SA33761

55V Buck-Boost Controller for Automotive Front Lighting

General Description

The SA33761 Buck-Boost controller can automatically operate in Buck, Boost, and Buck-Boost modes based on input and output voltages. It accepts a wide input voltage range from 4.5V to 55V and can accommodate LED voltages from 2.5V to 55V.

The SA33761 operates in constant frequency current mode, with a switching frequency range of 200 kHz to 700 kHz. It provides analog dimming when the voltage on the SET pin is adjusted, and direct pulse-width modulation (PWM) dimming when a dimming signal is applied to the PWM pin.

The SA33761 offers reliable protections against faults including overvoltage, LED open/short, overtemperature, input overcurrent, and additional single faults, and includes cycle-by-cycle current limiting.

Features

- Wide Input Voltage Range from 4.5 V to 55V
- Wide Output Voltage Range from 2.5V to 55V
- Adaptive Switching between Pure Boost, Pure Buck, and Buck-Boost Modes
- Adjustable Switching Frequency 200kHz to 700kHz
- Spread Spectrum Operation
- Analog Dimming and Direct Dimming
- Adjustable Soft-Start Time
- Pre-Bias Startup
- Constant Frequency with Current Mode
- Overvoltage Protection, Open LED Protection, LED Short Protection, Overtemperature Protection
- Package: TSSOP24E

Applications

- Constant Current Buck-Boost for LED
- Constant Current Buck Controller for LED
- Constant Voltage Buck-Boost Controller

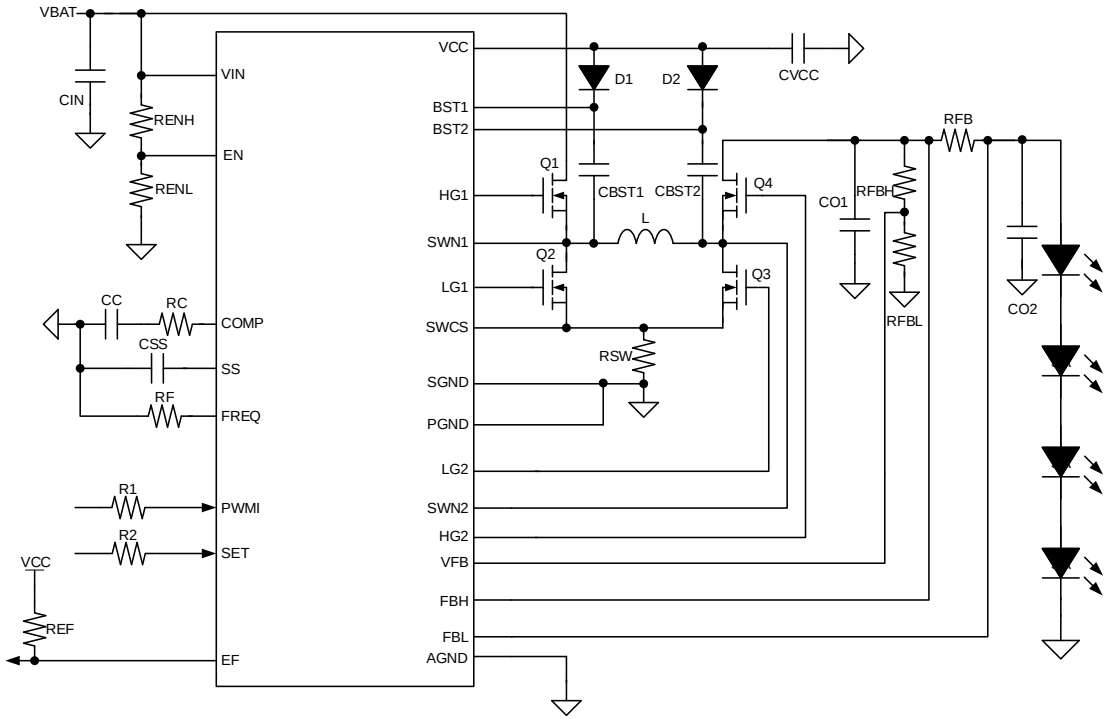


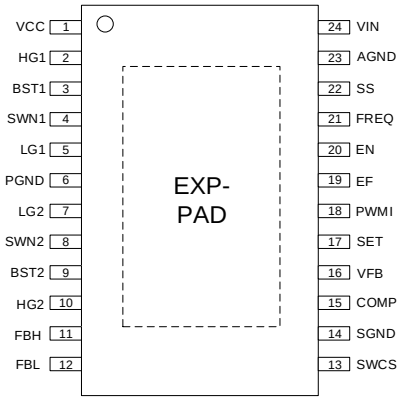
Figure 1. Typical Application Circuit

Ordering Information

Ordering Part Number	Package type	Top Mark
SA33761HHP	TSSOP24E RoHS-Compliant and Halogen-Free	**AAHYxyz**

x = year code, y = week code, z = lot number code

Pinout (top view)



Pin Description

Pin Number	Pin Name	Pin Description
1	VCC	Internal LDO connected to VIN output. Connect a capacitor between VCC and GND close to the device.
2	HG1	Buck MOSFET high side driver
3	BST1	Buck bootstrap capacitor connection
4	SWN1	Buck high side MOSFET and low side MOSFET connection
5	LG1	Buck low side MOSFET driver
6	PGND	GND for MOS driver loop
7	LG2	Boost low side MOSFET driver
8	SWN2	Boost high side and low side MOSFET connection
9	BST2	Boost bootstrap capacitor connect
10	HG2	Boost high side MOSFET driver
11	FBH	Output current sense positive
12	FBL	Output current sense negative
13	SWCS	Switching current sense
14	SGND	GND switching current sense. Use a Kelvin connection.
15	COMP	Loop compensation
16	VFB	Output voltage foldback
17	SET	Analog dimming
18	PWMI	Direct PWM dimming signal input
19	EF	Fault reporting. Open-drain output. High-impedance state when no faults are detected.
20	EN	Device enable
21	FREQ	Switching frequency. Connect a resistor between this pin and GND to set the switching frequency.
22	SS	Soft-start pin. A current source of 25μA (typ.) is used to charge the C_{SS} capacitor.
23	AGND	Device GND pin.
24	VIN	Device power supply pin.
Exposed pad		Exposed pad. The exposed pad is on the bottom side of the device.

Block Diagram

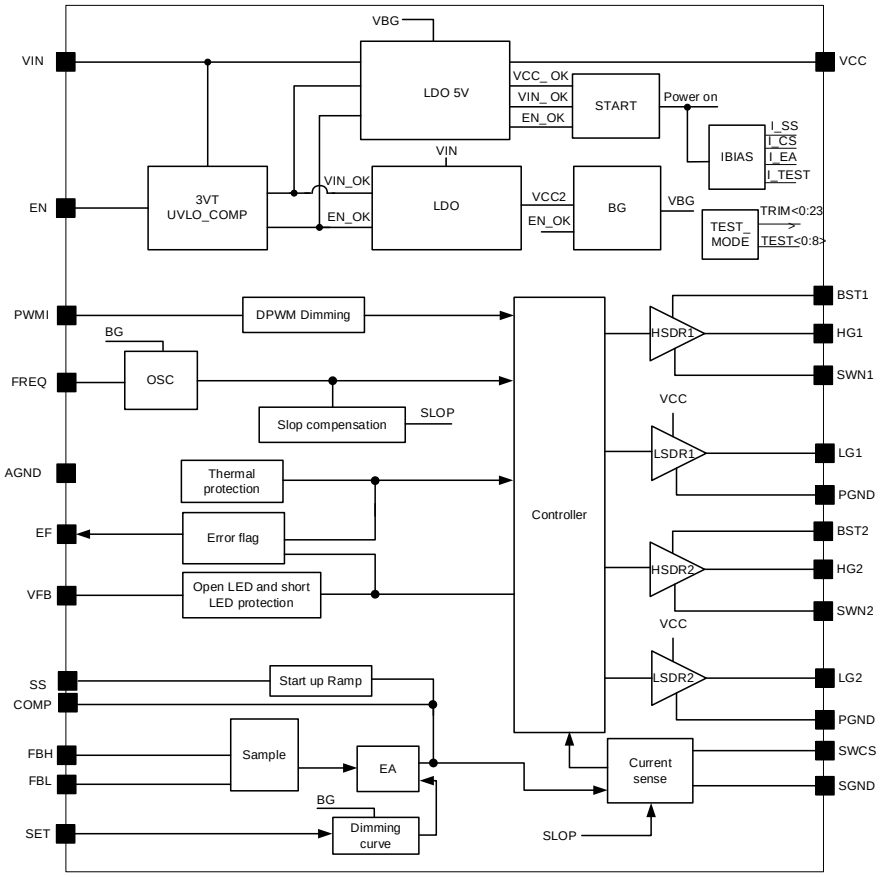


Figure 2. Block Diagram

Absolute Maximum Ratings

Parameter (Note 1)	Min	Max	Unit
VIN, SWN1, SWN2, FBH, FBL	-0.3	60	V
EN	-0.3	40	
BST1, BST2	-0.3	65	
VCC, BST1-SWN1, BST2-SWN2	-0.3	6	
LG1- PGND, LG2 –PGND, HG1 to SWN1, HG2 to SWN2, PWMI, FB, EF, SET	-0.3	5.5	
COMP, SS	-0.3	3.6	
SWCS-SGND, FBH-FBL	-0.3	0.3	
SWCS, SGND, PGND	-0.3	0.3	
Junction Temperature, Operating		150	°C
Lead Temperature (Soldering, 10s)		206	
Storage Temperature Range	-65	150	

Thermal Information

Parameter (Note 2)	Typ	Unit
$R_{\theta JA}$ Junction-to-Ambient Thermal Resistance	35	°C/W
$R_{\theta JC}$ Junction-to-Case (Top) Thermal Resistance	13.7	°C/W

Recommended Operating Conditions

Parameter (Note 3)	Min	Max	Unit
VIN	4.5	55	V
VOUT	2.4	55	
Ambient Temperature Range	-40	125	°C

Electrical Characteristics

(V_{IN} =12V, VDD = 5V, T_J = -40°C to +125°C, unless otherwise noted (Note 4))

Parameter		Symbol	Min	Typ	Max	Unit
Functional Range	Supply Voltage	V_{VIN}	4.5	-	55	V
	Normal Operating T_J Range	T_J	-40	-	150	°C
Power Supply VIN	Input Voltage Startup	V_{VIN_ON}	4.0	4.2	4.4	V
	Input Voltage Startup Hysteresis	V_{VIN_HYS}	-	0.37	-	V
	IC Operating Current (without Driver Current when FS = 300KHz) PWMI = 0	I_Q		2.6	3.5	mA
	VIN shut down Mode Current	I_{SD}			20	μA
Regulator	V(FBH-FBL) Threshold (VSET = 2V)	$V_{REF\_CURRENT}$	145.5	150	154.5	mV
	V(FBH-FBL) Threshold @ Analog Dimming 10%(VSET = 0.32V)	$V_{REF\_CURRENT\_10\%}$	10	15	20	mV
	g_m of Current Loop	g_m		1000		μA/V
	Saturation Output Current of G_m	g_{m_MAX}		80		μA
	Minimum Boost t_{ON}	t_{ONMIN_BST}		230		ns
	Minimum Buck t_{ON}	t_{ONMIN_BUCK}		230		ns
	SWCS Current Limit					
	Switch Peak Overcurrent Boost Threshold	$V_{S\_LIM\_BST}$	38	50	62	mV
	Switch Peak Overcurrent Buck Threshold	$V_{S\_LIM\_BUCK}$	-62	-50	-38	mV
	Soft-Start Pullup Current	I_{SS_CHAREG}		26		μA
	Soft-Star Pulldown Current	$I_{SS\_DISCHARGE}$		2		μA
	Soft-Start Voltage during Regulation	V_{SS_REG}		2		V
	Soft-Start Done Threshold	V_{SS_DONE}		1.75		V
	Soft-Start Latch-Off Threshold	V_{SS_RESET}		0.2		V
	Switch Frequency for R_{FREQ} = 36kΩ, T_J = 25°C	f_{SW}	320	350	380	kHz
	Enable Rising Threshold	V_{EN_ON}	1.65	1.75	1.85	V
	Enable Voltage Hysteresis	V_{EN_HYS}		200		mV

Parameter		Symbol	Min	Typ	Max	Unit
Gate Driver	Gate Driver Undervoltage (V_{BST1} - V_{SWN1} and V_{BST2} - V_{SWN2})	$V_{(VBSTx-VSWx)\_UV}$		2.4		V
	HG1/HG2 MOS Driver Pullup Resistor	$R_{DSON\_HG\_UP}$		3.0		Ω
	HG1/HG2 MOS Driver Pulldown Resistor	$R_{DSON\_HG\_LOW}$		1.6		Ω
	LG1/LG2 MOS Driver Pullup Resistor	$R_{DSON\_LG\_UP}$		3.0		Ω
	LG1/LG2 MOS Driver Pulldown Resistor	$R_{DSON\_LG\_LOW}$		1.6		Ω
PWMI	PWMI Turn-On Threshold	V_{PWMI_ON}		2.18		V
	PWMI Turn-Off Threshold	V_{PWMI_OFF}		0.78		V
	VCC Regulator					
	VCC Output Voltage	V_{VCC}	4.8	5.0	5.2	V
	VCC Output Current Limit	I_{LIM_VCC}		100		mA
	Dropout Voltage from VIN to VCC when I_{VCC} = 10mA	V_{DR}		70		mV
	VCC On-Voltage	V_{CC_ON}		4.2	4.4	V
	VCC Undervoltage Hysteresis	V_{CC_HYS}		0.5		V
Protection	FB Detect Threshold for Short LED Protection	V_{FB_SLP}		0.16		V
	FB Detect Threshold for Overvoltage Protection	V_{FB_OVP}	1.38	1.46	1.54	V
	Output Overvoltage Hysteresis	$V_{FB\_OV\_HYS}$		50		mV
	Open Load Rising Threshold	$V_{FB\_OPL\_RISE}$	1.27	1.34	1.41	V
	Open Load Hysteresis	$V_{FB\_OPL\_HYS}$		50		mV
	Open Load Reference Threshold on V_{FBH} - V_{FBL}	V_{FBHL_LOW}		20		mV
	EF Output Impedance (1mA)	R_{EF}		2.7		kΩ
	Overtemperature(Note 5)	T_{SD}	150	160		°C
	Overtemperature Protection Hysteresis(Note 5)	T_{SD_HYS}		15		°C

Note 1: Stresses beyond the “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Note 2: θ_{JA} is measured in the natural convection at T_A = 25°C on a 2oz two-layer Silergy evaluation board. Case temperature θ_{JC} is measured at pin 4.

Note 3: The device is not guaranteed to function outside its operating conditions.

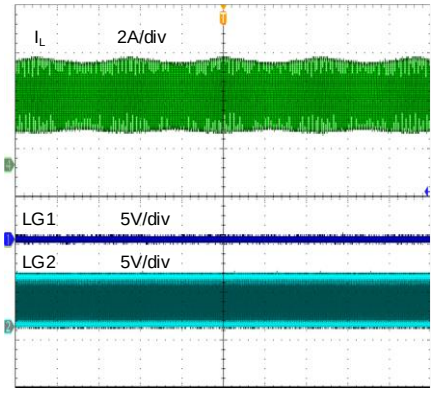
Note 4: Unless otherwise stated, limits are 100% production tested under pulsed load conditions such that $T_A \cong T_J$ = -40°C –125°C. Limits over the operating temperature range (see recommended operating conditions) and relevant voltage range(s) are guaranteed by design, test, or statistical correlation.

Note 5: Guaranteed by design or statistical correlation and not production tested.

Typical Performance Characteristics

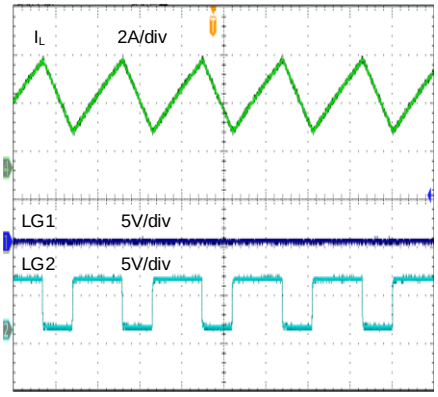
VIN=12V, VLED=30V,ILED=1A, Boost mode

Steady State
(±8% jitter)



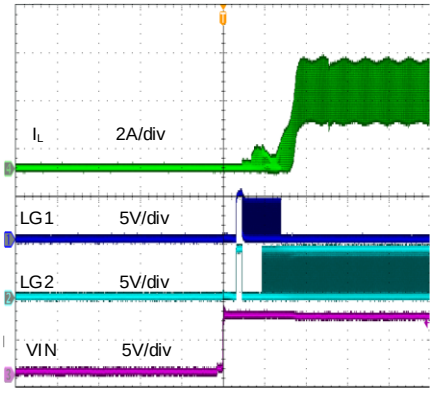
Time (200µs/div)

Steady State
(±8% jitter)



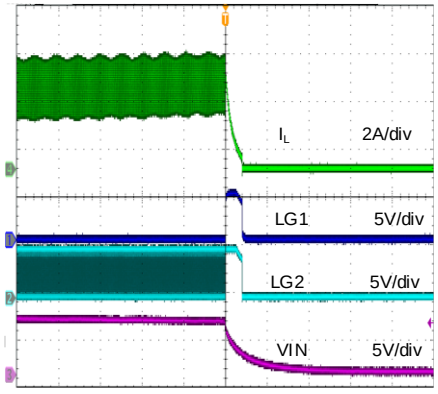
Time (2µs/div)

VIN ON



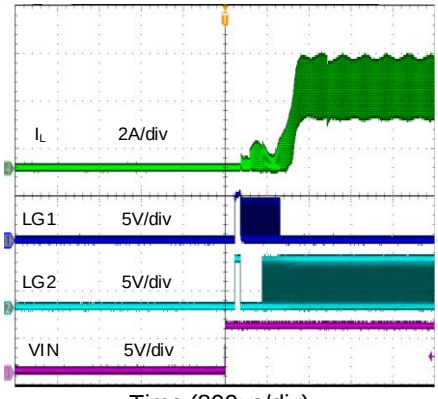
Time (800µs/div)

VIN OFF



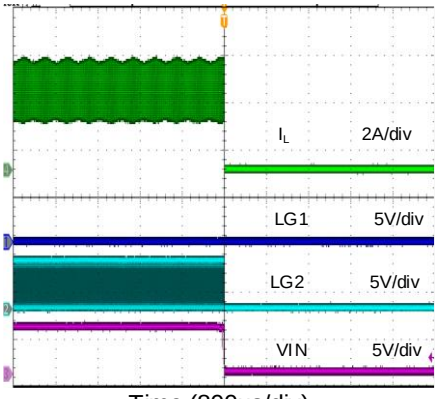
Time (800µs/div)

EN ON



Time (800µs/div)

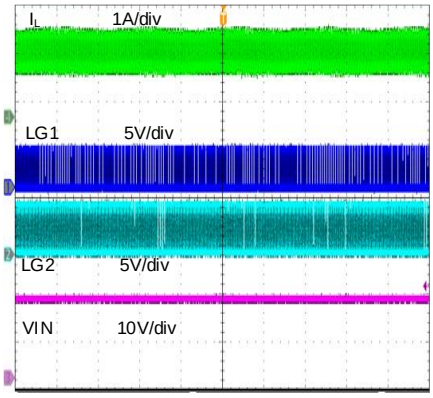
EN OFF



Time (800µs/div)

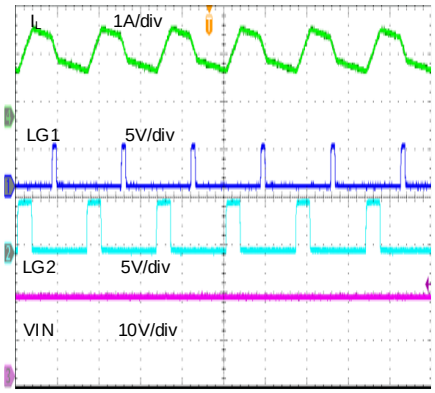
VIN=16V, VLED=20V,ILED=1A, Buck-Boost mode

Steady State



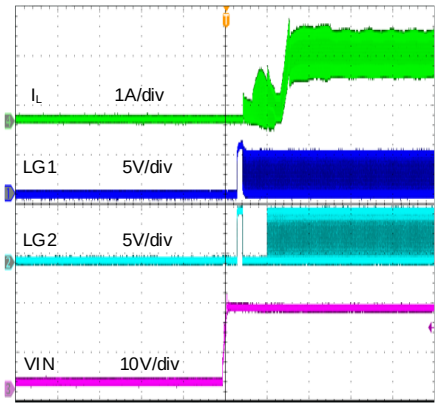
Time (200μs/div)

Steady State



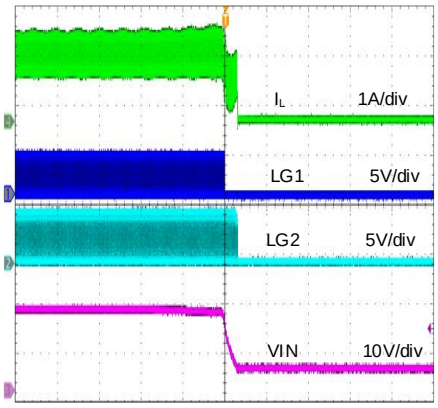
Time (2μs/div)

VIN ON



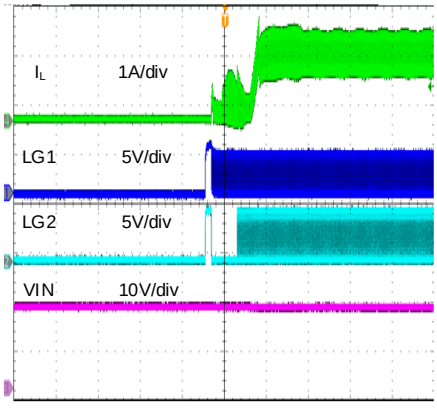
Time (800μs/div)

VIN OFF



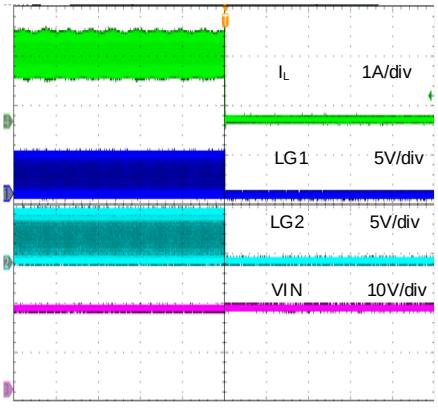
Time (800μs/div)

EN ON



Time (800μs/div)

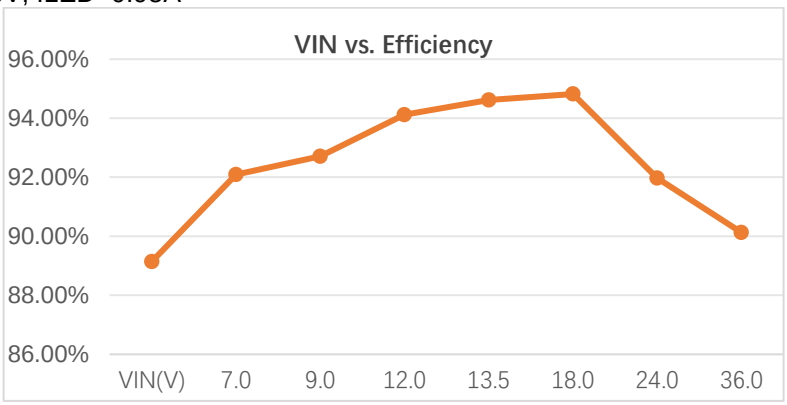
EN OFF



Time (800μs/div)

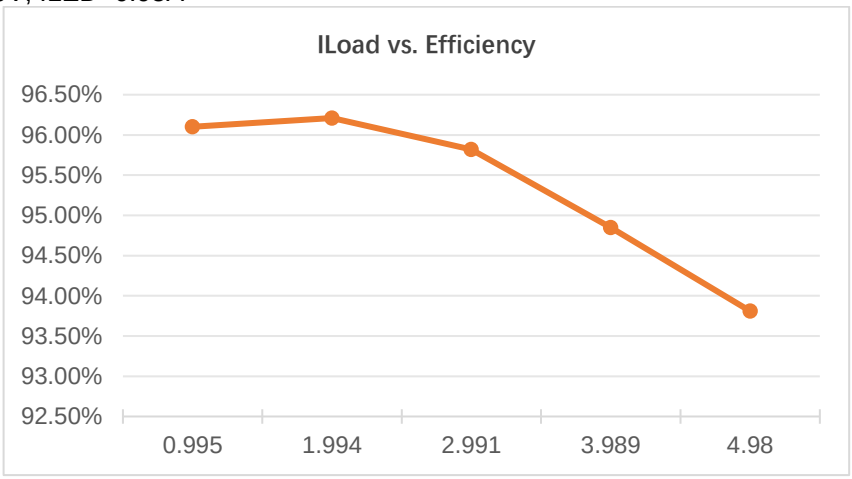
Efficiency Performance

Constant current VLED=20V, ILED=0.95A



V_{IN}(V)	I_{IN}(A)	V_{LED}(V)	I_{LED}(A)	Efficiency
7.0	3.013	19.81	0.949	89.14%
9.0	2.272	19.8	0.95	92.09%
12.0	1.66	19.57	0.946	92.71%
13.5	1.46	19.56	0.947	94.12%
18.0	1.09	19.56	0.947	94.62%
24.0	0.817	19.62	0.948	94.82%
36.0	0.562	19.65	0.948	91.97%

Constant voltage VLED=20V, ILED=0.95A



V_{IN}(V)	I_{IN}(A)	V_{LED}(V)	I_{LED}(A)	Efficiency
11.94	0.757	8.73	0.995	96.10%
12.07	1.499	8.73	1.994	96.21%
12.05	2.264	8.74	2.991	95.82%
11.84	3.108	8.75	3.989	94.85%
12.03	3.87	8.77	4.98	93.81%

Functional Description

The SA33761 Buck-Boost controller can automatically operate in Buck, Boost, and Buck-Boost modes based on the input and output voltages.

VIN Startup/Shutdown

Startup: When V_{VIN} exceeds V_{VIN_ON}, the SA33761 will charge VCC. When VCC exceeds V_{CC_ON}, both low side MOSFETs are turned ON for approximately 100μs to charge C_{BST}. After this charge time, the device will operate normally.

Shutdown: When V_{VIN} falls below V_{VIN_ON} - V_{VIN_HYS}, the device will enter shut down state and stop switching both the high side and low side MOSFETs.

The VCC is regulated to the V_{VCC} target value. When I_{VCC} = 10mA, the dropout voltage from VIN to VCC is V_{DR}.

When the device exits shut down mode, the internal current source I_{SS_CHARGE} will begin charging the capacitor C_{SS} connected between the SS pin and GND. Additionally, the rate at which the LED current increases can be adjusted by C_{SS}.

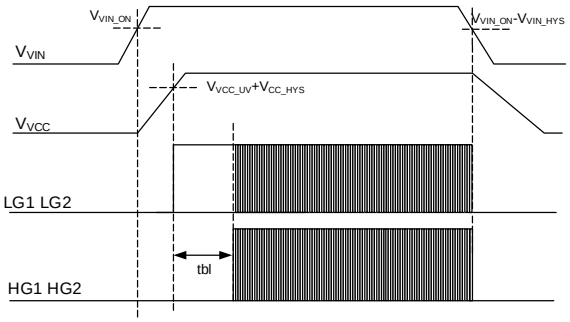
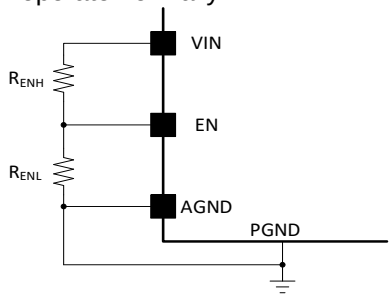


Figure 3. VIN Startup and Shutdown

EN ON/EN OFF

EN ON condition: When $V_{EN} > V_{EN\_ON}$, VCC starts ramping. LG1 and LG2 remain on for approximately 100μs to charge C_{BSTx} after VCC > V_{CC_ON}. Once $V_{CBST} > V_{(VBSTx-VSWx)\_UV}$, all MOSFETs will operate normally.



$$V_{EN} = VIN \times \frac{R_{ENL}}{R_{ENL} + R_{ENH}}$$

EN OFF condition: When $V_{EN} < V_{EN\_ON}$ - V_{EN_HYS}, VIN stops supplying VCC and all MOSFETs are turned off.

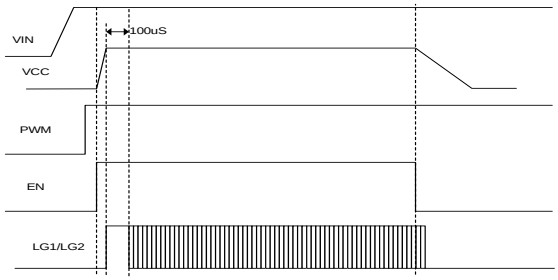


Figure 4. EN ON/OFF

PWM ON/PWM OFF

LG1 and LG2 are both turned ON before PWM to charge C_{BSTx}. When PWM is ON, the SA33761 operates normally. When PWM is OFF, the SA33761 will not detect open LED or short LED conditions, and C_{SS} will not be charged during soft-start.

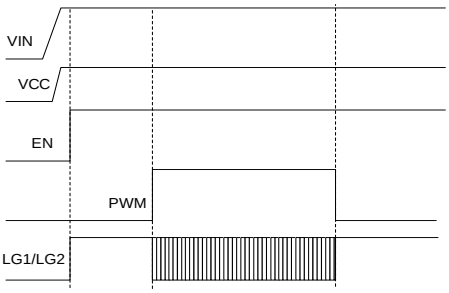


Figure 5. PWM ON/OFF

Switching Frequency

The switching frequency f_{SW} is set using the FREQ pin. The resistor value can be determined using the curve in Figure 6 or the following equation:

$$R_{FREQ} = e^{\frac{\ln(9735) - \ln(f_{SW})}{0.95}}$$

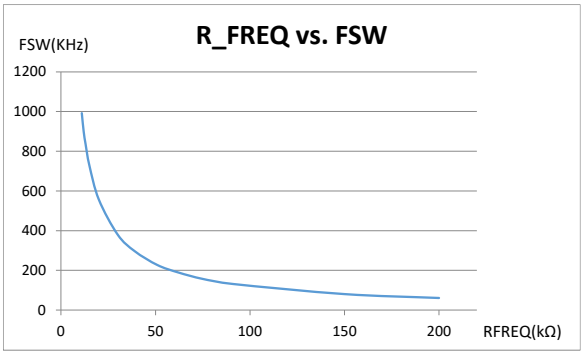


Figure 6. R_{FREQ} vs. f_{SW}

When the detected R_{FREQ} is abnormal, indicating that the FREQ pin is either open or shorted, the default f_{SW} of 300KHz is used.

Spread Spectrum

The SA33761 features Spread Spectrum operation to improve EMC performance. It varies the switching frequency by ±8% of f_{SW} over a triangle sequence of 128 switching cycles, as shown in Figure 7.

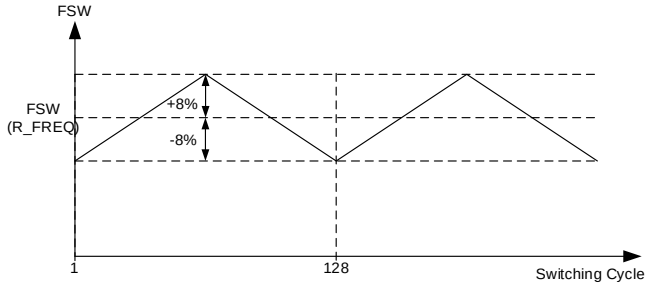


Figure 7. Spread Function

Loop Control

The SA33761 operates in constant frequency current mode, sensing the average LED current from FBH and FBL, and regulating I_{LED} through the COMP voltage. The COMP voltage controls the on-time (t_{ON}) of LG1 and LG2.

The suggested typical value for C_{COMP} is 22nF, Rcomp is 510Ω for constant current application.

$$Ccomp = \frac{RS \times gm}{f\_GBW \times 2\pi \times K \times RSW}$$

$$Rcomp = \frac{RLED \times COUT}{Ccomp}$$

(K is current sense coefficient, the value is 10, GBW is suggested about 10KHz; COUT=CO1+CO2, RLED is the equivalent LED internal resistor)

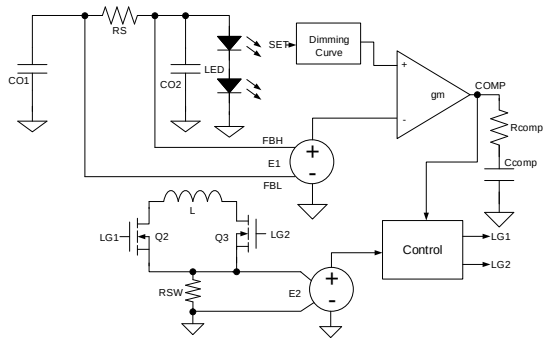


Figure 8. Loop Control

Operating Modes

The SA33761 has three operating modes: Buck, Boost, and Buck-Boost. The device automatically switches to the appropriate mode by detecting the input and output voltages:

- When VIN is much less than VOUT, the device operates in Boost mode, as shown in Figure 9.
- When VIN is much greater than VOUT, the device operates in Buck mode, as shown in Figure 10.
- When VIN is close to VOUT, the device operates in Buck-Boost mode, as shown in Figure 11.

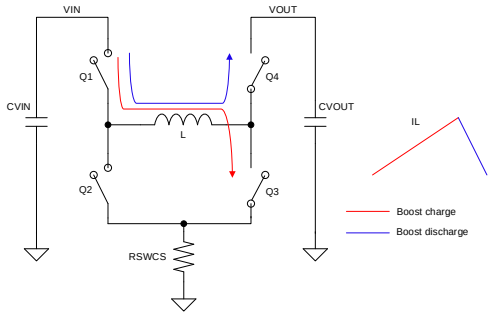


Figure 9. VIN << VOUT: Boost Mode

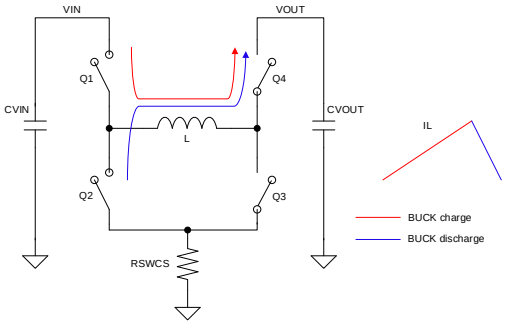


Figure 10. VIN >> VOUT: Buck Mode

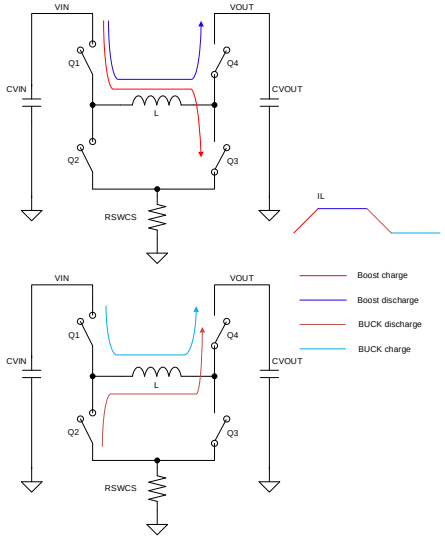


Figure 11. VIN = VOUT: Buck-Boost Mode

Analog Dimming

The SA33761 features an analog dimming function that allows the internal I_{LED} reference to be adjusted by changing V_{SET}, as shown in Figure 12 and Figure 13.

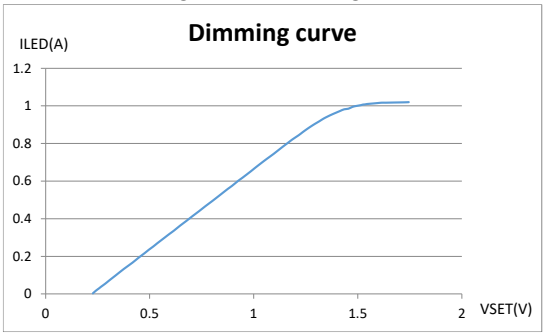


Figure 12. Dimming Curve

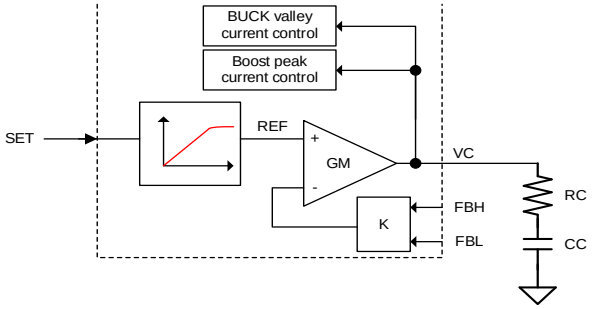


Figure 13. Analog Dimming

Direct Dimming

The SA33761 also supports direct PWM dimming. Connect the PWM dimming signal to the PWMI pin to control dimming as follows:

- When PWM = 1, the VC regular output LED current and all power MOSFETs operate normally
- When PWM = 0, COMP is held, both LG1 and LG2 are ON to charge C_{BSTx} while HG1 and HG2 are OFF

The supported PWM frequency range is 100Hz to 1kHz.

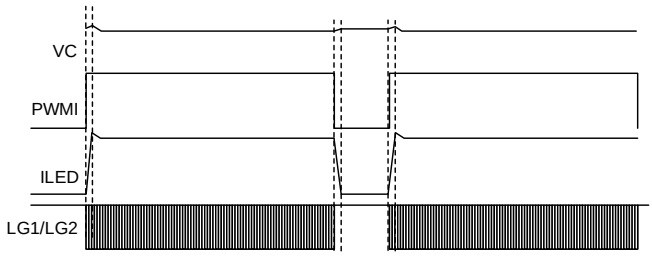


Figure 14. Direct Dimming

Fault Protection

Short LED Protection

The SA33761 detects the LED voltage from the FB pin after VSS exceeds V_{SS_DONE}. When VFB is less than V_{FB_SLP} for 8 cycles, the device will stop switching and pull SS low with $I_{SS\_DISCHARGE}$ until VSS falls below V_{SS_RESET}. The fault signal EF will be pulled low when short LED protection (SLP) is activated, as shown in Figure 15.

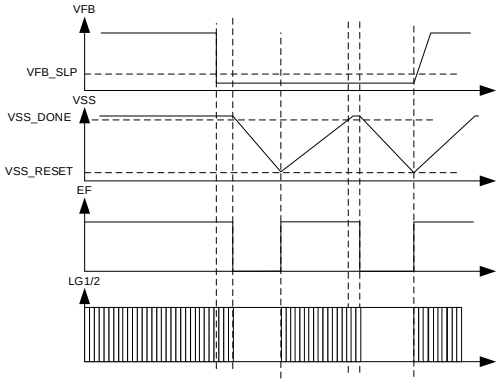


Figure 15. Short LED Protection

Output Overvoltage Protection

To prevent output overvoltage, when VFB exceeds V_{FB_OVP}, the SA33761 will pull HG1 and HG2 low and turn LG1 and LG2 ON to charge the C_{BST} until VFB < V_{FB_OVP} - $V_{FB\_OVP\_HYS}$. The EF signal is pulled low during overvoltage protection (OVP), as shown in Figure 16.

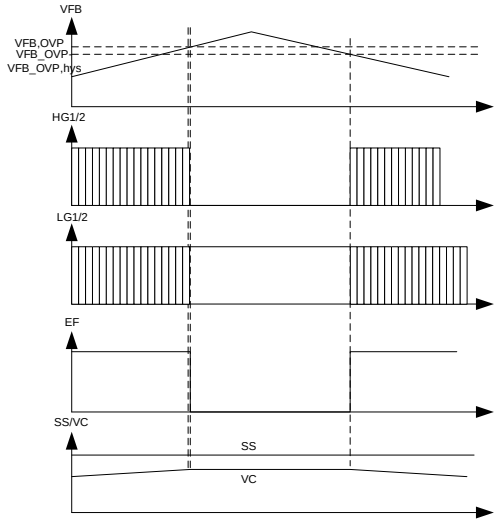


Figure 16. Output Overvoltage Protection

Open LED Protection

The SA33761 detects an LED open circuit by monitoring VFB and the difference between V_{FBH} and V_{FBL}. When VFB exceeds V_{FB_OLP} and $V_{FBH-VFBL} < V_{FBHL\_LOW}$, the device will disable HG1 and HG2, discharge C_{SS}, and pull EF low, as shown in Figure 17.

Thermal Shutdown Protection

To prevent the device junction temperature T_J from becoming excessively high and damage the device, the SA33761 enters shutdown when T_J exceeds the temperature threshold T_{SD}. When T_J falls below $T_{SD} - T_{SD\_HYS}$, the device will restart.

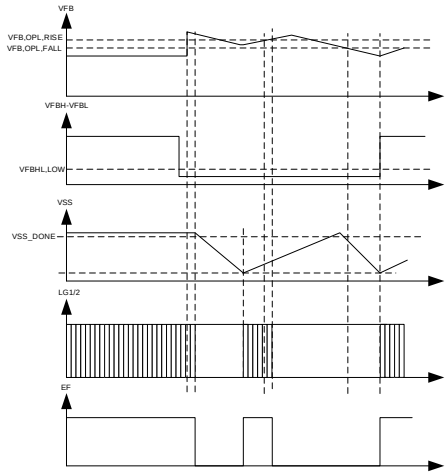
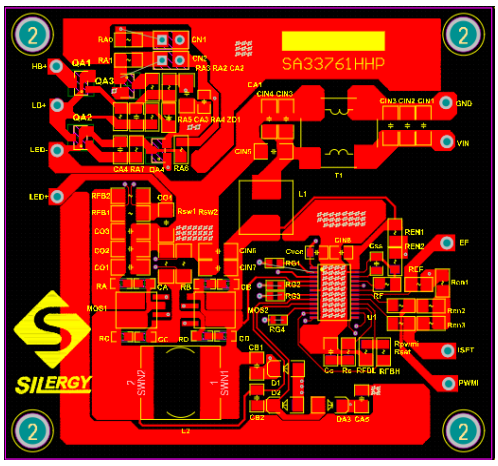
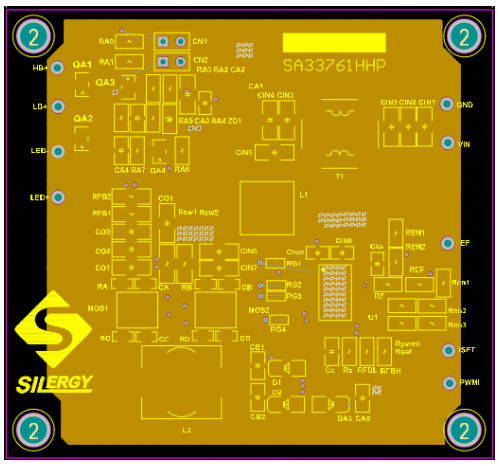


Figure 17. Open LED Protection

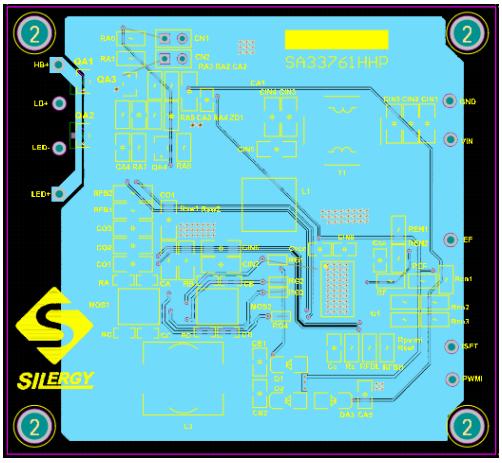
Layout Design



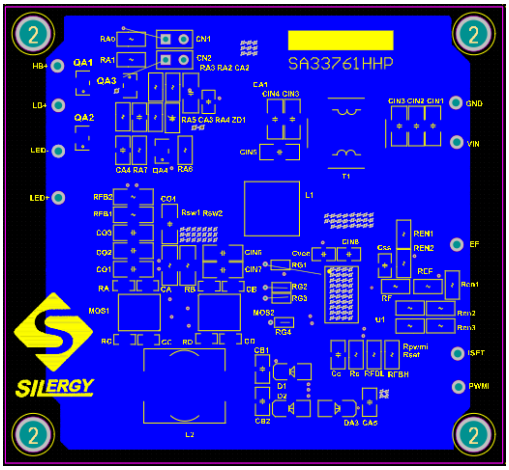
Top Layer



M2 Layer



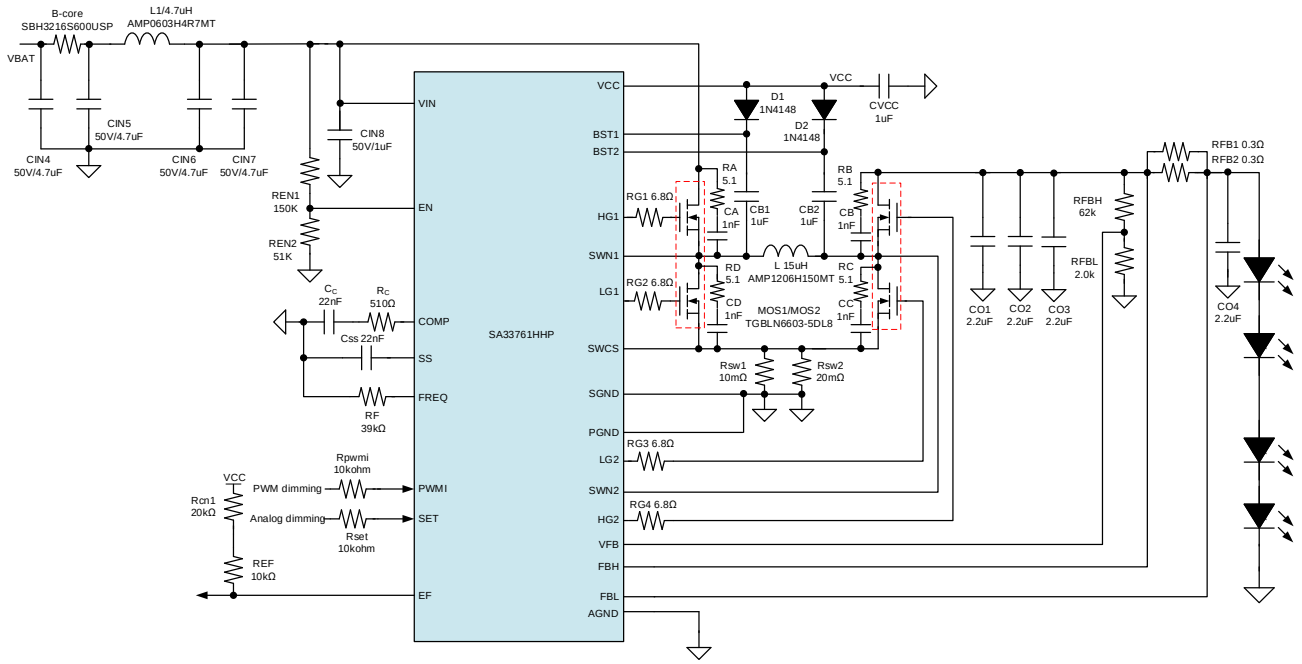
M3 Layer



Bottom Layer

Design Example 1 (Buck-Boost LED Application)

V_{IN} = 13.5V, V_{LED} = 36V, I_{LED} = 1.0A



BOM List

Reference Designator	Description	Part Number	Manufacturer
C_{IN4} , C_{IN5}, C_{IN6}, C_{IN7}	4.7μF/50V	MLCC	TDK
C_{IN8}	1μF/50V	MLCC	TDK
C_{VCC}, C_{B1}, C_{B2}	1μF/16V	MLCC	TDK
C_C, C_{SS}	22nF/16V	MLCC	TDK
C_{O4}	100nF/50V	MLCC	TDK
L1	4.7μH	AMP0603H4R7MT	
D1, D2	1N4148	1N4148	
MOS1, MOS2	60V/24A dual NMOS	TGBLN6603-5DL8	Galaxy
L	15μH	AMP1206H150MT	
IC	SA33761	SA33761HHP	Silergy
R_{CN1}, R_{EF}, R_{PWMI}, R_{SET}	10kΩ/0805		
R_{CN2}, R_{CN3}	0Ω/0805		
R_{G1}, R_{G2}, R_{G3}, R_{G4}	5.1Ω/0805		
R_F	39kΩ/0805		
R_{EN1}	150kΩ/0805		
R_{EN2}	51kΩ/0805		
R_{SW1}, R_{SW2}	10mΩ/1210		
R_{FB1}, R_{FB2}	0.3Ω/1206/1%		
R_{FBH}	62kΩ/0805		
R_{FBL}	2.0kΩ/0805		
R5, R_B, R_C, R_D	5.1Ω/0805		
C_A, C_B, C_C, C_D	1nF/50V	MLCC	
C_{O1}, C_{O2}, C_{O3}	2.2μF/50V	MLCC	TDK
B-core	SBH3216S600USP		

Table 1. Example 1 Efficiency

V_{IN}(V)	I_{IN}(A)	V_{LED}(V)	I_{LED}(A)	Efficiency
7	3.013	19.81	0.949	89.14%
8.99	2.272	19.8	0.95	92.09%
12.03	1.66	19.57	0.946	92.71%
13.48	1.46	19.56	0.947	94.12%
17.96	1.09	19.56	0.947	94.62%
24.01	0.817	19.62	0.948	94.82%
36.04	0.562	19.65	0.948	91.97%
50	0.414	19.68	0.948	90.13%
7	6.3	37.7	0.94	80.36%
9.07	4.4	37.69	0.941	88.87%
12	3.24	37.57	0.942	91.03%
13.5	2.863	37.63	0.944	91.91%
17.98	2.13	37.54	0.946	92.73%
24.01	1.576	37.57	0.947	94.02%
36.01	1.041	37.54	0.948	94.94%
50.1	0.756	37.59	0.948	94.09%

Design Example 2 (Buck LED Application)

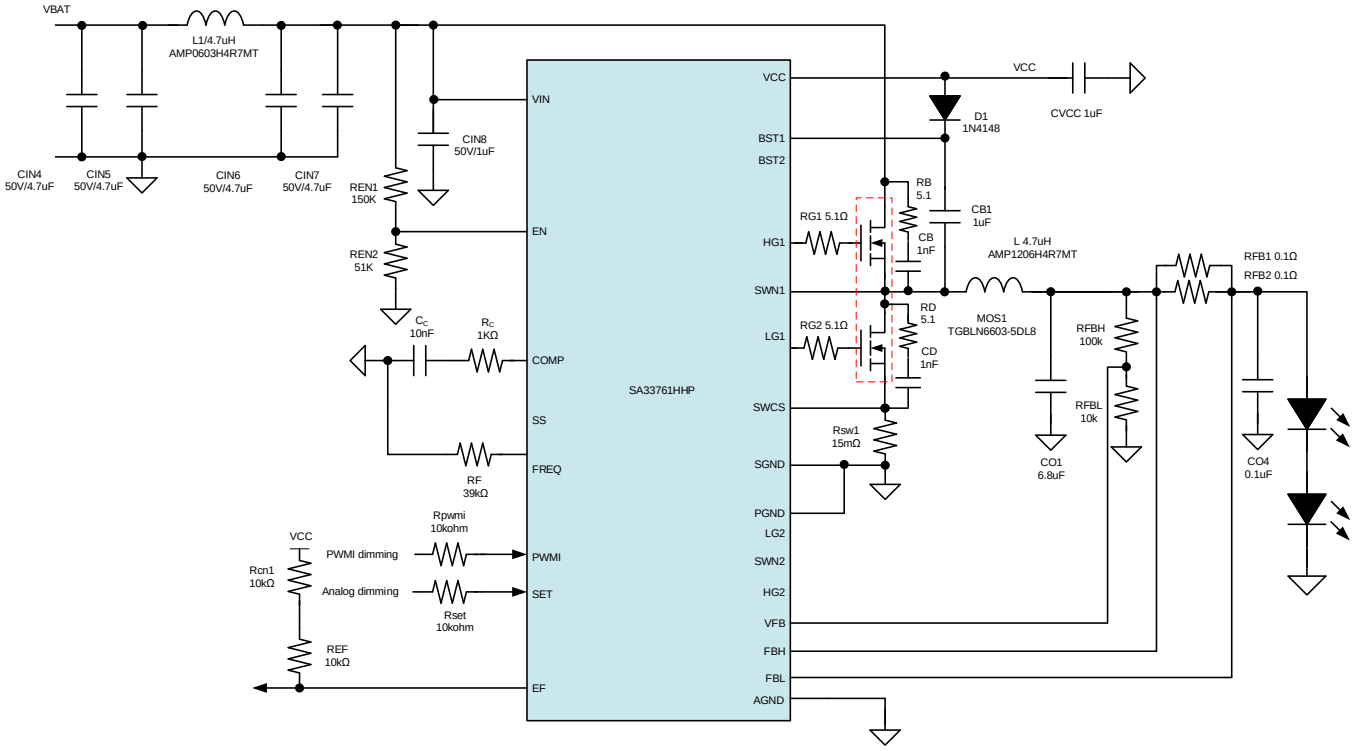


Table 2. Example 2 Efficiency

V_{IN}(V)	I_{IN}(A)	V_{LED}(V)	I_{LED}(A)	Efficiency
6.04	1.862	3.174	3.051	86.11%
8.96	1.264	3.174	3.051	85.51%
12.01	0.952	3.174	3.051	84.70%
18.01	0.646	3.174	3.051	83.23%
24.08	0.491	3.174	3.051	81.91%
40.02	0.307	3.174	3.049	78.77%
6.64	2.228	5.93	2.417	96.88%
9	2.195	5.93	3.051	91.58%
12.01	1.656	5.93	3.051	90.97%
18.07	1.114	5.93	3.051	89.88%
24.07	0.846	5.93	3.051	88.85%
40.05	0.521	5.93	3.051	86.71%

Design Example 3 (Buck-Boost CV Application)

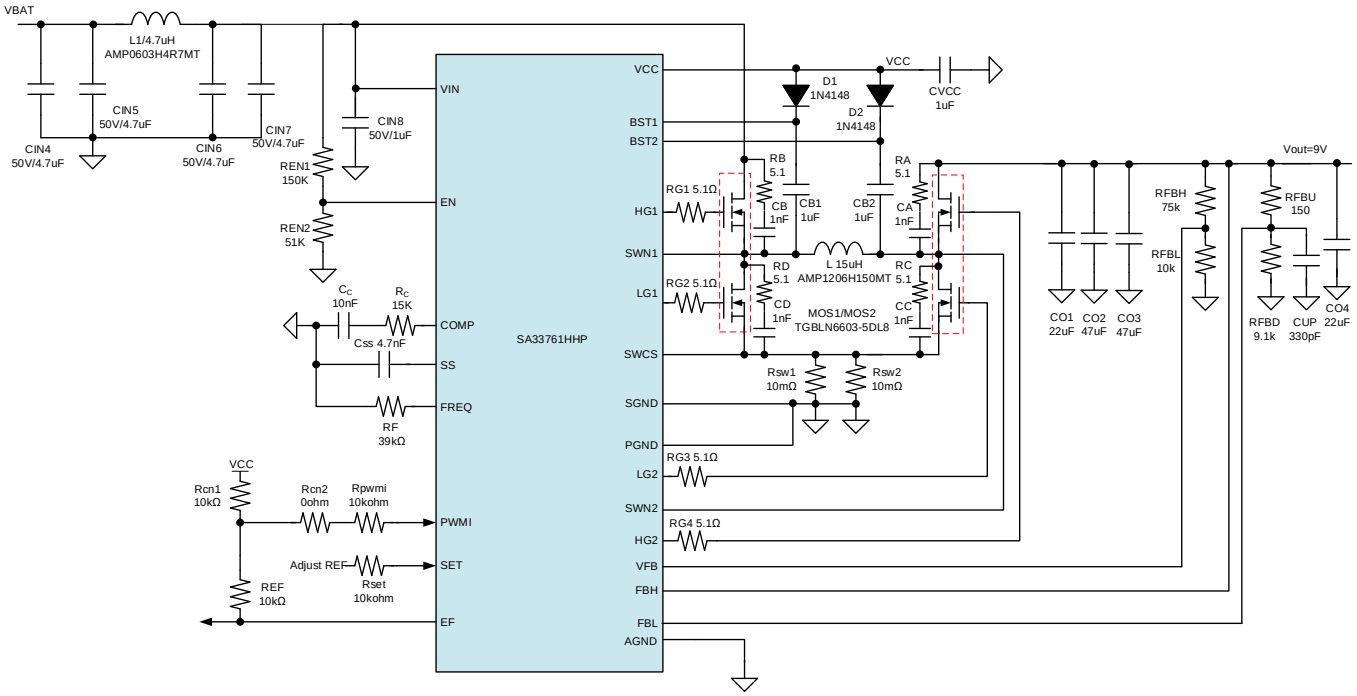
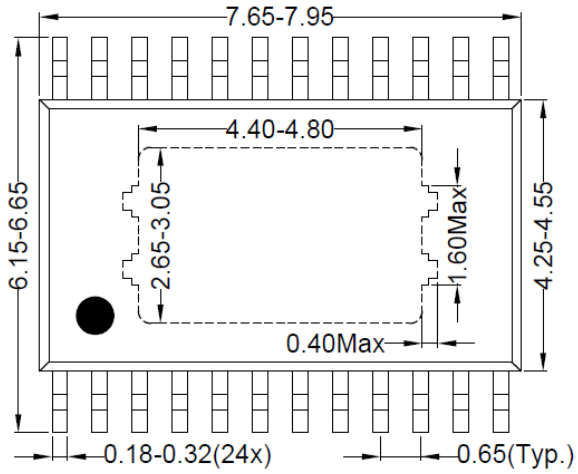


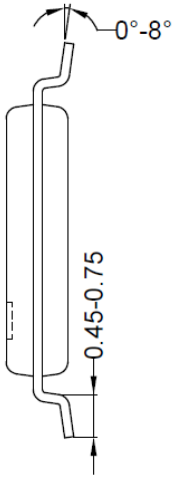
Table 3. Example 3 Efficiency

V_{IN}(V)	I_{IN}(A)	V_{LED}(V)	I_{LED}(A)	Efficiency
12	0.02013	8.72	0	NA
11.94	0.757	8.73	0.995	96.10%
12.07	1.499	8.73	1.994	96.21%
12.05	2.264	8.74	2.991	95.82%
11.84	3.108	8.75	3.989	94.85%
12.03	3.87	8.77	4.98	93.81%

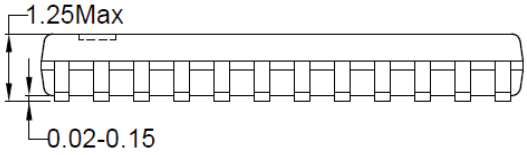
TSSOP24E Package Outline Drawing



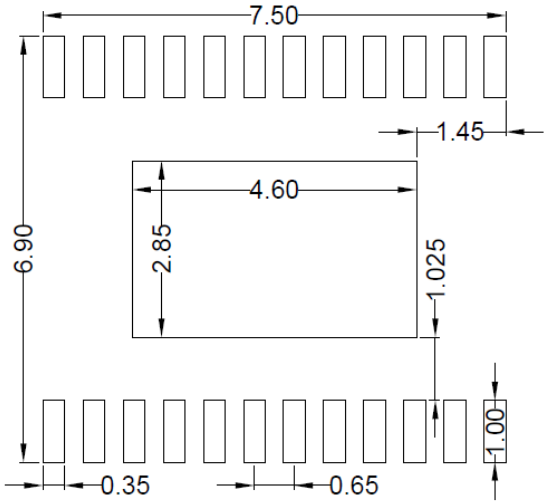
Top View



Side View



Front View

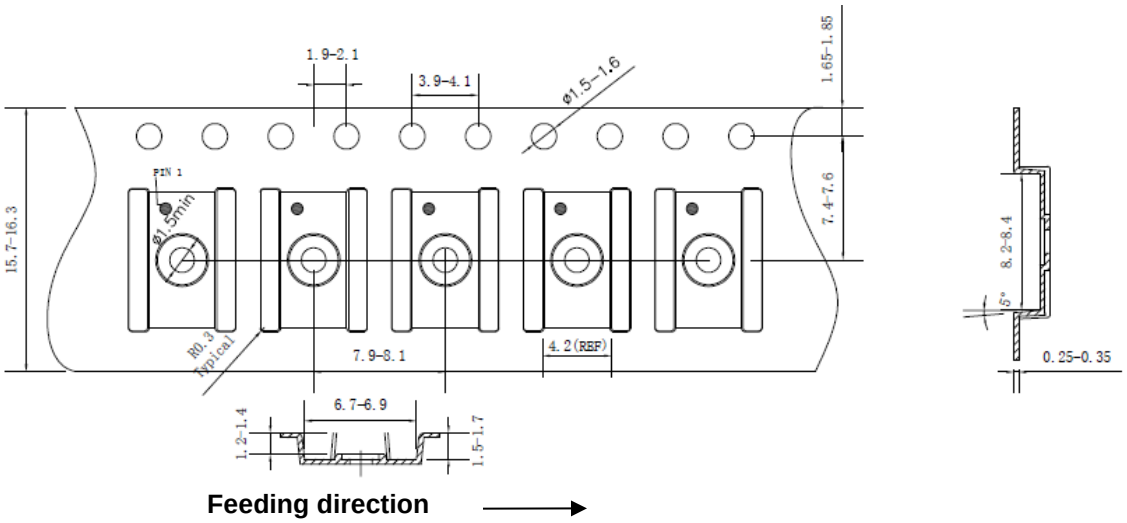


Recommended PCB Layout (Reference Only)

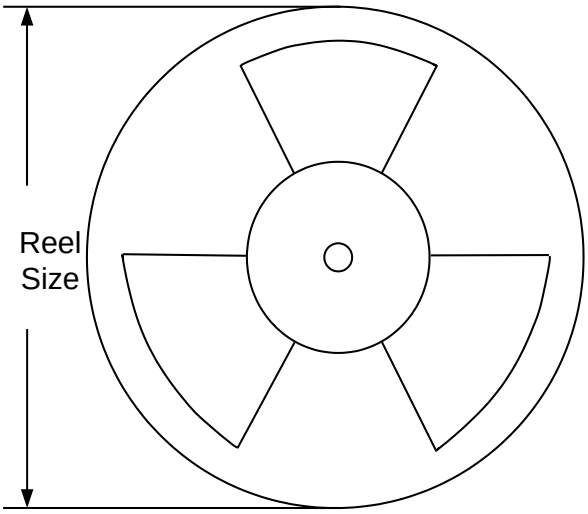
Note: All dimensions are in millimeters and exclude mold flash and metal burr.

Tape and Reel Structure

TSSOP24E Tape Orientation



Carrier Tape and Reel Specification



Package Types	Tape Width (mm)	Pocket Pitch (mm)	Reel Size (Inch)	Trailer Length (mm)	Leader Length (mm)	Qty per Reel
TSSOP24E	16	12	13"	400	400	3000

Others: NA

Revision History

The revision history provided is for informational purpose only and is believed to be accurate, however, not warranted. Please make sure that you have the latest revision.

Date	Revision	Change
January 22，2025	Revision 1.0	Initial Release

IMPORTANT NOTICE

1. **Right to make changes.** Silergy and its subsidiaries (hereafter Silergy) reserve the right to change any information published in this document, including but not limited to circuitry, specification and/or product design, manufacturing or descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products are sold subject to Silergy's standard terms and conditions of sale.

2. Applications. Application examples that are described herein for any of these products are for illustrative purposes only. Silergy makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification. Buyers are responsible for the design and operation of their applications and products using Silergy products. Silergy or its subsidiaries assume no liability for any application assistance or designs of customer products. It is customer's sole responsibility to determine whether the Silergy product is suitable and fit for the customer's applications and products planned. To minimize the risks associated with customer's products and applications, customer should provide adequate design and operating safeguards. Customer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Silergy assumes no liability related to any default, damage, costs or problem in the customer's applications or products, or the application or use by customer's third-party buyers. Customer will fully indemnify Silergy, its subsidiaries, and their representatives against any damages arising out of the use of any Silergy components in safety-critical applications. It is also buyers' sole responsibility to warrant and guarantee that any intellectual property rights of a third party are not infringed upon when integrating Silergy products into any application. Silergy assumes no responsibility for any said applications or for any use of any circuitry other than circuitry entirely embodied in a Silergy product.

3. **Limited warranty and liability.** Information furnished by Silergy in this document is believed to be accurate and reliable. However, Silergy makes no representation or warranty, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. In no event shall Silergy be liable for any indirect, incidental, punitive, special or consequential damages, including but not limited to lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges, whether or not such damages are based on tort or negligence, warranty, breach of contract or any other legal theory. Notwithstanding any damages that customer might incur for any reason whatsoever, Silergy' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the Standard Terms and Conditions of Sale of Silergy.

4. **Suitability for use.** Customer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of Silergy components in its applications, notwithstanding any applications-related information or support that may be provided by Silergy. Silergy products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of a Silergy product can reasonably be expected to result in personal injury, death or severe property or environmental damage. Silergy assumes no liability for inclusion and/or use of Silergy products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

5. **Terms and conditions of commercial sale**. Silergy products are sold subject to the standard terms and conditions of commercial sale, as published at http://www.silergy.com/stdterms, unless otherwise agreed in a valid written individual agreement specifically agreed to in writing by an authorized officer of Silergy. In case an individual agreement is concluded only the terms and conditions of the respective agreement shall apply. Silergy hereby expressly objects to and denies the application of any customer's general terms and conditions with regard to the purchase of Silergy products by the customer.

6. **No offer to sell or license**. Nothing in this document may be interpreted or construed as an offer to sell products that is open for acceptance or the grant, conveyance or implication of any license under any copyrights, patents or other industrial or intellectual property rights. Silergy makes no representation or warranty that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right. Information published by Silergy regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from Silergy under the patents or other intellectual property of Silergy.

For more information, please visit: www.silergy.com