

LM2704 Micropower Step-up DC/DC Converter with 550mA Peak Current Limit

Check for Samples: [LM2704](#)

FEATURES

- 550mA, 0.7 Ω , Internal Switch
- Uses Small Surface Mount Components
- Adjustable Output Voltage up to 20V
- 2.2V to 7V Input Range
- Input Undervoltage Lockout
- 0.01 μ A Shutdown Current
- Small 5-Lead SOT-23 Package

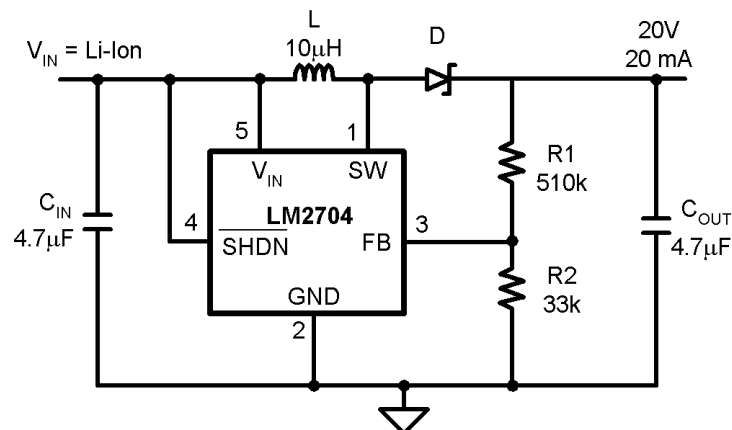
APPLICATIONS

- LCD Bias Supplies
- White LED Back-Lighting
- Handheld Devices
- Digital Cameras
- Portable Applications

DESCRIPTION

The LM2704 is a micropower step-up DC/DC in a small 5-lead SOT-23 package. A current limited, fixed off-time control scheme conserves operating current resulting in high efficiency over a wide range of load conditions. The 21V switch allows for output voltages as high as 20V. The low 400ns off-time permits the use of tiny, low profile inductors and capacitors to minimize footprint and cost in space-conscious portable applications. The LM2704 is ideal for LCD panels requiring low current and high efficiency as well as white LED applications for cellular phone back-lighting. The LM2704 can drive up to 8 white LEDs from a single Li-Ion battery.

Typical Application Circuit



C_{IN} : Taiyo Yuden Ceramic
 C_{OUT} : Taiyo Yuden Ceramic
L: Coilcraft DO1608C-103
D: Motorola MBRM130LT3



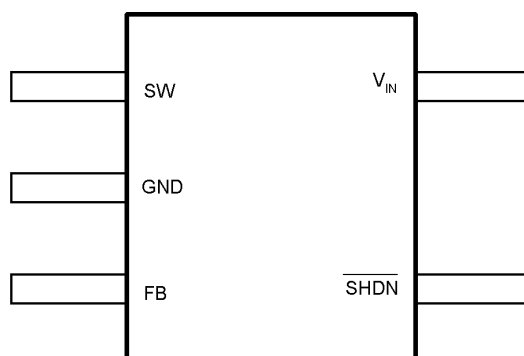
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Connection Diagram



The maximum allowable power dissipation is a function of the maximum junction temperature, $T_J(\text{MAX})$, the junction-to-ambient thermal resistance, θ_{JA} , and the ambient temperature, T_A . See the Electrical Characteristics table for the thermal resistance. The maximum allowable power dissipation at any ambient temperature is calculated using: $P_D(\text{MAX}) = (T_J(\text{MAX}) - T_A)/\theta_{JA}$. Exceeding the maximum allowable power dissipation will cause excessive die temperature.

Figure 1. SOT23-5 - Top View
 $T_{J\text{max}} = 125^\circ\text{C}$, $\theta_{JA} = 220^\circ\text{C/W}$

PIN DESCRIPTIONS

Pin	Name	Function
1	SW	Power Switch input.
2	GND	Ground.
3	FB	Output voltage feedback input.
4	SHDN	Shutdown control input, active low.
5	V _{IN}	Analog and Power input.

SW(Pin 1): Switch Pin. This is the drain of the internal NMOS power switch. Minimize the metal trace area connected to this pin to minimize EMI.

GND(Pin 2): Ground Pin. Tie directly to ground plane.

FB(Pin 3): Feedback Pin. Set the output voltage by selecting values for R1 and R2 using:

$$R1 = R2 \left(\frac{V_{\text{OUT}}}{1.237\text{V}} - 1 \right) \quad (1)$$

Connect the ground of the feedback network to an AGND plane which should be tied directly to the GND pin.

SHDN(Pin 4): Shutdown Pin. The shutdown pin is an active low control. Tie this pin above 1.1V to enable the device. Tie this pin below 0.3V to turn off the device.

V_{IN}(Pin 5): Input Supply Pin. Bypass this pin with a capacitor as close to the device as possible.



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

Absolute Maximum Ratings⁽¹⁾⁽²⁾

V _{IN}	7.5V
SW Voltage	21V
FB Voltage	2V
SHDN Voltage	7.5V
Maximum Junction Temp. T _J ⁽³⁾	150°C
Lead Temperature (Soldering 10 sec.)	300°C
Vapor Phase (60 sec.)	215°C
Infrared (15 sec.)	220°C
ESD Ratings ⁽⁴⁾ Human Body Model Machine Model ⁽⁵⁾	2kV 200V

- (1) Absolute maximum ratings are limits beyond which damage to the device may occur. Operating Ratings are conditions for which the device is intended to be functional, but device parameter specifications may not be guaranteed. For guaranteed specifications and test conditions, see the Electrical Characteristics.
- (2) If Military/Aerospace specified devices are required, please contact the TI Sales Office/Distributors for availability and specifications.
- (3) The maximum allowable power dissipation is a function of the maximum junction temperature, T_J(MAX), the junction-to-ambient thermal resistance, θ_{JA} , and the ambient temperature, T_A. See the Electrical Characteristics table for the thermal resistance. The maximum allowable power dissipation at any ambient temperature is calculated using: $P_D (MAX) = (T_{J(MAX)} - T_A)/\theta_{JA}$. Exceeding the maximum allowable power dissipation will cause excessive die temperature.
- (4) The human body model is a 100 pF capacitor discharged through a 1.5 k Ω resistor into each pin. The machine model is a 200 pF capacitor discharged directly into each pin.
- (5) ESD susceptibility using the machine model is 150V for SW pin.

Operating Conditions

Junction Temperature (1)	-40°C to +125°C
Supply Voltage	2.2V to 7V
SW Voltage Max.	20.5V

- (1) All limits guaranteed at room temperature (standard typeface) and at temperature extremes (bold typeface). All room temperature limits are 100% production tested or guaranteed through statistical analysis. All limits at temperature extremes are guaranteed via correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).

Electrical Characteristics⁽¹⁾

Specifications in standard type face are for T_J = 25°C and those in **boldface type** apply over the full **Operating Temperature Range** (T_J = -40°C to +125°C). Unless otherwise specified. V_{IN} = 2.2V.

Symbol	Parameter	Conditions	Min (1)	Typ (2)	Max (1)	Units
I _Q	Device Disabled	FB = 1.3V		40	70	μ A
	Device Enabled	FB = 1.2V		235	300	
	Shutdown	SHDN = 0V		0.01	2.5	
V _{FB}	Feedback Trip Point		1.189	1.237	1.269	V
I _{CL}	Switch Current Limit		490 420	550	610 620	mA
I _B	FB Pin Bias Current	FB = 1.23V ⁽³⁾		30	120	nA
V _{IN}	Input Voltage Range		2.2		7.0	V
R _{DS(on)}	Switch R _{DS(on)}			0.7	1.6	Ω
T _{OFF}	Switch Off Time			400		ns

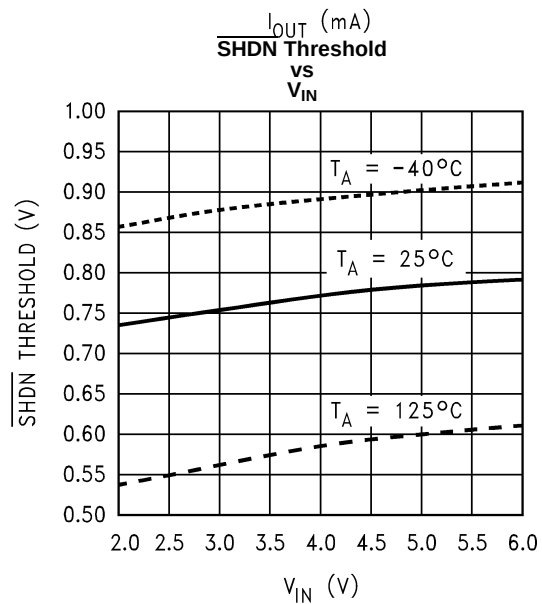
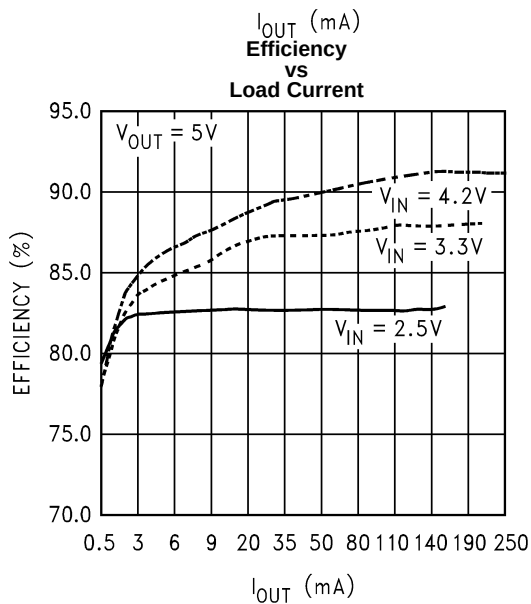
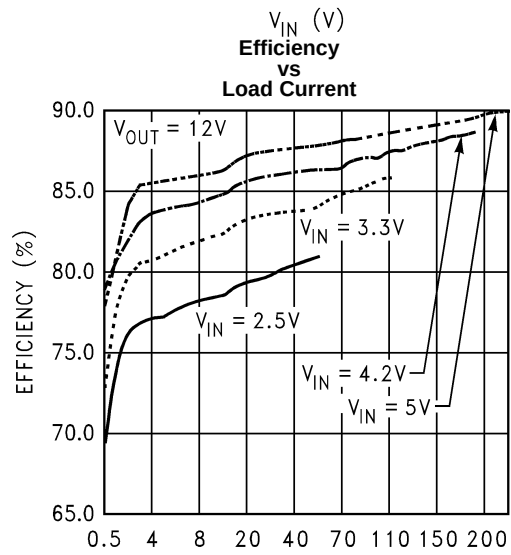
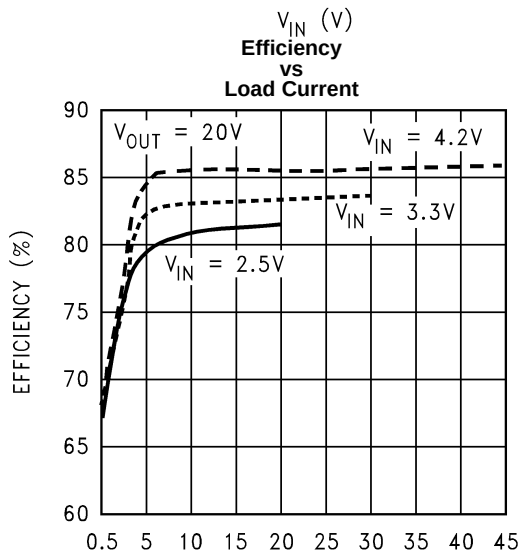
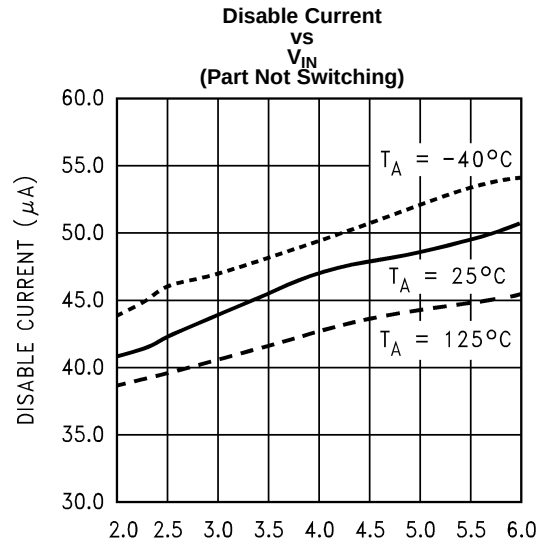
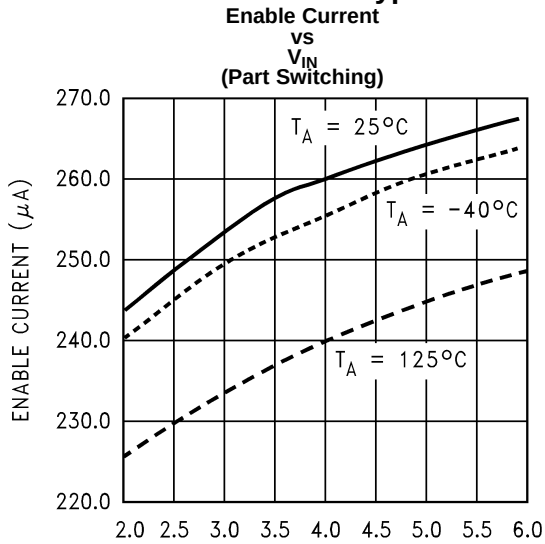
- (1) All limits guaranteed at room temperature (standard typeface) and at temperature extremes (bold typeface). All room temperature limits are 100% production tested or guaranteed through statistical analysis. All limits at temperature extremes are guaranteed via correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).
- (2) Typical numbers are at 25°C and represent the most likely norm.
- (3) Feedback current flows into the pin.

Electrical Characteristics⁽¹⁾ (continued)

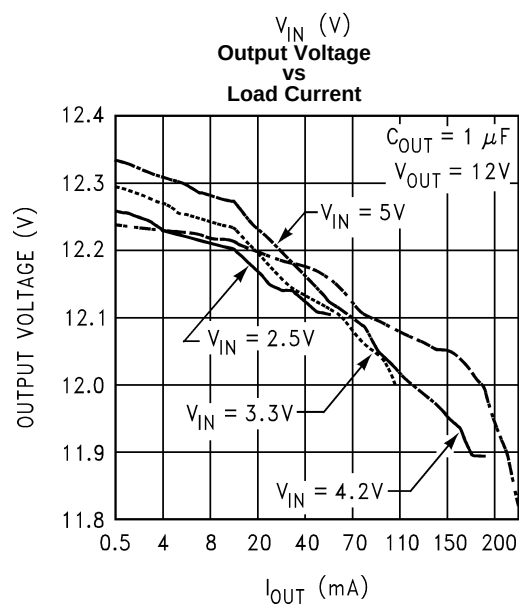
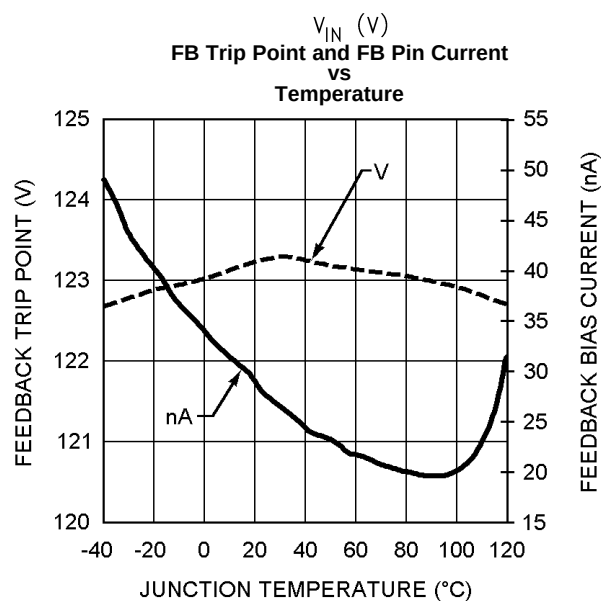
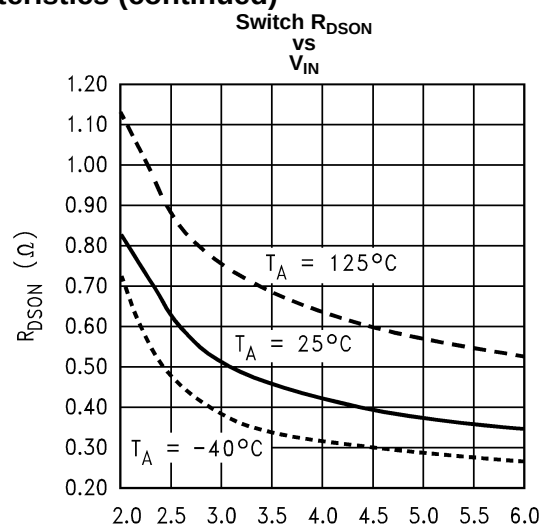
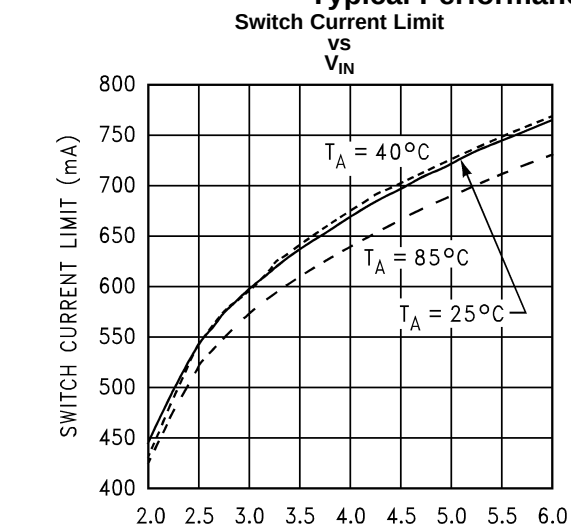
Specifications in standard type face are for $T_J = 25^\circ\text{C}$ and those in **boldface type** apply over the full **Operating Temperature Range** ($T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$). Unless otherwise specified. $V_{IN} = 2.2\text{V}$.

Symbol	Parameter	Conditions	Min (1)	Typ (2)	Max (1)	Units
I_{SD}	$\overline{\text{SHDN}}$ Pin Current	$\overline{\text{SHDN}} = V_{IN}$, $T_J = 25^\circ\text{C}$		0	80	nA
		$\overline{\text{SHDN}} = V_{IN}$, $T_J = 125^\circ\text{C}$		15		
		$\overline{\text{SHDN}} = \text{GND}$		0		
I_L	Switch Leakage Current	$V_{SW} = 20\text{V}$		0.05	5	μA
UVP	Input Undervoltage Lockout	ON/OFF Threshold		1.8		V
V_{FB} Hysteresis	Feedback Hysteresis			8		mV
$\overline{\text{SHDN}}$ Threshold	$\overline{\text{SHDN}}$ low			0.7	0.3	V
	$\overline{\text{SHDN}}$ High		1.1	0.7		
θ_{JA}	Thermal Resistance			220		$^\circ\text{C/W}$

Typical Performance Characteristics

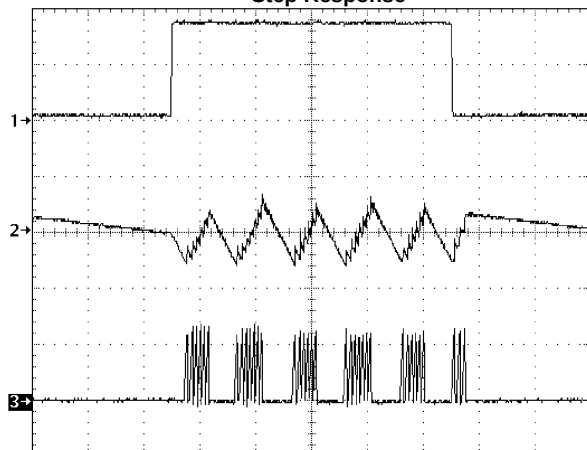


Typical Performance Characteristics (continued)



Typical Performance Characteristics (continued)

Step Response



$V_{OUT} = 20V$, $V_{IN} = 3.0V$

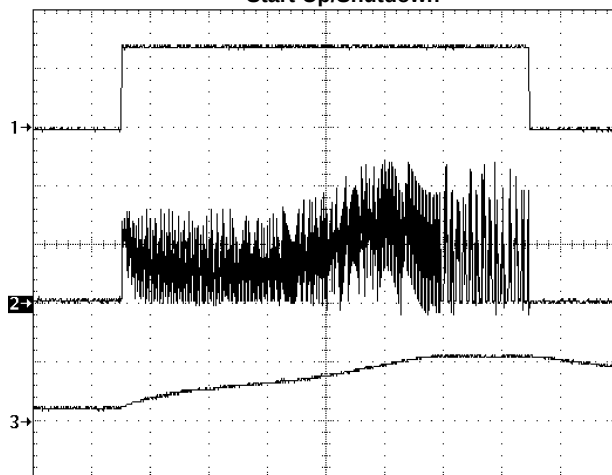
1) Load, 1mA to 17mA to 1mA, DC

2) V_{OUT} , 200mV/div, AC

3) I_L , 500mA/div, DC

$T = 40\mu s/div$

Start-Up/Shutdown



$V_{OUT} = 20V$, $V_{IN} = 2.5V$

1) $\overline{SHDN}$, 1V/div, DC

2) I_L , 250mA/div, DC

3) V_{OUT} , 20V/div, DC

$T = 400\mu s/div$

$R_L = 1.3k\Omega$

OPERATION

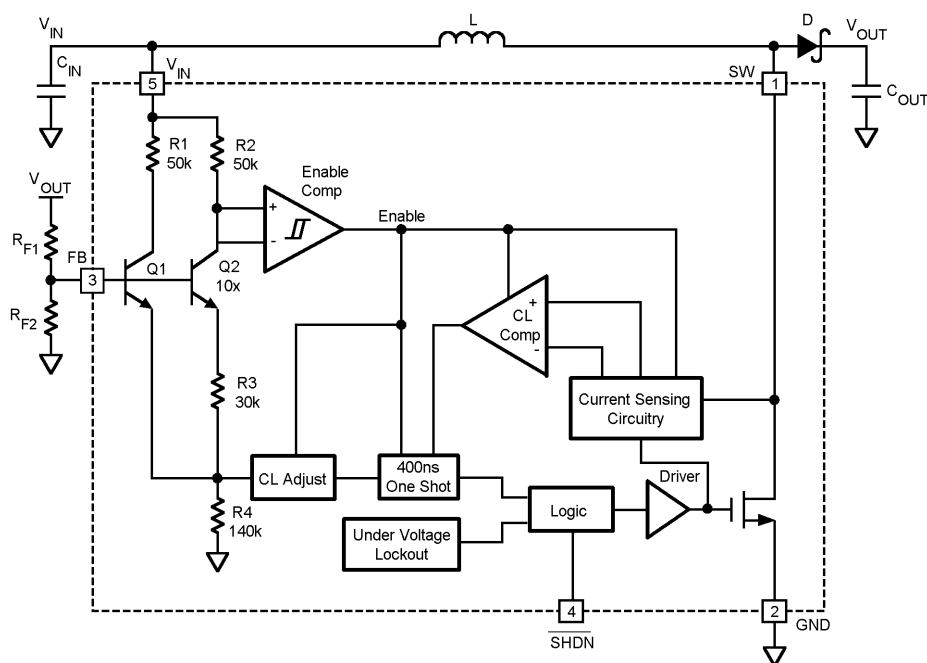
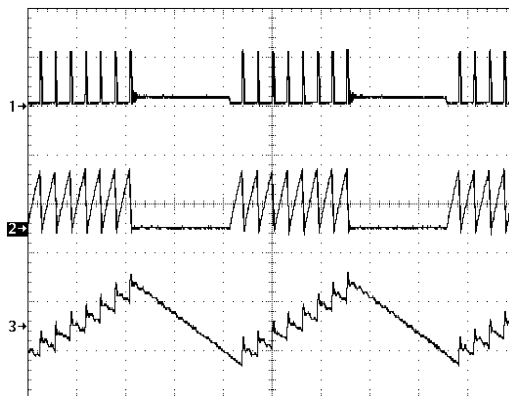


Figure 2. LM2704 Block Diagram



$V_{OUT} = 20V$, $V_{IN} = 2.5V$

1) V_{SW} , 20V/div, DC

2) Inductor Current, 500mA/div, DC

3) V_{OUT} , 100mV/div, AC

$T = 10\mu s/div$

Figure 3. Typical Switching Waveform

The LM2704 features a constant off-time control scheme. Operation can be best understood by referring to [Figure 2](#) and [Figure 3](#). Transistors Q1 and Q2 and resistors R3 and R4 of [Figure 2](#) form a bandgap reference used to control the output voltage. When the voltage at the FB pin is less than 1.237V, the Enable Comp in [Figure 2](#) enables the device and the NMOS switch is turned on pulling the SW pin to ground. When the NMOS switch is on, current begins to flow through inductor L while the load current is supplied by the output capacitor C_{OUT} . Once the current in the inductor reaches the peak current limit, the CL Comp trips and the 400ns One Shot

turns off the NMOS switch. The SW voltage will then rise to the output voltage plus a diode drop and the inductor current will begin to decrease as shown in [Figure 3](#). During this time the energy stored in the inductor is transferred to C_{OUT} and the load. After the 400ns off-time the NMOS switch is turned on and energy is stored in the inductor again. This energy transfer from the inductor to the output causes a stepping effect in the output ripple as shown in [Figure 3](#).

This cycle is continued until the voltage at FB reaches 1.237V. When FB reaches this voltage, the enable comparator then disables the device turning off the NMOS switch and reducing the I_q of the device to 40uA. The load current is then supplied solely by C_{OUT} indicated by the gradually decreasing slope at the output as shown in [Figure 3](#). When the FB pin drops slightly below 1.237V, the enable comparator enables the device and begins the cycle described previously. The SHDN pin can be used to turn off the LM2704 and reduce the I_q to 0.01uA. In shutdown mode the output voltage will be a diode drop lower than the input voltage.

APPLICATION INFORMATION

INDUCTOR SELECTION

The appropriate inductor for a given application is calculated using the following equation:

$$L = \left(\frac{V_{OUT} - V_{IN(min)} + V_D}{I_{CL}} \right) T_{OFF} \quad (2)$$

where V_D is the schottky diode voltage, I_{CL} is the switch current limit found in the [Typical Performance Characteristics](#) section, and T_{OFF} is the switch off time. When using this equation be sure to use the minimum input voltage for the application, such as for battery powered applications. For the LM2704 constant-off time control scheme, the NMOS power switch is turned off when the current limit is reached. There is approximately a 200ns delay from the time the current limit is reached in the NMOS power switch and when the internal logic actually turns off the switch. During this 200ns delay, the peak inductor current will increase. This increase in inductor current demands a larger saturation current rating for the inductor. This saturation current can be approximated by the following equation:

$$I_{PK} = I_{CL} + \left(\frac{V_{IN(max)}}{L} \right) 200ns \quad (3)$$

Choosing inductors with low ESR decrease power losses and increase efficiency.

Care should be taken when choosing an inductor. For applications that require an input voltage that approaches the output voltage, such as when converting a Li-Ion battery voltage to 5V, the 400ns off time may not be enough time to discharge the energy in the inductor and transfer the energy to the output capacitor and load. This can cause a ramping effect in the inductor current waveform and an increased ripple on the output voltage. Using a smaller inductor will cause the I_{PK} to increase and will increase the output voltage ripple further. This can be solved by adding a 4.7pF capacitor across the R_{F1} feedback resistor ([Figure 2](#)) and slightly increasing the output capacitor. A smaller inductor can then be used to ensure proper discharge in the 400ns off time.

DIODE SELECTION

To maintain high efficiency, the average current rating of the schottky diode should be larger than the peak inductor current, I_{PK}. Schottky diodes with a low forward drop and fast switching speeds are ideal for increasing efficiency in portable applications. Choose a reverse breakdown of the schottky diode larger than the output voltage.

CAPACITOR SELECTION

Choose low ESR capacitors for the output to minimize output voltage ripple. Multilayer ceramic capacitors are the best choice. For most applications, a 1uF ceramic capacitor is sufficient. For some applications a reduction in output voltage ripple can be achieved by increasing the output capacitor.

Local bypassing for the input is needed on the LM2704. Multilayer ceramic capacitors are a good choice for this as well. A 4.7uF capacitor is sufficient for most applications. For additional bypassing, a 100nF ceramic capacitor can be used to shunt high frequency ripple on the input.

LAYOUT CONSIDERATIONS

The input bypass capacitor C_{IN} , as shown in [Typical Application Circuit](#), must be placed close to the IC. This will reduce copper trace resistance which effects input voltage ripple of the IC. For additional input voltage filtering, a 100nF bypass capacitor can be placed in parallel with C_{IN} to shunt any high frequency noise to ground. The output capacitor, C_{OUT} , should also be placed close to the IC. Any copper trace connections for the C_{OUT} capacitor can increase the series resistance, which directly effects output voltage ripple. The feedback network, resistors R1 and R2, should be kept close to the FB pin to minimize copper trace connections that can inject noise into the system. The ground connection for the feedback resistor network should connect directly to an analog ground plane. The analog ground plane should tie directly to the GND pin. If no analog ground plane is available, the ground connection for the feedback network should tie directly to the GND pin. Trace connections made to the inductor and schottky diode should be minimized to reduce power dissipation and increase overall efficiency.

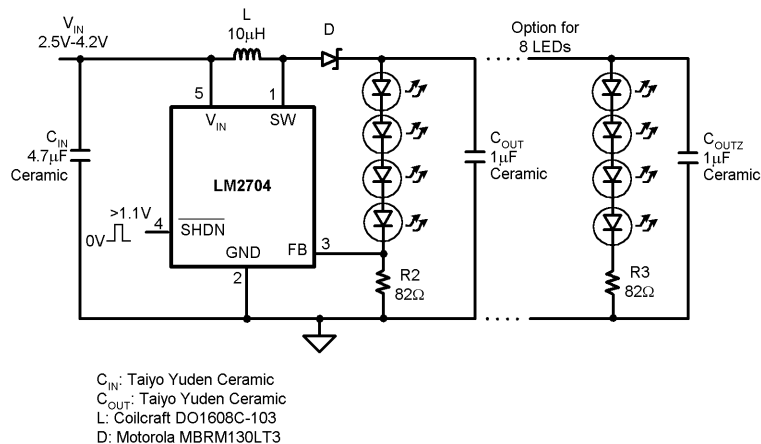


Figure 4. White LED Application

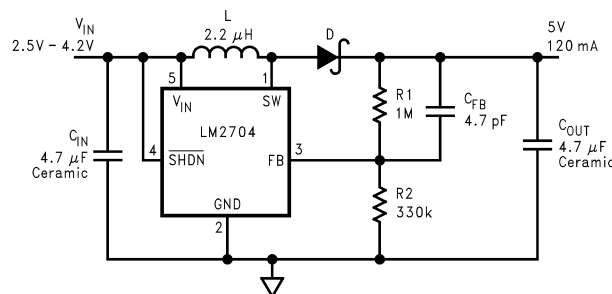


Figure 5. Li-Ion 5V Application

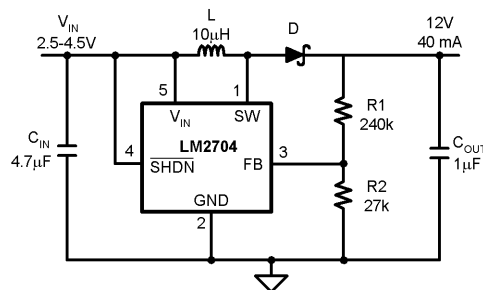


Figure 6. Li-Ion 12V Application

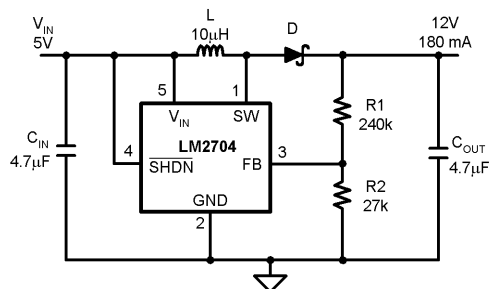


Figure 7. 5V to 12V Application

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
LM2704MF-ADJ	ACTIVE	SOT-23	DBV	5	1000	TBD	Call TI	Call TI	-40 to 85	S28B	Samples
LM2704MF-ADJ/NOPB	ACTIVE	SOT-23	DBV	5	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	S28B	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.

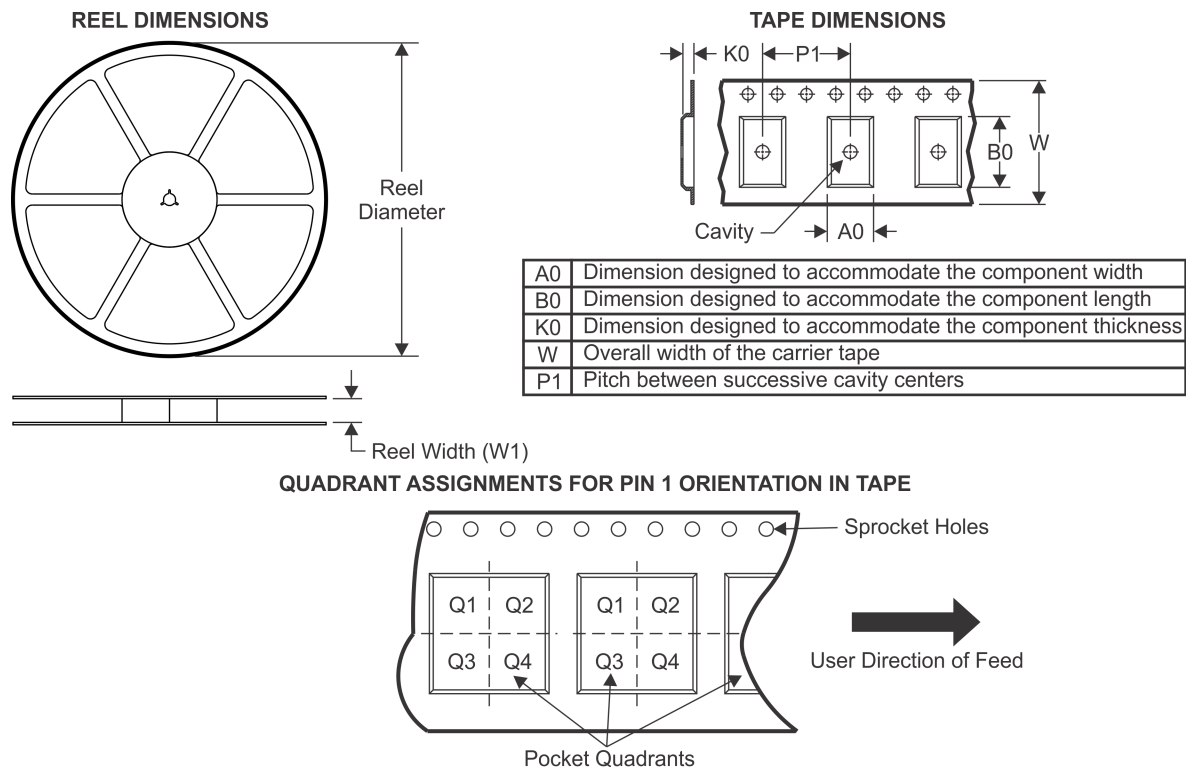
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(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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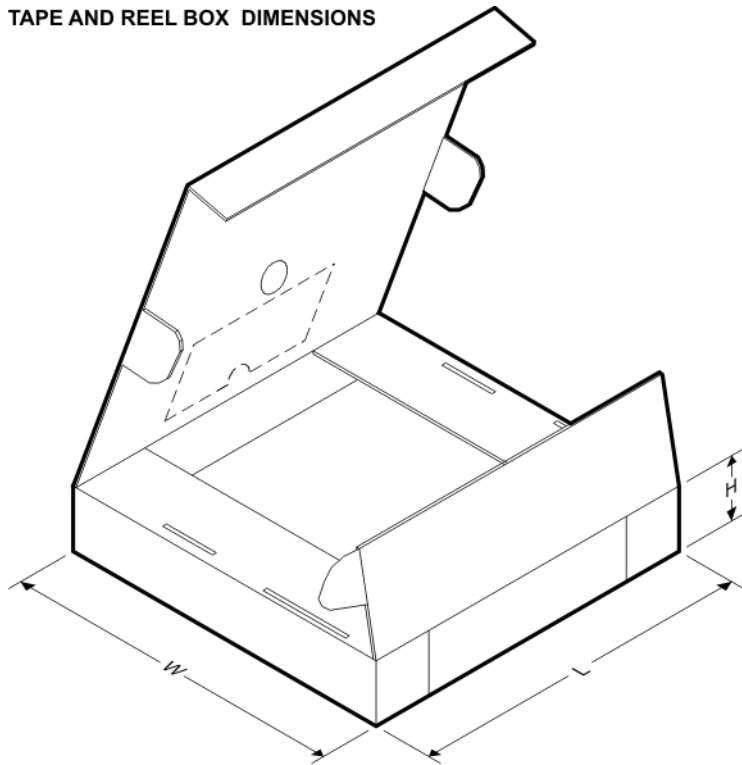
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TAPE AND REEL INFORMATION


*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
LM2704MF-ADJ	SOT-23	DBV	5	1000	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
LM2704MF-ADJ/NOPB	SOT-23	DBV	5	1000	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS

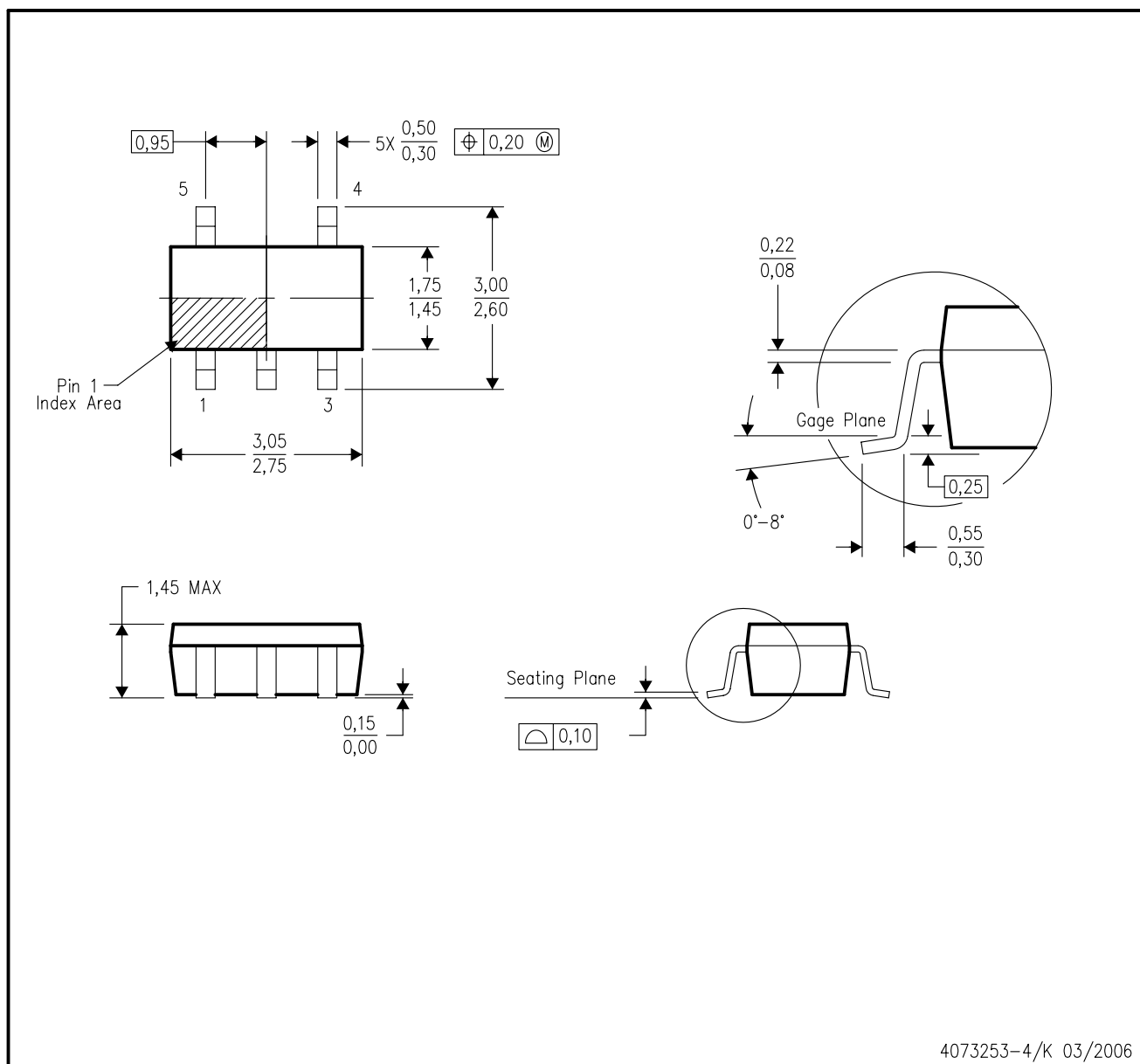


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM2704MF-ADJ	SOT-23	DBV	5	1000	203.0	190.0	41.0
LM2704MF-ADJ/NOPB	SOT-23	DBV	5	1000	203.0	190.0	41.0

DBV (R-PDSO-G5)

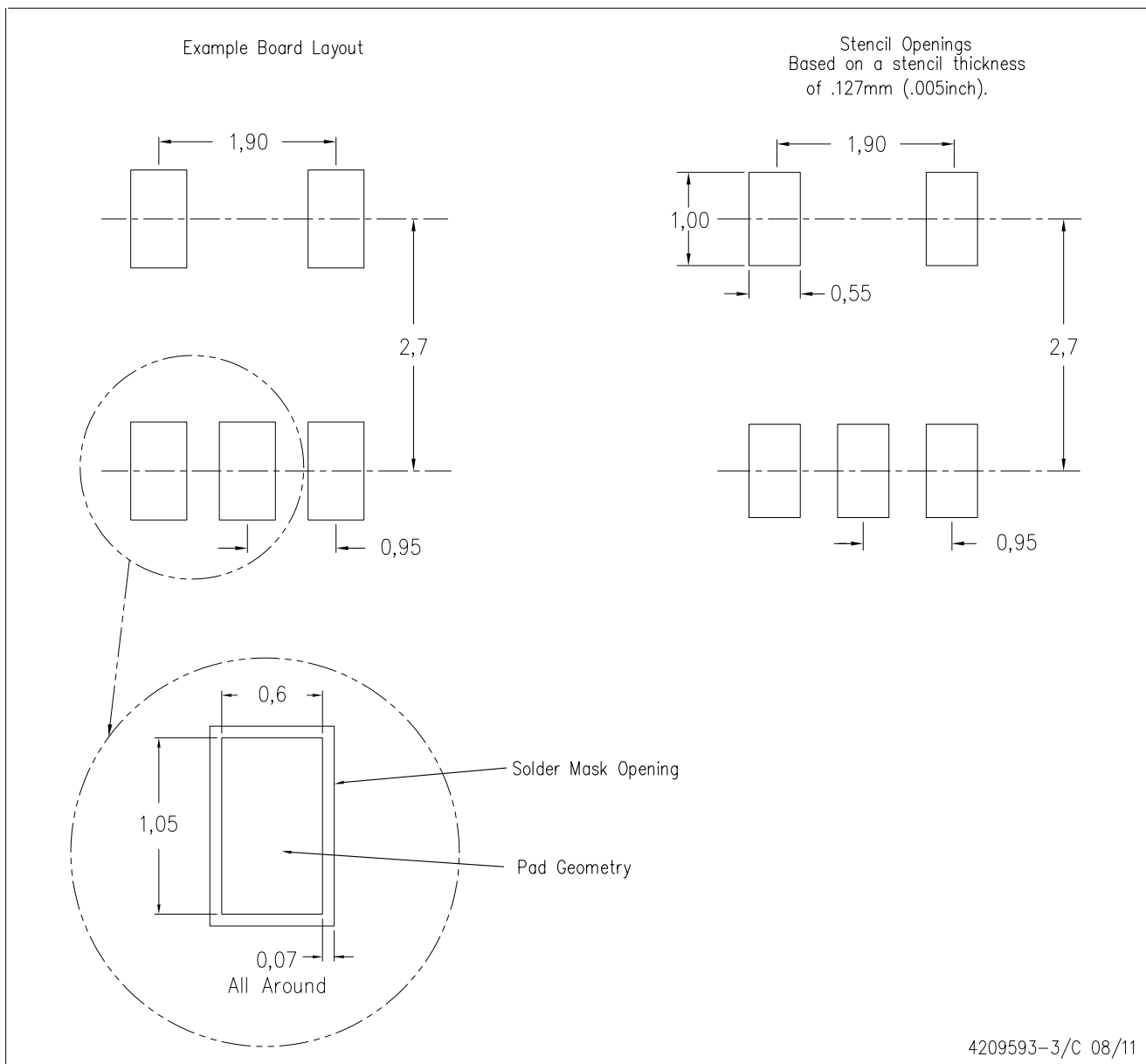
PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
 - Falls within JEDEC MO-178 Variation AA.

DBV (R-PDSO-G5)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
 - D. Publication IPC-7351 is recommended for alternate designs.
 - E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.

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Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

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