ACT4515

Rev PrB, 07-Aug-09

Preliminary Product Information—All Information Subject to Change

Wide-Input Sensorless CC/CV Step-Down DC/DC Converter

FEATURES

- Up to 40V Input Voltage Range
- Patent Pending ActiveCC Constant Current Control
  - Integrated Current Control Improves Efficiency, Lowers Cost, and Reduces Component Count
- Resistor Programmable Outputs
  - Output Current from 400mA to 1.5A
  - Output Voltage from 0.8V to 90% of V_{IN}
  - DC Cable Compensation from 0Ω to 0.5Ω
- 5% CC Accuracy
  - Independent of Input/Output Voltage Change
  - Temperature Compensation
  - Independent of Inductance and Inductor DCR
- 2% Feedback Voltage Accuracy
- Up to 93% Efficiency
- 200kHz Switching Frequency Eases EMI Design
- Advanced Feature Set
  - Integrated Soft Start
  - Thermal Shutdown
  - Secondary Cycle-by-Cycle Current Limit
  - Protection Against Shorted ISET Pin
- SOP-8 Package

APPLICATIONS

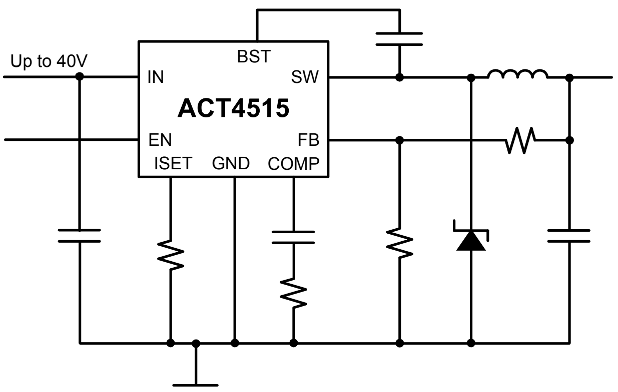
- Car Charger
- Rechargeable Portable Devices
- High-Brightness Lighting
- General-Purpose CC/CV Supply

GENERAL DESCRIPTION

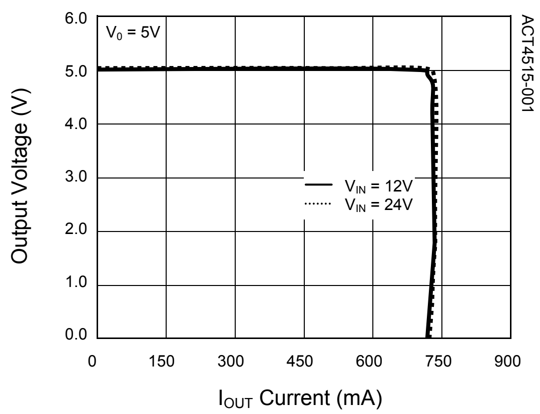
ACT4515 is a wide input voltage, high efficiency ActiveCC step-down DC/DC converter that operates in either CV (Constant Output Voltage) mode or CC (Constant Output Current) mode. ACT4515 provides up to 1.5A output current at 200kHz switching frequency.

ActiveCC is a patent-pending control scheme to achieve highest accuracy sensorless constant current control. ActiveCC eliminates the expensive, high accuracy current sense resistor, making it ideal for battery charging applications and high-brightness LED drive for architectural lighting. The ACT4515 achieves higher efficiency than traditional constant current switching regulators by eliminating the sense resistor and its associated power loss.

Protection features include cycle-by-cycle current limit, thermal shutdown, and frequency foldback at short circuit. The devices are available in a SOP-8 package and require very few external devices for operation.



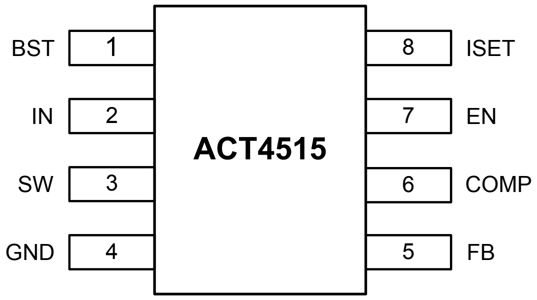
CC/CV Curve vs. Load Current



ORDERING INFORMATION

PART NUMBER	TEMPERATURE RANGE	PACKAGE	PINS	PACKING
ACT4515SH-T	-40°C to 85°C	SOP-8	8	TAPE & REEL

PIN CONFIGURATION



SOP-8

PIN DESCRIPTIONS

PIN	NAME	DESCRIPTION
1	BST	Bootstrap Pin. This provides power to the internal high-side MOSFET gate driver. Connect a 10nF capacitor from BST pin to SW pin.
2	IN	Power Supply Input. Bypass this pin with a 10µF ceramic capacitor to GND, placed as close to the IC as possible.
3	SW	Power Switching Output to External Inductor.
4	GND	Ground. Connect this pin to a large PCB copper area for best heat dissipation. Return FB, COMP, and ISET to this GND, and connect this GND to power GND at a single point for best noise immunity.
5	FB	Feedback Input. The voltage at this pin is regulated to 0.808V. Connect to the resistor divider between output and GND to set the output voltage.
6	COMP	Error Amplifier Output. This pin is used to compensate the converter.
7	EN	Enable Input. EN is pulled up to 5V with a 4µA current, and contains a precise 0.8V logic threshold. Drive this pin to a logic-high or leave unconnected to enable the IC. Drive to a logic-low to disable the IC and enter shutdown mode.
8	ISET	Output Current Setting Pin. Connect a resistor from ISET to GND to program the output current.

ABSOLUTE MAXIMUM RATINGS①

PARAMETER	VALUE	UNIT
IN to GND	-0.3 to 40	V
SW to GND	-1 to V_{IN} + 1	V
BST to GND	V_{SW} - 0.3 to V_{SW} + 7	V
FB, EN, ISET, COMP to GND	-0.3 to + 6	V
Junction to Ambient Thermal Resistance	105	°C/W
Operating Junction Temperature	-40 to 150	°C
Storage Junction Temperature	-55 to 150	°C
Lead Temperature (Soldering 10 sec.)	300	°C

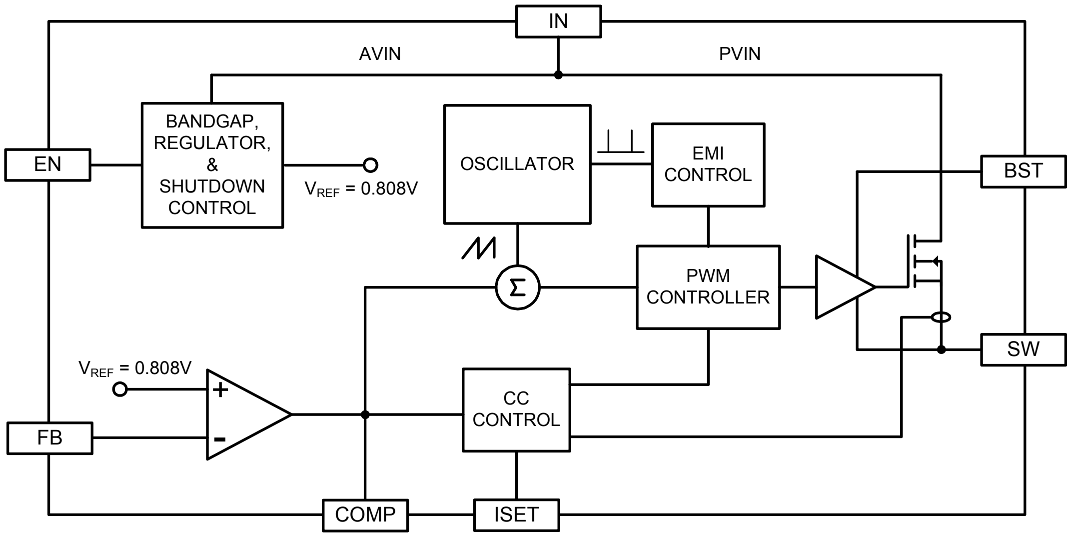
①: Do not exceed these limits to prevent damage to the device. Exposure to absolute maximum rating conditions for long periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{IN} = 14V, T_A = 25°C, unless otherwise specified.)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input Voltage		10		40	V
V_{IN} UVLO Turn-On Voltage	Input Voltage Rising	9.05	9.35	9.65	V
V_{IN} UVLO Hysteresis	Input Voltage Falling		1.1		V
V_{IN} OVP Turn-Off Voltage	Input Voltage Rising	32.5	34.5	36.5	V
V_{IN} OVP Hysteresis	Input Voltage Falling		1.75		V
Standby Supply Current	V_0 = 5V, No Load		1.6	2	mA
Shutdown Supply Current	V_{EN} = 0V		75	100	µA
Feedback Voltage		792	808	824	mV
Internal Soft-Start Time			200		µs
Error Amplifier Transconductance	V_{FB} = V_{COMP} = 0.8V, ΔI_{COMP} = ± 10µA		650		µA/V
Error Amplifier DC Gain			4000		V/V
Switching Frequency	V_{FB} = 0.808V	175	200	225	kHz
Foldback Switching Frequency	V_{FB} = 0V		30		kHz
Maximum Duty Cycle		90	93		%
Minimum On-Time			400		ns
COMP to Current Limit Transconductance	V_{COMP} = 1.2V		2		A/V
Secondary Cycle-by-Cycle Current Limit	Minimum Duty Cycle, no CC		2.5		A
Slope Compensation	Duty = 100%		0.8		A
ISET Voltage			1		V
ISET to IOUT DC Room Temp Current Gain	IOUT / ISET		25000		A/A
CC Controller DC Accuracy	R_{ISET} = 33k	712.5	750	787.5	mA
EN Threshold Voltage	EN Pin Rising	0.75	0.8	0.85	V
EN Hysteresis	EN Pin Falling		75		mV
EN Internal Pull-up Current			4		µA
High-Side Switch ON-Resistance			0.3		Ω
SW Off Leakage Current	V_{EN} = V_{SW} = 0V		1	10	µA
Thermal Shutdown Temperature	Temperature Rising		155		°C

FUNCTIONAL BLOCK DIAGRAM



FUNCTIONAL DESCRIPTION

CV/CC Loop Regulation

As seen in *Functional Block Diagram*, the ACT4515 is a peak current mode pulse width modulation (PWM) converter with CC and CV control. The converter operates as follows:

A switching cycle starts when the rising edge of the Oscillator clock output causes the High-Side Power Switch to turn on and the Low-Side Power Switch to turn off. With the SW side of the inductor now connected to IN, the inductor current ramps up to store energy in the magnetic field. The inductor current level is measured by the Current Sense Amplifier and added to the Oscillator ramp signal. If the resulting summation is higher than the COMP voltage, the output of the PWM Comparator goes high. When this happens or when Oscillator clock output goes low, the High-Side Power Switch turns off.

At this point, the SW side of the inductor swings to a diode voltage below ground, causing the inductor current to decrease and magnetic energy to be transferred to output. This state continues until the cycle starts again. The High-Side Power Switch is driven by logic using BST as the positive rail. This pin is charged to V_{SW} + 5V when the Low-Side Power Switch turns on. The COMP voltage is the integration of the error between FB input and the internal 0.808V reference. If FB is lower than the reference voltage, COMP tends to go higher to increase current to the output. Output current will increase until it reaches the CC limit set by the ISET resistor. At this point, the device will transition from regulating output voltage to regulating output current, and the output voltage will drop with increasing load.

The Oscillator normally switches at 200kHz. However, if FB voltage is less than 0.6V, then the switching frequency decreases until it reaches a typical value of 30kHz at V_{FB} = 0.15V.

Enable Pin

The ACT4515 has an enable input EN for turning the IC on or off. The EN pin contains a precision 0.8V comparator with 75mV hysteresis and a 4μA pull-up current source. The comparator can be used with a resistor divider from V_{IN} to program a startup voltage higher than the normal UVLO value. It can be used with a resistor divider from V_{OUT} to disable charging of a deeply discharged battery, or it can be used with a resistor divider containing a thermistor to provide a temperature-dependent shutoff protection for over temperature battery. The thermistor should be thermally coupled to the battery pack for this usage.

If left floating, the EN pin will be pulled up to roughly 5V by the internal 4μA current source. It can be driven from standard logic signals greater than 0.8V, or driven with open-drain logic to provide digital on/off control.

Thermal Shutdown

The ACT4515 disables switching when its junction temperature exceeds 155°C and resumes when the temperature has dropped by 20°C.

APPLICATIONS INFORMATION

Output Voltage Setting

Figure 1:

Output Voltage Setting

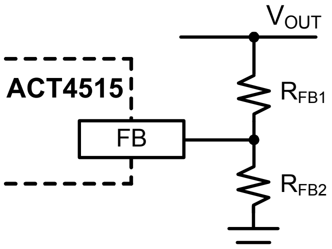


Figure 1 shows the connections for setting the output voltage. Select the proper ratio of the two feedback resistors R_{FB1} and R_{FB2} based on the output voltage. Typically, use $R_{FB2} \approx 10k\Omega$ and determine R_{FB1} from the following equation:

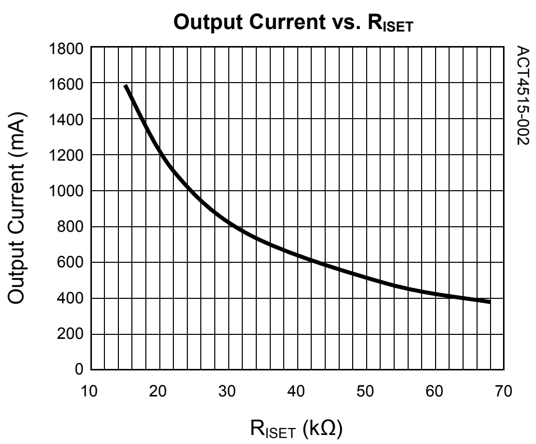
$$R_{FB1} = R_{FB2}\left(\frac{V_{OUT}}{0.808V} - 1\right) \qquad (1)$$

CC Current Setting

ACT4515 constant current value is set by a resistor connected between the ISET pin and GND. The CC output current is linearly proportional to the current flowing out of the ISET pin. The voltage at ISET is roughly 1V and the current gain from ISET to output is roughly 25000 (25mA/1µA). To determine the proper resistor for a desired current, please refer to Figure 2 below.

Figure 2:

Curve for Programming Output CC Current



Inductor Selection

The inductor maintains a continuous current to the output load. This inductor current has a ripple that is dependent on the inductance value:

Higher inductance reduces the peak-to-peak ripple current. The trade off for high inductance value is the increase in inductor core size and series resistance, and the reduction in current handling capability. In general, select an inductance value L based on ripple current requirement:

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} f_{SW} I_{OUTMAX} K_{RIPPLE}} \qquad (2)$$

where V_{IN} is the input voltage, V_{OUT} is the output voltage, f_{SW} is the switching frequency, I_{OUTMAX} is the maximum output current, and K_{RIPPLE} is the ripple factor. Typically, choose K_{RIPPLE} = 30% to correspond to the peak-to-peak ripple current being 30% of the maximum output current.

With this inductor value, the peak inductor current is $I_{OUT} \times (1 + K_{RIPPLE}/2)$. Make sure that this peak inductor current is less than the controller's current limit. Finally, select the inductor core size so that it does not saturate at the peak inductor current. Typical inductor values for various output voltages are shown in Table 2.

Table 1:

Typical Inductor Values

V_{OUT}	1.5V	1.8V	2.5V	3.3V	5V
L	22µH	22µH	47µH	68µH	82µH

Input Capacitor

The input capacitor needs to be carefully selected to maintain sufficiently low ripple at the supply input of the converter. A low ESR capacitor is highly recommended. Since large current flows in and out of this capacitor during switching, its ESR also affects efficiency.

The input capacitance needs to be higher than 10µF. The best choice is the ceramic type, however, low ESR tantalum or electrolytic types may also be used provided that the RMS ripple current rating is higher than 50% of the output current. The input capacitor should be placed close to the IN and G pins of the IC, with the shortest traces possible. In the case of tantalum or electrolytic types, they can be further away if a small parallel 0.1µF ceramic capacitor is placed right next to the IC.

APPLICATIONS INFORMATION CONT'D

Output Capacitor

The output capacitor also needs to have low ESR to keep low output voltage ripple. The output ripple voltage is:

$$V_{RIPPLE} = I_{OUTMAX} K_{RIPPLE} R_{ESR} + \frac{V_{IN}}{28 \times f_{SW}^{2} L C_{OUT}} \quad (3)$$

where I_{OUTMAX} is the maximum output current, K_{RIPPLE} is the ripple factor, R_{ESR} is the ESR of the output capacitor, f_{SW} is the switching frequency, L is the inductor value, and C_{OUT} is the output capacitance. In the case of ceramic output capacitors, R_{ESR} is very small and does not contribute to the ripple. Therefore, a lower capacitance value can be used for ceramic type. In the case of tantalum or electrolytic capacitors, the ripple is dominated by R_{ESR} multiplied by the ripple current. In that case, the output capacitor is chosen to have sufficiently low ESR.

For ceramic output capacitor, typically choose a capacitance of about 22µF. For tantalum or electrolytic capacitors, choose a capacitor with less than 50mΩ ESR.

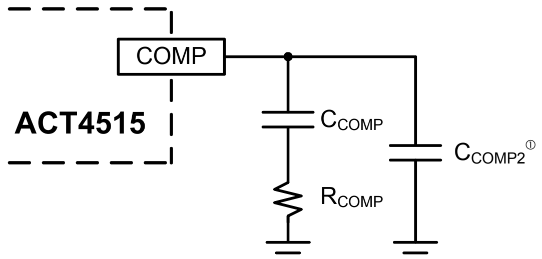
Rectifier Diode

Use a Schottky diode as the rectifier to conduct current when the High-Side Power Switch is off. The Schottky diode must have current rating higher than the maximum output current and a reverse voltage rating higher than the maximum input voltage.

STABILITY COMPENSATION

Figure 3:

Stability Compensation



①: C_{COMP2} is needed only for high ESR output capacitor

The feedback loop of the IC is stabilized by the components at the COMP pin, as shown in Figure 3. The DC loop gain of the system is determined by the following equation:

$$A_{VDC} = \frac{0.808V}{I_{OUT}} A_{VEA} G_{COMP} \qquad (4)$$

The dominant pole P1 is due to C_{COMP}:

$$f_{P1} = \frac{G_{EA}}{2\pi A_{VEA} C_{COMP}} \qquad (5)$$

The second pole P2 is the output pole:

$$f_{P2} = \frac{I_{OUT}}{2\pi V_{OUT} C_{OUT}} \qquad (6)$$

The first zero Z1 is due to R_{COMP} and C_{COMP}:

$$f_{Z1} = \frac{1}{2\pi R_{COMP} C_{COMP2}} \qquad (7)$$

And finally, the third pole is due to R_{COMP} and C_{COMP2} (if C_{COMP2} is used):

$$f_{P3} = \frac{1}{2\pi R_{COMP} C_{COMP2}} \qquad (8)$$

The following steps should be used to compensate the IC:

STEP 1. Set the cross over frequency at 1/10 of the switching frequency via R_{COMP}:

$$R_{COMP} = \frac{2\pi V_{OUT} C_{OUT} f_{SW}}{10 G_{EA} G_{COMP} \times 0.808V}$$

$$= 2.75 \times 10^{8} V_{OUT} C_{OUT} \quad (\Omega) \qquad (9)$$

STEP 2. Set the zero f_{Z1} at 1/4 of the cross over frequency. If R_{COMP} is less than 15kΩ, the equation for C_{COMP} is:

$$C_{COMP} = \frac{1.8 \times 10^{-5}}{R_{COMP}} \quad (F) \qquad (10)$$

If R_{COMP} is limited to 15kΩ, then the actual cross over frequency is 3.4 / ($V_{OUT}C_{OUT}$). Therefore:

$$C_{COMP} = 1.2 \times 10^{-5} V_{OUT} C_{OUT} \quad (F) \qquad (11)$$

STEP 3. If the output capacitor's ESR is high enough to cause a zero at lower than 4 times the cross over frequency, an additional compensation capacitor C_{COMP2} is required. The condition for using C_{COMP2} is:

$$R_{ESRCOUT} \geq Min\left(\frac{1.1 \times 10^{-6}}{C_{OUT}}, 0.012 \times V_{OUT}\right) \quad (\Omega) \qquad (12)$$

And the proper value for C_{COMP2} is:

$$C_{COMP2} = \frac{C_{OUT} R_{ESRCOUT}}{R_{COMP}} \qquad (13)$$

Though C_{COMP2} is unnecessary when the output capacitor has sufficiently low ESR, a small value C_{COMP2} such as 100pF may improve stability against PCB layout parasitic effects.

Table 2 shows some calculated results based on the compensation method above.

Table 2:

Typical Compensation for Different Output Voltages and Output Capacitors

V_{OUT}	C_{OUT}	R_{COMP}	C_{COMP}	C_{COMP2}①
2.5V	22µF Ceramic	8.2kΩ	2.2nF	None
3.3V	22µF Ceramic	12kΩ	1.5nF	None
5V	22µF Ceramic	15kΩ	1.5nF	None
2.5V	47µF SP CAP	15kΩ	1.5nF	None
3.3V	47µF SP CAP	15kΩ	1.8nF	None
5V	47µF SP CAP	15kΩ	2.7nF	None
2.5V	470µF/6.3V/30mΩ	15kΩ	15nF	1nF
3.3V	470µF/6.3V/30mΩ	15kΩ	22nF	1nF
5V	470µF/6.3V/30mΩ	15kΩ	27nF	None

①: C_{COMP2} is needed for high ESR output capacitor.

CC Loop Stability

The constant-current control loop is internally compensated over the 400mA-1500mA output range. No additional external compensation is required to stabilize the CC current.

Output Cable Resistance Compensation

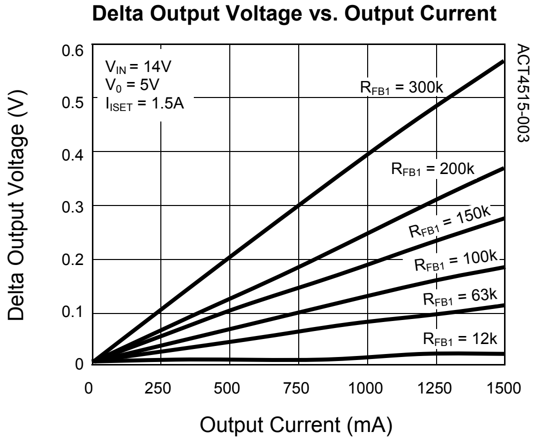
To compensate for resistive voltage drop across the charger's output cable, the ACT4515 integrates a simple, user-programmable cable voltage drop

STABILITY COMPENSATION CONT'D

compensation using the impedance at the FB pin. Use the curve in Figure 4 to choose the proper feedback resistance values for cable compensation. R_{FB1} is the high side resistor of voltage divider.

Figure 4:

Cable Compensation at Various Resistor Divider Values



PC Board Layout Guidance

When laying out the printed circuit board, the following checklist should be used to ensure proper operation of the IC.

1) Arrange the power components to reduce the AC loop size consisting of C_{IN}, IN pin, SW pin and the schottky diode.

2) Place input decoupling ceramic capacitor C_{IN} as close to IN pin as possible. C_{IN} is connected power GND with vias or short and wide path.

3) Return FB, COMP and ISET to signal GND pin, and connect the signal GND to power GND at a single point for best noise immunity.

4) Use copper plane for power GND for best heat dissipation and noise immunity.

5) Place feedback resistor close to FB pin.

6) Use short trace connecting BST-C_{BST}-SW loop

Figure 5 and Figure 6 give two typical car charger application schematics and associated BOM list.

Figure 5:
Typical Application Circuit for 5V/0.75A Car Charger

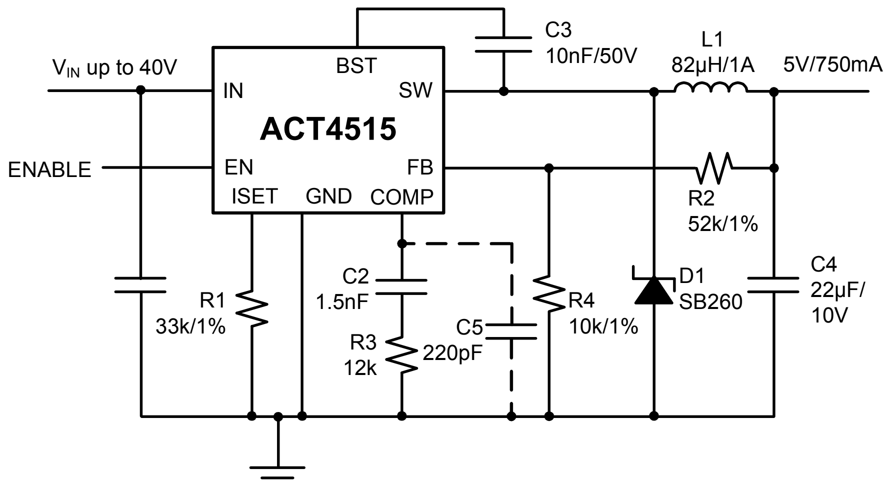


Table 4:
BOM List for 5V/0.75A Car Charger

ITEM	REFERENCE	DESCRIPTION	MANUFACTURER	QTY
1	U1	IC, ACT4515, SOP-8	Active-Semi	1
2	C1	Capacitor, Ceramic, 10µF/50V, 1210, SMD	Murata, TDK	1
3	C2	Capacitor, Ceramic, 1.5nF/6.3V, 0603, SMD	Murata, TDK	1
4	C3	Capacitor, Ceramic, 10nF/50V, 0603, SMD	Murata, TDK	1
5	C4	Capacitor, Ceramic, 22µF/10V, 1206, SMD	Murata, TDK	1
6	C5 (Optional)	Capacitor, Ceramic, 220pF/6.3V, 0603	Murata, TDK	1
7	L1	82µH, 1A, 20%, SMD 1058-MGDN6-00013	Tyco Electronics	1
8	D1	Diode, Schottky, 60V/2A, SB260, DO-15	Diodes	1
9	R1	Chip Resistor, 33kΩ, 0603, 1%	Murata, TDK	1
10	R2	Chip Resistor, 52kΩ, 0603, 1%	Murata, TDK	1
11	R3	Chip Resistor, 12kΩ, 0603, 5%	Murata, TDK	1
12	R4	Chip Resistor, 10kΩ, 0603, 1%	Murata, TDK	1

Figure 6:
Typical Application Circuit for 5V/1.2A Car Charger

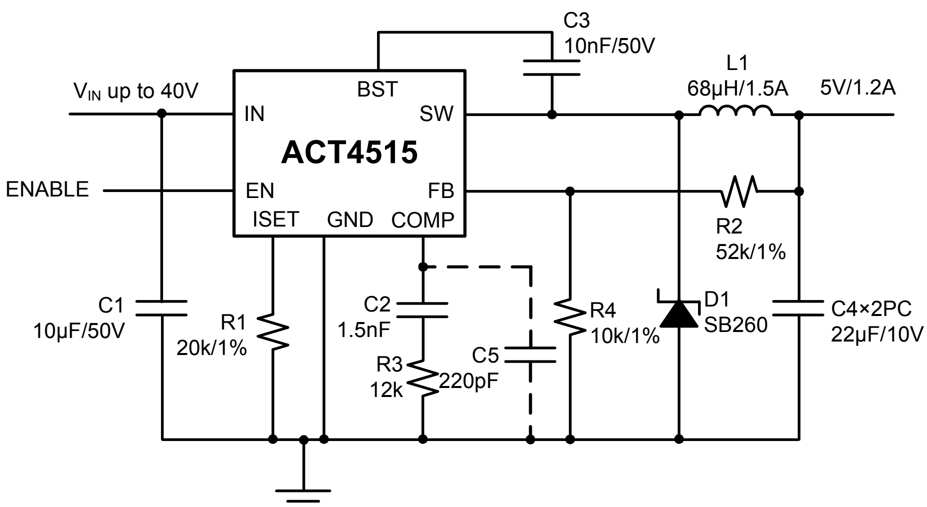


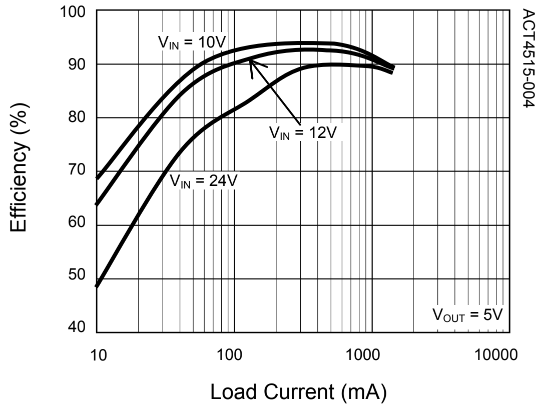
Table 5:
BOM List for 5V/1.2A Car Charger

ITEM	REFERENCE	DESCRIPTION	MANUFACTURER	QTY
1	U1	IC, ACT4515, SOP-8	Active-Semi	1
2	C1	Capacitor, Ceramic, 10μF/50V, 1210, SMD	Murata, TDK	1
3	C2	Capacitor, Ceramic, 1.5nF/6.3V, 0603, SMD	Murata, TDK	1
4	C3	Capacitor, Ceramic, 10nF/50V, 0603, SMD	Murata, TDK	1
5	C4	Capacitor, Ceramic, 22μF/10V, 1206, SMD	Murata, TDK	2
6	C5 (Optional)	Capacitor, Ceramic, 220pF/6.3V, 0603	Murata, TDK	1
7	L1	68μH, 1.5A, 20%, SMD CDRH125-680M	Sumida	1
8	D1	Diode, Schottky, 60V/2A, SB260, DO-15	Diodes	1
9	R1	Chip Resistor, 20kΩ, 0603, 1%	Murata, TDK	1
10	R2	Chip Resistor, 52kΩ, 0603, 1%	Murata, TDK	1
11	R3	Chip Resistor, 12kΩ, 0603, 5%	Murata, TDK	1
12	R4	Chip Resistor, 10kΩ, 0603, 1%	Murata, TDK	1

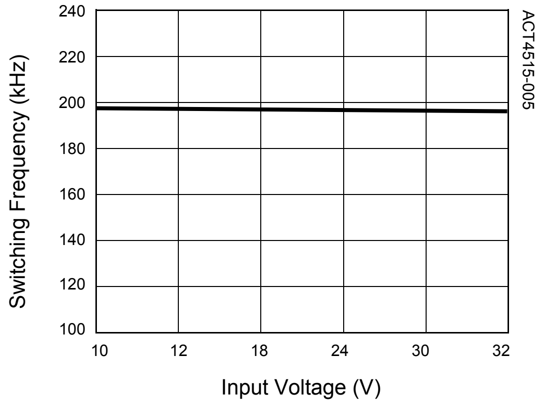
TYPICAL PERFORMANCE CHARACTERISTICS

(Circuit of Figure 5, L = 82µH, C_{IN} = 10µF, C_{OUT} = 22µF, T_A = 25°C, unless otherwise specified.)

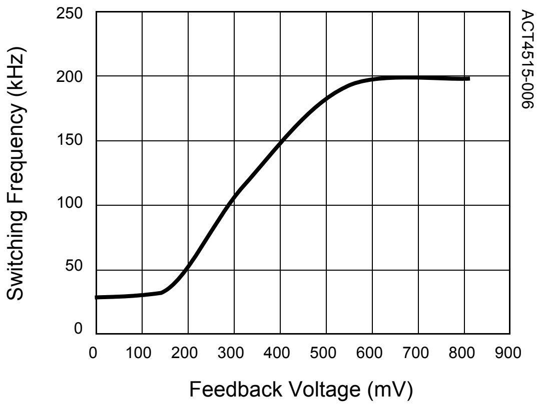
Efficiency vs. Load Current



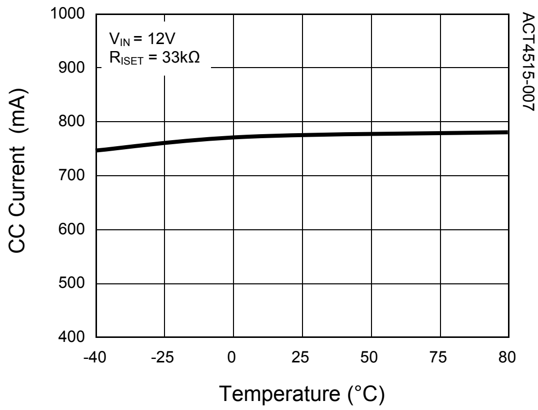
Switching Frequency vs. Input Voltage



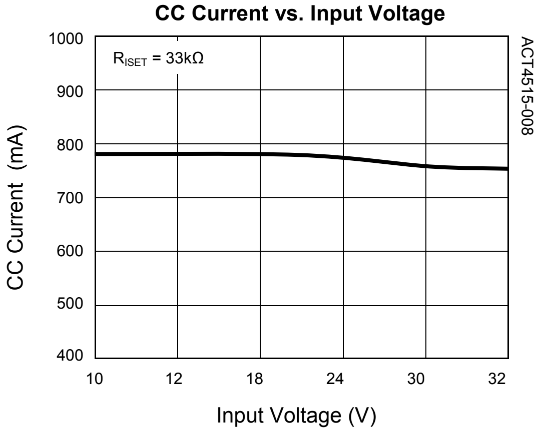
Switching Frequency vs. Feedback Voltage



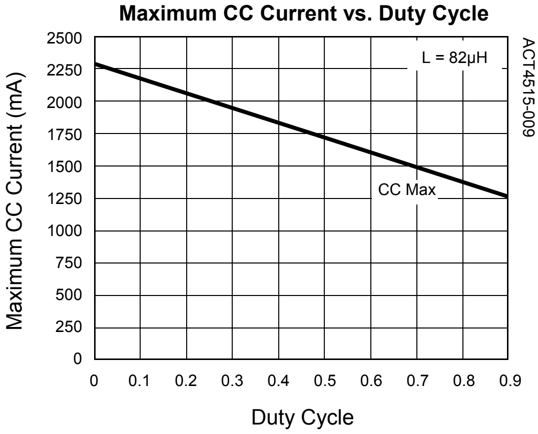
CC Current vs. Temperature



CC Current vs. Input Voltage



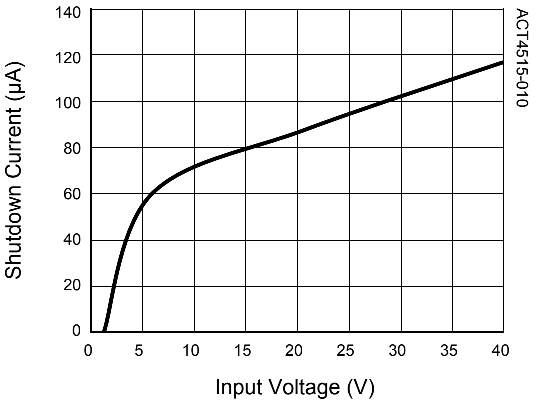
Maximum CC Current vs. Duty Cycle



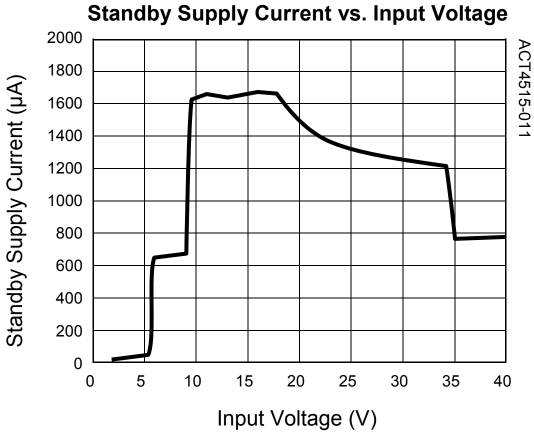
TYPICAL PERFORMANCE CHARACTERISTICS CONT'D

(Circuit of Figure 5, L = 82µH, C_{IN} = 10µF, C_{OUT} = 22µF, T_A = 25°C, unless otherwise specified.)

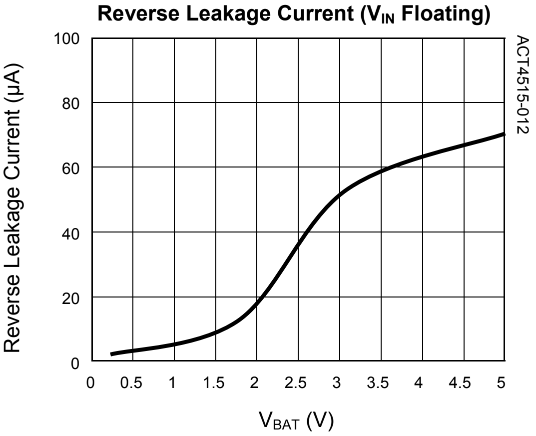
Shutdown Current vs. Input Voltage (EN pulled low)



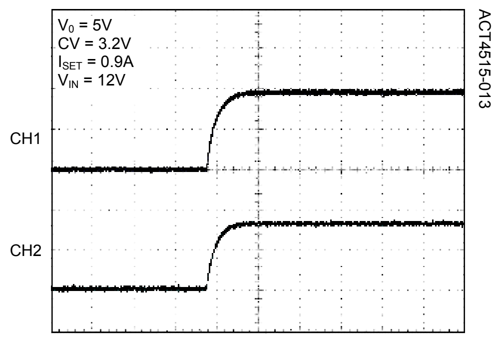
Standby Supply Current vs. Input Voltage



Reverse Leakage Current (V_{IN} Floating)

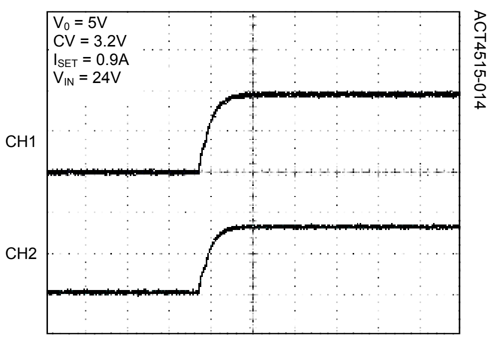


Waveform Start up into CV mode by EN



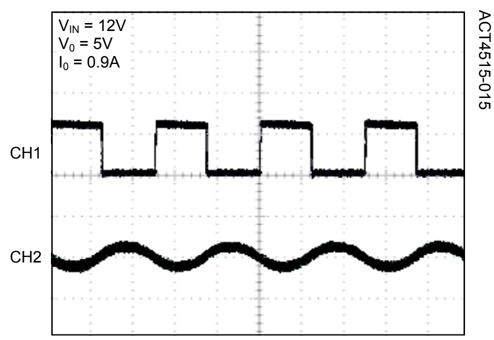
CH1: I_{OUT}, 500mA/div
CH2: V_{OUT}, 2V/div
TIME: 200µs/div

Waveform Start up into CV mode by EN



CH1: I_{OUT}, 500mA/div
CH2: V_{OUT}, 2V/div
TIME: 200µs/div

SW vs. Output Voltage Ripples

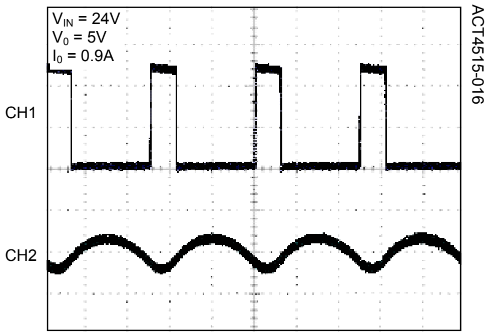


CH1: SW, 10V/div
CH2: V_{RIPPLE}, 50mV/div
TIME: 2µs/div

TYPICAL PERFORMANCE CHARACTERISTICS CONT'D

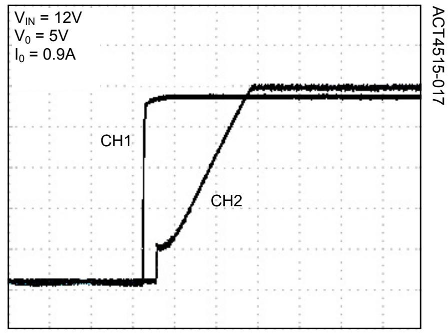
(Circuit of Figure 5, L = 82µH, C_{IN} = 10µF, C_{OUT} = 22µF, T_A = 25°C, unless otherwise specified.)

SW vs. Output Voltage Ripples



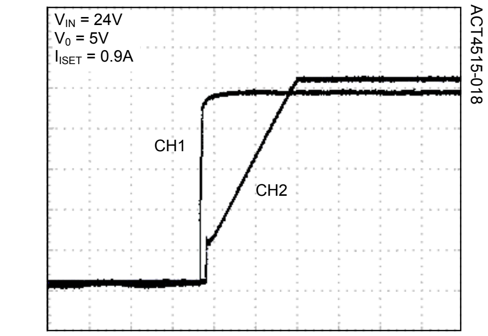
CH1: SW, 10V/div
CH2: V_{RIPPLE}, 50mV/div
TIME: 2µs/div

Start up with EN



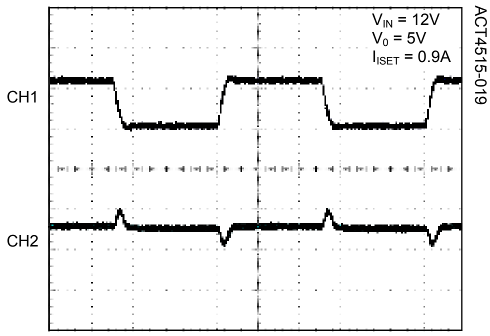
CH1: EN, 1V/div
CH2: V_{OUT}, 1V/div
TIME: 10ms/div

Start up with EN



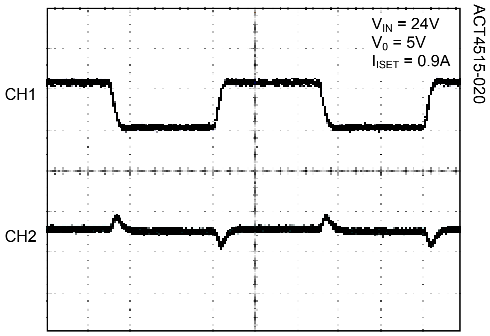
CH1: EN, 1V/div
CH2: V_{OUT}, 1V/div
TIME: 10ms/div

Load Step Waveforms



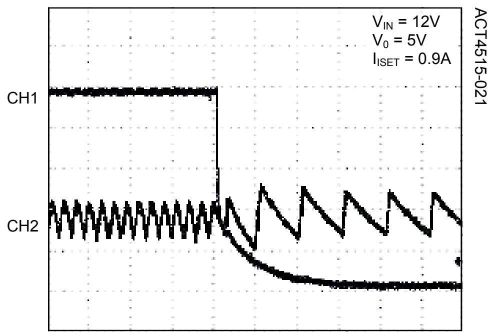
CH1: I_{OUT}, 500mA/div
CH2: V_{OUT}, 500mV/div
TIME: 100µs/div

Load Step Waveforms



CH1: I_{OUT}, 500mA/div
CH2: V_{OUT}, 500mV/div
TIME: 100µs/div

Short Circuit

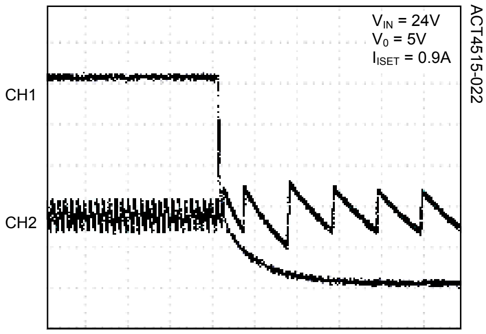


CH1: V_{OUT}, 1V/div
CH2: I_L, 500mA/div
TIME: 40µs/div

TYPICAL PERFORMANCE CHARACTERISTICS CONT'D

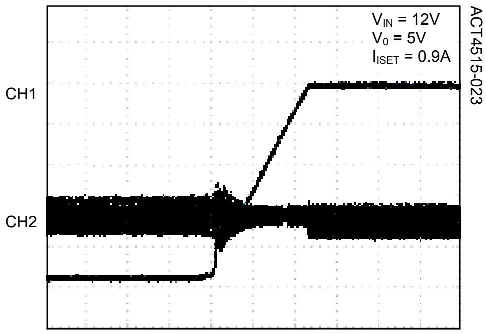
(Circuit of Figure 5, L = 82μH, C_{IN} = 10μF, C_{OUT} = 22μF, T_A = 25°C, unless otherwise specified.)

Short Circuit



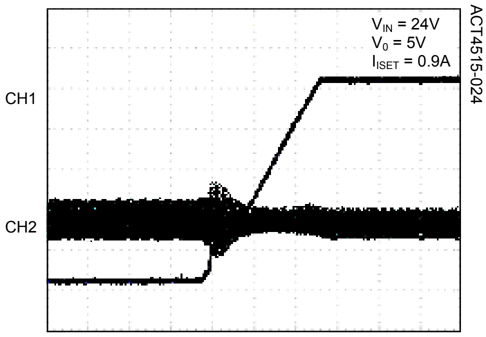
CH1: V_{OUT}, 1V/div
CH2: I_L, 500mA/div
TIME: 40μs/div

Short Circuit Recovery



CH1: V_{OUT}, 1V/div
CH2: I_L, 500mA/div
TIME: 10ms/div

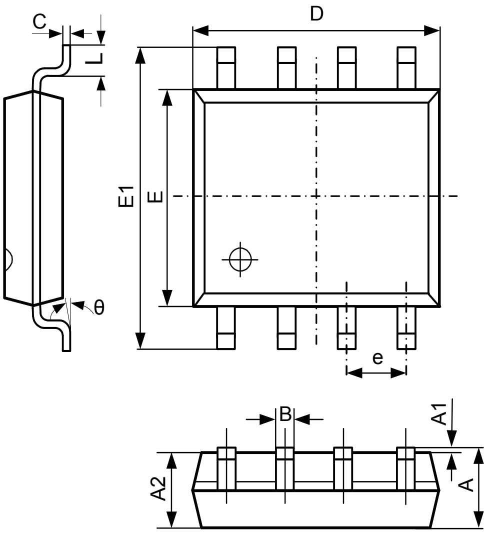
Short Circuit Recovery



CH1: V_{OUT}, 1V/div
CH2: I_L, 500mA/div
TIME: 10ms/div

PACKAGE OUTLINE

SOP-8 PACKAGE OUTLINE AND DIMENSIONS



SYMBOL	DIMENSION IN MILLIMETERS		DIMENSION IN INCHES	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
B	0.330	0.510	0.013	0.020
C	0.190	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	3.800	4.000	0.150	0.157
E1	5.800	6.300	0.228	0.248
e	1.270 TYP		0.050 TYP	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°