Exploring current sense amplifiers

STMicroelectronics Tech Days

Power-supply rejection ratio (SVR)

Chapter 7

User guide

This presentation provides a written explanation of the topic covered in the seventh chapter of the video: “**Power-supply rejection ratio (SVR) #7**”, which is available on our YouTube channel at the following link:

Video on YouTube

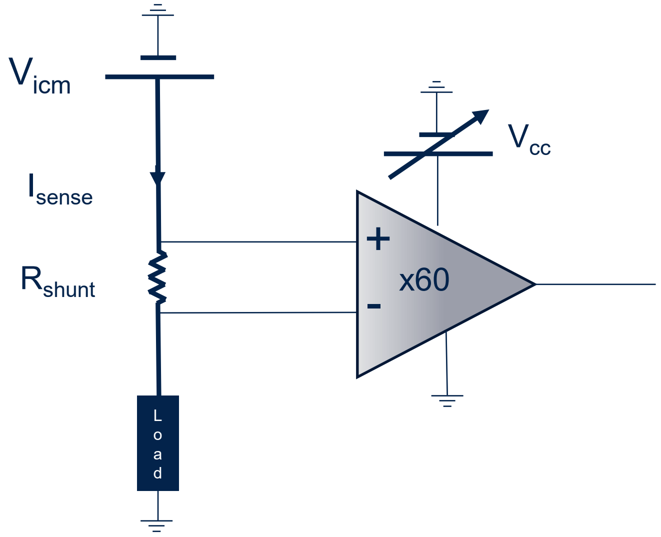
Recommendations

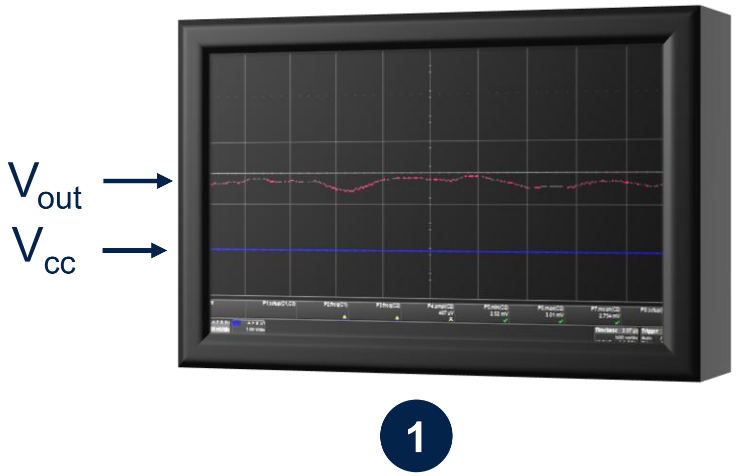
In this document you will find key concepts explained through informative tables, graphs, sequences of graphs, followed by a detailed explanation.

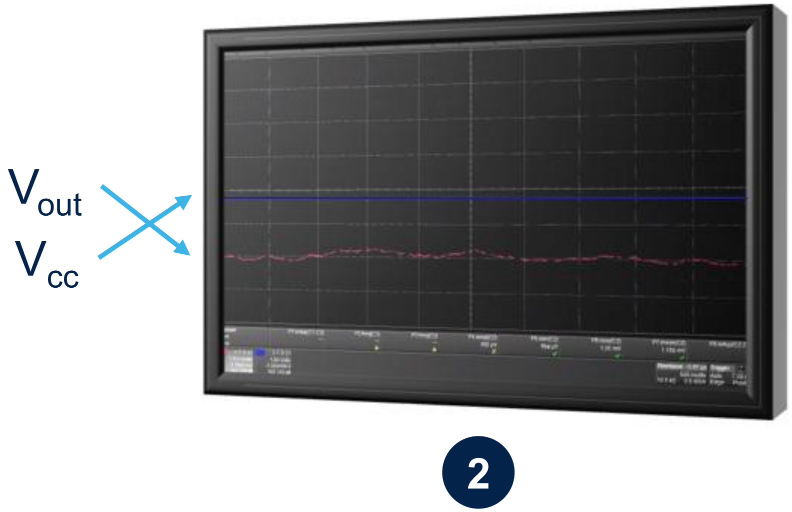
- When you see this icon: Explanation the topic is explained in detail on the following page(s)
- Each explanation page shows the page or page range where the topic is explained: (page # to #)
- If you see this icon: Continue the explanation continues on the next page(s)

What is power-supply voltage rejection ratio?

SVR is also called PSRR







TSC2010

SVR	Supply voltage rejection	V_{CC} = 2.7 to 5.5 V $T_{min} < T < T_{max}$	80 75	100		dB

Explanation

What is power-supply voltage rejection ratio?

Explanation of page 4

The **power-supply rejection ratio (SVR, also called PSRR)** is the ratio between a change in the **supply voltage** and the resulting change in the **output voltage**.
The associated error can be evaluated in the same way as for the **CMR** parameter.

To clarify what SVR represents, we use the TSC2010 current-sense amplifier as an example. In the datasheet, SVR is specified in **dB**.

In this setup, the **current through the shunt is constant**, so the V_{sense} **voltage across the shunt does not change**. We therefore expect the amplifier output to remain stable.

1 **Oscilloscope observation – output and supply**
On the oscilloscope, the **pink trace** shows the **output voltage** V_{out}.
The **blue trace** shows the **supply voltage** V_{CC} ,which is swept from **2.7 V to 5.5 V**, while V_{sense} is kept constant.

What is power-supply voltage rejection ratio?

Explanation of page 4

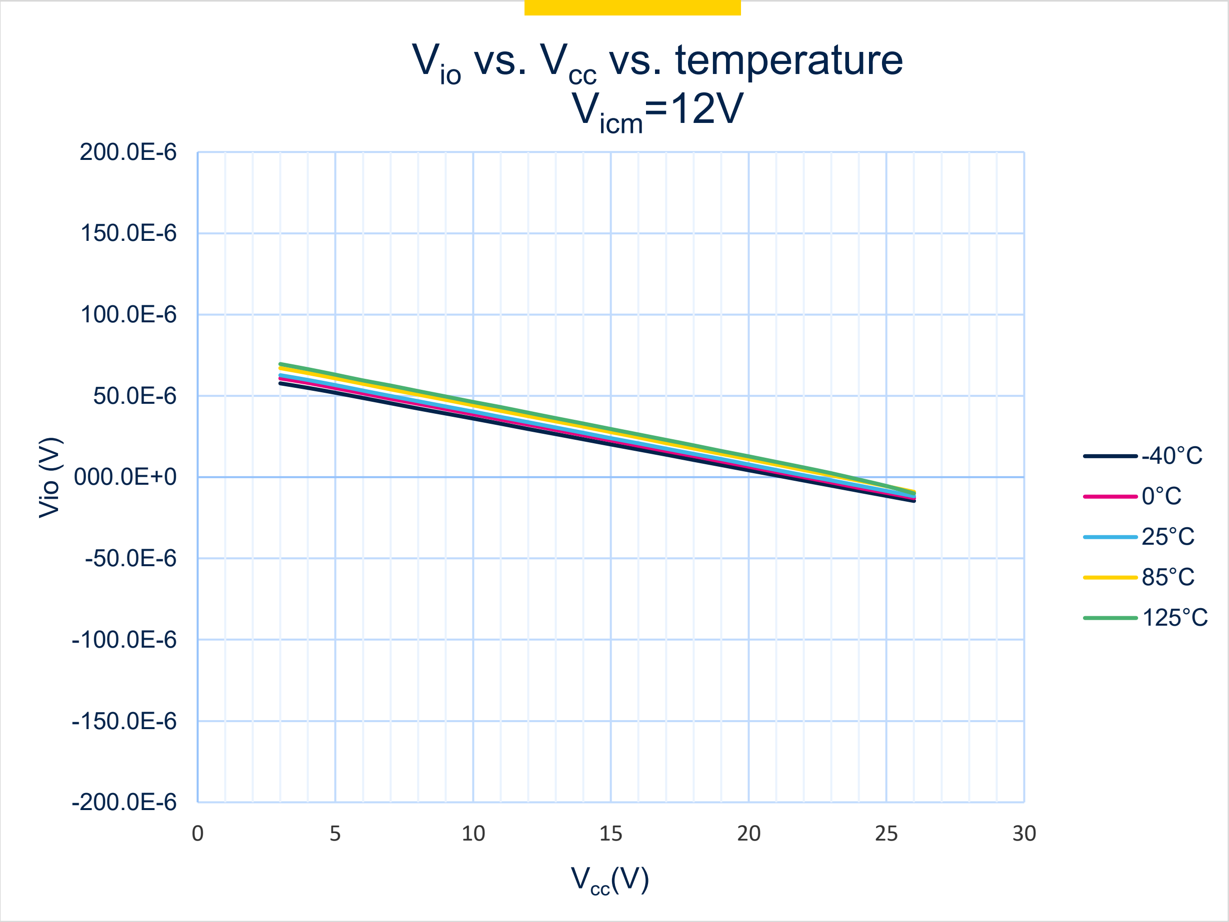
2 **Effect of supply variation**

The oscilloscope reveals that V_{out} **varies with** V_{CC} ,even though V_{sense} is unchanged.
This variation is not caused by the shunt voltage, but by a change in the **input offset voltage** V_{io} versus the supply voltage.

SVR quantifies this dependence of V_{io} **on the supply voltage.**
Since SVR is expressed in **dB**, a **lower SVR value corresponds to poorer supply-voltage rejection** by the amplifier.

Origin of the power-supply rejection ratio

TSC213



$$SVR(dB) = 20.\log\left(\frac{\Delta V_{io}}{\Delta V_{cc}}\right)$$

Explanation

Origin of the power-supply rejection ratio

Explanation of page 7

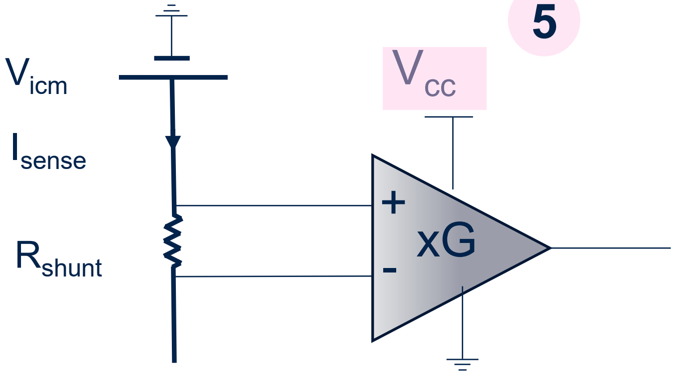
As seen previously, the common-mode voltage influences the input-offset voltage.

The supply voltage, V_{CC} ,also affects the bias point of the input differential pair. When this bias point changes, the input offset voltage, V_{io} ,changes as well because of the inherent mismatch in the input circuitry.

The curve below shows how V_{io} varies with the supply voltage, V_{CC} .The power-supply rejection ratio, SVR, is commonly expressed in dB and represents the variation of V_{io} with respect to V_{CC}. A higher SVR indicates better current-sensing accuracy.

How SVR affects precision

5



1 $$SVR\ error = \pm\frac{|Vcc - Vcc_{DS}|}{SVR}$$

TSC2010 series

2

Table 5. Electrical characteristics (V_{CC} = 5 V, V_{icm} = 12 V, T = 25 °C unless otherwise specified)

SVR	Supply voltage rejection	V_{CC} = 2.7 to 5.5 V $T_{min} < T < T_{max}$	80 75	100	dB

6

When SVR is expressed in dB in the datasheet

3 $$SVR\ impact\ (\%) = \frac{|Vcc - Vcc_{DS}|}{R_{shunt} * I_{sense} * 10^{\frac{SVR}{20}}} * 100$$

4

TSC210 series

TSC210, TSC213: V_{CC}= 5 V, V_{IN+}=12 V, V_{REF}= V_{CC}/2 (unless otherwise specified),

PSRR	Power supply rejection ratio	V_{CC}= 2.7 to 26 V V_{IN}+=18 V, V_{SENSE} = 0 mV	0.1	10	µV/V

7

When SVR is expressed in V/V in the datasheet

$$SVR\ impact\ (\%) = \frac{|Vcc - Vcc_{DS}| * PSRR}{R_{shunt} * I_{sense}} * 100$$

Note:

Higher the SVR (dB), higher the precision
Lower the SVR (V/V), higher the precision

Explanation

How SVR affects precision

Explanation of page 9

To evaluate how SVR affects measurement precision, first identify the supply voltage at which the input offset voltage, V_{io} ,is specified in the datasheet. If the application uses a different supply voltage, the SVR contribution must be included in the error calculation in order to estimate the actual V_{io} in the application.

1 Since SVR describes the variation of input-offset voltage with the circuit supply voltage, V_{CC} ,the following equation can be used to estimate the offset error. $SVR\ error = \pm\frac{|Vcc-Vcc_{DS}|}{SVR}$

2 In many datasheets, SVR is expressed in dB, as in the TSC2010 series.

3 When SVR is given in dB, the impact on the current-measurement error can be calculated using the equation shown here.

$$SVR\ impact\ (\%) = \frac{\frac{|Vcc-Vcc_{DS}|}{R_{shunt}*I_{sense}*10^{\frac{SVR}{20}}}}{}*100$$

4 As with CMRR-based error calculations, it is first necessary to know the supply voltage condition used for the datasheet specification.

How SVR affects precision

Explanation of page 9

5 This value must then be compared with the supply voltage used in the application.

6 The SVR value expressed in dB from the datasheet is then used in the equation. For a worst-case error estimate, it is recommended to use the **minimum** specified value. Other approaches to error calculation will be presented later.

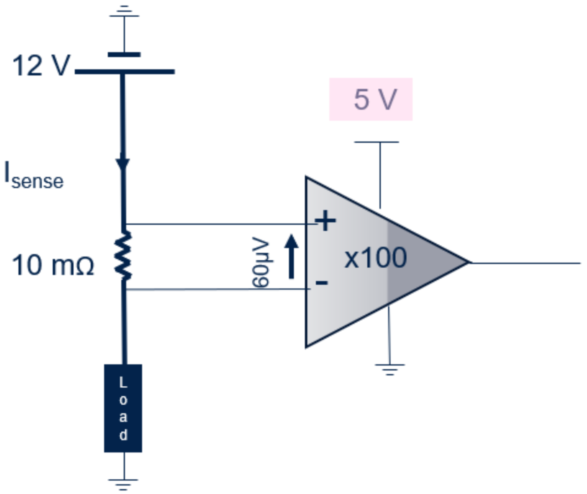
7 In some datasheets, SVR, sometimes referred to as PSRR, is expressed directly in V/V, as in the [TSC210](TSC210) series. In this case, the error related to SVR is calculated with the corresponding V/V-based equation.

$$SVR\ impact\ (\%) = \frac{|Vcc - Vcc_{DS}| * PSRR}{R_{shunt} * I_{sense}} * 100$$

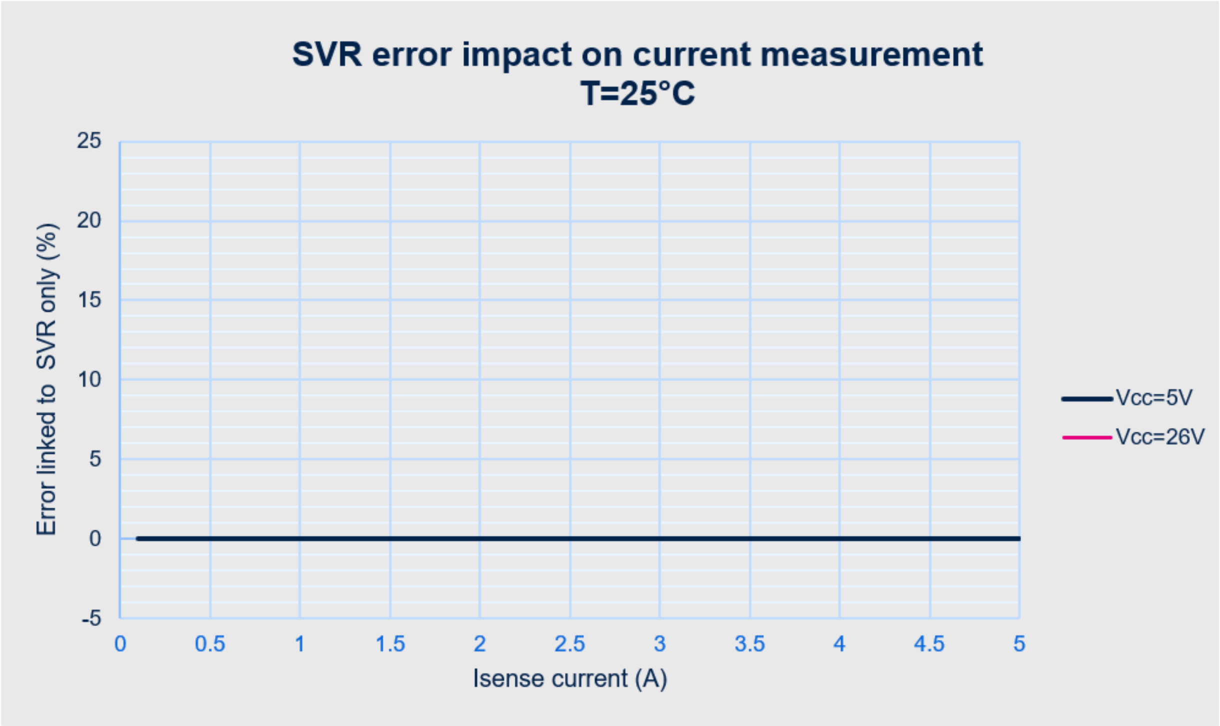
A useful guideline is:

- a **higher** SVR value in dB means better precision;
- a **lower** SVR value in V/V means better precision.

Example



$$SVR\ impact\ (\%) = \frac{|5\ V - 5\ V| * PSRR}{10\ m\Omega * I_{sense} *} * 100$$



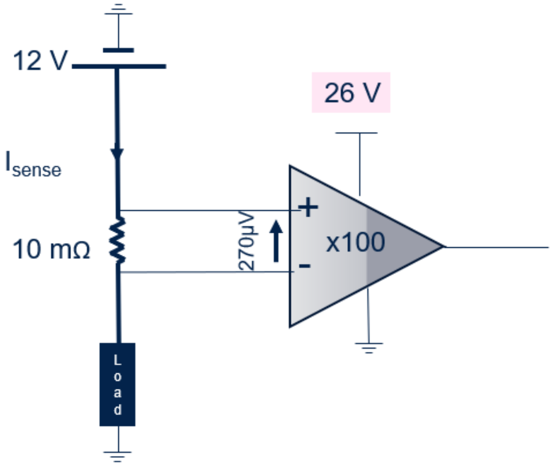
TSC214

Table 5. Electrical characteristics, T = 25 °C, $V_{SENSE} = V_{IN+} - V_{IN-}$ (unless otherwise specified), TSC210, TSC213, TSC214, TSC215: V_{CC}= 5 V, V_{IN+}=12 V, V_{REF}= V_{CC}/2 (unless otherwise specified), TSC211, TSC212: V_{CC} = 12 V, V_{IN+} = 12 V, V_{REF} = V_{CC}/2 (unless otherwise specified)

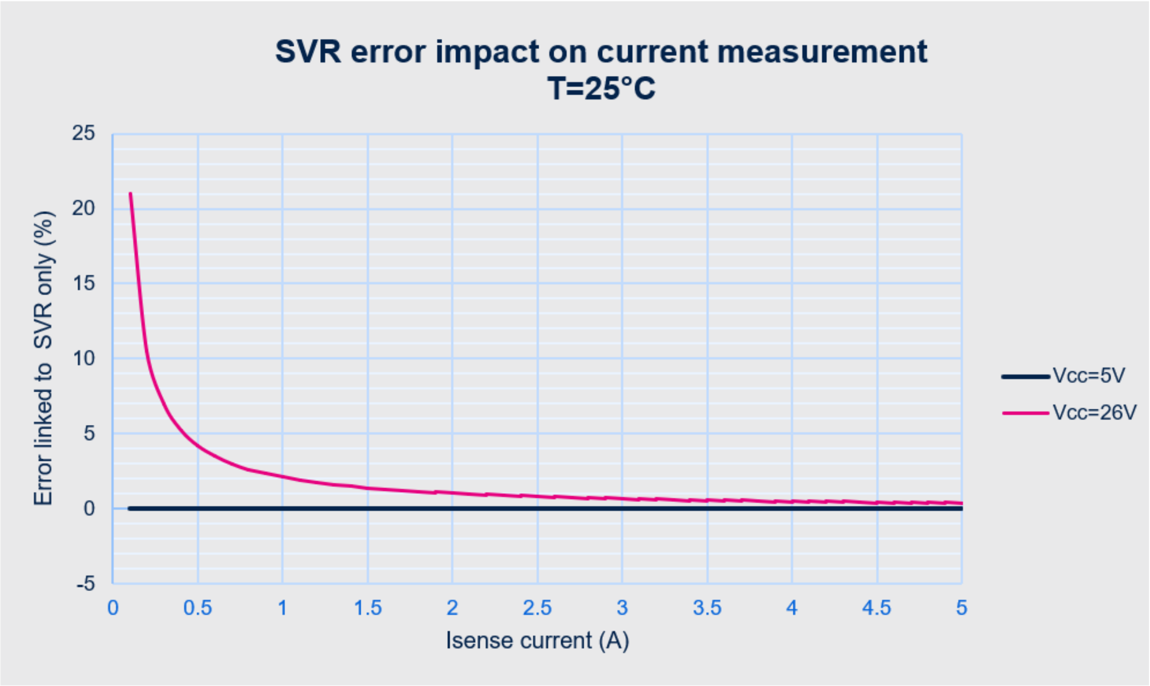
PSRR	Power supply rejection ratio	V_{cc}= 2.7 to 26 V V_{IN+}=18 V, V_{SENSE} = 0 mV	0.1	10	µV/V

Explanation

Example



$$SVR\ impact\ (\%) = \frac{|26\ V - 5\ V| * PSRR}{10\ m\Omega * I_{sense}} * 100$$



TSC214

Table 5. Electrical characteristics, T = 25 °C, $V_{SENSE} = V_{IN+} - V_{IN-}$ (unless otherwise specified), TSC210, TSC213, TSC214, TSC215: V_{CC}= 5 V, V_{IN+}=12 V, V_{REF}= V_{CC}/2 (unless otherwise specified), TSC211, TSC212: V_{CC} = 12 V, V_{IN+} = 12 V, V_{REF} = V_{CC}/2 (unless otherwise specified)

PSRR	Power supply rejection ratio	V_{cc}= 2.7 to 26 V V_{IN}+=18 V, V_{SENSE} = 0 mV	0.1	10	µV/V

Explanation

Example

Explanation of pages 12–13

(page 12) This example illustrates the impact of SVR on current-measurement accuracy using the TSC214, a bidirectional current-sense amplifier with a gain of 100.

First, consider an application powered at $5\ \mathrm{V}$. In the datasheet, all parameters are specified for $V_{CC} = 5\ \mathrm{V}$.

Since the application supply voltage is the same as the datasheet reference voltage, the SVR contribution is zero, as shown by the equation. In this case, the error calculation only includes the input offset voltage, V_{io} ,specified in the datasheet, which is $60\ \mu\mathrm{V}$ maximum at $25°\mathrm{C}$.

The blue curve represents the error due to SVR only.

Explanation of pages 12–13

(page 13) Now consider the same application with a supply voltage of $26\ \mathrm{V}$.

Since V_{io} is not specified in the datasheet at this supply voltage, its variation should be estimated using the SVR equation. For a supply-voltage variation of $21\ \mathrm{V}$, the input offset voltage changes by $210\ \mu\mathrm{V}$.

The red curve shows the error due only to the SVR impact of the amplifier, in other words, the error caused by the input offset voltage corresponding to the application supply voltage.

If the application operates at a supply voltage different from the one specified in the datasheet, the error introduced by SVR must be taken into account.

PSRR error summary

PSRR defines how the output voltage changes depending on the voltage applied to the input pins

It can be compared directly to the V_{sense} voltage to get a first error estimate

Its variation with temperature must also be considered

It has the most significant impact at low current

For a chosen device with a good V_{io}, PSRR must be good as well

Two ways to minimize the offset error

- Increase the shunt resistance value
- Choose a device with a higher SVR (dB) value

Explanation

PSRR error summary

Explanation of page 16

In this chapter, we introduced power-supply rejection in current-sensing devices, referred to as SVR or sometimes PSRR.

SVR describes how the input offset voltage varies with the application supply voltage, V_{CC} ,and therefore, how the output voltage is affected. Its error can be compared directly with the shunt voltage for a first estimate, and its impact is greatest at low current.

The first step is to check the supply voltage at which V_{io} is specified in the datasheet. If the application uses the same supply voltage, the SVR contribution can be neglected. If not, SVR must be considered to estimate the actual value of V_{io} at the application supply voltage.

To improve precision, two main options are available:

- increase the shunt resistor value;
- select a device with low V_{io} and strong SVR performance.

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