TEXAS INSTRUMENTS

TPS62770

ZHCSEV1A – FEBRUARY 2016 – REVISED MARCH 2016

# TPS62770 面向可穿戴应用的多轨 DC/DC 转换器

## 1 特性

- VIN 范围为 2.5V 至 5.5V
- 370nA Iq 降压转换器
  - 8 个可选输出电压（1.0V 至 3.0V）
  - 300mA 输出电流
  - 输出放电功能
- 受转换率控制的负载开关，具有放电功能
- 双模式降压转换器
  - 负载断开
  - 恒定输出电压，最高可调节至 15V ($V_{FB}$ 0.8 V) /12V（固定值）
  - 发光二极管 (LED) 电流驱动器，提供脉宽调制 (PWM) 用于电流转换（D = 100% 时的最大 $V_{FB}$ 电压为 200mV）
- 超小型 16 引脚 1.58mm x 1.58mm WCSP 封装，0.4mm 间距

## 2 应用

- 可穿戴和个人电子产品
- 健身配件
- 健康状况监控和医疗配件

## 3 说明

TPS62770 是一套面向可穿戴 应用 的超小型电源解决方案，其包括一个 370nA 超低 Iq 降压转换器、一个受转换率控制的负载开关以及一个双模式降压转换器。该降压转换器的输出电压可通过三个 VSEL 引脚在 1.0V、1.05V、1.1V、1.2V、1.8V、1.9V、2.0V 和 3.0V 之间选择。可以在运行期间更改输出电压。在关断模式下，该降压转换器的输出拉至 GND。集成的负载开关从内部连接至降压转换器的输出， 并且 接通阶段可控制转换率。关闭后，其输出连接到 GND。

双模式降压转换器既可以生成最高达 15V 的恒定输出电压（例如 PMOLED 电源），也可以提供恒定输出电流（例如 LED 背光电源）。输出电压可通过外部电阻最高调节至 15V，也可以通过将 FB 引脚连接至 VIN 设为 12V 固定电压。该器件 具有 17.7V 内部过压保护，用于 FB 节点悬空或接地情况。该器件包含内部整流器和负载断开功能。用作恒定输出电流驱动器时，该器件可为模拟转换器提供 PWM，以便其根据 PWM 信号的占空比按比例减小基准电压。

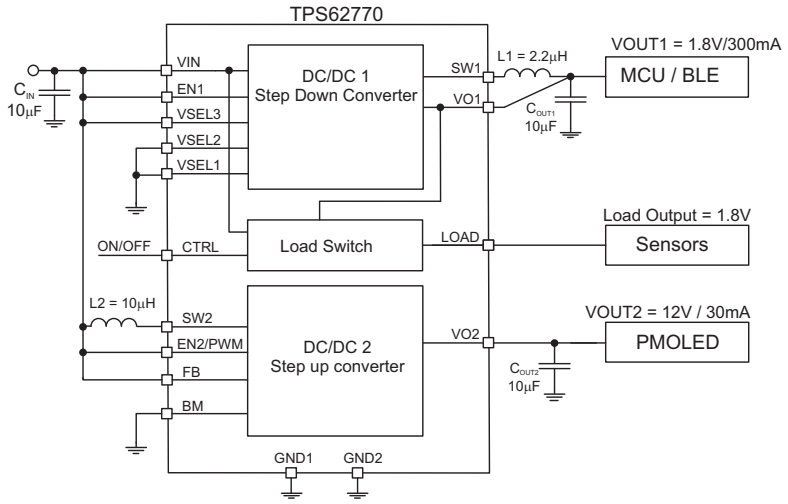
该器件采用小型 16 引脚 0.4mm 间距的 WCSP 封装。

器件信息(1)

| 器件型号 | 封装 | 封装尺寸（标称值） |
|---|---|---|
| TPS62770 | DSBGA (16) | 1.58mm x 1.58mm |

(1) 要了解所有可用封装，请见数据表末尾的可订购产品附录。

典型应用电路原理图




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 修订历史记录

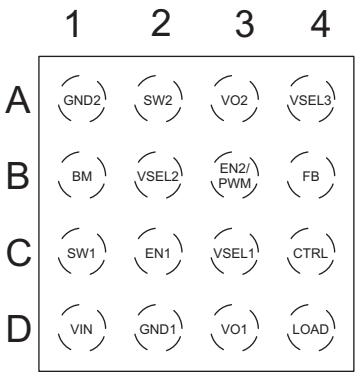
**Changes from Original (February 2016) to Revision A** **Page**

- 已更改 器件状态至“量产数据”且已发布完整数据表。 ... 1


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# 5 Pin Configuration and Functions

**YFP Package**
**16-Pin DSBGA**
**Top View**




**Pin Functions**

| PIN | | I/O | DESCRIPTION |
|---|---|---|---|
| NAME | NO | | |
| EN2/PWM | B3 | IN | Enable pin for the step-up converter. High level enables the devices, low level turns the device into shutdown mode. A PWM signal can be applied to this pin when used as a constant current driver (BM pin connected to VIN). The pin must be terminated. |
| GND2 | A1 | PWR | GND supply pin for the step-up converter. Connect this pin close to the GND terminals of the input and output capacitors. |
| SW2 | A2 | IN | The switch pin of the step-up converter. It is connected to the drain of the internal power MOSFET. Connect the inductor L2 between this pin and the input capacitor CIN |
| VO2 | A3 | OUT | Output of the step-up converter. |
| BM | B1 | IN | This pin controls the operation mode of the step-up converter. With BM = high, the device features a low feedback voltage of 200mV, which can be scaled down by the integrated PWM to analog converter. With BM = low, the device operates with a 0.8V feedback voltage and operates as a step-up converter with voltage regulation. This pin must be terminated and set before the device is enabled. |
| FB | B4 | IN | Feedback pin for the step-up converter to set the output voltage / current. Connect the pin to the center tap of a resistor divider to program the output voltage. When it is connected to the VIN pin, the output voltage is set to 12 V by an internal feedback divider network. When used as a LED current driver connect the sense resistor between this pin and GND. The LED string is connected between FB pin and VO2. |
| EN1 | C2 | IN | Enable pin for the step-down converter. High level enables the devices, low level turns the device into shutdown mode. The pin must be terminated. |
| VSEL1 | C3 | IN | Output voltage selection pins. See Table 1 for $V_{OUT}$ selection. These pins must be terminated. The pins can be dynamically changed during operation. |
| VSEL2 | B2 | IN | |
| VSEL3 | A4 | IN | |
| CTRL | C4 | IN | This pin controls the load switch between VO1 and LOAD. With CTRL = low, the LOAD switch is disabled. The pin must be terminated. |
| VIN | D1 | PWR | VIN power supply pin. Connect the input capacitor close to this pin for best noise and voltage spike suppression. A ceramic capacitor of 10µF is required. |
| GND1 | D2 | PWR | GND supply pin for the step-down converter. Connect this pin close to both, the GND terminal of the input and output capacitor. |
| SW1 | C1 | OUT | This is the switch pin of the step-down converter and is connected to the internal MOSFET switches. Connect the inductor L1 between this terminal and the output capacitor. |
| VO1 | D3 | OUT | Output of the step-down converter. The output voltage is sensed via this pin to the internal feedback divider network for the regulation loop. In addition the internal load switch is connected between VO1 pin and LOAD pin. Connect this pin directly to the output capacitor with a short trace. The pin is connected to GND1 and discharges the output capacitor when the converter is disabled. |
| LOAD | D4 | OUT | Output terminal of the internal load switch. With CTRL = high, the internal load switch connects VO1 to the LOAD pin. The switch features a slew rate control. This pin is pulled to GND with the CTRL = low. If not used, leave the pin open. |

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**Table 1. Output Voltage Setting Step-Down Converter**

| VO1 [V] | VSEL3 | VSEL2 | VSEL1 |
|---|---|---|---|
| 1.0 | 0 | 0 | 0 |
| 1.05 | 0 | 0 | 1 |
| 1.1 | 0 | 1 | 0 |
| 1.2 | 0 | 1 | 1 |
| 1.8 | 1 | 0 | 0 |
| 1.9 | 1 | 0 | 1 |
| 2.0 | 1 | 1 | 0 |
| 3.0 | 1 | 1 | 1 |

# 6 Specifications

## 6.1 Absolute Maximum Ratings

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

| | | MIN | MAX | UNIT |
|---|---|---|---|---|
| Pin voltage(2) | VIN, FB | –0.3 | 6 | V |
| | SW1 | –0.3 | $V_{IN}$ +0.3V | V |
| | EN1, EN2/PWM, CTRL, BM, VSEL1-3 | –0.3 | $V_{IN}$ +0.3V | V |
| | SW2, VO2 | -0.3 | 32 | V |
| | VO1, LOAD | –0.3 | 3.7 | V |
| $T_J$ | Operating junction temperature range | –40 | 125 | °C |
| $T_{stg}$ | Storage temperature range | –65 | 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.
(2) All voltage values are with respect to network ground terminal GND.

## 6.2 ESD Ratings

| | | | VALUE | UNIT |
|---|---|---|---|---|
| $V_{(ESD)}$ | Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins(1) | ± 2000 | V |
| | | Charged device model (CDM), per JEDEC specification JESD22-C101, all pins(2) | ±500 | |

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process. The human body model is a 100-pF capacitor discharged through a 1.5-kΩ resistor into each pin.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.


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## 6.3 Recommended Operating Conditions

| | | | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|---|
| $V_{IN}$ | Input voltage range at VIN pin | | 2.5 | | 5.5 | V |
| $I_{OUT1}$ | DC/DC 1 Step down converter output current | L1 = 2.2µH, $C_{OUT1}$ = 10 µF | | | 300 | mA |
| $I_{OUT2}$ | DC/DC 2 Step up converter output current | 2.5V < VIN < 5.5V, VOUT2 = 12V, $C_{OUT2}$ = 10uF, L = 10µH | | | 30 | mA |
| | | 2.5V < VIN < 5.5V, VOUT2 = 12V, $C_{OUT2}$ = 2x 10uF, L = 10µH | | | 100 | |
| | | 3V < VIN < 5.5V, VOUT2 = 5V, $C_{OUT2}$ = 2x 10uF, L = 4.7µH | | | 200 | |
| $I_{LOAD}$ | Load current (current from LOAD pin) | | | | 100 | |
| $T_J$ | Operating junction temperature range | | -40 | | 125 | °C |
| $T_A$ | Ambient temperature range | | -40 | | 85 | |

## 6.4 Thermal Information

| THERMAL METRIC(1) | | TPS62770 YFP TERMINALS | UNIT |
|---|---|---|---|
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 90.6 | °C/W |
| $R_{\theta JCtop}$ | Junction-to-case (top) thermal resistance | 0.6 | |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 13.8 | |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 2.8 | |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 13.7 | |
| $R_{\theta JCbot}$ | Junction-to-case (bottom) thermal resistance | n/a | |

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

## 6.5 Electrical Characteristics

$V_{IN}$ = 3.6V, $T_A$ = –40°C to 85°C typical values are at $T_A$ = 25°C (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **SUPPLY** | | | | | | |
| $I_{SD}$ | Shutdown current into $V_{IN}$ | EN1 = EN2/PWM = GND, CTRL GND, BM = GND, | | 0.1 | 1850 | nA |
| $V_{TH_UVLO+}$ | Undervoltage lockout threshold | Rising $V_{IN}$ | | 2.1 | 2.22 | V |
| $V_{TH_UVLO-}$ | | Falling $V_{IN}$ | | 1.9 | 2 | |
| **INPUTS EN1, EN2/PWM, BM, CTRL,VSEL 1-3** | | | | | | |
| $V_{IH\ TH}$ | High level input threshold | | | | 1.2 | V |
| $V_{IL\ TH}$ | Low level input threshold | | 0.4 | | | V |
| $I_{IN}$ | Input bias Current | $T_J$ = 25°C | | | 10 | nA |
| | | $T_J$ = –40°C to 85°C | | | 25 | |

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## Electrical Characteristics (continued)

$V_{IN}$ = 3.6V, $T_A$ = –40°C to 85°C typical values are at $T_A$ = 25°C (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| **STEP-DOWN CONVERTER** | | | | | | | |
| $I_Q$ | Operating quiescent current | EN1 = $V_{IN}$, EN2/PWM = GND, CTRL = GND, $I_{OUT}$ = 0µA, $V_{OUT}$ = 1.8V, device not switching, | | | 370 | 1850 | nA |
| | | EN1 = $V_{IN}$, EN2/PWM = GND, $I_{OUT}$ = 0mA, CTRL = GND, $V_{OUT}$ = 1.8V , device switching | | | 500 | | |
| $V_{VOUT}$ | Output voltage range | | | 1.0 | | 3.0 | V |
| | Output voltage accuracy | PFM mode | | -2.5 | 0 | 2.5 | % |
| | | PWM mode | | -2 | 0 | 2 | |
| | DC output voltage load regulation | $V_{OUT}$ = 1.8V | | | 0.001 | | %/mA |
| | DC output voltage line regulation | $V_{OUT}$ = 1.8V, $I_{OUT}$ = 10 mA, 2.5V ≤ $V_{IN}$ ≤ 5.5V | | | 0 | | %/V |
| $R_{DS(ON)}$ | High side MOSFET on-resistance | $I_{OUT}$ = 50mA | | | 0.45 | | Ω |
| | Low Side MOSFET on-resistance | | | | 0.22 | | |
| $I_{LIMF}$ | High side MOSFET switch current limit | | | 480 | 600 | 720 | mA |
| | Low side MOSFET switch current limit | | | | 600 | | mA |
| $R_{DSCH_VO1}$ | Discharge switch on-resistance | EN = GND, $I_{VO1}$ = -10mA into VO1 pin | | | 20 | 65 | Ω |
| $I_{IN_VO1}$ | Bias current into VO1 pin | EN = $V_{IN}$, $V_{OUT}$ = 1.8V | $T_J$ = 25°C | | 40 | 100 | nA |
| | | | $T_J$ = –40°C to 85°C | | | 1010 | |
| $V_{TH_100+}$ | Auto 100% Mode leave detection threshold (1) | Rising $V_{IN}$,100% Mode is left with $V_{IN}$ = $V_{OUT}$ + $V_{TH_100+}$ , max value at $T_J$ = 85°C | | 150 | 250 | 370 | mV |
| $V_{TH_100-}$ | Auto 100% Mode enter detection threshold (1) | Falling $V_{IN}$, 100% Mode is entered with $V_{IN}$ = $V_{OUT}$ + $V_{TH_100-}$, max value at $T_J$ = 85°C | | 85 | 200 | 310 | |
| $t_{ONmin}$ | Minimum ON time | $V_{OUT}$ = 2.0V, $I_{OUT}$ = 0 mA | | | 225 | | ns |
| $t_{OFFmin}$ | Minimum OFF time | | | | 50 | | ns |
| $t_{Startup_delay}$ | Regulator start up delay time | From transition EN1 = low to high until device starts switching | | | 1 | 5 | ms |
| $t_{Softstart}$ | Softstart time with reduced switch current limit | | | | 700 | 1200 | µs |
| $I_{LIM_softstart}$ | High side MOSFET switch current limit | Reduced switch current limit during softstart | | 80 | 150 | 200 | mA |
| | Low side MOSFET switch current limit | | | | 150 | | |
| **LOAD SWITCH** | | | | | | | |
| $R_{LOAD}$ | MOSFET on-resistance | $I_{LOAD}$ = 50mA, CTRL = $V_{IN}$, $V_{OUT}$ = 1.8V, | | | 0.6 | 1.27 | Ω |
| $t_{rise_LOAD}$ | $V_{LOAD}$ rise time | Starting with CTRL low to high transition, time to ramp $V_{LOAD}$ from 95%, $V_{OUT}$ = 1.8V, $I_{LOAD}$ = 20mA | | | 315 | 800 | µs |
| $R_{DCHRG}$ | MOSFET on-resistance | | | | 20 | 65 | Ω |

(1) $V_{IN}$ is compared to the programmed output voltage ($V_{OUT}$). When $V_{IN}$–$V_{OUT}$ falls below $V_{TH_100-}$ the device enters 100% Mode by turning the high side MOSFET on. The 100% Mode is exited when $V_{IN}$–$V_{OUT}$ exceeds $V_{TH_100+}$ and the device starts switching. The hysteresis for the 100% Mode detection threshold $V_{TH_100+}$ - $V_{TH_100-}$ will always be positive and will be approximately 50 mV(typ.)


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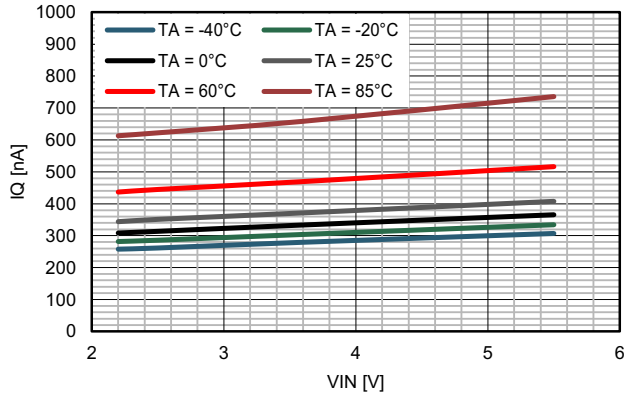
## Electrical Characteristics (continued)

$V_{IN}$ = 3.6V, $T_A$ = –40°C to 85°C typical values are at $T_A$ = 25°C (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **STEP-UP CONVERTER** | | | | | | |
| $I_{Q_VIN}$ | Quiescent current into VIN pin | EN2/PWM = VIN, BM = GND, EN1 = GND, no load, no switching, $V_{OUT}$ = 12 V | | 110 | 200 | µA |
| $V_{OUT}$ | Output voltage range | EN2/PWM = VIN, BM = GND | 4.5 | | 15 | V |
| $V_{OUT_12V}$ | 12-V output voltage accuracy | FB pin connected to VIN pin, EN2/PWM = $V_{IN}$, BM = GND | 11.7 | 12 | 12.3 | V |
| $V_{FB}$ | Feedback voltage | PWM mode, BM = GND, EN2/PWM = $V_{IN}$ | 0.775 | 0.795 | 0.814 | V |
| | | PFM mode, BM = GND, EN2/PWM = $V_{IN}$ | | 0.803 | | V |
| | Feedback regulation voltage under brightness control | EN2/PWM = VIN, BM = VIN, | 189 | 200 | 206 | mV |
| | | VFB =50mV, BM = VIN, D(PWM) @ EN2/PWM = 25%, | 40 | 50 | 60 | mV |
| | | VFB = 20mV, BM = VIN, D(PWM) @ EN2/PWM = 10% | 13 | 20 | 27 | |
| $t_{Dim_Off}$ | Dimming signal on pin EN2/PWM | | | 270 | 160 | µs |
| $t_{Dim_On}$ | | | 1 | | | µs |
| $V_{OVP}$ | Output overvoltage protection threshold | | 17 | 17.7 | 18.4 | V |
| $V_{OVP_HYS}$ | Over voltage protection hysteresis | | | 800 | | mV |
| $I_{FB_LKG}$ | Leakage current into FB pin | | | 5 | 200 | nA |
| $I_{SW_LKG}$ | Leakage current into SW pin | EN2/PWM = GND | | 5 | 500 | nA |
| $R_{DS(on)}$ | Isolation MOSFET on resistance | $V_{OUT}$ = 12 V | | 850 | | mΩ |
| | Low-side MOSFET on resistance | $V_{OUT}$ = 12 V | | 450 | | |
| $f_{SW}$ | Switching frequency | $V_{OUT}$ = 12 V, PWM mode | 850 | 1050 | 1250 | kHz |
| $t_{ON_min}$ | Minimal switch on time | | | 150 | 250 | ns |
| $I_{LIM_SW}$ | Peak switch current limit | $V_{OUT}$ = 12 V | 730 | 970 | 1230 | mA |
| $I_{LIM_CHG}$ | Pre-charge current | $V_{OUT}$ = 0 V | | 30 | 55 | mA |
| $t_{Softstart}$ | Pre-charge time | BM = GND, EN2/PWM from low to high until device starts switching, $I_{OUT2}$ = 0mA, $C_{OUT2}$ = 10uF | | 6 | | ms |
| | Startup time | $V_{OUT}$ from $V_{IN}$ to 12 V, $C_{OUT_effective}$ = 2.2 µF, $I_{OUT}$ = 0 A | | 6 | | |

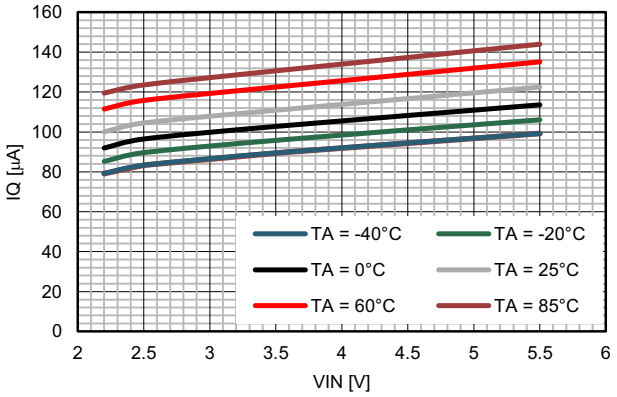
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## 6.6 Typical Characteristics



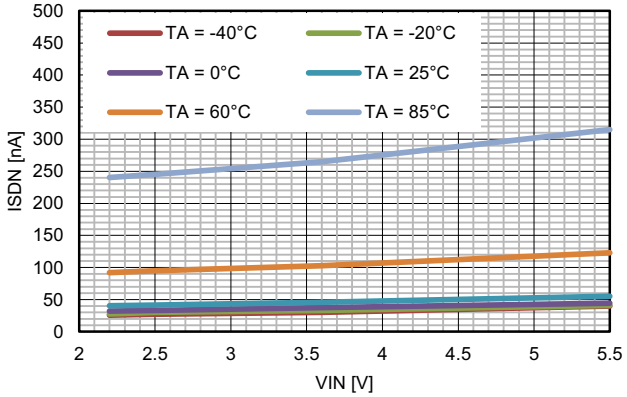

EN2/PWM = low
EN1 = high
VOUT1 set to 1.8V
device not switching

**图 1. Quiescent current $I_Q$ Step-Down converter**




EN2/PWM = high
EN1 = low
VOUT2 set to 12V
device not switching

**图 2. Quiescent current $I_Q$ Step-Up converter**




EN1 = EN2/PWM = low

**图 3. Shutdown current $I_{SDN}$**


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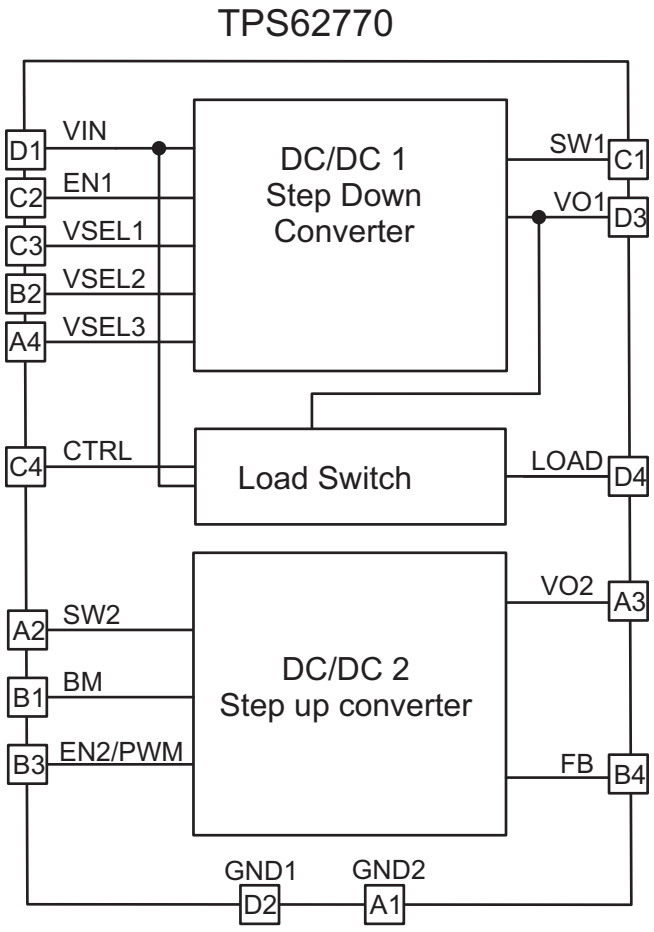
# 7 Detailed Description

## 7.1 Overview

The TPS62770 is a tiny power solution for wearable applications including a 370nA ultra low Iq step-down converter, a slew rate controlled load switch and a dual mode step-up converter. The output voltage of the step-down converter can be selected with three VSEL pins between 1.0 V, 1.05 V, 1.1 V, 1.2 V, 1.8 V, 1.9 V, 2.0 V and 3.0 V.

The dual mode step-up converter can generate a constant output voltage up to 15 V, such as PMOLED supply or, a constant output current, such as LED back light supply.

## 7.2 Functional Block Diagram



## 7.3 Feature Description

### 7.3.1 Step-Down Converter Device

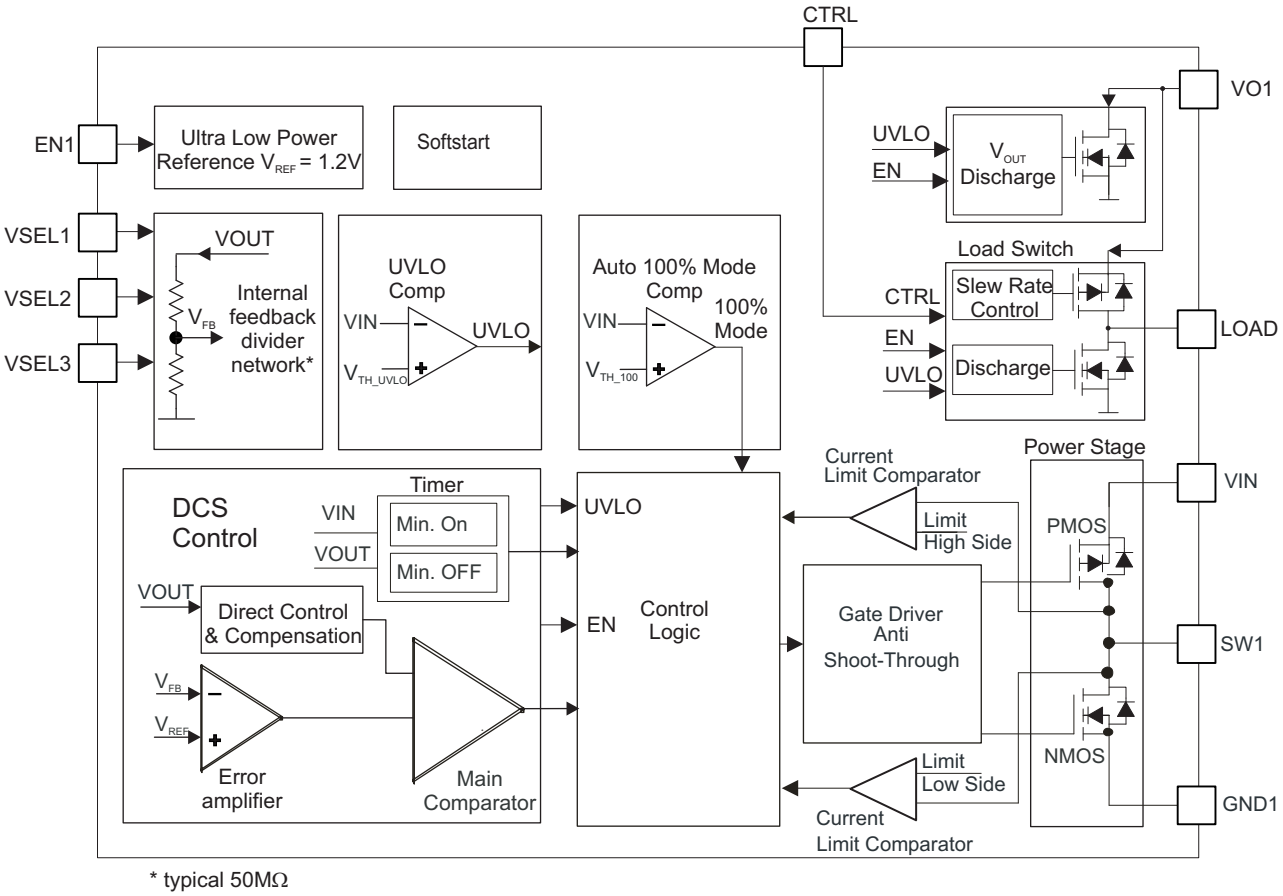



**图 4. Block diagram Step-Down Converter with Load Switch**

#### *7.3.1.1 DCS-Control™*

TI's DCS-Control™ (Direct Control with Seamless Transition into Power Save Mode) is an advanced regulation topology, which combines the advantages of hysteretic and voltage mode control. Characteristics of DCS-Control ™ are excellent AC load regulation and transient response, low output ripple voltage and a seamless transition between PFM and PWM mode operation. DCS-Control™ includes an AC loop which senses the output voltage (VO1 pin) and directly feeds the information to a fast comparator stage. This comparator sets the switching frequency, which is constant for steady state operating conditions, and provides immediate response to dynamic load changes. In order to achieve accurate DC load regulation, a voltage feedback loop is used. The internally compensated regulation network achieves fast and stable operation with small external components and low ESR capacitors. The DCS-Control™ topology supports PWM (Pulse Width Modulation) mode for medium and high load conditions and a Power Save Mode at light loads. Since DCS-Control™ supports both operation modes within one single building block, the transition from PWM to Power Save Mode is seamless with minimum output voltage ripple. The step-down converter offers both excellent DC voltage and superior load transient regulation, combined with low output voltage ripple, minimizing interference with RF circuits.

#### *7.3.1.2 Output Voltage Selection with pins VSEL1-VSEL3*

The step-down converter doesn't require an external resistor divider network to program the output voltage. The device integrates a high impedance feedback resistor divider network that is programmed by the pins VSEL1-3. It supports an output voltage range from 1.0 V to 3.0 V. The output voltage is programmed according to Table 1 . The output voltage can be changed during operation. This can be used for simple dynamic output voltage scaling.


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## Feature Description (接下页)

### 7.3.1.3 CTRL / Output Load

With the CTRL pin set to high, the integrated loadswitch is activated and connects the LOAD pin to the VO1 pin to power up an additional sub-system. The load switch is slew rate controlled to support soft switching and not to impact the regulated output VO1. If CTRL pin is pulled to GND, the LOAD pin is disconnected from the VO1 pin and internally connected to GND by an internal discharge switch. The CTRL pin can be controlled by a micro controller.

### 7.3.1.4 Output Discharge At Pins VO1 And LOAD

Both the VO1 pin and the LOAD pin feature a discharge circuit to connect each rail to GND, once they are disabled. This feature prevents residual charge voltages on capacitors connected to these pins, which may impact proper power up of the main- and sub-system. With CTRL pin pulled to low, the discharge circuit at the LOAD pin becomes active. With the EN pin pulled to low, the discharge circuits at both pins VO1 and Load are active. The discharge circuits of both rails VO1 and LOAD are associated with the UVLO comparator as well. Both discharge circuits become active once the input voltage VIN has dropped below the UVLO comparator threshold VTH_UVLO- and the UVLO comparator triggers.

### 7.3.1.5 Undervoltage Lockout UVLO

The UVLO circuit shuts down the device if the input voltage $V_{IN}$ drops to typical 1.9V. The device will start up at an input voltage of typ. 2.1V.

### 7.3.1.6 Short Circuit Protection

The step-down converter integrates a current limit on the high side, as well on the low side MOSFETs to protect the device against overload or short circuit conditions. The peak current in the switches is monitored cycle by cycle. If the high side MOSFET current limit is reached, the high side MOSFET is turned off and the low side MOSFET is turned on until the switch current decreases below the low side MOSFET current limit. Once the low side MOSFET current limit trips, the low side MOSFET is turned off and the high side MOSFET turns on again.

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## Feature Description (接下页)

### 7.3.2 Step-Up Converter Device

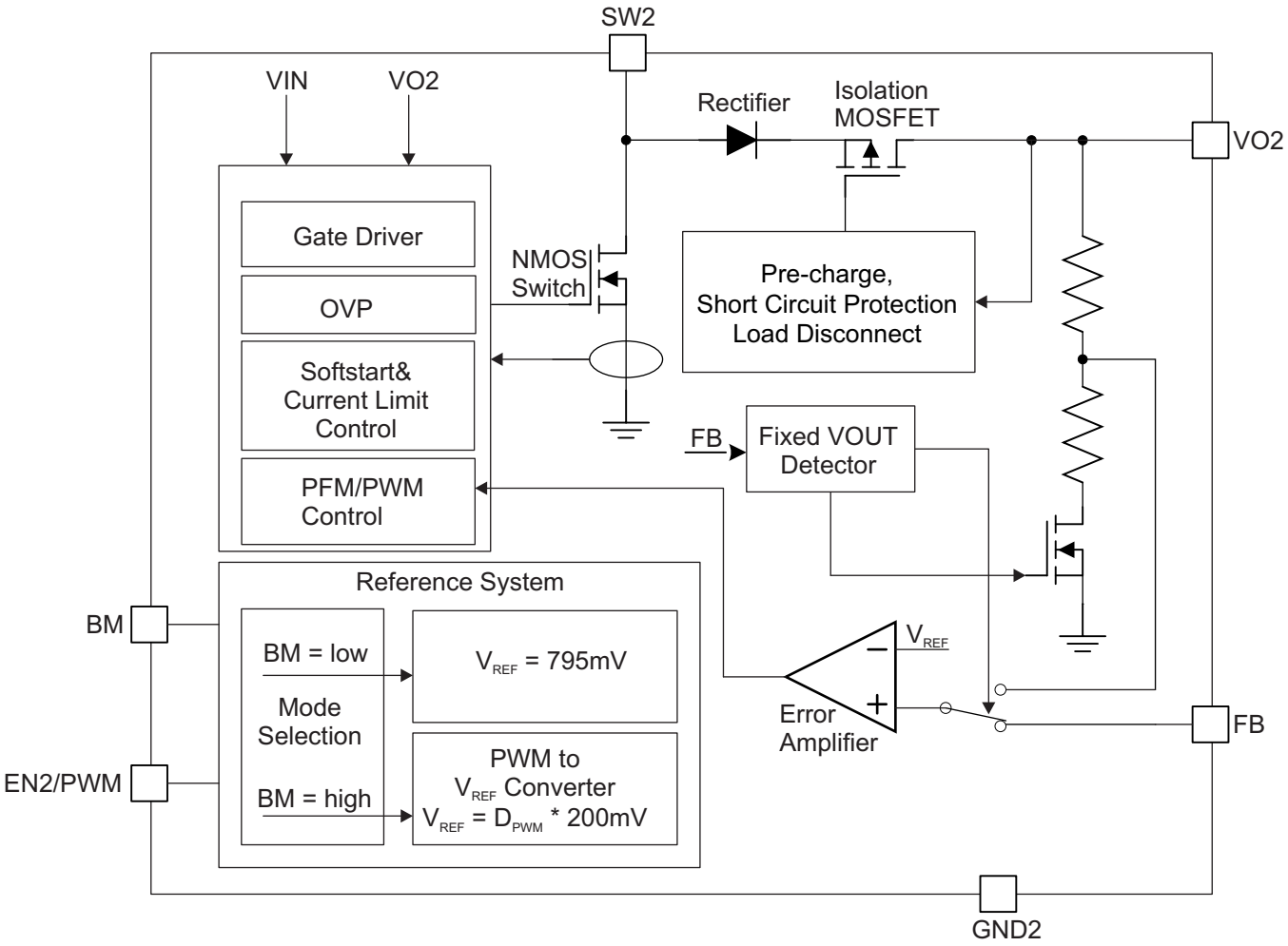



**图 5. Block Diagram Step-Up Converter**

The step-up converter is designed for applications requiring voltages up to 15V from an Li-Ion battery and tiny solution size such as PMOLED displays or LED back light for small size LCD displays. The step-up converter operates in two different modes, either as constant output voltage step-up converter operating with 0.8V internal reference or as a constant output current step-up converter operating with a reduced internal reference voltage of 200mV. The block integrates power switch, input/output isolation switch, and power diode.

#### *7.3.2.1 Under-Voltage Lockout*

See section *Undervoltage Lockout UVLO*

#### *7.3.2.2 Output Disconnect*

One common issue with conventional step-up regulators is the conduction path from input to output even when the device is disabled. It creates three problems, which are inrush current during start-up, output leakage current during shutdown and excessive over load current. The step-up converter has an integrated isolation (load disconnect) switch, which is turned off under shutdown mode and over load conditions, thereby opening the current path to the output VO2. Thus the device can truly disconnect the load from the input voltage and minimize the leakage current during shutdown mode.


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## Feature Description (接下页)

#### *7.3.2.3 12V Fixed Output Voltage*

The step-up converter features an internal default 12-V output voltage setting by connecting the FB pin to the VIN pin. Therefore no external resistor divider network is required minimizing the total solution size.

#### *7.3.2.4 Mode Selection With Pin BM*

The step-up converter can operate in two different modes. With pin BM = low the device regulates to a constant output voltage, with BM = high, the device can regulate a constant output current. Further details in section *Constant-Current Step-Up Mode Operation* and section *Constant-Voltage Step-Up Mode Operation*. The operation mode need to be selected before the device is enabled. The pin BM may not be changed during operation.

#### *7.3.2.5 Output Overvoltage Protection*

When the output voltage exceeds the OVP threshold of 17.7 V, the device stops switching. Once the output voltage falls 0.8 V below the OVP threshold, the device resumes operation again.

#### *7.3.2.6 Output Short Circuit Protection*

The step-up converter starts to limit the output current whenever the output voltage drops below 4 V. When the VOUT pin is shorted to ground, the output current is limited. This function protects the device from being damaged when the output is shorted to ground.

#### *7.3.2.7 PWM to Analog Converter AT PIN EN2/PWM*

In constant current step-up mode operation two control functions are associated with the pin EN2/PWM:

a) Enable/ disable of the step-up converter

b) PWM to analog conversion to scale the internal reference voltage.

The internal reference voltage scales proportional with the duty cycle of the PWM signal applied at the pin EN2/PWM. More details in section *Constant-Current Step-Up Mode Operation*.

## 7.4 Device Functional Modes

### 7.4.1 Step-Down Converter

#### *7.4.1.1 Enable and Shutdown*

The step-down converter is turned on with EN1 = high. With EN1 = low the step-down converter is turned off. This pin must be terminated.

#### *7.4.1.2 Power Save Mode Operation*

At light loads, the device operates in Power Save Mode. The switching frequency varies linearly with the load current. In Power Save Mode the device operates in PFM (Pulse Frequency Modulation) that generates a single switching pulse to ramp up the inductor current and recharges the output capacitor, followed by a sleep period where most of the internal circuits are shutdown to achieve lowest operating quiescent current. During this time, the load current is supported by the output capacitor. The duration of the sleep period depends on the load current and the inductor peak current. During the sleep periods, the current consumption is reduced to 360 nA. This low quiescent current consumption is achieved by an ultra low power voltage reference, an integrated high impedance feedback divider network and an optimized Power Save Mode operation.

#### *7.4.1.3 PWM Mode Operation*

At moderate to heavy load currents, the device operates in PWM mode with continuos conduction. The switching frequency is up to 1.6 MHz with a controlled frequency variation depending on the input voltage and load current. If the load current decreases, the converter seamlessly enters Power Save Mode to maintain high efficiency down to very light loads.

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## Device Functional Modes (接下页)

#### *7.4.1.4 Device Start-up and Soft Start*

The step-down converter has an internal soft start to minimize inrush current and input voltage drop during start-up. Once the device is enabled the device starts switching after a typical delay time of 1 ms. Then the soft start time of typical 700 µs begins with a reduced current limit of typical 150mA. When this time expires the device enters full current limit operation.

#### *7.4.1.5 Automatic Transition Into 100% Mode*

Once the input voltage comes close to the output voltage, the DC/DC converter stops switching and enters 100% duty cycle operation. It connects the output $V_{OUT}$ via the inductor and the internal high side MOSFET switch to the input VIN, once the input voltage $V_{IN}$ falls below the 100% mode enter threshold, $V_{TH_100-}$. The DC/DC regulator is turned off, switching stops and therefore no output voltage ripple is generated. Because the output is connected to the input, the output voltage follows the input voltage minus the voltage drop across the internal high side switch and the inductor. Once the input voltage increases and trips the 100% mode exit threshold, $V_{TH_100+}$ , the DC/DC regulator turns on and starts switching again.

### 7.4.2 Step-Up Converter

#### *7.4.2.1 Enable and Shutdown*

The device is turned on with EN2/PWM = high. With EN2/PWM = low the device enters shutdown mode. In constant current step-up mode (BM = high) the pin EN2/PWM has to be pulled to low level for longer than $t_{Dim_Off}$ max to enter shutdown mode. This pin must be terminated.

#### *7.4.2.2 Soft Start*

The step-up converter begins soft start when the EN2/PWM pin is pulled high. At the beginning of the soft start period, the isolation FET is turned on slowly to charge the output capacitor with 30-mA current for about 6 ms. This is called the pre-charge phase. The output is charged up to the level of the input voltage VIN. After the pre-charge phase, the device starts switching and the output voltage ramps up. This is called switching soft start phase. An internal soft start circuit limits the peak inductor current.

#### *7.4.2.3 Power Save Mode*

The step-up converter integrates a power save mode with pulse frequency modulation (PFM) to improve efficiency at light load. When the load current decreases, the inductor peak current set by the output of the error amplifier declines to regulate the output voltage. When the inductor peak current hits the low limit of 240 mA, the output voltage will exceed the set voltage as the load current decreases further. The device enters power save mode once the FB voltage exceeds the PFM mode threshold, which is 1% above the nominal output voltage. It stops switching, the load is supplied by the output capacitor and the output voltage begins to decline. When the FB voltage falls below the PFM mode threshold voltage, the device starts switching again to ramp up the output voltage.


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## Device Functional Modes (接下页)

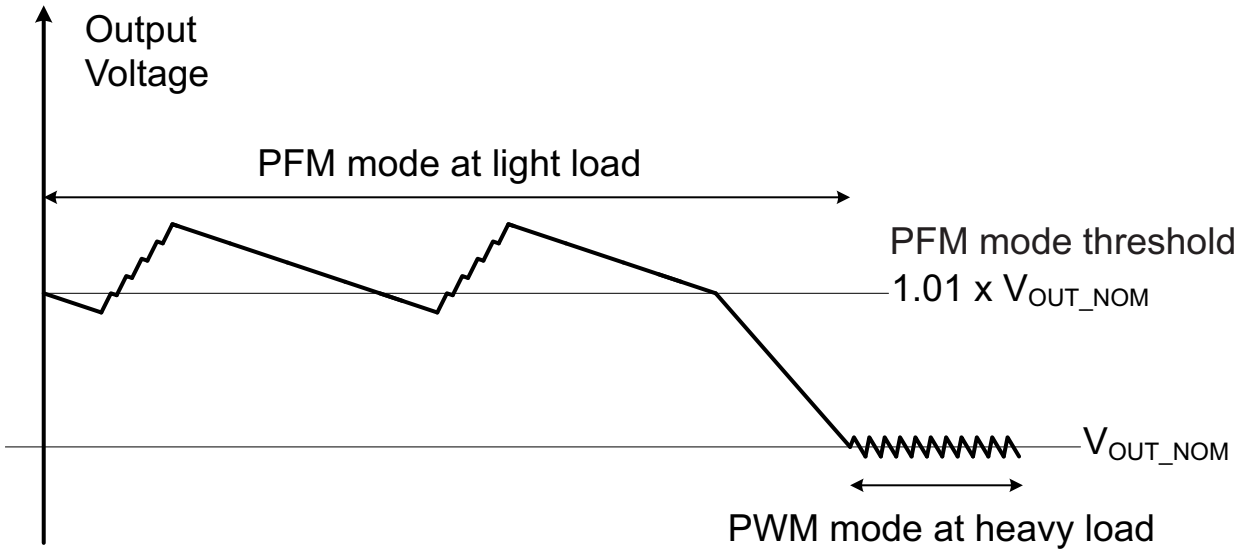



**图 6. Output Voltage in PFM and PWM Mode**

#### *7.4.2.4 PWM Mode*

The step-up converter uses a quasi-constant 1.0-MHz frequency pulse width modulation (PWM) at moderate to heavy load current. Based on the input voltage to output voltage ratio, a circuit predicts the required off-time. At the beginning of the switching cycle, the NMOS switching FET is turned on. The input voltage is applied across the inductor and the inductor current ramps up. In this phase, the output capacitor is discharged by the load current. When the inductor current hits the current threshold that is set by the output of the error amplifier, the PWM switch is turned off, and the power diode is forward-biased. The inductor transfers its stored energy to charge the output capacitor and supply the load. When the off-time is expired, the next switching cycle starts again. The error amplifier compares the FB pin voltage with an internal reference voltage, and its output determines the inductor peak current.

#### *7.4.2.5 Constant-Current Step-Up Mode Operation*

With pin BM = high the converter can regulate to a constant output current. The internal reference voltage is therefore reduced to 200mV. In order to regulate a constant output current, a sense resistor has to be connected between pin FB and GND, see 图 7. The device features in this operation mode a PWM to analog converter at pin EN2/PWM. The internal reference voltage is scaled according to the duty cycle of the PWM signal applied to pin EN2/PWM, see 图 8. When the pin EN2/PWM is pulled low longer than $t_{Dim_OFF}$ max, the step-up converter enters shutdown mode. The constant output current $I_{OUT2}$ can be calculated according equations 公式 1 and 公式 2.

## Device Functional Modes (接下页)

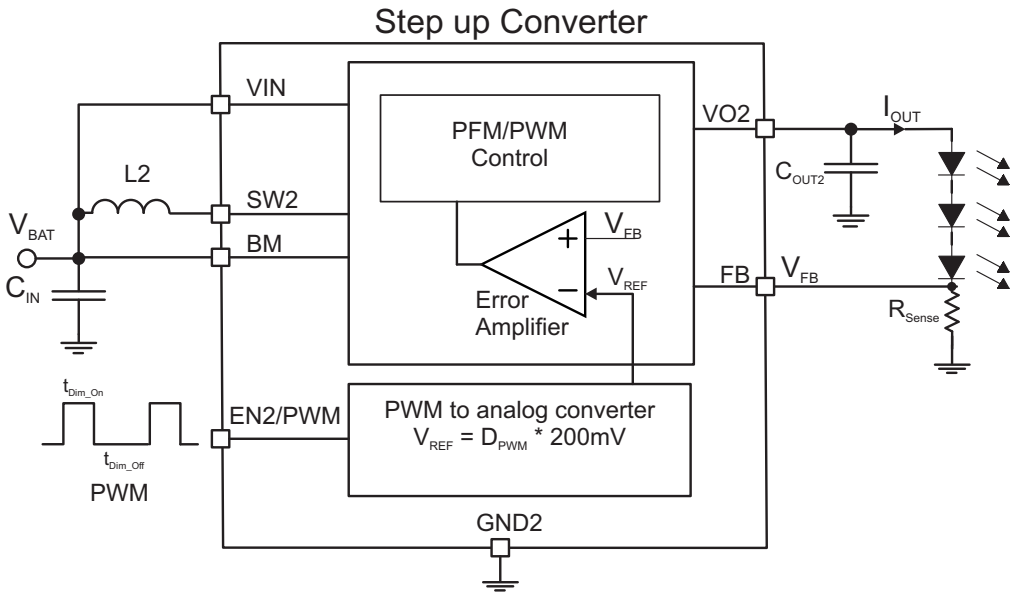



**图 7. Step-Up Converter in Constant-Current Operation Mode**

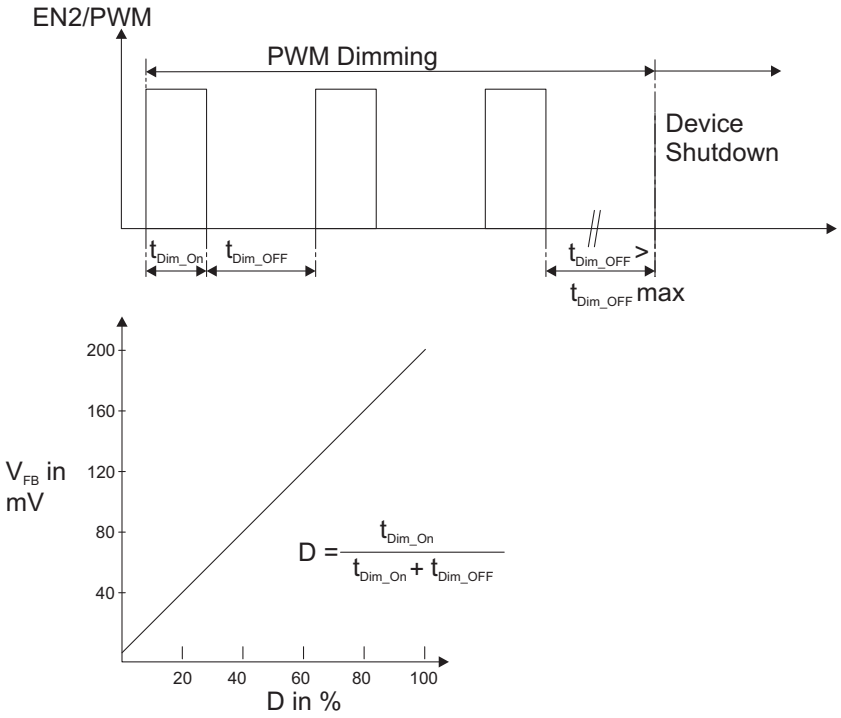



**图 8. EN2/PWM Pin Function**

$$I_{OUT2} = \frac{V_{FB}}{R_{Sense}} \quad (1)$$

$$I_{OUT2} = D_{PWM} \times \frac{200mV}{R_{Sense}} \quad (2)$$


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## Device Functional Modes (接下页)

### *7.4.2.6 Constant-Voltage Step-Up Mode Operation*

With pin BM = low the converter operates as a constant output voltage step-up converter. The internal reference voltage is set to 795 mV. A feedback resistor divider need to be connected between VOUT, FB and GND with its tap point connected to FB pin. The device provides a fixed set 12 V output voltage if the FB pin is connected to VIN. In this case no external resistor divider network is needed.

# 8 Application and Implementation

注

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.

## 8.1 Application Information

The TPS62770 is a tiny power solution for wearable applications including a 370nA ultra low Iq step-down converter, a slew rate controlled load switch and a dual mode step-up converter. The output voltage of the step-down converter can be selected between 1.0V and 3.0V. The output voltage can be changed during operation. In shutdown mode, the output of the step-down converter is pulled to GND. The integrated load switch is internally connected to the output of the step-down converter and features slew rate control during turn on phase. Once turned off, its output is connected to GND.

The dual mode step-up converter can generate a constant output voltage up to 15V, e.g. for PMOLED supply, or a constant output current, e.g. for LED back light supply. The output voltage can be adjusted up to 15V with external resistors, or set to fixed 12V by connecting the FB pin to VIN. The device features an internal over voltage protection of 17V in case the FB node is left open or tight to GND. It includes an internal rectifier and load disconnect function. When used as constant output current driver, the device offers a PWM to analog converter to scale down the reference voltage according to the duty cycle of the PWM signal.

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## 8.2 Typical Application

### 8.2.1 System and PMOLED Supply

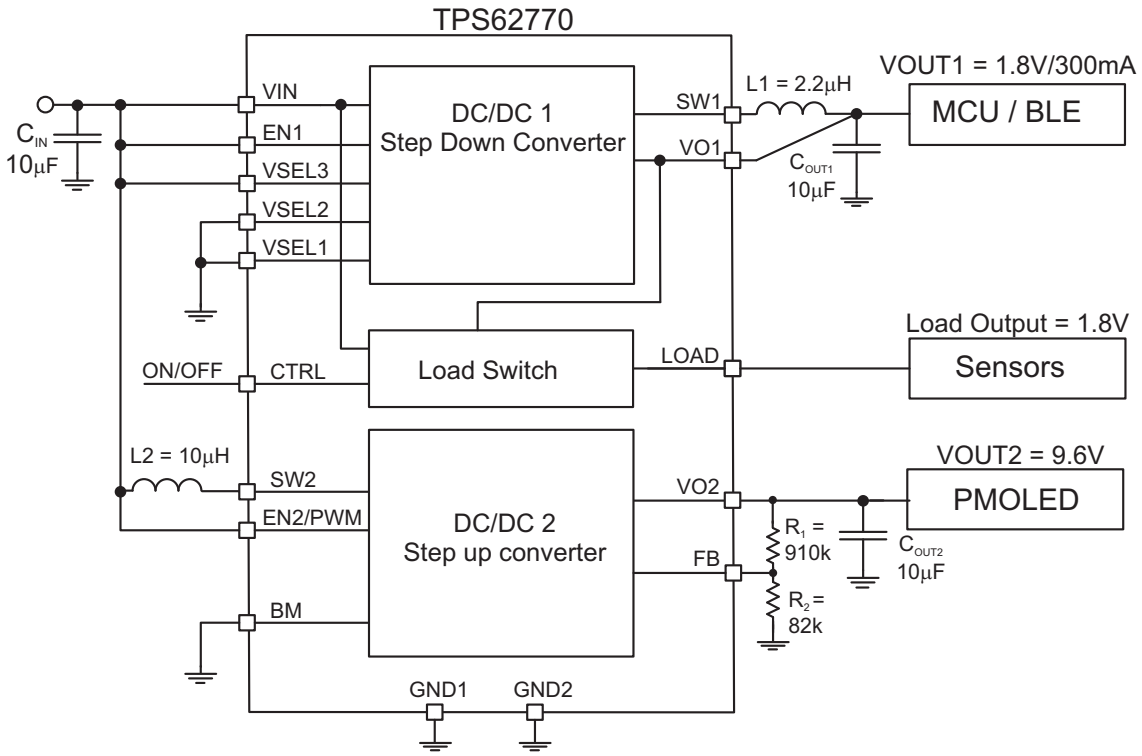



**图 9. Step-Up Converter with Adjustable Output Voltage**


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## Typical Application (接下页)

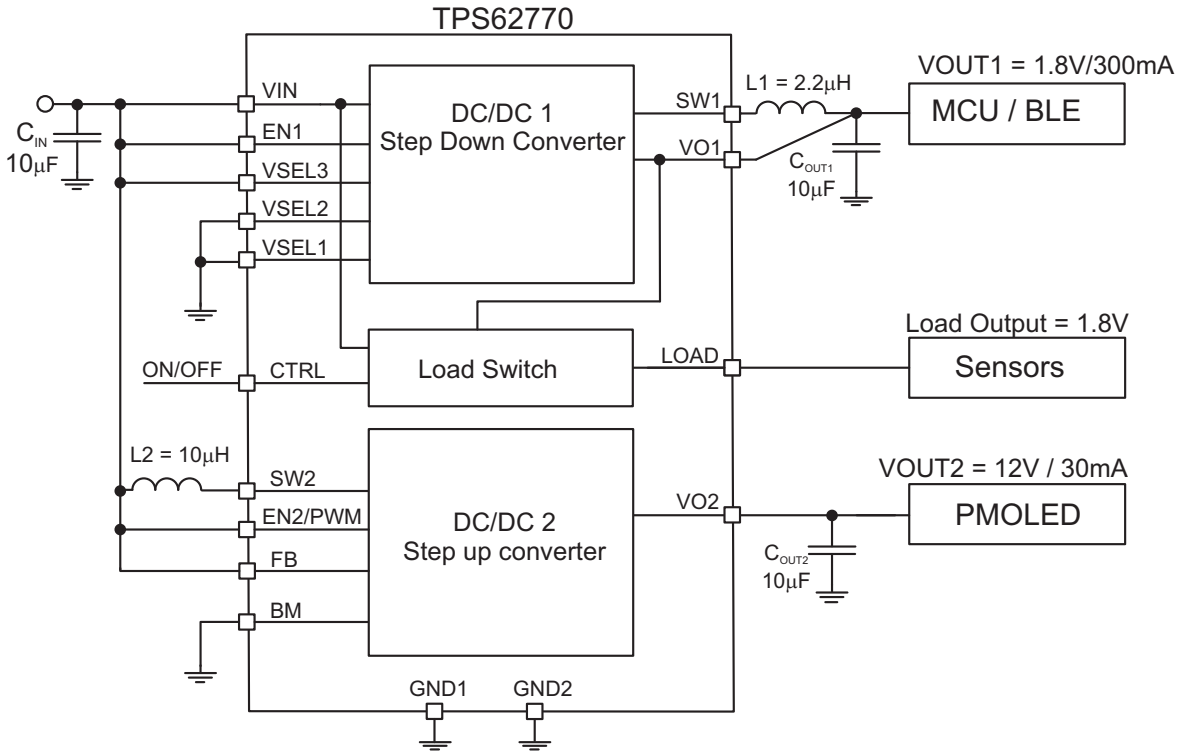



**图 10. Step-Up Converter with Fixed 12-V Output**

### *8.2.1.1 Design Requirements*

The device is supplied by an input voltage between 2.5V and 5.5V. In wearable personal electronics this is usually a rechargeable Li-Ion battery / USB port. The step-down converter supplies the system (MCU/BLE radio). In order to supply a PMOLED display, the step-up converter must be configured to operate in constant output voltage mode with BM pin tied to GND before the step-up converter is enabled. Ideally the BM pin is hardwired to GND. The output voltage of the step-up converter is either set by an external resistor divider network (R1/R2), shown in 图 9. The step-up converter supports an internally fixed 12V output voltage by connecting the FB pin to VIN, shown in 图 10.

The LOAD output is internally connected to the output of the buck regulator and can supply a sensor or a sub-system, which are temporarily used. In order to achieve better supply voltage decoupling / noise reduction a capacitor can be connected on the LOAD output.

The design guideline provides a component selection to operate the device within the recommended operating conditions. 表 2 shows the components used for the application characteristic curves.

**表 2. Components for Application Characteristic Curves**

| REFERENCE | DESCRIPTION | VALUE | PACKAGE CODE / SIZE [mm x mm x mm] | MANUFACTURER |
|---|---|---|---|---|
| CIN | Ceramic capacitor X5R 6.3V, GRM155R60J106ME11 | 10 µF | 0402 / 1.0 x 0.5 x 0.5 | Murata |
| COUT1 | Ceramic capacitor X5R 6.3V, GRM155R60J106ME11 | 10 µF | 0402 / 1.0 x 0.5 x 0.5 | Murata |
| COUT2 | Ceramic capacitor X5R 25V, GRM188R61E106MA73 | 10 uF | 0603 / 1.6 x 0.8 x 0.8 | Murata |
| L1 | Inductor DFE201610C | 2.2 µH | 2.0 x 1.6 x 1.0 | Toko |
| L2 | Inductor VLS302515 | 10 µH | 3.0 x 2.5 x 1.5 | TDK |

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### 8.2.1.2 Application Curves Step-Down Converter

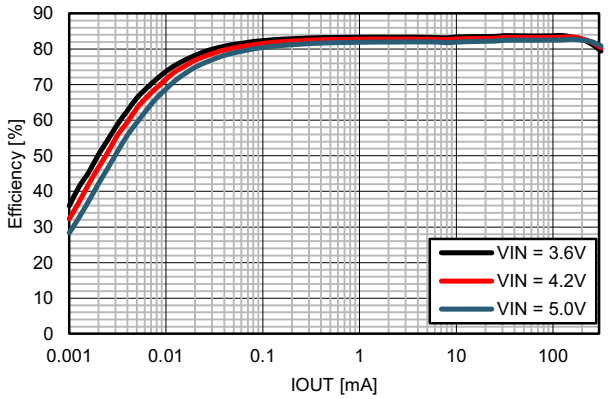



图 11. Efficiency vs. IOUT, VOUT1 = 1.0 V

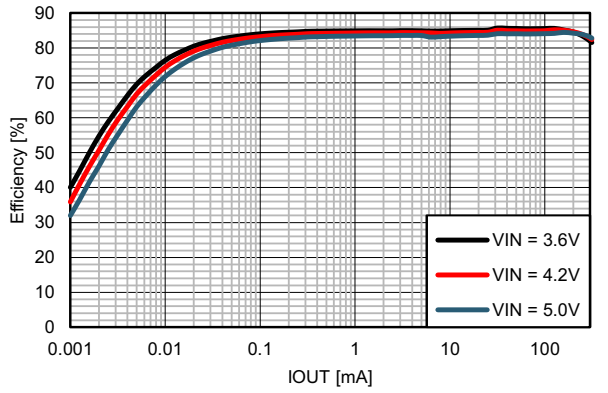



图 12. Efficiency vs. IOUT, VOUT1 = 1.2 V

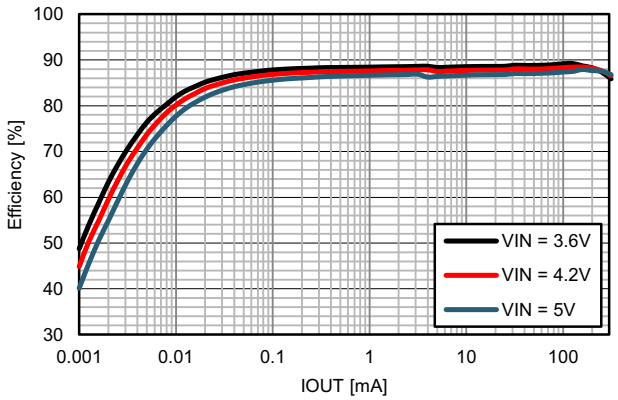



图 13. Efficiency vs. IOUT, VOUT1 = 1.8 V

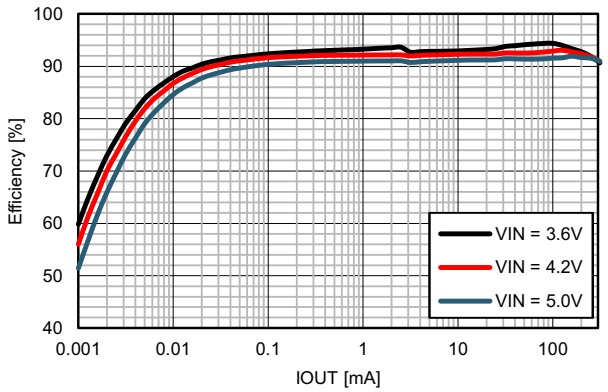



图 14. Efficiency vs. IOUT, VOUT1 = 3.0 V

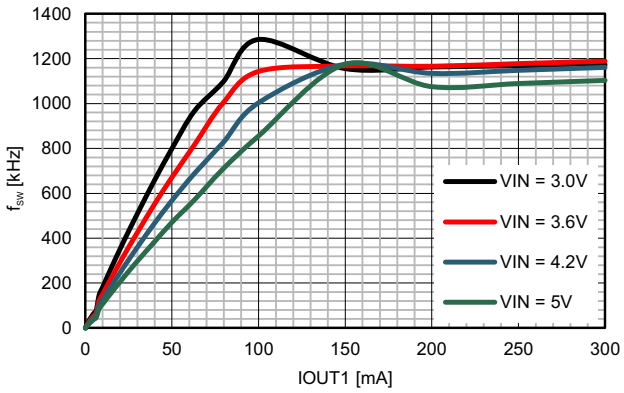



图 15. $F_{SW}$ vs. IOUT1, VOUT1 = 1.1 V

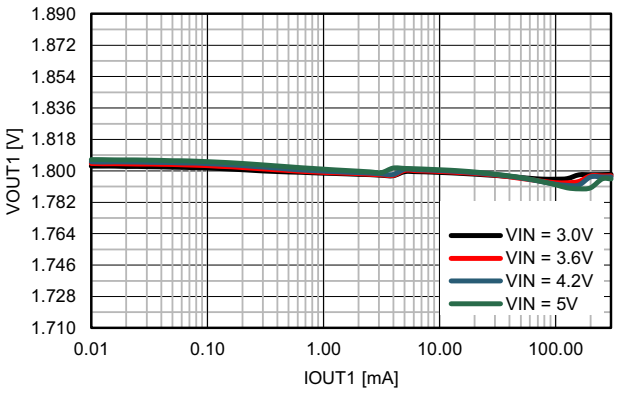
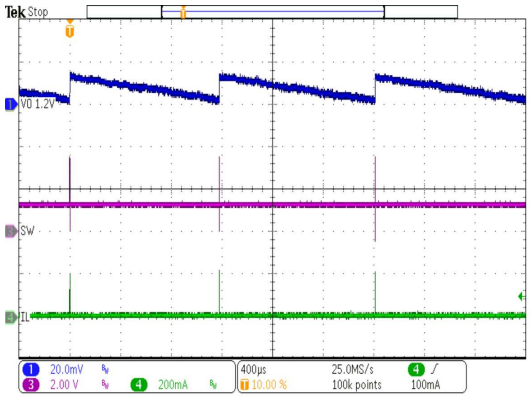


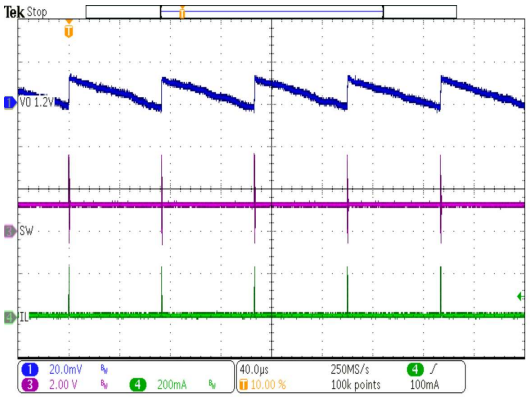

图 16. VOUT1 = 1.8 V vs IOUT1


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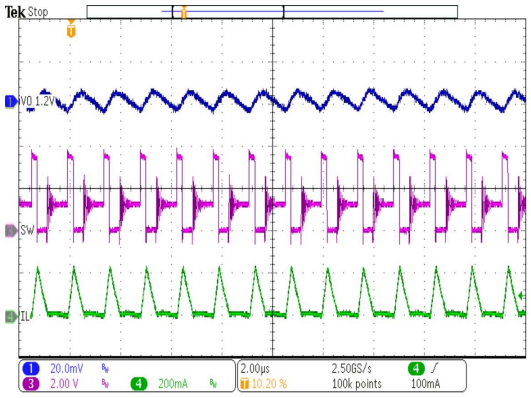

$V_{IN}$ = 3.6V
$V_{OUT}$ = 1.2V
$I_{OUT}$ = 50 µA

**图 17. Typical Operation in Power Save Mode**



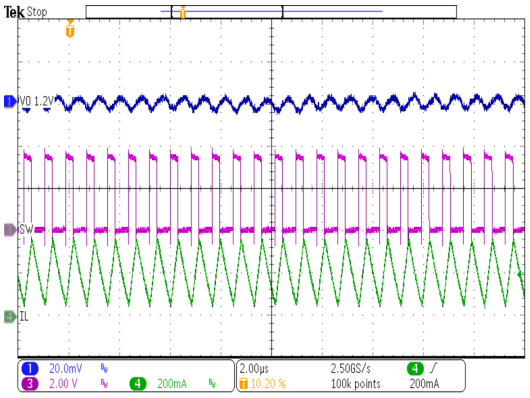

$V_{IN}$ = 3.6V
$V_{OUT}$ = 1.2V
$I_{OUT}$ = 1 mA

**图 18. Typical Operation in Power Save Mode**



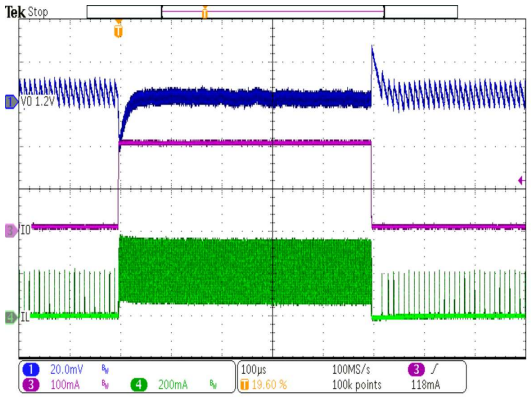

$V_{IN}$ = 3.6V
$V_{OUT}$ = 1.2V
$I_{OUT}$ = 50 mA

**图 19. Typical Operation in Power Save Mode**



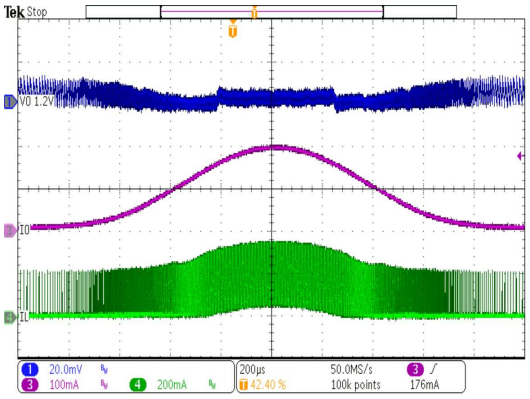

$V_{IN}$ = 3.6V
$V_{OUT}$ = 1.2V
$I_{OUT}$ = 200 mA

**图 20. Typical Operation in PWM Mode**



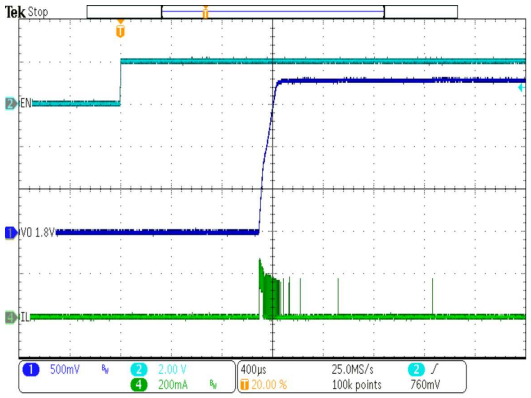

$V_{IN}$ = 3.6V
$V_{OUT}$ = 1.2V
$I_{OUT}$ = 5mA to 200mA
1 µs rise/fall time

**图 21. Load Transient Performance**



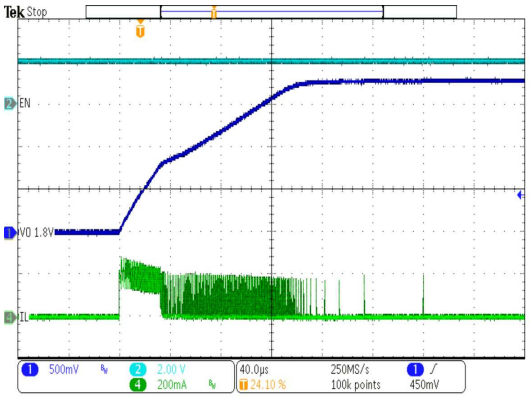

$V_{IN}$ = 3.6V
$V_{OUT}$ = 1.2V
$I_{OUT}$ = 5mA to 200mA
sinusodial $I_{OUT}$ sweep

**图 22. AC Load Regulation Performance**



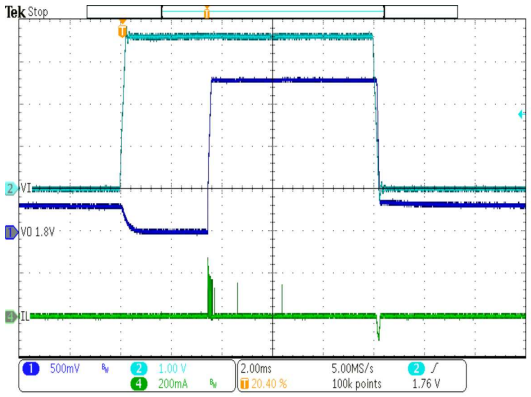

$V_{IN}$ = 3.6V
$V_{OUT}$ = 1.8V
$I_{OUT}$ = 0mA

**图 23. Startup After EN High**



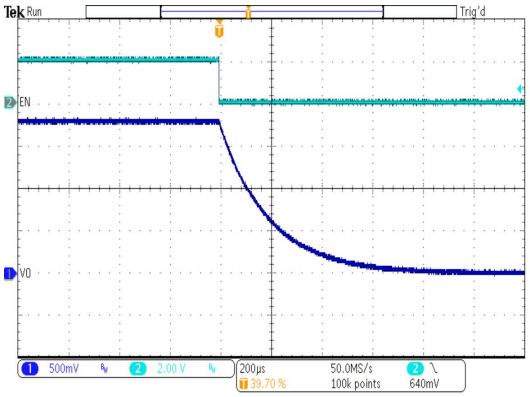

$V_{IN}$ = 3.6V
$V_{OUT}$ = 1.8V
$I_{OUT}$ = 0mA
EN altered from low to high

**图 24. VOUT Ramp Up**



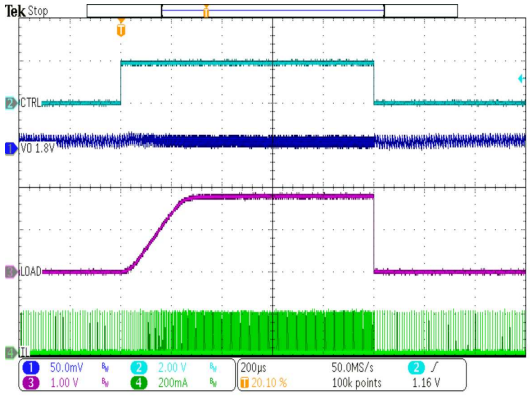

$V_{IN}$ = 0 V to 3.6 V in 100 µs
$V_{OUT}$ = 1.8V
EN = VIN
$I_{OUT}$ = 0 mA

**图 25. VIN Ramp Up/Down**




$V_{IN}$ = 3.6V
$V_{OUT}$ = 1.8V
$I_{OUT}$ = 0mA

**图 26. Output Discharge**




$V_{IN}$ = 3.6V
$V_{OUT}$ = 1.8V
$I_{OUT1}$ = 5mA
$R_{LOAD}$ = 150Ω

**图 27. Output Load Enable/Disable**


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### 8.2.1.3 Application Curves Step-Up Converter Constant 12 V/15 V Output Voltage

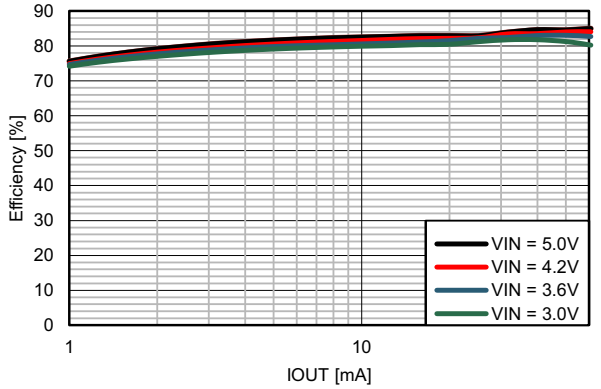



图 28. Efficiency vs. IOUT, VOUT = 15V

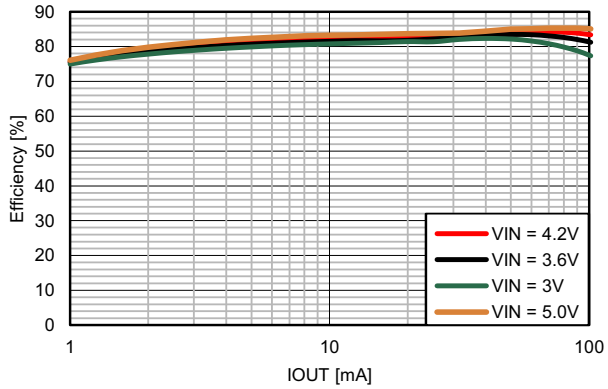



图 29. Efficiency vs. IOUT, VOUT = 12V

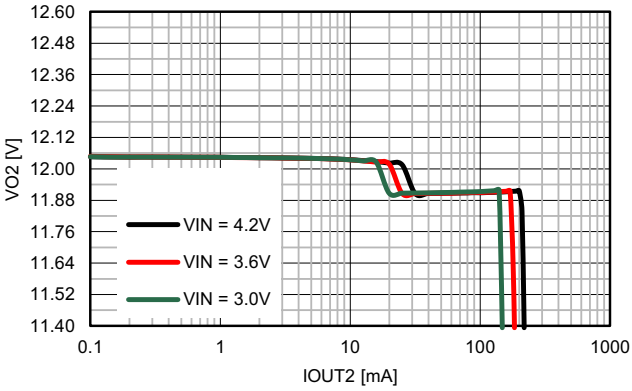
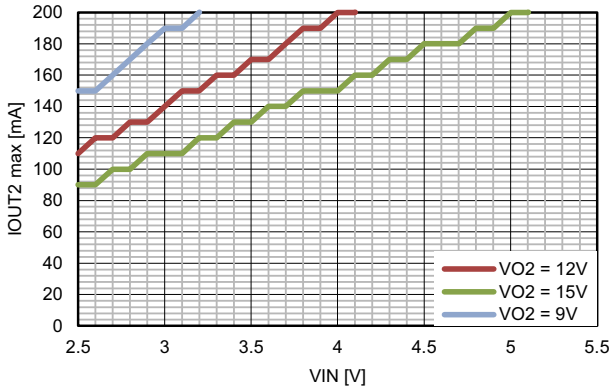


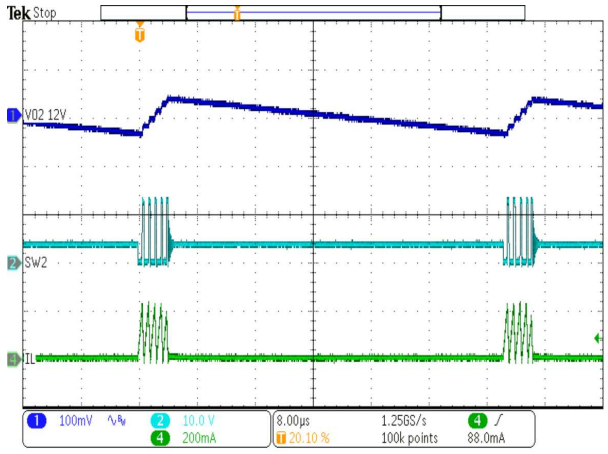

图 30. VOUT2 = 12V vs IOUT2




TA = 25°C
L = 10µH

typical switch current lmit $I_{LIM_SW}$
$I_{OUT2}$ max @ -3% VOUT drop
COUT2 = 2x 10µF

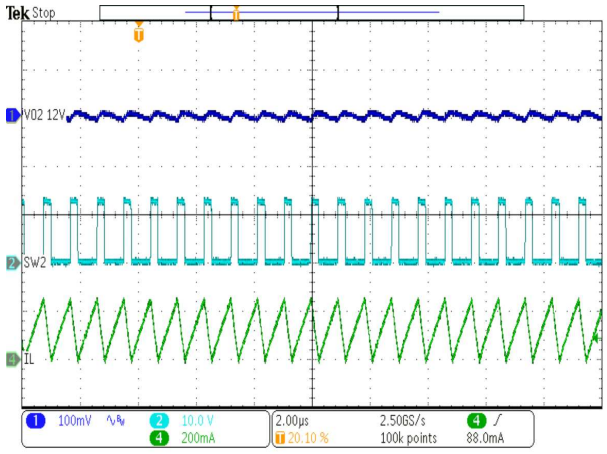
图 31. Maximum Output Current vs VIN for Typical $I_{LIMSW}$




$V_{IN}$ = 3.6V
$V_{OUT}$ = 12V

$I_{OUT2}$ = 2mA
L = 10µH

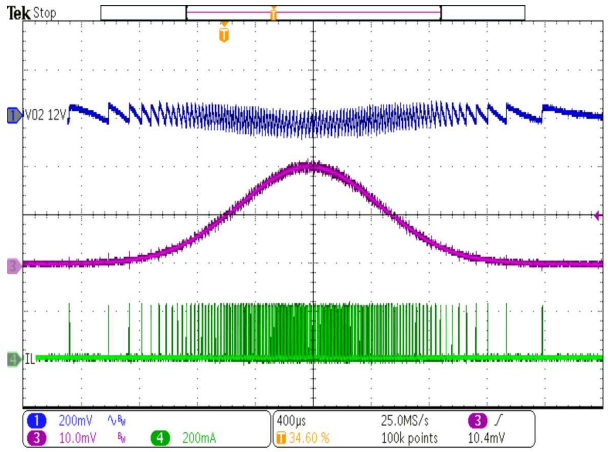
图 32. Typical Operation PFM Mode




$V_{IN}$ = 3.6V
$V_{OUT}$ = 12V

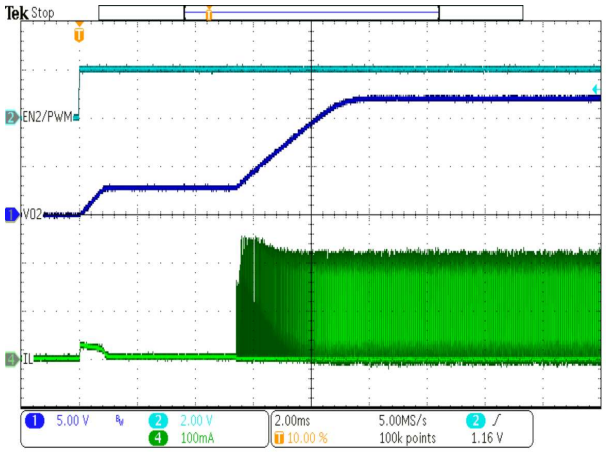
$I_{OUT2}$ = 30mA
L = 10µH

图 33. Typical Operation PWM Mode




$V_{IN}$ = 3.6V
$V_{OUT}$ = 12V
$I_{OUT2}$ = 0 mA to 20 mA
L = 10µH

**图 34. AC Load Regulation Performance**




$V_{IN}$ = 3.6 V
$V_{OUT}$ = 12 V
$R_{LOAD}$ = 1 kΩ
L = 10 µH

**图 35. Startup after EN High**

### 8.2.2 Step-Up Converter with 5-V Output Voltage

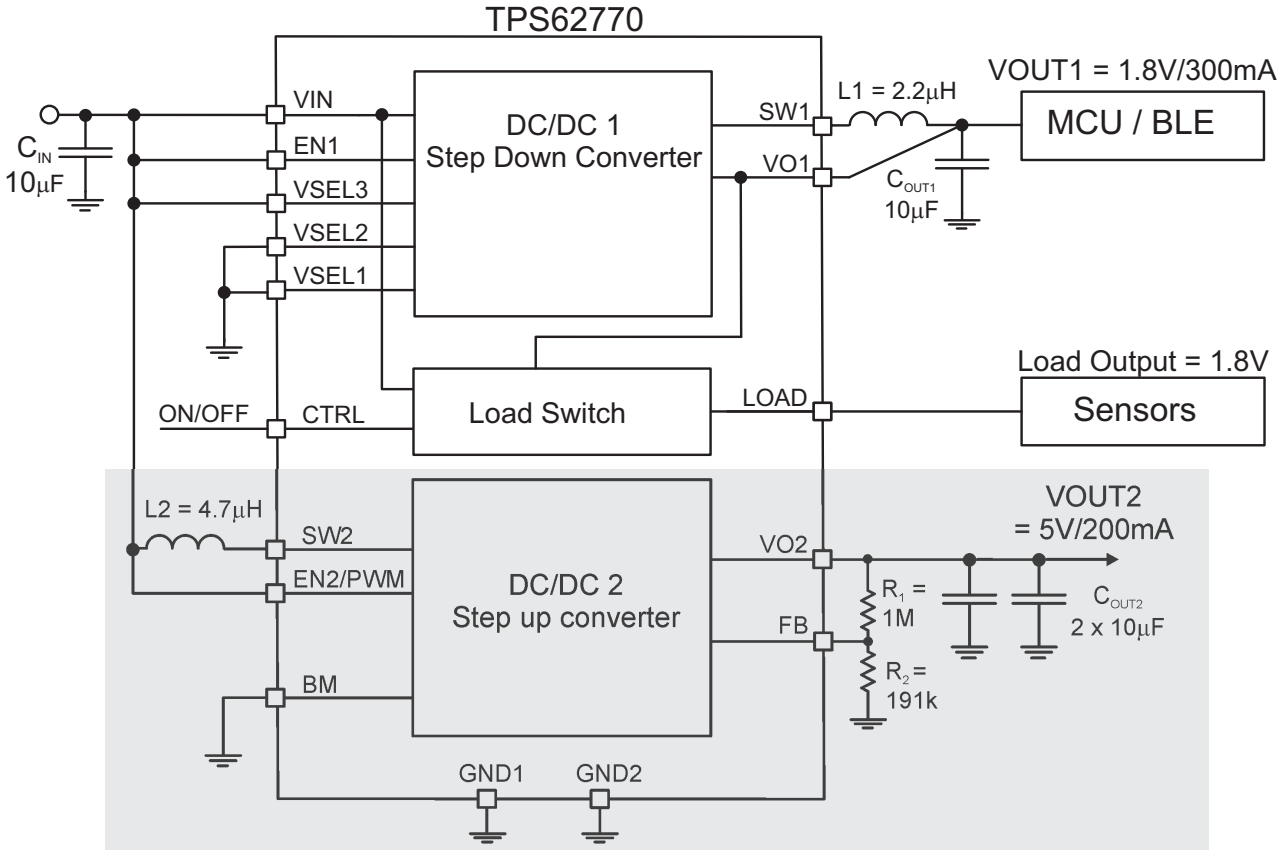



**图 36. Step-Up Converter Providing 5-V $V_{OUT2}$**


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### 8.2.2.1 Design Requirements

**表 3. Components for Application Characteristic Curves**

| REFERENCE | DESCRIPTION | VALUE | PACKAGE CODE / SIZE [mm x mm x mm] | MANUFACTURER |
|---|---|---|---|---|
| CIN | Ceramic capacitor X5R 6.3V, GRM155R60J106ME11 | 10 µF | 0402 / 1.0 x 0.5 x 0.5 | Murata |
| COUT2 (2x) | Ceramic capacitor X5R 25V, GRM188R61E106MA73 | 10 uF | 0603 / 1.6 x 0.8 x 0.8 | Murata |
| L2 | Inductor VLS302515 | 4.7 µH | 3.0 x 2.5 x 1.5 | TDK |

### 8.2.2.2 Application Curves

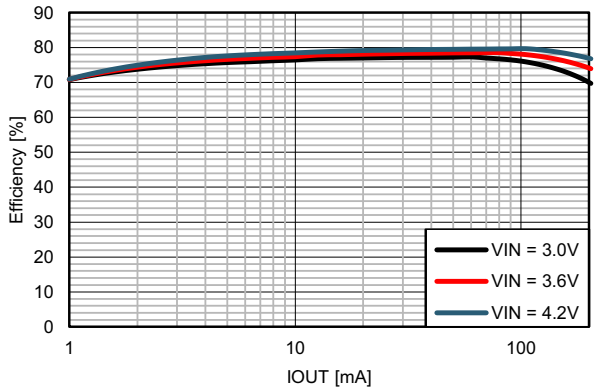



**图 37. Efficiency vs. IOUT, VOUT = 5.0 V**

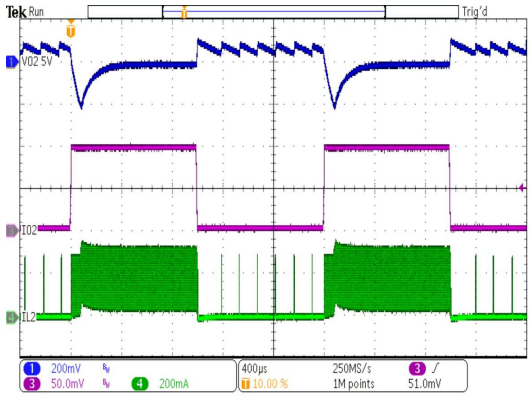



**图 38. Transient Response $V_{OUT2}$ = 5 V**

### 8.2.3 Step-Up Converter Operating with Constant Output Current

The step-up converter device can be configured to operate as a constant current driver e.g. to power 3 to 4 white LED's in a string. The current through the string is set by the sense resistor $R_{Sense}$ as shown in 图 39 To minimize the losses in the sense resistor, the device features a 200mV internal reference. This section describes an application delivering 10mA through an LED string with 4 LED's which is suitable for small display used in wearable applications.

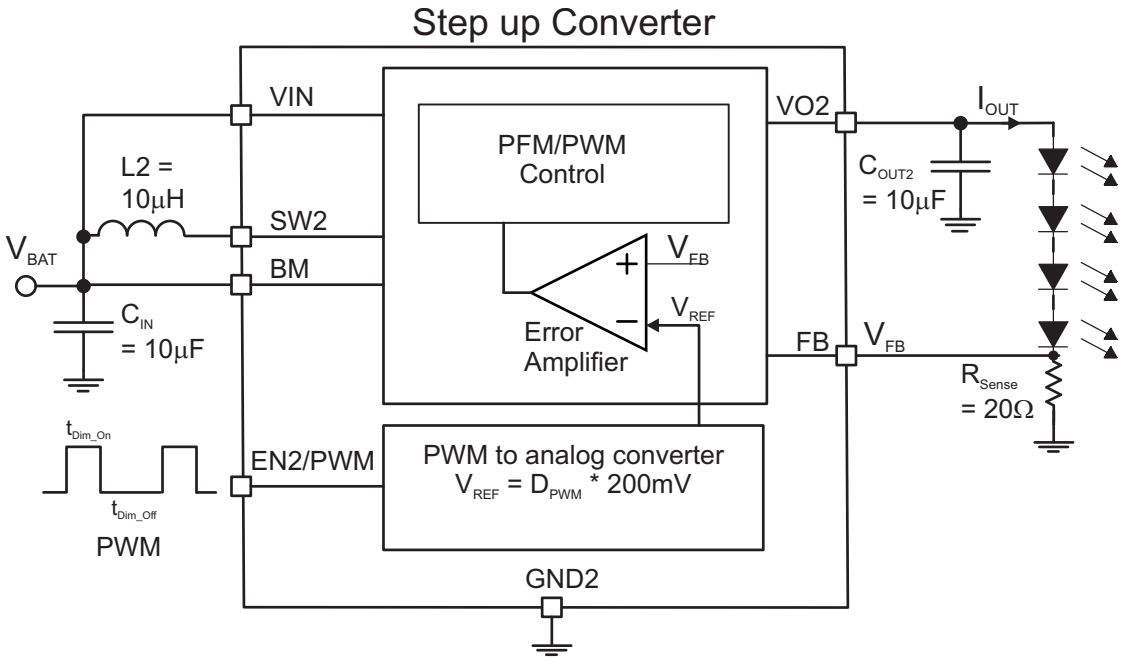



**图 39. Step-Up Converter with Constant Output Current - Simplified Block Diagram**

#### *8.2.3.1 Design Requirements*

The Sense resistor to set the maximum output current can be calculated according to 公式 3 The output current IOUT2 can be reduced by applying a PWM signal at pin EN2/PWM according to 公式 4

$$R_{Sense} = \frac{200\ mV}{I_{OUT2}} \quad (3)$$

$$I_{OUT2} = D_{PWM} \times \frac{200mV}{R_{Sense}} \quad (4)$$

Where:

$R_{Sense}$ = sense resistor in [Ω]

$I_{OUT2}$ = output current in [mA]

$D_{PWM}$ = Dutycycle of the PWM singal at pin EN2/PWM

**表 4. Components for Application Characteristic Curves**

| REFERENCE | DESCRIPTION | VALUE | PACKAGE CODE / SIZE [mm x mm x mm] | MANUFACTURER |
|---|---|---|---|---|
| CIN | Ceramic capacitor X5R 6.3V, GRM155R60J106ME11 | 10 µF | 0402 / 1.0 x 0.5 x 0.5 | Murata |
| COUT2 | Ceramic capacitor X5R 25V, GRM188R61E106MA73 | 10 uF | 0603 / 1.6 x 0.8 x 0.8 | Murata |
| L2 | Inductor VLS302515 | 10 µH | 3.0 x 2.5 x 1.5 | TDK |
| D1-D4 | LED LTW-E670DS | n/a | | Lite ON |


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### 8.2.3.2 Detailed Design Procedure

#### 8.2.3.2.1 Setting The Output Voltage Of The Step-Down Converter

The output voltage is set with the VSEL1-3 pins according to Table 1. No further external components are required.

#### 8.2.3.2.2 Programming the Output Voltage Of The Step-Up Converter

There are two ways to set the output voltage of the step-up converter. When the FB pin is connected to the input voltage, the output voltage is fixed to 12 V. This function reduces the external components to minimize the solution size. The second way is to use an external resistor divider to set the desired output voltage.

By selecting the external resistor divider R1 and R2, as shown in 公式 5, the output voltage is programmed to the desired value. When the output voltage is regulated, the typical voltage at the FB pin is $V_{REF}$ of 795 mV.

$$R1 = \left( \frac{V_{OUT}}{V_{REF}} - 1 \right) \times R2 \tag{5}$$

Where:

$V_{OUT}$ is the desired output voltage

$V_{REF}$ is the internal reference voltage at the FB pin

#### 8.2.3.2.3 Recommended LC Output Filter

**表 5. Recommended LC Output Filter Combinations for the Step-Down Converter**

| INDUCTOR VALUE [µH](1) | OUTPUT CAPACITOR VALUE [µF](2) | |
|---|---|---|
| | 10 µF | 22 µF |
| 2.2 | √(3) | √ |

(1) Inductor tolerance and current de-rating is anticipated. The effective inductance can vary by 20% and -30%.
(2) Capacitance tolerance and bias voltage de-rating is anticipated. The effective capacitance can vary by 20% and -50%.
(3) This LC combination is the standard value and recommended for most applications.

**表 6. Recommended LC Output Filter Combinations for Step-Up Converter**

| INDUCTOR VALUE [µH](1) | VOUT | IOUT | OUTPUT CAPACITOR VALUE [µF](2) | |
|---|---|---|---|---|
| | | | 10 µF | 2 x 10µF |
| 10 | 9 V –15 V | (IOUT ≤ 30 mA) | √(3) | √ |
| | | (IOUT ≤ 100 mA) | | √(3) |
| 4.7 | 5 V | (IOUT ≤ 200 mA) | | √(3) |

(1) Inductor tolerance and current de-rating is anticipated. The effective inductance can vary by 20% and -30%.
(2) Capacitance tolerance and bias voltage de-rating is anticipated. The effective capacitance can vary by 20% and -50%.
(3) This LC combination is the standard value and recommended for most applications.

#### 8.2.3.2.4 Inductor Selection Step-Down Converter

The inductor value affects its peak-to-peak ripple current, the PWM-to-PFM transition point, the output voltage ripple and the efficiency. The selected inductor has to be rated for its DC resistance and saturation current. The inductor ripple current ($\Delta I_L$) decreases with higher inductance and increases with higher $V_{IN}$ or $V_{OUT}$ and can be estimated according to 公式 6.

公式 7 calculates the maximum inductor current under static load conditions. The saturation current of the inductor should be rated higher than the maximum inductor current, as calculated with 公式 7. This is recommended because during a heavy load transient the inductor current rises above the calculated value. A more conservative way is to select the inductor saturation current above the high-side MOSFET switch current limit, $I_{LIMF}$.

$$\Delta I_L = Vout \times \frac{1 - \frac{Vout}{Vin}}{L \times f} \quad (6)$$

$$I_{Lmax} = I_{outmax} + \frac{\Delta I_L}{2} \quad (7)$$

With:

f = Switching Frequency
L = Inductor Value
$\Delta I_L$= Peak to Peak inductor ripple current
$I_{Lmax}$ = Maximum Inductor current

In DC/DC converter applications, the efficiency is essentially affected by the inductor AC resistance (i.e. quality factor) and by the inductor DCR value. Increasing the inductor value produces lower RMS currents, but degrades transient response. For a given physical inductor size, increased inductance usually results in an inductor with lower saturation current.

The total losses of the coil consist of both the losses in the DC resistance ($R_{DC}$) and the following frequency-dependent components:

- The losses in the core material (magnetic hysteresis loss, especially at high switching frequencies)
- Additional losses in the conductor from the skin effect (current displacement at high frequencies)
- Magnetic field losses of the neighboring windings (proximity effect)
- Radiation losses

#### 8.2.3.2.5 Inductor Selection Step-Up Converter

The step-up converter is optimized to work with an inductor values of 10 µH. Follow 公式 8 to 公式 10 to calculate the inductor's peak current for the application. To calculate the current in the worst case, use the minimum input voltage, maximum output voltage, and maximum load current of the application. To have enough design margin, choose the inductor value with -30% tolerance, and a low power-conversion efficiency for the calculation.

In a step-up regulator, the inductor dc current can be calculated with 公式 8.

$$I_{L(DC)} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times \eta} \quad (8)$$

Where:

$V_{OUT}$ = output voltage
$I_{OUT}$ = output current
$V_{IN}$ = input voltage
η = power conversion efficiency, use 80% for most applications

The inductor ripple current is calculated with the 公式 9 for an asynchronous step-up converter in continuous conduction mode (CCM).

$$\Delta I_{L(P-P)} = \frac{V_{IN} \times (V_{OUT} + 0.8V - V_{IN})}{L \times f_{SW} \times (V_{OUT} + 0.8V)} \quad (9)$$

Where:

$\Delta I_{L(P-P)}$ = inductor ripple current
L = inductor value
$f_{SW}$ = switching frequency
$V_{OUT}$ = output voltage
$V_{IN}$ = input voltage

Therefore, the inductor peak current is calculated with 公式 10.


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$$I_{L(P)} = I_{L(DC)} + \frac{\Delta I_{L(P-P)}}{2} \quad (10)$$

The following inductor series from different suppliers have been used:

**表 7. List Of Inductors**

| CONVERTER | INDUCTANCE [µH] | DIMENSIONS [mm³] | INDUCTOR TYPE | SUPPLIER(1) |
|---|---|---|---|---|
| Step-down | 2.2 | 2.9 x 1.6 x 1.0 | DFE201610C | TOKO |
| | 2.2 | 2.0 × 1.25 × 1.0 | MIPSZ2012D 2R2 | FDK |
| | 2.2 | 2.0 x 1.2 x 1.0 | MDT2012CH2R 2 | TOKO |
| Step-up | 10 | 2.0x1.6x1.2 | VLS201610 | TDK |
| | 10 | 3.0 x 2.5 x 1.5 | VLS302515 | TDK |
| | 4.7 | 3.0 x 2.5 x 1.5 | VLS302515 | TDK |
| | 4.7 | 2.0 x 1.6 x 1.5 | VLS201612 | TDK |

(1) See *Third-party Products Disclaimer*

#### 8.2.3.2.6 DC/DC Input and Output Capacitor Selection

Ceramic capacitors with low ESR values have the lowest output voltage ripple and are recommended. The output capacitor requires either an X7R or X5R dielectric. Y5V and Z5U dielectric capacitors, aside from their wide variation in capacitance over temperature, become resistive at high frequencies. At light load currents, the converter operates in Power Save Mode and the output voltage ripple is dependent on the output capacitor value and the PFM peak inductor current. A 10 µF ceramic capacitor is recommended as input capacitor.

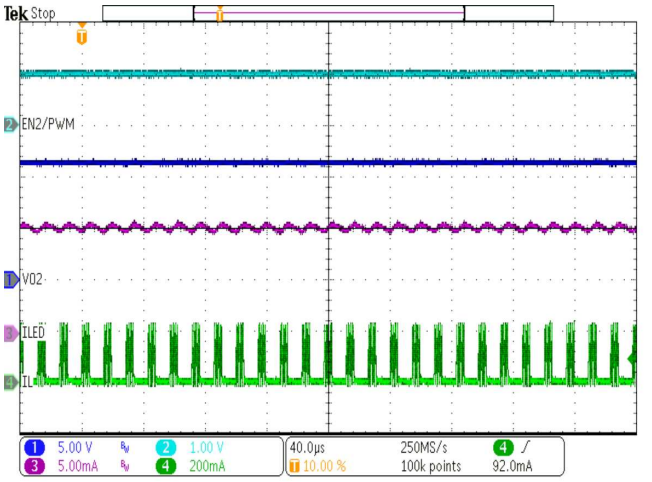
表 8 shows a list of tested input/output capacitors.

**表 8. List Of Capacitors**

| REFERENCE | DESCRIPTION | VALUE | PACKAGE CODE / SIZE [mm x mm x mm] | MANUFACTURER(1) |
|---|---|---|---|---|
| CIN | Ceramic capacitor X5R 6.3V, GRM155R60J106ME11 | 10µF | 0402 / 1.0 x 0.5 x 0.5 | Murata |
| COUT1 | Ceramic capacitor X5R 6.3V, GRM155R60J106ME11 | 10µF | 0402 / 1.0 x 0.5 x 0.5 | Murata |
| COUT2 | Ceramic capacitor X5R 25V, GRM188R61E106MA73 | 10uF | 0603 / 1.6 x 0.8 x 0.8 | Murata |
| | Ceramic capacitor X5R 6.3V, GRM188R60J106ME84 | 10uF | 0603 / 1.6 x 0.8 x 0.8 | Murata |

(1) See *Third-party Products Disclaimer*

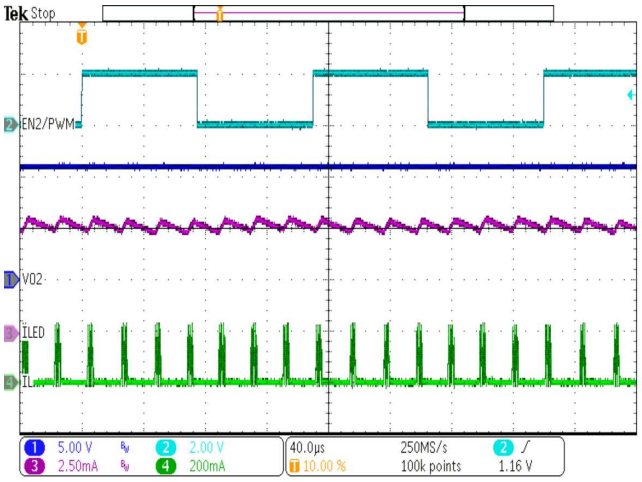
### 8.2.3.3 Application Curves




$V_{IN}$ = 3.6V
EN2/PWM = high
D = 100%, $I_{LED}$ = 10mA

$R_{Sense}$= 20Ω
4 LEDs in series
L = 10µH

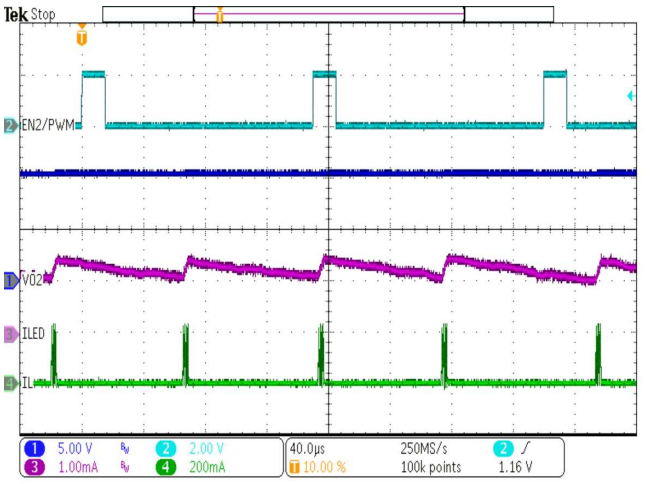
**图 40. Constant Current Operation with EN2/PWM = 100% D**




$V_{IN}$ = 3.6V
$t_{Dim_On}$ = 75 µs, $t_{Dim_Off}$ = 75µs
D = 50%, $T_{Dlim}$ = 140µs, $I_{LED}$ = 5mA

$R_{Sense}$= 20Ω
4 LED's in series
L = 10µH

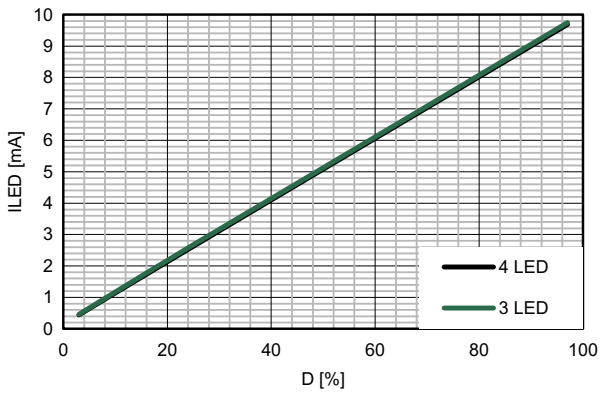
**图 41. Constant Current with EN2/PWM = 50% D**




$V_{IN}$ = 3.6V
$t_{Dim_On}$ = 15 µs, $t_{Dim_Off}$ = 135 µs
D = 10%, $T_{Dlim}$ = 140 µs, $I_{LED}$ = 1 mA

$R_{Sense}$= 20 Ω
4 LED's in series
L = 10 µH

**图 42. Constant Current with EN2/PWM = 10% D**




$V_{IN}$ = 3.6V
$T_A$ = 25°C
$T_{Dlim}$ = 50 µs (F = 20kHz)

$R_{Sense}$= 20 Ω
LED's in string configuration
L = 10 µH

**图 43. Constant Current vs D**


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# 9 Power Supply Recommendations

The power supply must provide a current rating according to the supply voltage, output voltage and output current of the TPS62770.

# 10 Layout

## 10.1 Layout Guidelines

- As for all switching power supplies, the layout is an important step in the design. Care must be taken in board layout to get the specified performance.
- If the layout is not carefully done, the regulator could show poor line and/or load regulation, stability issues as well as EMI problems and interference with RF circuits.
- It is critical to provide a low inductance, impedance ground path. Therefore, use wide and short traces for the main current paths.
- The input capacitor should be placed as close as possible to the IC pins VIN and GND. The output capacitors should be placed close between VO1/2 and GND pins.
- The VO1/2 line should be connected to the output capacitor and routed away from noisy components and traces (e.g. SW line) or other noise sources.
- See 图 44 and 图 45 for the recommended PCB layout.

## 10.2 Layout Example

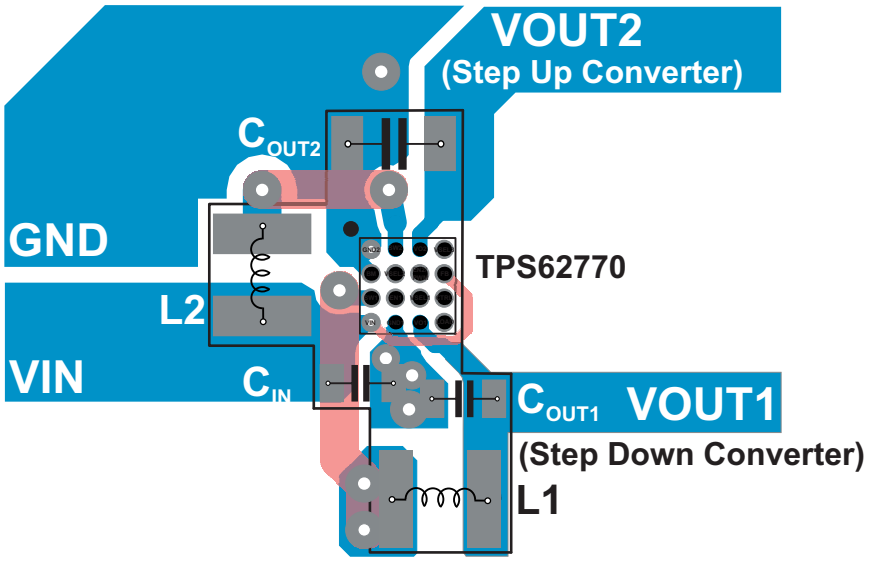



**图 44. Recommended PCB Layout with 12 V Fixed VOUT2**

## Layout Example (接下页)

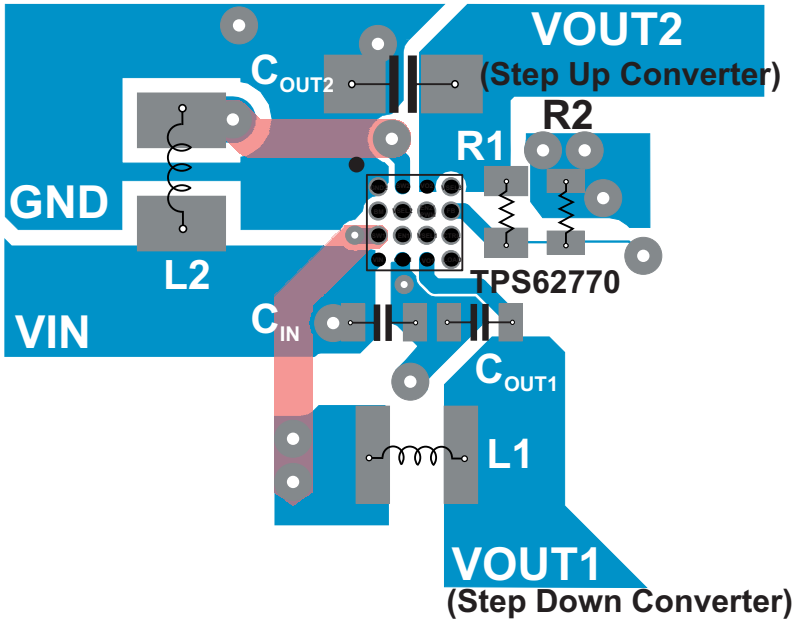



图 45. Recommended PCB Layout with Adjustable VOUT2


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# 11 器件和文档支持

## 11.1 器件支持

### 11.1.1 开发支持

#### *11.1.1.1 Third-Party Products Disclaimer*

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## 11.2 文档支持

### 11.2.1 相关文档

另请参见《*TPS62770EVM-734 评估模块用户指南*》（文献编号：SLVUAO2）和应用笔记《*精确测量超低 IQ 器件的效率*》（文献编号：SLYT558）。

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## 11.5 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

# 12 机械、封装和可订购信息

以下页中包括机械、封装和可订购信息。这些信息是针对指定器件可提供的最新数据。这些数据会在无通知且不对本文档进行修订的情况下发生改变。欲获得该数据表的浏览器版本，请查阅左侧的导航栏。

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## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TPS62770YFPR | ACTIVE | DSBGA | YFP | 16 | 3000 | RoHS & Green | SNAGCU | Level-1-260C-UNLIM | -40 to 85 | 62770 | Samples |
| TPS62770YFPT | ACTIVE | DSBGA | YFP | 16 | 250 | RoHS & Green | SNAGCU | Level-1-260C-UNLIM | -40 to 85 | 62770 | Samples |

(1) The marketing status values are defined as follows:
**ACTIVE:** Product device recommended for new designs.
**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.
**OBSOLETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

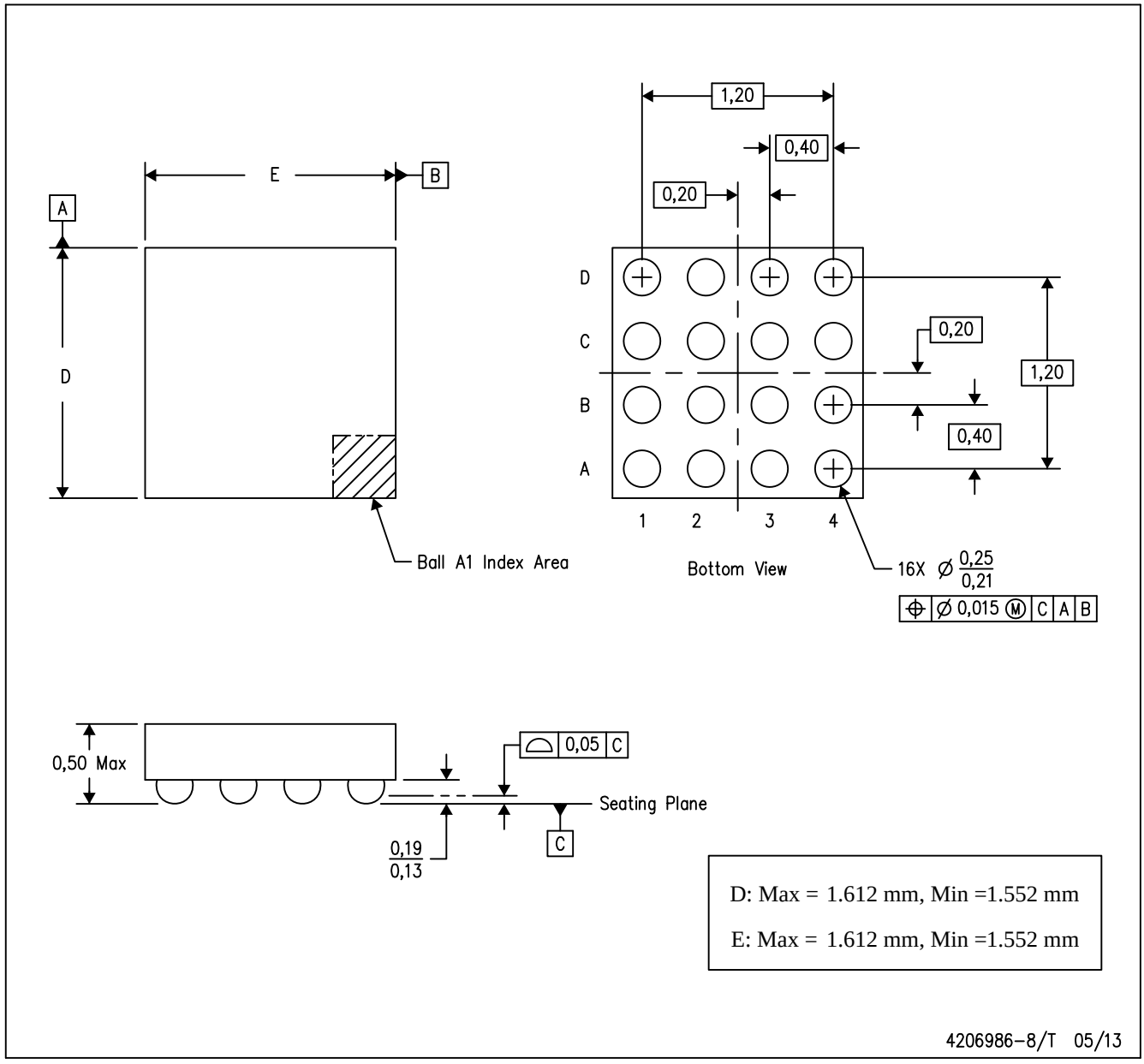
(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices 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.

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YFP (S–XBGA–N16) DIE–SIZE BALL GRID ARRAY




NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. NanoFree™ package configuration.

NanoFree is a trademark of Texas Instruments

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