APPLICATION NOTES

TECHNICAL NOTE TN 494

MAXIMUM PERMISSIBLE LENGTHS OF ELECTRIC CABLES FOR THE CONNECTION OF HYDRAULIC VALVES WITH INTEGRATED ELECTRONICS

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1 Introduction

Usually, our hydraulic valves with integrated electronics are supplied with 24 V and are controlled via analog or digital signal cables.

This technical note shall assist in the dimensioning and design of the power and signal cabling, to ensure a sufficient supply voltage and signal quality under all permissible operating conditions.

The maximum permissible length of supply and signal cables is limited by the impedance (resistance and capacitance) of the cable.

2 Typ. values for copper cables

The typical values mentioned below are used in the exemplary calculations of the following sections.

2.1 Cable resistance

The typical resistance R_{typ} of a copper cable of the length ℓ is calculated as follows:

$$R_{typ} = \frac{\rho_{Cu}}{q_{typ}} \cdot \ell = 23.73 \, \frac{m\Omega}{m} \cdot \ell$$

where:

q_{typ} =	0,75 mm^2 (18 AWG)	typical cross-section of connection cables
ρ_{Cu} =	0,0178 $\frac{\Omega \, mm^2}{m}$	specific resistance of copper at 20 °C (68 °F)

2.2 Cable capacitance

The typical distributed capacitance of copper cables is 50 pF/m.
The typical capacitance C_{typ} of a copper cable of the length ℓ is calculated as follows:

$$C_{typ} = 50 \, \frac{pF}{m} \cdot \ell$$

3 24 Volt power supply cables

The maximum permissible length ℓ_{max} of the power supply cable is calculated as follows:

$$\ell_{max} = \frac{U_{ab\_max}}{\left(\frac{U_{ab}}{\ell}\right)_{typ}}$$

$$U_{ab\_max} = \ell_{max} \cdot \left(\frac{U_{ab}}{\ell}\right)_{typ}$$

where:

U_{ab_max} = 6 V	maximum permissible voltage drop over the supply cable U_{ab_max} = 24 V - U_{min}
U_{min} = 18 V	lowest permissible valve power supply voltage
$\left(\frac{U_{ab}}{\ell}\right)_{typ}$	length related voltage drop (⇨ "3.1 Length related voltage drop")

ⓘ This calculation does not include a potential reduction of the output voltage of the power supply due to the connected load. It does neither include the voltage drops, which may be caused by switching on further loads.

3.1 Length related voltage drop

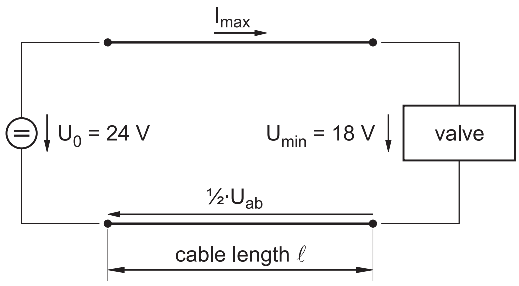

Figure 1: Voltage drop on the power supply cable

The length related voltage drop over the main and the return line of the supply cable is calculated as follows:

$$\left(\frac{U_{ab}}{\ell}\right)_{typ} = 2 \cdot I_{max} \cdot \left(\frac{R_{typ}}{\ell}\right) = 2 \cdot I_{max} \cdot 23.73 \, \frac{m\Omega}{m}$$

where:

I_{max}	maximum current consumption of the valve (can be taken from the operating instructions of the valve)
R_{typ}	typical cable resistance (⇨ "2.1 Cable resistance")
ℓ	supply cable length

3.2 Examples

Valve series	Max. current consumption I_{max}	Voltage drop $\left(\frac{U_{ab}}{\ell}\right)_{typ}$	Max. permissible cable length ℓ_{max}
D661	300 mA	14 mV/m	428 m (1,404 ft.)
D941	350 mA	17 mV/m	364 m (1,194 ft.)
D681	800 mA	38 mV/m	157 m (515 ft.)
D636/8	1200 mA	57 mV/m	106 m (347 ft.)
D634	2200 mA	104 mV/m	58 m (190 ft.)

4 Signal cables

4.1 Analog signal cables

4.1.1 Influence of the resistance R

Due to small values of signal currents, the influence of the resistance R of the cable used on the maximum permissible cable length ℓ_{max} for signal cables is very small.

Example:
In accordance with the following formula, the resistance R for a cable length of 428 m (1,404 ft.) is only 10 Ω.

$$R = \frac{\rho_{Cu}}{q_{typ}} \cdot \ell = 23.73\,\frac{m\Omega}{m} \cdot 428\ m \approx 10\ \Omega$$

4.1.2 Influence of the distributed capacitance

The influence of the distributed capacitance of the cable used on the maximum permissible cable length ℓ_{max} for signal cables is significantly larger.

This capacitance C increases with cable length. Together with the input resistance, it forms a first order high pass filter. High frequency interferences may be coupled into the input circuitry as a result. The cut-off frequency of the high pass is calculated as follows:

$$f_g = \frac{1}{2 \cdot \pi \cdot R \cdot C}$$

Thus, the filter cut-off frequency f_g of the high pass decreases with the length of cable.

Example:
A cable length ℓ of 10 m (32.8 ft.) a typical analog input resistance R of 10 kΩ results in accordance with the following formula in a cut-off frequency f_g of 32 kHz.

$$f_g = \frac{1}{2 \cdot \pi \cdot R \cdot C} = \frac{1}{2 \cdot \pi \cdot R \cdot 50\,\frac{pF}{m} \cdot \ell}$$

$$f_g = \frac{1}{2 \cdot \pi \cdot 10\ k\Omega \cdot 50\,\frac{pF}{m} \cdot 10\ m}$$

$$f_g = 32\ kHz$$

4.1.3 Recommendations

EMC testing according to EN 61000-6-2:2001-10 was performed using 10 m (32.8 ft.) of cable and a differential voltage command signal. The deviation of the spool position signal during interference testing (electromagnetic coupling, fast transients) was less than 1 %. This may increase when using longer cables.

Experience shows that with cables longer than 15 m, a current input configuration should be used. With this configuration, the input resistances are 50 times lower. The cut-off frequency f_g of the high pass filter (⇨ "4.1.2 Influence of the distributed capacitance") increases by the same factor. This leads to the input becoming less sensitive to interference.

Furthermore, when using a current input source there is no influence due to a voltage drop over the cable.

We always recommend a differential input configuration, irrespective of whether a current or voltage command is used. In this configuration, symmetrical interference on both input lines is effectively cancelled out.

4.2 Digital signal cables

4.2.1 Digital signal input cables

Signal input cables, for instance Valve Enable, are less critical regarding their length, because the signal currents are low (< 20 mA) and a greater signal-to-noise ratio is easier to achieve, because only two conditions/voltage level must be differentiated.

4.2.2 Digital signal output cables

The current in signal output cables, for instance Enable Acknowledgement or Error Signal, can be up to 1.5 A. In this case the voltage drop over the cable length cannot be disregarded. Therefore for these cables the same requirements are applicable as for the power cables (⇨ "3 24 Volt power supply cables").

4.2.3 Field bus cables

The maximum digital field bus cable lengths can vary immensely. Normally they are terminated by a low impedance to avoid signal reflection (power matching), which allows longer cables. The maximum permissible cable length for an individual field bus is defined in the respective standards and is, amongst other things, dependent on the data transmission rate.

For your notes.

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