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American National Standard

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**Compatibility of Analog  
Signals for Electronic  
Industrial Process  
Instruments**



ANSI/ISA-S50.1 — Compatibility of Analog Signals for Electronic Industrial Process Instruments

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## Preface

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This Preface is included for informational purposes and is not a part of ISA-S50.1.

This Standard has been prepared as a part of the service of ISA toward a goal of uniformity in the field of instrumentation. To be of real value, this document should not be static, but should be subject to periodic review. Toward this end, the Society welcomes all comments and criticisms, and asks that they be addressed to the Secretary, Standards and Practices Board, ISA, 67 Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709, Telephone (919) 549-8411, e-mail: standards@isa.org.

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# 1 Scope and purpose

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This standard applies to analog dc signals used in process control and monitoring systems to transmit information between subsystems or separated elements of systems.

Its purpose is to provide for compatibility between the several subsystems or separated elements of given systems.

This standard need not apply to signals entirely used within a subsystem. When signals are to be transmitted to or received from subsystems or elements provided by different suppliers, they shall comply with the specified requirements for transmitters and receivers herein.

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## 2 Definitions

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(Reference: I.E.C. publication 381)

### 2.1 Elements of process control systems

Elements which ensure the transducing, transmitting and processing of measured values, control quantities, controlled variables and reference variables. (Transmitters, indicators, controllers, recorders, computers, actuators, signal conditioners.)

### 2.2 Subsystems

Interconnected elements provided by a single supplier.

### 2.3 Analog dc current signal

A signal used for transmission which varies in a continuous manner according to one or several physical quantities.

### 2.4 Measured value of an analog dc current signal

The measured value of an analog dc current signal is its specified mean value during a stated duration.

### 2.5 Range of an analog dc current signal

The range of an analog dc current signal is determined by stating the lower and the upper limit of the signal current. (It is not intended that the output of the device be incapable of functioning beyond the limits stated in [Section 3](#).)

### 2.6 Lower limit

The lower limit of the signal current is the current corresponding to the minimum value of the dc current signal.

### 2.7 Upper limit

The upper limit of the signal current is the current corresponding to the maximum value of the dc current signal.

## **2.8 Load resistance**

The load resistance is the sum of the resistances of all connected receivers and the connection lines.

## **2.9 Ripple content**

The ripple content is the ratio between the peak to peak value of the ac part and the range of the dc current signal.

## **2.10 Signal common**

The signal common shall refer to a point in the signal loop which may be connected to the corresponding points of other signal loops. It may or may not be connected to earth ground.

## **2.11 Signal isolation**

Signal isolation refers to the absence of a connection between the signal loop and all other terminals and earth ground.

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# **3 Standard signals**

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## **3.1 Polarity**

The standard polarity for all signals shall be positive with respect to signal common, if any.

## **3.2 Transmitters**

The standard output signal shall be of a constant current nature having a range of 4 mA to 20 mA, dc (a 16 mA span).

## **3.3 Receivers**

**3.3.1** The standard current input signal shall be 4 mA to 20 mA, dc (a 16 mA span).

**3.3.2** The standard voltage input signal shall be 1 volt to 5 volt dc (a 4 volt span). See 5.1.2.

**3.3.3** The standard current output signal shall be of a constant current nature having a range of 4 mA to 20 mA, dc, and shall deliver rated current into any external load between zero and 600 ohms, minimum.

**3.3.4** The standard voltage output signal shall be 1 volt to 5 volt dc, and shall have a source resistance no higher than 250 ohms.

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# **4 Standard transmitters**

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## **4.1 General**

The purpose of this section is to establish a standard and uniform language with which the specific parameters of a transmitter can be described. This section is intended as a guide to



those who would use the standard values as a means of achieving compatibility between subsystems or separated elements of many possible systems configurations.

## 4.2 System compatibility

To achieve system compatibility, it is necessary to consider at least the following factors:

- a) The number of wires required for operation of the transmitter.
- b) The interdependence of the transmitter's load resistance capability and its power supply voltage.
- c) The transmitter's isolation characteristics.
- d) The transmitter's output signal ripple and noise.

## 4.3 Classification

All transmitters shall be identified using a type number and a class suffix as follows.

**4.3.1** The type number (2,3,4) will identify the number of wires required to provide power and output circuits for the transmitter. Shields and input circuit wiring will not be counted in determining the number designation. (See Fig. 1).

**4.3.2** The class suffix (H, L, or U) will identify the transmitter's load resistance capability with respect to its supply voltage according to Table 1.

**Table 1**

	<b>Class L</b>	<b>Class H</b>	<b>Class U</b>
Load resistance, ohms	300	800	300 to 800
Supply voltage, minimum	23	32.7	23 to 32.7

(See Appendix)

**4.3.2.1** Transmitters of type and class 2L, 3L or 4L shall be capable of delivering rated current into an external load resistance of at least 300 ohms when supplied with power at a minimum value of 23 V., dc (See Appendix.)

**4.3.2.2** Transmitters of type and class 2H, 3H or 4H shall be capable of delivering rated current into an external load resistance of at least 800 ohms when supplied with power at a minimum value of 32.7 V., dc (See Appendix).

**4.3.2.3** Transmitters of type and class 2U, 3U or 4U shall be a universal type able to comply with both paragraphs above, and therefore, able to operate at any intermediate voltage as well, with appropriate load.

**4.3.2.4** Transmitters of type 4 which are ac powered shall have their external load resistance capability designated by use of the subscript L for 300 ohms and H for 800 ohms when applied with ac power at the manufacturer's specified minimum value.

**4.3.2.5** Class L transmitters shall be able to work into zero load resistance without damage and without a requirement to set an internal rheostat or select a particular "load tap" to insert some internal limiting resistance.

**4.3.2.6** Class H and U transmitters may have a built-in energy limiting resistance for transmitter protection when loading resistance is too low. A special distinctively marked terminal or other means is allowed for bypassing this limit-resistance where manufacturer or user desires to accommodate a full 800 ohm external load resistance, or any "intrinsic safety" resistor.

## **4.4 Load resistance specification**

**4.4.1** The transmitter minimum load resistance capability shall be stated at 20 mA with respect to a selected power voltage. This shall include consideration, for its operation at its rated environmental limits and such a safety factor as the manufacturer considers proper.

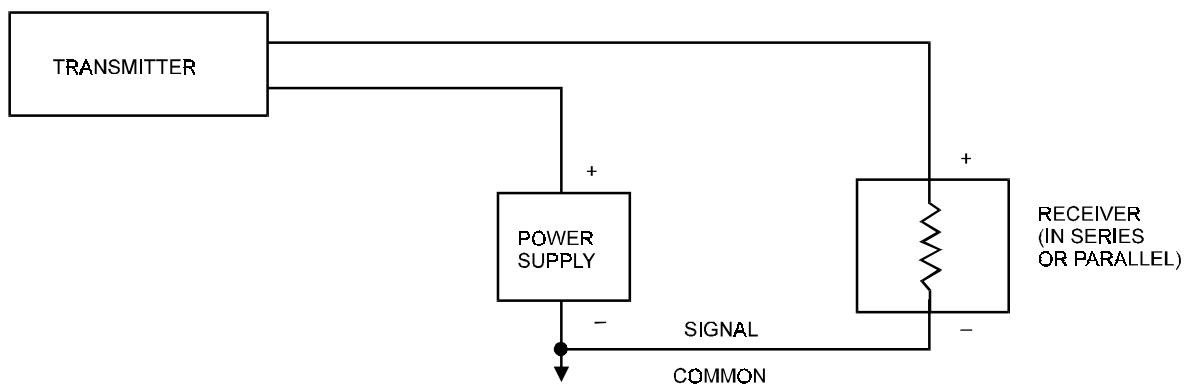
**4.4.2** The transmitter's maximum safe voltage capability shall be stated at its lowest output current capability, including input over-range conditions. This shall include consideration for its operation at its rated environmental limits and such a safety factor as the manufacturer considers proper.

## **4.5 Electrical isolation**

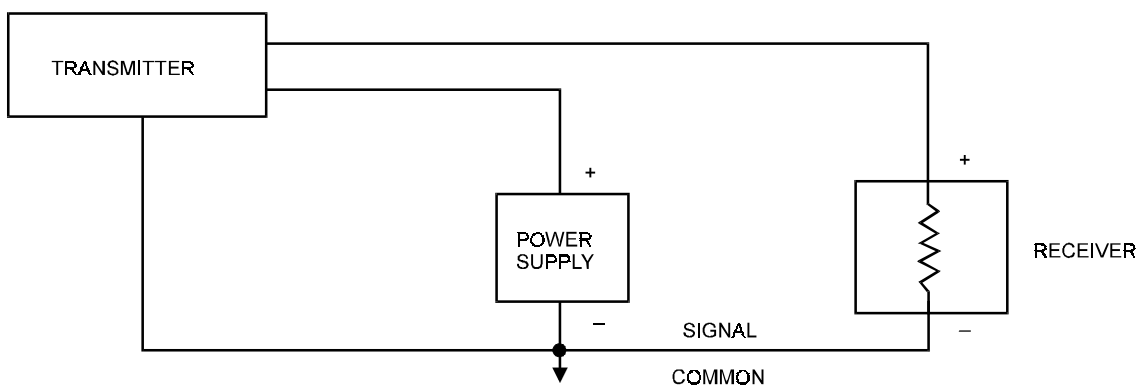
Isolation of transmitters shall be determined and specified in accordance with the following: (Refer to [Figure 2](#) for illustrations of the varied isolation categories: also see Appendix.)

**4.5.1** "Fully Isolated" shall mean that the power, output and electrical signal input terminals (where provided) are all electrically isolated from each other.

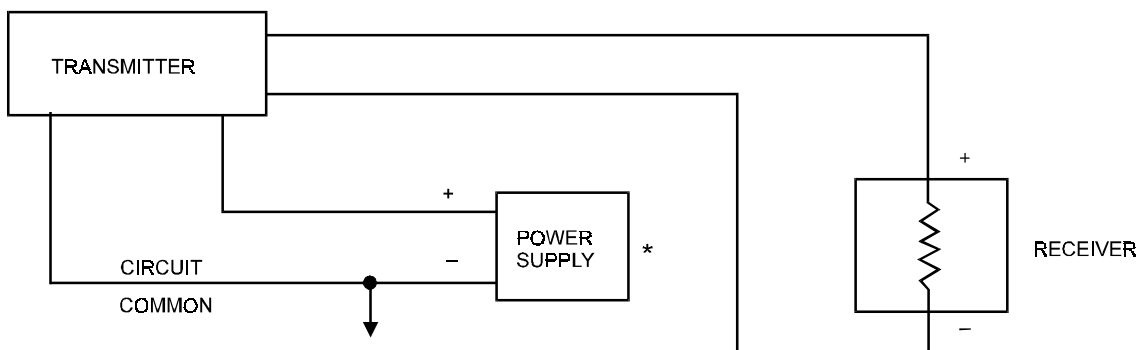
TYPE 2 - 2 WIRE CIRCUIT



TYPE 3 - 3 WIRE CIRCUIT

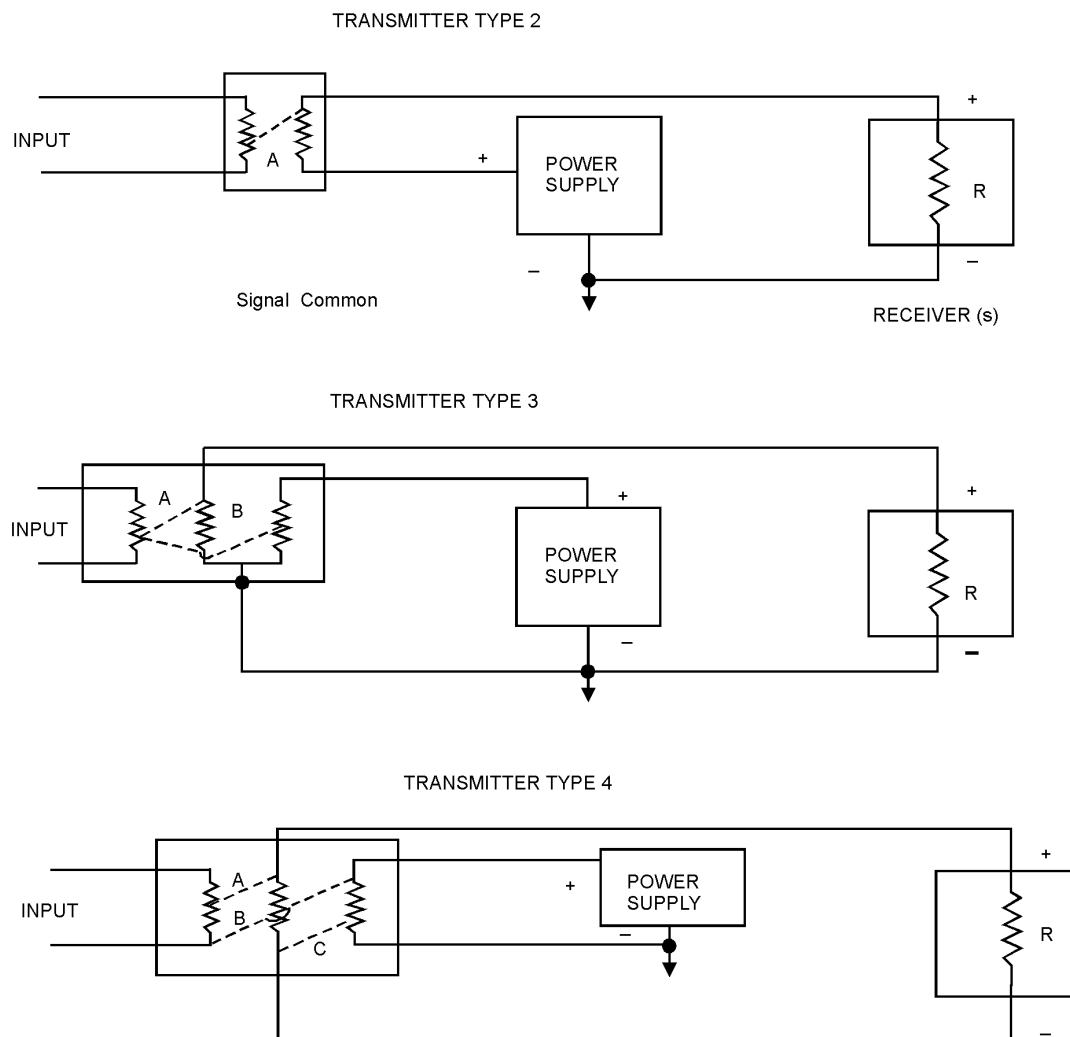


TYPE 4 - 4 WIRE CIRCUIT



\* OMIT POLARITY & CIRCUIT COMMON SYMBOL  
FOR AC POWERED TRANSMITTERS

**Figure 1 — Consideration of transmitter types**



EXISTENCE OF CONNECTION

For Transmitter Type	2	3	4		
Path	A	A B	A	B	C
Fully Isolated	N.A.	N.A.	No	No	No
Input Isolated	No	No No	No	No	Yes *
Output Isolated	N.A.	N.A.	No	Yes	No
Power Isolated	N.A.	N. A.	Yes	No	No
Non-Isolated	Yes	Yes Yes	Yes	Yes	Yes

N.A. = Not Applicable

\* Should use Type 3 in this case

Note: For transmitters not having an electrical input, an isolation category is only required for a Type 4 transmitter.

**Figure 2 — Consideration of electrical isolation for transmitters**

**4.5.2** "Input Isolated" shall mean that the signal input terminals are electrically isolated from all other terminals.

**4.5.3** "Output Isolated" shall mean that the output terminals are electrically isolated from all other terminals.

**4.5.4** "Power Isolated" shall mean that the power terminals are electrically isolated from all other terminals.

**4.5.5** "Electrically Isolated" in the above definition is used per the meaning in 2.11.

**4.5.6** "Non-Isolated" shall mean that electrical connections exist internally or externally between all terminals.

**4.5.7** "Grounded Output" shall mean that one side of the output signal will normally become grounded through the instrument mounting unless it is intentionally isolated from earth ground.

## **4.6 Ripple and noise content**

The peak to peak ripple and total noise level shall not exceed 0.25% of the maximum signal. This is further defined as not exceeding 10 mV peak to peak on a 5 volt signal (derived by resistive drop from a 20 mA signal, or a voltage signal) when measured at the output of a 10 Hz low pass, single stage R-C filter and when operated from a dc test power source having the maximum allowed ripple and noise permitted in 6.5.2, or from its normal ac power supply. (See Appendix.)

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## **5 Standard receivers**

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### **5.1 Inputs**

**5.1.1** Conversion of a standard current input signal to the standard voltage input signal may employ a resistor of 250 ohms  $\pm$  0.25 ohms having a temperature coefficient of not over 0.01%/°C.

**5.1.2** Receivers of less than 1 to 5 volt range can be operated from a tap on such a resistor as long as the receiver is designed with a live zero which is at 20% of full scale.

**5.1.3** A voltage receiver shall not alter the voltage drop across the standard 250 ohm input resistor by more than  $\pm$  4 mV.

**5.1.4** Receivers shall not be damaged by an input of 10 volts or 40 mA, whichever is applicable.

**5.1.5** Receivers may have less than 250 ohms resistance provided that they shall not be connected to signal common if a standard voltage signal for other receivers must also be developed from the same input current.

### **5.2 Outputs**

**5.2.1** When a dual independent current and voltage output signal are both provided by a receiver (such as controller), the load applied to the current output terminals can be required to be a fully isolated type.

**5.2.2** The peak to peak ripple and total noise level shall not exceed 0.25% of the maximum signal.

This is further defined as not exceeding 10 mV peak to peak on a 5 volt signal (derived by resistive drop from a 20 mA signal, or a voltage signal) when measured at the output of a 10 Hz low pass, single stage R-C filter and when operated from a dc test power source having the maximum allowed ripple and noise permitted in 6.5.2, or its normal ac power supply. (See Appendix.)

### 5.3 Isolation

Isolation of receivers shall be determined and specified in accordance with the terminology of 4.5, Electrical Isolation. (Refer to [Figure 3](#) for illustrations of the various isolation categories. Also see Appendix.)

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## 6 System

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### 6.1 Signal common

Signal common for the system will be specified as follows:

**6.1.1** For systems in which transmitters of type 2 and 3 are used, the circuit common, if any, shall be the negative terminal of the power supply and receiver signal. (See [Figure 1](#) and Appendix).

**6.1.2** For systems in which transmitters of type 4 are used, with dc power supplies, the negative terminal of the power supply will be connected to circuit common. (See [Figure 1](#) and Appendix).

**NOTE:** It is expected that circuit common will be earth grounded rather than left floating. See Appendix.

### 6.2 Power supplies

**6.2.1** It is not, at present, the intent of this Standard to define, specify, or standardize upon power supplies. The need for standard test power sources is recognized so as to provide a common reference for evaluation of transmitter and receiver performance.

**6.2.2** To comply with the most generally accepted standards for personnel safety, power supplies should be limited to an upper level of 42.4 volts dc or 30 volts rms ac (whose peak value is 42.4 volts).

**6.2.3** When ac powered equipment is designed for other than line voltage, a nominal 24 volts rms (+10 to -15%) is recommended. (See Appendix.)

### 6.3 Transmitters

Transmitters of types 2, 3, and 4 may be expected to share a common dc power supply or be connected to individual power supplies.

**6.3.1** Type 4 transmitters, when designed for ac operation, should employ the recommended nominal values stated in 6.2.3.

### 6.4 Receivers or signal processors

Receivers or signal processors may share a common dc power supply, or be operated from individual internal power supplies receiving their energy from ac power lines, or may receive a portion of their energy from both dc and ac power sources.

**6.4.1** Receivers, when designed for ac operation, should employ the recommended nominal values stated in 6.2.3.

## 6.5 Test power sources

**6.5.1** The standard dc test power source shall be variable between the limits of 23 volts and 42.4 volts.

**6.5.2** The ripple and other noise, peak to peak shall not exceed 1.0 percent of the test voltage when measured at the output of a 120 Hz single stage low pass R-C filter.

**6.5.3** The standard test power source for low voltage ac powered instruments shall be a nominal 24 volt rms (+10 to -15%), 50 or 60 Hz.

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## 7 Appendix

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This section is intended to provide supportive information for the sections of the Standard designated.

### 4.3.2 Load resistance—general purpose applications:

The 300 and 800 ohm values represent a commonly adequate need for receivers and line resistance drops. Many transmitters will have significantly greater load resistance capability. Additional capability permits the use of other instruments and accessory devices which may be necessary or desirable to use in specific control loops.

### 4.3.2 Load resistance—intrinsically safe applications:

A basic requirement for intrinsically safe applications is that the transmitter/power supply combination have sufficient load capability so as to permit the addition of the necessary current and voltage limiting to the loop. Many standard transmitter/power supply combinations will have such capability. Detailed specifications for intrinsic safety are beyond the scope of this Standard.

**4.3.2.1** The class L parameters were determined from the following considerations:

Transmitter minimum drop	12.0 volt
Receiver drop (250 ohms)	5.0 volt
Line drop (50 ohms)	1.0 volt
Intrinsic Safety Resistor (250 ohms)	<u>5.0 volt</u>
Total	23.0 volt

This standard recognizes that many systems have already been designed for use with a 24 volt nominal or minimum power supply voltage value, and is not suggesting that 23 volts is a necessarily desirable minimum voltage to which all systems should comply.

**4.3.2.2** The 32.7 volt supply for class H was determined by the consideration that a usual tolerance for an unregulated power supply is about +10 percent, -15 percent. If its upper limit is held to 42.4 volts for personnel safety, the lower limit calculates to be 32.7 volts. The 800 ohms resistance is obtained by considering that the extra 10 volts (approx.) allows 500 ohms additional loop resistance.

Minimum voltage means minimum available in the loop with system fully loaded and minimum power line voltage or a nearly discharged battery. Line drop in a common low voltage distribution system including fuses, circuit breakers, etc. must be taken into account.

#### **4.4.1 and 4.4.2 Load resistance**

The transmitter load resistance capability will decrease by 50 ohms for each 1 volt reduction in the power supply. Similarly, it will increase by 50 ohms per volt increase in the power supply, but must not exceed the safe voltage capability of the transmitters.

#### **4.5 and 5.3 Signal isolation**

This Standard assumes that future instrument systems including receivers may share a common power supply between several instrument loops and that their signal common may be interconnected and referenced to earth ground. To avoid "ground loop" errors, compliance with the following isolation requirements is essential unless signal isolators, individual floating power supplies or other special engineering techniques are employed.

- a) When grounded electrical input sensors are to be employed, type 2 and 3 transmitters should be specified as "input isolated" and type 4 transmitters should be specified as "fully isolated."
- b) When ungrounded electrical input sensors are to be employed, type 2 and 3 transmitters may be specified as "non-isolated," but "input isolated" designs provide more protection against an input ground which might subsequently occur. Type 4 transmitters should be specified as either "power isolated" or "input isolated," while again "fully isolated" provides the maximum protection against subsequent grounding faults.
- c) In no event should transmitters with "grounded output" per 4.5.7 be connected to grounded receivers. They require an isolator in the loop or floating receiver system.
- d) Specifying the correct isolation category is not necessarily sufficient. The Standard does not include interference rejection specifications, source resistance limitations, and such considerations which are felt to be beyond the practical scope of this standard.

#### **4.6 and 5.2.2 Ripple and noise**

The use of a defined bandwidth in measuring ripple and noise should result in less ambiguity and is a common practice in stating of noise performance specifications. For controllers and other analog receivers, dc to Hz is judged to be adequate for most applications and broader response is not normally provided by most manufacturers. Such devices should be designed to reject frequencies above the bandwidth of interest to the user.

The presence of higher frequency components should always be avoided as they are generally undesirable, even if they can be more easily removed by filtering.

### **6.1 Signal common**

**6.1.1** This section does not imply that the circuit commons of two or more transmitter-receiver loops must necessarily be joined together.

**6.1.2** Circuit common is not specified for the signal output of type 4 transmitters as it is expected that the purpose of this type is to permit the user to ground either polarity output or to leave the output floating if so desired. It does provide for an expected sharing of a common dc power supply, if desired.

### **6.2 Power supplies**

The range of adverse conditions within which the power supply must operate should be stated. Factors to be considered are:

Expected line voltage variation or interruption.



Expected frequency variation.

Expected ambient temperature variation.

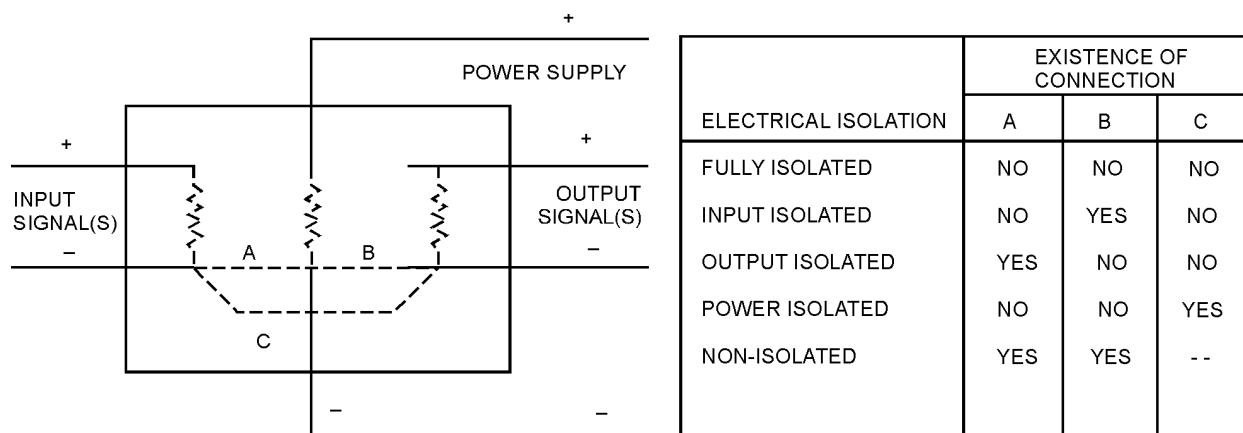
Expected maximum to minimum load swing.

R.F.I. chokes in the power supply leads might also be considered necessary. Fusing and overvoltage protection might also be desired, etc.

A power supply for intrinsic safety loops may also have some form of energy limiting means provided which may differ depending on equipment design.

These factors are considered to be outside the practical scope of this Standard.

Paragraph 6.2.3 is not intended to imply that normal line voltage powered transmitters are not acceptable or non-standard, but that when other than line voltage is to be used, 24 volts ac be the value. This would, of course, only apply to type 4 transmitters.



**Figure 3 — Consideration of electrical isolation for receivers**





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