High Precision CC/CV Primary-Side PWM Power Switch

❖ GENERAL DESCRIPTION

AX2535 is a high performance offline PWM Power switch for low power AC/DC charger and adapter applications. It operates in primary-side sensing and regulation. Consequently, the photo-coupler and TL431 could be eliminated. Proprietary Constant Voltage (CV) and Constant Current (CC) control is integrated as shown in the figure below.

In CC control, the current and output power setting can be adjusted externally by the sense resistor R_S at CS pin. In CV control, multi-mode operations are utilized to achieve high performance and high efficiency. In addition, good load regulation is achieved by the built-in cable drop compensation. Device operates in PFM in CC mode as well at large load condition and it operates in PWM with frequency reduction at light/medium load.

AX2535 offers power on soft start control and protection coverage with auto-recovery features including Cycle-by-Cycle current limiting, VDD OVP, VDD clamp and UVLO. Excellent EMI performance is achieved by frequency shuffling technique.

High precision constant voltage (CV) and constant current (CC) can be achieved by AX2535.
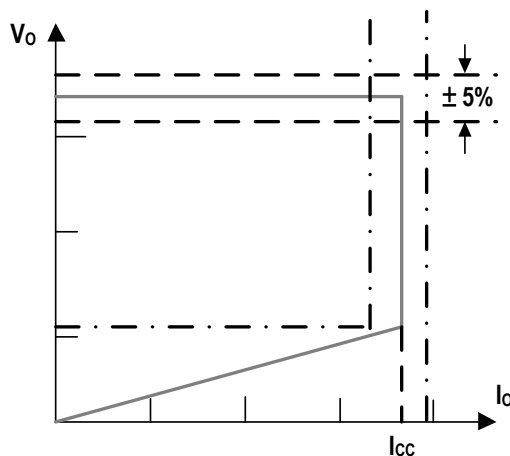
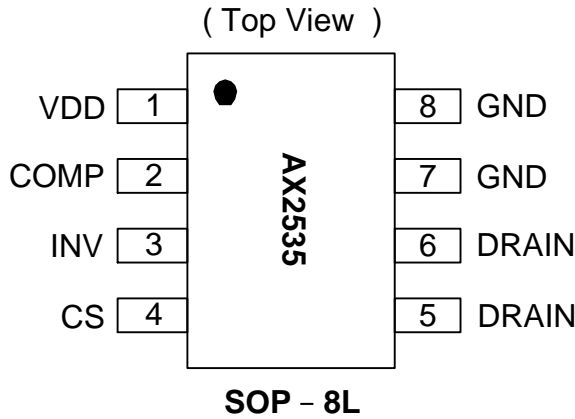

Fig.1. CC/CV control characteristic

❖ **FEATURES**

- ±5% Constant Voltage Regulation at Universal AC input
- High Precision Constant Current Regulation at Universal AC input
- Primary-Side Sensing and Regulation Without TL431 and photo-coupler
- Programmable CV and CC Regulation
- Adjustable Constant Current and Output Power Setting
- Built-in Secondary Constant Current Control with Primary-Side Feedback
- Built-in Adaptive Current Peak Regulation
- Built-in Primary winding inductance compensation
- Programmable Cable drop Compensation
- Power on Soft Start
- Built-in Leading Edge Blanking (LEB)
- Cycle-by-Cycle Current Limiting
- VDD Under Voltage Lockout with Hysteresis (UVLO)
- VDD OVP
- VDD Clamp

❖ **BLOCK DIAGRAM**

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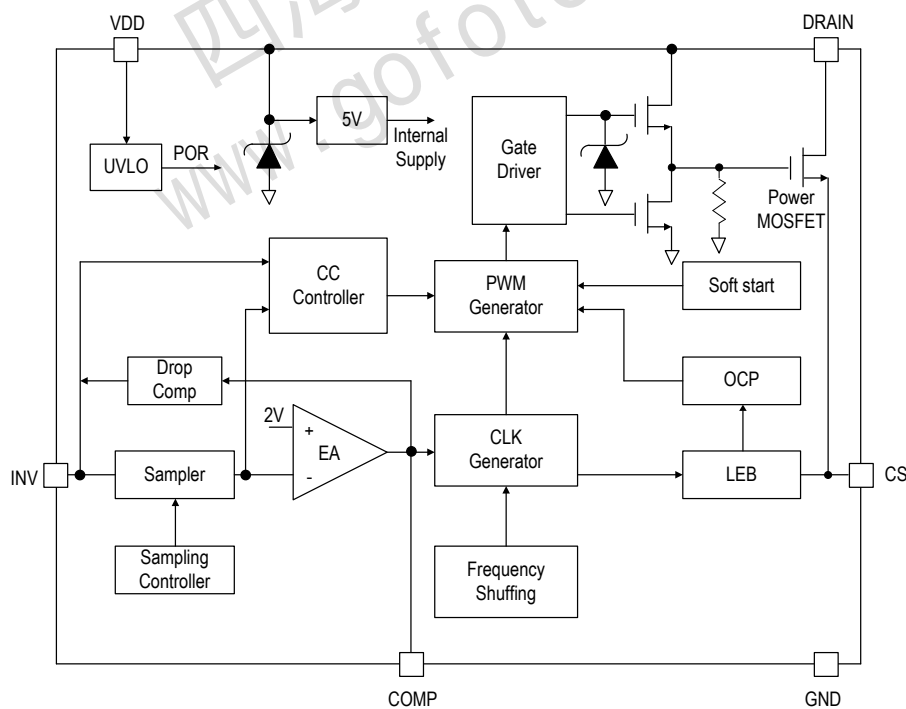
❖ PIN ASSIGNMENT

The package of AX2535 is SOP-8L; the pin assignment is given by:

(Top View)

```
         ┌─────────────┐
VDD  │ 1 │●          │ 8 │ GND
COMP │ 2 │    AX2535  │ 7 │ GND
INV  │ 3 │           │ 6 │ DRAIN
CS   │ 4 │           │ 5 │ DRAIN
         └─────────────┘
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SOP－8L

Name	Pin No.	I/O	Description
VDD	1	P	Power Supply
COMP	2	I	Loop Compensation for CV Stability
INV	3	I	The voltage feedback from auxiliary winding reflecting output voltage. PWM duty cycle is determined by EA output and current sense signal at pin 4.
CS	4	I	Current sense input
DRAIN	5,6	O	HV MOSFET Drain Pin. The Drain pin is connected to the primary lead of the transformer
GND	7,8	P	Ground

❖ ORDER/MARKING INFORMATION

Order Information	Top Marking
AX2535 X X Package S: SOP-8L Packing Blank : Tube	Logo ← **AX** 2 5 3 5 → Part number YYWWX → ID code:internal WW:01~52 Year: 10=2010 11=2011

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❖ **ABSOLUTE MAXIMUM RATINGS** (T_A=25°C)

Characteristics	Symbol	Rating	Unit
Drain Voltage (off state)		-0.3 to BV_{DSS}	V
VDD Voltage		-0.3 to V_{DD_CLAMP}	V
VDD Zener Clamp Continuous Current		10	mA
COMP Voltage		-0.3 to 7	V
CS Input Voltage		-0.3 to 7	V
INV Input Voltage		-0.3 to 7	V
Max Operating Junction Temperature	T_J	150	°C
Min/Max Storage Temperature	T_{STG}	-55 to 150	°C
Lead Temperature (Soldering, 10secs)		260	°C
Thermal Resistance from Junction to case	θ_{JC}	25	°C/W
Thermal Resistance from Junction to ambient	θ_{JA}	70	°C/W

Note: θ_{JA} is measured with the PCB copper area (need connect to OUT pin) of approximately 1.5 in^2 (Multi-layer).

❖ **ELECTRICAL CHARACTERISTICS**

(T_A=25°C, V_{DD}=V_{DDG}=16V, unless otherwise specified)

| Characteristics	Symbol	Conditions	Min	Typ	Max	Units
Supply Voltage (VDD) Section						
Standby Current	$I_{DD\ ST}$	V_{DD}=13V	-	5	20	uA
Operation Current	$I_{DD\ OP}$	Operation supply current I_{NV}=2V, C_S=0V, V_{DD}=V_{DDG}=18V	-	2	3	mA
VDD Under Voltage Lockout Enter	$U_{VLO(ON)}$	VDD falling	8.2	9.0	10.5	V
VDD Under Voltage Lockout Exit	$U_{VLO(OFF)}$	VDD rising	13.5	14.8	16.0	V
Maximum VDD Operation Voltage	V_{DD_CLAMP}	IDD=10mA	27	28.5	30	V
Over Voltage Protection Voltage	OVP	Ramp VDD until gate shut down	26	27.5	29	V
Current Sense Input						
LEB Time	TLEB			625		ns
Over Current Threshold	V_{TH_OC}		880	910	940	mV
OCP Propagation Delay	T_{D_OC}			110		ns
Input Impedance	Z_{IN}		50			KΩ
Soft Start Time	T_{SS}			17		ms

❖ ELECTRICAL CHARACTERISTICS (CONTINUOUS)

(T_A=25°C, V_{DD}=V_{DDG}=16V, unless otherwise specified)

Characteristics	Symbol	Conditions	Min	Typ	Max	Units
Frequency Section						
IC Maximum Frequency	F_{MAX}	(Note)	55	60	65	KHz
System Nominal Switch Frequency	F_{NOR}		-	50	-	KHz
System Startup Frequency	F_{STR}	I_{NV}=0V, Comp=5V	-	14	-	KHz
Frequency Shuffling Range	$\Delta F/F_{REQ}$		-	+/-6	-	%
Error Amplifier section						
Reference Voltage for EA	V_{REF}		1.97	2	2.03	V
DC Gain of EA	Gain		-	60	-	dB
Max. Cable Compensation Current	I_{COMP_MAX}	I_{NV}=2V, Comp=0V	-	37.5	-	uA
Power MOSFET Section						
MOSFET Drain-Source Breakdown Voltage	BV_{DSS}		600	-	-	V
On Resistance	$R_{DS(ON)}$	Static, Id=0.4A	-	12	15	Ω

Note: F_{MAX} indicates IC internal maximum clock frequency. In system application, the maximum operation frequency of 60KHz nominal occurs at maximum output power or the transition point from CV to CC

❖ APPLICATION CIRCUIT

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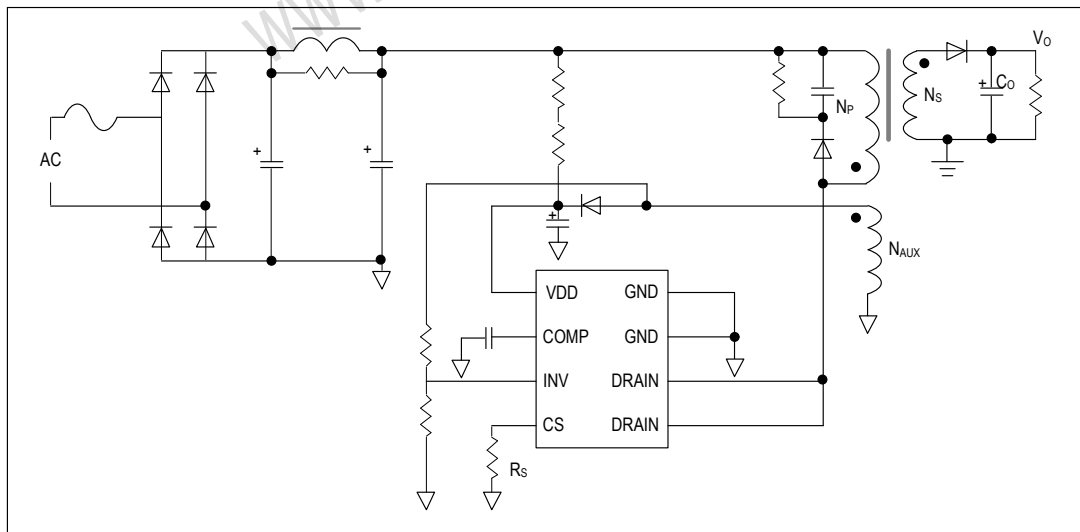
❖ **FUNCTION DESCRIPTIONS**

AX2535 is a cost effective PWM power switch optimized for off-line low power AC/DC applications including battery chargers and adapters. It operates in primary-side sensing and regulation, thus photo-coupler and TL431 are not required. Proprietary built-in CV and CC control can achieve high precision CC/CV control meeting most adapter and charger application requirements.

Startup Current and Startup Control

Startup current of AX2535 is designed to be very low so that VDD could be charged up above UVLO threshold and startup quickly. A large value startup resistor can therefore be used to minimize the power loss in application.

Operating Current

The operating current of AX2535 is as low as 2.5mA. Good efficiency is achieved with the low operating current together with "Multi-Mode" control features.

Soft Start

AX2535 features an internal soft start to minimize the component electrical over-stress during power on startup. As soon as VDD reaches UVLO (OFF), the control algorithm will ramp peak current voltage threshold gradually from nearly zero to normal setting of 0.90V. Every restart is a soft start.

CC/CV Operation

AX2535 is designed to produce good CC/CV control characteristic as shown in the Fig.1. In charger applications, a discharged battery charging starts in the CC portion of the curve until it is nearly full charged and smoothly switches to operate in CV portion of the curve. In an AC/DC adapter, the normal operation occurs only on the CV portion of the curve. The CC portion provides output current limiting. In CV operation, the output voltage is regulated through the primary-side control. In CC operation mode, AX2535 will regulate the output current constant regardless of the output voltage drop.

Principle of Operation

To support AX2535 proprietary CC/CV control, system needs to be designed in DCM mode for flyback system (refer to "Application Circuit" on page 5). In the DCM flyback converter, the output voltage can be sensed via the auxiliary winding. During MOSFET turn-on time, the load current is supplied from the output filter capacitor Co. The current in the primary winding ramps up. When MOSFET turns off, the primary current transfers to the secondary at the amplitude of

$$I_S = \frac{N_P}{N_S} \cdot I_P \qquad (1)$$

The auxiliary voltage reflects the output voltage as shown in Fig.2 and it is given by

$$V_{AUX} = \frac{N_{AUX}}{N_S} \cdot (V_O + \Delta V) \qquad (2)$$

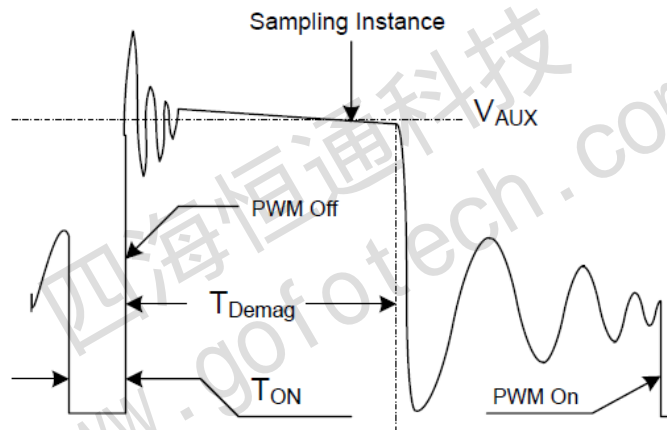Where ΔV indicates the drop voltage of the output Diode.

Fig.2. Auxiliary voltage waveform

Via a resistor divider connected between the auxiliary winding and INV (pin 3), the auxiliary voltage is sampled at the end of the demagnetization and it is hold until the next sampling. The sampled voltage is compared with V_{REF} (2.0V) and the error is amplified. The error amplifier output COMP reflects the load condition and controls the PWM switching frequency to regulate the output voltage, thus constant output voltage can be achieved.

When sampled voltage is below V_{REF} and the error amplifier output COMP reaches its maximum, the switching frequency is controlled by the sampled voltage thus the output voltage to regulate the output current, the constant output current can be achieved.

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Adjustable CC point and Output Power

In AX2535, the CC point and maximum output power can be externally adjusted by external current sense resistor R_S at CS pin as illustrated in "Application Circuit". The output power is adjusted through CC point change. The larger R_S, the smaller CC point is, and the smaller output power becomes, and vice versa as shown in Fig.3
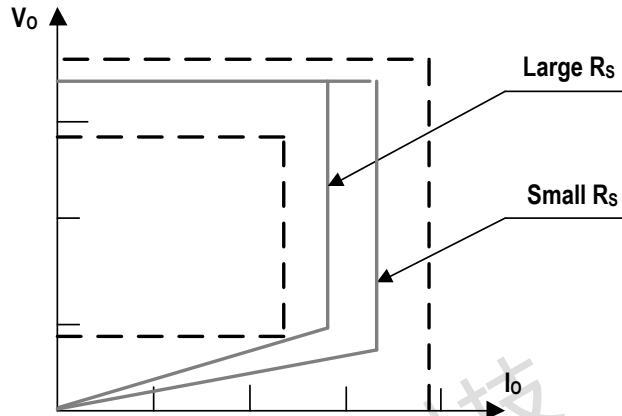

Fig.3 Adjustable output power by changing R_S

Operation switching frequency

The switching frequency of AX2535 is adaptively controlled according to the load conditions and the operation modes. No external frequency setting components are required. The operation switching frequency at maximum output power is set to 60KHz internally.

For flyback operating in DCM, The maximum output power is given by

$$Po_{MAX} = \frac{1}{2}L_P F_{SW} I_p^2 \qquad (3)$$

Where L_P indicates the inductance of primary winding and I_P is the peak current of primary winding. Refer to the equation (3), the change of the primary winding inductance results in the change of the maximum output power and the constant output current in CC mode. To compensate the change from variations of primary winding inductance, the switching frequency is locked by an internal loop such that the switching frequency is

$$F_{SW} = \frac{1}{2T_{Demag}} \qquad (4)$$

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Since T_{Demag} is inversely proportional to the inductance, as a result, the product L_P and F_{SW} is constant, thus the maximum output power and constant current in CC mode will not change as primary winding inductance changes. Up to ±10% variation of the primary winding inductance can be compensated. Frequency shuffling for EMI improvement the frequency shuffling (switching frequency modulation) is implemented in AX2535. The oscillation frequency is modulated so that the tone energy is spread out. The spread spectrum minimizes the conduction band EMI and therefore eases the system design.

Current Sensing and Leading Edge

Blanking

Cycle-by-Cycle current limiting is offered in AX2535 current mode PWM control. The switch current is detected by a sense resistor into the CS pin. An internal leading edge blanking circuit chops off the sensed voltage spike at initial internal power MOSFET on state so that the external RC filtering on sense input is no longer needed. The PWM duty cycle is determined by the current sense input voltage and the EA output voltage.

Gate Driver

The internal power MOSFET in AX2535 is driven by a dedicated gate driver for power switch control. Too weak the gate driver strength results in higher conduction and switch loss of MOSFET while too strong gate driver compromises EMI. A good tradeoff is achieved through the built-in totem pole gate design with right output strength control.

Programmable Cable drop Compensation

In AX2535, cable drop compensation is implemented to achieve good load regulation. An offset voltage is generated at INV (pin 3) by an internal current flowing into the resister divider. The current is inversely proportional to the voltage across pin COMP, as a result, it is inversely proportional to the output load current and the drop due to the cable loss can be compensated. As the load current decreases from full-load to no-load, the offset voltage at INV will increase. It can also be programmed by adjusting the resistance of the divider to compensate the drop for various cable lines used.
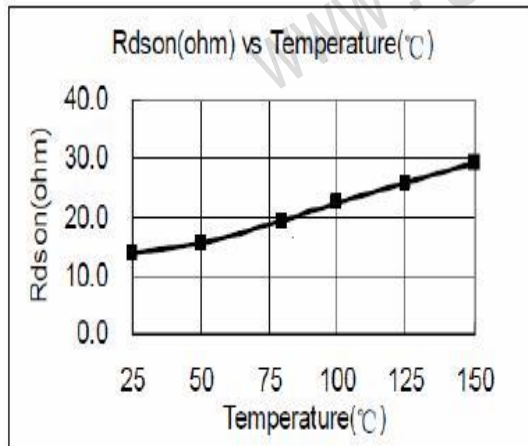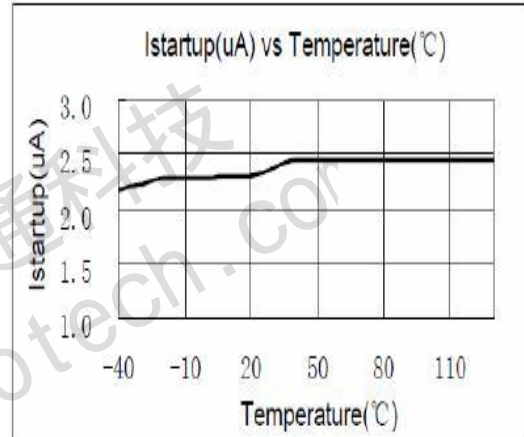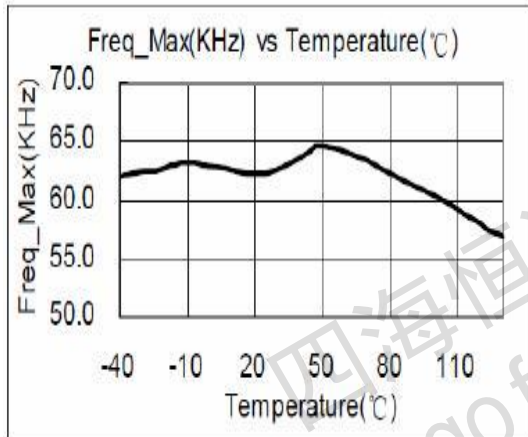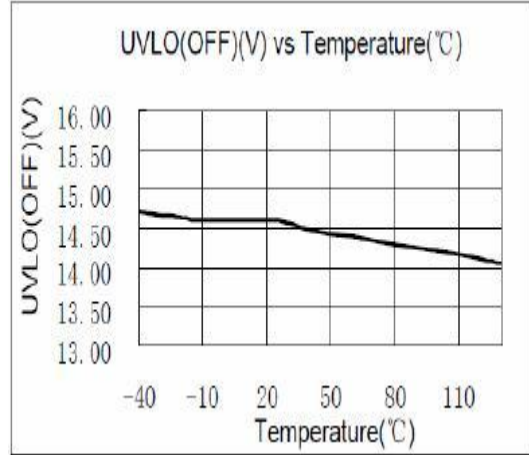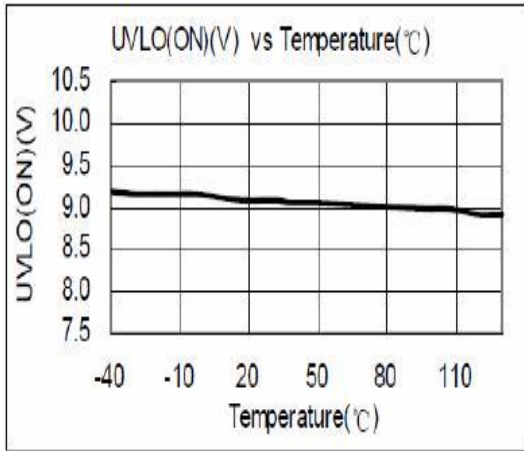
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Protection Control

Good power supply system reliability is achieved with its rich protection features including Cycle-by-Cycle current limiting (OCP), VDD clamp, Power on Soft Start, and Under Voltage Lockout on VDD (UVLO).
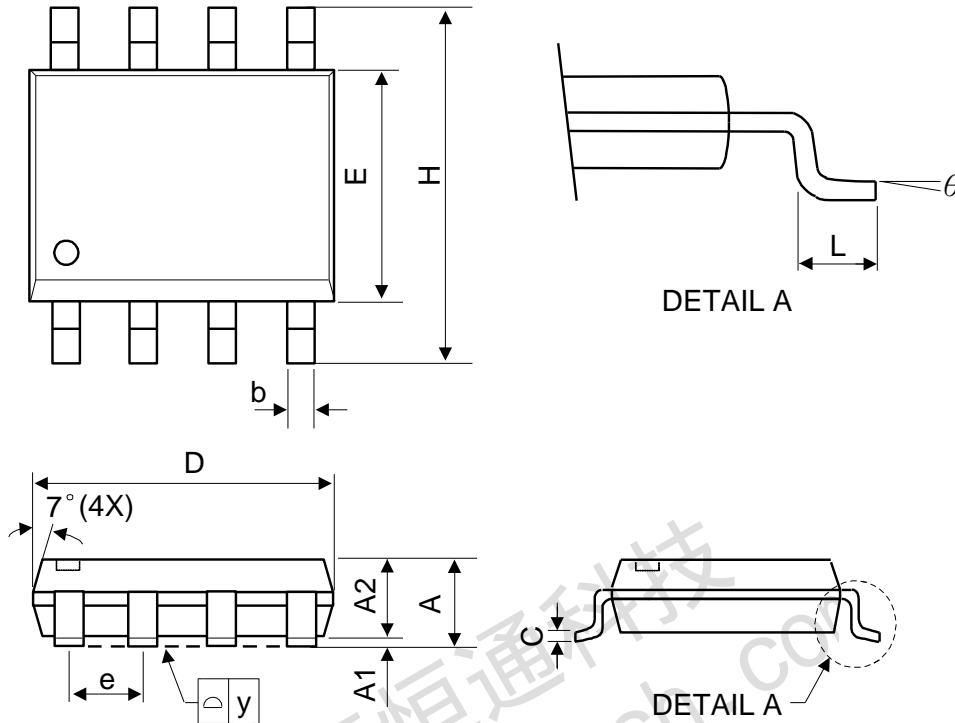
VDD is supplied by transformer auxiliary winding output. The output of AX2535 is shut down when VDD drops below UVLO (ON) limit and switcher enters power on startup sequence thereafter.

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❖**TYPICAL CHARACTERISTICS**

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❖ **PACKAGE OUTLINES**

DETAIL A

DETAIL A

Symbol	Dimensions in Millimeters			Dimensions in Inches		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	-	-	1.75	-	-	0.069
A1	0.1	-	0.25	0.04	-	0.1
A2	1.25	-	-	0.049	-	-
C	0.1	0.2	0.25	0.0075	0.008	0.01
D	4.7	4.9	5.1	0.185	0.193	0.2
E	3.7	3.9	4.1	0.146	0.154	0.161
H	5.8	6	6.2	0.228	0.236	0.244
L	0.4	-	1.27	0.015	-	0.05
b	0.31	0.41	0.51	0.012	0.016	0.02
e	1.27 BSC			0.050 BSC		
y	-	-	0.1	-	-	0.004
θ	0º	-	8º	0º	-	8º

Mold flash shall not exceed 0.25mm per side

JEDEC outline: MS-012 AA

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