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APPLICATION NOTE 4280

# Using the DS4424 to Margin the Output Voltage of a DC-DC Converter

*Abstract: A DS4424 adjustable-current DAC is used to adjust the margin of a DC-DC converter's output voltage. This article describes how to properly select the resistor values of a DC-DC converter's feedback divider network when the DS4424 is employed in the design.*

## Introduction

The [DS4424](#) adjustable-current DAC is similar to the DS4404 adjustable-current DAC with two major differences. First, the DS4424 has 127 settings each for sink and source mode, while the DS4404 has 31 settings. Second, the DS4424's default I<sup>2</sup>C address is set to 20h, whereas the DS4404's default I<sup>2</sup>C address is 90h. Both devices' addresses are determined by the states of the A0 and A1 address pins.

This article focuses on the DS4424, which can be used to adjust the margin of a DC-DC converter's output voltage. The article explains how to properly select resistor values of the DC-DC converter's feedback divider network when the DS4424 is employed in the design.

## The Adjustable Power Supply

The DS4424 contains four I<sup>2</sup>C adjustable current sources capable of sinking and sourcing current. A typical application for these DACs is margining the output voltage of a DC-DC converter (**Figure 1**).

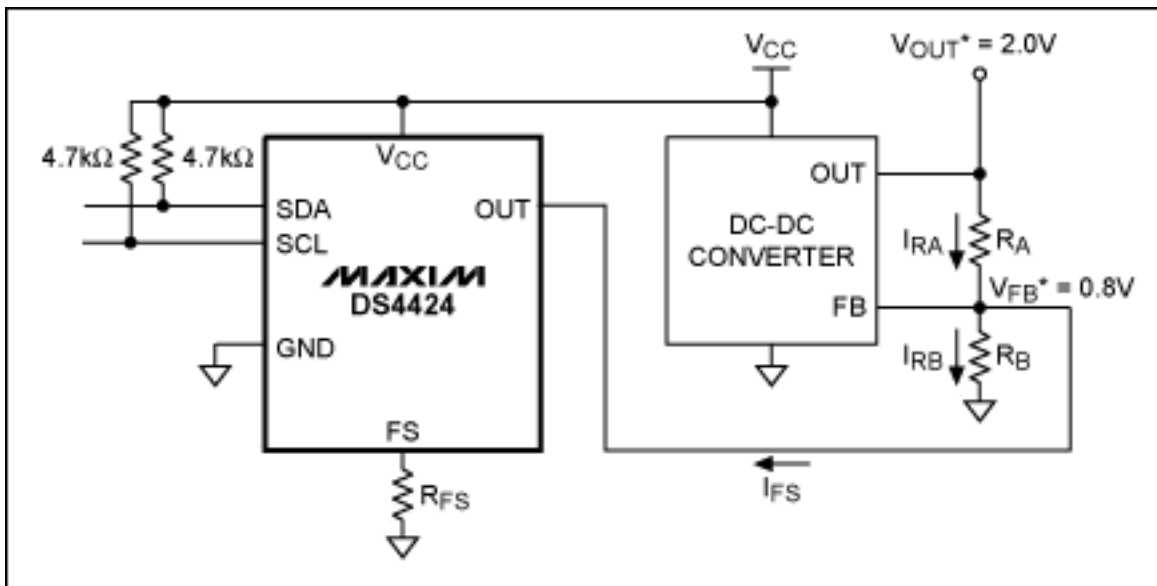


Figure 1. DC-DC converter circuit with adjustable-current DACs used to margin the converter's output voltage. \* $V_{OUT}$  and  $V_{FB}$  values are determined by the DC-DC converter, and should not be confused with  $V_{OUT}$  and  $V_{RFS}$  of the DS4424.

The DS4424 sinks and sources from its OUT pins. Valid full-scale current values range from 50µA to 200µA. The value of the full-scale current,  $I_{FS}$ , is determined by the size of the resistor connected to the DAC's FS pin of the corresponding OUT pin. The source/sink current generated by the DS4424 is commonly used to adjust the DC-DC converter's feedback voltage-divider.

## Determining the Relationship Between $V_{OUT}$ and $I_{FS}$

Choosing the right  $I_{FS}$  depends on how much margin is desired on the DC-DC converter's  $V_{OUT}$  pin. To determine this margin, we must discover the relationship between  $V_{OUT}$  and  $I_{FS}$ .

Summing currents into the  $V_{FB}$  node, we find that:

$$I_{RA} = I_{FS} + I_{RB} \quad (\text{Eq. 1})$$

Where:

$$I_{RB} = \frac{V_{FB}}{R_B} \quad (\text{Eq. 2})$$

And:

$$I_{RA} = \frac{V_{OUT} - V_{FB}}{R_A} \quad (\text{Eq. 3})$$

However, since  $R_B$  and  $V_{FB}$  are constant, there is no change in  $I_{RB}$ . Thus:

$$\Delta I_{RA} = \Delta I_{FS} \quad (\text{Eq. 4})$$

We are looking for the relationship between the margin on  $V_{OUT}$ ,  $\Delta V_{OUT}$ , and the selected range of  $I_{FS}$ ,  $\Delta I_{FS}$ . Since we know that the change in the  $I_{FS}$  current equals the change in the current across  $R_A$ , we can subtract one set of  $V_{OUT}$  and  $I_{RA}$  values from the other to determine the relationship between  $V_{OUT}$  and  $I_{FS}$ .

First, solving Equation 3 to find  $V_{OUT}$ , we determine that:

$$V_{OUT} = V_{FB} - I_{RA} \times R_A \quad (\text{Eq. 5})$$

Use Equation 5 to create two equations. For one equation, we choose the maximum margin on  $V_{OUT}$ ,  $V_{OUTMAX}$ , and the maximum  $I_{RA}$  current,  $I_{RAMAX}$ . For the other equation, we choose the nominal values for  $V_{OUT}$  and  $I_{RA}$ ,  $V_{OUTNOM}$  and  $I_{RANOM}$ . Subtracting the two equations, we get:

$$\begin{aligned} V_{OUTMAX} &= V_{FB} - I_{RAMAX} \times R_A \\ - (V_{OUTNOM} &= V_{FB} - I_{RANOM} \times R_A) \\ \hline \Delta V_{OUT} &= \Delta I_{RA} \times R_A \end{aligned} \quad (\text{Eq. 6})$$

Using Equation 4, Equation 6 translates into the relationship:

$$\Delta V_{OUT} = \Delta I_{FS} \times R_A \quad (\text{Eq. 7})$$

Equation 7 shows that the relationship between the margin on  $V_{OUT}$  and  $I_{FS}$  is determined by the value of the resistor  $R_A$ .

## Calculating the Right Resistor Value for the Margin on $V_{OUT}$

Now that we know the relationship between  $V_{OUT}$  and  $I_{FS}$ , we can select the correct value of  $R_A$  and, thus,  $R_B$  to generate the desired margin on  $V_{OUT}$ . Since the full-scale current sink/source range of the DS4424 is  $50\mu\text{A}$  to  $200\mu\text{A}$ , we select  $100\mu\text{A}$  as the  $I_{FS}$  current for the DAC. To set this value, choose  $R_{FS}$  based on the following equation (also found on page 6 of the DS4424 data sheet):

$$R_{FS} = \frac{V_{RFS}}{I_{FS}} \times \frac{127}{16} \quad (\text{Eq. 8})$$

With  $V_{RFS} = 0.976\text{V}$ , we solve Equation 8 and find that  $R_{FS}$  needs to be  $80\text{k}\Omega$  ( $77.47\text{k}\Omega$ ) to produce a  $100\mu\text{A}$  full-scale current.

With the DS4424  $I_{FS}$  selected, we must determine the size of  $R_A$  to achieve the desired margin on  $V_{OUT}$ . A  $2.0\text{V}$   $V_{OUT}$  with a 20% margin requires  $\pm 0.4\text{V}$  of change. Sinking and sourcing the settings of the DS4424 will manage the sign. The change in  $I_{FS}$  equals the  $I_{FS}$  value of  $1\text{mA}$ , and the desired change in  $V_{OUT}$  is  $0.4\text{V}$ . After substituting for  $\Delta V_{OUT}$  and  $\Delta I_{FS}$  in Equation 7, we solve for  $R_A$  and get  $R_A = 4.0\text{k}\Omega$ .

## Determining the Relationship Between $R_A$ and $R_B$

The feedback network of the circuit in Figure 1 is a voltage-divider with resistors  $R_A$  and  $R_B$ . Looking at Figure 1 and assuming  $I_{FS} = 0\text{A}$ , we can create a simple voltage-divider equation:

$$V_{FB} = \frac{R_B}{R_A + R_B} \times V_{OUT} \quad (\text{Eq. 9})$$

We assume that the desired nominal value for  $V_{OUT}$  is  $2.0\text{V}$ , and that the DC-DC converter has a feedback voltage,  $V_{FB}$ , of  $0.8\text{V}$ . Substituting the values for  $V_{OUT}$  and  $V_{FB}$ , the relationship between  $R_A$  and  $R_B$  is determined to be:

$$R_A = 1.5 \times R_B \quad (\text{Eq. 10})$$

We use Equation 10 to solve for  $R_B$  and get  $R_B = 2.67\text{k}\Omega$ .

## Conclusion

The resistive-feedback-divider network and the current-sinking/sourcing capabilities of the DS4424 DACs control the margin of  $V_{OUT}$  on a DC-DC converter. The relationship between the full-scale current,  $I_{FS}$ , to the margin on  $V_{OUT}$  is determined by the value of the resistor  $R_A$ . By choosing the correct  $I_{FS}$  value for your application, you can determine the correct resistor values for the feedback divider network, and achieve the desired margin on  $V_{OUT}$ .

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Application Note 4280: [www.maxim-ic.com/an4280](http://www.maxim-ic.com/an4280)

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