

SECONDARY SIDE SYNCHRONOUS RECTIFICATION CONTROLLER

Description

The DIODES™ APR345 is a secondary side MOSFET driver for synchronous rectification, supports CCM, DCM and Quasi-Resonant Flyback Topologies.

The synchronous rectification can effectively reduce the secondary side rectifier power dissipation and provide high performance solution. By sensing primary MOSFET gate-to-source voltage, APR345 can output ideal drive signal with less external components. It can provide high performance solution for 5V to 12V output voltage application.

The APR345 is available in SOT26 package.

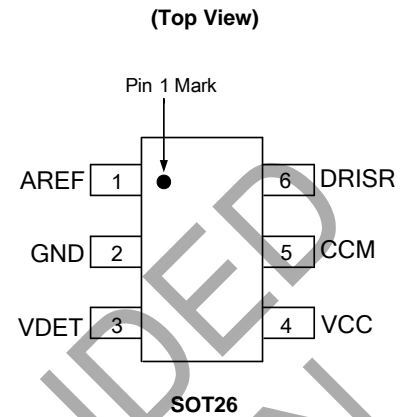
Features

- Synchronous Rectification for CCM, DCM Operation Flyback
- Eliminate Resonant Ring Interference
- Fewest External Components
- **Totally Lead-free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**

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 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.

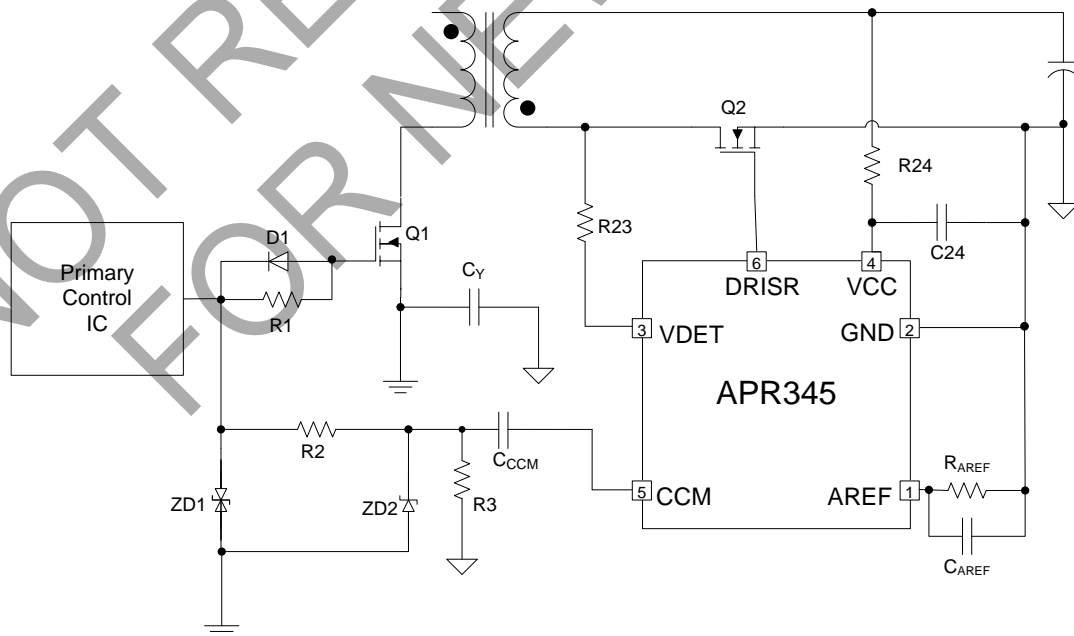
Pin Assignments



Applications

- Adapters/Chargers for Cell/Cordless Phones, ADSL Modems, MP3 and Other Portable Apparatus

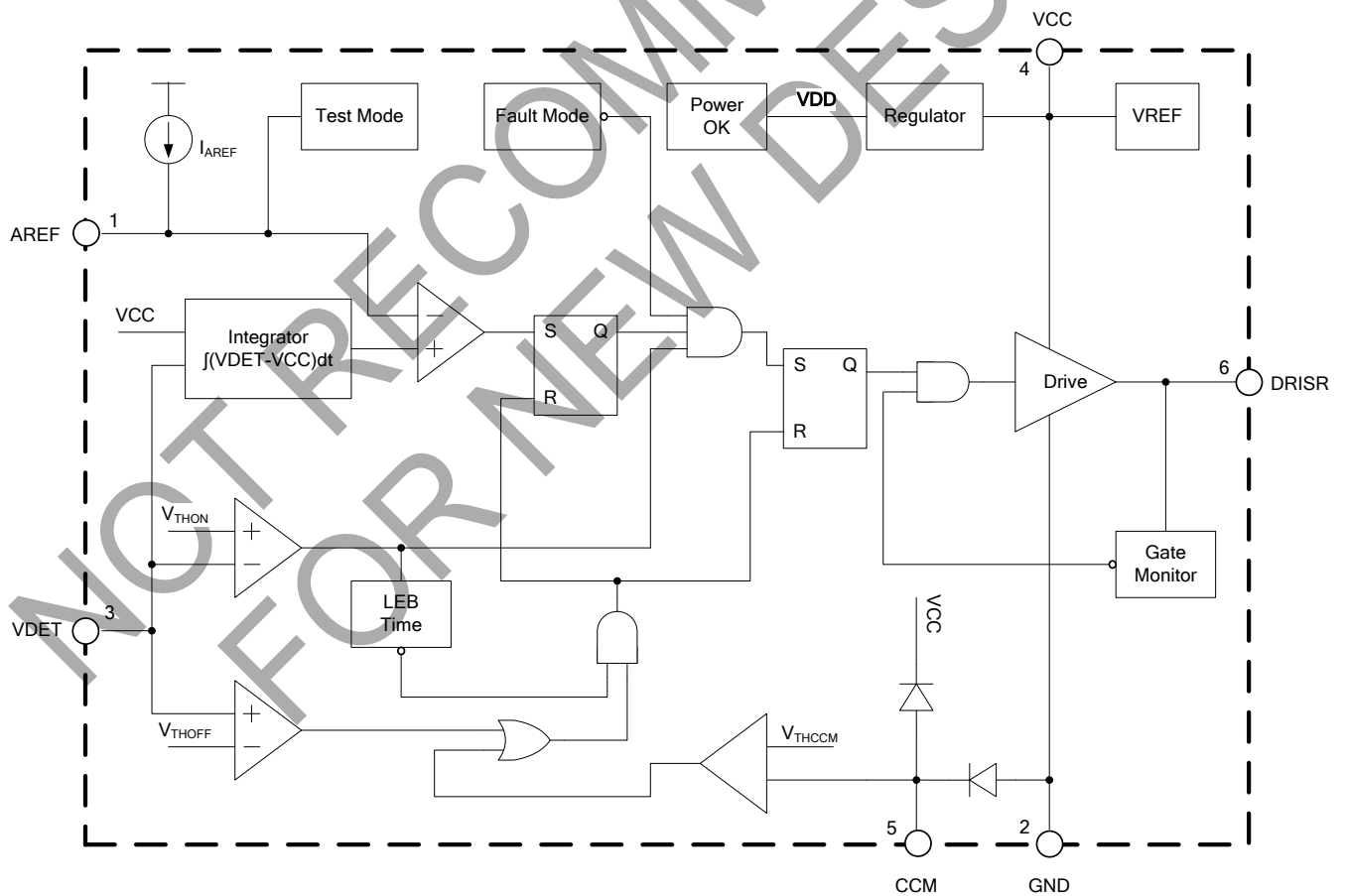
Typical Applications Circuit



Pin Descriptions

Pin Number	Pin Name	Function
1	AREF	Program a voltage reference with a resistor from AREF to GND, to enable synchronous rectification MOSFET drive signal
2	GND	Ground
3	VDET	SR MOS drain-to-source voltage sense input, connected to drain pin of SR MOSFET through a resistor
4	VCC	Power supply, connected with system output
5	CCM	Primary trigger signal sense input
6	DRISR	Synchronous rectification MOSFET Gate drive

Functional Block Diagram



Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Rating	Unit
V _{CC}	Supply Voltage	-0.3 to 16	V
V _{DET}	Voltage at VDET Pin	-0.7 to 120	V
V _{DRISR}	Voltage at DRISR Pin	-0.3 to 16	V
P _D	Power Dissipation at T _A = +25°C	TBD	W
T _J	Operating Junction Temperature	+150	°C
T _{STG}	Storage Temperature	-65 to +150	°C
T _{LEAD}	Lead Temperature (Soldering, 10 sec)	+300	°C
θ _{JA}	Thermal Resistance (Junction to Ambient)	TBD	°C/W
θ _{JC}	Thermal Resistance (Junction to Case)	TBD	°C/W

Note 4: 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.

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V _{CC}	Supply Voltage	0	13	V
T _A	Ambient Temperature	-40	+85	°C

Electrical Characteristics (@V_{CC} = 5V, T_A = +25°C, unless otherwise specified.)

Symbol	Parameters	Conditions	Min	Typ	Max	Unit
Supply Voltage (VCC Pin)						
I _{STARTUP}	Startup Current	V _{CC} = V _{STARTUP} -0.1V	–	100	150	μA
I _{OP}	Operating Current	VDET pin floating V _{CC} = 5V	–	100	150	μA
V _{STARTUP}	Startup Voltage	–	–	3.1	–	V
–	UVLO	–	–	2.8	–	V
Gate Driver						
V _{THON}	Gate Turn On Threshold	–	0	–	1	V
V _{THOFF}	Gate Turn Off Threshold	–	-20	-11.5	-3	mV
t _{DON}	Turn On Delay Time	From V _{THON} to V _{DRISR} = 1V	–	70	130	ns
t _{DOFF}	Turn Off Propagation Delay Time	From V _{THOFF} to V _{DRISR} = 4V	–	100	150	ns
t _{RG}	Turn On Rising Time	From 1V to 4V, V _{CC} =5V, C _L =4.7nF	–	50	100	ns
t _{FG}	Turn Off Falling Time	From 4V to 1V, V _{CC} =5V, C _L =4.7nF	–	20	35	ns
t _{ON_MIN}	Minimum On Time	–	1.2	1.6	2	μs
V _{DRISR}	V _{DRI_HIGH}	Drive Maximum Voltage	–	–	V _{CC}	V
	V _{DRI_HOLD}	SR Drive Hold Voltage	V _{CC} <5V	–	V _{CC}	V
			V _{CC} >=5V	5	–	
K _{qs}	–	–	0.32	0.42	0.52	mA*μs
V _{S_MIN}	Synchronous Rectification (SR) Minimum Operating Voltage (Note 5)	–	–	–	4.5	V
Synchronous Rectification Detection						
V _{TH_CCM}	V _{DRISR} Rising Threshold	V _{DRISR} output transitions from High to Low	0.43	0.53	0.63	V
t _{DCCM}	CCM Propagation Delay	From CCM rising to V _{DRISR} falling 10%	–	20	35	ns

Note 5: This item specifies the minimum SR operating voltage of V_{IN_DC}, V_{IN_DC} ≥ N_{PS} * V_{S_MIN}.

Synchronous Rectification Principle Description

SR MOSFET Turn on

APR345 determines the synchronous rectification MOSFET turning on time by monitoring the MOSFET drain-to-source voltage. For both of DCM and CCM operation, the turning on principle is same. When the drain voltage is lower than the turn-on threshold voltage V_{THON} , the IC outputs a positive drive voltage after a turn-on delay time (t_{DON}). The MOSFET will turn on and the current will transfer from the body diode into the MOSFET's channel. Since of parasitic parameter, the voltage on MOSFET drain pin has moderate voltage ringing at this moment, which maybe impact on SR controller VDET voltage sense and bring about turning off fault. To avoid fault situation happening, a Minimum On Time (t_{ONMIN}) blanking period is used that will maintain the power MOSFET on for a minimum amount of time.

In Figure 1, the turn on blanking time t_{ONMIN} is to prevent the MOSFET drain-to-source voltage ringing affect. During this time, the V_{DRISR} is pulled up to V_{CC} ; after t_{ONMIN} , the drive voltage stops be pulled up by the driver, and begins to drop; when V_{DRISR} drops to V_{DRI_HOLD} , it will be held at this voltage until be pulled down.

DCM Turn off Operation

The DCM operation of the SR is described with timing diagram shown in Figure 1.

In the process of drain current decreasing linearly toward zero, the drain-source voltage rises synchronically. When it rises over the turn off threshold voltage V_{THOFF} , APR345 pulls the drive signal down after a turn-off delay (t_{DOFF}).

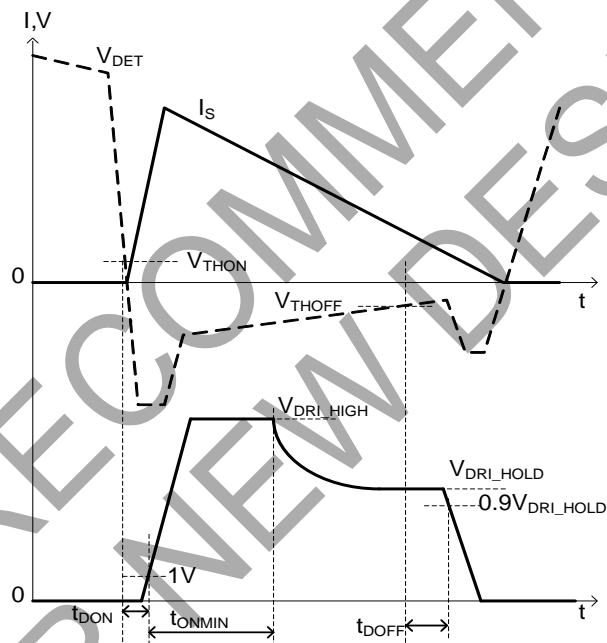


Figure 1. Typical Waveforms of APR345 in DCM

CCM Turn off Operation

The CCM pin is used to sense trigger signal for turning off the SR MOSFET before primary switch turning on in Continuous Conduction Mode (CCM) system. After t_{ONMIN} , if the CCM pin voltage rises over the threshold voltage V_{THCCM} , the drive voltage will be pulled down after a short delay time t_{DCCM} to turn off SR MOSFET. The CCM pin senses trigger signal coming from primary switch turn on signal through a RC networks circuit, a Y-type isolating capacitor C_{CCM} , two resistors R2 and R3. Note variations of these resistors, of C_{CCM} , and of the dV/dt across C_{CCM} require that worst-case tolerances be taken into account when determining the minimum value of C_{CCM} . For example, the value of this resistor will impact the rise time of CCM voltage. The bigger resistor, the slower the CCM voltage rises.

The zener diode ZD1 is used for ESD test.

The value of C_Y should be much higher than that of C_{CCM} . If necessary, increase the value of C_Y to ensure that $C_Y \gg C_{CCM}$; do not decrease C_{CCM} .

C_Y is the main common-mode capacitance between the primary and the secondary sides of the system. This is usually a discrete component, whose value ranges from 47pF to 2200pF. Aside from any EMI-control purposes, it also serves as the return path for the CCM signal charging and discharging current pulses.

Synchronous Rectification Principle Description (Cont.)

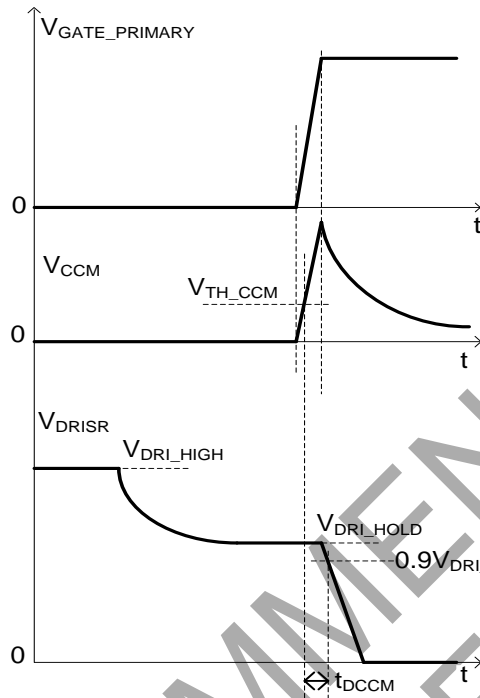


Figure 2. Typical Turn off Waveforms of APR345 in CCM

Minimum On Time

When the controlled MOSFET gate is turned on, some ringing noise is generated. The minimum on-time timer blanks the V_{THOFF} comparator and CCM comparator, keeping the controlled MOSFET on for at least the minimum on time. During the minimum on time, the turn off threshold (DCM and CCM) is totally blanked.

The Value and Meaning of AREF Resistor

As to DCM operation Flyback converter, after secondary rectifier stops conduction, the primary MOSFET Drain-to-source ringing waveform is resulted from the resonant of primary inductance and equivalent switch device output capacitance. This ringing waveform probably leads to Synchronous Rectifier error conduction. To avoid this fault happening, APR345 has a special function design by means of volt-second product detecting. From the sensed voltage of VDET pin to see, the volt-second product of voltage above V_{CC} at primary switch on time is much higher than the volt-second product of each cycle ringing voltage above V_{CC} . Therefore, before every time Synchronous Rectifier turning on, APR345 judges if the detected volt-second product of VDET voltage above V_{CC} is higher than a threshold and then turn on synchronous Rectifier. The purpose of AREF resistor is to determine the volt-second product threshold. APR345 has a parameter, K_{qs} , which converts R_{AREF} value to volt-second product,

$$Area2 = R_{AREF} * K_{qs}$$

In general, Area1 and Area3 value depend on system design and are always fixed after system design frozen. As to Diodes PSR design, the Area1 value changes with primary peak current value and Area3 value generally keeps constant at all of conditions. So the AREF resistor design should consider the worst case, the minimum primary peak current condition. Since of system design parameter distribution, Area1 and Area3 have moderate tolerance. So Area2 should be designed between the middle of Area1 and Area3 to keep enough design margin.

Note: To keep the volt-second product threshold stable, a capacitor is suggested to parallel with AREF resistor. And the recommended value of this capacitor is 20nF.

$$Area3 < R_{AREF} * K_{qs} < Area1$$

Synchronous Rectification Principle Description (Cont.)

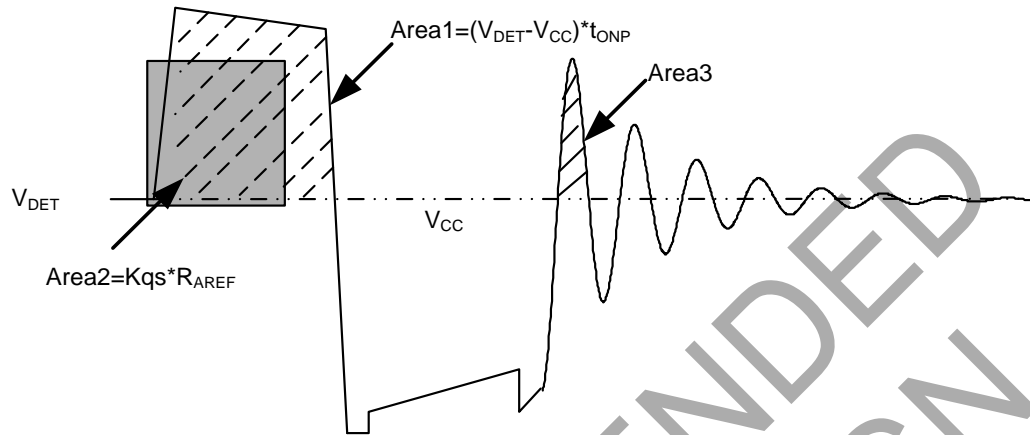


Figure 3. AREF Function

SR Minimum Operating Voltage

APR345 sets a minimum SR operating voltage by comparing the difference between V_{DET} and output voltage (V_{CC}). The value of $V_{DET} - V_{CC}$ must be higher than its internal reference, then APR345 will begin to integrate the area of $(V_{DET} - V_{CC}) * t_{ONP}$. If not, the area integrating will not begin and the SR driver will be disabled.

SR Turning Off Timing Impact on PSR CV Sampling

As to synchronous rectification on Flyback power system, SR MOSFET need to turn off in advance of secondary side current decreasing to zero to avoid current flowing reversely. When SR turns off in advance, the secondary current will flow through the body diode. The SR turning off time is determined by the V_{THOFF} at a fixed system. When V_{THOFF} is more close to zero, the SR turning on time gets longer and body diode conduction time gets shorter. Since of the different voltage drop between SR MOSFET and body diode, the PSR feedback signal V_{FB} appears a voltage jump at the time of SR MOSFET turning off. If the PSR CV sampling time t_{SAMPLE} is close to even behind this voltage jump time, there will be system unstable operation issue or the lower output voltage issue.

To ensure stable operating of system, it must be met:

$$t_{BODYDIODE} < t_{ONS} - t_{SAMPLE}$$

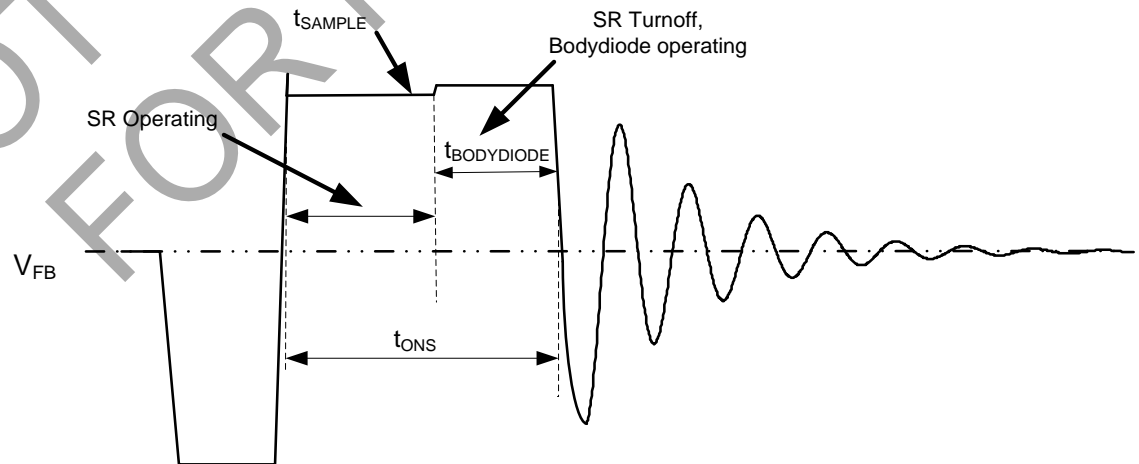


Figure 4. SR Turning Off Timing Impact on PSR CV Sampling

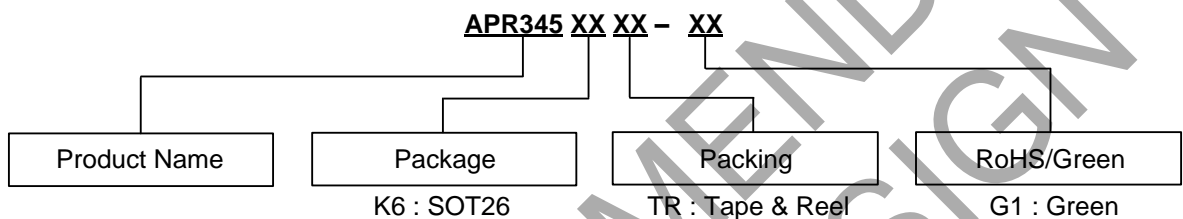
Synchronous Rectification Principle Description (Cont.)

Recommended Application Circuit Parameters

The two resistors R23 and R24 are used to pass ESD test. The value of R23 and R24 should be over 20Ω and below 47Ω respectively because of the undershoot performance. The package of R23 and R24 should be at least 0805 and there isn't any trace under these two resistors.

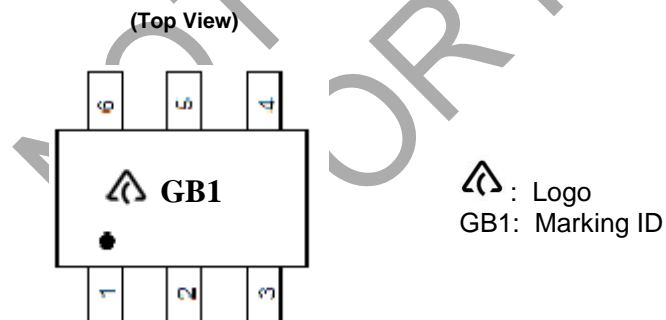
C_{AREF} is suggested to parallel with AREF resistor to keep the volt-second product threshold stable. And the recommended value of C_{AREF} is 20nF. The recommended value of C24 is 100nF.

Ordering Information



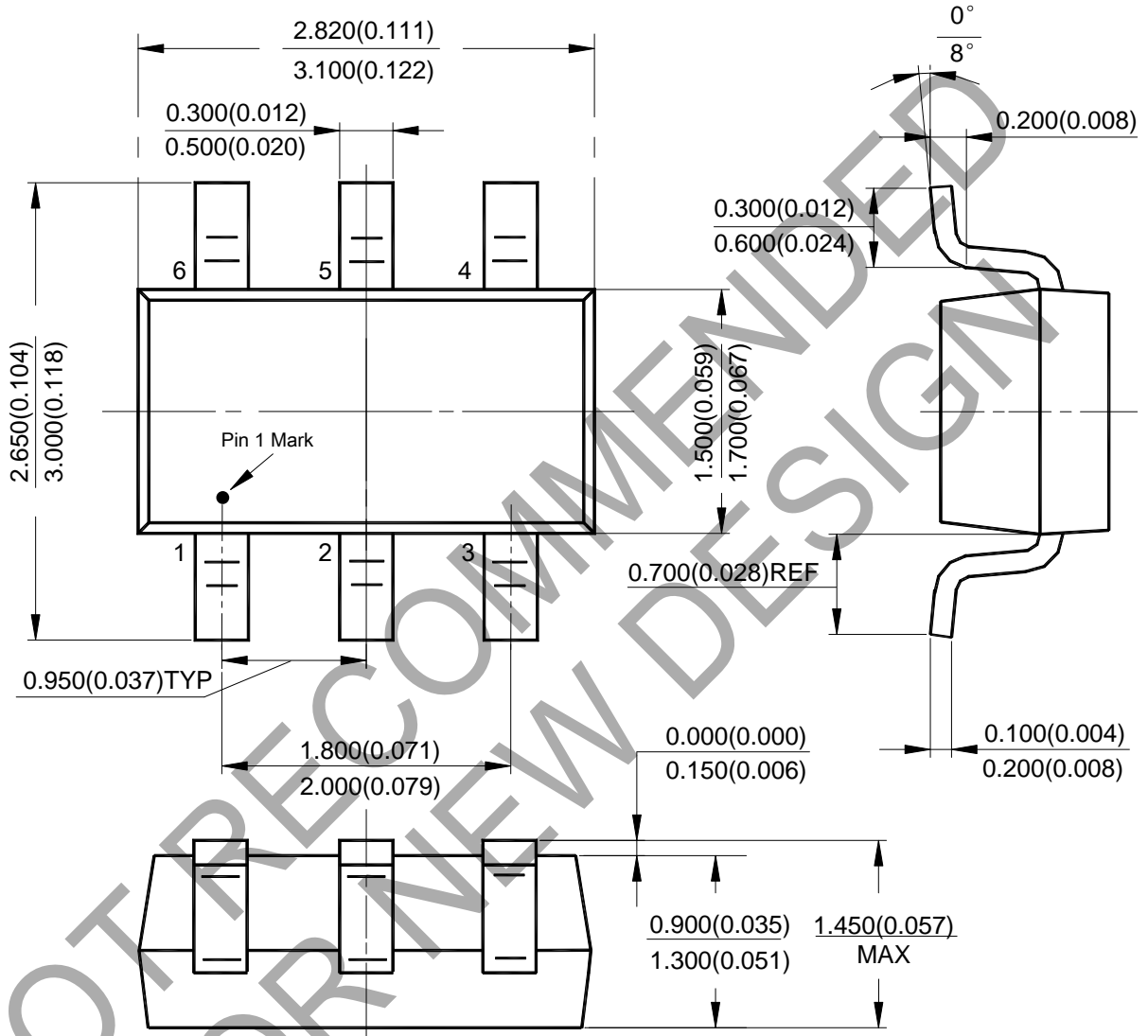
Package	Temperature Range	Part Number	Marking ID	Packing
SOT26	-40°C to +85°C	APR345K6TR-G1	GB1	3000/Tape & Reel

Marking Information



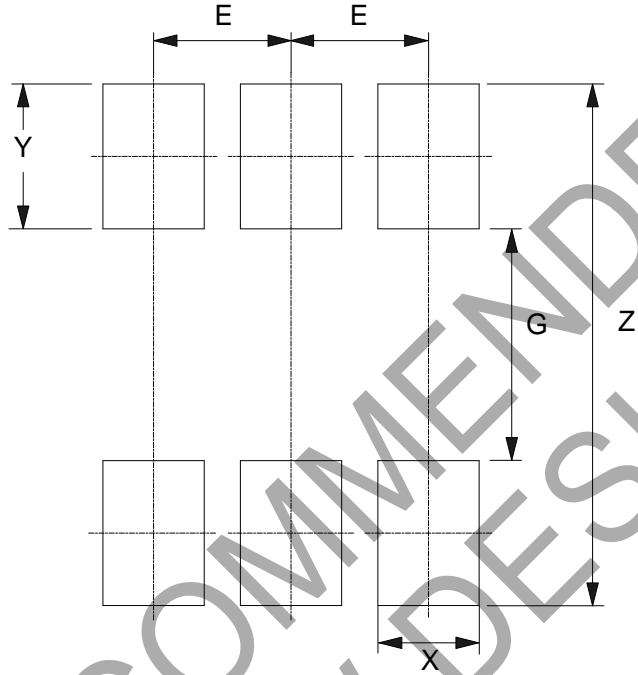
Package Outline Dimensions (All dimensions in mm(inch).)

(1) Package Type: SOT26



Suggested Pad Layout

(1) Package Type: SOT26



Dimensions	Z (mm)/(inch)	G (mm)/(inch)	X (mm)/(inch)	Y (mm)/(inch)	E (mm)/(inch)
Value	3.600/0.142	1.600/0.063	0.700/0.028	1.000/0.039	0.950/0.037

NOT RECOMMENDED FOR NEW DESIGN

IMPORTANT NOTICE

1. DIODES INCORPORATED (Diodes) AND ITS SUBSIDIARIES MAKE NO WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, WITH REGARDS TO ANY INFORMATION CONTAINED IN THIS DOCUMENT, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION).
2. The Information contained herein is for informational purpose only and is provided only to illustrate the operation of Diodes' products described herein and application examples. Diodes does not assume any liability arising out of the application or use of this document or any product described herein. This document is intended for skilled and technically trained engineering customers and users who design with Diodes' products. Diodes' products may be used to facilitate safety-related applications; however, in all instances customers and users are responsible for (a) selecting the appropriate Diodes products for their applications, (b) evaluating the suitability of Diodes' products for their intended applications, (c) ensuring their applications, which incorporate Diodes' products, comply the applicable legal and regulatory requirements as well as safety and functional-safety related standards, and (d) ensuring they design with appropriate safeguards (including testing, validation, quality control techniques, redundancy, malfunction prevention, and appropriate treatment for aging degradation) to minimize the risks associated with their applications.
3. Diodes assumes no liability for any application-related information, support, assistance or feedback that may be provided by Diodes from time to time. Any customer or user of this document or products described herein will assume all risks and liabilities associated with such use, and will hold Diodes and all companies whose products are represented herein or on Diodes' websites, harmless against all damages and liabilities.
4. Products described herein may be covered by one or more United States, international or foreign patents and pending patent applications. Product names and markings noted herein may also be covered by one or more United States, international or foreign trademarks and trademark applications. Diodes does not convey any license under any of its intellectual property rights or the rights of any third parties (including third parties whose products and services may be described in this document or on Diodes' website) under this document.
5. Diodes' products are provided subject to Diodes' Standard Terms and Conditions of Sale (<https://www.diodes.com/about/company/terms-and-conditions/terms-and-conditions-of-sales/>) or other applicable terms. This document does not alter or expand the applicable warranties provided by Diodes. Diodes does not warrant or accept any liability whatsoever in respect of any products purchased through unauthorized sales channel.
6. Diodes' products and technology may not be used for or incorporated into any products or systems whose manufacture, use or sale is prohibited under any applicable laws and regulations. Should customers or users use Diodes' products in contravention of any applicable laws or regulations, or for any unintended or unauthorized application, customers and users will (a) be solely responsible for any damages, losses or penalties arising in connection therewith or as a result thereof, and (b) indemnify and hold Diodes and its representatives and agents harmless against any and all claims, damages, expenses, and attorney fees arising out of, directly or indirectly, any claim relating to any noncompliance with the applicable laws and regulations, as well as any unintended or unauthorized application.
7. While efforts have been made to ensure the information contained in this document is accurate, complete and current, it may contain technical inaccuracies, omissions and typographical errors. Diodes does not warrant that information contained in this document is error-free and Diodes is under no obligation to update or otherwise correct this information. Notwithstanding the foregoing, Diodes reserves the right to make modifications, enhancements, improvements, corrections or other changes without further notice to this document and any product described herein. This document is written in English but may be translated into multiple languages for reference. Only the English version of this document is the final and determinative format released by Diodes.
8. Any unauthorized copying, modification, distribution, transmission, display or other use of this document (or any portion hereof) is prohibited. Diodes assumes no responsibility for any losses incurred by the customers or users or any third parties arising from any such unauthorized use.
9. This Notice may be periodically updated with the most recent version available at <https://www.diodes.com/about/company/terms-and-conditions/important-notice>

DIODES is a trademark of Diodes Incorporated in the United States and other countries.
The Diodes logo is a registered trademark of Diodes Incorporated in the United States and other countries.
© 2022 Diodes Incorporated. All Rights Reserved.

www.diodes.com