Description

The AP1661 is an active power factor control IC which is designed mainly for use as pre-converter in electronic ballast, AC-DC adapters and off-line SMPS applications.

The AP1661 includes an internal start-up timer for stand-alone applications, a one-quadrant multiplier to realize near unity power factor and a zero current detector to ensure DCM boundary conduction operation. The totem pole output stage is capable of driving power MOSFET with 600mA source current and 800mA sink current.

Designed with advanced BiCMOS process, the AP1661 features low start-up current, low operation current and low power dissipation. The AP1661 also has rich protection features including over-voltage protection, input under-voltage lockout with hysteresis and multiplier output clamp to limit maximum peak current.

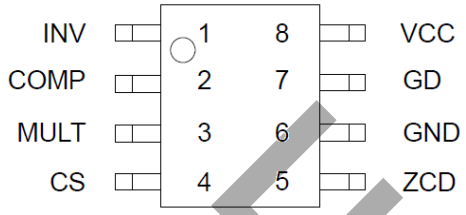
This IC is available in SOIC-8 and DIP-8 packages.

Features

- Zero Current Detection Control for DCM Boundary Conduction Mode
- Adjustable Output Voltage with Precise Over-Voltage Protection
- Low Start-up Current with 50μA Typical Value
- Low Operating Supply Current with 4mA Typical Value
- 1% Precision Internal Reference Voltage
- Internal Start-up Timer
- Disable Function for Reduced Current Consumption
- Totem Pole Output with 600mA Source Current and 800mA Sink Current Capability
- Under-Voltage Lockout with 2.5V of Hysteresis
- **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/

Pin Assignments

(Top View)

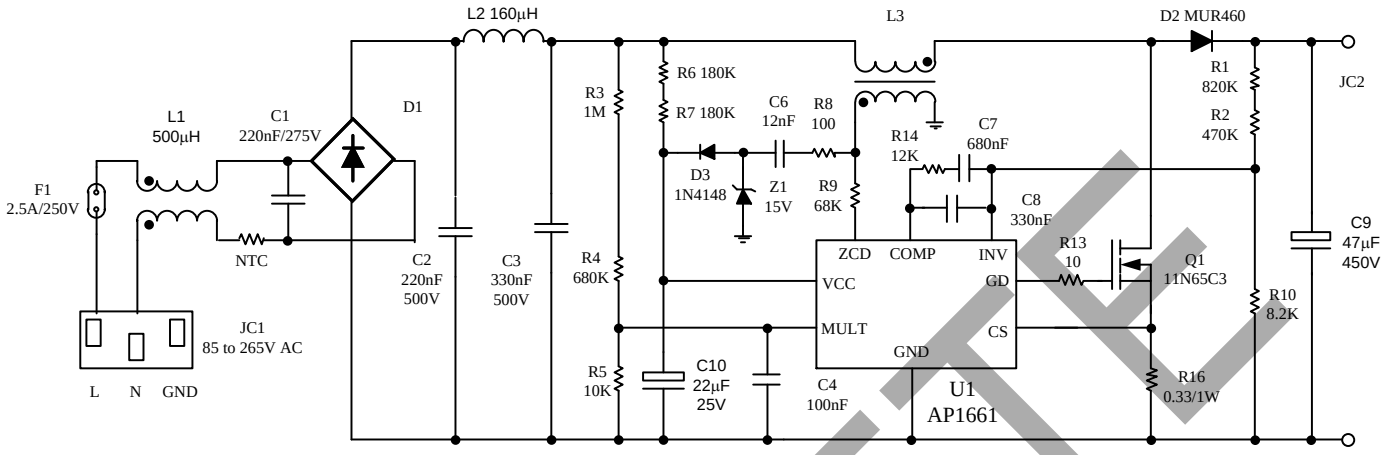


M Package/P Package
(SOIC-8/DIP-8)

Applications

- AC-DC Adapter
- Off-line SMPS
- Electronic Ballast

Typical Applications Circuit



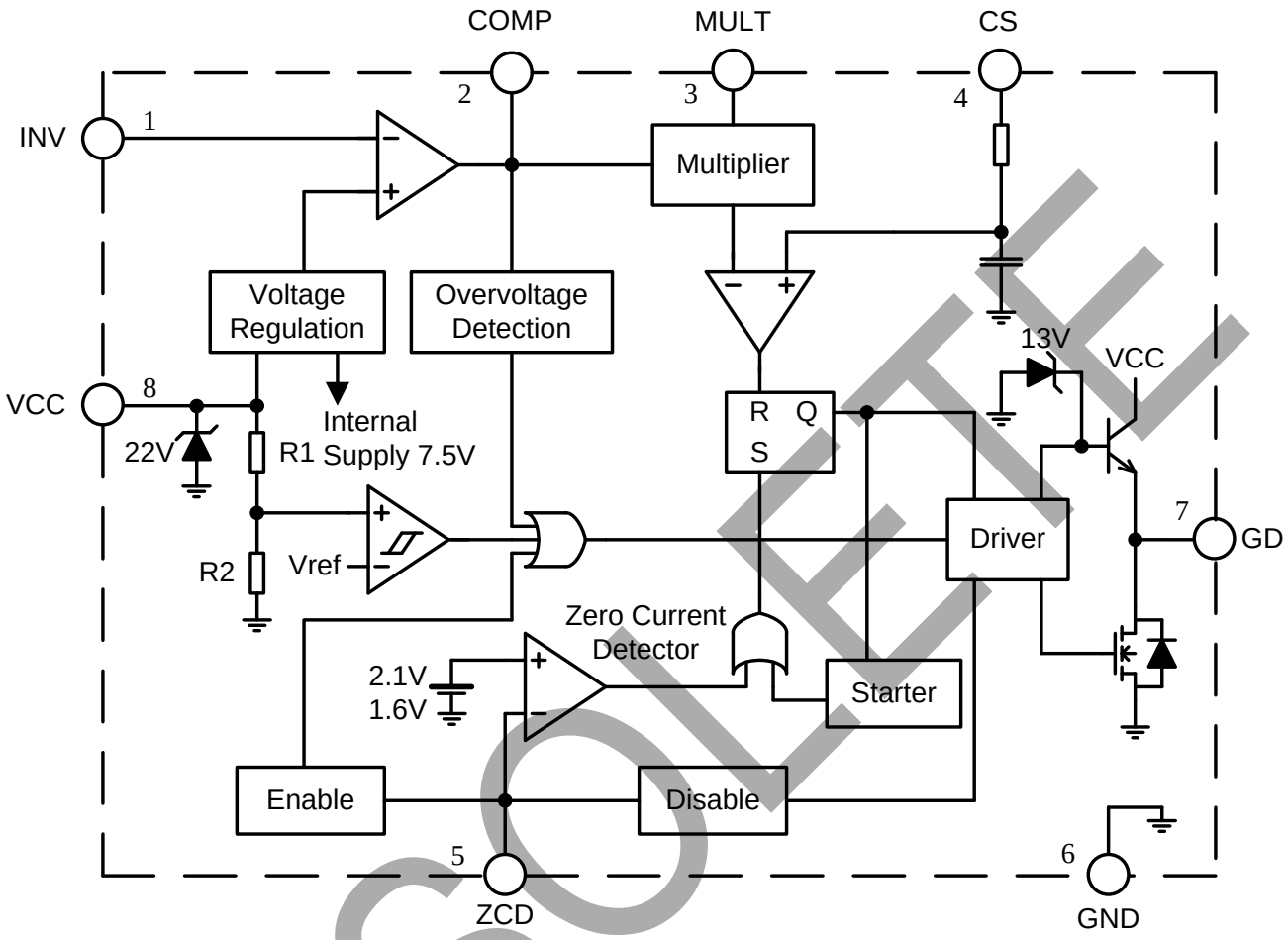
L3:
Core type RM10, material 3C90
primary: 660µH, 66 turns of litze wire 0.1mm*30
secondary: 7 turns wire of 0.2mm

85 to 265V Wide Range Input 90W PFC Demo Board Electrical Schematic Circuit

Pin Descriptions

Pin Number	Pin Name	Function
1	INV	Inverting input of the error amplifier
2	COMP	Output of the error amplifier
3	MULT	Input of the multiplier
4	CS	Input of the current control loop comparator
5	ZCD	Zero current detection input. If it is connected to GND, the device is disabled.
6	GND	Ground. Current return for gate driver and control circuits of the IC
7	GD	Gate driver output
8	VCC	Supply voltage of gate driver and control circuits of the IC

Functional Block Diagram



Absolute Maximum Ratings (Note 1)

Symbol	Parameter	Rating		Unit
V_{CC}	Power Supply Voltage	20		V
I_{CC}	Operating Supply Current	30		mA
I_{OUT}	Driver Output Current	±800		mA
V_{INV}, V_{COMP}, V_{MULT}	Input/Output of Error Amplifier, Input of Multiplier	-0.3 to 7		V
V_{CS}	Current Sense Input	-0.3 to 7		V
I_{ZCD}	Zero Current Detector Input	Source	-50	mA
		Sink	10	
$R_{\theta JA}$	Thermal Resistance Junction-Ambient	DIP-8	100	°C/W
		SOIC-8	150	
P_{TOT}	Power Dissipation and Thermal Characteristics @ T_A=+50°C	DIP-8	1	W
		SOIC-8	0.65	
T_J	Operating Junction Temperature	-40 to +150		°C
T_{STG}	Storage Temperature Range	-65 to +150		°C
T_{LEAD}	Lead Temperature (Soldering, 10 Seconds)	+260		°C
—	ESD (Human Body Model)	3000		V
—	ESD (Machine Model)	300		V

Note 1: 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.

Electrical Characteristics (V_{CC}=14.5V, T_A=-25°C to +125°C, unless otherwise specified.)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
Under Voltage Lockout Section						
V_{CC-ON}	Turn-on Threshold	V_{CC} rising	11	12	13	V
V_{CC-OFF}	Turn-off Threshold	V_{CC} falling	8.7	9.5	10.3	V
V_{CC-HYS}	Hysterisis	—	2.2	2.5	2.8	V
V_{CC}	V_{CC} Operating Range	After turn-on	10.3	—	20	V
Total Supply Section						
$I_{START-UP}$	Start-up Current	V_{CC}=11V before turn-on	20	50	90	μA
I_{CC}	Operating Supply Current	C_L=1nF @frequency=70kHz	—	4	5.5	mA
		In OVP condition Vpin1=2.7V	—	1.4	2.1	
I_Q	Quiescent Current	—	—	2.6	4	mA
I_Q	Quiescent Current	Vpin5≤150mV, V_{CC}>V_{CC-OFF}	—	1.4	2.1	mA
		Vpin5≤150mV, V_{CC}<V_{CC-OFF}	20	50	90	μA
V_Z	V_{CC} Zener Voltage	I_{CC}=20mA	20	22	24	V
Error Amplifier Section						
V_{INV}	Voltage Feedback Input Threshold	T_A=+25°C	2.465	2.5	2.535	V
		10.3V<V_{CC}<20V	2.44	—	2.56	
—	Line Regulation	V_{CC}=10.3V to 20V	—	2	5	mV
I_{INV}	Input Bias Current	V_{INV}=0V	—	-0.1	-1	μA
G_V	Voltage Gain	Open Loop	60	80	—	dB
GB	Gain Bandwidth	—	—	1	—	MHz
V_{COMP-H}	Output Voltage	Upper Clamp Voltage	I_{SOURCE}=0.5mA	—	5.8	—	V
V_{COMP-L}		Lower Clamp Voltage	I_{SINK}=0.5mA	—	2.25	—	
I_{COMP-H}	Output Current	Source Current	V_{COMP}=4V, V_{INV}=2.4V	-2	-4	-8	mA
I_{COMP-L}		Sink Current	V_{COMP}=4V, V_{INV}=2.6V	2.5	4.5	—	
V_{INV-TH}	Enable Threshold		—	—	—	720	mV
Multiplier Section						
V_{MULT}	Linear Input Voltage Range	—	0 to 3	0 to 3.5	—	V
$\Delta V_{CS}/\Delta V_{MULT}$	Output Maximum Slope	V_{MULT}: 0 to 0.5V, V_{COMP}=Upper Clamp Voltage	—	1.7	—	—
k	Gain	V_{MULT}=1V, V_{COMP}=4V	0.45	0.6	0.75	1/V

Electrical Characteristics (V_{CC}=14.5V, T_A=-25°C to +125°C, unless otherwise specified.) (continued)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
Current Sense Section						
I_{CS}	Input Bias Current	V_{CS}=0V	—	-0.05	-1.0	μA
$V_{CS-OFFSET}$	Current Sense Offset Voltage	V_{MULT}=0V	—	30	—	mV
		V_{MULT}=2.5V	—	5	—	
$V_{CS-CLAMP}$	Current Sense Reference Clamp	V_{COMP}=Upper Clamp Voltage, V_{MULT}=2.5V	1.6	1.7	1.8	V
$t_{d(H-L)}$	Delay to Output	—	—	200	450	ns
Zero Current Detection Section						
V_{ZCD-R}	Input Threshold Voltage, V_{ZCD} Rising Edge	(Note 2)	—	2.1	—	V
$V_{ZCD-RTH}$	Hysteresis Voltage	(Note 2)	0.3	0.5	0.7	V
V_{ZCD-H}	Upper Clamp Voltage	I_{ZCD}=20μA	4.5	5.1	5.9	V
		I_{ZCD}=3mA	4.7	5.2	6.1	
V_{ZCD-L}	Lower Clamp Voltage	I_{ZCD}=-3mA	0.3	0.65	1	V
I_{ZCD-SR}	Source Current Capability	—	-3	—	-10	mA
I_{ZCD-SN}	Sink Current Capability	—	3	—	10	mA
I_{ZCD-B}	Sink Bias Current	1V≤V_{ZCD}≤4.5V	—	2	—	μA
$V_{ZCD-DIS}$	Disable Threshold	—	150	200	250	mV
$V_{ZCD-HYS}$	Disable Hysterisis	—	—	100	—	mV
$I_{ZCD-RES}$	Restart Current After Disable	V_{ZCD}<V_{DIS}; V_{CC}>V_{CC-OFF}	-100	-200	-300	μA
Drive Output Section						
V_{OH}	Dropout Voltage	$I_{GD-SOURCE}$=200mA, V_{CC}=12V	—	2.5	3	V
		$I_{GD-SOURCE}$=20mA, V_{CC}=12V	—	2	2.6	
V_{OL}		$I_{GD-SINK}$=200mA, V_{CC}=12V	—	0.9	1.9	V
t_R	Output Voltage Rise Time	C_L=1nF	—	40	100	ns
t_F	Output Voltage Fall Time	C_L=1nF	—	40	100	ns
$V_{O-CLAMP}$	Output Clamp Voltage	$I_{GD-SOURCE}$=5mA, V_{CC}=20V	10	13	15	V
V_{OS}	UVLO Saturation	V_{CC}=0 to V_{CC-ON}, I_{SINK}=10mA	—	—	1.1	V

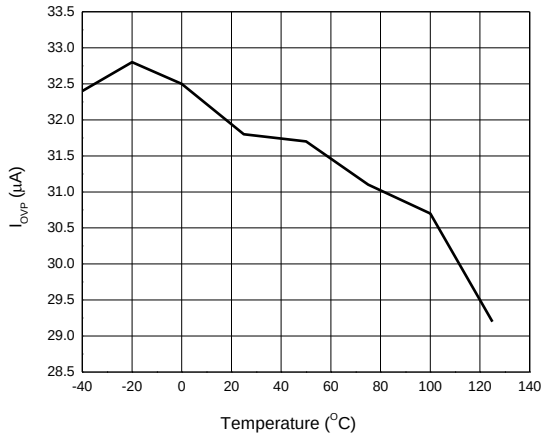
Electrical Characteristics (V_{CC}=14.5V, T_A=-25°C to +125°C, unless otherwise specified.) (continued)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
Output Over Voltage Section						
I_{OVP}	OVP Triggering Current	—	35	40	45	μA
V_{OVP-TH}	Static OVP Threshold	—	2.1	2.25	2.4	V
Restart Timer						
t_{START}	Restart Timer	—	70	150	400	μs

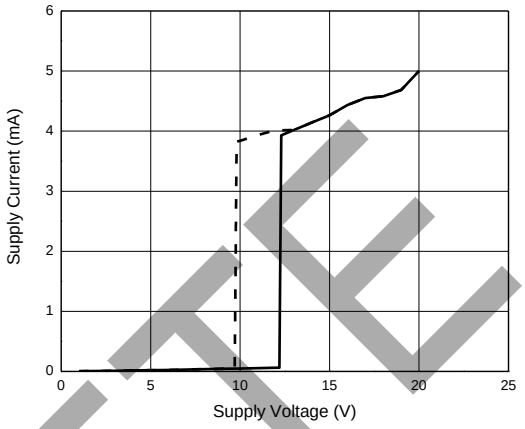
Note 2: Limits over the full temperature are guaranteed by design, but not tested in production.

Performance Characteristics

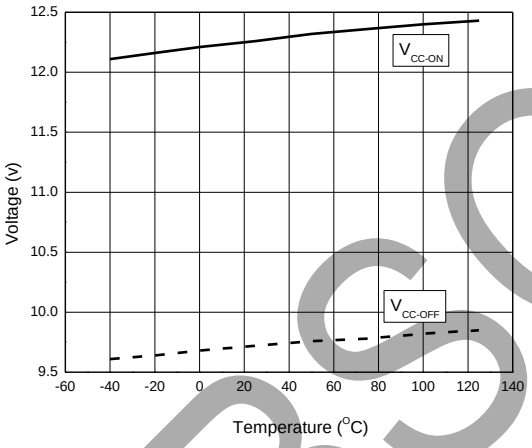
OVP Current Threshold vs. Temperature



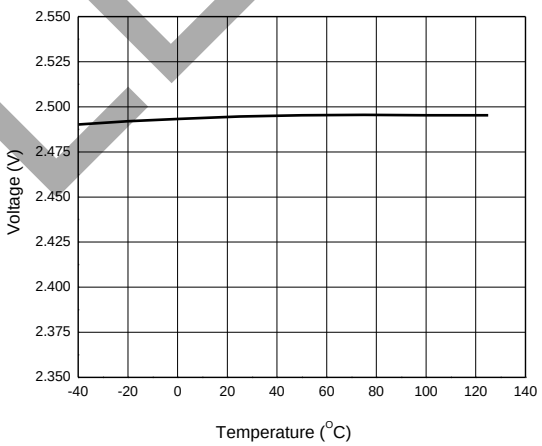
Supply Current vs. Supply Voltage



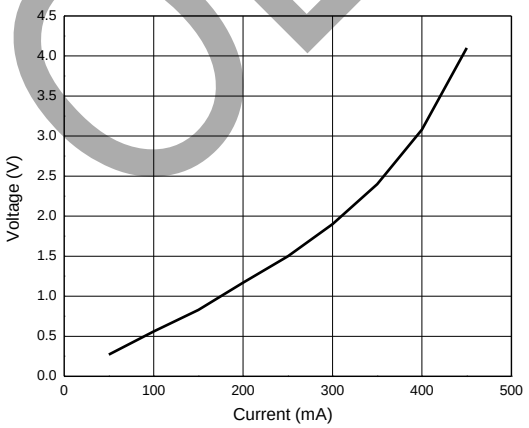
Under Voltage Lockout Threshold vs. Temperature



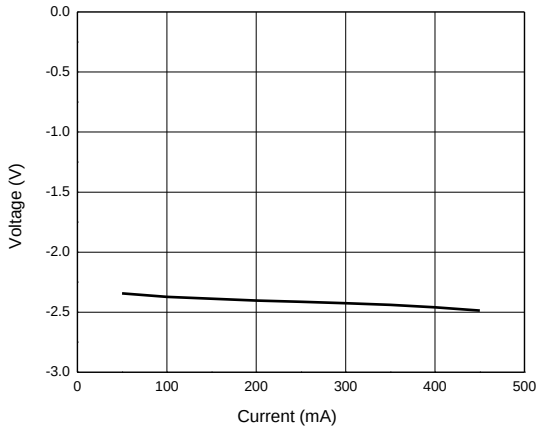
Voltage Feedback Input Threshold vs. Temperature



Output Saturation Voltage vs. Sink Current

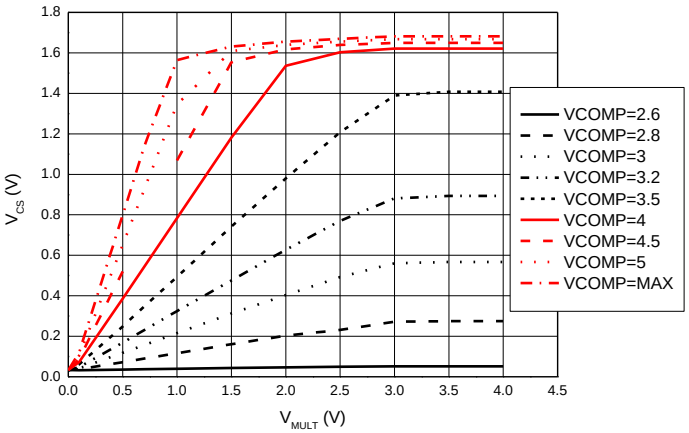


Output Saturation Voltage vs. Source Current



Performance Characteristics (continued)

Multiplier Characteristics Family



Functional Block Description

AP1661 is a high performance power factor correction controller which operates in DCM boundary conduction mode. The PFC converter's switch will be turned on when the inductor current reduces to zero and turned off when the sensed inductor current reaches the required reference which is decided by the output of multiplier.

Error Amplifier and Over-Voltage Protection

The error amplifier regulates the PFC output voltage. The internal reference on the non-inverting input of the error amplifier is 2.5V. The error amplifier's inverting input (INV) is connected to an external resistor divider which senses the output voltage. The output of error amplifier is one of the two inputs of multiplier. A compensation loop is connected outside between INV and the error amplifier output. Normally, the compensation loop bandwidth is set very low to realize high power factor for PFC converter.

To make the over voltage protection fast, the internal OVP function is added. If the output over voltage happens, excess current will flow into the output pin of the error amplifier through the feedback compensation capacitor. (see Figure 1) The AP1661 monitors the current flowing into the error amplifier output pin. When the detected current is higher than 40μA, the dynamic OVP is trigged. The IC will be disabled and the drive signal is stopped. If the output over voltage lasts so long that the output of error amplifier goes below 2.25V, static OVP will take place. Also the IC will be disabled until the output of error amplifier goes back to its linear region. R1 and R2 (see Fig. 1) will be selected as below:

$$\frac{R1}{R2} = \frac{Vo}{2.5V} - 1$$

$$R1 = \frac{\Delta V_{OVP}}{40\mu A}$$

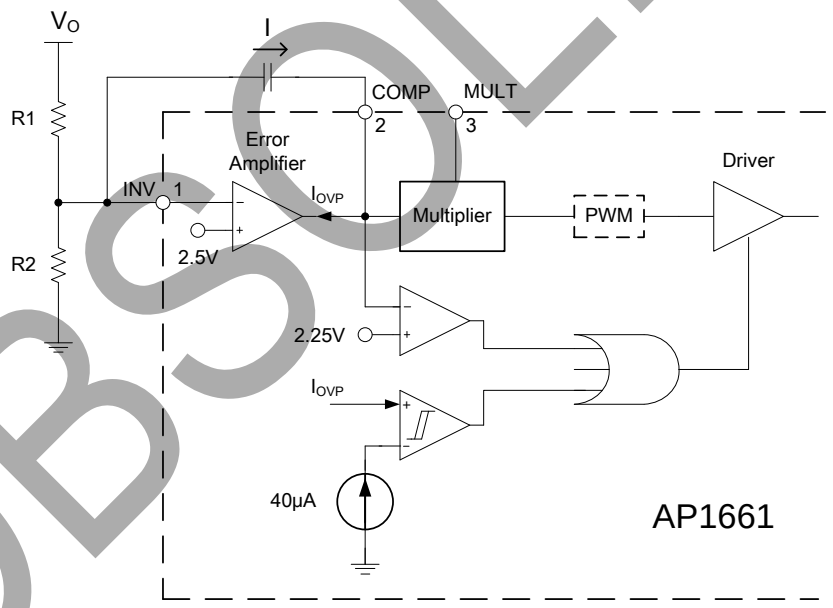


Figure 1. Error Amplifier and OVP Block

Multiplier

The multiplier has two inputs. One (Pin 3) is the divided AC sinusoidal voltage which makes the current sense comparator threshold voltage vary from zero to peak value. The other input is the output of error amplifier (Pin 2). In this way, the input average current wave will be sinusoidal as well as reflects the load status. Accordingly a high power factor and good THD are achieved. The multiplier transfer character is designed to be linear over a wide dynamic range, namely, 0V to 3V for Pin 3 and 2.0V to 5.8V for Pin 2. The relationship between the multiplier output and inputs is described as below equation.

$$V_{CS} = k \times (V_{COMP} - 2.5) \times V_{MULT}$$

Functional Block Description (continued)

Where V_{CS} (Multiplier output) is the reference for the current sense, k is the multiplier gain, V_{COMP} is the voltage on pin 2 (error amplifier output) and V_{MULT} is the voltage on pin 3.

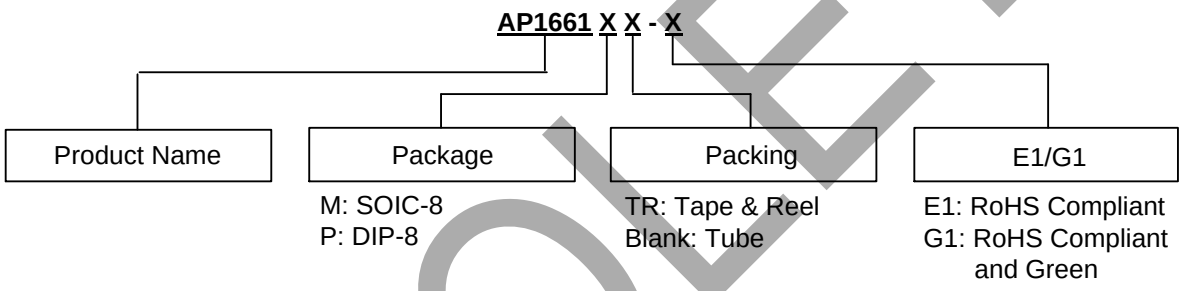
Current Sense/Current Sense Comparator

The PFC switch's turn-on current is sensed through an external resistor in series with the switch. When the sensed voltage exceeds the threshold voltage (the multiplier output), the current sense comparator will become low and the external MOSFET will be turned off. This insures a cycle-by-cycle current mode control operation. The maximum current sense reference is 1.8V. The max value usually happens at startup process or abnormal conditions such as short load.

Zero Current Detection

AP1661 is a DCM boundary conduction current mode PFC controller. Usually, the zero current detection (ZCD) voltage signal comes from the auxiliary winding of the boost inductor. When the ZCD pin voltage decreases below 1.6V, the gate drive signal becomes high to turn on the external MOSFET. 500mV of hysteresis is provided to avoid false triggering. The ZCD pin can be used for disabling the IC. Making its voltage below 0.15V or short to the ground will disable the device thus reduce the IC supply current consumption.

Ordering Information

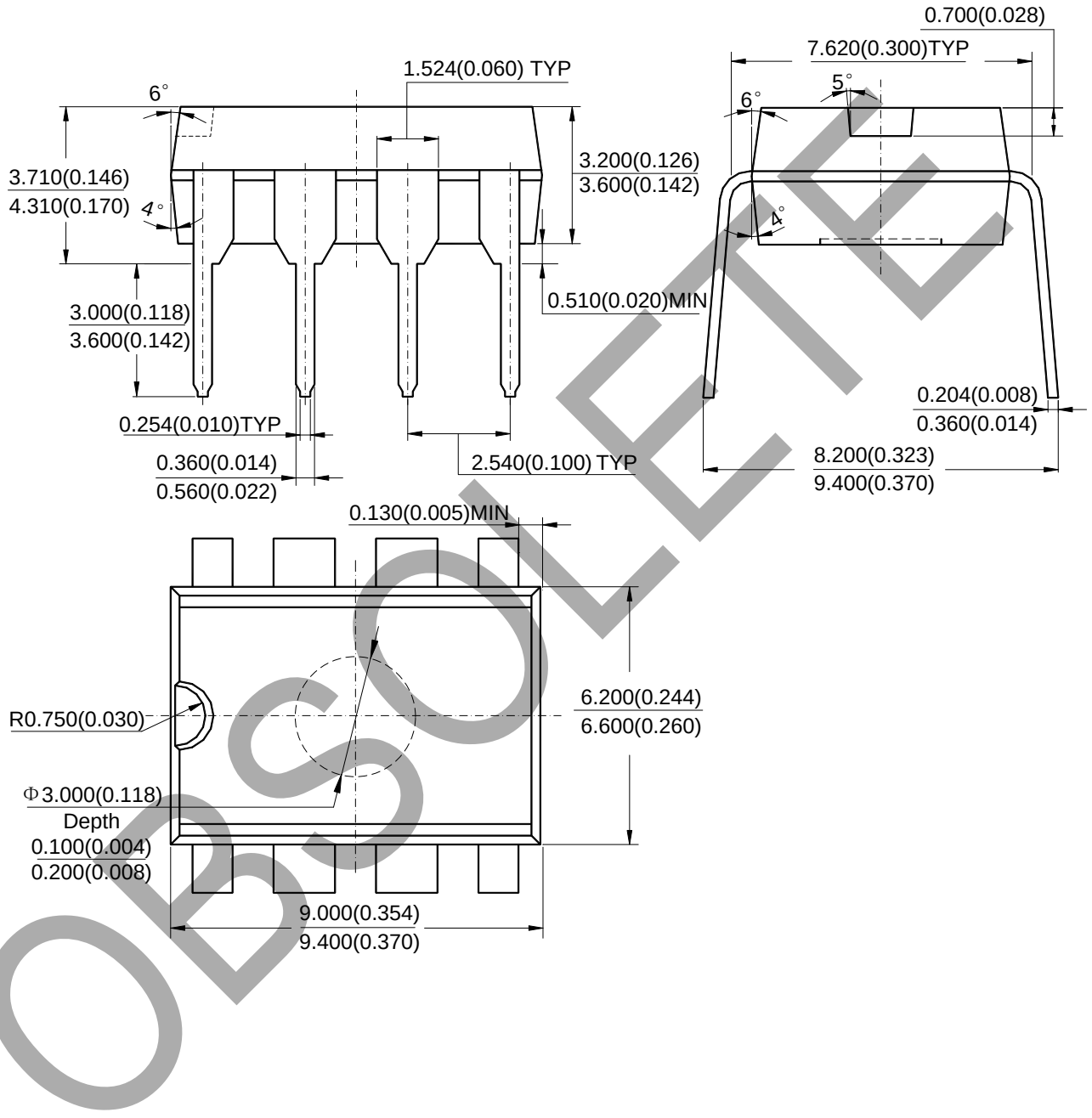


Package	Temperature Range	Part Number		Marking ID		Packing
		RoHS Compliant	RoHS Compliant and Green	RoHS Compliant	RoHS Compliant and Green	
SOIC-8	-40 to +85°C	AP1661M-E1	AP1661M-G1	1661M-E1	1661M-G1	Tube
		AP1661MTR-E1	AP1661MTR-G1	1661M-E1	1661M-G1	Tape & Reel
DIP-8	-40 to +85°C	AP1661P-E1	AP1661P-G1	AP1661P-E1	AP1661P-G1	Tube

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

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

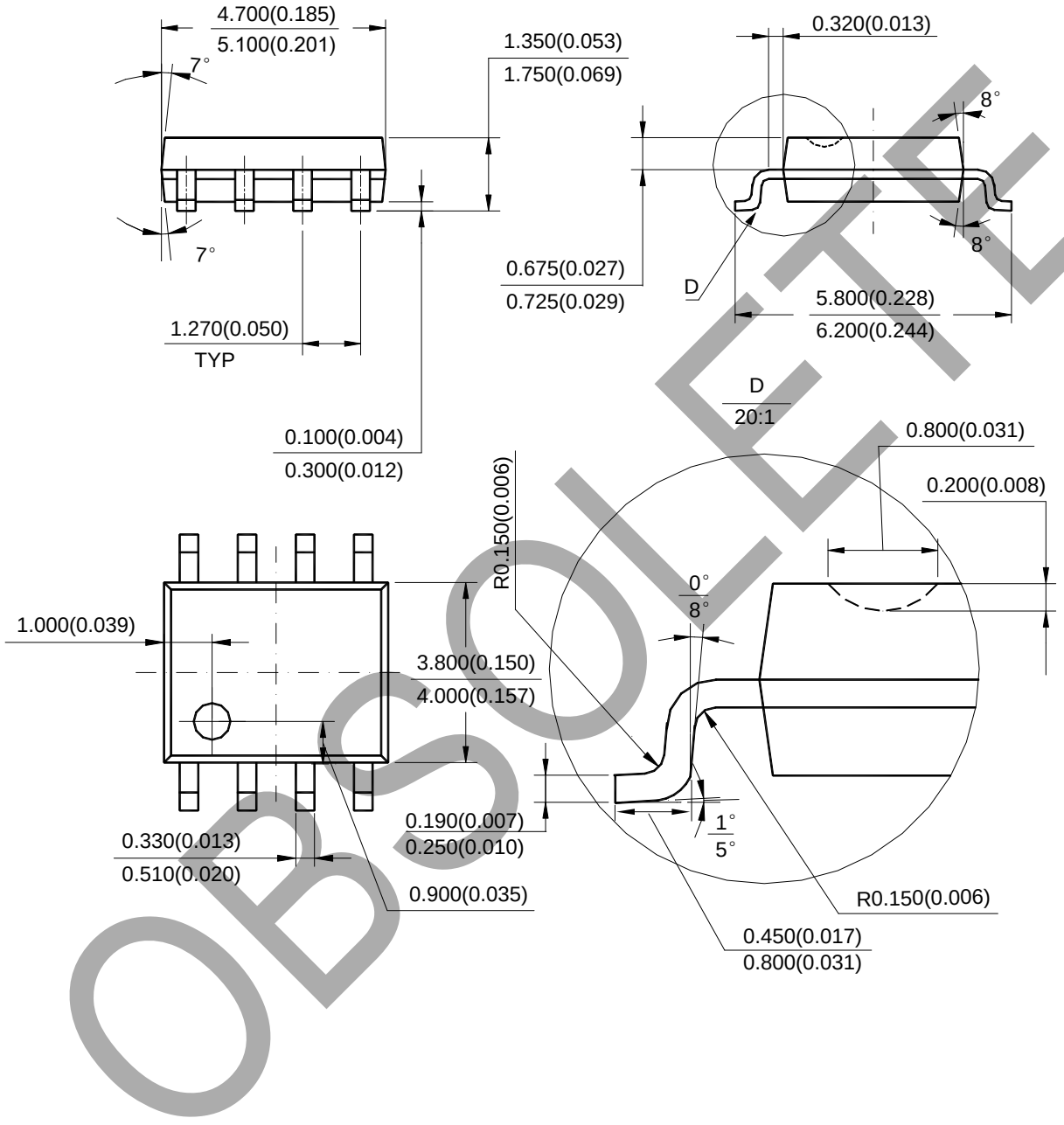
(1) Package Type: DIP-8



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

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

(2) Package Type: SOIC-8



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