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**

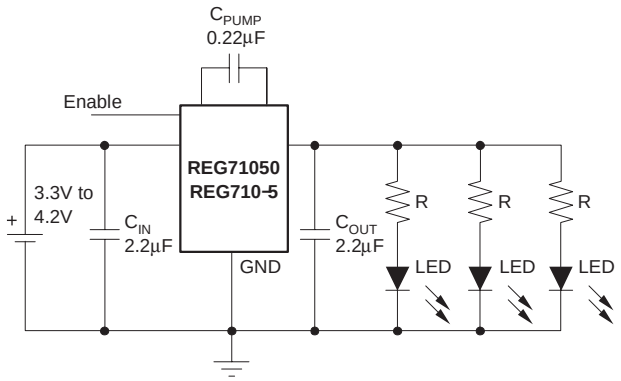
APPLICATIONS

- **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 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.



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.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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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.

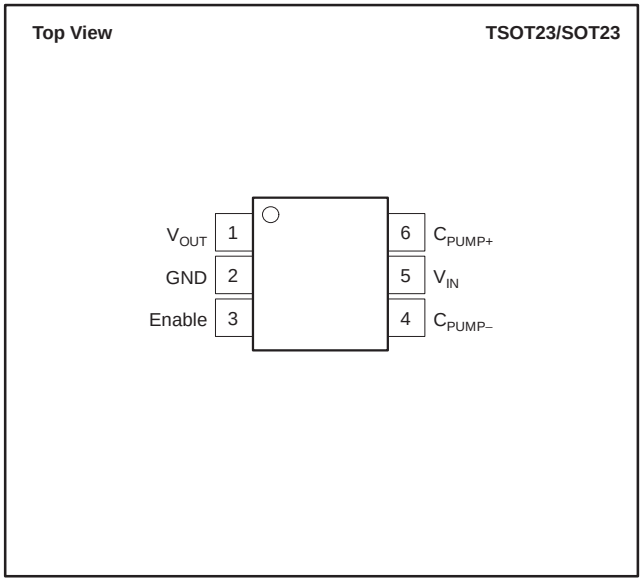
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE ORDERING INFORMATION

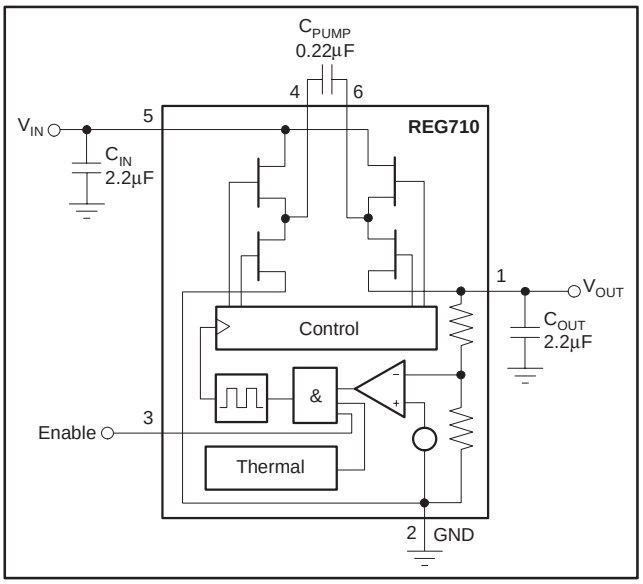
PRODUCT	OUTPUT VOLTAGE	PACKAGE-LEAD	PACKAGE DESIGNATOR(1)	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING(2)	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
5.5V Output REG71055DDC	5.5V	TSOT23−6	DDC	−40°C to +85°C	R10H	REG71055DDCT	Tape and Reel, 250
						REG71055DDCR	Tape and Reel, 3000
5V Output REG710NA-5	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°C to +85°C**

At T_A = +25°C, V_{IN} = V_{OUT}/2 + 0.75V, I_{OUT} = 10mA, C_{IN} = C_{OUT} = 2.2µF, C_{PUMP} = 0.22µF, V_{ENABLE} = 1.3V, unless otherwise noted.

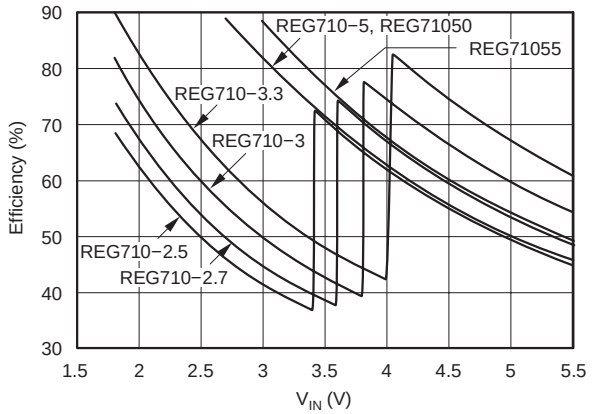
PARAMETER	CONDITIONS	REG710NA			UNITS
		MIN	TYP	MAX	
INPUT VOLTAGE					
Tested Startup					
REG71055	See conditions under Output Voltage with a resistive load not lower than typical V_{OUT}/I_{OUT}.	**3.0**		**5.5**	V
REG710-5		**2.7**		**5.5**	V
All Other Models		**1.8**		**5.5**	V
OUTPUT VOLTAGE					
REG71055	I_{OUT} ≤ 10mA, 3.0V ≤ V_{IN} ≤ 5.5V	**5.2**	5.5	**5.8**	V
	I_{OUT} ≤ 30mA, 3.25V ≤ V_{IN} ≤ 5.5V	**5.2**	5.5	**5.8**	V
REG710-5, REG71050	I_{OUT} ≤ 10mA, 2.7V ≤ V_{IN} ≤ 5.5V	**4.7**	5.0	**5.3**	V
	I_{OUT} ≤ 30mA, 3.0V ≤ V_{IN} ≤ 5.5V	**4.7**	5.0	**5.3**	V
	I_{OUT} ≤ 60mA, 3.3V ≤ V_{IN} ≤ 4.2V	**4.6**	5.0	**5.4**	V
REG710-3.3	I_{OUT} ≤ 10mA, 1.8V ≤ V_{IN} ≤ 5.5V	**3.10**	3.3	**3.50**	V
	I_{OUT} ≤ 30mA, 2.2V ≤ V_{IN} ≤ 5.5V	**3.10**	3.3	**3.50**	V
REG710-3	I_{OUT} ≤ 10mA, 1.8V ≤ V_{IN} ≤ 5.5V	**2.82**	3.0	**3.18**	V
	I_{OUT} ≤ 30mA, 2.2V ≤ V_{IN} ≤ 5.5V	**2.82**	3.0	**3.18**	V
REG710-2.7	I_{OUT} ≤ 10mA, 1.8V ≤ V_{IN} ≤ 5.5V	**2.54**	2.7	**2.86**	V
	I_{OUT} ≤ 30mA, 2.0V ≤ V_{IN} ≤ 5.5V	**2.54**	2.7	**2.86**	V
REG710-2.5	I_{OUT} ≤ 10mA, 1.8V ≤ V_{IN} ≤ 5.5V	**2.35**	2.5	**2.65**	V
	I_{OUT} ≤ 30mA, 2.0V ≤ V_{IN} ≤ 5.5V	**2.35**	2.5	**2.65**	V
OUTPUT CURRENT					
Nominal		30			mA
Short Circuit(1)			100		mA
OSCILLATOR FREQUENCY(2)			1.0		MHz
EFFICIENCY(3)	I_{OUT} = 10mA, V_{IN} = 1.8V, REG710−3.3		90		%
RIPPLE VOLTAGE(4)	I_{OUT} = 30mA		35		mVp−p
ENABLE CONTROL	V_{IN} = 1.8V to 5.5V				
Logic High Input Voltage		**1.3**		**V_{IN}**	V
Logic Low Input Voltage		**−0.2**		**0.4**	V
Logic High Input Current				100	nA
Logic Low Input Current				100	nA
THERMAL SHUTDOWN					
Shutdown Temperature			160		°C
Shutdown Recovery			140		°C
SUPPLY CURRENT					
(Quiescent Current)	I_{OUT} = 0mA		65	100	µA
In Shutdown Mode	V_{IN} = 1.8V to 5.5V, Enable = 0V		0.01	1	µA
TEMPERATURE RANGE					
Specification Ambient Temperature T_A		−40		+85	°C
Operating Ambient Temperature T_A		−55		+125	°C
Storage Ambient Temperature T_A		−65		+150	°C
Thermal Resistance, θ_{JA}	SOT23−6		200		°C/W
	TSOT23−6		220		°C/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 < 0.1Ω.

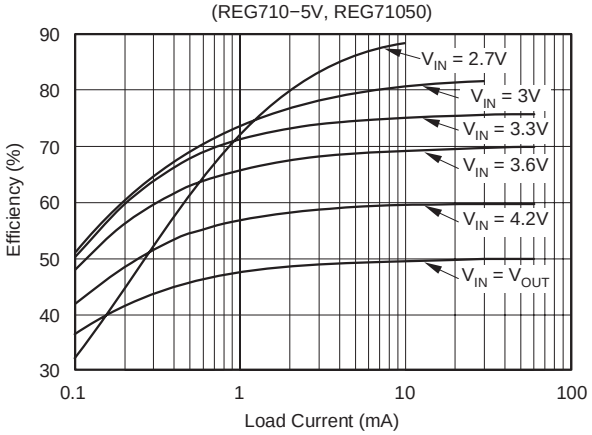
TYPICAL CHARACTERISTICS

At T_A = +25°C, V_{IN} = V_{OUT}/2 + 0.75V, I_{OUT} = 5mA, C_{IN} = C_{OUT} = 2.2µF, C_{PUMP} = 0.22µF, V_{ENABLE} = 1.3V, unless otherwise noted.

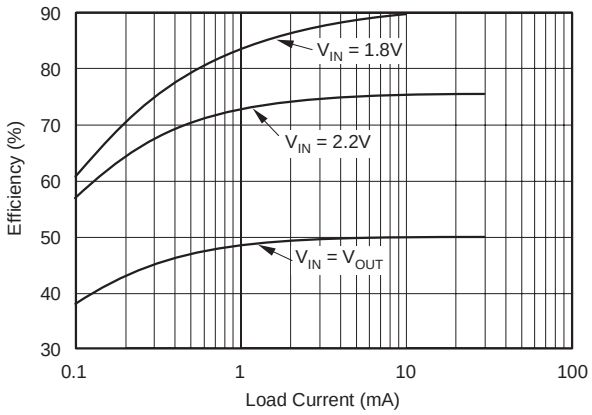
EFFICIENCY vs V_{IN}



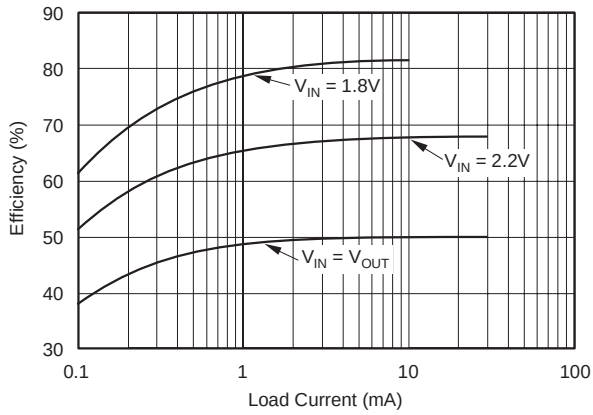
EFFICIENCY vs LOAD CURRENT
(REG710−5V, REG71050)



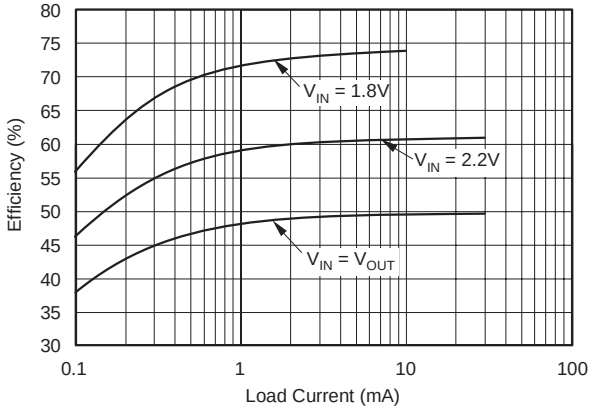
EFFICIENCY vs LOAD CURRENT
(REG710−3.3V)



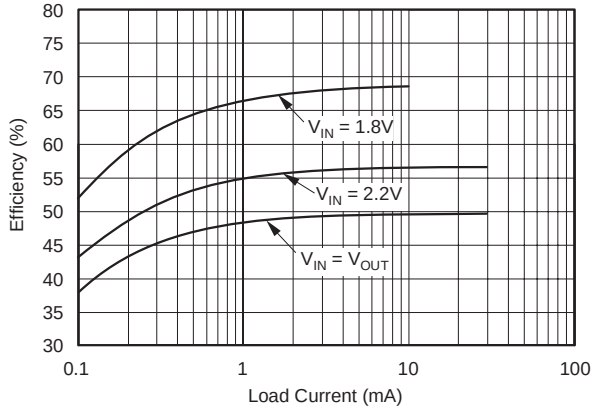
EFFICIENCY vs LOAD CURRENT
(REG710−3V)



EFFICIENCY vs LOAD CURRENT
(REG710−2.7V)



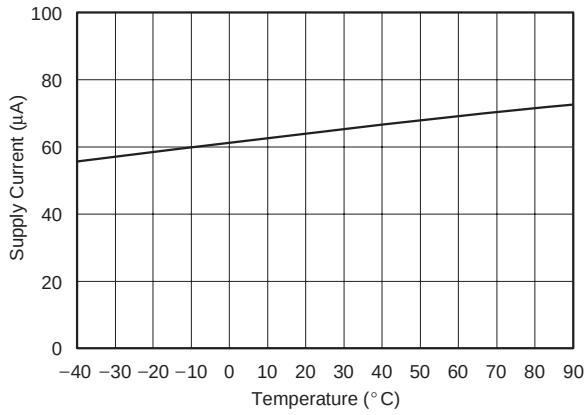
EFFICIENCY vs LOAD CURRENT
(REG710−2.5V)



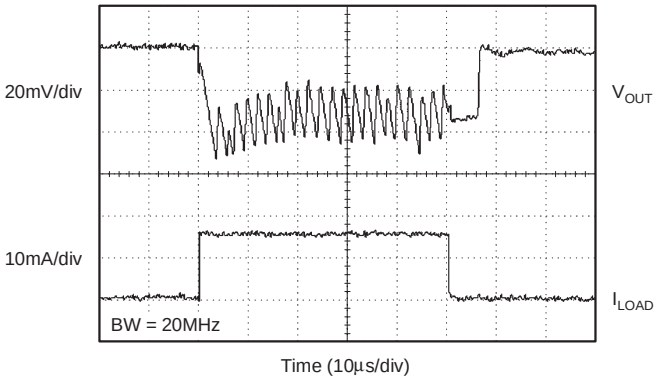
TYPICAL CHARACTERISTICS (Cont.)

At T_A = +25°C, V_{IN} = V_{OUT}/2 + 0.75V, I_{OUT} = 5mA, C_{IN} = C_{OUT} = 2.2µF, C_{PUMP} = 0.22µF, V_{ENABLE} = 1.3V, unless otherwise noted.

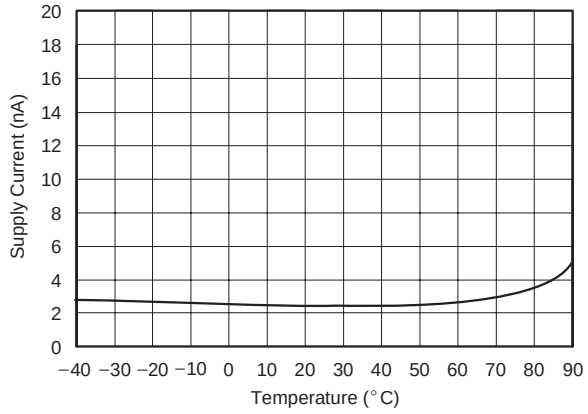
SUPPLY CURRENT vs TEMPERATURE
(No Load)



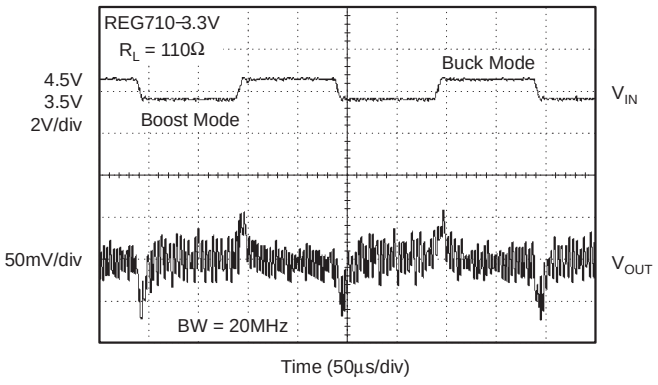
LOAD TRANSIENT RESPONSE



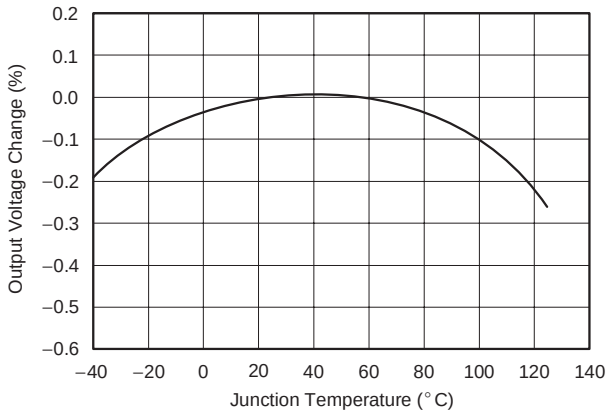
SUPPLY CURRENT vs TEMPERATURE
(Not Enabled)



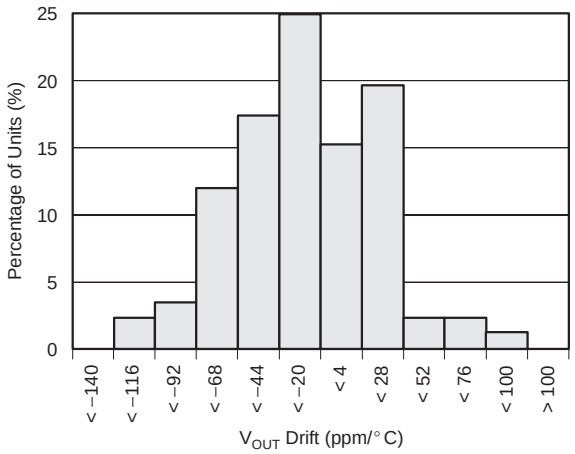
LINE TRANSIENT RESPONSE



OUTPUT VOLTAGE vs TEMPERATURE



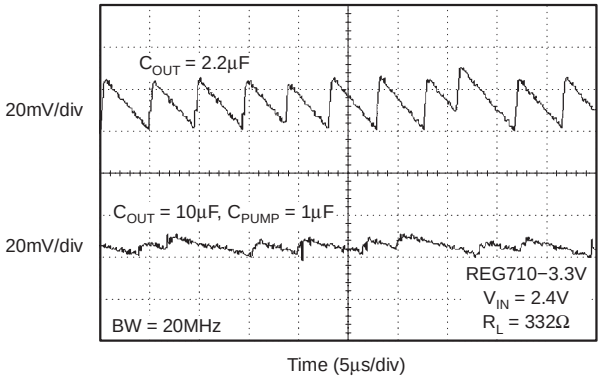
OUTPUT VOLTAGE DRIFT HISTOGRAM



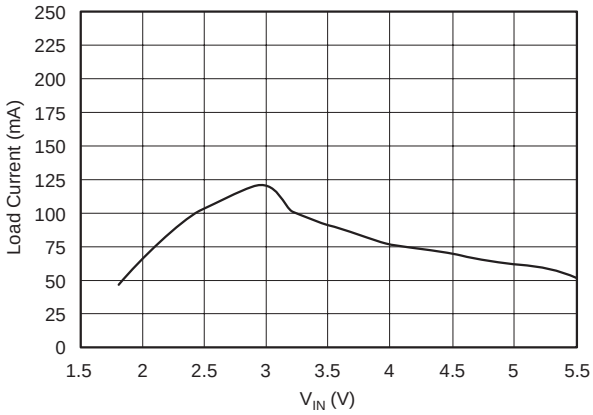
TYPICAL CHARACTERISTICS (Cont.)

At T_A = +25°C, V_{IN} = V_{OUT}/2 + 0.75V, I_{OUT} = 5mA, C_{IN} = C_{OUT} = 2.2µF, C_{PUMP} = 0.22µF, V_{ENABLE} = 1.3V, unless otherwise noted.

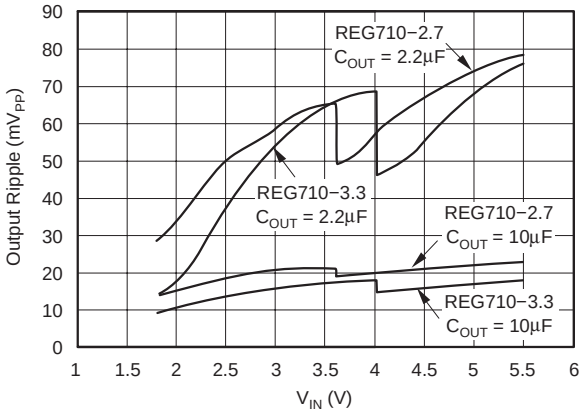
OUTPUT RIPPLE VOLTAGE



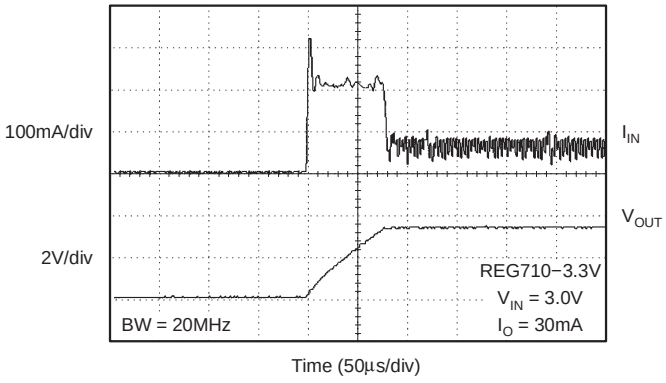
SHORT-CIRCUIT LOAD CURRENT vs V_{IN}



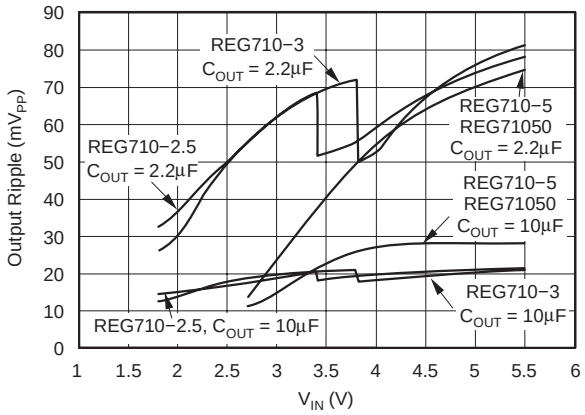
OUTPUT RIPPLE VOLTAGE vs V_{IN}
(REG710−2.7V, 3.3V)



INPUT CURRENT AT TURN-ON



OUTPUT RIPPLE VOLTAGE vs V_{IN}
(REG710−2.5V, 3V, 5V)



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.

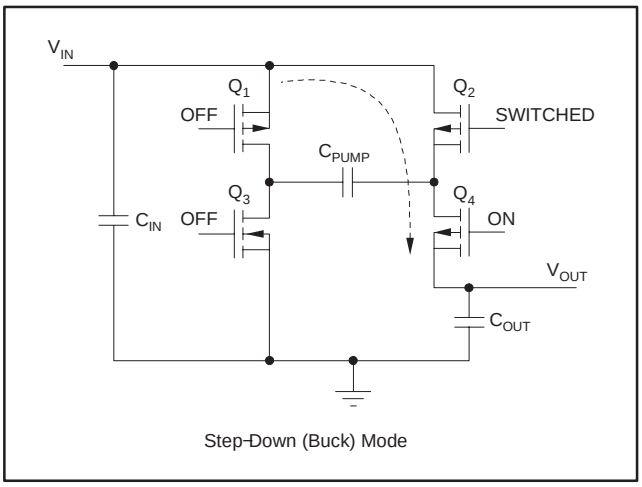


Figure 1. Simplified Schematic of the REG710 Operating in the Step-Down Mode

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}.

During the second half cycle the FET switched 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°C, allowing the device to cool. When the junction temperature cools to approximately 140°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 1µA maximum.

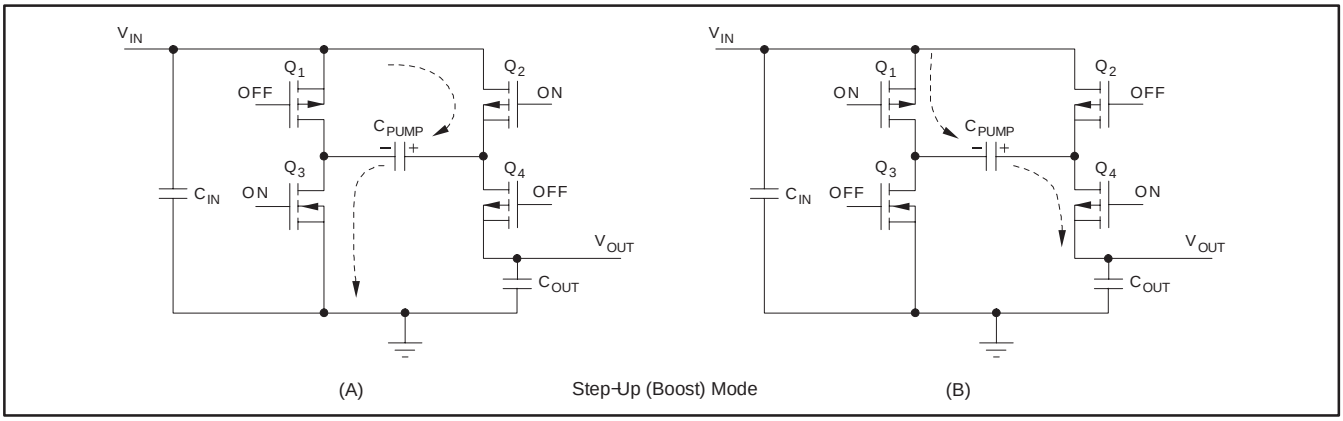


Figure 2. Simplified Schematic of the REG710 Operating in the Step-Up or Boost Mode

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 3 for component values.

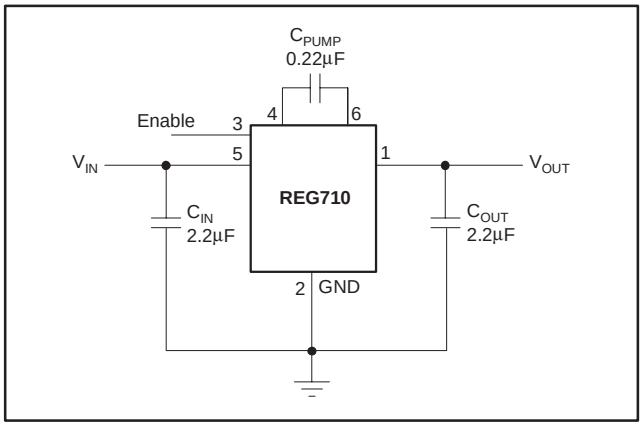


Figure 3. Typical Operating Circuit

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:

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

(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.

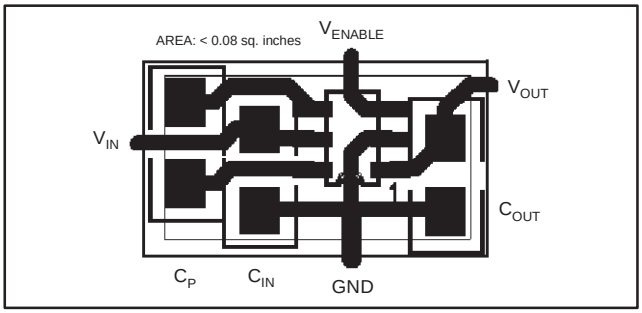


Figure 4. Suggested PCB Design for Minimum Ripple

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

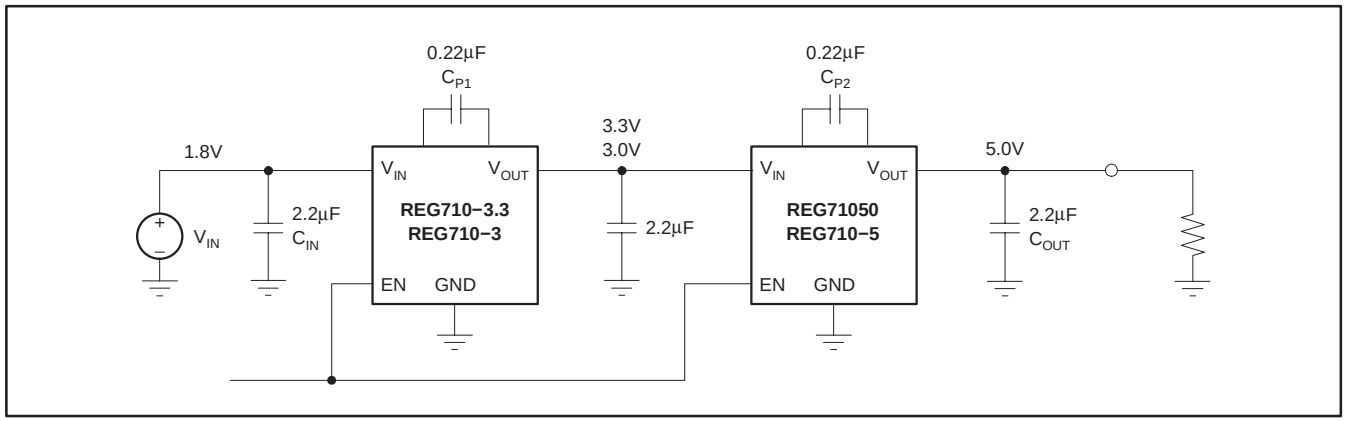


Figure 5. REG710 Circuit for Step-Up Operation from 1.8V to 5.0V with 10mA Output Current

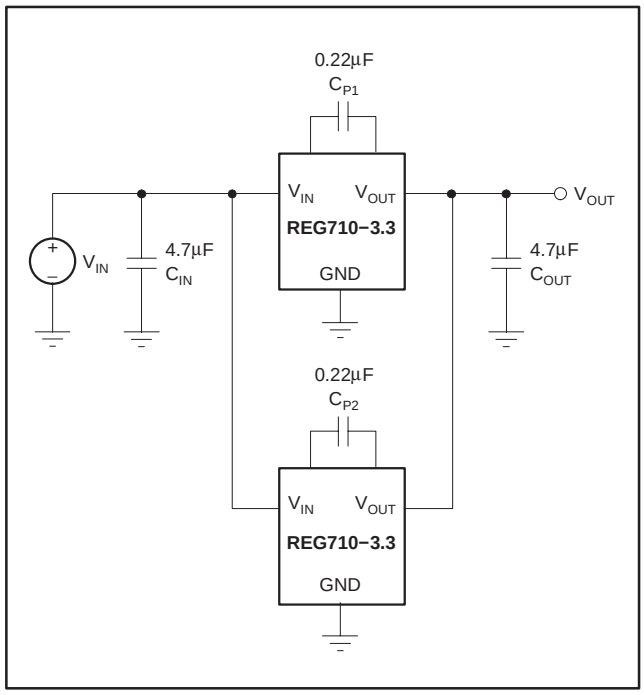


Figure 6. REG710 Circuit for Doubling the Output Current

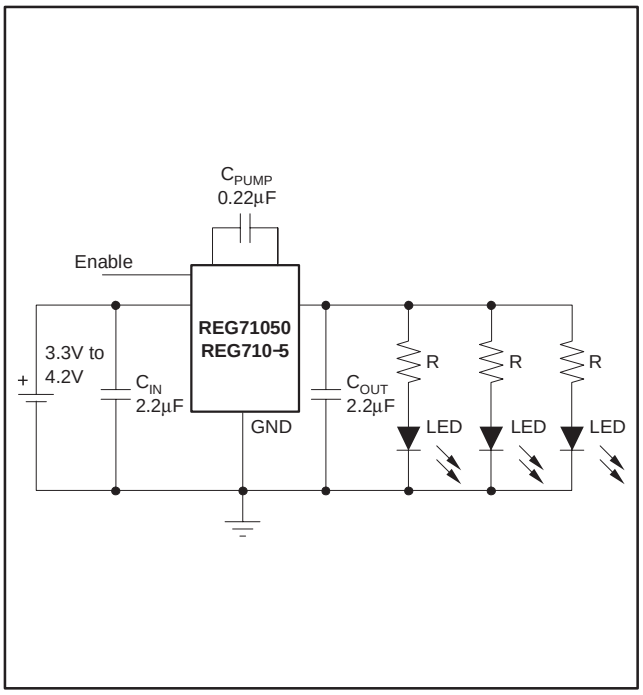


Figure 7. REG710 Circuit for Driving LEDs

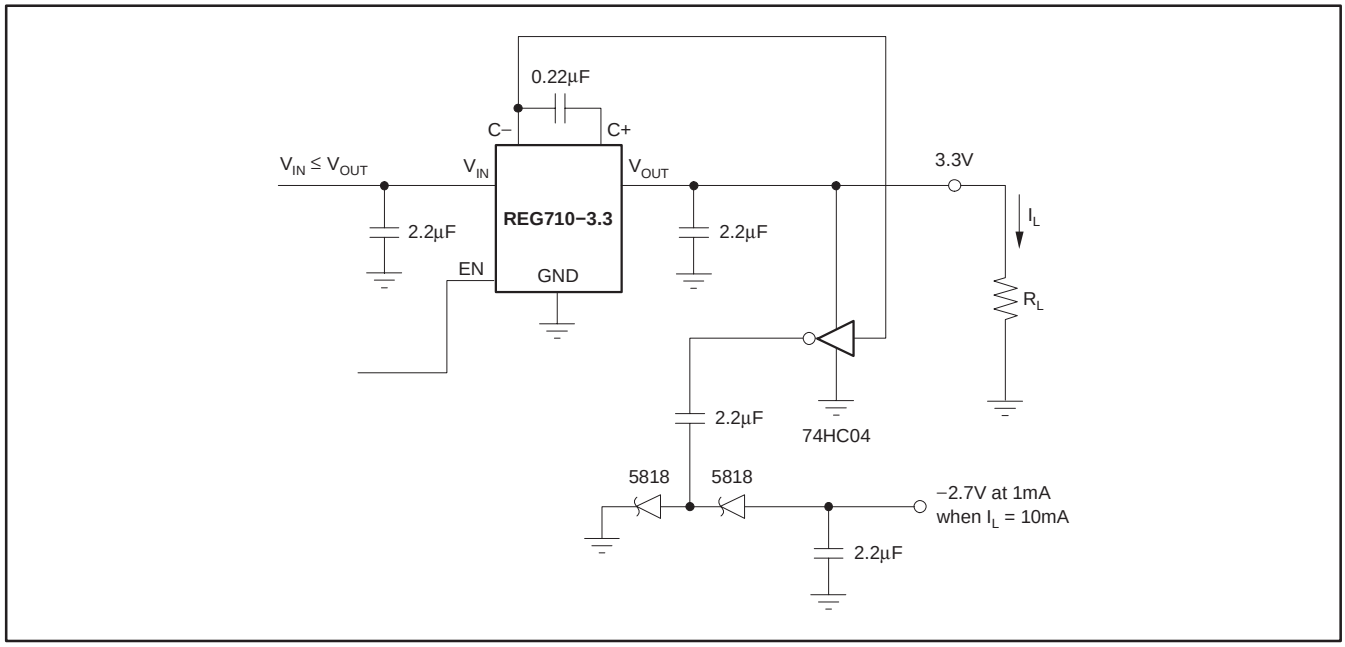


Figure 8. REG710 with Negative Bias Supply

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
REG71050DDCR	ACTIVE	TO/SOT	DDC	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG71050DDCRG4	ACTIVE	TO/SOT	DDC	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG71050DDCT	ACTIVE	TO/SOT	DDC	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG71055DDCR	ACTIVE	TO/SOT	DDC	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG71055DDCRG4	ACTIVE	TO/SOT	DDC	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG71055DDCT	ACTIVE	TO/SOT	DDC	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-2.5/250	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-2.5/3K	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-2.5/3KG4	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-2.7/250	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-2.7/3K	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-2.7/3KG4	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-3.3/250	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-3.3/250G4	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-3.3/3K	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-3.3/3KG4	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-3/250	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-3/250G4	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-3/3K	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-5/250	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-5/250G4	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-5/3K	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
REG710NA-5/3KG4	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

(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.

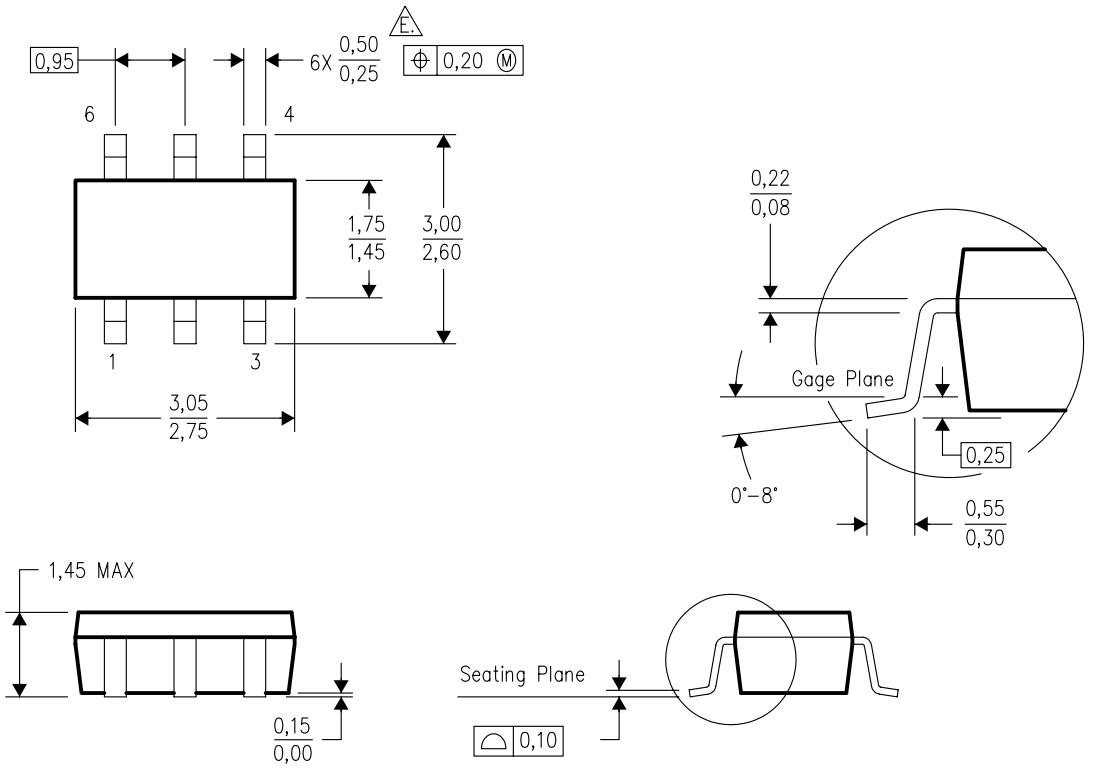
(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS) or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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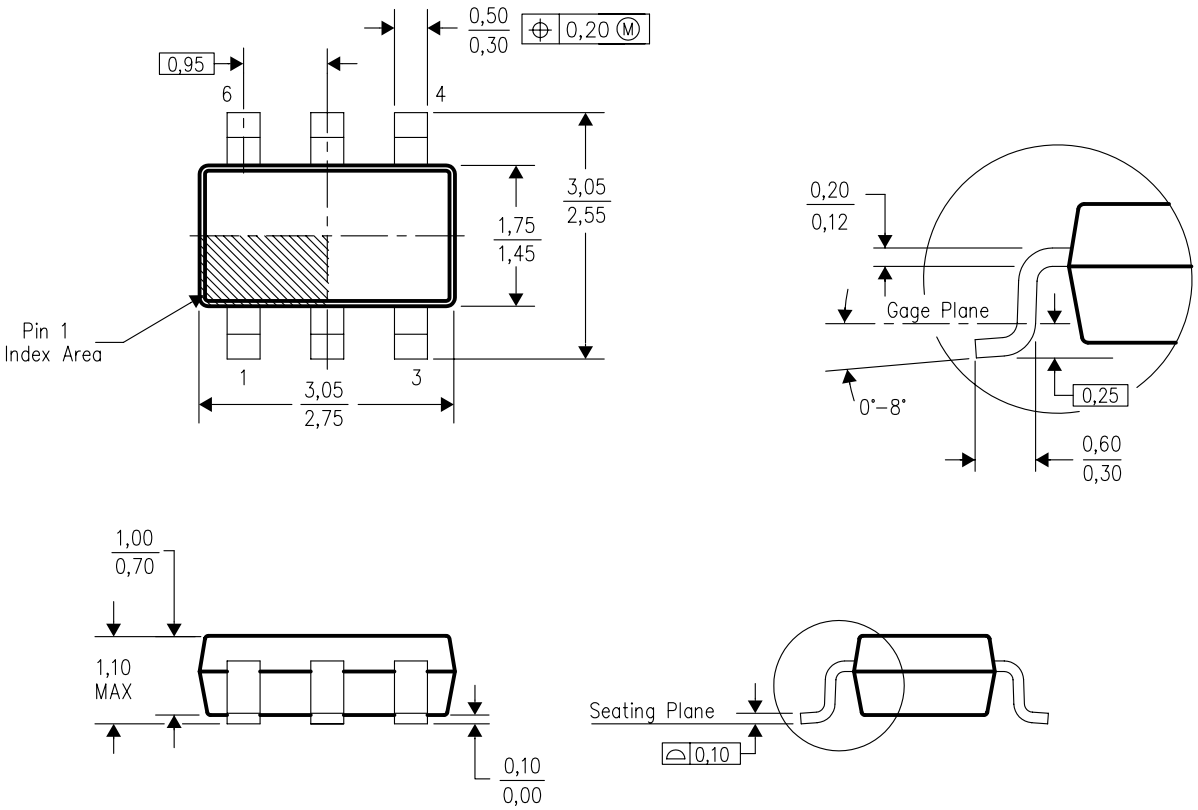
DBV (R–PDSO–G6) PLASTIC SMALL–OUTLINE PACKAGE



4073253–5/J 10/2005

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
D. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
E. Falls within JEDEC MO–178 Variation AB, except minimum lead width.

DDC (R–PDSO–G6) PLASTIC SMALL–OUTLINE



4204403–3/E 06/05

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

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