QUICK CHARGER CONTROLLER COMPATIBLE WITH QUALCOMM QC3.0

Description

The DIODES™ AP43331N is a highly integrated secondary side constant voltage (CV) and constant current (CC) controller, which is compatible with Qualcomm® Quick Charge™ 3.0 (QC3.0) High Voltage Dedicated Charging Port (HVDCP) Class A specification.

The AP43331N allows for selection of the output voltage of an AC−DC USB charger based on commands from the Portable Device (PD) being powered. Selecting a higher charging voltage will reduce the charging current for a given power level resulting in reduced IR drops and increased system efficiency. The USB−bus voltage can be controlled in discreet steps (QC3.0's step is 0.2V). The output current is limited not to exceed maximum allowable power level.

The AP43331N resides at the secondary side of the charger. It includes voltage and current feedback regulation, eliminating the need for a shunt regulator such as DIODES™ TL431.

The AP43331N has a current sense amplifier to amplify the detected output current signal for contribution to accomplishing CC feature and output cable voltage compensation function.

The AP43331N incorporates a decoder used to translate Qualcomm QC3.0 protocol into internal configuration indicator, according to which the CV/CC loops will regulate the output voltage and current.

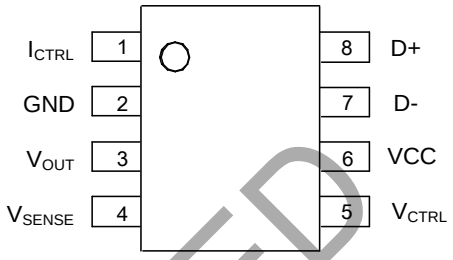
The AP43331N integrates a safe-discharge circuitry to quickly and reliably discharge output capacitors when the output voltage is switched down.

The AP43331N automatically keeps 5V output voltage in case that the connected portable device is not compatible with the QC3.0.

The AP43331N is available in SO-8 package.

Pin Assignments

SO-8



Top View

Features

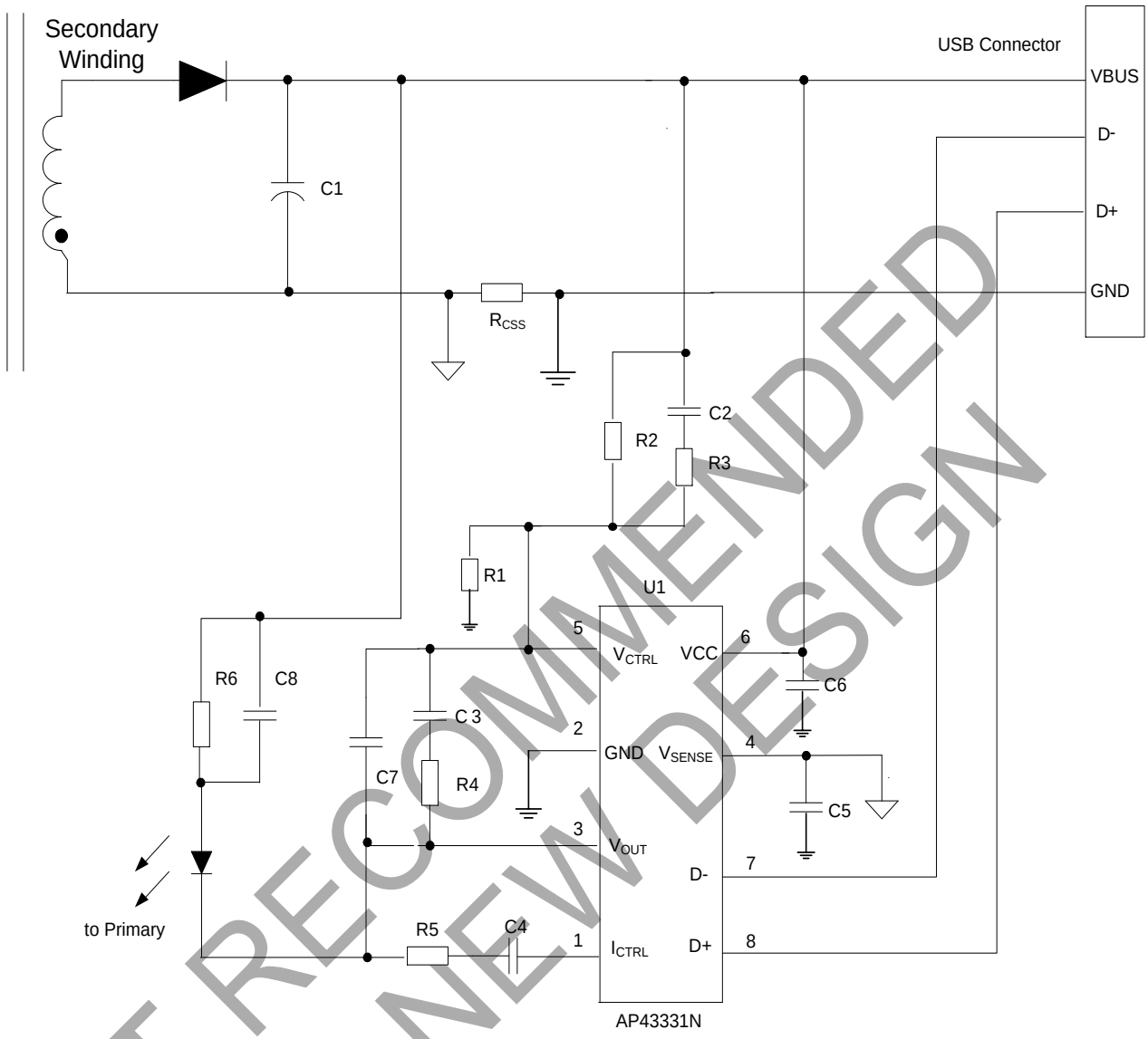
- Constant Voltage and Constant Current Regulation
- Supporting Qualcomm QC3.0 Class A (3.6V up to 12V)
- Output Cable Voltage Compensation
- High Precision CV/CC References
- Fast Dynamic Response
- Removing the Need for a Shunt Regulator Such as TL431
- Output Capacitor Safe-Discharge Circuitry at the Output Voltage Switched Down.
- Output Over Voltage Protection (OVP)
- Output Under Voltage Protection (UVP)
- Operating Supply Voltage: 3.2V to 12V
- **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-Q100/101/104/200, 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

- AC/DC adapters
- Battery chargers
- LED drivers

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



$$V_O = V_{REF\_CV} \times \frac{R1 + R2}{R1} + R_{CABLE} \times I_O$$

$$I_{O\_CC} = \frac{V_{REF\_CC}}{R_{CSS}}$$

I_O : The Current Which Flows Through Current Sensor R_{CSS}

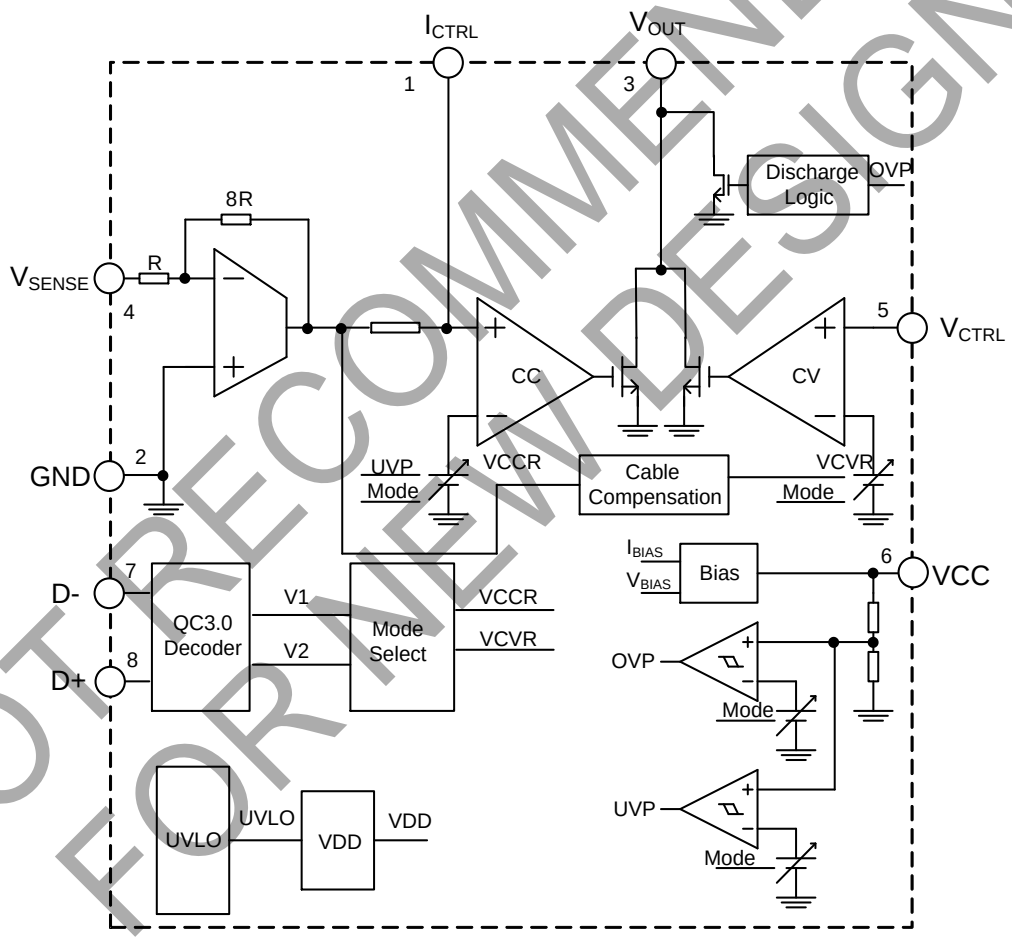
V_{REF_CV} : Constant Voltage Reference

I_{O_CC} : Output Constant Current Point

Pin Descriptions

Pin Number	Pin Name	Function
1	I_{CTRL}	Non-inverting input pin of the current control loop
2	GND	Ground return
3	V_{OUT}	Output pin. Sinking current only
4	V_{SENSE}	Inverting input pin of the current control loop
5	V_{CTRL}	Input pin of the voltage control loop
6	VCC	IC supply voltage, connected to a ceramic capacitor
7	D-	Connected to USB D-
8	D+	Connected to USB D+

Functional Block Diagram



VCCR: Voltage Control Current Reference

VCVR: Voltage Control Voltage Reference

VDD: Internal Voltage Source

Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Rating	Unit
V_{CC}	Power Supply Voltage	-0.3 to 20	V
V_{OUT}	V_{OUT} Pin Voltage	-0.3 to V_{CC}	V
V_{ICTRL}	I_{CTRL} Pin Voltage	-0.3 to 7	V
V_{SENSE}	V_{SENSE} Pin Voltage	-0.3 to 7	V
V_{VCTRL}	V_{CTRL} Pin Voltage	-0.3 to 7	V
T_J	Junction Temperature	+150	°C
T_{STG}	Storage Temperature	-55 to +150	°C
T_{LEAD}	Lead Temperature (Soldering, 5 sec)	+260	°C
θ_{JA}	Thermal Resistance (Junction to Ambient) (Note 5)	129	°C/W
ESD	ESD (Human Body Model)	6	kV
	ESD (Machine Model)	300	V

Notes: 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.
5. Device mounted on FR-4 substrate PC board, 2oz copper, with 1inch^2 pad layout.

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{CC}	Power Supply Voltage	3.2	12	V
T_A	Ambient Temperature	-40	+85	°C

Electrical Characteristics (@V_{CC} = 5V, -40°C < T_A < +85°C, unless otherwise specified.)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
TOTAL CURRENT CONSUMPTION						
V_{ST}	Start-up Voltage	—	2.8	3	3.2	V
V_{CC_UVLO}	V_{CC} Under Voltage Lock Out Voltage	—	2.6	2.8	3	V
I_{CC}	Operating Supply Current	V_{CC} = 5V, V_{SENSE} = 0V V_{CTRL}= 0V	—	670	880	µA
VOLTAGE CONTROL LOOP						
G_{MV}	CV Amplifier Transconductance	—	1.5	5.0	12.0	mA/mV
V_{REF_CV5}	Reference Voltage for 5V CV Control	—	0.49	0.50	0.51	V
V_{REF_CV9}	Reference Voltage for 9V CV Control	—	0.88	0.90	0.92	V
V_{REF_CV12}	Reference Voltage for 12V CV Control	—	1.17	1.20	1.23	V
$V_{REF\_0.2V\_CV\_STEP}$	Reference Voltage for QC3.0 0.2V Step CV Control	—	—	0.02	—	V
R_{CABLE}	Cable Compensation	—	90	100	110	mV/A
I_{IBV}	CV Amplifier Input Bias Current	—	5	30	100	nA
CURRENT CONTROL LOOP						
G_{MI}	CC Amplifier Transconductance	—	2	5	20	mA/mV
V_{REF_CC5}	5V CC Mode Reference Voltage	—	71.25	75	78.75	mV
V_{REF_CC9}	9V CC Mode Reference Voltage	—	47.5	50	52.5	mV

Electrical Characteristics (@V_{CC} = 5V, -40°C < T_A < +85°C, unless otherwise specified.) (continued)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
V_{REF_CC12}	12V CC Mode Reference Voltage	—	35.63	37.5	39.38	mV
R_{CC}	Internal CC Amplifier Input Resistor	—	5	13	20	kΩ
PROTECTION FUNCTION						
V_{OVP5V}	OVP_5V Enable Voltage	—	5.7	6	6.3	V
V_{OVP9V}	OVP_9V Enable Voltage	—	10.26	10.8	11.34	V
V_{OVP12V}	OVP_12V Enable Voltage	—	13.68	14.4	15.12	V
I_{OVD}	Average OVP Discharge Current	—	—	70	—	mA
$t_{DEBOUNCE\_OVP}$	OVP Debounce Time	—	80	100	120	ms
V_{UVP5V}	UVP_5V Enable Voltage	@ Below 8.8V	2.99	3.15	3.3	V
V_{UVP9V}	UVP_9V Enable Voltage	@11.8V-9V	6.67	7.02	7.37	V
V_{UVP12V}	UVP_12V Enable Voltage	@12V	8.892	9.36	9.82	V
$t_{DEBOUNCE\_UVP}$	UVP Debounce Time	—	24	30	36	ms
SECONDARY SIDE FEEDBACK SECTION						
V_{OL}	V_{OUT} Pin Voltage under 2mA Internal Amplifier Sinking Current	—	—	30	100	mV
I_{OS}	Maximum V_{OUT} Pin Sink Current	V_{OUT} = 4V	10	20	50	mA
QC3.0 DECODER SECTION						
V_{DAT_REF}	Data Detect Voltage	—	0.25	0.325	0.40	V
V_{SEL_REF}	Output Voltage Selection Reference	—	1.8	2.0	2.2	V
R_{DAT_LKG}	Data Line Leakage Resistance	—	300	500	800	kΩ
R_{DCP_DAT}	D+ to D- Resistance During DCP Mode	D+ is supplied with 0.6V	—	20	40	Ω
R_{DM_DWM}	D- Pull-Down Resistance	—	14.25	19.53	24.80	kΩ
$t_{GLITCH\_BC\_DONE}$	D+ High Glitch Filter Time	—	1.0	1.25	1.5	s
$t_{GLITCH\_DM\_LOW}$	D- Low Glitch Filter Time	—	1.0	2.5	4.0	ms
$t_{GLITCH\_V\_CHANGE}$	Output Voltage Glitch Filter Time	—	20	40	60	ms
$t_{D+\_D-\_SHORT}$	D+ and D- HVDCP Short Time	—	—	10	20	ms
$t_{GLITCH\_DP\_LOW}$	D+ Low Glitch Filter Time	—	35	50	65	ms
C_{DCP_PWR}	D+/- Equivalent Capacitance	—	—	—	0.5	nF
$t_{GLITCH\_CONT\_CHANGE}$	Continuous Mode Glitch Filter Time for D+/- Pull Up or Down	—	100	—	200	µs
t_{ACTIVE}	Active Pulse Time in Continuous Mode	—	0.2	—	15	ms
$t_{INACTIVE}$	Time Between Pulses in Continuous Mode	—	200	—	—	µs
Output Voltage Discharge (OVD)						
V_{OVD}/V_{CV}	Ratio of the OVD Trigger Voltage to CV Reference	When the output voltage is switched down	—	102	—	%
I_{OVD}	Average OVD Current		—	70	—	mA
t_{OVD}	OVD Discharge Time		96	120	144	ms

Operation Principle Description

Constant Voltage Operation

The output voltage is sensed on the V_{CTRL} pin via resistor divider R1/R2 (See Page 2), and compared with the CV operational amplifier's reference voltage for constant voltage regulation to generate a CV compensation signal on the V_{OUT} pin. Via an opto-coupler, the compensation signal is transferred to the Diodes Incorporated's primary controller to control duty cycle. Given that the AP43331N is integrated with output cable voltage compensation function, the output voltage can be calculated as follows:

$$V_O = V_{REF\_CV} \times \frac{R1 + R2}{R1} + R_{CABLE} \times I_O$$

Where V_{REF_CV} is CV operational amplifier reference voltage; R1/R2 is the output voltage divider resistor; R_{CABLE} is the parameter for output cable voltage compensation; I_O is the output current flowing through R_{CSS}. The recommended resistance value is 6.81kΩ paralleled with 16.2kΩ for R1, and 43.2kΩ for R2.

Constant Current Operation

The output current is sensed on V_{SENSE} pin via current sense resistor R_{CSS} placed on the output ground return path. The sensed signal is amplified by the internal current sensing amplifier, then is compared with the CC operational amplifier's reference voltage for constant current regulation to generate a CC compensation signal on the V_{OUT} pin. Via an opto-coupler, the compensation signal is transferred to the Diodes Incorporated's primary-side controller to determine the duty cycle. The typical output constant current can be calculated as follows:

$$I_{O\_CC} = \frac{V_{REF\_CC}}{R_{CSS}}$$

Where V_{REF_CC} is CC operational amplifier reference voltage; R_{CSS} is output current sense resistance.

Qualcomm QC3.0 Decoder

The AP43331N default output voltage and current limit is 5V. For the connected portable device compatible to QC3.0, the AP43331N will complete the handshake, and decode D+/D- signals to set the related V_{REF_CV}/V_{REF_CC}, and then provide the targeted output voltage and current limit. See Table1 below for the details (The AP43331N is only compatible with Class A):

Decoder	V_{D+} (V)	V_{D-} (V)	HV DCP (Class A)	HV DCP (Class B)
Qualcomm Quick Charge 3.0 Protocol	0.6	0.6	12V	20V
	3.3	0.6	9V	9V
	0.6	3.3	Continuous Mode	Continuous Mode
	3.3	3.3	Previous Voltage	Previous Voltage
	3.3	GND	Previous Voltage	Previous Voltage
	0.6	GND	5V	5V
	GND	0.6 or 3.3 or GND	5V, Protocol Handshake Reset	5V, Protocol Handshake Reset

Table 1. D+/D- Voltage Qualcomm QC3.0 Decoder

Over Voltage Protection (OVP)

Output voltage is detected through the AP43331N V_{CC} pin for OVP monitor. Once output voltage rises to OVP enable voltage, the AP43331N will have OVP function triggered to generate the discharged current.

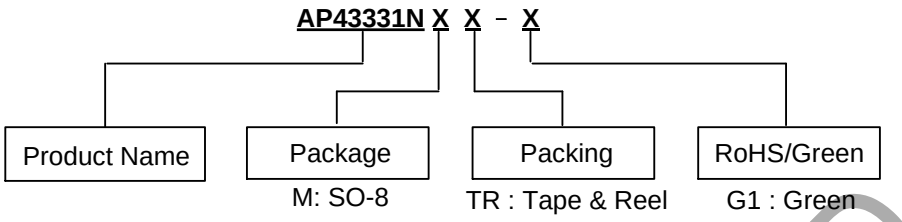
Under Voltage Protection (UVP)

The AP43331N will fully depend on the Diodes Incorporated's primary controller to take charge of UVP. The primary controller can detect output voltage via its V_{CC} winding's waveform to trigger primary UVP function once the output voltage drops below the UVP threshold voltage.

Over Voltage Discharge (OVD)

When the portable device requests a lower output voltage, the AP43331N will have over voltage discharge function work to accelerate output voltage decrease.

Ordering Information



Part Number	Package	Temperature Range	Marking ID	Packing	
				Qty.	Carrier
AP43331NMTR-G1	SO-8	-40 to +85°C	43331NM-G1	4000	Tape & Reel

Marking Information

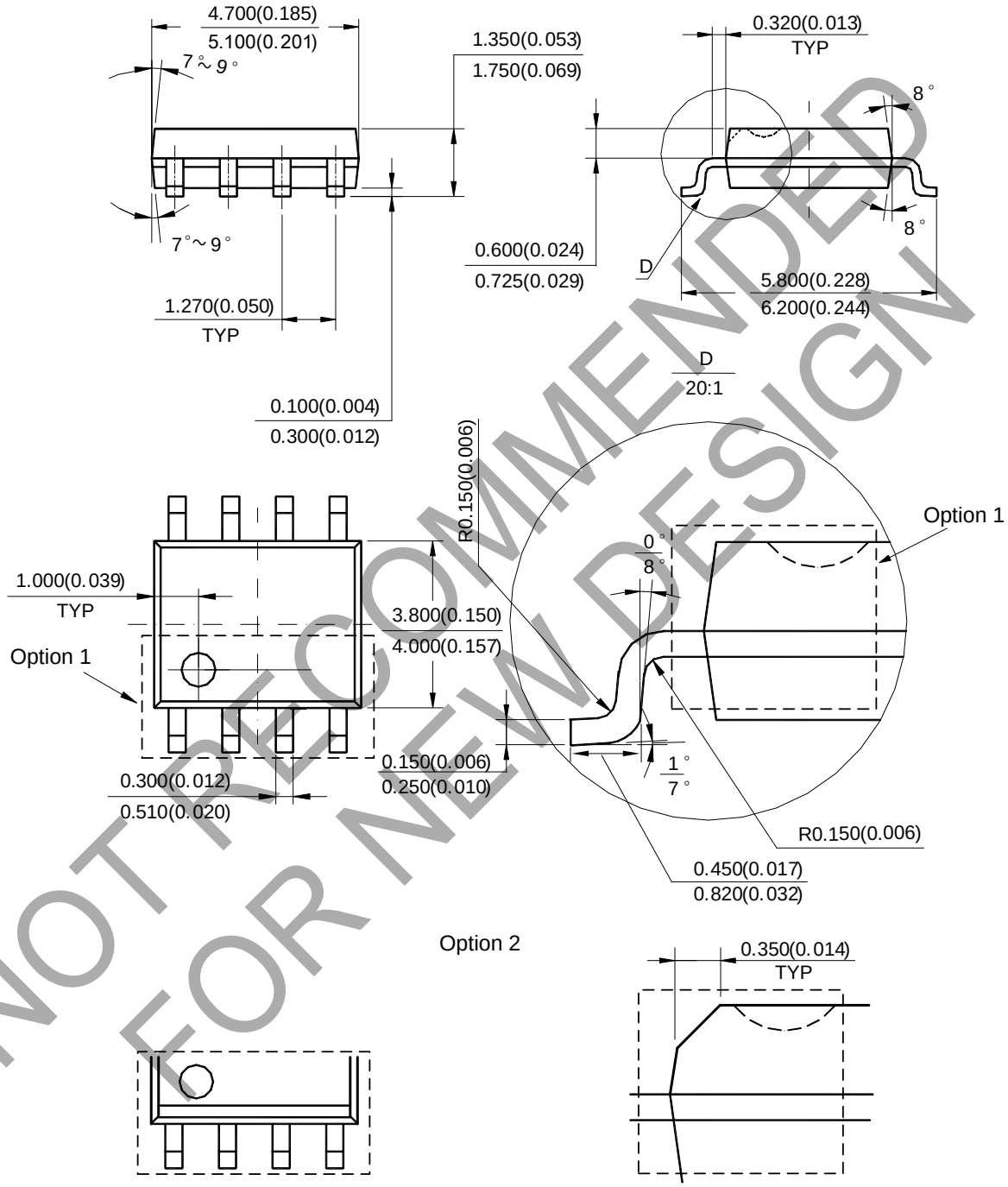
(Top View)

First and Second Lines: Logo and Marking ID
Third Line: Date Code
Y: Year
WW: Work Week of Molding
A: Assembly House Code
XX: 7th and 8th Digits of Batch No.

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

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

(1) Package Type: SO-8

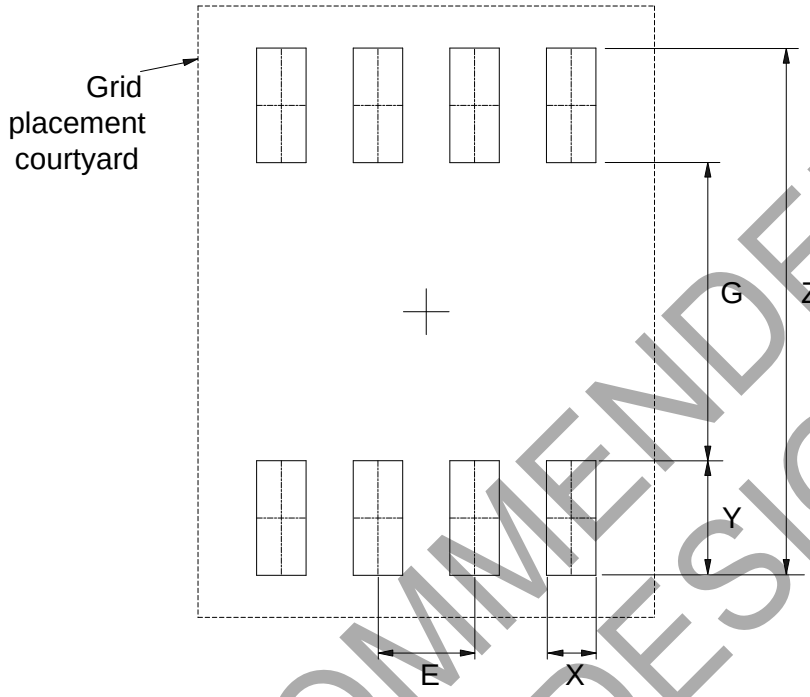


Note: Eject hole, oriented hole and mold mark is optional.

Suggested Pad Layout

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

(1) Package Type: SO-8



Dimensions	Z (mm)/(inch)	G (mm)/(inch)	X (mm)/(inch)	Y (mm)/(inch)	E (mm)/(inch)
Value	6.900/0.272	3.900/0.154	0.650/0.026	1.500/0.059	1.270/0.050

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