Features

- 18V to 36V Input Voltage Range
- Programmable Output Voltage Range: 1.3V to 3.5V
- -40° to +100°C Operating Temp
- 1500 VDC Isolation
- 89% Efficiency
- Remote On/Off
- Differential Remote Sense
- 60A Output with PT4495
- Over-Current Protection *(Foldback Current Limit)*
- Over-Temperature Protection
- Over-Voltage Protection
- Space-Saving Package
- Solderable Copper Case
- Safety Approvals:
  UL 60950
  CSA 22.2 950
  VDE EN60950 Pending

Description

The PT4472 Excalibur™ DC/DC converter module combines state-of-the-art power conversion technology with un-paralleled flexibility. Incorporating high efficiency and ultra-fast transient response, these modules provide up to 30A of output current over the programmable voltage range of 1.3V to 3.5V. This represents a full 100W output at 3.3V.

The modules include a number of inbuilt features to facilitate system integration. These include a foldback output current limit, over-temperature protection, and an inhibit on/off control. A differential remote sense is also provided to compensate for voltage drop between the converter and load.

For additional output current, one PT4472 may be operated with up to two PT4495 compatible booster modules. Each PT4495 adds an additional 30A of output current capability.

Ordering Information

PT 4472❑ = 1.3 to 3.5 Volts
PT 4495❑ = 30-A Booster

PT Series Suffix (PT1234 x)

Case/Pin Configuration	Order Suffix	Package Code
Vertical	**N**	(EKD)
Horizontal	**A**	(EKA)
SMD	**C**	(EKC)

(Reference the applicable package code drawing for the dimensions and PC board layout)

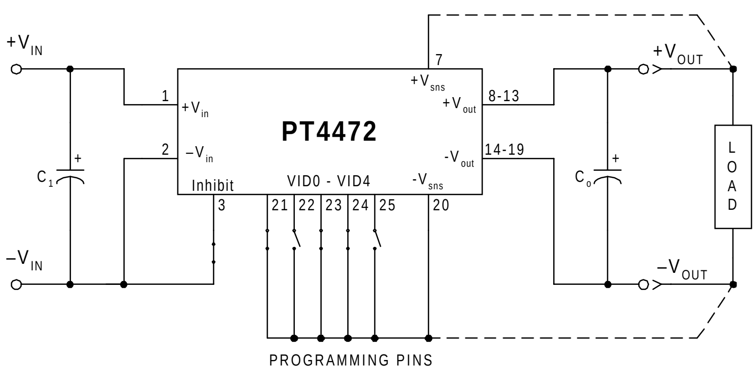
Pin-Out Information

Pin	Function	Pin	Function
1	$+V_{in}$	14	$-V_{out}$
2	$-V_{in}$	15	$-V_{out}$
3	Inhibit	16	$-V_{out}$
4	V_r †	17	$-V_{out}$
5	V_a †	18	$-V_{out}$
6	No Connect	19	$-V_{out}$
7	(+)Remote Sense	20	(–)Remote Sense
8	$+V_{out}$	21	VID0
9	$+V_{out}$	22	VID1
10	$+V_{out}$	23	VID2
11	$+V_{out}$	24	VID3
12	$+V_{out}$	25	VID4
13	$+V_{out}$	26	DRV †

† *Pins 4, 5, & 26 are used for booster applications. For stand-alone operation, leave open circuit.*

- *Shaded functions indicate those pins that are referenced to primary-side potential.*

Standard Application



- C_o = Optional 330µF electrolytic capacitor
- C_1 = Optional 33µF, 100V electrolytic capacitor
- C_2 = Optional 1µF, 100V ceramic capacitor
- Programming pins, VID0–VID4, are shown configured for Vo =3.3V
- For normal operation, pin 3 (Inhibit) must be connected to –Vin.

Programming Information

VID3	VID2	VID1	VID0	VID4=1 Vout	VID4=0 Vout
1	1	1	1	2.0V	1.30V
1	1	1	0	2.1V	1.35V
1	1	0	1	2.2V	1.40V
1	1	0	0	2.3V	1.45V
1	0	1	1	2.4V	1.50V
1	0	1	0	2.5V	1.55V
1	0	0	1	2.6V	1.60V
1	0	0	0	2.7V	1.65V
0	1	1	1	2.8V	1.70V
0	1	1	0	2.9V	1.75V
0	1	0	1	3.0V	1.80V
0	1	0	0	3.1V	1.85V
0	0	1	1	3.2V	1.90V
0	0	1	0	3.3V	1.95V
0	0	0	1	3.4V	2.00V
0	0	0	0	3.5V	2.05V

Logic 0 = Connect to (–)Remote Sense, pin 20
Logic 1 = Open circuit (no pull-up resistors)

PT4470 Series Comparison

		Functionality	Output Voltage Program Range	Configuration for Parallel Operation
	PT4471	Regulator	1.3V– 3.5V	N+1 with other PT4471s
#	PT4472	Regulator	1.3V– 3.5V	With PT4495 boosters
#	PT4495	PT4472 Booster	N/A	Used only with PT4472
	PT4473	Regulator	4.6V–5.7V	N+1 with other PT4473s
	PT4474	Regulator	4.6V–5.7V	With PT4494 boosters
	PT4494	PT4474 Booster	N/A	Used only with PT4474
	PT4475	Regulator	6.5V– 17.5V	N+1 with other PT4475s
	PT4476	Regulator	6.5V–17.5V	With PT4493 boosters
	PT4493	PT4476 Booster	N/A	Used only with PT4476

This specification covers only the PT4472 regulator and PT4495 booster

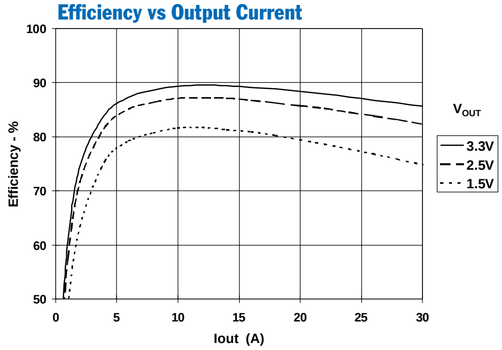
Specifications (Unless otherwise stated, T_a =25°C, V_{in} =24V, V_o =3.3V, C_o =0µF, and I_o =$I_o$max)

Characteristic	Symbol	Conditions	PT4472 Min	PT4472 Typ	PT4472 Max	Units
Output Current	I_o	Over V_{in} range	0	—	30	A
Input Voltage Range	V_{in}	Over I_o Range	18	24	36	VDC
Set Point Voltage Tolerance	V_o tol		—	±1	±1.5	%V_o
Temperature Variation	Reg_{temp}	–40° ≤T_c≤ +100°C, I_o =0	—	±0.5	—	%V_o
Line Regulation	Reg_{line}	Over V_{in} range	—	±0.1	±1	%V_o
Load Regulation	Reg_{load}	Over I_o range	—	±0.2	±1	%V_o
Total Output Voltage Variation	ΔV_otot	Includes set-point, line, load, –40° ≤T_c≤ +100°C	—	±2	±3	%V_o
Efficiency	η	I_o =15A — V_o =3.3V V_o =2.5V V_o =1.5V	— — —	89 87 81	— — —	%
V_o Ripple (pk-pk)	V_r	20MHz bandwidth	—	55	75	mV_{pp}
Transient Response	t_{tr} ΔV_{tr}	0.1A/µs load step, 50% to 75% $I_o$max V_o over/undershoot	— —	N/A 1	— —	µs %V_o
		1A/µs load step, 50% to 100% $I_o$max V_o over/undershoot	— —	75 ±5	— —	µs %V_o
Current Limit Threshold	I_{lim} thld	V_{in} =18V, ΔV_o = –1% foldback continuous limit	—	35	—	A
Current Share Tolerance	I_{shr} tol	with PT4495 booster	—	±10	—	%
Switching Frequency	f_s	Over V_{in} range	270	300	350	kHz
Under-Voltage Lockout	UVLO		—	17	—	V
Inhibit (Pin 3) Input High Voltage Input Low Voltage	 V_{IH} V_{IL}	Referenced to $-V_{in}$ (pin 2)	 2.5 –0.5	 — —	 Open (1) +0.8	V
Input Low Current	I_{IL}		—	–0.2	—	mA
Standby Input Current	I_{in} standby	pins 3 & 2 connected	—	4	10	mA
Internal Input Capacitance	C_{in}		—	3	—	µF
External Output Capacitance	C_{out}	Between $+V_o$ and $-V_o$	0	—	10,000	µF
Isolation Voltage Capacitance Resistance		Input–output/input–case Input to output Input to output	1500 — 10	— 1100 —	— — —	V pF MΩ
Operating Temperature Range	T_c	Over V_{in} range Measured at center of case	-40	—	+115 (2)	°C
Over-Temperature Shutdown	OTP	Case temperature, auto reset	—	120	—	°C
Storage Temperature	T_s	—	-40	—	+125	°C
Reliability	MTBF	Per Bellcore TR-332 50% stress, T_a =40°C, ground benign	1.4	—	—	10^6 Hrs
Mechanical Shock	—	Per Mil-Std-883D, method 2002.3, 1mS, half-sine, mounted to a fixture	—	500	—	G's
Mechanical Vibration	—	Mil-Std-883D, Method 2007.2 Horizontal 20-2000Hz, pcb mounted	—	20 (3)	—	G's
Weight	—	—	—	90	—	grams
Flammability	—	Materials meet UL 94V-0				

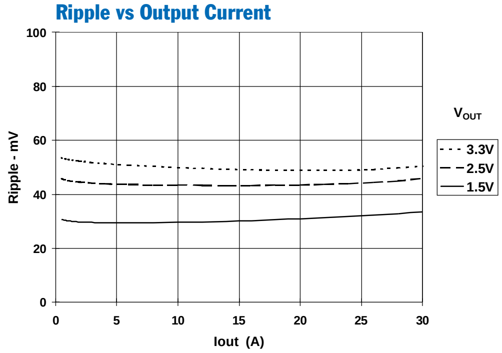
Notes: (1) *The Inhibit (pin 3) has an internal pull-up, which if left open circuit allows the converter to operate when input power is applied. The open-circuit is limited to 6.5V. Refer to the application notes for interface considerations.*
(2) *See Safe Operating Area curves or contact the factory for the appropriate derating.*
(3) *The case pins on through-hole pin configuration (suffix A) must be soldered. For more information see the applicable package outline drawing.*

PT4472 Performance Characteristics (See Note A)

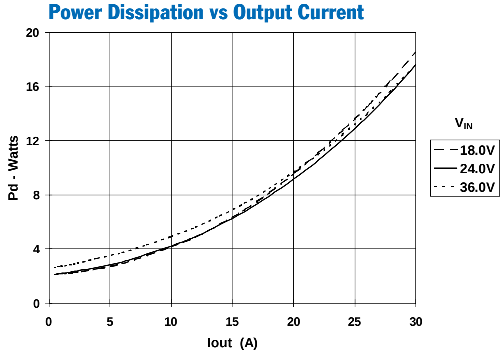
Efficiency vs Output Current



Ripple vs Output Current

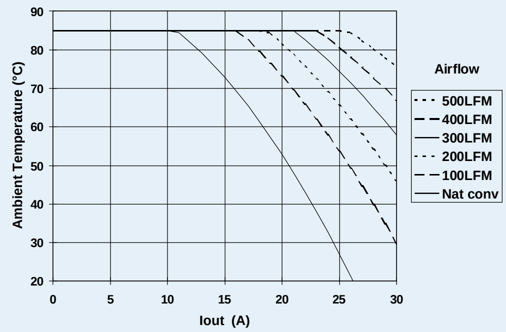


Power Dissipation vs Output Current



Safe Operating Area, V_{in} =24V (See Note B)

Stand Alone, No Heatsink



Note A: *Characteristic data has been developed from actual products tested at 25°C. This data is considered typical data for the Converter.*
Note B: *SOA curves represent the conditions at which internal components are at or below the manufacturer's maximum operating temperatures*

Increasing the Output Current of the PT4472 with the PT4495 Compatible Current Booster

The PT4495 is a 30-A "Current Booster" module designed specifically for the PT4472 programmable DC/DC converter. The booster is controlled directly by the regulator, and effectively adds an additional output stage that operates in parallel. This allows the system to run sychronously, providing a low noise solution. Up to two booster modules can be connected to a PT4472 converter. Each booster module increases the available output current by 30A. A combination of one PT4472 converter and two PT4495 booster modules can supply up to 90A of output current; enough to supply virtually any multi-processor application. Figure 1-1 shows the connection schematic for the regulator and current booster combination.

A current booster is not a stand-alone product, and can only operate with a regulator. It is housed in the same package as its compatible regulator, and shares the same mechanical outline. Except for an increase in output current, the overall performance of a converter/booster combination is identical to that of a stand-alone converter.

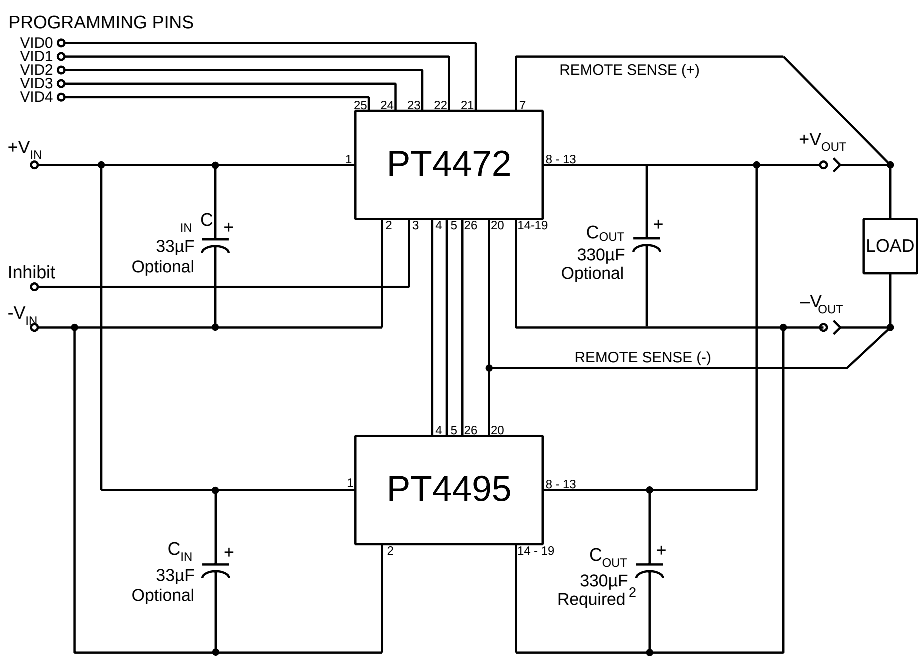
Notes:

1. Refer to the PT4472 specification table for the performance of the regulator/booster combination.
2. The pin-out of the current booster modules include a number pins identified, "No Connect" (see Table 1-1). These pins are not connected internally to the module but must be soldered to a pad to preserve the unit's mechanical integrity.
3. A minimum of 330µF of output capacitance is required across the output of each PT4495 booster for proper operation. A value greater than 330µF will further reduce transients due to large and/or fast load steps.
4. The converter and all boosters must be located on the same printed circuit board. A similar footprint and trace layout for each module will also facilitate current sharing.

Table 1-1; PT4495 Pin-Out Information

Pin	Function	Pin	Function	Pin	Function
1	$+V_{in}$	10	$+V_{out}$	19	$-V_{out}$
2	$-V_{in}$	11	$+V_{out}$	20	(–)Vsense
3	No Connect	12	$+V_{out}$	21	No Connect
4	V_r	13	$+V_{out}$	22	No Connect
5	V_a	14	$-V_{out}$	23	No Connect
6	No Connect	15	$-V_{out}$	24	No Connect
7	No Connect	16	$-V_{out}$	25	No Connect
8	$+V_{out}$	17	$-V_{out}$	26	DRV
9	$+V_{out}$	18	$-V_{out}$		

Figure 1-1; Current Booster Application Schematic



Operating Features of the PT4470 and PT4480 Series of Isolated DC/DC Converters

Under-Voltage Lockout

An Under-Voltage Lock-Out (UVLO) inhibits the operation of the converter until the input voltage is above the UVLO threshold (see the applicable data sheet specification). Below this voltage, the module's output is held off, irrespective of the state of the *Inhibit* control (pin 3). If the *Inhibit* control is connected to $-V_{in}$ (pin 2), the module will automatically power up when the input voltage rises above the UVLO threshold. The UVLO allows the module to produce a clean transition during both power-up and power-down, even when the input voltage is rising or falling slowly. It also reduces the high start-up current during normal power-up of the converter, and minimizes the current drain from the input source during low-input voltage conditions. The UVLO threshold includes about 2V of hysteresis. Once operational, the converter will conform to its operating specifications when the minimum specified input voltage is reached.

Over-Current Protection

To protect against load faults, the PT4470/80 series of DC/DC converters incorporate an output current limit. Once the load current drawn from the module reaches the current limit threshold, any attempt by the load to draw additional current will result in a significant drop in the module's regulated output voltage. The current limit circuitry incorporates a limited amount of foldback. This has the effect of slightly reducing the output current from the module when supplying an absolute short circuit. Upon removal of the load fault, the output voltage from the converter will automatically recover to its programmed regulation voltage.

Output Over-Voltage Protection

The PT4470/80 series of DC/DC converters incorporate circuitry that continually senses the output for an over-voltage (OV) condition. The OV threshold automatically tracks the VID output voltage program setting to a level 25% higher than that programmed at the control pins, VID0 through VID4. If the converter output voltage exceeds the OV threshold, the converter is immediately shut down and remains in a latched-off state. To resume normal operation the converter must be actively reset. This is accomplished by either cycling the status of the *Inhibit* control (pin 3) from "On" to "Off" and then back "On" again, or by momentarily removing the input power to the converter. For failsafe operation and redundancy, the OV protection uses circuitry that is independent of the converter's internal feedback loop.

Over-Temperature Protection

Over-temperature protection is provided by an internal temperature sensor, which closely monitors the temperature of the converter's metal case. If the case temperature exceeds the specified limit (see applicable data sheet), the converter will shut down. The converter will then automatically restart when the sensed temperature drops by about 10°C. When operated outside its recommended thermal derating envelope (see data sheet SOA curves), the converter will typcially cycle on and off at intervals from a few seconds to one or two minutes. This is to ensure that the internal components are not permanently damaged from excessive thermal stress.

Primary-Secondary Isolation

Electrical isolation is provided between the input terminals (primary) and the output terminals (secondary). All converters are production tested to a primary-secondary withstand voltage of 1500VDC. This specification complies with UL60950 and EN60950 and the requirements for operational isolation. Operational isolation allows these converters to be configured for either a positive or negative input voltage source. The data sheet 'Pin-Out Information' uses shading to indicate which pins are associated with the primary. They include pins 1 through 5, inclusive.

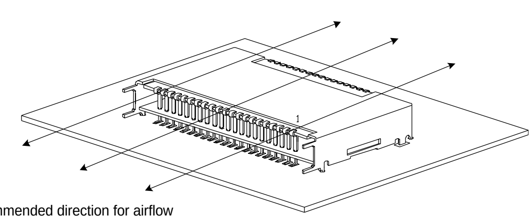
Fuse Recommendations

If desired, an input fuse may be added to protect against the application of a reverse input voltage.

Thermal Considerations

Airflow may be necessary to ensure that the module can supply the desired load current in environments with elevated ambient temperatures. The required airflow rate may be determined from the Safe Operating Area (SOA) thermal derating chart (see converter specifications). The recommended direction for airflow is into the longest side of the module's metal case. See Figure 1.

Figure 1



Recommended direction for airflow is across longest side.

Using the Inhibit Function on the PT4470 & PT4480 Series of Isolated DC/DC Converters

The PT4470/44480 series of DC/DC converters incorporate an On/Off Inhibit function. This function may be used in applications that demand battery conservation, power-up/shutdown sequencing, and/or to coordinate power-up for active in-rush current control.

The On/Off feature is provided by the *Inhibit* control, pin 3. The *Inhibit* pin of the PT4470/4480 series of converters is an active low enable. The pin must be either connected, or actively pulled low, to $-V_{in}$ (pin 2) to enable the converter output (see standard application schematic). When pins 2 & 3 are connected, the converter provides a regulated output whenever a valid source voltage[3] is applied between $+V_{in}$ (pin 1), and $-V_{in}$ (pin 2). If pin 3 is disconnected, or allowed to become high impedance, the regulator output will be disabled. [5]

Table 2-1 provides details of the interface requirements for the *Inhibit* pin. Figure 2-1 shows how a discrete MOSFET (Q_1) [4], may be referenced to $-V_{in}$ and used to control the input.

Table 2-1 Inhibit Control Requirements

Parameter	Min	Max
Enable (V_{IH})	–0.5V	0.8V
Disable (V_{IL})	2.5V	(Open Circuit)

Notes:

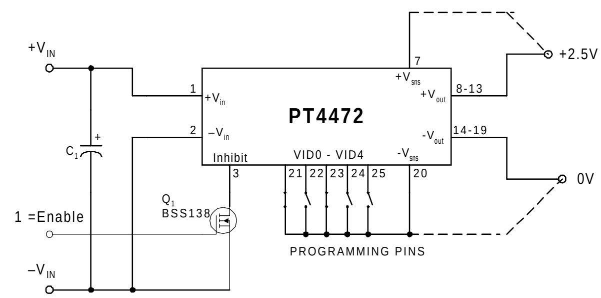
1. The *Inhibit* control uses $-V_{in}$ (pin 2), on the primary side of the converter, as its ground reference. All voltages specified are with respect to $-V_{in}$.
2. The internal circuitry is simple pull-up resistor. The open-circuit voltage may be as high as 6.5Vdc.
3. These converters incorporate an "Under-Voltage Lockout" (UVLO) function. This function automatically disables the converter output until there is sufficient input voltage to produce a regulated output. Table 2 gives the applicable UVLO thresholds.

Table 2-2 UVLO Thresholds [1]

Series	UVLO Threshold	V_{in} Range
PT4470	17.0V Typical	18 – 36V
PT4480	34.5V Typical	36 – 75V

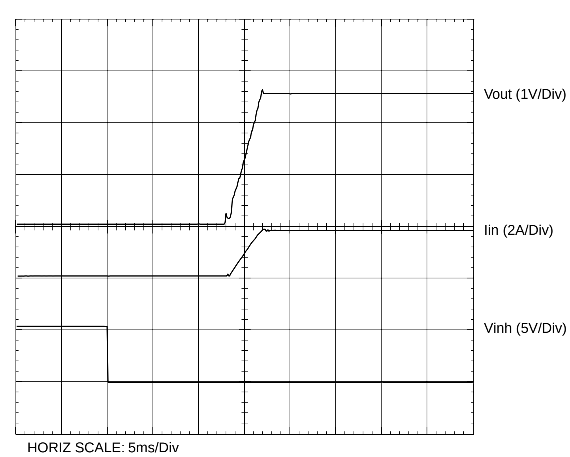
4. The *Inhibit* input must be controlled with an open-collector (or open-drain) discrete transistor or MOSFET. Do not use a pull-up resistor.
5. When the converter output is disabled, the current drawn from the input supply is typically reduced to 4mA (10mA maximum).
6. Keep the on/off transition to less than 1ms. This prevents erratic operation of the ISR, whereby the output voltage may drift un-regulated between 0V and the rated output during power-up.

Figure 2-1



Turn-On Time: With input power applied, the converter typically produces a fully regulated output voltage within 25ms after applying a low-voltage signal to the *Inhibit* control pin. The actual turn-on time will vary with the input voltage, output load, and the total amount of capacitance connected to the output. Using the circuit of Figure 2-1, Figure 2-2 shows the typical output voltage and input current waveforms of a PT4472 after Q_1 is turned on. The turn on of Q_1 correlates to the fall in V_{inh}. The output voltage was set to 2.5V. The waveform was measured with a 48-Vdc input voltage, and 15-A load current.

Figure 2-2



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Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265