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Lead-free Green

AL1665

HIGH PERFORMANCE DIMMABLE LED CONTROLLER

Description

The AL1665 is a high-performance single-stage flyback and buck-boost controller, targeting dimmable LED lighting application. It is a primary side regulation (PSR) controller that can provide accurate constant current (CC) regulation without optocoupler and secondary control circuitry. It can be operated at BCM mode, which results in low EMI and high efficiency, and keeps high power factor (PF) and low total harmonic distortion (THD) under universal input voltage.

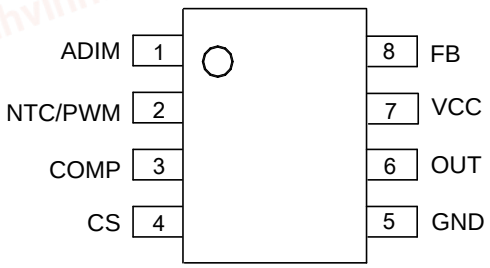
The AL1665 can support analog/PWM dimming modes. When a 50mV to 2.5V DC signal is applied on ADIM pin, the device is operated in analog dimming mode. The analog dimming range is 5% to 100%. When a PWM signal is applied to NTC/PWM pin, the device is operated at PWM dimming mode. The PWM dimming range is 0.5% to 100% (1k PWM dimming frequency).

The AL1665 has full protection features. It integrates multiple protections including undervoltage lockout (UVLO), output overvoltage (OVP), output short circuit (OSP), overcurrent protection (OCP), winding short circuit, secondary diode short, internal thermal foldback (TFP), and overtemperature protection (OTP).

The AL1665 is available in SO-8 (Standard) package.

Pin Assignments

(Top View)



SO-8 (Standard)

Features

- Primary Side Regulation without Optocoupler
- Valley Switching for Low Switching Loss
- Tight CS Reference Voltage 0.4V±1.5%
- High PF>0.9 and Low THD<20%
- Support Analog and PWM Dimming
  - Analog Dimming Range: 5% to 100%
  - PWM Dimming Range: 0.5% to 100% (1k PWM Frequency)
- Internal Protections
  - Undervoltage Lockout (UVLO)
  - Output Overvoltage Protection (OVP)
  - Output Short Protection (OSP)
  - Overcurrent Protection (OCP)
  - Winding Short-Circuit Protection
  - Secondary Diode Short Protection
  - Shorted Current Sense Protection
  - User Programmable NTC Based Thermal Foldback
  - Internal Thermal Foldback Protection (TFP)
  - Overtemperature Protection (OTP)
- Tight LED Current Variation Range
  - LED Current Line Regulation: ±2%
  - LED Current Load Regulation: ±2% Full Load to Half Load
- Tight Output Open Voltage Variation Range
- Package: SO-8 (Standard)
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3**)
- **For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please contact us or your local Diodes representative. https://www.diodes.com/quality/product-definitions/**

Applications

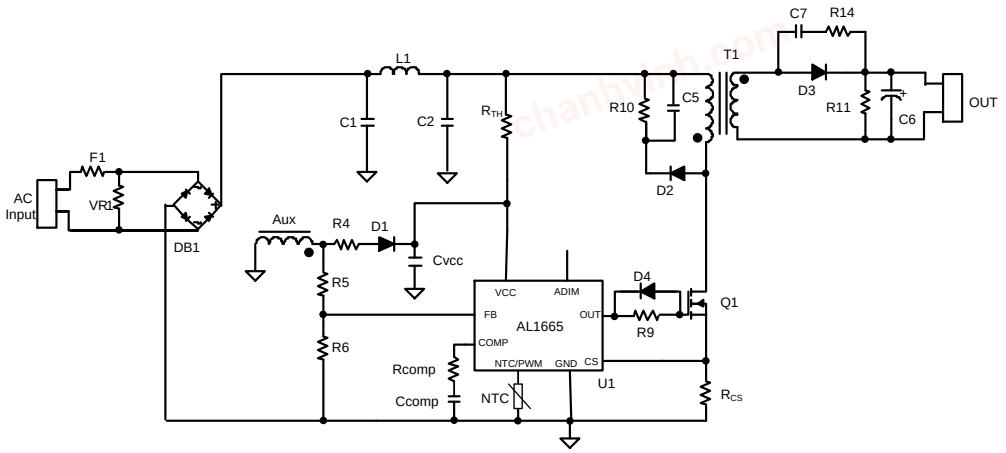
- General LED Lighting Driver with Dimming Function
- General Purpose Constant Current Source
- LED Backlighting Driver
- Smart LED Lighting

Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. See https://www.diodes.com/quality/lead-free/ for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

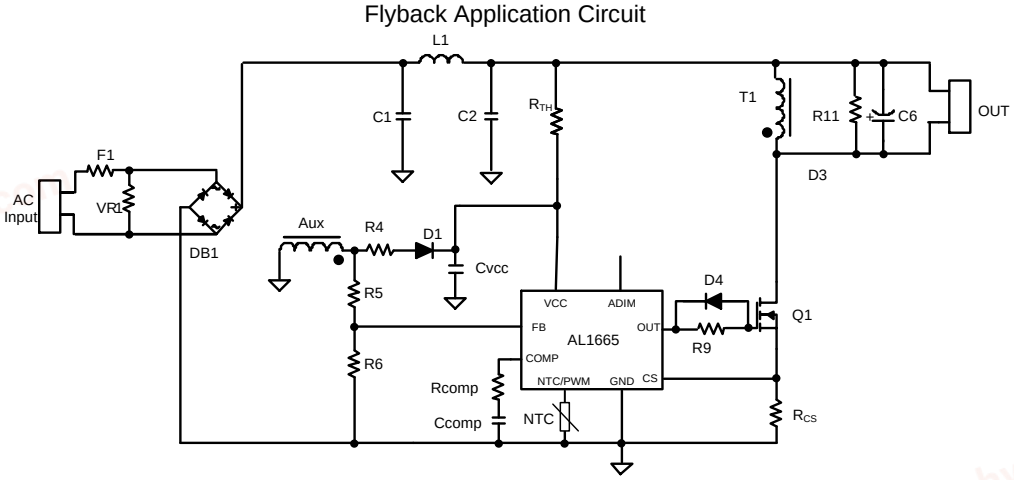
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Typical Applications Circuit



Flyback Application Circuit



Buck-Boost Application Circuit

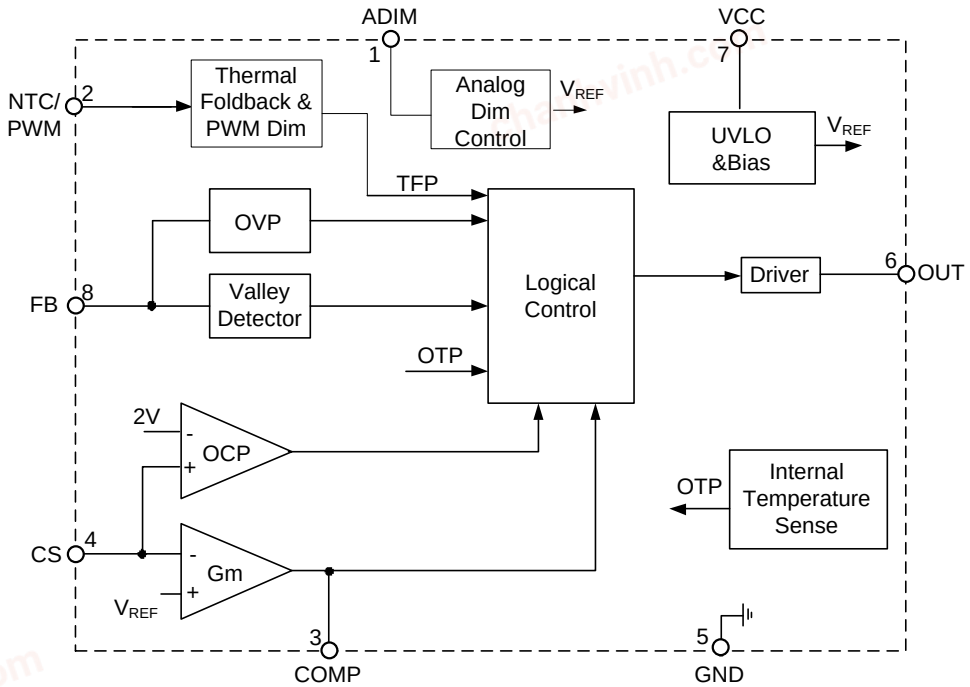
Pin Descriptions

Pin Number	Pin Name	Function
1	ADIM	Analog Dimming Input Pin
2	NTC/PWM	NTC Input Pin for Thermal Foldback/PWM Dimming Input Pin
3	COMP	Loop Compensation Pin
4	CS	Current Sense Pin, Connect This Pin to the Source of the Primary Switch
5	GND	Ground
6	OUT	Gate Driver Output
7	VCC	Supply Voltage of Gate Driver and Control Circuits of the IC
8	FB	The Feedback Voltage Sensing from the Auxiliary Winding

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Functional Block Diagram



Absolute Maximum Ratings (@T_A = +25°C, unless otherwise specified.) (Note 4)

Symbol	Parameter	Rating	Unit
V_{CC}	Power Supply Voltage	-0.3 to 30	V
V_{CS}	Voltage at CS to GND	-0.3 to 7	V
V_{FB}	FB Input Voltage	-0.3 to 7	V
V_{COMP}	Voltage at Loop Compensation Pin	-0.3 to 7	V
V_{OUT}	Driver Output Voltage	-0.3 to 20	V
$V_{NTC/PWM}$	Voltage at NTC/PWM to GND	-0.3 to 7	V
V_{ADIM}	Voltage at ADIM to GND	-0.3 to 7	V
T_J	Operating Junction Temperature	-40 to +150	°C
T_{STG}	Storage Temperature	-65 to +150	°C
T_{LEAD}	Lead Temperature (Soldering, 10s)	+300	°C
P_D	Power Dissipation at T_A = +50°C	0.65	W
Θ_{JA}	Thermal Resistance (Junction to Ambient)	136	°C/W
Θ_{JC}	Thermal Resistance (Junction to Case)	30	°C/W
—	ESD (Human Body Model)	2000	V
	ESD (Charged-Device Model)	1000	V

Note: 4. Stresses greater than those listed under *Absolute Maximum Ratings* can cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to *Absolute Maximum Ratings* for extended periods can affect device reliability. All voltages unless otherwise stated are measured with respect to GND.

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Recommended Operating Conditions (@T_A = +25°C, unless otherwise specified.)

Symbol	Parameter	Min	Max	Unit
T_A	Ambient Temperature (Note 5)	-40	+105	°C
V_{CC}	Operating VCC Voltage (Note 6)	8.5	V_{CC_OVP} (Min)	V

Notes: 5. The device may operate normally at +125°C ambient temperature under the condition not triggers temperature protection.
6. I_{CC} should be limited less than 5mA.

Electrical Characteristics (@T_A = +25°C, unless otherwise specified.)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
UVLO Section						
V_{CC_TH}	Startup Threshold Voltage	—	15.8	18.5	19.5	V
V_{OPR_MIN}	Minimal Operating Voltage	After Turn On	5.8	7.8	9	V
V_{CC_OVP}	V_{CC} OVP Voltage	—	21.8	25	29.5	V
Standby Current Section						
I_{ST}	Startup Current	V_{CC} = V_{CC_TH} -0.5V, Before Start Up	—	120	300	μA
I_{CC}	Operating Current @ 4KHz	V_{CC}=20V, VDIM=3V, V_{FB}=V_{CS}=V_{COMP}=1V, C_{OUT}=1nF	—	1	2	mA
I_{CC_OVP}	Shunt Current in OVP Mode	V_{CC} > V_{CC_OVP}	3.1	—	—	mA
Drive Output Section						
t_R	Output Voltage Rise Time (Note 7)	C_L = 1nF	—	100	—	ns
t_F	Output Voltage Fall Time (Note 7)	C_L = 1nF	—	100	—	ns
V_{OUT_CLAMP}	Output Clamp Voltage	V_{CC} = 20V	9.8	12	15.5	V
t_{ON_MIN}	Minimum On Time (Note 7)	—	—	1000	2010	ns
t_{ON_MAX}	Maximum On Time	—	—	15	—	μs
t_{OFF_MAX}	Maximum Off Time	—	—	290	405	μs
f_{MAX}	Maximum Frequency	—	—	150	—	kHz
Internal CS Reference						
V_{REF}	Internal Reference Voltage	—	0.394	0.4	0.406	V
V_{CS_CLAMP}	Primary Current Clamp Voltage	—	—	2	—	V
V_{CS_OCP}	Primary Overcurrent Voltage	—	—	3	—	V
Error Amplifier						
Gm	Trans-Conductance	—	—	27	—	μA/V
I_{SOURCE}	Amplifier Source Current	—	—	7.2	—	μA
Feedback Input Section						
V_{FB_CV}	FB CV Threshold	—	2.86	3.0	3.26	V
ADIM Section						
—	Analog Dimming Range on ADIM	—	0.05	—	2.5	V
—	Analog Dimming High Level	—	2.45	2.5	2.55	V
—	Analog Dimming Range Ratio	—	5%	—	100%	—

Note: 7. These parameters, although guaranteed by design, are not 100% tested in production.

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Electrical Characteristics (@T_A = +25°C, unless otherwise specified.) (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
NTC/PWM Section						
$V_{NTC/PWM(PULL-UP)}$	Pullup Voltage when NTC/PWM Open	NTC/PWM Pin Open	—	2.5	—	V
$I_{OTP(REF)}$	Reference Current for Direct Connection of NTC/PWM (Note 9)	—	70.5	85	91	µA
$V_{OTP(OFF)}$	Fault Detection Level for OTP (Note 8)	$V_{NTC/PWM}$ Falling	—	0.50	—	V
$V_{OTP(ON)}$	NTC/PWM Pin Level for Operation Recovery after an OTP Detection	$V_{NTC/PWM}$ Rising	—	0.70	—	V
$t_{OTP(START)}$	OTP Blanking Time when Circuit Starts Operating (Note 9)	—	250	—	370	µs
$V_{TF(START)}$	NTC/PWM Pin Voltage at which Thermal Foldback Starts (V_{REF} is Decreased)	—	0.94	1.00	1.06	V
$V_{TF(STOP)}$	NTC/PWM Pin Voltage at which Thermal Foldback Stops (V_{REF} is Clamped to V_{REF50})	—	0.64	0.69	0.74	V
$V_{REF(50)}$	V_{REF} @ $V_{NTC/PWM}$ = 600mV (Percent of V_{REF})	—	40	50	60	%
Thermal Foldback Section						
T_{REG}	Overheating Temperature Regulation (Note 7)	—	—	+150	—	°C
Overtemperature Protection Section						
—	Shutdown Temperature (Notes 7, 8)	—	—	+180	—	°C

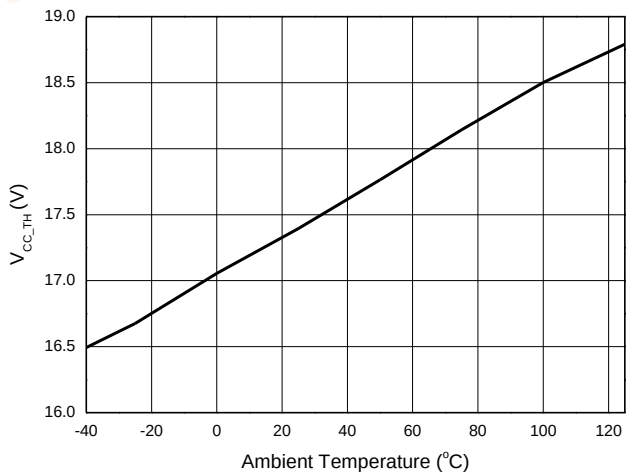
Notes:
7. These parameters, although guaranteed by design, are not 100% tested in production.
8. The device will latch when OTP occurs and will not be operated constantly at this temperature.
9. At startup, when V_{CC} reaches $V_{CC(ON)}$, the controller blanks OTP for more than 250µs to avoid detecting an OTP fault by allowing the NTC/PWM pin voltage to reach its nominal value if a filtering capacitor is connected to the NTC/PWM pin.

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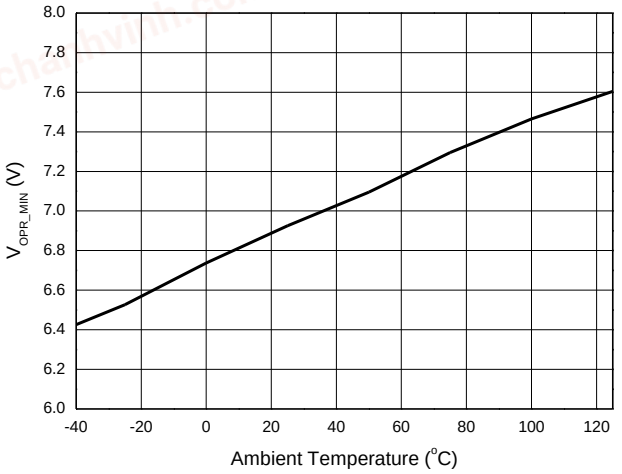
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Performance Characteristics (Note 10)

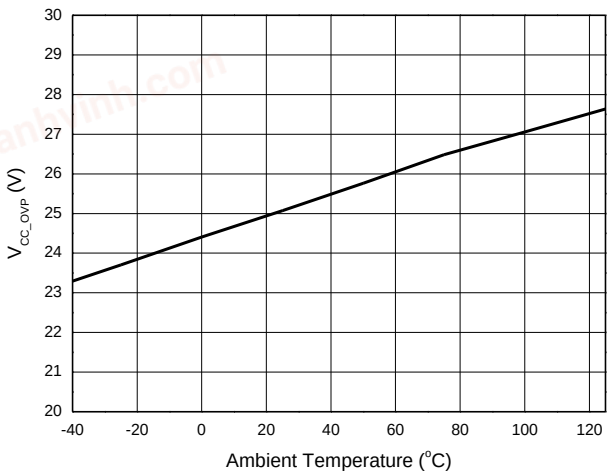
Startup Threshold Voltage vs. Ambient Temperature



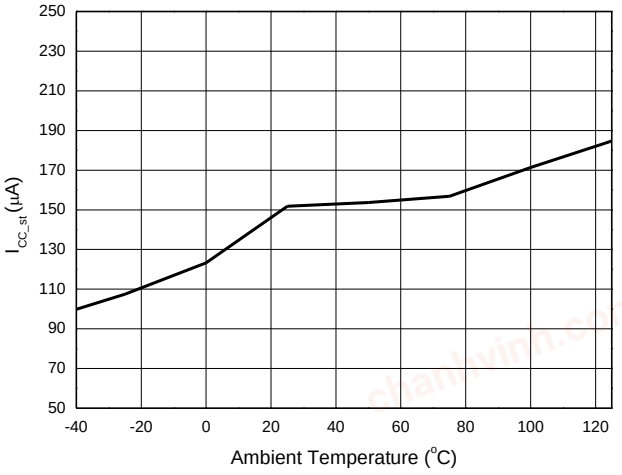
Minimum Operating Voltage vs. Ambient Temperature



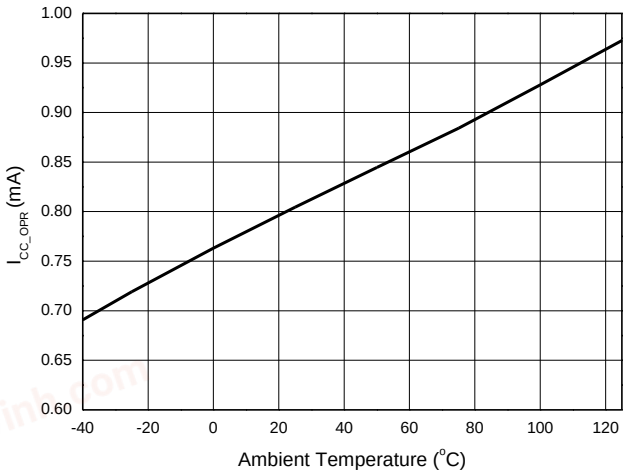
V_{CC} OVP Voltage vs. Ambient Temperature



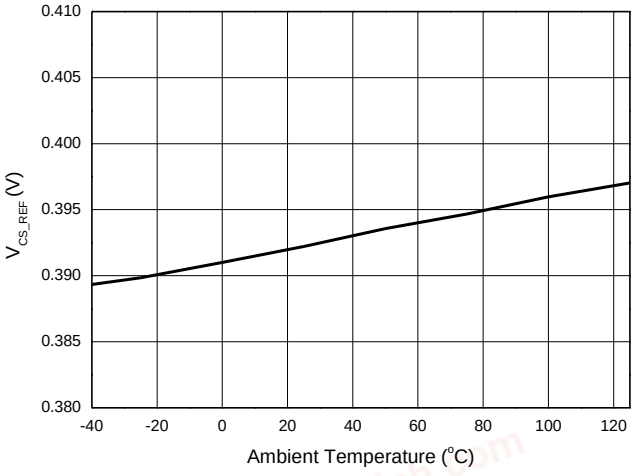
Startup Current vs. Ambient Temperature



Operating Current vs. Ambient Temperature



CS Reference Voltage vs. Ambient Temperature



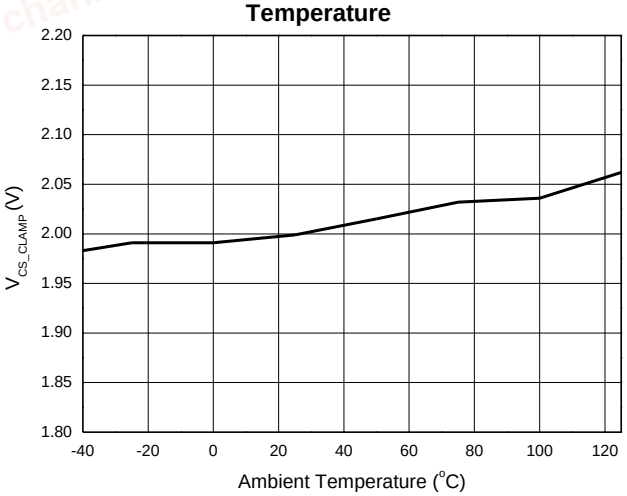
Note: 10. These electrical characteristics are tested under DC condition. The ambient temperature is equal to the junction temperature of the device.

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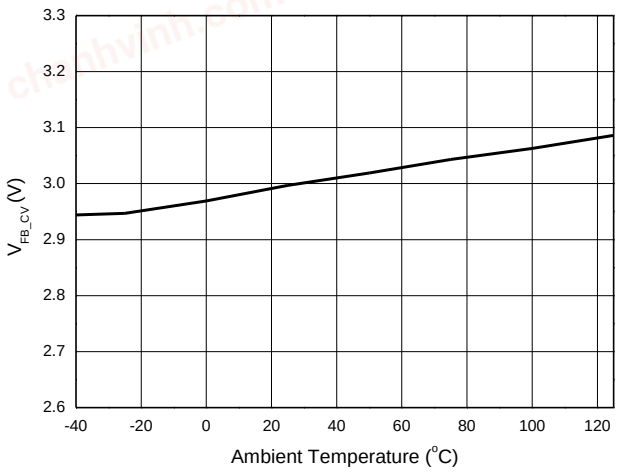
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Performance Characteristics (continued)

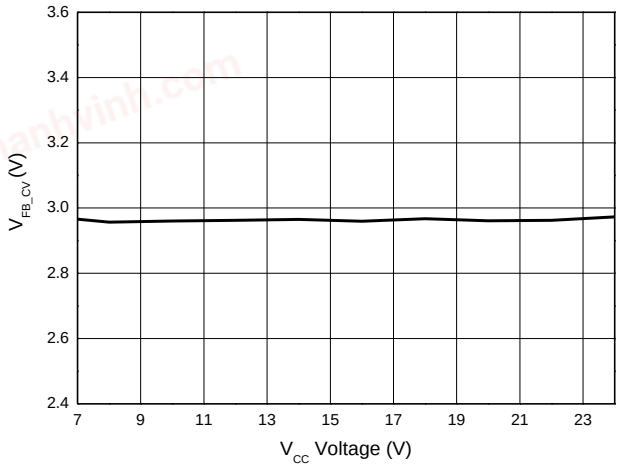
CS Clamp Reference Voltage vs. Ambient Temperature



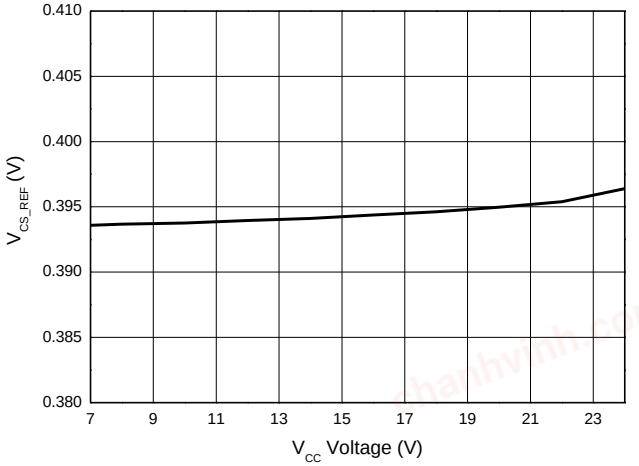
FB CV Threshold vs. Ambient Temperature



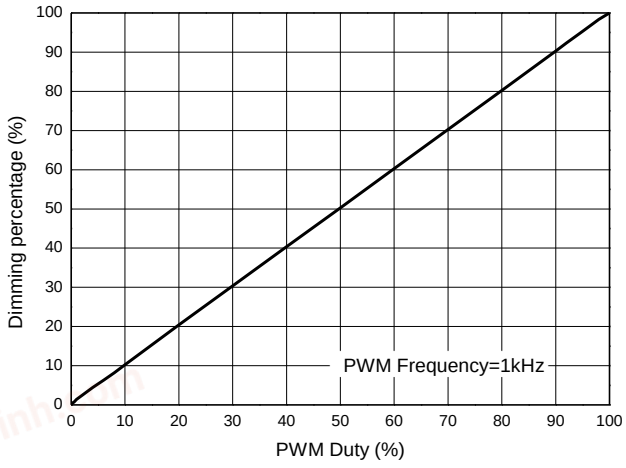
FB CV Threshold vs. V_{CC} Voltage



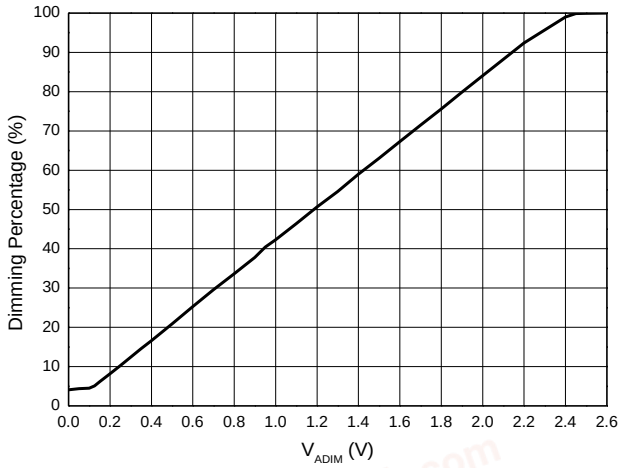
CS Reference Voltage vs. V_{CC} Voltage



PWM Dimming Curve



Analog Dimming Curve



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Application Information

The AL1665 is a constant-current high-PF flyback and buck-boost controller with primary side regulation (PSR), targeting LED lighting applications. The device eliminates the optocouplers or the secondary feedback circuits, which is helpful to minimize the cost of the whole system. High power factor is achieved by constant on-time operation. In order to reduce the switching losses and improve EMI performance, quasi-resonant switching mode is applied. The AL1665 integrates multiple protections including UVLO protection, V_{CC} overvoltage protection, output open-voltage protection, overcurrent protection, thermal foldback protection, and overtemperature protection. The AL1665 can support analog and PWM dimming modes.

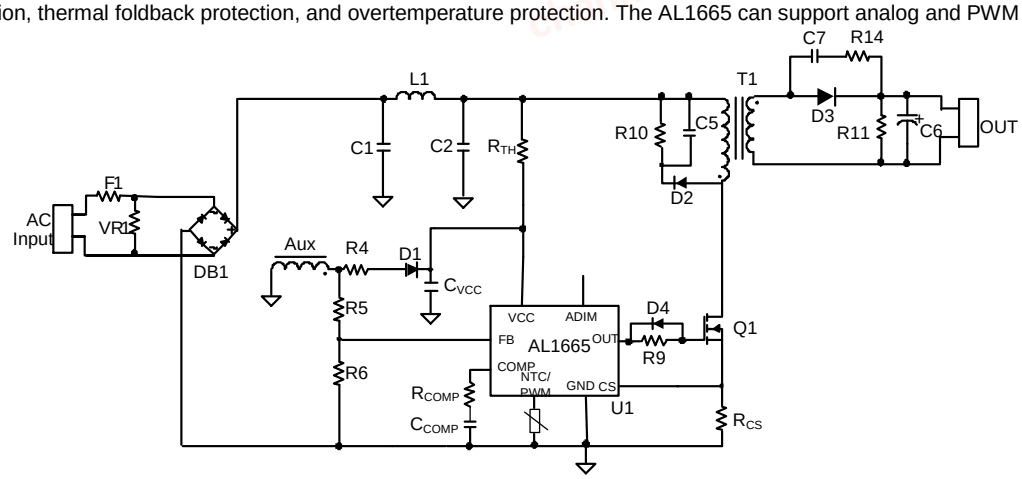


Figure 1. Flyback Application Circuit

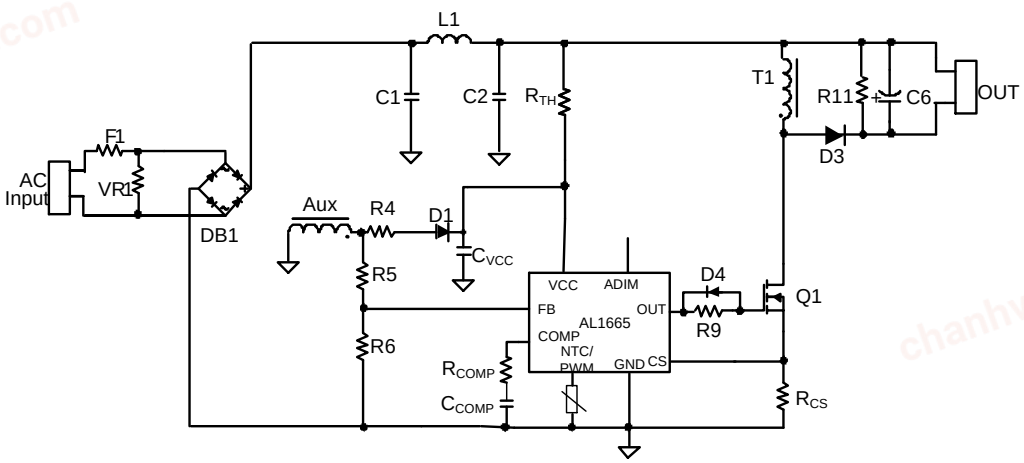


Figure 2. Buck-Boost Application Circuit

Start Up

After AC supply is powered on, the capacitor C_{VCC} across VCC and GND pin charges up by BUS voltage through a start-up resistor R_{TH}. Once V_{CC} reaches V_{CC_TH}, the internal blocks start to work. V_{CC} is supplied by V_{BUS} until the auxiliary winding of flyback transformer could supply enough energy to maintain V_{CC} above V_{OPR_MIN}. If V_{CC} voltage is lower than V_{OPR_MIN}, the switch turns off.

After V_{CC} exceeds V_{CC_TH}, the drive blocks do not start to switch on/off signals until V_{COMP} is higher than the initial voltage V_{COMP_ST}, which can be programmed by R_{COMP}. The formula is shown below. Such design can program startup on time to reduce the startup time or the output overshoot current.

$$V_{COMP_ST} = 1.4V - 700\mu A \cdot R_{COMP}$$

Where V_{COMP_ST} is the pre-charged voltage of COMP pin. Figure 1 shows R_{COMP}.

Generally, a big capacitance of C_{COMP} is necessary to achieve high power factor and stabilize the system loop (1μF to 2μF is recommended). The pre-charged voltage in start-up procedure can be programmed by R_{COMP}.

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Application Information (continued)

Protections

1. Output Open Protection (OVP)

The output voltage is reflected by the voltage on transformer's auxiliary winding. Both the FB pin and the VCC pin of IC have the overvoltage protection function. When there is a rapid line and load transient, the output voltage can exceed the regulated value. If V_{CC} exceeds V_{CC_OVP}, the V_{CC} overvoltage protection triggers, the switch turns off, and the V_{CC} discharges. Once V_{CC} is lower than V_{OPR_MIN}, the IC shuts down and powers on again by BUS voltage through the start-up resistor. If V_{FB} exceeds V_{FB_CV}, the FB overvoltage protection triggers, the switch turns off, and V_{CC} latches for 16s then V_{CC} discharges. Once V_{CC} is below V_{OPR_MIN}, the IC shuts down and powers on again by BUS voltage through the start-up resistor. Power dissipation is low when FB overvoltage protection occurs.

Thus, output overvoltage depends on the minimum voltage between both OVP protections' limitation, which can be found with the below formula.

$$V_{OVP} = Min\left(\frac{N_S}{N_{AUX}} \cdot V_{CC_OVP}, \frac{N_S}{N_{AUX}} \cdot \frac{R5+R6}{R6} \cdot V_{FB_CV}\right)$$

Where:

- V_{OVP} is the output overvoltage setting
- R5 and R6 shown in Figure 1 are divider resistors connected from the auxiliary winding
- N_{AUX} is the turns of auxiliary wind
- N_S is turns of the secondary wind
- V_{CC_OVP} is the OVP voltage of V_{CC}

2. Output Short Protection (OSP)

When the output is shorted, the output voltage is clamped to zero. The output voltage of the auxiliary winding, which is proportional to the output winding, will drop down too. If V_{FB} drops below 0.4V, the output short protection will be triggered, the device cannot detect the t_{OFF} time, and the device controls the system operation at 4kHz low frequency.

3. Overcurrent Protection (OCP)

The AL1665 has a built-in cycle-by-cycle overcurrent protection of primary inductor current. When the CS pin voltage reaches the voltage V_{CS_CLAMP}, the switch turns off until the next switch period. The maximum peak current ($I_{PEAK\ (MAX)}$) of the inductor can be calculated as follows:

$$I_{PEAK_MAX} = \frac{V_{CS_CLAMP}}{R_{CS}}$$

Where:

- V_{CS_CLAMP} means primary current clamp voltage, which is 2V.
- R_{CS} is current sense resister, which is shown as Figure 1

4. CS Short Protection

When the CS pin shorts to GND, CS voltage latches to zero. If CS is detected lower than 0.3V for seven pulses, the CS short protection triggers, the switch turns off, and V_{CC} latches for 16s then V_{CC} discharges. Once V_{CC} is below V_{OPR_MIN}, the IC shuts down and powers on again by the BUS voltage through the startup resistor. High rush current appears when CS is shorted to GND, and it may damage the components.

5. Secondary Diodes/Primary Windings/Secondary Windings Short Protection

The CS voltage is high when secondary diodes/primary windings/secondary windings short. If the CS voltage is higher than V_{CS_OCP}, the protection triggers, the switch turns off, and V_{CC} latches for 16s then V_{CC} discharges. Once V_{CC} is below V_{OPR_MIN}, the IC shuts down and powers on again by the BUS voltage through the startup resistor. Power dissipation is low when output short protection occurs.

6. Thermal Foldback Protection (TFP)

Connect a NTC between the NTC/PWM pin and ground to detect an overtemperature condition. In response to a high temperature (detected if $V_{NTC/PWM}$ drops below $V_{TF(START)}$), the circuit gradually reduces the LED current down 50% of its nominal value when $V_{NTC/PWM}$ reaches $V_{TF(STOP)}$, in accordance with the characteristic of Figure 3. If this thermal foldback cannot prevent the temperature from rising (testified by $V_{NTC/PWM}$ dropping below V_{OTP}), the circuit latches off or enters the auto-recovery mode and cannot be reoperated until $V_{NTC/PWM}$ exceeds $V_{OTP(ON)}$ to provide some temperature hysteresis (around +10°C typically).

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Application Information (continued)

The OTP thresholds nearly correspond to the following resistances of the NTC:

- Thermal foldback starts when R_{NTC} <=$R_{TF(START)}$(11.7kΩ typically)
- Thermal foldback stops when R_{NTC} <=$R_{TF(STOP)}$ (8.0kΩ typically)
- OTP triggers when R_{NTC} <= $R_{OTP(OFF)}$ (5.9kΩ typically)
- OTP is removed when R_{NTC} >= $R_{OTP(ON)}$ (8.0kΩ typically)

At startup, when V_{CC} reaches $V_{CC(ON)}$, the OTP comparator blanks for at least 250μs in order to allow the NTC/PWM pin voltage to reach its nominal value if a filtering capacitor is connected to the NTC/PWM pin. This would avoid flickering of the LED light during turn-on.

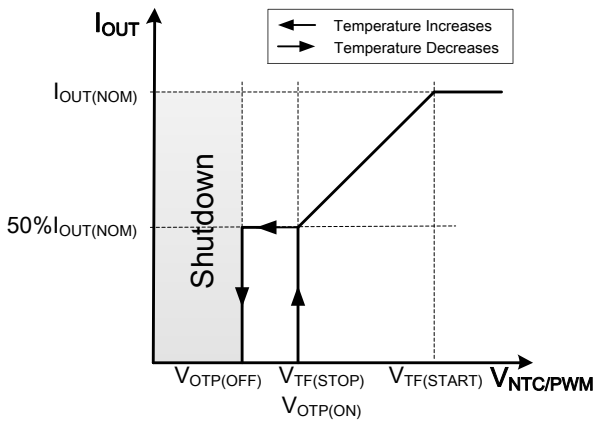


Figure 3. Output Current Reduction vs NTC/PWM Pin Voltage

7. Overtemperature Protection (OTP)

The AL1665 has built-in overtemperature protection (OTP) function. When the temperature goes up to +180°C, the overtemperature protection is triggered, which leads to VCC UVLO. When OTP recovers, the system can be restarted.

Output Constant Current Control

According to the definition of mean output current, the mean output current can be obtained as following:

$$I_{O_MEAN} = \frac{1}{\pi} \cdot \int_0^{\pi} \frac{1}{2} \cdot I_{SP} \cdot \frac{t_{ONS}}{t_{SW}} dt$$

Where:

- I_{O_MEAN} is the mean output current
- I_{SP} is the secondary peak current of transformer
- t_{ONS} is the discharge time of secondary side of transformer
- t_{SW} is the switch period

According to the principle of AL1665 closed-loop control, the voltage of R_{CS} is sampled when the switch turns off, and the value is held until the discharge time t_{ONS} is over. It can be described by following formula:

$$V_{REF} = \frac{1}{\pi} \int_0^{\pi} I_P \cdot R_{CS} \cdot \frac{t_{ONS}}{t_{SW}} dt$$

Where:

- I_P is the primary peak current of transformer
- R_{CS} is the current sense resister, which is shown in Figure 1
- t_{ONS} is the discharge time of secondary side of transformer
- t_{SW} is the switch period
- V_{REF} is internal reference voltage that is equal to 0.4V

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Application Information (continued)

The peak current at secondary side has the following relationship with primary side peak current if the effect of the leakage inductor is neglected.

$$I_{SP} = N_{PS} \cdot I_P$$

Where N_{PS} is the turns' ratio of flyback transformer (N_{PS}=1 for buck-boost), and I_P is the primary peak current of the transformer.

According to these above formulas, the mean output current can be induced finally by the following equation:

$$I_{O_MEAN} = \frac{N_{PS} \cdot V_{REF}}{2 \cdot R_{CS}}$$

Where:

- I_{O_MEAN} is the mean output current
- R_{CS} is the current sense resister, which is shown as Figure 1 and Figure 2
- V_{REF} is the internal reference voltage that is equal to 0.4V
- N_{PS} is the turns' ratio of flyback transformer (N_{PS} = 1 for buck-boost)

Therefore, the constant output current control can be realized with appropriate parameter design.

PF and THD Compensation Circuit

In typical application, AL1665 can provide PF>0.9 and THD <40%. It can improve PF>0.95 and THD<20% by adding the compensation circuit as below. The V_{BUS} is connected to bus line, which is after the rectifier bridge. The COMP pin voltage increases an offset that is almost followed with bus line voltage in the circuit. Due to the COMP voltage controls, the switch-on time, the phase difference between input voltage and input current, is reduced, which can optimize the PF and THD. In the circuit, the range of resister value R12 is from 800kΩ to 1.5MΩ, and the range of resistor value R13 is from 500Ω to 5.1kΩ. The range of capacitance C11 is 1μF to 2μF. The PF and THD circuit can be improved by fine-tuning these components.

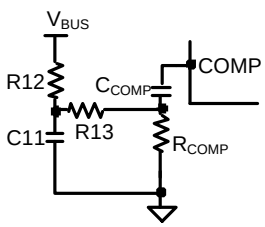


Figure 4. PF and THD Compensation Circuit

Line Regulation Compensation Function

The AL1665 can achieve good line regulation by adjusting the FB pull-up resistor R_{FB1} and the CS external horizontal resistor R_{CS1}. R_{FB2} is the FB pull-down resistor. Figure 5 shows this circuit. As R_{FB2} is far larger than R_{FB3}, during t_{ONP}, the V_{FB} can be calculated approximately as:

$$V_{FB} = \frac{\sqrt{2} \cdot V_{IN_RMS} \cdot N_{AP} \cdot R_{FB3}}{R_{FB1} + R_{FB3}}$$

And the V_{CS_OFFSET} can be got:

$$V_{CS_OFFSET} = \frac{K \cdot \sqrt{2} \cdot V_{IN_RMS} \cdot N_{AP} \cdot R_{FB3}}{R_{FB1} + R_{FB3}} \cdot (R_{CS1} + R_{CS2})$$

Where:

- K is conversion coefficient of I_{FB3} that is equal to $0.013*10^{-3}$
- V_{IN_RMS} is the input RMS voltage
- N_{AP} is the turns' ratio of auxiliary winding and primary winding
- R_{FB3} is the internal FB pulldown resistor that is connected to the system during t_{ONP} time and equals to 184Ω
- R_{CS2} is the internal horizontal resistor that is 6kΩ

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Application Information (continued)

The output current can be calculated as:

$$I_{O_MEAN}=\frac{N_{PS}}{2\cdot R_{CS}}\cdot(V_{REF}-V_{CS_OFFSET})=\frac{N_{PS}}{2\cdot R_{CS}}\cdot\left[V_{REF}-\frac{K\cdot\sqrt{2}\cdot V_{IN_RMS}\cdot N_{AP}\cdot R_{FB3}}{R_{FB1}+R_{FB3}}\cdot(R_{CS1}+R_{CS2})\right]$$

Where:

- V_{REF} is the internal reference voltage that is equal to 0.4V

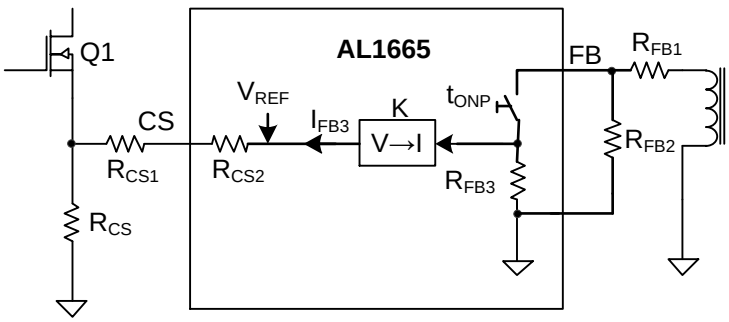


Figure 5. Line Regulation Compensation Circuit

Dimming Mode

The AL1665 can support two dimming modes: analog dimming and PWM dimming.

1. Analog Dimming Mode

In analog dimming mode, the dimming signal is added to ADIM pin directly to realize dimming function. Figure 6 shows the setting circuit. When V_{APWM} is higher than 2.5V, the driver outputs 100% of rated current, and when the voltage V_{ADIM} is within the 50mV to 2.5V range, the output current changes linearly with the voltage V_{APWM}. Figure 7 shows the dimming curve, and the dimming range is from 5% to 100%.

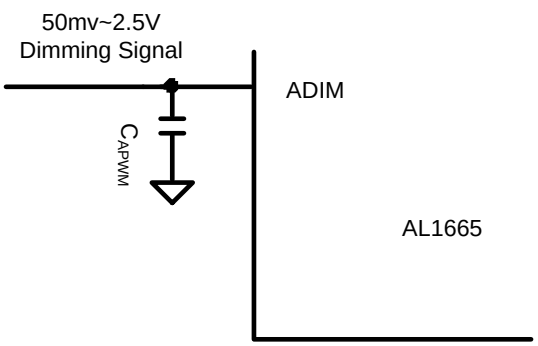


Figure 6. Analog Dimming Setting Circuit

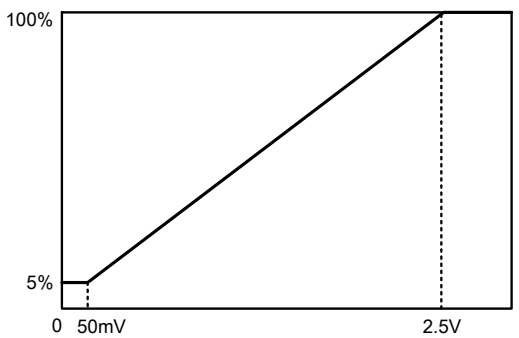


Figure 7. Analog Dimming Curve

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Application Information (continued)

2. PWM Dimming Mode

In PWM dimming mode, the dimming signal is added to NTC/PWM pin. Figure 8 shows the setting circuit. The output current is chopped by the dimming signal directly. The logic high level of the dimming signal must be higher than 1V while the logic low level is lower than 0.5V. The switch turns off at logic low level. Figure 9 shows the dimming curve. The dimming range can be 100% to 0.5% with 1KHz frequency of PWM signal.

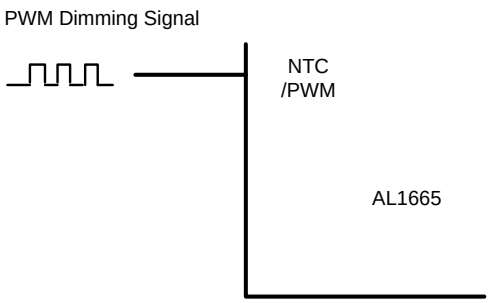


Figure 8. PWM Dimming Setting Circuit

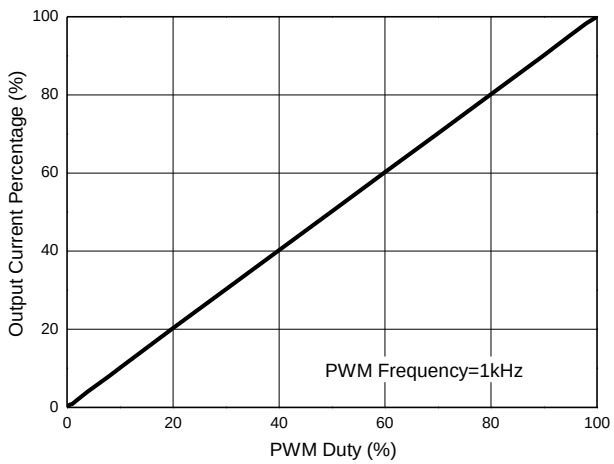


Figure 9. PWM Dimming Curve

Operation Parameters Design

1. Setting the Current Sense Resistor R_{CS}

The current sense resistance is calculated using the following equation:

$$R_{CS} = \frac{N_{PS} \cdot V_{REF}}{2 \cdot I_{O_MEAN}}$$

Where:

- I_{O_MEAN} is the mean output current
- R_{CS} is the current sense resister, which is shown as Figure 1
- V_{REF} is the internal reference voltage that is equal to 0.4V
- N_{PS} is the turns' ratio of flyback transformer (N_{PS}=1 for buck-boost)

2. Setting Transformer Selection (T1)

N_{PS} is limited by the electrical stress of the switch MOSFET and can be calculated with the following formula:

$$N_{PS} \le \frac{V_{MOS_(BR)DS} \cdot 90\% - \sqrt{2} \cdot V_{IN_MAX} - \Delta V_S}{V_O + V_{D_F}}$$

Where:

- $V_{MOS_(BR)DS}$ is the breakdown voltage of the switch MOSFET
- V_{IN_MAX} is the max rated input voltage
- ΔV_S is the overshoot voltage clamped by RCD snobbier during OFF time
- V_O is the output voltage
- V_{D_F} is the forward voltage of secondary diode
- N_{PS} is the turns' ratio of flyback transformer (N_{PS}=1 for buck-boost)

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Application Information (continued)

For boundary conduction mode and constant on-time method, the peak current of primary inductance can be calculated as:

$$I_P = \frac{2 \cdot \pi \cdot I_{O_MEAN}}{N_{PS} \cdot \int_0^{\pi} \sin(\theta) \cdot \frac{\sqrt{2} \cdot V_{IN_RMS} \cdot \sin(\theta)}{\sqrt{2} \cdot V_{IN_RMS} \cdot \sin(\theta) + N_{PS} \cdot Vo} d\theta}$$

Where

- V_{IN_RMS} is the rate input voltage
- I_P is the primary inductance current
- N_{PS} is the turns' ratio of flyback transformer (N_{PS}=1 for buck-boost)
- I_{O_MEAN} is the mean output current
- V_O is the output voltage

The switching frequency is not constant for AL1665 due to boundary conduction mode. To set the minimum switching frequency f_{MIN} at the crest of the minimum AC input, primary inductance can be obtained by the following formula:

$$L_P = \frac{\sqrt{2} \cdot V_{IN_RMS} \cdot N_{PS} \cdot V_O}{I_P \cdot (\sqrt{2} V_{IN_RMS} + N_{PS} V_O) \cdot f_{MIN}}$$

Where

- V_{IN_RMS} is the rate input voltage
- I_P is the primary inductance current
- N_{PS} is the turns' ratio of flyback transformer (N_{PS}=1 for buck-boost)
- V_O is the output voltage
- f_{MIN} is the minimum switching frequency at the crest of the minimum AC input

According to the Faraday's Law, the winding number of the inductance can be calculated by:

$$N_P = \frac{L_P \cdot I_P}{A_e \cdot B_m}$$

$$N_S = \frac{N_P}{N_{PS}}$$

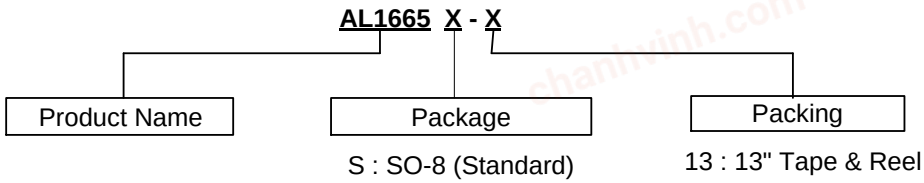
Where:

- A_e is the core effective area
- B_m is the maximum magnetic flux density

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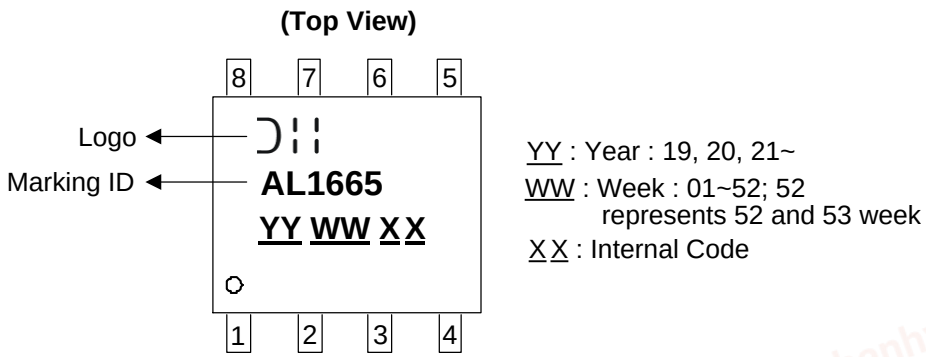
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Ordering Information



Part Number	Package Code	Package	13" Tape and Reel	
			Quantity	Part Number Suffix
AL1665S-13	S	SO-8 (Standard)	4000/Tape & Reel	-13

Marking Information



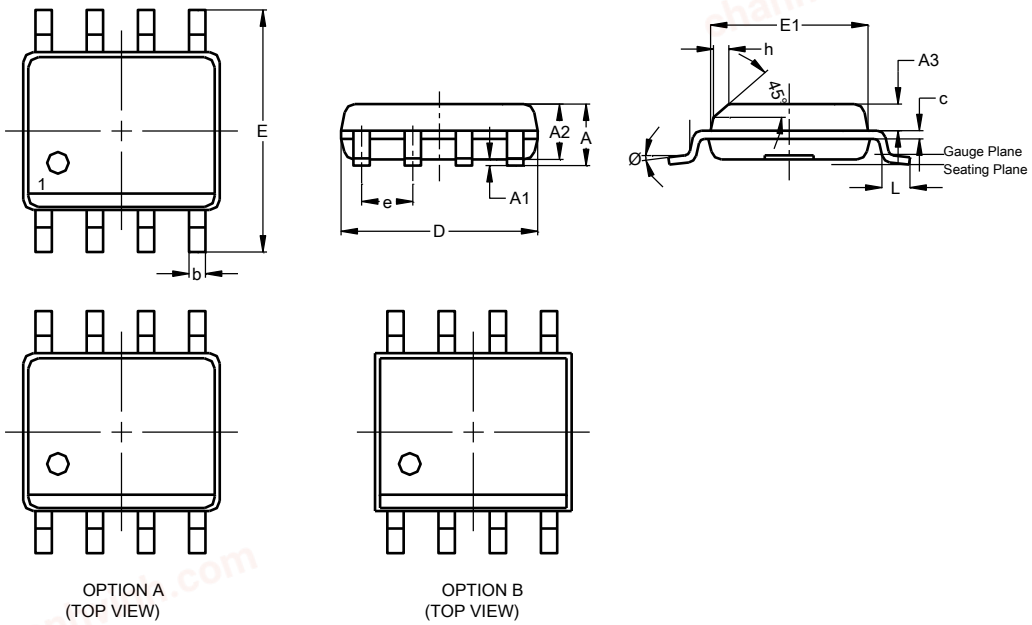
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Package Outline Dimensions (All dimensions in mm.)

Please see http://www.diodes.com/package-outlines.html for the latest version.

SO-8 (Standard)

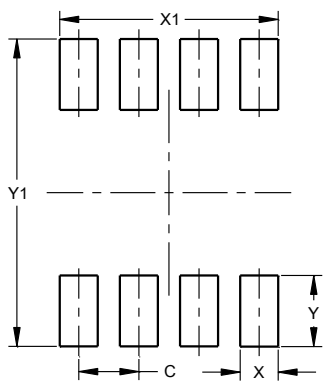


SO-8 (Standard)			
Dim	**Min**	**Max**	**Typ**
A	--	1.75	--
A1	0.10	0.25	--
A2	1.25	1.65	--
A3	0.50	0.70	--
b	0.30	0.51	--
c	0.15	0.25	--
D	4.80	5.00	--
E	5.80	6.20	6.00
E1	3.80	4.00	--
e	--	--	1.27
h	0.25	0.50	--
L	0.45	0.82	--
Ø	0°	8°	--
All Dimensions in mm			

Suggested Pad Layout

Please see http://www.diodes.com/package-outlines.html for the latest version.

SO-8 (Standard)



Dimensions	Value (in mm)
C	1.27
X	0.802
X1	4.612
Y	1.505
Y1	6.50

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