icECAT.
EtherCAT Master Stack for Embedded Systems

TECHNOLOGY EtherCAT

CHARACTERISTICS

- EtherCAT MainDevice stack, specifically designed for embedded systems: optimized for high performance with minimal resource usage
- Target platforms: from small microcontrollers to Industrial PCs
- Written in portable ANSI-C. Operating system and network interface dependent parts are located in separate modules for easy adaptation to new platforms.
- Various options for Ethernet communication interfaces:
  - Raw Ethernet access via the network driver of the operating system (e. g. Raw Socket, BPF, PCAP)
  - Optimized link layer driver with zero-copy buffers for shorter cycle times and reduced CPU load
- Shipped in source code, project-based license, no royalties

ARCHITECTURE

- The MainDevice stack is a passive library which provides a C API for the application. Both cyclic and acyclic tasks can be driven by the application. Flexible scheduling options: single-threaded, multi-threaded and cycle synchronization.
- Easy integration in applications: The stack does not impose a specific software architecture on the application. Multiple instances of the MainDevice stack can run within the same application.
- Scalable architecture: Features can be disabled at compile-time to minimize the footprint.

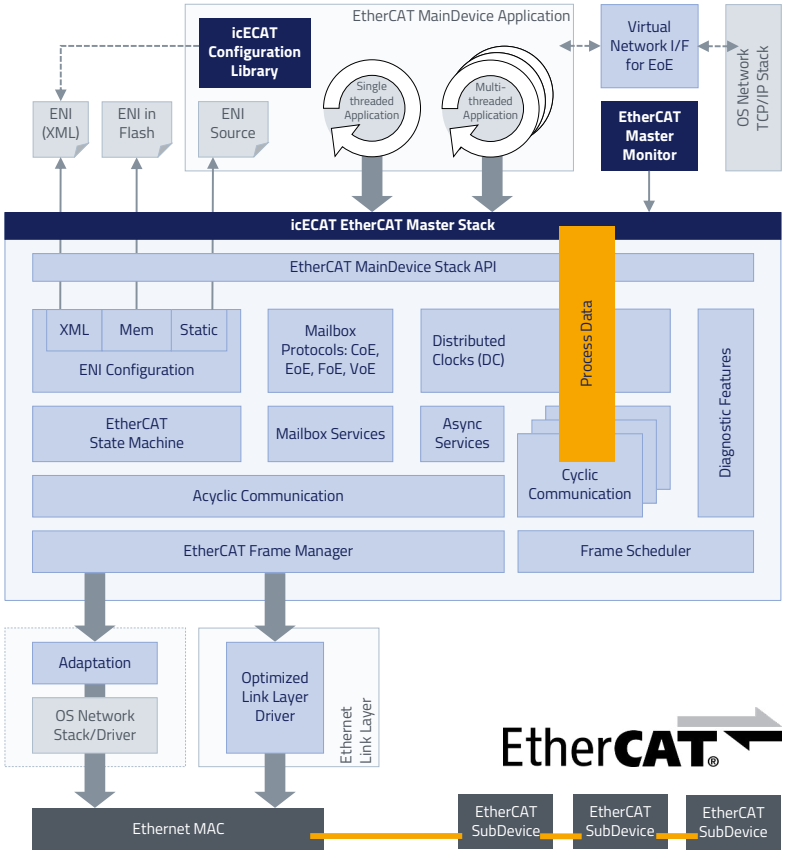


Figure 1: Architecture of the icECAT EtherCAT Master Stack and adaption to the EtherCAT MainDevice application. *Access to the Ethernet MAC via the operating system's network stack (left side) or an optimized link layer driver (right side)*

FEATURES

Basic features

- EtherCAT MainDevice stack, compliant with ETG.1500 EtherCAT Master Class-A and Class-B feature set
- Supports all EtherCAT (DLPDU) datagrams 101
- Compatible with simple and complex SubDevices 103
- Verification of working counters, SubDevice responses and lost frames 105
- Enhanced error handling for SubDevice and network errors
- Support for EtherCAT frames over Ethernet at the link layer 107

EtherCAT network configuration

- Configuration via ENI file or online network scan 301
- Integrated, OS-independent XML parser. ENI data can be accessed via standard ANSI C file operations
- Option for static network configuration: ENI information can be converted and embedded in the source code, eliminating the need for a file system on the target device.
- Comparison of configured and actual network topology via ENI-defined initialization commands 302
- Read/write access to Configured Station Alias (Explicit Device ID) 303
- Read/write access to the SII (Slave Information Interface) 305
- Skipping of non-existent SubDevices in a given ENI
- Automatic target-side ENI configuration (with icECAT Configuration Library)

EtherCAT state machine (ESM)

- Supports the EtherCAT State Machine for each configured SubDevice 104
- Parallel initialization of multiple EtherCAT SubDevices
- API for controlling the state of both the EtherCAT MainDevice and individual EtherCAT SubDevices
- State monitoring of the EtherCAT SubDevices

Cyclic communication (PDO)

- Supports process data exchange in cyclic frames 201
- Large process images over multiple frames are supported
- API for accessing the process image either in raw format or via I/O variables defined in the ENI file
- Macros for high-performance access to the process data
- Support for one or multiple cyclic tasks with different process images and cycle times 202
- Cyclic tasks are driven by the application, which can use hardware specific timers or synchronize the tasks with external events.

Acyclic communication

API for sending asynchronous frames with EtherCAT datagrams by the application

Frame scheduling

Different modes for scheduling of cyclic and acyclic frames:

- IMMEDIATE: Frames are sent by each task without scheduling.
- CHAINING: Frames are sent by a task with the priority defined in the ENI. Acyclic frames can be chained to one cyclic task.
- SCHEDULED: Frames are managed by a dedicated scheduler thread.

Slave-to-Slave communication

PDO communication between SubDevices (e. g. an FSoE master and FSoE slaves) is handled by the MainDevice 1201.

Mailbox support

- Support for EtherCAT mailbox transfers 401 402.
- Mailbox communication via polling 404 or synchronized with mailbox status events from the cyclic frames
- EtherCAT mailbox gateway via UDP [ETG.8200]

CAN application layer over EtherCAT (CoE)

- Supports SDO upload/download, normal, expedited and segmented transfers, and complete access 501 502 503
- Supports the SDO Info Service 504
- Supports emergency messages 505
- API with both blocking and non-blocking CoE functions
- Supports a Master Object Dictionary with mandatory objects (ETG.5001 MDP sub profile 1100) 1301

Ethernet over EtherCAT (EoE)

- Supports tunneling Ethernet communication in acyclic frames 601
- Includes virtual switch functionality 602
- Interface for the network stack of the host operating system (for some supported OS) 603

File transfer over EtherCAT (FoE)

- Supports file transfers to/from a SubDevice (no local file system required) 701
- Firmware upload/download support 702
- Supports Bootstrap state for firmware update 703

Servo drive profile over EtherCAT (SoE)

- Supports read/write access to IDNs via SSC service channel transfers 801
- Processes SoE initialization commands as defined in the ENI

Vendor-specific communication over EtherCAT (VoE)

Supports a vendor-specific protocol with direct access to the mailbox communication 1001

= EtherCAT feature ID according to ETG.1500

FEATURES

Distributed Clocks (DC)

- Support for EtherCAT Distributed Clocks (DC) in master mode. The MainDevice synchronizes the network to the DC clock of a reference slave 1101.
- Support for DC slave mode to synchronize the DC reference slave to the MainDevice
- Continuous calculation of the propagation delay and adjustment 1102
- Continuous monitoring of the synchronization deviations in the SubDevices 1103
- Runtime monitoring of the DC accuracy

Cable Redundancy

Support for the FP Cable Redundancy as a compile-time configuration: Basic functions FPCR_101 and diagnostic functions FPCR_102

Diagnostic features

- Application event API for error notification with detailed error information
- Various statistics and error counters
- Developer logging for different software layers

Hot Connect

- Support for connection and disconnection of SubDevices while EtherCAT communication is active in the network
- Hot Connect groups can be connected at any free port in the network.
- In combination with DC, newly connected SubDevices are synchronized to the active network.
- Available as an add-on package for the icECAT Master Stack

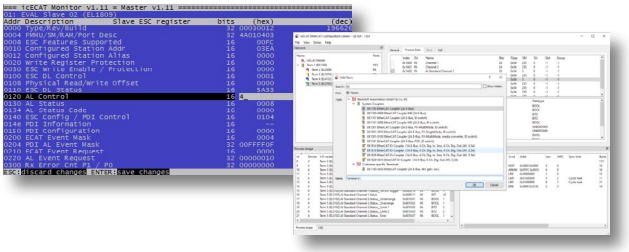
Remote Interface

- Remote API for icECAT Master: ESM control, network scan, ENI exchange, CoE upload/download, SII reading, SDO Info Service, read/write Explicit Device ID, etc.
- Based on a TCP/IP connection, protocol can be replaced by a custom transport channel.

Further features

- Access to Slave Information Interface (SII), reading and writing SubDevice's EEPROM
- Ask the IBV sales team for the product roadmap or missing features.

TOOLING



EtherCAT Master Monitor

A terminal-based development tool for monitoring the EtherCAT network and controlling the EtherCAT MainDevice and SubDevices. The tool can run on the MainDevice or a remote host via a TCP connection.

Features:

- Displays and controls MainDevice and SubDevice states
- Allows viewing and modifying process image I/O variables
- Enables manual access to ESC SubDevice registers
- Supports manual sending of SDO commands
- Displaying statistics and error counters

EtherCAT Performance Monitor

- Measures key performance indicators such as processing time and frame jitter in real-time on the target system

ENI Tool

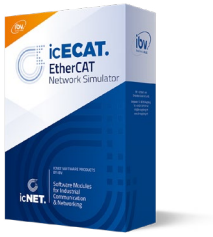
Command-line tool for converting ENI files into source code

EtherCAT Configuration Library

- Library for configuring an EtherCAT network for integration into a custom application, an engineering tool, or on the target for auto-configuration
- Supports online network scanning 301 and ENI file generation
- Retrieves SubDevice information from ESI files or SII as a fallback
- Online configuration features:
  - Explicit Device ID via Configured Station Alias and I/O mapped DIP switches
  - PDO Upload for retrieving PDO mapping from SubDevices
  - Reading the CoE Object Dictionary via SDO Info Service
- Available with a Qt based Graphical User Interface (GUI) or with a Node.js based web server and Vue.js based browser application example

see also: www.ibv-augsburg.de/icnet/ethercat-configuration

EtherCAT Network Simulator



- Software-in-the-loop (SiL) simulation of an EtherCAT network based on an ENI file
- Simulation of process data and CoE objects
- Useful for the development and testing of a control application

see also: www.ibv-augsburg.de/icnet/ethercat-network-simulation

icNET.

Software Modules for Industrial Communication & Networking

SUPPORTED PLATFORMS

Operating Systems:

- Linux with or w/o Preempt-RT Patch
- Xenomai *)
- QNX Neutrino RTOS
- FreeRTOS *)
- Zephyr *)
- Bare-metal, no operating system *)

**) optimized link layer driver is required*

CPU Architectures:

- Arm Cortex-A
- Arm Cortex-M
- Arm Cortex-R
- Intel x86 (32-/64-bit)

AVAILABLE OPTIMIZED LINK LAYER DRIVERS

- Intel I210/I211 *)
- Intel I225/226 *)
- Intel TSN GbE MAC *)
- Texas Instruments AM64x/AM243x and J784S4/TDA4 on R5F Core
- Rockchip RK3399
- NXP i.MX 8, i.MX 6
- NXP i.MX RT1170, i.MX RT1064, i.MX RT1050
- Renesas RZ/T2M
- STMicroelectronics STM32: STM32H7, STM32F7, STM32F4, STM32MP2
- others on request

**) with TTS (time triggered send) support*

LICENSING

The **icECAT.** EtherCAT software products are offered under a project-based license for a one-time fee without royalties. The libraries and tools are shipped in source code.

EVALUATION

An evaluation is possible on various supported platforms and evaluation boards. Contact IBV for getting access.

Support and Services

IBV provides professional engineering, integration, support and consulting services for Industrial Ethernet technologies on real-time and embedded systems.

Contact

For getting more details or for requesting an evaluation version, please visit our website or write an email

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About IBV

Custom software solutions for real-time and embedded systems. The company shows a broad expertise in embedded systems and real-time applications. The services and products made by IBV are used in the industrial automation, medical devices, IoT and smart home applications, telecommunication, test and measurement. In addition to the engineering services, IBV offers software products for implementing Industrial Ethernet solutions.

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