DESCRIPTION

The A7320 is a monolithic synchronous buck regulator. The device integrates 130mΩ MOSFETS that provide 2A continuous load current over a wide operating input voltage of 4.75V to 23V. Current mode control provides fast transient response and cycle-by-cycle current limit.

An adjustable soft-start prevents inrush current at turn-on. Shutdown mode drops the supply current to 1µA.

This device, available in an 8-pin SOP package, provides a very compact system solution with minimal reliance on external components.

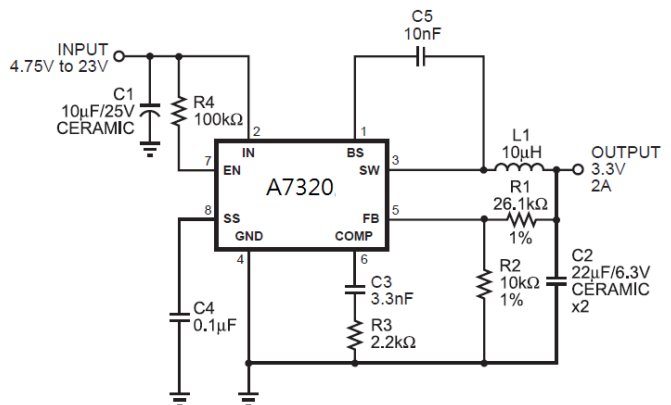A7320 is available in SOP8 Package

FEATURES

- 2A Output Current
- Wide 4.75V to 23V Operating Input Range
- Integrated 130mΩ Power MOSFET Switches
- Output Adjustable from 0.923V to 20V
- Up to 93% Efficiency
- Programmable Soft-Start
- Stable with Low ESR Ceramic Output Capacitors
- Fixed 450KHz Frequency
- Cycle-by-Cycle Over Current Protection
- Input Under Voltage Lockout
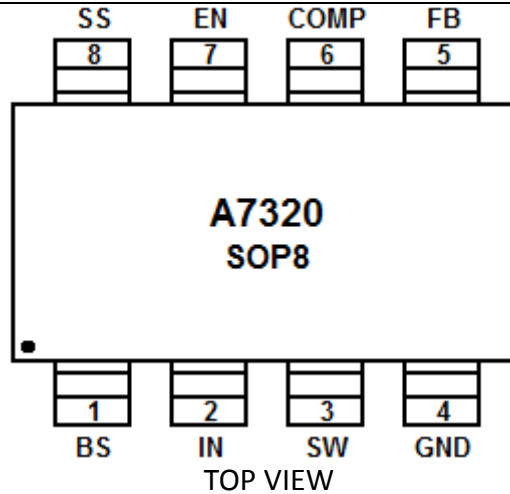- Available in SOP8 Package

APPLICATIONS

- Distributed Power Systems
- Networking Systems
- FPGA, DSP, ASIC Power Supplies
- Notebook Computers

ORDERING INFORMATION

Package Type		Part Number
SOP8	M8	A7320M8R
		A7320M8VR
Note		V: Halogen free Package R : Tape & Reel
AiT provides all RoHS products Suffix " V " means Halogen free Package		

TYPICAL APPLICATION

PIN DESCRIPTION

```
        SS      EN     COMP     FB
        8       7       6        5


              A7320
              SOP8



        1       2       3        4
        BS      IN      SW      GND
              TOP VIEW
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Pin #	Symbol	Function
1	BS	High-Side Gate Drive Boost Input. BS supplies the drive for the high-side N-Channel MOSFET switch. Connect a 0.01µF or greater capacitor from SW to BS to power the high side switch.
2	IN	Power Input. IN supplies the power to the IC, as well as the step-down converter switches. Drive IN with a 4.75V to 23V power source. Bypass IN to GND with a suitably large capacitor to eliminate noise on the input to the IC. See Input Capacitor.
3	SW	Power Switching Output. SW is the switching node that supplies power to the output. Connect the output LC filter from SW to the output load. Note that a capacitor is required from SW to BS to power the high-side switch.
4	GND	Ground.
5	FB	Feedback Input. FB senses the output voltage to regulate that voltage. Drive FB with a resistive voltage divider from the output voltage. The feedback threshold is 0.923V. See Setting the Output Voltage.
6	COMP	Compensation Node. COMP is used to compensate the regulation control loop. Connect a series RC network from COMP to GND to compensate the regulation control loop. In some cases, an additional capacitor from COMP to GND is required. See Compensation Components.
7	EN	Enable Input. EN is a digital input that turns the regulator on or off. Drive EN high to turn on the regulator, drive it low to turn it off. Pull up with 100kΩ resistor for automatic startup.
8	SS	Soft-Start Control Input. SS controls the soft start period. Connect a capacitor from SS to GND to set the soft-start period. A 0.1µF capacitor sets the soft-start period to 15ms. To disable the soft-start feature, leave SS unconnected.

ABSOLUTE MAXIMUM RATINGS[NOTE1]

V_{IN}, Supply Voltage	–0.3V to +26V
V_{SW}, Switch Voltage	–1V to V_{IN} +0.3V
V_{BS}, Boost Voltage	V_{SW}– 0.3V to V_{SW} + 6V
All Other Pins	–0.3V to +6V
Junction Temperature	150°C
Lead Temperature	260°C
Storage Temperature	–65°C to +150°C

Stresses above may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the Electrical Characteristics is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

NOTE1: Exceeding these ratings may damage the device.

RECOMMENDED OPERATING CONDITIONS[NOTE2]

V_{IN}, Input Voltage	4.75V to 23V
V_{OUT}, Output Voltage	0.923V to 20V
Ambient Operating Temperature	–40°C to +85°C

NOTE2: The device is not guaranteed to function outside of its operating conditions.

THERMAL RESISTANCE[NOTE3]

PACKAGE	θ_{JA}	θ_{JC}	Units
SOP8	90	45	°C/W

NOTE3: Measured on approximately 1" square of 1 oz copper.

ELECTRICAL CHARACTERISTICS

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

Parameter	Symbol	Conditions	Min	Typ.	Max	Units
Shutdown Supply Current		V_{EN} = 0V		1	3.0	µA
Supply Current		V_{EN} = 2.0V; V_{FB} = 1.0V		1.3	1.5	mA
Feedback Voltage	V_{FB}	4.75V ≤ V_{IN} ≤ 23V	0.900	0.923	0.946	V
Feedback Overvoltage Threshold				1.1		V
Error Amplifier Voltage Gain[Note4]	A_{EA}			400		V/V
Error Amplifier Transconductance	G_{EA}	ΔI_C = ±10µA		800		µA/V
High-Side Switch On Resistance [Note4]	$R_{DS(ON)1}$			130		mΩ
Low-Side Switch On Resistance [Note4]	$R_{DS(ON)2}$			130		mΩ
High-Side Switch Leakage Current		V_{EN} = 0V, V_{SW} = 0V			10	µA
Upper Switch Current Limit		Minimum Duty Cycle	2.4	3.4		A
Lower Switch Current Limit		From Drain to Source		1.1		A
COMP to Current Sense Transconductance	G_{CS}			3.5		A/V
Oscillation Frequency	F_{osc1}		400	450	500	KHz
Short Circuit Oscillation Frequency	F_{osc2}	V_{FB} = 0V		100		KHz
Maximum Duty Cycle	D_{MAX}	V_{FB} = 1.0V		90		%
Minimum On Time[Note4]				220		ns
EN Shutdown Threshold Voltage		V_{EN} Rising	1.1	1.5	2.0	V
EN Shutdown Threshold Voltage Hysteresis				210		mV
EN Lockout Threshold Voltage			2.2	2.5	2.7	V
EN Lockout Hysteresis				210		mV

NOTE4: Guaranteed by design, not tested.

Parameter	Symbol	Conditions	Min	Typ.	Max	Units
Input Under Voltage Lockout Threshold		V_{IN} Rising	3.80	4.10	4.40	V
Input Under Voltage Lockout Threshold Hysteresis				210		mV
Soft-Start Current		V_{SS} = 0V		6		µA
Soft-Start Period		C_{SS} = 0.1µF		15		ms
Thermal Shutdown[Note4]				160		°C

NOTE4: Guaranteed by design, not tested.

TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 12V, V_O = 3.3V, L = 10µH, C1 = 10µF, C2 = 22µF, T_A = +25°C, unless otherwise noted

Figure 1. Steady State Test

V_{IN} = 12V, V_{OUT} = 3.3V, I_{OUT} = 0A, I_{IN}= 8.2mA

2µs/div.
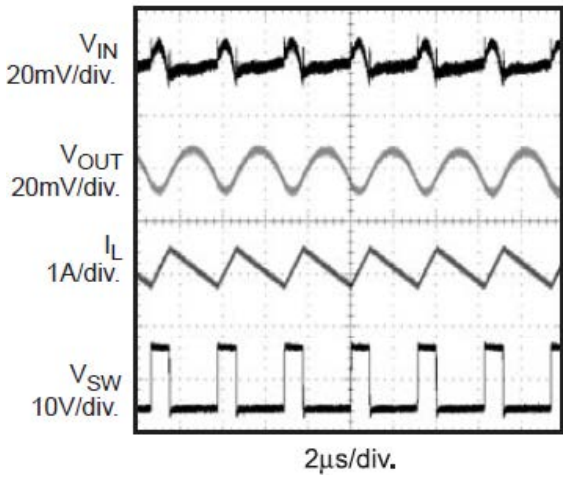
Figure 2. Startup through Enable

V_{IN} = 12V, V_{OUT} = 3.3V, I_{OUT} = 1A (Resistance Load)

2ms/div.
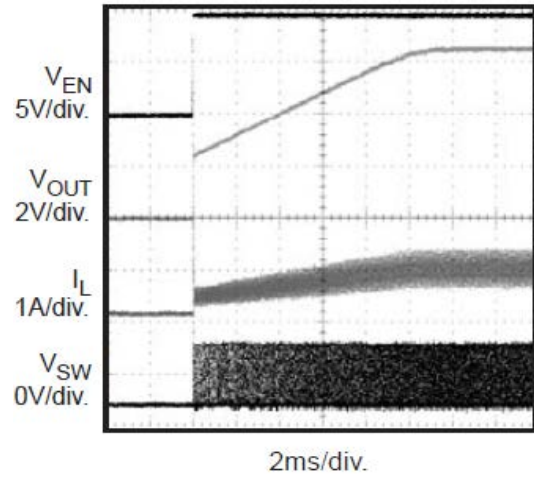
Figure 3. Shutdown through Enable

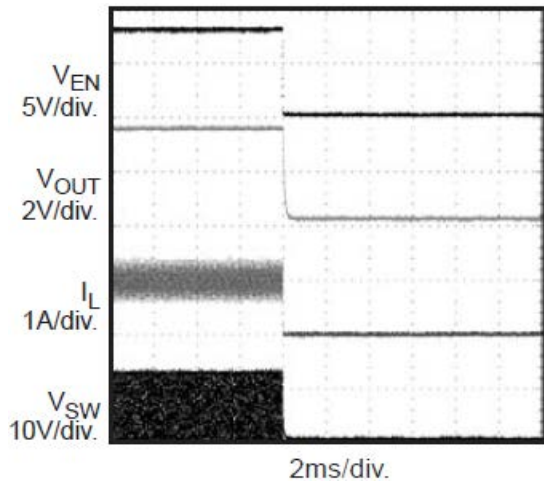V_{IN} = 12V, V_{OUT} = 3.3V,I_{OUT} = 1A (Resistance Load)

2ms/div.

Figure 4. Heavy Load Operation

2A Load

2µs/div.
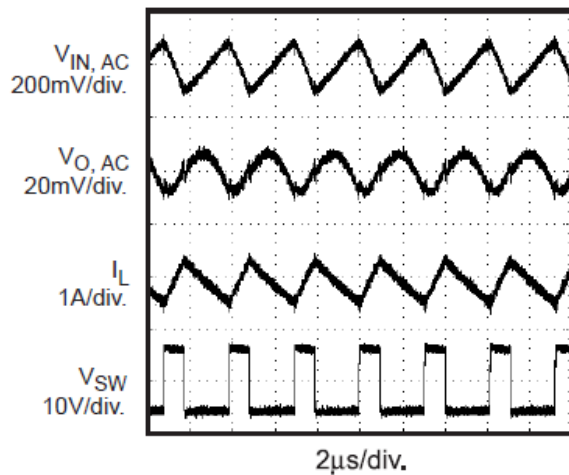
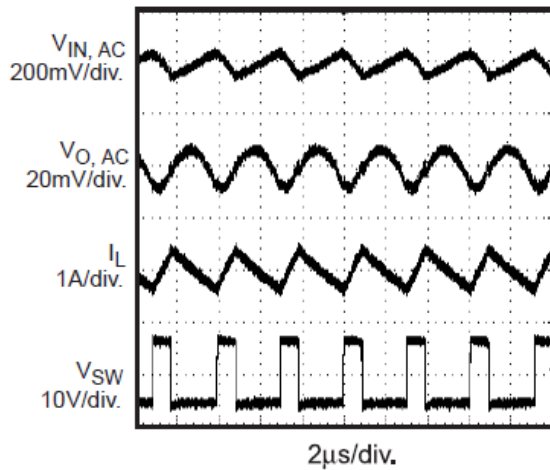Figure 5.   Medium Load Operation

1A Load

2μs/div.

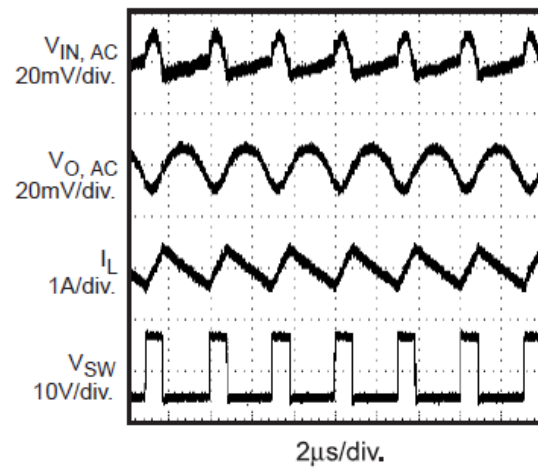Figure 6.   Light Load Operation

No Load

2μs/div.

Figure 7.   Short Circuit Protection

20μs/div.
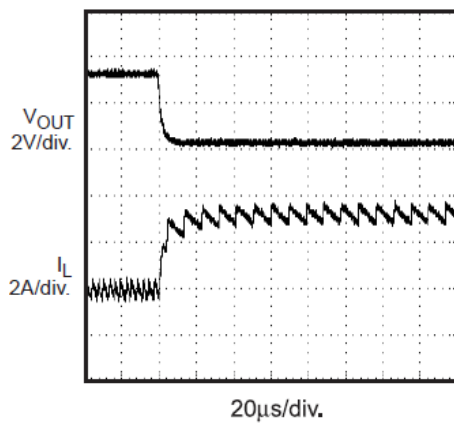
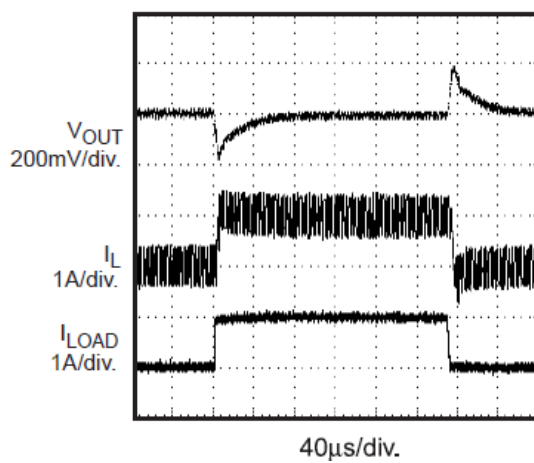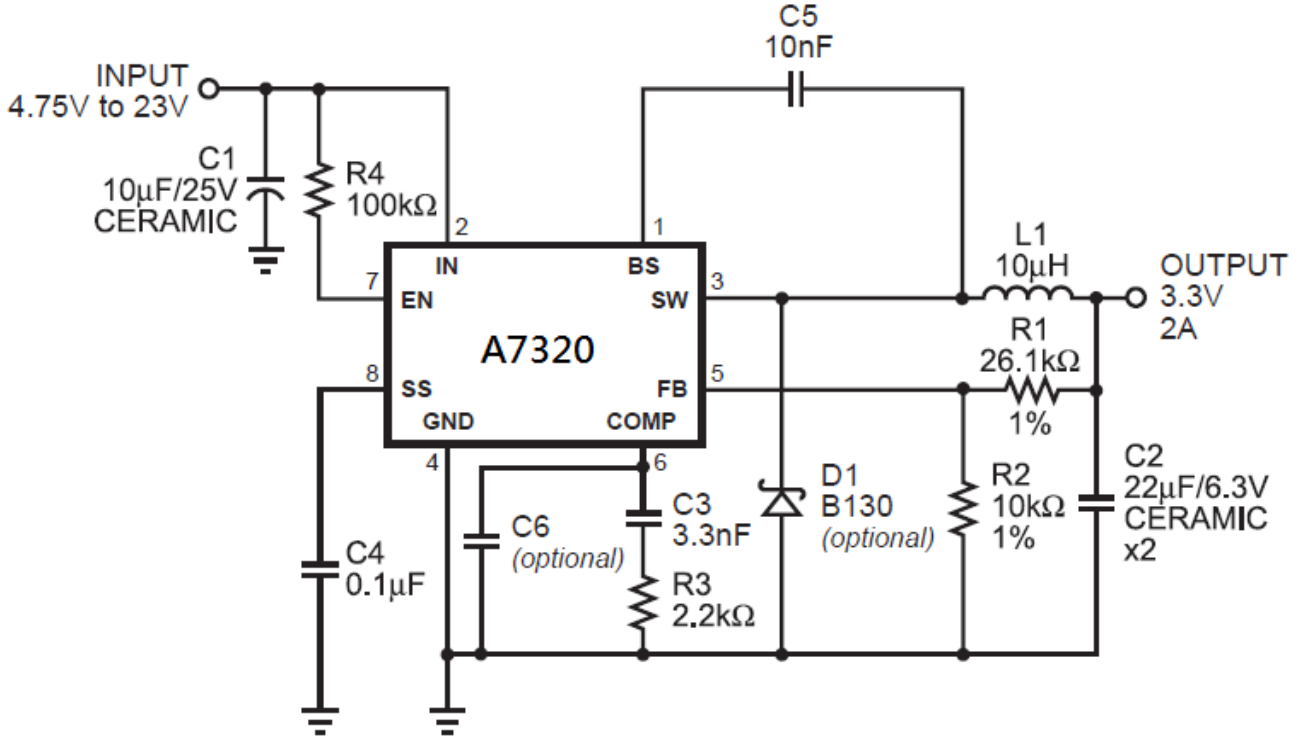Figure 8.   Short Circuit Recovery

20μs/div.
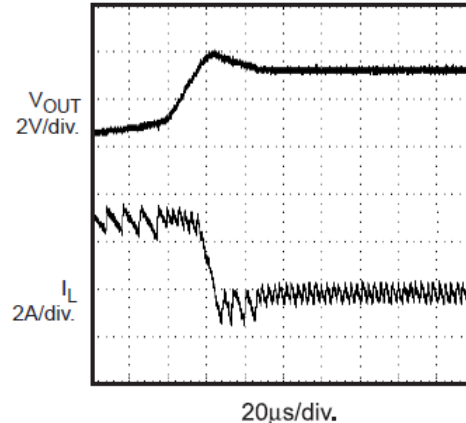
Figure 9.   Load Transient
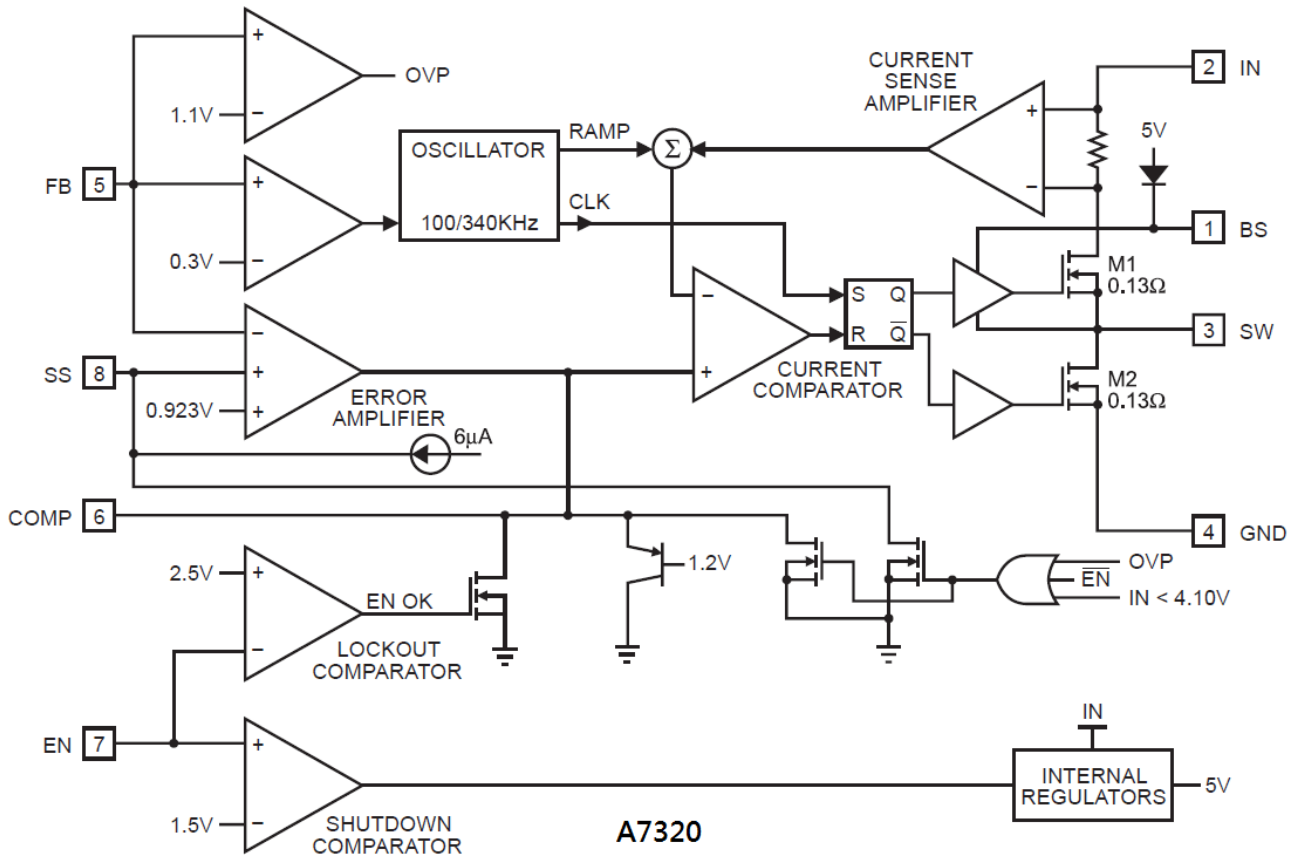

40μs/div.

TEST CIRCUIT

Figure 10. A7320 with 3.3V Output, 22µF/6.3V Ceramic Output Capacitor

BLOCK DIAGRAM

APPLICATIONS INFORMATION

COMPONENT SELECTION

Setting the Output Voltage

The output voltage is set using a resistive voltage divider from the output voltage to FB pin.

The voltage divider divides the output voltage down to the feedback voltage by the ratio:

$$V_{FB} = V_{OUT} \frac{R2}{R1+R2}$$

Where V_{FB} is the feedback voltage and V_{OUT} is the output voltage. Thus the output voltage is:

$$V_{OUT} = 0.923 \times \frac{R1+R2}{R2}$$

R2 can be as high as 100kΩ, but a typical value is 10kΩ. Using the typical value for R2, R1 is determined by:

$$R1 = 10.83 \times (V_{OUT} - 0.923) \ (k\Omega)$$

For example, for a 3.3V output voltage, R2 is 10kΩ, and R1 is 26.1kΩ.

Inductor

The inductor is required to supply constant current to the output load while being driven by the switched input voltage. A larger value inductor will result in less ripple current that will result in lower output ripple voltage. However, the larger value inductor will have a larger physical size, higher series resistance, and/or lower saturation current. A good rule for determining the inductance to use is to allow the peak-to-peak ripple current in the inductor to be approximately 30% of the maximum switch current limit. Also, make sure that the peak inductor current is below the maximum switch current limit. The inductance value can be calculated by:

$$L = \frac{V_{OUT}}{f_S \times \Delta I_L} \times \left(1 - \frac{V_{OUT}}{V_{IN}} \right)$$

Where V_{OUT} is the output voltage, V_{IN} is the input voltage, f_S is the switching frequency, and ΔI_L is the peak-to-peak inductor ripple current.

Choose an inductor that will not saturate under the maximum inductor peak current. The peak inductor current can be calculated by:

$$I_{LP} = I_{LOAD} + \frac{V_{OUT}}{2 \times f_S \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}} \right)$$

Where I_{LOAD} is the load current. The choice of which style inductor to use mainly depends on the price vs. size requirements and any EMI requirements.

Optional Schottky Diode

During the transition between high-side switch and low-side switch, the body diode of the low-side power MOSFET conducts the inductor current. The forward voltage of this body diode is high. An optional Schottky diode may be paralleled between the SW pin and GND pin to improve overall efficiency.

Input Capacitor

The input current to the step-down converter is discontinuous, therefore a capacitor is required to supply the AC current to the step-down converter while maintaining the DC input voltage. Use low ESR capacitors for the best performance. Ceramic capacitors are preferred, but tantalum or low-ESR electrolytic capacitors may also suffice. Choose X5R or X7R dielectrics when using ceramic capacitors. Since the input capacitor (C1) absorbs the input switching current it requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated by:

$$I_{C1} = I_{LOAD} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}} \right)}$$

The worst-case condition occurs at $V_{IN} = 2V_{OUT}$, where $I_{C1} = I_{LOAD}/2$. For simplification, choose the input capacitor whose RMS current rating greater than half of the maximum load current.

The input capacitor can be electrolytic, tantalum or ceramic. When using electrolytic or tantalum capacitors, a small, high quality ceramic capacitor, i.e. 0.1μF, should be placed as close to the IC as possible. When using ceramic capacitors, make sure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at input. The input voltage ripple for low ESR capacitors can be estimated by:

$$\Delta V_{IN} = \frac{I_{LOAD}}{C1 \times f_S} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}} \right)$$

Where C1 is the input capacitance value.

Output Capacitor

The output capacitor is required to maintain the DC output voltage. Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low. The output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_S \times C2}\right)$$

Where C2 is the output capacitance value and R_{ESR} is the equivalent series resistance (ESR) value of the output capacitor. In the case of ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance. The output voltage ripple is mainly caused by the capacitance. For simplification, the output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_S^2 \times L \times C2} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

In the case of tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be approximated to:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times R_{ESR}$$

The characteristics of the output capacitor also affect the stability of the regulation system. The A7320 can be optimized for a wide range of capacitance and ESR values.

Compensation Components

A7320 employs current mode control for easy compensation and fast transient response.

The system stability and transient response are controlled through the COMP pin. COMP pin is the output of the internal transconductance error amplifier. A series capacitor-resistor combination sets a pole-zero combination to control the characteristics of the control system.

The DC gain of the voltage feedback loop is given by:

$$A_{VDC} = R_{LOAD} \times G_{CS} \times A_{EA} \times \frac{V_{FB}}{V_{OUT}}$$

Where A_{VEA} is the error amplifier voltage gain; G_{CS} is the current sense transconductance and R_{LOAD} is the load resistor value. The system has two poles of importance. One is due to the compensation capacitor (C3) and the output resistor of the error amplifier, and the other is due to the output capacitor and the load resistor. These poles are located at:

$$f_{P1} = \frac{G_{EA}}{2\pi \times C3 \times A_{VEA}}$$

$$f_{P2} = \frac{1}{2\pi \times C2 \times R_{LOAD}}$$

Where G_{EA} is the error amplifier transconductance.

The system has one zero of importance, due to the compensation capacitor (C3) and the compensation resistor (R3). This zero is located at:

$$f_{Z1} = \frac{1}{2\pi \times C3 \times R3}$$

The system may have another zero of importance, if the output capacitor has a large capacitance and/or a high ESR value. The zero, due to the ESR and capacitance of the output capacitor, is located at:

$$f_{ESR} = \frac{1}{2\pi \times C2 \times R_{ESR}}$$

In this case (as shown in Figure 2), a third pole set by the compensation capacitor (C6) and the compensation resistor (R3) is used to compensate the effect of the ESR zero on the loop gain. This pole is located at:

$$f_{P3} = \frac{1}{2\pi \times C6 \times R3}$$

The goal of compensation design is to shape the converter transfer function to get a desired loop gain. The system crossover frequency where the feedback loop has the unity gain is important. Lower crossover frequencies result in slower line and load transient responses, while higher crossover frequencies could cause system instability. A good rule of thumb is to set the crossover frequency below one-tenth of the switching frequency.

To optimize the compensation components, the following procedure can be used.

1. Choose the compensation resistor (R3) to set the desired crossover frequency. Determine the R3 value by the following equation:

$$R3 = \frac{2\pi \times C2 \times f_C}{G_{EA} \times G_{CS}} \times \frac{V_{OUT}}{V_{FB}} < \frac{2\pi \times C2 \times 0.1 \times f_S}{G_{EA} \times G_{CS}} \times \frac{V_{OUT}}{V_{FB}}$$

Where f_C is the desired crossover frequency which is typically below one tenth of the switching frequency.

2. Choose the compensation capacitor (C3) to achieve the desired phase margin. For applications with typical inductor values, setting the compensation zero, f_{Z1}, below one-forth of the crossover frequency provides sufficient phase margin.

Determine the C3 value by the following equation:

$$C3 > \frac{4}{2\pi \times R3 \times f_C}$$

Where R3 is the compensation resistor.

3. Determine if the second compensation capacitor (C6) is required. It is required if the ESR zero of the output capacitor is located at less than half of the switching frequency, or the following relationship is valid:

$$\frac{1}{2\pi \times C2 \times R_{ESR}} < \frac{f_S}{2}$$

If this is the case, then add the second compensation capacitor (C6) to set the pole f_{P3} at the location of the ESR zero. Determine the C6 value by the equation:

$$C6 = \frac{C2 \times R_{ESR}}{R3}$$

External Bootstrap Diode

It is recommended that an external bootstrap diode be added when the system has a 5V fixed input or the power supply generates a 5V output. This helps improve the efficiency of the regulator.

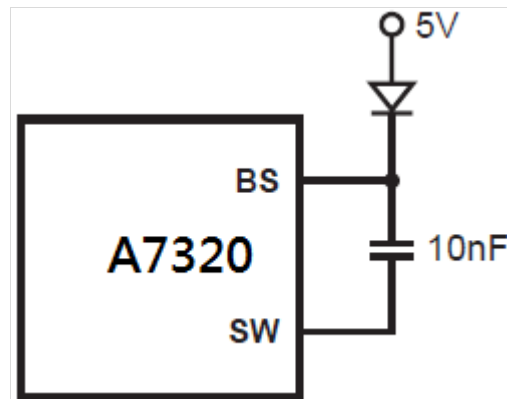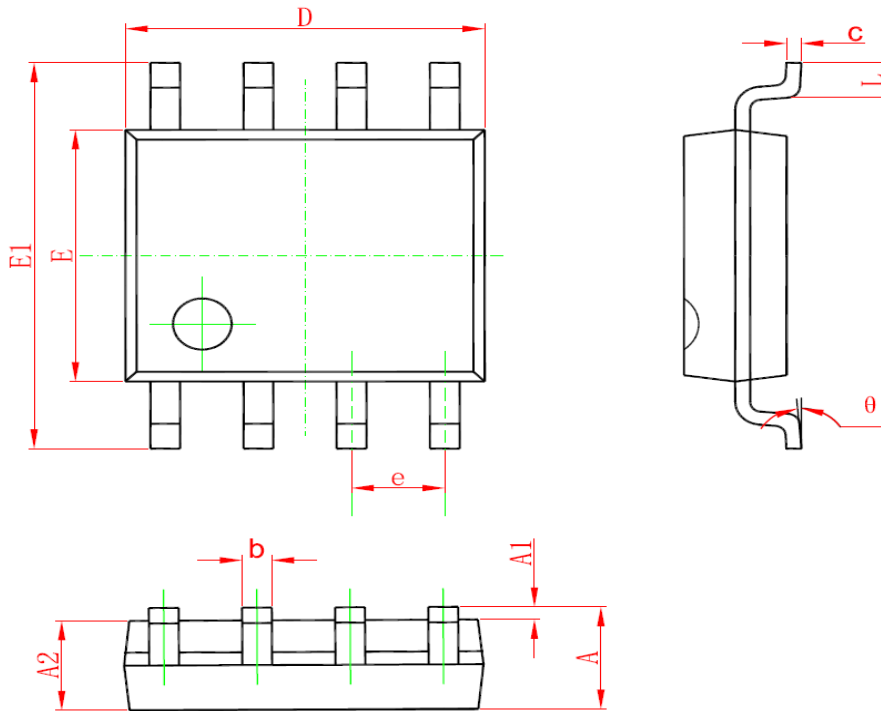The bootstrap diode can be a low cost one such as IN4148 or BAT54.

Figure 2—External Bootstrap Diode

This diode is also recommended for high duty cycle operation (when $V_{OUT}/V_{IN} > 65\%$)and high output voltage ($V_{OUT} > 12V$) applications.

PACKAGE INFORMATION

Dimension in SOP8 Package (Unit: mm)

Symbol	Min	Max
A	1.350	1.750
A1	0.100	0.250
A2	1.350	1.550
b	0.330	0.510
c	0.190	0.250
D	4.800	5.000
E	3.800	4.000
E1	5.800	6.200
e	1.270(BSC)	
L	0.410	1.270
θ	0°	8°

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