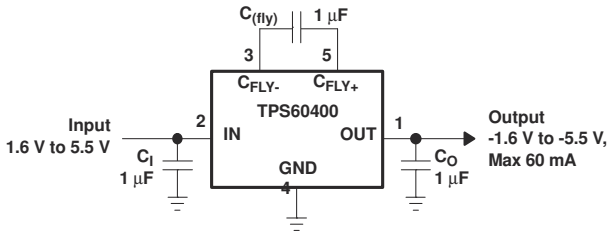
# TPS6040x Unregulated 60-mA Charge Pump Voltage Inverter

## 1 Features

- Inverts Input Supply Voltage
- Up to 60-mA Output Current
- Only Three Small 1-µF Ceramic Capacitors Needed
- Input Voltage Range From 1.6 V to 5.5 V
- PowerSave-Mode for Improved Efficiency at Low-Output Currents (TPS60400)
- Device Quiescent Current Typical 65 µA
- Integrated Active Schottky-Diode for Start-up Into Load
- Small 5-Pin SOT-23 Package
- Evaluation Module Available TPS60400EVM-178

## 2 Applications

- LCD Bias
- GaAs Bias for RF Power Amps
- Sensor Supply in Portable Instruments
- Bipolar Amplifier Supply
- Medical Instruments
- Battery-Operated Equipment




**Typical Application**

## 3 Description

The TPS6040x family of devices generates an unregulated negative output voltage from an input voltage ranging from 1.6 V to 5.5 V. The devices are typically supplied by a preregulated supply rail of 5 V or 3.3 V. Due to its wide input voltage range, two or three NiCd, NiMH, or alkaline battery cells, as well as one Li-Ion cell can also power them.

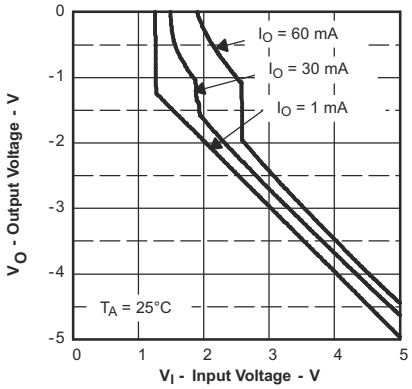
Only three external 1-µF capacitors are required to build a complete DC-DC charge pump inverter. Assembled in a 5-pin SOT-23 package, the complete converter can be built on a 50-mm$^2$ board area. Additional board area and component count reduction is achieved by replacing the Schottky diode that is typically needed for start-up into load by integrated circuitry.

The TPS6040x can deliver a maximum output current of 60 mA with a typical conversion efficiency of greater than 90% over a wide output current range. Three device options with 20-kHz, 50-kHz, and 250-kHz fixed-frequency operation are available. TPS60400 comes with a variable switching frequency to reduce operating current in applications with a wide load range and enables the design with low-value capacitors.

**Device Information**

| PART NUMBER | PACKAGE (1) | BODY SIZE (NOM) |
|---|---|---|
| TPS6040x | SOT-23 (5) | 2.90 mm x 1.60 mm |

(1) For all available packages, see the orderable addendum at the end of the datasheet.




**Output Voltage vs Input Voltage**

An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

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## 4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| Changes from Revision B (April 2015) to Revision C (October 2020) | Page |
|---|---|
| • Updated the numbering format for tables, figures and cross-references throughout the document | 1 |

| Changes from Revision A (November 2004) to Revision B (April 2015) | Page |
|---|---|
| • Added *Handling Rating* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section | 1 |


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## 5 Device Comparison Table

| PART NUMBER(1) | MARKING DBV PACKAGE | TYPICAL FLYING CAPACITOR [µF] | FEATURE |
|---|---|---|---|
| TPS60400DBV | PFKI | 1 | Variable switching frequency 50 kHz-250 kHz |
| TPS60401DBV | PFLI | 10 | Fixed frequency 20 kHz |
| TPS60402DBV | PFMI | 3.3 | Fixed frequency 50 kHz |
| TPS60403DBV | PFNI | 1 | Fixed frequency 250 kHz |

(1) The DBV package is available taped and reeled. Add R suffix to device type (for example, TPS60400DBVR) to order quantities of 3000 devices per reel. Add T suffix to device type (for example, TPS60400DBVT) to order quantities of 250 devices per reel.

## 6 Pin Configuration and Functions

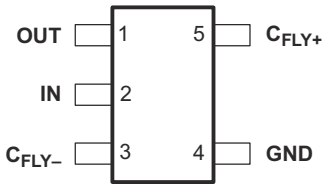



**Figure 6-1. DBV Package 5 Pins Top View**

**Table 6-1. Pin Functions**

| PIN | | I/O | DESCRIPTION |
|---|---|---|---|
| NAME | NO. | | |
| $C_{FLY+}$ | 5 | | Positive terminal of the flying capacitor $C_{(fly)}$ |
| $C_{FLY-}$ | 3 | | Negative terminal of the flying capacitor $C_{(fly)}$ |
| GND | 4 | | Ground |
| IN | 2 | I | Supply input. Connect to an input supply in the 1.6-V to 5.5-V range. Bypass IN to GND with a capacitor that has the same value as the flying capacitor. |
| OUT | 1 | O | Power output with $V_O = -V_I$ Bypass OUT to GND with the output filter capacitor $C_O$. |

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# 7 Specifications

## 7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

| | | MIN | MAX | UNIT |
|---|---|---|---|---|
| Voltage range | IN to GND | -0.3 | 5.5 | V |
| | OUT to GND | -5.5 | 0.3 | V |
| | $C_{FLY-}$ to GND | 0.3 | $V_O$ - 0.3 | V |
| | $C_{FLY+}$ to GND | -0.3 V | $V_I$ + 0.3 | V |
| Continuous power dissipation | | See *Section 9.2.1.2.5* | | |
| Continuous output current | | | 80 | mA |
| Maximum junction temperature, $T_J$ | | | 150 | °C |

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

## 7.2 Handling Ratings

| | | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $T_{stg}$ | Storage temperature range | | -55°C | 150°C | °C |
| $V_{(ESD)}$ | Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins(1) | -1000 | 1000 | V |
| | | Charged device model (CDM), per JEDEC specification JESD22-C101, all pins(2) | -500 | 500 | |

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

## 7.3 Recommended Operating Conditions

| | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|
| Input voltage range, $V_I$ | 1.8 | | 5.25 | V |
| Output current range at OUT, $I_O$ | | | 60 | mA |
| Input capacitor, $C_I$ | 0 | $C_{(fly)}$ | | µF |
| Flying capacitor, $C_{(fly)}$ | | 1 | | µF |
| Output capacitor, $C_O$ | | 1 | 100 | µF |
| Operating junction temperature, $T_J$ | -40 | | 125 | °C |

## 7.4 Thermal Information

| THERMAL METRIC(1) | | TPS6040x DBV 5 PINS | UNIT |
|---|---|---|---|
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 221.2 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 81.9 | |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 39.8 | |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 3.3 | |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 38.9 | |
| $R_{\theta JC(bot)}$ | Junction-to-case (bottom) thermal resistance | n/a | |

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.


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## 7.5 Electrical Characteristics

$C_I = C_{(fly)} = C_O$ (according to Table 1), $T_C$ = -40°C to 85°C, $V_I$ = 5 V over recommended operating free-air temperature range (unless otherwise noted)

| PARAMETER | | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_I$ | Supply voltage range | | At $T_C$ = -40°C to 85°C, $R_L$ = 5 kΩ | | 1.8 | | 5.25 | V |
| | | | At $T_C$≥ 0°C, $R_L$= 5 kΩ | | 1.6 | | | |
| $I_O$ | Maximum output current at $V_O$ | | | | 60 | | | mA |
| $V_O$ | Output voltage | | | | | -$V_I$ | | V |
| $V_{P-P}$ | Output voltage ripple | TPS60400 | $I_O$ = 5 mA | $C_{(fly)}$ = 1 µF, $C_O$ = 2.2 µF | | 35 | | $mV_{P-P}$ |
| | | TPS60401 | | $C_{(fly)}$ = $C_O$ = 10 µF | | 20 | | |
| | | TPS60402 | | $C_{(fly)}$ = $C_O$ = 3.3 µF | | 20 | | |
| | | TPS60403 | | $C_{(fly)}$ = $C_O$ = 1 µF | | 15 | | |
| $I_Q$ | Quiescent current (no-load input current) | TPS60400 | At $V_I$ = 5 V | | | 125 | 270 | µA |
| | | TPS60401 | | | | 65 | 190 | |
| | | TPS60402 | | | | 120 | 270 | |
| | | TPS60403 | | | | 425 | 700 | |
| | | TPS60400 | At T ≤ 60°C, $V_I$ = 5 V | | | | 210 | µA |
| | | TPS60401 | | | | | 135 | |
| | | TPS60402 | | | | | 210 | |
| | | TPS60403 | | | | | 640 | |
| $f_{OSC}$ | Internal switching frequency | TPS60400 | VCO version | | 30 | 50-250 | 350 | kHz |
| | | TPS60401 | | | 13 | 20 | 28 | |
| | | TPS60402 | | | 30 | 50 | 70 | |
| | | TPS60403 | | | 150 | 250 | 300 | |
| | Impedance at 25°C, $V_I$ = 5 V | TPS60400 | $C_I = C_{(fly)} = C_O$ = 1 µF | | | 12 | 15 | Ω |
| | | TPS60401 | $C_I = C_{(fly)} = C_O$ = 10 µF | | | 12 | 15 | |
| | | TPS60402 | $C_I = C_{(fly)} = C_O$ = 3.3 µF | | | 12 | 15 | |
| | | TPS60403 | $C_I = C_{(fly)} = C_O$ = 1 µF | | | 12 | 15 | |

## 7.6 Typical Characteristics

**Table 7-1. Table of Graphs**

| | | | FIGURE |
|---|---|---|---|
| η | Efficiency | vs Output current at 3.3 V, 5 V<br>TPS60400, TPS60401, TPS60402, TPS60403 | Figure 7-1, Figure 7-2 |
| $I_I$ | Input current | vs Output current<br>TPS60400, TPS60401, TPS60402, TPS60403 | Figure 7-3, Figure 7-4 |
| $I_S$ | Supply current | vs Input voltage<br>TPS60400, TPS60401, TPS60402, TPS60403 | Figure 7-5, Figure 7-6 |
| | Output resistance | vs Input voltage at -40°C, 0°C, 25°C, 85°C<br>TPS60400, $C_I = C_{(fly)} = C_O$ = 1 µF<br>TPS60401, $C_I = C_{(fly)} = C_O$ = 10 µF<br>TPS60402 , $C_I = C_{(fly)} = C_O$ = 3.3 µF<br>TPS60403, $C_I = C_{(fly)} = C_O$ = 1 µF | Figure 7-7, Figure 7-8, Figure 7-9, Figure 7-10 |
| $V_O$ | Output voltage | vs Output current at 25°C, $V_{IN}$=1.8 V, 2.5 V, 3.3 V, 5 V<br>TPS60400, $C_I = C_{(fly)} = C_O$ = 1 µF<br>TPS60401, $C_I = C_{(fly)} = C_O$ = 10 µF<br>TPS60402 , $C_I = C_{(fly)} = C_O$ = 3.3 µF<br>TPS60403, $C_I = C_{(fly)} = C_O$ = 1 µF | Figure 7-11, Figure 7-12, Figure 7-13, Figure 7-14 |

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**Table 7-1. Table of Graphs (continued)**

| | | | FIGURE |
|---|---|---|---|
| $f_{OSC}$ | Oscillator frequency | vs Temperature at $V_I$ = 1.8 V, 2.5 V, 3.3 V, 5 V<br>TPS60400, TPS60401, TPS60402, TPS60403 | Figure 7-15, Figure 7-16, Figure 7-17, Figure 7-18 |
| $f_{OSC}$ | Oscillator frequency | vs Output current<br>TPS60400 at 2 V, 3.3 V, 5.0 V | Figure 7-19 |

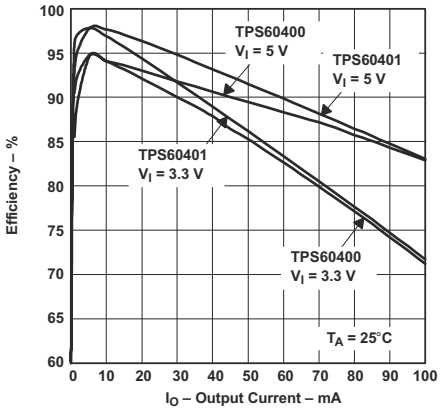



**Figure 7-1. Efficiency vs Output Current**

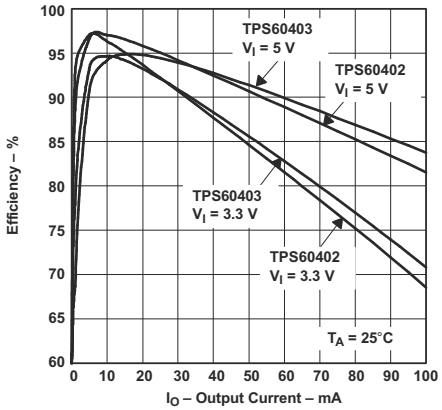



**Figure 7-2. Efficiency vs Output Current**

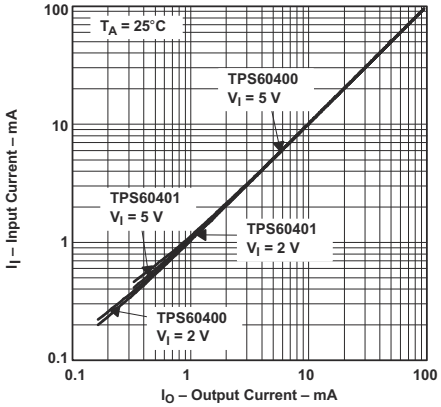



**Figure 7-3. Input Current vs Output Current**

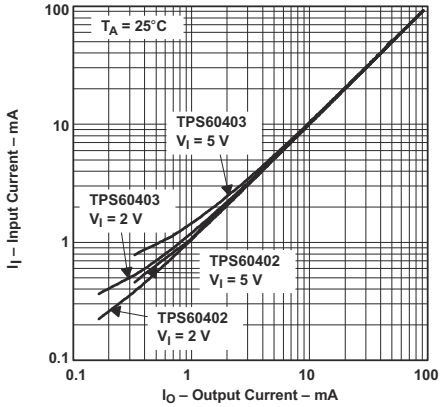



**Figure 7-4. Input Current vs Output Current**

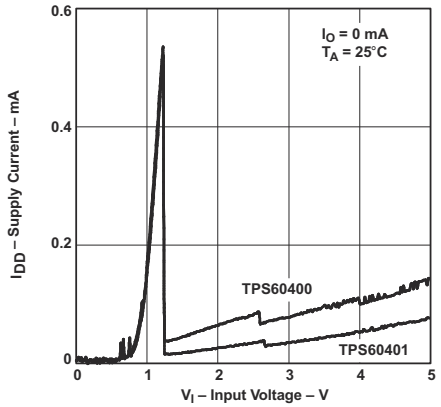



**Figure 7-5. Supply Current vs Input Voltage**

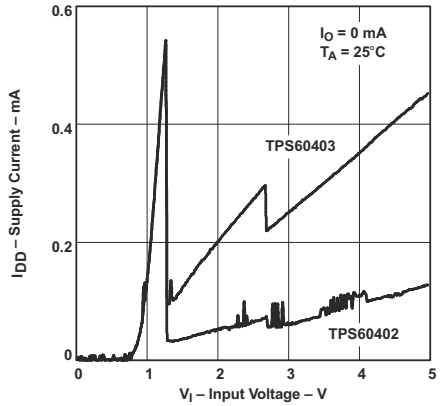



**Figure 7-6. Supply Current vs Input Voltage**


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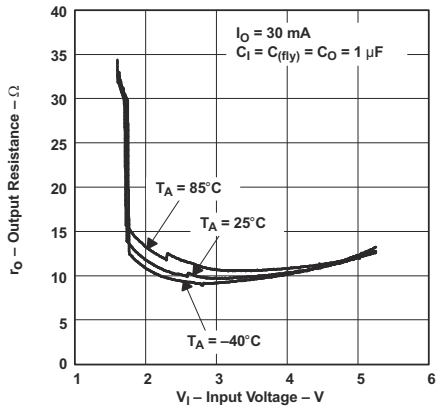



**Figure 7-7. Output Resistance vs Input Voltage**

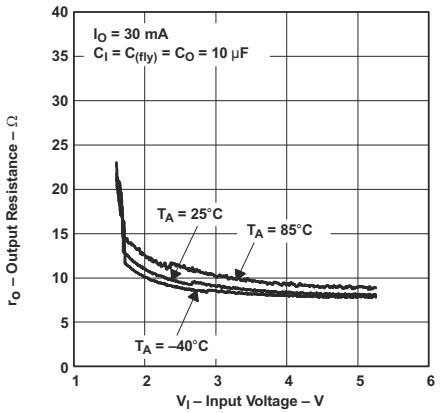



**Figure 7-8. Output Resistance vs Input Voltage**

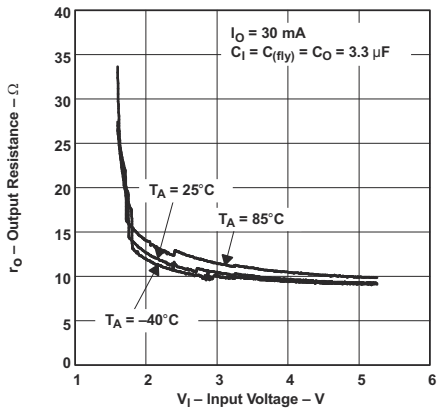



**Figure 7-9. Output Resistance vs Input Voltage**

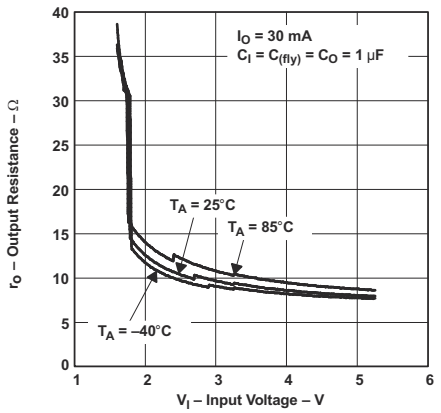



**Figure 7-10. Output Resistance vs Input Voltage**

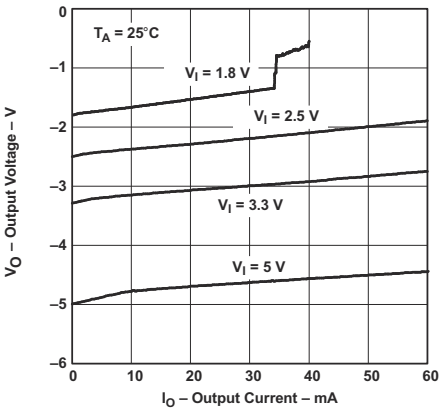



**Figure 7-11. Output Voltage vs Output Current**

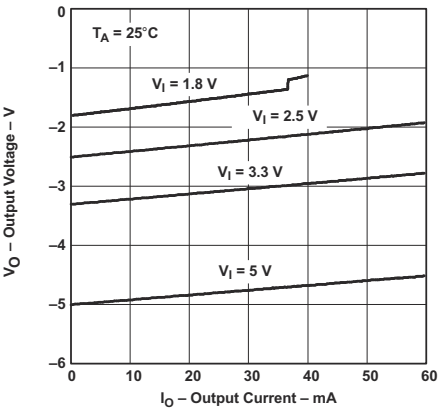



**Figure 7-12. Output Voltage vs Output Current**

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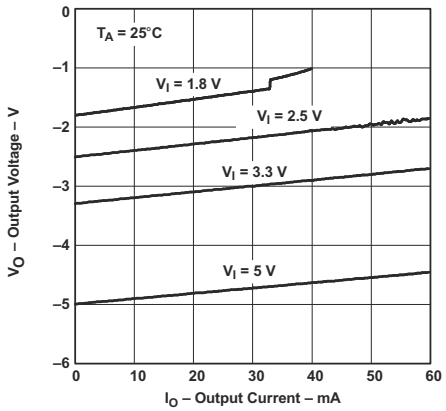



**Figure 7-13. Output Voltage vs Output Current**

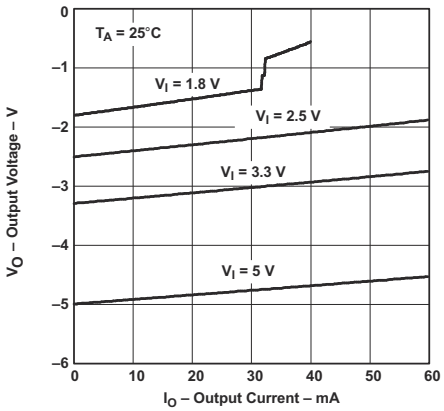



**Figure 7-14. Output Voltage vs Output Current**

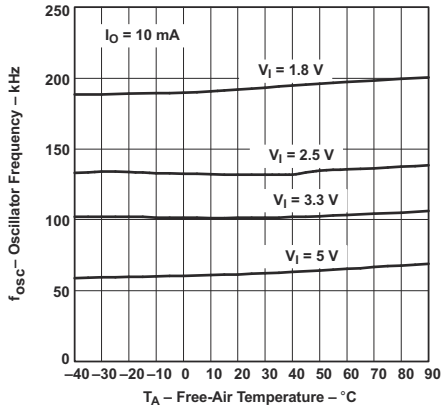



**Figure 7-15. Oscillator Frequency vs Free-Air Temperature**

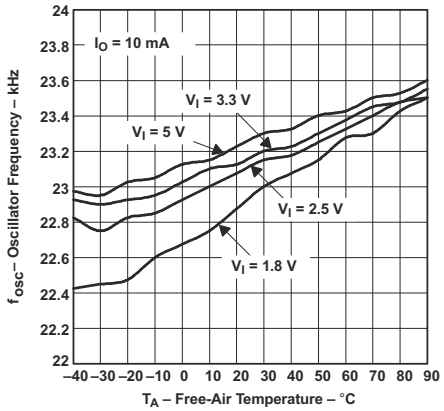



**Figure 7-16. Oscillator Frequency vs Free-Air Temperature**

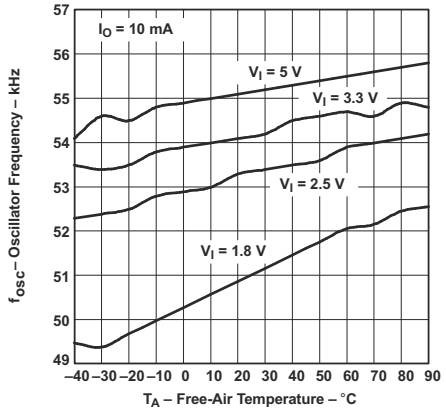



**Figure 7-17. Oscillator Frequency vs Free-Air Temperature**

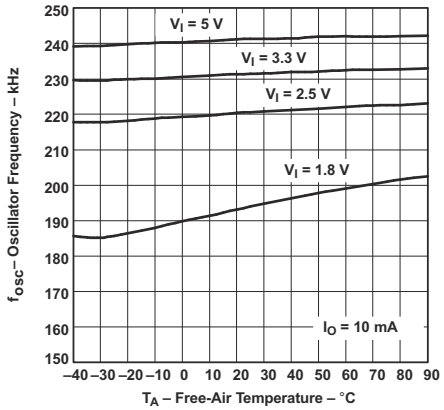



**Figure 7-18. Oscillator Frequency vs Free-Air Temperature**


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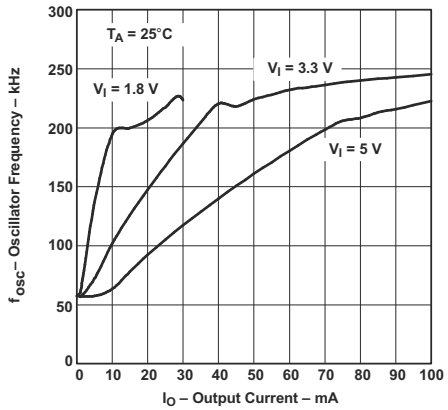



**Figure 7-19. Oscillator Frequency vs Output Current**

# 8 Detailed Description

## 8.1 Overview

The TPS60400, TPS60401 charge pumps invert the voltage applied to their input. For the highest performance, use low equivalent series resistance (ESR) capacitors (for example, ceramic). During the first half-cycle, switches S2 and S4 open, switches S1 and S3 close, and capacitor ($C_{(fly)}$) charges to the voltage at $V_I$. During the second half-cycle, S1 and S3 open, S2 and S4 close. This connects the positive terminal of $C_{(fly)}$ to GND and the negative to $V_O$. By connecting $C_{(fly)}$ in parallel, $C_O$ is charged negative. The actual voltage at the output is more positive than $-V_I$, since switches S1-S4 have resistance and the load drains charge from $C_O$.

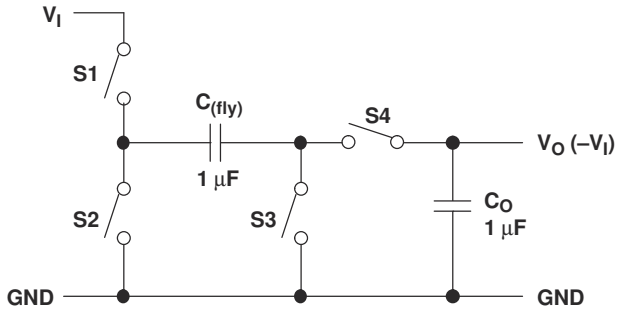
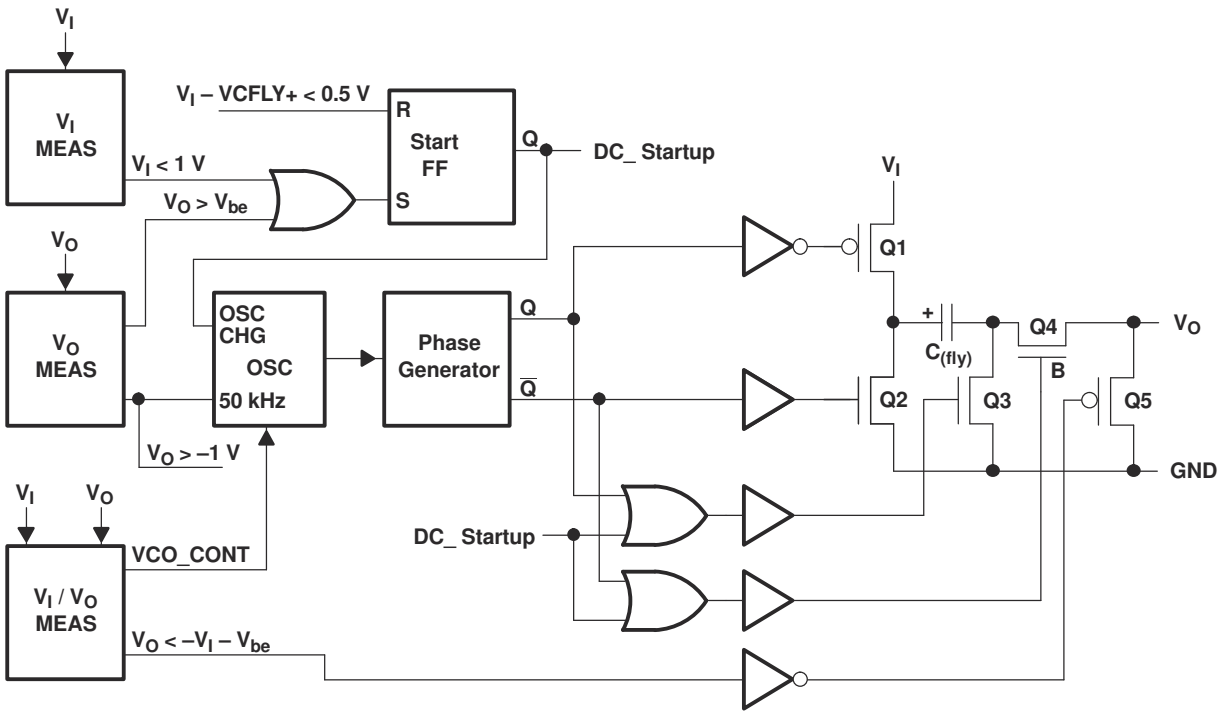



**Figure 8-1. Operating Principle**

## 8.2 Functional Block Diagram





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## 8.3 Feature Description

### 8.3.1 Charge-Pump Output Resistance

The TPS6040x devices are not voltage regulators. The charge pump's output source resistance is approximately 15 Ω at room temperature (with $V_I$ = 5 V), and $V_O$ approaches -5 V when lightly loaded. $V_O$ droops toward GND as load current increases.

$$V_O = -(V_I - R_O \times I_O) \tag{1}$$

$$R_O \approx \frac{1}{f_{OSC} \times C_{(fly)}} + 4\left(2R_{SWITCH} + ESR_{CFLY}\right) + ESR_{CO}$$

$R_O$ = output resistance of the converter (2)

### 8.3.2 Efficiency Considerations

The power efficiency of a switched-capacitor voltage converter is affected by three factors: the internal losses in the converter IC, the resistive losses of the capacitors, and the conversion losses during charge transfer between the capacitors. The internal losses are associated with the internal functions of the IC, such as driving the switches, oscillator, and so forth. These losses are affected by operating conditions such as input voltage, temperature, and frequency. The next two losses are associated with the output resistance of the voltage converter circuit. Switch losses occur because of the on-resistance of the MOSFET switches in the IC. Charge-pump capacitor losses occur because of their ESR. The relationship between these losses and the output resistance is as follows:

$$P_{CAPACITOR\ LOSSES} + P_{CONVERSION\ LOSSES} = I_O^2 \times R_O$$

$R_{SWITCH}$ = resistance of a single MOSFET-switch inside the converter
$f_{OSC}$ = oscillator frequency (3)

The first term is the effective resistance from an ideal switched-capacitor circuit. Conversion losses occur during the charge transfer between $C_{(fly)}$ and $C_O$ when there is a voltage difference between them. The power loss is:

$$P_{CONV.LOSS} = \left[\frac{1}{2} \times C_{(fly)}\left(V_I^2 - V_O^2\right) + \frac{1}{2}C_O\left(V_{RIPPLE}^2 - 2V_O V_{RIPPLE}\right)\right] \times f_{OSC} \tag{4}$$

The efficiency of the TPS6040x devices is dominated by their quiescent supply current at low output current and by their output impedance at higher current.

$$\eta \cong \frac{I_O}{I_O + I_Q}\left(1 - \frac{I_O \times R_O}{V_I}\right) \tag{5}$$

Where, $I_Q$ = quiescent current.

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## 8.4 Device Functional Modes

### 8.4.1 Active-Schottky Diode

For a short period of time, when the input voltage is applied, but the inverter is not yet working, the output capacitor is charged positive by the load. To prevent the output being pulled above GND, a Schottky diode must be added in parallel to the output. The function of this diode is integrated into the TPS6040x devices, which gives a defined startup performance and saves board space.

A current sink and a diode in series can approximate the behavior of a typical, modern operational amplifier. Figure 8-2 shows the current into this typical load at a given voltage. The TPS6040x devices are optimized to start into these loads.

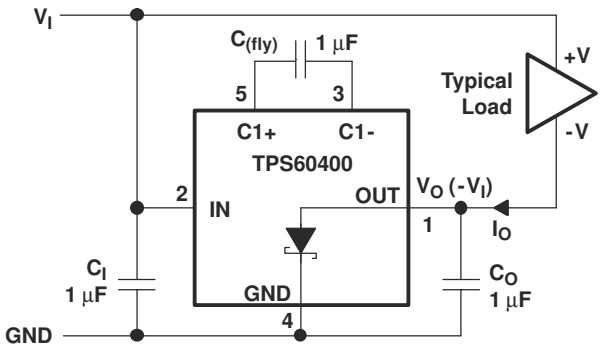



**Figure 8-2. Typical Load**

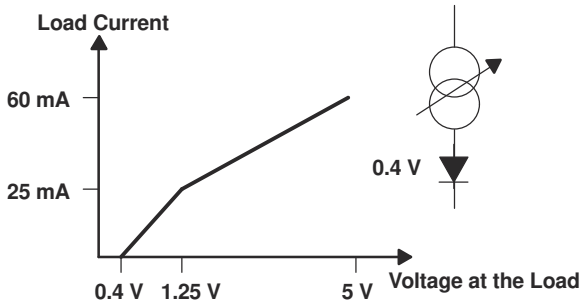



**Figure 8-3. Maximum Start-Up Current**


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# 9 Application and Implementation

**Note**

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

## 9.1 Application Information

The TPS6040x is a family of devices that generate an unregulated negative output voltage from an input voltage ranging from 1.6 V to 5.5 V.

## 9.2 Typical Application

### 9.2.1 Voltage Inverter

The design guidelines provide a component selection to operate the device within the recommended operating conditions.

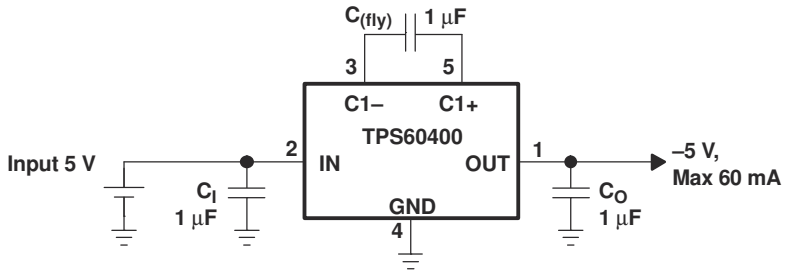



**Figure 9-1. Typical Operating Circuit**

#### *9.2.1.1 Design Requirements*

The TPS6040x is connected to generate a negative output voltage from a positive input.

#### *9.2.1.2 Detailed Design Procedure*

The most common application for these devices is a charge-pump voltage inverter (see Figure 9-1). This application requires only two external components; capacitors $C_{(fly)}$ and $C_O$, plus a bypass capacitor, if necessary. Refer to the capacitor selection section for suggested capacitor types.

For the maximum output current and best performance, three ceramic capacitors of 1 µF (TPS60400, TPS60403) are recommended. For lower currents or higher allowed output voltage ripple, other capacitors can also be used. It is recommended that the output capacitors has a minimum value of 1 µF. With flying capacitors lower than 1 µF, the maximum output power decreases.

##### 9.2.1.2.1 Capacitor Selection

To maintain the lowest output resistance, use capacitors with low ESR (see Table 9-1). The charge-pump output resistance is a function of $C_{(fly)}$'s and $C_O$'s ESR. Therefore, minimizing the charge-pump capacitor's ESR minimizes the total output resistance. The capacitor values are closely linked to the required output current and the output noise and ripple requirements. It is possible to only use 1-µF capacitors of the same type.

##### 9.2.1.2.2 Input Capacitor ($C_I$)

Bypass the incoming supply to reduce its ac impedance and the impact of the TPS6040x switching noise. The recommended bypassing depends on the circuit configuration and where the load is connected. When the inverter is loaded from OUT to GND, current from the supply switches between 2 x $I_O$ and zero. Therefore, use a large bypass capacitor (for example, equal to the value of $C_{(fly)}$) if the supply has high ac impedance. When the inverter is loaded from IN to OUT, the circuit draws 2 × $I_O$ constantly, except for short switching spikes. A 0.1-µF bypass capacitor is sufficient.

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#### 9.2.1.2.3 Flying Capacitor ($C_{(fly)}$)

Increasing the flying capacitor's size reduces the output resistance. Small values increases the output resistance. Above a certain point, increasing $C_{(fly)}$'s capacitance has a negligible effect, because the output resistance becomes dominated by the internal switch resistance and capacitor ESR.

#### 9.2.1.2.4 Output Capacitor ($C_O$)

Increasing the output capacitor's size reduces the output ripple voltage. Decreasing its ESR reduces both output resistance and ripple. Smaller capacitance values can be used with light loads if higher output ripple can be tolerated. Use the following equation to calculate the peak-to-peak ripple.

$$V_{O(ripple)} = \frac{I_O}{f_{osc} \times C_O} + 2 \times I_O \times ESR_{CO} \quad (6)$$

**Table 9-1. Recommended Capacitor Values**

| DEVICE | $V_I$ [V] | $I_O$ [mA] | $C_I$ [µF] | $C_{(fly)}$ [µF] | $C_O$ [µF] |
|---|---|---|---|---|---|
| TPS60400 | 1.8…5.5 | 60 | 1 | 1 | 1 |
| TPS60401 | 1.8…5.5 | 60 | 10 | 10 | 10 |
| TPS60402 | 1.8…5.5 | 60 | 3.3 | 3.3 | 3.3 |
| TPS60403 | 1.8…5.5 | 60 | 1 | 1 | 1 |

**Table 9-2. Recommended Capacitors**

| MANUFACTURER | PART NUMBER | SIZE | CAPACITANCE | TYPE |
|---|---|---|---|---|
| Taiyo Yuden | EMK212BJ474MG | 0805 | 0.47 µF | Ceramic |
| | LMK212BJ105KG | 0805 | 1 µF | Ceramic |
| | LMK212BJ225MG | 0805 | 2.2 µF | Ceramic |
| | EMK316BJ225KL | 1206 | 2.2 µF | Ceramic |
| | LMK316BJ475KL | 1206 | 4.7 µF | Ceramic |
| | JMK316BJ106KL | 1206 | 10 µF | Ceramic |
| TDK | C2012X5R1C105M | 0805 | 1 µF | Ceramic |
| | C2012X5R1A225M | 0805 | 2.2 µF | Ceramic |
| | C2012X5R1A335M | 0805 | 3.3 µF | Ceramic |

Table 9-3 contains a list of manufacturers of the recommended capacitors. Ceramic capacitors will provide the lowest output voltage ripple because they typically have the lowest ESR-rating.

**Table 9-3. Recommended Capacitor Manufacturers**

| CAPACITOR TYPE | MANUFACTURER | WEB ADDRESS |
|---|---|---|
| X5R / X7R ceramic | Taiyo Yuden | www.t-yuden.com |
| X5R / X7R ceramic | TDK | www.component.tdk.com |
| X5R / X7R ceramic | Vishay | www.vishay.com |
| X5R / X7R ceramic | Kemet | www.kemet.com |


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#### 9.2.1.2.5 Power Dissipation

As given in *Section 7.4*, the thermal resistance of TPS6040x is: $R_{\Theta JA}$ = 221°C/W.

The terminal resistance can be calculated using the following equation:

$$R_{\theta JA} = \frac{T_J - T_A}{P_D} \tag{7}$$

where:

$T_J$ is the junction temperature. $T_A$ is the ambient temperature. $P_D$ is the power that is dissipated by the device.

$$R_{\theta JA} = \frac{T_J - T_A}{P_D} \tag{8}$$

The maximum power dissipation can be calculated using the following equation:

$$P_D = V_I \times I_I - V_O \times I_O = V_{I(max)} \times (I_O + I_{(SUPPLY)}) - V_O \times I_O \tag{9}$$

The maximum power dissipation happens with maximum input voltage and maximum output current.

At maximum load the supply current is 0.7 mA maximum.

$$P_D = 5\ V \times (60\ mA + 0.7\ mA) - 4.4\ V \times 60\ mA = 40\ mW \tag{10}$$

With this maximum rating and the thermal resistance of the device on the EVM, the maximum temperature rise above ambient temperature can be calculated using the following equation:

$$\Delta T_J = R_{\Theta JA} \times P_D = 221°C/W \times 40\ mW = 8.8°C \tag{11}$$

This means that the internal dissipation increases $T_J$ by <10°C.

The junction temperature of the device shall not exceed 125°C.

This means the IC can easily be used at ambient temperatures up to:

$$T_A = T_{J(max)} - \Delta T_J = 125°C/W - 10°C = 115°C \tag{12}$$

### *9.2.1.3 Application Curves*

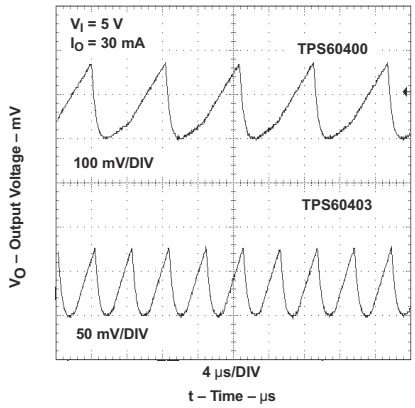



**Figure 9-2. Output Voltage vs Time for TPS60400 and TPS60401**

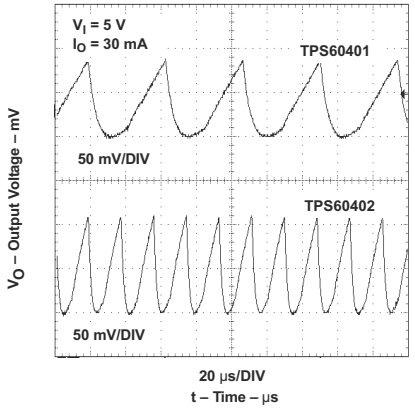



**Figure 9-3. Output Voltage vs Time for TPS60401 and TPS60402**

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## 9.3 System Examples

To reduce the output voltage ripple, a RC post filter can be used.

An output filter can easily be formed with a resistor ($R_P$) and a capacitor ($C_P$). Cutoff frequency is given by:

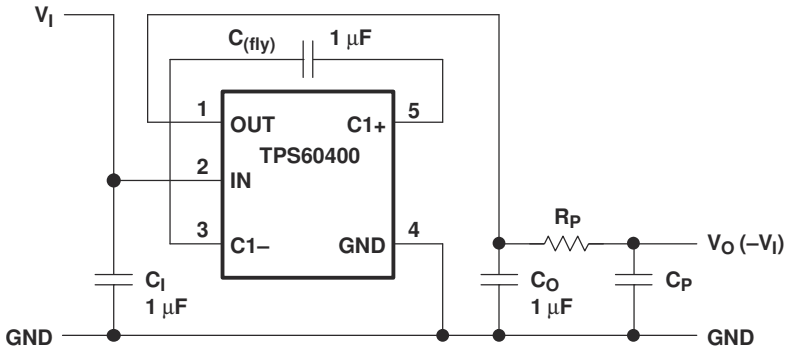



**Figure 9-4. TPS60400 with RC-Post Filter**

The equation refers only to the relation between output and input of the ac ripple voltages of the filter.

$$f_c = \frac{1}{2\pi R_P C_P} \quad (1)$$

and ratio $V_O/V_{OUT}$ is:

$$\left|\frac{V_O}{V_{OUT}}\right| = \frac{1}{\sqrt{1 + \left(2\pi f R_P C_P\right)^2}} \quad (2)$$

with $R_P$ = 50 Ω, $C_P$ = 0.1 µF and f = 250 kHz: $\left|\frac{V_O}{V_{OUT}}\right| = 0.125$ (13)

To reduce the output voltage ripple, a LC post filter can be used.

Figure 9-5 shows a configuration with a LC-post filter to further reduce output ripple and noise.

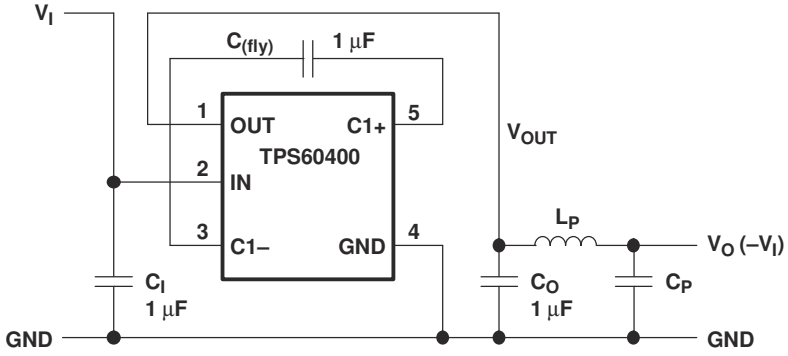



**Figure 9-5. LC-Post Filter**

The application allows to generate a voltage rail at a level of 1/2 of the input voltage.

A switched-capacitor voltage inverter can be configured as a high efficiency rail-splitter. This circuit provides a bipolar power supply that is useful in battery powered systems to supply dual-rail ICs, like operational amplifiers. Moreover, the SOT23-5 package and associated components require very little board space.


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After power is applied, the flying capacitor ($C_{(fly)}$) connects alternately across the output capacitors $C_3$ and $C_O$. This equalizes the voltage on those capacitors and draws current from $V_I$ to $V_O$ as required to maintain the output at 1/2 $V_I$.

The maximum input voltage between $V_I$ and GND in the schematic (or between IN and OUT at the device itself) must not exceed 6.5 V.

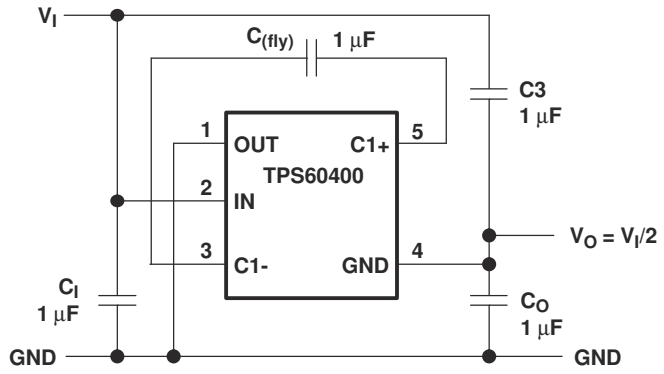



**Figure 9-6. TPS60400 as a High-Efficiency Rail Splitter**

The application allows to generate a voltage rail at a level of -Vi as well as 2 x Vi (V(pos)).

In the circuit of Figure 9-7, capacitors $C_I$, $C_{(fly)}$, and $C_O$ form the inverter, while C1 and C2 form the doubler. C1 and $C_{(fly)}$ are the flying capacitors; $C_O$ and C2 are the output capacitors. Because both the inverter and doubler use part of the charge-pump circuit, loading either output causes both outputs to decline toward GND. Make sure the sum of the currents drawn from the two outputs does not exceed 60 mA. The maximum output current at $V_{(pos)}$ must not exceed 30 mA. If the negative output is loaded, this current must be further reduced.

$$I_I \approx -I_O + 2 \times I_{O(POS)}$$

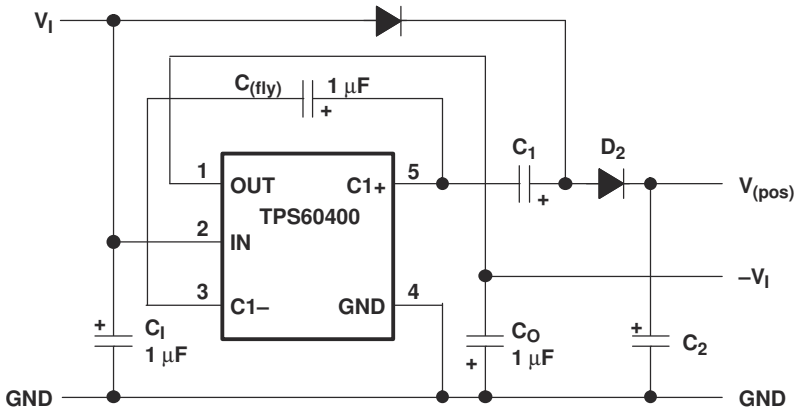



**Figure 9-7. TPS60400 as Doubler/Inverter**

The application generate a voltage rail at a level -2 x Vi.

Two devices can be cascaded to produce an even larger negative voltage (see Figure 9-8). The unloaded output voltage is normally -2 × $V_I$, but this is reduced slightly by the output resistance of the first device multiplied by the quiescent current of the second. When cascading more than two devices, the output resistance rises dramatically.

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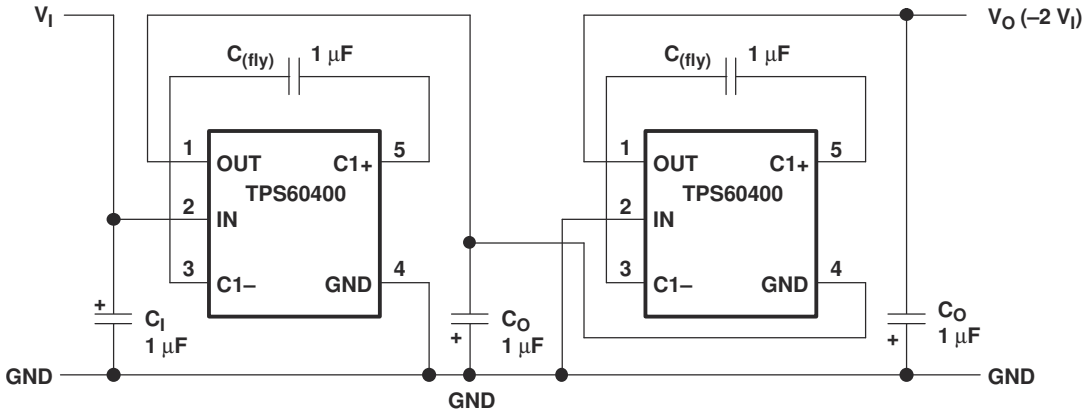



**Figure 9-8. Doubling Inverter**

The application allows to increase the output current by using two or more in parallel.

Paralleling multiple TPS6040xs reduces the output resistance. Each device requires its own flying capacitor ($C_{(fly)}$), but the output capacitor ($C_O$) serves all devices (see Figure 9-9). Increase $C_O$'s value by a factor of n, where n is the number of parallel devices. Equation 1 shows the equation for calculating output resistance.

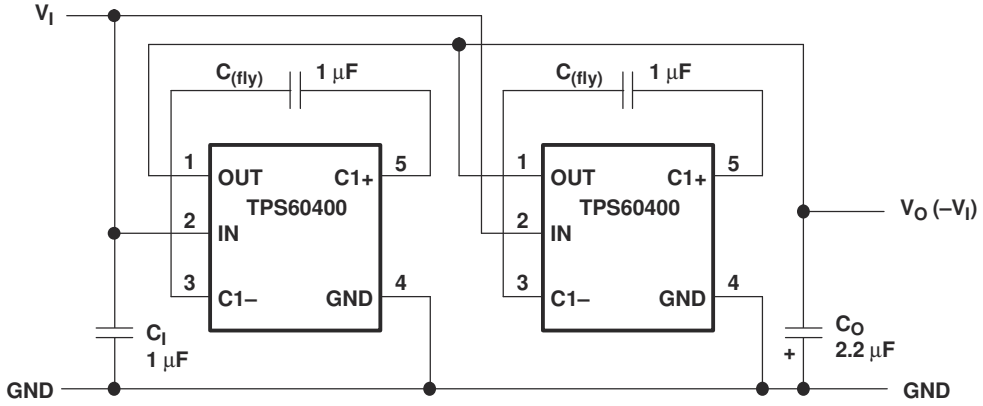



**Figure 9-9. Paralleling Devices**

The application adds a shutdown function.

If shutdown is necessary, use the circuit in Figure 9-10. The output resistance of the TPS6040x typically is 15 Ω plus two times the output resistance of the buffer.

Connecting multiple buffers in parallel reduces the output resistance of the buffer driving the IN pin.

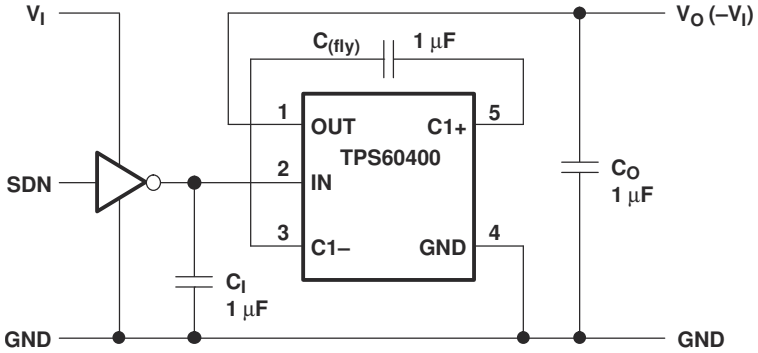



**Figure 9-10. Shutdown Control**

The application generates a regulated output voltage for a GaAs bias supply.


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A solution for a -2.7-V/3-mA GaAs bias supply is proposed in Figure 9-11. The input voltage of 3.3 V is first inverted with a TPS60403 and stabilized using a TLV431 low-voltage shunt regulator. Resistor $R_P$ with capacitor $C_P$ is used for filtering the output voltage.

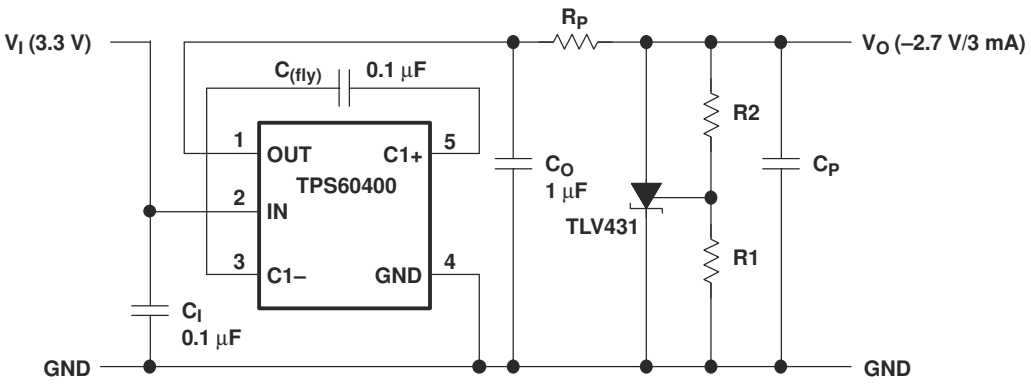



**Figure 9-11. GaAs Supply**

A 0.1-µF capacitor was selected for $C_{(fly)}$. By this, the output resistance of the inverter is about 52 Ω.

$R_{PMAX}$ can be calculated using the following equation:

$$V_O = -\left(1 + \frac{R1}{R2}\right) \times V_{ref} - R1 \times I_{I(ref)} \tag{14}$$

A 100-Ω resistor was selected for $R_P$.

The reference voltage across R2 is 1.24 V typical. With 5-µA current for the voltage divider, R2 gets:

$$R_{PMAX} = \left(\frac{V_{CO} - V_O}{I_O} - R_O\right)$$

With: $V_{CO}$ = –3.3 V; $V_O$ = –2.7 V; $I_O$ = –3 mA

$$R_{PMAX} = 200\ \Omega - 52\ \Omega = 148\ \Omega \tag{15}$$

With $C_P$ = 1 µF the ratio $V_O/V_I$ of the RC post filter is:

$$R2 = \frac{1.24\ V}{5\ \mu A} \approx 250\ k\Omega$$

$$R1 = \frac{2.7 - 1.24\ V}{5\ \mu A} \approx 300\ k\Omega \tag{16}$$

$$\left|\frac{V_O}{V_I}\right| = \frac{1}{\sqrt{1 + (2\pi 125000Hz \times 100\Omega \times 1\ \mu F)^2}} \approx 0.01 \tag{17}$$

The application generates an output voltage of 1/2 of the input voltage.

By exchanging GND with OUT (connecting the GND pin with OUT and the OUT pin with GND), a step-down charge pump can easily be formed. In the first cycle S1 and S3 are closed, and $C_{(fly)}$ with $C_O$ in series are charged. Assuming the same capacitance, the voltage across $C_{(fly)}$ and $C_O$ is split equally between the capacitors. In the second cycle, S2 and S4 close and both capacitors with $V_I/2$ across are connected in parallel.

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The maximum input voltage between $V_I$ and GND in the schematic (or between IN and OUT at the device itself) must not exceed 6.5 V. For input voltages in the range of 6.5 V to 11 V, an additional Zener-diode is recommended (see Figure 9-14).

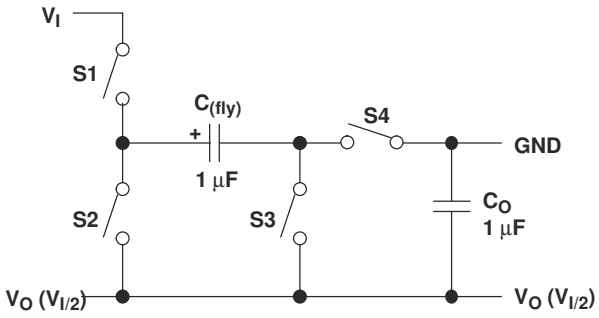



**Figure 9-12. Step-Down Principle**

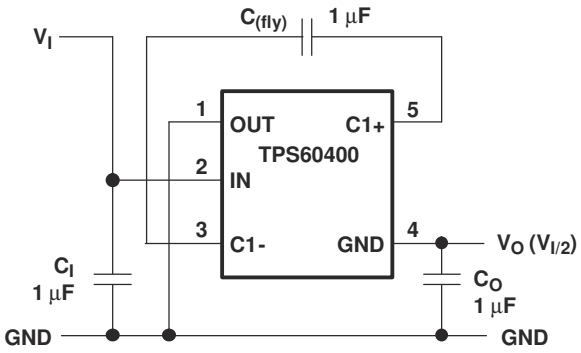



**Figure 9-13. Step-Down Charge Pump Connection**

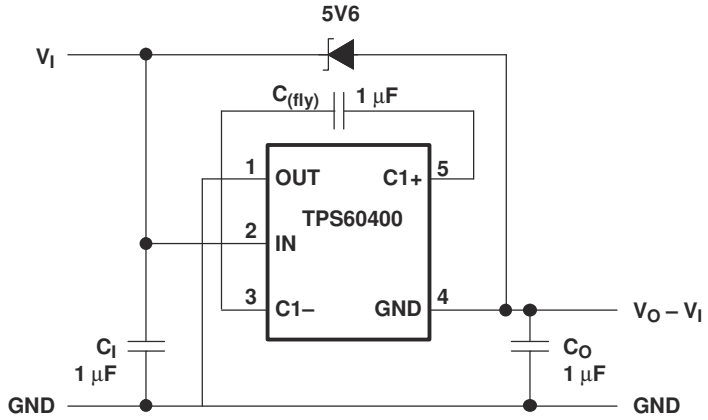



**Figure 9-14. Step-Down Charge Pump Connection for Higher Input Voltages**

## 10 Power Supply Recommendations

The TPS60400 device family has no special requirements for its power supply. The power supply output needs to be rated according to the supply voltage, output voltage and output current of the TPS6040x.


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# 11 Layout

## 11.1 Layout Guidelines

All capacitors should be soldered as close as possible to the IC. A PCB layout proposal for a single-layer board is shown in Figure 11-1. Care has been taken to connect all capacitors as close as possible to the circuit to achieve optimized output voltage ripple performance.

## 11.2 Layout Example

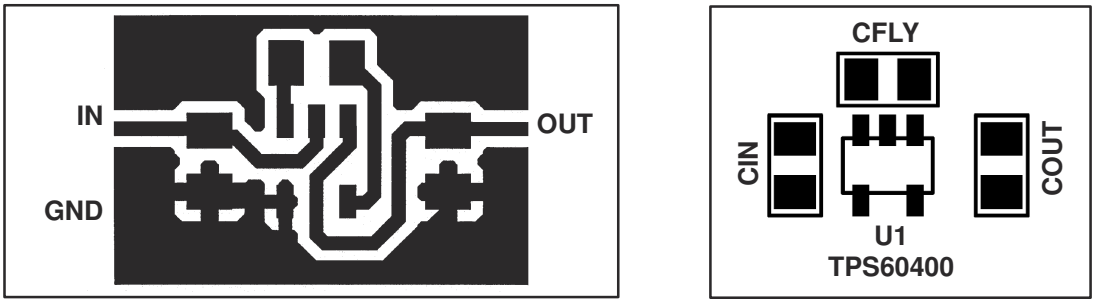



**Figure 11-1. Recommended PCB Layout for TPS6040x (Top Layer)**

# 12 Device and Documentation Support

## 12.1 Device Support

### 12.1.1 Third-Party Products Disclaimer

TI'S PUBLICATION OF INFORMATION REGARDING THIRD-PARTY PRODUCTS OR SERVICES DOES NOT CONSTITUTE AN ENDORSEMENT REGARDING THE SUITABILITY OF SUCH PRODUCTS OR SERVICES OR A WARRANTY, REPRESENTATION OR ENDORSEMENT OF SUCH PRODUCTS OR SERVICES, EITHER ALONE OR IN COMBINATION WITH ANY TI PRODUCT OR SERVICE.

### 12.1.2 Device Family Products

Other inverting DC-DC converters from Texas Instruments are listed in Table 12-1.

**Table 12-1. Product Identification**

| PART NUMBER | DESCRIPTION |
|---|---|
| TPS6735 | Fixed negative 5-V, 200-mA inverting dc-dc converter |
| TPS6755 | Adjustable 1-W inverting dc-dc converter |

## 12.2 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

**Table 12-2. Related Links**

| PARTS | PRODUCT FOLDER | SAMPLE & BUY | TECHNICAL DOCUMENTS | TOOLS & SOFTWARE | SUPPORT & COMMUNITY |
|---|---|---|---|---|---|
| TPS60400 | Click here | Click here | Click here | Click here | Click here |
| TPS60401 | Click here | Click here | Click here | Click here | Click here |
| TPS60402 | Click here | Click here | Click here | Click here | Click here |
| TPS60403 | Click here | Click here | Click here | Click here | Click here |

## 12.3 Trademarks

All other trademarks are the property of their respective owners.

## 12.4 Electrostatic Discharge Caution



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.

## 12.5 Glossary

**TI Glossary** This glossary lists and explains terms, acronyms, and definitions.

# 13 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.


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## PACKAGING INFORMATION

| Orderable part number | Status (1) | Material type (2) | Package \| Pins | Package qty \| Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|---|---|---|---|---|---|---|---|---|---|
| TPS60400DBVR | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | Call TI \| Sn | Level-1-260C-UNLIM | -40 to 85 | PFKI |
| TPS60400DBVR.A | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | PFKI |
| TPS60400DBVR.B | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | PFKI |
| TPS60400DBVRG4 | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | PFKI |
| TPS60400DBVRG4.B | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | PFKI |
| TPS60400DBVT | Active | Production | SOT-23 (DBV) \| 5 | 250 \| SMALL T&R | Yes | NIPDAU \| SN | Level-1-260C-UNLIM | -40 to 85 | PFKI |
| TPS60400DBVT.B | Active | Production | SOT-23 (DBV) \| 5 | 250 \| SMALL T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | PFKI |
| TPS60400DBVTG4 | Active | Production | SOT-23 (DBV) \| 5 | 250 \| SMALL T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | PFKI |
| TPS60400DBVTG4.B | Active | Production | SOT-23 (DBV) \| 5 | 250 \| SMALL T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | PFKI |
| TPS60401DBVR | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | Call TI \| Sn | Level-1-260C-UNLIM | -40 to 85 | PFLI |
| TPS60401DBVR.A | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | PFLI |
| TPS60401DBVR.B | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | PFLI |
| TPS60401DBVRG4 | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | PFLI |
| TPS60401DBVRG4.B | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | PFLI |
| TPS60401DBVT | Active | Production | SOT-23 (DBV) \| 5 | 250 \| SMALL T&R | Yes | NIPDAU \| SN | Level-1-260C-UNLIM | -40 to 85 | PFLI |
| TPS60401DBVT.B | Active | Production | SOT-23 (DBV) \| 5 | 250 \| SMALL T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | PFLI |
| TPS60401DBVTG4 | Active | Production | SOT-23 (DBV) \| 5 | 250 \| SMALL T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | PFLI |
| TPS60401DBVTG4.B | Active | Production | SOT-23 (DBV) \| 5 | 250 \| SMALL T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | PFLI |
| TPS60402DBVR | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | Call TI \| Sn | Level-1-260C-UNLIM | -40 to 85 | PFMI |
| TPS60402DBVR.A | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | PFMI |
| TPS60402DBVR.B | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | PFMI |
| TPS60402DBVRG4 | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | PFMI |
| TPS60402DBVRG4.B | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | PFMI |
| TPS60402DBVT | Active | Production | SOT-23 (DBV) \| 5 | 250 \| SMALL T&R | Yes | NIPDAU \| SN | Level-1-260C-UNLIM | -40 to 85 | PFMI |
| TPS60402DBVT.B | Active | Production | SOT-23 (DBV) \| 5 | 250 \| SMALL T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | PFMI |
| TPS60402DBVTG4 | Active | Production | SOT-23 (DBV) \| 5 | 250 \| SMALL T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | PFMI |
| TPS60402DBVTG4.B | Active | Production | SOT-23 (DBV) \| 5 | 250 \| SMALL T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | PFMI |
| TPS60403DBVR | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | Call TI \| Sn | Level-1-260C-UNLIM | -40 to 85 | PFNI |
| TPS60403DBVR.A | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | PFNI |

| Orderable part number | Status (1) | Material type (2) | Package \| Pins | Package qty \| Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|---|---|---|---|---|---|---|---|---|---|
| TPS60403DBVR.B | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | PFNI |
| TPS60403DBVRG4 | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | PFNI |
| TPS60403DBVRG4.B | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | PFNI |
| TPS60403DBVT | Active | Production | SOT-23 (DBV) \| 5 | 250 \| SMALL T&R | Yes | NIPDAU \| SN | Level-1-260C-UNLIM | -40 to 85 | PFNI |
| TPS60403DBVT.B | Active | Production | SOT-23 (DBV) \| 5 | 250 \| SMALL T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | PFNI |
| TPS60403DBVTG4 | Active | Production | SOT-23 (DBV) \| 5 | 250 \| SMALL T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | PFNI |
| TPS60403DBVTG4.B | Active | Production | SOT-23 (DBV) \| 5 | 250 \| SMALL T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | PFNI |

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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**OTHER QUALIFIED VERSIONS OF TPS60400, TPS60401, TPS60402, TPS60403 :**

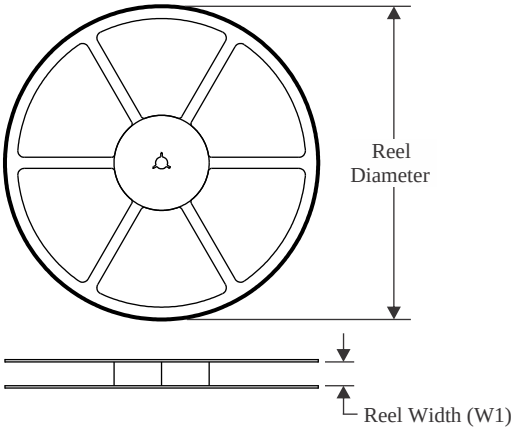
- Automotive : TPS60400-Q1, TPS60401-Q1, TPS60402-Q1, TPS60403-Q1

NOTE: Qualified Version Definitions:

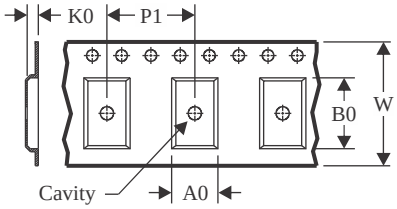
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

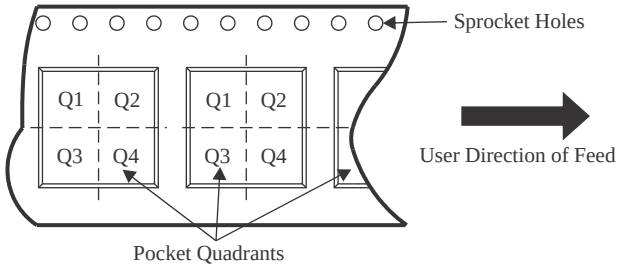



**TAPE DIMENSIONS**




| | |
|---|---|
| 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**

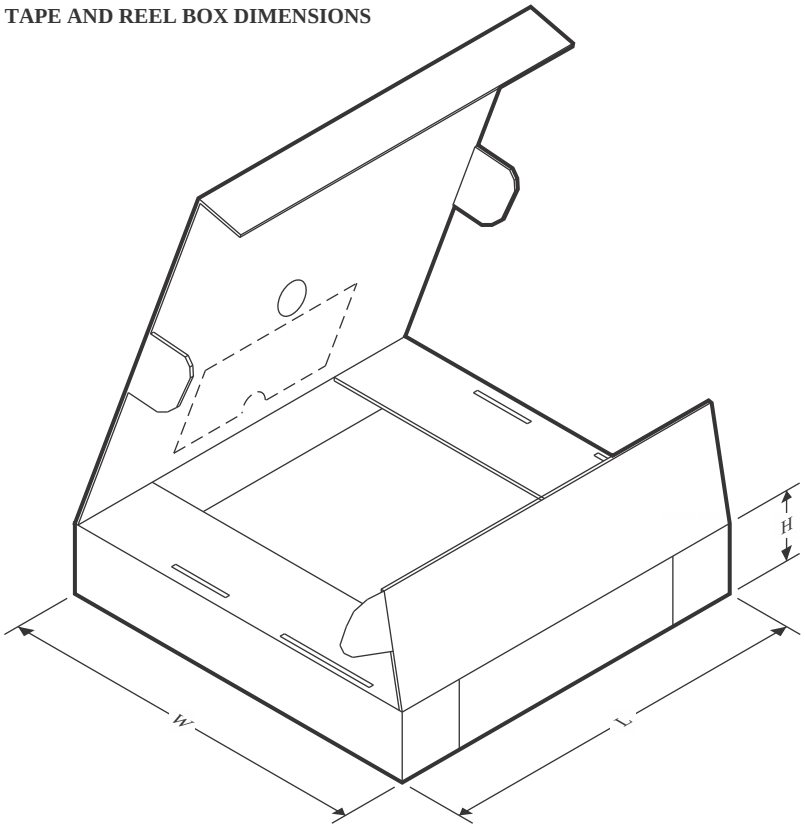



*All dimensions are nominal

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TPS60400DBVR | SOT-23 | DBV | 5 | 3000 | 180.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS60400DBVR | SOT-23 | DBV | 5 | 3000 | 178.0 | 9.0 | 3.23 | 3.17 | 1.37 | 4.0 | 8.0 | Q3 |
| TPS60400DBVR | SOT-23 | DBV | 5 | 3000 | 180.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS60400DBVRG4 | SOT-23 | DBV | 5 | 3000 | 178.0 | 9.0 | 3.23 | 3.17 | 1.37 | 4.0 | 8.0 | Q3 |
| TPS60400DBVT | SOT-23 | DBV | 5 | 250 | 180.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS60400DBVTG4 | SOT-23 | DBV | 5 | 250 | 178.0 | 9.0 | 3.23 | 3.17 | 1.37 | 4.0 | 8.0 | Q3 |
| TPS60401DBVR | SOT-23 | DBV | 5 | 3000 | 180.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS60401DBVR | SOT-23 | DBV | 5 | 3000 | 180.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS60401DBVR | SOT-23 | DBV | 5 | 3000 | 178.0 | 9.0 | 3.3 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS60401DBVRG4 | SOT-23 | DBV | 5 | 3000 | 178.0 | 9.0 | 3.3 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS60401DBVT | SOT-23 | DBV | 5 | 250 | 180.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS60401DBVTG4 | SOT-23 | DBV | 5 | 250 | 178.0 | 9.0 | 3.23 | 3.17 | 1.37 | 4.0 | 8.0 | Q3 |
| TPS60402DBVR | SOT-23 | DBV | 5 | 3000 | 180.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS60402DBVR | SOT-23 | DBV | 5 | 3000 | 178.0 | 9.0 | 3.3 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS60402DBVR | SOT-23 | DBV | 5 | 3000 | 180.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS60402DBVRG4 | SOT-23 | DBV | 5 | 3000 | 178.0 | 9.0 | 3.3 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TPS60402DBVT | SOT-23 | DBV | 5 | 250 | 180.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS60402DBVTG4 | SOT-23 | DBV | 5 | 250 | 178.0 | 9.0 | 3.23 | 3.17 | 1.37 | 4.0 | 8.0 | Q3 |
| TPS60403DBVR | SOT-23 | DBV | 5 | 3000 | 178.0 | 9.0 | 3.23 | 3.17 | 1.37 | 4.0 | 8.0 | Q3 |
| TPS60403DBVR | SOT-23 | DBV | 5 | 3000 | 180.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS60403DBVR | SOT-23 | DBV | 5 | 3000 | 180.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS60403DBVRG4 | SOT-23 | DBV | 5 | 3000 | 178.0 | 9.0 | 3.23 | 3.17 | 1.37 | 4.0 | 8.0 | Q3 |
| TPS60403DBVT | SOT-23 | DBV | 5 | 250 | 180.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| TPS60403DBVT | SOT-23 | DBV | 5 | 250 | 178.0 | 9.0 | 3.23 | 3.17 | 1.37 | 4.0 | 8.0 | Q3 |
| TPS60403DBVTG4 | SOT-23 | DBV | 5 | 250 | 178.0 | 9.0 | 3.23 | 3.17 | 1.37 | 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) |
|---|---|---|---|---|---|---|---|
| TPS60400DBVR | SOT-23 | DBV | 5 | 3000 | 210.0 | 185.0 | 35.0 |
| TPS60400DBVR | SOT-23 | DBV | 5 | 3000 | 180.0 | 180.0 | 18.0 |
| TPS60400DBVR | SOT-23 | DBV | 5 | 3000 | 210.0 | 185.0 | 35.0 |
| TPS60400DBVRG4 | SOT-23 | DBV | 5 | 3000 | 180.0 | 180.0 | 18.0 |
| TPS60400DBVT | SOT-23 | DBV | 5 | 250 | 210.0 | 185.0 | 35.0 |
| TPS60400DBVTG4 | SOT-23 | DBV | 5 | 250 | 180.0 | 180.0 | 18.0 |
| TPS60401DBVR | SOT-23 | DBV | 5 | 3000 | 210.0 | 185.0 | 35.0 |
| TPS60401DBVR | SOT-23 | DBV | 5 | 3000 | 210.0 | 185.0 | 35.0 |
| TPS60401DBVR | SOT-23 | DBV | 5 | 3000 | 180.0 | 180.0 | 18.0 |
| TPS60401DBVRG4 | SOT-23 | DBV | 5 | 3000 | 180.0 | 180.0 | 18.0 |
| TPS60401DBVT | SOT-23 | DBV | 5 | 250 | 210.0 | 185.0 | 35.0 |
| TPS60401DBVTG4 | SOT-23 | DBV | 5 | 250 | 180.0 | 180.0 | 18.0 |
| TPS60402DBVR | SOT-23 | DBV | 5 | 3000 | 210.0 | 185.0 | 35.0 |
| TPS60402DBVR | SOT-23 | DBV | 5 | 3000 | 180.0 | 180.0 | 18.0 |
| TPS60402DBVR | SOT-23 | DBV | 5 | 3000 | 210.0 | 185.0 | 35.0 |
| TPS60402DBVRG4 | SOT-23 | DBV | 5 | 3000 | 180.0 | 180.0 | 18.0 |
| TPS60402DBVT | SOT-23 | DBV | 5 | 250 | 210.0 | 185.0 | 35.0 |
| TPS60402DBVTG4 | SOT-23 | DBV | 5 | 250 | 180.0 | 180.0 | 18.0 |

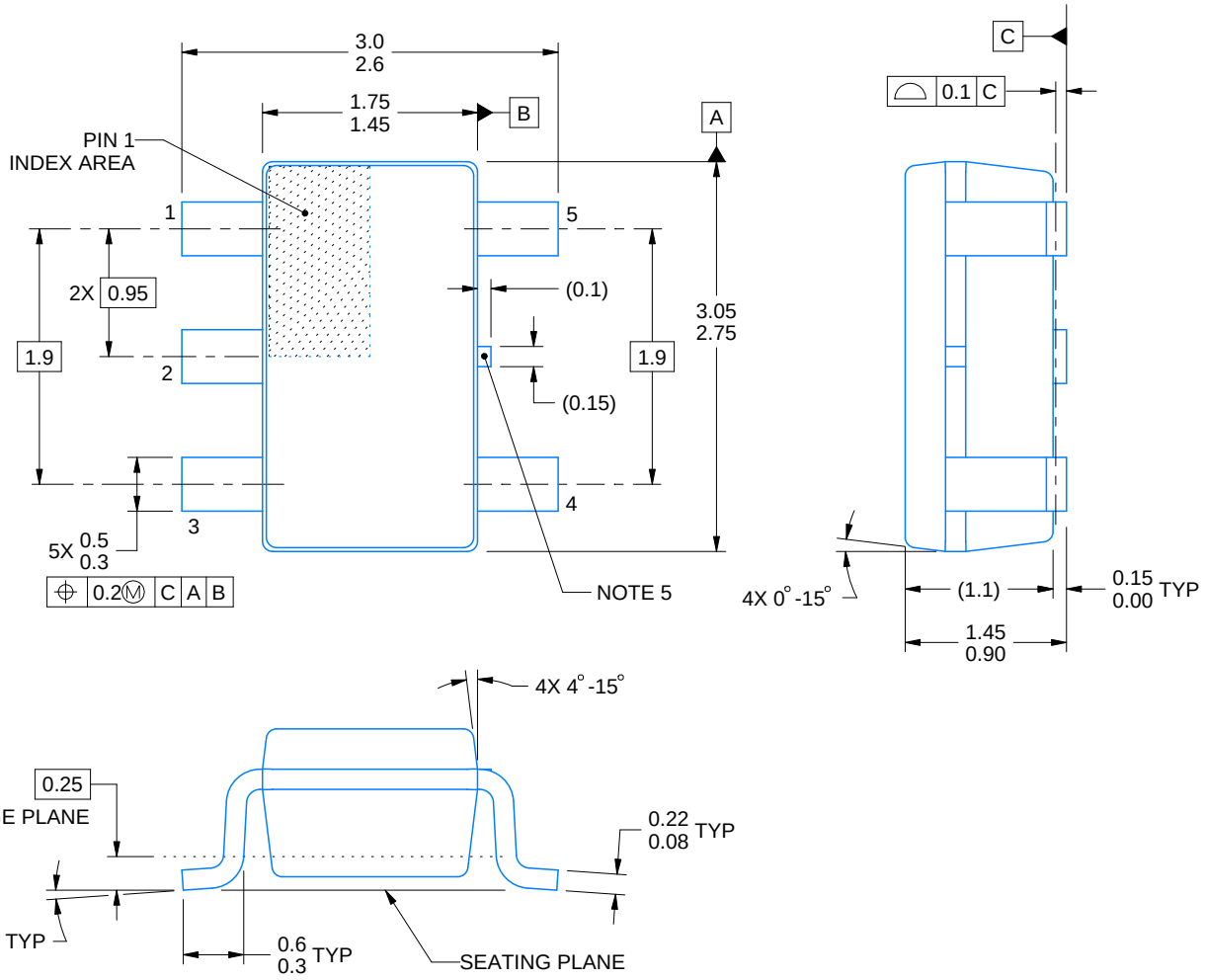
| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| TPS60403DBVR | SOT-23 | DBV | 5 | 3000 | 180.0 | 180.0 | 18.0 |
| TPS60403DBVR | SOT-23 | DBV | 5 | 3000 | 210.0 | 185.0 | 35.0 |
| TPS60403DBVR | SOT-23 | DBV | 5 | 3000 | 210.0 | 185.0 | 35.0 |
| TPS60403DBVRG4 | SOT-23 | DBV | 5 | 3000 | 180.0 | 180.0 | 18.0 |
| TPS60403DBVT | SOT-23 | DBV | 5 | 250 | 210.0 | 185.0 | 35.0 |
| TPS60403DBVT | SOT-23 | DBV | 5 | 250 | 180.0 | 180.0 | 18.0 |
| TPS60403DBVTG4 | SOT-23 | DBV | 5 | 250 | 180.0 | 180.0 | 18.0 |

# PACKAGE OUTLINE

## DBV0005A

## SOT-23 - 1.45 mm max height

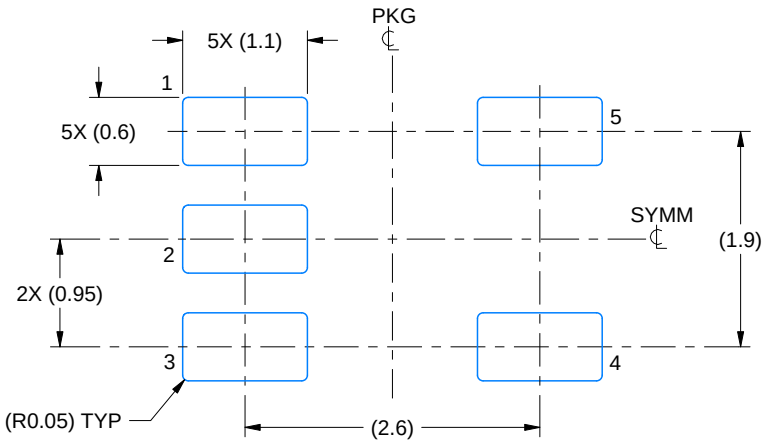
SMALL OUTLINE TRANSISTOR



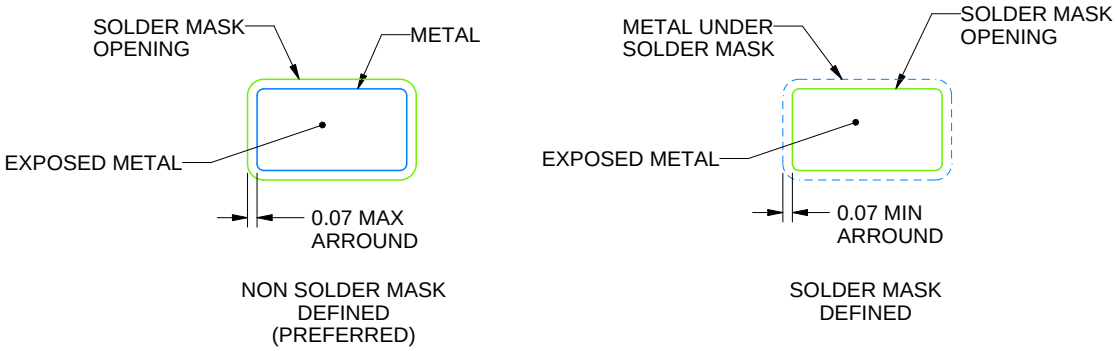

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NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Refernce JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25 mm per side.
5. Support pin may differ or may not be present.




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X

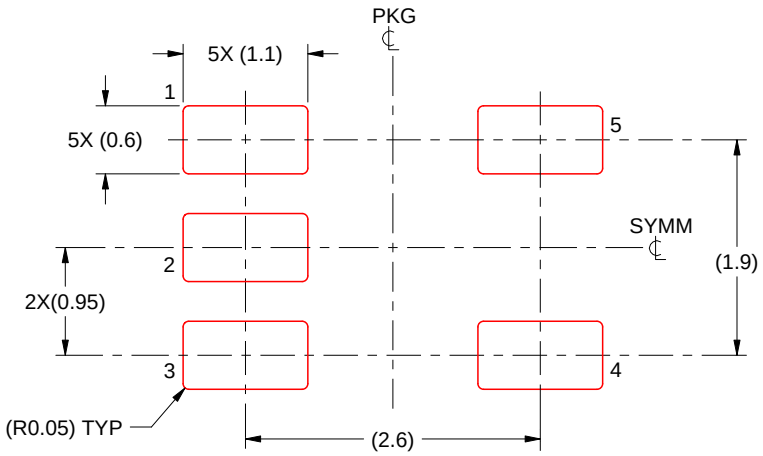



SOLDER MASK DETAILS

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NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.




SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

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NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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