

Micropower, Rail-to-Rail Input Current Sense Amplifier with Voltage Output

ISL28005

The ISL28005 is a micropower, uni-directional high-side and low-side current sense amplifier featuring a proprietary rail-to-rail input current sensing amplifier. The ISL28005 is ideal for high-side current sense applications where the sense voltage is usually much higher than the amplifier supply voltage. The device can be used to sense voltages as high as 28V when operating from a supply voltage as low as 2.7V. The micropower ISL28005 consumes only 50µA of supply current when operating from a 2.7V to 28V supply.

The ISL28005 features a common-mode input voltage range from 0V to 28V. The proprietary architecture extends the input voltage sensing range down to 0V, making it an excellent choice for low-side ground sensing applications. The benefit of this architecture is that a high degree of total output accuracy is maintained over the entire 0V to 28V common mode input voltage range.

The ISL28005 is available in fixed (100V/V, 50V/V and 20V/V) gains in the space saving 5 Ld SOT-23 package. The parts operate over the extended temperature range from -40°C to +125°C.

Features

- Low Power Consumption. 50µA, Typ
- Supply Range 2.7V to 28V
- Wide Common Mode Input. 0V to 28V
- Fixed Gain Versions
 - ISL28005-100 100V/V
 - ISL28005-50 50V/V
 - ISL28005-20 20V/V
- Operating Temperature Range. -40°C to +125°C
- Package. 5 Ld SOT-23

Applications

- Power Management/Monitors
- Power Distribution and Safety
- DC/DC, AC/DC Converters
- Battery Management/Charging
- Automotive Power Distribution

Related Literature

- See [AN1531](#) for “ISL28005 Evaluation Board User’s Guide”
- See [AN1567](#) for “ISL28005, ISL28006 Unidirectional Current Sense Amplifiers”

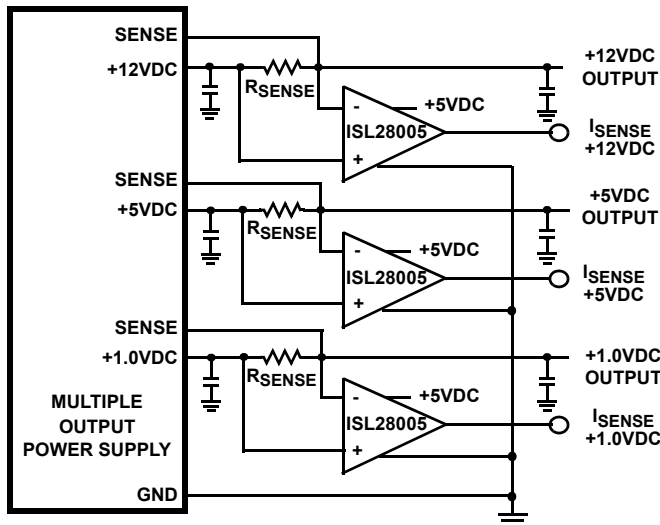


FIGURE 1. TYPICAL APPLICATION

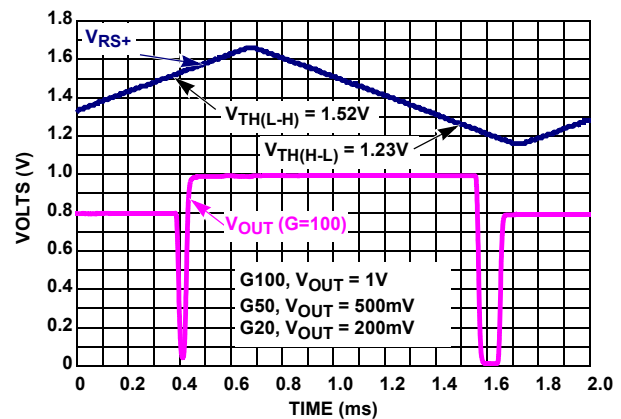
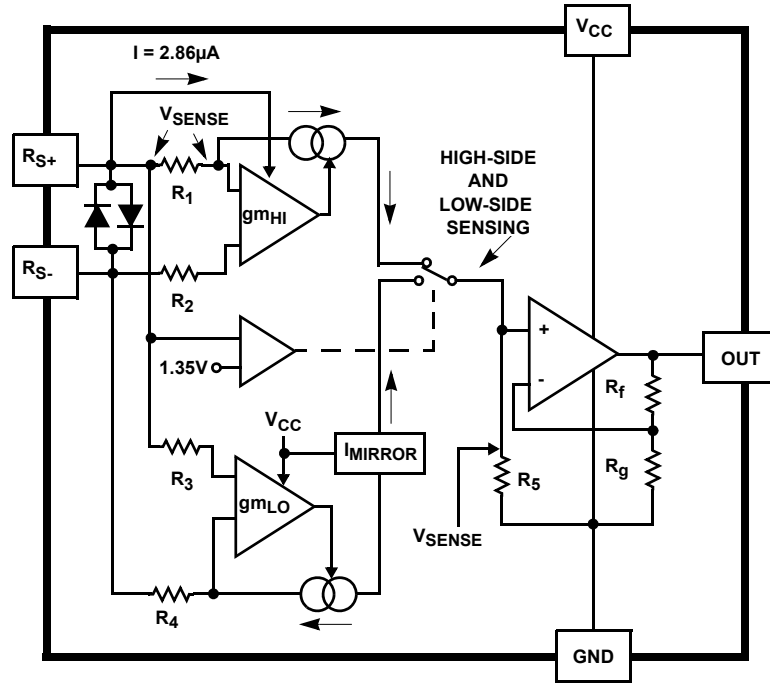
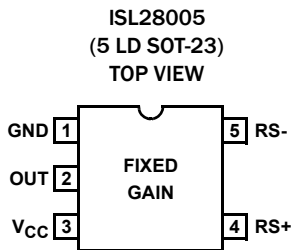


FIGURE 2. HIGH-SIDE AND LOW-SIDE THRESHOLD VOLTAGE

Block Diagram

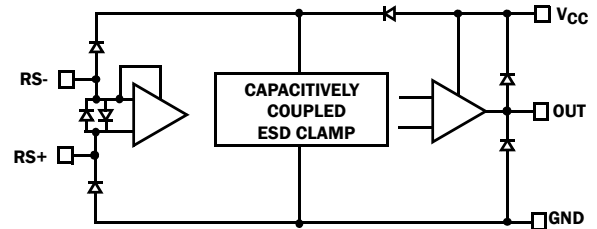


Pin Configuration



Pin Descriptions

| ISL28005 (5 LD SOT-23) | PIN NAME | DESCRIPTION |
|---------------------------|-----------------|-----------------------------------|
| 1 | GND | Power Ground |
| 2 | OUT | Amplifier Output |
| 3 | V _{CC} | Positive Power Supply |
| 4 | RS+ | Sense Voltage Non-inverting Input |
| 5 | RS- | Sense Voltage Inverting Input |



ISL28005

Ordering Information

| PART NUMBER (Notes 1, 2, 3) | GAIN | PART MARKING | PACKAGE Tape & Reel (Pb-Free) | PKG. DWG. # |
|--------------------------------|-------------------------|---------------|-------------------------------------|----------------|
| ISL28005FH100Z-T7 | 100V/V | BDEA (Note 4) | 5 Ld SOT-23 | P5.064A |
| ISL28005FH100Z-T7A | 100V/V | BDEA (Note 4) | 5 Ld SOT-23 | P5.064A |
| ISL28005FH50Z-T7 | 50V/V | BDDA (Note 4) | 5 Ld SOT-23 | P5.064A |
| ISL28005FH50Z-T7A | 50V/V | BDDA (Note 4) | 5 Ld SOT-23 | P5.064A |
| ISL28005FH20Z-T7 | 20V/V | BDCA (Note 4) | 5 Ld SOT-23 | P5.064A |
| ISL28005FH20Z-T7A | 20V/V | BDCA (Note 4) | 5 Ld SOT-23 | P5.064A |
| ISL28005FH-100EVAL1Z | 100V/V Evaluation Board | | | |
| ISL28005FH-50EVAL1Z | 50V/V Evaluation Board | | | |
| ISL28005FH-20EVAL1Z | 20V/V Evaluation Board | | | |

NOTES:

1. Please refer to [TB347](#) for details on reel specifications.
2. These Intersil Pb-free plastic packaged products employ special Pb-free material sets, molding compounds/die attach materials, and 100% matte tin plate plus anneal (e3 termination finish, which is RoHS compliant and compatible with both SnPb and Pb-free soldering operations). Intersil Pb-free products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC J STD-020.
3. For Moisture Sensitivity Level (MSL), please see device information page for [ISL28005](#). For more information on MSL please see techbrief [TB363](#).
4. The part marking is located on the bottom of the part.

ISL28005

Absolute Maximum Ratings

| | |
|--|-------------------|
| Max Supply Voltage | ..28V |
| Max Differential Input Current | ..20mA |
| Max Differential Input Voltage | ..±0.5V |
| Max Input Voltage (RS+, RS-) | ..GND-0.5V to 30V |
| Max Input Current for Input Voltage <GND -0.5V | ..±20mA |
| Output Short-Circuit Duration | ..Indefinite |
| ESD Rating | |
| Human Body Model | ..4kV |
| Machine Model | ..200V |
| Charged Device Model | ..1.5kV |

Thermal Information

| | | |
|---|---|----------------------|
| Thermal Resistance (Typical) | θ_{JA} (°C/W) | θ_{JC} (°C/W) |
| 5 Ld SOT-23 (Notes 5, 6) | 190 | 90 |
| Maximum Storage Temperature Range | ..-65°C to +150°C | |
| Maximum Junction Temperature (T _{JMAX}) | ..+150°C | |
| Pb-Free Reflow Profile | ..see link below http://www.intersil.com/pbfree/Pb-FreeReflow.asp | |

Recommended Operating Conditions

| | |
|---|-------------------|
| Ambient Temperature Range (T _A) | ..-40°C to +125°C |
|---|-------------------|

CAUTION: Do not operate at or near the maximum ratings listed for extended periods of time. Exposure to such conditions may adversely impact product reliability and result in failures not covered by warranty.

NOTES:

5. θ_{JA} is measured with the component mounted on a high effective thermal conductivity test board in free air. See Tech Brief [TB379](#) for details.
6. For θ_{JC} , the “case temp” location is taken at the package top center.

Electrical Specification V_{CC} = 12V, V_{RS+} = 0V to 28V, V_{SENSE} = 0V, R_{LOAD} = 1M Ω , T_A = +25°C unless otherwise specified. **Boldface limits apply over the operating temperature range, -40°C to +125°C. Temperature data established by characterization.**

| PARAMETER | DESCRIPTION | CONDITIONS | MIN (Note 7) | TYP | MAX (Note 7) | UNIT |
|-------------------------------------|---|---|---------------------|-------|-------------------|---------|
| V _{OS} | Input Offset Voltage (Notes 8, 9) | V _{CC} = V _{RS+} = 12V, V _S = 20mV to = 100mV | -500 -500 | 60 | 500 500 | μ V |
| | | V _{CC} = 12V, V _{RS+} = 0.2V, V _S = 20mV, V _S = 100mV | -3 -3.3 | -1.2 | 3 3.3 | mV |
| I _{RS+} , I _{RS-} | Leakage Current | V _{CC} = 0V, V _{RS+} = 28V | | 0.041 | 1.2 1.5 | μ A |
| I _{RS+} | Gain = 100 + Input Bias Current | V _{RS+} = 2V, V _{SENSE} = 5mV | | 4.7 | 6 7 | μ A |
| | | V _{RS+} = 0V, V _{SENSE} = 5mV | -500 -600 | -425 | | nA |
| | Gain = 50, Gain = 20 + Input Bias Current | V _{RS+} = 2V, V _{SENSE} = 5mV | | 4.7 | 6 8 | μ A |
| | | V _{RS+} = 0V, V _{SENSE} = 5mV | -700 -840 | -432 | | nA |
| I _{RS-} | Input Bias Current | V _{RS+} = 2V, V _{SENSE} = 5mV | | 5 | 50 75 | nA |
| | | V _{RS+} = 0V, V _{SENSE} = 5mV | -125 -130 | -45 | | nA |
| CMRR | Common Mode Rejection Ratio | V _{RS+} = 2V to 28V | 105 | 115 | | dB |
| PSRR | Power Supply Rejection Ratio | V _{CC} = 2.7V to 28V, V _{RS+} = 2V | 90 | 105 | | dB |
| V _{FS} | Full-scale Sense Voltage | V _{CC} = 28V, V _{RS+} = 0.2V, 12V | 200 | | | mV |
| G | Gain (Note 8) | ISL28005-100 | | 100 | | V/V |
| | | ISL28005-50 | | 50 | | V/V |
| | | ISL28005-20 | | 20 | | V/V |

ISL28005

Electrical Specification $V_{CC} = 12V$, $V_{RS+} = 0V$ to $28V$, $V_{SENSE} = 0V$, $R_{LOAD} = 1M\Omega$, $T_A = +25^\circ C$ unless otherwise specified. **Boldface limits apply over the operating temperature range, $-40^\circ C$ to $+125^\circ C$. Temperature data established by characterization. (Continued)**

| PARAMETER | DESCRIPTION | CONDITIONS | MIN (Note 7) | TYP | MAX (Note 7) | UNIT |
|--------------------|---|--|---------------------|-------|-------------------|------------|
| G _A | Gain = 100 Gain Accuracy (Note 10) | $V_{CC} = V_{RS+} = 12V$, $V_{SENSE} = 20mV$ to $100mV$ | -2 -3 | | 2 3 | % |
| | | $V_{CC} = 12V$, $V_{RS+} = 0.1V$, $V_{SENSE} = 20mV$ to $100mV$ | | -0.25 | | % |
| | Gain = 50, Gain = 20 Gain Accuracy (Note 10) | $V_{CC} = V_{RS+} = 12V$, $V_{SENSE} = 20mV$ to $100mV$ | -2 -3 | | 2 3 | % |
| | | $V_{CC} = 12V$, $V_{RS+} = 0.1V$, $V_{SENSE} = 20mV$ to $100mV$ | -3 -4 | -0.31 | 3 4 | % |
| V _{OA} | Gain = 100 Total Output Accuracy (Note 11) | $V_{CC} = V_{RS+} = 12V$, $V_{SENSE} = 100mV$ | -2.5 -2.7 | | 2.5 2.7 | % |
| | | $V_{CC} = 12V$, $V_{RS+} = 0.1V$, $V_{SENSE} = 100mV$ | | -1.25 | | % |
| | Gain = 50, Gain = 20 Total Output Accuracy (Note 11) | $V_{CC} = V_{RS+} = 12V$, $V_{SENSE} = 100mV$ | -2.5 -2.7 | | 2.5 2.7 | % |
| | | $V_{CC} = 12V$, $V_{RS+} = 0.1V$, $V_{SENSE} = 100mV$ | -6 -7 | -1.41 | 6 7 | % |
| V _{OH} | Output Voltage Swing, High $V_{CC} - V_{OUT}$ | $I_O = -500\mu A$, $V_{CC} = 2.7V$ $V_{SENSE} = 100mV$ $V_{RS+} = 2V$ | | 39 | 50 | mV |
| V _{OL} | Output Voltage Swing, Low V_{OUT} | $I_O = 500\mu A$, $V_{CC} = 2.7V$ $V_{SENSE} = 0V$, $V_{RS+} = 2V$ | | 30 | 50 | mV |
| R _{OUT} | Output Resistance | $V_{CC} = V_{RS+} = 12V$, $V_{SENSE} = 100mV$ $I_{OUT} = 10\mu A$ to $1mA$ | | 6.5 | | Ω |
| I _{SC+} | Short Circuit Sourcing Current | $V_{CC} = V_{RS+} = 5V$, $R_L = 10\Omega$ | | 4.8 | | mA |
| I _{SC-} | Short Circuit Sinking Current | $V_{CC} = V_{RS+} = 5V$, $R_L = 10\Omega$ | | 8.7 | | mA |
| I _{CC} | Gain = 100 Supply Current | $V_{RS+} > 2V$, $V_{SENSE} = 5mV$ | | 50 | 59 62 | μA |
| | Gain = 50, 20 Supply Current | $V_{RS+} > 2V$, $V_{SENSE} = 5mV$ | | 50 | 62 63 | μA |
| V _{CC} | Supply Voltage | Guaranteed by PSRR | 2.7 | | 28 | V |
| SR | Gain = 100 Slew Rate | Pulse on RS+ pin, $V_{OUT} = 8V_{P-P}$ (see Figure 25) | 0.58 | 0.76 | | V/ μs |
| | Gain = 50 Slew Rate | Pulse on RS+ pin, $V_{OUT} = 8V_{P-P}$ (see Figure 25) | 0.58 | 0.67 | | V/ μs |
| | Gain = 20 Slew Rate | Pulse on RS+ pin, $V_{OUT} = 3.5V_{P-P}$ (see Figure 25) | 0.50 | 0.67 | | V/ μs |
| BW _{-3dB} | Gain = 100 -3dB Bandwidth | $V_{RS+} = 12V$, $0.1V$, $V_{SENSE} = 100mV$ | | 110 | | kHz |
| | Gain = 50 -3dB Bandwidth | $V_{RS+} = 12V$, $0.1V$, $V_{SENSE} = 100mV$ | | 160 | | kHz |
| | Gain = 20 -3dB Bandwidth | $V_{RS+} = 12V$, $0.1V$, $V_{SENSE} = 100mV$ | | 180 | | kHz |

ISL28005

Electrical Specification $V_{CC} = 12V$, $V_{RS+} = 0V$ to $28V$, $V_{SENSE} = 0V$, $R_{LOAD} = 1M\Omega$, $T_A = +25^\circ C$ unless otherwise specified. **Boldface limits apply over the operating temperature range, $-40^\circ C$ to $+125^\circ C$. Temperature data established by characterization. (Continued)**

| PARAMETER | DESCRIPTION | CONDITIONS | MIN (Note 7) | TYP | MAX (Note 7) | UNIT |
|----------------|---|---|--------------|-----|--------------|---------|
| t_s | Output Settling Time to 1% of Final Value | $V_{CC} = V_{RS+} = 12V$, $V_{OUT} = 10V$ step, $V_{SENSE} > 7mV$ | | 15 | | μs |
| | | $V_{CC} = V_{RS+} = 0.2V$, $V_{OUT} = 10V$ step, $V_{SENSE} > 7mV$ | | 20 | | μs |
| | Capacitive-Load Stability | No sustained oscillations | | 300 | | μF |
| t_s Power-up | Power-Up Time to 1% of Final Value | $V_{CC} = V_{RS+} = 12V$, $V_{SENSE} = 100mV$ | | 15 | | μs |
| | | $V_{CC} = 12V$, $V_{RS+} = 0.2V$, $V_{SENSE} = 100mV$ | | 50 | | μs |
| | Saturation Recovery Time | $V_{CC} = V_{RS+} = 12V$, $V_{SENSE} = 100mV$, overdrive | | 10 | | μs |

NOTES:

7. Compliance to datasheet limits is assured by one or more methods: production test, characterization and/or design.

8. DEFINITION OF TERMS:

- $V_{SENSE A} = V_{SENSE} @ 100mV$
- $V_{SENSE B} = V_{SENSE} @ 20mV$
- $V_{OUT A} = V_{OUT} @ V_{SENSE A} = 100mV$
- $V_{OUT B} = V_{OUT} @ V_{SENSE B} = 20mV$
- $G = GAIN = \left(\frac{V_{OUT A} - V_{OUT B}}{V_{SENSE A} - V_{SENSE B}} \right)$

9. V_{OS} is extrapolated from the gain measurement. $V_{OS} = V_{SENSE A} - \frac{V_{OUT A}}{G}$

10. % Gain Accuracy = $G_A = \left(\frac{G_{MEASURED} - G_{EXPECTED}}{G_{EXPECTED}} \right) \times 100$

11. Output Accuracy % $V_{OA} = \left(\frac{V_{OUT MEASURED} - V_{OUT EXPECTED}}{-V_{OUT EXPECTED}} \right) \times 100$ where $V_{OUT} = V_{SENSE} \times GAIN$ and $V_{SENSE} = 100mV$

Typical Performance Curves $V_{CC} = 12V$, $R_L = 1M$, unless otherwise specified.

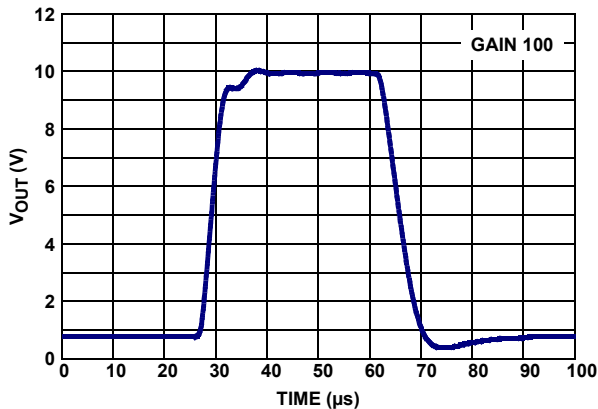


FIGURE 3. LARGE SIGNAL TRANSIENT RESPONSE $V_{RS+} = 0.2V$, $V_{SENSE} = 100mV$

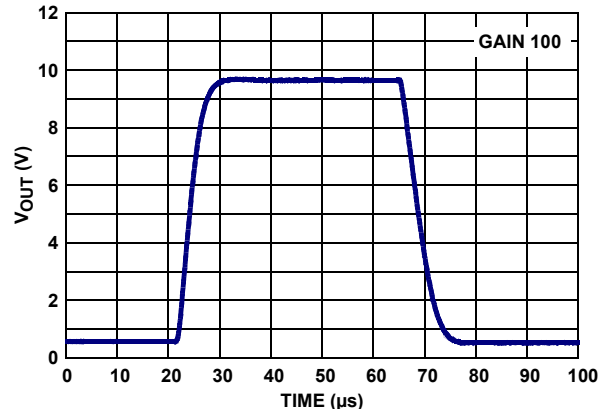


FIGURE 4. LARGE SIGNAL TRANSIENT RESPONSE $V_{RS+} = 12V$, $V_{SENSE} = 100mV$

Typical Performance Curves $V_{CC} = 12V, R_L = 1M$, unless otherwise specified. (Continued)

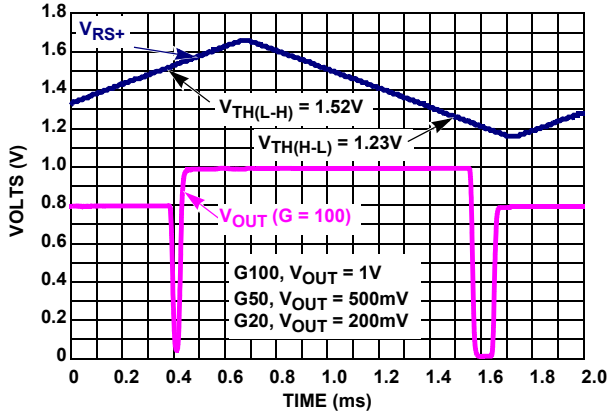


FIGURE 5. HIGH-SIDE and LOW-SIDE THRESHOLD VOLTAGE $V_{RS+(L-H)}$ and $V_{RS+(H-L)}$, $V_{SENSE} = 10mV$

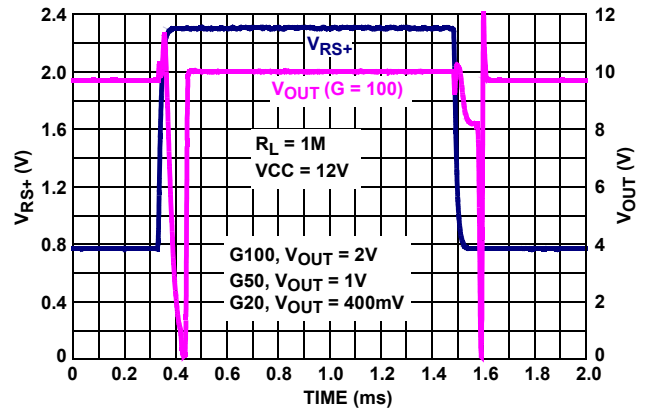


FIGURE 6. V_{OUT} vs V_{RS+} , $V_{SENSE} = 20mV$ TRANSIENT RESPONSE

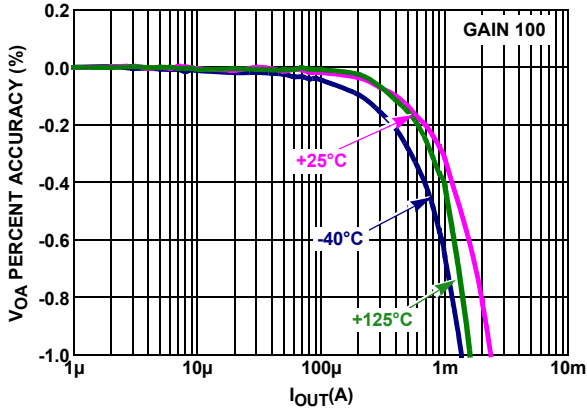


FIGURE 7. NORMALIZED V_{OA} vs I_{OUT}

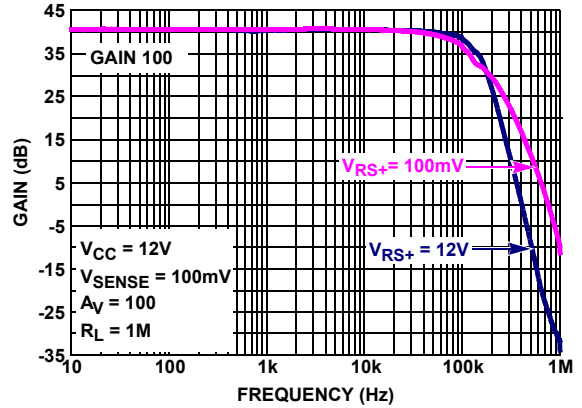


FIGURE 8. GAIN vs FREQUENCY $V_{RS+} = 100mV/12V$, $V_{SENSE} = 100mV$, $V_{OUT} = 250mV_{p-p}$

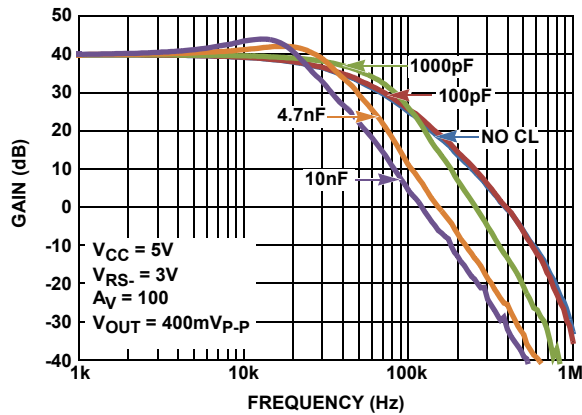


FIGURE 9. CAPACITIVE LOAD DRIVE GAIN vs FREQUENCY

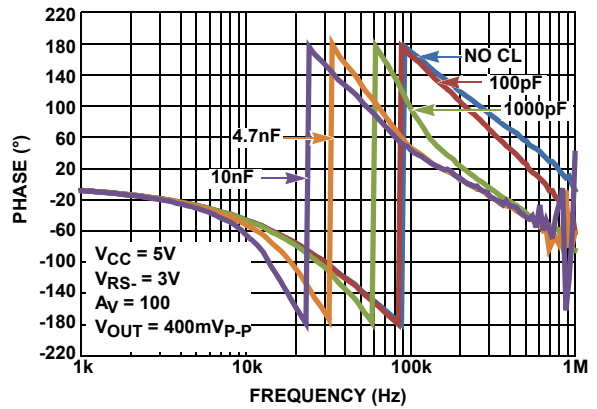


FIGURE 10. CAPACITIVE LOAD DRIVE PHASE vs FREQUENCY

Typical Performance Curves $V_{CC} = 12V, R_L = 1M$, unless otherwise specified. (Continued)

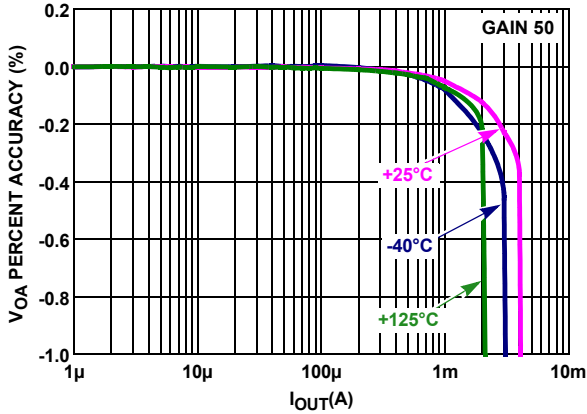


FIGURE 11. NORMALIZED V_{OA} vs I_{OUT}

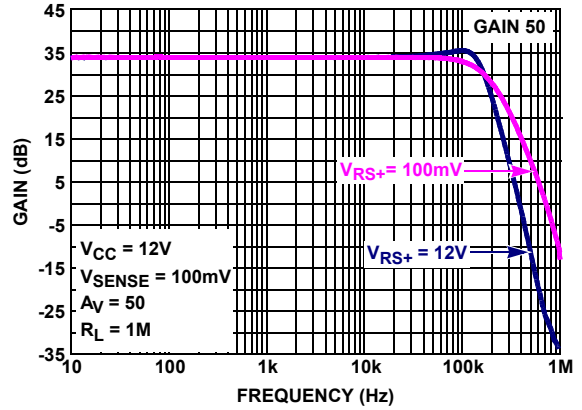


FIGURE 12. GAIN vs FREQUENCY $V_{RS+} = 100mV/12V$, $V_{SENSE} = 100mV, V_{OUT} = 250mV_{p-p}$

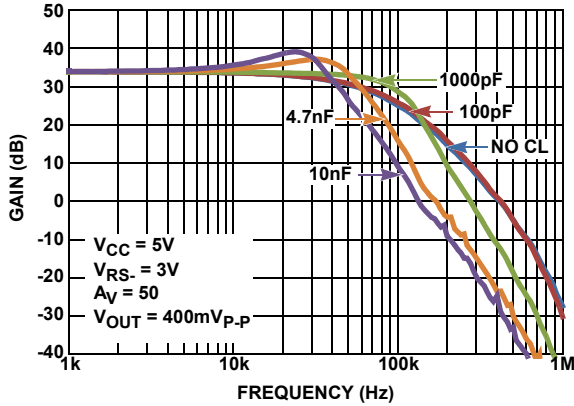


FIGURE 13. CAPACITIVE LOAD DRIVE GAIN vs FREQUENCY

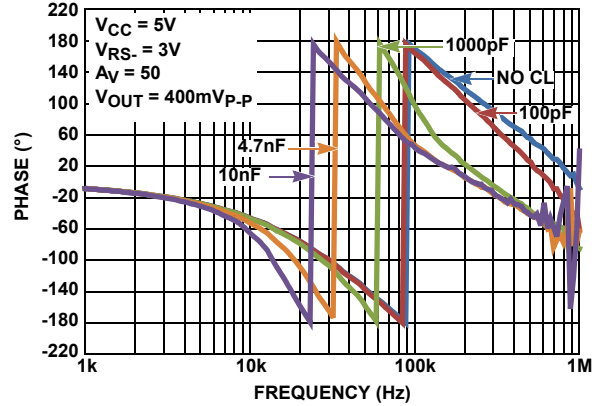


FIGURE 14. CAPACITIVE LOAD DRIVE PHASE vs FREQUENCY

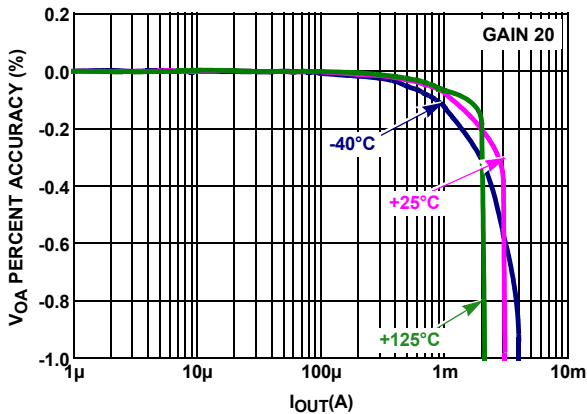


FIGURE 15. NORMALIZED V_{OA} vs I_{OUT}

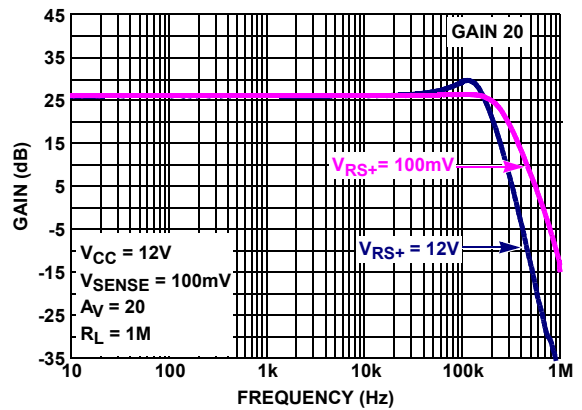


FIGURE 16. GAIN vs FREQUENCY $V_{RS+} = 100mV/12V$, $V_{SENSE} = 100mV, V_{OUT} = 250mV_{p-p}$

Typical Performance Curves $V_{CC} = 12V, R_L = 1M$, unless otherwise specified. (Continued)

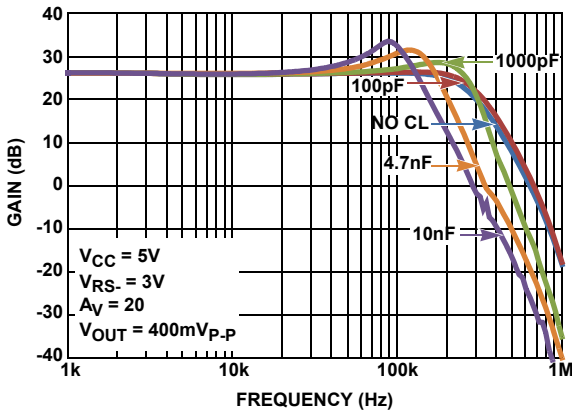


FIGURE 17. CAPACITIVE LOAD DRIVE GAIN vs FREQUENCY

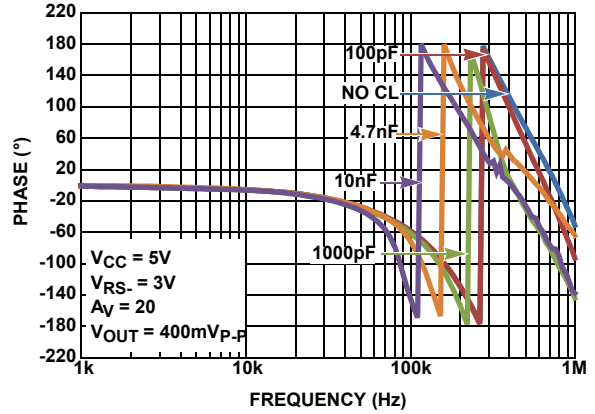


FIGURE 18. CAPACITIVE LOAD DRIVE PHASE vs FREQUENCY

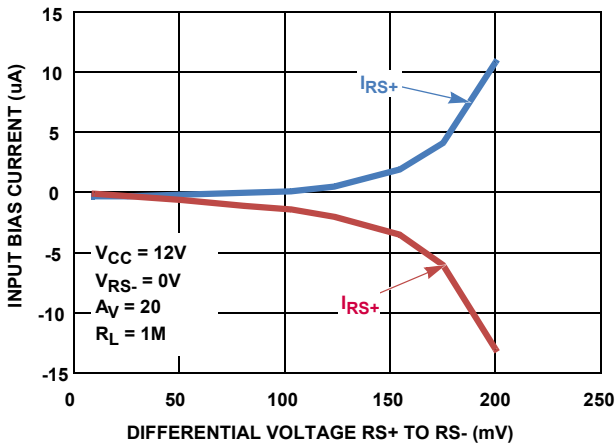


FIGURE 19. LOW-SIDE CURRENT SENSING INPUT BIAS CURRENTS

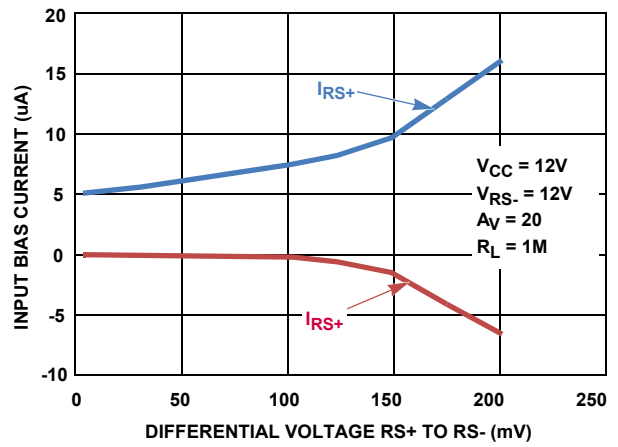


FIGURE 20. HIGH-SIDE CURRENT SENSING INPUT BIAS CURRENTS

Test Circuits and Waveforms

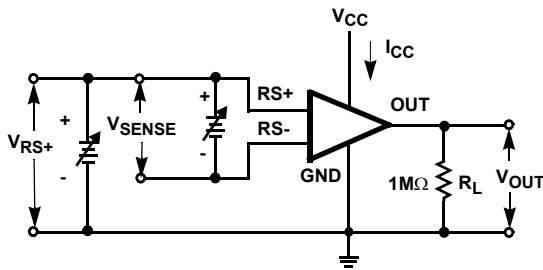


FIGURE 21. $I_{CC}, V_{OS}, V_{OA}, CMRR, PSRR, GAIN ACCURACY$

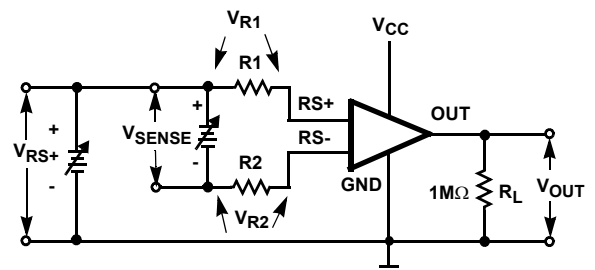


FIGURE 22. INPUT BIAS CURRENT, LEAKAGE CURRENT

Test Circuits and Waveforms (Continued)

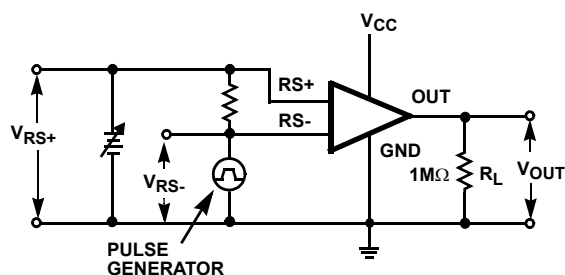


FIGURE 23. SLEW RATE, t_s , SATURATION RECOVERY TIME

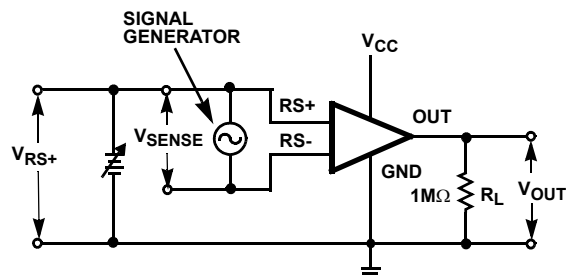


FIGURE 24. GAIN vs FREQUENCY

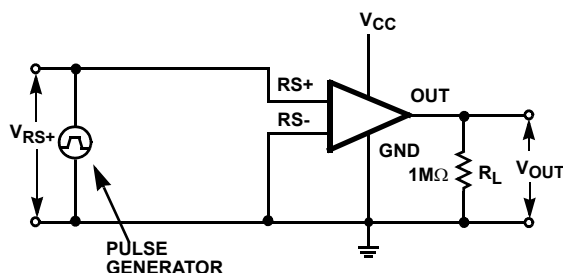


FIGURE 25. SLEW RATE

Applications Information

Functional Description

The ISL28005-20, ISL28005-50 and ISL28005-100 are single supply, uni-directional current sense amplifiers with fixed gains of 20V/V, 50V/V and 100V/V respectively.

The ISL28005 is a 2-stage amplifier. Figure 26 shows the active circuitry for high-side current sense applications where the sense voltage is between 1.35V to 28V. Figure 27 shows the active circuitry for ground sense applications where the sense voltage is between 0V to 1.35V.

The first stage is a bi-level trans-conductance amp and level translator. The g_m stage converts the low voltage drop (V_{SENSE}) sensed across an external milli-ohm sense resistor, to a current (@ $g_m = 21.3\mu A/V$). The trans-conductance amplifier forces a current through R_1 resulting to a voltage drop across R_1 that is equal to the sense voltage (V_{SENSE}). The current through R_1 is mirrored across R_5 creating a ground-referenced voltage at the input of the second amplifier equal to V_{SENSE} .

The second stage is responsible for the overall gain and frequency response performance of the device. The fixed gains (20, 50, 100) are set with internal resistors R_f and R_g . The only external component needed is a current sense resistor (typically 0.001Ω to 0.01Ω , 1W to 2W).

The transfer function is given in Equation 1.

$$V_{OUT} = GAIN \times (I_S R_S + V_{OS}) \quad (EQ. 1)$$

Where $I_S R_S$ is the product of the load current and the sense resistor and is equal to V_{SENSE} .

When the sensed input voltage is $>1.35V$, the g_{mHI} amplifier path is selected and the input g_m stage derives its $\sim 2.86\mu A$

supply current from the input source through the $RS+$ terminal. When the sense voltage at R_S+ drops below the 1.35V threshold, the g_{mLO} amplifier is enabled for Low Side current sensing. The g_{mLO} input bias current reverses, flowing out of the $RS-$ pin. Since the g_{mLO} amplifier is sensing voltage around ground, it cannot source current to R_5 . A current mirror referenced off V_{CC} supplies the current to the second stage for generating a ground referenced output voltage. See Figures 19 and 20 for typical input bias currents for High and Low side current sensing.

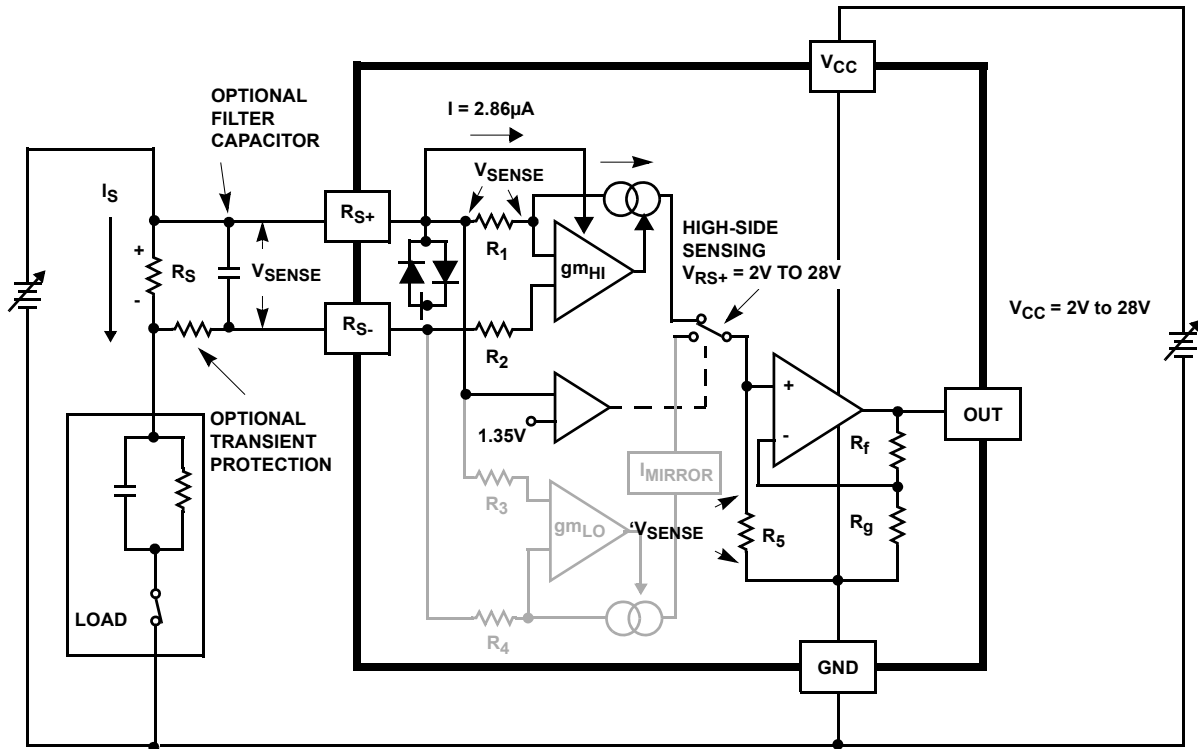


FIGURE 26. HIGH-SIDE CURRENT DETECTION

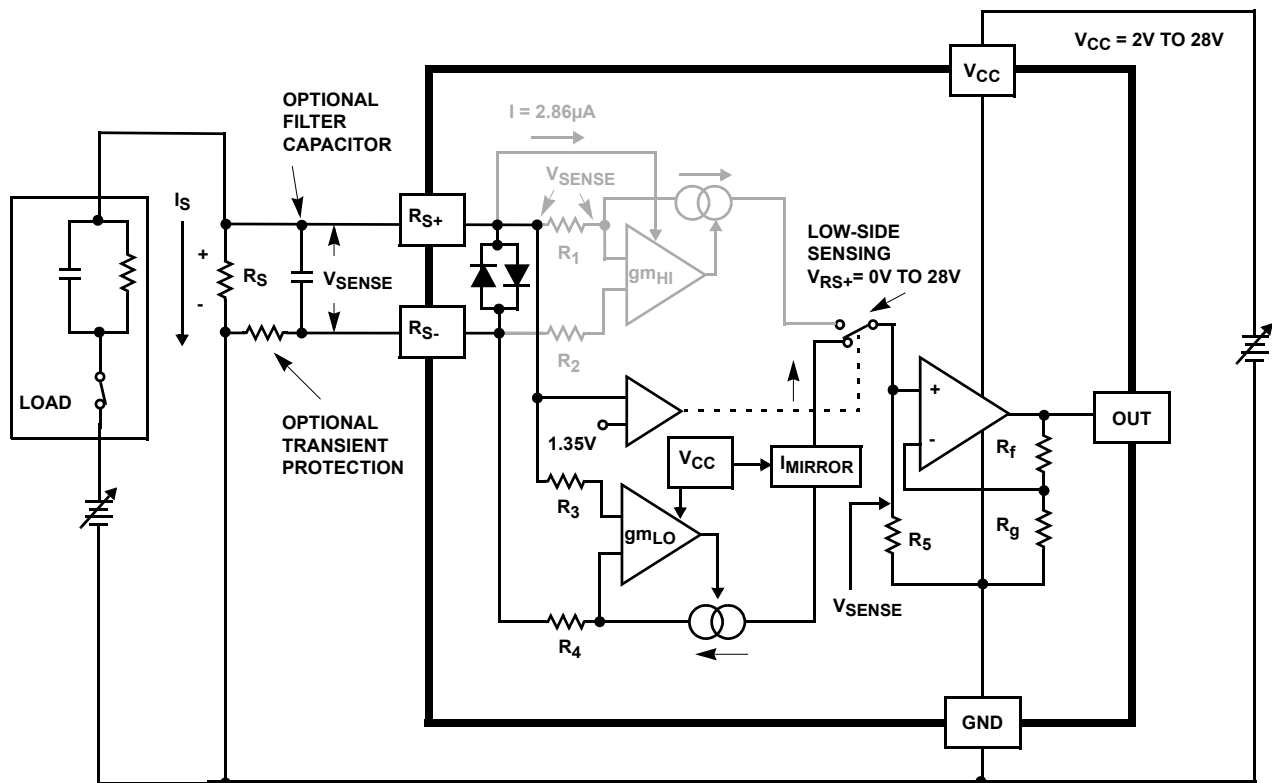


FIGURE 27. LOW-SIDE CURRENT DETECTION

Hysteretic Comparator

The input trans-conductance amps are under control of a hysteretic comparator operating from the incoming source voltage on the RS+ pin (see Figure 28). The comparator monitors the voltage on RS+ and switches the sense amplifier from the low-side gm amp to the high-side gm amplifier whenever the input voltage at RS+ increases above the 1.35V threshold. Conversely, a decreasing voltage on the RS+ pin, causes the hysteric comparator to switch from the high-side gm amp to the low-side gm amp as the voltage decreases below 1.35V. It is that low-side sense gm amplifier that gives the ISL28005 the proprietary ability to sense current all the way to 0V. Negative voltages on the RS+ or RS- are beyond the sensing voltage range of this amplifier.

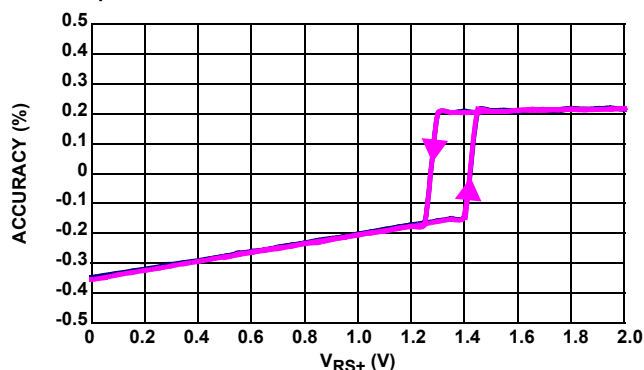


FIGURE 28. GAIN ACCURACY vs V_{RS+} = 0V TO 2V

Typical Application Circuit

Figure 30 shows the basic application circuit and optional protection components for switched-load applications. For applications where the load and the power source is permanently connected, only an external sense resistor is needed. For applications where fast transients are caused by hot plugging the source or load, external protection components may be needed. The external current limiting resistor (R_p) in Figure 30 may be required to limit the peak current through the internal ESD diodes to < 20mA. This condition can occur in applications that experience high levels of in-rush current causing high peak voltages that can damage the internal ESD diodes. An R_p resistor

value of 100Ω will provide protection for a 2V transient with the maximum of 20mA flowing through the input while adding only an additional 13μV (worse case over-temperature) of V_{OS}. Refer to the following formula:

$$((R_p \times I_{RS-}) = (100\Omega \times 130nA) = 13\mu V)$$

Switching applications can generate voltage spikes that can overdrive the amplifier input and drive the output of the amplifier into the rails, resulting in a long overload recovery time. Capacitors C_M and C_D filter the common mode and differential voltage spikes.

Error Sources

There are 3 dominant error sources: gain error, input offset voltage error and Kelvin voltage error (see Figure 29). The gain error is dominated by the internal resistance matching tolerances. The remaining errors appear as sense voltage errors at the input to the amplifier. They are V_{OS} of the amplifier and Kelvin voltage errors. If the transient protection resistor is added, an additional V_{OS} error can result from the I_xR voltage due to input bias current. The limiting resistor should only be added to the RS- input, due to the high-side gm amplifier (gm_H) sinking several micro amps of current through the RS+ pin.

Layout Guidelines

Kelvin Connected Sense Resistor

The source of Kelvin voltage errors is illustrated in Figure 29. The resistance of 1/2 oz. copper is ~1mΩ per square with a TC of ~3900ppm/°C (0.39%/°C). When you compare this unwanted parasitic resistance with the total of 1mΩ to 10mΩ resistance of the sense resistor, it is easy to see why the sense connection must be chosen very carefully. For example, consider a maximum current of 20A through a 0.005Ω sense resistor, generating a V_{SENSE} = 0.1 and a full scale output voltage of 10V (G = 100). Two side contacts of only 0.25 square per contact puts the V_{SENSE} input about 0.5 x 1mΩ away from the resistor end capacitor. If only 10A the 20A total current flows through the kelvin path to the resistor, you get an error voltage of 10mV (10A x 0.5sq x 0.001Ω/sq. = 10mV) added to the 100mV sense voltage for a sense voltage error of 10% ((0.110V - 0.1)/0.1V) x 100.

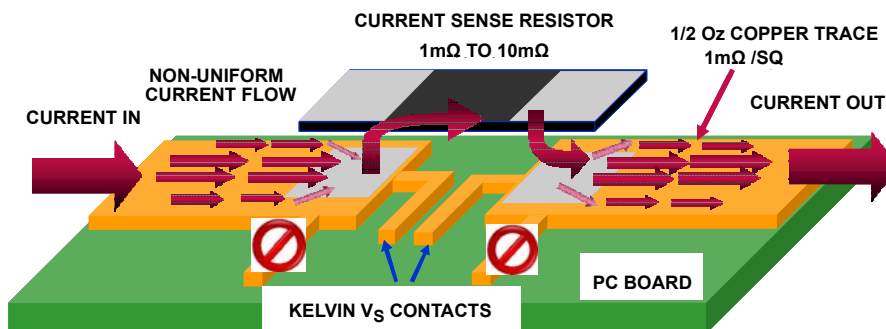


FIGURE 29. PC BOARD CURRENT SENSE KELVIN CONNECTION

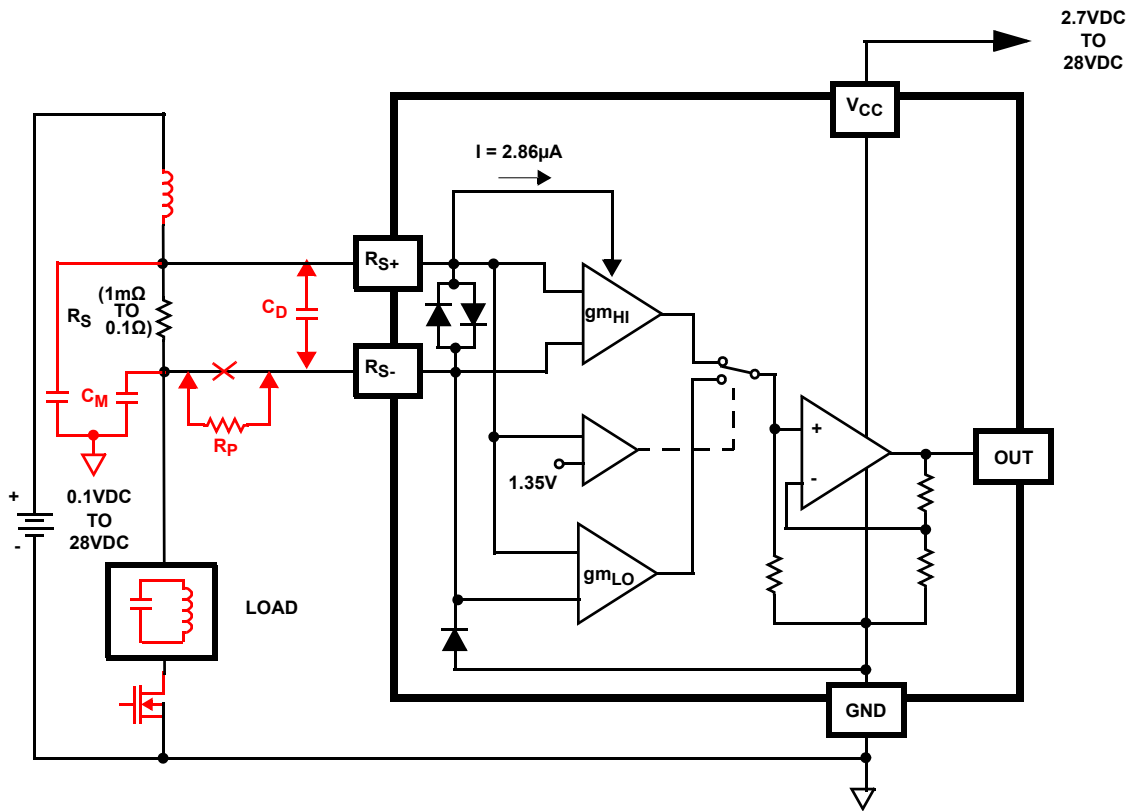


FIGURE 30. TYPICAL APPLICATION CIRCUIT

Overall Accuracy (V_{OA} %)

V_{OA} is defined as the total output accuracy Referred-to-Output (RTO). The output accuracy contains all offset and gain errors, at a single output voltage. Equation 2 is used to calculate the % total output accuracy.

$$V_{OA} = 100 \times \left(\frac{V_{OUT\text{actual}} - V_{OUT\text{expected}}}{V_{OUT\text{expected}}} \right) \quad (\text{EQ. 2})$$

where

$$V_{OUT\text{Actual}} = V_{\text{SENSE}} \times \text{GAIN}$$

Example: Gain = 100, For 100mV V_{SENSE} input we measure 10.1V. The overall accuracy (V_{OA}) is 1% as shown in Equation 3.

$$V_{OA} = 100 \times \left(\frac{10.1 - 10}{10} \right) = 1\text{percent} \quad (\text{EQ. 3})$$

Power Dissipation

It is possible to exceed the +150°C maximum junction temperatures under certain load and power supply conditions. It is therefore important to calculate the maximum junction temperature ($T_{J\text{MAX}}$) for all applications to determine if power supply voltages, load conditions, or package type need to be modified to remain in the safe operating area. These parameters are related using Equation 4:

$$T_{J\text{MAX}} = T_{\text{MAX}} + \theta_{JA} \times PD_{\text{MAXTOTAL}} \quad (\text{EQ. 4})$$

where:

- PD_{MAXTOTAL} is the sum of the maximum power dissipation of each amplifier in the package (PD_{MAX})
- PD_{MAX} for each amplifier can be calculated using Equation 5:

$$PD_{\text{MAX}} = V_S \times I_{q\text{MAX}} + (V_S - V_{\text{OUTMAX}}) \times \frac{V_{\text{OUTMAX}}}{R_L} \quad (\text{EQ. 5})$$

where:

- T_{MAX} = Maximum ambient temperature
- θ_{JA} = Thermal resistance of the package
- PD_{MAX} = Maximum power dissipation of 1 amplifier
- V_{CC} = Total supply voltage
- $I_{q\text{MAX}}$ = Maximum quiescent supply current of 1 amplifier
- V_{OUTMAX} = Maximum output voltage swing of the application
- R_L = Load resistance

Revision History

The revision history provided is for informational purposes only and is believed to be accurate, but not warranted. Please go to web to make sure you have the latest Rev.

| DATE | REVISION | CHANGE |
|-------------------|----------|--|
| October 24, 2013 | FN6973.5 | Added eight new Typical Performance Curves 1. Av = 100 Capacitive Load Drive Gain vs Freq 2. Av = 100 Capacitive Load Drive Phase vs Freq 3. Av = 50 Capacitive Load Drive Gain vs Freq 4. Av = 50 Capacitive Load Drive Phase vs Freq 5. Av = 20 Capacitive Load Drive Gain vs Freq 6. Av = 20 Capacitive Load Drive Phase vs Freq 7. High Side Operation Input Bias Currents 8. Low Side Operation Input Bias Currents Under Electrical Specifications Table: Changed parameter from Is to Icc to clarify supply current. |
| April 11, 2011 | FN6973.4 | Corrected location of the load in Figure 27. Moved Load from the ground side of the input sense circuit to the high side of the voltage source. Updated note in Min Max column of spec table from "Parameters with MIN and/or MAX limits are 100% tested at +25° C, unless otherwise specified. Temperature limits established by characterization and are not production tested." to "Compliance to datasheet limits is assured by one or more methods: production test, characterization and/or design." |
| September 2, 2010 | FN6973.3 | Added -T7A tape and reel package options to Ordering Information Table for all packages. |
| May 12, 2010 | FN6973.2 | Added Note 4 to Part Marking Column in "Ordering Information" on page 3. Corrected hyperlinks in Notes 1 and 3 in "Ordering Information" on page 3. Corrected ISL28005 hyperlink in "About Intersil" on page 14. |
| April 12, 2010 | | Added Eval boards to ordering info. |
| April 7, 2010 | | Added "Related Literature" on page 1 Updated Package Drawing Number in the "Ordering Information" on page 3 from MDP0038 to P50.64A. Revised package outline drawing from MDP0038 to P5.064A on page 15. MDP0038 package contained 2 packages for both the 5 and 6 Ld SOT-23. MDP0038 was obsoleted and the packages were separated and made into 2 separate package outline drawings; P5.064A and P6.064A. Changes to the 5 Ld SOT-23 were to move dimensions from table onto drawing, add land pattern and add JEDEC reference number. |
| February 3, 2010 | FN6973.1 | -Page1: Edited last sentence of paragraph 2. Moved order of GAIN listings from 20, 50, 100 to 100, 50, 20 in the 3rd paragraph. Under Featuresremoved "Low Input Offset Voltage 250µV,max" Under Features moved order of parts listing from 20, 50, 100 (from top to bottom) to 100, 50, 20. -Page 3: Removed coming soon on ISL28005FH50Z and ISL28005FH20Z and changes the order or listing them to 100, 50, 20. -Page 5: VOA test. Under conditions column ...deleted "20mV to". It now reads ... Vsense = 100mV SR test. Under conditions column ..deleted what was there. It now reads ... Pulse on RS+pin, See Figure 25 -Page 6: ts test. Removed Gain = 100 and Gain = 100V/V in both description and conditions columns respectively. -Page 9 Added Figure 25 and adjusted figure numbers to account for the added figure. |
| December 14, 2009 | FN6973.0 | Initial Release |

About Intersil

Intersil Corporation is a leader in the design and manufacture of high-performance analog, mixed-signal and power management semiconductors. The company's products address some of the largest markets within the industrial and infrastructure, personal computing and high-end consumer markets. For more information about Intersil, visit our website at www.intersil.com.

For the most updated datasheet, application notes, related documentation and related parts, please see the respective product information page found at www.intersil.com. You may report errors or suggestions for improving this datasheet by visiting www.intersil.com/en/support/ask-an-expert.html. Reliability reports are also available from our website at <http://www.intersil.com/en/support/qualandreliability.html#reliability>

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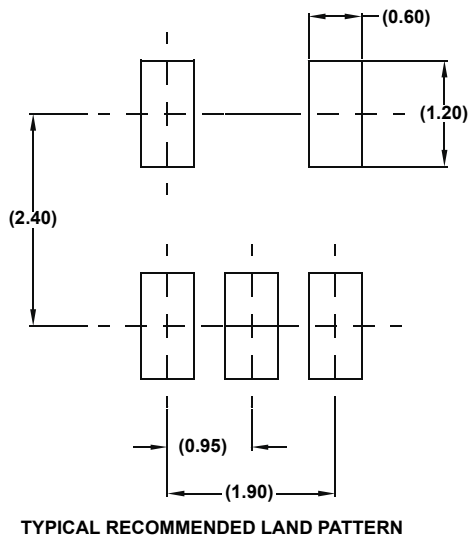
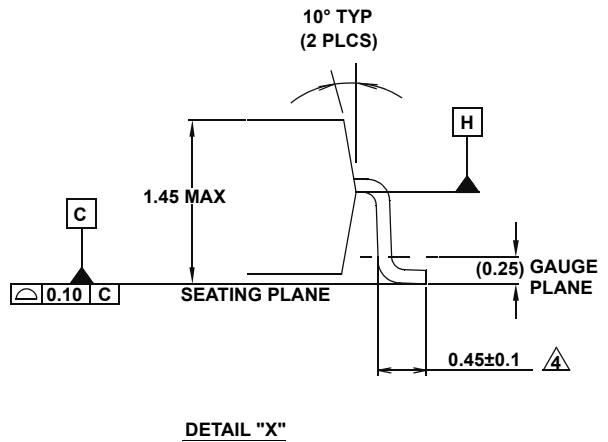
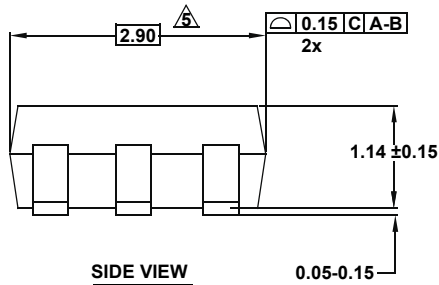
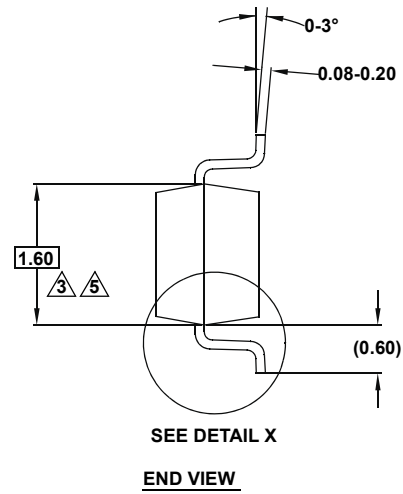
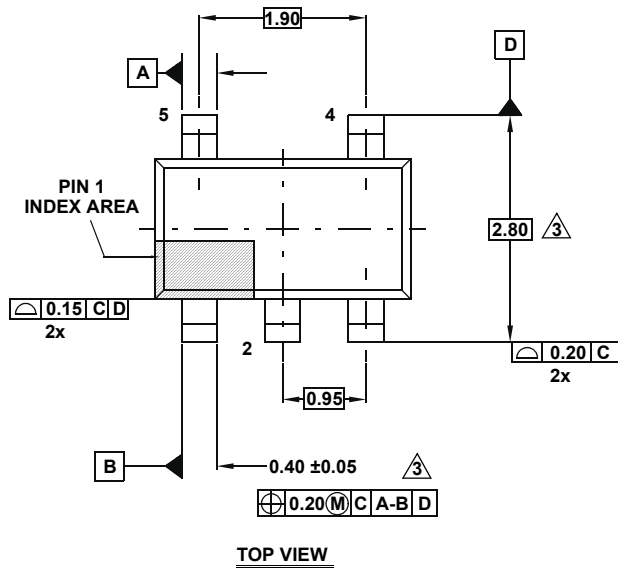
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Package Outline Drawing

P5.064A

5 LEAD SMALL OUTLINE TRANSISTOR PLASTIC PACKAGE

Rev 0, 2/10



NOTES:

- Dimensions are in millimeters.
Dimensions in () for Reference Only.
- Dimensioning and tolerancing conform to ASME Y14.5M-1994.
- Dimension is exclusive of mold flash, protrusions or gate burrs.
- Foot length is measured at reference to gauge plane.
- This dimension is measured at Datum "H".
- Package conforms to JEDEC MO-178AA.