

Study on PROFIBUS Network and Voltage Level

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1. Introduction

The configuration equipment (PLC, DCS, etc.) of Korean APR1400, a Digital Nuclear Power Plant (DNPP), uses PROFIBUS-DP (PROcess Field Bus) 5V-based.

Many scholarly journals describe the design of the 5V reference and the design of the 3.3V reference, but do not mention the characteristics and problems of the composite configuration.

When a PROFIBUS-based system is configured with 5V and 3.3V equipment, the network signal cannot be against to external noise signals so the network is lost.

In this paper, we explain why the combination of 5V and 3.3V should not be used when designing with 5V reference.

2. PROFIBUS

This chapter describes PROFIBUS technology and explains PROFIBUS classification.

2.1 PROFIBUS General

PROFIBUS is an open fieldbus used independently (Vendor-independence) for Factory-Automation (FA) equipment.

PROFIBUS is an industrial communication system for industrial installations using high-speed, complex communication. It is a very flexible and reliable communication technology, but it is also a bus that needs a lot of knowledge about high-speed communication [1].

2.2 PROFIBUS Classification

PROFIBUS is divided into three categories: PROFIBUS-FMS (Fieldbus Message Specification), PROFIBUS-DP (Decentralized Periphery) and PROFIBUS-PA (Process Automation).

PROFIBUS-FMS is the first model developed by the German Working Group to transmit structured data very sophisticated and flexible. However, there is a drawback that the cost is high.

After that, PROFIBUS-DP has been developed as a simplified and improved specification. PROFIBUS-DP has been developed to be the most suitable for the automation and control industry and is now the main technology.

Finally, PROFIBUS-PA was developed to replace the 4 to 20 mA transfer of PROFIBUS-DP and uses MBP (Manchester Bus Powered) transfer in the physical layer.

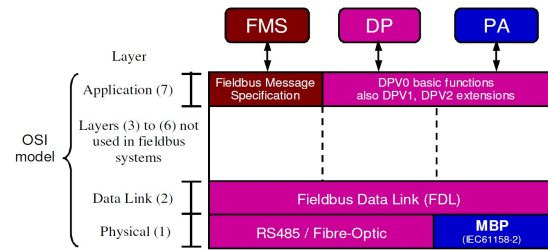


Fig. 1. The PROFIBUS OSI(Open System Interconnection) model.

2.3 Equipment configuration using PROFIBUS-DP

PROFIBUS-DP is connected to various equipment such as PC (Personal Computer), PLC (Programmable Logic Controller) and other equipment. Termination resistors are installed at both ends of the equipment connected to PROFIBUS.

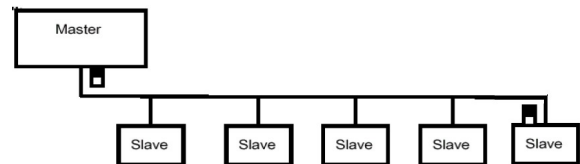


Fig. 2. Master and last slave have a termination resistor

Because PROFIBUS-DP performs high-speed communication, it obeys various precautions suggested in high-speed communication. The most important of them is termination resistance. PROFIBUS-DP is typically designed for 5V-based cabling and termination resistors.

2.4 Cable

PROFIBUS is based on RS485 communication, and the following PROFIBUS-DP cables are recommended for the PROFIBUS standard [2].

Table I: IEC 61158-2 Cable Character

Parameter	Cable type A
Impedance	135~165 Ω / 3~20 MHz
Capacity	< 30 pF/m
Resistance	< 110 Ω /km
Wire gauge	> 0.64 mm
Conductor area	> 0.34 mm

2.5 Reflection wave and termination resistor

In the high-speed communication, the part to be careful is the reflected wave. Reflection effect are one of the causes of signal distortion. The following is a description of the principle of reflected waves.

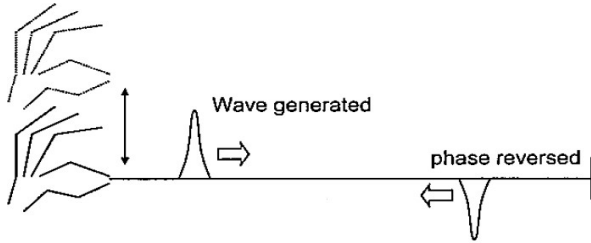


Fig. 3. Reflection effect concept

When a signal is generated and reaches the end, reflected waves are generated by the impedance mismatch of the input signal and the termination. The signal is distorted due to the overlap of the reflected generated signal and the reflected signal [3].

PROFIBUS uses a differential path, which is designed to resist distortion due to external signals. However, termination resistor design is essential for the reflection effect cancellation.

The termination resistance and the line-to-line impedance must match for the reflected wave attenuation. However, PROFIBUS-DP recommends a 150Ω impedance cable and a 171Ω (=220Ω // (330Ω + 330Ω)) termination resistor design. Cable impedance and termination resistance do not match, but it is not a big problem.

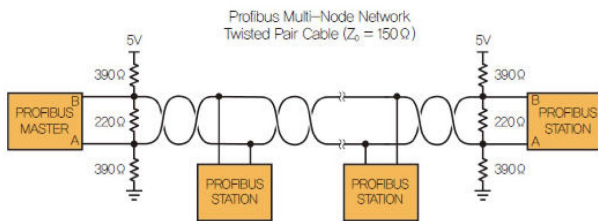


Fig. 4. Cable and termination of PROFIBUS-DP

2.6 Differential Output Voltage (V_{OD})

The peak-to-peak of the differential output voltage of PROFIBUS should be more than 4V and less than 7V. So the zero-to-peak is defined as 2.1V, and may be -2.1V or 2.1V depending on the polarity.

In addition, since the influence of the reflected wave may be large, a terminal voltage of 1.1 V must be distributed and maintained between the positive and negative ends at the idle time.

3. 5V Termination Design and Equipment Combinations between Different Voltages

3.1 Equipment combinations

The reference design of PROFIBUS is based on 5V. In special cases, 3.3V is used when it is installed in a dangerous place. Except in special cases, the PROFIBUS termination resistors are designed with a 5V reference.

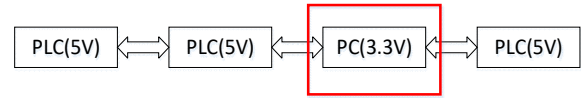


Fig. 5. Combination between different voltages

The advantage of PROFIBUS is that it can be connected to various facilities. However, when a combination of PLC (5V equipment) and PC (3.3V equipment) is made as shown in Fig. 5, abnormalities are found.

3.2 Voltage drop of signal

The following figure and equations show the calculation of the potential difference at the idle time of '+' and '-' when the 5V and 3.3V equipment are constructed.

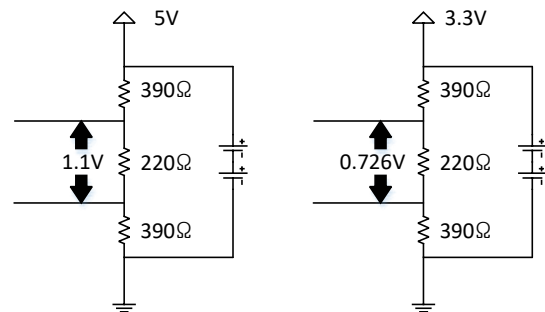


Fig. 6. Potential difference between 5V and 3.3V circuits

$$V_{out} = \frac{R_2}{R_1 + R_2 + R_3} \cdot V_{in} \quad (1)$$

a. 5V-based (left)

$$\frac{220\Omega}{(390\Omega + 220\Omega + 390\Omega)} \cdot 5V = 1.1V$$

b. 3.3V-based (right)

$$\frac{220\Omega}{(390\Omega + 220\Omega + 390\Omega)} \cdot 3.3V = 0.726V$$

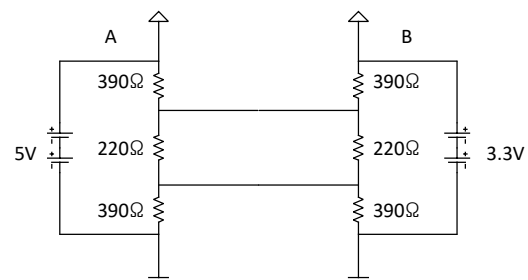


Fig. 7. 5V and 3.3V combination circuit

When the simulation is performed by configuring the circuit as shown Fig 7, the V_{OD} is about 1.914V, not 2.1V. This may lead to a blurring of the distinction between 1 and 0 in differential transmission.

Table II: Result of simulation

B sending	A (5V)		B (3.3V)	
	Vb	Va	Vb	Va
High	2.632V	0.681V	2.64V	0.66V
low	0.718V	2.594V	0.66V	2.64V

As can be seen from the results in Table II, when the high and low signals are transmitted from the 3.3V equipment, it is confirmed that the potential difference of the peak-to-peak is less than 2V in the receiving equipment. ($V_{pp} = 2.632 \text{ V} - 0.718 \text{ V} = 1.914 \text{ V}$)

3. Conclusions

In PROFIBUS-DP, the design of the termination resistor is very important to reduce the reflection effect. Note that the termination resistor of PROFIBUS-DP is designed for 5V-based.

PROFIBUS-DP can be connected to various equipment. However, you should not connect equipment that applies a different voltage to the bus. If a different voltage is applied, the signal becomes distorted due to the weakness of the disturbance. This distortion causes the entire system to fail.

PROFIBUS is a network from RS485, but V_{OD} and termination resistor design are different.

It is also completely different from the single ended design. In single ended, 3.3V is often applied in a 5V design. This is due to the use of blind spots where V_{Ref} is low. It is a very dangerous idea in PROFIBUS where the peak-to-peak of the signal voltage is important by applying a differential signal.

If you want to apply a voltage other than 5V, you must convert the bus contact to 5V for a stable network of PROFIBUS.

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