



## 60mA Switched-Cap Buck/Boost Converter

### FEATURES

- Pb-free SOT23-6 Package
- Wide Input Range: 2.7V to 5.5V
- Low Input Current Ripple
- Low Output Voltage Ripple
- Minimum Number of External Components—No Inductors
- 1MHz Internal Oscillator Allows Small Capacitors
- Shutdown Mode
- Thermal and Current Limit Protection

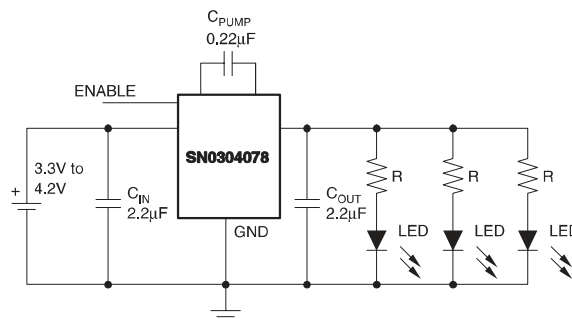
### APPLICATIONS

- Smart Card Readers
- SIM Card Supplies
- Cellular Phones
- Portable Communication Devices
- Personal Digital Assistants
- Notebook and Palm-Top Computers
- Modems
- Electronic Games
- Handheld Meters
- PCMCIA Cards
- Card Buses
- White LED Drivers
- LCD Displays
- Battery Backup Supplies

### DESCRIPTION

The SN0304078 is a switched capacitor voltage converter that produces a regulated, low-ripple output voltage from an unregulated input voltage. A wide-input supply voltage of 2.7V to 5.5V makes the SN0304078 ideal for a variety of battery sources, such as single cell Li-Ion, or two and three cell nickel- or alkaline-based chemistries.

The input voltage may vary above and below the output voltage and the output will remain in regulation. The SN0304078 provides low EMI dc/dc conversion without the need for an inductor. The high switching frequency allows the use of small surface-mount capacitors, saving board space and reducing cost. The SN0304078 is thermally protected and current limited, protecting the load and the regulator during fault conditions. Typical ground pin current (quiescent current) is 65µA with no load, and less than 1µA in shutdown mode.



SN0304078 Used in White LED Backlight Application



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

All trademarks are the property of their respective owners.

**ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>**

Supply Voltage . . . . .	-0.3V to +6.0V
Enable Input . . . . .	-0.3V to $V_{IN}$
Output Short-Circuit Duration . . . . .	Indefinite
Operating Temperature Range . . . . .	-55°C to +125°C
Storage Temperature Range . . . . .	-65°C to +150°C
Junction Temperature . . . . .	-55°C to +150°C
Lead Temperature (soldering, 3s) . . . . .	+260°C

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability.



**ELECTROSTATIC DISCHARGE SENSITIVITY**

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

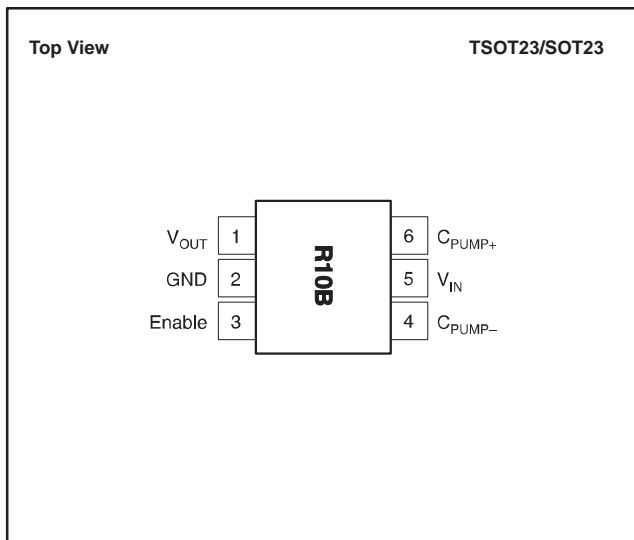
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

**PACKAGE ORDERING INFORMATION**

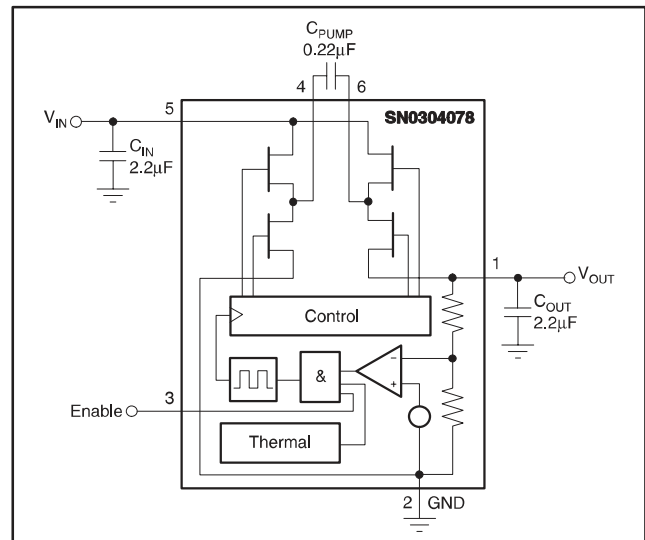
PRODUCT	OUTPUT VOLTAGE	PACKAGE-LEAD	PACKAGE DESIGNATOR <sup>(1)</sup>	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING <sup>(2)</sup>	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
SN0304078DBV	5.0V	SOT23-6	DBV	-40°C to +85°C	R10B	SN0304078DBVT SN0304078DBVR	Tape and Reel, 250 Tape and Reel, 3000

(1) For the most current specifications and product information, refer to our web site at [www.ti.com](http://www.ti.com).  
 (2) Voltage will be marked on reel.

**PIN CONFIGURATION**



**SIMPLIFIED BLOCK DIAGRAM**



**ELECTRICAL CHARACTERISTICS**
**Boldface** limits apply over the specified temperature range,  $T_A = -40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ 

 At  $T_A = +25^{\circ}\text{C}$ ,  $V_{IN} = V_{OUT}/2 + 0.75\text{V}$ ,  $I_{OUT} = 10\text{mA}$ ,  $C_{IN} = C_{OUT} = 2.2\mu\text{F}$ ,  $C_{PUMP} = 0.22\mu\text{F}$ ,  $V_{ENABLE} = 1.3\text{V}$ , unless otherwise noted.

PARAMETER	CONDITIONS	SN0304078NA			UNITS
		MIN	TYP	MAX	
<b>INPUT VOLTAGE</b> Tested Startup	See conditions under Output Voltage with a resistive load not lower than typical $V_{OUT}/I_{OUT}$ .	<b>2.7</b>		<b>5.5</b>	V
<b>OUTPUT VOLTAGE</b>	$I_{OUT} \leq 10\text{mA}$ , $2.7\text{V} \leq V_{IN} \leq 5.5\text{V}$	<b>4.7</b>	5.0	<b>5.3</b>	V
	$I_{OUT} \leq 30\text{mA}$ , $3.0\text{V} \leq V_{IN} \leq 5.5\text{V}$	<b>4.7</b>	5.0	<b>5.3</b>	V
	$I_{OUT} \leq 60\text{mA}$ , $3.3\text{V} \leq V_{IN} \leq 4.2\text{V}$	<b>4.6</b>	5.0	<b>5.4</b>	V
<b>OUTPUT CURRENT</b> Nominal		30			mA
Short Circuit <sup>(1)</sup>			100		mA
<b>OSCILLATOR FREQUENCY</b> <sup>(2)</sup>			1.0		MHz
<b>EFFICIENCY</b> <sup>(3)</sup>	$I_{OUT} = 10\text{mA}$ , $V_{IN} = 2.7\text{V}$		90		%
<b>RIPPLE VOLTAGE</b> <sup>(4)</sup>	$I_{OUT} = 30\text{mA}$		35		mVpp
<b>ENABLE CONTROL</b>	$V_{IN} = 2.7\text{V}$ to $5.5\text{V}$				
Logic High Input Voltage		<b>1.3</b>		<b><math>V_{IN}</math></b>	V
Logic Low Input Voltage		<b>-0.2</b>		<b>0.4</b>	V
Logic High Input Current				100	nA
Logic Low Input Current				100	nA
<b>THERMAL SHUTDOWN</b>					
Shutdown Temperature			160		$^{\circ}\text{C}$
Shutdown Recovery			140		$^{\circ}\text{C}$
<b>SUPPLY CURRENT</b>					
(Quiescent Current)	$I_{OUT} = 0\text{mA}$		65	100	$\mu\text{A}$
In Shutdown Mode	$V_{IN} = 2.7\text{V}$ to $5.5\text{V}$ , Enable = 0V		0.01	1	$\mu\text{A}$
<b>TEMPERATURE RANGE</b>					
Specification Ambient Temperature $T_A$		-40		+85	$^{\circ}\text{C}$
Operating Ambient Temperature $T_A$		-55		+125	$^{\circ}\text{C}$
Storage Ambient Temperature $T_A$		-65		+150	$^{\circ}\text{C}$
Thermal Resistance, $\theta_{JA}$	SOT23-6		200		$^{\circ}\text{C}/\text{W}$

(1) The supply current is twice the output short-circuit current.

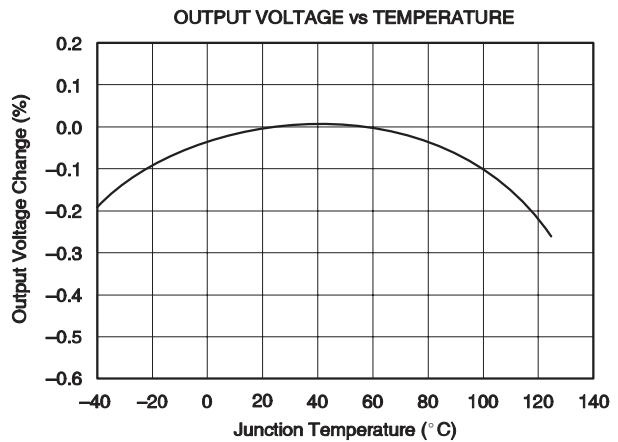
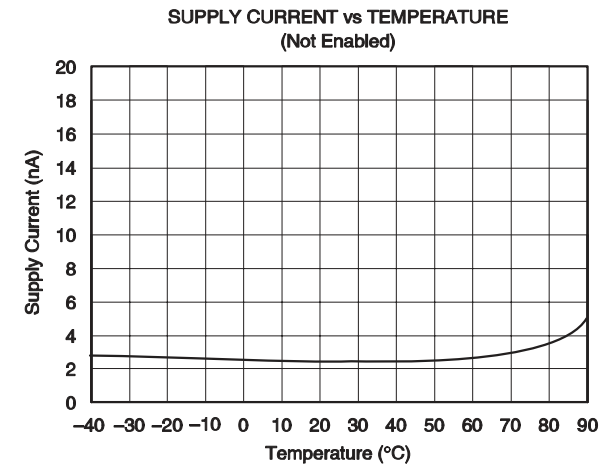
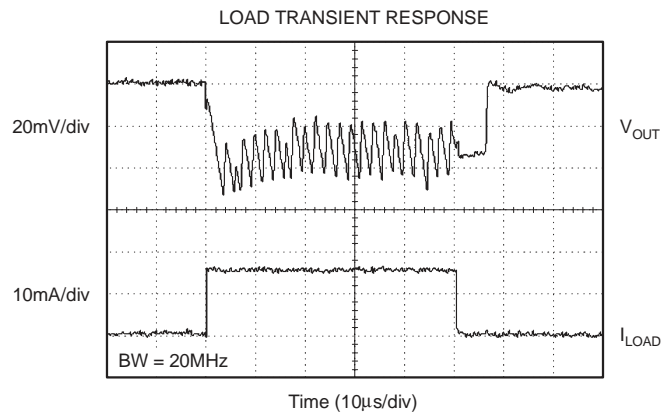
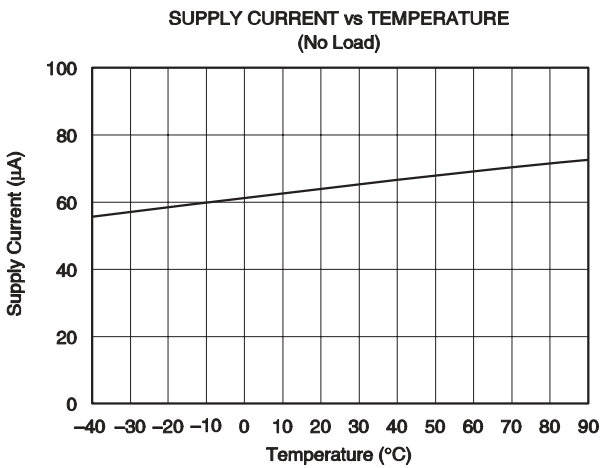
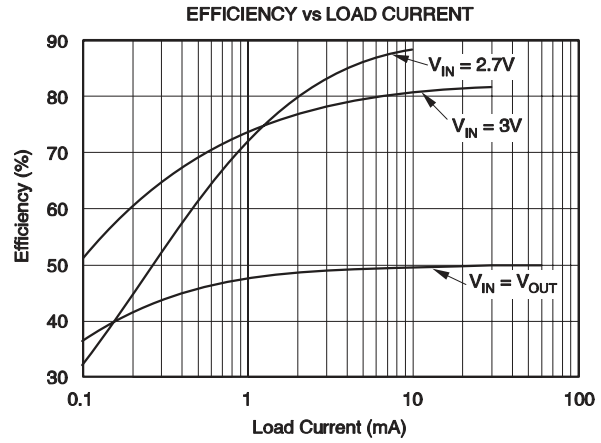
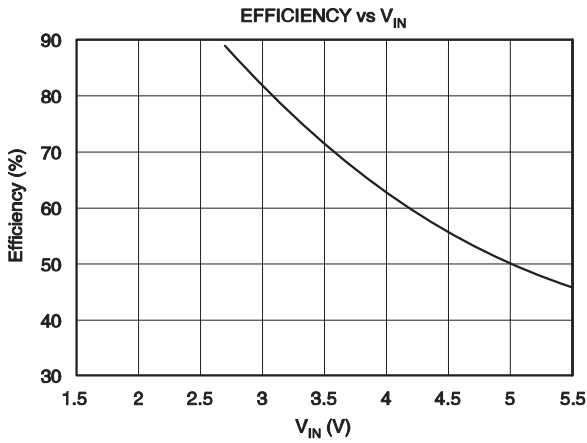
(2) The converter regulates by enabling and disabling periods of switching cycles. The switching frequency is the oscillator frequency during an active period.

 (3) See efficiency curves for other  $V_{IN}/V_{OUT}$  configurations.

 (4) Effective Series Resistance (ESR) of capacitors is  $< 0.1\Omega$ .

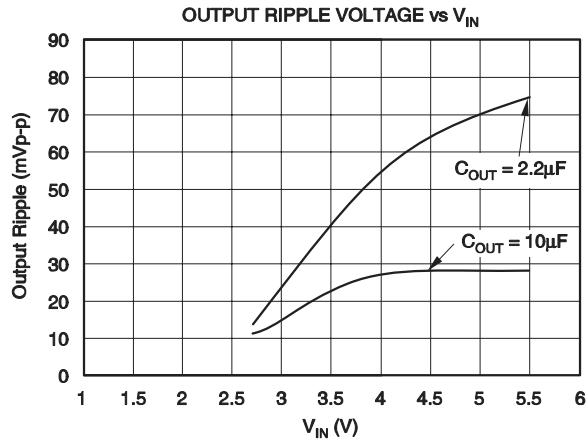
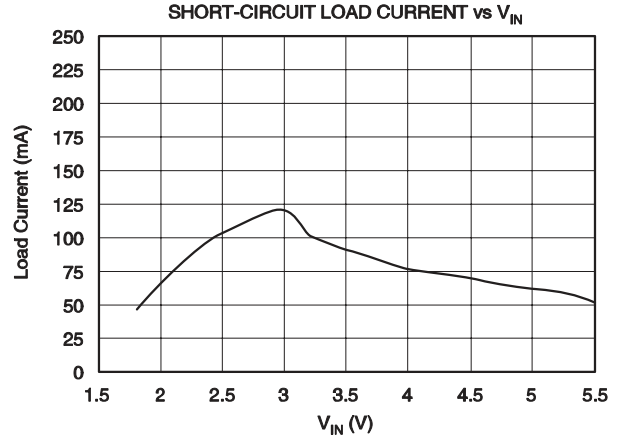
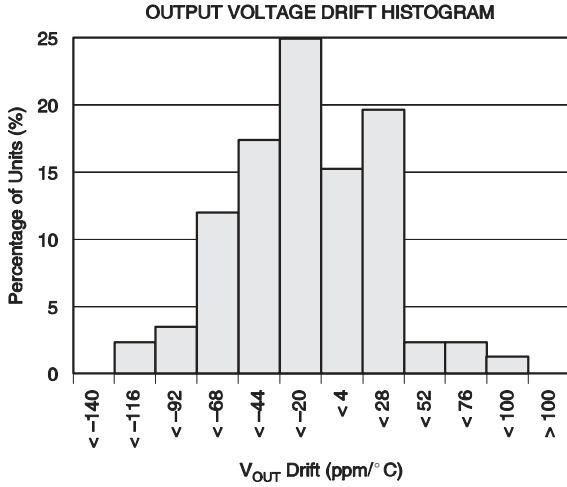
## TYPICAL CHARACTERISTICS

At  $T_A = +25^\circ\text{C}$ ,  $V_{IN} = V_{OUT}/2 + 0.75\text{V}$ ,  $I_{OUT} = 5\text{mA}$ ,  $C_{IN} = C_{OUT} = 2.2\mu\text{F}$ ,  $C_{PUMP} = 0.22\mu\text{F}$ ,  $V_{ENABLE} = 1.3\text{V}$ , unless otherwise noted.



## TYPICAL CHARACTERISTICS (Cont.)

At  $T_A = +25^\circ\text{C}$ ,  $V_{IN} = V_{OUT}/2 + 0.75\text{V}$ ,  $I_{OUT} = 5\text{mA}$ ,  $C_{IN} = C_{OUT} = 2.2\mu\text{F}$ ,  $C_{PUMP} = 0.22\mu\text{F}$ ,  $V_{ENABLE} = 1.3\text{V}$ , unless otherwise noted.



## THEORY OF OPERATION

The SN0304078 regulated charge pump provides a regulated output voltage for input voltages ranging from less than the output to greater than the output. The theory of operation is illustrated in Figure 1.

A conversion clock of 50% duty cycle is generated. During the first half-cycle the FET switches are configured as shown in Figure 1A, and  $C_{PUMP}$  charges to  $V_{IN}$ .

During the second half-cycle the FET switches are configured as shown in Figure 1B, and the voltage on  $C_{PUMP}$  is added to  $V_{IN}$ . The output voltage is regulated by skipping clock cycles as necessary.

## PEAK CURRENT REDUCTION

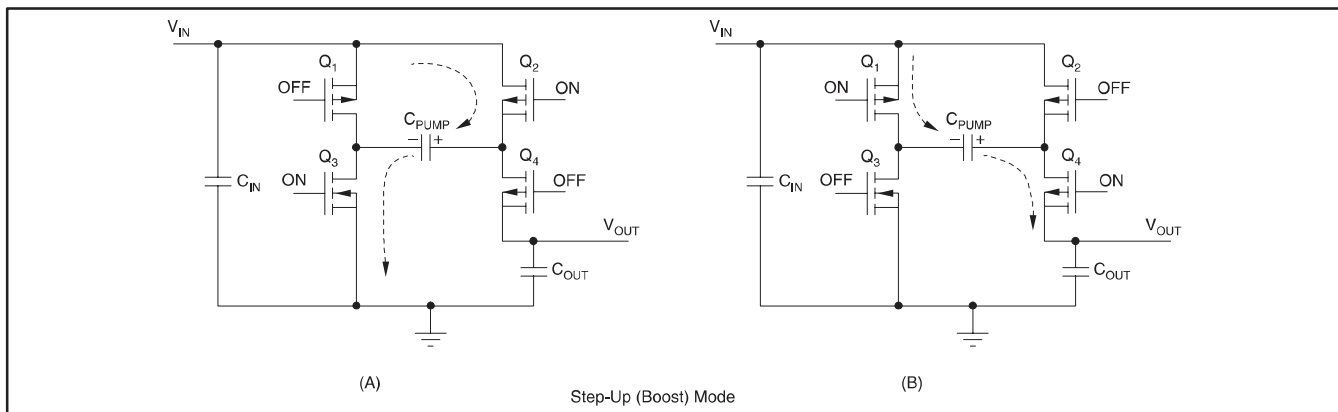
In normal operation, the charging of the pump and output capacitors usually leads to relatively high peak input currents which can be much higher than the average load current. The regulator incorporates circuitry to limit the input peak current, lowering the total EMI production of the device and lowering output voltage ripple and input current ripple. Input capacitor ( $C_{IN}$ ) supplies most of the charge required by input current peaks.

## PROTECTION

The regulator has thermal shutdown circuitry that protects it from damage caused by overload conditions. The thermal protection circuitry disables the output when the junction temperature reaches approximately 160°C, allowing the device to cool. When the junction temperature cools to approximately 140°C, the output circuitry is automatically re-enabled. Continuously running the regulator into thermal shutdown can degrade device reliability. The regulator also provides current limit to protect itself and the load.

## SHUTDOWN MODE

A control pin on the regulator can be used to place the device into an energy-saving shutdown mode. In this mode, the output is disconnected from the input as long as  $V_{IN}$  is greater than or equal to minimum  $V_{IN}$  and the input quiescent current is reduced to 1µA maximum.



**Figure 1. Simplified Schematic of the SN0304078 Operating in the Step-Up or Boost Mode**

## CAPACITOR SELECTION

For minimum output voltage ripple, the output capacitor  $C_{OUT}$  should be a ceramic, surface-mount type. Tantalum capacitors generally have a higher Effective Series Resistance (ESR) and may contribute to higher output voltage ripple. Leaded capacitors also increase ripple due to the higher inductance of the package itself. To achieve best operation with low input voltage and high load current, the input and pump capacitors ( $C_{IN}$  and  $C_{PUMP}$ , respectively) should also be surface-mount ceramic types. In all cases, X7R or X5R dielectric are recommended. See the typical operating circuit shown in Figure 2 for component values.

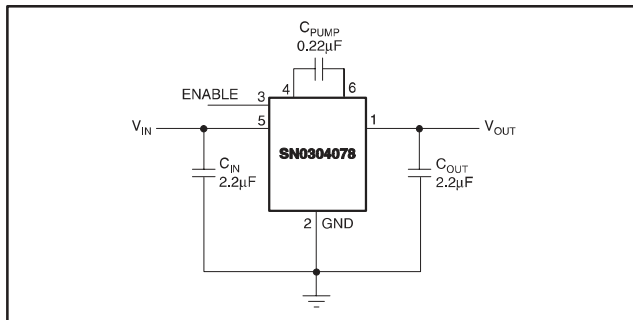


Figure 2. Typical Operating Circuit

With light loads or higher input voltage, a smaller  $0.1\mu\text{F}$  pump capacitor ( $C_{PUMP}$ ) and smaller  $1\mu\text{F}$  input and output capacitors ( $C_{IN}$  and  $C_{OUT}$ , respectively) can be used. To minimize output voltage ripple, increase the output capacitor,  $C_{OUT}$ , to  $10\mu\text{F}$  or larger.

The capacitors listed in Table 1 can be used with the SN0304078. This is only a representative list of those parts that are compatible.

## EFFICIENCY

The efficiency of the charge pump regulator varies with the output voltage, the applied input voltage, the load current, and the internal operation mode of the device.

The approximate efficiency is given by:

$$\text{Efficiency (\%)} = V_{OUT} / (2 \times V_{IN}) \times 100$$

See the efficiency curves in the Typical Characteristics section for various loads and input voltages.

## LAYOUT

Large transient currents flow in the  $V_{IN}$ ,  $V_{OUT}$ , and GND traces. To minimize both input and output ripple, keep the capacitors as close as possible to the regulator using short, direct circuit traces.

A suggested PCB routing is shown in Figure 3. The trace lengths from the input and output capacitors have been kept as short as possible.

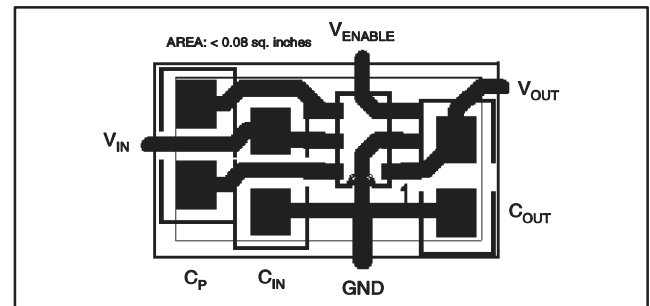


Figure 3. Suggested PCB Design for Minimum Ripple

Table 1. Suggested Capacitors.

MANUFACTURER	PART NUMBER	VALUE	TOLERANCE	DIELECTRIC MATERIAL	PACKAGE SIZE	RATED WORKING VOLTAGE
Kemet	C1206C255K8RAC	2.2µF	±10%	X7R	1206	10V
	C1206C224K8RAC	0.22µF	±10%	X7R	1206	10V
Panasonic	ECJ-2YBOJ225K	2.2µF	±10%	X5R	805	6.3V
	ECJ-2VBIC224K	0.22µF	±10%	X7R	805	16V
	ECJ-2VBIC104	0.1µF	±10%	X7R	805	16V
Taiyo Yuden	EMK316BJ225KL	2.2µF	±10%	X7R	1206	16V
	TKM316BJ224KF	0.22µF	±10%	X7R	1206	25V

APPLICATION CIRCUITS

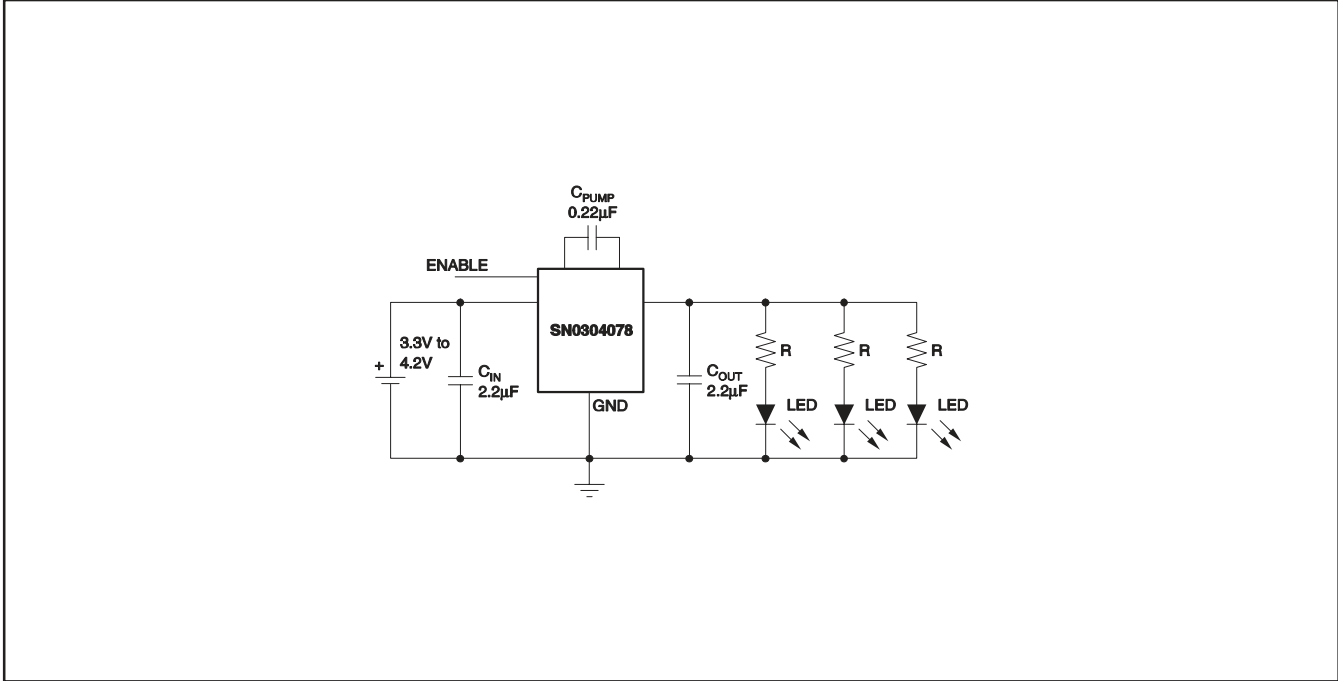


Figure 4. SN0304078 Circuit for Driving LEDs



---

## PACKAGING INFORMATION

ORDERABLE DEVICE	STATUS(1)	PACKAGE TYPE	PACKAGE DRAWING	PINS	PACKAGE QTY
SN0304078DBVR	ACTIVE	SOP	DBV	6	3000
SN0304078DBVT	ACTIVE	SOP	DBV	6	250

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSELETE:** TI has discontinued the production of the device.

---



## 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.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

<b>Products</b>		<b>Applications</b>	
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>	Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>	Automotive	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>	Broadband	<a href="http://www.ti.com/broadband">www.ti.com/broadband</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>	Digital Control	<a href="http://www.ti.com/digitalcontrol">www.ti.com/digitalcontrol</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>	Military	<a href="http://www.ti.com/military">www.ti.com/military</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>	Optical Networking	<a href="http://www.ti.com/opticalnetwork">www.ti.com/opticalnetwork</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>	Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
		Telephony	<a href="http://www.ti.com/telephony">www.ti.com/telephony</a>
		Video & Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>
		Wireless	<a href="http://www.ti.com/wireless">www.ti.com/wireless</a>

Mailing Address: Texas Instruments  
Post Office Box 655303 Dallas, Texas 75265

Copyright © 2003, Texas Instruments Incorporated