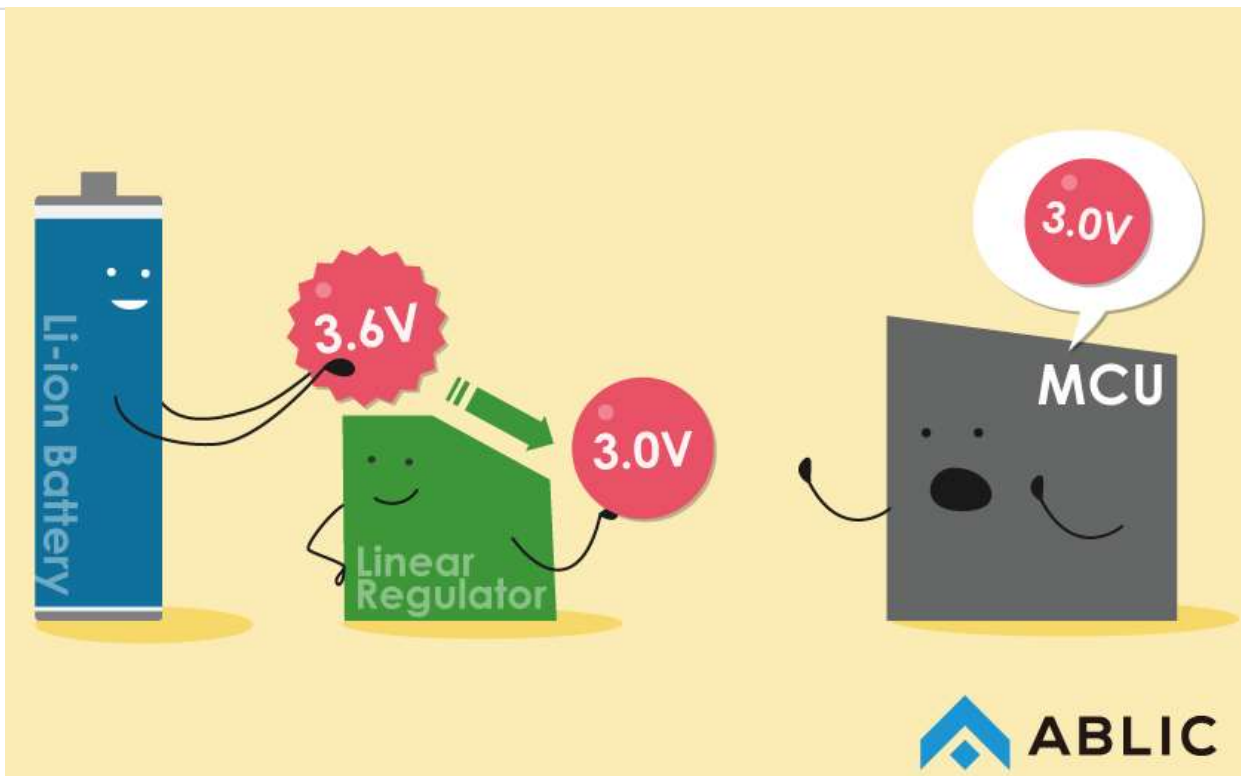


## Linear Regulators (LDO Regulators)

# Operating principle and configuration of a linear regulator



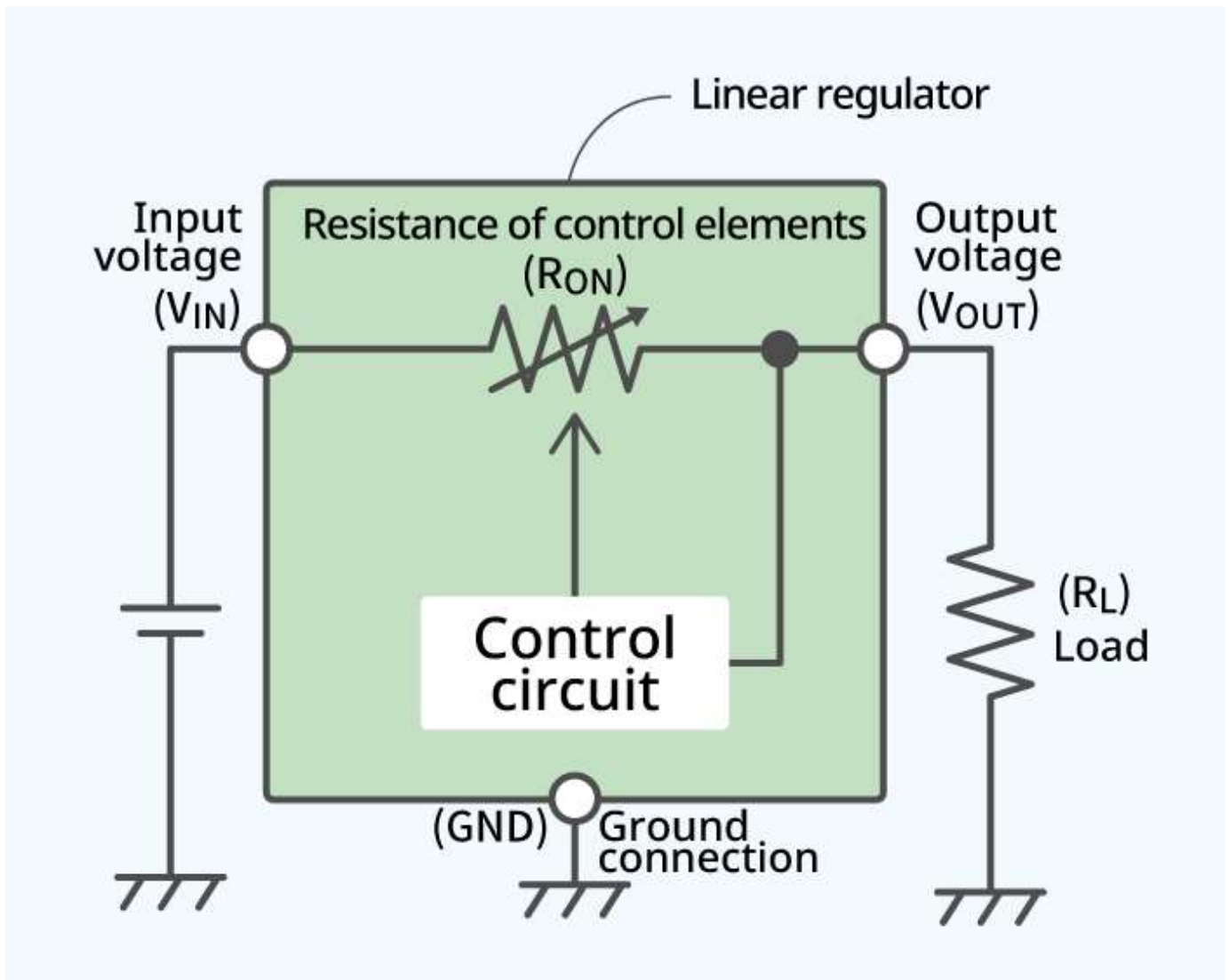
What is an LDO (low dropout voltage regulator)?

1. Basic role of a linear regulator
2. Linear regulator features
3. Cases that require use of a linear regulator

Operating principle and configuration of a linear regulator

1. Linear regulator operating principle
2. Internal configuration of a linear regulator

## 1. Linear regulator operating principle



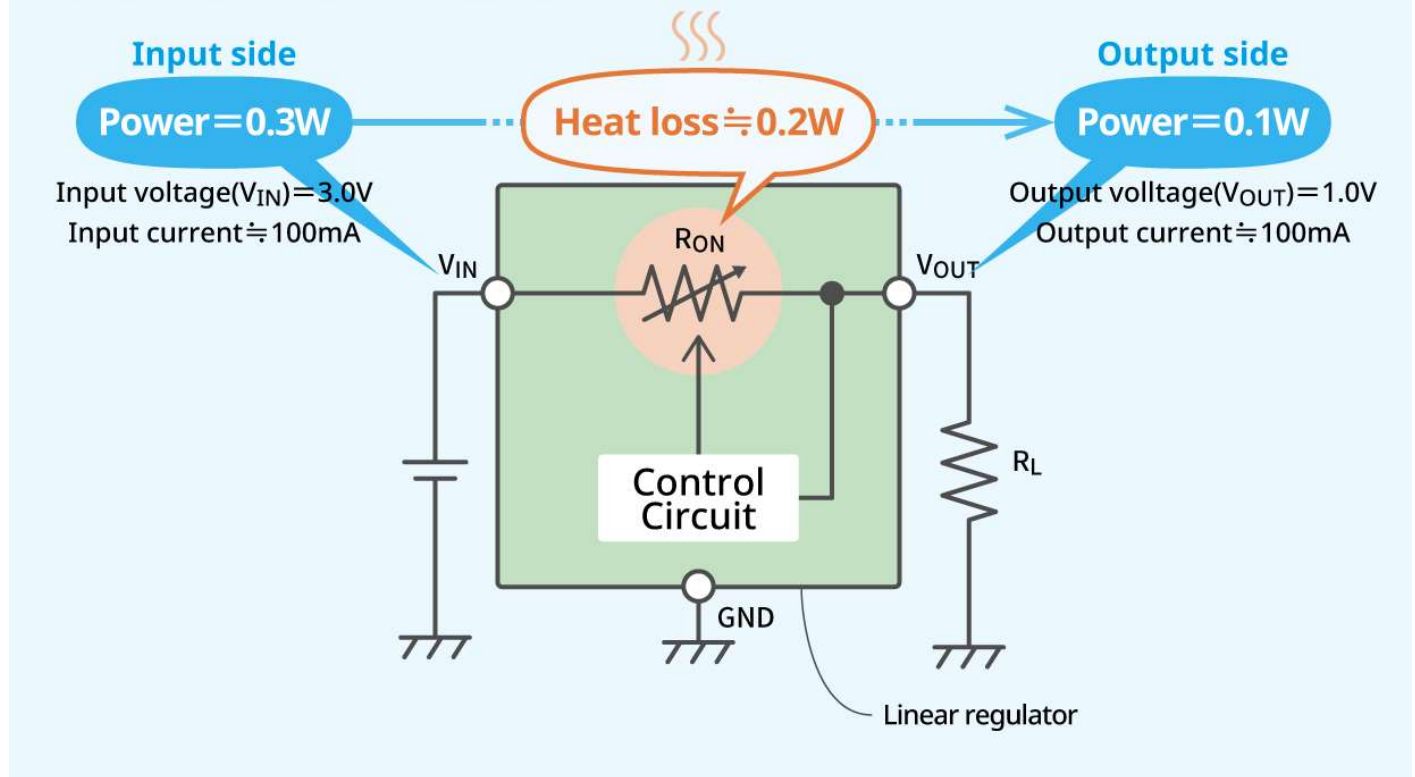
A linear regulator can maintain a steady output voltage ( $V_{OUT}$ ) by adjusting the resistance of control elements ( $R_{ON}$ ) to compensate for input voltage ( $V_{IN}$ ) and load ( $R_L$ ) changes. Details of internal configuration and control are explained in ["2. Internal configuration of a linear regulator."](#)

## • What is heat loss?

We will use this model to consider the "heat loss" that always occurs during operation of a linear regulator. The following is assumed:

Input voltage ( $V_{IN}$ ) = 3.0V, output voltage ( $V_{OUT}$ ) = 1.0V, output current ( $I_{OUT}$ ) = 100mA.

## ● Generation of “heat loss”



“Heat loss” in the linear regulator is what accounts for this difference, most of which is self-heating through control elements, and the remainder is consumed by the self-current consumption of the linear regulator. The larger the difference between input and output voltage and the greater the load current, the larger the heat loss will be.

For this reason, **thermal design is required in the use of a linear regulator.**

IC power dissipation is an important factor in implementing thermal design. IC power dissipation indicates the allowable heat loss value.

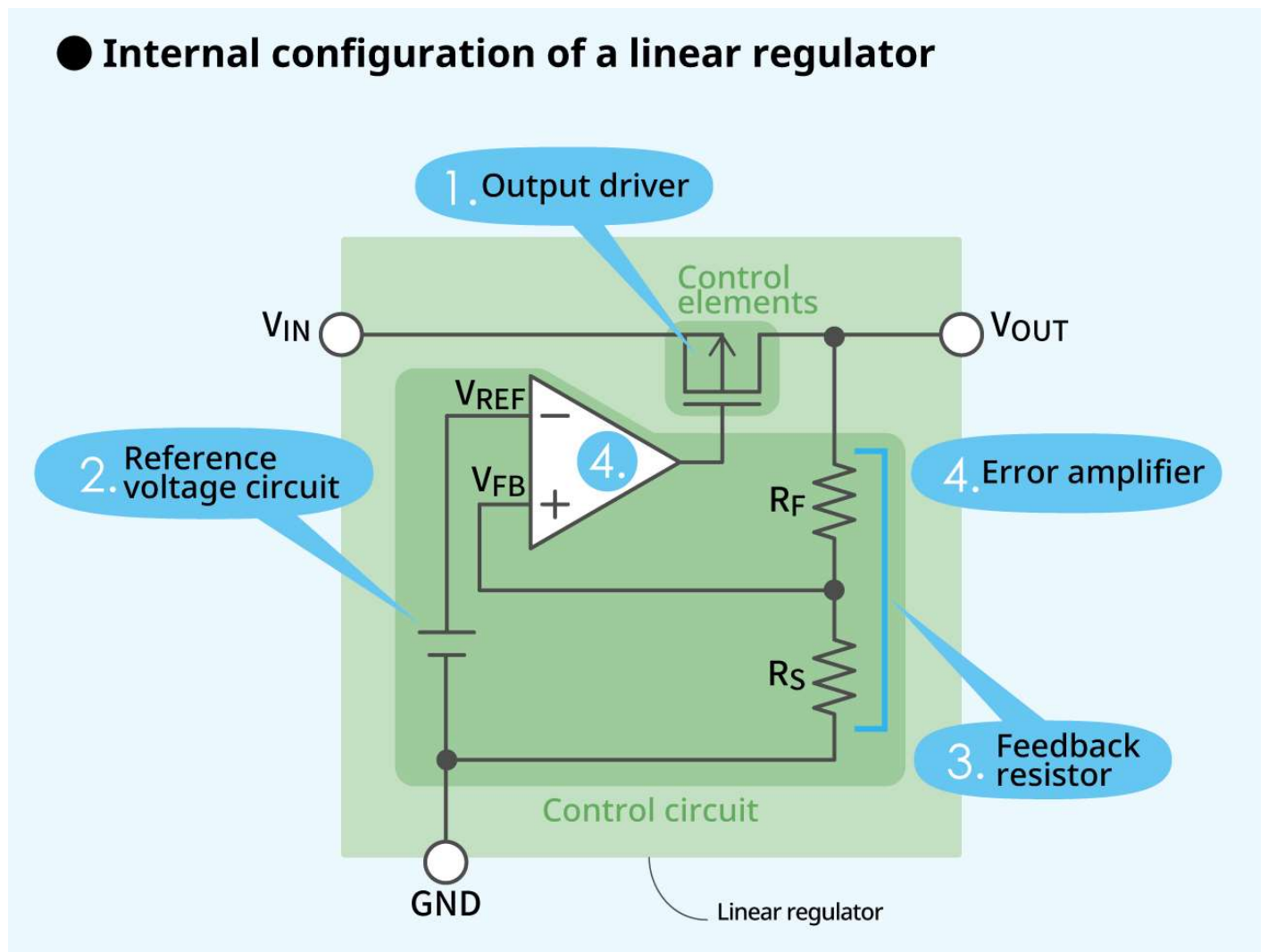
If the IC is used in operating conditions that exceed its power dissipation, the guaranteed operation temperature of the IC will be exceeded.

ABLIC provides a “Thermal simulation service” to support thermal design using ABLIC power supply ICs under customer usage conditions. This Thermal simulation service helps lower

## 2. Internal configuration of a linear regulator

Let's take a closer look at the internal configuration of a linear regulator.

### ● Internal configuration of a linear regulator

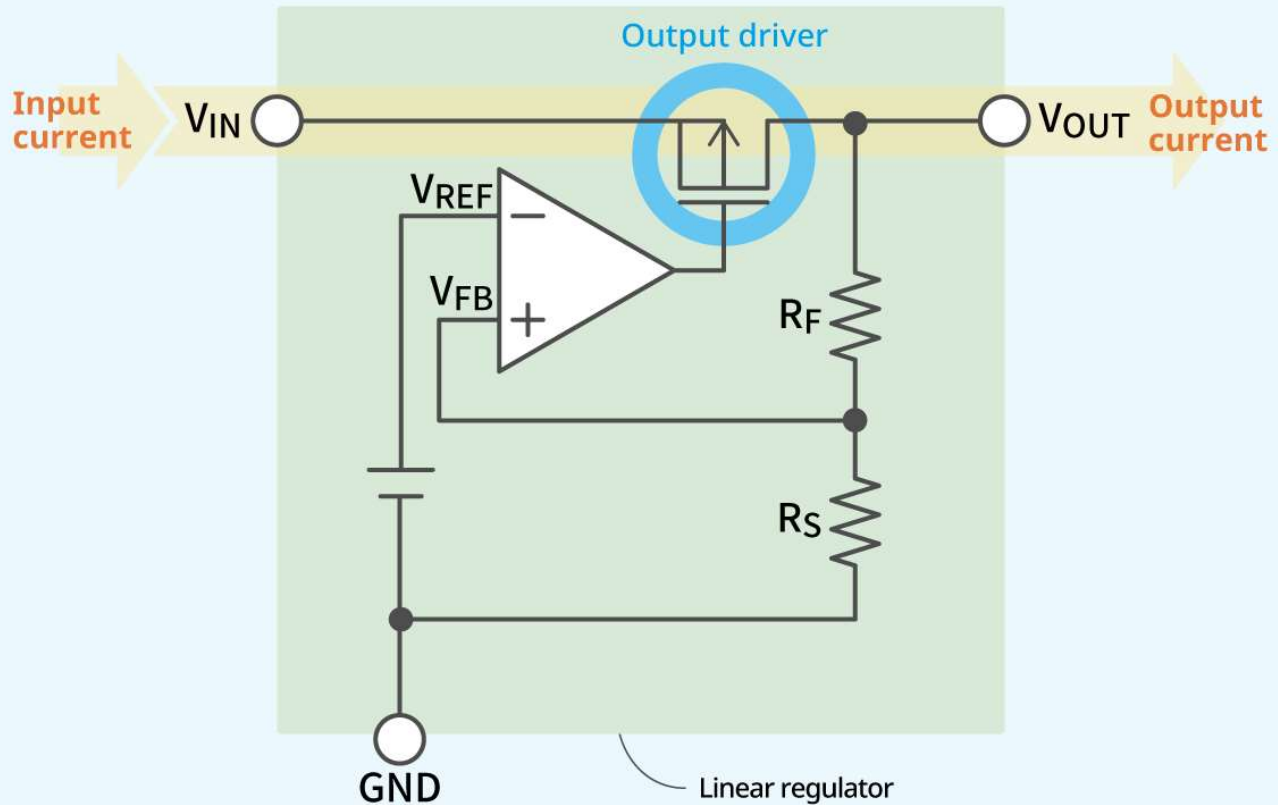


### 1. Output driver

Current passing from the input voltage ( $V_{IN}$ ) side to the output voltage ( $V_{OUT}$ ) side passes through the output driver.

## ● Output driver

Heat loss can be lowered by using an output driver with low on-resistance



Using an excellent output driver, that is, an output driver with low on-resistance, it will be possible even for a regulator with high output current to deliver the required output voltage from a low input voltage while also lowering heat loss.

A linear regulator that can deliver the required output voltage even at a low difference between input and output voltage is called an LDO regulator.

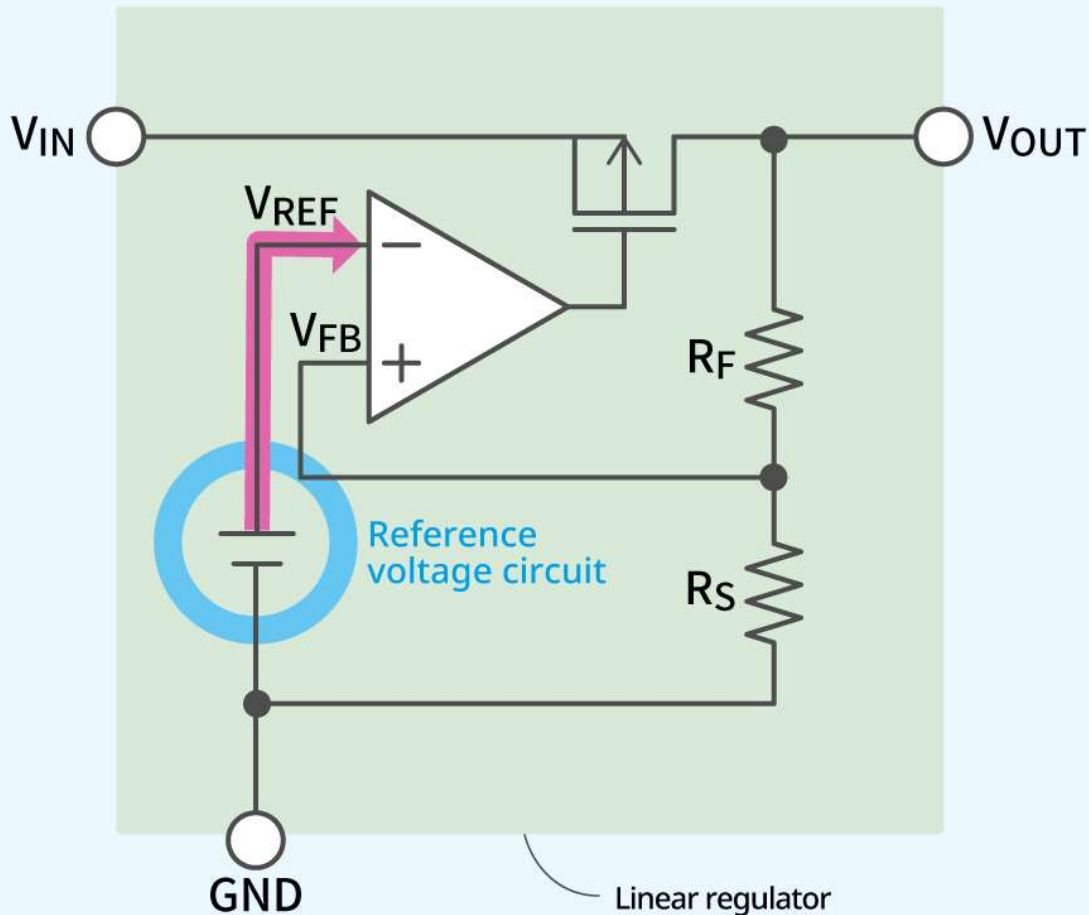
## 2.Reference voltage circuit

A reference voltage circuit outputs a voltage (= reference voltage,  $V_{REF}$ ) used as a standard to the error amplifier to determine whether an output voltage ( $V_{OUT}$ ) is higher or lower than the required voltage.

temperature and other surrounding environmental factors.

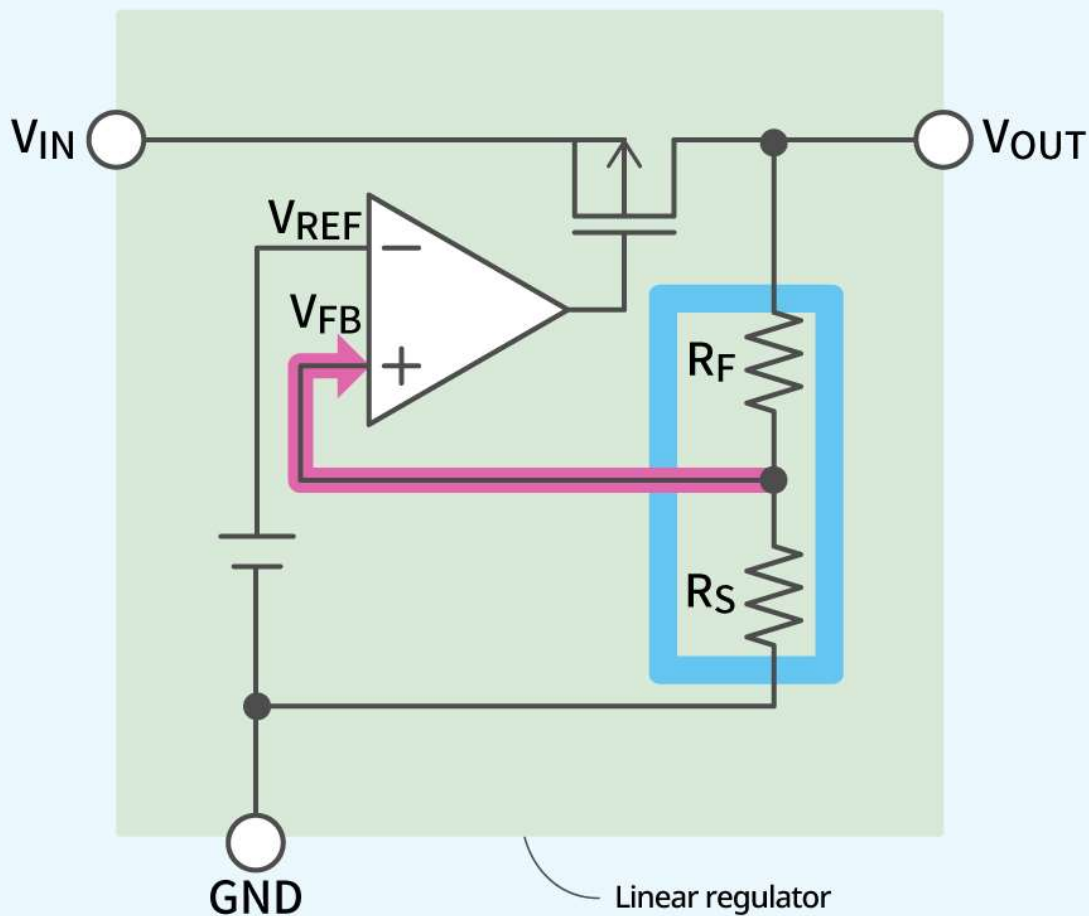
## ● Reference voltage circuit

A circuit that outputs a voltage used as a criterion for determining whether an output voltage is higher or lower than the required voltage



### 3. Feedback resistor

A feedback resistor is connected between the output pin and ground (GND) to divide the output voltage ( $V_{OUT}$ ) by the  $R_F$  and  $R_S$  resistors to output the resulting voltage ( $V_{FB}$ ) to an error amplifier.



The feedback resistor is required to output the voltage resulting ( $V_{FB}$ ) from dividing the output voltage ( $V_{OUT}$ ) by the required voltage to an error amplifier. Even if the criterion ( $V_{REF}$ ) is stable, the error amplifier will not be able to make a correct assessment unless it is able to correctly recognize the state of the output voltage ( $V_{FB}$ ).

#### 4. Error amplifier

The error amplifier compares the reference voltage ( $V_{REF}$ ) output by the reference voltage circuit and the feedback voltage ( $V_{FB}$ ) divided by the feedback resistor to control the output driver on-resistance to ensure the output voltage ( $V_{OUT}$ ) is maintained at the required voltage.



driver and when  $V_{OUT}$  is lower than the required value ( $V_{REF} > V_{FB}$ ), it lowers output driver on-resistance.

For details on error amplifiers, refer to ["What is an operational amplifier?"](#)

## ● Operation of error amplifier

The amplifier compares the reference voltage ( $V_{REF}$ ) to the feedback voltage ( $V_{FB}$ ) to control the on-resistance of the output driver

If  $V_{OUT}$  = the required value,

$$V_{REF} = V_{FB}$$

**Ideal state**

If  $V_{OUT} >$  the required value,

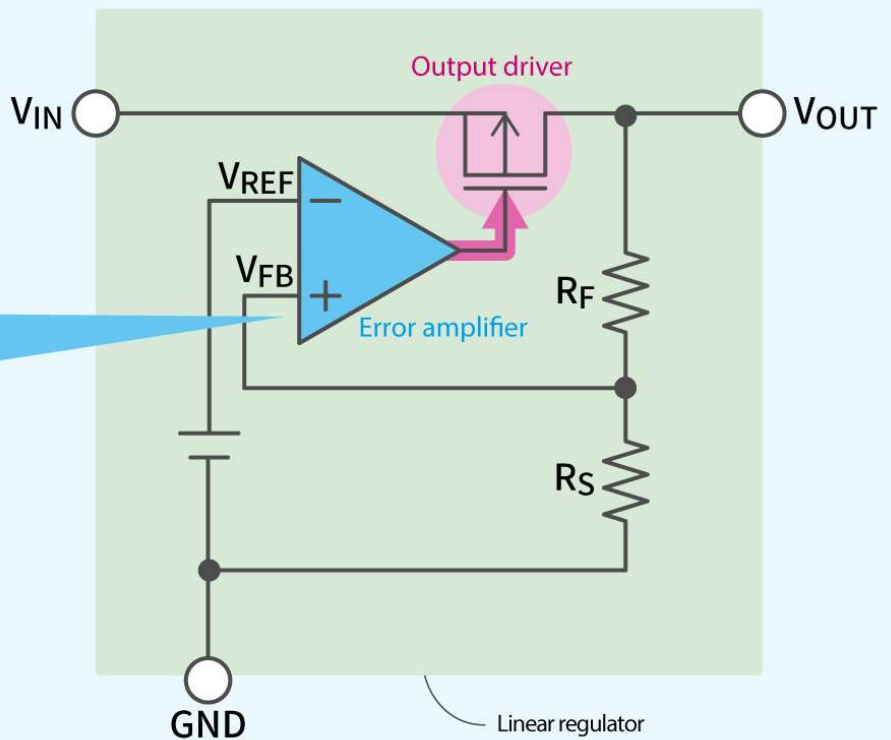
$$V_{REF} < V_{FB}$$

raises output driver on-resistance

if  $V_{OUT} <$  the required value,

$$V_{REF} > V_{FB}$$

lowers output driver on-resistance



>What is an LDO? What is a linear regulator?



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