36V 5A Synchronous Step-down Converter with Dual-Channel Current Limit

DESCRIPTION

The AIC2935B is a high-efficiency, high-voltage, synchronous step-down DC-DC converter with integrated high-side and low-side power MOSFETs. The AIC2935B uses proprietary constant on-time (COT) control to provide excellent line and load transient response. The AIC2935B features slew rate control and spread spectrum frequency modulation to minimize EMI/EMC emissions. With wide input range from 4V to 36V, the converter can deliver output voltage ranging from 0.8V to V_{IN} with up to 5A continuous output current. The converter can be configured as single output or dual outputs with independent constant current (CC) regulation for each output. In the event of output overload or short circuit, the converter will be into hiccup mode. Other protection features include cycle-by-cycle current limit, input under and over voltage protection and thermal shutdown. AIC2935B also provides programmable cable voltage drop compensation by selecting appropriate external resistor divider. Switching frequency is internally set to 180kHz. The AIC2935B is available in SOP8_EP package.

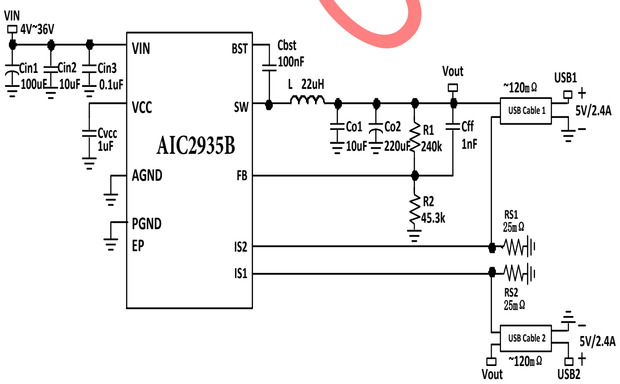
FEATURES

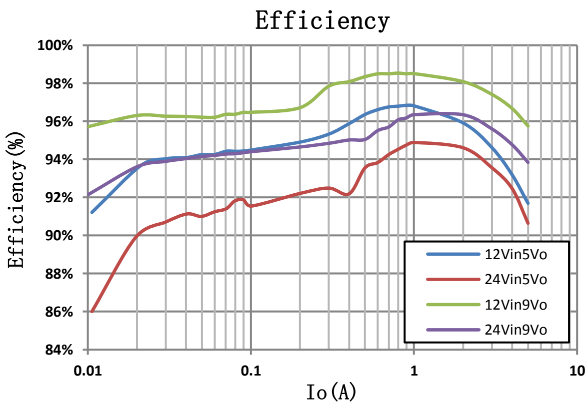
- Wide input Voltage Range from 4V to 36V
- 100% Duty Cycle Low Dropout Operation
- 70ns Minimum On Time
- Low EMI and Switching Noise
- 180kHz Switching Frequency with Spread Spectrum Modulation
- 5A Continuous Output Current
- Integrated 40mΩ High-side Switch and 40mΩ Low-side Switch
- Dual Outputs with Independent 8% Accurate Constant Current Regulation
- Programmable Output Cable Drop Compensation
- Internal 3ms Soft Start
- Short Circuit Protection with Hiccup mode
- Thermal Shutdown with Auto Recovery
- Cycle-by-Cycle current limit
- Available in SOP8_EP package

APPLICATIONS

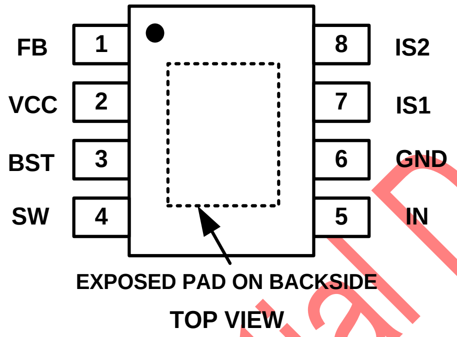
- Dual-Port Car Charger
- Automotive and Industrial Supplies
- Point of Load

TYPICAL APPLICATIONS





PIN CONFIGURATION



SOP8_EP TOP VIEW

Pin Description

Pin No	Pin Name	DESCRIPTION
1	FB	Feedback Input. Connect FB to the center of the external resistor divider from the output to the AGND to set the output voltage.
2	VCC	Internal 5V LDO output. The driver and control circuits are powered from this voltage. Decouple with a minimum 1µF ceramic capacitor to PGND as close to the pin as possible.
3	BST	High-Side Driver Bootstrap Supply. Connect a 0.1uF capacitor between SW and BST for proper operation.
4	SW	Output pin of internal power switches. Connect this pin to the inductor and bootstrap capacitor.
5	IN	Supply Voltage. The IN pin supplies power for internal MOSFET and regulator. The AIC2935B operates from a +4V to +36V input rail. Bypass IN to PGND with a 10uF or greater low ESR ceramic capacitor.
6	GND	System Analog Ground.
7	IS1	IS1: The Channel 1 output current sense input pin. Connect a sense resistor from this pin to AGND. When the voltage on this pin increases to 60mV, the AIC2935B reduces output voltage and regulates IS1 at 60mV.
8	IS2	IS2: The Channel 2 output current sense input pin. Connect a sense resistor from this pin to AGND. When the voltage on this pin increases to 60mV, the AIC2935B reduces output voltage and regulates IS2 at 60mV.
EP	PGND	Exposed Pad is connected to the low side MOSFET Power Ground. Connect EP to a large-area contiguous copper ground plane for effective power dissipation.

Functional Block Diagram

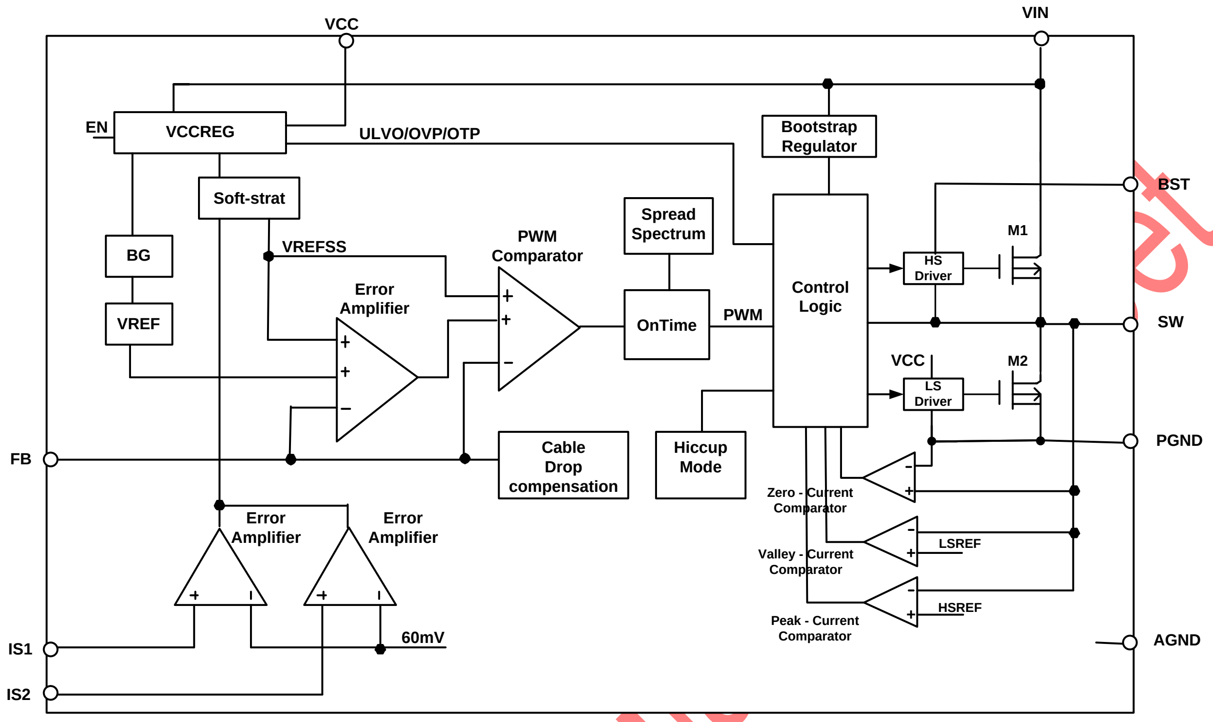


Figure 1—AIC2935B Car Charger Functional Block Diagram (IS1/IS2)

Absolute Maximum Rating (Reference to GND) (Note1)

- Supply Voltage IN to GND... +39V
- PGND to GND .... -0.3V to +0.3V
- SW to GND.. -0.3V to V_{IN}+0.3V
- SW Surge (30ns) to GND................................ -3V to V_{IN}+3V
- BST to SW.. –0.3V to +6V
- All Other Pins to GND.. –0.3V to +6V
- Lead Temperature .... +260°C
- Junction Temperature ………... +150°C
- Storage Temperature .... -65°C to +150°C

Recommend Operating Conditions (Note2)

- Supply Voltage V_{IN} ....+4V to +36V
- Output Voltage V_{OUT} .... 0.8V to V_{IN}
- Operating Junction Temp. (TJ)…………. -40°C to +125°C

Thermal information(Note3, 4)

- SOP8_EP maximum power dissipation …….………….2.1W
- Thermal Resistance(θ_{JA}) SOP8_EP…...…..……….. 51°C/W
- Thermal Resistance(θ_{JC}) SOP8_EP...…..........……...13°C/W

Note(1): Stress exceeding those listed “Absolute Maximum Ratings” may damage the device.
Note(2): The device is not guaranteed to function outside of the recommended operating conditions.
Note(3): Measured on JESD51-7, 4-Layer PCB.
Note(4): The maximum allowable power dissipation is a function of the maximum junction temperature T_{J_MAX}, the junction to ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by $P_{D\_MAX}= (T_{J\_MAX}-T_A)/\theta_{JA}$. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.

Electrical Characteristics

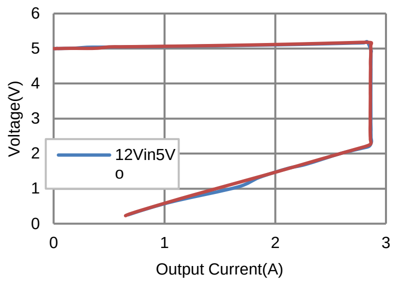
V_{IN} = 12V, T_A = +25°C, unless otherwise noted.

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Operating Input Voltage	V_{IN}		4		36	V
Input Under Voltage Lockout Threshold Rising	V_{UVLO}			3.80	4.05	V
Input Under Voltage Lockout Threshold Hysteresis	V_{UVHYS}			430		mV
Input Over Voltage Lockout Threshold Rising	V_{OVP}			38.3	40	V
Input Over Voltage Lockout Threshold Hysteresis	V_{HYS}			1.8		V
VCC Regulator	VCC	V_{FB}=0.84V I_{VCC}=0~30mA	4.8	5.1	5.4	V
Supply Current (Quiescent)	I_{IN}	V_{FB}=0.84V		100		μA
High-side Switch On Resistance	HSRDS-ON			40		mΩ
Low-side Switch On Resistance	LSRDS-ON			40		mΩ
Switch Leakage	SWLKG	V_{FB}=0.84V, V_{IN}=36V V_{SW}=0V or 36V	-20		+20	μA
Feedback Regulation Voltage	V_{FBREG}		784	800	816	mV
Feedback Pin Input Current	I_{FB}	V_{FB}=0.8V	-100		+100	nA
Minimum On Time	T_{ON_MIN}			70		ns
Minimum Off Time	T_{OFF_MIN}			100		ns
Maximum Duty Cycle	DMAX	V_{IN}=12V, V_{FB}=0.7V		100		%
High-Side Switch Peak Current Limit	I_{PK}			7.5		A
Low-Side Switch Valley Current Limit	I_{VALLEY}			6.5		A
Low-Side Switch Zero Current Detection	I_{ZX}			90		mA
Thermal Shutdown	T_{SD}			155		℃
Thermal Shutdown Hysteresis				25		℃
Switching Frequency	F_{SW}			180		kHz
Spread-Spectrum Modulation Frequency				3		kHz
Output Voltage Cable Compensation		V_{IN}=12V, R_1=240kΩ, I_{OUT}= I_{OUT1} + I_{OUT2} =5A		+0.6		V
IS1 / IS2 Reference Voltage	V_{IS}			60		mV

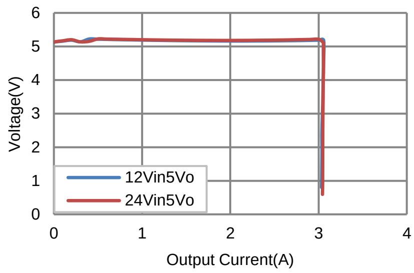
TYPICAL PERFORMANCE CHARACTERISTICS

Circuit of Figure 1, C_{IN}=100uF, C_{OUT}=10uF+220uF, L=22uH, R_{IS1}=R_{IS2}=20mΩ, T_A=+25℃

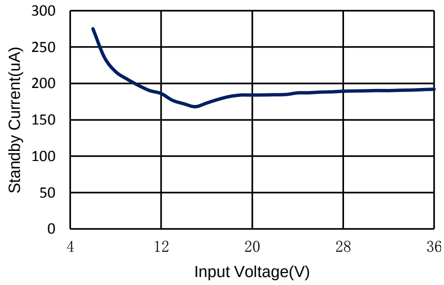
CV/CC Curve (MT3901N)



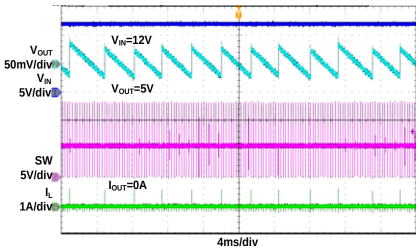
Disable CC Fold Back (MT3901X)



Standby Current vs Input Voltage



Steady State Test



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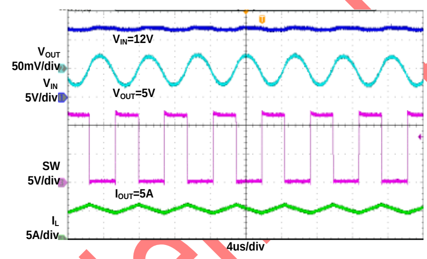

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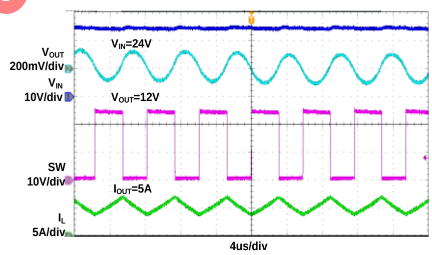

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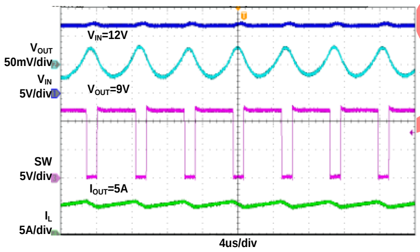

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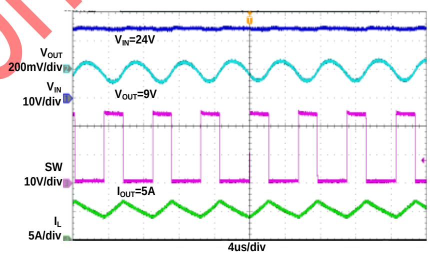
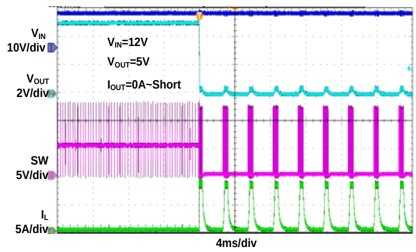


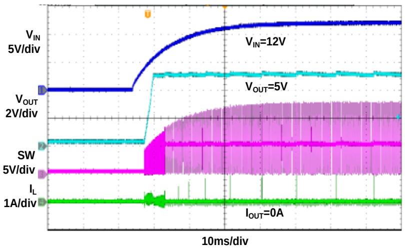
Short Protection



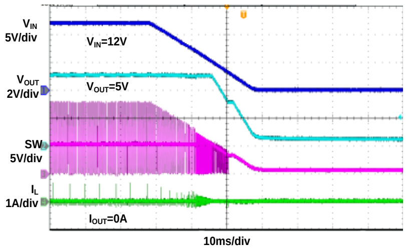
TYPICAL PERFORMANCE CHARACTERISTICS

Circuit of Figure 1, C_{IN}=100uF, C_{OUT}=10uF+220uF, L=22uH, R_{IS1}=R_{IS2}=20mΩ, T_A=+25℃

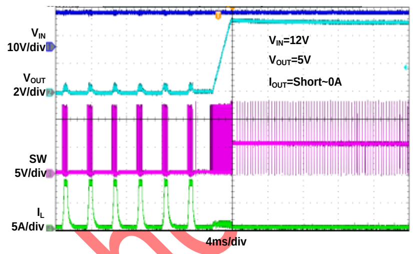
Vin Power on



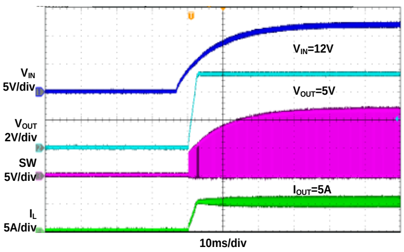
Vin Power off



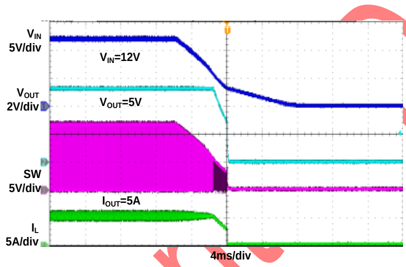
Short Protection



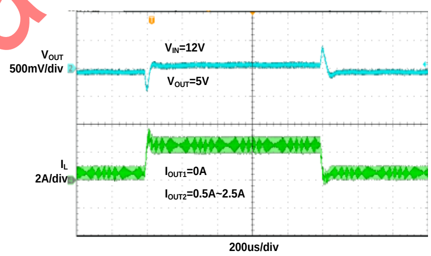
Vin Power on



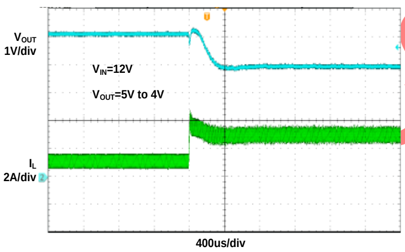
Vin Power off



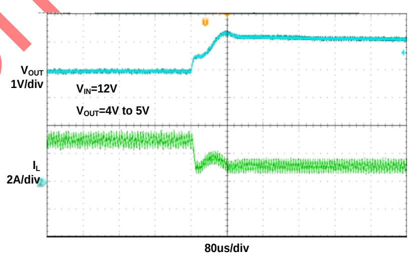
Load Transient



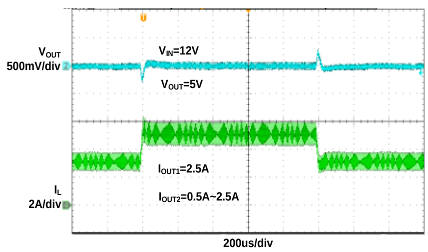
CV mode to CC mode



CC mode to CV mode



Load Transient



Detailed Description

The AIC2935B is a constant on-time controlled synchronous step-down converter with 4V to 36V input voltage range. The device can provide up to 5A continuous output current. Output voltage is set by an external resistor divider with feedback point connected to FB pin.

CC/CV mode control

The AIC2935B operates in either Constant Voltage (CV) mode or Constant Current (CC) mode depends on load condition. When channel 1 and channle2 output current is below constant current threshold, AIC2935B regulates output voltage in CV mode. As Channel 1 or Channel 2 output current increases and reaches the Constant Current threshold, AIC2935B enters CC mode and by reducing output voltage and maintaining relative channel output current constant. Once FB pin voltage falls below 0.4V, the regulated channel current level will linearly fold back as FB voltage continues to drop.

Spread-Spectrum Option

The AIC2935B has an internal spread-spectrum option to optimize EMI performance. The modulation signal is a triangular wave with a period of 340us at 180kHz. Therefore, switching frequency will linearly vary between 180kHz -6% to 180kHz every 330us.

Internal soft-start

The AIC2935B has built-in 3ms soft-start. During the soft start period, output voltage is ramped up linearly to the regulation voltage, independent of the load current level and output capacitor value.

Output Over Current Protection

AIC2935B has cycle-by-cycle HS current limit protection to prevent inductor current from running away. Once HS current limit is triggered, AIC2935B will turn on LS and wait for the inductor to drop down to a pre-determined level before the HS can be turned on again. If this current limit condition is repeated for a sustained long period of time, AIC2935B will consider it as over-load or short circuit. Either way, AIC2935B will enter hiccup mode, where it stop switching for a pre-determined period of time before automatically re-try to start up again. It always starts up with soft-start to limit inrush current and avoid output overshoot.

Application Information

Setting Output Voltage

The output voltage is set using the FB pin and a resistor divider connected to the output as shown in AP Circuit below. The output voltage (V_{OUT}) can be calculated according to the voltage of the FB pin (V_{FB}=0.8V Typical), Thus the output voltage is:

$$V_{OUT} = V_{FB} \times \left(\frac{R_1}{R_2} + 1 \right)$$

Programmable Cable Compensation

The AIC2935B provides programmable cable compensation by selecting appropriate external feedback resistor divider to compensate resistive voltage drop over the chargers' output cable. The cable compensation voltage can be expressed as

$$I_{FB} \times R1 = I_{OUT} \times R_{CABLE}$$

$$\Delta V_{OUT} = 2.5\mu A \times \frac{I_{OUT}}{5A} \times R1$$

I_{OUT} is equal to sum of channel 1 and channel 2 output current.

Setting the Channel 1 and 2 CC current

AIC2935B channel 1 constant current value is set by the resistor R_{IS1} connected between the IS1 and GND pins. Channel 2 constant current value is set by the resistor R_{IS2} between the IS2 and GND pins. The CC current is determined by the equation as follows

$$I_{CS1} = 60mV/R_{IS1}$$

$$I_{CS2} = 60mV/R_{IS2}$$

Input Capacitor Selection

The input capacitor must sustain the ripple current produced during the period of "ON" state of the high side MOSFET, so a low ESR ceramic capacitor is required to minimize the loss. The input ripple current RMS value can be calculated by the following equation:

$$I_{INRMS} = I_{OUT} \sqrt{D \times (1 - D)}$$

Where D is the duty cycle, I_{INRMS} is the input RMS current, and I_{OUT} is the load current. The equation reaches its maximum value with D = 0.5. The loss of the input capacitor can be calculated by the following equation:

$$P_{CIN} = ESR_{CIN} \times I_{INRMS}^2$$

Where P_{CIN} is the power loss of the input capacitor and ESR_{CIN} is the effective series resistance of the input capacitance. Due to large di/dt through the input capacitor, low ESR ceramic capacitors should be used.

Inductor Selection

The inductor is chosen to meet the requirements of the output voltage ripple and the load transient response. The higher inductance can reduce the inductor's ripple current and lower output ripple voltage. Use an inductor with a DC current rating of at least 25% percent higher than the maximum load current for most applications. For highest efficiency, select an inductor with a DC resistance less than 15mΩ. The inductor ripple current and output voltage ripple is approximated by the following equations:

$$\Delta I = \frac{V_{IN} - V_{OUT}}{F_S \times L} \bullet \frac{V_{OUT}}{V_{IN}}, \quad L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times F_S \times \Delta I}$$

$$I_{L\_MAX} = I_{LOAD} + \frac{\Delta I}{2}, \quad \Delta V_{OUT} = \Delta I \times ESR$$

Although the increase of the inductance reduces the ripple current and voltage, it contributes to the decrease of the response time for the regulator to load transient. The way to set a proper inductor value is to have the ripple current (△I) be approximately 20%~50% of the maximum output current. Once the value has been determined, select an inductor capable of carrying the required peak current without going into saturation. It is also important to have the inductance tolerance specified to keep the control accuracy of the system. 20% tolerance (at room temperature) is reasonable for the most inductor manufacturers. For some types of inductors, especially those with ferrite core, the ripple current will increase abruptly when it saturates, which will result in larger output ripple voltage. Use a larger inductance for improved light-load efficiency.

Output Capacitor Selection

An output capacitor is required to filter the output and supply the load transient current. The high capacitor value and low ESR will reduce the output ripple and the load transient drop. In typical switching regulator design, the ESR of the output capacitor bank dominates the transient response. The number of output capacitors can be determined by the following equations:

$$ESR_{MAX} = \frac{\Delta V_{ESR}}{\Delta I_{OUT}}$$

$$\text{Number of capacitors} = \frac{ESR_{CAP}}{ESR_{MAX}}$$

$\triangle V_{ESR}$= change in output voltage due to ESR

$\triangle I_{OUT}$ = load transient

ESR_{CAP} = maximum ESR per capacitor (specified in manufacturer's data sheet)

ESR_{MAX} = maximum allowable ESR

High frequency decoupling capacitors should be placed as closely to the power pins of the load as physically possible. For the decoupling requirements, please consult the capacitor manufacturers for confirmation.

Layout Consideration

To ensure stable, high efficiency and low noise operation of the power converter, system PCB layout is a critical step. Due to high current and voltage slew rate, several signal paths need to be carefully designed to minimize stray inductance and parasitic capacitance that could generate noise and degrade performance. Following are the layout guidelines:

(1).The loop (Vin-SW-L-Cout-GND) carries high current. The traces within this loop should be kept as wide and short as possible to reduce parasitic inductance and high-frequency loop area. It is also good for efficiency improvement.

(2). Place Input capacitor as close as possible to the IC Pins (Vin and GND) and the input loop area should be as small as possible to reduce parasitic inductance, input voltage spike and noise emission.

(3). Feedback components (R_1, R_2, R_T and C_{FF}) should be routed as far away from the inductor and the BST and SW pins to minimize noise coupling.

(4). For a typical 2-layer PCB layout, please refer to EVB Top Layer and EVB Bottom Layer below.

AIC2935B Car Charger Application Schematic

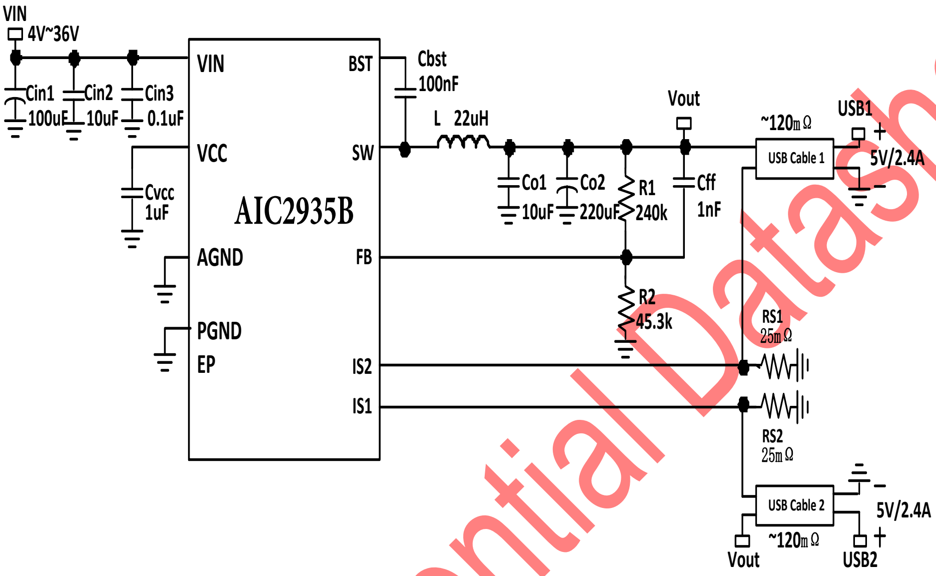


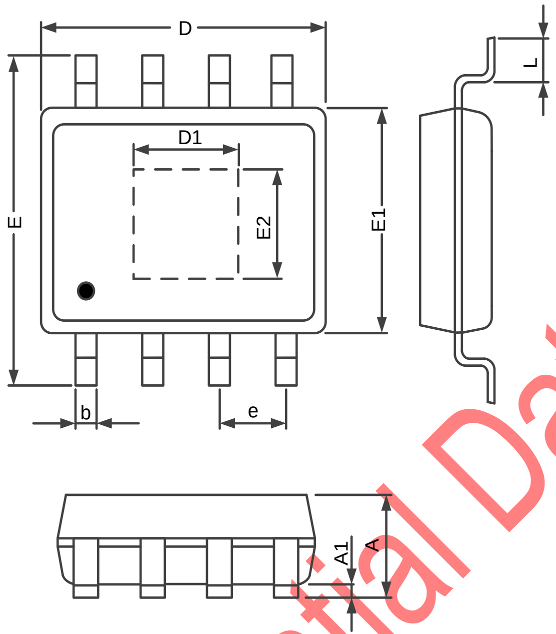
Figure 1. Typical Application Circuit for 5V/4.8ADual-output Car Charger

EVB BOM List

Qty	Ref	Value	Description	Package
1	C_{IN1}	100µF	Electrolytic Capacitor, 50V	EC 8*12mm
1	C_{IN2}	10µF	Ceramic Capacitor, 50V, X5R	0603
1	C_{IN3}	0.1µF	Ceramic Capacitor, 50V, X5R	0603
1	C_{O1}	10µF	Ceramic Capacitor, 50V, X5R	0805
1	C_{O2}	220µF	Solid-state Capacitor	8*12mm
1	C_{BST}	100nF	Ceramic Capacitor, 16V, X5R	0603
1	C_{VCC}	1uF	Ceramic Capacitor, 10V, X5R	0603
1	L	22µH	Inductor	SMD
2	RS1,RS2	25mΩ	Ceramic Capacitor, 10V, X5R	1206
1	R_1	240KΩ	Resistor, ±1%	0603
1	R_2	45.3KΩ	Resistor, ±1%	0603
1	R_{cable}	120mΩ	Resistor, ±1%	0805
1	C_{FF}	1nF	Ceramic Capacitor, 10V, X5R	0603
1	Power IC	AIC2935B	Step-Down DC/DC Converter	SOP8_EP

Package Information

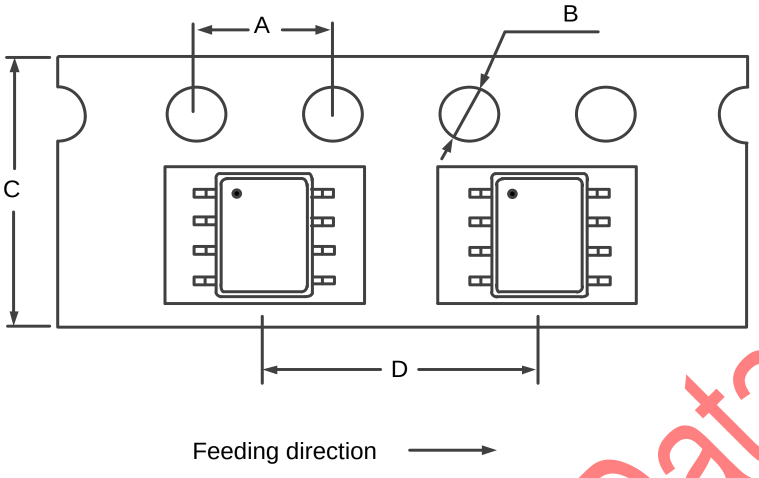
SOP8_EP Outline Dimensions
Unit: inches/mm



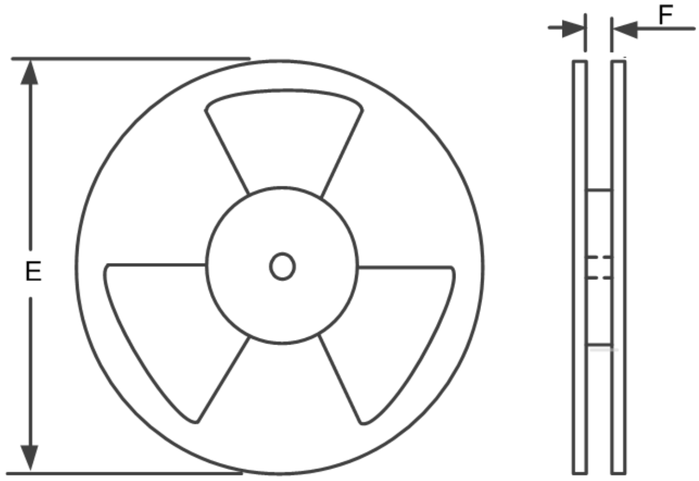
SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MIN.
A	1.35	1.75	0.053	0.069
A1	0.00	0.15	0.000	0.006
D	4.7	5.1	0.185	0.200
E1	3.7	4.1	0.145	0.161
D1	2.90	3.50	0.114	0.138
E2	2.00	2.50	0.080	0.098
E	5.80	6.20	0.228	0.244
L	0.40	1.27	0.016	0.050
b	0.31	0.51	0.012	0.020
e	1.16	1.37	0.046	0.054

Tape & Reel Carrier Dimensions

1. Orientation / Carrier Tape Information :



2. Rokreel Information :



3. Dimension Details :

PKG Type	A	B	C	D	E	F	Q'ty/Reel
SOP8EP	4.0 mm	1.5 mm	12.0 mm	8.0 mm	13 inches	13.0 mm	2,500

Reflow Profile

Classification Of IR Reflow Profile

Reflow Profile	Green Assembly
Average Ramp-Up Rate (Ts_{min} to Tp)	1~2℃/second, 3℃/second max.
Preheat & Soak -Temperature Min(Ts_{min}) -Temperature Max(Ts_{max}) -Time(ts_{min} to ts ts_{max})	 150℃ 200℃ 60~120 seconds
Time maintained above: -Temperature(T_L) -Time(t_L)	 217℃ 60~150 seconds
Peak Temperature(Tp)	See Classification Temp intable1
Time within 5℃of actual Peak Temperature(tp)	30 seconds max.
Ramp-Down Rate	6℃/second max.
Time 25℃ to Peak Temperature	8 minutes max.

* Tolerance for peak profile Temperature(T_p) is defined as a supplier minimum and a user maximum.

** Tolerance for time at peak profile temperature (t_p)is defined as a supplier minimum and a user maximum.

Table 1. Pb-freeProcess –Classification Temperatures (Tc)

Package Thickness	Volume mm^3 <350	Volume mm^3 350-2000	Volume mm^3 >2000
<1.6mm	260℃	260 ℃	260℃
1.6mm–2.5mm	260℃	250℃	245℃
≥2.5mm	250 ℃	245℃	245℃

Note: For all temperature information, please refer to topside of the package, measured on the package body surface.