1 HDrive17-ETC Servo Drive Manual

Servo Drive with EtherCAT Connectivity

Figure 1: HDrive17-ETC Device

1.1 Executive Summary

The **HDrive17-ETC** is a high-performance servo drive solution from Henschel-Robotics, designed for precision motion control applications. This compact, integrated servo motor combines advanced field-oriented control (FOC) technology with EtherCAT communication for seamless integration into industrial automation systems.

1.1.1 Key Features

Feature	Description
Communication	EtherCAT real-time communication
Control	Closed-loop position, velocity, and torque control
Performance	High dynamics and efficiency, low torque ripple
Accuracy	±0.1° (1 Sigma) positioning accuracy
Encoder	14-bit magnetic encoder system

The servo motor operates in three primary control modes: **Position**, **Velocity**, and **Torque**. The integrated magnetic encoder system provides factory-calibrated position feedback with high accuracy.

1.2 Company Information

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1.3 Document Information

1.3.1 Purpose

This technical manual provides comprehensive guidance for commissioning and operating the HDrive17-ETC servo drive system. It is intended for qualified technicians and engineers responsible for system integration and maintenance.

1.3.2 Scope

- Installation and commissioning procedures
- Technical specifications and parameters
- Safety guidelines and warnings
- Troubleshooting and maintenance information

1.3.3 Document Control

Version	Date	Author	Changes
1.0	08.09.2024	Technical Team	Initial document creation

 Important Notice: This document contains critical safety information. Please read all sections carefully before proceeding with installation or operation.

Contents

2 Legal & Safety

2.1 Liability Disclaimer

Henschel-Robotics GmbH assumes no liability for any damages resulting from improper use of the product. Familiarity with this handbook is considered an essential part of proper usage. Therefore, it is imperative to follow all instructions provided in this handbook and in the technical documentation for the encoder system.

Henschel-Robotics GmbH is not responsible for any malfunctions or failures arising from non-compliance with these operating instructions.

2.1.1 Intended Use

The **HDrive System** is an electronic servo motor device designed for use in industrial environments. It is intended for indoor operation within a protected setting. The servo motors are not water-resistant and must be installed accordingly to ensure safe and reliable operation.

- **Usage Restriction Notice**

  The HDrive Servo Motor may only be used for the purposes specified above. Any use outside the defined technical parameters, integration with incompatible components, or modifications that alter the product's intended function can lead to operational malfunctions. **Henschel-Robotics GmbH assumes no liability** for any issues or damages resulting from such misuse.

2.2 Safety Guidelines

2.2.1 General Safety Requirements

CRITICAL SAFETY REQUIREMENTS

2.2.1.1 Installation & Maintenance

- Installation and maintenance must be performed exclusively by **qualified personnel**
- Ensure **power supply is disconnected** and all mechanical components are stationary
- Always comply with **professional safety regulations** in force within your country

2.2.1.2 Electrical Hazards

- **High voltage, current, and moving mechanical parts** present risks of serious or fatal injury
- Do not operate the device in **explosive or flammable environments**
- The device must be operated **only for its intended purpose**

2.2.1.3 Compliance Notice

- Failure to observe these precautions constitutes a **breach of safety standards**
- Any misuse may cause **severe personal injury and/or environmental damage**

2.2.2 Electrical Safety Guidelines

ELECTRICAL SAFETY PROTOCOLS

2.2.2.1 Power Supply Requirements

- Ensure the **power supply is switched OFF** before connecting the device
- Connect according to instructions provided in this manual
- **Power supply must be stable and noise-free**
- Install **EMC filters** on the power line if necessary

2.2.2.2 Cable Management

- Any **unused output signal wires** must be **individually insulated**
- Always use **shielded cables**, preferably **twisted-pair** types
- Keep all cables **as short as possible**
- **Do not route signal cables** near high-voltage power lines

2.2.2.3 EMC Compliance (2014/30/EU Directive)

- **Discharge static electricity** from body and tools before handling
- **Apply shielding** if required
- **Avoid using strong magnets** on or near the device
- Connect cable shield to **clean ground** free from interference

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3 Product Overview

3.1 System Overview

The **Henschel-Robotics GmbH "HDrive"** is an integrated servo motor solution based on advanced multi-pole stepper motor technology. This comprehensive system integrates:

- **Power Unit** - High-efficiency motor drive electronics
- **Communication Module** - EtherCAT real-time communication interface
- **Position Sensor** - 14-bit magnetic encoder system
- **Control System** - ARM™ micro-controller with comprehensive axis planner

The integrated electronics provide **position**, **speed**, and **torque control** capabilities with factory-calibrated precision.

3.2 Product Variants

3.2.1 Product Naming Convention

The HDrive is available with or without gearbox options. The product naming follows this structure:

`HDrive[AA]-[BBB]-[i]`

3.2.2 Variant Specifications

Symbol	Options	Description
AA	17, 23	Flange size of the motor (Nema)

Symbol	Options	Description
BBB	ETC	Communication protocol (EtherCAT)
i	i	Industrial Version with VPwr = 48VDC

Example: `HDrive17-ETC-i` = Nema17 flange, EtherCAT, industrial

3.3 Compliance & Certifications

The HDrive has successfully passed comprehensive EMC testing according to European standards:

3.3.1 EMC Compliance Certificates

Emission

Standard	Description	Status
EN 550011:2016/A1:2017CISPR 11-2015+AMD1:2016	Radiated Emission	**PASS**

Immunity

Standard	Description	Status
EN 61000-4-3:2006 +A1 +A2IEC 61000-4-3:2006 +A1 + A2	Electromagnetic fields	**PASS**
EN 61000-4-4:2012IEC 61000-4-4:2012	Fast electric transients (Burst)	**PASS**

Standard	Description	Status
EN 61000-4-5:2014 +A1:2017IEC61000-4-5:2014 +AMD1:2017	Surges	**PASS**

Certification Date: Nov 21, 2025 **Compliance:** Full compliance with EU EMC Directive 2014/30/EU

4 Installation & Commissioning

This section provides comprehensive guidance for mechanical and electrical installation, as well as system commissioning procedures for the HDrive17-ETC servo drive.

4.1 Mechanical Installation

4.1.1 Mounting Requirements

The motor should be attached using the **four M3 threads** located on the front face (near the motor shaft) with the following specifications:

Parameter	Value	Notes
Thread Size	M3	Metric thread
Thread Depth	4.5 mm	Maximum engagement depth
Mounting Pattern	4 holes	Square pattern on front face

4.1.2 Centering Ring Specification

Use the **2mm deep centering ring** with precise dimensions to ensure proper alignment:

Centering Ring:

Parameter	Value
Ring Depth	2.0 mm
Ring Diameter	22+0-0.05 mm *(with tolerance)*

Motor Shaft:

- **Material:** Aluminium
- **Maximum Axial Load (Dynamic):** 10 N
- **Maximum Radial Load (Dynamic)** @ 20 mm shaft length: 21 N

 Critical: Proper centering is essential for optimal performance and longevity of the system.

4.2 Electrical Installation

4.2.1 Power Supply Requirements

The HDrive17-ETC requires a **24V DC power supply** with the following specifications:

Parameter	Value	Unit
Supply Voltage Vs	24	V DC
Supply Voltage Vp	24-48	V DC
Voltage Tolerance	±10%	V DC
Current Rating Vs	0.5	A
Current Rating Vp	1	A
Max. Power Consumption	36	W

4.2.2 Power Connector Pinout

The power connector is a **4-pin connector** with redundant connections for reliability:

Pin	Function	Description	Wire Color
1	+24V	Positive power supply Vs	Brown

Pin	Function	Description	Wire Color
2	GND	Ground reference	Blue
3	+24V	Positive power supply Vp	White
4	GND	Ground reference (redundant)	Black

Note: GND-P and GND-S are connected in the device

4.2.3 EtherCAT Connector Pinout

The power connector is a **4-pin connector** with redundant connections for reliability:

Pin	Function	Description	Wire Color
1	TX+	Positive TX pin	
2	RX+	Positive RX pin	
3	RX-	Negative TX pin	
4	TX-	Negative RX pin	

4.2.4 Digital I/O Connector Pinout

The power connector is a **4-pin connector** with redundant connections for reliability:

Pin	Function	Description	Wire Color
1	+24VDC	Positive Vs, 100mA fused	
2	Input 1	Input 1	
3	GND	GND	
4	Input 2	Input 2	

Note: Input logic turns 1 when input is higher than 12VDC. Input turns low when below 9VDC

4.3 System Startup Sequence

The HDrive follows a standardized startup sequence:

4.3.1 Startup Procedure

1. **Power On**
    - Apply 24V DC power supply
    - Motor LED turns white
    - Bootloader will take about 2 seconds to load the firmware
    - Motor LED turns solid red, yellow
2. **EtherCAT Initialization**
    - Establish communication with EtherCAT master
    - Motor LED blinks green
3. **Ready for Operation**
    - System ready for control commands
    - Motor LED turns solid green

    Typical startup time: 2-5 seconds depending on network configuration.

4.4 TwinCAT Configuration

4.4.1 Configuration Steps

For TwinCAT integration, follow these configuration steps:

1. **Network Setup**
    - Add HDrive to EtherCAT network topology
    - Configure network parameters
2. **Motor Parameters**
    - Set motor-specific parameters
    - Configure encoder settings
3. **Control Modes**
    - Configure position, velocity, and torque modes
    - Set control loop parameters
4. **Communication Test**
    - Verify EtherCAT communication

- Test control commands

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5 Technical Documentation

5.1 Control Architecture

The HDrive17-ETC employs sophisticated **time-discrete control algorithms** that provide independent adjustment of torque, position, and speed controllers. This modular control architecture enables precise tuning for specific application requirements.

5.1.1 Control System Overview

The drive contains several time-discrete control algorithms. With the HDrive, the **torque**, **position**, and **speed controllers** can be adjusted separately. All control loops are fully documented and parameterizable.

 Critical Warning The open and freely parameterizable control architecture must be carefully adjusted to the respective application. **Improper parameter tuning can damage the drive and attached load.**

5.1.2 Field-Oriented Control (FOC)

The stepper motor is controlled using **field-oriented control (FOC)** methodology, which provides:

- **Separate regulation** of torque-generating and reactive currents
- **Enhanced efficiency** compared to traditional stepper control
- **Cogging torque suppression** with reduced vibration and noise
- **Precise torque control** for demanding applications

5.1.2.1 FOC Implementation Details The HDrive17-ETC implements a sophisticated FOC algorithm with the following characteristics:

Coordinate Transformation

- **Park Transform** - Rotates αβ coordinates to synchronous DQ frame

- **Inverse Transforms** - Converts DQ back to ABC for PWM generation

Control Architecture

- **D-Axis Control** - Flux-producing current regulation
- **Q-Axis Control** - Torque-producing current regulation
- **Speed Control** - Controls the current of the motor to maintain a speed
- **Position Control** - Controls the position of the motor

Advanced Features

- **Current Filtering** - Low-pass filtering of DQ currents
- **Voltage Feedforward** - Back-EMF compensation
- **Phase Current Monitoring** - Real-time A/B phase current measurement
- **Torque Ripple Compensation** - Advanced ripple reduction algorithms

5.1.3 Control System Components

The control system consists of three primary components:

1. **Position Controller**
    - Controls motor position with high accuracy
    - Configurable PID parameters
    - Position error compensation
2. **Velocity Controller**
    - Manages motor speed and acceleration
    - Smooth velocity profiles
    - Dynamic response optimization
3. **Current Controller**
    - Direct torque control capability
    - Current limiting and protection
    - Field-oriented current regulation

5.1.4 Control Structure Overview

The HDrive17-ETC uses a **cascaded control structure** that provides smooth, precise motion control through three interconnected control loops:

5.1.4.1 Control Loop Hierarchy

```
Position Command → Position Controller → Speed Controller → Current Controller → Motor
       ↓                    ↓                    ↓                    ↓
   Target Pos          Target Speed         Target Current        Actual Motion
```

1. Position Control Loop (Outermost)

- **Purpose**: Achieves precise positioning
- **Input**: Target position command
- **Output**: Target speed command
- **Control Type**: Proportional (P) controller
- **Update Rate**: 2 kHz

2. Speed Control Loop (Middle)

- **Purpose**: Controls motor velocity
- **Input**: Target speed from position controller
- **Output**: Target current command
- **Control Type**: Proportional-Integral (PI) controller
- **Update Rate**: 2 kHz

3. Current Control Loop (Innermost)

- **Purpose**: Controls motor torque/current
- **Input**: Target current from speed controller
- **Output**: PWM signals to motor phases
- **Control Type**: Proportional-Integral (PI) controller
- **Update Rate**: 20 kHz

5.1.4.2 Control Modes

The system supports different control modes:

- **Position Mode**: Full cascaded control (Position → Speed → Current)
- **Speed Mode**: Direct speed control (Speed → Current)
- **Torque Mode**: Direct current control

5.1.5 System Architecture

5.1.5.1 Real-time Control System

The HDrive17-ETC operates with a sophisticated real-time control architecture:

Control Loop Timing

- **ADC Interrupt** - 20 kHz sampling rate
- **Current Control** - 20 kHz update rate
- **Position Control** - 2 kHz update rate
- **State Machine** - 2 kHz operation

5.1.5.2 State Machine Implementation

Comprehensive state machine for system operation:

Main States

- **Not Ready to Switch On** - System initialization
- **Switch On Disabled** - Power applied, not ready
- **Ready to Switch On** - System ready for operation
- **Switched On** - Motor enabled, not operational
- **Operation Enabled** - Full operational mode
- **Quick Stop Active** - Emergency stop condition
- **Fault Reaction Active** - Error handling mode
- **Fault** - System error state

Safety Monitoring

- **Voltage Monitoring** - Over/under voltage detection
- **Temperature Monitoring** - Thermal protection
- **Speed Monitoring** - Over-speed protection

5.2 Firmware Management

5.2.1 Firmware Upgrade Procedure

The firmware can be upgraded using the **EtherCAT interface**. The EEPROM configuration will be maintained:

5.2.1.1 Upgrade Process

1. **Connection Setup**
    - Connect to HDrive via EtherCAT to Beckhoff TwinCAT
    - Verify communication status

2. **Firmware Access**
    - Put EtherCAT statemachine from motor to Bootstrap State
3. **Upload Process**
    - Upload new firmware file with “File Access over EtherCAT FoE”
    - Monitor upload progress
4. **Completion Wait**
    - Wait for upgrade to complete
    - Switch EtherCAT statemachine to Init state
    - Drive is restarting, checking and loading the new Firmware. This will take about 1 minute

5.3 Performance Tuning

5.3.1 Control Bandwidth Optimization

The control bandwidth can be adjusted to optimize performance for different applications:

Application Type	Recommended Current Bandwidth	Use Case
General Positioning	300 Hz	Micro-positioning, precision assembly
High Precision Positioning	500 Hz	Standard automation, pick-and-place
High Precision and high Speed Applications	800 Hz	High-speed packaging, rapid positioning

The Position ctrl bandwidth should stay about 15 - 25Hz. The velocity Bandwidth is calculated out of the position Bandwidth and does not need to be entered manually.

> **Tuning Tip:** Start with conservative settings and gradually increase bandwidth while monitoring system stability.

5.4 Digital I/O Configuration

5.4.1 Digital Input/Output Capabilities

The HDrive provides **digital input capabilities** for system integration and position sensing:

Pin	Function	Type	Description	Voltage Level
DI1	Digital Input 1	Input	General purpose input	24V/0V
DI2	Digital Input 2	Input	General purpose input	24V/0V

Digital Input Features:

- **Pull-up resistors** configured for reliable signal detection
- **Debounced inputs** with 5-cycle stability requirement
- **Polarity inversion** support via EtherCAT configuration
- **Position latch functionality** for precise position capture

5.4.2 Position Latch Function

The HDrive includes an advanced **position latch system** that captures the exact motor position when triggered by digital input signals. This feature is essential for precise positioning applications and reference point detection.

5.4.2.1 Latch Trigger Modes The position latch supports three trigger configurations:

Trigger Mode	Description	EtherCAT Value
Rising Edge	Triggers when input transitions from LOW to HIGH	1
Falling Edge	Triggers when input transitions from HIGH to LOW	2
Both Edges	Triggers on both rising and falling transitions	Both modes

5.4.2.2 Latch Implementation Details

- **Debouncing**: 5-cycle stability requirement prevents false triggers from electrical noise
- **Position Capture**: Captures position with high precision (1/10 degree resolution)
- **Trigger Source**: Records which input and edge type caused the latch
- **Latch Reset**: Manual reset capability via EtherCAT object dictionary

5.4.2.3 EtherCAT Object Dictionary Entries The position latch functionality is accessible through the following EtherCAT objects:

Object Index	Name	Data Type	Description
0x6667	Latch Position 1	DINT (32-bit)	Captured position from DI1 trigger
0x6668	Latch Trigger Source 1	SINT (8-bit)	Trigger source (1=rising, 2=falling)
0x6669	Latch Reset 1	SINT (8-bit)	Reset latch 1 (write 1 to reset)
0x6670	Latch Position 2	DINT (32-bit)	Captured position from DI2 trigger
0x6671	Latch Trigger Source 2	SINT (8-bit)	Trigger source (1=rising, 2=falling)
0x6672	Latch Reset 2	SINT (8-bit)	Reset latch 2 (write 1 to reset)

5.4.2.4 Usage Example

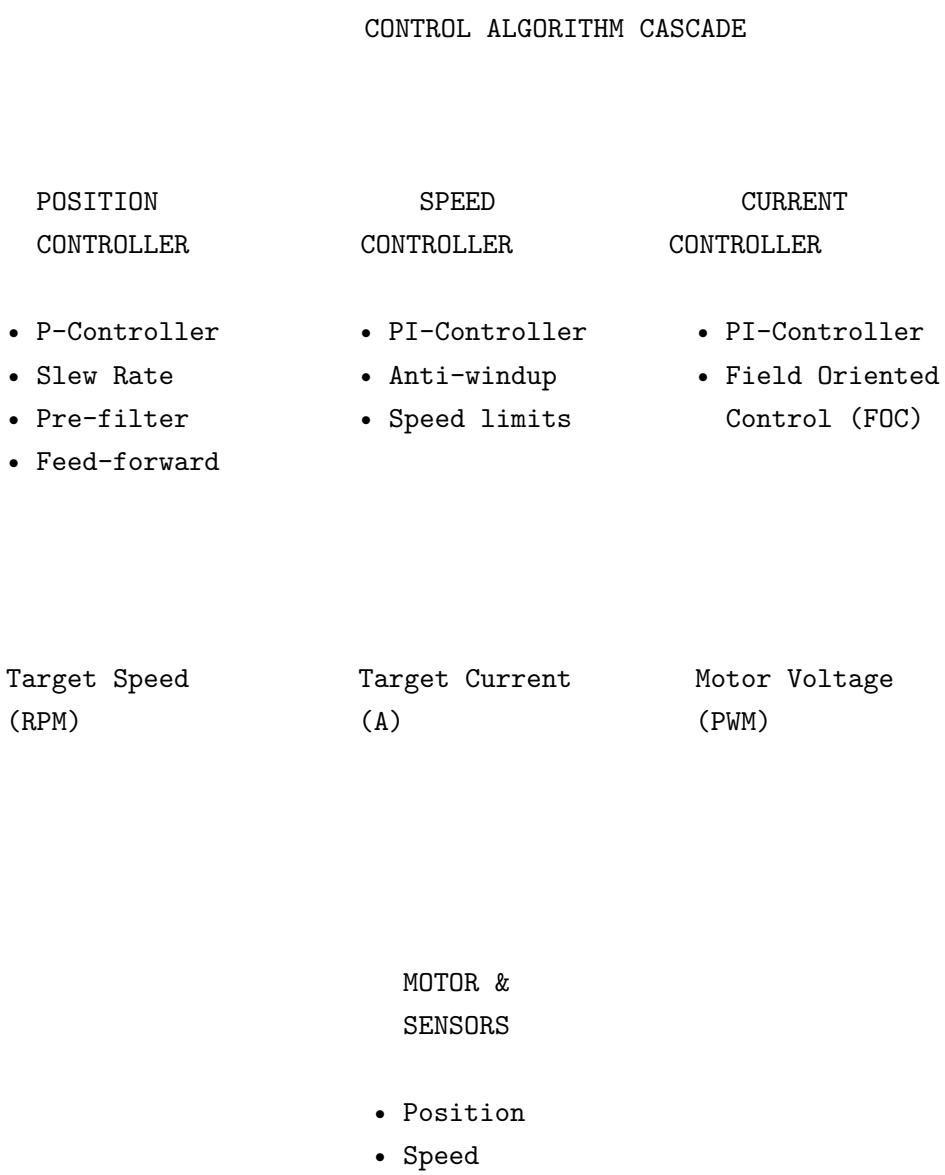
1. **Configure trigger mode** via EtherCAT master
2. **Connect sensor** to DI1 or DI2 (e.g., proximity switch, encoder index)
3. **Monitor latch status** through EtherCAT objects
4. **Read captured position** when latch is triggered
5. **Reset latch** to enable next capture cycle

   Note: Only one latch event is captured per reset cycle. The latch must be manually reset before it can capture a new position.

5.5 Control Algorithm Overview

The HDrive17-ETC implements a **three-level control cascade** consisting of position, speed, and current controllers. This hierarchical control structure provides precise motor control with excellent dynamic response and stability.

5.5.1 Control Cascade Diagram



- `Current`
- `Temperature`

`FEEDBACK SIGNALS`

- `Actual Pos`
- `Actual Speed`
- `Actual Current`

5.5.2 EtherCAT Object Mappings

The control system can be configured and monitored through the following EtherCAT objects:

5.5.2.1 Target Value Objects (Write from EtherCAT Master)

EtherCAT Object	Name	Data Type	Description	Control Mode
0x607A	Target Position	DINT (32-bit)	Target position in 1/10 degrees	Position Control
0x60FF	Target Velocity	DINT (32-bit)	Target speed in RPM	Speed Control
0x6071	Target Torque	INT (16-bit)	Target torque in mNm	Torque Control
0x6060	Mode of Operation	SINT (8-bit)	Control mode selection	All Modes

5.5.2.2 Control Parameter Objects (Configuration)

EtherCAT Object	Name	Description	Units
0x6660	Cascade Control Parameters	P/I gains for all controllers	Various
0x6660.1	Current P-Gain	Current controller proportional gain	A/A
0x6660.2	Current I-Gain	Current controller integral gain	A/(A·s)
0x6660.4	Speed P-Gain	Speed controller proportional gain	A/RPM
0x6660.5	Speed I-Gain	Speed controller integral gain	A/(RPM·s)
0x6660.6	Position P-Gain	Position controller proportional gain	RPM/°

5.5.2.3 Actual Value Objects (Read by EtherCAT Master)

EtherCAT Object	Name	Data Type	Description
0x6064	Position Actual Value	DINT (32-bit)	Current position in 1/10 degrees
0x606C	Velocity Actual Value	DINT (32-bit)	Current speed in RPM
0x6077	Torque Actual Value	INT (16-bit)	Current torque in mNm
0x6041	Status Word	UINT (16-bit)	Motor status and error flags

5.5.3 Control Mode Selection

The control mode is selected via **Object 0x6060** (Mode of Operation):

Mode Value	Control Type	Description
1	Profile Position	Position control with trajectory planning
3	Profile Velocity	Direct speed control
4	Profile Torque	Direct torque control

Mode Value	Control Type	Description
6	Homing	Reference position establishment
8	Interpolated Position	Cyclic synchronous position mode
-99	Calibration process	This mode will recalibrate the motor if the motor can spin free

5.5.4 Control Algorithm Features

5.5.4.1 Position Controller

- **P-Controller** with configurable gain
- **Pre-filter** for trajectory smoothing

5.5.4.2 Speed Controller

- **PI-Controller** with anti-windup protection
- **Speed limiting** for safety
- **Configurable bandwidth** for optimal response

5.5.4.3 Current Controller

- **PI-Controller** for d-q axis currents
- **Field Oriented Control (FOC)** implementation
- **High bandwidth** for precise current control

5.5.5 Bandwidth-Based Parameter Calculation

The HDrive17-ETC features an **automatic parameter calculation system** that derives optimal control parameters from user-defined bandwidth settings. This eliminates the need for manual tuning and ensures optimal performance across different motor configurations.

5.5.5.1 Bandwidth Configuration Objects

EtherCAT Object	Name	Data Type	Description	Units
0x6640	Control Bandwidth	DINT (32-bit)	Bandwidth settings for all controllers	
0x6640.1	Current Bandwidth	DINT (32-bit)	Current controller bandwidth (300-1000)	Hz
0x6640.2	Speed Bandwidth	DINT (32-bit)	Speed controller bandwidth (10-30)	Hz
0x6640.3	Position Bandwidth	DINT (32-bit)	Position controller bandwidth (10-30)	Hz

5.5.5.2 Damping Factor Configuration Objects

EtherCAT Object	Name	Data Type	Description	Units
0x6620	Motor Dynamic	USINT (8-bit)	Damping factors for all controllers	
0x6620.1	Current Damping Factor	USINT (8-bit)	Current controller damping	%
0x6620.2	Speed Damping Factor	USINT (8-bit)	Speed controller damping	%
0x6620.3	Position Damping Factor	USINT (8-bit)	Position controller damping	%

5.5.5.3 Parameter Calculation Process The automatic parameter calculation uses **control theory principles** to derive optimal gains:

5.5.5.4 Automatic Parameter Update **Trigger Object: 0x6637** - Trigger New Parameter Calculation

To control the parameter calculation and storage process, write the following values to the **0x6637 Trigger Object**:

- **Write** `1`:
  Triggers **automatic parameter calculation**.

The controller will:

- Read the current bandwidth and damping factor settings.
- Calculate optimal control parameters using control theory.
- Automatically update all controller gains for the motor.

- **Write** 2:
  Saves the current parameters into the Eeprom (persistent storage) for use after power cycles.
- **Write** 3:
  Restores factory default parameters.
  Loads default parameter values and stores them immediately to the Eeprom.

Note: These actions are performed automatically and take effect immediately after writing the trigger value.

5.5.5.5 Bandwidth Selection Guidelines

Controller	Typical Range	Recommended	Application
Current	100-1000 Hz	500 Hz	High precision, fast response
Speed	10-50 Hz	50 Hz	Smooth operation, good tracking
Position	1-30 Hz	20 Hz	Stable positioning, minimal overshoot

5.5.5.6 Damping Factor Guidelines

Controller	Typical Range	Recommended	Effect
Current	50-100%	70%	Fast settling, minimal overshoot
Speed	50-100%	70%	Smooth speed transitions
Position	100-150%	70%	Stable positioning, no oscillations

5.5.5.7 Motor Parameter Requirements For accurate parameter calculation, the following motor parameters must be configured:

Parameter	EtherCAT Object	Description	Units
Resistance	Motor Values	DC coil resistance	mΩ
Inductance	Motor Values	Coil inductance	µH
Torque Constant	Motor Values	Torque per ampere	mNm/A
Resonance Frequency	Motor Values	Mechanical resonance	Hz
Inertia	Motor Values	Rotor inertia	g·cm²
Damping	Motor Values	Mechanical damping	µN·m·s/rad

Note: The parameter calculation system automatically limits bandwidth values based on hardware constraints and control loop stability requirements to ensure safe operation.

5.5.5.8 Control Tuning Parameters For typical motor tuning, you primarily use the following EtherCAT objects:

Parameter	EtherCAT Object (Index)	Description	Units	Object Index / Subindex
Inertia	0x6633:01 (Motor Values)	Rotor inertia	g·cm²	0x6633:01
Damping	0x6634:01 (Motor Values)	Mechanical damping	µN·m·s/rad	0x6634:01
Current Bandwidth	0x6640:01 (Control Values)	Current control bandwidth	Hz	0x6640:01
Speed Bandwidth	0x6640:02 (Control Values)	Speed control bandwidth	Hz	0x6640:02
Position Bandwidth	0x6640:03 (Control Values)	Position control bandwidth	Hz	0x6640:03

Notes:

- All indices/subindices are hexadecimal, as per the EtherCAT object dictionary.

- See the EtherCAT object dictionary section for detailed type and access information.

5.5.5.9 Controller Tuning Best Practices

1. **Start with Low Bandwidths**
   Begin with conservative control bandwidth settings, such as:
   - **Current Bandwidth:** 400 Hz
   - **Position Bandwidth:** 15 Hz
2. **Initial Testing**
   Set the motor to run back and forth between two positions in reverse sequencing mode.
3. **Inertia Adjustment**
   Carefully adjust the **inertia parameter** so that the position control loop does **not overshoot**. The goal is smooth motion with no oscillation or ringing.
4. **Increase Bandwidth for Dynamics**
   Once the inertia is well tuned, gradually increase the bandwidth settings to achieve higher responsiveness and improved motor dynamics.

   Tip: Make small, incremental changes and retest each time for stable, reliable motion.

5.6 EtherCAT Object Dictionary

The **EtherCAT object dictionary** contains all configurable parameters and status information for the HDrive17-ETC system. The object dictionary is organized into five main categories for efficient data management and access.

5.6.1 Object Dictionary Structure

Category	Description	Access Level
Actual Motor Data	Real-time motor status and measurements	Read-only
Demanded Values	Target values from EtherCAT master	Write-only

Category	Description	Access Level
Control Values	Control loop parameters and tuning	Read/Write
Stored Values	System configuration and persistent data	Read/Write
Motor System Values	Motor-specific parameters and limits	Read/Write

5.6.2 Motor Control Modes (Object 0x6060)

The HDrive17-ETC supports comprehensive operation modes for various applications:

Value	Mode	Description	Application
1	Profile Position	Position control with trajectory planning	Precise positioning applications
3	Profile Velocity	Velocity control mode	Speed control applications
4	Profile Torque	Torque control mode	Force/torque control applications
6	Homing	Reference position establishment	System initialization
8	Interpolated Position	Cyclic synchronous position mode	Smooth trajectory following
-3	Stepper Mode	Direct stepper control	Legacy compatibility
-14	Chirp Mode	Frequency response analysis	System identification
-15	Current Step Response	Current control testing	Motor characterization
60	Motor Testing	Comprehensive motor analysis	Quality control

5.6.3 Control Parameters (Object Dictionary)

5.6.3.1 Position Control Parameters

Parameter	Object ID	Description	Units	Range
Position P-Gain	posPCas	Position controller proportional gain	-	0-1000
Max Position Speed	posMaxSpeedCas	Maximum position control speed	RPM	0-2000
Max Slew Rate	posMaxSlewRateCas	Maximum position change rate	deg/s	0-360
Position Pre-filter	posPreFilter	Position input filter frequency	Hz	1-1000
Feed-forward Filter	posFFFilter	Feed-forward filter frequency	Hz	1-1000

5.6.3.2 Speed Control Parameters

Parameter	Object ID	Description	Units	Range
Speed P-Gain	speedPCas	Speed controller proportional gain	-	0-1000
Speed I-Gain	speedICas	Speed controller integral gain	-	0-1000
Speed Feed-forward	speedFgCas	Speed feed-forward gain	-	0-100
Speed Back-emf	speedKbCas	Back-emf compensation gain	-	0-100
Speed I-Max	speedImaxCas	Maximum integral windup	A	0-5

5.6.3.3 Current Control Parameters

Parameter	Object ID	Description	Units	Range
Current P-Gain	currPCas	Current controller proportional gain	-	0-1000
Current I-Gain	currICas	Current controller integral gain	-	0-1000
Current Back-emf	currKbCas	Back-emf compensation gain	-	0-100

Parameter	Object ID	Description	Units	Range
Control Bandwidth	currentCtrlBW	Current control bandwidth	Hz	100-2000
Damping Factor	currentCtrlDF	Current control damping	-	0.1-2.0

5.6.4 Advanced Control Features

5.6.4.1 Comprehensive Error Codes

Error Code	Description	Action Required	Severity
0x0000	No error	Normal operation	Info
0x0010	Over temperature	Check cooling, reduce load	Critical
0x0011	Position overflow	Reset position reference	Warning
0x0012	Position underflow	Reset position reference	Warning
0x0013	Software position limit (positive)	Adjust limits or position	Warning
0x0014	Software position limit (negative)	Adjust limits or position	Warning
0x0015	Negative limit switch	Check limit switch configuration	Warning
0x0016	Positive limit switch	Check limit switch configuration	Warning
0x0017	Limit switch timeout	Check limit switch operation	Error
0x0018	Position sensor error	Check encoder connection	Critical
0x0019	Power stage error	Check power electronics	Critical
0x001A	Watchdog timeout	System reset required	Critical
0x001B	SPI position sensor error	Check SPI communication	Error
0x001C	Calibration error	Recalibrate system	Error
0x001D	Configuration error	Check parameter settings	Error
0x001E	Hardware incompatibility	Check hardware version	Critical

5.6.5 Performance Monitoring

5.6.6 Process Data Objects (PDOs)

5.6.6.1 RxPDO (Master to Slave) - Control Commands

Object	Description	Data Type	Units
Control Word (0x6040)	Operation mode commands	UINT16	-
Target Position (0x607A)	Position setpoint	INT32	0.1°
Target Velocity (0x60FF)	Velocity setpoint	INT32	RPM
Target Torque (0x6071)	Torque setpoint	INT16	mNm

5.6.6.2 TxPDO (Slave to Master) - Status Information

Object	Description	Data Type	Units
Status Word (0x6041)	System status and errors	UINT16	-
Actual Position (0x6064)	Current position	INT32	0.1°
Actual Velocity (0x606C)	Current velocity	INT32	RPM
Actual Torque (0x6077)	Current torque	INT16	mNm
Actual Current (0x6078)	Motor current	INT16	mA
Actual Temperature (0x6079)	System temperature	INT16	0.1°C

6 Troubleshooting & Maintenance

6.1 Diagnostic Procedures

6.1.1 Common Issues and Solutions

6.1.1.1 Communication Problems

Symptom	Possible Cause	Solution
EtherCAT communication lost	Network cable issue	Check cable connections and integrity

Symptom	Possible Cause	Solution
Intermittent communication	EMC interference	Install EMC filters, check grounding
Slow response	Network congestion	Optimize EtherCAT cycle time
Node not found	Incorrect addressing	Verify node address configuration

6.1.1.2 Control Performance Issues

Symptom	Possible Cause	Solution
Position overshoot	Wrong inertia Settings	Adapt inertia settings
Oscillations	Wrong bandwidth	Change system bandwidth
Slow response	Low bandwidth	Increase control bandwidth

6.1.1.3 Motor Issues

Symptom	Possible Cause	Solution
Excessive heating	High current	Check load, reduce current limits

7 Specifications

7.1 Electrical Specifications

7.1.1 Power Requirements

Parameter	Value	Unit	Notes
Supply Voltage Vs	24	V DC	Nominal operating voltage
Supply Voltage Vp	24-48	V DC	Nominal operating voltage
Voltage Tolerance	±10%	V DC	Operating range

Parameter	Value	Unit	Notes
Current Consumption Vs	0.5	A	Maximum continuous current
Current Consumption Vp	1.0	A	Maximum continuous current
Power Consumption	36	W	Maximum power draw
Power Factor	>0.9	-	Power efficiency

7.1.2 Communication Specifications

Parameter	Value	Unit	Notes
Protocol	EtherCAT	-	Real-time communication
Data Rate	100	Mbps	Ethernet speed
Cycle Time	1	ms	Typical update rate
Node Address	0-65535	-	Configurable

7.1.3 Encoder Specifications

Parameter	Value	Unit	Notes
Resolution	16384	counts/rev	14-bit resolution
Accuracy	±0.1	°	Positioning accuracy
Type	Magnetic	-	Non-contact sensing
Calibration	Factory	-	Pre-calibrated

7.1.4 Control Performance Specifications

Parameter	Value	Unit	Notes
Position Accuracy	±0.1	°	Static positioning accuracy
Repeatability	±0.05	°	Position repeatability
Current Control Bandwidth	100-1000	Hz	Configurable bandwidth
Position or Speed Control Bandwidth	10-30	Hz	Configurable bandwidth

7.1.5 Real-time Performance

Parameter	Value	Unit	Notes
ADC Sampling Rate	20	kHz	Current measurement
Control Update Rate	20	kHz	Current control
Position Update Rate	2	kHz	Position control
State Machine Rate	2	kHz	System state machine
Min. EtherCAT Cycle Time	50	us	Communication cycle

7.2 Environmental Specifications

7.2.1 Operating Conditions

Parameter	Value	Unit	Notes
Operating Temperature	-10 to +60	°C	Ambient temperature
Storage Temperature	-20 to +80	°C	Non-operating
Humidity	5 to 95	% RH	Non-condensing
Altitude	0 to 2000	m	Above sea level

7.2.2 Protection Ratings

Parameter	Value	Notes
IP Rating	IP40	Indoor use only
EMC	Class A	Industrial environment
Safety	CE Marked	EU compliance

7.3 Performance Characteristics

7.3.1 Torque and Speed Performance

HDrive17-ETC-i Speed / Torque Characteristics

Speed/Torque Curve

Figure 2: Speed/Torque Curve

7.3.2 Physical Specifications

Parameter	Value	Unit	Notes
Weight	470	g	Total system weight
Dimensions	See diagram	mm	Overall dimensions
Mounting	M3 x 4	-	Mounting holes
Connectors	4-pin + RJ45	-	Power + Communication

7.4 Support & Contact Information

For technical support, documentation updates, or product inquiries:

Henschel-Robotics GmbH Mulchlingerstrasse 67 CH-8405 Winterthur, Switzerland

Technical Support: info@henschel-robotics.ch **Website:** http://www.henschel-robotics.ch

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Document Version: 1.1 | Last Updated: November 2025 |