White LED Driver with Backlighting and Flash Mode

■ General Description

With a 40-V rated integrated switch FET, the OCP81780VAD-G1 is a boost converter that drives LEDs in series. The boost converter runs at 800KHz fixed switching frequency to reduce output ripple, improve conversion efficiency, and allows for the use of small external components.

In backlighting mode, default white LED current is set with the external sensor resistor Rset, and the feedback voltage is regulated to 200mV. During the operation, A pulse width modulation (PWM) signal can be applied to the EN/PWM pin through which the duty cycle determines the feedback reference voltage. In PWM mode, the OCP81780VAD-G1 does not burst the LED current; therefore, it does not generate audible noises on the output capacitor.

In flash mode, the feedback voltage is regulated to 400mV to 600mV through 1-wire control on FLASH pin.

For maximum protection, the device features integrated open LED protection that disables the OCP81780VAD-G1 to prevent the output voltage from exceeding the IC's absolute maximum voltage ratings during open LED conditions.

The OCP81780VAD-G1 is available in a space-saving, 2mm × 2mm DFN package with thermal pad.

● Features

- 3V to 5.5V Input Voltage Range
- 37V Open LED Protection
- 200mV Reference Voltage in Backlighting Mode
- PWM Brightness Control in Backlighting Mode
- Built-in Soft Start
- 400mV to 600mV Reference Voltage in Flash Mode
- Flash Current Controlled By 1-wire Interface
- Up to 90% Efficiency
- 2mm × 2mm × 0.8mm DNF2X2-6L(6-pin DFN) Package With Thermal Pad

● Applications

- Cellular Phones
- Portable Media Players
- Ultra Mobile Devices
- GPS Receivers
- White LED Backlighting for Media Form Factor Display

Pin Configuration

DFN2X2-6L(TOP VIEW)

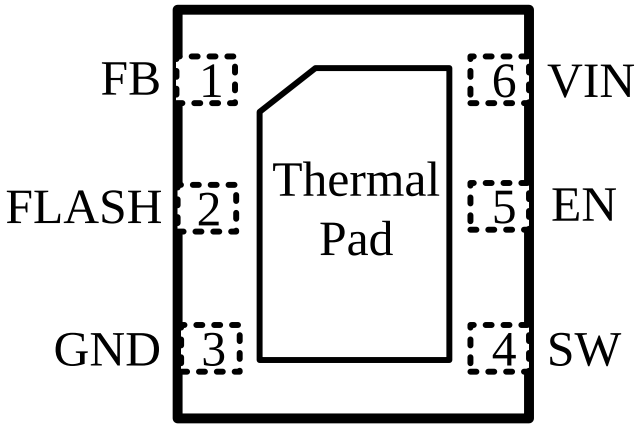


Figure 1, Pin Assignments of OCP81780VAD-G1

Pin Name	Pin No.	I/O	Pin Function
VIN	6	I	The input supply pin for the IC. Connect VIN to a supply voltage between 3V and 5.5V.
SW	4	O	This is the switching node of the IC. Connect the inductor between the VIN and SW pin. This pin is also used to sense the output voltage for open LED protection
GND	3	I	Ground
FB	1	I	Feedback pin for current. Connect the sense resistor from FB to GND.
FLASH	2	I	Flash mode 1-wire dimming interface pin.
EN/PWM	5	I	Control pin of the boost converter. It is a multi-functional pin which can be used for enable control, PWM dimming.
Thermal Pad			The thermal pad should be soldered to the analog ground plane. If possible, use thermal via to connect to ground plane for ideal power dissipation.

Typical Application Circuit

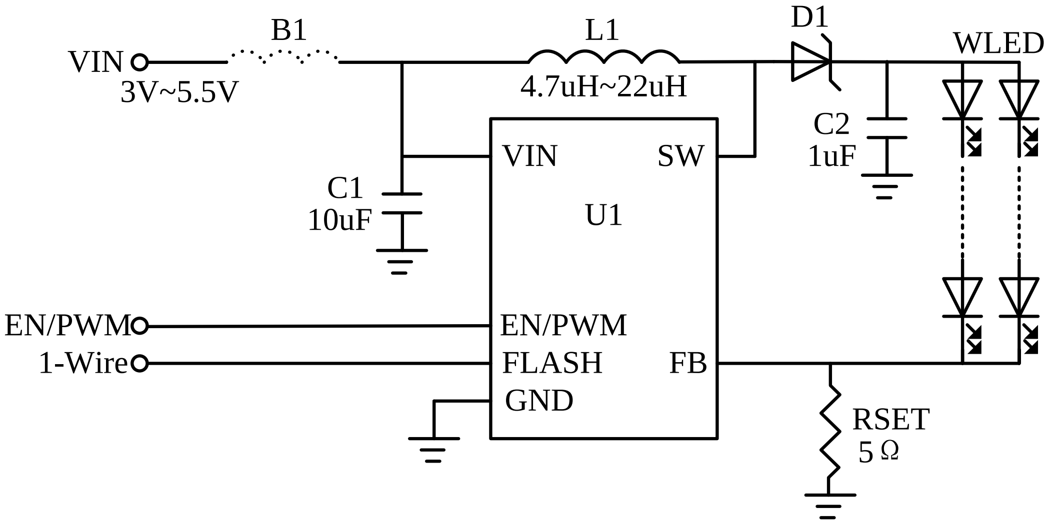


Figure 2, Typical Application Circuit of OCP81780VAD-G1

■ Block Diagram

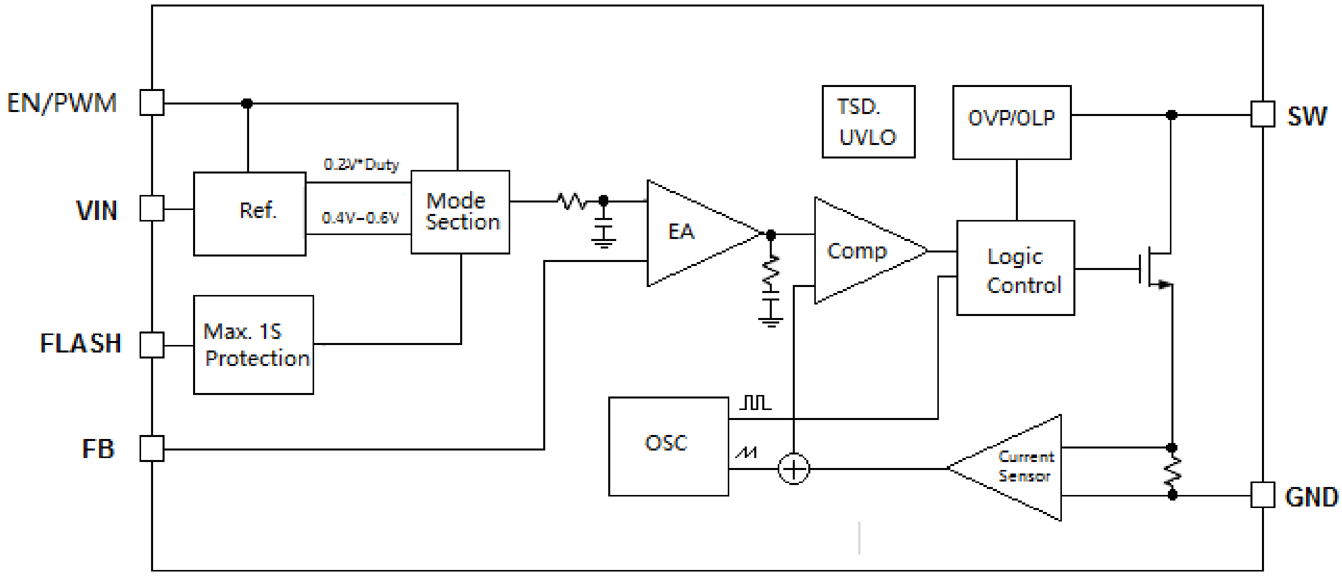


Figure 3, Block Diagram of OCP81780VAD-G1

■ Ordering Information

Part Number	Maximum VOUT	VFB	Package Type	Package Qty	Temperature	Eco Plan	Lead/Ball Finish
OCP81780VAD -G1	37V	200mV	DFN2X2-6L	7-in reel 3000pcs/reel	-40～85℃	Green	Ni/Pd/Au

Absolute Maximum Ratings (T_A=25°C, unless otherwise noted)

Parameter	Symbol	Rating	Unit
Supply Voltages on VIN	V_I	-0.3 to 6	V
V_{SW} Pin to GND	V_{SW}	-0.3 to 40	V
All Other Pins to GND		-0.3 to 6	V
Operating Junction Temperature Range	T_J	–40 to 150	℃
Storage Temperature Range	T_{STG}	–65 to 150	℃
Maximum Soldering Temperature (at leads, 10 sec)	T_{LEAD}	300	℃

Recommended Operating Conditions

Parameter	Symbol	Rating	Unit
Input voltage range	V_{IN}	3 to 5.5	V
Output voltage range	V_{SW}	V_{IN} to 37	V
Inductor	L1	4.7 to 22	μH
PWM dimming frequency	f_{dim}	5 to 100	kHZ
Output capacitor	C2	1 to 10	μF
Operating ambient temperature	T_A	-40 to 85	℃
Operating junction temperature	T_J	-40 to 125	℃

Electrical Characteristics

Typical limits tested at T_A= 25°C. Minimum and maximum limits apply over the full operating ambient temperature range(−40°C ≤T_A≤85°C). Unless otherwise specified, VIN= 3.6V, EN/PWM=High.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
SUPPLY CURRENT						
V_I	Input voltage range, VIN		3	-	5.5	V
I_Q	Operating quiescent current into VIN	Device PWM switching no load	-	-	1.8	mA
I_{SD}	Shutdown current	EN/PWM=GND, VIN = 4.2 V	-	-	1	μA
UVLO	Undervoltage lockout threshold	VIN falling	-	2.2	2.5	V
V_{hys}	Undervoltage lockout hysteresis		-	70	-	mV
EN/PWM AND FLASH CONTROL						
V_{IH}	logic high voltage	VIN = 3 V to 5.5 V	1.4	-	-	V
V_{IL}	logic low voltage	VIN = 3 V to 5.5 V	-	-	0.4	V
R_I	pull down resistor		400	800	1200	kΩ
$t_{min\_on\_en}$	Minimum on pulse width of EN/PWM pin		-	40	-	ns
$t_{sd\_delay\_en}$	EN/PWM shutdown delay time		-	1	-	ms
t_{H_flash}	high pulse width of Flash pin		5	-	50	μs
t_{L_flash}	low pulse width of Flash pin		5	-	50	μs
$t_{po\_delay\_flash}$	Flash power on delay time		-	500	-	μs
$t_{sd\_delay\_flash}$	Flash shutdown delay time		-	2.5	-	ms
Sd	Stable Dimming Range		0.3	1	100	%
VOLTAGE AND CURRENT CONTROL						
V_{REF}	Voltage feedback regulation voltage in backlighing mode	EN/PWM= High, FLASH=Low	-	200	-	mV
V_{REF_F}	Voltage feedback regulation voltage in flash mode	EN/PWM=High, FLASH=High(one pulse)	-	600	-	mV
I_{FB}	Voltage feedback input bias current	V_{FB}=200mV	-	-	2	μA
f_S	Oscillator frequency		-	800	-	kHz

D_{max}	Maximum duty cycle	V_{FB}= 100 mV, measured on the drive signal of the switching FET	93%	95%	-	
t_{max_flash}	Maximum flash time		-	1.2	-	s
POWER SWITCH						
$R_{DS(on)}$	N-channel MOSFET on-resistance	VIN=3.6	-	0.4	-	Ω
		VIN=3.0	-	-	0.7	
I_{LN_NFET}	N-channel leakage current	V_{SW}= 35 V	-	-	1	μA
OC and OLP						
I_{LIM}	N-Channel MOSFET current limit	D=D_{max}	-	1.2	-	A
I_{LIM_Start}	Start up current limit	D=D_{max}	-	0.6	-	A
I_{LIM_FLASH}	N-Channel MOSFET current limit in Flash Mode	D=D_{max}		1.8		A
t_{Half_LIM}	Time step for half current limit		-	5	-	ms
V_{ovp}	Open LED protection threshold	Measured on the SW pin	-	37	-	V
$V_{(FB\_OVP)}$	Open LED protection threshold on FB	Measured on the FB pin, percentage of Vref	-	50	-	%
t_{REF}	VREF filter time constant		-	180	-	μs
THERMAL SHUTDOWN						
$T_{shutdown}$	Thermal shutdown threshold		-	160	-	℃
$T_{hysteresis}$	hysteresis		-	15	-	℃

■ Typical Characteristics

Typical limits tested at T_A= 25°C. Minimum and maximum limits apply over the full operating ambient temperature range(−40°C ≤T_A≤85°C). Unless otherwise specified, VIN= 3.6V, EN/PWM=High.

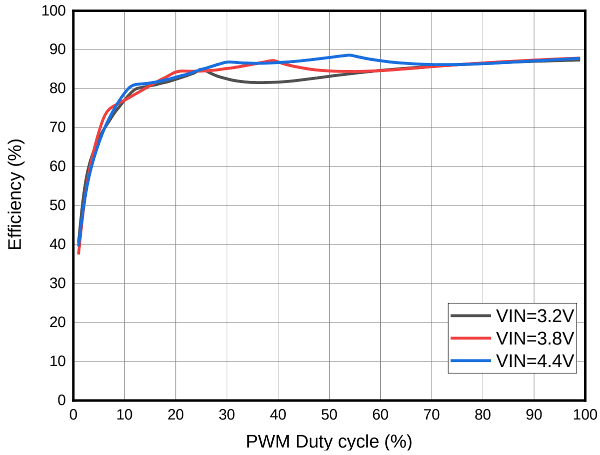


Figure 4-1. Efficiency&Duty（2P8S）

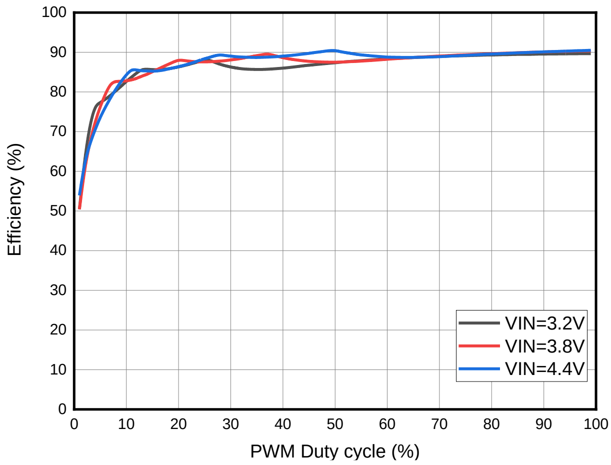


Figure 4-2. Efficiency&Duty（3P6S）

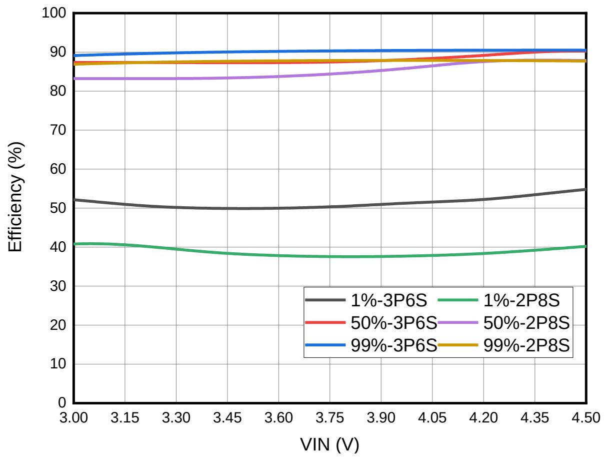


Figure 4-3． Efficiency&Input Voltage

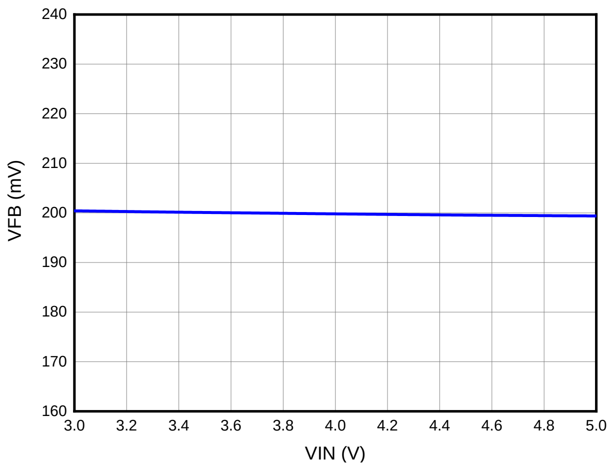


Figure 4-4． VIN&FB Voltage(Backlight Mode)

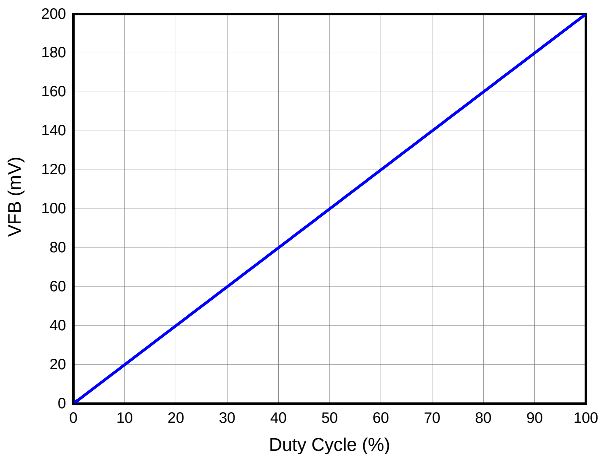


Figure 4-5． PWM Duty cycle&FB Voltage

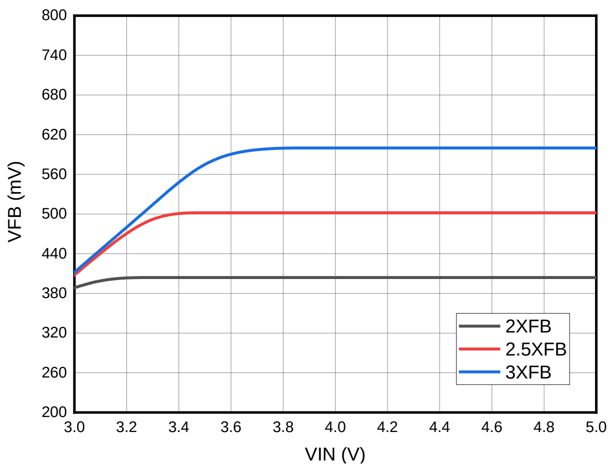


Figure 4-6． VIN&FB Voitage(Flash Mode)

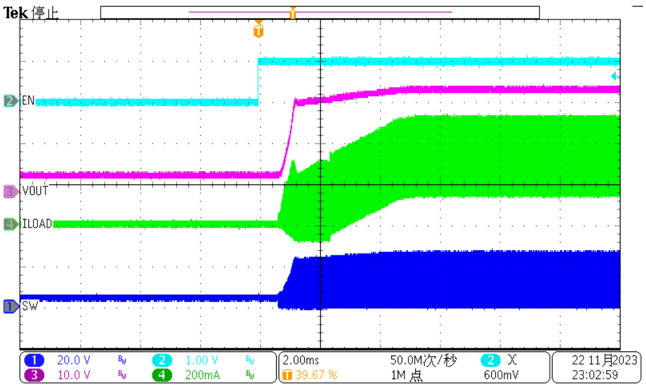


Figure 4-7．EN ON(Backlight Mode)

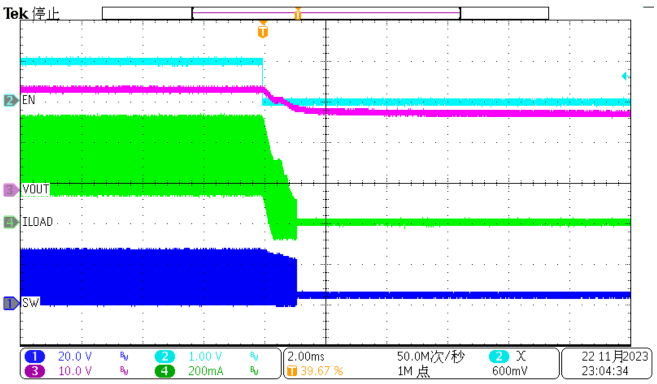


Figure 4-8．EN OFF(Backlight Mode)

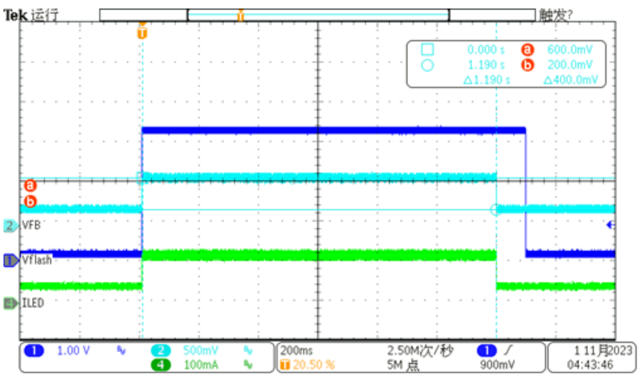


Figure 4-9．Timeout(Flash Mode)

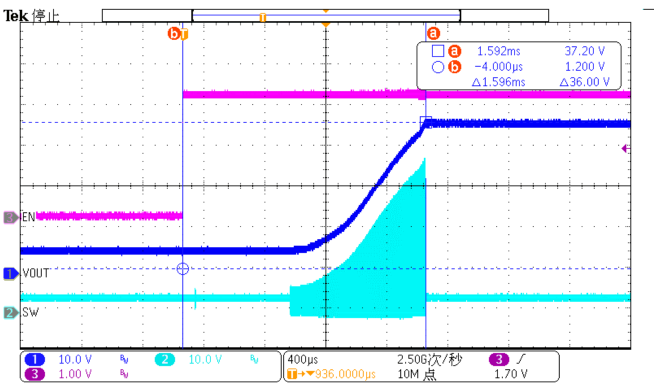


Figure 4-10．OVP(Backlight Mode)

■ Functional Description

1.OVERVIEW

The OCP81780VAD-G1 is a high efficiency, high output voltage boost converter in a small package size. The device is ideal for driving white LED in series. The serial LED connection provides even illumination by sourcing the same output current through all LEDs, eliminating the need for expensive factory calibration. The device integrates 40V/1.8A switch FET and operates in 800KHz fixed switching frequency. For operation see the block diagram. The duty cycle of the converter is set by the error amplifier output and the current signal applied to the PWM control comparator. The control architecture is based on traditional current mode control; therefore, a slope compensation is added to the current signal to allow stable operation for duty cycles larger than 50%. The OCP81780VAD-G1 can operate in two modes, In backlighting mode, The feedback loop regulates the FB pin to 200mV (typical). In flash mode, the feedback voltage is regulated to 400mV to 600mV through 1-wire control on FLASH pin.

2.BACKLIGHTING MODE

When FLASH=0, The OCP81780VAD-G1 works in backlighting mode, As shown in figure 4, The default white LED current is set with the external sensor resistor Rset, and the feedback voltage is regulated to 200V when EN/PWM pin's logic is high. A pulse width modulation (PWM) signal can be applied to the EN/PWM pin through which the duty cycle determines the feedback reference voltage. In PWM mode, the OCP81780VAD-G1 does not burst the LED current; therefore, it does not generate audible noises on the output capacitor.

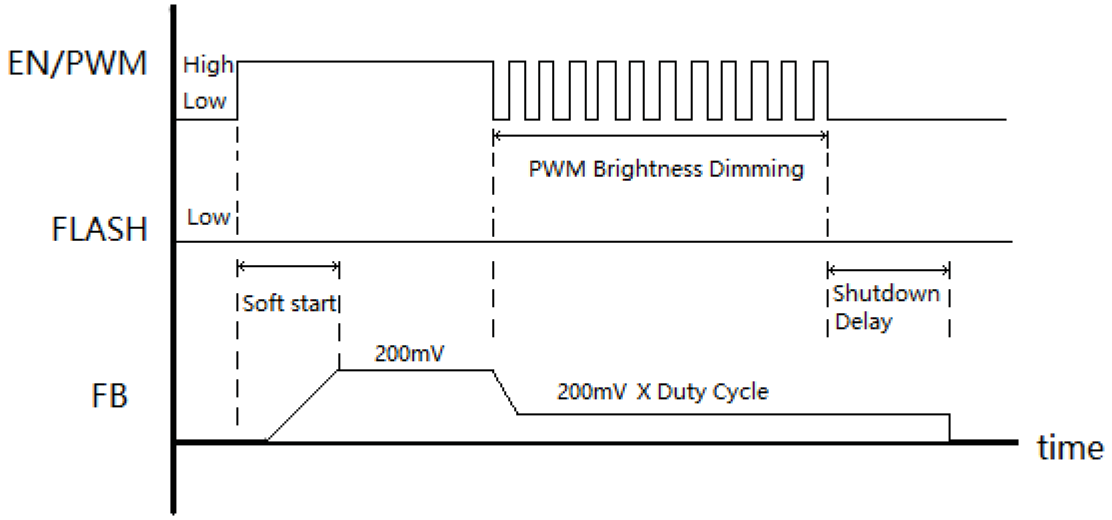


Figure 4, Backlighting Mode with Soft Start and PWM Brightness Dimming

2.1 Soft Strat-up

Soft-start circuitry is integrated into the IC to avoid a high inrush current during start-up. After the device is enabled, the voltage at FB pin ramps up to the reference voltage. This ensures that the output voltage rises slowly to reduce the input current. Additionally, for the first 5ms after the device enabled, the current limit of the switch is set to half of the normal current limit spec.

2.2 Shutdown

The OCP81780VAD-G1 enters shutdown mode when the EN/PWM voltage is logic low for more than 2.5ms. During shutdown, the input supply current for the device is less than 1μA (max). Although the internal FET does not switch in shutdown, there is still a DC current path between the input and the LEDs through the inductor and Schottky diode. The minimum forward voltage of the LED array must exceed the maximum input voltage to ensure that the LEDs remain off in shutdown. However, in the typical application with two or more LEDs, the forward voltage is large enough to reverse bias the Schottky and keep leakage current low.

2.3 Current Program

The FB voltage is regulated by a low 0.2V reference voltage. The LED current is programmed externally using a current-sense resistor in series with the LED string. The value of the R_{SET} is calculated using Equation 1:

$$I_{LED} = \frac{V_{FB}}{R_{SET}} \quad (1)$$

Where

I_{LED}=output current of LEDs

V_{FB}=regulated voltage of FB

R_{SET}=current sense resistor

The output current tolerance depends on the FB accuracy and the current sensor resistor accuracy

2.4 PWM Brightness Dimming

The EN/PWM pin can be used for the control input for PWM dimming mode. As shown in figure 5, the IC chops up the internal 200mV reference voltage at the duty cycle of the PWM signal. The pulse signal is then filtered by an internal low pass filter. The output of the filter is connected to the error amplifier as the reference voltage for the FB pin regulation. Therefore, although a PWM signal is used for brightness dimming, only the WLED DC current is modulated, which is often referred as analog dimming. This eliminates the audible noise which often occurs when the LED current is pulsed in replica of the frequency and duty cycle of PWM control. Unlike other scheme which filters the PWM signal for analog dimming, OCP81780VAD-G1 regulation voltage is independent of the PWM logic voltage level which often has large variations. Since the EN/PWM pin is logic only pin, adding an external RC filter applied to the pin does not work.

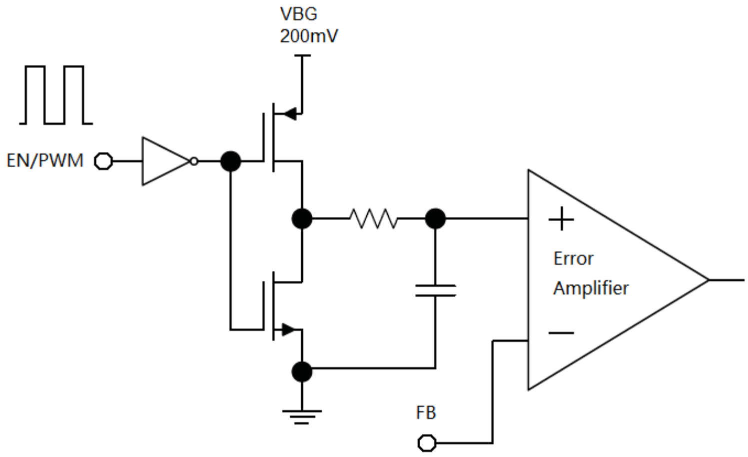


Figure 5, Block Diagram of Programmable FB Voltage Using PWM Signal

3.FLASH MODE

The flash mode is enabled when FLASH pin transitions from low to high and remain high for 500us, As shown in figure 6, the device includes a timer circuit of a 1s maximum time of flash mode, After timeout or FLASH pull down to low for 2.5ms,the voltage of FB roll back to voltage of backlighting mode.

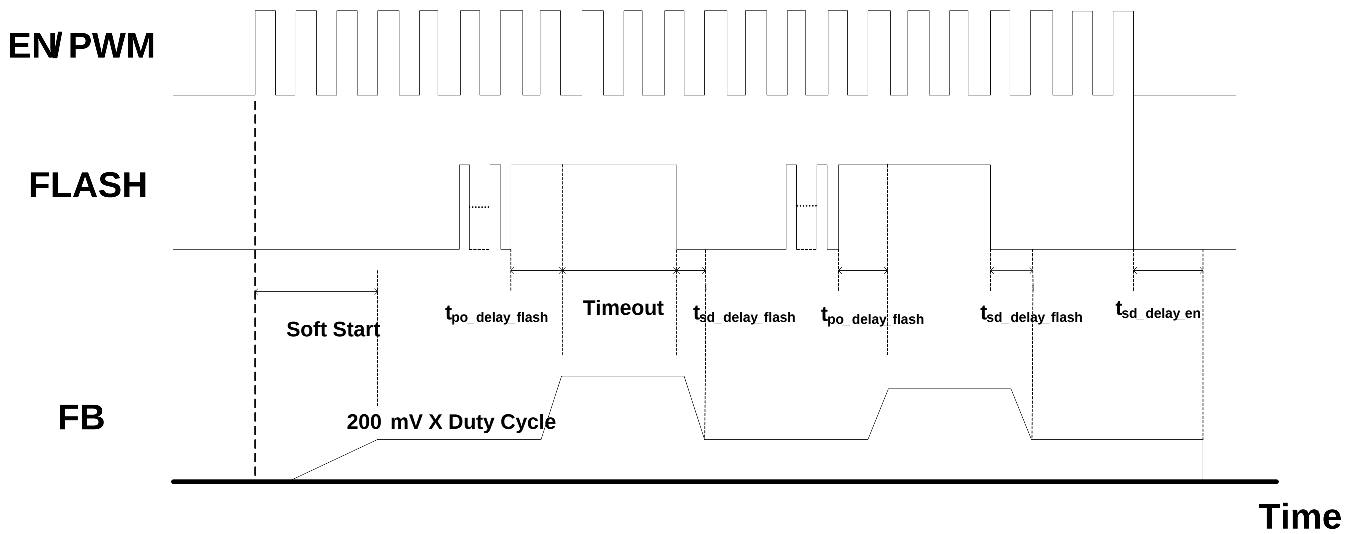


Figure 6, Flash Mode timing sequence

3.1 1-Wire Flash Current Dimming

The flash current can be programmed through 1-Wire control on FLASH pin as following describe, see Figure 7

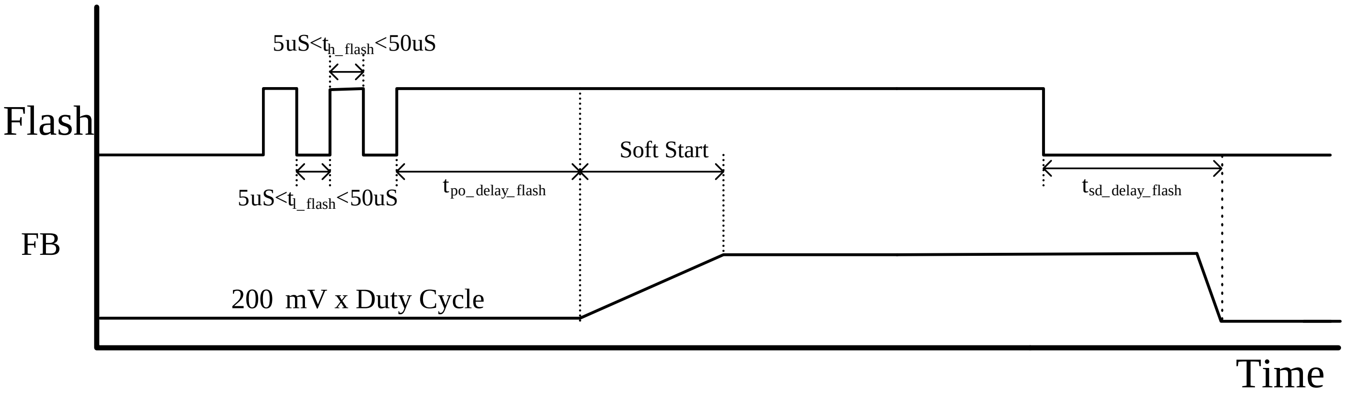


Figure 7, FLASH 1-Wire Control timing sequence

The range of $t_{min\_H\_flash}$ is 5us to 50us and 5us to50us for $t_{min\_L\_flash}$, flash mode shutdown when FLASH pin is logic low for more than 2.5ms.The voltage of FB depends on pulse numbers of FLASH pin as Table 1.

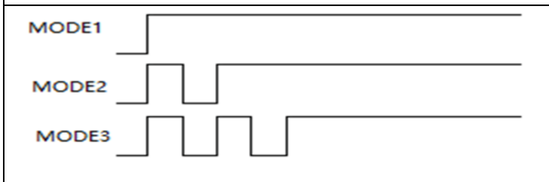
FLASH PIN INPUT	MODE	VFB(mV)
	MODE1	600
	MODE2	400
	MODE3	500

Table1, Flash Mode VFB setting

4.OPEN LED PROTECTION

Open LED protection circuitry prevents IC damage as the result of white LED disconnection. The OCP81780VAD-G1 monitors the voltage at the SW pin and FB pin during each switching cycle. The circuitry turns off the switch FET and shuts down the IC when both of the following conditions: (1) the SW voltage exceeds the V_{OVP} threshold and (2) the FB voltage is less than half of regulation voltage. As a result, the output voltage falls to the level of the input supply. The device remains in shutdown mode until it is enabled by toggling the EN/PWM pin logic. The threshold is set at 38V. Make sure that the product of the number of external LEDs and each LED's maximum forward voltage plus the 200mV reference voltage does not exceed the minimum OVP threshold or (N_{LEDS} X $V_{LED(MAX)}$)+200mV≤$V_{OVP(MIN)}$.

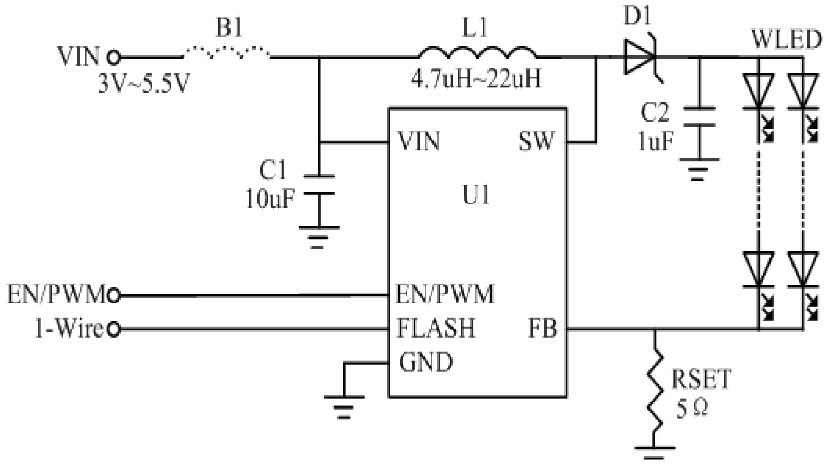
5.UNDERVOLTAGE LOCKOUT

An undervoltage lockout prevents operation of the device at input voltages below typical 2.2V. When the input voltage is below the undervoltage threshold, the device is shut down and the internal switch FET is turned off. If the input voltage rises by undervoltage lockout hysteresis, the IC restarts.

6.THERMAL SHUTDOWN

An internal thermal shutdown turns off the device when the typical junction temperature of 160°C is exceeded. The device is released from shutdown automatically when the junction temperature decreases by 15°C.

■ Application Information



Design Parameter	Example Value
PWM Dimming Control Frequency	5KHZ To 100KHZ
Inductor (L1)	4.7μH To 22μH
VOUT(max)	37V
B1	Optional for EMI design

Figure 8, OCP81780VAD-G1 Typical Application

Input Capacitor (C1) Selection

The input capacitor can reduce peak current and noise at power source. Choosing the correct size and type of input capacitor helps minimize the input voltage ripple caused by the switching of the OCP81780VAD-G1 's boost converter, and reduces noise on the boost converters input terminal that can feed through and disrupt internal analog signals. The capacitor in the range of 1uF to 10uF is recommended for input side. It is important to place the input capacitor as close as possible to the OCP81780VAD-G1 's input (VIN) terminals. This reduces the series resistance and inductance that can inject noise into the device due to the input switching currents.

Output Capacitor (C2) Selection

To estimate the output voltage ripple considering the ripple due to capacitor discharge (ΔVQ) and the ripple due to the capacitors ESR (ΔVESR) use the following equations.

The output capacitor is mainly selected to meet the requirements for the output ripple and loop stability. This ripple voltage is related to the capacitor's capacitance and its equivalent series resistance (ESR). Assuming a capacitor with zero ESR, the minimum capacitance needed for a given ripple can be calculated by:

$$C_{OUT}=\frac{I_{OUT}\times(V_{OUT}-V_{IN})}{V_{OUT}\times V_{RIPPLE}\times F_S} \quad (2)$$

Where, V_{RIPPLE}=peak-to-peak output ripple. The additional output ripple component caused by ESR is calculated using:

$$V_{RIPPLE\_ESR}=[(\frac{I_{OUT}\times V_{OUT}}{V_{IN}})+\frac{V_{IN}\times(V_{OUT}-V_{IN})}{2\times F_S\times L\times V_{OUT}}]\times R_{ESR} \quad (3)$$

Due to its low ESR, V_{RIPPLE_ESR} can be neglected for ceramic capacitors, but must be considered if tantalum or electrolytic capacitors are used.

Inductor (L1) Selection

The selection of the inductor affects steady state operation as well as transient behavior and loop stability. These factors make it the most important component in power regulator design. There are three important inductor specifications, inductor value, DC resistance and saturation current. Considering inductor value alone is not enough.

The OCP81780VAD-G1 is designed to use a 4.7µH to 22µH inductor. When the device is boosting (VOUT>VIN) the inductor is typically the largest area of efficiency loss in the circuit. Therefore, choosing an inductor with the lowest possible series resistance is important. Additionally, the saturation rating of the inductor should be greater than the maximum operating peak current of the OCP81780VAD-G1. This prevents excess efficiency loss that can occur with inductors that operate in saturation. For proper inductor operation and circuit performance, ensure that the inductor saturation and the peak current limit setting of the OCP81780VAD-G1 are greater than I_{PEAK} in the following calculation:

$$I_{PEAK} = \frac{I_{LOAD}}{\eta} \times \frac{V_{OUT}}{V_{IN}} + DI_L \tag{4}$$

Where

$$DI_L = \frac{V_{IN} \times (V_{OUT} - V_{IN})}{2 \times f_{SW} \times L \times V_{OUT}} \tag{5}$$

$$fSW = 800KHz \tag{6}$$

The inductor value determines the inductor ripple current. Choose an inductor that can handle the necessary peak current without saturating, according to half of the peak-to-peak ripple current given by Equation 3, pause the inductor DC current given by:

$$I_{in\_DC} = \frac{V_{out} \times I_{out}}{V_{in} \times \eta} \tag{7}$$

Inductor values can have ±20% tolerance with no current bias. When the inductor current approaches saturation level, its inductance can decrease 20% to 35% from the 0A value depending on how the inductor vendor defines saturation current. Using an inductor with a smaller inductance value forces discontinuous PWM when the inductor current ramps down to zero before the end of each switching cycle. This reduces the boost converter's maximum output current, causes large input voltage ripple and reduces efficiency. Large inductance value provides much more output current and higher conversion efficiency. For these reasons, a 4.7μH to 22μH inductor value range is recommended. A 10μH inductor optimized the efficiency for most application while maintaining low inductor peak to peak ripple.

OCP81780VAD-G1 has built-in slope compensation to avoid sub-harmonic oscillation associated with current mode control. If the inductor value is lower than 4.7μH, the slope compensation may not be adequate, and the loop can be unstable.

Maximum Output Current

The over current limit in a boost converter limits the maximum input current and thus maximum input power for a given input voltage. Maximum output power is less than maximum input power due to power conversion losses. Therefore, the current limit setting, input voltage, output voltage and efficiency can all change maximum current output. The current limit clamps the peak inductor current; therefore, the ripple has to be subtracted to derive maximum DC current. The ripple current is a function of switching frequency, inductor value and duty cycle. The following equations take into account of all the above factors for maximum output current calculation.

$$Ip = \frac{1}{L \times F_S \times \left(\frac{1}{V_{OUT} + V_f - V_{in}} + \frac{1}{V_{in}} \right)} \tag{8}$$

Where:
Ip= inductor peak to peak ripple;
L = inductor value;
V_f= Schottky diode forward voltage;
Fs = switching frequency;
Vout = output voltage of the boost converter. It is equal to the sum of VFB and the voltage drop across LEDs.

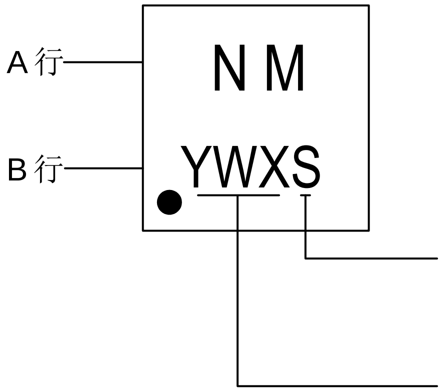
$$I_{out\_max} = \frac{V_{in} \times (I_{lim} - I_p/2) \times \eta}{V_{out}} \tag{9}$$

Where:
I_{out_max}= maximum output current of the boost converter;
I_{lim}= over current limit;
η = efficiency.

For instance, when VIN is 5V, 10 LEDs output equivalent to VOUT of 32V, the inductor is 10μH, the Schottky forward voltage is 0.2V; and then the maximum output current is 80mA in typical condition.

Marking Information

DFN2X2-6L：

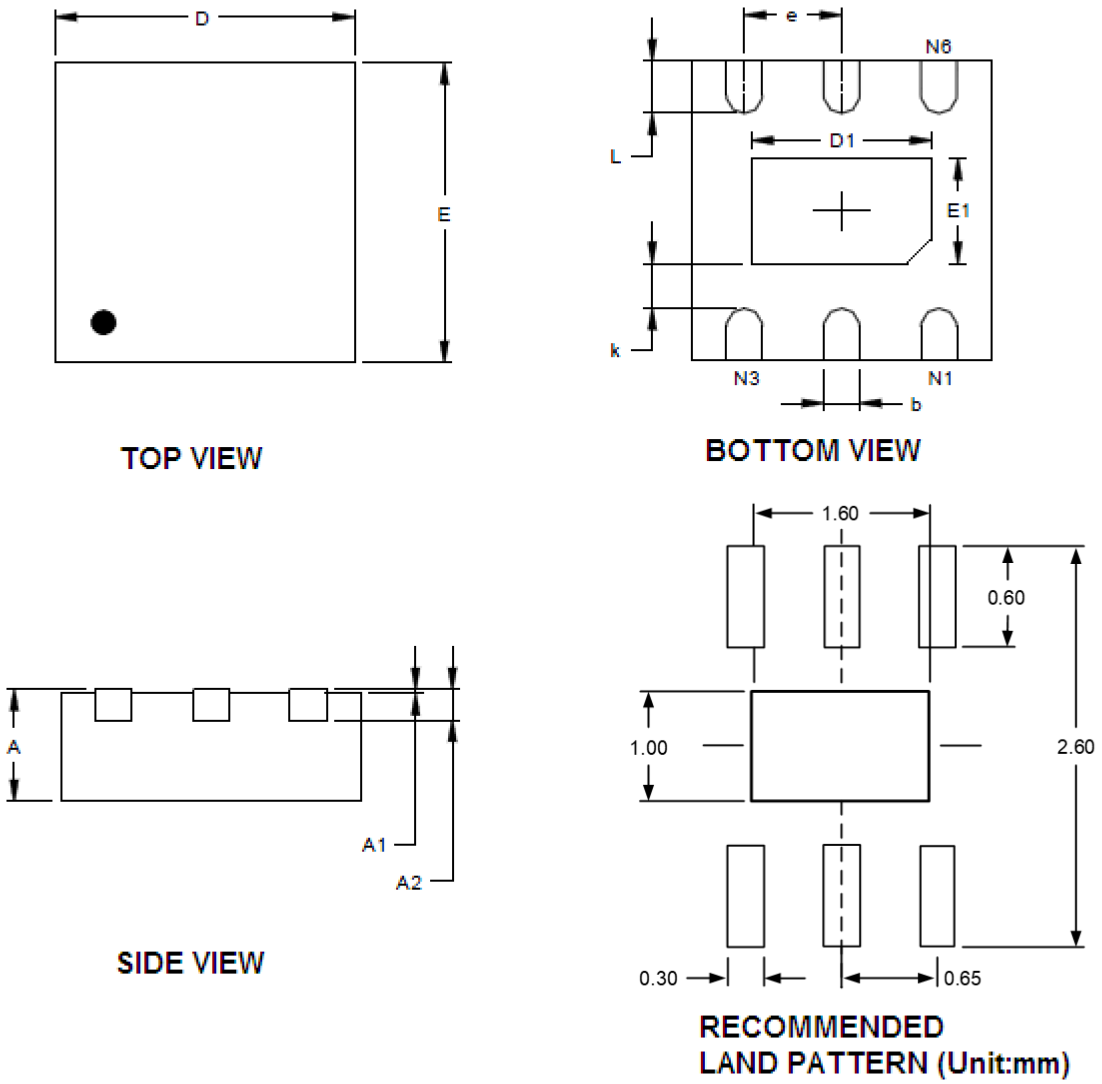


Internal code

Date code ：
Y： Year(1=2021)
W： Nth week(01~52)
A~Z：1 ~ 26 week
a~z：27~ 52 week
X： Lot No.A~Z,a~z,0~9

Package Information

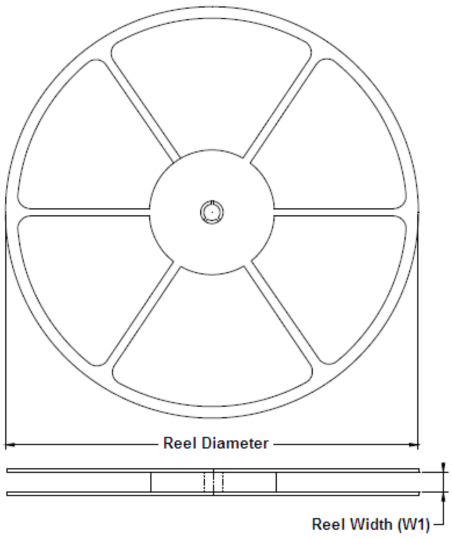
DFN2X2-6L:



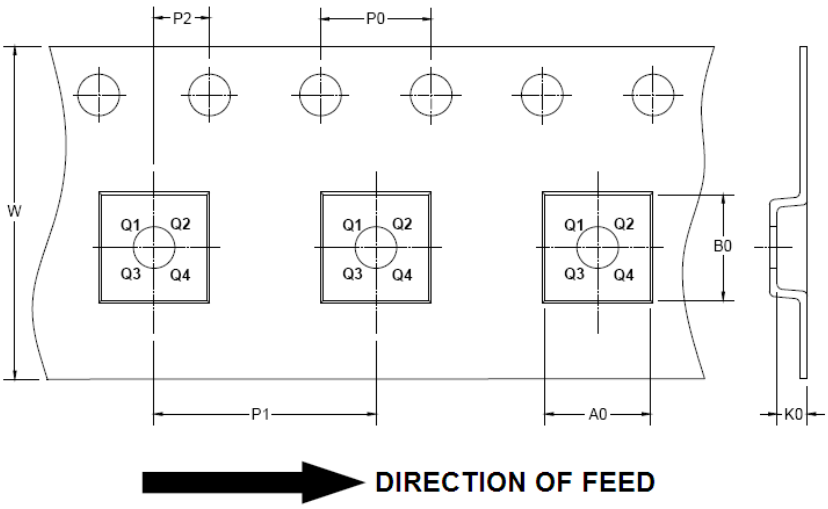
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN.	MAX.	MIN.	MAX.
A	0.7	0.8	0.028	0.031
A1	0	0.05	0	0.002
A2	0.203 REF		0.008 REF	
D	1.9	2.1	0.075	0.083
D1	1.5	1.7	0.059	0.067
E	1.9	2.1	0.075	0.083
E1	0.9	1.1	0.035	0.043
k	0.250 REF		0.010 REF	
b	0.25	0.35	0.010	0.014
e	0.650 TYP		0.026 TYP	
L	0.174	0.326	0.01	0.013

■ Packing Information

REEL DIMENSIONS



TAPE DIMENSIONS



Note: The picture is only for reference. Please make the object as the standard.

Key parameter list of tape and reel

Package Type	Reel Diameter	SPQ (PCS)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
DFN2X2-6L	7″	3000	9	2.3	2.3	1.1	4	4	2	8	Q1

IMPORTANT NOTICE

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