

Avoid Operational Amplifier Output Stage Saturation by Gain Control

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ABSTRACT

Analog systems sometimes have problems with operational amplifiers due to output stage saturation. This note describes a solution which avoids operational amplifier output stage saturation by using gain control.

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Design Problem Introduction

The problem of output stage saturation happens frequently in linear applications when a high amplitude input signal occurs and causes the output of the operational amplifier to move outside its real capabilities. This saturation can cause large distortion in the application. This document explains how to decrease the output saturation by using a feedback operational amplifier for gain control. The idea is to activate feedback only above a fixed reference voltage value, V_{ref} .

Solution

Figure 1 shows the application schematic based on the operational amplifier TLV2462. The device is used as noninverting with a 5-V single supply and a positive input voltage signal. The TLV2462 has a 6.4-MHz bandwidth product and is the solution for several applications. In this example, the gain of the first operational amplifier A1 is 2 V/V. Even by using a rail-to-rail output operational amplifier like the TLV2462, the output of the operational amplifier would go into saturation if the input signal V_{IN} is above 2.5 V. If this input over-voltage signal occurs, the gain of the operational amplifier A1 needs to be decreased. This can be done by using a second operational amplifier A2 as negative feedback.

The second operational amplifier A2 works as a subtractor with a gain of -2 V/V for V_{OUT} and a gain of 3 V/V for V_{ref} .

$$V_{(OUT2)} = 3 V_{ref} - 2 V_{OUT} \quad (1)$$

If the diode is blocked, A2 has no effect on the gain of A1.

If the output voltage of A2 together with the voltage drop across the diode goes below V_{IN} , the diode is conducting and accordingly the gain of A1 decreases. The feedback is in opposition with the input signal. Using the values shown in Figure 1 and without consideration of the forward characteristic of the diode, the gain calculation for changes in the input voltage for this case is as follows:

$$\frac{(dV_{IN} + A2dV_{OUT})}{2} = \frac{dV_{OUT}}{A1} \quad (2)$$

$$\frac{dV_{OUT}}{dV_{IN}} = \frac{A1}{(2-A1A2)} \quad (3)$$

In the schematic $A1 = 2$ V/V and $A2 = 2$ V/V

Then:

$$\frac{dV_{OUT}}{dV_{IN}} = \frac{1}{3} \quad (4)$$

The circuit shown in Figure 1 with $V_{ref} \approx 3$ V gives the following results when using a silicon diode:

- The output voltage variation versus the input voltage variation has a gain of 2 V/V until V_{OUT} reaches approximately 3.6 V. The total amount of output voltage can be calculated for this case using the following equation:

$$V_{OUT} = 2 V_{IN} \quad (5)$$

- The output voltage variation versus the input voltage variation has a gain of $1/3$ for an output voltage range of about 3.6 V to 4.5 V. This gain is increased to approximately 1 for output voltages above 4.5 V. This is illustrated in Figure 2. The output, V_{OUT} , will not be saturated even if the input voltage goes up to about 4.7 V.

This solution can be adapted to different voltage supplies as well as different reference voltages. It is easy to set the compensation by adjusting the feedback gain with different resistor choices.

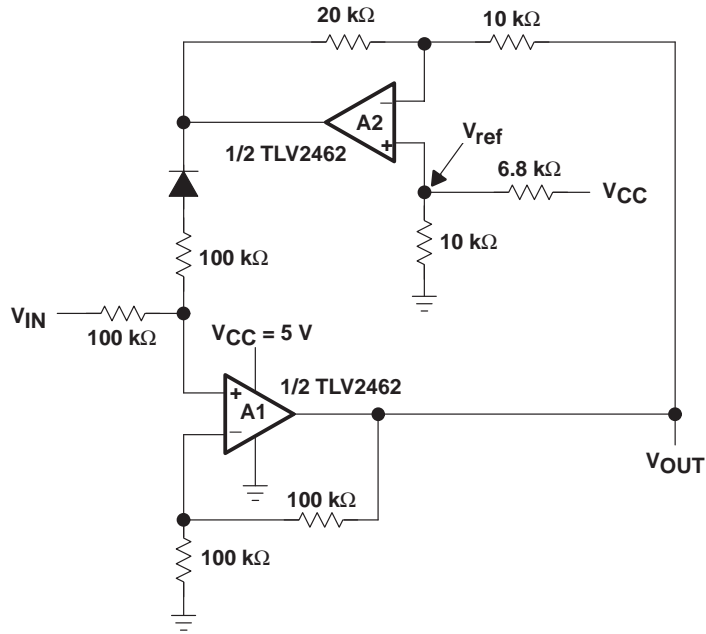


Figure 1. Application Schematic

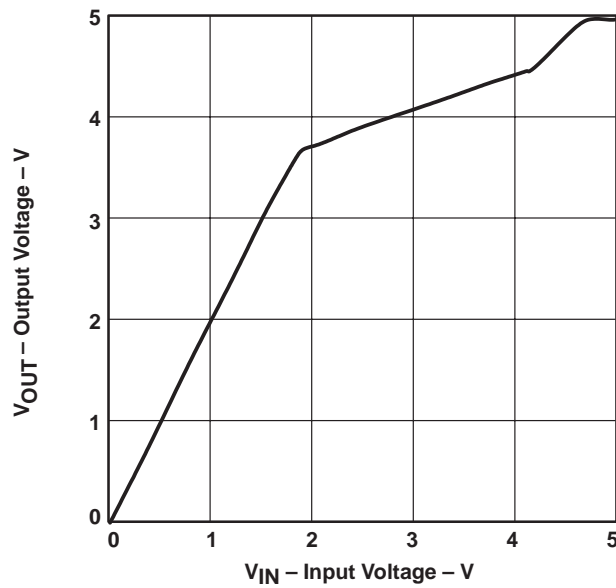


Figure 2. Output Voltage Variation vs Input Voltage Variation

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