

Description

The DIODES™ AP3304A is a peak-current control, multi-mode CCM+QR PWM controller which is optimized for high performance, low standby power and cost effective offline flyback converters.

At light load, AP3304A operates in burst mode with 23kHz switching frequency to minimize standby power consumption and avoid the audible noise. When the load increases, AP3304A will enter QR mode with frequency fold-back to improve system efficiency and EMI performance. In QR mode, the maximum switching frequency is clamped to 100kHz to reduce switching power loss. If the switching frequency reaches upper limit of AP3304A, the switching frequency starts to fall as the load increases until entering CCM with fixed switching frequency 80kHz to optimize power conversion efficiency. Furthermore, the frequency dithering function is built in to reduce EMI emission.

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

Comprehensive protection features are included, such as brown out protection, cycle-by-cycle current limit (OCP), V_{CC} over voltage protection (VOVP), secondary side output OVP (SOVP) and UVP (SUVP), internal OTP, over load protection (OLP) and pins' fault protection.

Features

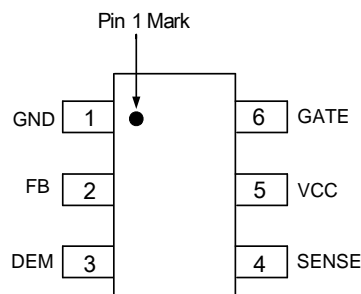
- Very Low Start-Up Current
- Multi-Mode Control with CCM+QR
- Soft Start During Startup Process
- Frequency Fold-Back for High Average Efficiency
- Constant Over Current Protection
- Secondary Winding Short Protection with FOCP
- Frequency Dithering for Reducing EMI
- Useful Pin Fault Protection:
SENSE Pin Floating
FB/Opto-Coupler Open/Short
- Comprehensive System Protection Feature:
V_{CC} Over Voltage Protection (VOVP)
Over Load Protection (OLP)
- Brown Out Protection (BNO)
- Secondary Side OVP (SOVP) and UVP (SUVP)
- Mini Size Package of SOT26 (Type A1)
- **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](mailto:contact@diodes.com) or your local Diodes representative. <https://www.diodes.com/quality/product-definitions/>**

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.

Pin Assignments

(Top View)



SOT26 (Type A1)

Applications

- Switching AC-DC adapters/chargers
- ATX/BTX auxiliary power
- Set-top box (STB) power supplies
- Open frame switching power supplies

Typical Applications Circuit

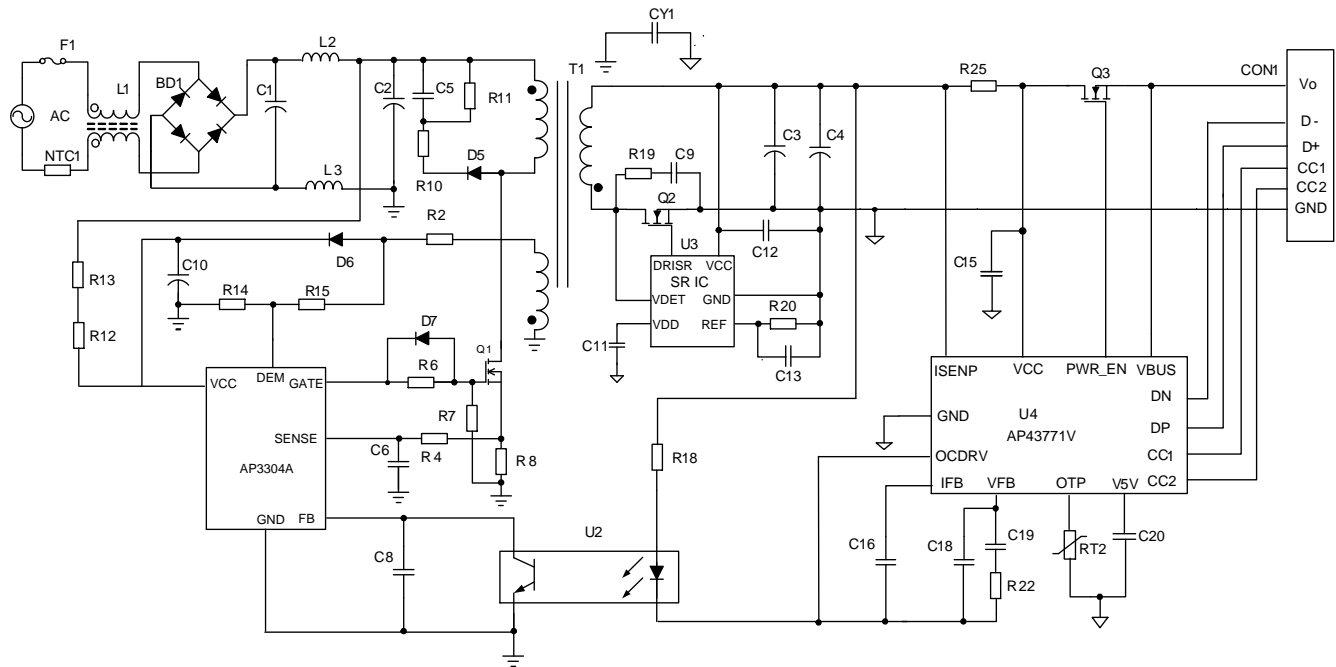


Figure 1

Pin Descriptions

Pin Number	Pin Name	Function
1	GND	Signal ground. Current return for driver and control circuits
2	FB	Feedback. Directly connected to the opto-coupler
3	DEM	Valley detection for QR control, AC line voltage detection for Brown-in/Brown-out, Sample output voltage for SOVP and SUVP, OCP line compensation current setting.
4	SENSE	Current sense
5	VCC	Supply voltage of driver and control circuits
6	GATE	Gate driver output

The block diagram illustrates the control logic for the VCC and GATE drivers. It includes several key components and their interconnections:

- VCC Pin:**
 - V_{BULK} Detector:** Provides BNO, BKOV, and IL_CMP signals.
 - Valley Detector:** Provides Valley signal.
 - V_{OUT} Detector:** Provides SOVP and SUVP signals.
 - Soft-Start & Jitter:** Provides Tb1 and Tb2 signals.
 - Power & Fault Management:** Receives VCC_OVP, OLP, OTP, BKOV, SUVP, SOVP, BNO, and FOCF signals. It outputs Burst and FOCF signals.
 - ON Logic:** Receives Tb1, Tb2, Valley, and f_{MIN} signals. It outputs a signal to the D flip-flop.
 - OSC:** Provides f_{MIN} and T_{ON_MAX} signals.
 - Burst Generator:** Receives V_{BURST-ET/ED} and 64ms signals. It outputs Burst and OLP signals.
 - D Flip-Flop:** Receives Burst and FOCF signals. It outputs a signal to the GATE pin.
 - Comparator:** Receives V_{CS_LIMIT} and V_{ST/V_{UVLO}} signals. It outputs a signal to the GATE pin.
 - BIAS:** Provides a bias signal to the comparator.
 - VCC_OVP:** Provides a signal to the comparator.
 - VCC:** The output of the VCC pin.
- GATE Pin:**
 - D Flip-Flop:** Receives Burst and FOCF signals. It outputs a signal to the GATE pin.
 - Comparator:** Receives V_{CS_LIMIT} and V_{ST/V_{UVLO}} signals. It outputs a signal to the GATE pin.
 - GATE:** The output of the GATE pin.
- Feedback and Control:**
 - FB:** Feedback signal from the GATE pin.
 - R_{FB}:** Feedback resistor.
 - X1:** Gain of 1.
 - 3R, 2R, R:** Resistor values in the feedback network.
 - 1.7V:** Reference voltage for the comparator.
 - 64ms:** Delay time for the comparator.
 - OLP:** Overload Protection signal.
 - Dithering:** Signal for the comparator.
 - Slope Comp.:** Slope Compensation signal.
 - LEB:** Load Error Buffer signal.
 - IL_CMP:** Current Limit Comparison signal.
 - SENSE:** SENSE pin output.
 - FOCF:** Fault Current Foldback signal.
 - 1.2V:** Reference voltage for the comparator.

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Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Rating	Unit
V _{CC}	Power Supply Voltage	-0.3 to 60	V
I _O	Gate Output Current	-800 to 300	mA
V _{FB} , V _{SENSE} , V _{DEM}	Input Voltage to FB, SENSE, DEM	-0.3 to 6.5	V
θ _{JA}	Thermal Resistance (Junction to Ambient)	250	°C/W
P _D	Power Dissipation at T _A < +25 °C	500	mW
T _J	Operating Junction Temperature	-40 to +150	°C
T _{STG}	Storage Temperature Range	+150	°C
—	ESD (Human Body Model)	2000	V
—	ESD (CDM)	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}	Supply Voltage	10	50	V
T _A	Ambient Temperature	-40	+85	°C

Electrical Characteristics (@T_A = -40°C to +85°C, V_{CC} = 18V, unless otherwise specified.)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
Supply Voltage (VCC Pin)						
I _{ST}	Startup Current	—	—	1	—	μA
I _{CC}	Operating Supply Current	V _{FB} = 2.5V, C _{GATE} = 1nF (Note 5)	1.5	2.0	2.5	mA
I _{CC-FAULT}	Operating Current If Fault Occurs	V _{FB} = 4V, V _{CS} = 0V (Note 5)	0.4	0.6	0.8	
I _{BURST}	Operating Current at Burst	V _{FB} = 0V	—	0.3	—	mA
V _{ST}	Startup Voltage	—	14.8	15.8	16.8	V
V _{UVLO}	Shutdown Voltage	—	6	6.5	7	V
V _{CC-OVP}	V _{CC} OVP	—	50	—	—	V
PWM Section/Oscillator Section						
f _{OSC-MAX}	Maximum Clamp Frequency (at QR)	—	90	100	110	kHz
—	Maximum Clamp Frequency (at CCM)	—	72	80	88	kHz
f _{OSC-MIN}	Minimum Clamp Frequency	—	21	23	25	kHz
f _{OSC-Dithering}	Frequency Dithering	—	—	±6	—	%
Current Sense Section (SENSE Pin)						
V _{CS-MAX}	Maximum SENSE Voltage for Valley One	V _{DEM} = 3V	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 6)	—	—	7	—	Cycles
t _{LEB}	LEB Time of SENSE	—	400	480	550	ns
Feedback Input Section (FB Pin)						
K _{FB-CS}	The Ratio of Input Voltage to Current Sense Voltage	—	—	6	—	V/V
R _{FB}	Input Impedance	—	—	32	—	kΩ
I _{FB-SOURCE}	Source Current	V _{FB} = 0V	—	0.15	—	mA
V _{BURST-ET}	Threshold for Entering Burst Mode	—	0.45	0.5	0.55	V
V _{BURST-ED}	Threshold for Ending Burst Mode	—	0.54	0.6	0.66	—
V _{FB-OLP}	Over Load Protection	—	—	3.4	—	V
t _{ON-MAX}	Maximum on Time	—	—	10	—	μs
t _{SOFT-ST}	Soft-Start Time (Note 6)	—	—	5	—	ms
t _{DELAY-OLP}	Delay of Over Load Protection	—	—	64	—	ms

Notes: 5. Data measured in IC test mode.
6. Guaranteed by design.

Electrical Characteristics (@T_A = -40°C to +85°C, V_{CC} = 18V, unless otherwise specified.) (continued)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
Output Section (GATE Pin)						
V _{GATE-L}	Output Low Level	I _O = 20mA	—	—	0.8	V
V _{GATE-H}	Output High Level	I _O = 20mA	9	—	—	V
V _{GATE-CLP}	Output Clamping Voltage	V _{CC} = 50V	10	11.5	13	V
t _{GATE-RISE}	Rising Time (Note 6)	C _{GATE} = 1nF	—	200	—	ns
t _{GATE-FALL}	Falling Time (Note 6)	C _{GATE} = 1nF	—	25	50	ns
Demagnetization Section (DEM Pin)						
V _{TH-DEM}	De-Magnetization Voltage (Note 6)	—	—	100	—	mV
I _{BNI}	Brown In Reference	—	—	170	—	μA
I _{BNO}	Brown Out Reference	—	—	155	—	μA
V _{TH-SOVP}	SOVP Threshold	—	3	3.2	3.4	V
V _{TH-SUVP}	SUVP Threshold (Note 6)	—	0.34	0.4	0.46	V
t _{SAMPLE}	Sample Delay Time (Note 6)	—	—	1.5	—	μs
Delay Time Section						
t _{DELAY-BNO}	Brown Out Debounce Time	—	—	64	—	ms
t _{DELAY-HICCUP}	Delay of Hiccup Protection (Note 6)	SOVP, SUVP, V _{CC} OVP	—	6	—	Cycles
t _{BLANK-SUVP}	SUVP Blank Time After Startup	—	—	5	—	ms
Internal OTP Section						
OTP	OTP Threshold (Note 6)	—	—	+150	—	°C
T _{HYS}	OTP Recovery Hysteresis (Note 6)	—	—	+25	—	°C

Note: 6. Guaranteed by design.

Operation Description

The AP3304A realizes Multi-Mode Operation including Burst mode, QR mode and CCM mode, which is specifically designed for off-line AC-DC power supply used in LCD monitor, notebook adapter and battery charger applications. At medium load, the IC will enter QR mode with frequency fold-back to improve system efficiency and EMI performance. It offers a cost effective solution with a versatile protection function.

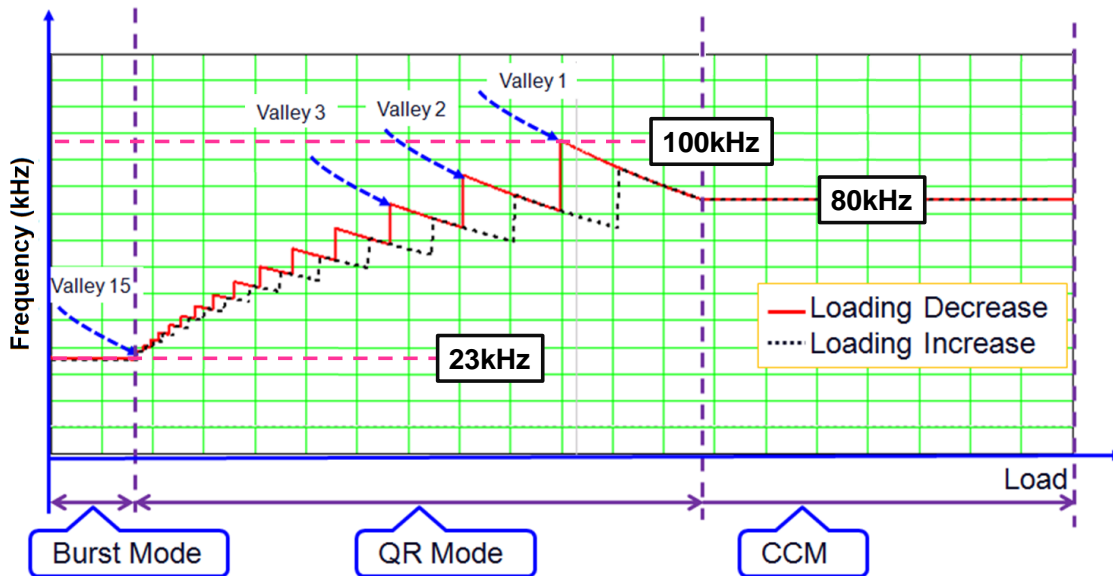


Figure 3

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 in burst mode with fixed switching frequency 23kHz to avoid audible noise. When the FB voltage is lower than $V_{BURST-ET}$, the controller will not provide driving signal and the FB voltage will rise above $V_{BURST-ED}$, 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 is the abbreviation of 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 on MOSFET. The V_{DS} valley is detected by DEM pin through the voltage divider network of R_{DEM} and R_{SOVP} . In QR mode, the trend of switching frequency is modulated by AP3304A.
- CCM**
 When AP3304A operates in QR mode with 1st valley, switching frequency starts to fall as load increases. If the switching frequency falls to 80kHz, CCM is implemented to achieve high efficiency. Usually at low line voltage, the system will enter CCM at heavy load, while at high line voltage, the system may still operate in QR mode with 1st or 2nd valley.

Operation Description (continued)

UVLO

A UVLO comparator is included in the AP3304A to detect the voltage on VCC pin. It ensures that the AP3304A 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 AP3304A 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:

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

Moreover, FOCP with 1.2V threshold is only about $t_{DELAY-FOCP}$ delay, which can avoid some catastrophic damage 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 higher 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).

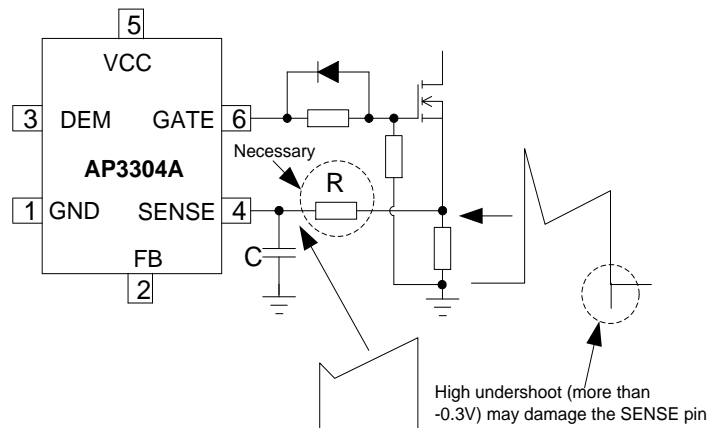


Figure 4

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 AP3304A, the system will enter hiccup mode to wait for the VCC to decrease to low UVLO level, then the IC will try to restart until the failure is removed. And when this voltage is less than $V_{BURST-ET}$, 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 over voltage protection function. The DEM pin compares 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 AP3304A will trigger SOVP function and the system will enter the protection mode. Since the value of VCC winding's waveform reflects the output voltage precisely, the Secondary Output Voltage Protection (SOVP) can be achieved by this function.

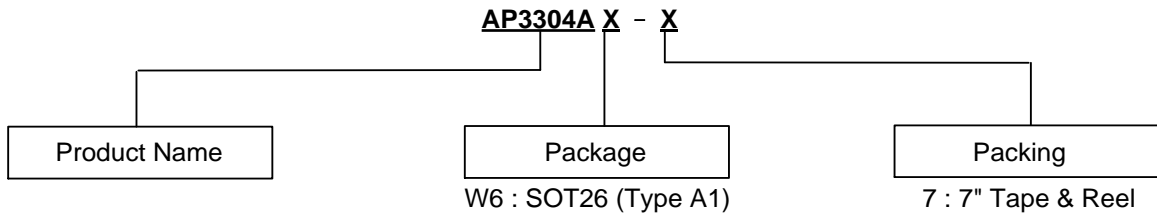
Other System Protection and Pin Fault Protection

The AP3304A 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 over voltage protection can be applied as the primary OVP or opto-coupler broken protection. The AP3304A 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 DEM pin is shorted to ground, PWM switching will be disabled, thus protecting the power system.

Internal OTP Protection Function

The AP3304A 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

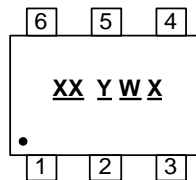


Part Number	Temperature Range	Package	Identification Code	Packing	
				Qty.	Carrier
AP3304AW6-7	-40°C to +85°C	SOT26 (Type A1)	D6	3,000	7" Tape and Reel

Marking Information

SOT26 (Type A1)

(Top View)

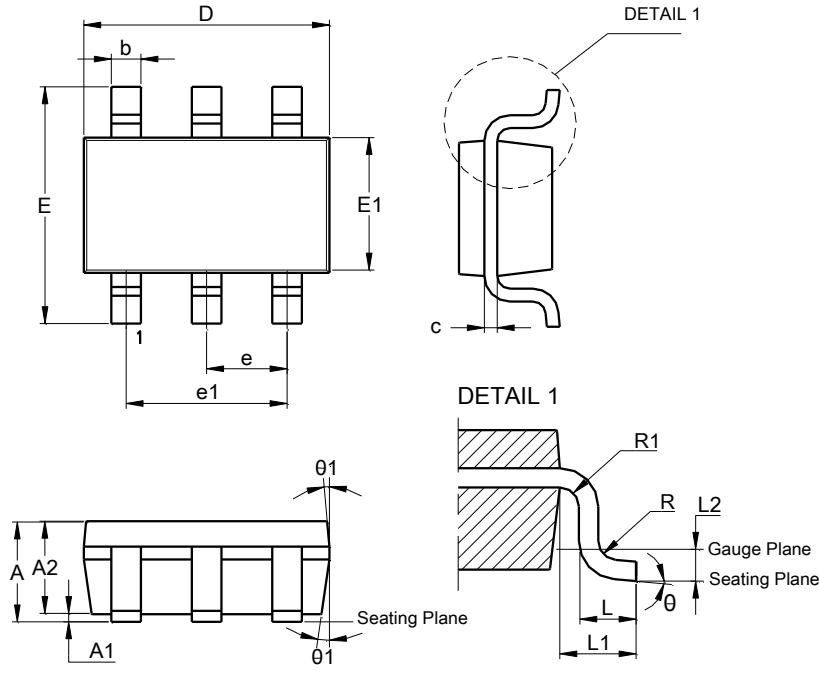


XX : Identification Code
Y : Year 0 to 9
W : Week : A to Z : 1 to 26 Week;
 a to z : 27 to 52 Week; z Represents
 52 and 53 Week
X : Internal Code

Package Outline Dimensions

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

SOT26 (Type A1)

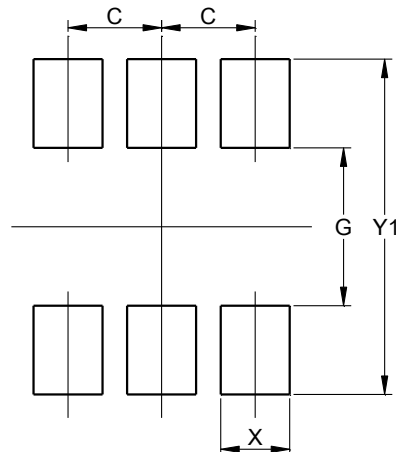


SOT26 (Type A1)			
Dim	Min	Max	Typ
A	--	1.45	--
A1	0.00	0.15	--
A2	0.90	1.30	1.15
b	0.30	0.50	--
c	0.08	0.22	--
D	2.90 BSC		
E	2.80 BSC		
E1	1.60 BSC		
e	0.95 BSC		
e1	1.90 BSC		
L	0.30	0.60	0.45
L1	0.60 REF		
L2	0.25 BSC		
R	0.10	--	--
R1	0.10	0.25	--
θ	0°	8°	4°
θ1	5°	15°	10°
All Dimensions in mm			

Suggested Pad Layout

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

SOT26 (Type A1)



Dimensions	Value (in mm)
C	0.950
G	1.600
X	0.700
Y	0.900
Y1	3.400

Mechanical Data

- Moisture Sensitivity: Level 1 per JESD22-A113
- Terminals: Finish – Matte Tin Plated Leads, Solderable per JESD22-B102 ③
- Weight: 0.016 grams (Approximate)

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