Output Voltage Tracking Solution Using MP8201

Application Note

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ABSTRACT

This application note introduces several output voltage tracking solutions of the typical DC-DC converter. One method utilizes the soft-start function of the DC-DC converter. It does not need external devices to achieve tracking function but it loses high tracking accuracy. The other one can achieve higher tracking accuracy, however, because of the external devices used it means higher cost and larger board space. This application note proposes a very accurate and at the same time also very compact voltage tracking solution by using only a MP8201 which has very small three-pin SOT-23 package.

Voltage Tracking Solution Using Only a MP8201

Figure 1 shows the final voltage tracking solution by using MP8201 with a typical DC-DC converter. The monolithic DC-DC converter has VIN, EN, SS, VCC, BST, SW, COM and FB pins. By simply choosing the appropriate external resisters, this voltage tracking solution can achieve very accurate tracking performance (VO follows VTRACK). And this solution is also robust for different DC-DC converters which may have different feedback voltage VFB. The idea of this solution and the design procedure will be introduced in this application note in detail for you to better understand and use it.

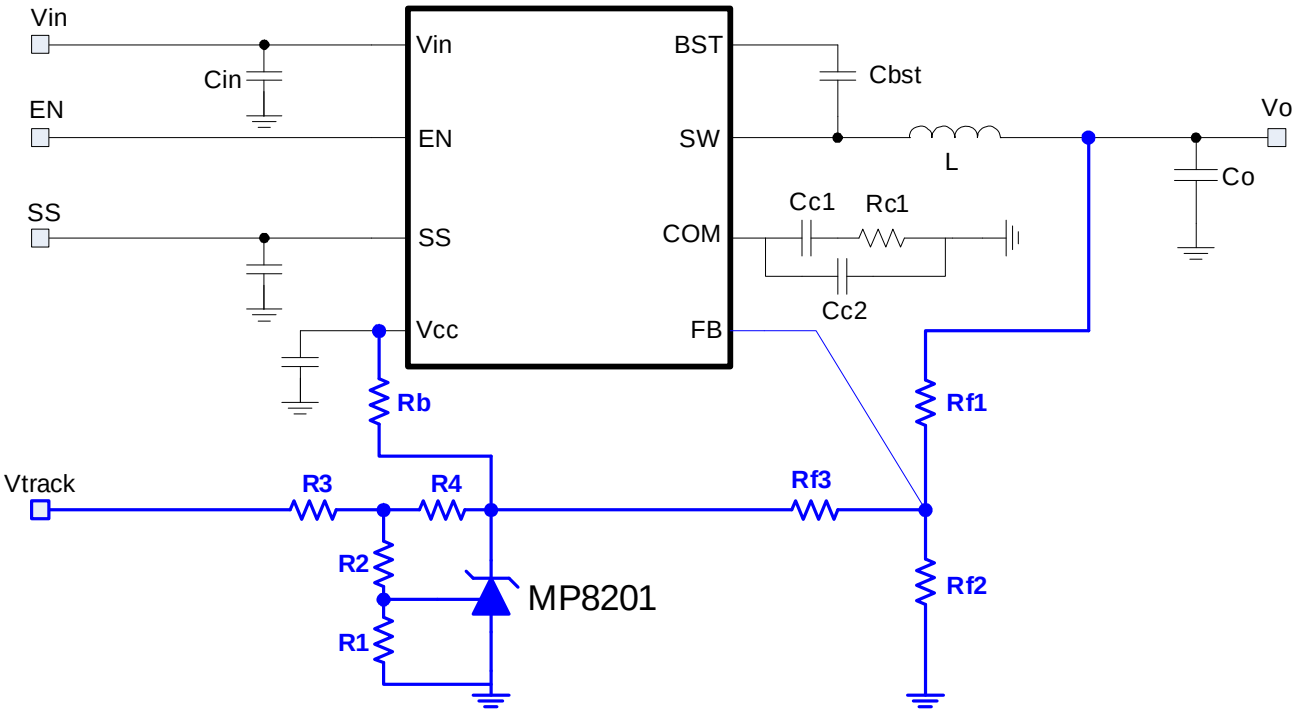

Figure 1—Output Voltage Tracking Solution Using MP8201

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INTRODUCTION

In some special applications or the test process, the output voltage needs to be regulated to different voltages according to what we desire. Usually, re-configuring the output voltage sensing divider is a way of doing this. But it cannot always be done in this way. For example, in some test conditions, the output voltage needs to be changed continuously in order to determine the optimal operating condition. Too much time and labor has to be spent to change the voltage divider resistors. In addition, some special applications also need the output voltage to be changed according to an external voltage command without changing the voltage divider. There has been no complete analog voltage tracking solutions summary before. This application note will summarize the methods to achieve output voltage tracking, and provide the one which can simultaneously achieve high tracking accuracy and low cost solution by just using a MP8201.

INTRODUCTION OF ANALOG VOLTAGE TRACKING METHODS

Two analog output voltage tracking methods are introduced in this section – using the soft-start function of DC-DC converter and using the external OPAMP and voltage reference. These two methods neither can achieve high tracking accuracy, nor few components for low cost due to their own limitation.

1. Using Soft-Start Function to Control Output Voltage

In a typical DC-DC converter IC, the soft-start function is always needed to avoid inrush current during the start up process. One typical implementation of the soft-start function is to make the SS voltage takes over the reference voltage, to make sure the output voltage follows the SS voltage and rises slowly. Since during the soft-start process, the output voltage will follow the SS voltage rather than the reference voltage, the output voltage tracking solution can be achieved by utilizing this characteristic. By connecting Vtrack input voltage to SS pin through an appropriate voltage divider and make sure the SS voltage is lower than the reference voltage for the whole range of Vtrack, the output voltage can be commanded by Vtrack as shown in Figure 2.

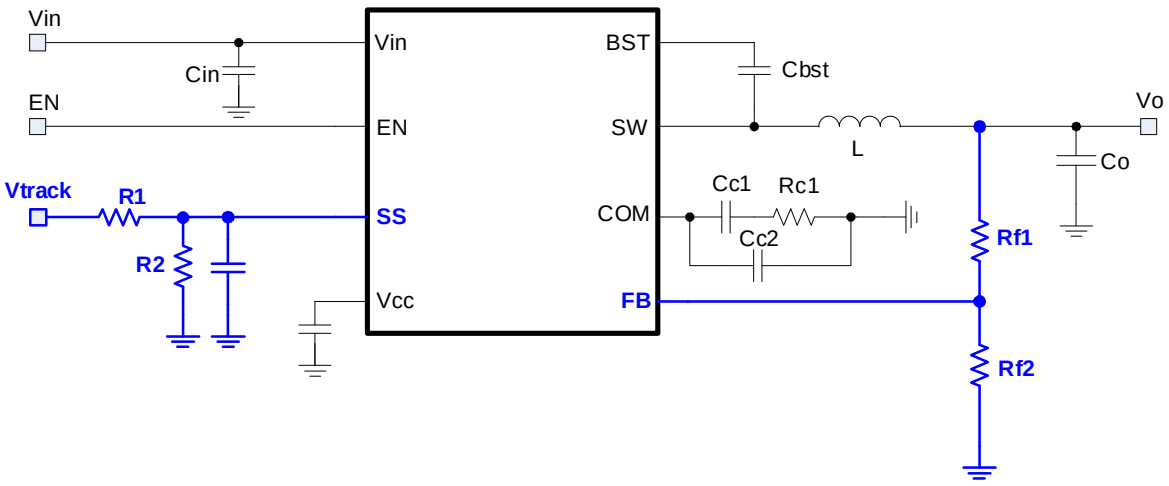

Figure 2—Voltage Tracking Solution by Using SS Function

a. Design Guideline for SS Voltage Tracking Solution

Using this method, appropriate R1 and R2 need to be chosen to make sure SS voltage is always lower than the reference voltage for all input tracking range. For example, if the tracking range is from 1V to 2V, and the internal reference voltage is 1V, the ratio of R1 to R2 should be smaller than 1 to make

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sure the SS voltage will be lower 1V when input tracking voltage is at its maximum value 2V. In most conditions, some margin is needed.

Other than this, the output voltage divider, which is Rf1 and Rf2 in Figure 2, also needed to be also chosen appropriately. Because the SS voltage takes over the reference voltage, in close loop, the feedback voltage will be the same as the SS voltage. The output voltage will be the same as the input tracking voltage by setting:

$$\frac{R1}{R2} = \frac{Rf1}{Rf2} \quad (1)$$

b. Performance of SS Voltage Tracking Solution

Using the typical Buck converter MP38873 with the SS voltage tracking method, the DC tracking voltage linearity by using the SS function is shown in the Figure 3. With the input tracking voltage from 0.8V to 1.0V, roughly 0.04V voltage error happens when the input voltage is 0.8V, which is 5% tracking error. This DC tracking error will also make the dynamic tracking performance very bad. The reason for the large error comes from the IC internal limitation. The SS voltage cannot completely take over the role of the reference voltage.

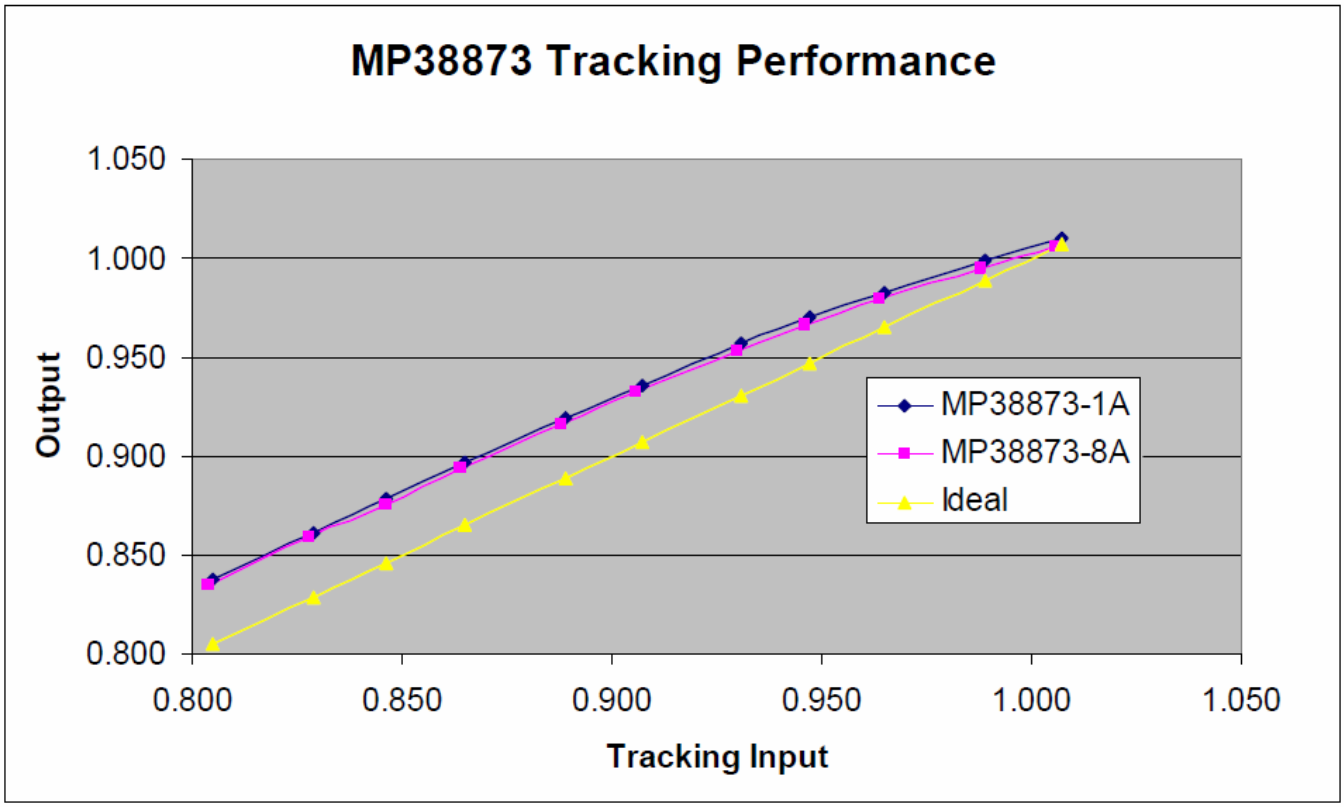

Figure 3—DC Tracking Linearity of Using SS function

2. Using External OPAMP to Generate GND Reference Voltage

In order to reduce the tracking error and improve the tracking accuracy, using an external OPAMP with a voltage reference equal to the FB voltage as shown in Figure 4. Through setting the OPAMP reference to be the same as the FB voltage, the relationship of the output voltage and the input tracking voltage is as follows:

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$$V_{out} = \frac{R_2 \cdot R_{f1}}{R_1 \cdot R_{f2}} V_{in_track} + (1 - \frac{R_2 \cdot R_{f1}}{R_1 \cdot R_{f2}}) V_{FB} \quad (2)$$

By setting R2xRf1=R1xRf2, the output voltage will track the input voltage as shown in equation (3)

$$V_{out} = V_{in_track} \quad (3)$$

However, only when the OPAMP reference voltage equals to the FB voltage, will the output voltage only follow the input tracking voltage. If the OPAMP reference voltage is different, there will always be a voltage offset between the input and the output. The output voltage will not track the input voltage.

Another aspect to interpret this solution is that the low output impedance OPAM circuit can provide the GND reference according to the input tracking voltage which is connected to the original “GND” of the output voltage divider, namely GND reference in this article. For example, if the positive reference voltage of the OPAMP is 0.8V, assume that R1=R2=Rf1=Rf2, when the input voltage is 1V, then the new GND reference voltage will be 0.6V, so that the output voltage would be 1V. The GND reference voltage is not fixed at certain fixed value anymore, it is controllable.

In Figure 4, R3 and R4 are used to set the OPAM positive input voltage to be the same as the FB. It is provided through VCC of the DCDC converter.

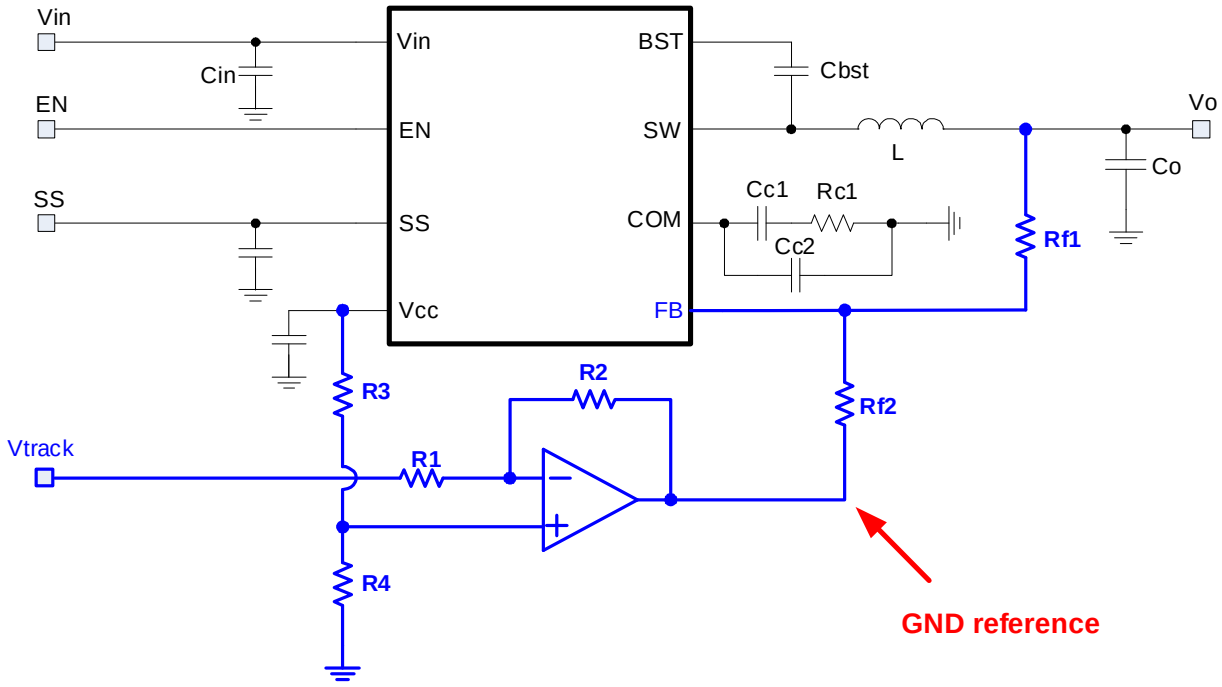

Figure 4—Output Voltage Tracking Solution Using External OPAM

a. Design Guideline for External OPAM Reference Voltage

Actually, the design tip of this solution is very simple. R3 and R4 are used to tune the positive reference to be the same as FB voltage. Then R1, R2, Rf1 and Rf2 are set to meet the following equation:

$$R_1 \cdot R_{f2} = R_2 \cdot R_{f1} \quad (4)$$

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b. Performance of External OPAM Voltage Tracking Solution

This solution was implemented using MP38873 and an OPAMP EL8176 to construct the voltage tracking solution as shown in Figure 4. By choosing appropriate external resisters, the DC linearity and error are shown in Figure 5. The input voltage is from 0.6V to 1.0V.

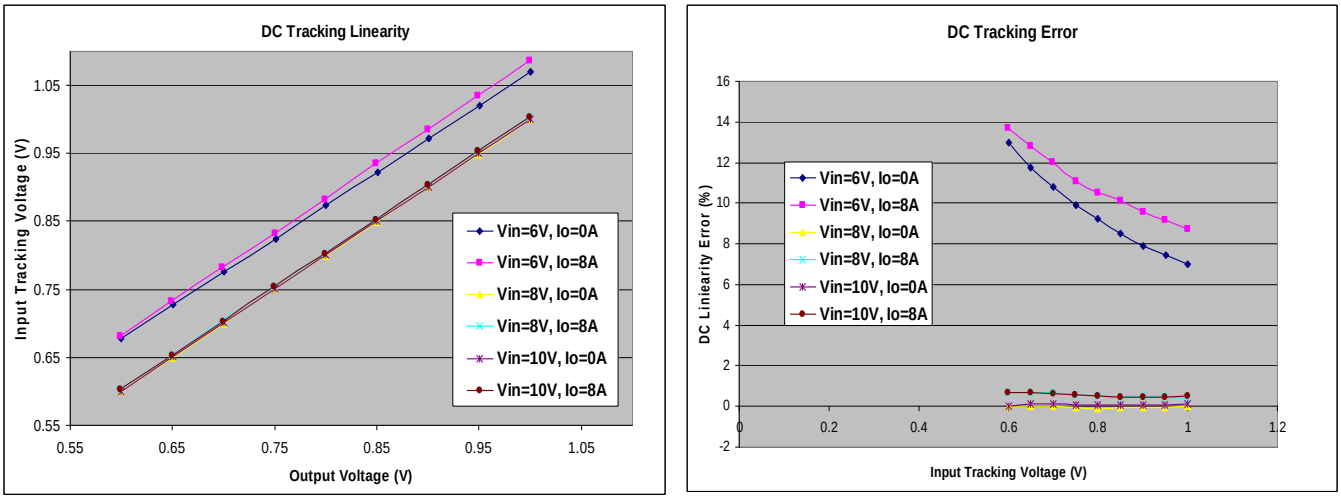

Figure 5—DC Linearity and Error of Using External OPAM Solution

As we can see, the DC linearity is good when the input voltage of the converter is 8V and 10V. But it is bad when input voltage is 6V. 12%-14% error happens at this condition. The reason for this error is because the reference voltage of the OPAMP comes from the VCC and the voltage divider. When the input voltage is high, the VCC voltage will be well regulated at certain voltage level, for example, 5V. If the input voltage is low, the VCC voltage will drop to certain level, for example, 4.5V because the energy of VCC comes from the input voltage. The VCC plus voltage divider cannot provide constant voltage reference for the OPAMP, especially for large input voltage range.

Actually, adding an external voltage reference for the OPAMP can solve the problem. For example, use a MP8201 to generate a constant voltage as FB voltage, 0.8V in MP38873. However, it means at least two devices are needed. From the cost and the board space point view, it is not a good solution.

USING ONLY MP8201 FOR VOLTAGE TRACKING SOLUTION

Is there any better solution? Through the previous analysis, we can see that an accurate voltage reference and an OPAMP are needed to construct a high performance voltage tracking solution. However, using both the accurate voltage reference IC and an additional OPAMP are not cost effective. By looking carefully at the MP8201, we can see that inside there is already an accurate voltage reference and an internal OPAMP. Just using a MP8201 to construct the voltage tracking system can cut costs and at the same time provide an accurate tracking solution.

MP8201—Precision Adjustable Shunt Voltage Regulator

The MP8201 is a low voltage, precision adjustable shunt regulator. It has a 160mV precise internal voltage reference and a current shunt (like an OPAM) for output voltage regulation. But, one limitation is that the voltage reference is always different from the FB voltage of a typical DC-DC converter. In addition, another limitation is that it can only work when the V+ voltage higher than 1.2V.

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Using MP8201 to Generate GND Reference Voltage

The voltage tracking solution using the MP8201 as shown in Figure 1 is re-drawn in Figure 6 here. The choice of the external resistance will be discussed in detail later. In short, the R1, R2, R3, R4 and Rb surrounding the MP8201 are used to generate an appropriate GND reference (which should be larger than 1V to make sure MP8201 works) and provide the low output impedance. The output voltage divider of Rf1, Rf2 and Rf3 is also needed to let the output voltage be controlled by the GND reference; in another words, by the input voltage. Thus, the output voltage is the same as the input tracking voltage.

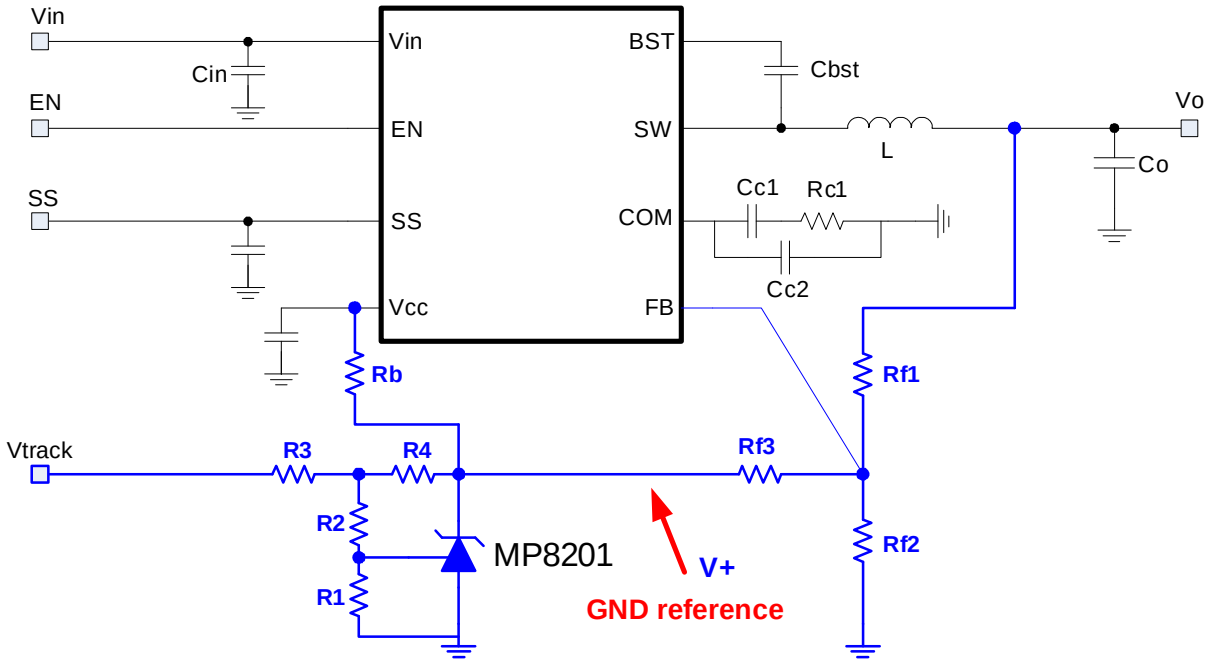

Figure 6—Output Voltage Tracking Solution Using MP8201

Design Guideline for Using MP8201

Using the proposed voltage tracking solution of only a MP8201, the relationship between the output voltage and input tracking voltage are solved by following two equations (5) (6)

$$V_+ = [(\frac{R_1 + R_2 + R_4}{R_1}) + (\frac{(R_1 + R_2)\cdot R_4}{R_1 \cdot R_3})]V_{ref} - (\frac{R_4}{R_3})V_{in_track} \quad (5)$$

$$V_o = (1 + \frac{R_{f1}}{R_{f2}} + \frac{R_{f1}}{R_{f3}})\cdot V_{FB} - (\frac{R_{f1}}{R_{f3}})\cdot V_+ \quad (6)$$

Where Vref is the voltage reference of MP8201 which is 160mV, it does not need to be the same as the FB voltage in order to achieve tracking function. There are two limitations for choosing appropriate external resistor. The first one is that the V+ voltage should be always higher than 1V which limits R1, R2, R3 and R4 choice. The other one, of course, is to let the output voltage to be the same as Vtrack. A detail design example is given in the following section for reference.

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AN DESIGN EXAMPLE

A voltage tracking solution design example with the detailed design procedure using only the MP8201 are given in this section.

The MP38873 is a monolithic 15A step-down switch mode converter with the FB voltage at 0.8V. Obviously, the FB voltage is different from the voltage reference of MP8201 which is 160mV.

a. How to choose R1, R2, R3, R4, Rb

Choose R1, R2, R3, R4 and R5 to achieve two purposes.

1. Make sure the V+ voltage is higher than 1.2V so that MP8201 can work properly
2. Create the appropriate V+ voltage that will proportionally change with the input tracking voltage

For example, if the input tracking voltage changes from 0.6V to 1.0V the output voltage will follow. Because it is negative feedback mechanism, the V+ voltage should be larger than 1.2V when the input at its maximum value. The following relationship can be established. When V_{track}=1V, V+=1.2V. When Vtrack=0.6V, V+=2V, so that according to equation (5), which is rewritten here

$$V_+ = [(\frac{R_1 + R_2 + R_4}{R_1}) + (\frac{(R_1 + R_2) \cdot R_4}{R_1 \cdot R_3})]V_{ref} - (\frac{R_4}{R_3})V_{in_track} \quad (5)$$

And the relationship we already established in equation (7):

$$V_+ = 3.2 - 2V_{in_track} \quad (7)$$

So that the following equations can be derived:

$$\frac{R_4}{R_3} = 2 \quad (8)$$

$$[(\frac{R_1 + R_2 + R_4}{R_1}) + (\frac{(R_1 + R_2) \cdot R_4}{R_1 \cdot R_3})] \times 0.16 = 3.2 \quad (9)$$

For example, we can choose R4=20k, R3=10k, R2=50k, R1=10k and this will meet equation (8) and (9), actually, the choice of R1 and R2 is not unique. Any combination which meets the equation (9) is fine.

The value of Rb should be chosen to be between 2K to 5K. Ideally, it will not impact the tracking performance. However, the close loop works best when the input current at the several mA level.

b. How to choose Rf1, Rf2, Rf3

Once the value of R1, R2, R3 and R4 are chosen, the relationship between V+ and Vtrack is satisfies equation (7). The value of Rf1, Rf2 and Rf3 are chosen such that the output voltage is the same as the tracking voltage. The relationship between output voltage and the GND reference voltage V+ is decided by equation (10)

$$V_o = (1 + \frac{R_{f1}}{R_{f2}} + \frac{R_{f1}}{R_{f3}}) \cdot V_{FB} - (\frac{R_{f1}}{R_{f3}})V_+ \quad (10)$$

Inserting equation (7) into (10), the relationship between input and output can be as follows:

$$V_o = (1 + \frac{R_{f1}}{R_{f2}} + \frac{R_{f1}}{R_{f3}}) \cdot V_{FB} - (\frac{R_{f1}}{R_{f3}} \cdot 3.2) + \frac{2R_{f1}}{R_{f3}} \cdot V_{in_track} \quad (11)$$

In order to make Vo=Vtrack, the following equations need to be met:

$$\frac{2R_{f1}}{R_{f3}} = 1 \quad (12)$$

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$$(1+\frac{R_{f1}}{R_{f2}}+\frac{R_{f1}}{R_{f3}})\cdot V_{FB}=(\frac{R_{f1}}{R_{f3}}\cdot 3.2) \quad (13)$$

In order to meet equation (12) and (13), Rf1=10k, Rf3=20k, Rf2=20k can be chosen as the solution. Now, the resistances are all determined to achieve the complete tracking solution.

c. Performance of MP8201 Voltage tracking solution

By constructing the circuit and the external resistance following above process, the voltage tracking solution using only a MP8201 can achieve very good DC linearity as shown in Figure 7.Very small DC tracking error, lower than 1%, can be achieved.

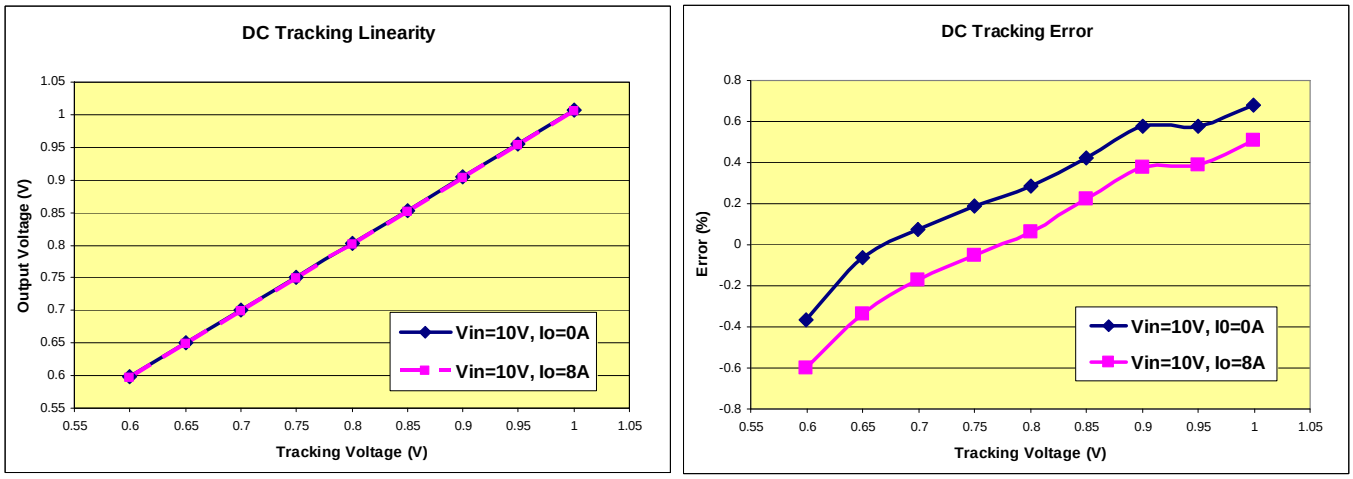

Figure 7—DC Linearity of Using Only MP8201 Voltage Tracking Solution

And also the dynamic tracking performance is good at light load and full load condition as shown in Figure 8.

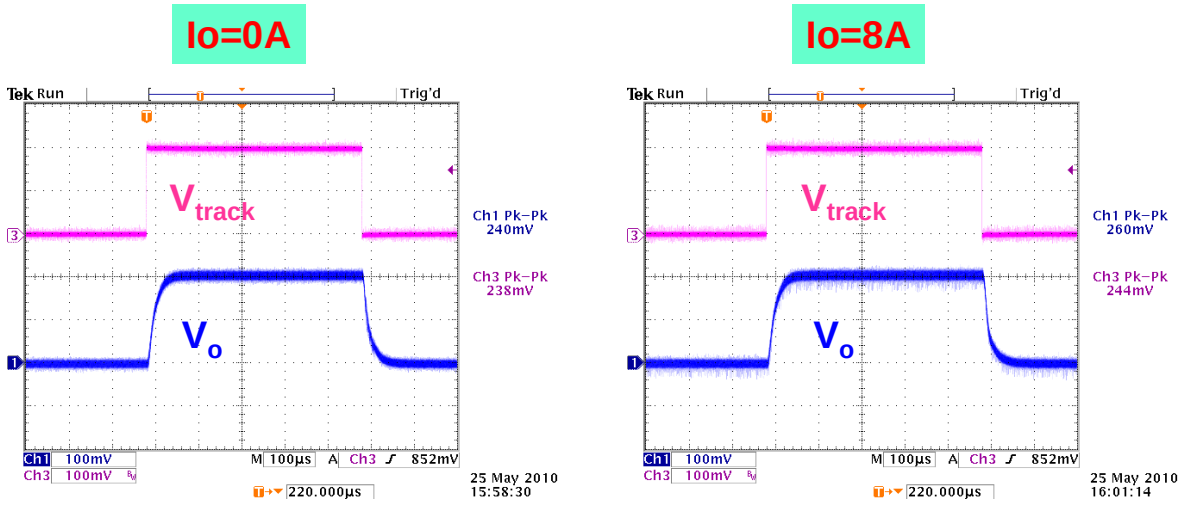

Figure 8—Dynamic Tracking Performance of Using Only MP8201 Voltage Tracking Solution

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CONCLUSION

Several output voltage tracking methods are introduced in this application note. The tracking performance is not accurate enough by using SS pin as the tracking reference. In order to improve the tracking accuracy, using an external OPAMP with a voltage reference the same as the FB voltage of the control IC can easily construct a better tracking solution except for the higher cost and relatively large space. Using only a MP8201, by the proposed external configuration circuit, an accurate, cheap and compact voltage tracking solution can be achieved. The design example and procedure will also help the engineers develop the tracking solution according to different Control ICs with different FB voltage references.

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