

**SECONDARY SIDE SYNCHRONOUS RECTIFICATION CONTROLLER**

**Description**

The APR3401 is a secondary side MOSFET driver for synchronous rectification in DCM/QR/ACF operation.

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, the APR3401 can output ideal drive signal with less external components.

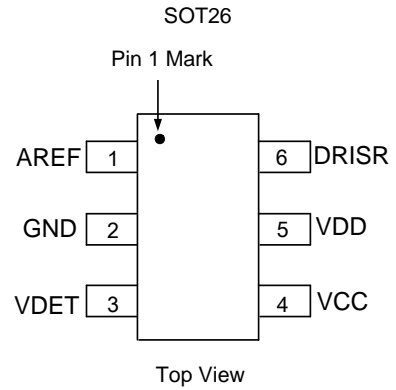
The APR3401 is available in the SOT26 package.

**Features**

- Synchronous Rectification for DCM/QR/ACF 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)**
- **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](https://www.diodes.com/contact-us) 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.

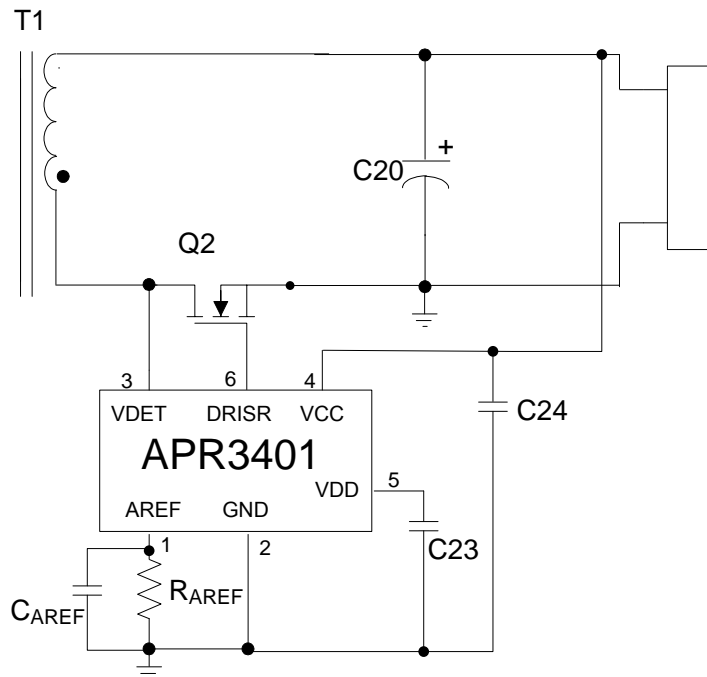
**Pin Assignments**



**Applications**

- Adapters/chargers for cells/cordless phones, ADSL modems, MP3 and other portable apparatus

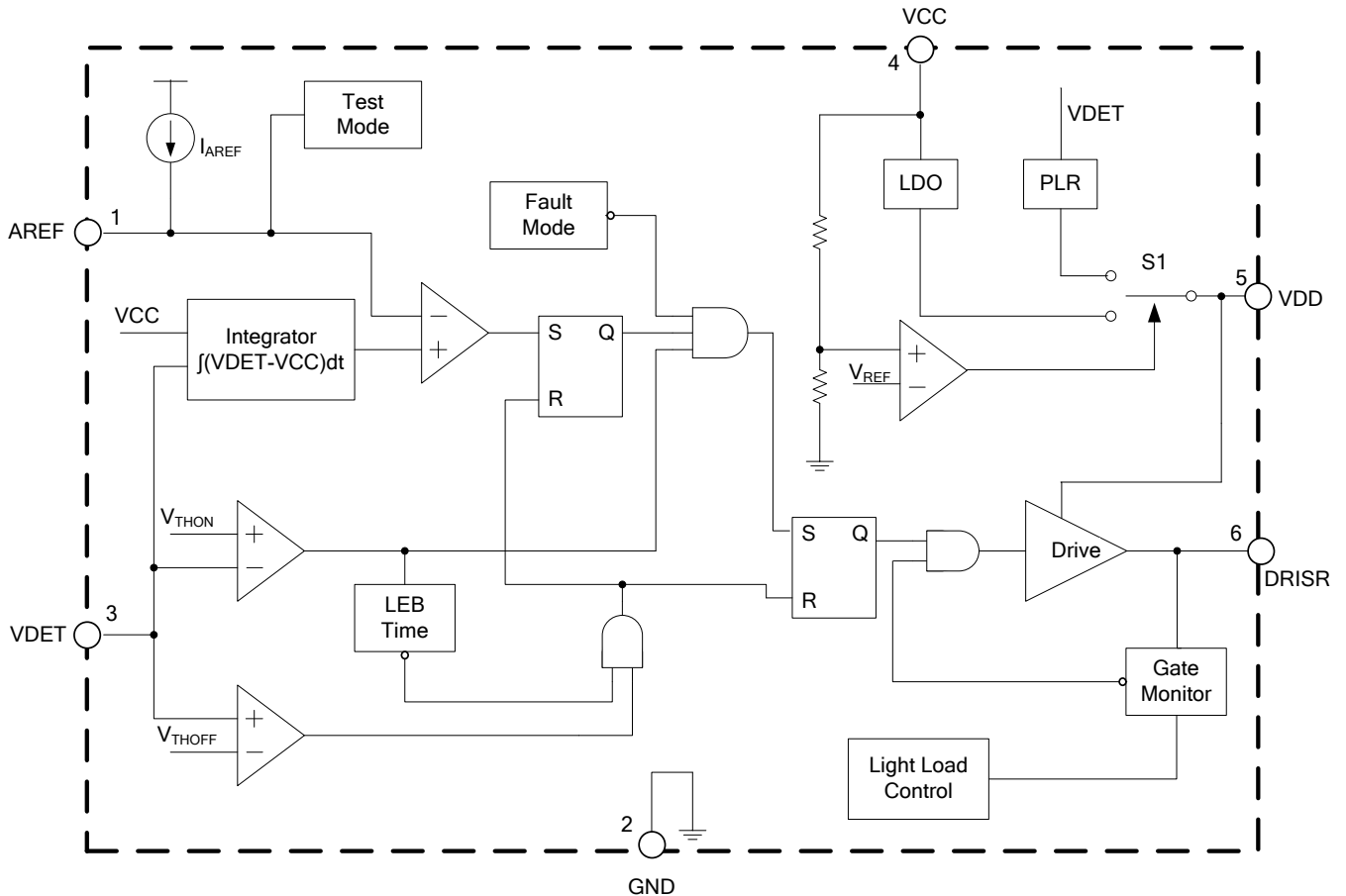
**Typical Applications Circuit**



**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 MOSFET drain-to-source voltage sense input, connected to drain pin of SR MOSFET through a resistor.
4	VCC	Power supply, connected with system output. Input of internal LDO and system output voltage sensing circuit.
5	VDD	Internal power supply. It provides bias voltage for MOSFET driver. Connect this pin to a capacitor.
6	DRISR	Synchronous rectification MOSFET Gate drive.

**Functional Block Diagram**



## Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Rating	Unit
V <sub>CC</sub>	Supply Voltage	-0.3 to 45	V
V <sub>DET</sub>	Voltage at VDET Pin (Note 5)	-0.7 to 175	V
V <sub>DRISR</sub>	Voltage at DRISR Pin	-0.3 to 14V	V
V <sub>DD</sub>	Internal Power Supply Voltage	-0.3 to 14V	V
P <sub>D</sub>	Power Dissipation at T <sub>A</sub> = +25°C	0.6	W
T <sub>J</sub>	Operating Junction Temperature	+150	°C
T <sub>STG</sub>	Storage Temperature Range	-65 to +150	°C
T <sub>LEAD</sub>	Lead Temperature (Soldering, 10s)	+300	°C
θ <sub>JA</sub>	Thermal Resistance (Junction to Ambient)	197	°C/W
θ <sub>JC</sub>	Thermal Resistance (Junction to Case)	76	°C/W
ESD	Human Body Model	2000	V
	Charged Device Model	1000	V

- Notes:
- 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.
  - The aging condition of VDET pin is 80% of AMR value.

## Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V <sub>CC</sub>	Supply Voltage	0	40	V
T <sub>A</sub>	Ambient Temperature	-40	+85	°C

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

Symbol	Parameter	Condition	Min	Typ	Max	Unit
<b>Supply Voltage (VCC Pin)</b>						
I <sub>STARTUP</sub>	Startup Current	$V_{CC} = V_{STARTUP} - 0.1V$	—	150	—	μA
I <sub>OP</sub>	Operating Current	V <sub>DET</sub> Pin Floating $V_{CC} = 5V$	—	190	—	μA
<b>VDD Pin</b>						
V <sub>DD</sub>	V <sub>DD</sub> Regulation Voltage	—	—	9	—	V
<b>Gate Driver</b>						
V <sub>THON</sub>	Gate Turn On Threshold	—	0	—	1	V
V <sub>T<sub>HOFF</sub></sub>	Gate Turn Off Threshold	—	-23	-15	-7	mV
t <sub>DON</sub>	Turn On Delay Time	From V <sub>THON</sub> to V <sub>D<sub>RISR</sub></sub> = 1V	—	70	180	ns
t <sub>DOFF</sub>	Turn Off Propagation Delay Time	From V <sub>T<sub>HOFF</sub></sub> to V <sub>D<sub>RISR</sub></sub> = 4V	—	100	150	ns
t <sub>RG</sub>	Turn On Rising Time	From 1V to 4V, $V_{CC} = 5V$ $C_L = 4.7nF$	—	50	100	ns
t <sub>FG</sub>	Turn Off Falling Time	From 4V to 1V, $V_{CC} = 5V$ $C_L = 4.7nF$	—	20	100	ns
t <sub>ON_MIN</sub>	Minimum On Time	—	1.6	2	2.4	μs
V <sub>D<sub>RISR</sub></sub>	SR Drive Voltage	V <sub>g_low</sub>	—	0.02	—	V
		V <sub>g_high</sub>	—	V <sub>DD</sub>	—	
K <sub>qs</sub>	(Note 6)	—	0.72	0.9	1.08	mA*μs
V <sub>S_MIN</sub>	Synchronous Rectification (SR) Minimum Operating Voltage (Note 7)	—	—	—	4.5	V
<b>Green Mode (Note 8)</b>						
t <sub>LL</sub>	Minimum Off Time to Enter Green Mode	—	—	600	—	μs

- Notes:
6. This item is used to specify the value of R<sub>AREF</sub>.
  7. This item specifies the minimum SR operating voltage of V<sub>IN\_DC</sub>,  $V_{IN\_DC} \geq N_{PS} * V_{S\_MIN}$ .
  8. These parameters are guaranteed by design and characterization.

## Synchronous Rectification Principle Description

### SR MOSFET Turn On

The APR3401 determines the synchronous rectification MOSFET turn-on time by monitoring the MOSFET drain-to-source voltage. 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. Because of the parasitic parameter, the voltage on the MOSFET drain pin may have a moderate voltage ringing at this moment, which may impact the  $V_{DET}$  voltage and result in a turning-off fault. To prevent this fault situation from happening, a minimum on-time ( $t_{ONMIN}$ ) blanking period is used to 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 effect.

### Turn Off Operation

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

In the process of the drain current decreasing linearly toward zero, the drain-source voltage rises synchronously. When it rises over the turn-off threshold voltage  $V_{THOFF}$ , the APR3401 pulls the drive signal down after a turn-off delay ( $t_{DOFF}$ ).

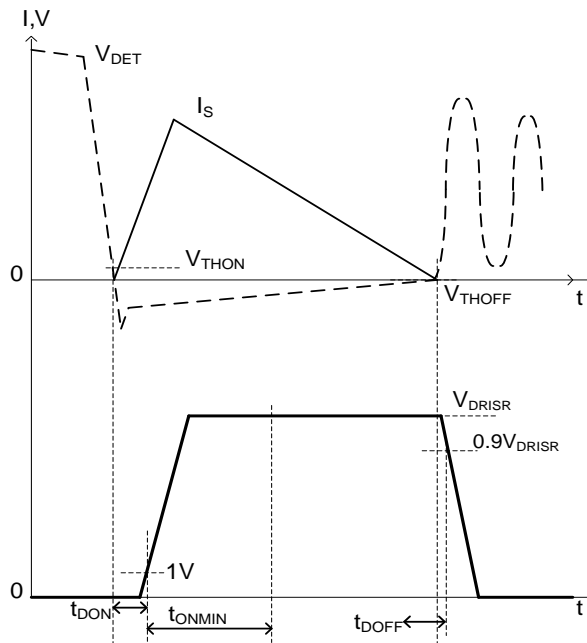


Figure 1. Typical Waveforms of APR3401 in DCM

### Minimum On

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

**Synchronous Rectification Principle Description** (continued)

**The Value and Meaning of AREF Resistor**

As to the DCM operation flyback converter—after the secondary rectifier stops conducting, the resonance of the primary inductance and output capacitance of the equivalent switch device creates the primary MOSFET drain-to-source ringing waveform. This ringing waveform may lead to Synchronous Rectifier error conduction. To avoid this fault occurrence, the APR3401 has a special function by means of volt-second product detecting. Regarding the sensed voltage of the VDET pin, the volt-second product of a voltage above VCC at primary switch on-time is much higher than that of each cycle ringing voltage above VCC. Therefore, before each time the Synchronous Rectifier turns on, the APR3401 judges if the detected volt-second product of the VDET voltage above VCC is higher than a threshold, and then turns on the Synchronous Rectifier. The purpose of the AREF resistor is to calculate the volt-second product threshold. The APR3401 has a parameter, Kqs, which converts the RAREF value to the volt-second product.

$$Area2 = R_{AREF} * Kqs$$

In general, the Area1 and Area3 values depend on the system design and are always fixed if the system design is frozen. The Area1 value changes with primary peak current value and Area3 value generally keeps constant in all conditions. So the AREF resistor design should consider the worst case scenario and the minimum primary peak current condition. Because of the distribution of the system design parameters, Area1 and Area3 may have moderate tolerance. So Area2 should be designed in the middle of Area1 and Area3 to ensure enough design margins.

$$Area3 < R_{AREF} * Kqs < Area1$$

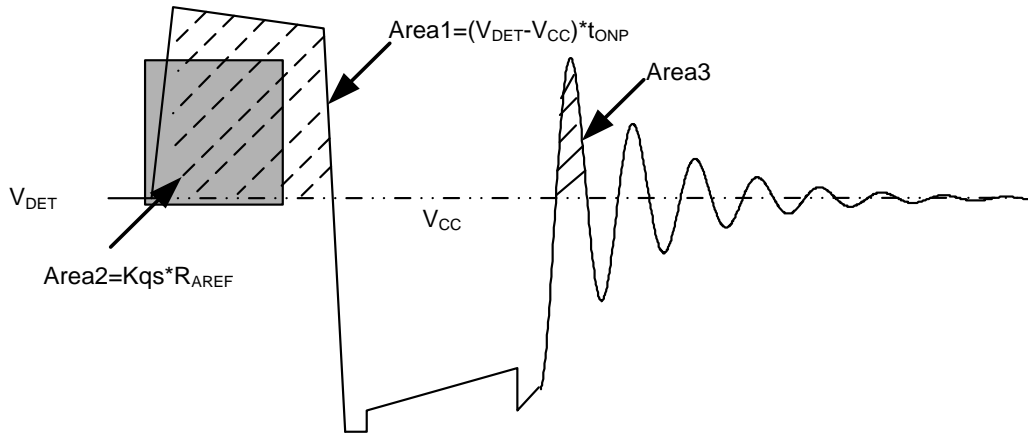


Figure 2. AREF Function

**SR Minimum Operating Voltage**

The APR3401 sets a minimum SR operating voltage by comparing the difference between VDET and the output voltage (VCC). When the value of VDET-VCC is higher than its internal reference, the APR3401 will begin to integrate the area of (VDET-VCC)\*tONP. If not, the area integrating will not begin and the SR driver will be disabled.

**Recommended Application Circuit Parameters**

The CAREF is recommended to be parallel with the AREF resistor to keep the volt-second product threshold stable. The recommended value of the CAREF is 1nF. The recommended value of the C24 is 100nF. The value of the VDD capacitor C23 is 4.7μF.

**Green Mode at Light Load**

When the system is running with light load, rectifier conduction loss no longer dominates the secondary-side power loss. In this condition, it is recommended that the SR MOSFET stays off to save from driver loss.

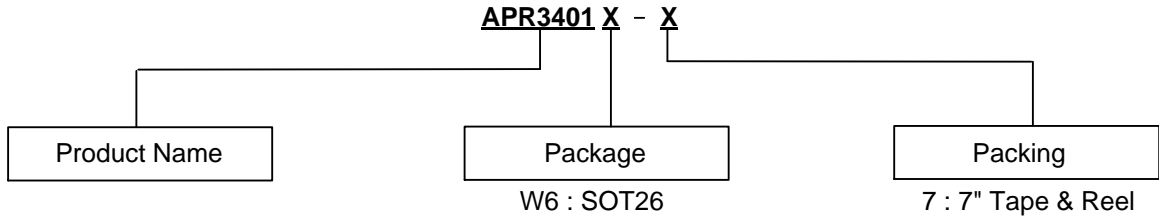
The APR3401 will sense the non-switching duration cycle-by-cycle. When the non-switching duration remains longer than the internal light load timing tLL, the IC will shut down the gate driver, which will stay off for the next two cycles.

**Synchronous Rectification Principle Description** (continued)

**V<sub>DD</sub>**

The V<sub>DD</sub> is the output voltage of the Pulse Linear Regulator (PLR) or the Low Dropout Regulator (LDO). It provides bias voltage for the controller. A capacitor (typically 4.7μF) should be connected between the VDD pin and GND pin.

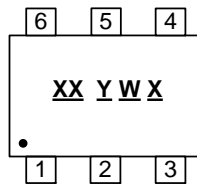
**Ordering Information**



Part Number	Part Number Suffix	Temperature Range	Package	Identification Code	Packing	
					Qty.	Carrier
APR3401W6-7	-7	-40°C to +85°C	SOT26	E3	3000	Tape and Reel

**Marking Information**

**(Top View)**

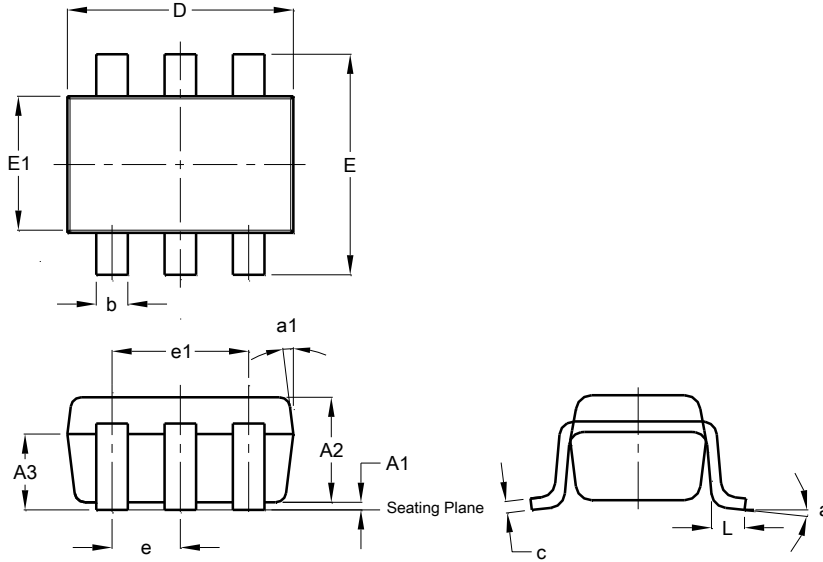


- XX : Identification Code
- Y : Year 0 to 9 (ex: 3 = 2023)
- W : Week : A to Z : Week 1 to 26;  
a to z : Week 27 to 52; z Represents Week 52 and 53
- X : Internal Code

**Package Outline Dimensions**

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

**SOT26**

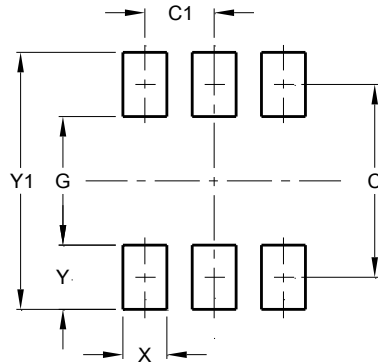


SOT26			
Dim	Min	Max	Typ
A1	0.013	0.10	0.05
A2	1.00	1.30	1.10
A3	0.70	0.80	0.75
b	0.35	0.50	0.38
c	0.10	0.20	0.15
D	2.90	3.10	3.00
e	-	-	0.95
e1	-	-	1.90
E	2.70	3.00	2.80
E1	1.50	1.70	1.60
L	0.35	0.55	0.40
a	-	-	8°
a1	-	-	7°
All Dimensions in mm			

**Suggested Pad Layout**

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

**SOT26**



Dimensions	Value (in mm)
C	2.40
C1	0.95
G	1.60
X	0.55
Y	0.80
Y1	3.20

**Mechanical Data**

- Moisture Sensitivity: Level 1 per JESD22-A113
- Terminals: Finish – Matte Tin Plated Leads, Solderable per JESD22-B102 ③
- Weight: 0.018 grams (Approximate)



**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>

The Diodes logo is a registered trademark of Diodes Incorporated in the United States and other countries.  
All other trademarks are the property of their respective owners.  
© 2023 Diodes Incorporated. All Rights Reserved.

[www.diodes.com](http://www.diodes.com)