ANPEC

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 NFET 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

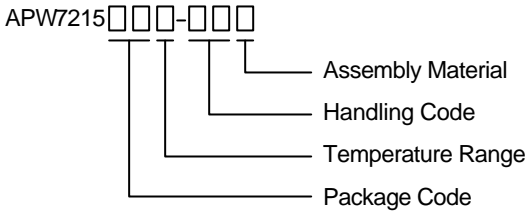**APW7215**
TDFN2x2-6
Top View
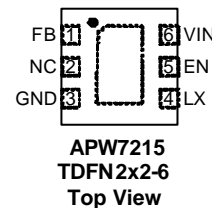
Simplified Application Circuit
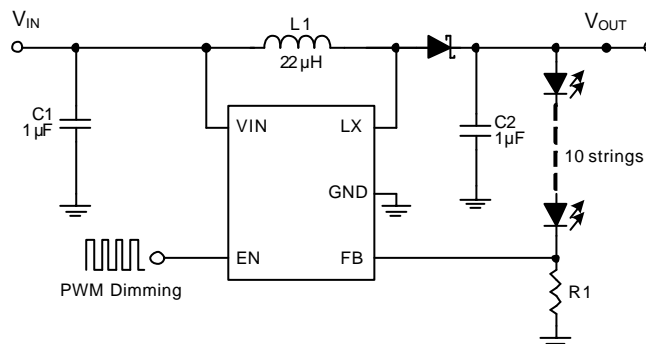
ANPEC reserves the right to make changes to improve reliability or manufacturability without notice, and advise customers to obtain the latest version of relevant information to verify before placing orders.

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Ordering and Marking Information

APW7215☐☐☐-☐☐☐
 	
        Assembly Material
       Handling Code
     Temperature Range
   Package Code
	Package Code
	  QB: TDFN2x2-6
	
	Operating Ambient Temperature Range
	  I : -40 to 85°C
	
	Handling Code
	  TR : Tape & Reel
	
	Assembly Material
	  G : Halogen and Lead Free Device

APW7215QB: [W15 ● X] X - Date Code	

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_{IN}	VIN Pin to GND	-0.3 to 7	V
	FB and EN to GND	-0.3 ~ V_{IN}	V
V_{LX}	LX Pin to GND	-0.3 to 40	V
P_D	Power Dissipation	Internally Limit	W
T_J	Maximum Junction Temperature	150	°C
T_{STG}	Storage Temperature Range	-65 to 150	°C
T_{SDR}	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_{JA}	Junction-to-Ambient Resistance in free air (Note 2)	TDFN2x2-6	165	°C/W
θ_{JC}	Junction-to-Case Resistance	TDFN2x2-6	20	°C/W

Note 2: θ_{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 Input Voltage	2.7 ~ 6	V
C_{IN}	Input Capacitor	1 ~	µF
C_{OUT}	Output Capacitor	1 ~	µF
L1	Converter Output Inductor	4.7 ~ 22	µH
T_A	Ambient Temperature	-40 ~ 85	°C
T_J	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_{IN}=3.6V, T_A=25°C.

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

Electrical Characteristics(Cont.)

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

Symbol	Parameter	Test Conditions	APW7215			Unit
			Min.	Typ.	Max.	
ENABLE AND SHUTDOWN						
	Enable Voltage Threshold	V_{EN} Rising	1	-	-	V
	Shutdown Voltage Threshold	V_{EN} Falling	-	-	0.4	V
	EN Pulled Low Resistance		-	800	-	kΩ
	EN Dimming Minimum Enable Pulsed Width	Use V_{EN}=3V to enable to device, PWM Dimmimg Frequency=5k to 100k Hz	4	-	-	%
OVER-TEMPERATURE PROTECTION						
T_{OTP}	Over-Temperature Protection[Note 4]	T_J Rising	-	150	-	°C
	Over-Temperature Protection Hysteresis [Note 4]	T_J Falling	-	40	-	°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 Commend.
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 1µA.
6	VIN	Main Supply Pin. Must be closely decoupled to GND with a 1µF or greater ceramic capacitor.
Exposed Pad	GND	Connecting this pad to GND.

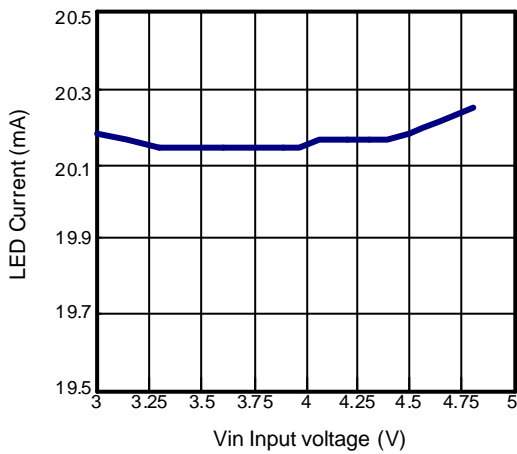## Typical Operating Characteristics

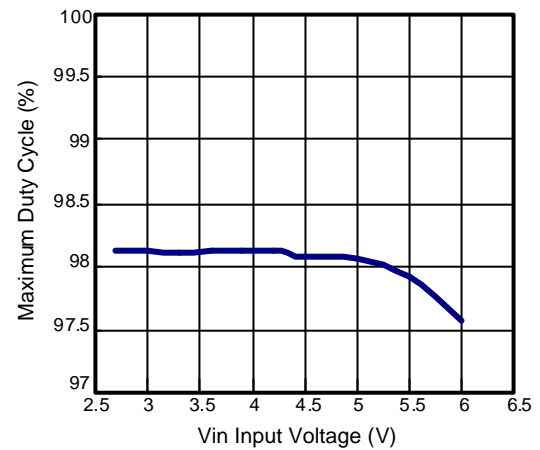### Vin Input Voltage vs. Efficiency
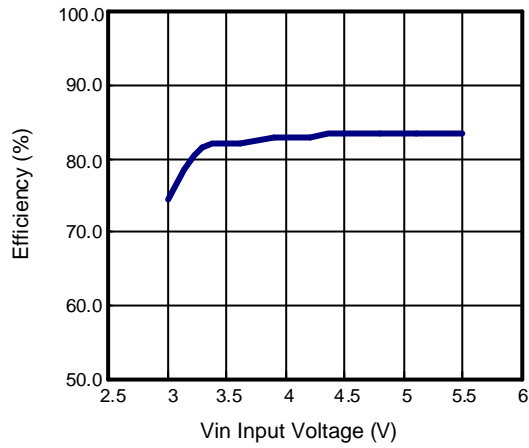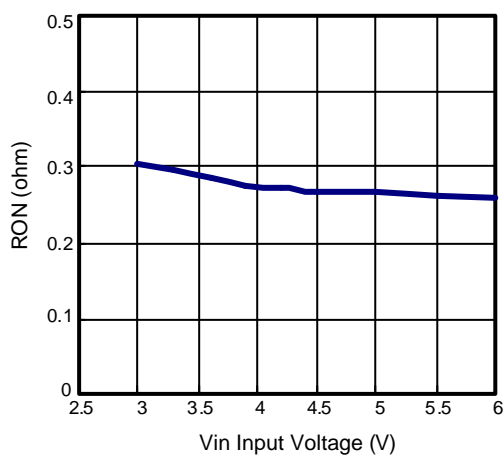

EN Dimming Cycle vs. LED Current
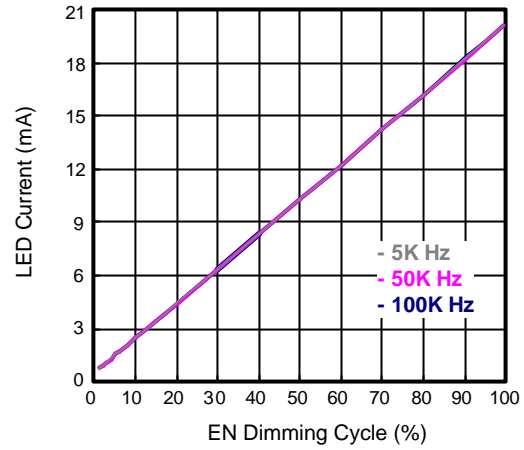
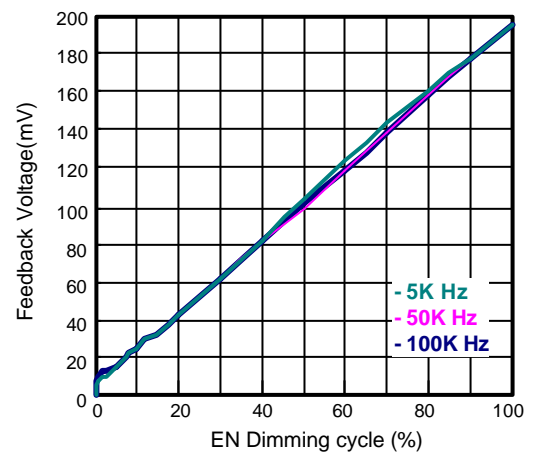### Vin Input Voltage vs. LED Current
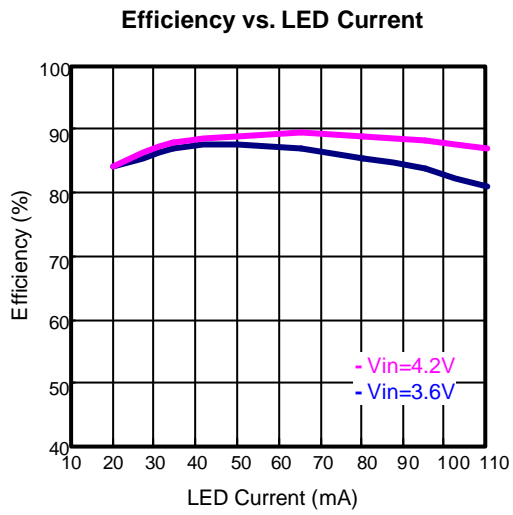

Vin Input Voltage vs. Max Duty Cycle

Vin Input Voltage vs. RON

EN Dimming cycle vs. Feedback Voltage
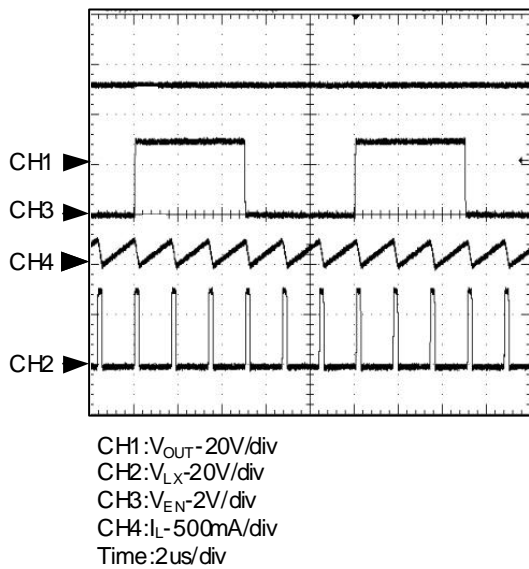
Typical Operating Characteristics
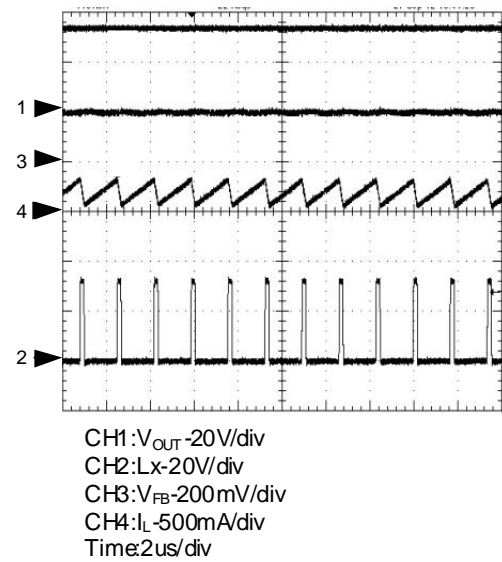
Efficiency vs. LED Current

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 : Lx - 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

Power Off

CH1:V_OUT-20V/div
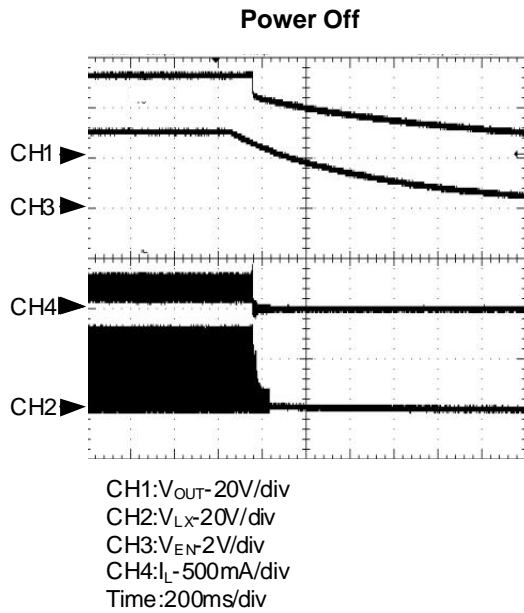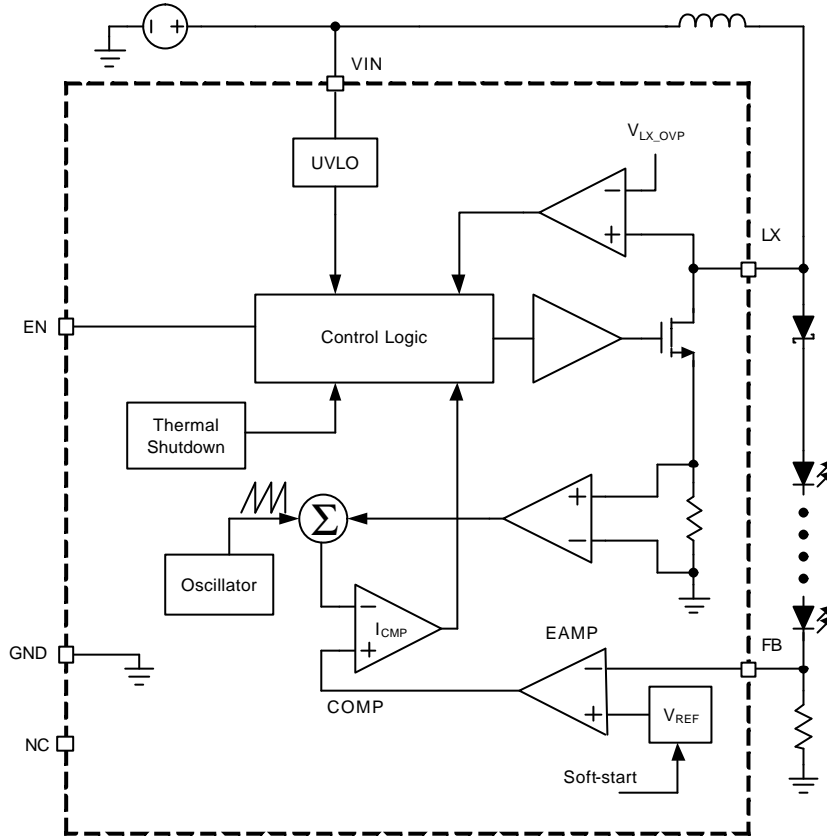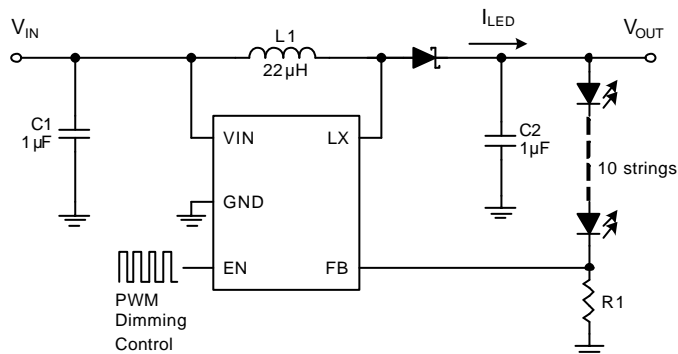CH2:V_LX-20V/div
CH3:V_EN-2V/div
CH4:I_L-500mA/div
Time:200ms/div
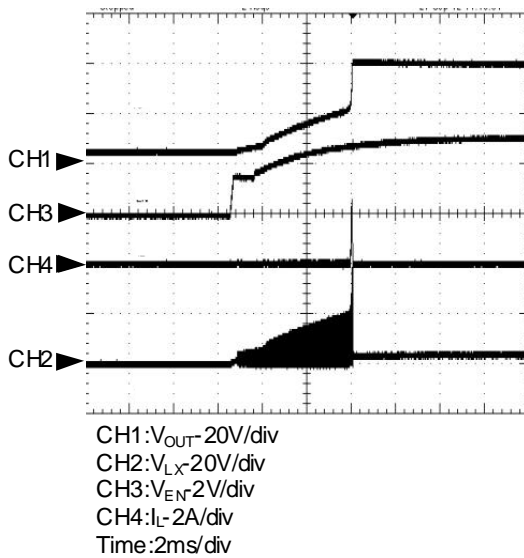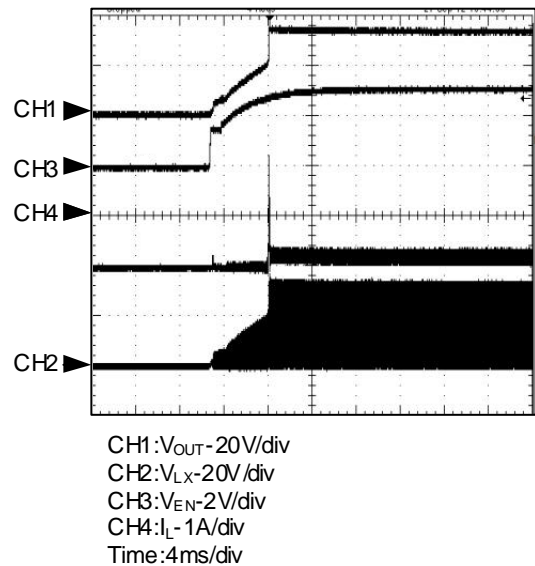
Block Diagram

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 dimmimg duty range is from 15% to 100% at 100kHz dimmimg 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, ΔI_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.

= 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:

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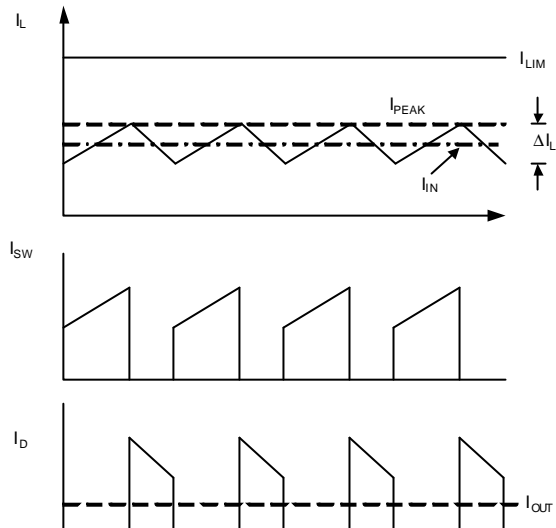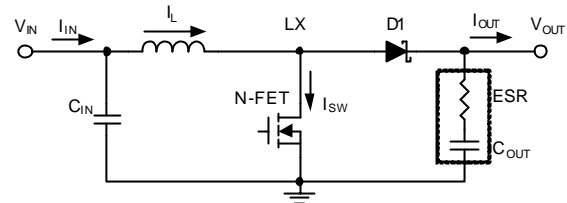
Output Capacitor Selection

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 ΔV_{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_{REF}. Therefore, the current (I_{LED}), flowing via the LEDs and the R1, is calculated by the following equation:

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

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 network 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
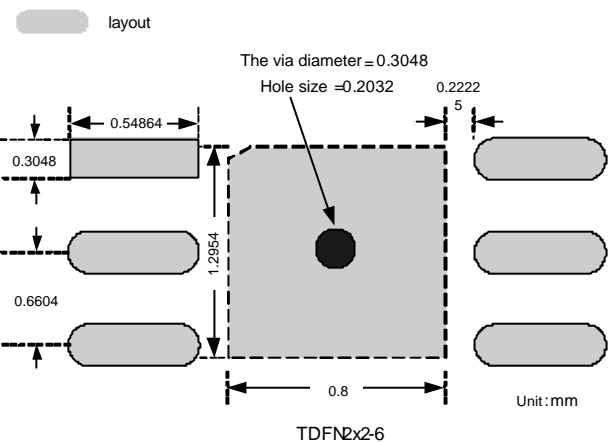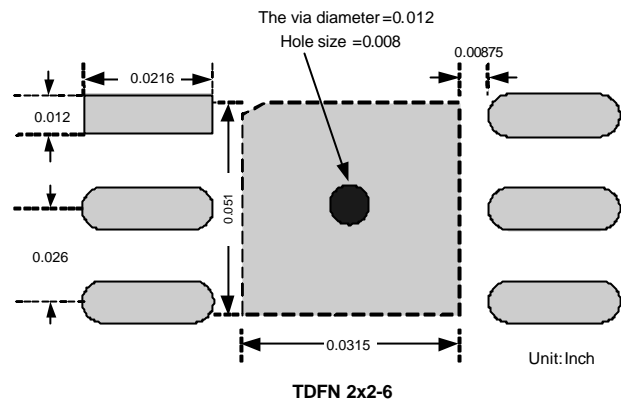
TDFN 2x2-6

TDFN2x2-6

Package Information

TDFN2x2-6
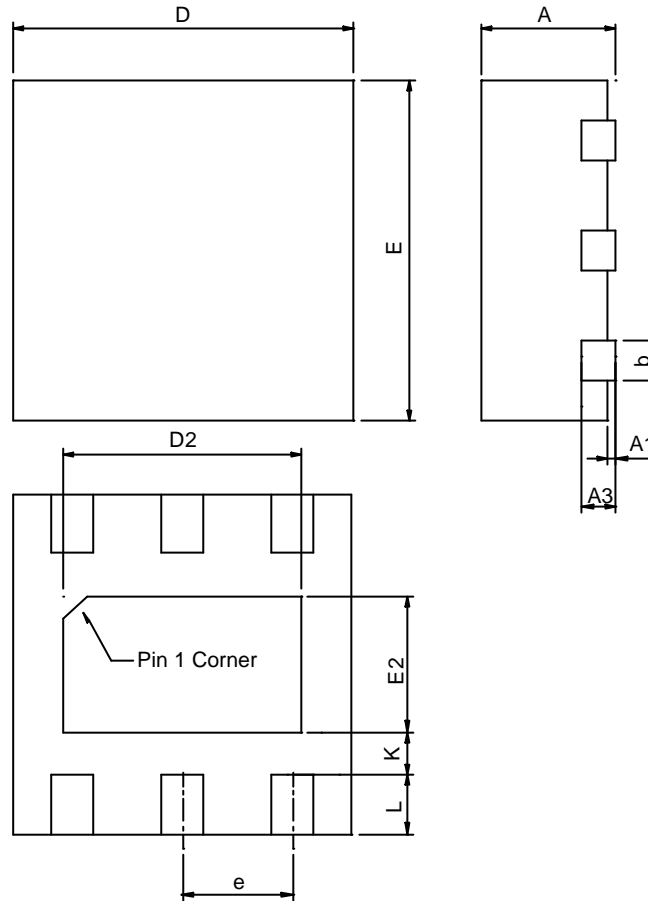
S Y M B O L	TDFN2x2-6			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.70	0.80	0.028	0.031
A1	0.00	0.05	0.000	0.002
A3	0.20 REF		0.008 REF	
b	0.18	0.30	0.007	0.012
D	1.90	2.10	0.075	0.083
D2	1.00	1.60	0.039	0.063
E	1.90	2.10	0.075	0.083
E2	0.60	1.00	0.024	0.039
e	0.65 BSC		0.026 BSC	
L	0.30	0.45	0.012	0.018
K	0.20		0.008	

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

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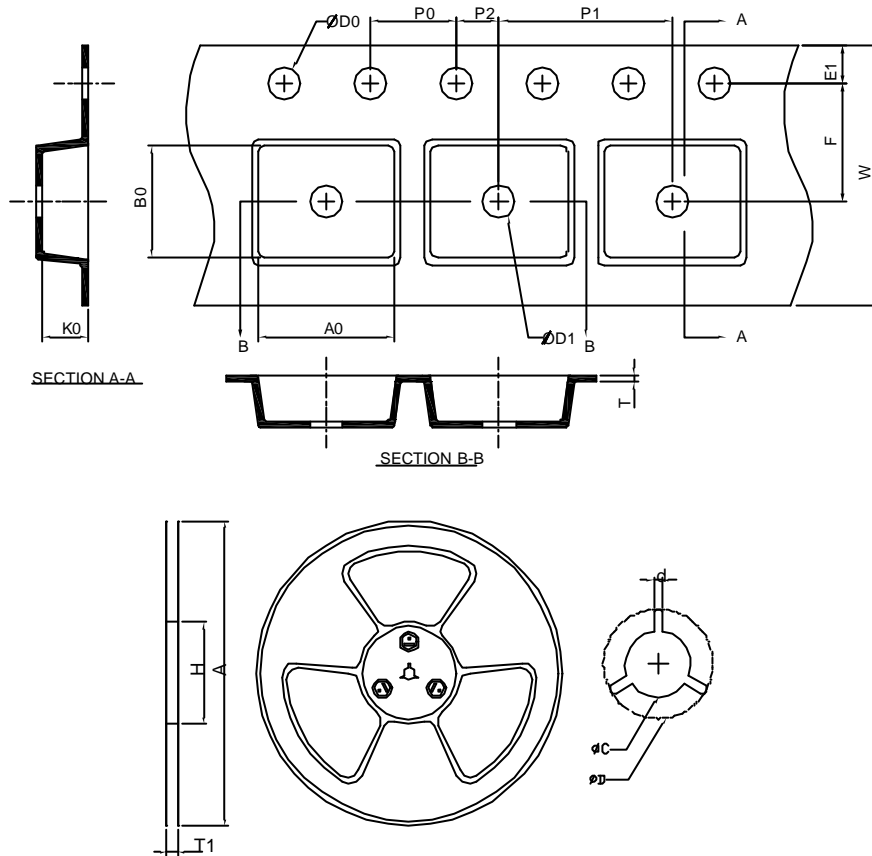
Application	A	H	T1	C	d	D	W	E1	F
	330.0±2.00	50 MIN.	12.4+2.00 -0.00	13.0+0.50 -0.20	1.5 MIN.	20.2 MIN.	12.0±0.30	1.75±0.10	5.5±0.05
TDFN2x2-6	P0	P1	P2	D0	D1	T	A0	B0	K0
	4.0±0.10	8.0±0.10	2.0±0.05	1.5+0.10 -0.00	1.5 MIN.	0.6+0.00 -0.40	2.35±0.20	2.35±0.20	1.30±0.20

(mm)

Devices Per Unit

Package Type	Unit	Quantity
TDFN2x2-6	Tape & Reel	3000

Taping Direction Information

TDFN2x2-6

USER DIRECTION OF FEED
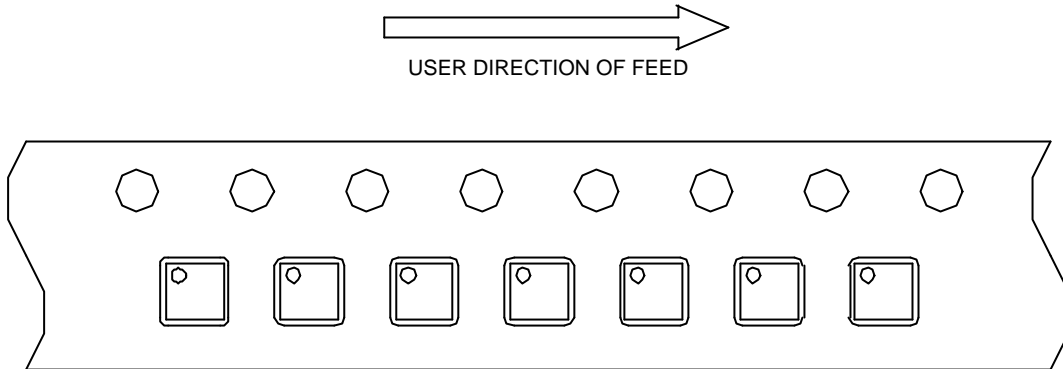
Classification Profile
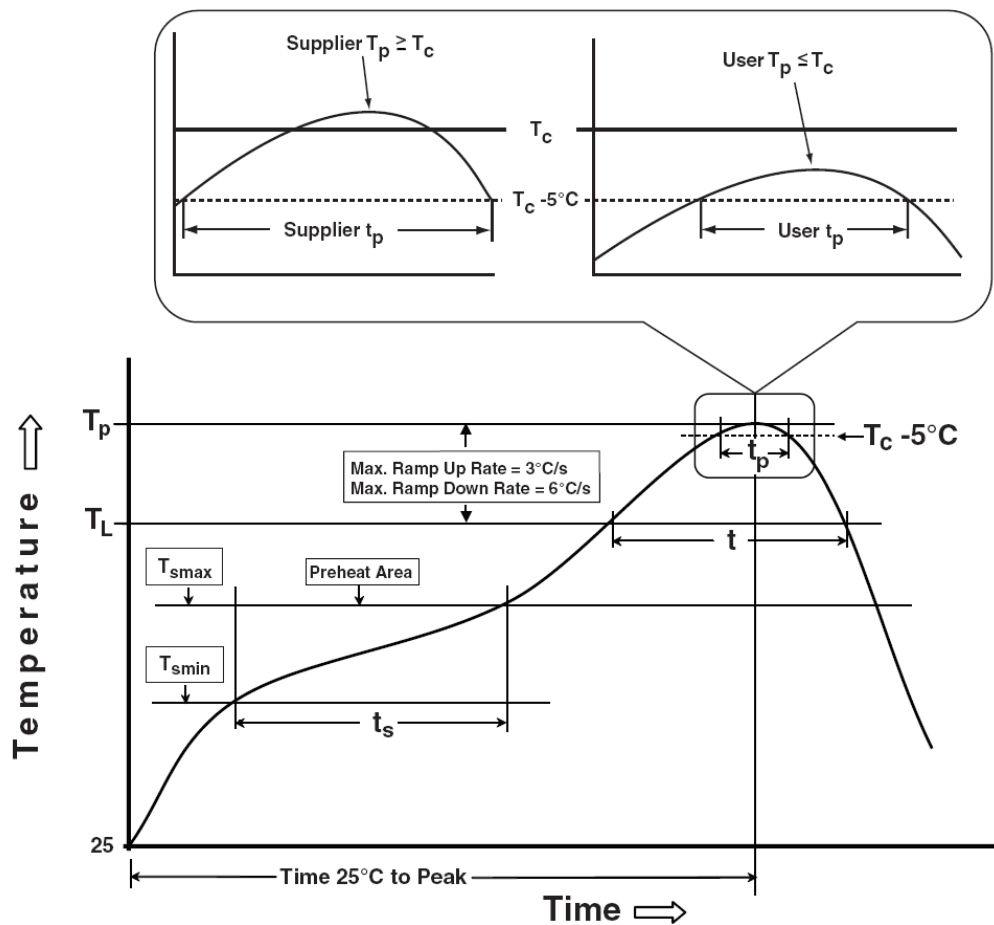
Classification Reflow Profiles

Profile Feature	Sn-Pb Eutectic Assembly	Pb-Free Assembly
Preheat & Soak Temperature min (T_{smin}) Temperature max (T_{smax}) Time (T_{smin} to T_{smax}) (t_s)	100 °C 150 °C 60-120 seconds	150 °C 200 °C 60-120 seconds
Average ramp-up rate (T_{smax} to T_P)	3 °C/second max.	3 °C/second max.
Liquidous temperature (T_L) Time at liquidous (t_L)	183 °C 60-150 seconds	217 °C 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 (Tc)

Package Thickness	Volume mm³ <350	Volume mm³ ³350
<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 mm³ <350	Volume mm³ 350-2000	Volume mm³ >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

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