Application Note

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How to Calculate the Threshold of NSI8608 Digital Input

AN-13-0007

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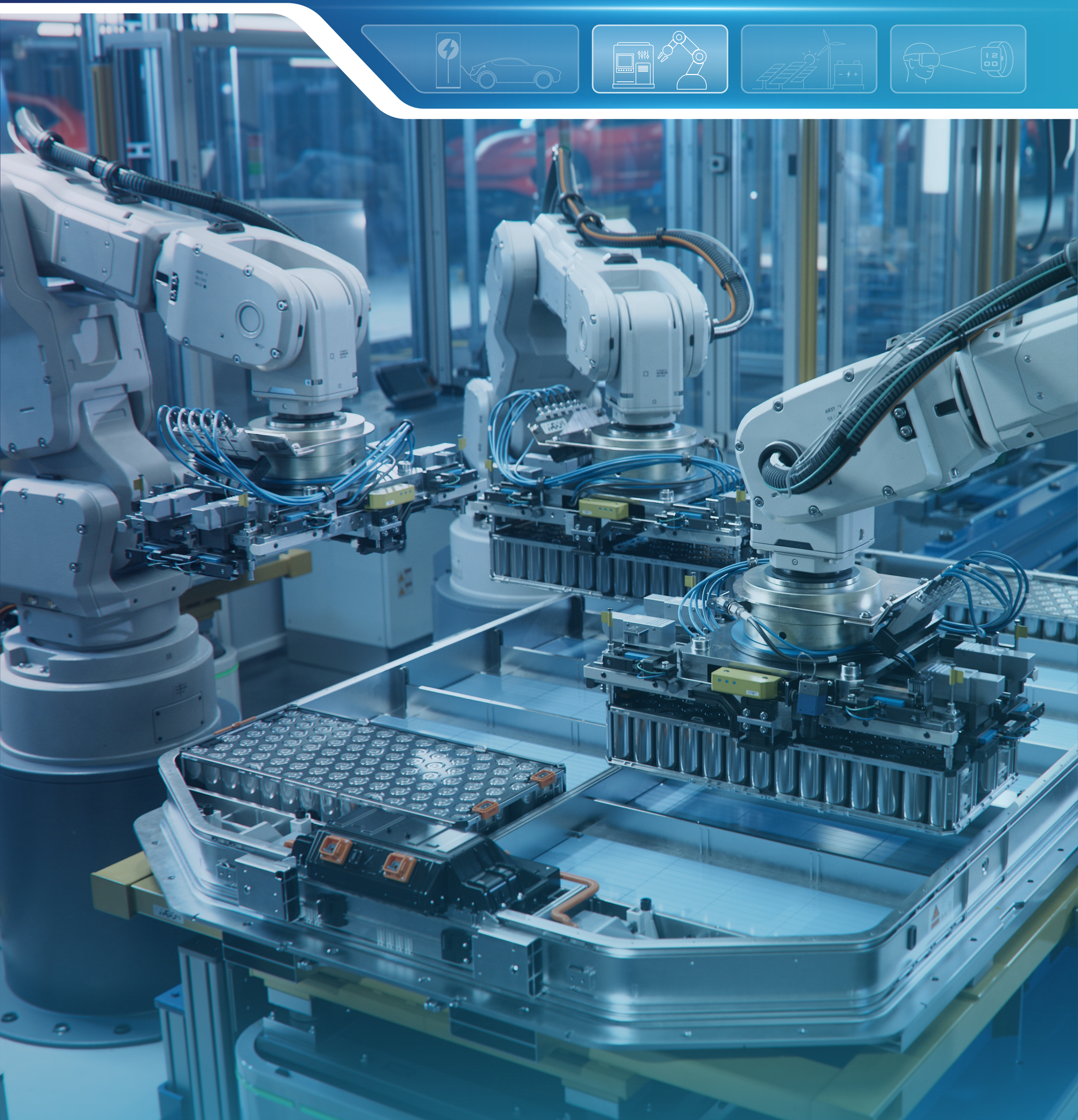

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ABSTRACT

The NSI8608 is a multi-channel digital isolation chip that supports digital inputs specified in IEC 61131-2. The chip supports digital signal inputs up to 60v without the need for separate power supply on the input side and provides isolated digital outputs. The internal integrated rectifier bridge supports both source and drain inputs. The input also integrates a current limiting function to effectively reduce the overall temperature of the solution.

In system design, different system requirements have different requirements for the voltage transition threshold and current of the chip, which can be calculated from the peripheral resistance. The NSI8608 has a simpler peripheral design than similar products on the market. This note explains how to calculate the threshold of relevant parameters and gives an example of calculation.

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1.Chip Characteristics

1.1.Functional Block Diagram

As shown in Figure 1.1, the chip input integrates a rectifier bridge to achieve positive and negative voltage inputs, and reduces chip power consumption through a current limiting module. The chip input first reaches the current limiting module through the internal rectifier bridge, and supplies power to other circuits at the same time.

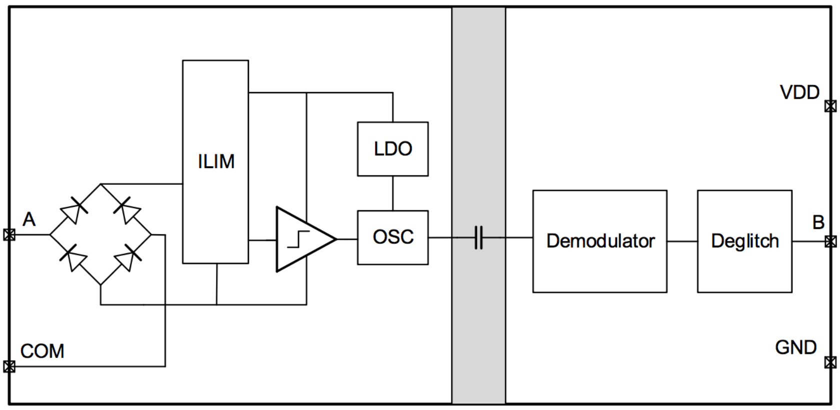

Figure 1.1 Functional Block Diagram

1.2.IV Characteristic Curve of Input

The relationship between input voltage and input current of the chip is shown in Figure 1.2. The voltage must first reach the forward conduction voltage of the diode, after which the current increases approximately linearly with the increase in voltage until the current hardly changes anymore after reaching the input current limit.

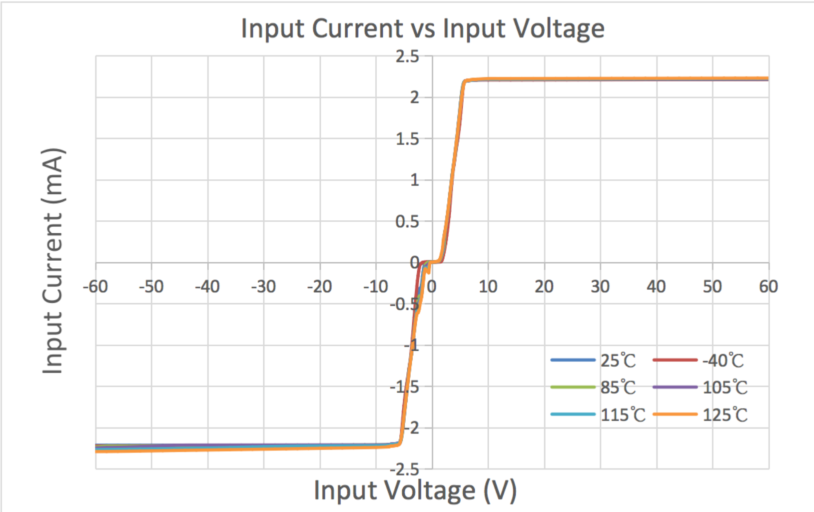

Figure 1.2 Relationship Between Input Current and Input Voltage

1.3.Input Threshold Voltage

The chip's input threshold voltage range is shown in the table below. It can work normally without a series threshold resistor (R_{THR}). The relationship between the threshold voltage and temperature of the chip is shown in Figure 1.3.

Parameters	Symbol	Min	Typ	Max	Unit	Comments
High level threshold voltage	VIH		8	9.2	V	voltage at Ax
Low level threshold voltage	VIL	6.1	7.3		V	
Threshold voltage hysteresis	VHYS		0.7		V	

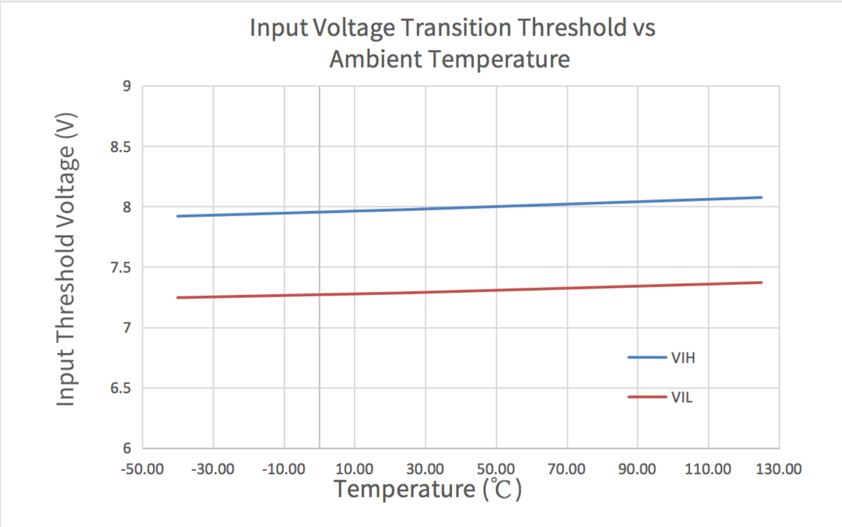

Figure 1.3 Relationship Between Threshold Voltage and Temperature

1.4.Input Current Limiting Function

The current limiting function integrated in the chip does not require a resistor for configuration. As long as the voltage reaches the voltage range, it can enter the current limiting state. The current limiting range is shown in the table below. Considering the overall heating of the system, the current is controlled in a very small range. If the system needs a larger current, the solution can be designed according to the method described below.

Parameters	Symbol	Min	Typ	Max	Unit	Comments
current drawn from Ax pin	IAx	1.55	2.1	2.62	mA	VIL≤|VAx|≤60V

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2.Threshold Calculation

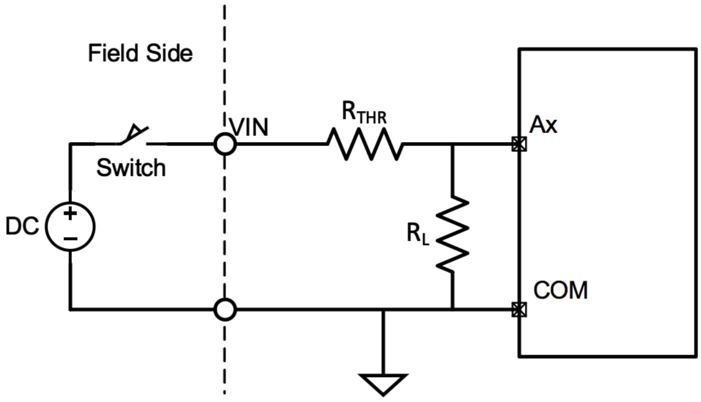

Figure 2.1 Input Peripheral Circuit

The device arrangement in the figure above is given for the chip input threshold design, which can be selected according to the instructions below.

First, you need to confirm whether the current limiting range of the chip itself can meet the system requirements. If it can, just refer to Section 2.1 to adjust the resistor R_{THR} to adapt to the voltage threshold requirements without the need to use the resistor R_L. If the system requires a larger current, refer to Section 2.2 to design the resistance values of R_{THR} and R_L.

2.1.No Need to Adjust Current

When the system does not need to adjust the current limit, there is no need to use the R_L resistor. The threshold can be calculated using the following formula:

- VIN = VAx + IAx * R_{THR}

VIN: External input voltage requirement

VAX: Voltage at chip pins

IAx: Chip current limit

R_{THR}: Series threshold resistance

Generally, the system has a clear requirement for the ON/OFF state voltage. At this time, the voltage value is substituted into VIN and VAx is substituted into the chip VIH/VIL value to calculate the range of the threshold resistor R_{THR}. You can also directly use the Excel tool provided by NOVOSENSE for calculation.

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2.2.Need to Adjust Current

When the system requires a larger current IIN, both R_{THR} and R_L need to be used to meet the requirement. The specific formula is as follows:

- IIN = IAx + VAx / R_L ——(1)
- VIN = (IAx + VAx / R_L) * R_{THR} + VAx ——(2)

IIN: External input current requirement
VIN: External input voltage requirement
VAX: Voltage at chip pins
IAx: Chip current limit
R_{THR}: Series threshold resistance
R_L: Shunt bleed resistance
There is a contradictory relationship between the shunt bleed resistance and the series threshold resistance, that is, the greater the bleed, the greater the series resistance voltage drop. Therefore, it is necessary to first calculate the maximum value of R_L by formula (1), and then calculate the maximum value of R_{THR}.

2.3.Application Example and Calculation Tool

Suppose that the existing system requires an ON state at an input voltage of up to 15V and the current must be at least 3mA at this time. The following explains how to design using the above method.
1）First determine whether the chip can meet the current requirement of the ON state. Obviously, the minimum requirement of 3mA exceeds the maximum value of chip IAx. At this time, the current needs to be adjusted using the peripheral design method in Section 2.2.
2）Substitute the minimum current requirement and maximum voltage requirement into formula (1) or the calculation tool to calculate the maximum value of R_L. The maximum value calculated at this time is 6.34kohm.
3）Select the maximum value of RL obtained in the previous step, for example, 5kohm, and substitute this value into formula (2) or the calculation tool to obtain the maximum value of R_{THR}.

			min	typ	max
RTHR(kohm)	RL(kohm)	I_{limt}(mA)	1.55	2.1	2.62
0	\	VIL(V)	6.10	7.30	
		VIH(V)		8.00	9.20
Maximum recommended resistance		customer specification input			
1.30	6.34	VIN(V)	15		
		IIN(mA)	3		
		RL	5		

The maximum RL value is calculated on the left side after filling in the VIN and IIN. Select the appropriate RL resistance value and fill it in here. The RTHR maximum value will be calculated on the left side.

Figure 2.2 Demonstration of Calculation Tool

3.System Heating Design

System heating is an important part of system design. The following compares the NSI8608 and its peripheral design with other solutions, illustrates the advantages of the NSI8608 solution, and provides technical suggestions related to heating.

In the discrete optocoupler solution, it is difficult to achieve multi-channel integration due to the characteristics of the optocoupler device itself. Although heating is relatively easy to control, the overall solution is costly and requires a large PCB footprint, making it only suitable for individual applications with a small number of channels.

Another common solution is the multi-channel integrated capacitive isolation DI. Although it solves the large PCB footprint problem of the discrete solution, the lack of integrated current limiting function causes serious heating around the peripheral devices and chip, forcing the increase of the spacing with other systems and the increase of the heat dissipation area to reduce the overall system temperature.

The NSI8608 effectively controls system heating from two dimensions: heating of the chip itself and heating of the peripheral devices, reducing the PCB footprint and also the selection pressure and cost of the peripheral devices.

3.1.Calculation of Chip Power Consumption

Due to the integrated current limiting function inside the chip, the power consumption calculation of the NSI8608 itself is very simple. The specific formula is as follows:

- $W = \Sigma VAx * IAx * \eta$

W: Total power consumption of the chip

VAX: Voltage at chip pins

IAx: Chip current limit

η: Signal duty cycle

x: Channel number actually used

Specifically, IAx can be directly based on the current limiting range in the chip manual, and the voltage of VAx can be calculated based on threshold calculation in the previous section.

3.2.Maximum Operating Ambient Temperature of Chip

To calculate the maximum operating ambient temperature of the chip, you need to confirm the corresponding thermal resistance first. The following table shows the thermal resistance of the two packages of NSI8608.

Parameters	Symbol	SSOP16	SSOP20	Unit
Junction-to-ambient thermal resistance	θ_{JA}	86.3	67.1	°C/W

The chip power W under different application conditions is calculated according to the chip power consumption calculation formula, and the maximum junction temperature of the chip Tjmax = 150°C
Maximum operating ambient temperature of chip: Tmax = Tjmax – W * θ_{JA}

3.3.Relationship Between Chip Power Consumption and Ambient Temperature

Based on the chip power consumption calculation formula, the maximum power consumption of the NSI8608 chip can be calculated as Wmax = 1257.6 mW (60V * 2.62mA * 8), the corresponding package thermal resistance is 67.1°C /W, and the maximum ambient temperature is calculated as Tmax = 65.6°C (150°C - 1257.6 mW*67.1°C /W).
Based on the above parameters, the relationship between power consumption and operating temperature under extreme conditions of the chip is shown in the figure below.

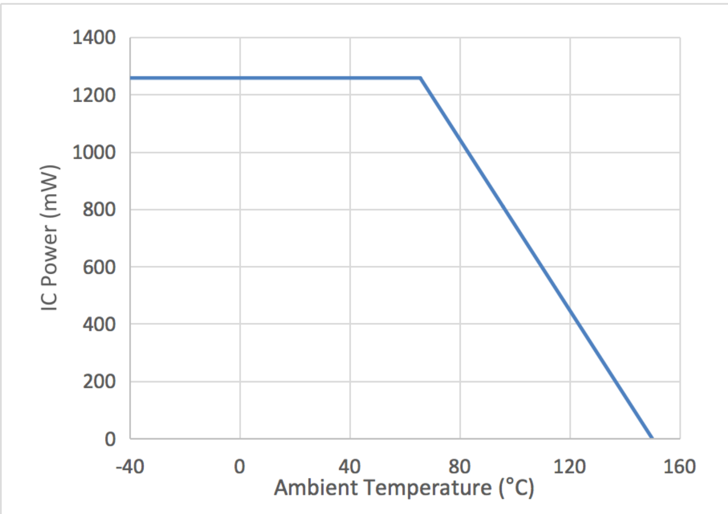

Figure 3.1 Relationship between Ambient Temperature and Chip Power Consumption

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3.4.Heating Measurement

Under room temperature of 25°C, the peripheral circuit is set up according to IEC 61131-2 type-3 (R_{THR}=0ohm, R_L is not used), and the heating test of single-channel 30V DC input is as shown in the figure below (tested using NOVOSENSE's DEMO board, front view in the left picture and back view in the right picture).

The NSI8608 integrates a current limiting design, which effectively controls both global and local heating.

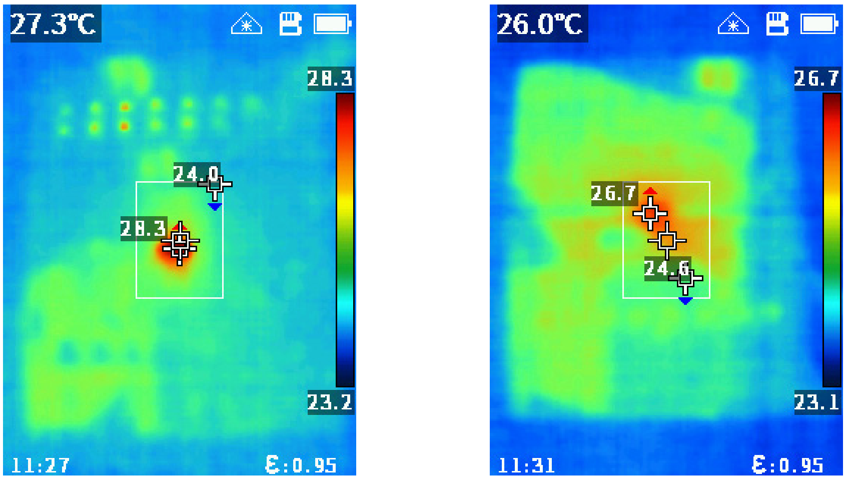

Figure 3.2 Infrared Thermal Imaging of NSI8608 in Operation

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4.Revision History

Revision	Description	Author	Date
1.0	Initial version	Runsheng Zhou, Huafu Mao	10/9/2024