30-mA 5.5-V BOOST CHARGE PUMP

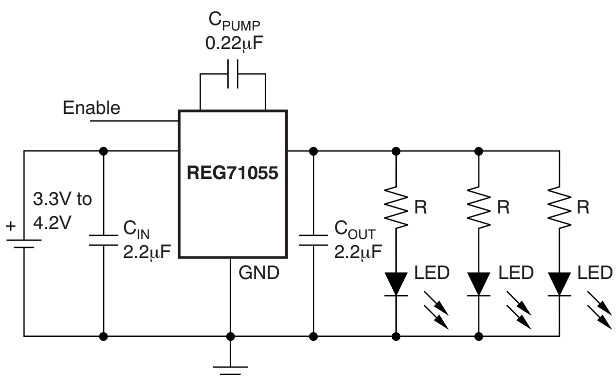
FEATURES

- **Qualified for Automotive Applications**
- **Input Voltage Range: 3.0 V to 5.5 V**
- **Automatic Step-Up Operation**
- **Low Input Current Ripple**
- **Low Output Voltage Ripple**
- **Minimum Number of External Components, No Inductors**
- **1-MHz Internal Oscillator Allows Small Capacitors**
- **Shutdown Mode**
- **Thermal and Current Limit Protection**
- **5.5-V Output Voltage**
- **Small TSOT23-6 (DDC) Package**

DESCRIPTION

The REG71055 is a switched capacitor voltage converter that produces a regulated, low-ripple output voltage from an unregulated input voltage. Input supply voltage of 3.0 V to 5.5 V makes the REG71055 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 below the output voltage and the output remains in regulation. It works equally well for step-up 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 REG71055 is thermally protected and current limited, protecting the load and the regulator during fault conditions. Typical ground pin current (quiescent current) is 65 µA with no load, and less than 1 µA in shutdown mode.



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.

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.

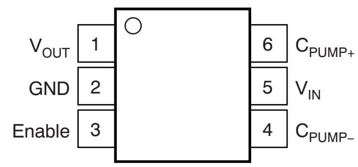
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

ORDERING INFORMATION(1)

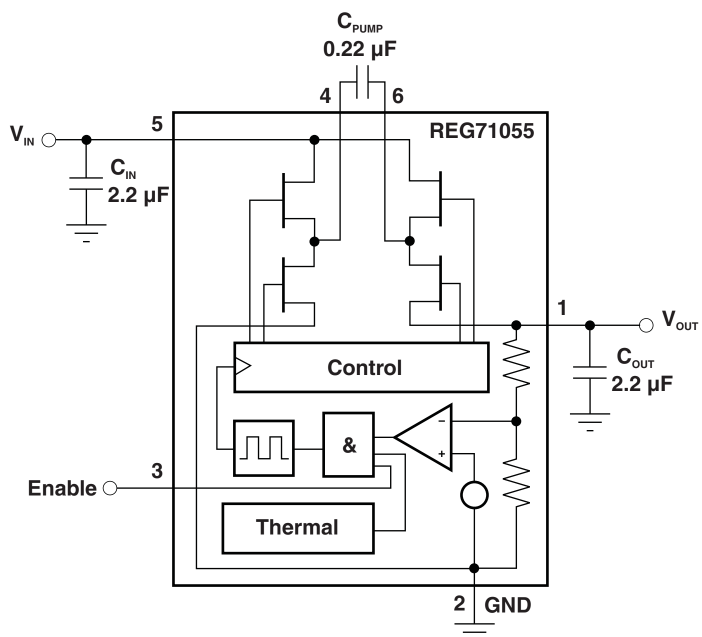
T_A	PACKAGE(2)		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	TSOT-23 – DDC	Reel of 3000	REG71055IDDCRQ1	GIXI

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.
(2) Package drawings, thermal data, and symbolization are available at www.ti.com/packaging.

DDC PACKAGE
(TOP VIEW)



SIMPLIFIED BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS[1]

V_{IN}	Supply voltage	3 V to 6 V
V_{EN}	Enable input voltage	–0.3 V to V_{IN}
t_{SC}	Output short-circuit duration	Indefinite
T_{STG}	Storage temperature range	–65°C to 150°C
T_{LEAD}	Lead temperature (soldering, 10 seconds)	260°C

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.

ELECTRICAL CHARACTERISTICS

Boldface limits apply over the specified temperature range, **T_A = –40°C to 85°C**
T_A = 25°C, V_{IN} = V_{OUT}/2 + 0.75 V, I_{OUT} = 10 mA, C_{IN} = C_{OUT} = 2.2 µF, C_{PUMP} = 0.22 µF, and V_{ENABLE} = 1.3 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input voltage, tested startup		See conditions under Output Voltage with a resistive load no lower than typical V_{OUT}/I_{OUT}	3.0		5.5	V
Output voltage		I_{OUT} ≤ 10 mA, 3.0 V ≤ V_{IN} ≤ 5.5 V	**5.2**	5.5	**5.8**	V
		I_{OUT} ≤ 30 mA, 3.25 V ≤ V_{IN} ≤ 5.5 V	**5.2**	5.5	**5.8**	V
Nominal output current			30			mA
Short-circuit output current[1]				100		mA
Oscillator frequency[2]				1.0		MHz
Efficiency[3]		I_{OUT} = 10 mA, V_{IN} = 3.0 V		90		%
Ripple voltage[4]		I_{OUT} = 30 mA		35		mV_{PP}
Logic high input voltage, Enable		V_{IN} = 3.0V to 5.5 V	**1.3**		**V_{IN}**	V
Logic low input voltage, Enable		V_{IN} = 3.0V to 5.5 V	**–0.2**		**0.4**	V
Logic high input current, Enable		V_{IN} = 3.0V to 5.5 V			100	nA
Logic low input current, Enable		V_{IN} = 3.0V to 5.5 V			100	nA
Thermal shutdown temperature				160		°C
Thermal shutdown recovery				140		°C
Quiescent current[5]		I_{OUT} = 0 mA, V_{IN} = 5.5 V		65	100	µA
Quiescent current in shutdown mode		V_{IN} = 3.0 V to 5.5 V, Enable = 0 V		0.01	1	µA
Specified ambient temperature	T_A		–40		85	°C
Thermal resistance	θ_{JA}	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.
(5) Measured when the device is not switching.

TYPICAL CHARACTERISTICS

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

EFFICIENCY vs V_{IN}

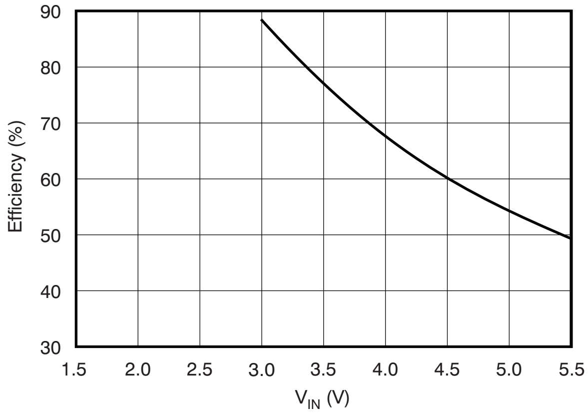


Figure 1.

SUPPLY CURRENT vs TEMPERATURE (No Load)

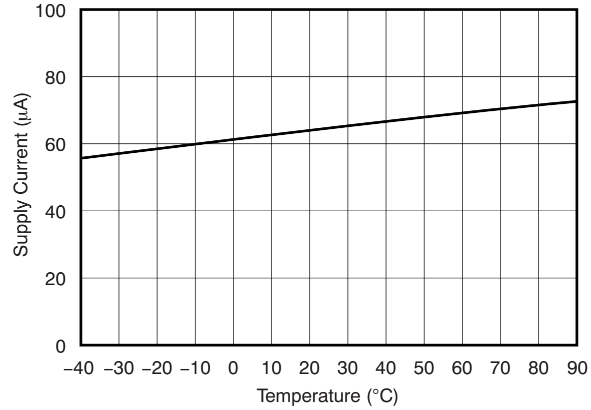


Figure 2.

LOAD TRANSIENT RESPONSE

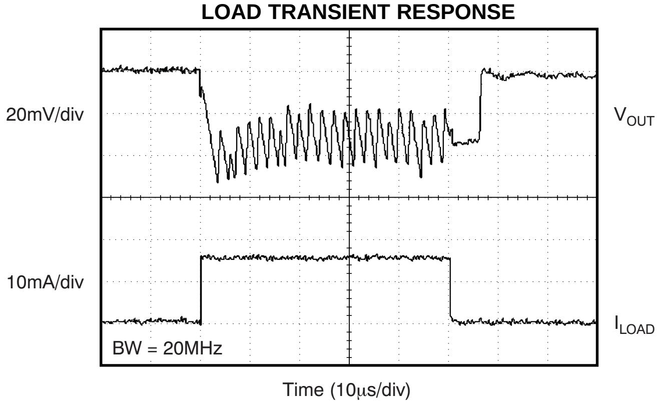


Figure 3.

SUPPLY CURRENT vs TEMPERATURE (Not Enabled)

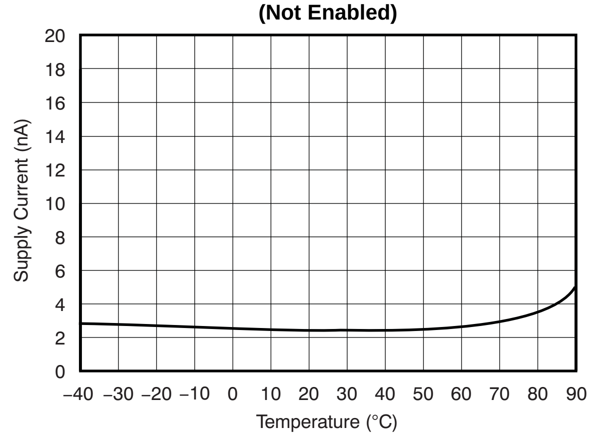


Figure 4.

OUTPUT VOLTAGE vs TEMPERATURE

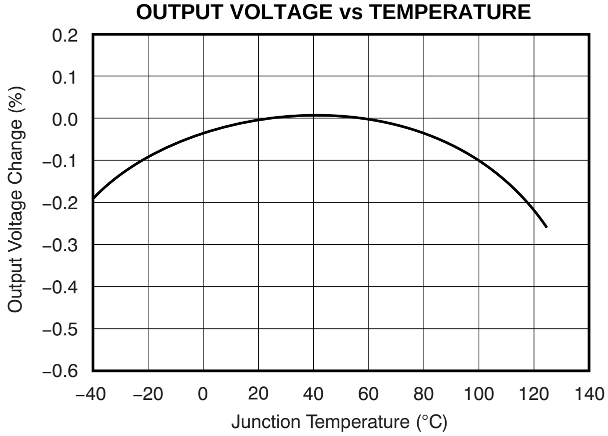


Figure 5.

OUTPUT VOLTAGE DRIFT HISTOGRAM

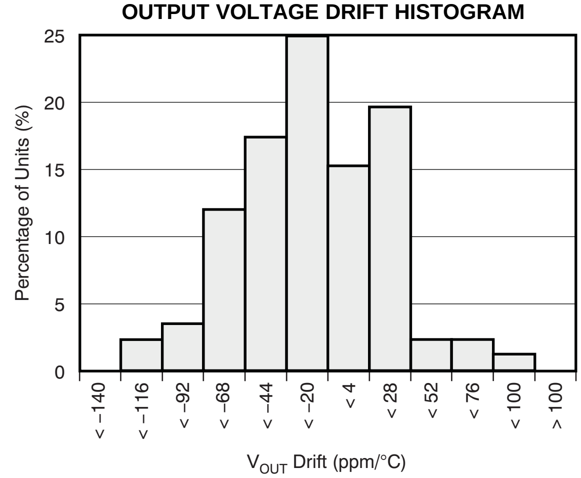


Figure 6.

TYPICAL CHARACTERISTICS (continued)

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

SHORT-CIRCUIT LOAD CURRENT vs V_{IN}

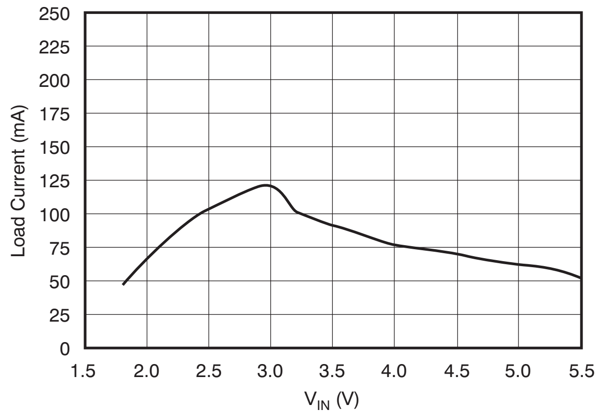


Figure 7.

THEORY OF OPERATION

The REG71055 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 8. 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.

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 9.

A conversion clock of 50% duty cycle is generated. During the first half cycle the FET switches are configured as shown in Figure 9A, and C_{PUMP} charges to V_{IN}.

During the second half cycle the FET switched are configured as shown in Figure 9B, 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.

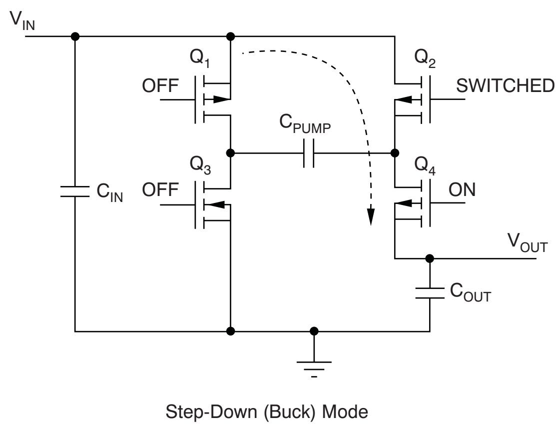


Figure 8. Simplified Schematic of the REG71055 Operating in the Step-Down Mode

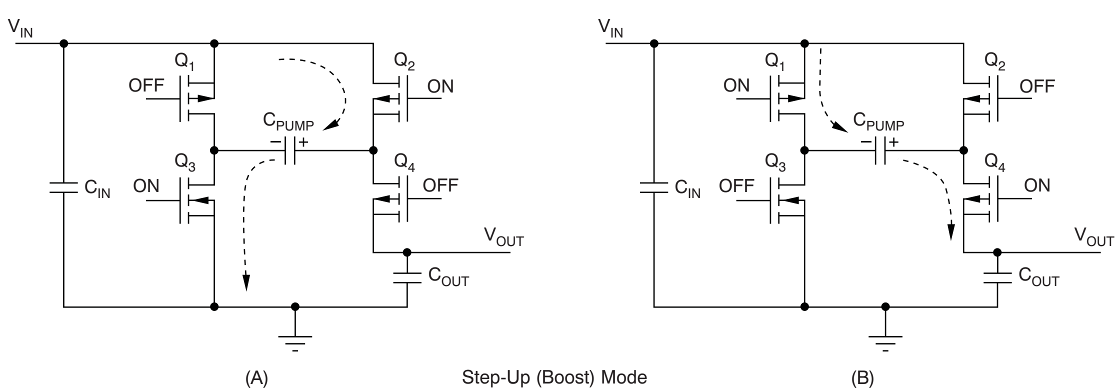


Figure 9. Simplified Schematic of the REG71055 Operating in the Step-Up or Boost Mode

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 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

The EN pin enables the IC when pulled high and places it into energy-saving shutdown mode when pulled low. When in shutdown mode, the output is disconnected from the input and the quiescent current is reduced to 0.01 µA typical. This shutdown mode functionality is only valid when V_{IN} is above the minimum recommended operating voltage. The EN pin cannot be left floating and must be actively terminated either high or low.

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 10 for component values.

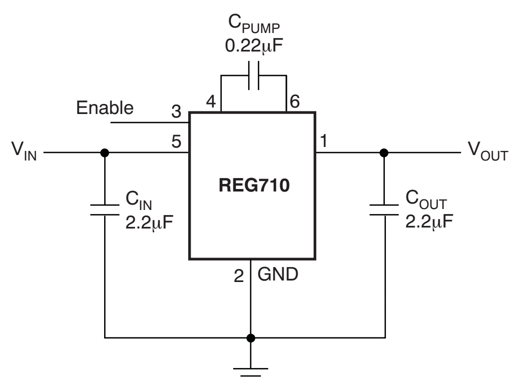


Figure 10. Typical Operating Circuit

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 REG71055. This table is only a representative list of compatible parts.

Table 1. Suggested Capacitors

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

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 vs V_{IN}

PRODUCT	OPERATING MODE CHANGES AT V_{IN} OF
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 printed circuit board (PCB) routing is shown in Figure 11. The trace lengths from the input and output capacitors have been kept as short as possible.

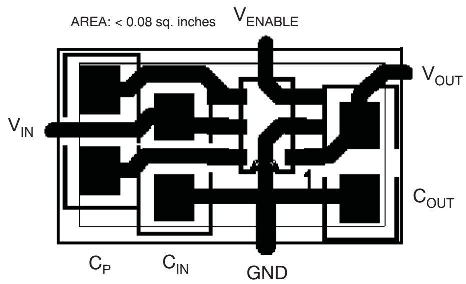


Figure 11. Suggested PCB Design for Minimum Ripple

APPLICATION CIRCUITS

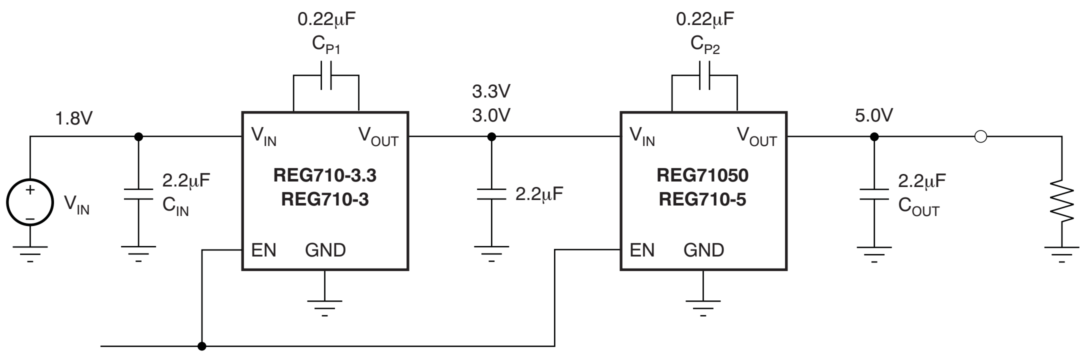


Figure 12. Circuit for Step-Up Operation From 1.8 V to 5 V With 10-mA Output Current

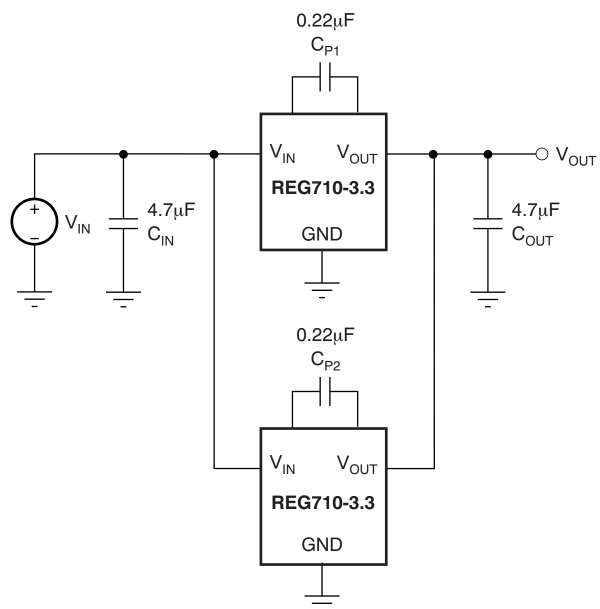


Figure 13. Circuit for Doubling the Output Current

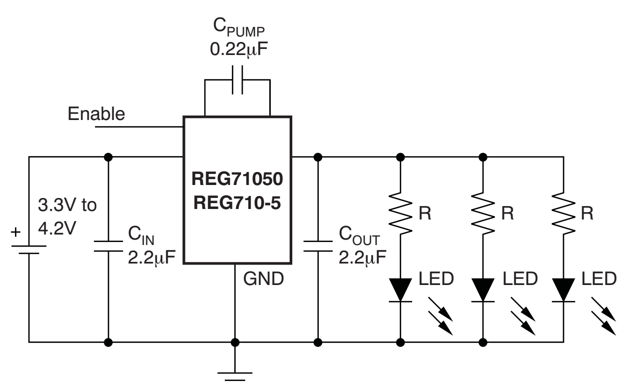


Figure 14. Circuit for Driving LEDs

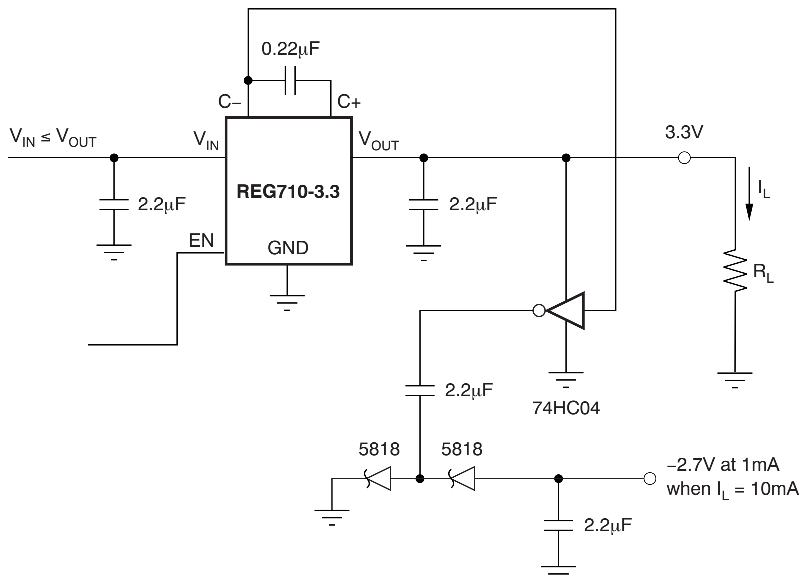


Figure 15. Negative Bias Supply

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
REG71055IDDCRQ1	ACTIVE	SOT	DDC	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	GIXI	Samples

(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), Pb-Free (RoHS Exempt), 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.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
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.

(4) Only one of markings shown within the brackets will appear on the physical device.

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OTHER QUALIFIED VERSIONS OF REG71055-Q1 :

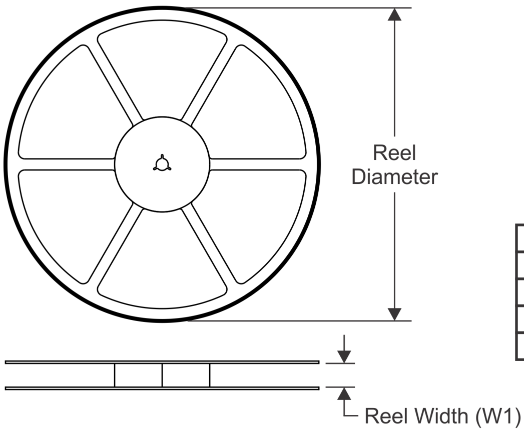
- Catalog: REG71055

NOTE: Qualified Version Definitions:

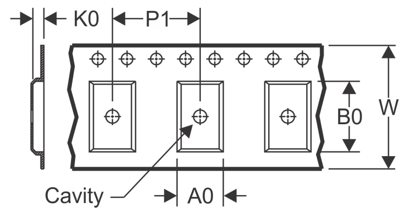
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION

REEL DIMENSIONS

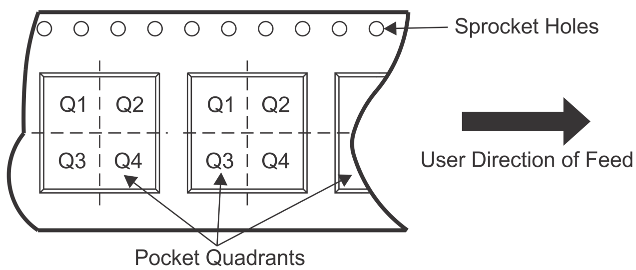


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

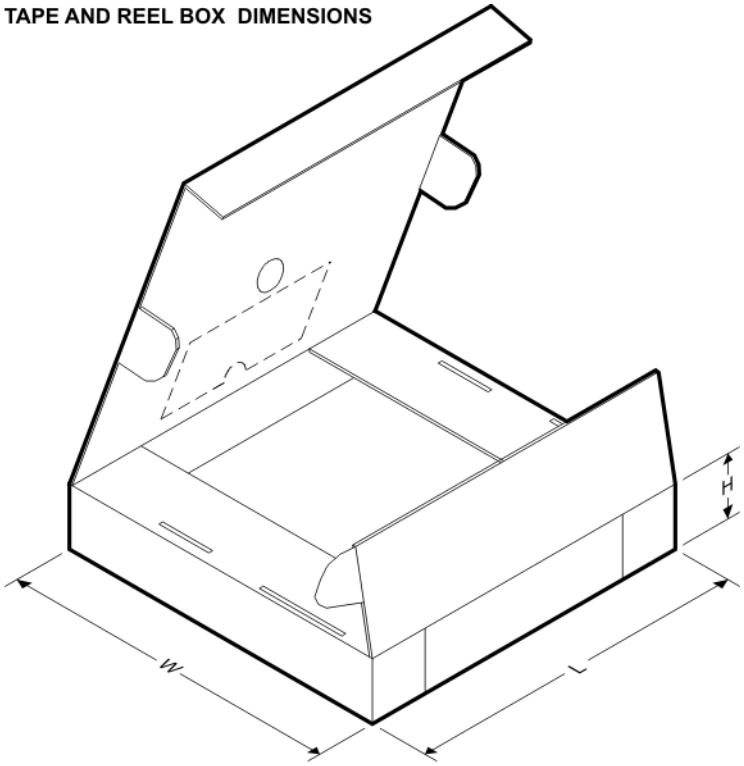
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
REG71055IDDCRQ1	SOT	DDC	6	3000	179.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3

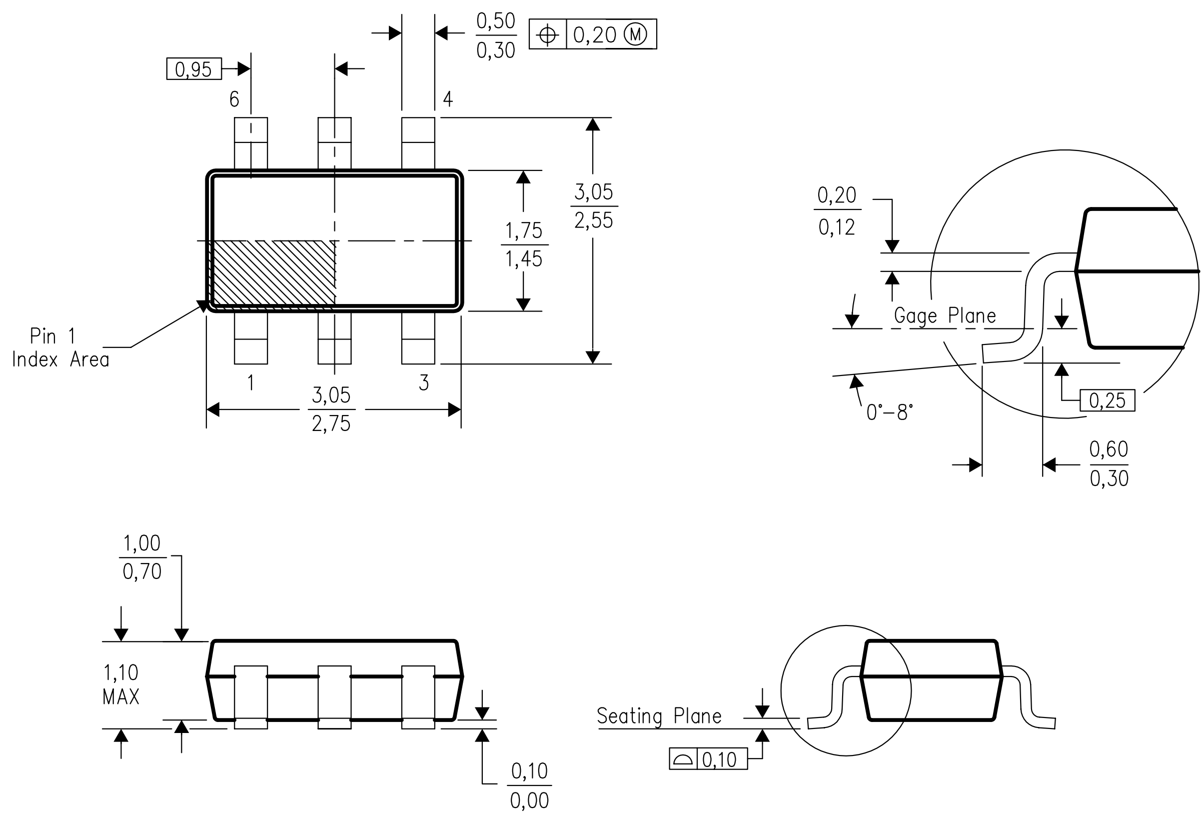
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
REG71055IDDCRQ1	SOT	DDC	6	3000	203.0	203.0	35.0

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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