Abstract: A DS4412 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 a DS4412 is employed in the design.

The Adjustable Power Supply

The DS4412 contains two I²C 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 DS4412 sinks and sources from its OUT pins. Valid full-scale current values range from 0.5mA to 2.0mA. 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 DS4412 is most
commonly used to adjust the DC-DC converter’s feedback voltage divider.

## Determining the Relationship Between V\text{OUT} and I\text{FS}

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

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

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

Where:

\[ I_{\text{RB}} = \frac{V_{\text{FB}}}{R_{\text{B}}} \quad \text{(Eq. 2)} \]

And

\[ I_{\text{RA}} = \frac{V_{\text{OUT}} - V_{\text{FB}}}{R_{\text{A}}} \quad \text{(Eq. 3)} \]

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

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

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

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

\[ V_{\text{OUT}} = V_{\text{FB}} - I_{\text{RA}} \times R_{\text{A}} \quad \text{(Eq. 5)} \]

Use Equation 5 to create two equations. For one equation, we chose the maximum margin on V\text{OUT}, V_{\text{OUT MAX}}, and the maximum I\text{RA} current, I_{\text{RAMAX}}. For the other equation, we choose the nominal values for V\text{OUT} and I\text{RA}, V_{\text{OUT NOM}} and I_{\text{RANOM}}. Subtracting the two equations, we get:

\[ \Delta V_{\text{OUT}} = \Delta I_{\text{RA}} \times R_{\text{A}} \quad \text{(Eq. 6)} \]

Using Equation 4, Equation 6 translates into the relationship:

\[ \Delta V_{\text{OUT}} = \Delta I_{\text{FS}} \times R_{\text{A}} \quad \text{(Eq. 7)} \]

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

## Calculating the Right Resistor Value for the Margin on 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 DS4412 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 found on page 6 of the DS4412 datasheet:

$$R_{FS} = \frac{V_{RFS}}{I_{FS}} \times 15 \times \frac{1}{1.974} \quad \text{(Eq. 8)}$$

With $V_{RFS} = 0.607V$, we solve Equation 8 and find that $R_{FS}$ needs to be 4.612kΩ to produce a 1mA full-scale current.

With the DS4412 $I_{FS}$ 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 DS4412 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 $I_{FS} = 0A$, 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 2.0V and 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 to be

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

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

**Conclusion**

The resistive-feedback-divider network and the current-sinking/sourcing capabilities of the DS4412 DACs control the margin of $V_{OUT}$ of 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**

| DS4412 | Dual-Channel, I²C Adjustable Sink/Source Current DAC | Free Samples |

**More Information**

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