DESCRIPTION

AP7442 is a High Efficiency Synchronous DC-DC Buck Converters with CV / CC modes, which can output up to 4.2 A in a wide input range from 6 V to 36 V. The A7442 operates either in CV (Constant Voltage) mode or CC (Constant Current) mode. With the CV / CC mode, adjustable current limit and output voltage, the A7442 is particularly suitable for QC 2.0 / 3.0 (12V / 1.5A, 9V / 2A and 5V / 3A), Type-C PD (5 V / 3 A) and Apple portable device (5V / 2.4A) applications. The output voltage and CC limit can be programed through the FB, CSP and CSN pins respectively.

In order to achieve better EMI performance and comply with Apple's MFi standard, the switching frequency was fixed at 130kHz. A7442 is capable to operate in CC mode down to 3V output voltage to protect the soft-short condition that is from the over current of the portable device

A discharge circuitry is integrated to quickly and reliably discharge output capacitors to avoid the faulty voltage delivery in case of output over voltage and ensure safe operation for QC 2.0 / 3.0 application. The hiccup mode output Under Voltage Protection(UVP) can reduce the average input current to 50mA. Features such as output cord voltage drop compensation and low voltage drop operation is especially suitable for car charger.

The A7442 is available in PSOP8 package.

ORDERING INFORMATION

| Package Type	Part Number	
PSOP8 SPQ: 4,000pcs/Reel	MP8	A7442MP8R
		A7442MP8VR
Note	V: Halogen free Package R: Tape & Reel	
AiT provides all RoHS products		

FEATURES

- Wide Input Supply Voltage Range of 6V ~ 40V
- Up to 4.2 A Output Current
- Up to 95 % Efficiency
- 130kHz Fixed Switching Frequency
- Internal Soft-start Circuitry
- Compensation for Output Cord Voltage Drop
- Input Under Voltage Lockout
- Input Over Voltage Protection
- Adjustable Constant Current Limit
- Output Over Voltage Protection
- Output Auto Discharge
- Cycle by Cycle Peak Current Limit
- Hiccup Mode Output UVP for Soft-short ≤ 3V
- Thermal Shutdown
- Available in PSOP8 Package

APPLICATION

- Car Charger
- Portable Charging Devices
- CV / CC regulation DC / DC converter

TYPICAL APPLICATION

PIN DESCRIPTION

	SW	BST	VCC	CC
	8	7	6	5

A7442
PSOP8
GND

	1	2	3	4
	VIN	FB	CSN	CSP
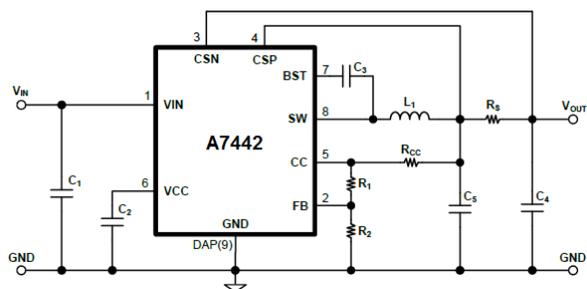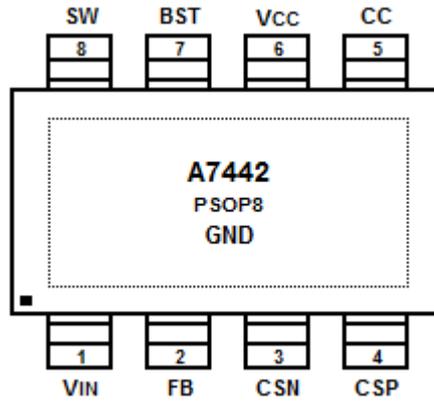
Top View

Pin #	Symbol	Function
1	V_{IN}	Input Voltage Supply. Connect a decoupling capacitor between V_{IN} and GND pins with least distance.
2	FB	Converter feedback input. Connect to the center point of the output feedback resistors divider to program the output voltage.
3	CSN	Current Limit Negative Feedback pin. Kevin sensing from this pin to the sensing resistor is recommended.
4	CSP	Current Limit Positive Feedback pin. Kevin sensing from this pin to the sensing resistor is recommended.
5	CC	Cable Compensation pin. Connect a resistor to output to adjust wire compensation gain.
6	V_{CC}	Internal 5V Power Supply. Connect a 100nF capacitor between V_{CC} and GND pins for stability and noise de-coupling;
7	BST	Boot-Strap pin. Supply input for the gate drive circuit of high-side NFET. Connect a 100nF capacitor between BST and SW pins.
8	SW	Switch Node between high-side NFET and low-side NFET. Connect this pin to the switching node of inductor.
DAP(9)	GND	Ground and Thermal Pad on the bottom of IC. Ground pin of internal circuitry and Power Return Pin for Sync-NFET source connection.

ABSOLUTE MAXIMUM RATINGS

V_{IN}	-0.3V ~ 42V
SW	-0.3V ~ (V_{IN} + 0.2V) ≤ 42V
BST to SW	-0.3V ~ 6V
CSP, CSN, CC	-0.3V ~ 14V
V_{CC}, FB	-0.3V ~ 6V
ESD Rating (Human Body Model)	±4kV[NOTE1]
Package Thermal Resistance[NOTE2]	
θ$_{JA}$	50°C/W
T_J, Min. Operating	-40°C
T_J, Max. Operating	Internally Limited
Storage Temperature	-55°C ~ 150°C
Lead Temperature (Soldering 10 sec.)	260°C

Stress beyond above listed "Absolute Maximum Ratings" may lead permanent damage to the device. These are stress ratings only and operations of the device at these or any other conditions beyond those indicated in the operational sections of the specifications are not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

NOTE1: Tested and classified as Class 3A per ESDA/JEDEC JDS-001-2014.

NOTE2: Thermal Resistance is measured in the natural convection at T_A = 25°C on a low effective single layer thermal conductivity test board of JEDEC 51-3 thermal measurement standard.

ELECTRICAL CHARACTERISTICS[NOTE3]

V_{IN} = 12V, T_A = 25℃, unless otherwise noted.

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Input Supply Voltage						
Input Voltage	V_{IN}		6	-	40	V
Input UVLO & OVP						
Input UVLO Threshold	V_{UVLO}	V_{IN} Rising	4.0	4.4	4.8	V
Input OVP Threshold	V_{IN_OVP}	V_{IN} Rising	36.5	39.5	-	V
Input OVP Hysteresis [NOTE4]	V_{IN_OVPHYS}	V_{IN} Falling	-	2.5	-	V
Input Supply Current						
Quiescent Current (non-switching)	I_Q	V_{FB} = 1.5V	-	500	850	µA
Output Voltage						
Output Voltage Range	V_{OUT}		3.4	-	13.0	V
Feedback Voltage Threshold	V_{FB_TH}		0.980	1.000	1.020	V
Feedback Current	I_{FB}		-	10	50	nA
CSP OVP Threshold	V_{CSP_OVP}	V_{CSP} Rising	13.2	14.0	14.9	V
CSP OVP Hysteresis	V_{CSP_HYS}	V_{CSP} Falling	-	840	-	mV
Feedback OVP Threshold	V_{FB_OVP}	V_{FB} Rising, % of V_{FB_TH}	-	113	-	%
Feedback OVP Threshold Hysteresis	V_{FB_HYS}	V_{FB} Falling, % of V_{FB_TH}	-	2	-	%
CSP UVP Threshold	V_{UVP}	V_{CSP} Falling	2.62	3.00	3.31	V
UVP Hiccup Interval [NOTE4]	t_{UVP}		-	0.7	-	s
Cable Compensation Voltage	V_{CCOMP}	R_{CC} = 18kΩ, I_{LOAD} = 2.4A, R_S = 18mΩ	-	200	-	mV
Auto Discharge Threshold	V_{TH_DIS}	% of V_{FB_TH}	-	113	-	%
Auto Discharge Current	I_{DIS}		-	60	-	mA
Oscillator						
Switching Frequency	f_{SW}	I_{LOAD} = 1A	109	130	160	kHz
Maximum Duty Cycle[NOTE4]	D_{MAX}		-	99	-	%

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
MOSFET						
High Side MOSFET On Resistance	$R_{DS(ON)H}$		-	52	-	mΩ
Low Side MOSFET On Resistance	$R_{DS(ON)L}$		-	52	-	mΩ
High-Side MOSFET Leakage Current	I_{LEAK_H}	V_{SW} = 0 V	-	-	9	µA
Low-Side MOSFET Leakage Current	I_{LEAK_L}	V_{SW} = V_{IN}	-	-	7	µA
Current Limit						
High Side MOSFET Peak Current Limit[NOTE4]	I_{LIM_HS}	V_{OUT} = 5V	-	7.5	-	A
Constant Current Limit Threshold	I_{CS}	R_S = 15mΩ, V_{OUT} = 5V	3.832	4.067	4.265	A
		R_S = 17mΩ, V_{OUT} = 5V	3.381	3.588	3.763	A
		R_S = 17mΩ, V_{OUT} = 9V	2.262	2.442	2.633	A
		R_S = 17mΩ, V_{OUT} = 12V	1.572	1.769	1.951	A
Regulator						
V_{CC} Regulator	V_{VCC_5}	T_A = 25°C, 0 < I_{CC} <5mA	4.541	4.896	5.109	V
V_{CC} Output Current	I_{CC_10}	V_{IN} = 12V, V_{CC} = 4.3 V, T_A = 25 °C	10	-	-	mA
Soft-start						
Soft-start Time [NOTE4]	t_{SS}		-	1.6	-	ms
Thermal Shutdown						
Thermal Shutdown Threshold[NOTE4]	T_{SDN}		-	165	-	°C
Thermal Shutdown Hysteresis[NOTE4]	T_{SDNHYS}		-	40	-	°C

NOTE3: Specifications over temperature range are guaranteed by design and characterization.

NOTE4: Guaranteed by design and characterization only.

TYPICAL PERFORMANCE CHARACTERISTICS

All curves taken at V_{IN} = 12 V, V_{OUT} = 5 V, RS = 15mΩ with configuration in Typical Application Circuit for High Current Output shown in this datasheet. T_A = 25 °C, unless otherwise specified.

1.   Efficiency vs. Load Current, V_{OUT} = 5V
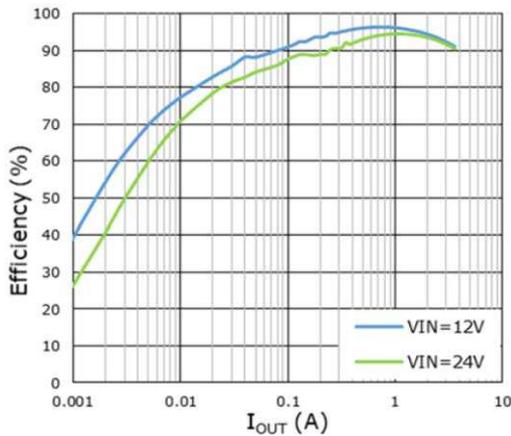

2.   Efficiency vs. Load Current, V_{OUT} = 9V
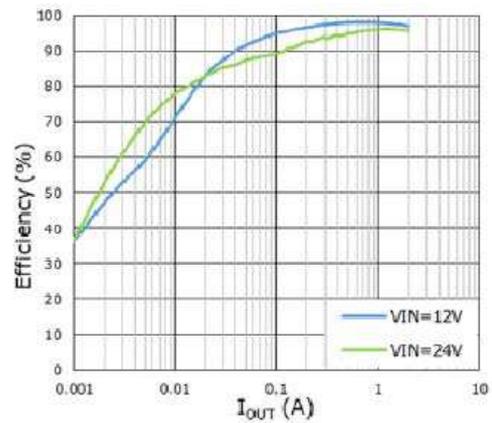
3.   Efficiency vs. Load Current, V_{OUT} = 12V
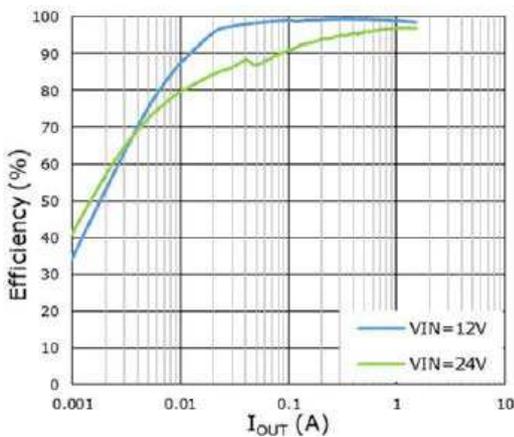

4.   Efficiency vs. Input Voltage
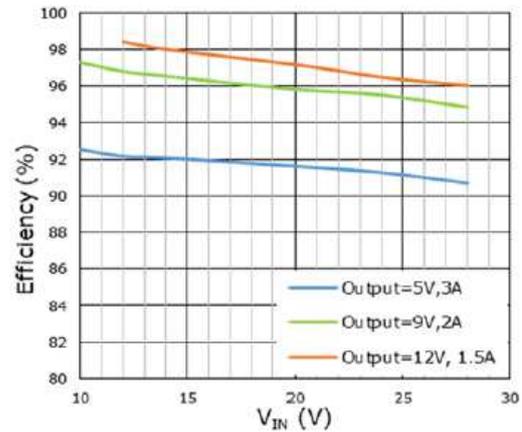
5. V_{OUT} Regulation vs. Load Current,
      R_{CC} = 0, R_1 = 100kΩ, R_S = 0
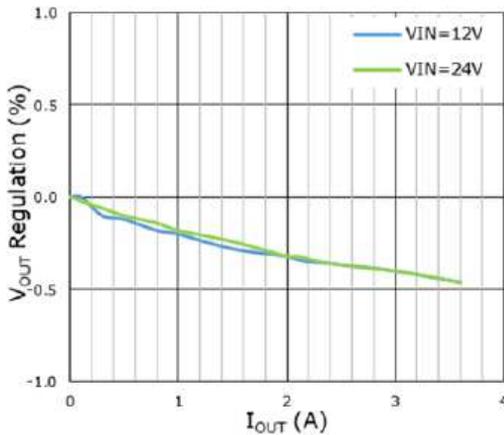
6.   Cable Compensation Voltage vs. Load Current,
      R_{CC} + R_1 = 100kΩ
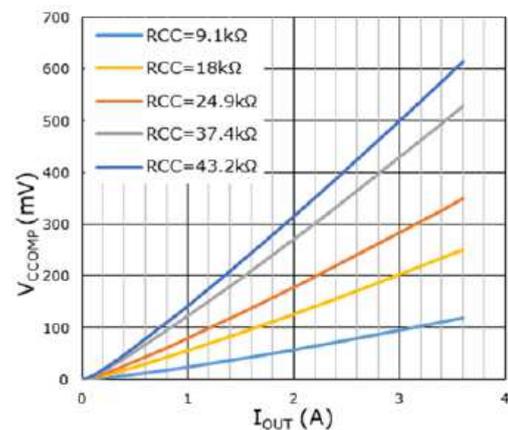
7. CCM Switching Frequency vs. V_{IN}, I_{OUT} = 1A
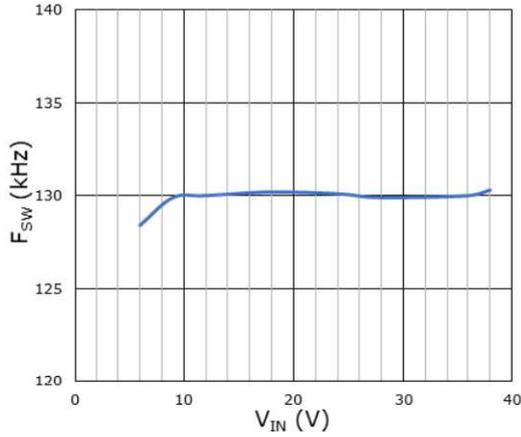
8. CCM Switching Frequency vs. Temperature
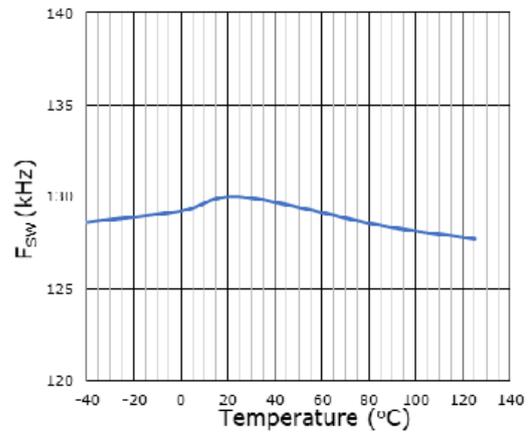
9. Reference Voltage vs. Temperature
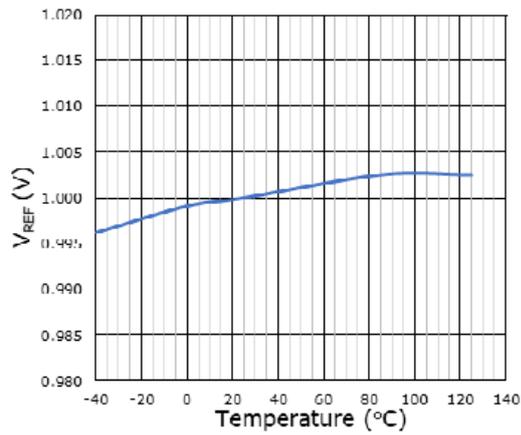
10. MOSFET $R_{DS(ON)}$ vs. Temperature
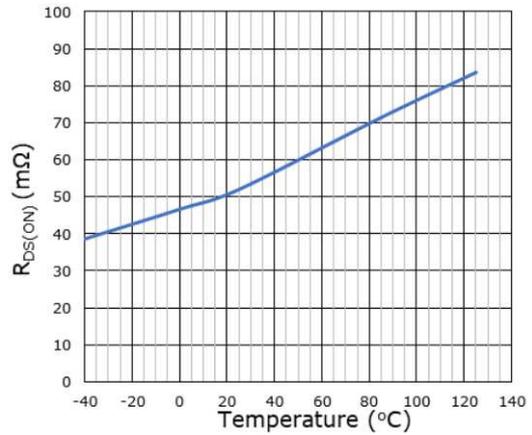
11. Constant Current Limit Threshold vs.

    Temperature
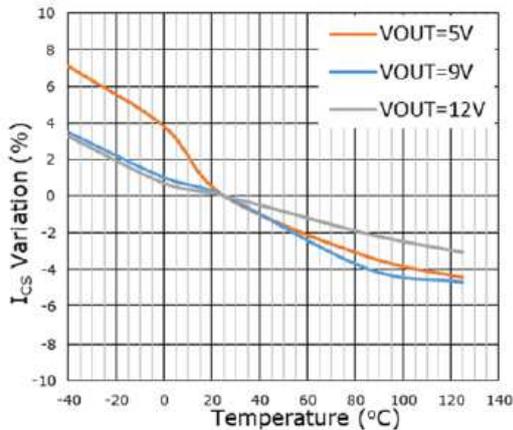
12. Quiescent Current vs. V_{IN}
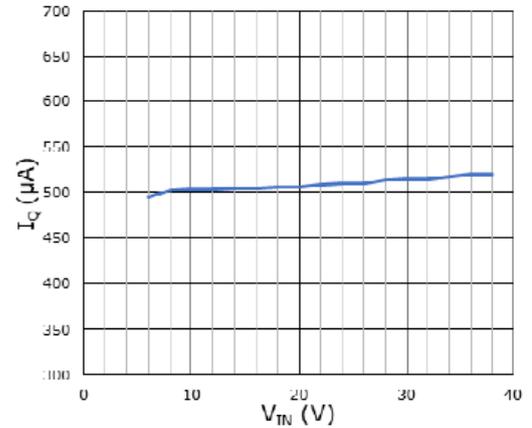
13. Output CC/CV Curve, V_{IN} = 24V, R_{CC} = 0Ω
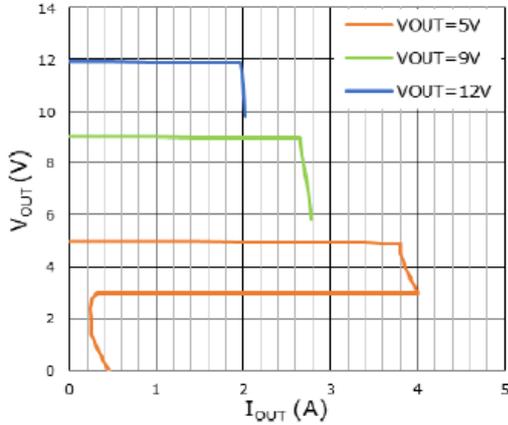

14. Power Up
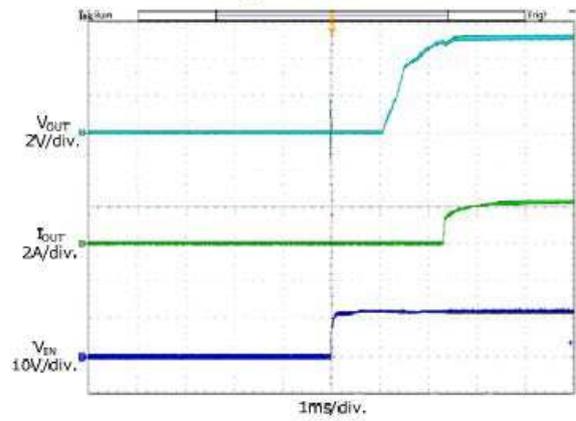
15. Power Down
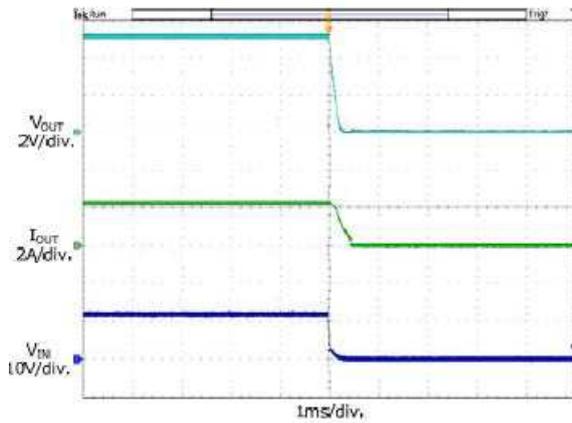
16. Load Transient
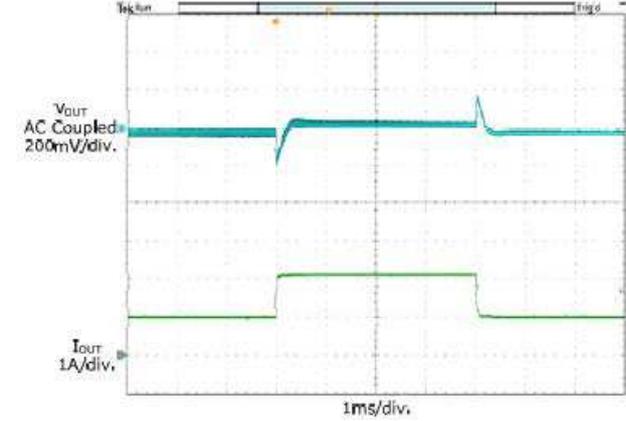
17. Continuous Mode Operation
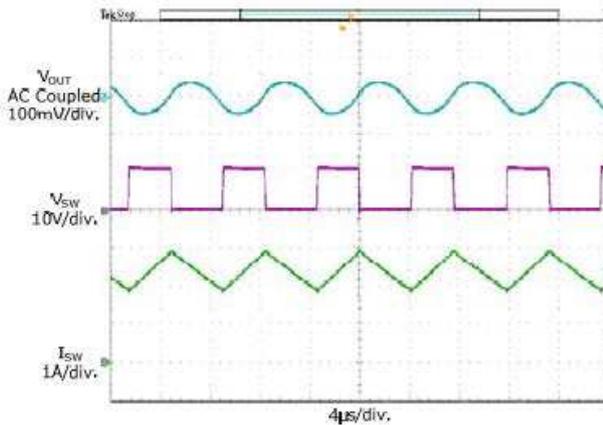

18. Discontinuous Mode Operation
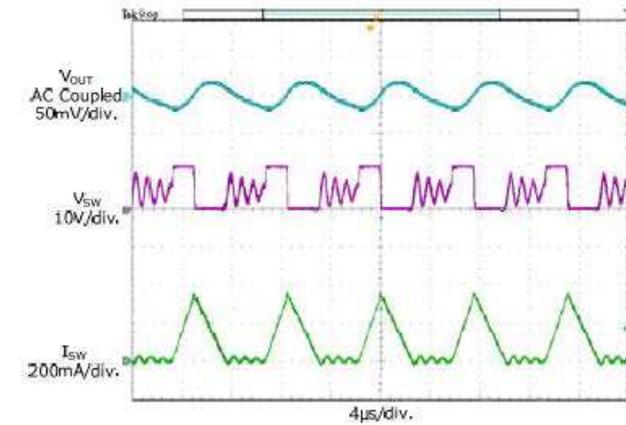
19. Short Circuit Protection
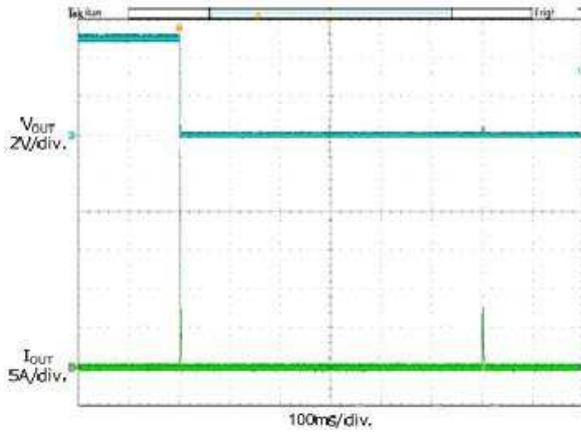
20. Short Circuit Protection
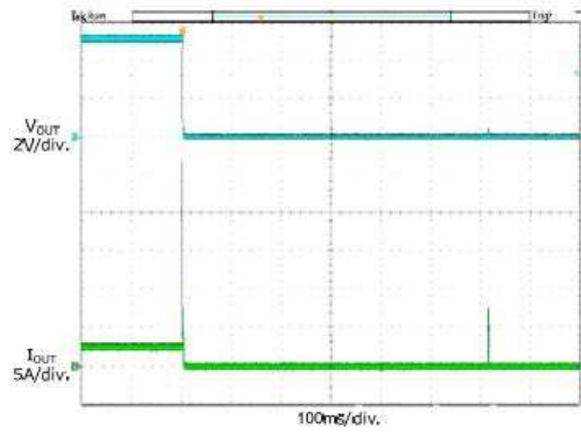
BLOCK DIAGRAM
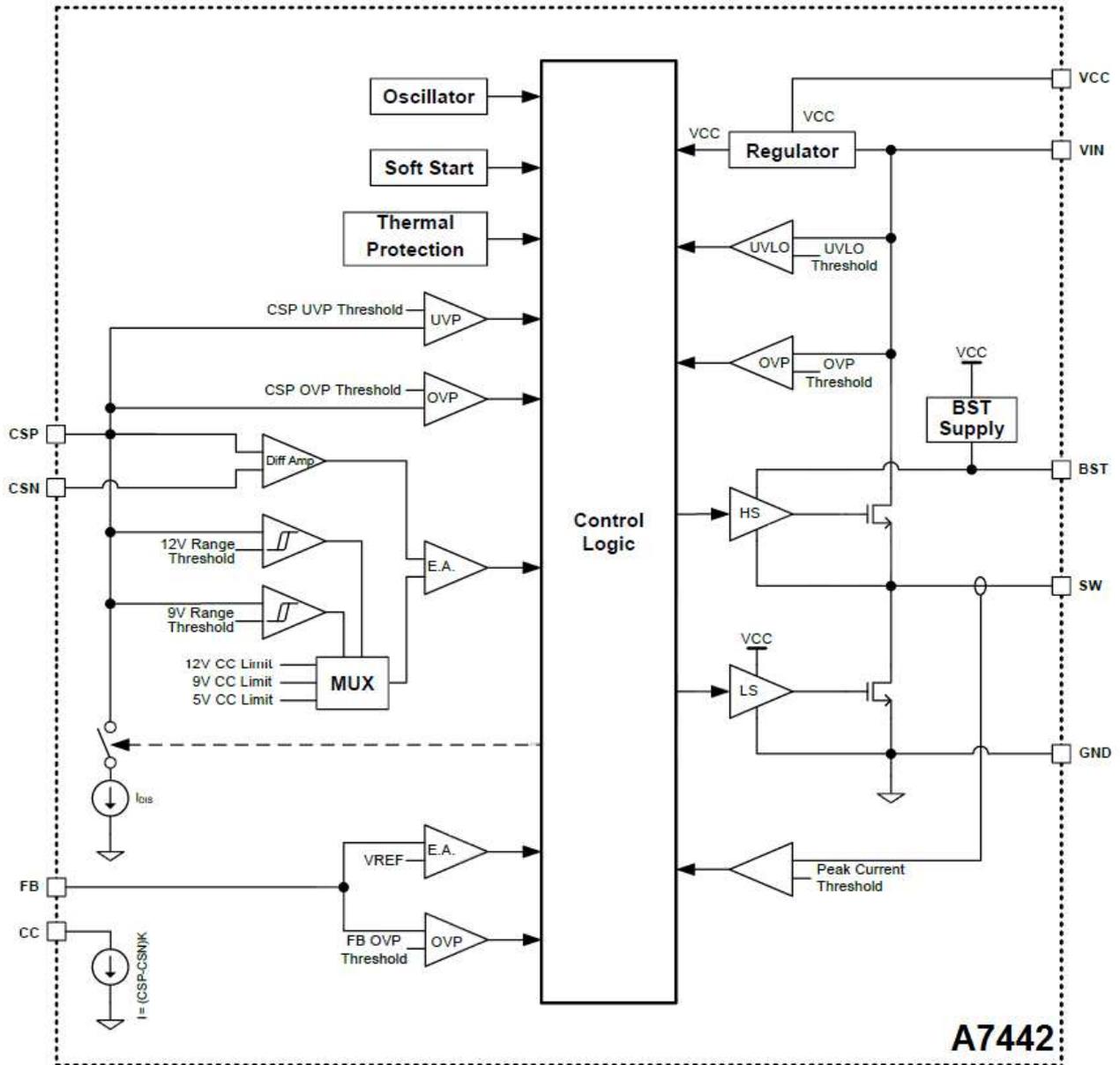
DETAILED INFORMATION

Operation

The A7442 is a monolithic high efficiency synchronous buck converters with CV / CC modes. It utilizes internal MOSFETs to achieve high efficiency and up to 4.2A output current in a wide input range from 6V to 36V. The output voltage and constant current limit can be programed through the FB, CSP and CSN pins respectively. The A7442 is capable to operate in CC mode down to 3V output voltage to protect the soft-short condition that is from the over current of the portable device.

With the slope compensated current mode PWM control, provides stable switching and cycle-by-cycle current limit for excellent load and line responses and protection of the internal switches. During normal operation, the internal main switch is turned on for a certain time to ramp up the inductor current at each rising edge of the internal oscillator, and turned off when the peak inductor current is above the error voltage. The current comparator limits the peak inductor current. Once the main switch is turned off, the synchronous rectifier will be turned on immediately and stay on until either the inductor current decay to zero, as indicated by the zero current comparator or the beginning of the next clock cycle.

Compensation for Output Cord Voltage Drop

In charger applications, the voltage drop across the output cord is significant in high current charging process. In some cases, excessive voltage drop across the output cord will even extend the charging time if high impedance output cord is used. The A7442 integrated a cable compensation function. When the output current increases, the CC pin sinks current into the IC to increase the voltage drop across the resistor, R_{CC}, in order to increase the output voltage. The sinking current of the CC pin is proportional to the voltage across CSP and CSN pins. Thus, the cable compensation function can increase the output voltage according to the load. The increment of the voltage measured at CSP pin(V_{CSP}) is called Cable Compensation Voltage(V_{CCOMP}). The value of RCC determines the gain of the cable compensation. After taking the voltage drop across the sensing resistor, RS, the value of RCC can be calculated using Equation 1.

$$R_{CC} = \frac{V_{CCOMP}}{(I_{OUT} \times R_S - V_{OS})K} \qquad (1)$$

Where

● R_{CC} is the value of the resistor between CC pin and the node of the inductor.

● V_{CCOMP} is the cable compensation voltage measured at the CSP pin.

● I_{OUT} is the output current of the converter.

● V_{OS} is the internal offset voltage which is equal to 3.3 mV

● K is a constant which is equal to 279μ.

● RS is the value of the sensing resistor.

Programmable CV / CC Mode Control

The A7442 features a CV / CC function. It operates either in CV mode or CC mode. The CV and the CC limits can be programed through FB, CSP and CSN pins respectively. With the programmable output voltage and constant current limit. The device is particularly suitable for QC 2.0, QC 3.0 Type-C PD and Apple portable device applications.

The CC mode provides an accurate current limiting function which is programed through the sensing resistor, R_S. Output current can increase until it reaches the CC limit set by the sensing resistor. At this point, the A7442 will transit from regulating output voltage to regulating output current, and the output voltage will drop with increasing load. The A7442 can output up to 4.2A current at 5V output voltage. In general, 3A output current is sufficient for charging purpose at 5 V output voltage. **Figure 1** shows the CC limit verse sensing resistor, R_S. In this case, the CC limit should be set at a level which is about 10% higher than 3A. A 18mΩ sensing resistor should be selected for ensuring 3A continuous output current. The CC limit is adaptive at different output voltages which is particularly useful in QC 2.0 / 3.0 application.
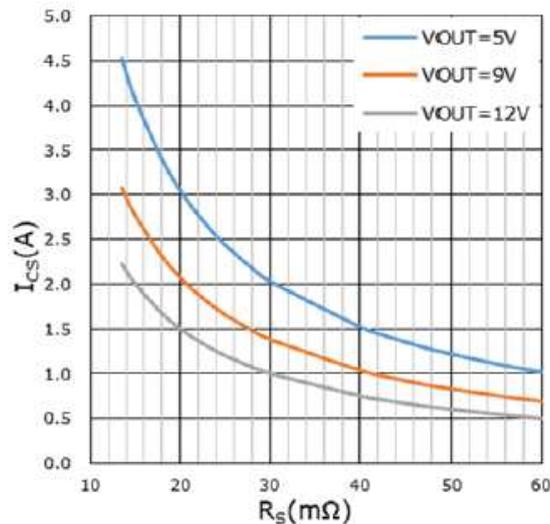

Figure 1. Constant Current Limit vs. Sensing Resistor

In CV mode, the feedback voltage is regulated at 1V and the output voltage is programed by the feedback divider R_{CC}, R_1 and R_2. R_{CC} and R_1 together form the upper feedback resistor and R_2 is the lower feedback resistor. The output voltage at no load can be calculated using Equation 2.

$$V_{OUT} = \frac{(R_{CC} + R_1) + R_2}{R_2} \qquad (2)$$

where

- V_{OUT} is the output voltage at no load.
- R_{CC} is the value of the resistor between CC pin and the node of the inductor.
- R_1 is the value of the resistor between CC and FB pins.
- R_2 is the value of the resistor between FB and GND pins.

Cycle by Cycle Peak Current Limit

The peak current limit prevents the A7442 from high inductor current and drawing excessive current from the input voltage rail. Excessive current might occur with a shorted or saturated inductor or a heavy load or a shorted output circuit condition. If the inductor current reaches the peak limit threshold, the high-side MOSFET is turned off and the low-side MOSFET is turned on to ramp down the inductor current.

Output Auto Discharge

The A7442 is designed for working with USB Interface IC (QC 2.0 / 3.0). Regarding to the output voltage changing capability of this application, the A7442 integrates an output auto discharge path to discharge the output capacitor at 60mA typically once the voltage at the FB pin raise above 113% of feedback voltage threshold. The function is crucial in high voltage charging scheme.

For instant, the output capacitor is charged-up by the high voltage which is set by the portable device. After the portable device is unplugged, the output capacitor takes time to be discharged if there is no high current discharge path. There is a chance that a conventional 5V portable device is damaged by a high voltage once it is connected to the power supply immediately after the detachment of QC 2.0 / 3.0 portable device.

Input Under-voltage Lockout(UVLO)

An input UVLO circuit prevents the converter from starting the operation until the input voltage rises above the typical UVLO threshold of 4.4V.

Input Over Voltage Protection(OVP)

The input OVP is an additional function to protect the device from damage in a condition which is above the specified input voltage range. Once the input voltage is raising above input OVP threshold, 39.5V typically, the A7442 stops switching to reduce the chance of damage by the voltage spike at SW pin. The device goes back to normal operation until the input voltage falls a hysteresis about 2.5V below the input OVP threshold.

Output Over Voltage Protection(OVP)

There are two individual output OVP functions in the A7442. Those are CSP OVP and FB OVP. The CSP OVP senses the output voltage directly. If the voltage at CSP pin is detected above CSP OVP threshold of 14V(typ.), the device stops switching immediately until the voltage at the CSP pin drops the hysteresis voltage lower than CSP OVP threshold. This function prevents the device as well as the output capacitors from damage by high voltage on the output even though the feedback resistors are faulty opened.

The operation of FB OVP is very similar to the CSP OVP except that it detects the voltage of the FB pin(V_{FB}). Once V_{FB} raises above 113% of the feedback voltage threshold, the FB OVP will be triggered immediately and stop switching. This OVP condition will be remove until V_{FB} drop 2% lower than FB OVP threshold.

Hiccup Mode Output Under Voltage Protection(UVP)

There is a CSP UVP threshold. If the threshold is hit, the hiccup mode output UVP will be triggered by disabling the converter and restarts soft-start after a predefined interval about 0.7s. The A7442 repeats this mode until the under voltage condition is removed. This function prevents the damage of the system from hard-short condition and a soft-short condition from the over current of portable device.

Soft-start

The A7442 implements the soft-start function to reduce the inrush current during startup. The soft-start begins once the input voltage raises above typical UVLO threshold of 4.4V. The soft-start time is typically 1.6ms.

Thermal Shutdown

A thermal shutdown is implemented to prevent the damage due to excessive heat and power dissipation. Typically, the thermal shutdown happens at the junction temperature of 165°C. When the thermal shutdown is triggered, the device stops switching until the junction temperature drops the hysteresis temperature lower than thermal shutdown threshold, then the device starts switching again.

APPLICATIONS INFORMATION

Design Requirement

Design Parameters	Target Values
Input Voltage Range	6V to 40V
Typical Input Voltage	24V
Output Voltage	5V
Output Current Rating	3.5A
V_{CCOMP} at Full Load	250mV

Table 1. Design Parameters

Setting the CC Limit

The simplified application circuit is showed on the front page. **Figure 1** shows the CC Limit at 5V output verse R_S. According to this figure, R_S should be set at around 15mΩ to output 3.5A continuous current.

Setting the Cable Compensation Resistor

The cable compensation resistor, R_{CC}, determines the gain of the cable compensation. By subtitling V_{CCOMP}, I_{OUT}, R_S, V_{OS} and K into the Equation 1, R_{CC} = 18.21kΩ. 18kΩ is the closest E24 standard value. **Table 2.** Shows the cable compensation voltage at different load with R_{CC} = 18kΩ and R_S = 15mΩ.

I_{LOAD} (A)	V_{CCOMP} (mV)
0	0
0.5	21
1	59
1.5	96
2	134
2.4	164
3	209
3.5	247

Table 2. Cable Compensation Voltage at Different Load

Setting the Output Voltage

The feedback resistors, R_1 and R_2, together with the cable compensation resistor, R_{CC}, program the output voltage at no load condition according to the Equation 2.

For QC 2.0 / 3.0 applications, the upper feedback resistor(R_{CC} + R_1) is fixed at 100kΩ generally for compatibility. Thus, R_1 = 100kΩ - 18kΩ = 82kΩ. By subtitling R_{CC}, R_1 and V_{OUT} into the Equation 2, R_2 = 25kΩ (24.9kΩ is the closest standard value).

Inductor Selection

Since the selection of the inductor affects the power supply's steady state operation, transient behavior, loop stability, and overall efficiency, the inductor is the most important component in switch power regulator design. Three most important specifications to the performance of the inductor are the inductor value, DC resistance, and saturation current.

The A7442 designed to work with inductor values between 15µH to 47µH. A 15µH inductor is typically available in a smaller or lower-profile package, while a 47µH inductor produces lower inductor current ripple. If the output current is limited by the peak current limit of the IC, using a 47µH inductor can maximize the converter's output current capability.

The tolerance of inductors can be ranging from 10% to 30%. The inductance will further decrease 20% to 35% from the value of zero bias current depending on the definition of saturation by inductor manufacturers. The basic requirements of selecting an inductor are the saturation current must be higher than the peak switching current and the DC rated current is higher than the average inductor current in normal operation. In buck converter, the average inductor current is equal to the output current. The inductor value can be derived from the Equation 3.

$$L = \frac{(V_{OUT} + V_{CCOMP}) \times (V_{IN} - V_{OUT} - V_{CCOMP})}{V_{IN} \times \Delta I_L \times F_{SW}} \qquad (3)$$

where

- ΔI_L is the inductor peak-to-peak ripple current.
- V_{OUT} is the output voltage at no load.
- V_{CCOMP} is the cable compensation voltage measured at the CSP pin.
- V_{IN} is the input voltage.
- F_{SW} is the switching frequency

Lower inductor value results in higher ripple current and vice versa. Choose inductor ripple current approximately 30% of the maximum load current, 3.5A, or ΔI_L = 1.05A. By subtitling V_{IN}(typ.), V_{OUT}, ΔI_L and V_{CCOMP}, ΔI_L and F_{SW}(typ.) into the above equation, the inductor value, L, is 31.3µH.

The common inductor value is 33µH.

The saturation current of the inductor must be higher than the maximum output current, 3.5A, plus half of the inductor ripple current in the worst case, i.e. highest operating V_{IN}(36V) lowest F_{SW}(109kHz), lowest inductor value(-10 ~ -30% from nominal value), to prevent the core from saturation. **Table 3** lists a typical toroid inductor specification that meets target application for the design requirement.

Core Manufacturer	Core Part Number	L(µH)	No. of Turns	Wire Ø (mm)	µ	AL (nH/N²)	Size[ODxIDxH] (mm)
KDM Magnetic Powder Cores	KS040-125A	33 ±10%	23	0.7	125	66	10.20x5.08x3.96

Table 3. Recommended Toroid Inductor

Input Capacitor Selection

The input capacitor reduces the surge current drawn from the input and the switching noise from the converter. The input capacitor impedance at the switching frequency should be less than the input source impedance to prevent high frequency switching current passing to the input. A low ESR input capacitor sized for maximum RMS current must be used. Multilayer Ceramic Capacitor(MLCC) with X5R or X7R dielectric is highly recommended because of their low ESR, low temperature coefficients and compact size characteristics. A 22μF MLCC is sufficient for most of applications.

Output Capacitor Selection

The output capacitor is required to keep the output voltage ripple small and to ensure regulation loop stability. The output capacitor must have low impedance at the switching frequency. MLCC with X5R or X7R dielectric Is recommended due to their low ESR, low temperature coefficients and compact size characteristics. The output ripple, ΔV_{OUT}, is determined by:

$$\Delta_{VOUT} \leq \frac{V_{OUTx}(V_{IN} - V_{OUT})}{V_{IN} \times F_{SW} \times L} \times \left(ESR + \frac{1}{8 \times F_{SW} \times C_{OUT}} \right) \qquad (4)$$

Layout Considerations

When doing the PCB layout, the following suggestions should be taken into consideration to ensure proper operation of the A7442. These suggestions are also illustrated graphically in **Figure 2** and **Figure 3**.

1. The power path including the GND trace, the SW trace and the V_{IN} trace should be as short as possible, direct and wide.

2. The FB pin should be connected directly to the center point of the output feedback resistors divider.

3. The resistor divider must be connected to the output capacitor and GND pin directly.

4. The input decoupling MLCC should be placed as close to the V_{IN} and GND pins as possible and connected to input power plane and ground plane directly. This capacitor provides the AC current to the internal power MOSFET.

5. The power path between the output MLCC, C5, and the power inductor should be kept short and the other terminal of the capacitor should connect to the ground plane directly to reduce noise emission.

6. Keep the switching node, SW, away from the sensitive FB node.

7. Keep the negative terminals of input capacitor and output capacitor as close as possible.

8. Use Kelvin sense connection techniques from the sensing resistor, Rs, pads directly to the CSP and CSN pins to achieve accurate CC limit.

9. Use large copper plane and thermal vias for GND for the best heat dissipation and noise immunity.
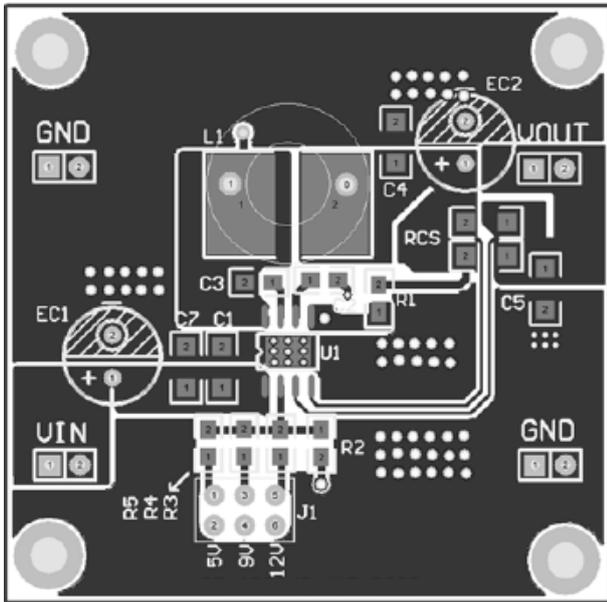
Figure 2. Top Layer
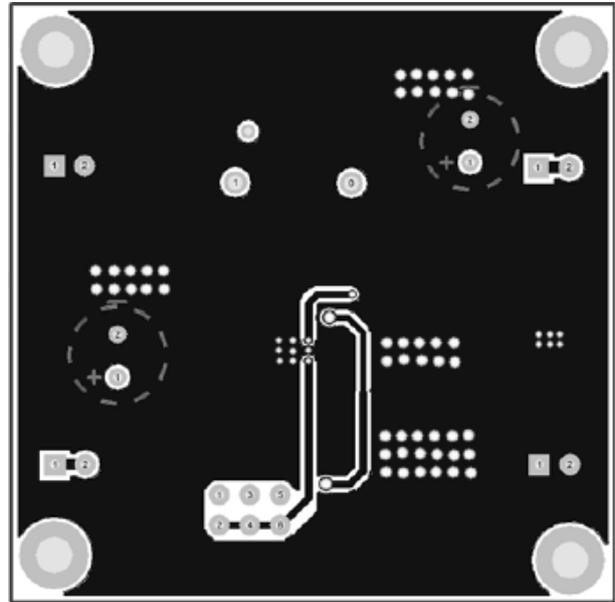

Figure 3. Bottom Layer

Typical Application Circuit with USB Interface IC
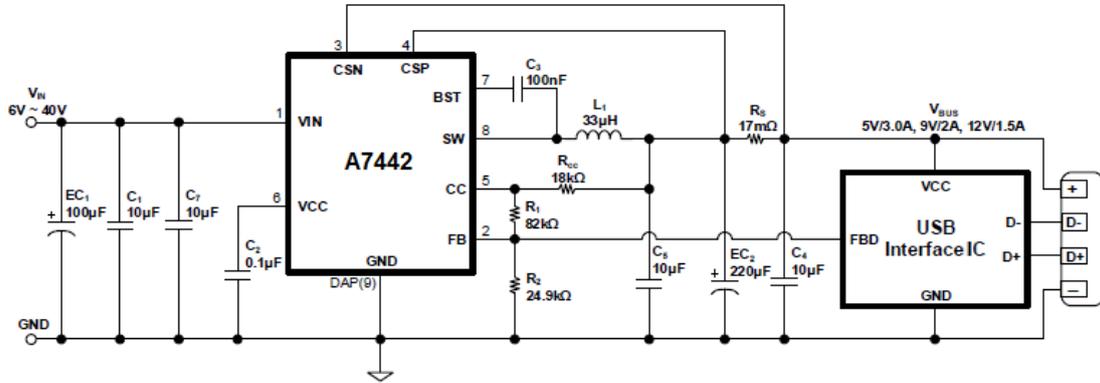
## Typical Application Circuit for High Current Output
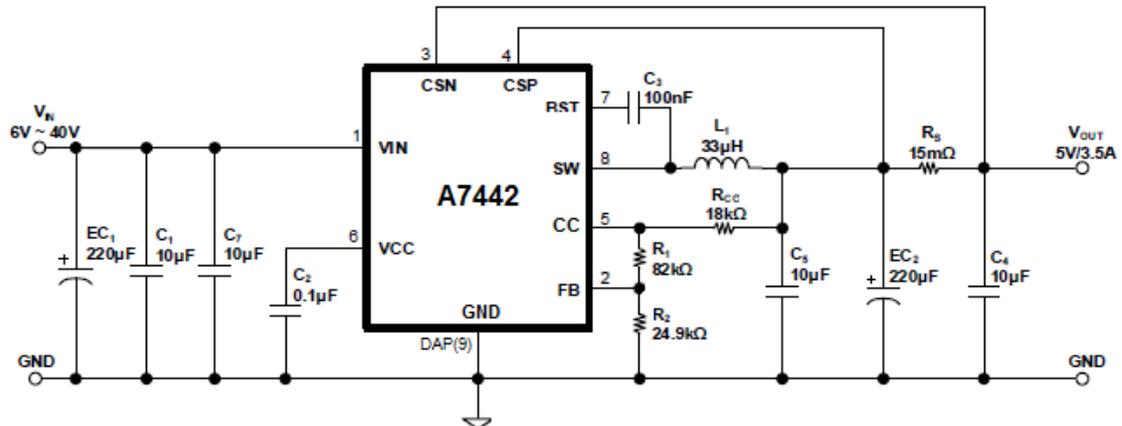
PACKAGE INFORMATION

Dimension in PSOP8 (Unit: mm)
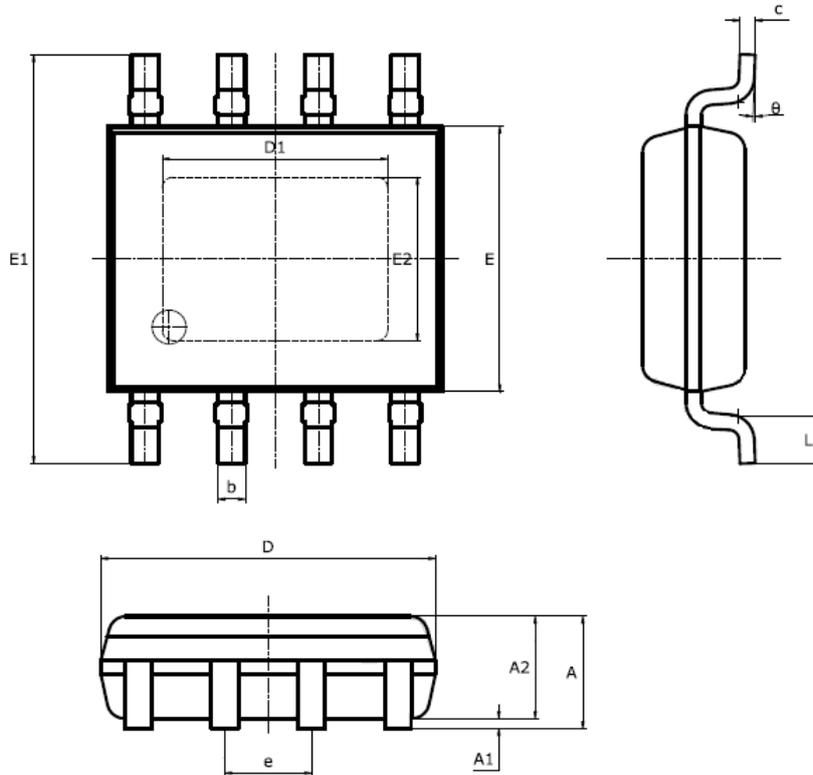
Symbol	Millimeters		Inches	
	Min	Max	Min	Max
A	1.300	1.700	0.051	0.067
A1	0.000	0.100	0.000	0.004
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
D1	3.050	3.350	0.120	0.132
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
E2	2.160	2.360	0.085	0.093
e	1.270 BSC		0.050 BSC	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

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