

LED Driver for LCD Backlights

White LED Driver for 4Ch Large LCD Panels (DC/DC converter type)

BD9415FS

1.1 General Description

BD9415FS is a high efficiency driver for white LEDs and designed for large LCDs. This IC has a built-in boost DC/DC converter that employs an array of LEDs as the light source. BD9415FS has various protection functions against fault conditions, such as over-voltage protection (OVP), over current limit protection of DC/DC (OCP), short circuit protection (SCP), over duty protection (ODP) and open detection of LED string. Therefore, BD9415FS is available for the fail-safe design over a wide range of output voltages.

Key Specifications

- Operating power supply voltage : 11.5V to 35.0V
- Oscillator frequency : 500kHz(RT=30kΩ)
- Operating current : 6.2mA (Typ)
- Operating temperature range : -40°C to +105°C

1.2 Package

SSOP-A32

W(Typ) x D(Typ) x H(Max)
13.60mm x 7.80mm x 2.01mm
Pin pitch 0.80mm

Features

- 4Ch LED constant current driver (external FET)
- Built-in boost DC/DC converter (external FET)
- PWM dimming (individual input terminal of 4ch)
- Analog dimming (Linear) function
- Low heat generation technology
- LED protection function (Open/Short protection)
- Output Short Protection (OCP)
- Over Duty Protection (ODP)
- Over Voltage Protection (OVP)
- Under Voltage Lockout Protection (UVLO)
- Auto restart function

Applications

- TV, Computer Display, Notebook, LCD Backlighting.

Typical Application Circuit

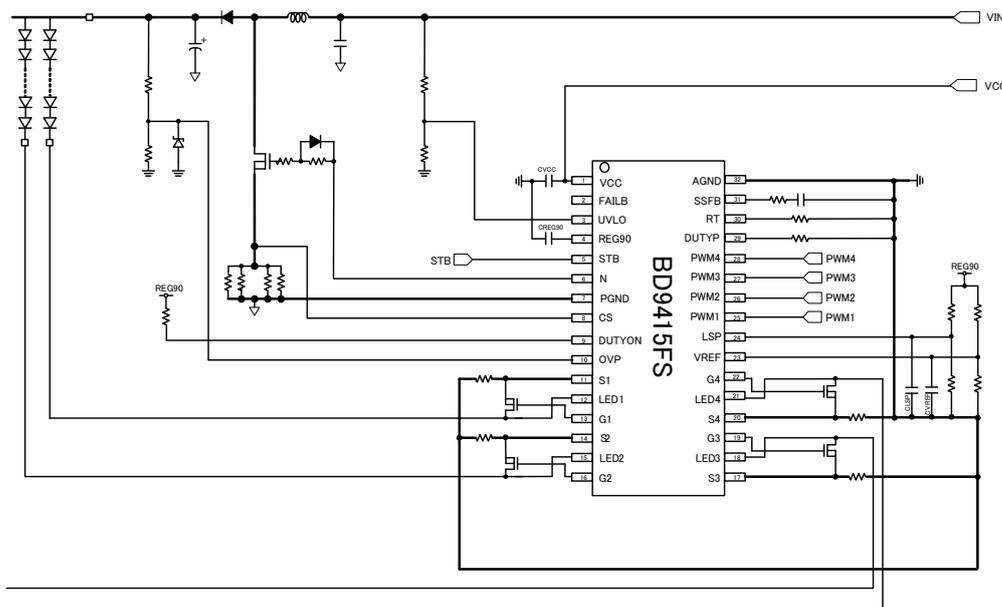


Figure 2. Typical Application Circuit

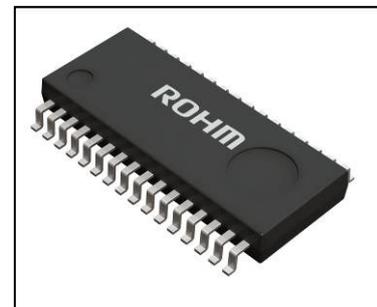


Figure 1. SSOP-A32

1.3 Pin Configuration

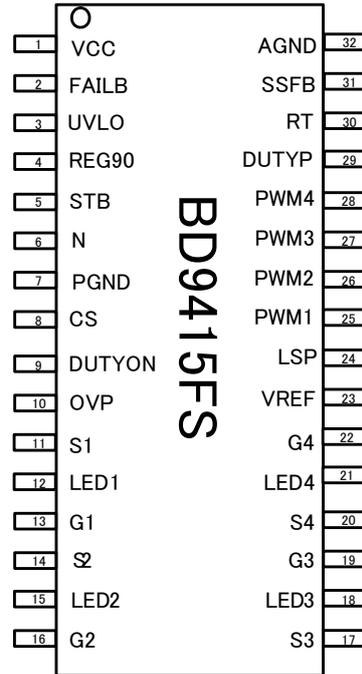


Figure 3. Pin Configuration

1.4 Pin Descriptions

Pin No.	Pin Name	Function	Pin No.	Pin Name	Function
1	VCC	Power supply terminal	32	AGND	Analog GND
2	FAILB	Error detection output pin (open drain)	31	SSFB	Soft start pin & Error amplifier pin
3	UVLO	Under voltage lockout detection pin	30	RT	DC/DC switching frequency setting pin
4	REG90	9.0V output voltage pin	29	DUTYP	Over voltage protection setting pin
5	STB	IC ON/OFF pin	28	PWM4	LED4 External PWM dimming signal input pin
6	N	DC/DC switching output pin	27	PWM3	LED3 External PWM dimming signal input pin
7	PGND	Power GND	26	PWM2	LED2 External PWM dimming signal input pin
8	CS	DC/DC output current detect pin, OCP input pin	25	PWM1	LED1 External PWM dimming signal input pin
9	DUTYON	Over duty protection ON/OFF pin	24	LSP	LED short voltage setting pin
10	OVP	Over voltage protection detection pin	23	VREF	Analog dimming signal input pin
11	S1	CH1 current detection input pin	22	G4	CH4 dimming signal output pin
12	LED1	CH1 LED output pin	21	LED4	CH4 LED output pin
13	G1	CH1 dimming signal output pin	20	S4	CH4 current detection input pin
14	S2	CH2 current detection input pin	19	G3	CH3 dimming signal output pin
15	LED2	CH2 LED output pin	18	LED3	CH3 LED output pin
16	G2	CH2 dimming signal output pin	17	S3	CH3 current detection input pin

1.5 Block Diagram

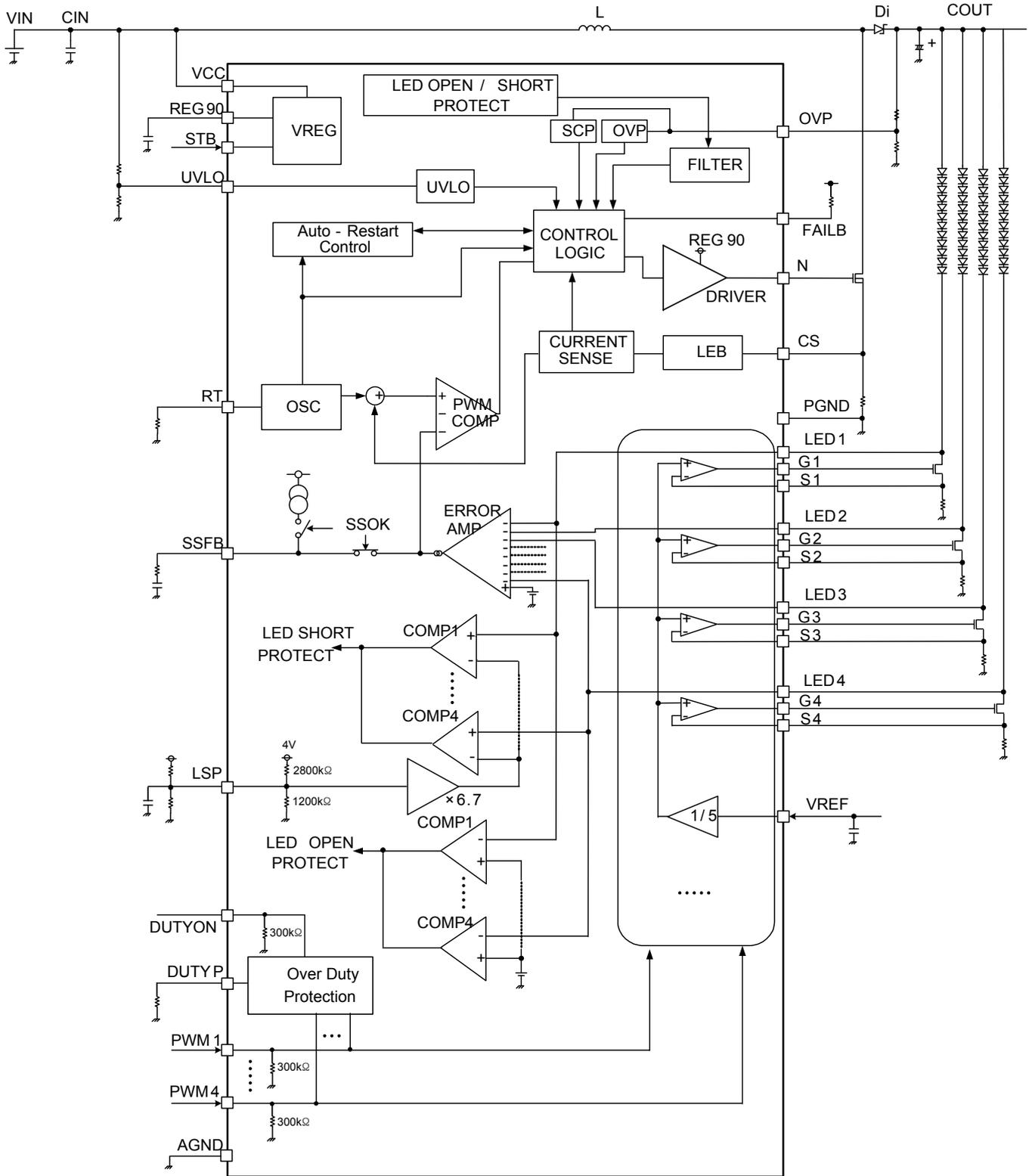


Figure 4. Block Diagram

1.6 Absolute Maximum Ratings (Ta=25°C)

Parameter	Symbol	Rating	Unit
Power Supply Voltage	VCC	-0.3 to +36	V
LED1-4	LED1, LED2, LED3, LED4	60	V
FAILB, STB, OVP, PWM1-4, UVLO, VREF, DUTYON	FAILB, STB, OVP, PWM1, PWM2, PWM3, PWM4, UVLO, VREF, DUTYON	20	V
N, REG90, G1-4	N, REG90, G1, G2, G3, G4	13	V
S1-4, DUTYP, RT, SSFB, CS, LSP	S1, S2, S3, S4, DUTYP, RT, SSFB, CS, LSP	7	V
Power Dissipation	P _d	0.95 *1	W
Operating Temperature Range	T _{opr}	-40 to +105	°C
Junction Temperature	T _{jmax}	150	°C
Storage Temperature	T _{stg}	-55 to +150	°C

(*1) Derate by 7.6mW/°C when operating above Ta=25°C.. (Mounted on 1-layer 70mm x 70mm x 1.6mm board)

1.7 Recommended Operating Conditions (Ta=25°C)

Parameter	Symbol	Rating	Unit
Power Supply Voltage	VCC	11.5 to 35.0	V
DC/DC Oscillating Frequency	F _{sw}	100 to 1000 ^(*1)	kHz
VREF Input Voltage	VREF	0.2 to 2.5	V
LSP Input Voltage	VLSP	0.8 to 3.0	V
PWM Input Frequency	FPWM	90 to 2000	Hz

The operating ranges above are acquired by evaluating the IC separately. Please take care when using the IC in applications.

(*1) When driving external FET as DC/DC, be careful about the input capacity of the FET being used.

1.8 Electrical Characteristics 1/2 (Unless otherwise specified, VCC=24V, Ta=25°C)

Parameter	Symbol	Min	Typ	Max	Unit	Condition
【Total Current Consumption】						
Circuit Current	ICC	-	6.2	12.4	mA	VSTB=3.0V, LED1-4=2V, RT=30kΩ
Standby Current	IST	-	14	25	μA	VSTB=0V
【Switching Block】						
N Pin Source ON Resistance	RONH	-	2.5	3.75	Ω	ION=-10mA
N Pin Sink ON Resistance	RONL	-	3.0	4.5	Ω	ION=10mA
【REG90 Block】						
REG90 Output Voltage	REG90	8.91	9.0	9.09	V	IO=0mA
REG90 Available Current	I _{REG90}	20	-	-	mA	
REG90_UVLO Detect Voltage	REG90_TH	4.7	5.4	6.1	V	V _{REG} =SWEEP DOWN, VSTB=0V
【Over Current Limit Protection (OCP) Block】						
OCP Detect Voltage	VOCP	0.405	0.450	0.495	V	V _{CS} =SWEEP UP
【Error Amplifier Block】						
Error Amplifier Base Voltage	VERR	0.7	0.8	0.9	V	VREF=1.5V
SSFB Source Current (Soft Start)	ISSFBSO_S	-13	-10	-7	μA	V _{SSFB} =2V
SSFB Sink Current	ISSFBSINK	80	100	120	μA	LED=2.0V, V _{SSFB} =1.0V
SSFB source Current	ISSFBSOUR	-115	-100	-85	μA	LED=0V, V _{SSFB} =1.0V
【CT Oscillator Block】						
Oscillation Frequency	FCT	440	500	560	kHz	RRT=30kΩ
MAX DUTY	DUTY_MAX	91	95	99	%	
【Short Circuit protection (SCP) detect Block】						
SCP Detect Voltage	VSCP	0.05	0.20	0.35	V	VOVP=SWEEP DOWN

1.8 Electrical Characteristics 2/2 (Unless otherwise specified, VCC=24V, Ta=25°C)

Parameter	Symbol	Min	Typ	Max	Unit	Condition
【Over Voltage Protection (OVP) Block】						
OVP Detect Voltage	VOVP	2.91	3.00	3.09	V	VOVP=SWEEP UP
OVP Detect Hysteresis	VOVP_HYS	50	100	200	mV	VOVP=SWEEP DOWN
OVP Pin Leak Current	IOVP	-2	0	2	μA	VOVP=4.0V
【UVLO Block】						
UVLO Unlock Voltage(VCC)	VUVLO_VCC	6.5	7.5	8.5	V	VCC=SWEEP UP
UVLO Hysteresis(VCC)	VUHYS_VCC	150	300	600	mV	VCC=SWEEP DOWN
UVLO Unlock Voltage	VUVLO	2.375	2.5	2.625	V	VUVLO=SWEEP UP
UVLO Hysteresis	VUHYS	50	100	150	mV	VUVLO=SWEEP DOWN
UVLO Input Resistance	RUVLO	360	600	840	kΩ	VUVLO=4.0V
【DUTYON Block】						
DUTYON Pin HIGH Voltage	DTYON_H	1.5	-	18	V	
DUTYON Pin LOW Voltage	DTYON_L	-0.3	-	0.8	V	
DUTYON Pin Pull Down Resistance	RDTYON	180	300	420	kΩ	VDUTYON=3.0V
【Over Duty Protection (ODP) Block】						
PWM ODP Protection Detect Duty	DODP	-	35	-	%	FPWM=120Hz, DUTYP=341kΩ
【Filter Block】						
AUTO Timer	TAUTO	-	163	-	ms	FCT=800kHz
Abnormal Detection Timer	TCP	-	20	-	ms	FCT=800kHz
【LED Driver Block】						
S Pin Voltage	VS	196	200	204	mV	VREF=1.0V
		294.6	300	305.4		VREF=1.5V
		392.8	400	407.2		VREF=2.0V
		491	500	509		VREF=2.5V
OPEN Detection Voltage	VOPEN	0.12	0.2	0.28	V	VLED=SWEEP DOWN
SHORT Detection Voltage	VSHORT	5.6	6.0	6.4	V	VLED=SWEEP UP, VLSP=0.895V
SHORT Mask Voltage	VSHORT_MASK	2.8	3.0	3.2	V	VLED=SWEEP UP
VREF Leak Current	IVREF	-2	0	2	μA	VREF=3.0V
【STB Block】						
STB Pin HIGH Voltage	STBH	2.0	-	18	V	
STB Pin LOW Voltage	STBL	-0.3	-	0.8	V	
STB Pull Down Resistance	RSTB	0.5	1.0	1.5	MΩ	VSTB=3V
【PWM Block】						
PWM Pin HIGH Voltage	VPWM_H	1.5	-	18	V	
PWM Pin LOW Voltage	VPWM_L	-0.3	-	0.8	V	
PWM Pin Pull Down Resistance	RPWM	180	300	420	kΩ	VPWM=3V
【FAILB Block(OPEN DRAIN)】						
FAILB LOW Output Voltage	VFAILB_L	0.25	0.5	1.0	V	IFAILB=1mA

1.9 Typical Performance Curves (Reference data)

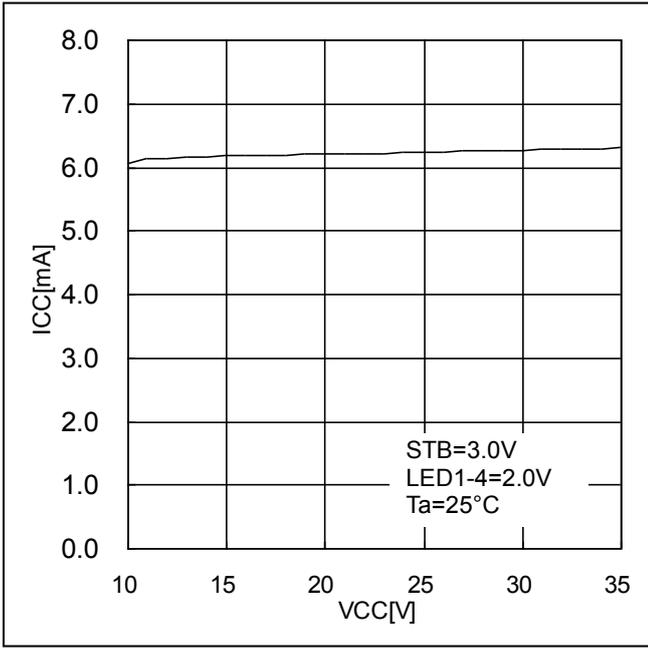


Figure 5. Operating Circuit Current

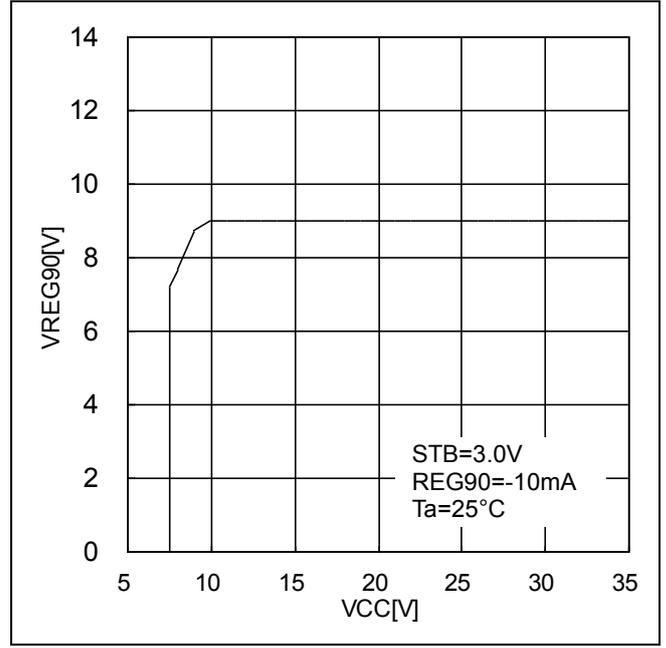


Figure 6. REG90 Line Regulation

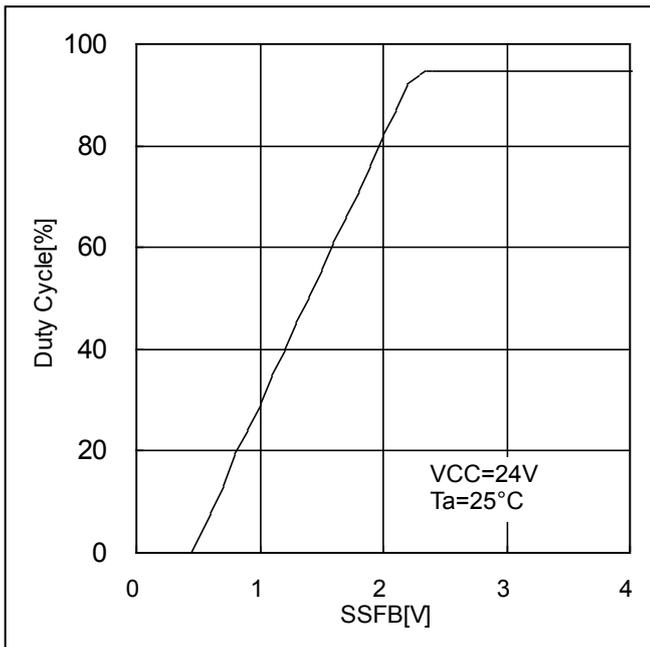


Figure 7. Duty Cycle vs SSFB Character

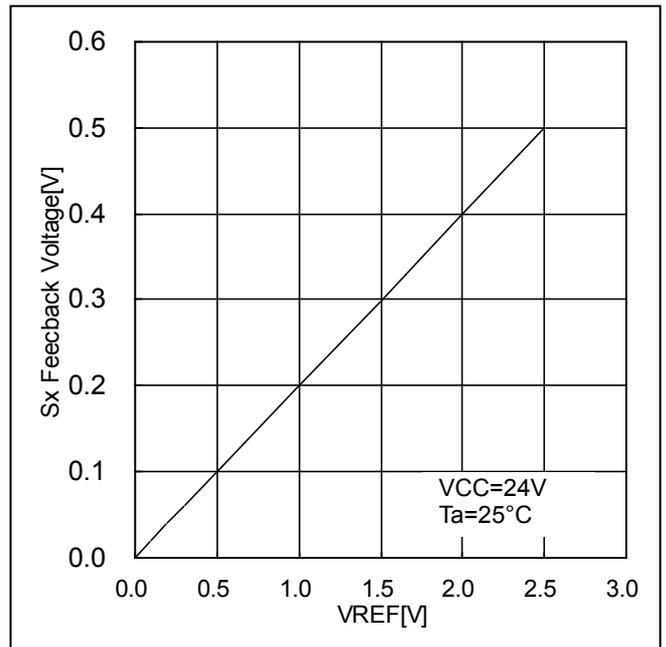


Figure 8. S Pin Feedback Voltage vs VREF Character

2.1 Pin Descriptions

○PIN1 : VCC

This is the power supply pin of the IC. Input range is from 11.5V to 35V.
The operation starts at more than 7.5V(Typ) and shuts down at less than 7.2V(Typ).

○PIN2 : FAILB

This is FAILB signal output (OPEN DRAIN) pin. At normal operation, NMOS will be in OPEN state, during abnormality detection NMOS will be in ON (500 ohm(Typ))state.

○PIN3 : UVLO

Under Voltage Lockout pin is the input voltage of the power stage. IC starts boost operation if UVLO is more than 2.5V(Typ) and stops if lower than 2.4V(Typ). It can also be used for reset when latched off by protection.
The power of step-up DC/DC converter needs to be set detection level by dividing the resistance.

○PIN4 : REG90

The REG pin is used in the DC/DC converter driver block to output 9V. Available current is 20mA(Min). Using the REG pin at current higher than 20mA can affect the IC base voltage, causing the IC to malfunction and leading to heat generation of the IC itself. To avoid this problem, it is recommended to make load setting to the minimum level.
The characteristic of VCC line regulation at REG90 is shown as [Figure 6]. VCC must be used in more than 11.5V for stable 9V output. Place the ceramic capacitor connected to REG90 pin (2.2uF to 10uF) closest to REG90-AGND pin.

○PIN5 : STB

This is the ON/OFF setting terminal of the IC. It is allowed for use to reset the IC from shutdown.
※The IC state is switched according to voltages input in the STB pin.
※Avoid using the STB pin between two states (0.8 to 2.0V).

○PIN6 : N

The N pin is used to output power to the external NMOS gate driver for the DC/DC converter in the amplitude range of approximately 0V to 9V. Output ON resistance H - side is 2.5Ω (Typ) and L-side is 3.0Ω (Typ).
Frequency can be set by the resistor connected to RT. Refer to <RT> pin description for the frequency setting.

○PIN7 : PGND

The PGND pin is a power ground pin for the driver block of the N output pin.

○PIN8 : CS

CS pin is current detector for DC/DC current mode inductor current control pin.
Current flowing through the inductor is converted into voltage by the current sensing resistor RCS connected to the CS pin and this voltage is compared with voltage set with the error amplifier to control the DC/DC output voltage. The CS pin also incorporates the over current protection (OCP) function. If the CS voltage reaches 0.45V(Typ) or more, switching operation will be forced to stopped.

○PIN9 : DUTYON

This is the ON/OFF setting terminal of the LED PWM Over Duty Protection (ODP). By adjusting DUTYON input voltage, it is ON/OFF of the ODP adjusted.

State	DUTYON input voltage
ODP=ON	DUTYON= -0.3V to +0.8V
ODP=OFF	DUTYON= +1.5V to +18.0V

○PIN10 : OVP

The OVP pin is an input pin for over voltage protection and short circuit protection of DC/DC output voltage. When voltage of it exceeds 3.0V(Typ), N pin will stop. This case is not CP count. When OVP pin voltage <0.2V(Typ) or lower, short circuit protection (SCP) function is activated, and output of gate driver will become low immediately. And system is stopped after a CP count. The setting example is separately described in the section "3.2.6 OVP Setting".

○PIN11, 14, 17, 20 : S1-S4, PIN23 : VREF

LED constant current driver is connected to the source of boost FET outside. Output current I_{LED} is inversely proportional to the resistance value. This is the input pin for analog dimming signal. Output current I_{LED} is directly proportional to the input voltage value. VREF pin is high impedance because the internal resistance is not connected to a certain bias. Even if VREF function is not used, pin bias is still required because the open connection of this pin is not a fixed potential.

VREF pin voltage is set as V_{VREF} , LED current I_{LED} can be calculated as below.

$$I_{LED}[A] = \frac{V_{REF}[V]}{R_S[\Omega]} \times 0.2$$

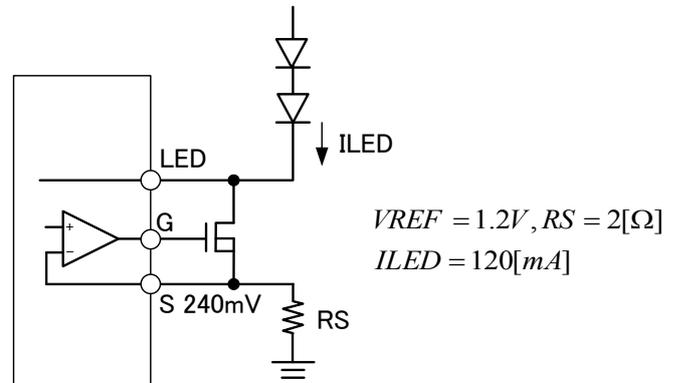


Figure 9. ILED setting example

For the adjustment of LED current with analog dimming by VREF, note that the output voltage of the DC/DC converter largely changes accompanied by LED VF changes if the VREF voltage is changed rapidly. In particular, when the VREF voltages changed from high to low, it makes the LED terminal voltage seem higher transiently, which may influence application such as activation of the LED short circuit protection. It needs to be adequately verified with an actual device when analog dimming is used.

○PIN12, 15, 18, 21 : LED1-LED4

LED constant current driver output pins. Drain of external NMOS is connected. Setting of LED current value is adjustable by setting the VREF voltage and connecting a resistor to S pin. For details, see the explanation of <PIN:11, 14, 17, 20 S1 - S4, Pin23 : VREF >.

The abnormal voltage of this pin activates the protection function of LED OPEN detection, LED SHORT detection. Please refer to < 2.2 List of The Protection Function Detection Condition > for details.

○PIN13, 16, 19, 22 : G1-G4

This is the output terminal for driving the gate of the boost MOSFET. The high level is REG90. Frequency can be set by the resistor connected to RT. Refer to <RT> pin description for the frequency setting.

○PIN24 : LSP

LED Short detection voltage setting pin. Resistance voltage divider is internally on IC. It is set as 1.2V. When need to establish the other voltage, use an external resistance voltage divider. LSP pin voltage is set as LED SHORT PROTECTION detection voltage and can be calculated as below.

$$LED_{SHORT} = 6.7 \times VLSP[V]$$

LED_{SHORT} : LSP detection voltage, VLSP : LSP pin voltage

Set LSP voltage in the range of 0.8V to 3.0V.

In addition to considering the voltage of the internal resistance voltage divider, it's necessary to establish the voltage of the LSP terminal.

○PIN25, 26, 27, 28 : PWM1-PWM4

These are the PWM dimming signal input terminals. The high / low level of PWM pins are the following.

State	PWM pin voltage
PWM=H	PWM= +1.5V to +18.0V
PWM=L	PWM= -0.3V to +0.8V

○ **PIN29 : DUTYP**

This is the ODP setting pin. The ODP (Over Duty Protection) is the function to limit DUTY of LED PWM frequency f_{PWM} by ODP detection Duty (ODPduty) set by resistance (RDUTYP) connected to DUTYP pin.

○ Relationship between LED PWM frequency f_{PWM} , ODP Detection Duty and DUTYP resistance (ideal)

$$R_{DUTYP} = \frac{1172 \times ODP_{duty} [\%]}{f_{PWM} [Hz]} \quad [k\Omega]$$

The RDUTYP setting ranges from 15k Ω to 600k Ω .

The setting example is separately described in section "3.2.6 ODP Setting".

○ **PIN30 : RT**

This is the DC/DC switching frequency setting pin. DCDC frequency is decided by connected resistor.

○ The relationship between the frequency and RT resistance value (ideal)

$$R_{RT} = \frac{15000}{f_{SW} [kHz]} \quad [k\Omega]$$

○ **PIN31 : SSFB**

The SSFB pin is used to make setting of soft start time and duty for soft start, and DC/DC current mode control error amplifier. It performs constant current charge of 10 μ A to the external capacitor connected to SSFB terminal, which enables soft-start of DC/DC converter.

The SSFB pin detects the voltages of LED pins (1 to 4) and controls inductor current so that the pin voltage of the LED located in the row with the highest V_f will come to 0.8V(Typ) ($V_{REF}=1.5V$). As a result, the pin voltages of other LEDs become higher by V_f variation. After completion of soft start, the SSFB pin is put into high-impedance state with the PWM signal being in the low state, thus maintaining the SSFB voltage.

Since the LED protection function (OPEN/SHORT detection) works when it turns to the LED feedback mode.

○ **PIN32 : AGND**

This is the GND pin of the IC.

2.2 List of the Protection Function Detection Condition (Typical Condition)

Protection Function	Detection Pin	Detection Condition			Release Condition	Protection Type
		Detection Condition	PWM	SS		
LED Open	LEDx	LEDx < 0.2V	H(4clk)	After Soft start	LEDx > 0.2V ^(*2) (3clk)	Auto Restart in relevant CH
LED Short	LEDx	LEDx > 6.7×VLSP	H(4clk)	After Soft start	LEDx < 6.7×VLSP (3clk)	Auto Restart in relevant CH
LED Driver FET D-S Short	Sx	Sx > 0.6V	—	—	Sx < 0.6V	Whole Auto Restart
LED GND Short	LEDx	LEDx < 0.2V And SSFB > 4.0V	H	—	LEDx > 0.2V Or SSFB < 3.6V	Whole Auto Restart
OVP	OVP	OVP > 3.0V	—	—	OVP < 2.9V	Return immediately.
SCP	OVP	OVP < 0.2V	—	—	OVP > 0.25V	Whole Auto Restart
VCCUVLO	VCC	VCC < 7.2V	—	—	VCC > 7.5V	Return immediately.
UVLO	UVLO	UVLO < 2.4V	—	—	UVLO > 2.5V	Return immediately.
OCP	CS	CS > 0.45V	—	—	—	Return immediately. (Pulse by Pulse)
Over PWM duty ^(*1)	PWM	DUTYON = H And PWM interval > setting by DUTYP resistor	H	—	—	Return immediately.

The clock number of timer operation corresponds to the boost pulse clock.

(*1)When PWM Duty count starts, PWM=H → L is input, when PWM=L → H is input, the ODP is reset.

The G (1 to 4) output, the N pin output maintain L until PWM=H → L is input in PWM = 100% again when ODP works once.

(*2) The release condition of OPEN protection depends on its release timing.

No.	The timing of release of LEDx voltage (LEDx > 0.2V)	The Release Condition
1	LED pin voltage is released during PWM=H.	LED pin voltage is normal range during 3clk (3 positive edge)
2	LED pin voltage is released during PWM=L.	As PWM=L, LED pin voltage do not exceed Short protection voltage (VLSP) during more than 3clk or PWM positive edge is input when LED pin voltage do not exceed VLSP for more than 3clk.

2.3 List of Protection function

Protection function	Operation of the Protection Function			
	DC/DC Gate Output	LED Driver	Soft-start	FAILB Pin
STB	Stop N output	Stop immediately	Discharge immediately	HiZ
LED Open	Normal operation (Stop when all LED CH stop)	Stop after 2 ¹⁴ count Stop in relevant CH	Normal operation	Low after timer latch
LED Short	Normal operation	Stop after 2 ¹⁴ count Stop in relevant CH	Normal operation	Low after timer latch
LED Driver FET D-S Short	Stop after 2 ¹⁴ count	Stop after 2 ¹⁴ count	Discharge after stop	Low after timer latch
LED GND Short	Stop after (CP ⁺ +2 ⁶)count	Only detected LED ch stops after CP count Other LED ch stop operation after (CP ⁺ +2 ⁶) count	(CP ⁺ +2 ⁶) Discharge after count	Low after timer latch
VCCUVLO	Stop N output	Stop immediately	Discharge immediately	HiZ
UVLO	Stop N output	Stop immediately	Discharge immediately	HiZ
OVP	Stop N output	Normal operation	Normal operation	HiZ
SCP	Stop N output	Normal operation	Normal operation	Low after timer latch
OCP	Stop N output (Pulse by Pulse)	Normal operation	Normal operation	HiZ
Over PWM duty	Normal operation	Stop in relevant CH	Normal operation	HiZ

※CP : Count movement after detection of D-S SHORT, LED_OPEN, SHORT.

3.1 Application Circuit Example

An example application using the BD9415FS.

3.1.1 Basic Application Example

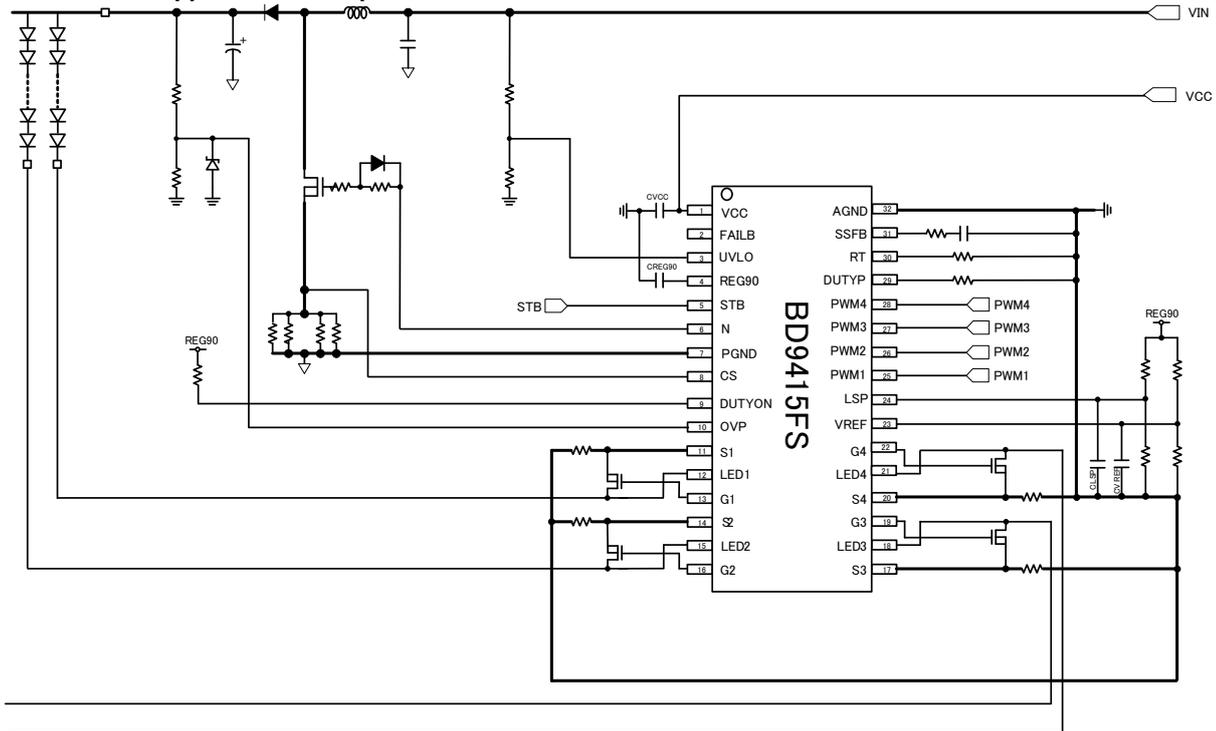


Figure 10. Basic Application Example

3.1.2 Application Example of Unused CH

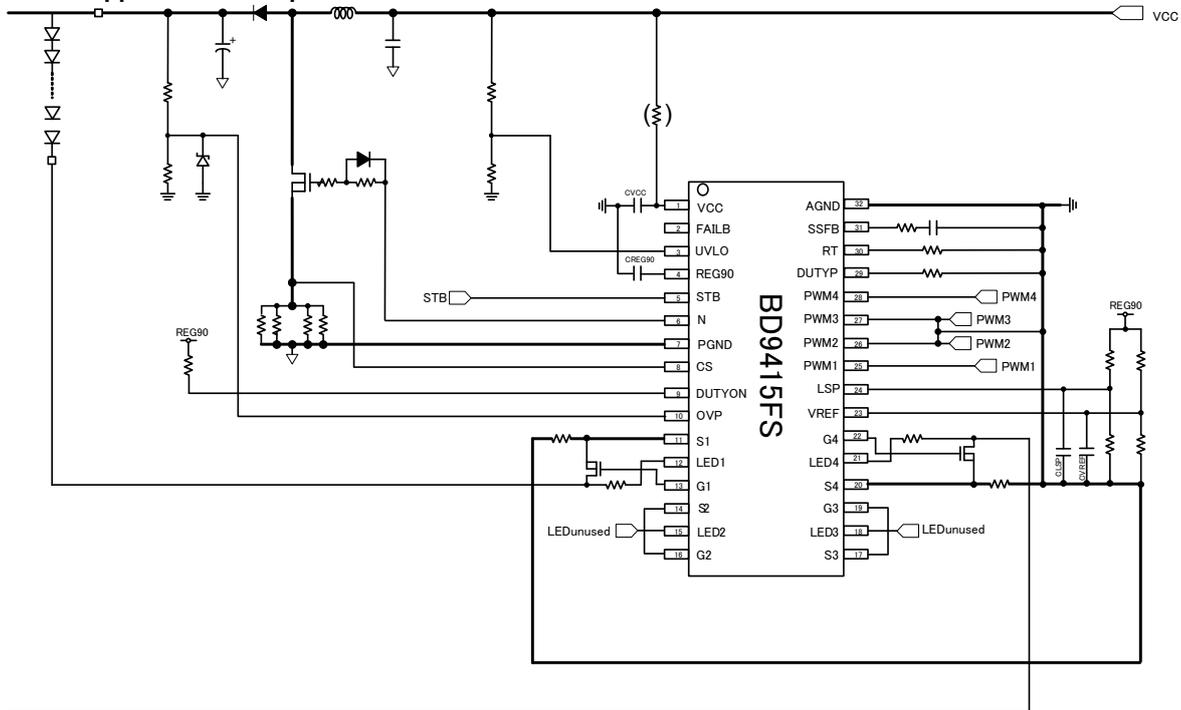


Figure 11. Application Example of Unused CH

When an LED terminal was unused, please dispose the unused CH as follows.

- Please input lower than 3.0V (typical) of voltage to a LEDx pin (ex. 1.0 to 2.0V).
- Gx pin, Sx pin is short
- Unused PWMx = L

3.2 External Components Selection

3.2.1 Startup operation and soft start (SSFB) capacitance setting

The following section describes the sequence for the startup of this IC.

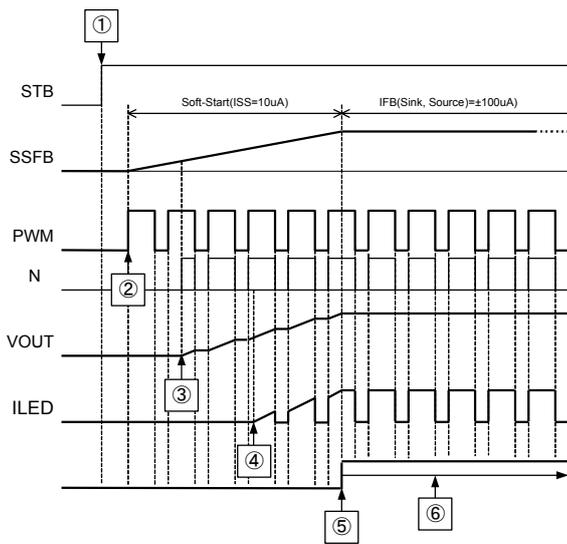


Figure 12. Startup Waveform

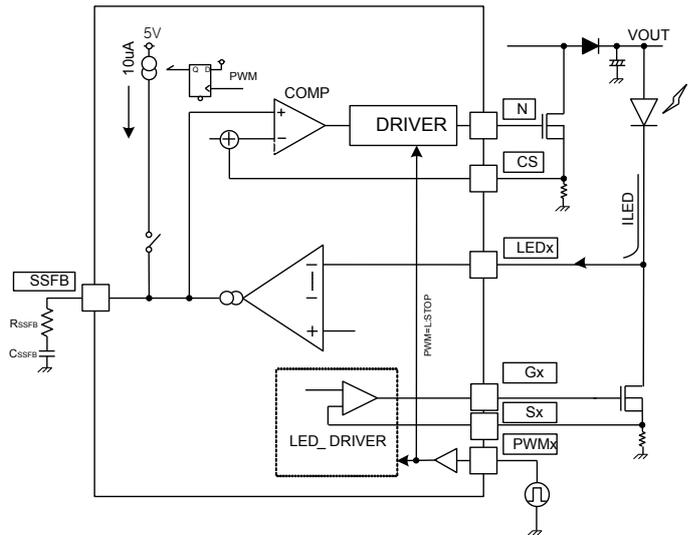


Figure 13. Circuit Behavior at Startup

○ Description of startup sequence

- (1) Set the STB and PWM pin to "ON".
 - (2) Set all systems to "ON", SSFB charge will be initiated.
 - (3) Since the SSFB pin reach the lower limit of the internal sawtooth wave of the IC, the DC/DC converter operates to start VOUT voltage rising.
 - (4) The VOUT voltage continuously rising to reach a voltage at which LED current starts flowing.
 - (5) When the LED current reaches the set amount of current, the startup operation is completed.
 - (6) After that, conduct normal operation following the feedback operation sequence with the LED pins.
- If the SSFB pin sink/source current is $\pm 100\mu A$, the LED protection function will be activated.

○ SSFB capacitance setting procedure

As aforementioned, this IC stops DC/DC converter when the PWM pin is set to Low level and conducts step-up operation only in the section in which the PWM pin is maintained at High level. Consequently, setting the PWM duty cycle to the minimum will extend the startup time. The startup time also varies with application settings of output capacitance, LED current, output voltage, and others.

Startup time at minimum duty cycle can be approximated according to the following method:

Make measurement of VOUT startup time with a 100% duty cycle, first. Take this value as "Trise100".

The startup time "Trise_min" for the relevant application with the minimum duty cycle is given by the following equation.

$$T_{rise_min} = \frac{T_{rise_100}[\text{sec}]}{\text{Min_Duty}[\text{ratio}]} \quad [\text{sec}]$$

However, since this calculation method is just for approximation, use it only as a guide.

Assuming that the SSFB pin voltage is VSSFB, the time is given by the following equation:

$$T_{SSFB} = \frac{C_{SSFB}[F] \times V_{SSFB}[V]}{10[\mu A]} \quad [\text{Sec}]$$

As a result, it is recommended to make SSFB capacitance setting so that "T_{SSFB}" will be greater than "Trise_min"

3.2.2 LED Current Setting (VREF pin, Sx pin)

First, VREF pin voltage is determined. When performing Analog dimming, be careful of VREF pin input range(0.2 to 2.5V) and decide typical voltage.

In BD9415FS, LED constant current is controlled by Sx pin voltage as a reference point. Sx pin is controlled to become one fifth of the voltage of VREF pin voltage. In the case of VREF=1V, it is set to Sx=0.2V.

Therefore, when the resistance to Sx pin versus GND is set to "RS", the relationship between RS, VREF and ILED is as follows

$$R_s [ohm] = \frac{V_{VREF} [V]}{I_{LED} [A] \times 5}$$

3.2.3 LED Short Detection Voltage Setting (LSP terminal)

The voltage of LED short detection can be arbitrarily set up with LSP pin voltage. It is possible to change the LED short detection voltage, please input (0.8V to 3.0V) to LSP pin.

About LED short detection voltage, if "VLEDshort" and LSP pin voltage are set to "VLSP", it is as follows

$$V_{LSP} = \frac{V_{LED_{SHORT}} [V]}{6.7}$$

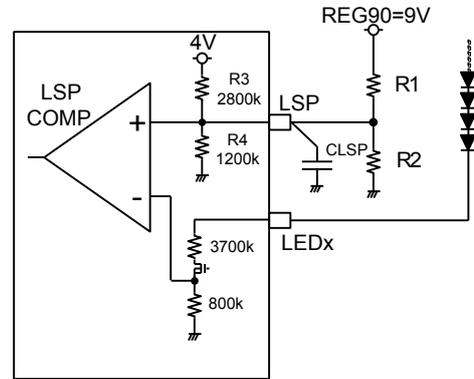


Figure 14. LSP setting example

Since the setting range of a LSP pin is set to 0.8V to 3.0V, VLEDshort can be set up in 5.36V to 20.1V.

o Equation of setting LSP detect Voltage

When the detection voltage VLSP of LSP is set up by resistance division of R1 and R2 using REG90, it becomes like the following formula.

$$LED_{SHORT} = \left(\frac{R2[k\Omega] \times R4[k\Omega] \times (REG90[V] \times R3 + 4[V] \times R1[k\Omega])}{(R1[k\Omega] \times R3[k\Omega] \times (R2 + R4) + R2[k\Omega] \times R4[k\Omega] \times (R1[k\Omega] + R3[k\Omega]))} \right) \times 6.7 [V] \dots (2)$$

【Setting example】

Assuming that LSP is approximated by Equation (1) in order to set LSP detection voltage to 6V, R1 comes to 68kΩ. and R2 comes to 7.6kΩ.

When calculating LSP detection voltage taking into account internal IC resistance by Equation (2), it will be given as:

$$LED_{SHORT} = \left(\frac{7.6[k\Omega] \times 1200[k\Omega] \times (9[V] \times 2800[k\Omega] + 4[V] \times 68[k\Omega])}{(68[k\Omega] \times 2800[k\Omega] \times (7.6[k\Omega] + 1200[k\Omega]) + 7.6[k\Omega] \times 1200[k\Omega] \times (68[k\Omega] + 2800[k\Omega]))} \right) \times 6.7 = 6.078[V] \dots (2)$$

*Also including the variation in IC, please also take the part variation in a set into consideration for an actual constant setup, and inquire enough to it.

3.2.4 DCDC Oscillation Frequency Setting

RRT which connects to RT pin sets the oscillation frequency f_{SW} of DCDC.
 Relationship between frequency f_{SW} and RT resistance (ideal)

$$R_{RT} = \frac{15000}{f_{SW}[kHz]} \quad [k\Omega]$$

【setting example】

When DCDC frequency f_{SW} is set to 200kHz, R_{RT} is as follows.

$$R_{RT} = \frac{15000}{f_{SW}[kHz]} = \frac{15000}{200[kHz]} = 75[k\Omega]$$

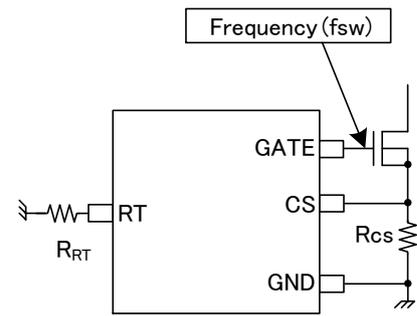


Figure 15. RT terminal setting example

3.2.5 UVLO Setting

Under Voltage Lockout pin is the input voltage of the power stage. IC starts boost operation if UVLO is more than 2.5V(Typ) and stops if lower than 2.4V(Typ). Since internal impedance exists in UVLO pin, cautions are needed for selection of resistance for resistance division. V_{in} detection voltage level can be calculated by the following formula using resistance division of R1 and R2 (unit: k Ω).

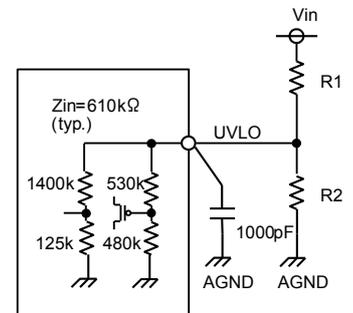


Figure 16. UVLO setting example

o **Equation of Setting UVLO Release**

$$V_{in_{DET}} = 2.5 \times \left\{ \frac{R1 + R2}{R2} + \left(\frac{1}{1400k + 125k} + \frac{1}{530k + 480k} \right) \times R1 \right\} \quad [V]$$

o **Equation of Setting UVLO Lock**

$$V_{in_{lock}} = 2.4 \times \left\{ \frac{R1 + R2}{R2} + \left(\frac{1}{1400k + 125k} + \frac{1}{530k + 480k + 40k} \right) \times R1 \right\} \quad [V]$$

*Also including the variation in IC, please also take the part variation in a set into consideration for an actual constant setup, and inquire enough to it.

3.2.6 OVP Setting

The OVP terminal is the input for over-voltage protection of output voltage. The OVP pin is high impedance, because the internal resistance is not connected to a certain bias.

Detection voltage of VOUT is set by dividing resistors R1 and R2. The resistor values can be calculated by the formula below.

○ **OVP Detect Equation**

If VOUT is boosted abnormally, VOVPDET, the detect voltage of OVP, R1, R2 can be expressed by the following formula.

$$R1 = R2[k\Omega] \times \frac{(VOVP_{DET}[V] - 3.0[V])}{3.0[V]} \quad [k\Omega]$$

○ **OVP Release Equation**

By using R1 and R2 in the above equation, the release voltage of OVP, VOVPCAN can be expressed as follows.

$$VOVP_{CAN} = 2.9[V] \times \frac{(R1[k\Omega] + R2[k\Omega])}{R2[k\Omega]}$$

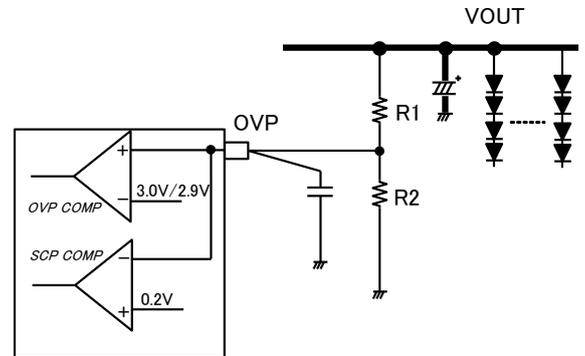


Figure 17 . OVP setting example

[setting example]

If the normal output voltage, VOUT is 58V, the detect voltage of OVP is 63V, R2 is 20kΩ, R1 is calculated as follows.

$$R1 = R2[k\Omega] \times \frac{(VOVP_{DET}[V] - 3.0[V])}{3.0[V]} = 20[k\Omega] \times \frac{(63[V] - 3.0[V])}{3.0[V]} = 400[k\Omega]$$

By using these R1 and R2, the release voltage of OVP, VOVP_{CAN} can be calculated as follows.

$$VOVP_{CAN} = 2.9[V] \times \frac{(R1[k\Omega] + R2[k\Omega])}{R2[k\Omega]} = 2.9[V] \times \frac{(400[k\Omega] + 20[k\Omega])}{20[k\Omega]} = 60.9[V]$$

3.2.7 SCP setting

[3.2.6] The SCP setting 「VSCP_{DET}」 voltage is calculated as below when R1,R2 is decided above:

$$VSCP_{DET} = 0.2[V] \times \frac{(R1[k\Omega] + R2[k\Omega])}{R2[k\Omega]} = 0.2[V] \times \frac{(400[k\Omega] + 20[k\Omega])}{20[k\Omega]} = 40.2[V]$$

*Also including the variation in IC, please also take the part variation in a set into consideration for an actual constant setup, and inquire enough to it.

3.2.8 FAILB Logic

FAILB signal output pin (OPEN DRAIN); when an abnormality is detected, NMOS is brought into GND Level. The rating of this pin is 20V.

State	FAILB output
In completion of an abnormality (After CP count※)	GND Level (500ohm (Typ))
In normal state, In STB	OPEN

※CP count : Count movement after detection of D-S SHORT, LED_OPEN, SHORT, SCP.

3.2.9 ODP setting

RDUTYP which connects to ODP pin sets the ODP detection duty.

Relationship between LED PWM frequency f_{PWM} , ODP Detection Duty and DUTYP resistance (ideal)

$$R_{DUTYP} = \frac{1172 \times ODP_{duty}[\%]}{f_{PWM} [Hz]} [k\Omega]$$

【setting example】

When LED PWM frequency f_{PWM} , is set to 120Hz and ODP Detection Duty (ODPduty) is set to 35%, RDUTYP is as follows.

$$R_{DUTYP} = \frac{1172 \times 35[\%]}{120[Hz]} = 341.8[k\Omega]$$

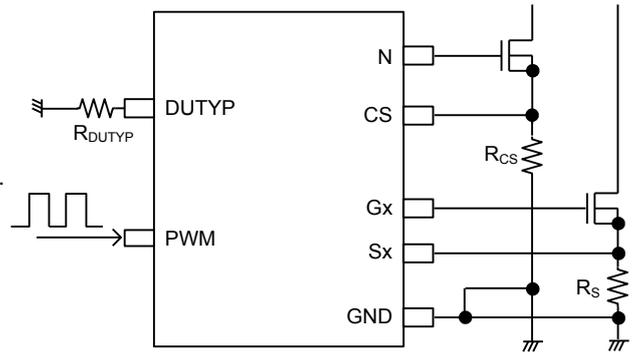


Figure 18. ODP setting example

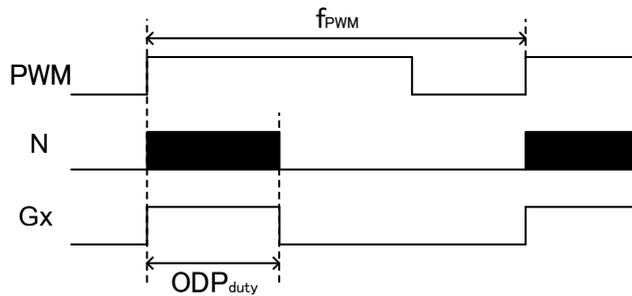


Figure 19. The GATE and the DIMOUT waveform as PWM dimming (ODP)

3.2.10 Timer Latch Time (CP Counter) Setting, Auto-Restart Timer Setting

Timer latch time (CP Counter) is set by counting the clock frequency which is set at the RT pin. About the behavior from abnormal detection to latch-off, please refer to the section “3.5.2 and 3.5.3 Timing Chart”.

When various abnormal conditions happen, counting starts from the timing, latch occurs after below time has passed. Furthermore, even if PWM=L, if abnormal condition continues, timer count will not reset.

$$LATCH_{TIME} = 2^{14} \times \frac{R_{RT} [\Omega]}{1.5 \times 10^{10}} = 16384 \times \frac{100[k\Omega]}{1.5 \times 10^7} = [s]$$

$$AUTO_{TIME} = 2^{17} \times \frac{R_{RT} [\Omega]}{1.5 \times 10^{10}} = 131072 \times \frac{100[k\Omega]}{1.5 \times 10^7} [s]$$

Here, LATCHTIME = time until latch condition occurs, AUTOTIME = auto restart timer’s time
RRT = Resistor value connected to RT pin

【setting example】

Timer latch time when RT=30kohm (500kHz)

$$LATCH_{TIME} = 16384 \times \frac{R_{RT} [k\Omega]}{1.5 \times 10^7} = 16384 \times \frac{30[k\Omega]}{1.5 \times 10^7} = 32.8[ms]$$

$$AUTO_{TIME} = 131072 \times \frac{R_{RT} [k\Omega]}{1.5 \times 10^7} = 131072 \times \frac{30[k\Omega]}{1.5 \times 10^7} = 262.1[ms]$$

3.3. DCDC Parts Selection

3.3.1. OCP Setting / Calculation Method for the Current Rating of DCDC Parts

OCP detection stops the switching when the CS pin voltage is more than 0.45V(Typ). The resistor value of CS pin, R_{CS} needs to be considered by the coil L current. And the current rating of DCDC external parts is required more than the peak current of the coil.

Shown below are the calculation method of the coil peak current, the selection method of R_{CS} (the resistor value of CS pin) and the current rating of the external DCDC parts at Continuous Current Mode.

(The calculation method of the coil peak current, I_{PEAK} at Continuous Current Mode)

At first, since the ripple voltage at CS pin depends on the application condition of DCDC, the following variables are used.

- Vout voltage = V_{OUT} [V]
- LED total current = I_{OUT} [A]
- DCDC input voltage of the power stage = V_{IN} [V]
- Efficiency of DCDC = η [%]

And then, the average input current I_{IN} is calculated by the following equation.

$$I_{IN} = \frac{V_{OUT}[V] \times I_{OUT}[A]}{V_{IN}[V] \times \eta[\%]} [A]$$

And the ripple current of the inductor L (ΔIL[A]) can be calculated by using DCDC the switching frequency, f_{SW}, as follows.

$$\Delta IL = \frac{(V_{OUT}[V] - V_{IN}[V]) \times V_{IN}[V]}{L[H] \times V_{OUT}[V] \times f_{SW}[Hz]} [A]$$

On the other hand, the peak current of the inductor I_{PEAK} can be expressed as follows.

$$I_{PEAK} = I_{IN}[A] + \frac{\Delta IL[A]}{2} [A] \quad \dots (1)$$

Therefore, the bottom of the ripple current I_{MIN} is

$$I_{min} = I_{IN}[A] - \frac{\Delta IL[A]}{2} \quad \text{or } 0$$

If I_{MIN}>0, the operation mode is CCM (Continuous Current Mode), otherwise the mode is DCM (Discontinuous Current Mode).

(The selection method of R_{CS} at Continuous Current Mode)

I_{PEAK} flows into R_{CS} and that causes the voltage signal to CS pin. (Please refer to the timing chart at the right)

Peak voltage V_{CSPEAK} is as follows.

$$V_{CSPEAK} = R_{CS} \times I_{PEAK} [V]$$

As this V_{CSPEAK} reaches 0.4V (typical), the DCDC output stops the switching.

Therefore, R_{CS} value is necessary to meet the condition below.

$$R_{CS} \times I_{PEAK} [V] \ll 0.45[V]$$

(The current rating of the external DCDC parts)

The peak current as the CS voltage reaches OCP level (0.4V (Typ)) is defined as I_{PEAK_DET}.

$$I_{PEAK_DET} = \frac{0.45[V]}{R_{CS}[\Omega]} [A] \quad \dots (2)$$

The relationship among I_{PEAK} (equation (1)), I_{PEAK_DET} (equation (2)) and the current rating of parts is required to meet the following

$$I_{peak} \ll I_{peak_det} \ll \text{The current rating of parts}$$

Please make the selection of the external parts such as FET, Inductor, diode meet the above condition.

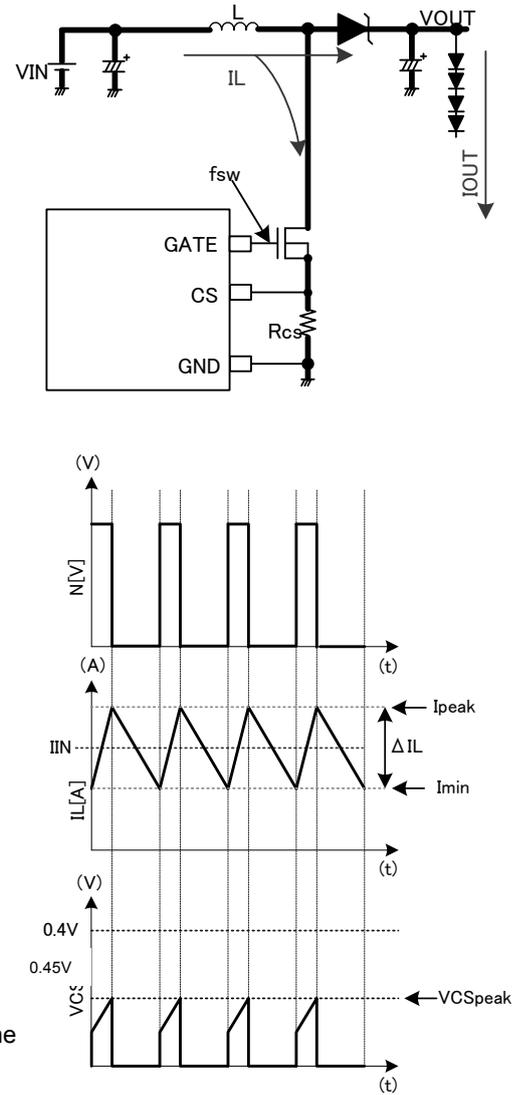


Figure 20. Coil Current Waveform

【setting example】Output voltage = V_{OUT} [V] = 40VLED total current = I_{OUT} [A] = 0.48ADCDC input voltage of the power stage = V_{IN} [V] = 24VEfficiency of DCDC= η [%]=90%Averaged input current I_{IN} is calculated as follows.

$$I_{IN} = \frac{V_{OUT}[V] \times I_{OUT}[A]}{V_{IN}[V] \times \eta[\%]} = \frac{40[V] \times 0.48[A]}{24[V] \times 90[\%]} = 0.89[A]$$

If the switching frequency, $f_{SW} = 200\text{kHz}$, and the inductor, $L=100\mu\text{H}$, the ripple current of the inductor L (ΔI_L [A]) can be calculated as follows.

$$\Delta I_L = \frac{(V_{OUT}[V] - V_{IN}[V]) \times V_{IN}[V]}{L[H] \times V_{OUT}[V] \times f_{SW}[Hz]} = \frac{(40[V] - 24[V]) \times 24[A]}{100 \times 10^{-6}[H] \times 40[V] \times 200 \times 10^3[Hz]} = 0.48[A]$$

Therefore the inductor peak current, I_{PEAK} is

$$I_{PEAK} = I_{IN}[A] + \frac{\Delta I_L[A]}{2} [A] = 0.89[A] + \frac{0.48[A]}{2} = 1.13[A]$$

...calculation result of the peak current

If R_{CS} is assumed to be 0.3Ω

$$V_{CS_{PEAK}} = R_{CS} \times I_{PEAK} = 0.3[\Omega] \times 1.13[A] = 0.339[V] \ll 0.45[V]$$

... R_{CS} value confirmation

The above condition is met.

And I_{PEAK_DET} , the current OCP works, is

$$I_{PEAK_DET} = \frac{0.45[V]}{0.3[\Omega]} = 1.35[A]$$

If the current rating of the used parts is 2A,

$$I_{peak} \ll I_{peak_det} \ll \text{The current rating} = 1.13[A] \ll 1.35[A] \ll 2.0[A]$$

...current rating confirmation of DCDC

This inequality meets the above relationship. The parts selection is proper.

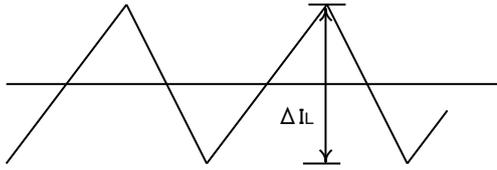
And I_{MIN} , the bottom of the IL ripple current, can be calculated as follows.

$$I_{MIN} = I_{IN}[A] - \frac{\Delta I_L[A]}{2} [A] = 1.13[A] - 0.48[A] = 0.65[A] \gg 0$$

This inequality implies that the operation is continuous current mode.

3.3.2. Inductor Selection

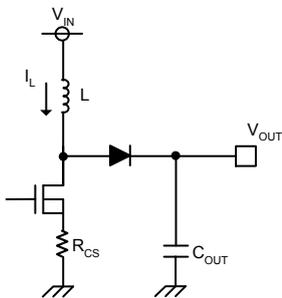
The inductor value affects the input ripple current, as shown the previous section 3.3.1.



$$\Delta IL = \frac{(V_{OUT}[V] - V_{IN}[V]) \times V_{IN}[V]}{L[H] \times V_{OUT}[V] \times f_{SW}[Hz]} [A]$$

$$I_{IN} = \frac{V_{OUT}[V] \times I_{OUT}[A]}{V_{IN}[V] \times \eta[\%]} [A]$$

$$I_{PEAK} = I_{IN}[A] + \frac{\Delta IL[A]}{2} [A]$$



Where
 L: coil inductance [H] V_{OUT}: DCDC output voltage [V]
 V_{IN}: input voltage [V]
 I_{OUT}: output load current (the summation of LED current) [A]
 I_{IN}: input current [A] f_{sw}: oscillation frequency [Hz]

Figure 21. Inductor current waveform and diagram

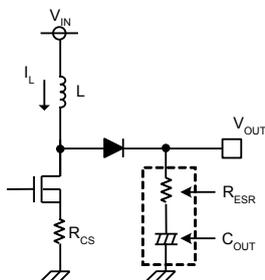
In continuous current mode, ΔL is set to 30% to 50% of the output load current in many cases.

In using smaller inductor, the boost is operated by the discontinuous current mode in which the coil current returns to zero at every period.

*The current exceeding the rated current value of inductor flown through the coil causes magnetic saturation, results in decreasing in efficiency. Inductor needs to be selected to have such adequate margin that peak current does not exceed the rated current value of the inductor.

*To reduce inductor loss and improve efficiency, inductor with low resistance components (DCR, ACR) needs to be selected.

3.3.3. Output Capacitance C_{OUT} Selection



Output capacitor needs to be selected in consideration of equivalent series resistance required to even the stable area of output voltage or ripple voltage. Be aware that set LED current may not be flown due to decrease in LED terminal voltage if output ripple component is high.

Output ripple voltage ΔV_{OUT} is determined by Equation (4):

$$\Delta V_{OUT} = \Delta IL \times R_{ESR} [V] \quad \dots \quad (4)$$

When the coil current is charged to the output capacitor as MOS turns off, much output ripple is caused. Much ripple voltage of the output capacitor may cause the LED current ripple.

Figure 22. Output capacitor diagram

* Rating of capacitor needs to be selected to have adequate margin against output voltage.

* To use an electrolytic capacitor, adequate margin against allowable current is also necessary. Be aware that the LED current is larger than the set value transitionally in case that LED is provided with PWM dimming especially.

3.3.4. MOSFET Selection

There is no problem if the absolute maximum rating is larger than the rated current of the inductor L, or is larger than the sum of the tolerance voltage of C_{OUT} and the rectifying diode VF. The product with small gate capacitance (injected charge) needs to be selected to achieve high-speed switching.

* One with over current protection setting or higher is recommended.

* The selection of one with small on resistance results in high efficiency.

3.3.5. Rectifying Diode Selection

A schottky barrier diode which has current ability higher than the rated current of L, reverse voltage larger than the tolerance voltage of C_{OUT}, and low forward voltage VF especially needs to be selected.

3.4 Loop Compensation

A current mode DCDC converter has each one pole (phase lag) f_p due to CR filter composed of the output capacitor and the output resistance (= LED current) and zero (phase lead) f_z by the output capacitor and the ESR of the capacitor. Moreover, a step-up DCDC converter has RHP zero (right-half plane zero point) f_{ZRHP} which is unique with the boost converter. This zero may cause the unstable feedback. To avoid this by RHP zero, the loop compensation that the cross-over frequency f_c , set as follows, is suggested.

$$f_c = f_{ZRHP} / 5 \quad (f_{ZRHP}: \text{RHP zero frequency})$$

Considering the response speed, the calculated constant below is not always optimized completely. It needs to be adequately verified with an actual device.

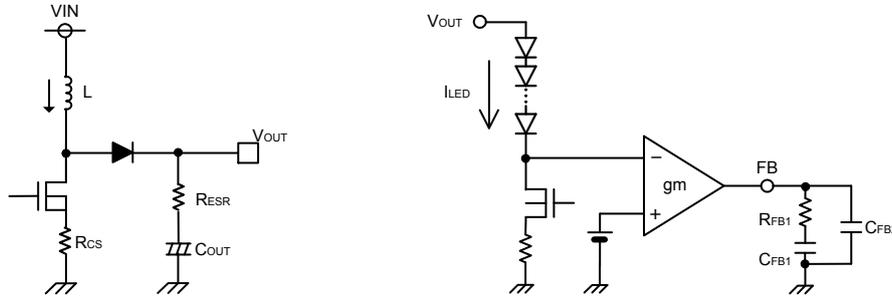


Figure 23. Output stage and error amplifier diagram

- i. Calculate the pole frequency f_p and the RHP zero frequency f_{ZRHP} of DC/DC converter

$$f_p = \frac{I_{LED}}{2\pi \times V_{OUT} \times C_{OUT}} [Hz] \qquad f_{ZRHP} = \frac{V_{OUT} \times (1-D)^2}{2\pi \times L \times I_{LED}} [Hz]$$

Where I_{LED} = the summation of LED current, $D = \frac{V_{OUT} - V_{IN}}{V_{OUT}}$ (Continuous Current Mode)

- ii. Calculate the phase compensation of the error amp output ($f_c = f_{ZRHP}/5$)

$$R_{FB1} = \frac{f_{ZRHP} \times R_{CS} \times I_{LED}}{5 \times f_p \times gm \times V_{OUT} \times (1-D)} [\Omega]$$

$$C_{FB1} = \frac{1}{2\pi \times R_{FB1} \times f_c} = \frac{5}{2\pi \times R_{FB1} \times f_{ZRHP}} [F]$$

$$gm = 4.0 \times 10^{-4} [S]$$

Above equation is described for lighting LED without the oscillation. The value may cause much error if the quick response for the abrupt change of dimming signal is required. To improve the transient response, RFB1 needs to be increased, and CFB1 needs to be decreased. It needs to be adequately verified with an actual device in consideration of variation from parts to parts since phase margin is decreased.

3.5. Timing Chart
3.5.1 PWM Start Up

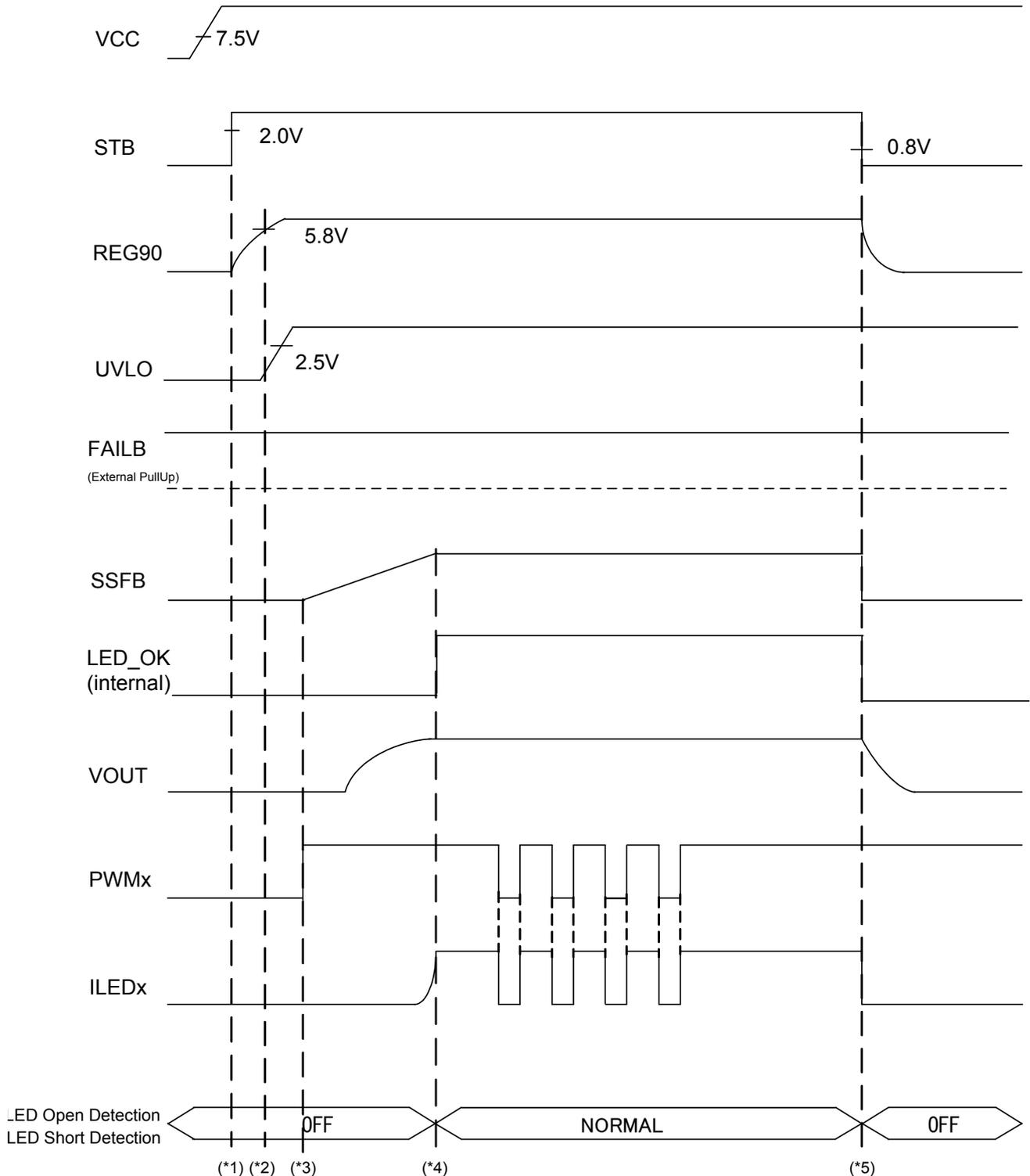


Figure 24. Start Up

- (*1)...REG90 starts up when STB is changed from Low to High. In the state where the PWM signal is not inputted, SS terminal is not charged and DCDC doesn't start to boost, either.
- (*2)...When REG90 is more than 5.8V(Typ), the reset signal is released.
- (*3)...The charge of the pin SS starts at the positive edge of PWM=L to H, and the soft start starts. The pin SS continues charging in spite of the assertion of PWM or OVP level.
- (*4)...The soft start interval will end if the LED_OK = H (internal signal), By this time, it boosts VOUT to the voltage where the set LED current flows. The abnormal detection of FBMAX starts to be monitored.
- (*5)...As STB=L, the boost operation is stopped instantaneously.(N=L, SSFB=L)

3.5.2 LED OPEN Detection

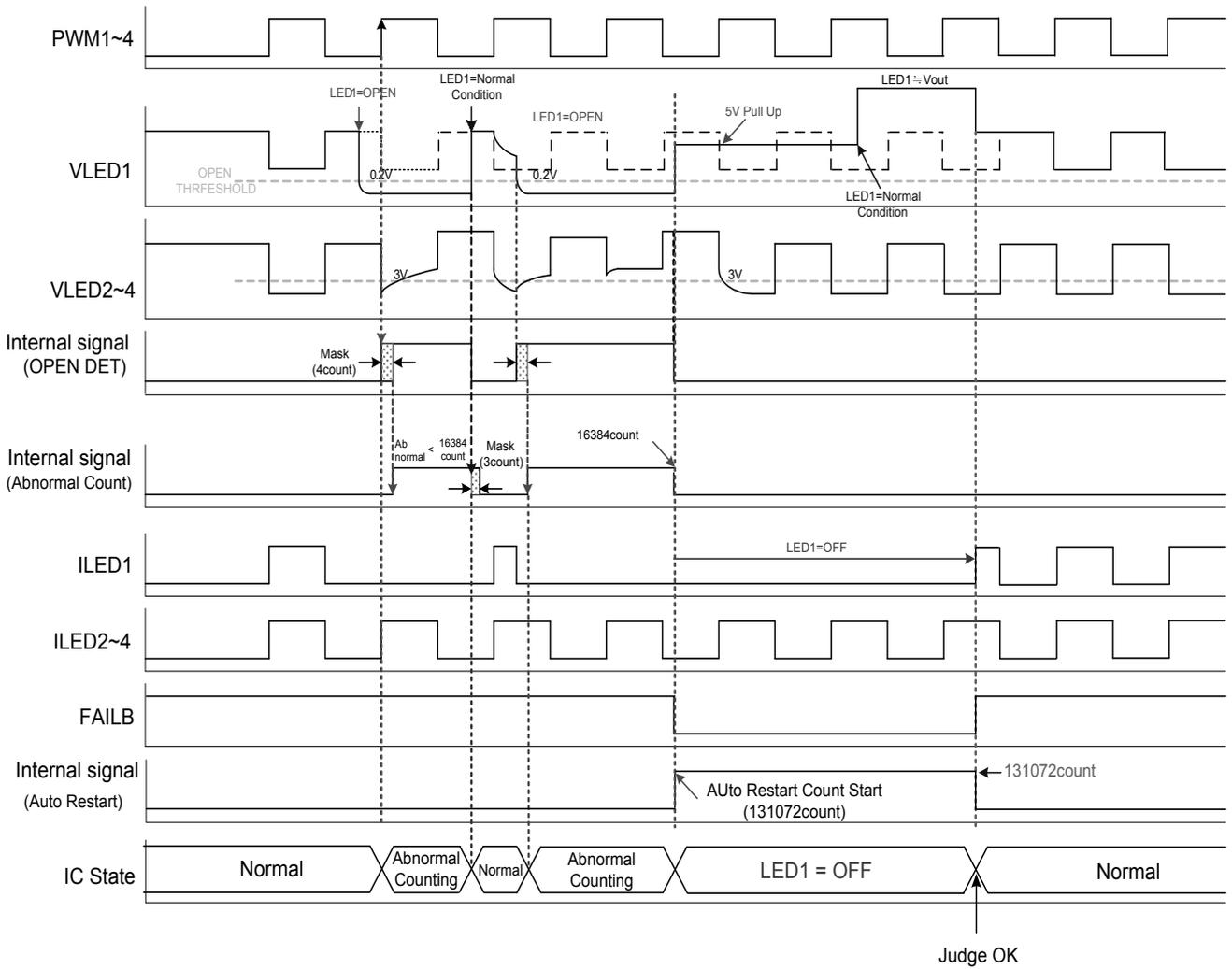


Figure 25. LED OPEN Detection

3.5.3 LED SHORT Detection

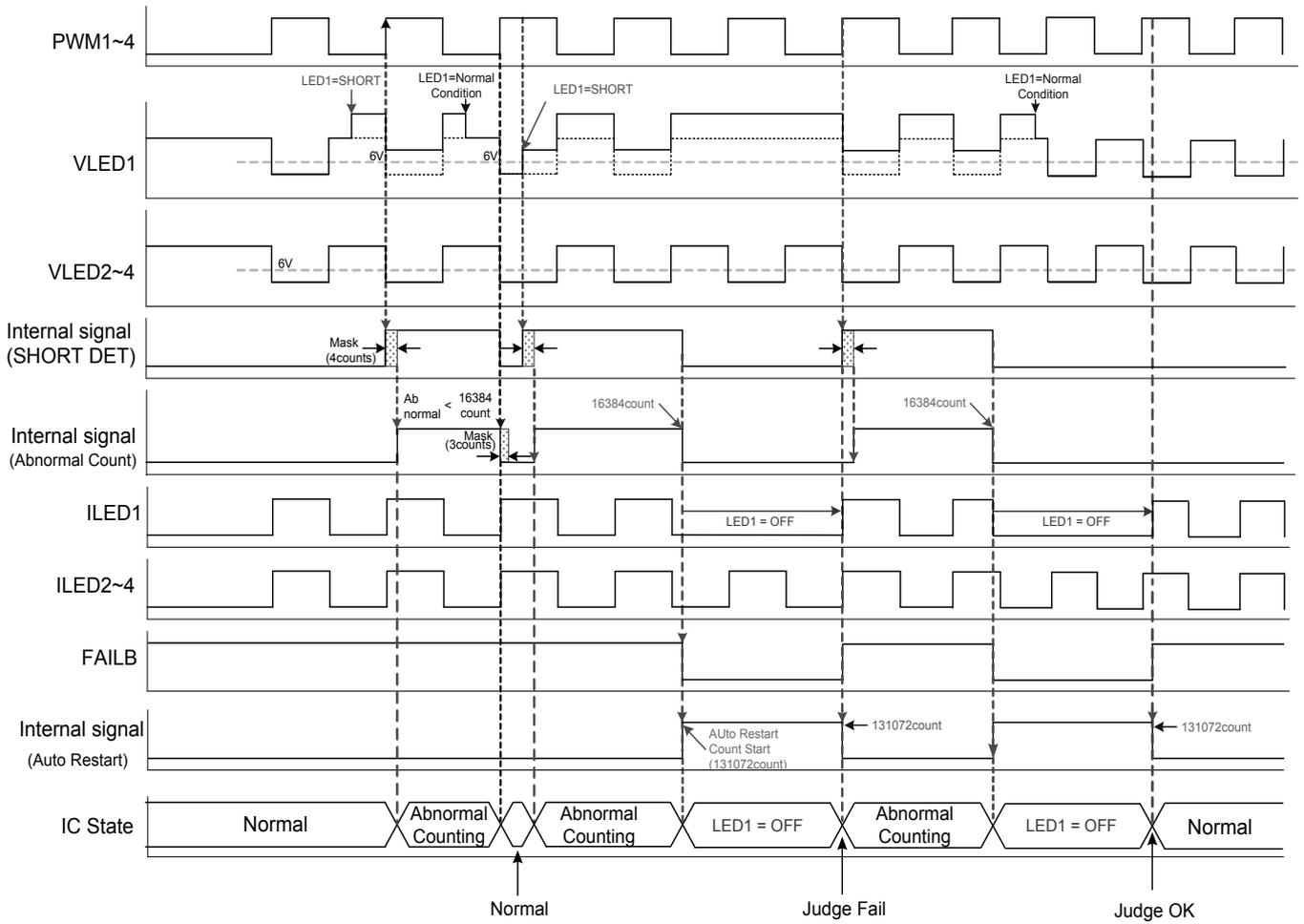


Figure 26. LED SHORT Detection

3.5.4 Over Duty Protection

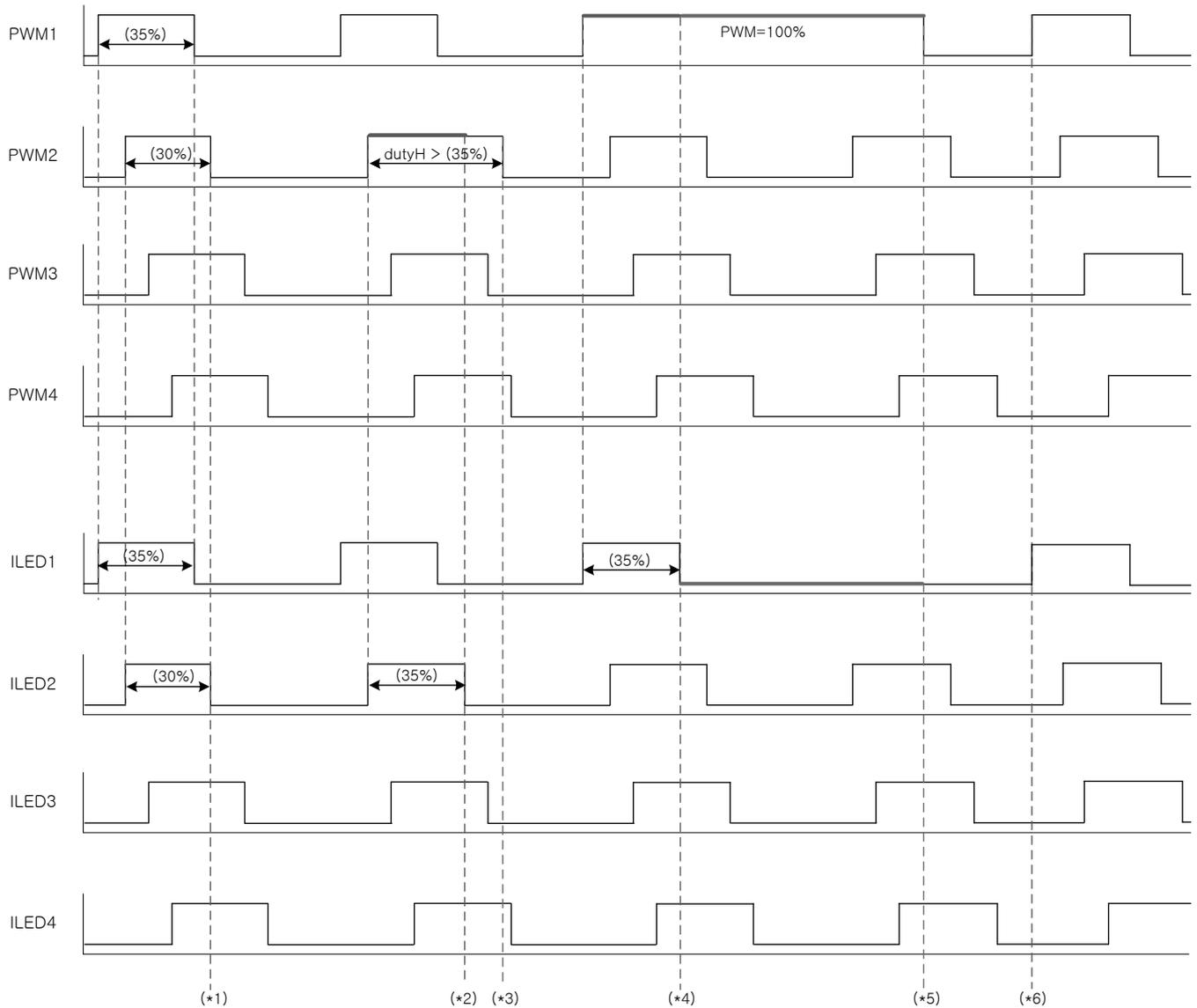


Figure 27. Over Duty Protection

ODP=35% setup

(*1) ...PWM < 35% : Turn on in relevant CH of same time PWM_DutyH.

(*2) ...PWM > 35% : An LED of relevant CH is turn off by PWM_DutyH=35%.

(*3) ...PWM=H signal beyond 35% is changed, and that doesn't react to IC in particular.

(*4) ...PWM > 35% : An LED of relevant CH is turn off by PWM_DutyH=35%.

(*5) ...ODP Function= ON : When a PWM signal is equivalent to 100%, LED=OFF continues after 35%.

(*6) ... When the next PWM=H signal is input, an LED is also turn on at the same time.

3.6 I/O Equivalent Circuits

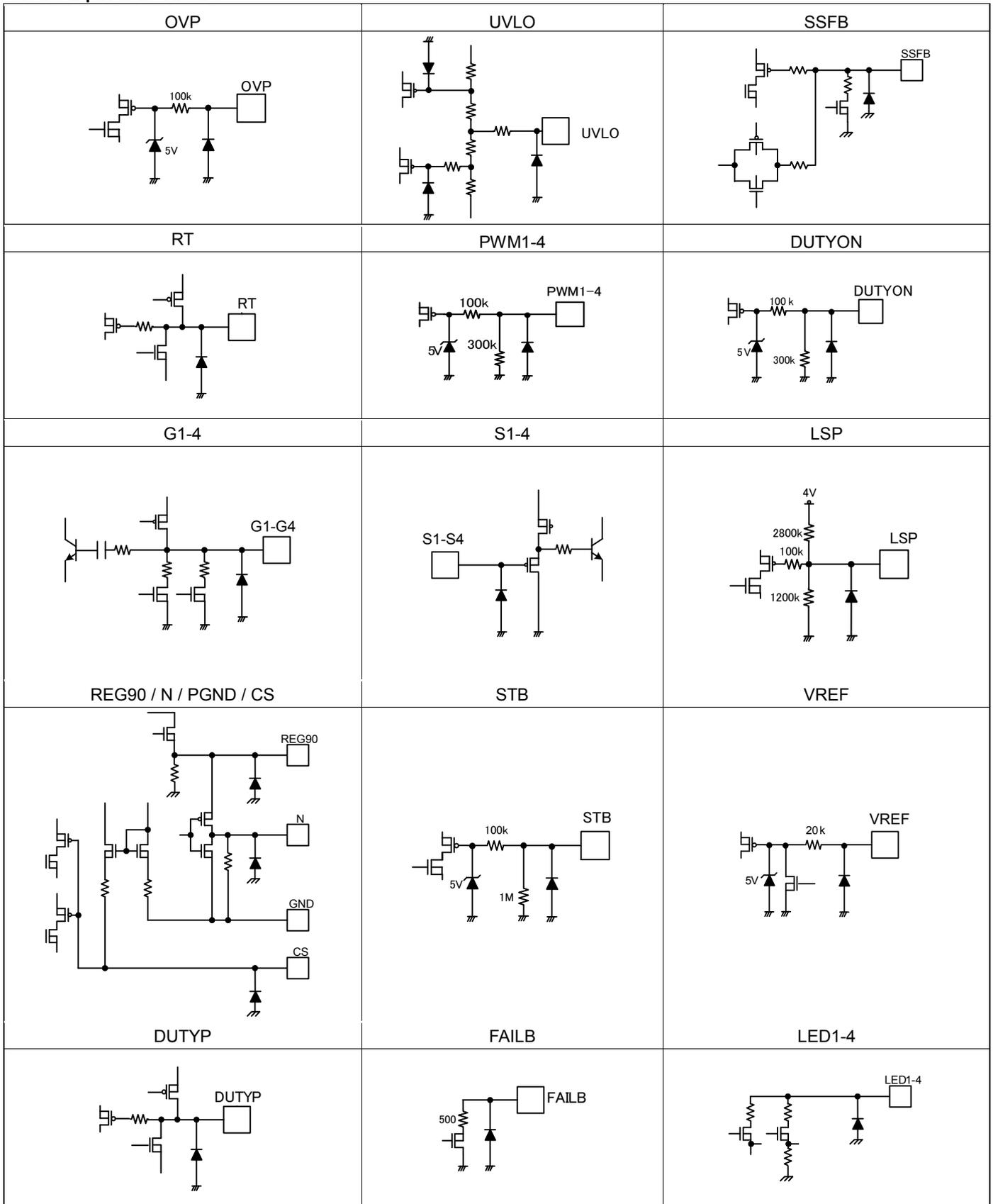


Figure 28. Internal Equivalent Circuits

Operational Notes

1. Reverse Connection of Power Supply

Connecting the power supply in reverse polarity can damage the IC. Take precautions against reverse polarity when connecting the power supply, such as mounting an external diode between the power supply and the IC's power supply pins.

2. Power Supply Lines

Design the PCB layout pattern to provide low impedance supply lines. Connect a capacitor to ground at all power supply pins. Consider the effect of temperature and aging on the capacitance value when using electrolytic capacitors.

3. Ground Voltage

Ensure that no pins are at a voltage below that of the ground pin at any time, even during transient condition.

4. Ground Wiring Pattern

When using both small-signal and large-current ground traces, the two ground traces should be routed separately but connected to a single ground at the reference point of the application board to avoid fluctuations in the small-signal ground caused by large currents. Also ensure that the ground traces of external components do not cause variations on the ground voltage. The ground lines must be as short and thick as possible to reduce line impedance.

5. Thermal Consideration

Should by any chance the maximum junction temperature rating be exceeded the rise in temperature of the chip may result in deterioration of the properties of the chip. In case of exceeding this absolute maximum rating, increase the board size and copper area to prevent exceeding the maximum junction temperature rating.

6. Recommended Operating Conditions

These conditions represent a range within which the expected characteristics of the IC can be approximately obtained. The electrical characteristics are guaranteed under the conditions of each parameter.

7. Inrush Current

When power is first supplied to the IC, it is possible that the internal logic may be unstable and inrush current may flow instantaneously due to the internal powering sequence and delays, especially if the IC has more than one power supply. Therefore, give special consideration to power coupling capacitance, power wiring, width of ground wiring, and routing of connections.

8. Operation Under Strong Electromagnetic Field

Operating the IC in the presence of a strong electromagnetic field may cause the IC to malfunction.

9. Testing on Application Boards

When testing the IC on an application board, connecting a capacitor directly to a low-impedance output pin may subject the IC to stress. Always discharge capacitors completely after each process or step. The IC's power supply should always be turned off completely before connecting or removing it from the test setup during the inspection process. To prevent damage from static discharge, ground the IC during assembly and use similar precautions during transport and storage.

10. Inter-pin Short and Mounting Errors

Ensure that the direction and position are correct when mounting the IC on the PCB. Incorrect mounting may result in damaging the IC. Avoid nearby pins being shorted to each other especially to ground, power supply and output pin. Inter-pin shorts could be due to many reasons such as metal particles, water droplets (in very humid environment) and unintentional solder bridge deposited in between pins during assembly to name a few.

11. Unused Input Pins

Input pins of an IC are often connected to the gate of a MOS transistor. The gate has extremely high impedance and extremely low capacitance. If left unconnected, the electric field from the outside can easily charge it. The small charge acquired in this way is enough to produce a significant effect on the conduction through the transistor and cause unexpected operation of the IC. So unless otherwise specified, unused input pins should be connected to the power supply or ground line.

12. Regarding the Input Pin of the IC

This monolithic IC contains P+ isolation and P substrate layers between adjacent elements in order to keep them isolated. P-N junctions are formed at the intersection of the P layers with the N layers of other elements, creating a parasitic diode or transistor. For example (refer to figure below):

When $GND > Pin A$ and $GND > Pin B$, the P-N junction operates as a parasitic diode.

When $GND > Pin B$, the P-N junction operates as a parasitic transistor.

Parasitic diodes inevitably occur in the structure of the IC. The operation of parasitic diodes can result in mutual interference among circuits, operational faults, or physical damage. Therefore, conditions that cause these diodes to operate, such as applying a voltage lower than the GND voltage to an input pin (and thus to the P substrate) should be avoided.

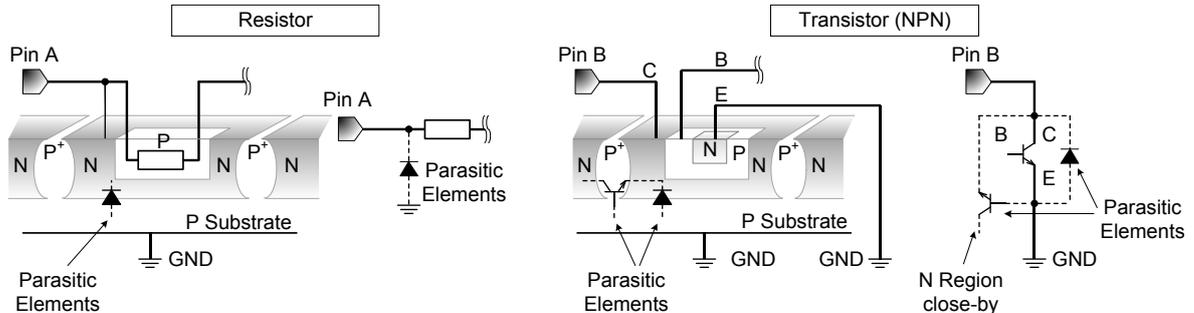


Figure 29. Example of monolithic IC structure

13. Ceramic Capacitor

When using a ceramic capacitor, determine the dielectric constant considering the change of capacitance with temperature and the decrease in nominal capacitance due to DC bias and others.

14. Area of Safe Operation (ASO)

Operate the IC such that the output voltage, output current, and the maximum junction temperature rating are all within the Area of Safe Operation (ASO).

15. Thermal Shutdown Circuit(TSD)

This IC has a built-in thermal shutdown circuit that prevents heat damage to the IC. Normal operation should always be within the IC's maximum junction temperature rating. If however the rating is exceeded for a continued period, the junction temperature (T_j) will rise which will activate the TSD circuit that will turn OFF all output pins. When the T_j falls below the TSD threshold, the circuits are automatically restored to normal operation.

Note that the TSD circuit operates in a situation that exceeds the absolute maximum ratings and therefore, under no circumstances, should the TSD circuit be used in a set design or for any purpose other than protecting the IC from heat damage.

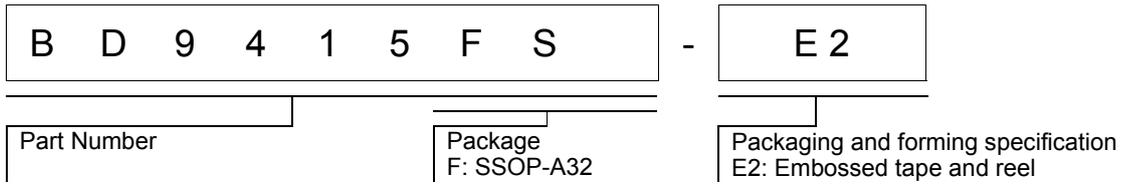
16. Over Current Protection Circuit (OCP)

This IC incorporates an integrated overcurrent protection circuit that is activated when the load is shorted. This protection circuit is effective in preventing damage due to sudden and unexpected incidents. However, the IC should not be used in applications characterized by continuous operation or transitioning of the protection circuit.

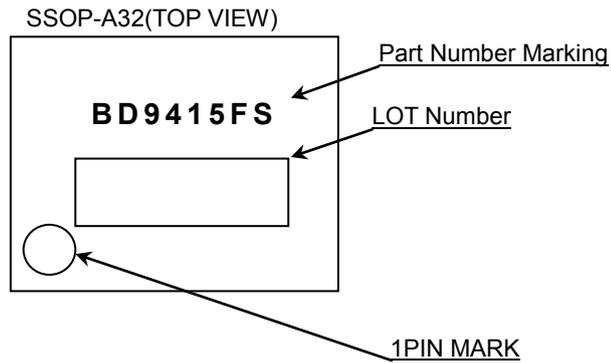
17. Disturbance light

In a device where a portion of silicon is exposed to light such as in a WL-CSP, IC characteristics may be affected due to photoelectric effect. For this reason, it is recommended to come up with countermeasures that will prevent the chip from being exposed to light.

Ordering Information

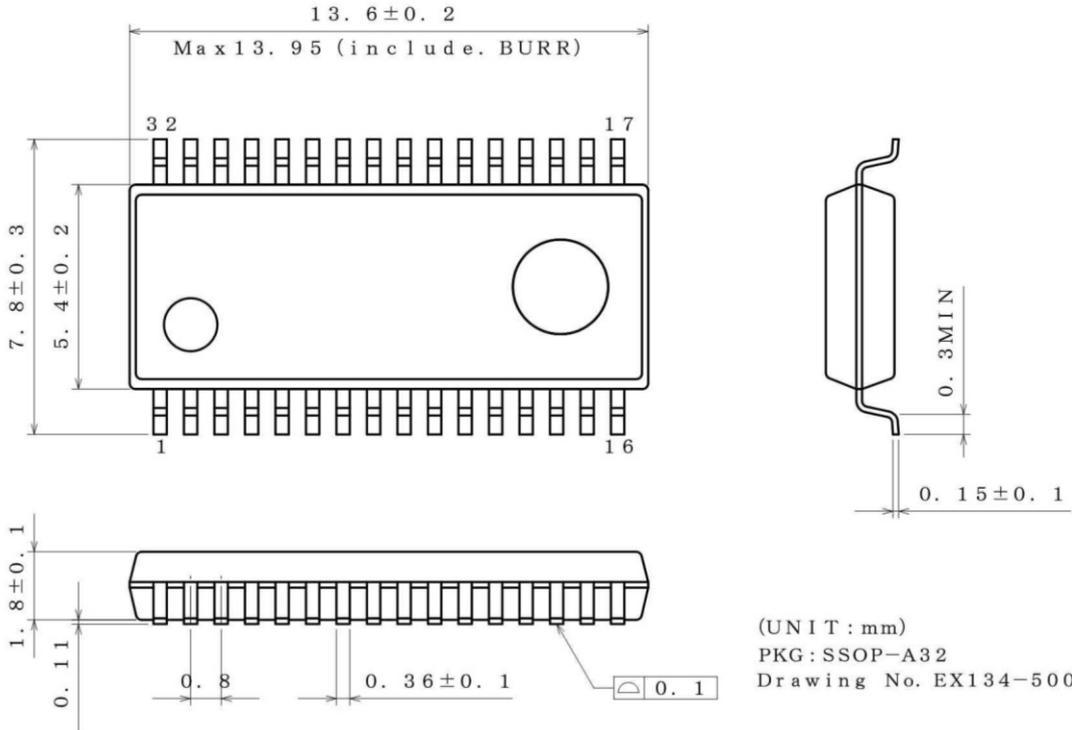


Marking Diagrams



Physical Dimension, Tape and Reel Information

Package Name	SSOP-A32
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<Tape and Reel information>

Tape	Embossed carrier tape
Quantity	2000pcs
Direction of feed	E2 (The direction is the 1pin of product is at the upper left when you hold reel on the left hand and you pull out the tape on the right hand)

Reel 1pin Direction of feed

*Order quantity needs to be multiple of the minimum quantity.

Revision History

Date	Revision	Change
12 May.2016	001	New Release

Notice

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- Our Products are designed and manufactured for application in ordinary electronic equipments (such as AV equipment, OA equipment, telecommunication equipment, home electronic appliances, amusement equipment, etc.). If you intend to use our Products in devices requiring extremely high reliability (such as medical equipment ^(Note 1), transport equipment, traffic equipment, aircraft/spacecraft, nuclear power controllers, fuel controllers, car equipment including car accessories, safety devices, etc.) and whose malfunction or failure may cause loss of human life, bodily injury or serious damage to property ("Specific Applications"), please consult with the ROHM sales representative in advance. Unless otherwise agreed in writing by ROHM in advance, ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of any ROHM's Products for Specific Applications.

(Note1) Medical Equipment Classification of the Specific Applications

JAPAN	USA	EU	CHINA
CLASS III	CLASS III	CLASS II b	CLASS III
CLASS IV		CLASS III	

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 - Installation of redundant circuits to reduce the impact of single or multiple circuit failure
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 - Use of our Products in any types of liquid, including water, oils, chemicals, and organic solvents
 - Use of our Products outdoors or in places where the Products are exposed to direct sunlight or dust
 - Use of our Products in places where the Products are exposed to sea wind or corrosive gases, including Cl₂, H₂S, NH₃, SO₂, and NO₂
 - Use of our Products in places where the Products are exposed to static electricity or electromagnetic waves
 - Use of our Products in proximity to heat-producing components, plastic cords, or other flammable items
 - Sealing or coating our Products with resin or other coating materials
 - Use of our Products without cleaning residue of flux (even if you use no-clean type fluxes, cleaning residue of flux is recommended); or Washing our Products by using water or water-soluble cleaning agents for cleaning residue after soldering
 - Use of the Products in places subject to dew condensation
- The Products are not subject to radiation-proof design.
- Please verify and confirm characteristics of the final or mounted products in using the Products.
- In particular, if a transient load (a large amount of load applied in a short period of time, such as pulse. is applied, confirmation of performance characteristics after on-board mounting is strongly recommended. Avoid applying power exceeding normal rated power; exceeding the power rating under steady-state loading condition may negatively affect product performance and reliability.
- De-rate Power Dissipation depending on ambient temperature. When used in sealed area, confirm that it is the use in the range that does not exceed the maximum junction temperature.
- Confirm that operation temperature is within the specified range described in the product specification.
- ROHM shall not be in any way responsible or liable for failure induced under deviant condition from what is defined in this document.

Precaution for Mounting / Circuit board design

- When a highly active halogenous (chlorine, bromine, etc.) flux is used, the residue of flux may negatively affect product performance and reliability.
- In principle, the reflow soldering method must be used on a surface-mount products, the flow soldering method must be used on a through hole mount products. If the flow soldering method is preferred on a surface-mount products, please consult with the ROHM representative in advance.

For details, please refer to ROHM Mounting specification

Precautions Regarding Application Examples and External Circuits

1. If change is made to the constant of an external circuit, please allow a sufficient margin considering variations of the characteristics of the Products and external components, including transient characteristics, as well as static characteristics.
2. You agree that application notes, reference designs, and associated data and information contained in this document are presented only as guidance for Products use. Therefore, in case you use such information, you are solely responsible for it and you must exercise your own independent verification and judgment in the use of such information contained in this document. ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of such information.

Precaution for Electrostatic

This Product is electrostatic sensitive product, which may be damaged due to electrostatic discharge. Please take proper caution in your manufacturing process and storage so that voltage exceeding the Products maximum rating will not be applied to Products. Please take special care under dry condition (e.g. Grounding of human body / equipment / solder iron, isolation from charged objects, setting of Ionizer, friction prevention and temperature / humidity control).

Precaution for Storage / Transportation

1. Product performance and soldered connections may deteriorate if the Products are stored in the places where:
 - [a] the Products are exposed to sea winds or corrosive gases, including Cl₂, H₂S, NH₃, SO₂, and NO₂
 - [b] the temperature or humidity exceeds those recommended by ROHM
 - [c] the Products are exposed to direct sunshine or condensation
 - [d] the Products are exposed to high Electrostatic
2. Even under ROHM recommended storage condition, solderability of products out of recommended storage time period may be degraded. It is strongly recommended to confirm solderability before using Products of which storage time is exceeding the recommended storage time period.
3. Store / transport cartons in the correct direction, which is indicated on a carton with a symbol. Otherwise bent leads may occur due to excessive stress applied when dropping of a carton.
4. Use Products within the specified time after opening a humidity barrier bag. Baking is required before using Products of which storage time is exceeding the recommended storage time period.

Precaution for Product Label

A two-dimensional barcode printed on ROHM Products label is for ROHM's internal use only.

Precaution for Disposition

When disposing Products please dispose them properly using an authorized industry waste company.

Precaution for Foreign Exchange and Foreign Trade act

Since concerned goods might be fallen under listed items of export control prescribed by Foreign exchange and Foreign trade act, please consult with ROHM in case of export.

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