

APPLICATION NOTE 4055

# Using the DS4402/DS4404 to Margin the Output Voltage of a DC-DC Converter

*Abstract: A DS4402 or DS4404 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 in a DC-DC converter's feedback divider network when a DS4402 or DS4404 is employed in the design.*

## The Adjustable Power Supply

The [DS4402/DS4404](#) DACs contain two/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. (See **Figure 1.**)

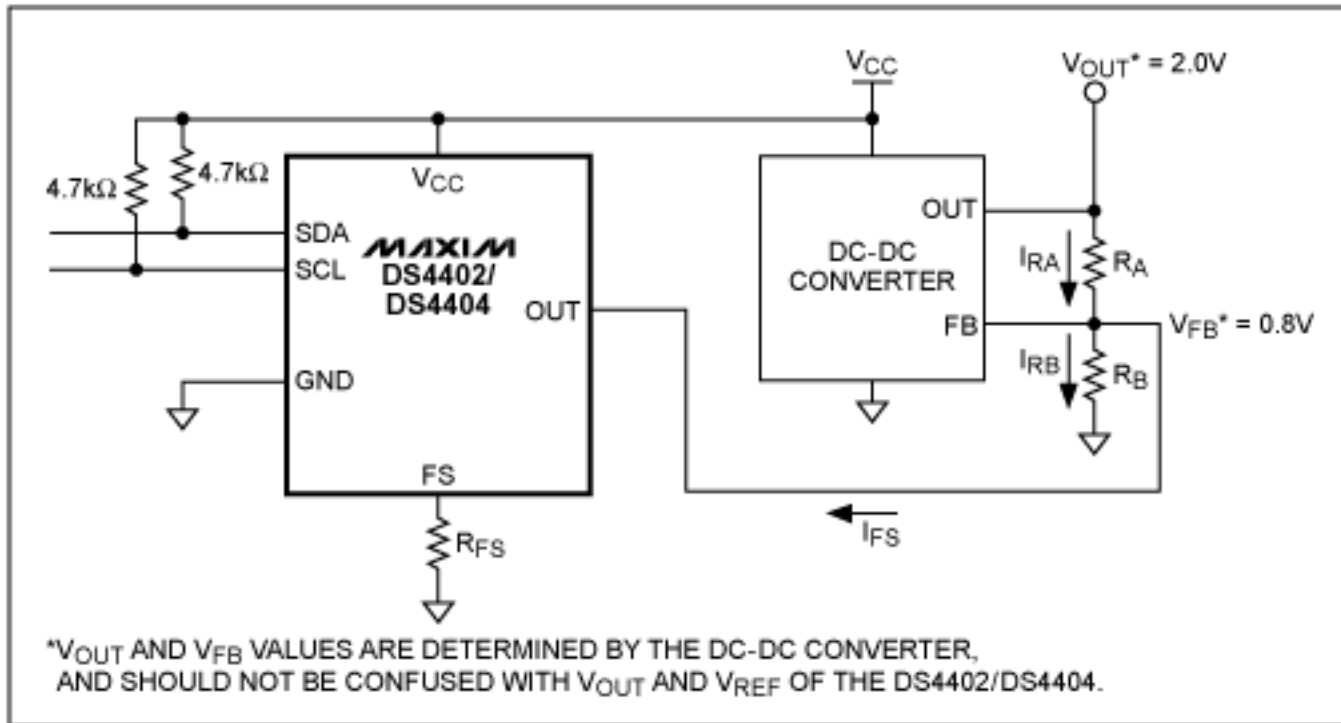


Figure 1. DC-DC converter circuit with adjustable-current DACs used to margin the converter's output voltage.

The DS4402/DS4404 sink and source current from their OUT pins. Valid full-scale current values range from 0.5mA to 2.0mA. The value of the full-scale current, I<sub>FS</sub>, 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 DS4402/DS4404 is most 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 subtract one set of  $V_{OUT}$  and  $I_{RA}$  values from another to determine the relationship between  $V_{OUT}$  and  $I_{FS}$ .

First, solving Equation 3 to find  $V_{OUT}$ , we find 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  $I_{RA}$ ,  $I_{RAMAX}$ . 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:

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

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 DS4402/DS4404 is 0.5mA to 2.0mA, we select 1mA as the  $I_{FS}$  current for the DAC. To set this value, choose  $R_{FS}$  based on the

following equation (Equation 1 in the DS4402/DS4404 data sheet):

$$R_{FS} = \frac{V_{REF}}{I_{FS}} \times \frac{31}{4} \quad (\text{Eq. 8})$$

With  $V_{REF} = 1.23\text{V}$ , we solve Equation 8 and find that  $R_{FS}$  needs to be  $9.53\text{k}\Omega$  to produce a  $1\text{mA}$  full-scale current.

With the DS4402/DS4404  $I_{FS}$  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 settings of the DS4402/DS4404 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  $R_A = 400\Omega$ .

## 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 that  $I_{FS} = 0\text{A}$ , we 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:

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

We use Equation 10 to solve for  $R_B$ , and get  $R_B = 267\Omega$ .

## Conclusion

The resistive-feedback-divider network and the current-sinking/sourcing capabilities of the DS4402/DS4404 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 4055: [www.maxim-ic.com/an4055](http://www.maxim-ic.com/an4055)

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