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Industrial Raspberry Pi 3: An Open-Source Ecosystem of Rich Automation Solutions

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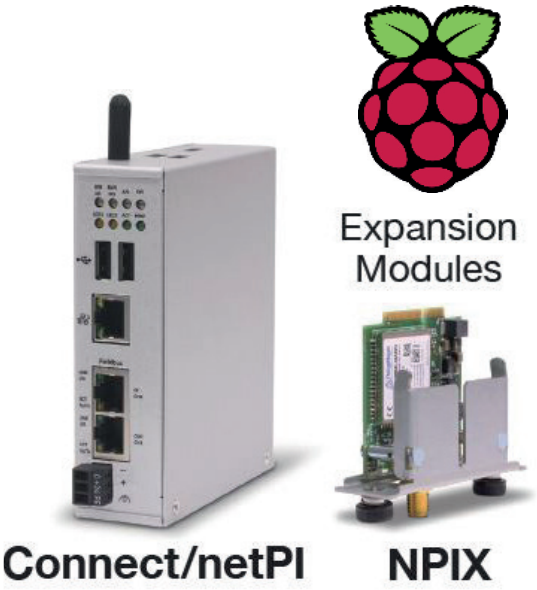
Industrial Raspberry Pi 3: An Open-Source Ecosystem of Rich Automation Solutions

EXECUTIVE SUMMARY

Since being launched as an educational device, the Raspberry Pi 3 micro-computer has gained millions of fans and been used in thousands of applications ranging from animated toys and home electronics to robotics.



The original Raspberry Pi was a low cost, credit-card sized "System on Module" with powerful computing facilities. It was intended for home or school use. However, professional engineers have "played" with it and discovered that it can be appropriate for industrial use too.

Although "engineer" versions and "industrial development kits" are now available, these are not designed to operate in tough environments. They lack security features and, in particular, do not have built-in Real-Time Ethernet capability.

Hilscher's Industrial Raspberry Pi 3 changes all that. Two versions offer a fully rounded open-source ecosystem capable of supporting automation functions ranging from simple I/O control to advanced cloud analytics. All versions of the Industrial Raspberry Pi family are UL, CE and RoHS certified.

All versions meet the full requirements for industrial use and incorporate advanced cyber-security features. Based around a Broadcom ARM chipset, they replicate the functionality of the standard Raspberry Pi 3, which can be used for development of applications.

This ecosystem can easily reduce deployment times from several man-months to days.
Users retain full control of their applications, which can also be easily and rapidly modified to suit market needs.

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1. What is Raspberry Pi: A brief overview of the original concept.

2. Why an “Industrial” Raspberry Pi 3: How and why the platform differs from the standard Raspberry Pi 3.

3. The Industrial Raspberry Pi 3 Ecosystem: How it supports a vast range of applications, from field to the cloud.

4. Docker Offers Choice, Agility, Security: The container concept and how it makes applications more secure, more flexible, more open and fully portable.

5. Node-RED to Create Data Flows with the Click of a Mouse: Why configuring data flows without knowing how to code makes the system so powerful.

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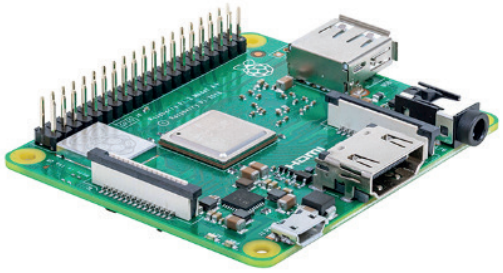
1. What is Raspberry Pi?



The Raspberry Pi is a credit-card sized micro-computer that can do almost anything a desktop computer can do. The product was designed to help users learn how to code, but its scope has grown dramatically. It's now available in a variety of form factors, focused designs and kits. As well as built-in ports, it can accept accessories such as a keyboard, mouse, monitor or camera, and connect to the Internet.

Today, Raspberry Pi projects cover an amazing range of applications: robotics, conveyors, home lighting, weather stations, voice assistants, warehouse control, game consoles, movie making, CCTV control and lots more. A very large user community has grown up in support, with on-line forums and a multitude of learning resources readily available online.

Flexibility and power, coupled with low cost and openness has resulted in many professional engineers becoming proficient in the use of Raspberry Pi, often in their spare time. Systems have begun to penetrate real-world automation environments, especially with the launch of the Raspberry Pi 3, an "engineering" version.

But there are obvious problems:

1. Even in its "engineer" format, the standard Raspberry Pi 3 cannot withstand tough industrial environments (high/low temperatures, vibration, corrosive fluids, etc.).
2. It cannot easily protect itself against malicious external attacks.
3. It does not offer Real-Time Ethernet support for factory-floor communication protocols such as PROFINET, EtherNet/IP and EtherCAT, or communications technologies such as OPC UA and MQTT.

Hilscher's Industrial Raspberry Pi 3 family changes all that. It is fully compliant with the Raspberry Pi 3 ethos and it overcomes the limitations of the standard product. It is built on Hilscher's 30 years of experience in supplying industrial communications solutions, resulting in a highly fl exible industrial platform for professional Raspberry Pi users.

A key factor in this is Hilscher's netX family of industrial network controllers. Developed specifi cally to support industrial communications, the netX family provides real-time protocol independence. All popular communications protocols are supported through simple confi guration. All fi rmware is fully certified and can be changed easily.

In the case of the Industrial Raspberry Pi 3, netX is used as a companion chip for the standard Broadcom chipset used by Raspberry Pi. Its use means industrial network protocols such as PROFINET, EtherNet/IP and EtherCAT become part of the Industrial Raspberry Pi 3 ecosystem.

2. Why an “Industrial” Raspberry Pi 3?

To bring the benefits of the proven Raspberry Pi 3 to industry, a number of enhancements had to be implemented.

- Physical Housing: Industrial environments are generally not favorable to electronic components. They can be wet or hot and may also be subject to continuous vibration. EMC and corrosive liquids are often present. Even when housed in a cabinet, sensitive electronic components need protection. Industrial Raspberry Pi 3 thus has a metal housing that can be fitted to the DIN rail-mount chassis found in the manufacturing industries.

- Reliability: By increasing the number of layers of the printed circuit board from six to eight and doubling the size of the board for better heat dissipation, industry-standard cooling can be achieved in the Industrial Raspberry Pi 3. A passive cooling block is attached to the CPU to transfer heat to the metal housing. These cooling solutions contribute to improved life cycles and much increased reliability over a temperature range of -20° C to 60° C.

- SD Cards: Industrial Raspberry Pi 3 is delivered with an industrial grade MLC 8GB SD card offering up to three times as many write cycles. Manufacturers pre-select cards too, so that performance and memory access time is always identical. SLC class memory cards can also be used, offering up to 30 times as many program/erase cycles.

- Retentive Memory: Automation applications often require the storage of process data for each cycle in order to be able to access the last data set after a power failure. For this reason, the Industrial Raspberry Pi 3 is equipped with an 8k Byte FRAM memory, which is able to reliably store data at high frequencies. This type of memory is as fast as a RAM and allows an endless number of write cycles.

- Real-Time Clock: Industrial Raspberry Pi 3 is equipped with a built-in hardware real-time clock buffered by a maintenance-free supercapacitor. During power failures, it maintains the time in the clock for at least seven days. In this way it is able to reliably compensate typical system downtimes (say, over a weekend), without need to worry about the finite capacity of a battery.

- WLAN: Hilscher's Industrial Raspberry Pi 3 has the same integrated wireless/Bluetooth antenna as the standard Raspberry Pi 3, allowing wireless communication according to IEEE 802.11 b/g/n or Bluetooth 4.1. For best possible radio transmission, the printed circuit board features a small bridge containing the antenna that reaches through the metallic housing and is surrounded by a protective dome. Onboard WiFi saves the user from purchasing an external USB wireless adapter.

- Support for Industrial Networking: Industrial applications require Real-Time Ethernet performance, and a dual port capability for ring networks. Hilscher’s netX network controller chip features multiprotocol support for PROFINET, EtherNet/IP and EtherCAT (as slaves). The netX driver features the same API 3 interface as Hilscher’s standard PC network cards, which allows easy porting of existing applications. Connectivity can be extended using NPIX modules that are fitted in a slot at the bottom of the Industrial Raspberry Pi unit.

- Cyber Security: Industrial Raspberry Pi 3’s system software is based on Yocto Custom Linux (Kernel 4.9 or higher) with AppArmor as the safety framework. This allows systems to be built in accordance with security standard IEC 62443.

Other security features include:

- Secure boot (to guarantee system software authenticity);
- Software extensions and updates requiring signed installation packages;
- User and rights management;
- De-activated SSH console access;
- Access to configuration pages exclusively via https connections;
- Physical separation of the IT and industrial network segments through the use of two separate chips: an application processer (Broadcom chip) and a network controller (netX chip);
- Docker containers, to isolate applications. There's more about Docker later in this document.

• IoT Connectivity: Industry 4.0 and the Internet of Things are based on data collection, data transmission and data storage. Industrial Raspberry Pi 3 uses a graphical programming tool called Node-RED to organize how data flows around a system. Using click-and-drag, data flows are established within seconds between sources, processes and destinations. Presently, more than 1,100 nodes are offered by the Node-RED community, 40% of which are of "professional" status. There's more about Node-RED later in this document.

3. The Industrial Raspberry Pi 3 Ecosystem

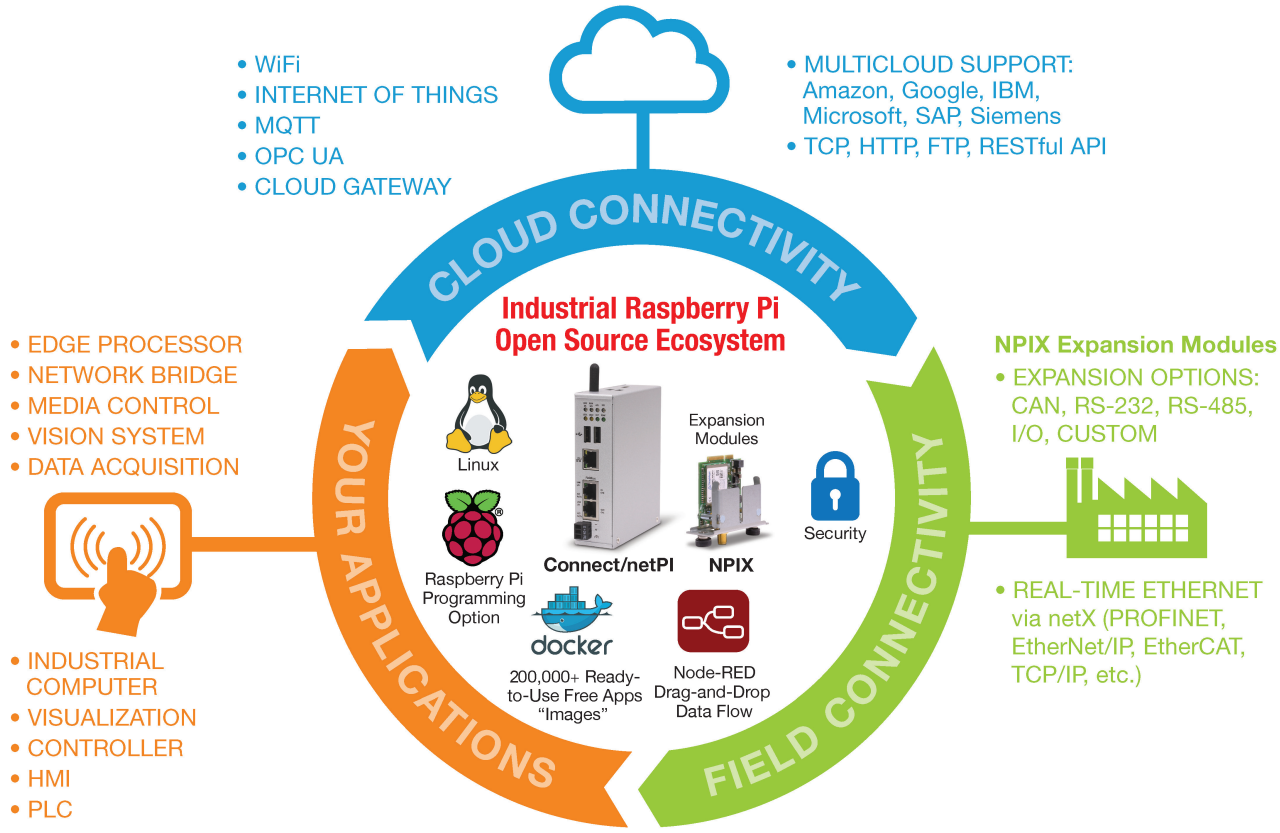
The Industrial Raspberry Pi 3 ecosystem offers a versatile set of tools for solving almost any automation challenge. The diagram below illustrates this. Typical applications are shown at left, with the many connectivity options shown at right and top.

The center circle illustrates the components of the Industrial Raspberry Pi ecosystem, including expansion modules, Node-RED, Docker, Linux, and security. These are explained more fully later in this paper.

Hilscher offers two Industrial Raspberry Pi 3 devices:

- netPI 3 RTE, the base model,
- Connect Edge Gateway, netPI 3 with additional software services, such as the powerful Edge Server. (See Appendix A for a listing of Edge Server offerings.)

Both are fully Raspberry Pi 3 compatible. Their comparative functionalities are listed in Appendix A.



Nearly all automation functions and input/output options are covered by this ecosystem, whether it be data flowing from the field to the cloud (i.e from bottom to top of the automation hierarchy), or from one network/connection to another (i.e. horizontal connectivity).

Security is embedded in the ecosystem, with the netX chip playing the key role. Application programs run in Docker containers (to isolate them) and data flows are defined using Node-RED (a click-and-drag GUI). Docker and Node-RED make things simple and secure. Below, you'll find them explained in more detail.

Real applications that have already emerged include:

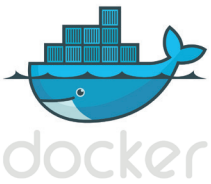
- Bridging CAN bus to a proprietary Ethernet.
- Connecting Siemens PLC to the MindSphere cloud.
- Greenhouse control system.
- Centralized control of web-based retail warehouses.

These applications were all realized in dramatically shortened development times. In some cases, development times have been reduced from several man-months (and third-party contracts), to days, using in-house engineering staff. This is because of:

a) The open source nature of the ecosystem;
b) The use of Docker and Node-RED (see more below);
c) The added value of Hilscher's own netX network controller chip;
d) The open source application environment;
e) The use of well-proven programming languages such as Python;
f) The possibility of using a low-cost standard Raspberry Pi 3 for development.

The following sections outline how this has all been achieved with Hilscher's Industrial Raspberry Pi 3 ecosystem.

4. Docker: Choice, Agility, Security



Docker technology was launched in 2013 and is fully standardized, open and widely used. It employs the container concept, whereby applications run in isolated virtual environments on a single computing platform to eliminate risk and aid portability. Here's how things work:

- A container is a standard unit of software that packages up code and all its dependencies so an application runs quickly and reliably. Containers isolate software from the environment and ensure that it works uniformly and securely, regardless of platform, and that it can be easily ported between different environments.

- A Docker container image is a lightweight, standalone, executable package that includes everything needed to run the application: code, runtime, system tools, system libraries and settings. A container image becomes a container at runtime. Docker open source projects can serve as building blocks for other Docker images.

- Containers work side by side, comparable to the apps installed on mobile phones. Docker allows preconfigured applications to be loaded in one step.

Docker eliminates old restrictions such as proprietary applications and vendor-controlled maintenance cycles. Development and engineering costs are much reduced, time to market is dramatically shortened and operations become simpler, safer and more easily maintainable.

Docker in Automation: Docker enables Industrial Raspberry Pi 3 users to cost-effectively build and manage a complete application portfolio at their own pace, and without fear of architecture and infrastructure lock-in. It enables developers and system operators to separate application dependencies from hardware, giving them full control over development costs and equipment life cycles. Applications can be containerized and ported to the Industrial Raspberry Pi 3 platform within minutes. Standard Raspberry Pi platforms can be used to develop applications for Hilscher's Industrial Raspberry Pi.

Examples of third-party software supported in Hilscher's Industrial Raspberry Pi, and suitable for running in a Docker container, include:

- Ignition from Inductive Automation
- deviceWise from Telit
- CODESYS (soft PLC) from 3S-Smart Software Solutions GmbH
- Oracle MySQL

The Docker Repository: Why re-invent the wheel? Docker HUB is the world's largest repository of container images. More than 200,000 Docker images have been developed and deposited in this repository, from where they can be accessed and used freely. There's also an array of content sources including container community developers, open source projects and independent software vendors (ISV) building and distributing their code in containers. Docker open source projects can serve as building blocks for other Docker images.

Hilscher has actively submitted images to the Docker repository, especially for industrial automation, networking and cloud connectivity. Currently, sample code for six cloud services are available and “ready-to-use”. They include Amazon, Google, IBM, Microsoft, SAP and Siemens cloud access. The following images are also available: PROFINET IO-device, EtherNet/IP adapter, EtherCAT slave, POWERLINK slave, Modbus/TCP server.

Hilscher has made many contributions to the container community to enhance Industrial Raspberry Pi functionality; see more in Resources.

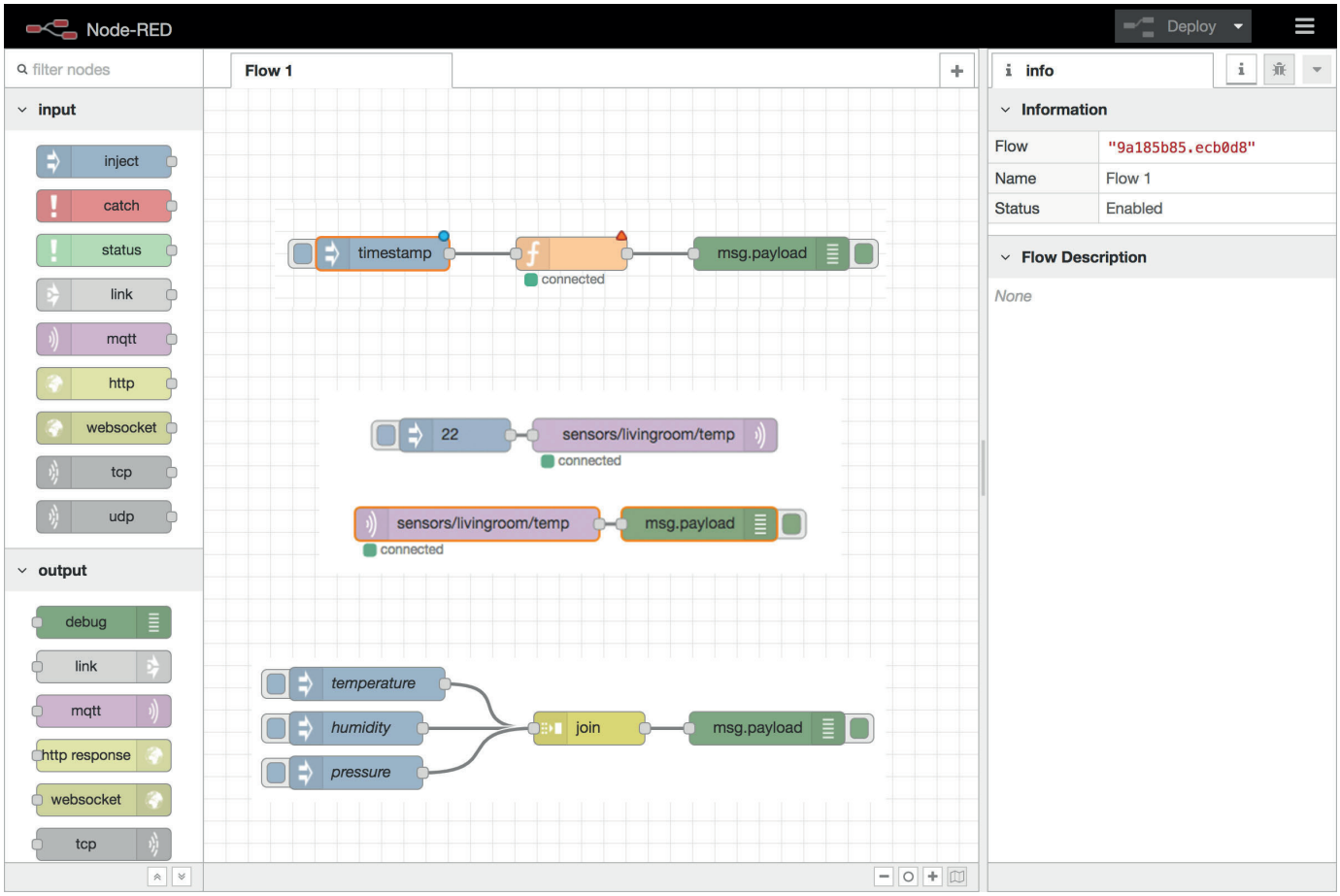
The Docker Community: Millions of developers are already using Docker, which means that a significant user community exists for anything and everything related to deploying Docker. The community offers many ways to engage with other Docker enthusiasts, from sharing knowledge, asking questions, and collaborating. Online forums, webinars and knowledge-bases support users in many ways. Real-world events are held, ranging from informal meetings to international conventions such as “DockerCon”.

Migrate Traditional Apps: Docker can containerize legacy software to transform it into portable, secure applications, without the need for touching code. This can accelerate the modernization of plants and equipment while increasing security via an additional layer of isolation. Legacy apps can all be brought under one governance model that includes scanning for vulnerabilities and authentication. Multi-tenant environments can be devised for your legacy apps by establishing secure zones.

5. Node-RED: Creating Data Flows with the Click of a Mouse

Node-RED started life in 2013 as a side-project of IBM's Emerging Technology Services group. What began as a proof-of-concept for visualizing and manipulating mappings between MQTT topics, soon became a much more general tool. It was open-sourced in September 2013 and has been developed in the open ever since, culminating in it being one of the founding projects of the JS Foundation in October 2016.

Fundamentally, Node-RED is a flow-based programming tool for wiring together hardware devices API 3s and online services in new and interesting ways. It is a way of describing an application's behavior as a network of boxes, or nodes.



Each node has a well-defined purpose; it is given some data, it does something with that data and then it passes that data on. The network is responsible for the flow of data between the nodes.

Click-and-drag is used to assemble wiring connections between nodes to create a flow. The network is responsible for the flow of data between nodes. This is a model that lends itself very well to a visual representation and makes it more accessible to a wider range of users. If someone can break down a problem into discrete steps, they can look at a flow and get a sense of what it is doing, without having to understand the individual lines of code.

JavaScript functions can be created within the editor. A built-in library allows useful functions to be saved as templates or flows for re-use. The light-weight runtime is built on Node.js, taking advantage of its event-driven, non-blocking model. This makes it ideal to run at the edge of the network on low-cost hardware such as the standard Raspberry Pi 3, as well as in the cloud.

New nodes are constantly being created. With over 225,000 in Node-RED‘s Repository, it is easy to add new capabilities to a project’s flow.

The Node-RED Community: There’s plenty of great information about Node-RED and how to use it, including various forums, blogs and social media resources run by the Node-RED community. The forum is the main place to discuss a project, ask questions, share ideas and anything else Node-RED related.

The Node-RED Library: Over 3000 flows are now available in the official Node-RED library. Some of them could be perfect for your next project. See “Resources” section below for more.

6. The Potential for Expansion

An expansion slot is located in the base of Hilscher's Industrial Raspberry Pi 3 unit to extend the I/O capability. This slot is called NPIX and it accommodates a range of expansion modules for direct connection to sensor and actuator levels. At time of writing, these include the following options:

- CAN bus
- Digital 4I/4O
- Analog 4I/4O (+/- 20V) (future)
- RS232
- RS485
- Evaluation board adapter, designed to evaluate NPIX socket and providing pins on pin headers

Internally, the slot uses a standard PCI Express physical connector. For efficiency reasons, this is wired in a Hilscher-defined way. However, the wiring specification is publicly available. Expansion modules can be interchanged at will.

The range of expansion modules is expected to increase. Custom (OEM) expansion modules can also be supplied. Hilscher is able to help design and engineer such custom designs on request.

Contact netPi@hilscher.com for more details.

7. netX: Communications with Security

A unique feature of Hilscher's Industrial Raspberry Pi 3 is the combination of the Raspberry Broadcom chipset and Hilscher's own netX chip; see left mounted on the netRAPID chip-carrier.

One weakness of the standard Raspberry Pi 3, that the Broadcom chip cannot deliver the Real-Time Ethernet capabilities needed by industrial users, has been solved by using the netX industrial network controller as a companion chip, to take on the task.

The netX chip family was created as a way of handling real-time communication issues in an automation world where a significant number of differing protocols (e.g. PROFINET, EtherNet/IP, EtherCAT, PROFIBUS, DeviceNet) are commonly used. This diversity causes difficulties for device vendors, OEMs and users alike.

netX chips can handle all popular protocols in a single hardware design. Used as a communications interface, they make a product protocol-independent. Which protocol to use is simply a matter of configuration. The protocol can also be changed easily to suit market requirements without affecting the hardware design.

The netX chip carries this advantage into Hilscher's Industrial Raspberry Pi 3. All supported protocols have been fully certified by their relevant Trade Associations so a user does not have be a protocol expert. netX additionally supports the improved security described above. It can also internally support a dual-stack architecture that separates control (OT) data from the IT data needed for management and analytics purposes. Both data flows can exist simultaneously without interfering with one another, allowing edge or cloud operations to work entirely independently of any control system.

8. Life Cycle Promise

The Connect Edge Gateway and netPI RTE will both be supported past 2027.

The netX 51 chip (currently used in the Industrial Raspberry Pi) will be available until 2024.
The Broadcom 3B Raspberry Processor will be available until 2023. Hilscher's intention is to maintain the usual Hilscher 10-year life cycle promise for the Industrial Raspberry Pi. Hence, support for both chips (or their equivalents) will be guaranteed for the full 10-year period.

Active users will be approached prior to End-of-Life (EOL) and given the option of creating a customer-specific EOL plan for products they are using.

9. Hilscher Profile

Hilscher Gesellschaft für Systemautomation mbH is a global specialist in network connectivity solutions for device makers, OEMs and end-user manufacturers. Founded in 1986 and with locations worldwide, Hilscher focuses on industrial communications, with all fieldbus, Real-Time Ethernet and emerging Industrial IoT protocols supported in its netX chip-based product lines.

To bring the benefits of Industry 4.0 and the Internet of Things to its customers, Hilscher has developed the netIOT family of products: Embedded chips and interfaces for IoT-enabling automation devices; Edge gateways for collecting and processing data over factory networks; and Service offerings to provide connection to popular IT and cloud-based applications. The netIOT family connects OT to IT, with a solution that turns plant-floor data into value-added information.

For more information, visit www.netiot.com/netpi, www.hilscher.com, or www.netIOT.com.

10. Resources

- Raspberry Pi: To learn more about the Raspberry Pi community START HERE (www.raspberrypi.org/forums/)
- netX: Learn more about Hilscher's netX family of industrial network Controllers (www.hilscher.com/netx/introduction/)
- Docker: There is much more information about Docker HERE (www.docker.com)
- Docker HUB: The world's largest library and community for container images (www.docker.com/products/docker-hub)
- Learn more about Hilscher's contribution to the Docker HUB container community HERE (https://hub.docker.com/u/hilschernetpi)
- Node-RED library: Access the library HERE (https://flows.nodered.org)

Appendix A: netPI and Connect Edge Gateaway

Feature Comparison	 netPI	 Edge Gateway Connect
Security		
Security Enhanced Linux	☑	☑
Yacto Linux	☑	☑
Secure Boot	☑	☑
https communications	☑	☑
User/right management	☑	☑
PKI Certificate handling	☑	☑
Signed package installations	☑	☑
Backup and restore	☐	☑
Event Log-Files	☐	☐
Edge Server		
REST API	☐	☑
Mobile Device Communication	☐	☑
Field Device Status	☐	☑
OT Network Status	☐	☑
Topology Identification	☐	☑
Web to OT Secure Link	☐	☑
Native Cloud connectors	☐	☑
Docker		
Docker	☑	☑
Containers	☑	☑
Node-RED		
Node-RED	◈ In Docker container	☑
Fieldbus node	☑	☑
Extra nodes (OPC-UA client, S7comm, etc.)	☐	☑
Install nodes from www	☑	☑
Other		
AIN Connector	☐	☐
OPC-UA Server	☐	☑
Passive mode	☐	☐
netIOT Diagnostics	☐	☑
Cloud Platform Support		
Microsoft Azure	☑	☑
Amazon AWS	☑	☑
Google Cloud	☑	☑
IBM BlueMix / Watson	☑	☑
SAP Leonardo / Hana	☑	☑
Alibaba	☑	☑
Siemens MindSphere (future)	☑	☑
3rd Party Edge Software		
Ignition from Inductive Automation	☑	☑
DeviceWise from Telit Device Drivers	☑	☑
CODESYS from 3S Soft Control	☑	☑
MySQL Oracle	☑	☑

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