

## 300mA Low-Noise LDO Regulators

### Features

- Low, 90 $\mu$ A No-Load Supply Current
- Guaranteed 300mA Output Current
- Dropout Voltage is 200mV @ 150mA Load
- PSRR=53dB @ 1kHz
- Over-Temperature Protection and Short-Circuit Protection
- Max. Supply Current in Shutdown Mode < 1 $\mu$ A
- Low Output Noise at 28 $\mu$ V<sub>RMS</sub>
- Stable with low cost ceramic capacitors
- Output voltage: 1.20V~5.00V

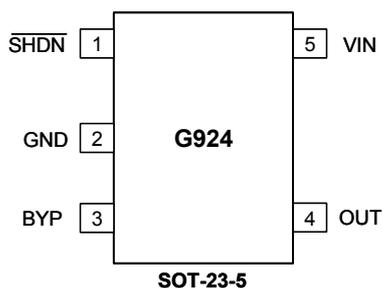
### Applications

- Notebook Computers
- Cellular Phones
- PDAs
- Digital still Camera and Video Recorders
- Hand-Held Devices
- Audio Codec

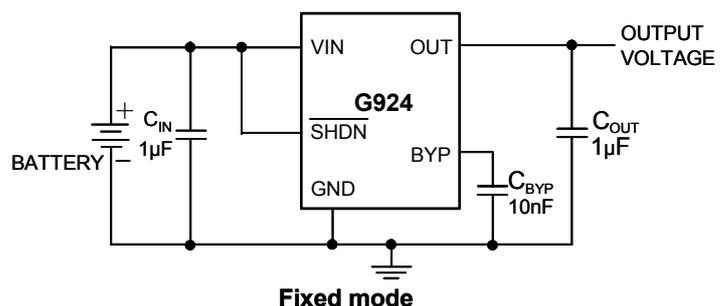
### General Description

The G924 is a low supply current, low dropout linear regulator that comes in a space saving SOT-23-5 package. The supply current at no-load is 90 $\mu$ A. In the shutdown mode, the maximum supply current is less than 1 $\mu$ A. Operating voltage range of the G924 is from 2.5V to 5.5V. The over-current protection limit is set at 550mA typical and 400mA minimum. An over-temperature protection circuit is built-in in the G924 to prevent thermal overload. These power saving features make the G924 ideal for use in the battery-powered applications such as notebook computers, cellular phones, and PDA's.

### Pin Configuration



### Typical Application Circuit



## Ordering Information

ORDER NUMBER	ORDER NUMBER (Pb free)	MARKING	VOLTAGE	TEMP. RANGE	PACKAGE
G924-330T1U	G924-330T1Uf	94AXx	3.30V	-40°C~ +85°C	SOT-23-5

For other output voltage, please contact us at sales@gmt.com.tw

Note: T1: SOT-23-5

U: Tape & Reel

## Selector Guide

ORDER NUMBER	ORDER NUMBER (Pb free)	OUTPUT VOLTAGE (V)	MARKING
G924-120T1U	G924-120T1Uf	1.20	94AAx
G924-130T1U	G924-130T1Uf	1.30	94ABx
G924-140T1U	G924-140T1Uf	1.40	94ACx
G924-150T1U	G924-150T1Uf	1.50	94ADx
G924-160T1U	G924-160T1Uf	1.60	94AEx
G924-170T1U	G924-170T1Uf	1.70	94AFx
G924-180T1U	G924-180T1Uf	1.80	94AGx
G924-190T1U	G924-190T1Uf	1.90	94AHx
G924-200T1U	G924-200T1Uf	2.00	94Aix
G924-210T1U	G924-210T1Uf	2.10	94AJx
G924-220T1U	G924-220T1Uf	2.20	94AKx
G924-230T1U	G924-230T1Uf	2.30	94ALx
G924-240T1U	G924-240T1Uf	2.40	94AMx
G924-250T1U	G924-250T1Uf	2.50	94ANx
G924-260T1U	G924-260T1Uf	2.60	94AOx
G924-270T1U	G924-270T1Uf	2.70	94APx
G924-280T1U	G924-280T1Uf	2.80	94AQx
G924-285T1U	G924-285T1Uf	2.85	94ARx
G924-290T1U	G924-290T1Uf	2.90	94ASx
G924-300T1U	G924-300T1Uf	3.00	94ATx
G924-310T1U	G924-310T1Uf	3.10	94AUx
G924-315T1U	G924-315T1Uf	3.15	94AVx
G924-320T1U	G924-320T1Uf	3.20	94AWx
G924-330T1U	G924-330T1Uf	3.30	94AXx
G924-340T1U	G924-340T1Uf	3.40	94AYx
G924-350T1U	G924-350T1Uf	3.50	94AZx
G924-360T1U	G924-360T1Uf	3.60	94BAx
G924-370T1U	G924-370T1Uf	3.70	94BBx
G924-380T1U	G924-380T1Uf	3.80	94BCx
G924-390T1U	G924-390T1Uf	3.90	94BDx
G924-400T1U	G924-400T1Uf	4.00	94BEx
G924-410T1U	G924-410T1Uf	4.10	94BFx
G924-420T1U	G924-420T1Uf	4.20	94BGx
G924-430T1U	G924-430T1Uf	4.30	94BHx
G924-440T1U	G924-440T1Uf	4.40	94Bix
G924-450T1U	G924-450T1Uf	4.50	94BJx
G924-460T1U	G924-460T1Uf	4.60	94BKx
G924-470T1U	G924-470T1Uf	4.70	94BLx
G924-475T1U	G924-475T1Uf	4.75	94BMx
G924-480T1U	G924-480T1Uf	4.80	94BNx
G924-490T1U	G924-490T1Uf	4.90	94BOx
G924-500T1U	G924-500T1Uf	5.00	94BPx

## Absolute Maximum Ratings

$V_{IN}$ to GND.....	-0.3V to +6.5V
Output Short-Circuit Duration.....	Infinite
$\overline{SHDN}$ to GND.....	-0.3V to $V_{IN}+0.3V$
OUT to GND.....	-0.3V to ( $V_{IN} + 0.3V$ )
Continuous Power Dissipation ( $T_A = +25^\circ C$ )	
SOT-23-5.....	520mW

Operating Temperature Range.....	-40°C to +85°C
Junction Temperature.....	+150°C
$\theta_{JA}^{(1)}$ .....	240°C/Watt
Storage Temperature Range.....	-65°C to +150°C
Reflow Temperature (soldering, 10sec).....	260°C

Note (1): See Recommended Minimum Footprint

Stresses beyond 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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## Electrical Characteristics

( $V_{IN}=5V$ ,  $V_{\overline{SHDN}}=V_{IN}$ ,  $T_A=T_J=25^\circ C$ , unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITION	MIN	TYP	MAX	UNIT	
Input Voltage (Note 2)	$V_{IN}$		2.5	---	5.5	V	
Output Voltage Accuracy	$V_{OUT}$	$V_{OUT} \geq 2.50V$ , $I_{OUT}=1mA$	-2	---	2	%	
		$2.50V > V_{OUT} \geq 1.80V$ , $I_{OUT}=1mA$	-3	---	3		
		$1.80V > V_{OUT} \geq 1.20V$ , $I_{OUT}=1mA$	-4	---	4		
Maximum Output Current			300	---	---	mA	
Current Limit (Note 3)	$I_{LIM}$		400	550	---	mA	
Short Circuit Current	$I_{SC}$		---	280	---	mA	
Ground Pin Current	$I_Q$		---	90	---	$\mu A$	
Dropout Voltage (Note 4)	$V_{DROP}$	$I_{OUT} = 300mA$	$V_{OUT}=1.50V$	---	1.36	---	V
			$V_{OUT}=1.80V$	---	1.10	---	
			$V_{OUT}=2.50V$	---	0.58	---	
			$V_{OUT}=3.00V$	---	0.41	---	
			$V_{OUT}=3.30V$	---	0.36	---	
			$V_{OUT}=4.75V$	---	0.25	---	
			$V_{OUT}=5.00V$	---	0.24	---	
Line Regulation	$\Delta V_{LNR}$	$V_{IN}=V_{OUT}+0.1V$ , to 5.5V $I_{OUT}=10mA$	---	0.06	---	%/V	
Load Regulation	$\Delta V_{LDR}$	$I_{OUT} = 10mA$ to 300mA	---	0.02	---	%/mA	
Ripple Rejection	PSRR	$F=1kHz$ , $0.45V_{P-P}$ , $I_{OUT}=10mA$	---	53	---	dB	
Output Voltage Noise (10Hz to 100kHz)	$e_n$	$C_{OUT} = 1\mu F$ , $I_{OUT} = 1mA$ , $C_{BYP} = 10nF$	---	28	---	$\mu V_{RMS}$	
<b>SHUTDOWN</b>							
$\overline{SHDN}$ Input Threshold	$V_{IH}$	Regulator enabled		1.5	---	---	V
	$V_{IL}$	Regulator shutdown		---	---	0.4	
$\overline{SHDN}$ Input Bias Current	$I_{\overline{SHDN}}$	$V_{\overline{SHDN}} = V_{IN}$	$T_A = +25^\circ C$	---	0.003	1	$\mu A$
Shutdown Supply Current	$I_{QSHDN}$	$V_{OUT} = 0V$	$T_A = +25^\circ C$	---	0.2	1	$\mu A$
<b>THERMAL PROTECTION</b>							
Thermal Shutdown Temperature	$T_{SHDN}$		---	145	---	$^\circ C$	
Thermal Shutdown Hysteresis	$\Delta T_{SHDN}$		---	25	---	$^\circ C$	

Note 1: Limits is 100% production tested at  $T_A = +25^\circ C$ . Low duty pulse techniques are used during test to maintain junction temperature as close to ambient as possible.

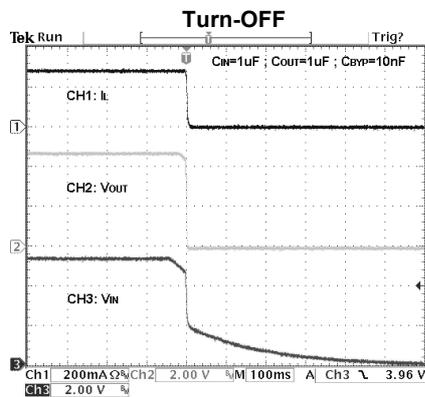
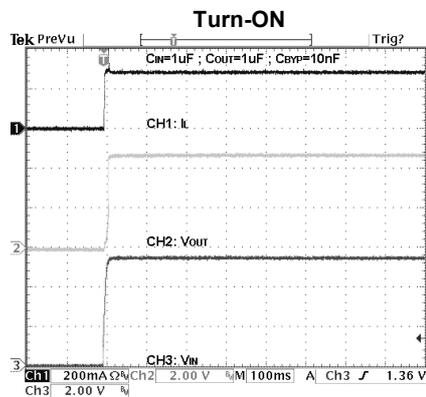
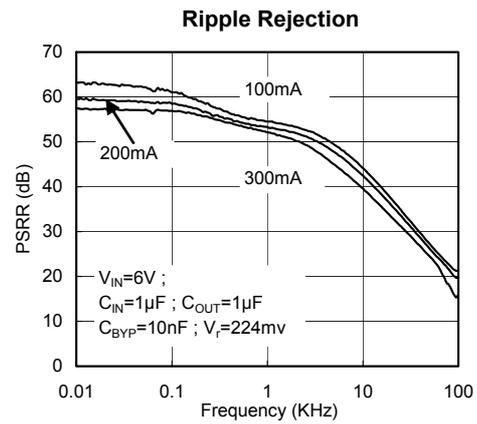
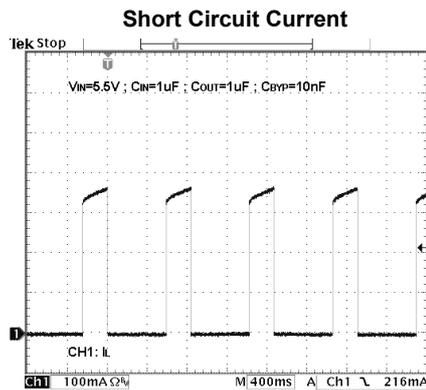
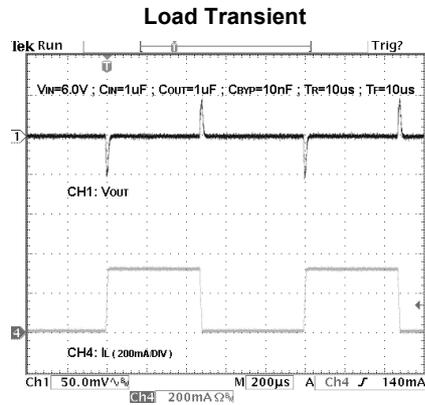
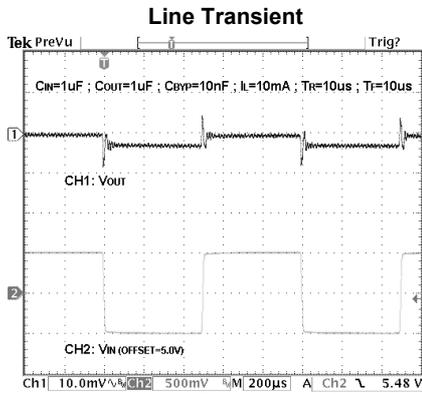
Note 2: Guaranteed by line regulation test.

Note 3: Not tested. For design purposes, the current limit should be considered 400mA minimum.

Note 4: The dropout voltage is defined as ( $V_{IN}-V_{OUT}$ ) when  $V_{OUT}$  is 100mV below the target value of  $V_{OUT}$ . The performance of every G924 part, see "Typical Performance Characteristics".

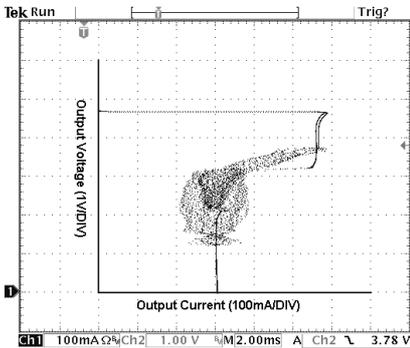
**Typical Performance Characteristics**

( $V_{IN}=5V$ ,  $C_{IN}=1\mu F$ ,  $C_{OUT}=1\mu F$ ,  $V_{SHDN} = V_{IN}$ , G924-475,  $T_A=25^\circ C$ , unless otherwise noted.)

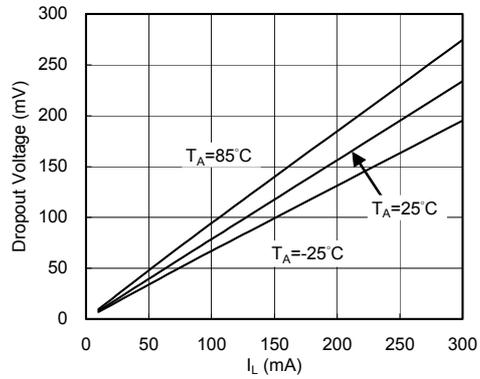


Typical Performance Characteristics (continued)

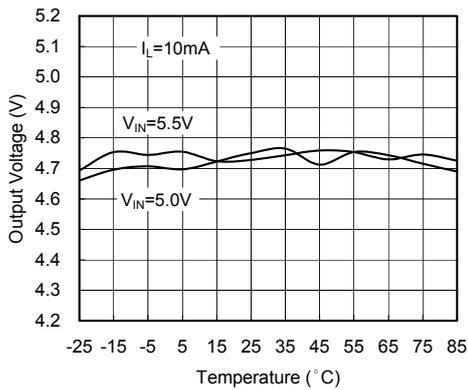
**Overcurrent Protection Characteristics**



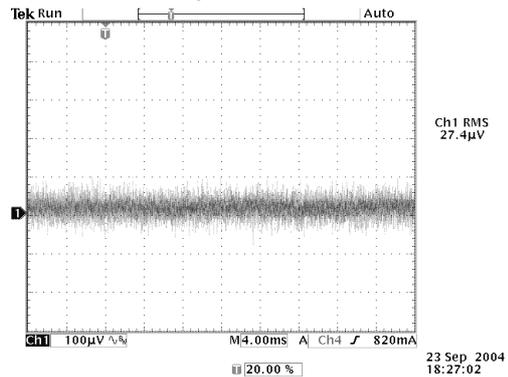
**Dropout Voltage vs.  $I_L$**



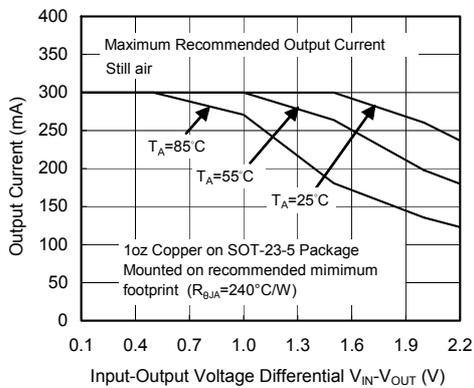
**Output Voltage vs. Temperature**



**Output Noise**

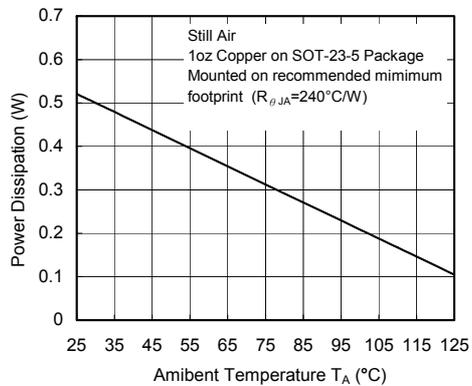


**Safe Operating Area [Power Dissipation Limit]**



Note:  $V_{IN(max)} \leq 5.5\text{V}$

**Max. Power Dissipation vs. Temperature**



## Pin Description

PIN	NAME	FUNCTION
1	$\overline{\text{SHDN}}$	Active-High Enable Input. A logic low reduces the supply current to less than 1 $\mu$ A. Connect to IN for normal operation.
2	GND	Ground. This pin also functions as a heat sink. Solder to large pads or the circuit board ground plane to maximize thermal dissipation.
3	BYP	This is a reference bypass pin. It should connect external 10nF capacitor to GND to reduce output noise. Bypass capacitor must be no less than 1nF. ( $C_{\text{BYP}} \geq 1\text{nF}$ )
4	OUT	Regulator Output. Sources up to 300mA. Bypass with a 1 $\mu$ F capacitor to GND.
5	VIN	Regulator Input. Supply voltage can range from +2.5V to +5.5V. Bypass with 1 $\mu$ F to GND.

## Detailed Description

The block diagram of the G924 is shown in Figure 1. It consists of an error amplifier, 1.20V bandgap reference, PMOS output transistor, internal feedback voltage divider, shutdown logic, over current protection circuit, and over temperature protection circuit.

The internal feedback voltage divider's central tap is connected to the non-inverting input of the error amplifier. The error amplifier compares non-inverting input with the 1.20V bandgap reference. If the feedback voltage is higher than 1.20V, the error amplifier's output becomes higher so that the PMOS output transistor has a smaller gate-to-source voltage ( $V_{\text{GS}}$ ). This reduces the current carrying capability of the PMOS output transistor, as a result the output voltage decreases until the feedback voltage is equal to 1.20V. Similarly, when the feedback voltage is less than

1.20V, the error amplifier causes the output PMOS to conduct more current to pull the feedback voltage up to 1.20V. Thus, through this feedback action, the error amplifier, output PMOS, and the voltage dividers effectively form a unity-gain amplifier with the feedback voltage force to be the same as the 1.20V bandgap reference. The output voltage,  $V_{\text{OUT}}$ , is then given by the following equation:

$$V_{\text{OUT}} = 1.20 (1 + R1/R2). \quad (1)$$

Alternatively, the relationship between R1 and R2 is given by:

$$R1 = R2 (V_{\text{OUT}} / 1.20 - 1). \quad (2)$$

For the output voltage versions of G924, the output voltages are 1.20V for G924-120, 2.50V for G924-250, 3.30V for G924-330, etc.

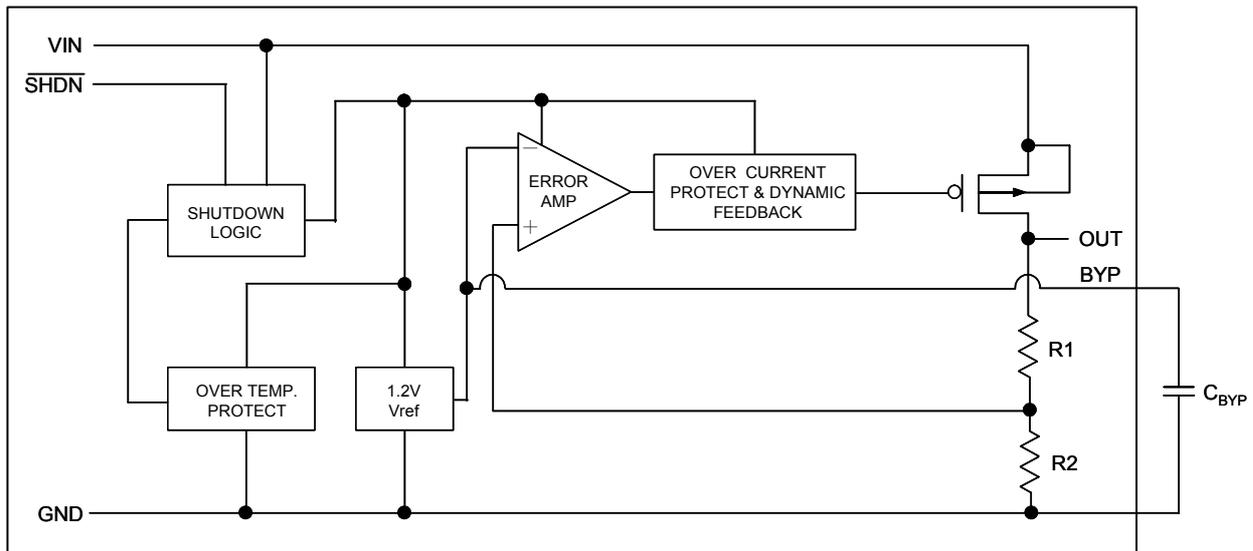


Figure 1. Functional Diagram

**Over Current Protection**

The G924 uses a current mirror to monitor the output current. A small portion of the PMOS output transistor's current is mirrored onto a resistor such that the voltage across this resistor is proportional to the output current. This voltage is compared against the 1.20V reference. Once the output current exceeds the limit, the PMOS output transistor is turned off. Once the output transistor is turned off, the current monitoring voltage decreases to zero, and the output PMOS is turned on again. If the over current condition persists, the over current protection circuit will be triggered again. Thus, when the output is shorted to ground, the output current will be alternating between 0 and the over current limit. The typical over current limit of the G924 is set to 550mA. Note that the input bypass capacitor of 1 $\mu$ F must be used in this case to filter out the input voltage spike caused by the surge current due to the inductive effect of the package pin and the printed circuit board's routing wire. Otherwise, the actual voltage at the IN pin may exceed the absolute maximum rating.

**Over Temperature Protection**

To prevent abnormal temperature from occurring, the G924 has a built-in temperature monitoring circuit. When it detects the temperature is above 145°C, the output transistor is turned off. When the IC is cooled down to below 120°C, the output is turned on again. In this way, the G924 will be protected against abnormal junction temperature during operation.

**Shutdown Mode**

When the  $\overline{\text{SHDN}}$  pin is connected a logic low voltage, the G924 enters shutdown mode. All the analog circuits are turned off completely, which reduces the current consumption to only the leakage current. The output is disconnected from the input. When the output has no load at all, the output voltage will be discharged to ground through the internal resistor voltage divider.

**Operating Region and Power Dissipation**

Since the G924 is a linear regulator, its power dissipation is always given by  $P = I_{\text{OUT}} (V_{\text{IN}} - V_{\text{OUT}})$ . The maximum power dissipation is given by:

$$P_{\text{DMAX}} = (T_{\text{J}} - T_{\text{A}}) / \theta_{\text{JA}} = (150 - 25) / 240 = 520\text{mW}$$

Where  $(T_{\text{J}} - T_{\text{A}})$  is the temperature difference the G924 die and the ambient air,  $\theta_{\text{JA}}$ , is the thermal resistance of the chosen package to the ambient air. For surface mount device, heat sinking is accomplished by using the heat spreading capabilities of the PC board and its copper traces. In the case of a SOT-23-5 package, the thermal resistance is typically 240°C/Watt. (See Recommended Minimum Footprint).

Refer to "Safe Operating Area" of the Typical Performance Characteristics is the G924 valid operating region & refer to "Maximum Power Dissipation vs. Temperature" is the maximum power dissipation of SOT-23-5.

The die attachment area of the G924's lead frame is connected to pin 2, which is the GND pin. Therefore, the GND pin of G924 can carry away the heat of the G924 die very effectively. To improve the power dissipation, connect the GND pin to ground using a large ground plane near the GND pin.

**Applications Information****Capacitor Selection and Regulator Stability**

Normally, use a 1 $\mu$ F capacitor on the input and a 1 $\mu$ F capacitor on the output of the G924. Larger input capacitor values and lower ESR provide better supply-noise rejection and transient response. A higher-value input capacitor (10 $\mu$ F) may be necessary if large, fast transients are anticipated and the device is located several inches from the power source.

**Power-Supply Rejection and Operation from Sources Other than Batteries**

The G924 is designed to deliver low dropout voltages and low quiescent currents in battery powered systems. Power-supply rejection is 53dB at low frequencies as the frequency increases above 20kHz; the output capacitor is the major contributor to the rejection of power-supply noise.

When operating from sources other than batteries, improve supply-noise rejection and transient response by increasing the values of the input and output capacitors, and using passive filtering techniques.

**Load Transient Considerations**

The G924 load-transient response graphs show two components of the output response: a DC shift of the output voltage due to the different load currents, and the transient response. Typical overshoot for step changes in the load current from 10mA to 300mA is 30mV. Increasing the output capacitor's value and decreasing its ESR attenuates transient spikes.

**Input-Output (Dropout) Voltage**

A regulator's minimum input-output voltage differential (or dropout voltage) determines the lowest usable supply voltage. In battery-powered systems, this will determine the useful end-of-life battery voltage. Because the G924 use a P-channel MOSFET pass transistor, their dropout voltage is a function of  $R_{\text{DS(ON)}}$  multiplied by the load current cause the G924 use a P-channel MOSFET pass transistor, their dropout voltage is a function of  $R_{\text{DS(ON)}}$  multiplied by the load current.

**Layout Guide**

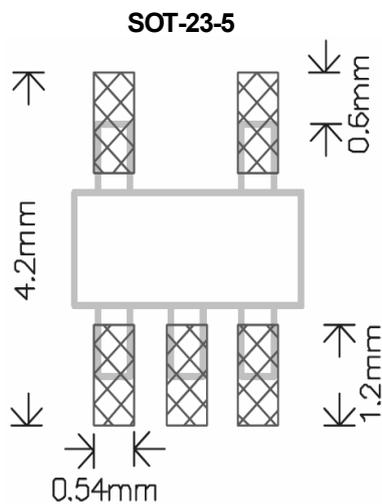
An input capacitance of 1 $\mu$ F is required between the G924 input pin and ground (the amount of the capacitance may be increased without limit), This capacitor must be located a distance of not more than 1cm from the input and return to a clean analog ground.

Input capacitor can filter out the input voltage spike caused by the surge current due to the inductive effect of the package pin and the printed circuit board's routing wire.

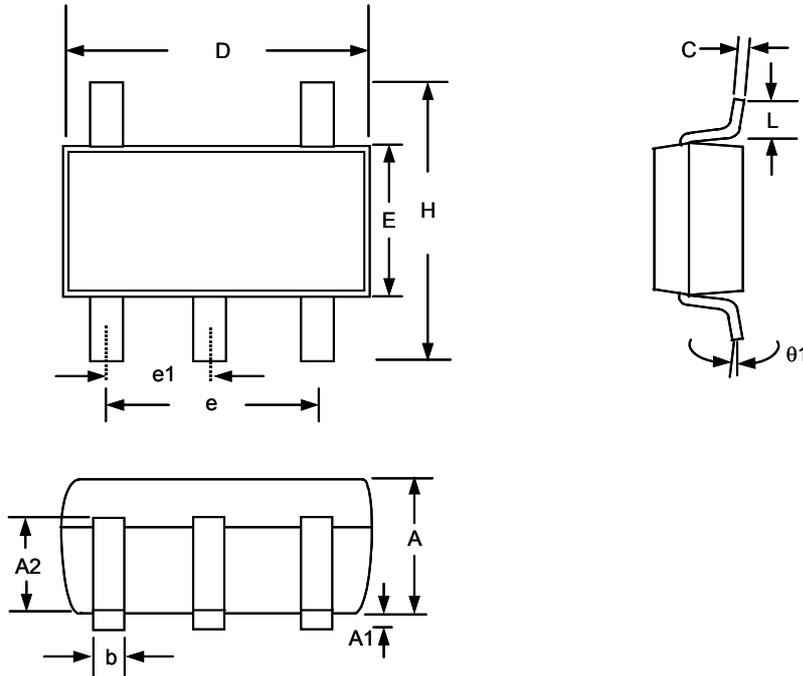
Otherwise, the actual voltage at the IN pin may exceed the absolute maximum rating.

The output capacitor also must be located a distance of not more than 1cm from output to a clean analog ground. Because it can filter out the output spike caused by the surge current due to the inductive effect of the package pin and the printed circuit board's routing wire.

**Recommend Minimum Footprint**



## Package Information

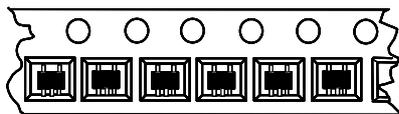


**Note:**

1. Package body sizes exclude mold flash protrusions or gate burrs
2. Tolerance  $\pm 0.1000$  mm (4mil) unless otherwise specified
3. Coplanarity: 0.1000mm
4. Dimension L is measured in gage plane

SYMBOLS	DIMENSIONS IN MILLIMETERS		
	MIN	NOM	MAX
A	1.00	1.10	1.30
A1	0.00	-----	0.10
A2	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
E	1.40	1.60	1.80
e	-----	1.90(TYP)	-----
e1	-----	0.95	-----
H	2.60	2.80	3.00
L	0.37	-----	-----
$\theta 1$	1°	5°	9°

## Taping Specification



**SOT-23-5 Package Orientation**

PACKAGE	Q'TY/REEL
SOT-23-5	3,000 ea

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