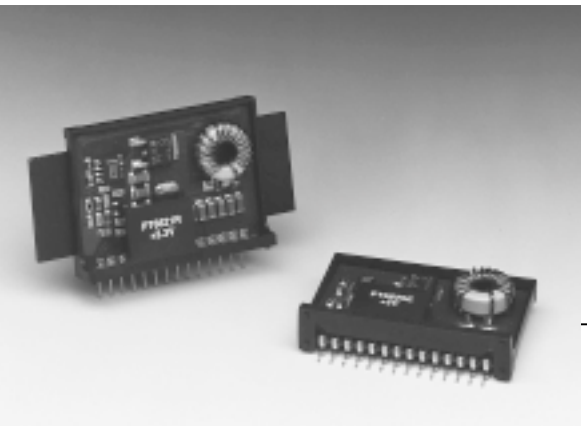
PT6650 Series

5 Amp 24V Input
Integrated Switching Regulator

Power Trends Products from Texas Instruments

SLTS038A

(Revised 6/30/2000)

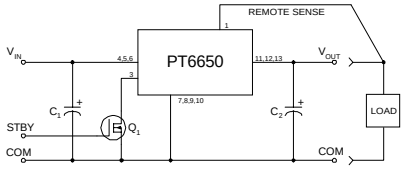


- Single Device: 5A Output
- Input Voltage Range: 9V to 28V
- Adjustable Output Voltage
- 80% Efficiency
- Remote Sense Capability
- Standby Function

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



C_1 = Required 560µF electrolytic (1, 2)
C_2 = Required 330µF electrolytic (1)
Q_1 = NFET-or Open Collector Gate

Pin-Out Information

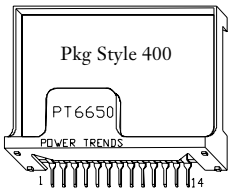
1	Remote Sense
2	Do Not Connect
3	STBY*- Standby
4	V_{in}
5	V_{in}
6	V_{in}
7	GND
8	GND
9	GND
10	GND
11	V_{out}
12	V_{out}
13	V_{out}
14	V_{out} Adjust

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

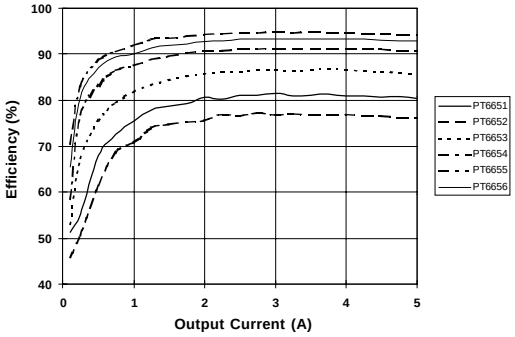
Specifications

Characteristics (T_a = 25°C unless noted)	Symbols	Conditions		PT6650 SERIES Min	Typ	Max	Units
Output Current	I_o	T_a = 60°C, 200 LFM, pkg P		0.1 (3)	—	5.0 (4)	A
		T_a = 25°C, natural convection		0.1 (3)	—	5.0 (4)	
Input Voltage Range	V_{in}	0.1A ≤ I_o ≤ 5.0A	V_o ≤ +6V	+9V	—	+28V	V
			V_o > +6V	V_o+3	—	+28V	
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	2.2	—	4.7	V
			V_o = +2.5V	1.8	—	4.3	
			V_o = +5.0V	3.0	—	6.5	
			V_o = +9.0V	6.0	—	10.2	
			V_o = +12V	9.0	—	13.6	
			V_o = +15V	10.0	—	17.0	
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	—	50	—	mVpp
			V_o > +6V		1.0		%V_o
Transient Response	t_{tr}	I_o step between 2.5A and 5.0A		—	100	—	µSec
with C_2 = 330µF	V_{os}	V_o over/undershoot		—	100	—	mV
Efficiency	η	V_{in} = +24V, I_o = 0.5x $I_{o\,max}$	V_o = +3.3V	—	81	—	%
			V_o = +2.5V	—	76	—	
			V_o = +5.0V	—	85	—	
		V_{in} = +24V, I_o = $I_{o\,max}$	V_o = +3.3V	—	80	—	%
			V_o = +2.5V	—	75	—	
			V_o = +5.0V	—	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

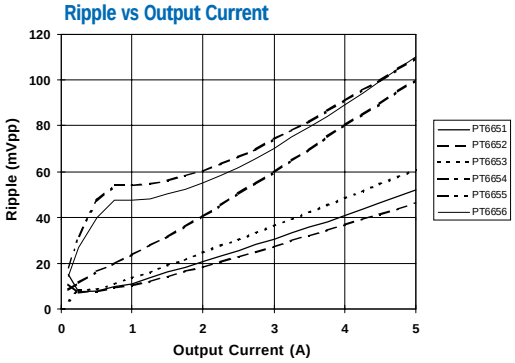
Notes: *(1) The PT6650 Series requires a 330µF electrolytic capacitor at the output, and a 560µF at the input for proper operation in all applications.*
(2) The input capacitor must be have a low ESR, and be rated for 1.4Arms of ripple current.
(3) ISR will operate down to no load with reduced specifications.
(4) See SOA curves, or contact the factory for the appropriate derating.

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

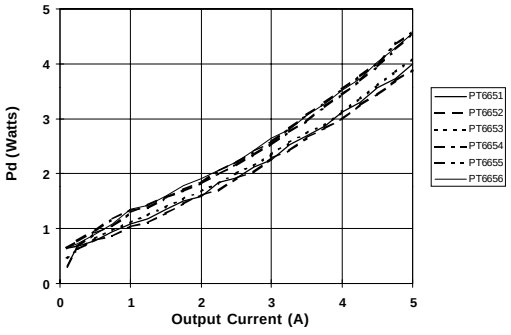
Efficiency vs Output Current



Ripple vs Output Current

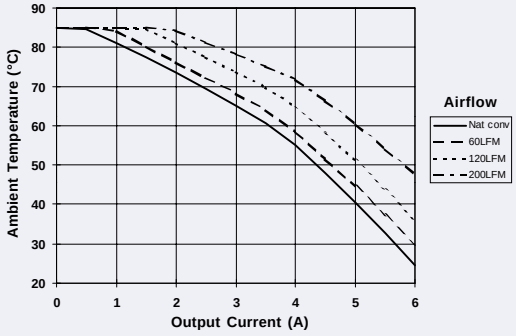


Power Dissipation vs Output Current

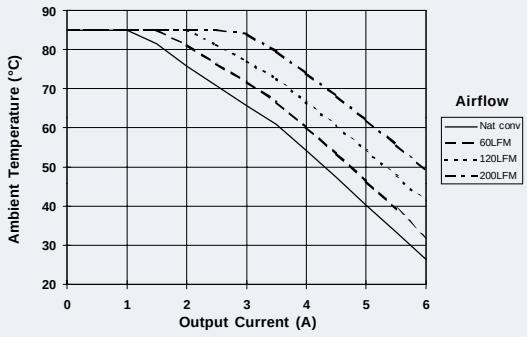


Safe Operating Area @Vin=+24V (See Note B)

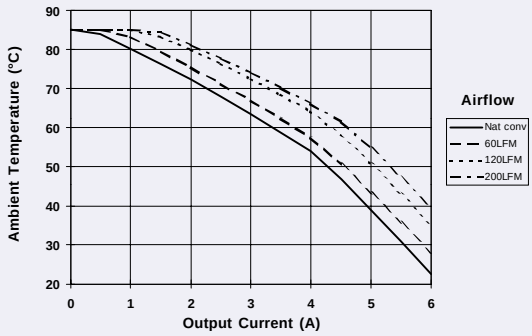
PT6651P, 3.3V



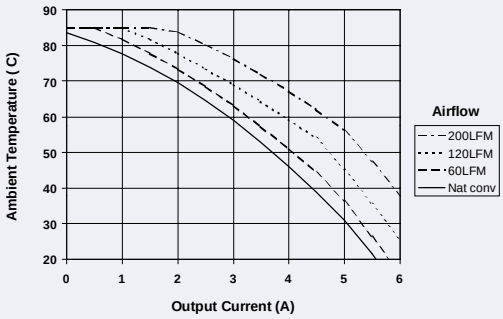
PT6652P, 2.5V



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.*

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:

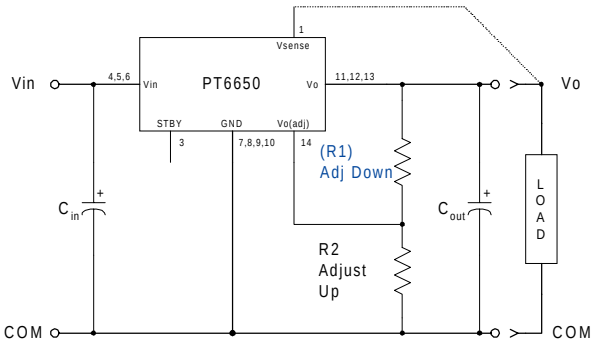
1. Use only a single 1% resistor in either the (R1) or R2 location. Place the resistor as close to the ISR as possible.
2. Never connect capacitors from V_o adjust to either GND, V_{out}, or the Remote Sense pin. Any capacitance added to the V_o adjust pin will affect the stability of the ISR.
3. If 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 or 9V, whichever is higher.

   V_{in} (max) = (10 x V_{out})V or 28V, whichever is less.

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

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 (kΩ)	4.99	4.22	2.49	2.0	2.0	2.0
R_s (kΩ)	2.49	4.99	4.99	12.7	12.7	12.7

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

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

R1 = (Blue) R2 = Black

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 ground [2] will disable the regulator output and reduce the input current to less than 30mA [4]. 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 TTL[3] compatible gate. Table 1 provides details of the threshold requirements.

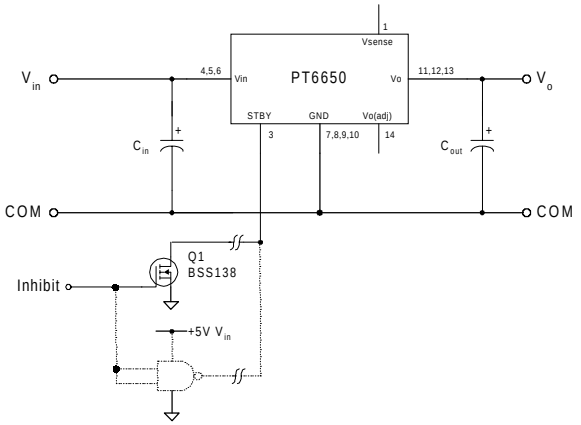
Table 1 Inhibit Control Thresholds [2,3]

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