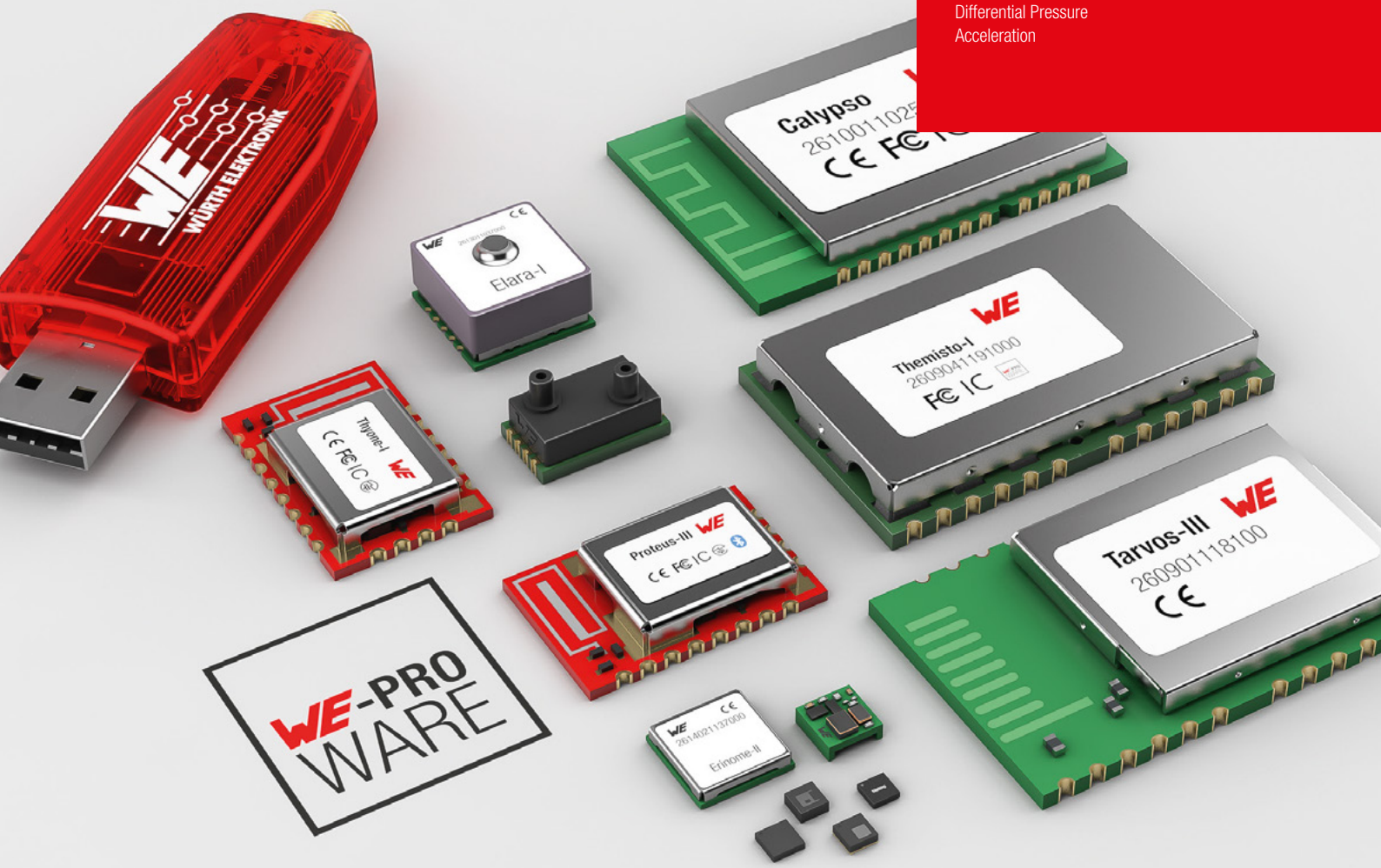
WÜRTH ELEKTRONIK

Wireless Connectivity & Sensors

Product Guide

Wireless Connectivity:
GNSS
Bluetooth®
Wi-Fi
Proprietary
Wirepas
Wireless M-Bus

Sensors:
Temperature
Humidity
Absolute Pressure
Differential Pressure
Acceleration



The Würth Elektronik eiSos Group

The Würth Elektronik Group

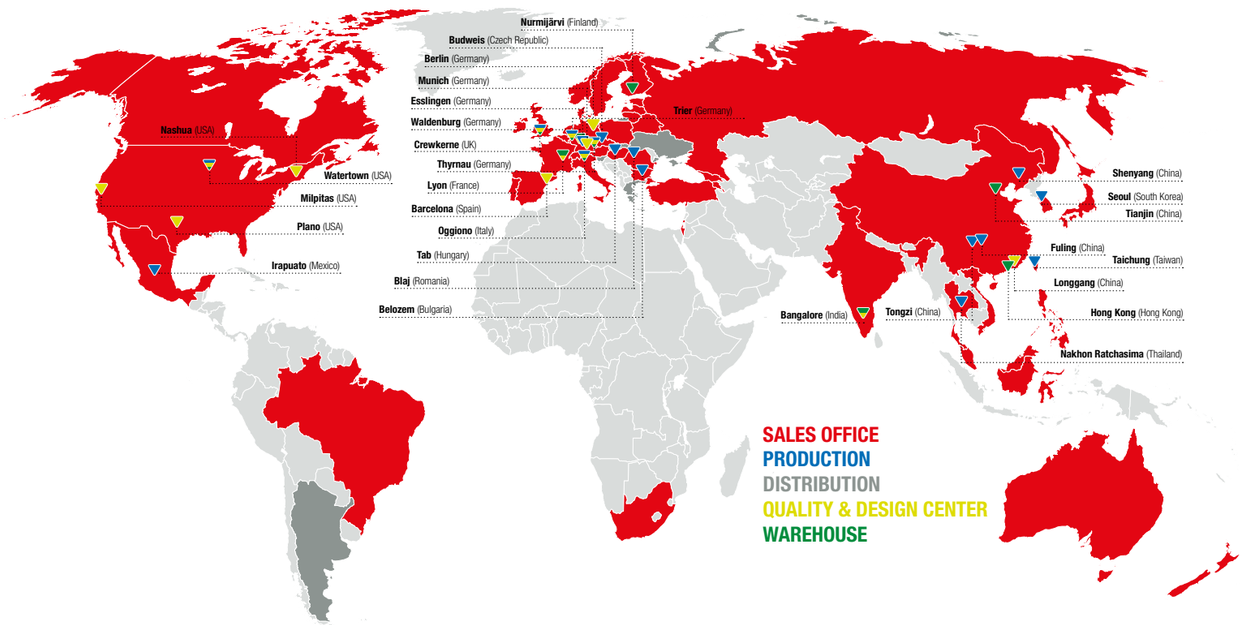
Employees: 7,300
Sales: 822 Mil. Euro

Würth Elektronik eiSos Group

- Printed Circuit Boards
- Intelligent Power and Control Systems

Passive Components	Power Modules & Optoelectronics	Electromechanical Components	Automotive & eMobility	Wireless Connectivity & Sensors
				
Würth Elektronik eiSos GmbH & Co. KG	Würth Elektronik eiSos GmbH & Co. KG	Würth Elektronik eiCan	Würth Elektronik eiSos GmbH & Co. KG	Würth Elektronik eiSos GmbH & Co. KG
Würth Electronics Midcom Inc.		Würth Elektronik Stelvio Kontek S.p.A.	Würth Elektronik iBE GmbH	(former AMBER wireless GmbH)
IQD Frequency Products Ltd.			Erwin Büchele GmbH & Co. KG	

Globally available. Locally present.



It`s about people – The AMBER wireless Story

Where we come from

AMBER wireless GmbH was acquired in August 2016 and was integrated into the Würth Elektronik eiSos Group on April 2018. With more than 20 years of experience in the development of radio products, AMBER wireless today forms the core of the new division „Wireless Connectivity & Sensors“.

1998
Foundation of AMBER wireless GmbH

2016
Aquisition by Würth Elektronik eiSos

2017
Development and expansion of the Sensor portfolio

2018
Integration of AMBER wireless into Würth Elektronik eiSos Group

Who we are

Wireless Connectivity & Sensors - these are not just wireless modules and sensors. Behind them is a team identifying themselves passionately with the products. But it`s not all about the products – it`s about people, these values make us strong. Following the old AMBER claim „One for all, all for one“, we are living our dedication towards the customers.

more than you expect

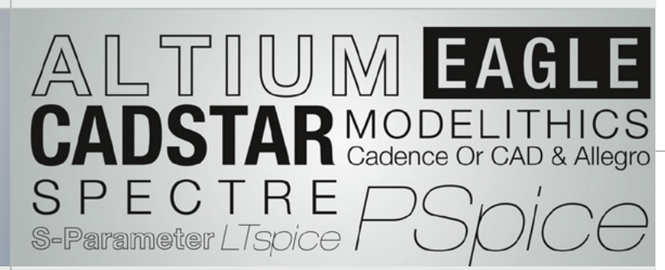
SAY YES TO OUR DIRECT DESIGN IN SUPPORT

WE TAILOR THE QUANTITIES TO YOUR NEEDS – NO MOQ

ALL CATALOGUE PRODUCTS AVAILABLE EX STOCK

SEMINARS AND WEBINARS

REDEXPERT – ONLINE PLATFORM FOR COMPONENT SELECTION & ANALYSIS



COMPONENT LIBRARIES – MAKING HARDWARE INTEGRATION EASY

APPLICATION NOTES

TOTAL QUALITY MANAGEMENT

page: 18

Full Service Products - Hardware + Firmware

Software Development Kits and Software-Tools

001101
010100
101101

Software Individualization

page: 20

Configurable User Settings with our Firmware WE-ProWare

User Friendly Manuals

Technical Support – Talk from Engineer to Engineer

page: 108

EV-Boards and USB Radio Sticks

page: 24

Certification and Conformity - CE, FCC, IC & ARIB

Small Packing Unit

Long Term Availability

EASY AND FAST ACCESS TO ALL INFORMATION

Product Guide Download:
www.we-online.com/wcs-product-guide

Download the Catalogue App of Würth Elektronik to access all product information on your mobile device:
www.we-online.com/app

Download on the App Store

Content

Information in this publication is subject to change. The process of continually improving our product range leads to changes in content. For new designs please refer to the latest data sheets on www.we-online.com or contact our technical field staff.

Webinars & Tutorials

Stay Up-To-Date

Check out our videos and webinars produced by our engineers and technology specialists. They will present to you uses and applications, explain the use of design rules and design tips and much more. Take the opportunity to gain information within a short presentation: independent, flexible and interactive!

we-online.com/wcs-webinars

Wireless Connectivity & Sensors
All videos on demand

Making your industrial device IoT compatible with Wi-Fi

Basics of GNSS positioning and receivers' technology

Bluetooth® LE vs 2.4 GHz Proprietary wireless

Bluetooth® LE New adaptions

The Smart-Metering Standard wireless M-Bus

Radio protocols in theory and practice

Certification, Policies & Guidelines for wireless communication

Discover Radio Communication

Accelerate your IoT development project with our MEMS 3-axis sensor

Digital silicon-based temperature sensors for industrial applications

Currently under pressure? Discover our new MEMS pressure sensors

Markets & Industries

- Industrial IoT
- Sensor Systems
- Measurement & Control
- Medical Devices
- E-Mobility
- Automation
- Tracking & Positioning
- Agriculture
- Automated Meter Reading
- ... and many more

WÜRTH ELEKTRONIK

DISCOVER THE WORLD OF WIRELESS CONNECTIVITY

Fundamentals

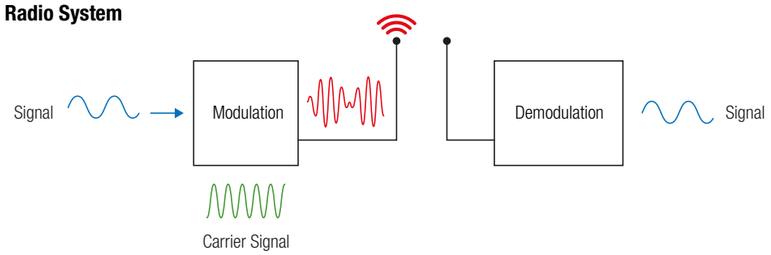
The History of Radio Technology

Radio technology is a wireless method of transmitting signals by means of modulated electro-magnetic waves. In 1884 James Clerk Maxwell predicted the existence of radio waves, which was experimentally confirmed by Heinrich Hertz on November 11th, 1886.

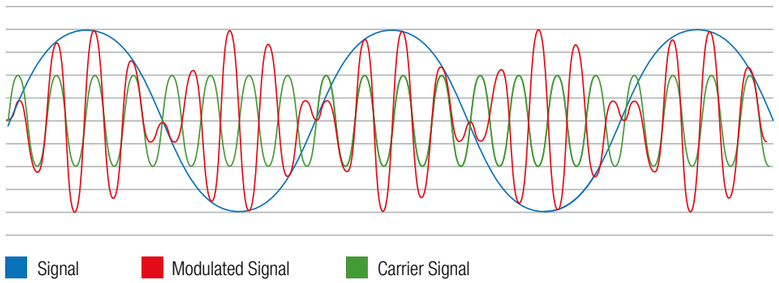
Transmission of the Signal

For the Transmission the signal will be modulated on a carrier signal, mostly sinus with constant amplitude. Thereby the amplitude or frequency will be adopted in the rhythm of the transmitted signal. The modulated wave is radiated by an antenna and received on the otherside with an antenna too. Due to demodulation at the receiver the transmitted signal can be used.

Radio System



Modulation



Range Estimation

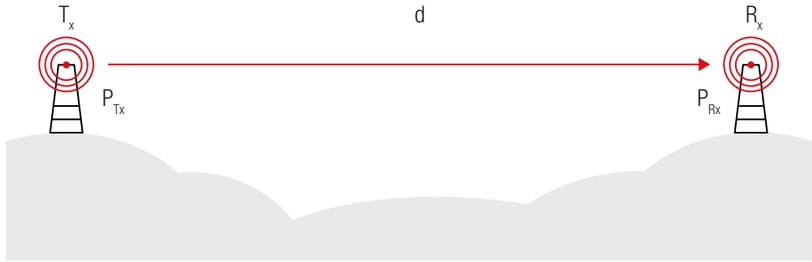
When a radio connection is planned, the given circumstances define largely the requirements for radio range, operating temperature and available space.

ANR010 Range Estimation
we-online.com/ANR010

Model 1: Friis Transmission for Free Space

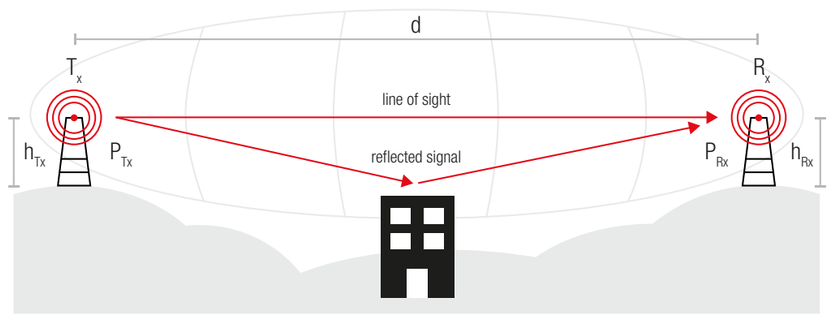
Friis transmission for Free Space is a model to calculates the path loss, to estimate the range of a radio link in a free space environment. Free field condition: The first Fresnel zone is free of objects.

This model makes the assumption, that the emitted power is radiated equally in every direction (isotropic) and calculates the power loss only taking into account the decreasing power density of the wavefront with increasing distance to the origin, without any reflection, absorption or attenuation.



Model 2: Two-ray Ground Reflection

The two-ray ground reflection model is applied, when transmitter and receiver are in line of sight but the first Fresnel zone is not free of objects. So the calculation considers the received power of the direct line of sight path and in addition the power of the reflection path with slight phase difference.



Conclusion

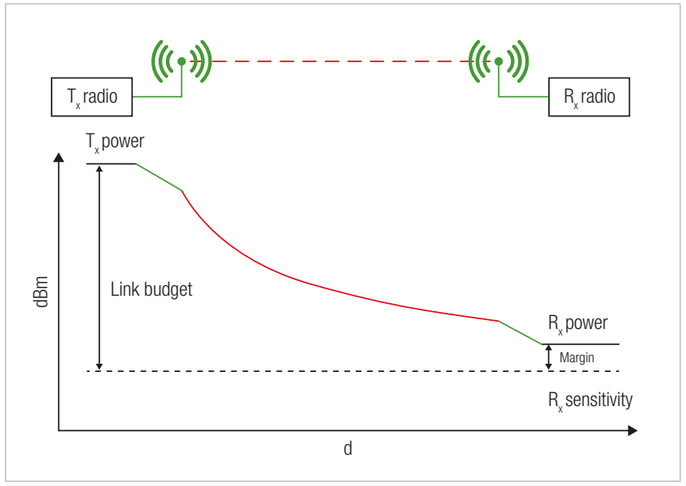
In a lot of cases there is the need of long distances with regard to the antenna height, so usually the two ray ground model is a good fitting estimation. Only for some special cases with the free space condition fulfilled the Friis model is useful. Having a closer look to the models there are several interesting points to mention.

The Dependency of the Frequency
Often it is mentioned in general, that the lower the frequency is, the greater the range is. We have learned, that this is only the case when free field conditions are met. But there are other effects of the frequency, as the fact, that for higher frequencies smaller objects will cause reflections, or that for low frequencies it might be hard to find an antenna with acceptable size and efficiency.

The Influence of the Antenna Height on the Range
The higher the antennas can be placed, the longer is the range that can be reached. Placing an antenna directly above ground reduces the range so radical, a layman could hardly imagine.

Link Budget

A link budget is an accounting of all of the power gains and losses that a communication signal experiences in a telecommunication system; from a transmitter, through a medium (free space, cable, waveguide, fiber, etc.) to the receiver. It is an equation giving the received power from the transmitter power, after the attenuation of the transmitted signal due to propagation, as well as the antenna gains and feedline and other losses, and amplifications of the signal in the receiver or any repeaters it passes through.



Power [dBm]	Power [watt]
- 120 dBm	1 fW
- 110 dBm	0.01 pW
- 100 dBm	0.1 pW
- 90 dBm	1 pW
- 80 dBm	10 pW
- 70 dBm	100 pW
- 60 dBm	1 nW
- 50 dBm	10 nW
- 40 dBm	100 nW
- 30 dBm	1 µW
- 20 dBm	10 µW
- 10 dBm	100 µW
- 1 dBm	794 µW
0 dBm	1 mW
1 dBm	1.26 mW
10 dBm	10 mW
20 dBm	100 mW
30 dBm	1 W
40 dBm	10 W

Duty Cycle

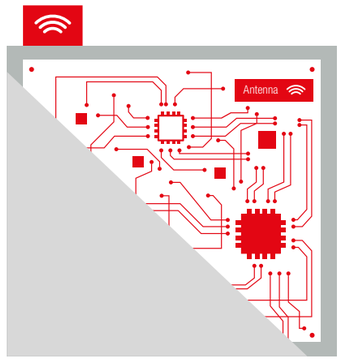
A duty cycle or power cycle is the fraction of one period in which a signal or system is active. Duty cycle is commonly expressed as a percentage or a ratio. A period is the time it takes for a signal to complete an on-and-off cycle. E.g. using a duty cycle of 10 %, means that the used transmitter is allowed to send 6 minutes in between one hour.

Polite Spectrum Access – listen before talk

When an application uses polite spectrum access, the duty cycle restrictions are loosened. Polite spectrum access encompasses two aspects: Listen Before Talk (LBT) and Adaptive Frequency Agility (AFA). LBT defines that the device must listen if the medium is already in use by a Clear Channel Assessment (CCA) check. When the medium is in use, the device must wait a random backoff interval or change the frequency before checking again. The latter is called AFA.

Integration of Radio Technology

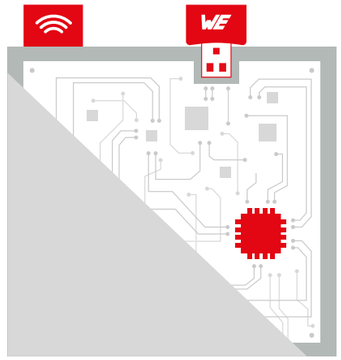
One of the last steps before a product with integrated wireless technology can be launched on the market is the certification. Manufacturers of products with integrated RF-technology may only market these with the necessary certification. The following graphics display the three options which are available for integrating wireless technology.



1

Device without certified radio chip and antenna

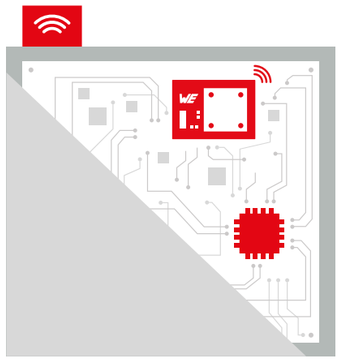
- ⊕ Flexible
- ⊖ High effort
- ⊖ High costs



2

Device with external radio dongle

- ⊕ Plugable
- ⊕ Easy integration
- ⊖ Not that flexible



3

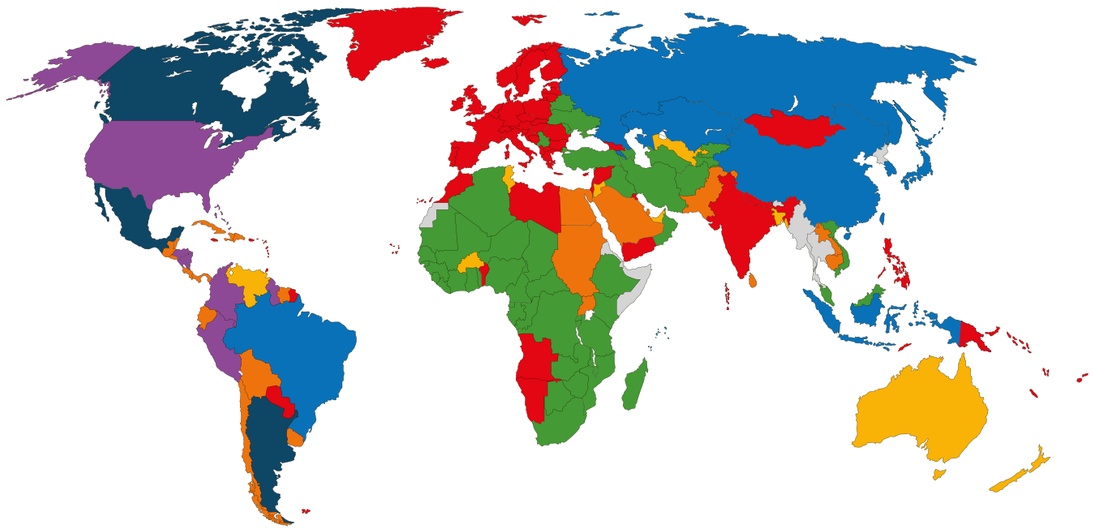
Device with certified radio module and antenna

- ⊕ Low design effort
- ⊕ Fully integrated
- ⊕ Low Certification effort
- ⊖ Not that flexible

Certification

Different Certification Systems

A product that is to be launched globally must meet the certification criteria of each country it is to be marketed in.
There is no worldwide certification applicable to all countries. The following presents the various certification systems.



CE RED | **FCC** | **National (Japan ARIB)** | **RED National** | **RED FCC** | **FCC National (Canada ISED)** | **RED FCC National**

Which Certification Rules apply where?

CE

For products distributed in the European market the CE mark is required. The manufacturer applies the CE mark after fulfilling the Radio Equipment Directive (RED). The tests may be conducted either by the manufacturer himself or by an accredited laboratory. As self declaration the manufacturer is responsible for the products conformity to legal restrictions and regulations.

FC

In North America, however, products with wireless technology require FCC certification. A certification through an verified authority with measurements is mantadory

National

For all other markets national regulations apply. For example, a product introduction in Canada or Japan require ISED or ARIB certification. Most countries are close to CE or FCC. Deadlines, requirements and measurements can differ.

ARIB

These, similar to other national regulations, are based on the existing certification bodies, so that only a small amount of additional testing is required.

Certificate Examples

CE

EU DECLARATION OF CONFORMITY

Radio equipment: **2611011024000**

The manufacturer: Würth Elektronik eiSos GmbH & Co. KG
Max-Eyth-Straße 1
74638 Waldenburg

This declaration of conformity is issued under the sole responsibility of the manufacturer.

Object of the declaration: 2611011024000

The object of the declaration described above is in conformity with the relevant Union harmonization legislation: Directive 2014/53/EU and 2011/65/EU.
Following harmonized norms or technical specifications have been applied:

EN 300 328 V2.1.1 (2016-11)
EN 301 489-1 V2.1.1 (2017-02)
EN 301 489-17 V3.1.1 (2017-02)
EN 62368-1:2014 + AC:2015 +A11:2019

Japanese Radio Law Compliance.
This device is granted pursuant to the Japanese Radio Law.
This device should not be modified (otherwise the granted designation number will become invalid)

ID-Code (Interference provision)

The MAC address of the radio device maintains the format 00:18:DA:xx:xx:xx. The latter part xx:xx:xx of the MAC address coincides with the serial number of the device.

Due to the size of the Proteus-III label, the certification label of the Proteus-III is not placed onto the module label.

2611011024000: R 201-190950

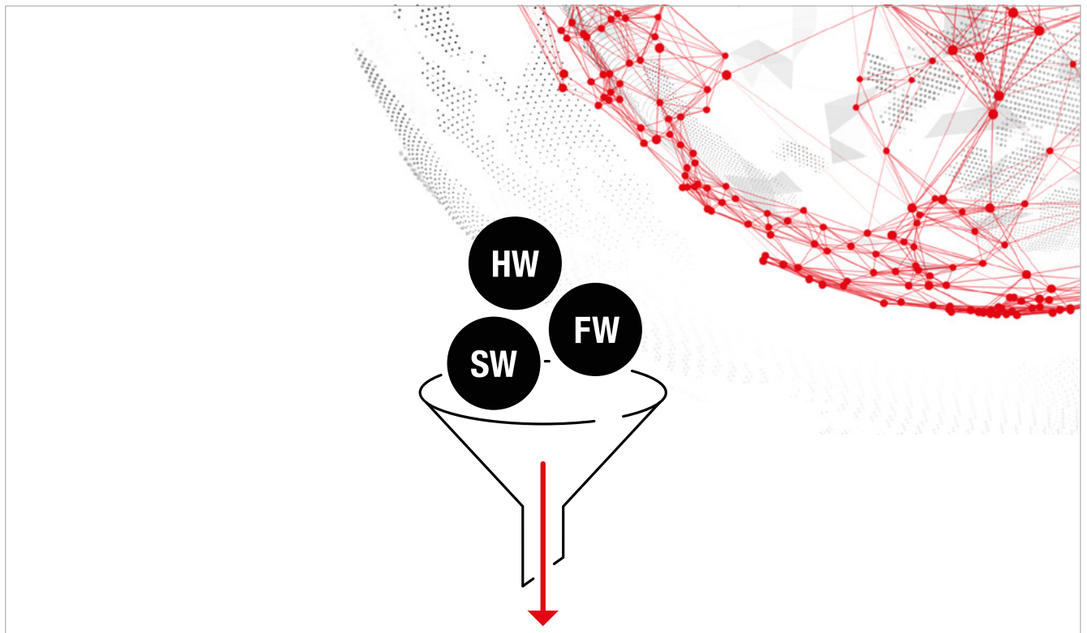
Benefits of Certification and Conformity

Be smart and ensure that your product will pass the certification process!

Obtain assurance – Pre-certification is half the battle won and reduces the final test effort.

Save time and money - the likelihood that the end product will pass is much greater with pre-certification.

Why using an RF-Module



Wireless Connectivity

HW

Hardware

- Powerful RF-Chips
- Design of Ready-to-use Modules
- Antenna-Design
- Edge Castellation allows hand soldering in prototyping or small series production

FW

Firmware

- WE-ProWare Radio Stack
- Requirement for approval (CE, FCC, IC, ARIB)
- 20 years of experience
- Developed for industrial and medical requirements
- Easy to handle and to integrate

SW

Software

- PC-Software for easy evaluation and testing
- Design libraries available for fast PCB design for Altium and Eagle
- Software Development Kit (C-Files) for comfortable coding of the HOST-controller system

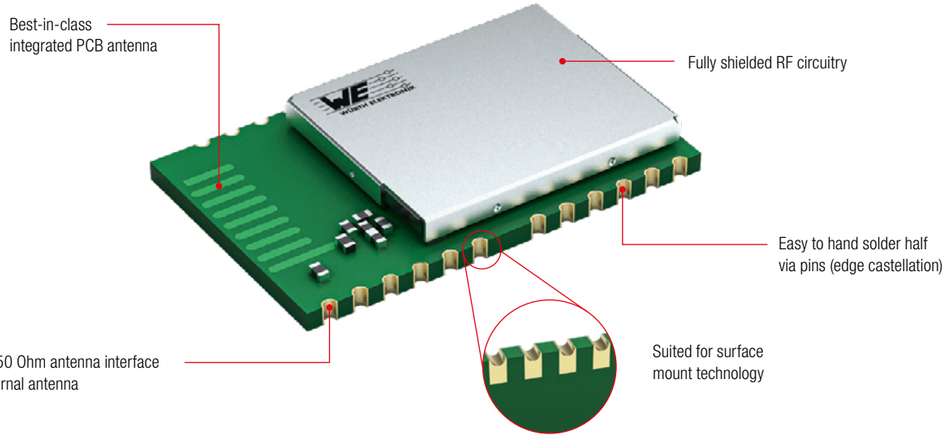
Hardware

Speed up your time-to-market

Our modules are fully developed, tested and validated. The modules include all essential components. Running WE-ProWare radio stack on our modules ensures a reliable communication through standard protocols and proven RF performance.

Open New Markets

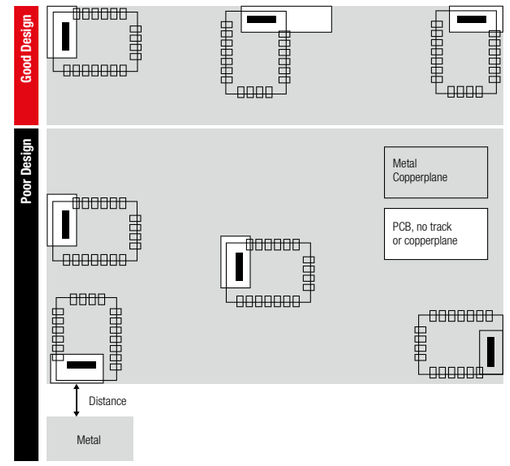
Most of our modules offer the same foot print and form factor. Make use of this feature to easily exchange modules and adapt your application to specific requirements.



Advantages

- Faster developement with a complete RF-module
- Possibility to work with RF even if there are limited resources in man power or knowlege
- No Antenna Design necessary. Integrated antenna!
- Easy soldering, even by hand for smaller quantities in Prototype-phase or for small series
- Design in guide for all modules
- Design in support by Hardware-, Software- and Application-engineers

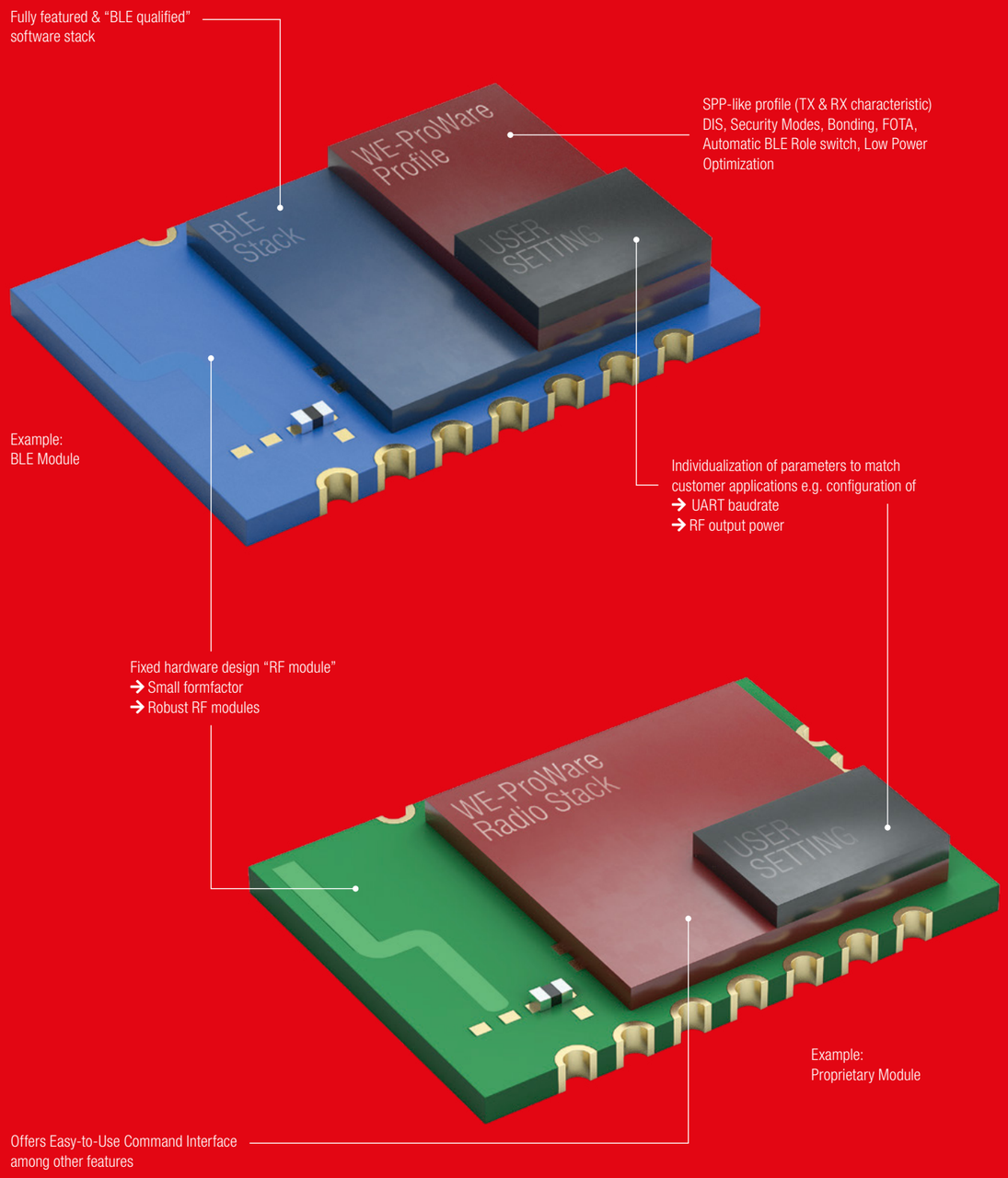
Placement of the module with integrated antenna



Design Libraries

- Available for fast PCB-unbundling
- For Altium and Eagle

Firmware: WE-ProWare



The WE-ProWare Radio Stack is an Industry Proven Robust Wireless Connection

With more than 20 years of experience, Würth Elektronik eiSos offers a radio stack ready to run, build and connect out of the box – called **WE-ProWare**. This radio stack is an easy-to-use and effective networking protocol. Without a radio stack an RF module is pure hardware. Even when Software Developement Kits (SDKs) are offered, you have to spend months, sometimes years, to get your module up and running.

It is pre-loaded on all Wireless Connectivity RF Modules

Our module added value is the **WE-ProWare** radio stack which is fully included. Communication functions are configured with simple AT commands. You can easily swap between radio channels and protocols. All this makes it very easy to enter new markets with your application.

Extensive Features

The **WE-ProWare** offers you the option to connect external peripherals using numerous interfaces, such as UART or digital and analog I/O. In **TRANSPARENT MODE** the WE-ProWare radio stack can carry any kind of application data, simple conversion of UART to radio and vice versa. In **COMMAND MODE** you have full control of all features. The UART interface is used for serial communication as well as for configuration.

The WE-ProWare radio stack supports different network topologies, incl.

- ✔ Point to Point
- ✔ Point to Multipoint
- ✔ Peer to Peer
- ✔ Mesh
- ✔ Multi-hop

Firmware: WE-ProWare

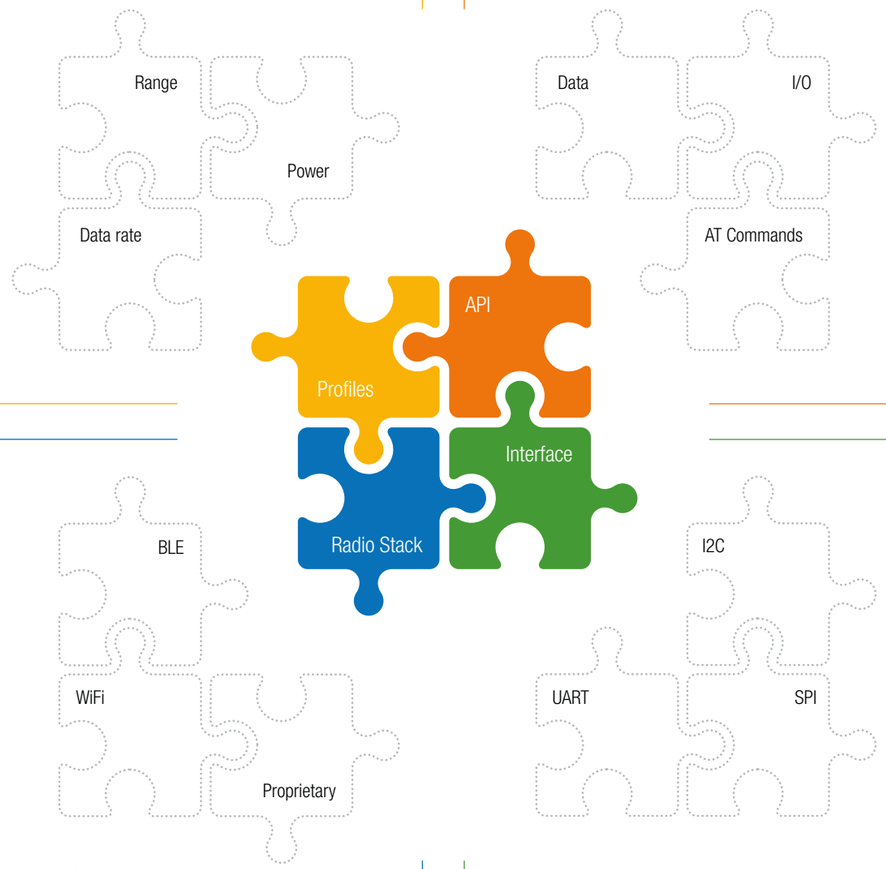
Profiles

The usable profiles offer high flexability in:

- Network topology
- Data rate
- Throughput
- Range
- Energy consumption

API

- Offers communication directly to the module
- Simple AT-Commands, well known and usable with nearly every microcontroller, regardless of its size



Radio Stack

- Bluetooth® LE Stack for easy communication with Smart Devices
- Wi-Fi Stack guarantees high data rates and IP based communication
- Proprietary stack developed for industrial and medical requirements

Interface

Different Interfaces available suiting every application:

- UART
- SPI
- I²C

Firmware Individualization

The best Wireless Solution for you

We align our standard firmware to your requirements which simplifies your production process.
You can choose between the following options:

Standard
A standard firmware with an update function.

Individualized Adaption
→ Adapted User Settings
→ Adapted Radio Parameters (i.e. RF power and RF channel)

Firmware Freeze
A firmware freeze guarantees a static behaviour of the module and no change in the module at all.

Pure Hardware
Get every module without WE Firmware to bring your own solution on it (remark the missing certifications).

Custom
A fully customized product with your dedicated application implemented on the module.

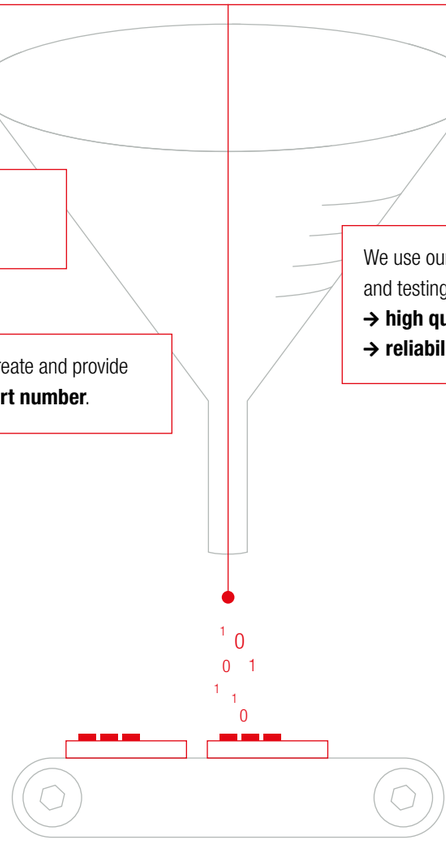
Thread | MIOTY | Zigbee | RS485 / CAN
Switch status | Bluetooth® Mesh | SPI / I²C
Application on the module | Sensor measuring | ...

Do you have a need for one of the mentioned customizations?
Get in contact with us. **We will find out, what fits best for you!**

We can **upload your** specific **firmware** to the modules

We use our proven programming and testing processes to ensure
→ **high quality** and
→ **reliability**

On top, we will create and provide you a **unique part number**.

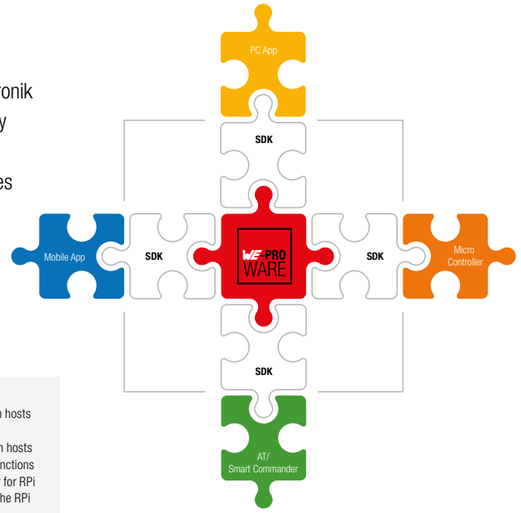


Software Development Kit

Software Development Kit

The SDK enables professional software integration of Würth Elektronik wireless modules into any host processors or operating systems by offering a set of drivers and sample applications.

- Typically as C-Files, for mobile Apps platform specific languages
- For comfortable coding of:
  - The HOST-controller system
  - PC Applications
  - Mobile Apps
- Code examples in Application notes and Manuals




```
/
├─ drivers.....................................Contains the code to be ported to custom hosts
│  ├─ gobal
│  │  ├─ global.h.........................Declares all functions to be defined on custom hosts
│  │  ├─ global.c.............................................Implements shared functions
│  │  ├─ globa _ ftdi.c.....................UART and GPIO of the FTDI USB driver for RPi
│  │  └─ global _ serial.c.................UART and GPIO of the serial interface of the RPi
│  ├─ ...
│  └─ Triton.....................................Command interface of the Triton module
│     ├─ Triton.h
│     └─ Triton.c
│     ...
├─ Example _ Triton.....................................Demo project using Triton module
│  ├─ main.c
│  └─ Example _ Triton.cbp
└─ ...
```

we-online.com/WCO-SDK

Example: Communication between Module A and Module B

Info	Module A	Module B
→ **Request** `CMD_BROADCAST_DATA_REQ:` Send "hello world"	02 06 0B 00 68 65 6C 6C 6F 20 77 6F 72 6C 64 2F	
← **Response** `CMD_DATA_CNF:` Request received, sending data now.	02 44 01 00 00 47	
← **Response** `CMD_TXCOMPLETE_RSP:` Data transmitted successfully.	02 44 01 00 00 47	
← **Indication** `CMD_DATA_IND:` Received hello world form a module with address 6C000001 with RSSI 0xC8(-56 dBm).		02 84 10 00 01 00 00 6C C8 68 65 6C 6C 6F 20 77 6F 72 6C 64 13

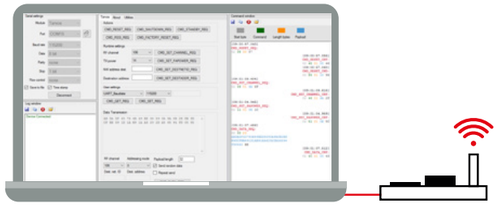
Info	Module A	Module B
→ **Request** `CMD_BROADCAST_DATA_REQ:` Send "hello world"		02 06 0B 00 68 65 6C 6C 6F 20 77 6F 72 6C 64 2F
← **Response** `CMD_DATA_CNF:` Request received, sending data now.		02 44 01 00 00 47
← **Response** `CMD_TXCOMPLETE_RSP:` Data transmitted successfully.		02 44 01 00 00 47
← **Indication** `CMD_DATA_IND:` Received hello world form a module with address 6C000002 with RSSI 0xC7(-57 dBm).	02 84 10 00 02 00 00 6C C7 68 65 6C 6C 6F 20 77 6F 72 6C 64 1F	

Software and Added Values

PC-Software

- For easy evaluation and test
- Smart Commander – RF-Modules
- AT Commander – Wi-Fi Products
- WENSS – GNSS Products
- ACC - FW Update and configuration

Download: Smart Commander
we-online.com/SmartCommander



Example: Smart Commander

Example: WENSS

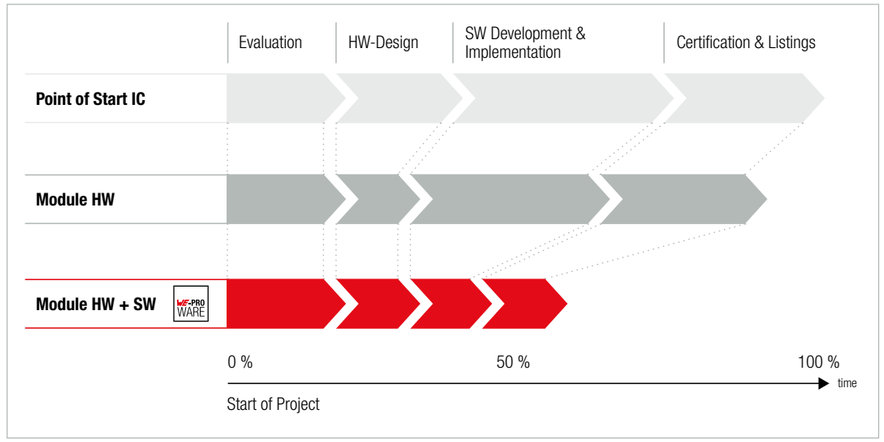
Added Values

In comparison there is big potential for saving time and money by using an RF-module instead of the single RF-IC.

With a pure HW-RF-module you can save HW-development ressources, since the required circuitry is completely included. An integrated antenna enables an easy integration, even with a minimum of RF knowledge.

The software integration and certification effort could be minimized if:

- FW available
- FW linked to module certification



Wireless Guide

How to find the suiting product?

This Wireless Guide will help you to find a solution for your application! Answer the following questions, as far as you can and with the information in the last pages, you will be able to take a decision.

1. Region

In which region will the application run or should be used in the future?

- ☐ Europe
- ☐ North America
- ☐ South America
- ☐ Asia
- ☐ worldwide
- ☐ other: _____

2. Range

What range do you need to cover in your application?

- ☐ 0 - 15 m
- ☐ 15 - 50 m
- ☐ 50 - 100 m
- ☐ 100 - 500 m
- ☐ 500 m - 2 km
- ☐ 2 km - 10 km
- ☐ >10 km

3. Environment

In which environment will your application be used?

- ☐ Indoor
- ☐ Outdoor
- ☐ Industrial
- ☐ Home Automation
- ☐ other: _____

4. Data

How much data has to be transmitted? Which data rate is required?

- ☐ Very low data rate (up to 1 kbps)
- ☐ Middle data rate (up to 100 kbps)
- ☐ High data rate (>100 kbps)
- ☐ Very high data rate (>500 kbps)

5. Energy

What about power consumption? How much energy is available? How long should a battery last?

- ☐ Long term battery powered
- ☐ Battery powered
- ☐ Main powered
- ☐ other: _____

6. Interface

Communication to…?

- ☐ Smart Device (Mobile, Tablet)
- ☐ PC, Server, etc.
- ☐ Device of own development
- ☐ Special communication interface (Wirepas, wM-Bus, CAN-Bus, …)
- ☐ Mesh (Wirepas, Bluetooth® Mesh, Closed Mesh)
- ☐ other: _____

Notes

REDEXPERT
www.we-online.com/redexpert

If there is any need of support:
Contact us!

www.we-online.com/wcs-support

more than you expect

Würth Elektronik eiSos GmbH & Co. KG
Max-Eyth-Str. 1
74638 Waldenburg
Germany

Wireless Sales
Support
Wireless Connectivity & Sensors

Phone: +49 651 99355-0
Wireless-sales@we-online.com
www.we-online.com/wcs-support

WIRELESS CONNECTIVITY

GNSS

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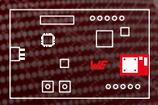
HIGHLIGHT

Our flexible locator



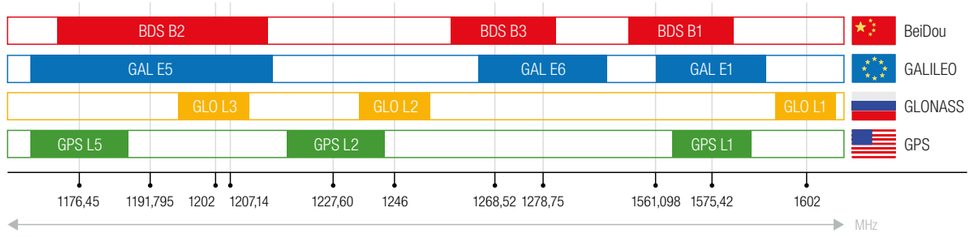
Evaluation Board

Introduction

GNSS

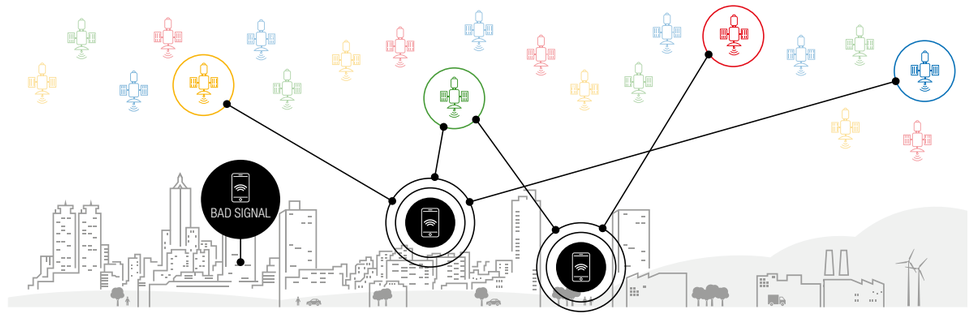
GNSS (Global Navigation Satellite System) is a system, which provides positioning and time synchronization capabilities to an unlimited number of users worldwide. The system is based on signals from the following four satellite constellations.

GNSS Frequency Bands



Signals from the different constellations can coexist on the same frequency bands. Each GNSS provides different signals and services over these frequency bands with different access policies. For example, open signals on the L1 frequency band are mostly used for civil commercial applications.

Beware of the environment



The application environment of the receiver plays an important role in the navigation, with best performance obtained in open-sky conditions. Presence of obstacles and multipath effects define a GNSS challenging environment (e.g. urban canyons), where the receiver has to work with fewer and weaker signals. This makes multi-GNSS even more decisive to the receiver's performance, since more satellites are available for tracking in a given area.

Areas of Application

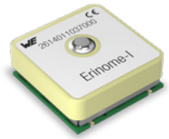
- ✔ Tracking and navigation devices
- ✔ Container localization
- ✔ Fleet management
- ✔ Location support for rescue
- ✔ Cartography
- ✔ Autonomous agricultural machines
- ✔ Geotagging for digital cameras
- ✔ Animal tracking
- ✔ Time reference for worldwide events/ machine synchronization

Product Overview

Elara-I

Elara-II

One of the smallest
GNSS modules on the market



Erinome-I

Erinome-II

Characteristics

Smallest GNSS module (Elara Series)

NMEA + OSP protocol

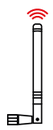
High update rate

Multi constellation

- Integrated / external antenna variants
- Multi-GNSS (+SBAS and QZSS) supported
- Unbeaten accuracy and time to first fix performances
- High update rate (up to 10 Hz)
- Low power modes
- UART, I²C and SPI interface
- EDA libraries
- Wireless Evaluation Board

Differences

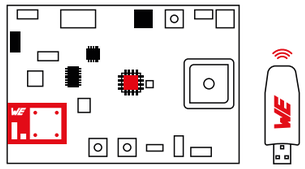
	Base Line		Advanced Line	
	Elara-I	**Elara-II**	**Erinome-I**	**Erinome-II**
Order Code	2613011037000	2613021137000	2614011037000	2614021137000
Onboard antenna	✔	-	✔	-
Dimensions [mm]	10 x 10 x 5.9	4.1 x 4.1 x 2.2	18 x 18 x 6.4	7 x 7 x 1.6
GNSS constellations supported	GPS GLONASS	GPS GLONASS	GPS GLONASS Galileo Beidou	GPS GLONASS Galileo Beidou
Accuracy [m]	1.5	1.5	1.5	1.5
Time To First Fix (cold start) [sec]	28	28	28	28
Max update rate [Hz]	5	5	10	10
Supply voltage [V]	1.8	1.8	3.3	1.8
Interfaces	UART, I²C, SPI	UART, I²C, SPI	UART, I²C, SPI	UART, I²C, SPI
GNSS chipset	SiRFstar V B01	SiRFstar V B01	SiRFstar V B02	SiRFstar V B02
High sensitivity	✔	✔	✔	✔



External Antenna Halimede-I

- Active GNSS antenna
- Power supply: 3 - 5 V
- SMA connector
- 3 meters cable
- GPS, GLONASS, Galileo, BeiDou
- IP66 - water resistant against powerful jets
- CE declaration
- ElektroG compliant (german Act Governing the Sale, Return und Environmentally Sound Disposal of Electrical and Electronic Equipment)
- Suitable for challenging GNSS environment

Our Flexible Locator: GNSS Evaluation



Evaluation Kit

For a better evaluation of our GNSS modules in the outdoor environment we have developed a special Evaluation Kit with our 2.4 GHz module Thyone-I.

Characteristics

Standalone - Adapted Thyone-I

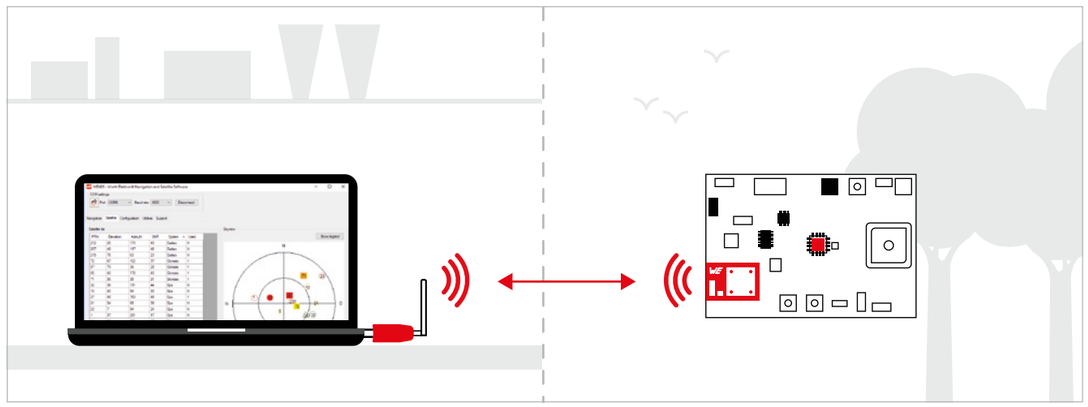
Wireless host connection

Flexible placement

Navigation Satellite Software - WENSS

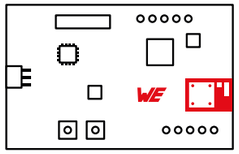
Wireless Operation of the GNSS Evaluation Board:

- ✔ The board provides several power options (USB, battery, external supply).
- ✔ Allows testing the GNSS module without cable connection between its evaluation board and the host PC.
- ✔ An adapted version of Thyone-I RF module is implemented. GNSS module is talking directly (without further µC) to Thyone-I.
- ✔ Messages coming from the GNSS module are delivered via UART to the Thyone-I module on the evaluation board.
- ✔ The Thyone-I module on the evaluation board broadcasts all arriving messages.
- ✔ Other Thyone-I units (e.g. our USB stick) in the area receive the messages.
- ✔ If these Thyone-I units are connected to a host PC, WENSS allows communicating with the GNSS module.
- ✔ Eval Board can be placed outside for evaluating in real conditions and the host is located indoor.



Added Values

Development Tools



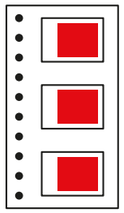
Eval Boards

- Easy testing
- Rapid prototyping
- FTDI integrated (UART to USB)
- Pins available on header
- Current measurement
- Evaluating different antenna variants (Elara-II, Erinome-II)
- Putting into operation

Overview: Eval Boards

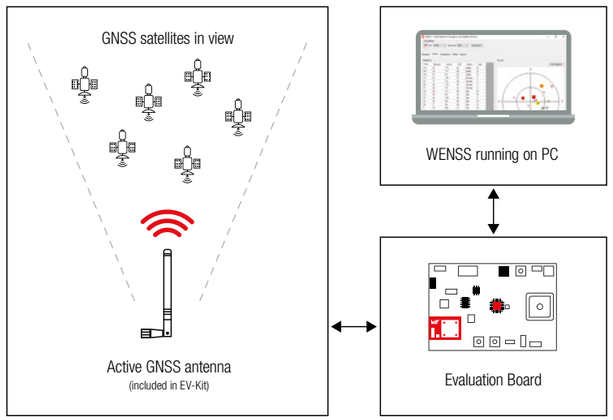
we-online.com/EVAL-GNSS

More information on page 108



Development Kit

- 3 GNSS modules on stock
- Delivery within 48 hours
- Hand soldering
- Ready to use



WENSS: Navigation and Satellite Software

- Proprietary, free-of-charge and user friendly PC tool
- Quick start
- Communication with the GNSS module from a host PC
- Testing module functionalities and features
- Understanding software protocols

Download: WENSS

www.we-online.com/wenss

AppNotes

ANR017 GNSS Antenna Selection

we-online.com/ANR017

ANR018 GNSS I²C Communication

we-online.com/ANR018

Software Development Kit

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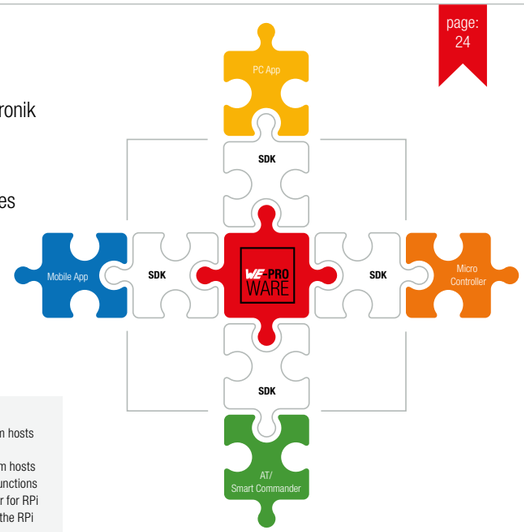
The SDK enables professional software integration of Würth Elektronik wireless modules into any host processor or operating system by offering a set of drivers and sample applications.

- Typically as C-Files, for mobile Apps platform specific languages
- For comfortable coding of:
  - The HOST-controller system
  - PC Applications
  - Mobile Apps
- Code examples in Application notes and Manuals




```
/
├ drivers.....................................Contains the code to be ported to custom hosts
│  ├ gobal
│  │  ├ global.h.....................Declares all functions to be defined on custom hosts
│  │  ├ global.c.....................................Implements shared functions
│  │  ├ globa _ ftdi.c.....................UART and GPIO of the FTDI USB driver for RPi
│  │  └ global _ serial.c.................UART and GPIO of the serial interface of the RPi
│  ├ ...
│  ├ Triton.....................................Command interface of the Triton module
│  │  ├ Triton.h
│  │  └ Triton.c
│  └ ...
├ Example _ Triton.................................Demo project using Triton module
│  ├ main.c
│  └ Example _ Triton.cbp
└ ...
```

we-online.com/WCO-SDK

Added Values

Antennas

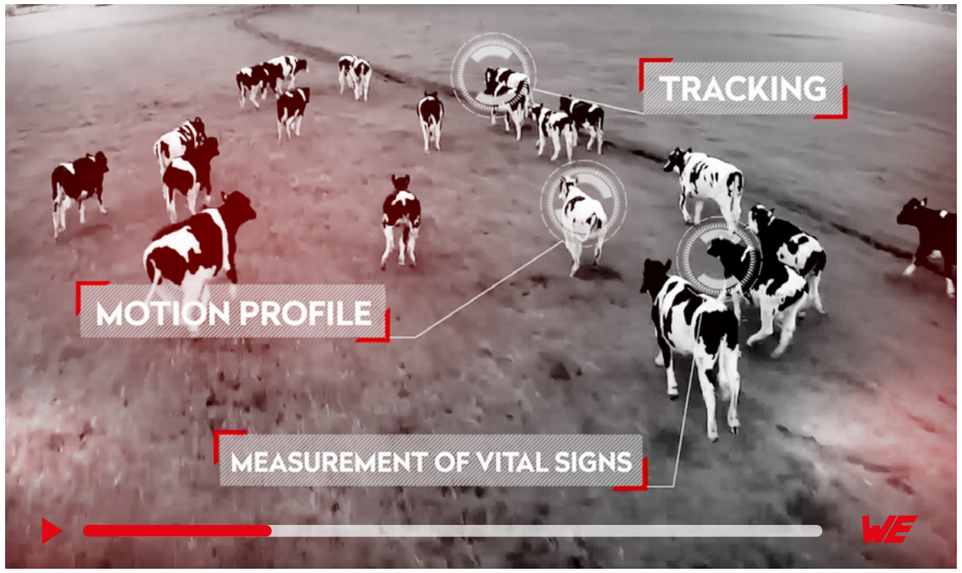
Libraries

Webinars

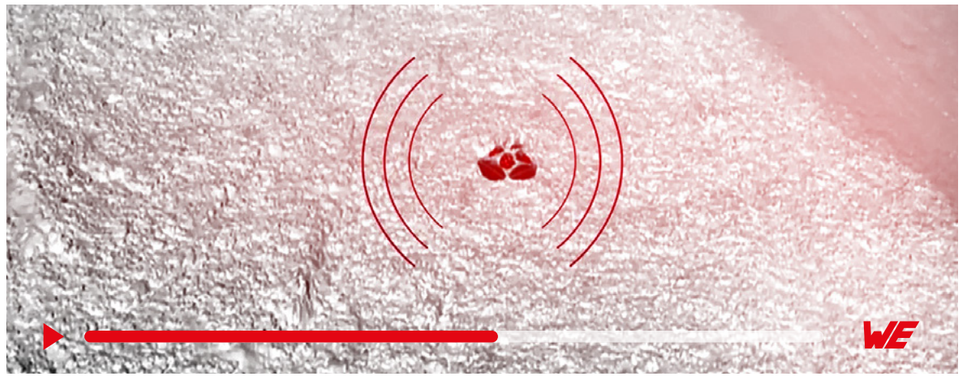
RedExpert

Webinar:
Basics of GNSS positioning and receivers' technology

Smart Farming



Smart Positioning



WIRELESS CONNECTIVITY

Bluetooth®

page: 43

HIGHLIGHT

Our Fastest

Proteus-III
Bluetooth® Low Energy 5.1 Standard
with 2 MBit PHY and Coded PHY (long range)

The Origin of the Name Bluetooth® – an Example of Harmonization of Different Languages

Surprisingly, the name dates back more than a millennia to King Harald “Bluetooth” Gormsson who was well known for two things: Uniting Denmark and Norway in 958 and uniting several languages. His dead tooth, which had a dark blue/grey color, earned him the nickname Bluetooth. That way, the Bluetooth-Logo was created out of the runes for H and B.

Nordic H Nordic B

As the aim of Harald was to unite countries and languages the aim of the Bluetooth® interface was to harmonise the communication between different electronic devices.

Bluetooth® – Harmonization of Interfaces

In 1996, three industry leaders, Intel, Ericsson and Nokia, met to plan the standardization of this short-range radio technology to support connectivity and collaboration between different products and industries.

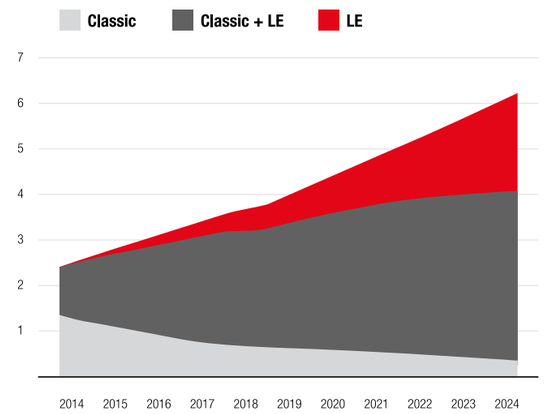
The Amount of Devices is rising steadily

With the success of Bluetooth® connectivity also the number of devices is rising steadily. In 2019 about 4 billion Bluetooth® devices were shipped worldwide. The early classic standard is decreasing while Bluetooth® Smart or also called Bluetooth® Low Energy is fast-growing. Bluetooth® can be found of course in every Phone, Tablet and PC. Connected Devices, Smart Building, Smart Industry, Smart Home and Smart City are the key markets for Bluetooth® Applications.

Bluetooth® as Industrial Communication Interface

Especially in the industry there is a need for easy connecting to different devices by Phone or Tablet. With no need of a display in the device itself, as the Smart Device is used for it, an immense potential of cost reduction is reachable.

Annual Bluetooth® Device Shipments by Radio Version



numbers in billions; Source: ABI Research, 2020

Standards and Versions

Bluetooth® Classic

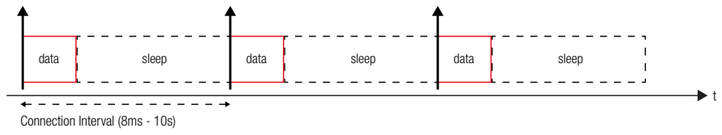
Bluetooth® Classic

- Introduced in Bluetooth® version 1.0
- Bluetooth® Classic versions are backward compatible
- 79 channels with 1MHz bandwidth (2.402 – 2.480 GHz)
- One master, up to 7 slaves
- Time (TDMA) and frequency (FHSS) synchronization done by master
- Slave may send data only if polled by master
- Last enhanced version 3.0. still available but not updated any more

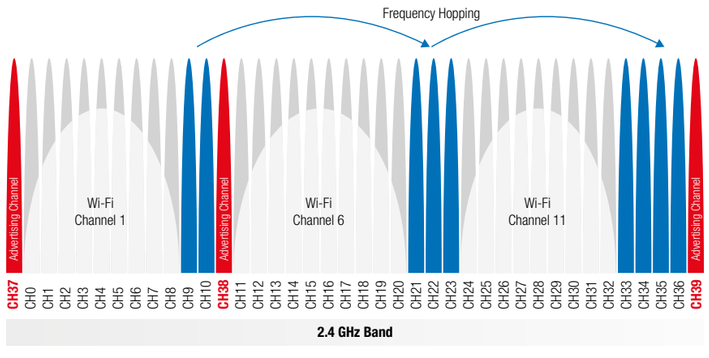
Bluetooth® Low Energy

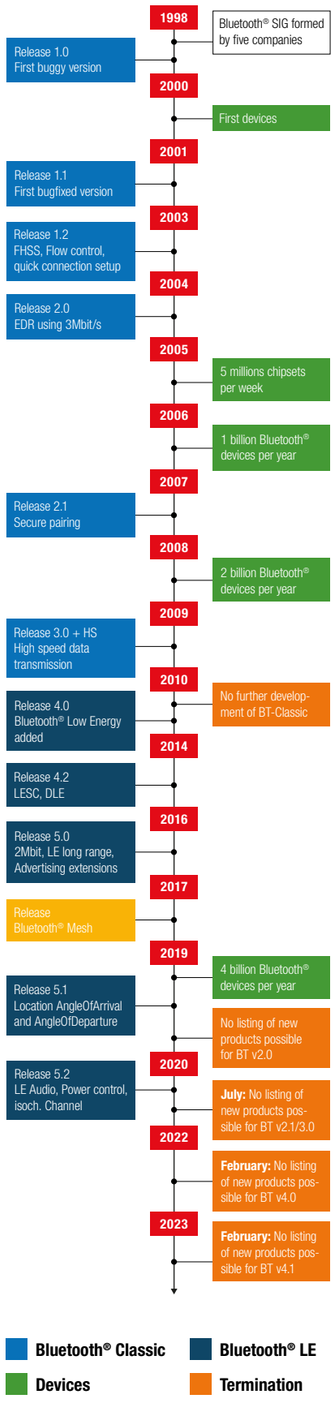
Bluetooth® LE

- Defined from Bluetooth® version 4.0 onwards
- Designed for IoT and battery operated applications
- Bluetooth® LE versions are backward compatible
- 40 channels with 2 MHz bandwidth (2.402 – 2.480 GHz)
- Lower transmitting power
- Mainly short connections (to save battery lifetime)
- Different application roles and profiles: Broadcaster, Observer, Peripheral, Central



Optimal Channel Utilization for simultaneous use of BLE and Wi-Fi





Bluetooth® Low Energy Versions

Bluetooth® LE 4.0

- First version of Bluetooth® LE
- Low energy as protocol stack specified
- 31 Bytes per radio data packet (→ low throughput)
- Output power lower than 10 mW (10 dBm)

Bluetooth® LE 4.1

- Better coexistence with 4G radio
- Optimisation of Bluetooth® LE behaviour through configurability of parameters (time interval for reconnection)
- Central and peripheral functions in one device
- New profiles, like IPSP (Internet Protocol Support Profile) for IPv6

Bluetooth® LE 4.2

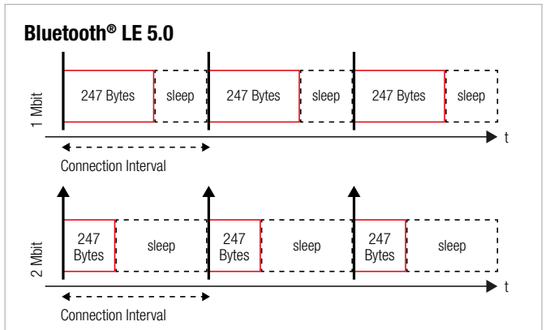
- (Optional) Data length extension (DLE) to support packets up to 255 Bytes (→ higher throughput)
- (Optional) Additional secure pairing modes (Low Energy Secure Connections - LESC)

All versions are downwards compatible.

Bluetooth® LE 5.0

- (Optional) Large advertising packets
- (Optional) New frequency hopping sequence for better coexistence
- (Optional) Increased maximum output power to 100 mW for higher range
- (Optional) 2 MBit/s phy data rate
- (Optional) Higher range due to LE Coded radio (Long Range mode)

Bluetooth® LE 5.0



doubled data rate → half transmission time, same throughput

Bluetooth® LE 5.1

- (Optional) Faster connection setup by GATT caching to save the discovery step
- (Optional) Advertising enhancements
- (Optional) Bluetooth® direction finding to detect the direction of a radio signal:
  - Angle of arrival (AoA) for item finding applications
  - Angle of departure (AoD) for indoor positioning applications

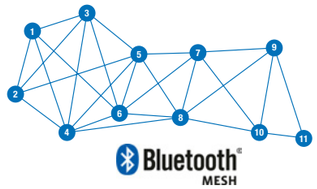
Bluetooth® LE 5.2

- (Optional) Enhanced Attribute Protocol Sharing radio sources of different profiles in one data packet
- (Optional) Adaptive power control to save power and reduce interference Monitor the RSSI and request the transmitter to reduce/increase its power
- (Optional) LE Isochronous Channels: allows the communication of time-bound data to one or more devices for time-synchronized processing discard data of radio packet after time to live (TTL)
- (Optional) New audio profiles (LE Audio)

Bluetooth® Mesh

What‘s a Mesh?

A Mesh is a network of multiple devices connecting to each other. The nodes connect directly to other nodes and there is no need of a master controlling the actions.

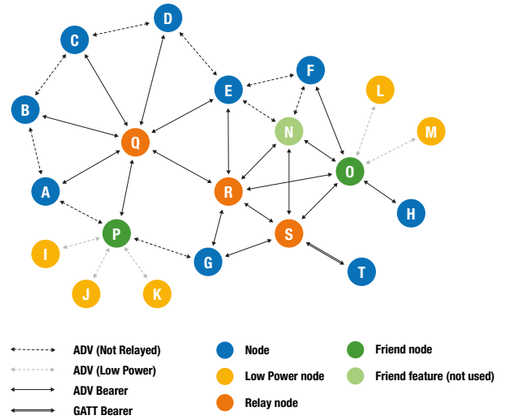


Bluetooth® Mesh

Bluetooth® released a Mesh Version in 2017. It is an own standard and strictly speaking not part of the Bluetooth standard. It uses Bluetooth® Low Energy link layer and radio and prefers Bluetooth® 5.0 or newer due to long advertising packets. As a flooding Mesh it includes time to live (TTL) in the messages. Security is approved by application key and network key.

How does it work?

The Network has nodes with different features. A node sends and receives data. Additionally there are relay nodes forwarding defined data. Special Low Power nodes are rarely active and only then send/receive data. The corresponding node is the Friend collecting data for the Low Power node. Only Low Power Nodes can be operated, since other nodes permanently receive and relay data.
Bluetooth® Low Energy devices (i.e. smart phones) can connect temporarily to push/pull data to/from the network. Nodes have to subscribe to groups to receive messages and publish to groups to transmit messages.



Mesh Models

Bluetooth® Mesh Models define basic functionality of nodes on a mesh network. Mesh Profile Specification defines foundation models used to configure and manage the network. Mesh Model Specification includes models defining functionality that is standard across device types. Those Models are: Generics (general functions), Timing, Lighting and Sensors.

Is a Bluetooth® Mesh the best Solution for my Scenario?

To sum it up, there are the following benefits and penalties in using Bluetooth® Mesh, which has to be considered:

\+ Extending the range by repeating messages, a self-healing network as there is the possibily of different routes of the messages make the Bluetooth® Mesh very useful.

– On the other hand it must be mentioned, that the performance of a Bluetooth® Mesh is quite poor. You could send 30 Bytes per 100 ms leading to a throughput of 2400 bps. Further, the Network must be installed by the end user himself, so technical knowhow is recommended. Furthermore each node has to be added to the network and provided with authentification and encryption keys which could make it time-consuming for the user.

Bluetooth® Special Interest Group (SIG)

Different Memberships

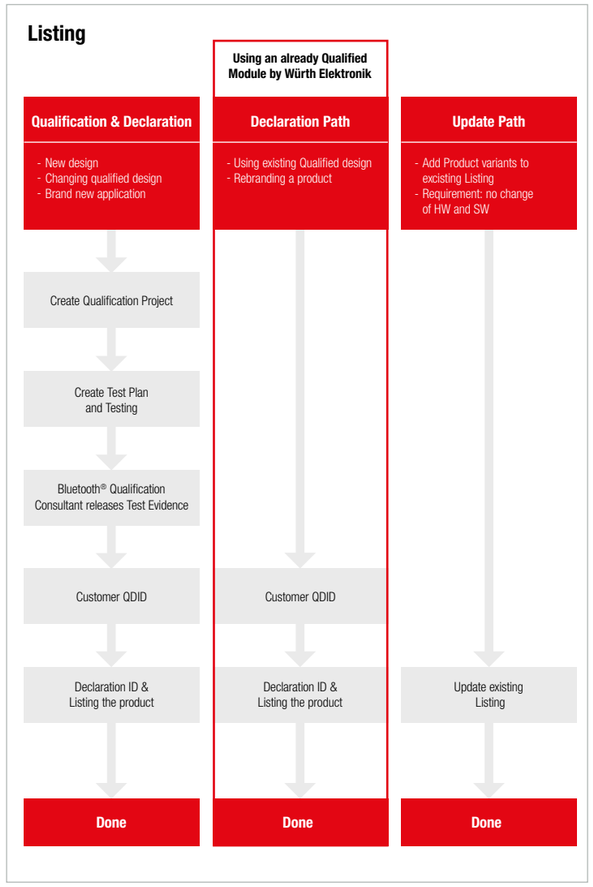
Promoter Members
Have considerable influence over both, the strategic and technological directions of Bluetooth® (Apple, Intel, IBM,…).

Associate Members
Get early access to draft specifications and are eligible to participate and gain a voting seat in working groups and committees. Furthermore, to work with other Associate and Promoter members on enhancing existing specifications.

Adopter Members
Use published Bluetooth® wireless specifications and Bluetooth trademarks.

Listing - Qualification and Declaration

- The Bluetooth® listing consists of qualification and declaration
- The qualification process is one of the most important aspects of Bluetooth technology, supporting interoperability and conformity to the Bluetooth® specifications.
- Bluetooth® Qualification Consultants (BQCs) are available to support members through the processes.
- Qualification means the whole process including tests and measurements.
- Members of the Bluetooth® SIG must complete the qualification and declaration process for their Bluetooth® enabled product to demonstrate and declare compliance.
- The distributor is responsible to ensure that the required listing is performed.
- A Listing is possible, if an already qualified product is used. Then there is no measuring or testing effort, only declaration and information work to be done.



Reasons for Bluetooth® in Industry

- ✓ Smart and innovative
- ✓ Robust and open communication
- ✓ Use smart device as display
- ✓ Worldwide common standard

Product overview

			
	Proteus-I	**Proteus-II**	**Proteus-III**
Order Code (PCB Antenna)	2608011024000	2608011024010	2611011024000*
Order Code (RF-Pad)	2608011124000	2608011124010	
Chipset	nRf52832		nRf52840
Bluetooth® Standard	4.2	5.0	5.1
Output Power [dBm]	4		8
Power Consumption Rx [mA]	5.4		7.7
Power Consumption Tx [mA]	7.5		18.9
Power Consumption Sleep [µA]	0.4		0.4
Supply Voltage min - max [V]	1.8 - 3.6		
op. Temp [°C]	-40 … +85		
Max Datarate [Mbps]	1	2	2
Payload [byte]	243	964	964
measured Throughput [kbps]	80	257	343
Antenna (PCB, RF-Pad, SAS*)	PCB / RF-Pad		SAS*
Long range Mode	-		✔
LoS Range (Int / ext. Antenna) [m]	50 / 100		100 / 400
LoS Test Conditions	2 m height		
Interface	UART		
SPP-like Profile	✔	✔	✔
USB-Radio Stick	-	✔	✔
FOTA	✔	✔	✔
Additional GPIO	-	-	6
Certification	CE, FCC, IC, ARIB		

* SmartAntennaSelection

Proteus Connect

The most important benefit of Bluetooth® LE Connections is mostly a mobile app. With the Proteus-App we provide you a fast and easy way of testing and also a base for your own app.

- Smart-Device Mobile App for easy testing for Android and iOS
- Scan – Connect – Transmit Commands directly
- Development files available on GitHub
- Built your own App on base of Proteus-App

we-online.com/Proteus-App

GET IT ON Google Play

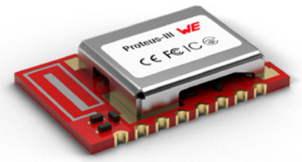
coming soon

Download on the App Store

GitHub

Our Fastest: Bluetooth® Low Energy 5.1

WÜRTH ELEKTRONIK



Proteus-III

Bluetooth® Low Energy 5.1 Standard with 2 MBit PHY and Coded PHY (long range)

Bluetooth®

NORDIC SEMICONDUCTOR

Characteristics

Security & Encryption | 4x High troughput | Long range | Smart antenna selection

- Bluetooth® 5.1 qualified end product
- Nano SIM size - 8 x 12 x 2 mm
- ARM® Cortex®-M4 32-bit processor with FPU, 64 MHz
- Nordic Semiconductor SoC nRF52840
- 1 MB flash memory, 256 kB RAM
- Up to 8 dBm output power for higher range
- 1 Mbit and 2 Mbit radio and long range modes
- High throughput mode, 4 times higher throughput with payload size of up to 964 bytes
- Scan and Connect in long range mode
- Improved throughput with transparent UART interface (Peripheral only mode)
- Serial data transmission (Smart Serial Profile)
- LE Secure Connections (LESC)
- Connect (1:n / n:1) as central or peripheral
- 6 configurable digital GPIOs (local & remote)
- Smart antenna selection (2-in-1 Module)
- Also available as proprietary radio module (Thyone-I)
- CE, FCC, IC, ARIB certification

Data sheet: Proteus-III
we-online.com/SPEC/Proteus-III

Manual: Proteus-III
we-online.com/Man/Proteus-III

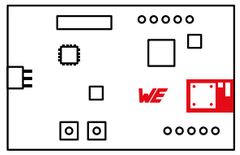
Manual: Eval Board
we-online.com/Man/EVAL-Proteus-III

Manual: USB radio stick
we-online.com/Man/USB-Proteus-III

Webinar:
Bluetooth® LE - new adaptions

Added Values

Development Tools

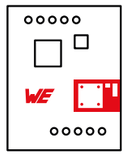


Eval Boards

- Easy testing
- Rapid prototyping
- FTDI integrated (UART to USB)
- Pins available on header
- Current measurement

Overview: Eval Boards
we-online.com/EVAL-BLE

More information on page 108



Mini Eval Boards

- Application-oriented, cost-effective and compact size
- USB connection with FTDI-cable possible (available as accessory)

Overview: Mini Eval Boards
we-online.com/EVAL-BLE

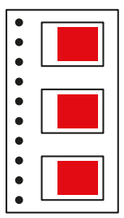
More information on page 108

USB-Radio Stick

- USB-FTDI-Proteus-III
- Bluetooth®-Listing included

Overview: USB-Radio Sticks
we-online.com/USB-BLE

More information on page 108



Development Kit

- 3 single modules
- On stock
- Delivery within 48 hours

Smart Commander

- PC-Tool for easy testing
- AT-Commands as buttons
- Monitoring UART-Communication
- Export Commands for easy integration in the former HOST-Controller
- Test Bluetooth®-App-Connectivity easily

we-online.com/SmartCommander

AppNotes

Proteus: Low Power Application With Periodic Wake-Up
we-online.com/ANR003

Proteus: How To Use The Peripheral Only Mode
we-online.com/ANR004

Proteus: High Throughput Mode
we-online.com/ANR006

Proteus Quickstart: Connect a smart phone to a Proteus
we-online.com/ANR014

Proteus-III: Advanced Developer Guide
we-online.com/ANR009

Proteus-III: Remote GPIO control – How To
we-online.com/ANR020

Software Development Kit

page: 24

The SDK enables professional software integration of Würth Elektronik wireless modules into any host processor or operating system by offering a set of drivers and sample applications.

- Typically as C-Files, for mobile Apps platform specific languages
- For comfortable coding of:
  - The HOST-controller system
  - PC Applications
  - Mobile Apps
- Code examples in Application notes and Manuals

```
/
├─ drivers.....................................Contains the code to be ported to custom hosts
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│  │  ├─ global.h.....................Declares all functions to be defined on custom hosts
│  │  ├─ global.c.....................................Implements shared functions
│  │  ├─ globa _ ftdi.c.....................UART and GPIO of the FTDI USB driver for RPi
│  │  └─ global _ serial.c.................UART and GPIO of the serial interface of the RPi
│  ├─ ...
│  ├─ Triton.....................................Command interface of the Triton module
│  │  ├─ Triton.h
│  │  └─ Triton.c
│  └─ ...
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│  └─ Example _ Triton.cbp
└─ ...
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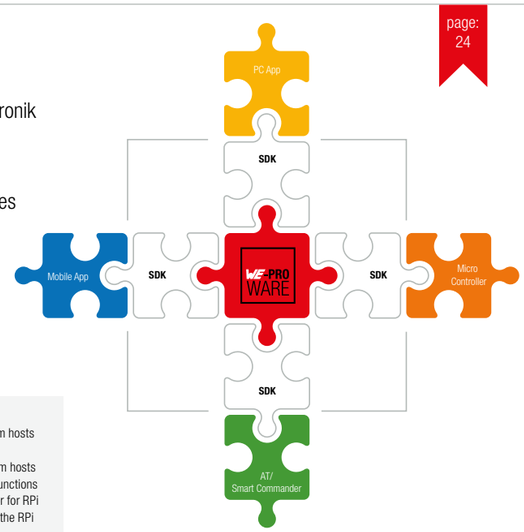


we-online.com/WCO-SDK

Added Values

Antennas

Libraries

Webinars

RedExpert

Applications

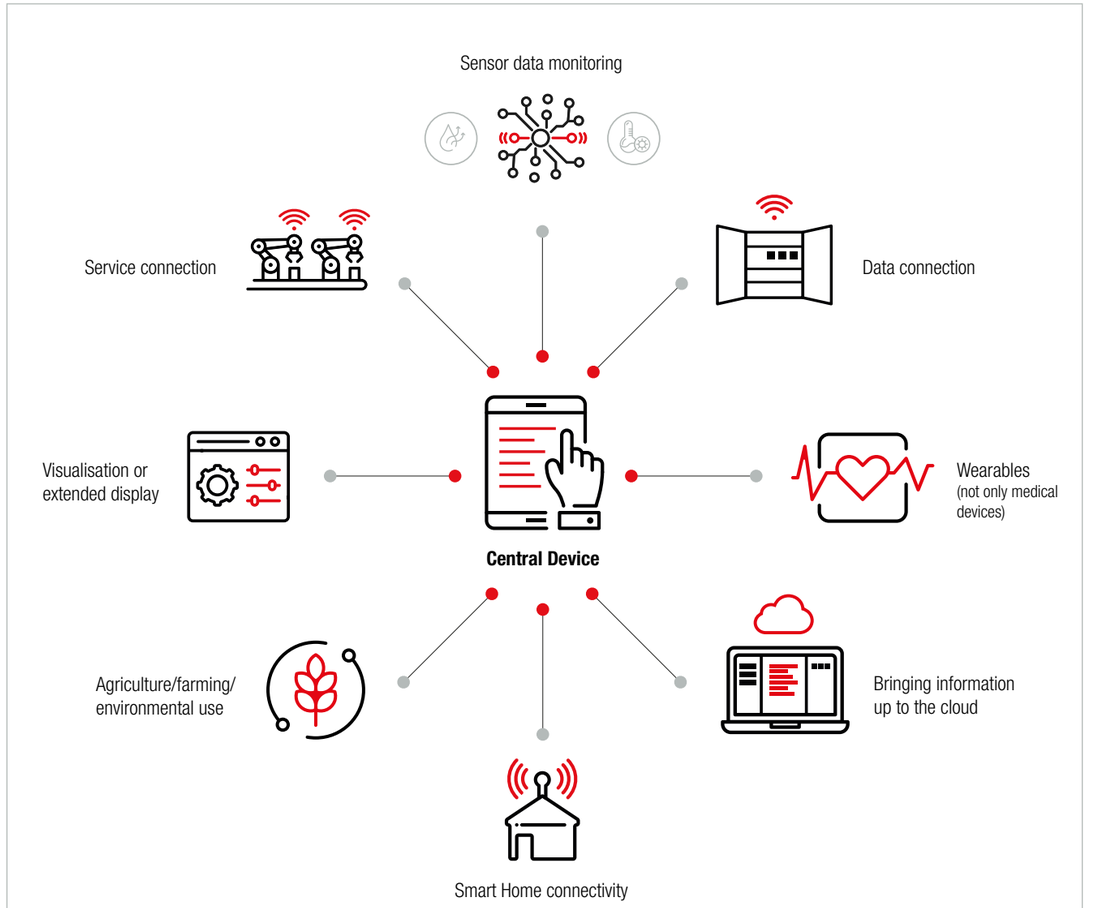
How to save Time and Money with Bluetooth® LE

The task is as simple as extensive. Configurating a machine mounted inaccessible i.e. at the roof. The service technician had to connect by wire to it to set parameters or recalibrating the system after changing parts of it. Therefore the whole machinery had to be stopped so that a ladder or stand could be placed there. If several devices received a service, the machinery couldn't work for hours. The procedure was inefficient, expensive and also somehow dangerous for the technician.

With a standard tablet using Bluetooth® LE Serial Connection the former used cable could be removed and time and cost could be used much more economical. No ladder or stage needed, stopping the machine is unnecessary, configuring different machines at the same time and getting more information about the state of the system adds up to a much faster service. Thus means saving time and money!

More Ideas

Bluetooth® LE can be the solution in plenty of scenarios. Here you find a few examples:



WIRELESS CONNECTIVITY

Wi-Fi

page: 52

HIGHLIGHT

Our Networker

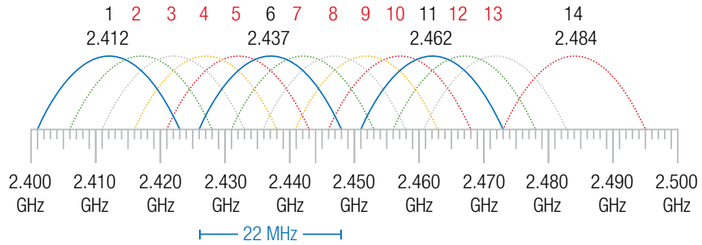
Calypso
Fully featured standalone Wi-Fi module
IEEE 802.11 b/g/n, 2.4 GHz

Wi-Fi - an Overview

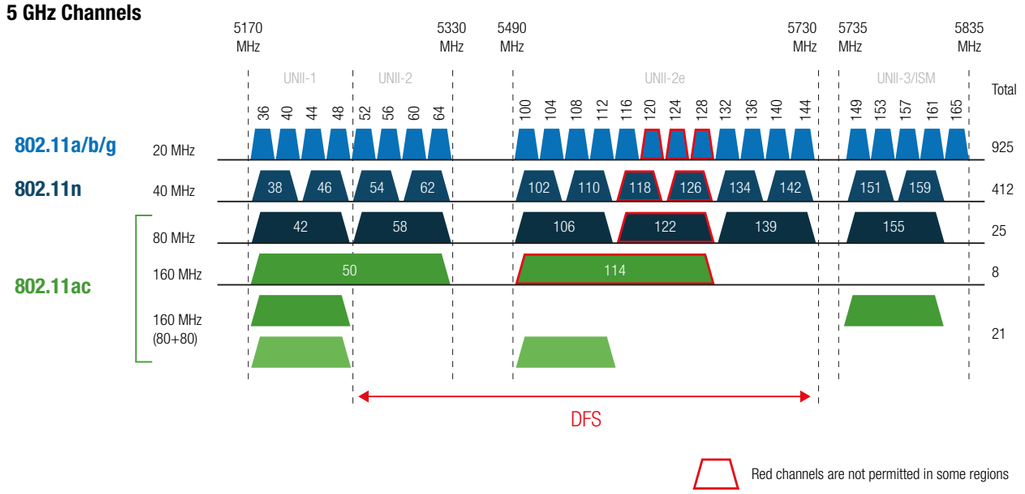
Wireless LAN - Wi-Fi
Wi-Fi is a family of wireless network protocols, based on the IEEE 802.11 family of standards, which are commonly used for local area networking of devices and Internet access. Wi-Fi is a trademark of the non-profit Wi-Fi Alliance, which restricts the use of the term Wi-Fi Certified to products that successfully complete interoperability certification testing.

Versions – old and new Notations (view also Table besides)
The different versions of Wi-Fi are specified by various IEEE 802.11 protocol standards, with the different radio technologies determining radio bands, and the maximum ranges, and speeds that may be achieved. Wi-Fi most commonly uses the 2.4 gigahertz and 5 gigahertz radio bands; these bands are subdivided into multiple channels (see figures below). Channels can be shared between networks but only one transmitter can locally transmit on a channel at any moment in time.

2.4 GHz Channels



5 GHz Channels



Wi-Fi 1	■ 1999 ■ IEEE 802.11 b ■ 2.4 GHz ■ 11 Mb/s
Wi-Fi 2	■ 1999 ■ IEEE 802.11 a ■ 5 GHz ■ 54 Mb/s
Wi-Fi 3	■ 2003 ■ IEEE 802.11 g ■ 2.4 GHz ■ 54 Mb/s
Wi-Fi 4	■ 2009 ■ IEEE 802.11 n ■ 2.4 / 5 GHz ■ 150 Mb/s
Wi-Fi 5	■ 2013 ■ IEEE 802.11 ac ■ 5 GHz ■ 3.5 Gb/s
Wi-Fi 6	■ 2018 ■ IEEE 802.11 ax ■ 2.4 / 5 GHz ■ 9.6 Gb/s

Range and Power

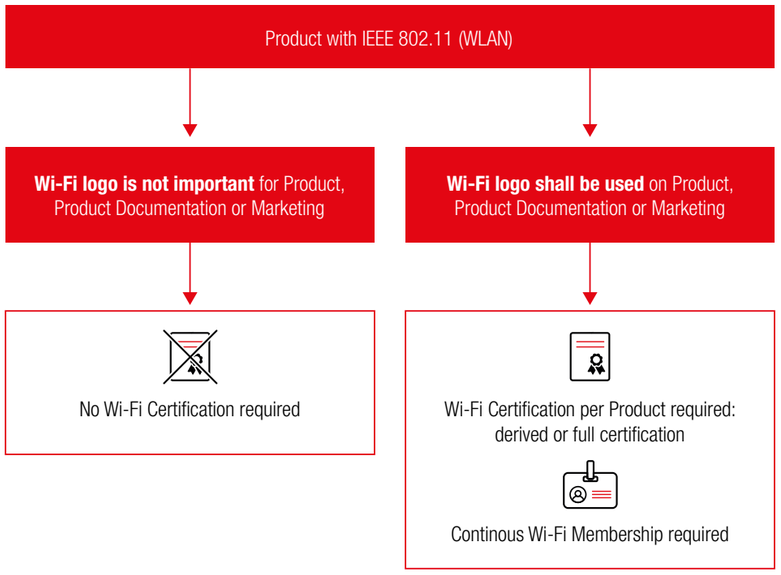
Wi-Fi's wavebands have relatively high absorption and work best for line-of-sight use. Many common obstructions such as walls, pillars, home appliances, etc. may greatly reduce range, but this also helps minimize interference between different networks in crowded environments. An access point (or hotspot) often has a range of about 20 metres indoors while some modern access points claim up to a 150-metre range outdoors. Over time the speed and spectral efficiency of Wi-Fi have increased. As of 2019, at close range, some versions of Wi-Fi, running on suitable hardware, can achieve speeds of over 1 Gbit/s (gigabit per second).

Connection

There are two modes in which Wi-Fi networks can operate. In the infrastructure mode, an access point acts as a central entity serving several connected clients. To connect to such a Wi-Fi network, a user typically needs the network name (the SSID) and a password. The password is used to encrypt Wi-Fi packets to block eavesdroppers. Wi-Fi Protected Access (WPA) is intended to protect information moving across Wi-Fi networks and includes versions for personal and enterprise networks.

The Wi-Fi direct mode offers a point-to-point connection without the need for a central entity.

Wi-Fi Certification



Description of the OSI/ISO Model

The Open Systems Interconnection model (OSI model) is a conceptual model that characterizes and standardizes the communication functions of a telecommunication or computing system without regard to its underlying internal structure and technology. Its goal is the interoperability of diverse communication systems with standard communication protocols.

The model partitions the flow of data in a communication system into seven abstraction layers. Each intermediate layer serves a class of functionality to the layer above it and is served by the layer below it. The OSI model was developed starting in the late 1970s to support the emergence of the diverse computer networking methods that were competing for application in the large national networking efforts in France, the United Kingdom, and the United States. In the 1980s, the model became a working product of the Open Systems Interconnection group at the International Organization for Standardization (ISO).

The OSI Model (Open Systems Interconnection)

OSI Model				WE Wi-Fi Module Calypso
Application	7	Provides services/protocols to applications	FTP services	**Application** - DHCP, SNTP, Ping - MQTT, HTTP(s)
Presentation	6	Data formatting, i.e. ANSI Compression/Encryption	ANSI	
Session	5	Controls conversations/Sessions (Dialog. Control) Integrity and Reliability Descriptive naming		
Transport	4	Fragmentation/Sequencing of data Reliable delivery Error recovery Flow Control Muliplexing (PORTS)	Ports Transparent data services Some Firewalls	**Transport** - TCP/UDP - SSL/TLS
Network	3	End to end delivery Logical addressing Fragmentation/Sequencing for MTU Routing	Routers	**Network** - IPv4 - IPv6
Data-Link LLC / MAC	2	Physical addressing Error detection (FCS/CRC) Acknowledgements Packet/Frame header and trailer bridging	Bridges or switches NIC Drivers	**MAC** - IEEE 802.11 b/g/n
Physical	1	Media interface Transmission method Signal strength Topology	Hubs Network Cards	**Physical** - IEEE 802.11b – 1/2 Mbps (DSSS) + 5.5/11 Mbps (CCK) - IEEE 802.11g – 6-54 Mbps (OFDM) - IEEE 802.11n – MCS0-MCS7 (20 MHz BW, 1 spatial stream)

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Our Networker:
Wi-Fi 2.4 GHz

Calypso

Fully featured standalone Wi-Fi module
IEEE 802.11 b/g/n, 2.4 GHz

Wi Fi CERTIFIED

Characteristics

Security and encryption

Global availability 2.4 GHz licence free band

Wi-Fi direct

Smart antenna selection

- Wi-Fi module based on ti – CC3220 SF wireless MCU
- Stand-alone operation
- On-board Wi-Fi stack
- On board TCP/IP protocol stack supporting IPv4 and IPv6
- AT style command interface
- Primary interface to host – UART
- 16 simultaneous transport layers sockets including up to 6 secure (SSL/TLS) sockets
- Industrial temperature range: -40 °C up to +85 °C
- Sleep current <10 µA
- Low power operation to support battery operated applications
- Extreme High Speed UART up to 3 Mbps
- Output power +18 dBm peak (1DSSS)
- Sensitivity -92 dBm (1DSSS, 8% PER)
- Form factor: 19 x 27.5 x 4 mm
- Edge castellated connections
- Multiple connections

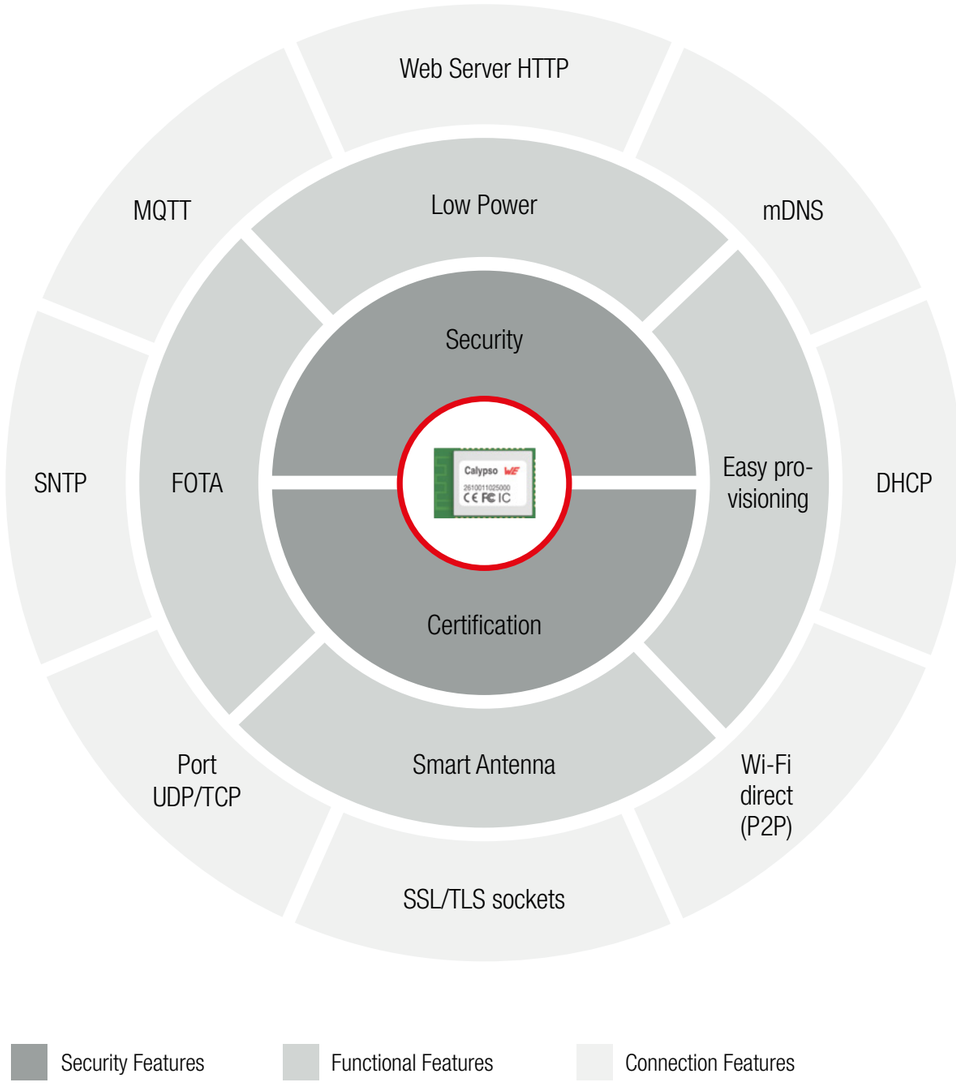
Product video

Calypso Wi-Fi Radio Module for Industrial Applications

bit.ly/WE_Calypso

Development tools

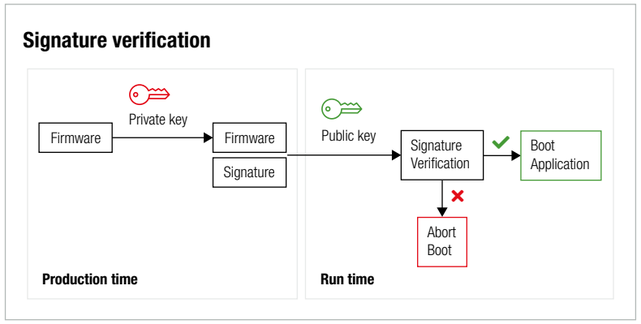
Evaluation-Board	Software-Development Kit	User Friendly Manuals and App-Notes



Security Features

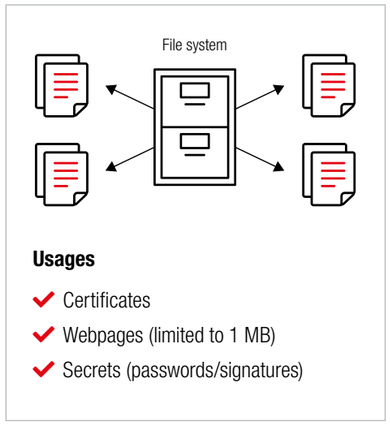
Secure Boot

- Würth Elektronik eiSos certificate stored in FLASH as standard
- Boot loader checks firmware before launching it
- Ensure it's signed by Würth Elektronik eiSos
- Prevents malware from hijacking your boot process



Secure Storage for User Data

- Encrypted file system on FLASH
- Created on first boot-up
- Failsafe
- AT-commands to operate the file system
- Secure storage of SSL/TLS certificates, other keys and secrets



Usages

- ✔ Certificates
- ✔ Webpages (limited to 1 MB)
- ✔ Secrets (passwords/signatures)

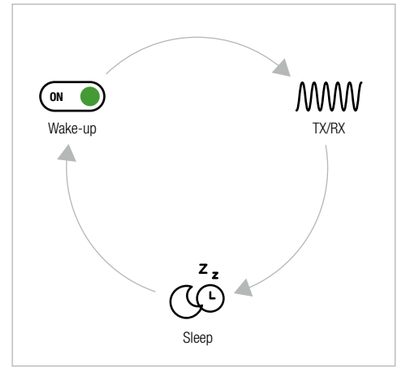
Security

- Good basis for secure end application:
  - Wi-Fi security - WPA2
  - Secure boot
  - Secure storage
  - Secure socket
  - Hardware accelerated crypto engine
  - Software tamper detection
- Nevertheless and finally, **the user determines end product security**

Functional Features

Low Power Operation

- Power-optimized out of the box: the included firmware makes sure, that all functions are optimized to low power consumption
- Single command: AT + sleep=<sleep period>
- Wake up:
  a) on time-out or
  b) rising edge on Wake-up pin
- Sleep current of only 5.5 µA
- Fast connect: from SLEEP to CONNECTED in ~250 ms



Smart Antenna Selection

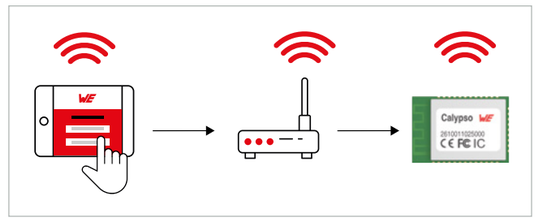
Calypso's smart antenna configuration enables the user to choose between two antenna options:

On-board PCB antenna
The Calypso has an on-board PCB antenna optimized for operation in the 2.4 GHz band. A simple short between the pins *RF* and *ANT* feeds the RF output of the module to the onboard antenna. In this configuration, the module does not require any additional RF circuitry.

External antenna
For applications that use an external antenna, the Calypso provides a 50Ω RF signal on pin *RF* of the module. In this configuration, pin *ANT* of the module has to be connected to ground and pin *RF* to the external antenna via 50Ω feed line.

Firmware Over The Air Update (FOTA)

- Update of firmware over the wireless network
- Pin triggered: physical access security
- Secure – HTTPS and signed image: malware cannot be uploaded
- Failsafe: module can always be put into factory settings



Provisioning

- Bring the device into an existing Wi-Fi network
- In field device configuration
- Access Point mode
- Host triggered (pin/command from host)
- Web-interface – Platform independent

Connection Features

Calypso Wi-Fi Direct (P2P)

- Peer-to-Peer without infrastructure
- Group-owner or client roles
- Auto device discovery
- Not battery optimized

Hypertext Transfer Protocol (HTTP)

The Hypertext Transfer Protocol (HTTP) is an application layer protocol for distributed, collaborative, hyper-media information systems. It works based on a client-server mechanism where the server responds to requests from the client. HTTP running on top of a secure transport (SSL/TLS) is referred to as HTTPS.

- HTTPS server on module for provisioning and OTA
- Customer specific webpages possible:
  – Limited storage for http server onboard
  – Easy to change the existing page by replacing logo, device name and company name in the provided file
- HTTPS client implementation over AT commands
- All standard request methods supported (Get, Put, Post, Delete)
- Root Certificate Authorities (CA) catalog for HTTPS onboard

Transport Layer Security (TLS) vs. Secure Sockets Layer (SSL)

Transport Layer Security (TLS), and its now-deprecated predecessor Secure Sockets Layer (SSL) are cryptographic protocols designed to provide communications security over a computer network. The TLS protocol aims primarily to provide privacy and data integrity between two or more communicating computer applications. When secured by TLS the connection has the following properties:

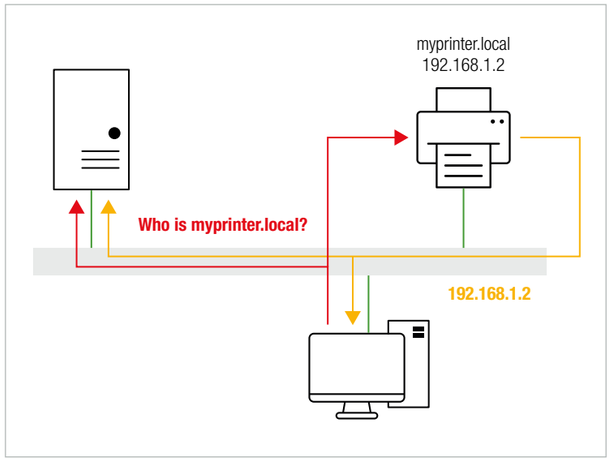
- The connection is private (encrypted by unique session key)
- The identity of both the communicating parties have been authenticated
- The message integrity guaranteed

Calypso supports SSL and TLS1.2

Multicast DNS

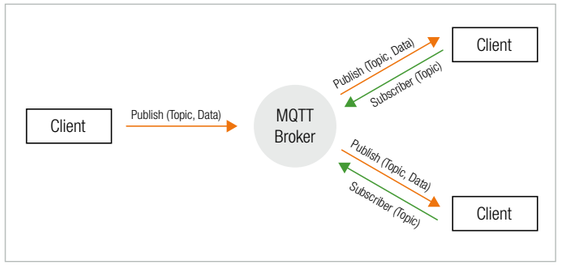
The mDNS protocol resolves hostnames to IP addresses in small networks that do not have a central name server. mDNS clients that needs to resolve a hostname send IP multicast query messages that asks for hosts having that name. The host then multicasts the IP address.

Calypso supports mDNS and advertises the webpage by default.



MQTT on Module

- MQTT – Message Queuing Telemetry Transport
- Lightweight application layer protocol
- For connections with remote locations (typically M2M) where:
  – A „small code footprint“ is required or
  – The network bandwidth is limited
- Calypso implements MQTT client:
  – Offers Publish/Subscribe mechanism
  – Runs on top of TCP/TLS
- Suitable for low-power, low-bandwidth applications
- Used extensively in M2M, IoT applications



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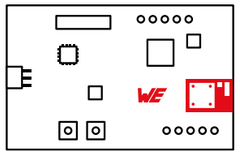

Eval Boards

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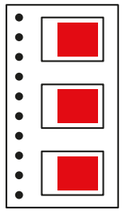
Overview: Eval Boards

we-online.com/EVAL-WiFi

More information on page 108



Development Kit

- 3 radio modules on stock
- Delivery within 48 hours
- Hand soldering (Edge castellation)
- Ready to use

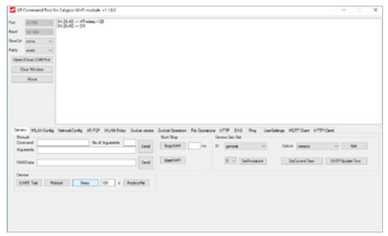
FeatherWing

- Adafruit standard
- Easy connectable
- For complex system tests

More information on page 106

AT Commander

- Complete control of module over UART
- ASCII based “Human readable” commands
- Intuitive request/response/event mechanism
- PC tool for quick prototyping “AT Commander Tool”



Download: AT Commander

we-online.com/AT-Commander

AppNotes

Calypso IoT Application Based On Calypso Module

we-online.com/ANR007

Wireless Connectivity Software Development Kit (SDK)

we-online.com/ANR008

Software Development Kit

page: 24

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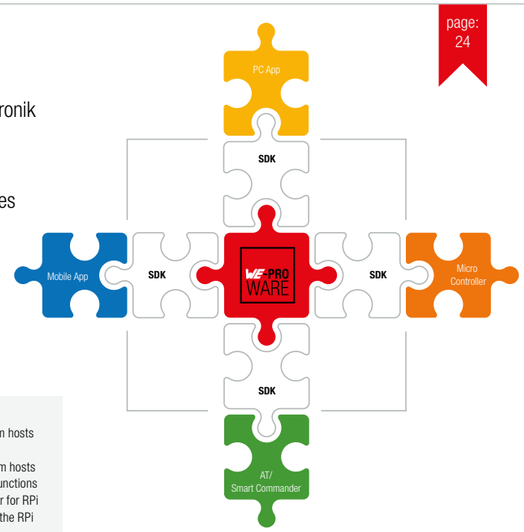


we-online.com/WCO-SDK

Added Values

Antennas

Libraries

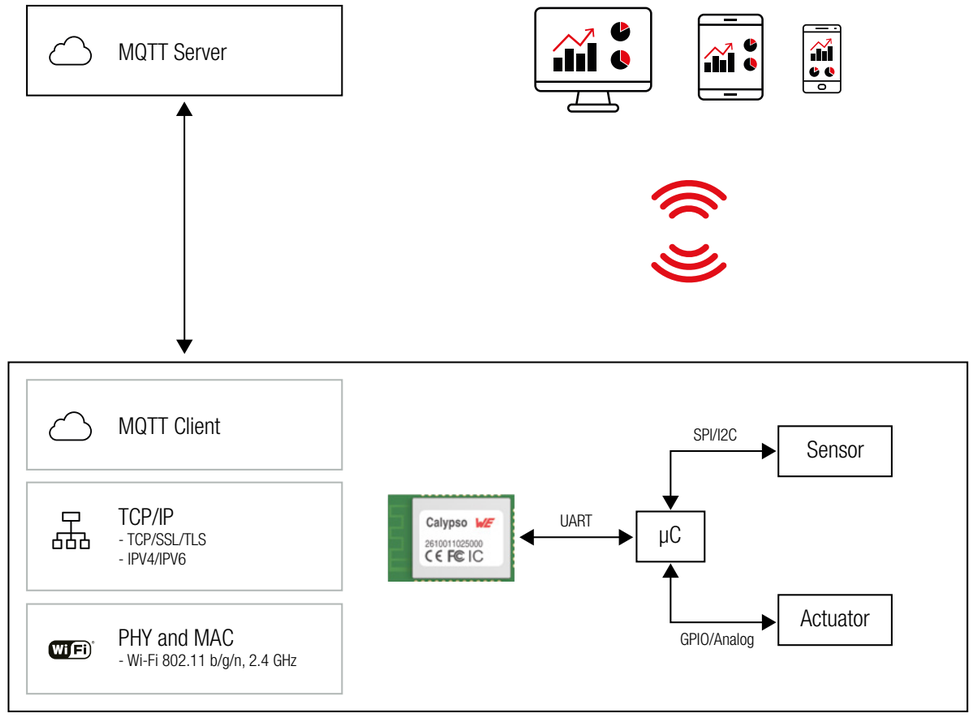
Webinars

RedExpert

User Application

IoT for Smart Machinery

With Wi-Fi application machine data could be sent easily. By using MQTT only the data has to be collected and sent to the Wi-Fi Module. Calypso organizes the packaging and serves as a MQTT Client. The Server or Broker gets the information and could organize it. With easy access over Internet or Intranet generated charts, figures or tables could be shown easy and with little effort in creating and maintenance of a data base.



Easy Interface to Cloud Platforms

- Online platform usable
- Keeping data on own server also possible

Interoperability using Standard TCP/IP

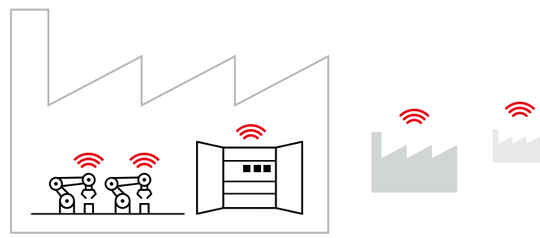
- On multiple devices with a standard PC, Tablet or Smartphone
- Normal browser usable
- No app has to be developed

Human Machine Interface

- Analysing production output figures
- Creating charts for increasing efficency

Machine Data

- Various machines
- From variable buildings, in diverse locations and even different countries



WIRELESS CONNECTIVITY

Proprietary

page: 68

HIGHLIGHTS

Our Strongest

Tarvos-III
Radio Module 868 MHz
Low Power Long Range

Thebe-II
Radio Module 868 MHz
High Power Ultra Long Range

Our Smallest

Thyone-I
Radio Module 2.4 GHz
High Throughput

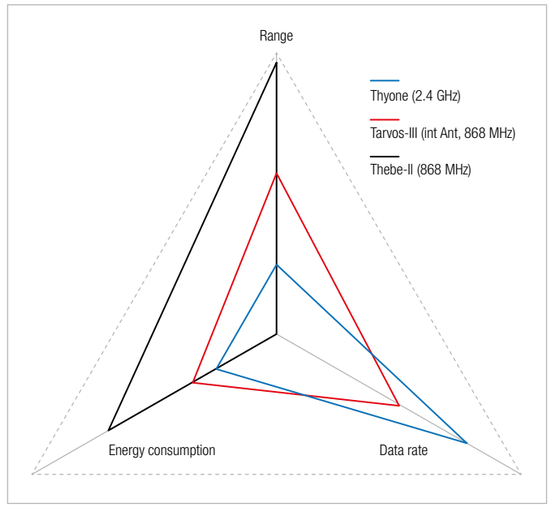
Introduction

Proprietary Radio Stack - Introduction and Explanation

Proprietary systems are closed systems that enable communication between each other. Communication with participants for whom the protocol is unknown is not possible. A proprietary radio system is always suitable if the transmitters exchange data with each other and no interface to a standard HMI is provided.

The radio frequency spectrum is regulated by designated regulatory authorities that define how specific spectrum bands can be used. The ISM (Industrial, Scientific and Medical) and SRD (Short Range Device) bands are free to use without license costs. As there is no single worldwide regulation, national authorities define which of the frequency bands are open for access in each specific country.

Furthermore in the proprietary radio no standard protocols are mandatory. Everybody can use individual firmware within the regulations of the frequency bands (output power, duty cycle, …). The correlation between data rate, range and battery life could be arranged individually.



Advantages

- Security due to closed system
- More flexibility compared to standard
- More scope for design
- No dependences
- No umbrella organization
- No license fees

Areas of Application

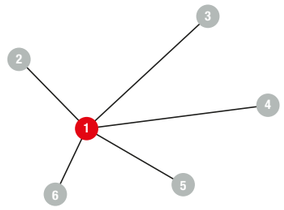
Machine to Machine	(Home) Automation	Wireless Sensor Networks
Internet of Things (IoT)	Monitoring / Control	Medical

... and many others

Network topologies

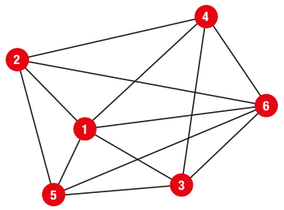
Point to Point

Point to point topology is the type of network topology which is used to connect to network nodes directly with each other through some link. In between these two nodes, the data is transmitted using this link.



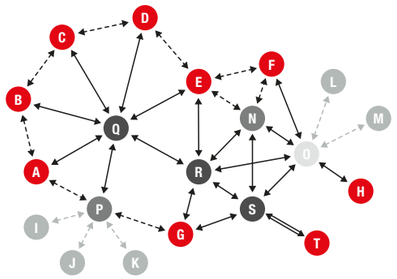
Star

In a star topology all nodes are connected via a central station. All communication is only possible via the central node



Peer to Peer

In peer to peer topology every node has a direct connection to the other nodes and can communicate to each other.



Flooding Mesh

In a flooding mesh topology an indirect communication between nodes is possible. The message will be repeated until it reaches the receiver.

SRD Frequency Bands

Short Range Device (SRD)

A short-range device (SRD) is a radio-frequency transmitter device used in telecommunication for the transmission of information, which has low capability of causing harmful interference to other radio equipment.

Short-range devices are low-power transmitters typically limited up to 500 mW effective radiated power (ERP) or less, depending on the frequency band, which limits their useful range to few hundred meters, and do not require a license from its user.

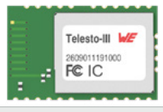
Frequency [MHz]	Band	TX Power [dBm]	TX Power [mW]	Duty cycle	max. occupied BW*	Notes
169.400 - 169.475	D	+ 27	500	≤ 1 %	50	For metering devices: 10 % DC;
169.400 - 169.4875	E	+ 10	10	≤ 0.1 %	whole band	
169.4875 - 169.5875	F	+ 10	10	≤ 0,001 %	whole band	0,1 % dc during 0:00 and 6:00 local time; Equipment that concentrates or multiplexes individual equipment is excluded.
169.5875 - 169.8125	G	+ 10	10	≤ 0,1 %	whole band	
433.050 - 434.790	H	+ 10	10	10 %	whole band	
433.050 - 434.790	I	0	1	no limits	whole band	-13 dBm / 10kHz PSD when bw > 250 kHz, audio/video applications are excluded
433.050 - 434.790	J	+ 10	10	no limits	25	audio/video applications are excluded
863.0 - 865.0	K	+ 14	25	≤ 0.1 % or psa**	whole band	OBW restictions except audio & video limited to 300 kHz
865.0 - 868.0	L	+ 14	25	≤ 1 % or psa**	whole band	
868.0 - 868.6	M	+ 14	25	≤ 1 % or psa**	whole band	
868.7 - 869.2	N	+ 14	25	≤ 0.1 % or psa**	whole band	
869.4 - 869.65	P	+ 27	500	≤ 10 % or psa**	whole band	
869.7 - 870.0	Q	+ 7	5		whole band	audio / video applications are excluded
869.7 - 870.0	R	+ 14	25	≤ 1 % or psa**	whole band	analogue audio / video are excluded
2400.0 - 2483.5		+ 10	10	no limits	whole band	non specific short range devices
2400.0 - 2483.5		+ 14	25	no limits	whole band	radio determination devices (radar, rfid,...)
2446.0 - 2454.0			500 / 4000		whole band	RFID only

* BW = Band width
**psa = Polite Spectrum Access

- License free bands
- Different frequency bands with different regulations
- Which band fits best your application
- Limitations in max TX power, Duty cycle and channel spacing

Source: EN 300 220 and EN 300 440

Product Overview

	Module	Order Code	Freq. / MHz	Output Power	LoS Range	LoS Test Conditions Antenna height/Datarate	Antenna	Datarate PHY/ RF-Profiles	RF-Channels	RF-Architecture	Power Consumption Rx	Power Consumption Tx	Power Consumption Sleep	Supply Voltage min-max	Communication Modes	Dimensions	Foot-print	Chipset	Certification	EVAL-Kit	USB-Radio Stick
Titania		2607011111000	169 MHz	15 dBm / 31.6 mW	3 km	2 m / 1.2 kbps	RF-Pad	1.2 kbps (0) 2.4 kbps (1) 9.6 kbps (2) 25 kbps (4)	5	P2P, star	28 mA	59 mA	10 µA	2 - 3.6 VDC	transparent, command	17 x 27 x 3.8 mm	WE-FP-1	MSP430 + TI-CC1120	CE	✓	✓
Thadeus		2605031141000	433 MHz	10 dBm / 10 mW	1 km	10.0 kbps (1) 38.4 kbps (2) 76.8 kbps (3) 100.0 kbps (4)	RF-Pad	4.8 kbps (0)	21	P2P, star	24 mA	38 mA	0.3 µA	2.2 - 3.6 VDC	transparent, command	17 x 27 x 3.6 mm	WE-FP-1	MSP430 + TI-CC1101	CE	✓	
Tarvos-I		2605041181000	868 MHz	11 dBm / 12.5 mW	1 km	10.0 kbps (1) 38.4 kbps (2) 76.8 kbps (3) 100.0 kbps (4)	RF-Pad	4.8 kbps (0)	11	P2P, star	24 mA	38 mA	0.3 µA	2.2 - 3.6 VDC	transparent, command	17 x 27 x 3.8 mm	WE-FP-1	MSP430 + TI-CC1101	CE	✓	✓
Tarvos-II		2607021181000	868 MHz	14 dBm / 25 mW	2 km	2 m / 2.4 kbps	RF-Pad	34.4 kbps (0) 2.40 kbps (1) 100 kbps (2)	41	P2P, star, mesh	30 mA	53 mA	3 µA	2 - 3.6 VDC	transparent, command	17 x 27 x 3.8 mm	WE-FP-1	MSP430 + TI-CC1125	CE	✓	✓
Highlight: Tarvos-III		2609011081000	868 MHz	14 dBm / 25 mW	300 m	2 m / 0.625 kbps	PCB	38.4 kbps (0) 100 kbps (2) 0.625 kbps (3) 2.50 kbps (4) 400 kbps (5)	41	P2P, star, mesh	8 mA	26 mA	0.2 µA	2.2 - 3.8 VDC	transparent, command	17 x 27 x 3.8 mm	WE-FP-1+	TI-CC1310	CE	✓	
		2609011181000			10 km	6 m / 0.625 kbps	RF-Pad													✓	✓
Highlight: Thebe-II		2609031181000	868 MHz	27 dBm / 500 mW	20 km	6 m / 0.625 kbps	RF-Pad	38.4 kbps (0) 100 kbps (2) 0.625 kbps (3) 2.50 kbps (4)	4	P2P, star, mesh	12 mA	500 mA	0.9 µA	2.2 - 3.7 VDC	transparent, command	17 x 27 x 3.8 mm	WE-FP-1+	TI-CC1310	CE	✓	
Telesto-I		2607021191000	915 MHz	-2 dBm / 0.6 mW	550 m	2 m / 38.4 kbps	RF-Pad	38.4 kbps (0) 2.40 kbps (1) 100 kbps (2)	51	P2P, star, mesh	30 mA	30 mA	3 µA	2 - 3.6 VDC	transparent, command	17 x 27 x 3.8 mm	WE-FP-1	MSP430 + TI-CC1125	FCC, IC	✓	✓
Telesto-II		2607021191010	915 MHz	15 dBm / 31 mW	700 m	2 m / 38.4 kbps	RF-Pad	38.4 kbps (0)	51	P2P, star, FHSS	30 mA	53 mA	3 µA	2 - 3.6 VDC	transparent, command	17 x 27 x 3.8 mm	WE-FP-1	MSP430 + TI-CC1125	FCC, IC	✓	✓
Telesto-III		2609011091000	915 MHz	14 dBm / 25 mW	40 m	2 m / 400 kbps	PCB	400 kbps (6)	51	P2P, star, mesh	8 mA	26 mA	0.2 µA	2.2 - 3.8 VDC	transparent, command	17 x 27 x 3.8 mm	WE-FP-1+	TI-CC1310	FCC, IC		
		2609011191000	915 MHz	14 dBm / 25 mW	800 m	2 m / 400 kbps	RF-Pad													✓	✓
Themisto-I		2609041191000	915 MHz	25 dBm / 315 mW	10.5 km	6 m / 30 kbps	RF-Pad	400 kbps (6) 240 kbps (8) 30.0 kbps (9)	51	P2P, star, mesh	12 mA	400 mA	0.9 µA	2.2 - 3.7 VDC	transparent, command	17 x 27 x 3.8 mm	WE-FP-1+	TI-CC1310	FCC, IC	✓	
Triton		2603011021000	2400 MHz	8 dBm / 6.3 mW	500 m	2 m / 1.50 kbps	Chip	1.50 kbps (1) 3.00 kbps (2) 6.00 kbps (3) 12.0 kbps (4) 24.0 kbps (5) 48.0 kbps (6) 72.0 kbps (7)	20	P2P, star	10 mA	38 mA	1 µA	1.9 - 3.6 VDC	command	16 x 27.5 x 3.2 mm	WE-FP-2	STM32 + EM9209	CE, FCC, IC	✓	
		2603011121000	2400 MHz	10 dBm / 10 mW	5 km	6 m / 1.50 kbps	RF-Pad													✓	
Thalassa		2606031021000	2400 MHz	-6 dBm / 250 µW	150 m	2 m / 1.50 kbps	Chip	1.50 kbps (1) 250 kbps (default)	166	P2P, star	21 mA	25 mA	6 µA	2.7 - 3.6 VDC	transparent, command	17 x 30.8 x 3.6 mm	WE-FP-3	MSP430 + TI-CC2500	CE, FCC, IC	✓	✓
		2606031121000	2400 MHz	0 dBm / 1 mW	450 m	2 m / 1.50 kbps	RF-Pad													✓	
Highlight: Thyone-I		2611011021000	2400 MHz	4 dBm / 2.5 mW			SAS -> PCB	125 kbps (0) 500 kbps (1) 1.0 Mbps (2) 2.0 Mbps (3)	39	P2P, star, mesh	7.7 mA	18.9 mA	0.4 µA	1.8 - 3.6 VDC	transparent, command	12 x 8 x 2 mm	WE-FP-4+	nRF52840	CE, FCC, IC, ARIB	✓	✓
			2400 MHz	8 dBm / 6.3 mW	750 m	2 m / 125 kbps	SAS -> RF-Pad														

Our Strongest: Proprietary 868 MHz

Tarvos-III

Long range radio module
868 MHz

Thebe-II

Long range radio module
868 MHz

Characteristics

Long range 10 / 20 km

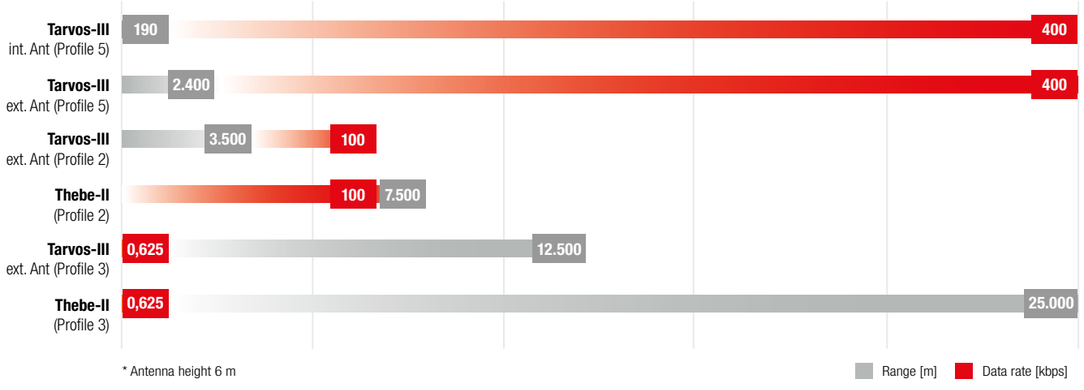
Small size

Mesh

High penetration

- 2 products - 1 footprint
- Footprint compatible to 915 MHz modules
- Flexibility in design
- Transparent mode
- Flexible addressing
- Powerful
- Interoperable Tarvos-III and Thebe-II
- Adjustable output power

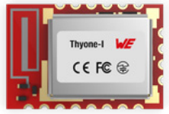
Correlation Range - Data Rate



Differences

	Tarvos-III	Thebe-II
Output power	14d Bm / 25 mW	27 dBm / 500 mW
Range	300 m / 10 km	20 km
RF channels	41	4
Power consumption	8 mA / 26 mA / 0,2 µA	12 mA / 500 mA / 0,9 µA
Antenna	PCB / external	external
	Data sheet: Tarvos-III we-online.com/SPEC/Tarvos-III-PCB we-online.com/SPEC/Tarvos-III-PAD **Manual: Tarvos-III** we-online.com/Man/Tarvos-III	**Data sheet: Thebe-II** we-online.com/SPEC/Thebe-II **Manual: Thebe-II** we-online.com/Man/Thebe-II

Our Smallest: Proprietary 2.4 GHz



Thyone-I

New

Proprietary radio module
2.4 GHz

Characteristics

Long life battery driven application with sleep current = 0.4 µA

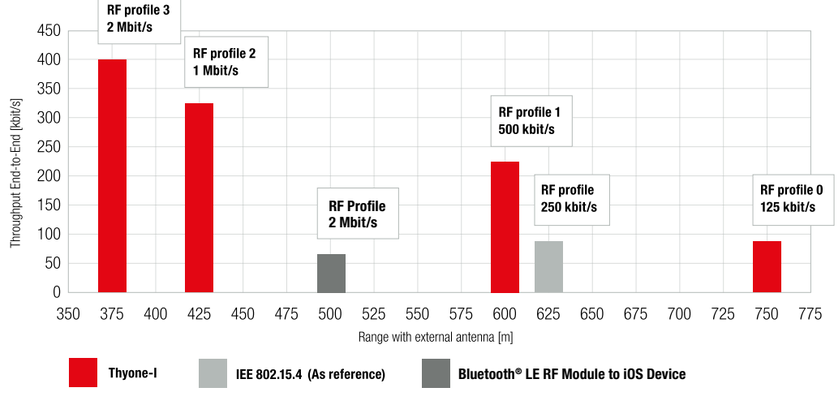
Global availability 2.4 GHz license free band

Mesh

Nano SIM size

- High throughput up to 400 kbit/s
- Range up to 750 m
- Control the GPIOs via remote and local access
- Easy serial cable replacement (transparent mode)
- Test modes for RF measurements
- Smart antenna selection (2-in-1 module)
- Encryption (AES128)
- Certifications: CE, FCC, IC, ARIB

Choose between Long Range and High Troughput



Data sheet: Thyone-I
we-online.com/SPEC/Thyone-I

Manual: Thyone-I
we-online.com/SPEC/Thyone-I

Development tools

Evaluation-Board

Software-Development Kit

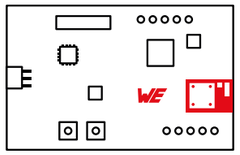
User Friendly Manuals and App-Notes

FeatherWing ■ Adafruit standard ■ Easy connectable ■ For complex system tests

More information on page 106

Added Values

Development Tools



Eval Boards

- Easy testing
- Rapid prototyping
- FTDI integrated (UART to USB)
- Pins available on header
- Current measurement

Overview: Eval Boards

we-online.com/EVAL-Prop

More information on page 108

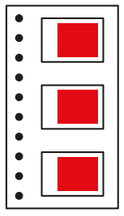
USB-Radio Stick

- USB-FTDI-RF-Module
- Range extension in Flooding Mesh networks
- Radio connection for computer

Overview: USB-Radio Sticks

we-online.com/USB-Prop

More information on page 108



Development Kit

- 3 radio modules on stock
- Delivery within 48 hours
- Hand soldering (Edge castellation)
- Ready to use

Smart Commander

- Easy testing
- AT-Commands as buttons
- Monitoring UART-Communication
- Export Commands for easy integration in the former HOST-Controller

Download: Smart Commander

we-online.com/SmartCommander

AppNotes

Wireless Connectivity Software Development Kit (SDK)

we-online.com/ANR008

Range Estimation

we-online.com/ANR010

Replacing 868 MHz Radio Modules by their 915 MHz counterparts

we-online.com/ANR015

Proprietary Migration Guide – Replacing a proprietary Radio Module by its successor

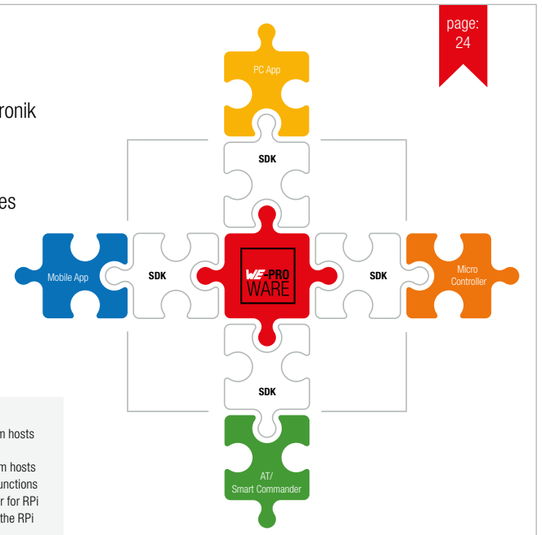
we-online.com/ANR016

Software Development Kit

page: 24

The SDK enables professional software integration of Würth Elektronik wireless modules into any host processor or operating system by offering a set of drivers and sample applications.

- Typically as C-Files, for mobile Apps platform specific languages
- For comfortable coding of:
  - The HOST-controller system
  - PC Applications
  - Mobile Apps
- Code examples in Application notes and Manuals




```
/
├ drivers.....................................Contains the code to be ported to custom hosts
│ ├ gobal
│ │ ├ global.h.....................Declares all functions to be defined on custom hosts
│ │ ├ global.c.....................................Implements shared functions
│ │ ├ globa _ ftdi.c.....................UART and GPIO of the FTDI USB driver for RPi
│ │ └ global _ serial.c.................UART and GPIO of the serial interface of the RPi
│ ├ ...
│ ├ Triton.....................................Command interface of the Triton module
│ │ ├ Triton.h
│ │ └ Triton.c
│ └ ...
├ Example _ Triton.................................Demo project using Triton module
│ ├ main.c
│ └ Example _ Triton.cbp
└ ...
```

we-online.com/WCO-SDK

Added Values

Antennas

Libraries

Webinars

RedExpert

Exchangeability

Compatibility Tarvos-Thebe-Telesto-Themisto Series

- Footprint compatible RF-modules
- Alternative usage by only changing the RF-module
- No change in the HW on Host-side required

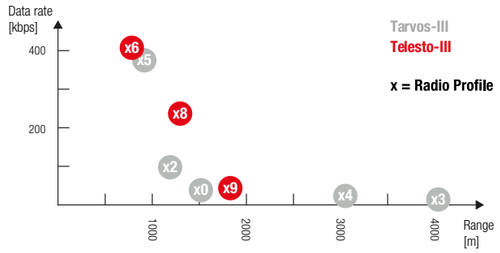
- Flexible use of both frequencies for different regions possible
- 868 MHz and 915 MHz exchangable

- Using Low or High Power modules for different ranges
- Modules with 14 dBm (25 mW): Tarvos-III and Telesto-III
- Modules with 27 dBm (500 mW): Thebe-II and Themisto-I

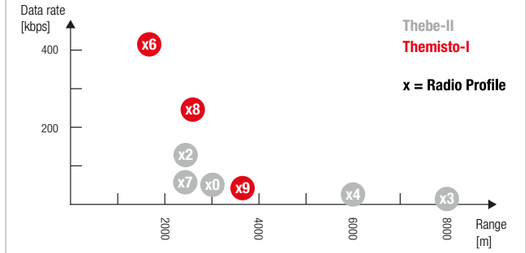
Replacing 868 MHz Radio Modules by their 915 MHz counterparts

we-online.com/ANR015

Tarvos-III & Telesto-III



Thebe-II & Themisto-I



In case, the **Tarvos-III** is replaced by a **Telesto-III** radio module, the following facts have to be considered:

Feature	Information	Actions needed
Form factor & footprint	Both modules have the same form factor and footprint.	None
Pinout	Both modules are pin compatible.	None
Antenna	Both modules are available with integrated antenna and a 50 Ω antenna pad to connect an external antenna.	In case of external antenna, check whether the connected 868 MHz antenna can be also used for 915 MHz.
UART protocol	Both modules provide a command interface using the same commands and functions.	None
Radio configuration	■ The radio profile 6 of the Telesto-III is comparable in range and speed with the radio profile 5 of the Tarvos-III. In case, the Tarvos-III uses another radio profile, the range of the Telesto-III is lower, but data rate is higher, such that the data can be transmitted much faster. ■ The channel numbering changes from 100 - 140 (868 - 870 MHz) to 200 - 252 (902 - 928 MHz).	■ Check the range requirements of your application. ■ Use the new channel numbers in your application code.
Certification	The 915 MHz range is regulated in North America by the FCC USA and ISED Canada.	Re-testing of the end-device is needed to determine unwanted emissions.

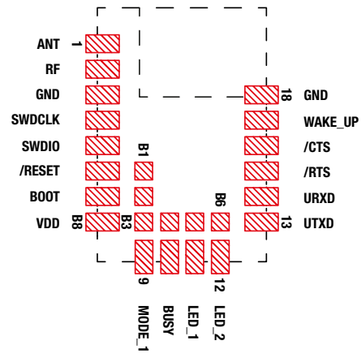
In case, the **Thebe-II** is replaced by a **Themisto-I** radio module, the following facts have to be considered:

Feature	Information	Actions needed
Form factor & footprint	Both modules have the same form factor and footprint.	None
Pinout	Both modules are pin compatible.	None
Antenna	Both modules are available with a 50Ω antenna pad to connect an external antenna.	Check whether the connected 868 MHz antenna can be also used for 915 MHz.
UART protocol	Both modules provide a command interface using the same commands and functions.	None
Radio configuration	■ The radio profiles of the Themisto-I provide a faster radio transmission at the cost of range. ■ The channel numbering changes from 129 - 132 (869.45 - 869.6 MHz) to 200 - 252 (902 - 928 MHz).	■ Check the range and timing requirements of your application. ■ Use the new channel numbers in your application code.
Certification	The 915 MHz range is regulated in North America by the FCC USA and ISED Canada.	Re-testing of the end-device is needed to determine unwanted emissions.

Exchangeability Thyone-I and Proteus-III

- Footprint compatible RF-modules
- Flexible use of both technologies possible
- Alternative usage by only changing the RF-module
- Future-proof circuit with adaptable interface
- No change in the HW on Host-side required

Pinout (top view)

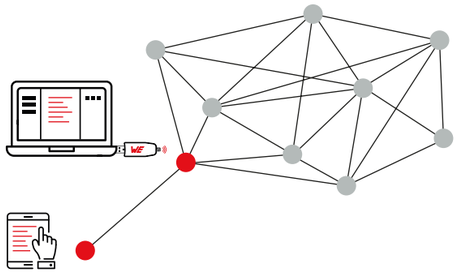


Proprietary Application with Thyone-I

- For applications with enclosed communication
- Communication invisible for smart devices
- Connection to a standard device only with a certain USB-radio stick possible
- Connected sensors building up a secure network

Usecase

- Secure network set up
- Easy connection between the nodes
- Extending interfaces by connecting a USB-radio stick
- A gateway connecting securely to the network provides the combined result to the user via Bluetooth, Wi-Fi, Cellular, MQTT or on any platform

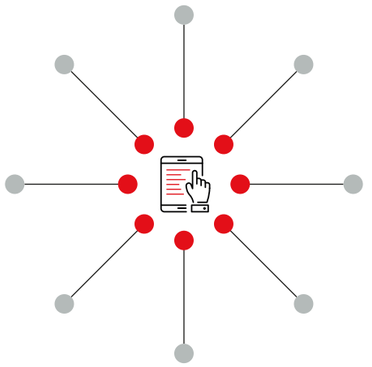


Bluetooth® Application with Proteus-III

- Connecting directly to smart devices
- Parameterization of a sensor
- Reading out results from a measuring device

Usecase

- Connecting manually to each sensor via smart device
- Easy and smart consumer-oriented



Webinar:
Bluetooth® LE vs 2.4 GHz Proprietary wireless

User Application: 868/915 MHz

Agriculture Measurement / Smart Farming

- ✔ Farming infrastructure
- ✔ Cattle monitoring
- ✔ Automated watering
- ✔ Monitoring of soil quality

Benefits

Saving costs | More efficiency | Animal welfare | Higher earnings | Protection of soil quality

User Application: 2.4 GHz

Proprietary Radio as Bluetooth® LE Alternative

- Connection only with authorized devices by the manufacturer
- Security aspect as argument for the endcustomers
- Closed communication is „invisible“ for Smart devices
- Higher throughput possible – no effort with big overhead of Bluetooth®
- Saving Bluetooth® Listing costs
- Business model to build the whole chain as user experience
- Binding the end customer to the product with additional accessory with the same communication

Best Practice:

Simplify communication with wireless connection to measuring devices

Idea to connect wireless to the device:
Parameterization for commissioning, start/stop measurement, read out results, notification danger, connecting for service, checking device state for predicitve maintanence, recalibration

Currently no connectivity available:
Tried to implement Bluetooth® a few years ago; Bluetooth® classic with to high energy consumption; Bluetooth® Listing Costs too high, small quantities cannot carry the high costs; Bluetooh® LE not flexible enough for the idea

Proprietary Communication as solution:
Easy adaption possible; fitting perfectly to the needs; no license costs arise; full control over application

Creating a High-Quality Remote Control as Accessories is more reasonable

- ✔ Also additional sensors (about measuring environmental conditions) should be connected
- ✔ In stationary usecase some more visualization is planned to connect also (measuring results)
- ✔ Combination of two or more measurement devices in one network as highest stage of extension

Remote control + Sensors = Visualization

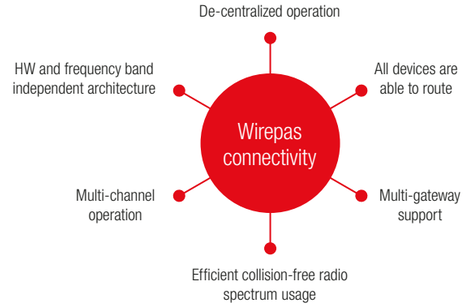
WIRELESS CONNECTIVITY

Wirepas

Introduction

What is Wirepas?

Wirepas Mesh is a de-centralized radio communication protocol for devices. The Wirepas Mesh protocol software can be used in any device, with most radio chipsets, and on any radio frequency band.



Main Benefits of Wirepas Mesh

Unlimited device amount and geographical coverage
– De-centralized operation, all devices able to route

Tens of millions of devices in the same network

Millions of km² coverage

Unlimited scale, coverage & density

High device density

Long device-to-device range

High density and sparse installations
– Efficient spectrum usage with locally synchronized operation, PHY independence

Highly reliable operation and high SLA
– Multi-channel interference avoidance and self-healing & -optimizing routing

99.9 %

Packet RX ratio

High reliability & high availability

100 %

Online status

High availability and 24/7 connectivity
– Continuous network maintenance

Minimized capital costs
– Low BoM, no infrastructure, easy & quick installation

Low CAPEX

Lowest total cost of ownership, fully automatic

Low OPEX

Minimized operational costs
– Fully automatic, high realibility & availability, low GW-to-node ratio

Continuous development
– Requirements evolve, Wirepas Connectivity evolves with them

Evolving requirements

Development

Future proof

OTAP

SW 1.0 → SW v2.0

Remote firmware upgrades
– Efficient and secure Over the Air Programming (OTAP)

Our Meshed:
Wirepas 2.4 GHz

Coming Soon!
Early Bird available

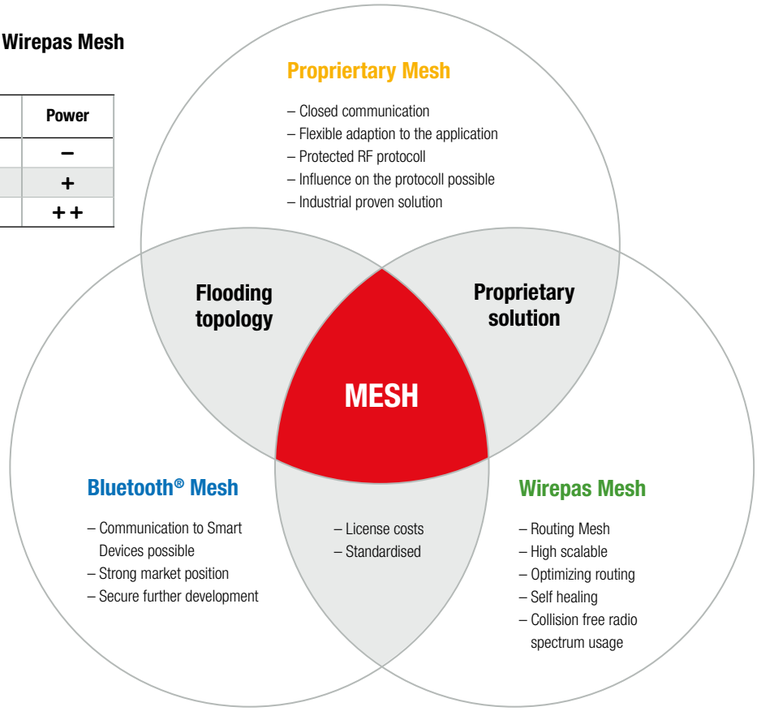
Characteristics

Mesh | Security & Encryption | Long life battery driven application | Smart antenna selection

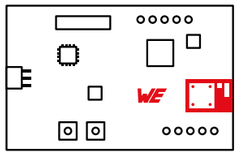
- Nano SIM size - 8 x 12 x 2 mm
- ARM® Cortex®-M4 32-bit processor with FPU, 64 MHz
- ARM Cryptocell cryptographic unit
- Nordic Semiconductor SoC nRF52840
- 1 MB flash memory, 256 kB RAM
- Wirepas „Dual CPU“ model, c-mesh api for hosts available through github (https://github.com/wirepas/c-mesh-api)
- +8 dBm TX power (ERP: 4 dBm)
- Encryption, Integrity & Authentication
- Smart antenna selection (2-in-1 Module)
- Also available as proprietary radio module (Thyone-I) or Bluetooth® LE radio module (Proteus-III)
- Routing Mesh
- CE, FCC, IC, ARIB certification

Comparison:
Bluetooth® Mesh – Proprietary Mesh – Wirepas Mesh

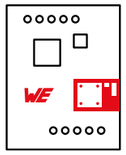
	Nodes	Latency	Power
Bluetooth® Mesh	+	–	–
Wirepas Mesh	++	–	+
Proprietary Mesh	+	+	++



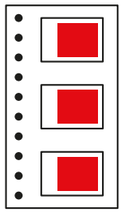
Added Values



Eval Boards
- Easy testing
- Rapid prototyping
- FTDI integrated (UART to USB)
- Pins available on header
- Current measurement

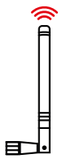


Mini Eval Boards
- Small and cheap
- USB connection with FTDI-cable possible (available as accessory)



Development Kit
- 3 single modules
- On stock
- Delivery within 48 hours

PC-Tool
- Easy testing
- AT-Commands as buttons
- Monitoring UART-Communication
- Export Commands for easy integration in the former HOST-Controller

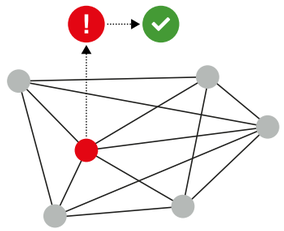


Antenna
- 2.4 GHz external Antenna Himalia

User Application: Industrial IoT

Wirepas Mesh is the perfect fit for Industrial IoT

The manufacturing industry has started seeing a growing need for monitoring the condition of their assets and to perform predictive maintenance if needed. The challenge is that smart industries require an industrial IoT connectivity solution, a self-healing mesh network that can handle a demanding radio environment.

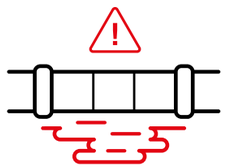


Predictive Maintenance

Machines, devices and equipment in production are lasting investments and keeping them operative is key. The sensors measure the condition data for the machines, devices and equipment and trigger predictive maintenance if needed. This reduces the need for multiple days of production halt to a few hours of maintenance.

Leakage Control

Pipes, ducts and vents carry and control many gas and liquid in production and from production plants to use. Monitoring and controlling valves and levers with sensors to ensure there are no leakages saves both money and the environment. The high number of sensors require a robust IoT connectivity to operate securely.



Monitoring and Measuring of Material Levels and Condition

Tanks, containers, vessels and sewage systems may carry dangerous liquids, gasses or material and the use levels need to be ensured to make sure safety and productivity is in check. Sensors may also keep tabs on for example safe temperature or ambient light levels to prevent accidents from happening.

Grow your Industrial IoT endlessly

The possibilities to use an industrial IoT mesh network in production are endless. The Wirepas Mesh grows organically and has automated interference avoidance so one network can handle multiple use cases and thousands of assets.

Benefits of Industrial IoT

Battery Lifetime

No additional mains-powered routers are required. Only large-scale wireless mesh connectivity technology in the market enabling battery-operated routers with over 5 year lifetime with 4000 mAh battery (1,5 packets per second.

Security & Reliability

Includes self-healing routing, multi-channel operation with local channel white/blacklisting. Proven over 99.99% reliability in large-scale & high interference buildings. Secure connectivity with industry standard AES-128 encryption.

Easy Retrofit

Easy retrofit is required due to factory floor design, large number of unsensored machinery and large number of outdated sensors that need replacement. Easy battery-operated mesh network with our sensors can be installed by anyone and anywhere.

Future Proof

Enables not only lighting control, but environmental sensoring and asset tracking in the same wireless network. Any device in the network can be updated over the air. Interoperable with BLE devices.

Source: https://wirepas.com/applications/industrial-iot/

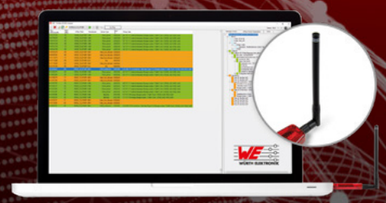
WIRELESS CONNECTIVITY

Wireless M-Bus

page: 87

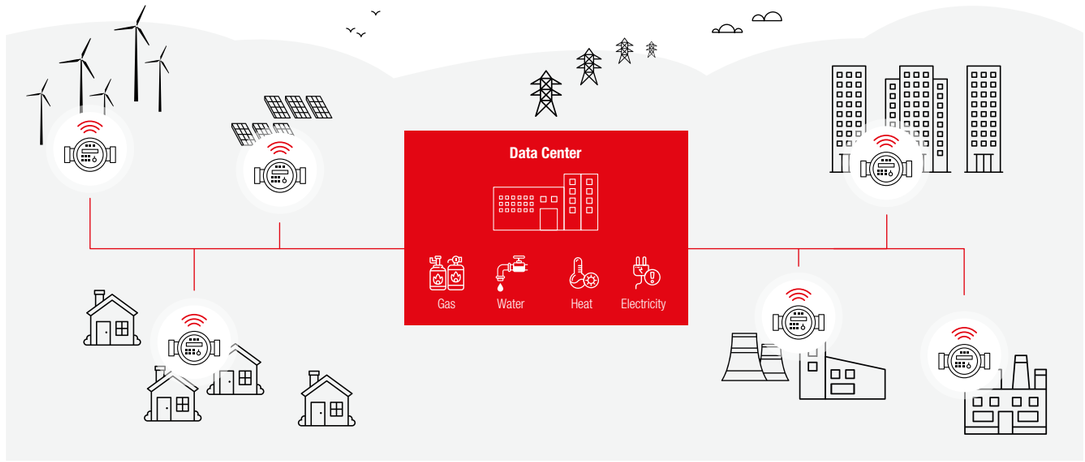
HIGHLIGHT

Our Analyzer



Introduction

Wireless M-Bus



Wireless Meter Bus (wM-BUS) is the extension of the meter Bus (M-BUS) with a wireless protocol and role scheme for handling communication over a standardized wireless communication interface between meters and data loggers – so called smart meter gateways (SMGW). This scheme is specified by the European standard EN 13757 and its sub-standards. The motivation of this standard is to allow an automated measuring and processing of data, track the usage of resources and to optimize provisioning in order to create an “Advanced Metering Infrastructure” (AMI).

Such Smart grid / meter devices are typically battery operated and in need for a long range and robust wireless communication. This is the reason for using the Sub GHz frequencies in the free ISM Bands. EN13757-4 is specifying radio options in the 169 MHz, 434 MHz or 868 MHz band, regarding to the region.

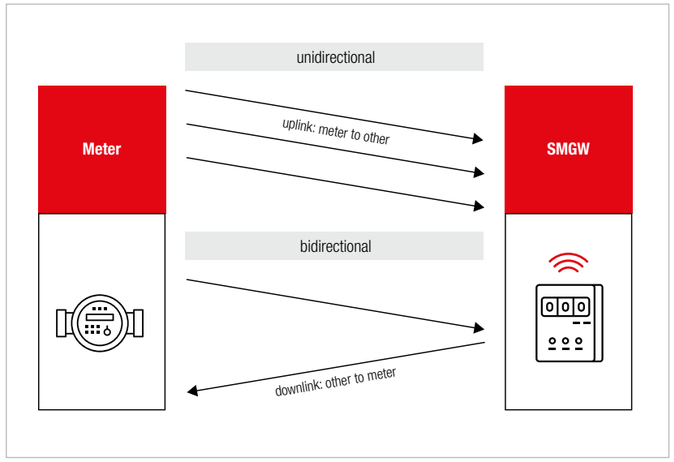
In between those frequencies there are different modes with different functions. In the table below you can see those specifications.

Mode	Frequency	Uni-/Bidirectional	Description of Use
S1, Stationary	868.3 MHz	Uni	Send data a few times per day. Optimized for battery operation and stationary operation. 32.7 kbps
S1-m, Stationary	868.3 MHz	Uni	Same as S1, but optimized for mobile receiver
S2, Stationary	868.3 MHz	Bi	Same as S1, but bi-directional communication
T1, Frequent transmit	868.95 MHz	Uni	Send data every few seconds. Configurable interval. 100 kbps
T2, Frequent transmit	868.95 MHz, 868.3 MHz	Bi	Same as T1, but bi-directional operation
C1, Compact	868.95 MHz	Uni	Unidirectional communication using NRZ coding. Similar to T1 but higher data-rate, 50 kbps. Stationary operation
C2, Compact	868.95 MHz, 869.525 MHz	Bi	Same as C1, but bi-directional operation
N1a-f, Narrowband	169 MHz @ 12.5 kHz	Uni	Unidirectional, 4.8 kbps, stationary operation
N2a-f, Narrowband	169 MHz @ 12.5 kHz	Bi	Same as N1a-f, but bi-directional operation
N1g, Narrowband	169 MHz @ 50 kHz	Uni	Unidirectional, 19.2 kbps, stationary operation
N2g, Narrowband	169 MHz @ 50 kHz	Bi	Same as N1g, but bi-directional operation

Uni- / Bidirectional

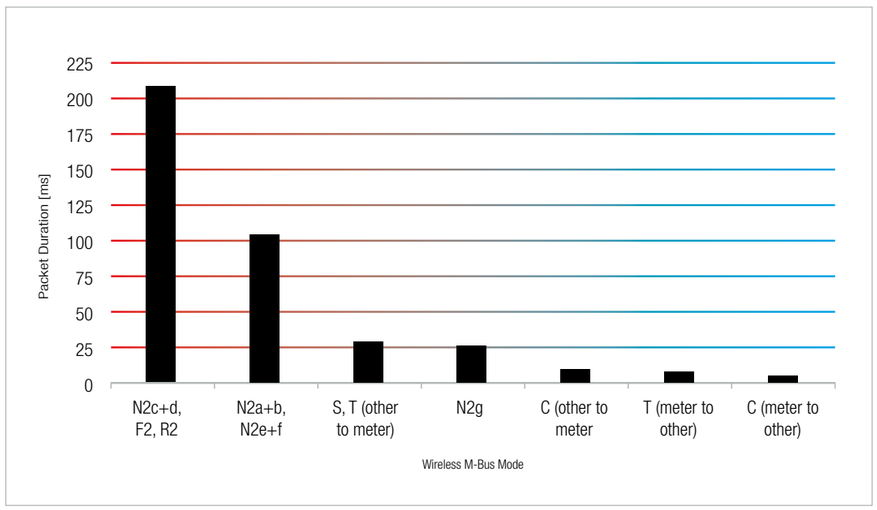
The wireless M-Bus (EN13757-4) differentiates the transfer in a network in 2 directions: uplink and downlink. Where uplink is used when a “meter” sends data to a receiver (“other”) and downlink is used when a sender (“other”) sends data to a “meter”.

This two directions are, depending on the wireless M-Bus mode, either symmetric (S and N modes) or asymmetric (T and C modes). Where symmetric means that the same radio parameters (radio data rate, coding, modulation, frequency) are used for both directions. On the other hand asymmetric means that those radio parameters are different for the two directions.



Payload

A wireless M-Bus mode containing a “1” means “sender only” so any radio frame reception is deactivated. Whereas a “2” in the wM-BUS mode means sender and receiver. The “sender only” mode of operation (e.g. C1 meter) has it’s right to exist in a battery operated meter which does not need any information in the downlink direction and should operate in the order of 10 years with the integrated battery - which applies for the majority of meters today.



The payload of a wireless M-Bus frame is coded according to EN13757-3. Any meter reading value is located in one data block and the frame can contain one or multiple of such blocks. This allows the meter reading values to be transferred efficiently and in a well-defined yet flexible manner to provide interoperability. The drawback of this is, that the raw data of a wM-BUS frame is not readable for a human without parsing the data back into a readable format.

Different “Standards” in Europe

Europe in general
- EN13757; 169, 434 and 868 MHz wM-BUS Modes
- Based on OMS group recommendations

France
- „GrDF“ (Gaz réseau distribution France)
- EN13757 N-Modus, 169 MHz narrow band

Italy
- „CIG“ (Italian Gas Committee)
- Italian UNI TS11291 Specification
- EN13757 N-Modus, 169 MHz narrow band

Product Overview

			
	Mimas-I	**Metis-I**	**Metis-II**
Order Code	2607011113000	2605041183000	2607021183000
Frequency	169 MHz	868 MHz	868 MHz
Wireless M-Bus modes	N1a to N1f N2a to N2f	S, T, C	S, T, C
Output Power	14 dBm	11 dBm	14 dBm
Power Consumption Rx	28 mA	22 mA	30 mA
Power Consumption Tx	59 mA	31 mA	53 mA
Power Consumption Sleep	10 µA	0.3 µA	3 µA
Supply Voltage min - max	2.0 - 3.6 VDC	2.2 - 3.6 VDC	2.0 - 3.6 VDC
Op. Temp	-40 ... +85 °C		
Max Datarate	4.8 kbps	100 kbps	100 kbps
Payload	255 Byte	255 Byte	255 Byte
Antenna	external		
LoS Range	3000 m	700 m	1000 m
LoS Test Conditions	2 m Antenna height / 2400 bit/s	2 m Antenna height / 32768 bit/s	2 m Antenna height / 32768 bit/s
Interface	UART		
Transparent Mode	✔	✔	✔
Repeater	-	-	✔
Certification	CE		
	Data sheet: Mimas-I we-online.com/SPEC/Mimas-I **Manual: Mimas-I** we-online.com/Man/Mimas-I	**Data sheet: Metis-I** we-online.com/SPEC/Metis-I **Manual: Metis-I** we-online.com/Man/Metis-I	**Data sheet: Metis-II** we-online.com/SPEC/Metis-II **Manual: Metis-II** we-online.com/Man/Metis-II

Development Tools

USB dongles	Evaluation-Board	Software-Development Kit	User Friendly Manuals and App-Notes

Our Analyzer: wM-Bus Tool

Wireless M-Bus Analyzer

The Wireless M-Bus Analyzer is a tool for receiving and parsing wireless M-Bus telegrams that comply with EN 13757-4:2013 transmitted by devices with role „meter“ or „other“. It currently supports both unencrypted and encrypted telegrams (supported encryption modes are: 0, 5, 7) in accordance with the OMS specification Vol2 V4.1.0 (draft June 2016) and EN13757-3:2013.

The data records in the telegrams are displayed in plain text by means of the integrated parser, which greatly simplifies the interpretation of a telegram. A review of the configuration settings or, for example, the meter readings can therefore be completed simply.

The Wireless M-Bus Analyzer is an excellent tool for analyzing errors and RF range of M-Bus devices. Thanks to the simplified representation and an integrated logging function, data can also be analyzed at a later time.
The software only works in combination with a licensed AMB8665-AT2 USB stick. This USB stick acts as the receiver for telegrams from the meters and supports the S-, T- and C-mode.

Name	Part No.	Frequency [MHz]	Range* [m]	Modes	Compatible Modules
Metis-Simulator (AMB8665-M-S)	2607056283011	868	800	S, T, C	Metis-II (AMB8426-M), Metis-III (AMB8626-M)
		Wireless M-Bus Simulator Plug transmitting meter frames in S-, T-, C-mode for range estimation and meter simulation			
Metis-Analyzer (AMB8665-AT2)	2607057283011	Wireless M-Bus Receiver Plug plus smart meter software analyzer tool for wireless M-Bus			

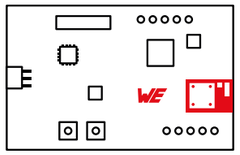
* Range stated is calculated assuming line-of-sight. Antenna above ground 1.5 m and 6 dB margin. Actual range will vary based upon specific board integration, antenna selection and environment.

Characteristics

- Tool for monitoring and analysis of wireless M-Bus communication
- Packet content visualization
- Supports data records according to EN13757-3:2013 standard
- OMS (Open metering System) parser (according to OMS 4.1.0 draft 06/2016)
- Message parser for deep packet analysis incl. M-Bus application layer
- Decryption function (AES128) for security profiles A and B (encryption modes 5 and 7)
- Log feature (.xlsx, MS Excel) for offline analysis
- Various wireless M-Bus modes supported (S-, T- and C-Mode)

Added Values

Development Tools



Eval Boards

- Easy testing
- Rapid prototyping
- FTDI integrated (UART to USB)
- Pins available on header
- Current measurement

Overview: Eval Boards

we-online.com/EVAL-wM-BUS

More information on page 108

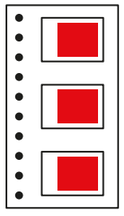
USB-Radio Stick

- USB-FTDI-RF-Module
- Range extension in Flooding Mesh networks
- Radio connection for computer

Overview: USB-Radio Sticks

we-online.com/USB-wM-BUS

More information on page 108



Development Kit

- 3 radio modules on stock
- Delivery within 48 hours
- Hand soldering (Edge castellation)
- Ready to use

AppNotes

ANR001 Metis-II Repeater Mode

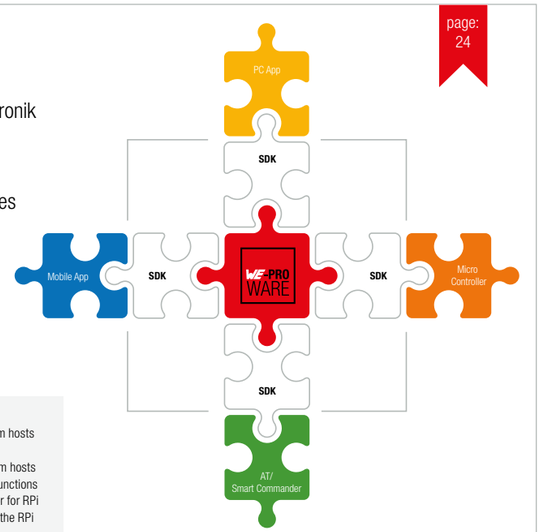
we-online.com/ANR001

Software Development Kit

page: 24

The SDK enables professional software integration of Würth Elektronik wireless modules into any host processor or operating system by offering a set of drivers and sample applications.

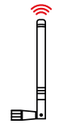
- Typically as C-Files, for mobile Apps platform specific languages
- For comfortable coding of:
  - The HOST-controller system
  - PC Applications
  - Mobile Apps
- Code examples in Application notes and Manuals




```
/
├─ drivers.....................................Contains the code to be ported to custom hosts
│  ├─ gobal
│  │  ├─ global.h.............................Declares all functions to be defined on custom hosts
│  │  ├─ global.c..............................Implements shared functions
│  │  ├─ globa _ ftdi.c.......................UART and GPIO of the FTDI USB driver for RPi
│  │  └─ global _ serial.c.....................UART and GPIO of the serial interface of the RPi
│  ├─ ...
│  ├─ Triton.....................................Command interface of the Triton module
│  │  ├─ Triton.h
│  │  └─ Triton.c
│  └─ ...
├─ Example _ Triton.....................................Demo project using Triton module
│  ├─ main.c
│  └─ Example _ Triton.cbp
└─ ...
```

we-online.com/WCO-SDK

Added Values



Antennas

Libraries

Webinars

REDEXPERT

RedExpert

User Application

A meter billing service provider switches from yearly manual reading to the use of wM-BUS based heat cost allocators and a smart meter gateway.

Advantages for the Customers

- „Almost live“ data access on his currently use of resources including a “live” cost estimation instead of yearly billing
- Comparison on a day-by-day basis when data is available
- No costs for the manual readout, no huddle with a yearly appointment for manual meter readout person
- Secure due to encryption, only the owner of the data knows the key required for decrypting the messages of the meters
- Several metering providers can share a single Smart meter Gateway (water, gas, electricity, heat cost, …)

Disadvantages for the Customers

- High initial costs: Smart meter gateway and meters with wireless interface
- Battery lifetime requires exchanging devices each 7 - 10 years in case of battery operated devices – due to security reasons “just” changing the battery is often prevented

The typical use-case contains only the transmission from the meter to the data logger, but no transmission from the data logger to the meter. Each meter sends a message in a certain period. This period always contains a randomly chosen part to avoid permanent collisions between two devices. This period varies according to the medium: for electricity the OMS recommends 7.5 minutes, for water 30 minutes and for heat cost allocators 240 minutes.

Metering media	Mandatory (billing and actuator)		Informative aspects (consumer)
	Average update interval maximum [min]	Visualization interval for energy provider [hour]	Visualization interval for consumer [min]
Electricity	7,5	1	15
Gas	30,0	1	60
Heat (district heating)	30,0	1	60
Water / Warm water	240,0	24	–
Heat cost allocators	240,0	24	–
Heat / Cost (sub metering)	240,0	24	–
Repeater*	240,0	–	–

* Limit refers to datagrams that are generated by the repeater itself. Not for repeated datagrams!
Source: OMS spec generation 4, volue 2 issue 4.2.1

The data logger forwards the (still encrypted) data to a data center or a smart meter gateway, which can also decrypt the data locally because it has received the keys of the meters through the exchange with this data center. The permitted procedure is also country-specific in Europe.

Advantages

- Time saving
- No personal contact needed
- Autonomous
- Measuring possible at any time
- Smart metering: Measure and control

SENSORS

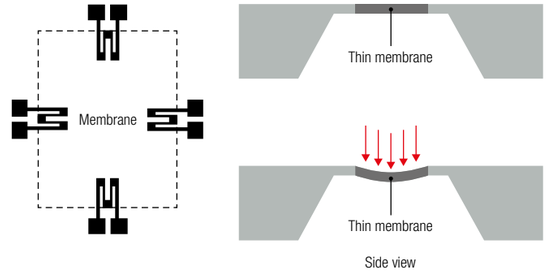
Introduction

MEMS Sensors

In a microcontroller the typical semiconductor can only control current and voltages. In a Micro-Electro-Mechanical System (MEMS), additional mechanical structures are used. This means that three-dimensional structures are usually added to the starting material silicon by etching processes. This allows the design of membranes or movable finger structures.

Functionality of a MEMS Pressure Sensor

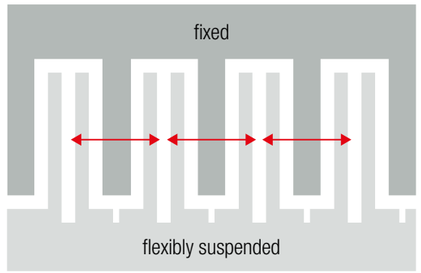
A MEMS pressure sensor is based on a thin membrane. Typically two principles are used. The first principle is based on a change in resistance of integrated resistors caused by the deflection of the membrane. The second principle is based on a capacitive effect: a counter electrode is located below the membrane and based on the deflection of the membrane, the distance and thus the capacitance is changed.



Source: https://www.radiolocman.com/review/article.html?id=148185

Functionality of a MEMS Acceleration Sensor

Another approach is the creation of finger structures. One side is fixed, the other side is flexibly suspended. If this system gets accelerated, the distance changes between the fixed and movable structure. This change in distance causes a change in the electrical capacitance (capacitor prinicple), which could be measured electrically and serves as a reference value for acceleration.

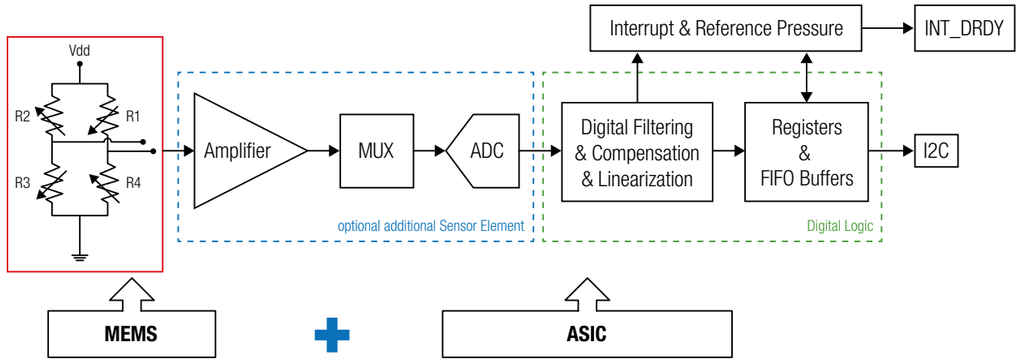


Functional Description

Block Diagram

The best way to explain the function of MEMS sensors is a block diagram. The biggest difference to conventional (analog) sensors is that not only the actual measuring cell but also the complete processing can be integrated to achieve a very small sensor system. This eliminates any analog data processing on application level and a digital signal can be used directly by a microcontroller. Since a complete system is combined in one component, a complete factory calibration is also possible.

Block Diagram



MEMS - Unit

- Bulk- or surface micromachining to create mechanical structures
- Very small dimensions possible
- Able to detect very small changes in physical dimension

ASIC – Unit

Analog front end:
- Amplifying the signal
- Multiplexing in case of different sensor elements
- Conversion from analog to digital value

Digital logic:
- Filtering
- Compensation and linearization
- Registers and buffering

Interfaces:
- I²C – digital interface
- Interrupt for special scenarios

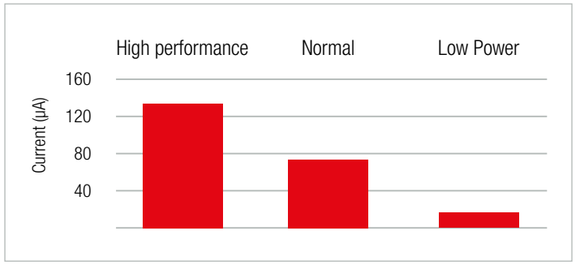
Comparison Analog vs Digital sensor

	Analog sensor	Digital sensor
Dimension	Mostly several parts needed, bigger formfactor	All-in-one, smaller formfactor
Costs	Several components like sensor, external resistors, stable voltage supply, ADC are needed	MEMS sensor covers the whole sensor system
Calibration	Field/system calibration needed (at multiple temperatures)	Off-the-shelf calibrated
Accuracy	System accuracy = sensor element + measuring circuitry	Sensor accuracy = System accuracy
Measuring	Mostly non-linear	Fully compensated and calibrated
Power Consumption	Voltage divider constantly drains power	Very low power, sleep mode between active sense cycles
Data Quality	Contact and load resistance as well as the absolute voltage supply level will have an influence on the accuracy. Additional inaccuracy based on the ADC has to be considered.	Stable output signal (digital value), additional possibilities to verify correct data transmission like parity or CRC. Also sensor status information can be sent.
Integration	External circuitry	Simple I/O pins with direct values from sensor

Different Modes for different Needs

Typically the mode selection is a tradeoff between current consumption and accuracy/noise.

- High Performance mode with highest data rate
- Normal mode as a perfect compromise
- Low power mode with lowest power consumption



WSEN-TIDS
Temperature Sensor IC

- Silicon based digital temperature sensor
- High accuracy (up to ±0.25 °C typ.)
- Fully calibrated 16 bit temperature output
- Selectable output data rate up to 200 Hz
- I²C digital communication interface
- Programmable temperature threshold and interrupt

Order Code	$T_{RANGE\ min}$ (°C)	$T_{RANGE\ max}$ (°C)	RES_T (bits)	ODR_{min} (Hz)	ODR_{max} (Hz)	$V_{DD\ min}$ (V)	$V_{DD\ max}$ (V)
2521020222501	-40	125	16	25	200	1.5	3.6

T_{RANGE}: Measurement range [min.]; RES_T: Resolution [typ.]; ODR_{min}: Output data rate [min.]; ODR_{max}: Output data rate [max.]; $V_{DD\ min}$: Operating supply voltage [min.]; $V_{DD\ max}$: Operating supply voltage [max.]

Product Features

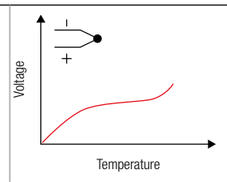
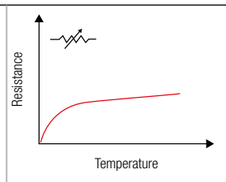
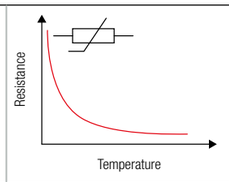
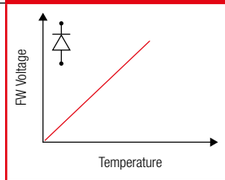
- Cut&Tape: No MOQ and small packing units
- Long term availability
- Small size
- Low Power Consumption

Data sheet: WSEN-TIDS
we-online.com/SPEC/WSEN-TIDS

Manual: WSEN-TIDS
we-online.com/Man/WSEN-TIDS

Manual: Eval Board
we-online.com/Man/EVAL-WSEN-TIDS

Webinar:
Digital silicon-based temperature sensors for industrial applications

				WSEN-TIDS 
	Thermocouple	**RTD**	**Thermistor**	**MEMS**
Measurement range	-250 °C to 2500 °C	-250 °C to 700 °C	-100 °C to 250°C	-55°C to 150°C
Accuracy	Average (require CJC)	Highest	Average	High
Sensitivity	Low-average	Average	High	High
Linearity	Average	Good	Low	Highest
Peripheral Circuits/ Calibration	CJC; Amplifier; Scaling	Resistance correction; Scaling	Scaling	No
Footprint	Large	Medium	Small	Smallest
Price	Moderate	Very high	Low	Low

CJC= Cold Junction Compensation → Reference Calibration

WSEN-HIDS
Humidity Sensor with integrated Temperature Sensor

- MEMS based capacitive sensing principle
- Relative humidity range 0% to 100%
- Embedded analog to digital converter
- Fully calibrated 16 bit humidity and temperature output
- I²C and SPI communication interface
- Selectable output data rate up to 12.5 Hz
- Operating temperature range: -40 °C to 120 °C

Order Code	$H_{RANGE\ min}$ (% rH)	$H_{RANGE\ max}$ (% rH)	RES_T (bits)	ODR_{min} (Hz)	ODR_{max} (Hz)	$V_{DD\ min}$ (V)	$V_{DD\ max}$ (V)
2525020210001	0	100	16	1	12.5	1.7	3.6

$H_{RANGE\ min}$: Measurement range [min.]; $H_{RANGE\ max}$: Measurement range [max.]; RES_T: Resolution [typ.]; ODR_{min}: Output data rate [min.]; ODR_{max}: Output data rate [max.]; $V_{DD\ min}$: Operating supply voltage [min.]; $V_{DD\ max}$: Operating supply voltage [max.]

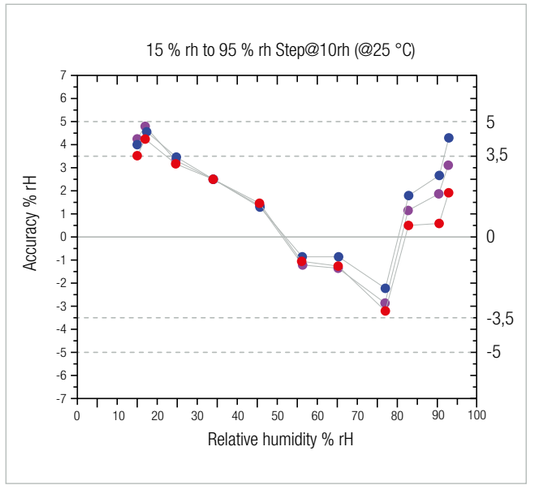
Product Features

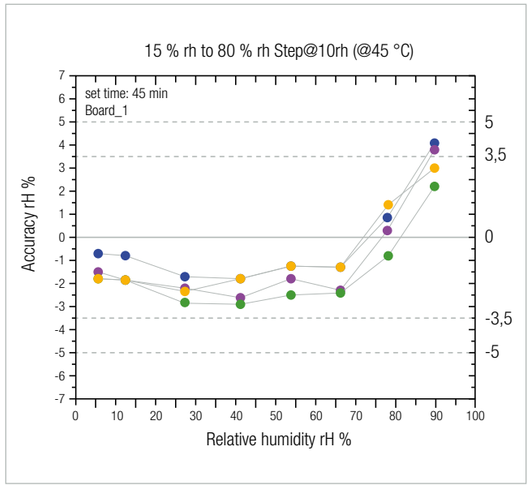
- Cut&Tape: No MOQ and small packing units
- Long term availability
- Small size
- Low Power Consumption

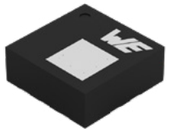
Data sheet: WSEN-HIDS
we-online.com/SPEC/WSEN-HIDS

Manual: WSEN-HIDS
we-online.com/Man/WSEN-HIDS

Manual: Eval Board
we-online.com/Man/EVAL-WSEN-HIDS







WSEN-PADS
Absolute Pressure Sensor

- MEMS based piezo-resistive sensing principle
- 24 bit pressure output resolution
- Selectable output data rate up to 200 Hz
- 128 level FIFO buffer
- Embedded temperature sensor
- I²C digital communication interface
- Application specific interrupt event setting
- Temperature range: -40 °C up to +85 °C

Order Code	$P_{RANGE\ min}$ (kPa)	$P_{RANGE\ max}$ (kPa)	RES_P (bits)	ODR_{min} (Hz)	ODR_{max} (Hz)	$V_{DD\ min}$ (V)	$V_{DD\ max}$ (V)
2511020213301	26	126	24	1	200	1.7	3.6

$P_{RANGE\ min}$: Measurement range [min.]; $P_{RANGE\ max}$: Measurement range [max.]; RES_P: Resolution (ADC) [typ.]; ODR_{min}: Output data rate [min.]; ODR_{max}: Output data rate [max.]; $V_{DD\ min}$: Operating supply voltage [min.]; $V_{DD\ max}$: Operating supply voltage [max.]

Product Features

Cut&Tape: No MOQ and small packing units

Long term availability

Small size

Low Power Consumption

Data sheet: WSEN-PADS
we-online.com/SPEC/WSEN-PADS

Manual: WSEN-PADS
we-online.com/Man/WSEN-PADS

Manual: Eval Board
we-online.com/Man/EVAL-WSEN-PADS

Pressure Altimeter using Absolute Pressure Sensor WSEN-PADS
we-online.com/ANM003

Webinar:
Currently under pressure? Discover our new MEMS pressure sensors

WSEN-PDUS
Differential Pressure Sensor

- MEMS based piezo-resistive sensing principle
- Very high accuracy (up to ±0.25 % FSS tolerance)
- Different transfer functions from ±0.1 kPa to 1 MPa
- 15 bit digital & 11 bit analog pressure output resolution
- Embedded temperature sensor
- Analog & I²C digital communication interface
- Temperature range: -25 °C up to +85 °C

Order Code	$P_{RANGE\ min}$ (kPa)	$P_{RANGE\ max}$ (kPa)	ACC_{P_TOT}	$V_{DD\ min}$ (V)	$V_{DD\ max}$ (V)
2513130810001	-0.1	0.1	±2.5 %FSS	4.75	5.25
2513130810101	-1	1	±0.75 %FSS		
2513130810201	-10	10	±0.75 %FSS		
2513130810401	-100	1000	±0.25 %FSS		
2513130810301	0	100	±0.25 %FSS		

$P_{RANGE\ min}$: Measurement range [min.]; $PR_{ANGE\ max}$: Measurement range [max.]; ACC_{P_TOT}: Total accuracy [typ.]; $V_{DD\ min}$: Operating supply voltage [min.]; $V_{DD\ max}$: Operating supply voltage [max.]

Conversion Table

1	Pa			0.01	mBar
2.5	Pa			0.025	mBar
10	Pa			0.1	mBar
0.1	kPa	1	hPa	1	mBar
1	kPa	10	hPa	10	mBar

10	kPa	100	hPa	100	mBar
26	kPa	260	hPa	260	mBar
100	kPa	1000	hPa	1	Bar
126	kPa	1260	hPa	1.26	Bar
1000	kPa	10,000	hPa	10	Bar

Product Features

Cut&Tape: No MOQ and small packing units

Long term availability

Small size

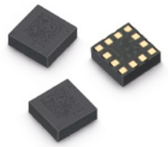
Custom calibration values possible

Data sheet: WSEN-PDUS
we-online.com/SPEC/WSEN-PDUS-01
we-online.com/SPEC/WSEN-PDUS-1
we-online.com/SPEC/WSEN-PDUS-10
we-online.com/SPEC/WSEN-PDUS-1000
we-online.com/SPEC/WSEN-PDUS-100

Manual: WSEN-PDUS
we-online.com/Man/WSEN-PDUS

Manual: Eval Board
we-online.com/Man/EVAL-WSEN-PDUS

Products



WSEN-ITDS
3 Axis Acceleration Sensor

- MEMS based capacitive sensing principle
- 14 bit output resolution
- Full scale ±2 g, ±4 g, ±8 g, ±16 g
- Bandwidth up to 1600 Hz
- 32 level FIFO buffer
- Embedded temperature sensor
- I²C digital communication interface
- Application specific functionality: Free-fall, wakeup, tap, activity, motion and orientation detection
- Temperature range: -40 °C up to +85 °C

Order Code	a_{RANGE}	RES_a (bits)	ODR_{max} (Hz)	f_{BW} (Hz)	$V_{DD\ min}$ (V)	$V_{DD\ max}$ (V)
2533020201601	±2/ ±4/ ±8/ ±16 *g*	14	1600	400	1.7	3.6

a_{RANGE}: Acceleration range [typ.]; RES_a: Resolution [max.]; ODR_{max}: Output data rate [max.]; f_{BW}: Bandwidth [max.]; $V_{DD\ min}$: Operating supply voltage [min.]; $V_{DD\ max}$: Operating supply voltage [max.]

Product Features

Cut&Tape: No MOQ and small packing units

Long term availability

Small size

Low Power Consumption

Data sheet: WSEN-ITDS
we-online.com/SPEC/WSEN-ITDS

Manual: WSEN-ITDS
we-online.com/Man/WSEN-ITDS

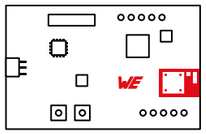
Manual: Eval Board
we-online.com/Man/EVAL-WSEN-ITDS

Human Fall Detection with 3-Axis MEMS Acceleration Sensor
we-online.com/ANM002

Webinar:
Accelerate your IoT development project with our MEMS 3-axis sensor

Added Values

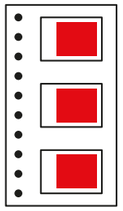
Development Tools



Eval Boards
- Easy fast testing
- No problem with hand soldering of small sensors
- I²C directly accessable

Overview: Eval Boards
we-online.com/EVAL-SENS

More information on page 108



Development Kit
- 5 (2 for WSEN-PDUS) sensors on stock
- Delivery within 48 hours
- Ready to use

FeatherWing
- Adafruit standard
- Easy connectable
- For complex system tests

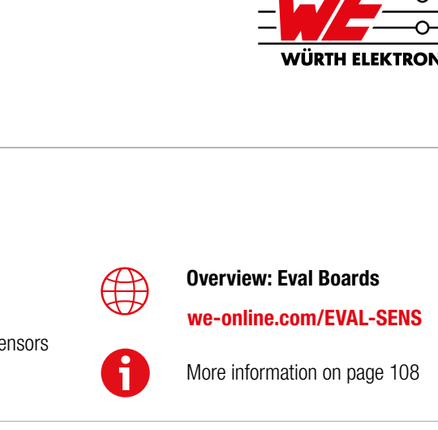
More information on page 106

Software Development Kit

page: 24

The SDK enables professional software integration of Würth Elektronik sensors into any host processors by offering a set of drivers and sample applications.
- Typically as C-Files, for mobile Apps platform specific languages
- For comfortable coding of:
  - The HOST-controller system
  - PC Applications
  - Mobile Apps
- Code examples in Application notes and Manuals

we-online.com/WSEN-SDK



Added Values

Libraries

Webinars

Ever since the industrial revolution, machines have simplified our lives for the better. Manufacturing companies in particular have felt the benefit of using machinery. However there is one major drawback; machines require maintenance.

Some machine parts wear out faster than others, depending on the degree of use and duration of use and load. Unfortunately, this is something which is not easily detected just by monitoring the machine from the outside. Poorly maintained machines produce reject parts, increase production costs and waste resources. A poorly maintained machine can cause malfunctions, which can result in lengthy downtimes of a product line and even be hazardous for the operator.

In order to avoid malfunctions, machine maintenance is typically carried out at regular intervals in accordance with the manufacturer's guidelines. However in-between scheduled maintenance a problem may go undetected. In our era of digital transformation, big data, Internet of Things and increasing automation, this surely is outdated. Predictive maintenance provides the solution, where machines communicate with us whenever they need to be serviced.

The Internet of Things describes the networking, communication and interaction of devices. These devices and the data generated by them lead to new applications. These new applications facilitate automation, smart homes, smart farming and create the foundation for smart cities. Typically, the IoT refers to consumer applications whereas the networking of machines, products and processes in the manufacturing industry is referred to as the IIoT – Industrial Internet of Things.

The IoT is a central component of Industry 4.0 (the digitization, interconnection and automation of industrial equipment and processes). The IIoT is also necessary for predictive maintenance because measurement data from machines is used to determine the exact maintenance requirement of individual components and machines. The objective of predictive maintenance is to service machines intelligently; applying maintenance only when required, and when appropriate, to maximize production.

Benefits of Predictive Maintenance

Minimized machine downtimes
If a machine is only serviced as and when required, unnecessary machine downtimes can be avoided.

Higher productivity
Maintenance can be scheduled to take place when the machine is not required for production.

Increased maintenance efficiency
The data used for predictive maintenance signals that a machine needs servicing and specifies which component requires attention, minimizing the time spent on failure diagnostics.

Optimized staff resources
Maintenance only needs to be performed when required, allowing staff to be used more effectively.

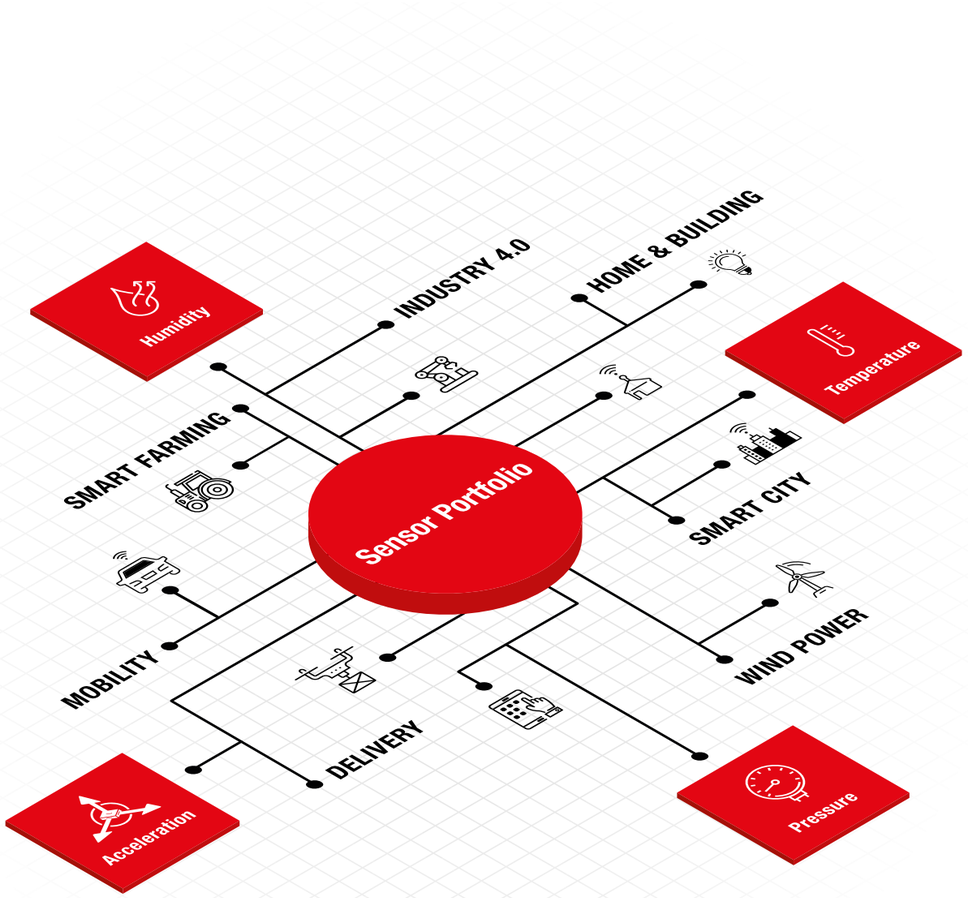
Optimized material resources
The machine will produce far less rejects and save time by avoiding the repetition of production runs.

In short, predictive maintenance helps to increase efficiency by saving time, material, manpower resources and ultimately also money. Furthermore, predictive maintenance creates a new business area, an IoT service supplier who facilitates the processing and analysis of machine data.

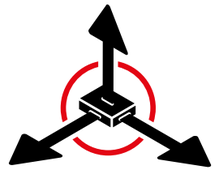
User Application

Our Sensor Portfolio

To take advantage of the benefits that predictive maintenance presents, some challenges have to be overcome. Predictive maintenance doesn't require big data, but it does need the right data. Therefore, it is important to be able to identify useful data and understand how it can be transmitted. Würth Elektronik offers solutions for a diverse range of applications. The sensors which are used, continuously monitor the condition of machinery and equipment. When it comes to different types of wear, different sensors are used. Below are some examples.



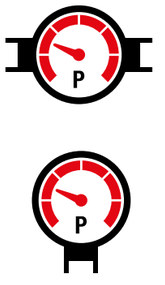
Sensors for detecting Imbalance or Vibration



Bearing and gear damage, defective shafts, loose anchoring, worn straps or damaged windmill blades and turbine wheels often cause an imbalance or vibration. To detect these we recommend the 3 axis acceleration sensor (WSEN-ITDS, 2533020201601) by Würth Elektronik. It measures the acceleration for each of the three spatial axes. This means that a suitable position within the application does not need to be considered. Any torsion can be compensated with matrix calculations. Depending on the application, it might also be useful to determine the absolute acceleration vector based on the three individual axes.

Any change in vibrational behavior often indicates towards the wear and tear of a mechanical component. This can also be confirmed using the acceleration sensor. To make the acceleration sensor work, output signal of the acceleration sensor is spectrally decomposed, typically by applying Fourier transformation. The above mentioned types of damage change this spectrum, mostly because several harmonic waves are produced. The relative change of this spectrum and not the absolute values, often predict the beginning of destructive wear and tear.

Sensors for detecting Filter Conditions

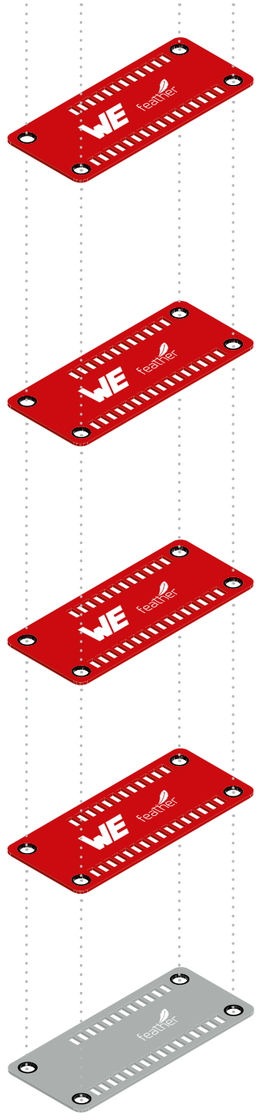


Pressure sensors can be used in filters to determine the optimal time of replacement or cleaning. If particles clog the filter, the dynamic pressure increases, resulting in a pressure difference across the filter. For this purpose, differential pressure sensors of the WSEN-PDUS (2513130810x01) range can be used to measure on both sides of the filter.

Depending on your application, you might also want to place an absolute pressure sensor before and another after the filter. Then the measured values can be calculated as differential pressure using a microcontroller. For this purpose, the absolute pressure sensor (WSEN-PADS, 2511020213301) can be used.

Würth Elektronik FeatherWings

Adafruit Feather is a complete line of development boards that are both standalone and stackable. They're able to be powered by LiPo batteries for on-the-go use or by their micro-USB plugs for stationary projects. Feathers are flexible, portable, and as light as their namesake.
FeatherWings are stacking boards and add functionality and room for prototyping. At its core, the Adafruit Feather is a complete ecosystem of products - and the best way to get your project flying.
With our open-source Würth Elektronik FeatherWings you can dive into the existing ecosystem and add following functionalities with maximized compatibility :



Sensor FeatherWing (2501000201291) page: 94-98
- Acceleration (WSEN-ITDS)
- Absolute Pressure (WSEN-PADS)
- Temperature (WSEN-TIDS)
- Humidity (WSEN-HIDS)
- Sparfun QWIIC compatible to easily add hundreds of extension boards

Thyone-I Wireless FeatherWing (2611059021001) page: 67
- Proprietary 2.4 GHz RF-Module
- Connecting wirelessly up to 300 m
- Easy build up network
- Connect to Thyone-I modules or USB-Sticks

Calypso Wi-Fi FeatherWing (2610039025001) page: 52
- Wi-Fi-Connection 2.4 GHz
- Easy connection to Smart Devices
- Sending data to the server
- Handling multiple nodes

MagI³C Power FeatherWing (2601157100001)
Can be powered with 5 V USB connection and industrial input voltage rails of 9 V, 12 V, 15 V, 18 V and 24 V with maximum nominal input voltage of 36 V.

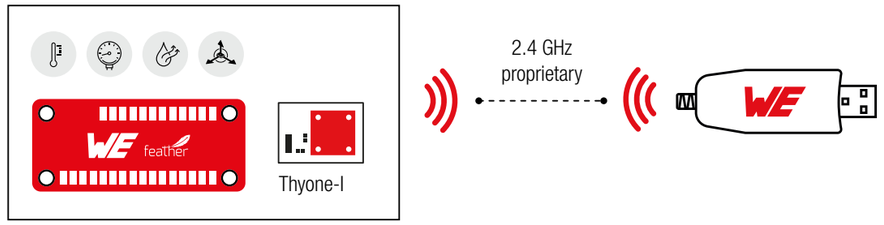
Connect any FeatherWing Microcontroller
- Request sensor data
- Transfer data to RF-Module
- Examples and Sourcecode available on Github

Example Scenario

Easily build your own Wireless Sensor Tag without the need of hardware development.

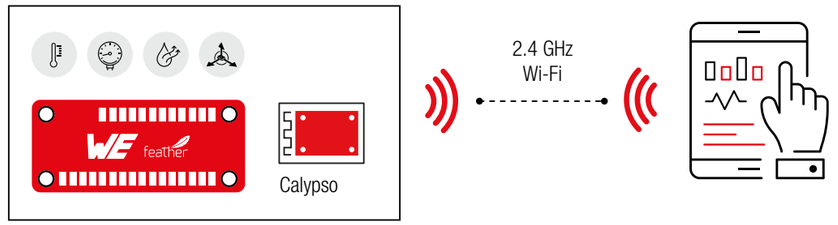
Example 1: Built up a Proprietary Network

- Select a microprocessor of your choice from the Adafruit Feather ecosystem
- Use the Sensor FeatherWing for measuring condition parameters like temperature, air pressure, humidity and acceleration
- Send out data with Thyone-I FeatherWing on 2.4 GHz proprietary radio
- Thyone-I USB radio stick or another Thyone-I FeatherWing can receive the data and you get access to all information
- Even various Tags could be connected wirelessly
- We support you with libraries and examples available on Github for some microcontrollers



Example 2: Connect with Wi-Fi

- Select a microprocessor of your choice from the Adafruit Feather ecosystem
- Use the Sensor FeatherWing for measuring condition parameters like temperature, air pressure, humidity and acceleration
- Send out data with the Calypso FeatherWing on 2.4 GHz Wi-Fi
- Receive data on smart devices or server structures



Accessories

Order Code	Name	Information	Eval Board	USB-Stick	Antenna	Dev-Kits*
2613011037000	Elara-I	GPS, GLONASS with Integrated Antenna	2613019037001	-	-	2613011037009
			2.4 GHz RF connect: 2613019037011	2611036021001		
2613021137000	Elara-II	GPS, GLONASS with RF pad	2613029237001	-	2600130016 (Halimede-I) 7488920157 (WE-MCA)	2613021137009
			2.4 GHz RF connect: 2613029237011	2611036021001		
2614011037000	Erinome-I	GPS, GLONASS, Galileo, BeiDou with Integrated Antenna	2614019037001	-	-	2614011037009
			2.4 GHz RF connect: 2614019037011	2611036021001		
2614021137000	Erinome-II	GPS, GLONASS, Galileo, BeiDou with RF pad	2614029237001	-	2600130016 (Halimede-I) 7488920157 (WE-MCA)	2614011037009
			2.4 GHz RF connect: 2614029237011	2611036021001		
2608011024000	Proteus-I	Bluetooth® LE 4.2 with integrated antenna	2608019024001	-	-	2608011024009
2608011124000	Proteus-I	Bluetooth® LE 4.2 with RF pad	2608019324001	-	2600130021 (Himalia)	2608011124009
2608011024010	Proteus-II	Bluetooth® LE 5.0 with integrated antenna	2608019024011	2608036024011	-	2608011024019
2608011124010	Proteus-II	Bluetooth® LE 5.0 with RF pad	2608019324011	2608036024011	2600130021 (Himalia)	2608011124019
2611011024000	Proteus-III	Bluetooth® LE 5.1 with smart antenna selection	2611019024001	2611036024001	2600130021 (Himalia)	2611011024009
			Mini Eval Board**: 2611069024001			
2610011025000	Calypso	2.4 GHz Wi-Fi module	2610019225001	-	2600130021 (Himalia)	2610011025009
2603011021000	Triton	2.4 GHz proprietary module with integrated antenna	2603019021001	-	-	2603011021009
2603011121000	Triton	2.4 GHz proprietary module with RF pad	2603019321001	-	2600130081 (Hyperion-I)	2603011121009
2606031021000	Thalassa	2.4 GHz proprietary module with integrated antenna	2606039021001	2606046021001	-	2606031021009
2606031121000	Thalassa	2.4 GHz proprietary module with RF pad	-	2606046021001	2600130021 (Himalia)	2606031121009
2606031321000	Thalassa	2.4 GHz proprietary module with U.FL connector	-	2606046021001	2600130021 (Himalia)	2606031321009
2607011111000	Titania	169 MHz proprietary module with RF pad	2607019211001	2607046211001	2600130011 (Helike)	2607011111009
2605031141000	Thadeus	434 MHz proprietary module with RF pad	2605039241001	-	2600130041 (Herse)	2605031141009
2605041181000	Tarvos-I	868 MHz proprietary module with RF pad	2605049281001	2605056081001	2600130081 (Hyperion-I) 2600130082 (Hyperion-II)	2605041181009
2607021181000	Tarvos-II	868 MHz proprietary module with RF pad	2607029281001	2607056281001	2600130081 (Hyperion-I) 2600130082 (Hyperion-II)	2607021181009
2609011081000	Tarvos-III	868 MHz proprietary module with integrated antenna	-	2609026281001	-	2609011081009
2609011181000	Tarvos-III	868 MHz proprietary module with RF pad	2609019281001	2609026281001	2600130081 (Hyperion-I) 2600130082 (Hyperion-II)	2609011181009
2609031181000	Thebe-II	868 MHz proprietary module with RF pad	2609039281001	-	2600130081 (Hyperion-I) 2600130082 (Hyperion-II)	2609031181009
2607021191000	Telesto-I	915 MHz proprietary module with RF pad	2607029291001	2607056291001	-	2607021191009
2607021191010	Telesto-II	915 MHz proprietary module with RF pad	2607029291011	2607056291011	-	2607021191019
2609011091000	Telesto-III	915 MHz proprietary module with integrated antenna	-	2609026291001	-	2609011091009
2609011191000	Telesto-III	915 MHz proprietary module with RF pad	2609019291001	2609026291001	-	2609011191009
2609041191000	Themisto-I	915 MHz proprietary module with RF pad	2609049291001	-	2600130083 (Hydra-I)	2609041191009
2611011021000	Thyone-I	2.4 GHz proprietary module; smart antenna selection	2611019021001	2611036021001	2600130021 (Himalia)	2611011021009
			Mini Eval Board**: 2611079021001			
			Long Range Board: 2611017221001			

* not available online ** Connector Kit 699100

Order Code	Name	Information	Eval Board	USB-Stick	Antenna	Dev-Kits*
2607011113000	Mimas-I	169 MHz wM-BUS module	2607019213001	2607046213001	2600130011 (Helike)	2607011113009
2605041183000	Metis-I	868 MHz wM-BUS module	2605049283001	2605056083001	2600130081 (Hyperion-I) 2600130082 (Hyperion-II)	2605041183009
2607021183000	Metis-II	868 MHz wM-BUS module	2607029283001	2607056283001		2607021183009
2607056283011	Metis-II	868 MHz wM-BUS radio simulation USB-Stick	-	-		-
2607057283011	Metis-Analyzer Tool	868 MHz wM-BUS radio Analyzer USB-Stick	-	-		-

Order Code	Name	Information	Eval Board	USB-Stick	Antenna	Dev-Kits*
2533020201601	WSEN-ITDS	3 axis acceleration sensor	2533203301691	-	-	2533020201681
2521020222501	WSEN-TIDS	Temperature sensor	2521020222591	-	-	2521020222581
2525020210001	WSEN-HIDS	Humidity sensor	2525020210091	-	-	2525020210081
2511020213301	WSEN-PADS	Absolute pressure sensor	2511223013391	-	-	2511020213381
2513130810001	WSEN-PDUS	Differential pressure sensor (-0.1 - 0.1 kPa; -1-1 mbar)	2513254510091	-	-	2513130810081
2513130810101	WSEN-PDUS	Differential pressure sensor (-1-1 kPa; -10-10 mbar)	2513254510191	-	-	2513130810181
2513130810201	WSEN-PDUS	Differential pressure sensor (-10-10 kPa; -0.1-0.1 bar)	2513254510291	-	-	2513130810281
2513130810301	WSEN-PDUS	Differential pressure sensor (0-100 kPa; 0-1 bar)	2513254510391	-	-	2513130810381
2513130810401	WSEN-PDUS	Differential pressure sensor (-100-1000 kPa; -1-10 bar)	2513254510491	-	-	2513130810481

Order Code	Name	Information	Eval Board	USB-Stick	Antenna	Dev-Kits*
2609017281001	AMBER PI	Design Kit for Raspberry PI	-	-	-	-
2501000201291	Sensor FeatherWing	WSEN-ITDS, -PADS, -TIDS, -HIDS integrated	-	-	-	-
2611059021001	Thyone-I FeatherWing	Proprietary 2.4 GHz RF-Module Connection	-	2611036021001	2600130021 (Himalia)	-
2610039025001	Calypso FeatherWing	Wi-Fi-Connection 2.4 GHz	-	-	2600130021 (Himalia)	

*not available online

General Terms and Conditions of the Würth Elektronik eiSos Group

As of: May 2018

1. Application

1.1 These General Terms and Conditions (hereinafter "**Conditions**") shall apply to all deliveries and services of Würth Elektronik eiSos GmbH & Co. KG, Würth Elektronik iBE GmbH and Erwin Büchele GmbH & Co. KG (hereinafter "**Würth Elektronik**") even if they are not referred to in subsequent contracts. Any terms and conditions of the customer that conflict with, supplement, or deviate from these Conditions shall not become part of the contract unless their application is expressly approved by Würth Elektronik in writing. These Conditions shall apply even if Würth Elektronik accepts a delivery or service from the customer without reservations whilst being aware of the customer's conflicting or deviating terms and conditions.

1.2 Agreements which supplement or deviate from these Conditions and which are made between the customer and Würth Elektronik for the performance of a contract must be set out in writing in the contract. This also applies to the cancellation of this requirement of the written form.

1.3 Any rights beyond these Conditions to which Würth Elektronik is entitled by law shall remain unaffected.

2. Offer and formation of contract

2.1 Offers from Würth Elektronik shall be subject to change and non-binding, unless they are expressly stated to be binding.

2.2 Pictures, drawings, information as to weight, measurement, performance and consumption as well as other descriptions of the goods in the documentation pertaining to the offer shall be approximations only, unless they are expressly stated to be binding. They do not constitute an agreement on, or guarantee of, the corresponding quality of the goods.

2.3 Würth Elektronik reserves all proprietary rights and copyrights in any offer documents. Such documents may not be made available to any third party.

2.4 Orders from the customer shall be binding. Würth Elektronik may accept orders by sending a written order confirmation, by making delivery or providing the services.

2.5 Executing orders according to the documents to be provided by the customer shall require written approval by Würth Elektronik.

2.6 Contracts that are concluded shall oblige the customer to accept and pay for the goods or services ordered.

3. Prices, payment, set-off

3.1 The agreed price shall always be decisive. Not included in the price shall, in particular, be the costs for packaging, freight, insurance, customs, public levies and VAT. Statutory VAT shall be stated separately in the invoice, at the statutory rate applicable on the day the invoice is issued.

3.2 For services that shall not be performed within a period of four month after the contract has been concluded Würth Elektronik shall be entitled to adjust the price in line with any increases in wages and in the cost of materials that may have occurred in the meantime. The same shall apply for services that are to be provided as part of continuous obligations. If Würth Elektronik has agreed with the customer that the prices shall depend on specific price factors, for example, raw material prices, changes in the price factors can lead to price adjustments, irrespective of the performance period.

3.3. Unless otherwise agreed, payment shall be made net within 30 days after the date of the invoice. Würth Elektronik shall, however, be entitled to make the execution of outstanding deliveries or the provision of services contingent upon pre-payment or the provision of security if no previous business relationship exists with the customer, deliveries are to be made abroad, the customer's registered office is abroad or if there are any other reasons that give Würth Elektronik reason to doubt that payment will be made promptly after delivery or provision of the services.

3.4 If after the contract has been entered into Würth Elektronik becomes aware of circumstances that could considerably reduce the customer's creditworthiness and which could endanger the payment of outstanding receivables of Würth Elektronik by the customer under the individual contract, Würth Elektronik shall be entitled to refuse to continue to execute the contract until the customer makes payment or provides security for such. If the customer is in default of payment, all the receivables of Würth Elektronik that are outstanding with the customer shall become due immediately.

3.5 Payment shall be deemed made on the date on which Würth Elektronik can dispose of the amount owed. When paying by cheque, payment shall only be deemed made after the cheque has been cashed and Würth Elektronik can dispose of the amount. Discount charges and other cheque costs shall be borne by the customer. In the event of default of payment, the customer shall pay default interest at the rate of 9 percentage points above the base rate. The right to assert a further claim for damages is not excluded.

3.6 Würth Elektronik shall be entitled to credit payments made by the customer towards the customer's oldest debt first. If costs and interest have already accrued, Würth Elektronik shall be entitled to credit the payment towards the costs first, then towards interest, and finally towards the principal claim.

3.7 Counterclaims of the customer may only be set off or used to assert a right of retention by the customer if they have become final by virtue of a judgment or if they are undisputed. A right to retain may be asserted by the customer only if the customer's counterclaim is based on the same contractual relationship.

4. Deliveries

4.1 Delivery periods and dates shall only be binding for Würth Elektronik if Würth Elektronik explicitly states or confirms that they are binding. Agreed delivery periods shall be deemed met if the goods have been handed over to the person in charge of the transport at Würth Elektronik's registered office or at one of Würth Elektronik's warehouses before this period has expired or if Würth Elektronik has provided notification that they are ready for dispatch but have not left the registered office or warehouse because the customer has declared that it will not accept the goods.

4.2 If making the agreed deliveries or providing the services of Würth Elektronik requires the cooperation of the customer, the customer shall ensure that Würth Elektronik is provided with all the necessary and appropriate information and data within good time and that such is of the required quality. If programming is required, the customer shall provide Würth Elektronik with the necessary computer processing power, test data and data inputting capacities within good time and to a sufficient extent.

4.3 The delivery period shall not start before all the documents, information, approvals and permits that are to be provided by the customer have been provided in full and any technical issues have been clarified and any agreed down-payment has been received. As a prerequisite for compliance with the delivery period or the delivery date, the customer must perform its other obligations properly and in due time. Compliance with the agreed delivery deadlines and delivery dates is subject to the condition that Würth Elektronik is supplied by its own suppliers in due time and properly. Any changes or amendments that are subsequently agreed with Würth Elektronik may result in a reasonable extension of the agreed delivery dates.

4.4 Würth Elektronik shall be entitled to make reasonable part deliveries and provide partial services. Unless otherwise expressly agreed, deliveries and services ahead of schedule shall be allowed.

4.5 If the customer is in default of acceptance or violates other duties to cooperate, Würth Elektronik can claim compensation for the damage caused including any additional expenditure and storage costs. Any other claims remain unaffected. Würth Elektronik shall be entitled, after setting a reasonable subsequent deadline, to otherwise dispose of the goods and to supply the customer with new goods within a reasonable extended deadline.

5. Passing of risk/dispatch

5.1 The risk of accidental loss or accidental deterioration of the goods shall pass to the customer at the latest when the goods are handed over to the customer or, if it is agreed that the goods will be shipped, already with the handing over of the goods to the shipping company, freight carrier or to any other person instructed to carry out the dispatch. This shall also apply to part deliveries or if it has been agreed that the dispatch is “freight paid” or free of charge. In the absence of written instructions from the customer, Würth Elektronik shall be entitled to choose the carrier and the itinerary at its own discretion and after a due assessment of the circumstances. At the request and expense of the customer, Würth Elektronik shall take out transport insurance to insure the goods against the risks specified by the customer.

5.2 If there is a delay in handing over or dispatch for reasons for which the customer is responsible, the risk shall pass to the customer on the day the goods are ready to be dispatched and Würth Elektronik informs the customer of such.

5.3 If Würth Elektronik chooses the type of dispatch, the dispatch route and/or the person to carry out the dispatch, Würth Elektronik shall only be liable for wilful misconduct or gross negligence resulting from this choice.

6. Retention of title

6.1 The goods supplied remain the property of Würth Elektronik until all receivables owed to Würth Elektronik by the customer as a result of the business relationship have been fully paid. If Würth Elektronik's obligations to be performed include delivering software, up until payment in full has been made of any receivables, the customer shall in any case only be granted a revocable usage right. These receivables also include claims under cheques and bills of exchange, as well as current-account claims. The customer shall be obliged to handle all goods to which title is retained, and as long as title is retained, with due care. In particular, the customer is obliged to sufficiently insure the goods at the customer’s own expense against damage by fire, water, and theft at their replacement value. The customer hereby assigns to Würth Elektronik all claims for compensation arising from such insurance. Würth Elektronik hereby accepts the assignment. If an assignment is not allowed, the customer hereby irrevocably instructs its insurer to make payments, if any, only to Würth Elektronik. This does not affect any further claims of Würth Elektronik. Upon request, the customer must provide Würth Elektronik with evidence of the conclusion of the insurance policy.

6.2 The customer shall only be allowed to sell the goods which are subject to retention of title in the ordinary course of business. The customer shall not be entitled to pledge the goods which are subject to retention of title, to transfer them by way of security or to make any other dispositions which may jeopardize Würth Elektronik's ownership. In the event of attachments or other encroachments by third parties, the customer must notify Würth Elektronik without undue delay in textual form and provide all the information required, advise the third party of Würth Elektronik’s property rights and assist with the measures taken by Würth Elektronik to protect the goods which are subject to retention of title. The customer shall bear any costs for which it is responsible and which are necessary for the removal of the encroachment and the recovery of the goods, if and to the extent that these costs cannot be obtained from the third party.

6.3 The customer hereby assigns to Würth Elektronik all receivables arising from the resale of the goods, including all ancillary rights, irrespective of whether the goods which are subject to retention of title are resold without or after further processing. Würth Elektronik hereby accepts this assignment. In the event that such assignment is not allowed, the customer hereby irrevocably instructs the third-party debtor to make payments, if any, only to Würth Elektronik. The customer has the authority, which may be revoked at any time, to collect the receivables assigned to Würth Elektronik as a trustee on behalf of Würth Elektronik. All amounts collected must be remitted to Würth Elektronik immediately. Würth Elektronik may revoke the customer’s authority to collect receivables and its right to resell the goods if the customer fails to properly perform its payment obligations to Würth Elektronik, if the customer is in default of payment or stops payment, or if the creditworthiness or financial position of the customer deteriorates, he cease any other business activity essential for the contractual performance or if he becomes incapable for other reasons to fulfil the contractual duties. Any resale of these receivables is subject to prior approval by Würth Elektronik. The customer’s authority to collect shall expire with the notification of the assignment to the third-party debtor. In the event of a revocation of the authority to collect, Würth Elektronik may request that the customer disclose all receivables assigned, as well as the respective debtors' names, provide all information necessary for collection, provide the related documents and inform the debtors of the assignment.

6.4 In the event of default of payment on the part of the customer, Würth Elektronik shall be entitled to rescind the contract without prejudice to its other rights. The customer must immediately grant Würth Elektronik, or any third party commissioned by Würth Elektronik, access to the goods that are subject to retention of title, surrender such goods and inform Würth Elektronik where these goods are located. After a timely warning to such effect, Würth Elektronik may otherwise dispose of the goods that are subject to retention of title for the purpose of satisfying its due claims against the customer.

6.5 Any processing or alterations made by the customer to the goods which are subject to retention of title shall always be deemed made on behalf of Würth Elektronik. The customer’s right to acquire ownership of the goods which are subject to retention of title continues to exist as a right to acquire ownership of the processed or altered item. If the goods are processed, combined or mixed with other goods that are not owned by Würth Elektronik, Würth Elektronik shall acquire a co-ownership interest in the new item that is equal to the ratio of the value of the goods supplied to the value of the other items processed at the time of processing. The customer shall store the new items on behalf of Würth Elektronik. In all other respects, the item created through processing or alteration shall be governed by the same provisions as the goods that are subject to retention of title.

6.6 If requested by the customer, Würth Elektronik shall be obliged to surrender the security interests to which Würth Elektronik is entitled to the extent that the realizable value of these security interests exceeds Würth Elektronik’s receivables arising from the business relationship with the customer by more than 20% upon deduction of the mark-downs customary in the banking business. For valuation purposes, goods that are subject to retention of title shall be assessed on the basis of their invoice value and receivables shall be assessed on the basis of their nominal value.

6.7 In the event that goods are delivered to destinations with other legal systems in which the retention of title pursuant to clauses 6.1 to 6.6 above does not offer the same degree of protection as in the Federal Republic of Germany, the customer hereby grants Würth Elektronik the equivalent security interest. If the creation of this security interest requires further declarations or actions, the customer shall make these declarations and perform these actions. The customer shall assist with all measures required for, and conducive to, the validity and enforceability of such security interests.

7. Claims for quality defects and liability

7.1 Würth Elektronik shall manufacture its products according to the state of the art in technology applicable at time of entering into the contract. Any intended usage that goes beyond the customary usage of the products or that requires a quality that deviates from the norm, in particular, any usage that is relevant for safety purposes, for example, aerospace or automobile usage, must be agreed in advance in writing.

7.2 The customer's defect rights shall require that the customer has fulfilled its statutory obligations to inspect and give notice of defects (Sec. 377, 381 German Commercial Code (*HGB*)), in particular that the customer has checked the delivered goods upon receipt and notified Würth Elektronik without undue delay and in textual form upon receipt of the goods of any obvious defects and defects that could be identified during such inspection. The customer shall inform Würth Elektronik in writing of any hidden defects without undue delay after they have been discovered. The notification shall be deemed without undue delay if made within two weeks after delivery for obvious defects and defects that could be identified during a proper inspection or after discovery in the event of hidden defects; to meet the deadline, the dispatch of the notification or complaint shall suffice. If the customer fails to carry out a proper inspection and/or notification of the defects, Würth Elektronik shall not be liable for the defect. When reporting defects to Würth Elektronik, the customer must supply a detailed description of the defects in textual form.

7.3 Unless otherwise agreed, the customer shall initially deliver the goods at its own expense to Würth Elektronik so that the defects can be examined. The expenses that are required for the inspection and subsequent performance, in particular transportation, travel, labour and

material costs within the meaning of Sec. 439 (2 and 3) German Civil Code (*BGB*) shall only be borne by Würth Elektronik if it is determined during the inspection that a defect actually exists and provided these expenses are not increased due to the fact that the customer took the goods to a different location than the original delivery address. Personnel and material costs claimed by the customer in this connection shall be charged on the basis of net costs. The reimbursement of the costs for removal and installation in the context of supplementary performance regardless of fault is excluded. Equally excluded is the applicability of Sec. 445 a and 445 b German Civil Code (*BGB*).

7.4 If the goods are defective, Würth Elektronik shall be entitled - for the purposes of subsequent performance - to choose between remedying the defect or delivering goods that are free from defects.

7.5 If Würth Elektronik is not prepared or is not in a position to carry out subsequent performance after a reasonable deadline has expired, the customer can choose to rescind the agreement or reduce the purchase price. The same shall apply if the subsequent performance fails, if it is unacceptable to the customer or if a reasonable deadline is exceeded due to reasons for which Würth Elektronik is responsible.

7.6 The customer shall have no right to rescind the contract if the customer is unable to return the goods received and this is not due to the fact that it is impossible to return such due to their nature, if Würth Elektronik is responsible for such or if the defect did not become apparent until after the goods were processed or altered. The right to rescind the contract shall furthermore not exist if Würth Elektronik is not responsible for the defect and if instead of the received goods or services being returned by the customer, Würth Elektronik has to pay compensation for lost value.

7.7 Claims for defects shall not exist with respect to defects that are due to natural wear and tear, to improper handling by the customer or a third party, or to changes or repairs to the goods that have been carried out by the customer or a third party in an improper manner. The same shall apply to defects which can be attributed to the customer or which arise as a result of technical reasons other than the original defect. The customer shall, in particular, comply with the operational, storage and/or maintenance recommendations provided by Würth Elektronik or the manufacturer.

7.8 The customer's claim for reimbursement of expenses in place of damages in lieu of performance shall be excluded if and to the extent that such expenses would not have been made by a reasonable third party.

7.9 Würth Elektronik shall not be liable for damage for which it is not responsible, in particular, it shall not be liable for damage that is caused by improper usage or handling of the products. The customer is obliged to comply with the operational, storage and/or maintenance recommendations provided by Würth Elektronik or the manufacturer, to only make authorised changes, replace spare parts professionally and use the consumables that have the necessary specifications. Where applicable the customer shall, both before and also regularly after the deliveries have been made or the services have been provided by Würth Elektronik, perform backups to its computer systems at sufficiently regular intervals. Würth Elektronik shall assume no liability for damage which is caused by or can be attributed to a breach of the aforesaid obligations of the customer.

7.10 Würth Elektronik shall be liable without limitation for any damage resulting from breach of guarantee or from death, bodily injury, or damage to health. The same shall apply to wilful misconduct and gross negligence, to mandatory statutory liability for product defects (in particular under the German Product Liability Act *(ProdHaftG)* and to liability if defects were concealed with fraudulent intent. In cases of slight negligence, Würth Elektronik shall only be liable if material obligations are breached that result from the nature of the contract and the performance of which is of particular importance in order for the purpose of the contract to be achieved. If such obligations are breached, as well as in the event of default or if performance is impossible, Würth Elektronik's liability shall be limited to the damage which can typically be expected with such contract.

7.11 The limitation period for claims for defects of the customer shall be one year, unless the defective good has been used in its customary manner for a building and this has caused a defect to the building. The limitation period shall also apply to claims resulting from a tortious act that are based on a defect of the goods. The limitation period shall start with the delivery of the goods. This shall not affect the unlimited liability of Würth Elektronik for damage resulting from a breach of guarantee or from death, bodily injury or damage to health, for wilful misconduct and gross negligence, and product defects. If Würth Elektronik makes a statement with regard to a claim for defects asserted by the customer, this shall not be deemed as the start of negotiations with regard to the claim or the circumstances on which the claim is based, provided the claim for defects is fully rejected by Würth Elektronik.

8. Intellectual property and usage rights relating to software and other protected products, information and co-operation duties

8.1 Unless otherwise provided in the contract or by law, any rights relating to software or other protected products which are delivered to the customer or which are produced for the customer, in particular, copyrights, industrial property rights such as, patents, trademarks and registered designs, shall remain the property of Würth Elektronik or the individual proprietor of the rights. This shall also apply if the software or any other protected products are produced according to the specifications of or in co-operation with the customer.

8.2 If Würth Elektronik uses the customer's software, Würth Elektronik shall only use such software for the contractually agreed purpose. If Würth Elektronik requires the source codes for the software to make contractually agreed changes or remedy defects, the customer shall provide Würth Elektronik with such free of charge for use.

8.3 The customer shall only receive a simple right of use to the software and other protected products to such extent as is required for the purpose of the contract, unless otherwise provided in the contract, in particular, the applicable licencing terms of the software or an individual licence agreement, or by mandatory statutory law. With regard to software provided by Würth Elektronik, unless expressly permitted under the contract or by law, the customer shall in particular be forbidden from reproducing, distributing, disclosing, changing, translating, extending, making other modifications to and/or decompiling such.

8.4 For backup purposes, the customer may create the necessary backup copies of the software, provided the individual licence agreement does not contain provisions to the contrary. Sec. 69d (2) Germany Act on Copyright and Related Rights (*UrhG*) remains unaffected. Backup copies on moveable data carriers shall be marked as such and shall be endorsed with the copyright notice of the original data carrier.

8.5 In the event of unlawful use Würth Elektronik and/or third parties, in particular, the manufacturer of the software or other protected products, reserve the right to assert claims for compensation.

8.6 In the event that a third party alleges it has a claim which conflicts with the right of use granted to the customer, the customer shall inform Würth Elektronik without undue delay in text form. The notification shall also include information as to whether the customer has changed the software or the product or combined such with other software and whether this, from the customer's perspective, could justify the third party's claim. If so requested by Würth Elektronik, the customer shall allow Würth Elektronik to handle the defence against these claims and, to the extent permissible and possible, shall allow Würth Elektronik to represent the customer or shall conduct the defence itself as instructed by Würth Elektronik. Up until receiving notification as to whether Würth Elektronik will deal with the defence, the customer shall not acknowledge or enter into a settlement agreement regarding the alleged claims of the third party without the express approval of Würth Elektronik. If Würth Elektronik deals with the defence, this obligation shall continue to apply. In addition, the customer shall support Würth Elektronik in its defence, if this is required for an appropriate defence. In return, Würth Elektronik shall indemnify and hold the customer harmless against any necessary external costs and any third party compensation claims and claims for reimbursement of expenses resulting from the defence, provided these can be attributed to the fault of Würth Elektronik. In the event that Würth Elektronik does not deal with the defence, the customer shall be entitled to defend itself at its own discretion. If existing third party claims cannot be attributed to the fault of Würth Elektronik, the customer shall not be entitled to assert claims against Würth Elektronik.

8.7 Notwithstanding Sec. 439 (1) German Civil Code (*BGB*), Würth Elektronik shall also be entitled with regard to title defects relating to software to attempt subsequent performance, if Würth Elektronik so chooses (cf. 7.4). In all other respects, the statutory provisions for warranty obligations for title defects with regard to software shall apply irrespective of whether Würth Elektronik is dealing with the defence against third party claims under clause 8.6 of these Conditions, however, with the following exceptions: (i) for the recovery of data, Würth Elektronik shall only be liable insofar as the loss of data would also have occurred if the customer had carried out the usual backups; (ii) clause 7.3 of these Conditions applies accordingly.

9. Product liability

9.1 The customer shall not modify the goods; in particular, the customer shall not modify or remove existing warnings relating to risks by improperly using the goods. If this duty is violated, the customer must inter partes indemnify and hold Würth Elektronik harmless from and against any product liability claims of third parties to the extent that the customer is responsible for the defect giving rise to liability.

9.2 If Würth Elektronik has to carry out a product recall or issue a product warning because of a product defect to the goods, the customer shall assist Würth Elektronik and take all measures ordered by Würth Elektronik, provided that these do not pose an unreasonable burden to the customer. The customer shall be obliged to bear the costs of the product recall or product warning, provided the customer is responsible for the product defect and the damage sustained. This does not affect any further claims of Würth Elektronik.

9.3 The customer shall inform Würth Elektronik without undue delay in textual form of any risks in the use of the goods and any possible product defects of which the customer becomes aware.

10. Force majeure

10.1 If Würth Elektronik is prevented by force majeure from performing its contractual obligations, in particular from delivering the goods, Würth Elektronik shall be released from its obligation to perform for the duration of the impediment and for a reasonable start-up period without being liable to the customer for damages. The same shall apply if the performance of its obligations by Würth Elektronik becomes unreasonably complicated or temporarily impossible because of unforeseeable circumstances for which Würth Elektronik is not responsible, in particular, because of industrial action, official acts, energy shortages, delivery problems on the part of suppliers, or major disruptions of operations.

10.2 Würth Elektronik shall have the right to rescind the contract if such an impediment continues for more than three months and if, as a result of such impediment, the performance of the contract is no longer of interest to Würth Elektronik. At the request of the customer, Würth Elektronik shall declare after the expiry of the aforesaid three-month period whether it intends to make use of its right to rescind the contract or whether it intends to deliver the goods within a reasonable period of time.

11. Confidentiality

The customer shall be obliged for an unlimited period of time to maintain the confidentiality of any and all information received through Würth Elektronik which is stated to be confidential or which due to other circumstances can be identified as a trade or business secret; the customer may neither record nor disclose or use any such information. The customer must ensure by means of suitable contractual agreements with its employees and those agents working on its behalf that such persons also refrain for an unlimited period of time from any use, disclosure and unauthorised recording of such trade and business secrets for their own purposes.

12. Final provisions

12.1 Any rights and obligations of the customer may only be assigned or transferred to a third party with the written consent of Würth Elektronik.

12.1 The legal relations between the customer and Würth Elektronik shall be governed by the laws of the Federal Republic of Germany, without regard to the United Nations Convention on Contracts for the International Sale of Goods (CISG).

12.3 Exclusive place of jurisdiction for all disputes arising from the business relationship between Würth Elektronik and the customer shall be the registered office of Würth Elektronik. Würth Elektronik may in addition sue the customer at the latter's registered office, as well as at any other permissible place of jurisdiction.

12.4 The place of performance for any and all obligations to be performed by the customer and by Würth Elektronik shall be the registered office of Würth Elektronik.

12.5 If a provision of this agreement is or becomes invalid or impracticable in whole or in part, or if this agreement is incomplete, this shall not affect the validity of the remaining provisions hereof. In lieu of the invalid or impracticable provision, such valid and impracticable provision shall be deemed agreed as comes closest to the purpose of the invalid or impracticable provision. In the event that this agreement is incomplete, such provision shall be deemed agreed as corresponds to what would have been agreed according to the purpose of this agreement if the contracting parties had considered the matter from the outset.

13. Environmental declaration

Würth Elektronik is committed to people and the environment. Therefore, we undertake to manufacture our products in a manner that conserves resources and to systematically realise any potential for saving energy in manufacturing processes and in transportation. We pay close attention to ecological alternatives as concerns the selection of sources of energy and raw materials and pursue a consistent policy of waste reduction and product recycling.

Notes

Electronic & Electromechanical Components

EMC Components

Power Magnetics

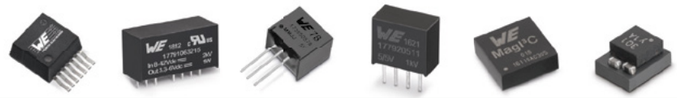
Signal & Communications

Quartz & Oscillators

Capacitors

Resistors

Automotive Standard Products



Optoelectronics

Power Modules

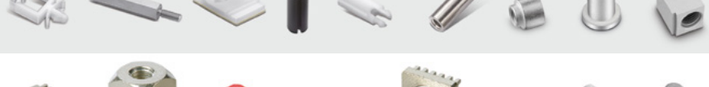
Wireless Connectivity & Sensors

Connectors

Fuseholders

Switches

Assembly Technique



REDCUBE Terminals

WÜRTH ELEKTRONIK

more than you expect

Würth Elektronik eiSos differs from all other component manufacturers in several aspects:

- We guarantee all products are available ex stock
- Samples available
- Orders below MOQ
- Evaluation kits available
- Software tools available
- Long term availability
- Design Seminars and Webinars free of charge
- Technical support: From engineer to engineer
- Worldwide technical sales force and field sales engineers on site

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