# APW7584

3MHz 1A, Synchronous Step-Down IR-LED Driver

## Features

- **Input Voltage Range: 4.2V to 5.5V**
- **Low Switching Quiescent Current**
- **1A Output Current**
- **0.1V Reference Voltage**
- **Constant On Time Mode Operation**
- **3MHz Switching Frequency**
- **Power-On-Reset Detection on VIN**
- **Integrated Soft Start Time**
- **Over-Temperature Protection**
- **Over-Current Protection**
- **TDFN1.6x1.6 Package**

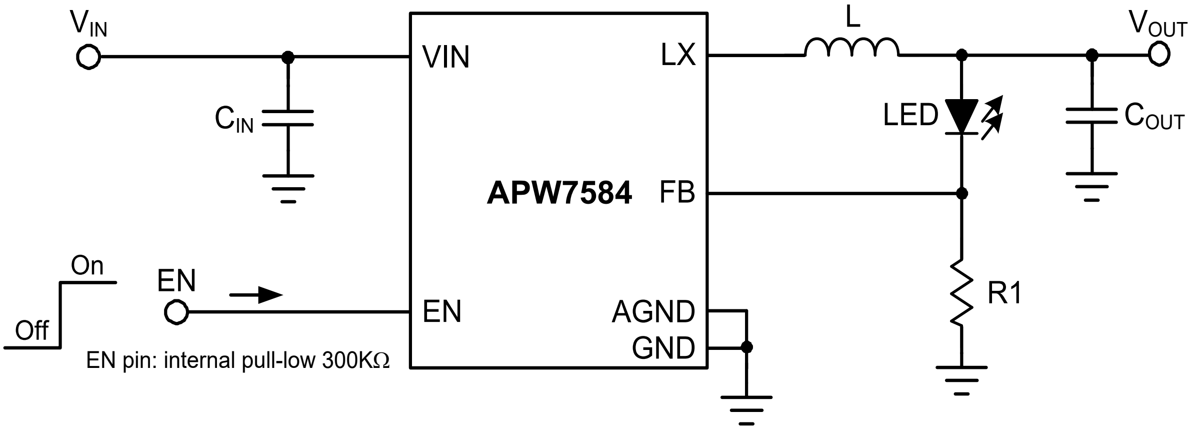
## General Description

The APW7584 is a synchronous step-down IR-LED driver adopting constant on time control mode. Due to increasing the oscillation to high frequency, the mounting area including peripheral components can be reduced. APW7584 also has low switching quiescent current to improve efficiency and battery-powered equipment using time.
The APW7584 is equipped with Power-on-reset, internal soft start and over-current protection, over temperature into a single low cost TDFN package.

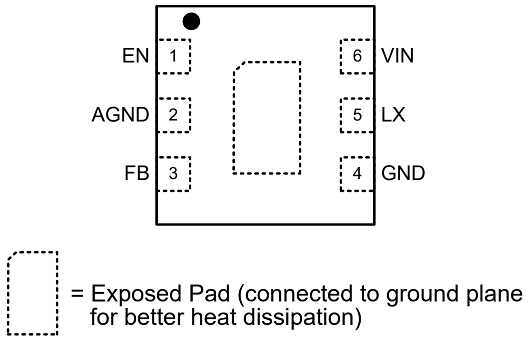
## Applications

- **NB-Cam Module**

## Simplified Application Circuit

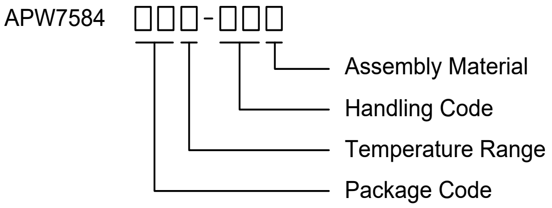


## Pin Configuration (Top View)



**TDFN1.6x1.6-6**

## Ordering and Marking Information



Package Code
QB : TDFN1.6x1.6-6
Operating Ambient Temperature Range
I : -40 to 85°C
Handling Code
TR : Tape & Reel
Assembly Material
G : Green Part

APW7584QBI :

X - Date Code

Note: ANPEC's green product compliant RoHS and Halogen free.

## Absolute Maximum Ratings (Note 1)

| Symbol | Parameter | Rating | Unit |
|---|---|---|---|
| $V_{IN}$ | VIN Supply Voltage to GND | -0.3 ~ 6 | V |
| $V_{LX}$ | LX Voltage to GND (< 20ns Pulse Width) | -3 ~ 7 | V |
|  | LX Voltage to GND (> 20ns Pulse Width) | -0.3 ~ 6 | V |
| $V_{EN}$ | EN Voltage to GND | -0.3 ~ 6 | V |
| $V_{FB}$ | FB Voltage to GND | -0.3 ~ 6 | V |
| $T_J$ | Junction Temperature | 150 | °C |
| $T_{STG}$ | Storage Temperature | -65 ~ 150 | °C |
| $T_{SDR}$ | Maximum Lead Soldering Temperature (10 Seconds) | 260 | °C |

Note 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 rating conditions for extended periods may affect device reliability.

## Thermal Characteristics

| Symbol | Parameter | Typical Value | Unit |
|---|---|---|---|
| $\theta_{JA}$ | Junction-to-Ambient Resistance (Note 2) | 160 | °C/W |

Note 2: $\theta_{JA}$ is measured with the component mounted on a high effective thermal conductivity test board in free air.

## Recommended Operating Conditions (Note 3)

| Symbol | Parameter | Range | Unit |
|---|---|---|---|
| $V_{IN}$ | VIN Supply Voltage to GND | 4.2 ~ 5.5 | V |
| $V_{EN}$ | EN Voltage to GND | -0.3 ~ 5.5 | V |
| $I_{OUT}$ | Output Current (continue) | 0 ~ 1 | A |
| $T_A$ | Ambient Temperature | -40 ~ 85 | °C |
| $T_J$ | Junction Temperature | -40 ~ 125 | °C |

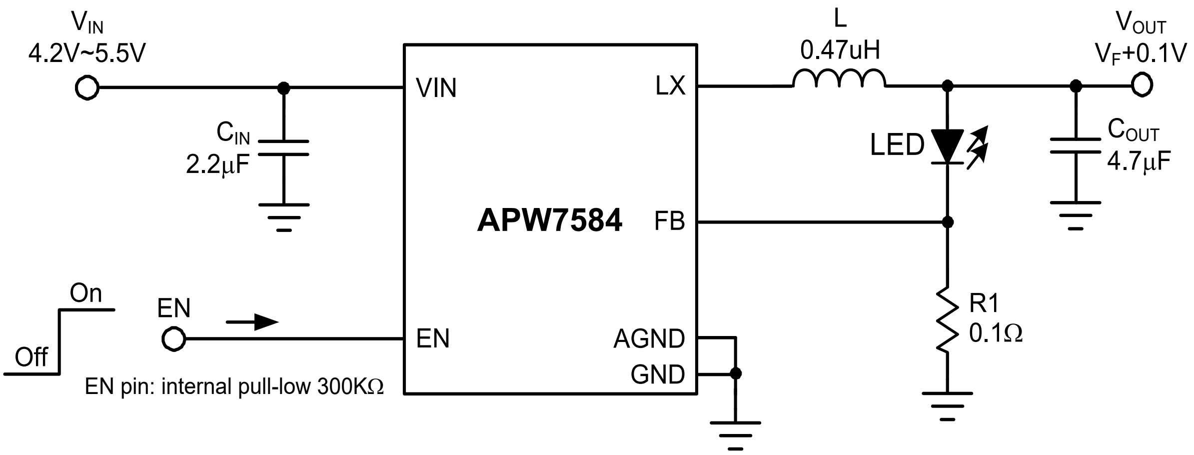
Note 3: Refer to the typical application circuit.

## Electrical Characteristics

Unless otherwise specified, these specifications apply over $V_{IN}$=5V, $T_A$=25°C.

| Symbol | Parameter | Test Conditions | APW7584 | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min. | Typ. | Max. | |
| **SUPPLY POWER** | | | | | | |
| $I_Q$ | Quiescent Current Into VIN | $V_{IN}$=5V, No Load, Switching Current | - | 30 | - | μA |
| $I_{SD}$ | Shutdown Current Into VIN | $V_{EN}$=0V | - | 0.7 | 1 | μA |
| $V_{UVLO}$ | UVLO Rising Threshold Voltage | $V_{IN}$ Rising | 2.3 | 2.4 | 2.8 | V |
| $V_{UVLO\_HYS}$ | UVLO Hysteresis | $V_{IN}$ Falling | - | 200 | - | mV |
| **EN THRESHOLD** | | | | | | |
| $V_{ENH}$ | Logic-High Threshold Voltage | EN Rising | 1.5 | - | - | V |
| $V_{ENL}$ | Logic-Low Threshold Voltage | EN Falling | - | - | 0.4 | V |
| $t_{D(ON)}$ | EN Turn On Delay Time | Time From $V_{ENH}$ to LX Switching | - | 150 | - | us |
| $R_{EN}$ | Enable Pull Low Resistor | $V_{IN}$=5V, $V_{EN}$=5V | - | 300 | - | KΩ |
| **REGULATOR** | | | | | | |
| $I_{FB}$ | FB Input Leakage Current | $V_{IN}$=5.5V, $V_{FB}$=5.5V | - | - | 1 | uA |
| $V_{FB}$ | Feedback Voltage | | - | 0.1 | - | V |
| | Accuracy | $T_A$= -40 ~ 85°C | -7 | - | 7 | % |
| $t_{SS}$ | Soft Start Time | 10% to 90% of 1A ILED | - | 200 | - | us |
| **OSCILLATOR** | | | | | | |
| $F_{SW}$ | Switching Frequency | PWM Mode | - | 3 | - | MHz |
| **POWER MOSFET** | | | | | | |
| $R_{ON\_H}$ | High Side MOSFET Resistance | $V_{IN}$=5V, $I_{LX}$=0.5A | - | 350 | - | mΩ |
| $R_{ON\_L}$ | Low Side MOSFET Resistance | $V_{IN}$=5V, $I_{LX}$=0.5A | - | 110 | - | mΩ |
| $I_{LEAK\_H}$ | High Side MOSFET Leakage Current | $V_{IN}$=5.5V, LX=GND | - | 1 | - | μA |
| $I_{LEAK\_L}$ | Low Side MOSFET Leakage Current | $V_{IN}$=LX=5.5V, No Switching | - | 1 | - | μA |
| **PROTECTIONS** | | | | | | |
| $I_{CL\_H}$ | High-Side Current Limit | | 1500 | - | - | mA |
| OTP | Over Temperature Protection | | - | 150 | - | °C |
| | Over Temperature Hysteresis | | - | 30 | - | °C |

## Typical Application Circuit

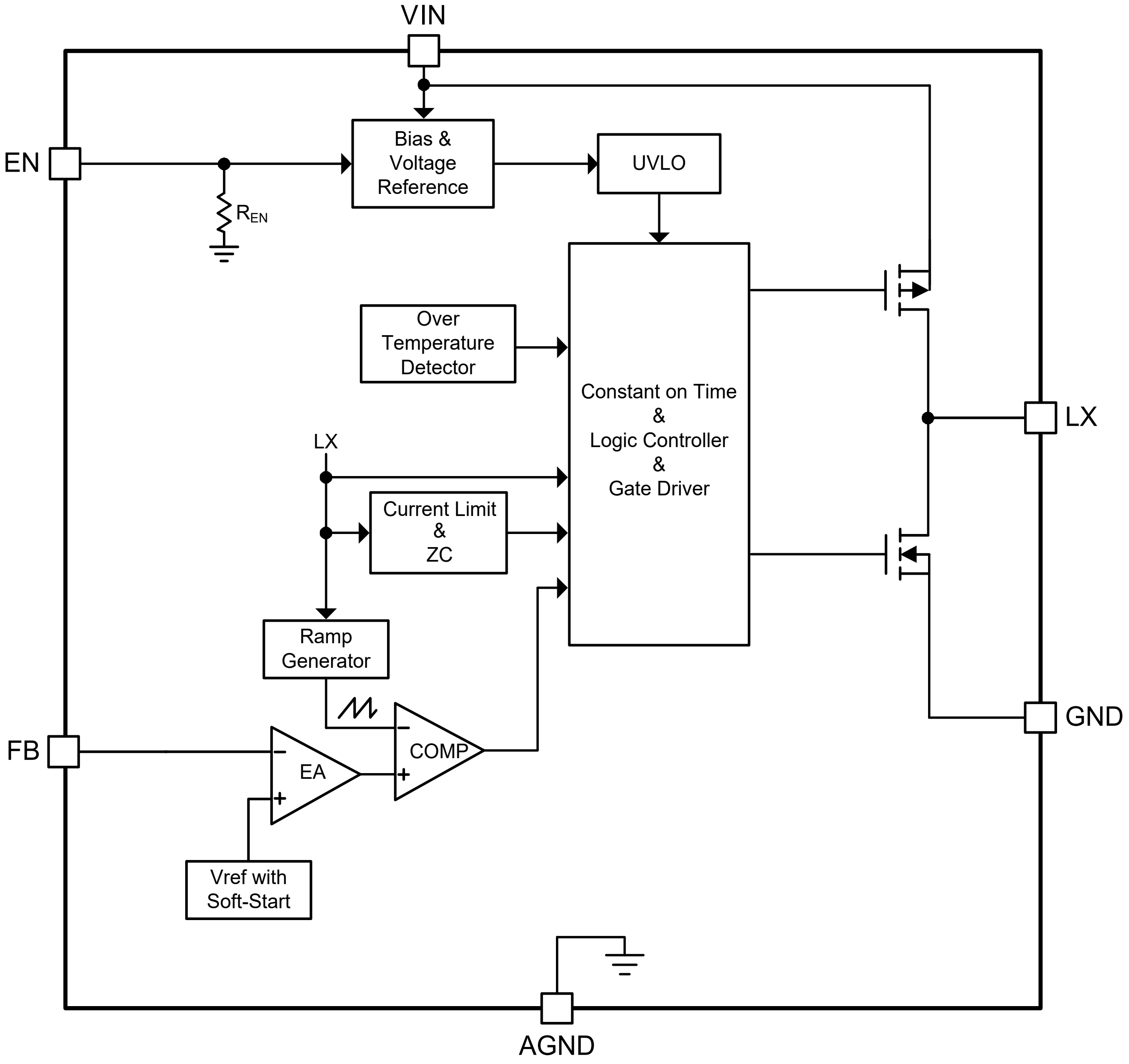


| Designator | Value | Case Size | Part Number |
|---|---|---|---|
| $C_{IN}$ | 2.2uF/6.3V/X5R | 0201 | GRM033R60J225ME15D |
| $C_{OUT}$ | 4.7uF/6.3V/X5R | 0201 | GRM033R60J475ME05D |
| L | 0.47uH | 0402 | MCEE1005TR47MHN |

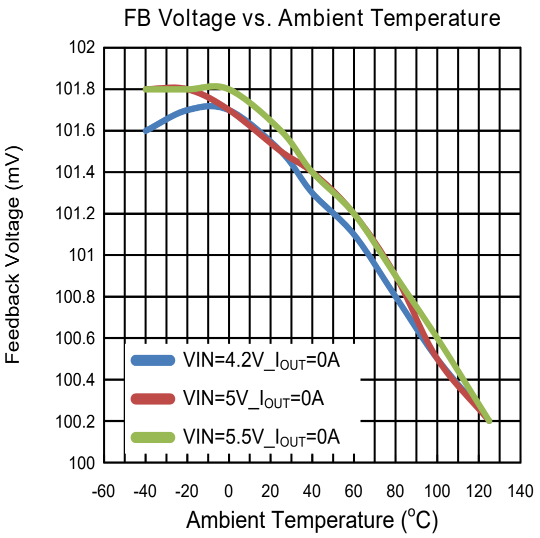
## Pin Description

| PIN | | FUNCTION |
|---|---|---|
| **NO.** | **NAME** | |
| 1 | EN | Enable Input Pin.<br>Drive EN high to turn the converter on and pull it low to turn it off. |
| 2 | AGND | Analog Ground Pin.<br>Signal Ground for the Control Circuitry. |
| 3 | FB | Output Voltage sense pin.<br>This pin is used to detect the output voltage. |
| 4 | GND | Ground Pin.<br>The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation. |
| 5 | LX | Switching Output Pin.<br>Connect this pin to the output inductor. |
| 6 | VIN | Power Input Pin.<br>VIN supplies the power to the buck converter and the internal control circuitry. |

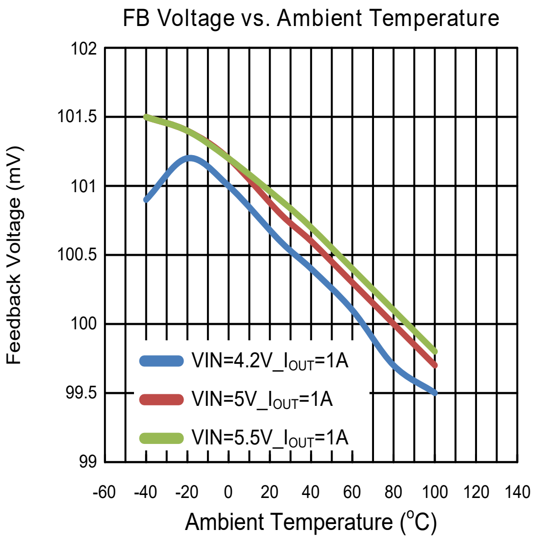
## Block Diagram



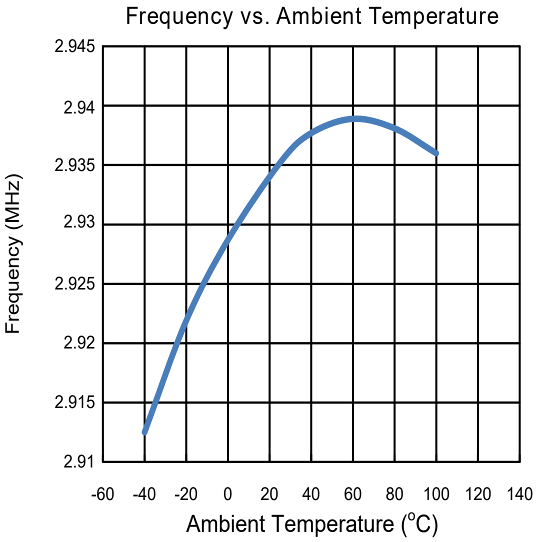
## Typical Operating Characteristics



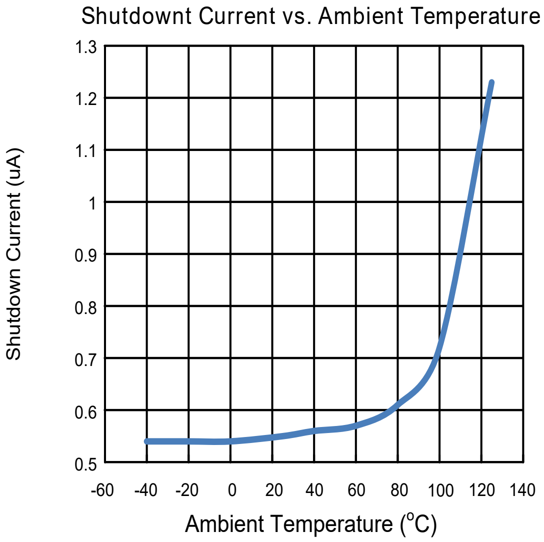
FB Voltage vs. Ambient Temperature



FB Voltage vs. Ambient Temperature



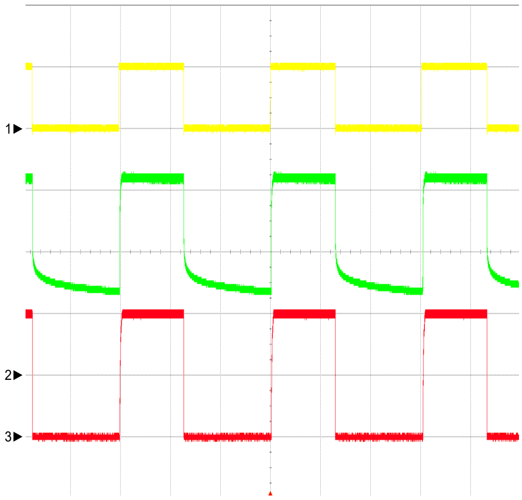
Frequency vs. Ambient Temperature



Shutdownt Current vs. Ambient Temperature

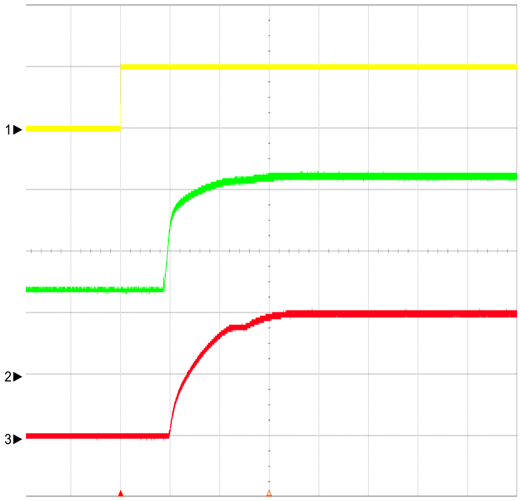
## Operating Waveforms

30Hz Dimming Via EN Pin



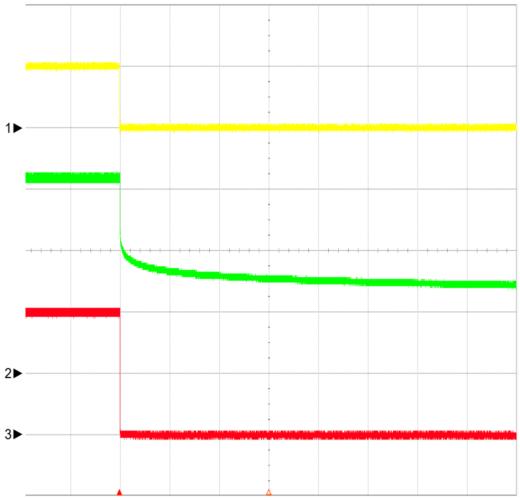
CH1: $V_{EN}$, 2V/Div, DC
CH2: $V_{OUT}$, 1V/Div, DC
CH3: $I_{LED}$, 500mA/Div, DC
TIME: 10ms/Div

EN Turn On



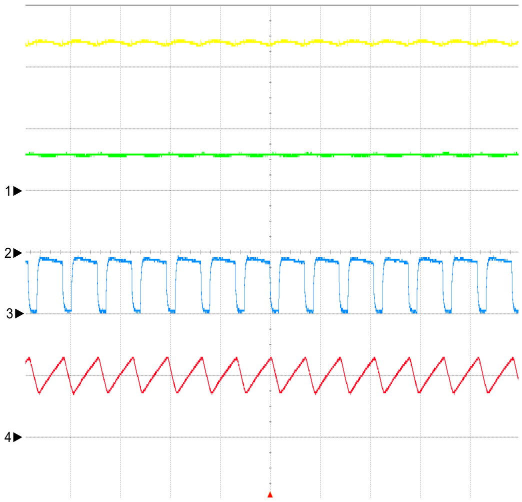
CH1: $V_{EN}$, 2V/Div, DC
CH2: $V_{OUT}$, 1V/Div, DC
CH3: $I_{LED}$, 500mA/Div, DC
TIME: 200us/Div

EN Turn Off



CH1: $V_{EN}$, 2V/Div, DC
CH2: $V_{OUT}$, 1V/Div, DC
CH3: $I_{LED}$, 500mA/Div, DC
TIME: 1ms/Div

Normal Operation



CH1: $V_{IN}$, 2V/Div, DC
CH2: $V_{OUT}$, 2V/Div, DC
CH3: $V_{LX}$, 5V/Div, DC
CH4: $I_{LED}$, 1A/Div, DC
TIME: 500ns/Div

## Function Descriptions

### Operation

The APW7584 integrates a synchronous buck PWM controller and high/low side power MOSFETs to generate VOUT. It offers the lower quiescent current that can provide up to 0.6A continuous output current over wide input supply range. Input voltage range of the PWM converter is 4.2V to 5.5V.

### Constant-On-Time PWM Controller

This IC uses constant on-time control, has a simple control loop, and allows it to use ceramic-type capacitors for excellent transient response. This architecture is pseudo-fixed frequency with input voltage feed forward.

On-time is inversely proportional to input voltage and proportional to output voltage. When the voltage on FB is lower than the internal reference voltage, the high-side switch will be turned on for a calculated on-time. The on-time can be estimated by the formula as below:

$$T_{ON} \approx \frac{V_{OUT}}{V_{IN}} \times 0.33\mu s$$

In addition, the high side MOS driver transistor might keep on turning on and the 100% duty cycle mode might be set. The 100% duty cycle mode achieves high output voltage stability and highspeed response even under full load conditions and the condition where the input-output voltage difference is small.

### VIN Power-On-Reset (POR)

The IC continuously monitors the voltage on the VIN pin. The soft start is activated when the VIN voltage and the EN voltage are above their respective POR thresholds. VIN POR is used to protect the IC from erroneous operation with insufficient VIN voltage. VIN POR also has hysteresis to resist ripple on the VIN voltage.

### Enable and Shutdown

The IC provides the EN pin, which is a digital input that turns the converter on or off. Drive EN high to turn the converter on and pull it low to turn it off.

### Soft-Start

The IC includes a built-in soft-start function that controls the rising time of the output voltage during start-up to reduce input current surges and prevent output overshooting.

The soft-start function is enabled whenever a condition triggers output start-up, such as powering up the IC (applying VIN or EN), or restarting the converter from over-temperature protection (OTP).

### Over-Temperature Protection (OTP)

The IC features over-temperature protection that monitors the junction temperature to prevent damage during high-temperature operating.

When the junction temperature exceeds the OTP threshold, the IC shuts down to reduce the temperature. Once the temperature drops below the hysteresis threshold, the device restarts automatically.

### Current-Limit Protection

The IC monitors the current through the power MOSFET to limit the inductor peak current to prevent IC from being damaged in the event of an overload or short circuit.

When the current limit protection is activated, the output current will be limited at peak current until output loading is down below to the valley current threshold.

## Application Information

### Input Capacitor Selection

The input capacitor is chosen based on the voltage rating and the RMS current rating. For reliable operation, select the capacitor voltage rating to be at least 1.3 times higher than the maximum input voltage.

Use low ESR capacitors for the best performance.

Ceramic capacitors with X5R or X7R dielectrics are recommended highly because of their low ESR and small temperature coefficients.

Since the input capacitor (CIN) absorbs the input-switching current, it requires an adequate ripple-current rating. The RMS current in the input capacitor can be estimated by:

$$I_{CIN} = I_{OUT} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)}$$

The worst-case condition occurs at VIN=2VOUT, where:

$$I_{CIN} = \frac{I_{OUT}}{2}$$

For simplification, choose an input capacitor with an RMS current rating greater than half of the maximum load current.

The input capacitor can be electrolytic, tantalum or ceramic. When using electrolytic or tantalum capacitors, a small, high-quality ceramic capacitor (e.g. 0.1μF) should be placed as close to the IC as possible. When using ceramic capacitors, make sure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at the input. The input voltage ripple caused by the capacitance can be estimated by:

$$\Delta V_{IN} = \frac{I_{OUT}}{F_{OSC} \times C_{IN}} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

### Output Capacitor Selection

The output capacitor is required to filter the output and provide load transient current. The higher capacitance value will provide a smaller output ripple and better load transient. Ceramic electrolytic capacitors with X5R or X7R dielectrics and low ESR are recommended to keep the output voltage ripple low. The output voltage ripple caused by the capacitance can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{F_{OSC} \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times F_{OSC} \times C_{OUT}}\right)$$

Where L is the inductor value and $R_{ESR}$ is the equivalent series resistance (ESR) value of the output capacitor.

### Output Inductor Selection

The inductance value will determine the inductor ripple current and affect the load transient response and output ripple voltage.

The larger inductance value will result in a smaller ripple current, which will result in a lower output ripple voltage but a slower transient response, while a smaller inductance value will have opposite result.

A good rule is to choose the inductor ripple current that is about 30% of the maximum output current. Use the following equation to derive the inductance value for most designs:

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times F_{OSC}}$$

Where, $\Delta I_L$ is the inductor-ripple current.

To avoid inductor saturation, the inductor current rating should be at least the converter's maximum output current plus the inductor ripple current. The maximum inductor peak current can be estimated by:

$$I_{L(MAX)} = I_{OUT} + \frac{\Delta I_L}{2}$$

In addition, choosing an inductor with a smaller DCR will provide better efficiency.

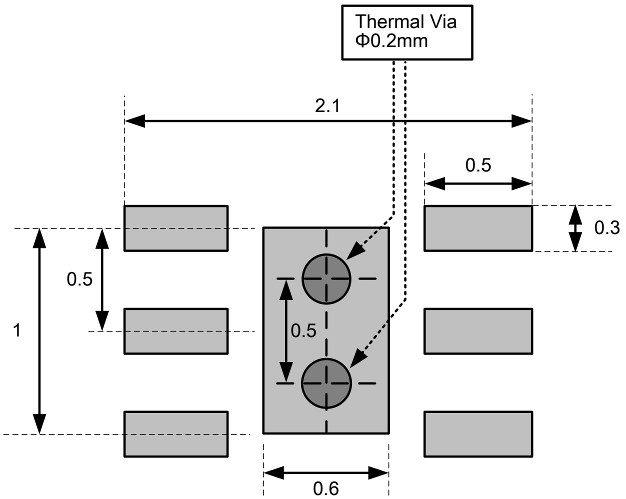
## Application Information (Cont.)

### Layout Consideration

For all switching power supplies, the layout is an important step in the design; especially at high peak currents and switching frequencies. If the layout is not carefully done, the regulator might show noise problems and duty cycle jitters.

1. The VIN input capacitor should be placed close to the VIN and GND pins. Connecting the capacitor and VIN/GND pins with short and wide trace without any holes for good input voltage filtering.
2. Place the inductor as close as possible to the LX pin to minimize noise coupling into other circuits.
3. The ground of the output capacitor and input capacitor and the GND of the IC should be as close as possible.
4. It is recommended to place the input capacitor, output capacitor and inductor on top layer, and use a large power GND plane to connect the grounds of the input capacitor, output capacitor, and the IC.

### Recommended Minimum Footprint

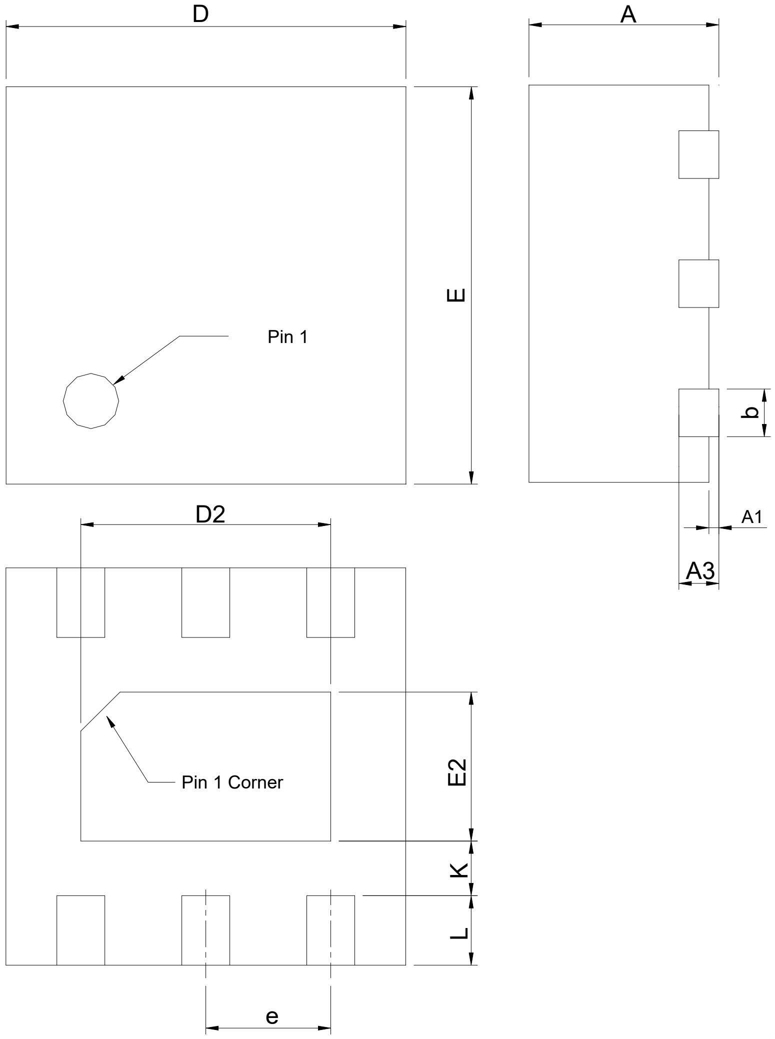


Unit: mm

* Just Recommend

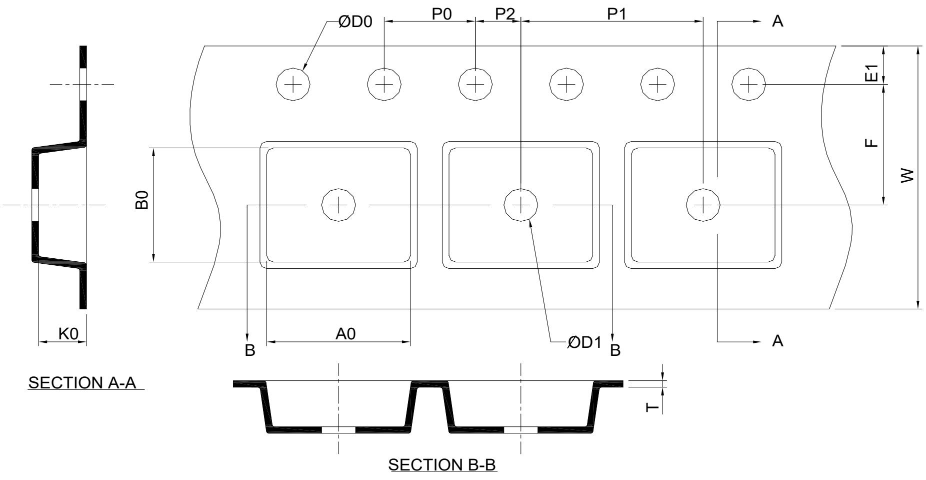
## Package Information

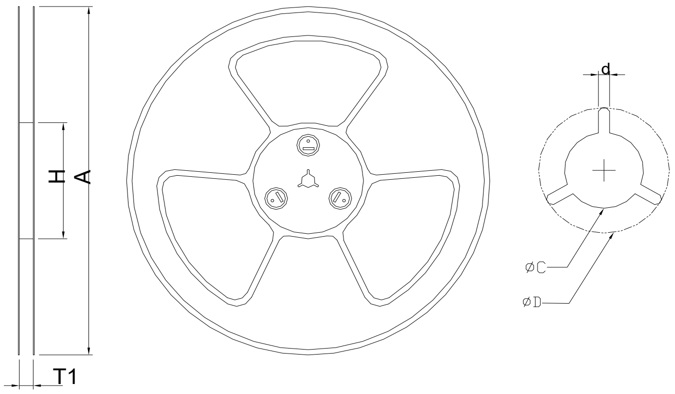
**TDFN1.6x1.6-6**



| SYMBOL | TDFN1.6x1.6-6 | | | |
|---|---|---|---|---|
| | MILLIMETERS | | INCHES | |
| | MIN. | MAX. | MIN. | MAX. |
| A | 0.70 | 0.80 | 0.028 | 0.031 |
| A1 | 0.00 | 0.05 | 0.000 | 0.002 |
| A3 | 0.20 REF | | 0.008 REF | |
| b | 0.20 | 0.30 | 0.008 | 0.012 |
| D | 1.55 | 1.65 | 0.061 | 0.065 |
| D2 | 0.95 | 1.05 | 0.037 | 0.041 |
| E | 1.55 | 1.65 | 0.061 | 0.065 |
| E2 | 0.55 | 0.65 | 0.022 | 0.026 |
| e | 0.50 BSC | | 0.020 BSC | |
| K | 0.20 | - | 0.008 | - |
| L | 0.19 | 0.29 | 0.007 | 0.011 |

## Carrier Tape & Reel Dimensions





| Application | A | H | T1 | C | d | D | W | E1 | F |
|---|---|---|---|---|---|---|---|---|---|
| TDFN 1.6x1.6 | 178.0±2.00 | 50 MIN. | 8.4+2.00<br>-0.00 | 13.0+0.50<br>-0.20 | 1.5 MIN. | 20.2 MIN. | 8.0±0.30 | 1.75±0.10 | 3.5±0.05 |
| | **P0** | **P1** | **P2** | **D0** | **D1** | **T** | **A0** | **B0** | **K0** |
| | 4.0±0.10 | 4.0±0.10 | 2.0±0.05 | 1.5+0.10<br>-0.00 | 1.5 MIN. | 0.6+0.00<br>-0.40 | 1.80±0.20 | 1.80±0.20 | 1.00±0.20 |

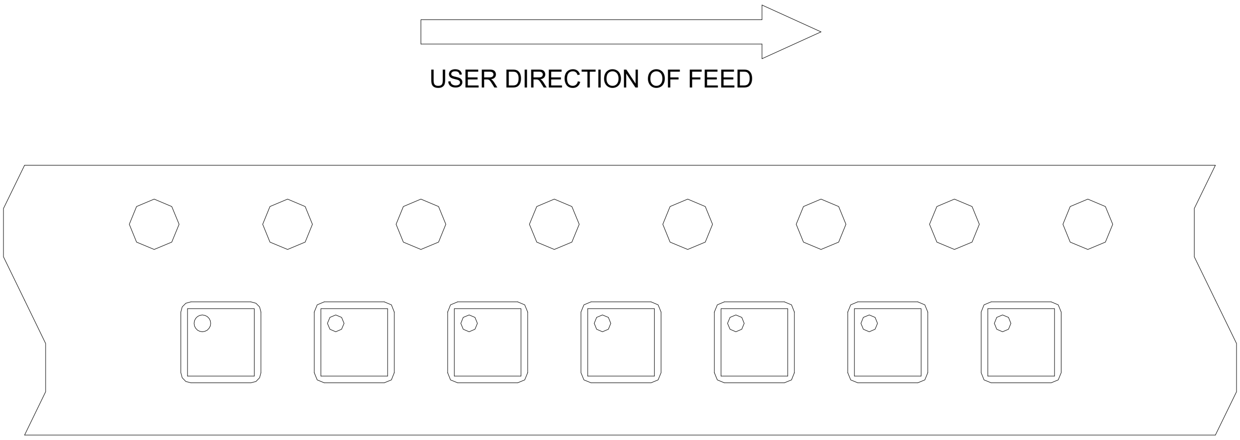
(mm)

## Devices Per Unit

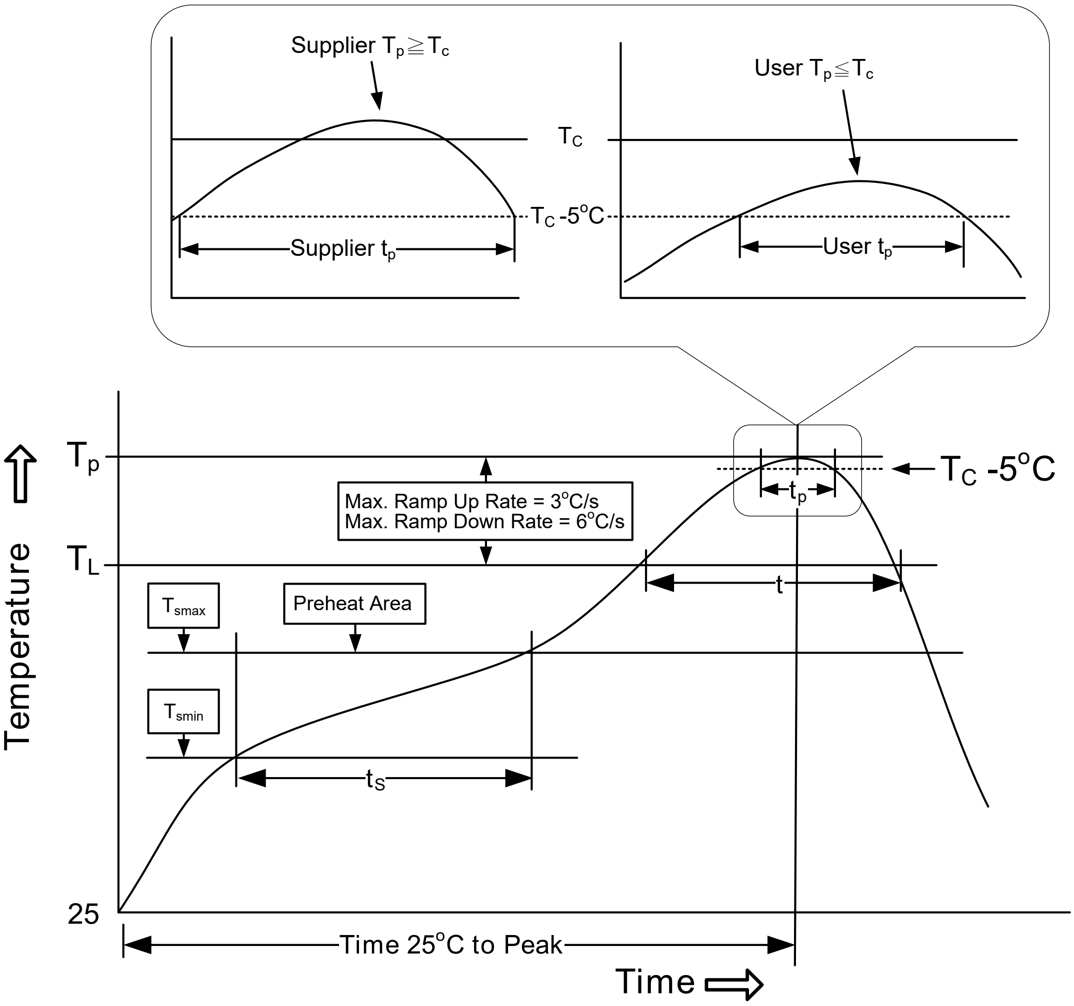
| Package Type | Packing | Quantity |
|---|---|---|
| **TDFN 1.6x1.6** | Tape & Reel | 3000 |

## Taping Direction Information

**TDFN1.6x1.6-6**



## Classification Profile



## Classification Reflow Profiles

| Profile Feature | Sn-Pb Eutectic Assembly | Pb-Free Assembly |
|---|---|---|
| **Preheat & Soak**<br>Temperature min ($T_{smin}$)<br>Temperature max ($T_{smax}$)<br>Time ($T_{smin}$ to $T_{smax}$) ($t_s$) | 100°C<br>150°C<br>60-120 seconds | 150°C<br>200°C<br>60-120 seconds |
| Average ramp-up rate ($T_{smax}$ to $T_P$) | 3°C/second max. | 3°C/second max. |
| Liquidous temperature ($T_L$)<br>Time at liquidous ($t_L$) | 183°C<br>60-150 seconds | 217°C<br>60-150 seconds |
| Peak package body Temperature ($T_p$)* | See Classification Temp in table 1 | See Classification Temp in table 2 |
| Time ($t_P$)** within 5°C of the specified classification temperature ($T_c$) | 20** seconds | 30** seconds |
| Average ramp-down rate ($T_p$ to $T_{smax}$) | 6°C/second max. | 6°C/second max. |
| Time 25°C to peak temperature | 6 minutes max. | 8 minutes max. |
| * Tolerance for peak profile Temperature ($T_p$) is defined as a supplier minimum and a user maximum.<br>** Tolerance for time at peak profile temperature ($t_p$) is defined as a supplier minimum and a user maximum. | | |

Note: ANPEC's green products meet or exceed the lead-free requirements of IPC/JEDEC J-STD-020D for MSL classification at lead-free peak reflow temperature.

Table 1. SnPb Eutectic Process – Classification Temperatures (Tc)

| Package Thickness | Volume mm$^3$ <350 | Volume mm$^3$ ≥350 |
|---|---|---|
| <2.5 mm | 235°C | 220°C |
| ≥2.5 mm | 220°C | 220°C |

Table 2. Pb-free Process – Classification Temperatures (Tc)

| Package Thickness | Volume mm$^3$ <350 | Volume mm$^3$ 350-2000 | Volume mm$^3$ >2000 |
|---|---|---|---|
| <1.6 mm | 260°C | 260°C | 260°C |
| 1.6 mm – 2.5 mm | 260°C | 250°C | 245°C |
| ≥2.5 mm | 250°C | 245°C | 245°C |

## Reliability Test Program

| Test Item | Method | Description |
|---|---|---|
| SOLDERABILITY | JESD-22, B102 | 5 Sec, 245°C |
| HOLT | JESD-22, A108 | 1000 Hrs, Bias @ $T_j$=125°C |
| PCT | JESD-22, A102 | 168 Hrs, 100%RH, 2atm, 121°C |
| TCT | JESD-22, A104 | 500 Cycles, -65°C~150°C |
| HBM | MIL-STD-883-3015.7 | VHBM ≧ 2KV |
| MM | JESD-22, A115 | VMM ≧ 200V |
| Latch-Up | JESD-78 | 10ms, $1_{tr}$ ≧ 100mA |

## Customer Service

**Anpec Electronics Corp.**
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