HIGH-PERFORMANCE GREEN MODE PWM CONTROLLER

Description

The AP3128 is a peak-current control, multi-mode (QR+CCM) PWM controller optimized for high performance, low standby power and cost-effective offline flyback converters.

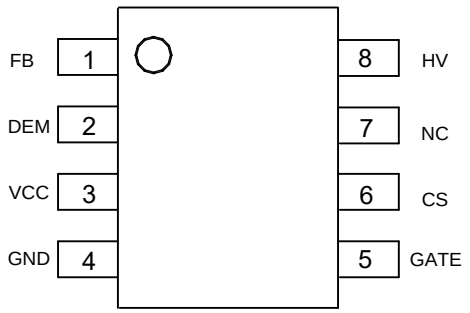
At no load or light load, the IC will enter burst mode to minimize standby power consumption. The minimum switching frequency is set to avoid audible noise. When the load increases, the IC will enter QR mode with frequency foldback to improve system efficiency and EMI performance. The maximum switching frequency about 105kHz is set to clamp the QR frequency to reduce switching power loss. Furthermore, the frequency dithering function is built in to reduce EMI emission.

Internal piecewise linear line compensation ensures constant output power limit over the entire universal line voltage range.

Comprehensive protection features are included, such as brown-out protection, cycle-by-cycle current limit (OCP), V_{CC} Overvoltage Protection (VOVP), Secondary-side Output OVP (SOVP) and UVP (SUVP), internal OTP, Overload Protection (OLP), and pins' fault protection.

Pin Assignments

(Top View)



SO-8

Features

- Multi-Mode Control
- Quasi-Resonant (QR) Operation at High Line Voltage
- Continuous Current Mode (CCM) Operation at Low Line Voltage
- Non-Audible-Noise Quasi-Resonant Control
- Soft Start During Startup Process
- Frequency Fold Back for High Average Efficiency
- Constant Over Current Protection
- Secondary Winding Short Protection with FOCP
- Frequency Dithering for Reducing EMI
- Useful Pin Fault Protection:
  SENSE Pin Floating
  FB/Opto-Coupler Open/Short
- Comprehensive System Protection Feature:
  V_{CC} Overvoltage Protection (VOVP)
  Overload Protection (OLP)
- Brown Out Protection (BNO)
- Secondary Side OVP (SOVP) and UVP (SUVP)
- **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

- Cell Phone Charger
- Power Delivery (PD) Application
- ATX/BTX Auxiliary Power
- Set -Top Box (STB) Power Supply
- Open Frame Switching Power Supply

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.

Typical Applications Circuit

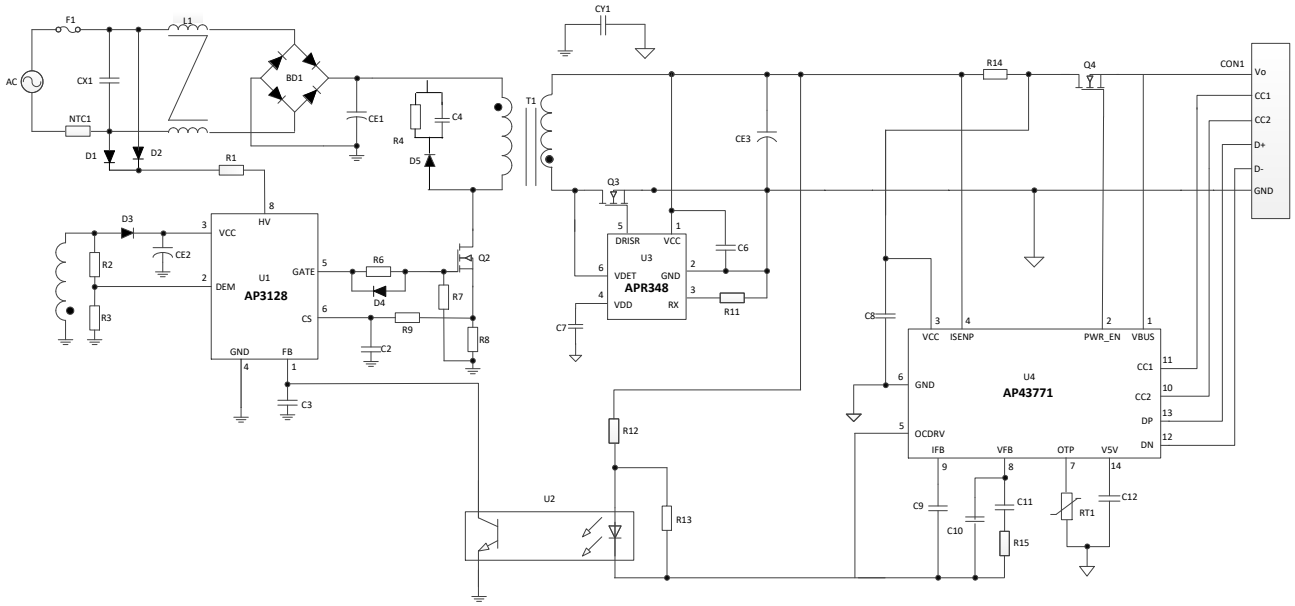


Figure 1. Typical Application Circuit for PD3.0 PPS Charger

Pin Descriptions

Pin Number	Pin Name	Function
1	FB	Feedback. Directly connected to the opto-coupler.
2	DEM	Valley detection for QR control, AC line voltage detection for Brown-in/Brown-out, Sample output voltage for SOVP and SUVP, Set OCP line compensation current.
3	VCC	Supply voltage of driver and control circuits.
4	GND	Signal Ground. Current return for driver and control circuits.
5	GATE	Gate Driver Output.
6	CS	Current Sense.
7	NC	—
8	HV	High Voltage Input. Sense line voltage and provide startup current to V_{CC}.

Functional Block Diagram

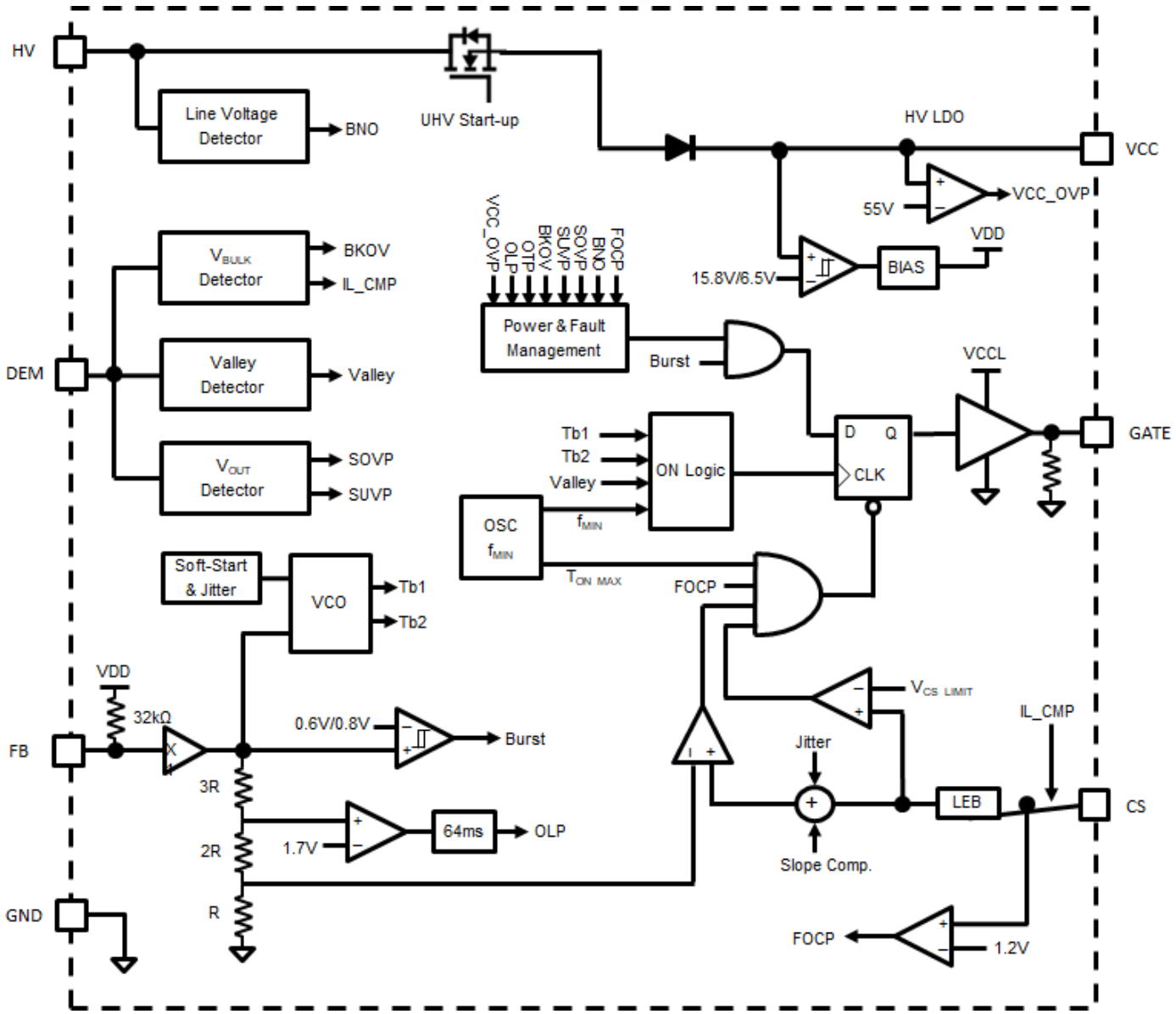


Figure 2. Functional Block Diagram

Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Rating	Unit
V_{HV}	HV Pin Input Voltage	700	V
V_{CC}	Power Supply Voltage	60	V
I_O	Gate Output Current	-800 to 300	mA
V_{FB}, V_{CS}, V_{DEM}	Input Voltage to FB, CS,DEM	-0.3 to 6.5	V
θ_{JA}	Thermal Resistance (Junction to Ambient)	165	°C/W
P_D	Power Dissipation at T_A < +25°C	550	mW
T_J	Operating Junction Temperature	-40 to +150	°C
T_{STG}	Storage Temperature Range	+150	°C
ESD	Human Body Model	2000	V
ESD	Charged Device Model	750	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.

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{CC}	Power Supply Voltage	10	50	V
T_A	Ambient Temperature	-40	+85	°C

Electrical Characteristics (@T_A = +25°C, V_{CC} = 16V, unless otherwise specified.)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
Power Supply Voltage (VCC Pin)						
I_{ST}	Startup Current	—	—	1	10	μA
I_{CC}	Operating Supply Current	V_{FB} = 2.5V, C_{GATE} = 1nF	1.5	2	2.5	mA
I_{BURST}	Operating Current at Burst	V_{FB} = 0V, C_{GATE} = 1nF	—	0.25	—	mA
V_{ST}	Turn-On Threshold Voltage	—	14.8	15.8	16.8	V
$V_{CC-UVLO}$	VCC UVLO Voltage	—	—	6.5	7	V
V_{CC-OVP}	VCC OVP Threshold Voltage	—	50	55	—	V
HV Section(HV Pin)						
I_{CHARGE}	Charge Current	V_{CC} = 10V, V_{HV} = 50V	—	2	—	mA
V_{BR-IN}	Brown In Voltage	—	92	102	112	V
V_{BR-HYS}	Voltage Gap between Brown-In and Brown-Out Voltage.	—	7	8.5	—	V
t_{BR-OUT}	Delay of Brown Out (Note 5)	—	—	64	—	ms
PWM Section/Oscillator Section						
t_{ON-MAX}	Maximum On Time	—	—	10	—	μs
$f_{PWM-MAX}$	Maximum Clamp Frequency	—	90	105	120	kHz
$f_{PWM-CCM}$	CCM Oscillation Frequency	—	72	80	88	kHz
$f_{OSC-MIN}$	Minimum Clamp Frequency	—	20	23	—	kHz
$f_{OSC-JITTER}$	Frequency Dithering (Note 5)	—	—	±6	—	%
Current Sense Section (SENSE Pin)						
V_{CS-MAX}	Maximum SENSE Voltage	V_{DEM} = 3.1V	0.51	0.56	0.61	V
$V_{TH-FOCP}$	FOCP Voltage	—	1.0	1.2	1.4	V
$t_{DELAY-FOCP}$	FOCP Debounce Time (Note 5)	—	—	7	—	Cycles
t_{LEB}	LEB Time of SENSE	—	—	400	500	ns
Feedback Input Section (FB Pin)						
K_{FB-CS}	The Ratio of FB Input Voltage to Current Sense Voltage	—	—	6	—	V/V
R_{FB}	Input Impedance	—	—	32	—	kΩ

Note: 5. Guaranteed by design.

Electrical Characteristics (@T_A = +25°C, V_{CC} = 16V, unless otherwise specified.)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
$t_{DELAY-OLP}$	Delay of Overcurrent Protection (Note 5)	—	—	64	—	ms
$I_{FB-SOURCE}$	Source Current	V_{FB} = 0V	—	0.15	—	mA
$V_{BURST-OFF}$	Input Voltage for Zero Duty	—	0.45	0.5	0.55	V
$V_{BURST-ON}$	—	—	0.63	0.70	0.77	V
Output Section (GATE Pin)						
V_{GATE-L}	Output Low-Level Voltage	I_O = 10mA, V_{CC} = 18V	—	—	0.8	V
V_{GATE-H}	Output High-Level Voltage	I_O = 10mA, V_{CC} = 18V	7	—	—	V
$V_{GATE-CLP}$	Output Clamping Voltage	—	8	9.5	12	V
$t_{GATE-RISE}$	Rising Time (Note 5)	C_L = 1nF, V_{CC} = 18V	—	70	—	ns
$t_{GATE-FALL}$	Falling Time (Note 5)	C_L = 1nF, V_{CC} = 18V	—	20	—	ns
De-magnetization Section (DEM Pin)						
V_{QR}	De-Magnetization Voltage (Note 5)	—	—	100	—	mV
$V_{TH-SOVP}$	SOVP Threshold	—	3	3.2	3.4	V
$V_{TH-SUVP}$	SUVP Threshold	—	0.34	0.4	0.46	V
t_{SAMPLE}	Sample Delay Time (Note 5)	—	—	1.2	—	μs
Internal OTP Section						
OTP	OTP Threshold	—	—	+150	—	°C
T_{HYS}	OTP Recovery Hysteresis	—	—	+25	—	°C

Note: 5. Guaranteed by design.

Operation Description

The AP3128's Multi-Mode Operation includes Burst mode, QR mode, and CCM mode (which are specifically designed for off-line AC-DC power supplies used in LCD monitors), notebook adapters, and battery charger applications. At medium load, the IC will enter QR mode with frequency foldback to improve system efficiency and EMI performance. It offers a cost-effective solution with versatile protection functions.

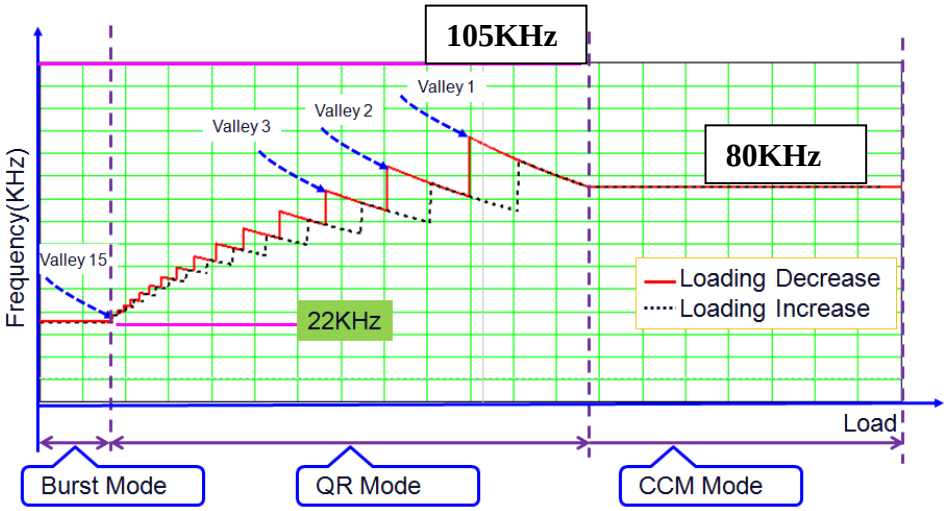


Figure 3

Multi-Mode Operation

The switching frequency curve in Figure 3 shows three operation modes.

- **Burst Mode**

  At no load and light load, the system will operate at burst mode. In burst mode, the switching frequency is fixed at about 22kHz to avoid audible noise. When the FB voltage is lower than 0.6V, the controller will not provide driving signal and the FB voltage will rise above 0.8V, then the driving signal will resume. By this control strategy, the system will eliminate a bunch of pulses and the power loss is reduced.

- **QR Mode**

  QR stands for Quasi-Resonant, which means that the power MOSFET is forced to turn on at valleys of V_{DS}. With QR control, the switching power loss will be reduced by lower voltage stress of MOSFET. The V_{DS} valley is detected by the DEM pin through the voltage divider network of R_{DEM} and R_{SOVP}. Once the divided voltage is less than 100mV during the internal turning off of the MOSFET, the counter in the AP3128 will count it as one valley. At light load and medium load, the system will enter QR mode. As the load changes, the trend of the switching frequency in QR mode is modulated by the AP3128.

- **CCM Mode**

  With the load increases, if the switching frequency decreases below 80KHz in valley1 mode, CCM mode is implemented to achieve high efficiency. Usually at low line voltage, the system will enter CCM mode at heavy load, while at high line voltage the system may still operate at QR mode with the 1st or 2nd valley on.

Operation Description (continued)

UVLO

A UVLO comparator is included in the AP3128 to detect the voltage on the VCC pin. It ensures that the AP3128 can draw adequate energy from hold-up capacitor during power-on. The turn-on threshold is 15.8V and the turn-off threshold is 6.5V.

Current Sense Comparator and PWM Latch

The AP3128 operates as a current mode controller, the output switch conduction is initiated by every oscillator cycle and is terminated when the peak inductor current reaches the threshold level established by the FB pin. The inductor current signal is converted to a voltage signal by inserting a reference sense resistor R_S. The inductor current under normal operating conditions is controlled by the voltage at FB pin. The relation between peak inductor current (I_{PK}) and V_{FB} is:

$$I_{PK} = (V_{FB} / 6R_S)$$

Moreover, FOCP with 1.2V threshold is only about $t_{DELAY-FOCP}$ delay, which can avoid some catastrophic damages such as secondary rectifier short test. Few drive cycles can alleviate the destruction range and get better protection.

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 t_{LEB} time 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.

At the time of turning off the MOSFET, a negative undershoot (maybe larger than -0.3V) can occur on the SENSE pin. So it is strongly recommended to add a small RC filter or at least connect a resistor “R” on this pin to protect the IC (shown as Figure 4).

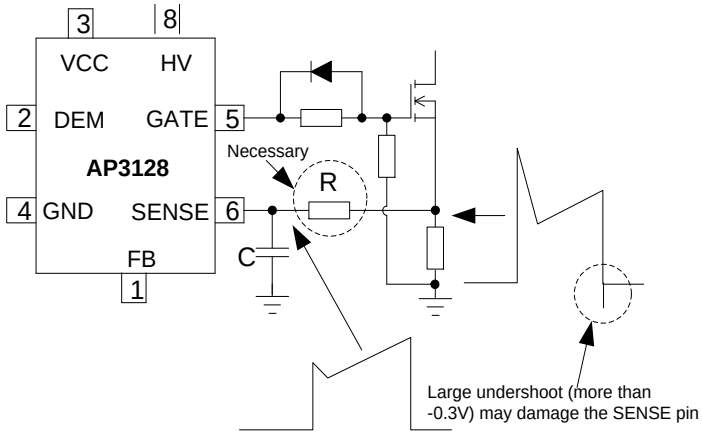


Figure 4

Built-in Slope Compensation

It is well known that a continuous current mode SMPS may become unstable when the duty cycle exceeds 50%. The built-in slope compensation can improve the stability, so there is no need for design engineer to spend much time on that.

FB Pin and Short Circuit Protection

This pin is normally connected to the opto-coupler and always paralleled with a capacitor for loop compensation. When the voltage at this pin is greater than V_{FB-OLP} and lasts for about $t_{DELAY-OLP}$, the IC will enter the protection mode. For the AP3128, the system will enter hiccup mode to wait the V_{CC} decreasing to low UVLO level, then the IC will try to restart until the failure removed. And when this voltage is less than 1.2V, the IC will stop the drive pulse immediately. Therefore, this feature can be used for short circuit protection, which makes the system immune from damage. Normally, output short makes the V_{FB} value to the maximum because the opto-coupler is cut off.

Operation Description (continued)

SOVP Protection Function

For some applications, the system requires the output overvoltage protection function. The DEM pin will comapre the divided voltage from the VCC winding with the inner threshold. When the voltage between R_{DEM} and R_{SOVP} is higher than $V_{TH-SOVP}$ during primary power MOSFET turning off duration, the AP3128 will trigger SOVP function and the system will enter the latch protection mode. The Secondary Output Voltage Protection (SOVP) can be achieved by this function since the value of the VCC winding's waveform reflects the output voltage precisely.

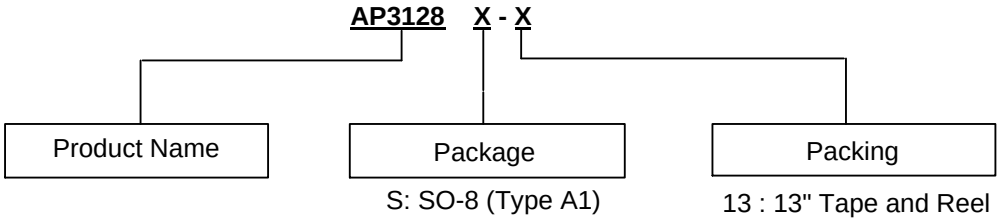
Other System Protection and Pin Fault Protection

The AP3128 provides versatile system and pin fault protections. The OCP comparator realizes the cycle-by-cycle current limiting (OCP). In universal input line voltage, the IC realizes the constant over load protection (OLP). VCC overvoltage protection can be applied as the primary OVP or opto-coupler broken protection. The AP3128 also has pin fault connection protection, including floating and short connection. The floating pin protection includes the SENSE, FB, etc. The short pin protection includes the DEM pin short protection. When these pins are floated or the DEM pin is shorted to ground, PWM switching will be disabled, thus protecting the power system.

Internal OTP Protection Function

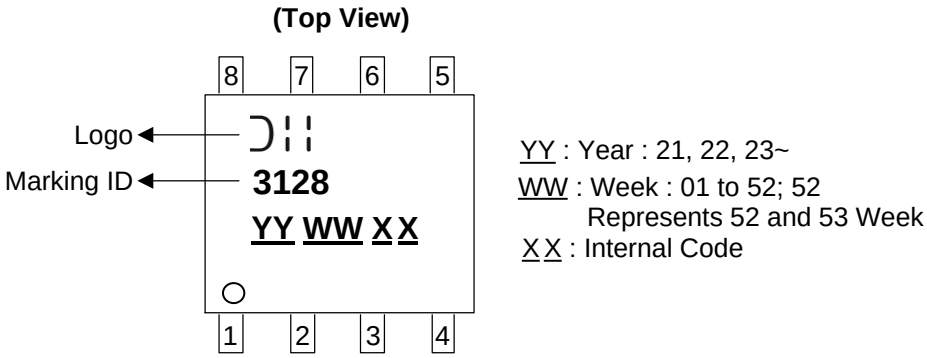
The AP3128 integrates an internal temperature sensor. It has a trigger window of entering OTP mode at +150°C and exiting at +125°C. The internal OTP protection mode is auto-recovery mode.

Ordering Information



Package	Temperature Range	Part Number	Marking ID	13''Tape and Reel	
				Quantity	Part Number Suffix
SO-8 (Type A1)	-40°C to +85°C	AP3128S-13	3128	2500/Tape and Reel	-13

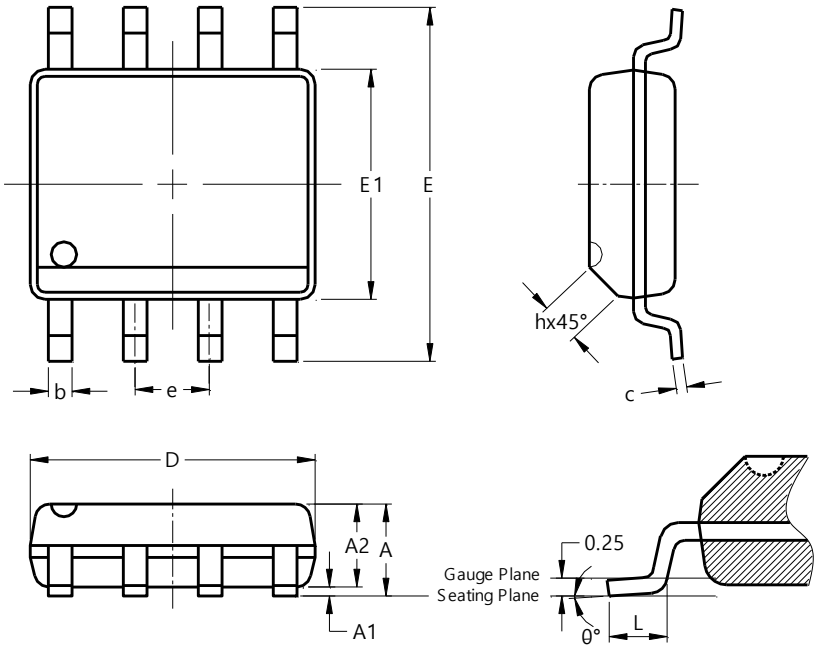
Marking Information



Package Outline Dimensions

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

SO-8 (Type A1)

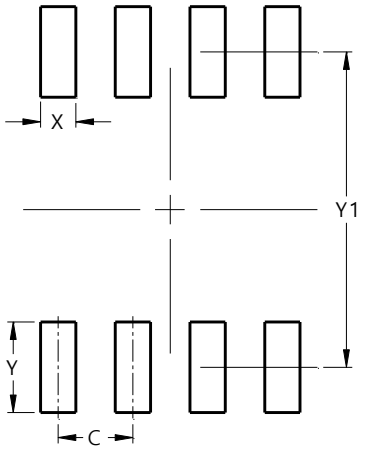


SO-8 (Type A1)			
Dim	**Min**	**Max**	**Typ**
A	--	1.75	--
A1	0.10	0.25	--
A2	1.25	--	--
b	0.31	0.51	--
c	0.10	0.25	--
D	4.90 BSC		
E	6.00 BSC		
E1	3.90 BSC		
e	1.27BSC		
h	0.25	0.50	--
L	0.40	1.27	--
θ	0°	8°	--
All Dimensions in mm			

Suggested Pad Layout

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

SO-8 (Type A1)



Dimensions	Value (in mm)
C	1.27
X	0.60
Y	1.55
Y1	5.40

Mechanical Data

- Moisture Sensitivity: Level 1 per JESD22-A113
- Terminals: Finish – Matte Tin Plated Leads, Solderable per JESD22-B102 (e3)
- Weight: 0.079 grams (Approximate)

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