Design Guide: TIDA-011026

Field Transmitter Platform: Three-Wire 4mA to 20mA Interface Reference Design

TEXAS INSTRUMENTS

Description

This reference design gives an example implementation of a 4–20mA interface for 3-wire voltage and current interface sensors. The design enables evaluation of the XTR200 alongside the current loop protector TPS2661. The XTR200 integrates the output drive circuitry for voltage and current field transmitter communication interfaces with standard industrial signal levels such as 4-20mA, 0-20mA, and 0-10V. The reference design provides access over a pin header to a pulse-width modulated (PWM) interface that drives the output stage. This pin header also provides 3.3V to power a connected microcontroller.

Resources

TIDA-011026	Design Folder
XTR200, TPS2661	Product Folder
TLV9302, OPA2991	Product Folder
TVS3301, ADS122S14	Product Folder
SN74LV8T165	Product Folder
MSPM0-SDK, SNSR-DUAL-ADC-EVM	Tool Folder

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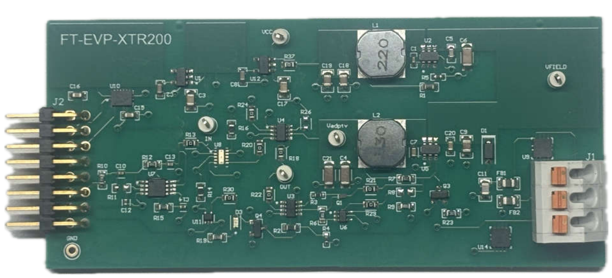
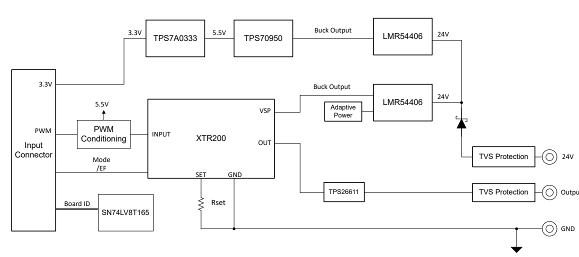
Features

- Implementation of 4–20mA loop interface for 3-wire sensor
- Low-pass filter circuit to drive output stage via MCU PWM
- Integrated current loop protection and miswiring protection
- Adaptive power circuit to maximize power efficiency
- MCU interface providing power output (3.3V), SPI

Applications

- Flow transmitter
- Level transmitter
- Pressure transmitter
- Temperature transmitter
- Analog output module





1 System Description

This reference design implements 3-wire voltage and current industrial interface output. The design incorporates a PWM filter at the input stage and an integrated output stage within the XTR200. The system is capable of switching between voltage and current output mode with set gains for 0-20mA, 4-20mA, and 0-10V output ranges.

The field power supply is regulated by two buck converters. One powers the output stage and the other provides a lower voltage for local low dropout (LDO) regulators. The buck converter that powers the output stage implements an adaptive power circuit which increases the supply voltage of the XTR200 as the voltage output of the module increases. This circuit maintains that there is enough headroom to drive the output load according to the XTR200 requirements. The other buck converter output is regulated down to 5V and 3.3V with two LDOs in series. The 5V power signal is used locally for the PWM filter. The 3.3V power signal is used to provide power over the pin header to a sensing module with an MCU. LDOs (TPS7A0333 and TPS70950) with low I_Q are used to maintain a stable and efficient power output keeping the available power for the system high.

The PWM filter is a 4th order active low-pass filter (LPF) which is intended to convert a PWM signal into an analog input signal to drive the XTR200. This allows evaluating the design without having to implement a dedicated digital-to-analog converter (DAC) or an internal DAC to the MCU.

1.1 Key System Specifications

Table 1-1. Specifications

PARAMETER	SPECIFICATION
Field supply voltage	8V to 36V
Output current range	0mA to 27mA
Output voltage range	0 to 12.375V
Resolution	8.057uA, 3.02mV
Current output mode RMS noise	385nA
Current output mode peak-to-peak noise	2.3uA
Voltage output mode RMS noise	129uV
Voltage output mode peak-to-peak noise	775uV
Settling time	202us
Power supply output	3.3V
Power supply output current	2mA
Interface to MCU	SPI

2 System Overview

2.1 Block Diagram

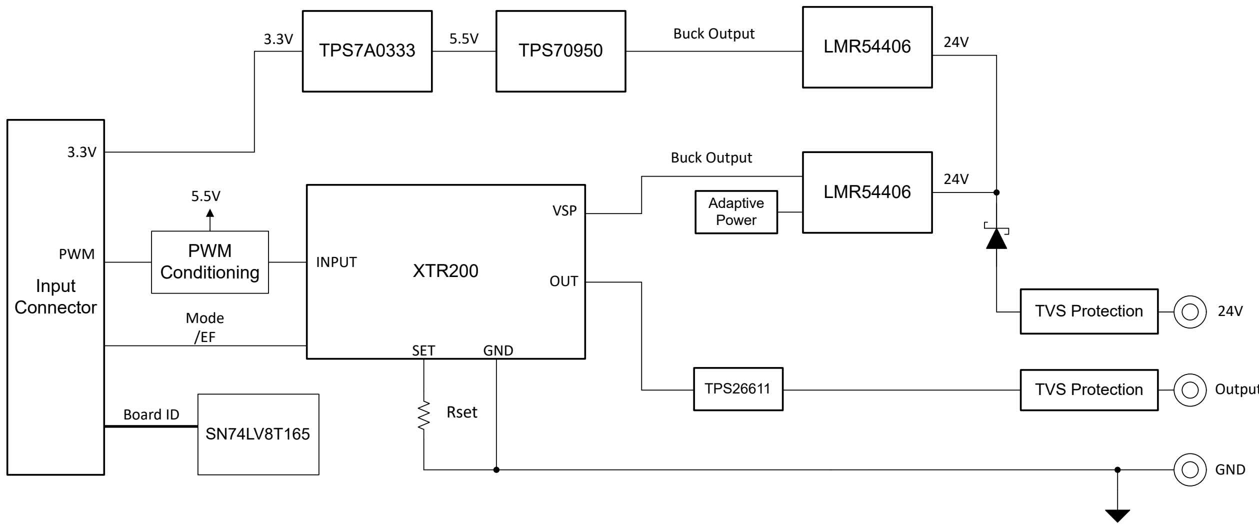


Figure 2-1. TIDA-011026 Block Diagram

2.2 Design Considerations

This design implements the 0mA to 20mA, 4mA to 20mA, and 0V to 10V output stage for field transmitters and sensors. The XTR200 integrates the signal chain gain according to the output mode (voltage or current) and the output stage drive circuitry with a low-leakage PMOS output transistor.

This module is designed to be connected to the sensor module SNSR-DUAL-ADC-EVM. The sensor module can be powered by this board from the field power connection. The sensor module also features a single firmware (FW) design to identify and drive the circuitry of this design.

The input to the XTR200 is driven by the sensor board's MCU which outputs a PWM signal. A 4th-order active LPF modulates the PWM signal and this signal is fed to the XTR200 input. The LPF is designed with a cutoff frequency of 1.95kHz and the PWM signal runs at a frequency of 19.5kHz. The LPF architecture enables a clean output signal from the filter and therefore a clean input to the XTR200; eliminating the need for a dedicated DAC. Alternatively, the LPF can be bypassed by driving the XTR200 input with a DAC or signal generator attached to testpoint TP4 for debugging purposes.

In terms of protection, the TPS2661 covers overcurrent, overvoltage, and reverse polarity protection of the output. Reverse polarity protection of supply and ground is covered by a forward-biased diode (D1). Transient voltage protection is provided by the TVS3301 TVS diode, safeguarding against excessive voltage levels due to transient events on the supply and output lines. High-frequency noise is reduced with ferrite beads on the supply and output lines.

The buck converter that powers the output stage contains an adaptive power circuit. The adaptive power circuit acts as a current sink which draws current from the feedback pin of the buck converter as the output voltage of the module increases. The purpose of this circuit is to maximize power efficiency and reduce the heat dissipation of the XTR200 by keeping the supply voltage at the minimum headroom required. This is particularly important in current output mode when higher a higher load is present. The headroom requirement is dictated by the XTR200 data sheet specifications. The adaptive power circuit is designed so that the headroom of the XTR200 is always at least 3V above the output voltage.

2.3 Highlighted Products

2.3.1 TPS7A03

The TPS7A03 is an ultra-small, ultra-low quiescent current low-dropout linear regulator (LDO) that can source 200mA with excellent transient performance.

The TPS7A03, with an ultra-low I_Q of 200nA, is designed specifically for applications where very-low quiescent current is a critical parameter. This device maintains low I_Q consumption even in dropout mode to further increase battery life. When in shutdown or disabled mode, the device consumes ultra-low, 3nA I_Q that helps increase the shelf life of the battery.

The TPS7A03 has an output range of 0.8V to 5.0V available in 50mV steps to support the lower core voltages of modern microcontrollers (MCUs).

The TPS7A03 features a smart enable circuit with an internally controlled pulldown resistor that keeps the LDO disabled even when the EN pin is left floating and helps minimize the external components used to pulldown the EN pin. This circuit also helps minimize the current drawn through the external pulldown circuit when the device is enabled.

2.3.2 TPS709

The TPS709 series of linear regulators are ultra-low, quiescent current devices designed for power-sensitive applications. A precision band-gap and error amplifier provides 2% accuracy over temperature. Quiescent current of only 1µA makes these devices ideal solutions for battery-powered, always-on systems that require very little idle-state power dissipation. These devices have thermal-shutdown, current-limit, and reverse-current protections for added safety.

Shutdown mode is enabled by pulling the EN pin low. The shutdown current in this mode goes down to 150nA, typical.

2.3.3 TVS3301

The TVS3301 device shunts up to 27A of IEC 61000-4-5 fault current to protect systems from high-power transients or lightning strikes. The device survives the common industrial signal line EMC requirement of 1kV IEC 61000-4-5 open circuit voltage coupled through a 42Ω impedance. The TVS3301 uses a feedback mechanism to provide precise flat clamping during a fault, keeping system exposure lower than traditional TVS diodes. The tight voltage regulation allows designers to confidently select system components with a lower voltage tolerance, lowering system costs and complexity without sacrificing robustness. The TVS3301 has a ±33V operating range to enable operation in systems that require protection against reverse wiring conditions.

In addition, the TVS3301 is available in a small SON footprint designed for space constrained applications, offering a significant size reduction compared to standard SMA and SMB packages. Low device leakage and capacitance provide a minimal effect on the protected line. To provide robust protection over the lifetime of the product, TI tests the TVS3301 against 5000 repetitive surge strikes at 125°C with no shift in device performance.

2.3.4 XTR200

The XTR200 is a high-voltage, precision, output driver for 3-wire current or voltage systems, designed for standard industrial signal levels such as 0mA to 20mA, 4mA to 20mA, and 0V to 10V. The mode pin configures the device for either current or voltage output and eliminates the need to change external components to switch between modes. In currentoutput mode, the ratio between input voltage and output current is set by a single resistor, RSET. In voltage-output mode, the XTR200 has a fixed gain of 3.75V/V which is set by integrated, high-precision, thin-film, resistors.

The device integrates a low-leakage PMOS output transistor and short-circuit current protection, further reducing the need for external components. An external PNP or PMOS transistor can be used with the XTR200 to reduce on-chip power dissipation. The on-chip short-circuit protection also protects external transistors from damaging overcurrent events.

The XTR200 error flag pin (EF) indicates several temperature or output fault conditions. The output disable pin (OD) places the output pin into a highimpedance state with very low leakage.

2.3.5 TPS2661

The TPS2661x is a compact, feature-rich, fully integrated current loop protector suitable for analog inputs, analog outputs, sensor transmitters, HART inputs, and UART IO protection. The device provides universal input protection for ±20mA, 0mA to 20mA, and 4mA–20mA. Low RON values of 7.5Ω minimizes drop in the current loop, thereby extending operating range and supporting operation even with lower voltage power supplies. The device can withstand and protect the loads from positive and negative supply voltages up to ±50V. The MODE pin allows flexibility to enable 2× current limit through the device to enable proper start-up of two wire transmitters. Device is capable of operating from an external bipolar supply as low as ± 2.25V to ±20V. The device can also be powered from unipolar supplies as low as 3V to 30V. The TPS26610 and TPS26613 feature loop power mode to facilitate loop testing in un-powered state without ±Vs supplies.

The device also protects the system from output side miswiring in analog outputs and sensor transmitters by turning off the current path. The internal robust protection control blocks along with the 50V rating of the TPS2661x help to protect against surge (IEC61000-4-5) and EFT (IEC61000-4-4) transients for signal lines.

2.3.6 OPAX991

The OPAx991 family (OPA991, OPA2991, and OPA4991) is a family of high voltage (40V) general purpose operational amplifiers. These devices offer exceptional DC precision and AC performance, including rail-to-rail input/output, low offset (±125µV, typical), low offset drift (±0.3µV/°C, typical), low noise (10.5nV/√Hz and 1.8µVPP), and 4.5MHz bandwidth.

Unique features such as differential and commonmode input-voltage range to the supply rail, high output current (±75mA), high slew rate (21V/µs), high capacitive load drive (1nF), and shutdown functionality make the OPAx991 a robust, high-performance operational amplifier for high-voltage industrial applications.

2.3.7 TLV930X

The TLV930x family (TLV9301, TLV9302, and TLV9304) is a family of 40V, cost-optimized operational amplifiers. These devices offer strong general-purpose DC and AC specifications, including rail-to-rail output, low offset (±0.5mV, typ), low offset drift (±2µV/°C, typ), and 1MHz bandwidth.

Convenient features such as wide differential input voltage range, high output current (±60mA), and high slew rate (3V/µs) make the TLV930x a robust operational amplifier for high-voltage, cost-sensitive applications.

2.3.8 LMR544XX

The LMR544xx is a wide-VIN, easy-to-use synchronous buck converter capable of driving up to 1A and 0.6A load current. With a wide input range of 4V to 36V, the device is designed for a wide range of industrial applications for power conditioning from an unregulated source. The LMR544xx operates at 1.1MHz switching frequency to support use of relatively small inductors for an optimized design size.

The devices have a PFM version to realize high efficiency at light load and a FPWM version to achieve constant frequency and small output voltage ripple over the full load range. Soft-start and compensation circuits are implemented internally, which allow the device to be used with minimal external components.

The device has built-in protection features, such as cycle-by-cycle current limit, hiccup mode short-circuit protection, and thermal shutdown in case of excessive power dissipation.

2.3.9 SN74LV8T165

The SN74LV8T165 device is a parallel- or serial-in, serial-out 8-bit shift register. This device has two modes of operation: load data, and shift data which are controlled by the SH/LD input. The output level is referenced to the supply voltage (VCC) and supports 1.8V, 2.5V, 3.3V, and 5V CMOS levels.

The input is designed with a lower threshold circuit to support up translation for lower voltage CMOS inputs (for example 1.2V input to 1.8V output or 1.8V input to 3.3V output). In addition, the 5V tolerant input pins enable down translation (for example 3.3V to 2.5V output).

3 System Design Theory

This section provides information about the different blocks of this design. Figure 3-1 shows the location of these blocks.

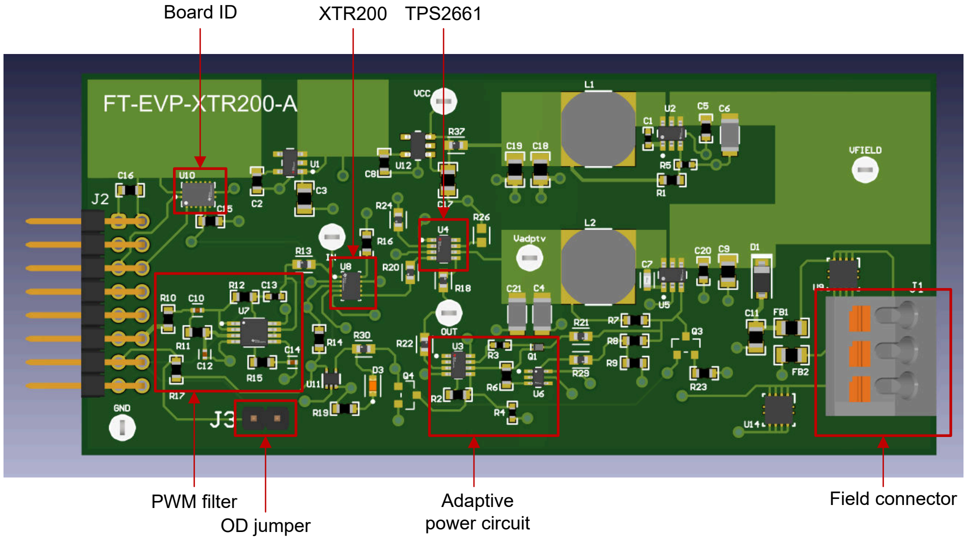


Figure 3-1. TIDA-011026 Functional Block

To be able to identify the board in the software, each board has a shift register of which the input pins code a board ID number, which can be read from the MCU through SPI.

The XTR200 is the main component of the design. This device integrates the circuitry needed to drive both the voltage and current output modes. The output mode is controlled by the mode pin of the device which is accessible to a GPIO of the MCU platform via the header pin. The XTR200 also integrates the current-drive transistor and short-circuit protection.

The supply is protected against reverse polarity using a Schottky diode and against transient voltages using a TVS3301 TVS diode. Some filtering from high frequency noise is available using a ferrite bead. The output is protected against overvoltage, overcurrent, and reverse polarity using TPS2661.

For the power supply, two buck converters regulate the field power supply voltage. One of which powers the XTR200 and the TPS2661. This buck converter features an adaptive power circuit. The other buck converter is used to step down the supply voltage to two LDOs that are onboard to generate clean 5V and 3.3V rails from the field supply voltage. These LDOs power the PWM circuit locally (5V) and provide power to the sensor board (3.3V).

The adaptive power circuit is designed using a TLV9302 for a buffer and a step-down stage and a TLV9301 which provides an offset so that the supply voltage output of the buck converter increases only when the board output is greater than 5V. The step-down stage is designed so that the adaptive power circuit draws just enough current from the buck-converter's feedback pin to keep the supply voltage 3V higher than the output voltage of the module with respect to the supply's ground.

The PWM filter is an active 4th-order LPF which is designed using OPA2991 that enables rail-to-rail output voltage so that the input to the XTR200 is as close to 0V as possible. The OPA2991 is able to drive as low as 10mV in this design.

4 Hardware, Software, Testing Requirements, and Test Results

4.1 Hardware Requirements

Figure 4-1 shows the TIDA-011026 testpoints, jumpers, and connectors for proper functionality and debugging.

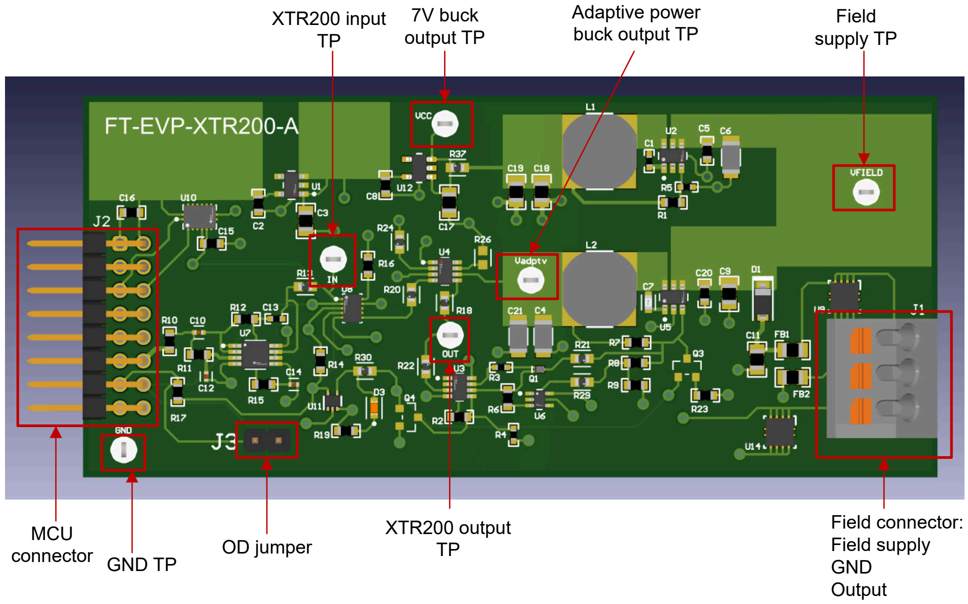


Figure 4-1. TIDA-011026 Testpoints, Jumper, and Connectors

Table 4-1. Testpoint, Jumper, and Connector Descriptions

DESIGNATOR	Silkscreen ID	JUMPER, CONNECTOR	DESCRIPTION
J1	J1	Field connector	Connection for field supply and field transmitter output.
J2	J2	MCU Connector	Connection to microcontroller board.
J3	J3	OD jumper	This jumper connection enables the XTR200 output when shorted. This allows to evaluate the transmitter board without the sensor board.
TP1	GND	GND testpoint	GND testpoint for debugging purposes.
TP2	OUT	OUT testpoint	Field transmitter module output testpoint for debugging purposes.
TP3	VFIELD	Vfield testpoint	Field voltage supply tespoint for debugging purposes.
TP4	IN	XTR_IN testpoint	XTR200 input testpoint for debugging purposes. This allows to evaluate and drive the transmitter board without the sensor board.
TP5	VCC	LDO_IN testpoint	Buck output testpoint for debugging purposes.
TP6	Vadptv	Vbuck_out testpoint	Adaptive power buck output for debugging purposes.

The connector J1 connects to an MCU board, Table 4-2 shows the pinout. Pin one is marked on the PCB.

Table 4-2. J1 Connector Pinout

PIN	SIGNAL
1	GND
2	VDD-3V3
3	Not used
4	Not used
5	ID0
6	SCLK
7	Not used
8	Not used
9	Not used
10	SDO
11	Not used
12	PWM_Input
13	OD
14	MODE
15	Not used
16	$\overline{\text{EF}}$

4.2 Test Setup

For all tests, the reference design is combined with SNSR-DUAL-ADC-EVM containing a MSPM0G1507 and two ADS122S14 ADCs. The MSPM0G1507 drives the XTR200 and controls the ADCs.

The software used for evaluation is part of the MSPM0-SDK as an example and can be imported from: SDK_INSTALL_PATH\examples\nortos\LP_MSPM0G3507\demos\field_transmitter into Code Composer Studio

The software implements a typical signal chain for a simple sensor. The system reads data from the ADCs and conditions the values, for example, through linearization. The software scales values to an interface such as the 4mA to 20mA current or 0V to 10V voltage interfaces. The process includes interface-specific calibration values and controls the output stage. To decrease power dissipation, the MCU is in a low power mode and only wakes up at a defined clock rate and operates the signal chain. Figure 4-2 shows the software flow as well as all helper functions.

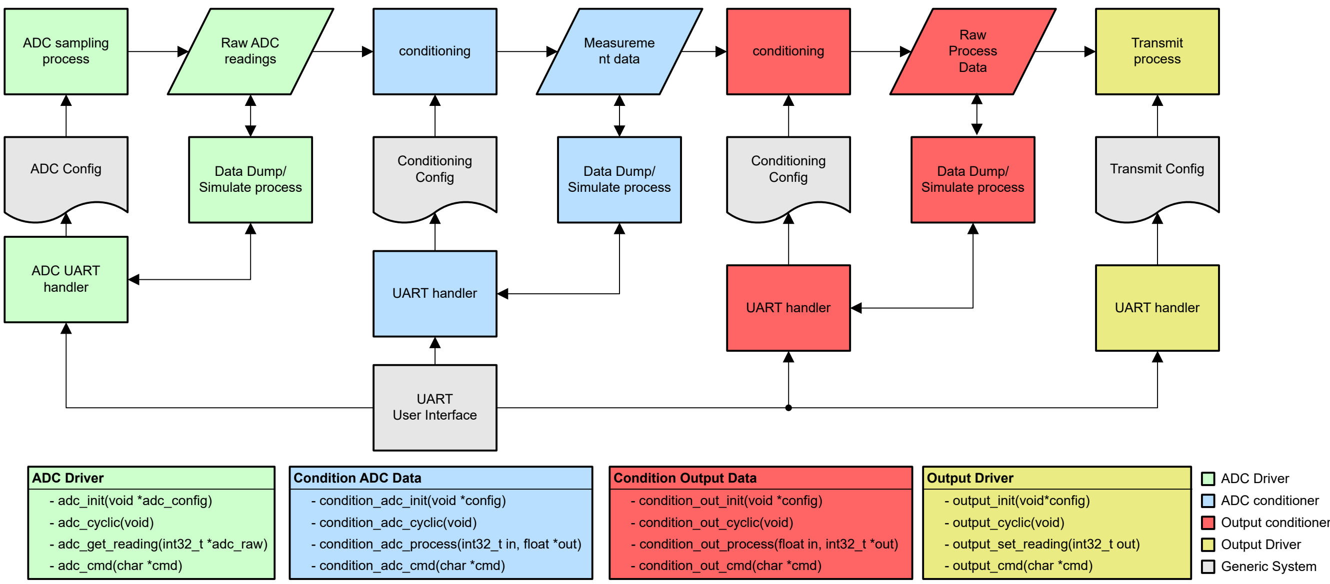


Figure 4-2. Software Flow

The software uses function pointers to represent main blocks for flexibility across different ADCs, interfaces, and scaling functions. At start-up, the software fills these pointers with correct drivers based on the ID read from connected cards. Two relevant structures exist. The first structure defines the analog input side with ADC functions and input scaling functions. The second structure covers the output side and requires specifying a function for setting the CPU clock.

```
struct id_func_input_map_struct {
    /** adc initialisation function */
    adc_init_func adc_init;
    /** This function gets called regularly by the main function, do not block here */
    adc_cyclic_func adc_cyclic;
    /**  read adc reading and return it */
    adc_get_reading_func adc_get_reading;
    /** handle uart commands and execute them */
    adc_cmd_func adc_cmd;

    /** adc conditioning init function **/
    condition_adc_init_func condition_adc_init;
    /** adc conditioning cyclic function **/
    condition_adc_cyclic_func condition_adc_cyclic;
    /** adc conditioning processing function **/
    condition_adc_process_func condition_adc_process;
    /** adc conditioning uart cmd handler **/
    condition_adc_cmd_func condition_adc_cmd;
};
struct id_func_output_map_struct {
    /** output conditioning init **/
    condition_out_init_func condition_out_init;
    /** output conditioning cyclic function **/
```

```
    condition_out_cyclic_func condition_out_cyclic;
    /** output conditioning set the output value **/
    condition_out_process_func condition_out_process;
    /** output conditioning uart cmd handler **/
    condition_out_cmd_func condition_out_cmd;

    /** output stage init **/
    output_init_func output_init;
    /** output cyclic function **/
    output_cyclic_func output_cyclic;
    /** output setter **/
    output_set_reading_func output_set_reading;
    /** output uart handler **/
    output_cmd_func output_cmd;

    /** init cpu clock **/
    cpu_clock_init_func cpu_clock_init;
};
```

Each of the drivers shown in Table 4-3 needs to contain four common functions.

Table 4-3. Driver Functions

DRIVER NAME	FUNCTION
init	Initializes all necessary components: configuration memory, peripherals, and variables
cyclic	The main loop calls this function with every cycle at a fixed frequency. The function generates timings or performs cyclic polling.
get_reading, process, set_reading	These functions actually process the data. The functions read data from the ADC, perform scaling, and set the output value to a DAC.
cmd	This function handles the command line interface. The system calls the function when a user enters a command for this driver.

All drivers can contain other static functions that other drivers must not use.

The software offers a command line interface over a USB UART to control the ADC and the data flow. All commands work with two levels. The first level specifies which driver receives the command. The second level contains the actual command relevant for the specific driver. The specific function of the driver handles all other parts. All levels offer a help command (*help*, *adc help*).

Table 4-4 explains the first-level commands.

Table 4-4. First Level Commands

NAME	EXPLANATION	FILE (EXACT FILE DEPENDS ON BOARD ID AND CONFIGURATION)
sys	System relevant commands like reset, flash	system/system.c
adc	ADC driver specific commands	adc/
out	Output specific commands	output/
cin	ADC input conditioning specific commands	condition/
cout	Output conditioning specific commands	condition/

An example command to get one ADC sample uses *adc get* to print the last ADC reading to UART. To get ADC readings continuously, use *adc stream* for further testing.

4.3 Test Results

4.3.1 Linearity Tests

For this test, this reference design is connected to a microcontroller to drive the XTR200 and the analog output is connected to a power supply and an ammeter or a voltmeter for either current output mode or voltage output mode respectively. The system is powered by the field supply and interfaced to a PC through an isolated UART. All tests are done with 24V field supply voltage. The XTR200 is driven by a PWM from the MCU which has a resolution of 4096 steps over a 3.3V dynamic range. In this test, the PWM code is stepped up by 1 LSB and each step is sampled 10 times.

Figure 4-3 through Figure 4-7 show the complete setup.

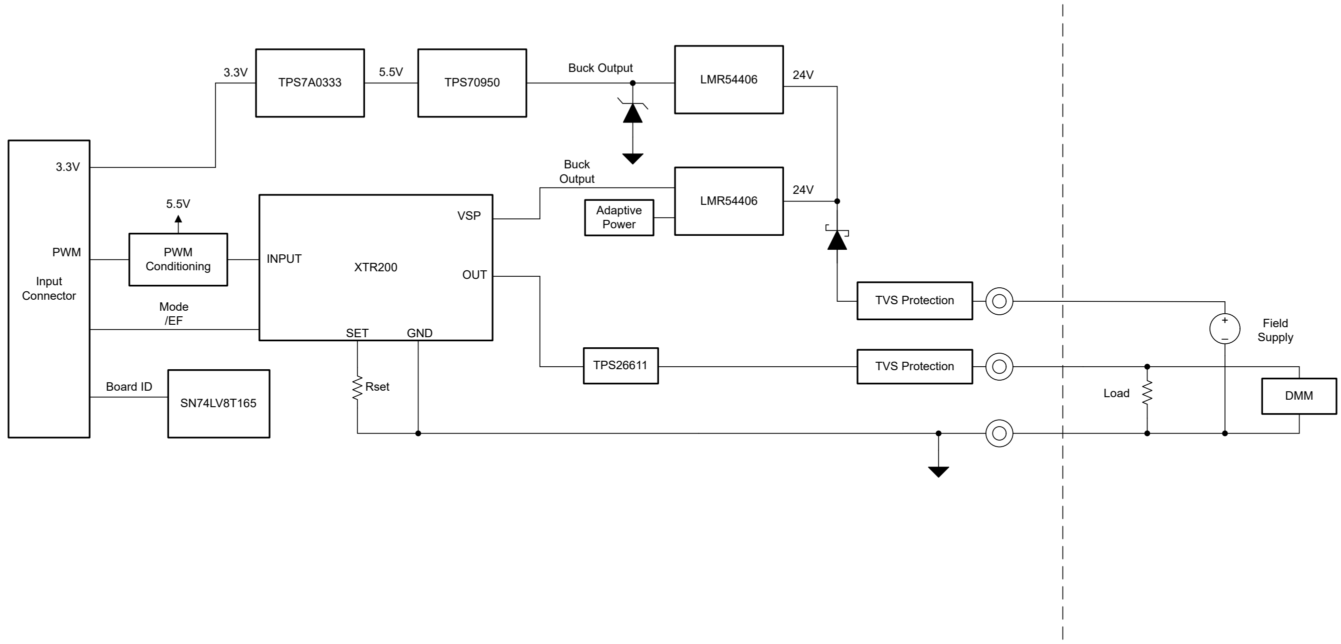


Figure 4-3. Test Setup for Linearity Test

Figure 4-4 through show the linearity test graphs including a linear trend line which represents the ideal current or voltage and is also used to calculate the linearity error. Both current output and voltage output modes are shown. The different equations of the trend lines are shown for reference.

Figure 4-4:

$$y \;=\; (7.962E-3)\;x \;-\; 1.486E-2$$

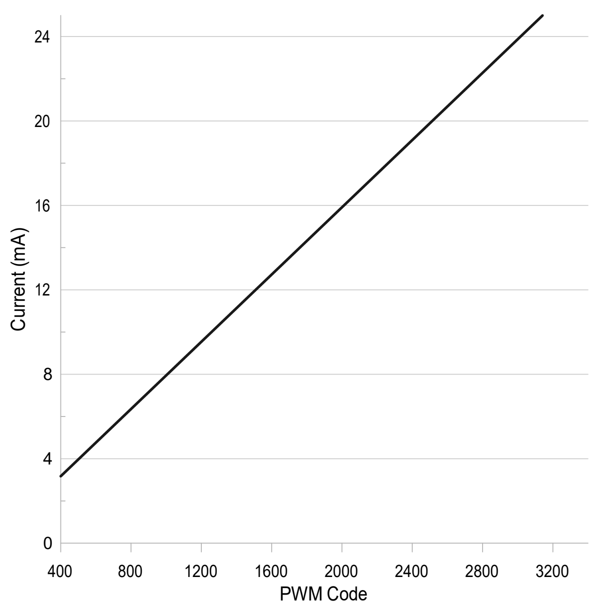


Figure 4-4. Current Output Mode

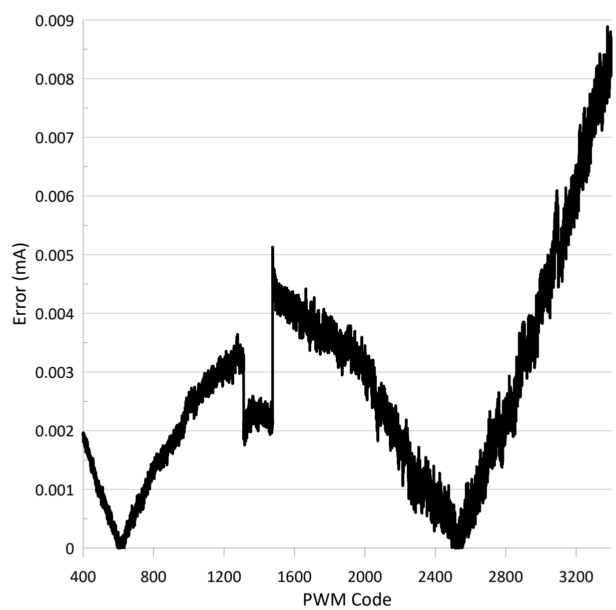


Figure 4-5. Current Output Error

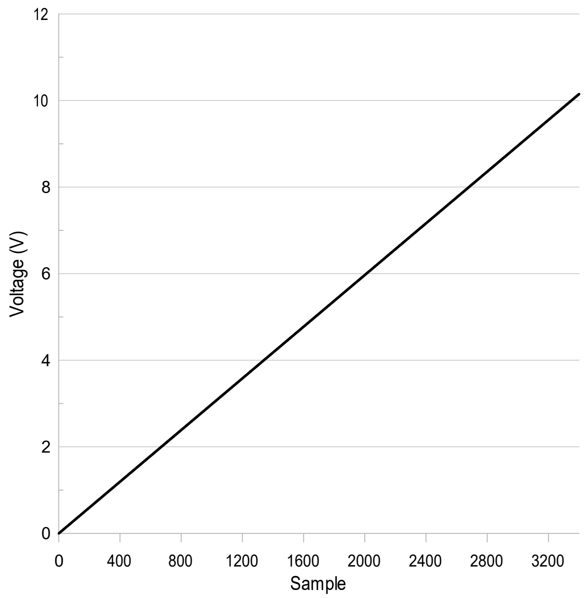


Figure 4-6. Voltage Output Mode (V)

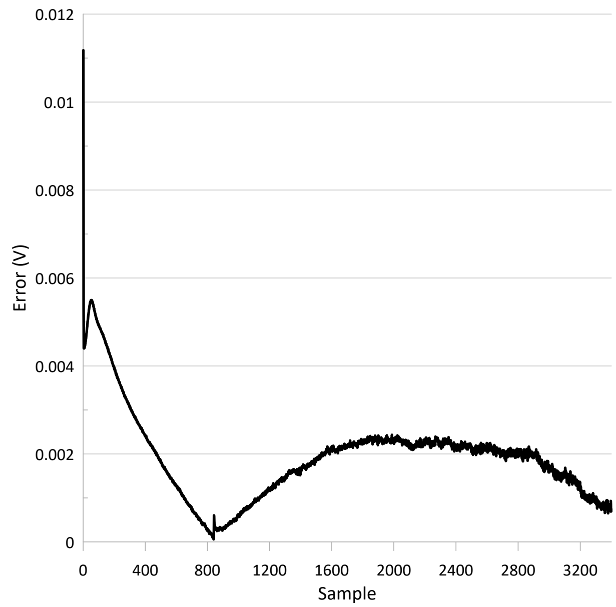


Figure 4-7. Voltage Output Error

4.3.1.1 Linearity Tests Summary

For all configurations, all results are well within the specification and no configuration shows signs of instability or other non-linear effects.

4.3.2 Noise Tests and Current Histogram

For this test, the test setup is similar to Section 4.3.1. To measure the noise performance, the XTR200 is set to three different output currents and voltages (zero [minimum], midpoint, maximum) and the resulting current or voltage is measured 10000 times.

Figure 4-8 shows the complete setup.

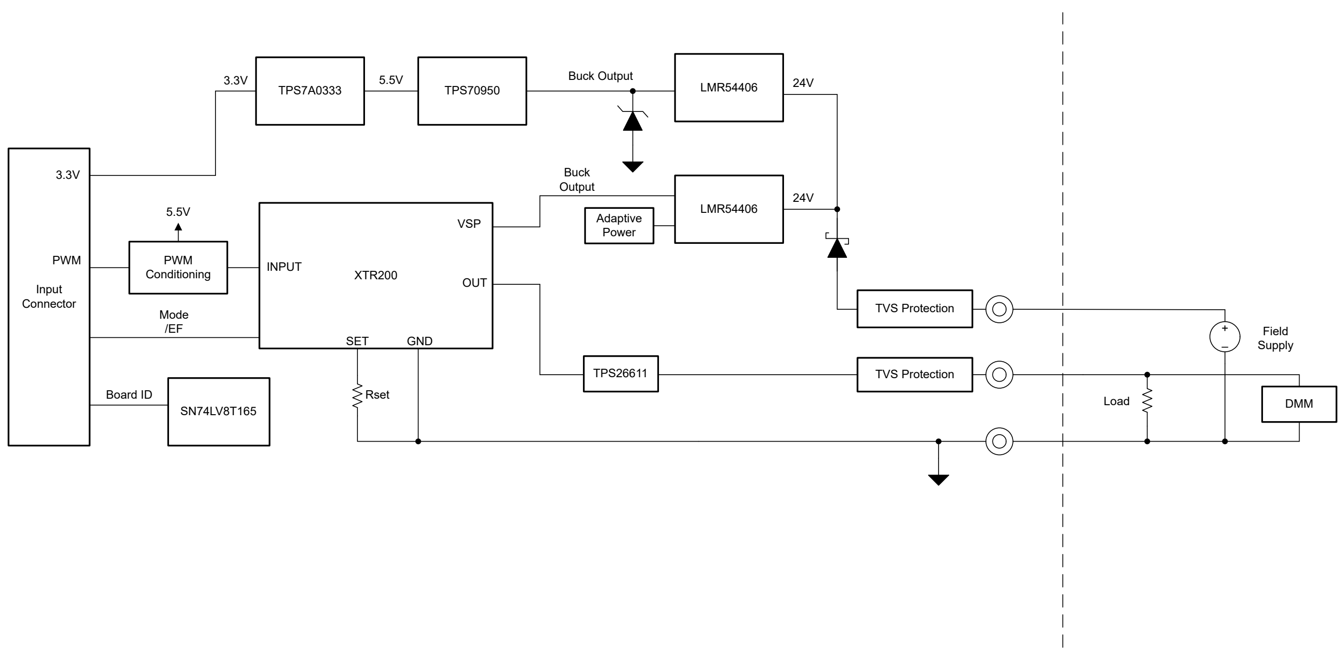


Figure 4-8. Test Setup for Noise Test

Figure 4-9 through Figure 4-14 show the histogram of the measured current.

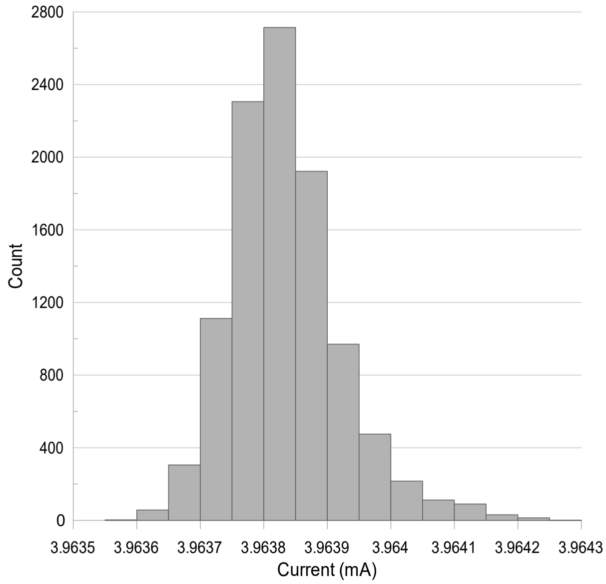


Figure 4-9. Histogram Current Output Mode, Minimum Setting

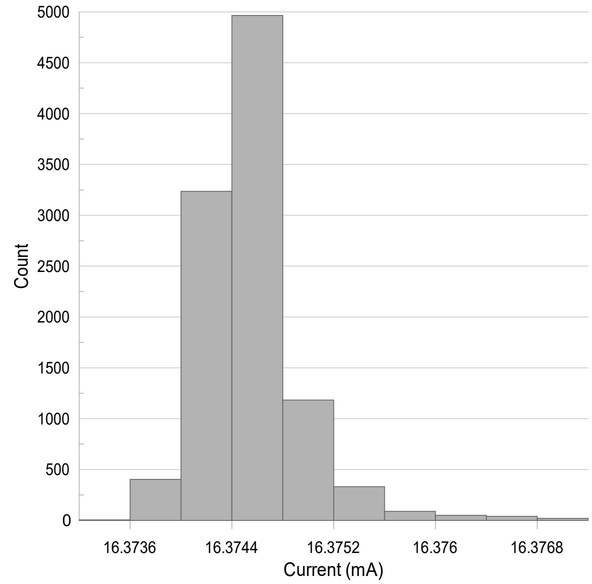


Figure 4-10. Histogram Current Output Mode, Midpoint Setting

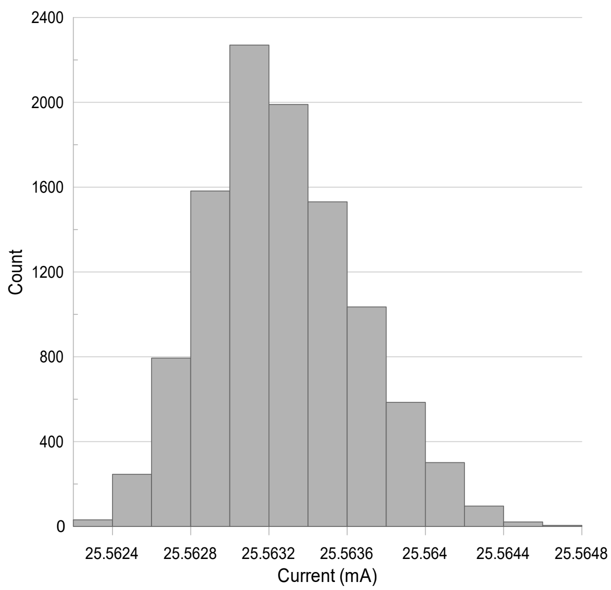


Figure 4-11. Histogram Current Output Mode, Maximum Setting

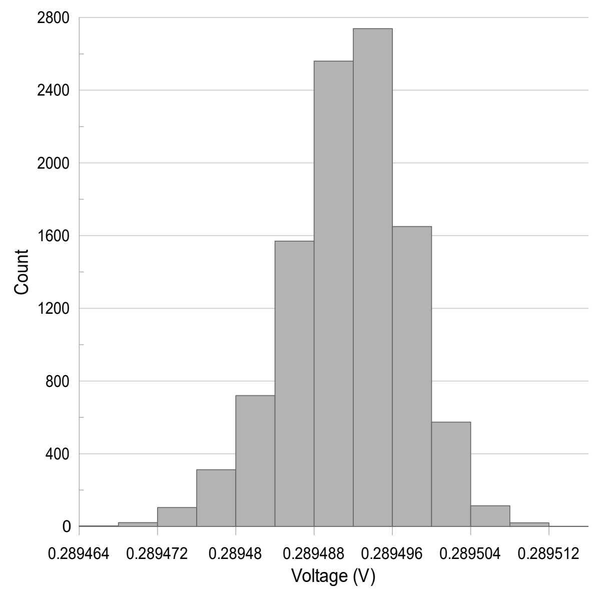


Figure 4-12. Histogram Voltage Output Mode, Minimum Setting

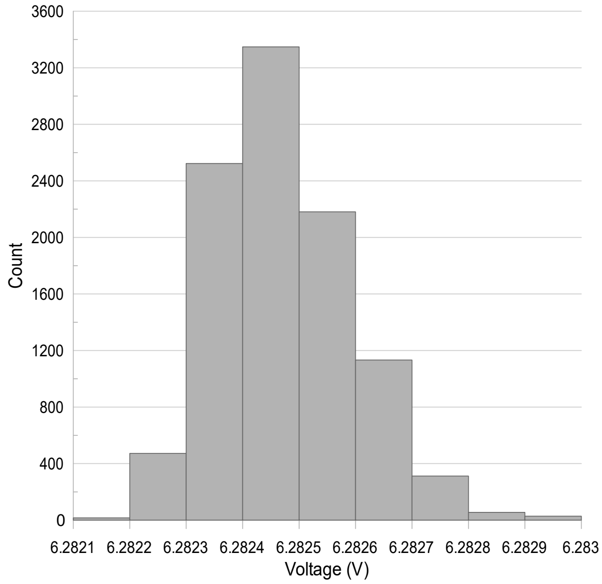


Figure 4-13. Histogram Voltage Output Mode, Midpoint Setting

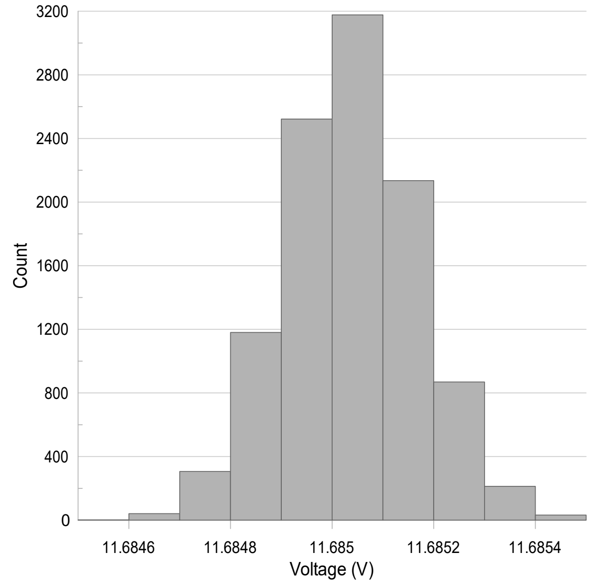


Figure 4-14. Histogram Voltage Output Mode, Maximum Setting

4.3.2.1 Noise Tests and Current Histogram Summary

Table 4-5 shows the calculated results from the raw data in Figure 4-9.

Table 4-5. Noise Summary

Output Mode	PWM Setting	Minimum Output	Average Output	Maximum Output	Peak-to-Peak Noise	RMS Noise
Current	0	3.9636mA	3.9638mA	3.9643mA	0.522µA	87.0nA
Current	2047	16.3735mA	16.3745mA	16.3771mA	2.31µA	385nA
Current	4095	25.5622mA	25.5633mA	25.5647mA	2.30µA	383nA
Voltage	0	0.2895V	0.2895V	0.2895V	36.6µV	6.09µV
Voltage	2047	6.2821V	6.2825V	6.2830V	717µV	120µV
Voltage	4095	11.6846V	11.6850V	11.6855V	775µV	129µV

Overall, the histogram plots show the expected Gaussian distribution for this type of signal without any oscillation or otherwise disturbed signal. This also proves, the peak currents drawn by the MCU when waking up are not seen on the loop and are regulated properly. The peak-to-peak noise calculations for the current and voltage output modes are well within 1 LSB since the current output resolution is 6.2µA and the voltage output resolution is 3.021mV.

4.3.3 Step Response

To test the step response of the circuit, the circuit is again connected to a 24V power supply. Current transient response is captured using an oscilloscope as the PWM is manually set from 0 to 4095 by the sensor board for the step-up response. This process is then repeated to capture the step-down response by setting the PWM manually from 4095 to 0.

Figure 4-15 shows the complete setup.

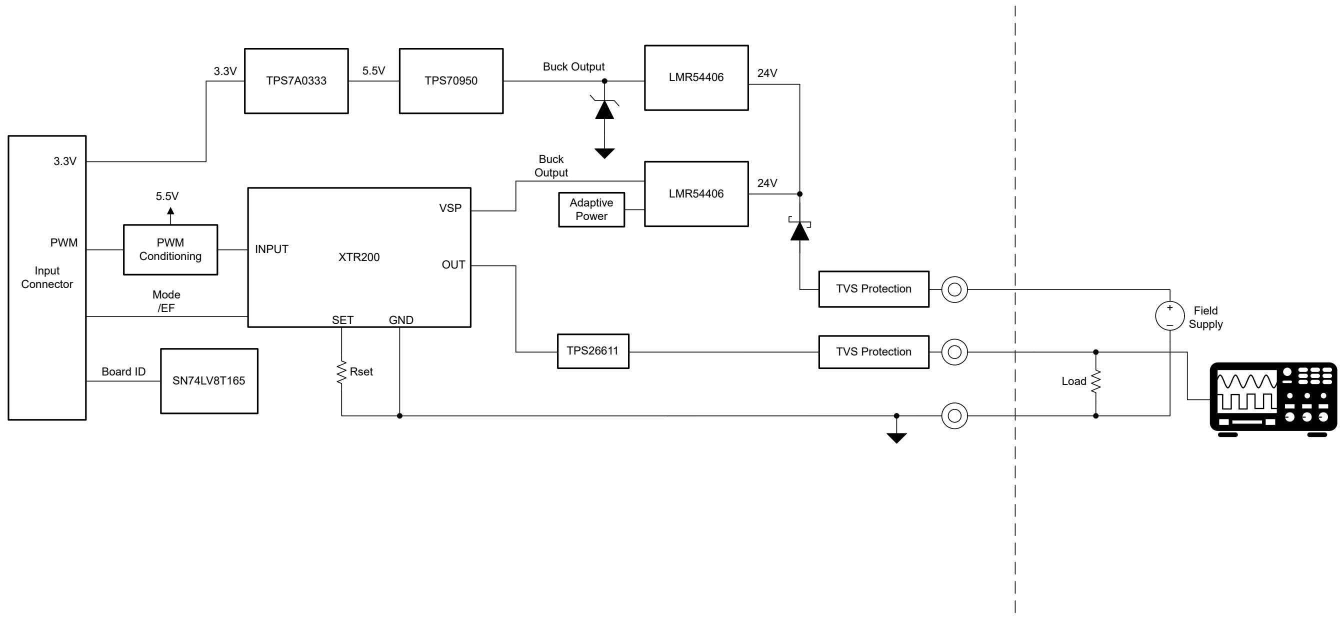


Figure 4-15. Test Setup for Step Response Measurements

Figure 4-16 through Figure 4-19 show the step responses of the current.

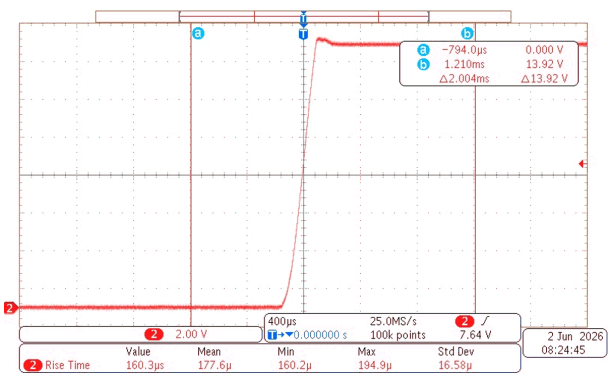


Figure 4-16. Current Output Mode, Rise Time

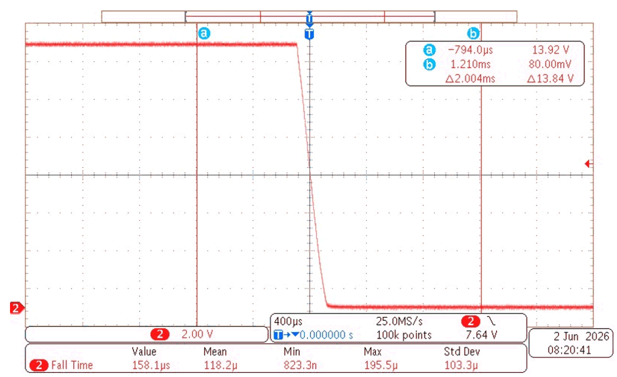


Figure 4-17. Current Output Mode, Fall Time

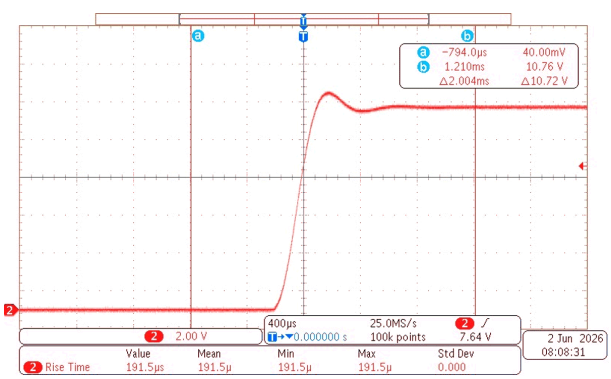


Figure 4-18. Voltage Output Mode, Rise Time

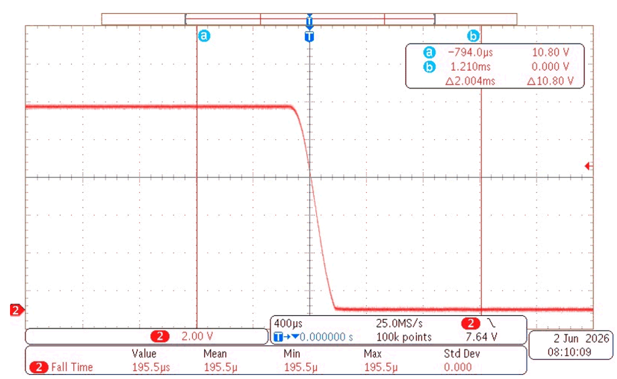


Figure 4-19. Voltage Output Mode, Fall Time

4.3.3.1 Step Response Summary

Table 4-6 shows a summary of the rise and fall times. As seen in the scope shots, there is a slight overshoot in the step up response for both output modes. This is due to the PWM filter circuit which features a 4th order Butterworth LPF. In this case, it is assumed that this overshoot would not cause a problem in the system.

If needed, the architecture could be changed to feature a slower step response by designing a Bessel filter architecture instead.

Table 4-6. Rise Time and Fall Time Summary

Output Mode	PWM Setting	RISE TIME (µs)	FALL TIME (µs)
Current	0 to 4095 (rise time) 4095 to 0 (fall time)	160	158
Voltage	0 to 4095 (rise time) 4095 to 0 (fall time)	192	196

4.3.4 Start-Up

The start-up behavior of the system is also tested to verify proper power-up sequence without instability or other issues occurring when the field power is turned on. This is tested by taking scope shots (during power-on) of the field supply as reference, the buck converters that power the XTR200, the 3.3V LDO output which is powered by the second buck converter, and the output of the module.

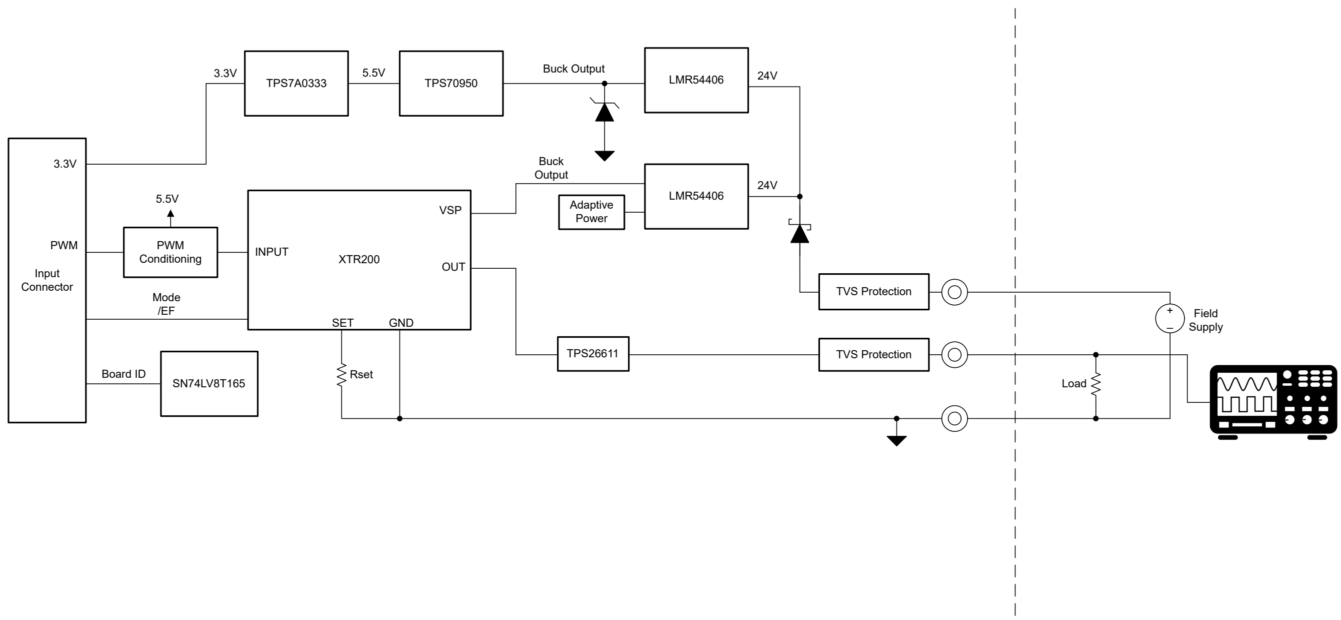


Figure 4-20. Test Setup for Start-Up Measurements

Taking a measurement using the configuration in Figure 4-20 yields the scope shots illustrated in Figure 4-21 and Figure 4-20 .

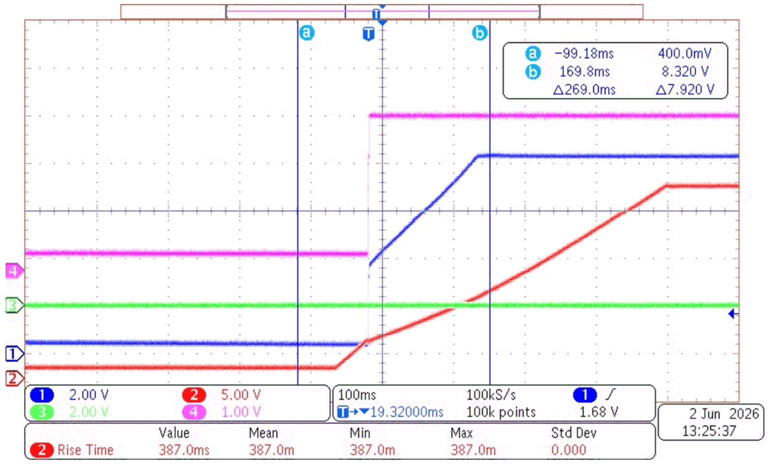


Figure 4-21. Current Output Mode Start-Up

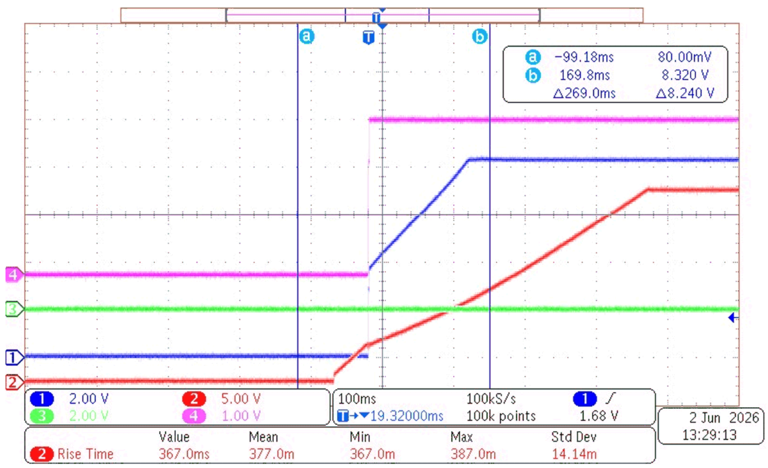


Figure 4-22. Voltage Output Mode Start-Up

As shown in these scope shots, the buck converter and the LDO both ramp up steadily once the voltage is high enough to power the devices and voltage can be regulated. Additionally, the output of the module is not affected by the start-up of the module in either mode which maintains that there is no damage to this module or the load connected to the field transmitter.

5 Design and Documentation Support

5.1 Design Files

5.1.1 Schematics

To download the schematics, see the design files at TIDA-011026.

5.1.2 BOM

To download the bill of materials (BOM), see the design files at TIDA-011026.

5.1.3 PCB Layout Recommendations

5.1.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-011026.

5.2 Tools and Software

Tools

XTR200EVM	XTR200 evaluation module for a high-voltage, precision output driver for 3-wire current or voltage systems.
LP-MSPM0G3507	MSPM0G3507 LaunchPad™ development kit for 80MHz Arm® Cortex®-M0+ MCU

Software

MSPM0-SDK	MSPM0 software development kit

5.3 Documentation Support

1. Texas Instruments, *XTR200 Precision, 3-Wire, Current-and-Voltage Transmitter datasheet*
2. Texas Instruments, *TPS7A03 Nanopower I_Q, 200nA, 200mA, Low-Dropout Voltage Regulator With Fast Transient Response Data Sheet*
3. Texas Instruments, TPS709 150-mA, 30-V, 1-μA IQ Voltage Regulators With Enable datasheet
4. Texas Instruments, *TVS3301 33V Bidirectional Flat-Clamp Surge Protection Device Data Sheet*
5. Texas Instruments, *SN74LV8T165 Parallel-Load 8-Bit Shift Registers Data Sheet*
6. Texas Instruments, TPS2661x: 50-V, Universal 4–20 mA, ±20-mA Current Loop Protector With Input and Output Miswiring Protection datasheet
7. Texas Instruments, OPAx991 40-V Rail-to-Rail Input/Output, Low Offset Voltage, Low Noise Op Amp datasheet
8. Texas Instruments, TLV930x 40-V, 1-MHz, RRO Operational Amplifiers for Cost-Sensitive Systems datasheet
9. Texas Instruments, LMR544xx SIMPLE SWITCHER Power Converter 4V to 45V, 0.6A/1A Buck Converter in a SOT-23 Package datasheet

5.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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6 About the Author

Simon Rojas Avila is a systems engineer at Texas Instruments, where he is responsible for developing reference designs in the industrial segment. Simon has experience in analog signal chain design, semiconductor-based sensing, and functional safety. He earned his Bachelor of Science degree in electrical and electronics engineering at Texas Tech University in Lubbock, Texas.

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