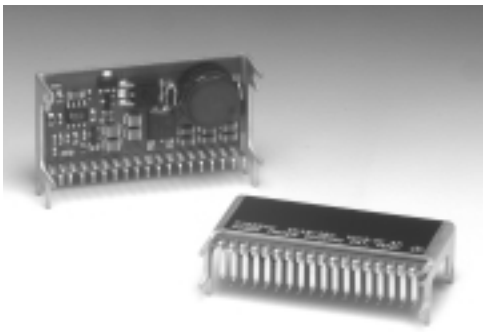
PT6880 Series

EXCALIBUR

5-A, 15-36-V Input
Integrated Switching Regulator

SLTS103B -JULY 2000 - REVISED JANUARY 2003



Features

- 5A Non-Isolated Output
- >90% Efficiency
- Low-cost Alternative to Isolated Converters
- 15 to 36V Input Voltage Range
- Adjustable Output Voltage
- Output Remote Sense
- Standby Function
- Solderable Copper Case
- Surface Mountable
- IPC Lead Free 2

Description

The PT6880 product family is a series of highly efficient, non-isolated integrated switching regulator (ISR) modules. Designed to operate off a wide-input bus, these regulators produce a tightly regulated output voltage at load currents of up to 5A. The series includes standard output voltage options ranging from 2.5V to 15V.

The series is an ideal choice for general purpose and industrial applications that operate off a 24/28V battery providing a low-cost alternative to a fully isolated converter.

The PT6880 series is packaged in a thermally efficient, 18-pin, space-saving copper case. Both vertical and horizontal configurations are available, including surface-mount.

Ordering Information

PT6881❒	=	3.3 Volts
PT6882❒	=	2.5 Volts
PT6883❒	=	5.0 Volts
PT6884❒	=	9.0 Volts
PT6885❒	=	15.0 Volts
PT6886❒	=	12.0 Volts

PT Series Suffix (PT1234x)

Case/Pin Configuration	Order Suffix	Package Code *
Vertical	**N**	(EPD)
Horizontal	**A**	(EPA)
SMD	**C**	(EPC)

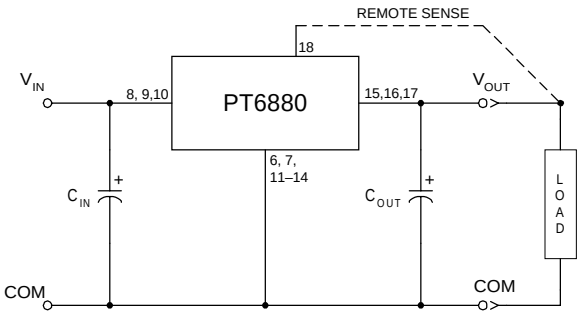
** Previously known as package styles 1500/10. (Reference the applicable package code drawing for the dimensions and PC board layout).*

Pin-Out Information

Pin	Function
1	Vo Adjust
2	No Connect
3	No Connect
4	STBY *
5	No Connect
6	GND
7	GND
8	Vin
9	Vin
10	Vin
11	GND
12	GND
13	GND
14	GND
15	Vout
16	Vout
17	Vout
18	Remote Sense

* *For further information, see application notes.*

Standard Application



C_{in} = Required 560µF electrolytic
C_{out} = Required 330µF electrolytic

Specifications (Unless otherwise stated, T_a =25°C, V_{in} =28V, C_{in} =560µF, C_{out} =330µF, and I_o =$I_o$max)

Characteristic	Symbol	Conditions		PT6880 SERIES Min	Typ	Max	Units
Output Current	I_o	T_a =60°C, 200LFM	V_o ≤ 12V V_o > 12V	0.1 (1) 0.1 (1)	— —	5 4	A
Input Voltage Range	V_{in}	Over I_o range	V_o=2.5V V_o=3.3V V_o=5.0V V_o≥6.5V	15 15 15 18	— — — —	25 (2) 33 (2) 36 36	Vdc
Set Point Voltage Tolerance	V_o tol			—	±0.5	±1	%V_o
Temperature Variation	Reg_{temp}	–40° ≤T_a≤ +85°C, I_o =$I_o$min		—	±0.5	—	%V_o
Line Regulation	Reg_{line}	Over V_{in} range		—	±0.5	±1	%V_o
Load Regulation	Reg_{load}	Over I_o range		—	±0.5	±1	%V_o
Total Output Voltage Variation	ΔV_otot	Includes set-point, line, load, –40° ≤T_a≤ +85°C		—	±1.5	±2	%V_o
Efficiency	η		V_o= 15V V_o= 12V V_o=9.0V V_o=5.0V V_o=3.3V V_o=2.5V	— — — — — —	90 88 87 82 73 78	— — — — — —	%
V_o Ripple (pk-pk)	V_r	20MHz bandwidth	V_o≤5V	—	50	—	mV_{pp}
			V_o>5V	—	1	—	%V_o
Transient Response	t_{tr}	5A/µs load step, 50% to 100% $I_o$max		—	100	—	µs
	ΔV_{tr}	V_o over/undershoot		—	±100	—	mV
Switching Frequency	f_s	Over V_{in} and I_o range		500	550	600	kHz
On/Off Standby (Pin 4) Input High Voltage Input Low Voltage Input Low Current	 V_{IH} V_{IL} I_{IL}	Referenced to GND (pin 6)		 2.0 –0.1 —	 — — –0.5	 Open (3) +0.4 –	V mA
Standby Input Current	I_{in} standby	pins 4 & 6 connected		—	16	35	mA
External Input Capacitance	C_{in}	See application schematic		560 (4)	—	—	µF
External Output Capacitance	C_{out}	See application schematic		330 (4)	—	1,000	µF
Operating Temperature Range	T_a	Over V_{in} range		–40	—	85 (5)	°C
Solder Reflow Temperature	T_{reflow}	Surface temperature of module pins or case		—	—	215 (6)	°C
Storage Temperature	T_s	—		–40	—	125	°C
Reliability	MTBF	Per Bellcore TR-332 50% stress, T_a =40°C, ground benign		7.7	—	—	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	Suffix N, A Suffix C	— —	20 (7) 15 (7)	— —	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 stated maximum input voltage assumes the nominal output voltage. If the output voltage is adjusted (trimmed) to some other value, consult the related application note on output voltage adjustment for the revised input voltage limitations.

(3) The STBY control (pin 4) 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 low (less than 5V). Consult the related application note for interface considerations.*

(4) For guidance on suitable input and output capacitors consult the accompanying application note, "Capacitor Recommendations for the PT6880 Series."

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

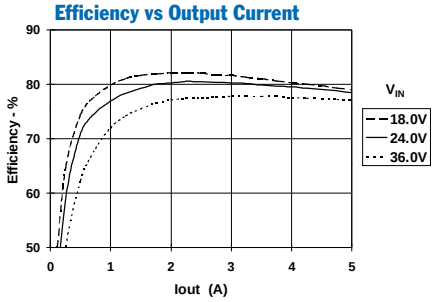
(6) During solder reflow of SMD package version do not elevate the module case, pins, or internal component temperatures above a peak of 215°C. For further guidance refer to the application note, "Reflow Soldering Requirements for Plug-in Power Surface Mount Products," (SLTA051).

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

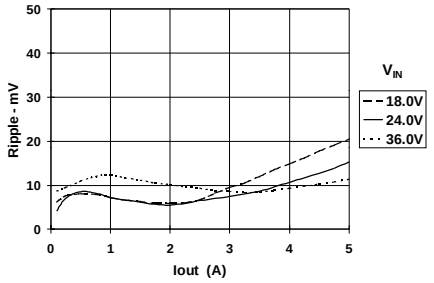
Typical Characteristics

PT6881, V_{out} =3.3V (Note A)

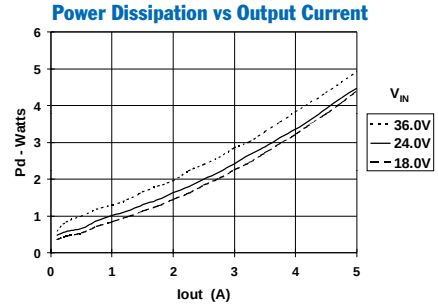
Efficiency vs Output Current



Ripple vs Output Current

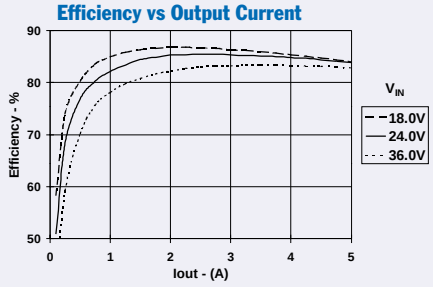


Power Dissipation vs Output Current

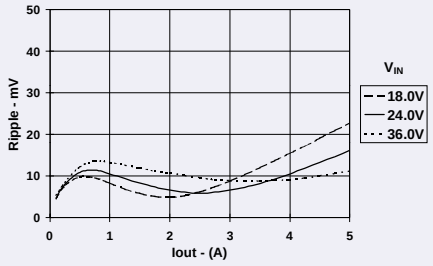


PT6883 V_{out} =5V (Note A)

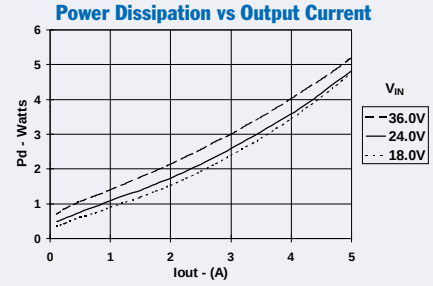
Efficiency vs Output Current



Ripple vs Output Current

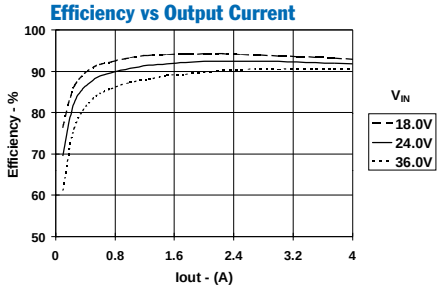


Power Dissipation vs Output Current

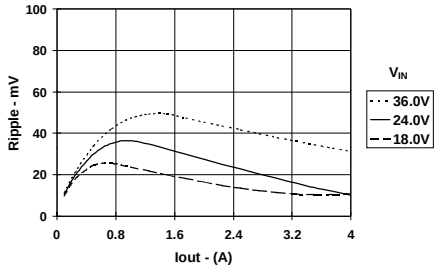


PT6886, V_{out} =12V (Note A)

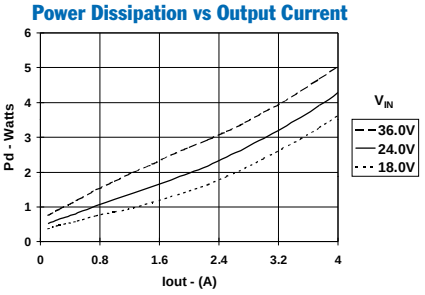
Efficiency vs Output Current



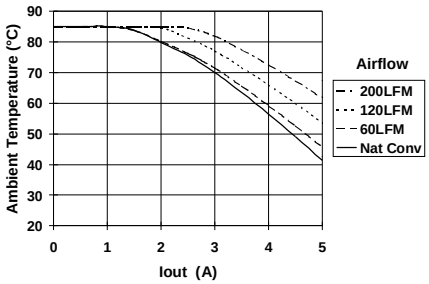
Ripple vs Output Current



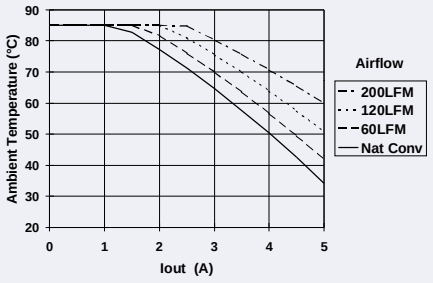
Power Dissipation vs Output Current



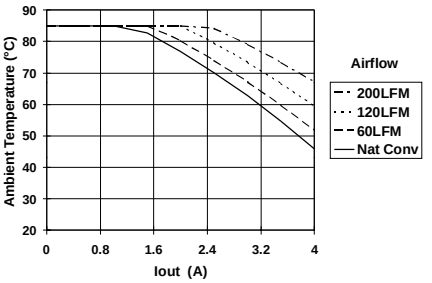
SOA Curves @V_{in}=+24V (Note B)



SOA Curves @V_{in}=+24V (Note B)



SOA Curves @V_{in}=+24V (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 PT6880 Regulator Series

Input Capacitor:

The required input capacitor is determined by a 1.2Arms minimum ripple current rating and 560µF capacitance value. The ripple current rating and <120mΩ equivalent series resistance (ESR) are the major considerations, along with temperature, when designing with different types of capacitors.

Tantalum/Os-Con® capacitors are not recommended due to a minimum voltage rating of 2× (the maximum DC voltage + AC ripple). This is necessary to improve the reliability of these capacitors in high bus applications.

Output Capacitors:

The ESR specification of the output capacitor should be at least 50mΩ. Electrolytic capacitors have marginal ripple performance at frequencies greater than 400kHz but excellent low frequency transient response. Above the ripple frequency ceramic capacitors are necessary to improve the transient response and reduce any high-frequency noise components apparent during higher current excursions. Electrolytic capacitors with appropriate ESR values are identified in Table 1-1. In low-temperature applications (<0°C), a higher capacitance with lower ESR will improve performance.

Os-Con® and ultra low ESR type capacitors are not recommended on the output bus as they degrade regulator stability.

Tantalum Capacitors (For V_{out} <5.1V)

Tantalum type capacitors can be used on the output bus for output voltages less than 5.1V. Voltages higher than this will exceed the capacitor's published surge voltage limits.

If tantalum capacitors are located on the output bus, an appropriate fuse with I^2t current derating is recommended along with an external clamp component. An Output Over-voltage Clamp (OOVC) will fault the output fuse protecting the capacitors in event of an over-voltage condition. The OOVC can be a simple zener high power diode, 3-5W, located on the load side of the output bus. The zener diode should be rated to 1.3 times the normal output voltage.

Capacitor Table

Table 1-1 identifies the characteristics of capacitors from a number of vendors with acceptable ESR and ripple current (rms) ratings. The number of capacitors required at both the input and output buses is identified for each capacitor type.

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 1-1: Input/Output Capacitors

Capacitor Vendor/ Series	Capacitor Characteristics					Quantity		
	Working Voltage	Value(µF)	(ESR) Equivalent Series Resistance	105°C Maximum Ripple Current(Irms)	Physical Size(mm)	Input Bus	Output Bus	Vendor Part Number
Panasonic FC (Radial)	50V 50V 50V	560 390 390	0.068Ω 0.080Ω 0.080Ω	1900mA 1610mA 1610mA	18×15 16x15 16×15	1 2 2	1 1 1	EEUFC1H561 EEUFC1H391S EEUFC1H391S
FC/FK (Surface Mtg)	63V 35V 50V	680 330 1000	0080Ω 0.080Ω 0.073Ω	1690mA 850mA 1610mA	18×16.5 10×10.2 16×16.5	1 N/R (1) 1	1 1 1	EEVFK1J681M EEVFK1V331P EEVFK1H102M
United Chemi-con LXZ/LXV Series	50V 35V	680 330	0.048Ω 0.068Ω	1840mA 1050mA	16×20 10×16	1 N/R (1)	1 1	LXZ50VB681M16X20LL LXV35VB331M10X16LL
MVY (Surface Mtg)	35V	220	0.150Ω	670mA	10×10.3	N/R (1)	2	MVY35VC2211M10X10TP
Nichicon PM Series	50V 63V 50V	560 560 330	0.044Ω 0.039Ω 0.060Ω	1550mA 1400mA 1210mA	16×20 18×20 16×15	1 1 2	1 1 1	UPM1H561MHH6 UPM1J561MHH6 UPM1H331MHH6
AVX Tantalum TPS (Surface Mtgt)	10V 10V	330 330	0.10Ω 0.06Ω	>2500mA >3000mA	7.3L ×5.7W ×4.1H	N/R (1) N/R (1)	1 1	TPSE337M010R0100 (V_o <5.1V) TPSV337M010R0060 (V_o <5.1V)
Kemet Tantalum (2) T496 /T495 Series (Surface Mount)	10V 10V	220 220	0.500Ω 0.070Ω	500mA >2000mA	4.3W ×7.3L ×4.0H	N/R (1) N/R (1)	2 2	T496X227M010AS (V_o <5.1V) T495X227M0100AS (V_o <5.1V)
Sprague Tantalum (2) 594D Series (Surface Mount)	10V	330	0.130Ω	1393mA	7.2L ×6W ×4.1H	N/R (1)	1	595D337X0010R2'T (V_o <5.1V)

Notes: (1) N/R –Not recommended. The voltage rating does not meet the minimum operating limits.
(2) A fused input bus is recommended when tantalum capacitors are used on the output bus.

Using the On/Off Standby Function on the PT6880 Excalibur™ Series of ISRs

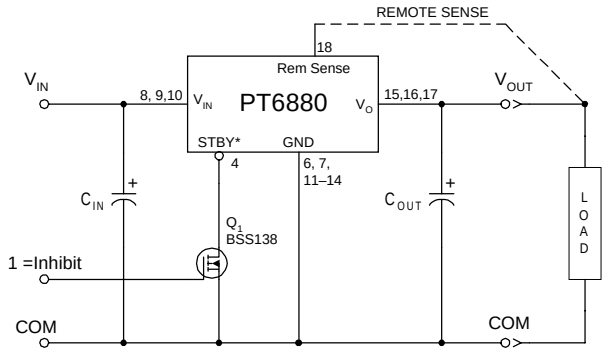
The PT6880 series of integrated switching regulators (ISRs) incorporate an on/off standby function, which may be used to disable the regulator output. This function is provided by the *STBY** control (pin 4). If pin 4 is left open-circuit the regulator operates normally, providing a regulated output whenever a valid supply voltage is applied to V_{in} (pins 8–10) with respect to *GND* (pins 6, 7, & 11–14). If the *STBY** control is driven low to ground [1], the regulator output is disabled and the input current drawn by the ISR drops to its idle value [2].

The *STBY** pin must be controlled with a low-leakage open-collector (or open-drain) discrete transistor [3]. See Figure 2-1 for the application schematic, and Table 2-1 for the input parameters.

Table 2-1 Standby Control Requirements

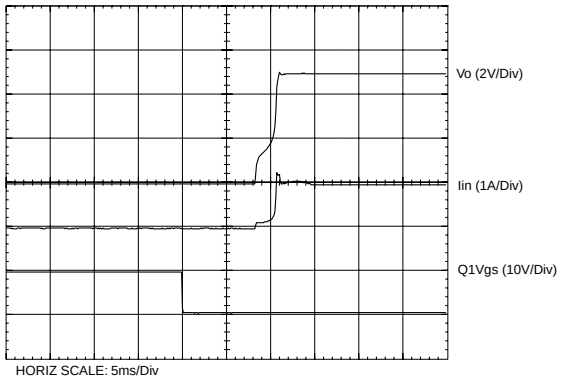
Parameter	Min	Typ	Max
Enable (V_{IH})	—		Open Circuit
Disable (V_{IL})	–0.2V		0.3V
I_{stby} (pin 4 =ground)		–50µA	
V_{stby} (open circuit)		1.4V	2V

Figure 2-1



Turn-On Time: In the circuit of Figure 2-1, turning Q_1 on applies a low voltage to pin 4 and disables the regulator output. Correspondingly, turning Q_1 off removes the low-voltage signal and enables the output. Once enabled the output will typically experience a 5–10ms delay followed by a quick ramp-up of voltage. The regulator should provide a fully regulated output within 20ms. The waveforms of Figure 1-2 show the rise of both the output voltage and input current for a PT6883 (5V). The turn off of Q_1 corresponds to the drop of Q_1Vgs. The waveform was measured with a 24Vdc input voltage and 4-ADC load.

Figure 2-2



Notes:

1. To ensure that the regulator output is disabled, the control pin must be pulled to less than 0.3Vdc with a low-level 0.1mA sink to ground.
2. When the regulator output is disabled the current drawn from the V_{in} input source is typically reduced to less than 20mA.
3. The standby control input is NOT compatible with TTL devices that incorporate a totem-pole output drive. Use only a true open-collector device, preferably a low-leakage discrete bipolar transistor (or MOSFET). Do Not use a pull-up resistor, or drive the *STBY** pin with an external voltage.

Adjusting the Output Voltage of the PT6880 5-A Excalibur™ Converter Series

The output voltage of the Power Trends PT6880 Excalibur series of ISRs may be adjusted higher or lower than the factory trimmed pre-set voltage with the addition of a single external resistor [1]. Table 3-1 gives the respective 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 R_2, between pin 1 (V_o Adjust) and pins 6, 7 /11-14 (GND).

Adjust Down: Add a resistor (R_1), between pin 1 (V_o Adjust) and pins 15-17 (V_{out}).

Refer to Figure 3-1 and Table 3-2 for both the placement and value of the required resistor, either (R_1) or R_2 as appropriate.

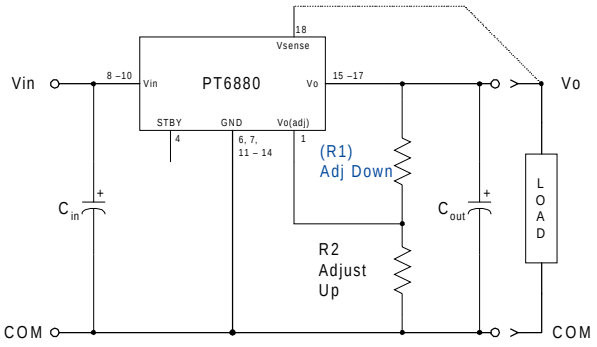
Notes:

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 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 (R_1) between pin 1 (V_o Adjust) and pin 18 (Remote Sense) can benefit load regulation.
4. For output voltages above 10Vdc, the maximum output current must be limited to 4Adc.
5. 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 15V, whichever is higher.

V_{in} (max) = (10 x V_{out})V or 36V, whichever is less.

Figure 3-1



The values of (R_1) [adjust down], and R_2 [adjust up], can also be calculated using the following formulas.

$$(R_1) = \frac{R_o (V_o - 1.25)(V_a - 1.25)}{1.25 (V_o - V_a)} - R_s \quad k\Omega$$

$$R_2 = \frac{R_o (V_o - 1.25)}{V_a - V_o} - R_s \quad k\Omega$$

Where: V_o = Original output voltage
V_a = Adjusted output voltage
R_o = The resistance value in Table 3-1
R_s = The series resistance from Table 3-1

Table 3-1

PT6880 ADJUSTMENT AND FORMULA PARAMETERS

Series Pt #	PT6882	PT6881	PT6883	PT6884	PT6886	PT6885
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 3-2

PT6880 ADJUSTMENT RESISTOR VALUES

Series Pt #	PT6882	PT6881	PT6883	Series Pt #	PT6884	PT6886	PT6885
Current	5Adc	5Adc	5Adc	Current	5Adc	4Adc	4Adc
V_o (nom)	2.5Vdc	3.3Vdc	5Vdc	V_o (nom)	9Vdc	12Vdc	15Vdc
V_a (req'd)				V_a (req'd)			
1.8	(1.4)kΩ			6.0	(6.9)kΩ		
1.9	(2.9)kΩ			6.2	(9.2)kΩ		
2.0	(5.0)kΩ			6.4	(11.9)kΩ		
2.1	(8.1)kΩ			6.6	(14.0)kΩ		
2.2	(13.3)kΩ	(1.0)kΩ		6.8	(18.6)kΩ		
2.3	(23.7)kΩ	(2.3)kΩ		7.0	(23.0)kΩ		
2.4	(54.9)kΩ	(3.9)kΩ		7.2	(28.3)kΩ		
2.5		(5.8)kΩ		7.4	(35.0)kΩ		
2.6	59.9kΩ	(8.4)kΩ		7.6	(43.5)kΩ		
2.7	28.7kΩ	(11.7)kΩ		7.8	(55.0)kΩ		
2.8	18.3kΩ	(16.5)kΩ		8.0	(71.0)kΩ		
2.9	13.1kΩ	(23.6)kΩ		8.2	(95.0)kΩ		
3.0	10.0kΩ	(35.4)kΩ	(1.6)kΩ	8.4	(135.0)kΩ		
3.1	7.9kΩ	(59.0)kΩ	(2.3)kΩ	8.6	(215.0)kΩ		
3.2	6.4kΩ	(130.0)kΩ	(3.1)kΩ	8.8	(455.0)kΩ		
3.3	5.3kΩ		(4.0)kΩ	9.0		(31.7)kΩ	
3.4	4.4kΩ	81.5kΩ	(5.1)kΩ	9.2	64.8kΩ	(36.1)kΩ	
3.5	3.8kΩ	38.3kΩ	(6.2)kΩ	9.4	26.1kΩ	(41.2)kΩ	
3.6	3.2kΩ	23.8kΩ	(7.6)kΩ	9.6	13.1kΩ	(47.1)kΩ	
3.7	2.7kΩ	16.6kΩ	(9.1)kΩ	9.8	6.7kΩ	(54.1)kΩ	
3.8	2.3kΩ	12.3kΩ	(10.9)kΩ	10.0	2.8kΩ	(62.6)kΩ	(25.8)kΩ
3.9	2.0kΩ	9.4kΩ	(13.0)kΩ	10.2	0.2kΩ	(72.8)kΩ	(28.3)kΩ
4.0	1.7kΩ	7.4kΩ	(15.6)kΩ	10.4		(85.7)kΩ	(31.1)kΩ
4.1	1.4kΩ	5.8kΩ	(18.7)kΩ	10.6		(102.0)kΩ	(34.1)kΩ
4.2	1.2kΩ	4.6kΩ	(22.6)kΩ	10.8		(124.0)kΩ	(37.3)kΩ
4.3	1.0kΩ	3.7kΩ	(27.6)kΩ	11.0		(155.0)kΩ	(40.9)kΩ
4.4		2.9kΩ	(34.2)kΩ	11.2		(201.0)kΩ	(44.9)kΩ
4.5		2.2kΩ	(43.6)kΩ	11.4		(278.0)kΩ	(49.3)kΩ
4.6		1.7kΩ	(57.6)kΩ	11.6		(432.0)kΩ	(54.3)kΩ
4.7		1.2kΩ	(80.9)kΩ	11.8		(895.0)kΩ	(59.8)kΩ
4.8			(128.0)kΩ	12.0			(66.1)kΩ
4.9			(268.0)kΩ	12.2		94.8kΩ	(73.3)kΩ
5.0				12.4		41.1kΩ	(81.6)kΩ
5.1			88.4kΩ	12.6		23.1kΩ	(91.3)kΩ
5.2			41.7kΩ	12.8		14.2kΩ	(103.0)kΩ
5.3			26.1kΩ	13.0		8.8kΩ	(117.0)kΩ
5.4			18.4kΩ	13.2		5.2kΩ	(133.0)kΩ
5.5			13.7kΩ	13.4		2.7kΩ	(154.0)kΩ
5.6			10.6kΩ	13.6		0.7kΩ	(181.0)kΩ
5.7			8.4kΩ	13.8			(217.0)kΩ
5.8			6.7kΩ	14.0			(268.0)kΩ
5.9			5.4kΩ	14.2			(343.0)kΩ
6.0			4.4kΩ	14.5			(570.0)kΩ
6.1			3.5kΩ	15.0			
6.2			2.8kΩ	15.5			42.3kΩ
6.3			2.2kΩ	16.0			14.8kΩ
6.4			1.7kΩ	16.5			5.6kΩ
6.5			1.2kΩ	17.0			1.1kΩ

R_1 = (Blue) R_2 = Black

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

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

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third–party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265

Copyright © 2003, Texas Instruments Incorporated