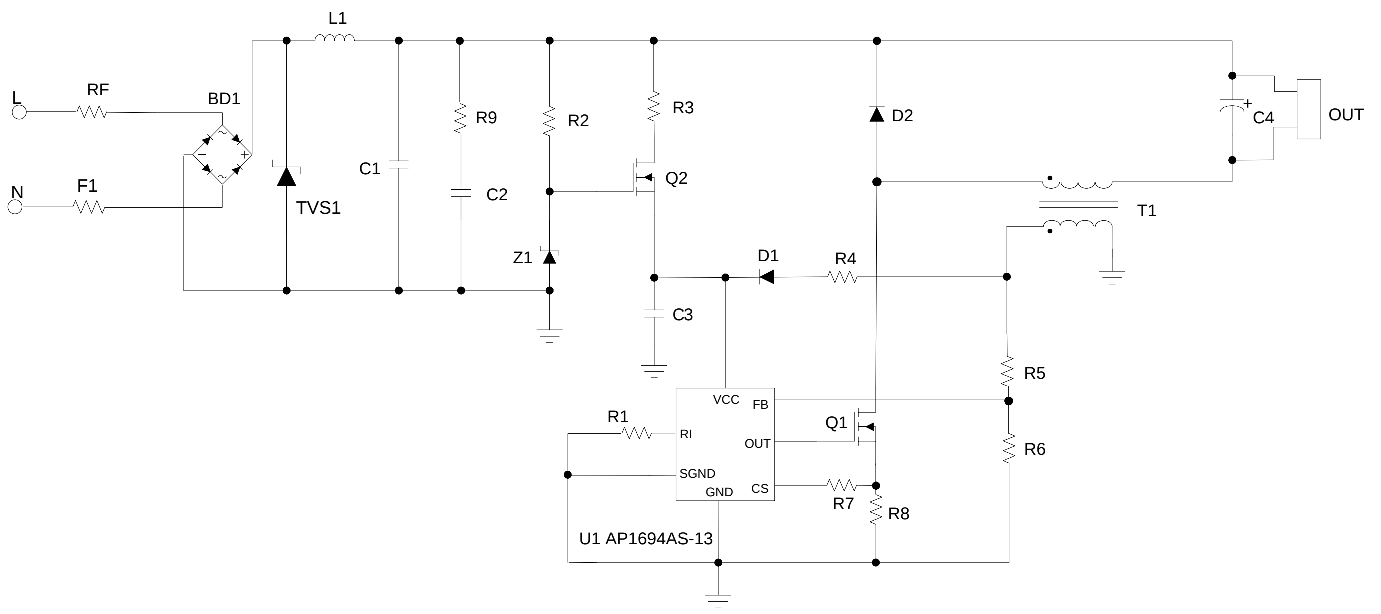
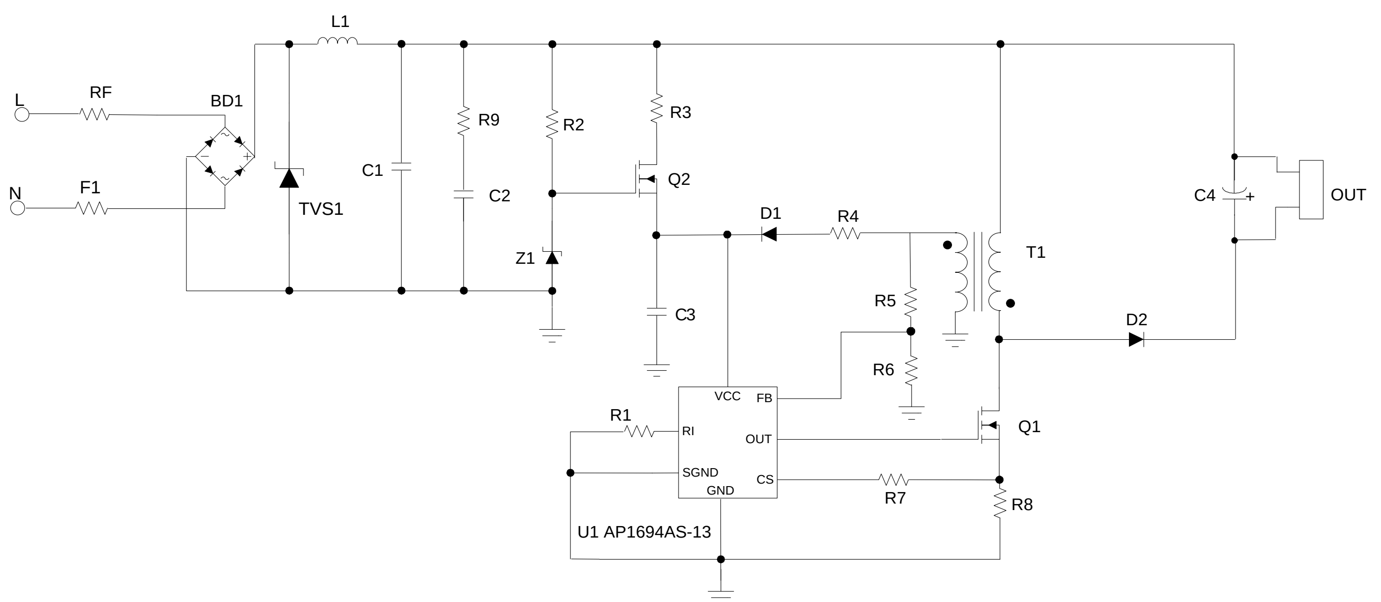
Typical Applications Circuit



Typical Buck Application



Typical Buck-Boost Application

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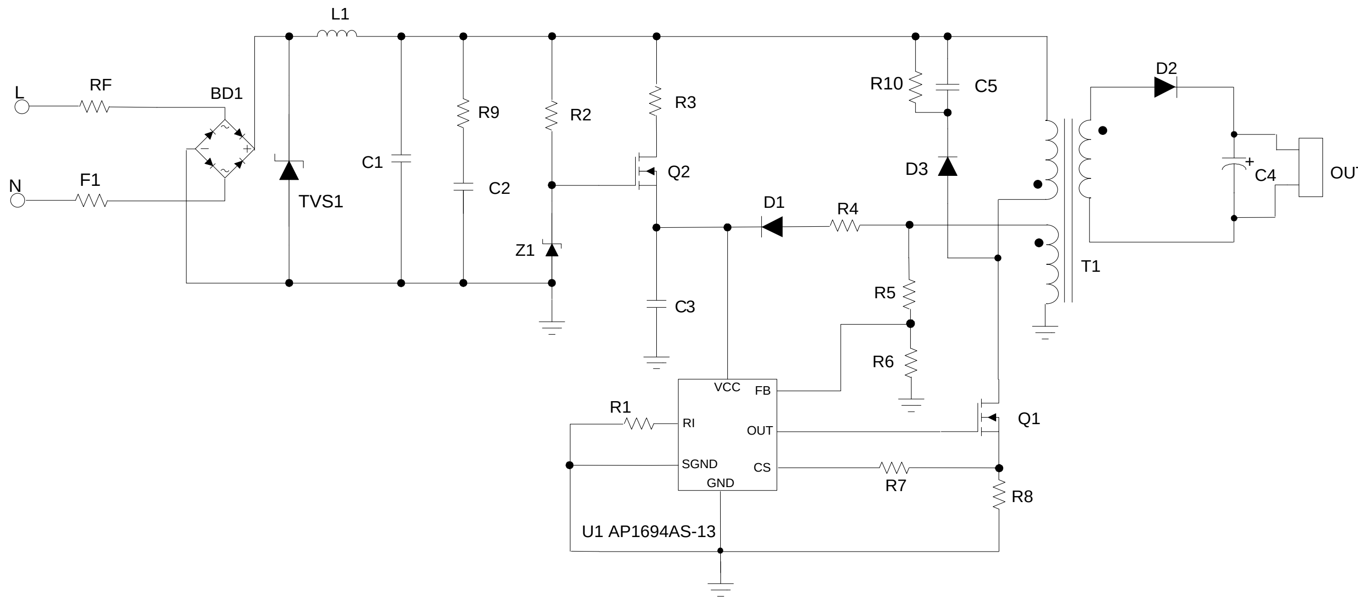
Typical Applications Circuit (continued)

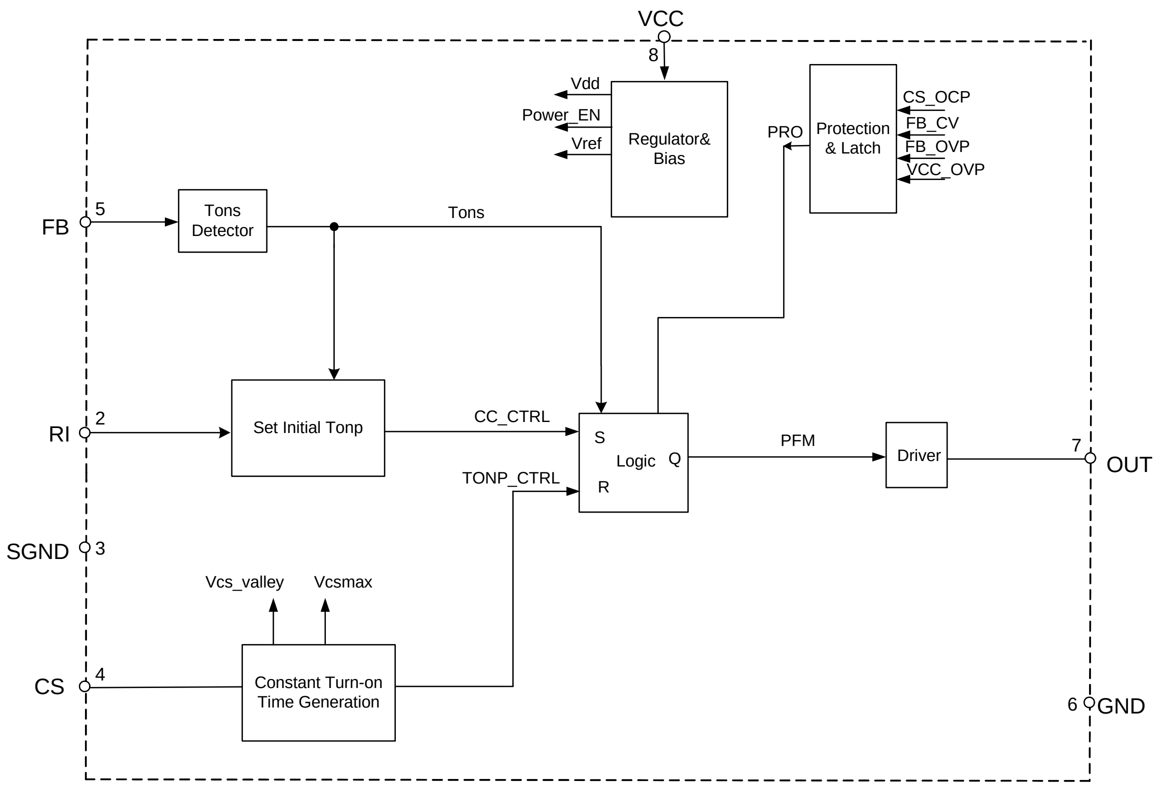


Typical Fly-Back Application

Pin Descriptions

Pin Number	Pin Name	Function
1	NC	No connection.
2	RI	The initial on time setting resistor.
3	SGND	Must connect to GND.
4	CS	Primary current sensing.
5	FB	The feedback voltage from auxiliary winding.
6	GND	Ground.
7	OUT	Gate driver output.
8	VCC	Supply voltage of gate driver and control circuits of the IC.

Functional Block Diagram



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

Symbol	Parameter	Rating	Unit
V_{CC}	Power Supply Voltage	-0.3 to 35	V
I_{OUT}	Driver Output Current	150	mA
V_{CS}	Voltage at CS to GND	-0.3 to 7	V
V_{FB}	FB Input Voltage	-40 to 10	V
T_J	Operating Junction Temperature	-40 to +150	°C
T_{STG}	Storage Temperature	-65 to +150	°C
T_{LEAD}	Lead Temperature (Soldering, 10 sec)	+300	°C
P_D	Power Dissipation (T_A = +50°C)	0.65	W
θ_{JA}	Thermal Resistance (Junction to Ambient)	160	°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.

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Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{CC}	Power Supply Voltage	7	25	V
T_A	Ambient Temperature	-40	+105	°C

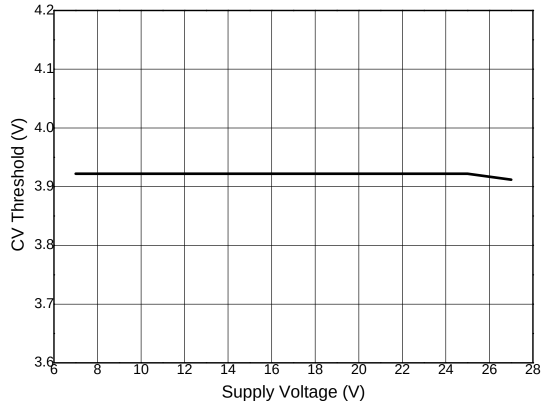
Electrical Characteristics (@T_A = +25°C, unless otherwise specified.)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
UVLO Section						
V_{TH} (ST)	Start-up Threshold	–	13	14.5	16	V
V_{OPR} (Min)	Minimum Operating Voltage	After turn on	5.5	6.5	7.5	V
V_{CC_OVP}	VCC OVP Voltage	–	27	29	31	V
–	VCC Delatch Voltage (Note 5)	–	3	4	5	V
Standby Current Section						
I_{ST}	Start-up Current	V_{CC} = V_{TH} (ST) -0.5V, Before start up	–	–	20	µA
I_{CC} (OPR)	Operating Current	Static	–	900	1,300	µA
Drive Output Section						
V_{GATE}	Gate Voltage	–	11	12	14	V
I_{SOURCE_L}	Low Driver Source Current	–	35	40	45	mA
I_{SOURCE_H}	High Driver Source Current	–	90	100	120	mA
$R_{DS(on)}$	Sink Resistance	–	6	7	8	Ω
Current Sense Section						
V_{CS_REF}	Current Sense Reference	–	–	1	–	V
V_{CS_CLAMP}	Current Sense Reference Clamp	–	1.2	1.4	–	V
t_{ONP_MIN}	Minimum t_{ONP}	–	700	–	1,000	ns
$t_{D(H-L)}$	Delay to Output (Note 5)	–	50	150	250	ns
Feedback Input Section						
I_{FB}	Feedback Pin Input Leakage Current	V_{FB} = 2V	–	–	4	µA
V_{FB_CV}	FB CV Threshold	–	3.8	4	4.2	V
V_{FB_OVP}	FB OVP Threshold	–	4.5	6	7.5	V
Output Current						
–	System Output Current On Final Test Board	–	–	–	±2	%
Over Temperature Protection Section						
–	Shutdown Temperature (Note 5)	–	+150	–	–	°C
–	Temperature Hysteresis (Note 5)	–	–	+20	–	°C

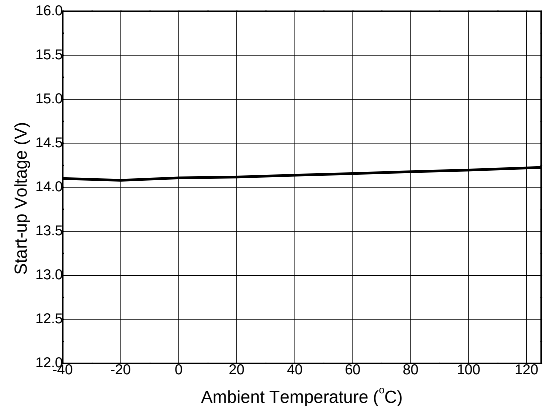
Note 5: These parameters, although guaranteed by design, are not 100% tested in production.

Performance Characteristics

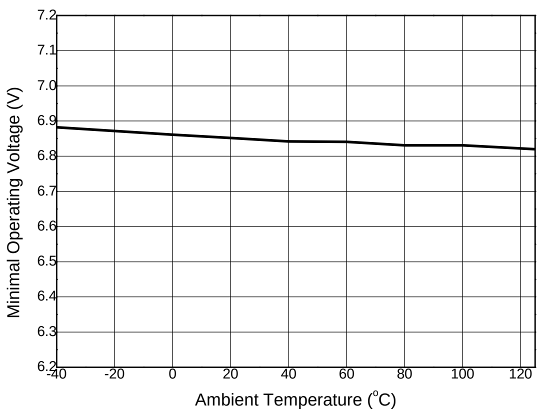
CV Threshold vs. Supply Voltage



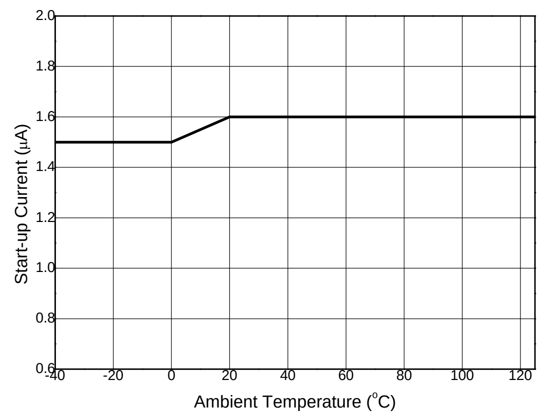
Start-up Voltage vs. Ambient Temperature



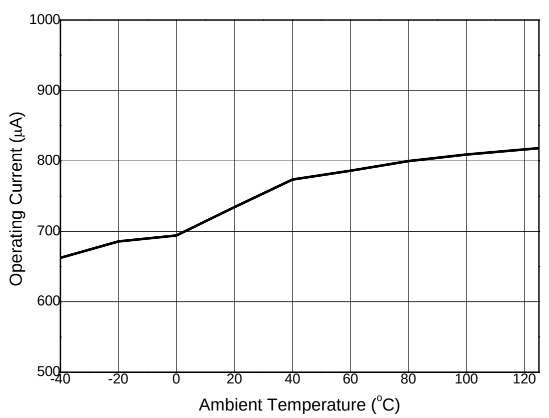
Minimal Operating Voltage vs. Ambient Temperature



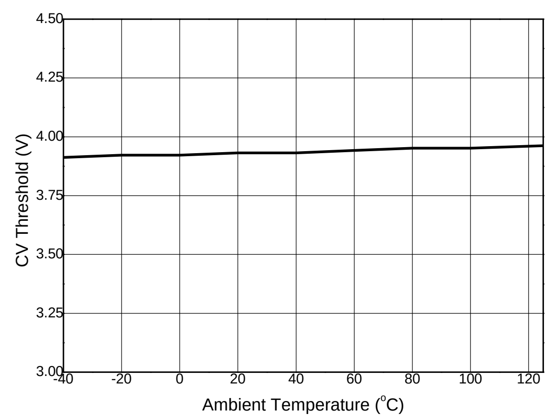
Start-up Current vs. Ambient Temperature



Operating Current vs. Ambient Temperature



CV Threshold vs. Ambient Temperature



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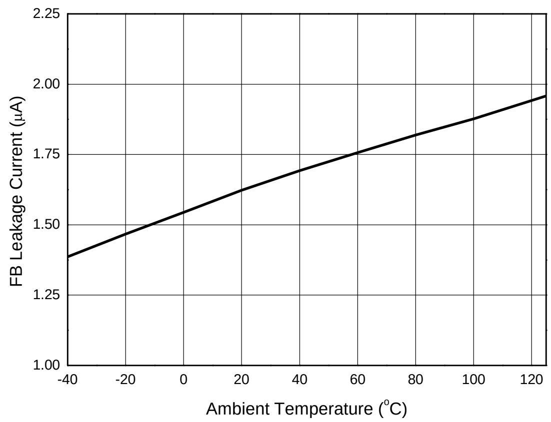
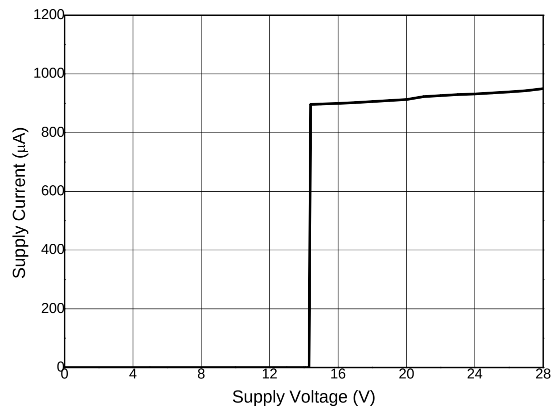
Performance Characteristics (continued)

FB Leakage Current vs. Ambient Temperature



Supply Current vs. Supply Voltage



Application Information Based on Buck Structure

The AP1694AS-13 uses constant on time control method within one AC cycle to achieve the high power factor. When the dimmer is connected to the driver, although a part of input voltage is cut off by the dimmer, the system still operates in constant on time mode. In this way, good dimmer compatibility can be realized.

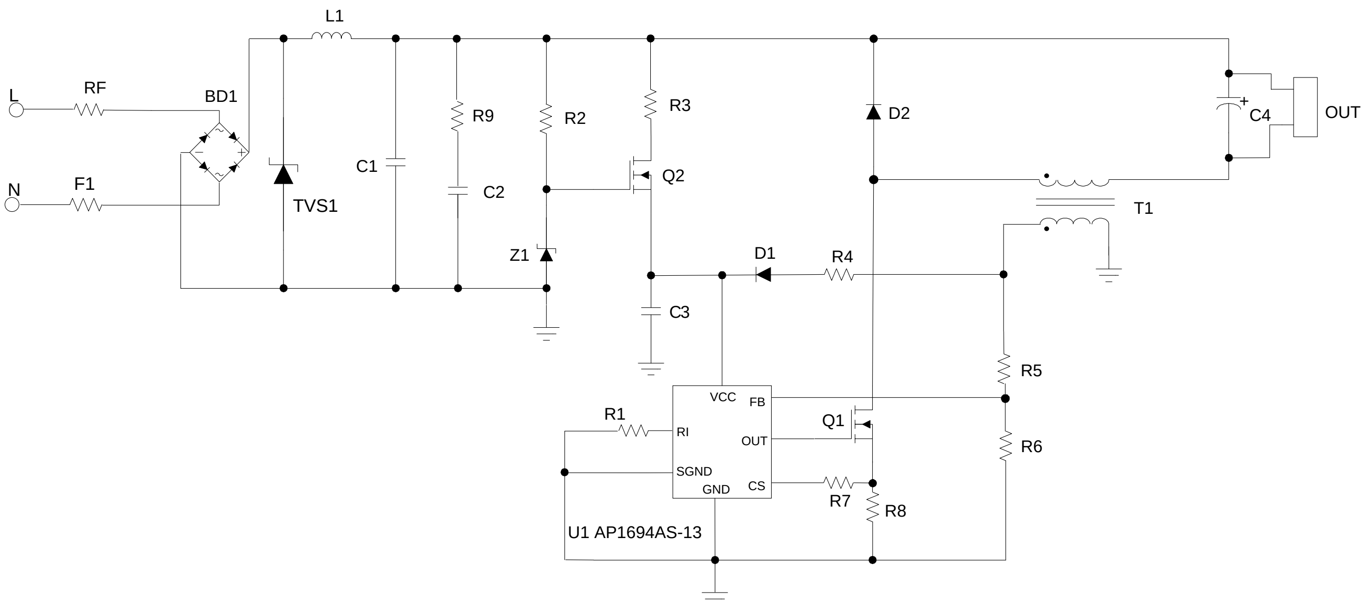


Figure 1. Typical Buck Application Circuit

When the dimmer is connected, and the conduction angle of the dimmer is $\pi - \alpha$; according to the control principle of the IC, the output current can be determined as:

$$I_o(\alpha,\theta) = \frac{1}{2} \cdot I_{pk}(\alpha,\theta) = \begin{cases} \frac{1}{2} \cdot \frac{V_{cs\_ref}}{R8} \cdot \sin(\theta) & if(\theta > \alpha) \\ 0 & else \end{cases}$$

In consideration of the dead zone of the buck structure, the output current DC value can be calculated as below:

$$I_{o\_mean} = k \cdot \frac{1}{\pi} \int_0^{\pi} I_o(\alpha,\theta) d\theta$$

Where,

V_{cs_ref} is the reference of the current sense, and the typical value is 1V.

α is the cutoff angle of dimmer.

θ is the phase of the input voltage.

k is the current modification coefficient , and the value is approximate to be 0.7.

When no dimmer is connected with the driver ($\alpha = 0$), the output current DC value can be calculated by:

$$I_{o\_mean} = k \cdot \frac{1}{\pi} \cdot \frac{V_{cs\_ref}}{R8}$$

Application Information Based on Buck Structure (continued)

Design Parameters

Setting the Current Sense Resistor R8

According to the equation of the output current, the current sense resistor R8 is determined:

$$R8 = k \cdot \frac{V_{cs\_ref}}{\pi \cdot I_{o\_mean}}$$

Transformer Selection

The typical non-isolated buck circuit in Figure 1 is usually selected, and the system is operating at boundary conduction mode. The switching frequency at the crest is set as f_{min}, the inductance can be calculated as below:

$$L = \frac{(\sqrt{2} \cdot V_{in\_rms} - V_o) \cdot R8 \cdot V_o}{V_{cs\_ref} \cdot \sqrt{2} \cdot V_{in\_rms} \cdot f_{\min}}$$

Where,

V_o is the output voltage.

V_{in_rms} is the RMS value of the input voltage.

According to Ferrari's law of electromagnetic induction, the winding turns number of the buck inductance N_L is:

$$N_L = \frac{L \cdot i_{pk}}{A_e \cdot B_m} = \frac{L \cdot V_{cs\_ref}}{A_e \cdot B_m \cdot R8}$$

Where,

A_e is the core effective area.

B_m is the maximum magnetic flux density.

The auxiliary winding is the power supply for V_{CC}, the winding turns number N_{aux} is:

$$N_{aux} = N_L \cdot \frac{V_{cc}}{V_o + V_d}$$

Where,

V_{CC} is the power supply voltage for IC from auxiliary winding.

V_d is the voltage drop of the freewheel diode.

Setting the Initial On Time

As the AP1694AS-13 adopts the constant on time control method, the AP1694AS-13 will generate an initial on time to start a working cycle. If the initial on time is longer than the rated on time, overshoot will happen. The initial on time is determined by resister R1 shown in Figure 1.

According to the initial on time generation mechanism, the $t_{on\_initial}$ is:

$$t_{on\_initial} = 80 \cdot R1 \cdot 10^{-12} s$$

To guarantee the system with no overshoot phenomenon, the resistor R1 is selected:

$$R_1 \le \frac{1.25 \cdot L}{R8 \cdot \sqrt{2} U_{in\_rms\_\max}} \cdot 10^{10} \Omega$$

Application Information Based on Buck Structure (cont.)

In dimmable application, on the condition of the acceptable line regulation, the smaller R1 is selected, as it will be better for dimming performance.

Valley On Control Method

The valley on function can provide low turn-on switching losses for buck converter. The voltage across the power-switch is reflected by the auxiliary winding of the buck transformer. The voltage is sensed by FB pin.

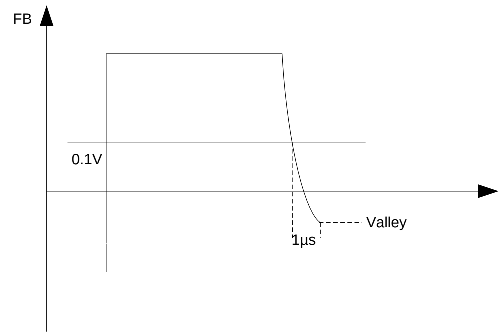


Figure 2.Valley On-Control

According to Figure 2, when the falling edge of 0.1V is sensed by FB pin, the AP1694AS-13 will see the toff time is over and delay 1µs to start a new operating cycle. By this way we can realize valley on function.

Passive Damping and Bleeder Design

The passive bleeder is designed to supply latching and holding current to eliminate misfire and flicker.

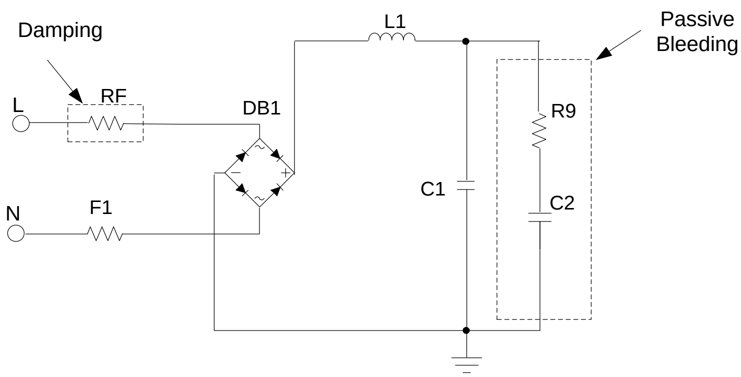


Figure 3. LED Driver Schematic with Passive Bleeder

A passive bleeder is composed of a resister (R9) and a capacitor (C2). C1 is input filter capacitor and RF is damper resistor.

The passive bleeder includes a capacitor (C2, hundreds of nF) to provide latching current. To remove the voltage and current spike, a resistor (R9) is necessary to dampen the spike.

In dimmable application, because a large C2 will affect the PF, THD and efficiency, the value of the capacitor (C2) selected should be suitable. Generally, 100nF/400V to 330nF/400V is recommended.

RF is the damper for reducing the spike current caused by quick charging of C2 at firing. RF is selected from 20Ω to 100Ω for low-line application, and 51Ω to 200Ω for high-line application. If R9 is too small, R9 can't fully dampen the spike current and ringing current will occur. The ringing current will cause the TRIAC misfire which will cause LED flicking. Another consideration in R9 selection is power loss; an R9 that is too large will make more power dissipation. Generally, a 200Ω to 2KΩ resistor is selected for R9.

Application Information Based on Buck Structure (cont.)

Fault Protection
Over Voltage Protection and Output Open Protection

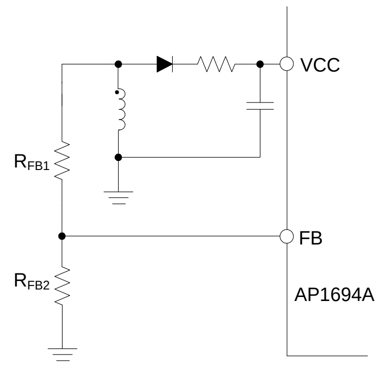


Figure 4. OVP Circuit

The output voltage is sensed by the auxiliary winding voltage of the Buck transformer. The VCC pin and FB pin provide over voltage protection function. When the output is open or large transient happens, the output voltage will exceed the rated value. When the voltage of $V_{cc\ cap}$ exceeds V_{CC_OVP} or V_{FB_CV}, the over voltage is triggered and the IC will discharge V_{CC}. When the V_{CC} is below the UVLO threshold voltage, IC will start a new work cycle and the $V_{cc\ cap}$ is charged again by start resistance. If the over voltage condition still exists, the system will work in hiccup mode.

Attention: If the external fast startup circuit is adding in the application and the over voltage protection and output open protection happen, the IC will trigger latch.

Output Short Protection
When the output is shorted, the output voltage will be clamped at zero. At this condition, V_{CC} will drop down without auxiliary winding for power supply, and the V_{CC} will drop to UVLO threshold voltage. The IC will shut down and restart a new operating cycle, and the V_{CC} is charged by startup resistance. When V_{CC} is higher than V_{cc_start} voltage, IC will output a bunch of pulses to control power switch on and off. When still no FB signal detected, the device will not output more pulses. The V_{CC} will again drop to V_{CC} UVLO threshold. If output short condition still exists, the system will operate in hiccup mode.

Attention: If the external fast startup circuit is adding in the application, the device will not work at UVLO mode, and the device will work at minimum toff mode.

Over Temperature Protection
AP1694AS-13 has two kinds of over-temperature protection processes. First, if the system is operating normally, the ambient temperature is changed to +170°C, and suddenly the IC will trigger over-temperature protection which leads to a latch work mode. Second, if the system starts when the ambient temperature is higher than +150°C, over temperature protection will be triggered. So, the AP1694AS-13 can startup successfully when the ambient temperature is less than +150°C.

Components Selection Guide
If the system's spec is changed, please refer to the design sheet of the AP1694AS-13 and select the compatible system parameter. When the system needs to be adjusted slightly, please refer to the table below and adjust the value of the related component.

Item	Description	Related Components
I_O	Output current	R8
Output Current Ripple	Small current ripple is good for LED life	C4
$t_{on\_initial}$	System initial on time, used to startup the system	R1
Output Open Voltage	Setting the output voltage when the LED is open	R5, R6
Dimming Performance	Improve the dimming performance	R1, RF, R9, C2, C4
EMI	Pass EN 55022 class B with 6DB margin	L1, C1
Line Compensation	To get a good line regulation	R7

Ordering Information

AP1694A X - 13

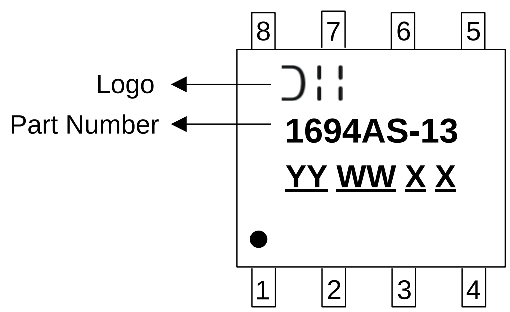
Package
S: SO-8

Packing
13 : 13" Tape & Reel

Part Number	Package Code	Packaging	13" Tape and Reel	
			Quantity	Part Number Suffix
AP1694AS-13	S	SO-8	4,000/Tape & Reel	-13

Marking Information

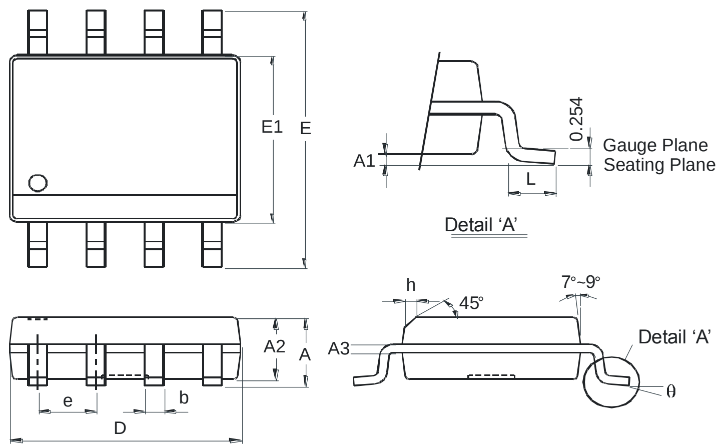
(Top View)



YY : Year : 15,16,17 ~
WW : Week : 01~52; 52 represents 52 and 53 week
X X : Internal Code

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

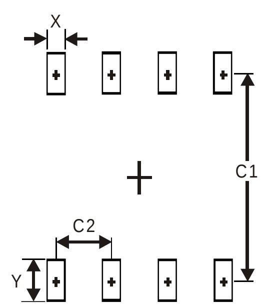
Please see AP02002 at http://www.diodes.com/datasheets/ap02002.pdf for the latest version.



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