

**1.5MHz, 1A, STEP DOWN DC-DC CONVERTER** **AUR9713**

### General Description

The AUR9713 is a high efficiency step-down DC-DC voltage converter. The chip operation is optimized using constant frequency, peak-current mode architecture with built-in synchronous power MOS switchers and internal compensators to reduce external part counts. It is automatically switching between the normal PWM mode and LDO mode to offer improved system power efficiency covering a wide range of loading conditions.

The oscillator and timing capacitors are all built-in providing an internal switching frequency of 1.5MHz that allows the use only small surface mount inductors and capacitors for portable product implementations. Additional features included integrated Soft Start (SS), Under Voltage Lock OUT (UVLO).

The device is available in adjustable output voltage versions ranging from 1V to 3.3V, and is able to deliver up to 1A.

The AUR9713 is available in TSOT-23-5 package.

### Features

- High Efficiency Buck Power Converter
- Low Quiescent Current
- Output Current: 1A
- Adjustable Output Voltage from 1V to 3.3V
- Wide Operating Voltage Range: 2.5V to 5.5V
- Built-in Power Switches for Synchronous Rectification with High Efficiency
- Feedback Voltage: 600mV
- 1.5MHz Constant Frequency Operation
- Automatic PWM/LDO Mode Switching Control
- Thermal Shutdown Protection
- Low Drop-out Operation at 100% Duty Cycle
- No Schottky Diode Required
- **For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please [contact us](#) or your local Diodes representative.**
- <https://www.diodes.com/quality/product-definitions/>

### Applications

- Mobile Phone, Digital Camera and MP3 Player
- Headset, Radio and Other Hand-held Instrument
- Post DC-DC Voltage Regulation
- PDA and Notebook Computer

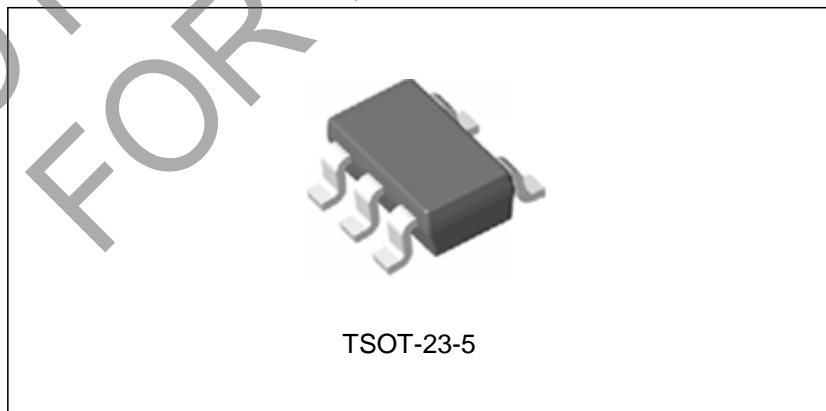


Figure 1. Package Type of AUR9713

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**Pin Configuration**

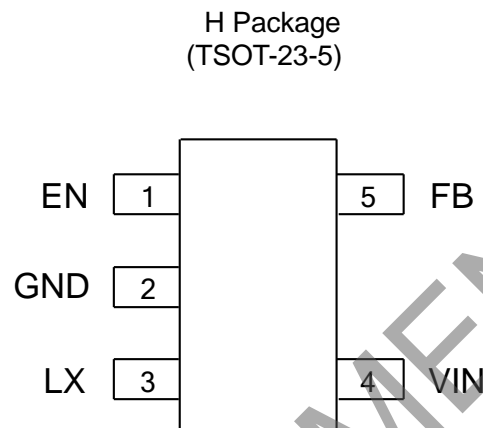


Figure 2. Pin Configuration of AUR9713 (Top View)

**Pin Description**

Pin Number	Pin Name	Function
1	EN	Enable signal input, active high
2	GND	This pin is the GND reference for the NMOS power stage. It must be connected to the system ground
3	LX	Connected to inductor
4	VIN	Power supply input
5	FB	Feedback voltage from the output

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**Functional Block Diagram**

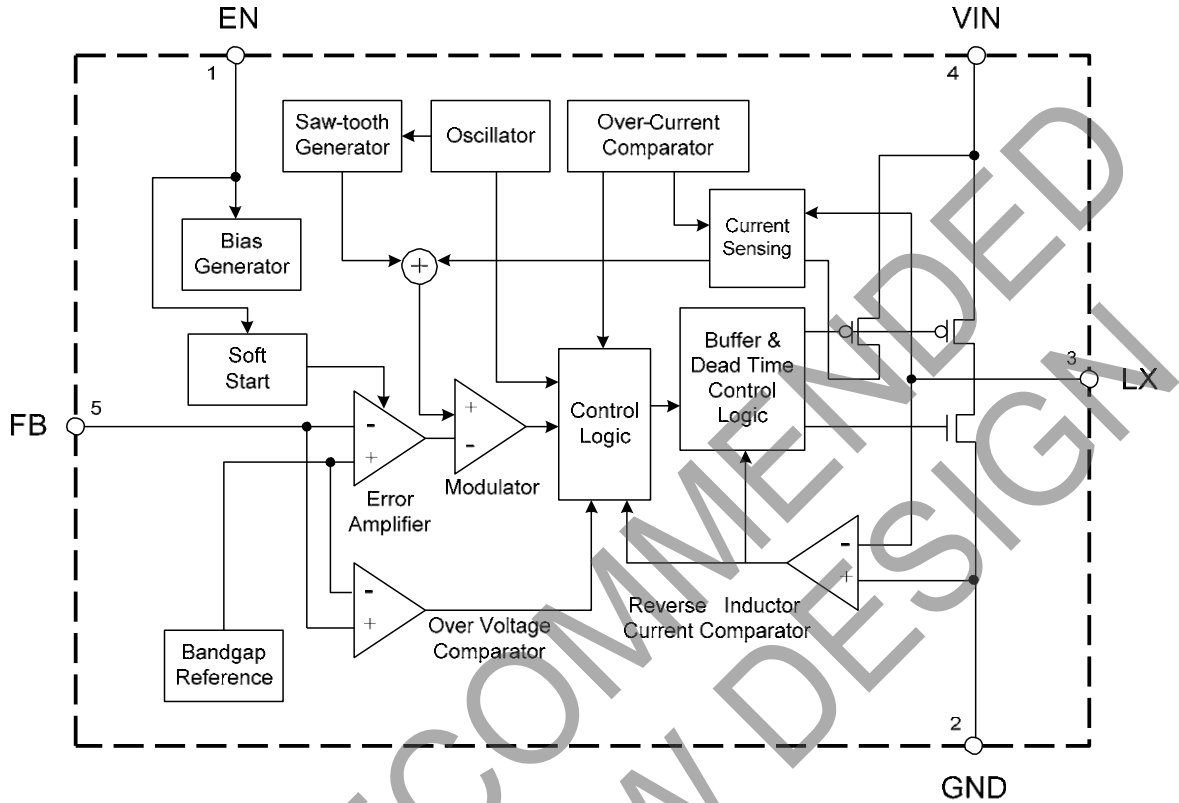
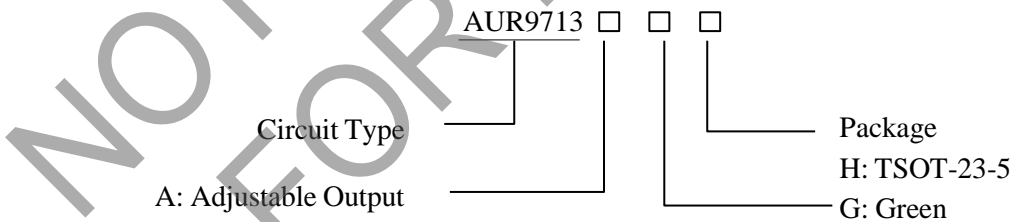


Figure 3. Functional Block Diagram of AUR9713

**Ordering Information**



Package	Temperature Range	Part Number	Marking ID	Packing Type
TSOT-23-5	-40 to 80 °C	AUR9713AGH	9713AG	Tape & Reel

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**Absolute Maximum Ratings (Note 1)**

Parameter	Symbol	Value	Unit
Supply Input Voltage	$V_{IN}$	0 to 6.5	V
Enable Input Voltage	$V_{EN}$	-0.3 to $V_{IN}+0.3$	V
Output Voltage	$V_{OUT}$	-0.3 to $V_{IN}+0.3$	V
Power Dissipation (On PCB, $T_A=30\text{ }^\circ\text{C}$ )	$P_D$	0.96	W
Thermal Resistance (Junction to Ambient, Simulation)	$\theta_{JA}$	98.4	$^\circ\text{C/W}$
Thermal Resistance (Junction to Case, Simulation)	$\theta_{JC}$	35.2	$^\circ\text{C/W}$
Operating Junction Temperature	$T_J$	160	$^\circ\text{C}$
Operating Temperature	$T_O$	-40 to 85	$^\circ\text{C}$
Storage Temperature	$T_S$	-55 to 150	$^\circ\text{C}$
ESD (Human Body Model)	$V_{HBM}$	2000	V
ESD (Machine Model)	$V_{MM}$	200	V

Note 1: Stresses greater than those listed under “Absolute Maximum Ratings” 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 under “Recommended Operating Conditions” is not implied. Exposure to “Absolute Maximum Ratings” for extended periods may affect device reliability.

**Recommended Operating Conditions**

Parameter	Symbol	Min	Max	Unit
Supply Input Voltage	$V_{IN}$	2.5	5.5	V
Junction Temperature Range	$T_J$	-20	125	$^\circ\text{C}$
Ambient Temperature Range	$T_A$	-40	80	$^\circ\text{C}$

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**Electrical Characteristics**
 $V_{IN}=3.6V$ ,  $V_{OUT}=2.5V$ ,  $V_{REF}=0.6V$ ,  $L=2.2\mu H$ ,  $C_{IN}=4.7\mu F$ ,  $C_{OUT}=10\mu F$ ,  $T_A=25^\circ C$ ,  $I_{MAX}=1A$ .

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Input Voltage Range	$V_{IN}$		2.5		5.5	V
Shutdown Current	$I_{OFF}$	$V_{EN}=0$		0.1	1	$\mu A$
Regulated Feedback Voltage	$V_{FB}$	For Adjustable Output Voltage	0.585	0.6	0.615	V
Regulated Output Voltage Accuracy	$\Delta V_{OUT}/V_{OUT}$	$V_{IN}=2.5V$ to $5.5V$ ; $I_{OUT}=0$ to $1A$	-3		3	%
Peak Inductor Current	$I_{PK}$	$V_{IN}=3V$ , $V_{FB}=0.5V$ or $V_{OUT}=90%$ , Duty Cycle $< 35\%$		1.5		A
Oscillator Frequency	$f_{OSC}$	$V_{IN}=3.6V$	1.2	1.5	1.8	MHz
PMOSFET $R_{ON}$	$R_{ON(P)}$	$V_{IN}=3.6V$ , $I_{OUT}=200mA$		0.28		$\Omega$
NMOSFET $R_{ON}$	$R_{ON(N)}$	$V_{IN}=2.5V$ , $I_{OUT}=200mA$		0.38		$\Omega$
Quiescent Current	$I_Q$	$I_{LOAD}=0mA$ , $V_{FB}=V_{REF}+5\%$		100		$\mu A$
LX Leakage Current	$I_{LX}$	$V_{IN}=5V$ , $V_{EN}=0V$ , $V_{LX}=0V$ or $5V$		0.01	0.1	$\mu A$
Feedback Current	$I_{FB}$				30	nA
EN Leakage Current	$I_{EN}$			0.01	0.1	$\mu A$
EN High-level Input Voltage	$V_{EN\_H}$	$V_{IN}=2.5V$ to $5.5V$	1.5			V
EN Low-Level Input Voltage	$V_{EN\_L}$	$V_{IN}=2.5V$ to $5.5V$			0.6	V
Under Voltage Lock Out				1.8		V
Hysteresis				0.1		V
Thermal Shutdown	$T_{SD}$			150		$^\circ C$

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**Typical Performance Characteristics**

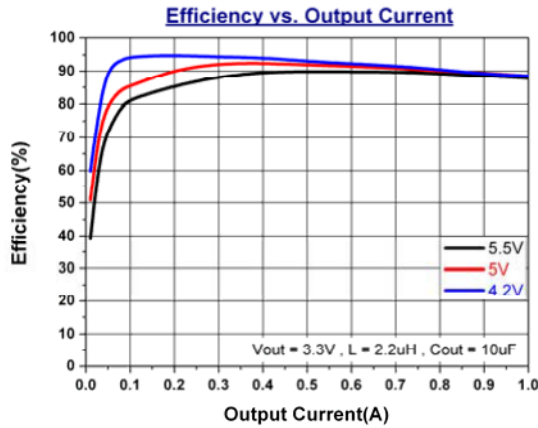


Figure 4. Efficiency vs. Output Current

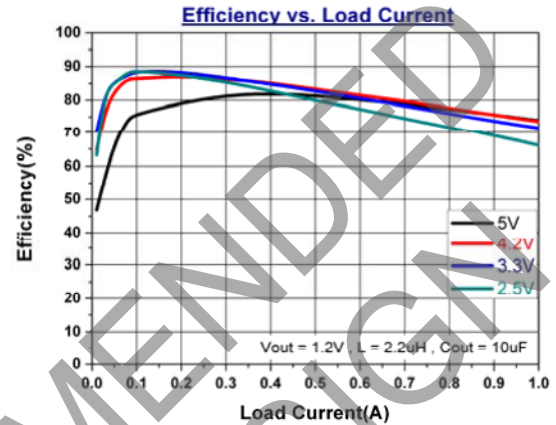


Figure 5. Efficiency vs. Load Current

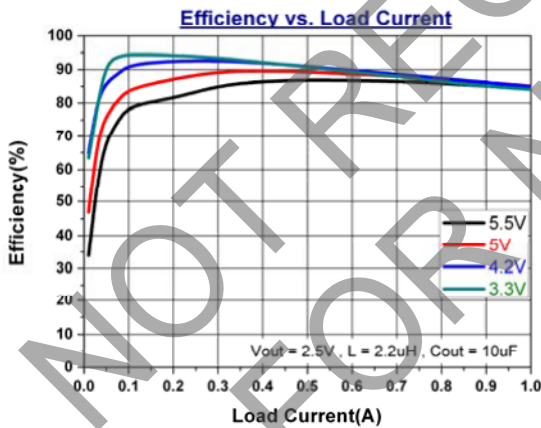


Figure 6. Efficiency vs. Load Current

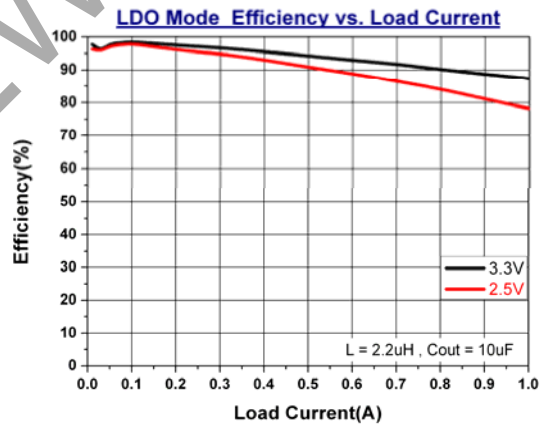


Figure 7. LDO Mode Efficiency vs. Load Current

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**Typical Performance Characteristics (Continued)**

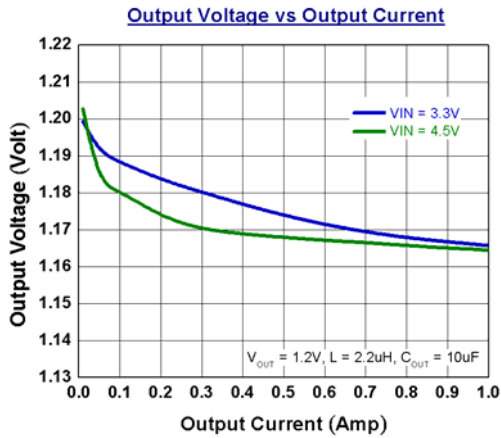


Figure 8. Output Voltage vs. Output Current

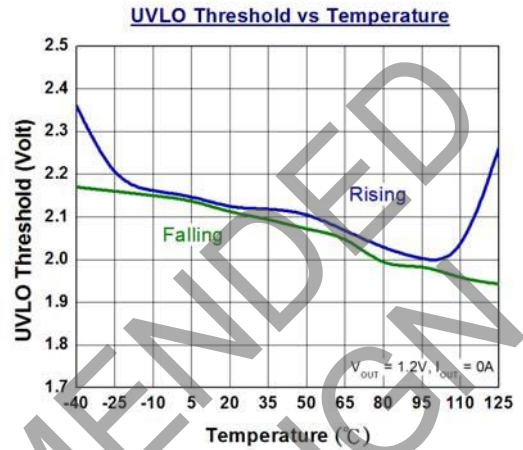


Figure 9. UVLO Threshold vs. Temperature

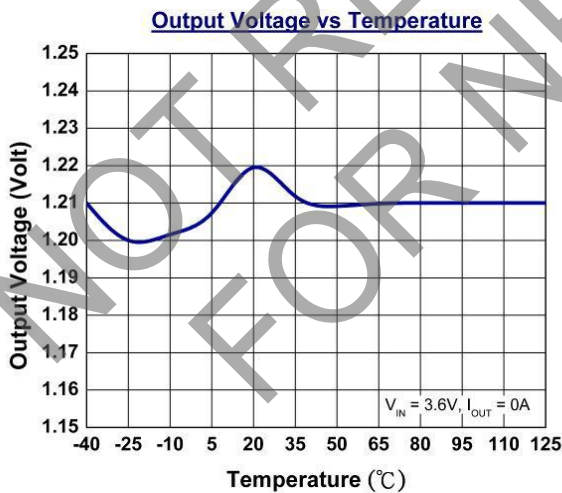


Figure 10. Output Voltage vs. Temperature

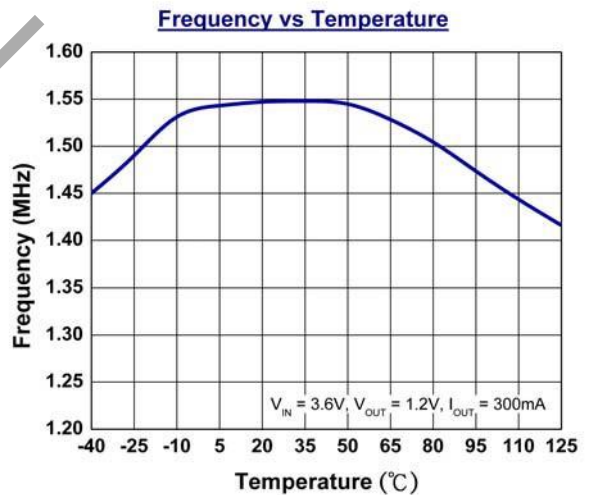


Figure 11. Frequency vs. Temperature

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**Typical Performance Characteristics (Continued)**

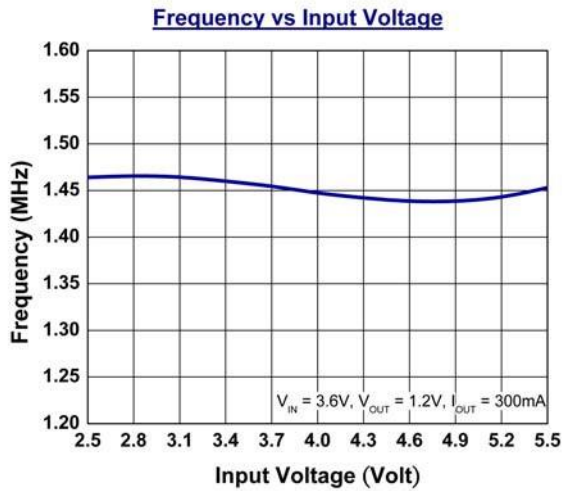


Figure 12. Frequency vs. Input Voltage

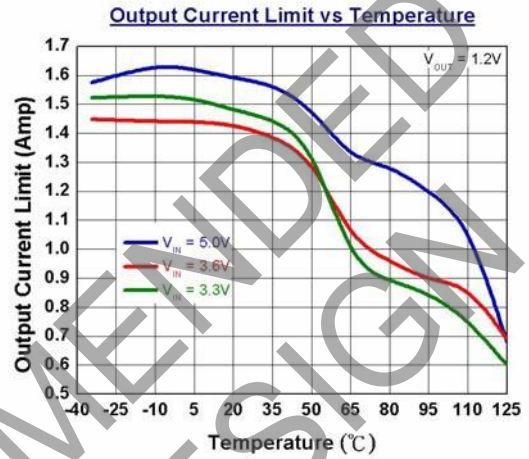


Figure 13. Output Current Limit vs. Temperature

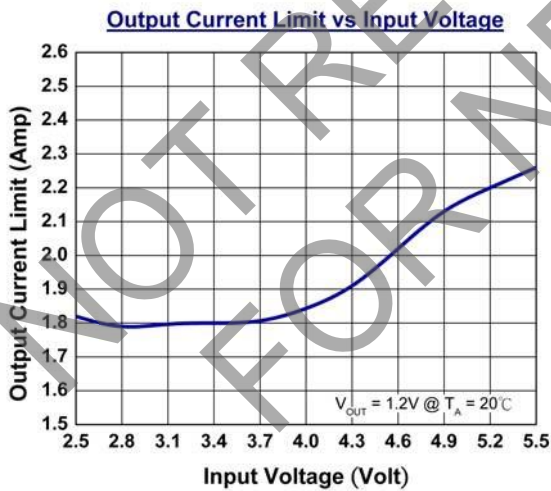


Figure 14. Frequency vs. Input Voltage

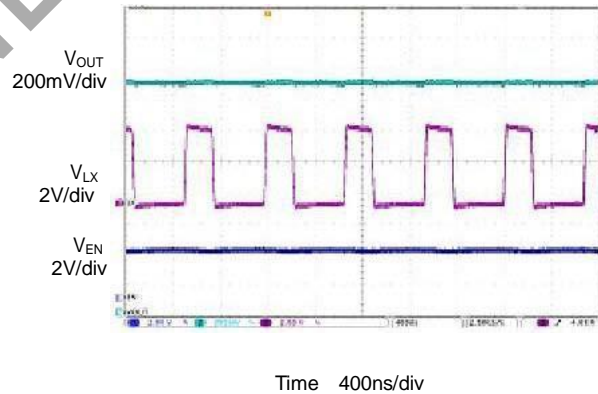


Figure 15. Waveform of  $V_{IN}=4.5V$ ,  $V_{OUT}=1.5V$ ,  $L=2.2\mu H$



**Typical Performance Characteristics (Continued)**

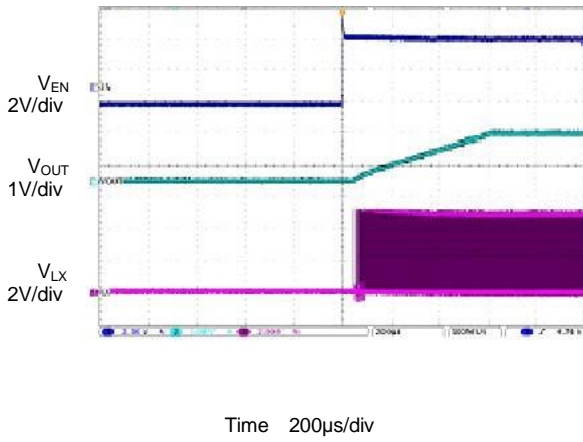


Figure 16. Soft Start

NOT RECOMMENDED  
FOR NEW DESIGN

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**Application Information**

The basic AUR9713 application circuit is shown in Figure 18, external components selection is determined by the load current and is critical with the selection of inductor and capacitor values.

**1. Inductor Selection**

For most applications, the value of inductor is chosen based on the required ripple current with the range of 2.2µH to 4.7µH.

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

The largest ripple current occurs at the highest input voltage. Having a small ripple current reduces the ESR loss in the output capacitor and improves the efficiency. The highest efficiency is realized at low operating frequency with small ripple current. However, larger value inductors will be required. A reasonable starting point for ripple current setting is  $\Delta I_L = 40\% I_{MAX}$ . For a

maximum ripple current stays below a specified value, the inductor should be chosen according to the following equation:

$$L = \left[ \frac{V_{OUT}}{f \times \Delta I_L (MAX)} \right] \left[ 1 - \frac{V_{OUT}}{V_{IN} (MAX)} \right]$$

The DC current rating of the inductor should be at least equal to the maximum output current plus half the highest ripple current to prevent inductor core saturation. For better efficiency, a lower DC-resistance inductor should be selected.

**2. Capacitor Selection**

The input capacitance,  $C_{IN}$ , is needed to filter the trapezoidal current at the source of the top MOSFET. To prevent large ripple voltage, a low ESR input capacitor sized for the maximum RMS current must be used. The maximum RMS capacitor current is given by:

$$I_{RMS} = I_{OMAX} \times \left[ \frac{V_{OUT}}{V_{IN}} \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \right]^{\frac{1}{2}}$$

It indicates a maximum value at  $V_{IN} = 2V_{OUT}$ , where  $I_{RMS} = I_{OUT}/2$ . This simple worst-case condition is commonly used for design because even significant

deviations do not much relieve. The selection of  $C_{OUT}$  is determined by the Effective Series Resistance (ESR) that is required to minimize output voltage ripple and load step transients, as well as the amount of bulk capacitor that is necessary to ensure that the control loop is stable. Loop stability can be also checked by viewing the load step transient response as described in the following section. The output ripple,  $\Delta V_{OUT}$ , is determined by:

$$\Delta V_{OUT} \leq \Delta I_L \left[ ESR + \frac{1}{8 \times f \times C_{OUT}} \right]$$

The output ripple is the highest at the maximum input voltage since  $\Delta I_L$  increases with input voltage.

**3. Load Transient**

A switching regulator typically takes several cycles to respond to the load current step. When a load step occurs,  $V_{OUT}$  immediately shifts by an amount equal to  $\Delta I_{LOAD} \times ESR$ , where ESR is the effective series resistance of output capacitor.  $\Delta I_{LOAD}$  also begins to charge or discharge  $C_{OUT}$  generating a feedback error signal used by the regulator to return  $V_{OUT}$  to its steady-state value. During the recovery time,  $V_{OUT}$  can be monitored for overshoot or ringing that would indicate a stability problem.

**4. Output Voltage Setting**

The output voltage of AUR9713 can be adjusted by a resistive divider according to the following formula:

$$V_{OUT} = V_{REF} \times \left(1 + \frac{R_1}{R_2}\right) = 0.6V \times \left(1 + \frac{R_1}{R_2}\right)$$

The resistive divider senses the fraction of the output voltage as shown in Figure 17.

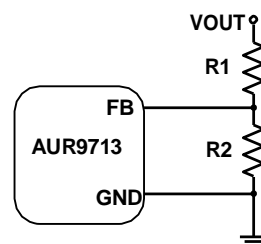


Figure 17. Setting the Output Voltage

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**Application Information (Continued)**
**5. Efficiency Considerations**

The efficiency of switching regulator is equal to the output power divided by the input power times 100%. It is usually useful to analyze the individual losses to determine what is limiting efficiency and which change could produce the largest improvement. Efficiency can be expressed as:

$$\text{Efficiency} = 100\% - L_1 - L_2 - \dots$$

Where L1, L2, etc. are the individual losses as a percentage of input power.

Although all dissipative elements in the regulator produce losses, two major sources usually account for most of the power losses:  $V_{IN}$  quiescent current and  $I^2R$  losses. The  $V_{IN}$  quiescent current loss dominates the efficiency loss at very light load currents and the  $I^2R$  loss dominates the efficiency loss at medium to heavy load currents.

**5.1** The  $V_{IN}$  quiescent current loss comprises two parts: the DC bias current as given in the electrical characteristics and the internal MOSFET switch gate charge currents. The gate charge current results from switching the gate capacitance of the internal power MOSFET switches. Each cycle the gate is switched from high to low, then to high again, and the packet of charge,  $dQ$  moves from  $V_{IN}$  to ground. The resulting  $dQ/dt$  is the current out of  $V_{IN}$  that is typically larger than the internal DC bias current. In continuous mode,

$$I_{GATE} = f \times (Q_P + Q_N)$$

Where  $Q_P$  and  $Q_N$  are the gate charge of power PMOSFET and NMOSFET switches. Both the DC bias current and gate charge losses are proportional to the  $V_{IN}$  and this effect will be more serious at higher input voltages.

**5.2**  $I^2R$  losses are calculated from internal switch resistance,  $R_{SW}$  and external inductor resistance  $R_L$ . In continuous mode, the average output current flowing through the inductor is chopped between power PMOSFET switch and NMOSFET switch. Then, the series resistance looking into the LX pin is

a function of both PMOSFET  $R_{DS(ON)}$  and NMOSFET

$R_{DS(ON)}$  resistance and the duty cycle (D):

$$R_{SW} = R_{DS(ON)P} \times D + R_{DS(ON)N} \times (1 - D)$$

Therefore, to obtain the  $I^2R$  losses, simply add  $R_{SW}$  to  $R_L$  and multiply the result by the square of the average output current.

Other losses including  $C_{IN}$  and  $C_{OUT}$  ESR dissipative losses and inductor core losses generally account for less than 2 % of total additional loss.

**6. Thermal Characteristics**

In most applications, the part does not dissipate much heat due to its high efficiency. However, in some conditions when the part is operating in high ambient temperature with high  $R_{DS(ON)}$  resistance and high duty cycles, such as in LDO mode, the heat dissipated may exceed the maximum junction temperature. To avoid the part from exceeding maximum junction temperature, the user should do some thermal analysis. The maximum power dissipation depends on the layout of PCB, the thermal resistance of IC package, the rate of surrounding airflow and the temperature difference between junction and ambient.

**7. PCB Layout Considerations**

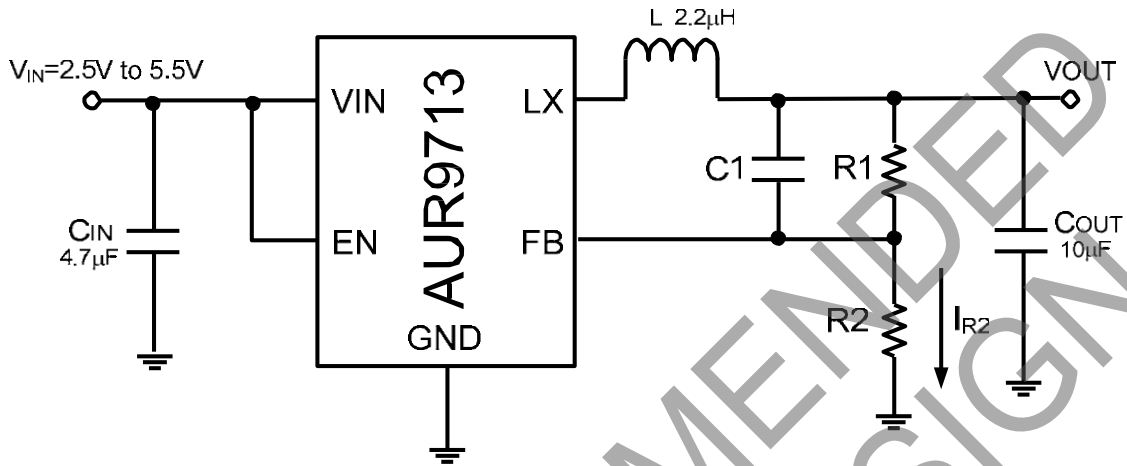
When laying out the printed circuit board, the following checklist should be used to optimize the performance of AUR9713.

- 1) The power traces, including the GND trace, the LX trace and the VIN trace should be kept direct, short and wide.
- 2) Put the input capacitor as close as possible to the VIN and GND pins.
- 3) The FB pin should be connected directly to the feedback resistor divider.
- 4) Keep the switching node, LX, away from the sensitive FB pin and the node should be kept small area.

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**Typical Application**



Note 3:  $V_{OUT} = V_{REF} \times (1 + \frac{R_1}{R_2})$  ;

When R2=300kΩ to 60 kΩ, the IR2=2µA to 10µA, and R1×C1 should be in the range between 3×10<sup>-6</sup> and 6×10<sup>-6</sup> for component selection.

Figure 18. Typical Application Circuit of AUR9713

**Table 1. Component Guide**

V <sub>OUT</sub> (V)	R1 (kΩ)	R2 (kΩ)	C1 (pF)	L1 (µH)
3.3	450	100	13	2.2
2.5	320	100	18	2.2
1.8	200	100	30	2.2
1.2	100	100	56	2.2
1.0	66	100	91	2.2



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