APPLICATION NOTE

Practical Signal Isolation of 4-20mA Signals

How to isolate your 4-20mA signals without affecting loop integrity

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Table of Contents

Abstract

A ubiquitous problem with every industrial plant is the interface of plant measurement signals to the monitoring and control systems.

Unfortunately for many plants this is the single biggest area of weakness and with the success of the organisation depending on these measurements, more attention should be afforded to the integrity of signal conditioning systems.

This paper provides practical guidelines on when and how to introduce signal isolation into 4-20mA loops without affecting loop integrity.

What is the problem?

A ubiquitous problem with every industrial plant is the interface of plant measurement signals to the monitoring and control systems.

Unfortunately for many plants this is the single biggest area of weakness and with the success of the organisation depending on these measurements, more attention should be afforded to the integrity of signal conditioning systems.

The problems faced by these systems are numerous:

- Aged Cabling and Interfaces
- Long Cable Runs
- Earth Loops
- Interference from other plant devices
- Floating Earth Potentials
- Isolation of signals from PLC, SCADA and DCS
- Legacy Instrumentation
- Isolate Grounded Equipment
- Adding Instruments to existing Loops
- Poor Design
- Converting current loops into accurate 1-5V
- Protecting against open circuit loops
- Load dependency calibration

The consequences are even more onerous on the bottom line

* Damaged PLCs and DCS front ends costs $$$
* Downtime losses $$$
* Inaccurate readings affect plant efficiency - loss $$$
* Heavy Reactive Plant Troubleshooting and Maintenance Load- Loss $$$

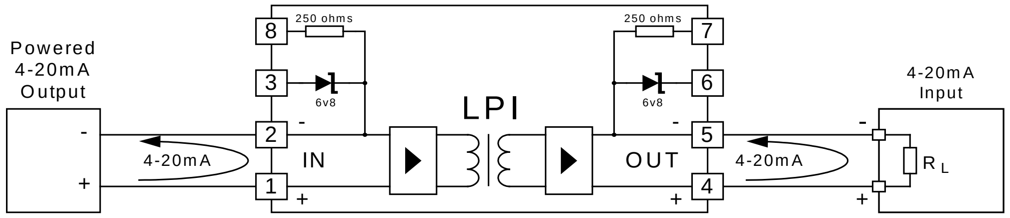
Many well informed Plant Owners and System Integrators fit signal conditioning interfaces as standard during the design phase – the increase in cost on the signal interface more than pays for itself later in productivity and reliability. This is often sacrificed and traded off in the initial design.

Omniflex has accumulated 40+ years of experience in signal conditioning system design and has produced many innovative products in this particular field.

Retrofitting this to plant is easy with DIN rail mounted modules which can be located in marshalling panels or termination boxes. A compendium of common plant interface problems is addressed using Loop Powered Isolators in the following applications.

Each one addresses a different application area including inputs and outputs, isolation and termination.

Application 1:
Using an Omniterm LPI to isolate a powered 4-20mA transmitter output from a resistive load



This is the basic circuit for inserting a Loop Powered Isolator (LPI) into a current loop. The LPI can simply be “cut” into any existing current loop to isolate the current transmitter from the load.

NOTE: The “IN” side of the LPI is always connected to the side of the loop supplying the loop power.

The LPI will consume less than 3 Volts of the available loop voltage. This is equivalent to inserting less 150 ohms of additional resistance into the current loop.

To determine the maximum loop resistance that you can tolerate in your cabling, apply the following formula:

$$R_{MAX} = R_T - R_L - 150$$

where:

R_{MAX} is the maximum resistance in the loop without causing measurement error.

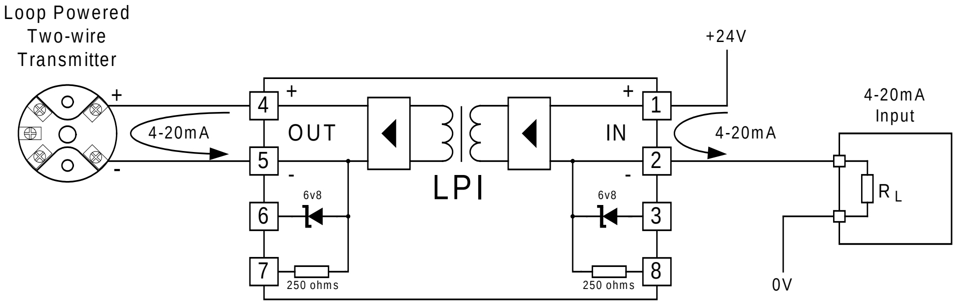
R_T is the maximum load resistance that the current transmitter can drive.

R_L is the total resistance of all loads in the loop (excluding the LPI)

For reliable operation over the long term, you should design for less initial cable resistance than this maximum value. This provides a safety factor to account for increase in resistance of terminations and wiring with age/weathering etc.

A sensible value to use for this safety factor would be 100 ohms (equal to 2 Volts at 20mA).

Application 2:
Using the Omniterm LPI to isolate a field mounted 4-20mA two-wire transmitter from a PLC, RTU or DCS



This is the basic circuit for isolating a field-mounted two-wire transmitter from the control circuitry using an LPI. The LPI can simply be “cut” into any existing two-wire current loop to isolate the transmitter from the panel power supply.

NOTE: The “IN” side of the LPI is always connected to the side of the loop supplying the loop power, so in this application the two-wire transmitter is connected to the OUT terminals of the LPI.

Because of the $2mm^2$ wire size capability of the LPI terminals, the LPI can also act as the field interface terminals, saving you the extra termination and wiring cost. For multiple loops where space is a concern, use the LPD dual module. (See Application 7, 8 and 9)

The LPI will consume less than 3 Volts of the available loop voltage. This is equivalent to inserting less 150 ohms of additional resistance into the current loop.

To determine the maximum loop resistance that you can tolerate in your cabling, apply the following formula:

$$R_{MAX} = \frac{(V_{S\min} - V_{T\min})}{.02} - R_L - 150$$

where:

R_{MAX} is the maximum resistance in the loop without causing measurement error (in Ohms).

V_{Smin} is the minimum voltage of the power supply used to drive the loop (in Volts).

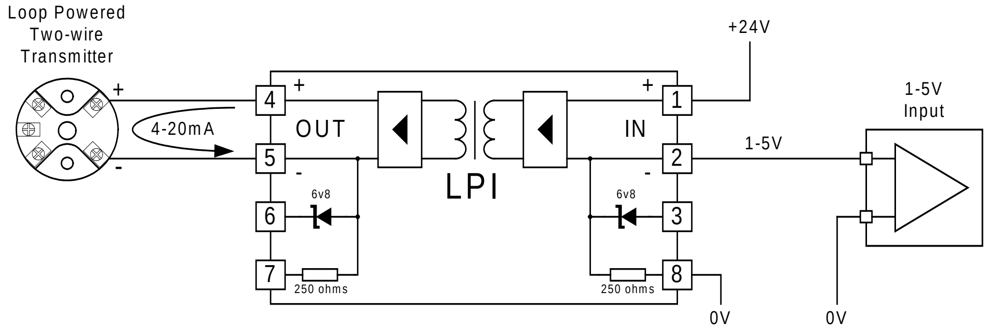
V_{Tmin} is the minimum voltage required by the two-wire transmitter for operation (in Volts).

R_L is the total resistance of all loads in the loop (excluding the LPI) (in Ohms)

For reliable operation over the long term, you should design for less initial cable resistance than this maximum value. This provides a safety factor to account for increase in resistance of terminations and wiring with age/weathering etc.

A sensible value to use for this safety factor would be 100 ohms (equal to 2 Volts at 20mA).

Application 3:
Using the LPI's internal resistor with a 2 wire transmitter to provide 1-5V to your PLC/RTU/DCS



There are many cases when using 4-20mA inputs to your PLC or RTU or DCS is inconvenient. For example:

1. Your analogue input does not support 4-20mA, and mounting an external resistor is inconvenient.
2. Your analogue input has plug in terminals, and you do not want to lose power to your field transmitter or disrupt the loop if the terminal block is unplugged.

In these cases you can use the internal resistor on the IN side of the LPI to conveniently convert your 4-20mA signal into a 1-5V signal. For the most accurate result, ensure that the 0V reference of the LPI (terminal 8), and the 0V reference of your analogue input are referenced to the same point. NOTE: The "IN" side of the LPI is always connected to the side of the loop supplying the loop power, so in this application the two-wire transmitter is connected to the OUT terminals of the LPI.Because of the 2mm^2 wire size capability of the LPI terminals, the LPI can also act as the field interface terminals, saving you the extra termination and wiring cost.

The LPI will consume less than 3 Volts of the available loop voltage. This is equivalent to inserting less 150 ohms of additional resistance into the current loop.

To determine the maximum loop resistance that you can tolerate in your cabling in this application, apply the following formula:

$$R_{MAX} = \frac{(V_{S\min} - V_{T\min})}{.02} - 400$$

where:

R_{MAX} is the maximum resistance in the loop without causing measurement error (in Ohms).

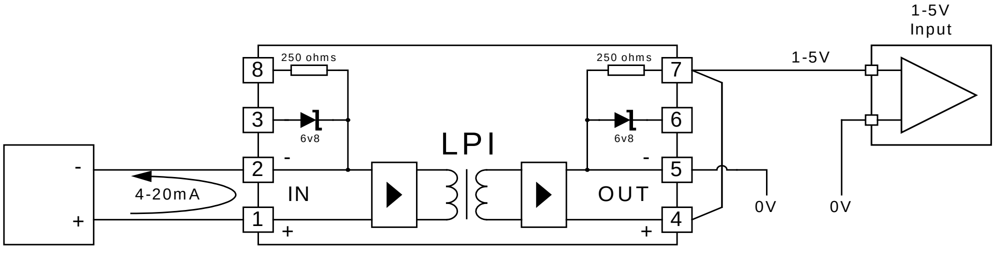
V_{Smin} is the minimum voltage of the power supply used to drive the loop (in Volts).

V_{Tmin} is the minimum voltage required by the two-wire transmitter for operation (in Volts).

For reliable operation over the long term, you should design for less initial cable resistance than this maximum value. This provides a safety factor to account for increase in resistance of terminations and wiring with age/weathering etc.

A sensible value to use for this safety factor would be 100 ohms (equal to 2 Volts at 20mA).

Application 4:
Using the LPI's internal resistor with a 4 wire transmitter to provide 1-5V to your PLC/RTU/DCS



There are many cases when using 4-20mA inputs to your PLC or RTU or DCS is inconvenient. For example:

1. Your analogue input does not support 4-20mA, and mounting an external resistor to convert the signal to 1-5V is inconvenient.
2. Your analogue input has plug in terminals, and you do not want to lose power to your field transmitter or disrupt the loop if the terminals are unplugged.

In these cases you can use the internal resistor on the OUT side of the LPI to conveniently convert your 4-20mA signal into a 1-5V signal.

For the most accurate result, ensure that the 0V reference to the LPI (terminal 5), and the 0V reference of your analogue input are referenced to the same point.

NOTE: The "IN" side of the LPI is always connected to the side of the loop supplying the loop power, so in this application the four-wire transmitter is connected to the IN terminals of the LPI.

Because of the 2mm^2 wire size capability of the LPI terminals, the LPI can also act as the field interface terminals, saving you the extra termination and wiring cost.

The LPI will consume less than 8 Volts of the available loop voltage. This is equivalent to inserting less than 400 ohms of resistance into the current loop.

To determine the maximum loop resistance that you can tolerate in your cabling in this application, apply the following formula:

$$R_{MAX} = R_T - 400$$

where:

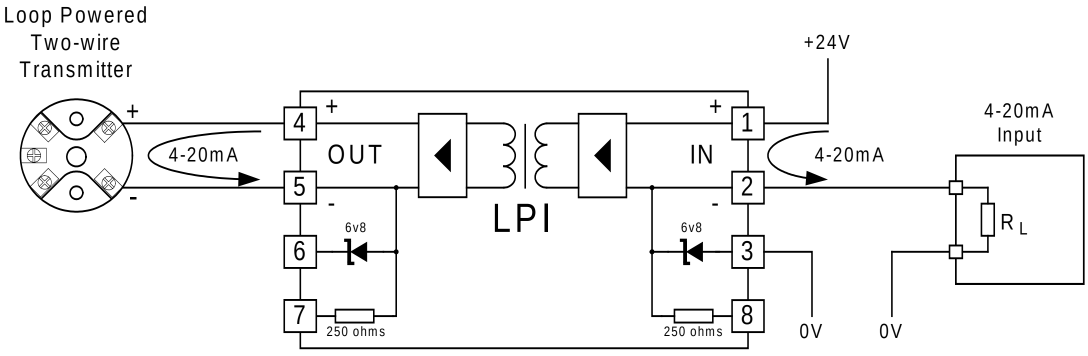
R_{MAX} is the maximum resistance in the loop without causing measurement error (in Ohms).

R_T is the maximum load resistance that the current transmitter can drive (in Ohms).

For reliable operation over the long term, you should design for less initial cable resistance than this maximum value. This provides a safety factor to account for increase in resistance of terminations and wiring with age/weathering etc.

A sensible value to use for this safety factor would be 100 ohms (equal to 2 Volts at 20mA).

Application 5:
Using the LPI's internal clamp with a 2 wire transmitter to protect the loop against open circuit.



There are cases, when using 4-20mA inputs to your PLC, RTU or DCS, where it is important that the current loop is not disrupted when the analogue input to your PLC or RTU or DCS is unplugged or disconnected.

In these cases you can use the internal clamp of the LPI to protect the loop from open circuit if your PLC or RTU or DCS input is unplugged or disconnected. This is simply achieved by connecting the input clamp terminal 3 to your 0V reference. If the analogue input to your PLC or RTU or DCS is disconnected, the current will be diverted to 0V through the clamp, saving the current loop from disconnection.

The voltage across the LPI will be clamped to 6.8Volts in this condition – only slightly higher than the normal operating voltage of 1-5 Volts. This higher clamp voltage should be used when calculating maximum allowable loop resistance. NOTE: The "IN" side of the LPI is always connected to the side of the loop supplying the loop power, so in this application the two-wire transmitter is connected to the OUT terminals of the LPI.

Because of the $2mm^2$ wire size capability of the LPI terminals, the LPI can also act as the field interface terminals, saving you the extra termination and wiring cost.

To determine the maximum loop resistance of your cabling that you can tolerate in your loop with the clamp in operation, apply the following formula:

$$R_{MAX} = \frac{(V_{S\min} - V_{T\min})}{.02} - 500$$

where:

R_{MAX} is the maximum resistance in the loop without causing measurement error (in Ohms).

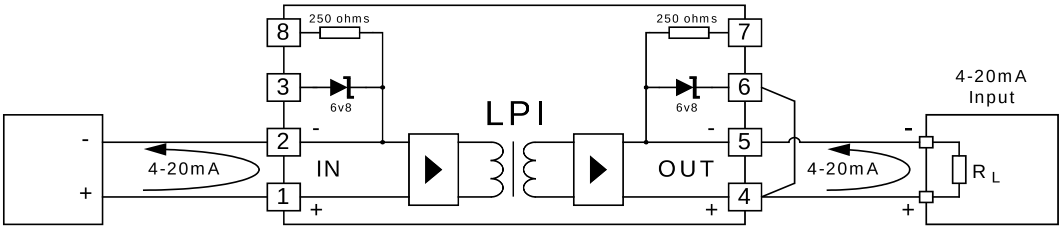
V_{Smin} is the minimum voltage of the power supply used to drive the loop (in Volts).

V_{Tmin} is the minimum voltage required by the two-wire transmitter for operation (in Volts).

For reliable operation over the long term, you should design for less initial cable resistance than this maximum value. This provides a safety factor to account for increase in resistance of terminations and wiring with age/weathering etc.

A sensible value to use for this safety factor would be 100 ohms (equal to 2 Volts at 20mA).

Application 6:
Using the LPI's internal clamp with a 4 wire transmitter to protect the loop against open circuit.



When using 4-20mA inputs to your PLC, RTU or DCS, there are cases where it is important that the current loop is not disrupted when the analogue input to your PLC or RTU or DCS is unplugged or disconnected.

In these cases you can use the internal clamp of the LPI to protect the loop from open circuit if your PLC or RTU or DCS input is unplugged or disconnected.

In four-wire current transmitter applications this is simply achieved by connecting the output clamp terminal 6 to the current output terminal 4 of the LPI. If the analogue input to your PLC or RTU or DCS is disconnected, the current will be diverted through the clamp, saving the current loop from disconnection.

The voltage across the LPI will be clamped to 6.8Volts in this condition – slightly higher than the normal operating voltage of 1-5 Volts. This higher clamp voltage should be used when calculating maximum allowable loop resistance.

NOTE: The "IN" side of the LPI is always connected to the side of the loop supplying the loop power, so in this application the four-wire transmitter is connected to the IN terminals of the LPI.

Because of the 2mm^2 wire size capability of the LPI terminals, the LPI can also act as the field interface terminals, saving you the extra termination and wiring cost.

To determine the maximum loop resistance of your cabling that you can tolerate in your loop with the clamp in operation, apply the following formula:

$$R_{MAX} = R_T - 500$$

where:

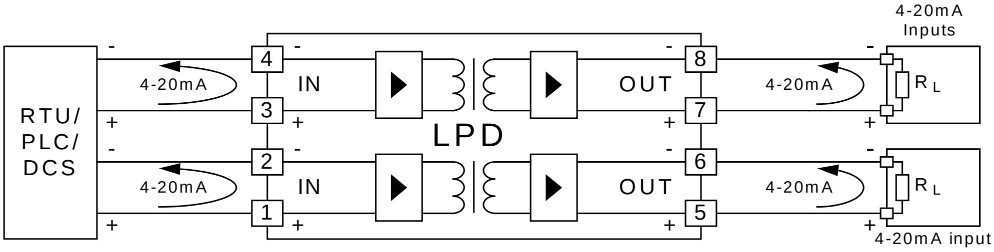
R_{MAX} is the maximum resistance in the loop without causing measurement error (in Ohms).

R_T is the maximum load resistance that the current transmitter can drive (in Ohms).

For reliable operation over the long term, you should design for less initial cable resistance than this maximum value. This provides a safety factor to account for increase in resistance of terminations and wiring with age/weathering etc.

A sensible value to use for this safety factor would be 100 ohms (equal to 2 Volts at 20mA).

Application 7:
Using the LPD to isolate multiple 4-20mA Outputs from a PLC or DCS



In this application, the LPD can be inserted directly into the 4-20mA output loops between the transmitter and the load.

Each LPD circuit will consume less than 3Volts from the loop. For loop resistance calculation purposes this is equivalent to inserting an additional resistance of 150 ohms into the current loop.

NOTE: The “IN” side of the LPD is always connected to the side of the loop supplying the loop power, and so in this application, the Transmitter outputs are connected to the IN side of the LPD.

Because of the 2mm^2 wire size capability of the LPI terminals, the LPI can also act as the field interface terminals, saving you the extra termination and wiring cost.

To determine the maximum loop resistance of your cabling that you can tolerate in your loop, apply the following formula:

$$R_{MAX} = R_T - R_L - 150$$

where:

R_{MAX} is the maximum resistance in the loop without causing measurement error (in ohms).

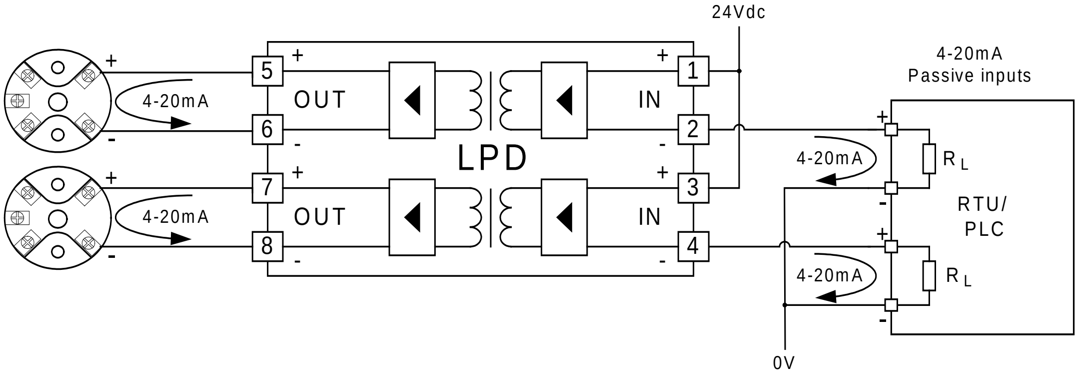
R_T is the maximum load resistance that the current transmitter can drive (in ohms).

R_L is the total resistance of all loads in the loop (excluding the LPI) (in Ohms)

For reliable operation over the long term, you should design for less initial cable resistance than this maximum value. This provides a safety factor to account for increase in resistance of terminations and wiring with age/weathering etc.

A sensible value to use for this safety factor would be 100 ohms (equal to 2 Volts at 20mA).

Application 8:
Using the LPD to isolate multiple 4-20mA inputs to a PLC or RTU (with passive inputs)



In this application, the LPD can be inserted directly into the 4-20mA input loops between the field mounted two-wire transmitter and the PLC or RTU input.

Each LPD circuit will consume less than 3Volts from the loop. For loop resistance calculation purposes this is equivalent to inserting an additional resistance of 150 ohms into the current loop.

NOTE: The "IN" side of the LPD is always connected to the side of the loop supplying the loop power, and so in this application, the two-wire transmitters are connected to the OUT side of the LPD.

Because of the 2mm^2 wire size capability of the LPD terminals, the LPD can also act as the field interface terminals, saving you the extra termination and wiring cost.

To determine the maximum loop resistance of your cabling that you can tolerate in your loop, apply the following formula:

$$R_{MAX} = \frac{(V_{S\min} - V_{T\min})}{.02} - R_L - 150$$

where:

R_{MAX} is the maximum resistance in the loop without causing measurement error (in Ohms).

V_{Smin} is the minimum voltage of the power supply used to drive the loop (in Volts).

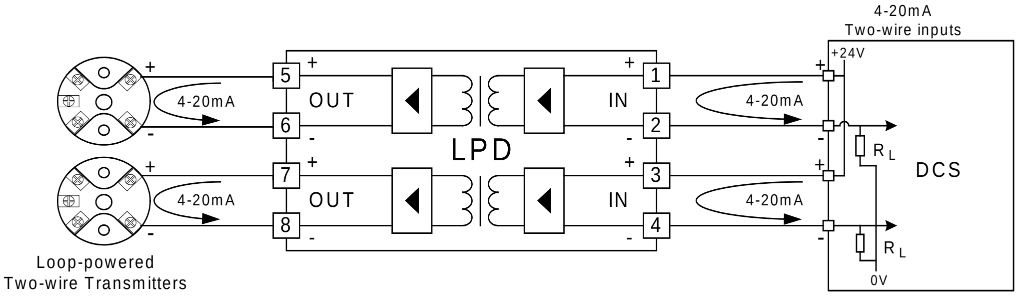
V_{Tmin} is the minimum voltage required by the two-wire transmitter for operation (in Volts).

R_L is the resistance of the PLC/RTU input (in Ohms)

For reliable operation over the long term, you should design for less initial cable resistance than this maximum value. This provides a safety factor to account for increase in resistance of terminations and wiring with age/weathering etc.

A sensible value to use for this safety factor would be 100 ohms (equal to 2 Volts at 20mA).

Application 9:
Using the LPD to isolate multiple 4-20mA inputs to a DCS with active (two-wire tx) inputs.



In this application, the LPD can be inserted directly into the 4-20mA input loops between the field mounted two-wire transmitter and the DCS input.

Each LPD circuit will consume less than 3Volts from the loop. For loop resistance calculation purposes this is equivalent to inserting an additional resistance of 150 ohms into the current loop.

NOTE: The “IN” side of the LPD is always connected to the side of the loop supplying the loop power, and so in this application, the two-wire transmitters are connected to the OUT side of the LPD.

Because of the 2mm^2 wire size capability of the LPD terminals, the LPD can also act as the field interface terminals, saving you the extra termination and wiring cost.

To determine the maximum loop resistance of your cabling that you can tolerate in your loop, apply the following formula:

$$R_{MAX} = \frac{(V_{S\min} - V_{T\min})}{.02} - R_L - 150$$

where:

R_{MAX} is the maximum resistance in the loop without causing measurement error (in Ohms).

V_{Smin} is the minimum voltage of the power supply used to drive the loop (in Volts).

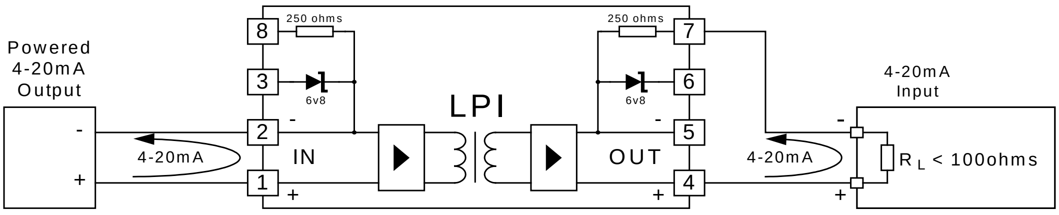
V_{Tmin} is the minimum voltage required by the two-wire transmitter for operation (in Volts).

R_L is the resistance of the PLC/RTU input (in Ohms)

For reliable operation over the long term, you should design for less initial cable resistance than this maximum value. This provides a safety factor to account for increase in resistance of terminations and wiring with age/weathering etc.

A sensible value to use for this safety factor would be 100 ohms (equal to 2 Volts at 20mA).

Application 10:
Dealing with zero loop resistance when using the LPI.



The LPI is optimised to minimise the effective inserted loop impedance, but does require a minimum of 100 ohms of load impedance, (or 2 volts) on the output to maintain operation.

In some applications, when using four-wire transmitters, the load being driven is lower than this minimum value, and additional load needs to be inserted into the output loop to bring the minimum load up to the required 100 ohms.

One solution for this is to use the internal 250 ohm resistor to provide this additional resistance. When connected as shown in the diagram above, the internal resistor is used in series with the current loop to provide an additional 250 ohms of loop resistance. This brings the LPI back into specification without the need for any additional resistors.

NOTE: The "IN" side of the LPI is always connected to the side of the loop supplying the loop power, so in this application the four-wire transmitter is connected to the IN terminals of the LPI.

Because of the 2mm^2 wire size capability of the LPI terminals, the LPI can also act as the field interface terminals, saving you the extra termination and wiring cost.

To determine the maximum loop resistance of your cabling that you can tolerate in your loop with the clamp in operation, apply the following formula:

$$R_{MAX} = R_T - R_L - 400$$

where:

R_{MAX} is the maximum resistance in the loop without causing measurement error (in Ohms).

R_T is the maximum load resistance that the current transmitter can drive (in Ohms).

R_L is the resistance of the connected load (in Ohms)

For reliable operation over the long term, you should design for less initial cable resistance than this maximum value. This provides a safety factor to account for increase in resistance of terminations and wiring with age/weathering etc.

A sensible value to use for this safety factor would be 100 ohms (equal to 2 Volts at 20mA).

