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

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% Accu-rate Constant Current Regulation
- Programmable Output Cable Drop Compen-sation
- Internal 3ms Soft Start
- Short Circuit Protection with Hiccup mode
- Thermal Shutdown with Auto Recovery
- Cycle-by-Cycle current limit
- Available in ESOP-8 Exposed Pad package

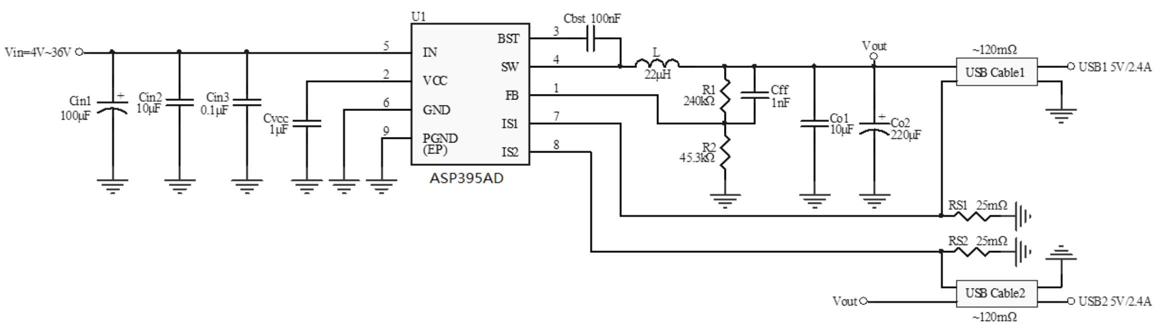
APPLICATIONS

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

DESCRIPTION

The ASP395AD is a high-efficiency, high-voltage, synchronous step-down DC-DC converter with integrated high-side and low-side power MOSFETs. The ASP395AD uses proprietary con-stant on-time (COT) control to provide excellent line and load transient response. The ASP395AD 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 VIN with up to 5A continuous output current. The converter can be configured as sin-gle output or dual outputs with independent con-stant current (CC) regulation for each output. In the event of output overload or short circuit, the converter will be into hiccup mode. Other protec-tion features include cycle-by-cycle current limit, input under and over voltage protection and thermal shutdown. ASP395AD also provides pro-grammable cable voltage drop compensation by selecting appropriate external resistor divider. Switching frequency is internally set to 180kHz. The ASP395AD is available in ESOP-8 exposed pad package.

APPLICATIONS CIRCUIT



Typical Application Circuit

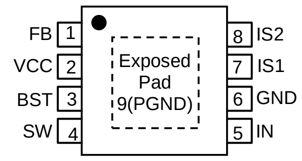
ORDERING INFORMATION

ASP395ADW-R

- PACKING TYPE
  R: TAPE & REEL
- PACKAGING TYPE
  W: ESOP-8 Exposed Pad
- D: Dual-Channel Current Limit

PIN CONFIGURATION

ESOP-8 Exposed Pad TOP VIEW



Example P/N:

ASP395ADW-R (Quantity: 4000pcs/Reel)

ABSOLUTE MAXIMUM RATINGS

Supply Voltage IN to GND .... +39V
PGND to GND .... -0.3V to +0.3V
SW to GND .... -0.3 V to V_{IN}+0.3V
SW Surge (30ns) to GND .... -3 V to V_{IN}+3V
BST to SW .... -0.3 V to +6V
All Other Pins to GND .... -0.3 V to +6V
Junction Temperature T_J .... +150°C
Storage Temperature Range T_{STG} .... -65°C to 150°C
Lead Temperature (Soldering 10 Sec.) .... 260°C
Operating Junction Temperature (T_J) .... -40°C to 125°C
Thermal Resistance Junction to Case (θ_{JC}) ESOP-8 Exposed Pad* .... 13°C/W
Thermal Resistance Junction to Ambient (θ_{JA}) ESOP-8 Exposed Pad* .... 51°C/W
Maximum Power Dissipation (Note 3) ESOP-8 Exposed Pad* 2.1W
(Assume no Ambient Airflow)

Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

* Measured on JESD51-7, 4-Layer PCB.

ELECTRICAL CHARACTERISTICS

(V_{IN} = 12V, T_A = +25°C, unless otherwise noted.)(Note 1)

PARAMETER	CONDITIONS	SYMBOL	MIN	TYP	MAX	UNITS
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_{UVHSY}		43.0		mV
Input Over Voltage Lockout Threshold Rising		V_{OVP}		38.3	40	V
Input Over Voltage Lockout Threshold Hysteresis		V_{HSY}		1.8		V
VCC Regulator	V_{FB}=0.84V, I_{VCC}=0~30mA	VCC	4.8	5.1	5.4	V
Supply Current (Quiescent)	V_{FB}=0.84V	I_{IN}		100		μA
High-side Switch On Resistance	V_{FB} = 0.63V	HSRDS-ON		40		mΩ
Low-side Switch On Resistance		LSRDS-ON		40		mΩ
Switch Leakage	V_{FB}=0.84V, V_{IN}=36V, V_{SW}=0V or 36V	SWLKG	-20		+20	μA
Feedback Regulation Voltage		V_{FBREG}	784	800	816	mV
Feedback Pin Input Current	V_{FB} = 0.8V	I_{FB}	-100		+100	nA
Minimum On Time		T_{ON_MIN}		70		ns
Minimum Off Time		T_{OFF_MIN}		100		ns
Maximum Duty Cycle	V_{IN}=12V, V_{FB}=0.7V	DMAX		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		°C
Thermal Shutdown Hysteresis				25		°C
Switching Frequency		F_{SW}		180		kHz
Spread-Spectrum Modulation Frequency				3		kHz

■ ELECTRICAL CHARACTERISTICS (Continued)

PARAMETER	CONDITIONS	SYMBOL	MIN	TYP	MAX	UNITS
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

Note 1: Specifications are production tested at T_A=25°C. Specifications over the -40°C to 85°C operating temperature range are assured by design, characterization and correlation with Statistical Quality Controls (SQC).

Note 2: The device is not guaranteed to function outside of the recommended operating conditions.

Note 3: 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.

TYPICAL PERFORMANCE CHARACTERISTICS

(C_{IN}=100μF, C_{OUT}=10μF+220μF, L=22μH, R_{IS1}=R_{IS2}=20mΩ, T_A=+25°C)

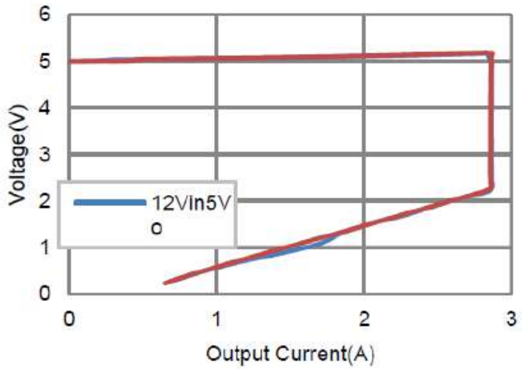


Fig. 1 CV/CC Curve

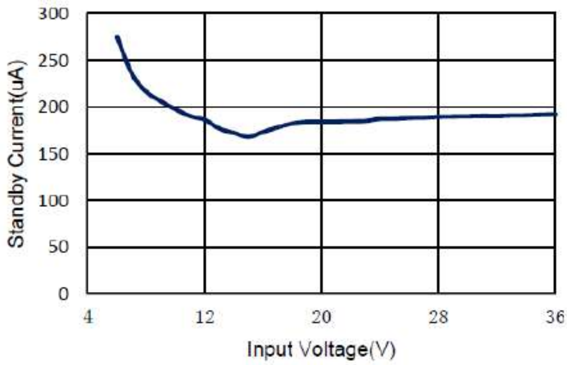


Fig. 2 Standby Current vs Input Voltage

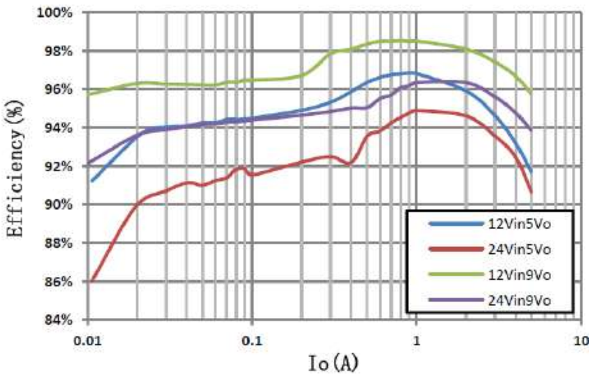


Fig. 3 Efficiency

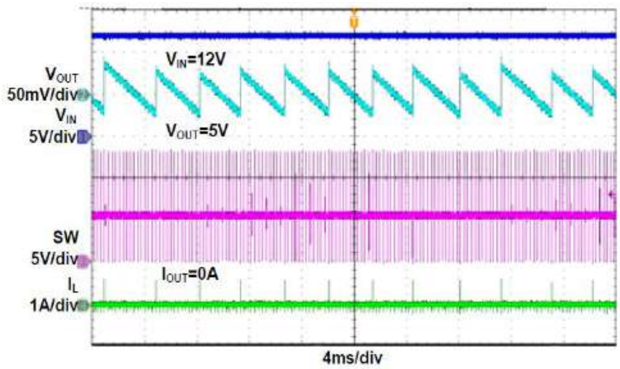


Fig. 4 Steady State Test

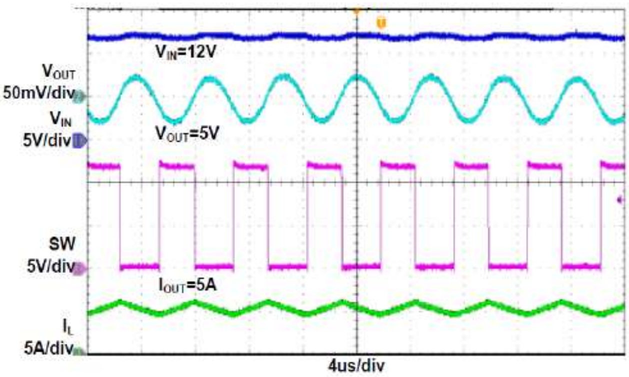


Fig. 5 Steady State Test

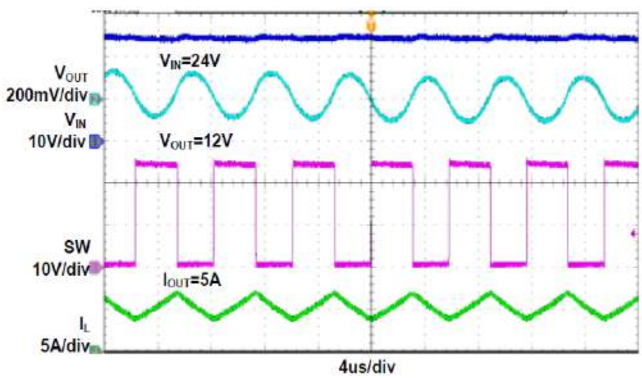


Fig. 6 Steady State Test

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(C_{IN}=100μF, C_{OUT}=10μF+220μF, L=22μH, R_{IS1}=R_{IS2}=20mΩ, T_A=+25°C)

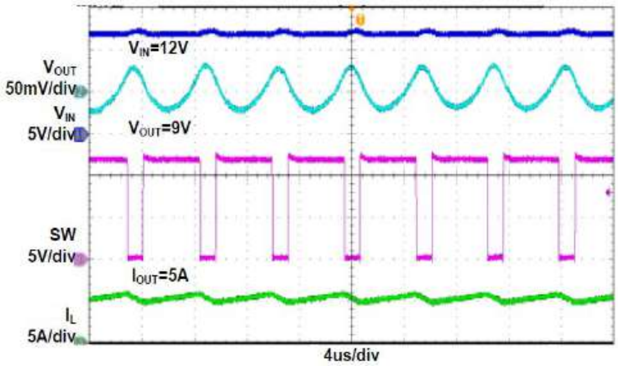


Fig. 7 Steady State Test

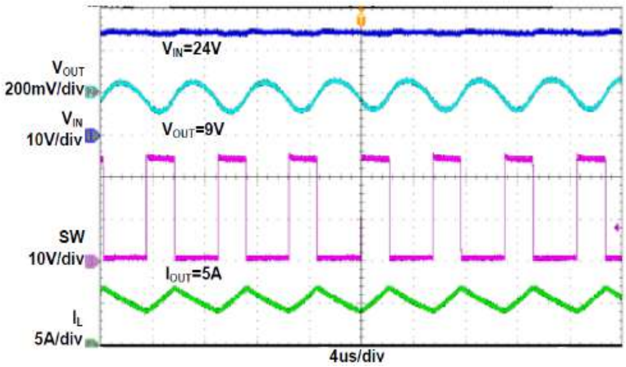


Fig. 8 Steady State Test

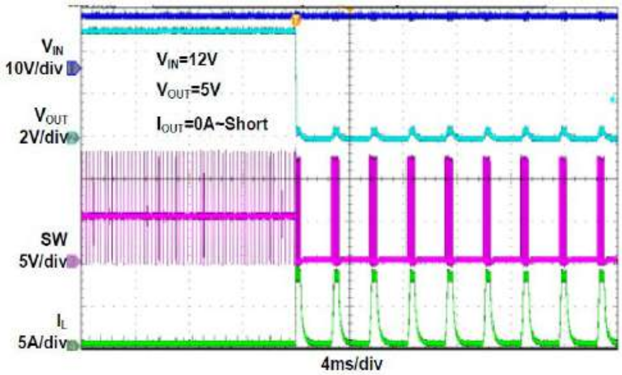


Fig. 9 Short Protection

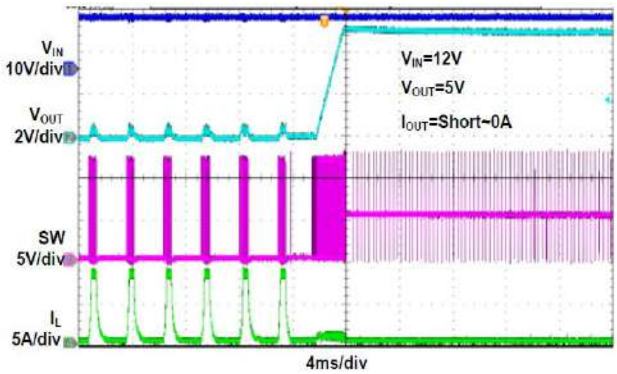


Fig. 10 Short Protection

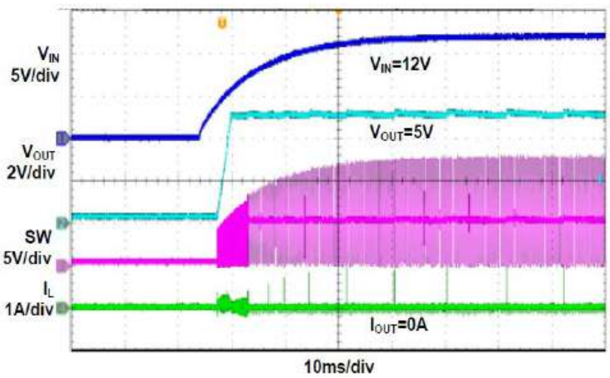


Fig. 11 V_{IN} Power On

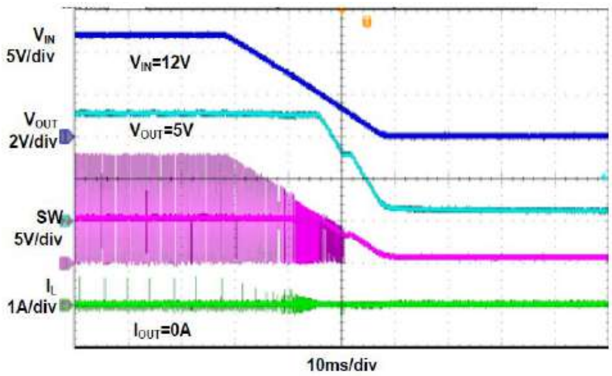


Fig. 12 V_{IN} Power Off

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(C_{IN}=100μF, C_{OUT}=10μF+220μF, L=22μH, R_{IS1}=R_{IS2}=20mΩ, T_A=+25°C)

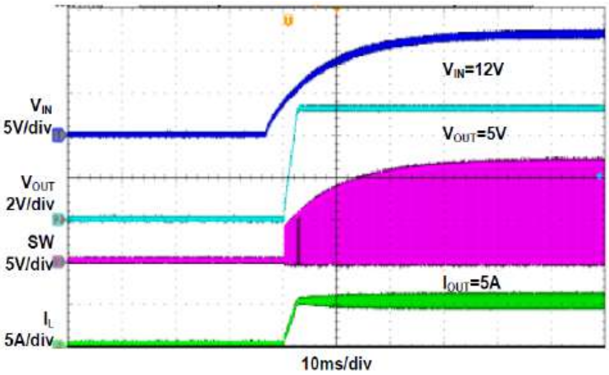


Fig. 13 V_{IN} Power On

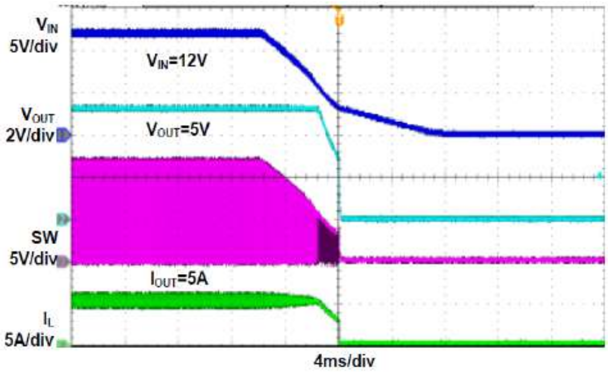


Fig. 14 V_{IN} Power Off

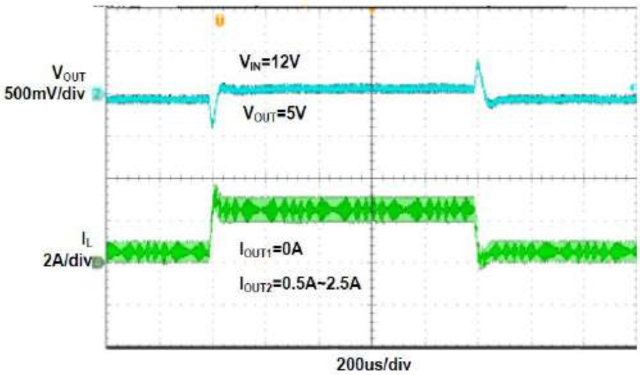


Fig. 15 Load Transient Response

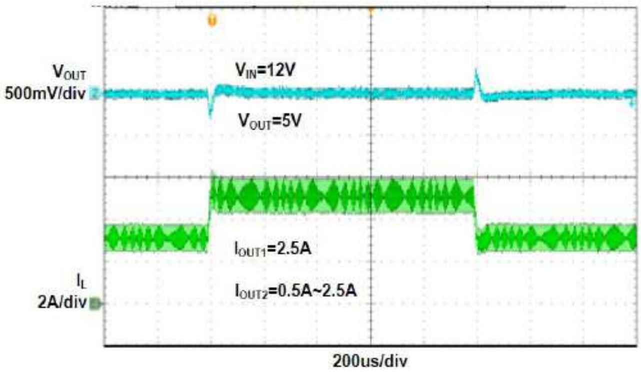


Fig. 16 Load Transient Response

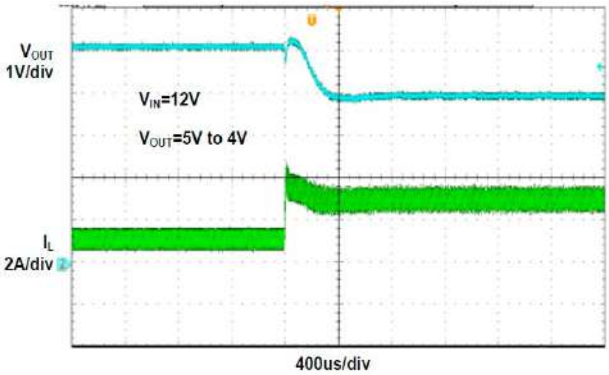


Fig. 17 CV mode to CC mode

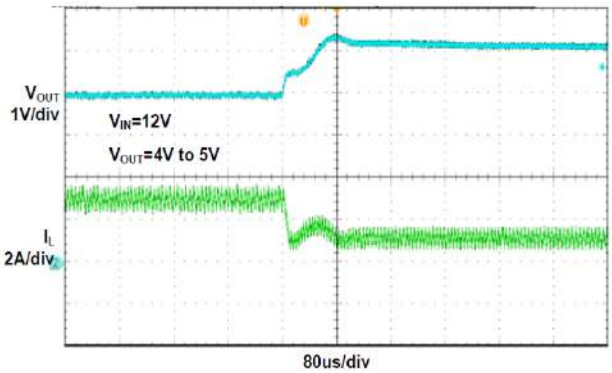
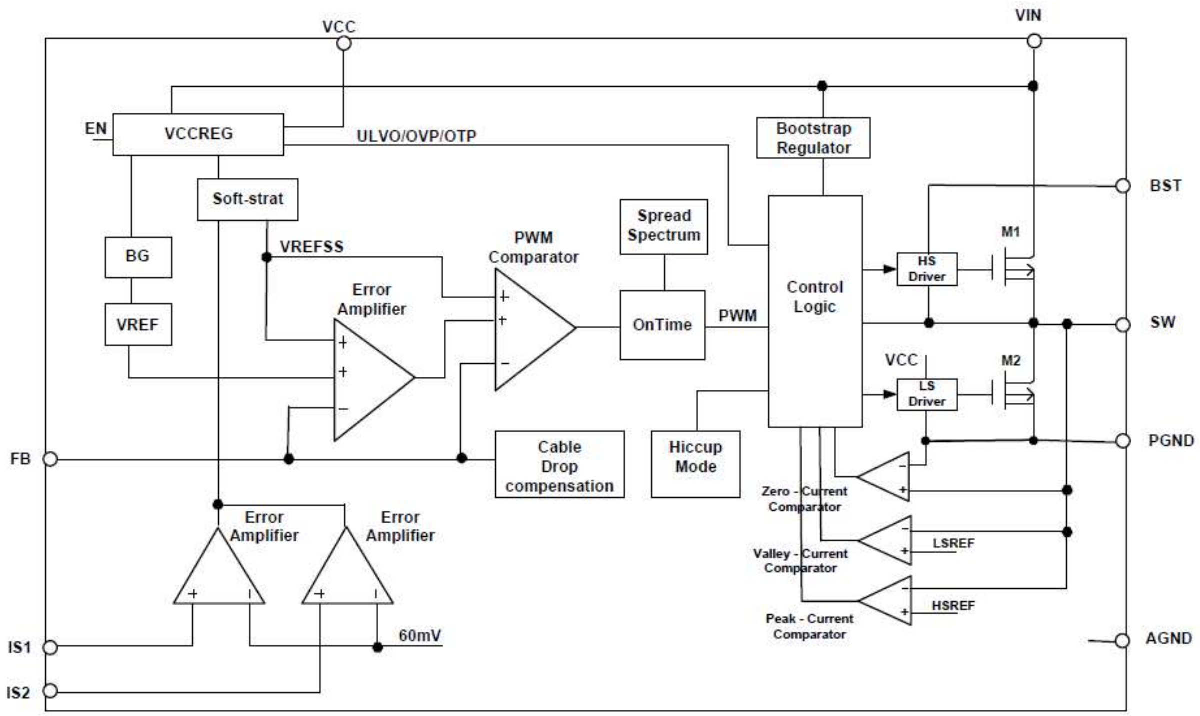


Fig. 18 CC mode to CV mode

BLOCK DIAGRAM



Functional Block Diagram of ASP395AD

PIN DESCRIPTIONS

Pin No.	Pin Name	Pin Function
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 boot-strap capacitor.
5	IN	Supply Voltage. The IN pin supplies power for internal MOSFET and regulator. The ASP395AD 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 ASP395AD 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 ASP395AD reduces output voltage and regulates IS2 at 60mV
9	PGND (Exposed Pad)	Exposed Pad is connected to the low side MOSFET Power Ground. Connect EP to a large-area contiguous copper ground plane for effective power dissipa-tion.

APPLICATION INFORMATION

Detailed Description

The ASP395AD 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 ASP395AD 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, ASP395AD regulates output voltage in CV mode. As Channel 1 or Channel 2 output current increases and reaches the Constant Current threshold, ASP395AD 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 ASP395AD has an internal spread-spectrum option to optimize EMI performance. The modulation signal is a triangular wave with a period of 340μs at 180kHz. Therefore, switching frequency will linearly vary between 180kHz -6% to 180kHz every 330μs.

Internal soft-start

The ASP395AD 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

ASP395AD has cycle-by-cycle HS current limit protection to prevent inductor current from running away. Once HS current limit is triggered, IC 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, ASP395AD will consider it as over-load or short circuit. Either way, ASP395AD 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.

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:

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

Programmable Cable Compensation

The ASP395AD 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

$$I_{FB} \times R_1 = I_{OUT} \times R_{CABLE}$$

$$\Delta V_{OUT} = 2.5\mu A \times \frac{I_{OUT}}{5A} \times R_1$$

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

Setting the Channel 1 and 2 CC current

ASP395AD 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

$$I_{CS1} = \frac{60mV}{R_{IS1}}$$

$$I_{CS2} = \frac{60mV}{R_{IS2}}$$

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 in-put 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:

$$\Delta I = \frac{V_{IN} - V_{OUT}}{F_S \times L} \cdot \frac{V_{OUT}}{V_{IN}}$$

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

$$I_{L\_MAX} = I_{LOAD} + \frac{\Delta I}{2}$$

$$\Delta V_{OUT} = \Delta I \times ESR$$

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 (ΔI) 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:

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

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

ΔV_{ESR}= change in output voltage due to ESR

ΔI_{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.

APPLICATION EXAMPLES

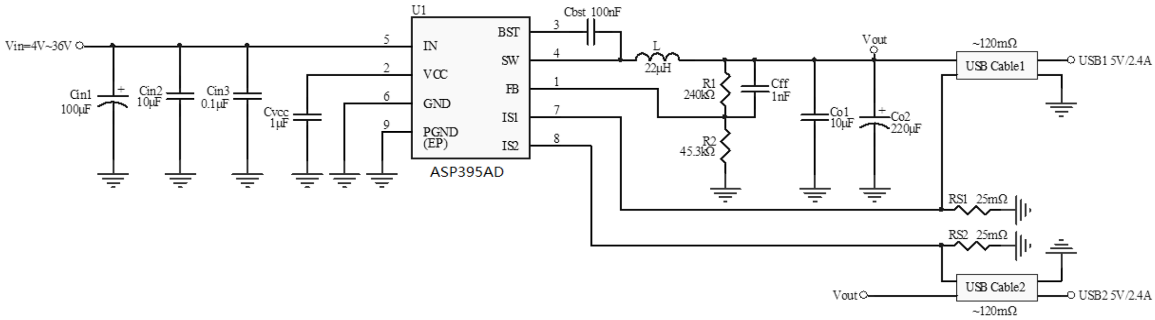


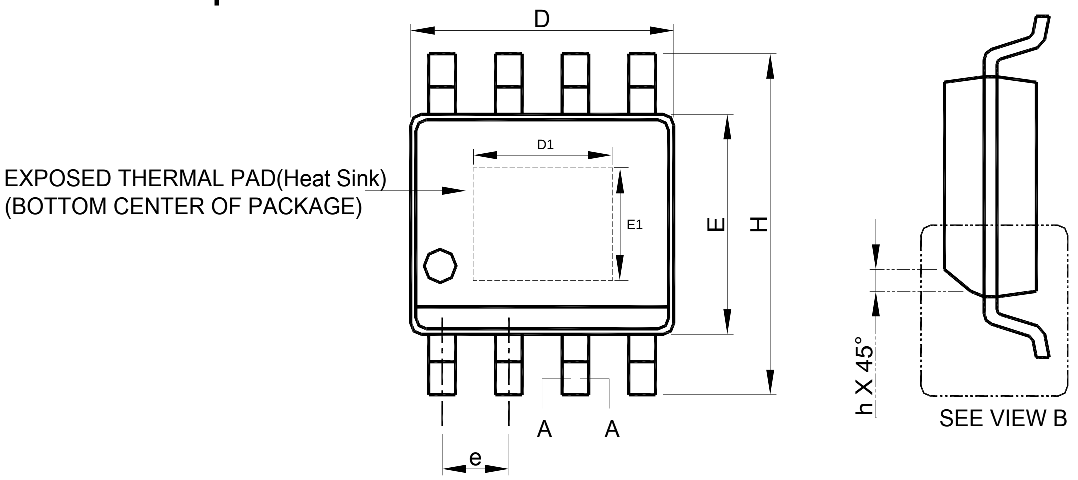
Fig. 19 Typical Application Circuit for 5V/4.8ADual-output Car Charger

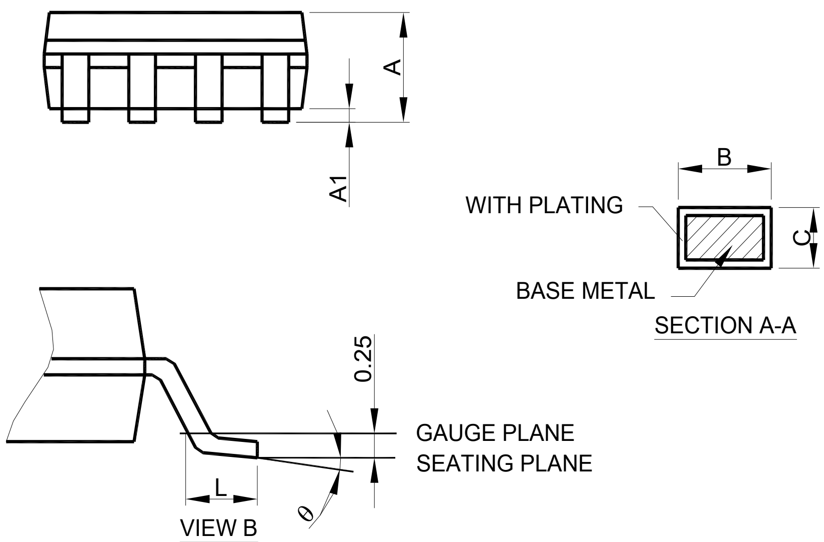
Table 1 BOM List

Ref	Value	Description	Package	Qty
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}	1µF	Ceramic Capacitor, 10V, X5R	0603	1
L	22µH	Inductor	SMD	1
RS1,RS2	25mΩ	Resistor, ±1%	1206	2
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	ASP395AD	Step-Down DC/DC Converter	ESOP-8	1

PHYSICAL DIMENSIONS

- **ESOP-8 Exposed Pad**





Note : 1. Refer to JEDEC MS-012E.
2. Dimension "D" does not include mold flash, protrusions or gate burrs. Mold flash, protrusion or gate burrs shall not exceed 6 mil per side .
3. Dimension "E" does not include inter-lead flash or protrusions.
4. Controlling dimension is millimeter, converted inch dimensions are not necessarily exact.

SYMBOL	SOP-8 Exposed Pad	
	MILLIMETERS	
	MIN.	MAX.
A	1.35	1.75
A1	0.00	0.15
B	0.31	0.51
C	0.17	0.25
D	4.80	5.00
D1	1.50	3.50
E	3.80	4.00
E1	1.0	2.55
e	1.27 BSC	
H	5.80	6.20
h	0.25	0.50
L	0.40	1.27
θ	0°	8°

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