

TPS60300, TPS60301, TPS60302, TPS60303 SINGLE-CELL TO 3.0-V/3.3-V, 20-mA DUAL OUTPUT, HIGH-EFFICIENCY CHARGE PUMP

SLVS302A – DECEMBER 2000 – REVISED MARCH 2001

features

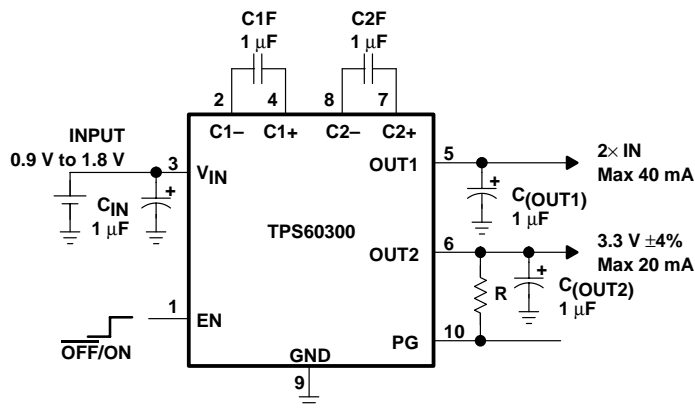
- Regulated 3-V or 3.3-V Output Voltage With up to 20-mA Output Current From a 0.9-V to 1.8-V Input Voltage Range
- High Power Conversion Efficiency (up to 90%) Over a Wide Output Current Range, Optimized for 1.2-V Battery Voltage
- Additional Output With 2 Times V_{IN} (OUT1)
- Device Quiescent Current Less Than 35 μ A
- Supervisor Included; Open Drain or Push-Pull Power Good Output
- No Inductors Required/Low EMI
- Only Five Small, 1- μ F Ceramic Capacitors Required
- Load Isolated From Battery During Shutdown
- Microsmall 10-Pin MSOP Package

description

The TPS6030x step-up, regulated charge pumps generate a 3-V \pm 4% or 3.3-V \pm 4% output voltage from a 0.9-V to 1.8-V input voltage (one alkaline, NiCd, or NiMH battery).

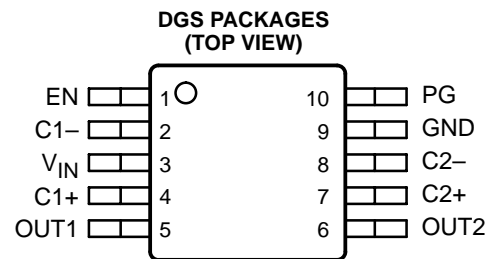
Only five small 1- μ F ceramic capacitors are required to build a complete high efficiency dc/dc charge pump converter. To achieve the high efficiency over a wide input voltage range, the charge pump automatically selects between a 3x or 4x conversion mode.

typical application circuit

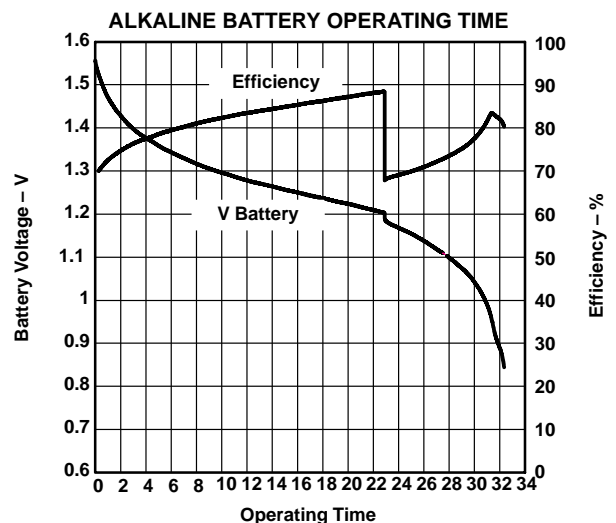


applications

- Pagers
- Battery-Powered Toys
- Portable Measurement Instruments
- Home Automation Products
- Medical Instruments (Like Hearing Instruments)
- Metering Applications Using MSP430 Microcontroller
- Portable Smart Card Readers



ACTUAL SIZE
3,05 mm x 4,98 mm



Operating time (hours) with an alkaline battery (2000 mAh) until power good goes low @ $I_L = 20$ mA



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

**TEXAS
INSTRUMENTS**

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description (continued)

Output 1 (OUT1) can deliver a maximum of 40 mA, from a 1-V input, with output 2 (OUT2) not loaded. OUT2 can deliver a maximum of 20 mA, from a 1-V input, with OUT1 not loaded. Both outputs can be loaded in the same time, but the total output current of the first voltage doubler must not exceed 40 mA. For example, the load at OUT1 is 20 mA and the load at output 2 is 10 mA.

The devices operate in the newly developed LinSkip mode. In this operating mode, the device switches seamlessly from the power saving, pulse-skip mode at light loads, to the low-noise, constant-frequency linear-regulation mode, once the output current exceeds the device-specific output current threshold.

A power-good function supervises the output voltage of OUT2 and can be used for power up and power down sequencing. Power good (PG) is offered as either open-drain or push-pull output.

AVAILABLE OPTIONS

| PART NUMBER† | MARKING DGS PACKAGE | OUTPUT CURRENT 1 [mA]‡ | OUTPUT CURRENT 2 [mA]§ | OUTPUT VOLTAGE 1 [V] | OUTPUT VOLTAGE 2 [V] | FEATURE |
|---------------------|----------------------------|-------------------------------|-------------------------------|-----------------------------|-----------------------------|------------------------------|
| TPS60300DGS | ALF | 40 | 20 | 2 x V _{IN} | 3.3 | Open-drain power-good output |
| TPS60301DGS | ALG | 40 | 20 | 2 x V _{IN} | 3.0 | Open-drain power-good output |
| TPS60302DGS | ALI | 40 | 20 | 2 x V _{IN} | 3.3 | Push-pull power-good output |
| TPS60303DGS | ALK | 40 | 20 | 2 x V _{IN} | 3.0 | Push-pull power-good output |

† The DGS package is available taped and reeled. Add R suffix to device type (e.g. TPS60300DGSR) to order quantities of 2500 devices per reel.

‡ If OUT2 is not loaded

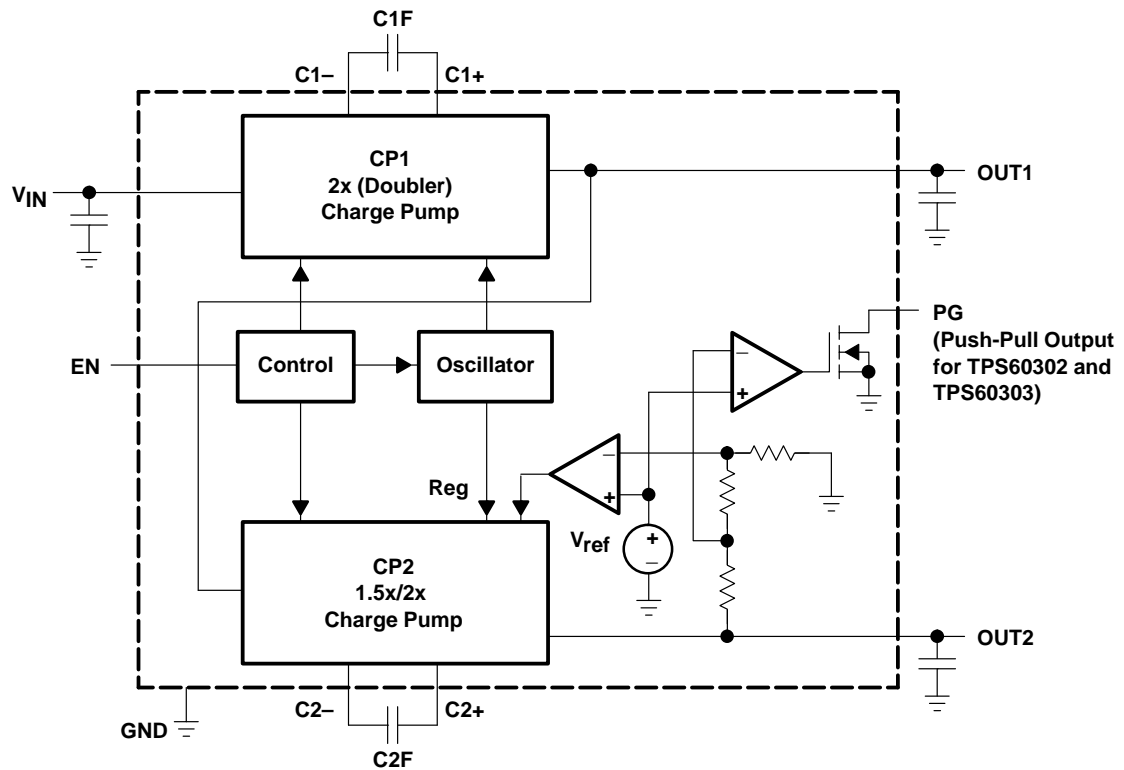
§ If OUT1 is not loaded



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TPS60300 and TPS60301 functional block diagram



Terminal Functions

| TERMINAL NAME | NO. | I/O | DESCRIPTION |
|-----------------|-----|-----|---|
| C1+ | 4 | | Positive terminal of the flying capacitor C1F |
| C1- | 2 | | Negative terminal of the flying capacitor C1F |
| C2+ | 7 | | Positive terminal of the flying capacitor C2F |
| C2- | 8 | | Negative terminal of the flying capacitor C2F |
| EN | 1 | I | Device-enable input – EN = Low disables the device. Output and input are isolated in shutdown mode. – EN = High enables the device. |
| GND | 9 | | GROUND |
| OUT1 | 5 | O | $2 \times V_{IN}$ power output. Bypass OUT1 to GND with the output filter capacitor $C_{(OUT1)}$. |
| OUT2 | 6 | O | Regulated 3.3-V power output (TPS60300, TPS60302) or 3-V power output (TPS60301, TPS60303), respectively Bypass OUT2 to GND with the output filter capacitor $C_{(OUT2)}$. |
| PG | 10 | O | Power good detector output. As soon as the voltage on OUT2 reaches about 98% of its nominal value this pin goes high. Open drain output on TPS60300 and TPS60301. A pullup resistor should be connected between PG and OUT1 or OUT2. Push-pull output stage on TPS60302 and TPS60303 |
| V _{IN} | 3 | I | Supply input. Bypass V _{IN} to GND with a $\geq 1\text{-}\mu\text{F}$ capacitor. |



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detailed description

operating principle

The TPS6030x charge pumps are voltage quadruplers that provide a regulated 3.3-V or 3.0-V output from a 0.9-V to 1.8-V input. They deliver a maximum load current of 20 mA. Designed specifically for space critical battery powered applications, the complete converter requires only five external capacitors and enables the design to use low-cost, small-sized, 1- μ F ceramic capacitors. The TPS6030x circuits consist of an oscillator, a voltage reference, an internal resistive feedback circuit, an error amplifier, two charge pump stages with MOSFET switches, a shutdown/start-up circuit, and a control circuit.

shutdown

Driving EN low disables the converter. This disables all internal circuits, reducing input current to only 0.05 μ A. Leakage current drawn from the output pins OUT1 and OUT2 is a maximum of 1 μ A. The device exits shutdown once EN is set high (see start-up procedure described below). The typical no-load, start-up time is 400 μ s. When the device is disabled, the load is isolated from the input. This is an important feature in battery operated products because it extends the battery shelf life.

start-up procedure

The device is enabled when EN is set from logic low to logic high. CP1 will first enter a dc start-up mode during which the capacitor on OUT1 is charged up to about V_{IN} . After that, it starts switching to boost the voltage further up to about two times V_{IN} . CP2 will then follow and charge up the capacitor on OUT2 to about the voltage on OUT1, after that, it will also start switching and boost up the voltage to its nominal value. EN must not exceed the highest voltage applied to the device.

NOTE:

During start-up with $V_{OUT} = 0$ V, the highest voltage is the input voltage.

power-good detector

The power-good output is an open-drain output on the TPS60300 and TPS60301 or a push-pull output on the TPS60302 and TPS60303. The PG-output pulls low when the output of OUT2 is out of regulation. When the output rises to within 98% of regulation, the power-good output goes active high. In shutdown, power-good is pulled low. In normal operation, an external pullup resistor with the TPS60300 and TPS60301 is typically used to connect the PG pin to VOUT. The resistor should be in the 100-k Ω to 1-M Ω range. If the PG output is not used, it should remain unconnected. Output current at PG (TPS60302, TPS60303) will reduce maximum output current at OUT2.



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absolute maximum ratings over operating free-air temperature (unless otherwise noted)†

| | |
|---|---------------------------------|
| Input voltage, V_I (IN to GND) (see Note 1) | -0.3 V to 2 V |
| Output voltage, V_O (OUT1,OUT2, EN, PG to GND) (see Note 1) | -0.3 V to 3.6 V |
| Voltage, (C1+ to GND) | -0.3 V to $V_{O(OUT1)} + 0.3$ V |
| Voltage, (C1- to GND, C2- to GND) | -0.3 V to $V_{IN} + 0.3$ V |
| Voltage, (C2+ to GND) | -0.3 V to $V_{O(OUT2)} + 0.3$ V |
| Continuous power dissipation | See Dissipation Rating Table |
| Output current, I_O (OUT1) | 80 mA |
| Output current, I_O (OUT2) | 40 mA |
| Storage temperature range, T_{stg} | -55°C to 150°C |
| Maximum junction temperature, T_J | 150°C |

† 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.

NOTE 1: The voltage at EN and PG can exceed IN up to the maximum rated voltage without increasing the leakage current drawn by these pins.

DISSIPATION RATING TABLE

| PACKAGE | $T_A < 25^\circ\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING |
|---------|--|---|--|--|
| DGS | 424 mW | 3.4 mW/°C | 271 mW | 220 mW |

NOTE: The thermal resistance junction to ambient of the DGS package is $R_{TH-JA} = 294^\circ\text{C/W}$.

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|--|-----|-----|-----|---------------|
| Input voltage, V_I | 0.9 | | 1.8 | V |
| Output current (OUT2), $I_{O(OUT2)}$ | | | 20 | mA |
| Output current (OUT1), $I_{O(OUT1)}$ | | | 40 | mA |
| Input capacitor, C_I | 1 | | | μF |
| Flying capacitors, C1F, C2F | | 1 | | μF |
| Output capacitors, $C_{O(1)}$, $C_{O(2)}$ | 1 | | | μF |
| Operating junction temperature, T_J | -40 | | 125 | °C |

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electrical characteristics at $C_{IN} = C1F = C2F = C_{(OUT1)} = C_{(OUT2)} = 1 \mu F$, $T_C = -40^\circ C$ to $85^\circ C$, $V_{IN} = 1.0 V$, $V_{(EN)} = V_{IN}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT | |
|---|---|---|---------------------|------|---------------------|-------------------|----|
| V_{IN} | Supply voltage range | | 0.9 | | 1.8 | V | |
| $I_{O(OUT1)}$ | Maximum output current for TPS60300, TPS60302 | $V_{IN} \geq 1.1 V$, $I_{O(OUT2)} = 0 mA$, $I_{(PG,1)} = 0 mA$ | 40 | | | mA | |
| | | $V_{IN} = 0.9 V$, $I_{O(OUT2)} = 0 mA$, $I_{(PG,1)} = 0 mA$ | 20 | | | | |
| $V_{IN} \geq 1.1 V$, $I_{O(OUT1)} = 0 mA$, $I_{(PG,1)} = 0 mA$ | | 20 | | | | | |
| $V_{IN} = 0.9 V$, $I_{O(OUT1)} = 0 mA$, $I_{(PG,1)} = 0 mA$ | | 10 | | | | | |
| $I_{O(OUT2)}$ | Maximum output current for TPS60301, TPS60303 | $V_{IN} \geq 1.1 V$, $I_{O(OUT2)} = 0 mA$, $I_{(PG,1)} = 0 mA$ | 40 | | | mA | |
| | | $V_{IN} = 0.9 V$, $I_{O(OUT2)} = 0 mA$, $I_{(PG,1)} = 0 mA$ | 20 | | | | |
| $V_{IN} \geq 1.0 V$, $I_{O(OUT1)} = 0 mA$, $I_{(PG,1)} = 0 mA$ | | 20 | | | | | |
| $V_{IN} = 0.9 V$, $I_{O(OUT1)} = 0 mA$, $I_{(PG,1)} = 0 mA$ | | 12 | | | | | |
| $V_{O(OUT2)}$ | Output voltage for TPS60300, TPS60302 | $1.1 V < V_{IN} < 1.8 V$, $I_{O(OUT1)} = 0 mA$ $0 < I_{O(OUT2)} < 20 mA$ | 3.17 | 3.30 | 3.43 | V | |
| | | $0.9 V < V_{IN} < 1.1 V$, $I_{O(OUT1)} = 0 mA$, $I_{O(OUT2)} < 10 mA$ | 3.17 | 3.30 | 3.43 | | |
| $V_{O(OUT2)}$ | Output voltage for TPS60301, TPS60303 | $1.0 V < V_{IN} < 1.8 V$, $I_{O(OUT1)} = 0 mA$, $0 < I_{O(OUT2)} < 20 mA$ | 2.88 | 3 | 3.12 | V | |
| | | $V_{IN} > 1.65 V$, $I_{O(OUT1)} = 0 mA$, $25 \mu A < I_{O(OUT2)} < 20 mA$ | 2.88 | 3 | 3.15 | | |
| V_{P-P} | Output voltage ripple | OUT2 $I_{O(OUT2)} = 20 mA$, $I_{O(OUT1)} = 0 mA$ | | 20 | | mV _{P-P} | |
| | | OUT1 $I_{O(OUT1)} = 40 mA$, $I_{O(OUT2)} = 0 mA$ | | 40 | | | |
| I_Q | Quiescent current (no-load input current) | $I_{O(OUT)} = 0 mA$, $V_{IN} = 1.8 V$ | | 35 | 70 | μA | |
| $I_{(SD)}$ | Shutdown supply current | $V_{IN} = 1.8 V$, See Note 2 $V_{(EN)} = 0 V$ | | 0.05 | 2.5 | μA | |
| | | $V_{IN} = 1.8 V$, $T_C = 25^\circ C$, $V_{(EN)} = 0 V$, See Note 2 | | | 0.5 | | |
| f_{OSC} | Internal switching frequency | | 470 | 700 | 900 | kHz | |
| $V_{IL(EN)}$ | EN input low voltage | $V_{IN} = 0.9 V$ to $1.8 V$ | | | $0.3 \times V_{IN}$ | V | |
| $V_{IH(EN)}$ | EN input high voltage | $V_{IN} = 0.9 V$ to $1.8 V$ | $0.7 \times V_{IN}$ | | | V | |
| I_{lkg} | EN input leakage current | $V_{(EN)} = 0 V$ or V_{IN} or $V_{O(OUT2)}$ or $V_{O(OUT1)}$ | | 0.01 | 0.1 | μA | |
| | LinSkip switching threshold | $V_{IN} = 1.25 V$ | | 7.5 | | mA | |
| | Short circuit current | $V_{IN} = 1.8 V$ | $V_{O(OUT2)} = 0 V$ | 5 | 20 | 50 | mA |
| | | | $V_{O(OUT1)} = 0 V$ | 2 | 80 | 150 | |
| | Output leakage current | OUT2 $V_{O(OUT1)} = 3 V$, $V_{O(OUT2)} = \text{nominal}$, $EN = 0 V$ | | | 1 | μA | |

NOTE 2: OUT1 not loaded. If OUT1 is connected to GND via a resistor, leakage current will be increased.



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electrical characteristics at $C_{IN} = C1F = C2F = C_{(OUT1)} = C_{(OUT2)} = 1 \mu F$, $T_C = -40^\circ C$ to $85^\circ C$, $V_{IN} = 1.0 V$, $V_{(EN)} = V_{IN}$ (unless otherwise noted) (continued)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|--|------|------|-----|----------|
| Output load regulation | $V_{IN} = 1.25 V$, $T_C = 25^\circ C$ $2 mA < I_{O(OUT2)} < 20 mA$ | | 0.1 | | %/mA |
| Output line regulation | $1.0 V < V_{IN} < 1.65 V$; $T_C = 25^\circ C$, $I_{O(OUT)} = 10 mA$ | | 0.75 | | %/V |
| No-load start-up time | | | 400 | | μs |
| Impedance of first charge pump stage | | | 4 | | Ω |
| Start-up performance at OUT2 (minimum start-up load resistance) | $V_{IN} \geq 1.1 V$ | 165 | | | Ω |
| | $V_{IN} \geq 1.0 V$ | 330 | | | |
| | $V_{IN} = 0.9 V$ | 1000 | | | |
| Start-up performance at OUT1 (minimum start-up load resistance) | $V_{IN} = 1.0 V$ | 500 | | | Ω |

electrical characteristics for power good comparator of devices TPS6030x at $T_C = -40^\circ C$ to $85^\circ C$, $V_{IN} = 1.0 V$ and $V_{(EN)} = V_{IN}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---------------------------------|--------------------------|-------|----------|
| $V_{(PG)}$ Power good trip voltage | V_O ramping positive | | $V_O - 2\%$ | V_O | V |
| V_{hys} Power good trip voltage hysteresis | V_O ramping negative | | 10% | | |
| V_{OL} Power good output voltage low | $V_O = 0 V$, $I_{(PG)} = 1.6 mA$ | | | 0.3 | V |
| I_{lkg} Power good leakage current | TPS60300 $V_O = 3.3 V$, $V_{(PG)} = 3.3 V$ | | 0.01 | 0.1 | μA |
| | TPS60301 $V_O = 3.0 V$, $V_{(PG)} = 3.0 V$ | | 0.01 | 0.1 | |
| V_{OH} Power good output voltage high | TPS60302 | | 3 | | V |
| | TPS60303 | $I_{(PG)} = -5 mA$ | 2.7 | | |
| $I_{O(PG,1)}$ Output current at power good (source) | TPS60302, TPS60303 | | -5 | | mA |
| $I_{O(PG,0)}$ Output current at power good (sink) | All devices $V_{(PG)} = 0 V$ | 1.6 | | | mA |
| $R_{(PG,1)}$ | Output resistance at power good | TPS60302, TPS60303 | $V_{(PG)} = V_{O(OUT2)}$ | 15 | Ω |
| $R_{(PG,0)}$ | | All devices $V_{(PG)} = 0 V$ | | 100 | Ω |

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TYPICAL CHARACTERISTICS

Table of Graphs

| | | | FIGURE |
|-------------|-------------------------------|---|---------------|
| η | Efficiency | vs Output current | 1, 2 |
| I_S | Supply current | vs Output current | 3 |
| I_Q | Quiescent current | vs Input voltage | 4 |
| $V_O(OUT2)$ | Output voltage at OUT2 | vs Output current | 5, 6 |
| $V_O(OUT1)$ | Output voltage at OUT1 | vs Output current at 25°C, $V_{IN} = 0.9\text{ V}, 1.1\text{ V}, 1.25\text{ V}, 1.4\text{ V}, 1.6\text{ V}, 1.8\text{ V}$ | 7 |
| $V_O(OUT2)$ | Output voltage at OUT2 | vs Input voltage | 8, 9 |
| $V_O(OUT1)$ | Output voltage at OUT1 | vs Input voltage | 10 |
| $V_O(OUT2)$ | Output voltage at OUT2 | vs Free-air temperature | 11, 12 |
| $V_O(OUT2)$ | Output voltage ripple at OUT2 | | 13 |
| | Minimum input voltage | vs Output current for TPS60301, TPS60303 | 14, 15 |
| | Start-up timing | Enable, OUT1 no load, OUT2 at full load | 16 |
| | Switching frequency | vs Input voltage | 17 |
| | Load transient response | $V_{IN} = 1.25\text{ V}, I_Q(OUT2) = 2\text{ mA} \quad 18\text{ mA} \quad 2\text{ mA}, OUT1: \text{no load}$ | 18 |
| | Line transient response | | 19 |



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TYPICAL CHARACTERISTICS

TPS60300, TPS60302
 EFFICIENCY
 vs
 OUTPUT CURRENT

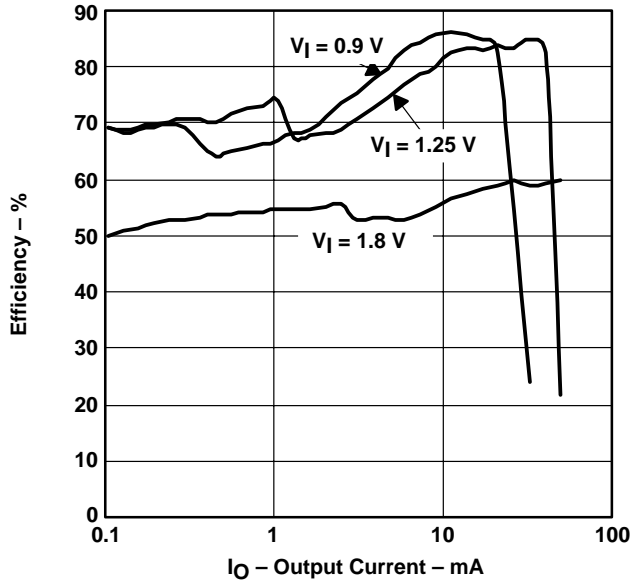


Figure 1

TPS60301, TPS60303
 EFFICIENCY
 vs
 OUTPUT CURRENT

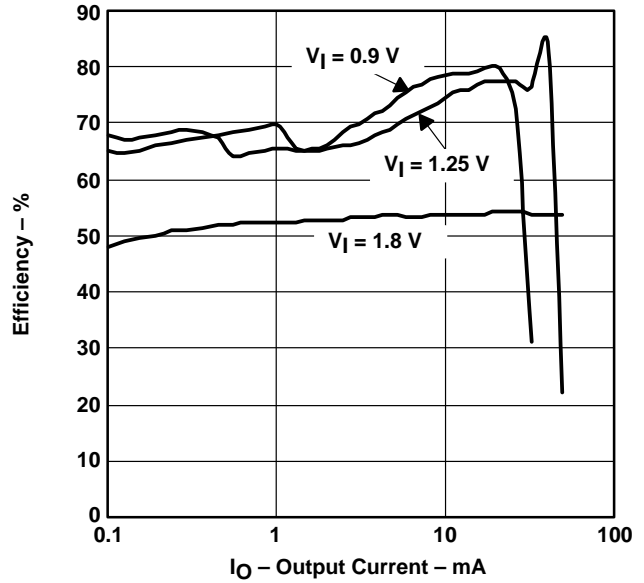


Figure 2

TPS6030
 SUPPLY CURRENT
 vs
 OUTPUT CURRENT

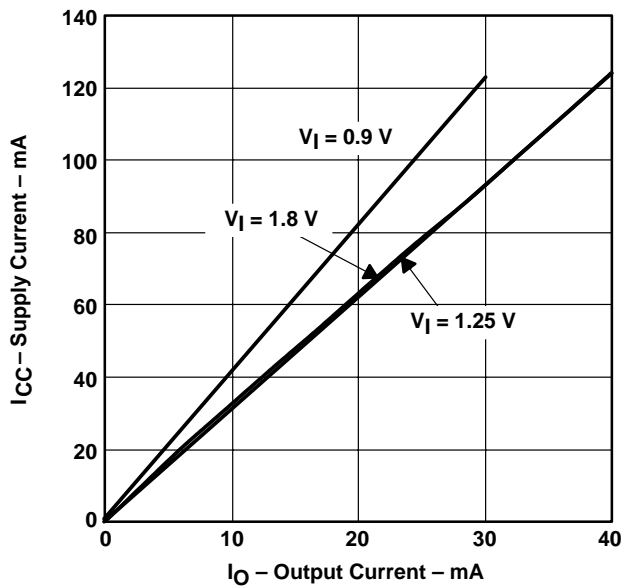


Figure 3

TPS6030x
 QUIESCENT CURRENT
 vs
 INPUT VOLTAGE

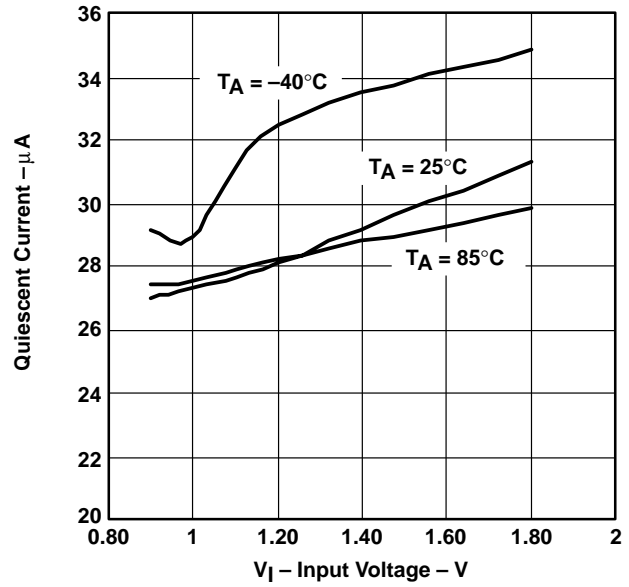
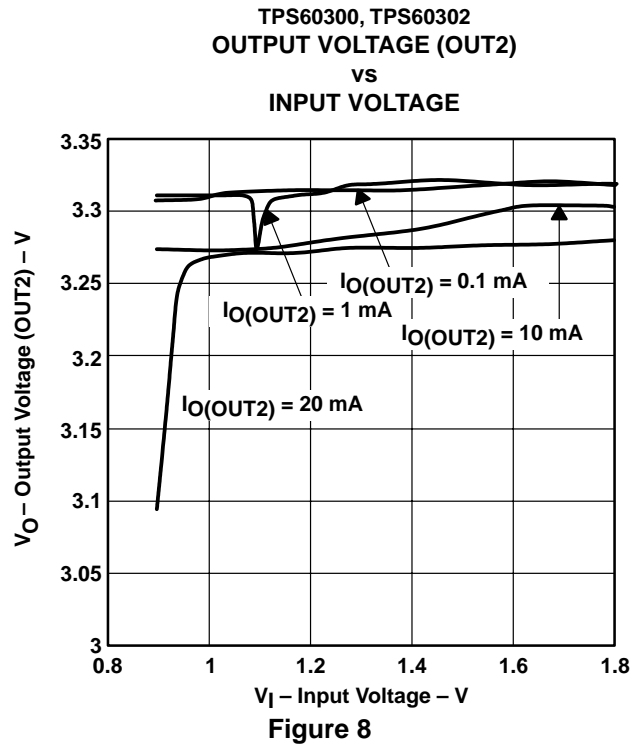
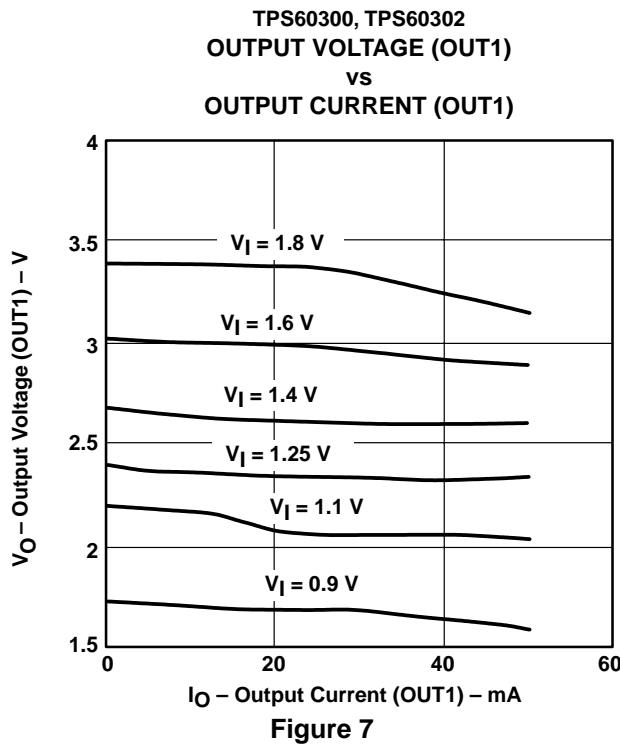
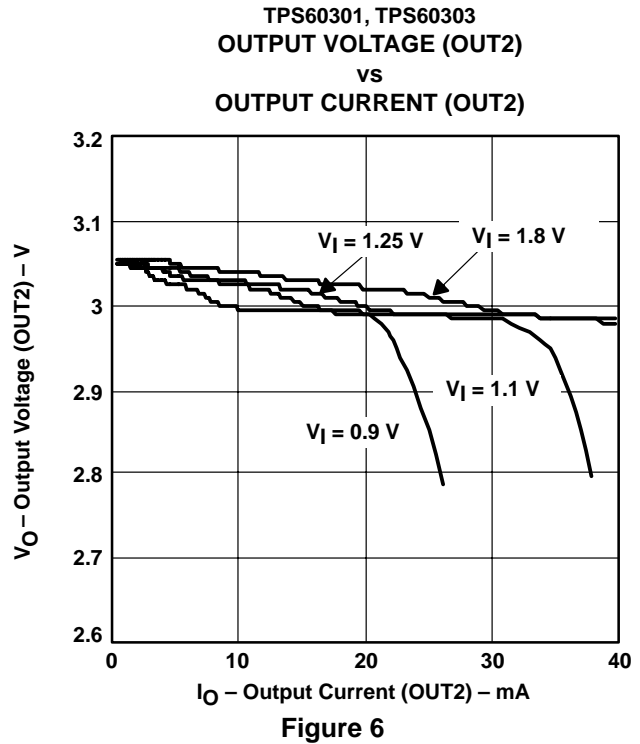
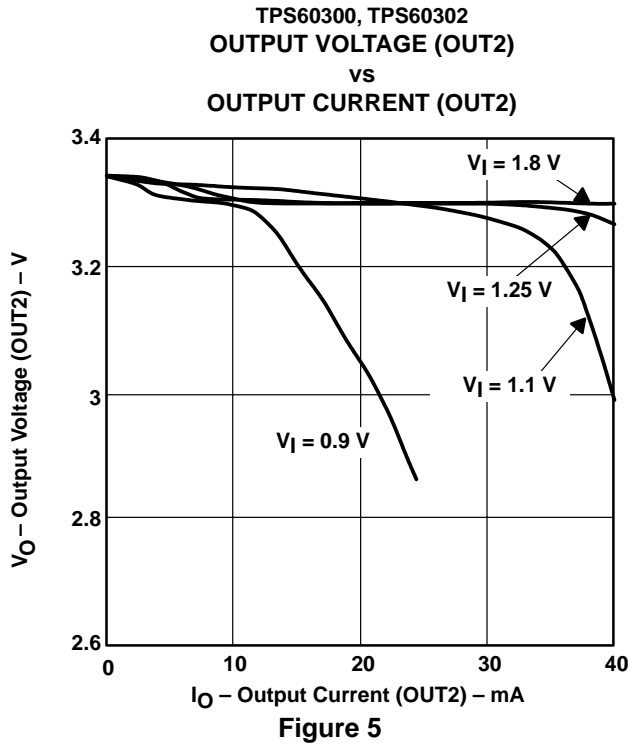


Figure 4

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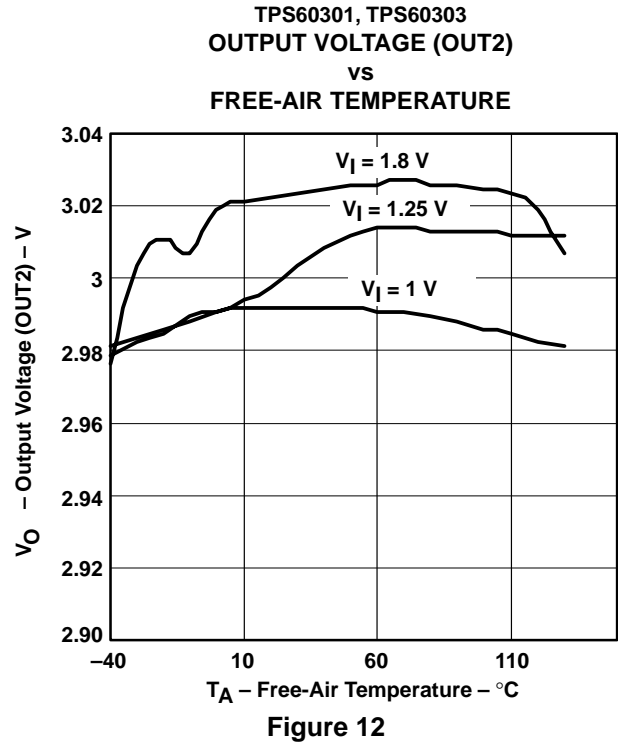
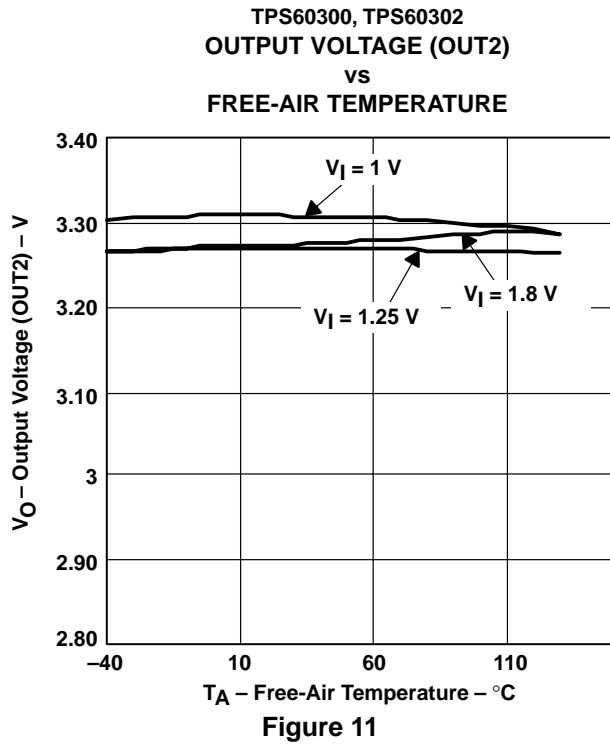
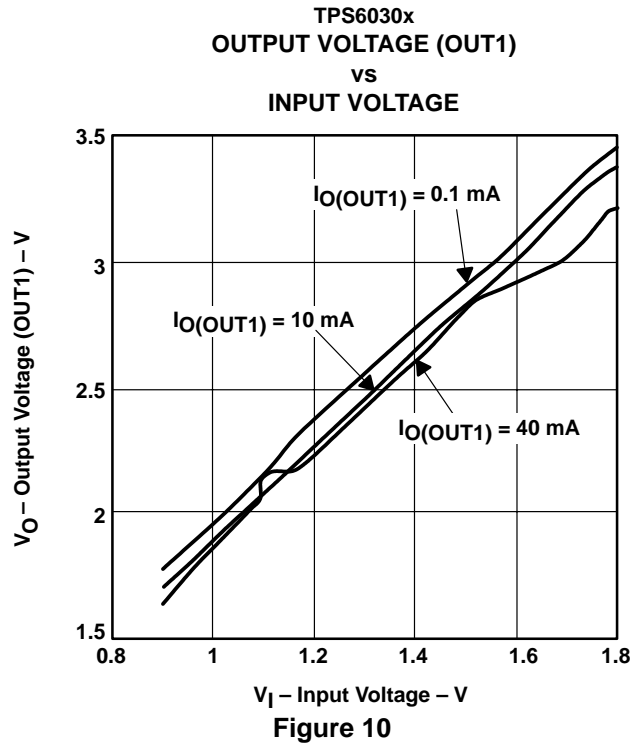
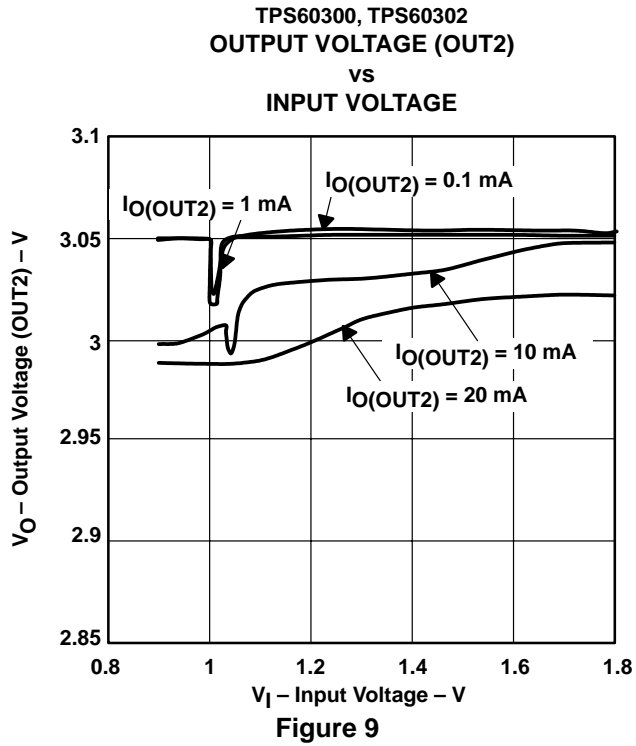
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TYPICAL CHARACTERISTICS

TPS6030x
OUTPUT VOLTAGE RIPPLE (OUT2)

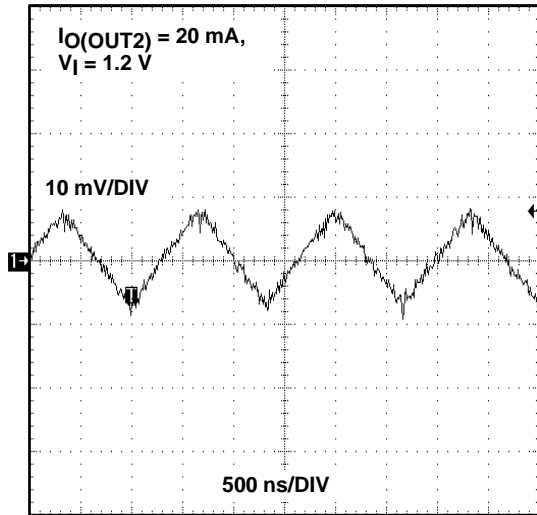


Figure 13

TPS60300, TPS60302
MINIMUM INPUT VOLTAGE
vs
OUTPUT CURRENT

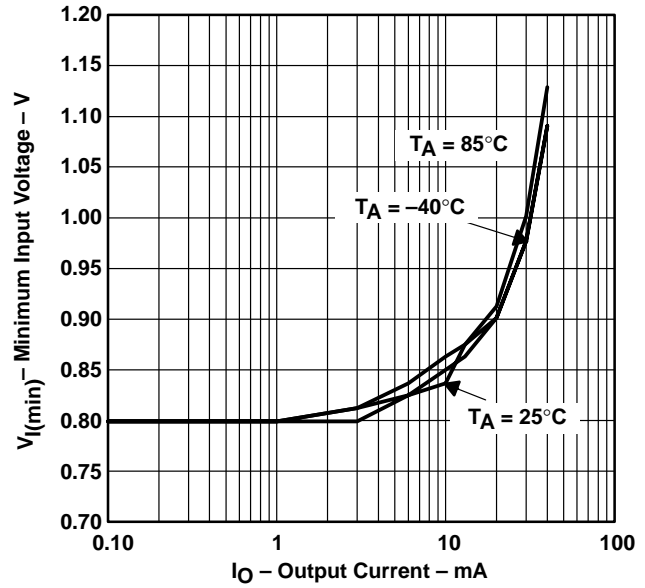


Figure 14

TPS60301, TPS60303
MINIMUM INPUT VOLTAGE
vs
OUTPUT CURRENT

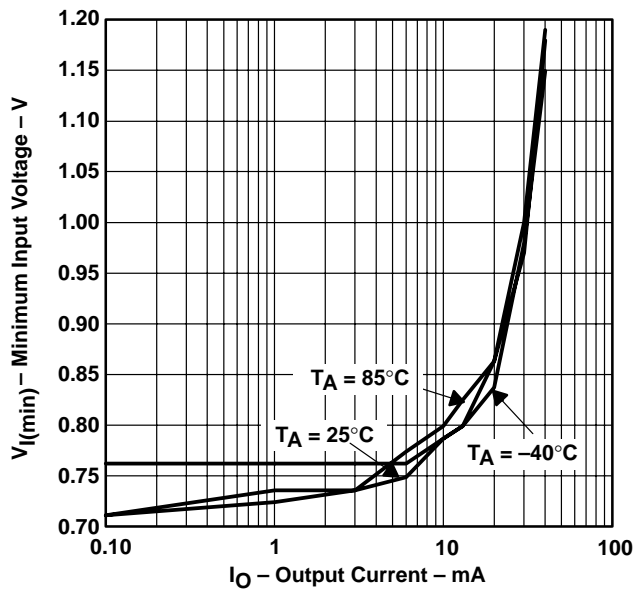


Figure 15

START-UP TIMING ENABLE

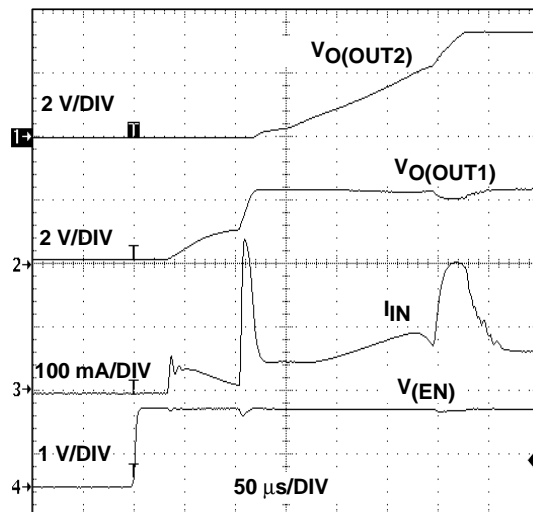


Figure 16

TYPICAL CHARACTERISTICS

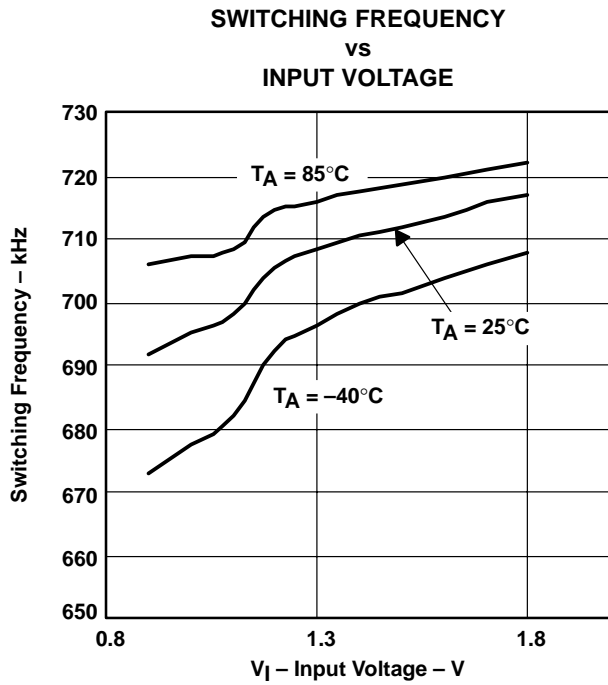


Figure 17

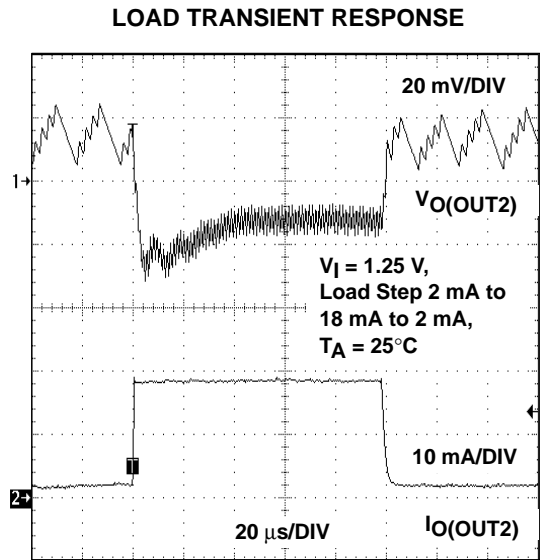


Figure 18

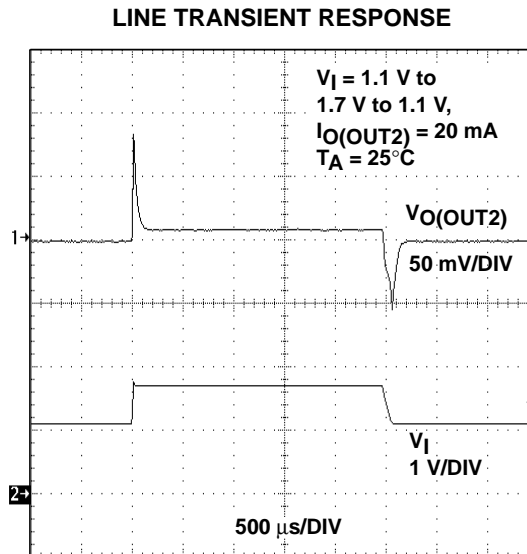


Figure 19

TPS60300, TPS60301, TPS60302, TPS60303
SINGLE-CELL TO 3.0-V/3.3-V, 20-mA DUAL OUTPUT,
HIGH-EFFICIENCY CHARGE PUMP

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APPLICATION INFORMATION

design procedure

capacitor selection

The TPS6030x devices require only five external capacitors. Their values are closely linked to the required output current and the output noise and ripple requirements. It is possible to only use 1- μ F capacitors of the same type.

The input capacitor improves system efficiency by reducing the input impedance and stabilizing the input current.

The minimum required capacitance of the output capacitor (C_O) that can be selected is 1 μ F. Depending on the maximum allowed output ripple voltage, larger values can be chosen. Table 1 shows capacitor values recommended for low output voltage ripple operation. A recommendation is given for the smallest size.

Table 1. Recommended Capacitor Values for Low Output Voltage Ripple Operation

| V_{IN} [V] | $I_{O(OUT2)}$ [mA] | C_{IN} [μ F] | C_{XF} [μ F] | C_{OUT} [μ F] | V_{P-P} [mV] @ 20 mA/ $V_{IN} = 1.1$ V |
|-----------------|-----------------------|------------------------|------------------------|-------------------------|---|
| | | CERAMIC | CERAMIC | CERAMIC | |
| 0.9...1.8 | 0...20 | 1 | 1 | 1 | 16 |
| 0.9...1.8 | 0...20 | 1 | 1 | 2.2 | 10 |
| 0.9...1.8 | 0...20 | 1 | 1 | 10 // 0.1 | 6 |

Table 2. Recommended Capacitors

| MANUFACTURER | PART NUMBER | SIZE | CAPACITANCE | TYPE |
|--------------|----------------|------|-------------|---------|
| Taiyo Yuden | UMK212BJ104MG | 0805 | 0.1 μ F | Ceramic |
| | LMK212BJ105KG | 0805 | 1 μ F | Ceramic |
| | LMK212BJ225MG | 0805 | 2.2 μ F | Ceramic |
| | JMK316BJ475KL | 1206 | 4.7 μ F | Ceramic |
| AVX | 0805ZC105KAT2A | 0805 | 1 μ F | Ceramic |
| | 1206ZC225KAT2A | 1206 | 2.2 μ F | Ceramic |

Table 3 lists the manufacturers of recommended capacitors. However, ceramic capacitors will provide the lowest output voltage ripple due to their typically lower ESR.

Table 3. Recommended Capacitor Manufacturers

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



APPLICATION INFORMATION

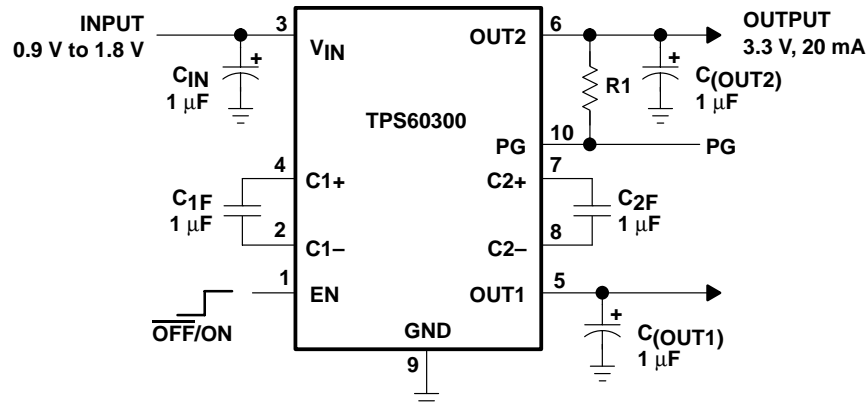


Figure 20. Typical Operating Circuit

For the maximum output current and best performance, five ceramic capacitors of 1 μF are recommended. For lower currents or higher allowed output voltage ripple, other capacitors can be used. It is recommended that the input and output capacitors have a minimum value of 1 μF . This value is necessary to assure a stable operation of the system due to the linear mode. With flying capacitors lower than 1 μF , the maximum output power will decrease. This means that the device will work in the linear mode with lower output currents.

output filter design

The power-good output is capable of driving light loads up to 5 mA (see Figure 21). Therefore, the output resistance of the power-good pin, in addition with an output capacitor, can be used as an RC-filter.

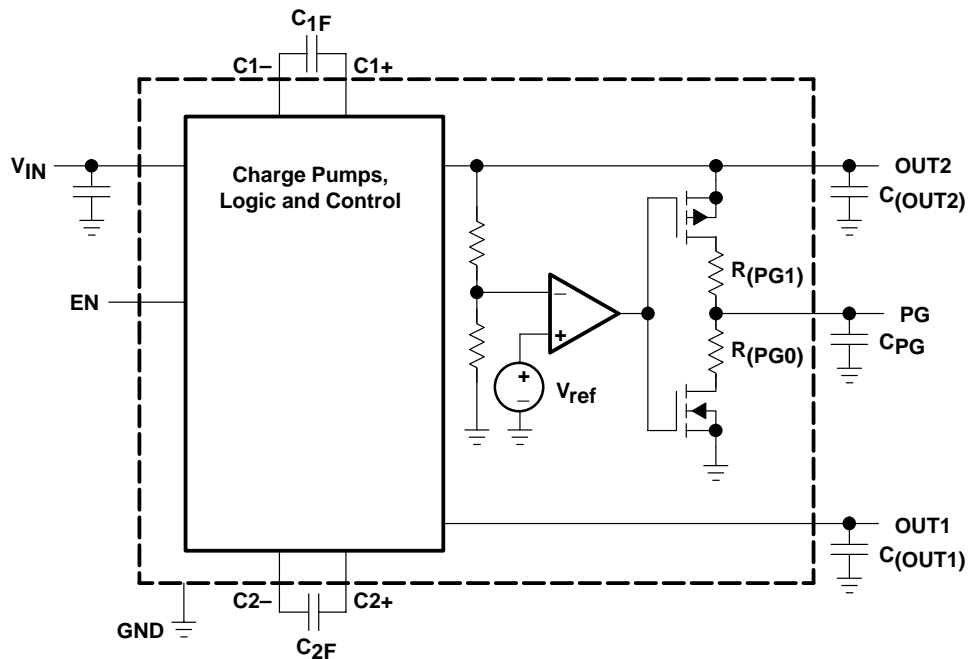


Figure 21. TPS60302, TPS60303 Push-Pull Power-Good Output-Stage as Filtered Supply

TPS60300, TPS60301, TPS60302, TPS60303
SINGLE-CELL TO 3.0-V/3.3-V, 20-mA DUAL OUTPUT,
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design procedure (continued)

Due to $R_{(PG,1)}$, an output filter can easily be formed with an output capacitor (C_{PG}). Cut-off frequency is given by:

$$f_c = \frac{1}{2\pi R_{(PG,1)} C_{(PG)}} \tag{1}$$

and ratio V_{OUT}/V_{IN} is:
$$\left| \frac{V_{(PG,1)}}{V_{O(OUT2)}} \right| = \frac{1}{\sqrt{1 + \left(2\pi f R_{(PG,1)} C_{(PG)} \right)^2}} \tag{2}$$

with $R_{(PG,1)} = 15 \Omega$, $C_{(PG)} = 0.1 \mu F$ and $f = 600 \text{ kHz}$ (at nominal switching frequency)

$$\left| \frac{V_{(PG,1)}}{V_{O(OUT2)}} \right| = 0.175$$

Load current sourced by power-good output reduces maximum output current at OUT2. During start-up (power good going high) current charging $C_{(PG)}$ will discharge $C_{(OUT2)}$. Therefore, $C_{(PG)}$ must not be larger than 0.1 $C_{(OUT2)}$ or the device will not start. By charging $C_{(PG)}$ through $C_{(OUT2)}$, the output voltage at OUT2 will decrease. If the capacitance of $C_{(PG)}$ is too large, the circuit will detect power bad. The power-good output will go low and discharge $C_{(PG)}$. Then the cycle starts again. Figure 22 shows a configuration with an LC-post filter to further reduce output ripple and noise.

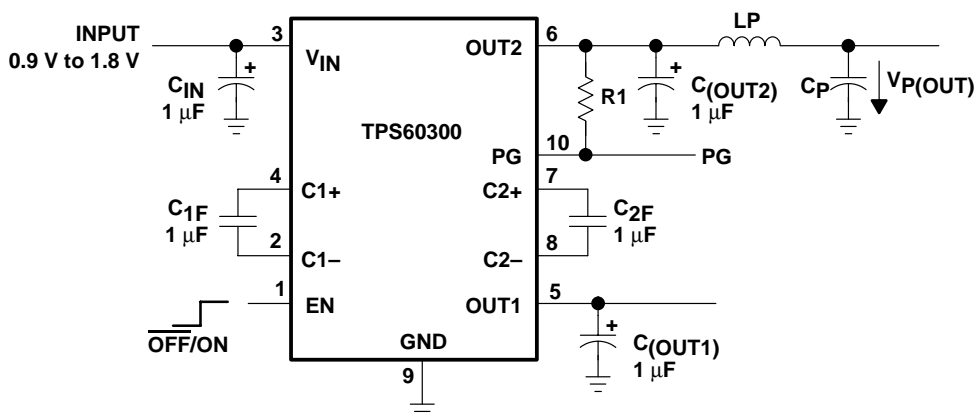


Figure 22. LC-Post Filter

Table 4. Recommended Values for Lowest Output Voltage Ripple

| V_{IN} [V] | $I_{O(OUT2)}$ [mA] | $C_{IN}[\mu F]$ | $C_{XF}[\mu F]$ | $C_{OUT}[\mu F]$ | $L_p[\mu H]$ | $C_p[\mu F]$ | $V_{P(OUT)}$ $V_{P-p}[\text{mV}]$ |
|-----------------|-----------------------|-----------------|-----------------|------------------|--------------|----------------|--------------------------------------|
| | | CERAMIC | CERAMIC | CERAMIC | | CERAMIC | |
| 0.9...1.8 | 20 | 1.0 | 1.0 | 1.0 | 0.1 | 0.1 (X7R) | 16 |
| 0.9...1.8 | 20 | 1.0 | 1.0 | 1.0 | 0.1 | 1 // 0.1 (X7R) | 12 |
| 0.9...1.8 | 20 | 1.0 | 1.0 | 1.0 | 1.0 | 0.1 (X7R) | 14 |
| 0.9...1.8 | 20 | 1.0 | 1.0 | 10 | 1.0 | 1 // 0.1 (X7R) | 3 |

design procedure (continued)

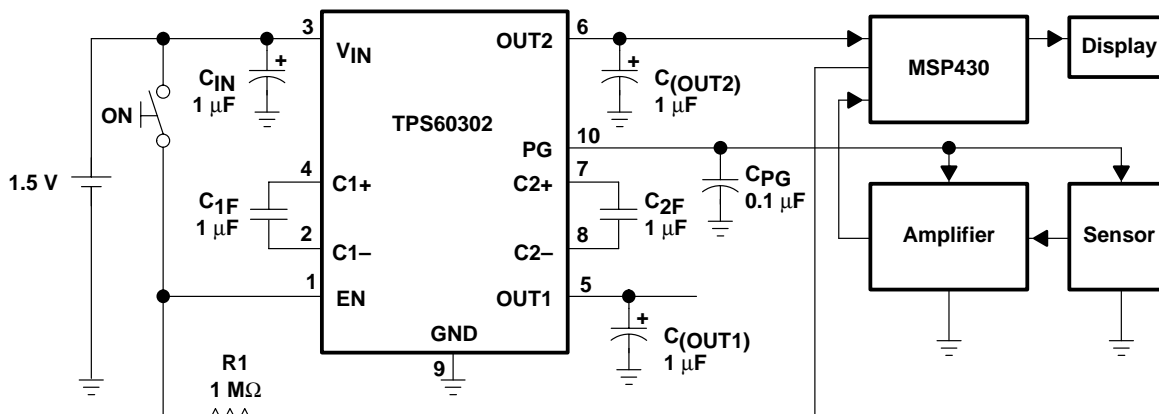


Figure 23. Application With MSP430; PG as Supply for Analog Circuits

power dissipation

As given in the data sheet, the thermal resistance of the unsoldered package is $R_{\theta JA} = 294^{\circ}\text{C}/\text{W}$. Soldered on the EVM, a typical thermal resistance of $R_{\theta JA(\text{EVM})} = 200^{\circ}\text{C}/\text{W}$ was measured.

The thermal resistance can be calculated as follows:

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

Where:

T_J is the junction temperature.

T_A is the ambient temperature.

P_D is the power that needs to be dissipated by the device.

The maximum power dissipation can be calculated with the following formula:

$$P_D = V_{IN} \times I_{IN} - V_O \times I_O = V_{IN(\text{max})} \times (3 \times I_O + I_{(\text{SUPPLY})}) - V_O \times I_O$$

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

At maximum load the supply current is approximately 2 mA.

$$P_D = 1.8 \text{ V} \times (3 \times 20 \text{ mA} + 2 \text{ mA}) - 3.3 \text{ V} \times 20 \text{ mA} = 46 \text{ mW}$$

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

$$\Delta T_J = R_{\theta JA} \times P_D = 200^{\circ}\text{C}/\text{W} \times 46 \text{ mW} = 10^{\circ}\text{C}$$

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

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

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

$$T_A = T_{J(\text{max})} - \Delta T_J = 125^{\circ}\text{C} - 10^{\circ}\text{C} = 115^{\circ}\text{C}$$

layout and board space

All capacitors should be soldered as close as possible to the IC. A PCB layout proposal for a two-layer board is shown in Figure 24. Care has been taken to connect all capacitors as close as possible to the circuit to achieve optimized output voltage ripple performance. The bottom layer is not shown in Figure 24. It only consists of a ground-plane with a single track between the two vias that can be seen in the left part of the top layer.

TPS60300, TPS60301, TPS60302, TPS60303
SINGLE-CELL TO 3.0-V/3.3-V, 20-mA DUAL OUTPUT,
HIGH-EFFICIENCY CHARGE PUMP

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layout and board space (continued)

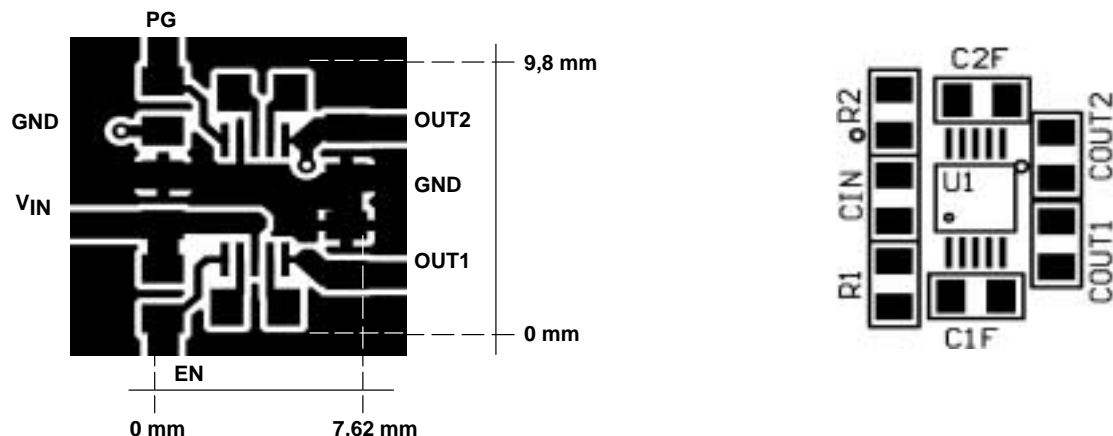


Figure 24. Recommended PCB Layout for TPS6030x (top layer)

device family products

Other charge pump dc-dc converters in this family are:

Table 5. Product Identification

| PART NUMBER | DESCRIPTION |
|-------------|---|
| TPS60100 | 2-cell to regulated 3.3-V, 200-mA low-noise charge pump |
| TPS60101 | 2-cell to regulated 3.3-V, 100-mA low-noise charge pump |
| TPS60110 | 3-cell to regulated 5-V, 300-mA low-noise charge pump |
| TPS60111 | 3-cell to regulated 5-V, 150-mA low-noise charge pump |
| TPS60120 | 2-cell to regulated 3.3-V, 200-mA high efficiency charge pump with low-battery comparator |
| TPS60121 | 2-cell to regulated 3.3-V, 200-mA high efficiency charge pump with power-good comparator |
| TPS60122 | 2-cell to regulated 3.3-V, 100-mA high efficiency charge pump with low-battery comparator |
| TPS60123 | 2-cell to regulated 3.3-V, 100-mA high efficiency charge pump with power-good comparator |
| TPS60124 | 2-cell to regulated 3-V, 200-mA high efficiency charge pump with low-battery comparator |
| TPS60125 | 2-cell to regulated 3-V, 200-mA high efficiency charge pump with power-good comparator |
| TPS60130 | 3-cell to regulated 5-V, 300-mA high efficiency charge pump with low-battery comparator |
| TPS60131 | 3-cell to regulated 5-V, 300-mA high efficiency charge pump with power-good comparator |
| TPS60132 | 3-cell to regulated 5-V, 150-mA high efficiency charge pump with low-battery comparator |
| TPS60133 | 3-cell to regulated 5-V, 150-mA high efficiency charge pump with power-good comparator |
| TPS60140 | 2-cell to regulated 5-V, 100-mA charge pump voltage tripler with low-battery comparator |
| TPS60141 | 2-cell to regulated 5-V, 100-mA charge pump voltage tripler with power-good comparator |
| TPS60200 | 2-cell to regulated 3.3-V, 100-mA low-ripple charge pump with low-battery comparator in MSOP10 |
| TPS60201 | 2-cell to regulated 3.3-V, 100-mA low-ripple charge pump with power-good comparator in MSOP10 |
| TPS60202 | 2-cell to regulated 3.3-V, 50-mA low-ripple charge pump with low-battery comparator in MSOP10 |
| TPS60203 | 2-cell to regulated 3.3-V, 50-mA low-ripple charge pump with power-good comparator in MSOP10 |
| TPS60210 | 2-cell to regulated 3.3-V, 100-mA low-ripple charge pump with ultralow operating current and low-battery comparator in MSOP10 |
| TPS60211 | 2-cell to regulated 3.3-V, 100-mA low-ripple charge pump with ultralow operating current and power-good comparator in MSOP10 |
| TPS60212 | 2-cell to regulated 3.3-V, 100-mA low-ripple charge pump with ultralow operating current and low-battery comparator in MSOP10 |
| TPS60213 | 2-cell to regulated 3.3-V, 50-mA low-ripple charge pump with ultralow operating current and power-good comparator in MSOP10 |

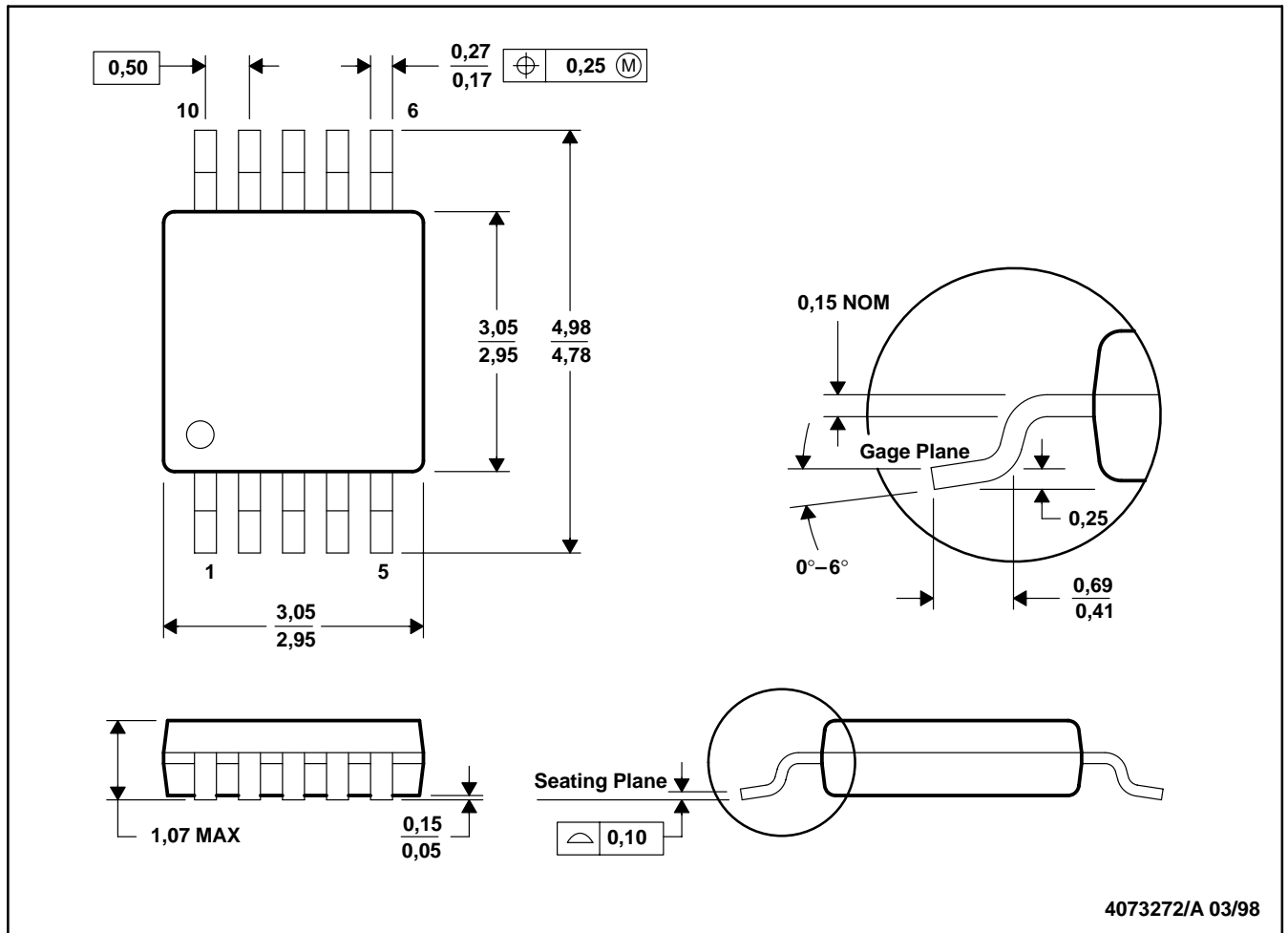
TPS60300, TPS60301, TPS60302, TPS60303
 SINGLE-CELL TO 3.0-V/3.3-V, 20-mA DUAL OUTPUT,
 HIGH-EFFICIENCY CHARGE PUMP

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MECHANICAL DATA

DGS (S-PDSO-G10)

PLASTIC SMALL-OUTLINE PACKAGE



- 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.

PACKAGING INFORMATION

| Orderable Device | Status ⁽¹⁾ | Package Type | Package Drawing | Pins | Package Qty | Eco Plan ⁽²⁾ | Lead/Ball Finish | MSL Peak Temp ⁽³⁾ |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| TPS60300DGS | ACTIVE | MSOP | DGS | 10 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS60300DGSG4 | ACTIVE | MSOP | DGS | 10 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS60300DGSR | ACTIVE | MSOP | DGS | 10 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS60300DGSRG4 | ACTIVE | MSOP | DGS | 10 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS60301DGS | ACTIVE | MSOP | DGS | 10 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS60301DGSG4 | ACTIVE | MSOP | DGS | 10 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS60301DGSR | ACTIVE | MSOP | DGS | 10 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS60301DGSRG4 | ACTIVE | MSOP | DGS | 10 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS60302DGS | ACTIVE | MSOP | DGS | 10 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS60302DGSG4 | ACTIVE | MSOP | DGS | 10 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS60302DGSR | ACTIVE | MSOP | DGS | 10 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS60302DGSRG4 | ACTIVE | MSOP | DGS | 10 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS60303DGS | ACTIVE | MSOP | DGS | 10 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS60303DGSG4 | ACTIVE | MSOP | DGS | 10 | 80 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS60303DGSR | ACTIVE | MSOP | DGS | 10 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |
| TPS60303DGSRG4 | ACTIVE | MSOP | DGS | 10 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM |

⁽¹⁾ The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

⁽²⁾ Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), 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.

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

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

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TAPE AND REEL INFORMATION



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 |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPS60300DGSR | MSOP | DGS | 10 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| TPS60301DGSR | MSOP | DGS | 10 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| TPS60302DGSR | MSOP | DGS | 10 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| TPS60303DGSR | MSOP | DGS | 10 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TPS60300DGSR | MSOP | DGS | 10 | 2500 | 340.5 | 338.1 | 20.6 |
| TPS60301DGSR | MSOP | DGS | 10 | 2500 | 340.5 | 338.1 | 20.6 |
| TPS60302DGSR | MSOP | DGS | 10 | 2500 | 346.0 | 346.0 | 29.0 |
| TPS60303DGSR | MSOP | DGS | 10 | 2500 | 340.5 | 338.1 | 20.6 |

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