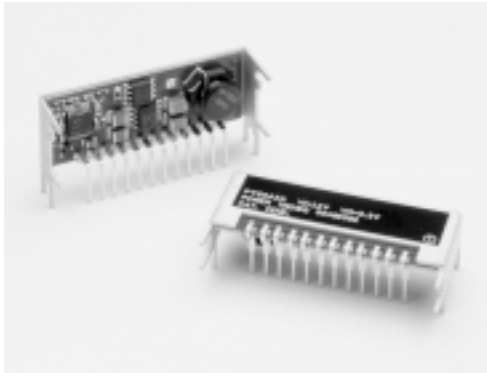




**THE DATASHEET OF  
PT6446C**





## Features

- 6A Output Current
- Input Voltage Range:  
3.1 V to 5.5 V
- 90% Efficiency
- Adjustable Output Voltage
- Standby Function
- Short Circuit Protection
- Small Footprint (0.61 in<sup>2</sup>)
- Solderable Copper Case
- 8.8 10<sup>6</sup> Hours MTBF

## Description

The PT6440 Excalibur™ power modules are a series of high performance Integrated Switching Regulators (ISRs), housed in a thermally efficient solderable copper case. These modules operate from input voltages as low as 3.1V to produce a high-output low-voltage power source; ideal for powering the industry's latest DSP and microprocessors. The series includes standard output bus voltages as low as 1.0VDC.

The innovative copper case construction provides superior thermal performance in a small footprint. Both through-hole and surface mount pin configurations are available. The PT6440 series operating features include external output voltage adjustment, an On/Off inhibit, and short-circuit protection. A 100µF input, and 330µF output capacitor are required for proper operation.

## Ordering Information

- PT6441□ = 3.3 Volts  
 † PT6442□ = 2.5 Volts  
 † PT6443□ = 2.0 Volts  
 † PT6444□ = 1.8 Volts  
 † PT6445□ = 1.5 Volts  
 † PT6446□ = 1.2 Volts  
 † PT6447□ = 1.0 Volts

† 3.3V Input Bus Capable

## PT Series Suffix (PT1234x)

Case/Pin Configuration	Order Suffix	Package Code *
Vertical	N	(EPH)
Horizontal	A	(EPJ)
SMD	C	(EPK)

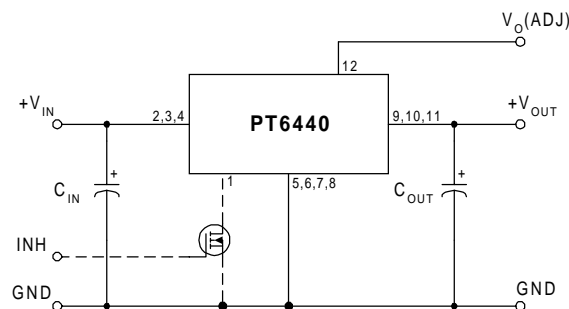
\* Previously known as package styles 1540/50.  
 (Reference the applicable package code drawing for the dimensions and PC board layout)

## Pin-Out Information

Pin	Function
1	Inhibit *
2	V <sub>in</sub>
3	V <sub>in</sub>
4	V <sub>in</sub>
5	GND
6	GND
7	GND
8	GND
9	V <sub>out</sub>
10	V <sub>out</sub>
11	V <sub>out</sub>
12	V <sub>out</sub> Adj *

\* For further information, see application notes.

## Standard Application



C<sub>in</sub> = Required 100µF electrolytic  
 C<sub>out</sub> = Required 330µF electrolytic

# PT6440 Series

## 6-A 5-V/3.3-V Input Adjustable Integrated Switching Regulator

**Specifications** (Unless otherwise stated,  $T_a = 25^\circ\text{C}$ ,  $V_{in} = 5\text{V}$ ,  $C_{in} = 100\mu\text{F}$ ,  $C_{out} = 330\mu\text{F}$ , and  $I_o = I_{o,max}$ )

Characteristic	Symbol	Conditions	PT6440 SERIES			Units	
			Min	Typ	Max		
Output Current	$I_o$	$T_a = +60^\circ\text{C}$ , 200LFM $T_a = +25^\circ\text{C}$ , natural convection	0.1 (1) 0.1 (1)	— —	6 6	A	
Input Voltage Range	$V_{in}$	Over $I_o$ Range	$V_o = 3.3\text{V}$ $V_o \leq 2.5\text{V}$	4.5 3.1	— —	5.5 5.5	VDC
Set Point Voltage Tolerance	$V_o, \text{tol}$		—	$\pm 1$	$\pm 2$ (2)	$\%V_o$	
Temperature Variation	$\text{Reg}_{\text{temp}}$	$-40^\circ \leq T_a \leq +85^\circ\text{C}$ , $I_o = I_{o,min}$	—	$\pm 0.5$	—	$\%V_o$	
Line Regulation	$\text{Reg}_{\text{line}}$	Over $V_{in}$ range	—	$\pm 6$	$\pm 10$	mV	
Load Regulation	$\text{Reg}_{\text{load}}$	Over $I_o$ range	—	$\pm 10$	$\pm 25$	mV	
Total Output Voltage Variation	$\Delta V_{o,tot}$	Includes set-point, line, load, $-40^\circ \leq T_a \leq +85^\circ\text{C}$	—	$\pm 2$	$\pm 3$	$\%V_o$	
Efficiency	$\eta$	$I_o = 4\text{A}$	$V_o = 3.3\text{V}$ $V_o = 2.5\text{V}$ $V_o = 2.0\text{V}$ $V_o = 1.8\text{V}$ $V_o = 1.5\text{V}$ $V_o = 1.2\text{V}$ $V_o = 1.0\text{V}$	— — — — — — —	91 89 85 85 81 80 78	— — — — — — —	%
$V_o$ Ripple (pk-pk)	$V_r$	20MHz bandwidth	—	20	—	$\text{mV}_{pp}$	
Transient Response	$t_{tr}$	$5\text{A}/\mu\text{s}$ load step, 50% to 100% $I_{o,max}$	—	50	—	$\mu\text{s}$	
	$\Delta V_{tr}$	$V_o$ over/undershoot	—	$\pm 70$	—	mV	
Short Circuit Threshold	$I_{sc}$ threshold		—	10	—	A	
Switching Frequency	$f_s$	Over $V_{in}$ and $I_o$ range	300	350	400	kHz	
Inhibit (Pin 1)		Referenced to $-V_{in}$ (pin 8)					
Input High Voltage	$V_{IH}$		$V_{in} - 0.5$	—	Open (2)	V	
Input Low Voltage	$V_{IL}$		$-0.2$	—	$+0.5$		
Input Low Current	$I_{IL}$		—	$-0.5$	—	mA	
Standby Input Current	$I_{in, standby}$	pins 1 & 5 connected	—	$+0.5$	—	mA	
External Output Capacitance	$C_{out}$	See application schematic	330	—	1,000	$\mu\text{F}$	
External Input Capacitance	$C_{in}$	See application schematic	100	—	—	$\mu\text{F}$	
Operating Temperature Range	$T_a$	Over $V_{in}$ range	$-40$ (3)	—	$+85$ (4)	$^\circ\text{C}$	
Storage Temperature	$T_s$	—	$-40$	—	$+125$	$^\circ\text{C}$	
Reliability	MTBF	Per Bellcore TR-332 50% stress, $T_a = 40^\circ\text{C}$ , ground benign	8.8	—	—	$10^6$ 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, 20-2000Hz, soldered in PCB	—	20 (5)	—	G's	
Weight	—		—	23	—	grams	
Flammability	—	Materials meet UL 94V-0					

**Notes:** (1) The ISR will operate at no load with reduced specifications.

(2) The Inhibit control (pin 1) has an internal pull-up and if it is left open circuit the module will operate when input power is applied. The open-circuit voltage is the input voltage  $V_{in}$ . Use a discrete MOSFET to control the Inhibit pin, and ensure a transition time of less than  $\leq 10\mu\text{s}$ . Consult the related application note for other interface considerations.

(3) For operation below  $0^\circ\text{C}$ ,  $C_{in}$  and  $C_{out}$  must have stable characteristics. Use either low ESR tantalum or Oscon® capacitors.

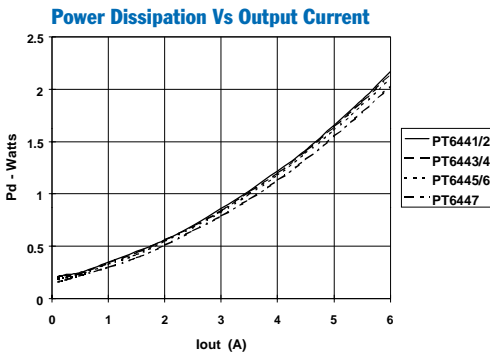
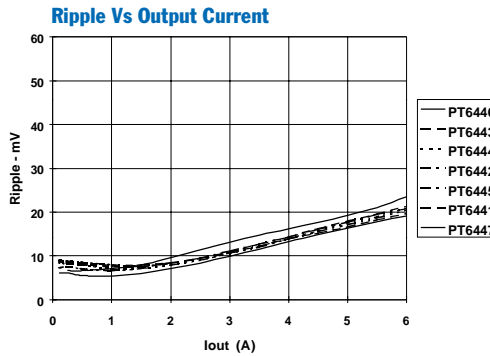
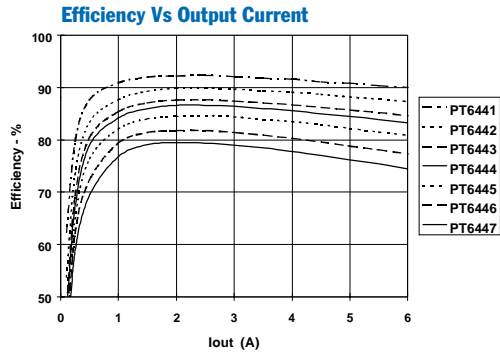
(4) See Safe Operating Area curves or contact the factory for the appropriate derating.

(5) The case pins on through-hole package types (suffixes N & A) must be soldered. For more information consult the applicable package outline drawing.

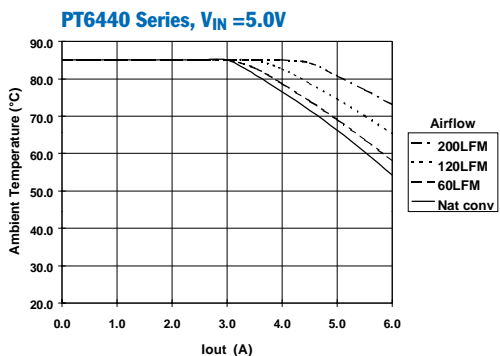
**Input/Output Capacitors:** The PT6440 regulator series requires a  $100\mu\text{F}$  electrolytic (or tantalum) capacitor at the input and  $330\mu\text{F}$  at the output for proper operation in all applications. In addition, the input capacitance,  $C_{in}$ , must be rated for a minimum of  $350\text{mA}$  rms of ripple current, and the ESR of the output capacitor,  $C_{out}$ , must be less than  $100\text{m}\Omega$  @  $100\text{kHz}$ . For transient or dynamic load applications additional output capacitance may be necessary. For more information consult the related application note on capacitor recommendations.

6-A 5-V/3.3-V Input Adjustable  
Integrated Switching Regulator

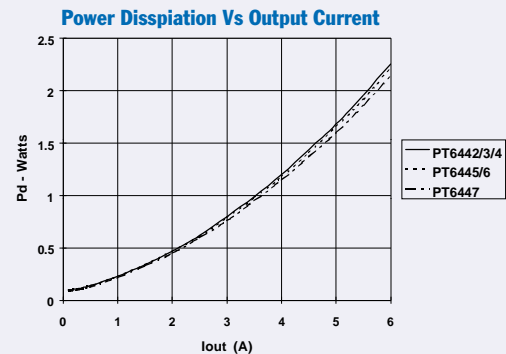
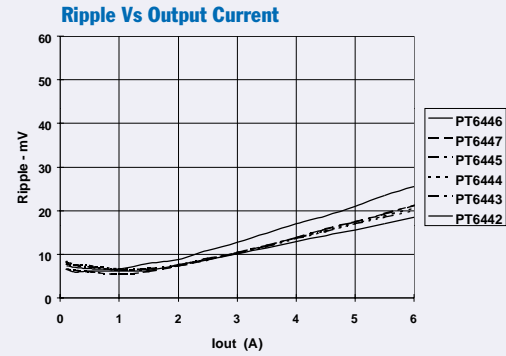
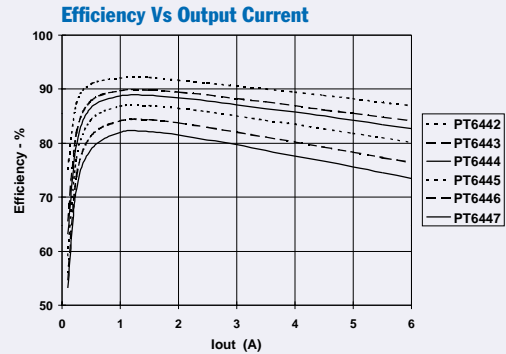
**PT6440 Series Performance; @ $V_{IN} = 5.0V$**  (See Note A)



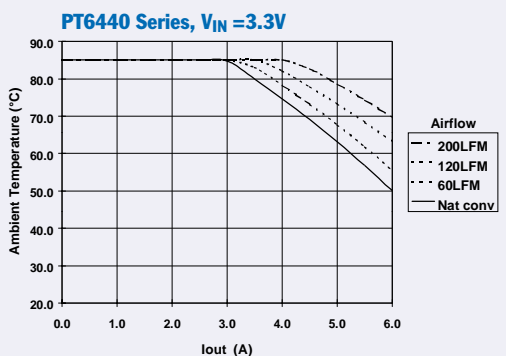
**Safe Operating Area Curves** (See Note B)



**PT6440 Series Performance; @ $V_{IN} = 3.3V$**  (See Note A)



**Safe Operating Area Curves** (See Note B)



**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

## Capacitor Recommendations for the PT6440 Excalibur™ 5V/3.3V Bus Step-Down ISRs

### Input Capacitors

The recommended input capacitance is determined by 350 milli-amperes (rms) minimum ripple current rating and 100µF minimum capacitance. Capacitors placed at the input must be rated for a minimum of twice the input voltage with +5V operation. Ripple current and  $\leq 200\text{m}\Omega$  Equivalent Series Resistance (ESR) values are the major considerations, along with temperature, when selecting the proper input capacitor.

### Output Capacitors

The ESR of the required 330µF output capacitor must be less than or equal to 100mΩ. Failure to observe this requirement may lead to regulator instability or oscillation. Electrolytic capacitors have poor ripple performance at frequencies greater than 300kHz but excellent low frequency transient response. Above the ripple frequency, ceramic decoupling capacitors are necessary to improve the transient response and reduce any high frequency noise components apparent during higher current excursions. The preferred low ESR type capacitor part numbers are identified in Table 1.

### Tantalum Capacitors

Tantalum capacitors are recommended on the output bus but only the AVX TPS series, Sprague 593D/594/595 series or Kemet T495/T510 series. These capacitors are specified over many other types due to their higher surge current, power dissipation and ripple current capability. As a caution, the TAJ Series by AVX is not recommended. This series exhibits considerably higher ESR and lower ripple current capability. The TAJ series is also less reliable than the TPS series when determining power dissipation capability. Tantalum or Oscon® types are recommended in applications where ambient temperatures fall below 0°C.

### Capacitor Table

Table 1 identifies vendors with acceptable ESR and maximum allowable ripple current (rms) ratings. The suggested minimum quantities per regulator for both the input and output buses are identified.

*This is not an extensive capacitor list. Capacitors from other vendors are available with comparable specifications. Those listed are for guidance. The RMS ripple current rating and ESR (Equivalent Series Resistance at 100kHz) are critical parameters necessary to insure both optimum regulator performance and long capacitor life.*

**Table 1; Input/Output Capacitors**

Capacitor Vendor/ Component Series	Capacitor Characteristics					Quantity		Vendor Number
	Working Voltage	Value(µF)	(ESR) Equivalent Series Resistance	85°C Maximum Ripple Current(Irms)	Physical Size(mm)	Input Bus	Output Bus	
Panasonic, FC (Radial)	35V	390µF	0.065Ω	1205mA	12.5×15	1	1	EEUFC1V391S
	35V	100µF	0.117Ω	555mA	8×11.5	1	N/R	EEUFC1V101
	25V	330µF	0.090Ω	755mA	10×12.5	1	1	EEUFC1E331
FC (Surface Mount)	16V	220µF	0.15Ω±2	670mA	10×10.2	1	2	EEVFC1C221P
	25V	100µF	0.40Ω	450mA	8×10.2	1	N/R	EEVFC1101P
	35V	330µF	0.065Ω	1205mA	12×16.5	1	1	EEVFC1V471LQ
United Chemi-Con LXV/LXZ	25V	330µF	0.084Ω	825mA	10×16	1	1	LXV25VB331M10X16LL
	35V	220µF	0.090Ω±2	760mA	10×12.5	1	2	LXZ35VB221M10X12LL
FS	10V	330µF	0.025Ω	3500mA	10×10.5	1	1	10FS330M
	10V	100µF	0.040Ω	2100mA	6.3×9.8	1	N/R	10FS100M
Nichicon, PL (Radial)	35V	330µF	0.065Ω	1020mA	12.5×15	1	1	UPL1V331MHH6
UD (Surface Mount)	35V	330µF	0.090Ω	670mA	10×10	1	1	UUD1V331MNR1GS
	35V	220µF	0.17Ω±2	450mA	8×10	1	2	UUD1V2211MNR1GS
Oscon, SS (Radial)	10V	330µF	0.025Ω	>3500mA	10×10.5	1	1	10SS330M
SV (Surface Mount)	10V	330µF	0.025Ω	>3800mA	10.3×10.3	1	1	10SV300M
	16V	100µF	0.045Ω	2200mA	10.3×10.3	1	N/R	16SV100M
AVX Tantalum TPS	10V	330µF	0.100Ω	1414mA	7.3L	1	1	TPSV337M010R0100
	10V	330µF	0.060Ω	1826mA	<4.3V	1	1	TPSV337M010R0060
	10V	150µF	0.100Ω	1095mA	<4.1H	1	2	TPSD107M010R100
Kemet, T510 T495	10V	330µF	0.033Ω	1400mA	7.3L ×5.7W	1	1	T510X337M010AS
	10V	220µF	0.070Ω±2	>2000mA	<4.0H	1	2	T495X227M010AS
Sprague 594D	10V	330µF	0.045Ω	2350mA	7.3L ×6W	1	1	594D337X0010R2T
	10V	150µF	0.090Ω	1100mA	<4.1H	1	2	594D157X0010C2T

## Adjusting the Output Voltage of the PT6440 Excalibur™ 5V/3.3V Bus Step-Down ISRs

The output voltage of the PT6440 Series ISRs may be adjusted higher or lower than the factory trimmed pre-set voltage with the addition of a single external resistor. Table 1 gives the allowable adjustment range for each model for either series as  $V_a$  (min) and  $V_a$  (max).

**Adjust Up:** An increase in the output voltage is obtained by adding a resistor  $R_2$ , between  $V_o$  Adj (pin 12) and GND (pins 5–8).

**Adjust Down:** Add a resistor ( $R_1$ ), between  $V_o$  Adj (pin 12) and  $V_{out}$  (pins 9–11).

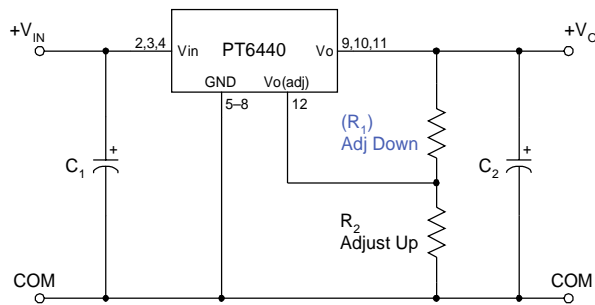
The values of ( $R_1$ ) [adjust down], and  $R_2$  [adjust up], can also be calculated using the following formulas. Refer to Figure 1 and Table 2 for both the placement and value of the required resistor; either ( $R_1$ ) or  $R_2$  as appropriate.

$$(R_1) = \frac{R_o (V_a - 0.9)}{V_o - V_a} - R_s \quad \text{k}\Omega$$

$$R_2 = \frac{0.9 R_o}{V_a - V_o} - R_s \quad \text{k}\Omega$$

Where:  $V_o$  = Original output voltage  
 $V_a$  = Adjusted output voltage  
 $R_o$  = The resistance value from Table 1  
 $R_s$  = The series resistance from Table 1

Figure 1



**Notes:**

1. Use only a single 1% resistor in either the ( $R_1$ ) or  $R_2$  location. Place the resistor as close to the ISR as possible.
2. Never connect capacitors from  $V_o$  adj to either GND or  $V_{out}$ . Any capacitance added to the  $V_o$  adjust pin will affect the stability of the ISR.
3. For each model, adjustments to the output voltage may place additional limits on the minimum input voltage. The revised minimum input voltage must comply with the following requirement.

$$V_{in(min)} = (V_a + 0.5)V \text{ or as specified in the data sheet, whichever is greater.}$$

Table 1

ISR ADJUSTMENT RANGE AND FORMULA PARAMETERS							
Series Pt. #	PT6441	PT6442	PT6443	PT6444	PT6445	PT6446	PT6447
$V_o$ (nom)	3.3	2.5	2.0	1.8	1.5	1.2	1.0
$V_a$ (min)	2.88	1.97	1.64	1.5	1.3	1.08	0.97
$V_a$ (max)	3.5	2.95	2.45	2.25	1.95	1.65	1.45
$R_o$ (k $\Omega$ )	10.0	10.0	10.0	10.0	10.0	10.0	10.2
$R_s$ (k $\Omega$ )	49.9	20.0	20.0	20.0	20.0	20.0	20.0

PT6440 Series

**Table 2**

**ISR ADJUSTMENT RESISTOR VALUES**

Series Pt. #	PT6441	PT6442	PT6443	PT6444	PT6445	PT6446	PT6447
V <sub>o</sub> (nom)	3.3	2.5	2.0	1.8	1.5	1.2	1.0
V <sub>a</sub> (req.d)							
0.97							(0.4)kΩ
1.0							
1.05							164.0kΩ
1.1						(0.0)kΩ	71.8kΩ
1.15						(30.0)kΩ	41.2kΩ
1.2							25.9kΩ
1.25						160.0kΩ	16.7kΩ
1.3					(0.0)kΩ	70.0kΩ	10.6kΩ
1.35					(10.0)kΩ	40.0kΩ	6.2kΩ
1.4					(30.0)kΩ	25.0kΩ	3.0kΩ
1.45					(90.0)kΩ	16.0kΩ	0.4kΩ
1.5				(0.0)kΩ		10.0kΩ	
1.55				(6.0)kΩ	160.0kΩ	5.7kΩ	
1.6				(15.0)kΩ	70.0kΩ	2.5kΩ	
1.65			(1.4)kΩ	(30.0)kΩ	40.0kΩ	0.0kΩ	
1.7			(6.7)kΩ	(60.0)kΩ	25.0kΩ		
1.75			(14.0)kΩ	(150.0)kΩ	16.0kΩ		
1.8			(25.0)kΩ		10.0kΩ		
1.85			(43.3)kΩ	160.0kΩ	5.7kΩ		
1.9			(80.0)kΩ	70.0kΩ	2.5kΩ		
1.95			(190.0)kΩ	40.0kΩ	0.0kΩ		
2.0		(2.0)kΩ		25.0kΩ			
2.05		(5.6)kΩ	160.0kΩ	16.0kΩ			
2.1		(10.0)kΩ	70.0kΩ	10.0kΩ			
2.15		(15.7)kΩ	40.0kΩ	5.7kΩ			
2.2		(23.3)kΩ	25.0kΩ	2.5kΩ			
2.25		(34.0)kΩ	16.0kΩ	0.0kΩ			
2.3		(50.0)kΩ	10.0kΩ				
2.35		(76.7)kΩ	5.7kΩ				
2.4		(130.0)kΩ	2.5kΩ				
2.45		(284.0)kΩ	0.0kΩ				
2.5							
2.55		160.0kΩ					
2.6		70.0kΩ					
2.65		40.0kΩ					
2.7		25.0kΩ					
2.75		16.0kΩ					
2.8		10.0kΩ					
2.85		5.7kΩ					
2.9	(0.0)kΩ	2.5kΩ					
2.95	(8.5)kΩ	0.0kΩ					
3.0	(20.1)kΩ						
3.05	(36.1)kΩ						
3.1	(60.1)kΩ						
3.15	(100.0)kΩ						
3.2	(180.0)kΩ						
3.25	(420.0)kΩ						
3.3							
3.35	130.0kΩ						
3.4	40.1kΩ						
3.45	10.1kΩ						
3.48	0.0kΩ						

R1 = (Blue) R2 = Black

## Using the Inhibit Function on the PT6440 Excalibur™ 5V/3.3V Bus Step-Down ISRs

For applications requiring output voltage On/Off control, the 12-pin PT6440 series products incorporate an *Inhibit* function. This function may be used wherever there is a requirement for the module to be switched off. The function is provided by the *Inhibit* control (pin 1) input.

The ISR functions normally with pin 1 open-circuit, <sup>1</sup> providing a regulated output whenever a valid source voltage is applied to  $V_{in}$ , (pins 2–4), with respect to GND (pins 5–8). When a low-level ground signal is applied to pin 1, the regulator output is disabled.

Figure 1 shows an application schematic, which details the typical use of the Inhibit function. Note the discrete transistor ( $Q_1$ ). The Inhibit control has its own internal pull-up to  $+V_{in}$  potential. An open-collector or open-drain device is required to control this pin. <sup>2</sup>

The Inhibit pin control thresholds are given in Table 1. Equation 1 may be used to determine the approximate current drawn from the input source, and by  $Q_1$  when the regulator is placed in the inhibit state.

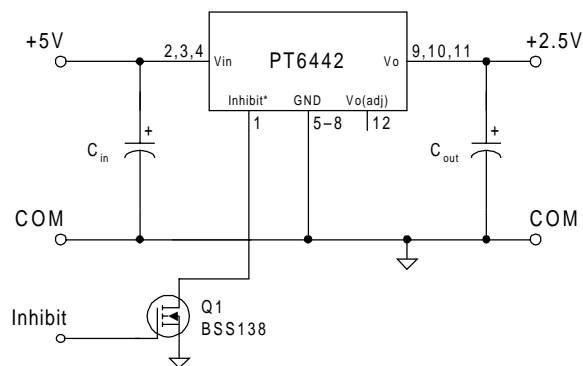
**Table 1; Inhibit Control Requirements <sup>3</sup>**

Parameter	Min	Max
Enable ( $V_{IH}$ )	$V_{in} - 0.5$	$V_{in}$
Disable ( $V_{IL}$ )	-0.2V	0.5V
Transition Time	10 $\mu$ s <sup>4</sup>	

**Equation 1; Off Input Current**

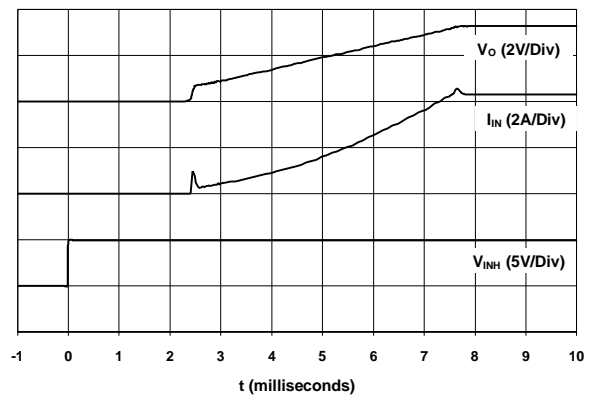
$$I_{stby} = V_{in} \div 10k\Omega \pm 20\%$$

**Figure 1**



**Turn-On Time:** In the circuit of Figure 1, turning  $Q_1$  on applies a low-voltage to the *Inhibit* control (pin 1) and disables the regulator output. Correspondingly, turning  $Q_1$  off allows the *Inhibit* control pin to be pulled high by its internal pull-up resistor. The ISR produces a fully regulated output voltage within 10 milliseconds of the release of the Inhibit control pin. The actual turn-on time will vary with input voltage, output load, and the total amount of load capacitance. Figure 2 shows the typical rise in both output voltage and input current for a PT6441 (3.3V) following the turn-off of  $Q_1$  at time  $t = 0$ . The waveform was measured with a 5Vdc input voltage, and 6 Adc resistive load.

**Figure 2**



**Notes:**

1. Use an open-collector device (preferably a discrete transistor) for the Inhibit input. A pull-up resistor is not necessary. To disable the output voltage, the control pin should be pulled low to less than +0.5VDC.
2. Do not control the Inhibit input with an external DC voltage. This will lead to erratic operation of the ISR and may over-stress the regulator.
3. Avoid capacitance greater than 500pF at the Inhibit control pin. Excessive capacitance at this pin will cause the ISR to produce a pulse on the output voltage bus at turn-on.
4. Keep the On/Off transition to less than 10 $\mu$ s. This prevents erratic operation of the ISR, which could cause the output voltage to be momentarily higher than normal.

## IMPORTANT NOTICE

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