Linear Regulator Series

Connecting LDOs in Parallel

When you want to increase the output current capacity of an LDO, or when the power dissipation of a single LDO is insufficient, you might think of connecting LDOs in parallel if you need to disperse the dissipation using two LDOs. This application note provides some hints on how to connect LDOs in parallel.

Looking at Figure 1, although it may appear that directly connecting the outputs of two LDOs disperses the loss, this is actually not the correct way to connect them. Even though the two LDOs may use the same rated output voltage, in actuality the output voltages vary between manufacturers. In this situation, current is supplied from the LDO with the higher output voltage. For example, Figure 2 shows the change in output current when the output voltage of LDO1 is 0.5% higher than that of LDO2. In this example, we can see that current is always supplied from LDO1, and is not dispersed to LDO2.

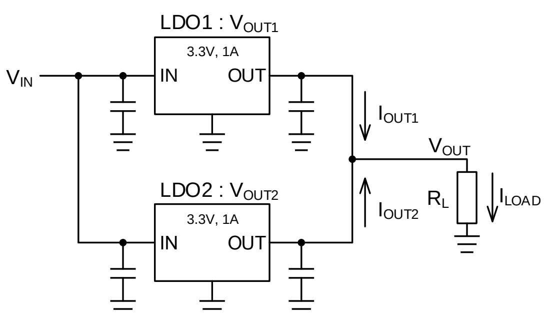

Figure 1. Circuit with the outputs of two LDOs connected directly

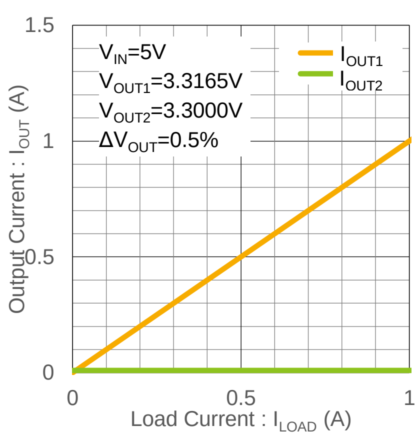

Figure 2. Output current characteristics when there is a 0.5% variance in output voltage

Parallel connection using a diode

Figure 3 shows a parallel connection using diodes. Since there are diodes in the output circuit, the output voltage only drops as far as the forward direction voltage (hereafter indicated as V_F). Predicting this behavior, it is necessary to take countermeasures, for instance by ensuring that the LDO's set voltage only rises as much as V_F. Also, since V_F will change due to the load current and temperature, and V_F will be inconsistent, we cannot expect that the output voltage will be precise.

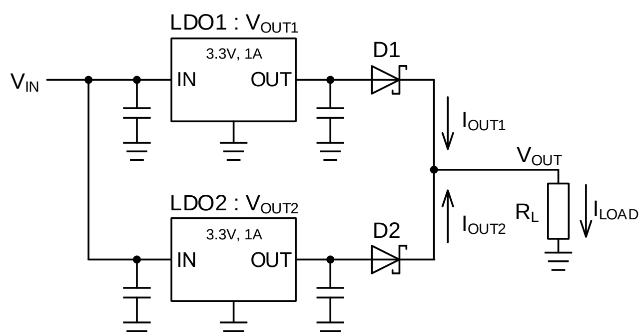

Figure 3. Circuit with the outputs of two LDOs connected with diodes

Current is supplied from the LDO with the higher output voltage in this circuit as well, but since the diode V_F changes with the current flow, the voltage variance between the two LDOs can be absorbed. The following equation shows a balanced output voltage relationship.

$$V_{OUT1} - V_{F1(IOUT1)} = V_{OUT2} - V_{F2(IOUT2)} \quad (1)$$

V_{OUT1}: LDO1 output voltage
V_{OUT2}: LDO2 output voltage
$V_{F1(IOUT1)}$: V_F of D1 during I_{OUT1}
$V_{F2(IOUT2)}$: V_F of D2 during I_{OUT2}

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As an example, Figure 4 shows the distribution of current for each LDO to supply the load when the output voltage of LDO1 is 1% higher than LDO2 with a 3.3 V/1 A output LDO. Looking at the 1 A load current, we can see that even when the LDO output voltage variance is 1%, the current distribution is 0.64 A for LDO1 and 0.36 A for LDO2, which is a large variance.

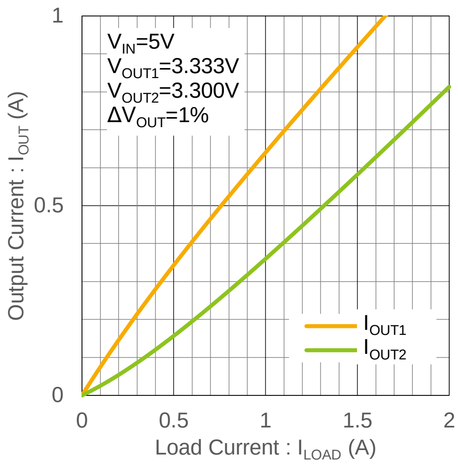

Figure 4. Output current characteristics when there is a 1% variance in output voltage

Figure 5 shows the impact that a variance in output voltage between the two LDOs can have on output current. This graph shows the ratio of output current for each LDO, when the output voltage of LDO1 is higher than that of LDO2. If the output voltage for both LDOs is exactly the same, the output current ratio will be 50% (the current will be output uniformly). However, the current ratio will be larger as the output voltage variance increases. For example, if there is an output voltage variance with LDO1 at +1% and LDO2 at -1%, the circuit must carry an unbalanced current output of 77% for LDO1 and 23% for LDO2.

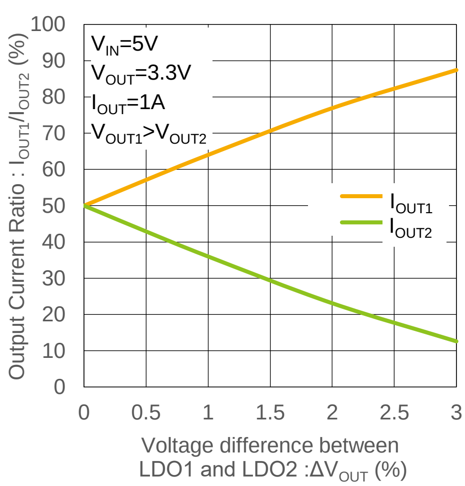

Figure 5. Impact on output current ratio due to variance in output voltage

The graph in Figure 6 shows the impact that an output voltage variance between LDOs has on the output current of an LDO parallel circuit, when each LDO used has a maximum value of 1 A for the recommended output current. When there is absolutely no voltage variance between LDOs, the current for both LDOs flows uniformly, allowing for a 2 A output (1 A+1 A). The current value that can be outputted will decrease as the LDO output voltage differential increases. When there is a variance in output voltages, such as +1% for LDO1 and -1% for LDO2, the system can only output up to 1.37 A with a 2 A current capacity. This is because for an LDO with a maximum recommended output current value of 1 A, when either LDO reaches 1 A, this will be the system's maximum output current.

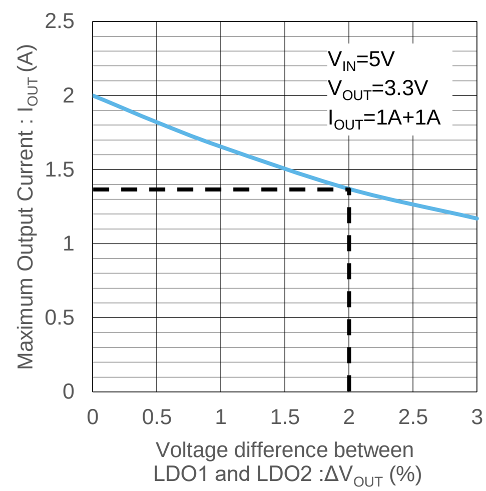

Figure 6. Impact on maximum output current due to variance in output voltage

The graph in Figure 7 shows the load regulation. As the output voltage falls below the LDO output at the amount of V_F and the load current increases, V_F will increase, and thus the output voltage will fall further.

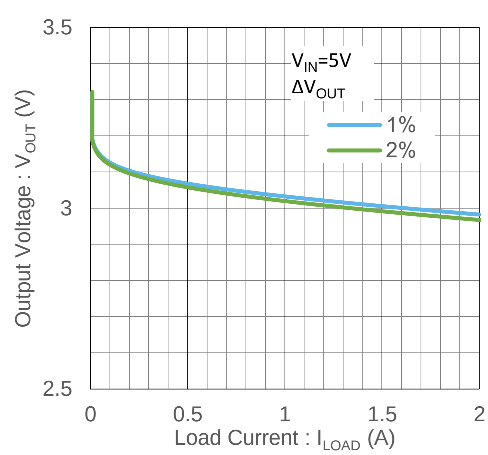

Figure 7. Load regulation

Parallel connection using a ballast resistor

Figure 8 shows a parallel connection using resistors. Since there are resistors in the output circuit, the output voltage drops along with the increase in load current.

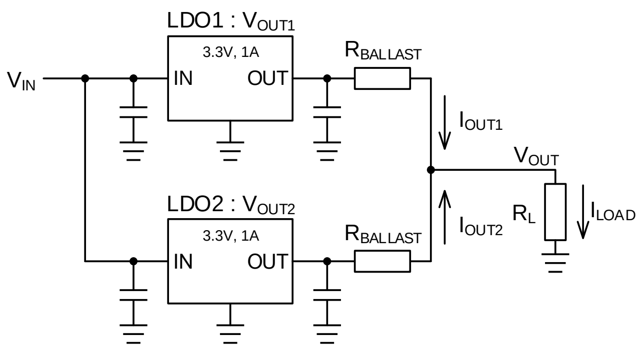

Figure 8. Circuit with the outputs of two LDOs connected with resistors

In this circuit as well, current is supplied from the LDO with the higher output voltage. When the output current of the LDO on the higher voltage side passes through the ballast resistor and the voltage drops, making the voltage of the LDO on the lower voltage side the same, power supply will begin from the LDO on the lower voltage side as well. In this way, current is supplied to the load from each LDO, while balancing the output voltage using the drop in voltage from the resistor. The following equation shows a balanced output voltage relationship.

$$V_{OUT1} - I_{OUT1} \times R_{BALLAST} = V_{OUT2} - I_{OUT2} \times R_{BALLAST} \qquad (2)$$

V_{OUT1}: LDO1 output voltage [V]
V_{OUT2}: LDO2 output voltage [V]
I_{OUT1}: LDO1 output current [A]
I_{OUT2}: LDO2 output current [A]
$R_{BALLAST}$: Ballast resistor [Ω]

The relationship between the ballast resistor, the current split between I_{OUT1} and I_{OUT2}, and the voltage variance between LDOs is shown in the following formula.

$$R_{BALLAST} = \frac{|V_{OUT2} - V_{OUT1}|}{|I_{OUT2} - I_{OUT1}|} \quad [\Omega] \qquad (3)$$

if $I_{OUT1} + I_{OUT2} = I_{LOAD}$

From this equation, we can see that when we try to improve the current balance between I_{OUT1} and I_{OUT2}, the resistor value increases; and even with a large voltage variance between LDOs, the resistor value will get larger. Further, when the resistor value gets larger, the voltage drop at the load point increases.

For example, with a LDO1 and LDO2 at 3.3 V/1 A output having a variance of +1% and -1% respectively, the output voltage variance will be 66 mV (2% of 3.3 V). If we distribute the load current of 2 A to the LDOs at 1.2 A and 0.8 A respectively, the ballast resistor value will be 0.165Ω from equation (3).

Figure 9 shows the distribution of output current for each LDO to supply the load. The current from LDO1 only flows up to a load current of 0.4 A, but this is because the output voltage of LDO1 is higher. Since the voltage drop due to the ballast resistor around 0.4 A exceeds 66 mV (=0.4 A × 0.165Ω), the output voltage of LDO1 and LDO2 will be the same at the point of V_{OUT}, and the LDO2 current will begin to flow. At 2 A, the current will be distributed at 1.2 A and 0.8 A, as calculated. Although we want to get a 2 A output current by connecting two 1 A output LDOs in parallel, when either one reaches 1 A, on LDOs with a maximum recommended output current of 1 A, the output current becomes this system's maximum output current, which is the 1.6 A shown on the graph.

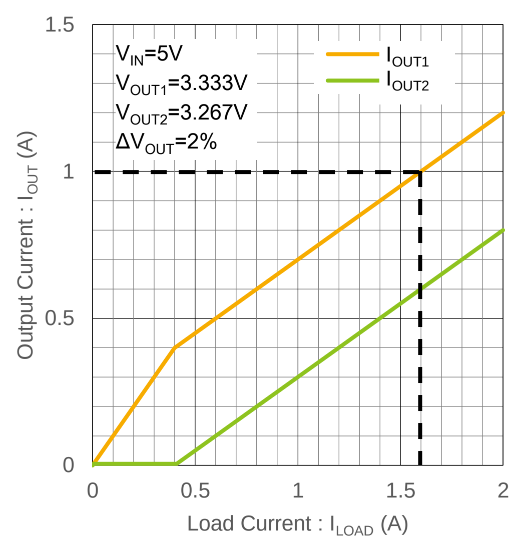

Figure 9. Output current characteristics when there is a 2% variance in output voltage $R_{BALLAST}$ = 0.165Ω

The graph in Figure 10 shows the load regulation. As the load current increases, the drop in output voltage will increase due to resistance. The drop in voltage can be calculated with the following equation. For the actual drop in voltage, the load regulation voltage of the LDO itself will be added to this voltage.

$$V_{DROP} = V_{DIFF} + \frac{R_{BALLAST} \times I_{LOAD} - V_{DIFF}}{2} \quad [V] \qquad (4)$$

V_{DIFF}: LDO1 and LDO2 output voltage variance [V]

$R_{BALLAST}$: Ballast resistor [Ω]

I_{LOAD}: Load current [A]

if within the region where both LDO1 and LDO2 current flows.

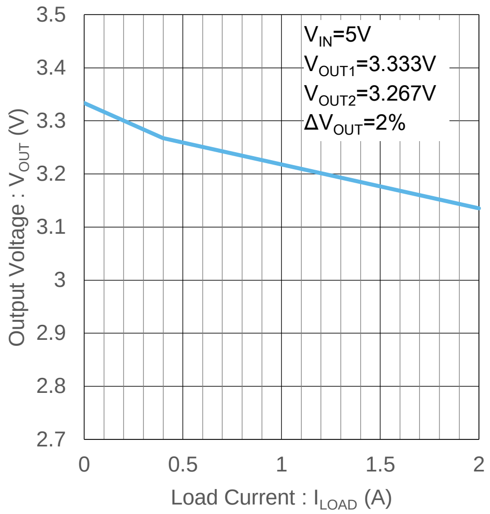

Figure 10. Load regulation

$R_{BALLAST}$ = 0.165Ω

Shown next is an example of an LDO with an output voltage precision of ±3%, including temperature characteristics. With a LDO1 and LDO2 at 3.3 V/1A output having a variance of +3% and -3% respectively, the output voltage variance will be 198 mV (6% of 3.3 V). If we distribute the load current of 2 A to the LDOs at 1.2 A and 0.8 A respectively, the ballast resistor value will be 0.495Ω from equation (3).

Figure 11 shows the distribution of output current for each LDO to supply the load. As with the previous example where the output voltage variance is ±1%, the current will be distributed as calculated.

The graph in Figure 12 shows the load regulation. As the ballast resistor value gets larger, the voltage drop due to the load current increases.

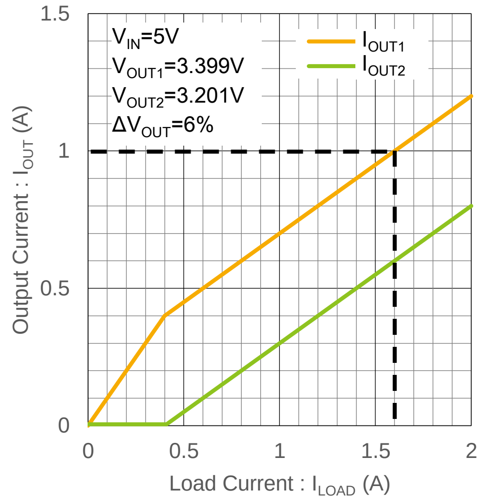

Figure 11. Output current characteristics when there is a 6% variance in output voltage $R_{BALLAST}$ = 0.495Ω

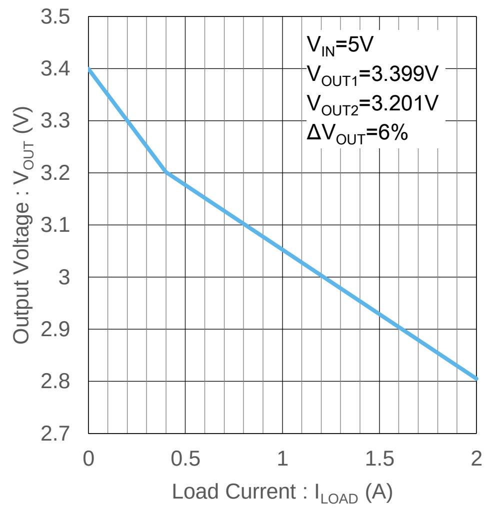

Figure 12. Load regulation

$R_{BALLAST}$ = 0.495Ω

As explained above, the output voltage variances for each LDO, the distribution of output current and the drop in output voltage have a trade-off relationship. It is necessary to determine the ballast resistor value while considering the entire balance of characteristics.

Since the output current flows to the ballast resistor, a large power loss occurs. Confirm that the rated power of the resistors that will be used are fulfilling the specs. According to JEITA (RCR-2121A/B Guideline of Notabilia for Fixed Resistors for Use in Electronic Equipment), resistors are recommended for use at a rated power of 50% or lower.

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