LM2793 Low Noise White LED Constant Current Supply with Dual Function Brightness Control

Check for Samples: LM2793

FEATURES

- **Two Regulated Current Outputs, up to 16mA Each, Matched to Within ±0.3% (typ.)**
- **High Efficiency, 1.5× Regulated Charge Pump**
- **Input Voltage Range: 2.7V to 5.5V**
- **Soft Start Limits Inrush Current**
- **Analog Voltage Brightness Control**
- **PWM Brightness Control**
- **Very Small Solution Size - NO INDUCTOR**
- **500kHz Switching Frequency**
- **3µA (typ.) Shutdown Current**
- **10-Pin WSON Package: 3.0mm X 3.0mm X 0.8mm**

APPLICATIONS

- **White LED Display Backlights**
- **White LED Keypad Backlights**
- **1-Cell LiIon Battery-Operated Equipment Including PDAs, Hand-held PCs, Cellular Phones**
- **Flat Panel Displays**

DESCRIPTION

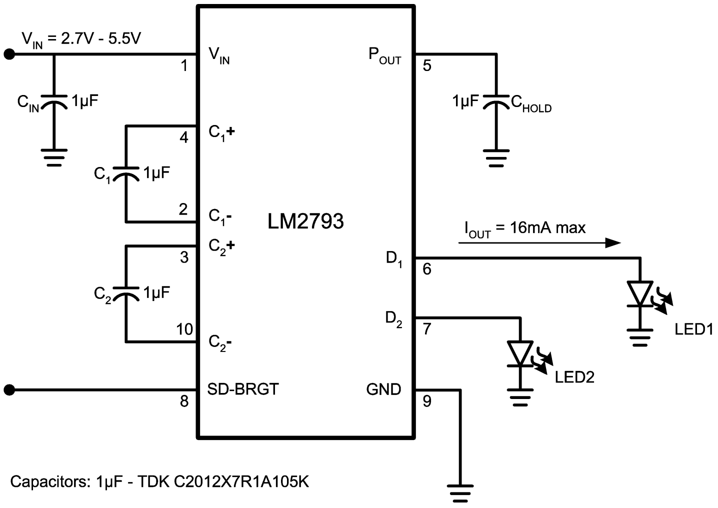
The LM2793 is a highly efficient, semi-regulated 1.5x CMOS charge pump that provides dual constant current outputs. The LM2793 has an input voltage range of 2.7V to 5.5V.

To control LED brightness, the amount of current driven to the current-mode outputs can be adjusted with an analog voltage and/or a pulse-width-modulated (PWM) square wave.

Pre-regulation of the charge pump minimizes conducted noise on the input. Combined with a fixed switching frequency of 500kHz, the LM2793 is a low-noise solution.

The LM2793 is available in a 10-pin WSON.

TYPICAL APPLICATION CIRCUIT



Capacitors: 1µF - TDK C2012X7R1A105K

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

CONNECTION DIAGRAM

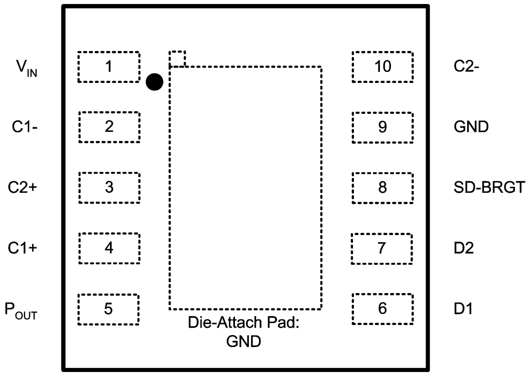


Figure 1. 10-Pin WSON
3mmx3mmx0.8mm (Top View)
See NGY0010A Package

PIN DESCRIPTION

Pin	Name	Description
1	V_{IN}	Power supply voltage connection
2	C1–	Flying capacitor C1 connection
3	C2+	Flying capacitor C2 connection
4	C1+	Flying capacitor C1 connection
5	P_{OUT}	Charge pump output
6	D1	Current source output / LED connection
7	D2	Current source output / LED connection
8	SD-BRGT	Dual function Shutdown - Brightness. Grounding pin shuts down part. Voltage between 0.75V and 2.75V (typ.) linearly adjusts current outputs. Output current equals 16mA at voltages above 2.75V.
9	GND	Power supply ground connection
10	C2–	Flying capacitor C2 connection

ABSOLUTE MAXIMUM RATINGS (1) (2)

If Military/Aerospace specified devices are required, contact the Texas Instruments Sales Office/Distributors for availability and specifications.

	VALUE / UNITS
V_{IN}	-0.3V to 6.0V
$V_{SD\text{-}BRGT}$	-0.3V to (V_{IN} + 0.3V) w/ 6.0V max
Continuous Power Dissipation (3)	Internally Limited
Junction Temperature ($T_{J\text{-}MAX\text{-}ABS}$)	150°C
Storage Temperature Range	-65°C to 150°C
Lead Temp. (Soldering, 5 sec.)	260°C
ESD Rating Human Body Model (4)	2kV
Machine Model	200V

(1) Absolute Maximum Ratings indicate limits beyond which damage to the component may occur. Operating Ratings are conditions under which operation of the device is specified. Operating Ratings do **not** imply guaranteed performance limits. For performance limits and associated test conditions, see the Electrical Characteristics tables.
(2) All voltages are with respect to the potential at the GND pin.
(3) Thermal shutdown circuitry protects the device from permanent damage. D_1 and D_2 may be shorted to GND without damage.
(4) The human-body model is a 100 pF capacitor discharged through a 1.5 k resistor into each pin. The machine model is a 200pF capacitor discharged directly into each pin.

RECOMMENDED OPERATING CONDITIONS (1) (2)

	VALUE / UNITS
Input Voltage V_{IN}	2.7V to 5.5V
$V_{SD\text{-}BRGT}$	0V to V_{IN}
Brightness Adjustment Control Range of $V_{SD\text{-}BRGT}$	0.75V to 2.75V
Junction Temperature Range (T_J)	-30°C to +100°C
Ambient Temperature Range (T_A)	-30°C to +85 °C (3)

(1) All voltages are with respect to the potential at the GND pin.
(2) All room temperature limits are 100% tested or specified through statistical analysis. All limits at temperature extremes are ensured by correlation using standard Statistical Quality Control methods (SQC). All limits are used to calculate Average Outgoing Quality Level (AOQL). Typical numbers are **not** guaranteed, but do represent the most likely norm.
(3) Maximum ambient temperature ($T_{A\text{-}MAX}$) is dependent on the maximum operating junction temperature ($T_{J\text{-}MAX\text{-}OP}$ = 100ºC), the maximum power dissipation of the device in the application ($P_{D\text{-}MAX}$), and the junction-to-ambient thermal resistance of the part/package in the application (θ_{JA}), as given by the following equation: $T_{A\text{-}MAX} = T_{J\text{-}MAX\text{-}OP} - (\theta_{JA} \times P_{D\text{-}MAX})$. The ambient temperature operating rating is provided merely for convenience. This part may be operated outside the listed T_A rating, so long as the junction temperature of the device does not exceed the maximum operating rating of 100ºC.

THERMAL INFORMATION

Junction-to-Ambient Thermal Resistance, WSON Package (θ_{JA}) (1)	55°C/W

(1) Junction-to-ambient thermal resistance is highly application and board-layout dependent. In applications where high maximum power dissipation exists, special care must be paid to thermal dissipation issues. For more information on these topics, refer to the **Power Dissipation** section of this datasheet.

ELECTRICAL CHARACTERISTICS(1) (2)

Limits in standard typeface are for T_J = 25°C, and limits in **boldface** type apply over the full operating junction temprature range. Unless otherwise specified: C_1=C_2=C_{IN}=C_{HOLD}=1µF; V_{IN}=3.6V; $V_{SD\text{-}BRGT}$=3.0V; V_{DX}=3.6V

Symbol	Parameter	Conditions	Min	Typ	Max	Units
I_{DX}	Output Current Regulation	3.3V ≤ V_{IN} ≤ 5.5V, V_{DX} = 3.9V	14.7 **13.7**	15.9	17.2 **17.3**	mA
		3.0V ≤ V_{IN} ≤ 5.5V, V_{DX} = 3.8V	14.7 **13.7**	15.9	17.2 **17.3**	
		2.7V ≤ V_{IN} ≤ 5.5V, V_{DX} = 3.4V	14.7 **13.7**	15.9	17.2 **17.3**	
		2.5V ≤ V_{DX} ≤ 3.9V (3)	14.7 **13.7**	15.9	17.2 **17.3**	
		$V_{SD\text{-}BRGT}$= 2.0V		10		
		$V_{SD\text{-}BRGT}$= 0.75V		0.1		
$I_{D\text{-}MATCH}$	I_{D1}-to-I_{D2} Current Matching			0.3	**3.0**	%
R_{OUT}	Charge Pump Output Resistance	V_{IN} = 2.7V		3.5		Ω
$V_{HR\text{-}min}$	Minimum Current Source Voltage Headroom (V_{POUT} - V_{IDx}) (4)	I_{DX} = 16mA		400		mV
I_Q	Quiescent Supply Current	I_{DX}, I_{POUT} = 0		1.2	**2.2**	mA
I_{SD}	Shutdown Supply Current	2.7V ≤ V_{IN} ≤ 5.5V, $V_{SD\text{-}BRGT}$ = 0V		3	**5**	µA
ON/OFF	SD-BRGT Pin Thresholds for Active and Shutdown Modes	Active, V_{IN} = 3.0V	**0.70**			V
		Shutdown, V_{IN} = 3.0V			**0.25**	
$I_{LEAK\text{-}SD}$	SD-BRGT Pin Leakage Current(5)			17		µA
f_{SW}	Switching Frequency	2.7V ≤ V_{IN} ≤ 5.5V	**325**	500	**675**	kHz
t_{START}	Startup Time	I_{DX} = 90% steady state		30		µs

(1) All voltages are with respect to the potential at the GND pin.

(2) All room temperature limits are 100% tested or specified through statistical analysis. All limits at temperature extremes are ensured by correlation using standard Statistical Quality Control methods (SQC). All limits are used to calculate Average Outgoing Quality Level (AOQL). Typical numbers are **not** guaranteed, but do represent the most likely norm.

(3) Maximum LED voltage (V_{DX}) is highly dependent on the application's minimum input voltage and the amount of current flowing through the LEDs. Maximum LED voltage for a given application can be approximated with the following equations:

$V_{IN\text{-}MIN}$< 3.0V: $V_{Dx\text{-}MAX}$ = (1.5 × $V_{IN\text{-}MIN}$) - (I_{DX}× 25 mV/mA) - (3.5Ω × 2 × I_{DX})

$V_{IN\text{-}MIN}$ ≥ 3.0V: $V_{Dx\text{-}MAX}$ = 4.3V - (I_{DX} × 25 mV/mA)

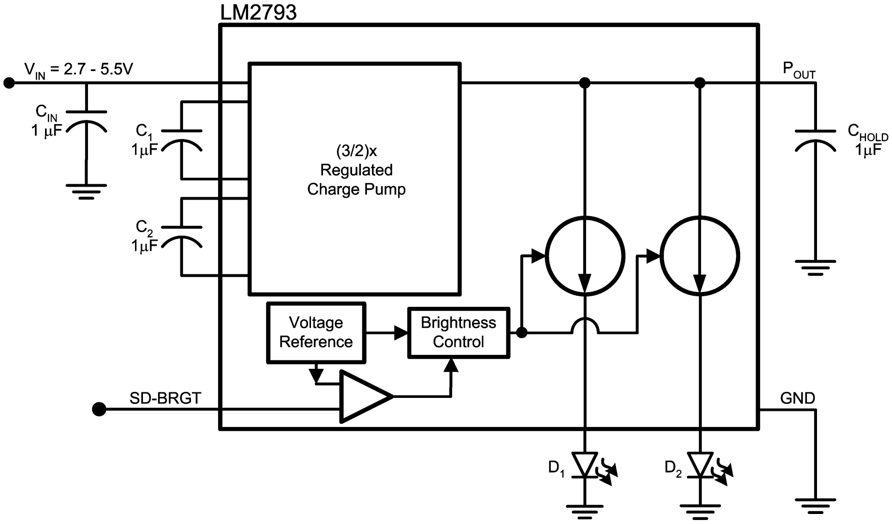
The equations above assume LEDs are connected to outputs D_1 and D_2, and no current drawn from the charge pump output (P_{OUT}). For a more precise and thorough analysis of maximum LED voltage, please refer to text sections of the datasheet (to appear in future datasheet revisions - in the interim, contact Texas Instruments Semiconductor for more information).

(4) Current sources are connected internally between P_{OUT} and I_{Dx}. The voltage across each current source, [V(P_{OUT}) - V(I_{Dx})], is referred to as headroom voltage. For current sources to regulate properly, a minimum headroom voltage must be present across them. Minimum required headroom voltage is proportional to the current flowing through the current source, as dictated by this equation:

$V_{HR\text{-}min}$ = 400mV × (I_{Dx} / 16mA).

(5) Voltage on the SD-BRGT pin should not exceed 6V.

BLOCK DIAGRAM



TYPICAL PERFORMANCE CHARACTERISTICS

Unless otherwise specified: T_A = 25°C, 2 LEDs, V_{DX} = 3.6V, V_{IN} = 3.6, $V_{SD\text{-}BRGT}$ = 3.0, $C_1 = C_2 = C_{IN} = C_{HOLD}$ = 1µF. Capacitors are low-ESR multi-layer ceramic capacitors (MLCC's).

LED Current vs. Input Voltage

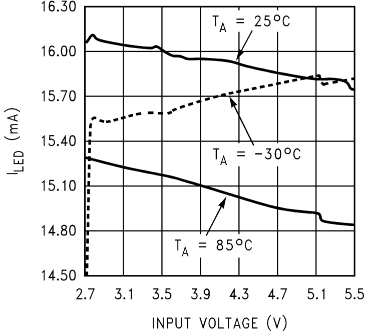


Figure 2.

LED Current vs. SD-BRGT Voltage

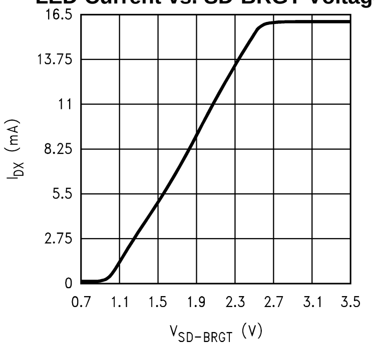


Figure 3.

Efficiency vs. Input Voltage

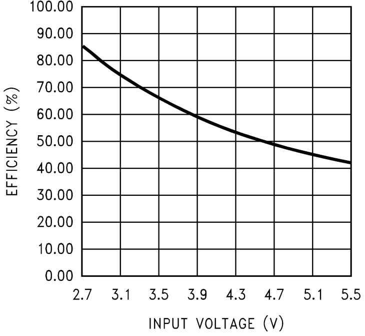


Figure 4.

LED Current vs. LED Voltage

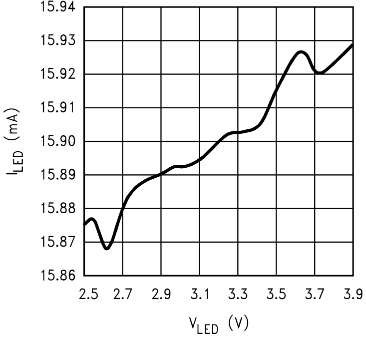


Figure 5.

Quiescent Current vs. Input Voltage

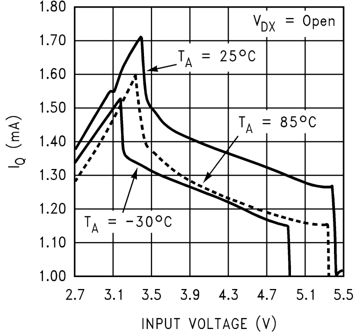


Figure 6.

Shutdown Supply Current vs. Input Voltage

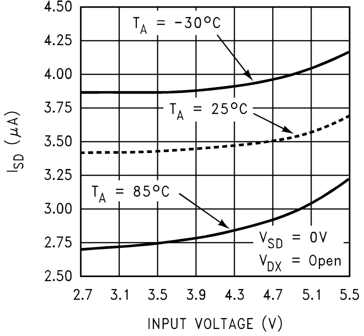


Figure 7.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Unless otherwise specified: T_A = 25°C, 2 LEDs, V_{DX} = 3.6V, V_{IN} = 3.6, $V_{SD\text{-}BRGT}$ = 3.0, $C_1 = C_2 = C_{IN} = C_{HOLD}$ = 1µF. Capacitors are low-ESR multi-layer ceramic capacitors (MLCC's).

Output Resistance vs. Temperature

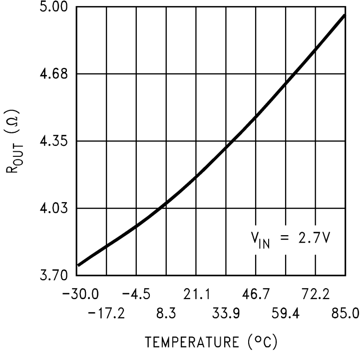


Figure 8.

Startup Response

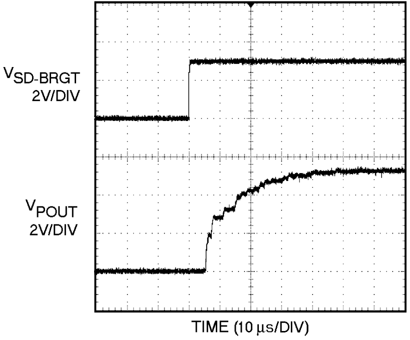


Figure 9.

APPLICATION INFORMATION

CIRCUIT DESCRIPTION

The LM2793 is a 1.5x CMOS charge pump that provides two matched constant current outputs for driving up to 16mA through high forward voltage drop White LEDs from Li-Ion battery sources. The device has two regulated current sources connected to the output of the device's 1.5x loosely regulated charge pump (P_{OUT}). The device's loosely-regulated charge pump has both open loop and closed loop modes of operation. When the device is in open loop, the voltage at P_{OUT} is 1.5 times the voltage at the input. When the device is in closed loop, the voltage at P_{OUT} is loosely regulated to 4.9V (typ.). To set the LED drive current, the device uses the voltage applied to the dual function shutdown-brightness pin (SD-BRGT) to set a reference current. This reference current is then multiplied and mirrored to each current output. The LED brightness can be controlled by both analog and/or digital methods. The digital technique uses a PWM (Pulse Width Modulation) signal applied to the SD-BRGT pin. The analog technique applies an analog voltage in the range of 0.7V to 2.75 to the SD-BRGT pin to vary the LED current (see Shutdown and Brightness Control).

SOFT START

LM2793 includes a soft start function to reduce the inrush currents and high peak current during power up of the device. Soft start is implemented internally by ramping the reference voltage more slowly than the applied voltage. During soft start, the switch resistances limit the inrush current used to charge the flying and hold capacitors.

SHUTDOWN AND BRIGHTNESS CONTROL

The LM2793 has an active-low dual function shutdown-brightness control pin, SD-BRGT. A voltage higher than 0.65V (typ.) on SD-BRGT will put the LM2793 in active mode. Applying a voltage below 0.35V (typ.) on the SD-BRGT pin will turn off the device, reducing the quiescent current to 3µA (typ.).

The LM2793 has the ability to adjust LED brightness by applying an analog voltage or a PWM signal to the SD-BRGT pin. For constant brightness or analog brightness control, continue with “Analog brightness control” below. Otherwise go to “Brightness control using PWM”.

1. Analog brightness control
   - The current for the dual LED outputs can be adjusted by varying the voltage on the SD-BRGT pin. The typical range for adjusting LED brightness is between 0.7 and 2.75V. Figure 1 shows how the current changes with respect to the voltage applied to SD-BRGT. If full brightness (16mA) is desired, the voltage on SD-BRGT should be greater than 2.75V (typ.) but not more than V_{IN}.
2. Brightness control using PWM
   - Increasing and decreasing the duty cycle of the PWM signal controls the LED brightness. Zero duty cycle will turn off the LEDs and a 50% duty cycle will result in an average I_{LED} being half of the maximum LED current. The recommended frequency range for the PWM signal is between 100Hz and 1KHz. If the PWM frequency is much less than 100Hz, flicker may be seen in the LEDs. If the frequency is much higher than 1kHz, brightness in the LEDs will not adjust linearly with duty cycle due to the 30µs (typ.) start-up time of the device. The voltage level for the PWM signal should be greater than 2.75V (typ.) but not exceed the voltage on V_{IN}.

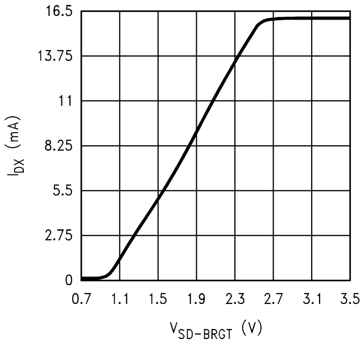


Figure 10. LED Current vs. $V_{SD\text{-}BRGT}$ 2 LEDs, V_{DX} = 3.6V, V_{IN} = 3.6V

CAPACITOR SELECTION

The LM2793 requires 4 external capacitors for proper operation. Surface-mount multi-layer ceramic capacitors are recommended. These capacitors are small, inexpensive and have very low equivalent series resistance (ESR, ≤15mΩ typ.). Tantalum capacitors, OS-CON capacitors, and aluminum electrolytic capacitors are generally not recommended for use with the LM2793 due to their high ESR, as compared to ceramic capacitors.

For most applications, ceramic capacitors with X7R or X5R temperature characteristic are preferred for use with the LM2793. These capacitors have tight capacitance tolerance (as good as ±10%), hold their value over temperature (X7R: ±15% over −55°C to 125°C; X5R: ±15% over −55°C to 85°C), and typically have little voltage coefficient. Capacitors with Y5V or Z5U temperature characteristic are generally not recommended for use with the LM2793. Capacitors with these temperature characteristics typically have wide capacitance tolerance (+80%, −20%), vary significantly over temperature (Y5V: +22%, −82% over −30°C to +85°C range; Z5U: +22%, −56% over +10°C to +85°C range), and have poor voltage coefficients. Under some conditions, a nominal 1µF Y5V or Z5U capacitor could have a capacitance of only 0.1µF. Such detrimental deviation is likely to cause Y5V and Z5U capacitors to fail to meet the minimum capacitance requirements of the LM2793. Table 1 lists suggested capacitor suppliers for the typical application circuit.

Table 1. Ceramic Capacitor Manufacturers

Manufacturer	Contact
TDK	www.component.tdk.com
Murata	www.murata.com
Taiyo Yuden	www.t-yuden.com

LED SELECTION

The LM2793 is designed to drive LEDs with a forward voltage of about 3.0V to 4.0V. The typical and maximum diode forward voltage depends highly on the manufacturer and their technology. Table 2 lists two suggested manufacturers. Forward current matching is assured over the LED process variations due to the constant current output of the LM2793.

Table 2. White LED Selection

Manufacturer	Contact
Osram	www.osram-os.com
Nichia	www.nichia.com

PARALLEL DX OUTPUTS FOR INCREASED CURRENT DRIVE

Outputs D_1 and D_2 may be connected together to drive a single LED. In such a configuration, two parallel current sources of equal value drive the single LED. The voltage on SD-BRGT should be chosen so that the current through each of the outputs is programmed to 50% of the total desired LED current. For example, if 30mA is the desired drive current for the single LED, SD-BRGT should be selected so that the current through each of the outputs is 15mA. Connecting the outputs in parallel does not affect internal operation of the LM2793 and has no impact on the Electrical Characteristics and limits previously presented. The available diode output current, maximum diode voltage, and all other specifications provided in the Electrical Characteristics table apply to this parallel output configuration, just as they do to the standard 2-LED application circuit.

P_{OUT}

P_{OUT} uses pre-regulation to loosely regulate the output of the LM2793 1.5x charge pump. Pre-regulation uses the voltage present at P_{OUT} to limit the gate drive of the 1.5x switched capacitor charge pump. Pre-regulation helps to reduce input current noise and large input current spikes normally associated with switched capacitor charge pumps. At voltages below 3.3V (typ.), the LM2793 acts as an open loop charge pump. When the device is in open loop, the voltage at P_{OUT} is 1.5 times the input voltage. At input voltages higher than 3.3V (typ.) P_{OUT} is loosely regulated to 4.9V (typ.).

POWER EFFICIENCY

Figure 11 shows the efficiency of the LM2793.

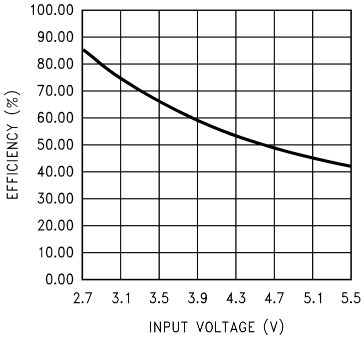


Figure 11. Efficiency vs. V_{IN}
2 LEDs, V_{LED} = 3.6V, I_{LED} = 16mA

Efficiency (E) of the LM2793 is defined here as the ratio of the power consumed by LEDs (P_{LED}) to the power drawn from the input source (P_{IN}). In the equations below, I_Q is the quiescent current of the LM2793, I_{LED} is the current flowing through one LED, and V_{LED} is the forward voltage at that LED current. In the input power calculation, the 1.5 multiplier reflects the 3/2 switched capacitor gain of the LM2793.

$$P_{LED} = N \times V_{LED} \times I_{LED} \quad (1)$$

$$P_{IN} = V_{IN} \times I_{IN} \quad (2)$$

$$P_{IN} = V_{IN} \times (1.5 \times N \times I_{LED} + I_Q) \quad (3)$$

$$E = (P_{LED} \div P_{IN}) \quad (4)$$

It is also worth noting that efficiency as defined here is in part dependent on LED voltage. Variation in LED voltage does not affect power consumed by the circuit and typically does not relate to the brightness of the LED. For an advanced analysis, it is recommended that power consumed by the circuit (V_{IN} x I_{IN}) be evaluated rather than power efficiency. Power consumption of the LM2793 Typical Application Circuit is shown in Figure 12.

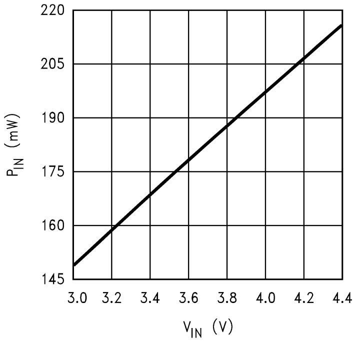


Figure 12. I_{LED} current vs. P_{IN}, 2 LEDs, 2.5 ≤ V_{LED} ≤ 3.9V, I_{LED} = 16mA

THERMAL PROTECTION

When the junction temperature exceeds 150°C, the LM2793 internal thermal protection circuitry disables the part. This feature protects the device from damage due to excessive power dissipation. The device will recover and operate normally when the junction temperature falls below 125°C. It is important to have good thermal conduction with a proper layout to reduce thermal resistance.

POWER DISSIPATION

When operating within specified operating ratings, the peak power dissipation ($P_{DISSIPATION}$) of the LM2793 occurs at an input voltage of 5.5V. Assuming a typical junction-to-ambient thermal resistance (θ_{JA}) for the WSON package of 55°C/W, a LED forward voltage (V_{DX}) of 3.6V, and a total load (I_{LOAD}) of 32mA for two White LEDs connected to D_1 and D_2, the power dissipation and junction temperature (T_J) are calculated below for a part operating at the maximum rated ambient temperature (T_A) of 85°C. In the equations below, V_{IN} is the input voltage to the LM2793, P_{IN} is the power generated by the 1.5x charge pump, and P_{LED} is the power consumed by the LEDs.

$$P_{DISSIPATION} = P_{IN} - P_{LED} = (1.5V_{IN} - V_{DX}) \times I_{LOAD} = ((1.5 \text{ x } 5.5V) - 3.6V) \times 0.032A = 149mW \tag{5}$$

$$T_J = T_A + (P_{DMAX} \times \theta_{JA}) = 85°C + (0.149W \times 55°C/W) = 93°C \tag{6}$$

The junction temperature rating takes precedence over the ambient temperature rating. The LM2793 may be operated outside the ambient temperature rating, so long as the junction temperature of the device does not exceed the maximum operating rating of 100°C. The maximum ambient temperature rating must be derated in applications where high power dissipation and/or poor thermal resistance causes the junction temperature to exceed 100°C.

PCB Layout Considerations

The WSON is a leadframe based Chip Scale Package (CSP) with very good thermal properties. This package has an exposed DAP (die attach pad) at the center of the package measuring 2.0mm x 1.2mm. The main advantage of this exposed DAP is to offer lower thermal resistance when it is soldered to the thermal land on the PCB. For PCB layout, TI highly recommends a 1:1 ratio between the package and the PCB thermal land. To further enhance thermal conductivity, the PCB thermal land may include vias to a ground plane. For more detailed instructions on mounting WSON packages, please refer to SNOA401.

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Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

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