



## 60mA Switched-Cap BUCK/BOOST CONVERTER

### FEATURES

- **Wide Input Range: 1.8V to 5.5V**
- **Automatic Step-Up/Step-Down Operation**
- **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**
- **Six Output Voltages Available: 5.5V, 5.0V, 3.3V, 3.0V, 2.7V, 2.5V**
- **Small Packages:**
  - SOT23-6
  - TSOT23-6 (REG71055 and REG71050 Only)
- **Evaluation Modules Available: REG710EVM-33, REG710EVM-5**

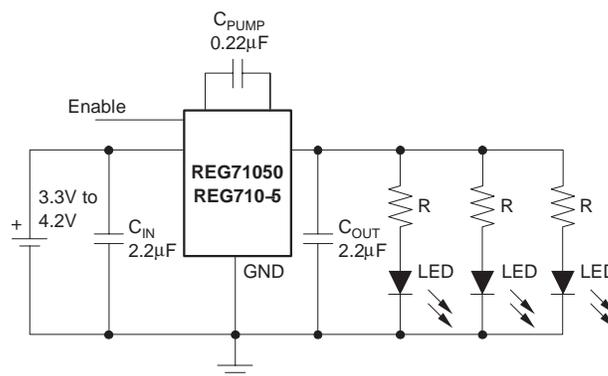
### DESCRIPTION

The REG710 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 1.8V to 5.5V makes the REG710 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. It works equally well for step-up or step-down applications without the need for an inductor, providing low EMI DC/DC conversion. The high switching frequency allows the use of small surface-mount capacitors, saving board space and reducing cost. The REG710 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. The 5.5V version of the REG710 is available in a thin TSOT23-6 package. All other versions are available in a small SOT23-6 package.

### 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**



REG710 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.

**ABSOLUTE MAXIMUM RATINGS(1)**

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)	+240°C

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



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.

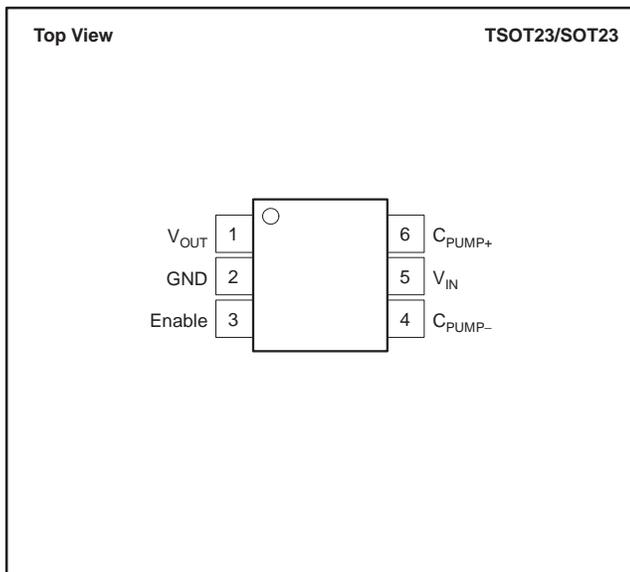
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

**PACKAGE ORDERING INFORMATION**

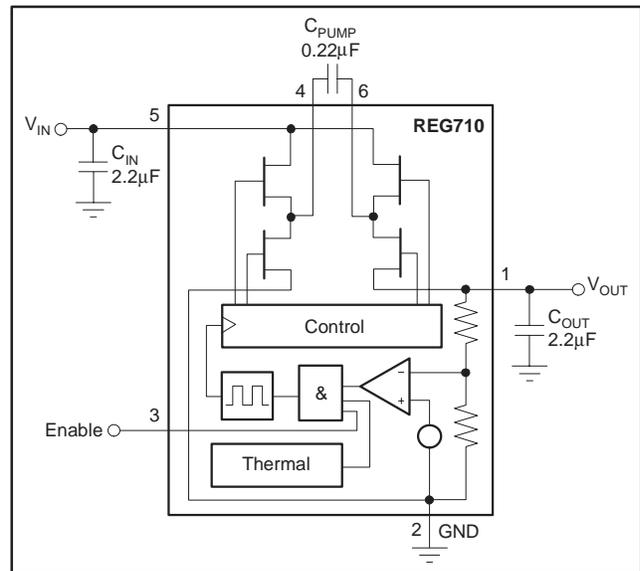
PRODUCT	OUTPUT VOLTAGE	PACKAGE-LEAD	PACKAGE DESIGNATOR(1)	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING(2)	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
5.5V Output REG71055DDC	5.5V	TSOT23-6	DDC	-40°C to +85°C	R10H	REG71055DDCT	Tape and Reel, 250
						REG71055DDCR	Tape and Reel, 3000
5V Output REG710NA-5	5.0V	SOT23-6	DBV	-40°C to +85°C	R10B	REG710NA-5/250	Tape and Reel, 250
						REG710NA-5/3K	Tape and Reel, 3000
5V Output REG71050DDC	5.0V	TSOT23-6	DDC	-40°C to +85°C	GAAI	REG71050DDCT	Tape and Reel, 250
						REG71050DDCR	Tape and Reel, 3000
3.3V Output REG710NA-3.3	3.3V	SOT23-6	DBV	-40°C to +85°C	R10C	REG710NA-3.3/250	Tape and Reel, 250
						REG710NA-3.3/3K	Tape and Reel, 3000
3V Output REG710NA-3	3.0V	SOT23-6	DBV	-40°C to +85°C	R10D	REG710NA-3/250	Tape and Reel, 250
						REG710NA-3/3K	Tape and Reel, 3000
2.7V Output REG710NA-2.7	2.7V	SOT23-6	DBV	-40°C to +85°C	R10F	REG710NA-2.7/250	Tape and Reel, 250
						REG710NA-2.7/3K	Tape and Reel, 3000
2.5V Output REG710NA-2.5	2.5V	SOT23-6	DBV	-40°C to +85°C	R10G	REG710NA-2.5/250	Tape and Reel, 250
						REG710NA-2.5/3K	Tape and Reel, 3000

NOTES: (1) For the most current specifications and product information, refer to our web site at 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	REG710NA			UNITS
		MIN	TYP	MAX	
<b>INPUT VOLTAGE</b>					
Tested Startup					
REG71055	See conditions under Output Voltage with a resistive load not lower than typical $V_{OUT}/I_{OUT}$ .	<b>3.0</b>		<b>5.5</b>	V
REG710-5		<b>2.7</b>		<b>5.5</b>	V
All Other Models		<b>1.8</b>		<b>5.5</b>	V
<b>OUTPUT VOLTAGE</b>					
REG71055	$I_{OUT} \leq 10\text{mA}$ , $3.0\text{V} \leq V_{IN} \leq 5.5\text{V}$	<b>5.2</b>	5.5	<b>5.8</b>	V
	$I_{OUT} \leq 30\text{mA}$ , $3.25\text{V} \leq V_{IN} \leq 5.5\text{V}$	<b>5.2</b>	5.5	<b>5.8</b>	V
REG710-5, REG71050	$I_{OUT} \leq 10\text{mA}$ , $2.7\text{V} \leq V_{IN} \leq 5.5\text{V}$	<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
REG710-3.3	$I_{OUT} \leq 10\text{mA}$ , $1.8\text{V} \leq V_{IN} \leq 5.5\text{V}$	<b>3.10</b>	3.3	<b>3.50</b>	V
	$I_{OUT} \leq 30\text{mA}$ , $2.2\text{V} \leq V_{IN} \leq 5.5\text{V}$	<b>3.10</b>	3.3	<b>3.50</b>	V
REG710-3	$I_{OUT} \leq 10\text{mA}$ , $1.8\text{V} \leq V_{IN} \leq 5.5\text{V}$	<b>2.82</b>	3.0	<b>3.18</b>	V
	$I_{OUT} \leq 30\text{mA}$ , $2.2\text{V} \leq V_{IN} \leq 5.5\text{V}$	<b>2.82</b>	3.0	<b>3.18</b>	V
REG710-2.7	$I_{OUT} \leq 10\text{mA}$ , $1.8\text{V} \leq V_{IN} \leq 5.5\text{V}$	<b>2.54</b>	2.7	<b>2.86</b>	V
	$I_{OUT} \leq 30\text{mA}$ , $2.0\text{V} \leq V_{IN} \leq 5.5\text{V}$	<b>2.54</b>	2.7	<b>2.86</b>	V
REG710-2.5	$I_{OUT} \leq 10\text{mA}$ , $1.8\text{V} \leq V_{IN} \leq 5.5\text{V}$	<b>2.35</b>	2.5	<b>2.65</b>	V
	$I_{OUT} \leq 30\text{mA}$ , $2.0\text{V} \leq V_{IN} \leq 5.5\text{V}$	<b>2.35</b>	2.5	<b>2.65</b>	V
<b>OUTPUT CURRENT</b>					
Nominal		30			mA
Short Circuit <sup>(1)</sup>			100		mA
<b>OSCILLATOR FREQUENCY<sup>(2)</sup></b>			1.0		MHz
<b>EFFICIENCY<sup>(3)</sup></b>	$I_{OUT} = 10\text{mA}$ , $V_{IN} = 1.8\text{V}$ , REG710-3.3		90		%
<b>RIPPLE VOLTAGE<sup>(4)</sup></b>	$I_{OUT} = 30\text{mA}$		35		mVp-p
<b>ENABLE CONTROL</b>	$V_{IN} = 1.8\text{V}$ 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	$V_{IN} = 1.8\text{V}$ 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		$^{\circ}\text{C}/\text{W}$
	TSOT23-6		220		$^{\circ}\text{C}/\text{W}$

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

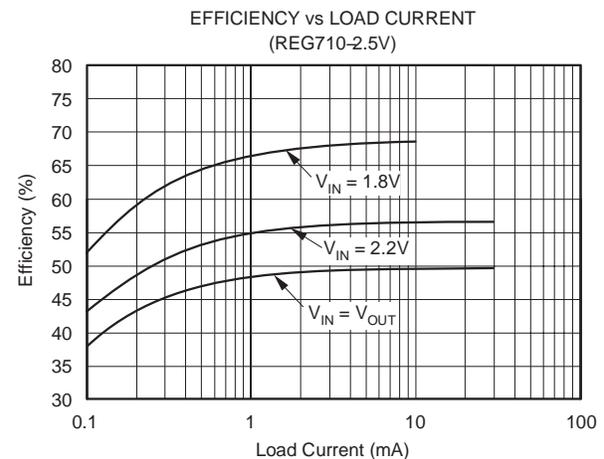
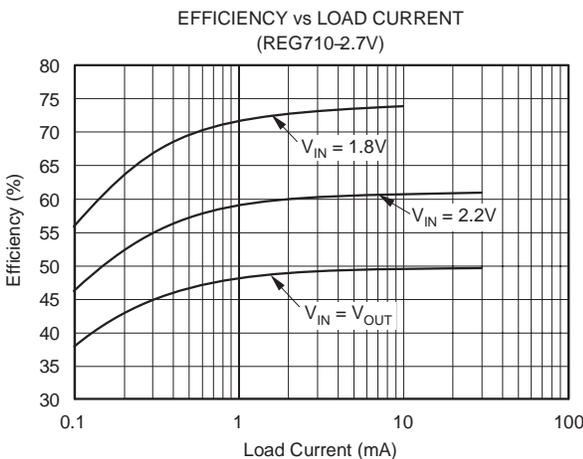
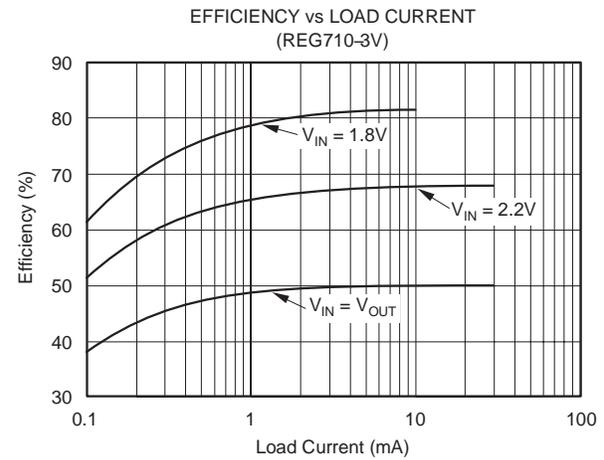
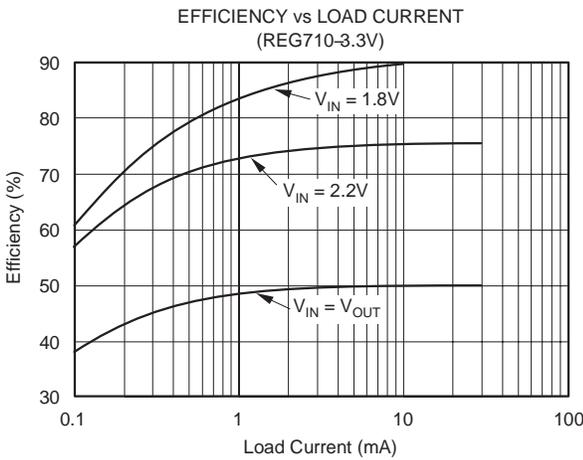
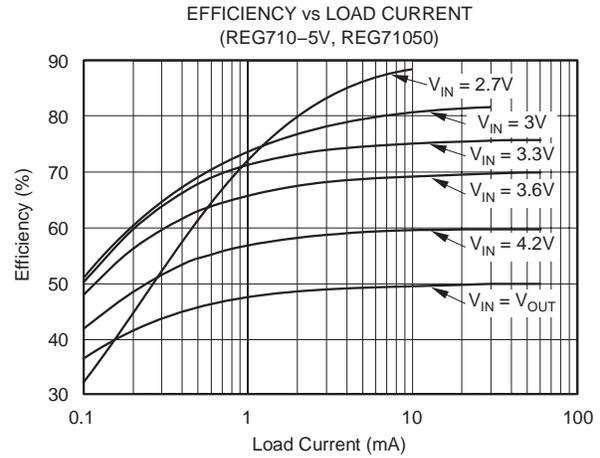
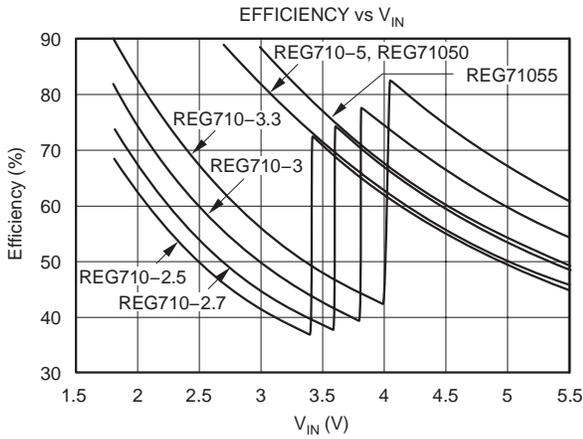
(2) The converter regulates by enabling and disabling periods of switching cycles. The switching frequency is the oscillator frequency during an active period.

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

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

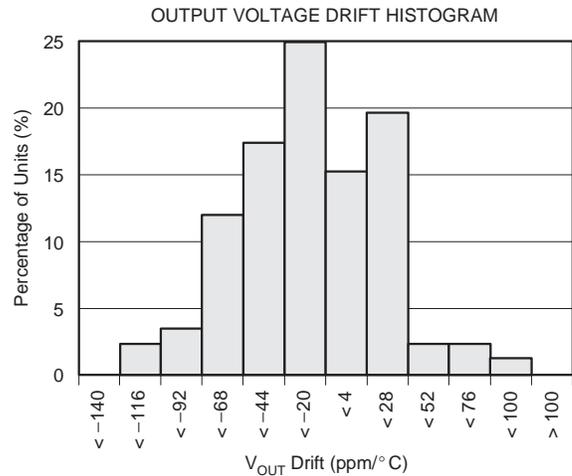
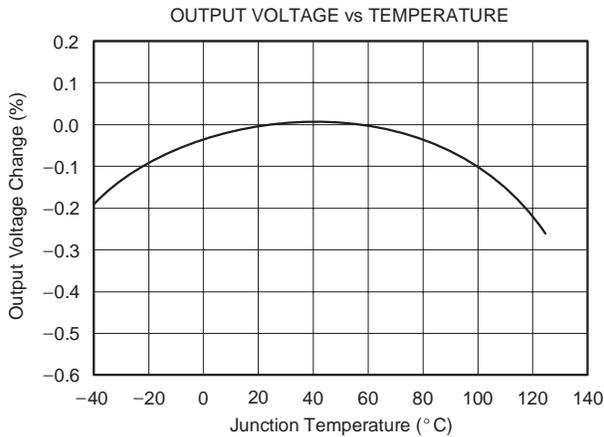
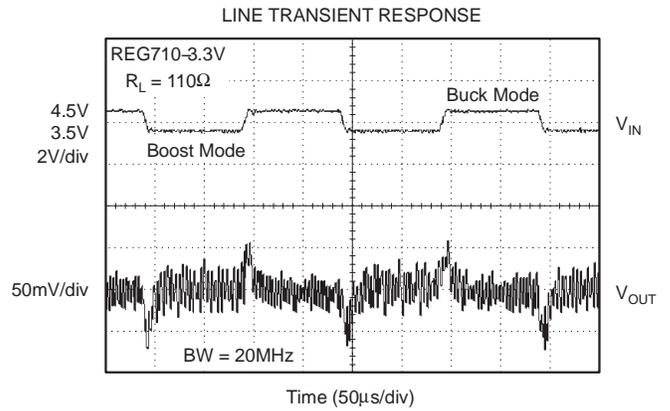
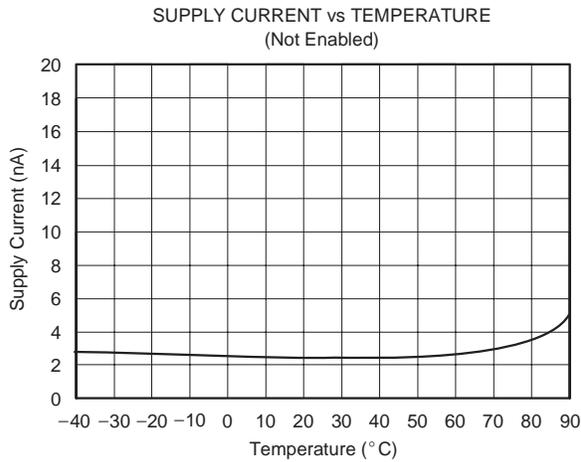
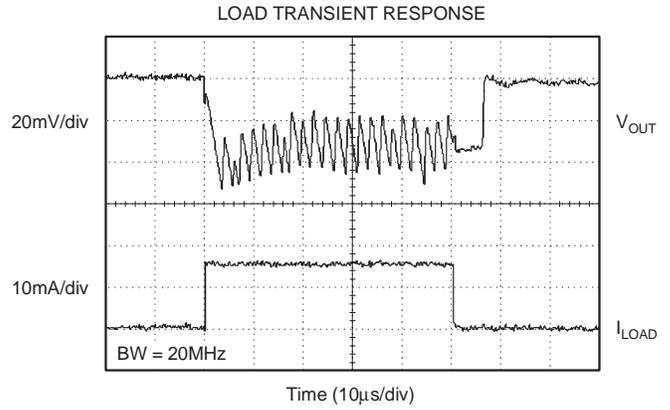
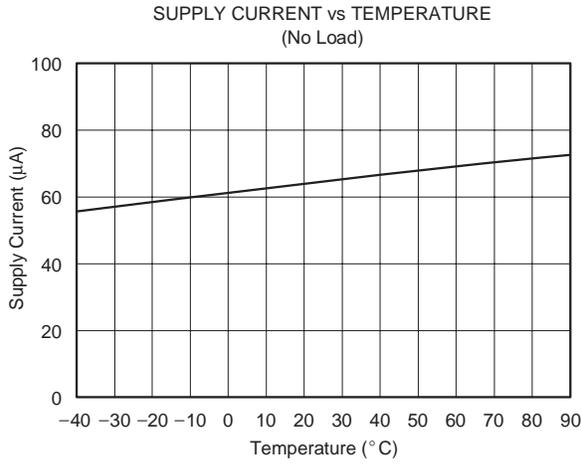
TYPICAL CHARACTERISTICS

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.



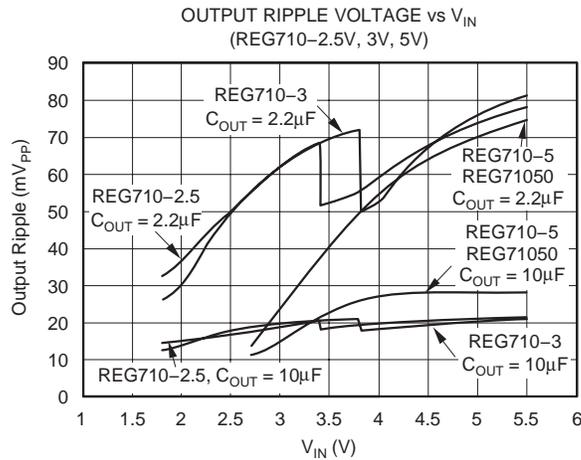
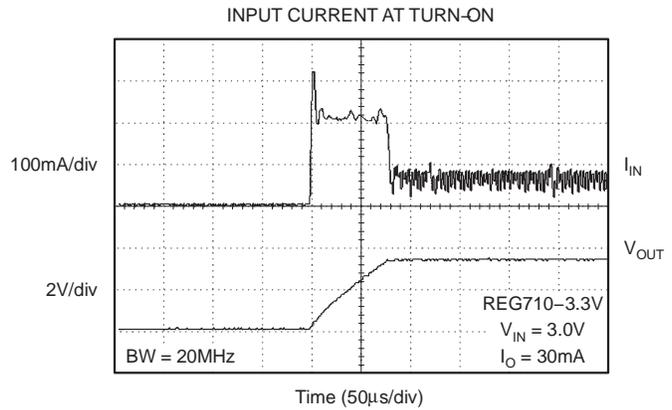
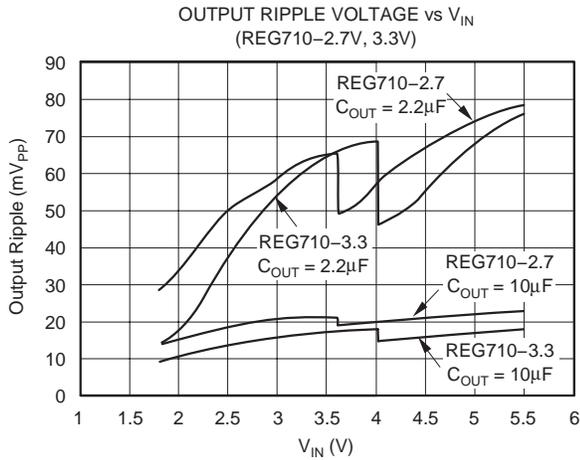
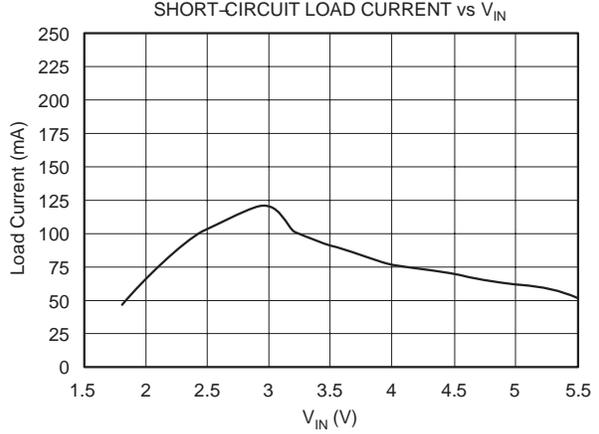
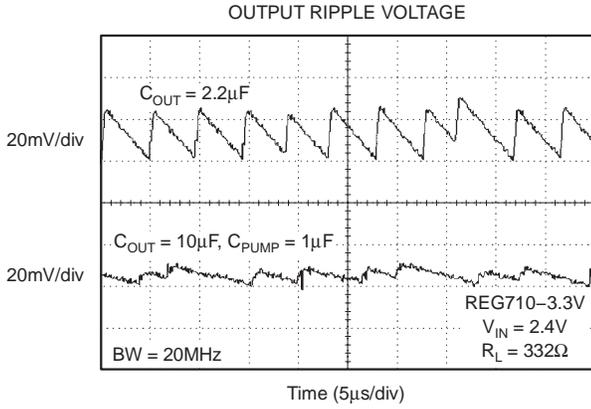
**TYPICAL CHARACTERISTICS (Cont.)**

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.



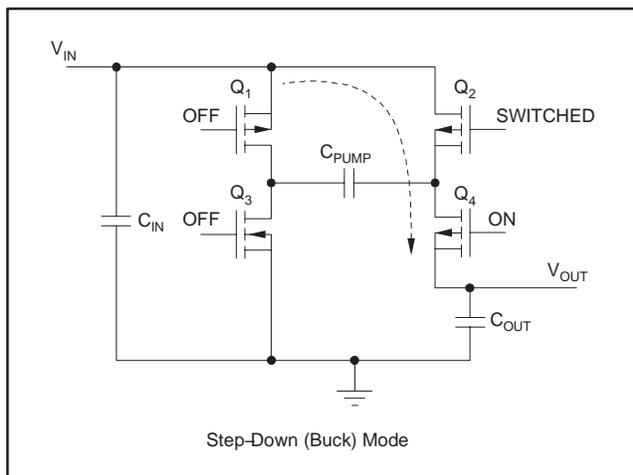
**TYPICAL CHARACTERISTICS (Cont.)**

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## THEORY OF OPERATION

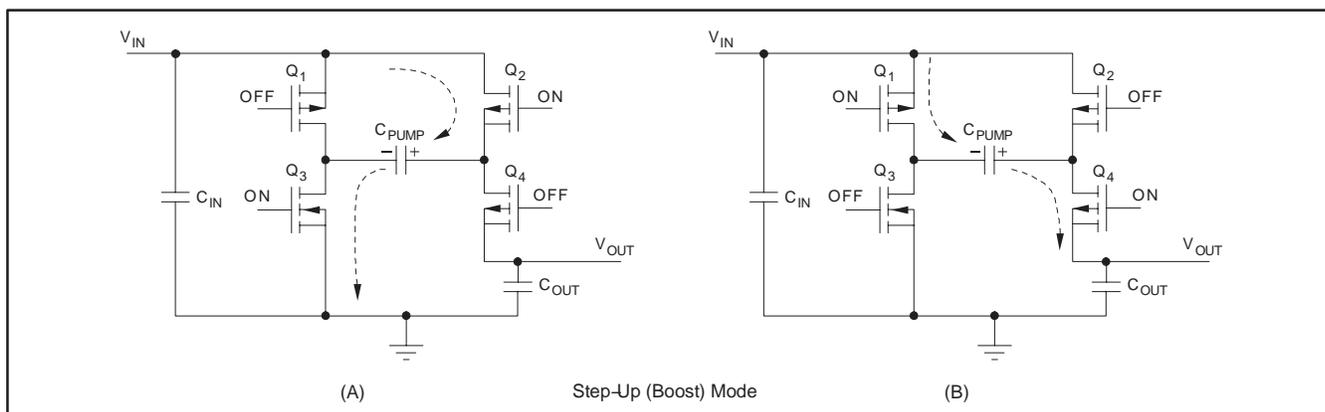
The REG710 regulated charge pump provides a regulated output voltage for input voltages ranging from less than the output to greater than the output. This is accomplished by automatic mode switching within the device. When the input voltage is greater than the required output, the unit functions as a variable frequency switch-mode regulator. This operation is shown in Figure 1. Transistors  $Q_1$  and  $Q_3$  are held off,  $Q_4$  is on, and  $Q_2$  is switched as needed to maintain a regulated output voltage.



**Figure 1. Simplified Schematic of the REG710 Operating in the Step-Down Mode**

When the input voltage is less than the required output voltage, the device switches to a step-up or boost mode of operation, as shown in Figure 2.

A conversion clock of 50% duty cycle is generated. During the first half cycle the FET switches are configured as shown in Figure 2A, and  $C_{PUMP}$  charges to  $V_{IN}$ .



**Figure 2. Simplified Schematic of the REG710 Operating in the Step-Up or Boost Mode**

During the second half cycle the FET switches are configured as shown in Figure 2B, 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 that of 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

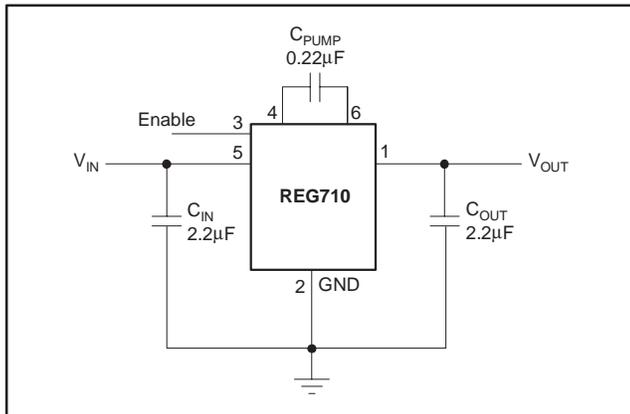
The regulator has thermal shutdown circuitry that protects it from damage caused by overload conditions. The thermal protection circuitry disables the output when the junction temperature reached approximately  $160^{\circ}\text{C}$ , allowing the device to cool. When the junction temperature cools to approximately  $140^{\circ}\text{C}$ , the output circuitry is automatically reenabled. Continuously running the regulator into thermal shutdown can degrade 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  $1\mu\text{A}$  maximum.

**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 3 for component values.



**Figure 3. Typical Operating Circuit**

With light loads or higher input voltage, a smaller 0.1µF pump capacitor ( $C_{PUMP}$ ) and smaller 1µF 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 10µF or larger.

The capacitors listed in Table 1 can be used with the REG710. 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 version, the applied input voltage, the load current, and the internal operation mode of the device.

The approximate efficiency is given by:

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

(step-up operating mode)

or

$$\frac{V_{OUT}}{V_{IN}} \times 100$$

(step-down operating mode)

Table 2 lists the approximate values of the input voltage at which the device changes internal operating mode.

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

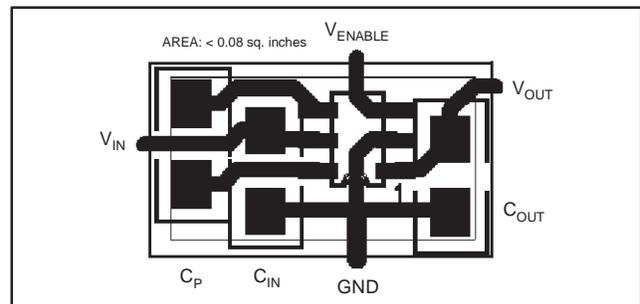
**Table 2. Operating Mode Change Versus  $V_{IN}$**

PRODUCT	OPERATING MODE CHANGES AT $V_{IN}$ OF
REG710-2.5	> 3.2V
REG710-2.7	> 3.4V
REG710-3	> 3.7V
REG710-3.3	> 4.0V
REG710-5, REG71050, REG71055	Step-Up Only

**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 4. The trace lengths from the input and output capacitors have been kept as short as possible.

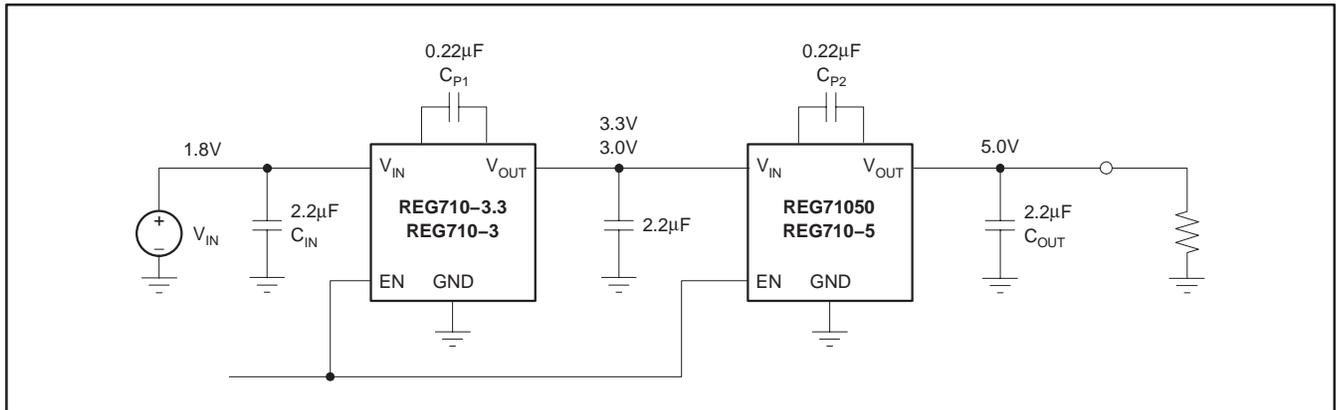


**Figure 4. Suggested PCB Design for Minimum Ripple**

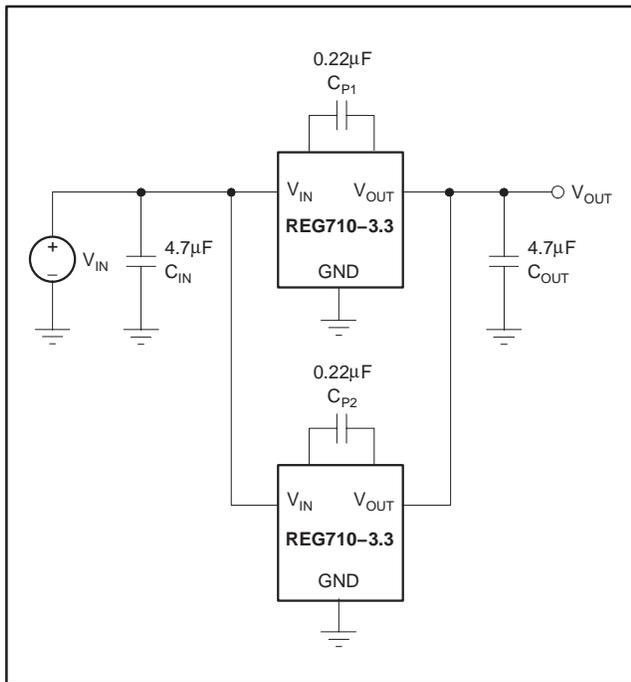
**Table 1. Suggested Capacitors**

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

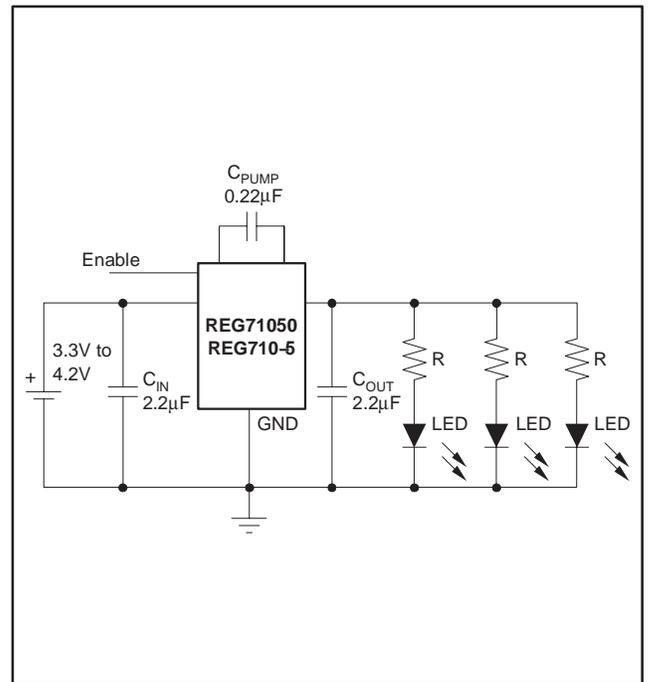
**APPLICATION CIRCUITS**



**Figure 5. REG710 Circuit for Step-Up Operation from 1.8V to 5.0V with 10mA Output Current**



**Figure 6. REG710 Circuit for Doubling the Output Current**



**Figure 7. REG710 Circuit for Driving LEDs**

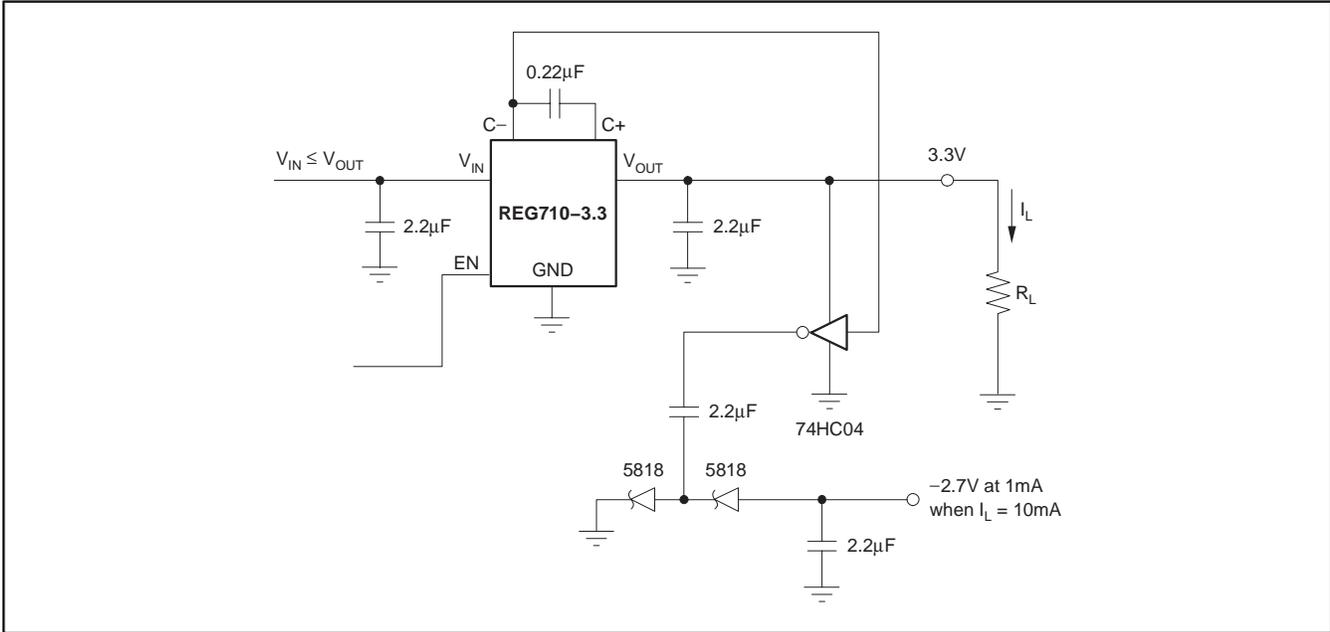


Figure 8. REG710 with Negative Bias Supply

**PACKAGING INFORMATION**

ORDERABLE DEVICE	STATUS(1)	PACKAGE TYPE	PACKAGE DRAWING	PINS	PACKAGE QTY
REG71055DDCR	ACTIVE	TO/SOT	DDC	6	3000
REG71055DDCT	ACTIVE	TO/SOT	DDC	6	250
REG710NA-2.5/250	ACTIVE	SOP	DBV	6	250
REG710NA-2.5/3K	ACTIVE	SOP	DBV	6	3000
REG710NA-2.7/250	ACTIVE	SOP	DBV	6	250
REG710NA-2.7/3K	ACTIVE	SOP	DBV	6	3000
REG710NA-3.3/250	ACTIVE	SOP	DBV	6	250
REG710NA-3.3/3K	ACTIVE	SOP	DBV	6	3000
REG710NA-3/250	ACTIVE	SOP	DBV	6	250
REG710NA-3/3K	ACTIVE	SOP	DBV	6	3000
REG710NA-5/250	ACTIVE	SOP	DBV	6	250
REG710NA-5/3K	ACTIVE	SOP	DBV	6	3000

(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.

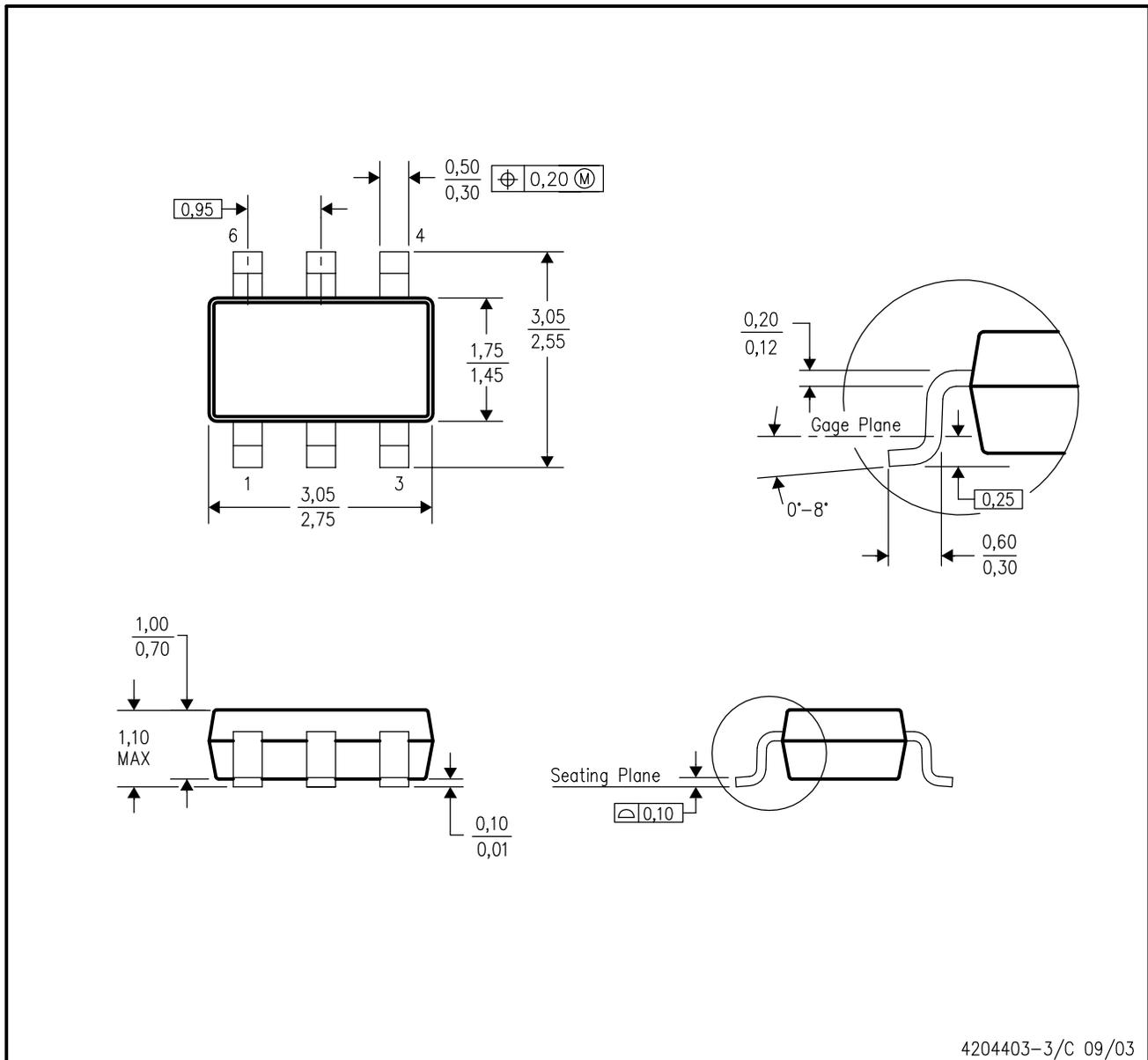
**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

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



DDC (R-PDSO-G6)

PLASTIC SMALL-OUTLINE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Body dimensions do not include mold flash or protrusion.
  - Falls within JEDEC MO-193 variation AA (6 pin).

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