of the converter will stay at the set point. This feature allows the user to program the output voltage waveform during turn-on and turn-off of the converter by applying a voltage signal of desired shape at the SEQ pin. When using this function, one should pay careful attention to the following aspects:

- 1). This feature is intended mainly for startup and shutdown sequencing control. In normal operation, the voltage at SEQ pin should be maintained higher than the output voltage set point;
- 2). The input voltage should be valid for this feature to work. During startup, it is recommended to have a delay of at least 10 ms between the establishment of a valid input voltage, and the application of a voltage at the SEQ pin;
- 3). The ON/OFF pin should be in “Enabled” state when this function is effective.
- 4). The converter’s pre-bias startup is affected by this function. The converter will still be able to start under a pre-bias condition, but the output voltage waveform will have a glitch during startup if this feature is selected.





## Frequency Synchronization

When multiple converters are used in a system, it is desirable to have all converters running at the same switching frequency to avoid the so-called “beat frequency” phenomenon, and reduce the system noise. The switching frequency of this series of POL converters can be synchronized to an outside clock with a frequency at least 10-20 kHz higher than the maximum free-running switching frequency of the converter. For example for converters with a nominal switching frequency of 300 kHz, the minimum frequency of the synchronous clock should be at least 340 kHz. With the use of synch clock, the under-voltage lock-out (UVLO) point of the converter becomes higher. The Higher the synch frequency is, the higher UVLO becomes. Please contact NetPower if the UVLO point is to remain unchanged with a given synch frequency. The following table shows a relationship between synch frequency and UVLO on a 300 kHz converter:

Synch Freq. (kHz)	340	380	420	460	500	540	580	620	660	700
UVLO (V)	9.5	10	11	11.4	12.1	12.7	14	14	14.8	15.5

The key parameters of the clock signal are: pulse width at least 50nS, logic HIGH level in 2 - 5V, logic LOW level less than 0.8V, and being able to source and sink at least 10 uA current. The clock signal should be connected to the optional PIN B (SEQ pin), which is also used for the optional voltage sequencing (tracking) pin. Therefore, the voltage tracking function and the frequency synchronization function can not be selected at the same time. This pin can be left open or shorted to GND if the synch function is not used.

The effective edge of the synchronization pulse is the falling edge of the clock signal. Through properly phase-shift of the clock signals, multiple converters can work in an interleaved manner, reducing the strength of the switching noise.

## Design Considerations

The stability of the NAT2 converters, as with any DC/DC converter, may be compromised if the source impedance is too high or too inductive. It's desirable to keep the input source AC impedance as low as possible. To reduce switching frequency ripple current getting into the input circuit (especially the ground/return conductor), it is desirable to place

some low ESR capacitors at the input. Ceramic capacitors of at least 10uF total capacitance are recommended. Due to the existence of inductance (such as the trace inductance, connector inductance, etc) in the input circuit, possible oscillation may occur at the input of the converter. Because the relatively high input current of low input voltage power system, it may not be practical or economical to have separate damping or soft start circuit in front of POL converters. We recommend to use a combination of ceramic capacitors and Tantalum/Polymer/Aluminum capacitors at the input, so the relatively higher ERS of Tantalum/Polymer capacitors can help damp the possible oscillation between the ceramic capacitors and the inductance.

Similarly, although the converter is designed to be stable without external capacitor at the output, some low ESR capacitors at the output may be desirable to further reduce the output voltage ripple or improve the transient response. Again, a combination of ceramic capacitors and Tantalum/Polymer/Aluminum capacitors usually can achieve good results.

## Safety Considerations

The NAT2 Series of converters is designed in accordance with EN 60950 Safety of Information Technology Equipment Including Electrical Equipment. The converters are recognized by UL in both USA and Canada to meet the requirements in UL 60950, Safety of Information Technology Equipment and applicable Canadian Safety Requirement, and ULc 60950. Flammability ratings of the PWB and plastic components in the converter meet 94V-0.

The converter's output meets SELV requirements if all of its input meets SELV requirements.

## Thermal Considerations

The NAT2 converters can operate in various thermal environments. Due to high efficiency and optimal heat distribution, these converters exhibit excellent thermal performance.

The maximum allowable output power of any power converter is usually determined by the electrical design and the maximum operating temperature of its components. The NAT2 converters have been tested comprehensively under various conditions to



generate the derating curves with consideration for long term reliability.

Thermal derating curves are highly influenced by derating guideline, the test conditions and setup, such as test temperatures, the interface method between the converter and the test fixture board, spacing and construction (especially copper weight, holes and openings) of the fixture board and the spacing board, temperature measurement method, and the ambient temperature measurement point. The thermal derating curves in this datasheet are obtained by thermal tests in a wind-tunnel. The converter's power pins are soldered to a 2-layer test fixture board through 18 AWG wires. The space between the test board and a PWB spacing board is 1". Usually, the end system board has more layer count, and has better thermal conductivity than our test fixture board.

Note that the natural convection condition was measured at 0.05 m/s to 0.15 m/s (10ft./min. to 30 ft./min).

### Heat Transfer without a Baseplate

Convection heat transfer is the primary cooling means for NAT2 converters. Therefore, airflow speed is important and Increasing the airflow over the converter enhances the heat transfer via convection.

Figures 12 (a) - (f) show the current derating curves under typical input voltage 12V for a few output voltages. To maintain long-term reliability, the module should be operated within these curves in steady state.

Proper cooling in the end system can be verified by monitoring the temperature of the key components. Figure 16 shows the recommended temperature monitoring points. The temperature at these locations should not exceed 120 °C continuously.

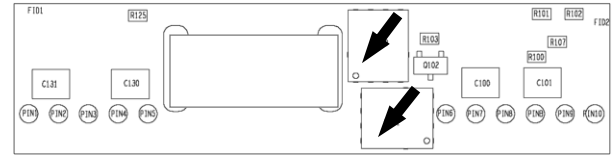


Figure 17. Temperature Monitoring Locations

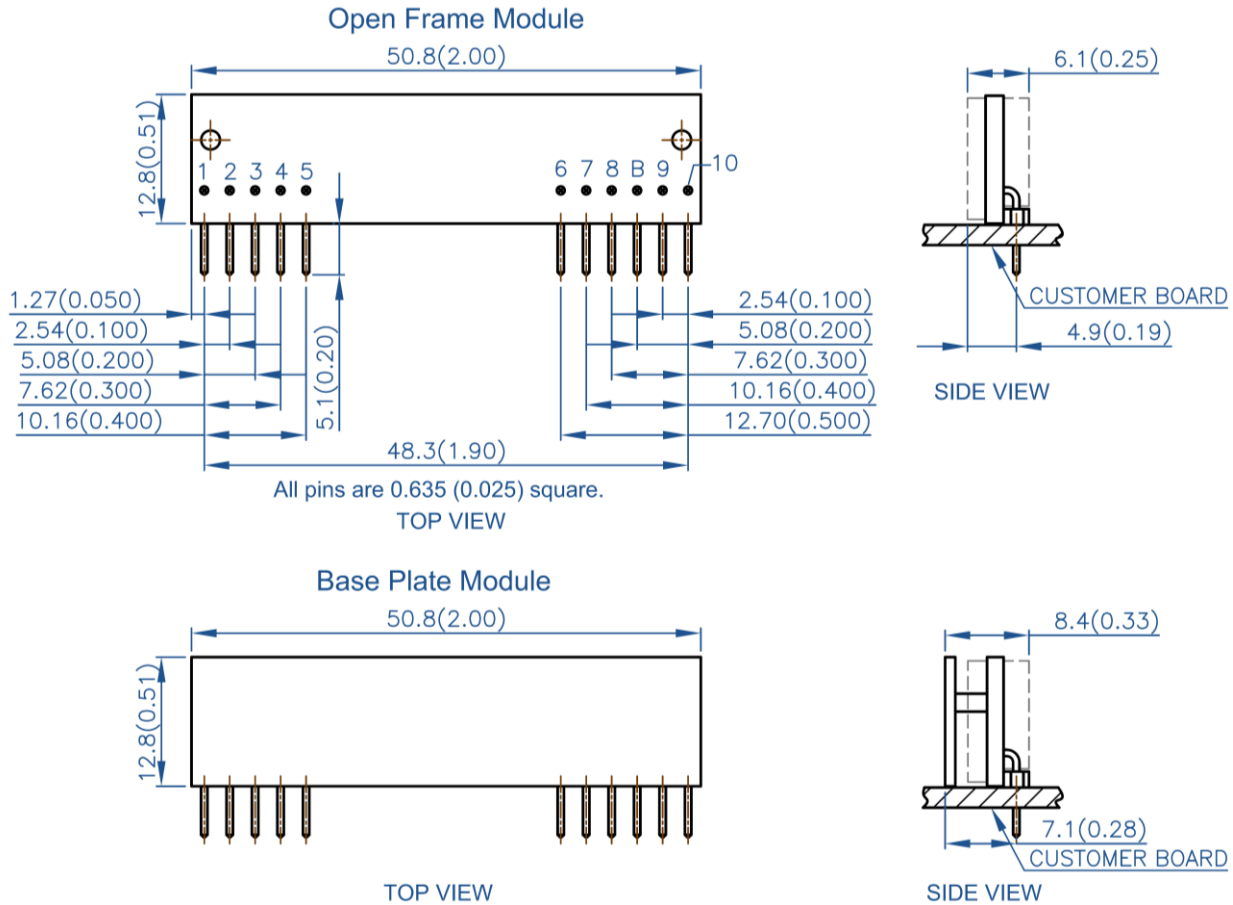
### Heat Transfer with a Baseplate

The NAT2 Series of converters have the options of using a baseplate for enhanced thermal performance. The typical width of the converter with the baseplate option is 0.35".

For reliable operation, the baseplate temperature should not continuously exceed 100 °C.



## Mechanical Information



Pin	Name	Function
1	Vout(+)	Positive input voltage
2	Vout(+)	Remote control
3	SENSE(+)	Negative input voltage
4	Vout(+)	Negative output voltage
5	GND	OPTIONAL Negative remote sense
6	GND	Output voltage adjust
7	Vin(+)	OPTIONAL Positive remote sense
8	Vin(+)	Positive output voltage
B	SEQ	Tracking/Sequencing
9	TRIM	Output voltage adjust
10	ON/OFF	Remote control

### Notes:

- 1) All dimensions in mm (inch) ( 1 inch = 25.4mm).  
Tolerances: x (.xx):  $\pm 0.5$  (0.020")  
.xxx:  $\pm 0.25$  (0.010")
- 2) All pins are 0.635mm (0.025") square.
- 3) A converter's thickness is increased to 0.35" with a baseplate option.
- 4) All pins are coated with 90%/10% solder finish, or Matte Tin, or Gold.
- 5) Weight: 7 g open frame converter
- 6) Workmanship: Meet or exceeds IPC-A-610 Class II
- 7) Baseplate flatness tolerance is 0.10mm (0.004") TIR for surface.