maxim integrated™

System Board 6894

MAXREFDES171#: IO-LINK DISTANCE SENSOR

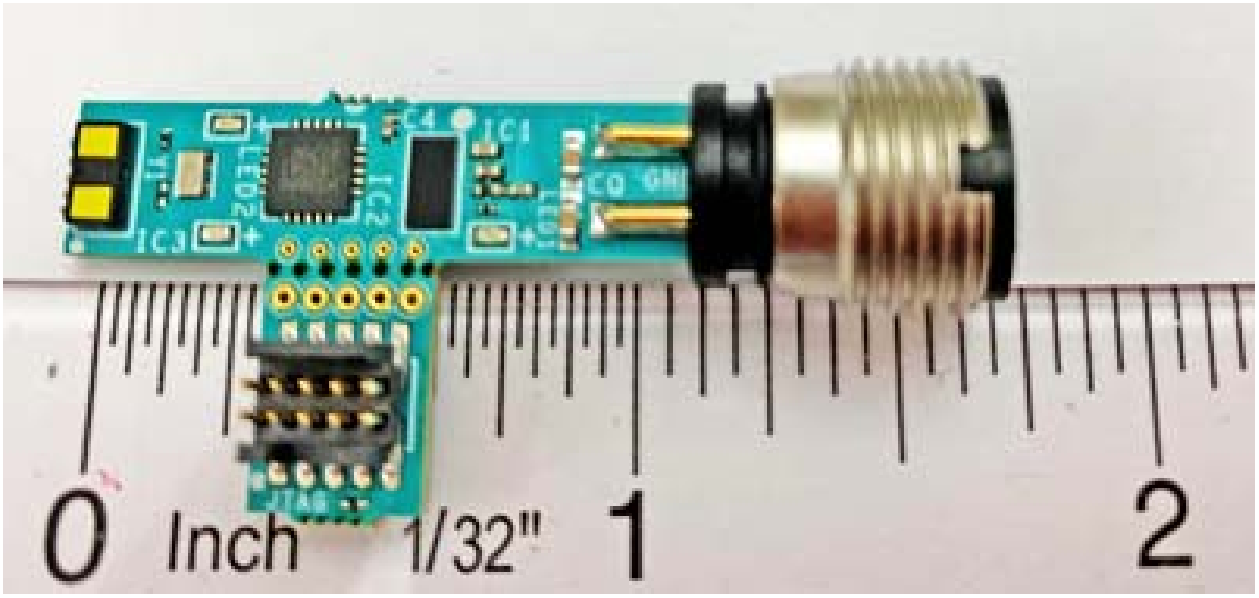
Active in Production.

Introduction

Advanced factory automation solutions, such as Industry 4.0, require increasing numbers of smart sensors, which are typically controlled using IO-Link® for the point-to-point serial communication between the sensor and controller (master). As a leading provider of IO-Link sensor transceiver and master transceiver ICs, Maxim also provides complete reference design solutions to help our customers improve their time to market. These proven designs cover all of the hardware and software requirements needed for compliance with the IO-Link standard. The complete reference design, including all of the ICs and external protection devices such as TVS diodes, is provided on a 30mm x 7.5mm printed circuit board (PCB).

Maxim Integrated and Technologie Management Gruppe Technologie und Engineering (TMG TE) collaborated in designing the MAXREFDES171# as a reference design that is compliant with the IO-Link version 1.1/1.0 standard. The MAXREFDES171# design consists of an industry-standard MAX22513 IO-Link device transceiver, a MAX32660 ultra-low-power 16-bit microcontroller utilizing the TMG TE IO-Link device stack, and a commercially available VL53L1 distance sensor.

MAXREFDES171 Board



Features

- IEC 61131-9
- TMG TE IO-Link Stack
- IO-Link version 1.1 compliant
- Measures Distances up to 4m

Applications

- Industrial Automation
- Distance/Proximity Measurement
- 1D Gesture Recognition
- Smart Sensors

System Diagram

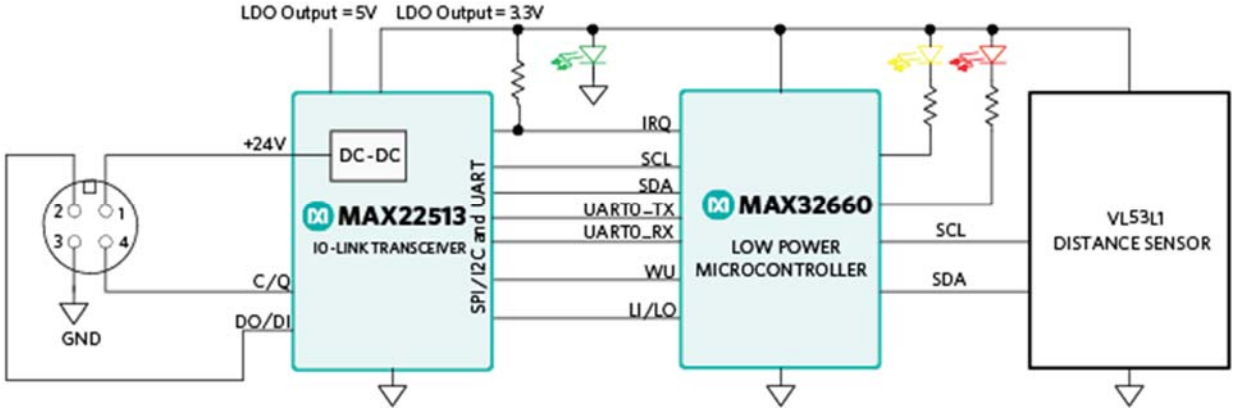


Figure 1. The MAXREFDES171# reference design block diagram.

Detailed Description

Detailed Description of Hardware

The MAXREFDES171# IO-Link distance sensor consumes minimal power, space, and cost, making it a complete solution for distance and proximity sensing in many industrial control and automation applications.

The MAX22513 IO-Link device transceiver is compliant with the IO-Link version 1.1/1.0 physical layer specification. It integrates the high-voltage functions commonly found in industrial sensors, including drivers, a high-efficiency DC-DC buck regulator, and two linear regulators all in a tiny 4.1mm x 2.1mm WLP. The MAX22513 features extensive integrated protection to ensure robust communication in harsh industrial environments. All four IO pins (V24, C/Q, DO/DI, and GND) are reverse-voltage and short-circuit protected, and feature integrated ±1kV/500Ω surge protection. This enables a very small PCB area with no required external components (such as TVS diodes). The low-on resistance drivers (C/Q and DO/DI) further reduce power dissipation, thus this reference design consumes minimal power with very low thermal dissipation. Operation is specified for normal 24V supply voltages up to 36V. Transient protection is simplified

due to high voltage tolerance (65V absolute maximum rating) in addition to the integrated surge protection.

The DC-DC buck regulator significantly reduces system power dissipation by dropping from 24V to lower voltage more efficiently than a linear regulator. The two integrated LDO regulators within MAX22513 allow the 3.3V and 5V rails to be generated, saving external components and space. The DC-DC regulator can supply up to 300mA load current, making this transceiver ideal for sensors that require high load current, but at lower voltages than 24V where LDOs are inefficient in translating 24V directly to lower voltages.

The MAX22513 features a flexible control interface, allowing control through either an SPI or I²C interface. In this design, we use I²C to reduce the number of pins required by the microcontroller. I²C allows both the MAX22513 and the sensor IC to be on the same bus. The I²C (or SPI) interface provides extensive diagnostics (from MAX22513), and a 3-wire UART interface is provided for IO-Link operation.

The MAX32660 is an ultra-low-power, cost-effective, highly integrated microcontroller that combines a flexible and versatile power management unit with the powerful Arm®Cortex®-M4 with floating point unit (FPU). The device integrates up to 256KB of flash memory and 96KB of RAM to accommodate application and sensor code. It supports SPI, UART, and I²C communication in a tiny, 1.6mm x 1.6mm, 16 WLP.

The VL53L1X is a ToF, laser-ranging sensor that provides accurate distance ranging up to 400cm. The ranging sensor is programmed with firmware and is controlled by a simple I²C interface that only requires SCL and SDA, since the device address is preprogrammed by default to 0x52 (saving address pins). The module does not have a cover for the receiving lens, so care needs to be taken to keep the lens clean, otherwise distance measurement performance will be impacted. The VL53L1X is in a small, 4.9mm x 2.5mm x 1.6mm module and operates over the -20°C to +85°C temperature range. This is the limiting item for the reference design operating temperature range, as the MAX22513 IO-Link transceiver can operate over the -40°C to +125°C temperature range.

The MAXREFDES171# does NOT require external devices such as varistors or TVS diodes for protection due to the integrated surge protection within MAX22513 at the IO-Link interface. This reference design meets both IEC 61000-4-2 (ESD) and IEC 61000-4-4 (EFT) standards. It is designed to meet surge capability (2A at t = 1.2/50µs) and has a low clamping voltage of <70V.

The MAXREFDES171# uses an industry-standard M12 connector, allowing a 4-wire or a conventional 3-wire cable to be used, which keeps costs low. The MAXREFDES171# consumes less than 9mA (typ), including the green LED “3.3V alive signal” and the yellow LED that blinks for each distance sensor reading. A red LED indicates if a fault occurs.

Detailed Description of Software

As seen in **Figure 2**, the MAXREFDES171# was verified using the TMG IO-Link Device

Tool V5, which comes with the MAXREFDES165# IO-Link master. Download the IODD file (*.xml) located in the Design Resources tab and go to the **Quick Start Guide** section below for step-by-step instructions on how to use the software. **Figure 3**shows a screen shot of the TMG IO-Link Device Tool V5 communicating with the master and sensor.

Figure 2. The MAXREFDES171# reference design (right) connected to the MAXREFDES165# IO-Link master reference design (left) for verification.

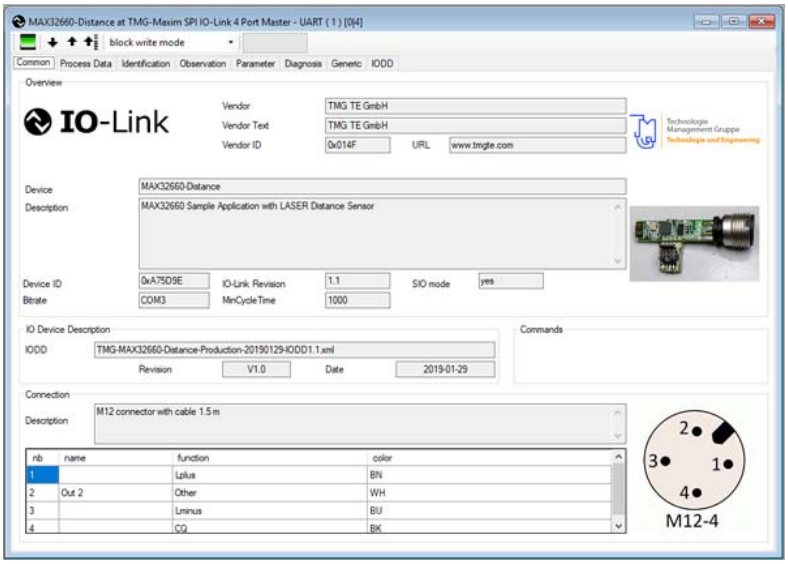


Figure 3. The TMG IO-Link device tool with the MAXREFDES171#.

Detailed Description of Firmware

The MAXREFDES171# ships preprogrammed as a working IO-Link distance sensor ready to connect to an IO-Link master. The firmware targets a MAX32660 microcontroller and follows the simple flow chart shown in **Figure 4**. The firmware utilizes the TMG TE IO-Link device stack. After hot plug-in, the MAXREFDES171# waits for a wake-up signal from the IO-Link master. After receiving the wake-up signal, the MAXREFDES171# synchronizes to the IO-Link master's 230.4kbps baud rate (COM3). Communication parameters are exchanged. The MAXREFDES165# then starts a cyclic data exchange by requesting the sensor process data. If the sensor is removed, the IO-Link master will detect a missing sensor.

Note: This document does not describe in detail the use modes of the sensor. See the sensor vendor's documentation for details regarding the use modes, calibration, etc. After any calibration, the user should wait about 10 seconds. After that, the sensor should be powered down and powered up again.

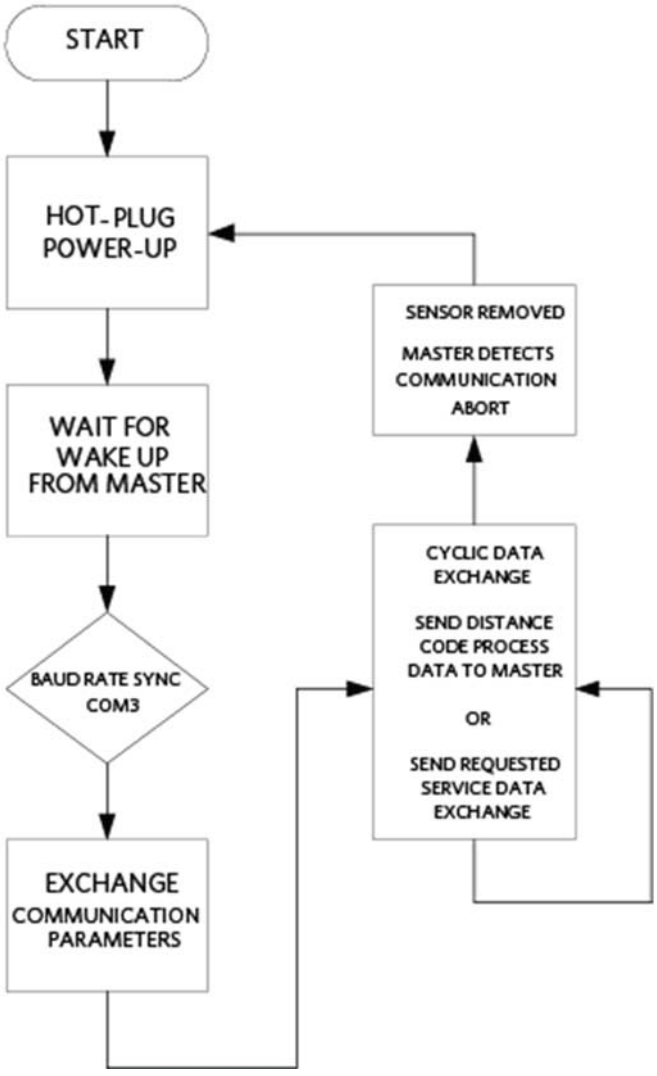


Figure 4. The MAXREFDES171# firmware flow chart.

The TMG IO-Link Device Tool Windows®-compatible software features IODD file import capability, connects to a PC through USB, and is available to download from the Design Resources tab of the MAXREFDES165#. The TMG IO-Link Device Tool software is shown in Figure 3, and a complete step-by-step Quick Start Guide is also downloadable from the Design Resources tab of the MAXREFDES165#.

Source code for the MAXREFDES171# is not provided. The TMG TE IO-Link master stack ships preprogrammed inside the MAXREFDES171# hardware with a perpetual license. TMG TE contact information is as follows:

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EMC Testing

The MAXREFDES171# was tested in Maxim's lab for the common industrial compliance standards, and the test methodology and results are presented in this section.

Equipment Used

- MAXREFDES171# IO-Link Sensor and MAXREFDES145# IO-Link Master
- Haefely Technology ECompact4 EFT/Surge Generator
- Teseq® CDN 117 Signal Line Coupling Network
- Teseq CDN 3425 EFT Data Line Coupling Clamp
- Teseg NSG438 ESD Generator

Surge Testing

The MAXREFDES171# module was tested to withstand up to ±1.2kV of 1.2/50µs IEC 61000-4-5 surge with a total source impedance of 500Ω. Surge testing was performed using the MAXREFDES145 IO-Link master, and 10 surge pulses were applied for each test as shown in Table 1. The MAXREFDES171# was not damaged by the tests.

L+ to GND: Communicating with the master, the module continued to execute code and transfer data, and the MAX22513 registers were not corrupted.
CQ to GND: Communicating with the master, the module continued to execute code and transfer data, and the MAX22513 registers were not corrupted.
DI to GND: Communicating with the master, the module continued to execute code and transfer data, and the MAX22513 registers were not corrupted.
DI to L+: Communicating with the master, the module continued to execute code and transfer data, and the MAX22513 registers were not corrupted.

Table 1. Surge Test Results

Test Condition	L+ to GND	CQ to GND	DI to GND	DI to L+
+1kV	Pass	Pass	Pass	Pass
-1kV	Pass	Pass	Pass	Pass
+1.2kV	Pass	Pass	Pass	Pass
-1.2kV	Pass	Pass	Pass	Pass

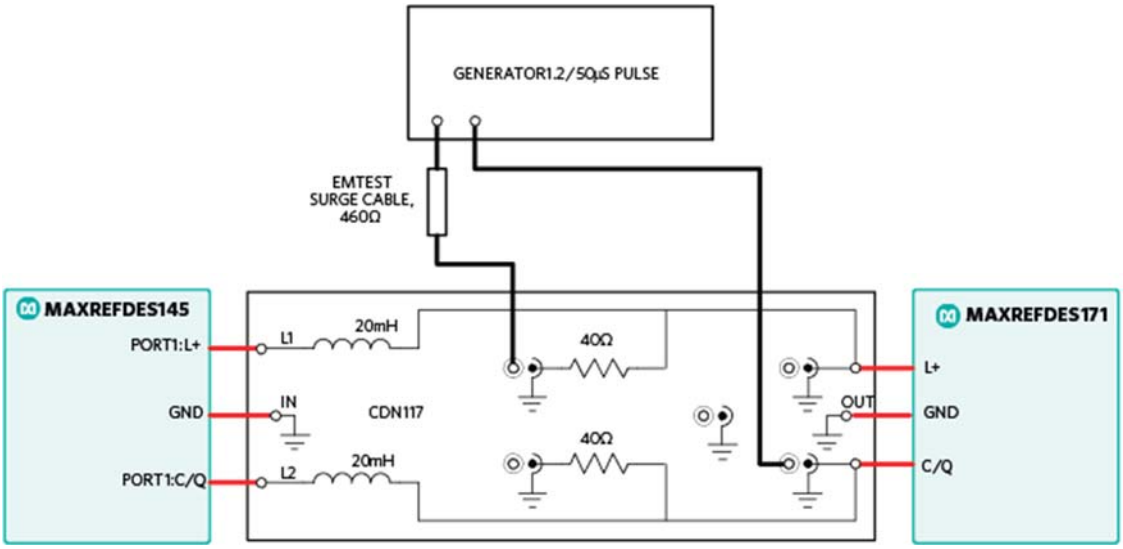

Figure 5. Surge testing setup.

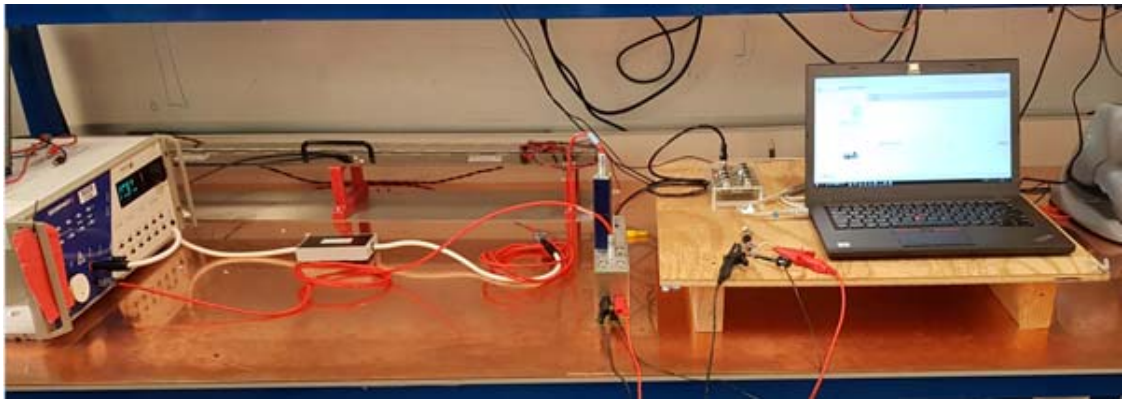

Figure 6. Surge testing.

EFT/Burst Testing
Using a 5m IO-Link cable with standard M12 connectors, the MAXREFDES171# was tested to withstand electrical fast transient (EFT)/burst up to ±4kV according to IEC 61000-4-4. EFT testing was performed using the MAXREFDES145 IO-Link master, and 10 EFT pulses were applied for each test, as shown in Table 2. Repetition rates of 5kHz and 100kHz were tested, along with burst lengths of 15ms and 0.75ms. The MAXREFDES171# was not damaged by the test, and the MAX22513 registers were not corrupted.

Table 2. EFT/Burst Test Results

Test Condition	5kHz/15ms	100kHz/0.75ms
+4kV	Pass	Pass
-4kV	Pass	Pass

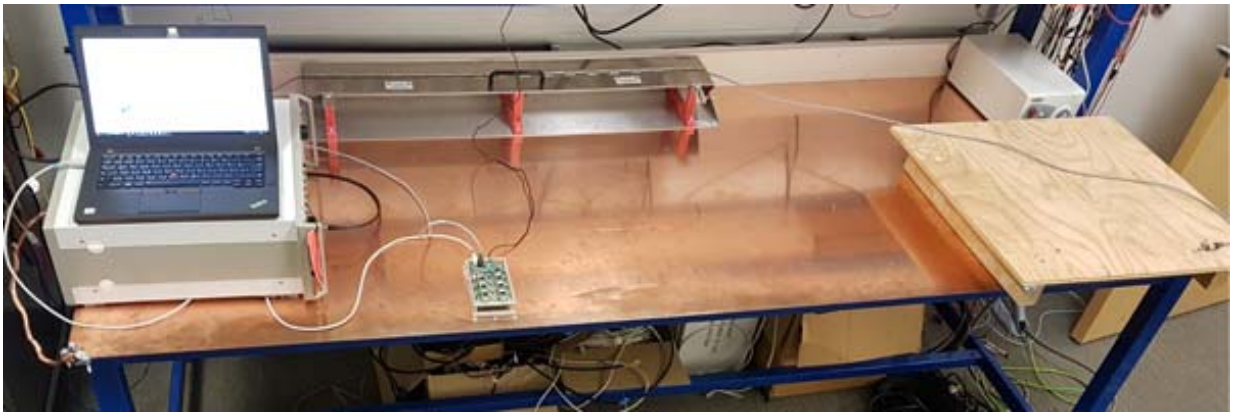

Figure 7. EFT/burst testing.

ESD Testing
The MAXREFDES171# was tested to withstand electrostatic discharge (ESD) for contact and airgap up to ±4kV according to IEC 61000-4-2. EFT testing was performed on the MAXREFDES171#, and then operation was tested using the MAXREFDES145 IO-Link master to transfer data, as shown in Table 3. The MAXREFDES171# was not damaged by these tests and continued to operate normally.

Table 3. ESD Test Results

Test Condition	L+ to GND	CQ to GND
+4kV contact	Pass	Pass
-4kV contact	Pass	Pass
+4kV airgap	Pass	Pass
-4kV airgap	Pass	Pass

Figure 8. ESD testing.

Quick Start Guide

To test the MAXREFDES171# sensor, connect it to a port of an IO-Link master. In the following example, a MAXREFDES165# master is used, but any IO-Link compliant master and associated IO-Link device GUI should work.

Required Equipment
Supplied by Maxim:

- MAXREFDES171#

Note: Download files from the Design Resources tab.

User Supplied:

- IO-Link master (for example, the MAXREFDES165#) with an AC-to-DC 24V power adapter
- TMG IO-Link Device Tool Software
- One IO-Link Cable
- USB 2.0 Type B Cable (for Use with the MAXREFDES165#)
- Windows 7, Windows 8, or Windows 10 PC with a USB Port