Current Sensing Example Circuits

TI Precision Labs – Current Sense Amplifiers

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Hello and welcome to the TI precision labs series on current sense amplifiers. My name is Ian Williams, and I’m the applications manager for current sensing products. In this video, we will introduce several useful example circuits for current sensing. These include summing, differencing, paralleling, overcurrent detection, warning and shutdown, and window comparator circuits.

Current sensing example circuits

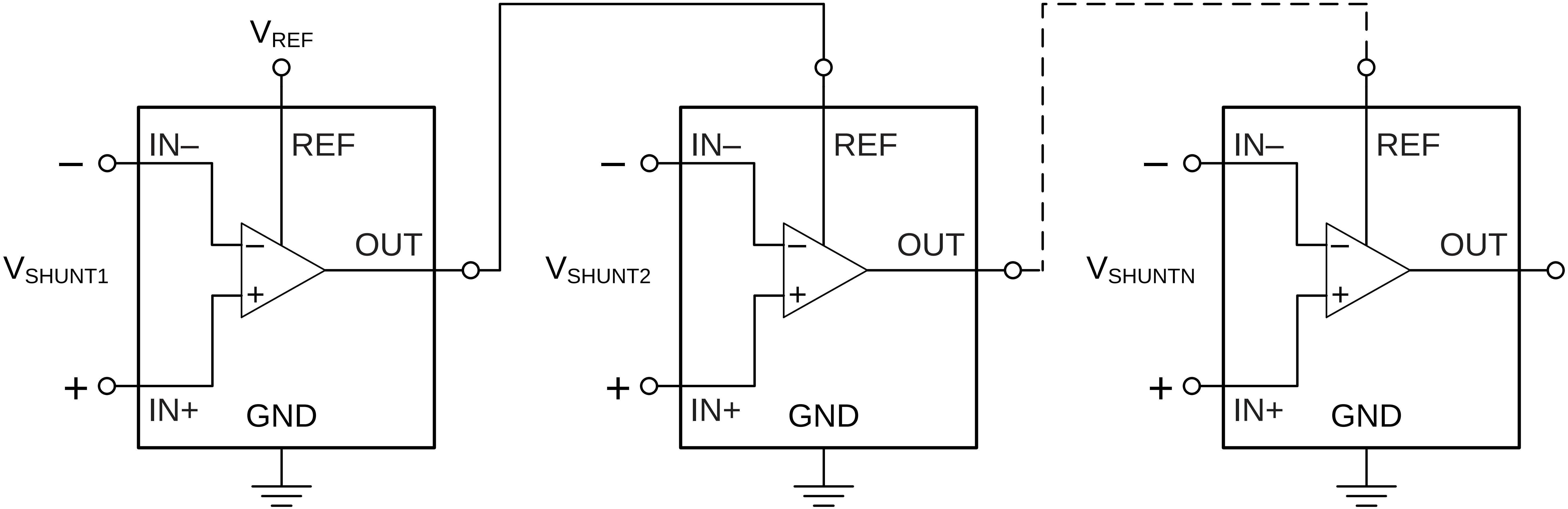
CATEGORY	NAME	BENEFITS
Linear	Summing	Measures the total current flow through different loads, even on different supply rails.
	Differencing	Measures the difference of currents into and out of a system load. Can detect leakage paths.
	Paralleling	Handles higher load currents than a single circuit by splitting load current into two or more shunt resistors.
Comparator-based	Overcurrent detection	Provides an alert signal when load current has exceeded a specified threshold. Used for protection and control.
	Warning and shutdown	Provides a warning signal when load current has exceeded an initial threshold, and a shutdown signal when load current has exceeded a second, higher threshold.
	Window comparator	Provides an alert signal when load current moves out of a specific minimum and maximum range. Used to check normal operation.

The example circuits covered in today's video fall into two main categories: linear, and comparator-based.

The summing, differencing, and paralleling circuits fall into the linear category and are used for continuous current monitoring and control. The overcurrent detection, warning and shutdown, and window comparator circuits make up the comparator-based category, and are used to provide alert signals under specific load current conditions, so that system power can be turned off or other decisions can be made to ensure safe and reliable operation.

The benefits of each are summarized here, and I'll give more details as we explore each one.

Summing circuit



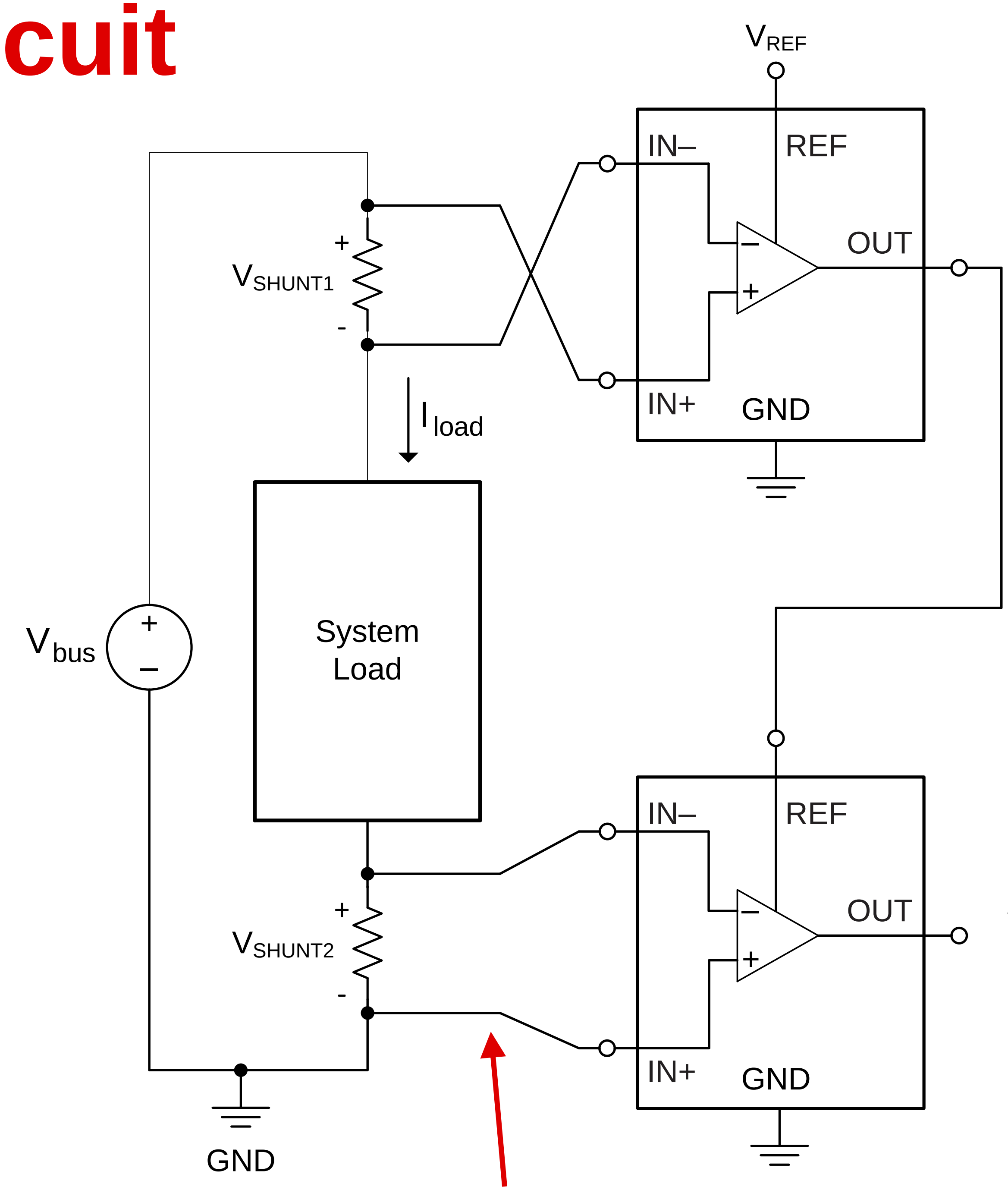
$$V_O = (V_{shunt1} + V_{shunt2} + \cdots + V_{shuntn}) * Gain + V_{ref}$$

In some cases, it’s desirable to measure the total current flow through different loads in a larger system. These loads may even be powered by different bus voltages, such as the CPU and memory of a computer system. In that case, a summing circuit is very helpful to take a combined current measurement.

In this implementation, the inputs to multiple current sense amplifiers can be added together by connecting the output of the previous stage to the REF input of the next stage. This implementation can be chained as many times as needed, within reason. The output voltage is equal to the sum of the inputs of all stages multiplied by their gain and added to VREF. This circuit requires the gain of each stage to be the same.

The technique of connecting the output of one device to the REF pin of another one enables more useful circuits, as shown in the following examples.

Differencing circuit



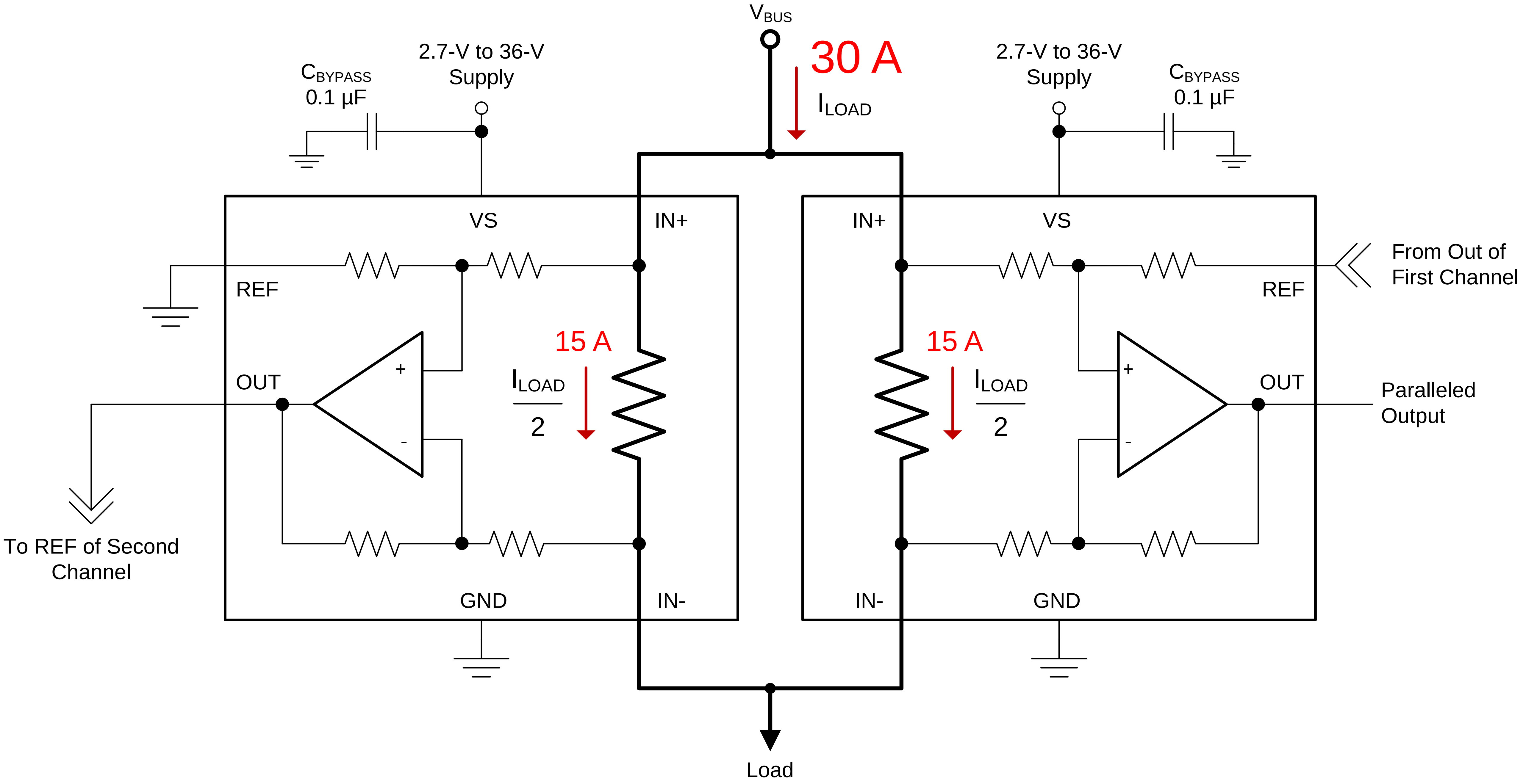
$$V_O = (V_{shunt1} - V_{shunt2}) * Gain + V_{ref}$$

Wiring reversed on low side

There may be a need to measure the difference of the currents into and out of the system load. It’s reasonable to expect that the current into and out of a load would be the same in a closed system. However, unexpected leakage currents can develop which create this difference.

The implementation shown here is a 2 stage summing configuration with the wiring to the second stage reversed. Therefore in this example, if the current into and out of the load is equal, then the output is equal to VREF. If the currents are different, then the difference in current is amplified by the device gain and added to VREF.

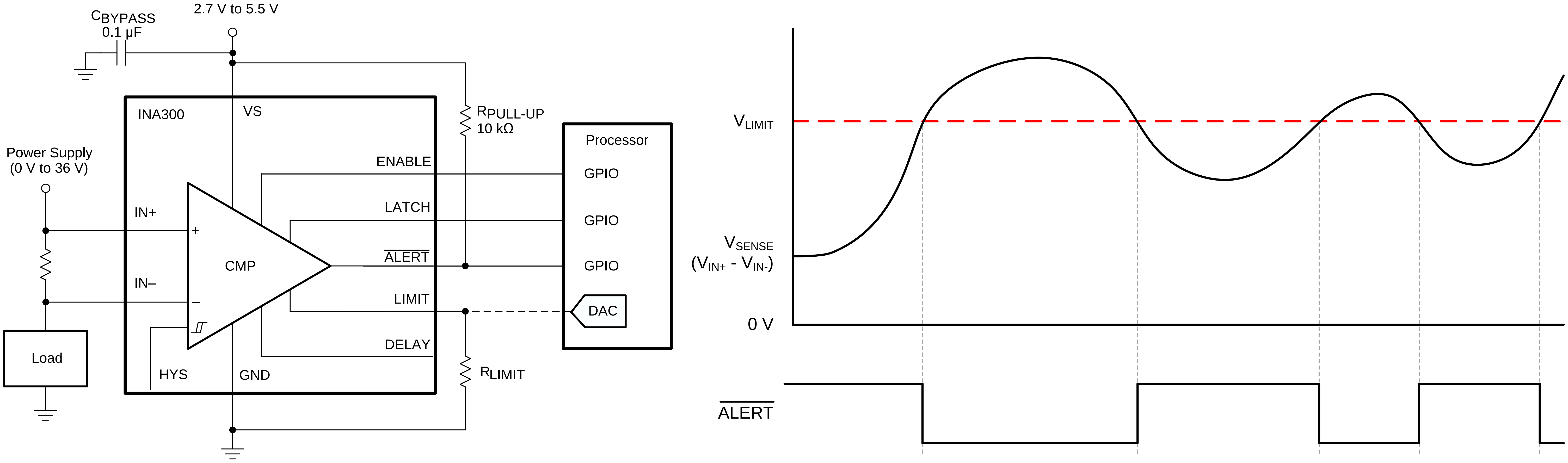
Paralleling circuit



Some of our current sense amplifiers feature integrated shunt resistors. The INA250, for example, is one such device which can handle 15 amps of continuous current through the shunt. If your application requires higher currents to be measured, a paralleling circuit can double the current detection capacity. Because the internal shunt resistances are the same, the load current is split between the two shunts. The output of the first channel is connected to the REF pin of the second channel, adding the outputs together. As you may have guessed, this is another variation of the summing circuit.

Please note that this is not limited to use with integrated shunt devices! The same technique can be applied to external shunt devices in order to reduce power losses and manage the power dissipation and thermal limits of a single shunt resistor. The shunt resistor values and gain of the current sense amplifiers must be the same for proper operation.

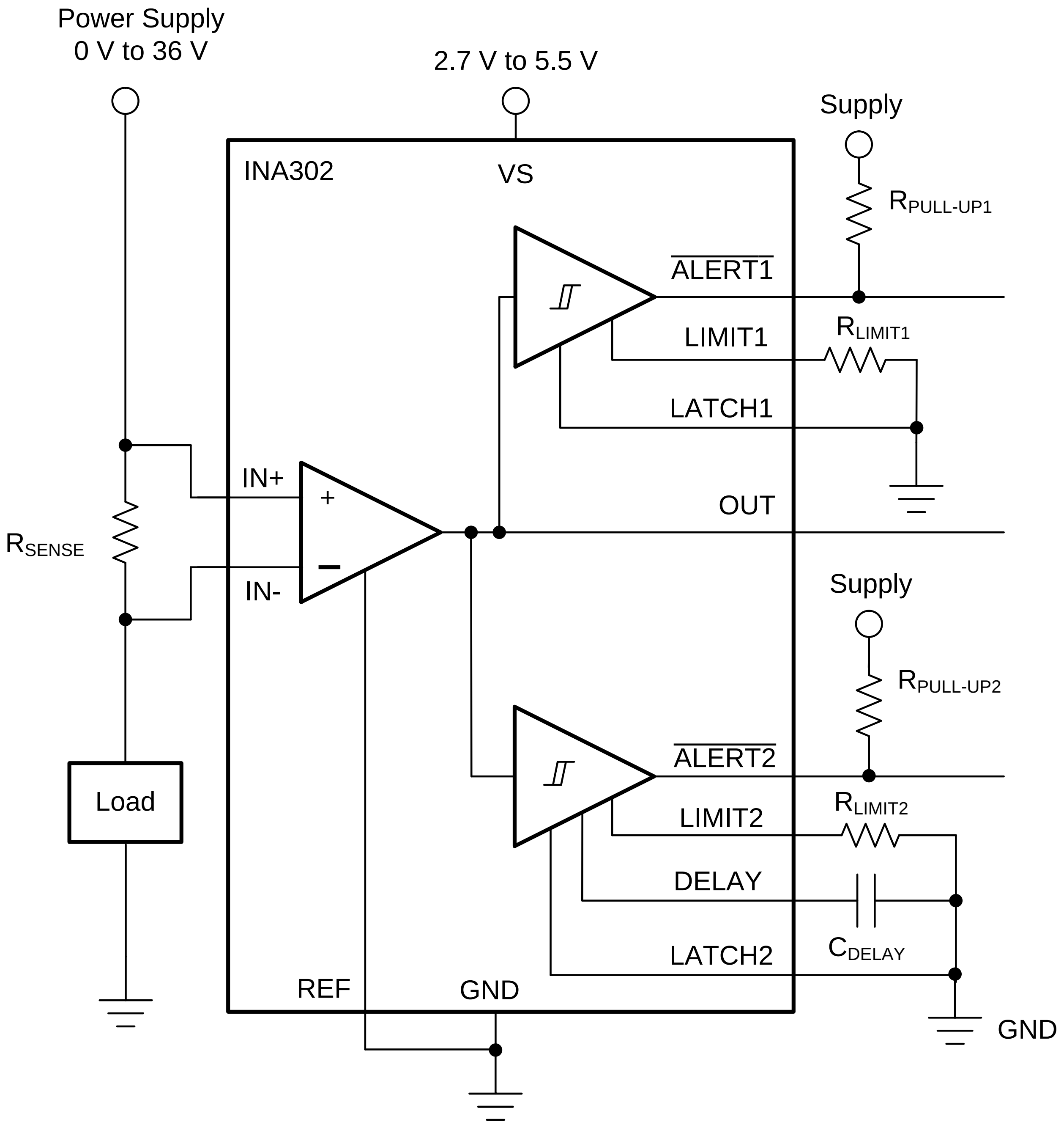
Overcurrent detection

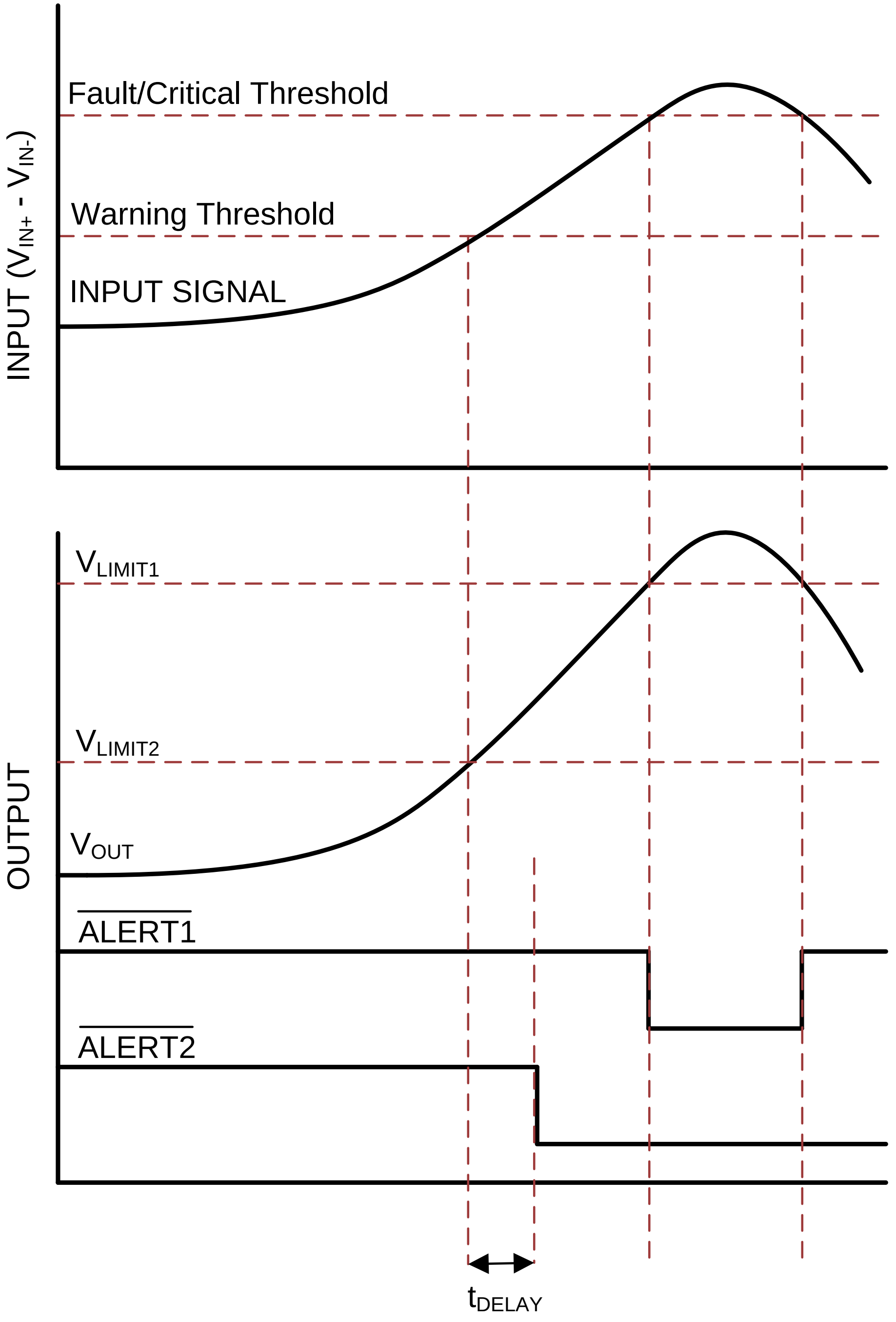


In many cases, current sense amplifiers are used to check for overcurrent conditions. Here is a common implementation of overcurrent detection using the INA300, a current sense comparator. The overcurrent limit can be set using an external Rlimit resistor, as well as a DAC or other voltage source. The alert pin is pulled up to the supply through a pull-up resistor. When the differential input voltage Vsense goes above the set limit, then the ALERT output goes low, indicating an overcurrent condition.

Most current sense comparators have additional features, such as a latch mode and programmable delay time.

Warning and shutdown circuit

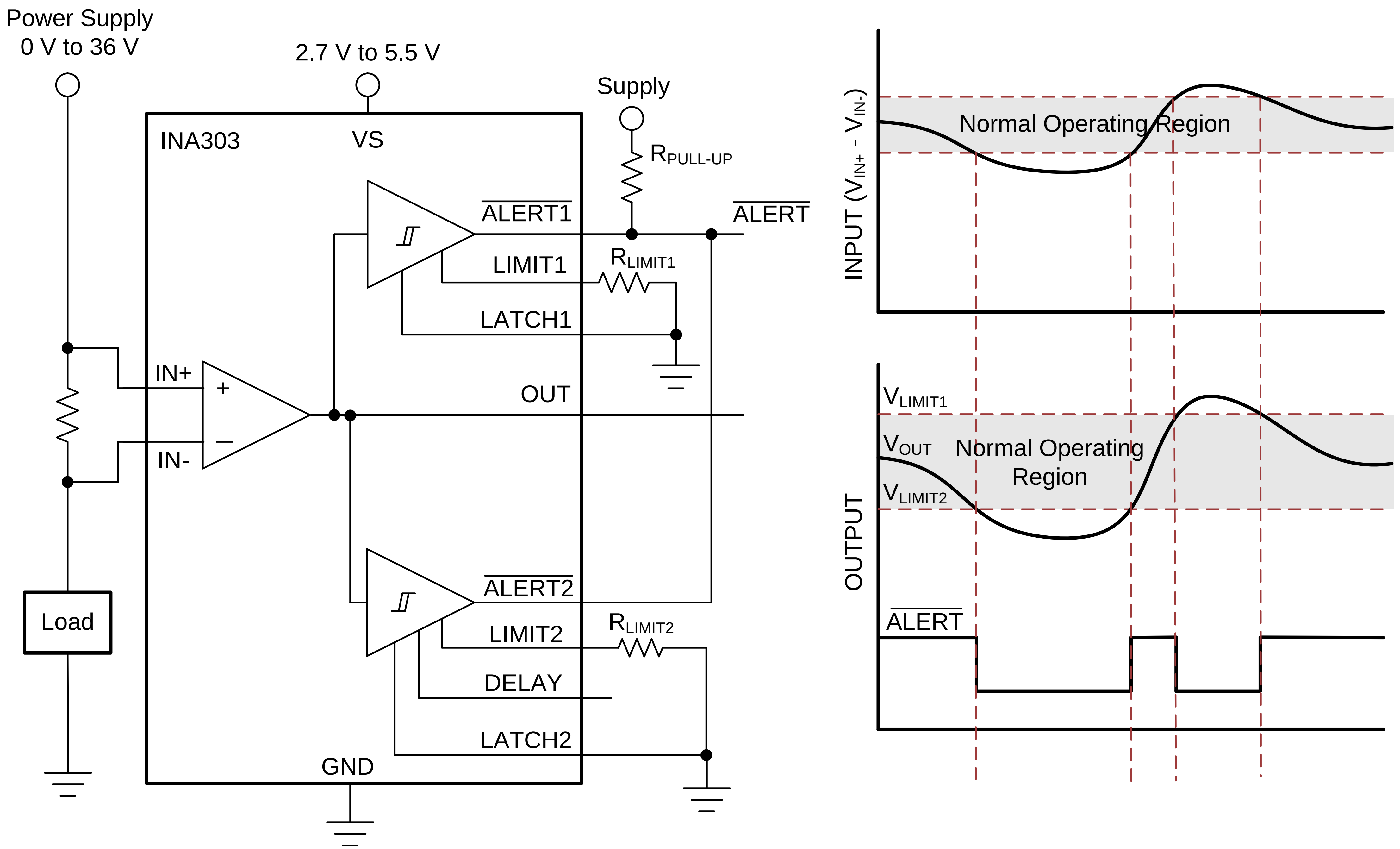




Next let’s consider a warning and shutdown circuit. The goal here is to provide a first alert when current has exceeded a warning threshold, and a second alert when current has exceeded a critical threshold.

This circuit is simple to implement with the INA302, a current sense amplifier with dual comparators. The warning and critical thresholds are set with external resistors, and the alert pins are pulled up to the supply through pull-up resistors. In the example shown, ALERT2 will go low once load current exceeds the warning threshold, and ALERT1 will go low once load current exceeds the critical threshold. Notice that a time delay is implemented on ALERT2 by connecting an external capacitance to the DELAY pin.

Window comparator



Finally, here is a window comparator circuit, which alerts whenever the load current is outside a set window. The device shown here is INA303, another current sense amplifier with dual comparators. The output of the internal amplifier is passed to each comparator and checked against limits set by external resistors. These two limits create the window of normal operation.

Both the comparator outputs are connected together and pulled up to the supply through a pull-up resistor. When ever the output of the current sense amplifier is outside the window, the composite comparator output will ALERT by pulling the voltage low.

To find more current sense amplifier technical resources and search products, visit ti.com/currentsense

That concludes this video - thank you for watching! Please try the quiz to check your understanding of the content.

For more information and videos on current sense amplifiers please visit ti.com/currentsense.

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Quiz

Current sensing example circuits – quiz

1. Overcurrent detection and warning and shutdown are examples of:
   a) Linear circuits
   b) Comparator-based circuits
   c) Audio circuits
   d) None of the above

2. The summing circuit works by:
   a) Connecting OUT of the previous stage to REF of the next stage
   b) Connecting OUT of the previous stage to GND of the next stage
   c) Connecting OUT of the previous stage to IN+ of the next stage
   d) Connecting all the OUT pins together

Current sensing example circuits – quiz

3. The differencing circuit is useful for:
   a) Detecting overcurrent conditions
   b) Measuring the total current through different loads
   c) Checking for leakage currents within a system
   d) Measuring higher currents than possible with one stage

4. Load current is split evenly between stages in a paralleling circuit because:
   a) The maximum continuous current of each device is limited
   b) OUT of the first stage is connected to REF of the second stage
   c) The gains are the same
   d) The shunt resistances are the same

Current sensing example circuits – quiz

5. Overcurrent detection is used to:
   a) Alert when load current has exceeded a specified threshold
   b) Help ensure that electronic systems operate safely
   c) Help a control system decide if power needs to be turned off
   d) All of the above

6. The INA302 and INA303 are examples of:
   a) A current sense comparator
   b) A current sense amplifier with dual comparators
   c) A dual-channel current sense amplifier
   d) An operational amplifier

Answers

Current sensing example circuits – quiz

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