

# Introduction to 4-20mA Current Loop Transmitters

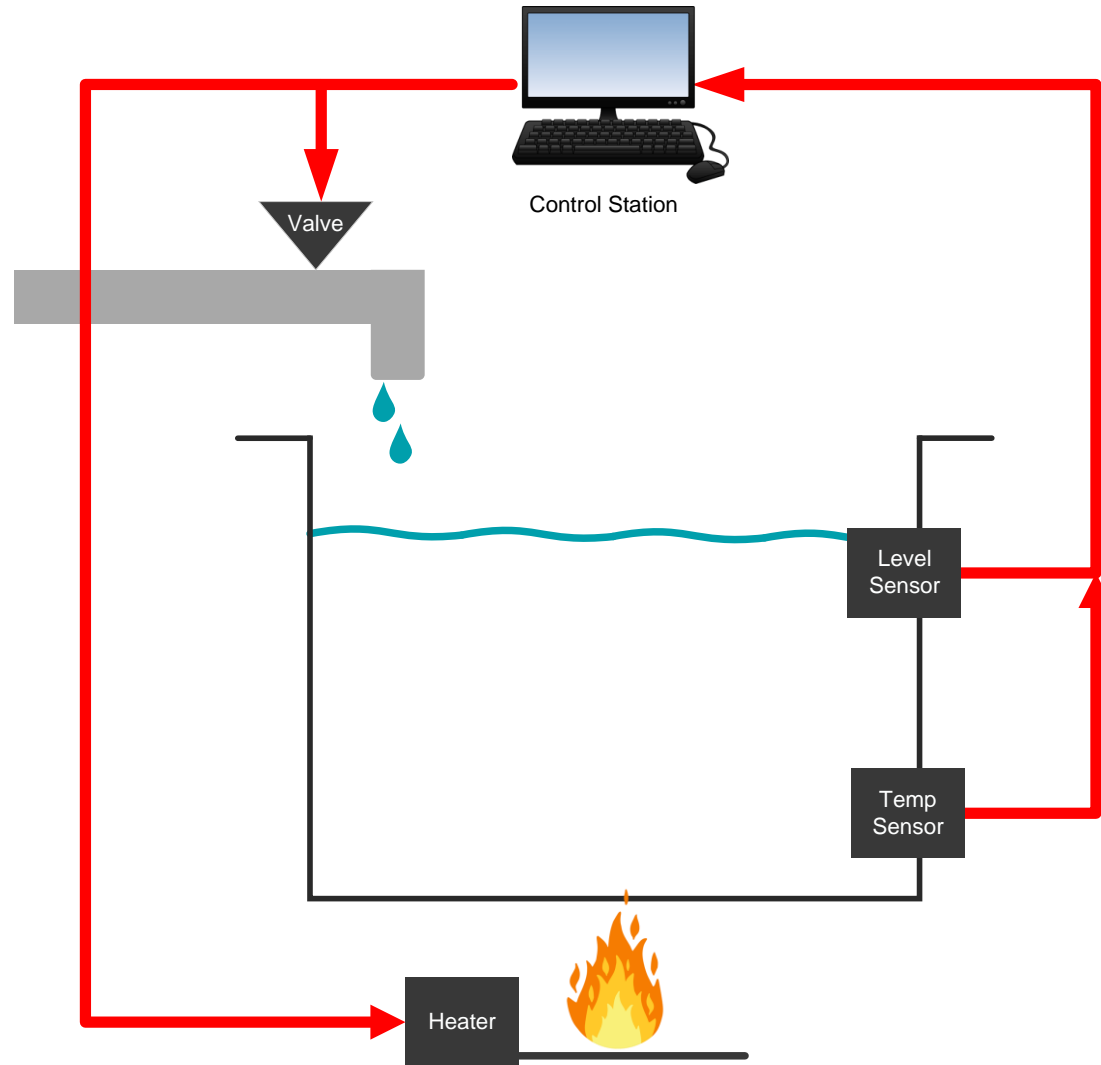
TI Precision Labs – Current Loop Transmitters

Presented by Katlynne Jones

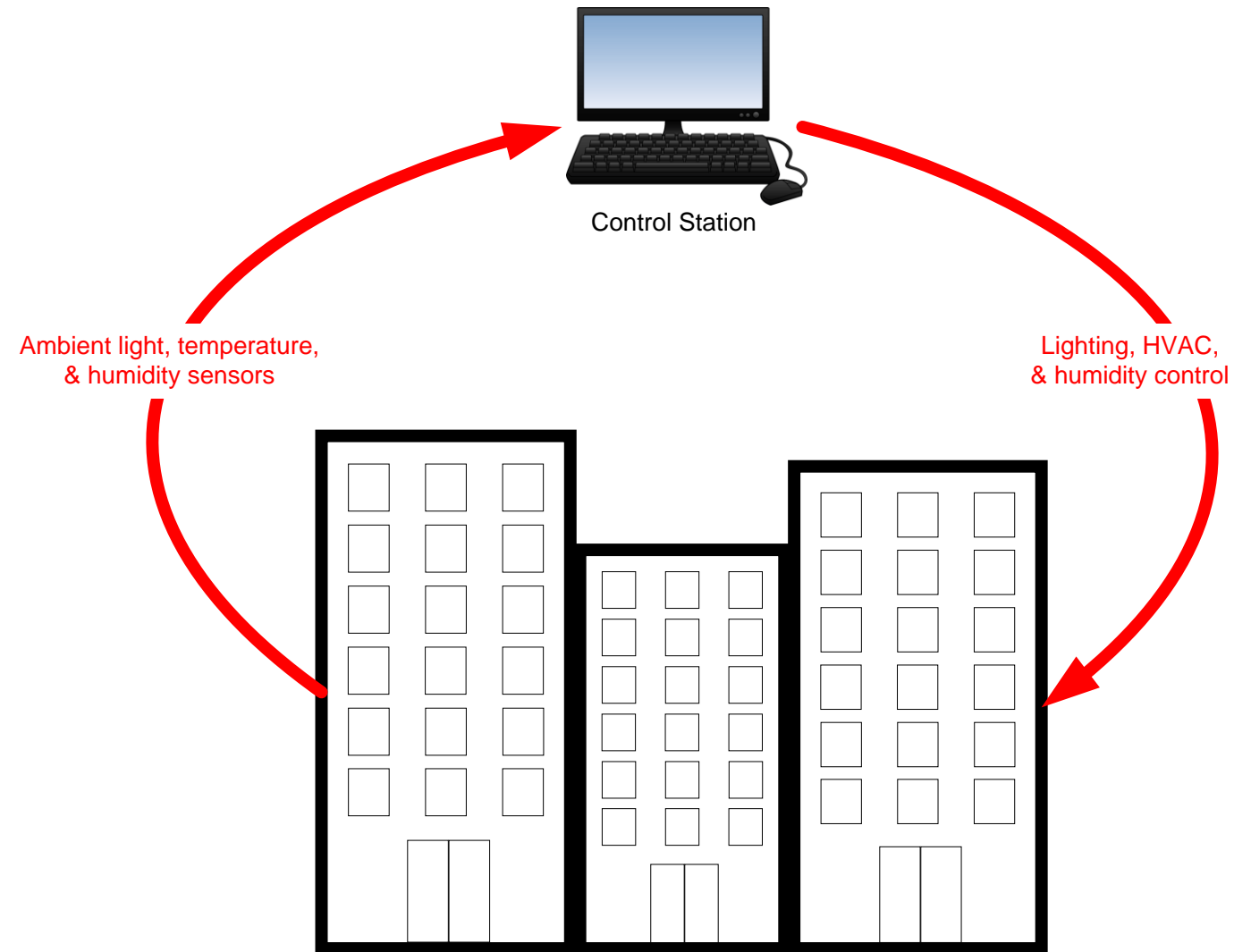
Prepared by Katlynne Jones

# Current transmitter applications

## Industrial automation

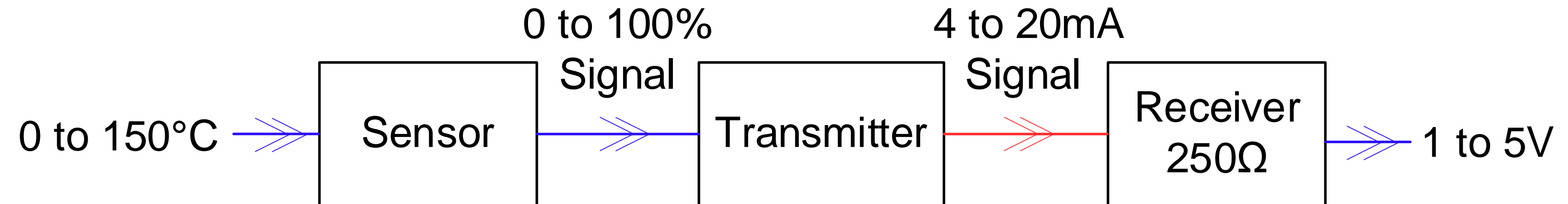


## Building automation



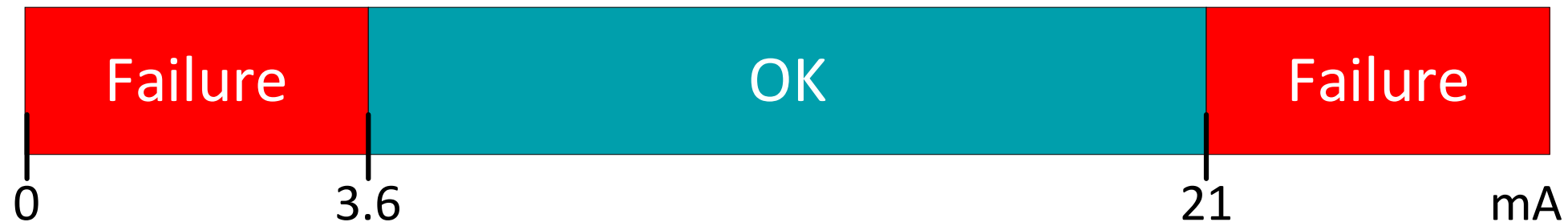
# 4-20mA overview

- 4mA represents 0% input level
  - Allows up to 4mA to power external input circuitry
  - 4mA zero level allows under-scale settings and fault detection
- 20mA represents 100% input level
  - Over-scale can also be used to detect fault conditions



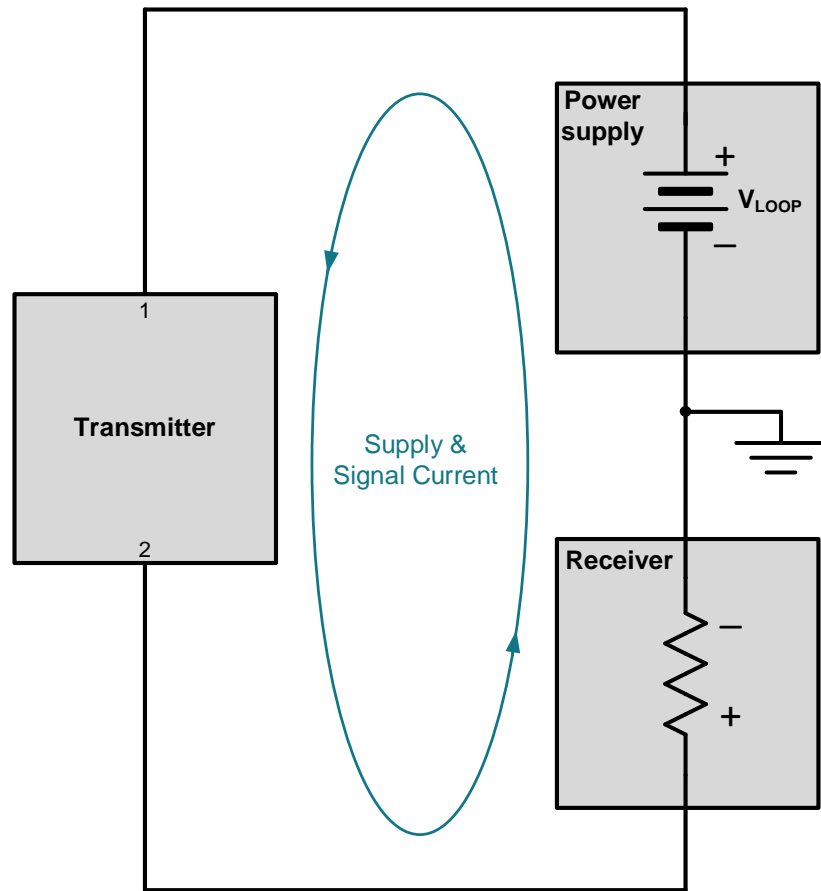
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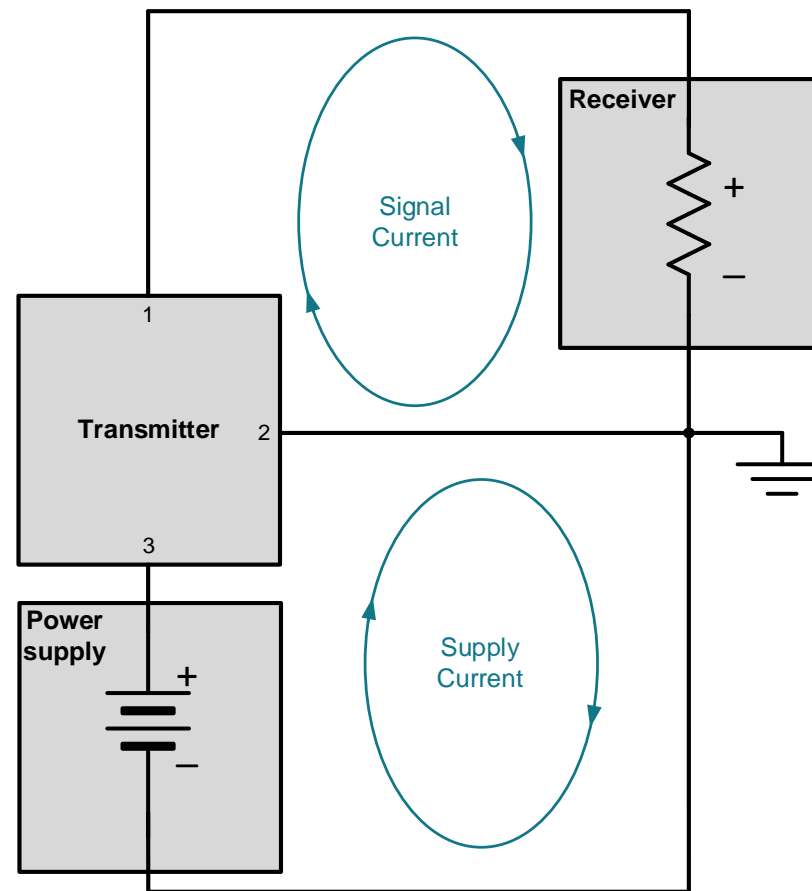


# Transmitter configurations

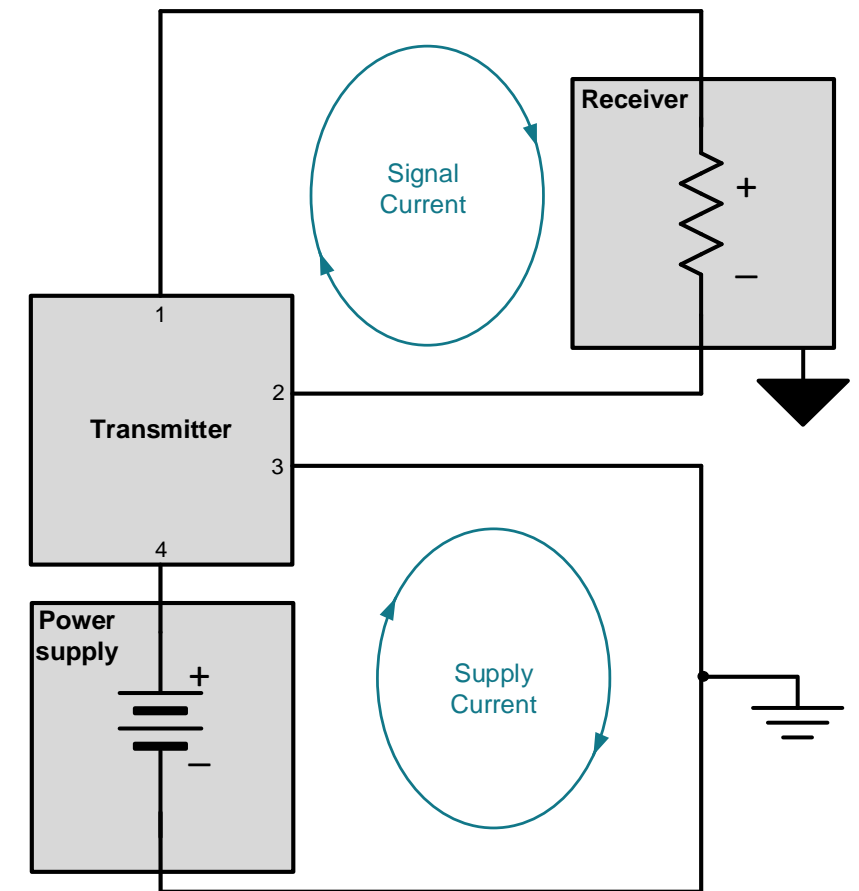
## 2-wire block diagram



## 3-wire block diagram



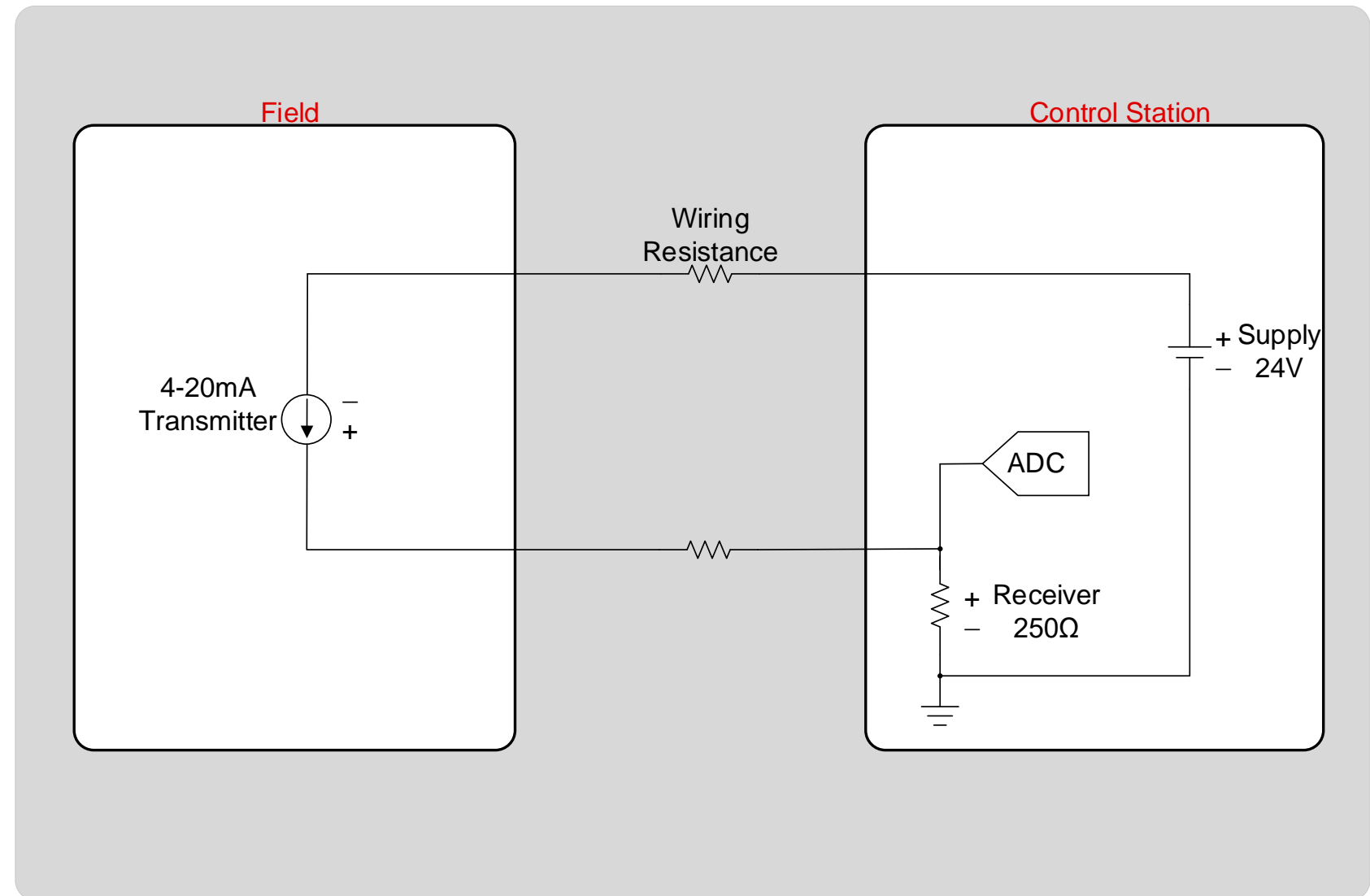
## 4-wire block diagram





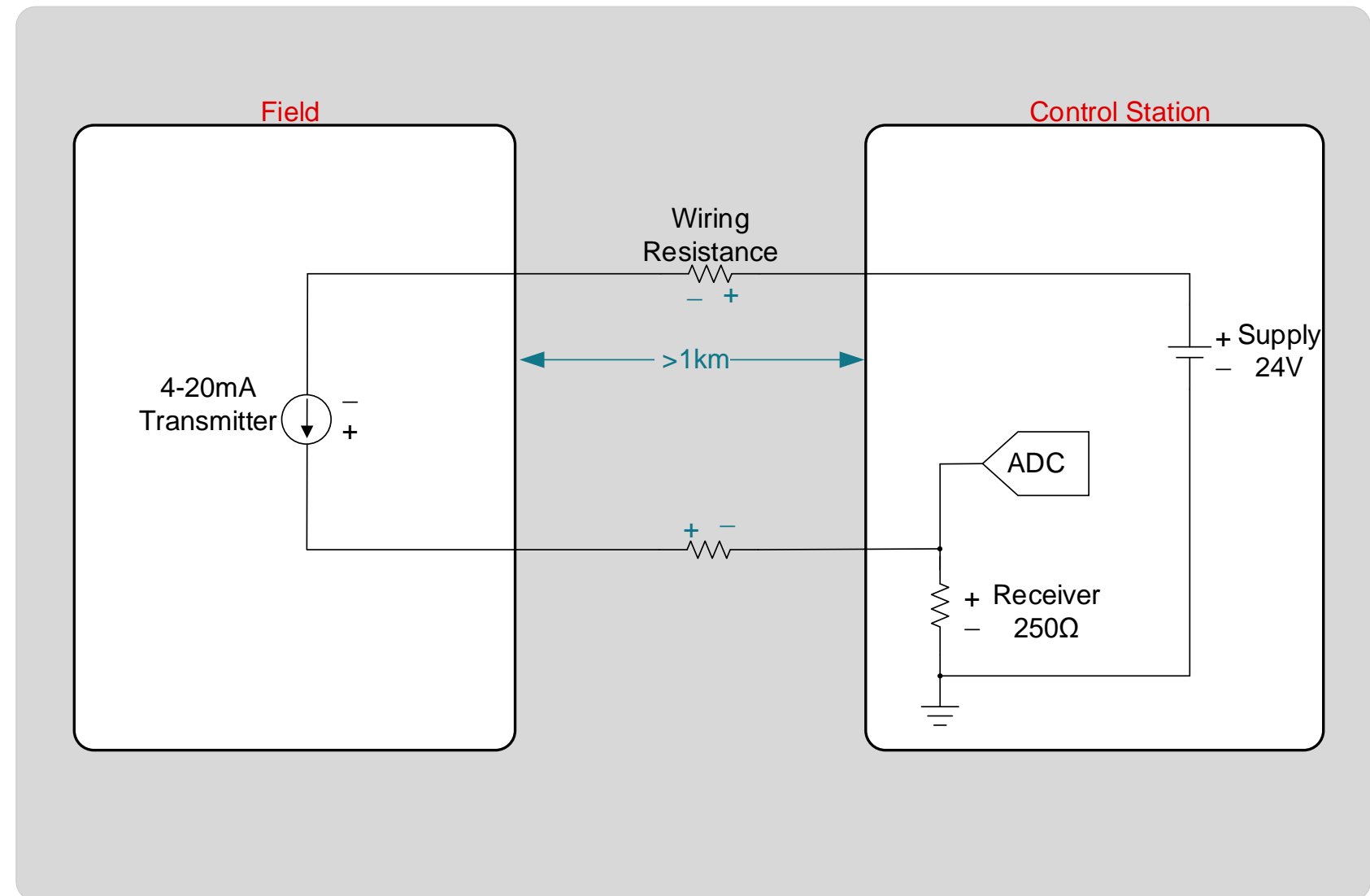
# Why use current transmitters?

- Current transmission block diagram
  - Transmitter: current source
  - Receiver:  $250\Omega$  resistor translates current to voltage
  - ADC: translates voltage to digital signal



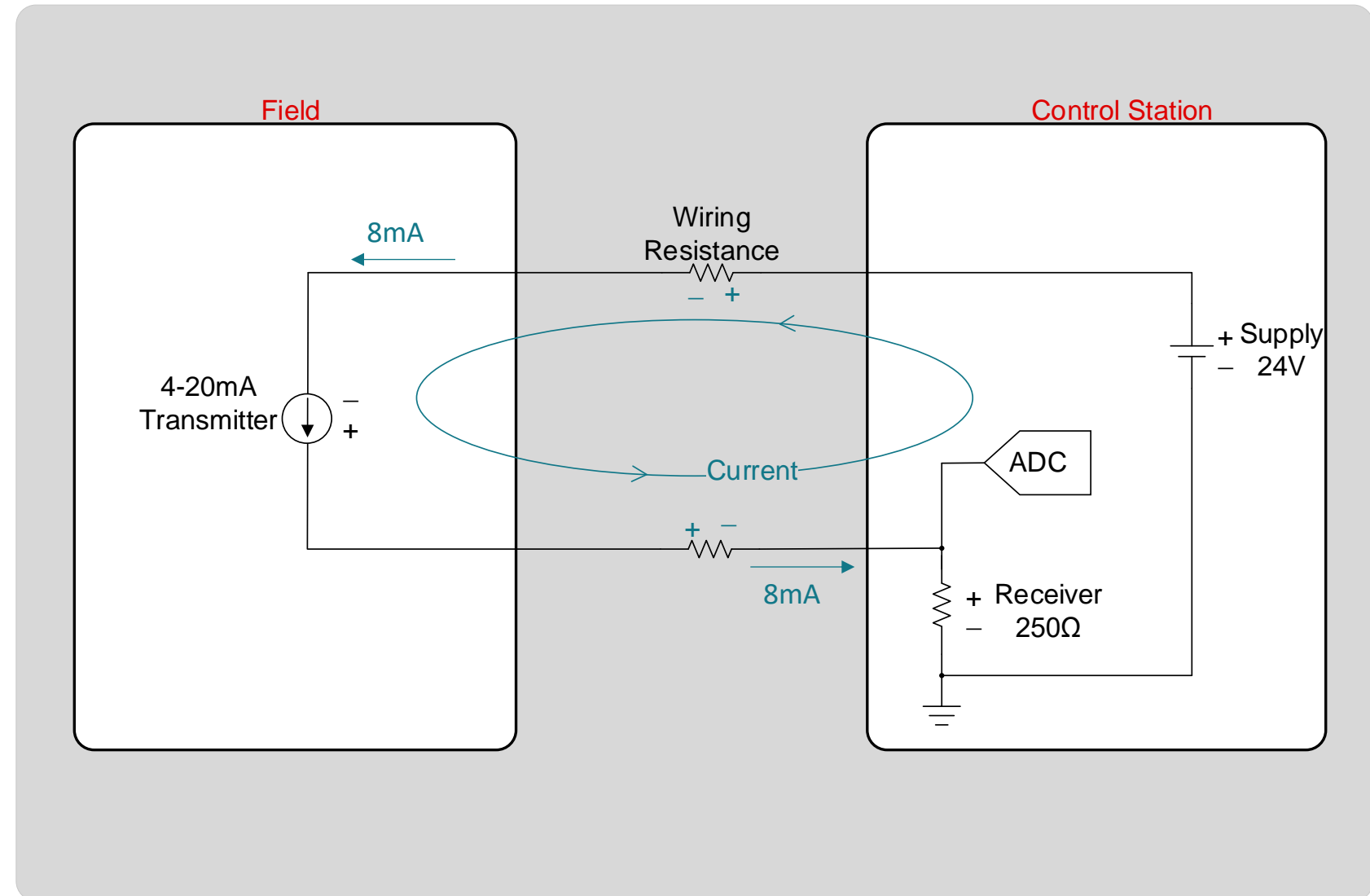
# Why use current transmitters?

- Current transmission block diagram
  - Signals travel >1km
  - Voltage transmission would be attenuated
  - Current loops are essentially lossless



# Why use current transmitters?

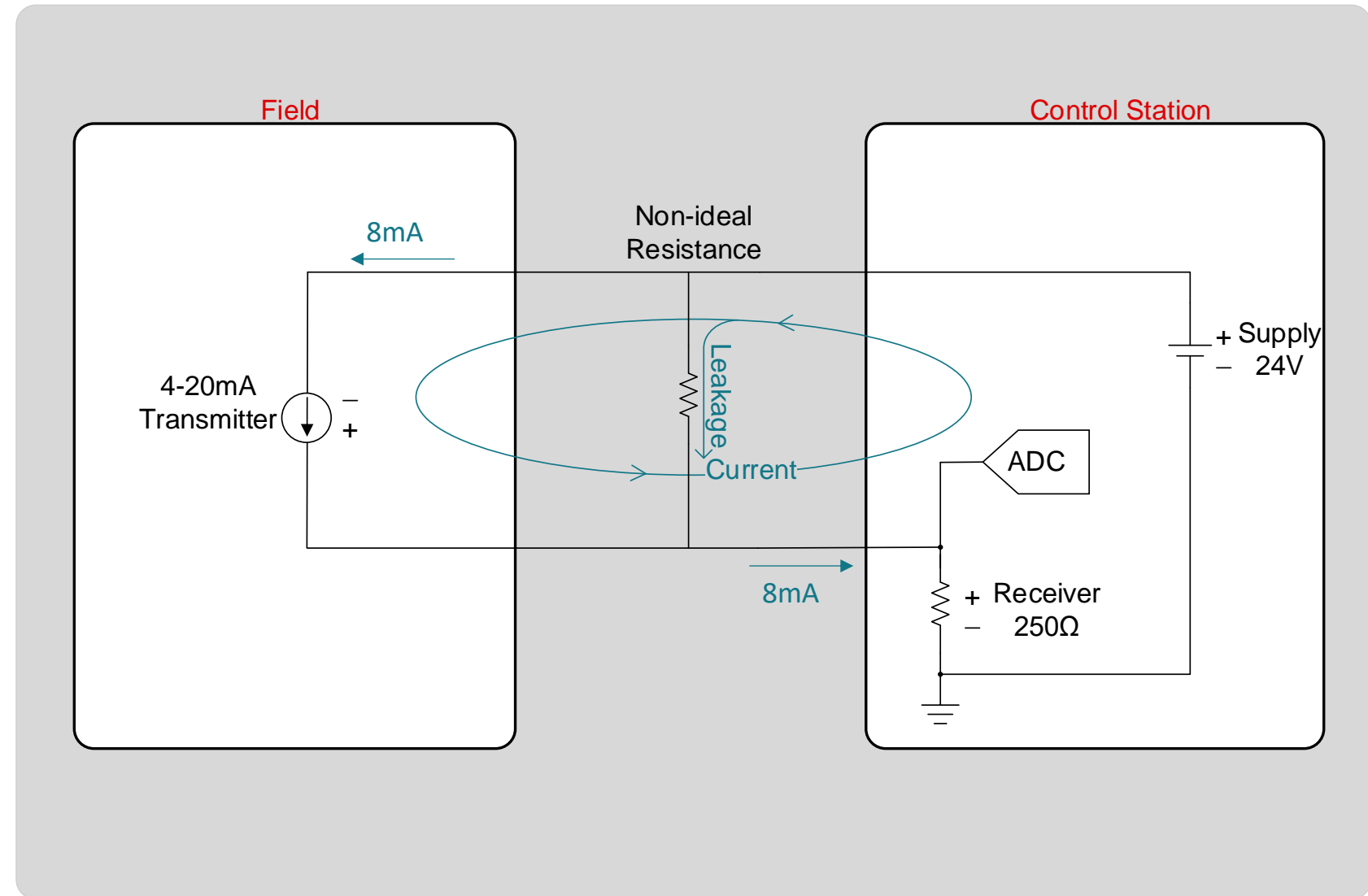
- Current transmission block diagram
  - Current in a loop is equivalent at any point in the loop
  - Current leakage can introduce error





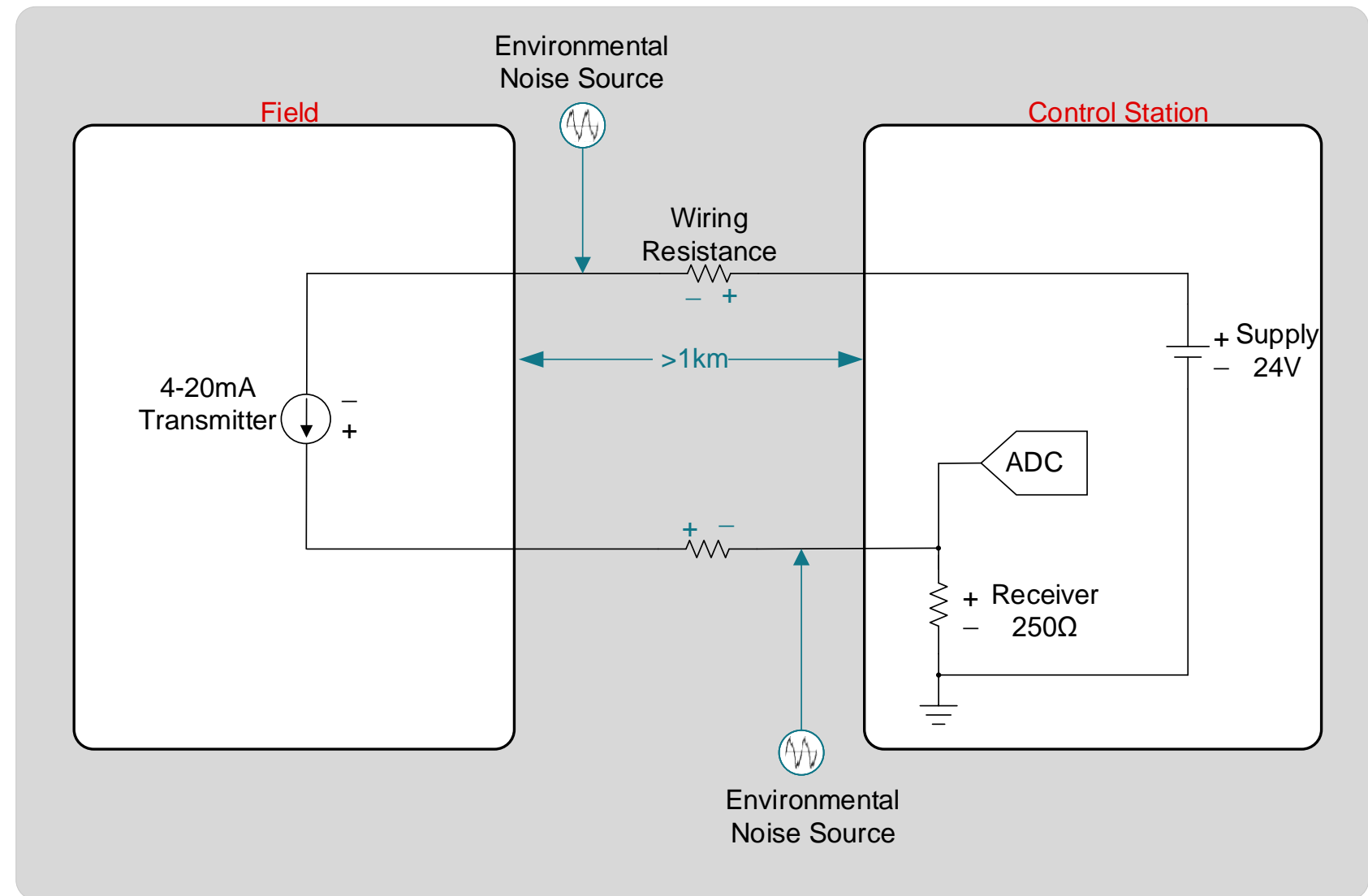
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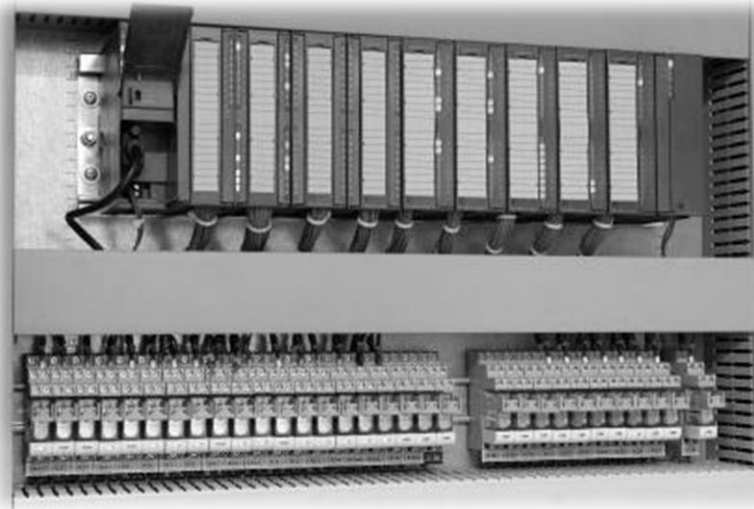
# Why use current transmitters?

- Current transmission block diagram
  - Many noise sources in industrial environments
  - Low impedance of a current loop system makes it much less sensitive to induced noise

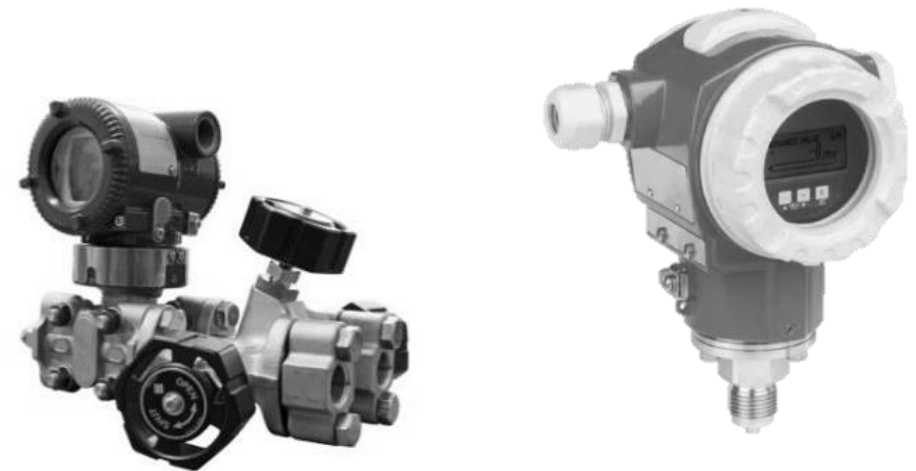


# How are analog outputs used in industrial automation?

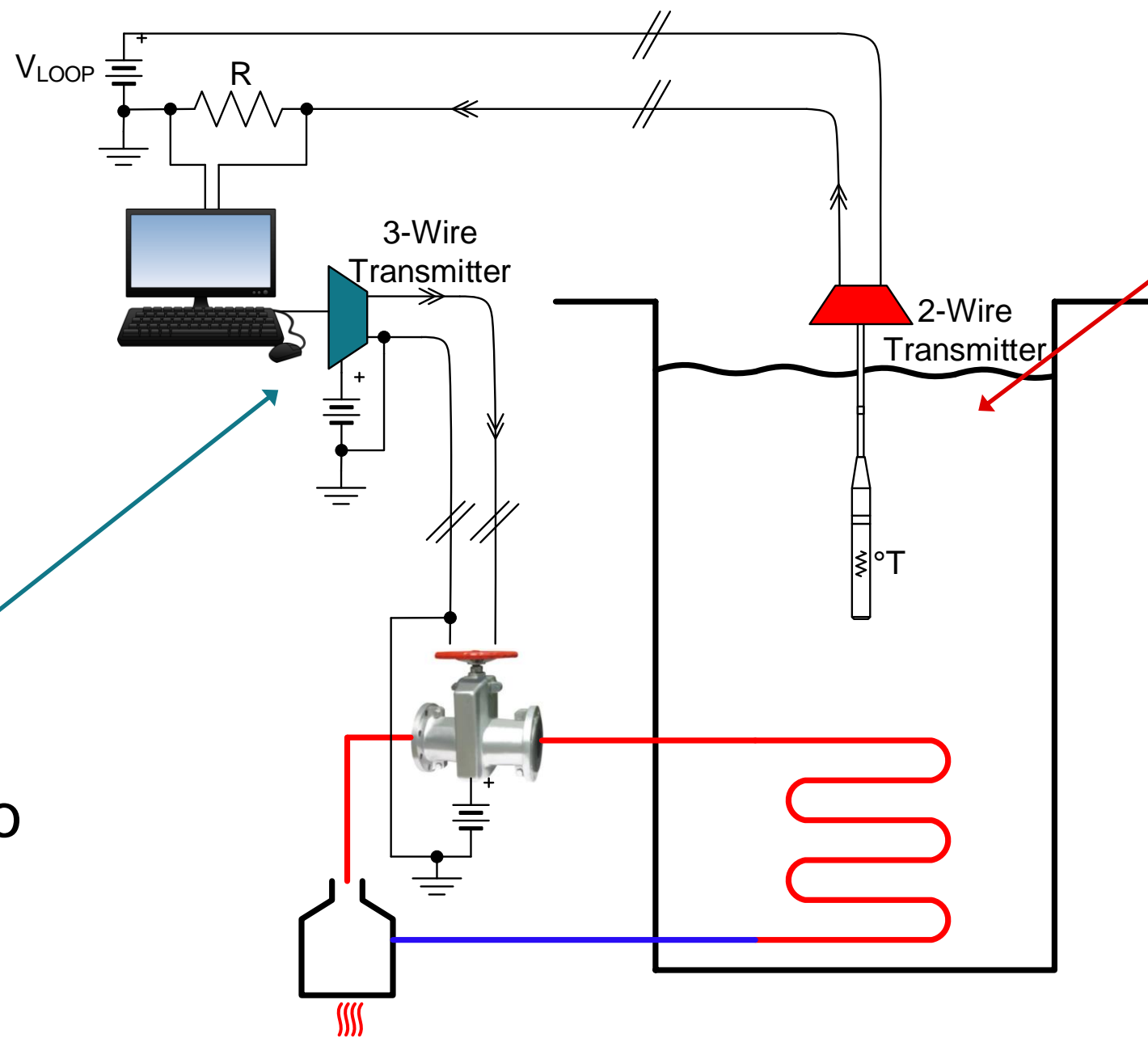
- Programmable logic controllers (PLCs)
  - Analog output modules that control something placed in the field
    - Communication, valve position, position of linear actuator, etc.
  - Analog output module is powered by PLC back-plane
    - Primarily 3-wire systems



- Field elements
  - Analog outputs paired with sensors, placed remotely in the field
  - Comprise a majority of the market for industrial analog outputs
  - Most often 2-wire, or loop-powered, 4-20mA sensor transmitters



# Typical 4-20mA applications



Report a process variable from a remote sensor to a control station.

- Temperature
- 2-wire transmitter

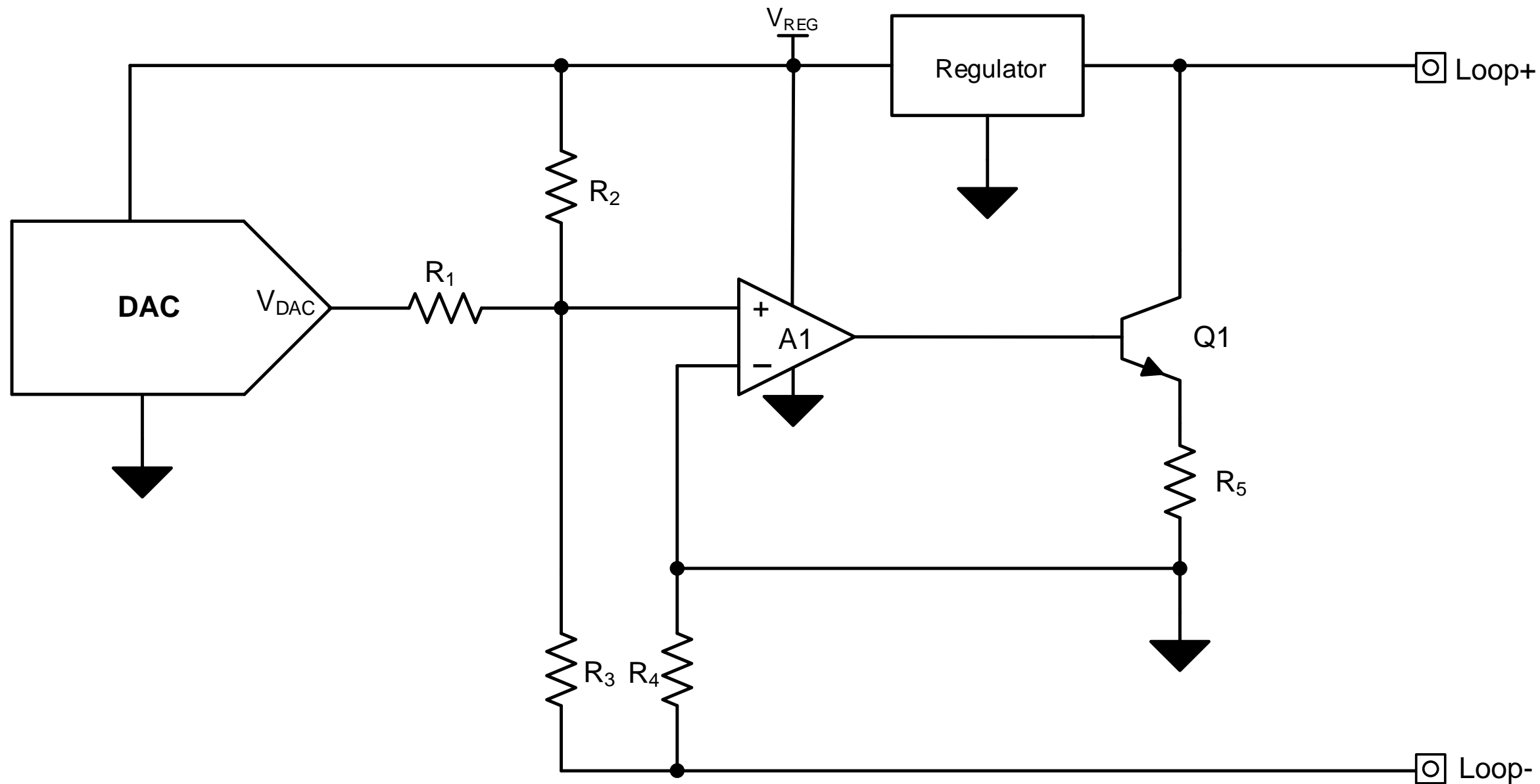
Transmit control signals from a control station out to a remote device.

- Valve, heater
- 3-wire transmitter

# Designing 4-20mA transmitters

- Discrete
  - Customizable
- Partially integrated
  - Reduces size while still allowing for various input types
- Fully integrated
  - Further reduces size
  - HART interface

# 4-20mA transmitters – fully discrete



**TI Designs – Precision: Certified Design**  
**Low Cost Loop-Powered 4-20mA Transmitter EMC/EMI Tested Reference Design**

Keyin Duke

TEXAS INSTRUMENTS

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**Circuit Description**  
 This low cost loop-powered transmitter can accurately source currents from 4 mA to 20 mA. The circuit also includes an input protection circuit for ESD/ESD+ immunity and a diode bridge to enable functionality regardless of the polarity of supply connections.

**Design Resources**

TI Design Files: SPICE Simulator, Product Folder, Product Folder

Ask The Analog Experts: WEBENCH Design Center, TI Designer Desktop Library

TI E2E Community

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Low Cost Loop-Powered 4-20mA Transmitter, EMC/EMI Tested  
 TIPS158 October 2014 Copyright © 2014, Texas Instruments Incorporated

**TIPD158**

**TI Precision Designs: Verified Design**  
**High-Side Voltage-to-Current (V-I) Converter**

Colin Wells, David F. Chan

TEXAS INSTRUMENTS

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**Circuit Description**  
 This high-side voltage-to-current (V-I) converter delivers a well-regulated current to a ground-referenced load. The design utilizes a two-stage approach to allow the high-side current source to accept a ground-referenced input. The first stage uses an op amp and n-channel MOSFET to translate the ground-referenced input to a supply-referenced signal. The supply-referenced signal drives the second stage op amp that controls the gate of a p-channel MOSFET to regulate the load current.

**Design Resources**

TI Design Files: SPICE Simulator, Product Folder

Ask The Analog Experts: WEBENCH Design Center, TI Designer Desktop Library

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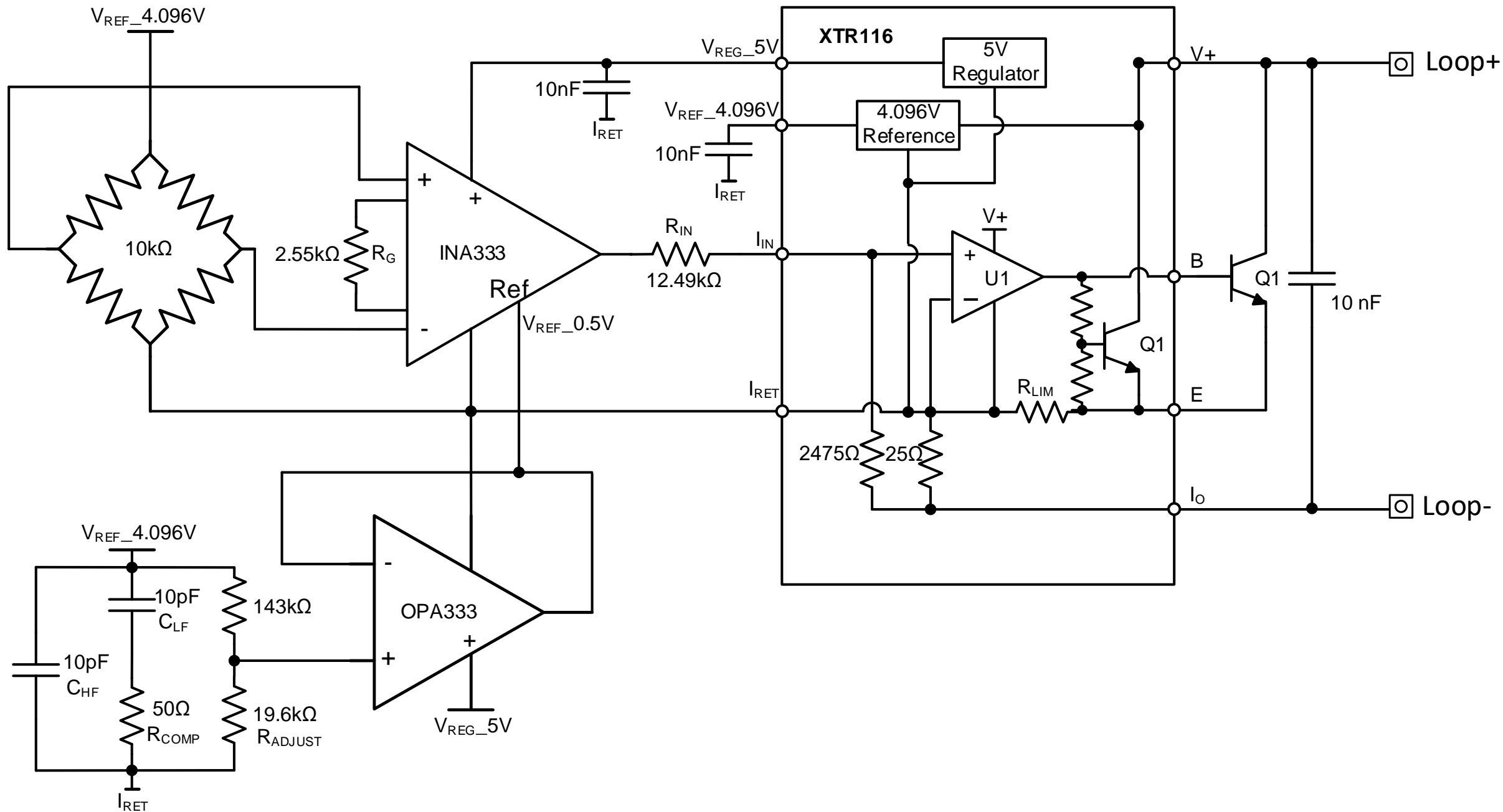
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High-Side Voltage-to-Current (V-I) Converter  
 TIPS102 June 2015 Copyright © 2015, Texas Instruments Incorporated

**TIPD102**

# 4-20mA transmitters – partially integrated



**TI Designs – Precision: CerTified Design**  
**2-wire 4-20mA Transmitter, EMC/EMI Tested Reference Design**

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**Circuit Description**  
 This 2-wire, or loop-powered, analog output can accurately control the loop current from 4 mA to 20 mA. The design also includes an output protection circuit for ESD/ESD immunity and a bridge rectifier to enable functionality regardless of the polarity of loop supply connections.

**Design Resources**  
 All Design Files  
 All Design Files  
 All Design Files  
 All Design Files

**Ask The Analog Experts**  
 TI E2E™ Community

**TIPD190**

**TI Designs – Precision: CerTified Design**  
**Two-Channel Source/Sink Combined Voltage & Current Output, Isolated, EMC/EMI Tested Reference Design**

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**Circuit Description**  
 This two channel combined voltage and current analog output module features two independent outputs that can source and sink voltage and current over the standard industrial output ranges. The possible outputs of the design include: ±24 mA, 4-20 mA, 0-20 mA, 0-5 V, 0-10 V, ±10 V. The design has been successfully tested for immunity to the IEC61000-4 levels.

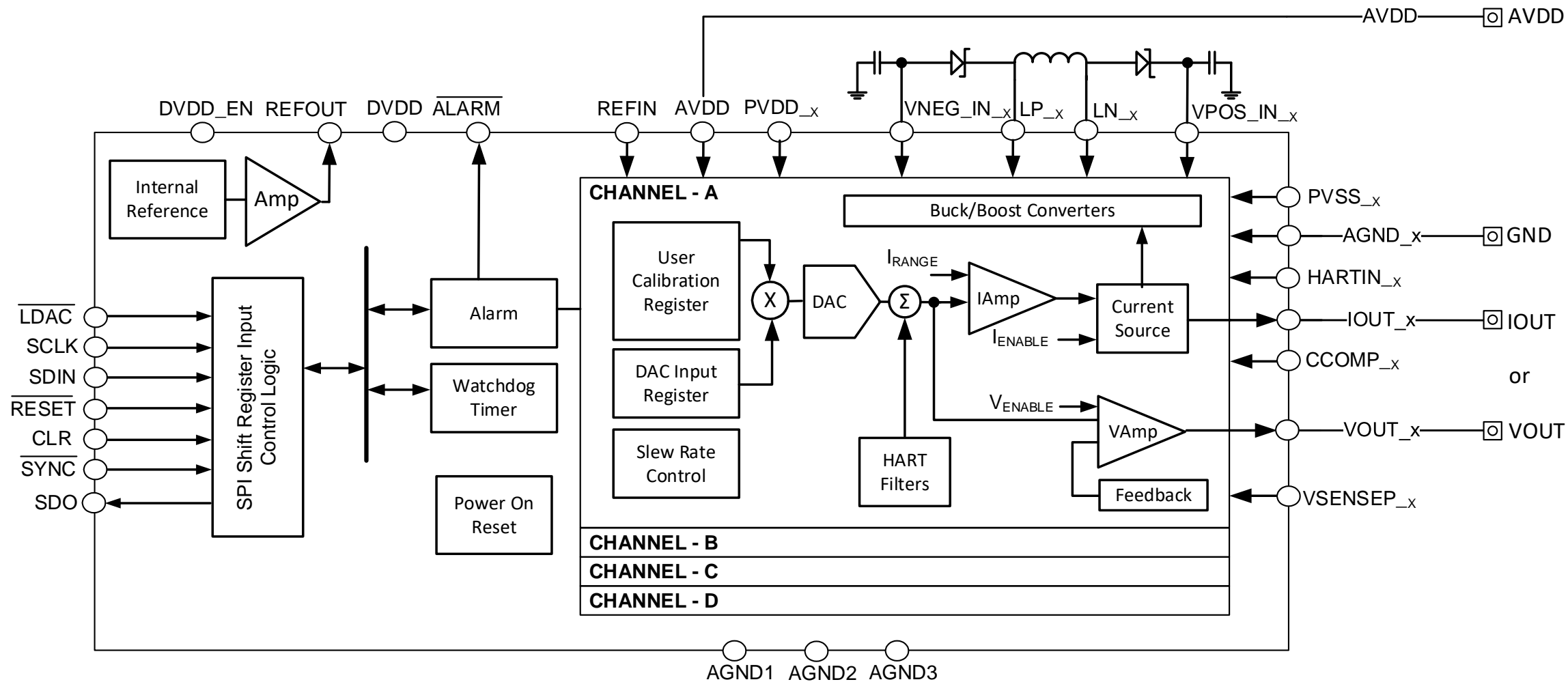
**Design Resources**  
 All Design Files  
 All Design Files  
 All Design Files  
 All Design Files

**Ask The Analog Experts**  
 TI E2E™ Community

**TIPD155**



# 4-20mA transmitters – fully integrated



**TI Designs: TIPD216**  
**Quad-Channel Industrial Voltage and Current Output Driver Reference Design (EMC/EMI Tested)**

**DESCRIPTION**  
 The quad-channel analog output module delivers voltage and current outputs using the highly integrated DACS751 analog front end (AFE). Integrated adaptive power management minimizes the power dissipation of the chip. Additionally, an external protection circuit is implemented to provide immunity to the IEC61000-4 suite of tests.

**RESOURCES**  
 TIPD216 Design Folder  
 DACS751 Product Folder

**FEATURES**  
 • Quad-Channel Analog Outputs for Factory Automation & Control  
 • 4-mA to 20-mA Current Outputs  
 • ±10-V Voltage Outputs  
 • 12-V to 28-V Input Supply Range  
 • Adaptive Power Management for Current Outputs  
 • Class A results for IEC61000-4 ESD, EFT and Radiated Emission; Class B Results for IEC61000-4 Radiated Immunity and Conducted Immunity. Refer to Section 2.1.1.2 for Further Detail.

**APPLICATIONS**  
 • Factory Automation & Control  
 • Building Automation  
 • Motor Drives

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TIPD216 - March 2017 - Revised October 2018  
 Quad-Channel Industrial Voltage and Current Output Driver Reference Design (DAC751 Based)

## TIPD216

**TI Precision Designs: Verified Design**  
**Combined Voltage and Current Output Terminal for Analog Outputs (AO) in Industrial Applications**

**TI Precision Designs**  
 TI Precision Designs are analog solutions created by TI's analog experts. Verified Designs offer the theory, part selection, simulation, complete PCB schematic & layout, set of materials, and measured performance of useful circuits. Circuit modifications that help to meet alternate design goals are also discussed.

**Circuit Description**  
 Standard industrial analog output (AO) circuits are dedicated to either voltage or current outputs. This design using the DACS751 can output both the standard industrial voltage and current outputs on a single terminal. Thus, reducing the number of terminals needed from three to two. A combined output succeeds in reducing the wiring cost, component count, and increasing the versatility of the AO design. The possible outputs of the design include: 4-20 mA, 0-20 mA, 0-24 mA, 0-0 V, 0-10 V, +15 V, +4-10 V, as well as voltage over-ranges.

**DESIGN RESOURCES**  
 All Design Files  
 SPICE Simulations  
 Product Folder

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**TI Precision Designs**  
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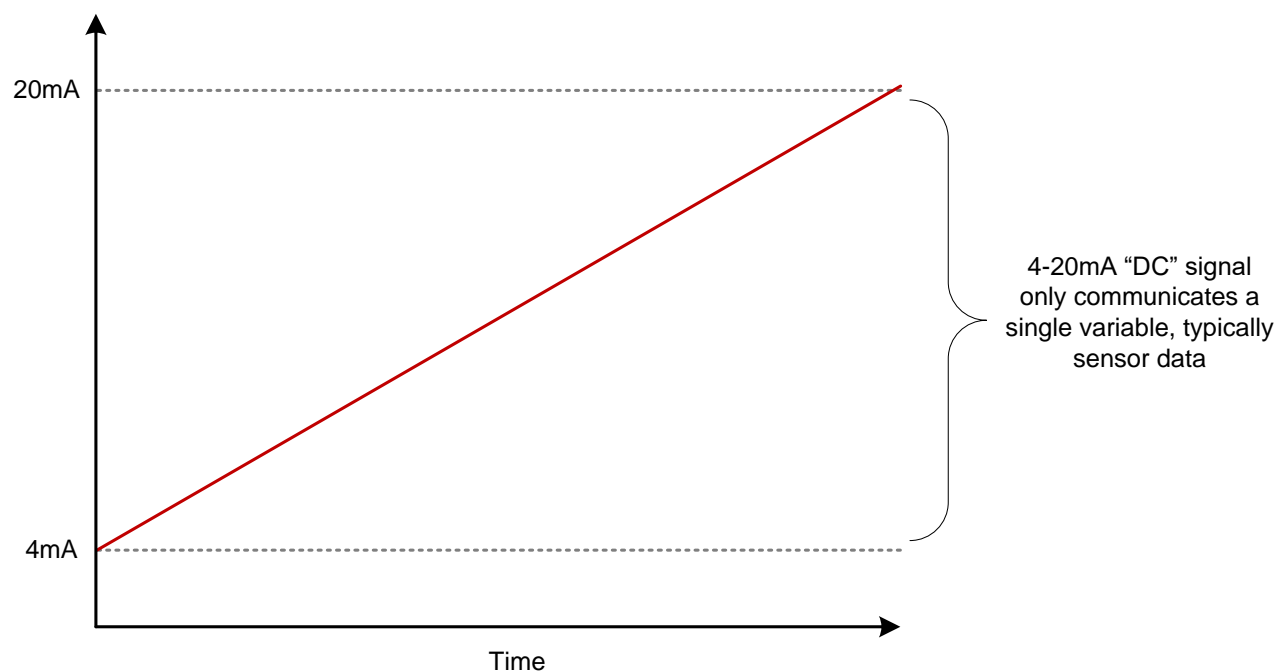
TIPD119 - December 2017 - Revised December 2017  
 Combined Voltage and Current Output Terminal for Analog Outputs (AO) in Industrial Applications

## TIPD119

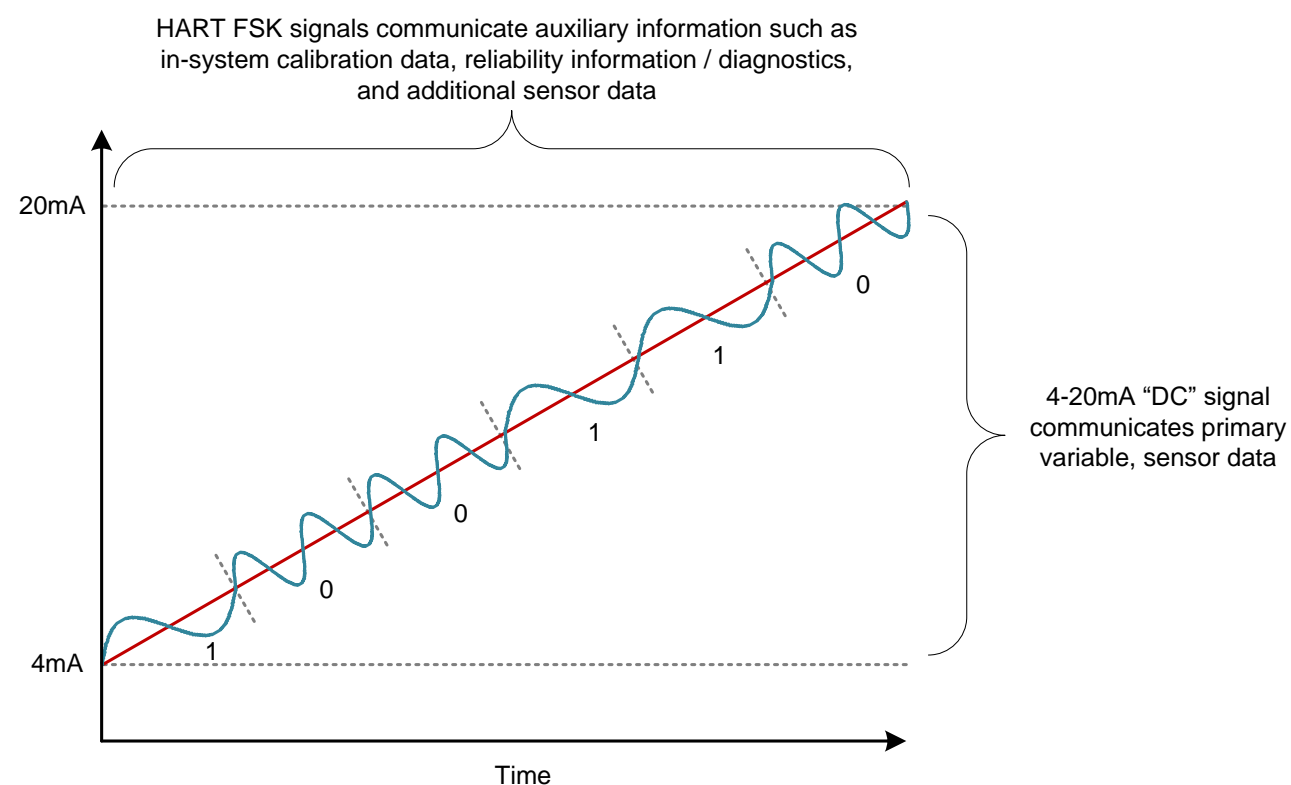
# HART – what is it? why is it useful?



- HART – Highway Addressable Remote Transducer
  - Bell 202 Frequency Shift Keying Standard at 1200 bps
- “Mark” and “Space” symbols (1mAmp)
  - Mark: 1200 Hz sinusoid, represents 1
  - Space: 2200 Hz sinusoid, represents 0



“Simple” sensor transmitter



“Smart” sensor transmitter

**Thanks for your time!**  
**Please try the quiz.**



# Quiz: Introduction to 4-20mA Current Loop Transmitters

TI Precision Labs – Current Loop Transmitters

Presented by Katlynn Jones

Prepared by Katlynn Jones

# Quiz: Introduction to 4-20mA Current Loop Transmitters || Question

1. True/False: The function of a 4-20mA transmitter is to convert a 0-100% signal to a 4-20mA current signal to be transmitted across a long distance.

# Quiz: Introduction to 4-20mA Current Loop Transmitters || Answer

1. **True**/False: The function of a 4-20mA transmitter is to convert a 0-100% signal to a 4-20mA current signal to be transmitted across a long distance.

# Quiz: Introduction to 4-20mA Current Loop Transmitters || Question

2. Fill in the blanks: \_\_\_\_\_ transmitters are less sensitive to noise than \_\_\_\_\_ transmitters due to their inherent \_\_\_\_\_ impedance.

- a) Current, voltage, high
- b) Voltage, current, high
- c) Current, voltage, low
- d) Voltage, current, low



# Quiz: Introduction to 4-20mA Current Loop Transmitters || Answer

2. Fill in the blanks: \_\_\_\_\_ transmitters are less sensitive to noise than \_\_\_\_\_ transmitters due to their inherent \_\_\_\_\_ impedance.

- a) Current, voltage, high
- b) Voltage, current, high
- c) Current, voltage, low**
- d) Voltage, current, low

# Quiz: Introduction to 4-20mA Current Loop Transmitters || Question

3. Which type of transmitter is loop supplied?

- a) 2-wire transmitter
- b) 3-wire transmitter
- c) 4-wire transmitter
- d) None of the above

# Quiz: Introduction to 4-20mA Current Loop Transmitters || Answer

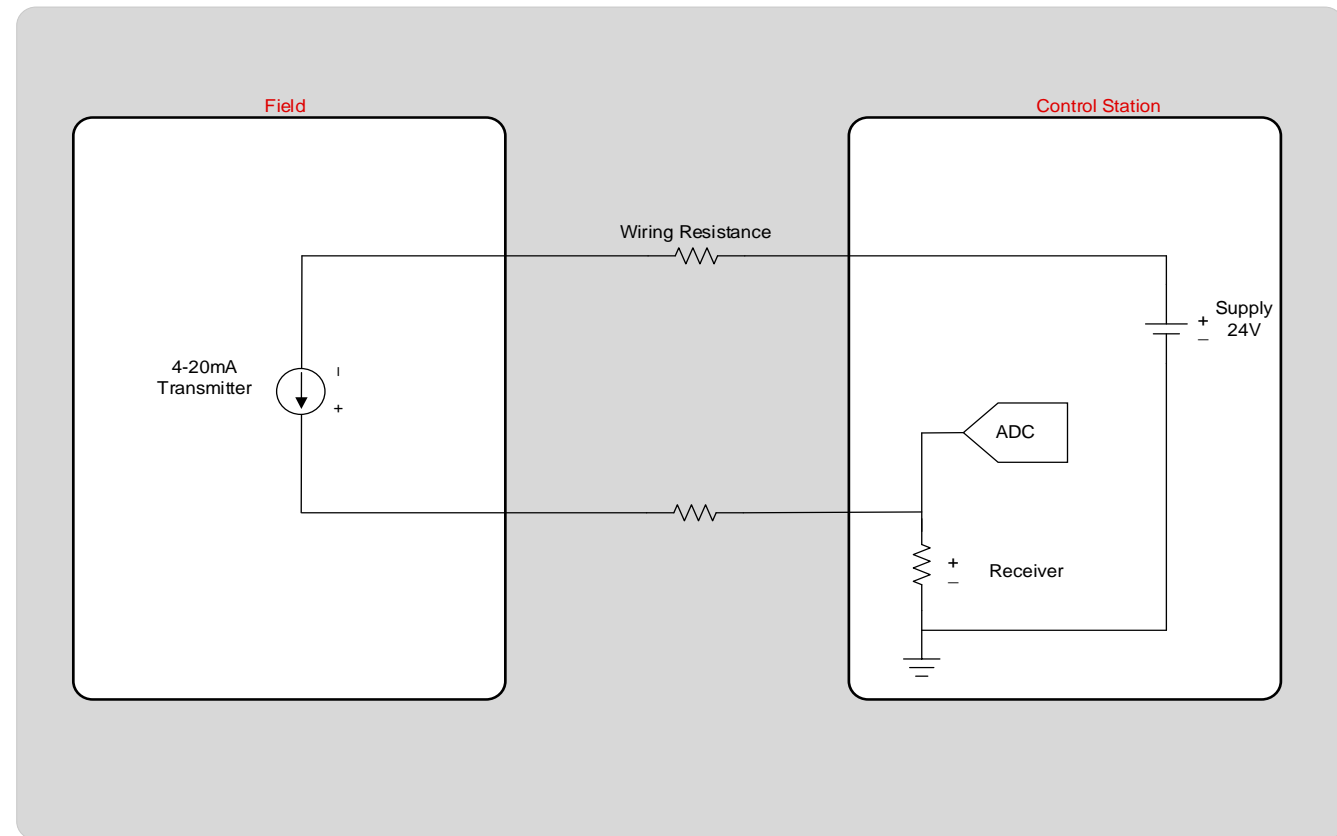
3. Which type of transmitter is loop supplied?

- a) **2-wire transmitter**
- b) 3-wire transmitter
- c) 4-wire transmitter
- d) None of the above

# Quiz: Introduction to 4-20mA Current Loop Transmitters || Question

4. What receiver resistor value would convert a 4-20mA signal to 2-10V?

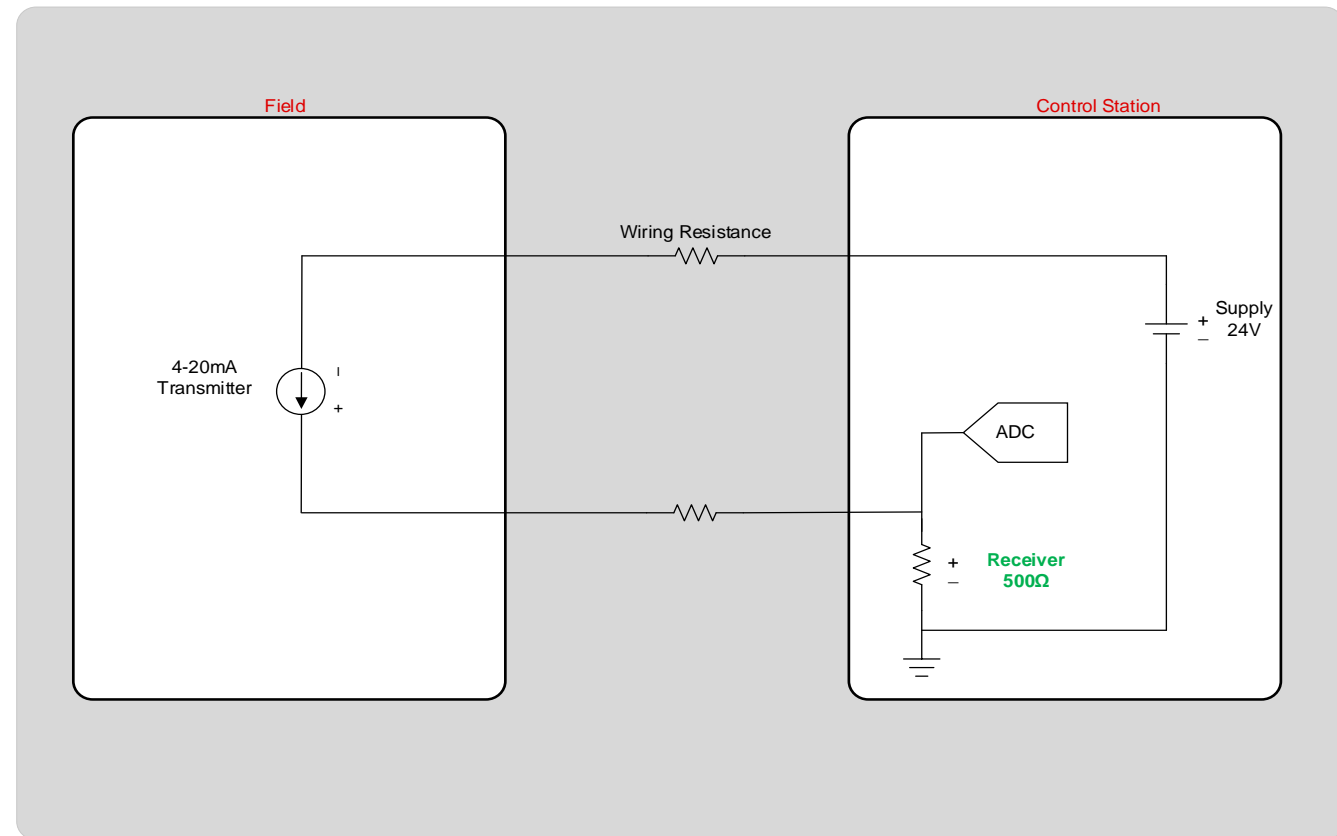
- a) 1k $\Omega$
- b) 500 $\Omega$
- c) 250 $\Omega$
- d) 100 $\Omega$



# Quiz: Introduction to 4-20mA Current Loop Transmitters || Answer

4. What receiver resistor value would convert a 4-20mA signal to 1-5V?

- a) 1k $\Omega$
- b) 500 $\Omega$**
- c) 250 $\Omega$
- d) 100 $\Omega$



# Quiz: Introduction to 4-20mA Current Loop Transmitters || Question

5. Which of the following is not a main component in a discrete current transmitter?
- a) Inductors
  - b) Resistors
  - c) Transistors
  - d) Op-amps

# Quiz: Introduction to 4-20mA Current Loop Transmitters || Answer

5. Which of the following is not a main component in a discrete current transmitter?

- a) **Inductors**
- b) Resistors
- c) Transistors
- d) Op-amps



# Quiz: Introduction to 4-20mA Current Loop Transmitters || Question

6. The NAMUR NE43 signal standard allows for which of the following failure modes?
- a) Over-scale
  - b) Under-scale
  - c) Over-scale, and under-scale
  - d) None of the above

# Quiz: Introduction to 4-20mA Current Loop Transmitters || Answer

6. The NAMUR NE43 signal standard allows for which of the following failure modes?
- a) Over-scale
  - b) Under-scale
  - c) Over-scale, and under-scale**
  - d) None of the above

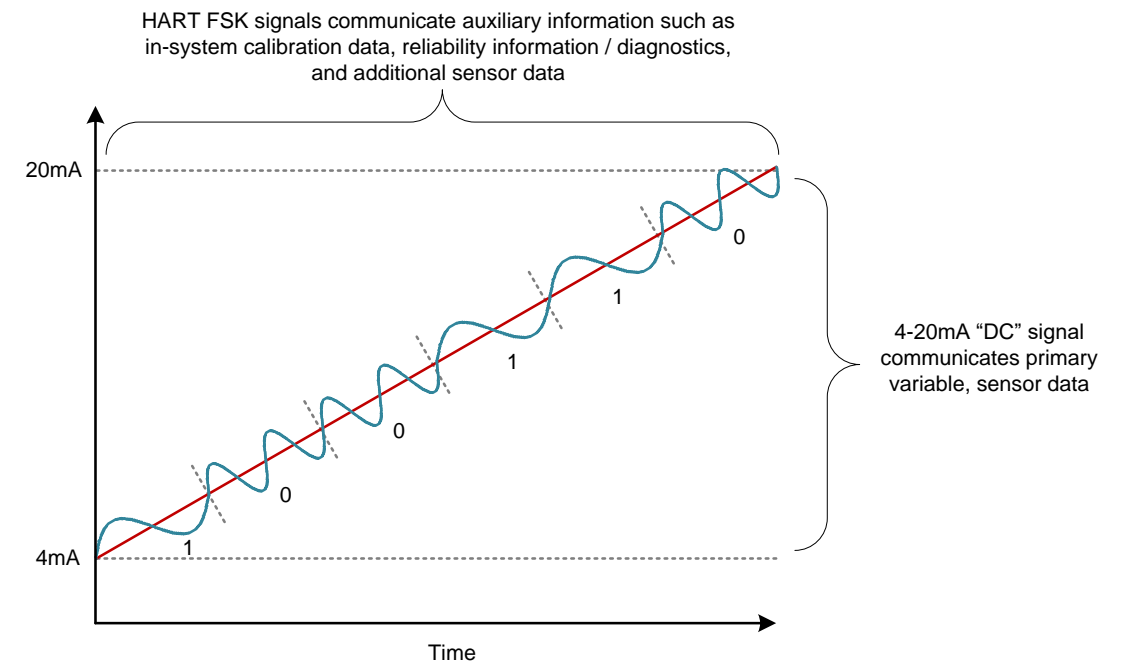
# Quiz: Introduction to 4-20mA Current Loop Transmitters || Question

7. What does HART stand for?
- a) Highway Addressable Resistive Transmitter
  - b) Highway Addressable Resistive Transducer
  - c) Highway Addressable Remote Transmitter
  - d) Highway Addressable Remote Transducer

# Quiz: Introduction to 4-20mA Current Loop Transmitters || Answer

7. What does HART stand for?

- a) Highway Addressable Resistive Transmitter
- b) Highway Addressable Resistive Transducer
- c) Highway Addressable Remote Transmitter
- d) Highway Addressable Remote Transducer**



HART uses frequency shift keying to represent binary data with two waveforms.

**Thanks for your time!**

**To find more Current Transmitter  
technical resources and search  
products, visit:**

**[https://www.ti.com/amplifier-  
circuit/special-function/4-20ma-signal-  
conditioners.html](https://www.ti.com/amplifier-circuit/special-function/4-20ma-signal-conditioners.html)**