

## Fixed 600kHz Step-UP Converter for White LEDs

### Features

- **Wide Input Voltage from 2.7V to 6V**
- **Fixed 600kHz Switching Frequency**
- **Reference Voltage : 0.2V**
- **PWM brightness control with wide frequency range of 5KHz to 100KHz**
- **Build-in Power MOSFET: 0.3W**
- **Over-Voltage Protection**
- **Under Voltage Lockout Protection**
- **Over Temperature Protection**
- **<1mA Quiescent Current during Shutdown**
- **TDFN2x2-6 Package**
- **Halogen and Lead Free Available (RoHS Compliant)**

### Applications

- **White LED Display Backlighting**
- **Cell Phone and Smart Phone**
- **PDA, PMP, MP3**
- **Digital Camera**

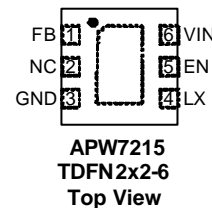
### General Description

The APW7215 is a current-mode and fixed frequency 600kHz boost converter with an integrated N-FET to drive white LEDs.

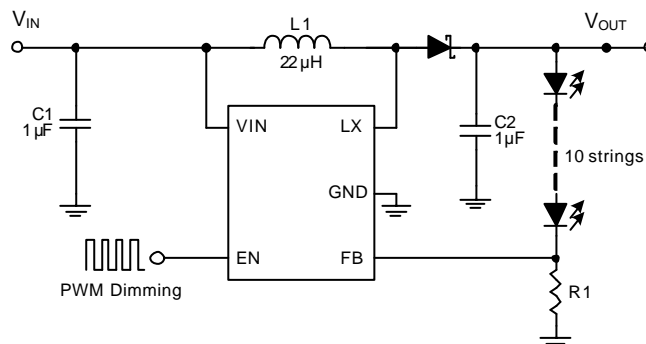
The series connection allows the LED current to be identical for uniform brightness. Its low on-resistance of N-FET and low feedback voltage reduce power loss and achieve high efficiency. 600kHz Constant switching frequency allows using small-size inductor and both of input and output capacitors. An over voltage protection function, which monitors the output voltage via LX pin, stops switching of the IC if the LX voltage exceeds the over voltage threshold. An internal soft-start circuit eliminates the inrush current during start-up.

The APW7215 also integrates under-voltage lockout and over-temperature protection to protect the IC in abnormal conditions. The APW7215 is available in TDFN2x2-6 package.

### Pin Configuration

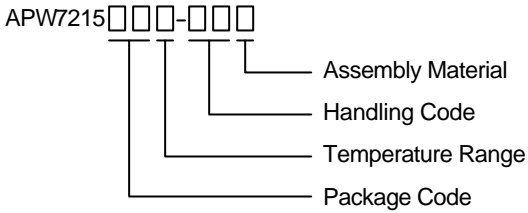


### Simplified Application Circuit



ANPEC reserves the right to make changes to improve reliability or manufacturability without notice, and advise customers to obtain the latest version of relevant information to verify before placing orders.

## Ordering and Marking Information

<p>APW7215□□□-□□□</p>  <p>Assembly Material Handling Code Temperature Range Package Code</p>	<p>Package Code QB: TDFN2x2-6</p> <p>Operating Ambient Temperature Range I : -40 to 85°C</p> <p>Handling Code TR : Tape &amp; Reel</p> <p>Assembly Material G : Halogen and Lead Free Device</p>		
<p>APW7215QB: <table border="1" style="display: inline-table; vertical-align: middle;"><tr><td>W15</td></tr><tr><td>● X</td></tr></table> X - Date Code</p>		W15	● X
W15			
● X			

Note: ANPEC lead-free products contain molding compounds/die attach materials and 100% matte tin plate termination finish; which are fully compliant with RoHS. ANPEC lead-free products meet or exceed the lead-free requirements of IPC/JEDEC J-STD-020D for MSL classification at lead-free peak reflow temperature. ANPEC defines "Green" to mean lead-free (RoHS compliant) and halogen free (Br or Cl does not exceed 900ppm by weight in homogeneous material and total of Br and Cl does not exceed 1500ppm by weight).

## Absolute Maximum Ratings (Note 1)

Symbol	Parameter	Rating	Unit
V <sub>N</sub>	V <sub>IN</sub> Pin to GND	-0.3 to 7	V
	FB and EN to GND	-0.3 ~ V <sub>IN</sub>	V
V <sub>LX</sub>	LX Pin to GND	-0.3 to 40	V
P <sub>D</sub>	Power Dissipation	Internally Limit	W
T <sub>J</sub>	Maximum Junction Temperature	150	°C
T <sub>STG</sub>	Storage Temperature Range	-65 to 150	°C
T <sub>SDR</sub>	Maximum Lead Soldering Temperature, 10 Seconds	260	°C

Note1: 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
θ <sub>JA</sub>	Junction-to-Ambient Resistance in free air (Note 2)	TDFN2x2-6	165	°C/W
θ <sub>JC</sub>	Junction-to-Case Resistance	TDFN2x2-6	20	°C/W

Note 2: θ<sub>JA</sub> 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 <sub>IN</sub>	VIN Input Voltage	2.7 ~ 6	V
C <sub>IN</sub>	Input Capacitor	1 ~	μF
C <sub>OUT</sub>	Output Capacitor	1 ~	μF
L1	Converter Output Inductor	4.7 ~ 22	μH
T <sub>A</sub>	Ambient Temperature	-40 ~ 85	°C
T <sub>J</sub>	Junction Temperature	-40 ~ 125	°C

Note 3: Please refer to the typical application circuit.

## Electrical Characteristics

Refer to the typical application circuits. These specifications apply over. V<sub>IN</sub>=3.6V, T<sub>A</sub>=25°C.

Symbol	Parameter	Test Conditions	APW7215			Unit
			Min.	Typ.	Max.	
<b>SUPPLY VOLTAGE AND CURRENT</b>						
V <sub>IN</sub>	Input Voltage Range		2.7	-	6	V
I <sub>DD1</sub>	Input DC Bias Current	V <sub>FB</sub> = 0.4V, no switching	-	-	800	μA
I <sub>DD2</sub>		V <sub>FB</sub> = GND, switching	-	1.2	1.7	mA
I <sub>SD</sub>		EN = GND	-	-	1	μA
<b>UNDER-VOLTAGE LOCKOUT</b>						
	UVLO Threshold Voltage	V <sub>N</sub> Rising	1.9	2.2	2.4	V
	UVLO Hysteresis Voltage	V <sub>N</sub> Falling	50	100	200	mV
<b>REFERENCE AND OUTPUT VOLTAGES</b>						
V <sub>REF</sub>	Regulated Feedback Voltage	V <sub>N</sub> =2.7V ~ 6V	192	200	208	mV
I <sub>FB</sub>	FB Input Current	V <sub>FB</sub> =1.23V	-1	-	1	μA
<b>INTERNAL POWER SWITCH</b>						
F <sub>SW</sub>	Switching Frequency		540	600	660	kHz
R <sub>ON</sub>	Power Switch On Resistance	V <sub>IN</sub> =3.6V	-	0.3	0.7	Ω
		V <sub>IN</sub> =3V	-	-	0.7	
	LX Leakage Current	V <sub>EN</sub> =0V, V <sub>LX</sub> =35V, V <sub>N</sub> = 6V	-	-	100	μA
D <sub>MAX</sub>	LX Maximum Duty Cycle		92	95	-	%
<b>OUTPUT OVER VOLTAGE PROTECTION</b>						
V <sub>LX_OVP</sub>	Over Voltage Threshold	V <sub>LX</sub> Rising	36	38	40	V
<b>POWER SWITCH CURRENT LIMIT</b>						
I <sub>LM</sub>	N-Channel MOSFET Current Limit	Duty = D <sub>MAX</sub>	1.5	-	-	A

## Electrical Characteristics(Cont.)

Refer to the typical application circuits. These specifications apply over.  $V_{IN}=3.6V$ ,  $T_A=25^{\circ}C$ .

Symbol	Parameter	Test Conditions	APW7215			Unit
			Min.	Typ.	Max.	
<b>ENABLE AND SHUTDOWN</b>						
	Enable Voltage Threshold	$V_{EN}$ Rising	1	-	-	V
	Shutdown Voltage Threshold	$V_{EN}$ Falling	-	-	0.4	V
	EN Pulled Low Resistance		-	800	-	k $\Omega$
	EN Dimming Minimum Enable Pulsed Width	Use $V_{EN}=3V$ to enable to device, PWM Dimming Frequency=5k to 100k Hz	4	-	-	%
<b>OVER-TEMPERATURE PROTECTION</b>						
$T_{OTP}$	Over-Temperature Protection <sup>(Note 4)</sup>	$T_J$ Rising	-	150	-	$^{\circ}C$
	Over-Temperature Protection Hysteresis <sup>(Note 4)</sup>	$T_J$ Falling	-	40	-	$^{\circ}C$

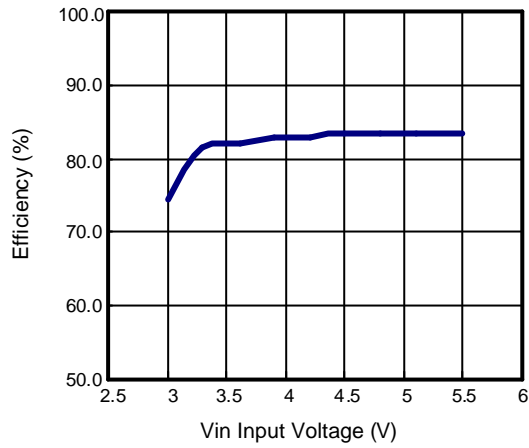
Note 4: Guaranteed by design, not production tested.

## Pin Description

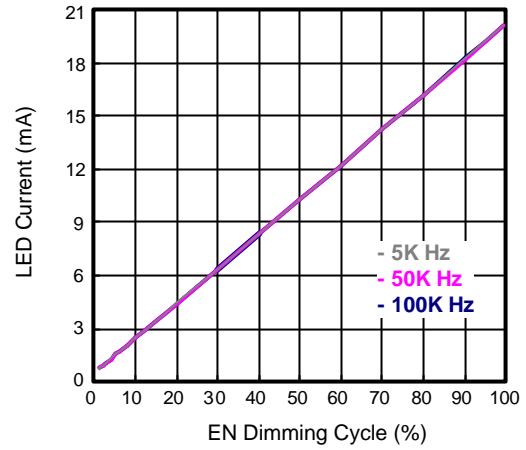
PIN.		FUNCTION
TDFN-2x2-6	NAME	
1	FB	Feedback Pin. Connect this pin to cathode of the lowest LED and current-sense resistor (R1). Calculate resistor value according to $R1=V_{REF}/I_{LED}$ .
2	NC	No Comment.
3	GND	Power and signal ground pin.
4	LX	Switch pin. Connect this pin to inductor/diode here.
5	EN	Enable Control Input. Forcing this pin above 1.0V enables the device, or forcing this pin below 0.4V to shut it down. In shutdown, all functions are disabled to decrease the supply current below 1 $\mu$ A.
6	VIN	Main Supply Pin. Must be closely decoupled to GND with a 1 $\mu$ F or greater ceramic capacitor.
Exposed Pad	GND	Connecting this pad to GND.

### Typical Operating Characteristics

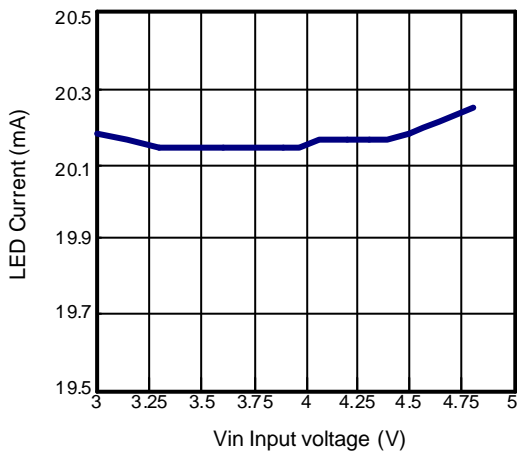
Vin Input Voltage vs. Efficiency



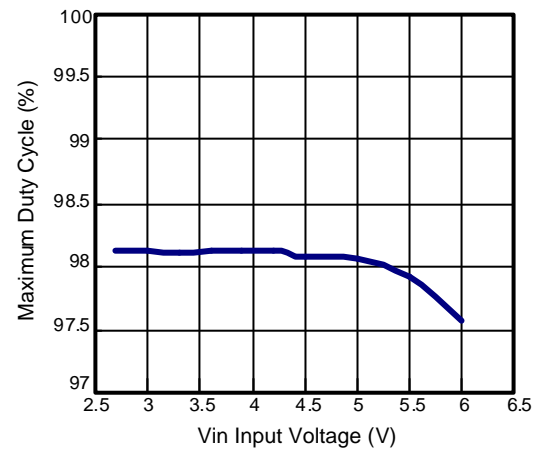
EN Dimming Cycle vs. LED Current



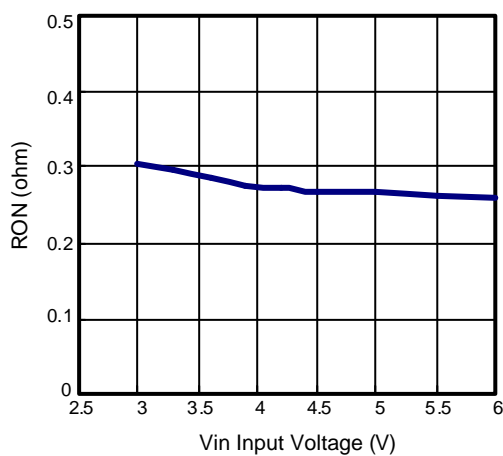
Vin Input Voltage vs. LED Current



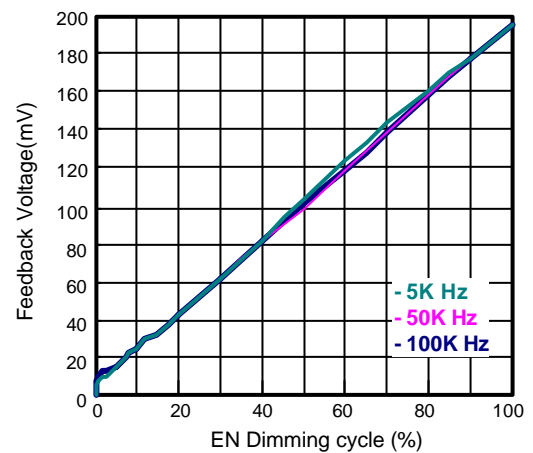
Vin Input Voltage vs. Max Duty Cycle



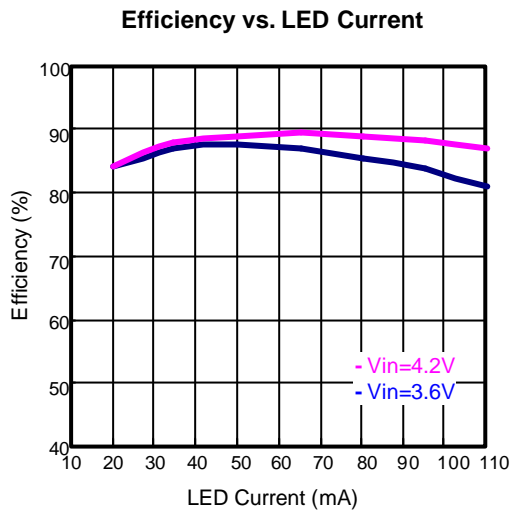
Vin Input Voltage vs. RON



EN Dimming cycle vs. Feedback Voltage

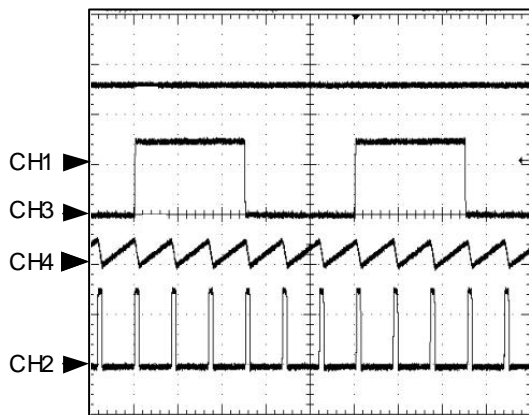


### Typical Operating Characteristics



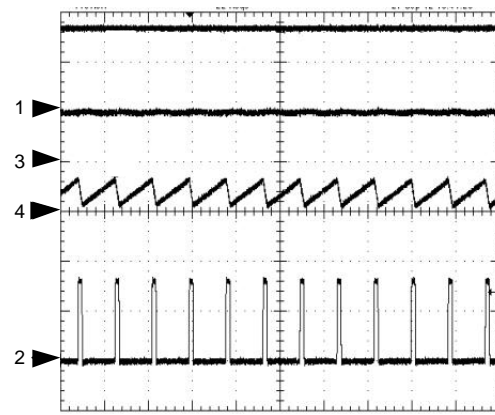
Operating Waveforms

Dimming, 100K Hz @50% duty



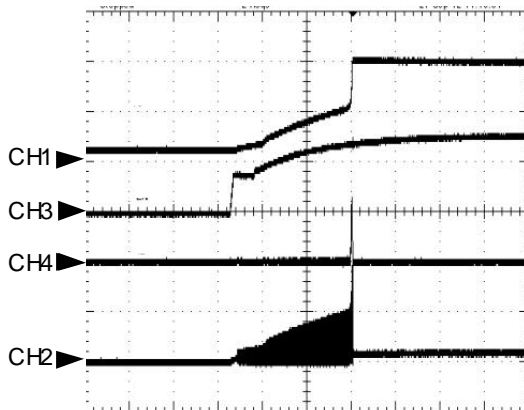
CH1:  $V_{OUT}$ -20V/div  
 CH2:  $V_{LX}$ -20V/div  
 CH3:  $V_{EN}$ -2V/div  
 CH4:  $I_L$ -500mA/div  
 Time: 2us/div

Normal Operation



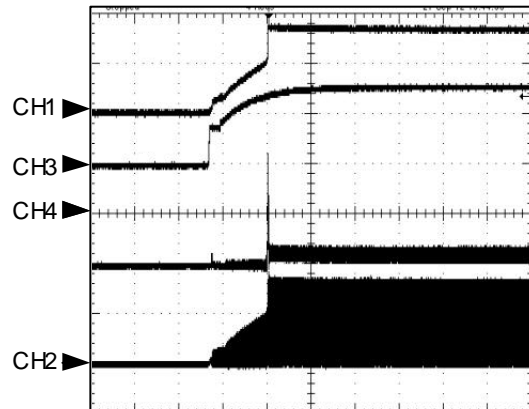
CH1:  $V_{OUT}$ -20V/div  
 CH2:  $L_X$ -20V/div  
 CH3:  $V_{FB}$ -200mV/div  
 CH4:  $I_L$ -500mA/div  
 Time: 2us/div

OVP



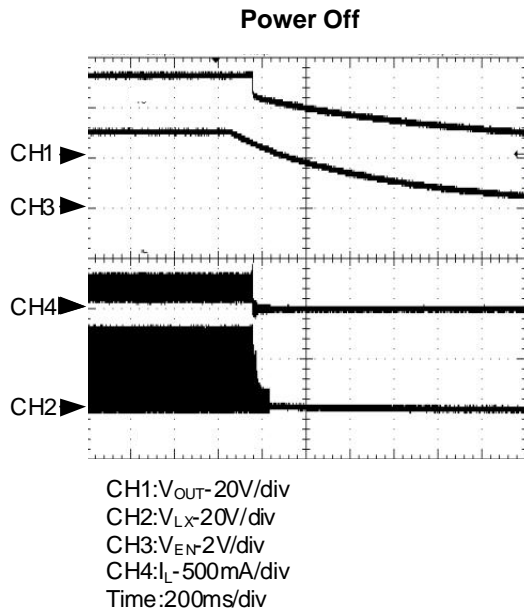
CH1:  $V_{OUT}$ -20V/div  
 CH2:  $V_{LX}$ -20V/div  
 CH3:  $V_{EN}$ -2V/div  
 CH4:  $I_L$ -2A/div  
 Time: 2ms/div

Power On



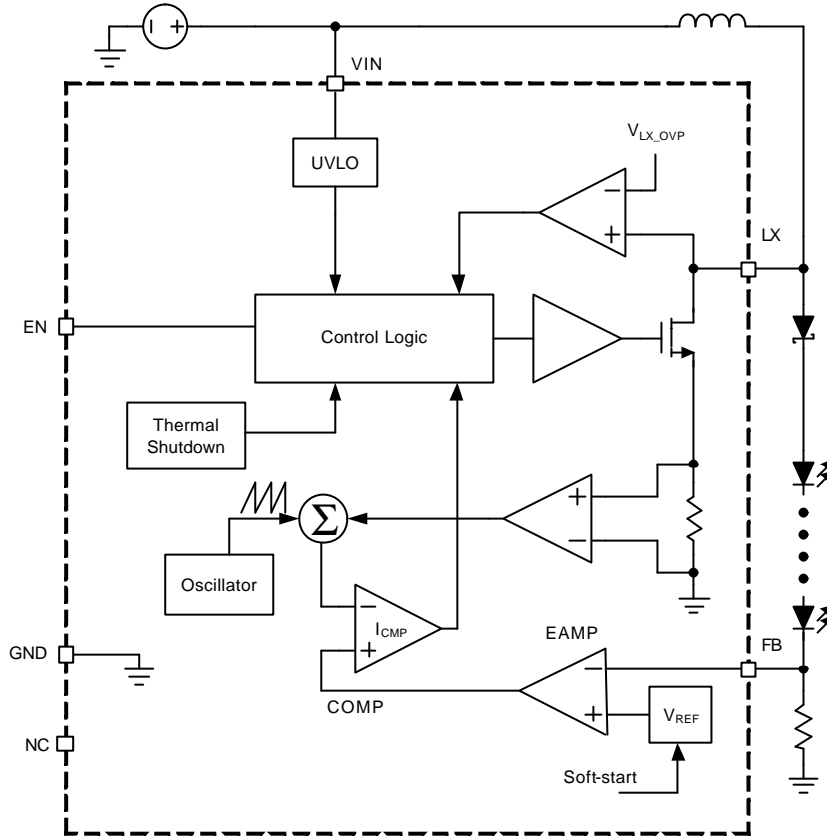
CH1:  $V_{OUT}$ -20V/div  
 CH2:  $V_{LX}$ -20V/div  
 CH3:  $V_{EN}$ -2V/div  
 CH4:  $I_L$ -1A/div  
 Time: 4ms/div

## Operating Waveforms

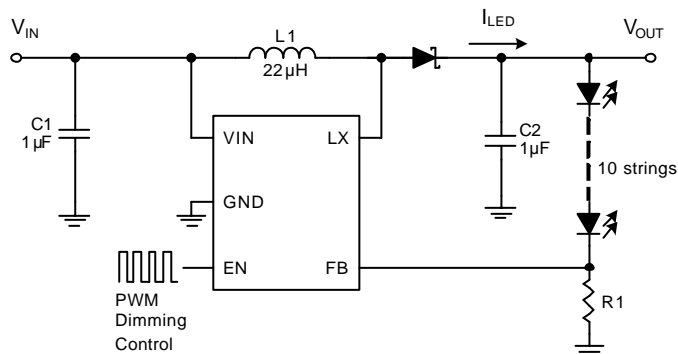




Block Diagram



Typical Application Circuits



## Function Description

### Main Control Loop

The APW7215 is a constant frequency current-mode switching regulator. During normal operation, the internal N-channel power MOSFET is turned on each cycle when the oscillator sets an internal RS latch and turned off when an internal comparator (ICMP) resets the latch. The peak inductor current at which ICMP resets the RS latch is controlled by the voltage on the internal COMP node, which is the output of the error amplifier (EAMP). An external current-sense resistor connected between cathode of the lowest LED and ground allows the EAMP to receive a current feedback voltage  $V_{FB}$  at FB pin. When the LEDs voltage decreases to cause the LEDs current to decrease, it causes a slightly decrease in  $V_{FB}$  relative to the reference voltage, which in turn causes the internal COMP voltage to increase until the LEDs current reaches the set point.

### VIN Under-Voltage Lockout (UVLO)

The Under-Voltage Lockout (UVLO) circuit compares the input voltage at VIN with the UVLO threshold (2.2V rising, typical) to ensure the input voltage is high enough for reliable operation. The 100mV (typ) hysteresis prevents supply transients from causing a restart. Once the input voltage exceeds the UVLO rising threshold, startup begins. When the input voltage falls below the UVLO falling threshold, the controller turns off the converter.

### Soft-Start

The APW7215 has a built-in soft-start to control the N-channel MOSFET current raises during start-up. During soft-start, an internal ramp voltage connected to one of the inverting inputs of the current limit comparator. The inductor current limit is proportional to the voltage. When the threshold voltage of the internal soft-start comparator is reached, the full current limit is released.

### Current-Limit Protection

The APW7215 monitors the inductor current flowing through the N-channel MOSFET, and limits the current peak at current-limit level to prevent loads and the device from damages in overload conditions.

### Over-Temperature Protection (OTP)

The over-temperature circuit limits the junction temperature of the APW7215. When the junction temperature exceeds 150°C, a thermal sensor turns off the power MOSFET, allowing the device to cool. The thermal sensor allows the converter to start a soft-start process and regulate the LEDs current again after the junction temperature cools by 40°C. The OTP is designed with a 40°C hysteresis to lower the average Junction Temperature ( $T_J$ ) during continuous thermal overload conditions, increasing the lifetime of the device.

### Enable/Shutdown

Driving EN to ground places the APW7215 in shutdown mode. When in shutdown, the internal power MOSFET turns off, all internal circuitry shuts down and the quiescent supply current reduces to 1μA maximum. This pin also could be used as a digital input allowing brightness controlled by using a PWM signal with frequency from 5kHz to 100kHz. The 0% duty cycle of PWM signal corresponds to zero LEDs current and 100% corresponds to full one. If use EN Pin to enable the device, suggestion dimming duty range is from 15% to 100% at 100kHz dimming frequency.

### Open-LED Protection

In driving LED applications, the feedback voltage on FB pin falls down if one of the LEDs, in series, is failed. Meanwhile, the converter unceasingly boosts the output voltage like an open-loop operation. Therefore, an over-voltage protection monitoring the output voltage via LX pin prevents the LX and the output voltages from exceeding their maximum voltage ratings. Once the voltage on the LX pin rises above the OVP threshold, the converter stops switching and prevents the output voltage from rising. The converter can work again when the LX voltage falls below the falling of OVP voltage threshold.

## Application Information

### Input Capacitor Selection

The input capacitor ( $C_{IN}$ ) reduces the ripple of the input current drawn from the input supply and reduces noise injection into the IC. The reflected ripple voltage will be smaller when an input capacitor with larger capacitance is used. For reliable operation, it is recommended to select the capacitor with maximum voltage rating at least 1.2 times of the maximum input voltage. The capacitors should be placed close to the VIN and the GND.

### Inductor Selection

Selecting an inductor with low dc resistance reduces conduction losses and achieves high efficiency. The efficiency is moderated whilst using small chip inductor which operates with higher inductor core losses. Therefore, it is necessary to take further consideration while choosing an adequate inductor. Mainly, the inductor value determines the inductor ripple current: larger inductor value results in smaller inductor ripple current and lower conduction losses of the converter. However, larger inductor value generates slower load transient response. A reasonable design rule is to set the ripple current,  $\Delta I_L$ , to be 30% to 50% of the maximum average inductor current,  $I_{L(AVG)}$ . The inductor value can be obtained as below,

$$L \geq \left( \frac{V_{IN}}{V_{OUT}} \right)^2 \times \frac{V_{OUT} - V_{IN}}{F_{SW} \cdot I_{OUT(MAX)}} \times \frac{\eta}{\left( \frac{\Delta I_L}{I_{L(AVG)}} \right)}$$

where

$V_{IN}$  = input voltage

$V_{OUT}$  = output voltage

$F_{SW}$  = switching frequency in MHz

$I_{OUT}$  = maximum output current in amp.

$\eta$  = Efficiency

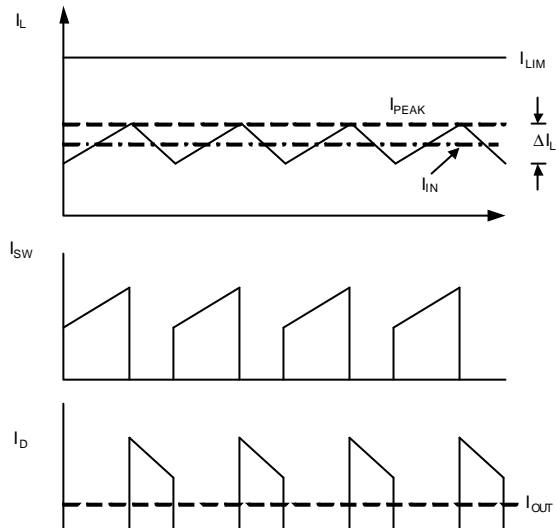
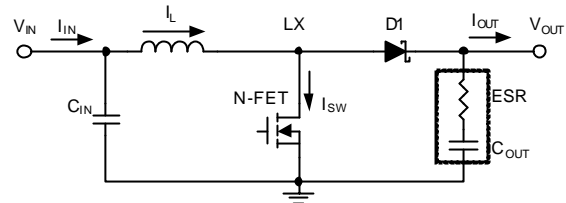
$\Delta I_L / I_{L(AVG)}$  = inductor ripple current/average current  
(0.3 to 0.5 typical)

To avoid the saturation of the inductor, the inductor should be rated at least for the maximum input current of the converter plus the inductor ripple current. The maximum input current is calculated as below:

$$I_{IN(MAX)} = \frac{I_{OUT(MAX)} \cdot V_{OUT}}{V_{IN} \cdot \eta}$$

The peak inductor current is calculated as the following equation:

$$I_{PEAK} = I_{IN(MAX)} + \frac{1}{2} \cdot \frac{V_{IN} \cdot (V_{OUT} - V_{IN})}{V_{OUT} \cdot L \cdot F_{SW}}$$



### Output Capacitor Selection

The current-mode control scheme of the APW7215 allows the usage of tiny ceramic capacitors. The higher capacitor value provides good load transients response. Ceramic capacitors with low ESR values have the lowest output voltage ripple and are recommended. If required, tantalum capacitors maybe used as well. The output ripple is the sum of the voltages across the ESR and the ideal output capacitor.

$$V_{OUT} = V_{ESR} + V_{COUT}$$

$$\Delta V_{COUT} \approx \frac{I_{OUT}}{C_{OUT}} \cdot \left( \frac{V_{OUT} - V_{IN}}{V_{OUT} \cdot F_{SW}} \right)$$

$$\Delta V_{ESR} \approx I_{PEAK} \cdot R_{ESR}$$

where  $I_{PEAK}$  is the peak inductor current.

## Application Information (Cont.)

### Output Capacitor Selection (Cont.)

For ceramic capacitor application, the output voltage ripple is dominated by the  $\Delta V_{\text{COUT}}$ . When choosing the input and output ceramic capacitors, the X5R or X7R with their good temperature and voltage characteristics are recommended.

### Output Voltage Setting

In figure 1, the converter regulates the voltage on FB pin, connected with the cathode of the lowest LED and the current-sense resistor R1 at  $V_{\text{REF}}$ . Therefore, the current ( $I_{\text{LED}}$ ), flowing via the LEDs and the R1, is calculated by the following equation:

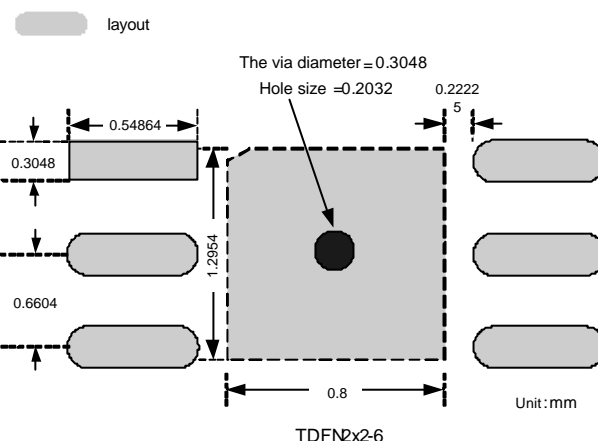
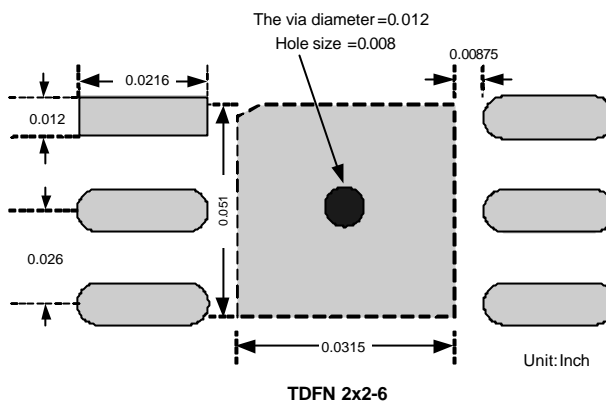
$$I_{\text{LED}} = \frac{V_{\text{REF}}}{R1}$$

### 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 jitter.

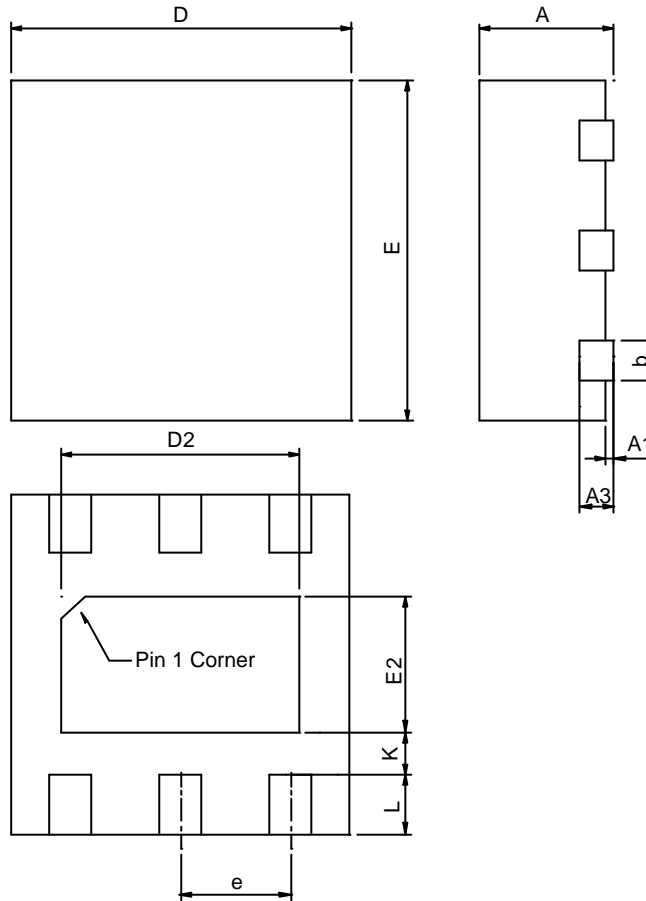
1. The input capacitor should be placed close to the VIN and the GND without any via holes for good input voltage filtering.
2. To minimize copper trace connections that can inject noise into the system, the inductor should be placed as close as possible to the LX pin to minimize the noise coupling into other circuits.
3. Since the feedback pin and network is a high impedance circuit the feedback networks should be routed away from the inductor. The feedback pin and feedback network should be shielded with a ground plane or trace to minimize noise coupling into this circuit.
4. A star ground connection or ground plane minimizes ground shifts and noise is recommended.

### Recommended Minimum Footprint



Package Information

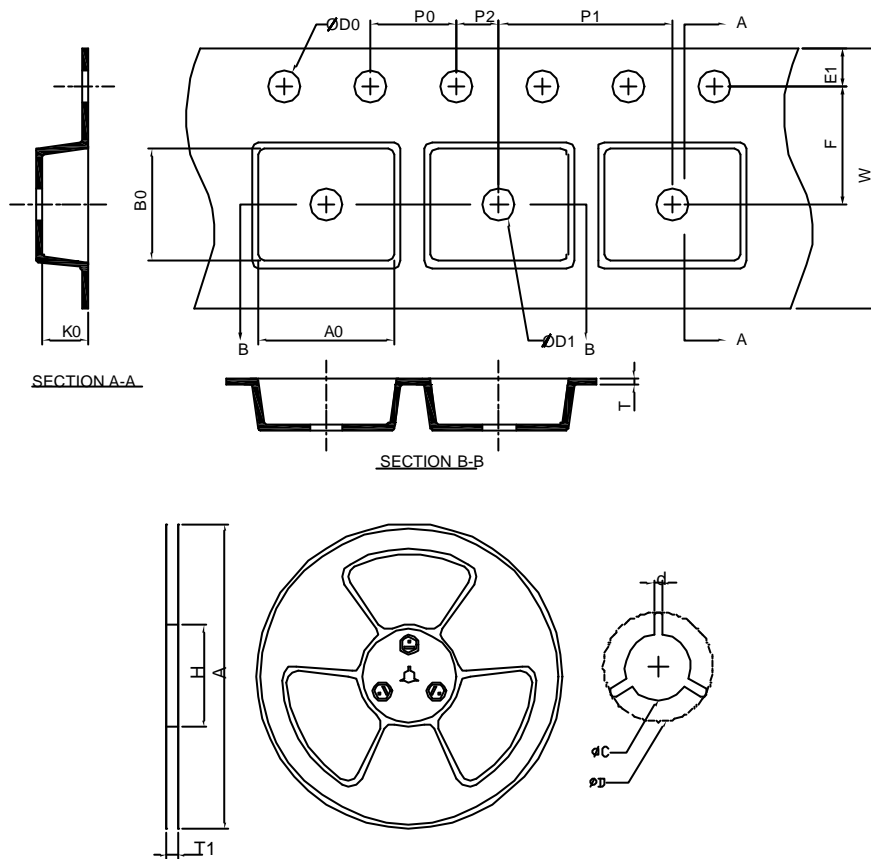
TDFN2x2-6



DIMENSIONS	TDFN2x2-6			
	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	0.18	0.30	0.007	0.012
D	1.90	2.10	0.075	0.083
D2	1.00	1.60	0.039	0.063
E	1.90	2.10	0.075	0.083
E2	0.60	1.00	0.024	0.039
e	0.65 BSC		0.026 BSC	
L	0.30	0.45	0.012	0.018
K	0.20		0.008	

Note : 1. Followed from JEDEC MO-229 WCCG.

### Carrier Tape & Reel Dimensions



Application	A	H	T1	C	d	D	W	E1	F
TDFN2x2-6	330.0 ±0.00	50 MIN.	12.4+2.00 -0.00	13.0+0.50 -0.20	1.5 MIN.	20.2 MIN.	12.0 ±0.30	1.75 ±0.10	5.5 ±0.05
	<b>P0</b>	<b>P1</b>	<b>P2</b>	<b>D0</b>	<b>D1</b>	<b>T</b>	<b>A0</b>	<b>B0</b>	<b>K0</b>
	4.0 ±0.10	8.0 ±0.10	2.0 ±0.05	1.5+0.10 -0.00	1.5 MIN.	0.6+0.00 -0.40	2.35±0.20	2.35±0.20	1.30 ±0.20

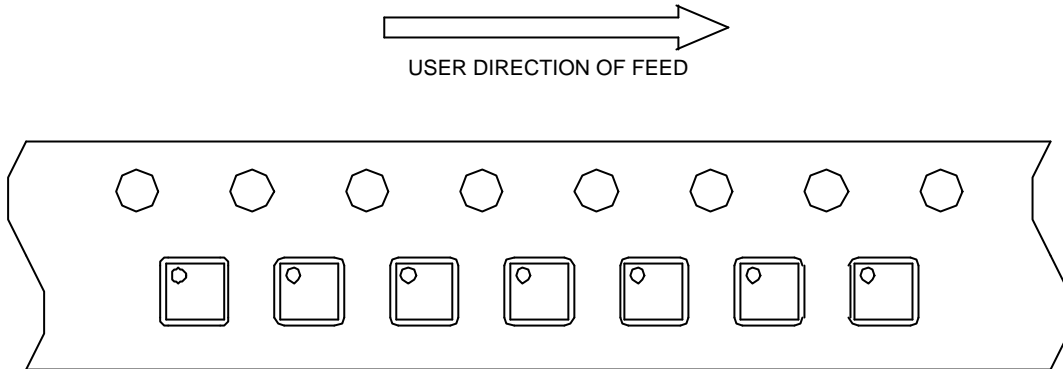
(mm)

### Devices Per Unit

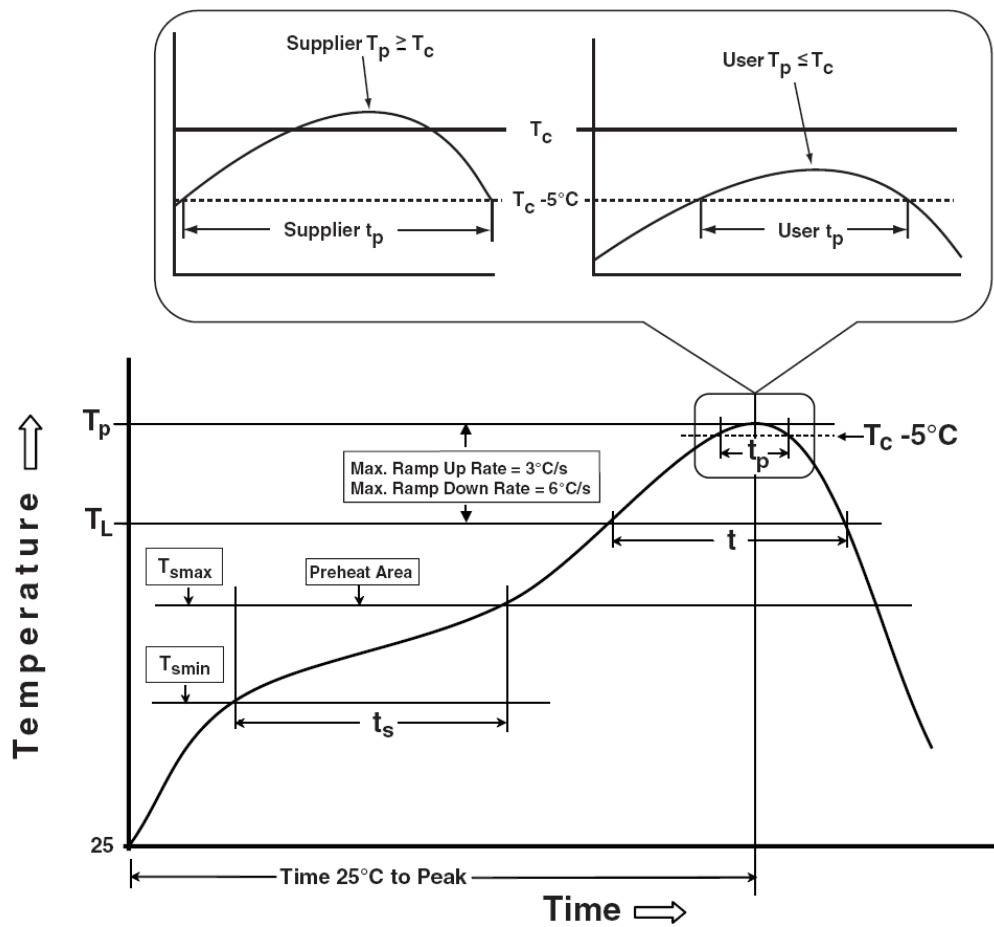
Package Type	Unit	Quantity
TDFN2x2-6	Tape & Reel	3000

### Taping Direction Information

TDFN2x2-6



### Classification Profile



### Classification Reflow Profiles

Profile Feature	Sn-Pb Eutectic Assembly	Pb-Free Assembly
<b>Preheat &amp; Soak</b>		
Temperature min ( $T_{smin}$ )	100 °C	150 °C
Temperature max ( $T_{smax}$ )	150 °C	200 °C
Time ( $T_{smin}$ to $T_{smax}$ ) ( $t_s$ )	60-120 seconds	60-120 seconds
Average ramp-up rate ( $T_{smax}$ to $T_p$ )	3 °C/second max.	3°C/second max.
Liquidous temperature ( $T_L$ )	183 °C	217 °C
Time at liquidous ( $t_L$ )	60-150 seconds	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.		
** Tolerance for time at peak profile temperature ( $t_p$ ) is defined as a supplier minimum and a user maximum.		

Table 1. SnPb Eutectic Process – Classification Temperatures ( $T_c$ )

Package Thickness	Volume mm <sup>3</sup> <350	Volume mm <sup>3</sup> ≥350
<2.5 mm	235 °C	220 °C
≥2.5 mm	220 °C	220 °C

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

Package Thickness	Volume mm <sup>3</sup> <350	Volume mm <sup>3</sup> 350-2000	Volume mm <sup>3</sup> >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 @ $T_r=125^\circ\text{C}$
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 <sub>r</sub> 100mA



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