

Texas Instruments

Power & Interface Solutions for Field Transmitters



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Systems Engineer // Factory Automation & Control
November 2017

This webinar will answer:

- What isolated ultra-low power solutions can I use for a field transmitter?
- How can I harvest energy from a 4-20mA loop to power other devices?
- How can I implement a wireless user interface from a 4-20mA interface?
- How can I increase system scalability by integrating several protocol in one IC?

What is a TIDesign?

A web folder

Find everything in one place

www.ti.com/tool/TIDA-01442

The screenshot shows the TI Design web page for TIDA-01442. It includes a navigation bar with 'Home', 'Features & Benefits', 'Technical Documents', 'Support & Training', and 'Order Now'. The main content area is titled 'Direct RF-Sampling Radar Receiver for L-, S-, C-, and X-Band Using ADC12DJ3200 Reference Design'. It lists key documents, a description of the design, and features. The design is a direct RF-sampling radar receiver for L-, S-, C-, and X-band using the ADC12DJ3200 reference design.

Documented results

Ti Designs: TIDA-01442 Direct RF-Sampling Radar Receiver for L-, S-, C- and X-Band Using ADC12DJ3200 Reference Design

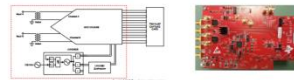


Description
The TIDA-01442 TI Design utilizes the ADC12DJ3200 EVM to demonstrate a direct RF-sampling receiver for a radar operating in HF, VHF, UHF, L-, S-, C-, and X-band. The wide analog input bandwidth and high sampling rate (8.4 GSps) of the analog on-chip converter (ADC) provides multi-band coverage with a single receiver of ADC. The direct RF-sampling capabilities of the ADC reduce the component count by eliminating several down-conversion stages, thereby reducing overall system complexity.

Resources

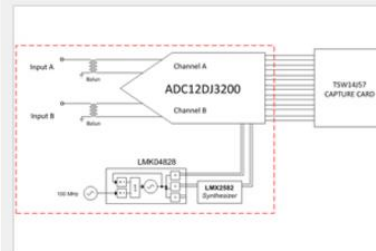
TIDA-01442	Design Folder
ADC12DJ3200	Product Folder
LMK6288	Product Folder
LMK6282	Product Folder
TSPH4871A	Product Folder

Ask Our E2E Experts



As an IMPORTANT NOTICE at the end of this TI reference design addresses authorized user, intellectual property matters and other relevant disclosures and information.

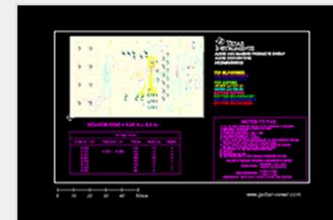
Schematics



Download Schematic

Design Files

Download ready-to-use system files to speed your design process. Get Viewer.



Download Design Files

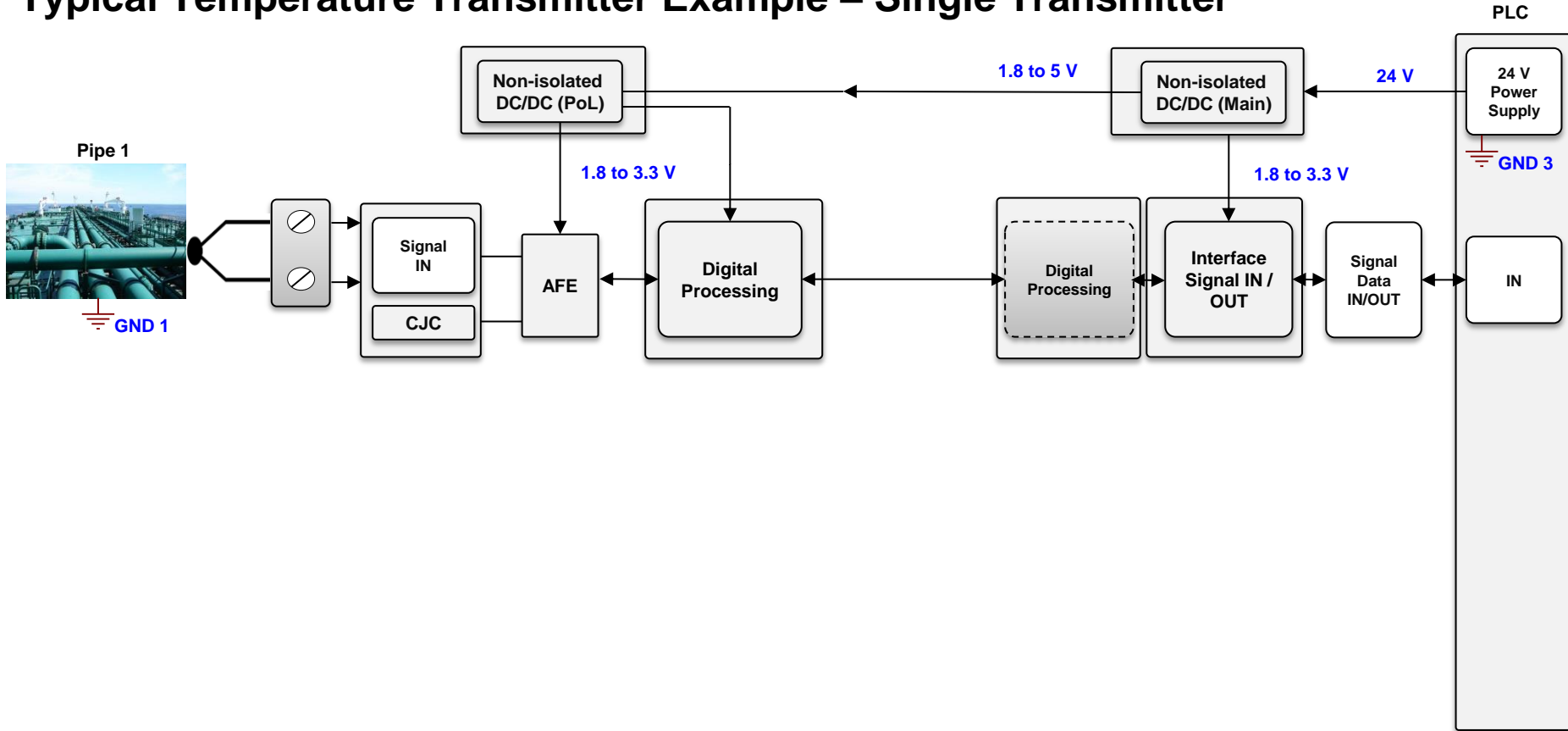


- go beyond the product datasheet to show how to solve a common problem, use in a sub-system or how a device performs in a specific application

Isolated ultra-low power solutions

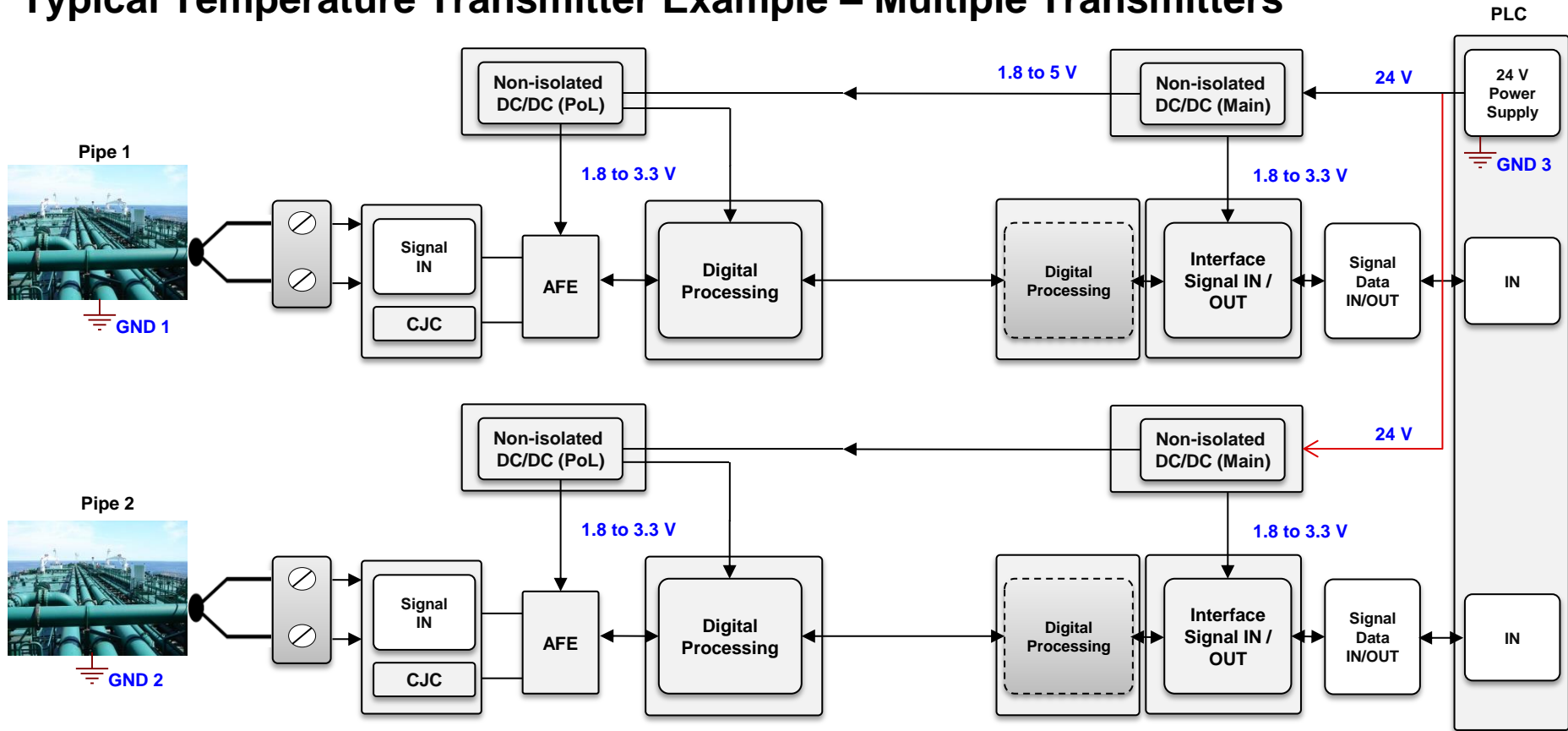
Overview

Typical Temperature Transmitter Example – Single Transmitter



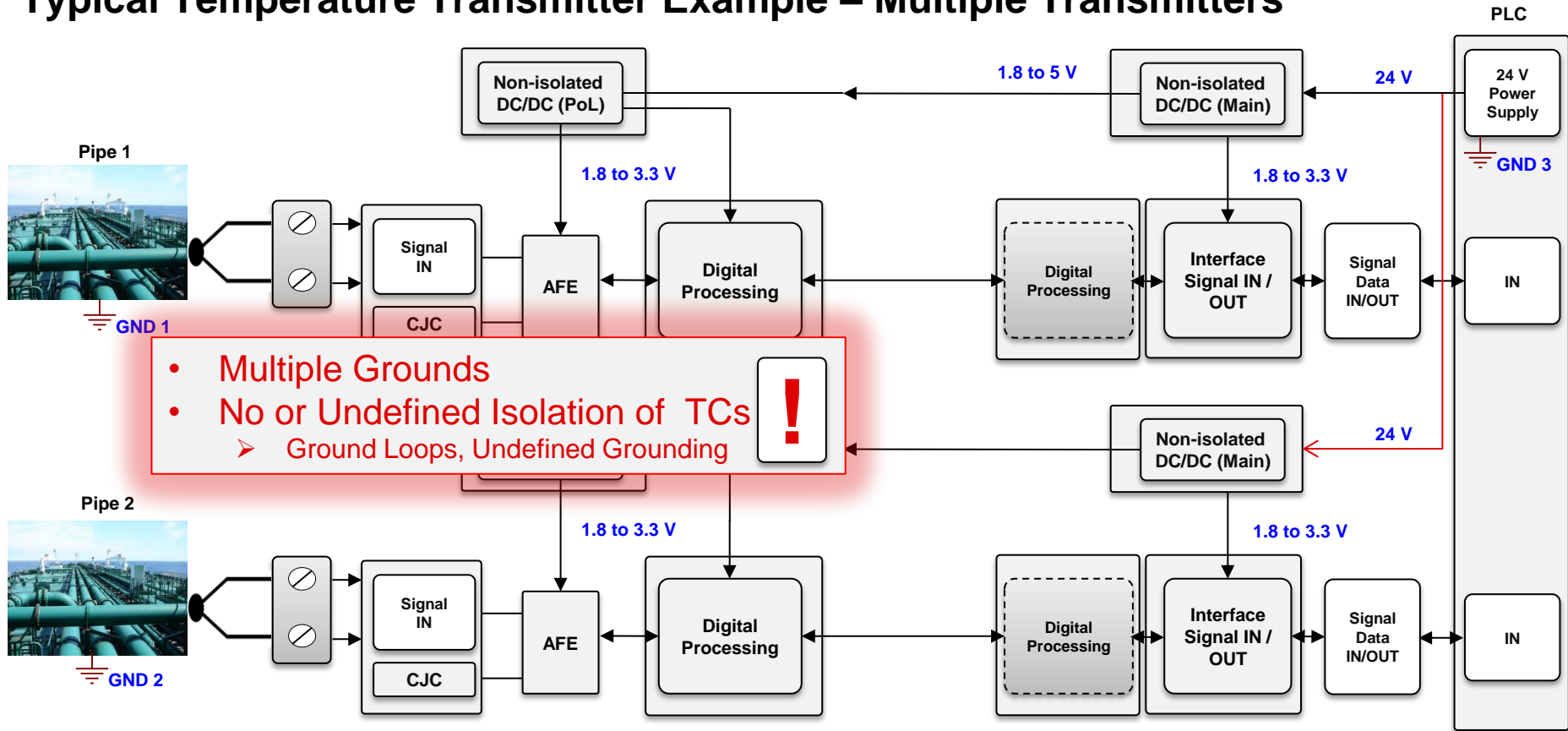
Overview

Typical Temperature Transmitter Example – Multiple Transmitters



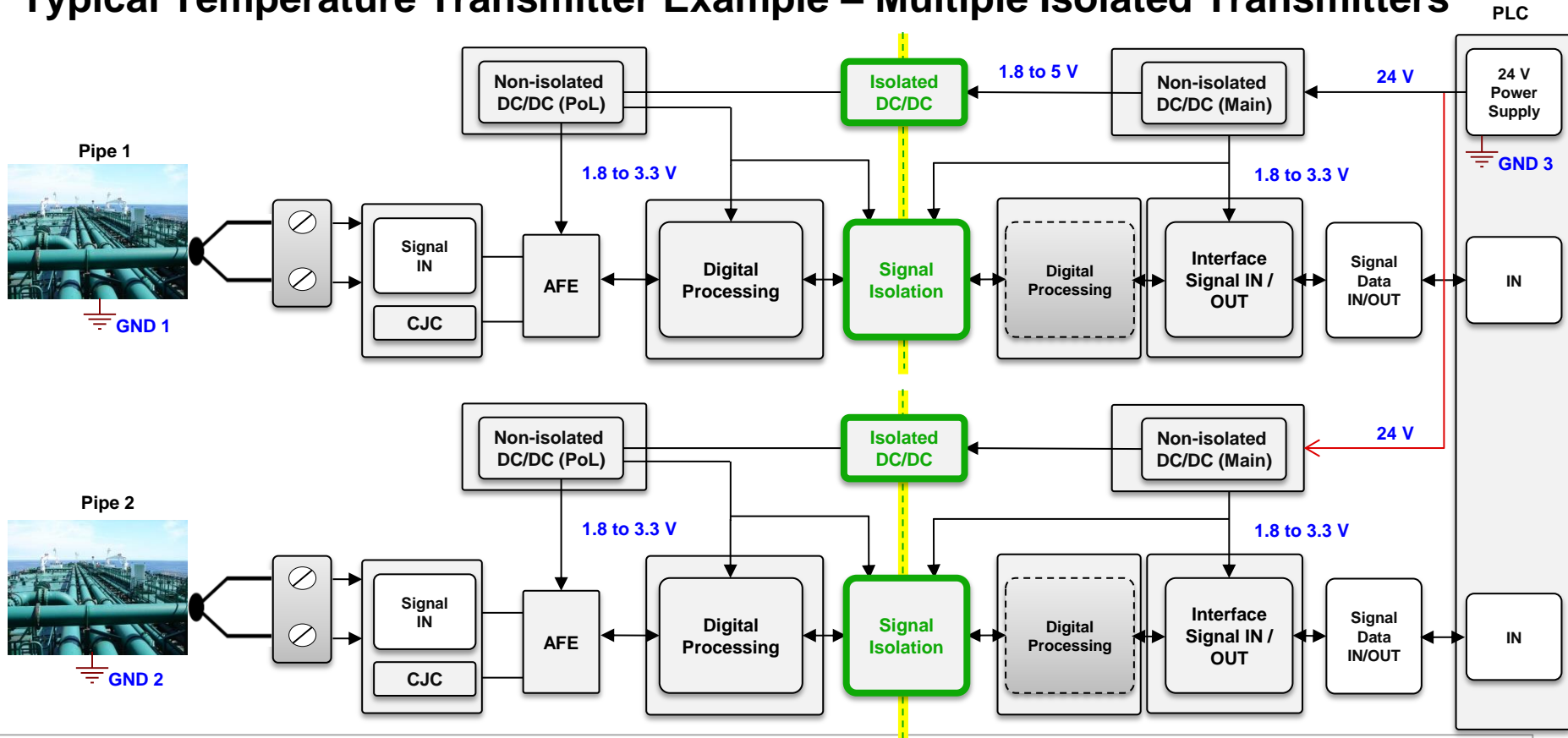
Overview – Need for Isolation

Typical Temperature Transmitter Example – Multiple Transmitters



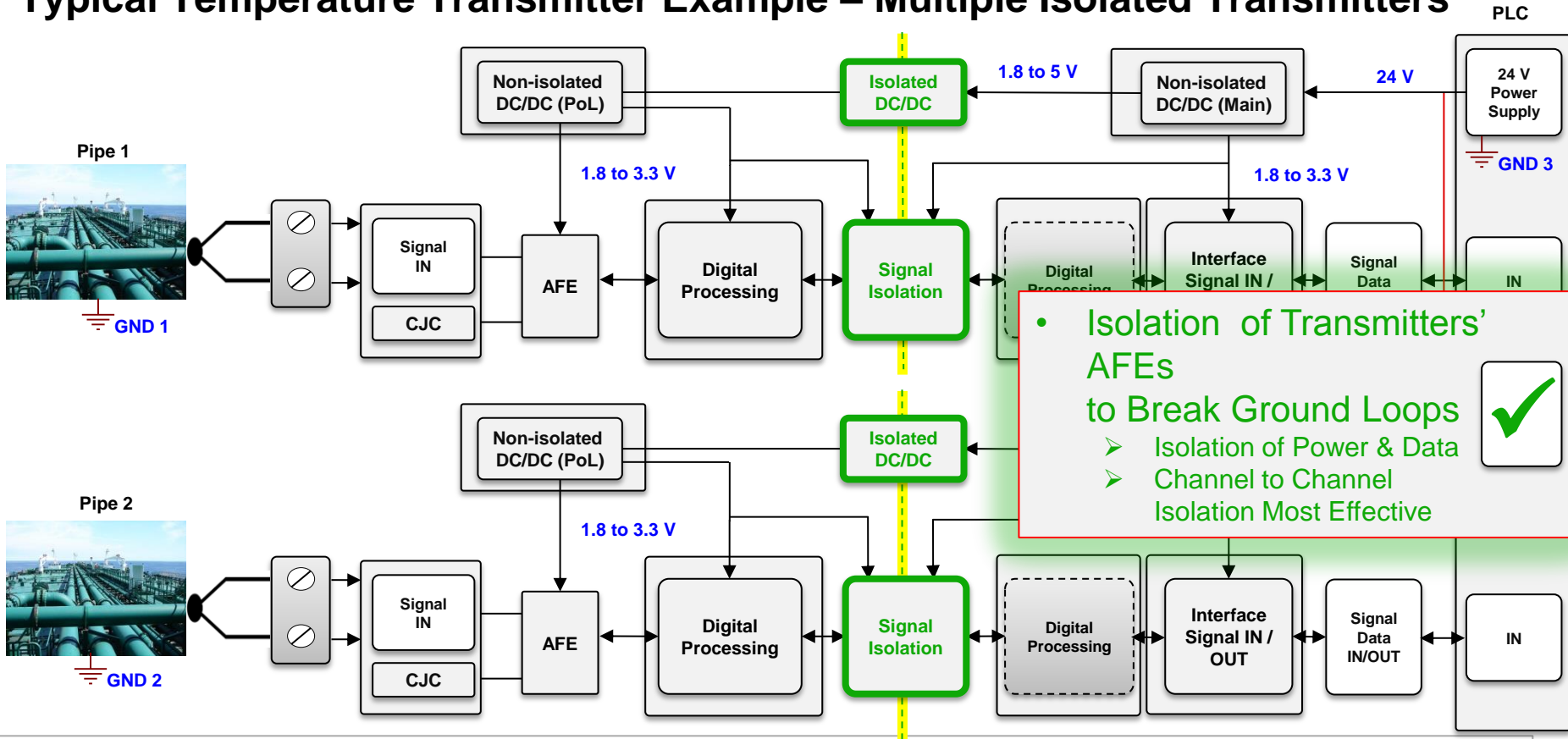
Overview – Need for Isolation

Typical Temperature Transmitter Example – Multiple Isolated Transmitters



Overview – Need for Isolation

Typical Temperature Transmitter Example – Multiple Isolated Transmitters



Existing “General Purpose “ Isolated (Power) Solutions

24 V Input; Multiple 10s of mW up to 100s of mW Output Power,
typical for 3-or more-wire transmitters, PLC AI & AO Modules, **Low PWR Efficiency not Critical**

Pre-Regulator

3 to 5.5 VIN

2.25 to 5.5 VIN

2.95 to 6 VIN

7.5 to (42) 100 VIN
4.5 to 65 VIN

***Fully Integrated
Iso PWR + Data
10.3 x 10.3 mm²***

Push-Pull

Fly-Buck

ISOW784x

SN6501

SN6505A / B

TPS55010

**LM(2)5017 / 18 / 19
LM5160 / A**

- 3.3 or 5V reg. VOUT
- Up to 0.65 W POUT
- Up to 1Mbps Data
- 7071 Vpk Reinforced Isolation

- I_{switch_prim} < 150 to 350 mA
- fSW ~ 400 kHz

- I_{switch_prim} < 0.75 to 1 A
- fSW ~ 160 / 420 kHz
- synchronizable up to 600 / 1600 kHz

- I_{switch_prim} < 2 A
- fSW ~ 100 to 2000 kHz
- synchronizable

- I_{switch_prim} < 0.7 / 0.39 / 0.15 A < 1.9A
- fSW up to 1000 kHz

Loop Powered 2-wire, 4 - 20 mA Transmitter System

High Efficiency at Ultra-Low Power Level Needed

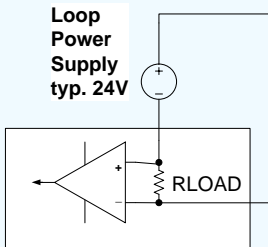
$I_{\text{LOOP-RANGE}}$

Nominal: 4 to 20 mA
 4 mA: 0% FS
 20 mA: 100% FS

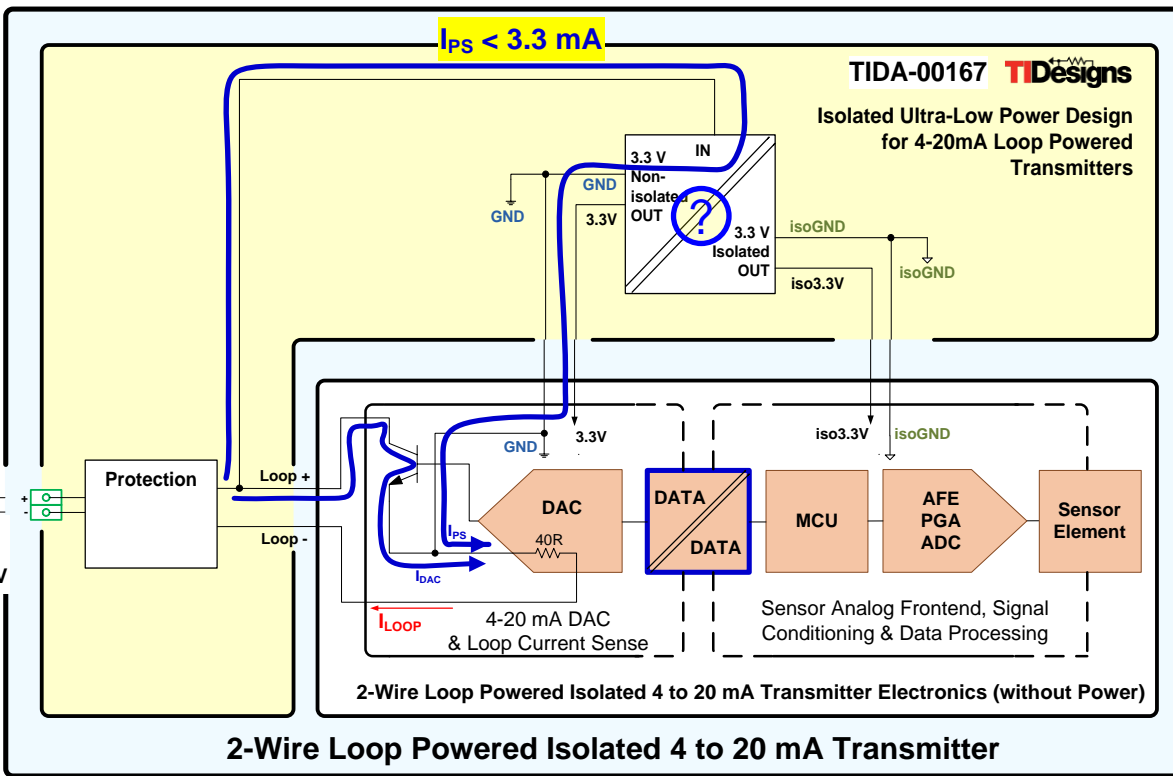
NAMUR NE 43 (Recommendation for Error Levels)

Extended Nominal $I_{\text{LOOP-RANGE}}$: 3.8 – 20.5 mA
 Error High: ≥ 21 mA
 Error Low: ≤ 3.6 mA

DAC161P997
 Default Error High: 21.750 mA
 Default Error Low: 3.375 mA



Loop Receiver (PLC)



Existing Isolated (Ultra-Low Power) Solutions

24 V Input; 100s of μW up to 10s of mW Output Power,
Typical for 2-Wire Loop Powered 4-20mA Transmitters, **Low PWR Efficiency is Very Critical**

Pre-Regulator

Isolated Power Topology: Half-Bridge, based on TPS60402

TIDA-00167

- Power Reference Design for 2-Wire Loop Powered 4-20mA Transmitter
- **4.5 VIN of Iso DC/DC**
- Silicon Diodes on Secondary
- **72 % Efficiency @ 10 mW POUT**

TIDA-00189

- Reference Design for 2-Wire Loop Powered 4-20mA Temperature Transmitter
- Iso Power Part based on TIDA-00167

TIDA-00349

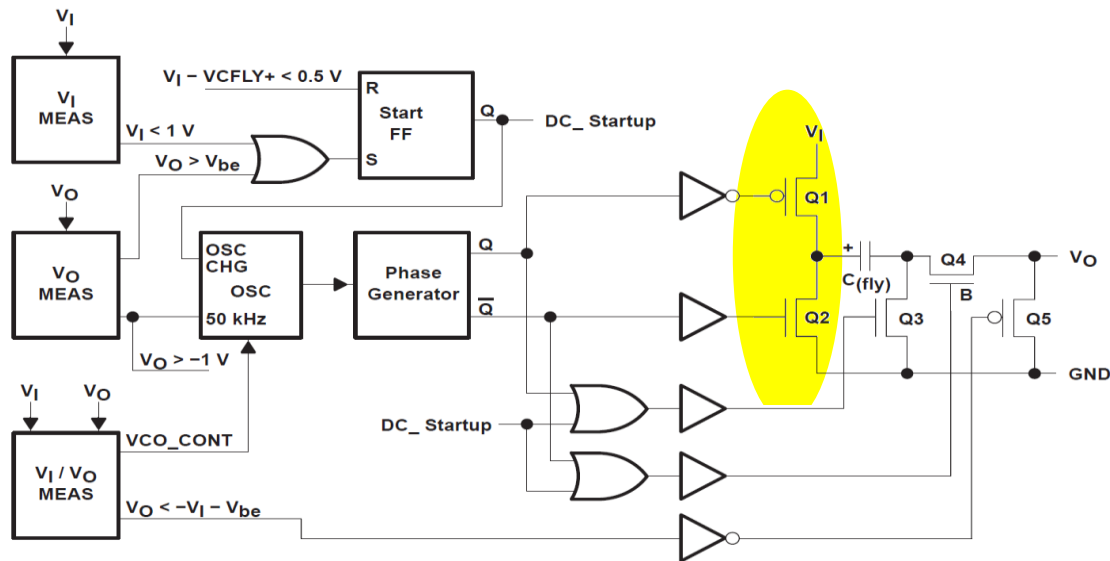
- Uniquely Efficient Isolated DC/DC Converter for Ultra-Low Power Applications
- **3 to 5.2 VIN of Iso DC/DC**
- Schottky Diodes on Secondary
- **85 % Efficiency @ 10 mW POUT**

TIDA-00459

- Highly Efficient Power & Data Transmission for Isolated Low Power Applications
- **3 to 3.6 VIN of Iso DC/DC**
- Iso Power Part based on TIDA-00349 + selectable LDO or DC/DC as Post Regulator

Isolated DC/DC Converter

Selection of Half-Bridge Driver



TPS6040x Unregulated 60-mA Charge Pump Voltage Inverter

- Input voltage from 1.6 V to 5.25 V
- Integrated FETs
- Multiple fixed frequency versions
- I_q down to 65 μ A (TPS60401)
- Small 5-Pin SOT-23 package

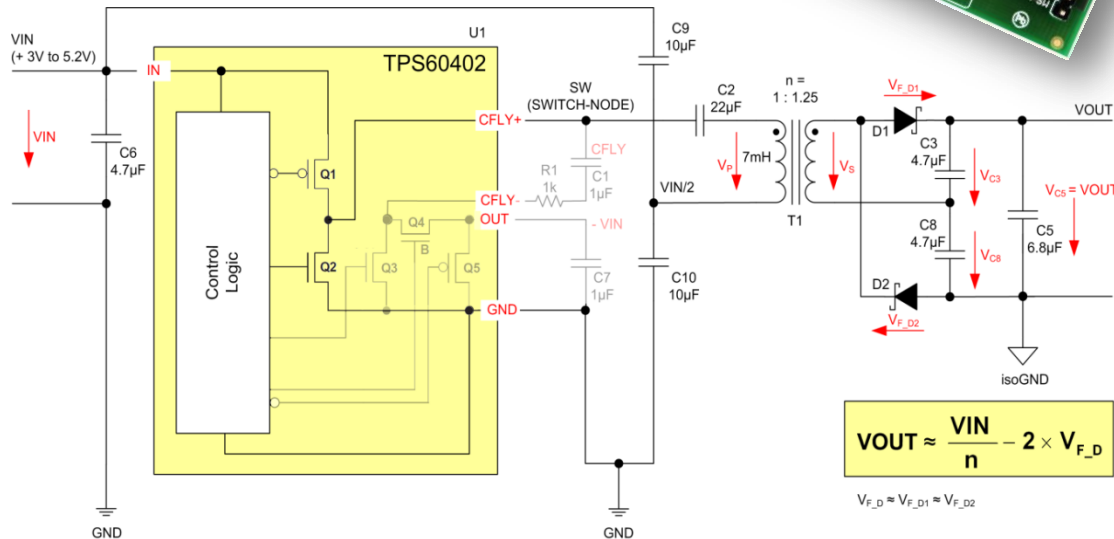
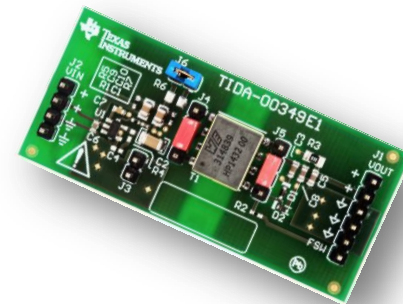


	TPS60400	TPS60401	TPS60402	TPS60403
Typ Switching Frequency	Variable 50 kHz to 250 kHz	20 kHz	50 kHz	250 kHz
Typ Quiescent Current	125 μ A	65 μ A	120 μ A	425 μ A

TPS60402 Based Isolated DC/DC Converter

Basic Circuit Diagram

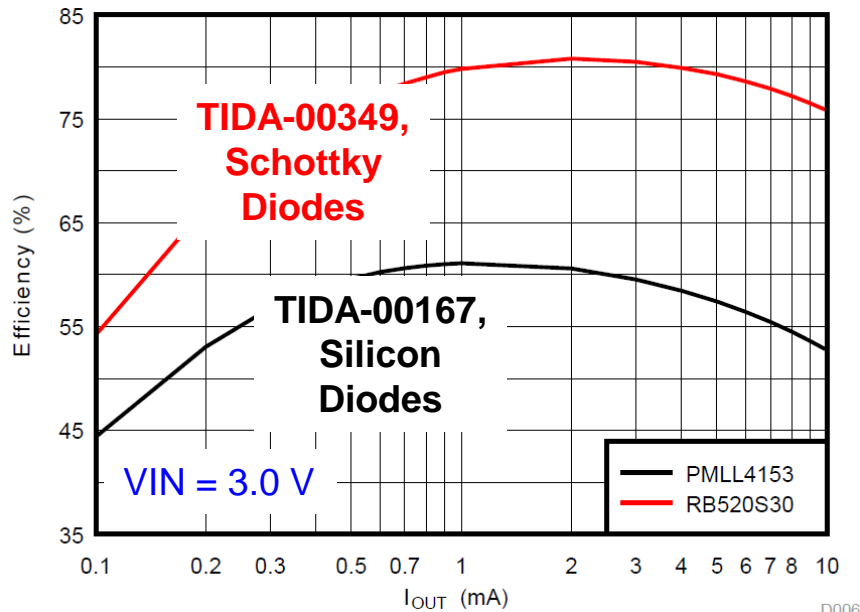
- TPS60402 as Half-Bridge driver on primary
- Fixed 50% duty cycle
- Voltage doubler circuit on secondary
- Forward voltage drop of diodes as main contributor for deviations from ideal VOUT; depends on
 - IOUT
 - Temperature



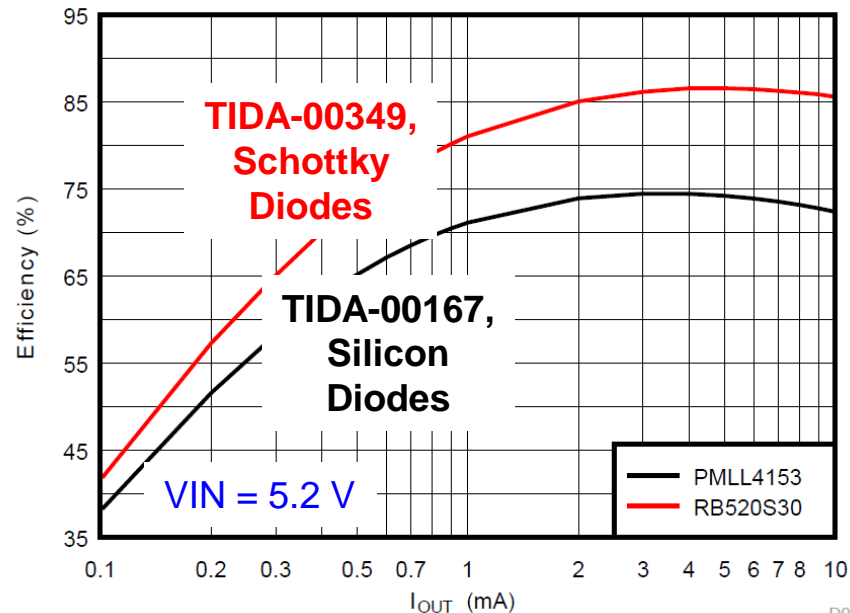
V_{F_D} taken out of diodes' datasheet at 2 X IOUT and at respective temperature

TPS60402 Based Isolated DC/DC Converter

Efficiency Results, TA = 25°C



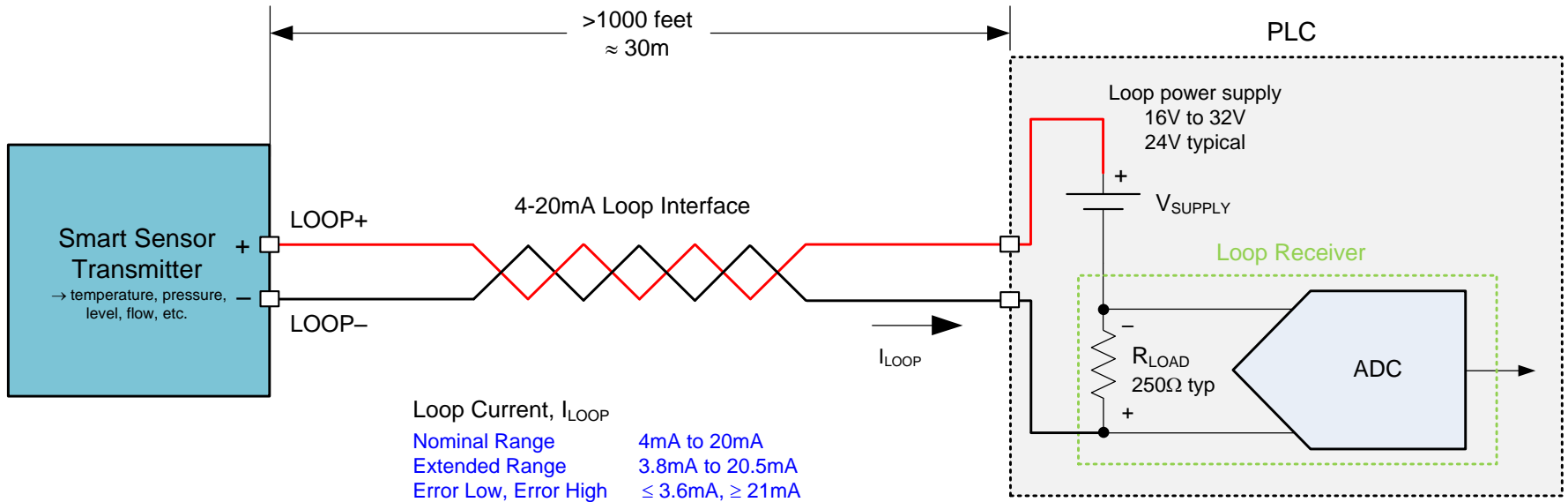
D006



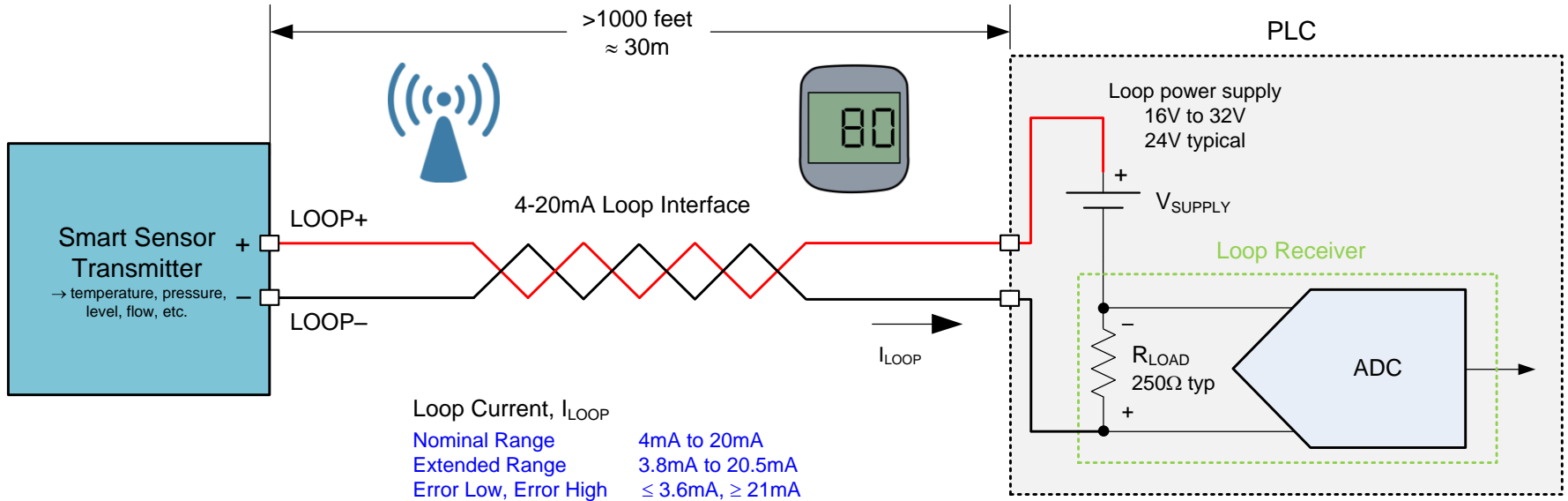
D007

4-20mA loop energy harvester

4–20mA current loop architecture

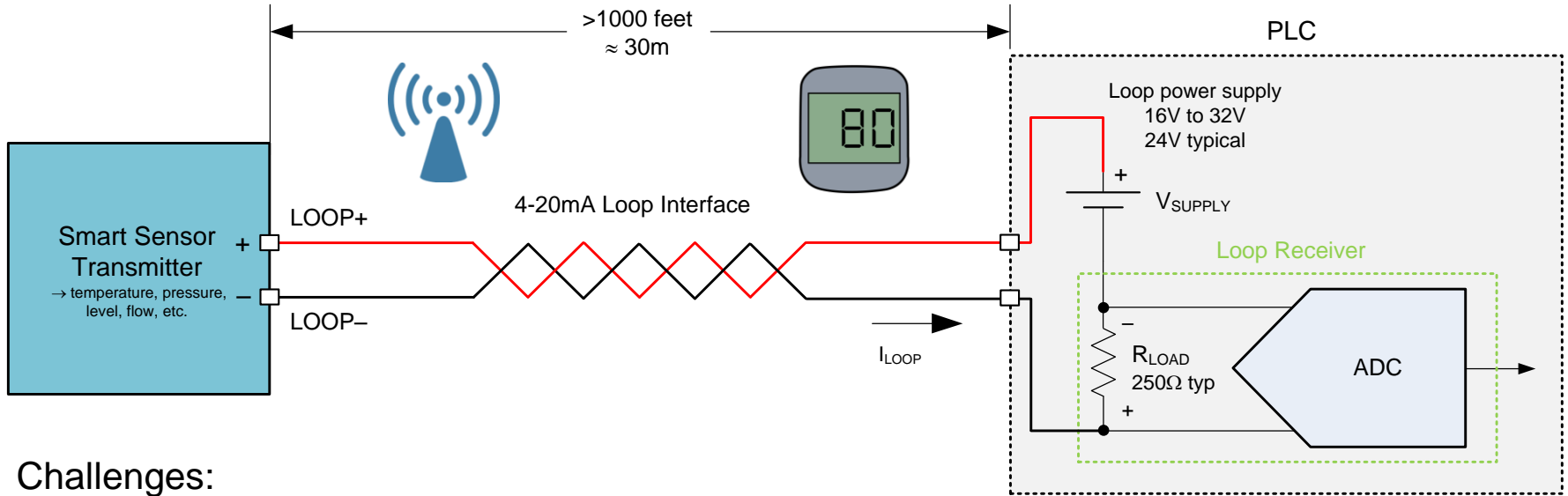


4–20mA current loop architecture



- WirelessHART® Adapters
- Loop Powered 4 to 20-mA Indicators and Displays

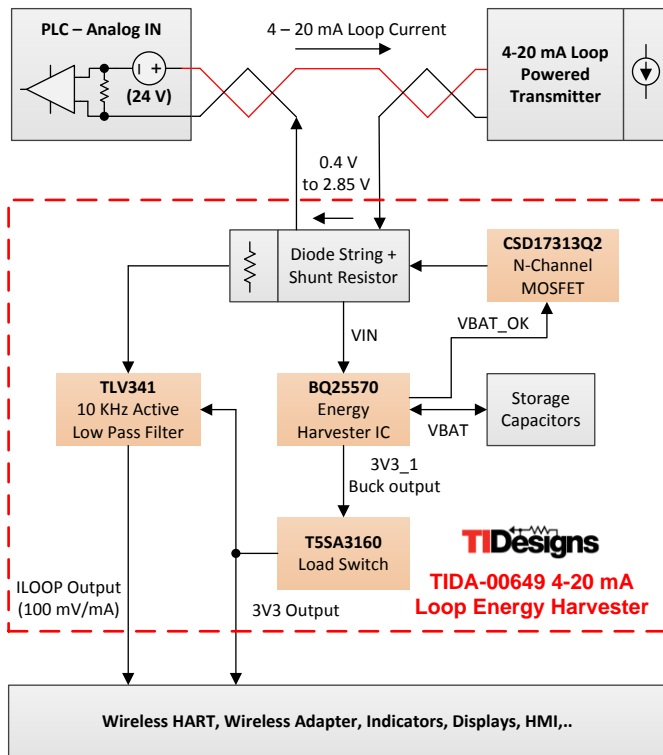
4–20mA current loop architecture



Challenges:

- Seamless integration in existing loop powered systems
- Simple Installation
- No additional power supply
 - Powered from the 4-20mA loop
 - Very small insertion voltage drop to optimize the use of available loop power

4-20mA Loop Energy Harvester Block Diagram



4-20mA Loop Energy Harvester Reference Design

TI-Design: TIDA-00649



Features

- Minimal Insertion Loss (0.4 V to 2.85 V), Selectable
 - Adaptable to Voltage Margin in Loop & Required Output Pwr
- Adjustable Output Voltage Between 1.8 V to 3.8 V
- 15-mA Peak-Pulsed Output Current
- Loop Current Sensing
 - Analog Output 100 mV/mA, Active 10-kHz Low-Pass Filter
- Reverse Polarity Protection
- Designed to Withstand Surges According to IEC 61000-4-5; ± 1 kV; 40 Ω
- Flexible Configurations for Test and Evaluation

Target Applications

- Loop-Powered Adapters (WirelessHART®, BLE, and so forth)
- Loop-Powered Indicators, Displays, and HMIs

Tools & Resources



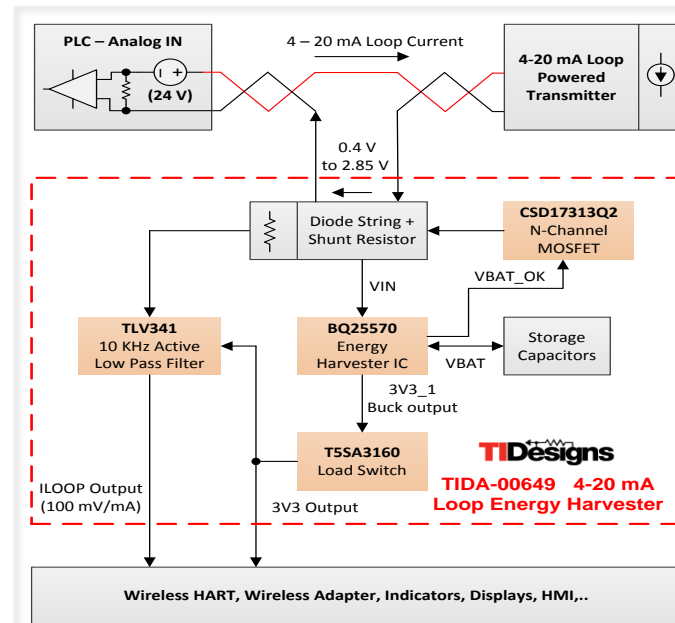
TIDA-00649

- [Design Guide](#) [Design Files](#)
- [BQ25570](#) [TS5A3160](#) [TLV341](#) [CSD17313Q2](#)

Device Datasheets:

Benefits

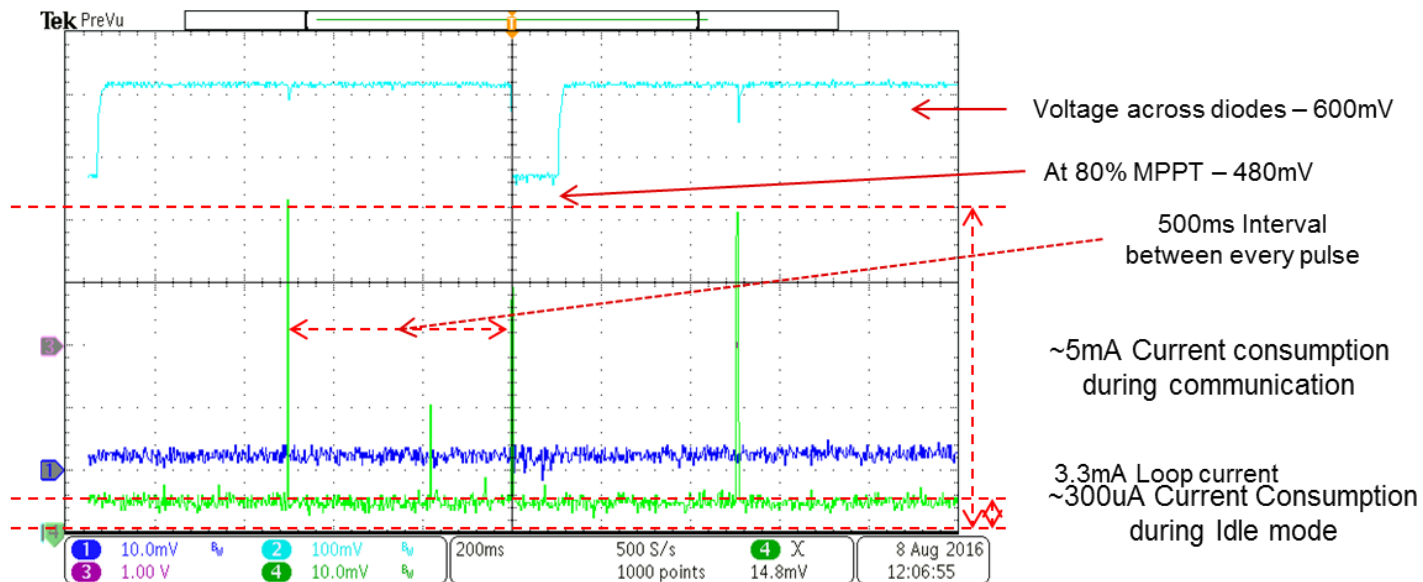
- Seamless integration in existing loop powered systems
- Simple installation
- Ease of use



Application curves

Note: Shunt resistor used = 10 Ohms

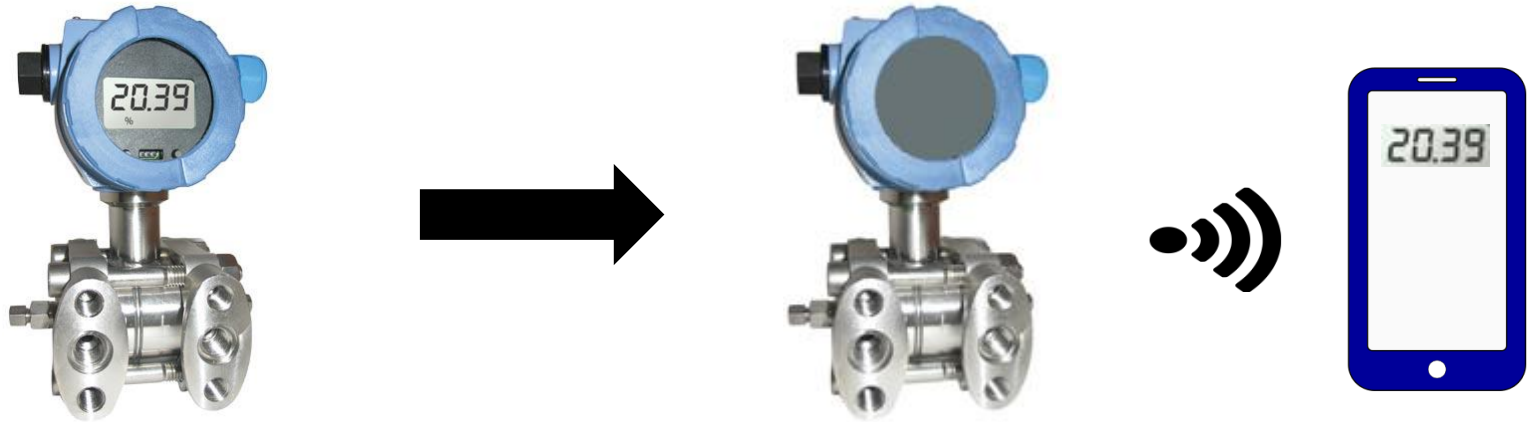
— Voltage drop across diode
— Current through loop
— Input current to CC2650



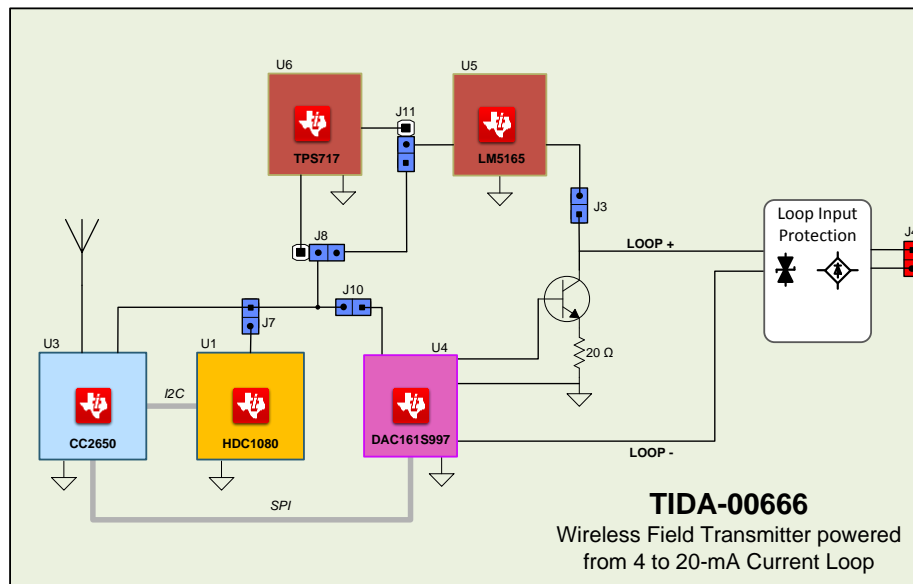
Wireless HMI

From LCD to remote BLE display

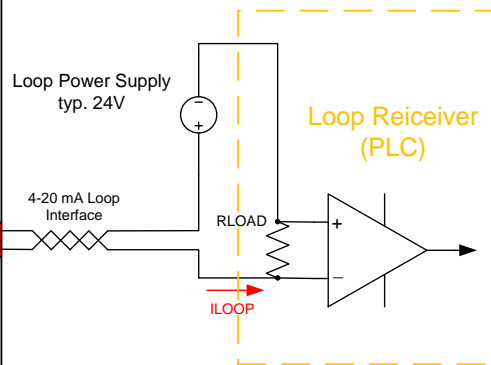
- **Today:** Segment LCD, few control buttons, basic menu system, hard to setup and configure, bad user experience
- **Tomorrow:** Smartphone app with powerful features, easy setup and configuration, easy data access



Block diagram of a field transmitter with BLE connectivity powered from 4-20mA current loop



Transmitter must be powered on less than ~3.3mA of loop current



ILOOP-Range

Nominal:	4 – 20 mA
Extended:	3.8 – 20.5 mA
Error High:	≥ 21 mA
Error Low:	≤ 3.6 mA

DAC161S997

Default Error High:	21.750 mA
Default Error Low:	3.375 mA

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Field transmitter with BLE connectivity powered from 4-20mA current loop

TI-Design: TIDA-00666



Features

- 4-20mA loop powered Bluetooth Low Energy communication
- 4-20mA current-loop output signal
- 8V - to 33-V input voltage range
- 16-Bit loop current resolution
- On board humidity and temperature sensor

Target Applications

- Industrial
- Factory Automation and Process Control
- Sensors and Field Transmitters
- Internet of Things (IoT)

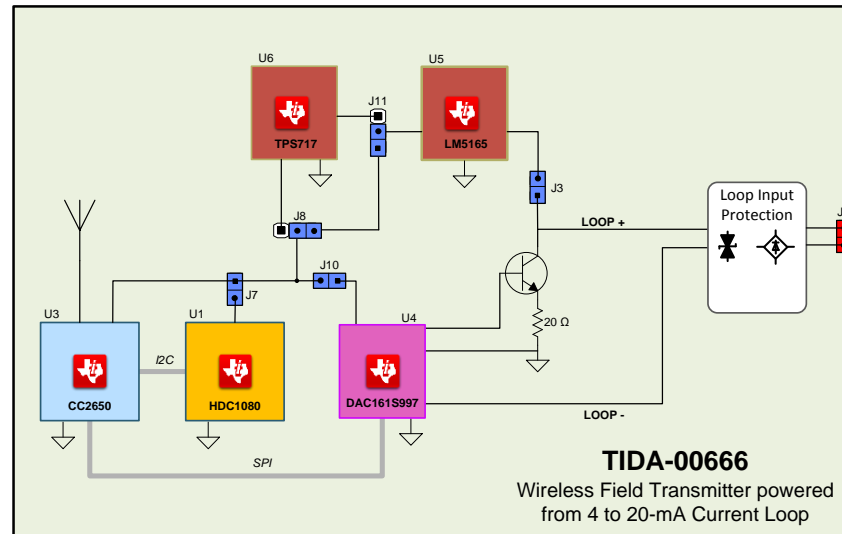
Tools & Resources



- **TIDA-00666**
- [Design Guide](#)
- [Design Files](#)
- **Device Datasheets:**
 - [CC2650](#)
 - [DAC161S997](#)
 - [LM5165](#)
 - [TPS717](#)
 - [HDC1080](#)

Benefits

- Open source firmware
- Precision sensor interface for easy evaluation (analog & digital input stimulus on board)
- Small, integrated solution size due to the integrated sensor and radio SoC

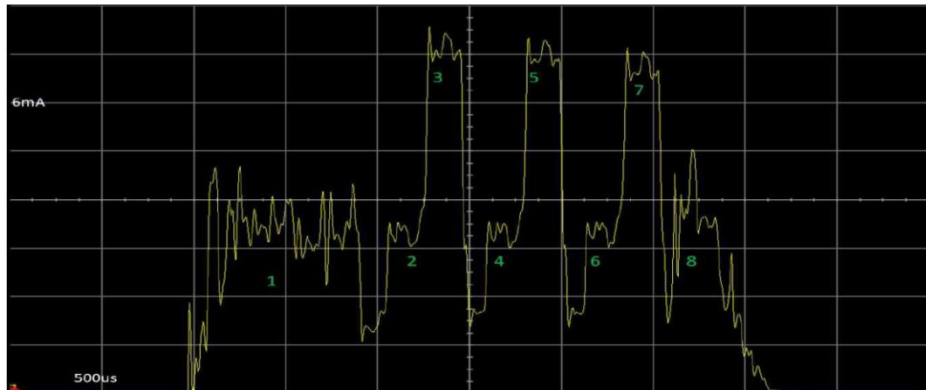


TIDA-00666

Wireless Field Transmitter powered from 4 to 20-mA Current Loop

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CC2650 beacon event

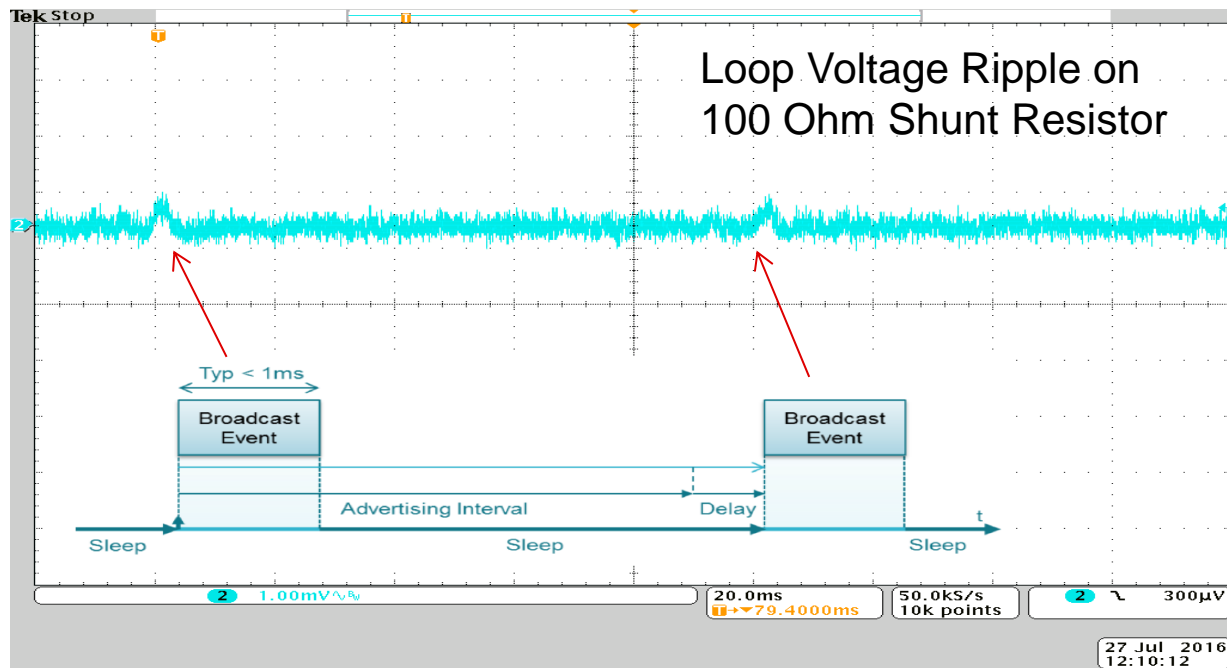


0 dBm output power

	State	Time [μ s]	Current [mA]	Comments
1	Pre-processing	1160	3.26	RTOS wake-up, radio setup, XTAL guard time
2	Radio preparation	101	4.3	Radio is turned on and in transition to TX
3	TX	144	7.47	Tha radio transmits an advertismt packets with 3 bytes data on Channel 37. Time is dependent on amount of transmitted data
4	TX-to-TX transition	372	3.56	TX to TX transition
5	TX	144	7.47	Tha radio transmits an advertismt packets with 3 bytes data on Channel 38. Time is dependent on amount of transmitted data
6	TX-to-TX transition	372	3.56	TX to TX transition
7	TX	144	7.47	Tha radio transmits an advertismt packets with 3 bytes data on Channel 39. Time is dependent on amount of transmitted data
8	Post-processing and going to standby	685	2.45	BLE protocol stack sets up the sleep timer in preparation for the next event. And then going to standby afterwards

Loop current influence

VCC Loop Terminal	TX Power	CC2650 Mode	DAC161S997 Loop Current Setting
24V	0dBm	Broadcast (every 100ms)	3.3mA



VCC on 100 ohm
loop shunt (1mV/div)

< 10uA current ripple

Powering sensor transmitters

Problem: how to power sensor transmitter from 4–20mA loop and not exceed 3.3mA current budget

- Limited PCB area dedicated to power solution
- LDO with $I_{IN} \approx I_{OUT}$ draws too much current from loop
- Must be **efficient** and **low cost**

Solution: replace LDO with **LM5165 synchronous DC/DC converter**

- High efficiency, $\eta > 90\%$ from 1mA to 25mA load
- Ultra-low I_Q of 10 μ A
- Wide V_{IN} operating range of 3V to 65V with programmable UVLO
- Supports transients to 65V, inrush current, reverse polarity, surge protection

LM5165

150mA Ultra-Low I_Q Synchronous Buck Regulator

Features

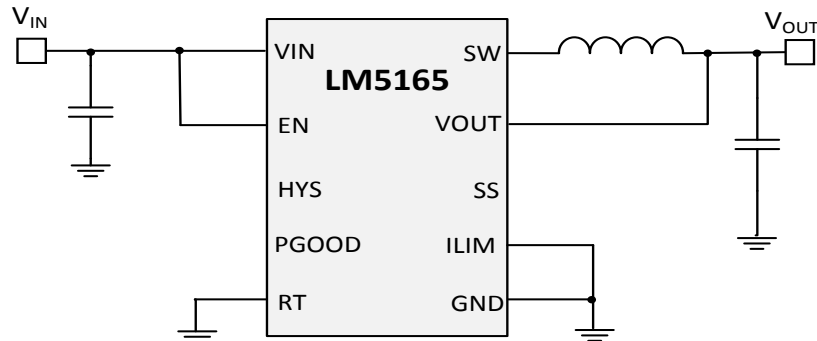
- **Wide Operating V_{IN} Range from 3V to 65V**
- **10.5 μ A No-load Quiescent Current**
- **4-Level Programmable Peak Current Limit**
 - **240mA, 180mA, 120mA or 60mA**
- Fixed 3.3V, 5.0V and Adjustable V_{OUT} Options
- PMOS High-Side Buck Switch
 - Eliminates bootstrap capacitor
 - 100% duty cycle for low dropout operation
- Two Control Mode Options
 - COT for nearly constant frequency
 - PFM for maximum efficiency
- Flexible Soft-start Options
 - Internal fixed, externally adjustable or no Soft-start
- Enable/ UVLO with Adjustable Hysteresis
- Power Good Flag
- 150°C Operating Junction Temperature

Applications

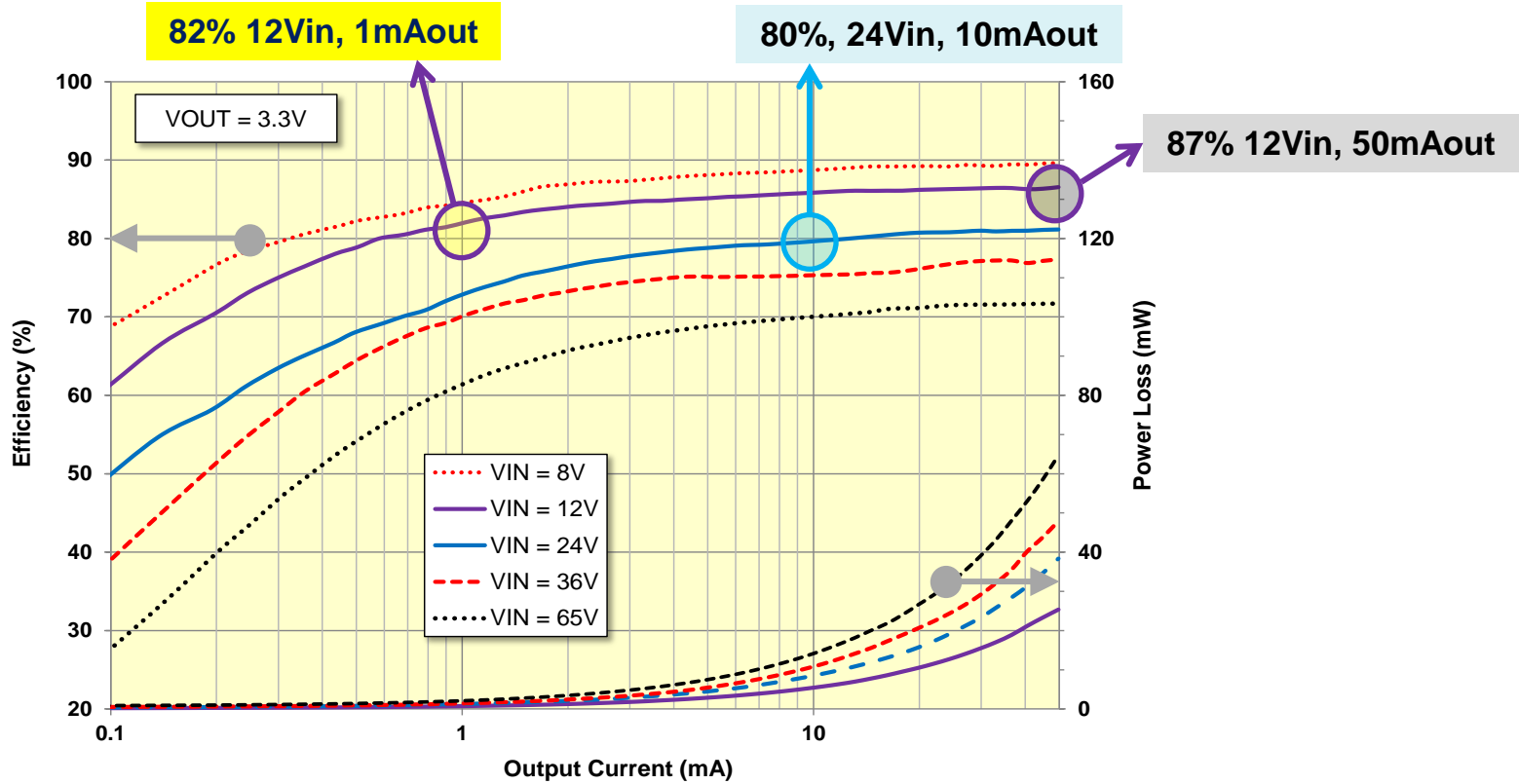
- Ideal for current-loop powered sensors
- Always-on automotive bias supply
- Industrial control systems

Benefits

- Low quiescent current and PFM for improved efficiency at low output currents
 - Target efficiency > 90% at 1mA–5mA I_{OUT}
- Wide input voltage range suitable for industrial & automotive applications
- Adjustable peak current limit controls inrush & fault mode input currents
- Minimum external components and tiny solution size



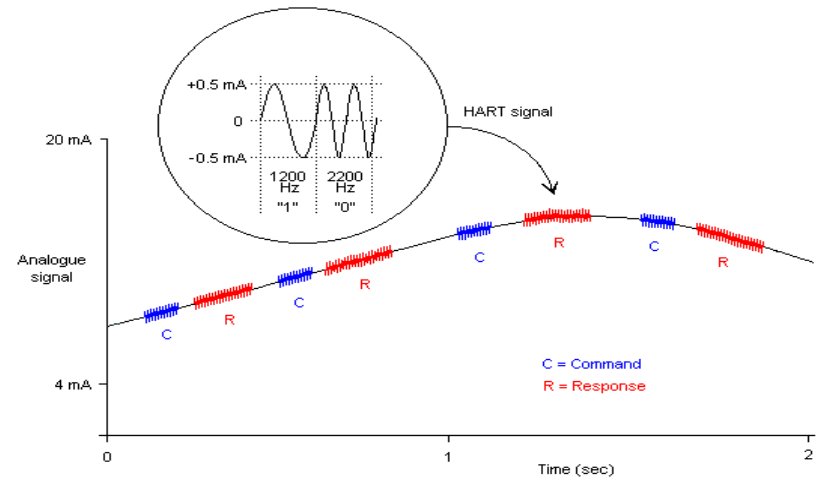
Efficiency vs. I_{OUT} & V_{IN} , $V_{OUT} = 3.3V$



Integrating several protocols into one IC

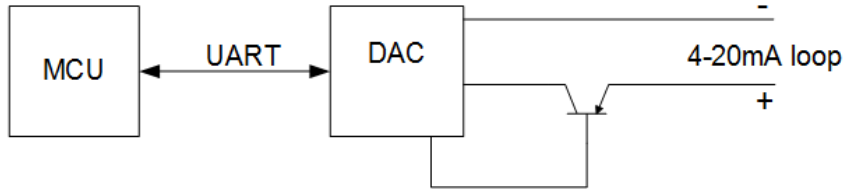
HART - principle

- HART (Highway Addressable Remote Transducer) was developed by Fisher-Rosemount to retrofit 4-to-20mA current loop transducers with digital data communication.
- HART modulates the 4-20mA current with a low-level frequency-shift-keyed (FSK) sine-wave signal, without affecting the average analogue signal.
- HART uses low frequencies (1200Hz and 2200 Hz) to deal with poor cabling, its rate is 1200 Bd - but sufficient.

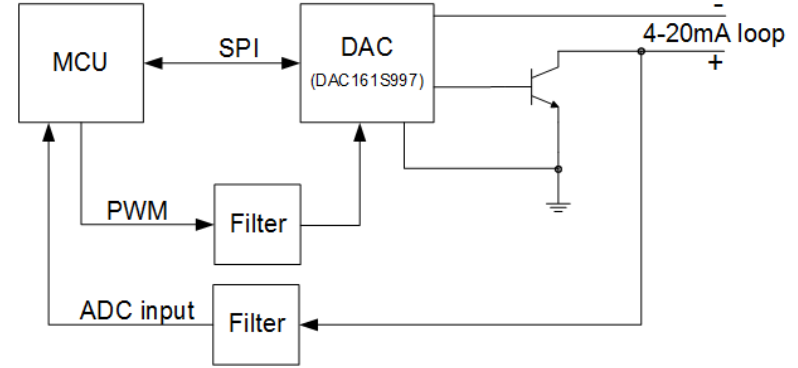


Possible HART implementations

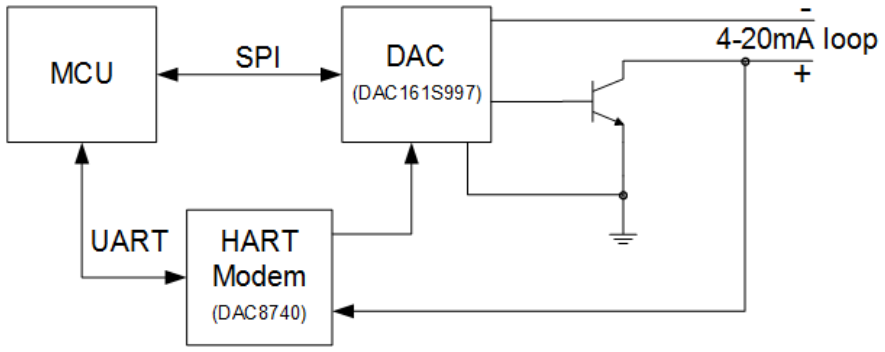
DAC 4-20mA & HART modem (single chip)



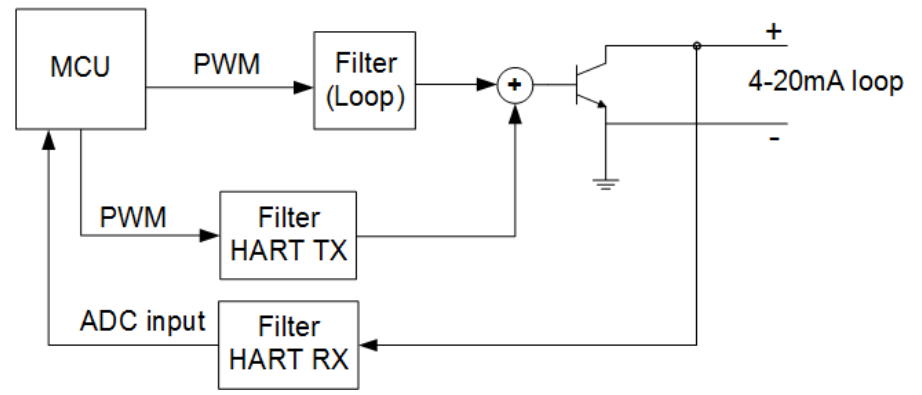
DAC 4-20mA & Soft HART modem



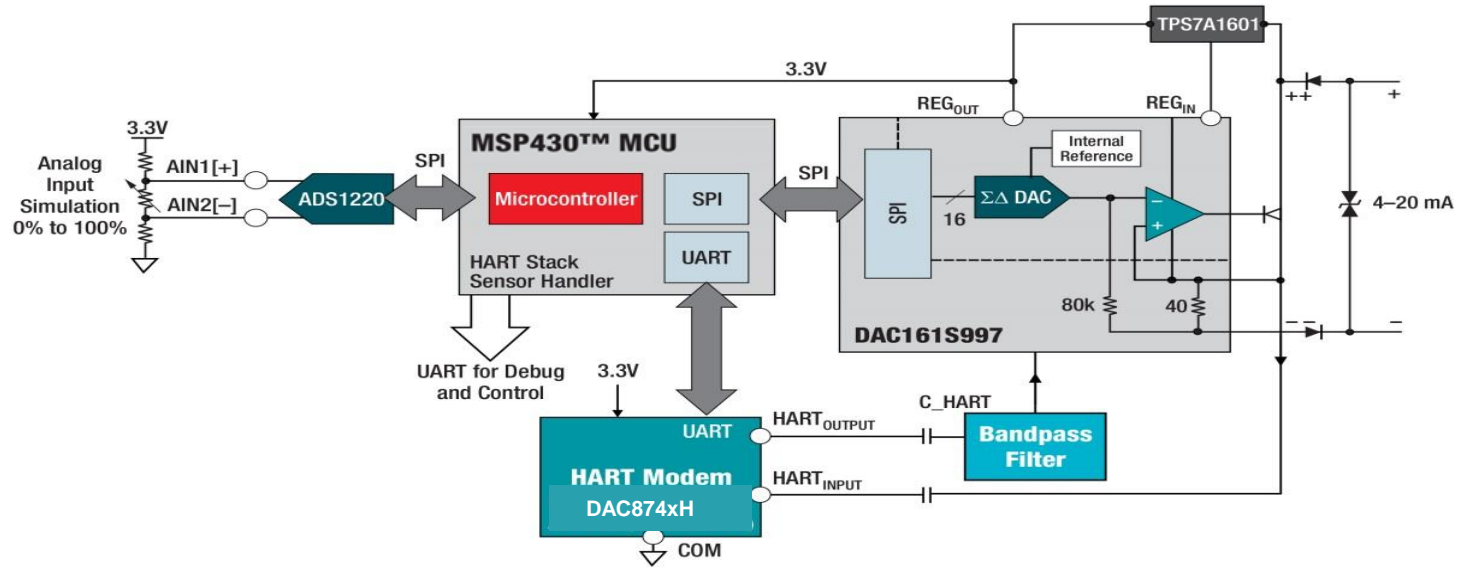
DAC 4-20mA & HART modem (two chip)



PWM 4-20mA & Soft HART modem



HART field transmitter design



- MCU to run the HART protocol and a separate device to carry out the required physical layer (HART Modem)

DAC161S997 / DAC161P997

16-bit 2-wire Current Output DACs with SPI or 1-Wire Interfaces

Features

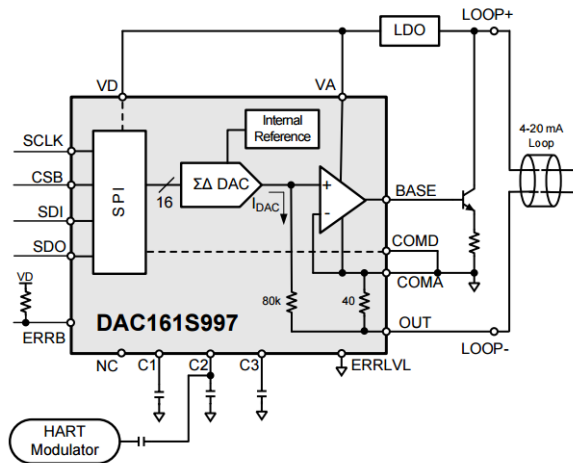
- 16-bit $\Sigma\Delta$ DAC
- 2-wire Current Output
 - 0-24mA output range
 - Pin-Programmable Power-Up Current
 - Programmable NAMUR Output Current Levels
- TUE: 0.1% FSR max
- Internal Reference
- Wide Temp Range: -40°C to +105°C
- Reliability: Loop error, SPI timeout, and frame error alarms
- HART Interface
- 4x4mm 16-QFN

Applications

- Sensor Transmitters
- Industrial Automation
- Building Automation

Benefits

- Integrates DAC, reference, loop amplifier, and gain setting resistors required for 2-wire transmitter applications
- 1-wire interface relaxes needs from digital isolation
- Very small package saves space / cost
- Ability to AC couple FSK signals to 4-20mA loop enables HART applications



DAC8740H, DAC8741H, DAC8742H

HART, Foundation Fieldbus, & Profibus PA Modems

Features

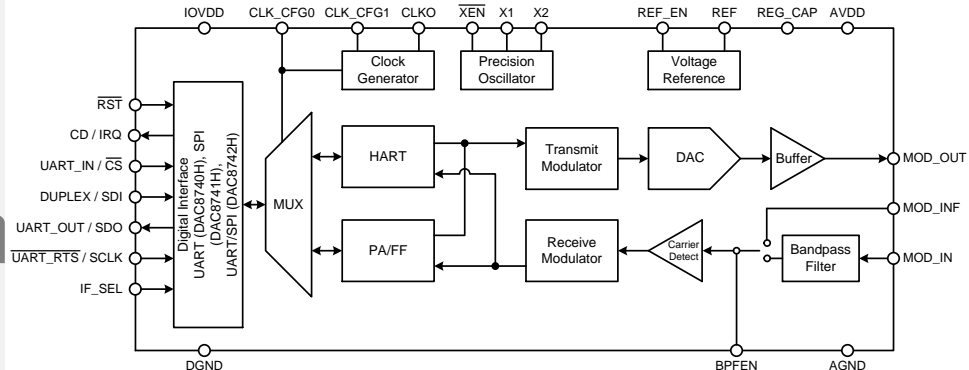
- HART/FF/PA compliant FSK Modem
- 1.8-5.5V operation
- Low Quiescent Current
 - Modulator/Demodulator: 150uA (target max)
 - Internal Oscillator: TBD uA
- Flexible Clocking Options
 - Internal Oscillator
 - External Crystal Oscillator
 - External CMOS clock input
- Integrated Receive band-pass filter, optional external filter
- Buffered Voltage Output
- Interface Options
 - SPI with extended features (DAC8741H / DAC8742H)
 - Simple UART “feedthrough” (DAC8740H / DAC8742H)
- Wide Temp Range: -55°C to +125°C

Applications

- Industrial Process Control and Automation
- PLC I/O Modules
- 4 to 20mA, loop powered transmitters
- Smart transmitters

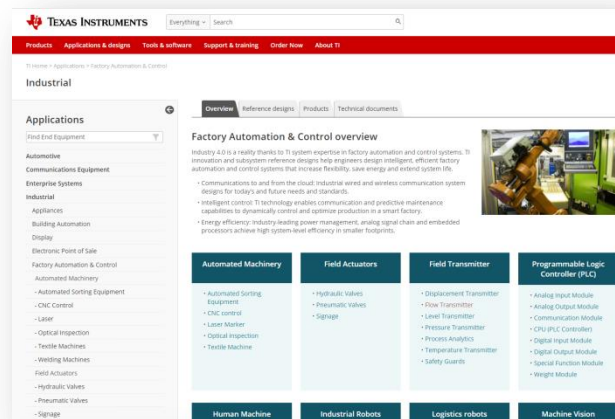
Benefits

- Minimal power consumption
- HART modem and oscillator eases processing burden
- Reliable operation to extended industrial temp range
- Pairs easily with DAC8760 & DAC8775 families

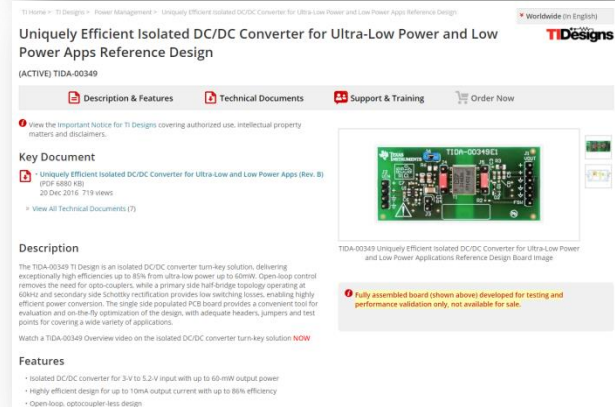


Additional resources available to you:

- **Web Overview:** [Factory Automation & Control Overview page](#)
- **Reference Design:** [Uniquely Efficient Isolated DC/DC Converter for Ultra-Low Power and Low Power Apps](#)
- **Reference Design:** [4-mA to 20-mA Loop Energy Harvester](#)
- **Reference Design:** [Field Transmitter with BLE Connectivity Powered from 4 to 20-mA Current Loop](#)
- **Product Highlight:** [LM5165, 3V-65V, 150mA Synchronous Buck Converter With Ultra-Low IQ](#)
- **Product Highlight:** [DAC8740H, HART®, FOUNDATION Fieldbus™, and PROFIBUS PA-Compliant Modem With UART Interface](#)
- **Product Highlight:** [DAC161S997, SPI 16-bit Precision DAC for 4-20mA Loops](#)
- **Product Highlight:** [CC2650, SimpleLink multi-standard 2.4 GHz ultra-low power wireless MCU](#)



The screenshot shows the Texas Instruments website's 'Factory Automation & Control overview' page. The page is structured with a top navigation bar, a sidebar for navigation, and a main content area. The sidebar lists various application categories such as Automotive, Industrial, and Field End Equipment. The main content area includes an 'Overview' section with introductory text, a grid of product highlights (Automated Machinery, Field Actuators, Field Transmitters, Programmable Logic Controller (PLC)), and a bottom navigation bar with categories like Human Machine, Industrial Robots, Logistics robots, and Machine Vision.



The screenshot displays the 'Uniquely Efficient Isolated DC/DC Converter for Ultra-Low Power and Low Power Apps Reference Design' page. It features a title, a 'Description' section, a 'Key Document' section with a PDF icon, and a 'Features' section. The 'Description' section provides a detailed overview of the TIDA-00349 TI Design, highlighting its efficiency and power conversion capabilities. The 'Key Document' section includes a PDF icon and a link to the document. The 'Features' section lists technical specifications such as input/output voltage, efficiency, and current ratings.



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