40-A Programmable Integrated Switching Regulator Module

EXCALIBUR

SLTS152
(Revised 10/24/2001)

Features

- Single Device: 40ADC
- +5V Input
- 5-bit Programmable: 1.3V to 3.5V
- 90% Efficiency
- Differential Remote Sense
- Short-Circuit Protection
- Space-Saving Package
- Solderable Copper Case
- “Current Booster” Compatible
- Shutdown Control

Description

The PT7761 is a high performance integrated switching regulator (ISR), housed in a solderable, 31-pin space-saving copper package. Operating from and input voltage of +5V, the PT7761 provides up to 40A of low-voltage power for the industry’s latest DSPs, and µ-Processors.

The PT7761 performance extends both the flexibility and output current range of the “Big Hammer” series of Plug-in Power modules, and provides a state-of-the-art solution for highly integrated digital systems that demand high power supply currents at low output voltages.

The PT7761 is programmable from 1.3V to 3.5V via a 5-bit input, which is compatible with Intel’s Pentium® series microprocessors.

The PT7761’s features include a momentary-interrupt style of short-circuit protection, a standby control, and a differential remote sense to compensate for voltage drop between the ISR and load. For additional output current the PT7761 can operate with up to three current boosters.

Ordering Information

PT 7761❑ = 1.3 to 3.5V Regulator
* PT 7769❑ = 40-A Current Booster

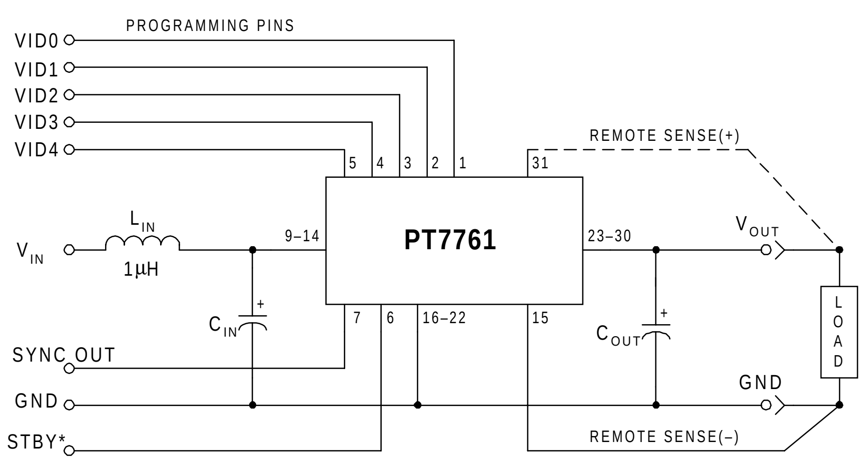
* *Consult application notes for information on Current Booster operation*

PT Series Suffix (PT1234x)

Case/Pin Configuration	Order Suffix	Package Code
Vertical	**N**	(EKH)
Horizontal	**A**	(EKF)
SMD	**C**	(EKG)

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

Standard Application



C_{in} = Required 1500µF electrolytic
C_{out} = Required 330µF electrolytic
L_{in} = Optional 1µH input choke

TEXAS INSTRUMENTS

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 = Pin 15 potential (Remote Sense GND)
Logic 1 = Open circuit (no pull-up resistors)
VID3 and VID4 may not be changed while the unit is operating.

Pin-Out Information

Pin	Function	Pin	Function	Pin	Function
1	VID0	11	V_{in}	21	GND
2	VID1	12	V_{in}	22	GND
3	VID2	13	V_{in}	23	V_{out}
4	VID3	14	V_{in}	24	V_{out}
5	VID4	15	Rem Sense GND [2]	25	V_{out}
6	STBY*	16	GND	26	V_{out}
7	Sync	17	GND	27	V_{out}
8	No Connect	18	GND	28	V_{out}
9	V_{in}	19	GND	29	V_{out}
10	V_{in}	20	GND	30	V_{out}
				31	Rem Sense V_{out}

** For STBY* pin:*
Open =Output Enabled
Ground =Output Disabled

Specifications

(Unless otherwise stated, T_a =25°C, C_{in} =1,500µF, C_{out} =330µF, V_{in} =5V, V_o =3.3V, & I_o =$I_o$max)

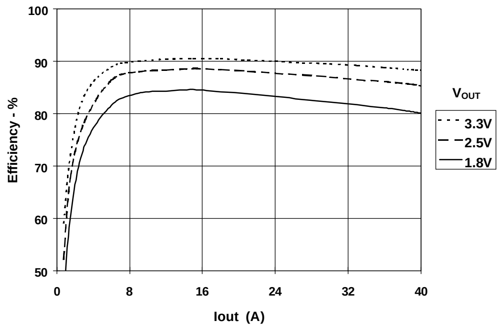
Characteristics	Symbols	Conditions	PT7761 Min	Typ	Max	Units
Output Current	I_o	T_a =25°C, Natural convection T_a =60°C, 200LFM, Pkg N	0.1 (1) 0.1 (1)	— —	40 38	A
Input Voltage Range	V_{in}	Over I_o range	4.5	—	5.5	V
Set-Point Voltage Tolerance	$V_o$tol	All output voltages	—	—	±25 (2)	mV
Temperature Variation	ΔReg_{temp}	–40°C≤ T_a ≤85°C, I_o =$I_o$min	—	±0.75	—	%V_o
Line Regulation	ΔReg_{line}	Over V_{in} range	—	±5	—	mV
Load Regulation	ΔReg_{load}	Over load range	—	±5	—	mV
Total Output Variation	ΔV_otol	Includes set-point, line, load, –40°C ≤T_a ≤ +85°C	—	±1	±3	%V_o
Efficiency	η	I_o =20A V_o = 3.3V V_o = 2.5V V_o = 1.8V	— — —	90 89 83	— — —	%
		I_o =40A V_o = 3.3V V_o = 2.5V V_o = 1.8V	— — —	86 85 80	— — —	%
V_o Ripple (pk-pk)	V_r	20MHz bandwidth	—	50	—	mV
Transient Response	t_{tr} ΔV_{tr}	1A/µs load step from 50% to 100% $I_o$max V_o over/undershoot	— —	50 100	— —	µSec mV
Short Circuit Threshold	$I_{sc(pk)}$	Reset and auto-recovery	—	75	—	A
Switching Frequency	f_s	Over V_{in} and I_o ranges	300	350	400	kHz
Standby Control (pin 6) Input High Voltage Input Low Voltage	V_{IH} V_{IL}	Referenced to GND (pins 16–22)	2 -0.2	— —	Open (3) 0.8	V
Input Low Current	I_{IL}	Pin 6 to GND	—	0.4	—	mA
Quiescent Current	I_{in} stby	Pin 6 to GND	—	30	—	mA
External Output Capacitance	C_{out}	Between +V_o and GND	330	—	30,000	µF
Operating Temperature Range	T_a	Over V_{in} Range	–40 (4)	—	+85 (5)	°C
Storage Temperature	T_s	—	-40	—	+125	°C
Mechanical Shock		Mil-STD-883D, Method 2002.3 1 msec, Half Sine, mounted to a fixture	—	TBD	—	G's
Mechanical Vibration Mil-STD-883D, 20-2000 Hz		Vertical Horizontal	— —	TBD (6) TBD (6)	— —	G's
Weight	—	Vertical/Horizontal	—	55	—	grams
Flammability	—	Materials meet UL 94V-0				

Notes: (1) *ISR-will operate down to no load with reduced specifications.*
(2) *If the Remote Sense Ground (Pin 15) is not used, it must be connected to pin 16 for optimum output voltage accuracy.*
(3) *The Standby control (pin 6) has an internal pull-up, and if left open-circuit the module will operate when input power is applied.*
(4) *For operation below 0°C, C_{in} and C_{out} must have stable characteristics. Use either low ESR tantalum or Oscon® capacitors.*
(5) *See safe Operating Area curves or consult factory for the appropriate derating.*
(6) *The case pins on the through-hole package types (suffixes N & A) must be soldered. For more information see the applicable package outline drawing.*

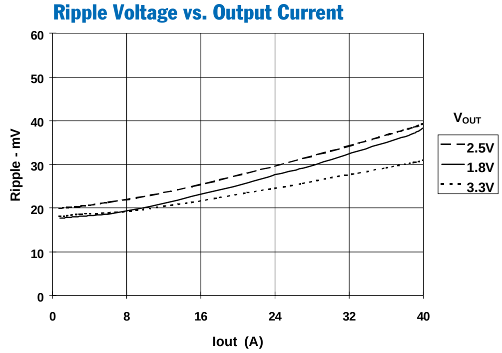
External Capacitors: *The PT7761 series requires a minimum ouput capacitance of 330µF for proper operation. The PT7761 also requires a minimum input capacitance of 1,500µF, which must be rated for a minimum of 1.4Arms of ripple current. For transient or dynamic load applications, additional capacitance may be required. For further information refer to the application note regarding capacitor selection for this product.*
Input Inductor: *An input inductor is optional for most applications. The input inductor must be sized to handle 30ADC with a typical value of 1µH.*

Characteristic Data, V_{IN} =5VDC (See Note A)

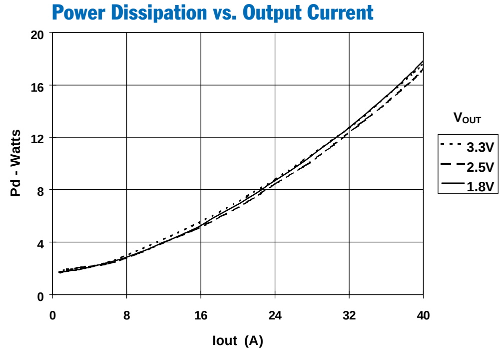
Efficiency vs. Output Current



Ripple Voltage vs. Output Current

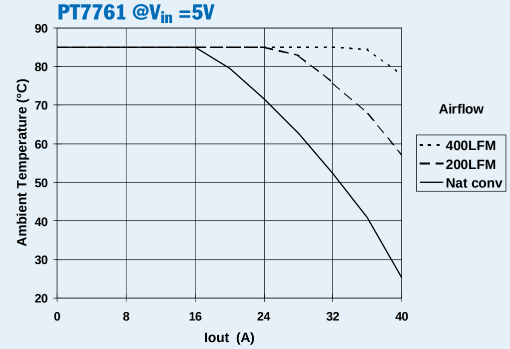


Power Dissipation vs. Output Current



Safe Operating Area Curves (See Note B)

PT7761 @V_{in} =5V



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

Increasing the PT7761 Output Current with the PT7769 Compatible Current Booster

The PT7769 is a 40-A "Current Booster" module for the PT7761 regulator. The booster is controlled directly by the regulator, and effectively adds a parallel output stage. This allows the system to run sychronously, providing a low noise solution. Up to three booster modules can be connected to a single regulator. Each booster increases the available output current by 40A. Combinations of a regulator and booster modules can supply power for virtually any multi-processor application.

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 PT7761/booster combination is identical to that of a stand-alone regulator. Refer to the appropriate data sheet for the performance specifications.

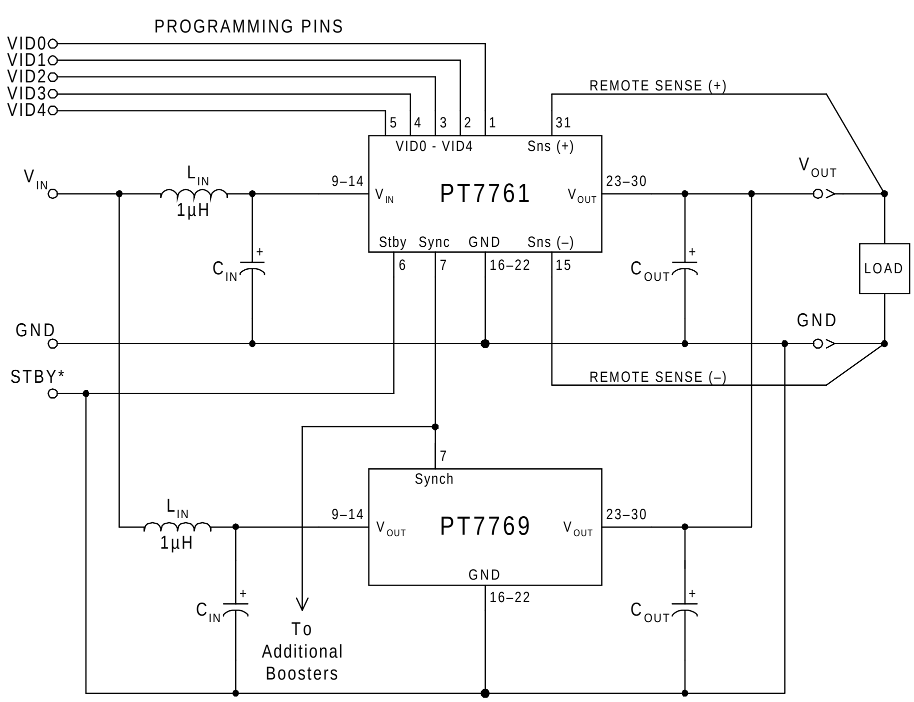
Notes:

1. Each booster requires the same amount of input and output capacitance as recommended for a stand-alone regulator. See the Standard Application schematic and the respective input/output filter notes in the PT7761 product data sheet. Recommendations on specific capacitor types are also detailed in the application note, "Capacitor Recommendations for the PT7761 Integrated Switching Regulator."
2. The 1-µH filter choke located at the input of each regulator and booster module (L_{in}) is optional for most applications. If specified, each inductor must be sized to handle 30ADC at full output load.
3. The pin-out of the current booster modules include a number pins identified, "No Connect" (see Table 1). These pins are not connected internally to the module but must be soldered to a pad to preserve the unit's mechanical integrity.
4. A similar PCB footprint and trace layout between the regulator and each booster will facilitate current sharing between all modules.

Table 1; PT7769 Pin-Out Information

Pin	Function	Pin	Function	Pin	Function
1	No Connect	11	V_{in}	21	GND
2	No Connect	12	V_{in}	22	GND
3	No Connect	13	V_{in}	23	V_{out}
4	No Connect	14	V_{in}	24	V_{out}
5	No Connect	15	No Connect	25	V_{out}
6	No Connect	16	GND	26	V_{out}
7	Sync	17	GND	27	V_{out}
8	No Connect	18	GND	28	V_{out}
9	V_{in}	19	GND	29	V_{out}
10	V_{in}	20	GND	30	V_{out}
				31	No Connect

Current Booster Application Schematic



Capacitor Recommendations for the PT7761 Integrated Switching Regulator

Input Capacitors

The recommended input capacitance is determined by 1.4 ampere minimum ripple current rating and 1500µF minimum capacitance. Capacitors listed below must be rated for a minimum of 2x the input voltage with +5V operation. Ripple current and ≤100mΩ Equivalent Series Resistance (ESR) values are the major considerations along with temperature when selecting the proper capacitor.

Output Capacitors

The minimum required output capacitance is 330µF with a maximum ESR 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 400kHz, but excellent low frequency transient response. Above the ripple frequency ceramic decoupling capacitors are necessary to improve the transient response and reduce any microprocessor high frequency noise components apparent during higher current excursions. Preferred low ESR type capacitor part numbers are identified in the Table 1 below.

Tantalum Characteristics

Tantalum capacitors with a minimum 10V rating are recommended on the output bus, but only the AVX TPS series, Sprague 594/595 series, or Kemet T495/T510 series. These AVX, Sprague, and Kemet capacitors are specified over other types due to their higher surge current, excellent power dissipation, and ripple current ratings. As a caution, the TAJ series by AVX is not recommended. This series exhibits considerably higher ESR, reduced power dissipation and lower ripple current capability. The TAJ series is also less reliable than the TPS series when determining power dissipation capability.

Capacitor Table

Table 1 identifies the characteristics of capacitors from a number of vendors with acceptable ESR and 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. The table below is a selection guide for input and output capacitors. Other capacitor vendors are available with comparable RMS ripple current rating and ESR (Equivalent Series Resistance at 100kHz). These critical parameters are necessary to insure both optimum regulator performance and long capacitor life.

Table 1 Capacitors Characteristic Data

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 Number
Panasonic FC Surface Mtg FA	16V 35V 10V 16V	2200 330 680 1800	0.038Ω 0.065Ω 0.090Ω 0.032Ω	2000mA 1205mA 755mA 2000mA	18x16.5 12.5x16.5 10x12.5 18x15	1 1	1 1 1 1	EEVFC1C222N EEVFC1V331LQ EEUFA1A681 EEUFA1C182A
United Chemi -Con LFVSeries	25V 16V 16V	330 2200 470	0.084Ω 0.038Ω 0.084Ω÷2 =0.042Ω	825mA 1630mA 825mA x2	10x16 16x20 10x16	 1 	1 1 1	LXV25VB331M10X16LL LXV16VB222M16X20LL LXV16VB471M10X16LL
Nichicon PL Series PM Series	10V 10V 25V	680 1800 330	0.090Ω 0.044Ω 0.095Ω	770mA 1420mA 750mA	10x15 16x15 10x15	 1 	1 1 1	UPL1A681MHH6 UPL1A182MHH6 UPL1E331MPH6
Oscon SS SV	10V 10V	330 330	0.025Ω÷4 =0.006Ω 0.02Ω÷4 =0.005Ω	>9800mA >9800mA	10x10.5 10.3x12.6	4 4	N/R (Note)	10SS330M 10SV330M (Surface Mount)
AVX Tanatalum TPS- Series	10V 10V	330 330	0.1Ω÷5 =0.02Ω 0.06Ω	3500mA 1826mA	7.3Lx 4.3Wx 4.1H	5 5	1 1	TPSV337M010R0100 TPSV337M010R0060
Sprague Tantalum 595D/594D	10V 10V	330 680	0.045Ω÷4 =0.011Ω 0.09Ω	>4500mA >1660mA	7.3L x 5.7W x 4.0H	5 2	1 1	594D337X0010R2T 595D687X0010R2T (Surface Mount)
Kemet Tantalum T510/T495 Series	10V 10V	330 220	0.035Ω 0.07Ω÷2 =0.035Ω	2000mA >2000mA	4.3Wx7.3L x4.0H	5 6	1 2	510X337M010AS T495X227M010AS (Surface Mount)
Sanyo Poscap TPB	10V	220	0.04Ω	3000mA	7.2L x 4.3W x 3.1H	6	2	10TPB220M (Surface Mount)

Note: *(N/R) is not recommended for this application, due to extremely low Equivalent Series Resistance (ESR)*

Using the Standby Function on the PT7761 Excalibur™ Integrated Switching Regulator

For applications requiring output voltage On/Off control, the PT7761 integrated switching regulator (ISR) module incorporates a standby function. This feature may be used for power-up/shutdown sequencing, and to change the output voltage while input power is applied. *See related application notes:* “Pin-Coded Output Voltage Adjustment of PT7761 Excalibur ISRs.”

The standby function is provided by the *STBY** control, pin 6. If pin 6 is left open-circuit the regulator operates normally, providing a regulated output whenever a valid supply voltage is applied to V_{in} (pins 9–14) with respect to GND (pins 16–22). Connecting pin 6 to ground [1] will set the regulator output to zero volts [2]. This places the regulator in standby mode, and reduces the input current to typcially 30mA (60mA max). If a ground signal is applied to pin 6 prior to power-up, the regulator output will be held at zero volts during the period that input power is applied.

The standby input must be controlled with an open-collector (or open-drain) discrete transistor (See Figure 1). Table 1 gives the threshold requirements.

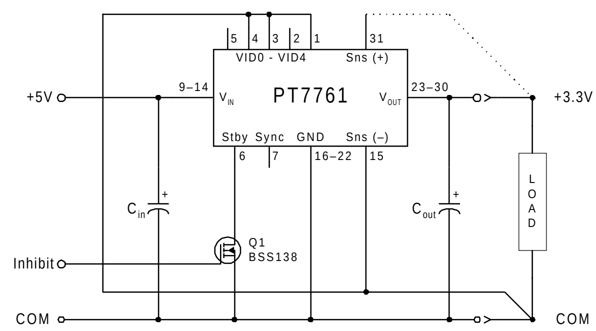
Table 1 Standby Control Input Requirements [1]

Parameter	Min	Typ	Max
Enable	2V		Open Cct. [1]
Disable	–0.2V		0.8V
I_{stby}			0.4mA
Vstby (o/c)		V_{in}	

Notes:

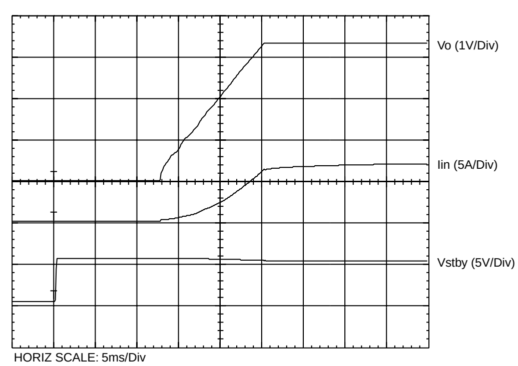
1. The Standby input on the PT7761 regulator must be controlled using an open-collector (or open-drain) discrete transistor. *Do Not* use a pull-up resistor. The control input has an open-circuit voltage equal to V_{in}. To set the regulator output to zero, the control pin must be “pulled” to less than 0.8Vdc with a 0.5mA sink to ground.
2. When placed in the standby mode, the regulator output discharges the output capacitance with a low impedance to ground.
3. The turn-off time of Q_1, or rise time of the standby input is not critical for the PT7761. Turning Q_1 off slowly, over periods up to 100ms, will not affect regulator operation. However, a slow turn-off time will increase both the initial delay and rise-time of the output voltage.

Figure 1



Turn-On Time: Turning Q_1 in Figure 1 off, removes the low-voltage signal at pin 6 and enables the output. Following a brief delay of approximately 10ms [3], the output voltage of the PT7761 series regulators rise to full regulation within 15ms [3]. Figure 2 shows the typical output voltage waveform of the PT7761 following the prompt turn-off of Q_1 at time t =0 secs. The output voltage in Figure 1 is set to 3.3V by connecting VID0 (pin 1), VID2 (pin 3), and VID3 (pin 4) to the Rem Sense GND (pin 15)*. The waveform in Figure 2 was measured with a +5V input source voltage, and 10A resistive load.

Figure 2



* Consult the data sheet for details on other VID codes.

Pin-Coded Output Voltage Adjustment of PT7761 “Excalibur™” ISRs

The PT7761 Excalibur power module incorporates a pin-coded output voltage control. These regulators include five control pins, identified VID0–VID4 (pins 1–5) respectively. By selectively grounding VID0-VID4, the output voltage of this regulator can be programmed in incremental steps over the output voltage range, 1.3V to 3.5V. The program code and voltage range is designed to be compatible with the “Voltage ID” specification defined for popular microprocessors. Refer to Figure 1 for the connection schematic, and the applicable data sheet for the program code.

Notes:

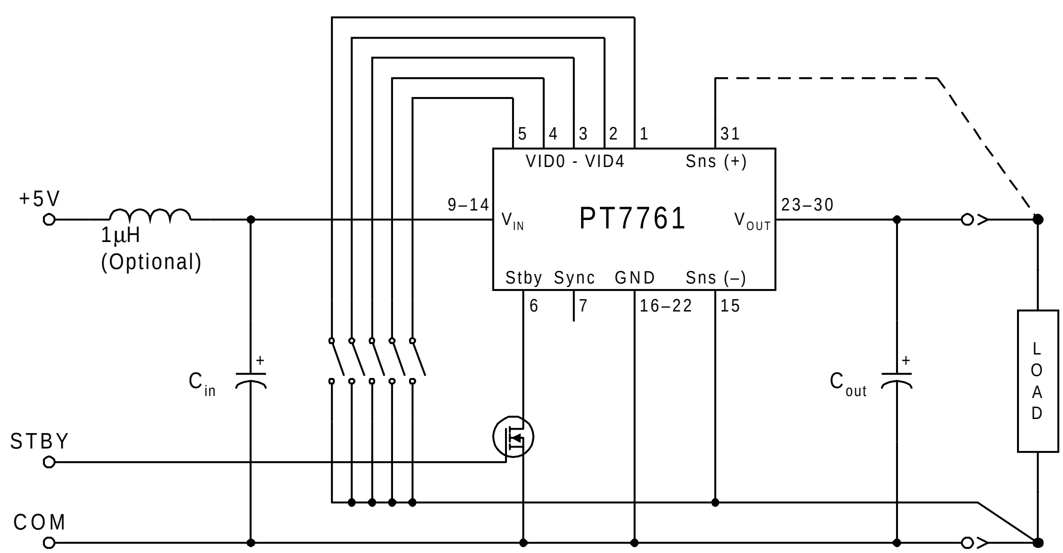
1. The programming convention is as follows:-

   Logic 0: Connect to pin15 (Remote Sense Ground).

   Logic 1: Open circuit/open drain (See notes 2, & 4)
2. Do not connect pull-up resistors to the voltage programming pins.
3. Use pin 15 (Rem Sense Gnd) as the logic “0” reference. While the regular ground (pins 16–22) can also be used for programming, doing so will degrade the load regulation of the product. If the remote sense ground is not used, pin 15 must be connected to pin 16 for optimum output voltage accuracy.
4. If active devices are used to ground the voltage control pins, low-level open drain MOSFET devices should be used over bipolar transistors. The inherent V_{ce}(sat) in bipolar devices introduces errors in the device’s internal voltage control circuit. Discrete transistors such as the BSS138, 2N7002, IRLML2402, are examples of appropriate devices.

Active Voltage Programming:
Special precautions should be taken when making changes to the voltage control progam code while the unit is powered. It is highly recommended that the ISR be either powered down or held in standby. Changes made to the program code while V_{out} is enabled induces high current transients through the device. This is the result of the electrolytic output capacitors being either charged or discharged to the new output voltage set-point. The transient current can be minimized by making only incremental changes to the binary code, i.e. one LSB at a time. A minimum of 100µs settling time between each program state is also recommended. Making non-incremental changes to VID3 and VID4 with the output enabled is discouraged. If they are changed, the transients induced can overstress the device. If the program code cannot be asserted prior to power-up, pull pin 6 (STBY) to GND during the period that the input voltage is applied. The release of pin 6 will then to allow the device to initiate a soft-start power-up to the program voltage.

Figure 1



IMPORTANT NOTICE

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