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## Description

The AL1677 is a universal AC-input (85~277 V<sub>AC</sub>), high-efficiency and high-accuracy Buck LED-driver converter. The AL1677 topology provides accurate constant current (CC) line and load regulation, operating at boundary conduction mode (BCM) to ease in EMI/EMC qualification and testing to meet the latest regulatory laws.

The AL1677 system removes the auxiliary winding and external high-voltage MOSFET with few external components to create a low bill of material (BOM) cost solution. The AL1677 has rich protection features to enhance system safety and reliability. With thermal foldback function, the AL1677 can reduce output current when the driver's temperature is higher than the setting value.

The AL1677 is available in SO-8 package.

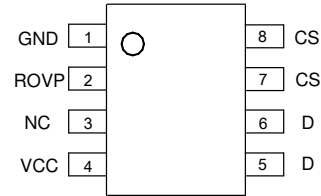
## Features

- > 90% Efficiency
- Valley Detection to Minimize Switching Loss
- Universal 85 to 277 V<sub>AC</sub> Input Range
- Internal MOSFET up to 500V
- Tight Current Sense Tolerance :  $\pm 3\%$
- Low Startup Current: 170 $\mu$ A
- Low Operation Current: 100 $\mu$ A (Static)
- Standard Inductor (no auxiliary winding)
- Internal Protections
  - Undervoltage Lockout (UVLO)
  - Leading-Edge Blanking (LEB)
  - Cycle-by-cycle Overcurrent Protection(OCP)
  - Output Open/Short Protection(OVP/OSP)
  - Open-Load and Reload Detection
  - Thermal Foldback Function(TFP)
  - Over-Temperature Protection(OTP)
- SO-8 Package
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**

Notes: 1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant.  
 2. See [http://www.diodes.com/quality/lead\\_free.html](http://www.diodes.com/quality/lead_free.html) 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.

## Pin Assignments

(Top View)

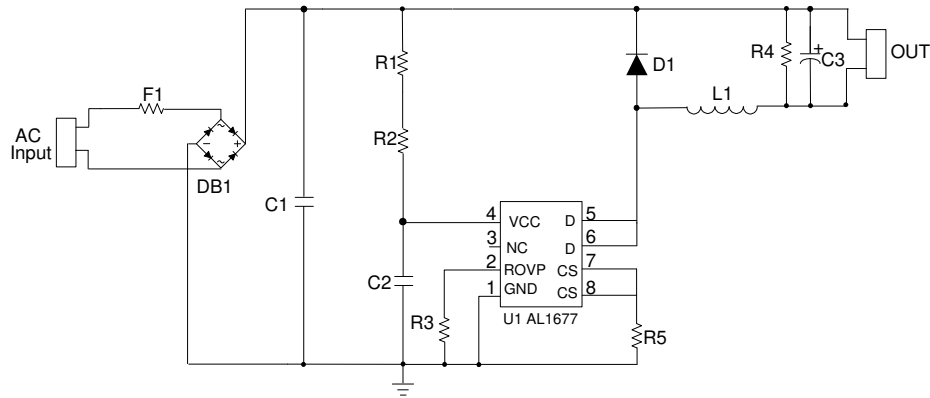


SO-8

## Applications

- Retrofit LED Lamps
- High Voltage DC-DC LED Driver
- General Purpose Constant Current Source

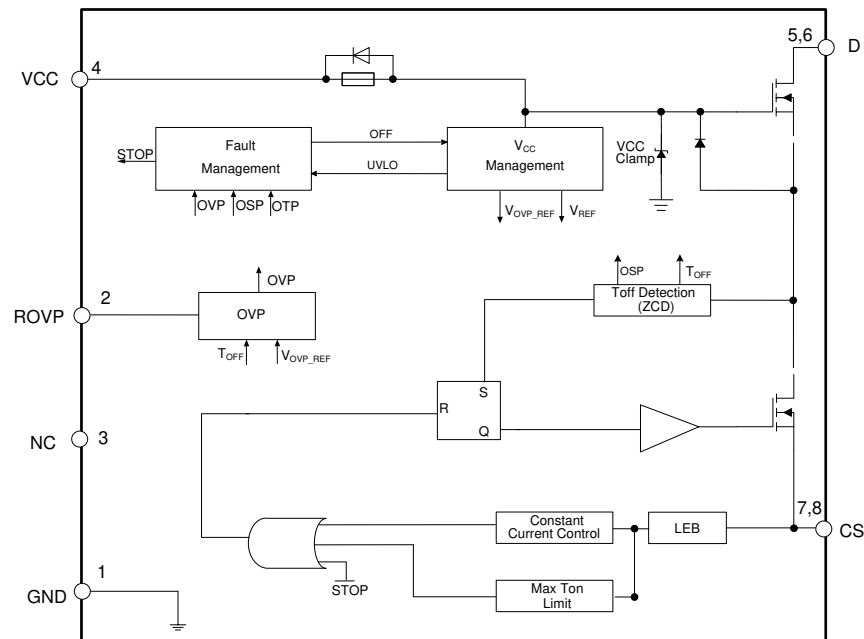
## Typical Applications Circuit



## Pin Descriptions

Pin Number	Pin Name	Function
1	GND	Ground
2	ROVP	Setting the Open Voltage of the Output
3	NC	No Connection
4	VCC	Power Supply for the Device
5,6	D	Internal High Voltage MOSFET's Drain
7,8	CS	Current Sensing

## Functional Block Diagram



## Absolute Maximum Ratings (@T<sub>A</sub> = +25°C, unless otherwise specified.) (Note 4)

Symbol	Parameter		Rating	Unit
V <sub>CC</sub>	Power Supply Voltage		18	V
V <sub>D</sub>	Voltage on D Pin	AL1677-05BS-13	500	V
		AL1677-08BS-13	500	V
		AL1677-10BS-13	500	V
		AL1677-20BS-13	500	V
I <sub>D</sub>	Continuous Drain Current T <sub>C</sub> = +25°C	AL1677-05BS-13	0.5	A
		AL1677-08BS-13	0.8	A
		AL1677-10BS-13	1.0	A
		AL1677-20BS-13	2.0	A
V <sub>CS</sub>	Voltage on CS Pin		-0.3 to 7	V
V <sub>ROVP</sub>	Voltage on ROVP Pin		-0.3 to 7	V
T <sub>J</sub>	Operating Junction Temperature		-40 to +150	°C
T <sub>STG</sub>	Storage Temperature		-65 to +150	°C
T <sub>LEAD</sub>	Lead Temperature (Soldering, 10 seconds)		+260	°C
P <sub>D</sub>	Power Dissipation and Thermal Characteristics (T <sub>A</sub> = +50°C)		0.65	W
θ <sub>JA</sub>	Thermal Resistance (Junction to Ambient)		190	°C/W
-	ESD (Human Body Model)		2,000	V
	ESD (Machine Model)		200	V

Note: 4. Stresses greater than those listed under "Absolute Maximum Ratings" may 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 may affect device reliability.

## Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
T <sub>A</sub> (Note 5)	Ambient Temperature	-40	+105	°C

Note: 5. The device can operate normally at +125°C ambient temperature under the condition that the junction temperature is less than +150°C.



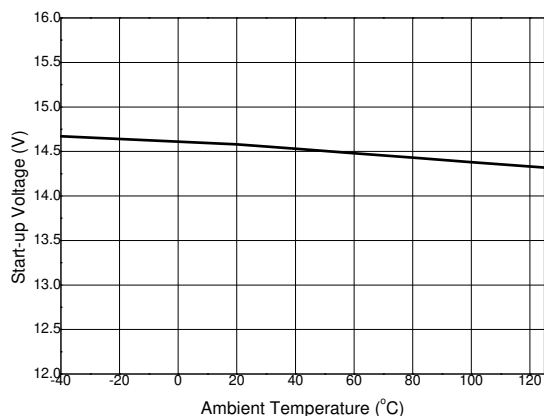
**Electrical Characteristics** (@T<sub>A</sub> = +25°C, unless otherwise specified.)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
UVLO Section						
V <sub>TH (ST)</sub>	Startup Threshold	–	–	14.5	–	V
V <sub>OPR (Min)</sub>	Minimal Operating Voltage	After Turn On	–	8.5	–	V
V <sub>cc_clamp</sub>	V <sub>cc</sub> Clamp Voltage	–	–	16.2	–	V
Standby Current Section						
I <sub>ST</sub>	Start-Up Current	V <sub>CC</sub> = V <sub>TH (ST)</sub> -0.5V, Before Start Up	–	170	–	μA
I <sub>CC (OPR)</sub>	Operating Current	Static	–	100	–	μA
Internal High Voltage MOSFET						
R <sub>DS(on)</sub>	Drain-Source On-State Resistance	AL1677-05BS-13	–	24	26	Ω
		AL1677-08BS-13	–	16	20	
		AL1677-10BS-13	–	10	12	
		AL1677-20BS-13	–	5.4	6	
I <sub>DS</sub>	Continuous Drain-Source Current	AL1677-05BS-13	–	–	0.5	A
		AL1677-08BS-13	–	–	0.8	
		AL1677-10BS-13	–	–	1.0	
		AL1677-20BS-13	–	–	2.0	
V <sub>DS</sub>	Drain-Source Voltage	AL1677-05BS-13	500	–	–	V
		AL1677-08BS-13	500	–	–	
		AL1677-10BS-13	500	–	–	
		AL1677-20BS-13	500	–	–	
I <sub>DSS</sub>	Drain-Source Leakage Current	AL1677-05BS-13	–	–	1	μA
		AL1677-08BS-13	–	–	1	
		AL1677-10BS-13	–	–	1	
		AL1677-20BS-13	–	–	1	
ROVP Section						
V <sub>ROVP</sub>	Reference Voltage of ROVP pin	–	–	0.5	–	V
Current Sense Section						
V <sub>CS-REF</sub>	Current Sense Reference	–	0.388	0.400	0.412	V
t <sub>ON_MIN</sub>	Minimum t <sub>ON</sub>	–	400	–	700	ns
t <sub>ON_MAX</sub>	Maximum t <sub>ON</sub>	–	–	35	–	μs
t <sub>OFF_MAX</sub>	Maximum t <sub>OFF</sub>	–	–	200	–	μs
t <sub>OFF_MIN</sub>	Minimum t <sub>OFF</sub> (Note 6)	–	–	6	–	μs
Thermal Foldback and Over-Temperature Protection Section						
T <sub>REG</sub>	Overheating Temperature Regulation (Notes 6 & 8)	–	–	+140	–	°C
–	Shutdown Temperature (Notes 6 & 7 & 8)	–	–	+170	–	°C

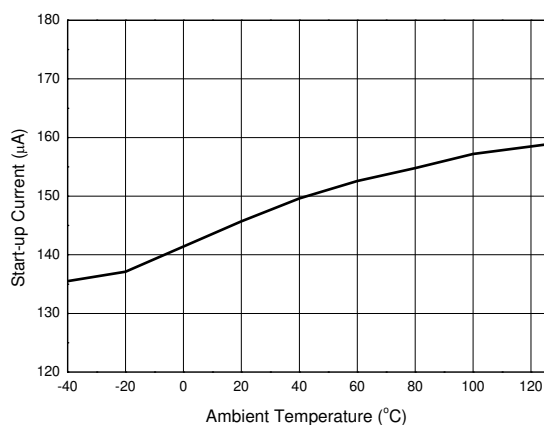
Notes: 6. These parameters, although guaranteed by design, are not 100% tested in production.  
 7. The device will latch when OTP happen and the device won't operate constantly at this temperature.  
 8. This regulation temperature is junction temperature.

## Performance Characteristics (Note 9)

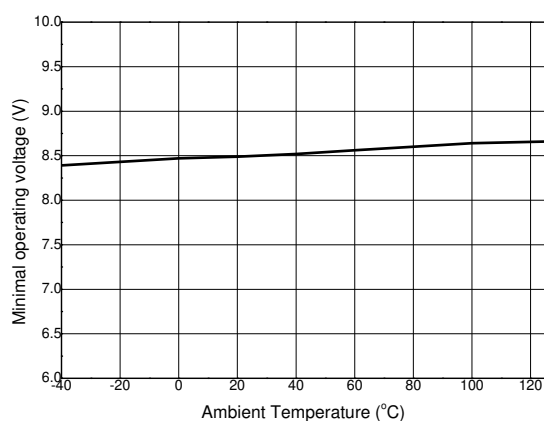
**Start-up Voltage vs. Ambient Temperature**



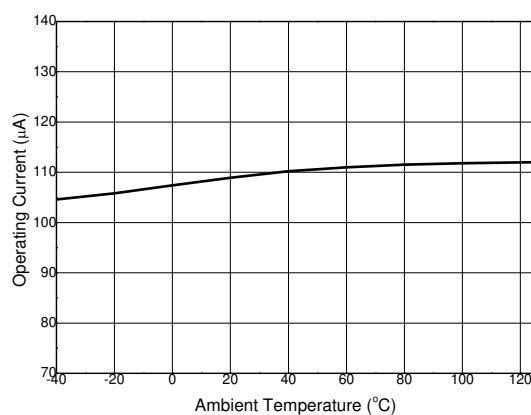
**Start-up Current vs. Ambient Temperature**



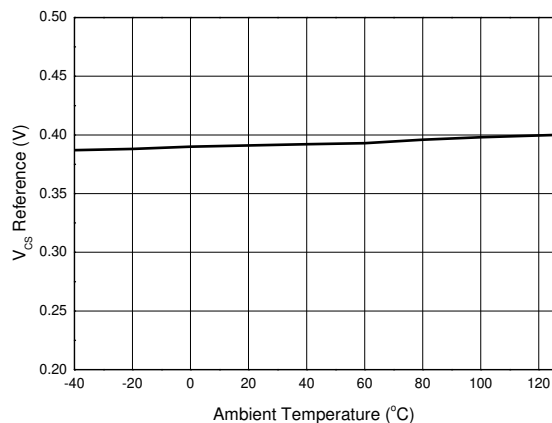
**Minimal Operating Voltage vs. Ambient Temperature**



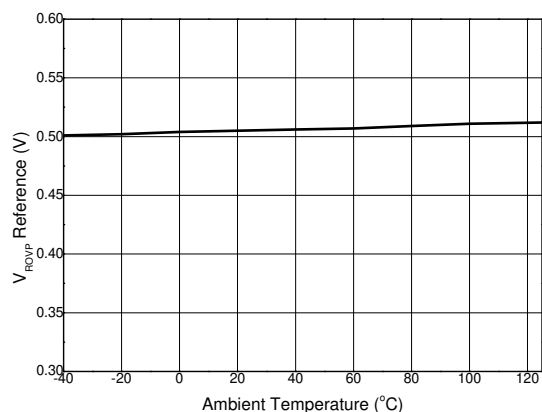
**Operating Current vs. Ambient Temperature**



**V<sub>CS</sub> Reference vs. Ambient Temperature**

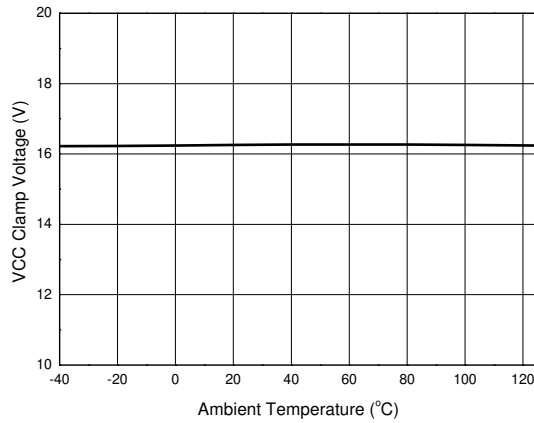


**V<sub>ROVP</sub> Reference vs. Ambient Temperature**

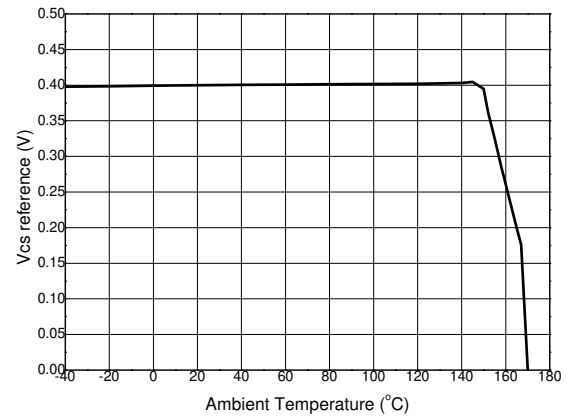


## Performance Characteristics (continued) (Note 9)

**VCC Clamp Voltage vs. Ambient Temperature**



**Vcs Reference vs. Ambient Temperature**



Note: 9. These electrical characteristics are tested under DC condition. The ambient temperature is equal to the junction temperature of the device.

## Application Information

### Convertor Operation

The AL1677 is designed for single-inductance buck application and is an extremely low BOM cost solution widely used in non-isolated situations. The AL1677 operates at boundary conduction mode (BCM) which can get good EMI performance. The device internally integrates a 500V high-voltage MOSFET. The AL1677 adopts a novel method to detect the  $t_{OFF}$  time and achieve an extremely low operation current, so the device does not need the auxiliary winding for  $V_{CC}$  supply and detecting the  $t_{OFF}$  time. It also has good constant current control which can guarantee the system current accuracy.

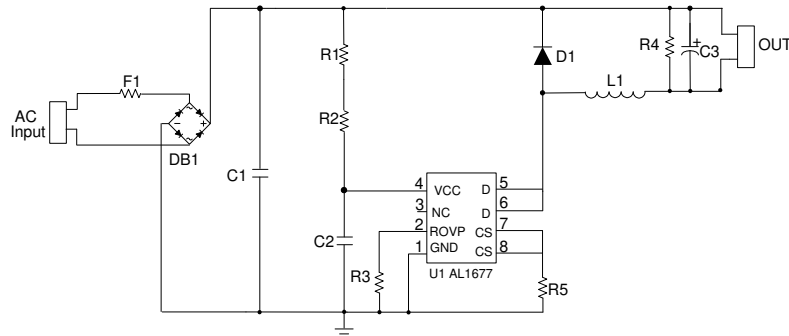


Figure 1 Typical Application Circuit

### Start-up and Supply Voltage

Before start-up, the VCC capacitor C2 is charged by the startup resistors (R1, R2) from the high voltage mains. When the start-up voltage is reached, the AL1677 starts switching. During normal operation, the VCC supply is provided by start-up resistors (R1, R2) and internal source driver circuit.

The AL1677 has an internal VCC clamp voltage (typical 16.2V), which is limited by one internal active Zener diode.

When VCC voltage drops to below the undervoltage lockout (UVLO), switching is stop, the IC can restart when the voltage on VCC pin is exceeding the startup voltage ( $V_{TH(ST)}$ ).

### Protections

#### Undervoltage Lockout (UVLO)

When the voltage on the VCC pin drops to below  $V_{OPR(Min)}$ , the IC stops switching. The IC can restart when the voltage on VCC is exceeds the startup voltage ( $V_{TH(ST)}$ ).

#### Leading-Edge Blanking (LEB)

To prevent false detection of the peak current of the inductor, a blanking time following switch-on is designed. When the internal switch turns on, a short current spike can occur because of the capacitive discharge of the voltage over the drain and source. It is disregarded during the LEB time ( $t_{ON\_MIN}$ ).

#### Cycle-by-cycle Overcurrent Protection (OCP)

The AL1677 has a built-in peak current detector. It triggers when the voltage on CS pin reaches the peak level  $V_{CS\_CLAMP}$ . The R5 is connected to the CS pin to sense the current of the inductor. The maximum peak current ( $I_{PEAK(MAX)}$ ) of the inductor can be calculated as below:

$$I_{PEAK} = \frac{V_{CS\_REF}}{R5}$$

The detection circuit is activated after the LEB time. When the detection circuit sense the CS voltage is higher than 0.4V, the IC will turn off the switching to limit the output current. It automatically provides protection for the maximum LED current during operation. A propagation delay exists between overcurrent detection and actual source-switch off, so the actual peak current is a little higher than the OCP level set by the R5.

#### Output-Short Protection (OSP)

When LED is shorted, the device cannot detect the  $t_{OFF}$  time, and the device controls the system operation at 5kHz low frequency.



## Application Information (continued)

### Output Open Protection (OVP)

AL1677 has output open-voltage protection controlled when the LED is open, which can prevent the output voltage from increasing to a very high value. This feature can help the system designer select a smaller volume capacitor. The output voltage is set by the external resistor R3, shown in Figure 1.

When LED is open, the  $t_{off}$  time can be calculated as:

$$t_{off} = \frac{L1 \cdot V_{CS\_REF}}{V_{OVP} \cdot R5}$$

Where

$V_{OVP}$  is the output open voltage,

The output voltage is set by R3, and R3 is:

$$R3 = \frac{V_{ROVP\_REF} \cdot t_{off}}{12 \cdot C_{REF} \cdot V_{CS\_REF}} = \frac{V_{ROVP\_REF} \cdot L1}{12 \cdot C_{REF} \cdot V_{OVP} \cdot R5}$$

Where

$V_{ROVP\_REF}$  is the internal ROVP pin 0.5V's reference,

$C_{REF}$  is the internal 6pF capacitor.

### Thermal Foldback Protection (TFP)

AL1677 has a thermal foldback function and adopts a self-adaptive control method, which can prevent the system from breaking down due to high temperatures. The overheating temperature is set at +140°C typical. When the junction temperature of the IC is higher than +140°C typical, the device will linearly decrease the internal reference voltage to decrease the output current. As a result of this feature, the device can control the system's output power at high ambient temperatures, to control the quantity of heat of the system. This enhances the safety of the system at high temperatures.

The thermal foldback waveform is shown below:

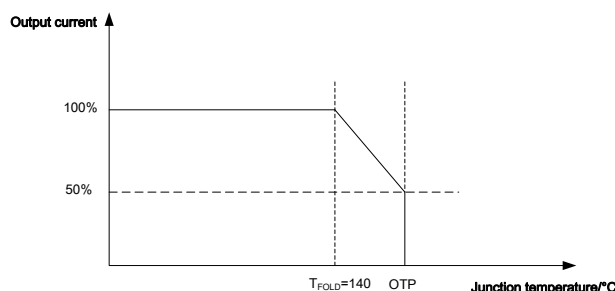


Figure 2. Thermal foldback waveform

### Over-Temperature Protection (OTP)

The AL1677 has OTP protection function. When the junction temperature reach to +170°C typical, the IC will trigger an over-temperature protection condition which causes the device to shut down and latched. Once OTP has triggered, the system will resume after the system's AC source supply has been reset and power up.

## Design Parameters

### Setting the Current Sense Resistor R5

The AL1677 uses peak current control method to obtain constant current control and senses the peak current of the inductance cycle by cycle. The sample value is compared with the internal 0.4V reference. When the sampling value is up to 0.4V, the IC control of the internal MOSFET will turn off.

The peak current of the inductance is:

## Application Information (continued)

$$I_{peak} = \frac{V_{CS\_REF}}{R5}$$

Where,

$V_{CS\_REF}$  is the reference of the current sense, and the typical value is 0.4V.  
R5 is the current sense resistor.

In no PF buck topology, the system operates at boundary conduct mode. The output current is:

$$I_{o\_mean} = \frac{1}{2} \cdot I_{peak}$$

Therefore, the current sense resistor R5 is determined:

$$R5 = \frac{1}{2} \cdot \frac{V_{CS\_REF}}{I_{o\_mean}}$$

### Inductance Selection (L1)

The AL1677 controls the system operating at boundary conduction mode, and the systems' operating frequency does not keep constant because of the fluctuation of the bus voltage. Set the minimum switching frequency  $f_{min}$  at the maximum bus voltage, and the buck inductance value L1 can be calculated by:

$$L1 = \frac{(\sqrt{2}V_{in\_rms} - V_o) \cdot R5 \cdot V_o}{V_{cs\_ref} \cdot \sqrt{2}V_{in\_rms} \cdot f_{min}}$$

Where,

$V_o$  is the output voltage.

$V_{in\_rms}$  is the RMS value of the input voltage.

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

$$N_{L1} = \frac{L1 \cdot I_{peak}}{A_e \cdot B_m} = \frac{L1 \cdot V_{CS\_REF}}{A_e \cdot B_m \cdot R5}$$

Where,

$A_e$  is the core effective area.

$B_m$  is the maximum magnetic flux density.

The AL1677 has designed the minimum  $t_{ON}$  time and maximum  $t_{ON}$  time. The  $t_{ON\_MIN}$  is about 700ns and the  $t_{ON\_MAX}$  time is about 35μs. In buck topology we can get the equation  $V_{in\_rms} \cdot V_o = L \cdot I_{peak} / t_{ON}$ . If the inductance is very small, leading the  $t_{ON}$  to become smaller, when the system's  $t_{ON}$  is smaller than  $t_{ON\_MIN}$ , the device cannot detect the peak current of the system, leading to incorrect output current. If the inductance is very large, leading  $t_{ON}$  to become larger when the system's  $t_{ON}$  is larger than the  $t_{ON\_MAX}$ , the system's output current will decrease because of the limit of the  $t_{ON\_MAX}$ . Therefore, the suitable value of the inductance is very important.

The AL1677  $t_{OFF\_MIN}$  time is about 6μs and  $t_{OFF\_MAX}$  time is about 200μs. In buck topology we use the equation  $V_o = L \cdot I_{peak} / t_{OFF}$ . If the inductance is very small, leading the  $t_{OFF}$  to become much smaller when the system's  $t_{OFF}$  is smaller than  $t_{OFF\_MIN}$ , the system will enter DCM mode, and the output current will be incorrect. If the inductance is very large, leading  $t_{OFF}$  to become much larger when the system's  $t_{OFF}$  is larger than the  $t_{OFF\_MAX}$ , the system will enter CCM mode, and the output current will also be incorrect. Therefore, the suitable value of the inductance is very important.

Consider these parameters, two examples of the typical application inductance is recommended as below:

System Spec.	Inductance Value	System Frequency	$T_{ON}$ Min	$T_{OFF}$
60V/150mA (185~265V <sub>AC</sub> )	2.3mH	60K(230 V <sub>AC</sub> )	2.5μs(265 V <sub>AC</sub> )	11.5μs
42V/100mA (85~265 V <sub>AC</sub> )	2.5mH	62K(230 V <sub>AC</sub> )	1.7μs(265 V <sub>AC</sub> )	12.1μs

## Application Information (continued)

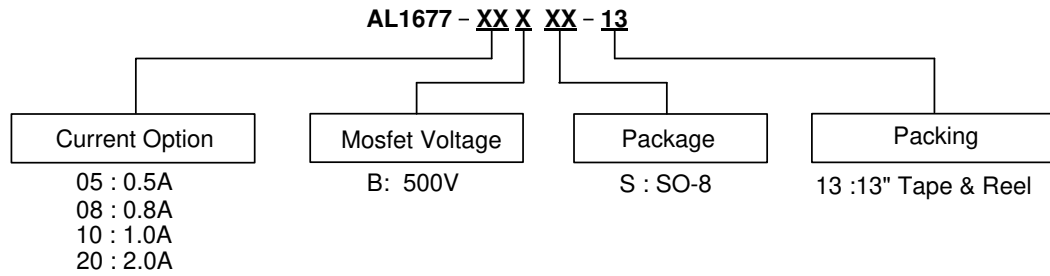
### Recommended Applications

The AL1677 integrates different MOSFETs to adapt different wattage applications. The output current is limited by the internal integrated MOSFET, and the SO-8 package's heat dissipation capability. The minimum output voltage is limited by the LEB time, and is recommended to 15V. The recommended application is given below:

Device	Output Power Coverage	Maximum Output Current (Note 10)	Minimum Output Voltage
AL1677-05BS-13	$\leq 5W$	$\leq 100mA$	15V
AL1677-08BS-13	$\leq 8W$	$\leq 120mA$	15V
AL1677-10BS-13	$\leq 10W$	$\leq 180mA$	15V
AL1677-20BS-13	$\leq 15W$	$\leq 240mA$	15V

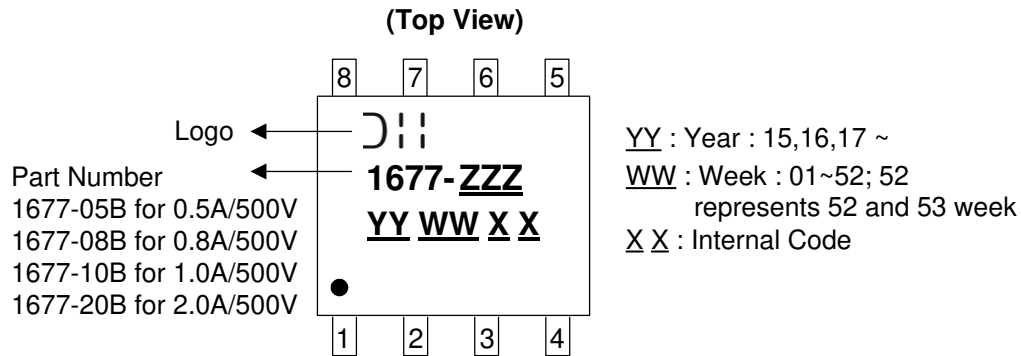
Note: 10. The higher output current is possible with extra power dissipation solution.

## Ordering Information



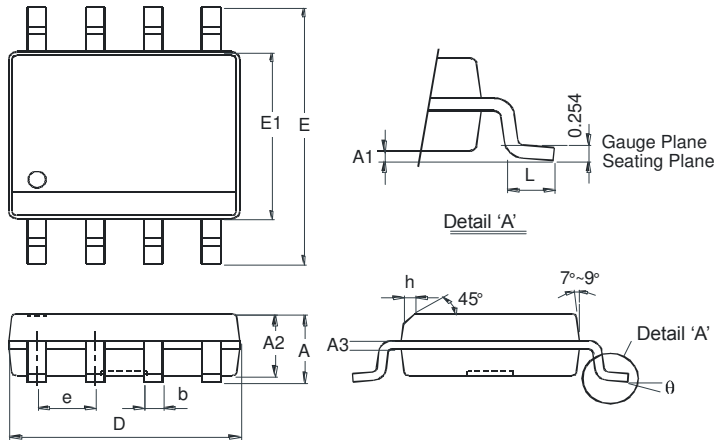
Part Number	Package Code	Package	13" Tape and Reel	
			Quantity	Part Number Suffix
AL1677-05BS-13	S	SO-8	4,000/Tape & Reel	-13
AL1677-08BS-13	S	SO-8	4,000/Tape & Reel	-13
AL1677-10BS-13	S	SO-8	4,000/Tape & Reel	-13
AL1677-20BS-13	S	SO-8	4,000/Tape & Reel	-13

## Marking Information



## Package Outline Dimensions (All dimensions in mm (inch).)

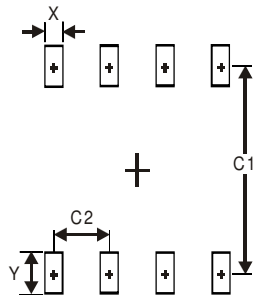
Please see AP02002 at <http://www.diodes.com/datasheets/ap02002.pdf> for the latest version.



SO-8		
Dim	Min	Max
A	-	1.75
A1	0.10	0.20
A2	1.30	1.50
A3	0.15	0.25
b	0.3	0.5
D	4.85	4.95
E	5.90	6.10
E1	3.85	3.95
e	1.27 Typ	
h	-	0.35
L	0.62	0.82
θ	0°	8°
All Dimensions in mm		

## Suggested Pad Layout

Please see AP02001 at <http://www.diodes.com/datasheets/ap02001.pdf> for the latest version



Dimensions	Value (in mm)
X	0.60
Y	1.55
C1	5.4
C2	1.27

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