1.5MHz, 600mA, Step-Down DC-DC Converter

Features

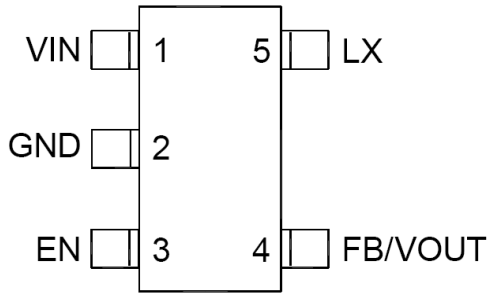
- High efficiency Buck Power Converter
- Low Quiescent Current
- 600mA Output Current
- Adjustable Output Voltage from 0.5V to Vin
- Wide Operating Voltage Ranges : 2.5 V to 5.5 V
- Built-in Power Switches for Synchronous Rectification with high Efficiency
- 500mV Feedback Voltage
- 1.5MHz Constant Frequency Operation
- Automatic PWM/LDO Mode switching control
- Thermal Shutdown protection
- Low Drop-out Operation at 100% Duty-Cycle
- No Schottky Diode Required

Applications

- Battery-Powered Devices
- Mobile Phones, Digital Cameras and MP3 Players
- Headsets, Radios and other Hand-Held Instruments
- Post DC-DC Voltage Regulation
- PDA and Notebook Computers

Package Information

(TOP VIEW)



SOT-23-5/TSOT-23-5

Description

AUR9704 is a high efficiency step-down DC-DC voltage converter designed ideally for portable applications with battery voltage supplies. 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.

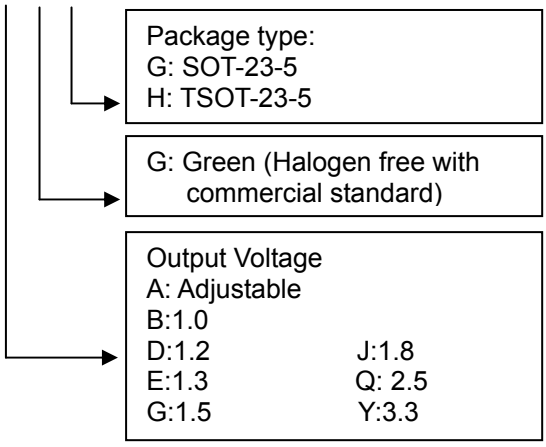
The oscillator and timing capacitors are all built-in providing an internal switching frequency of 1.5MHz that allows the use only small surface mount inductors and capacitors for portable product implementations.

Additional features included integrated soft-start (SS), under-voltage-lock-out (UVLO) and thermal shutdown detection (TSD) to provide reliable product applications.

The device is available in adjustable output voltage versions ranging from 0.5V to Vin, and is able to deliver up to 600mA.

Order Information

AUR9704□□□



Typical Application Circuits

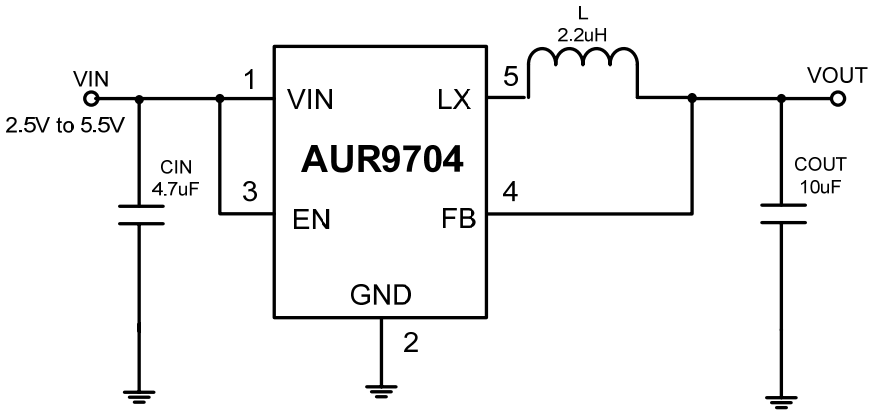


Figure1. Fixed Voltage Regulator

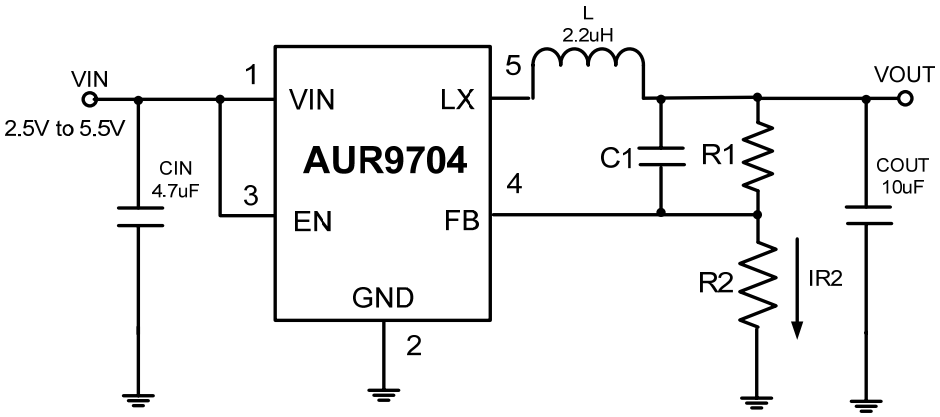


Figure2. Adjustable Voltage Regulator

$$V_{OUT} = V_{REF} \times (1 + \frac{R_1}{R_2}) = 0.5 \times \left(1 + \frac{R_1}{R_2}\right)$$

With R2=300 kΩ to 60 kΩ so the IR2=2uA to 10uA, $R_1 + R_2 \leq 1M\Omega$

And (R1 x C1) should be in the range between 3×10^{-6} and 6×10^{-6} for component selection

VOUT	R1(kΩ)	R2(kΩ)	C1(pF)	L1(uH)
3.3V	295	52	20	2.2
2.5V	295	73	20	2.2
1.8V	295	110	20	2.2
1.5V	295	145	20	2.2
1.2V	295	210	20	2.2
1.0V	295	250	20	2.2

Table 1. Component guide

Pin Functions

Pin No.	Pin Name	Pin Function
1	VIN	Power supply input
2	GND	This pin is the GND reference for the NMOS power stage. It must be connected to the system ground.
3	EN	Enable Signal Input, Active High.
4	FB/VOUT	Feedback voltage from the output of the power supply.
5	LX	Connection from power MOS to Inductor

Maximum Ratings

Characteristic	Symbol	Rating	Unit
Supply Input Voltage	VIN	0~7.0	V
Enable Input voltage	VI	-0.3~VIN+0.3	V
Output Voltage	VOUT	-0.3~VIN+0.3	V
Bypass Pin Voltage	VBP	-0.3~VIN+0.3	V
Power Dissipation, SOT-23-5 , TSOT-23-5 (on PCB, Ta=30°C)		--	W
Thermal resistance, SOT-23-5 , TSOT-23-5 (simulation)	θ_{JA}	--	°C/W
Thermal resistance, SOT-23-5 , TSOT-23-5 (simulation)	θ_{JC}	--	°C/W
Operating junction temperature		160	°C
Operating temperature		-40~+85	°C
Storage temperature		-55~+150	°C
ESD Withstand Voltage Human Body Model Machine Model	Vesd	 2 200	 KV V

Recommended Operating Condition

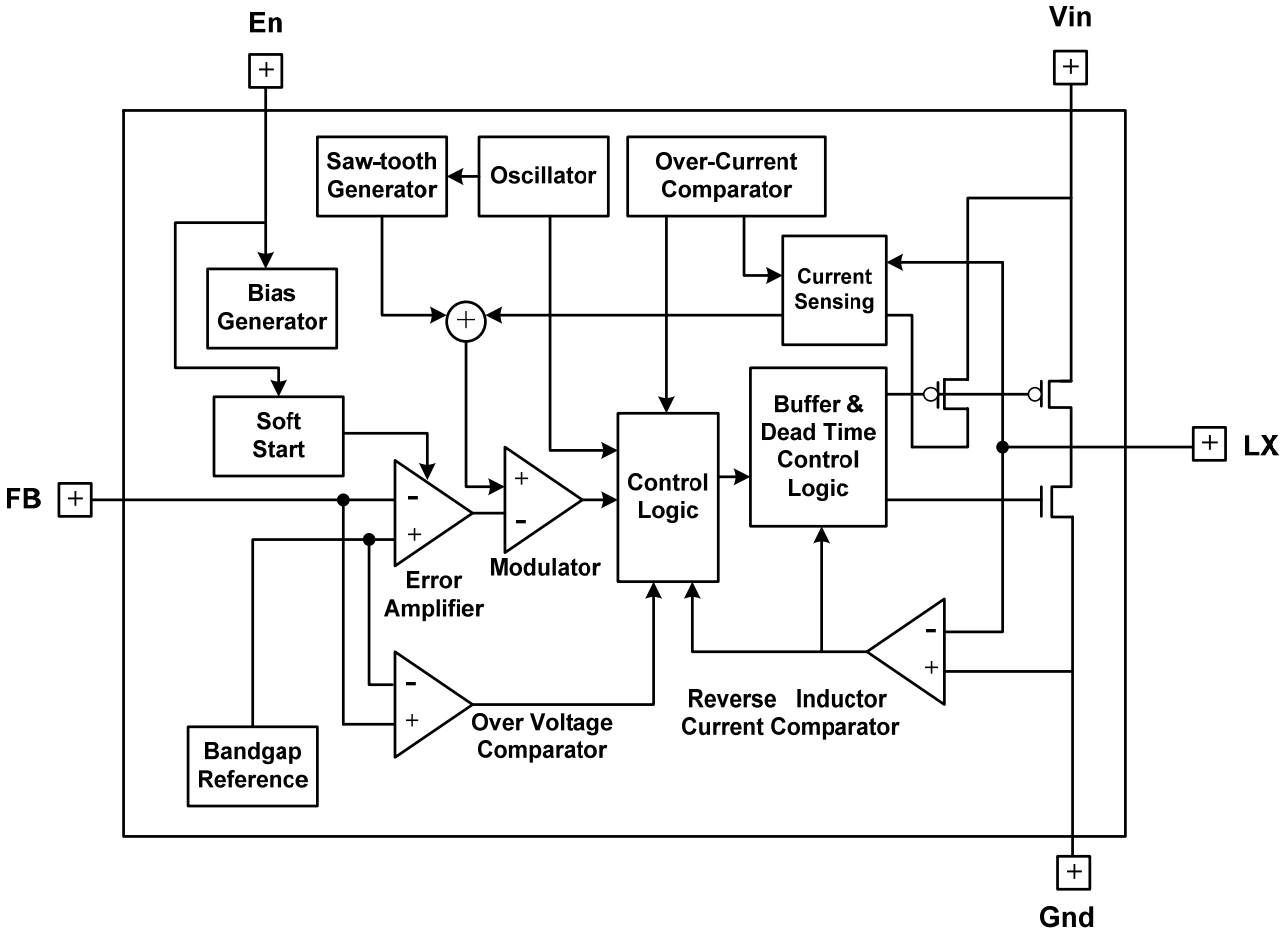
Characteristic	Symbol	Rating	Unit
Supply Input Voltage	V_{IN}	2.5 ~ 5.5	V
Junction Temperature Range		-40 ~ 125	°C
Ambient Temperature Range		-40 ~ 80	°C

Electrical Characteristics

(Vin=3.6V, Vout=2.5V, Vref=0.6V, L=4.7uH, Cin=4.7uF, Cout=10uF, Ta=25℃, Imax=600mA)

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
Input voltage Range	Vin		2.5		5.5	V
Shutdown Current	Ioff	EN=0		0.1	1	uA
Regulated Feedback voltage	VFB	For adjustable output voltage	0.49	0.5	0.51	V
Regulated Output Voltage	Vout	Vin=Vout to +5.5V 0mA<I_{out}<600mA	-3		+3	%
Peak Inductor Current	I_{PK}	Vin=3V, $V_{FB}=0.5V$ or Vout=90%, Duty Cycle<35%	0.75	1	1.25	A
Oscillator Frequency	fosc	Vin=3.6	1.2	1.5	1.8	MHz
PMOSFET Ron	Ron(P)	Vin=3.6, Iout=100mA		0.4	0.5	Ω
NMOSFET Ron	Ron(N)	Vin=3.6, Iout=100mA		0.35	0.45	Ω
Input DC Bias Current	I_S	$V_{FB}=0.5V$ or $V_{OUT}=90\%$, $I_{LOAD}=0A$		300	400	uA
LX leakage	I_{LX}	Ven=0, VLX=0V, 5V, VIN=5V		0.01	0.1	uA
Feedback Current	Ifb				30	nA
En Leakage Current	Ien			0.01	0.1	uA
En High-Level Input Voltage	VenH	Vin=2.5V ~ 5.5V	1.5			V
En Low-Level Input Voltage	VenL	Vin=2.5V ~ 5.5V			0.4	V
Under Voltage Lock Out				1.8		V
Hysteresis				0.1		V
Thermal Shutdown	Tsd			150		℃

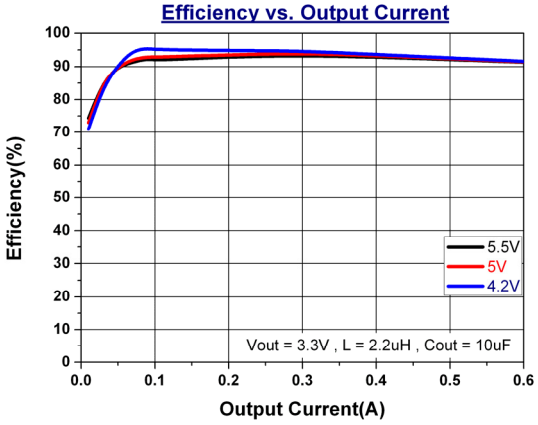
Block Diagram



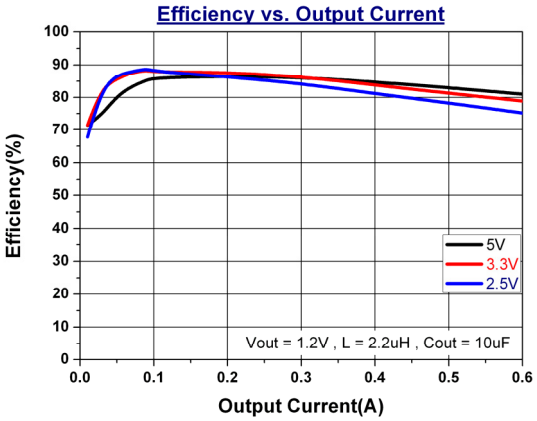
Typical Performance Characteristics

$L = 2.2\mu H, C_{IN} = 4.7\mu F, C_{OUT} = 10\mu F$

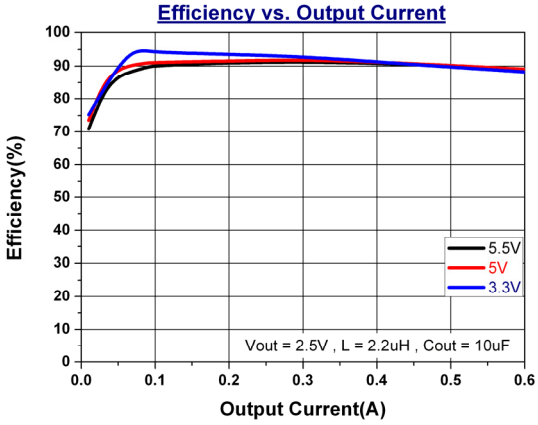
Efficiency vs. Output Current



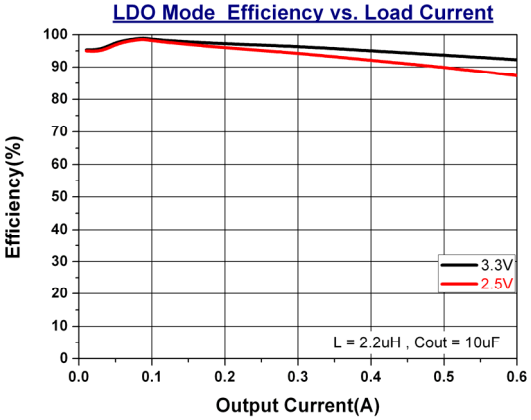
Efficiency vs. Output Current



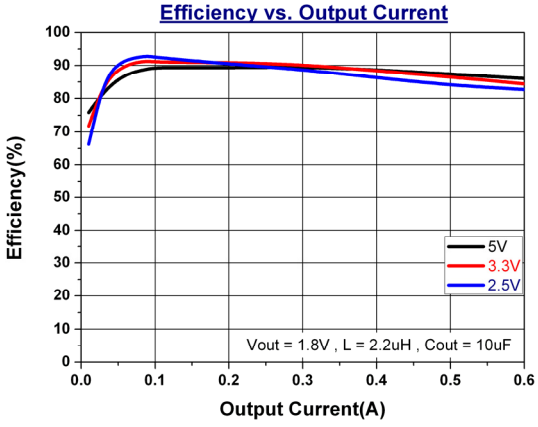
Efficiency vs. Output Current

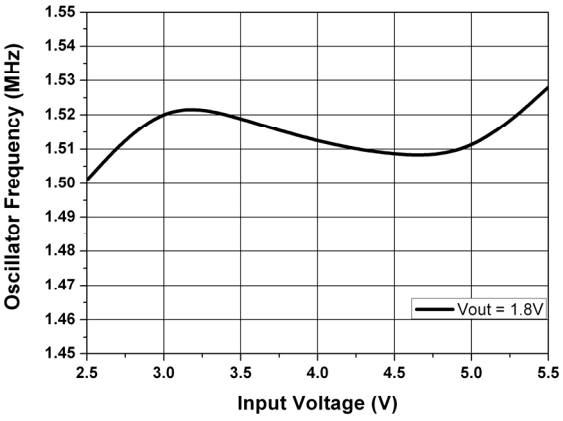


LDO Mode Efficiency vs. Load Current

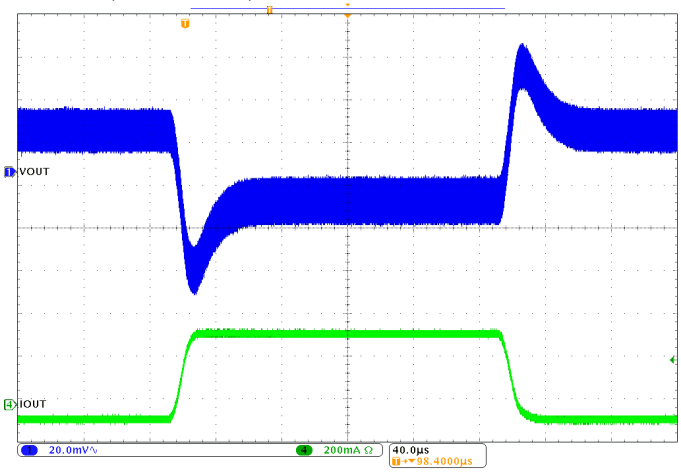


Efficiency vs. Output Current

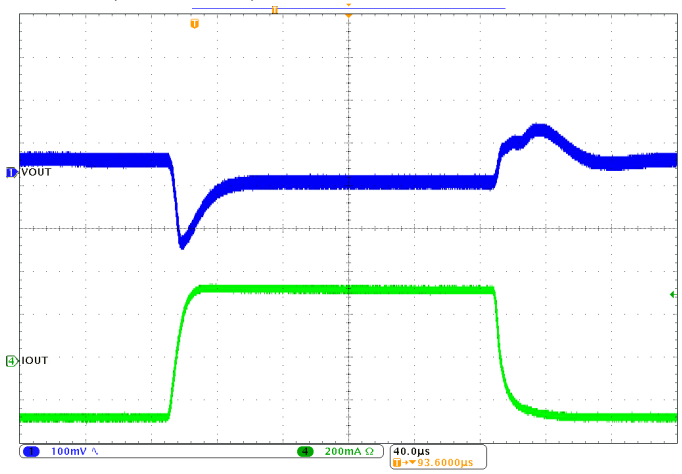




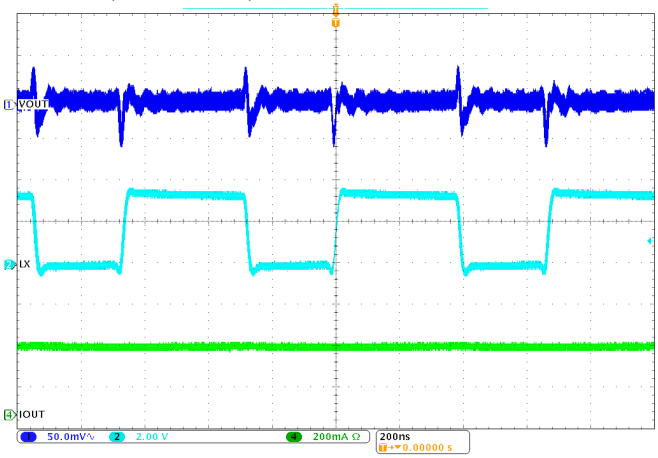
Load Step
Vin=3.6V, Vout=1.8V, Iout=0mA to 300mA



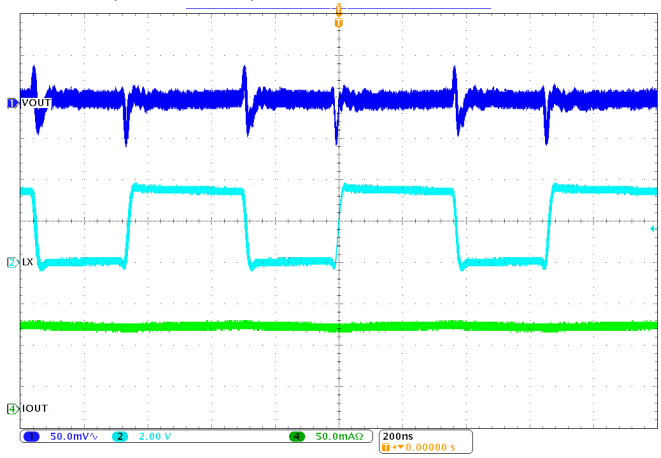
Load Step
Vin=3.6V, Vout=1.8V, Iout=0mA to 600mA



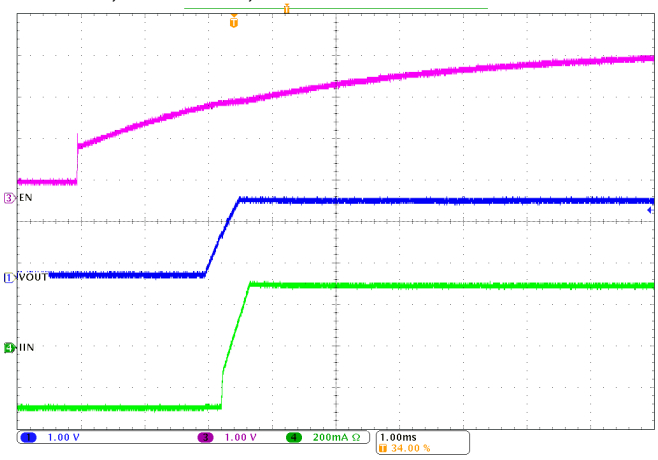
Output Ripple
Vin=3.6V, Vout=1.8V, Iout=600mA



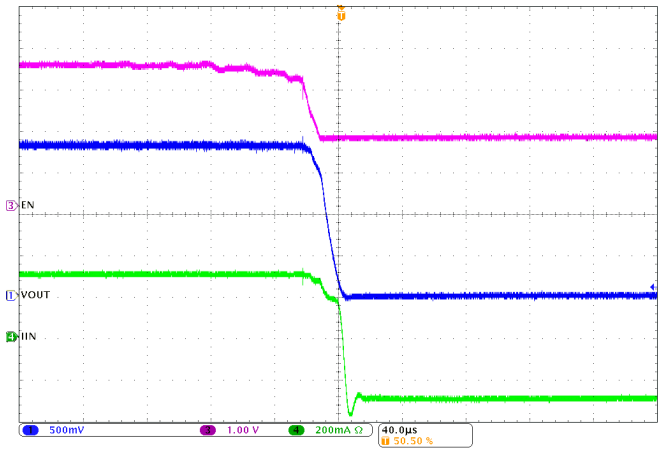
Output Ripple
Vin=3.6V, Vout=1.8V, Iout=300mA



Power Turn On
Vin=3.6V, Vout=1.8V, Iout=600mA



Power Turn Off
Vin=3.6V, Vout=1.8V, Iout=600mA



Application Information

The basic AUR9704 application circuits are shown as in Figure 1 and 2 External components selection is determined by the load current and is critical with the selection of inductor and capacitor values.

Inductor Selection

For the given input and output voltage, the inductor and operating frequency are determined ripple current. The ripple voltage ΔI_L increases with higher Vin and reduces the inductance.

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

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, the 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:

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

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, the lower DC-resistance inductor should be selected

Capacitor Selection

The input capacitance, Cin, is needed to filer the trapezoidal current at the source of the top MOSFET. To prevent the 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:

$$I_{RMS} = I_{OUTMAX} \times \frac{V_{OUT}}{V_{IN}} \left(\sqrt{\frac{Vin}{Vout}} - 1 \right)$$

It indicates a maximum value at Vin=2Vout, of Cout 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 the control loop condition is commonly used for design because even significant deviations do not much relief. The selection where $I_{RMS} = \frac{I_{OUT}}{2}$. This simple is worse-case stable.

Loop stability can be also checked by viewing the load step transient response as described in a latter section. The output ripple, ΔV_{OUT} , is determined by:

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

The output ripple is the highest at the maximum input voltage since ΔI_L increase with input voltage.

Load Transient

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

Output Voltage Setting (AUR9704A Only)

The output voltage of AUR9704A can be adjusted by a resistive divider according to the following formula:

$$V_{OUT} = V_{REF} \times (1 + \frac{R1}{R2}) = 0.5V \times (1 + \frac{R1}{R2})$$

The resistive divider senses the fraction of the output voltage as shown in Figure3.

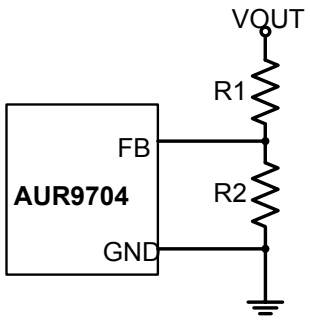


Figure3. Setting the Output Voltage

Efficiency Considerations

The efficiency of switching regulator is equal to the input power divided by the output 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:

Efficiency=100%-L1-L2-…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: Vin quiescent current and I^2R losses. The Vin quiescent current loss dominates the efficiency loss at very light load currents but the I^2R loss dominates the efficiency loss at medium to heavy load currents.

1. The Vin 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 to high again, the packet of charge ,dQ moves from Vin to ground. The resulting $\frac{dQ}{dt}$ is the current out of Vin that is typically larger than the internal DC bias current. In continuous mode,

$$I_{gate} = f \times (Q_p + Q_n)$$

Where Q_p , Q_n are the gate charge of power PMOSFET and NMOSFET switching. Both the DC bias current and gate charge losses are proportional to the Vin and this effect will be more serious at higher input voltages.

2. I^2R losses are calculated from internal switch resistance, Rsw and external inductor resistance RL. In continuous mode, the average output current flowing 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 and NMOSFET Rds(on) resistance and the duty cycle (D) as follows:

$$R_{SW} = [R_{DS(on)p} \times D + R_{DS(on)n} \times (1 - D)]$$

Therefore, to obtain the I^2R losses, simply add Rsw to RL and multiply the result by the square of the average output current.

Other losses including Cin and Cout ESR dissipative losses and inductor core losses generally account for less than 2 % of total additional loss.

Thermal Characteristics

In most application, the part does not dissipate much heat due to its high efficiency. But, in some conditions where the part is operating high ambient temperature with high Rds(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 to ambient.

PC Board layout considerations

Please follow the PCB layout guidelines for optimal performance of AUR9704, Evaluation board schematic is show in Figure 4.

1. The power traces, including the GND trace, the LX trace and the V_{IN} 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.

5. The following is an example of 2-layer PCB layout as shown in Figure 5 to Figure 6 for reference.

V_{OUT} = 3.3V / 600mA Buck Converter Application

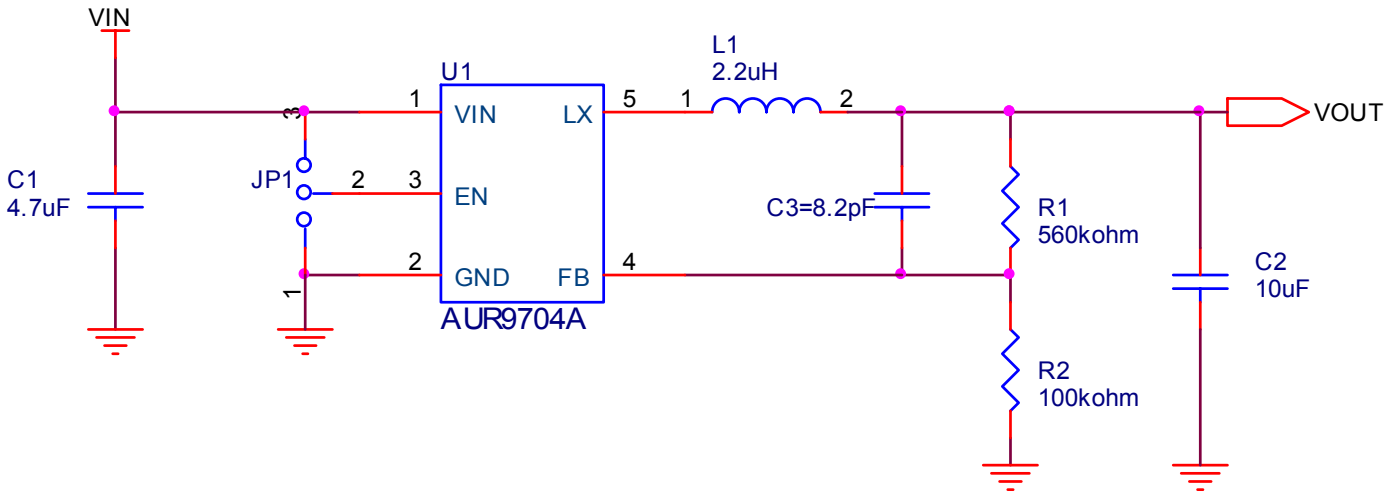


Figure4. The Evaluation Board Schematic

Evaluation Board Layout

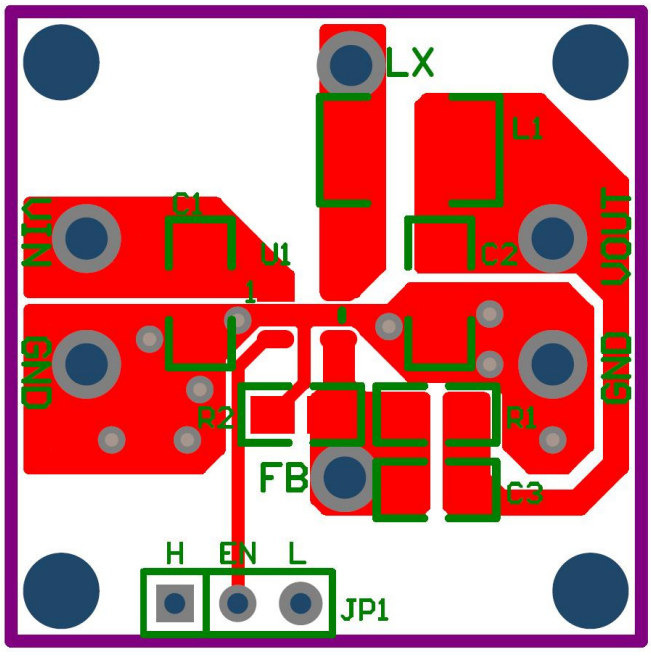


Figure5. Top Layer Layout

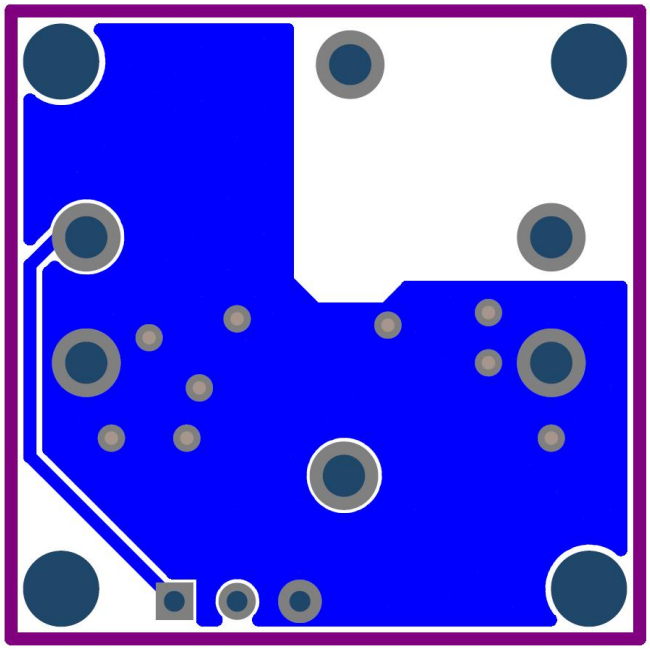


Figure6. Bottom Layer Layout

Package Information:

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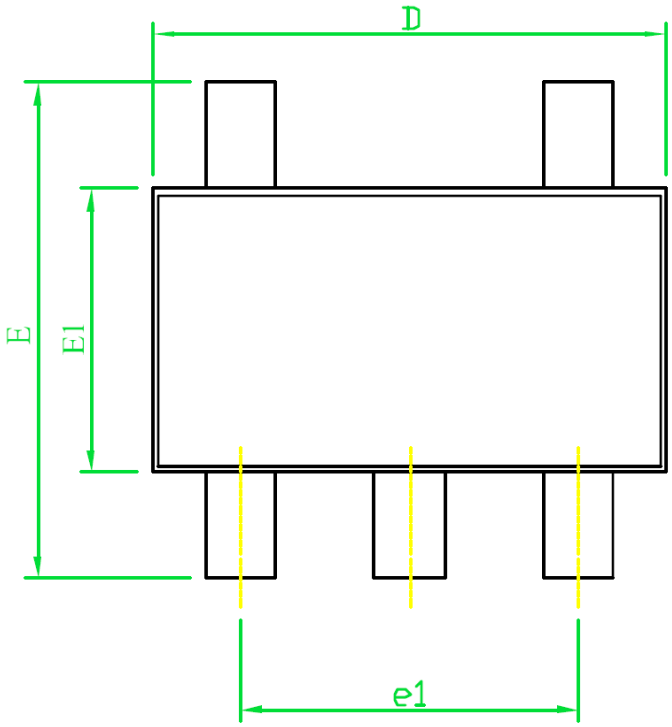
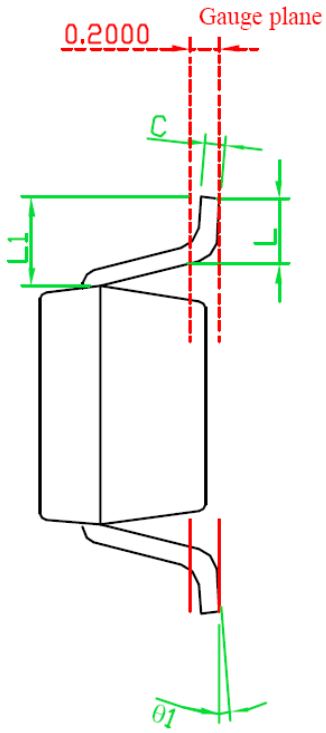
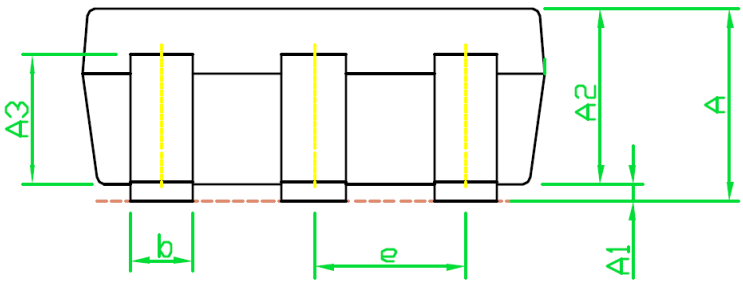
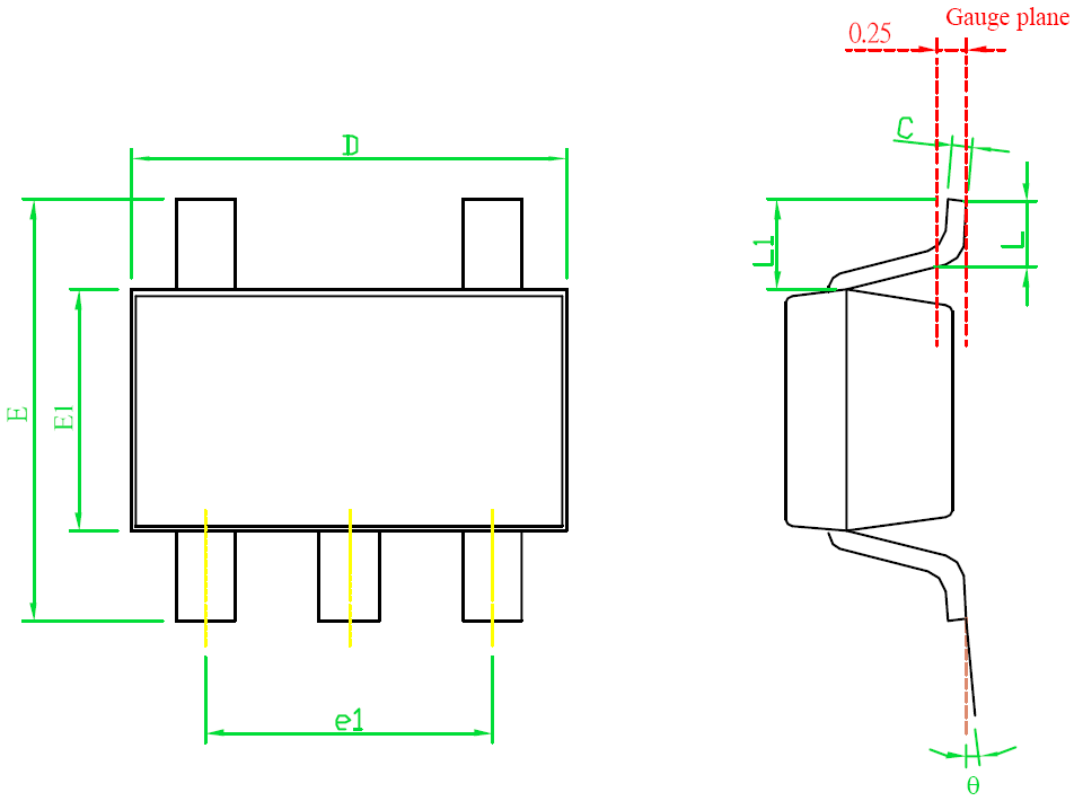


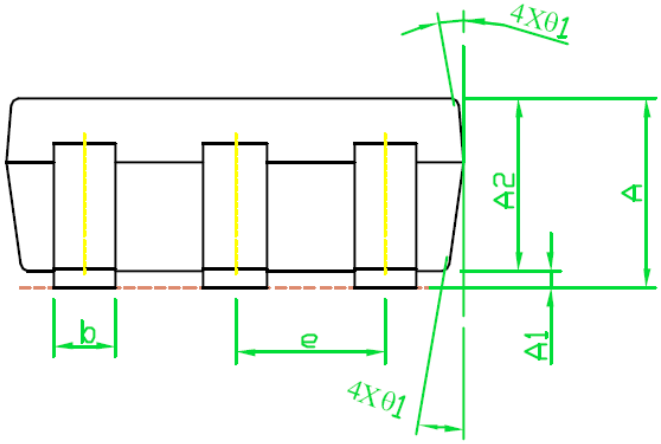




SYMBOLS	DIMENSIONS IN MILLIMETERS		
	MIN	NOM	MAX
A	1.00	1.10	1.40
A1	0.00	---	0.10
A2	1.00	1.10	1.30
A3	0.70	0.80	0.90
b	0.35	0.40	0.50
C	0.10	0.15	0.25
D	2.70	2.90	3.10
E1	1.50	1.60	1.80
e1	---	1.90(TYP)	---
E	2.60	2.80	3.00
L	0.37	---	---
θ1	1°	5°	9°
e	---	0.95(TYP)	---
L1	0.5	0.6	0.7

TSOT-23-5





SYMBOLS	DIMENSIONS IN MILLIMETERS		
	MIN	NOM	MAX
A	---	---	1.00
A1	0.00	0.05	0.10
A2	0.84	0.87	0.90
b	0.35	0.40	0.50
C	0.10	0.125	0.15
D	2.70	2.90	3.10
E1	1.40	1.60	1.80
e1	---	1.90(TYP)	---
E	2.60	2.80	3.00
L	0.30	0.40	0.60
θ	0°	4°	8°
θ1	4°	10°	12°
e	---	0.95(TYP)	---
L1	0.5	0.6	0.7