Description

The AL17050 is a universal AC high voltage input step down regulator that provides accurate constant voltage (CV) and outstanding dynamic performance without requiring an opto-coupler over line and Load regulation. Typical applications are offline low power applications including home appliance applications and IoT applications.

Working with a single winding inductor and integrating a 500V MOSFET internal can make it use fewer external components and create a low Bill Of Material (BOM) cost solution.

The AL17050 achieves excellent regulation and high power efficiency. The characteristics of max peak current and driving frequency vary as the load change can get excellent efficiency performance at light load and improve the overall average efficiency.

The AL17050 has rich protection features to enhance the system safety and reliability. It has Over Temperature Protection, V_{CC} Under Voltage Lock function, Output Short Protection, Over Load Protection and Open Loop Protection.

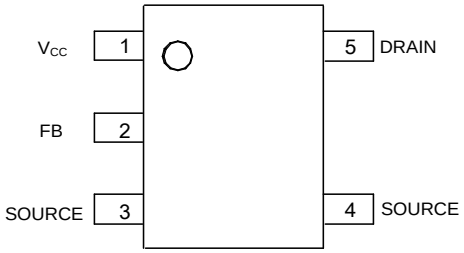
The AL17050 is available in the SOT25 package.

Features

- Universal 85 to 265 V_{AC} Input Range
- Constant Voltage (CV) Control
- Internal MOSFET up to 500V
- Low Operation Current: 100μA (Static)
- Under Voltage Lock Out (UVLO)
- Output Short Protection
- Over Load Protection
- Over Temperature Protection (OTP)
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**

Pin Assignments

(Top View)



SOT25

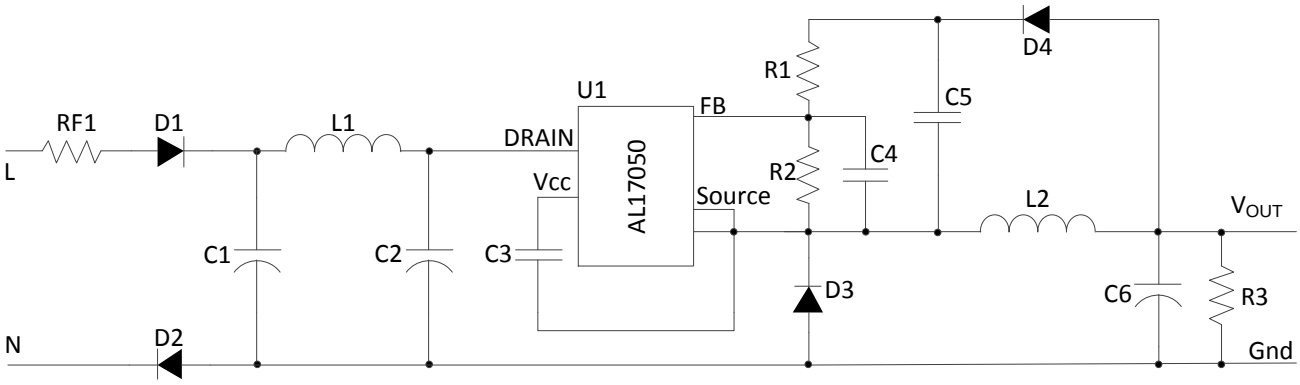
Applications

- Home Appliance Applications
- IoT Applications
- Industrial Controls
- Standby Power

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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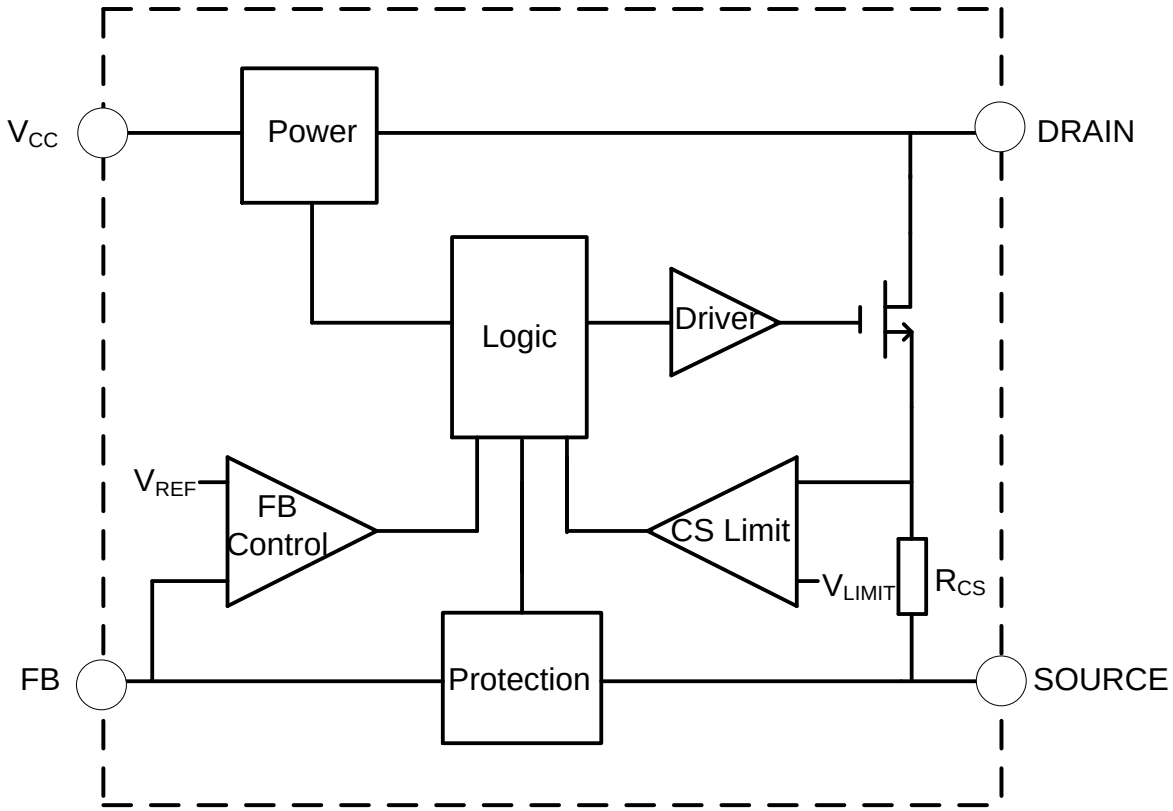
Typical Applications Circuit



Pin Descriptions

Pin Number	Pin Name	Function
1	V_{CC}	Control Circuit Power Supply
2	FB	Regulator Feedback
3,4	SOURCE	Internal power MOSFET Source. Ground reference for V_{CC} and FB Pins
5	DRAIN	Internal power MOSFET Drain. High voltage current source input

Functional Block Diagram



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Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Rating	Unit
V_{DSS}	Drain to Source	-0.7 to 500	V
	All Other Pins	-0.7 to 6.5	V
VCC	Operating V_{CC} Voltage	-0.7 to 6.5	V
P_D	Continuous Power Dissipation (T_A = +25°C) SOT25	1	W
T_{JSTOP}	Junction Temperature	+150	°C
T_J	Operating Junction Temperature	+125	°C
T_{STG}	Storage Temperature	-65 to +150	°C
T_{LEAD}	Lead Temperature (Soldering, 10s)	+300	°C
θ_{JA}	θ_{JA} Thermal Resistance (Junction to Ambient) SOT25	200	°C/W
ESD	ESD (Human Body Model)	4000	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 condition 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_A	Ambient Temperature	-40	+105	°C
VCC	Operating V_{CC} Voltage	5.3	5.6	V
I_{OUT}	Output Current with 3.3V/5V Output Voltage	-	60	mA
V_{DRAIN}	Operating DRAIN Voltage	-	400	V

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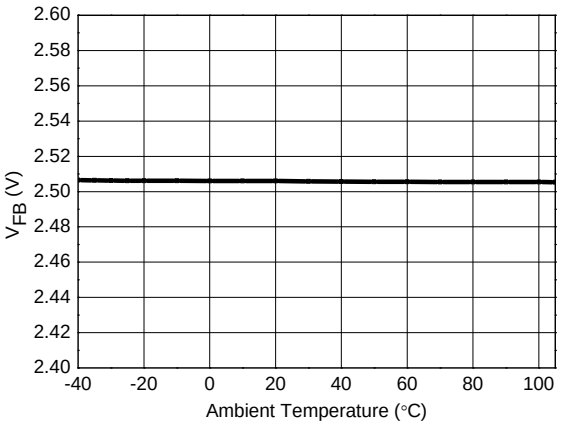
Electrical Characteristics (V_{CC} = 5.8V, T_A=+25°C, unless otherwise specified.)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
HV Start-up Current Source						
I_{HV}	HV Supply Current	V_{CC} = 4V; V_{DRAIN} = 100V	-	3.5	-	mA
I_{LEAK}	Leakage Current of Drain	V_{CC} = 5.8V; V_{DRAIN} = 400V	-	5	-	μA
Vcc Voltage Management						
VCC_HV_{OFF}	HV Supply OFF Threshold Voltage	-	-	5.6	-	V
VCC_HV_{ON}	HV Supply ON Threshold Voltage	-	-	5.3	-	V
-	HV Supply ON and OFF Hysteresis Voltage	-	-	300	-	mV
VCC_{UVLO}	Min Operating Voltage	-	-	3.4	-	V
$VCC_{RESTART}$	Restart Voltage	-	-	2.4	-	V
I_{CC_FULL}	Operating Current	V_{CC} = 5.8V, fs = 37kHz, D = 40%	-	320	-	μA
I_{CC_NL}	Standby Current	-	-	100	-	μA
I_{CC_LATCH}	Latch Off Current	V_{CC} = 5.3V	-	17	-	μA
Internal MOSFET						
V_{DS}	Breakdown Voltage	–	500	-	-	V
$R_{DS(ON)}$	ON Resistance	–	-	30	-	Ω
Internal Current Sense						
I_{PK_MAX}	Peak Current	-	-	220	-	mA
I_{PK_MIN}	Minimum Peak Current	-	-	70	-	mA
t_{LEB}	Leading Edge Blanking Time	-	-	350	-	ns
I_{SCP}	SCP Point Current	-	-	450	-	mA
Feedback Input (FB Pin)						
t_{MINOFF}	Minimum Off Time	-	-	14	-	μs
V_{FB}	MOSFET Feedback Switch-On Threshold	-	2.4	2.5	2.6	V
V_{FB_OLP}	OLP Feedback Trigger Threshold Voltage	-	-	1.7	-	V
t_{OLP}	OLP Delay Time	f_S = 37kHz	-	170	-	ms
V_{OLD}	Open-loop Detection Voltage	-	-	60	-	mV
t_{OLD}	OLD Active Time	f_S = 18kHz	-	3.6	-	ms
Thermal Shutdown						
T_{SD}	Thermal Shutdown Threshold Temperature	-	-	+150	-	°C

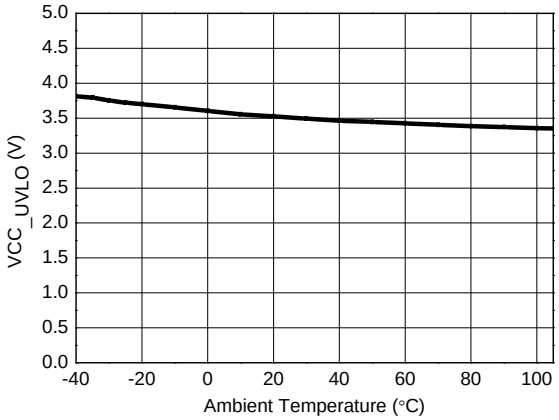
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Typical Characteristics (Note 5)

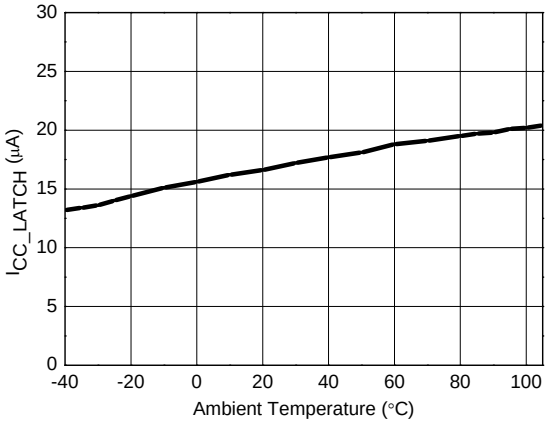
Feedback Threshold Voltage vs. Ambient Temperature



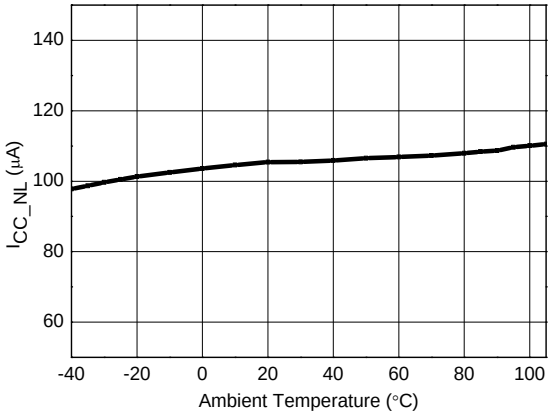
Min Operating Voltage vs. Ambient Temperature



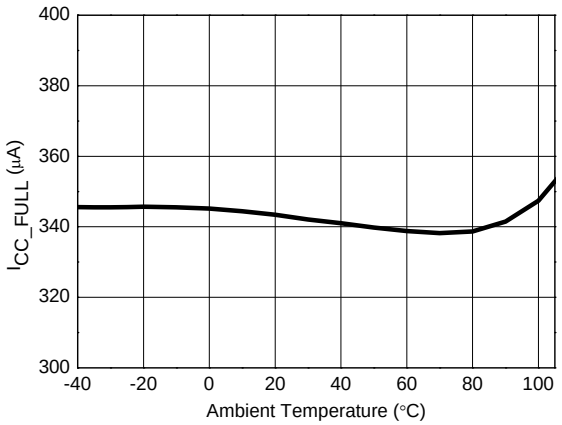
Standby Current vs. Ambient Temperature



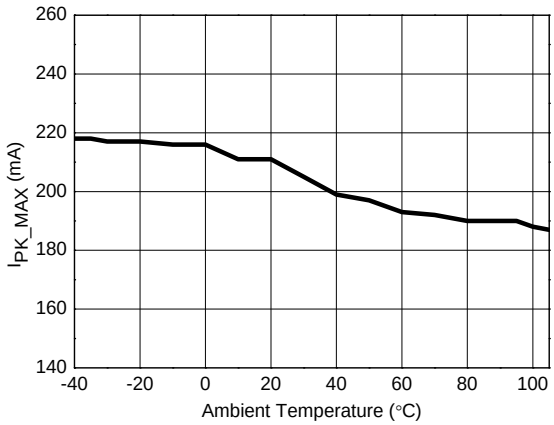
Latch Off Current vs. Ambient Temperature



Operating Current vs. Ambient Temperature



Peak Current vs. Ambient Temperature



Note 5: These electrical characteristics are tested under DC condition. The ambient temperature is equal to the junction temperature of the device.

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Function Description

Overall Introduction

The AL17050 is a universal AC input step down regulator. Max peak current limitation and driving frequency vary as the load change can get excellent efficiency performance at light load and improve the overall efficiency of system. Working with a single winding inductor and integrating a 500V MOSFET internal can make it use fewer external components and create a low BOM cost solution. Figure 1 shows a typical application example of a Buck power supply.

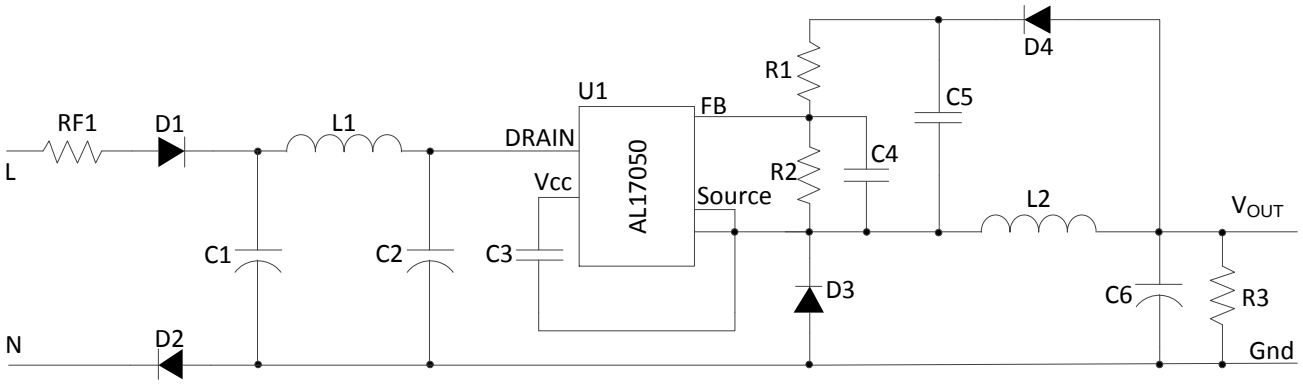


Figure 1 Typical Application Circuit

Converter Operation

Start-up and Under Voltage Lock-out

The IC control voltage VCC is charged by internal high voltage regulator. When the VCC voltage is charged to 5.6V, IC startups and the internal high voltage regulator is turned off; When the VCC voltage drops below 5.3V, the internal high voltage regulator turns on again to charge the external VCC capacitor. When the voltage on VCC drops below 3.4V, the IC stops; then the internal high-voltage regulator charges the VCC capacitor. Figure 2 shows the typical waveform with VCC.

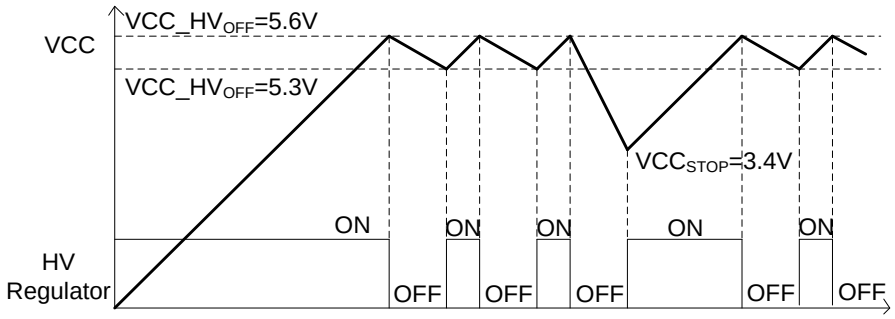


Figure 2 VCC Waveform and HV Regulator ON/OFF Status

Constant Voltage Operation

The AL17050 is a step down regulator with a 500V MOSFET integrated. It can be used in Buck circuit as shown in the typical application circuit.

In the course of running of IC, when the voltage of FB pin is below the reference voltage (2.5V), the internal integrated MOSFET turns ON. The peak current limit and the initial inductance current value altogether with the input voltage determine the ON period time. When the current reaches peak current limit, the internal integrated MOSFET turns OFF. The inductor current charges the sampling capacitor (C_5) and the output capacitor (C_6) via the freewheeling diode D_4 and D_3 respectively. The sampling capacitor voltage is the mapping of the output voltage. The output voltage can be controlled by sampling the voltage of feedback pin which is derived from the voltage of sampling capacitor. In the OFF stage of internal MOSFET, when the inductor current drops below the output current, the sampling capacitor voltage begins to decreases. When the voltage of feedback pin falls below the reference voltage (2.5V), a new switching cycle begins.

Figure 3 shows the detailed operation timing diagram under Discontinuous Conduction Mode (DCM).

Generally, the output voltage can be described as the following equation:

$$V_O = 2.5 \times (R_1 + R_2)/R_2 \quad \text{.....(1)}$$

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Function Description (Cont.)

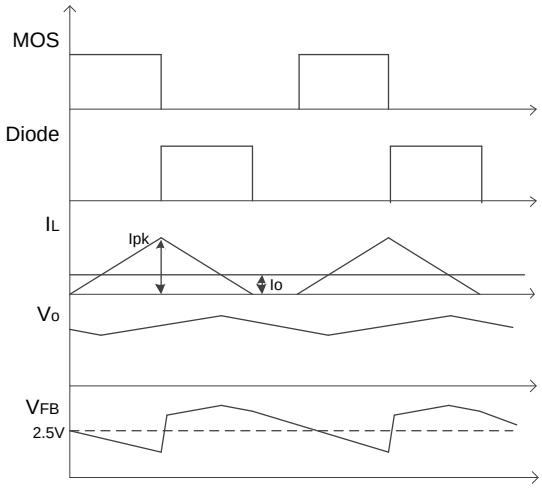


Figure 3 Operation Timing in DCM Mode

Frequency and Peak Current

To maintain high efficiency under different load condition, AL17050 adjusts the switching frequency automatically. Since AL17050 should be set to work in DCM mode under full load, the switching frequency can be obtained as:

$$f_s = \frac{2(V_{IN}-V_o)}{L \cdot I_{PK}^2} \cdot \frac{I_O V_O}{V_{IN}} \quad \text{.....(2)}$$

In the meantime, the peak current of the inductor (I_{PK}) is determined by the following equation:

$$I_{PK} = 220mA - (1mA/\mu s) \times (t_{OFF} - 14\mu s) \quad \text{.....(3)}$$

In the equation, t_{OFF} is internal MOSFET OFF time of the IC, and 220mA is peak current limit and 14μs is the minimum t_{OFF} value.

As the load decreases, the switching frequency decreases and the MOSFET OFF time t_{OFF} increases, leading to the decrease of peak current. In no load condition, in which only a dummy load is retained, the frequency and the peak current are both minimized. This helps to reduce the no load power consumption.

Start Up Control

The AL17050 implements a minimum OFF time control. In normal condition, the minimum OFF time limit is 14μs.

In the startup process, the output voltage is not established and more demagnetizing time is needed. Therefore, the soft start technique is adopted. During the startup process, the minimum MOSFET OFF time varies with three stages, and it gradually drops from 56μs, to 28μs, and then to 14μs. Each stage contains 128 switching cycles and the startup process will end if the desired output voltage is reached.

EA Compensation

To improve load regulation and load transient performance, AL17050 is designed with an error amplifier (EA) compensation function.

The compensation is related to the load condition. With an increasing load, the compensation value increases and the reference voltage of the internal feedback comparator is slightly pulled down. A faster change in the load will lead to a greater compensation step, and then the output voltage will be regulated back to the desired voltage faster. This compensation will precisely maintain the output voltage.

Leading-Edge Blanking

A narrow spike on the leading edge of the current waveform can usually be observed when the power MOSFET is turned on. A 350ns leading-edge blank is built-in to prevent the false-triggering caused by the turn-on spike. During this period, the current limit comparator is disabled and the gate driver cannot be switched off.

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Function Description (Cont.)

Protection

Short-Circuit Protection (SCP)

The AL17050 shuts down when the peak current exceeds the short-circuit protection threshold (450mA). The AL17050 will resume operation when the fault is removed.

Over Load Protection (OLP)

With the increase of load, the peak current and the switching frequency increase. When the peak current reaches the peak current limit value, the output voltage will decrease if the load continues to increase. When the feedback pin voltage drops below OLP trigger threshold (1.7V) and this state maintains 170ms, the OLP occurs.

This 170ms maintain time avoids triggering OLP when the power supply starts up or enters a load transition phase, and therefore requires that the power supply start up in less than 170ms.

Open Loop Detection

When the VFB drops below 60mV, the AL17050 will stop working and begins a re-start cycle. The open loop detection is blanked for 64 switching cycles during start-up stage.

Thermal shutdown (TSD)

AL17050 integrates an internal thermal shutdown protection function. If the IC junction temperature rises above TJ_{STOP} (typical value: +150°C), the thermal shutdown (TSD) protection is triggered and the internal MOSFET stops switching. To recover the switching of internal MOSFET, the IC junction temperature has to fall by a hysteresis of +30°C below the T_{JSTOP}. During TSD protection, V_{CC} drops to $VCC_{RESTART}$ (typical value 2.4V), and then the internal high voltage regulator recharges VCC.

Application and Implementation

AL17050 is a universal high voltage step-down regulator. Figure 1 shows a typical application for reference. The application can be used in a wide variety of home appliances and industrial control devices, or any other application where mains isolation is not required.

Input Stage

The input stage consists of RF_1, D_1, D_2, C_1, C_2 and L_1, Resistor RF_1 is a fusible resistor. RF_1 limits the inrush current, and also provides protection in case any component failure causes a short circuit. Value for its resistance is generally selected between 4.7Ω to15Ω. A half-wave rectifier is implemented with the diode D_1. It is a general purpose 1A/1000V diode. D_2 is added for improving common-mode conducted EMI noise performance and can be removed if not needed. Component C_1, L_1, C_2 forms a Pi EMI filter; Capacitor C_1 and C_2 also act as storage capacitors for the high-voltage input DC voltage.

When using the half-wave rectifier, set the input capacitor 3μF/W for the universal input condition. When using the full-wave rectifier, choose a smaller capacitor. To avoid thermal shutdown, capacitance selection must avoid the minimum DC voltage below 70V. And if passing surge test is needed for the converter, adjusting input capacitance can help to meet different surge test requirements.

VCC Capacitor

The VCC capacitor (C_3) acts as the storage capacitor for the IC internal power supply. A typical selection is a 2.2μF/10V SMD ceramic capacitor.

Inductor

AL17050 should be set to work in DCM mode under full load. In DCM Buck converter, the inductor peak-to-peak current ripple is the peak current, and it should be bigger than double of the output current.

$$\Delta I_L = I_{\mathrm{PK}} > 2 \times I_{OUT} \quad \text{.....(4)}$$

Therefore, the available output current with AL17050 should be less than half of the peak current limit, generally limited to 60mA.

In DCM mode, the peak current limit and the inductor determine the internal MOSFET turn-on time (t_{ON}). And t_{ON} can be given by Equation 5.

$$t_{ON} = \frac{L \cdot I_{PK}}{V_{IN} - V_O} \quad \text{.....(5)}$$

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Function Description (Cont.)

To guarantee normal operation, t_{ON} must be bigger than t_{LEB} with margin.

The Buck converter reaches maximum power when the off-time equals the minimum off time (t_{MINOFF}). Thus the maximum output power can be calculated as:

$$P_{OMAX} = \frac{1}{2} L \cdot I_{PK}^2 \cdot \frac{1}{t_{ON}+t_{\mathrm{MINOFF}}} \approx \frac{1}{2} L \cdot I_{PK}^2 \cdot \frac{1}{t_{\mathrm{MINOFF}}} \quad (6)$$

Since the on-time is generally far smaller than the off-time, the above approximation can be reasonable for estimation.

To design an inductor, the desired maximum output power is given according to the output specification. The desired peak current is also estimated, generally between 180mA and 220mA. Since t_{MINOFF} is 14μs, a minimum inductance can be calculated with Equation 6. The inductance should be checked with Equation 2, Equation 3, and Equation 5, and it should be adjusted to ensure that the on-time limitation is satisfied and the desired peak current under full load is met. Some inductance margin is also needed for tolerance.

With the inductance and its peak current value, a standard off-the-shelf inductor can be used to reduce cost.

Freewheeling Diode

The maximum reverse voltage that the diode would experience during normal operation is given by the following equation.

$$V_{D-MAX} = \sqrt{2} \times V_{INAC-MAX} \quad (7)$$

For a universal AC input application, the $265V_{AC}$, thus $V_{D\text{-}MAX}$ value is 375V .Considering a margin of 20%, a 600V diode is a general selection.

A fast recovery diode is required for the Buck application. Since AL17050 works in DCM under full load, slower diode can be used, but the reverse recovery time should be kept less than 100 ns. If even slower diode is to be chosen, special review is needed.

Output Capacitor

The output capacitor maintains the DC output voltage, and the value impacts the output ripple. Since AL17050 works in DCM mode, the output voltage ripple can be estimated as:

$$V_{OUT_RIPPLE} = \frac{I_{OUT}}{f_S C_{OUT}} \cdot \left(\frac{I_{PK}-I_{OUT}}{I_{PK}}\right) + I_{PK} \cdot R_{ESR} \quad (8)$$

Where f_S is the switching frequency, and R_{ESR} is ESR of output capacitor. For a typical application, the capacitor value can range from 47μF to hundreds of μF. If the total ripple is higher than the requirement, increasing the capacitance and reducing the ESR can help.

Dummy Load

The output requires a dummy load (R_3) to maintain the load regulation under no-load condition. This can ensure sufficient inductor energy to charge the sample-and-hold capacitor to detect the output voltage. Most applications can use a 3mA dummy load, and the dummy load can be adjusted according to the regulation. Increasing the dummy load adversely affects the efficiency and no-load consumption.

Feedback Path

R_1 and R_2 form a resistor divider that determines the output voltage. The values of R_1 and R_2 should be set to maintain the FB voltage at 2.5V. The typical value for R_2 is between 5kΩ to10kΩ and precision of R_1 and R_2 must be 1%.

$$V_{OUT} = V_{FB} \cdot \frac{R_1+R_2}{R_2} + V_{D3} - V_{D2} \approx V_{FB} \cdot \frac{R_1+R_2}{R_2} \quad (9)$$

For low output voltage application, the difference caused by D_3 and D_4 cannot be neglected and R_1 should be set larger to compensate the difference. Since the diode forward voltage is positively related with the current flows through it and the current through D_3 is much higher than D_4, V_{D3} is higher than V_{D4}.

The feedback capacitor provides a sample-and hold function and the capacitance selection should conform to the following equation.

$$\frac{V_{OUT}}{2(R_1+R_2)} \cdot \frac{C_6}{I_{OUT}} < C_5 < \frac{V_{OUT}}{(R_1+R_2)} \cdot \frac{C_6}{I_{OUT}} \quad (10)$$

The capacitor C_5 is discharged with a time constant that is $\tau_{FB} = C_5 \cdot (R_1 + R_2)$ and $\tau_{OUT} = C_6 \cdot V_{OUT}/I_{OUT}$ Can be regarded as the load time constant. If τ_{FB} is larger than τ_{OUT}, voltage on C_5 could be larger than V_{OUT} when sampling, leading to wrong sampling of V_{OUT} and wrong regulation. And if $\tau_{FB}$is too small, voltage on FB pin could drop to 1.7V before the next MOSFET OFF time come and thus mis-trigger Over Load Protection(OLP). Therefore, an appropriate value of C_5 is important.

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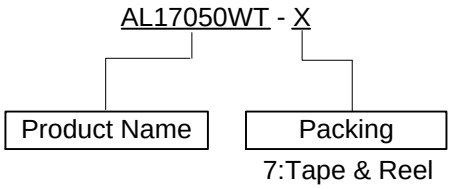
Function Description (Cont.)

Layout Guidelines

PCB layout is important to achieve reliable operation, good EMI, and thermal performance. Follow these guidelines to optimize performance.

- Minimize the loop area formed by the input capacitor, IC part, freewheeling diode, inductor and output capacitor.
- The copper area of the FB signal should be minimized to reduce coupling to feedback path.
- A several-hundred pF capacitor should be added between the FB and source pins, and be placed as close as to the FB pin as possible.
- Place the power inductor far away from the input filter.
- Connect the exposed pad with the Drain pin to a large copper area to improve thermal performance.

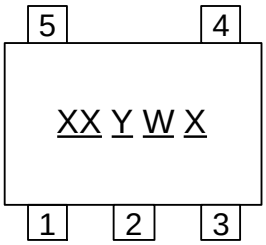
Ordering Information



Part Number	Package	Identification Code	7' Tape and Reel	
			Quantity	Part Number Suffix
AL17050WT-7	SOT25	AK	3000/Tape & Reel	-7

Marking Information

(Top View)

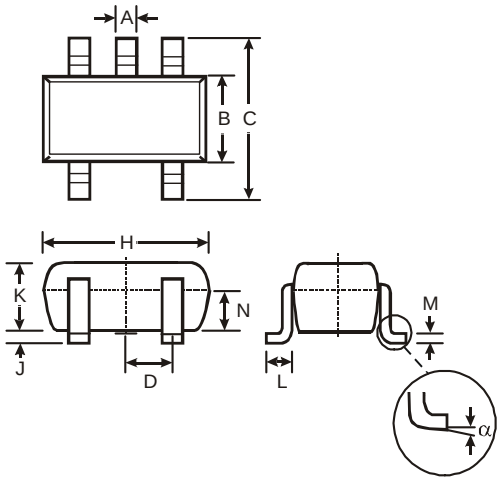


XX : Identification Code
Y : Year 0 to 9
W : Week : A to Z : 1 to 26 week;
a to z : 27 to 52 week; z represents 52 and 53 week
X : Internal Code

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

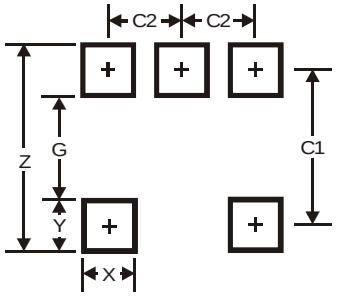
Please see http://www.diodes.com/package-outlines.html for the latest version.
Package Type: SOT25



SOT25			
Dim	**Min**	**Max**	**Typ**
A	0.35	0.50	0.38
B	1.50	1.70	1.60
C	2.70	3.00	2.80
D	-	-	0.95
H	2.90	3.10	3.00
J	0.013	0.10	0.05
K	1.00	1.30	1.10
L	0.35	0.55	0.40
M	0.10	0.20	0.15
N	0.70	0.80	0.75
α	0°	8°	-
All Dimensions in mm			

Suggested Pad Layout (Note 6 and Note 7)

Please see http://www.diodes.com/package-outlines.html for the latest version.
Package Type: SOT25

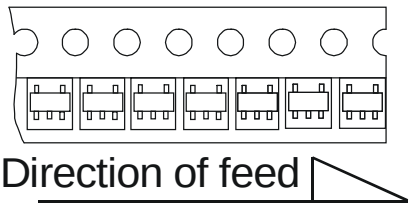


Dimensions	Value
Z	3.20
G	1.60
X	0.55
Y	0.80
C1	2.40
C2	0.95

Note 6: The suggested land pattern dimensions have been provided for reference only, as actual pad layouts may vary depending on application. These dimensions may be modified based on user equipment capability or fabrication criteria. A more robust pattern may be desired for wave soldering and is calculated by adding 0.2 mm to the 'Z' dimension. For further information, please reference document IPC-7351A, Naming Convention for Standard SMT Land Patterns, and for International grid details, please see document IEC, Publication 97.

Note7: For high voltage applications, the appropriate industry sector guidelines should be considered with regards to creepage and clearance distances between device Terminals and PCB tracking.

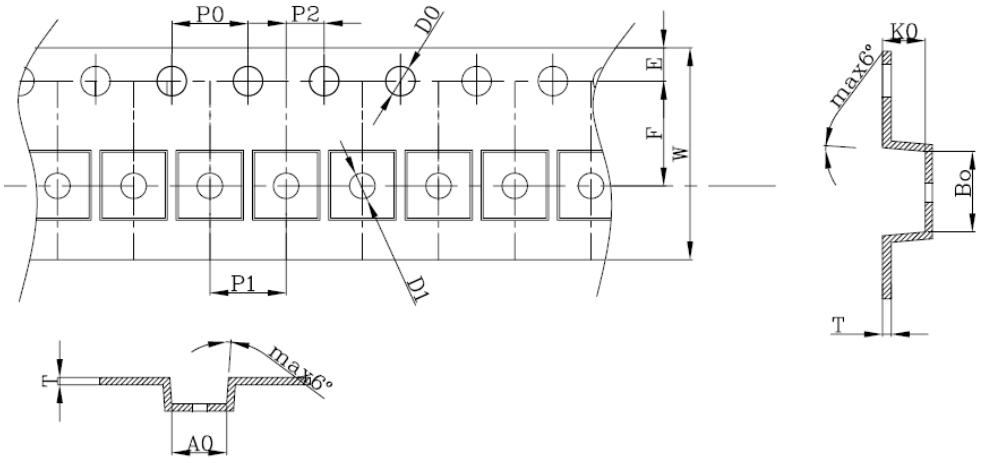
Device Tape Orientation

Tape Width	Tape Orientation
8mm	***Note 8: Analogue Only*** 

Note 8: Tape and package drawings are not to scale and are shown for device tape orientation only.

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Embossed Carrier Tape Specification

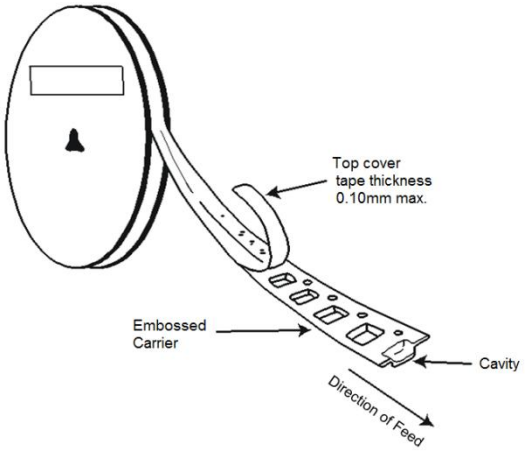


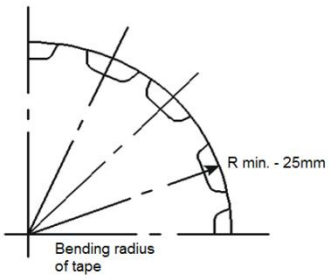
First Source

Tape Width (W)	Dimension	Value (mm)	Dimension	Value (mm)	Dimension	Value (mm)
8mm	**A0**	3.25 ± 0.1	**P1**	4.0 ± 0.1	**F**	3.5 ± 0.05
	B0	3.15 ± 0.1	**P2**	2 ± 0.05	**D0**	1.55 ± 0.05
	K0	1.5 ± 0.1	**T**	0.2 ± 0.02	**D1**	1.1 ± 0.1
	P0	4.0 ± 0.1	**E**	1.75 ± 0.1	**W**	8/+0.3/-0.1
	A0 B0 K0	Determined by component size. The clearance between the component and the cavity must comply to the rotational and lateral movement requirement provided in figures in the "Maximum Component Movement in Tape Pocket" section.				

Second Source

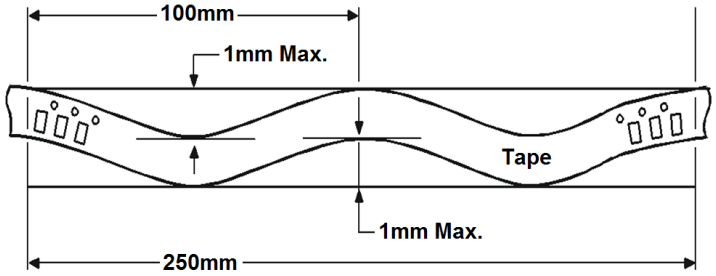
Tape Width (W)	Dimension	Value (mm)	Dimension	Value (mm)	Dimension	Value (mm)
8mm	**A0**	3.23 ± 0.1	**P1**	4.0 ± 0.1	**F**	3.5 ± 0.05
	B0	3.17 ± 0.1	**P2**	2 ± 0.05	**D0**	1.50+0.1
	K0	1.37 ± 0.1	**T**	0.23 ± 0.02	**D1**	1.0+0.25
	P0	4.0 ± 0.1	**E**	1.75 ± 0.1	**W**	8/+0.3/-0.1
	A0 B0 K0	Determined by component size. The clearance between the component and the cavity must comply to the rotational and lateral movement requirement provided in figures in the "Maximum Component Movement in Tape Pocket" section.				





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Embossed Carrier Tape Specification (Cont.)



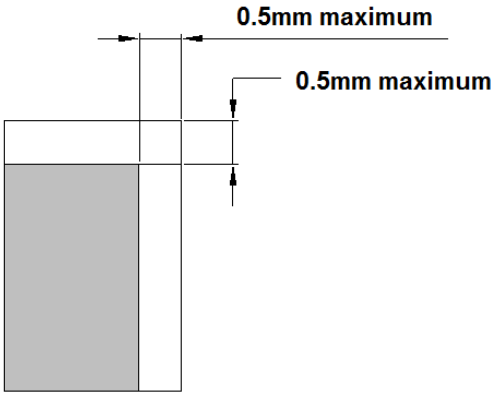
Camber (Top View)

Allowable camber to be 1mm/100mm tape, non-cumulative

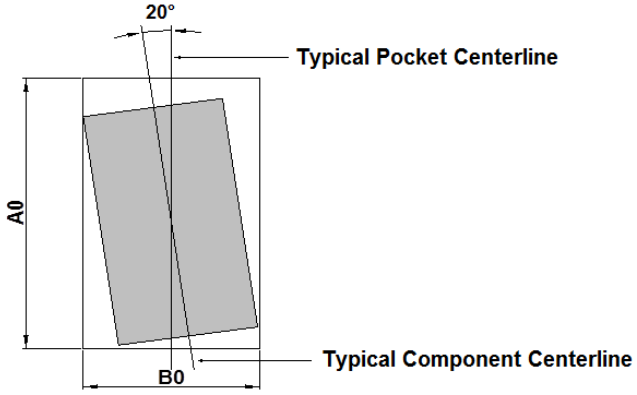
Maximum Component Movement in Tape Pocket

Component Lateral Movement

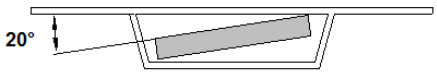
8mm Tape



Maximum Component Rotation Top View

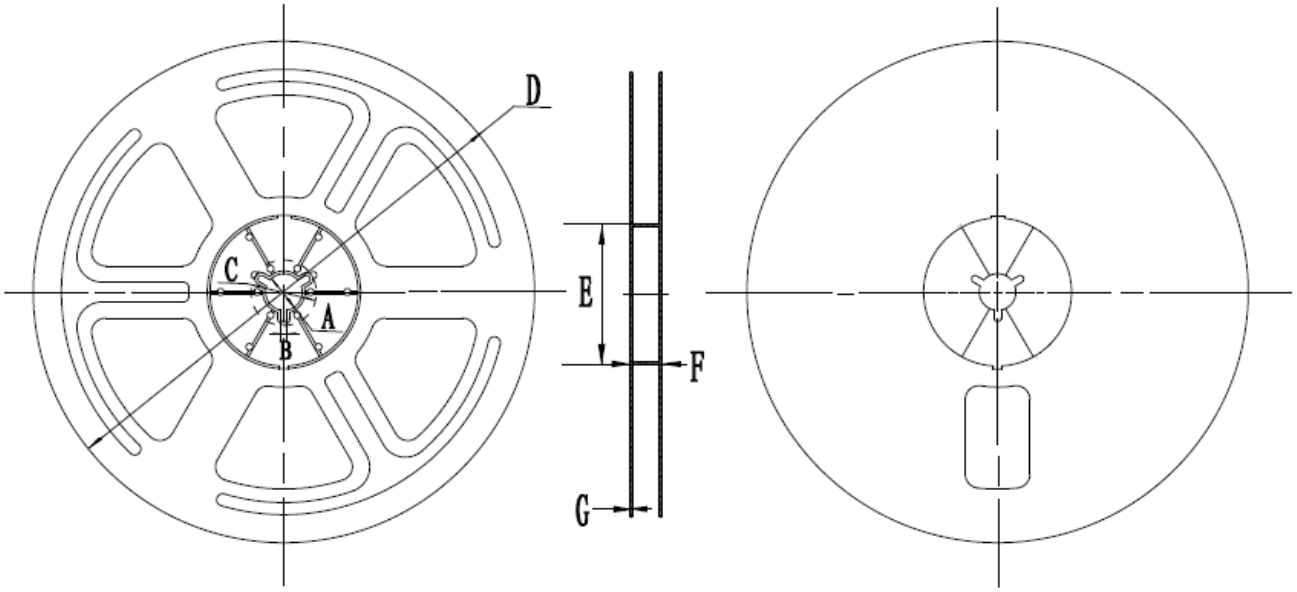


Maximum Component Rotation Side View



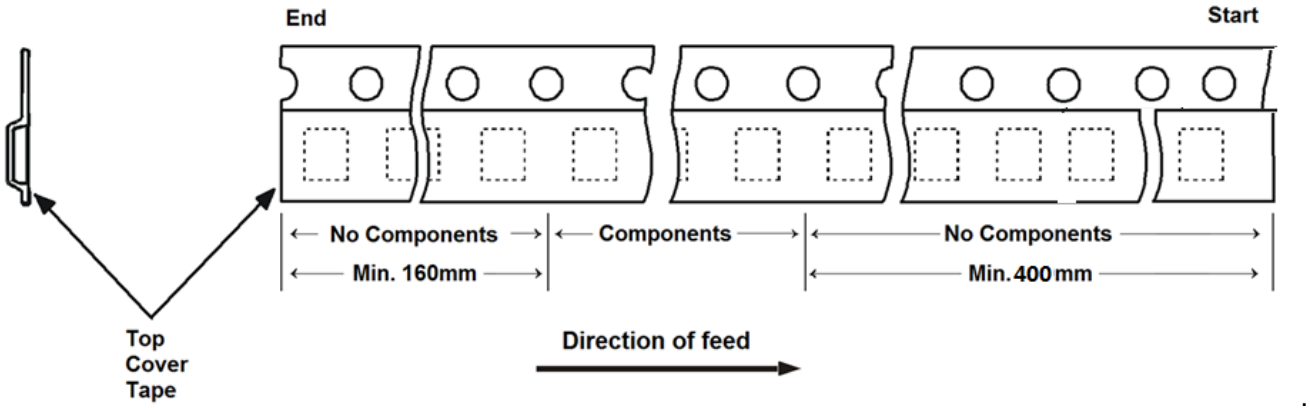
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Surface Mount Reel Specifications



Tape Width	Reel Size	A (mm)	B (mm)	C (mm)	D (mm)	E (mm)	F (mm)	G (mm)
8mm	7”	12.8~13.5	≥1.6	≥20.2	Φ178±2	54~54.5	8.4~9.9	1.4 ± 0.3

Tape Leader and Trailer Specifications (Note 9 and Note 10)



Note 9: There shall be a leader of at least 400mm empty carrier tape sealed with cover tape.

Note 10: There shall be a trailer of at least 160mm of empty carrier tape sealed with cover tape. The entire carrier tape must release from the reel hub as the last portion of the tape unwinds from the reel without damage to the carrier tape and the remaining components in the cavities.

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