hilscher
COMPETENCE IN COMMUNICATION

WHITEPAPER

netX 90:
A Single-Chip Device Connectivity Solution for IIoT

www.hilscher.com

EXECUTIVE SUMMARY

The Industrial Internet of Things (IIOT) demands that OT (Operational Technology) and IT (Information Technology) become more integrated to unlock enterprise-wide benefits.
The key challenge is “data connectivity”. We need to create faster, better and more relevant communications between our enterprise systems and factory automation devices so data can flow easily between every node. This is leading us towards next-generation technologies such as Time Sensitive Networking (TSN), OPC UA and MQTT. It also makes us confront perhaps the biggest IIoT challenge of all – cyber-security.

Slave devices such as sensors and actuators are at the heart of data generation and for complete IIoT deployments they must deliver better and more relevant data to higher automation levels. Hilscher’s netX 90 is the first “connectivity” chip to address all the issues involved. It combines Hilscher’s many years of experience in industrial communications and gateway interfaces such as netTAP with those latest technology developments. It is capable of interconnecting virtually any field device to Real Time Ethernet (RTE) protocols safely and securely.

netX 90 features two ARM cores to provide logical separation of the application from the communications, safeguarding devices from cyber-intrusion. It enables systems to be designed in accordance with IEC 62443 specifications (incorporating HTTPS, TLS, etc) and it’s delivered with a complete “ecosystem” of development tools, software and support to enable rapid prototyping.

netX 90 can also be supplied on a chip carrier called netRAPID 90 – a compact “System on a Module” containing all necessary peripheral circuitry. This can cut development times and costs, and significantly shorten “time to market.”

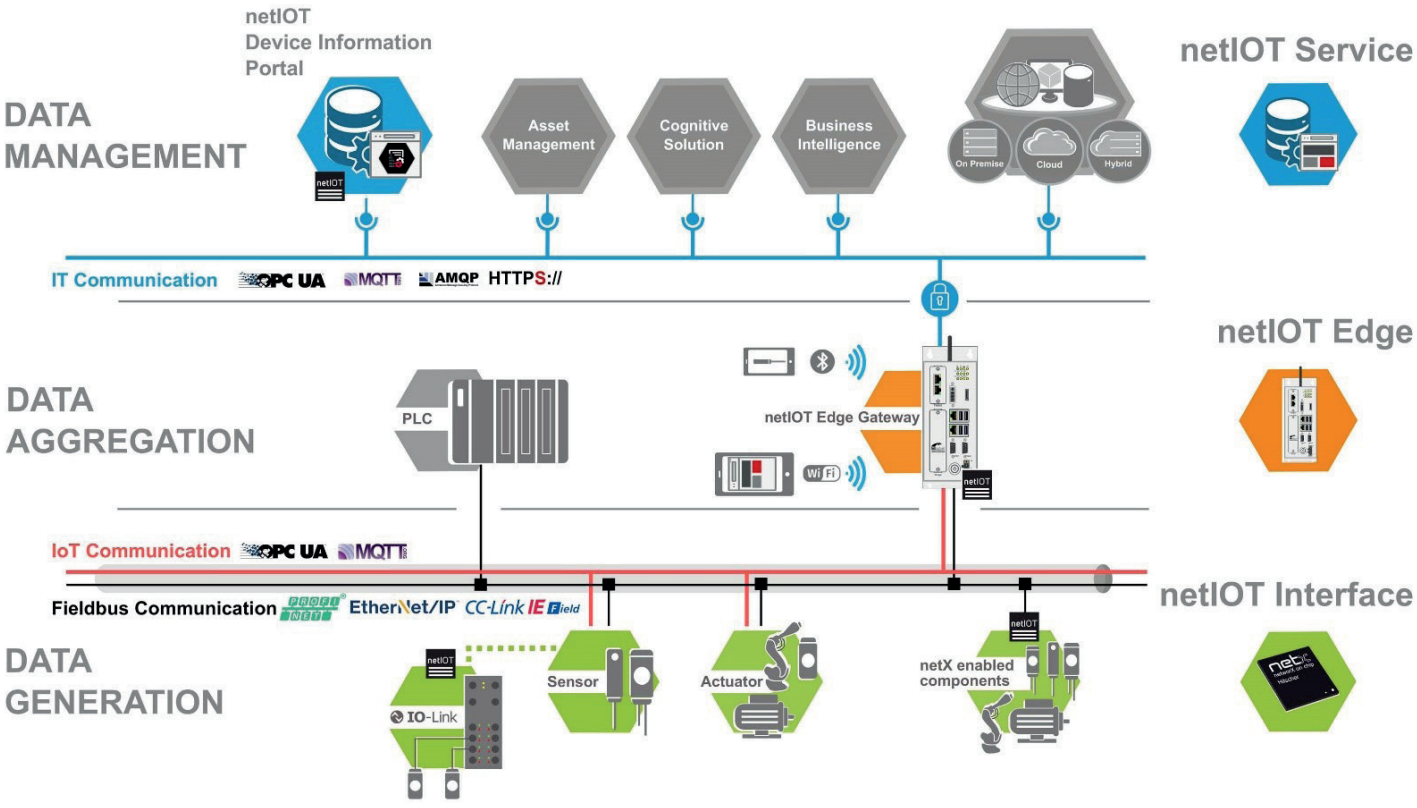
With netX 90 and netRAPID 90, field devices can easily be made Industry 4.0 and IIoT-ready today.

The Internet of Things: An Overview

The “Internet of Things” describes the way anything and everything can be connected to everything else, and “communicate”. It assumes that data moves freely about the network – whether internet, WAN or LAN – and it encompasses all kinds of concepts and benefits related to how that data is used.

The way this works depends on the industry or market sector. In the home context, refrigerators might be automatically re-stocked, or heating systems remotely monitored and controlled. In a city context it could involve street lamps being turned on only when daylight fades, or traffic systems being managed according to traffic density. In the industrial world, IoT can mean the aggregation of data from the lowest sensor and field levels for processing via cloud and software services to provide predictive maintenance, asset management and other business intelligence. (See architecture diagram below.)

Some big issues are involved - not the least of which is device and system interoperability. There are risks too, perhaps the biggest being security. Commercial hacking, cyber-attacks and the growing possibility of cyber-warfare are issues that demand we adopt a totally professional (almost military) attitude towards IoT system design.



Hilscher‘s view of the Internet of Things in the industrial automation context.

The Parameters for Next-Generation Communications

For the Industrial IoT, next generation automation systems need to be both future-proof and backwards compatible. Since current industrial networking protocols will not disappear, all existing standards and current practises must still be supported (and co-exist in this new eco-system). But new functionalities must be added. Here are the most important:

1. **Time Sensitive Networking:** TSN as vendor-neutral real-time Ethernet architecture compatible with conventional Ethernet is one of the most talked about technologies of recent years. It promises to lead towards converged networks (vertical and horizontal communications over the same network). Today, network technology organizations are integrating TSN into prototypes to work collectively on issues such as interoperability, conformance and configuration. It's generally accepted that, as greater interoperability becomes a reality, plants will become simpler to design and maintain, and that new automation methodologies could arise.

2. **Semantic Data Transfer:** OPC UA with its clever information model concept and with TSN included (OPC UA TSN), promises network transparency literally from plant floor to cloud. And not just for raw data but also for "information" – i.e. data that carries meaning. Some experts predict it could open up new ways to architect plants. MQTT, a "light" messaging protocol, will also be important in this context, though probably linked with middleware products that can add the semantics needed by higher level systems.

3. **Security:** The increased need for security has significant implications for historical automation architectures and may force the redesign of virtually all automation products in the market place. Security must encompass the entire life cycle of products and plants. Suppliers must be trustworthy, and every component part must be delivered, and operate, free of suspicion. Products must be securely bootable, underpinned by a "chain of trust" that allows firmware and application software to be loaded safely. Systems must exhibit resistance and resilience against attack and be able to deflect or neutralize attacks. Data integrity becomes key. Since operational data streams can be compromised anywhere between source and recipient, every party to the transaction, including intermediates, must prove their security before transmission can take place.

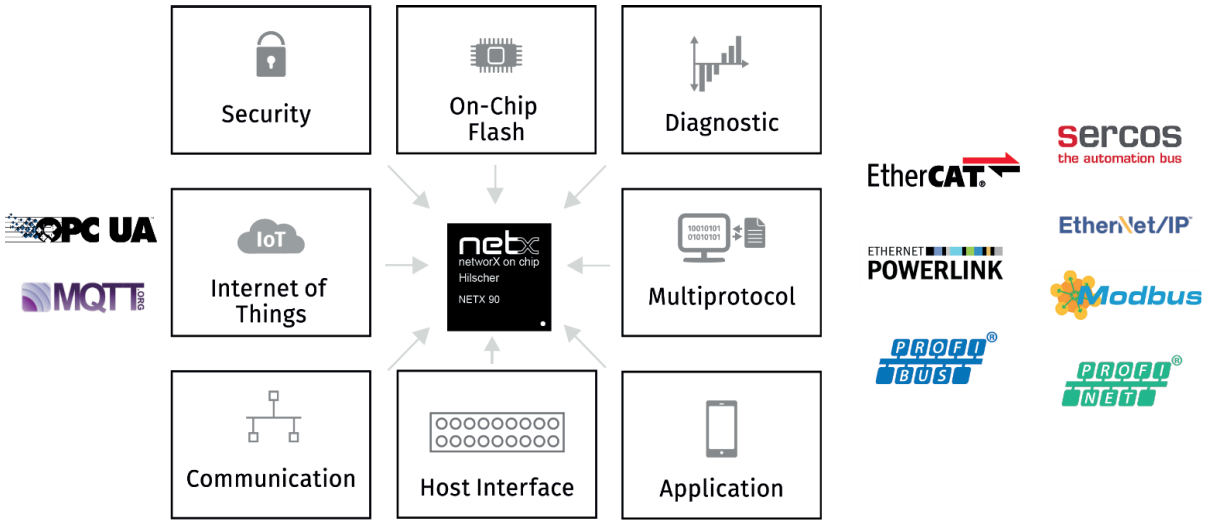
4. **Easy sensor connectivity:** As in automation system networking, different protocols are used to connect field devices to the outside world. Some are proprietary, some are open. They include, for instance, BiSS, EnDat 2.2 and IO-Link. If slave devices are to be used successfully in IIoT applications, a simple way of connecting them all into the automation hierarchy has to be supported.

5. **Diagnostics:** To ensure data integrity and system reliability throughout the IIoT hierarchy it will become more and more crucial that predictive maintenance processes be built-in. Internal temperature readings will be necessary, along with established monitoring techniques such as power watch, clock supervision and time-stamping.

How netX 90 delivers Next-Gen Connectivity

In essence, netX 90 is a powerful slave-to-network gateway solution that supports data communications for motion control, sensors, actuators, encoders, remote IO, and even functional safety devices. It meets the five key requirements listed above and is the first (and only) microcontroller in the market to provide multiprotocol capacity for real-time communications for factory and process automation.

netX 90 is housed in a 144-pin BGA, 10x10 mm^2 package and includes two ARM Cortex-M4 cores, on-chip Flash memory, Fast Ethernet PHYs, DC/DC converter, and POR circuit.
netX 90 connects to external networks using a single hardware design that supports all popular Real Time Ethernet and fieldbus protocols. For security, the chip is divided between the network-facing parts and slave-facing segments. These are logically isolated, separating the communications functions from the application tasks. Should a cyber-intrusion occur, this separation provides another layer of security to limit network attacks from harming the application.



One chip. All protocols. Your application.

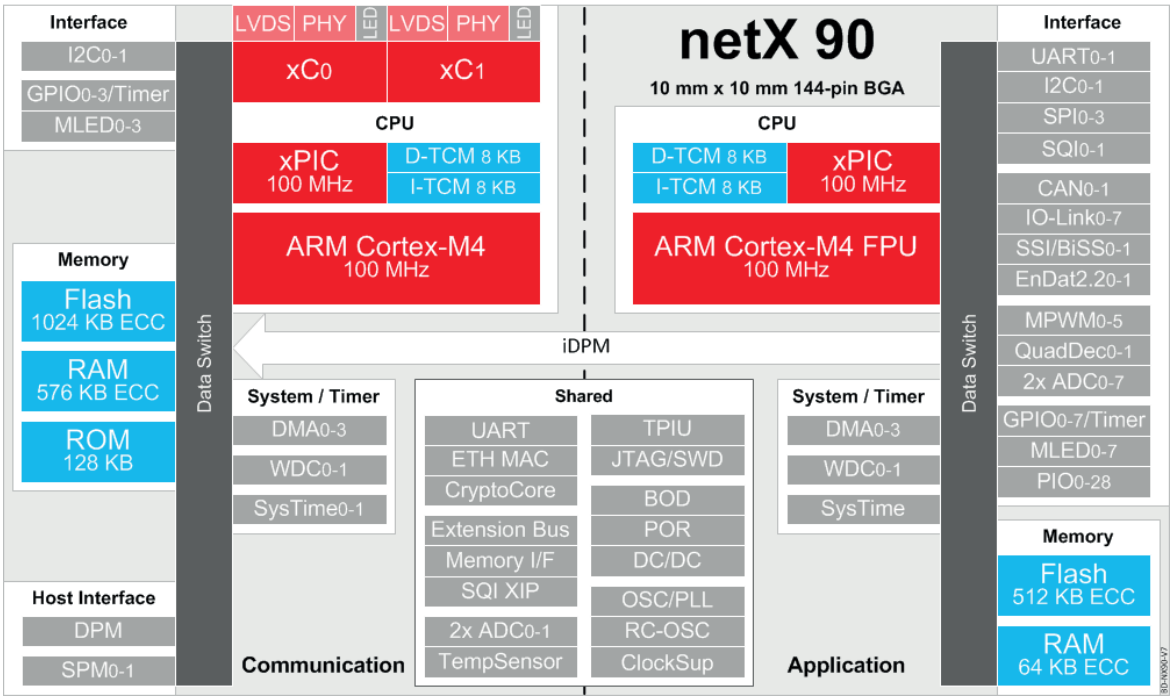
Hilscher's netX 90 supports all popular Real Time Ethernet, fieldbus and IoT protocols in one chip design.

Secure boot procedures deliver a "Root of Trust" platform on which subsequent software can be loaded. The resulting "Chain of Trust" ensures that neither the application nor the communications are compromised during start-up. Cryptography based on FIPS 140-2 is available to support authentication and verification procedures that enable IEC 62443-compliant security systems to be created.

Hardware-accelerated cryptography is employed, with an on-chip hardware accelerator module to handle the encryption processes. This significantly improves I/O cycle time by reducing CPU load and on-chip memory footprint (i.e. program code size, RAM usage) and ensures fast, secure, and reliable connections at speeds that can support modern automation systems. Software upgrades in existing products cannot match the performance of this hardware-accelerated solution.

netX 90 can be used as a companion chip in conjunction with an external host processor and as a stand-alone solution for board-level projects. Hilscher also supplies the netX 90 on a chip carrier called netRAPID that significantly cuts development efforts and your time-to-market. (More on netRAPID 90 later in this paper).

netX 90 Technical Overview



Above is a block diagram of the netX 90. The two ARM Cortex M4 cores in the center are surrounded by various functional units and extensive peripherals. Separation of the communications and applications segments provides a layer of protection against the impact of network attacks on the application.

On the application side, proven technology from earlier netX chip types is used (e.g. UART, SPI, I2C, CAN, IO-Link and GPIO interfaces). However, additional interface IPs have been added for popular slave IC protocols such as SSI, EnDat 2.2 and BiSS, ensuring netX 90 can support virtually all types of slave devices in use today.

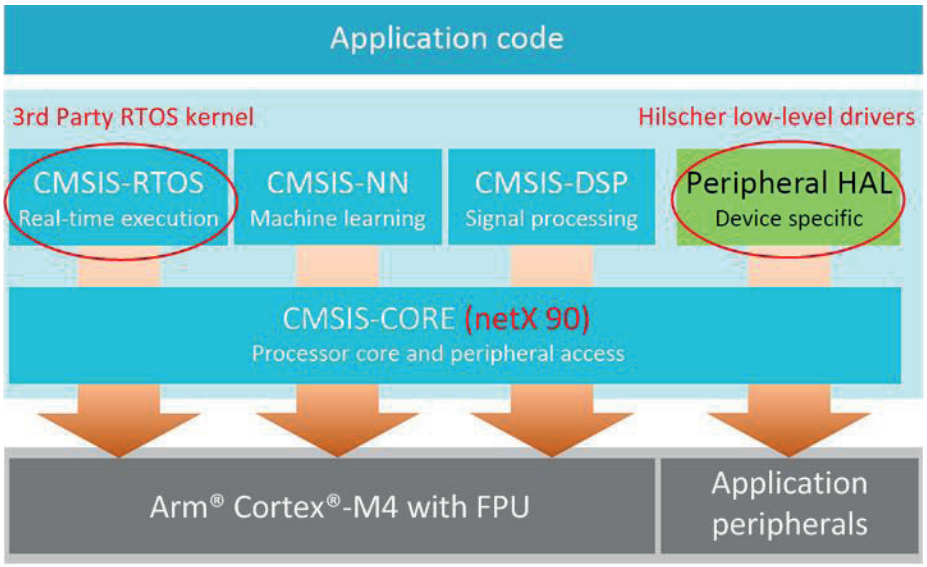
netX 90 fully supports emerging Industry 4.0 and IIoT standards such as OPC UA and MQTT so slaves will be able to exchange data with any other node over Real Time Ethernet networks. Crucially, its specialized architecture adapts to emerging Time Sensitive Networking (TSN) standards, perhaps the most important requirement of next-generation industrial systems.

Flexible, programmable, dual-channel xC sub-systems, with switch and IEEE 1588 functionality support all popular Real Time Ethernet (RTE) and fieldbus protocols, plus their extensions. The network-facing interfaces use proven Hilscher IP. RTE protocols are supported with pre-certified stacks, so designers don't have to be experts on the various protocols. Stacks are downloadable over the web and can be deployed according to customer needs just prior to shipment if needed. Once an interface has been designed for one Hilscher stack, it accepts all the rest.

A block of functions – including cryptography and memory extensions (see lower part of the diagram) – serve both segments of the chip. These can be accessed by both sides. Therefore, Hilscher added in front of each peripheral a firewall to properly regulate access rights. Also included in the shared functions are temperature-based diagnostics to monitor chip conditions, a valuable predictive maintenance indicator. Additional diagnostic features include power watch and a clock supervisor. The on-chip ADCs can also be used for voltage monitoring, etc.

In addition to the JTAG interface, netX 90 enables a range of options to support firmware programming and update procedures, managed via Serial, Ethernet or Host Interfaces. The procedure either involves the integrated bootloader (ROM code) or is handled by firmware. Security, if enabled by the user, enforces heavy restrictions, for example, execution of signed code only, locked debug interface, etc.

The Open Source Potential of netX 90

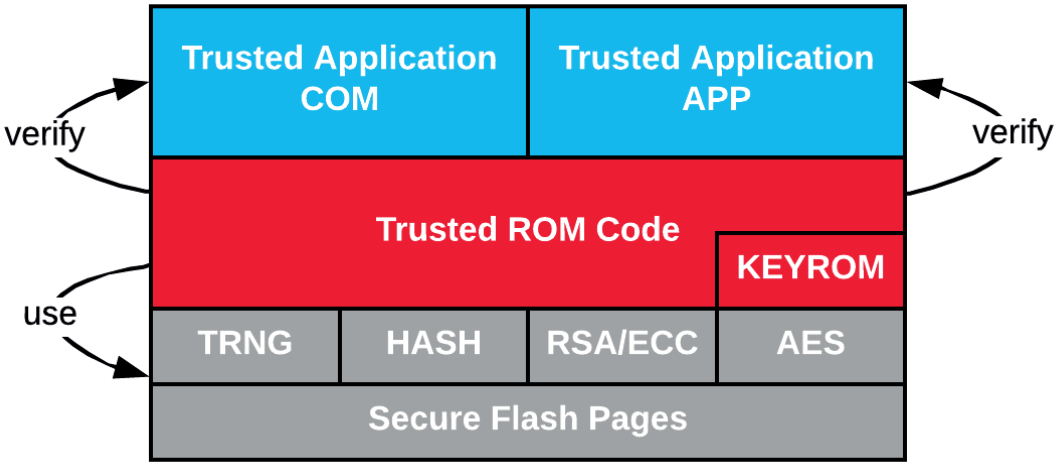


Hilscher created the CMSIS-CORE for the netX 90 (see illustration above) and provides the low-level drivers for application peripherals as open source software. Included in the package is a cifX API driver for the internal dual-ported memory (iDPM) to interface the protocol stack. For the Companion Chip Use Case with host interface, Hilscher delivers a cifX API toolkit for the host application processor.

The Cortex Microcontroller Software Interface Standard (CMSIS) defined by ARM enables developers to re-use embedded software components, or to combine them with third-party software components. Thus, the low-level drivers provided by Hilscher can be combined with a CMSIS-compliant RTOS kernel to create a board support package (BSP). Popular embedded RTOS kernels for the Cortex-M4 include FreeRTOS or Keil RTX. Hilscher has prepared a reference example for FreeRTOS. The Keil RTX with full source code is available under the Apache 2.0 license as a free download by ARM.

netX 90 Security: The Chain of Trust

netX 90 was conceived to support Defense-in-Depth security solutions in accordance with IEC 62443 norms. Users have considerable choice in how this security is deployed. Security policies, threat models, etc. must be determined and implemented by the user, but netX 90 provides a range of mechanisms for protecting against attack and ensuring data integrity.



At switch-on, the mask-based ROM code drives a “secure boot” process to establish the Root of Trust on which application software modules are loaded. The resulting “Chain of Trust” guarantees systems start up in a well-defined state. Protection against unauthorized modification is ensured with verification of the software publisher/vendor using a signature scheme based on public-key mechanisms (ECC, RSA). Properly implemented, this means users can be confident that the device has been deployed correctly, safely and securely. In order to conform with the fast startup requirements some Real Time Ethernet protocol stacks have, the secure boot procedure is fully hardware accelerated.

However, communication channels have to be open, which means that data transfers between the netX 90 and an external network must be protected separately. Ensuring that the right data is transferred to the correct recipient without interference is achieved using cryptographic techniques applied by the mbed TLS from ARM. This offers a lightweight TLS library that’s well-suited to embedded devices. Public and private keys can be used, with the choice of cipher suite (FIPS 140-2 algorithms and key lengths up to RSA-4096, ECC1-512 and AES-256) decided by the user. There are 141 cipher suites in total.

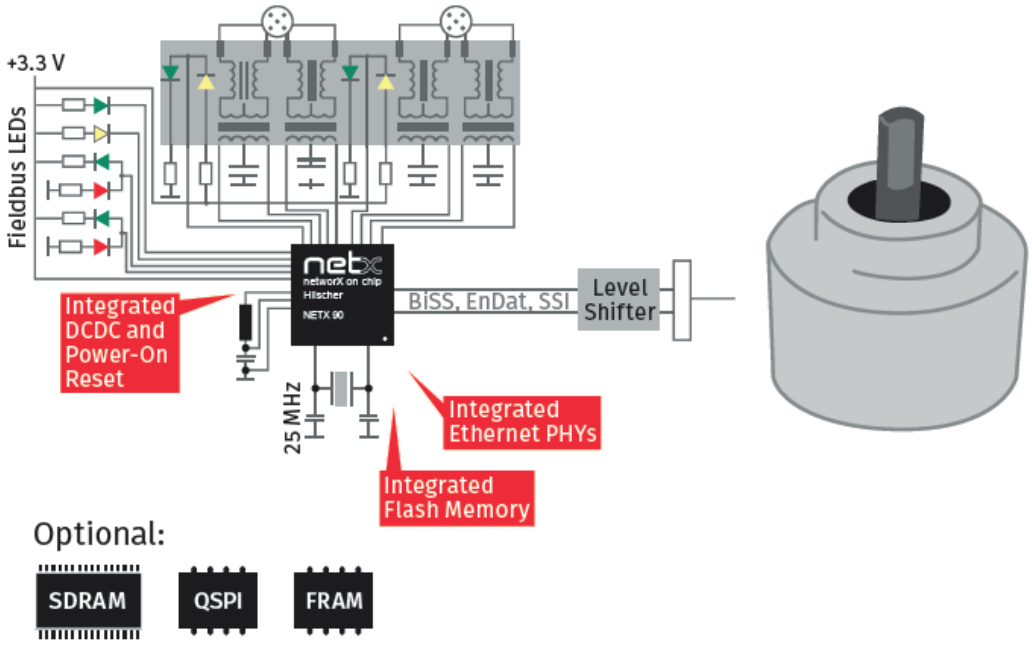
The on-chip hardware accelerator handles the computationally expensive cryptographic functions, including decryption, key-generation, key exchange, authentication, data integrity algorithms, etc. This relieves the main CPU of load and at the same time reduces on-chip memory footprint (for example, program code, RAM usage). Compared to software-based solutions this significantly improves performance and ensures the real-time capability of the device.

Use Case Scenarios

netX 90 is a highly versatile slave connectivity solution for industrial automation, especially in the IoT context. Acting as a gateway between RTE/fieldbus protocols and slave devices such as sensors, it enables secure data transfers between virtually any kind of field device and higher-level IT systems.

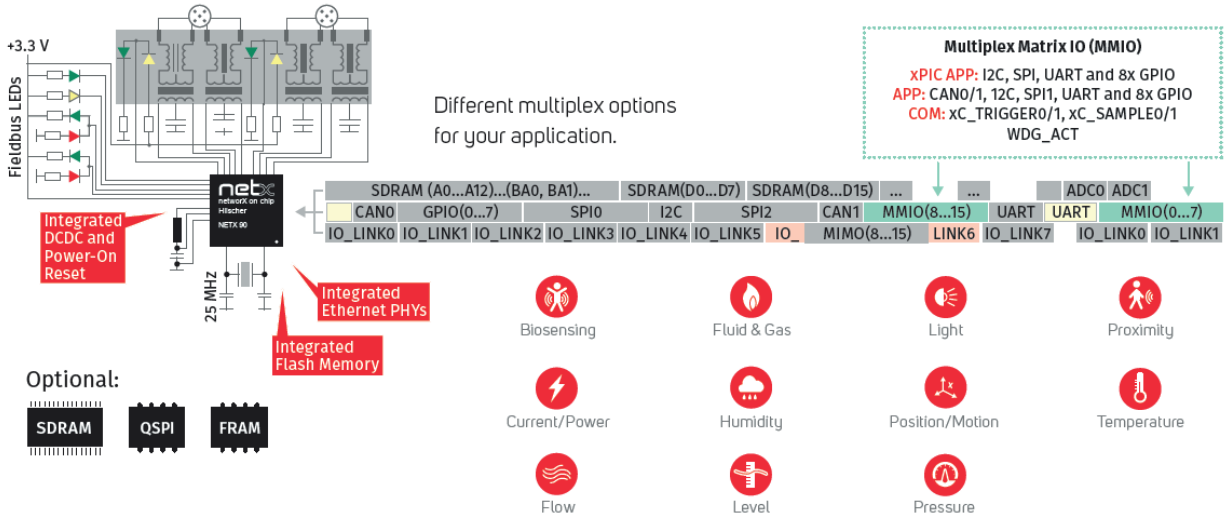
Hilscher's experience in supporting network-facing communications is widely recognized and needs little expansion here. It's useful however to describe the device-facing potential of netX 90 using a series of Use Cases, as follows:

Use Case 1: Encoders



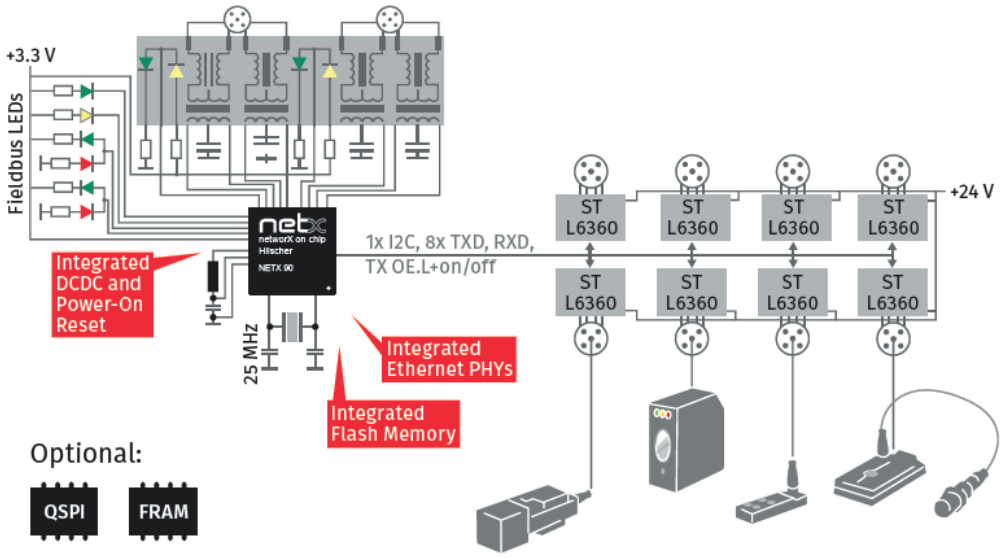
With on-chip BiSS, EnDat 2.2 and SSI peripheral drivers, netX 90 offers the functionality needed for modern encoder applications. Specialized Hilscher IP has been incorporated into the netX 90 to meet these requirements, and the netX Studio build environment and its hardware support makes development work easy. If those connectivity options don't suit your needs, the comprehensive netX 90 architecture also includes parallel sampling ADCs, UART, GPIO, SPI, SQI, CAN and I2C interfaces. One design supports all RTE protocols and these are easily updated/upgraded via the integrated web server.

Use Case 2: General Purpose I/O



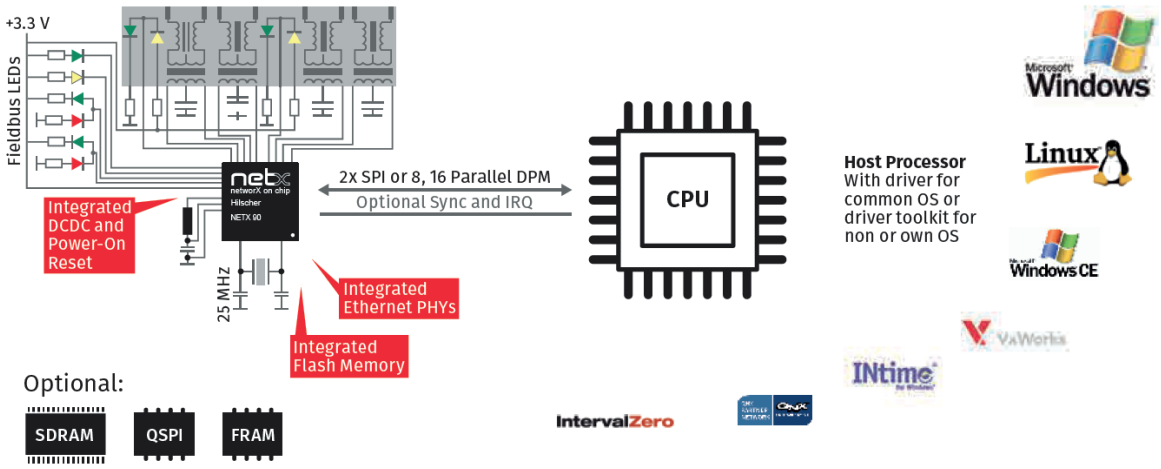
There's an almost unlimited number of possibilities for connecting I/O. In combination with our GPIO unit – equipped with a flexible time-base (down to 10 ns resolution), pulse-width modulation, input capture and IRQ – netX 90 excels in any sensor application. There are multiple 12-bit 2Msps ADC channels, any two of which can be sampled in parallel, providing an array of connections for slave devices. I/O data collection is via an external shift register and one design supports all RTE protocols. Firmware updates in the field can be implemented via the integrated web server.

Use Case 3: IO-Link



netX 90 boasts fully integrated IO-Link master functionality. It supports up to eight master channels, with four digital control signals per channel, including TX, TX_ENABLE, RX, and WAKEUP. Lower layer tasks of the IO-Link stack run on an internal xPIC CPU, giving maximum flexibility and high determinism. All components, including the IO-Link master stack and the outgoing RTE or fieldbus stack are integrated and there's even an optional IoT stack to deploy should you need it.

Use Case 4: Companion Chip

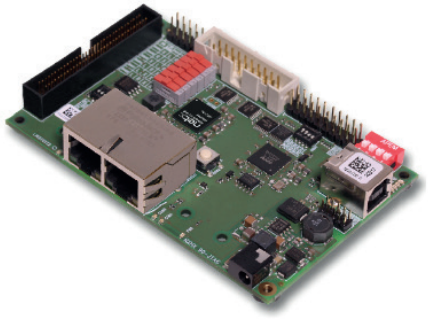


For high end applications netX 90 can be paired with an additional host CPU. The netX 90 handles the complex communications tasks, which frees developers to focus on the application. There is no need to worry about protocols as that's taken care of with netX 90; it's only necessary to organize the connections on the PCB. Take it one step further and integrate the netRAPID 90 chip carrier sub-module (described below) to make things even easier. There's predefined firmware with Dual-Port-Memory access and an easy-to-integrate SPI host. One design supports all RTE protocols, with firmware updates via an integrated web server. Finally, there's netPROXY-based firmware with protocol-independent object interface to the host. All engineering (work flow, programming and configuration) is done using Hilscher's netX Studio suite. The integrated MQTT client and OPC UA server means there's immediate IIoT capability.

The netX 90 Advantage: Software and Hardware from a Single Source

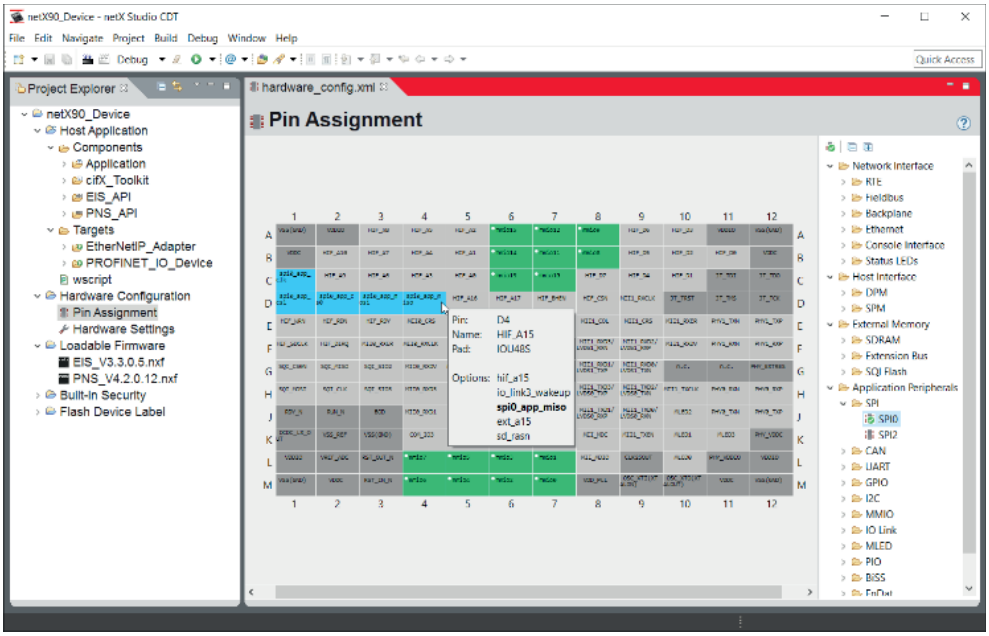
netX differs from most other chip interface solutions, where hardware and software may need to be procured from different sources. With netX, a single vendor—Hilscher—supplies the full eco-system of integrated and optimized support services.

JTAG development boards are available along with fieldbus connectivity modules and host interface cards for rapid configuration of designs, prototyping and commissioning.



An Integrated Development Environment (IDE), called netX Studio, is provided free of charge. This powerful development platform has all the components required to configure, develop and debug embedded applications. It works out of the box with Hilscher's NXJTAG-USB adapter and NXHX 90-JTAG board.

The compartmentalized project manager features a set of utility tools to set up the prebuilt communication firmware. Pin sharing and multiplexing options are easily configured. There are also simplified processes for generating advanced IoT data transfers using MQTT and OPC UA from within the same cyclic and acyclic data assignments.



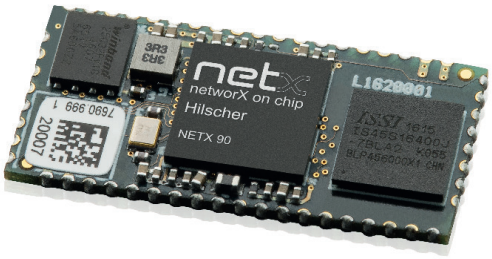
Hilscher offers full backup, with training services and workshops to help speed your time to market, as well as hardware design, software and production services.

netRAPID 90: A Chip-Carrier Solution to Speed Time-to-Market

The arrival of IIoT-based concepts and their increased data handling and security responsibilities mean that up to 90 percent of automation products will have to be re-engineered over the next few years. This will involve a substantial amount of re-design and engineering work for device manufacturers.

netX 90 is the first chip to address all the issues surrounding today's and tomorrow's automation needs. Its innovative concepts, as described above, are pioneering the way forward. netX 90 is the ideal component on which to base new designs.

But the cost of re-design and re-engineering, setting up new manufacturing procedures, testing, certification, and on-going procurement can be substantial. Many vendors will prefer to avoid this if they can. What if there was a simpler, less-costly approach for new product designs based on netX 90? Well, there is, with the netRAPID module.



The netRAPID 90 is a 60 pin-out chip-carrier solution that incorporates all the benefits of the netX 90 chip itself, along with many other advantages.

The netRAPID 90 is a stand-alone sub-system that delivers standardized connectivity (i.e. communications) between a variety of slave devices and popular industrial Ethernet (RTE) networks, plus it offers all the security and data handling capabilities demanded by next-generation IIoT architectures. Developers use Hilscher's IDE environment netX Studio in a similar way to that described above (together with a similar JTAG prototyping board) to develop a "personality profile" for the netRAPID 90 module, covering all elements of the required functionality, from pin-outs to firmware. This "profile" is then submitted to Hilscher for pre-loading into vendor-specific netRAPID modules before shipment. Because modules arrive fully tested and certified as "components" ready for placing on a PCB, they can save considerable effort, time and cost. Future upgrades are performed more easily too.

In summary, netRAPID 90 offers:

FEATURE	BENEFITS
Hilscher's fixed-price, 10-year supply guarantee	Protection against changing and/or obsolete semiconductor technologies; no worries about procurement or having to re-design products again and again as chip technologies get updated; FLASH and RAM supply issues do not occur
Standardized physical size	15mm x 32mm module with 60 configurable pin-outs; small solution with SPI Host interface for field devices; flexible options for harsh environments; no connector onboard; same form factor and interface for different functionality and assembly.
"Component" approach	Reduced design efforts and easier Integration; easier place and solder; simpler PCB design; all external comms, sensor interfacing issues taken care of at the Hilscher factory; single design for all RTE Slave networks; flexible security and data transfer options "ready-to-go;" faster "time to market."
Pre-loaded firmware	Operation customized for your needs; Hilscher will deliver an IIoT-ready product that can simply be placed on a PCB during board manufacture; minimal labor costs for configuration and set up.
One-off quantities	An Industry 4.0 service established at the Hilscher factory will deliver to your schedule; order on-line for Just-in-Time delivery.
Attractive pricing	Competitive options, particularly for higher volumes.
netX Studio compatible	Engineers can access and configure the module using the same development tools as for other Hilscher devices.
Future-proof	Start small and grow; add functionality to meet customer's needs, and as the market changes; new functions (e.g. OPC UA and TSN) easily added.
Lower "whole-life" costs	Higher reliability; easier maintenance; remote access; faster response times

netX 90: Device Communications for Today and Tomorrow

netX 90 is the first interface chip to recognize and deliver the five essential elements of slave device communications development:

1. **Unlimited network connectivity:** Connects to existing Real Time Ethernet and fieldbus protocols and emerging protocols (TSN) with two Ethernet PHYs and firmware.

2. **Concurrent semantic data support** for industrial automation connectivity and cloud-based connectivity.

3. **Security "built in":** Includes secure boot procedures and software verification, hardware-accelerated encryption, physical separation of application and communications, and TLS-protected communications during data transfers.

4. **Support for virtually all slave device types:** From general purpose remote IO to protocol-specific standards such as BiSS, EnDat 2.2 and IO-Link.

5. **A comprehensive eco-system** of prototyping, configuration, diagnostics and application development tools.

For more information about the netX 90, please visit the Hilscher Web Site: https://www.hilscher.com.

Appendix: netX 90 Overview

netX 90	Communication	Application
Core Processor		
ARM® Processor	Cortex-M4 at 100 MHz with MPU	Cortex-M4 at 100 MHz with MPU and FPU
Hilscher 32-bit RISC	xPIC at 100 MHz with 2x 8 KB TCM	xPIC at 100 MHz with 2x 8 KB TCM
Memory		
SRAM	576 KB	64 KB
Flash	1024 KB	512 KB
Mask ROM	128 KB	-
System		
DMA Controller	4 channels	4 channels
WDC (ARM / xPIC)	1 / 1	1 / 1
Timer (ARM / xPIC)	2x 32-bit / 3x 32-bit	2x 32-bit / 3x 32-bit
Network		
xC Subsystem	2 channels	-
IEEE 1588 SysTime	2	1
Fast Ethernet PHY	Dual-port, FX support	-
100 Mbps LVDSPHY	Dual-port	-
Ethernet MAC	10/100 Mbps, MII	
Peripheral		
UART (Up to 6.25 Mbaud)	1 (shared)	3
SPI (Up to 50 MHz)	-	4
SQI (Up to 50 MHz)	-	2 (Master only)
I^2C (Up to 3.4 MHz)	2	2
CAN 2.0B (Up to 1 Mbps)	-	2
IO-Link V1.1 Controller	-	8 channels
MLED (PWM tuned)	4	8
HIF PIO / PIO / GPIO / MMIO	- / - / 4 / -	Up to 41 / 29 / 8 / 18

Mixed Signal		
Timer (PWM, IC/OC)	4x 32-bit	8x 32-bit (min. 10 ns)
Motion PWM Unit	-	1
ADC SAR (12-bit, 2 Msps)	2x 2 channels and 2x 8 channels	
Quadrature Decoder	-	2
EnDat 2.2 (Master E6)	-	2 (With RTM)
BiSS / SSI (Master BiSS C)	-	2 / 2
Host Interface		
Parallel (DPM)	8/16-bit (Read access min. 55 ns)	Internal 32-bit
Serial (SPM)	2x SPI/SQI (Up to 125 MHz/33 MHz)	-
MAC (PHY Mode)	MII (10/100 Mbps)	
External Memory		
SRAM / NOR / NAND / SDRAM	✓ / ✓ / - / ✓ (8/16-bit)	
SD/MMC / SDIO	SPI Mode / -	
SQI (XIP)	✓	
Security		
Crypto Core	SSL/TLS accelerator, up to RSA-4096, ECC-512, AES-256, and SHA-512	
Secure Boot	Mask ROM Code, EMSA-PSS	
Built-in support	Security levels, AHB Firewall	
Debug		
Debug / Trace	JTAG/SWD / 4-bit TPIU	
Boundary Scan	JTAG	
Analog		
DC/DC / POR / BOD	✓ / ✓ / ✓	
Thermal diode	✓	
Clock Supervisor	Xtal (RC-Osc)	
Electrical		
Power supply	Single 3.3 V	
Temperature range	T_a -40°C ... +85°C	
Power consumption	≤ 1 W	
Package dimension	144-pin BGA, 10x10 mm^2, 0.8 mm Ball Pitch	

Notes

Contact

Headquarters

Germany
Hilscher Gesellschaft für
Systemautomation mbH
Rheinstrasse 15
65795 Hattersheim

Phone: +49 (0) 6190 9907-0
Fax: +49 (0) 6190 9907-50
E-Mail: info@hilscher.com

Support
Phone: +49 (0) 6190 9907-99
E-Mail: de.support@hilscher.com

Subsidiaries

China
Hilscher Systemautomation (Shanghai) Co. Ltd.
200010 Shanghai
Phone: +86 (0) 21-6355-5161
E-Mail: info@hilscher.cn

Support
Phone: +86 (0) 21-6355-5161
E-Mail: cn.support@hilscher.com

France
Hilscher France S.a.r.l.
69800 Saint Priest
Phone: +33 (0) 4 72 37 98 40
E-Mail: info@hilscher.fr

Support
Phone: +33 (0) 4 72 37 98 40
E-Mail: fr.support@hilscher.com

India
Hilscher India Pvt. Ltd.
New Delhi - 110 065
Phone: +91 11 26915430
E-Mail: info@hilscher.in

Italy
Hilscher Italia S.r.l.
20090 Vimodrone (MI)
Phone: +39 02 25007068
E-Mail: info@hilscher.it

Support
Phone: +39 02 25007068
E-Mail: it.support@hilscher.com

Japan
Hilscher Japan KK
Tokyo, 160-0022
Phone: +81 (0) 3-5362-0521
E-Mail: info@hilscher.jp

Support
Phone: +81 (0) 3-5362-0521
E-Mail: jp.support@hilscher.com

Korea
Hilscher Korea Inc.
Seongnam, Gyeonggi, 463-400
Phone: +82 (0) 31-789-3715
E-Mail: info@hilscher.kr

Switzerland
Hilscher Swiss GmbH
4500 Solothurn
Phone: +41 (0) 32 623 6633
E-Mail: info@hilscher.ch

Support
Phone: +49 (0) 6190 9907-99
E-Mail: ch.support@hilscher.com

USA
Hilscher North America, Inc. Lisle, IL 60532
Phone: +1 630-505-5301
E-Mail: info@hilscher.us

Support
Phone: +1 630-505-5301
E-Mail: us.support@hilscher.com