

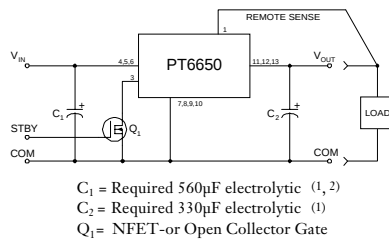
- Single Device: 5A Output
- Input Voltage Range: 9V to 28V
- Adjustable Output Voltage
- 80% Efficiency
- Remote Sense Capability
- Standby Function

The PT6650 series is line of 24V bus Integrated Switching Regulators (ISRs). Designed for general purpose

industrial applications requiring as much as 5A of output current, the PT6650 is packaged in a 14-Pin SIP (Single In-line Package) and is available in a surface-mount configuration.

Only two external capacitors are required for proper operation. Please note that this product does not include short circuit protection.

Standard Application



Pin-Out Information

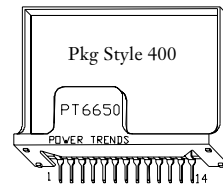
1	Remote Sense
2	Do Not Connect
3	STBY*- Standby
4	V _{in}
5	V _{in}
6	V _{in}
7	GND
8	GND
9	GND
10	GND
11	V _{out}
12	V _{out}
13	V _{out}
14	V _{out} Adjust

Ordering Information

PT6651	= +3.3 Volts
PT6652	= +2.5 Volts
PT6653	= +5.0 Volts
PT6654	= +9.0 Volts
PT6655	= +15.0 Volts
PT6656	= +12.0 Volts

PT Series Suffix (PT1234X)

Case/Pin Configuration	Heat Spreader	Heat Spreader with Side Tabs
Vertical Through-Hole	P	R
Horizontal Through-Hole	D	G
Horizontal Surface Mount	E	B



Note: Back surface of product is conducting metal

Specifications

Characteristics (T _a = 25°C unless noted)	Symbols	Conditions	PT6650 SERIES			Units
			Min	Typ	Max	
Output Current	I _O	T _a = 60°C, 200 LFM, pkg P T _a = 25°C, natural convection	0.1 (3) 0.1 (3)	—	5.0 (4) 5.0 (4)	A
Input Voltage Range	V _{in}	0.1A ≤ I _O ≤ 5.0A V _O ≤ +6V V _O > +6V	+9V V _O +3	—	+28V +28V	V
Output Voltage Tolerance	ΔV _O	Over V _{in} range T _a = -40°C to +65°C	V _O -0.1	—	V _O +0.1	V
Output Voltage Adjust Range	V _{oadj}	Pin 14 to V _O or ground V _O = +3.3V V _O = +2.5V V _O = +5.0V V _O = +9.0V V _O = +12V V _O = +15V	2.2 1.8 3.0 6.0 9.0 10.0	— — — — — —	4.7 4.3 6.5 10.2 13.6 17.0	V
Line Regulation	Reg _{line}	+9V ≤ V _{in} ≤ +28V, I _O = 5.0A	—	±0.5	±1.0	% V _O
Load Regulation	Reg _{load}	V _{in} = +24V, 0.1 ≤ I _O ≤ 5.0A	—	±0.5	±1.0	% V _O
V _O Ripple/Noise	V _n	V _{in} = +24V, I _O = 5.0A V _O ≤ +6V V _O > +6V	—	50 1.0	—	mV _{pp} % V _O
Transient Response with C ₂ = 330µF	t _{tr} V _{os}	I _O step between 2.5A and 5.0A V _O over/undershoot	— —	100 100	— —	µSec mV
Efficiency	η	V _{in} = +24V, I _O = 0.5x I _{O max} V _O = +3.3V V _O = +2.5V V _O = +5.0V	— — —	81 76 85	— — —	%
		V _{in} = +24V, I _O = I _{O max} V _O = +3.3V V _O = +2.5V V _O = +5.0V	— — —	80 75 84	— — —	
Switching Frequency	f _o	9V ≤ V _{in} ≤ 28V Over I _O range	500	550	600	kHz
Absolute Maximum Operating Temperature Range	T _a	Over V _{in} range	-40	—	+85 (4)	°C
Storage Temperature	T _s	—	-40	—	+125	°C
Mechanical Shock	—	Per Mil-STD-883D, Method 2002.3	—	500	—	G's
Mechanical Vibration	—	Per Mil-STD-883D, Method 2007.2, 20-2000 Hz, soldered in a PC board	—	7.5	—	G's
Weight	—	—	—	14	—	grams

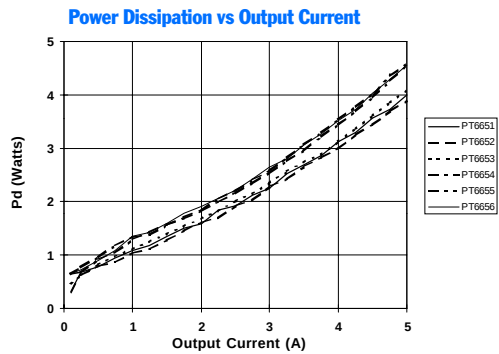
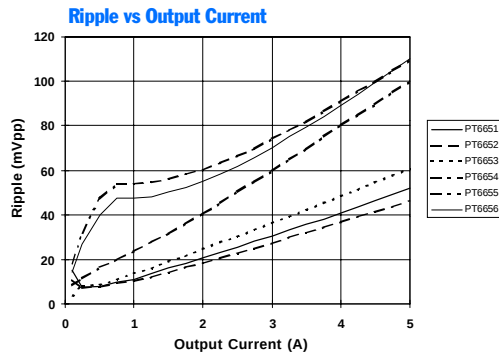
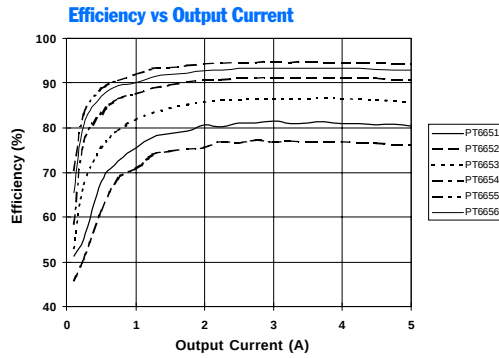
Notes: (1) The PT6650 Series requires a 330µF electrolytic capacitor at the output, and a 560µF at the input for proper operation in all applications.

(2) The input capacitor must have a low ESR, and be rated for 1.4Arms of ripple current.

(3) ISR will operate down to no load with reduced specifications.

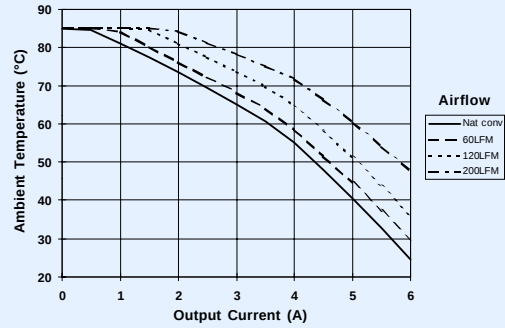
(4) See SOA curves, or contact the factory for the appropriate derating.

PT6650 Series @Vin=+24V (See Note A)

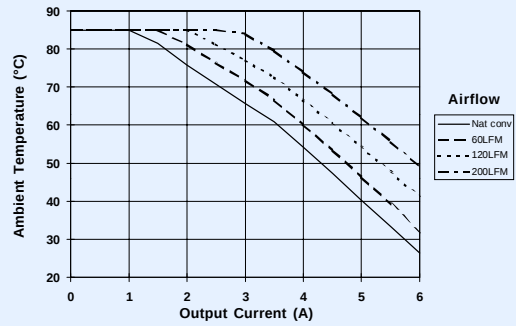


Safe Operating Area @Vin=+24V (See Note B)

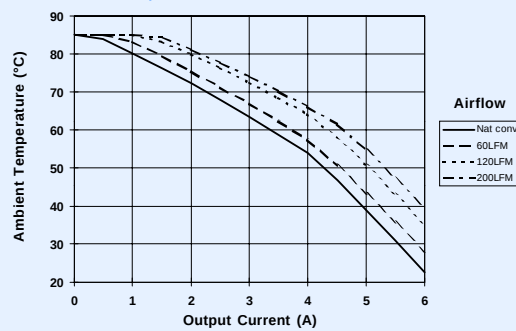
PT6651P, 3.3V



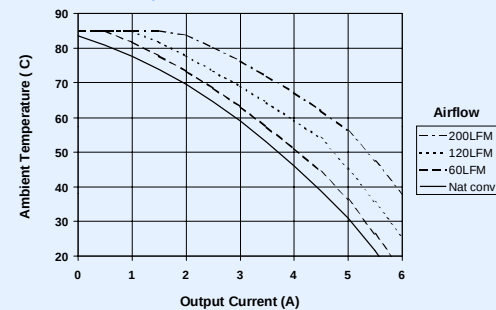
PT6652P, 2.5V



PT6653P, 5.0V



PT6656P, 12.0V



Note A: All data listed in the above graphs has been developed from actual products tested at 25°C. This data is considered typical data for the ISR.

Note B: SOA curves represent the conditions at which internal components are at or below manufacturer's maximum operating temperatures.

PT6650 Series

Adjusting the Output Voltage of the PT6650 5Amp 24V Bus Converter Series

The output voltage of the Power Trends PT6650 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 accordingly gives the allowable adjustment range for each model in the series as V_a (min) and V_a (max).

Adjust Up: An increase in the output voltage is obtained by adding a resistor R2, between pin 14 (V_o adjust) and pins 7-10 (GND).

Adjust Down: Add a resistor (R1), between pin 14 (V_o adjust) and pins 11-13 (V_{out}).

Refer to Figure 1 and Table 2 for both the placement and value of the required resistor, either (R1) or R2 as appropriate.

Notes:

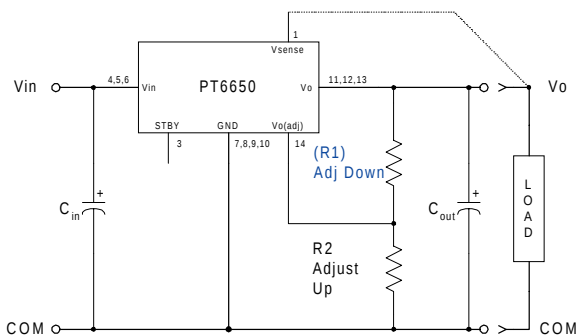
1. Use only a single 1% resistor in either the (R1) or R2 location. Place the resistor as close to the ISR as possible.
2. Never connect capacitors from V_o adjust to either GND, V_{out} , or the Remote Sense pin. Any capacitance added to the V_o adjust pin will affect the stability of the ISR.
3. If the Remote Sense feature is being used, connecting the resistor (R1) between pin 14 (V_o adjust) and pin 1 (Remote Sense) can benefit load regulation.
4. Adjustments to the output voltage may place additional limits on the input voltage for the part. The revised limits must comply with the following requirements.

$$V_{in}(\min) = (V_{out} + 3)V \text{ or } 9V, \text{ whichever is higher.}$$

$$V_{in}(\max) = (10 \times V_{out})V \text{ or } 28V, \text{ whichever is less.}$$

5. For output voltages above 12.5Vdc, the maximum output current must be limited to 4A dc.

Figure 1



The values of (R1) [adjust down], and R2 [adjust up], can also be calculated using the following formulae.

$$(R1) = \frac{R_o (V_o - 1.25)(V_a - 1.25)}{1.25 (V_o - V_a)} - R_s \quad k\Omega$$

$$R2 = \frac{R_o (V_o - 1.25)}{V_a - V_o} - R_s \quad k\Omega$$

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

Table 1

PT6650 ADJUSTMENT AND FORMULA PARAMETERS

Series Pt #	PT6652	PT6651	PT6653	PT6654	PT6656	PT6655
V_o (nom)	2.5V	3.3V	5.0V	9.0V	12.0V	15.0V
V_a (min)	1.8V	2.2V	3.0V	6.0V	9.0V	10.0V
V_a (max)	4.3V	4.7V	6.5V	10.2V	13.6V	17.0V
R_o (k Ω)	4.99	4.22	2.49	2.0	2.0	2.0
R_s (k Ω)	2.49	4.99	4.99	12.7	12.7	12.7

PT6650 Series

Table 2

PT6650 ADJUSTMENT RESISTOR VALUES

Series Pt #	PT6652	PT6651	PT6653
Current	5Adc	5Adc	5Adc
V _o (nom)	2.5Vdc	3.3Vdc	5.0Vdc
V _a (req'd)			
1.8	(1.4)kΩ		
1.9	(2.9)kΩ		
2.0	(5.0)kΩ		
2.1	(8.1)kΩ		
2.2	(13.3)kΩ	(1.0)kΩ	
2.3	(23.7)kΩ	(2.3)kΩ	
2.4	(54.9)kΩ	(3.9)kΩ	
2.5		(5.8)kΩ	
2.6	59.9kΩ	(8.4)kΩ	
2.7	28.7kΩ	(11.7)kΩ	
2.8	18.3kΩ	(16.5)kΩ	
2.9	13.1kΩ	(23.6)kΩ	
3.0	10.0kΩ	(35.4)kΩ	(1.6)kΩ
3.1	7.9kΩ	(59.0)kΩ	(2.3)kΩ
3.2	6.4kΩ	(130.0)kΩ	(3.1)kΩ
3.3	5.3kΩ		(4.0)kΩ
3.4	4.4kΩ	81.5kΩ	(5.1)kΩ
3.5	3.8kΩ	38.3kΩ	(6.2)kΩ
3.6	3.2kΩ	23.8kΩ	(7.6)kΩ
3.7	2.7kΩ	16.6kΩ	(9.1)kΩ
3.8	2.3kΩ	12.3kΩ	(10.9)kΩ
3.9	2.0kΩ	9.4kΩ	(13.0)kΩ
4.0	1.7kΩ	7.4kΩ	(15.6)kΩ
4.1	1.4kΩ	5.8kΩ	(18.7)kΩ
4.2	1.2kΩ	4.6kΩ	(22.6)kΩ
4.3	1.0kΩ	3.7kΩ	(27.6)kΩ
4.4		2.9kΩ	(34.2)kΩ
4.5		2.2kΩ	(43.6)kΩ
4.6		1.7kΩ	(57.6)kΩ
4.7		1.2kΩ	(80.9)kΩ
4.8			(128.0)kΩ
4.9			(268.0)kΩ
5.0			
5.1			88.4kΩ
5.2			41.7kΩ
5.3			26.1kΩ
5.4			18.4kΩ
5.5			13.7kΩ
5.6			10.6kΩ
5.7			8.4kΩ
5.8			6.7kΩ
5.9			5.4kΩ
6.0			4.4kΩ
6.1			3.5kΩ
6.2			2.8kΩ
6.3			2.2kΩ
6.4			1.7kΩ
6.5			1.2kΩ

R1 = (Blue) R2 = Black

Series Pt #	PT6654	PT6656	PT6655
Current	5Adc	5Adc	4Adc
V _o (nom)	9.0Vdc	12.0Vdc	15.0Vdc
V _a (req'd)			
6.0	(6.9)kΩ		
6.2	(9.2)kΩ		
6.4	(11.9)kΩ		
6.6	(14.0)kΩ		
6.8	(18.6)kΩ		
7.0	(23.0)kΩ		
7.2	(28.3)kΩ		
7.4	(35.0)kΩ		
7.6	(43.5)kΩ		
7.8	(55.0)kΩ		
8.0	(71.0)kΩ		
8.2	(95.0)kΩ		
8.4	(135.0)kΩ		
8.6	(215.0)kΩ		
8.8	(455.0)kΩ		
9.0		(31.7)kΩ	
9.2	64.8kΩ	(36.1)kΩ	
9.4	26.1kΩ	(41.2)kΩ	
9.6	13.1kΩ	(47.1)kΩ	
9.8	6.7kΩ	(54.1)kΩ	
10.0	2.8kΩ	(62.6)kΩ	(25.8)kΩ
10.2	0.2kΩ	(72.8)kΩ	(28.3)kΩ
10.4		(85.7)kΩ	(31.1)kΩ
10.6		(102.0)kΩ	(34.1)kΩ
10.8		(124.0)kΩ	(37.3)kΩ
11.0		(155.0)kΩ	(40.9)kΩ
11.2		(201.0)kΩ	(44.9)kΩ
11.4		(278.0)kΩ	(49.3)kΩ
11.6		(432.0)kΩ	(54.3)kΩ
11.8		(895.0)kΩ	(59.8)kΩ
12.0			(66.1)kΩ
12.2		94.8kΩ	(73.3)kΩ
12.4		41.1kΩ	(81.6)kΩ
12.6		23.1kΩ	(91.3)kΩ
12.8		14.2kΩ	(103.0)kΩ
13.0		8.8kΩ	(117.0)kΩ
13.2		5.2kΩ	(133.0)kΩ
13.4		2.7kΩ	(154.0)kΩ
13.6		0.7kΩ	(181.0)kΩ
13.8			(217.0)kΩ
14.0			(268.0)kΩ
14.2			(343.0)kΩ
14.5			(570.0)kΩ
15.0			
15.5			42.3kΩ
16.0			14.8kΩ
16.5			5.6kΩ
17.0			1.1kΩ

PT6650 Series

Using the Standby Function on the PT6650 Series of 24V Bus Converters

For applications requiring output voltage On/Off control, the 14-pin PT6650 ISR series incorporates a standby function. This feature may be used for power-up/shut-down sequencing, and wherever there is a requirement for the output status of the module to be controlled by external circuitry.

The standby function is provided by the *STBY** control, pin 3. If pin 3 is left open-circuit the regulator operates normally, providing a regulated output whenever a valid supply voltage is applied to V_{in} (pins 4, 5, & 6) with respect to GND (pins 7-10). Connecting pin 3 to ground² will disable the regulator output and reduce the input current to less than 30mA⁴. Grounding the standby control will also hold-off the regulator output during the period that input power is applied.

The standby input is ideally controlled with an open-collector (or open-drain) discrete transistor (See Figure 1). It can also be driven directly from a dedicated TTL³ compatible gate. Table 1 provides details of the threshold requirements.

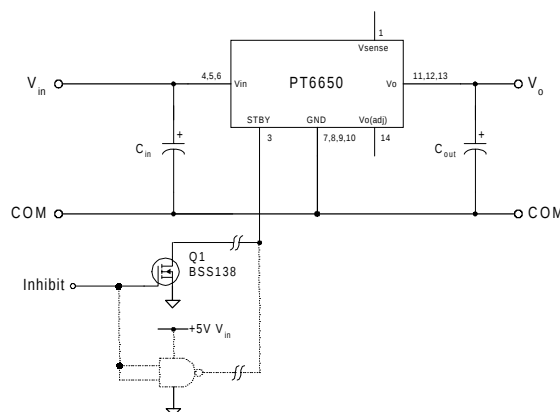
Table 1 Inhibit Control Thresholds ^(2,3)

Parameter	Min	Max
Enable (V_{IH})	1V	5V
Disable (V_{IL})	-0.1V	0.3V

Notes:

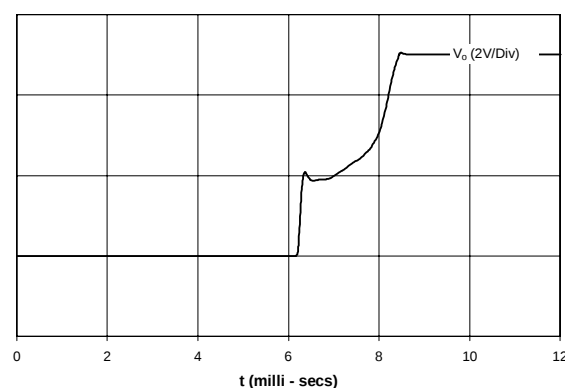
1. The Standby/Inhibit control logic is similar for all Power Trends' modules, but the flexibility and threshold tolerances will be different. For specific information on this function for other regulator models, consult the applicable application note.
2. The Standby input on the PT6650 regulator series may be controlled using either an open-collector (or open-drain) discrete transistor, or a device with a totem-pole output. A pull-up resistor is not necessary. The control input has an open-circuit voltage of about 1.5Vdc. To disable the regulator output, the control pin must be "pulled" to less than 0.3Vdc with a low-level 0.25mA max. sink to ground.
3. The Standby input on the PT6650 series is also compatible with TTL logic. A standard TTL logic gate will meet the 0.3V V_{IL} (max) requirement (Table 1) at 0.25mA sink current. Do not drive the Standby control input above 5Vdc.
4. When the regulator output is disabled the current drawn from the input source is reduced to approximately 15mA (30mA maximum).
5. The turn-off time of Q_1 , or rise time of the standby input is not critical on the PT6650 series. Turning Q_1 off over periods up to 100ms will not damage the regulator. However, a slow turn-off time will increase both the initial delay and rate-of-rise of the output voltage.

Figure 1



Turn-On Time: Turning Q_1 off in Figure 1, removes the low-voltage signal at pin 3 and enables the output. The PT6650 series of regulators will provide a fully regulated output voltage within 12ms. The actual turn-on time may vary with load and the total amount of output capacitance. Figure 2 shows the typical output voltage waveform of a PT6653 (5.0V) following the prompt turn-off of Q_1 at time $t=0$ secs. The waveform was measured with a 24V input voltage, and 5A resistive load.

Figure 2



IMPORTANT NOTICE

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgment, including those pertaining to warranty, patent infringement, and limitation of liability.

TI warrants performance of its semiconductor products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

Customers are responsible for their applications using TI components.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such semiconductor products or services might be or are used. TI's publication of information regarding any third party's products or services does not constitute TI's approval, warranty or endorsement thereof.