

## Description

The AP43331N is a highly integrated secondary side constant voltage (CV) and constant current (CC) controller, which is compatible with Qualcomm Quick Charge 3.0 (QC 3.0) 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 (QC 3.0'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 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.

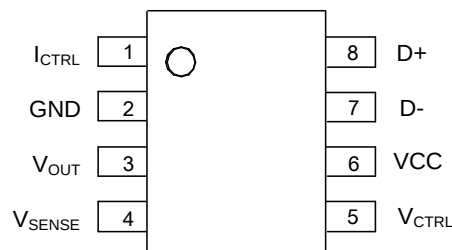
The AP43331N integrates a safe-discharge circuitry to quickly and reliably discharge output capacitors when the output voltage is switched down.

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

(Top View)



SO-8

## Features

- Constant Voltage and Constant Current Regulation
- Supporting Qualcomm QC 3.0 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)**

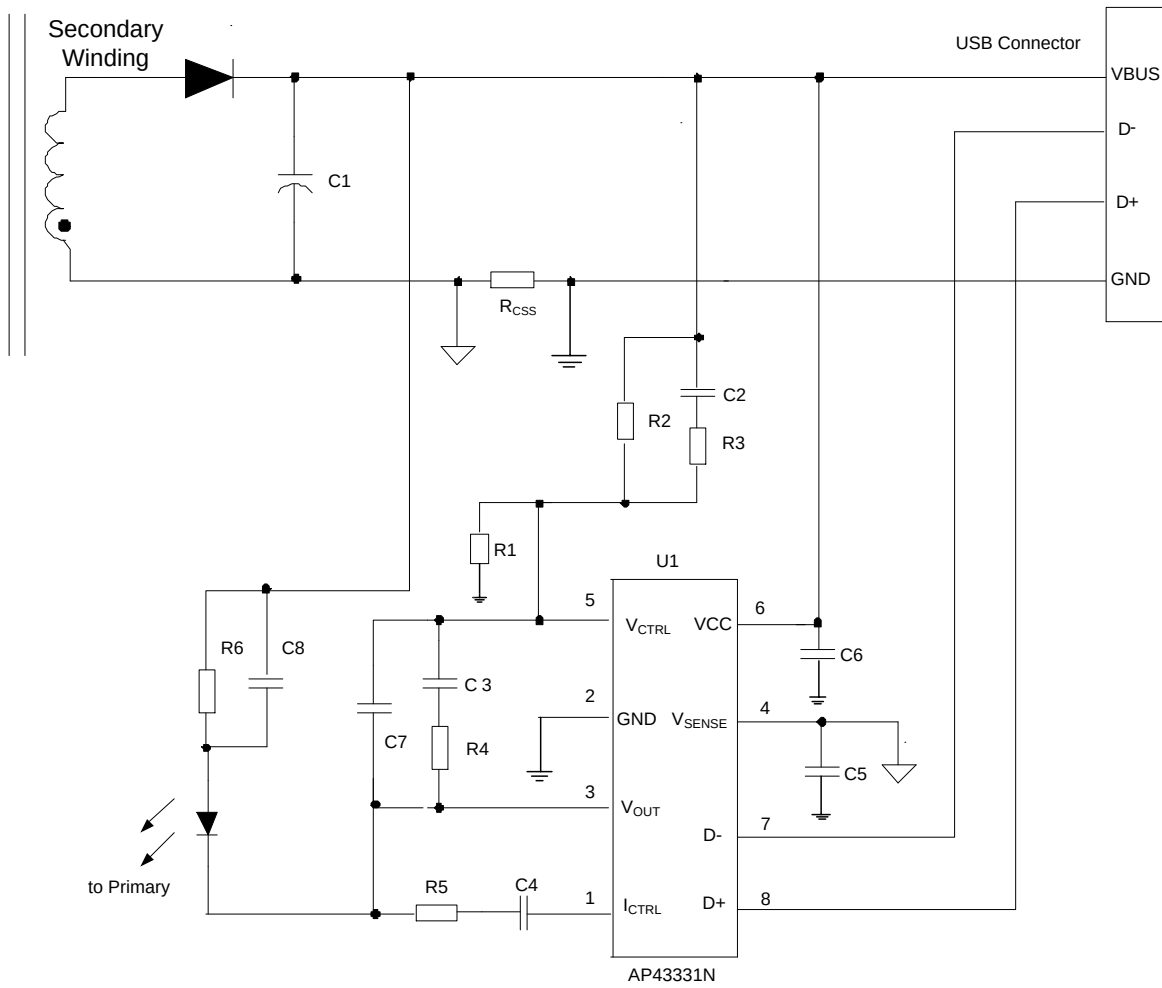
## Applications

- 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) compliant.
2. See [http://www.diodes.com/quality/lead\\_free.html](http://www.diodes.com/quality/lead_free.html) 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  $R_{CSS}$

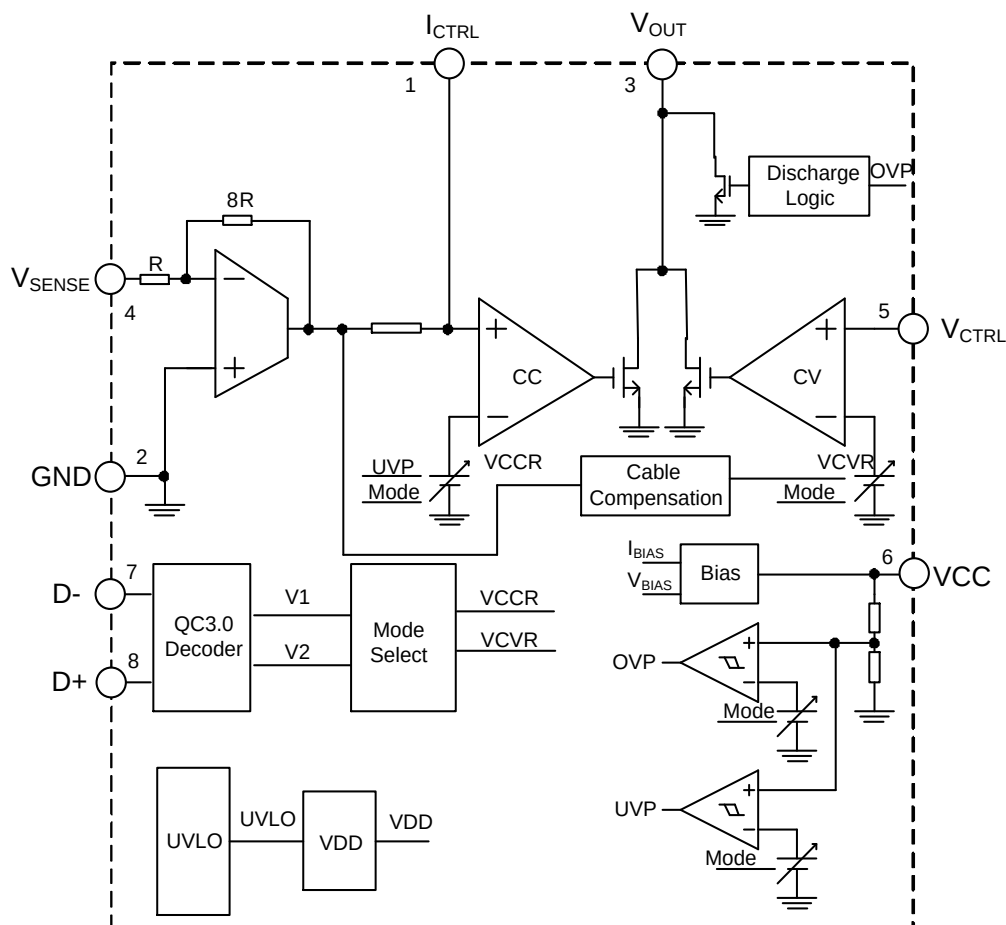
$V_{REF\_CV}$  : Constant Voltage Reference

$I_{O\_CC}$  : Output Constant Current Point

## Pin Descriptions

| Pin Number | Pin Name           | Function                                            |
|------------|--------------------|-----------------------------------------------------|
| 1          | I <sub>CTRL</sub>  | Non-inverting input pin of the current control loop |
| 2          | GND                | Ground return                                       |
| 3          | V <sub>OUT</sub>   | Output pin; Sinking current only                    |
| 4          | V <sub>SENSE</sub> | Inverting input pin of the current control loop     |
| 5          | V <sub>CTRL</sub>  | 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 <sub>CC</sub>    | Power Supply Voltage                             | -0.3 to 20              | V    |
| V <sub>OUT</sub>   | V <sub>OUT</sub> Pin Voltage                     | -0.3 to V <sub>CC</sub> | V    |
| V <sub>CTRL</sub>  | I <sub>CTRL</sub> Pin Voltage                    | -0.3 to 7               | V    |
| V <sub>SENSE</sub> | V <sub>SENSE</sub> Pin Voltage                   | -0.3 to 7               | V    |
| V <sub>VCTRL</sub> | V <sub>CTRL</sub> Pin Voltage                    | -0.3 to 7               | V    |
| T <sub>J</sub>     | Junction Temperature                             | +150                    | °C   |
| T <sub>STG</sub>   | Storage Temperature                              | -55 to +150             | °C   |
| T <sub>LEAD</sub>  | Lead Temperature (Soldering, 5 sec)              | +260                    | °C   |
| θ <sub>JA</sub>    | Thermal Resistance (Junction to Ambient, Note 5) | 129                     | °C/W |
| ESD                | ESD (Human Body Model)                           | 6                       | kV   |
|                    | ESD (Machine Model)                              | 300                     | V    |

Notes:

- 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.
- Device mounted on FR-4 substrate PC board, 2oz copper, with 1inch<sup>2</sup> pad layout.

## Recommended Operating Conditions

| Symbol          | Parameter            | Min | Max | Unit |
|-----------------|----------------------|-----|-----|------|
| V <sub>CC</sub> | Power Supply Voltage | 3.2 | 12  | V    |
| T <sub>A</sub>  | Ambient Temperature  | -40 | +85 | °C   |

## Electrical Characteristics (@V<sub>CC</sub> = 5V, -40°C < T<sub>A</sub> < +85°C, unless otherwise specified.)

| Symbol                           | Parameter                                        | Condition                                                             | Min   | Typ  | Max   | Unit  |
|----------------------------------|--------------------------------------------------|-----------------------------------------------------------------------|-------|------|-------|-------|
| <b>TOTAL CURRENT CONSUMPTION</b> |                                                  |                                                                       |       |      |       |       |
| V <sub>ST</sub>                  | Start-Up Voltage                                 | –                                                                     | 2.8   | 3    | 3.2   | V     |
| V <sub>CC_UVLO</sub>             | V <sub>CC</sub> Under Voltage Lock Out Voltage   | –                                                                     | 2.6   | 2.8  | 3     | V     |
| I <sub>CC</sub>                  | Operating Supply Current                         | V <sub>CC</sub> = 5V, V <sub>SENSE</sub> = 0V, V <sub>CTRL</sub> = 0V | –     | 670  | 880   | μA    |
| <b>VOLTAGE CONTROL LOOP</b>      |                                                  |                                                                       |       |      |       |       |
| G <sub>MV</sub>                  | CV Amplifier Transconductance                    | –                                                                     | 1.5   | 5.0  | 12.0  | mA/mV |
| V <sub>REF_CV5</sub>             | Reference Voltage for 5V CV Control              | –                                                                     | 0.49  | 0.50 | 0.51  | V     |
| V <sub>REF_CV9</sub>             | Reference Voltage for 9V CV Control              | –                                                                     | 0.88  | 0.90 | 0.92  | V     |
| V <sub>REF_CV12</sub>            | Reference Voltage for 12V CV Control             | –                                                                     | 1.17  | 1.20 | 1.23  | V     |
| V <sub>REF_0.2V_CV_STEP</sub>    | Reference Voltage for QC3.0 0.2V Step CV Control | –                                                                     | –     | 0.02 | –     | V     |
| R <sub>CABLE</sub>               | Cable Compensation                               | –                                                                     | 90    | 100  | 110   | mV/A  |
| I <sub>IBV</sub>                 | CV Amplifier Input Bias Current                  | –                                                                     | 5     | 30   | 100   | nA    |
| <b>CURRENT CONTROL LOOP</b>      |                                                  |                                                                       |       |      |       |       |
| G <sub>MI</sub>                  | CC Amplifier Transconductance                    | –                                                                     | 2     | 5    | 20    | mA/mV |
| V <sub>REF_CC5</sub>             | 5V CC Mode Reference Voltage                     | –                                                                     | 71.25 | 75   | 78.75 | mV    |
| V <sub>REF_CC9</sub>             | 9V CC Mode Reference Voltage                     | –                                                                     | 47.5  | 50   | 52.5  | mV    |

# Electrical Characteristics (@V<sub>CC</sub> = 5V, -40°C < T<sub>A</sub> < +85°C, unless otherwise specified.) (Cont.)

| Symbol                                 | Parameter                                                                 | Condition                                | Min   | Typ   | Max   | Unit |
|----------------------------------------|---------------------------------------------------------------------------|------------------------------------------|-------|-------|-------|------|
| V <sub>REF_CC12</sub>                  | 12V CC Mode Reference Voltage                                             | –                                        | 35.63 | 37.5  | 39.38 | mV   |
| R <sub>CC</sub>                        | Internal CC Amplifier Input Resistor                                      | –                                        | 5     | 13    | 20    | kΩ   |
| <b>PROTECTION FUNCTION</b>             |                                                                           |                                          |       |       |       |      |
| V <sub>OVP5V</sub>                     | OVP_5V Enable Voltage                                                     | –                                        | 5.7   | 6     | 6.3   | V    |
| V <sub>OVP9V</sub>                     | OVP_9V Enable Voltage                                                     | –                                        | 10.26 | 10.8  | 11.34 | V    |
| V <sub>OVP12V</sub>                    | OVP_12V Enable Voltage                                                    | –                                        | 13.68 | 14.4  | 15.12 | V    |
| I <sub>OVD</sub>                       | Average OVP Discharge Current                                             | –                                        | –     | 70    | –     | mA   |
| t <sub>DEBOUNCE_OVP</sub>              | OVP Debounce Time                                                         | –                                        | 80    | 100   | 120   | ms   |
| V <sub>UVP5V</sub>                     | UVP_5V Enable Voltage                                                     | @ Below 8.8V                             | 2.99  | 3.15  | 3.3   | V    |
| V <sub>UVP9V</sub>                     | UVP_9V Enable Voltage                                                     | @11.8V-9V                                | 6.67  | 7.02  | 7.37  | V    |
| V <sub>UVP12V</sub>                    | UVP_12V Enable Voltage                                                    | @12V                                     | 8.892 | 9.36  | 9.82  | V    |
| t <sub>DEBOUNCE_UVP</sub>              | UVP Debounce Time                                                         | –                                        | 24    | 30    | 36    | ms   |
| <b>SECONDARY SIDE FEEDBACK SECTION</b> |                                                                           |                                          |       |       |       |      |
| V <sub>OL</sub>                        | V <sub>OUT</sub> Pin Voltage under 2mA Internal Amplifier Sinking Current | –                                        | –     | 30    | 100   | mV   |
| I <sub>OS</sub>                        | Maximum V <sub>OUT</sub> Pin Sink Current                                 | V <sub>OUT</sub> = 4V                    | 10    | 20    | 50    | mA   |
| <b>QC3.0 DECODER SECTION</b>           |                                                                           |                                          |       |       |       |      |
| V <sub>DAT_REF</sub>                   | Data Detect Voltage                                                       | –                                        | 0.25  | 0.325 | 0.40  | V    |
| V <sub>SEL_REF</sub>                   | Output Voltage Selection Reference                                        | –                                        | 1.8   | 2.0   | 2.2   | V    |
| R <sub>DAT_LKG</sub>                   | Data Line Leakage Resistance                                              | –                                        | 300   | 500   | 800   | kΩ   |
| R <sub>DCP_DAT</sub>                   | D+ to D- Resistance During DCP Mode                                       | D+ is supplied with 0.6V                 | –     | 20    | 40    | Ω    |
| R <sub>DM_DWM</sub>                    | D- Pull-Down Resistance                                                   | –                                        | 14.25 | 19.53 | 24.80 | kΩ   |
| t <sub>GLITCH_BC_DONE</sub>            | D+ High Glitch Filter Time                                                | –                                        | 1.0   | 1.25  | 1.5   | s    |
| t <sub>GLITCH_DM_LOW</sub>             | D- Low Glitch Filter Time                                                 | –                                        | 1.0   | 2.5   | 4.0   | ms   |
| t <sub>GLITCH_V_CHANGE</sub>           | Output Voltage Glitch Filter Time                                         | –                                        | 20    | 40    | 60    | ms   |
| t <sub>D+D-_SHORT</sub>                | D+ and D- HVDSP Short Time                                                | –                                        | –     | 10    | 20    | ms   |
| t <sub>GLITCH_DP_LOW</sub>             | D+ Low Glitch Filter Time                                                 | –                                        | 35    | 50    | 65    | ms   |
| C <sub>DCP_PWR</sub>                   | D+/- Equivalent Capacitance                                               | –                                        | –     | –     | 0.5   | nF   |
| t <sub>GLITCH_CONT_CHANGE</sub>        | Continuous Mode Glitch Filter Time for D+/- Pull Up Or Down               | –                                        | 100   | –     | 200   | μs   |
| t <sub>ACTIVE</sub>                    | Active Pulse Time in Continuous Mode                                      | –                                        | 0.2   | –     | 15    | ms   |
| t <sub>INACTIVE</sub>                  | Time Between Pulses in Continuous Mode                                    | –                                        | 200   | –     | –     | μs   |
| <b>Output Voltage Discharge (OVD)</b>  |                                                                           |                                          |       |       |       |      |
| V <sub>OVD/V<sub>CV</sub></sub>        | Ratio of the OVD Trigger Voltage to CV Reference                          | When the output voltage is switched down | –     | 102   | –     | %    |
| I <sub>OVD</sub>                       | Average OVD Current                                                       |                                          | –     | 70    | –     | mA   |
| t <sub>OVD</sub>                       | 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 integrates 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 QC 3.0 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.

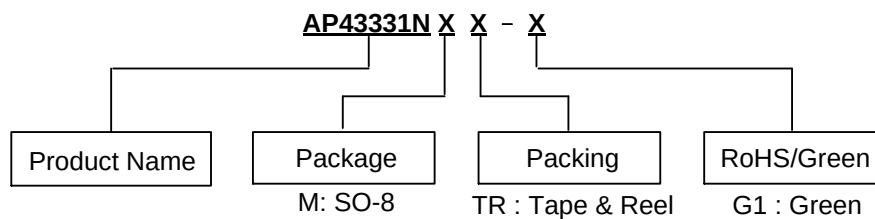
### Under Voltage Protection (UVP)

The AP43331N will fully depends 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.

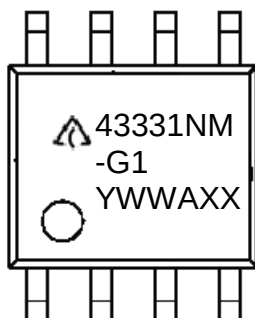
## Ordering Information



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

## Marking Information

(Top View)

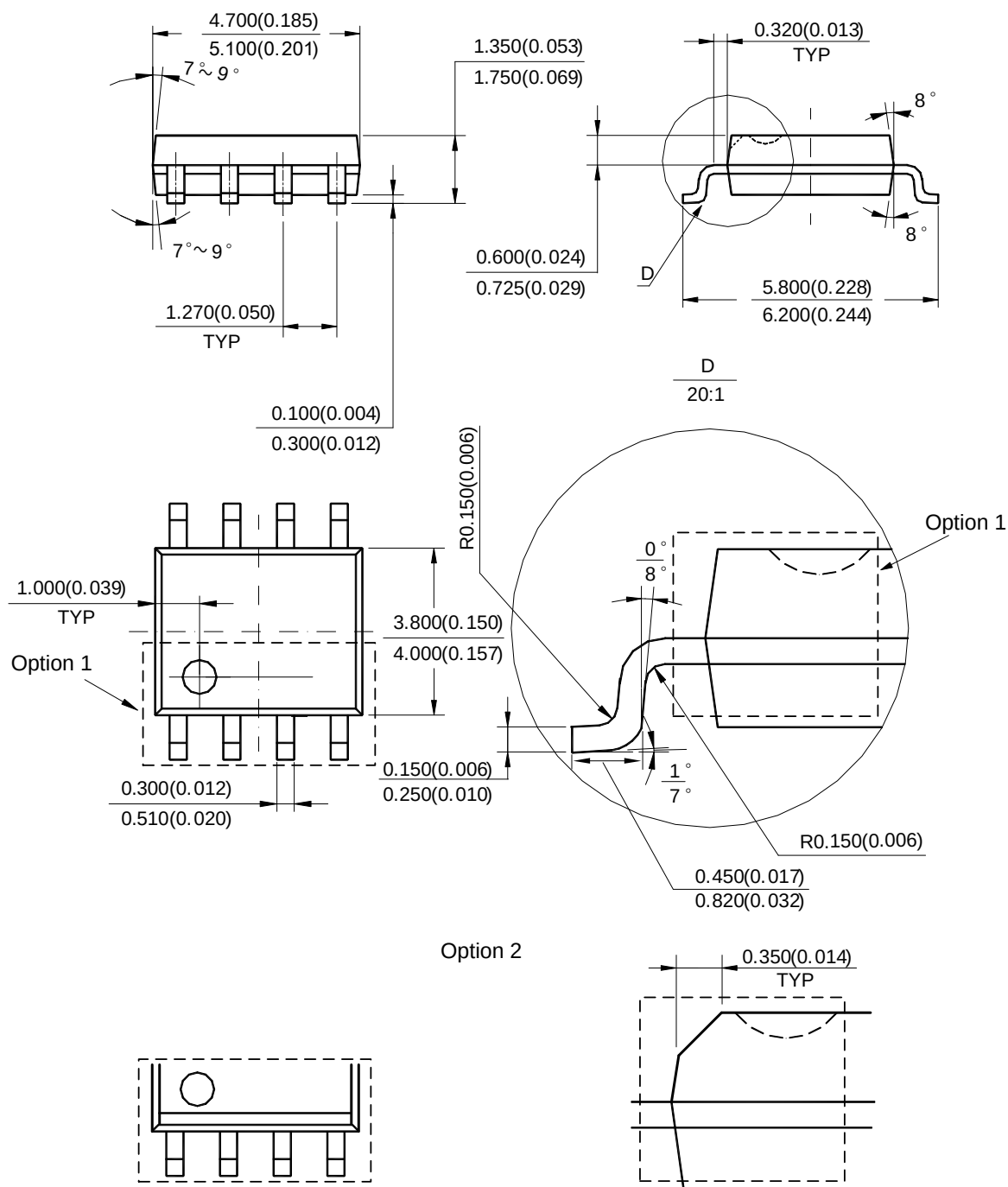


First and Second Lines: Logo and Marking ID  
 Third Line: Date Code  
 Y: Year  
 WW: Work Week of Molding  
 A: Assembly House Code  
 XX: 7th and 8th Digits of Batch No.



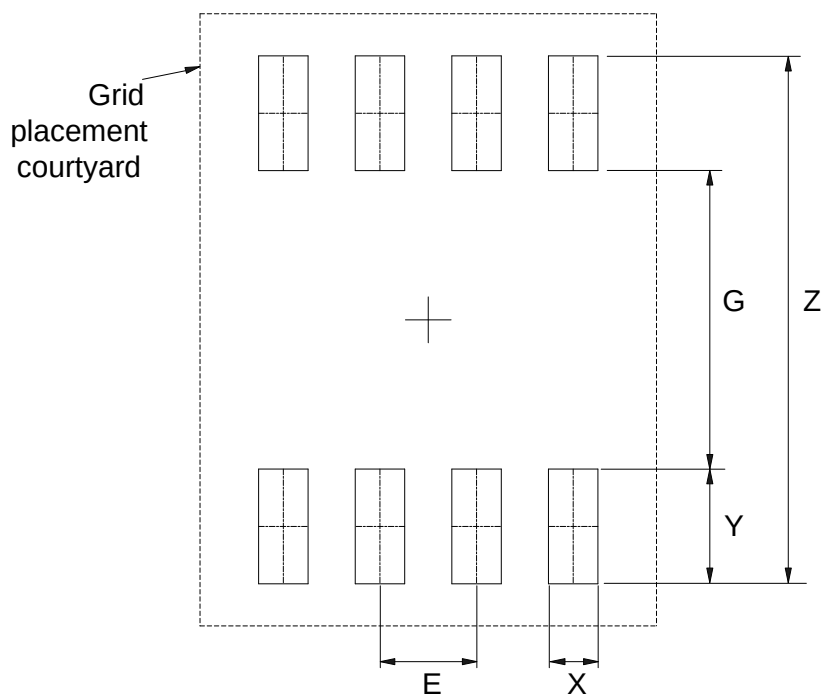
**Package Outline Dimensions** (All dimensions in mm(inch).)

(1) Package Type: SO-8



## Suggested Pad Layout

(1) Package Type: SO-8



| Dimensions | Z<br>(mm)/(inch) | G<br>(mm)/(inch) | X<br>(mm)/(inch) | Y<br>(mm)/(inch) | E<br>(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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