National Semiconductor

PRELIMINARY
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LM2791/LM2792
Current Regulated Switched Capacitor LED Driver with Analog Brightness Control

General Description

The LM2791/92 is a CMOS charge-pump voltage doubler and regulator that provides two regulated current sources. They are designed to drive two white (or blue) LEDs with matched currents (within ±1%) to produce balanced light sources for display backlights. They accept an input voltage range from 2.9V to 5.5V and maintain a constant current determined by an external set resistor.

The LM2791's architecture delivers up to 40mA of load current to accommodate two high forward voltage (typically white) LEDs. The switching frequency is 800kHz (min.) to keep the conducted noise spectrum away from sensitive frequencies within portable RF devices.

In the LM2791, brightness over a 5 to 1 range is controlled by applying a voltage between GND and 3.0V to the BRGT pin. The LM2792 offers full off to maximum current control through the BRGT pin. The output current linearly tracks the BRGT pin voltage. Both devices are available in active high or low shutdown versions. The shutdown pin reduces the operating current to 2µA (max.).

The LM2791/92 is available in a 10 pin leadless leadframe (LLP) CSP package.

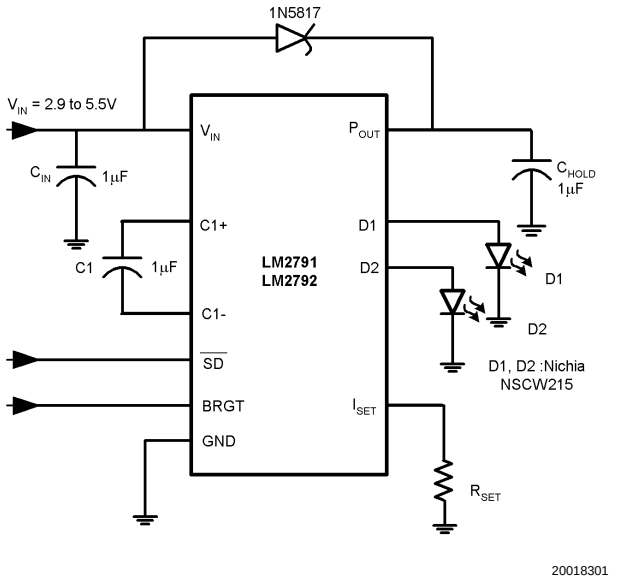
Features

- Output matching of ±1%
- Regulated IOUT with ±7% accuracy over the full input range
- Drives up to two LED's
- 2.9V to 5.5V Input Voltage
- Up to 40mA output current
- Soft start limits inrush current
- Analog brightness control
- Separate shutdown input
- Very small solution size - no inductor
- 1500µA typical operating current
- 2µA (max.) shutdown current
- 800kHz switching frequency (min.)
- Linear regulation generates predictable noise spectrum
- LLP-10 package: 3mm X 3mm X 0.8mm

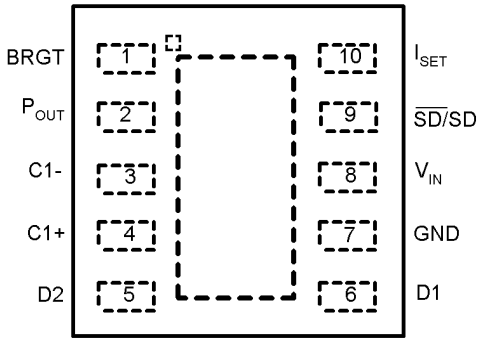
Applications

- White LED Display Backlights
- White LED Keypad Backlights
- 1-Cell LiIon battery-operated equipment including PDAs, hand-held PCs, cellular phones
- Flat Panel Dispalys

Basic Application Circuit



Connection Diagram



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Top View
10-Lead LLP

Ordering Information

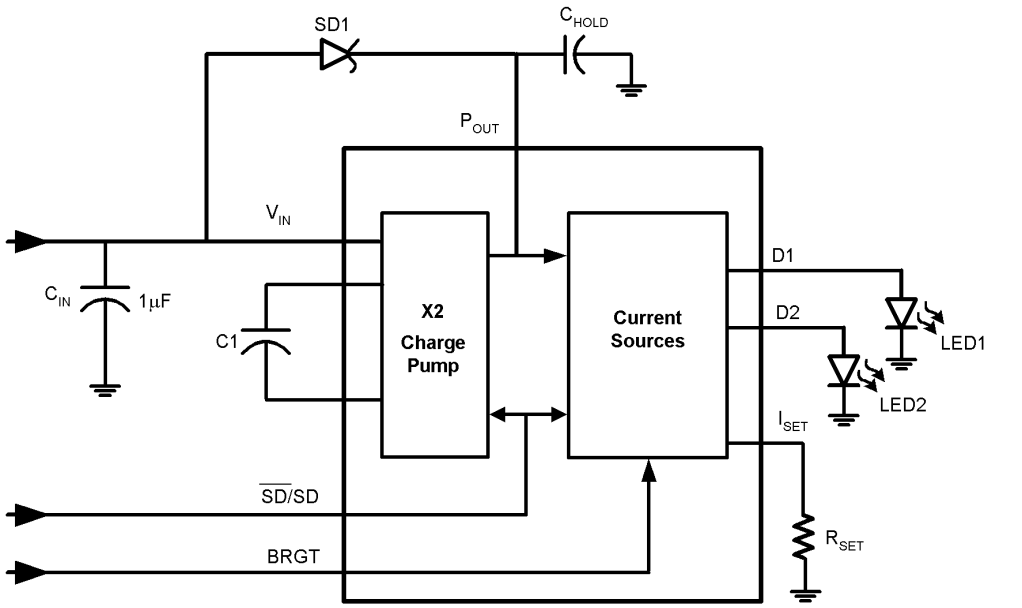
Order Number	Shutdown Polarity	NSC Package Drawing	Package Marking	Supplied As
LM2791LD-L	Active Low	LLP-10	SNB	1000 Units, Tape and Reel
LM2791LDX-L	Active Low	LLP-10	SNB	4500 Units, Tape and Reel
LM2791LD-H	Active High	LLP-10	SLB	1000 Units, Tape and Reel
LM2791LDX-H	Active High	LLP-10	SLB	4500 Units, Tape and Reel

Order Number	Shutdown Polarity	NSC Package Drawing	Package Marking	Supplied As
LM2792LD-L	Active Low	LLP-10	SRP	1000 Units, Tape and Reel
LM2792LDX-L	Active Low	LLP-10	SRP	4500 Units, Tape and Reel
LM2792LD-H	Active High	LLP-10	SPB	1000 Units, Tape and Reel
LM2792LDX-H	Active High	LLP-10	SPB	4500 Units, Tape and Reel

Pin Description

Pin	Name	Function
1	BRGT	Variable voltage input controls output current.
2	P_{OUT}	Charge pump output.
3	C1−	Connect this pin to the negative terminal of C1
4	C1+	Connect this pin to the positive terminal of C1
5	D2	Current source outputs. Connect directly to LED
6	D1	Current source outputs. Connect directly to LED
7	GND	Power supply ground input
8	V_{IN}	Power supply voltage input
9	SD/$\overline{SD}$	Shutdown input. Device operation is inhibited when pin is asserted.
10	I_{SET}	Current Sense Input. Connect resistor to ground to set constant current through LED.

Block Diagram



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Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

V_{IN} BRGT, SD	−0.5 to 5.8V
Power Dissipation (T_A = 25˚C (Note 2)	400 mW
T_{JMAX} (Note 2)	150˚C
θ_{JA} (Note 2)	100˚C/W
Storge Temperature	−65˚C to +150˚C
Lead Temp. (Soldering, 5 sec.)	260˚C
ESD Rating	2kV

Operating Conditions

Input Voltage (V_{IN})	2.7V to 5.5V
BRGT	0 to 3.0V
R_{SET}	250Ω to 2.5KΩ
Ambient Temperature (T_A)	−30˚C to +85˚C
Junction Temperature (T_J)	−30˚C to +125˚C

Electrical Characteristics

Limits in standard typeface are for T_J = 25˚C and limits in **boldface type** apply over the full **Operating Temperature Range**. Unless otherwise specified, $C_1 = C_{IN} = C_{OUT}$ = 1 µF, V_{IN} = 3.6V, BRGT pin = 0V.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
I_{DX}	Available Current at Output Dx	3.0V ≤ V_{IN} ≤ 5.5V V_{Dx} ≤ 4.0V R_{SET} = 250Ω V_{BRGT} = 0V	20			mA
		2.7V ≤ V_{IN} ≤ 3.0V V_{Dx} ≤ 3.6V R_{SET} = 330Ω V_{BRGT} = 0V	15			mA
V_{DX}	Available Voltage at Output Dx	3V ≤ V_{IN} ≤ 5.5V IDx ≤ 20mA	4.0			V
ΔI_{DX}	Line Regulation of Dx Output Current	3.0V ≤ V_{IN} ≤ 5.5V V_{Dx} = 3.6V	18.6	20	21.4	mA
ΔV_{DX}	Load Regulation of Dx Output Current	V_{IN} = 3.6V 3.0V ≤ V_{Dx} ≤ 4.0V	18.6	20	21.4	mA
$I_{D\text{-}MATCH}$	Current Matching Between Any Two Outputs			1.0		%
I_Q	Quiescent Supply Current	3.0V ≤ V_{IN} ≤ 5.5V, Active, No Load Current		1500	2500	µA
V_{SD}	Shutdown Supply Current	3.0V ≤ V_{IN} ≤ 5.5V, Shutdown		0.1	2	µA
V_{IH}	SD Input Logic High	3.0V ≤ V_{IN} ≤ 5.5V	1.0			V
V_{IL}	SD Input Logic Low	3.0V ≤ V_{IN} ≤ 5.5V			0.2	V
$I_{LEAK\text{-}SD}$	SD Input Leakage Current	0V ≤ V_{SD} ≤ V_{IN}		0.1		µA
R_{BRGT}	BRGT Input Resistance			150		kΩ
BRGT	Brightness Voltage Range		0		3.0	V
I_{SET}	I_{SET} Pin Output Current			I_{Dx}/25		mA
f_{SW}	Switching Frequency (Note 4)	3.0V ≤ V_{IN} ≤ 5.5V	800	1100	1500	kHz
t_{START}	Startup Time	I_{Dx} = 90% steady state		10		µs

Note 1: Absolute maximum ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.

Note 2: D1 and D2 may be shorted to GND without damage. P_{OUT} may be shorted to GND for 1sec without damage.

Note 3: In the test circuit, all capacitors are 1.0µF, 0.3Ω maximum ESR capacitors. Capacitors with higher ESR will increase output resistance, reduce output voltage and efficiency.

Note 4: The output switches operate at one half of the oscillator frequency, $f_{OSC} = 2f_{SW}$.

Circuit Description

The LM2791/92 provides two matched current sources for driving high forward voltage drop LEDs from LiIon battery sources. They have on-chip current regulators which are composed of current mirrors with a 25 to 1 ratio. The mirrors control the LED current without using current limiting resistors in the LED current path. The device can drive up to 40mA total with 20mA in each LED.

After setting the maximum LED current through R_{SET}, LED brightness can be controlled by both analog and/or digital methods. The digital technique uses a PWM (Pulse Width

Circuit Description (Continued)

Modulation) signal applied to the shutdown input. The analog technique applies an analog voltage to the brightness (BRGT) pin. For lowest cost, the LM2791 can be used for constant brightness by grounding BRGT and enabling the shutdown pin. Please refer to the values in *Table 1*for R_{SET} and LED current selection.

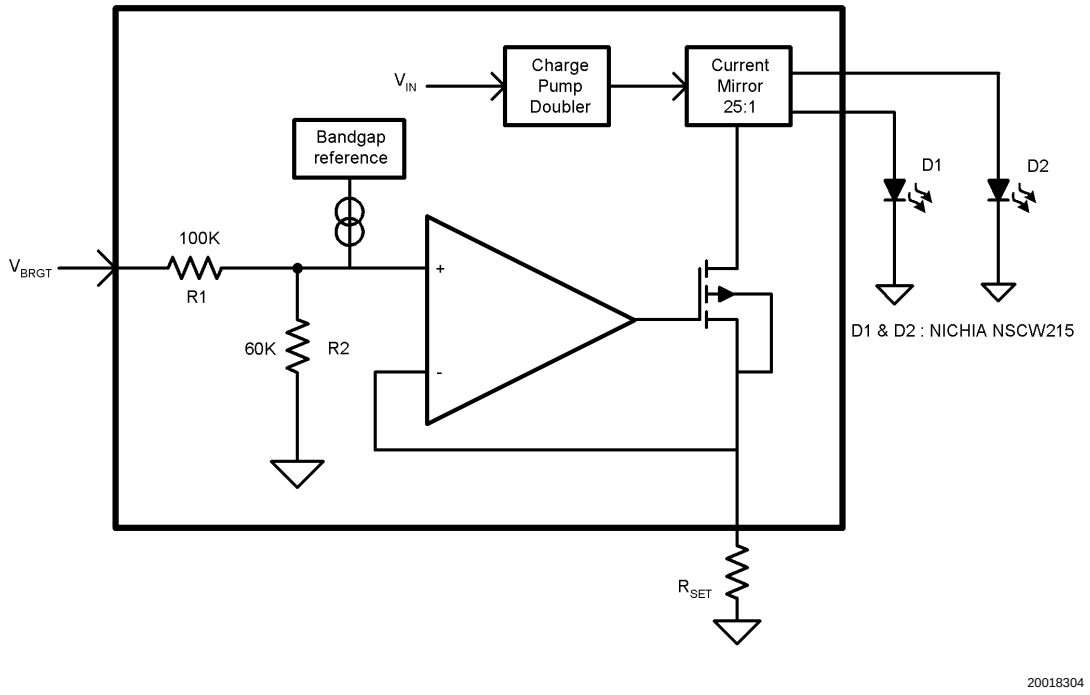


FIGURE 1.

Application Information

Soft Start

LM2791/92 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 bandgap more slowly than the applied voltage. This is done by holding the bandgap in shutdown for a short time. During soft start, the switch resistances limit the inrush current used to charge the flying and hold capacitors.

Shutdown Mode

A shutdown pin (SD or /SD) is available to disable the LM2791/92 and reduce the quiescent current to 2µA maximum. LM2791/92 offer shutdown high level and low level flexibility. Both the LM2791 and LM2792 are available with both senses of shutdown polarity.

During normal operation mode of the ″-L″ options, an active high logic signal to /SD pin or tying the /SD pin to V_{IN}, will enable the device. Pulling /SD low or connecting /SD to ground will disable the device.

During normal operation mode of the ″-H″ options, an active low logic signal to SD pin or tying the SD pin to GND, will enable the device. Pulling SD high or connecting SD to V_{IN} will disable the device.

Capacitor Selection

Low equivalent series resistance (ESR) capacitors are recommended to be used for C_{IN}, C1, and C_{HOLD} for best performance. Ceramic capacitors with less than or equal to 0.3 ohms ESR value are recommended for this application. *Table 1* below lists suggested capacitor suppliers for the typical application circuit.

TABLE 1. Low ESR Capacitor Manufactures

Manufacturer	Contact	Capacitor Type
MuRata	(800) 831 9172	Low ESR Ceramic capacitors are recommended for best performance.
Taiyo Yuden	(800) 348 2496	
Tokin	(408) 432 8020	

Schottky Diode Selection

A schottky diode (D1) must be used between V_{IN} and P_{OUT} for proper operation. During start-up, the low voltage drop across this diode is used to charge C_{OUT} and start the oscillator. It is necessary to protect the device from turning-on its own parasitic diode and potentially latching-up. As a result, it is important to select a schottky diode that will carry at least 500mA or higher current to charge the output capacitor during start-up. A schottky diode like 1N5817 can be used for most applications or a BAT54-series surface mount diode can be used to reduce the circuit size. *Table 2* below lists suggested schottky diode manufactures.

Application Information (Continued)

TABLE 2. Low ESR Capacitor Manufactures

Manufacturer	Contact	Schottky Diodes
ON Semiconductor	(800) 344 3860	1N5817/18/19 Lead Rectifiers
Phillips Semiconductors	(800) 234 7381	BAT54 Series Surface Mount

I_{SET} Pin

An external resistor, R_{SET}, sets the mirror current that is required to provide a constant current through the LEDs. The current through R_{SET} and the LED is set by the internal current mirror circuitry with a ratio of 25:1 (Please refer to the I_{SET} chart below for calculation). The currents through each LED are matched within 1%. R_{SET} should be chosen not to exceed the maximum current delivery capability of the device. For the case where the BRGT pin is not used, R_{SET} alone controls the brightness. The I_{SET} calculation is:

Calculation of LED Current When Grounding BRGT (LM2791):

V_{IN} = 3.6V

V_{SET} = 200mV(offset of bandgap)

R_{SET} = 250Ω

$I_{LED} = (V_{SET} / (R_{SET})) * 25$

I_{LED} = (200mV/250) *25 = 20mA

BRGT Pin

The BRGT pin can be used to smoothly vary the brightness of the White LEDs. In the LM2791, current on BRGT is connected to an internal resistor divider of 100KΩ and 60KΩ (see *Figure 1*) and summed with an offset voltage from the internal bandgap (200mV). This voltage is fed to the operational amplifier that controls the current through the mirror resistor R_{SET}. The nominal range on BRGT is 0V to 3V.

The LM2792 operates similarly to the LM2791, but without the internal offset current from the bandgap. This means some current must be provided on the BRGT pin or no current will flow through the LEDs. Where the LM2791 provides a maximum 5:1 LED current ratio, the LM2792 can provide an infinite ratio, from fully off (zero current) to the maximum current set by the RSET resistor. Care must be taken to prevent voltages on BRGT that cause LED current to exceed 20mA/LED. Although this will not cause damage to the IC, it will not meet the guaranteed specifications listed in the Electrical Characteristics.

Table 3 shows the current through each LED for the LM2791 with various BRGT and R_{SET} values.

Calculation of LED Current When Using BRGT (LM2791):

V_{IN} = 3.6V

R_{SET} = 1500Ω

V_{SET} = 200mV(offset of bandgap)

$I_{SET} = ((V_{BRGT} * (R2/R1+R2) + V_{SET})/ RSET)* 25$

I_{SET} = (((2.6*(60/160)) + 0.20)/1500)*25 = 20mA (for LM2791)

Calculation of LED Current When Using BRGT (LM2792):

V_{IN} = 3.6V

R_{SET} = 1500Ω

V_{SET} = 0mV(offset of bandgap not used)

$I_{SET} = ((V_{BRGT} * (R2/R1+R2) + V_{SET})/ R_{SET})* 25$

I_{SET} = ((2.6*(60/160))/1500)*25 = 16mA (for LM2792)

Note that making V_{BRGT} = 0V results in I_{SET} = 0mA

TABLE 3. LED Current When Using BRGT Input (using LM2791)
(Values Highlighted in Boldface exceeded maximum current range of the device)

R_{SET} (Ω)	250Ω	500Ω	1000Ω	1500Ω	2000Ω
V_{BRGT} (V)	I_{LED} (A)	I_{LED} (A)	I_{LED} (A)	I_{LED} (A)	I_{LED} (A)
0.0	0. 02	0.011	0.0055	0.004	0.003
0.2	**0.030**	0.015	0.007	0.005	0.004
0.4	**0.037**	0.019	0.009	0.006	0.005
0.6	**0.045**	**0.022**	0.011	0.007	0.006
0.8	**0.052**	**0.026**	0.013	0.009	0.007
1.0	**0.060**	**0.030**	0.015	0.010	0.007
1.2	**0.067**	**0.034**	0.017	0.011	0.008
1.4	**0.075**	**0.037**	0.019	0.012	0.009
1.6	**0.082**	**0.041**	**0.021**	0.014	0.010
1.8	**0.090**	**0.045**	**0.022**	0.014	0.011
2.0	**0.097**	**0.049**	**0.024**	0.016	0.012
2.2	**0.105**	**0.052**	**0.026**	0.017	0.013
2.4	**0.112**	**0.056**	**0.028**	0.019	0.014
2.6	**0.120**	**0.060**	**0.030**	0.020	0.015
2.8	**0.127**	**0.064**	**0.032**	**0.021**	0.016
3.0	**0.135**	**0.067**	**0.034**	**0.022**	0.017

For Brightness control using a PWM signal, it is recommended to generate the PWM signal between 100Hz to 1KHz (5% minimum duty cycle) for best performance.

Thermal Protection

The LM2791/92 has internal thermal protection circuitry to disable the charge pump if the junction temperature exceeds 150˚C. This feature will protect the device from damage due

Application Information (Continued)

to excessive power dissipation. The device will recover and operate normally when the junction temperature falls below the maximum operating junction temperature of 125˚C. It is important to have good thermal conduction with a proper layout to reduce thermal resistance.

Power Dissipation

The maximum allowable power dissipation is calculated by using $P_{DMax} = (T_{JMax} - T_A)\ \theta_{JA}$, where T_{JMax} is the maximum junction temperature, T_A is the ambient temperature, and θ_{JA} is the junction-to-ambient thermal resistance of the specified package. As an example, if VIN in the target application is 4.2V, V_{DIODE}= 3.0V and worse case current consumption is 40mA (20mA for each diode). The power dissipation can then be calculated as:

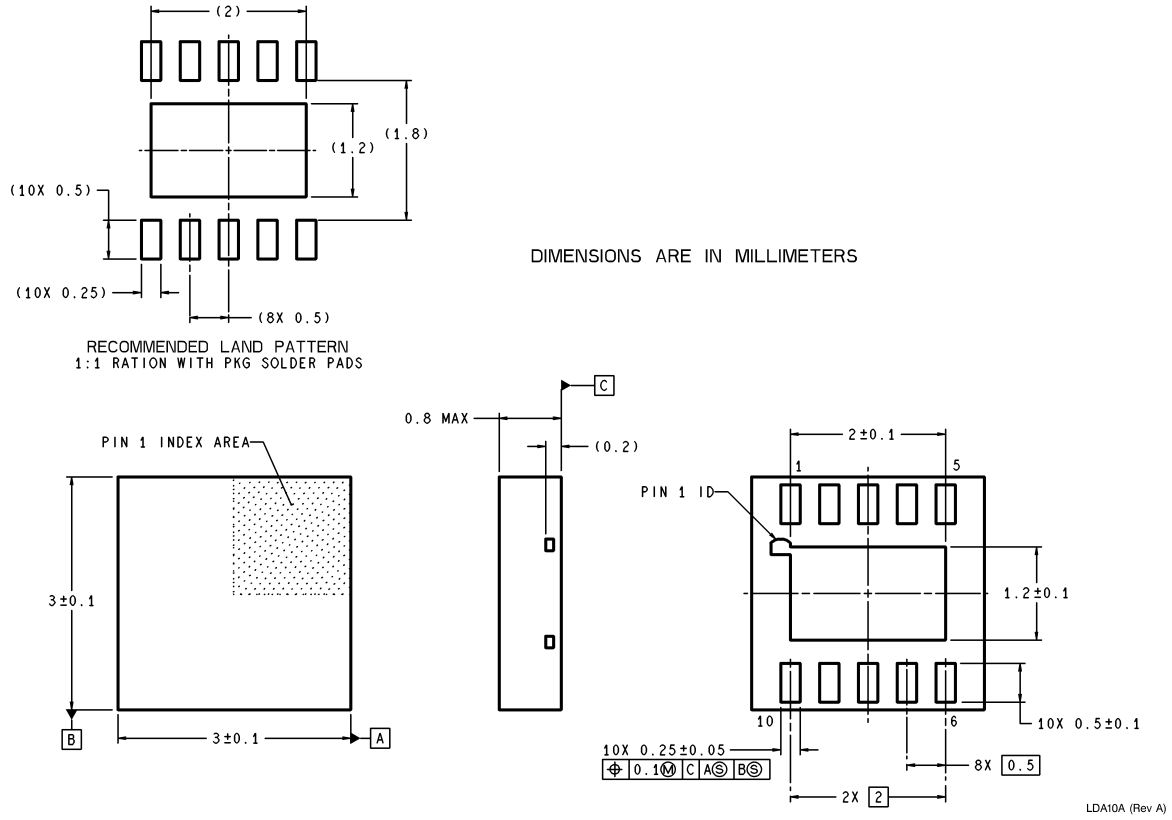
$$P_{Max\_}Dissipation = (2V_{IN} - V_{OUT})*I_{LOAD} = ((2*4.2) - 3.0)*0.04 = 216mW.$$

Power dissipation must be less than that allowed by the package. Please refer to the Absolute Maximum Rating of the LM2791/92.

PCB Layout Considerations

The LLP 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 PCB. For PCB layout, National 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 LLP packages, please refer to National Semiconductor Application Note AN-1187.

Physical Dimensions inches (millimeters) unless otherwise noted



LLP-10 Pin Package (LDA)
For Ordering, Refer to Ordering Information Table
NS Package Number LDA10A

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