Description

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

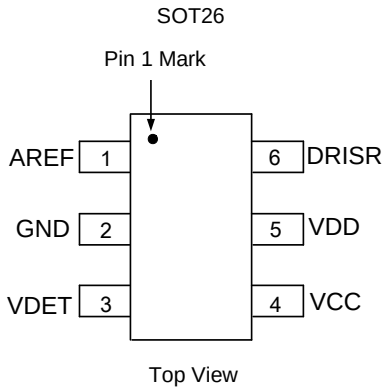
The synchronous rectification can effectively reduce the secondary side rectifier power dissipation and provide high-performance solution. By sensing primary MOSFET gate-to-source voltage, the APR3401 can output ideal drive signal with less external components.

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 or your local Diodes representative. https://www.diodes.com/quality/product-definitions/**

Pin Assignments

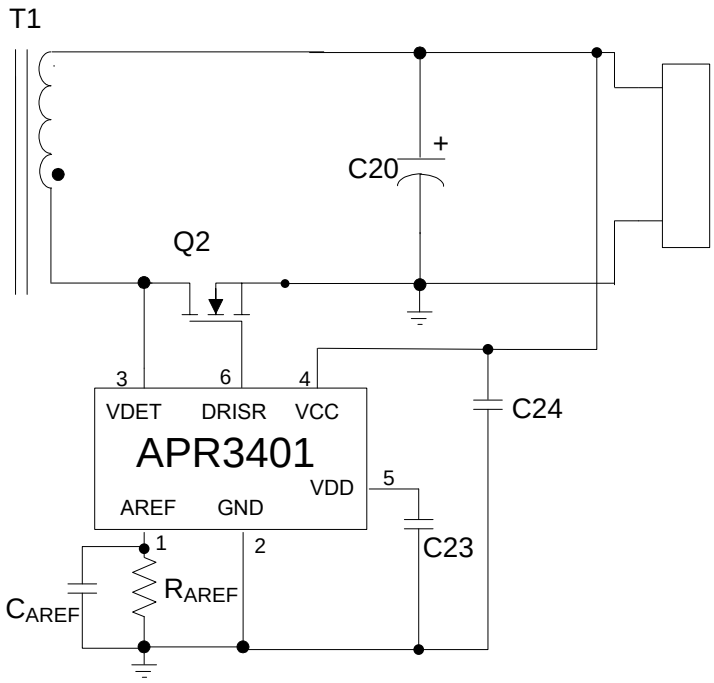


Applications

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

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



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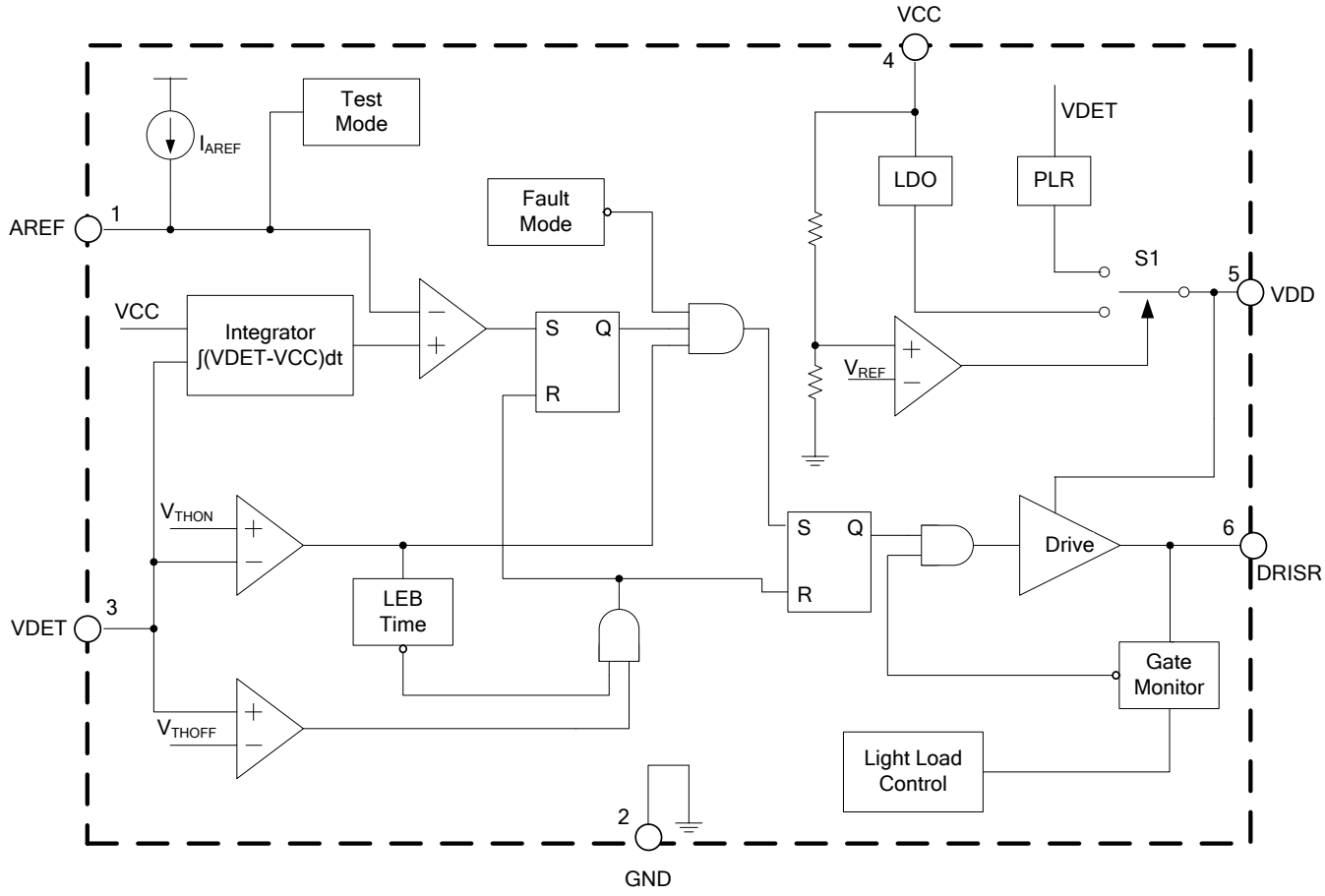
Pin Descriptions

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



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Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Rating	Unit
V_{CC}	Supply Voltage	-0.3 to 45	V
V_{DET}	Voltage at VDET Pin (Note 5)	-0.7 to 175	V
V_{DRISR}	Voltage at DRISR Pin	-0.3 to 14V	V
V_{DD}	Internal Power Supply Voltage	-0.3 to 14V	V
P_D	Power Dissipation at T_A = +25°C	0.6	W
T_J	Operating Junction Temperature	+150	°C
T_{STG}	Storage Temperature Range	-65 to +150	°C
T_{LEAD}	Lead Temperature (Soldering, 10s)	+300	°C
θ_{JA}	Thermal Resistance (Junction to Ambient)	197	°C/W
θ_{JC}	Thermal Resistance (Junction to Case)	76	°C/W
ESD	Human Body Model	2000	V
	Charged Device Model	1000	V

Notes: 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.

5. The aging condition of VDET pin is 80% of AMR value.

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{CC}	Supply Voltage	0	40	V
T_A	Ambient Temperature	-40	+85	°C

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

Symbol	Parameter	Condition	Min	Typ	Max	Unit
Supply Voltage (VCC Pin)						
$I_{STARTUP}$	Startup Current	V_{CC} = $V_{STARTUP}$-0.1V	—	150	—	μA
I_{OP}	Operating Current	VDET Pin Floating V_{CC} = 5V	—	190	—	μA
VDD Pin						
V_{DD}	V_{DD} Regulation Voltage	—	—	9	—	V
Gate Driver						
V_{THON}	Gate Turn On Threshold	—	0	—	1	V
V_{THOFF}	Gate Turn Off Threshold	—	-23	-15	-7	mV
t_{DON}	Turn On Delay Time	From V_{THON} to V_{DRISR} = 1V	—	70	180	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	100	ns
t_{ON_MIN}	Minimum On Time	—	1.6	2	2.4	μs
V_{DRISR}	SR Drive Voltage	V_{g_low}	—	0.02	—	V
		V_{g_high}	—	V_{DD}	—	
Kqs	(Note 6)	—	0.72	0.9	1.08	mA*μs
V_{S_MIN}	Synchronous Rectification (SR) Minimum Operating Voltage (Note 7)	—	—	—	4.5	V
Green Mode (Note 8)						
t_{LL}	Minimum Off Time to Enter Green Mode	—	—	600	—	μs

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

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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 VDET 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 synchronically. 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}).

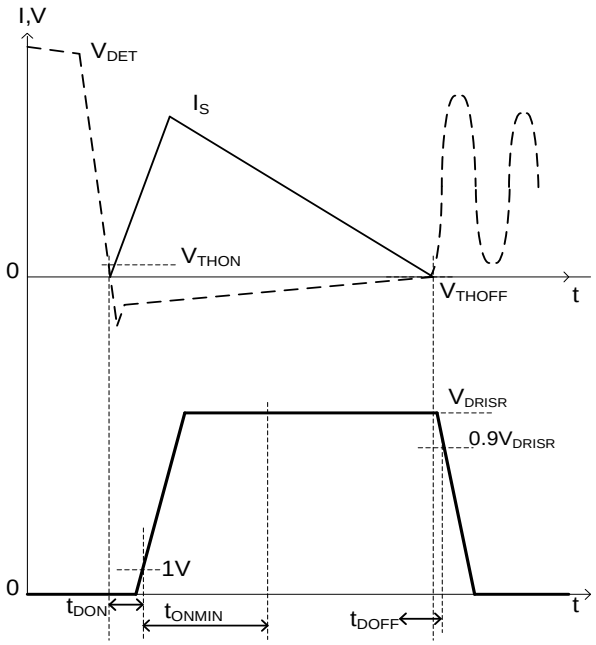

Figure 1. Typical Waveforms of APR3401 in DCM

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.

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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 V_{CC} at primary switch on-time is much higher than that of each cycle ringing voltage above V_{CC}. Therefore, before each time the Synchronous Rectifier turns on, the APR3401 judges if the detected volt-second product of the VDET voltage above V_{CC} 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 R_{AREF} 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.

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

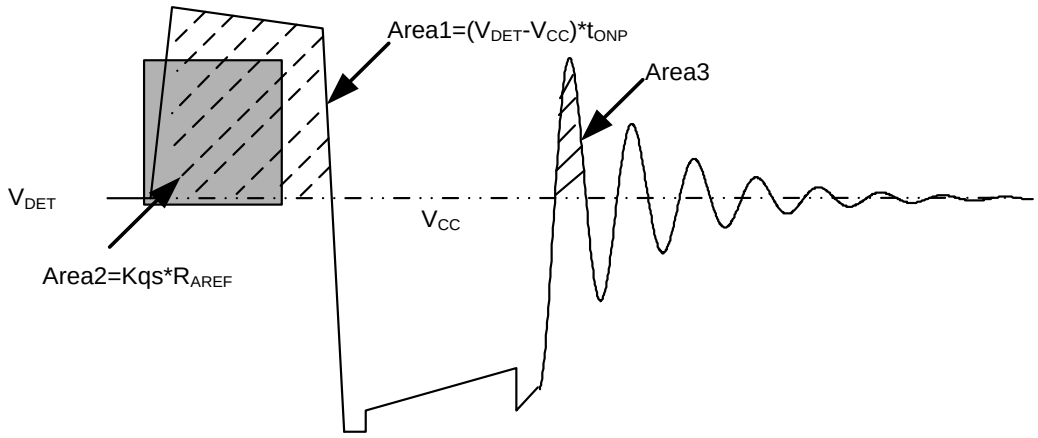

Figure 2. AREF Function

SR Minimum Operating Voltage

The APR3401 sets a minimum SR operating voltage by comparing the difference between V_{DET} and the output voltage (V_{CC}). When the value of V_{DET}–V_{CC} is higher than its internal reference, the APR3401 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.

Recommended Application Circuit Parameters

The C_{AREF} is recommended to be parallel with the AREF resistor to keep the volt-second product threshold stable. The recommended value of the C_{AREF} is 1nF. The recommended value of the C24 is 100nF. The value of the V_{DD} 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 t_{LL}, the IC will shut down the gate driver, which will stay off for the next two cycles.

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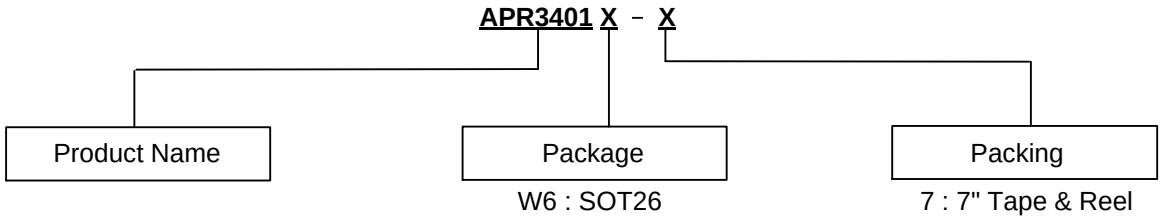
Synchronous Rectification Principle Description (continued)

V_{DD}

The V_{DD} 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.

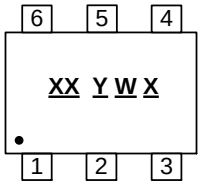
Ordering Information



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

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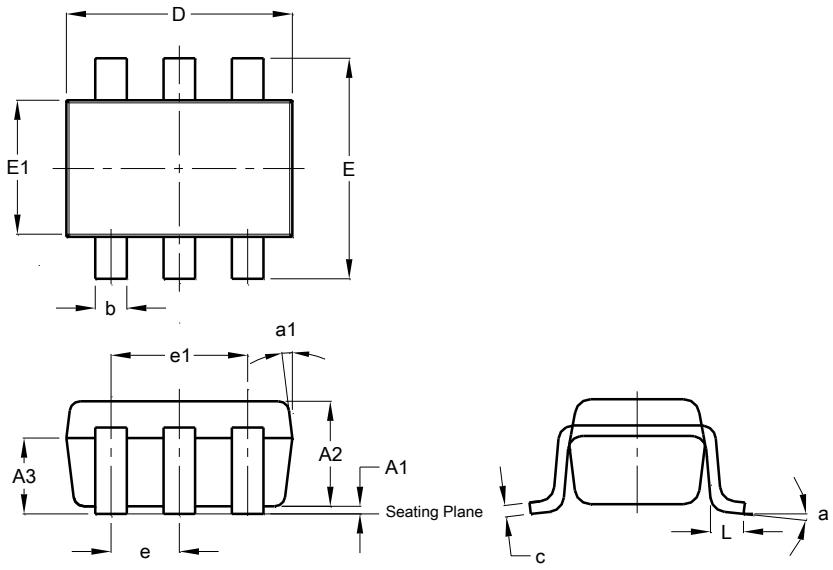
Package Outline Dimensions

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

SOT26

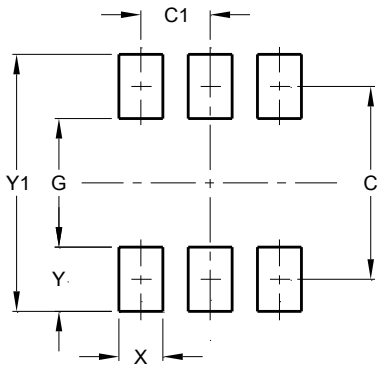


SOT26			
Dim	**Min**	**Max**	**Typ**
A1	0.013	0.10	0.05
A2	1.00	1.30	1.10
A3	0.70	0.80	0.75
b	0.35	0.50	0.38
c	0.10	0.20	0.15
D	2.90	3.10	3.00
e	-	-	0.95
e1	-	-	1.90
E	2.70	3.00	2.80
E1	1.50	1.70	1.60
L	0.35	0.55	0.40
a	-	-	8°
a1	-	-	7°
All Dimensions in mm			

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 (e3)
- Weight: 0.018 grams (Approximate)

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