

**SECONDARY SIDE SYNCHRONOUS RECTIFICATION SWITCHER**

## Description

The DIODES™ APR34509 is a secondary side Combo IC, which combines an N-Channel MOSFET and a driver circuit designed for Synchronous Rectification (SR), supports CCM, DCM and Quasi-Resonant Flyback Topologies.

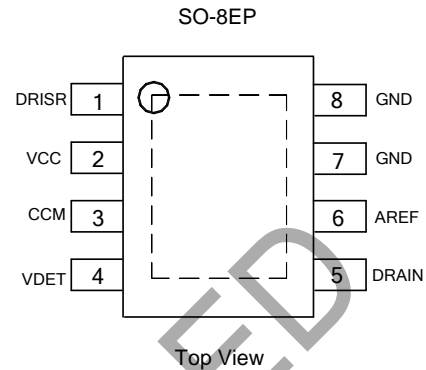
The N-Channel MOSFET is optimized for low gate charge, low  $R_{DS(ON)}$ , fast switching speed and body diode reverse recovery performance.

The synchronous rectification can effectively reduce the secondary side rectifier power dissipation and provide high performance solution. By sensing MOSFET drain-to-source voltage, the APR34509 can output ideal drive signal with less external components.

It can provide high performance solution for 5V to 12V output voltage application.

The APR34509 is available in SO-8EP package.

## Pin Assignments



Note: The DRAIN pin of internal MOSFET is exposed PAD, which is at the bottom of IC (the dashed box). The secondary current should flow from GND (pins 7 and 8) to this exposed PAD.

## Features

- Synchronous Rectification for DCM Operation Flyback
- Eliminate Resonant Ring Interference
- Fast Detector of Supply Voltages
- 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](#) or your local Diodes representative. <https://www.diodes.com/quality/product-definitions/>**

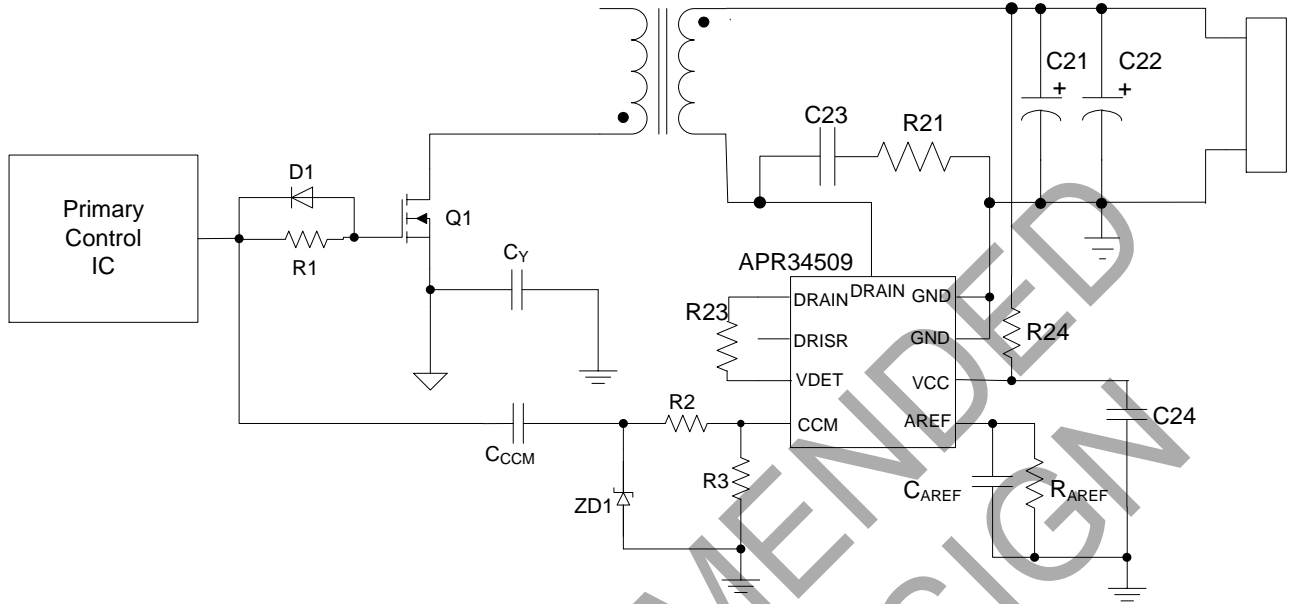
## Applications

- Adapters/chargers for cell/cordless phones, ADSL modems, MP3 and other portable apparatus
- Standby and auxiliary power supplies

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.

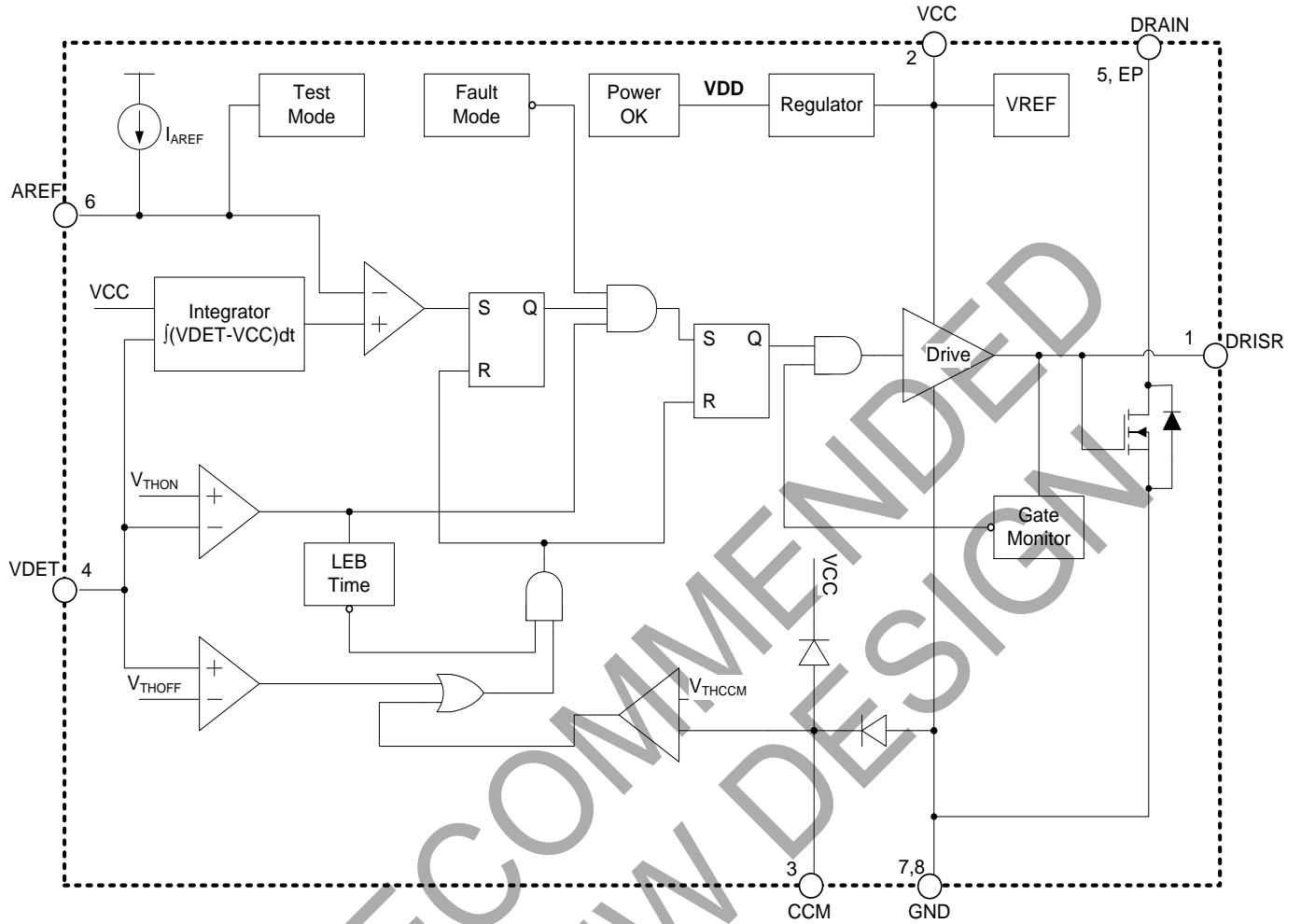
**Typical Applications Circuit**



**Pin Descriptions**

Pin Number	Pin Name	Function
1	DRISR	Synchronous rectification MOSFET drive.
2	VCC	Power supply, connected with system output.
3	CCM	Primary trigger signal sense input.
4	VDET	Synchronous rectification sense input and dynamic function output, connected to DRAIN through a resistor.
5	DRAIN	Drain pin of internal MOSFET. The Drain voltage signal can be obtained from this pin.
6	AREF	Program a voltage reference with a resistor from AREF to GND, to enable synchronous rectification MOSFET drive signal.
7, 8	GND	Source pin of internal MOSFET, connected to Ground.
Exposed PAD	DRAIN	Drain pin of internal MOSFET. The secondary current should flow from GND (Pins 7 and 8) to this DRAIN pad.

**Functional Block Diagram**



NOT RECOMMENDED FOR NEW DESIGN

### Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Value	Unit
V <sub>CC</sub>	Supply Voltage	-0.3 to 16	V
V <sub>DET</sub> , V <sub>DRAIN</sub>	Voltage at V <sub>DET</sub> , DRAIN Pins	-2 to 62	V
V <sub>AREF</sub> , V <sub>DRISR</sub>	Voltage at AREF, DRISR Pins	-0.3 to 16	V
I <sub>D</sub>	Continuous Drain Current	20	A
I <sub>DM</sub>	Pulsed Drain Current	80	A
P <sub>D</sub>	Power Dissipation at T <sub>A</sub> = +25°C	2.2	W
θ <sub>JA</sub>	Thermal Resistance (Junction to Ambient) (Note 5)	56	°C/W
θ <sub>JC</sub>	Thermal Resistance (Junction to Case) (Note 5)	12	°C/W
T <sub>J</sub>	Operating Junction Temperature	+150	°C
T <sub>STG</sub>	Storage Temperature	-65 to +150	°C
T <sub>LEAD</sub>	Lead Temperature (Soldering, 10s)	+300	°C
ESD	Human Body Model	4000	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.
  - Test condition: Device mounted on FR-4 substrate PC board, 2oz copper, with 1inch<sup>2</sup> cooling area.

### Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V <sub>CC</sub>	Supply Voltage	3.3	13	V
T <sub>A</sub>	Ambient Temperature	-40	+85	°C

**Electrical Characteristics** (@T<sub>A</sub> = +25°C, V<sub>CC</sub> = 5V, unless otherwise specified.)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
<b>Supply Voltage ( VCC Pin )</b>						
I <sub>STARTUP</sub>	Startup Current	V <sub>CC</sub> = V <sub>STARTUP</sub> -0.1V	—	100	150	μA
I <sub>OP</sub>	Operating Current	V <sub>DET</sub> Pin Floating V <sub>CC</sub> = 5V	—	100	150	μA
V <sub>STARTUP</sub>	Startup Voltage	—	2.75	3.1	3.55	V
—	UVLO	—	2.45	2.8	3.25	V
<b>Gate Driver</b>						
V <sub>THON</sub>	Gate Turn-On Threshold	—	0	—	1	V
V <sub>THOFF</sub>	Gate Turn-Off Threshold	—	-14	-7.5	-1	mV
t <sub>DON</sub>	Turn-On Delay Time	From V <sub>THON</sub> to V <sub>DRISR</sub> = 1V	—	70	130	ns
t <sub>DOFF</sub>	Turn-Off Propagation Delay Time	From V <sub>THOFF</sub> to V <sub>DRISR</sub> = 4V	—	100	150	ns
t <sub>RG</sub>	Turn-On Rising Time	From 1V to 4V, V <sub>CC</sub> = 5V, C <sub>L</sub> = 4.7nF	—	50	100	ns
t <sub>FG</sub>	Turn-Off Falling Time	From 4V to 1V, V <sub>CC</sub> = 5V, C <sub>L</sub> = 4.7nF	—	20	35	ns
t <sub>ON_MIN</sub>	Minimum On Time	—	1.2	1.6	2	μs
V <sub>DRISR</sub>	V <sub>DRI_HIGH</sub>	Drive Maximum Voltage	—	—	V <sub>CC</sub>	V
	V <sub>DRI_HOLD</sub>	SR Drive Hold Voltage	V <sub>CC</sub> < 5V	—	V <sub>CC</sub>	V
		V <sub>CC</sub> ≥ 5V	—	5	—	V
K <sub>qs</sub>	(Note 6)	—	0.44	0.52	0.6	mA*μs
V <sub>S_MIN</sub>	Synchronous Rectification (SR) Minimum Operating Voltage (Note 7)	—	—	—	4.5	V
<b>Synchronous Rectification Detection</b>						
V <sub>TH_CCM</sub>	V <sub>DRISR</sub> Rising Threshold	V <sub>DRISR</sub> Output Transitions from High to Low	0.43	0.53	0.71	V
t <sub>DCCM</sub>	CCM Propagation Delay	From CCM Rising to V <sub>DRISR</sub> Falling 10%	—	20	35	ns

Notes: 6. This item is used to specify the value of R<sub>REF</sub>.  
7. This item specifies the minimum SR operating voltage of V<sub>IN\_DC</sub>, V<sub>IN\_DC</sub> ≥ N<sub>PS</sub>\*V<sub>S\_MIN</sub>.

NOT RECOMMENDED FOR NEW DESIGN

## Electrical Characteristics (@T<sub>A</sub> = +25°C, unless otherwise specified.) (continued)

### MOSFET Static Characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
V <sub>DSS(BR)</sub>	Drain to Source Breakdown Voltage	V <sub>GS</sub> = 0V, I <sub>D</sub> = 0.25mA	62	—	—	V
V <sub>GS(TH)</sub>	Gate Threshold Voltage	V <sub>DS</sub> = V <sub>GS</sub> , I <sub>D</sub> = 0.25mA	0.7	1.3	2	V
I <sub>DSS</sub>	Zero Gate Voltage Drain Current	V <sub>DS</sub> = 50V, V <sub>GS</sub> = 0V	—	—	1	μA
I <sub>GSS</sub>	Gate to Source Leakage Current	V <sub>GS</sub> = 4.5V, V <sub>DS</sub> = 0V	—	—	±100	nA
R <sub>DS(ON)</sub>	Drain to Source On-State Resistance	V <sub>GS</sub> = 4.5V, I <sub>D</sub> = 3A	—	8	—	mΩ

### MOSFET Dynamic Characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
C <sub>iss</sub>	Input Capacitance	V <sub>GS</sub> = 0V, V <sub>DS</sub> = 25V f = 1MHz	—	1872	—	pF
C <sub>oss</sub>	Output Capacitance		—	506	—	
C <sub>rss</sub>	Reverse Transfer Capacitance		—	43	—	
Q <sub>gs</sub>	Gate to Source Charge	V <sub>GS</sub> = 0V to 10V V <sub>DD</sub> = 25V, I <sub>D</sub> = 15A	—	3.1	—	nC
Q <sub>gd</sub>	Gate to Drain Charge (Miller Charge)		—	4.8	—	
Q <sub>g</sub>	Total Gate Charge	V <sub>GS</sub> = 4.5V	—	15	—	
R <sub>g</sub>	Gate Resistance	—	—	1.8	—	Ω

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## Synchronous Rectification Principle Description

### SR MOSFET Turn-On

The APR34509 determines the synchronous rectification MOSFET turn-on time by monitoring the MOSFET drain-to-source voltage. For both of DCM and CCM operations, the turn-on principle is the 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. Because of parasitic parameter, the voltage on MOSFET drain pin has moderate voltage ringing at this moment, which may impact on SR controller VDET voltage sense and bring about turn-off fault. To prevent fault situation from 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 effect. During this time, the  $V_{DRISR}$  is pulled up to  $V_{CC}$ ; after  $t_{ONMIN}$ , the drive voltage stops being 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 being 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  $V_{THOFF}$ , the APR34509 pulls the drive signal down after a turn-off delay ( $t_{DOFF}$ ).

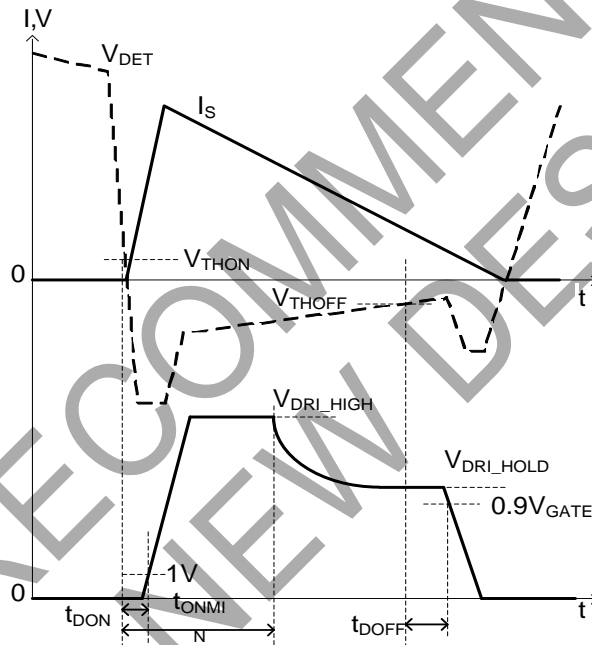


Figure 1. Typical Waveforms of APR34509 in DCM

### CCM Turn-Off Operation

The CCM pin is used to sense trigger signal for turning off the SR MOSFET before primary switch turn-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  $C_Y > C_{CCM}$ ; 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** (continued)

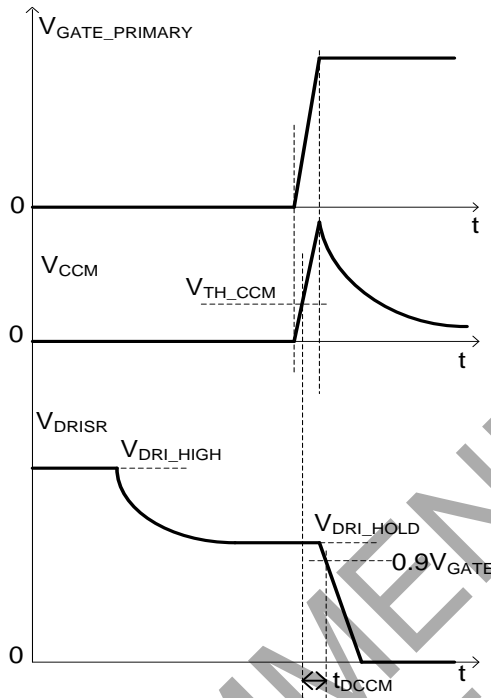


Figure 2. Typical Turn-Off Waveforms of APR34509 in CCM

**Minimum On Time**

When the controlled MOSFET gate is turned on, some ringing noise is generated. The minimum on-time timer blanks the V<sub>THOFF</sub> 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 results from the resonant of primary inductance and equivalent switch device output capacitance. This ringing waveform probably leads to Synchronous Rectifier error conduction. To prevent this fault from happening, the APR34509 has a special function design by means of volt-second product detecting. From the sensed voltage of VDET pin, the volt-second product of voltage above V<sub>CC</sub> at primary switch on time is much higher than the volt-second product of each cycle ringing voltage above V<sub>CC</sub>. Therefore, every time before Synchronous Rectifier turns on, the APR34509 judges if the detected volt-second product of VDET voltage above V<sub>CC</sub> is higher than a threshold and then turns on synchronous rectifier. The purpose of AREF resistor is to determine the volt-second product threshold. The APR34509 has a parameter, Kqs, which converts R<sub>AREF</sub> value to volt-second product,

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

In general, Area1 and Area3 values depend on system design and are always fixed after system design is frozen. As to Diodes Incorporated's PSR design, the Area1 value changes with primary peak current value and Area3 value generally keeps constant at all conditions. So the AREF resistor design should consider the worst case, the minimum primary peak current condition. Because 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: 8. 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.

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



**Synchronous Rectification Principle Description** (continued)

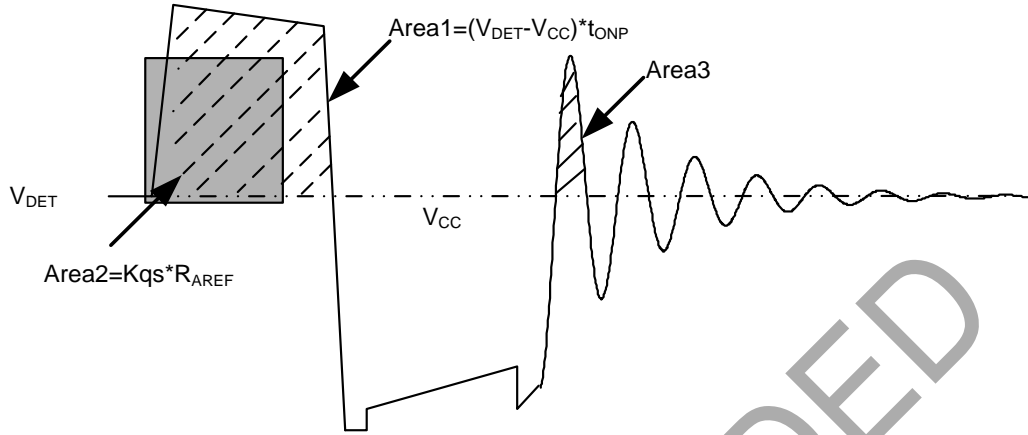


Figure 3. AREF Function

**SR Minimum Operating Voltage**

The APR34509 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 the APR34509 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 Turn-Off Timing Impact on PSR CV Sampling**

As for the synchronous rectification on Flyback power system, SR MOSFET must turn off before the secondary side current decreases to zero in order to avoid reverse-current flow. When SR turns off in advance, the secondary current will flow through the body diode. The SR turn-off time is determined by the  $V_{THOFF}$  at a fixed system. When  $V_{THOFF}$  is closer to zero, the SR turn-on time gets longer and body diode conduction time gets shorter. Because 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 turn-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 operation of system, it must meet:

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

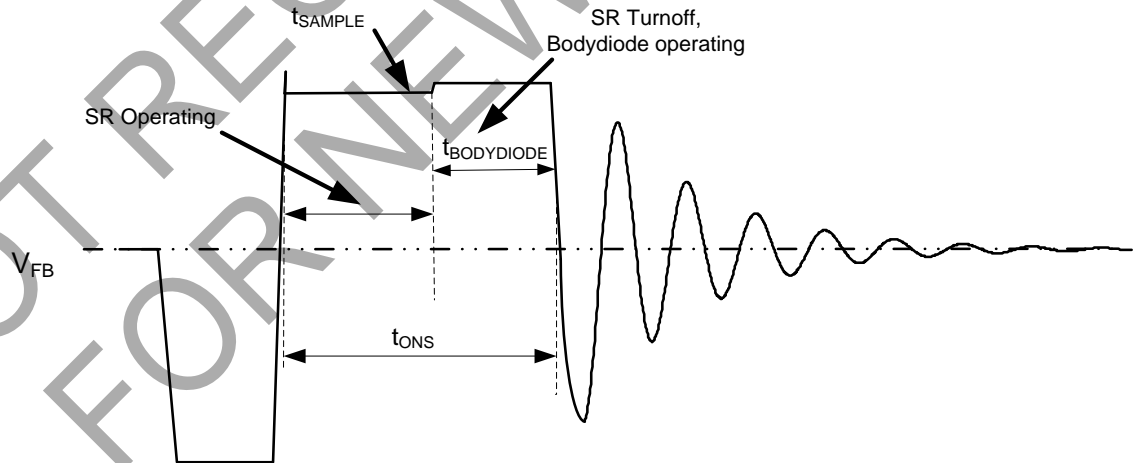


Figure 4. SR Turn-Off Timing Impact on PSR CV Sampling

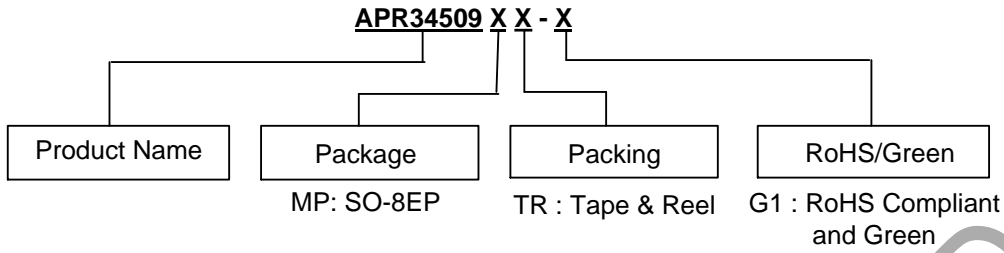
**Recommended Application Circuit Parameters**

The two resistors R23 and R24 are used to pass ESD test. The values of R23 and R24 should be over  $20\Omega$  and below  $47\Omega$  respectively because of the undershoot performance. The package of R23 and R24 must be at least 0805 and there is not any trace under these two resistors.

$C_{AREF}$  is recommended to parallel with AREF resistor to keep the volt-second product threshold stable.

A 20nF  $C_{AREF}$  and a 100nF C24 are recommended.

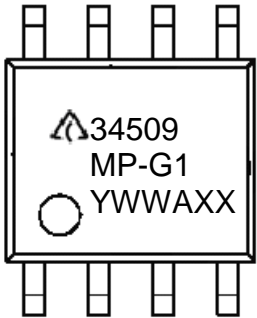
**Ordering Information**



Part Number	Package	Temperature Range	Marking ID	Packing	
				Qty.	Carrier
APR34509MPTR-G1	SO-8EP	-40 to +85°C	34509MP-G1	4000	Tape & Reel

**Marking Information**

(Top View)



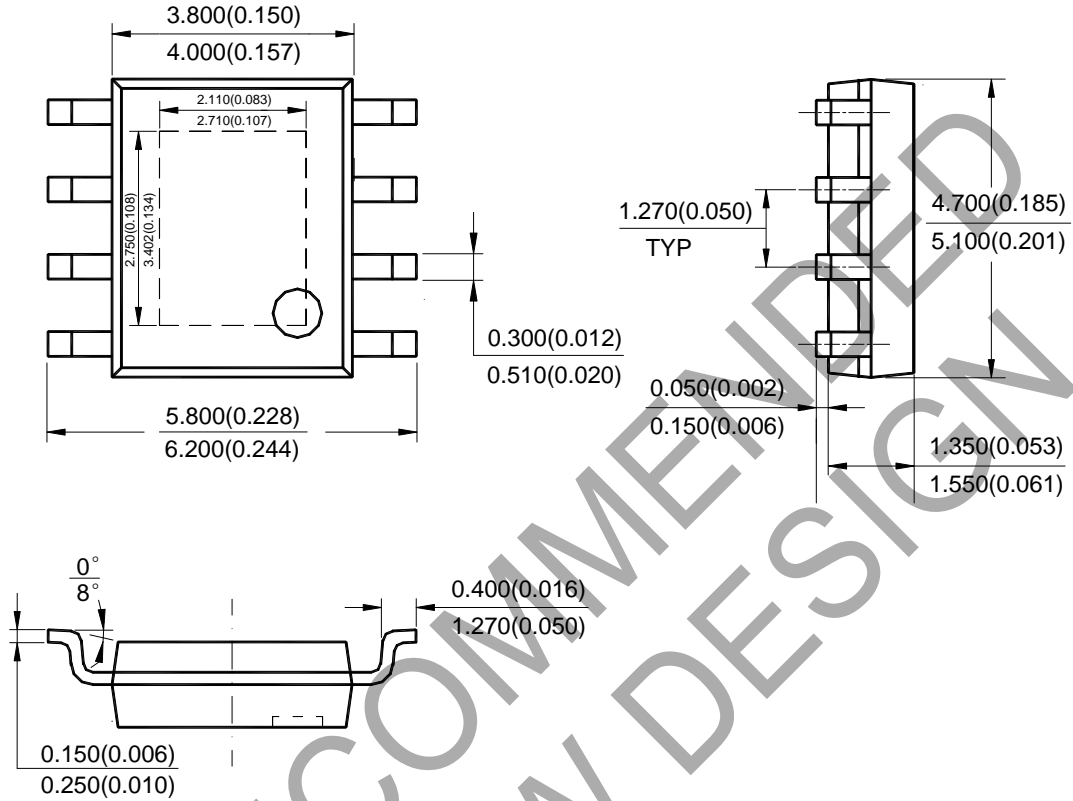
First and Second Lines: Logo and Marking ID  
 Third Line: Date Code  
 Y: Year  
 WW: Work Week of Molding  
 A: Assembly House Code  
 XX: 7<sup>th</sup> and 8<sup>th</sup> Digits of Batch No.

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**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-8EP



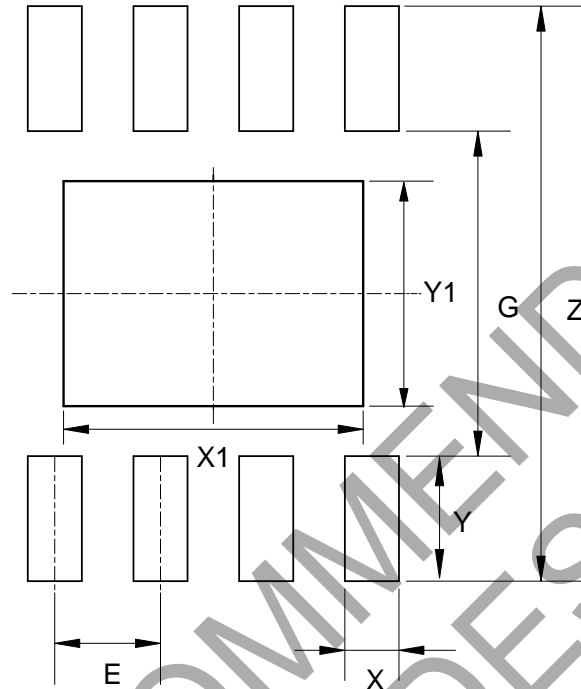
Note: Eject hole, oriented hole and mold mark is optional.

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**Suggested Pad Layout**

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

(1) Package Type: SO-8EP



Dimensions	Z (mm)/(inch)	G (mm)/(inch)	X (mm)/(inch)	Y (mm)/(inch)	X1 (mm)/(inch)	Y1 (mm)/(inch)	E (mm)/(inch)
Value	6.900/0.272	3.900/0.154	0.650/0.026	1.500/0.059	3.600/0.142	2.700/0.106	1.270/0.050

**Mechanical Data**

- Moisture Sensitivity: MSL Level 3 per J-STD-020
- Terminals: Finish – Matte Tin Plated Leads, Solderable per M2003 JESD22-B102 Ⓢ
- Weight: 0.081 grams (Approximate)

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