TOSHIBA

Basic Knowledge of Discrete Semiconductor Device

Chapter IV

Local Power Supply ICs

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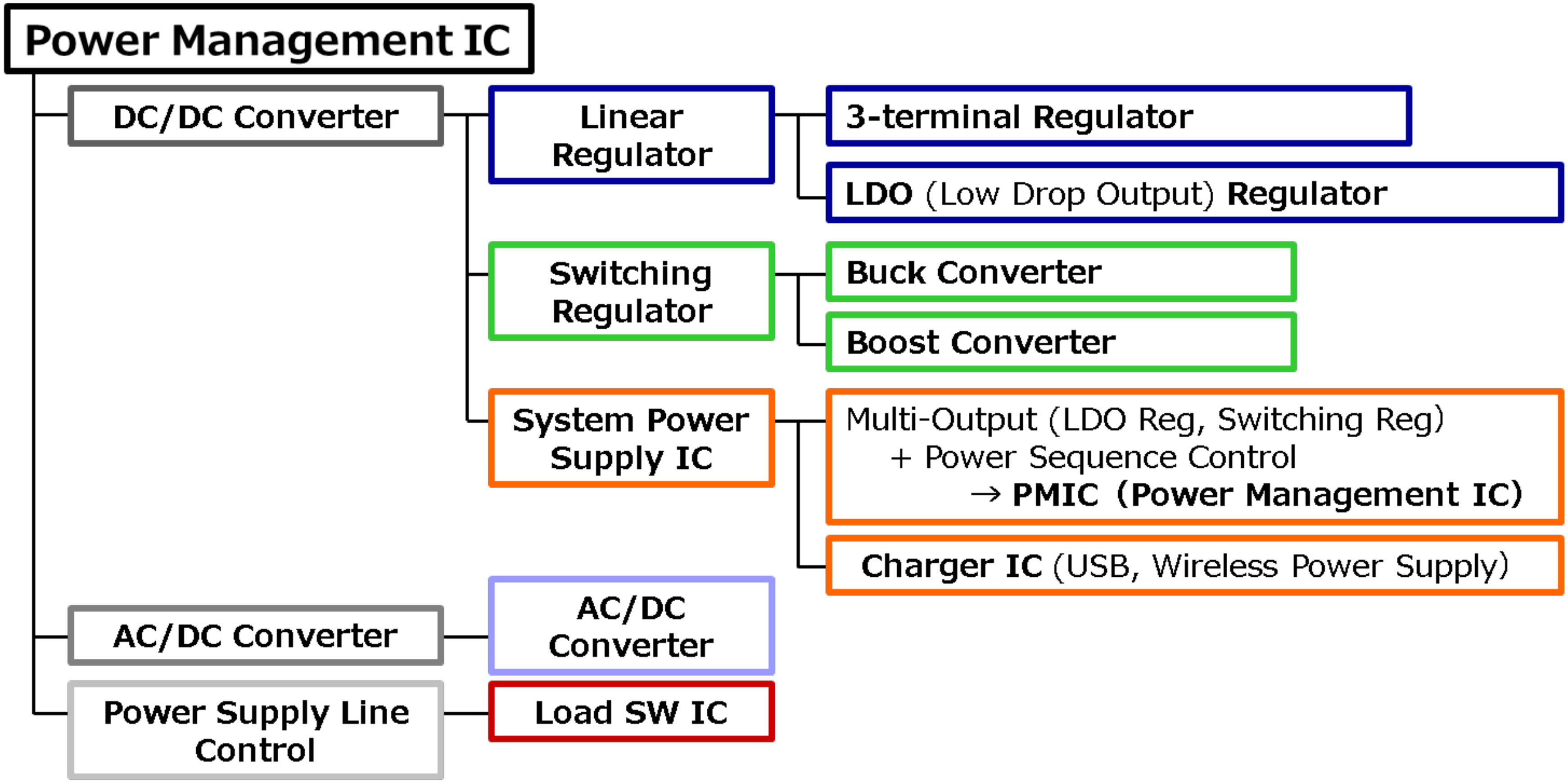
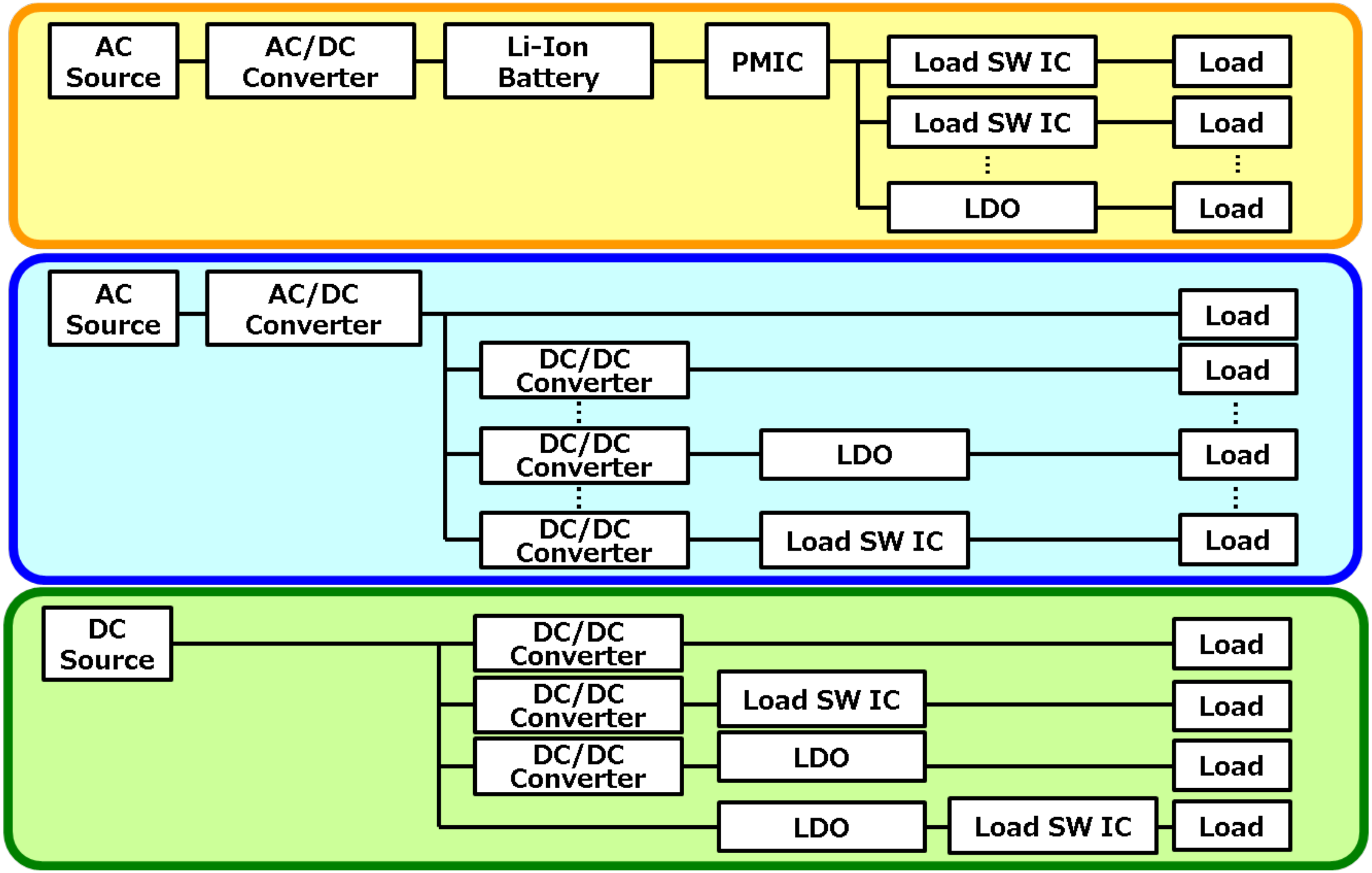
Power Management IC

Power management is a function to manage power supply to support multi-functionalization of equipment and power saving. This IC is called a power management IC.
In addition to a simple linear regulator IC, a switching regulator IC, and a multifunctional system power supply IC, the power management IC includes a load switch IC that stops power supply to the load during standby and controls the power supply sequence.



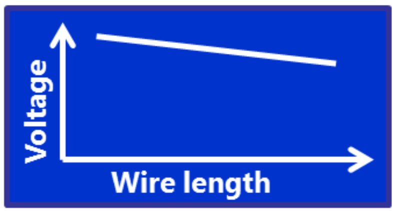
Example of Power Line Structure in a System

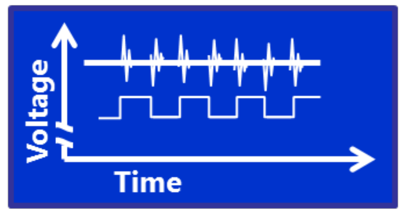
Various kinds of power management ICs are used for the power supply in the set according to the specification required by the system.



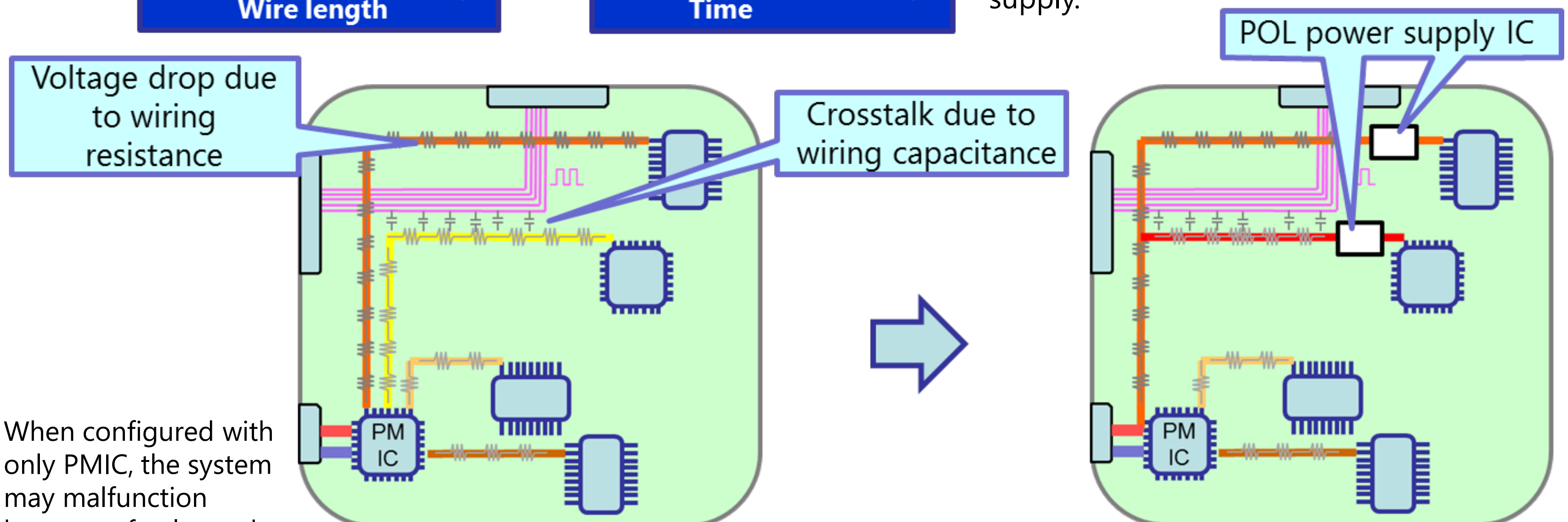
Why POL Supply ICs Are Wanted ?

Low voltage-tolerance and low-noise power supply is required owing to low voltage and multi-functionalization of the LSI used. Meanwhile, because of long wiring in the circuit board, voltage drop and power supply noise due to crosstalk have become problems.
For this application, the POL (Point of Load) power supply IC that generates and supplies voltage near the load end (near the circuit block to be used) is attracting attention.





By placing the POL power supply IC close to the LSI to be used, it is possible to supply high-precision and low-noise power supply.



When configured with only PMIC, the system may malfunction because of voltage drop and noise.

Power supply image on product board

In long wiring portions or for circuits susceptible to noise, local power supply ICs are arranged near the LSIs.

Types of Local Power Supply ICs

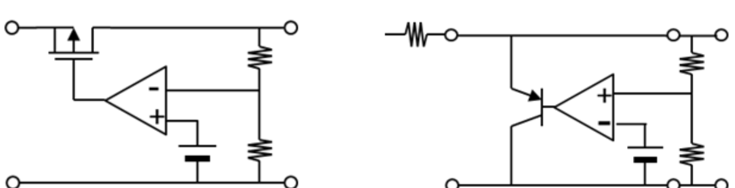
There are two types of local power supply ICs: (1) linear type and (2) switching type. The circuit designer can maximize the performance of the equipment by appropriately selecting these power ICs and placing them in the appropriate place.

Linear type

Linear type includes a series regulator (typically LDO and 3-terminal regulator) and a shunt regulator. A low-noise, high-precision, local power supply can be easily and inexpensively produced with few external parts. However, losses are high (inefficient) and only step-down type can be used. In particular, shunt regulators are inefficient and tend not to be used nowadays.

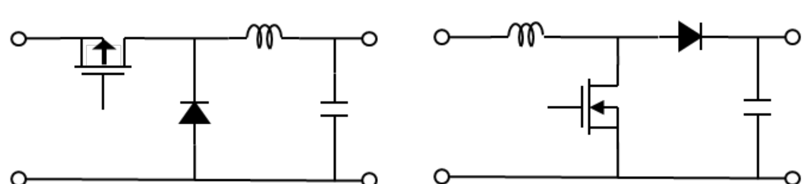
Switching type

It is often called a DC/DC converter. Depending on the circuit configuration, either boost type or buck type can be used. Although the loss is low (high efficiency), external parts such as coil are necessary, and the circuit size becomes large and expensive.
The input DC voltage is switched (~ 1 MHz) to create a rectangular wave, and this rectangular wave is smoothed and converted to the desired DC voltage.
Although the variety of ICs offered by our company is limited, we offer a wide variety of MOSFETs for use in DC/DC converter applications.



Series regulator | Shunt regulator

Linear type



Buck | Boost

Switching type

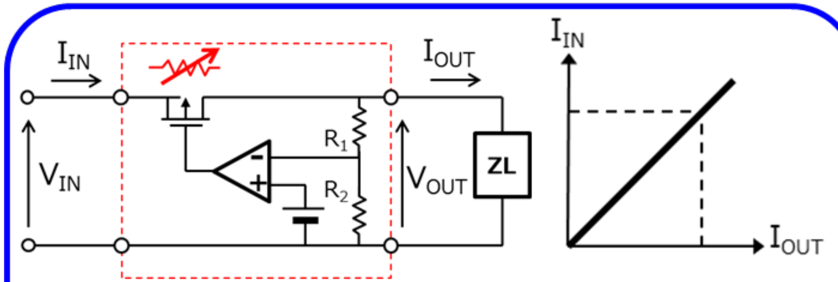
Operation of Linear Regulators

Series regulators

External parts are unnecessary as shown in the lower left figure. (Input/Output capacitors are necessary.) The MOSFET operates as a variable resistor so that the output voltage becomes constant voltage. The potential difference (V_{IN} - V_{OUT}) × input current (I_{IN}) between the drain and source of the MOSFET is a loss. For example, if the input is 5 V and the output is 3 V, the efficiency is 60%. It is used as a power supply for circuits requiring low noise and output voltage accuracy.

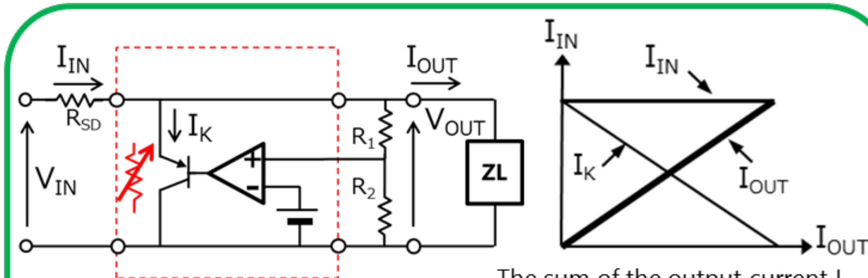
Shunt regulators

The area surrounded by the dotted line shown in the lower right figure is the IC. It needs three external resistors. The built-in transistor operates as a variable resistor so that I_K + I_{OUT} = I_{IN} = constant. As a result, the voltage generated at R_{SD} becomes constant and the output voltage is made constant voltage. But in addition to the output current, a cathode current flowing through the transistor is required. Also, there is a voltage drop at the input-side resistor R_{SD}, which reduces the efficiency. It is used for low-current (~ 20 mA) applications such as switching power supply reference voltage and switching power supply photocoupler driver.



Series regulator

Output current I_{OUT} equals input I_{IN} current.



Shunt regulator

The sum of the output current I_{OUT} and the current I_K flowing through the transistor is always constant.
I_K + I_{OUT} = I_{IN} (Const.)

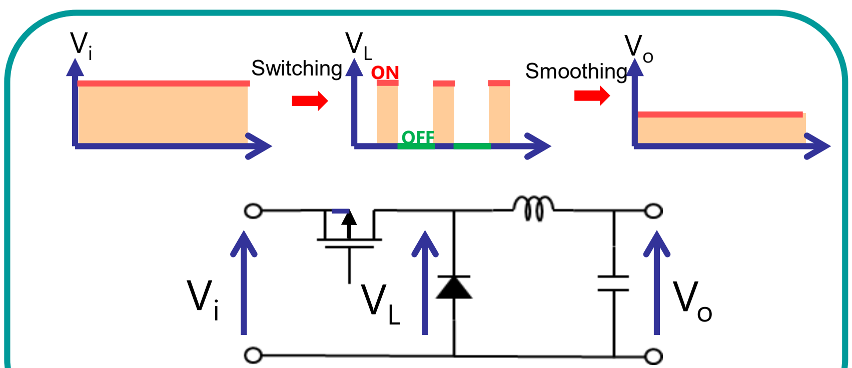
Operation of Switching Regulators

Buck converter

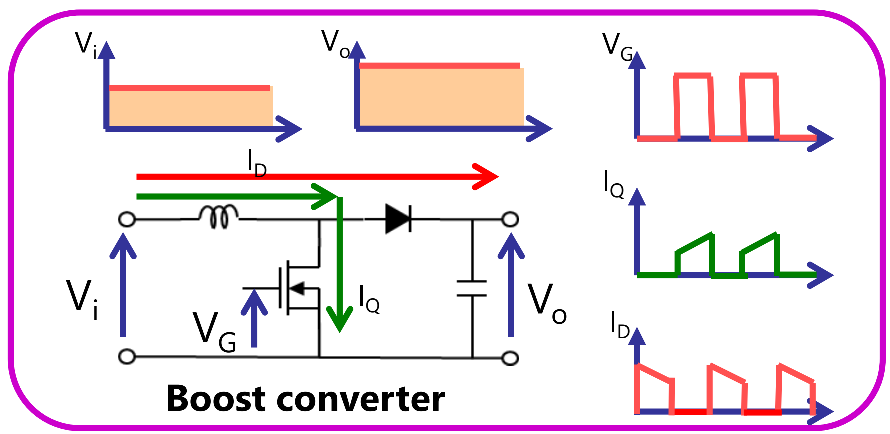
The figure below on the left shows the motion image. A rectangular wave is created by MOSFET repeating ON/OFF. This wave is applied to the coil. A desired DC voltage can be obtained by smoothing (averaging) this rectangular wave. The output voltage value is determined by the duty ratio of the rectangular wave.

Boost converter

As the figure below on the right shows, when the MOSFET is ON, current mainly flows through the coil and the MOSFET. At this time, energy is accumulated in the coil. The coil operates so as to release the accumulated energy and suppress the change of the current. When the MOSFET turns OFF, the current flowing through the coil will lose the path up to now. However, due to the property of continuing the current of the coil, the voltage at the coil end rises and the current flows through the diode and the capacitor is charged. This causes voltage exceeding the input voltage to be generated.

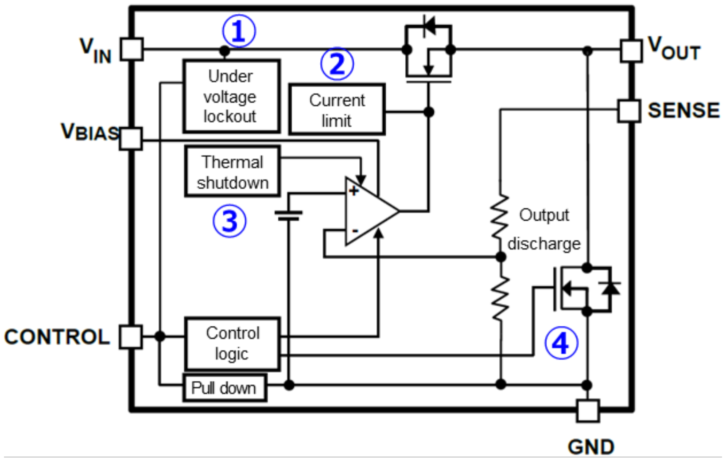


Buck converter



Boost converter

Functions of LDO



LDO block diagram

1. **Under voltage lock out (UVLO):** This function places the IC in the standby state when the input voltage drops below the specified input voltage so that the internal circuit becomes unstable and malfunction does not occur.

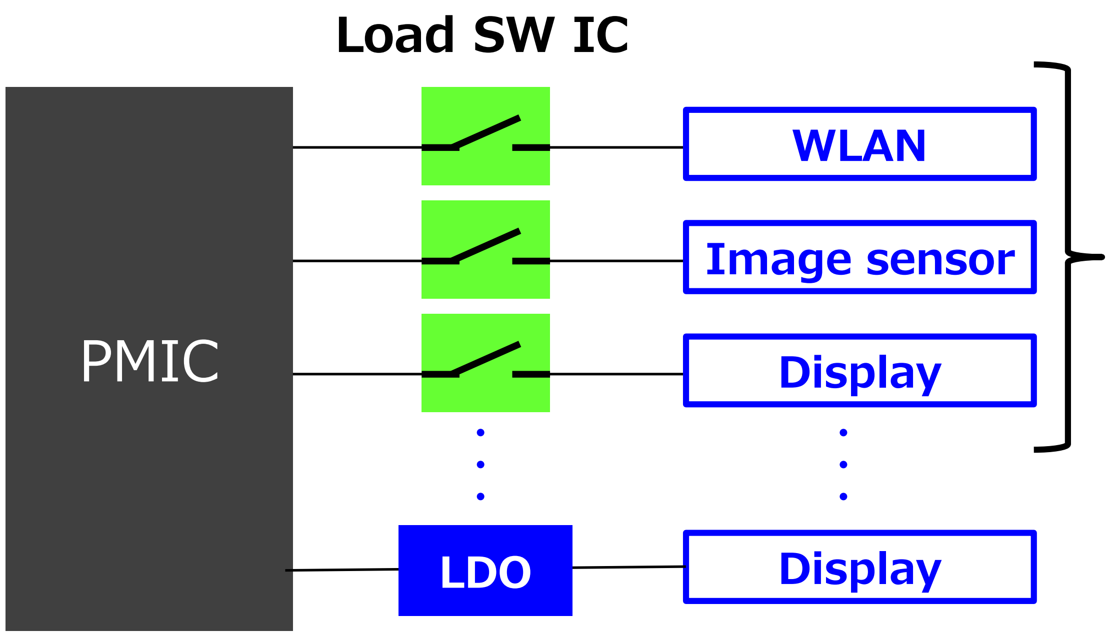
2. **Current limit:** This function protects against degradation and destruction due to heat generation of the device itself when the output terminal V_{OUT} goes into an unintentional short mode state. There are two types of overcurrent protection: the foldback type that simultaneously reduces the output current and output voltage, and the current limiter type that reduces the output voltage while keeping the output current constant.

3. **Thermal shut down (TSD):** It is a circuit to prevent deterioration and destruction of the device because of remarkable ambient temperature rise, heat generation of the device itself due to unintentional high current load etc. When the specified temperature is detected by the internal temperature detection circuit, the output transistor is turned off.

4. **Output discharge:** When the output transistor is turned off, the terminal voltage of V_{OUT} may remain for a certain time depending on the load capacitance connected to the output terminal. This circuit rapidly discharges the charge accumulated on the load side and drops the V_{OUT} terminal voltage to near the IC GND.

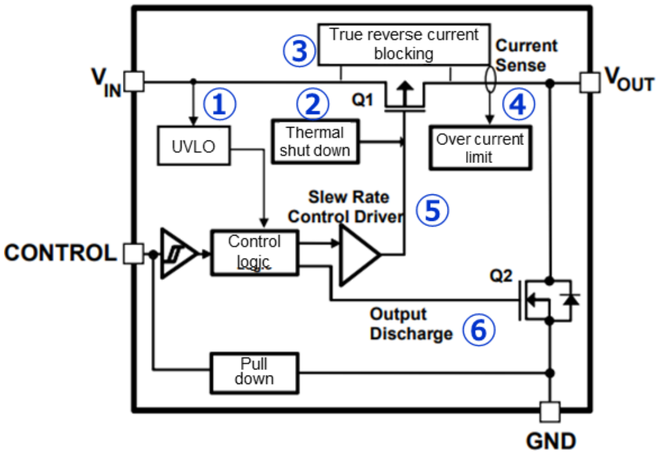
Load Switch IC

The load switch IC is connected between the power supply and the load (IC or LSI). It is a power management IC that reduces power consumption by controlling on/off of power supply lines supplied to ICs and LSIs depending on the operating mode of the system. A similar switch can be configured with a mechanical relay or a discrete (MOSFET), but the load switch IC has low power consumption and various protection functions built in, so that improvement of system reliability can be expected.



The power supply to each system is optimally controlled according to the operation mode of the equipment.

Functions of Load Switch IC



Load SW IC block diagram

1. **Under voltage lock out (UVLO):** This function places the IC in the standby state when the input voltage drops below the specified input voltage so that the internal circuit becomes unstable and malfunction does not occur.
2. **Thermal shut down (TSD):** It is a circuit to prevent deterioration and destruction of the device because of remarkable ambient temperature rise, heat generation of the device itself due to unintentional high current load etc. When the specified temperature is detected by the internal temperature detection circuit, the output transistor is turned off.
3. **True reverse current blocking:** When input voltage V_{IN} becomes higher than output voltage V_{OUT}, current flows back from V_{OUT} pin to V_{IN} pin. This function prevents reverse flow and protects the power supply etc. connected to the V_{IN} terminal from deterioration and destruction.
4. **Over current limit:** When the output terminal V_{OUT} becomes unintentionally shorted, it protects against deterioration and destruction due to the heat generation of the device itself.
5. **Slew rate control driver:** This circuit suppresses inrush current generated during switching transient.
6. **Output discharge:** In a general load switch circuit, when the output transistor is turned off, the terminal voltage of V_{OUT} may remain for a certain time depending on the load capacitance connected to the output terminal. This circuit rapidly discharges the charge accumulated on the load side and drops the V_{OUT} terminal voltage to near the IC GND.

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