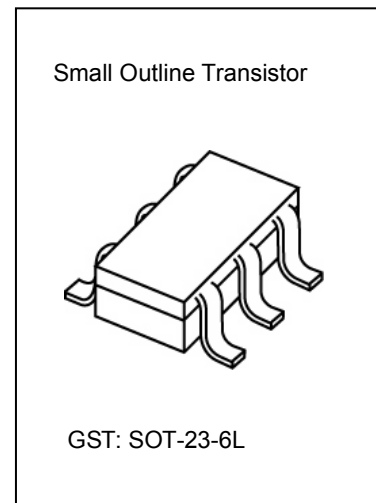




# Regulated Charge Pump

## Features

- 5V fixed output voltage
- Max. output current: 80mA@  $V_{IN} > 3.2V$
- Power conversion efficiency: 81.8%@ $V_{IN}=3V, I_{OUT}=60mA$
- Input voltage range : 2.8V to 5V
- Built-in internal soft-start function
- Over-current protection
- Short-circuit protection
- Thermal shutdown
- RoHS compliant and lead (Pb)-free



## Product Description

The MBI6501 is a high performance charge pump DC/DC converter that produces a regulated 5V output. No external inductor is required for operation. The operating voltage range is 2.8V to 5V. Internal soft-start circuitry effectively reduces the in-rush current both while start-up and mode change.

The MBI6501 features very low quiescent current, over-current protection, thermal shutdown and short-circuit protection. The MBI6501 is available in SOT-23-6 package.

## Applications

- LED backlight for mobile phone, smart phone
- Camera flash white LED
- Power supply for LCD modules

Typical Application Circuit

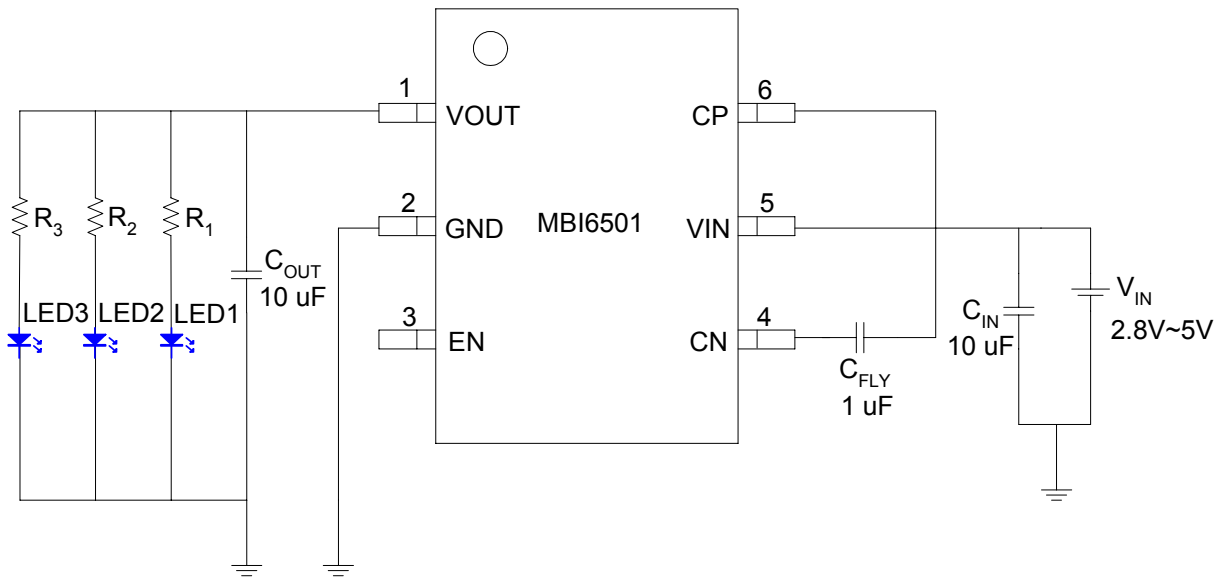


Fig. 1

Functional Diagram

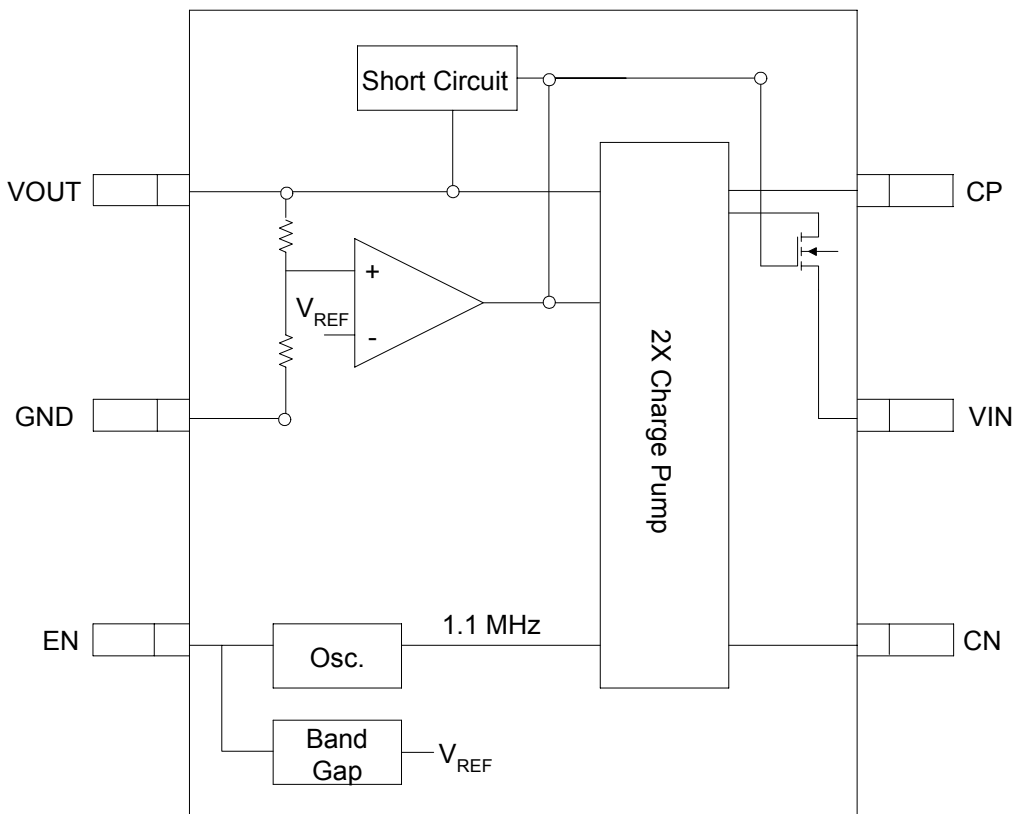
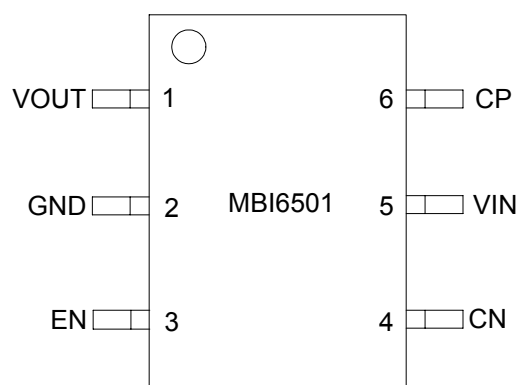


Fig. 2

**Pin Configuration**



**Pin Description**

Pin Name	Function
VOUT	Output voltage terminal
GND	Ground terminal for control logic and current sink
EN	Chip enable terminal (high active)
CN	Flying capacitor negative terminal
VIN	Supply voltage terminal
CP	Flying capacitor positive terminal

**Maximum Ratings**

Characteristics	Symbol	Rating	Unit
Supply Voltage	$V_{IN}$	-0.3~6V	V
Other I/O Pin Voltage	-	0~6	V
Power Dissipation (By simulation)	$P_D$	0.51	W
Thermal Resistance (By simulation)	$R_{th(j-a)}$	244	°C/W
Operating Junction Temperature	$T_{j,max}$	150	°C
Operating Temperature	$T_{opr}$	-40~+85	°C
Storage Temperature	$T_{stg}$	-55~+150	°C

**Electrical Characteristics**

( $V_{IN}=3.7V$ ,  $T_a=25^{\circ}C$ , unless otherwise specified)

Characteristics	Symbol	Condition	Min.	Typ.	Max.	Unit
Supply Voltage	$V_{IN}$	$V_{OUT}=5V$	2.8	-	$V_{OUT}$	V
Output Voltage	$V_{OUT}$	$V_{IN}>3.2V$ , $I_{OUT}<80mA$	4.8	5	5.2	V
Quiescent Current	$I_Q$	$I_{OUT}=0mA$ , no load	-	2.2	4	mA
Shutdown Current	$I_{SHD}$	$V_{IN}=4.5V$ , $V_{EN}<0.4V$	-	0.5	1	$\mu A$
Maximum Output Current	$I_{OUT}$	$V_{IN}>3.2V$	80	-	-	mA
Over-Current Threshold	$I_1$	As Fig. 3	-	150	-	mA
Short-Circuit Current Threshold	$I_2$	As Fig. 4	-	60	-	mA
Output Ripple	-	$I_{OUT}=60mA$ , $C_{OUT}=10\mu F$	-	30	-	mV
Operation Frequency	$F_{OSC}$	-	0.9	1.1	1.6	MHz
Input Voltage of EN pin (Digital)	High Level	$V_{IH}$	-	1.5	-	V
	Low Level	$V_{IL}$	-	-	0.4	V
Thermal Shutdown Junction Temperature Threshold	$T_{SHD}$	When $T_j$ approaches $T_{SHD}^*$	-	160	-	$^{\circ}C$

\* $T_j$  means junction temperature.

**Test Circuit for Electrical Characteristics**

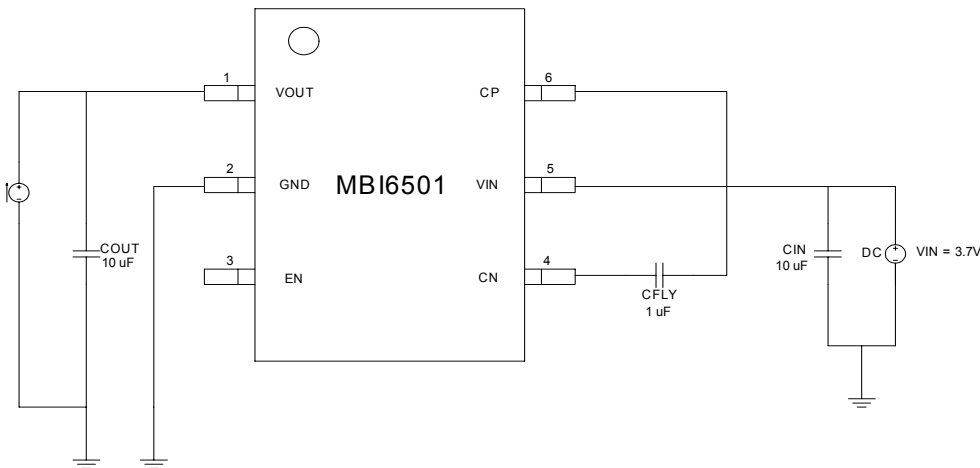


Fig. 3

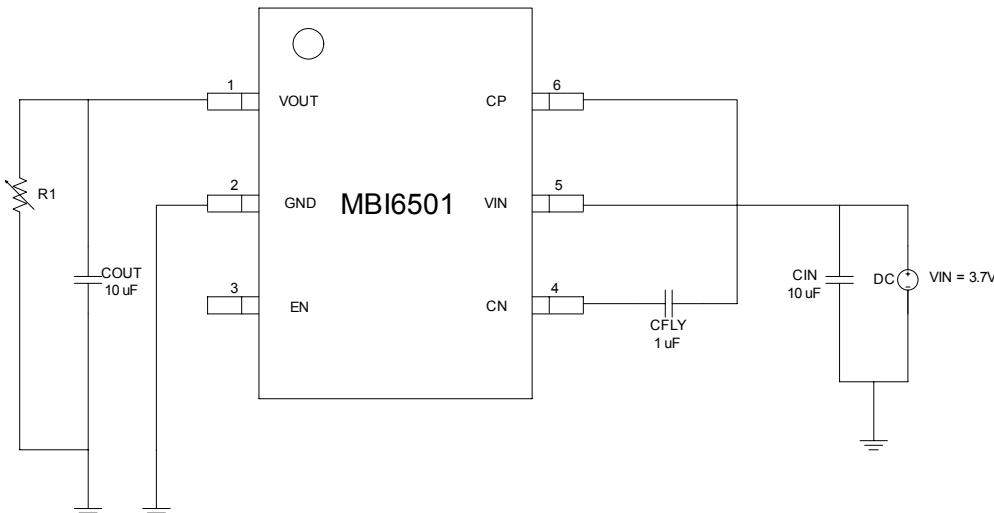


Fig. 4

Typical Operating Characteristics

( $C_{IN}=C_{OUT}=10\mu F$ ,  $C_{FLY}=1\mu F$ ,  $T_a=25^\circ C$ , unless otherwise specified)

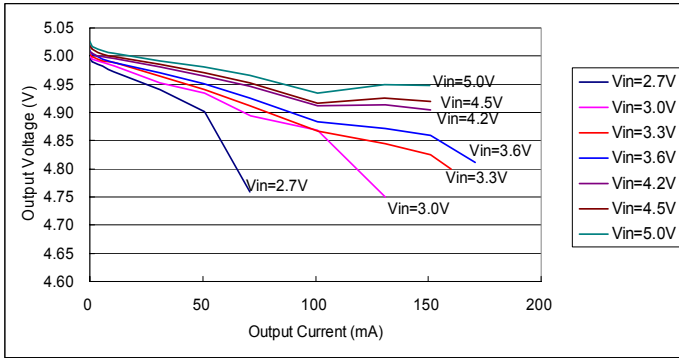


Fig. 5 Output Voltage vs. Output Current ( $C_{IN}=C_{OUT}=10\mu F$ ,  $C_{FLY}=1\mu F$ )

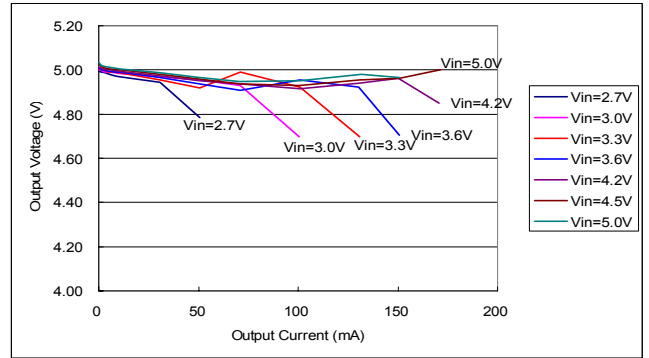


Fig. 6 Output Voltage vs. Output Current ( $C_{IN}=C_{OUT}=1\mu F$ ,  $C_{FLY}=0.1\mu F$ )

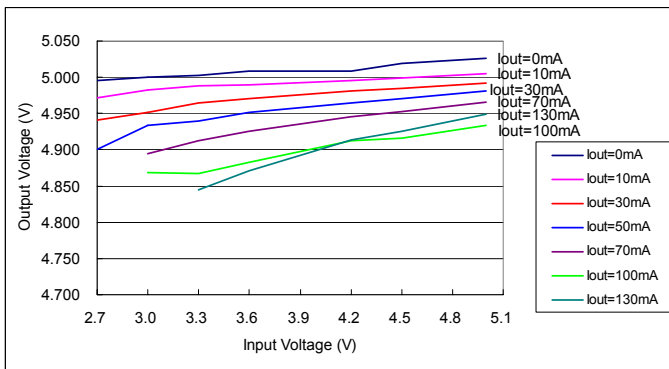


Fig. 7 Output Voltage vs. Input Voltage ( $C_{IN}=C_{OUT}=10\mu F$ ,  $C_{FLY}=1\mu F$ )

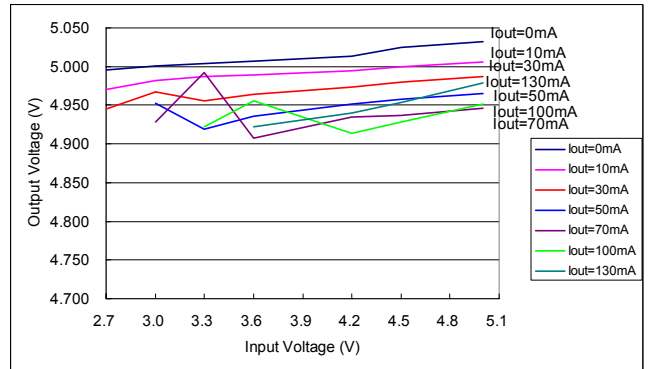


Fig. 8 Output Voltage vs. Input Voltage ( $C_{IN}=C_{OUT}=1\mu F$ ,  $C_{FLY}=0.1\mu F$ )

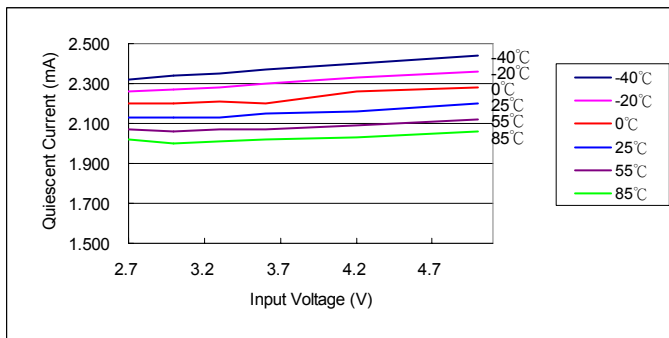


Fig. 9 Quiescent Current vs. Input Voltage

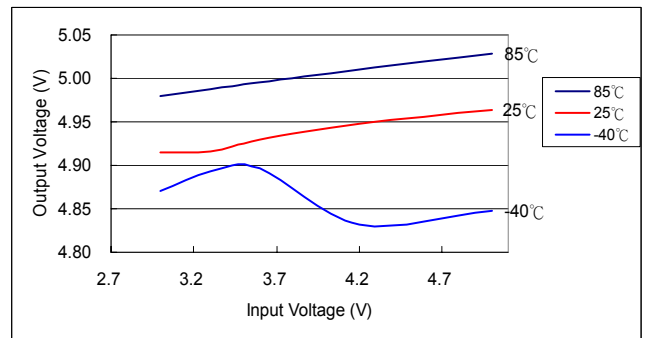


Fig. 10 Output Voltage vs. Input Voltage ( $I_{OUT}=60mA$ )

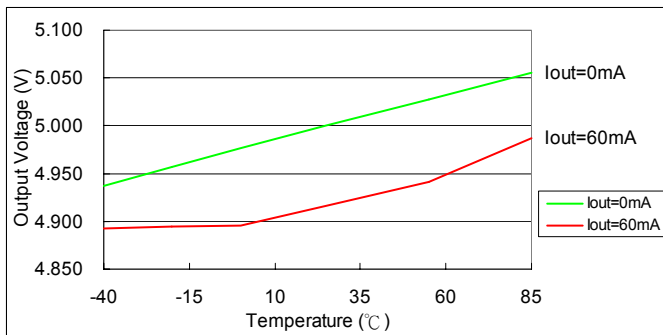


Fig. 11 Output Voltage vs. Temperature ( $V_{IN}=3.3V$ )

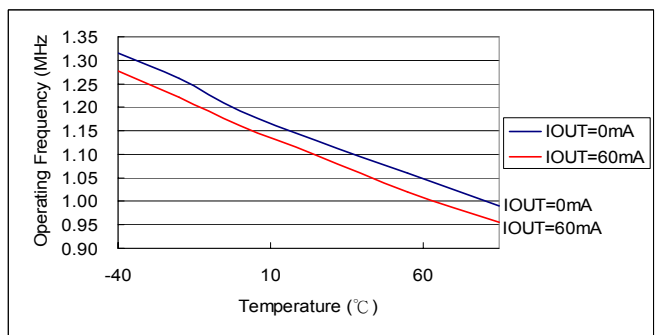


Fig. 12 Operating Frequency vs. Temperature ( $V_{IN}=3.7V$ )

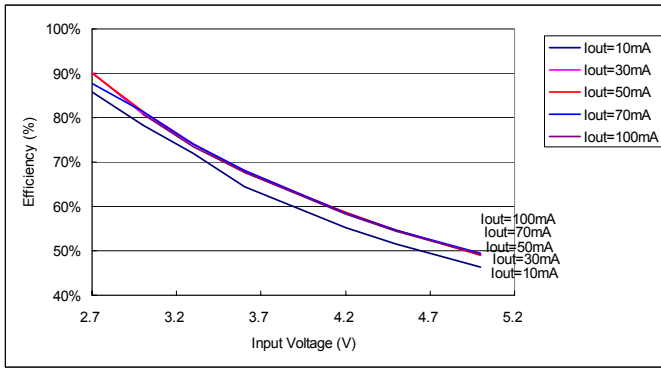


Fig. 13 Efficiency vs. Input Voltage

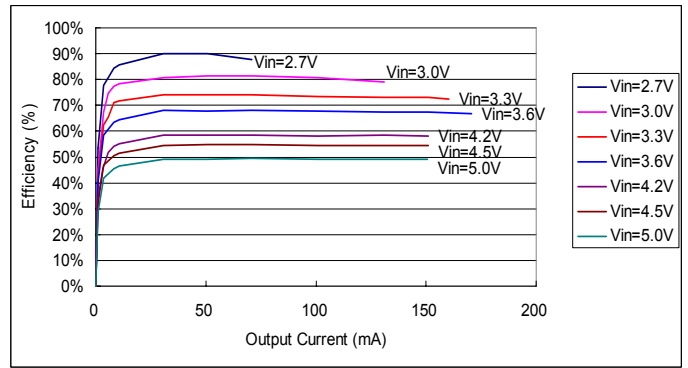


Fig. 14 Efficiency vs. Output Current

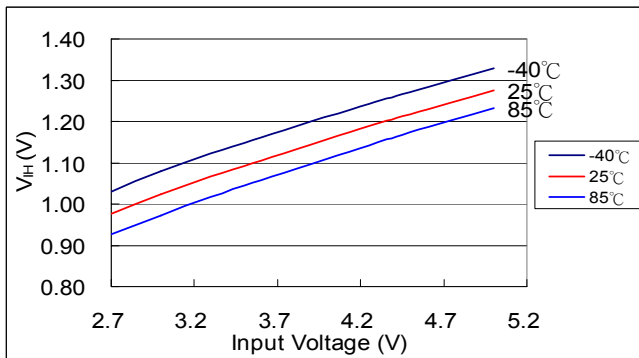


Fig. 15  $V_{IH}$  vs. Input Voltage

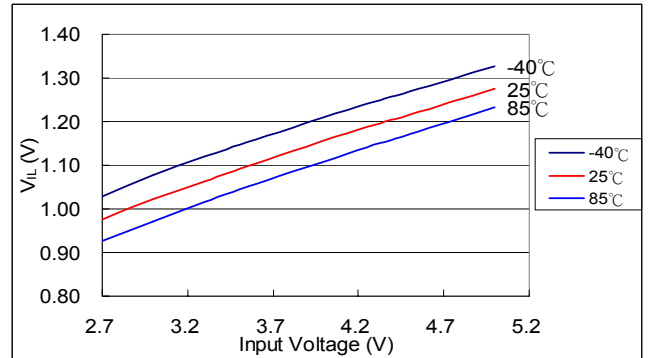


Fig. 16  $V_{IL}$  vs. Input Voltage

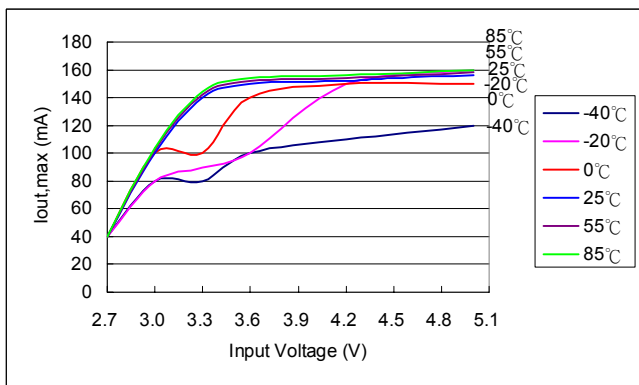


Fig. 17 Maximum Output Current vs. Input Voltage

Switching Characteristics

( $C_{IN}=C_{OUT}=10\mu F$ ,  $C_{FLY}=1\mu F$ ,  $T_a=25^\circ C$ , unless otherwise specified)

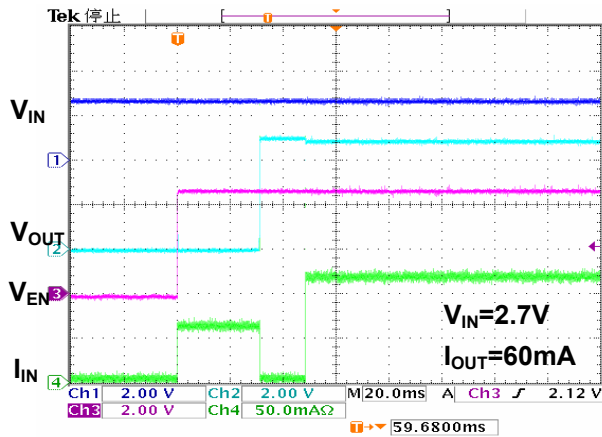


Fig. 18 Inrush Current

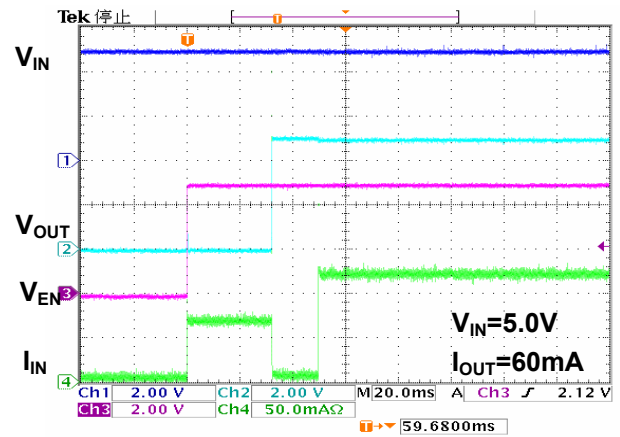


Fig. 19 Inrush Current ( $V_{IN}=5.0V$ ,  $I_{OUT}=60mA$ )

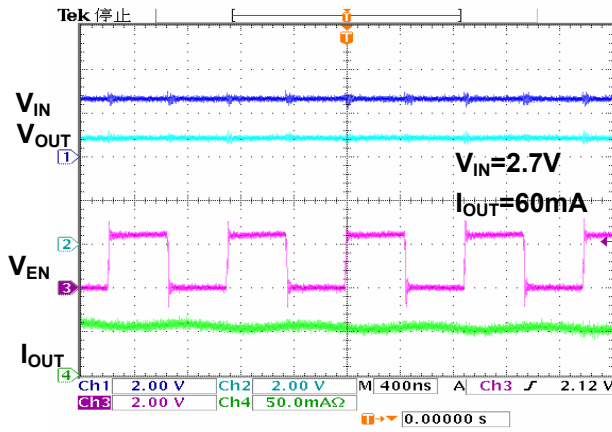


Fig. 20 Normal Operation

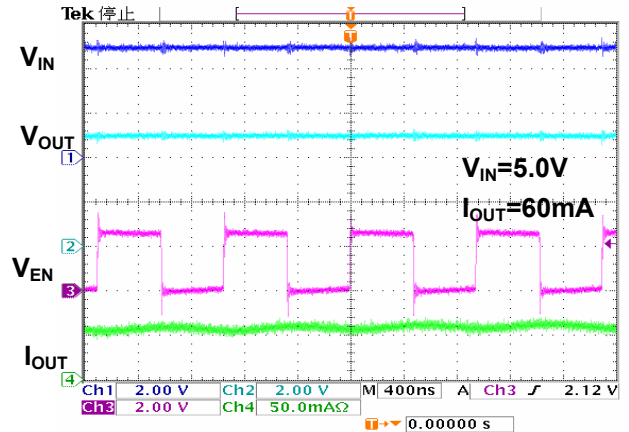


Fig. 21 Normal Operation

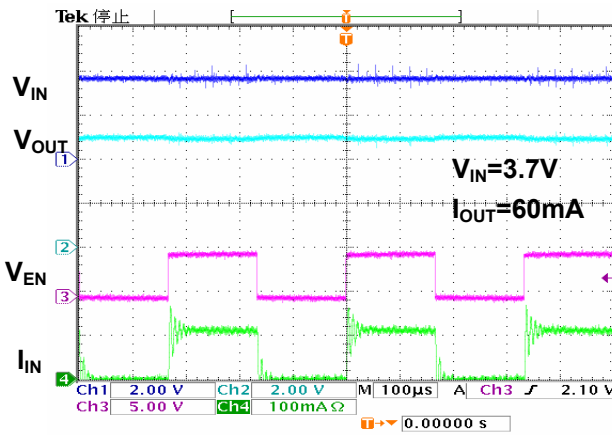


Fig. 22 Dimming Operation

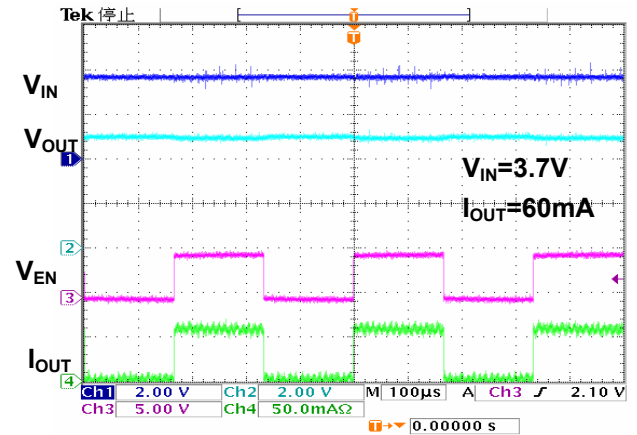


Fig. 23 Dimming Operation

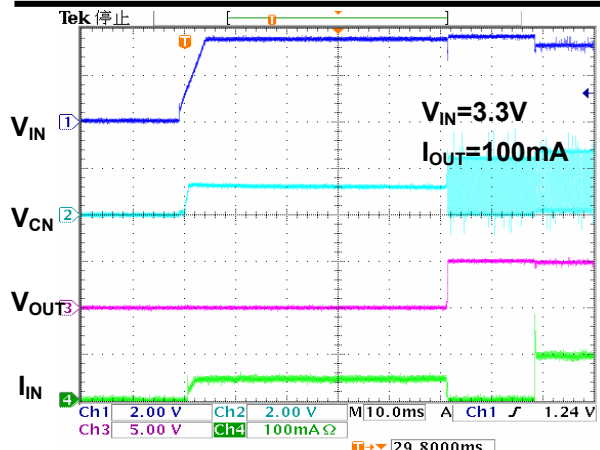


Fig. 24 Start-Up Waveform ( $V_{IN}=3.3V$ ,  $I_{OUT}=100mA$ )

**Application Information**

The MBI6501 uses a switched capacitor charge pump to boost  $V_{IN}$  to a regulated output voltage. Regulation is achieved by sensing the output voltage through a voltage divider and modulating the charge pump output current according to the error signal. A 2-phase non-overlapping clock activates the charge pump switches. The flying capacitor is charged from  $V_{IN}$  on the first phase of the clock. On the second phase of the clock, the flying capacitor is stacked in series with  $V_{IN}$  and connected to  $V_{OUT}$ . This sequence of charging and discharging the flying capacitor continues at a free running frequency of 1.1MHz (typ.).

**Shutdown Mode**

The MBI6501 is in the shutdown mode when a logic “0” is applied to the EN pin. In the shutdown mode, all circuitry is turned off and the MBI6501 draws only leakage current from the  $V_{IN}$  supply. Furthermore,  $V_{OUT}$  is disconnected from  $V_{IN}$ . The EN pin is a CMOS input with a threshold voltage of approximately 0.4V. Since the EN pin is a very high impedance CMOS input, it should never be allowed to float. To ensure that its state is defined, it must always be driven with a valid voltage level.

**Soft-Start Protection**

The MBI6501 has built in soft-start circuitry to prevent excessive current flow during start-up. The soft-start is achieved by charging an internal capacitor with a very weak current source. The voltage on this capacitor, in turn, slowly ramps the amount of current available to the output storage capacitor from zero to a value of 300mA over a period of approximately 0.75ms. The soft-start circuit is reset in the event of a commanded shutdown or thermal shutdown.

**Over-Current Protection**

In normal operation, the charging of the pump and output capacitors usually leads to relatively high peak input currents which can be much higher than that of the average load current. The MBI6501 has built in over-current circuit to limit the input peak current, lowering the total EMI production of the device and lowering output voltage ripple and input current ripple. Input capacitor ( $C_{IN}$ ) supplies most of the charge required by input current peaks.

**Short-Circuit Protection**

The MBI6501 has built in short-circuit current protection to prevent output voltage can't reach 5V at short-circuit condition. During a short-circuit condition, the MBI6501 will automatically limit its output current to 60mA.

**Thermal Shutdown**

At higher temperatures, or if the input voltage is high enough to cause excessive self-heating of the part, the thermal shutdown circuitry will shut down the charge pump once the junction temperature exceeds 160°C (typ.). The charge pump resumes working once the junction temperature is below 140°C (typ.). The MBI6501 will cycle in and out of thermal shutdown indefinitely without latch-up or damage.

**Power Conversion Efficiency**

The power conversion efficiency of the MBI6501 is similar to that of a linear regulator with an effective input voltage of twice the actual input voltage. This occurs because the input current for a voltage doubling charge pump is approximately twice the output current. In an ideal regulating voltage doubling the power efficiency would be given by:

$$\text{Efficiency (\%)} = P_{OUT} / P_{IN} = V_{OUT} * I_{OUT} / V_{IN} * I_{OUT} * 2 = V_{OUT} / (2 * V_{IN})$$

At moderate to high output power, the switching losses and the quiescent current of the MBI6501 are negligible and the expression above is valid. For example, with  $V_{IN}=3V$ ,  $I_{OUT}=60mA$  and  $V_{OUT}$  regulating to 5V, the measured efficiency is 81.8% which is in close agreement with the theoretical 83.3% calculation.

**External Capacitor Selection**

Three external capacitors,  $C_{IN}$ ,  $C_{OUT}$  and  $C_{FLY}$ , determine the MBI6501 performances. Optimum performance can be obtained by using a low-ESR ceramic capacitors. Due to high ESR, tantalum and aluminum capacitors are not recommended for charge pump application. To reduce noise and ripple, a low-ESR ceramic capacitor is recommended for  $C_{IN}$  and  $C_{OUT}$ . The value of  $C_{OUT}$  determines the amount of output ripple voltage. An output capacitor with larger value results in smaller ripple.  $C_{FLY}$  is critical for the charge pump. The larger  $C_{FLY}$  is, the larger output current and smaller ripple voltage obtain. However, large  $C_{IN}$  and  $C_{OUT}$  are required when large  $C_{FLY}$  is applied.  $C_{IN} : C_{FLY}$  and  $C_{OUT} : C_{FLY}$  should be approximately 10:1.

**Layout Considerations**

Due to the switching frequency and high transient current of the MBI6501, careful consideration of PCB layout is necessary. To achieve the best performance of the MBI6501, minimize the distance between every two components and also minimize every connection length with a maximum trace width.

**Package Heat Dissipation (PD)**

The maximum package heat dissipation,  $P_D(max)=(T_j-T_a)/R_{th(j-a)}$ , decreases as the ambient temperature increases.

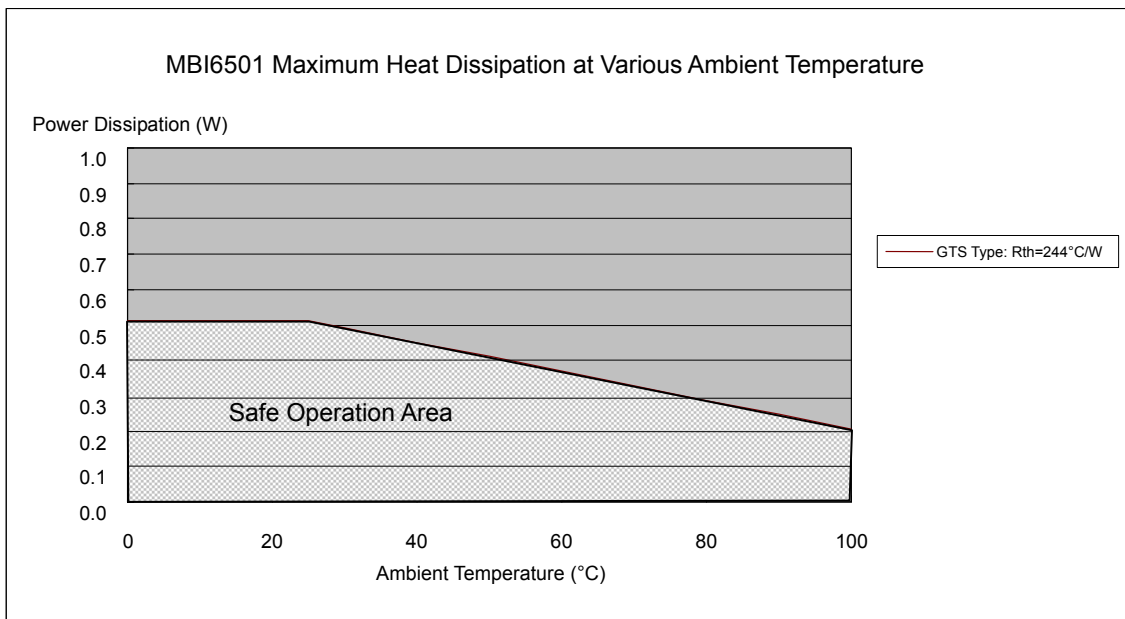
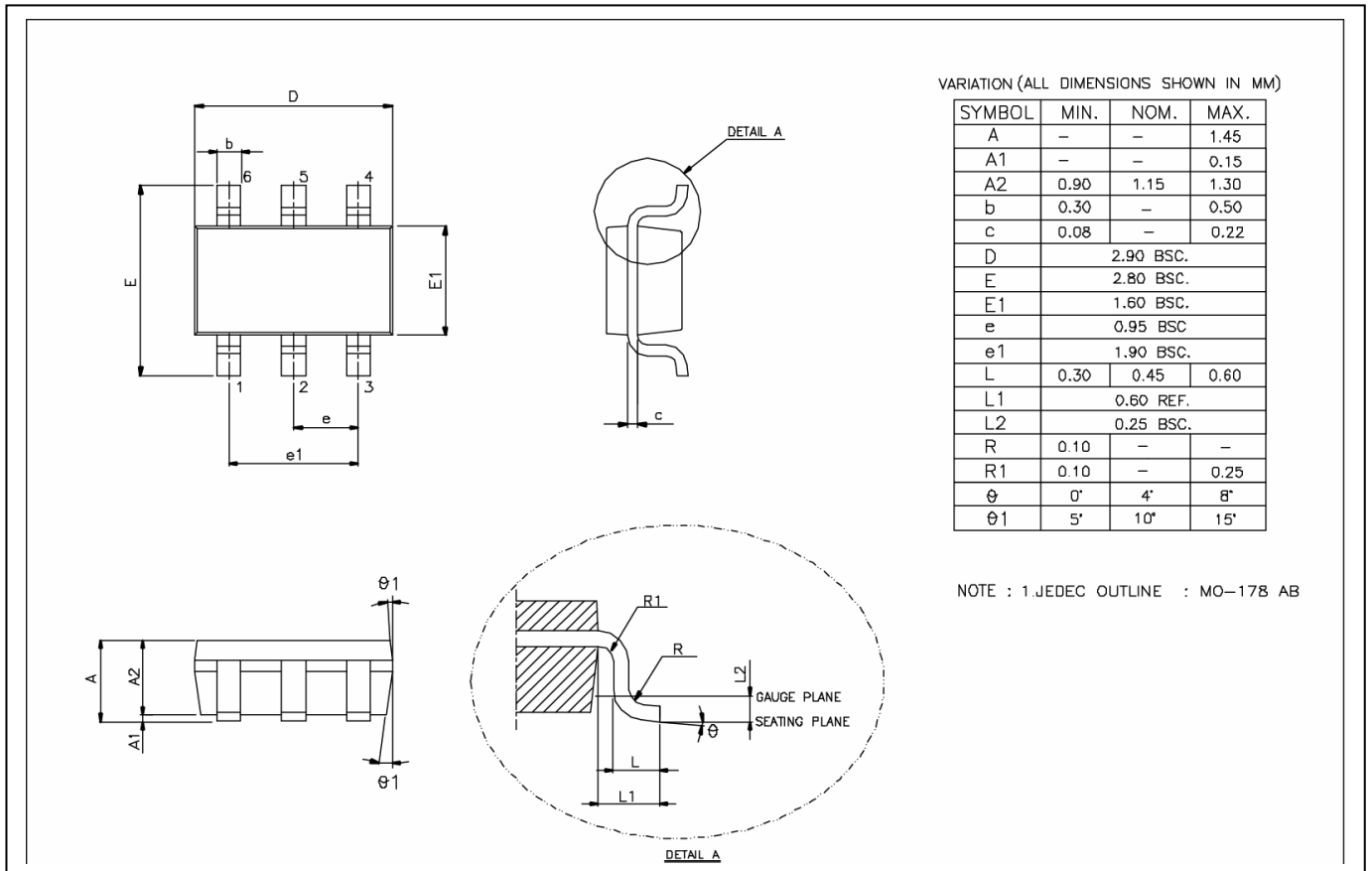


Fig. 25

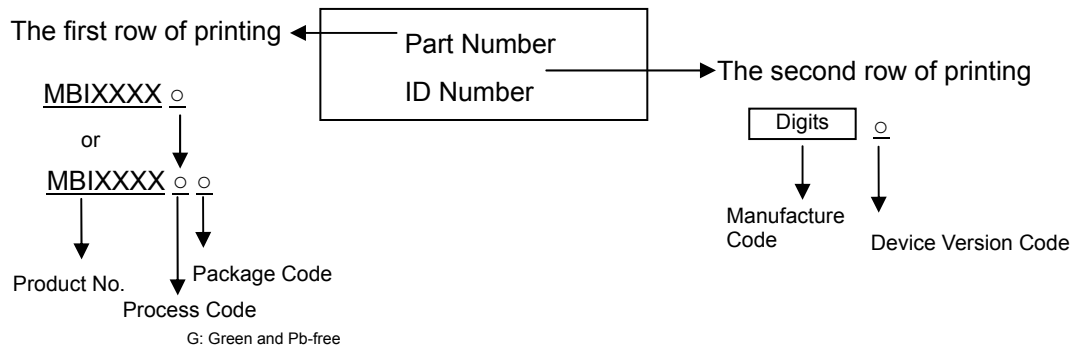
Outline Drawing



MBI6501GST Outline Drawing

Note: The unit for the outline drawing is mm.

**Product Top Mark Information**



**Product Revision History**

Datasheet Version	Device Version Code
V1.00	A

**Product Ordering Information**

Product Number	Green Package Type	Weight (g)
MBI6501GST	SOT-23-6L	0.000016

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