



## 50mA SWITCHED-CAP DC/DC CONVERTER

### FEATURES

- WIDE INPUT RANGE: 1.8V TO 5.5V  
5V VERSION: 2.7V 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
- FIVE OUTPUT VOLTAGES AVAILABLE: 5.0V, 3.3V, 3.0V, 2.7V, 2.5V
- THIN, SMALL PACKAGE: MSOP-8

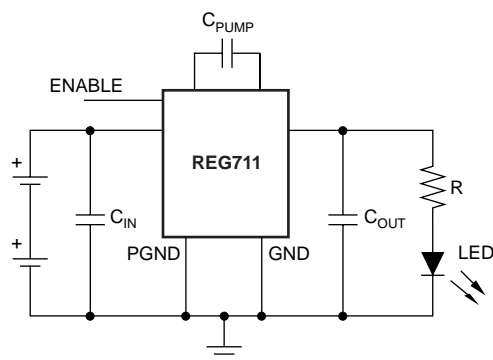
### APPLICATIONS

- SMART CARD READERS
- CELLULAR PHONES
- SIM CARD SUPPLIES
- PORTABLE COMMUNICATION DEVICES
- PERSONAL DIGITAL ASSISTANTS
- MODEMS
- NOTEBOOK AND PALM-TOP COMPUTERS
- ELECTRONIC GAMES
- HANDHELD METERS
- PCMCIA CARDS
- CARD BUSES
- LCD DISPLAYS

### DESCRIPTION

The REG711 is a switched capacitor voltage converter, which 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 REG711 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 down 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 REG711 is thermally protected and current limited, protecting the load and the regulator during fault conditions. Typical ground pin current (quiescent current) is 1mA at full load, 60µA with no load, and less than 1µA in shutdown mode. This regulator comes in a thin MSOP-8 package with a component height of less than 1.1mm.



# SPECIFICATIONS

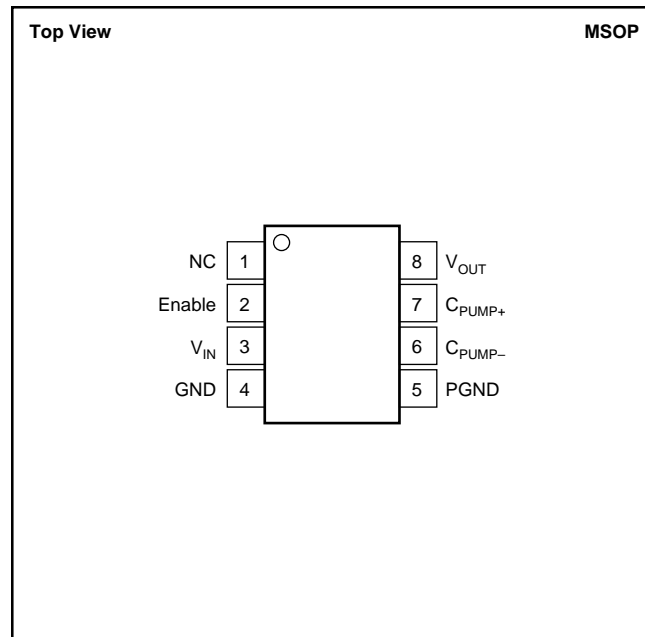
**Boldface** limits apply over the specified temperature range,  $T_A = -40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$

At  $T_A = +25^{\circ}\text{C}$ ,  $V_{IN} = V_{OUT}/2 + 0.75\text{V}$ ,  $I_{OUT} = 5\text{mA}$ ,  $C_{IN} = C_{OUT} = 2.2\mu\text{F}$ ,  $C_{PUMP} = 0.22\mu\text{F}$ ,  $V_{ENABLE} = 1.3\text{V}$ , unless otherwise noted<sup>(1)</sup>.

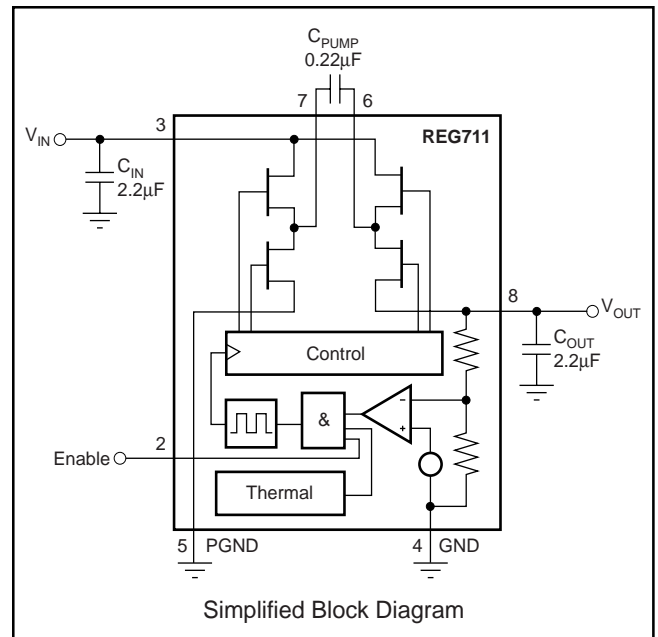
PARAMETER	CONDITIONS	REG711EA			UNITS
		MIN	TYP	MAX	
<b>INPUT VOLTAGE</b> Guaranteed Startup REG711-5.0 All Other Models	See conditions under "output voltage" with a resistive load not lower than typical $V_{OUT}/I_{OUT}$ .	<b>2.7</b> <b>1.8</b>		<b>5.5</b> <b>5.5</b>	V V
<b>OUTPUT VOLTAGE</b> REG711-5.0	$I_{OUT} \leq 15\text{mA}$ , $2.7\text{V} < V_{IN} < 5.5\text{V}$ $I_{OUT} \leq 50\text{mA}$ , $3.0\text{V} < V_{IN} < 5.5\text{V}$	<b>4.75</b>	5.0	<b>5.25</b>	V
REG711-3.3	$I_{OUT} \leq 15\text{mA}$ , $1.8\text{V} < V_{IN} < 5.5\text{V}$ $I_{OUT} \leq 50\text{mA}$ , $2.2\text{V} < V_{IN} < 5.5\text{V}$	<b>3.14</b>	3.3	<b>3.46</b>	V
REG711-3.0	$I_{OUT} \leq 15\text{mA}$ , $1.8\text{V} < V_{IN} < 5.5\text{V}$ $I_{OUT} \leq 50\text{mA}$ , $2.2\text{V} < V_{IN} < 5.5\text{V}$	<b>2.85</b>	3.0	<b>3.15</b>	V
REG711-2.7	$I_{OUT} \leq 15\text{mA}$ , $1.8\text{V} < V_{IN} < 5.5\text{V}$ $I_{OUT} \leq 50\text{mA}$ , $2.0\text{V} < V_{IN} < 5.5\text{V}$	<b>2.57</b>	2.7	<b>2.83</b>	V
REG711-2.5	$I_{OUT} \leq 15\text{mA}$ , $1.8\text{V} < V_{IN} < 5.5\text{V}$ $I_{OUT} \leq 50\text{mA}$ , $2.0\text{V} < V_{IN} < 5.5\text{V}$	<b>2.38</b>	2.5	<b>2.62</b>	V
<b>OUTPUT CURRENT</b> Nominal Short Circuit <sup>(2)</sup>		50	80		mA mA
<b>OSCILLATOR FREQUENCY</b>	NOTE <sup>(3)</sup>		1.0		MHz
<b>EFFICIENCY</b> <sup>(4)</sup>	$I_{OUT} = 15\text{mA}$ , $V_{IN} = 2.7\text{V}$ , REG711-5.0		90		%
<b>RIPPLE VOLTAGE</b> <sup>(1)</sup>	$I_{OUT} = 50\text{mA}$		40		mVp-p
<b>ENABLE CONTROL</b> Logic High Input Voltage Logic Low Input Voltage Logic High Input Current Logic Low Input Current	$V_{IN} = 1.8$ to $5.5\text{V}$	<b>1.3</b> <b>-0.2</b>		<b><math>V_{IN}</math></b> <b>0.4</b> 100 100	V V nA nA
<b>THERMAL SHUTDOWN</b> Shutdown temperature Shutdown recovery			160 140		$^{\circ}\text{C}$ $^{\circ}\text{C}$
<b>SUPPLY CURRENT</b> (quiescent current) In Shutdown Mode	$I_{OUT} = 0\text{mA}$ $V_{IN} = 1.8$ to $5.5\text{V}$ , Enable = 0V		60 0.01	100 2	$\mu\text{A}$ $\mu\text{A}$
<b>TEMPERATURE RANGE</b> Specification Operating Storage Thermal Resistance, $\theta_{JA}$	$T_A$ $T_A$ $T_A$ MSOP-8	-40 -55 -65		+85 +125 +150	$^{\circ}\text{C}$ $^{\circ}\text{C}$ $^{\circ}\text{C}$ $^{\circ}\text{C}/\text{W}$

NOTES: (1) Effective series resistance (ESR) of capacitors is  $< 0.1\Omega$ . (2) The supply circuit is twice the output short-circuit current. (3) The converter regulates by enabling and disabling periods of switching cycles. The switching frequency is the oscillator frequency during an active period. (4) See efficiency curves for other  $V_{IN}/V_{OUT}$  configurations.

## PIN CONFIGURATION



## SIMPLIFIED BLOCK DIAGRAM



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

Supply Voltage .....	–0.3V to +5.5V
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.



## 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.

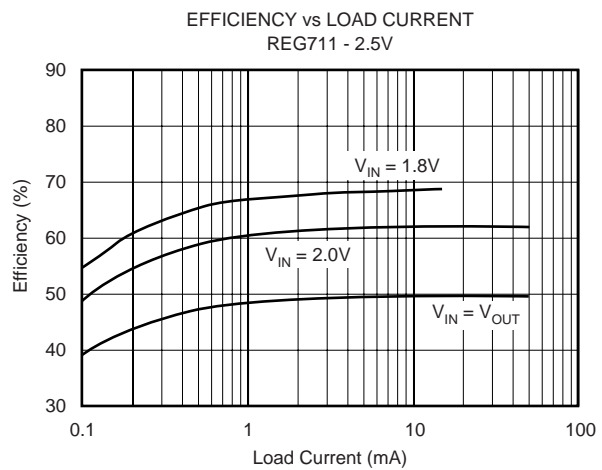
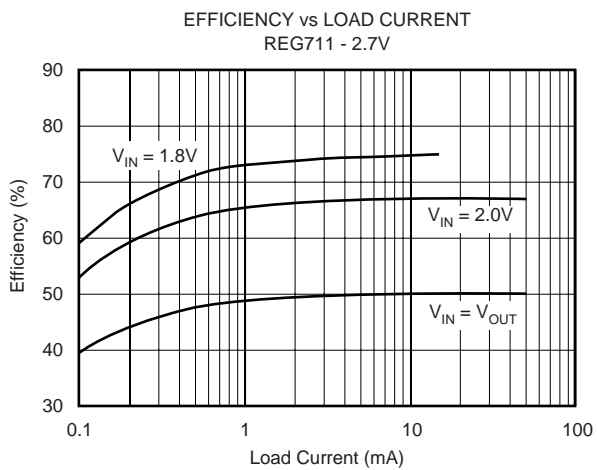
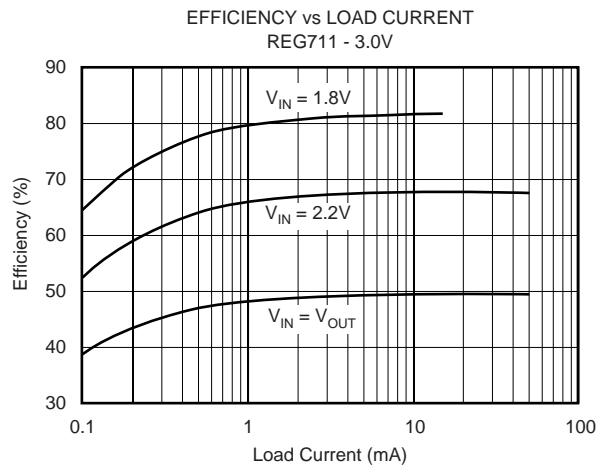
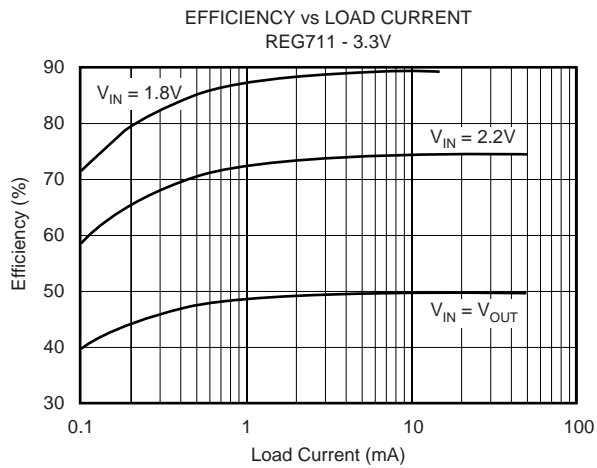
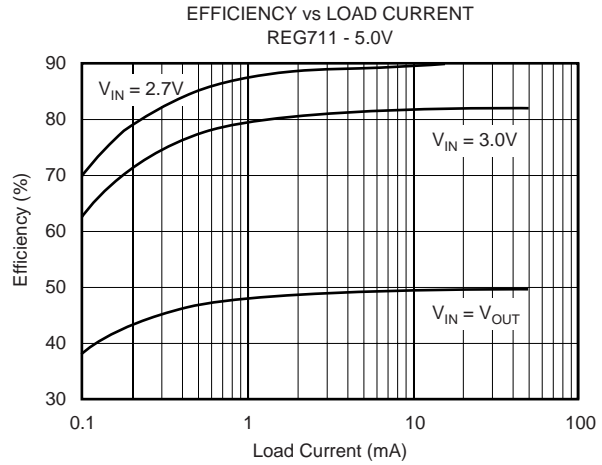
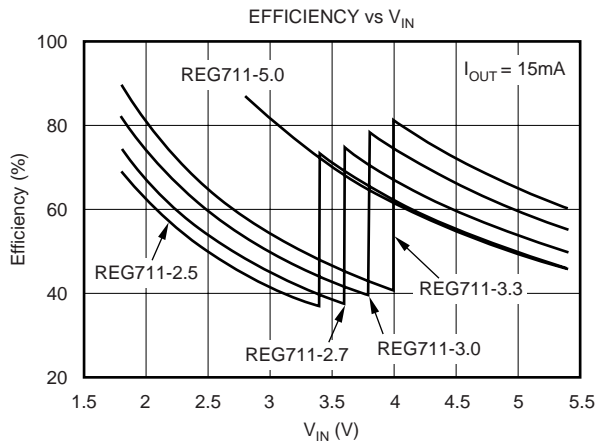
## PACKAGE/ORDERING INFORMATION

PRODUCT	OUTPUT VOLTAGE	PACKAGE	PACKAGE DRAWING NUMBER	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING <sup>(1)</sup>	ORDERING NUMBER <sup>(2)</sup>	TRANSPORT MEDIA
<b>5V Output</b> REG711EA-5 "	5.0V " "	MSOP-8 " "	337 " "	–40°C to +85°C " "	C11B " "	REG711EA-5 REG711EA-5/250 REG711EA-5/2K5	Rails Tape and Reel Tape and Reel
<b>3.3V Output</b> REG711EA-3.3 "	3.3V " "	MSOP-8 " "	337 " "	–40°C to +85°C " "	C11C " "	REG711EA-3.3 REG711EA-3.3/250 REG711EA-3.3/2K5	Rails Tape and Reel Tape and Reel
<b>3V Output</b> REG711EA-3.0 "	3.0V " "	MSOP-8 " "	337 " "	–40°C to +85°C " "	C11D " "	REG711EA-3 REG711EA-3/250 REG711EA-3/2K5	Rails Tape and Reel Tape and Reel
<b>2.7V Output</b> REG711EA-2.7 "	2.7V " "	MSOP-8 " "	337 " "	–40°C to +85°C " "	C11F " "	REG711EA-2.7 REG711EA-2.7/250 REG711EA-2.7/2K5	Rails Tape and Reel Tape and Reel
<b>2.5V Output</b> REG711EA-2.5 "	2.5V " "	MSOP-8 " "	337 " "	–40°C to +85°C " "	C11G " "	REG711EA-2.5 REG711EA-2.5/250	Rails Tape and Reel

NOTE: (1) Voltage will be marked on reel. (2) Models with a slash (/) are available only in Tape and Reel in the quantities indicated (e.g., /2K5 indicates 2500 devices per reel). Ordering 2500 pieces of "REG711EA-5/2K5" will get a single 2500-piece Tape and Reel.

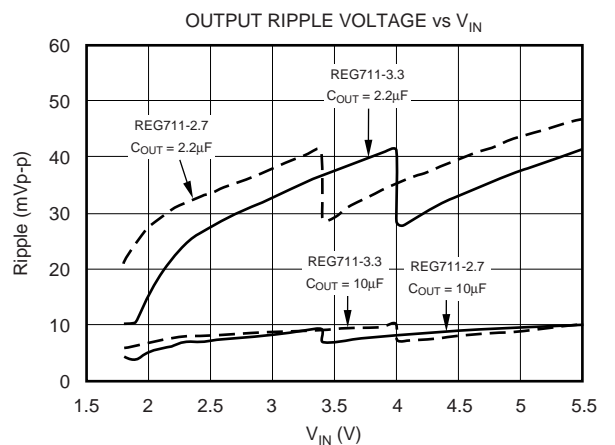
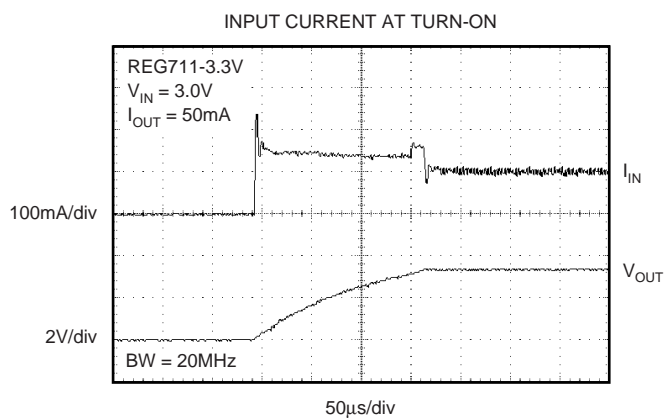
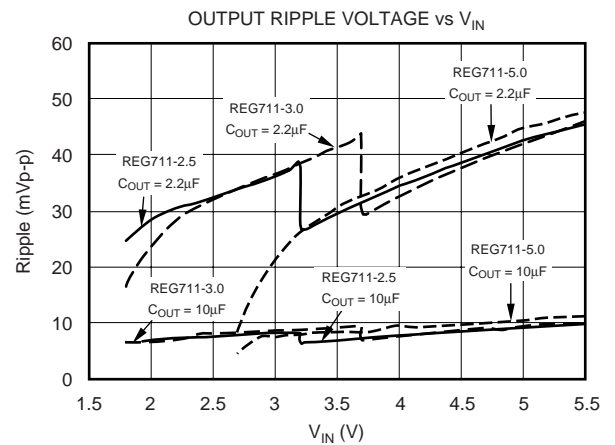
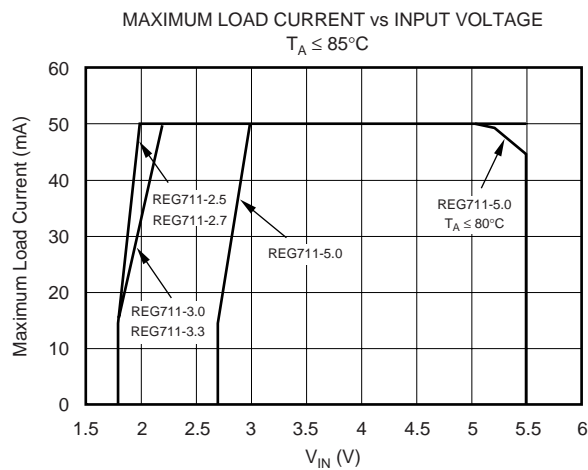
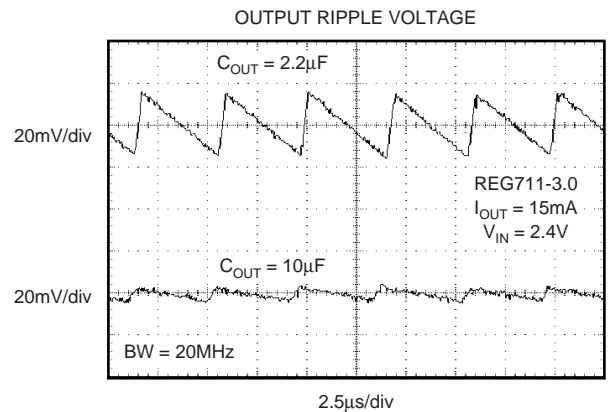
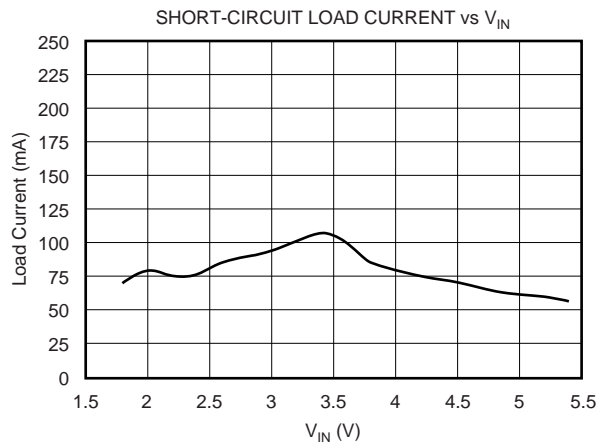
# TYPICAL PERFORMANCE CURVES

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



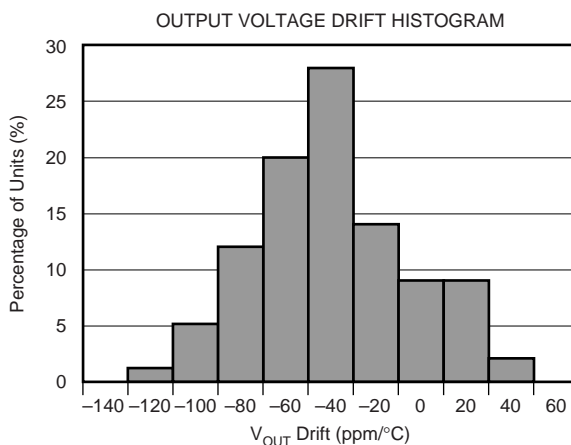
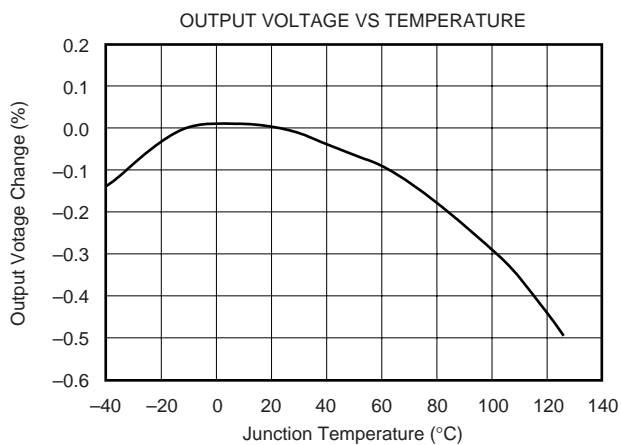
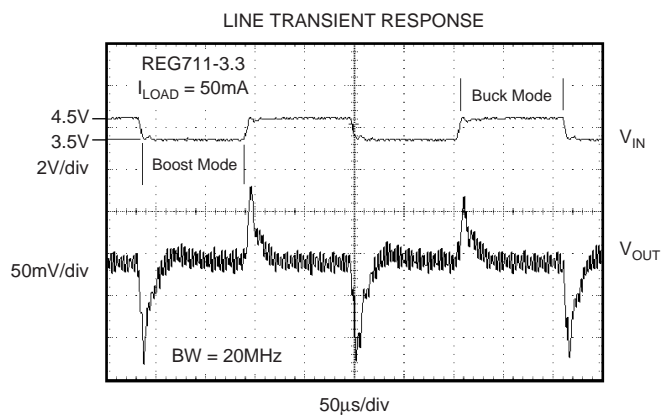
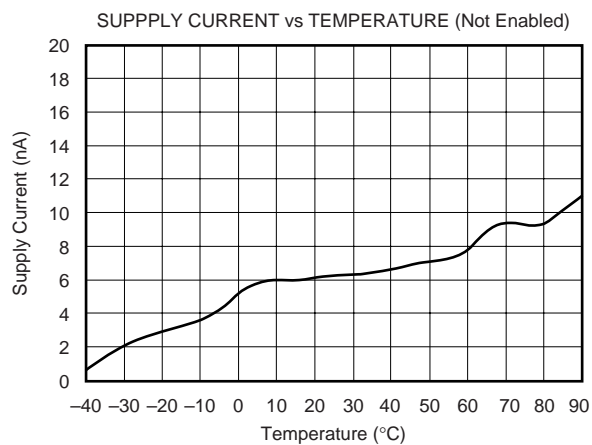
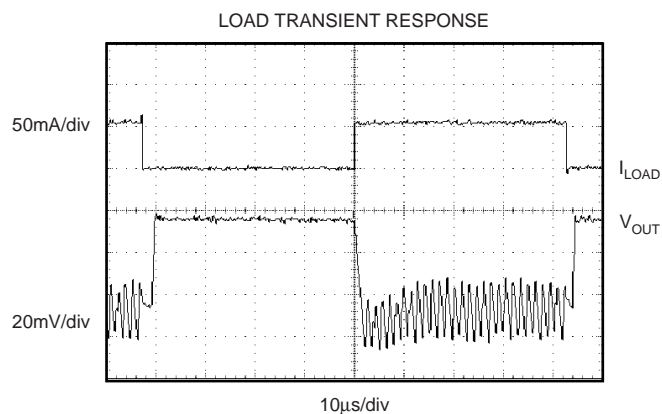
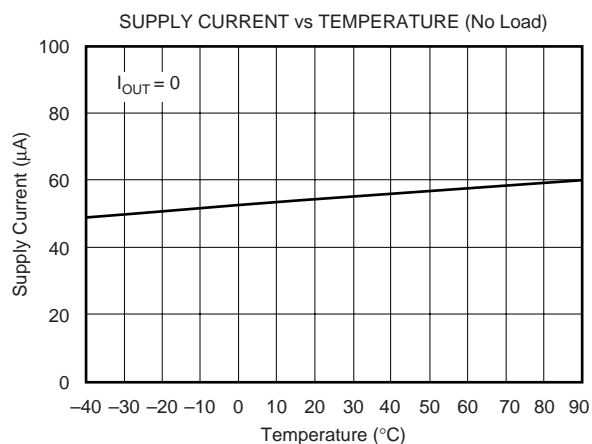
# TYPICAL PERFORMANCE CURVES (Cont.)

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



# TYPICAL PERFORMANCE CURVES (Cont.)

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



# THEORY OF OPERATION

The REG711 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 pulse-width 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.

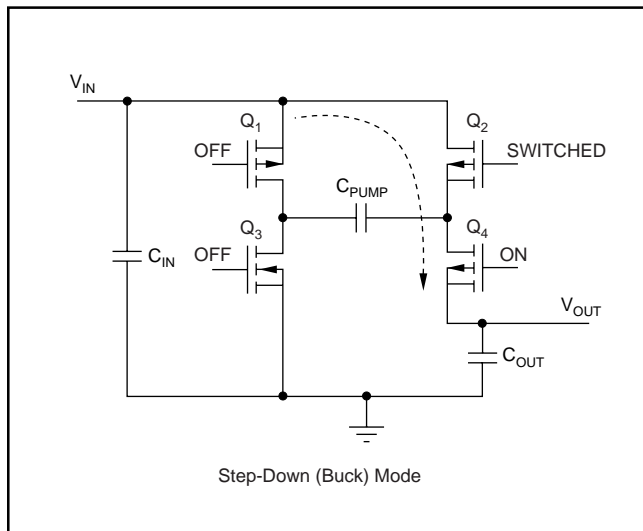


FIGURE 1. Simplified Schematic of the REG711 Operating in the Step-Down Mode.

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

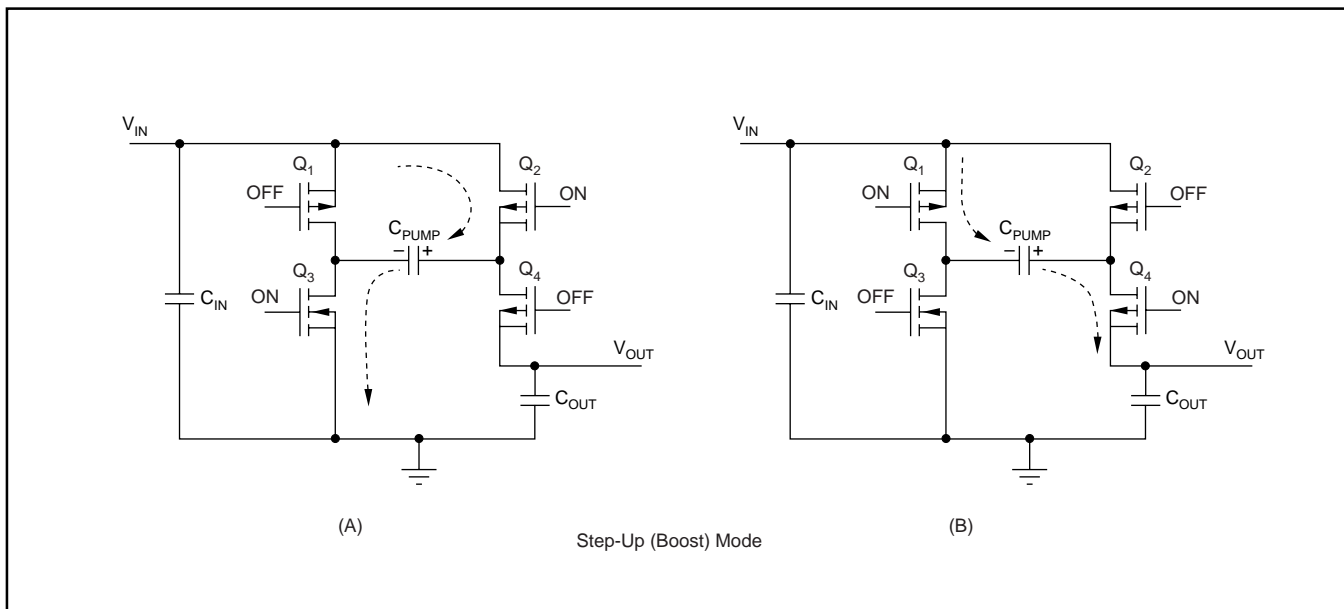


FIGURE 2. Simplified Schematic of the REG711 Operating in the Step-Up or Boost Mode.

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 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 reaches 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 re-enabled. 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  $2\mu\text{A}$  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 ( $C_{IN}$ ,  $C_{PUMP}$  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.

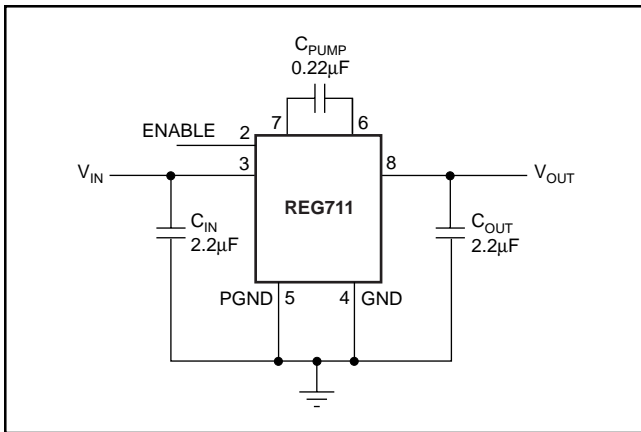


FIGURE 3. Typical Operating Circuit.

With light loads or higher input voltage, a smaller  $0.1\mu\text{F}$  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 I have been used with the REG711. This is only a representative list of those parts that are compatible, and not the results of a complete survey of an industry-wide offering.

## 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:

$$\text{Efficiency (\%)} = \frac{V_{OUT}}{2 \cdot V_{IN}} \cdot 100 \text{ (step-up operating mode)}$$

or

$$V_{OUT} \cdot 100 / V_{IN} \text{ (step-down operating mode)}$$

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

PRODUCT	OPERATING MODE CHANGES AT $V_{IN}$ OF
REG711-2.5	> 3.2V
REG711-2.7	> 3.4V
REG711-3.0	> 3.7V
REG711-3.3	> 4.0V
REG711-5.0	Step-up only

TABLE II.

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

## LAYOUT

Large ripple currents flow in the  $V_{IN}$ , PGND and  $V_{OUT}$  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. A star ground system has been implemented, with pin 5 as the center of the star. No ground plane is provided in other layers, as this will provide capacitive coupling for noise spikes.

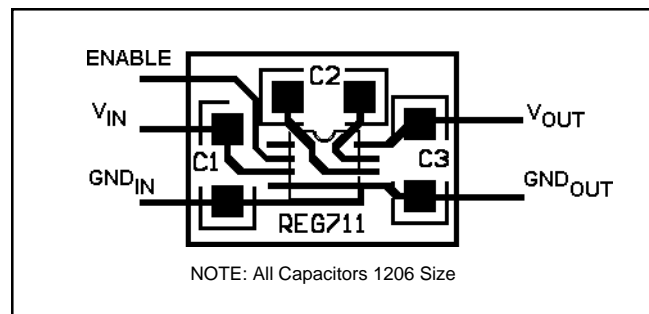


FIGURE 4. Suggested PCB Design for Minimum Ripple.

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	ECJ3YB1A225K	2.2µF	±10%	X7R	1206	10V
	ECJ3VB1C224K	0.22µF	±10%	X7R	1206	16V
Taiyo Yuden	LMK325BJ106KN	10µF	±10%	X5R	1210	10V
	EMK316BJ225KL	2.2µF	±10%	X7R	1206	16V
	TKM316BJ224KF	0.22µF	±10%	X7R	1206	25V

TABLE I. Capacitors That Have Been Successfully Used With The REG711.



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