

## Single-Powered Synchronous Step-Down DC/DC Controller

### ■ FEATURES

- High Efficiency: Up to 93%
- Single-Powered N-channel MOSFETs Synchronous Driver
- Wide Input Voltage Operation Range, 8V to 25V
- Accurate Internal temperature compensated 0.8V Bandgap Reference Voltage with  $\pm 1\%$  precision.
- Fast Transient Response
  - Duty cycle 0% to 95 %
- PWM Operation at 300KHz
- Built-in Soft-Start function.
- Over Voltage Protection with Latch Up.
- Under Voltage Protection at Vout with Latch Up.
- Over Current Protection.
- Package: MSOP10

### ■ APPLICATIONS

- Information Appliances
- LCD TV
- Graphic Card
- Telecomm Equipments

### ■ GENERAL DESCRIPTION

The AIC1591 is a voltage mode synchronous buck PWM controller that drives external N-channel power MOSFET using a 300kHz fixed frequency architecture. This device is capable of producing an output voltage as low as 0.8V. It uses external divider to adjust output voltage with the exact right line and load regulation.

The AIC1591 provides adjustable overcurrent protection threshold from external component, fixed threshold both undervoltage and overvoltage protection. LDO is built in to provide AIC1591 logic power source, and application circuit just uses one single power supply.

A multifunction pin (COMP) allows external compensation for optimum load step response and shutdown. Soft start can also be implemented with this pin to properly sequence supplies.

The AIC1591 is available in space-saving 10 pins MSOP package.

■ **TYPICAL APPLICATION CIRCUIT**

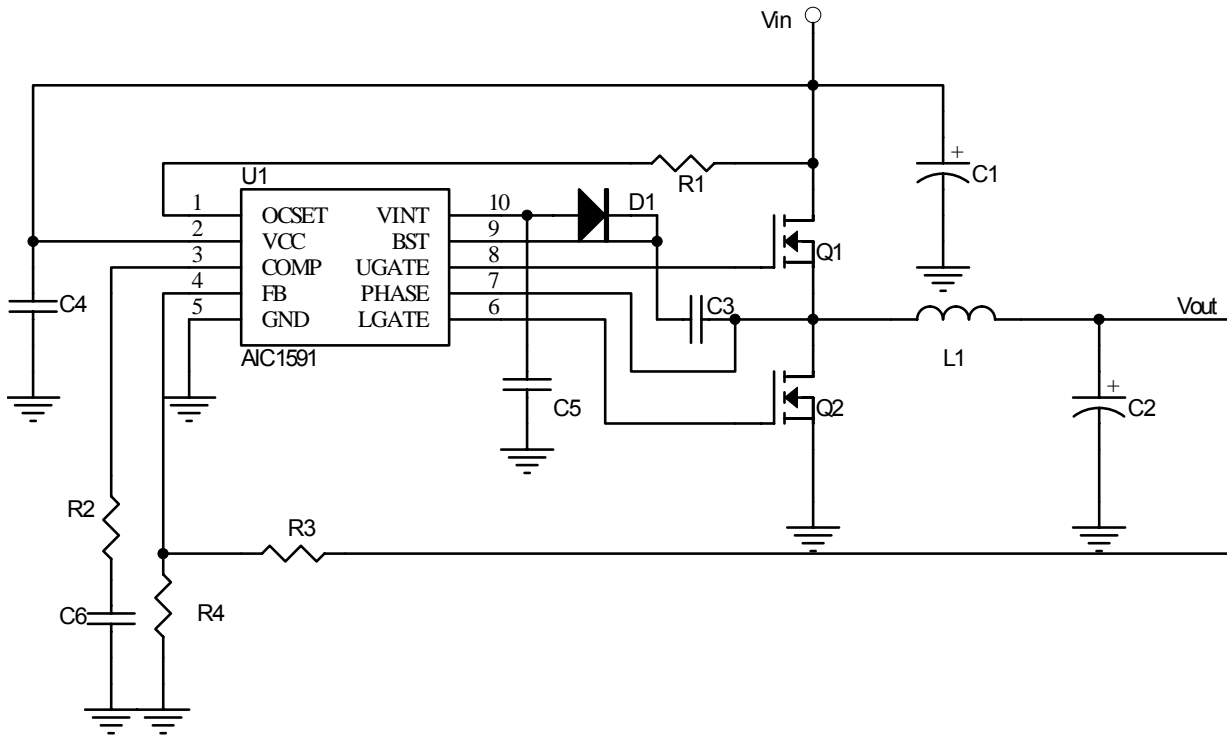


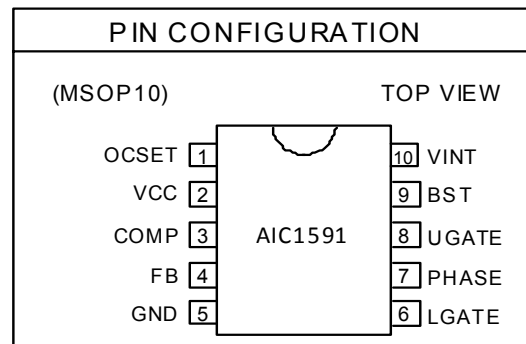
Fig.1 General Application Circuit

■ **ORDERING INFORMATION**

AIC1591X~~X~~XXXX

- PACKING TYPE  
TR: TAPE & REEL  
TB: TUBE
- PACKAGING TYPE  
OB: MSOP-10
- P: Lead Free Commercial  
G: Green Package

Example: AIC1591POBTR  
 → In MSOP-10 Lead Free Package  
 & Taping & Reel Packing Type  
 AIC1591GOBTR  
 → In MSOP-10 Green Package &  
 Taping & Reel Packing Type



**ABSOLUTE MAXIMUM RATINGS**

Supply Voltage (VCC), OCSET.....	26V
Differential BST Voltage (BST to PHASE).....	7.8V
UGATE, BST .....	32V
LGATE, PHASE, .....	26V
FB, COMP, .....	5V
(VINT LDO Continuous Driver Current = 30mA, it depends on thermal condition.)	
Operation Temperature Range .....	-40°C ~ 85°C
Junction Temperature .....	125°C
Storage Temperature Range.....	-65°C ~ 150°C
Lead Temperature (Soldering 10s).....	260°C
Thermal Resistance Junction to Case.....	45°C/W
Thermal Resistance Junction to Ambient.....	120°C/W

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

**ELECTRICAL CHARACTERISTICS** ( $V_{CC}=12V, T_J=25^{\circ}C$ , Unless otherwise specified)

PARAMETER	TEST CONDITIONS	SYMBOL	MIN.	TYP.	MAX.	UNIT
<b>VCC Supply Current</b>						
Supply Current	Open: UGATE, LGATE PHASE=0V	I <sub>CC</sub>			2	mA
<b>Power On Reset</b>						
Rising VCC Threshold		V <sub>CCTHR</sub>	4.0	4.2	4.4	V
Falling VCC Threshold		V <sub>CCTHF</sub>	V <sub>CCTHR</sub> -0.2			V
<b>Oscillator and PWM Controller</b>						
Switching Frequency		F <sub>OSC</sub>	250	300	350	KHz

Reference/ FB		V <sub>REF</sub>	0.784	0.8	0.816	V
Duty Cycle			0		95	%
<b>VINT LDO</b>						
Voltage				6.1		V
Tolerance	PHASE=0V, I <sub>INT</sub> =0mA to 10mA			5%		
VINT OCP				60		mA

**■ ELECTRICAL CHARACTERISTICS (Continued)**

PARAMETER	TEST CONDITIONS	SYMBOL	MIN.	TYP.	MAX.	UNIT
<b>Shut Down</b>						
Normal	COMP voltage				1.2	V
Shut Down	COMP voltage		0.6	0.8		V
Shut Down Current				20		μA
Normal operation Current	Open: UGATE, LGATE PHASE=0V			1	2	mA

<b>PWM Control Gate Driver</b>						
Upper Drive Source	BST=VINT,I=60mA	R <sub>UGH</sub>		5.2	6.5	Ω
Upper Drive Sink	BST=VINT,I=10mA	R <sub>UGL</sub>		3.3	5	Ω
Lower Drive Source	BST=VINT,I=10mA	R <sub>LGH</sub>		5.2	6.5	Ω
Lower Drive Sink	BST=VINT,I=10mA	R <sub>LGL</sub>		3	5	Ω
<b>Error Amplifier</b>						
Open Loop DC Gain	Design guaranteed	A <sub>o</sub>		84		dB
FB to COMP Transconductance		G <sub>m</sub>		0.9		mA/V
<b>OVP at FB</b>						
Trigger voltage	7.5% OVP		0.838	0.86		V
<b>UVP at FB</b>						
Trigger voltage	25% UVP			0.6	0.615	V
<b>OCSET</b>						
Current source			36	40	47	μA
<b>Soft Start</b>						
Soft Start Time				5		mS

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

**Note 2:** Dynamic supply current is higher due to the gate charge being delivered at the switching frequency.

**Note 3:** It is recommended to use duty ratio among 12% to 80% for optimizing transient response and minimizing resultant duty cycle jitter.

## ■ TYPICAL PERFORMANCE CHARACTERISTICS

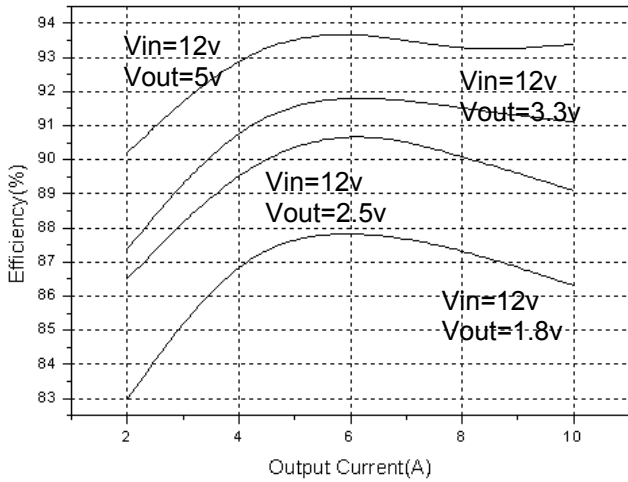


Fig.2 Efficiency vs. Output Current

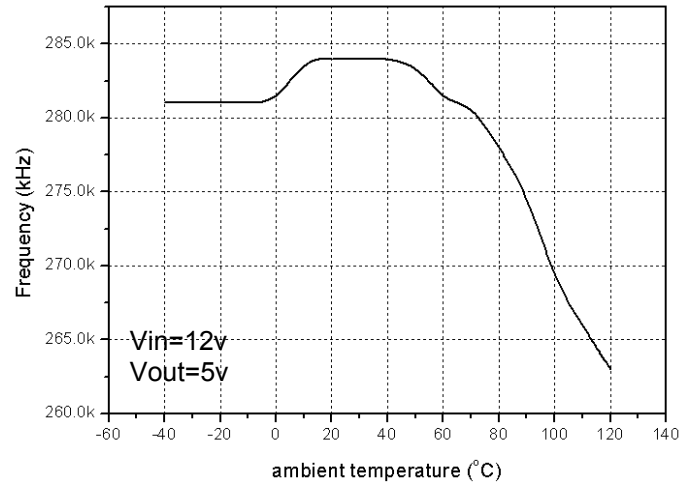


Fig.3 Frequency vs. Temperature

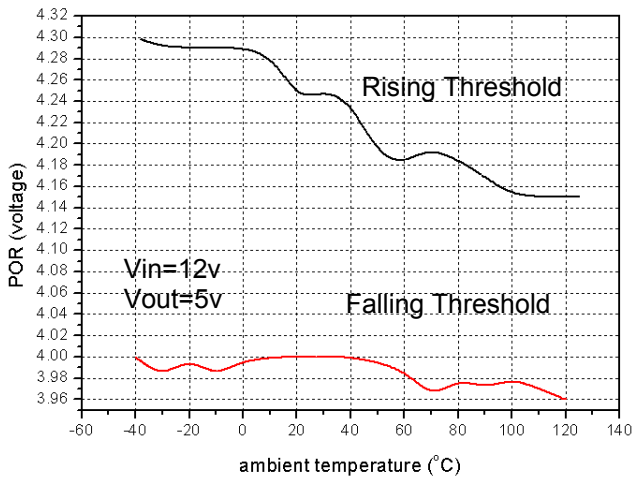


Fig.4 Power On Reset vs. Temperature

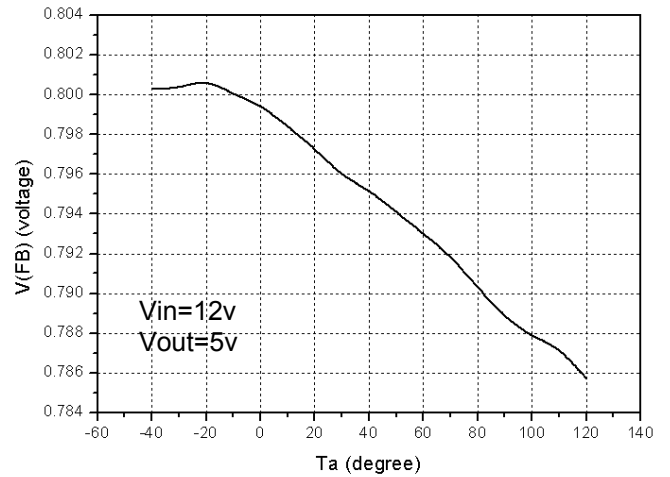


Fig.5 Reference Voltage vs. Temperature

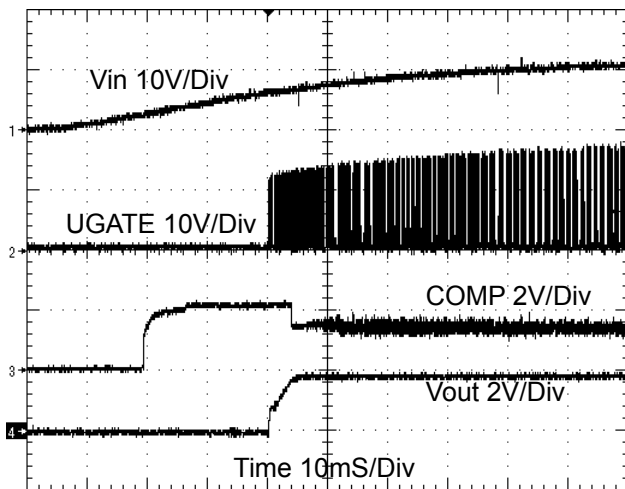


Fig.6 Power On

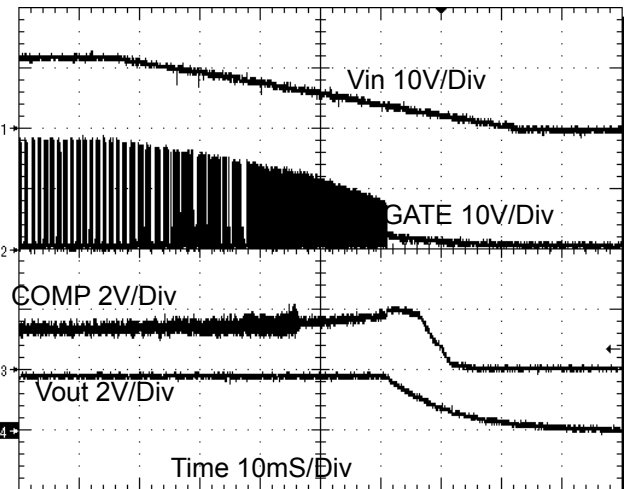


Fig.7 Power Off

■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

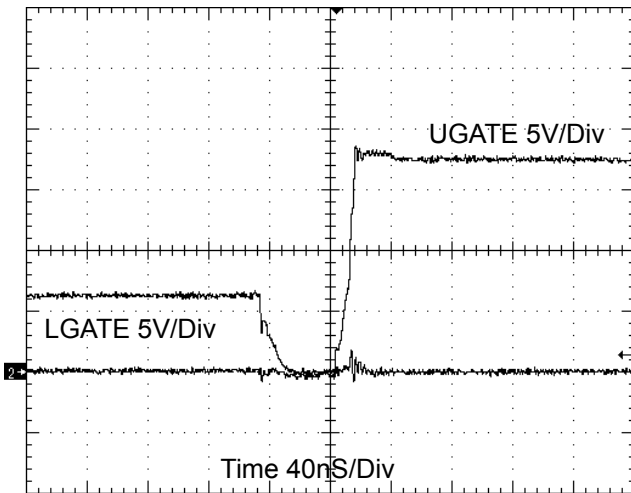


Fig.8 Dead Time (Rising)

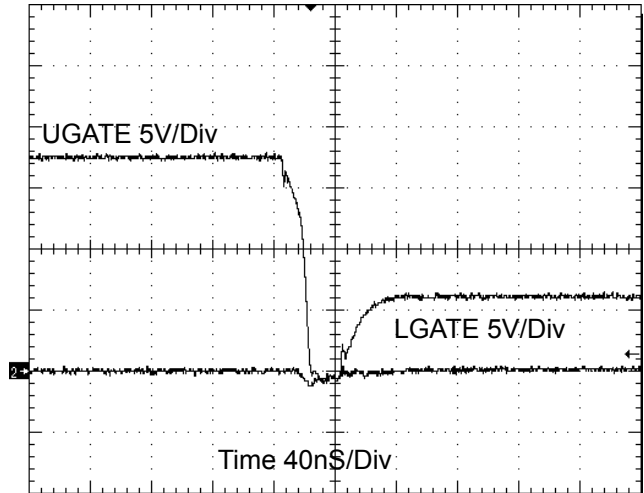


Fig.9 Dead Time (Falling)

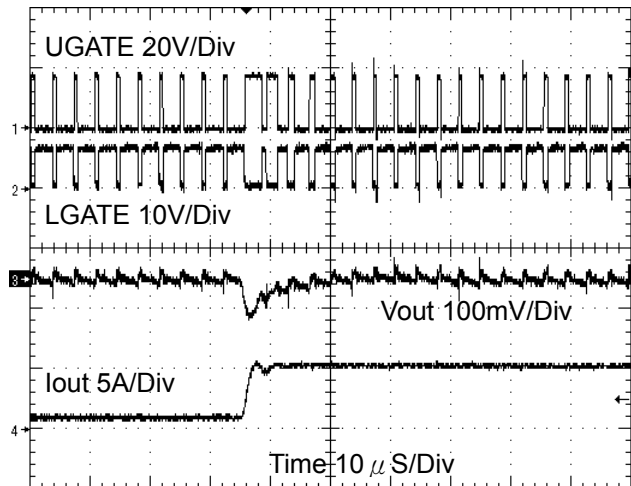


Fig.10 Transient Response (Rising)

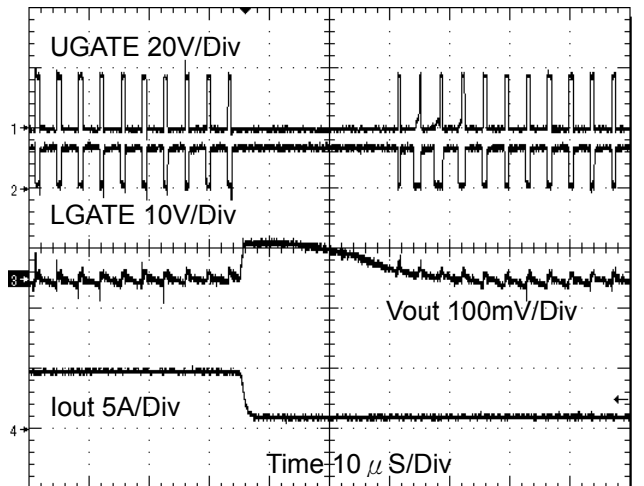


Fig.11 Transient Response (Falling)

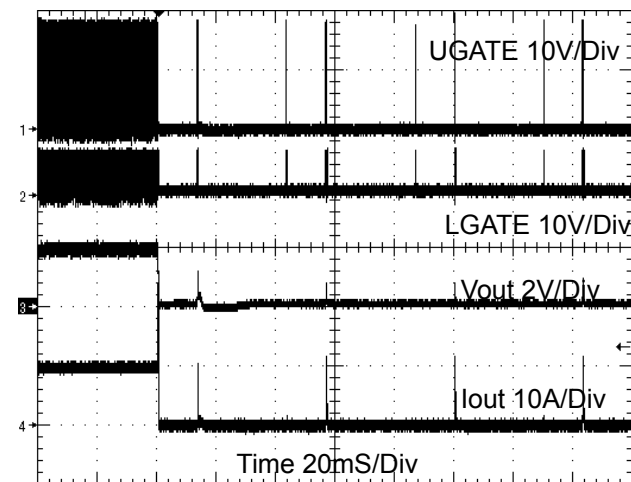


Fig.12 Short Circuit Protection

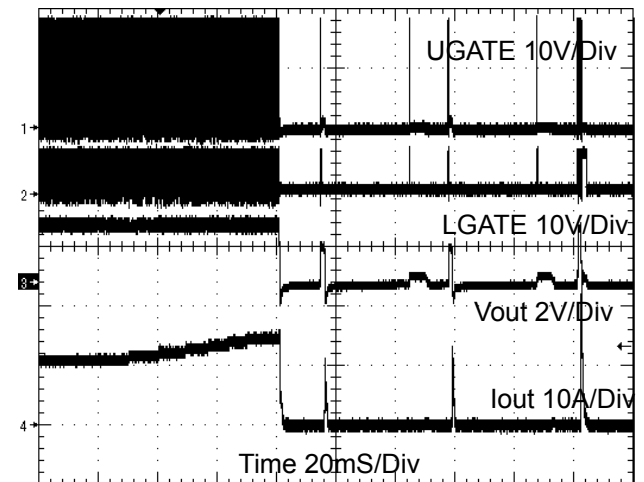


Fig.13 Overcurrent Protection

**TYPICAL PERFORMANCE CHARACTERISTICS (Continued)**

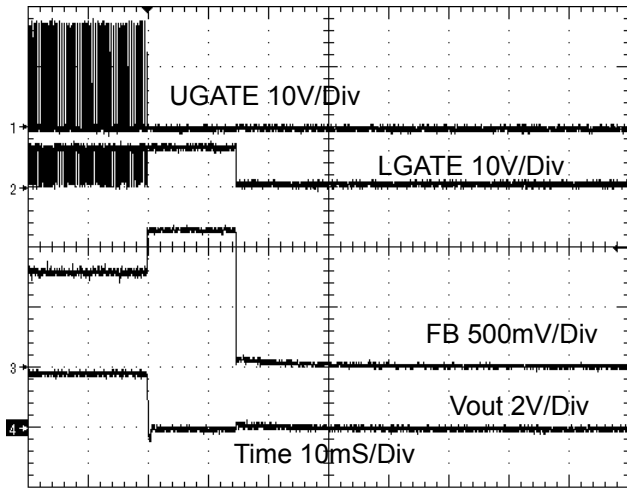


Fig.14 Over Voltage Protection

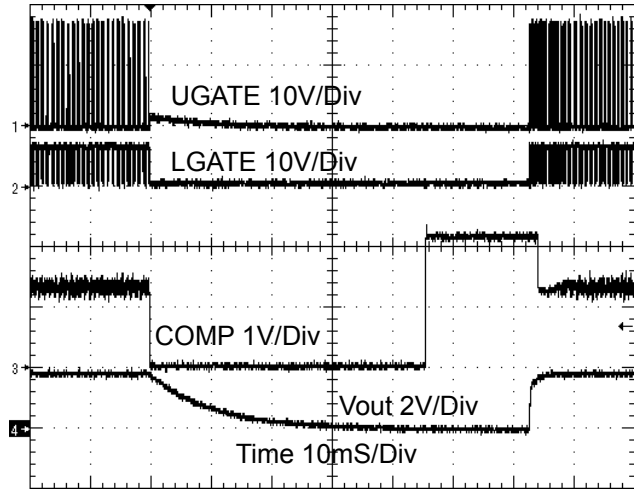


Fig.15 Shutdown

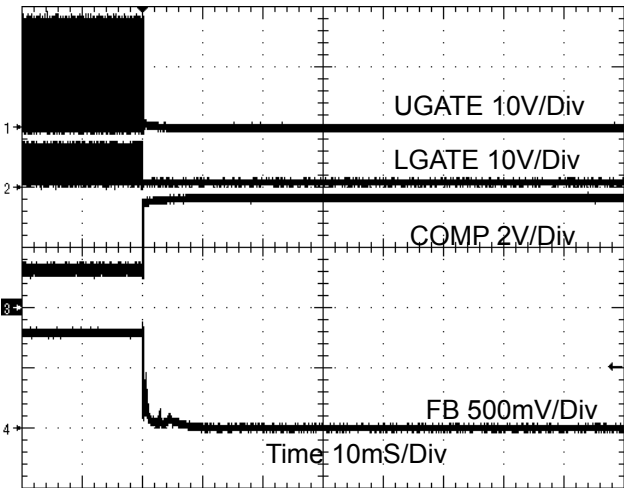
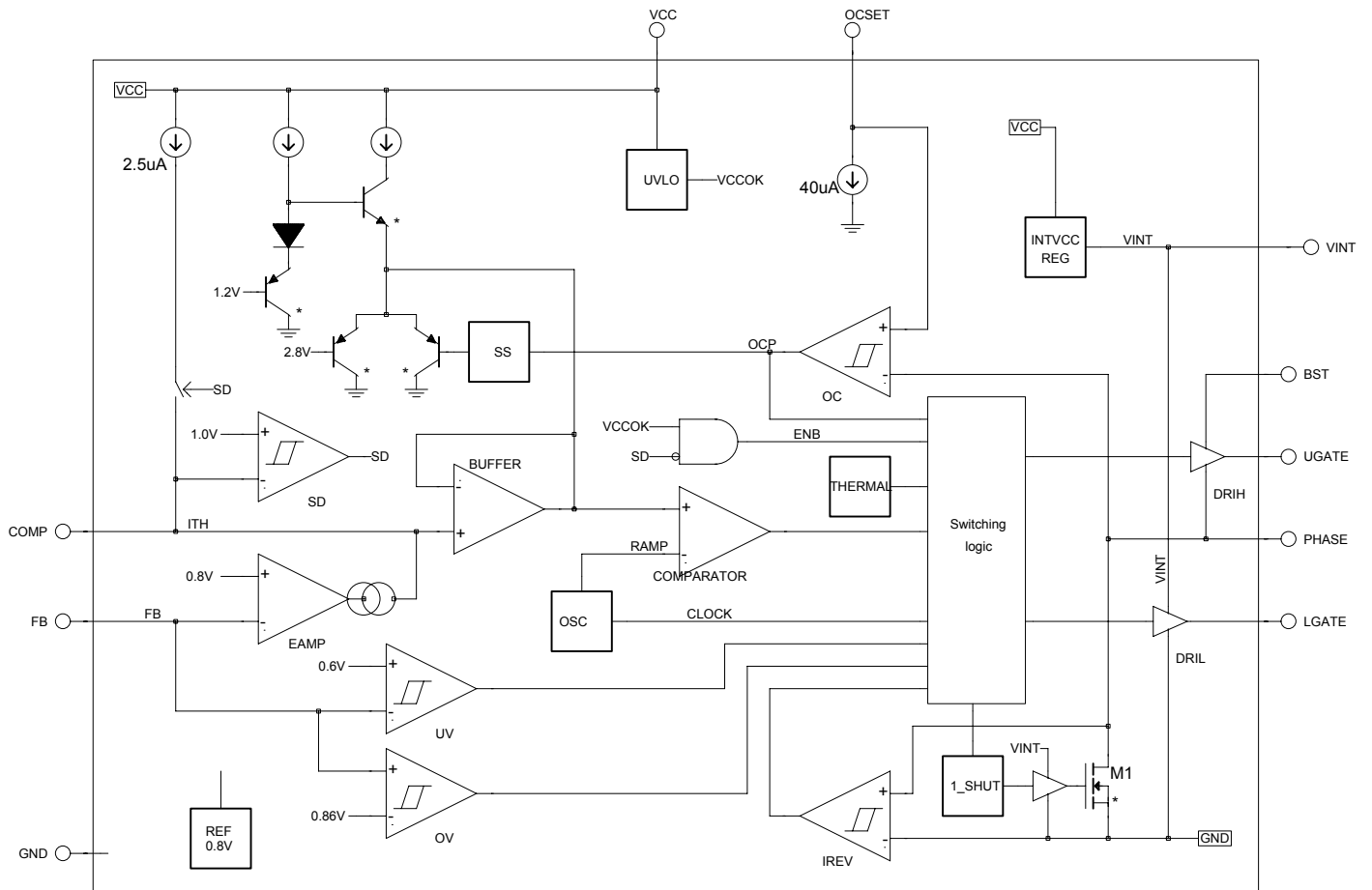


Fig.16 Under Voltage Protection

■ BLOCK DIAGRAM





## ■ PIN DESCRIPTIONS

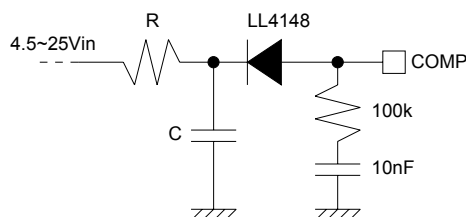
- Pin 1: OCSET: Over Current Protection function. There is a  $40\ \mu\text{A}$  current source inside OCSET.
  
- Pin 2: VCC: The chip power supply pin. It also provides the gate bias charge for all the MOSFETs controlled by the IC.
  
- Pin 3: COMP: External compensation pin. This pin is connected to error amplifier output and PWM comparator. A RC network is to compensate the voltage control feedback loop of the converter.  
 Normal Operation:  $\text{COMP} > 1.2\text{V}$   
 Shut Down:  $\text{COMP} < 0.6\text{V}$
  
- Pin 4: FB: The error amplifier inverting input pin.
  
- Pin 5: GND: Ground pin for IC. All voltage levels are measured with respect to this pin.

- Pin 6: LGATE: Lower N-MOSFET gate drive pin. It is used to connect LGATE to the gate of the external high-side N-MOSFET.
  
- Pin 7: PHASE: Connect the PHASE pin to source of the external high-side N-MOSFET.
  
- Pin 8: UGATE: External high-side N-MOSFET gate drive pin. It is used to connect UGATE to the gate of the external high-side N-MOSFET.
  
- Pin 9: BST: Bias voltage for high side driver, a VINT voltage source is connected to this pin via a diode. Connecting a capacitor externally to PHASE pin provides a charge pump voltage to high side driver.
  
- Pin 10: VINT: LDO output.

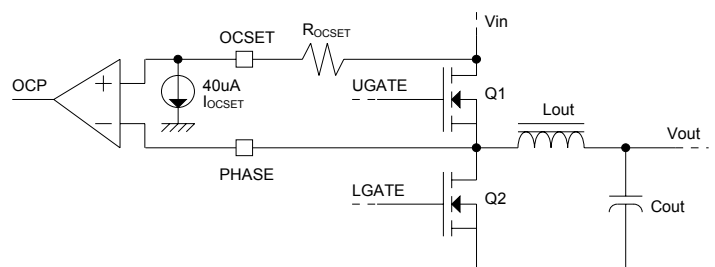
## APPLICATION INFORMATION

### Soft-Start

A built-in soft start is used to ease inrush current from power supply during start-up. Internal counter controls the soft-start voltage. It is powered by internal LDO. Soft start interval can be adjustable from external component (R,C) as the following circuit.



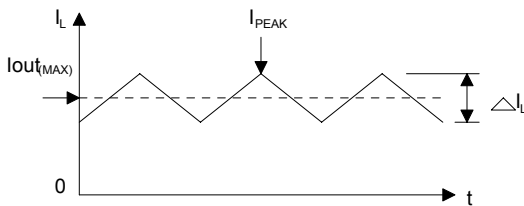
### Over Current Protection



Sense the  $R_{DS\_ON}$  of high-side MOSFET (Q1) sets over-current trip point. An external resistor ( $R_{OCSET}$ ) is programmed to the over-current tripping level. An internal  $40\ \mu\text{A}$  current source ( $I_{OCSET}$ ) develops a voltage across  $R_{OCSET}$  that is referenced to  $V_{in}$ . When the voltage across the  $R_{DS\_ON}$  of high-side MOSFET

exceeds  $V_{OCSET}$  that will cause over current protect. When over current protection is triggered, a hiccup restart sequence will be initialized until over-current even disappears.

The over-current trip point is based on the following equation:



$$I_{PEAK} = \frac{I_{OCSET} \times R_{OCSET}}{R_{DS\_ON}}$$

$$I_{PEAK} > I_{OUT(MAX)} + (\Delta I_L)/2$$

Where  $\Delta I_L$  is output inductor( $L_{out}$ ) ripple current.

## Under Voltage Protection

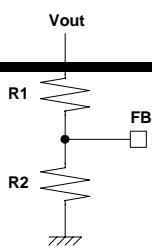
The FB pin is monitored during converter operation by separate under voltage comparator. If the FB voltage drops below 0.6v, the output will latch off right away.

## Over Voltage Protection

The FB pin is monitored during converter operation by separate over voltage comparator. If the FB voltage rises to 0.86v and above, the output will latch off right away.

## Output Voltage Selection

The output voltage can be programmed to any level between  $V_{in}$  and the internal reference voltage, 0.8v. An external resistor divider is used to scale the output voltage. The output voltage can be calculated based on the following equation:



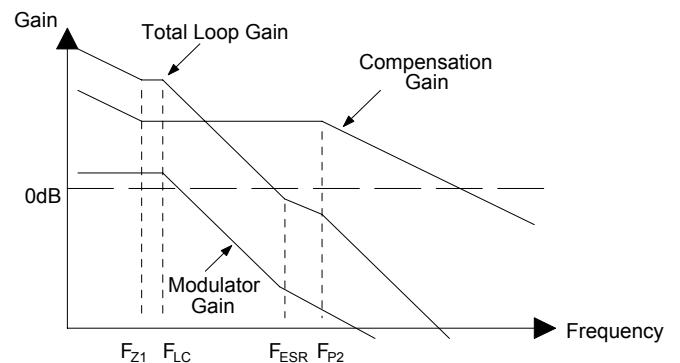
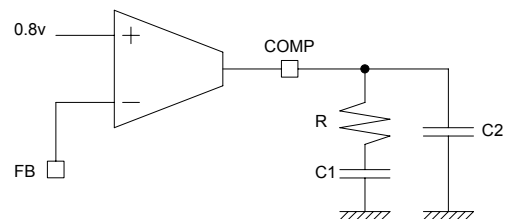
$$V_{OUT} = V_{FB} \times \left(1 + \frac{R1}{R2}\right)$$

Where  $V_{FB}$  is 0.8v reference voltage.

## Shutdown

Pulling low the COMP pin by a small single transistor can shutdown the AIC1591 PWM controller as shown in typical application circuit.

## Compensation



Poles:

$$P1 = 0, P2 = \frac{1}{R(C_1 // C_2)}$$

Zero:

$$Z1 = \frac{1}{RC_1}$$

1. Set the  $F_{Z1}$  below the output filter double pole. ( $\sim 3/4 F_{LC}$ )
2. Set the  $F_{P2}$  at half the converter switching frequency. ( $\sim 1/2 F_{SW}$ )
3. Lower crossover frequencies result in slower response and worse transient load recovery. Higher crossover frequencies can cause instability.

## Component Selection Guidelines

## Output Inductor Selection

The inductor value determines the ripple current. The approximate ripple current and inductance value are measured by the following equations:

$$\Delta I_L = \frac{V_{OUT}(1-D)}{L f_{SW}}$$

Where  $\Delta I_L$  = inductor ripple current  
 $f_{SW}$  = free running frequency  
 $D$  = duty cycle,  $V_{out}/V_{in}$

Increasing the value of inductance will reduce the output ripple current and ripple voltage. However, increasing the inductance value will slow the converter response time to a load transient.

## Input Capacitor Selection

Select input capacitors with voltage and current ratings above the maximum input voltage and the circuit requires the largest RMS current. The capacitor voltage rating should be at least 1.25 times greater than maximum input voltage. The RMS current rating requirement is approximately 1/2 of the DC load current.

## Output Capacitor Selection

The buck filter capacitor selection depends on series resistance (ESR), output ripple voltage and ripple current. These factors can be calculated as follows:

$$\Delta V_{OUT} = \frac{\Delta I_L}{8C f_{SW}}, \quad ESR = \frac{\Delta V_{OUT}}{\Delta I_L},$$

$$I_{C(RMS)} = \frac{\Delta I_L}{2\sqrt{3}}$$

Where  $I_{C(RMS)}$  = capacitor ripple current

## Switch MOSFET Selection

In high current applications, the MOSFET power dissipation and heat sink are the dominant design factor. The power dissipation includes two losses section: conduction loss and switching loss.

Upper MOSFET conduction loss

$$\cong I_{OUT}^2 \times R_{DS\_ON} \times D$$

Lower MOSFET conduction loss

$$\cong I_{OUT}^2 \times R_{DS\_ON} \times (1-D)$$

$$\text{Switching loss} \cong \frac{1}{2} \times I_{OUT} \times V_{IN} \times t_{ON,OFF} \times f_{SW}$$

Where  $t_{ON,OFF}$  = switching interval

Large gate-charge ( $C_{iss}$ , MOSFET input capacitance) will increase the switching interval,  $t_{ON,OFF}$ , which increase the MOSFET switching loss. Selects low  $R_{DS\_ON}$  and low  $C_{iss}$  can reduce the MOSFET power dissipation.

## PCB Layout Considerations

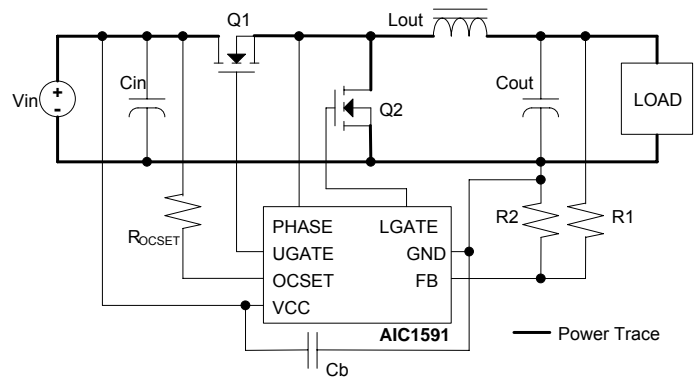
The voltage spikes is the thought-provoking problem in switching converter design. It can affect the application-circuit's stability and performance. Careful component layout and printed circuit board design minimizes the voltage spikes in the converter.

The voltage spikes comes from MOSFET switching, therefore; placing the input capacitors and high-frequency ceramic decoupling capacitors are helpful to reduce voltage spike at input power supply. Laying the output inductor and output capacitors between the MOSFET and the load are effective to reduce voltage spike at output load. These components must be closed jointly to minimize the voltage spikes.

It is necessary to use a shorter and wider power plane that provides lower impedance to reduce the voltage drop. For this reason, a multi-layer printed circuit board is recommended. It is shown the connections of the critical components in the converter in Fig 17:

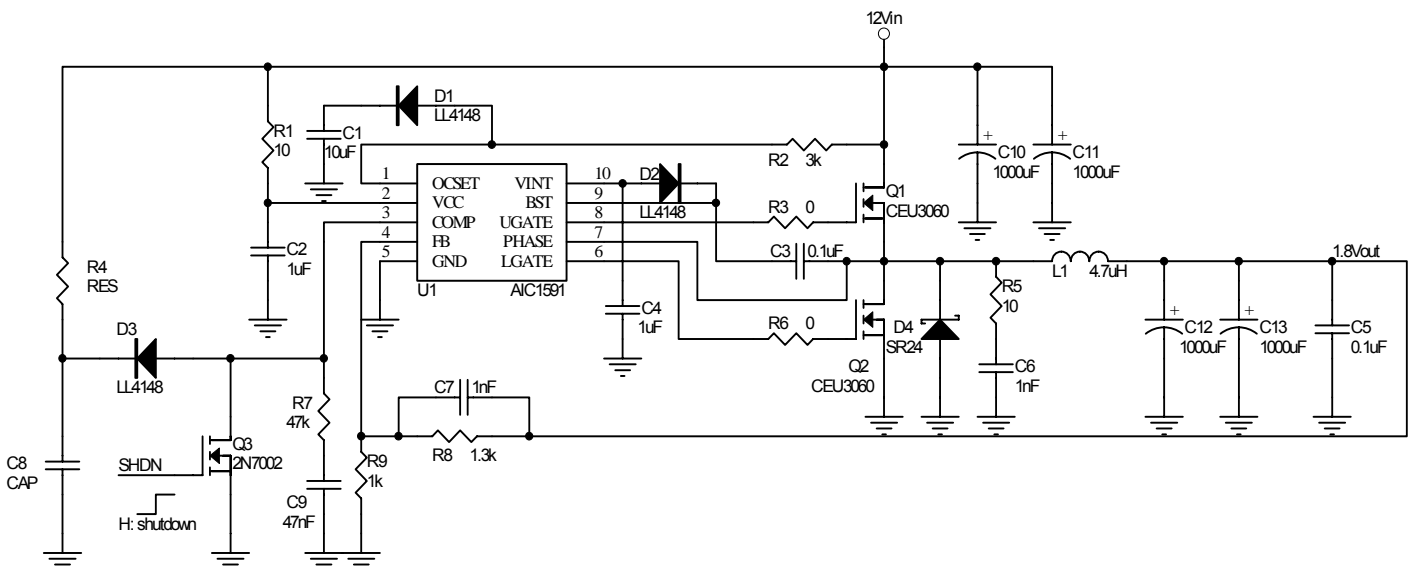
- The capacitors,  $C_{in}$  and  $C_{out}$  representing numerous physical capacitors.
- Use a dedicated grounding plane and use vias to ground all critical components to this layer.
- Keep the metal running from the PHASE terminal to the output inductor short.
- Use copper filled polygons on the top and bottom circuit layers for the phase node.

- The wiring traces from the UGATE pin to the MOSFET gate should be kept short and wide enough to handle the 2A of peak current.



**Fig.17 Connections of the circuit components**

## APPLICATION CIRCUIT

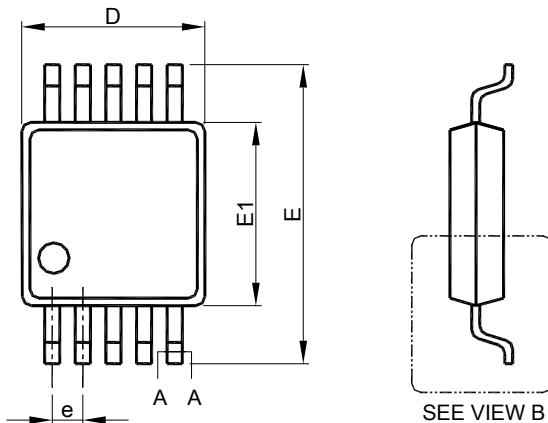


\*The output current is based on switching components.

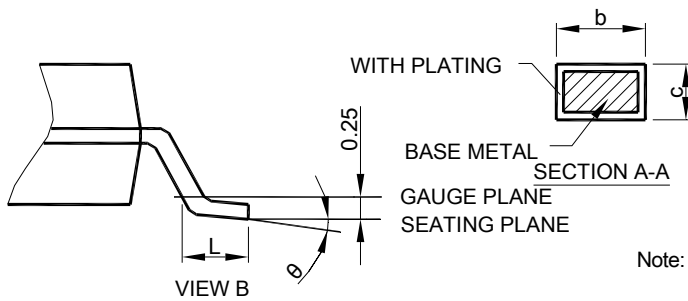
**Fig. 18 Synchronous PWM buck step-down controller with high performance circuit**

■ PHYSICAL DIMENSIONS (unit: mm)

● MSOP10



SYMBOL	MSOP-10	
	MILLIMETERS	
	MIN.	MAX.
A		1.10
A1	0.05	0.15
A2	0.75	0.95
b	0.15	0.30
c	0.13	0.23
D	2.90	3.10
E	4.90 BSC	
E1	2.90	3.10
e	0.50 BSC	
L	0.40	0.70
q	0°	6°



- Note: 1. Refer to JEDEC MO-187BA.  
 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.

**Note:**

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