Description

The YB1315 charge pump is designed to drive up to 5 white LEDs with regulated constant current in backlight display application. The device can provide up to 25mA per LED for a total 5 channels. The output current can also be combined into one single channel with 125mA output current for flash-light applications. 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.

YB1315 monitors the power-supply input voltage and LED forward voltage and current, and does an automatic selection to a switching mode that is optimized for the power conversion efficiency as well as battery operating time. The 1MHz fixed 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. YB1315 also provides short circuit protection, over-temperature protection and over-voltage protection. In shutdown mode, the shutdown current is less than 1µA. YB1315 is available in a TQFN-16 3x3 package.

Features

- Voltage Input Range From 2.7V to 5.5V
- Drives From 3 to 5 LEDs at Up to 25mA Each
- Fractional Conversion Modes for High Conversion Efficiency, 1x and 1.5x
- 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
- 3mm x 3mm TQFN Package

Applications

- White LED Backlighting
- Handheld PCs and PDAs
- Mobile Phone
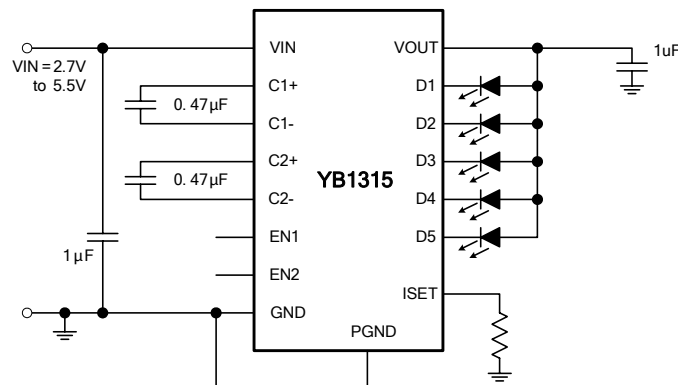- DSC and DV flash light application

Typical Application Circuit

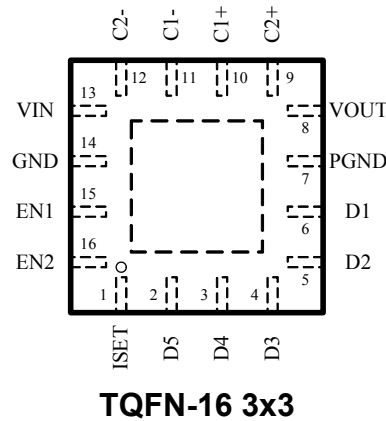**Figure 1: Typical Application Circuit**

Pin Configuration

TQFN-16 3x3

Figure 2: Pin Configuration

Pin Description

Table 1

Pin	Name	Description
1	I_{SET}	Connect a R_{SET} resistor between this pin and GND. R_{SET}=7.5K, set I_{LED} to 20mA. (Recommended)
2	D5	Current sink output #5. If not used, connected to V_{IN} or floating.
3	D4	Current sink output #4. If not used, connected to V_{IN} or floating.
4	D3	Current sink output #3. If not used, connected to V_{IN} or floating.
5	D2	Current sink output #2. If not used, connected to V_{IN} or floating.
6	D1	Current sink output #1. If not used, connected to V_{IN} or floating.
7	PGND	Power GND.
8	V_{OUT}	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_{IN}	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_{SET}.

Ordering Information

Table 2

Order Number	Package Type	Supplied As	Package Marking
YB1315A316	TQFN-16 3x3	2500 Units Tape & Reel	Please contact sales representative

YOBON TECHNOLOGIES

Preliminary YB1315
High Efficiency Charge Pump White LED Driver

Absolute Maximum Ratings

Supply Voltage.......................................5.5V

Output Short-Circuit Duration...... Continuous

Junction Temperature Range...............150℃

Storage Temperature Range..-65℃ to 150℃

Lead Temperature...............................250℃

Recommended Operating Conditions

Input Supply Voltage............... 2.7V to 5.5V

Operating Temperature..........-40℃ to 85℃

Electrical Characteristics

Table 3   (V_{IN}=3.6V, EN1=EN2=V_{IN}, T_A=25°C, unless otherwise noted.)

Description	Symbol	Test Conditions	MIN	TYP	MAX	Units
SUPPLY VOLTAGE AND CURRENT						
Input Voltage Range	V_{IN}	I_{OUT} = 0~70mA	2.7		5.5	V
Operating Quiescent Current	I_Q	V_{IN} =4.2V, x1-mode, EN1=EN2=1, I_{SET} =20µA		250		µA
		I_{OUT} = 0mA, x1.5-mode		2		mA
Shutdown Current	I_{SD}	EN1=EN2=GND		0.1	1	µA
CHARGE PUMP STAGE						
Over Voltage Limit	V_{OUT}	LED1 unconnected, V_{IN} =4.2V		5.3		V
Startup Time		C_{OUT} =1µF, $I_{DX} \geq 0.9 I_{DX}$		750		µs
Softstart Duration				500		µs
Switching Frequency	f		0.7	1	1.3	MHz
Efficiency	η	V_{IN} =3.75V, I_{LED}=20mA each V_{DX} =3.2V		83		%
Shutdown Temperature				160		℃
Shutdown Temperature Hysteresis				20		℃
CURRENT SINKS						
Recommended Maximum Current Per Current Sink	I_{DX}	3.2V$\leq V_{IN} \leq$5.5V		25		mA
Current into Each Current Sink when I_{SET} is Shorted to GND	I_{DX}	3.0V$\leq V_{IN} \leq$5.5V I_{SET} short to GND			60	mA
Current Matching Between Any Two Outputs		V_{DX} =3.2V, T_A =25℃			±3	%
Line Regulation		3.2V$\leq V_{IN} \leq$5.5V, V_{DX} =3.2V EN1=EN2=1, I_{SET} =80µA			±3	%
Reference Voltage for Current Set	V_{ISET}	EN2=0, EN1=1		200		mV
		EN2=1, EN1=0		400		
		EN2=1, EN1=1	580	600	620	
Recommended I_{SET} Pin Current Range	I_{SET}		4		100	µA
I_{DX} to I_{SET} Current Ratio	k	EN2=1, EN1=1, I_{SET} =80µA	220	250	280	
Voltage at Dx to GND	V_{SOURCE}			0.4		V

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| ENABLE 1, ENABLE 2						
EN1, EN2 High Level Input Voltage	V_{IH}	Supply voltage falling	1.3			V
EN1, EN2 Low Level Input Voltage	V_{IL}				0.3	V
EN1, EN2 Trip Point Hysteresis				50		mV
EN2 Input Leakage Current	I_{IKG}			0.1	1	µA
EN1 Input Current	I_I			0.1	1	µA
Under Voltage Lockout Threshold	$V_{(UVLO)}$	Input voltage falling		2.1		V
Under Voltage Lockout Hysteresis				50		mV
Frequency Range at PWM					50	KHz
Recommended ON-Time for PWM Signal				2.5		µs
Shutdown Delay Time		Delay time when EN1=EN2 go to GND after which the YB1315 shuts down completely.	0.5	1	1.5	ms

Typical Performance Characteristics

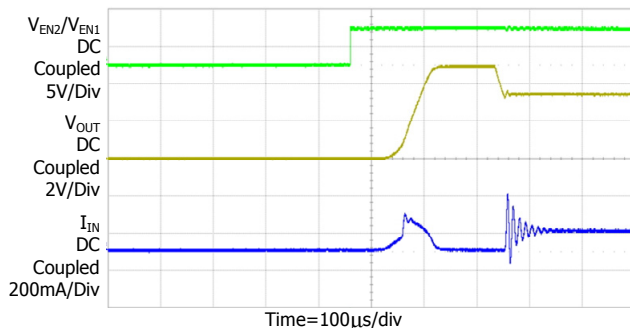V_{IN} =3.6V, C_{IN} =4.7μF, C1=C2=0.47μF, C_{OUT} = 1μF, unless otherwise noted.
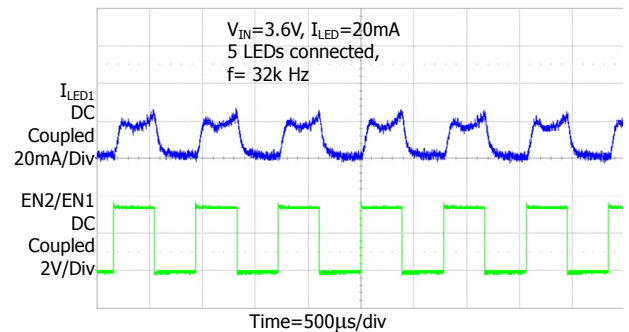
Efficiency vs. Supply Voltage (I_{LED}=20mA)

LED Efficiency
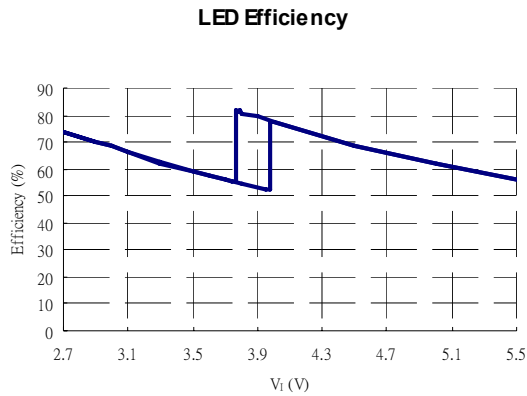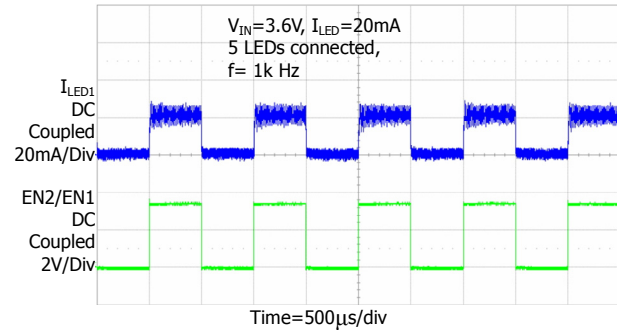
Dimming Response

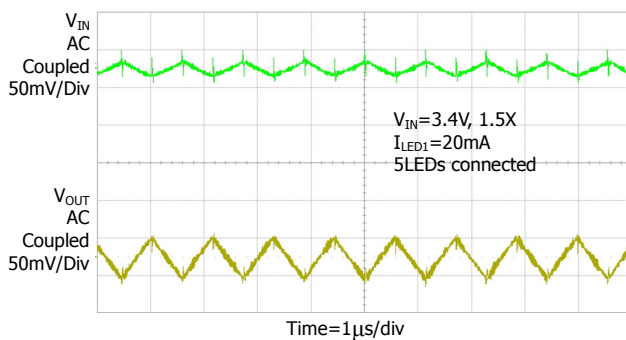### 1X Mode, Software

Dimming Respons

Input and Output Voltage Ripple

LED1 Current VS Duty Cycle
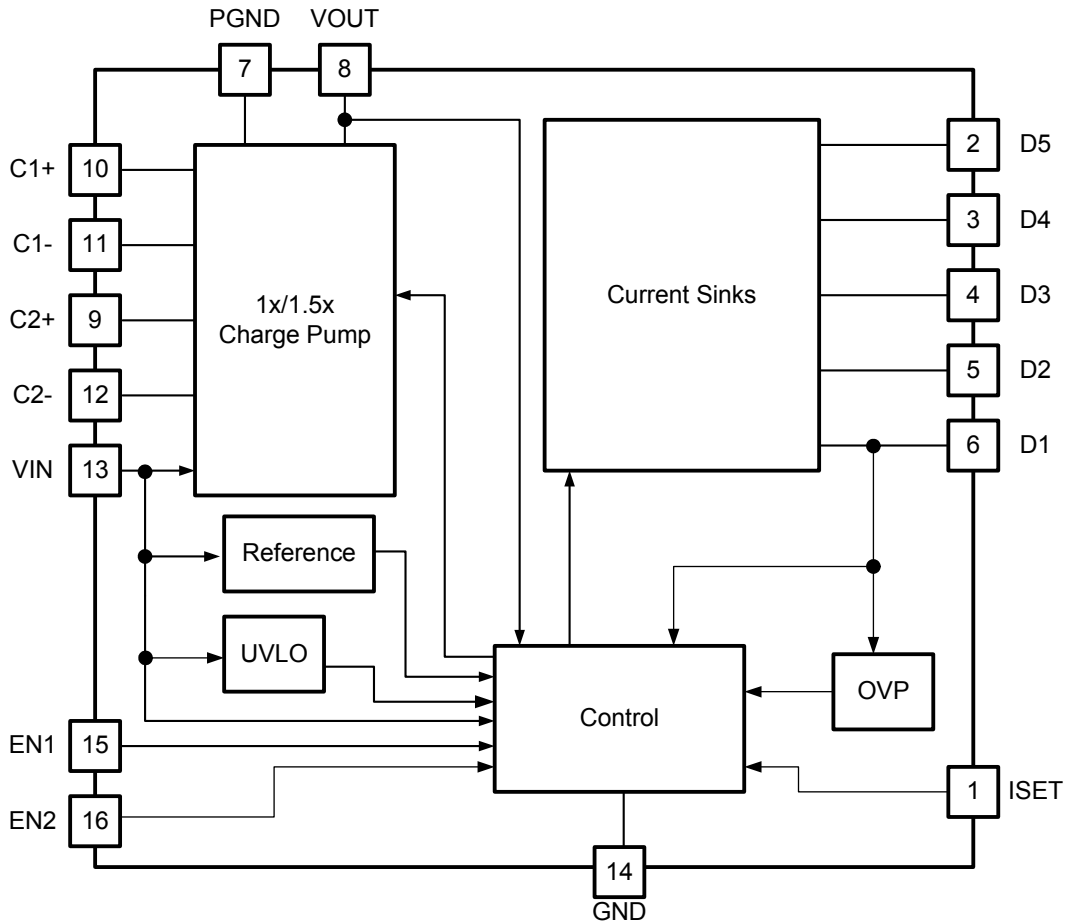
Function Block

Figure 3: Function Block

Functional Description

The YB1315 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, or 1.5x mode, depending on the input voltage and output current loading. The overall power consumption is best optimized by automatically switching among the 2 different operation mode.

The charge pump is possible to generate a total output current of 125mA or more, 25mA for each LED. But it is recommended to operate the device under total 120mA.

Application Information

Soft-Start Circuitry

The YB1315 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 or 1.5x mode is required. In the case of 1x mode, the soft-start is terminated and normal operation begins. In the case of 1.5x mode, soft-start operated until the lowest of LED1-LED5 reaches regulation.

ENABLE (EN1, EN2)

The enable pins EN1 and EN2 are used to enable or shutdown the device. The YB1315 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 above. Pulling both pins to GND, after a delay, forces the device into to shutdown mode. 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.

Methods for Dimming Control

YB1315 offers flexible ways for dimming control.

1. EN1 and EN2 can 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 described later.

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}=600mV	Full

2. EN1 and EN2 can also be used for PWM dimming. The LED brightness level is directly dependent on the duty cycle of the PWM signal and the configuration. The PWM signal can either be applied to EN1 or EN2, or both tied together, and the PWM signal can be applied to both pins. Depending on the configuration, the current during PWM dimming is switched between 0mA and its maximum (EN1 and EN2 connected to the PWM signal) or between 0mA 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 0mA and 2/3 of the full range.

LED Current Setting

The current of white LED connected to YB1315 can be set by R_{SET}. Every current flow through the white LED is 250 times

greater than the current through that of R_{SET}.

The white LED can be estimated by following equation:

$$I_{LED} = 250 \times \left(\frac{V_{ISET}}{R_{SET}} \right)$$

To set the LED current, the device uses a R_{SET} resistor connected the pin I_{SET} to ground to generate a reference current V_{ISET}/R_{SET} , where V_{ISET} is the voltage from I_{SET} pin to ground.

This reference current is amplified by K (250 typical) to generate the LED current. Following table shows the relation between R_{SET} and LED current.

Rset (KΩ)	6	7.5	10	15	150
Iled (mA)	25	20	15	10	1

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℃, allowing the device to cool. When the junction temperature cools to approximately 140℃, the device is automatically re-enabled. Continuously running the regulator into thermal shutdown can degrade reliability.

Under-voltage Lockout

The under-voltage lockout circuit shuts down the device when the voltage at V_{IN} drops below a typical threshold of 2.2V. This prevents damage to the devices.

Power Efficiency

The battery current and efficiency of the YB1315 are mostly dependent on the charge pump mode of operation. To get the best performance from the YB1315 it is better to use LEDs with consistently lower V_F voltage.

Lower V_F will keep the charge pump in 1x mode longer and will uses less battery current, extending the run time of the battery. The power conversion efficiency of the YB1315 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 mode the voltage conversion efficiency is as output power divided by input power:

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

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

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

$$\text{Mode} = 1.5$$

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 YB1315. 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 YB1315.

Table 5. Recommended Capacitors and WLED

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

Package Information (TQFN-16 3x3)
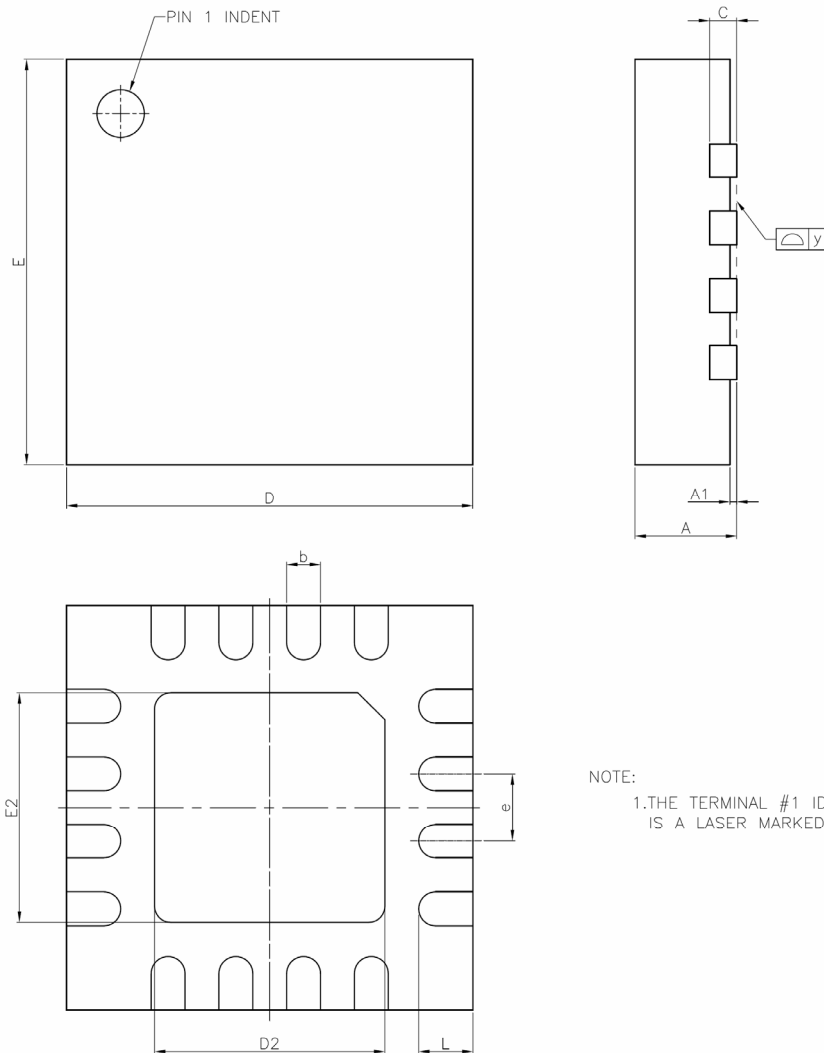
NOTE:
1. THE TERMINAL #1 IDENTIFIER
   IS A LASER MARKED FEATURE

SYMBOLS	DIMENSIONS IN MILLIMETERS		
	MIN	NOM	MAX
A	0.70	0.75	0.80
A1	0.00	0.02	0.05
b	0.18	0.25	0.30
C	——	0.20 REF.	——
D	2.90	3.00	3.10
D2	1.65	1.70	1.75
E	2.90	3.00	3.10
E2	1.65	1.70	1.75
e	——	0.50	——
L	0.35	0.40	0.45
y	0.00	——	0.075

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