

### Description

The YB1313 charge pump is designed to drive up to 5 white LEDs with regulated constant current in back lit display application. The device can provide up to 25 mA per LED for a total of more than 125 mA. The input voltage ranges from 2.7V to 5.5V and is ideal for applications powered by a single LI-Ion or 3 to 4 NiCd, NiMH or Alkaline batteries.

The 1MHz fix-frequency switching allows for tiny external components, and the regulation scheme is optimized to ensure low EMI and low input ripple.

Internal soft-start circuitry effectively reduces the in-rush current. YB1313 also provides short circuit protection, over-temperature protection and over-voltage protection. In shutdown mode, the shutdown current is less than 1 $\mu$ A. YB1313 is available in a TQFN-16 3x3 package.

### Features

- Input Range : 2.7V to 5.5V
- Drives up to 5 LEDs at 25mA Each
- 1MHz Internal Oscillator
- Thermal Protection Shutdown
- Output Short-circuit Current Limit and Over-voltage Protection
- Under-Voltage Lockout With Hysteresis
- Automatic Soft-Start Reduces In-Rush Current
- Three Charge Pump Mode : 1x/1.5x/2x
- 3mm x 3mm TQFN package

### Applications

- White LED Backlighting
- Handheld PCs and PDAs
- Mobile Phone

### Typical Application Circuit

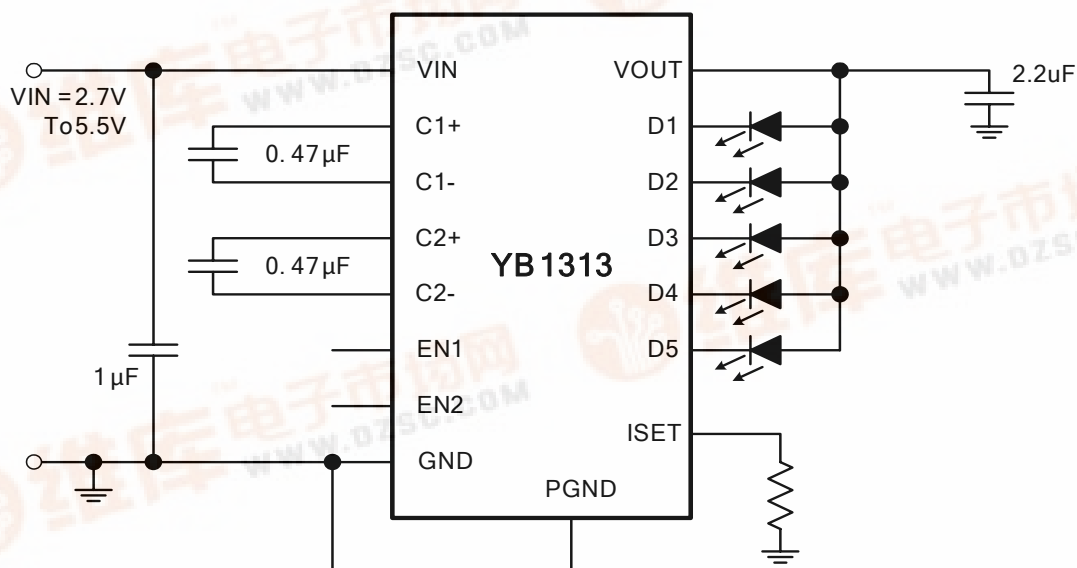


Figure 1. Typical application circuit

### Pin Configuration

TQFN-16 3x3 Package

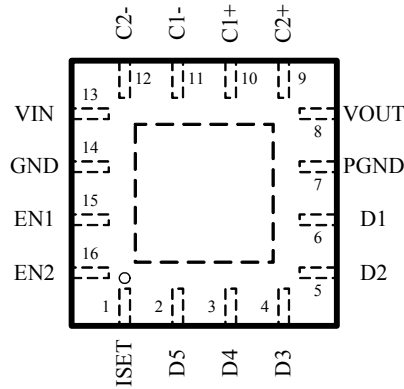


Figure 2. Pin configuration

### Pin Description

Table 1

Pin	Name	Description
1	I <sub>SET</sub>	Connect a R <sub>SET</sub> resistor between this pin and GND. R <sub>SET</sub> =10K, set I <sub>LED</sub> to 20 mA (Recommended)
2	D5	Current sink output #5. If not used, connected to V <sub>IN</sub> or floating
3	D4	Current sink output #4. If not used, connected to V <sub>IN</sub> or floating
4	D3	Current sink output #3. If not used, connected to V <sub>IN</sub> or floating
5	D2	Current sink output #2. If not used, connected to V <sub>IN</sub> or floating
6	D1	Current sink output #1. If not used, connected to V <sub>IN</sub> or floating
7	PGND	Power GND
8	V <sub>OUT</sub>	Charge pump output
9	C2+	Flying capacitor 2 positive terminal. Connect a 0.47μF capacitor between C2+ and C2-.
10	C1+	Flying capacitor 1 positive terminal. Connect a 0.47μF capacitor between C1+ and C1-
11	C1-	Flying capacitor 1 negative terminal
12	C2-	Flying capacitor 2 negative terminal
13	V <sub>IN</sub>	Input Voltage
14	GND	Analog GND
15	EN1	Enable input1
16	EN2	Enable input2. EN1 and EN2 can be used for digital dimming with 4 steps from 0mA to the maximum current set with I <sub>SET</sub> .

### Ordering Information

Table 2

Order Number	Package Type	Supplied as	Package Marking
YB1313QF33	TQFN 3X3	2500 units Tape & Reel	1313

### Absolute Maximum Ratings

- Supply Voltage..... 6.5V
- Output Voltage..... 5.5V
- Output Short-Circuit Duration..... Continuous
- Junction Temperature Range ..... +125°C
- Storage Temperature Range.....-65°C to +150°C
- Lead Temperature ..... +250°C

### Recommended Operating Conditions

- Input Supply Voltage..... 2.7V to 5.5V
- Operating Temperature..... -40°C to +85°C

### Electrical Characteristics

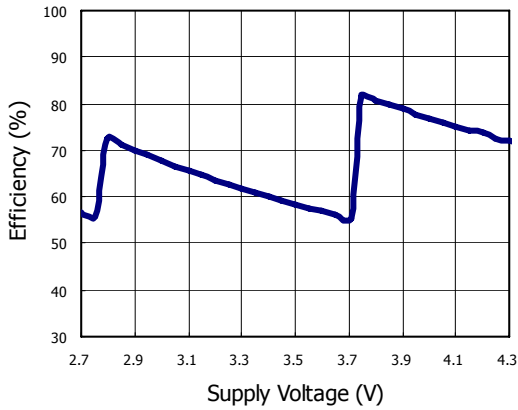
**Table 3** At  $T_A=25^\circ\text{C}$ ,  $V_{IN}=3.5\text{V}$ ,  $C_{IN}=1\mu\text{F}$ ,  $C_1=C_2=0.47\mu\text{F}$ ,  $C_{OUT}=2.2\mu\text{F}$ ,  $EN1=EN2=V_{IN}$ , unless otherwise noted.

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>SUPPLY VOLTAGE AND CURRENT</b>						
$V_{IN}$	Input voltage range		2.7		5.5	V
$I_Q$	Operating quiescent current	1x		800		$\mu\text{A}$
		1.5x		3		mA
$I_{SD}$	Shutdown current	$V_{IN} = 3.5\text{V}$ , $EN1 = EN2 = 0\text{V}$			1	$\mu\text{A}$
<b>CHARGE PUMP STAGE</b>						
$V_{OUT}$	Over-voltage limit	LED unconnected, $V_{IN}=4.2\text{V}$		5.5		V
$F_{OSC}$	Switching frequency		0.6	0.8	1	MHz
$\eta_{CP}$	Charge pump efficiency	$V_{IN} = 3.5\text{V}$ , 1.5x mode		93		%
	Shutdown temperature	Temperature rising		160		$^\circ\text{C}$
	Recovery temperature	Temperature falling		140		$^\circ\text{C}$
<b>CURRENT SINKS</b>						
k	$I_{LED}$ to $I_{SET}$ current ratio	$EN1=EN2=1$ , $R_{ISET}=10\text{K}$	290	320	350	
$\Delta I_{LED}/I_{LED}(\text{min})$	Current matching between any two outputs <sup>2</sup>	$V_{LED} = 3.5\text{V}$ , $T_A = 25^\circ\text{C}$		0.4	2.0	%
$\Delta I_{LED}/\Delta V_{IN}$	Line regulation	$2.7\text{V} \leq V_{IN} \leq 4.3\text{V}$	2.0	3.0	4.0	%/V
$V_{ISET}$	Reference voltage for current set	$EN1 = 1$ , $EN2 = 0$		200		mV
		$EN1 = 0$ , $EN2 = 1$		400		mV
		$EN1 = 1$ , $EN2 = 1$	600	620	640	mV
<b>ENABLE 1, ENABLE 2</b>						
$V_{(UVLO)}$	Under-Voltage Lockout	Supply voltage falling		2.3		V
	UVLO hysteresis			100		mV
$V_{IH}$	EN1, EN2 Threshold high	$V_{IN} = 5.5\text{V}$	1.6			V
$V_{IL}$	EN1, EN2 Threshold low	$V_{IN} = 2.7\text{V}$			0.4	V
$F_{PWM}$	Frequency range at PWM	EN1, EN2 shorted for PWM control	0		5	kHz

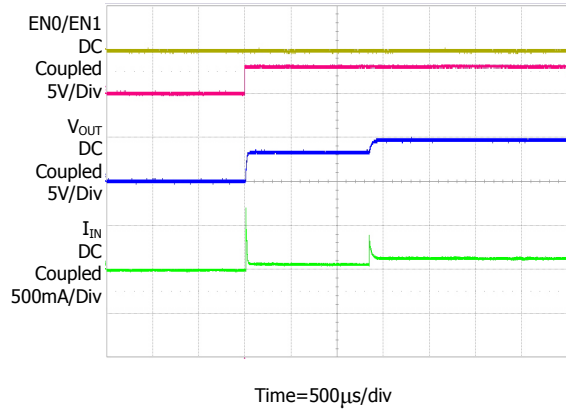
**Typical Characteristics**

$V_{IN}=3.6V$ ,  $C_{IN}=C_1=C_2=1\mu F$ ,  $C_{OUT}=2.2\mu F$ , unless otherwise noted.

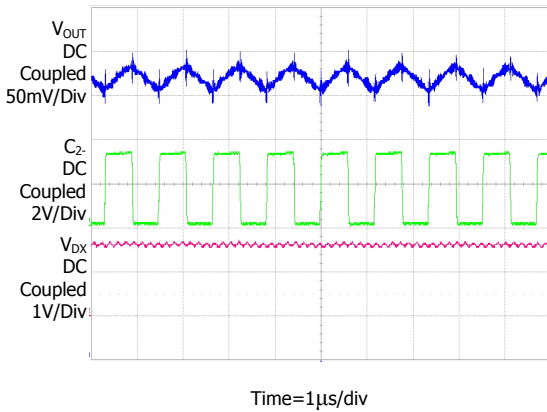
**Efficiency vs. Supply Voltage (Full Load)**



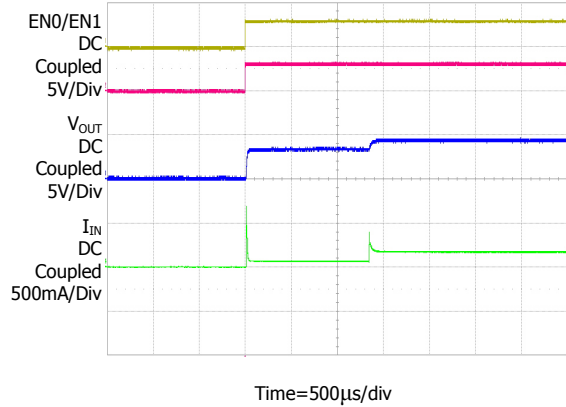
**1.5X Mode Inrush Current 2/3 Load**



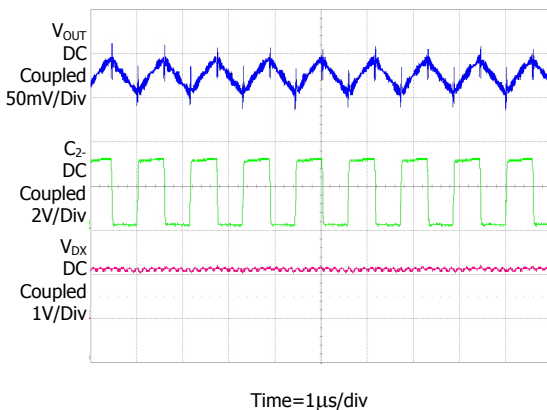
**1.5X Mode, 2/3 Load**



**1.5X Mode Inrush Current Full Load**



**1.5X Mode, Full Load**



**Functional Block**

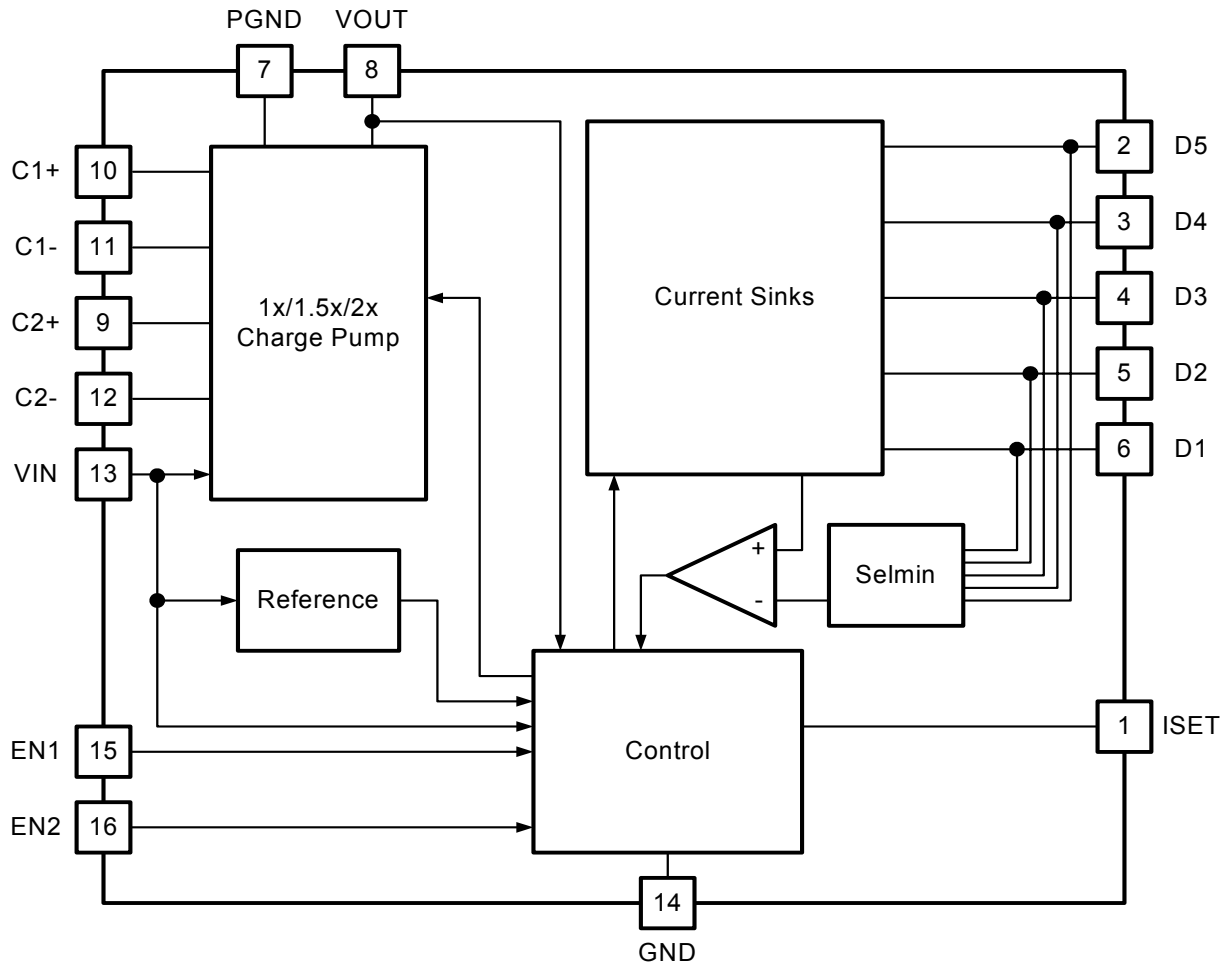


Figure 3. Block Diagram

**Functional Description**

The YB1313 uses a multi-mode fractional charge pump to generate a supply voltage and a precise sink circuitry to ensure a constant driving current for each LED. The charge pump operates in either 1x mode, 1.5x mode or 2x mode, depending on the input voltage and output current loading. The overall power consumption is best optimized by automatically switching among the 3 different operation mode.

The charge pump is possible to generate a total output current of more than 125 mA, more than 25 mA for each LED. But it is recommended to operate the device under total 125 mA. Connecting a  $R_{SET}$  resistor of 10K ohm from pin  $I_{SET}$  to ground generates around 20 mA LED output current and a  $R_{SET}$  of 7.5K generates around 26 mA.

### Applications Information

#### Soft-Start Circuitry

The YB1313 includes soft-start circuitry to limit inrush current at turn-on. Once the input voltage is applied, the output capacitor is charged directly from the input with a ramped current source (with no charge-pump action) until the output voltage approaches the input voltage. Once this occurs, the charge pump determines if 1x, 1.5x, 2x mode is required. In the case of 1x mode, the soft-start is terminated and normal operation begins. In the case of 1.5x or 2x mode, soft-start operated until the lowest of LED1-LED4 reaches regulation.

#### ENABLE (EN1, EN2)

The enable pins EN1 and EN2 are used to enable the device or set it into shutdown. The YB1313 is enabled if one of the enable pins is pulled higher than the enable trip point of 1.2V. The device starts up by going through the soft start routine as described in the section Soft Start. Pulling both pins to GND, after a delay, programs the device to shutdown. In shutdown, the charge pump, current sources, voltage reference, oscillator, and all other functions are turned off and the supply current is reduced to 0.1μA.

EN1 and EN2 can also be used for dimming. The logic levels at EN1 and EN2 set the minimum voltage at the current mirrors and the voltage at the ISET pin to GND. This sets the current at the LEDs to be either the full current or a fraction of the full current. See Table 4 for further details. The maximum current through the LEDs is set by a resistor connected between

ISET and GND.

EN1 and EN2 can also be used for PWM dimming. The PWM signal can either be applied to EN1 or EN2, or both inputs can be tied together and the PWM signal can be applied to both pins. Depending on the configuration, the current during PWM dimming is switched between 0 mA and its maximum (EN1 and EN2 connected to the PWM signal) or between 0 mA and 1/3 of the full LED current if EN2=0 and EN1 is toggled. When EN1 = 0 and EN2 is toggled, the output current can be changed between 0 mA and 2/3 of the full range.

Table 4. Enable Levels

Enable Level		MODE	LED Current
EN2	EN1		
0	0	Shutdown	0
0	1	$V_{ISET}=200mV$	1/3
1	0	$V_{ISET}=400mV$	2/3
1	1	$V_{ISET}=620mV$	Full

#### LED Current Setting

The current of white LED connected to YB1313 can be set by  $R_{SET}$ . Every current flows through the white LED is 320 times greater than the current of  $R_{SET}$ . The white LED can be estimated by following equation:

$$I_{LED} = 320 \times \left( \frac{V_{ISET}}{R_{SET}} \right)$$

### Thermal Protection

The regulator has thermal shutdown circuitry that protects it from damage caused by high temperature conditions. The thermal protection circuitry shut down the device when the junction temperature reached approximately 160°C, allowing the device to cool. When the junction temperature cools to approximately 140°C, the device is automatically reenabled. Continuously running the regulator into thermal shutdown can degrade reliability.

### Undervoltage Lockout

The undervoltage lockout circuit shuts down the device when the voltage at VIN drops below a typical threshold of 2.2V. The prevents damage to the devices.

### Termination of Unused Current Source Outputs

If any outputs (D1 to D5) are not used, the LEDs pin should be connected to V<sub>DD</sub> or floating. Figure 4 shows the connection for 4LEDs application, D5 pin is connection to V<sub>DD</sub> directly.

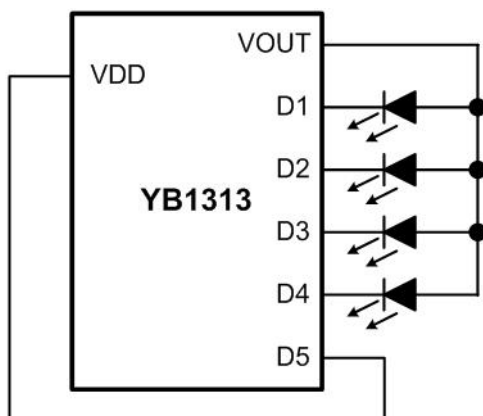


Figure 4. Application for 4 LEDs.

### Power Efficiency

The battery current and efficiency of the YB1313 are mostly dependent on the charge pump mode of operation. To get the best performance from the YB1313 it is better to use LEDs with consistently lower V<sub>F</sub> voltage. Lower V<sub>F</sub> will keep the charge pump in 1x mode longer and will use less battery current, extending the run time of the battery. The power conversion efficiency of the YB1313 can be calculated by adding up the products of each LED current and voltage and dividing it by the product of the input voltage and current. With a fully charged battery where the input voltage is typically above the LED forward voltage, the charge pump operates in the 1x mode and efficiency is high. As the battery discharges, there is a point where the current sources no longer have enough voltage overhead to maintain a constant current regulation. At that point, the charge pump switches into the 1.5x mode. The conversion efficiency is lowest at the crossover. When in 1x mode the voltage conversion efficiency is defined as output power divided by input power:

$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times I_{IN}} \times 100\%$$

$$I_{IN} = I_{OUT} + I_Q$$

$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times (I_{OUT} + I_Q)} \times 100\%$$

When in 1.5x or 2x mode the voltage conversion efficiency is as output power divided by input power:

$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times I_{IN}} \times 100\%$$

$$I_{IN} = I_{OUT} + I_Q$$

$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times (I_{OUT} \times \text{Mode} + I_Q)} \times 100\%$$

Mode = 1.5 or 2

And then LEDs efficiency is defined as LED forward voltage produces output current divided by input power:

$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{V_F \times I_{OUT}}{V_{IN} \times (I_{OUT} \times \text{Mode} + I_Q)} \times 100\%$$

### Capacitor Selection

Ceramic capacitors such as X5R or X7R are recommended to be used with the YB1313. For the two flying capacitors C1 and C2, it is important to use low ESR capacitors to avoid unnecessary efficiency losses. Low ESR capacitors on VOUT reduce the ripple voltage on the supply of the current sources. Table 5 lists capacitor types that have been tested with the YB1313.

**Table 5. Recommended Capacitors and WLED**

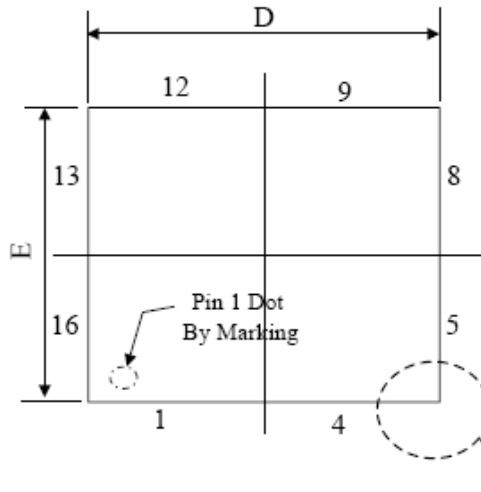
Part	Value	Voltage	Manufacturer	Size	Website
C1608X5R1A105KT000E	1μF	10V	TDK	0603	<a href="http://www.component.tdk.com">www.component.tdk.com</a>
C1608X7R1A105KT0S0N	1μF	10V		0805	
C2012X7R1C225KT000N	2.2μF	16V		0805	
ECJ1VB1A105K	1μF	10V	Panasonic	0603	<a href="http://www.panasonic.com">www.panasonic.com</a>
ECJ2FB1A105K	1μF	10V		0805	
ECJ2FB1A225K	2.2μF	16V		0805	
LTW-193TS5	—	—	Lite-On	—	<a href="http://www.liteon.com.tw">www.liteon.com.tw</a>



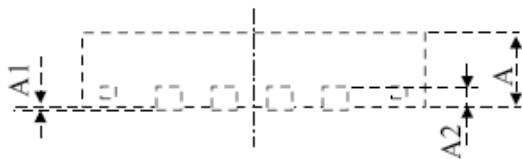
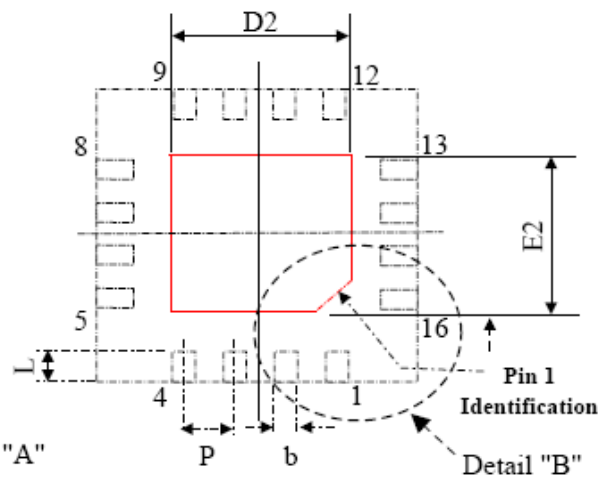
**Package Information**

Dimension	mm			Dimension	mm		
	MIN.	NOM.	MAX.		MIN.	NOM.	MAX.
A	0.65	0.75	0.85	D2	1.7REF		
A1	0.005	0.0200	0.050	E	2.95	3.00	3.05
A2	0.177	0.203	0.280	E2	1.7REF		
b	0.18	0.24	0.30	L	0.30	0.40	0.50
C	----	0.25REF	----	P	0.45	0.50	0.55
D	2.95	3.00	3.05	S	0.25REF		

**TOP VIEW**



**BOTTOM VIEW**



**Side VIEW**

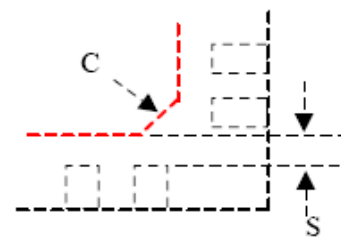
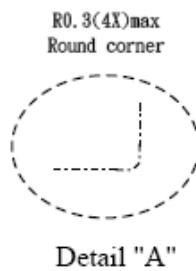


Figure 5.