

# 1.4MHz Thin Package Current-Mode Step-Up DC/DC Converter

## FEATURES

- Fixed Frequency 1.4MHz Current-Mode PWM Operation.
- Adjustable Output Voltage up to 30V.
- Guaranteed 13V/ 200mA Output with 5V Input.
- 2.5V to 10V Input Range.
- Maximum 0.1 $\mu$ A Shutdown Current.
- Programmable Soft-Start.
- Tiny Inductor and Capacitors are allowed.
- Space-Saving SOT-23-6 and TSOT-23-6 Package.

## APPLICATIONS

- White LED Backlight.
- OLED Driver.
- LCD Bias

## DESCRIPTION

AIC1896 is a current-mode pulse-width modulation (PWM), step-up DC/DC Converter. The built-in high voltage N-channel MOSFET allows AIC1896 for step-up applications with up to 30V output voltage, as well as for Single Ended Primary Inductance Converter (SEPIC) and other low-side switching DC/DC converter.

The high switching frequency (1.4MHz) allows the use of small external components. The Soft-Start function is programmable with an external capacitor, which sets the input current ramp rate.

The AIC1896 is available in a space-saving SOT-23-6 and TSOT-23-6 package.

## TYPICAL APPLICATION CIRCUIT

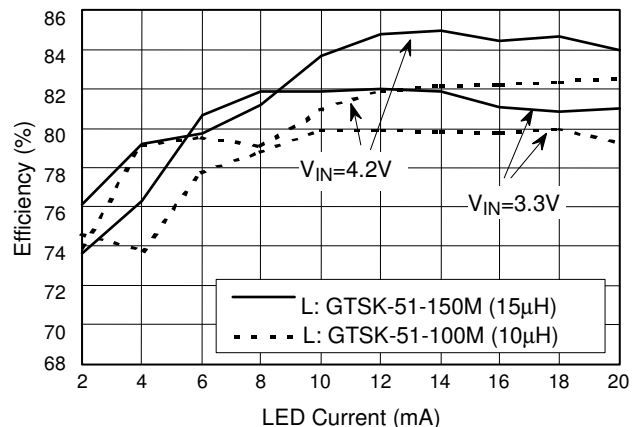
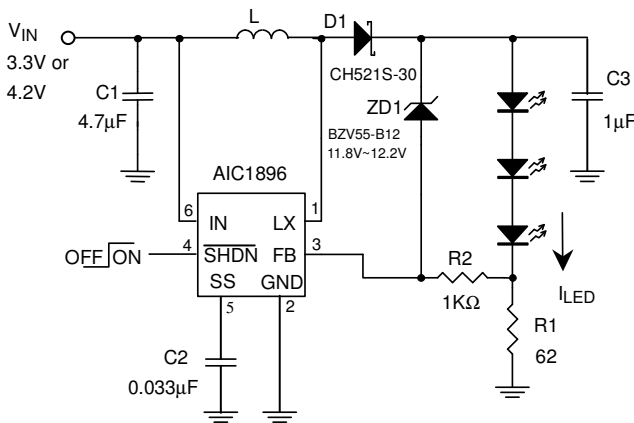


Fig. 1 Li-Ion Powered Driver for three white LEDs

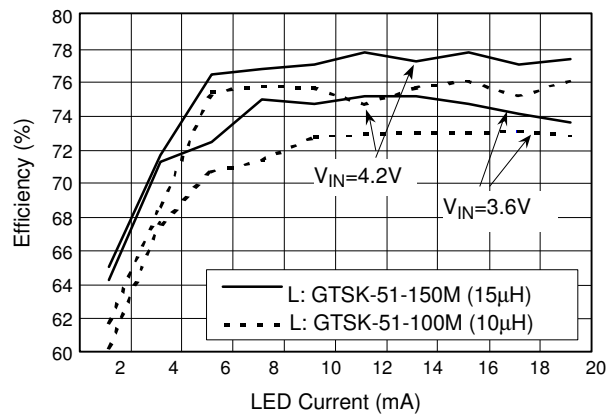
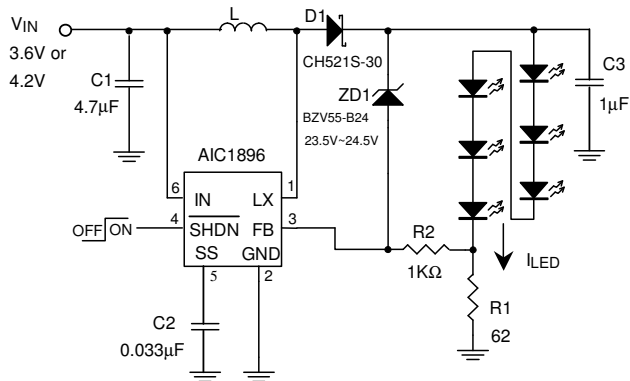
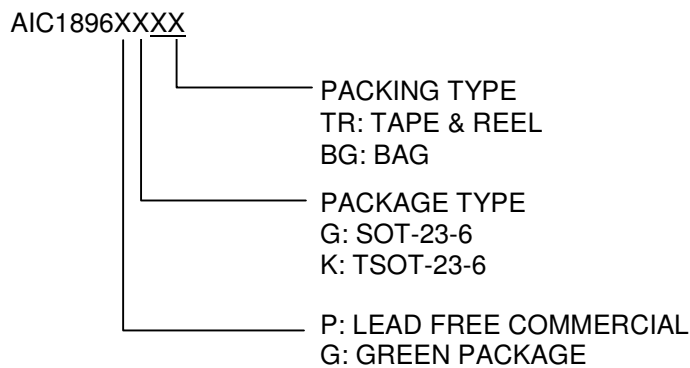
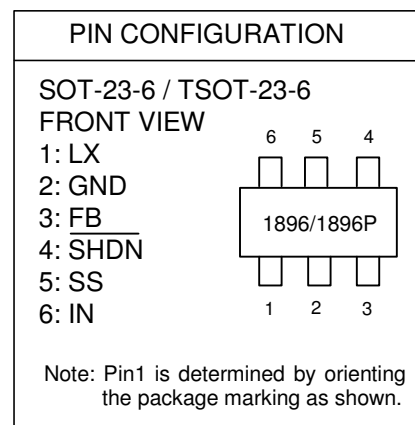


Fig. 2 Li-Ion Powered Driver for six white LEDs

## ORDERING INFORMATION



Example: AIC1896PKTR  
 → in Lead Free TSOT-23-6 Package & Tape & Reel Packing Type  
 AIC1896PGTR  
 → in Lead Free SOT-23-6 Package & Tape & Reel Packing Type



### ● TSOT-23-6 Marking

Part No.	Marking
AIC1896PK	896PK
AIC1896GK	896GK

### ● SOT-23-6 Marking

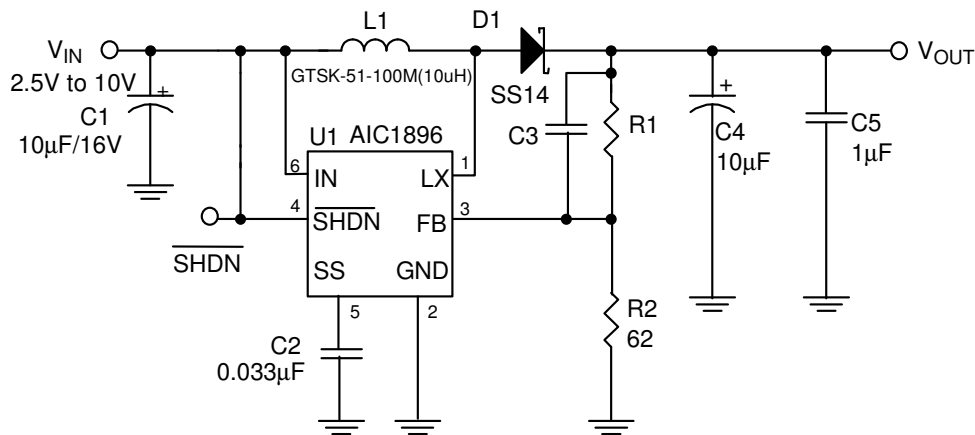
Part No.	Marking
AIC1896PG	1896P
AIC1896GG	1896G

## ■ ABSOLUTE MAXIMUM RATINGS

LX to GND .....	-0.3V to +33V
FB to GND .....	-0.3V to +6V
IN, $\overline{\text{SHDN}}$ .....	-0.3V to +11V
SS to GND .....	-0.3V to +6V
LX Pin RMS Current .....	0.6A
Continuous Power Dissipation .....	727mW
Operating Temperature Range .....	-40°C to 85°C
Junction Temperature .....	125°C
Storage Temperature Range .....	-65°C to 150°C
Lead Temperature (soldering, 10s) .....	260°C

**Absolute Maximum Ratings** are those values beyond which the life of a device may be impaired.

## ■ TEST CIRCUIT



## ■ ELECTRICAL CHARACTERISTICS

( $V_{IN}=V_{\overline{SHDN}}=3V$ ,  $FB=GND$ ,  $SS=Open$ ,  $T_A=25^\circ C$ , unless otherwise specified) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Supply Range	$V_{IN}$		2.5		10	V
Output Voltage Adjust Range	$V_{OUT}$				30	V
$V_{IN}$ Undervoltage Lockout	UVLO	$V_{IN}$ rising, 50mV hysteresis		2.2		V
Quiescent Current	$I_{IN}$	$V_{FB} = 1.3V$ , not switching		0.1	0.2	mA
		$V_{FB} = 1.0V$ , switching		1	5	
Shutdown Supply Current		$V_{\overline{SHDN}} = 0$ , $T_A = +25^\circ C$		0.01	0.5	$\mu A$
		$V_{\overline{SHDN}} = 0$		0.01	10	
<b>ERROR AMPLIFIER</b>						
Feedback Regulation Set Point	$V_{FB}$		1.205	1.23	1.255	V
FB Input Bias Current	$I_{FB}$	$V_{FB} = 1.24V$		21	80	nA
Line Regulation		$2.6V < V_{IN} < 5.5V$		0.05	0.20	%/V
<b>OSCILLATOR</b>						
Frequency	$f_{OSC}$		1000	1400	1800	KHz
Maximum Duty Cycle	DC		82	86		%
<b>POWER SWITCH</b>						
Steady State Output Current	$I_o$	Refer to Fig. 13				A
On-Resistance	$R_{DS(ON)}$	$V_{in} = 5V$		1	1.4	$\Omega$
Leakage Current	$I_{LX(OFF)}$	$V_{LX} = 30V$ , $T_A = +25^\circ C$		0.1	1	$\mu A$
		$V_{LX} = 30V$			10	
<b>SOFT-START</b>						
Reset Switch Resistance		Guaranteed By Design			100	$\Omega$
Charge Current		$V_{SS} = 1.2V$	1.5	4	7.0	$\mu A$
<b>CONTROL INPUT</b>						
Input Low Voltage	$V_{IL}$	$V_{\overline{SHDN}}$ , $V_{IN} = 2.5V$ to $10V$			0.3	V
Input High Voltage	$V_{IH}$	$V_{\overline{SHDN}}$ , $V_{IN} = 2.5V$ to $10V$	1.0			V
$\overline{SHDN}$ Input Current	$I_{\overline{SHDN}}$	$V_{\overline{SHDN}} = 1.8V$		25	50	$\mu A$
		$V_{\overline{SHDN}} = 0$		0.01	0.1	

Note 1: Specifications are production tested at  $T_A=25^\circ C$ . Specifications over the  $-40^\circ C$  to  $85^\circ C$  operating temperature range are assured by design, characterization and correlation with Statistical Quality Controls (SQC).

**TYPICAL PERFORMANCE CHARACTERISTICS**

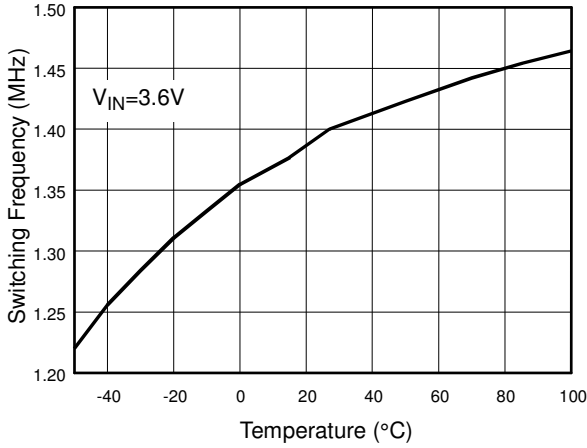


Fig. 3 Switching Frequency vs. Temperature

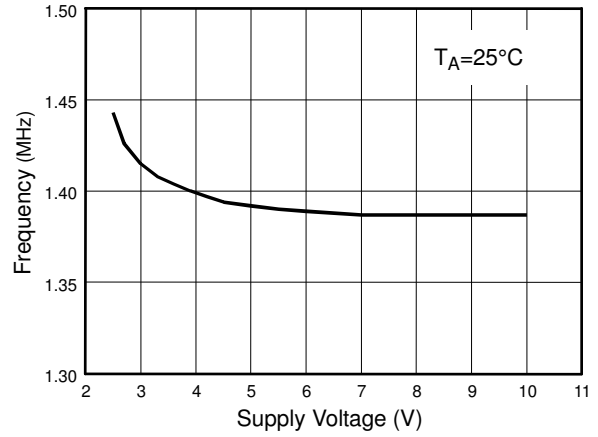


Fig. 4 Frequency vs. Supply Voltage

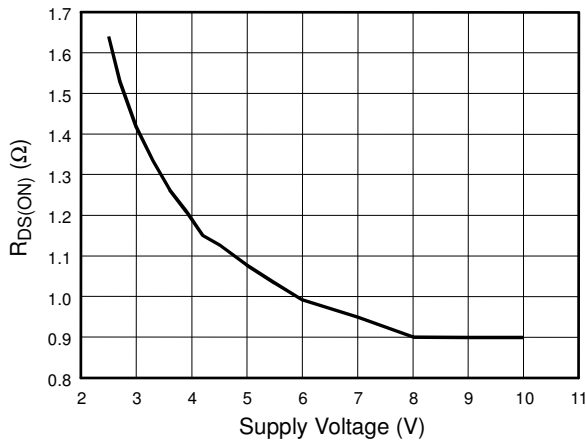


Fig. 5 R\_DS(ON) vs. Supply Voltage

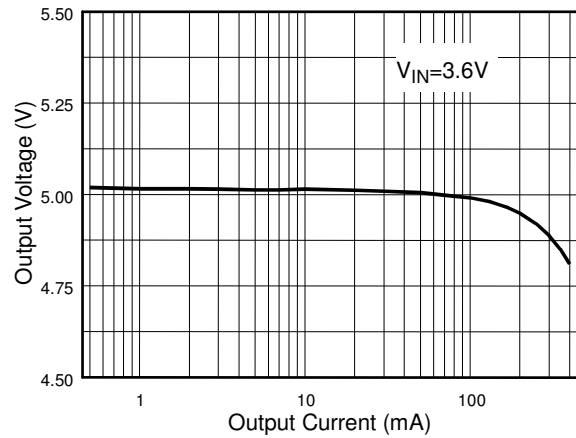


Fig. 6 Load Regulation (L1=10 μH)

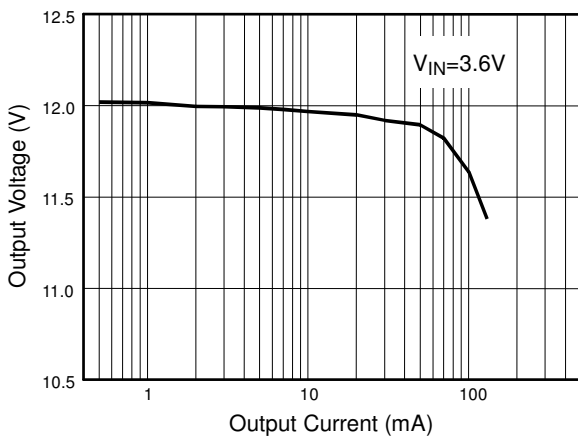


Fig. 7 Load Regulation (L1=22 μH)

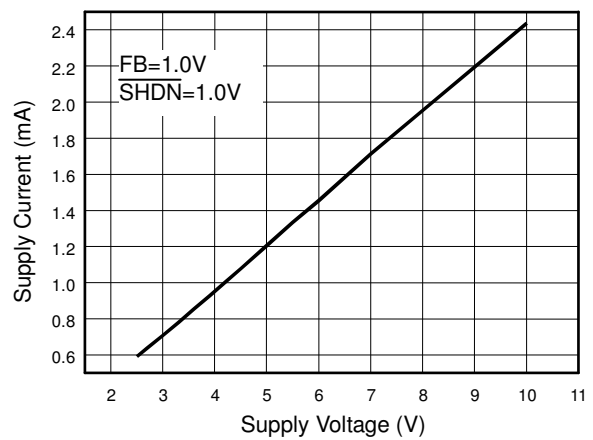


Fig. 8 Switching Current

■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

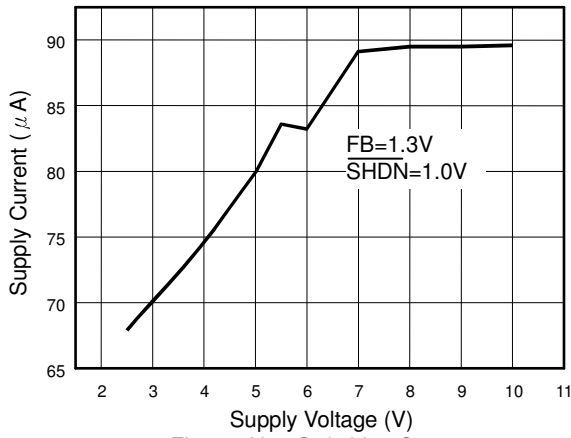


Fig. 9 Non-Switching Current

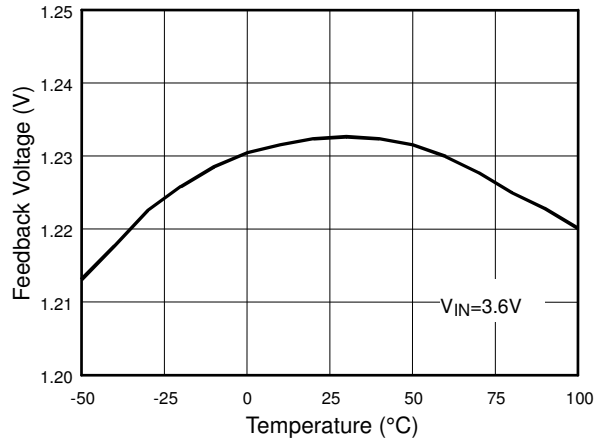


Fig. 10 Feedback Pin Voltage

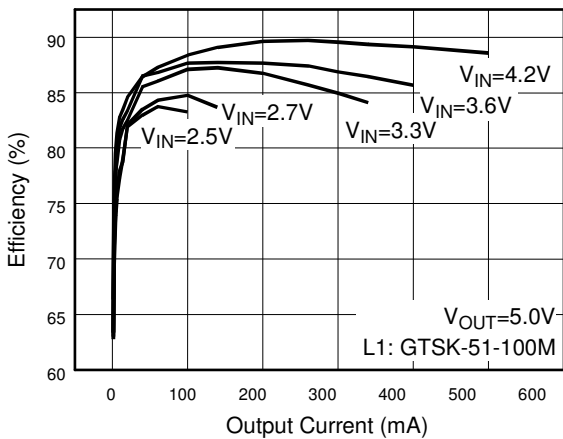


Fig. 11 Efficiency vs. Output Current  
(L1=10µH, test circuit refer to p.3)

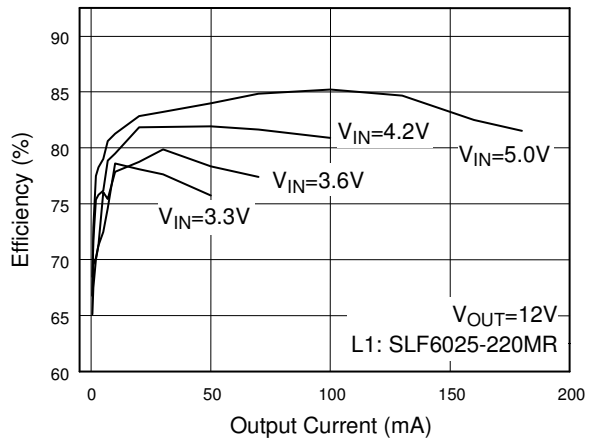


Fig. 12 Efficiency vs. output current  
(L1=22µH, test circuit refer to p.3)

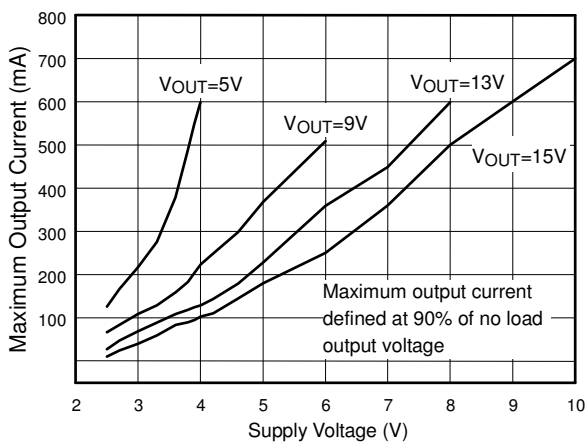


Fig. 13(a) Maximum Output current vs. Supply Voltage  
(L1: 10µH, test circuit refer to p.3)

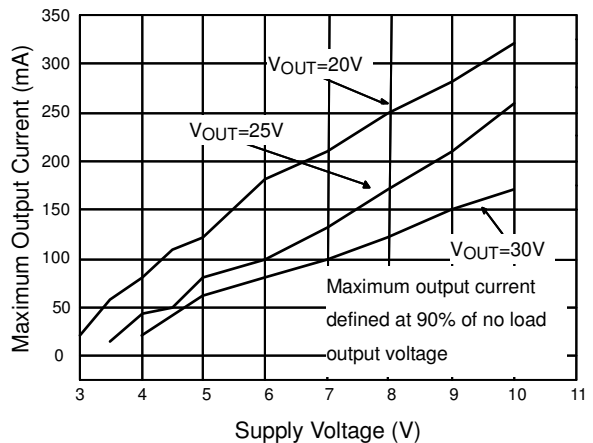


Fig. 13(b) Maximum Output Current vs. Supply Voltage  
(L1:22µH, test circuit refer to p.3)

■ **TYPICAL PERFORMANCE CHARACTERISTICS (Continued)**

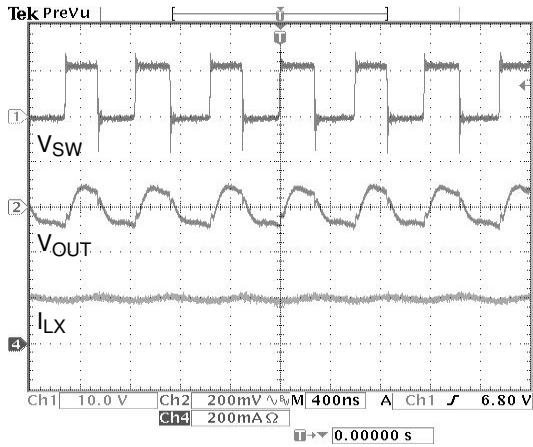


Fig. 14 Operation Wave Form  
 ( $V_{IN}=5V$ ;  $V_{OUT}=12V$ ;  $L1=22\mu H$ ;  $R1=105K$ ;  
 $R2=12K$ ;  $C3=1nF$ ;  $I_{OUT}=200mA$ , test circuit refer to p.3)

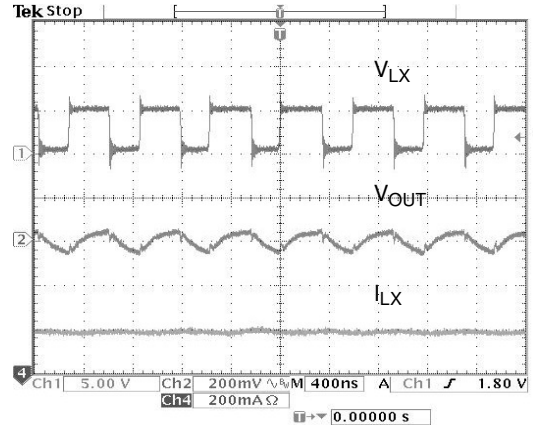


Fig. 15 Operation Wave Form  
 ( $V_{IN}=3V$ ;  $V_{OUT}=5V$ ;  $L1=10\mu H$ ;  $R1=36K$ ;  $R2=12K$ ;  
 $C3=39pF$ ;  $I_{OUT}=200mA$ , test circuit refer to p.3)

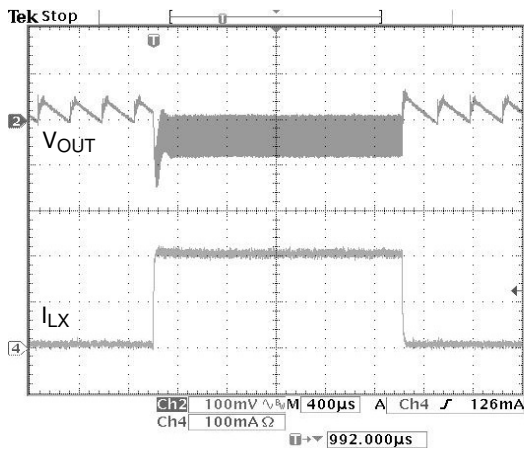


Fig. 16 Load Step Response  
 ( $V_{IN}=3.3V$ ;  $V_{OUT}=5V$ ;  $L1=10\mu H$ ;  $I_{OUT}=5mA$  to  $200mA$ ,  
 test circuit refer to p.3)

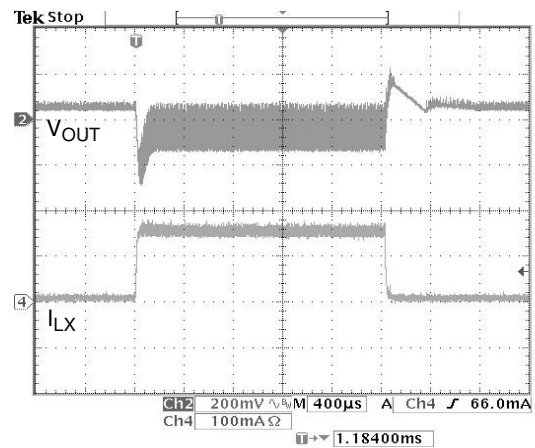


Fig. 17 Load Step Response  
 ( $V_{IN}=5V$ ;  $V_{OUT}=12V$ ;  $L1=22\mu H$ ;  $I_{OUT}=5mA$  to  $150mA$ ,  
 test circuit refer to p.3)

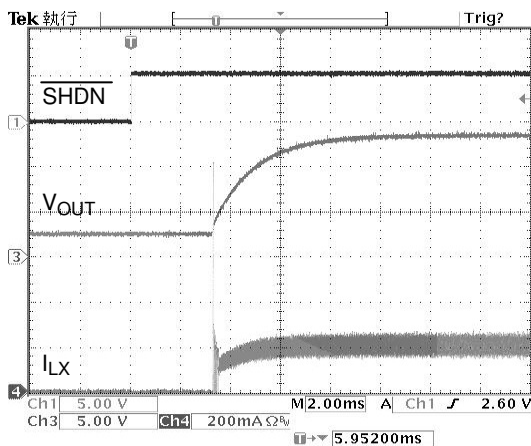
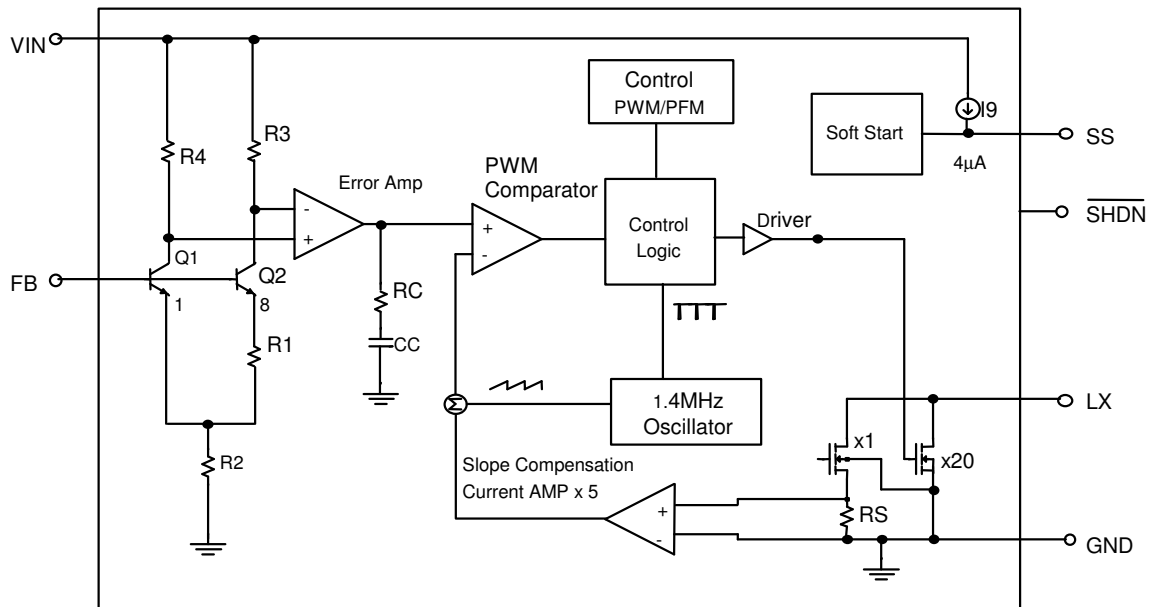


Fig. 18 Start-Up from Shutdown  
 ( $V_{IN}=3.3V$ ;  $V_{OUT}=13V$ ;  $R_{LOAD}=300\Omega$ ,  
 test circuit refer to p.3)

## ■ BLOCK DIAGRAM



## ■ PIN DESCRIPTIONS

PIN 1: LX - Power Switching Connection. Connect LX to inductor and output rectifier. Keep the distance between the components as close to LX as possible.

PIN 2: GND - Ground.

PIN 3: FB - Feedback Input. Connect a resistive voltage-divider from the output to FB to set the output voltage.

PIN 4:  $\overline{\text{SHDN}}$  - Shutdown Input. Drive  $\overline{\text{SHDN}}$  low to turn off the converter. To automatically start the converter, connect  $\overline{\text{SHDN}}$  to IN. Drive

$\overline{\text{SHDN}}$  with a slew rate of  $0.1\text{V}/\mu\text{s}$  or greater. Do not leave  $\overline{\text{SHDN}}$  unconnected.  $\overline{\text{SHDN}}$  draws up to  $50\mu\text{A}$ .

PIN 5: SS - Soft-Start Input. Connect a soft-start capacitor from SS to GND in order to soft-start the converter. Leave SS open to disable the soft-start function.

PIN 6: IN - Internal Bias Voltage Input. Connect IN to the input voltage source. Bypass IN to GND with a capacitor sitting as close to IN as possible.



## ■ APPLICATION INFORMATION

### Inductor Selection

A 15 $\mu$ H inductor is recommended for most AIC1896 applications. Although small size and high efficiency are major concerns, the inductor should have low core losses at 1.4MHz and low DCR (copper wire resistance).

### Capacitor Selection

The small size of ceramic capacitors makes them ideal for AIC1896 applications. X5R and X7R types are recommended because they retain their capacitance over wider ranges of voltage and temperature than other types, such as Y5V or Z5U. A 4.7 $\mu$ F input capacitor and a 1 $\mu$ F output capacitor are sufficient for most AIC1896 applications.

### Diode Selection

Schottky diodes, with their low forward voltage drop and fast reverse recovery, are the ideal choices for AIC1896 applications. The forward voltage drop of a Schottky diode represents the conduction losses in the diode, while the diode capacitance (CT or CD) represents the switching losses. For diode selection, both forward voltage drop and diode capacitance need to be considered. Schottky diodes with higher current ratings usually have lower forward voltage drop and larger diode capacitance, which can cause significant switching losses at the 1.4MHz switching frequency of AIC1896. A Schottky diode rated at 100mA to 200mA is sufficient for most AIC1896 applications.

### LED Current Control

LED current is controlled by feedback resistor (R1 in Fig. 1). The feedback reference is 1.23V. The LED current is  $1.23V/R1$ . In order to have

accurate LED current, precision resistors are preferred (1% recommended). The formula for R1 selection is shown below.

$$R1 = 1.23V/I_{LED} \dots \dots \dots (1)$$

### Open-Circuit Protection

In the cases of output open circuit, when the LEDs are disconnected from the circuit or the LEDs fail, the feedback voltage will be zero. AIC1896 will then switch to a high duty cycle resulting in a high output voltage, which may cause SW pin voltage to exceed its maximum 30V rating. A zener diode can be used at the output to limit the voltage on SW pin (Fig. 20). The zener voltage should be larger than the maximum forward voltage of the LED string. The current rating of the zener should be larger than 0.1mA.

### Dimming Control

There are three different types of dimming control circuits as follows:

#### 1. Using a PWM signal

PWM brightness control provides the widest dimming range by pulsing LEDs on and off at full and zero current, respectively. The change of average LED current depends on the duty cycle of the PWM signal. Typically, a 0.1kHz to 10kHz PWM signal is used. Two applications of PWM dimming with AIC 1896 are shown in Fig 21. One, as fig. 21(a), uses PWM signal to drive  $\overline{SHDN}$  pin directly for dimming control. The other, as fig. 21(b), employs PWM signal going through a resistor to drive FB pin. If the  $\overline{SHDN}$  pin is used, the increase of duty cycle results in LED brightness enhancement. If the FB pin is used, on the contrary, the increase of duty cycle will decrease its brightness. In this application, LEDs

are dimmed by FB pin and turned off completely by  $\overline{\text{SHDN}}$ .

## 2. Using a DC Voltage

For some applications, the preferred method of a dimming control uses a variable DC voltage to adjust LED current. A dimming control using a DC voltage is shown as Fig. 22. As DC voltage increases, the voltage drop over R2 increases and the voltage drop over R1 decreases.

Cautiously selecting R2 and R3 is essential so that the current from the variable DC source is much smaller than the LED current and much larger than

the FB pin bias current. With a VDC ranging from 0V to 5V, the selection of resistors in Fig. 22 results in dimming control of LED current from 20mA to 0mA, respectively.

## 3. Using a Filtered PWM Signal

Filtered PWM signal can be considered as an adjustable DC voltage. It can be used to replace the variable DC voltage source in dimming control. The circuit is shown in Fig. 23.

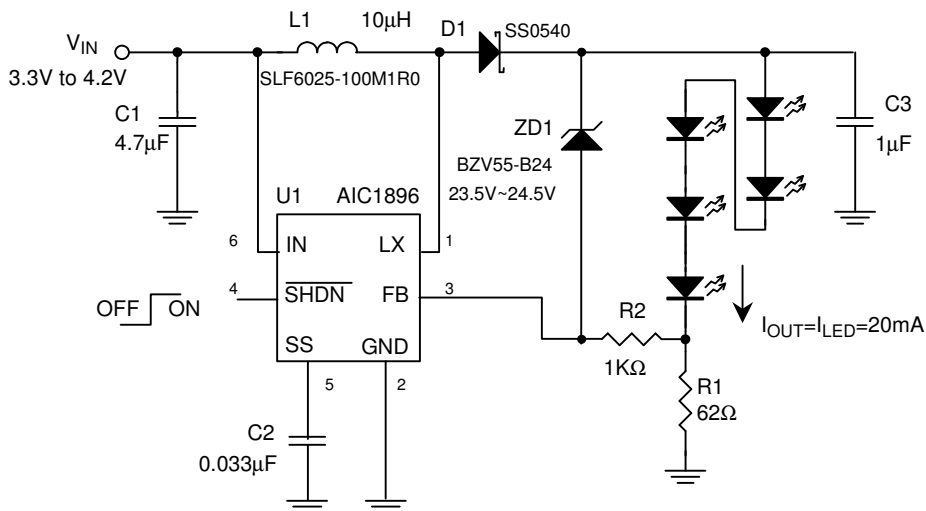


Fig. 19 White LED Driver with Open-Circuit Protection

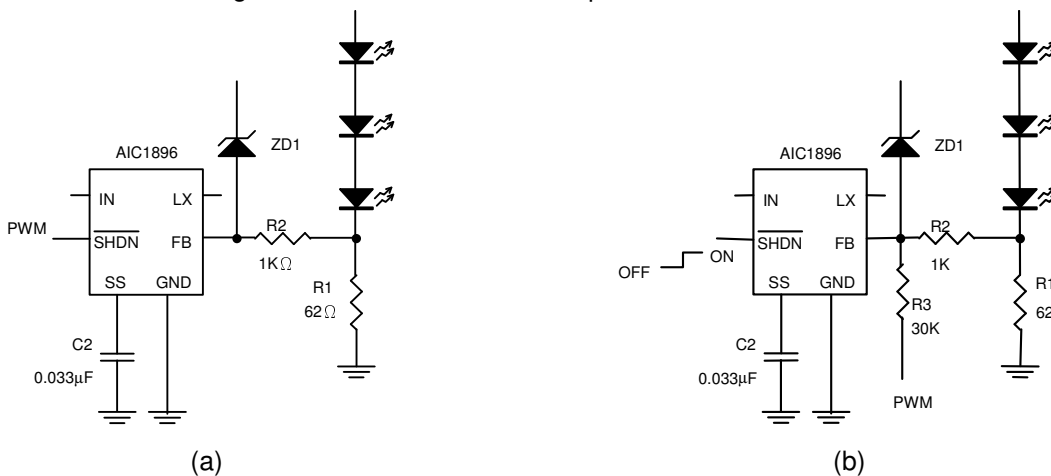


Fig. 20 Dimming Control Using a PWM Signal

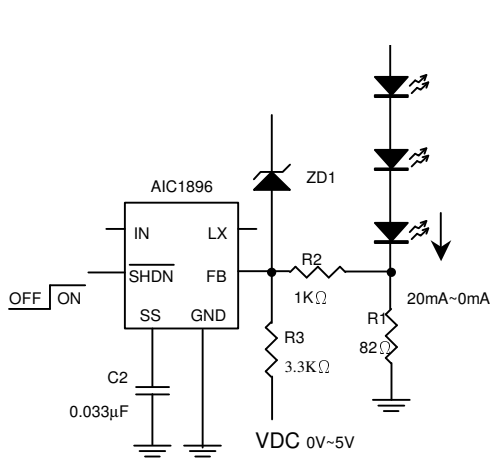


Fig. 21 Dimming Control Using a DC Voltage

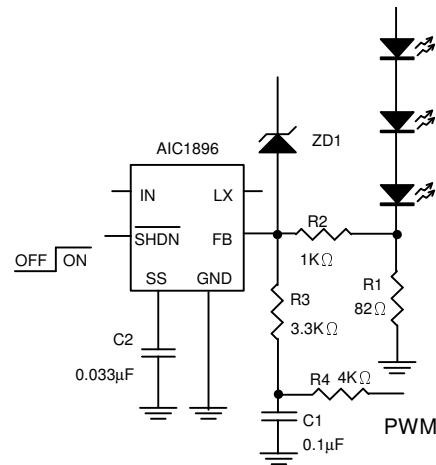


Fig. 22 Dimming Control Using a Filtered PWM Signal

## APPLICATION EXAMPLES

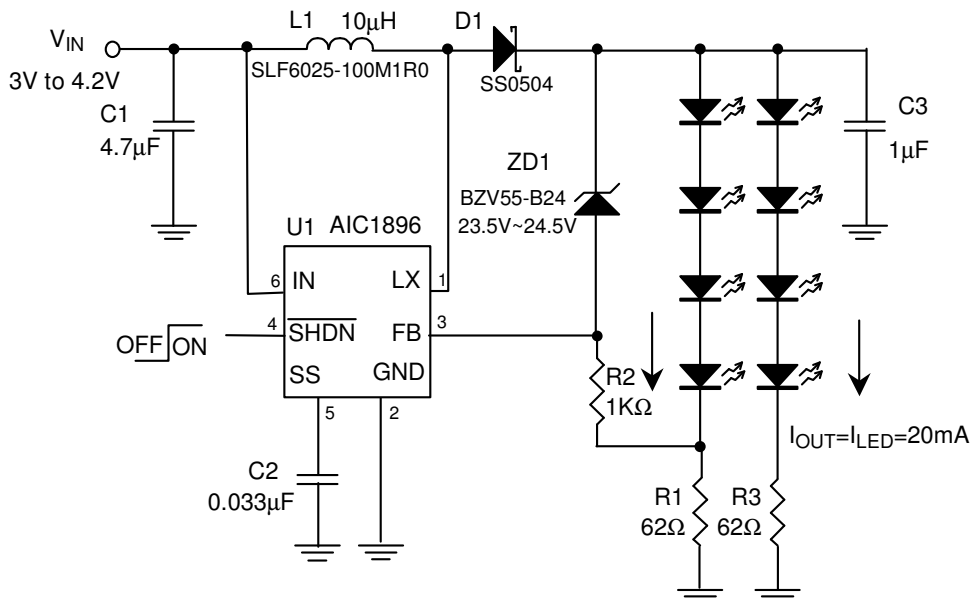


Fig. 23 1-Cell Li-Ion Powered Driver for eight White LEDs with Open-Circuit Protection

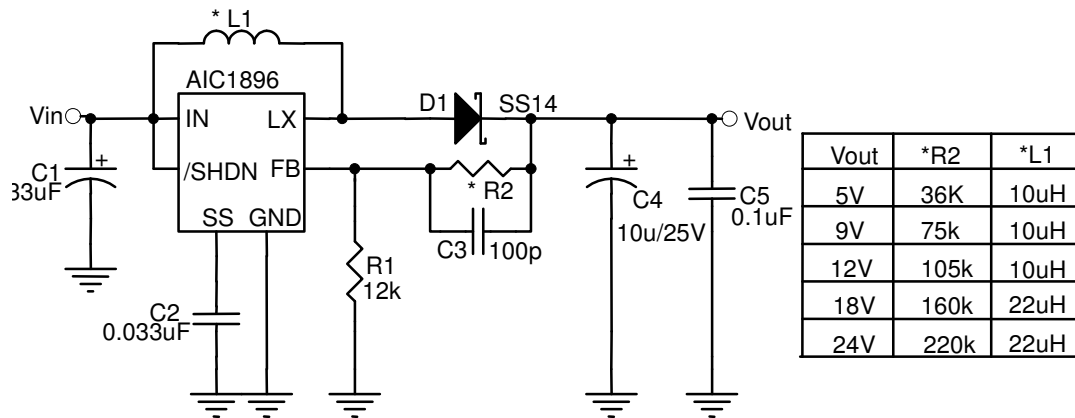


Fig. 24 Typical Step up Application Circuit

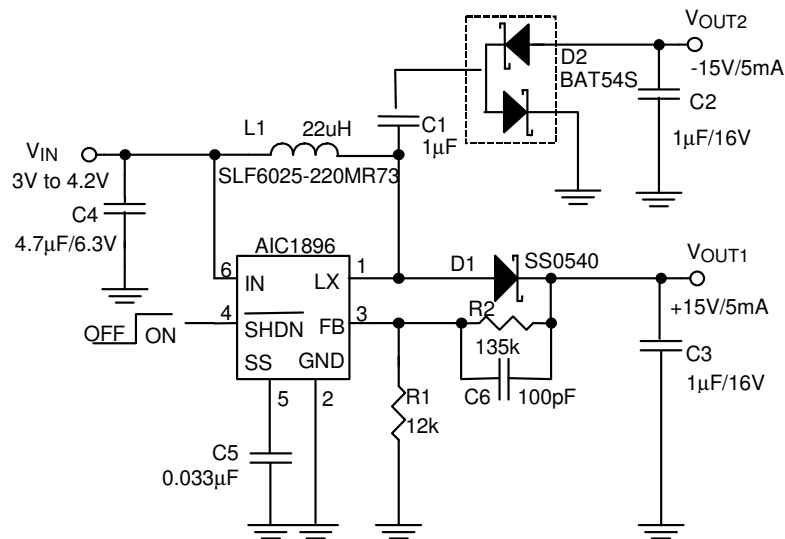
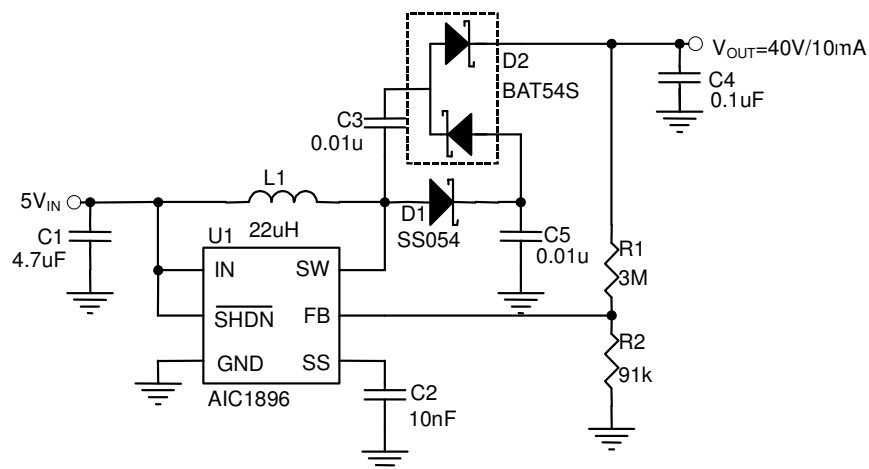

 Fig. 25 1-Cell Li-Ion to  $\pm 15V/5mA$  Dual Output Converter for LCD Bias


Fig. 26 High 40V Output Voltage for Electrophoretic Display (EPD) Application

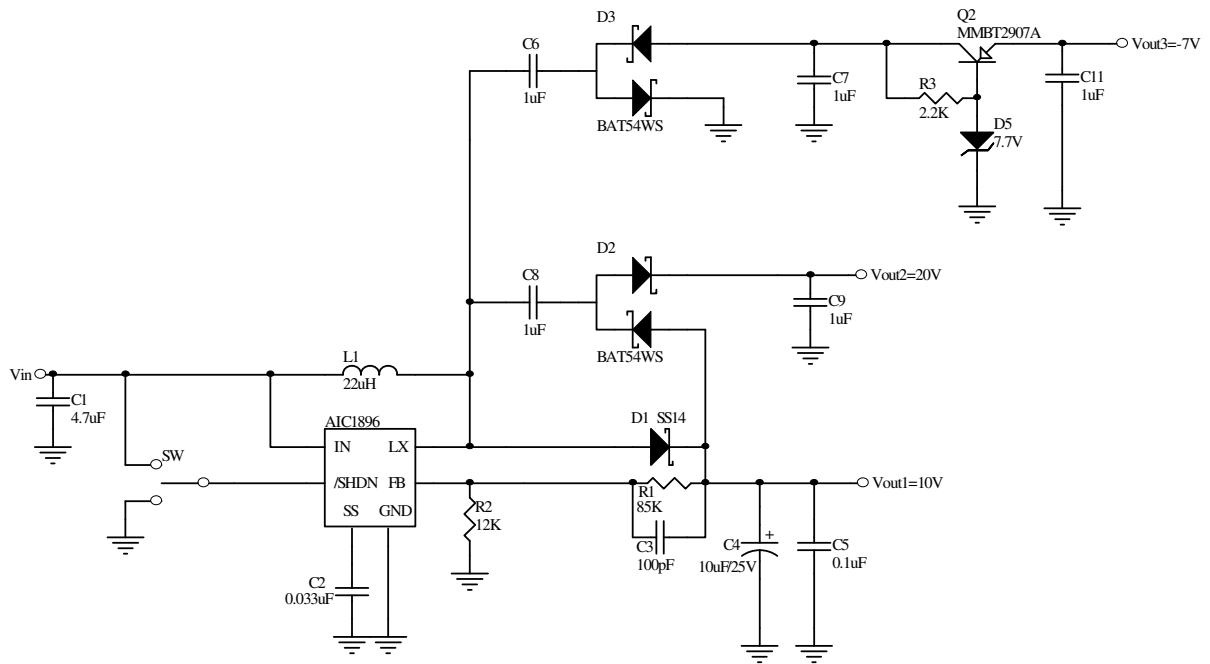
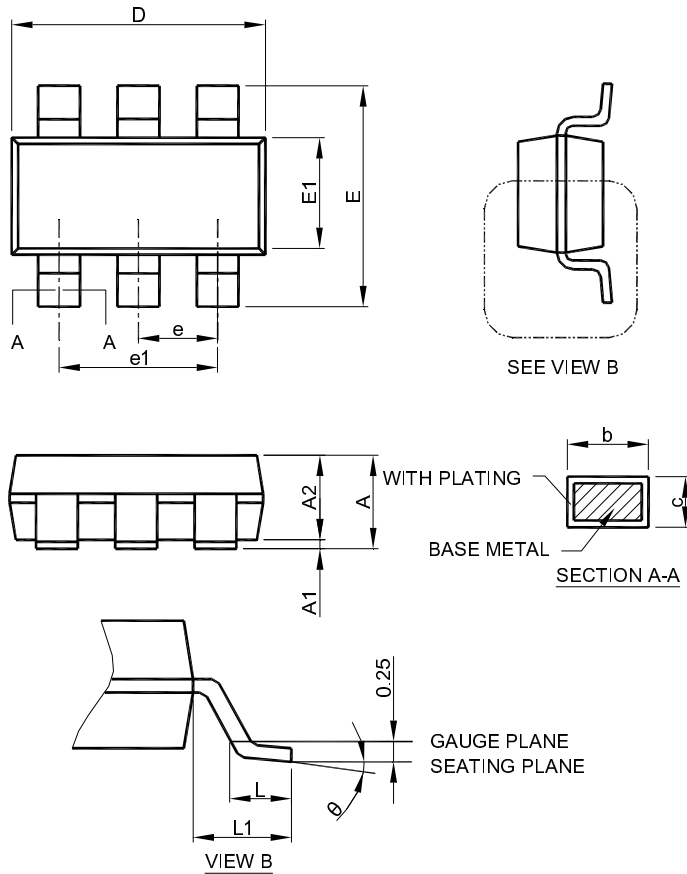


Fig. 27 Three output voltage for LCD

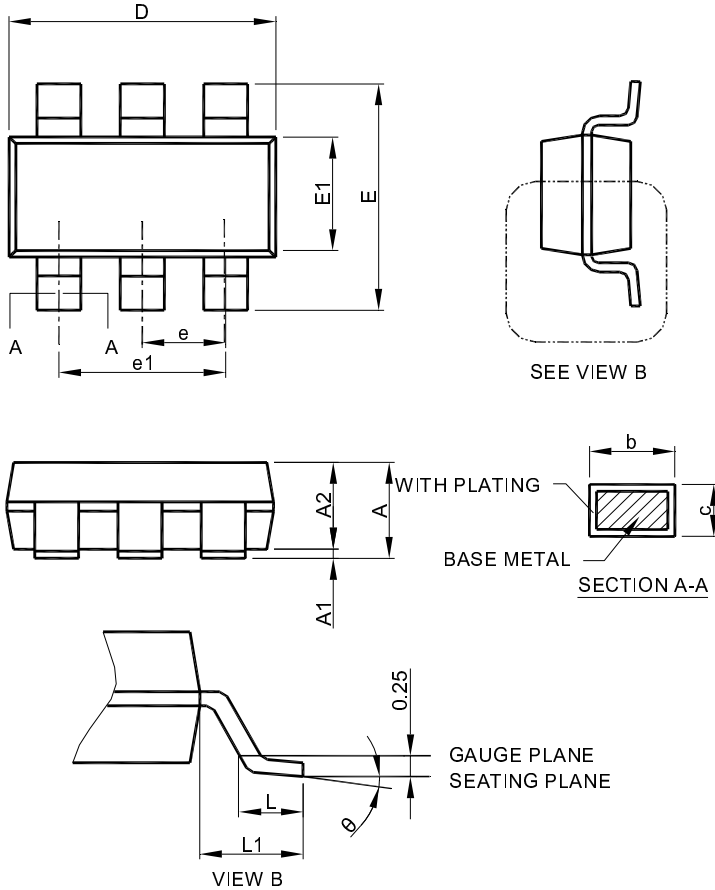
**PHYSICAL DIMENSIONS (unit: mm)**
**TSOT-23-6**


SYMBOL	TSOT-23-6	
	MILLIMETERS	
	MIN.	MAX.
A	-	1.00
A1	0	0.10
A2	0.70	0.90
b	0.30	0.50
c	0.08	0.22
D	2.80	3.00
E	2.60	3.00
E1	1.50	1.70
e	0.95 BSC	
e1	1.90 BSC	
L	0.30	0.60
L1	0.60 REF	
$\theta$	0°	8°

Note : 1. Refer to JEDEC MO-193AA.

2. Dimension "D" does not include mold flash, protrusions or gate burrs. Mold flash, protrusion or gate burrs shall not exceed 6 mil per side.
3. Dimension "E1" does not include inter-lead flash or protrusions.
4. Controlling dimension is millimeter, converted inch dimensions are not necessarily exact.

● SOT-23-6



SYMBOL	SOT-23-6	
	MILLIMETERS	
	MIN.	MAX.
A	0.95	1.45
A1	0.05	0.15
A2	0.90	1.30
b	0.30	0.50
c	0.08	0.22
D	2.80	3.00
E	2.60	3.00
E1	1.50	1.70
e	0.95 BSC	
e1	1.90 BSC	
L	0.30	0.60
L1	0.42 REF	
$\theta$	0°	8°

- Note : 1. Refer to JEDEC MO-178AB.  
 2. Dimension "D" does not include mold flash, protrusions or gate burrs. Mold flash, protrusion or gate burrs shall not exceed 10 mil per side.  
 3. Dimension "E1" does not include inter-lead flash or protrusions.  
 4. Controlling dimension is millimeter, converted inch dimensions are not necessarily exact.

**Note:**

Information provided by AIC is believed to be accurate and reliable. However, we cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in an AIC product; nor for any infringement of patents or other rights of third parties that may result from its use. We reserve the right to change the circuitry and specifications without notice.

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