

Output High Voltage Error Budget Analysis for the TS1100 Current Sense Amplifier

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Introduction

When implementing a part such as Touchstone's TS1100 current sense amplifier, it is important to know how much error is present in the output. This allows for accurate interpretations of the data. For the TS1100 current sense amplifier, the output error can be measured by the Output High Voltage parameter. The parameter is defined as the difference in voltage from the VRS- pin to the Output pin. The typical error that can be expected for the TS1100 is defined in the Electrical Characteristics (EC) table found on page 3 of the datasheet, listed at 50mV. Although this is what one can expect for most cases, it is still important to know how this parameter can be calculated based upon the TS1100's circuit setup. Therefore, this calculation demonstration will walk through the error budget analysis for Touchstone's TS1100 current sense amplifier.

To watch the TS1100 Error Budget analysis video, please follow the links provided:

- Website Video: <http://touchstonesemi.com/videos/ts1100-error-budget-analysis>
- YouTube Video: <http://www.youtube.com/watch?v=K6R2IZds2n8>

Calculation Demonstration

For this demonstration, a voltage power supply of 3.6V has been selected, as well as the TS1100-100 gain option, with a gain of $100\frac{V}{V}$. First, the full scale voltage across the RSENSE resistor must be found. The equation for the full scale V_{SENSE} is provided in Note 6 listed below the EC table on page 3 of the datasheet.

$$V_{SENSE(FS)} = \frac{V_{SUPPLY}}{GAIN} \quad [1]$$

Substituting the 3.6V power supply and the $100\frac{V}{V}$ gain option into equation [1], the resulting full scale V_{SENSE} is shown below.

$$V_{SENSE(FS)} = 0.036 \text{ V}$$

Next, the gain across the entire temperature range (-40°C to +105°C) must be found. Therefore, the maximum gain error across the entire temperature range must be considered. The maximum Gain Error (GE) across temperature is found in the EC table, and is shown below.

$$GE = \pm 0.6 \%$$

Considering the plus-minus error specification, a maximum and minimum swing for the gain across temperature is found. The inequality is defined below.

$$GAIN \times (1 - GE) \leq GAIN \leq GAIN \times (1 + GE) \quad [2]$$

Solving the inequality results in the TS1100-100 exhibiting the following gain over the entire temperature range.

$$99.4 \frac{V}{V} \leq \text{GAIN} \leq 101.6 \frac{V}{V}$$

Now, the voltage output can be determined by also considering the effects from the input offset voltage over temperature. The voltage output equation to solve for can be found on page 9 of the datasheet.

$$V_{\text{OUT}} = [\text{GAIN} \times (1 \pm \text{GE}) \times V_{\text{SENSE(FS)}}] \pm (\text{GAIN} (1 \pm \text{GE}) \times V_{\text{OS}}) \quad [3]$$

The Input Offset Voltage parameter is listed in the EC table. For this demonstration, the maximum and minimum input offset voltage over the entire temperature range has been accounted for. It is important to note, over the entire temperature range, the input offset voltage will vary from a negative value to a positive value as defined below.

$$-200 \mu\text{V} \leq V_{\text{OS}} \leq +200 \mu\text{V}$$

The voltage output equation has been rewritten, as shown below, to define the absolute maximum and minimum voltage outputs.

$$V_{\text{OUT}_{\text{Max}}} = [\text{GAIN}_{\text{Max}} \times V_{\text{SENSE}}] + (V_{\text{OS}_{\text{Max}}} \times \text{GAIN}_{\text{Max}}) \quad [4]$$

$$V_{\text{OUT}_{\text{Min}}} = [\text{GAIN}_{\text{Min}} \times V_{\text{SENSE}}] + (V_{\text{OS}_{\text{Min}}} \times \text{GAIN}_{\text{Min}}) \quad [5]$$

It is important to notice the absolute minimum voltage output equation. Due to the negative value of the absolute minimum input offset voltage, the equation was rewritten to accommodate the negative value so it would not drop out. Substituting the previously defined values into equations [4] and [5], the absolute voltage output is calculated to have the following swing over the entire temperature range.

$$3.558 \text{ V} \leq V_{\text{OUT}} \leq 3.642 \text{ V}$$

Please note, a 3.6V power supply was selected for this demonstration and obtaining a voltage output higher than the power supply is unrealistic. Therefore, the absolute maximum voltage output value that was calculated is disregarded. The 3.6V power supply is inserted into the voltage output inequality as the maximum possible value. The actual absolute voltage output across temperature is defined below.

$$3.558 \text{ V} \leq V_{\text{OUT}} \leq 3.6 \text{ V}$$

Lastly, the Output High Voltage parameter (V_{OH}) is calculated. The parameter is defined in the EC table.

$$V_{\text{OH}} = V_{\text{RS}_-} - V_{\text{OUT}} \quad [6]$$

Please note the voltage on the load side of the RSENSE resistor is equal to the voltage on the supply side of RSENSE, and subsequently equal to the power supply voltage. Solving equation [6], the TS1100-100, with an input offset voltage of 200 μV and a gain error of $\pm 0.6\%$ over temperature, will exhibit the Output High Voltage range shown below.

$$0 \text{ V} \leq V_{\text{OH}} \leq 0.042 \text{ V}$$

This calculation was performed using the selected TS1100-100 gain option and a 3.6V power supply, as well as considering the maximum possible error specifications. If the same calculations were to be carried out

considering the same errors, and considering the same 3.6V power supply, while just varying the gain option for the TS1100, the ranges over temperature that can be expected for the Output High Voltage are shown below.

Part	V_{OH}
TS1100-25	$0 \leq V_{OH} \leq 0.027$
TS1100-50	$0 \leq V_{OH} \leq 0.032$
TS1100-100	$0 \leq V_{OH} \leq 0.042$
TS1100-200	$0 \leq V_{OH} \leq 0.062$

Conclusion

As shown in the EC Table on page 3 of the datasheet, the Output High Voltage (V_{OH}) parameter is listed with a maximum possible value of 0.2V. Considering this calculation walk-through accounted for the maximum possible error specifications across temperature, the Output High Voltage for all of gain options of the TS1100 is still well below the max spec listed in the datasheet. This proves that under high error scenarios the TS1100 performs at a very high level.

For additional information, please follow the links to the corresponding product pages:

- [TS1100 Op Amp Product Information](#)
- [Web Site Video](#)
- [YouTube Video](#)

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