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 \textsuperscript{1}P\textsubscript{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.](image)

\*\*\*\*OUT AND V\_FB VALUES ARE DETERMINED BY THE DC-DC CONVERTER, AND SHOULD NOT BE CONFUSED WITH V\_OUT AND V\_REF OF THE DS4402/DS4404.\*\*\*\*

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, $I_{\text{FS}}$, 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
DS4402/DS4404 is most commonly used to adjust the DC-DC converter’s feedback voltage-divider.

Determining the Relationship Between \( \text{V}_{\text{OUT}} \) and \( \text{IFS} \)

Choosing the right \( \text{IFS} \) depends on how much margin is desired on the DC-DC converter’s \( \text{V}_{\text{OUT}} \) pin. To determine this margin, we must discover the relationship between \( \text{V}_{\text{OUT}} \) and \( \text{IFS} \).

Summing currents into the \( \text{V}_{\text{FB}} \) node, we find that:

\[
\text{I}_{\text{RA}} = \text{IFS} + \text{I}_{\text{RB}} \quad \text{(Eq. 1)}
\]

Where:

\[
\text{I}_{\text{RB}} = \frac{\text{V}_{\text{FB}}}{\text{R}_{\text{B}}} \quad \text{(Eq. 2)}
\]

And:

\[
\text{I}_{\text{RA}} = \frac{\text{V}_{\text{OUT}} \cdot \text{V}_{\text{FB}}}{\text{R}_{\text{A}}} \quad \text{(Eq. 3)}
\]

However, since \( \text{R}_{\text{B}} \) and \( \text{V}_{\text{FB}} \) are constant, there is no change in \( \text{I}_{\text{RB}} \). Thus:

\[
\Delta \text{I}_{\text{RA}} = \Delta \text{IFS} \quad \text{(Eq. 4)}
\]

We are looking for the relationship between the margin on \( \text{V}_{\text{OUT}} \), \( \Delta \text{V}_{\text{OUT}} \), and the selected range of \( \text{IFS} \), \( \Delta \text{IFS} \). Since we know that the change in the \( \text{IFS} \) current equals the change in the current across \( \text{R}_{\text{A}} \), we subtract one set of \( \text{V}_{\text{OUT}} \) and \( \text{I}_{\text{RA}} \) values from another to determine the relationship between \( \text{V}_{\text{OUT}} \) and \( \text{IFS} \).

First, solving Equation 3 to find \( \text{V}_{\text{OUT}} \), we find that:

\[
\text{V}_{\text{OUT}} = \text{V}_{\text{FB}} \cdot \text{I}_{\text{RA}} \cdot \text{R}_{\text{A}} \quad \text{(Eq. 5)}
\]

Use Equation 5 to create two equations. For one equation, we choose the maximum margin on \( \text{V}_{\text{OUT}} \), \( \text{V}_{\text{OUTMAX}} \), and the maximum \( \text{I}_{\text{RA}} \), \( \text{I}_{\text{RAMAX}} \). For the other equation, we choose the nominal values for \( \text{V}_{\text{OUT}} \) and \( \text{I}_{\text{RA}} \), \( \text{V}_{\text{OUTNOM}} \) and \( \text{I}_{\text{RANOM}} \). Subtracting the two equations, we get:

\[
\frac{\Delta \text{V}_{\text{OUT}} = \text{V}_{\text{FB}} \cdot \text{I}_{\text{RAMAX}} \cdot \text{R}_{\text{A}} - (\text{V}_{\text{OUTNOM}} = \text{V}_{\text{FB}} \cdot \text{I}_{\text{RANOM}} \cdot \text{R}_{\text{A}})}{\Delta \text{I}_{\text{RA}} \cdot \text{R}_{\text{A}}} \quad \text{(Eq. 6)}
\]

Using Equation 4, Equation 6 translates into the relationship:

\[
\Delta \text{V}_{\text{OUT}} = \Delta \text{IFS} \times \text{R}_{\text{A}} \quad \text{(Eq. 7)}
\]

Equation 7 shows that the relationship between the margin on \( \text{V}_{\text{OUT}} \) and \( \text{IFS} \) is determined by the value of the resistor \( \text{R}_{\text{A}} \).

Calculating the Right Resistor Value for the Margin on \( \text{V}_{\text{OUT}} \)
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):

$$R_{FS} = \frac{V_{REF}}{I_{FS}} \times \frac{31}{4}$$  \hspace{1cm} (Eq. 8)

With $V_{REF} = 1.23V$, we solve Equation 8 and find that $R_{FS}$ needs to be 9.53kΩ to produce a 1mA 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 2.0V $V_{OUT}$ with a 20% margin requires ±0.4V 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 1mA, and the desired change in $V_{OUT}$ is 0.4V. 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 $I_{FS} = 0A$, we create a simple voltage-divider equation:

$$V_{FB} = \frac{R_B}{R_A + R_B} \times V_{OUT}$$  \hspace{1cm} (Eq. 9)

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

$$R_A = 1.5 \times R_B$$  \hspace{1cm} (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 $V_{OUT}$.

### Related Parts

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