IO-LINK HANDBOOK

Second Edition

www.maximintegrated.com/io-link

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Introduction

Today's fanless programmable logic controller (PLC) and IO-Link® gateway systems must dissipate large amounts of power depending on the I/O configuration (IO-Link, digital input/output, analog input/outputs). As these PLCs evolve into new Industry 4.0 smart factories, special attention must be considered to achieve smarter, faster, and lower power solutions. At the heart of this revolution is an exciting new technology called IO-Link, which enables flexible manufacturing to improve factory throughput and operational efficiency. This exciting new technology enables traditional sensors to become intelligent sensors.

At Maxim, we provide a portfolio of advanced factory automation solutions that create pathways toward achieving Industry 4.0, enhanced by our **IO-Link technology portfolio**. A recent addition to this portfolio is the **MAX22513**, a tiny dual-channel IO-Link transceiver with integrated surge protection and DC-DC converter, to reduce heat dissipation and increase the robustness of sensors on the factory floor.

To help our customers reduce their time-to-market, we have partnered with software stack vendors from the IO-Link consortium to develop a range of fully verified and tested reference designs, which are described in detail in this handbook.

IO-Link is a powerful technology that will play a pivotal role over time in factory process automation as well as other industries. It will not only save manufacturers billions every year but will expand new markets for more customization of products. If you are involved in factory process automation, watch IO-Link technology as it continues to unleash the true power of Industry 4.0 and changes the way we think of manufacturing.

Jeff DeAngelis,
Managing Director
Industrial & Healthcare Business Unit
Maxim Integrated

Section 1: Introduction to IO-Link

Old School Sensor

Historically, a sensor included a sensing element and a way to get the sensing data to a controller. Data was often transferred in analog format (Figure 1) and was unidirectional (sensor to master only). This added extra steps to the process (such as digital-to-analog and analog-to-digital conversion) which, in turn, added extra cost, larger footprints and susceptibility to noise. Binary (or digital) sensors were used to simply indicate the status of a switch e.g... a thermostat to provide a high (24V) or low (0V) signal to indicate if the measured temperature is above or below a preset threshold. These "old school" sensors worked, but as technology advanced, sensor manufacturers integrated more functionality into sensors, eliminating some of these problems with these early sensors.

However, data was still limited to unidirectional communication from the sensor to the master, limiting error control and requiring a technician on the factory floor for updates or recalibration.

Manufacturers needed a better solution to meet the demands of Industry 4.0, smart sensors, and reconfigurable factory floors. The solution that emerged is IO-Link.

Tiny Binary Sensor Drivers

Binary sensors have only two states: On or Off. Examples of binary sensors are pressure switches, temperature switches, through-beam photoelectric sensors, proximity sensors, and pushbuttons. Binary sensor output drivers, such as the **MAX14838**/**MAX14839** (Figure 2), are 24V/100mA drivers optimized for use in industrial sensors. These devices integrate the high-voltage (24V) circuitry commonly found in industrial sensors, such as a configurable or pin-selectable PNP/NPN/push-pull driver and an integrated linear regulator that meets common sensor power requirements. The output driver interfaces between the sensor or sensor microcontroller unit (MCU) and the digital input (DI) module of the PLC.

To provide flexibility in supporting a broad range of physical sensor types, logic inputs allow the output driver to be configured for high-side (PNP), low-side (NPN), or push-pull operation. An additional input allows the user to select between normally open and normally closed logic. The MAX14838/MAX14839 are highly integrated products, making them ideal for robust sensor solutions in a tiny footprint due to integrated reverse-polarity protection, an on-board LDO, and LED drivers.

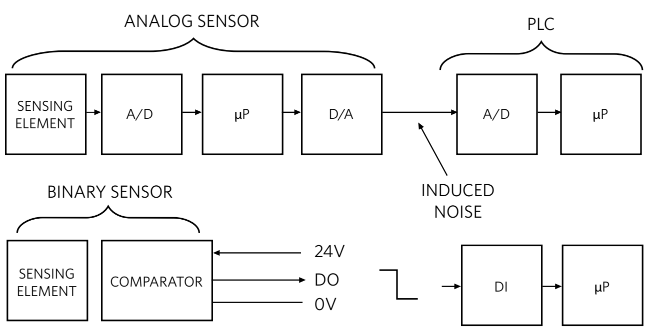


Figure 1. "Old School" Sensors - Analog and Binary

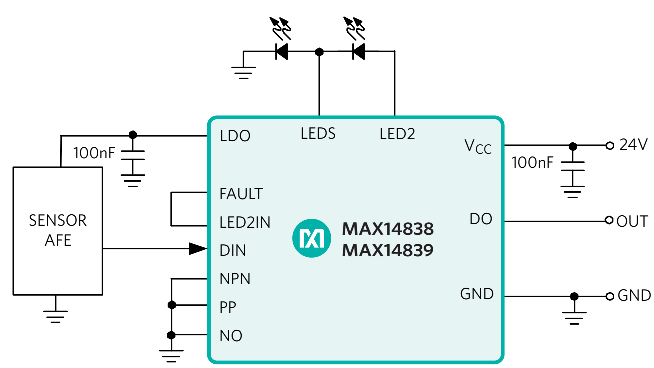


Figure 2. 24V Pin-Configurable Industrial Sensor Output Driver

IO-Link: An Open, Low-Cost Sensor Interface

IO-Link is a standardized technology (IEC 61131-9) regulating how sensors and actuators in industrial systems interact with a controller. The IO-Link Company Community (www.io-link.com) was formed in 2008 by a group of 41 sensor and actuator manufacturers who started the IO-Link consortium with the goal to standardize the hardware (PHY layer) interface and the communication (data) protocol for IO-Link products. Currently, there are over 100 companies in the consortium including semiconductor vendors and software vendors. Maxim has been a member of the IO-Link consortium since 2009.

IO-Link is a point-to-point communication link with standardized connectors, cables, and protocols. The IO-Link system is designed to work within the industry-standard 3-wire sensor and actuator infrastructure and is comprised of "IO-Link master" and "IO-Link device" products (Figure 3).

IO-Link Nodes

The number of installed IO-Link nodes continues to rapidly grow as sensor companies move from older analog sensors to "smart" IO-Link-based sensors, enabling the promise of reconfigurable manufacturing as outlined by Industry 4.0 (Figure 4).

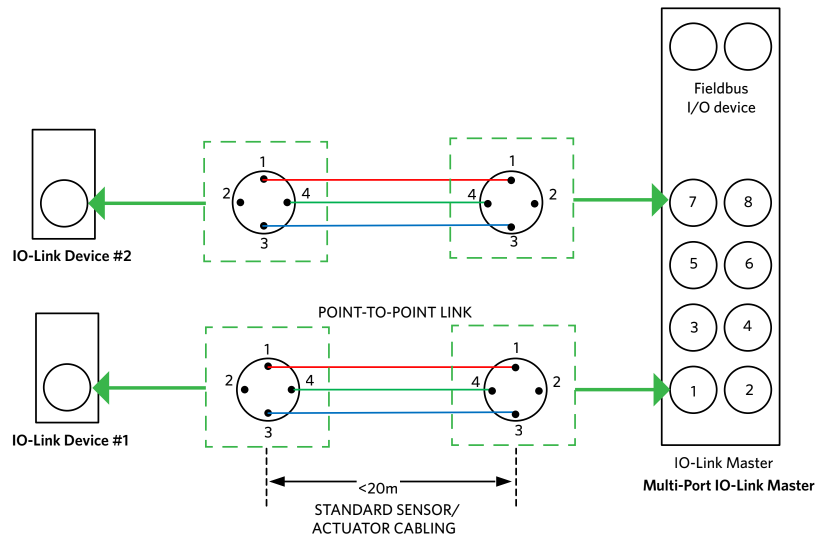


Figure 3. IO-Link Master/Device Interface

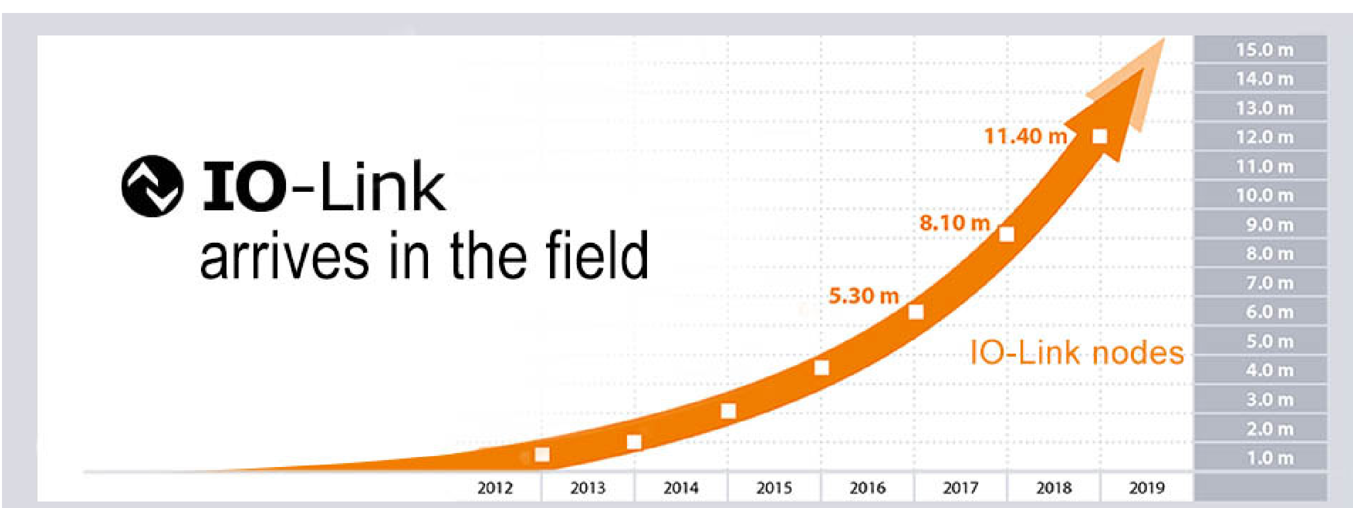


Figure 4. Projected Growth in Number of IO-Link Nodes

IO-Link System

The point-to-point connection between the IO-Link master (multi-port controller or gateway) and the IO-Link device (sensor or actuator) uses standard connectors (usually M12) and a 3- or 4-wire cable up to 20 meters in length. The master can have multiple ports (commonly four or eight). Each port of the master connects to a unique IO-Link device, which can operate in either SIO mode or bidirectional communication mode. IO-Link is designed to work with existing industrial architectures such as fieldbus or industrial Ethernet and connects to existing PLCs or human-machine interfaces (HMIs), enabling rapid adoption of this technology (Figure 5).

For full details of IO-Link, refer to the IO-Link Interface and System Specification Version 1.1.3 dated June 2019 at www.io-link.com.

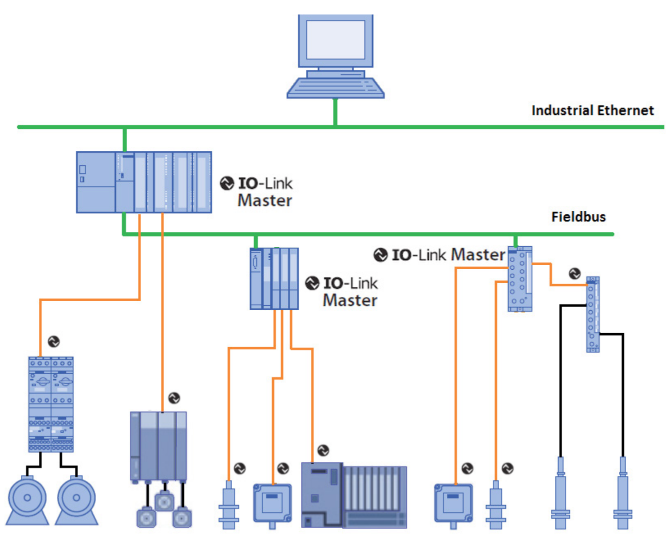


Figure 5. IO-Link Compatibility with Existing Industry Protocols

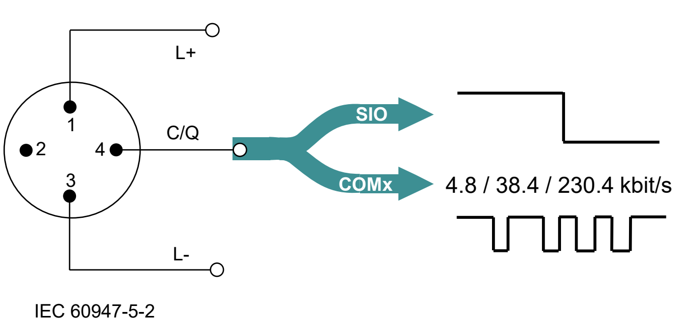


Figure 6. IO-Link Pin Definitions

IO-Link Interface Standardized as SDCI in IEC-61131-9

IO-Link is a standard for Single-Drop Communication Interface (SDCI), which was standardized as IEC-61131-9, while also providing backwards-compatibility with binary sensors IEC 60974-5-2 (Figure 6 and Table 1). IO-Link sensors have the best features of binary sensors while adding bidirectional data capability. IO-Link masters can interface with both binary and IO-Link sensors, allowing IO-Link to be easily added to an existing system. The IO-Link standard states that communications must be within 20 meters with unshielded cables using standard connectors common to industrial systems. M8 and M12 connectors are the most predominant. Communication is point-to-point and requires a 3-wire interface (L+, C/Q, and L-). Communication between master and slave devices is half-duplex with 3 transmission rates: COM1 4800 baud, COM2 38.4k baud, COM3 230.4k baud.

The supply range in an IO-Link system is 20V to 30V for the master, and 18V to 30V for the device (sensor or actuator). The IO-Link device must function within 300ms after L+ exceeds the 18V threshold.

The two communication modes are standard I/O (SIO) and SDCI. In SIO mode, backward compatibility is ensured with existing sensors in the field, using 0V or 24V to signal OFF or ON to the IO-Link master. In IO-Link mode, communication is bidirectional at one of three data rates. The IO-Link device only supports one data rate while the IO-Link master must support all three data rates. Communication is with 24V pulses using a nonreturn-to-zero (NRZ) on the C/Q line where a logic 0 is 24V between CQ and L- and a logic 1 is 0V between CQ and L-. In IO-Link mode, pin 2 can be in DI mode as a digital input, or DO mode as a digital output, or not connected (NC).

Table 1. IO-Link Pin Definitions

Pin	Signal	Designation	Standard
1	L+	24V	IEC 61131-2
2	I/Q	Not connected, DI, or DO	IEC 61131-2
3	L-	0V	IEC 61131-2
4	Q	"Switching signal" (SIO)	IEC 61131-2
	C	"Coded switching" (COM1, COM2, COM3)	IEC 61131-9

Physical Layer IO-Link Standardized Connectors

Standardized connectors and cables are used as defined by IEC 61131-9. Port Class A connectors have 4-wire connections (maximum) to support the 3-wire connection system (L+, L-, C/Q) with a fourth wire that can be used as an additional signal line (DI or DO). Port Class B connectors have 5-wire connections for devices that require extra power from an independent 24V supply (Figure 7 and Table 2).

Table 2. Alternative IO-Link Pin Definitions

Pin	Signal	Designation	Remark
1	L+	Power supply (+)	See Table 7*
2	I/Q P24	NC/DI/DO (port class A) P24 (port class B)	Option 1: NC (not connected) Option 2: DI Option 3: DI, then configured DO Option 4: Extra power supply for power devices (port class B)
3	L-	Power supply (-)	See Table 7*
4	C/Q	SIO/SDCI	Standard I/O mode or SDCI
5	NC N24	NC (port class A) N24 (port class B)	Option 1: Shall not be connected on the master side (port class A) Option 2: Reference to the extra power supply (port class B)
Note: M12 is always a 5 pin version on the Master side (female)			

*In the **IO-Link Interface and System Specification Version 1.1.3, June 2019**.

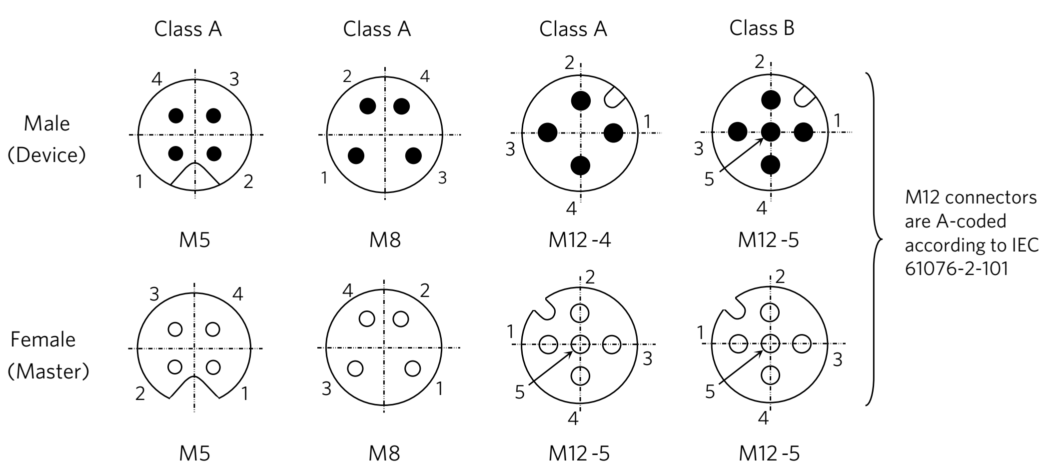


Figure 7. Alternative IO-Link Connectors

Physical Layer Electrical Specifications

The supply range in an IO-Link system is 20V to 30V for the master, or 18V to 30V for the device (sensor or actuator). Important related specifications (Table 3) include:

- A rising IO-Link signal must be above 13V to be registered as a "logic high."
- A falling IO-Link signal must be below 8V to be registered as a "logic low."

Note that the high and low detection time (t_H and t_L in the timing diagram) are 1/16 of a bit (minimum). t_{ND} is the noise suppression duration (t_{ND} must be less than 1/16 of a bit) (Figures 8a and 8b).

Communication uses a UART frame consisting of 11 bits = 1 start bit + 8 data bits + 1 parity bit + 1 STOP bit. Durations are defined by the transmission rate which depends upon the device.

Table 3. IO-Link Signal Electrical Specifications

Property	Designation	Min	Typ	Max	Unit	Remark
$VTHH_{D,M}$	Input threshold 'H'	10.5	N/A	13	V	See Note 1
$VTHL_{D,M}$	Input threshold 'L'	8	N/A	11.5	V	See Note 1
$VHYS_{D,M}$	Hysteresis between input thresholds 'H' and 'L'	0	N/A	N/A	V	Shall not be negative. See Note 2
$VIL_{D,M}$	Permissible voltage range 'L'	$VO_{D,M}$ - 1.0	N/A	N/A	V	With reference to relevant negative supply voltage.
$VIH_{D,M}$	Permissible voltage range 'H'	N/A	N/A	$V+_{D,M}$ + 1.0	V	With reference to relevant positive supply voltage.

Note 1: Thresholds are compatible with the definitions of type 1 digital inputs in IEC 61131-2.
Note 2: Hysteresis voltage $V_{HYS} = V_{THH} - V_{THL}$.

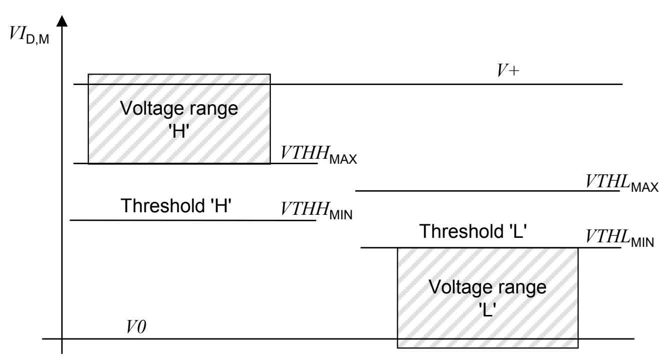


Figure 8a. IO-Link Signal Electrical Thresholds

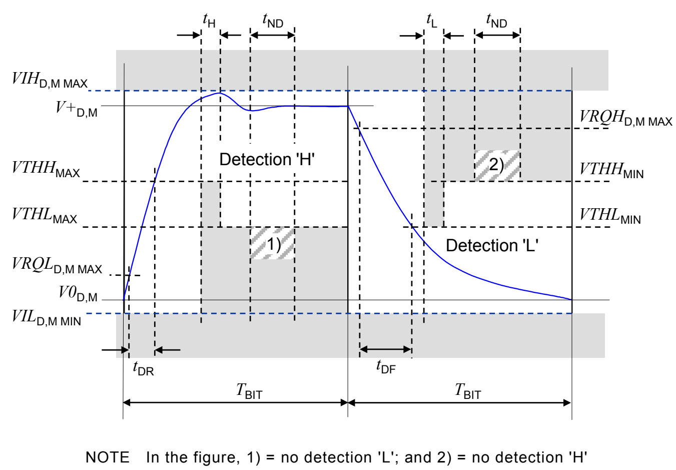


Figure 8b. IO-Link Signal Electrical Characteristics

IO-Link in the Automation Hierarchy

An IO-Link device is connected as a point-to-point link to a port in an IO-Link master. If implemented as a PLC plug-in module, it does not have gateway functionality and as such, is not a fieldbus. The IO-Link master is essentially a gateway, with responsibility for establishing communication using fieldbuses or some other type of backplane, enabling the IO-Link devices to become fieldbus I/O nodes (Figure 9).

IO-Link functionality in a system reduces maintenance, increases uptime, and transforms a manual sensor installation into one which allows a user to "plug-and-play and walk away." The parameter settings can be downloaded from the controller to set up (or reconfigure) a device. This means a technician is no longer needed on the shop floor to do initial setup and machine downtime is reduced when it is required to reconfigure devices.

IO-Link allows for continuous diagnostics and improved data logging and error detection to further reduce operating costs. Commonly used connectors and cables enable standardized installation with direct binary sensor upgrades. Since IO-Link sensors have configurable settings (for example PNP, NPN, or push-pull outputs that can be changed while in progress), the number of product units the sensor vendor needs to support is also reduced.

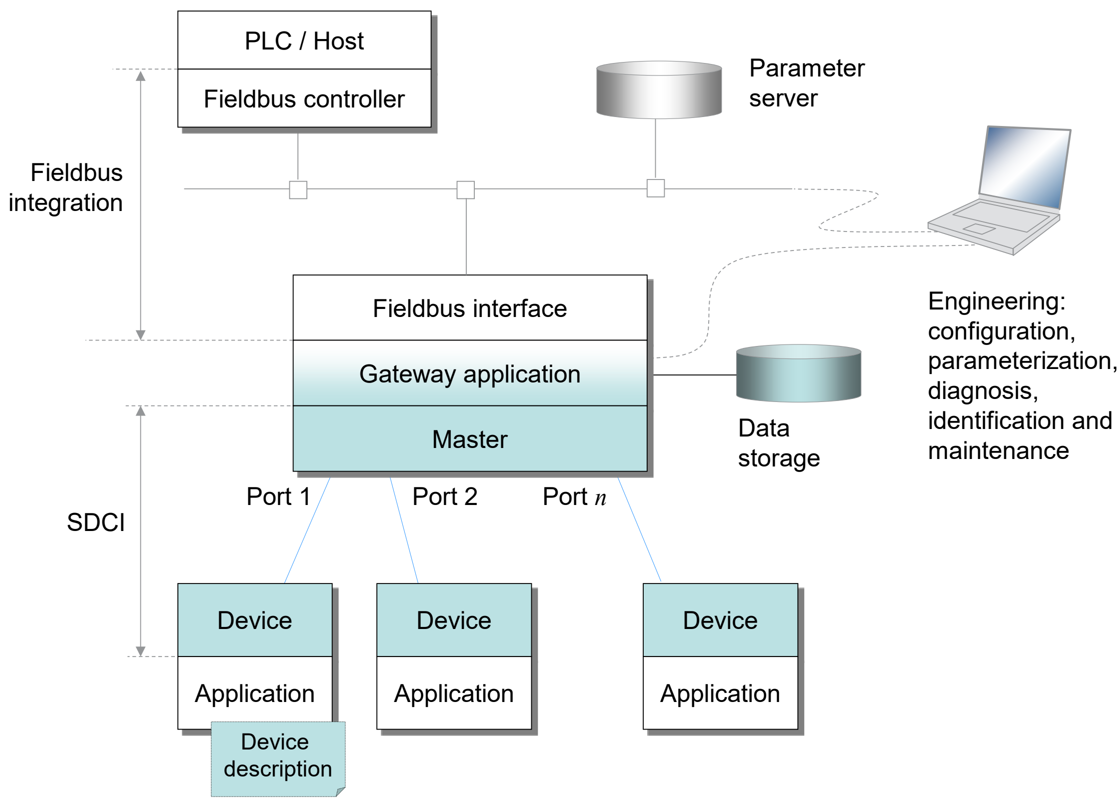


Figure 9. IO-Link Fieldbus Interconnection

IO-Link – Enabling Intelligent Sensors

To summarize, IO-Link is a point-to-point connection that may be layered over any given network. As an integral part of the I/O module, the IO-Link master is installed either in the control cabinet or directly in the field as a remote I/O with an IP 65/67 enclosure rating. The IO-Link device is coupled with the master using a standard sensor/actuator cable measuring up to 20 meters in length. The device—which may be any sensor, any actuator, or a combination of the two, transmits and receives data (binary switching, analog, input, output) that are transmitted directly via IO-Link in a digital format.

IO-Link is very powerful and flexible, allowing some of the intelligence to be moved from the PLC closer to the sensors on the factory floor. For example, by using pin 2 (I/Q) as a DI/DO, in addition to the C/Q line, the user can take in digital input signals from a binary sensor and then drive a lamp with the DO (to signify, for instance, if a threshold has been surpassed). This can be done from the sensor itself.

As mentioned, IO-Link is backwards-compatible with SIO binary signals. With IO-Link-capable sensors, users communicate with existing PLCs through a standard digital input communication. As PLC modules are upgraded with an IO-Link master, bidirectional communication is enabled through the C/Q line on an IO-Link channel.

Industrial Sensor Ecosystem

Figure 10 shows an example of our industrial sensor ecosystem which includes products for all key functions, including binary sensor output drivers, IO-Link devices, and IO-Link masters.

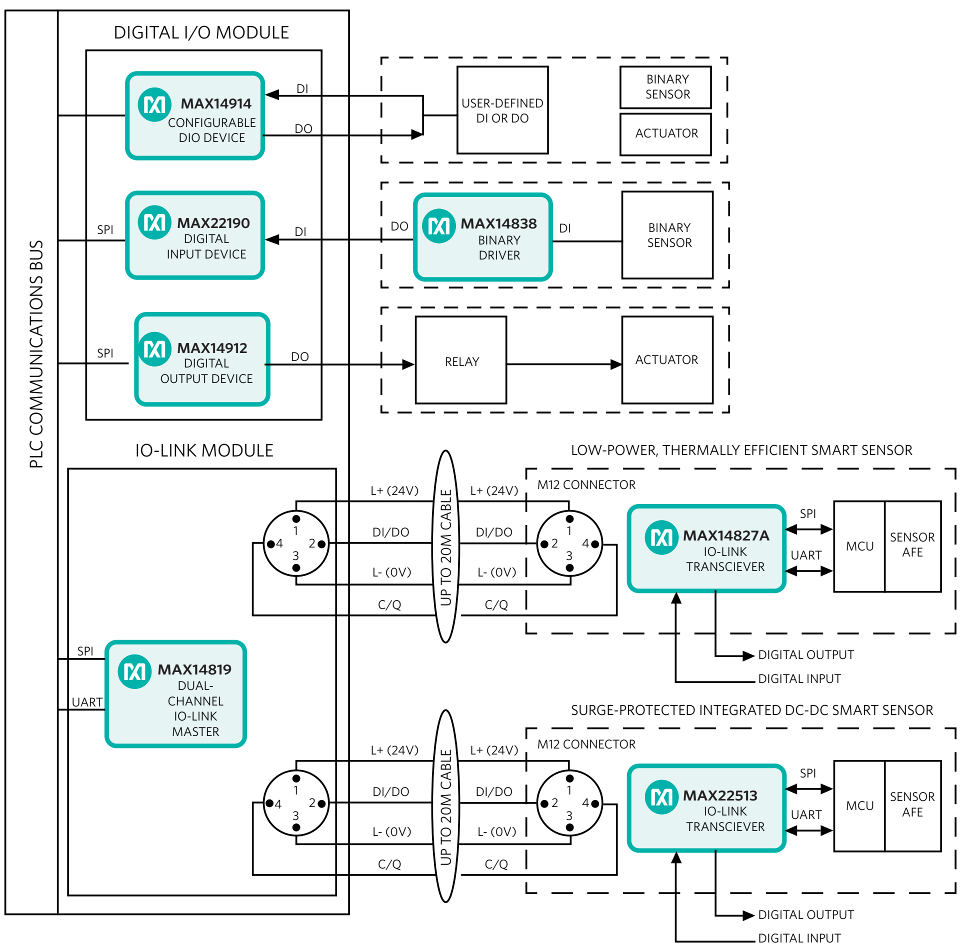


Figure 10. Industrial Sensor Ecosystem

Section 2: IO-Link Environment

Data Link Layer

All IO-Link data exchange is master-slave based, with the IO-Link master sending a request and the device required to answer. The data link layer manages the exchange of messages between the IO-Link master and device. Messages are called M-sequences which are frames that have a length between 1 and 66 UART words. The messages can contain process data, on-request data, and system management commands/requests. A special DL handler in the master manages operating modes (SIO, wake-up, COM rates) and handles errors and wake-up requests.

The process data handler ensures the cyclical process data exchange while the on-request handler manages the acyclic exchange of event, control, parameter and ISDU data.

Data Types

IO-Link data communication is either cyclic or acyclic (Figure 11). Cyclic communication occurs during normal operation. For example, the master requests sensing data from the sensor. Acyclic data is on-request and can contain:

1. Configuration or maintenance information. For example, the master may configure the device after power-up or request the device configuration right before power-down
2. Event triggered, which is reported with three levels of severity:
    - Notifications
    - Warnings
    - Errors
3. Service data for large data structures.
4. Page data for direct reading of device parameters.

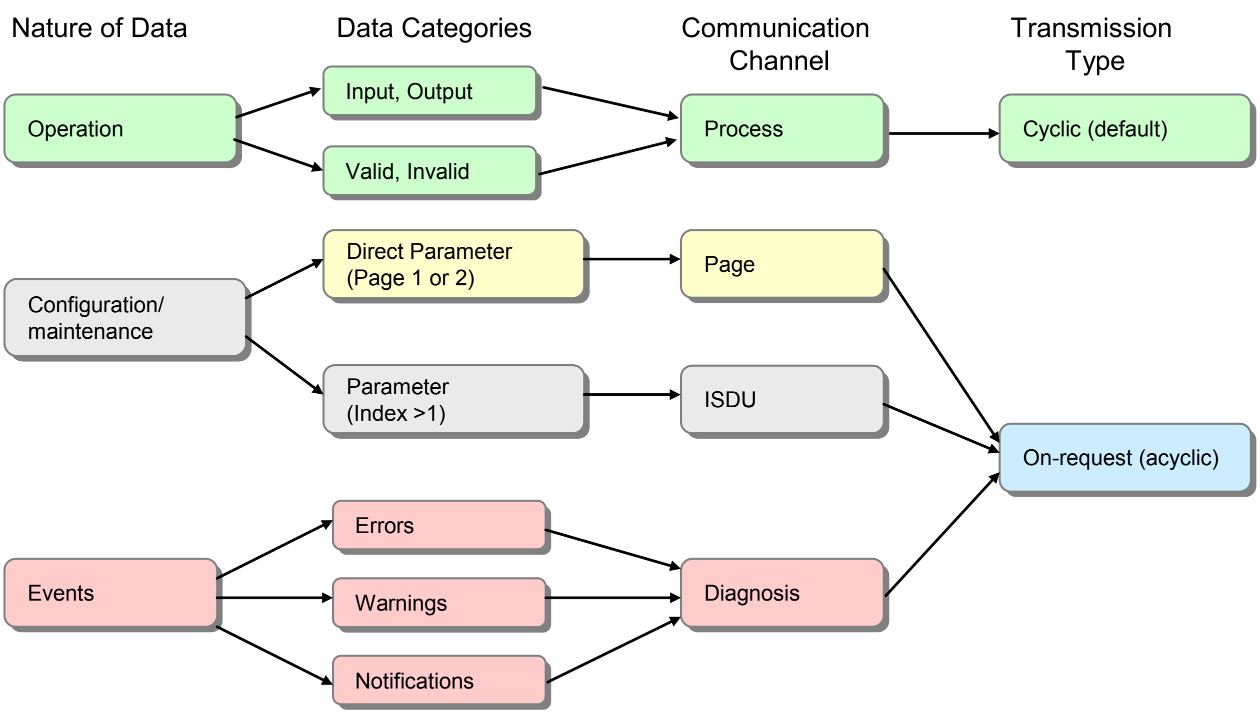


Figure 11. IO-Link Transmission Types

Master-Device Communication

All communication between the master and a device (sensor or actuator) begins with a request from the master and follows a fixed schedule (Figure 12). A device must answer all master requests. The sum of this back-and-forth communication is called an M-sequence (message sequence). An M-sequence can take many different forms and varies in total length. Although M-sequence communication may vary, all communication between a master and device takes place on this fixed schedule.

UART Data on the C/Q Line

All data is UART framed. The master initiates communication and the device must answer within t_A < 11-bit intervals (Figure 13).

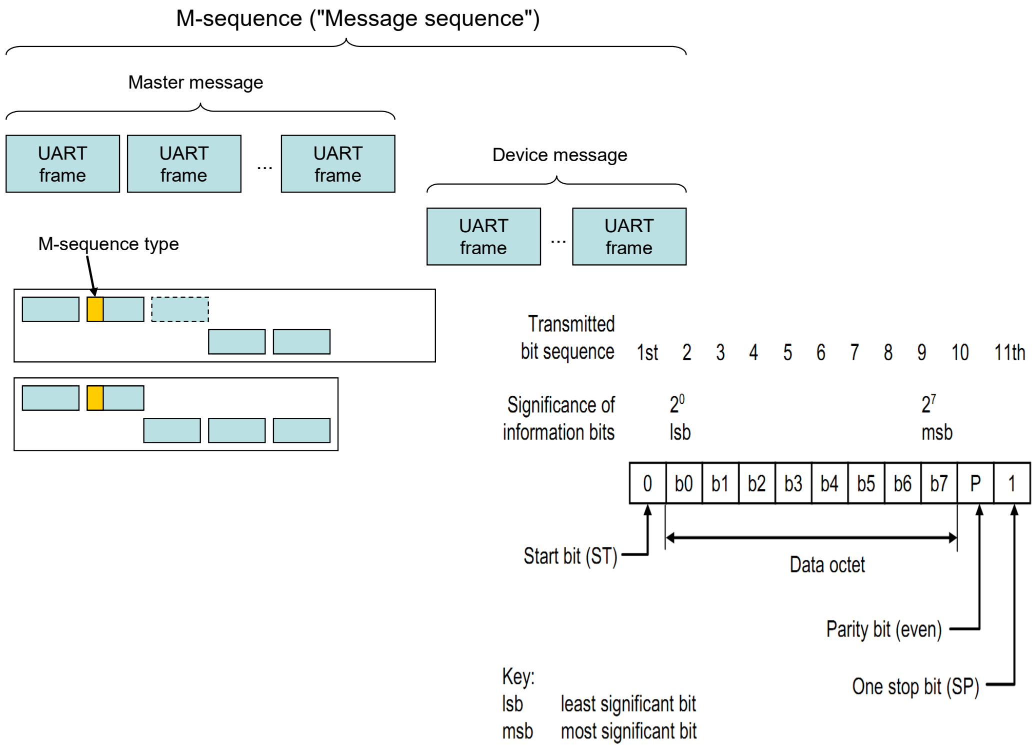


Figure 12. IO-Link Master-Device Communication Sequence

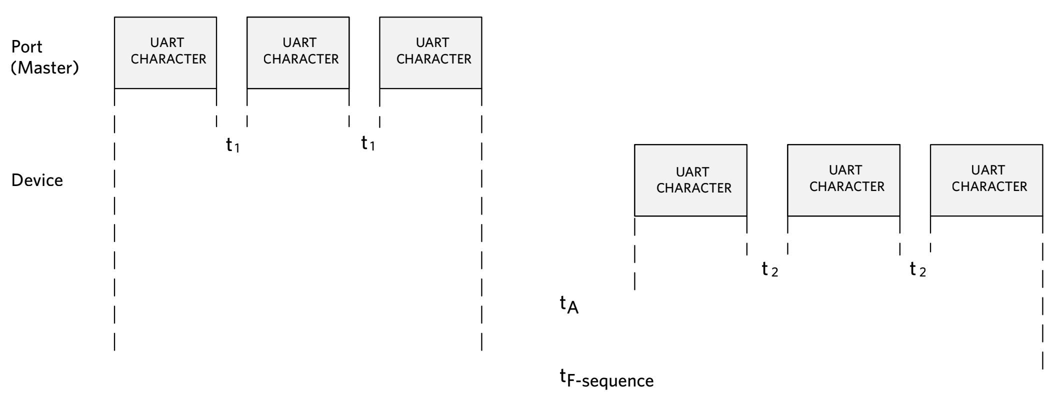


Figure 13. UART Framing

Wake-Up Request

When a master wants to configure a device (sensor or actuator) or communicate with it for the first time, it will send a wake-up request. A wake-up request starts by shorting the C/Q line for 80µs with a current pulse of at least 500mA (Figure 14). The device must be ready for communication within 500µs (T_{REN}).

- A wake-up period is typically 80µs (75µs, min or 85µs, max).
- The master sources (or sinks) the current to generate the wake-up pulse. If the line is low, the master will source current to pull it high. If the line is high, the master will sink current to pull it low.
- The wake-up pulse is detected by the IO-link device (which either monitors the current on the line or detects a voltage change of low-to-high or high-to-low).
- When the wake-up request is received, the IO-Link device must configure itself to receive mode. This must occur within 500µs of receiving the request, or an error will be generated by the master.

IO-Link Data Rate Selection

Once the master has sent a wake-up request to the device (to set it to receive mode), the master then learns more about it by establishing the data rate for communication (Figure 15):

- The master sends multiple messages at the COM3, COM2, and COM1 data rates (fastest to slowest), and waits for the device to respond after each send:
  - Any given device is required to support only one of the COM1, COM2, or COM3 data rates.
- The device will respond at its rated data rate:
  - When the device responds, the master is then able to communicate with the device.
  - The master can then read out the minimum cycle time capability of the IO-Link device.
- The master can retry the wake-up sequence a maximum of two times to establish IO-Link communication.
  - If the wake-up request fails, and then fails a second time (max retries = 2), the device must set the C/Q line to SIO (DI/DO binary sensor) mode.

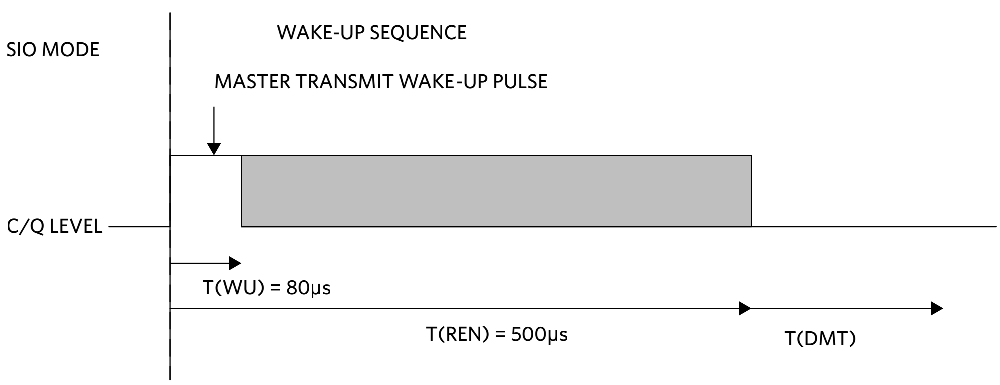


Figure 14. Wake-Up Sequence

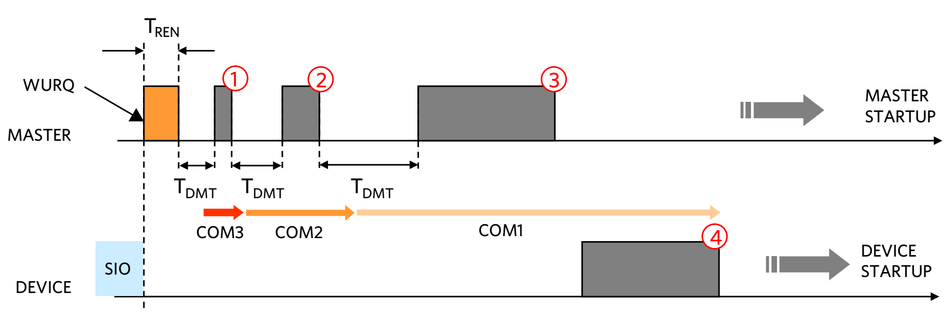


Figure 15. Data Rate Selection

The IO-Link IODD

All IO-Link devices (sensors or actuators) must have an associated IO-Link Device Description (IODD) file available (Figure 16). This is used by the IO-Link master for purposes of identification, data interpretation, and configuration.

- The IODD contains:
    - All necessary properties to establish communication
    - Device parameters
    - Identification information
    - Process and diagnostic information
    - An image of the device and the manufacturer's logo
- IODD files are XML files
- The structure of the IODD is outlined in a separate document from the IEC 61131-9 standard.
- The IO-Link Consortium maintains a centralized, multi-vendor database for IODD files on the **IO-Link** website

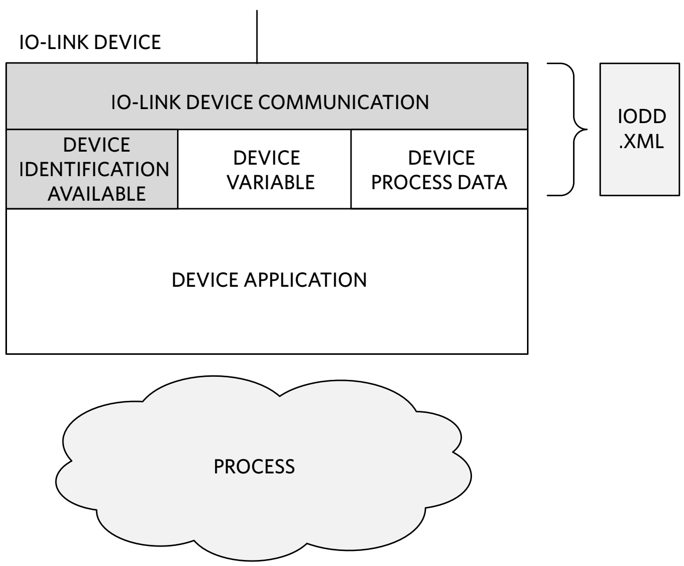


Figure 16. IODD File

Section 3: Designing an IO-Link Sensor

In this section, we will look at reference design examples that demonstrate how to design a smart sensor system as well as a system to support legacy binary sensors that interface to an IO-Link port.

Sensor Design Considerations

The basic structure of an IO-Link sensor includes some fundamental building blocks (Figure 17a and Figure 17b) which the system designer must consider:

- Sensor type (optical, temperature, etc.,)
- MCU that interfaces with the sensor and runs the IO-Link device stack
- IO-Link transceiver (or physical layer/PHY)
- Power supply and the various voltage and current ratings required
- Connector type
- External protection (TVS for surge, EFT/burst, ESD, etc.)

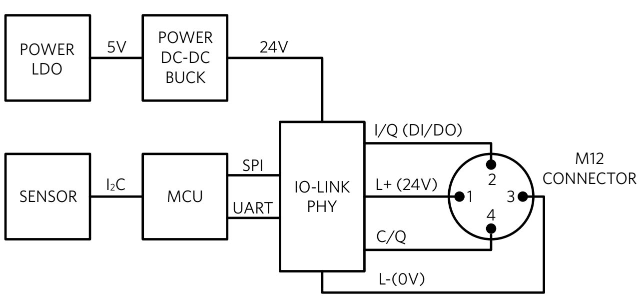


Figure 17a. Building Blocks of an IO-Link Sensor

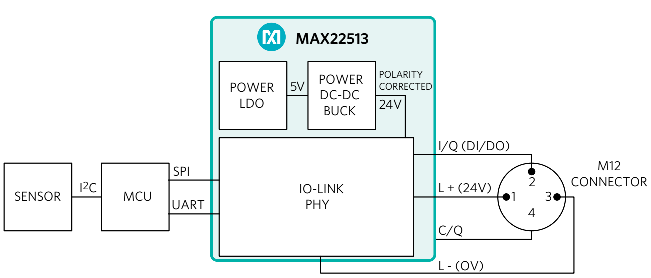


Figure 17b. Building Blocks of a Highly Integrated IO-Link Sensor

IO-Link Smart Sensor Design Features

Figure 18 shows the **MAXREFDES164** temperature sensor and the **MAXREFDES171** distance sensor. The **MAXREFDES173** temperature sensor and the **MAXREFDES174** distance sensor are also discussed in this section. These designs are compliant with IO-Link version 1.1 and 1.0 and include transient voltage suppression as well as reverse-polarity and short-circuit protection. For MAXREFDES164, the IO-Link transceiver is the single-channel **MAX14828**, which is very low power but requires external varistors for surge protection. The microcontroller used is the **MAX32660** running a TMG or TEConcept stack. For MAXREFDES173, the IO-Link transceiver is the dual-channel **MAX14827A** and the microcontroller is a Renesas RL78 running an IQ^2 stack.

The MAXREFDES171 and MAXREFDES174 use the MAX22513 IO-Link transceiver, which features integrated surge protection (no external TVS required) as well as an integrated DC-DC buck converter, making it more efficient for 'higher powered' sensors (such as distance sensors) that require a larger load current. The use of the DC-DC buck compared to a linear regulator greatly improves the thermal performance of such a sensor. For MAXREFDES171, the microcontroller is the MAX32660 running a TMG stack while the MAXREFDES174's microcontroller is a Renesas RL78 running an IQ^2 stack.

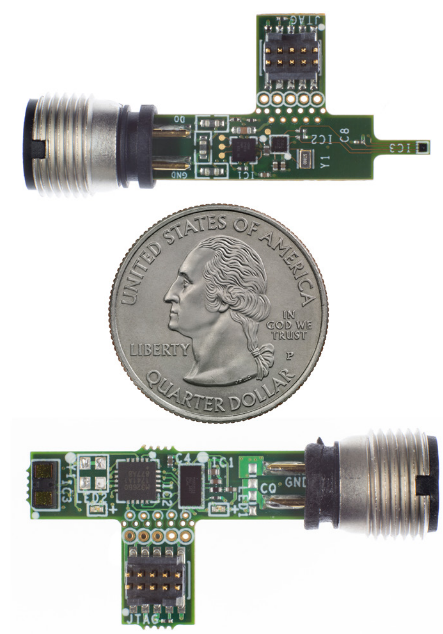


Figure 18. MAXREFDES164 Temperature Sensor and MAXREFDES171 Distance Sensor

IO-Link Temperature Sensor: MAXREFDES164 and MAXREFDES173

We have collaborated with Technologie Management Gruppe Technologie und Engineering (TMG TE) and TEConcept in designing the **MAXREFDES164** as a temperature sensor reference design that is compliant with the IO-Link version 1.1.3/1.0 standard. The MAXREFDES164 design consists of an industry-standard Maxim IO-Link device transceiver (MAX14828), a MAX32660 ultra-low-power 32-bit microcontroller utilizing TMG TE's or TEConcept's IO-Link device stack, and a Maxim local temperature sensor (**MAX31875**). Figure 19 shows the system block diagram.

The MAXREFDES164 IO-Link local temperature sensor consumes minimal power, space, and cost, making it an all-around solution for many industrial control and automation local temperature sensing applications.

The MAX14828 IO-Link device transceiver is IO-Link version 1.1.3/1.0 physical layer-compliant and integrates the high-voltage functions commonly found in industrial sensors, including drivers and regulators, all in a tiny 2.5mm x 2.5mm WLP package. The MAX14828 features two ultra-low-power drivers with active reverse-polarity protection. Operation is specified for normal 24V supply voltages up to 60V. Transient protection is simplified due to high voltage tolerance (65V absolute maximum rating) allowing the use of varistors or micro TVS.

The MAX14828 features a flexible control interface. A SPI interface is available with extensive diagnostics, and for IO-Link operation, a three-wire UART interface is provided. The MAXREFDES164 takes advantage of the multiplexed UART/SPI option which allows using one serial microcontroller interface for shared SPI and UART interfaces. The MAX14828 includes integrated 3.3V and 5V linear regulators which provide the low-noise supply rails for the other components on the board.

The MAX32660 is an ultra-low-power, cost-effective highly integrated microcontroller which 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 MAX31875 is a ±1°C-accurate local temperature sensor with I²C/SMBus interface. The combination of a tiny package and excellent temperature measurement accuracy makes this product ideal for a variety of equipment. The MAX31875 temperature sensor measures temperature and converts the data into digital form. An I²C-compatible two-wire serial interface allows access to conversion results. Standard I²C commands allow reading the data and configuring other operating characteristics. The MAX31875 is available in a 4-bump WLP and operates over the -50°C to +150°C temperature range.

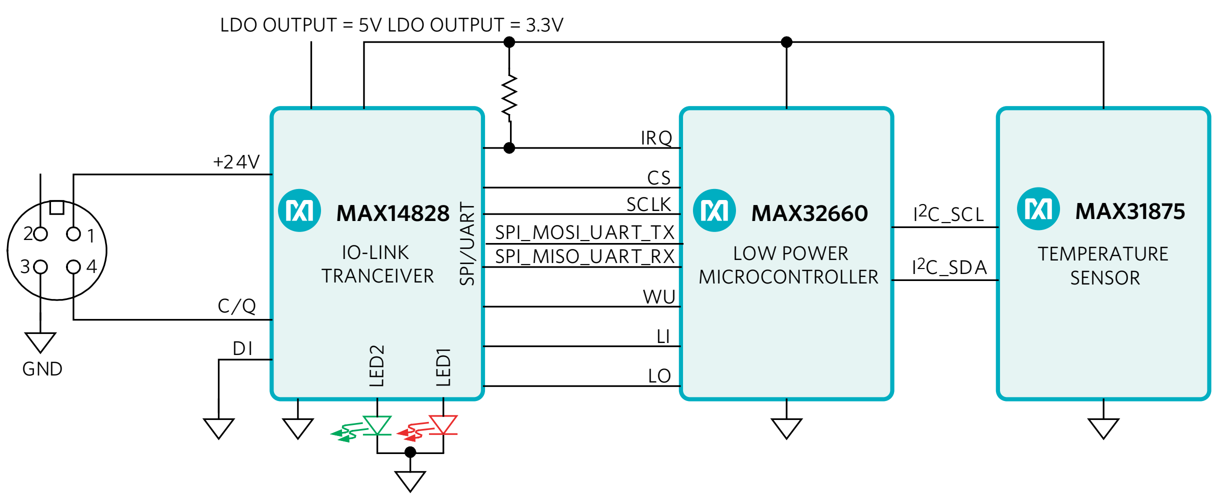


Figure 19. MAXREFDES164 IO-Link Temperature Sensor Block Diagram

For protection, the MAXREFDES164 uses varistors (MOV) at the IO-Link interface. The VC060330A650DP varistors have a working voltage of 30V and a breakdown voltage of 41V. With these varistors, this reference design meets both IEC 61000-4-2 (ESD) and IEC 61000-4-4 (EFT). It is designed to meet surge capability (±1kV/500Ω at t = 1.2/50µs) and a low clamping voltage of < 70V. The MAX14828 absolute maximum (Abs Max) voltage rating of 65V on the IO-Link pins allows the use of these tiny and simple varistors where other vendors' transceiver ICs (with lower Abs Max ratings) require much larger sized TVS diodes.

The MAXREFDES164 uses an industry-standard M12 connector that allows the use of a 4-wire cable. The MAXREFDES164 consumes less than 6mA (typ) including the green LED "alive signal," which pulses rather than remains constantly on to reduce power consumption. Note the red LED, if illuminated, indicates a FAULT condition.

To demonstrate the performance of our IO-Link transceivers with different microcontrollers and stack software, the **MAXREFDES173** implements a similar sensor but uses the MAX14827A IO-Link transceiver and Renesas RL78 with IQ² stack.

Description of Software

The MAXREFDES164 was verified using TMG TE's IO-Link Device Tool V5 and our **MAXREFDES165** 4-port IO-Link master reference design. Download the IODD file (*.xml) located under the Design Resources section of the MAXREFDES164 product page and go to the Quick Start section for step-by-step instructions on how to use the software (Figure 20). Note: The MAXREFDES164 also works seamlessly with the **MAXREFDES145** 8-port IO-Link master and the TEConcept IO-Link Control Tool.

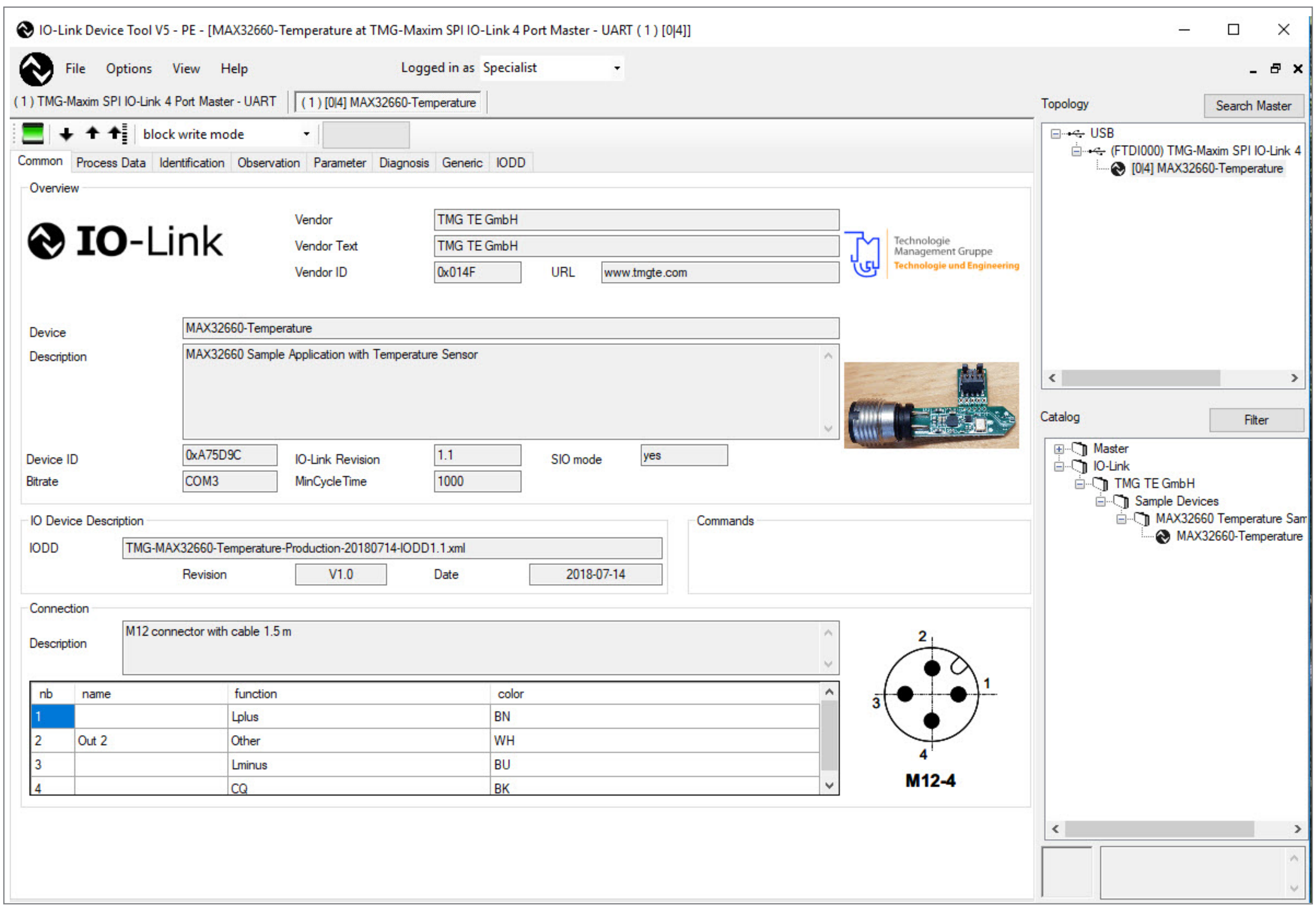


Figure 20. MAXREFDES164 IO-Link Device Software Interface

IO-Link Distance Sensor: MAXREFDES171 and MAXREFDES174

We have collaborated with Technologie Management Gruppe Technologie und Engineering (TMG TE) in designing the **MAXREFDES171** (Figure 21) as a reference design that is compliant with the IO-Link version 1.1.3/1.0 standard. The MAXREFDES171 design consists of an industry-standard MAX22513 IO-Link device transceiver, a MAX32660 ultra-low-power 32-bit microcontroller that utilizes the TMG TE IO-Link device stack, and a commercially available time-of-flight (ToF) laser-ranging sensor.

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 contained 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 I/O pins (V24, C/Q, DO/DI, and GND) are reverse-voltage and short-circuit protected, and feature an 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, allowing the reference design to consume minimal power and have very low thermal dissipation. Operation is specified for the typical 24V supply and operates with voltages up to 36V. Transient protection is simplified due to high-voltage tolerance (65V absolute maximum rating) in addition to the integrated surge protection.

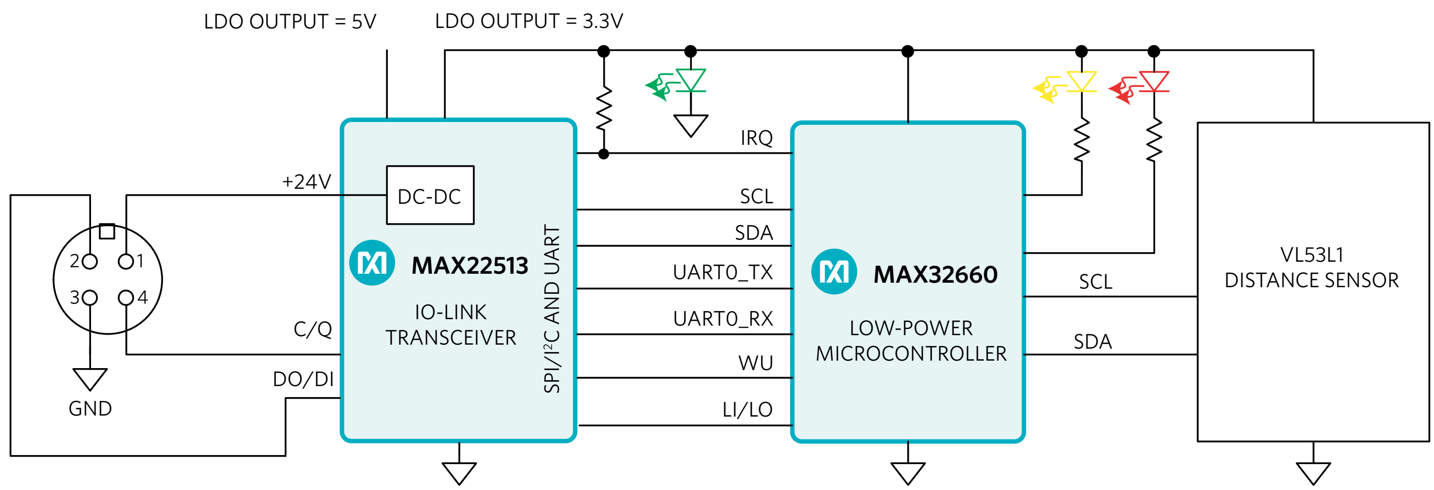


Figure 21. MAXREFDES171 IO-Link Device Distance Sensor

The integrated DC-DC buck regulator significantly reduces system power dissipation by dropping the available 24V to a lower voltage more efficiently than a linear regulator. The two integrated LDO regulators within MAX22513 generate 3.3V and 5V, saving external components and space. The DC-DC regulator can provide 300mA at low voltages much more efficiently than an LDO, making this transceiver ideal to power high current sensors.

The MAX22513 features a flexible control interface, allowing control through either an SPI or I^2C interface. In this design, we use I^2C to reduce the number of pins required by the microcontroller. I^2C allows both the MAX22513 and the sensor IC to be on the same bus. The I^2C (or SPI) interface provides extensive diagnostics (from MAX22513), and a 3-wire UART interface is provided for IO-Link communication.

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 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 I^2C communication in a tiny, 1.6mm x 1.6mm, 16 WLP.

The VL53L1X is a ToF, laser-ranging sensor that provides accurate distance that ranges up to 400cm. The ranging sensor is programmed with firmware and is controlled by a simple I^2C interface that only requires SCL and SDA. 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 operates 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 also designed to meet surge capability (up to ±1kV/500Ω 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 cable to be used.

To demonstrate the performance of Maxim's IO-Link transceivers with different microcontrollers and stack software , the **MAXREFDES174** implements a similar sensor but uses a Renesas RL78 microcontroller with IQ^2 stack.

Description of Software

The MAXREFDES171 was verified using TMG TE's IO-Link Device Tool V5 and our MAXREFDES165 4-port IO-Link master. Download the IODD file (*.xml) located in the Download All Design Files section of the MAXREFDES171 product page's Design Resources tab. Go to the Quick Start section for step-by-step instructions on how to use the software. Figure 22 shows a screenshot of the TMG TE IO-Link Device Tool.

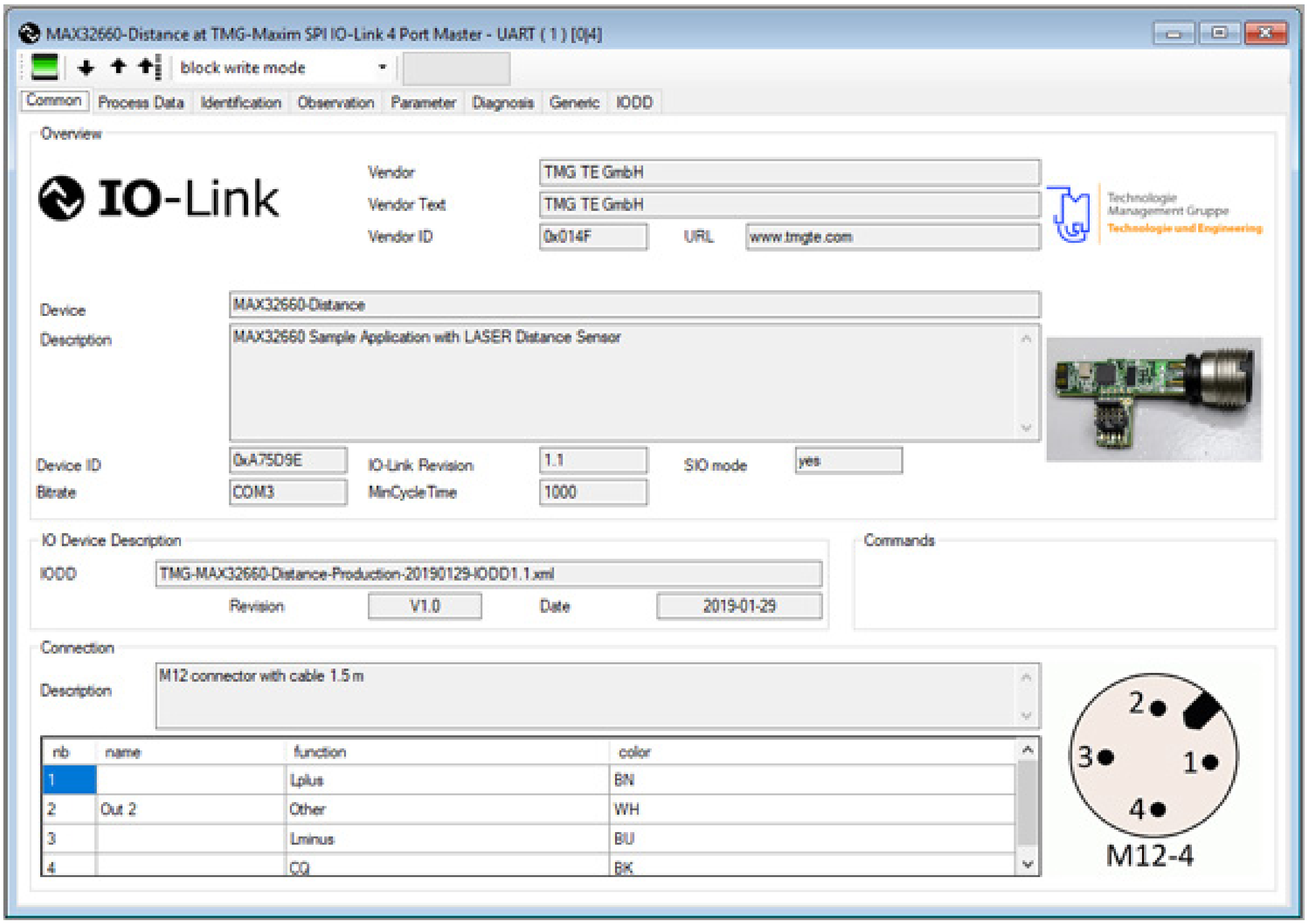


Figure 22. MAXREFDES171 IO-Link Device Software Interface

For complete details of each reference design, including full design files please visit **www.maximintegrated.com**.

Section 4: Designing an IO-Link Master

In this section, we will look at reference design examples that demonstrate how to design a multi-port master for a smart sensor system using IO-Link.

IO-Link Master Design Objectives

When designing an IO-Link master solution, there are common system design questions that must be considered:

Hardware Design:

- How many IO-Link ports should the system have?
- Should the ports be Class A or Class B?
- Should the connectors in a Class A port support pin 2?
- What miswiring cases should be accommodated for over-voltages or reverse polarity?
- Should the PCB design be modular and able to accommodate different port counts?
- How much current should the L+ supply provide?
- What is the form-factor?

EMC Compliance:

- Who will perform the compliance testing?

As an example, our design team for the MAXREFDES145 eight-port IO-Link master reference design chose to create an 8-port master due to the popularity of the configuration and to provide an alternative to their existing 4-port master. They used the MAX14819 dual-channel IO-Link master transceiver and the STM 32F4 Arm Cortex-M4 microcontroller, implementing isolation between the USB interface and the IO-Link channels. The reference design fits on a single 5in. x 3in. PCB. For software, the design team partnered with TEConcept, who supplied the IO-Link-compliant software stack and performed the compliance testing. The design includes a TVS diode at each of the IO-Link ports, and is tested to IEC 610004-2 and IEC 610004-5 for transient immunity to ESD and surge immunity.

8-Port IO-Link Master: MAXREFDES145

The **MAXREFDES145** is a fully IO-Link-compliant, eight-port IO-Link master reference design (Figure 23). This design uses TEConcept's IO-Link master stack and is both an IO-Link master reference design as well as an IO-Link sensor/actuator development and test system. Eight IO-Link ports allow for simultaneous testing of up to eight different sensors (or actuators). The reference design has eight robust female M12 connectors, the most common connector used for IO-Link, and ships with two black IO-Link cables to quickly connect to IO-Link-compatible sensors and actuators. An AC-to-DC (24VDC/3A) power supply provides at least 125mA simultaneously to each port (more when fewer ports are used). A micro-USB connector allows for quick connectivity to a Windows® PC.

The easy-to-use TEConcept Control Tool (CT) GUI software, with IODD file import capability, makes the MAXREFDES145 a must-have for any company or engineer serious about developing IO-Link products.

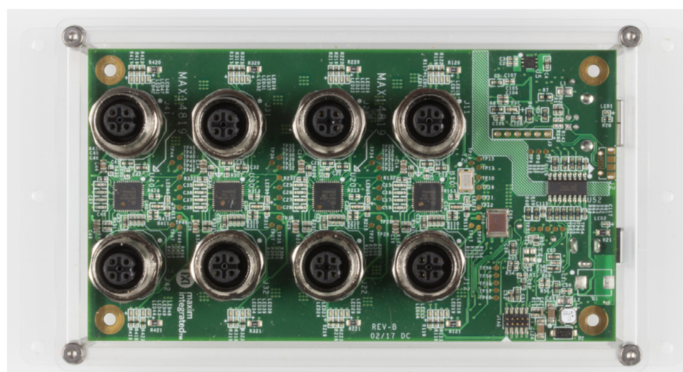


Figure 23. MAXREFDES145 8-Port IO-Link Master Reference Design

Description of Hardware

The MAXREFDES145 IO-Link master consists of four main blocks: four dual-channel **MAX14819** IO-Link master transceivers, two digital isolators for the SPI interface, a microcontroller, and a USB connection as shown in Figure 24. The MAX14819 IO-Link master transceivers are IO-Link version 1.1.2 physical layer-compliant. These transceivers feature integrated 5V linear regulators, configurable C/Q outputs (push-pull, high side, or low side) with configurable output drive capability, auxiliary digital inputs, and reverse-polarity/overvoltage or short-circuit protection.

An STM32F4 Arm Cortex-M4 microcontroller provides system control. A USB port is implemented using the FTDI FT2232 USB-to-SPI transceiver and driver. An on-board **MAX15062** high voltage, synchronous step-down converter provides power to the STM32F4 microcontroller from the 24V supply. Two digital isolators, the four-channel **MAX14931** and the two-channel **MAX12931**, protect the USB interface from high voltage and large ground differentials that may occur when the MAX14819 master transceivers are connected to IO-Link peripherals. All communication between the USB port/ PC and the SMT32F4 microcontroller passes through these isolators. A stand-alone SPI header (J3) is available on the MAXREFDES145 to allow the user to bypass the USB interface or directly communicates with the STM32F4 using an external SPI master.

High-level protection TVS diodes at each of the eight IO-Link interface ports and at the power-supply inputs provide 1kV/42Ω surge and reverse-polarity protection for each master transceiver on the MAXREFDES145. Additionally, power and status LEDs (for each channel) provide quick visual confirmation that the board is working and communicating.

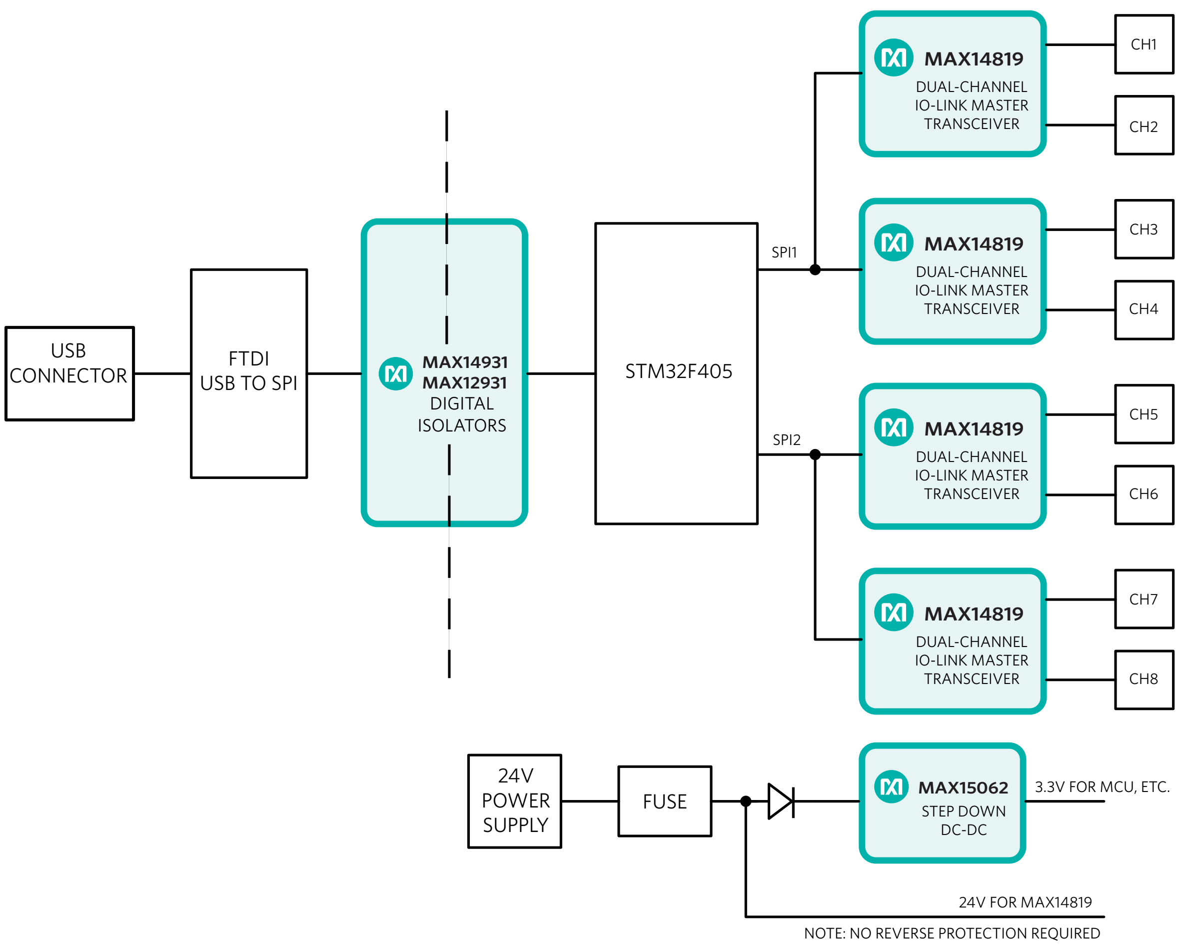


Figure 24. MAXREFDES145 8-Port IO-Link Master Block Diagram

Description of Software

The TEConcept CT Windows-compatible GUI software features IODD file import capability, connects to a PC via USB, and is available for download from the Design Resources tab of the MAXREFDES145 product page. The TEConcept CT software is shown in the Details tab of the MAXREFDES145's product page and a complete step-by-step Quick Start guide is also downloadable from the MAXREDES145's Design Resources tab.

The TEConcept IO-Link master stack ships preprogrammed inside the MAXREFDES145 hardware with a perpetual time license displayed by the TEConcept CT software. This allows MAXREFDES145 to be used for development and testing purposes. Users wishing to design their own products can purchase firmware for the IO-Link master from TE-Concept. Appendix of Technical Resources.

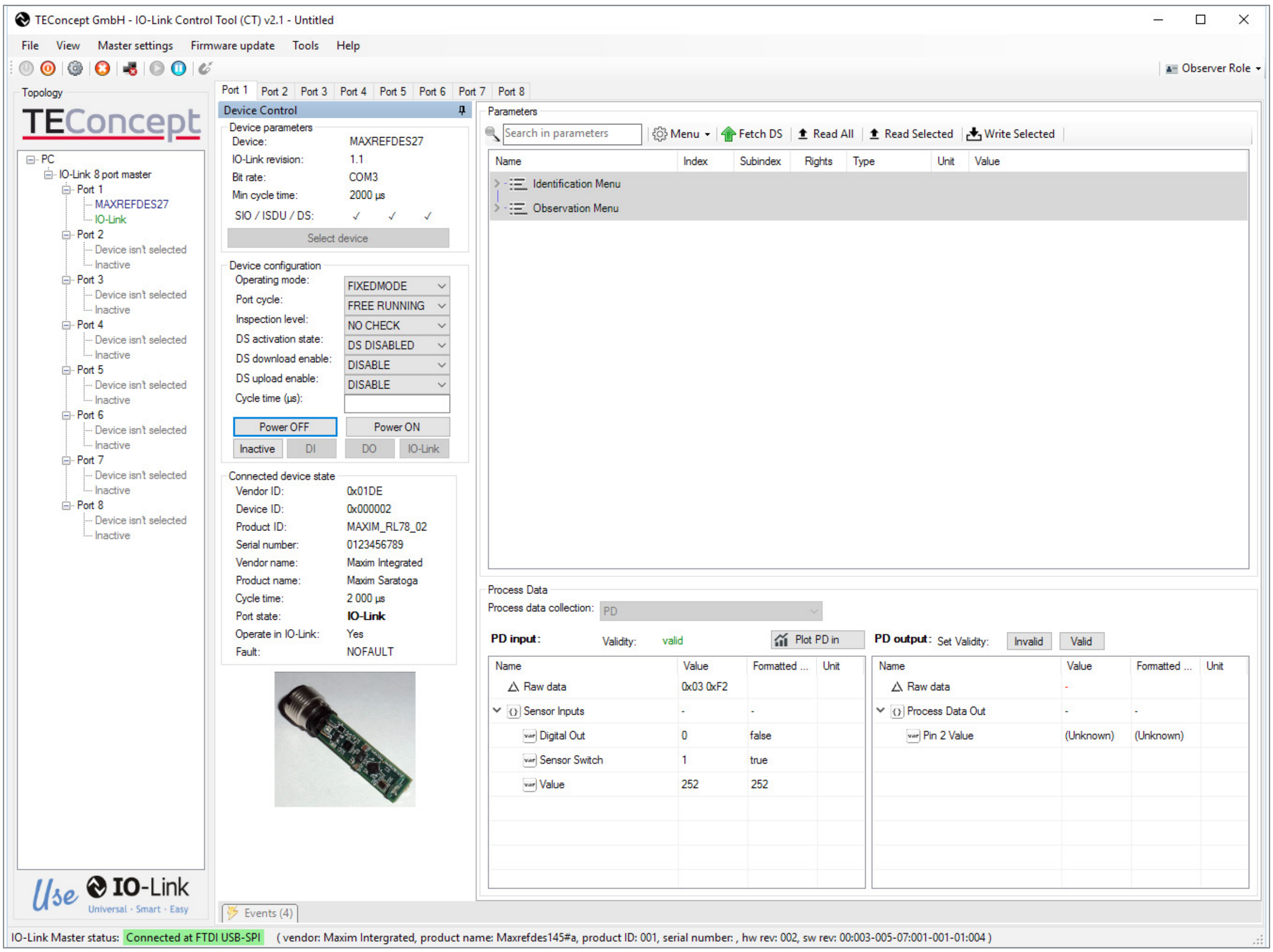


Figure 25. TE Concept IO-Link Software

4-Port IO-Link Master: MAXREFDES165

The **MAXREFDES165** (Figure 26) is a fully IO-Link-compliant, 4-port IO-Link master reference design. This design uses the TMG TE IO-Link master stack and is both an IO-Link master reference design and a development and test system for IO-Link sensors/actuators. Four IO-Link ports allow for simultaneous testing of up to four different sensors (or actuators). The reference design has four robust female M12 connectors—the most common connector used for IO-Link—and ships with an IO-Link cable for connecting quickly to IO-Link-compatible sensors and actuators. An AC-to-DC (24VDC/3A) power supply can provide at least 250mA to each port simultaneously, and more when fewer ports are used. A USB 2.0 Type B connector allows for quick connectivity to a Windows® PC.

Figure 26. MAXREFDES165 4-Port IO-Link Master Reference Design

Description of Hardware

The MAXREFDES165 IO-Link master comprises of four main blocks: two dual-channel MAX14819 IO-Link master transceivers, a MAX14931 digital isolator for the SPI interface, a microcontroller, and a USB connection (shown in Figure 27).

The MAX14819 IO-Link master transceivers are IO-Link version 1.1.2 physical-layer compliant. These transceivers feature integrated 5V linear regulators, configurable C/Q outputs (push-pull, high-side, or low-side) with configurable output drive capability, auxiliary digital inputs, and reverse-polarity/short-circuit protection.

An STM32F4 Arm Cortex-M4 microcontroller in a 10mm x 10mm, 64-pin LQFP package provides system control. A USB port is implemented using the FTDI FT2232 USB-to-SPI transceiver and driver. An on-board MAX15062A high-voltage, synchronous step-down converter provides power to the STM32F4 microcontroller from the 24V supply.

A digital isolator, the four-channel MAX14931F, protects the USB interface from high-voltage and large ground differentials that can occur when the MAX14819 master transceivers are connected to IO-Link peripherals. All communication between the USB port/PC and the SMT32F4 microcontroller passes through this isolator.

A stand-alone SPI header (J3) is available on the MAXREFDES165 to allow the user to bypass the USB interface and communicate directly with the STM32F4 using an external SPI master. J3 is connected to the isolated side of the board and all digital communication from the external master to the STM32F4 goes through the isolators. An external 3.3V logic supply is required to power the isolators when using J3. High-level protection transient voltage suppressor (TVS) diodes at each of the four IO-Link interface ports and at the power supply inputs provide surge and reverse-polarity protection for each master transceiver on the MAXREFDES165.

Additionally, power and status LEDs (for each channel) provide quick visual confirmation that the board is working and communicating. The complete system block diagram is shown in Figure 27.

Note: The MAX14819 can be configured to operate with a UART interface (within the microcontroller) or by using the integrated framers on the IC. The advantage of the framer mode includes enabling support from smaller and lower cost microcontrollers with a limited number of integrated UARTs. The default stack that ships with the MAXREFDES165 is the UART version. If you require the Framer version, please contact the factory.

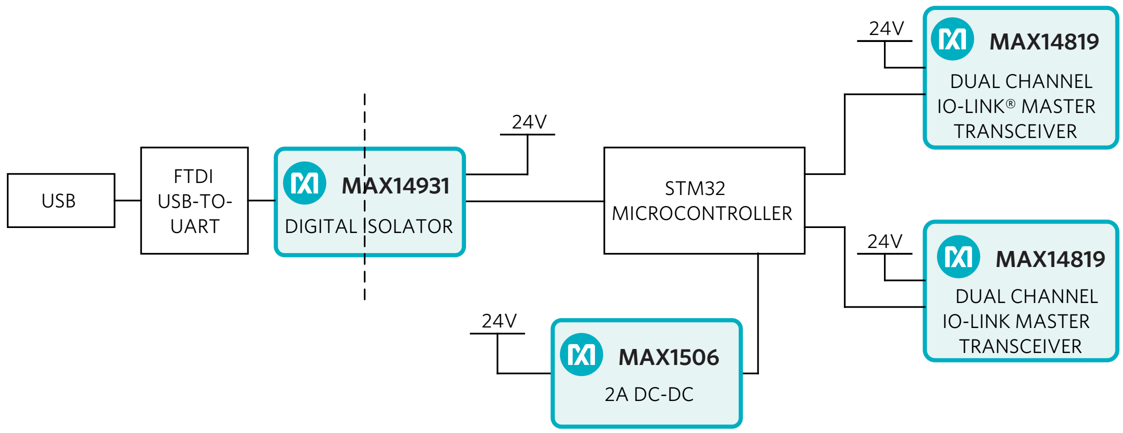


Figure 27. MAXREFDES165 Reference Design Block Diagram

Description of Software

TMG's IO-Link Device Tool Windows-compatible software features IODD file import capability, connects to a PC through USB, and is available on request from TMG. The TMG IO-Link Device Tool software is shown in Figure 28, and a complete step-by-step Quick Start guide is also downloadable from the Design Resources tab.

Note: The MAX14819 can be configured to operate with a UART interface (within the microcontroller) or by using the integrated framers on the IC. The default stack that ships with the MAXREFDES165 is the UART version. If you require the Framer version, please contact the factory.

The TMG TE IO-Link master stack ships preprogrammed inside the MAXREFDES165 hardware with a perpetual license. Contact information for TMG TE GmbH is found in the list of Software Stack Vendors in the IO-Link Handbook's **Appendix of Technical Resources**.

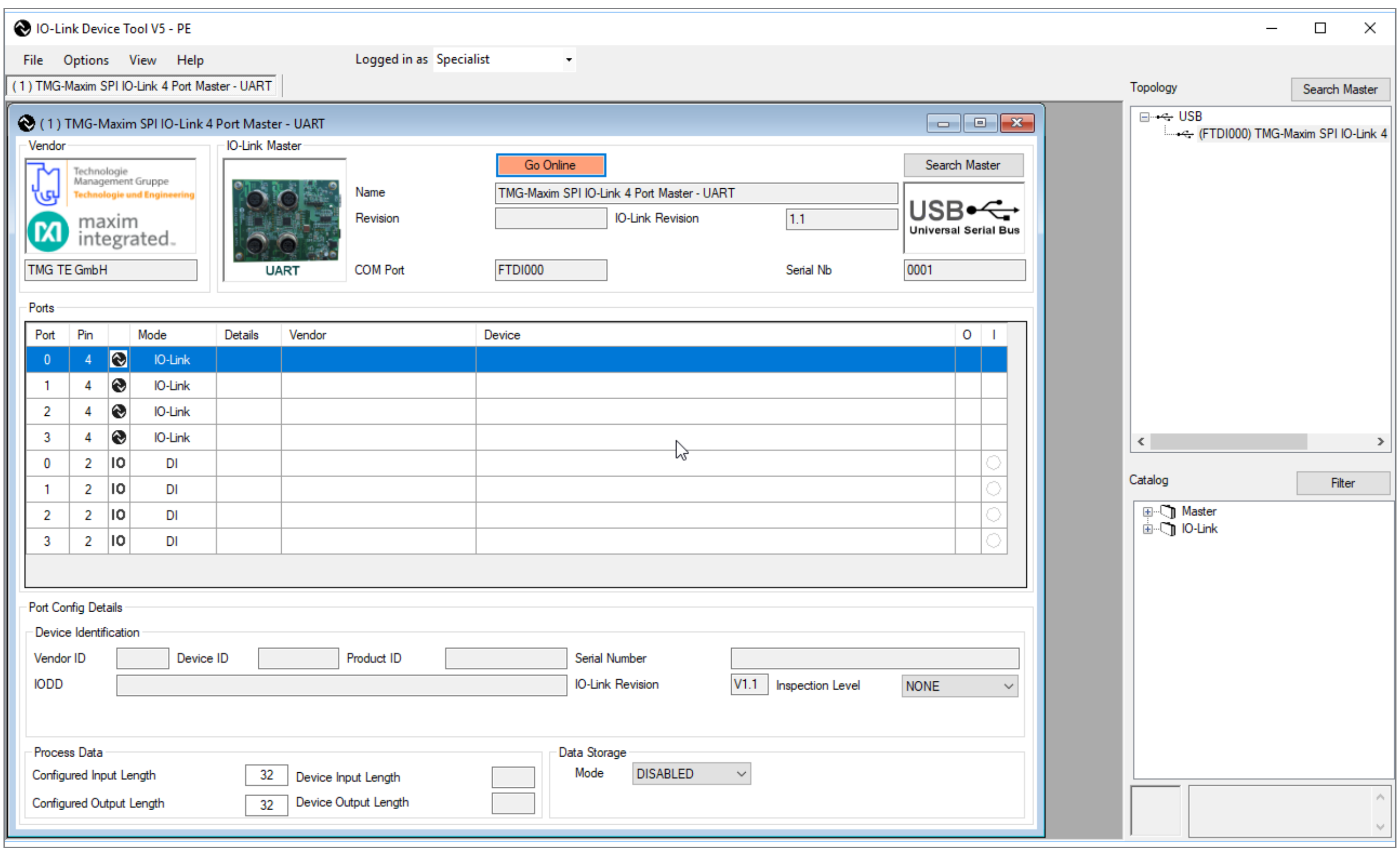


Figure 28. MAXREFDES165 TMG IO-Link Device Tool

IO-Link Master Test Reports

The MAXREFDES145 is a fully compliant IO-Link version 1.1.3 master. See the detailed test report (Figure 29) on our website at **MAXREFDES145 8-Port IO-Link Master Test Report**.

TEConcept IO-Link

Name	
Description	DUT Check Info
State	Successful
State info	
Expected result	Successful
Optional step	No
Comment	
Start of execution	2017-05-04 15:25:40.391
End of execution	2017-05-04 15:25:43.542
Vendor name	Maxim Integrated
Product name	Maxrefdes145#b
Product ID	001
Serial No.	
Hardware Rev.	002
Firmware Rev.	00:005-006-07:001-001-01:005
Description	8 port IO-Link Master.

Figure 29. Details of MAXREFDES145 IO-Link Master Test Report

The MAXREFDES165# is a fully compliant IO-Link version 1.1.3 master, according to the following test report. It was tested with golden device GD000009. See the detailed test report (Figure 30) for MAXREFDES165# **Four-Channel IO-Link Master Test Report**.

TEConcept IO-Link

GD Product Text	IO-Link Golden Device Master Test System
Device ID	0x004D47
GD Serial No	GD000009
GD Hardware Rev	0100
GD Firmware Rev	0036

DUT Check Info

Type	DUT Check Info
Name	
Description	DUT Check Info
State	Successful
State info	
Expected result	Successful
Optional step	No
Comment	
Start of execution	2018-07-17 13:59:04.955
End of execution	2018-07-17 13:59:04.982
Vendor name	TMG TE GmbH
Product name	IO-Link USB Master interface
Product ID	IOLUSBM
Serial No.	1
Hardware Rev.	1.0
Firmware Rev.	1.0
Description	Test interface fuer USB Master

Figure 30. Details of MAXREFDES165# IO-Link Master Test Report

Section 5: Improving System Performance

In IO-Link applications, the transceiver acts as the physical layer interface to a microcontroller running the data link layer protocol while supporting up to 24V digital inputs and outputs. Our transceivers have long supported all IO-Link specifications and feature the lowest power dissipation.

Our first IO-Link device transceiver, the MAX14820, dissipated just under 900mW with the drivers under full load conditions. The second-generation MAX14826 reduced the already low power dissipation of its predecessor by over 50%, dissipating only 400mW under full load conditions.

The third-generation MAX14828 single-channel transceiver, and the MAX14827A dual-channel transceiver, dissipate a remarkably low 70mW when driving a 100mA load—achieving more than 80% lower power dissipation than the closest competitive device. For even lower dissipation while driving, the C/Q and DO drivers on our transceivers can also be paralleled.

The most recent IO-Link transceiver, the MAX22513, features a selectable control interface, internal high-efficiency DC-DC buck regulator, two internal linear regulators, and integrated surge protection for robust communication. The device features low on-resistance drivers (C/Q and DO/DI), selectable driver current limits, and overcurrent protection to reduce power dissipation in small sensor applications.

Heat Dissipation

The results of the following tests highlight the evolution of power dissipation by our device transceivers under different load conditions compared to our competitors.

Test A

In Figure 31, each IC has a 200mA load on C/Q, meaning dual-channel parts have only one channel loaded. The image (taken with a thermal camera) clearly shows that the MAX14828 and MAX14827A dissipate significantly less power than the competitor's single-channel device.

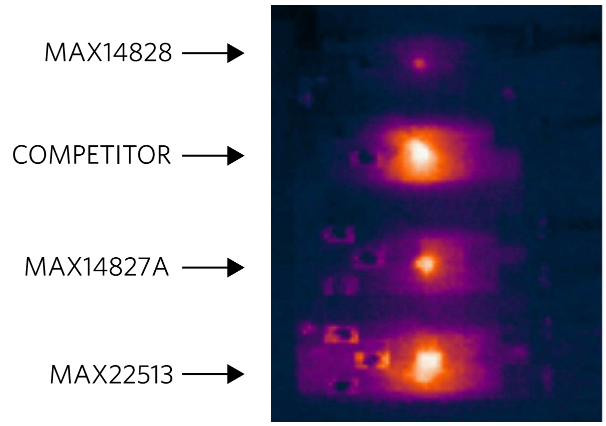


Figure 31. Test A – 200mA per Device

Test B

In Figure 32, a 200mA load on each channel means that dual-channel parts (MAX14827A and MAX22513) have twice the load of MAX14828 and the competitor part. The thermal camera clearly shows that the MAX14827A dual-channel device generates less heat or comparable to the competitor's single-channel device.

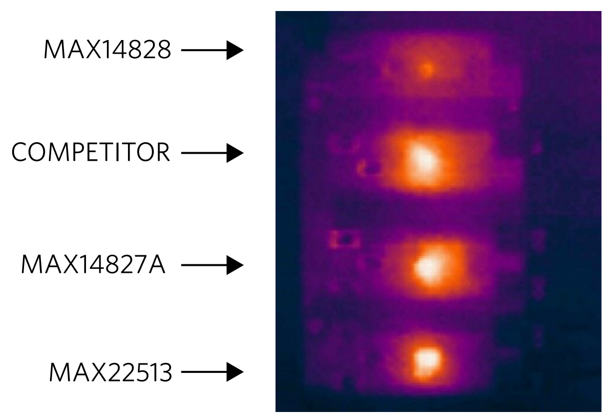


Figure 32. Test B – 200mA per Channel

Test C

In Figure 33, each IC has a 30mA load on the 5V LDO output (from the integrated linear regulator). For MAX14828, MAX14827A, and the competitor's device, the internal LDO must dissipate approximately (24V to 5V) x 30mA of power. The thermal camera clearly shows that the MAX22513 dissipates significantly less power than the devices without integrated DC-DC buck converters. This clearly demonstrates the benefit of the integrated DC-DC and its efficiency for sensors with an AFE that need more current from the integrated LDOs. The only heat signature for the MAX22513 is in fact an external resistor – the IC runs very cool due to the integrated buck converter.

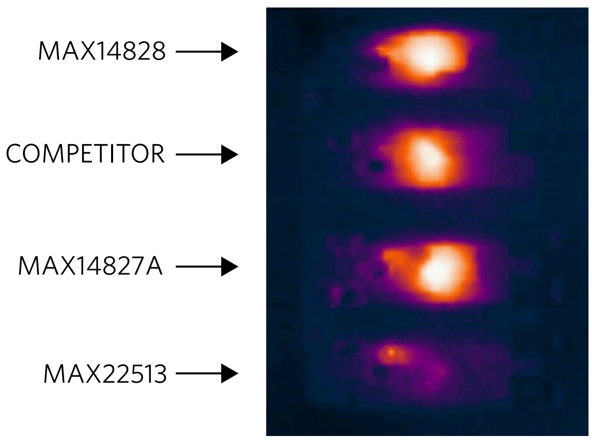


Figure 33. Test C – 30mA Load on 5V LDO

Thermal Performance

Most industrial sensors use either an M8 or a larger M12 cable connector. The type of connector used will impact the enclosure size of the sensor and therefore the amount of heat that can be dissipated. In the following example, we design an IO-Link sensor with a total power dissipation that does not exceed 400mW if an M8 connector is used, or 600mW for a sensor using an M12 connector.

Apart from a transducer (pressure/temperature/proximity), an IO-Link industrial sensor will also typically include an analog front-end (AFE), a microcontroller, status LEDs, and possibly an output stage to drive an actuator in response to sensor readings. Industrial sensors use a 24VDC signal voltage, but in a harsh factory environment, this can be up to 50% higher. While these voltage levels can be safely used to power the output driver stage, the AFE, LEDs, and microcontroller require much lower voltages (3V to 5V) for operation. Many IO-Link transceivers provide these voltage levels as linear regulated outputs. However, the decision to use them can have negative implications for overall sensor power consumption (and consequently, heat dissipation). This is especially true if an onboard LDO circuit is used to provide the current for these outputs. For example, consider the following power budget for a small sensor that draws just 15mA of current through an LDO, powered from a 24V (typ) DC rail, shown in Figure 34.

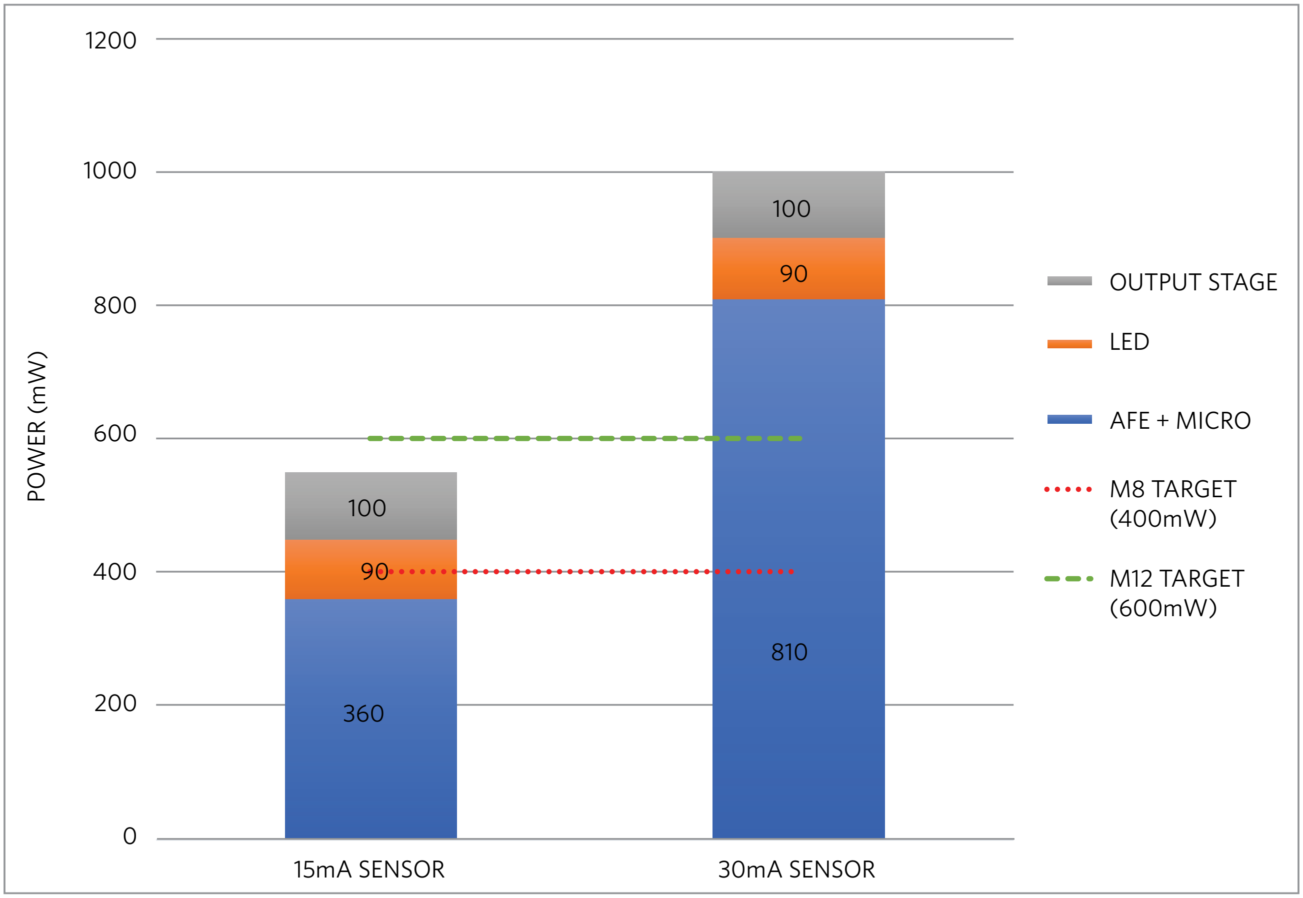


Figure 34. Power Budget for a Typical LDO-Powered IO-Link Sensor

Due to the high losses inside the LDO, this relatively low-power sensor has exceeded the ~400mW power-budget that can be dissipated in a typical M8-connected sensor, and therefore, a larger M12-connected enclosure would be required. Figure 34 also shows that a sensor drawing just 30mA of current will dissipate 900mW, exceeding even the target figure for an M12 connector sensor.

Discrete Solution

To reduce overall power consumption (and heat dissipation), the most common solution is to use an external DC-DC buck converter to power the AFE and the microcontroller.

For example, a DC-DC buck converter supplying a 30mA sensor with a 3V output voltage will dissipate just 90mW. Assuming the converter is 90% efficient (i.e. just 9mW power loss), the overall power consumption is just 90 + 9 = 99mW. Clearly, power dissipation is reduced by approximately a factor of 9 when compared to using the LDO (900mW). Including the power consumed by the output stage (100mW), the overall power reduction would be 1000mW/199mW, or approximately a factor of 5, as shown in Figure 35.

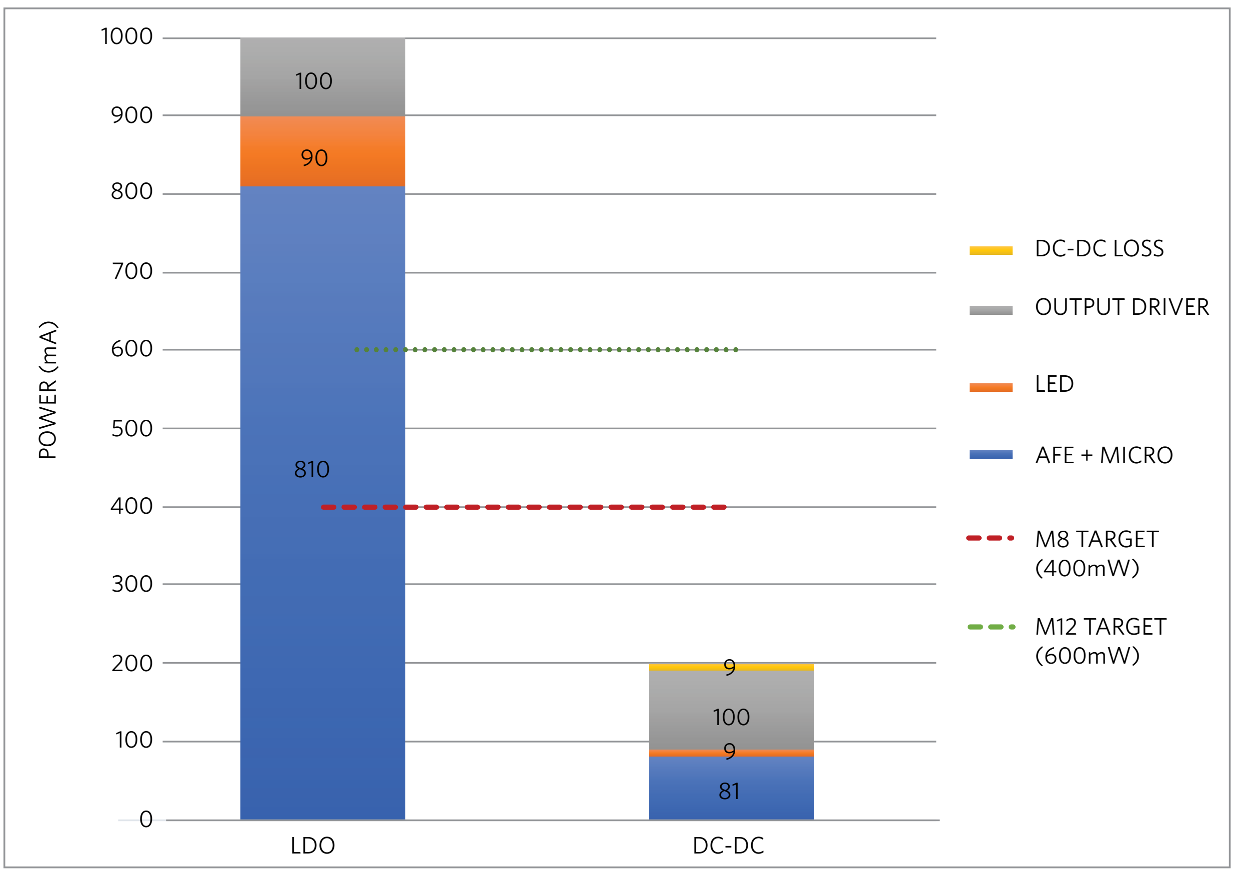


Figure 35. Power Reduction Using a Buck Converter vs. LDO for a 30mA Sensor

Clearly, the overall power consumption of the sensor (~200mW) is now well below the target figure for sensors using either type of connector. However, this power reduction is only achieved at the expense of extra external circuitry (i.e., the DC-DC converter and bulky discrete items such as an inductor, diodes, and capacitors), which increases the overall size of the sensor.

Integrated Solution

The MAX22513 IO-Link transceiver has several advantages when compared to the conventional approach. First, a reverse polarity-protected buck DC-DC converter has been fully integrated into the IC package, meaning there is no need for a separate DC-DC converter or additional external components. The converter can supply an output current of up to 300mA (for high-current sensor applications) with a 2.5V to 12V programmable output voltage. Secondly, unlike most other IO-Link transceivers, the IC also includes a second (auxiliary) IO-Link channel which can be used for DI/DO sensor switching while data is being transferred on the C/Q channel. Despite the inclusion of these extra features, the overall package size is only 2.1 × 4.1 = 8.6mm^2 in a wafer-level package (WLP). WLP packaging is visually similar to a BGA package with bumps or balls for soldering to the PCB, but the assembly process is different as explained in **Application Note 1891: Wafer Level Packaging (WLP) and its Applications**. This represents an almost 50% reduction in component area. Additionally, robust sensor performance in harsh industrial environments is provided by integrated surge protection (up to ±1kV/500Ω) circuitry that negates the need for external TVS diodes.

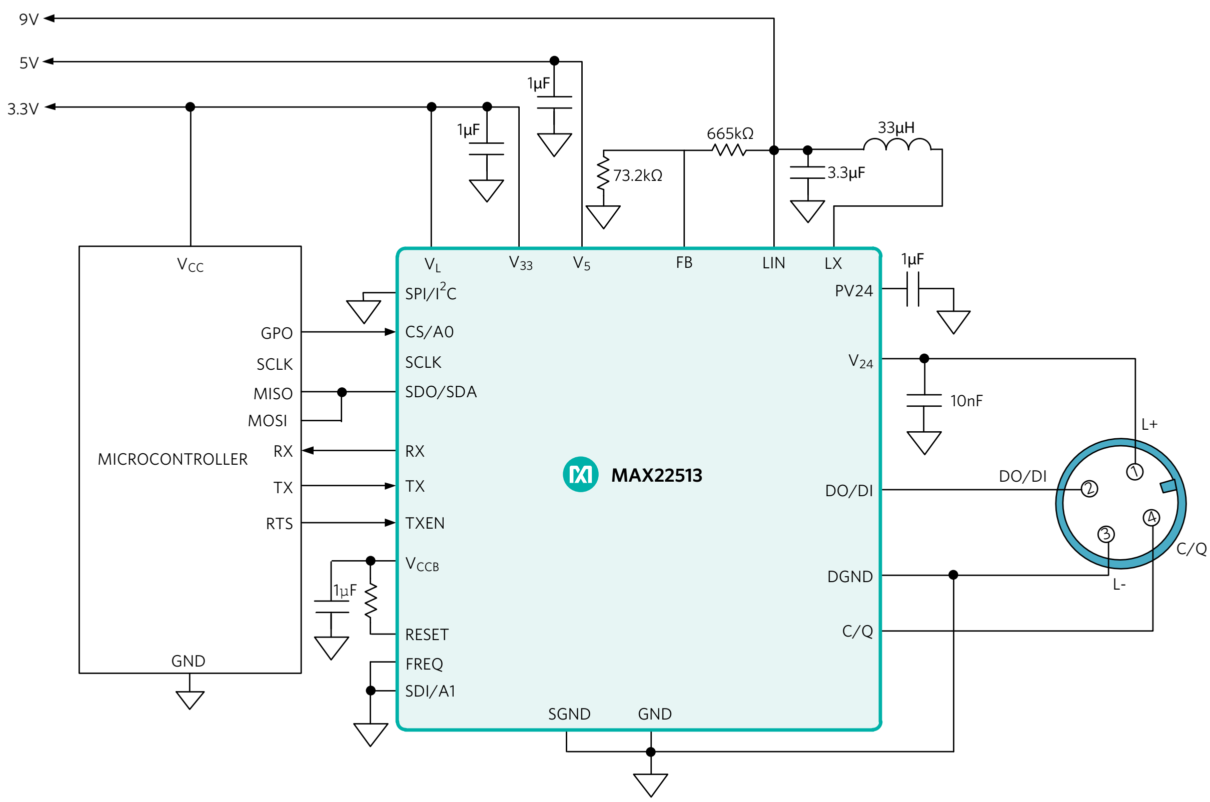


Figure 36. MAX22513 IO-Link Transceiver with Integrated DC-DC

The MAXREFDES171 is a distance sensor based on the MAX22513. This board has been tested to pass up to ±1kV/500Ω between the different pairs of pins. External TVS diodes may be used in systems that require higher levels of protection.

Selecting a TVS Diode

This section is a subset of the material covered by **Application Note 6965: How to Select a TVS Diode for Maxim's IO-Link Devices**.

IO-Link Protection

IO-Link devices (sensor transceiver or master transceiver) have 4 pins (L+, C/Q, L-, and DI/DO) that need to be protected. When testing for surge protection, for example, these pins need to survive surge pulses between any 2 pins (referred to as line-to-line testing), with both negative and positive polarity surges. It is important to understand the impact that the Abs Max Ratings for these pins have on TVS diode selection. The following examples demonstrate that the higher Abs Max values of Maxim IO-Link transceivers enable the use of significantly smaller TVS products, saving board space and cost.

How 65V (Abs Max) Helps with Protection (vs. 40V)

Let's consider a test case and see how the Abs Max Ratings can affect the final footprint of the circuit. Figure 37 shows the current flow and voltages across the protection scheme when a transient surge pulse is applied to the C/Q pin (referenced to L-) on the MAX14827A. Using the standard 42Ω impedance between the surge pulse (±1kV) and the device, the maximum current flow is ±24A.

Advantages of 65V Abs Max for Protection

The MAX14827A and MAX14828 have a guaranteed 65V Abs Max rating, allowing for flexible protection of the IO-Link pins for surge conditions. While competitor parts require bigger, more expensive TVSs, these high Abs Max Maxim ICs only require small, low-cost TVSs/varistors as follows

- Smallest TVS diode/standard surge (±1kV/500Ω): Semtech® μ Clamp®603; PCB area = 1.7mm^2
- Lowest cost TVS diode/standard surge (±1kV/500Ω): varistor; cost is ~50% of regular TVS diode
- High-level surge (±1kV/24A): SMAJ33 TVS diode (vs. competitor SMCJ33 TVS diode); 5x smaller PCB area

Summary

TVS diodes are included on a circuit to protect sensitive devices. During normal operation, the TVS diode must have no significant impact on circuit performance. However, when a high-voltage transient occurs, the TVS diode must activate and limit the voltage across the circuit. Large transient events (such as high voltage and current pulses) typically require large diodes for satisfactory protection. We offer the most robust IO-Link transceivers with high-voltage tolerances and abs max ratings of up to 65V to provide greater flexibility when selecting TVS protection diodes. Additionally, devices such as the MAX22513 integrate surge protection and remove the need for external TVS devices in many applications.

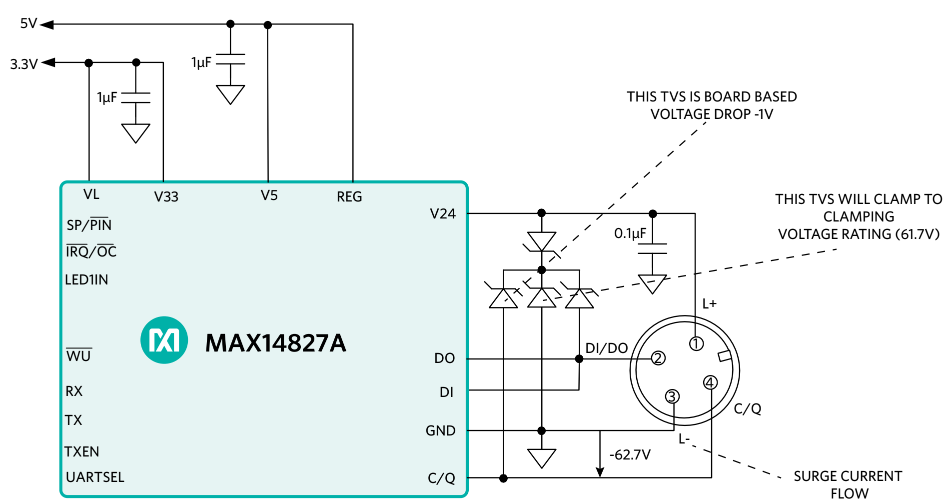


Figure 37. C/Q to L+ Surge

How Does the IO-Link Signal Slew Rate Affect Emissions From the IO-Link Cable?

Most Maxim IO-Link transceiver drivers have a controlled slew rate or even adjustable slew rate for the CQ pin, i.e. MAX14819, MAX14827A, MAX14828 have slew-rate limiting. MAX22513 has selectable slew rate.

IO-Link cables aren't shielded and the signal-level is quite high ($24V_{P-P}$). So the cable can act as an antenna. To reduce emissions from the cable it's important to limit the maximum frequency available on the cable to the minimum necessary.

The rise and fall-time of the IO-Link as specified for MAX22513 are specified as follows in Table 4.

Table 4. Rise and Fall Time of MAX22513

Driver Rise Time	t_{RISE}	Push-Pull or PNP mode, V_{24}(max) = 30V	0.1, 0.2, 0.325	µS
			0.40	
			1.22	
			4.7	
Driver Fall Time	t_{FALL}	Push-Pull or NPN mode, V_{24}(max) = 30V	0.2, 0.34, 0.475	µS
			0.66	
			1.64	
			7.1	

While the steepest rise and fall times (typ 0.2µs fall-time / typ 0.34µs rise-time) have strong transmit frequency components up to 1.8MHz, Max-Frequency = 1/T, while T= t_{RISE} + t_{FALL}. This also means the frequency content of the signal on the cable is 1.8MHz. However, the IO-Link Signaling fundamental frequency for highest IO-Link data rate of COM3 = 230.4kbps is 115.2kHz.

To reduce emissions from the cable it's better to use the slowest rise- and fall-times that still allow communication. Therefore it is recommended to reduce the slew rate when the COM rate is lower.

t_{RISE} + t_{FALL} = 0.2µs + 0.34µs result in a maximum frequency of about 1.8MHz.

t_{RISE} + t_{FALL} = 0.4µs + 0.66µs result in a maximum frequency of about 934kHz.

t_{RISE} + t_{FALL} = 1.22µs + 1.64µs result in a maximum frequency of about 349kHz.

t_{RISE} + t_{FALL} = 4.7µs + 7.1µs result in a maximum frequency of about 84.74kHz.

Electromagnetic Compatibility (EMC) Requirements

Industrial environments are harsh and system designers must meet minimum EMC requirements to ensure IO-Link devices can survive some common transients. We start by designing robust IO-Link ICs which typically meet these levels:

- ESD: ±8kV for air discharge
- ESD: ±4kV for contact discharge (based on the IEC 61000-4-2 standard).

Note: The IEC 61000-4-2 standard covers ESD testing and performance of finished equipment, but does not specifically refer to integrated circuits.

EMC Test Levels

Table 5 shows the various system-level EMC test levels from Table G.2 of the IO-Link Interface and System Specification.

Table 5. IO-Link EMC Test Levels

Phenomena	Test Level	Performance Criterion	Constraints
Electrostatic discharges (ESD) IEC 61000-4-2	Air discharge: ±8kV Contact discharge: ±4kV	B	See G.1.4. a)
Radio-frequency electromagnetic field. Amplitude modulated. IEC 61000-4-3	80MHz to 1000MHz 10V/m 1400MHz to 2000MHz 3V/m 2000MHz to 2700MHz 1V/m	A	See G.1.4. a) and G.1.4, b)
Fast transients (Burst) IEC 61000-4-4	±1kV	A	5kHz only. The number of M-sequencers in Table G.1 shall be increased by a factor of 20 due to the burst/cycle ratio 15ms/300ms. See G.1.4,c)
	±2kV	B	
Surge IEC 61000-4-5	Not required for an SDCI link (SDCI link is limited to 20 m)		—
Radio-frequency common mode IEC 61000-4-6	0.15MHz to 80MHz 10V EMF	A	See G.1.4. b) and G.1.4, d)
Voltage dips and interruptions IEC 61000-4-11	Not required for an SDCI link		—

Physical Layer: EMC Requirements Standardized

Note that the IEC 61000-4-2 standard covers ESD testing and performance of finished equipment, but does not specifically refer to integrated circuits. Typically, our transceivers can withstand around 1.5kV ESD transients on their own (based on the military standard used in the reliability reports) but will generally need external TVS diodes for added protection. However, we have reduced the size and requirements of these external diodes and reduced the BOM to save space and external component cost. Industrial environments are typically harsh requiring additional protection for circuits!

The IO-Link specification requires for equipment to be appropriately protected for robust operation:

- ESD: ±8kV for air discharge
- ESD: ±4kV for contact discharge (based on the IEC 61000-4-2 standard)
- Surge: Not required when the cable length is limited to 20m. Otherwise, protection levels range from ±500V to ±2kV
- Burst: ±1kV or ±2kV

While transceivers are increasingly robust, external protection is necessary for:

- ESD protection for the end product
- Surge and burst protection (TVS diodes)
- Optimized layout

Immunity Testing

Figures 38 and 39 demonstrate EFT, Surge, and ESD testing of the MAX14819 in the MAXREFDES145 8-port master or a device like the MAX22513 in the MAXREFDES171 sensor. The setup in Figure 38 is only for surge testing. Board-level transient immunity standards include:

- IEC 61000-4-2 Electrostatic Discharge (ESD)
- IEC 61000-4-4 Electrical Fast Transient/Burst (EFT)
- IEC 61000-4-5 Surge Immunity

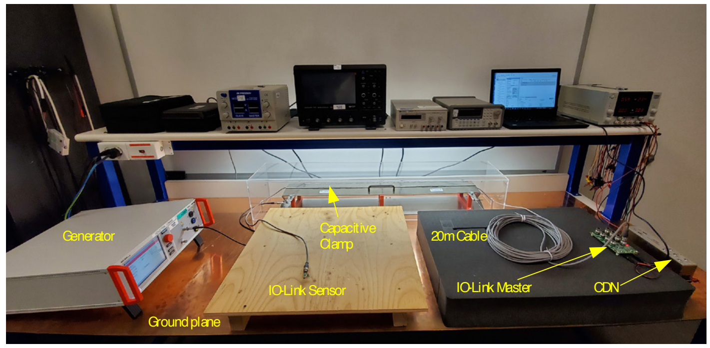


Figure 38. EFT Burst and Surge Testing Bench

Figure 39. ESD Testing of MAX14819

Section 6: IO-Link Solutions

Why Choose Maxim IO-Link Transceivers?

We joined the IO-Link consortium in 2009. We have a proven track record of long-term dedication and commitment to the industrial market and to our customers by having the industry's most complete IO-Link and binary sensor portfolios. These include the **MAX14828**, **MAX14827A**, and **MAX22513** device transceivers and the **MAX14824** and MAX14819 master transceivers. Note that IO-Link transceivers can also be used in binary sensor applications.

We have developed a complete ecosystem to make design-in fast and easy. The evaluation kits for all our transceivers include software (for configuration and reading/writing to the transceiver). Our IO-Link reference designs include both sensors and masters. Our dedicated team of designers, product definers, and applications engineers are readily available to provide customer support.

Our solutions are small and only getting smaller! Our IO-Link transceivers (Figure 40) are currently available in compact TQFN and WLP packages. The latest transceiver, the MAX22513, is offered in a WLP package and reduces the solution footprint by up to 50% compared to competitor parts. As our transceivers increase in robustness, less external protection is required. With higher absolute maximum ratings, external protection components such as external protective diodes, can be smaller. Our transceivers include integrated 3.3V and 5V LDOs that can power external circuitry, reducing the need for external LDOs and keeping the overall solution small. Additionally, the MAX22513 has an integrated DC-DC converter to reduce power dissipation for higher current sensors.

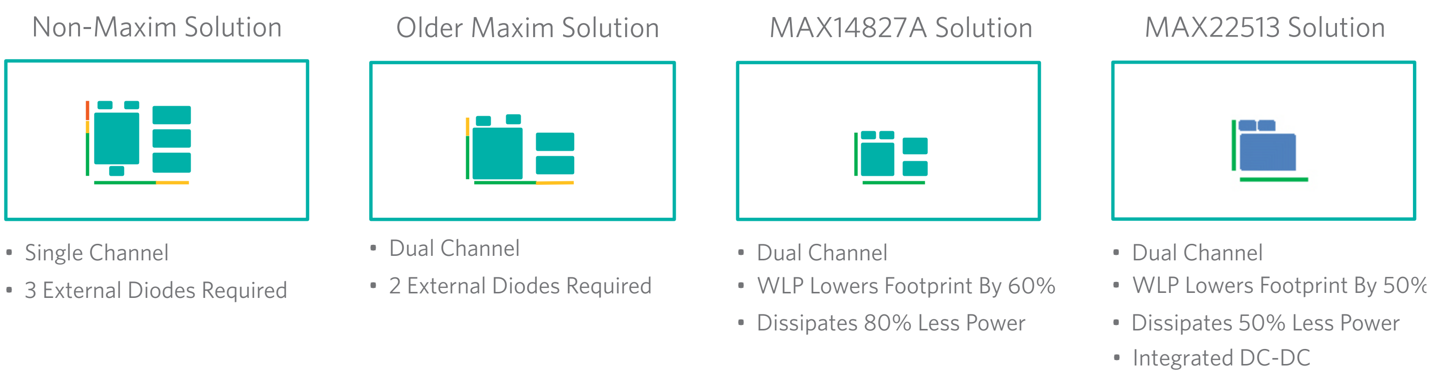


Figure 40. IO-Link Transceiver Solution Comparison

Product Selector Guide

Our long and committed history with IO-Link technology has resulted in the development of multi-generation transceivers on both the master and device side that focus on low power dissipation, small solution size, and robust communications (Table 6). With a full ecosystem of IO-Link device and master reference designs and evaluation kits, we are focused on providing quick evaluation of IO-Link technology.

Table 6. IO-Link Transceivers

Part Number	Interface	Description
IO-Link Master Transceivers		
MAX14819	IO-Link	Low-power dual-channel IO-Link master transceiver + supply controllers + UART/Framer + DI
MAX14824	IO-Link	Single-channel IO-Link transceiver
IO-Link Device Transceivers		
MAX14828	IO-Link	Tiny low-power single-channel IO-Link device transceiver
MAX14827A	IO-Link	Tiny low-power dual IO-Link device transceiver
MAX14829	IO-Link	Pin-driven, low-power dual IO-Link device transceiver
MAX22513	IO-Link	Surge-protected dual-channel IO-Link device transceiver with DC-DC
MAX22515	IO-Link	Pin or I^2C mode, dual-channel IO-Link device transceiver with surge protection
IO-Link Sensor Drivers		
MAX14838	Binary	24V/100mA pin-configurable industrial sensor output driver + protection
MAX14839	Binary	24V/100mA pin-configurable industrial sensor output driver + protection, 5V LDO
MAX14832	Binary	24V/100mA one-time-programmable (OTP) industrial sensor output driver + protection
MAX14836	Binary	24V dual-output sensor transceiver
MAX22520	Binary	24V one-time-programmable (OTP) industrial sensor with analog signal sensing circuitry

100mA Tiny Binary Sensor Drivers: MAX14838/MAX14839

The **MAX14838**/**MAX14839** 24V/100mA drivers are optimized for use in industrial sensors. These devices integrate the high-voltage (24V) circuitry commonly found in industrial sensors, including a configurable PNP/NPN/push-pull driver and an integrated linear regulator that meets common sensor power requirements.

- Pin-Selectable High-Side (PNP), Low-Side (NPN), or Push-Pull Driver
- On-Chip 5V Linear Regulator (MAX14838)/3.3V Linear Regulator (MAX14839) (Figure 41)
- Dual Integrated 2mA LED Drivers
- Integrated Protection Provides Robust Sensor Solutions
  - Reverse-Polarity Protection on DO, V_{CC}, and GND
  - 4.75V to 34V Supply Range (MAX14839)
  - V_{CC} Hot-Plug Protection
  - Thermal Shutdown Protection
  - ±8kV IEC 61000-4-2 Air Gap ESD Protection
  - -40°C to +105°C Temperature Range
  - ±1kV/500Ω Surge Protection

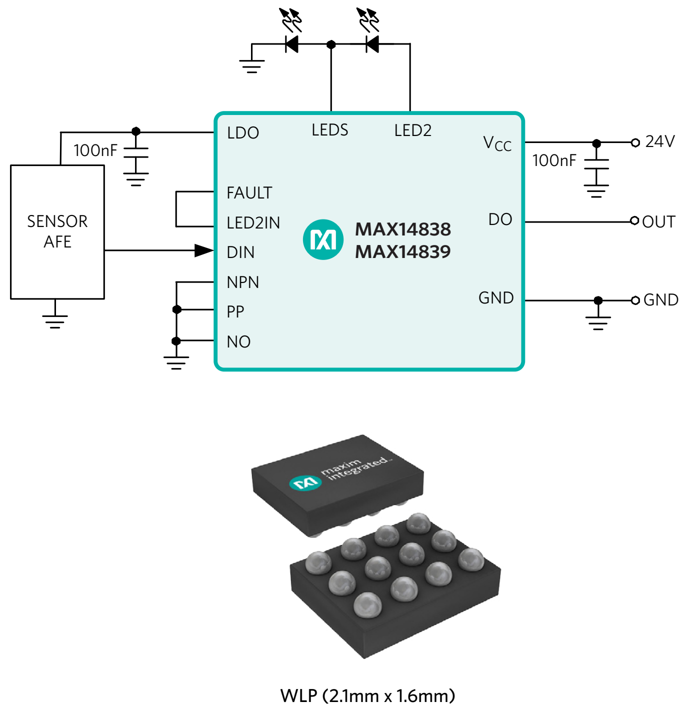


Figure 41. MAX14838/MAX14839 Binary Sensor Driver

OTP Programmable Sensor Interface: MAX22520

The **MAX22520** (Figure 42) industrial sensor output driver is configurable using Maxim's 1-Wire protocol and OTP interface to permanently operate in either normally-open or normally-closed configuration in PNP (high-side), NPN (low-side), or push-pull modes. The maximum load current is One-Time Programmable (OTP) to either 100mA or 200mA.

The device also features an OTP programmable comparator, PWM oscillator, and digital potentiometer. These blocks support calibration of sensors via signal generation and signal conditioning of analog sensing circuitry. An integrated LED driver provides visual feedback of the binary sensor's logic state.

- High Configurability
  - 4.75V/8V (min) to +36V Supply Voltage
  - Programmable Driver Configuration:
    - o PNP/NPN/Push-Pull
  - Programmable Driver Current Limit: 100mA or 200mA
  - Linear Regulator with Programmable Output: 3.3V or 5V
  - Comparator with Programmable Threshold
  - Digital Potentiometer with Programmable 6-Bit Tap
  - Oscillator with Programmable PWM Duty Cycle
- Robust Design
  - Fast Demagnetization of Inductive Loads
  - Reverse Polarity Protection on DO, VCC, GND
  - Short Circuit Protection on DO
  - Overtemperature Protection
  - ±8kV IEC61000-4-2 Air-Gap ESD Protection
  - ±6kV IEC61000-4-2 Contact Discharge ESD Protection
  - ±1kV/500Ω IEC61000-4-5 Surge Protection
  - -40°C to +105°C Operating Temperature Range
- Small Form Factor for Compact Designs
  - Ultra-Small (2mm x 2.5mm) 20-Bump WLP
  - Integrated LED Driver for Visual Feedback

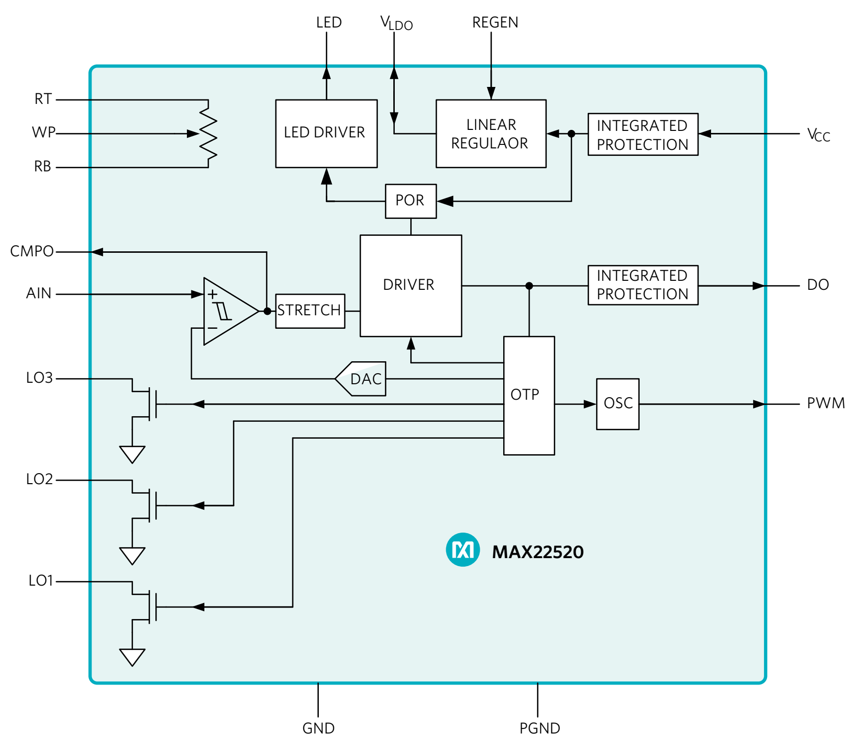


Figure 42. MAX22520 OTP Industrial Sensor Output Driver

Dual 250mA IO-Link Transceiver: MAX14827A

The **MAX14827A** integrates the high-voltage functions commonly found in industrial sensors, including drivers and regulators. The MAX14827A features two ultra-low-power drivers with active reverse-polarity protection (Figure 43). Operation is specified for normal 24V supply voltages up to 60V. Transient protection is simplified due to high-voltage tolerance allowing the use of micro TVS.

The device features a flexible control interface. Pin control logic inputs allow for operation with switching sensors that do not use a microcontroller. For sensors that use a microcontroller, an SPI interface is available with extensive diagnostics. For IO-Link operation, a three-wire UART interface is provided, allowing interfacing to the microcontroller UART. Finally, a multiplexed UART/SPI option allows using one serial microcontroller interface for shared SPI and UART interfaces.

The device includes on-board 3.3V and 5V linear regulators for low-noise analog/logic supply rails. The MAX14827A is available in a 24-pin TQFN package and a 25-pin WLP and is specified over the extended -40°C to +125°C temperature range.

- Lowest Power and Smallest IO-Link Transceiver
  - WLP Package (2.5mm x 2.5mm)
  - TQFN Package (4mm x 4mm)
- Low 2.3Ω (typ) R_{ON} Reduces Power Consumption
- Robust Protection: 65V Absolute Maximum for Smaller External Protection and Reverse-Polarity/Short-Circuit Protection
- A single-channel version, the MAX14828 is also available and this device has an even lower R_{ON} of 1.2Ω.

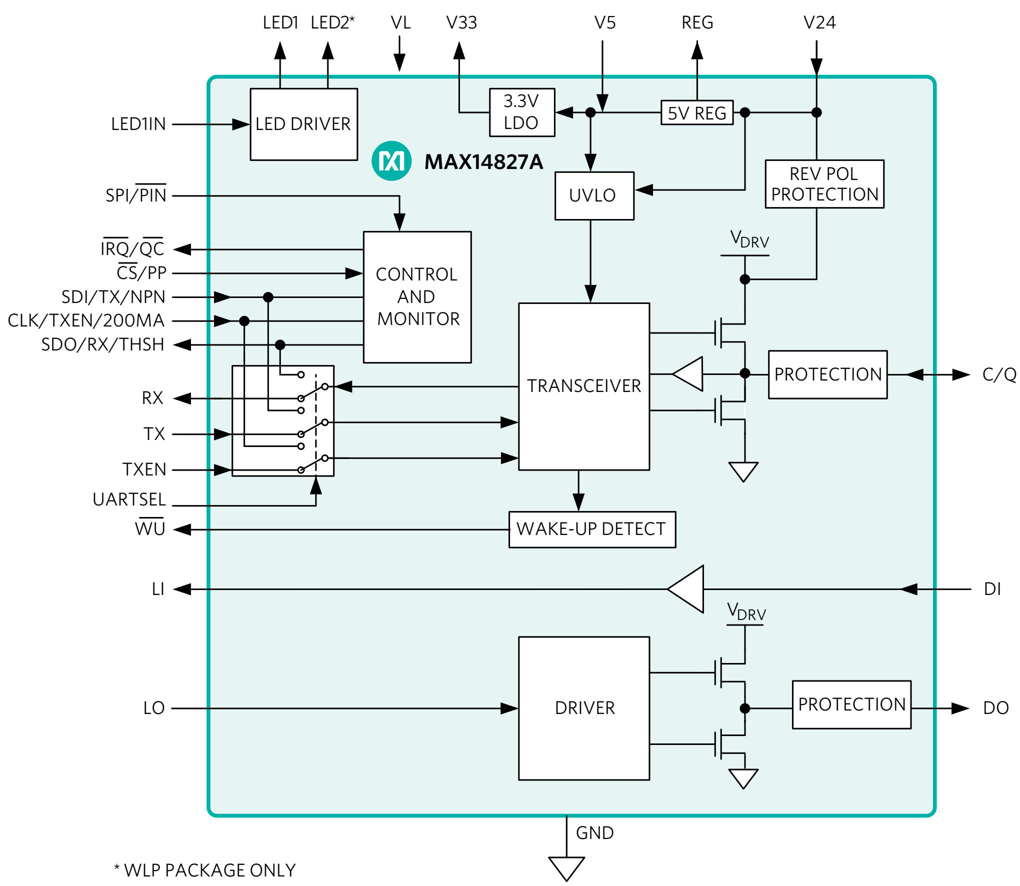


Figure 43. MAX14827A Dual-Channel IO-Link Transceiver

Pin-Control, Low-Power, Dual-Channel IO-Link Device Transceiver: MAX14829

The **MAX14829** dual-channel low-power IO-Link device (Figure 44) features a pin-based interface for control, configuration, and monitoring. Pin-control logic inputs allow for operation with switching sensors that do not use a microcontroller. For IO-Link operation, a three-wire UART interface is provided, allowing interfacing to the UART. The MAX14829 has selectable driver current from 100mA to 330mA.

- Low Power Dissipation Reduces the Thermal Footprint for Small Sensors
- 2.3Ω/2.7Ω (typ) Driver On-Resistance
- 70mW (typ) Power Dissipation at 100mA When Both C/Q and DO Drivers Are Driving
- High Configurability and Integration Reduce SKUs
- Auxiliary 24V Digital Output (DO) and Input (DI)
- Selectable Driver Integrated Protection Enables Robust Communication
- 65V Absolute Maximum Ratings on Interface and Supply Pins Allows for Flexible TVS Protection
- Reverse Polarity Protection of All Sensor Interface Inputs/ Outputs

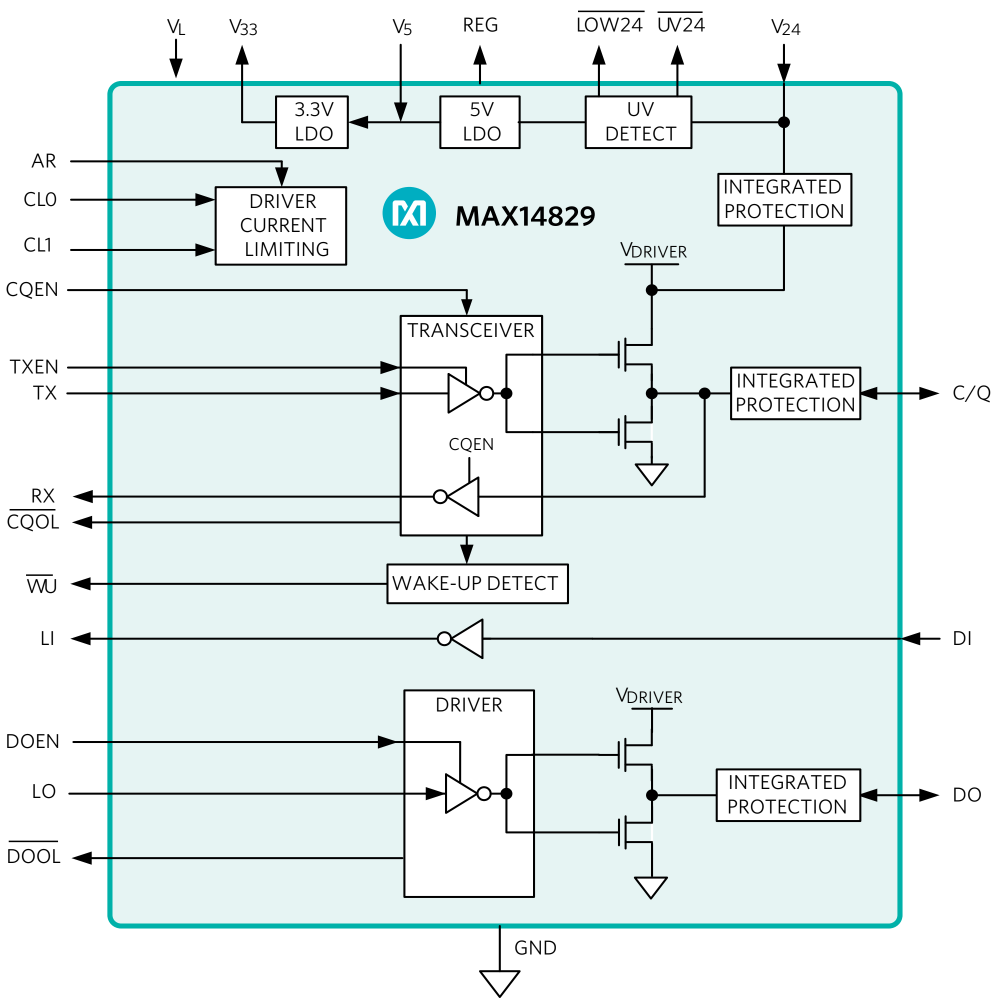


Figure 44. MAX14829 Pin-Control, Dual-Channel IO-Link Transceiver

Surge-Protected Dual-Channel IO-Link Device Transceiver with DC-DC: MAX22513

The **MAX22513** dual-channel low-power IO-Link device transceiver (Figure 45) features a selectable control interface, internal high-efficiency DC-DC buck regulator, two internal linear regulators, and integrated surge protection for robust communication. The device features low on-resistance drivers (C/Q and DO/DI), selectable driver current limits, and overcurrent protection to reduce power dissipation in small sensor applications.

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-protected, short-circuit-protected, and feature an integrated ±1kV/500Ω surge protection.

Surge Testing

The MAXREFDES171 (with the MAX22513) module was tested to withstand up to ±1kV 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 7. 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.
- C/Q to GND: Communicating with the master, the module continued to execute code and transfer data, and the MAX22513 registers were not corrupted.
- L+ to C/Q: Communicating with the master, the module continued to execute code and transfer data, and the MAX22513 registers were not corrupted.

Table 7. Surge Testing Results

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

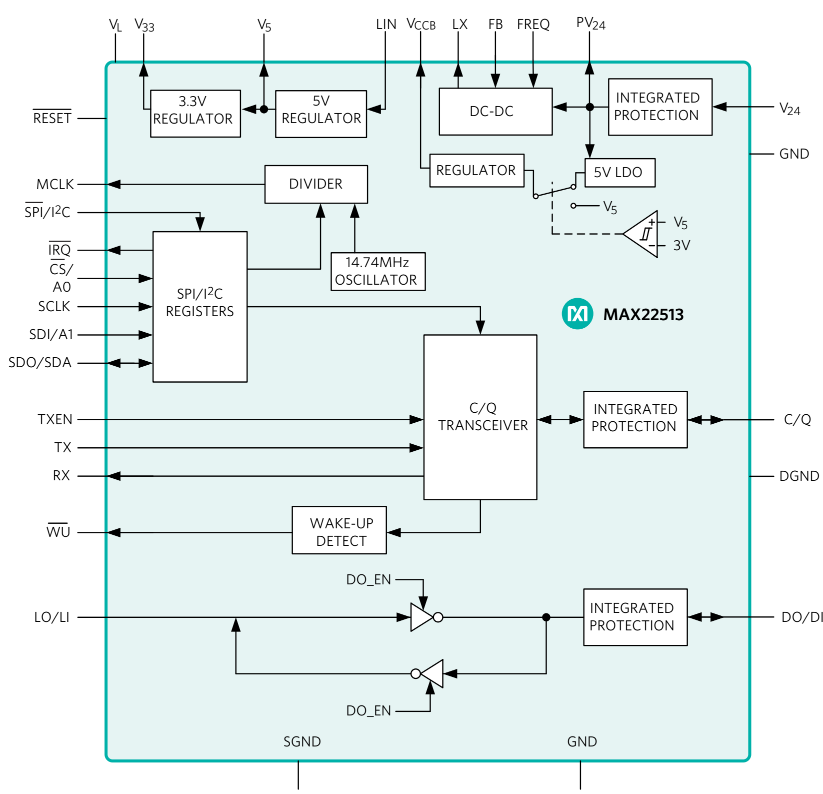


Figure 45. MAX22513 Dual-Channel IO-Link Transceiver with DC-DC Converter

IO-Link Transceiver with Integrated Protection: MAX22515

The **MAX22515** low-power industrial transceiver (Figure 46) operates as either an IO-Link device or a non-IO-Link sensor transceiver in industrial applications. The MAX22515 features a selectable control interface (pin-mode or I²C), two integrated linear regulators, and integrated surge protection for robust communication. The transceiver includes one C/Q input-output channel and one digital input (DI) channel.

The device features a flexible control interface. Pin-control logic inputs allow for operation with switching sensors that do not use a microcontroller. For sensors that use a microcontroller, an I²C interface is available to provide extensive configuration and diagnostics. Additionally, an integrated oscillator simplifies the clock generation for IO-Link devices.

The MAX22515 features extensive integrated protection to ensure robust communication in harsh industrial environments. All IO-Link line interface pins (V24, C/Q, DI, and GND) are reverse-voltage-protected, short-circuit-protected, hot-plug-protected, and feature integrated ±1.2kV/500Ω surge protection.

The MAX22515 is available in a tiny WLP package (2.5mm x 2.0mm) or a 24-pin TQFN-EP package (4mm x 4mm) and operates over the -40°C to +125°C temperature range.

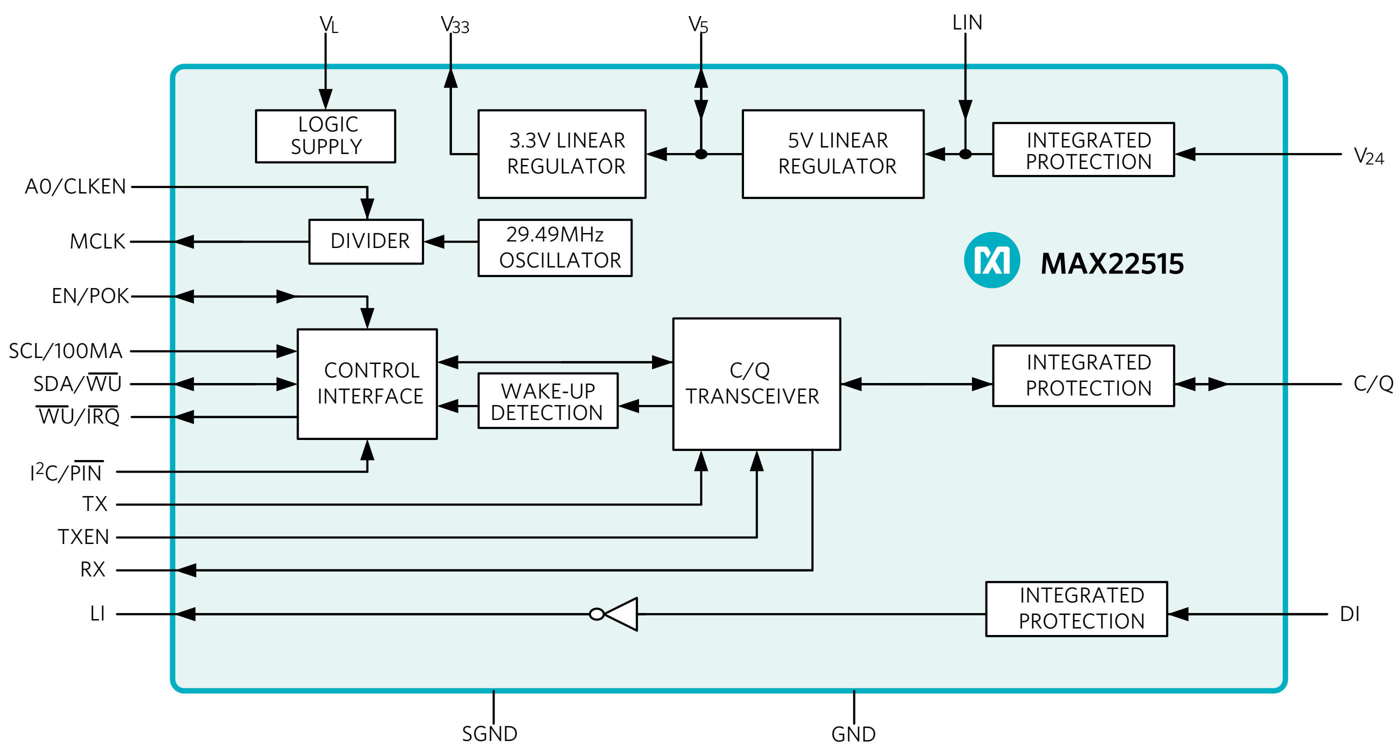


Figure 46. MAX22515 Block Diagram

Dual-Channel IO-Link Master Transceiver: MAX14819

The **MAX14819** low-power, dual-channel, IO-Link master transceiver with sensor/actuator power-supply controllers (Figure 47) is fully compliant with the latest IO-Link and binary input standards and test specifications, IEC 61131-2, IEC 61131-9 SDCI, and IO-Link 1.1.3. This master transceiver also includes two auxiliary Type 1/Type 3 digital input (DI) channels. The MAX14819 is configurable to operate either with external UARTs or using the integrated framers on the IC. To ease selection of a microcontroller, the master transceiver features frame handlers with UARTs and FIFOs. These are designed to simplify time-critical control of all IO-Link M-sequence frame types. The MAX14819 also features autonomous cycle timers, reducing the need for accurate controller timing. Integrated communication sequencers also simplify wake-up management.

The MAX14819 integrates two low-power sensor supply controllers with advanced current limiting, reverse-current blocking on L+, and reverse-polarity protection capability to enable low-power robust solutions.

The MAX14819 is available in a 48-pin (7mm x 7mm) TQFN package and is specified over the extended -40°C to +125°C temperature range.

- Low-Power Architecture
  - 1Ω (typ) Driver On-Resistance
  - 1.9mA (typ) Total Supply Current for 2 Channels
- Integrated Protection Enables Robust Systems

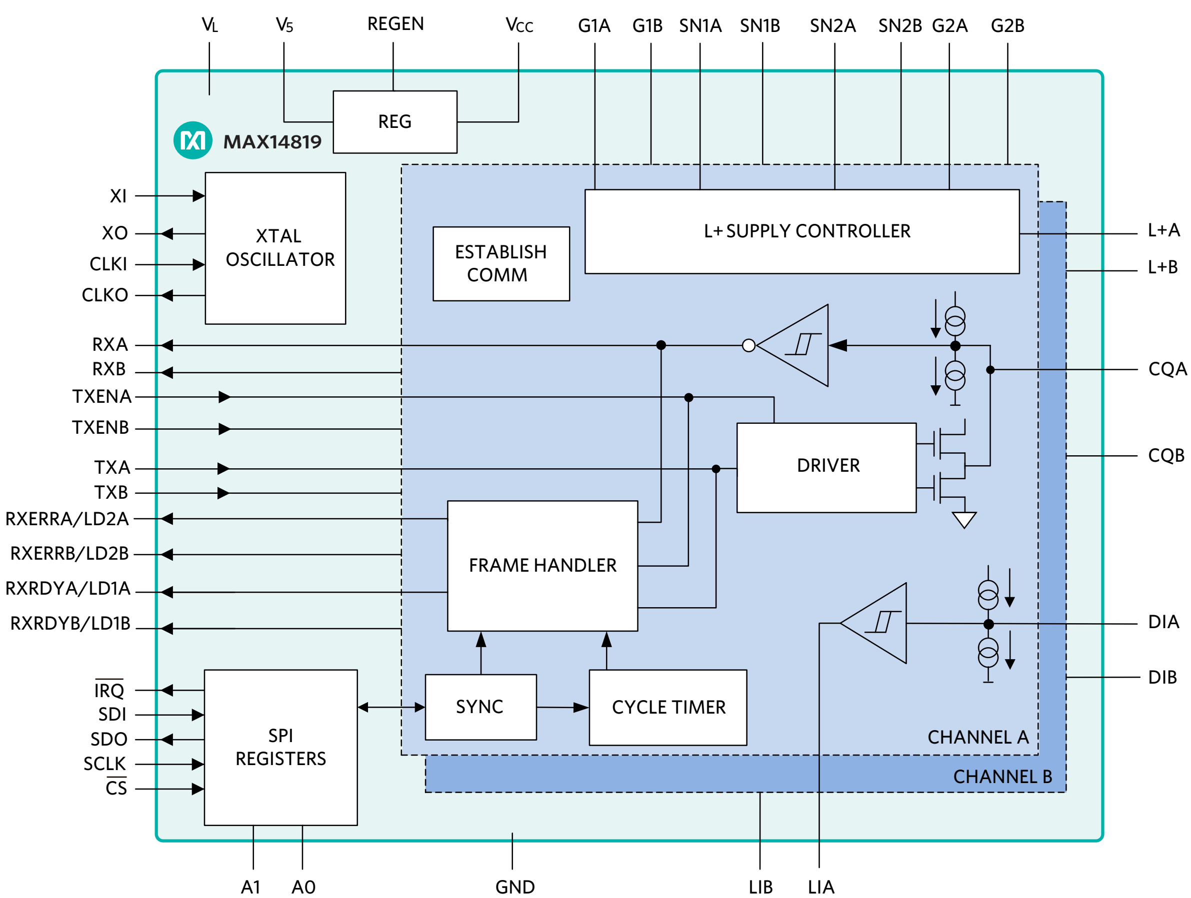


Figure 47. MAX14819 Dual IO-Link Master Transceiver

Evaluating an IO-Link Device

The **MAX22513 evaluation kit** (EV kit) consists of a MAX22513 evaluation board that is a fully assembled and tested circuit board that evaluates the MAX22513 IO-Link device transceiver. The MAX22513 EV kit (Figure 48) is designed to operate as a stand-alone board or with an Arduino®-compatible board (not supplied) for easy software evaluation. The EV kit provides the user with an IO-Link-compliant device transceiver with a proven PCB layout. The EV kit is fully assembled and tested with a free GUI to make it easy to use for product evaluation and testing. **The EV kit does NOT include an IO-Link device stack**.

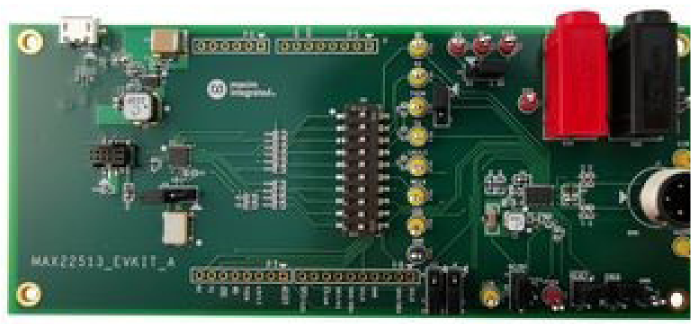


Figure 48. MAX22513 Evaluation Kit

Evaluating an IO-Link Master

The **MAX14819 evaluation kit** (EV kit) consists of the evaluation board and software. The EV kit (Figure 49) is a fully assembled and tested circuit board that evaluates the MAX14819 IO-Link dual-channel master transceiver. The MAX14819 EV kit includes Windows-compatible software that provides a GUI for exercising the features of the device. The EV kit is connected to a PC through a USB A-to-micro B cable. **The EV kit does NOT include an IO-Link master stack**.

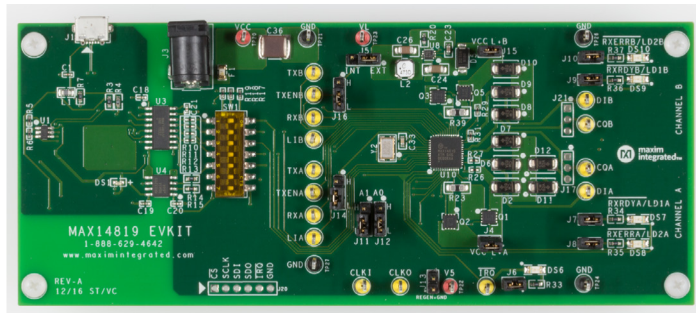


Figure 49. MAX14819 Evaluation Kit

Industrial IO-Link Reference Designs

To help our customers reduce their product development time, we have developed (in collaboration with IO-Link stack software vendors) a range of **IO-Link reference designs** (Table 8). Each reference design includes high-performance products in tested circuits .

All reference designs are provided with an IO-Link stack for use while evaluating this design.

Maxim Reference Design Use Restrictions and Warnings

Our reference designs have been verified and tested to meet IO-Link specifications while operating in harsh industrial environments, as required by IEC 61000-4-x standards for transient immunity.

Our reference design boards and associated software are designed to evaluate the performance of our IO-Link ICs but are not intended to be deployed as-is into an end-product in a factory automation system, nor should they be used in functional safety and/or safety critical systems.

All reference designs are provided with an IO-Link stack for use while evaluating this design.

Table 8. IO-Link Reference Designs

Reference Design	Maxim IO-Link Transceiver	Maxim Sensor/IO ICs	Description
IO-Link Sensor			
MAXREFDES23	MAX14821	MAX44008	IO-Link Optical Light Sensor (TMG)
MAXREFDES27	MAX14821	MAX44000	IO-Link Optical Proximity Sensor (TMG)
MAXREFDES36	MAX14821	MAX31913	IO-Link 16-Channel Digital Input Hub (TMG)
MAXREFDES37	MAX14821	MAX14821	IO-Link Quad Servo Driver (TMG)
MAXREFDES42	MAX14821	MAX31865	IO-Link RTD Temp Sensor (IQ^2)
MAXREFDES163	MAX14839	MAX14839	Binary Industrial Magnetic Sensor
MAXREFDES164	MAX14828	MAX31875	IO-Link Local Temp Sensor (TMG and TEConcept)
MAXREFDES171	MAX22513	MAX22513	IO-Link Distance Sensor (TMG)
MAXREFDES173	MAX14827A	MAX31875	IO-Link Local Temp Sensor (IQ^2)
MAXREFDES174	MAX22513	MAX22513	IO-Link Distance Sensor (IQ^2)
MAXREFDES176	MAX22515	MAX22190, MAX22192	IO-Link Digital Input Hub (TMG)
IO-Link Master			
MAXREFDES79	MAX14824	MAX14824	4-Port IO-Link Master (TEConcept)
MAXREFDES145	MAX14819	MAX14819	8-Port IO-Link Master (TEConcept)
MAXREFDES165	MAX14819	MAX14819	4-Port IO-Link Master (TMG)
MAXREFDES212	MAX14819	MAX14819	Go-IO with 4-Port IO-Link Master (TMG)

Digital Input Hub: MAXREFDES176

The **MAXREFDES176** (Figure 50) consists of a **MAX22515** IO-Link transceiver with integrated protection, and demonstrates an isolated digital input hub using the **MAX22192** isolated octal digital input device which is daisy-chained with the **MAX22190** octal digital input device to provide a total of 16 input channels. The stack is available from TMG or TEConcept.

By default, Type 1 and Type 3 sensors are supported but Type 2 sensors and can also be supported by modifying a resistor value which controls the value of the current source within the devices. The MAXREFDES176 uses an industry-standard M12 connector, allowing a 4-wire cable to be used. Digital inputs use industry-standard PCB terminal blocks.

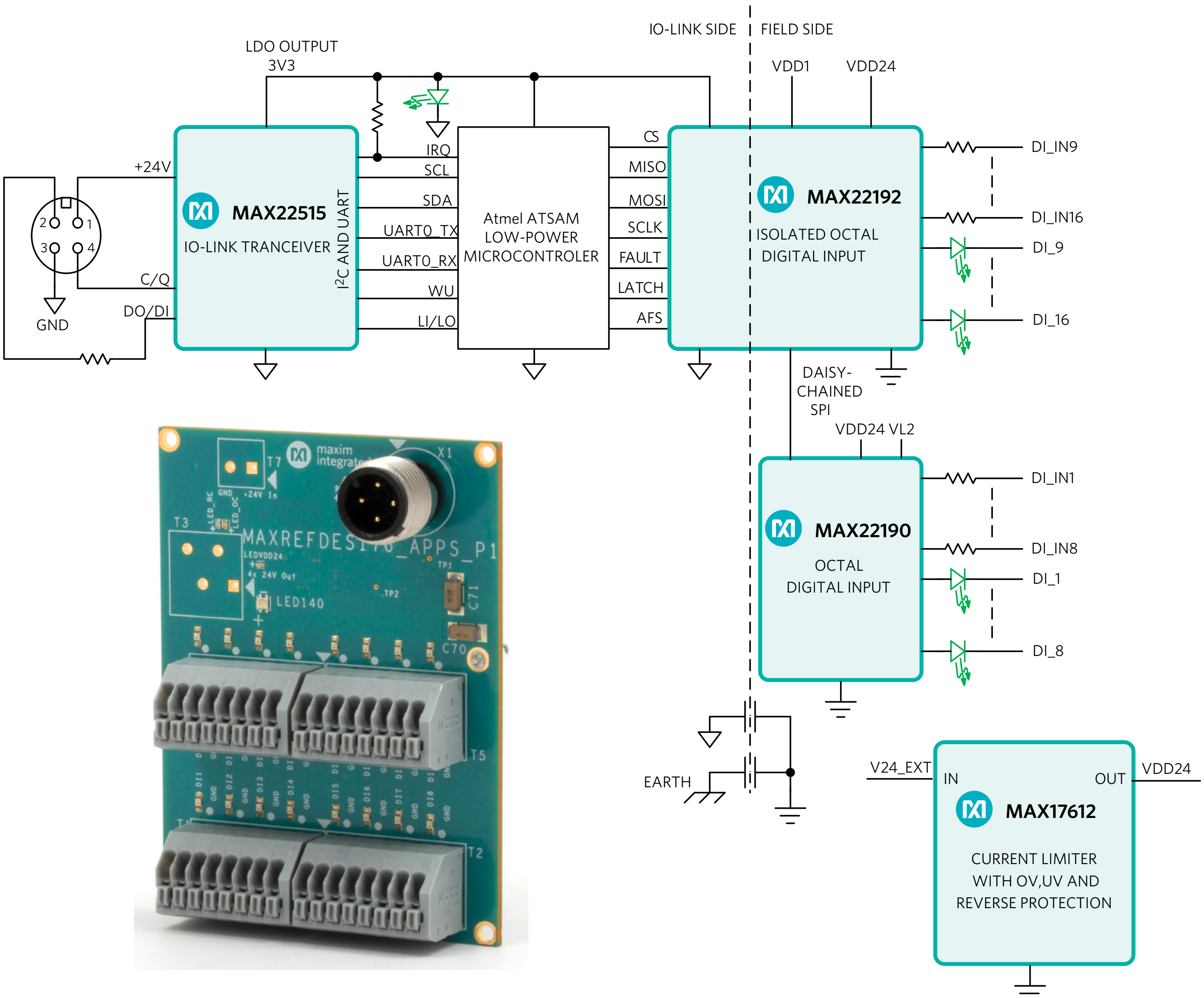


Figure 50. MAXREFDES176 Digital Input Concentrator

Appendix of Technical Resources

Software Stack Vendors

Typically, IO-Link master and sensor manufacturers require a third party to generate the software stack. We have collaborated with key software vendors to support our IO-Link transceivers for sensor and master designs. Please contact our software partners directly for specific details of their products.

TEConcept GmbH Wentzingerstraße 21 79106 Freiburg Germany Phone: +49 761 214436 40 Email: otto.witte@teconcept.de Web: **www.teconcept.de**	TEConcept
Technologie Management Gruppe Technologie und Engineering GmbH Zur Gießerei 10 76227 Karlsruhe Germany Phone: +49 721 8280 60 Email: willems@tmgte.de Web: **www.tmgte.com**	Technologie Management Gruppe Technologie und Engineering
IQ² Development GmbH & Co. KG Carl-Benz-Straße 3 72585 Riederich Germany Phone: +49 7127 5706100 Fax: +49 7127 5706102 E-Mail: info@iq2-development.de Web: **www.iq2-development.de**	IQ² Development IO-Link Intelligent Components

TMG Technologie und Engineering

Note: The following information is provided by TMG Technologie und Engineering as an example of the types of products and services each software vendor provides. Please contact the software partner for further details..

TMG Technologie und Engineering - Portfolio

PROFINET — Accredited by PROFIBUS & PROFINET International

IO-Link — Accredited by IO-Link Community Competence & Test Center

PROFIBUS — Accredited by PROFIBUS & PROFINET International

EtherCAT Technology Group

EtherNet/IP Member of ODVA

Consulting

- Trainings & Workshops
- System and architecture analyses
- Choice of Technology & Components
- Platform & System Concepts

Services

- Development
- Expertise
- Interoperability Tests
- Certification support
- Operate demo systems

Products

- Communication Stacks
- Engineering Tools
- Test Systems
- Communication Modules
  - IO-Link Device Module
  - IO-Link Master Modules

Technologie Management Gruppe Technologie und Engineering

IO-Link Device Technology from TMG

IO-Link

- **IO-Link V1.1 Device Stack**
  - complete layer 7 functionality, all telegram types
  - supports also IO-Link V1.0 compatibility
  - easy to port to all microcontrollers (8/16/32)
  - works with all IO-Link transceivers
  - small footprint
- **IO-Link V1.1.2 Stack Extensions**
  - Implements the IO-Link related device application with
    - Parameter Manager, Data storage, Block Parameterization,
    - Device Access Locks, Event Dispatcher,
    - Device Status and Detailed Device Status
    - Parameter Consistency Check, Reset to factory settings
  - Production settings (like serial number, calibration and pre parameterization of variants
  - Best practice implementation proved in many customer projects
- **IO-Link Device – Firmware Update**
  - Firmware update via IO-Link Bootloader
  - IODD based Firmware Packager including encryption
  - Supported from IO-Link Device Tool V5.1

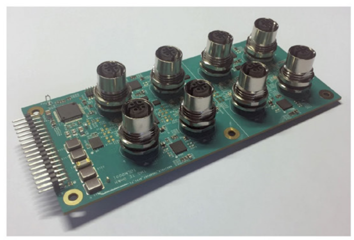
Technologie Management Gruppe Technologie und Engineering

TMG Technologie und Engineering

IO-Link Master Technology from TMG (1)

IO-Link

- **IO-Link V1.1 Master Stack**
  - supports all telegram types (230kBit/s, 400µs cycle time)
  - easy to port to many microcontrollers
  - Includes parameter server (data storage)
  - Already implemented to V850, Rx, 78K0R, 80C164, PIC32, STM32, R32, ARM9, CORTEX M3/M4/A7 and others
  - Support of all master Phys
  - Number of ports depends only on µC resources



- **IO-Link V1.1 Module and Module In Design Solution**
  - STM32F4 Cortex M4
  - Maxim Transceiver MAX14819
  - HW-Module 4 or 8 ports
  - In-Design-Solution: 2, 4 or 8 Ports
    - Schematics & Firmware
  - SPI communication to host controller
  - Firmware update via SPI
  - Host library, portable, ANSI-C
  - Pre certified with TMG test report

3

IO-Link Master Technology from TMG (2)

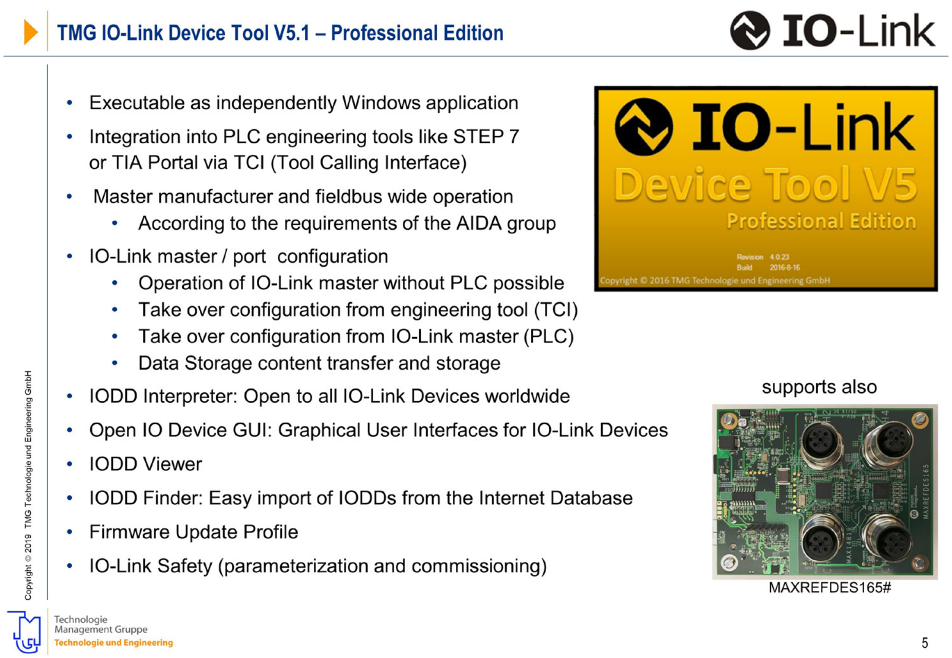
IO-Link

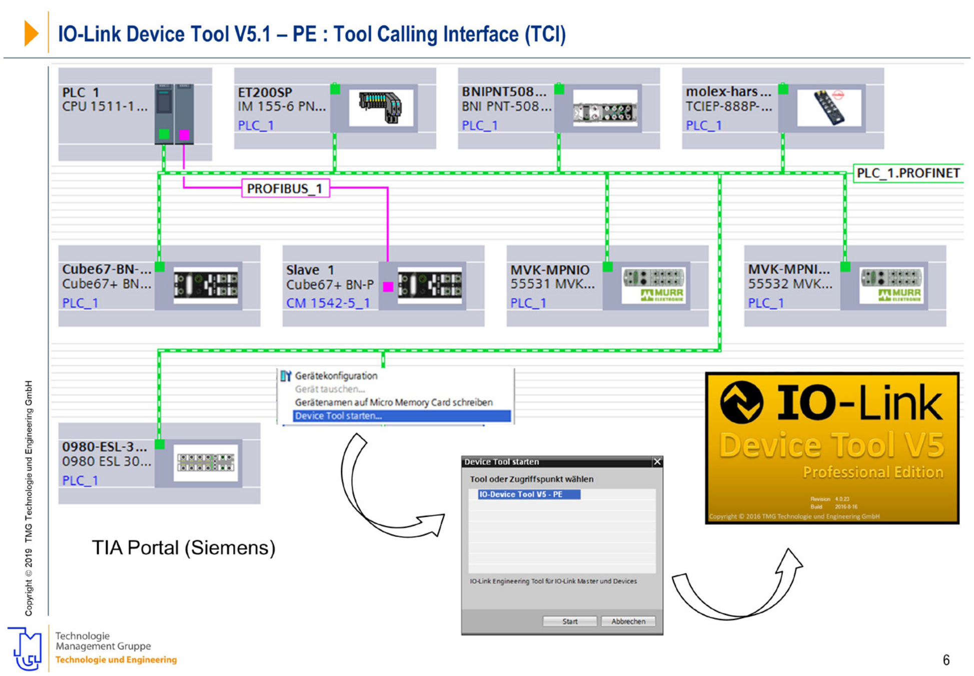
- **Smart Interface Protocol : SMI-TCP**
  - Fieldbus independent protocol for
    - IO-Link Device Tool V5.1 – Professional Edition
    - IO-Link Master Test
    - Industrie 4.0 and IOT applications, 2nd Channel
  - Properties
    - based on TCP/IP
    - Standard Master Interface (SMI, IO-Link Spec V1.1.3)
    - Multiple connections
    - Support of modular systems
    - Support of sub networks

- **Fieldbus Integration**
  - Based on Standard Master Interface (SMI)
  - PROFINET (Integration specification ED 2)
  - EthetNet/IP
  - EtherCAT
  - Modbus TCP
  - PROFIBUS
  - and others …

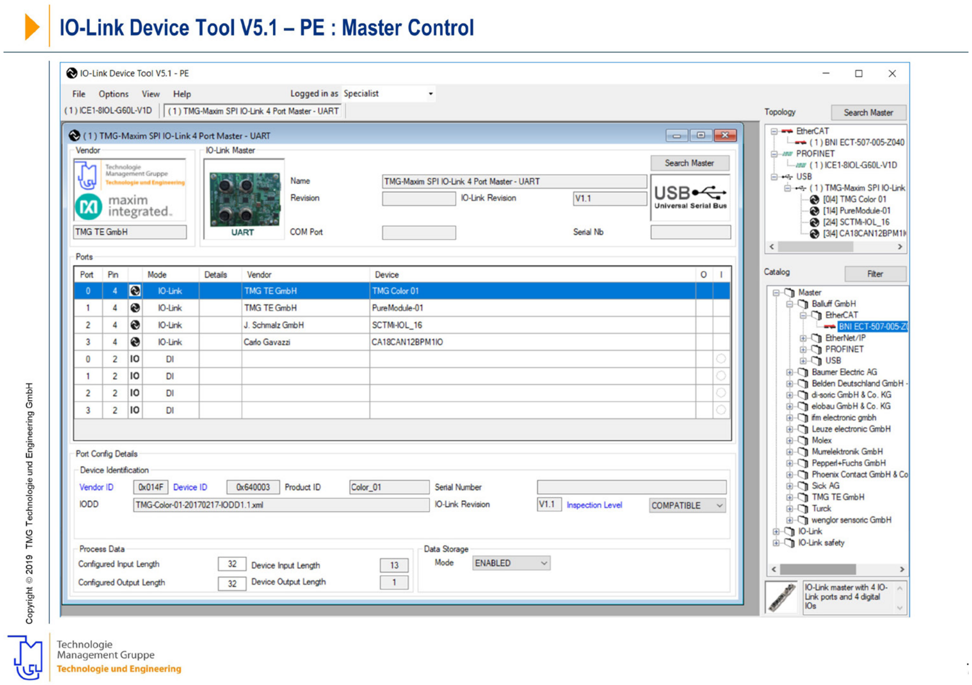
4

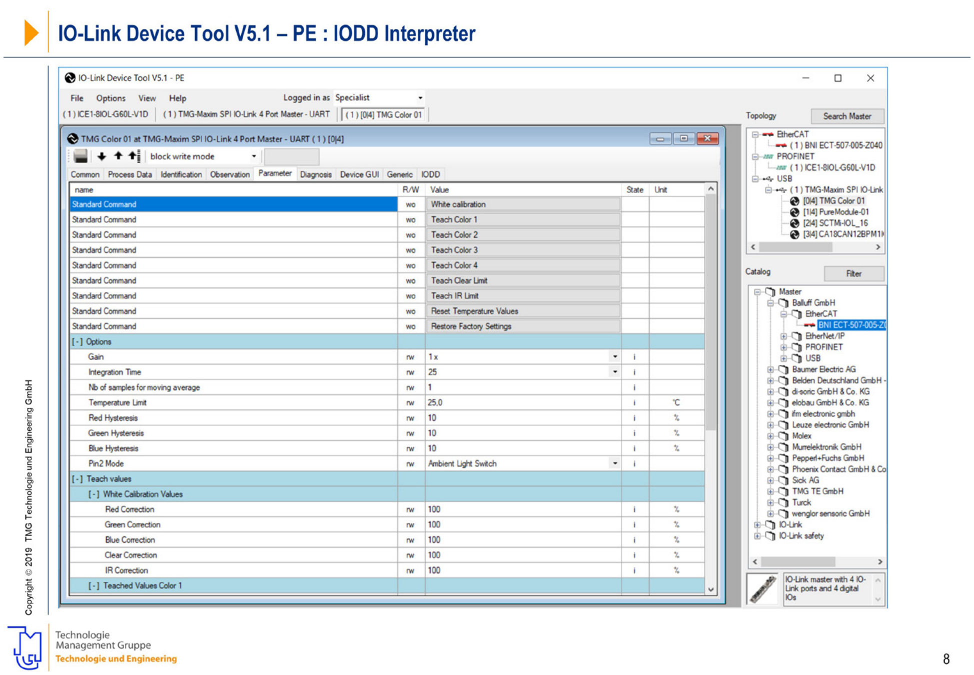
TMG Technologie und Engineering





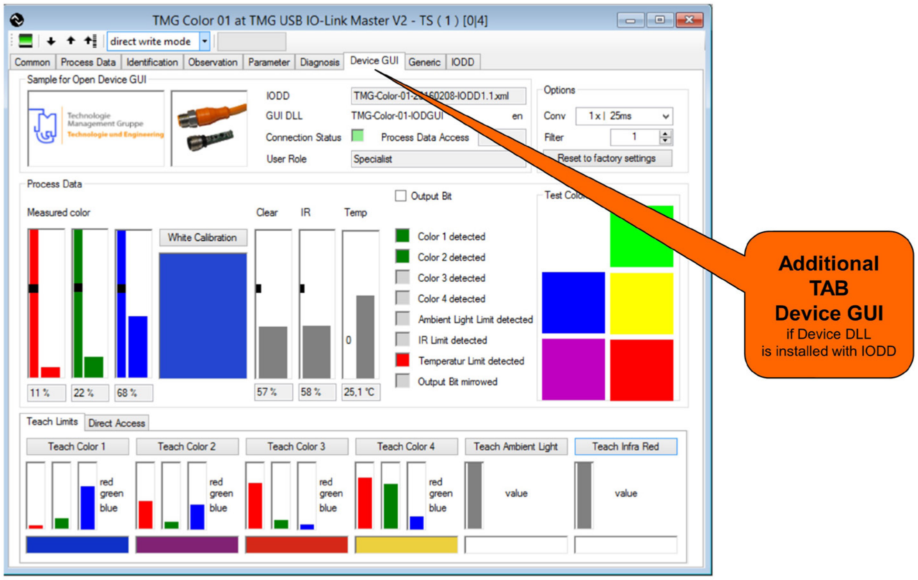
TMG Technologie und Engineering





TMG Technologie und Engineering

IO-Link Device Tool V5.1 – PE – Open IO Device Graphical User Interface



Technologie Management Gruppe Technologie und Engineering

TMG IO-Link Device Tool V5.1 with TMG USB – IO-Link Master V2

- **Standard Edition (Service and Sales)**
  - Parameterization, observation and diagnosis of IO-Link devices
  - Free updates from Internet File Server
- **IO-Link Device Test System**
  - Functionality of Standard Edition +
    - Execution of certification test for IO-Link V1.1 and V1.0 devices
    - Test configuration from IODD
    - Performs all test cases for protocol test
    - Performs also timing tests
    - Creates test report for manufacturer declaration
  - Free updates from Internet File Server
- **USB IO-Link Master V2 – EMC**
  - EMC Test Master to perform IO-Link EMC Test
    - Check robustness of IO-Link communication
  - Easy to use

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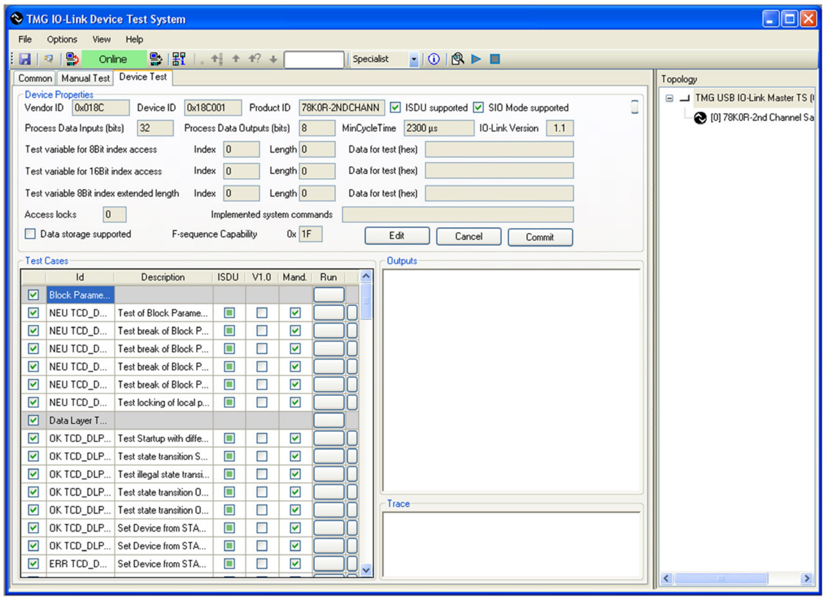
10

TMG Technologie und Engineering

IO-Link Device Tool V3 – Test System



Technologie
Management Gruppe
Technologie und Engineering

TEConcept Tools

Note: The following information is provided by TEConcept as an example of the types of products and services each software vendor provides. Please contact the software partner for further details.

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IO-Link Test Centre

- For IO-Link Masters and Devices (wired)
  - Execution of protocol tests
  - Physical layer tests
  - EMC tests (in cooperation with ELMAC – EMC Lab.)
- Test reports suitable as attachment for **Manufacture Declaration** of conformance (also for non-IO-Link members)
- IO-Link related issue fixing support

IO-Link Competence Centre

- Support on IO-Link related subjects
- IO-Link related consulting
- IO-Link workshops (Software and Hardware design)
- IO-Link Development Support, Compatibility checking
- Software stacks for IO-Link Masters and Devices
- Supporting IO-Link Profiles
- Industrial interfaces (integration to ProfiNet, EtherCat, etc.)
- IO-Link Master Modules and Development Kits
- Complete IO-Link Product development, Hardware prototypes, software development support

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IO-Link Master Stack

- Complies to the V1.1.2 IO-Link communication specification and ready for the V1.1.3 update.
- Multi-port support. The number of ports only limited by hardware resources.
- HW/SW Abstraction layers for easy porting.
- Fastest supported cycle times:
  - 0.4 ms @ 230.4 kBaud (COM3)
  - 2.3 ms @ 38.4 kBaud (COM2)
  - 18 ms @ 4.8 kBaud (COM1)
- System requirement: min 20MHz/port (for COM3).
- Software interface via shared parameters or by the Standardized Master Interface (SMI)
- Control and test API

Supported IO-Link ASICs:

- Maxim MAX14824, MAX14819
- (All common IO-Link PHYs with and without frame handler are supported)

Supported processors:

- STMicroelectronics STM32 series (Cortex M0, M3, M4, M7)
- Atmel ATSAM3S (Cortex M3)
- NXP LPC series (Cortex M0, M3, M4)
- NXP (Freescale) KL series (Cortex M0+)
- Texas Instruments Sitara AM4x (Cortex A9)
- Renesas RX23X, SH-2A (SuperH)
- Cypress S6E2H (Cortex M4F)

TEConcept Tools

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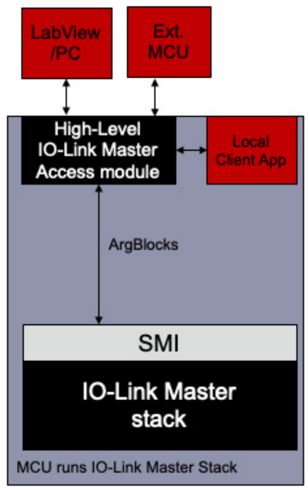
High-Level IO-Link Master Access module

- Provides easy-to-use access to IO-Link Master Stack
- Compatible with the latest V1.1.3 IO-Link specification
- Uses the Standardized Master Interface (SMI) of the IO-Link Master stack
- Communicates with the IO-Link Master through ArgBlocks
- Real-time Process Data exchange between the user application and the IO-Link Master
- Can be used directly on the IO-Link Master chip or on separate platform with a help of an ArgBlock transport mechanism
- Easy-to-use API, written in ANSI C with focus on efficiency
- Small footprint:
  - 30-50 kB of RAM usage

Supported platforms / processors:

- Completely platform-independent
- Supports any kind of C compilers
- Runs on any kind of microcontrollers
- Runs on desktop PCs with Windows and Linux operating systems



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Integration and mapping for IO-Link (Masters)

with JSON/REST API: {JSON}

- Compliant with the JSON integration for IO-Link standard specification.
- Diagnostics and parameterization over Web and cloud systems
- Provides a device data model, objects mapping for IO-Link system to IT
- Easy integration to any JSON clients (PDCT or HMI),
- IODD management and upload
- MQTT support
- Small memory footprint, ideal for embedded systems

Requirements:

- Requires V1.1.3 IO-Link Master stack (uses SMI), Ethernet connection, TCP/IP and HTTP server

With OPC UA: OPC UA

- Compliant with the OPC UA for IO-Link companion specification
- Generic model implementation
- Generic ISDU read/write, subscription to Device parameters and events.
- IO-Link Master stack on the same MCU possible
- Includes OPC UA embedded stack (ANSI C),
- Small footprint (~15kByte RAM per IO-Link port)
- TCP-Binary server access

Requirements:

- Requires V1.1.3 IO-Link Master stack (uses SMI), Ethernet connection, TCP/IP and BSD Sockets

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IO-Link Device Stack

- Compliant to IO-Link interface specification V1.1.2 and V1.1.3 supporting all described features
- Process data handling synchronous or asynchronous to IO-Link cycle
- System load ~50 % on 8-Bit processor @ 16 MHz
- Porting to different µCs and IO-Link PHYs requires only an exchange of drivers. HW/SW Abstraction layers for easy porting.
- Required µC peripherals: UART, GPIO, 16-bit timer
- Parameter Manager for easy access to custom ISDUs
- Interface to non-volatile storage of Parameters
- Sample application supporting common profile

Supported IO-Link ASICs:

- MAXIM IO-Link PHYs (MAX 14821/14827A/14828/22513)
- (All common IO-Link PHYs with and without frame-handler are supported)

Supported processors:

- Maxim MAX32660
- STM32 (Cortex M0, Cortex M3, Cortex M4)
- STMicroelectronics STM8L/STM8S
- Renesas RL78
- Silicon Labs C8051F31x
- NXP LPC11xx (Cortex M0)
- Atmel ATSAM3S (Cortex M3)
- Atmel ATmega32/64/128
- MSP430
- Kinetis KL-series
- **Portable to almost any platform…**

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IO-Link Device Stack: Firmware Update Profile

- Complies to IOL-Profile-Firmware-Update V1.1 specification
- Can be added to an existing IO-Link Device
- Bootloader with integrated firmware decryption function, encryption is done on a PC with the „IOLFW" file creator.
- Reference implementation for STM32 microcontroller, portable to other platforms
- Complete toolchain for firmware update:
    - IOLFW Package Creator including encryption
    - IO-Link Control-Tool supports firmware update and BLOB transfer
    - Bootloader firmware
    - Extended IO-Link Device stack with new System Commands

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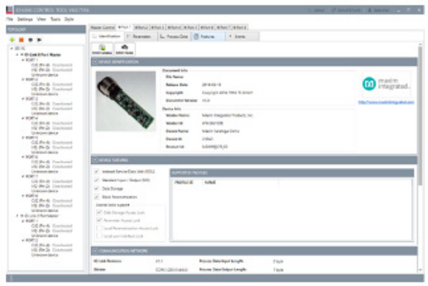
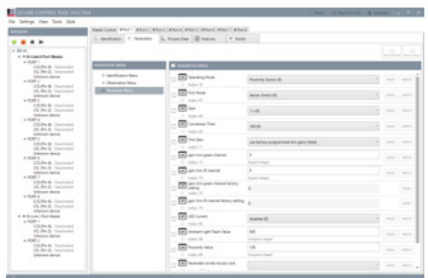
IO-Link Control Tool (4.0)

- Rich and Customizable UI (available for OEM/brand labeling)
- Multiple IO-Link Master Control (In Parallel)
- Easily Extendable (Plugins)
- Local IODD Catalog Handler, IODD Interpreter
- Remote IODD file download function, by the IODD Finder Integration
- IO-Link Port Configuration and Parametrization
- Supports any IO-Link Master which supports JSON integration
- Profile Support:
  - Device Firmware Download Support
  - BLOB Transfer Support
- Data Storage Content Exchange Support
- IO-Link Safety Support
- Role based Authorization





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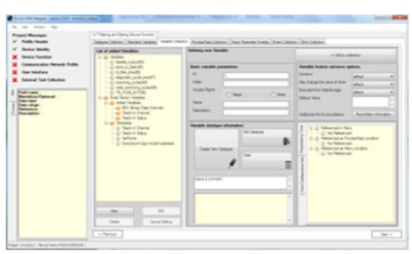
IODD Designer

- Simplifies generation and development of IO-Link Device Descriptor (IODD) files.
- Runs on any Windows 7/8/10 PC.
- Simple „wizard-like", step-by-step IODD generation
- Integarion with the offical IODD Checker is possible to verify and stamp the generated IODD.

Advantages:

- Supports V1.0 and V1.1 compliant IODD files and IO-Link Profiles
- No XML-Knowhow required
- Integrates the IODD Checkers
- Exiting IODDs can be imported
- Working state can be saved and restored



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IO-Link Diagnosis Tool

- Timing accurate IO-Link signal analysis
- Timing precise software UART decoding
- Optional hardware signal direction detection
- Byte-, frame-, protocol- or IODD-based decoding of IO-Link signal
- Sophisticated filtering and search features
- Configuration image based on transferred
- Recording to PC / SD-card
- Analog time signal view for UL+, IL+, UCQ, ICQ
- Eye diagram view separated for Device/Master
- Interactive rulers for analogue measurements
- Calibration of measured voltages and currents

Advantages:

- Fast and easy IO-Link issue analysis
- Logical and electrical issue detection
- Suitable for development and application

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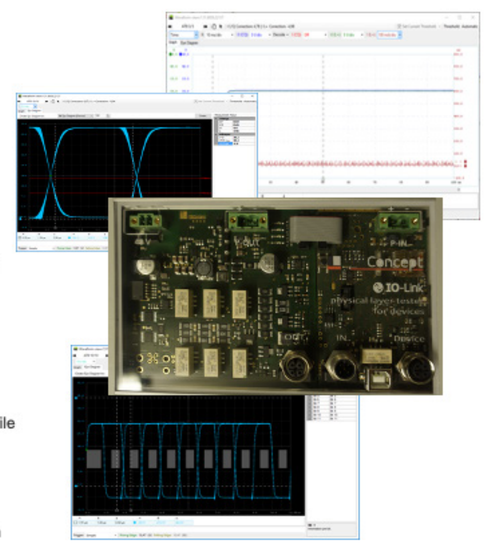
IO-Link Physical Layer Tester

- Compliant to IO-Link Test Specification V1.1.2 (V1.1.3 coming)
- User calibration support
- IODD support
- Integrated IO-Link Master
- Integrated Line Simulation
- Semiautomatic measurement procedure based on recorded waveforms
- SIO – Mode tests
- BIT – and UART Eye-Diagrams
- Test Report Generation (PDF)
- All test results are stored in a reloadable test data file

Advantages:

- All components to run physical Layer Tests are included
- Substantial reduction of test effort and test duration
- Automatic test report generation



TEConcept Tools

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IO-Link EMC Test Master

- Complies to IO-Link interface specification V1.1.2 (V1.1.3 coming) and the current IO-Link test specification.
- Error and Signal output
- 4 electrical IO-Link port configurations
  - COM1/2 speed port (good/bad signal)
  - COM3 speed port (good/bad signal)
- RS232 and USB interfaces
- Terminal based control command set
- Additional EMC test and control software with graphical user interface
- Test report generation in PDF Format
- Operates as standard "USB IO-Link Master„

Advantages:

- Sensitive Parts are located outside EMC chamber
- EMC robustness considerably better than required

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IO-Link EMC Test Device

- Device fully compliant to V1.1.2 IO-Link Interface Specification
- All 3 COM-Speeds supported (Switch Selector)
- Internal Pseudo-Random-Number Generators
- Error counter for Parity, Checksum, Data and Time-out Errors
- 7-Segment Error Counter Display
- 7-Segment Device Status Display
- Errors Counter accessible via IO-Link
- Optical Error Trigger Output

Advantages:

- No development effort for master manufacturers
- Better time-to-market
- Identification of EMC issues

TEConcept Tools

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IO-Link Device Tester System

- Test cases are defined in the IO-Link test specification
- TEConcept Device tester simplifies the execution protocol compliance tests.
- Generates **Manufacturer Declaration/Test report (PDF)**

Advantages:

- Complies to IO-Link Test specification V1.1.2 (V1.1.3 support in preparation)
- IO-Link profiles (FW-Update, BLOB Transfer, etc. are supported)
- Extendible with customer specific test cases
- Selectable Test Case execution
- Hex-Trace of IO-Link communication
- Log- and Trace File export
- Session store/restore (project file)

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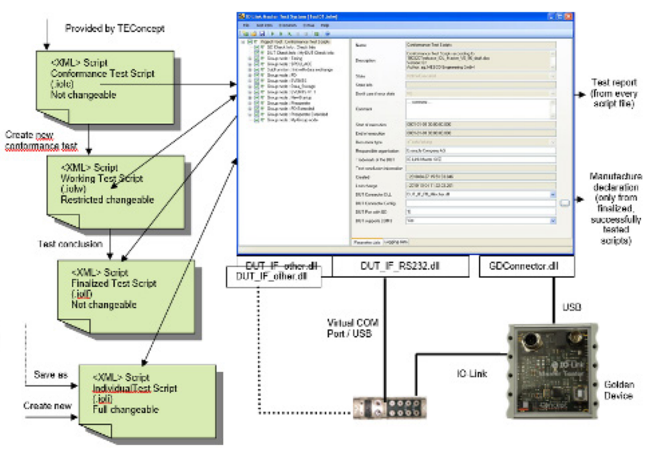
IO-Link Tools – Master Tester - Overview

- All baud rates supported
- Upgradeable for new IO-Link features
- Alternative adaption to for fieldbus interfaces via DLLs.

Advantages:

- Support for new serial Test Interface
- Generic serial DLL
- Windows 7/10 compliant (64bit)
- V1.1.2 Test-spec compliant (V1.1.3 coming soon)



IQ^2 Development Tools

Note: The following information is provided by IQ^2 as an example of the types of products and services it provides. Please contact them for further details.

IQ^2 Development

Complete Hardware and Software example for DEVICE STACK integration

To simplify IQ^2 Device stack integration into Customers device, a complete example (hardware and software) is available:

1. **Hardware**
   a. Hardware is based on "MAXIM IO-LINK TEMPERATURE SENSOR (MAXREFDES173)" Device. See more: www.maximintegrated.com

   b. IO-Link device transceiver: **MAX14827A (Low-Power, Ultra-Small, Dual Driver, IO-Link Device Transceiver)**
   c. Sensor: **MAX31875 (Low-Power I2C Temperature Sensor)**
   d. Main microcontroller: **Renesas RL78/G1A**
2. **Software**
   a. IO-Link Device stack: **IQ2 Development,** https://www.iq2-development.com/products/iqstacks.html
   b. IO-Link Device application: **IQ2 Development.**

The MAXREFDES173 is an IO-Link® temperature sensor reference design uses a ±2°C-accurate local temperature sensor with I2C/SMBus interface (**MAX31875**) and Low-Power, Ultra-Small, Dual Driver, IO-Link Device Transceiver (**MAX14827A**).
The sensor uses **IQ2 Development's IO-Link device stack** to communicate to any IO-Link version 1.1-compliant master (for example: iqLink (https://www.iq2-development.com/products/iqlink.html).
The board also contains a male M12 connector for connection to a compliant IO-Link master using a standard M12 cable.

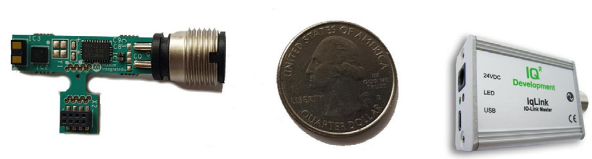
www.iq2-development.com

IQ^2 Development

Complete Hardware and Software example for DEVICE STACK integration

To simplify IQ^2 Device stack integration into Customers device, a complete example (hardware and software) is available:

1. **Hardware**
   a. Hardware is based on "MAXIM IO-LINK LASER DISTANCE SENSOR (MAXREFDES174)" Device. See more: www.maximintegrated.com



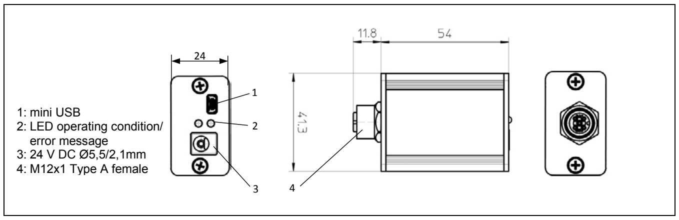
   b. IO-Link device transceiver: **MAX22513 (Surge Protected Dual Driver IO-Link Device Transceiver with DC-DC)**
   c. Sensor: **VL53L1X (long distance ranging Time-of-Flight sensor)**
   d. Main microcontroller: **Renesas RL78/G1A**
2. **Software**
   a. IO-Link Device stack: **IQ2 Development,** https://www.iq2-development.com/products/iqstacks.html
   b. IO-Link Device application: **IQ2 Development.**

The MAXREFDES174 is an IO-Link® distance sensor reference design uses a long distance ranging Time-of-Flight sensor (**VL53L1X**) and Surge Protected Dual Driver IO-Link Device Transceiver with DC-DC (**MAX22513**).
The sensor uses **IQ2 Development's IO-Link device stack** to communicate to any IO-Link version 1.1-compliant master (for example: iqLink (https://www.iq2-development.com/products/iqlink.html).
The board also contains a male M12 connector for connection to a compliant IO-Link master using a standard M12 cable.

www.iq2-development.com

IQ² Development Tools

DATA SHEET iqLink USB IO-LINK MASTER — IQ² Development



CE IO-Link

Product features	
USB IO-Link Master	
Parameterize devices and monitoring of process data	
Supported communication protocols: IO-Link, COM 1 (4.8 kBit/s) / COM 2 (38.4 kBit/s) / COM 3 (230 kBit/s)	
For operation with iqPDCT (Port and Device Configuration Tool)	
Electrical data	
Output voltage in USB mode, V	24 V DC ± 10%
Output voltage with external power supply, V	24 V DC ± 6V (max. input voltage)
Output current in USB mode, mA	80 mA
Output current with external power supply, A	max. input current <2,5 A
Input voltage on USB mode, V	5 V DC
Input voltage with external power supply, V	24 V DC ± 6V (according to DIN EN60950)
Input current in USB mode, mA	max. 600 mA
Input current with external power supply, A	max. 2,5 A
Outputs	
Short-circuit protection	yes
Interfaces	
IO-Link-Master transmission type	COM 1 / COM 2 / COM 3
IO-Link revision	V1.0 and V1.1
Number of ports	1
Port class	M12x1 / Type A / female
Environmental conditions	
Ambient temperature, °C	0 to +55 °C
IP protection class	IP 20

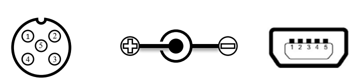
IQ² Development GmbH & Co. KG, Carl-Benz-Str. 3, 72585 Riederich
www.iq2-development.de, info@iq2-development.de

DATA SHEET iqLink USB IO-LINK MASTER — IQ² Development

Registrations / Checks	
EMV Guideline 2014/30/EU	DIN EN 61000-6-2:2005 DIN EN 61000-6-4:2007+A1:2011 DIN EN 61131-9:2013
RoHs Guideline 2011/65/EU	fulfilled
Mechanical data	
Weight, kg	0,066 kg (net) / 0,106 kg (gross)
Material	Aluminium anodized
Display / Diagnose	
Display	Operation condition: LED green light permanently on = iqLink ready, no IO-Link Communication LED green light, active IO-Link communication flashes at 900 msec and 100 msec off = iqLink ready
Diagnose	error indication: LED red light permanently on (LED green light out) = please send iqLink to the manufacturer
Electrical connection	

Connection Assignment::

1: +24 V
2: not occupied
3: GND
4: IO-LINK: CH1 (C/Q)
5: not occupied



1: +5 V
2: D-
3: D+
4: not occupied
5: GND

Remarks	
IO-Link Master Transceiver:	Maxim MAX14819ATM+
Main Microcontroller	Renesas RL78/G13 (R5F100)
Packaging unit, pieces	1 Piece
Country of origin	DE
HS-Code	85437090

Recycling remarks
This product is to be supplied after his use according to the topical disposal regulations of your administrative district, country and state as an electronic industry waste of a separate disposal.

The information contained in this data sheet was compiled with the greatest possible care.
For correctness, completeness and actuality the liability is limited to coarse fault.

IO-Link Glossary

(Reprinted with permission from www.io-link.com.)

Acyclic data	Data transmitted from the controller only after a request (e.g., parameter data, diagnostic data).
COM1-3	IO-Link data transmission rates.
Cyclic data	Data that is transmitted by the controller automatically and at regular intervals (process data, value status).
DI	Digital input.
DQ	Digital output.
GSD file	The properties of a PROFINET device are described in a GSD file (generic Station Description), which contains all information required for configuring.
HMI	Human machine interface of an automatic system.
IEC 61131-9	International standard that deals with the basics of programmable controllers. Part 9 describes IO-Link under the designation S*ingle-drop digital communication interface for small sensors and actuators (SDCI).*
IODD	Electronic device description of devices (IO Device Description).
IO-Link device	Field device that is monitored and controlled by an IO-Link master.
IO-Link master	Represents the connection between a higher-level fieldbus and the IO-Link devices. The IO-Link master monitors and controls the IO-Link devices.
Parameter Assignment server	An IO-Link master according to IO-Link Specification 1.1 can act as a parameter assignment server for the IO-Link device.
Port	A port is an IO-Link communication channel.

IO-Link FAQs

Q: What components are recommended for protection during burst events?

A: We generally recommend that customers place pads for two capacitors (~220pF) on the C/Q line (one to GND and one to V_{CC}) for burst testing (IEC 61000-4-4). These capacitors should be placed as close to the IC as possible. Depending on the board, these capacitors may not be needed to pass burst testing, so we recommend testing without the capacitors first and then adding them, if needed.

TVS diodes with a clamp voltage lower than the absolute maximum ratings for the transceiver are required for protection during a surge event. Place TVS diodes as close to the IC as possible.

Q: Some IO-Link designs appear to have isolated ground planes. What is the isolation for?

A: While there is no requirement for isolation in the IO-Link specification, all IO-Link systems have isolation at some point in the signal chain. Isolation ensures that the controller/backplane is protected from any transient events that occur on the local 24V field supply. The isolation is usually placed in a location where the cost is minimized, for example, between the backplane and the controller or between the controller and the IO-Link transceiver.

Q: What is SIO and how does it relate to IO-Link?

A: Per the IO-Link specification, every IO-Link master port can be configured to operate in SIO (single input/output) mode or IO-Link (SDCI) communication mode. In SIO mode, the port can be configured to operate as a digital input or a digital output. See IEC 61121-2 for more information.

Q: Some IO-Link master transceivers have a DI input and some do not. What is DI?

A: DI is a digital input. Digital inputs are the most common inputs in industrial systems. DI is used to connect to binary sensors.

Q: Why does IO-Link support three different data rates?

A: Many industrial systems have existed for many years. While data rates in communication systems have increased significantly, many of those original sensors (often still operating in their original systems) were designed with slower software/communication capabilities. The IO-Link specification incorporates communication at three data rates that include most sensor capabilities to allow upgrades and improvements to industrial systems already in place, without requiring complete (and very expensive) overhauls.

Q: Do IO-Link masters and devices have to be surge protected?

A: Since IO-Link cables are specified for a maximum length of 20m, and the IEC 61000-4-5 surge standard mandates surge for cables longer than 30m, the IO-Link standard does not require surge protection.

Q: What is the maximum input capacitance pin that an IO-Link master may have on the C/Q pin?

A: An IO-Link master's input capacitance must be ≤ 1nF in receive mode in the frequency range up to 4MHz.

Q: What is the maximum capacitance that an IO-Link device may have?

A: The IO-Link device input capacitance should be ≤ 1nF. An exception is made in cases of COM1 or COM2 data rates in combination with push-pull driver operation, in which case, the maximum input capacitance may be up to 10nF.

Q: What is an IO-Link cable?

A: An IO-Link cable has at least 3 wires (C/Q, L+, and L-). The cable is not shielded.

Q: What is the maximum length of IO-Link cable?

A: The maximum cable length is 20m.

Q: What is the cable's worst-case resistance and capacitance allowed to be?

A: The loop wire resistance is 6.0Ω (max) while the maximum cable capacitance (C/Q to L+/L-) is 3.0nF (to 1MHz).

Q: Is the IO-Link cable terminated?

A: There is no specification for the termination of IO-Link cables. Hence, the voltage waveform on an IO-Link cable can exhibit overshoots.

Q: What is meant by IO-Link Cycle Time?

A: The IO-Link Cycle Time is the repetition rate at which the IO-Link master sends out its master message to the IO-Link device in Operate mode. This is the rate at which the device is provided with or requested for process data i.e., the rate at which a sensor is asked for in its measurement data or an actuator is given new data.

Q: What is the minimum IO-Link cycle time possible by the IO-Link standard?

A: The minimum cycle time is 400µs. Such small cycle times are only feasible with COM3 data rates.

Q: Can every IO-Link master support 400µs cycle times?

A: The IO-Link standard does not require that an IO-Link master support the 400µs minimum cycle time. Every IO-Link master specifies its own minimum cycle time capability.

Q: What is IO-Link communication based on?

A: IO-Link is based on a master-slave dialogue in which the IO-Link master polls the IO-Link device, which must answer the master message.

Q: How fast must an IO-Link device respond to an IO-Link master message?

A: An IO-Link device must send out its first bit within 10 bit times after the last bit of the master message. Hence, the response time depends on the data rate (COM rate).

Q: What topology does IO-Link employ?

A: IO-Link is a point-to-point connection in which an IO-Link master is connected to only one IO-Link device.

Q: What is the current drive capability of an IO-Link master C/Q port?

A: The C/Q pin of an IO-Link master can drive at least 100mA (min) continuously and 500mA (min) for a short time (for the IO-Link wake-up).

Q: What is the supply voltage range that an IO-Link master must provide for powering IO-Link devices?

A: An IO-Link master must provide a 24V power supply with a tolerance range of 20V (min) to 30V (max) to power IO-Link devices.

Q: At what load current must an IO-Link master be able to provide to an IO-Link device?

A: The IO-Link master must supply 200mA continuously.

Q: What is the supply range of an IO-Link device?

A: An IO-Link device must operate with a 24V nominal supply with a voltage range of 18V (min) and 30V (max).

Q: How much load current can an IO-Link device drive?

A: An IO-Link device is specified to drive at least 50mA. It is common for IO-Link devices to drive at least 100mA.

Q: Why are some IO-Link device transceivers able to drive 200mA or more load current?

A: While such high currents are not needed for IO-Link operation, they may be needed if an IO-Link device (such as a switching sensor) is specified to drive large loads, as in valves or relays, in standard binary output mode.

Q: Can an IO-Link device driver operate in PNP or NPN mode during IO-Link communication?

A: IO-Link communication supports both push-pull and PNP modes. Push-pull is preferred, since the two logic states, defined when the device drives the C/Q line, are then defined by a low-impedance driver. PNP mode is possible for the lower COM rates, in which case, the C/Q low is defined by the 5mA pulldown in the IO-Link master.

Q: Can an IO-Link device operate in NPN mode?

A: An IO-Link device can only operate in NPN driver mode during SIO operation, if the IO-Link master supports NPN sensors. The IO-Link standard does not support NPN driver operation.

Q: I want to make my new IO-Link sensor compatible with older binary switching sensors that have PNP drivers. Can I operate the sensor in PNP mode?

A: When the sensor is operating in SIO mode, it can be operated in PNP mode so that it is compatible to the older sensors. When the sensor gets an IO-Link wake-up from the IO-Link master, it is suggested to switch its driver to push-pull mode.

Additional IO-Link Resources

IO-Link Webpages

- **IO-Link Transceivers and Binary Drivers**
- **IO-Link Master Transceivers**
- **IO-Link Device Transceivers**
- **Binary Drivers**
- **IO-Link Reference Designs**

IO-Link Application Notes and Articles

- **Application Note 6427: Calculating the Power Dissipation of the MAX14819 Dual-Channel IO-Link Master Transceiver**
- **Application Note 5151: Special Considerations for Mode Changes During Active Operation of MAX14820/MAX14821 Sensor/Actuator Transceivers**
- **Application Note 6965: How to Select a TVS Diode for Maxim's IO-Link Devices**
- **Maxim Blog: To IO-Link And Beyond!**
- **Maxim Blog: Vision Realized In Advancing Industry 4.0 Solutions**

Videos

- **What is IO-Link?**
- **Heat Map Comparison of IO-Link Device Transceivers**
- **In the Lab: IO-Link Smart Sensor System Demo**

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