

# ISL28005

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

FN6973  
Rev 5.00  
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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 50 $\mu$ A 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 $^{\circ}$ C to +125 $^{\circ}$ C.

## Features

- Low Power Consumption. . . . . 50 $\mu$ A, 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 $^{\circ}$ C to +125 $^{\circ}$ 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"

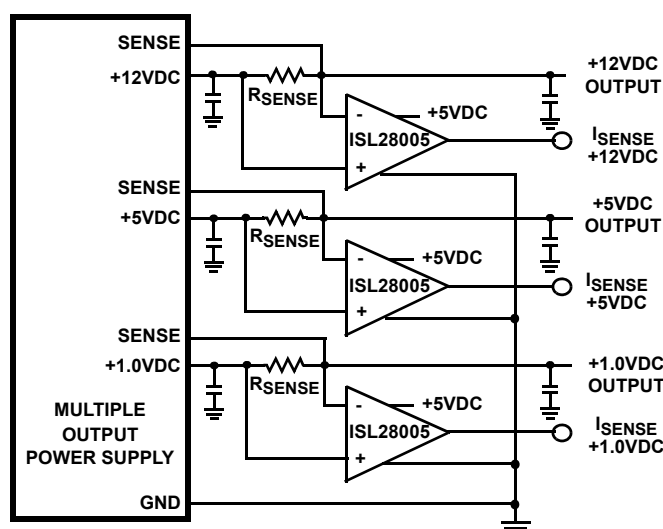


FIGURE 1. TYPICAL APPLICATION

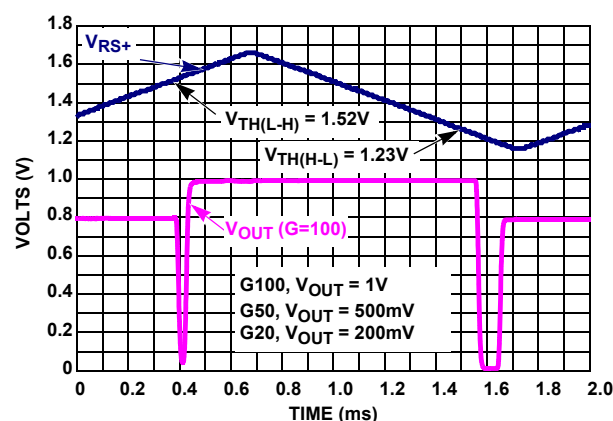
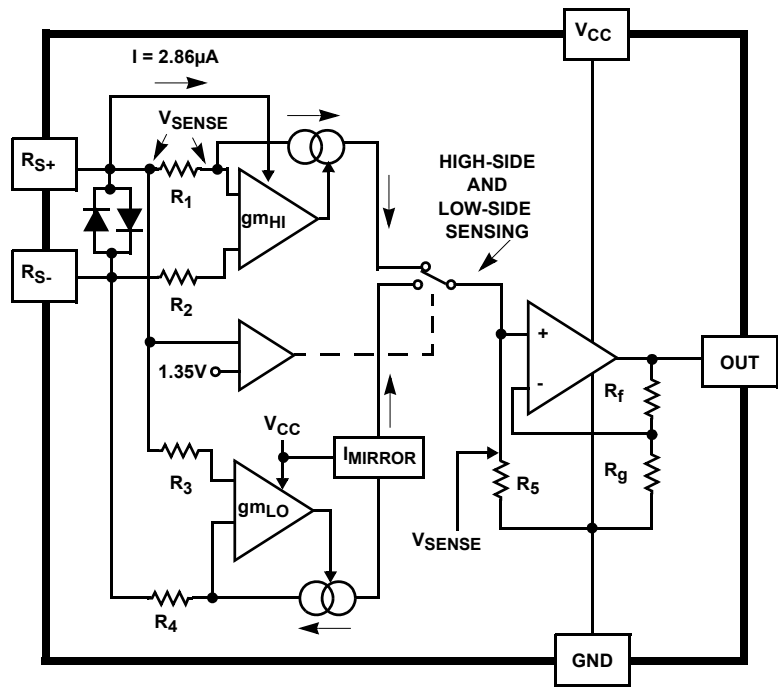
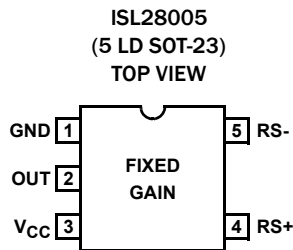


FIGURE 2. HIGH-SIDE AND LOW-SIDE THRESHOLD VOLTAGE

Block Diagram



Pin Configuration



Pin Descriptions

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

The diagram shows the ESD protection circuitry for the ISL28005. It includes a "CAPACITIVELY COUPLED ESD CLAMP" circuit and input/output protection diodes connected to V<sub>CC</sub> and GND.

## Ordering Information

| PART NUMBER<br>(Notes 1, 2, 3) | GAIN                    | PART MARKING  | PACKAGE<br>Tape & Reel<br>(Pb-Free) | PKG.<br>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                   | BDDB (Note 4) | 5 Ld SOT-23                         | P5.064A        |
| ISL28005FH50Z-T7A              | 50V/V                   | BDDB (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.

## 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)                      | $\theta_{JA}$ (°C/W)                                                                                                              | $\theta_{JC}$ (°C/W) |
| 5 Ld SOT-23 (Notes 5, 6)                          | 190                                                                                                                               | 90                   |
| Maximum Storage Temperature Range                 | -65°C to +150°C                                                                                                                   |                      |
| Maximum Junction Temperature (T <sub>JMAX</sub> ) | +150°C                                                                                                                            |                      |
| Pb-Free Reflow Profile                            | see link below<br><a href="http://www.intersil.com/pbfree/Pb-FreeReflow.asp">http://www.intersil.com/pbfree/Pb-FreeReflow.asp</a> |                      |

## Recommended Operating Conditions

|                                             |                 |
|---------------------------------------------|-----------------|
| Ambient Temperature Range (T <sub>A</sub> ) | -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.  $\theta_{JA}$  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  $\theta_{JC}$ , the "case temp" location is taken at the package top center.

**Electrical Specification**  $V_{CC} = 12V$ ,  $V_{RS+} = 0V$  to 28V,  $V_{SENSE} = 0V$ ,  $R_{LOAD} = 1M\Omega$ ,  $T_A = +25^\circ C$  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<br>(Note 7)     | TYP   | MAX<br>(Note 7)   | UNIT    |
|-------------------------------------|-------------------------------------------|---------------------------------------------------------------------|---------------------|-------|-------------------|---------|
| V <sub>OS</sub>                     | Input Offset Voltage<br>(Notes 8, 9)      | $V_{CC} = V_{RS+} = 12V$ ,<br>$V_S = 20mV$ to $= 100mV$             | -500<br><b>-500</b> | 60    | 500<br><b>500</b> | $\mu V$ |
|                                     |                                           | $V_{CC} = 12V$ , $V_{RS+} = 0.2V$ , $V_S = 20mV$ ,<br>$V_S = 100mV$ | -3<br><b>-3.3</b>   | -1.2  | 3<br><b>3.3</b>   | mV      |
| I <sub>RS+</sub> , I <sub>RS-</sub> | Leakage Current                           | $V_{CC} = 0V$ , $V_{RS+} = 28V$                                     |                     | 0.041 | 1.2<br><b>1.5</b> | $\mu A$ |
| I <sub>RS+</sub>                    | Gain = 100 + Input Bias Current           | $V_{RS+} = 2V$ , $V_{SENSE} = 5mV$                                  |                     | 4.7   | 6<br><b>7</b>     | $\mu A$ |
|                                     |                                           | $V_{RS+} = 0V$ , $V_{SENSE} = 5mV$                                  | -500<br><b>-600</b> | -425  |                   | nA      |
|                                     | Gain = 50, Gain = 20 + Input Bias Current | $V_{RS+} = 2V$ , $V_{SENSE} = 5mV$                                  |                     | 4.7   | 6<br><b>8</b>     | $\mu A$ |
|                                     |                                           | $V_{RS+} = 0V$ , $V_{SENSE} = 5mV$                                  | -700<br><b>-840</b> | -432  |                   | nA      |
| I <sub>RS-</sub>                    | Input Bias Current                        | $V_{RS+} = 2V$ , $V_{SENSE} = 5mV$                                  |                     | 5     | 50<br><b>75</b>   | nA      |
|                                     |                                           | $V_{RS+} = 0V$ , $V_{SENSE} = 5mV$                                  | -125<br><b>-130</b> | -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 <sub>F<sub>S</sub></sub>          | Full-scale Sense Voltage                  | $V_{CC} = 28V$ , $V_{RS+} = 0.2V$ , 12V                             | 200                 |       |                   | mV      |
| G                                   | Gain<br>(Note 8)                          | ISL28005-100                                                        |                     | 100   |                   | V/V     |
|                                     |                                           | ISL28005-50                                                         |                     | 50    |                   | V/V     |
|                                     |                                           | ISL28005-20                                                         |                     | 20    |                   | V/V     |

**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<br>(Note 7)     | TYP   | MAX<br>(Note 7)   | UNIT       |
|--------------------|---------------------------------------------------------|--------------------------------------------------------------------------------|---------------------|-------|-------------------|------------|
| $G_A$              | Gain = 100 Gain Accuracy<br>(Note 10)                   | $V_{CC} = V_{RS+} = 12V$ , $V_{SENSE} = 20mV$ to $100mV$                       | -2<br><b>-3</b>     |       | 2<br><b>3</b>     | %          |
|                    |                                                         | $V_{CC} = 12V$ , $V_{RS+} = 0.1V$ ,<br>$V_{SENSE} = 20mV$ to $100mV$           |                     | -0.25 |                   | %          |
|                    | Gain = 50, Gain = 20 Gain Accuracy<br>(Note 10)         | $V_{CC} = V_{RS+} = 12V$ , $V_{SENSE} = 20mV$ to $100mV$                       | -2<br><b>-3</b>     |       | 2<br><b>3</b>     | %          |
|                    |                                                         | $V_{CC} = 12V$ , $V_{RS+} = 0.1V$ ,<br>$V_{SENSE} = 20mV$ to $100mV$           | -3<br><b>-4</b>     | -0.31 | 3<br><b>4</b>     | %          |
| $V_{OA}$           | Gain = 100 Total Output Accuracy<br>(Note 11)           | $V_{CC} = V_{RS+} = 12V$ , $V_{SENSE} = 100mV$                                 | -2.5<br><b>-2.7</b> |       | 2.5<br><b>2.7</b> | %          |
|                    |                                                         | $V_{CC} = 12V$ , $V_{RS+} = 0.1V$ ,<br>$V_{SENSE} = 100mV$                     |                     | -1.25 |                   | %          |
|                    | Gain = 50, Gain = 20 Total Output<br>Accuracy (Note 11) | $V_{CC} = V_{RS+} = 12V$ , $V_{SENSE} = 100mV$                                 | -2.5<br><b>-2.7</b> |       | 2.5<br><b>2.7</b> | %          |
|                    |                                                         | $V_{CC} = 12V$ , $V_{RS+} = 0.1V$ ,<br>$V_{SENSE} = 100mV$                     | -6<br><b>-7</b>     | -1.41 | 6<br><b>7</b>     | %          |
| $V_{OH}$           | Output Voltage Swing, High<br>$V_{CC} - V_{OUT}$        | $I_O = -500\mu A$ , $V_{CC} = 2.7V$<br>$V_{SENSE} = 100mV$<br>$V_{RS+} = 2V$   |                     | 39    | 50                | mV         |
| $V_{OL}$           | Output Voltage Swing, Low<br>$V_{OUT}$                  | $I_O = 500\mu A$ , $V_{CC} = 2.7V$<br>$V_{SENSE} = 0V$ , $V_{RS+} = 2V$        |                     | 30    | 50                | mV         |
| $R_{OUT}$          | Output Resistance                                       | $V_{CC} = V_{RS+} = 12V$ , $V_{SENSE} = 100mV$<br>$I_{OUT} = 10\mu A$ to $1mA$ |                     | 6.5   |                   | $\Omega$   |
| $I_{SC+}$          | 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<br>Supply Current                            | $V_{RS+} > 2V$ , $V_{SENSE} = 5mV$                                             |                     | 50    | 59<br><b>62</b>   | $\mu A$    |
|                    | Gain = 50, 20<br>Supply Current                         | $V_{RS+} > 2V$ , $V_{SENSE} = 5mV$                                             |                     | 50    | 62<br><b>63</b>   | $\mu A$    |
| $V_{CC}$           | Supply Voltage                                          | Guaranteed by PSRR                                                             | 2.7                 |       | 28                | V          |
| SR                 | Gain = 100 Slew Rate                                    | Pulse on $RS+$ pin,<br>$V_{OUT} = 8V_{P-P}$<br>(see Figure 25)                 | 0.58                | 0.76  |                   | V/ $\mu s$ |
|                    | Gain = 50 Slew Rate                                     | Pulse on $RS+$ pin,<br>$V_{OUT} = 8V_{P-P}$<br>(see Figure 25)                 | 0.58                | 0.67  |                   | V/ $\mu s$ |
|                    | Gain = 20 Slew Rate                                     | Pulse on $RS+$ pin,<br>$V_{OUT} = 3.5V_{P-P}$<br>(see Figure 25)               | 0.50                | 0.67  |                   | V/ $\mu s$ |
| BW <sub>-3dB</sub> | Gain = 100<br>-3dB Bandwidth                            | $V_{RS+} = 12V$ , $0.1V$ , $V_{SENSE} = 100mV$                                 |                     | 110   |                   | kHz        |
|                    | Gain = 50<br>-3dB Bandwidth                             | $V_{RS+} = 12V$ , $0.1V$ , $V_{SENSE} = 100mV$                                 |                     | 160   |                   | kHz        |
|                    | Gain = 20<br>-3dB Bandwidth                             | $V_{RS+} = 12V$ , $0.1V$ , $V_{SENSE} = 100mV$                                 |                     | 180   |                   | kHz        |

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

**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.

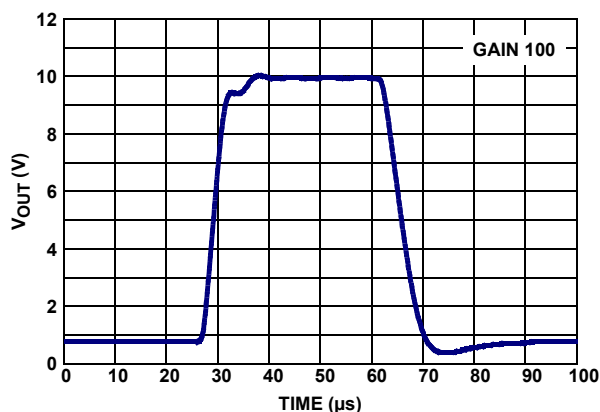


FIGURE 3. LARGE SIGNAL TRANSIENT RESPONSE  $V_{RS+} = 0.2V$ ,  $V_{SENSE} = 100mV$

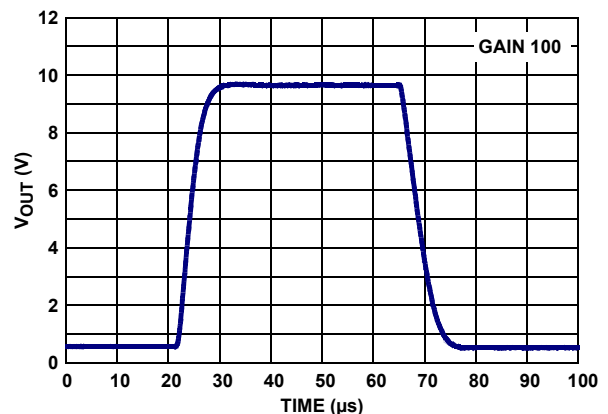


FIGURE 4. LARGE SIGNAL TRANSIENT RESPONSE  $V_{RS+} = 12V$ ,  $V_{SENSE} = 100mV$

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

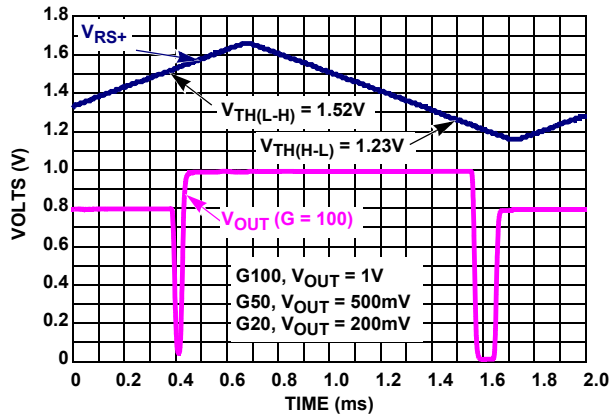


FIGURE 5. HIGH-SIDE and LOW-SIDE THRESHOLD VOLTAGE  $V_{RS+(L-H)}$  and  $V_{RS+(H-L)}$ ,  $V_{SENSE} = 10mV$

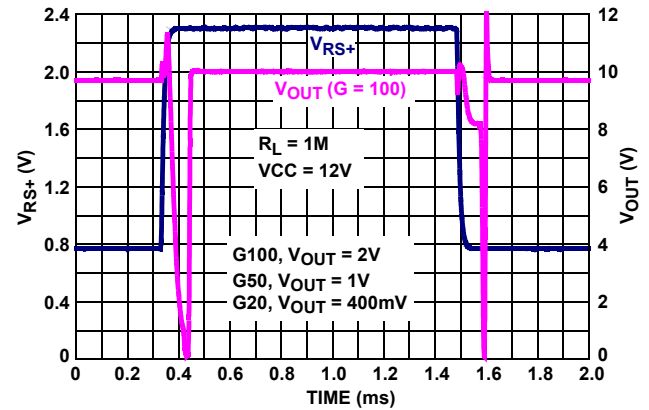


FIGURE 6.  $V_{OUT}$  vs  $V_{RS+}$ ,  $V_{SENSE} = 20mV$  TRANSIENT RESPONSE

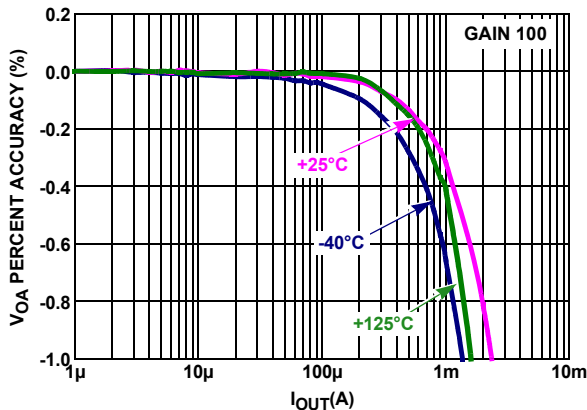


FIGURE 7. NORMALIZED  $V_{OA}$  vs  $I_{OUT}$

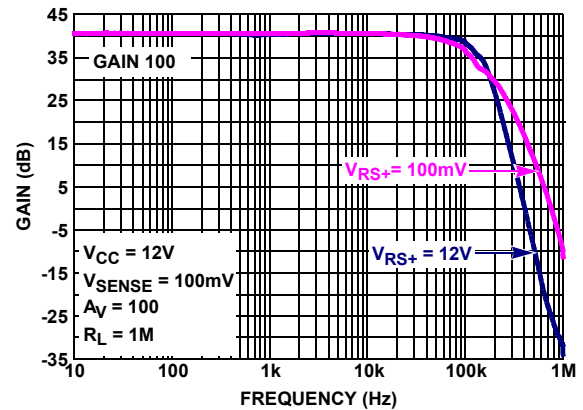


FIGURE 8. GAIN vs FREQUENCY  $V_{RS+} = 100mV/12V$ ,  $V_{SENSE} = 100mV$ ,  $V_{OUT} = 250mV_{p-p}$

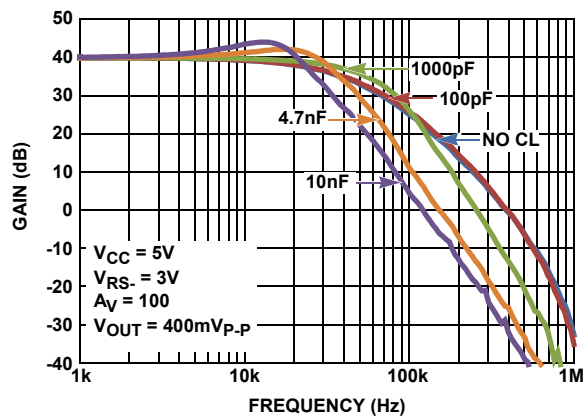


FIGURE 9. CAPACITIVE LOAD DRIVE GAIN vs FREQUENCY

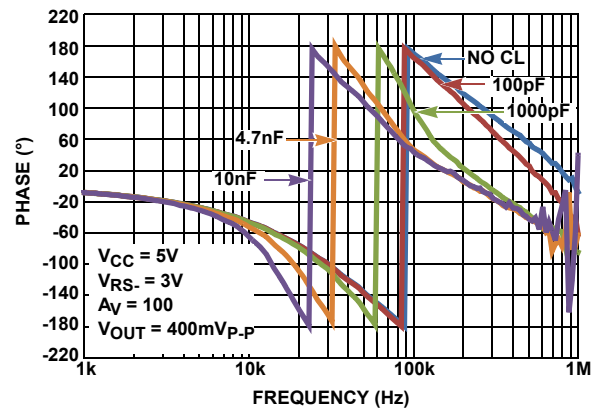


FIGURE 10. CAPACITIVE LOAD DRIVE PHASE vs FREQUENCY

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

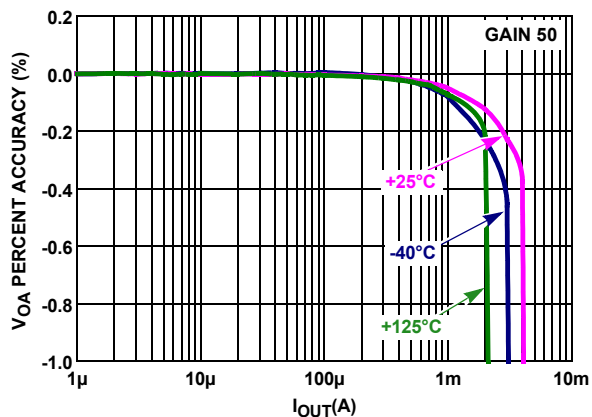
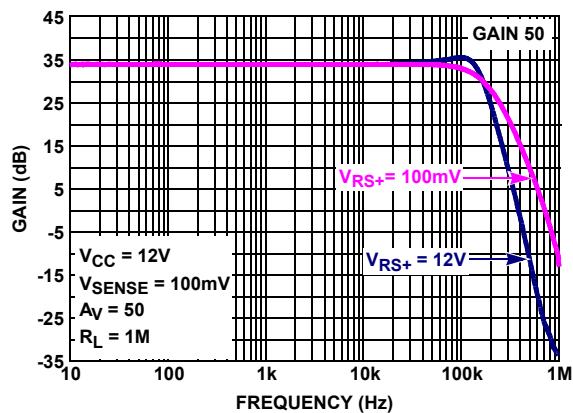
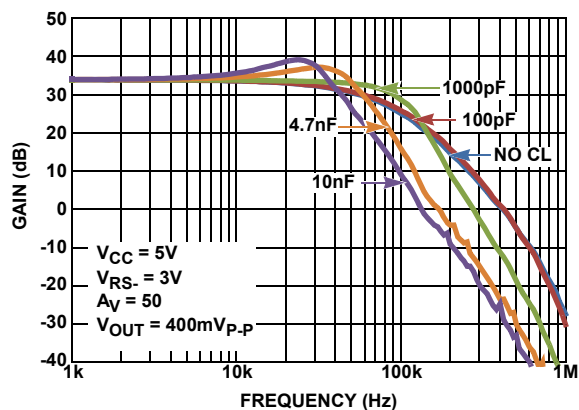
FIGURE 11. NORMALIZED  $V_{OA}$  vs  $I_{OUT}$ FIGURE 12. GAIN vs FREQUENCY  $V_{RS+} = 100mV/12V$ ,  
 $V_{SENSE} = 100mV$ ,  $V_{OUT} = 250mV_{p.p}$ 

FIGURE 13. CAPACITIVE LOAD DRIVE GAIN vs FREQUENCY

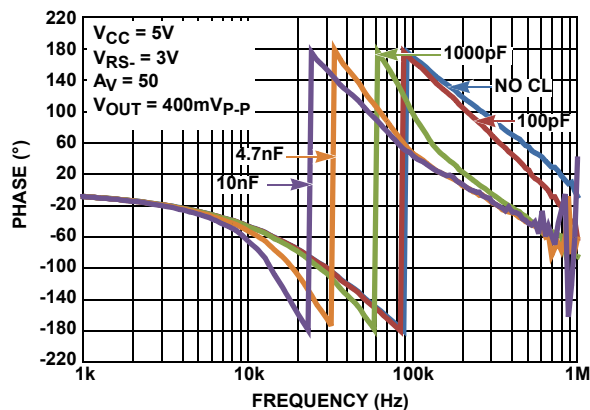
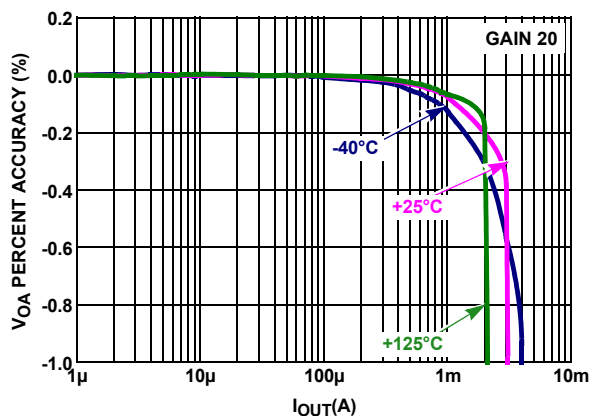
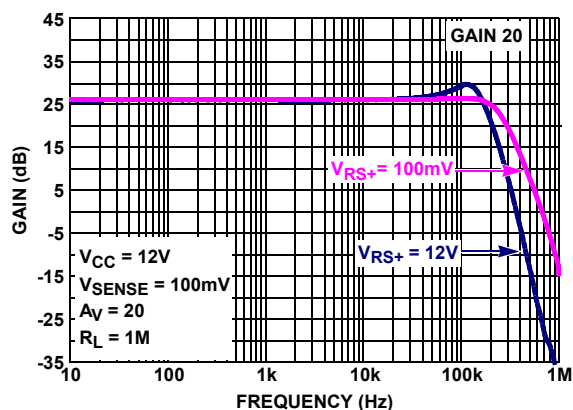


FIGURE 14. CAPACITIVE LOAD DRIVE PHASE vs FREQUENCY

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)

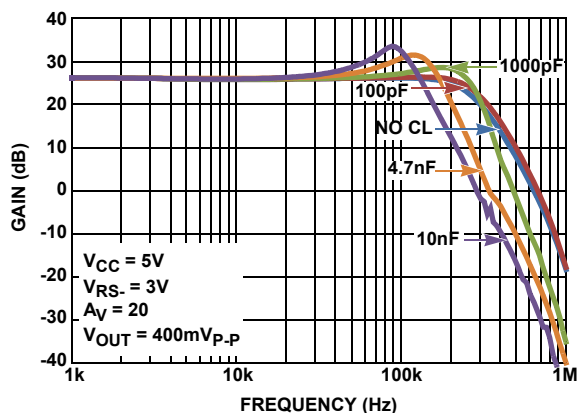


FIGURE 17. CAPACITIVE LOAD DRIVE GAIN vs FREQUENCY

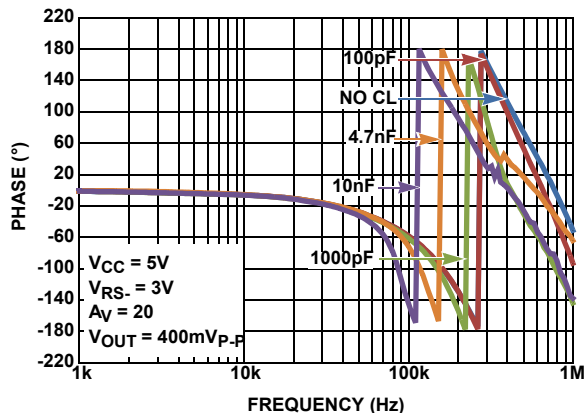


FIGURE 18. CAPACITIVE LOAD DRIVE PHASE vs FREQUENCY

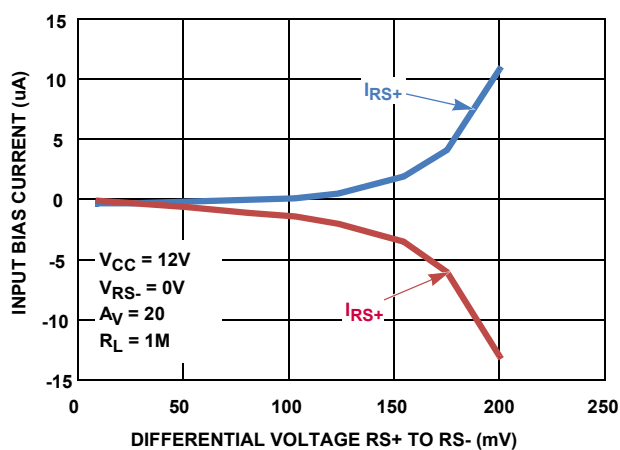


FIGURE 19. LOW-SIDE CURRENT SENSING INPUT BIAS CURRENTS

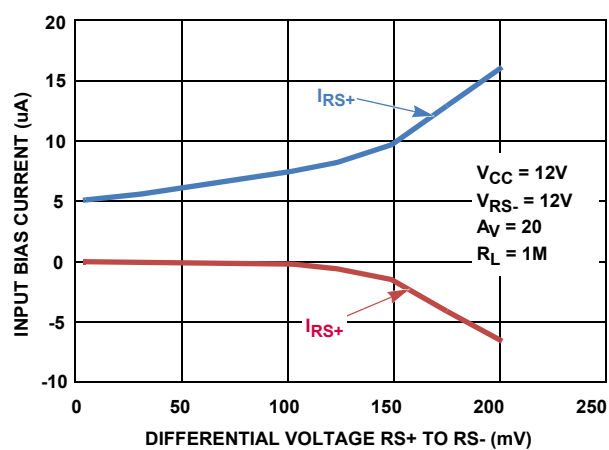


FIGURE 20. HIGH-SIDE CURRENT SENSING INPUT BIAS CURRENTS

## Test Circuits and Waveforms

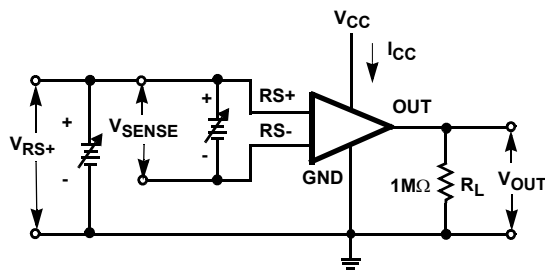
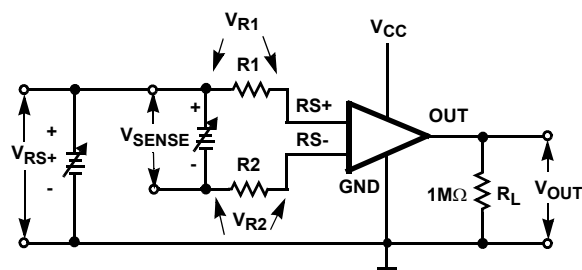
FIGURE 21.  $I_{CC}$ ,  $V_{OS}$ ,  $V_{OA}$ , CMRR, PSRR, GAIN ACCURACY

FIGURE 22. INPUT BIAS CURRENT, LEAKAGE CURRENT

## Test Circuits and Waveforms (Continued)

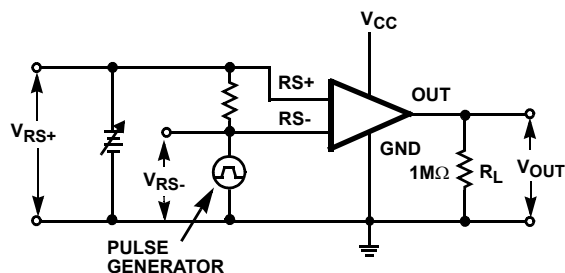
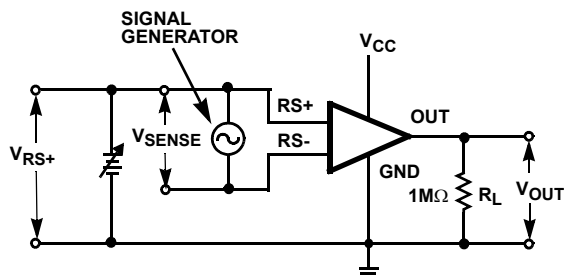
FIGURE 23. SLEW RATE,  $t_s$ , SATURATION RECOVERY TIME

FIGURE 24. GAIN vs FREQUENCY

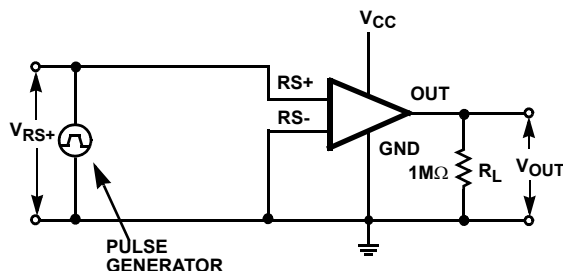


FIGURE 25. SLEW RATE

## 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  $g_{mLO}$  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  $0.001\Omega$  to  $0.01\Omega$ , 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  $RS+$  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.

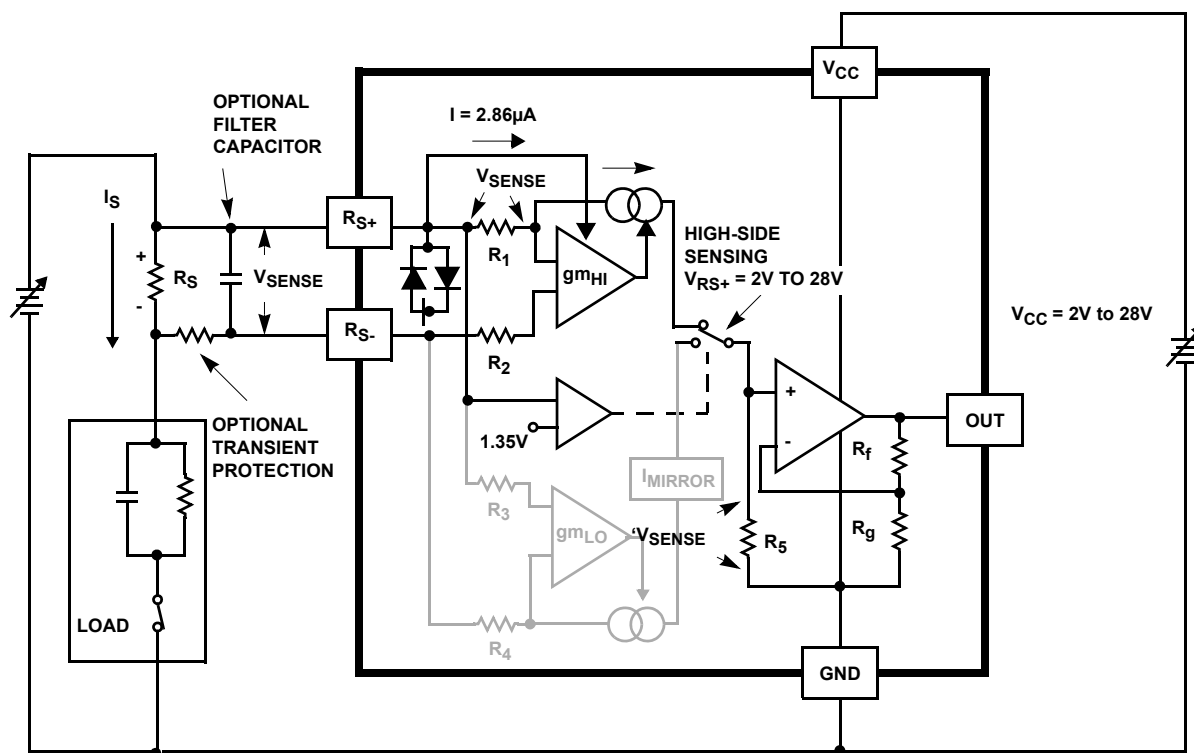


FIGURE 26. HIGH-SIDE CURRENT DETECTION

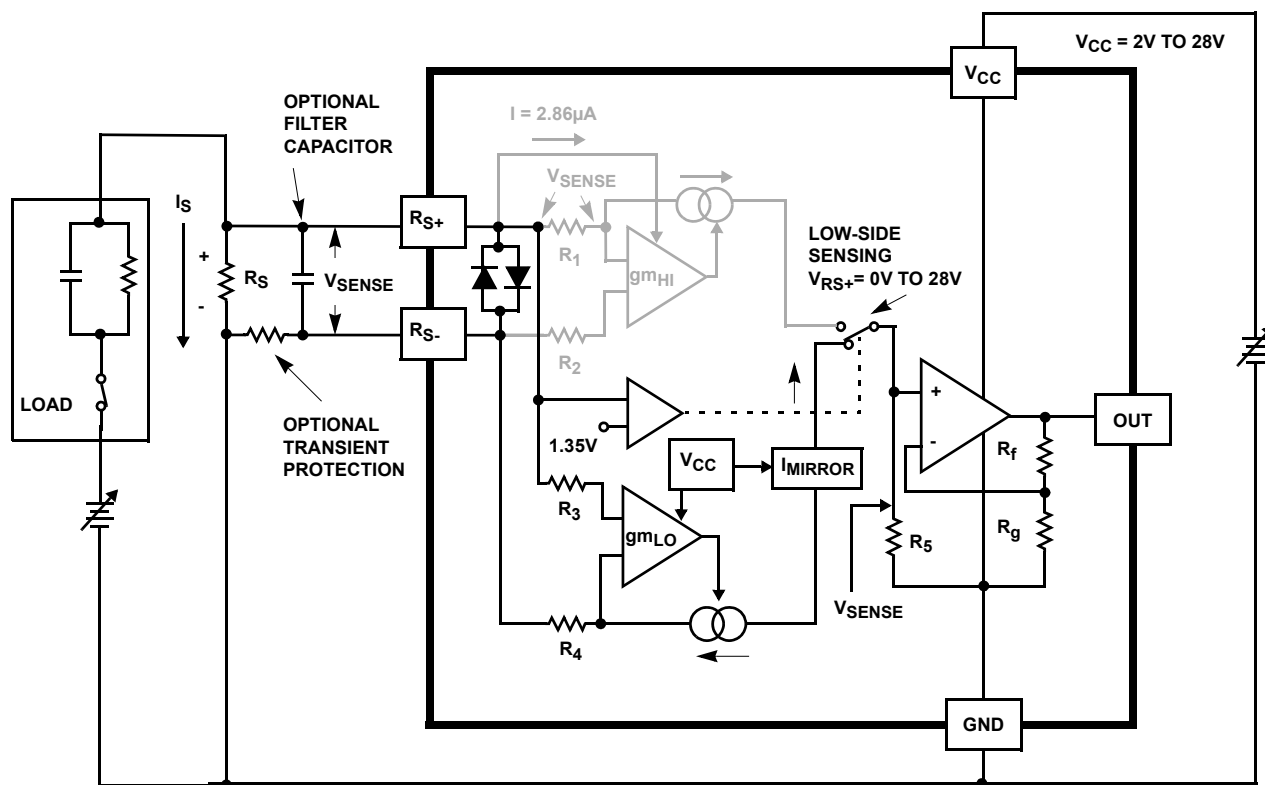


FIGURE 27. LOW-SIDE CURRENT DETECTION

## 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.

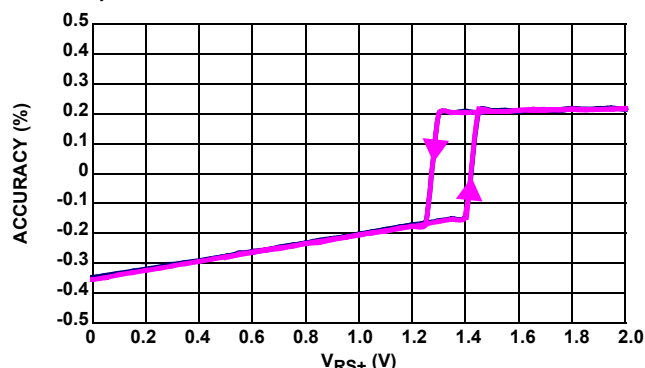


FIGURE 28. GAIN ACCURACY vs  $V_{RS+} = 0V$  TO  $2V$

## 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  $100\Omega$  will provide protection for a 2V transient with the maximum of 20mA flowing through the input while adding only an additional  $13\mu V$  (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 ( $gm_{HI}$ ) 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  $\sim 1m\Omega$  per square with a TC of  $\sim 3900ppm/^{\circ}C$  ( $0.39\%/^{\circ}C$ ). When you compare this unwanted parasitic resistance with the total of  $1m\Omega$  to  $10m\Omega$  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  $0.005\Omega$  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  $0.5 \times 1m\Omega$  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 ( $10A \times 0.5sq \times 0.001\Omega/sq = 10mV$ ) added to the 100mV sense voltage for a sense voltage error of 10%  $(0.110V - 0.1)/0.1V \times 100$ .

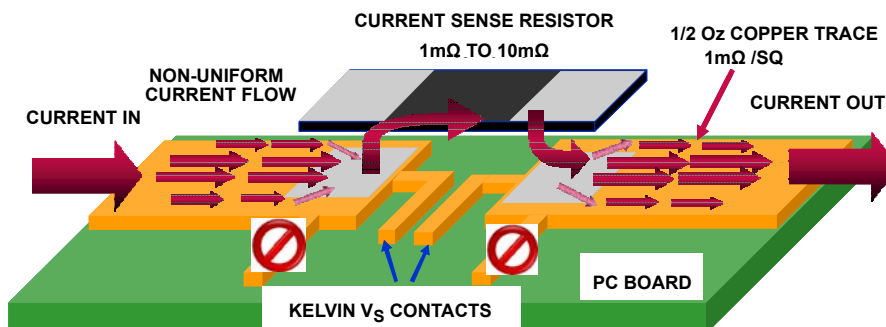


FIGURE 29. PC BOARD CURRENT SENSE KELVIN CONNECTION

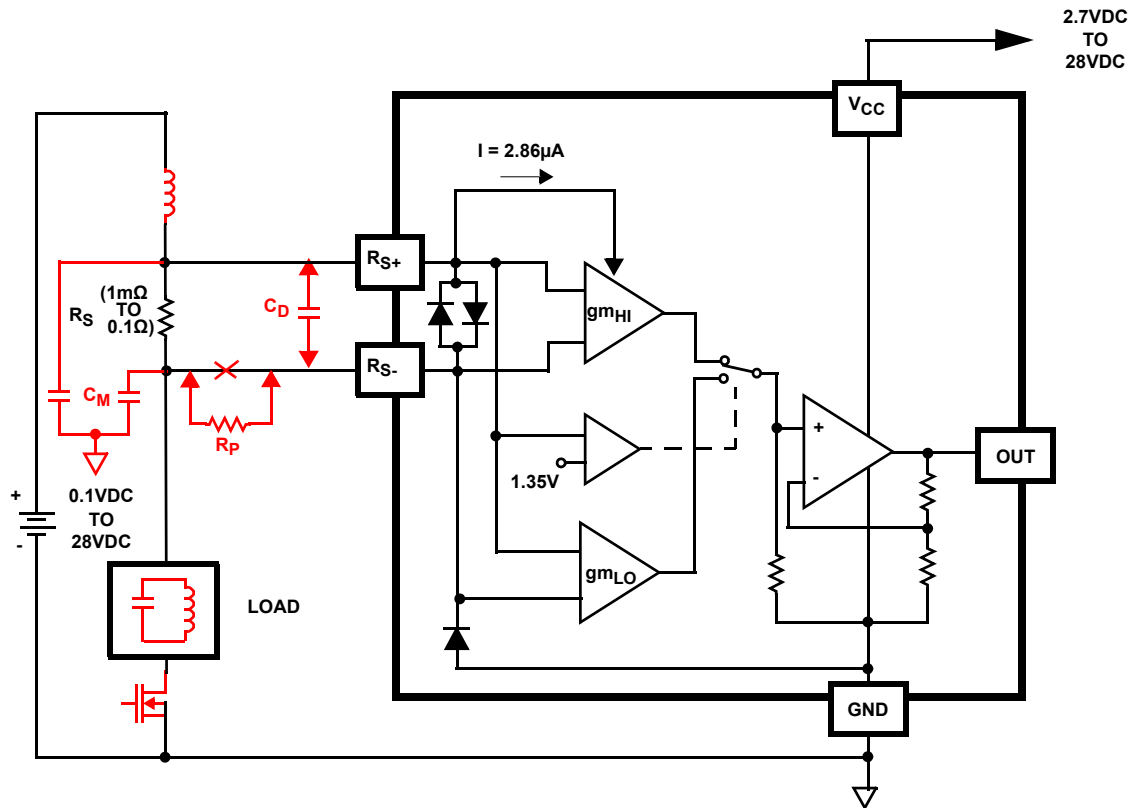


FIGURE 30. TYPICAL APPLICATION CIRCUIT

### 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

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

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 ( $T_{JMAX}$ ) 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:

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

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:

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

where:

- $T_{MAX}$  = Maximum ambient temperature
- $\theta_{JA}$  = Thermal resistance of the package
- $PD_{MAX}$  = Maximum power dissipation of 1 amplifier
- $V_{CC}$  = Total supply voltage
- $I_{qMAX}$  = 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 | <p>Added eight new Typical Performance Curves</p> <ol style="list-style-type: none"> <li>1. Av = 100 Capacitive Load Drive Gain vs Freq</li> <li>2. Av = 100 Capacitive Load Drive Phase vs Freq</li> <li>3. Av = 50 Capacitive Load Drive Gain vs Freq</li> <li>4. Av = 50 Capacitive Load Drive Phase vs Freq</li> <li>5. Av = 20 Capacitive Load Drive Gain vs Freq</li> <li>6. Av = 20 Capacitive Load Drive Phase vs Freq</li> <li>7. High Side Operation Input Bias Currents</li> <li>8. Low Side Operation Input Bias Currents</li> </ol> <p>Under Electrical Specifications Table:<br/>Changed parameter from Is to Icc to clarify supply current.</p>                                                                                                                                                                                                                                                        |
| April 11, 2011    | FN6973.4 | <p>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.</p> <p>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."</p>                                                                                                                                                                                                                                                                                                                                                                                               |
| September 2, 2010 | FN6973.3 | Added -T7A tape and reel package options to Ordering Information Table for all packages.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| May 12, 2010      | FN6973.2 | <p>Added Note 4 to Part Marking Column in "Ordering Information" on page 3.</p> <p>Corrected hyperlinks in Notes 1 and 3 in "Ordering Information" on page 3.</p> <p>Corrected ISL28005 hyperlink in "About Intersil" on page 15.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| April 12, 2010    |          | Added Eval boards to ordering info.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| April 7, 2010     |          | <p>Added "Related Literature" on page 1</p> <p>Updated Package Drawing Number in the "Ordering Information" on page 3 from MDP0038 to P5.064A.</p> <p>Revised package outline drawing from MDP0038 to P5.064A on page 16. 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.</p>                                                                                                                                                                                                                                                                                                                                                         |
| February 3, 2010  | FN6973.1 | <p>-Page1:<br/>Edited last sentence of paragraph 2.<br/>Moved order of GAIN listings from 20, 50, 100 to 100, 50, 20 in the 3rd paragraph.<br/>Under Features ....removed "Low Input Offset Voltage 250µV,max"<br/>Under Features .... moved order of parts listing from 20, 50, 100 (from top to bottom) to 100, 50, 20.</p> <p>-Page 3:<br/>Removed coming soon on ISL28005FH50Z and ISL28005FH20Z and changes the order or listing them to 100, 50, 20.</p> <p>-Page 5:<br/>VOA test. Under conditions column ...deleted "20mV to". It now reads ... Vsense = 100mV<br/>SR test. Under conditions column ...deleted what was there. It now reads ... Pulse on RS+pin, See Figure 25</p> <p>-Page 6:<br/>ts test. Removed Gain = 100 and Gain = 100V/V in both description and conditions columns respectively.</p> <p>-Page 9<br/>Added Figure 25 and adjusted figure numbers to account for the added figure.</p> |
| December 14, 2009 | FN6973.0 | Initial Release                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

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2. **Dimensioning and tolerancing conform to ASME Y14.5M-1994.**
3. **Dimension is exclusive of mold flash, protrusions or gate burrs.**
4. **Foot length is measured at reference to guage plane.**
5. **This dimension is measured at Datum "H".**
6. **Package conforms to JEDEC MO-178AA.**