PRIMARY SIDE REGULATED SWITCHING MODE POWER SUPPLY CONTROLLER

Description

The AP3190 is a high-performance offline PSR AC/DC power supply controller. It is specially designed for the applications that require the higher efficiency at light load and cost effectiveness. Using the multi-mode control scheme, AP3190 can also achieve high-conversion efficiency with full-load conditions.

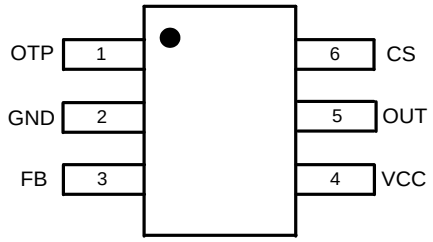
At heavy load and low line, AP3190 will operate in QR mode to achieve high performance. When the load is decreasing, it will enter fixed switching frequency operating mode. To optimize product performance, the fixed frequency is different in high line (60kHz) and low line (80kHz). At light load or no load, the IC will operate in burst mode to minimize power consumption.

The AP3190 provides comprehensive protections without additional circuitry. It includes V_{CC} overvoltage protection, output overvoltage protection, output short-circuit protection, etc. AP3190 has adjustable OTP by external NTC resistor. Besides, AP3190 consumes less than 65mW input power at no-load condition with high-line voltage.

AP3190 is packaged in SOT26 (Type SM).

Pin Assignments

(Top View)



SOT26 (Type SM)

Applications

- Adapters/chargers
- Smart speakers
- Set-top box power supplies
- Network adaptors

Features

- Burst Mode Operation for Light Load High Efficiency (at 10% Loading > 80%)
- Primary Side Control for Eliminating Optocoupler
- 65mW No-Load Input Power
- Adjustable Overtemperature Protection
- Multiple QR/AM Mode to Improve Audio Noise and Efficiency
- QR for Higher Efficiency and Better EMI
- **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/**

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.

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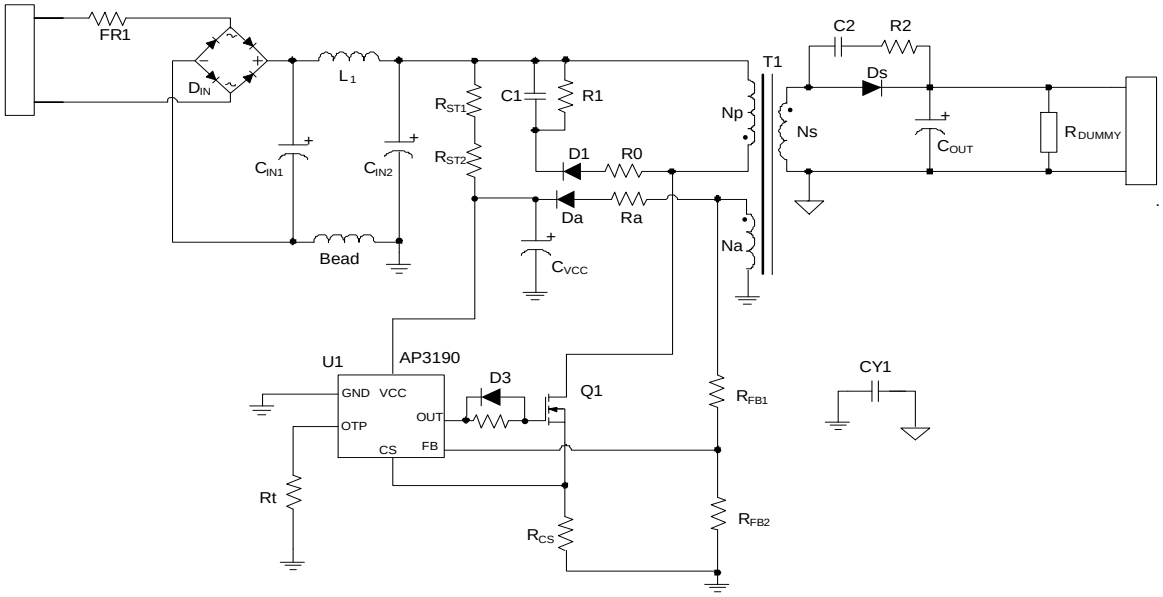
Typical Applications Circuit



Pin Descriptions

Pin Number	Pin Name	Function
1	OTP	Adjustable overtemperature protection by external NTC resistor
2	GND	The ground of the controller
3	FB	The CV and CC regulation are realized based on the voltage sampling of this pin.
4	VCC	The VCC pin supplies the power for the IC.
5	OUT	Output pin to drive external MOSFET
6	CS	The CS is the current sense pin of the IC. The IC will turn off the power MOSFET according to the voltage on the CS pin.

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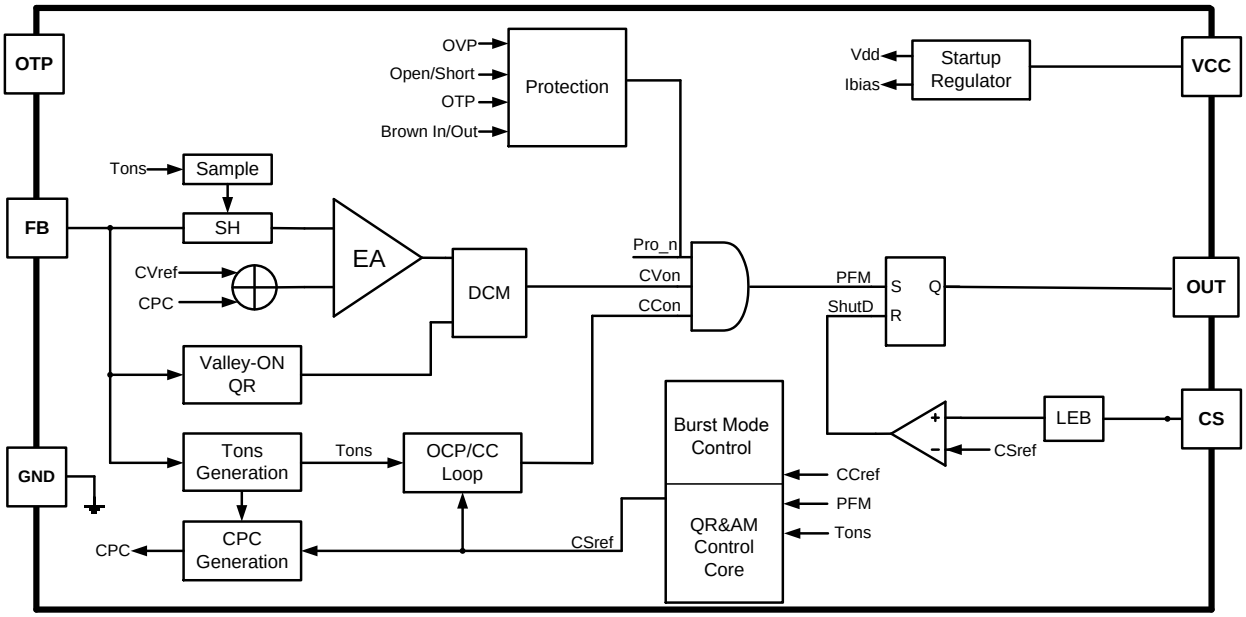
Functional Block Diagram



Absolute Maximum Ratings (Note 4)

Symbol	Parameter	Rating	Unit
V_{CC}	Supply Voltage	-0.3 to 33	V
V_{OUT}	V_{OUT}	-0.3 to 15.7	V
V_{CS}	Input Voltage	-0.3 to 7.9	V
V_{FB}	FB Input Voltage	-0.3 to 7.9	V
T_J	Operating Junction Temperature	-40 to +150	°C
T_{STG}	Storage Temperature	-65 to +150	°C
T_{LEAD}	Lead Temperature (Soldering, 10s)	+300	°C
θ_{JC}	Thermal Resistance (Junction to Case) (Note 5)	76	°C/W
θ_{JA}	Thermal Resistance (Junction to Ambient) (Note 5)	200	°C/W
—	ESD (Human Body Model)	4000	V
—	ESD (Charge 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. Test condition: device mounted on FR-4 substrate PC board, 2oz copper, with 1inch pad layout.

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{CC}	Supply Voltage	0	25	V
T_A	Ambient Temperature	-40	+85	°C

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Electrical Characteristics (@V_{CC} = 15V, T_A = +25°C, unless otherwise specified.)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
STARTUP AND UVLO SECTION						
V_{TH_ST}	Startup Threshold	—	13	15	17	V
$V_{OPR(MIN)}$	Minimum Operating Voltage	—	5.8	6.15	6.5	V
CURRENT SECTION						
I_{ST}	Startup Current	V_{CC} = V_{TH_ST}-1V before Startup	0.009	0.5	1.1	μA
I_{CC_OPR}	Operating Current	Static Current	396	450	502	μA
CURRENT SENSE SECTION						
V_{CS_H}	Maximum Current Sense Threshold Voltage at CV Mode	(Note 6)	968	1100	1232	mV
V_{CS_M}	Medium Current Sense Threshold Voltage at CV Mode	(Note 6)	642	730	818	mV
$V_{CS_MAX_BURST}$	The Maximum Current Sense Threshold Voltage at Burst Mode	(Note 6)	492	560	628	mV
$V_{CS_MIN_BURST}$	The Minimum Current Sense Threshold Voltage at Burst Mode	(Note 6)	316	360	403	mV
t_{LEB}	Leading Edge Blanking	—	198	275	352	ns
CONSTANT VOLTAGE SECTION						
V_{FB}	Feedback Threshold Voltage	Test @ 90% of I_{OUT}	2.7	2.74	2.784	V
R_{CABLE}	Cable Compensation Ratio	—	—	2.0	—	%
CONSTANT VOLTAGE SECTION						
V_{REF_CC}	Constant Current Reference	(Note 7)	0.427	0.45	0.473	V
R_{LINE_IC}	Fixed Line Compensation Resistor	—	158	173	189	Ω
DRIVE SECTION (OUT PIN)						
I_{SOURCE_L}	Minimum Drive Current	—	7.9	10.8	13.8	mA
I_{SOURCE_H}	Maximum Drive Current		21.0	27.7	34.3	mA
R_{DS_ON}	—	—	3.4	3.75	4.1	Ω
MAXIMUM OPERATING FREQUENCY						
f_{SW_MAX}	Maximum Frequency at Low Line	f_{SW} During AM2	72	80	88	kHz
	Maximum Frequency at High Line	f_{SW} During AM2	54	60	66	kHz
SAMPLE TIME						
t_{SAMPLE_H}	Sample Time at t_{ONS}	At Heavy Load (Note 6)	—	67	—	%
t_{SAMPLE_L}		At Light Load (Note 6)	—	51	—	
PROTECTION FUNCTION SECTION						
V_{CC_OVP}	—	—	29	30	31	V
V_{FB_SUVP}	Undervoltage Protection	—	1.617	1.65	1.683	V
t_{SUVP}	Delay Time for SUVP Protection	—	61	64	67	ms
V_{FB_SCP}	Short-Circuit Protection	—	1.07	1.1	1.13	V
t_{SCP}	Delay Time for SCP Protection	—	26	27	28	ms
Internal T_{OTP}	Shutdown Temperature	(Note 6)	—	+150	—	°C
Internal T_{HYS}	Temperature Hysteresis	(Note 6)	—	+40	—	°C
V_{OTP}	External OTP Shutdown Threshold	—	0.48	0.5	0.52	V
V_{OTP_REC}	External OTP Recovery Threshold	—	0.72	0.75	0.78	V
I_{OTP}	External OTP Shutdown Current	—	91.5	100	110	μA

Notes: 6. Guaranteed by design and characterization.
7. V_{REF_CC} is the equivalent of output current (w/o contacting resistor introduced by testing).

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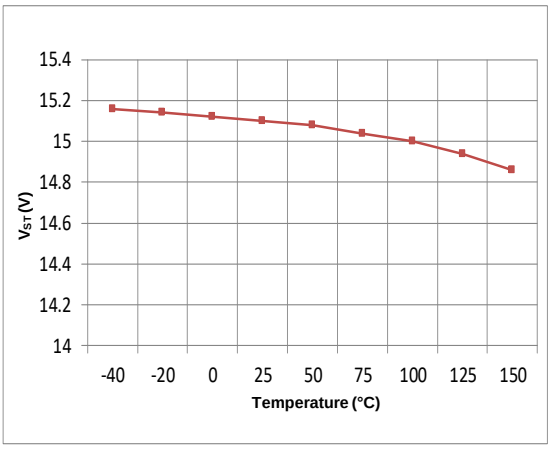
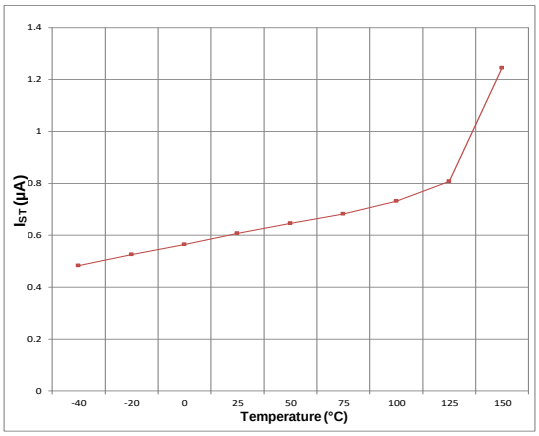
Performance Characteristics

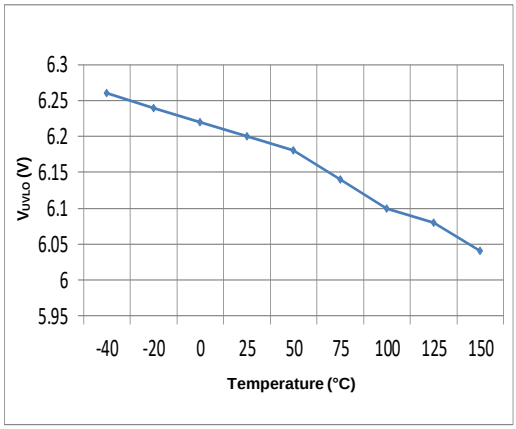
Startup Voltage vs. Temperature



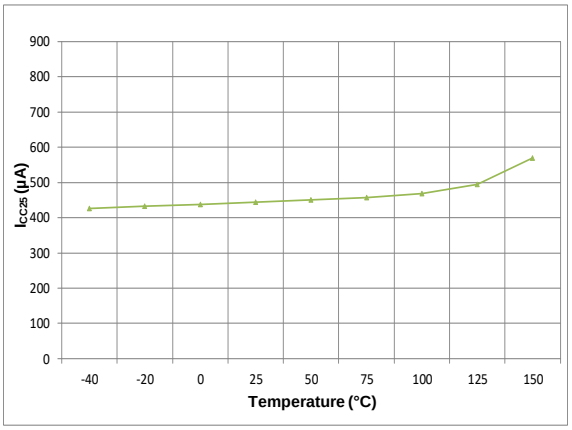
Startup Current vs. Ambient Temperature



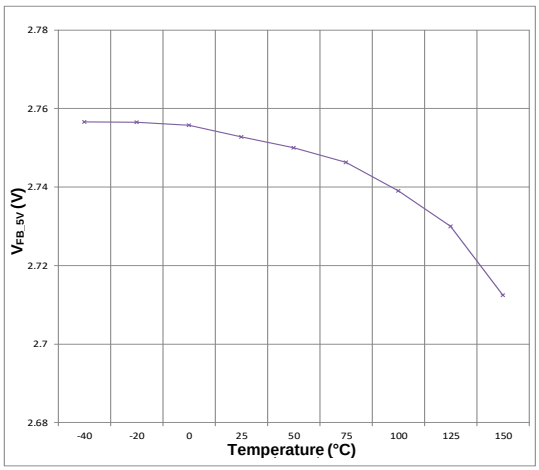
UVLO vs. Temperature



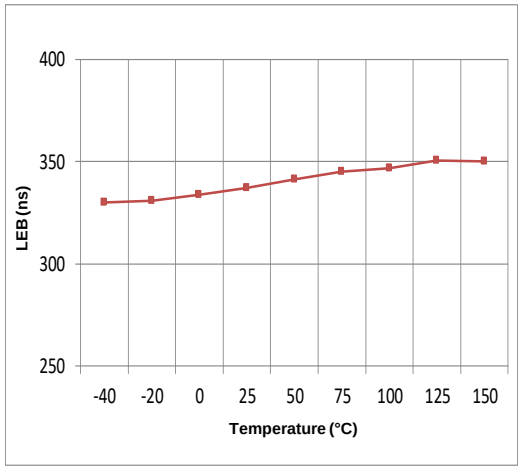
Operating Current vs. Ambient Temperature



Feedback Voltage vs. Ambient Temperature



LEB vs. Ambient Temperature



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Operation Description

Constant Voltage Operation

The AP3190 captures the auxiliary winding feedback voltage at FB pin and operates in constant-voltage (CV) mode to regulate the output voltage. Assuming the secondary winding is master, the auxiliary winding is slave during D_S's on-time. The auxiliary voltage is given by:

$$V_{AUX} = \frac{N_{AUX}}{N_S} \cdot (V_O + V_d) \quad \text{..... (1)}$$

Where V_D is D_S forward drop voltage, N_{AUX} is the turns of auxiliary winding, and N_S is the turns of secondary winding.

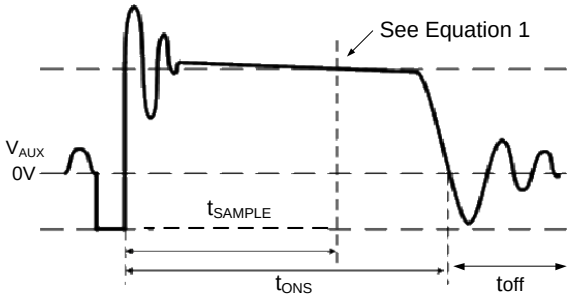

Figure 1. Auxiliary Voltage Waveform

The output voltage is different from the secondary voltage in a diode forward drop voltage V_D which depends on the current. If the secondary voltage is always detected at a constant secondary current, the difference between the output voltage and the secondary voltage will be a fixed V_D. The voltage detection point is at the t_{SAMPLE} of the D_S's on-time. The voltage detection point is changed with the different primary peak current. The CV loop control function of AP3190 then generates a D_S's off-time to regulate the output voltage.

Constant Current Operation

The AP3190 is designed to work in constant current (CC) mode. Figure 2 shows the secondary current waveforms.

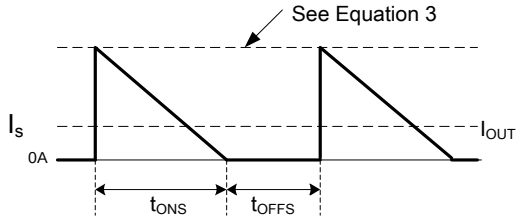

Figure 2. Secondary Current Waveform

In CC operation, the CC loop control function of the AP3190 will keep a fixed produce of the V_{CS} and the proportion between the D_S's on-time t_{ONS} and its off-time t_{OFFS}. This fixed produce is

$$V_{ref_CC} = V_{CS} \cdot \frac{t_{ONS}}{t_{ONS} + t_{OFFS}} \quad \text{..... (2)}$$

The relation between the output constant-current and secondary peak current I_{PKS} is given by:

$$I_{OUT} = \frac{1}{2} \times I_{PKS} \times \frac{t_{ONS}}{t_{ONS} + t_{OFFS}} \quad \text{..... (3)}$$

At the instant of D_S turn-on, the primary current transfers to the secondary at an amplitude of:

$$I_{PKS} = \frac{N_P}{N_S} \cdot I_{PK} \quad \text{..... (4)}$$

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Operation Description (continued)

Thus the output constant current is given by:

$$I_{OUT} = \frac{1}{2} \cdot \frac{N_P}{N_S} \cdot \frac{1}{R_{CS}} \cdot V_{ref_CC} \cdots\cdots\cdots (5)$$

Multi-Mode Operation

In CV control, the controller changes the mode of operation according to load condition. The switching frequency curve in Figure 3 shows operation modes. Proprietary CV control can achieve high precision CV control meeting most requirements.

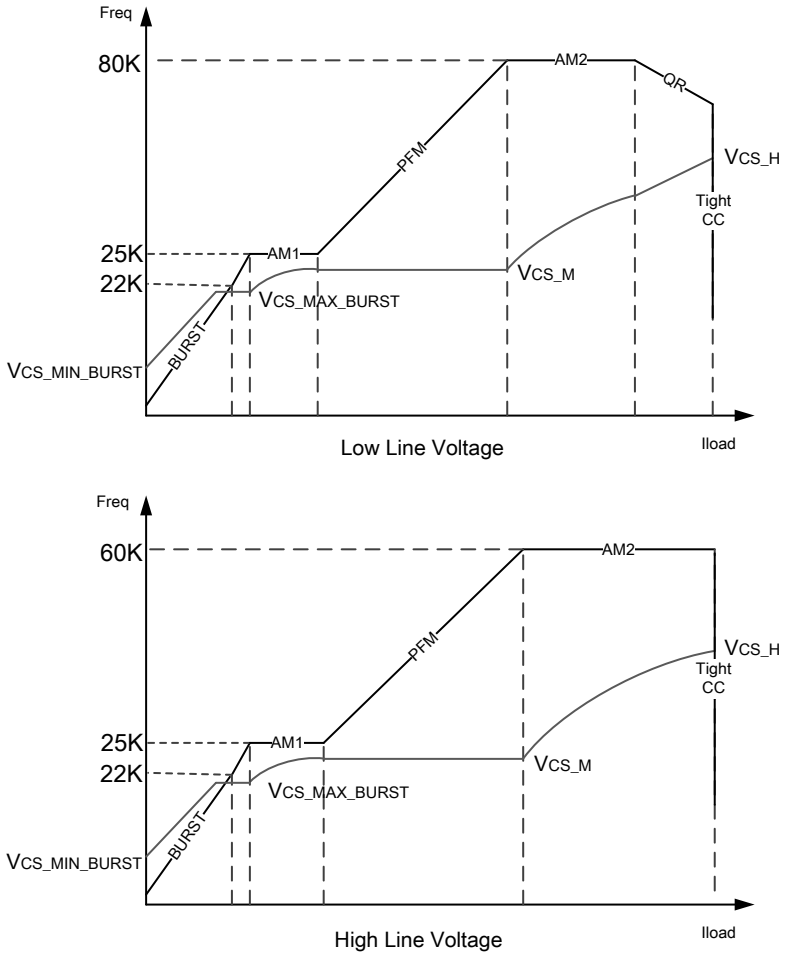

Figure 3. AP3190 Multi-Mode Operation Diagram

Burst Mode

To ensure a good system efficiency at light load, especially 10% of full load condition, AP3190 operates in burst mode to get a lower switching power dissipation.

QR Mode

At low line and heavy load, if the t_{OFF} = 0, AP3190 will operates in QR mode. QR is the abbreviation of Quasi-Resonant which is regarded as a soft switching technology. It means that the power MOSFET always turns on at the valley of the Drain-to-Source voltage (V_{DS}). Compared to traditional hard switching, QR switching-on can reduce the switching power loss of MOSFET and achieve good EMI behavior without additional BOM cost. The V_{DS} valley is detected by FB pin.

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Operation Description (continued)

Leading Edge Blanking

When the power switch is turned on, a turn-on spike will occur on the sense-resistor. To avoid false-termination of the switching pulse, a 275ns leading-edge blanking (from power BJT or MOSFET on) is built-in. During this blanking period, the current sense comparator is disabled and the gate driver cannot be switched off.

Valley Turn-On

When the off time (t_{OFF}) is lower than t_{VAL-ON}, AP3190 power system can work with valley turn-on. It can reduce BJT or MOSFET switching on power losses which result from the equivalent output capacitance to achieve highest overall efficiency. At the same time, because of valley turn-on the switching frequency has the random jitter feature, which will be benefit for conductive EMI performance. And valley turn-on can also reduce the power switch turn-on spike current and then achieve a better radiated EMI performance.

Adjustable Line Compensation

Since there is a delay time from the CS pin voltage reaching the given V_{CS} reference to the power MOSFET turning off, the real primary peak current value always has a gap with the ideal value. The gap value changes with different input line voltage, which is caused by different current rising slope, resulting in different system constant current value.

In order to eliminate the constant current deviation due to line voltage, the adjustable line compensation is introduced to AP3190 design. The negative voltage of FB pin which is linear to the line voltage is added up to V_{CS} reference by a certain proportion and creates an adjustable compensation voltage to clear up the primary current gap, so that the excellent line regulation of output current will be achieved.

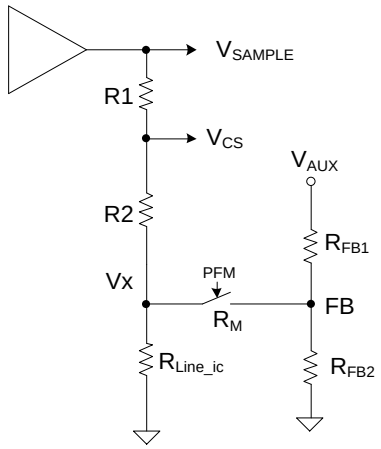

Figure 4. Adjustable Line Compensation Circuit

$$\Delta V_{CS} = -\frac{R_1}{R_1 + R_2} \cdot \frac{N_{AUX}}{N_P} \cdot \frac{R_{Line_ic}}{R_{LC} + R_M + R_{FB1}} \cdot V_{LINE} \quad \cdots\cdots\cdots (6)$$

So, the AP3190 can change the line compensation capability by adjusting the upper resistor at FB pin (R_{FB1}). Higher resistance means lower line compensation capability.

Protection

The AP3190 has various built-in single-point fault protection features: FB overvoltage protection, VCC overvoltage protection, output short-circuit protection, FB open-circuit protection, current sense resistor fault (short or open) protection and overtemperature protection. The fault conditions to trigger these protections are different and all of the protection modes to enter after the protections are triggered are auto-recovery.

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Operation Description (continued)

Short-Circuit Protection (SCP)

Short-Circuit Protection (SCP) detection principle is similar to the normal output voltage feedback detection by sensing FB pin voltage. When the detected FB pin voltage is below $V_{FB(SCP)}$ for a duration of about t_{SCP}, the SCP is triggered. Then the AP3190 enters hiccup mode that the IC immediately shuts down and then restarts, so that the VCC voltage changes between V_{TH_ST} and UVLO threshold until $V_{FB(SCP)}$ condition is removed.

As to the normal system startup, the time duration of FB pin voltage below $V_{FB(SCP)}$ should be less than t_{SCP} to avoid entering SCP mode. But for the output short condition or the output voltage below a certain level, the SCP mode should happen.

Overtemperature Protection (OTP)

External OTP

The AP3190 provides external overtemperature protection (OTP) by connecting a Negative-Temperature-Coefficient (NTC) resistor from OTP pin to GND. Internally, a 100μA current source is injected to the OTP pin, which generates a voltage proportional to the NTC resistance. At high ambient temperature, the NTC resistance becomes low, which results in a low voltage at the OTP pin. If the OTP pin voltage drops below an internally set threshold, then the OTP is triggered, and the AP3190 shuts down.

In the AP3190, the external OTP has a built-in hysteresis by having two thresholds. The device will be shut down when the OTP pin voltage is less than 0.5V and will be recovered when the OTP pin voltage is higher than 0.75V.

During startup and burst mode, the OTP function is disabled.

Internal OTP

If the IC junction temperature exceeds the threshold of +150°C, the AP3190 shuts down immediately and enters the hold mode. If the junction temperature decreases to hysteresis temperature of +110°C, the AP3190 can recover to normal operation. If not, the power system keeps the hold mode.

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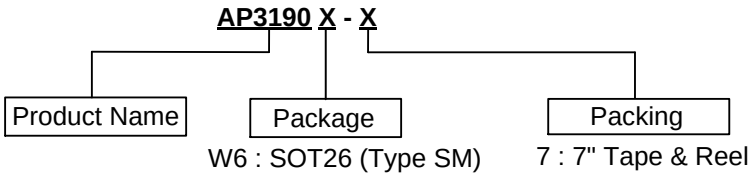
Ordering Information

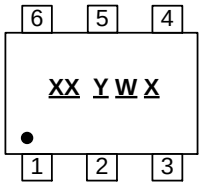


Part Number	Package	Identification Code	Packing	
			Qty.	Carrier
AP3190W6-7	SOT26 (Type SM)	B9	3000	Tape & Reel

Marking Information

SOT26 (Type SM)

(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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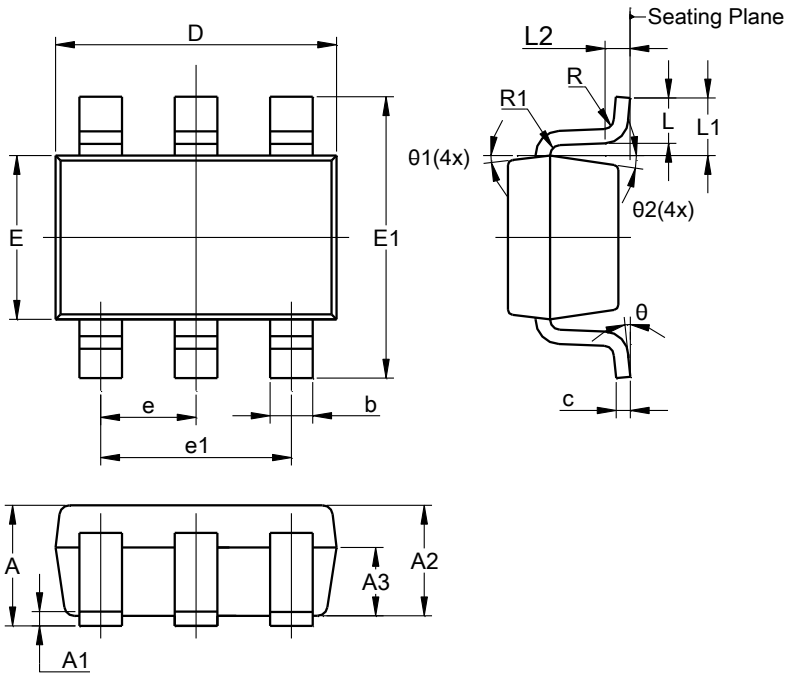
Package Outline Dimensions

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

SOT26 (Type SM)

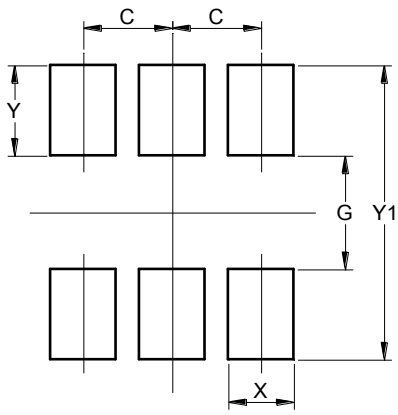


SOT26 (Type SM)			
Dim	**Min**	**Max**	**Typ**
A	--	1.45	--
A1	0.00	0.15	--
A2	0.90	1.30	1.10
A3	0.60	0.70	0.65
b	0.39	0.49	--
c	0.12	0.19	--
D	2.85	3.05	2.95
E	1.55	1.75	1.65
E1	2.60	3.00	2.80
e	0.85	1.05	0.95
e1	1.80	2.00	1.90
L	0.35	0.60	0.45
L1	0.59REF		
L2	0.25BSC		
R	0.05	--	--
R1	0.05	0.20	--
θ	0°	8°	--
θ1	8°	12°	10°
θ2	8°	12°	10°
All Dimensions in mm			

Suggested Pad Layout

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

SOT26 (Type SM)



Dimensions	Value (in mm)
C	0.950
G	1.250
X	0.700
Y	0.975
Y1	3.200

Mechanical Data

- Moisture Sensitivity: Level 3 per JESD22-A113
- Terminals: Finish – Matte Tin Plated Leads, Solderable per JESD22-B102 (e3)
- Weight: 0.018 grams (Approximate)

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