The standard for Industrial Ethernet
POWERLINK

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Technology

Online resources
Technology

POWERLINK is a software protocol Over Ethernet
Why Ethernet?

Old fieldbus technologies are limiting new demanding applications
  - Low bandwidth
  - Limited topologies

Ethernet is a safe investment
  - Ongoing evolution since 1972
  - Available in all microprocessors
  - Manufacturer independent technology
  - Access to web technologies
But…

Standard Ethernet is not deterministic
  Designed for office application

Ethernet medium access: CSMA/CD
  Carrier-Sense Multiple Access with Collision Detection
  Collisions generate repeat after random delay
  Induces unpredictable delays

Critical processes, control level and sensor systems
  Requirement: real-time
  The devices (PLC, I/Os, servo drives,..) must respond as rapidly as required
**Principle of operation**

**Synchronous phase**
- PLC
- SoA

**Asynchronous phase**
- Async. data
- PRes CN1
- PRes CN2
- PRes CNn
- Axis
- I/O

**T_{cycle} min. 100 \mu s**

**MN = Managing Node (master)**
**CN = Controlled Node (slave)**
**SoC = Start of Cycle**
**SoA = Start of Asynchronous**
POWERLINK frame structure

Standard Ethernet IEEE802.3

  - Physical layer (OSI Layer 1)
  - MAC Layer (OSI layer 2)

Ethernet payload: 42 – 1500 Byte
POWERLINK is CANopen over Ethernet

Same device profiles
CANopen application layer
Same mechanisms (PDO, SDO, Object Dictionary…)

Device Profiles:
- I/O
- Encoders
- Valves
- Drives
- Medical
- Others

Protocol Software:
- CANopen Application Layer - Object Dictionary Messaging (SDO and PDO)
- POWERLINK Transport
- Ethernet Driver

Hardware:
- Ethernet Controller
Standard architecture of an automatic machine

- PLC
- Axis control
- Bus 1
- Bus 2
- Axis
- Axis
- Axis
- Axis
- I/O
- I/O
- Sensor
- Sensor
- <1ms jitter
- <5ms cycle time
- >100 bytes
- <10$
- Bus 3
- Bus 4
- Safety PLC
- I/O
- I/O
- Sensor
- Sensor
- Bus 5
- Certification
- >1Mbits/s
- Vision
- Bus 6
100 ns jitter
100 µs cycle time
Up to 1500 bytes
100 Mbit/s
<10$
The fastest network in the world

728 axes in 400µs

... realized, not just theory
Possible any topology

- Daisy chain, star, tree, ring
- Easy to expand
- All over a real time network
“Building on 60 years of innovation, OCME launched Packetto™ in 2014. We developed this revolutionary new range of patented packaging solutions with our customers’ secondary packaging needs in mind. Packetto™ solutions are also available for our Vega shrink wrapper thanks to our trusted technology partner POWERLINK. POWERLINK allows us to equip our acclaimed packaging and filling solutions with distributed I/O and motor-mounted drives, all linked over a single real-time network.”

Ing. Davide Buratti
Research & Development Manager
OCME
POWERLINK is open source
"JUST POWERLINK"

"HP has decided on an automation solution based on POWERLINK. When implementing POWERLINK on our intelligent boards, we received a high level of commitment and cooperation. It is a comprehensive and cost-competitive solution. POWERLINK is a truly open solution and has no legal restrictions such as licenses or patents."

Alon Gazit
Vice President R&D, Hewlett-Packard Company / Indigo Division

hp
Performance

100% open
POWERLINK = standard Ethernet
POWERLINK is based on standard Ethernet

- Can use any standard networking device
- Compatible with all media (copper, fiber, wireless)
- No limit to system extensions

Free choice of network devices

- Hub
- Switch
- Copper/Fiber convertor
- RJ45 or M12 connectors
Hubs vs. switches

Store and forward switch
- Entire frame is received and interpreted
- Forwarding delay dependent on frame size
- $5.12 \mu s - 122 \mu s$ (1500 Byte frame)
- Too slow for real-time traffic

Cut through switch
- Only MAC address is interpreted
- Very fast (forwarding delay < 3 $\mu$s)

Hubs
- No interpretation of data
- Forwarding delay of 20 ns
- Preferred choice for POWERLINK networks
Hot plug

Device exchange during runtime

- No violation of real-time behavior
- Important feature for modular machines and process industry
Diagnostics

Unambiguous diagnostics
- Total view of the network on any place
- No data manipulation on path-transmission

Standard office diagnostic-tools
- PC with on-board Ethernet interface
- Wireshark, Omnipeak, etc.
Diagnostics

Example scenario with Wireshark

Data traced and saved on PC
Performance

100% open

Based on the Ethernet standard
**SoC** = Start of Cycle

**SoA** = Start of Asynchronous
POWERLINK ideal for Industry 4.0

Internet of Things (IoT)

For open, fast, secure networks
Fedegari THEMA4 Control System IoT – from field to cloud

- HTTP REST / JSON
- Full-duplex high performance protocols

- Cloud providers
- Cloud/SIoT platform interact with machines

- Mobile and web applications
  - Advanced and responsive user experience

- Fedegari cloud services
  - Cloud Backup
  - Remote monitoring
  - Predictive maintenance

- Sensors/Actuators
  - High reliable data acquisition

- Fieldbus controller
- Theme4 control system
- Firewall
- Real-time process control
“We strongly believe in standards and open-source technologies. Ethernet POWERLINK and the way it communicates provides the perfect solution for our many different processes. Our investments are protected in the future thanks to this technology’s vendor-independence as well as the possibility of actively participating in its further development.

That’s why we at FEDEGARI place our trust in POWERLINK.”

Ing. Massimo Ghelfi
Automation Manager
FEDEGARI AUTOCLOAVI S.p.A.
Performance

100% open

Hack proof

Based on the Ethernet standard
POWERLINK benefits
Poll response chaining

Fase sincrona

PLC

SoA

PRes CN1
Station 1

PRes CN2
Station 2

PRes CN3
Station 3

Fase asincrona

PRes CNn
I/O

Async. data
Multiple send in asynchronous phase

- PLC
- Axis 1
- Axis 2
- Vision sensor

- PRes CN1
- PRes CN2
- Async. data
- Async. data
- Async. data

Fase sincrona

Fase asincrona
“Our goal is to make it easy to integrate our machines in a plant using standard communication technology. POWERLINK is well established worldwide and ensures interoperability between all levels of an entire plant.

Asynchronous communication makes it possible to implement web-based diagnostics without disturbing the real-time process.”

Ing. Paolo Zanella
Managing Director
ANTIL S.p.a.
Ring redundancy

Downtime reduction
Master redundancy

Fast change-over

Media redundancy
Extremely fast axis synchronization
Centralized and decentralized architectures
Single frame principle is extremely robust

Very stable, even with large number of stations
“In automotive plants performing body welding there is a large amount of electromagnetic interference, so EMC stability is absolutely essential for their communication networks. We at COMAU Robotics have thousands of robots in the field operating with complete reliability. That’s why COMAU trust in POWERLINK.”

Ing. Giorgio Aletto
Hardware Engineering Manager
COMAU - Robotics Business Line
“In automotive plants performing body welding there is a large amount of electromagnetic interference, so EMC stability is absolutely essential for their communication networks. We at COMAU Robotics have thousands of robots in the field operating with complete reliability. That’s why COMAU trust in POWERLINK.”

Ing. Giorgio Alotto
Headware Engineering Manager
COMAU - Robotics Business Line
Performance

- Reduced cost ownership
- 100% open
- Hack proof
- Based on the Ethernet standard
Implementation
BSD licenses
- Copy, change and distribute
- A huge number of system integrators

Product variety on the market

EPSG standardization
- Coordination of POWERLINK activities

Advantages of membership
- Marketing
- Exhibition presence
- Work groups
- Tooling
- Product certification
Cyclone IV
NETX
Anybus
Fido5000 REM
I210 Ethernet controller
FPGA IP-Core
ARM Cortex A8 AM335x
Spartan®-6
16-core xCORE
Market
“We are faced with new challenges at work every day. We therefore rely on established standard technologies available on the market.

The number of POWERLINK products is constantly growing, ensuring that we will reach our goals. Integrating a new device is simple and cost-effective.

That’s why we at DOMOTECK place our trust in POWERLINK.”

Ing. Giampaolo Casaroli
General Manager
DOMOTECK
POWERLINK in all the world
Chinese standard GB/T-27960
Korean standard
http://www.ethernet-powerlink.org/

http://openpowerlink.sourceforge.net/web/openPOWERLINK.html
Working with POWERLINK: resources online

openPOWERLINK on Raspberry Pi2

OpenCONFIGURATOR

POWERLINK and CODESYS
Working with POWERLINK: openPOWERLINK on Raspberry Pi2

Open-source POWERLINK stack (MN and CN)
  - BSD license
  - Developed for Linux
  - Ported to Windows and VxWorks
  - Other platforms under development

Hosted at SourceForge.net
  http://sourceforge.net/projects/openpowerlink/
Working with POWERLINK: openPOWERLINK on Raspberry Pi2


Quick Start - POWERLINK on Raspberry Pi2

Step 1:
How do I start?

Step 2:
What hardware do I need?

Step 3:
What software do I need?

Step 4:
Get Ubuntu Linux on Raspberry Pi2

Step 5:
Environment setup to run openPOWERLINK

Step 6:
How to run openPOWERLINK binaries?

Step 7:
Cycle Time Measurements
Working with POWERLINK: openPOWERLINK on Raspberry Pi2

1. How do I start?
2. What hardware do I need?
3. What software do I need?
4. Get Ubuntu Linux on Raspberry Pi2
5. Environment setup to run openPOWERLINK
6. How to run openPOWERLINK binaries?
7. Cycle Time Measurements
8. Video tutorial for running POWERLINK on Raspberry Pi2
1. How do I start?

This article describes how you can use openPOWERLINK on the Raspberry Pi2 and build your own distributed automation platform and control the signals of motors, sensors, actuators, relays etc. You will also learn how to use openCONFIGURATOR to configure the network. You can then modify the C programs included to send and receive data using the IO pins.

2. What hardware do I need?

3. What software do I need?

4. Get Ubuntu Linux on Raspberry Pi2

5. Environment setup to run openPOWERLINK

6. How to run openPOWERLINK binaries?

7. Cycle Time Measurements

8. Video tutorial for running POWERLINK on Raspberry Pi2
Working with POWERLINK: openPOWERLINK on Raspberry Pi2

1. How do I start?

2. What hardware do I need?
   1. Raspberry Pi2 board to act as the master
   2. Raspberry Pi2 boards to act as the slaves
   3. Network Switch
   4. Ethernet Cables
   5. Micro SD Card Reader
   6. USB Thumb Drive
   7. HDMI displays, USB keyboards, and mice
   8. Micro USB cables to power the Raspberry Pi2 boards
   9. Windows PC

3. What software do I need?

4. Get Ubuntu Linux on Raspberry Pi2

5. Environment setup to run openPOWERLINK

6. How to run openPOWERLINK binaries?

7. Cycle Time Measurements
Working with POWERLINK: openPOWERLINK on Raspberry Pi2

1. How do I start?

2. What hardware do I need?

3. What software do I need?
   - On a Windows PC:
     - Download the Ubuntu-image from this link and extract it
     - Download and install Win32 disk imager from this link
     - Download the “openPOWERLINK_RaspberryPi2” package from this link
       Copy the "openPOWERLINK_RaspberryPi2" package into the thumb drive
     - Download the WiringPi package from this link
     - Download the “pcap library” - libpcap-dev_1.6.2-2_all.deb from this link
       Download the dependancy file 1 for “pcap library” - libpcap0.8_1.6.2-2_armhf.deb from this link
       Download the dependancy file 2 for “pcap library” - libpcap0.8-dev_1.6.2-2_armhf.deb from this link
       Download the "Install_pcap.sh" from this link
       Copy pcap library, dependancy file 1, dependancy file 2, Install_pcap.sh files into the thumb drive
   - Download wireshark from this link

4. Get Ubuntu Linux on Raspberry Pi2

5. Environment setup to run openPOWERLINK

6. How to run openPOWERLINK binaries?
1. How do I start?

2. What hardware do I need?

3. What software do I need?

4. Get Ubuntu Linux on Raspberry Pi2

The instructions in this section have to be followed for all three Raspberry Pi2 boards.

• Begin by slotting your SD card into the SD card reader and connect to the windows PC
• Launch Win32 disk imager
• Click on the blue folder icon next to the input box labeled 'Image File', browse to where your Ubuntu-image is and double click on it
• Next click on the button under 'Device' and pick the device you want to write the image from the drop down menu, making sure it matches the letter assigned to your SD card in the computer window, then click 'Write'. Doing this will wipe your card so make sure there's nothing on it you want to keep
• It will likely take at least 10 minutes or so to complete, but once the 'Write Successful' window appears then remove the micro SD card and insert it into the Raspberry Pi board
• Power on the Pi and it should boot into an intro screen showing two logins. Select the user 'linaro' and enter the password 'linaro' and you should be greeted with the desktop
• Next, plug in your USB keyboard and Mouse into the USB slots on the Raspberry Pi
• Make sure that your monitor or TV is turned on, and that you have selected the right input (e.g. HDMI 1, DVI, etc)
• Then connect your HDMI cable from your Raspberry Pi to your monitor or TV
• If you intend to connect your Raspberry Pi to the internet, plug in an Ethernet cable into the ethernet port next to the USB ports, otherwise skip this step
• When you are happy that you have plugged in all the cables and SD card required, finally plug in the micro usb power supply

Working with POWERLINK: openPOWERLINK on Raspberry Pi2
Working with POWERLINK: openPOWERLINK on Raspberry Pi2

1. How do I start?
2. What hardware do I need?
3. What software do I need?
4. Get Ubuntu Linux on Raspberry Pi2
5. Environment setup to run openPOWERLINK

Connect the USB thumb drive to transfer openPOWERLINK_RaspberryPi2.tar.gz package and all the dependency files for pcap to all three Raspberry Pi2 boards by connecting the drive to the USB port of the Raspberry Pi2 and following the instructions in the screenshot below.

Run the following commands to install pcap on all the three Raspberry Pi2 boards:

6. How to run openPOWERLINK binaries?
Working with POWERLINK: openPOWERLINK on Raspberry Pi2

1. How do I start?
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3. What software do I need?
4. Get Ubuntu Linux on Raspberry Pi2
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6. How to run openPOWERLINK binaries?
   Detailed sections with screenshots

7. Cycle Time Measurements
8. Video tutorial for running POWERLINK on Raspberry Pi2
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7. Cycle Time Measurements
   Objective: to measure performance of the POWERLINK demo while
   • IO data is exchanged in the isochronous phase and
   • A video is streamed over the asynchronous phase
   Observation:
   • We see that the network is stable and deterministic at 50 ms
   • To further reduce the cycle time, we can port the Ethernet driver into the linux kernel and try using RtPreempt

8. Video tutorial for running POWERLINK on Raspberry Pi2
Working with POWERLINK: openPOWERLINK on Raspberry Pi2

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https://www.youtube.com/watch?v=78M1_WZnFgQ
Working with POWERLINK: openCONFIGURATOR

openCONFIGURATOR

Open source tool for your POWERLINK configuration requirements
Configuration of POWERLINK modules

openCONFIGURATOR requirements

https://www.kalycito.com/index.php/openconfigurator/192-openconfigurator-open-source-tool-for-your-configuration-requirements
openCONFIGURATOR

Open source tool for your POWERLINK configuration requirements


Working with POWERLINK: openCONFIGURATOR
Webinar

Title: Optimizing Automation Machine Development Using Open Standards
Benefits for machine builders of using open standards like POWERLINK and CODESYS

50 minutes video
https://www.youtube.com/watch?v=gQiLfgakXHA
Rules

• Team: Up to 5 students + 1 university supervisor
• Project: Utilization of POWERLINK technology for the IIoT
• Results: Working prototype and scientific paper

Prices

• €17,500.- in cash for the winning teams
• Open-access article fees for the best scientific papers
• Discounts on automation tools and hardware components
• Social networking event

Contact information

• E-Mail: award@ethernet-powerlink.org
• Web: www.ethernet-powerlink.org/en/award
• LinkedIn: www.ethernet-powerlink.org/en/linkedin
• Source: openpowerlink.sourceforge.net

Sponsors:
Overview
Technology

Performance

- Reduced cost ownership
- 100% open
- Hack proof
- Based on the Ethernet standard

openPOWERLINK on Raspberry Pi2
openCONFIGURATOR
POWERLINK and CODESYS