Linear regulator

How to Select Reverse Current Protection Diodes for LDO Regulators

LDO regulators allow reverse current to flow inside the IC chip from the output pin to the input pin when the input/output voltage is reversed. To prevent damage to the IC, normally connect a reverse current protection diode outside the IC. This application note provides guidelines on whether a protection diode is necessary and how to select a diode.

1. Guidelines on whether or not a protection diode is necessary

Table 1 shows the guidelines as to whether or not a protective diode is necessary for each case. Note, however, that the guidelines vary depending on the type of output transistor. For details on each item, see the reference sections provided in the table.

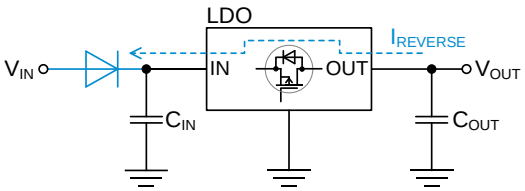
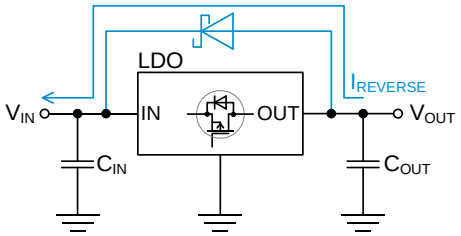
Table 1. Table for determining whether or not a protective diode is necessary

		Protection diode necessary or not	
Output transistor type →		Bipolar type → Refer to Section 4-1.	MOSFET type → Refer to Section 4-2.
Case 1	When voltage drops rapidly on the input side → Refer to Section 5-1.	- Necessary	- Necessary, but not necessary depending on the conditions
Case 2	When reverse current always flows → Refer to Section 5-2.	- Necessary	- Necessary
Case 3	When the input is open → Refer to Section 5-3.	- Not necessary	- Not necessary

2. Selection of the protection circuit

There are two ways to make a protection circuit: inserting a diode on the input side of the LDO to prevent reverse current (Figure 1) or placing a diode between the input and the output to bypass reverse current (Figure 2). The advantage and disadvantage of each protection circuit are shown in Table 2. Use a circuit that is suitable for your application.

Table 2. Types of protection circuits and their advantage and disadvantage

	Reverse current prevention circuit	Reverse current bypass circuit
Circuit diagram	 Figure 1	 Figure 2
Advantage	- Reverse current flow to the circuit of the previous stage can be prevented.	- The dropout voltage of the LDO is not affected.
Disadvantage	- The input/output voltage difference necessary for operations becomes large since the forward voltage of the diode is added to the dropout voltage of the LDO.	- Reverse current flows into the circuit of the previous stage.

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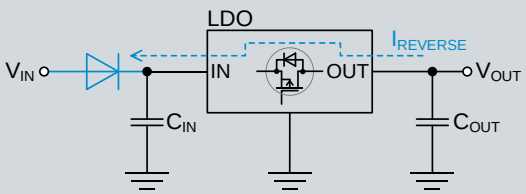
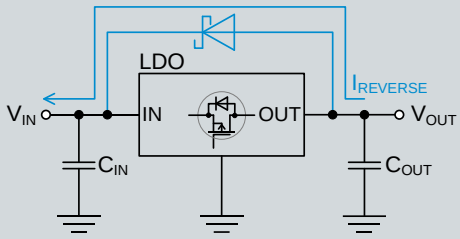
3. Selection of the diode

Table 3 summarizes the types of diodes used in the two types of protection circuits described in the previous section and the requirements for their electrical characteristics.

Table 3. Diode types and requirements for electrical characteristics

	Reverse current prevention circuit	Reverse current bypass circuit
		
Diode types	- Schottky barrier diode - Rectifier diode - Switching diode	- Schottky barrier diode
Reverse voltage V_R	- Use at 80% or less of the absolute maximum rating.	- Use at 80% or less of the absolute maximum rating.
Forward current I_O	- Use at 50% or less of the absolute maximum rating.	- Use at 50% or less of the absolute maximum rating.
Forward voltage V_F	- Select a product with a value that can be tolerated in the application.	- Select a product with a value of approximately 0.7 V or less.
Reverse current I_R	- Select a product with a value that can be tolerated in the application.	- Select a product with a value of 1 µA or less. - ROHM offers a lineup of ultra-small I_R products, among which typical product names are listed in Table 4.

3-1. Reverse current prevention circuit

As for the diode types, a Schottky barrier diode and rectifier diode are often used considering the electrical characteristics and cost, although a rectifier diode, Schottky barrier diode, fast recovery diode, and switching diode can all be used. For small currents of 100 mA or less, a switching diode can also be used. Although a fast recovery diode can also be used, its characteristics are excessive for this application.

If there is a margin for dropout voltage between input and output, a rectifier diode can be used. If there is not enough margin, use a Schottky barrier diode with a low forward voltage; however, note that the reverse current increases exponentially at high temperatures.

3-2. Reverse current bypass circuit

Since it is necessary for the bypass diode to turn on (conduct) before the parasitic elements inside the IC, use a Schottky barrier diode with a low forward voltage.

A Schottky barrier diode has a large reverse current I_R, which causes the current to increase exponentially as the temperature rises to several tens of mA in some products. Figure 3 is an example of an LDO with a shutdown switch function, where current flows into the load because of the reverse current I_R in the diode and because the input voltage is applied even though the LDO output is turned off. This may cause a malfunction in the circuit of the subsequent stage. In addition, the LDO allows a leakage current to always flow from the input to the output during normal operation, which may deteriorate the voltage regulation characteristics. Thus, it is necessary to select a product with a small I_R. Recommended Schottky barrier diodes are shown in Table 4.

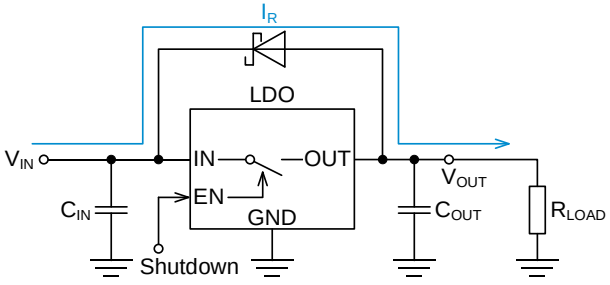


Figure 3. Current flows into the load because of the reverse current I_R in the diode even though the LDO output is shut down.

Table 4. Ultra-small I_R Schottky barrier diodes

Part No.	Package See Figure 4	Absolute maximum ratings		Forward voltage		Reverse current	AEC-Q101
		Reverse voltage V_R [V]	Forward current I_O [A]	Typ. V_F [V]	Max. V_F [V]	Max. I_R [μA]	
RB168VWM-30	PMDE	30	1	0.64 (1A)	0.69 (1A)	0.6 (30V)	−
RB168VWM-30TF		30	1	0.64 (1A)	0.69 (1A)	0.6 (30V)	✓
RB168VWM-40		40	1	0.64 (1A)	0.69 (1A)	0.5 (40V)	−
RB168VWM-40TF		40	1	0.64 (1A)	0.69 (1A)	0.5 (40V)	✓
RB168VWM-60		60	1	0.71 (1A)	0.76 (1A)	0.5 (60V)	−
RB168VWM-60TF		60	1	0.71 (1A)	0.76 (1A)	0.5 (60V)	✓
RB068VWM-30		30	2	0.70 (2A)	0.75 (2A)	0.6 (30V)	−
RB068VWM-30TF		30	2	0.70 (2A)	0.75 (2A)	0.6 (30V)	✓
RB068VWM-40		40	2	0.74 (2A)	0.79 (2A)	0.5 (40V)	−
RB068VWM-40TF		40	2	0.74 (2A)	0.79 (2A)	0.5 (40V)	✓
RB068VWM-60		60	2	0.79 (2A)	0.84 (2A)	0.5 (60V)	−
RB068VWM-60TF		60	2	0.79 (2A)	0.84 (2A)	0.5 (60V)	✓
RB168MM-30	PMDU	30	1	0.64 (1A)	0.69 (1A)	0.6 (30V)	−
RB168MM-30TF		30	1	0.64 (1A)	0.69 (1A)	0.6 (30V)	✓
RB168MM-40		40	1	0.60 (1A)	0.65 (1A)	0.55 (40V)	−
RB168MM-40TF		40	1	0.60 (1A)	0.65 (1A)	0.55 (40V)	✓
RB068MM-30		30	2	0.65 (2A)	0.7 (2A)	0.8 (30V)	−
RB068MM-30TF		30	2	0.65 (2A)	0.7 (2A)	0.8 (30V)	✓
RB068MM-40		40	2	0.675 (2A)	0.725 (2A)	0.55 (40V)	−
RB068MM-40TF		40	2	0.675 (2A)	0.725 (2A)	0.55 (40V)	✓
RB068MM100		100	2	0.82 (2A)	0.87 (2A)	0.4 (100V)	−
RB068MM100TF		100	2	0.82 (2A)	0.87 (2A)	0.4 (100V)	✓
RSX048LAP2S	PMDTP	200	3	0.80 (3A)	0.87 (3A)	0.2 (200V)	−
RSX088LAP2S		200	5	0.84 (5A)	0.92 (5A)	0.2 (200V)	−

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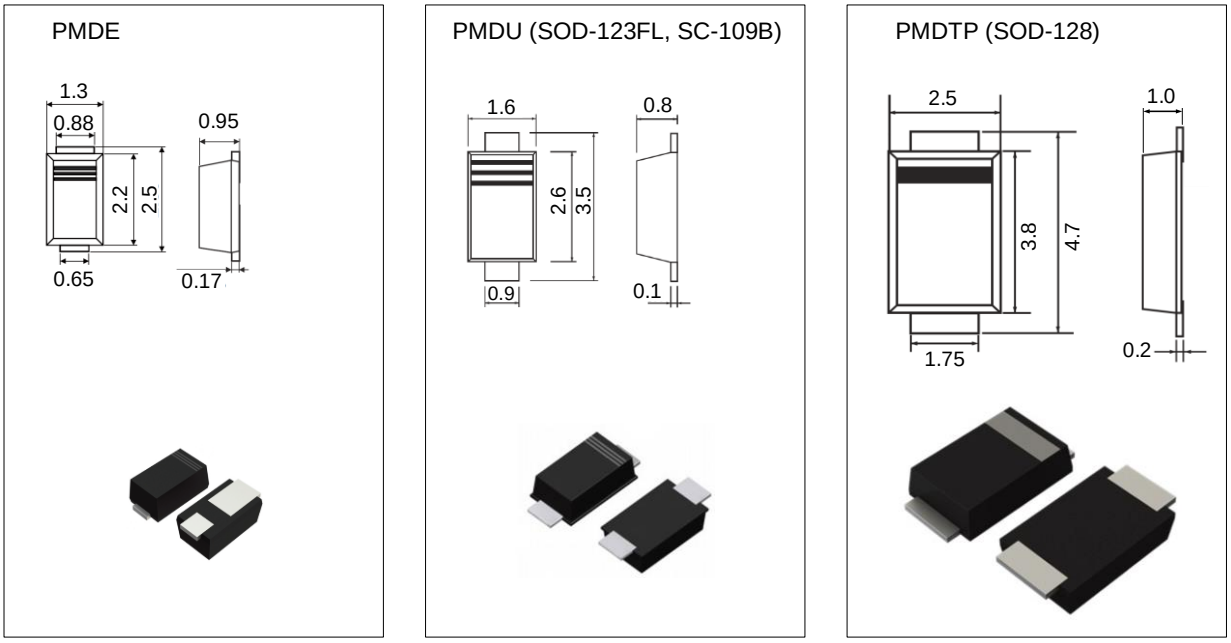

Figure 4. Package dimensions and appearance

4. Output transistor types

There are two types of output transistors for LDO regulators, the bipolar type and the MOSFET type, each of which has different guidelines. ROHM's bipolar type LDO regulators have product names that start with "BA," and MOSFET type LDO regulators start with "BD," "BU," or "BH."

4-1. Bipolar type

Figure 5 shows the block diagram. When viewing the input side from the output side, there may be a pn junction that functions as a parasitic diode due to the manufacturing structure of the silicon wafer. Since this parasitic diode is not designed as an electrical circuit, the device may be damaged, or the circuit may malfunction when current flows through it. For the bipolar type, be sure to implement countermeasures to prevent the flow of reverse current.

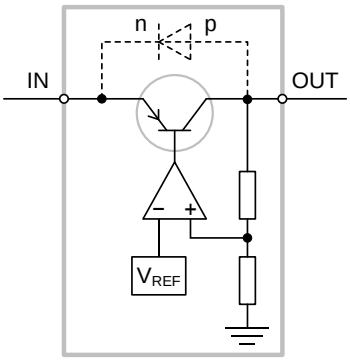

Figure 5. Block diagram of bipolar type LDO
Example of output with PNP transistor

4-2. MOSFET type

Figure 6 shows the block diagram. There is a body diode in the output MOSFET, through which reverse current flows. Figure 7 is a sectional view of a P-channel MOSFET. The body diode exists as a parasitic element at the pn junction between the drain and the back gate. Since the device size of this body diode is the same as the output transistor, a certain amount of current can be tolerated.

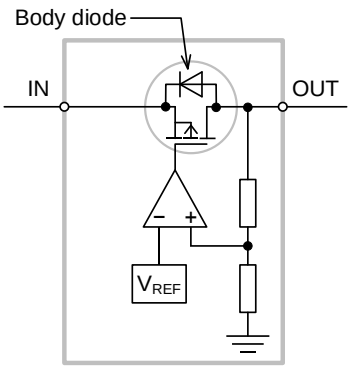

Figure 6. Block diagram of MOSFET type LDO
Example of output with P-channel MOSFET

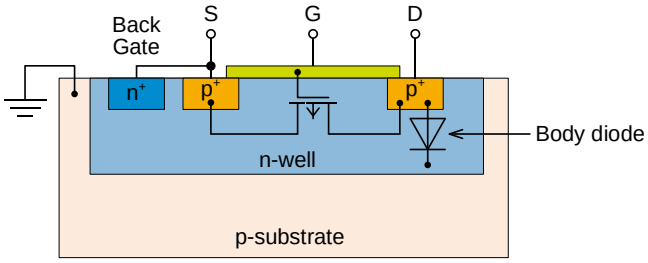

Figure 7. Sectional structure of P-channel MOSFET

5. Case-specific guidelines

This section describes for each case whether or not a protective diode is necessary.

5-1. When voltage drops rapidly on the input side

This is a common case. When the voltage of the power supply circuit of the previous stage of the LDO drops rapidly at power down, the voltage between the input and the output is temporarily reversed, causing reverse current $I_{REVERSE}$ to flow. This is because the charge remains in the capacitors connected on the output side of the LDO. The circuit diagram is shown in Figure 8 and the relationship between input/output voltage and the reverse current is shown in Figure 9. This reverse current flow is a temporary phenomenon that lasts until the output capacitor is discharged. The value of the reverse current and the time can vary depending on the circuit because they are determined by the impedance at power down with the power supply of the previous stage, the total charge of the capacitor on the output side, and the load current.

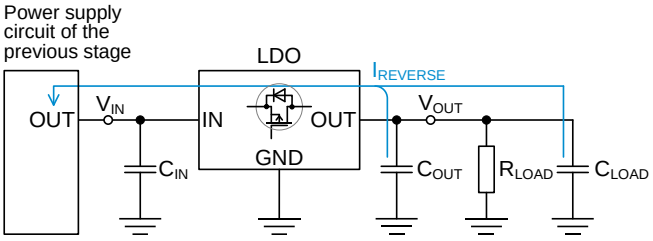

Figure 8. Circuit when voltage drops rapidly on input side

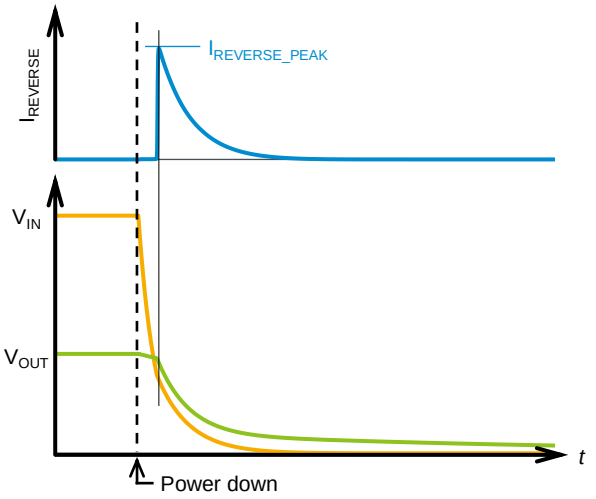

Figure 9. Input/output voltage and reverse current when voltage drops rapidly on input side

Basically, a protection diode is necessary if the reverse voltage is 0.6 V or higher but not necessary if all of the following conditions are met.

Conditions under which a diode is not necessary (all of the conditions must be met)

- The peak value of the reverse current must be no more than the maximum output current value written in the recommended operating range on the data sheet.
- The power supply must not be turned ON and OFF frequently.
- The final product must not require high reliability and safety.

5-2. When reverse current always flows

In a circuit configuration with multiple power supply systems, a protection diode is necessary regardless of the current value if reverse current constantly flows into the LDO from other circuit blocks at power down or if reverse current flows into the LDO when voltage is applied to the LDO output from another power supply during the product delivery inspection process.

5-3. When the input is open

The circuit diagram is shown in Figure 10 and the input/output voltage relationship is shown in Figure 11. When the input is open at power down, there is no difference in input/output voltage, so reverse current does not flow. For this reason, a protection diode is not necessary.

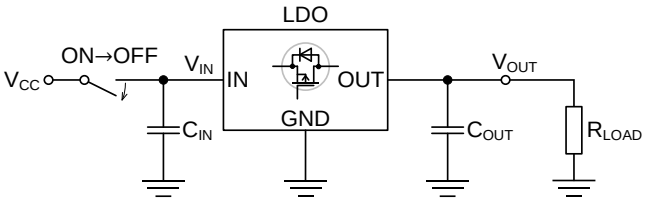

Figure 10. Circuit when input is open

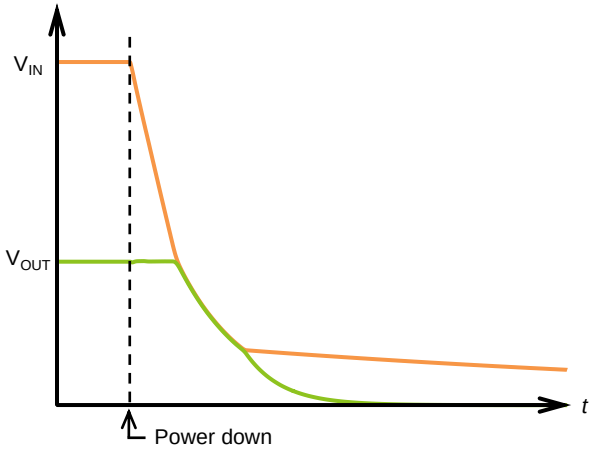

Figure 11. Relationship between input voltage and output voltage when input is open

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