

INA1x8 高侧测量电流分流监视器

1 特性

- 完整的单极高侧电流测量电路
- 宽电源和共模范围
- INA138: 2.7V 至 36V
- INA168: 2.7V 至 60V
- 独立电源和输入共模电压
- 单电阻增益设定
- 低静态电流: 25 μ A (典型值)
- 宽温度范围: -40°C 至 +125°C
- 5 引脚小外形尺寸晶体管 (SOT)-23 封装

2 应用

- 分流测量:
 - 电话、计算机
- 便携式和备用电池系统
- 电池充电器
- 电源管理
- 手机
- 精密电流源

3 说明

INA138 和 INA168 (INA1x8) 是高侧单极电流分流监视器。此类器件兼具宽输入共模电压范围和低静态电流, 并且采用小型 SOT-23 封装, 广泛适用于各类应用而设计。

输入共模和电源电压相互独立, INA138 的电压范围为 2.7V 至 36V, INA168 的电压范围为 2.7V 至 60V。静态电流仅为 25 μ A, 允许电源连接到电流测量分流器的任一侧, 同时误差非常小。

该器件可将一个差分输入电压转换为电流输出。此电流使用外部负载电阻转换回电压, 该电阻可设置的增益范围为 1 至 100 以上。尽管该电路专为分流测量而设计, 但同时也非常适用于创造性应用中的测量和电平转换。

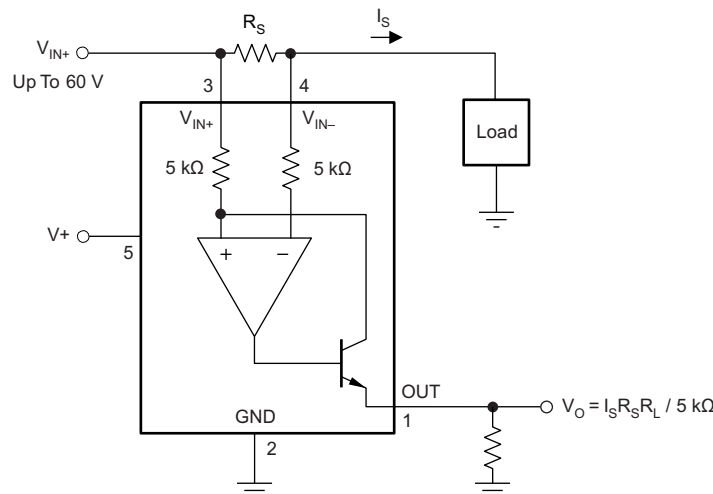
INA138 和 INA168 均采用 SOT23-5 封装, 额定温度范围为 -40°C 至 125°C。

器件信息⁽¹⁾

器件型号	封装	封装尺寸 (标称值)
INA138	SOT-23 (5)	2.90mm × 1.60mm
INA168		

(1) 要了解所有可用封装, 请见数据表末尾的封装选项附录。

典型应用电路



Copyright © 1999, Texas Instruments Incorporated



目录

1	特性	1	8	Application and Implementation	10
2	应用	1	8.1	Application Information	10
3	说明	1	8.2	Typical Applications	11
4	修订历史记录	2	9	Power Supply Recommendations	18
5	Pin Configuration and Functions	3	10	Layout	18
6	Specifications	4	10.1	Layout Guidelines	18
6.1	Absolute Maximum Ratings	4	10.2	Layout Example	18
6.2	ESD Ratings	4	11	器件和文档支持	19
6.3	Recommended Operating Conditions	4	11.1	文档支持	19
6.4	Thermal Information	5	11.2	相关链接	19
6.5	Electrical Characteristics	5	11.3	接收文档更新通知	19
6.6	Typical Characteristics	6	11.4	社区资源	19
7	Detailed Description	8	11.5	商标	19
7.1	Overview	8	11.6	静电放电警告	19
7.2	Functional Block Diagram	8	11.7	Glossary	19
7.3	Feature Description	9	12	机械、封装和可订购信息	19
7.4	Device Functional Modes	9			

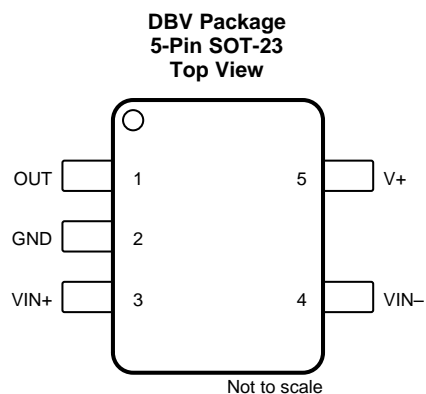
4 修订历史记录

注：之前版本的页码可能与当前版本有所不同。

Changes from Revision D (December 2014) to Revision E	Page
• 已添加 在首页顶部导航栏添加了参考设计链接	1
• 已更改 在器件信息表中将封装尺寸从 18.00mm × 18.00mm 更改成了 2.90mm × 1.60mm	1
• Changed pin numbers in pin functions table to match pin configuration figure	3
• Changed <i>Absolute Maximum Ratings</i> table for clarity; no values were changed	4
• Changed <i>Recommended Operating Conditions</i> table; moved some content from <i>Electrical Characteristics</i> table, but no values changed	4
• Changed all values in Thermal Information table	5
• Changed <i>Electrical Characteristics</i> table; reformatted for clarity; moved some content to <i>Recommended Operating Conditions</i> table, and deleted duplicate content	5
• Changed common-mode rejection test conditions to better highlight each device in <i>Electrical Characteristics</i> table	5
• Changed offset voltage vs temperature to offset voltage drift in <i>Electrical Characteristics</i> table	5
• Changed offset voltage vs power supply test conditions to better highlight each device in <i>Electrical Characteristics</i> table	5
• Changed reference in text from Figure 10 to Figure 11 in last paragraph of <i>Selecting the Shunt Resistor and R_L</i> section	12

Changes from Revision C (November 2005) to Revision D	Page
• 已添加 <i>ESD</i> 额定值表, 特性 描述 部分, 器件功能模式, 应用和 实施部分, 电源相关建议部分, 布局部分, 器件和文档支持部分以及 机械、封装和可订购信息部分。	1

5 Pin Configuration and Functions



Pin Functions

PIN		I/O	DESCRIPTION
NO.	NAME		
1	OUT	O	Output current
2	GND	—	Ground
3	VIN+	I	Positive input voltage
4	VIN–	I	Negative input voltage
5	V+	I	Power supply voltage

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) ⁽¹⁾

				MIN	MAX	UNIT
Voltage	Supply, V+	INA138		−0.3	60	V
		INA168		−0.3	75	
	Analog input, V _{IN+} , V _{IN−}	INA138	Common mode ⁽²⁾	−0.3	60	
			Sense voltage, V _{SENSE} = (V _{IN+} − V _{IN−})	−40	2	
		INA168	Common mode ⁽²⁾	−0.3	75	
			Sense voltage, V _{SENSE} = (V _{IN+} − V _{IN−})	−40	2	
	Analog output, OUT pin ⁽²⁾			−0.3	40	
Current	Input current into any pin			10	mA	
Temperature	Operating, T _A			−55	150	°C
	Junction, T _J			150		
	Storage, T _{stg}			−65	150	

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) The input voltage at any pin may exceed the voltage shown if the current at that pin is limited to 10 mA.

6.2 ESD Ratings

			VALUE	UNIT
V _(ESD)	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾	±1000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾	±500	

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
INA138					
V ₊	Supply voltage	2.7	5	36	V
V _{SENSE}	Full-scale sense voltage (V _{IN+} − V _{IN−})		100	500	mV
	Common-mode voltage	2.7	12	36	V
T _A	Operating temperature	−40	25	125	°C
INA168					
V ₊	Supply voltage	2.7	5	60	V
V _{SENSE}	Full-scale sense voltage (V _{IN+} − V _{IN−})		100	500	mV
	Common-mode voltage	2.7	12	60	V
T _A	Operating temperature	−40	25	125	°C

6.4 Thermal Information

THERMAL METRIC ⁽¹⁾		INA1x8	UNIT
		DBV	
		5 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	168.3	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	73.8	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	28.1	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	2.5	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	27.6	°C/W

- (1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

6.5 Electrical Characteristics

all other characteristics at $T_A = +25^\circ\text{C}$, $V_S = 5\text{ V}$, $V_{IN+} = 12\text{ V}$, and $R_{OUT} = 125\text{ k}\Omega$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS		INA1x8			UNIT
			MIN	TYP	MAX	
INPUT						
Common-mode rejection	$V_{\text{SENSE}} = 50\text{ mV}$	INA138, $V_{\text{IN}+} = 2.7\text{ V to }36\text{ V}$	100	120		dB
		INA168, $V_{\text{IN}+} = 2.7\text{ V to }60\text{ V}$	100	120		
Offset voltage ⁽¹⁾	$T_A = 25^\circ\text{C}$			± 0.2	± 1	mV
	$T_A = -40^\circ\text{C to }+125^\circ\text{C}$				± 2	
Offset voltage drift ⁽¹⁾	$T_A = -40^\circ\text{C to }+125^\circ\text{C}$			1		$\mu\text{V}/^\circ\text{C}$
Offset voltage vs power supply, V_+	$V_{\text{SENSE}} = 50\text{ mV}$	INA138, $V_+ = 2.7\text{ V to }36\text{ V}$		0.1	10	$\mu\text{V/V}$
		INA168, $V_+ = 2.7\text{ V to }60\text{ V}$		0.1	10	
Input bias current	$T_A = 25^\circ\text{C}$			2		μA
	$T_A = -40^\circ\text{C to }+125^\circ\text{C}$, INA138				10	
OUTPUT						
Transconductance	$V_{\text{SENSE}} = 10\text{ mV to }150\text{ mV}$, $T_A = 25^\circ\text{C}$		198	200	202	$\mu\text{A/V}$
	$V_{\text{SENSE}} = 100\text{ mV}$, $T_A = -40^\circ\text{C to }+125^\circ\text{C}$		196		204	$\mu\text{A/V}$
Transconductance drift	$T_A = -40^\circ\text{C to }+125^\circ\text{C}$			10		$\text{nA}/^\circ\text{C}$
Nonlinearity error	$V_{\text{SENSE}} = 10\text{ mV to }150\text{ mV}$			$\pm 0.01\%$	$\pm 0.1\%$	
Total output error	$V_{\text{SENSE}} = 100\text{ mV}$	$T_A = 25^\circ\text{C}$		$\pm 0.5\%$	$\pm 2\%$	
		$T_A = -40^\circ\text{C to }+125^\circ\text{C}$		$\pm 2.5\%$		
Output impedance				$1\parallel 5$		$\text{G}\Omega\parallel\text{pF}$
Voltage output swing	To power supply voltage, V_+			$(V_+) - 0.8$	$(V_+) - 1.0$	V
	To common-mode voltage, V_{CM}			$V_{\text{CM}} - 0.5$	$V_{\text{CM}} - 0.8$	V
FREQUENCY RESPONSE						
Bandwidth	$R_{\text{OUT}} = 5\text{ k}\Omega$			800		kHz
	$R_{\text{OUT}} = 125\text{ k}\Omega$			32		kHz
Settling time	To 0.1%	5-V step, $R_{\text{OUT}} = 5\text{ k}\Omega$		1.8		μs
		5-V step, $R_{\text{OUT}} = 125\text{ k}\Omega$		30		μs
NOISE						
Output-current noise density				9		$\text{pA}/\sqrt{\text{Hz}}$
Total output-current noise	$\text{BW} = 100\text{ kHz}$			3		nA RMS
POWER SUPPLY						
Quiescent current	$V_{\text{SENSE}} = 0\text{ V}$, $I_{\text{O}} = 0\text{ mA}$	$T_A = 25^\circ\text{C}$		25	45	μA
		$T_A = -40^\circ\text{C to }+125^\circ\text{C}$			60	μA

- (1) Defined as the amount of input voltage, V_{SENSE} , to drive the output to zero.

INA138, INA168

ZHCSFO2E – DECEMBER 1999 – REVISED DECEMBER 2017

www.ti.com.cn

6.6 Typical Characteristics

At $T_A = +25^\circ\text{C}$, $V_+ = 5\text{ V}$, $V_{IN+} = 12\text{ V}$, and $R_L = 125\text{ k}\Omega$, unless otherwise noted.

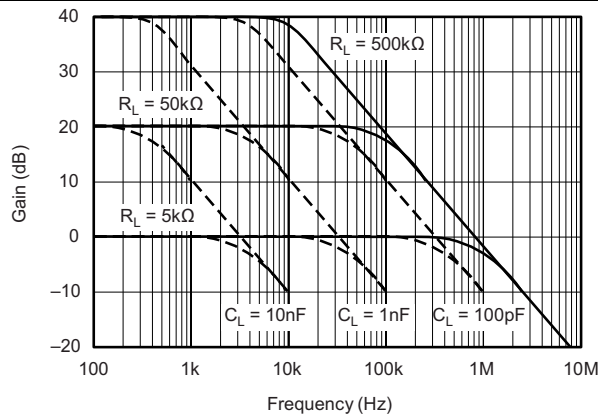


Figure 1. Gain vs Frequency

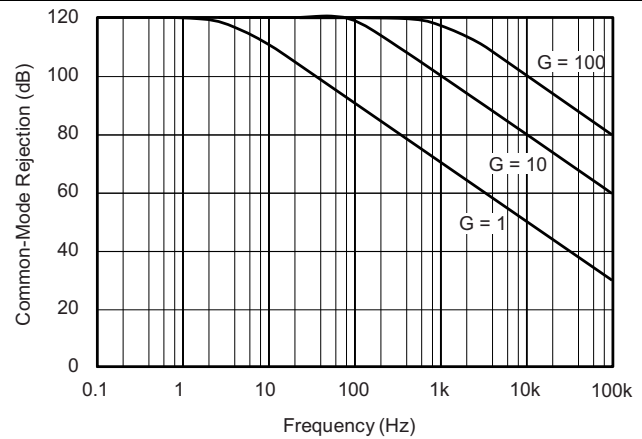


Figure 2. Common-Mode Rejection vs Frequency

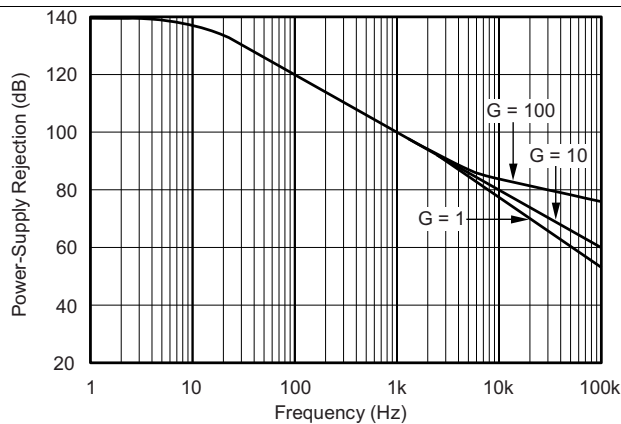


Figure 3. Power-Supply Rejection vs Frequency

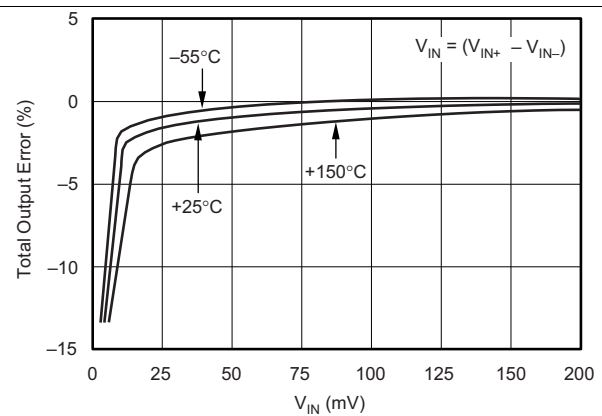


Figure 4. Total Output Error vs V_{IN}

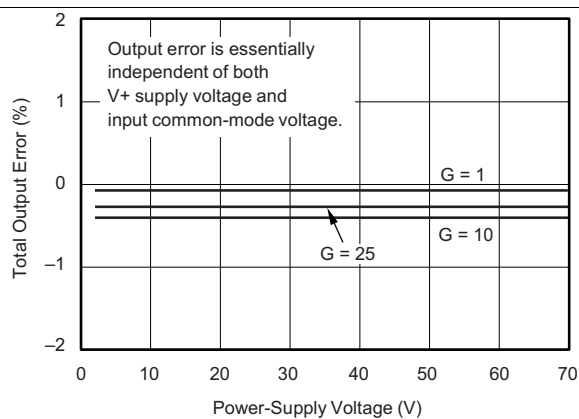


Figure 5. Total Output Error vs Power-Supply Voltage

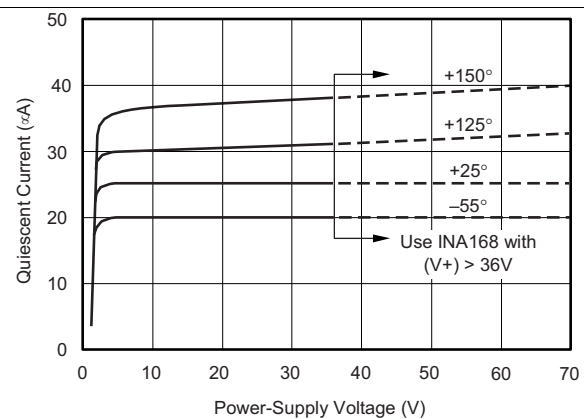
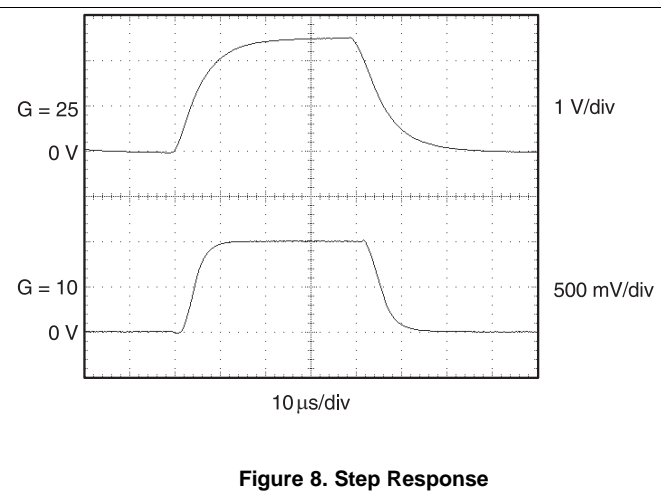
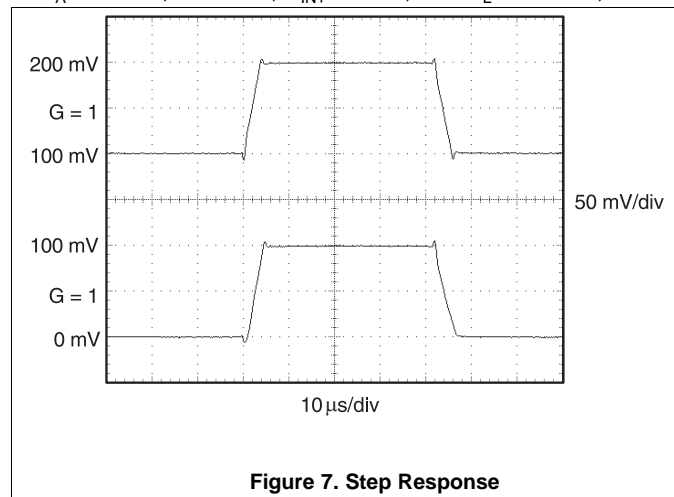


Figure 6. Quiescent Current vs Power-Supply Voltage

Typical Characteristics (continued)

At $T_A = +25^\circ\text{C}$, $V_+ = 5\text{ V}$, $V_{IN+} = 12\text{ V}$, and $R_L = 125\text{ k}\Omega$, unless otherwise noted.

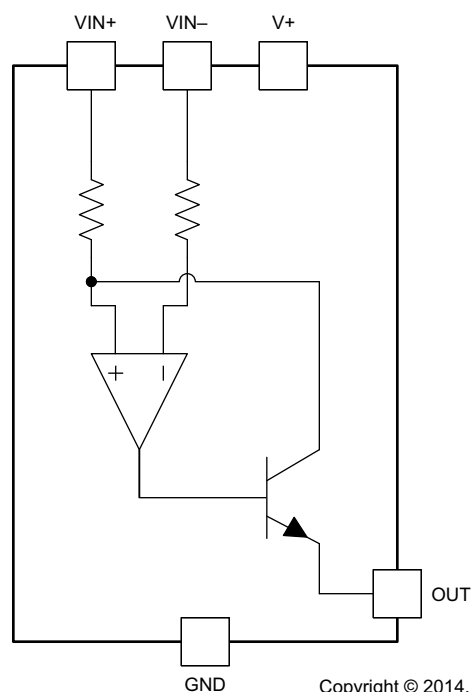


7 Detailed Description

7.1 Overview

The INA138 and INA168 devices (INA1x8) are comprised of a high voltage, precision operational amplifier, precision thin film resistors trimmed in production to an absolute tolerance and a low noise output transistor. The INA1x8 devices can be powered from a single power supply and their input voltages can exceed the power supply voltage. The INA1x8 devices are ideal for measuring small differential voltages, such as those generated across a shunt resistor, in the presence of large common-mode voltages. Refer to [Functional Block Diagram](#) which illustrates the functional components within both INA1x8 devices.

7.2 Functional Block Diagram



Copyright © 2014, Texas Instruments Incorporated

7.3 Feature Description

7.3.1 Output Voltage Range

The output of the INA1x8 device is a current that is converted to a voltage by the load resistor, R_L . The output current remains accurate within the compliance voltage range of the output circuitry. The shunt voltage and the input common-mode and power-supply voltages limit the maximum possible output swing. The maximum output voltage ($V_{out\ max}$) compliance is limited by either [Equation 1](#) or [Equation 2](#), whichever is lower:

$$V_{out\ max} = (V_+) - 0.7\ V - (V_{IN+} - V_{IN-}) \quad (1)$$

or

$$V_{out\ max} = V_{IN-} - 0.5\ V \quad (2)$$

7.3.2 Bandwidth

Measurement bandwidth is affected by the value of the load resistor, R_L . High gain produced by high values of R_L will yield a narrower measurement bandwidth (see [Typical Characteristics](#)). For widest possible bandwidth, keep the capacitive load on the output to a minimum. Reduction in bandwidth due to capacitive load is shown in the [Typical Characteristics](#).

If bandwidth limiting (filtering) is desired, a capacitor can be added to the output (see [Figure 12](#)). This will not cause instability.

7.4 Device Functional Modes

For proper operation the INA1x8 devices must operate within their specified limits. Operating either device outside of their specified power supply voltage range or their specified common-mode range will result in unexpected behavior and is not recommended. Additionally operating the output beyond their specified limits with respect to power supply voltage and input common-mode voltage will also produce unexpected results. Refer to [Electrical Characteristics](#) for the device specifications.

8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

图9给出了INA138和INA168器件的基本电路图，负载电流 I_S 从电源 V_S 通过分流电阻 R_S 汲取，分流电阻 V_S 的压降由内部运算放大器压降在 R_{G1} 两端，

8.1.1 Operation

从而使电流流入Q1的集电极。外部电阻 R_L 在OUT引脚上将输出电流转换为电压 V_{OUT} 。INA138器件的传递函数为：

Figure 9 illustrates the basic circuit diagram for both the INA138 and INA168 devices. Load current I_S is drawn from supply V_S through shunt resistor R_S . The voltage drop in shunt resistor V_S is forced across R_{G1} by the internal op amp, causing current to flow into the collector of Q1. External resistor R_L converts the output current to a voltage, V_{OUT} , at the OUT pin. The transfer function for the INA138 device is:

$$I_O = g_m(V_{IN+} - V_{IN-}) \quad (3)$$

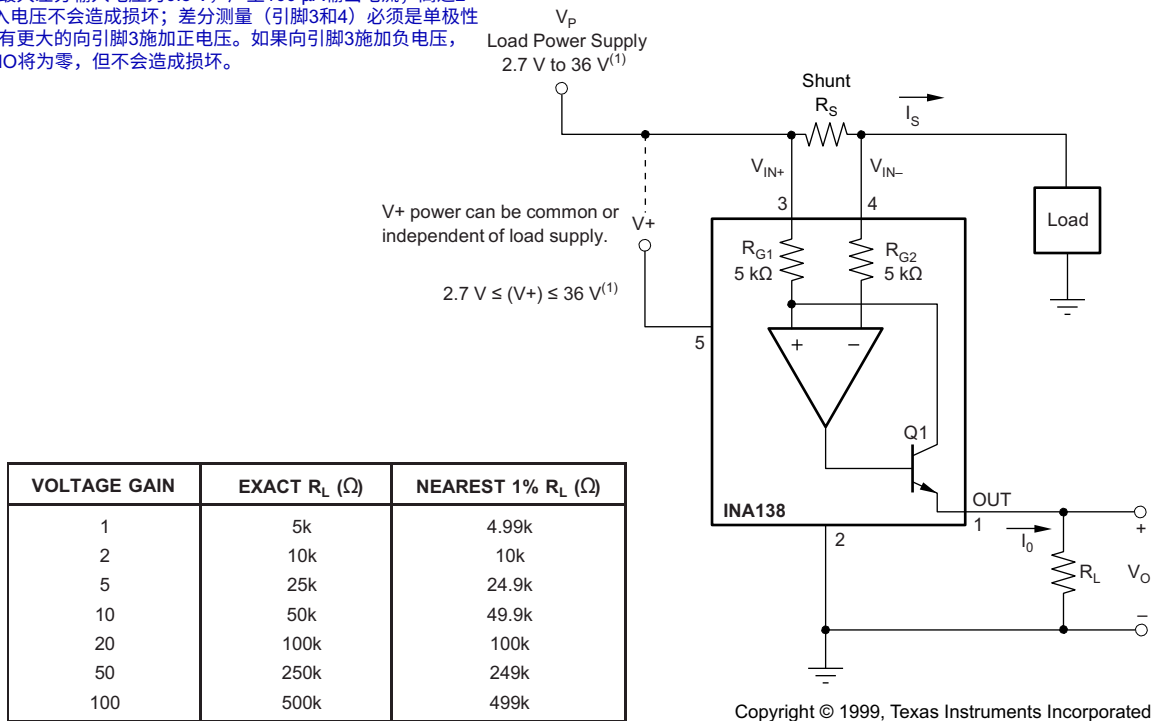
where $g_m = 200 \mu A/V$. 在图9的电路中，输入电压 ($V_{IN+} - V_{IN-}$) 等于 $I_S \times R_S$ ，输出电压 V_{OUT} 等于 $I_O \times R_L$ 。INA138器件的跨导 g_m 为 $200 \mu A/V$ 。此应用中电流测量放大器的完整传递函数为：

In the circuit of Figure 9, the input voltage, ($V_{IN+} - V_{IN-}$), is equal to $I_S \times R_S$ and the output voltage, V_{OUT} , is equal to $I_O \times R_L$. The transconductance, g_m , of the INA138 device is $200 \mu A/V$. The complete transfer function for the current measurement amplifier in this application is:

$$V_{OUT} = (I_S) (R_S) (200 \mu A/V) (R_L) \quad (4)$$

The maximum differential input voltage for accurate measurements is 0.5 V, which produces a 100- μA output current. A differential input voltage of up to 2 V will not cause damage. Differential measurements (pins 3 and 4) must be unipolar with a more-positive voltage applied to pin 3. If a more-negative voltage is applied to pin 3, the output current, I_O , will be zero, but it will not cause damage.

精确测量的最大差分输入电压为0.5 V，产生100 μA 输出电流；高达2 V的差分输入电压不会造成损坏；差分测量（引脚3和4）必须是单极性的，并且具有更大的向引脚3施加正电压。如果向引脚3施加负电压，则输出电流 I_O 将为零，但不会造成损坏。



(1) Maximum V_P and $V+$ voltage is 60 V with INA168.

Figure 9. Basic Circuit Connections

8.2 Typical Applications

INA1x8设备专为电流分流测量电路而设计，如图9所示，但基本的设备功能在各种电路中都非常有用，富有创造力的工程师会在测量和电平转换电路中发现许多无法预料的用途。如图10至图18所示。

The INA1x8 devices are designed for current shunt measurement circuits, as shown in Figure 9, but basic device function is useful in a wide range of circuitry. A creative engineer will find many unforeseen uses in measurement and level-shifting circuits. A few ideas are illustrated in Figure 10 through Figure 18.

8.2.1 Buffering Output to Drive an ADC

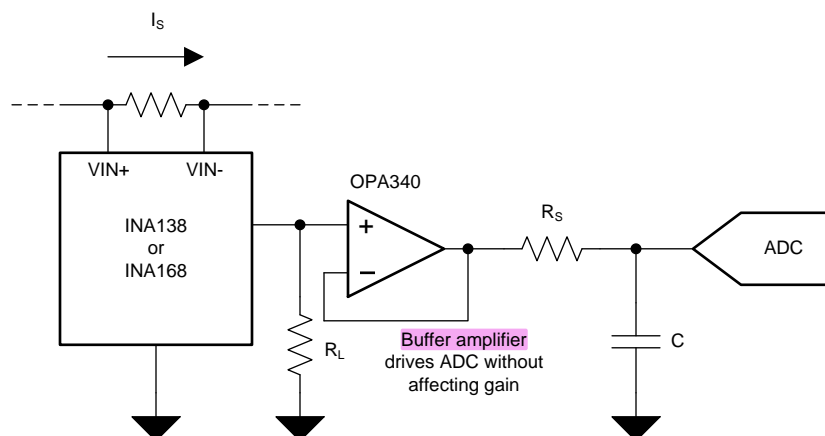


Figure 10. Buffering Output to Drive an ADC
缓冲输出以驱动ADC

8.2.1.1 Design Requirements

Digitize the output of the INA1x8 devices using a 1-MSPS analog-to-digital converter (ADC).

使用1-MSPS模数转换器(ADC)将INA1x8设备的输出数字化。在图9中，为分流电阻器选择的值取决于应用，并且是小信号精度与测量线中最大允许电压损失之间的折衷。高分流电阻器通过最小化失调的影响在较低电流下提供更好的精度较低的分流电阻器值可最大程度地减少电源线路中的电压损耗。对于大多数应用而言，分流电阻器值可提供50 mV至100 mV的满量程分流电压范围，以实现最佳性能。是500 mV。

8.2.1.2 Detailed Design Procedure

8.2.1.2.1 Selecting the Shunt Resistor and R_L INA1x8 OUT端子的输出阻抗非常高，允许以极高的精度使用高达500kΩ的 R_L 值。任何其他电路的输入阻抗。选择负载电阻 R_L 以提供所需的满量程输出电压。输出端的 R_L 值应大大高于 R_L 的值，以免降低精度。

In Figure 9 the value chosen for the shunt resistor depends on the application and is a compromise between small-signal accuracy and maximum permissible voltage loss in the measurement line. High values of shunt resistor provide better accuracy at lower currents by minimizing the effects of offset, while low values of shunt resistor minimize voltage loss in the supply line. For most applications, best performance is attained with a shunt resistor value that provides a full-scale shunt voltage range of 50 mV to 100 mV. Maximum input voltage for accurate measurements is 500 mV.

The load resistor, R_L , is chosen to provide the desired full-scale output voltage. The output impedance of the INA1x8 OUT terminal is very high which permits using values of R_L up to 500 kΩ with excellent accuracy. The input impedance of any additional circuitry at the output should be much higher than the value of R_L to avoid degrading accuracy.

Some analog-to-digital converters (ADCs) have input impedances that significantly affect measurement gain. The input impedance of the ADC can be included as part of the effective R_L if its input can be modeled as a resistor to ground. Alternatively, an op amp can be used to buffer the ADC input. The INA1x8 are current output devices, and as such have an inherently large output impedance. The output currents from the amplifier are converted to an output voltage via the load resistor, R_L , connected from the amplifier output to ground. The ratio of the load resistor value to that of the internal resistor value determines the voltage gain of the system.

In many applications digitizing the output of the INA1x8 device is required, and can be accomplished by connecting the output of the amplifier to an ADC. It is very common for an ADC to have a dynamic input impedance. If the INA1x8 output is connected directly to an ADC input, the input impedance of the ADC is effectively connected in parallel with the gain setting resistor R_L . This parallel impedance combination will affect the gain of the system and the impact on the gain is difficult to estimate accurately. A simple solution that eliminates the paralleling of impedances, simplifying the gain of the circuit is to place a buffer amplifier, such as the OPA340, between the output of the INA138 or INA168 device and the input to the ADC.

一些模数转换器(ADC)的输入阻抗会显著影响测量增益，如果ADC的输入可以建模为接地电阻，则可以将其输入阻抗作为有效 R_L 的一部分。放大器的输出电流通过与放大器相连的负载电阻 R_L 转换为输出电压INA1x8是电流输出设备，因此具有固有的大输出阻抗。负载电阻值与内部电阻值之比决定了系统的电压增益。

Typical Applications (continued)

Figure 10 illustrates this concept. Notice that a low pass filter is placed between the OPA340 output and the input to the ADC. The filter capacitor is required to provide any instantaneous demand for current required by the input stage of the ADC. The filter resistor is required to isolate the OPA340 output from the filter capacitor to maintain circuit stability. The values for the filter components will vary according to the operational amplifier used for the buffer and the particular ADC selected. More information can be found regarding the design of the low pass filter in the TI Precision Design , *16 bit 1MSPS Data Acquisition Reference Design for Single-Ended Multiplexed Applications (TIPD173)*.

Figure 11 shows the expected results when driving an analog-to-digital converter at 1MSPS with and without buffering the INA1x8 output. Without the buffer, the high impedance of the INA1x8 reacts with the input capacitance and sample and hold (S/H) capacitance of the ADC, and does not allow the S/H to reach the correct final value before it is reset and the next conversion starts. Adding the buffer amplifier significantly reduces the output impedance driving the S/H and allows for higher conversion rates than can be achieved without adding the buffer.

8.2.1.3 Application Curve

图10对此概念进行了说明，请注意，在OPA340输出与ADC的输入之间放置了一个低通滤波器，需要使用滤波电容器来提供ADC输入级所需的瞬时电流需求。需要将OPA340输出与滤波电容器隔离以保持电路稳定性。滤波元件的值将根据用于缓冲器的运算放大器和所选的特定ADC而变化。有关低通设计的更多信息，请参见TI Precision设计中针对单端多路复用应用的16位1MSPS数据采集参考设计（TIPD173）中的滤波器。

图11显示了在有和没有缓冲INA1x8输出的情况下以1MSPS驱动模数转换器时的预期结果。如果没有缓冲器，则INA1x8的高阻抗会与输入电容和采样保持（S/H）电容产生反应添加缓冲放大器会显著降低驱动S/H的输出阻抗，并提供比ADC更高的转换速率，并且不允许S/H在复位和开始下一次转换之前达到正确的最终值。无需添加缓冲区即可实现

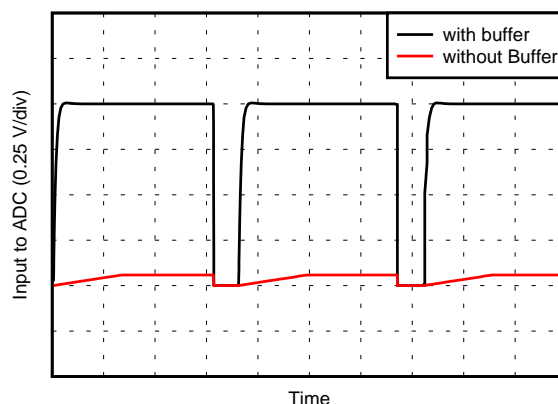


Figure 11. Driving an ADC With and Without a Buffer

Typical Applications (continued)

8.2.2 Output Filter

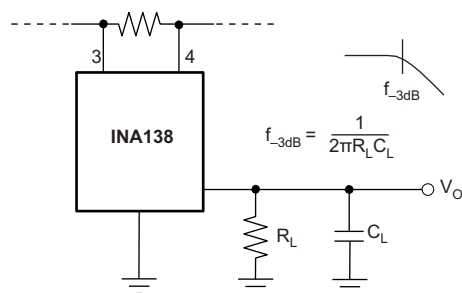


Figure 12. Output Filter

8.2.2.1 Design Requirements

Filter the output of the INA1x8 devices.

8.2.2.2 Detailed Design Procedure

A low-pass filter can be formed at the output of the INA1x8 devices simply by placing a capacitor of the desired value in parallel with the load resistor. First determine the value of the load resistor needed to achieve the desired gain. Refer to the table in Figure 9. Next, determine the capacitor value that will result in the desired cutoff frequency according to the equation shown in Figure 12. Figure 13 illustrates various combinations of gain settings (determined by R_L) and filter capacitors.

8.2.2.3 Application Curve

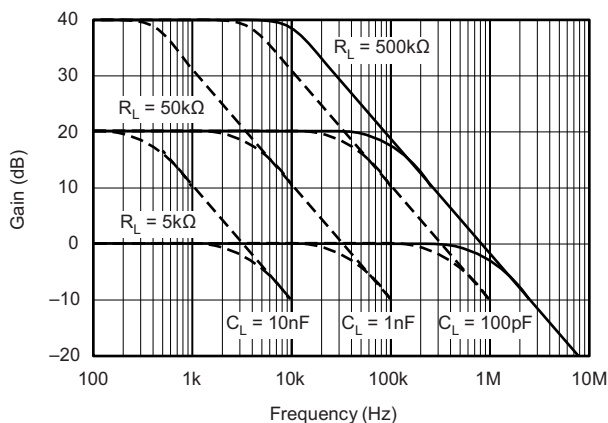


Figure 13. Gain vs Frequency

Typical Applications (continued)

8.2.3 Offsetting the Output Voltage

For many applications using only a single power supply it may be required to level shift the output voltage away from ground when there is no load current flowing in the shunt resistor. Level shifting the output of the INA1x8 devices is easily accomplished by one of two simple methods shown in Figure 14. The method on the left hand side of Figure 14 illustrates a simple voltage divider method. This method is useful for applications that require the output of the INA1x8 devices to remain centered with respect to the power supply at zero load current through the shunt resistor. Using this method the gain is determined by the parallel combination of R_1 and R_2 while the output offset is determined by the voltage divider ratio R_1 and R_2 . For applications that may require a fixed value of output offset, independent of the power supply voltage, the current source method shown on the right-hand side of Figure 14 is recommended. With this method a REF200 constant current source is used to generate a constant output offset. Using this method the gain is determined by R_L and the offset is determined by the product of the value of the current source and R_L .

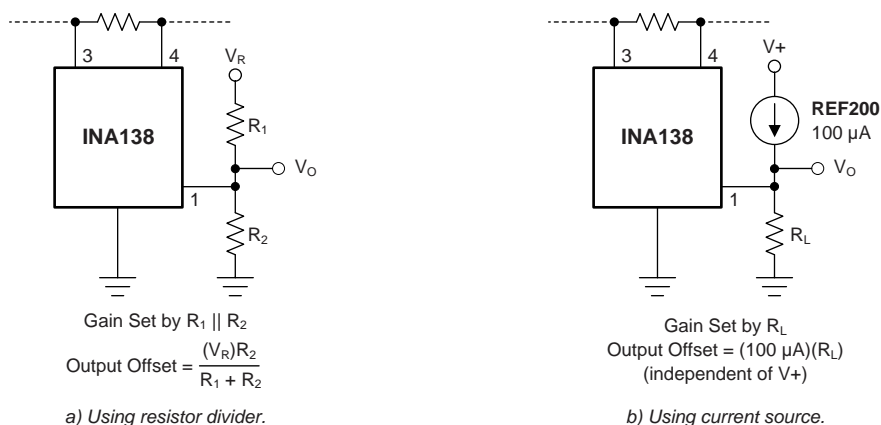


Figure 14. Offsetting the Output Voltage

Typical Applications (continued)

8.2.4 Bipolar Current Measurement 双向电流测量

The INA1x8 devices can be configured as shown in Figure 15 in applications where measuring current bi-directionally is required. Two INA devices are required connecting their inputs across the shunt resistor as shown in Figure 15. A comparator, such as the TLV3201, is used to detect the polarity of the load current. The magnitude of the load current is monitored across the resistor connected between ground and the connection labeled *Output*. In this example the 100-k Ω resistor results in a gain of 20 V/V. The 10-k Ω resistors connected in series with the INA1x8 output current are used to develop a voltage across the comparator inputs. Two diodes are required to prevent current flow into the INA1x8 output, as only one device at a time is providing current to the *Output* connection of the circuit. The circuit functionality is illustrated in Figure 16.

在需要双向测量电流的应用中，可以如图15所示配置INA1x8器件，需要两个INA器件将它们的输入跨接在分流电阻上，如图15所示，使用比较器（例如TLV3201）检测负载电流的极性。负载电流的大小跨接在接地和标有Output的连接之间的电阻器上进行监视。在此示例中，100k Ω 电阻器的增益为20 V/V。10k Ω 电阻器与INA1x8输出电流串联连接的电压用于在比较器输入两端产生电压，需要两个二极管来防止电流流入INA1x8输出，因为一次仅一个器件向电路的输出连接提供电流。电路功能如图16所示。

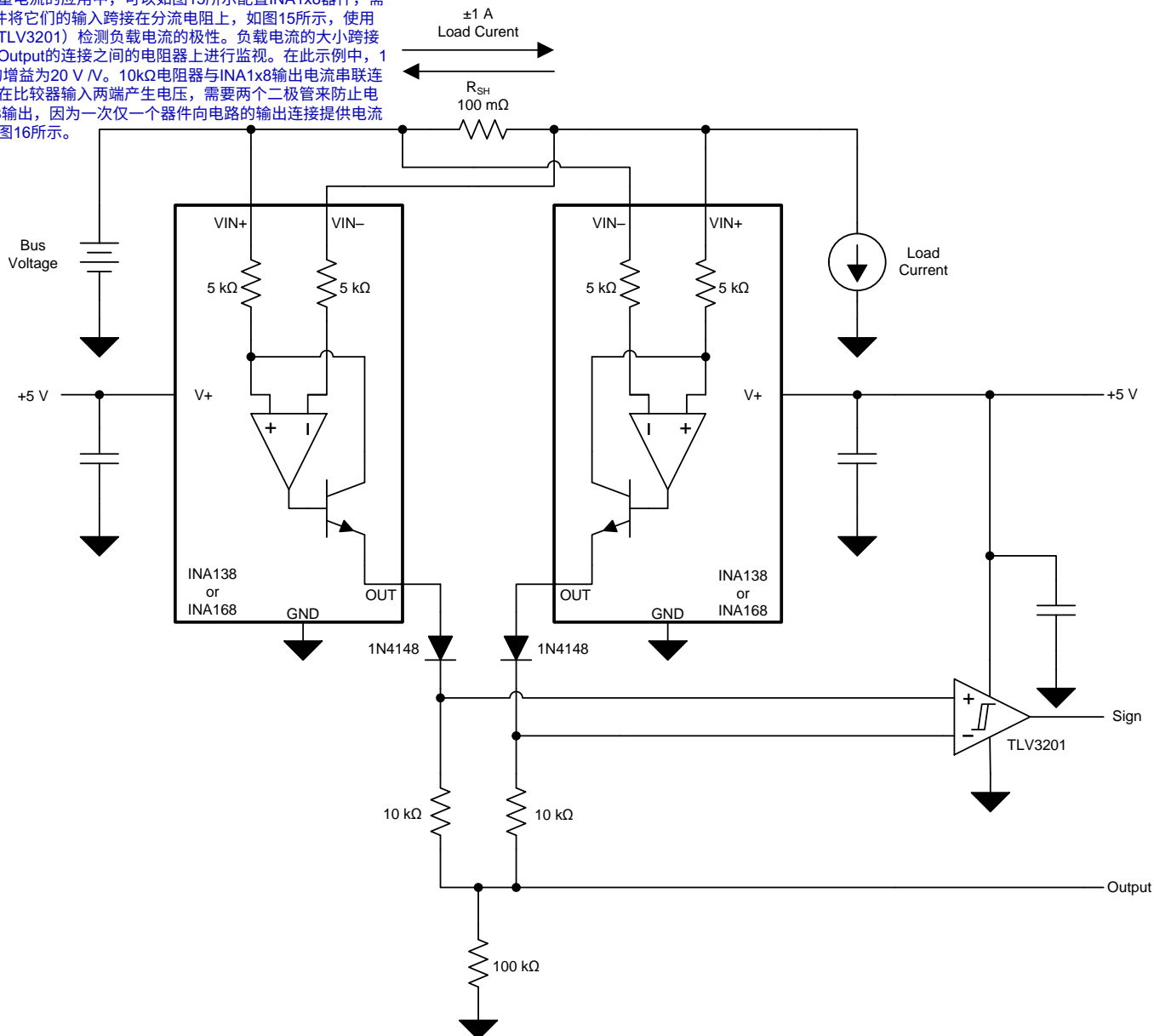


Figure 15. Bipolar Current Measurement

Typical Applications (continued)

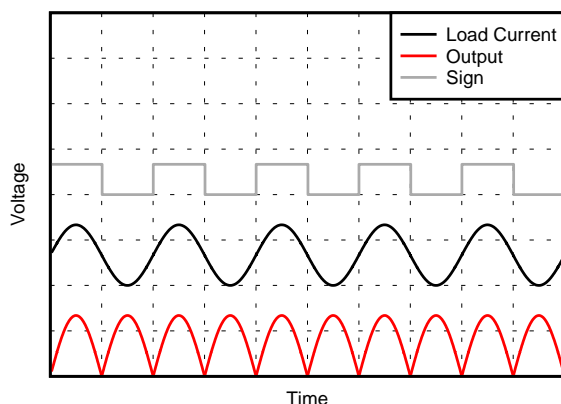


Figure 16. Bipolar Current Measurements Results (arbitrary scale)

8.2.5 Bipolar Current Measurement Using Differential Input of ADC

The INA1x8 devices can be used with an ADC such as the [ADS7870](#) programmed for differential mode operation. [Figure 17](#) illustrates this configuration. In this configuration the use of two INAs allows for bidirectional current measurement. Depending upon the polarity of the current, one of the INAs provides an output voltage, while the other output is zero. In this way the ADC reads the polarity of current directly, without the need for additional circuitry.

INA1x8器件可与ADC配合使用，例如为差分模式编程的ADS7870。工作原理图17说明了这种配置，在这种配置中，使用两个INA可以进行双向电流测量，其中一个INA提供一个输出电压，而另一个INA输出为零，这取决于电流的极性。ADC可以直接读取电流的极性，而无需其他电路。

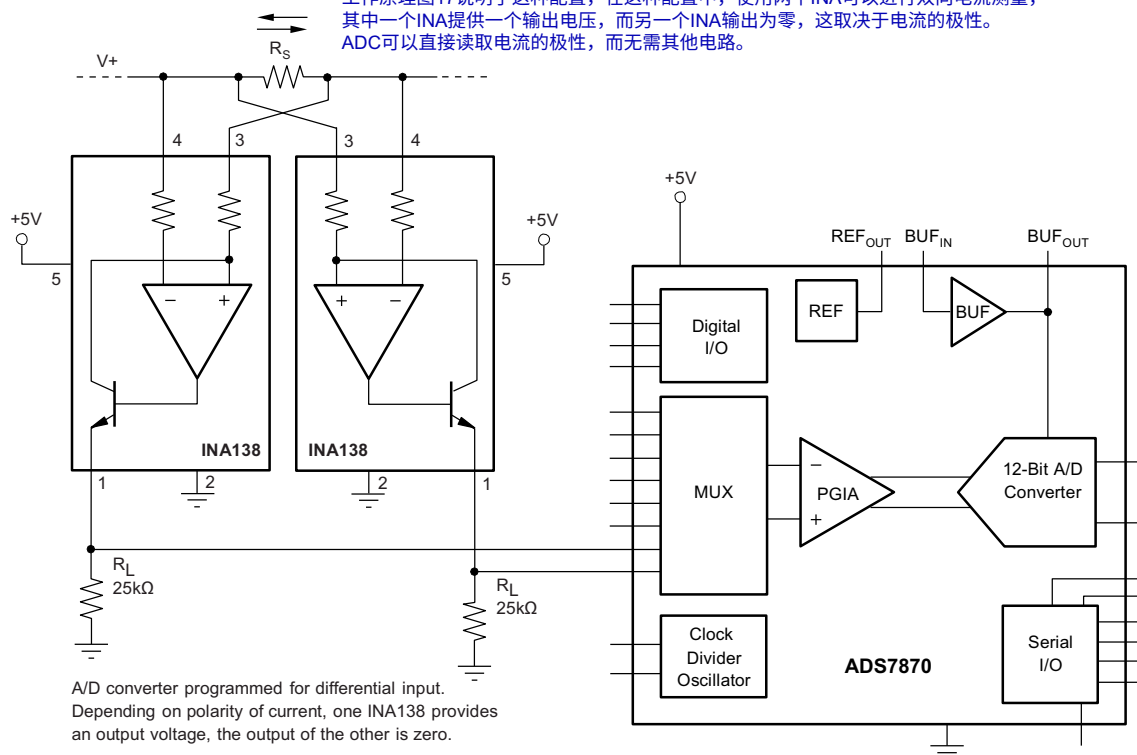


Figure 17. Bipolar Current Measurement Using Differential Input of ADC

Typical Applications (continued)

8.2.6 Multiplexed Measurement Using Logic Signal for Power

Multiple loads can be measured as illustrated in Figure 18. In this configuration each INA1x8 device is powered by the digital I/O from the ADS7870. Multiplexing is achieved by switching on or off each the desired I/O.

如图18所示，可以测量多个负载。在这种配置中，每个INA1x8器件均由ADS7870的数字I/O供电，通过打开或关闭每个所需的I/O来实现多路复用。

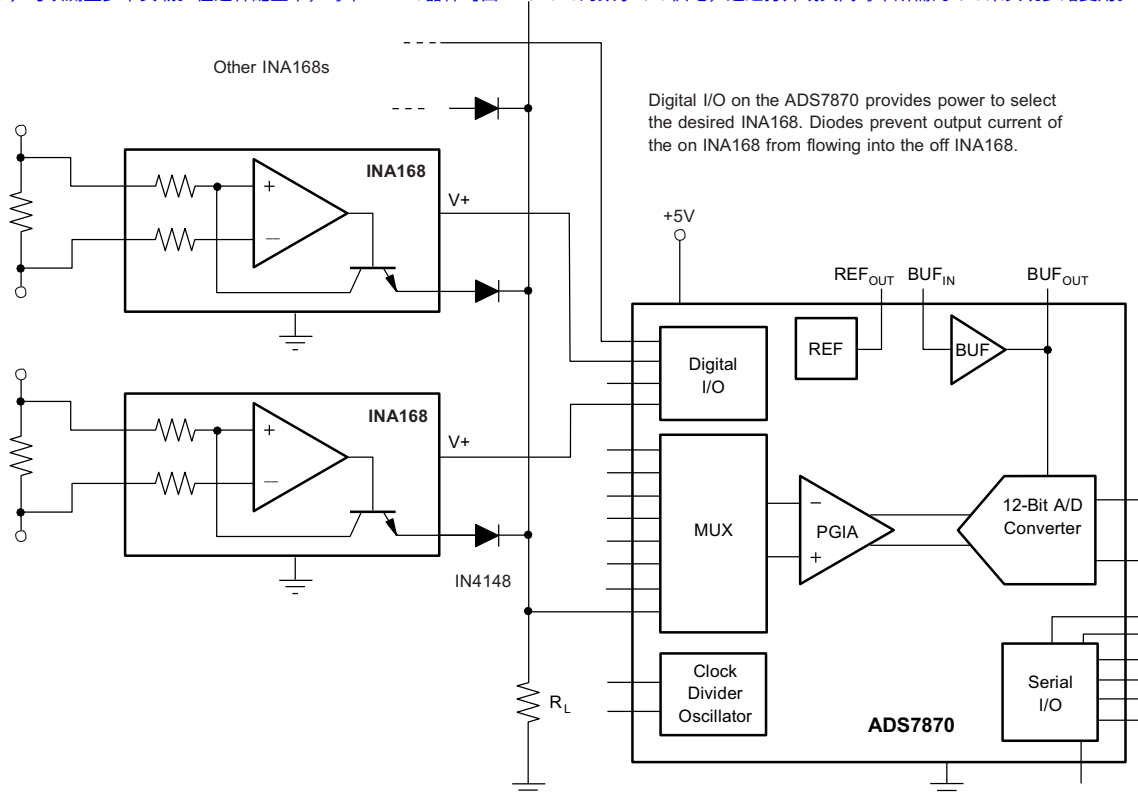


Figure 18. Multiplexed Measurement Using Logic Signal for Power

9 Power Supply Recommendations

The input circuitry of the INA138 can accurately measure beyond its power-supply voltage, $V+$. For example, the $V+$ power supply can be 5 V, whereas the load power supply voltage is up to 36 V (or 60 V with the INA168). The output voltage range of the OUT terminal, however, is limited by the lesser of the two voltages (see [Output Voltage Range](#)). A 0.1- μF capacitor is recommended to be placed near the power supply pin on the INA138 or INA168. Additional capacitance may be required for applications with noisy power supply voltages.

10 Layout

10.1 Layout Guidelines

[Figure 19](#) shows the basic connection of the INA138 device. The input pins, $V_{\text{IN}+}$ and $V_{\text{IN}-}$, should be connected as closely as possible to the shunt resistor to minimize any resistance in series with the shunt resistance. The output resistor, R_L , is shown connected between pin 1 and ground. Best accuracy is achieved with the output voltage measured directly across R_L . This is especially important in high-current systems where load current could flow in the ground connections, affecting the measurement accuracy.

No power-supply bypass capacitors are required for stability of the INA138. However, applications with noisy or high-impedance power supplies may require decoupling capacitors to reject power-supply noise. Connect bypass capacitors close to the device pins.

图19显示了INA138器件的基本连接，应将输入引脚 $V_{\text{IN}+}$ 和 $V_{\text{IN}-}$ 尽可能紧密地连接至分流电阻，以最大程度地减少与分流电阻串联的电阻，并显示输出电阻 R_L 。直接在 R_L 两端测量输出电压可获得最佳精度，这在大电流系统中尤为重要，在该系统中，负载电流可能在接地连接中流动，从而影响测量精度。INA138的稳定性是必需的，但是，对于有噪声或高阻抗电源的应用，可能需要进行去耦研究以抑制电源噪声，将旁路玻璃靠近设备引脚的地方连接。

10.2 Layout Example

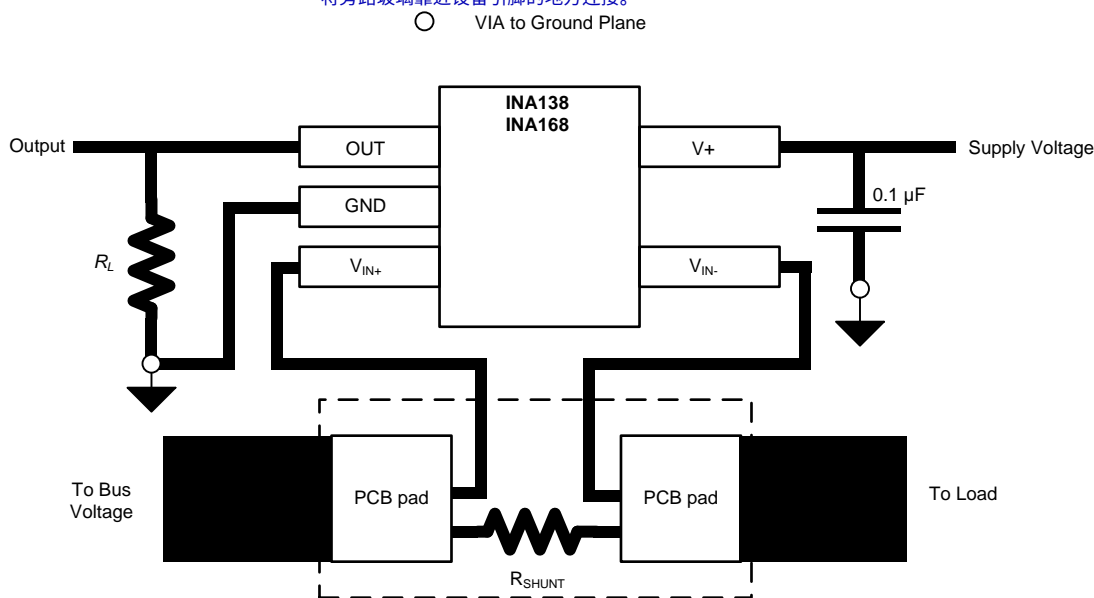


Figure 19. Typical Layout Example

11 器件和文档支持

11.1 文档支持

11.1.1 相关文档

请参阅如下相关文档：

- 《用于单端多路复用应用的 16 位 1MSPS 数据采集 参考设计》
- 《ADS7870 12 位 ADC、MUX、PGA 和内部基准数据采集系统》
- 《TLV3201、TLV3202 40ns 微功耗推挽式输出比较器》
- 《REF200 双路拉电流/灌电流》

11.2 相关链接

表 1 列出了快速访问链接。类别包括技术文档、支持与社区资源、工具和软件，以及申请样片或购买产品的快速链接。

表 1. 相关链接

器件	产品文件夹	样片与购买	技术文档	工具和软件	支持和社区
INA138	请单击此处	请单击此处	请单击此处	请单击此处	请单击此处
INA168	请单击此处	请单击此处	请单击此处	请单击此处	请单击此处

11.3 接收文档更新通知

如需接收文档更新通知，请导航至 TI.com 上的器件产品文件夹。单击右上角的通知我 进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查看任何已修订文档中包含的修订历史记录。

11.4 社区资源

下列链接提供到 TI 社区资源的连接。链接的内容由各个分销商“按照原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的《使用条款》。

TI E2E™ 在线社区 TI 的工程师对工程师 (E2E) 社区。此社区的创建目的在于促进工程师之间的协作。在 e2e.ti.com 中，您可以咨询问题、分享知识、拓展思路并与同行工程师一道帮助解决问题。

设计支持 TI 参考设计支持 可帮助您快速查找有帮助的 E2E 论坛、设计支持工具以及技术支持的联系信息。

11.5 商标

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

11.6 静电放电警告



ESD 可能会损坏该集成电路。德州仪器 (TI) 建议通过适当的预防措施处理所有集成电路。如果不遵守正确的处理措施和安装程序，可能会损坏集成电路。

ESD 的损坏小至导致微小的性能降级，大至整个器件故障。精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

11.7 Glossary

SLYZ022 — TI Glossary.

This glossary lists and explains terms, acronyms, and definitions.

12 机械、封装和可订购信息

以下页面包含机械、封装和可订购信息。这些信息是指定器件的最新可用数据。数据如有变更，恕不另行通知和修订此文档。如欲获取此数据表的浏览器版本，请参阅左侧的导航。

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
INA138NA/250	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	B38	Samples
INA138NA/3K	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	B38	Samples
INA138NA/3KG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	B38	Samples
INA168NA/250	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	NIPDAU	Level-2-260C-1 YEAR		A68	Samples
INA168NA/3K	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	A68	Samples

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
INA138NA/250	SOT-23	DBV	5	250	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
INA138NA/3K	SOT-23	DBV	5	3000	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
INA168NA/250	SOT-23	DBV	5	250	178.0	9.0	3.23	3.17	1.37	4.0	8.0	Q3
INA168NA/3K	SOT-23	DBV	5	3000	178.0	9.0	3.23	3.17	1.37	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
INA138NA/250	SOT-23	DBV	5	250	180.0	180.0	18.0
INA138NA/3K	SOT-23	DBV	5	3000	180.0	180.0	18.0
INA168NA/250	SOT-23	DBV	5	250	180.0	180.0	18.0
INA168NA/3K	SOT-23	DBV	5	3000	180.0	180.0	18.0

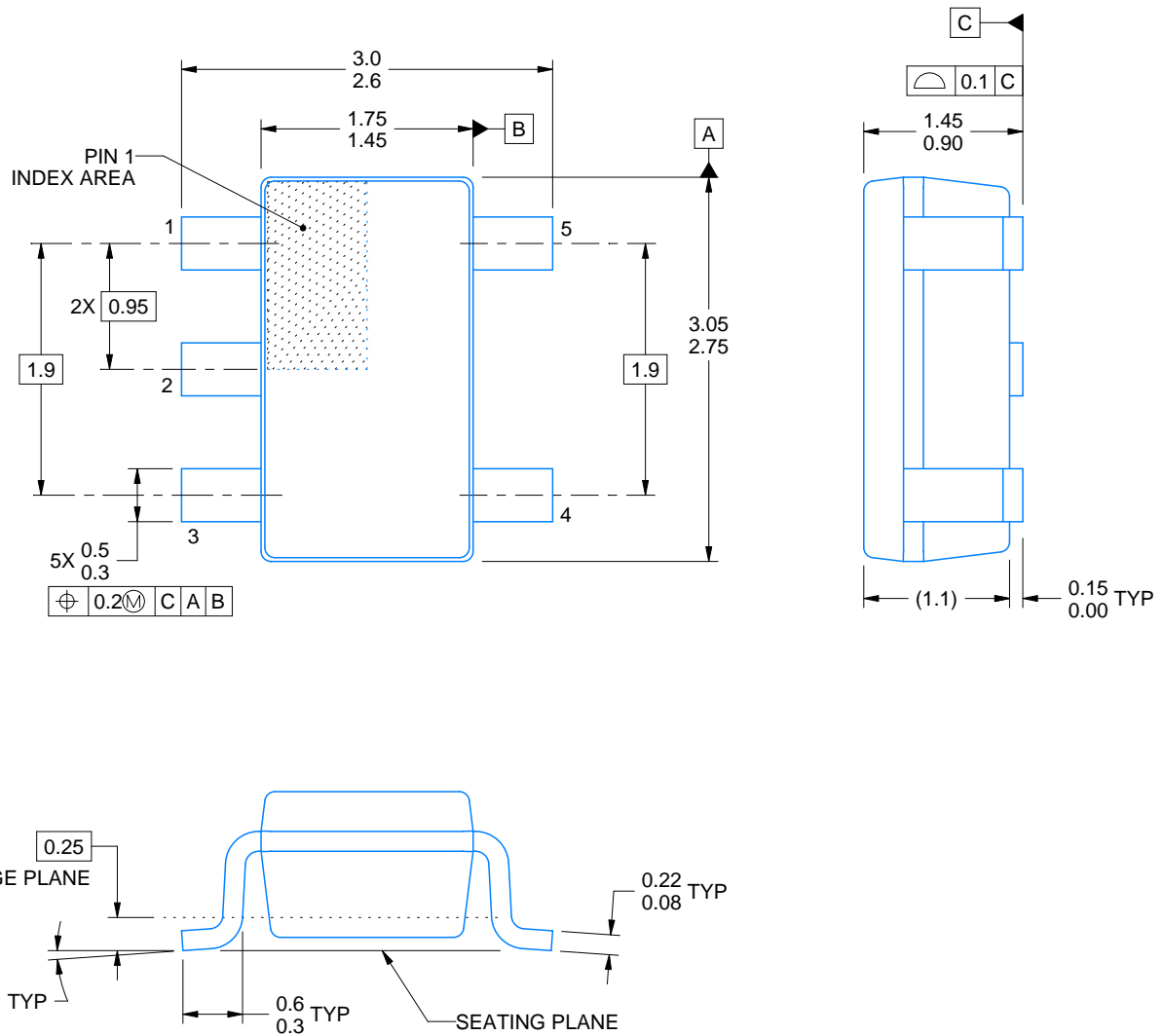
DBV0005A



PACKAGE OUTLINE

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



4214839/E 09/2019

NOTES:

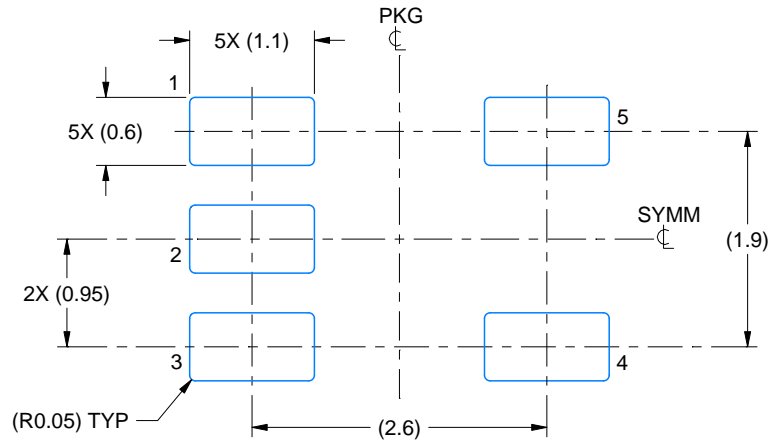
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.

EXAMPLE BOARD LAYOUT

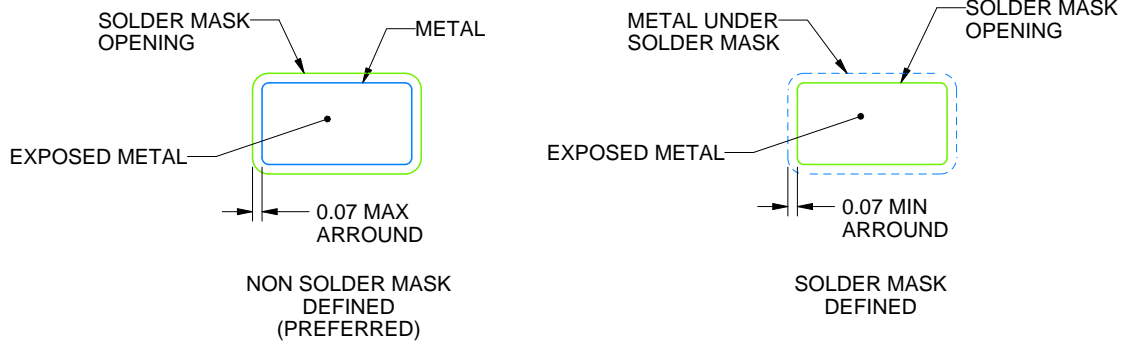
DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X



SOLDER MASK DETAILS

4214839/E 09/2019

NOTES: (continued)

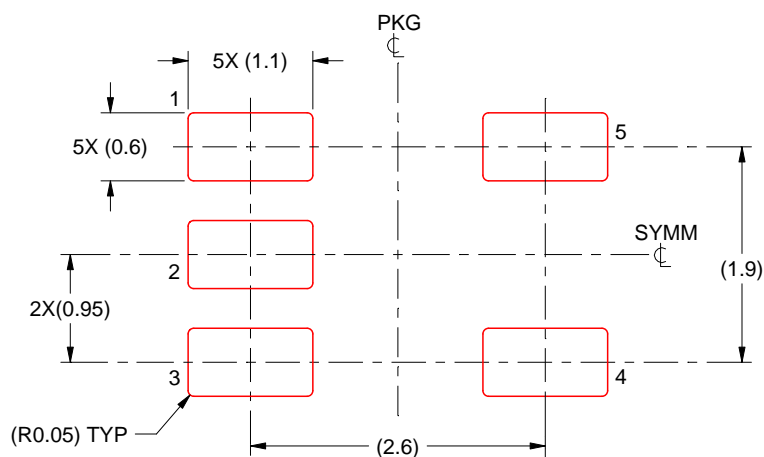
5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

4214839/E 09/2019

NOTES: (continued)

7. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
8. Board assembly site may have different recommendations for stencil design.

重要声明和免责声明

TI 均以“原样”提供技术性 & 可靠性数据（包括数据表）、设计资源（包括参考设计）、应用或其他设计建议、网络工具、安全信息和其他资源，不保证其中不含任何瑕疵，且不做任何明示或暗示的担保，包括但不限于对适销性、适合某特定用途或不侵犯任何第三方知识产权的暗示担保。

所述资源可供专业开发人员应用 TI 产品进行设计使用。您将对以下行为独自承担全部责任：(1) 针对您的应用选择合适的 TI 产品；(2) 设计、验证并测试您的应用；(3) 确保您的应用满足相应标准以及任何其他安全、安保或其他要求。所述资源如有变更，恕不另行通知。TI 对您使用所述资源的授权仅限于开发资源所涉及 TI 产品的相关应用。除此之外不得复制或展示所述资源，也不提供其它 TI 或任何第三方的知识产权授权许可。如因使用所述资源而产生任何索赔、赔偿、成本、损失及债务等，TI 对此概不负责，并且您须赔偿由此对 TI 及其代表造成的损害。

TI 所提供产品均受 TI 的销售条款 (<http://www.ti.com.cn/zh-cn/legal/termsofsale.html>) 以及 [ti.com.cn](http://www.ti.com.cn) 上或随附 TI 产品提供的其他可适用条款的约束。TI 提供所述资源并不扩展或以其他方式更改 TI 针对 TI 产品所发布的可适用的担保范围或担保免责声明。

邮寄地址：上海市浦东新区世纪大道 1568 号中建大厦 32 楼，邮政编码：200122
Copyright © 2020 德州仪器半导体技术（上海）有限公司