APPLICATION MANUAL

White LED Driver IC for Camera Lights
TK11891F

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MEETING YOUR NEEDS
TOKO, INC.

White LED Driver IC for Camera Lights
TK11891F

1. DESCRIPTION

The TK11891F is a step-up DC-DC converter designed for camera lights for mobile phones and portable equipment, using constant frequency PWM architecture, with the following built in: a very high current switching transistor (1.0A peak), a very high speed oscillator (2.0MHz), a switch over current detector, a low voltage reference (V_{EA}=0.495V), an error amplifier, a PWM comparator, a zener diode for open-circuit protection and ON/OFF control.
TK11891F can drive four LEDs in series at 100mA with a small coil because of the high oscillation frequency 2.0MHz. This IC works with a very wide operation supply range (2.65V~16V) and the adjustable output voltage can be set as high as 20V. The white LEDs are connected in series and driven at a constant current, resulting in uniform brightness and high efficiency. The reference voltage is a very low 0.495V, achieving high efficiency operation with the constant current output. The ON/OFF control is built-in and the circuit current can be decreased when the EN pin is low (shutdown mode). The white LEDs can be dimmed by applying a PWM signal to the EN (ON/OFF control) pin. With this method, the white LED brightness is still controlled by constant current, resulting in constant chromaticity.
The built-in zener diode can be used for open-circuit protection in case the output load is disconnected, such as the string of LEDs opened. The internal zener diode reduces the external component count.
The TK11891F can also be used in other applications as a step-up DC-DC converter.
The TK11891F is available in the SON3024-8 surface mount package.

2. FEATURES

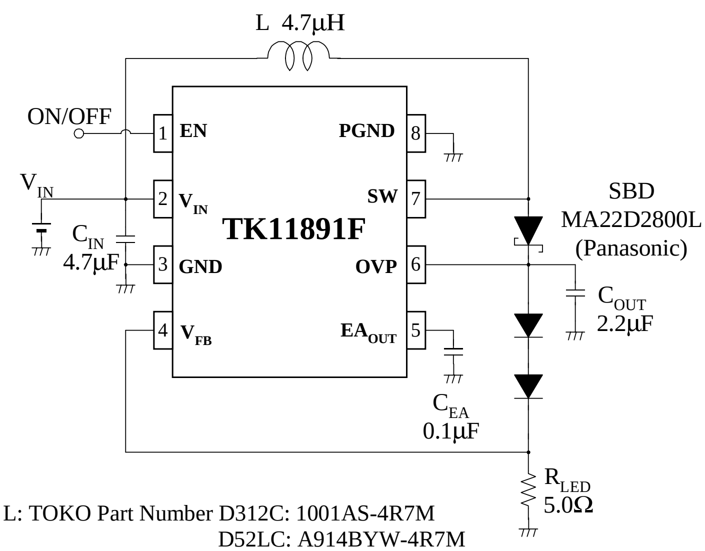
- Very Wide Operating Voltage Range (2.65V to 16V)
- 2.0MHz Operation
- Internal Switching Transistor
- Maximum Duty Cycle 90%
- Very Small Inductor Available
- Very Small Package SON-3024-8

3. APPLICATIONS

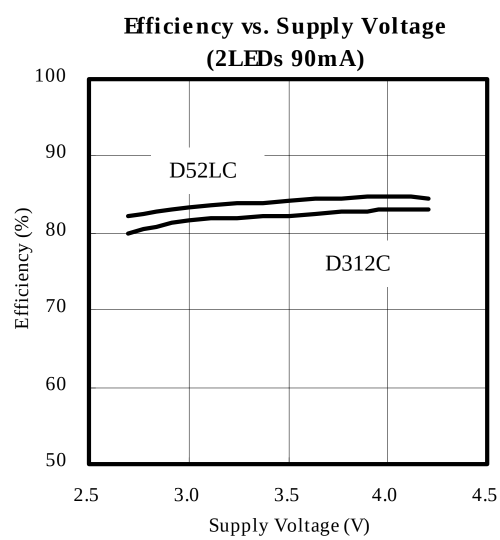
- Camera Lights for Mobile Phone and Portable Equipment
- LED Backlighting and Frontlighting
- Step-up DC-DC Converters

4. TYPICAL APPLICATION

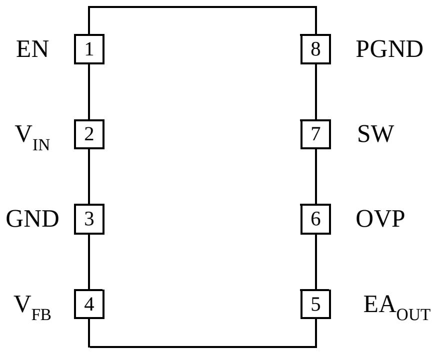
APPLICATION CIRCUIT (2LEDs in Series)



L: TOKO Part Number D312C: 1001AS-4R7M
D52LC: A914BYW-4R7M

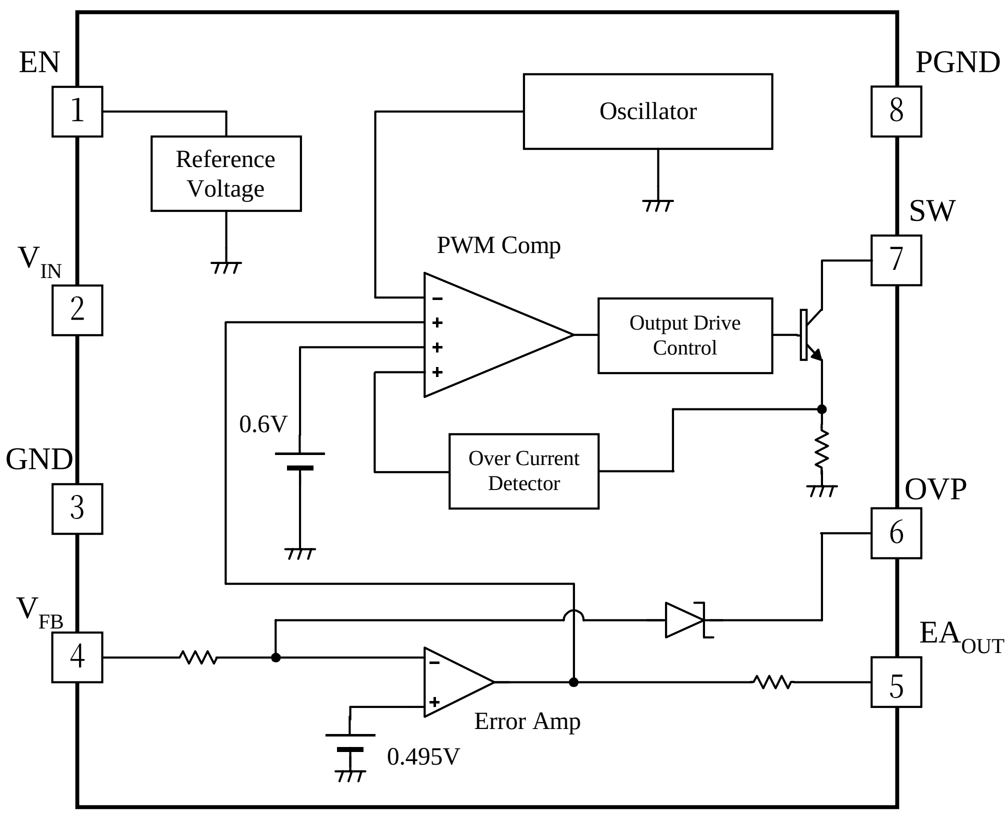


5. PIN CONFIGURATION



Pin No.	Symbol	Function
1	EN	Enable (ON/OFF) Input.
2	V_{IN}	Power Supply Voltage Input.
3	GND	Ground.
4	V_{FB}	Feedback Voltage.
5	EA_{OUT}	Error Amplifier Output.
6	OVP	Open-Circuit Protection.
7	SW	Switch. (Connect inductor and diode here.)
8	PGND	Power Ground.

6. BLOCK DIAGRAM



7. ABSOLUTE MAXIMUM RATINGS

T_A=25°C

Parameter	Symbol	Rating	Units	Conditions
Supply Voltage	V_{CC}	20	V	
Switch Voltage	$V_{SW\ MAX}$	22.5	V	
Switch Peak Current	$I_{SW\ PEAK\ MAX}$	2.1	A	
Power Dissipation	P_D	600	mW	*
Storage Temperature Range	T_{STG}	-55 ~ +150	°C	
Operating Temperature Range	T_{OP}	-30 ~ 85	°C	
Operating Voltage Range	V_{OP}	2.65 ~ 16	V	

* P_D must be decreased at the rate of 4.8mW/°C for operation above 25°C on TK11891's evaluation board.

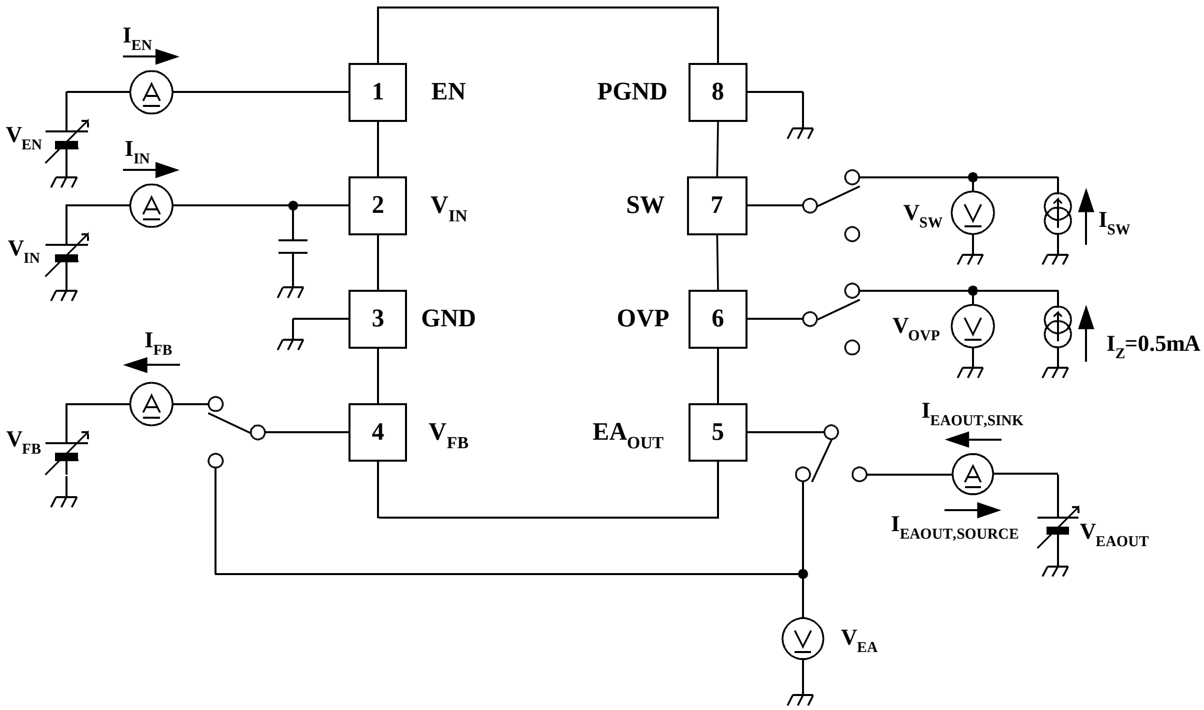
8. ELECTRICAL CHARACTERISTICS

V_{CC}=3V, T_A=25°C

Parameter	Symbol	Value			Units	Conditions
		MIN	TYP	MAX		
Oscillator Section						
Frequency	f	1.35	2.0	2.45	MHz	
Error Amplifier Section (V_{FB} Pin, EA_{OUT} Pin)						
Threshold Voltage	V_{EA}	475	495	515	mV	
Input Bias Current	I_{EAIN}	-1.0	-0.2	1.0	µA	V_{FB}=0V
Voltage Gain	A_V	37	40	43	dB	
Gain Band Width	GBW	-	2	-	MHz	A_V=0dB
Output High Voltage	$V_{EAOUT,HIGH}$	0.76	0.85	-	V	V_{FB}=0V
Output Low Voltage	$V_{EAOUT,LOW}$	-	0.05	0.2	V	V_{FB}=1.0V
Output Source Current	$I_{EAOUT,SOURCE}$	-	-36	-21	µA	V_{EAOUT}=0.45V
Output Sink Current	$I_{EAOUT,SINK}$	21	36	-	µA	V_{EAOUT}=0.45V
Dead Time Control Section						
Maximum Duty Cycle	D_{MAX}	85	90	-	%	
Shutdown Section (EN Pin)						
EN Input Voltage +	$V_{EN,HIGH}$	1.2	-	20	V	On mode
EN Input Voltage -	$V_{EN,LOW}$	0	-	0.3	V	Shutdown mode
EN Pin Input Bias Current	I_{ENIN}	-	25	40	µA	V_{EN}=3V
Output Switch Section (SW Pin)						
Switch Current Limit	$I_{SW,LIMIT}$	1.0	1.4	2.0	A	
Switch Saturation Voltage	$V_{SW,SAT}$	-	0.12	0.2	V	I_{SW}=200mA
Switch Leakage Current	$I_{SW,OFF}$	-	0.01	2.0	µA	V_{FB}=1V, V_{SW}=22V
Open-Circuit Protection Section (OVP Pin)						
Open-Circuit Voltage	V_{OVP}	18.5	20.0	22.0	V	I_z=0.5mA
V_{IN} Section (V_{IN} Pin)						
Low Voltage Stop	$V_{IN,LOW}$	2.20	2.45	2.65	V	
Quiescent Supply Current	$I_{CC,ON}$	3.0	5.0	7.0	mA	V_{FB}=1V
Shutdown Supply Current	$I_{CC,OFF}$	-	0.01	1.0	µA	V_{EN}=0V

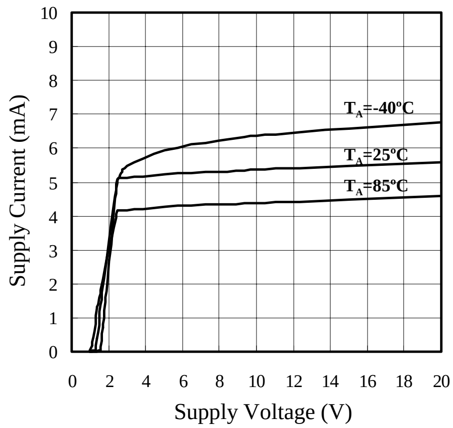
9. TEST CIRCUIT

TEST CIRCUIT

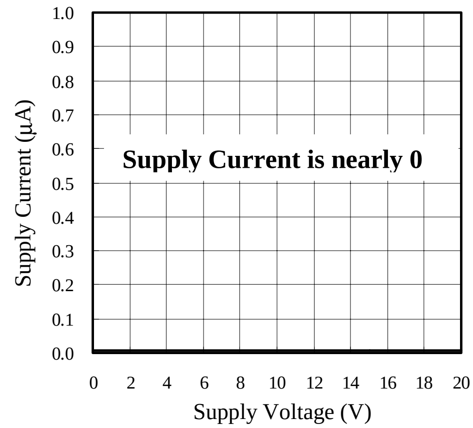


10. TYPICAL CHARACTERISTICS

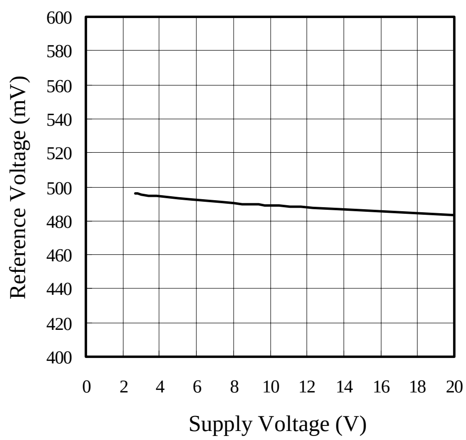
■ Quiescent Supply Current vs. Supply Voltage
$V_{IN}=V_{EN}$, $V_{FB}=1V$



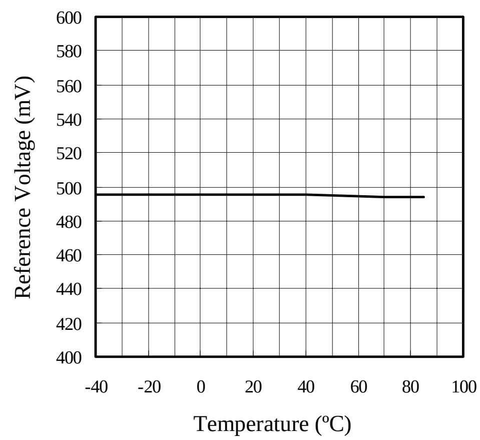
■ Shutdown Supply Current vs. Supply Voltage
$T_A=25ºC$, $V_{EN}=0V$



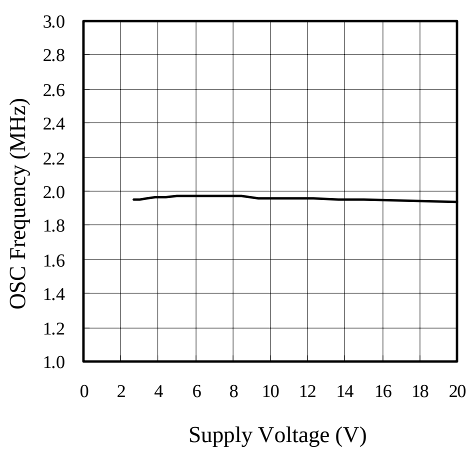
■ Reference Voltage vs. Supply Voltage
$V_{IN}=V_{EN}$, $V_{FB}=V_{EAOUT}$, $T_A=25ºC$



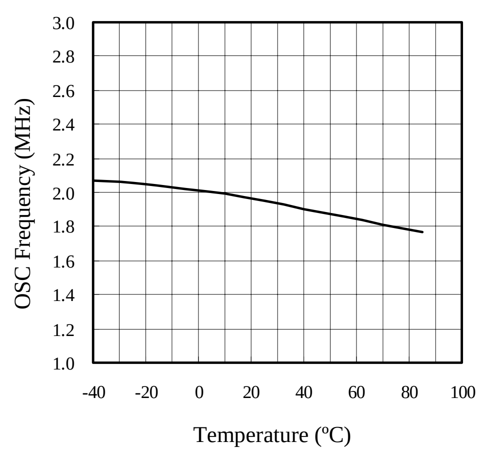
■ Reference Voltage vs. Temperature
$V_{IN}=V_{EN}=3V$, $V_{FB}=V_{EAOUT}$



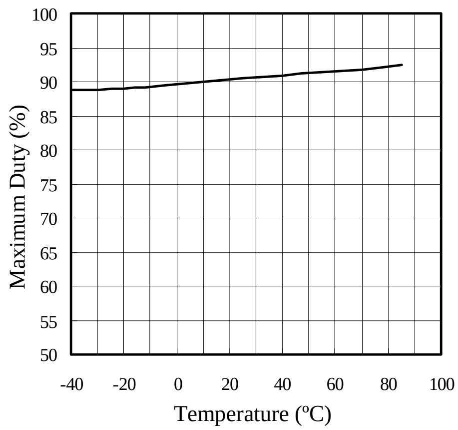
■ OSC Frequency vs. Supply Voltage
$V_{EN}=3V$, $V_{FB}=0V$, $I_{SW}=10mA$, $T_A=25ºC$



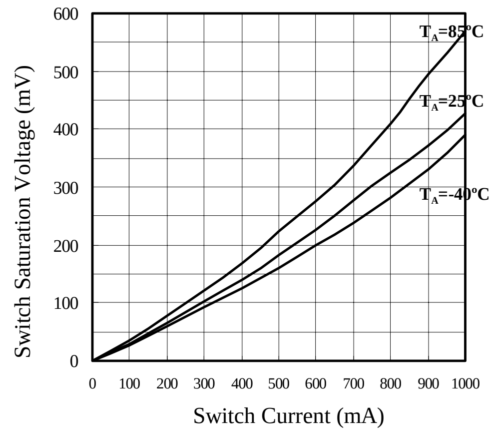
■ OSC Frequency vs. Temperature
$V_{IN}=V_{EN}=3V$, $V_{FB}=0V$, $I_{SW}=10mA$



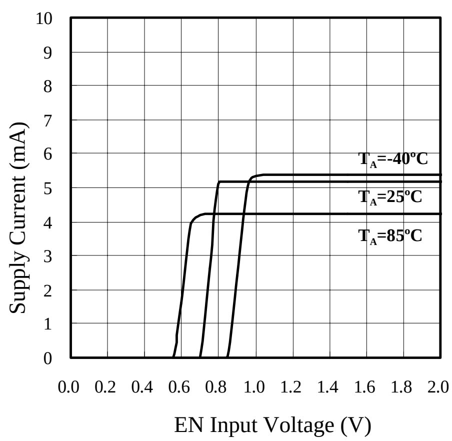
■ Maximum Duty vs. Temperature
$V_{IN}=V_{EN}=3V$, $V_{FB}=0V$, $I_{SW}=10mA$



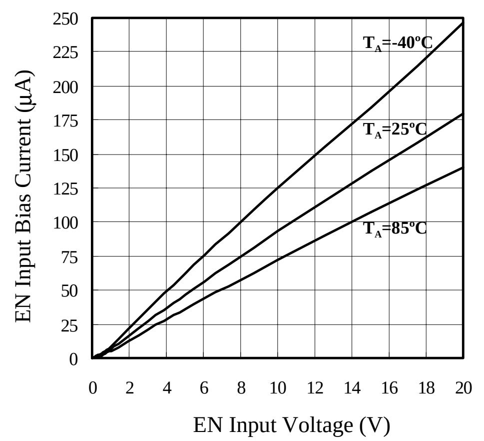
■ Switch Current vs. Switch Saturation Voltage
$V_{IN}=V_{EN}=3V$, $V_{FB}=0V$, $T_A=25ºC$



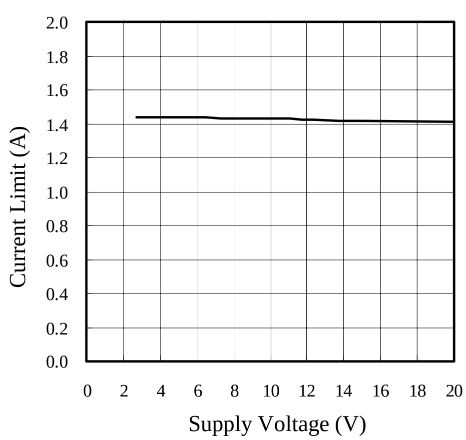
■Supply Current vs. EN Input Voltage
$V_{IN}=3V$, $V_{FB}=1V$



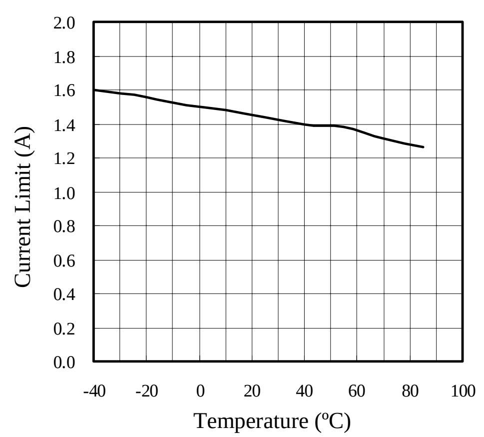
■ En Input Bias Current vs. EN Input Voltage
$V_{IN}=3V$



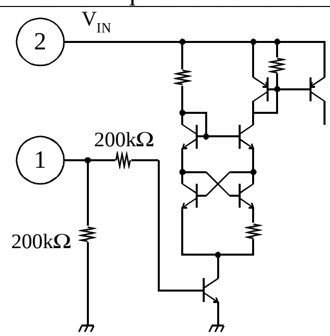
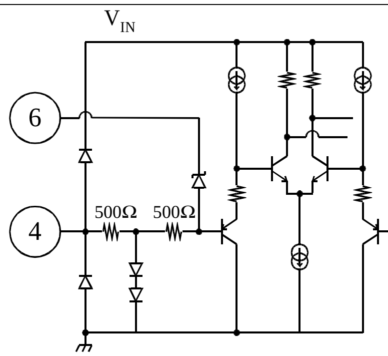
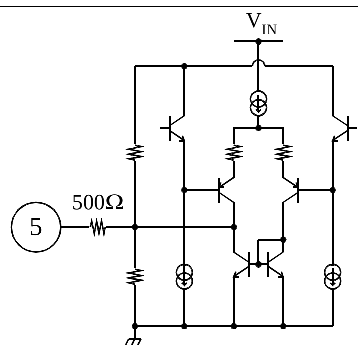
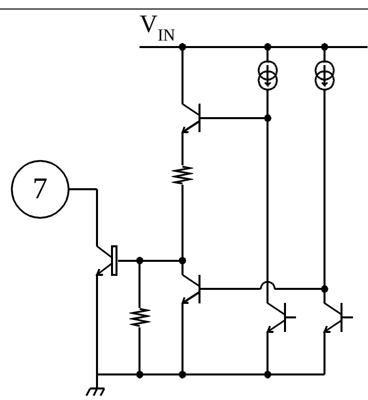
■ Current Limit vs. Supply Voltage
$V_{IN}=V_{EN}$, $V_{FB}=0V$, $T_A=25ºC$



■ Current Limit vs. Temperature
$V_{IN}=V_{EN}=3V$, $V_{FB}=0V$



11. PIN DESCRIPTION

No.	Symbol	Internal Equivalent Circuit	Description
1	EN		This is the chip-enable input with a built-in 200kΩ pull-down resistor. Set the EN-pin higher than 1.2V to enable the device. Set the EN-pin below 0.3V to disable the device. The EN pin can be pulled up to 20V, regardless of the supply voltage and output voltage.
2	V_{IN}		Power supply voltage input. When the supply voltage falls below 2.45V ($V_{IN,LOW}$), the TK11891F stops switching operation to avoid malfunction.
3	GND	–	Ground.
4	V_{FB}		Error amplifier inverting input. Feed back input. The error amplifier detects the output voltage of the DC-DC converter and outputs the PWM control signal. Threshold voltage is 0.495V
6	OVP		This pin will work as open-circuit protection. Connect OVP to Output (V_{OUT}) to avoid generating high voltage at the switch pin during open-circuit conditions. The Open-Circuit Voltage is approximately 20.0V.
5	EA_{OUT}		Error amplifier output. Compensation pin. A capacitor combination connected to this pin provides compensation for the control loop.
7	SW		This pin is the collector of the internal 20V NPN power switch. The switch transistor has a maximum 1A peak current capability.
8	PGND	–	Power Ground.

12. CIRCUIT DESCRIPTION

12.1 PWM Comparator

The voltage comparator has one inverting and three non-inverting inputs. The comparator is a voltage-pulse width converter that controls the ON time of the output pulse depending on the input voltage. The output level is high (H) when the sawtooth wave is lower than the error amplifier output voltage, current sense comparator output voltage, and idle period setting voltage.
Maximum duty cycle, which is a maximum ON time of output pulse, is decided by a idle period setting voltage. The maximum duty cycle is set to 90% including circuit delay and Turn-off delay of Switching Transistor.

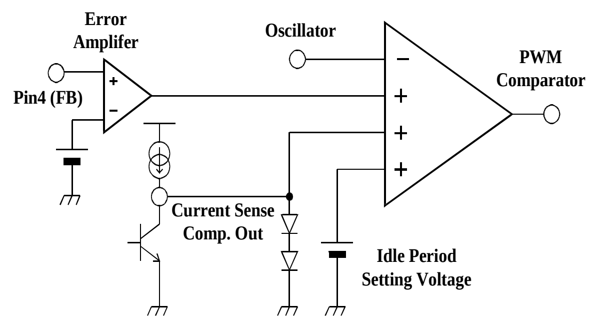


Fig.1: Internal equivalent circuit of PWM Comparator

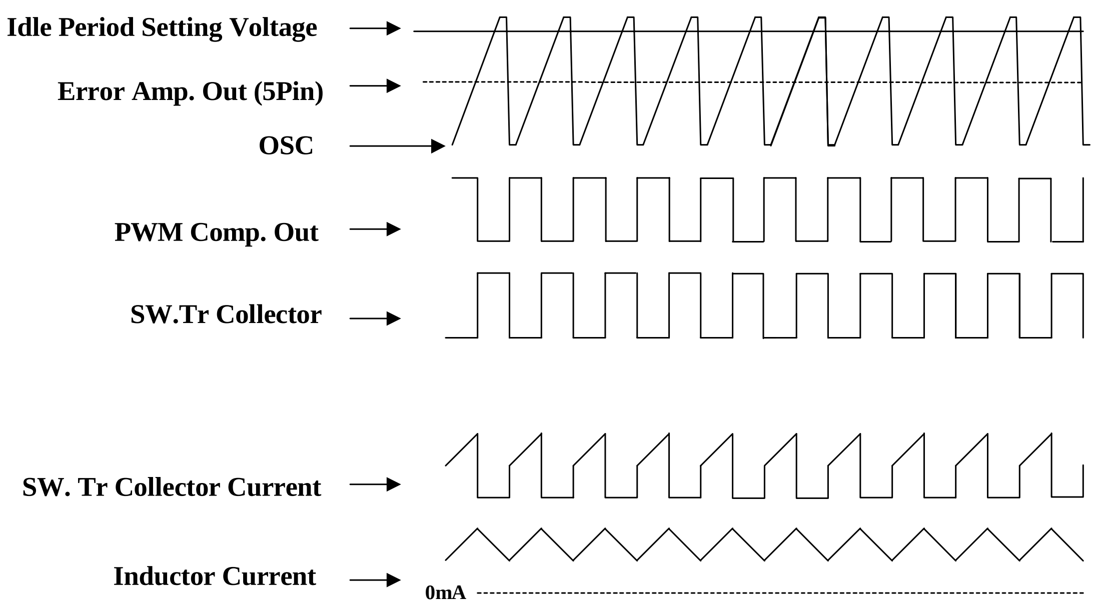


Fig.2: Timing Diagram of PWM Comparator

12.2 Error Amplifier

The error amplifier detects the output voltage of the DC-DC converter and outputs the PWM control signal. The voltage gain is fixed, and connecting a phase compensation capacitor to the V_{FB} pin (pin 8) provides stable phase compensation for the system. Reference Voltage (V_{EA}=0.495V) divided from the Band gap voltage is supplied to the inverting input of the error amplifier.

This architecture allows the series-connected white LEDs to be driven with a constant current. The LED current (I_{LED}) is set by an external resistor (R_{LED}) connected between the FB pin and GND (see Fig.3).
The current of each LED is

$$I_{LED} = \frac{V_{EA}}{R_{LED}} \quad (1)$$

Where V_{EA} : Error amplifier threshold voltage 0.495V

Output voltage V_{OUT} is given by

$$V_{OUT} = n \cdot V_F + V_{EA} \quad (2)$$

Where V_F : LED forward voltage drop
n : Number of LEDs connected in series

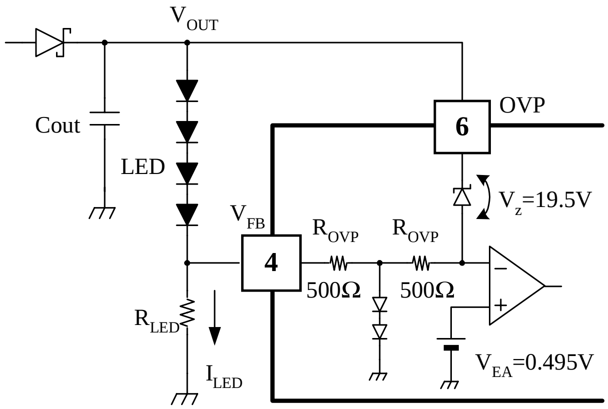


Fig3: Setting constant current through LED

To obtain a regulated output voltage for most common step-up regulator applications, connect a voltage divider from the output (V_{OUT}) to FB (see Fig.4). The regulated output voltage is determined by

$$V_{OUT} = V_{EA}\left(1 + \frac{R2}{R1}\right) \quad (3)$$

V_{OUT} can be set from V_{IN} to 18.0V, (Note that maximum V_{OUT} is limited to an internal open-circuit protection voltage 18.5V.)

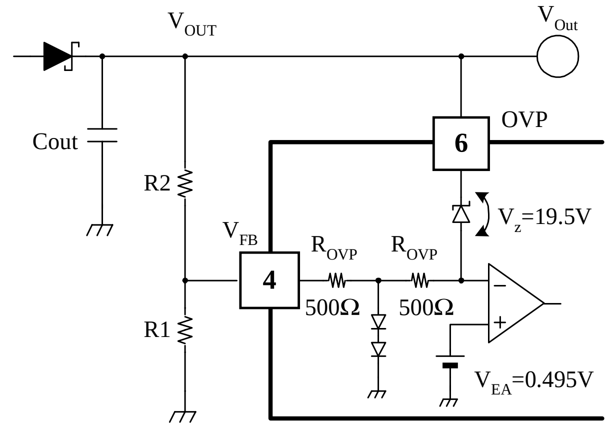


Fig.4: Setting Output voltage

12.3 Operating supply voltage range

When the supply voltage falls below 2.45V ($V_{IN,LOW}$), the TK11891F stops switching operation to avoid malfunction.
The recommended operating voltage range of this IC is 2.65V~16V. However, the maximum rating for the supply voltage is as high as 20V.

12.4. EN(ON/OFF)

Set the EN pin higher than 1.2V to enable the device. Set it below 0.3V to disable the device; that is, shutdown mode. During shutdown, the supply current drops to 1µA or less. The internal 200kΩ pull-down resistor ensures the shutdown mode when the EN pin remains open. The EN pin can be pulled up to 20V, regardless of the supply voltage and output voltage.

The relationship between control current (I_{EN}) and EN pin voltage (V_{EN}) is

$$I_{EN} = \frac{V_{EN}}{R_{DOWN}} + \frac{V_{EN} - V_{BE}}{R_{EN}} \quad (4)$$

Where $R_{DOWN}=R_{EN}=200k\Omega$, $R_{ENOUT}=0\Omega$

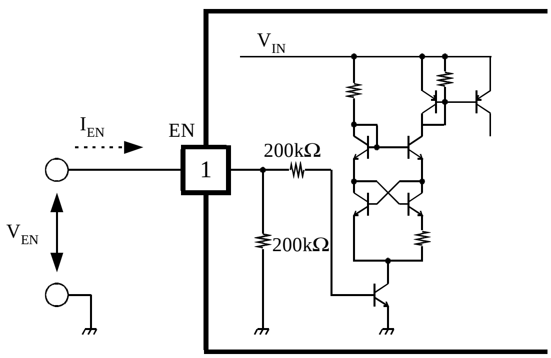


Fig.5: Internal equivalent circuit of EN Pin

If the voltage applied to the EN pin is too high, put R_{ENOUT} in series with the EN pin to reduce its bias current.

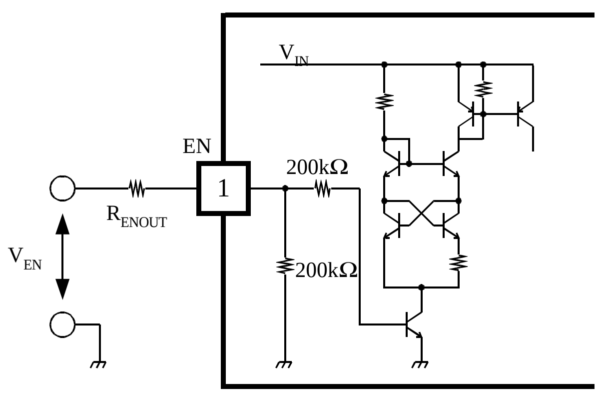


Fig.6: R_{ENOUT} with the EN pin

The EN pin is also used to provide LED-dimming (see DIMMING).

12.5 Open-Circuit Protection

The TK11891F has internal open-circuit protection. When the main feedback loop is opened, the internal zener diode will work as another path of the feedback loop. This prevents the switch node from generating high voltage. The voltage level at V_{OUT} is clamped at

$$V_{OUT} = V_{OVP} = V_Z + V_{REF} = 20.0V$$

Where $V_Z=19.5V$ zener voltage
$V_{EA}=0.495V$ Error amplifier threshold voltage.

During open-circuit, the current, I_Z of the zener diode is

$$I_Z = \frac{V_{EA}}{2 \cdot R_{OVP} + R_{LED}} \approx \frac{V_{EA}}{2 \cdot R_{OVP}} < 0.5mA \quad (5)$$

Where $R_{OVP}=500\Omega$, $R_{OVP}>>R_{LED}$

The clamped level of V_{OUT} is enough to drive 4 white LEDs connected in series.

13. APPLICATIONS INFORMATION

13-1 APPLICATION CIRCUIT (2-4LEDs in Series)

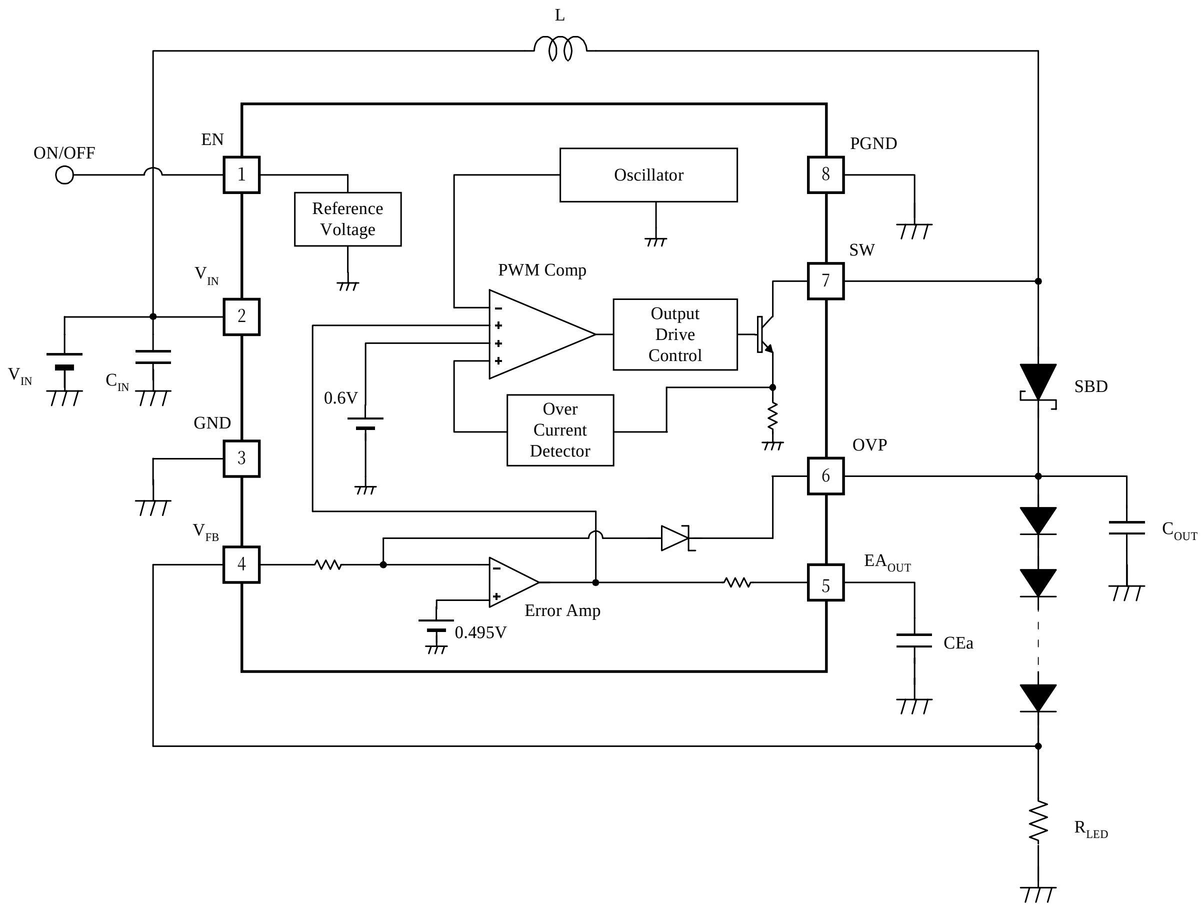


Fig.7: Typical 2-4 LEDs Application

Value of components

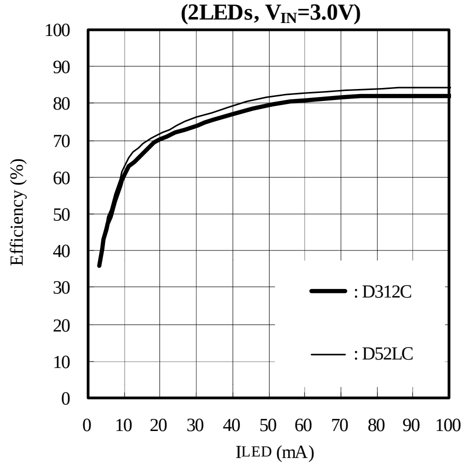
L : 4.7µH Type D312C TOKO Part Number: 1001AS-4R7M
Type D52LC TOKO Part Number: A914BYW-4R7M
D: MA22D28 (Panasonic 1.5A, 30V)
Cin: 4.7µF/6.3V
Cout: 2.2µF/16V(2, 3LEDs), 25V(4LEDs)
C_{Ea}: 0.1µF

Efficiency Curve

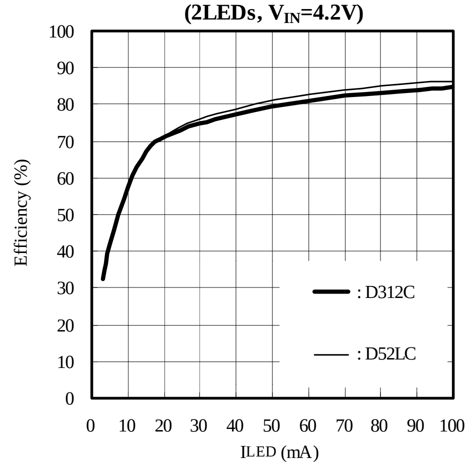
$$\text{Efficiency}(\%) = 100 \cdot V_{OUT} \cdot I_{LED} / (V_{IN} \cdot I_{IN})$$

2LEDs

Efficiency vs. ILED (2LEDs, V_{IN}=3.0V)

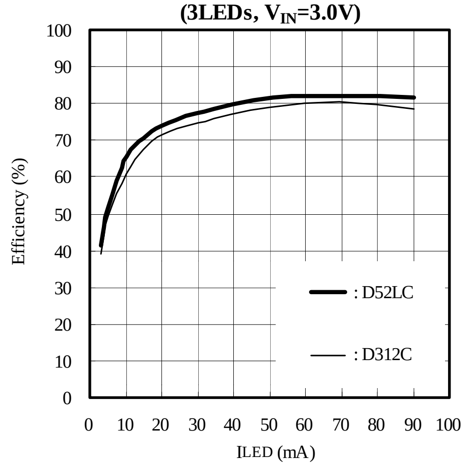


Efficiency vs. ILED (2LEDs, V_{IN}=4.2V)

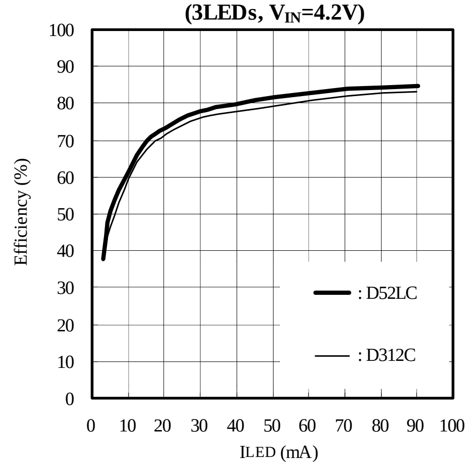


3LEDs

Efficiency vs. ILED (3LEDs, V_{IN}=3.0V)

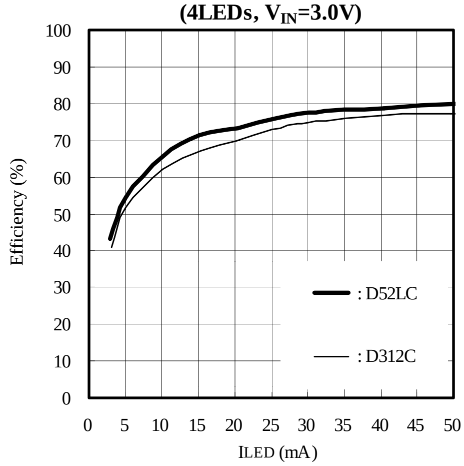


Efficiency vs. ILED (3LEDs, V_{IN}=4.2V)

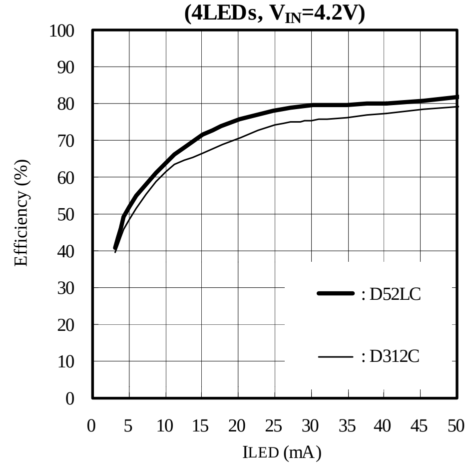


4LEDs

Efficiency vs. ILED (4LEDs, V_{IN}=3.0V)

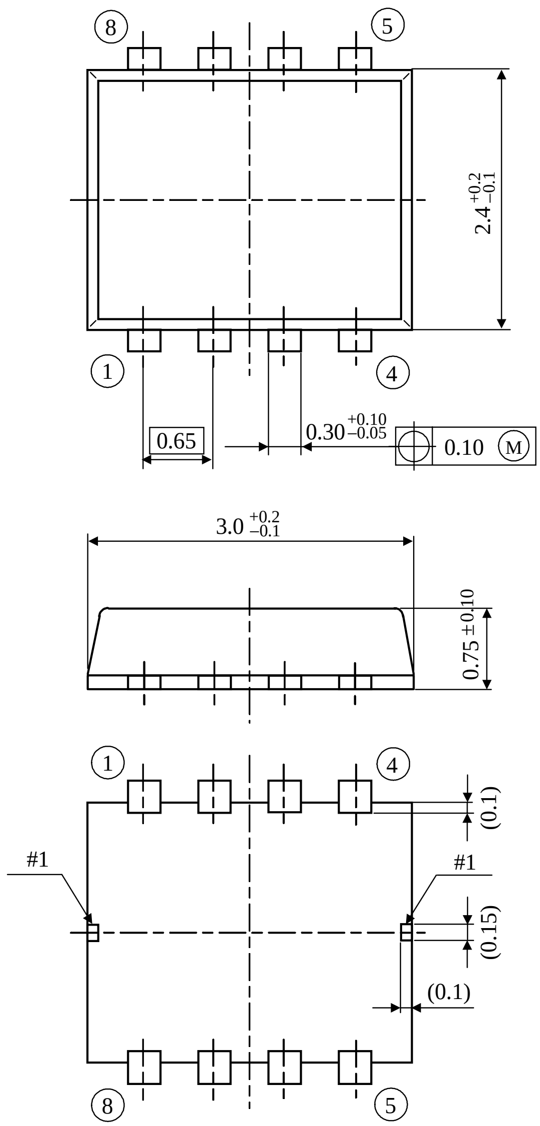


Efficiency vs. ILED (4LEDs, V_{IN}=4.2V)



14. PACKAGE DESCRIPTION

Package : SON3024-8



#1 : Exposed metal tabs

Unit : mm

15. NOTES

■ Please be sure that you carefully discuss your planned purchase with our office if you intend to use the products in this application manual under conditions where particularly extreme standards of reliability are required, or if you intend to use products for applications other than those listed in this application manual.

- Power drive products for automobile, ship or aircraft transport systems; steering and navigation systems, emergency signal communications systems, and any system other than those mentioned above which include electronic sensors, measuring, or display devices, and which could cause major damage to life, limb or property if misused or failure to function.
- Medical devices for measuring blood pressure, pulse, etc., treatment units such as coronary pacemakers and heat treatment units, and devices such as artificial organs and artificial limb systems which augment physiological functions.
- Electrical instruments, equipment or systems used in disaster or crime prevention.

■ Semiconductors, by nature, may fail or malfunction in spite of our devotion to improve product quality and reliability. We urge you to take every possible precaution against physical injuries, fire or other damages which may cause failure of our semiconductor products by taking appropriate measures, including a reasonable safety margin, malfunction preventive practices and fire-proofing when designing your products.

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■ None of the ozone depleting substances(ODS) under the Montreal Protocol are used in our manufacturing process.

16. OFFICES

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