HE9421M6R

30V,1.5A synchronous Step-Down Converter

Features

- Wide 4.5V to 30V Operating Input Range
- 1.5A Continuous Output Current
- 1.2MHz Switching Frequency
- Short Protection with Hiccup-Mode
- Built-in Over Current Limit
- Built-in Over Voltage Protection
- CCM for Low Nosie& Low EMI Signature
- 200mΩ/120mΩ Low $R_{DS(ON)}$ Internal Power MOSFETs
- Output Adjustable from 0.8V
- No Schottky Diode Required
- Integrated internal compensation
- Thermal Shutdown
- Available in SOT23-6 Package

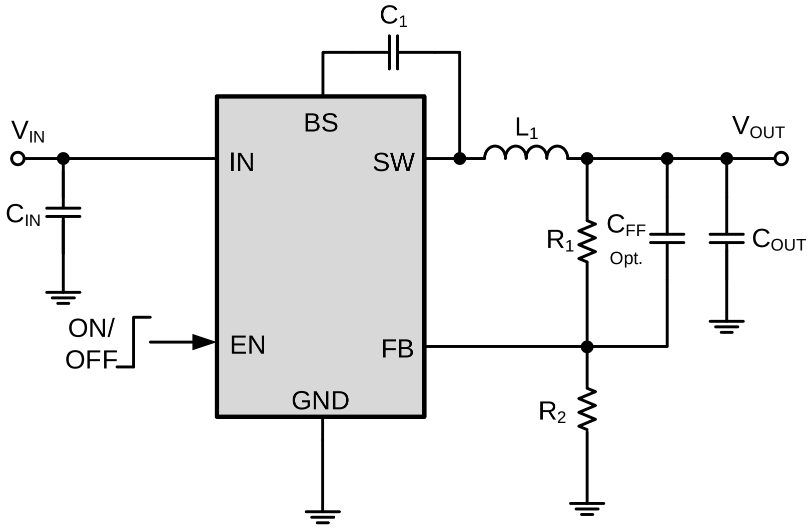
Applications

- Automotive Entertainment
- Wireless and DSL Modems
- Computer Entertainment
- Distributed Power Systems

General Description

The HE9421 is a low EMI signature, synchronous, step-down, switch-mode converter with internal power MOSFETs.It offers a very compact solution to provide 1.5A continuous current over a wide input supply range, with excellent load and line regulation. HE9421 achieves low EMI signature with well controlled switching edges. Fault condition protection includes programmable-output over-voltage protection, Constant on time Mode, and thermal shutdown.HE9421 requires a minimal number of readily available standard external components. It is available in SOT23-6 package.

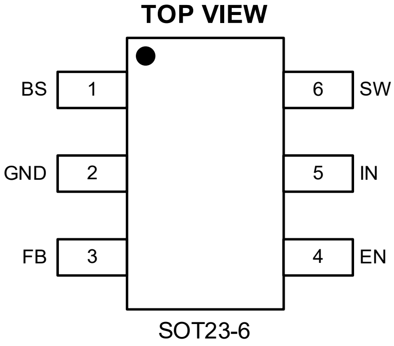
Typical Application Circuit



Basic Application Circuit

Pin Description

Pin Configuration



Top Marking: NABAB (device code: NA, B=year code, AB= lot number code)

Pin Description

Pin	Name	Function
1	BS	Bootstrap. A capacitor connected between SW and BST pins is required to form a floating supply across the high-side switch driver.
2	GND	Ground Pin
3	FB	Adjustable Version Feedback input. Connect FB to the center point of the external resistor divider
4	EN	Drive this pin to a logic-high to enable the IC. Drive to a logic-low to disable the IC and enter micro-power shutdown mode.
5	IN	Power Supply Pin
6	SW	Switching Pin

Order Information (1)

Marking	Part No.	Model	Description	Package	T/R Qty
NABAB	70301500	HE9421	HE9421 Buck, 4.5-30V, 1.5A, 1.2MHz, VFB 0.8V, SOT23-6	SOT23-6	3000PCS

Note (1): All HEERMICR parts are Pb-Free and adhere to the RoHS directive.

Absolute Maximum Ratings (1) (2)

Item	**Min**	**Max**	**Unit**
V_{IN} voltage	-0.3	33	V
EN voltage	-0.3	33	V
SW voltage	-0.3(-5V<10nS)	V_{IN}+0.5V(+36V<10nS)	V
BST voltage		Vsw+5	V
FB voltage	–0.3	6.5	V
Power dissipation		1.0	W
Operating junction temperature, TJ	-40	150	°C
Storage temperature, T_{stg}	–65	150	°C
Lead Temperature (Soldering, 10sec.)		260	°C

Note (1): Exceeding these ratings may damage the device.

Note (2): The device is not guaranteed to function outside of its operating conditions.

Recommended Operating Conditions

Item	**Min**	**Max**	**Unit**
Operating junction temperature (1)	–40	125	°C
Operating temperature range	-40	85	°C
Input voltage V_{IN}	4.5	30	V
Output current	0	1.5	A

Note (1): All limits specified at room temperature (T_A = 25°C) unless otherwise specified. All room temperature limits are 100% production tested. All limits at temperature extremes are ensured through correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).

Thermal Information

Item	**Description**	**SOT23-6**	**Unit**
$R_{\theta JA}$	Junction-to-ambient thermal resistance (1)(2)	170	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	130	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	46	°C/W

Note (1): The package thermal impedance is calculated in accordance to JESD 51-7.

Note (2): Thermal Resistances were simulated on a 4-layer, JEDEC board

Electrical Characteristics (1) (2)

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

Parameter	Conditions	Min.	Typ.	Max.	Unit
Input Voltage Range	VIN SOA	4.0		30	V
Over Voltage Protection Threshold			33		V
Quiescent current into VIN pin	V_{IN} =12V, Out=5V, Iload=0A	2	5.0	10	mA
Shutdown current into VIN pin	V_{EN} = 0V, V_{IN} = 12V			3	µA
Regulated Feedback Voltage	V_{IN}=12V, T_A=25°C	790	800	810	mV
Output Voltage Line Regulation	V_{IN} = 4.5V to 30V			1	%
Output Voltage Load Regulation	V_{IN} =12V, Out=5V, ΔV_{LOAD}(0.-1.5A)			1	%
Oscillation Frequency1	V_{IN} =12V, Out=5V, Iload=1A	1.0	1.2	1.5	MHz
High-Side Switch On-Resistance	I_{SW}= 1000mA		200		mΩ
Low-Side Switch On-Resistance	I_{SW}=-1000mA		120		mΩ
High-Side Switch Current Limit	V_{IN}= 12V, FB=90%		2.5		A
Low-Side Switch Current Limit	V_{IN}= 12V, FB=90%		2		A
V_{IN} Under-Voltage Lockout Threshold			3.7		V
V_{IN} Under-Voltage Lockout Threshold-Hysteresis			300		mV
EN Rising Threshold		1.5			V
EN Falling Threshold				0.4	V
EN Threshold Hysteresis			200		mV
EN Leakage Current				1.0	µA
SW Leakage Current	V_{EN}=0V, V_{IN}=Vsw=24V			1.0	µA
Soft Start		0.8	1	1.2	mS
Thermal Shutdown			160		℃
Thermal Hysteresis			30		℃

Note (1): MOSFET on-resistance specifications are guaranteed by correlation to wafer level measurements.

Note (2): Thermal shutdown specifications are guaranteed by correlation to the design and characteristics analysis.

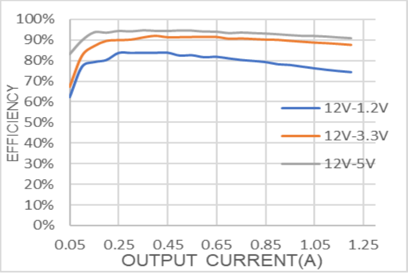
Typical Performance Characteristics (1) (2)

Note (1): Performance waveforms are tested on the evaluation board.

Note (2): V_{IN} =12V, V_{OUT}=3.3V, T_A = +25ºC, unless otherwise noted.

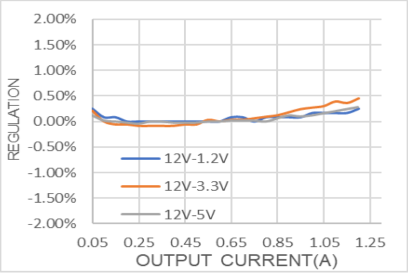
Efficiency vs Load Current

V_{OUT}=5V, 3.3V, 1.2V



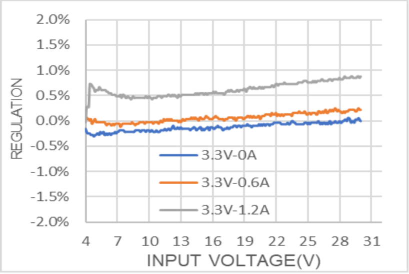
Load Regulation

V_{OUT}=5V, 3.3V, 1.2



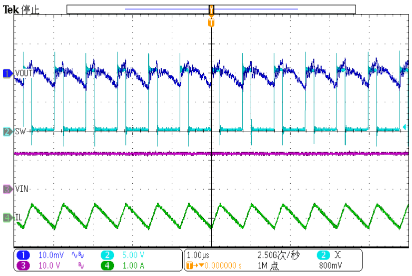
Line Regulation

V_{OUT}=3.3V



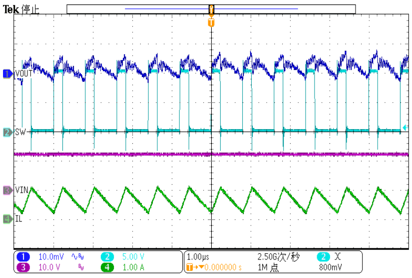
Output Ripple Voltage

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



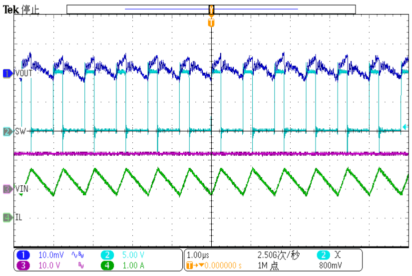
Output Ripple Voltage

V_{IN}=12V, V_{OUT}=3.3V, I_{OUT}=0.6A



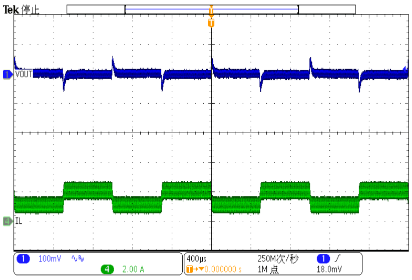
Output Ripple Voltage

V_{IN}=12V, V_{OUT}=3.3V, I_{OUT}=1.2A



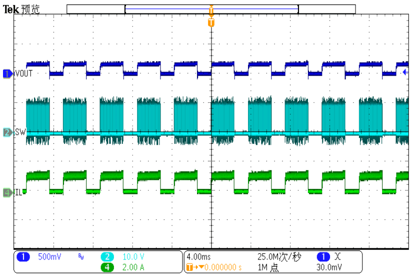
Loop Response

V_{IN}=12V, V_{OUT}=3.3V, I_{OUT}=0.6A-1.2A



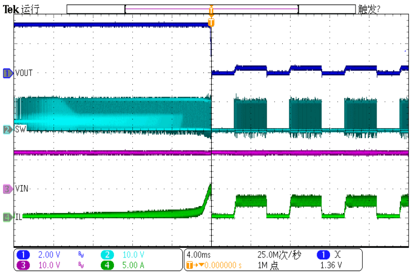
Output Short

V_{IN}=12V, V_{OUT}=3.3V



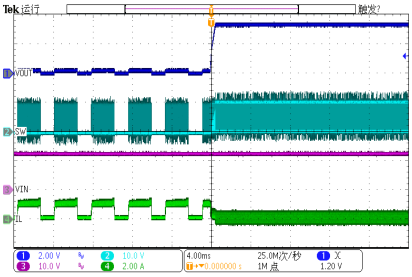
Short Circuit Entry

V_{IN}=12V, V_{OUT}=3.3V



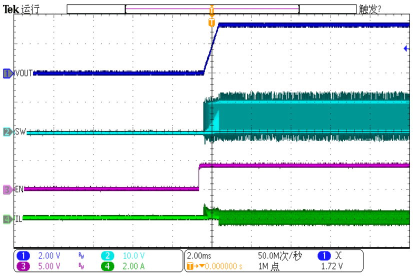
Short Circuit Recovery

V_{IN}=12V, V_{OUT}=3.3V



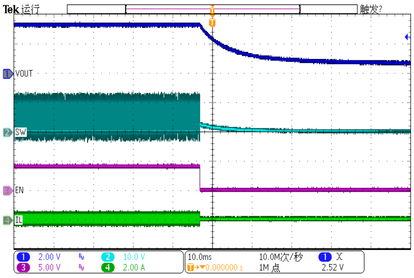
Enable Startup at No Load

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



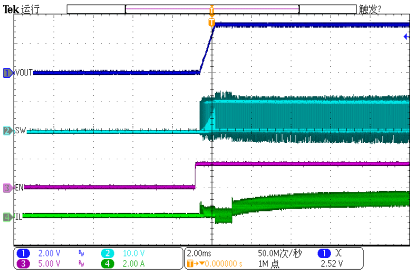
Enable Shutdown at No Load

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



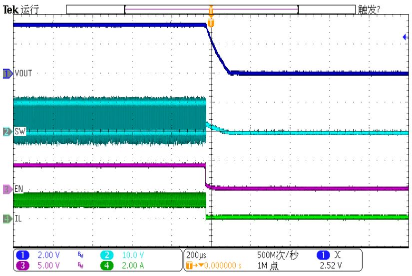
Enable Startup at Full Load

V_{IN}=12V, V_{OUT}=3.3V, I_{OUT}=1.2A



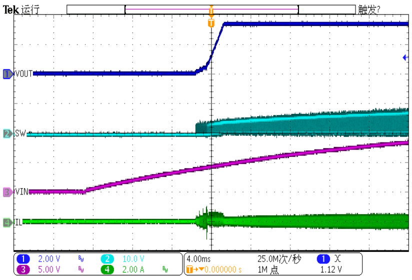
Enable Shutdown at Full Load

V_{IN}=12V, V_{OUT}=3.3V, I_{OUT}=1.2A



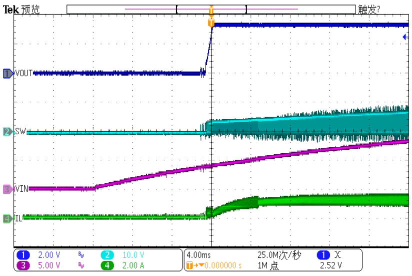
Power Up at No Load

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

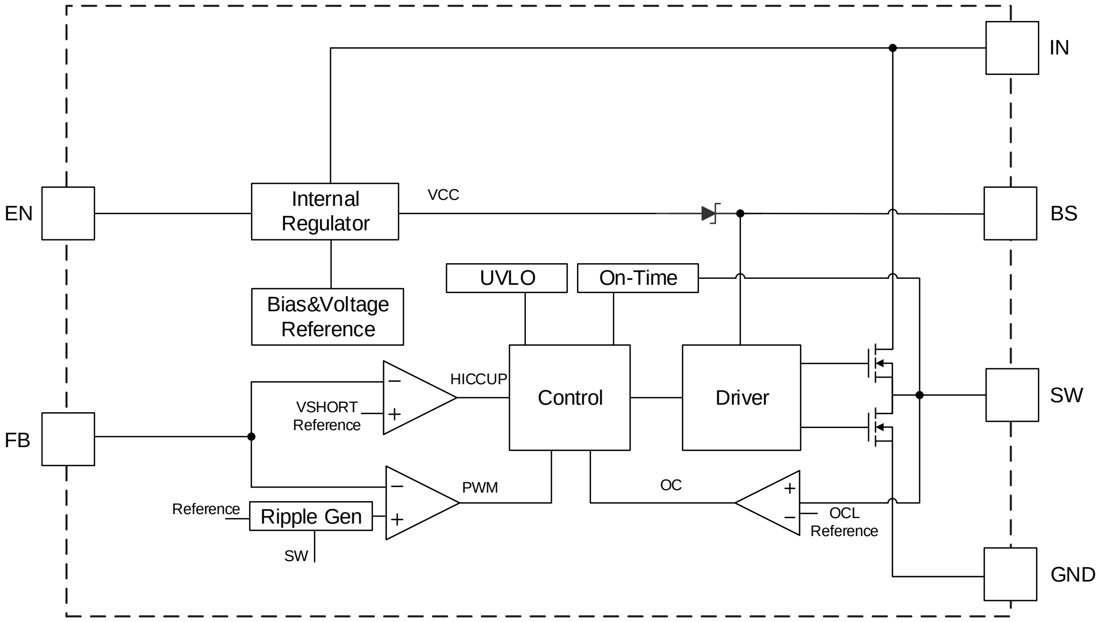


Power Up at Full Load

V_{IN}=12V, V_{OUT}=3.3V, I_{OUT}=1.2A



Functional Block Diagram



Block Diagram

Functions Description

Internal Regulator

The HE9421 is a current mode step down DC/DC converter that provides excellent transient response with no extra external compensation components. This device contains an internal, low resistance, high voltage power MOSFET, and operates at a high 1.2MHz operating frequency to ensure a compact, high efficiency design with excellent AC and DC performance.

Error Amplifier

The error amplifier compares the FB pin voltage with the internal FB reference (V_{FB}) and outputs a current proportional to the difference between the two. This output current is then used to charge or discharge the internal compensation network, which is used to control the power MOSFET current. The optimized internal compensation network minimizes the external component counts and simplifies the control loop design.

Under-Voltage Lockout (UVLO)

Under-voltage lockout (UVLO) protects the chip from operating at an insufficient supply voltage. UVLO protection monitors the internal regulator voltage. When the voltage is lower than UVLO threshold voltage, the device is shut off. When the voltage is higher than UVLO threshold voltage, the device is enabled again.

Thermal Shutdown

Thermal shutdown prevents the chip from operating at exceedingly high temperatures. When the silicon die temperature exceeds 160°C, it shuts down the whole chip. When the temperature falls below its lower threshold (Typ. 130°C) the chip is enabled again.

Internal Soft-Start

The soft-start is implemented to prevent the converter output voltage from overshooting during startup. When the chip starts, the internal circuitry generates a soft-start voltage (SS) ramping up from 0V to 0.8V. When it is lower than the internal reference (REF), SS overrides REF so the error amplifier uses SS as the reference. When SS is higher than REF, REF regains control. The SS time is internally max to 1ms.

Over Current Protection and Hiccup

The HE9421 has cycle-by-cycle over current limit when the inductor current peak value exceeds the set current limit threshold. Meanwhile, output voltage starts to drop until FB is below the Under-Voltage (UV) threshold. Once a UV is triggered, the HE9421 enters hiccup mode to periodically restart the part. This protection mode is especially useful when the output is dead-short to ground. The average short circuit current is greatly reduced to alleviate the thermal issue and to protect the regulator. The HE9421 exits the hiccup mode once the over current condition is removed.

Startup and Shutdown

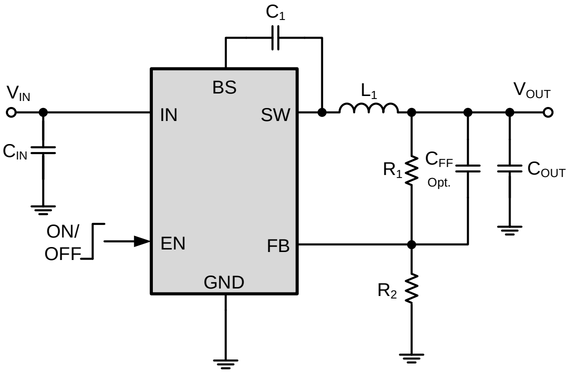
If both V_{IN} and EN are higher than their appropriate thresholds, the chip starts. The reference block starts first, generating stable reference voltage and currents, and then the internal regulator is enabled. The regulator provides stable supply for the remaining circuitries. Three events can shut down the chip: EN low, V_{IN} low and thermal shutdown. In the shutdown procedure, the signaling path is first blocked to avoid any fault triggering. The comp voltage and the internal supply rail are then pulled down. The floating driver is not subject to this shutdown command.

Applications Information

Setting the Output Voltage

HE9421 require an input capacitor, an output capacitor and an inductor. These components are critical to the performance of the device. HE9421 are internally compensated and do not require external components to achieve stable operation. The output voltage can be programmed by resistor divider.

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



V_{OUT}	**R1**	**R2**	**L1**	**C1**	**C_{IN}**	**C_{OUT}**	**C_{FF} Opt.**
3.3V	47KΩ 1%	15KΩ 1%	2.2-22µH 2A	>10V 0.1uF X5R	10uF X5R	22uF X5R	10-100pF
5.0V	43KΩ 1%	8.2KΩ 1%	2.2-22µH 2A	>10V 0.1uF X5R	10uF X5R	22uF X5R	10-100pF
12V	43KΩ 1%	3K 1%	6.8-22µH 2A	>10V 0.1uF X5R	10uF X5R	22uF X5R	10-100pF

Selecting the Inductor

The recommended inductor values are shown in the Application Diagram. It is important to guarantee the inductor core does not saturate during any foreseeable operational situation. The inductor should be rated to handle the maximum inductor peak current: Care should be taken when reviewing the different saturation current ratings that are specified by different manufacturers. Saturation current ratings are typically specified at 25°C, so ratings at maximum ambient temperature of the application should be requested from the manufacturer. The inductor value can be calculated with:

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times F_{OSC}}$$

Where ΔI_L is the inductor ripple current. Choose inductor ripple current to be approximately 30% to 40% of the maximum load current. The maximum inductor peak current can be estimated as:

$$I_{L(MAX)} = I_{LOAD} + \frac{\Delta I_L}{2}$$

Under light load conditions below 100mA, larger inductance is recommended for improved efficiency. Larger inductances lead to smaller ripple currents and voltages, but they also have larger physical dimensions, lower saturation currents and higher linear impedance. Therefore, the choice of inductance should be compromised according to the specific application.

Selecting the Input Capacitor

The input current to the step-down converter is discontinuous and therefore requires a capacitor to supply AC current to the step-down converter while maintaining the DC input voltage. For a better performance, use ceramic capacitors placed as close to VIN as possible and a 0.1μF input capacitor to filter out high frequency interference is recommended. Capacitors with X5R and X7R ceramic dielectrics are recommended because they are stable with temperature fluctuations.

The capacitors must also have a ripple current rating greater than the maximum input ripple current of the converter. The input ripple current can be estimated with Equation:

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

From the above equation, it can be concluded that the input ripple current reaches its maximum at $V_{IN}=2V_{OUT}$ where $I_{CIN} = \frac{I_{OUT}}{2}$. For simplification, choose an input capacitor with an RMS current rating greater than half of the maximum load current.

The input capacitance value determines the input voltage ripple of the converter. If there is an input voltage ripple requirement in the system, choose the input capacitor that meets the specification. The input voltage ripple can be estimate with Equation:

$$\Delta V_{IN} = \frac{I_{OUT}}{F_{OSC} \times C_{IN}} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Similarly, when $V_{IN}=2V_{OUT}$, input voltage ripple reaches its maximum of $\Delta V_{IN} = \frac{1}{4} \times \frac{I_{OUT}}{F_{OSC} \times C_{IN}}$.

Selecting the Output Capacitor

An output capacitor is required to maintain the DC output voltage. The output voltage ripple can be estimated with Equation:

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

There are some differences between different types of capacitors. 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 with Equation:

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

A larger output capacitor can achieve a better load transient response, but the maximum output capacitor limitation should also be considered in the design application. If the output capacitor value is too high, the output voltage will not be able to reach the design value during the soft-start time and will fail to regulate. The maximum output capacitor value (C_{OUT_MAX}) can be limited approximately with Equation:

$$C_{OUT\_MAX} = \left(I_{LIM\_AVG} - I_{OUT}\right) \times T_{SS}/V_{OUT}$$

Where L_{LIM_AVG} is the average start-up current during the soft-start period, and T_{SS} is the soft- start time.

On the other hand, special attention should be paid when selecting these components. The DC bias of these capacitors can result in a capacitance value that falls below the minimum value given in the recommended capacitor specifications table.

The ceramic capacitor's actual capacitance can vary with temperature. The capacitor type X7R, which operates over a temperature range of −55°C to +125°C, will only vary the capacitance to within ±15%. The capacitor type X5R has a similar tolerance over a reduced temperature range of −55°C to +85°C. Many large value ceramic capacitors, larger than 1uF are manufactured with Z5U or Y5V temperature characteristics. Their capacitance can drop by more than 50% as the temperature varies from 25°C to 85°C. Therefore, X5R or X7R is recommended over Z5U and Y5V in applications where the ambient temperature will change significantly above or below 25°C.

Feed-Forward Capacitor (C_{FF})

HE9421 has internal loop compensation, so adding C_{FF} is optional. Specifically, for specific applications, if necessary, consider whether to add feed-forward capacitors according to the situation.

The use of a feed-forward capacitor (C_{FF}) in the feedback network is to improve the transient response or higher phase margin. For optimizing the feed-forward capacitor, knowing the cross frequency is the first thing. The cross frequency (or the converter bandwidth) can be determined by using a network analyzer. When getting the cross frequency with no feed-forward capacitor identified, the value of feed-forward capacitor (C_{FF}) can be calculated with the following Equation:

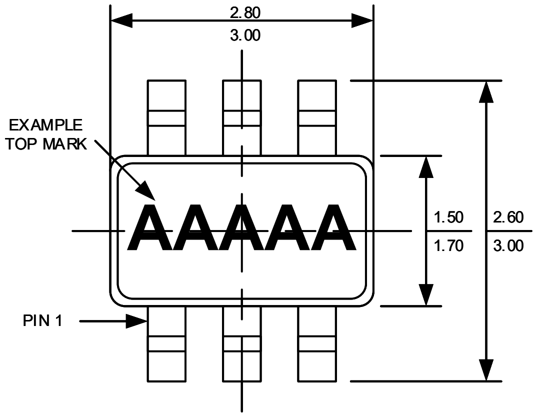
$$C_{FF} = \frac{1}{2\pi \times F_{CROSS}} \times \sqrt{\frac{1}{R1} \times \left(\frac{1}{R1} + \frac{1}{R2}\right)}$$

Where F_{CROSS} is the cross frequency.

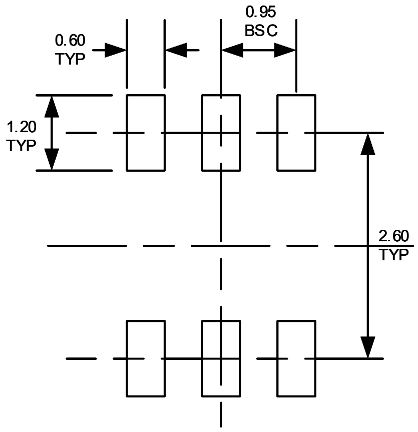
To reduce transient ripple, the feed-forward capacitor value can be increased to push the cross frequency to higher region. Although this can improve transient response, it also decreases phase margin and cause more ringing. In the other hand, if more phase margin is desired, the feed-forward capacitor value can be decreased to push the cross frequency to lower region.

Package Description

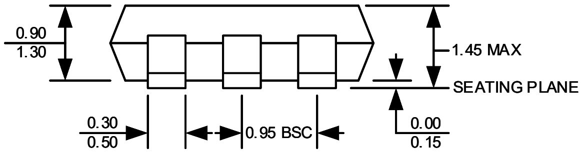
SOT23-6



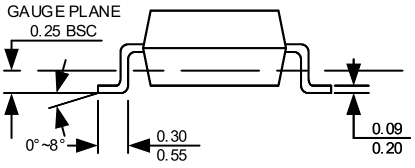
TOP VIEW



RECOMMENDED PAD LAYOUT



FRONT VIEW



SIDE VIEW

NOTE:

1. CONTROL DIMENSION IS IN INCHES. DIMENSION IN BRACKET IS IN MILLIMETERS.
2. PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.
3. PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.
4. LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.004" INCHES MAX.
5. DRAWING CONFORMS TO JEDEC MS-012, VARIATION BA.
6. DRAWING IS NOT TO SCALE.