User Manual

Document specification	
Project	Robotica
Document name	Instruction Manual J-Actuator
Document number	0003
Version	0
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Approved by	

Revision history

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Summary

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1. Introduction

1.1 Introduction

This instruction manual contains information for the use of the *'J-Actuator'* robotic joint. It is assumed that the reader has a basic knowledge of automation components with a motor and drive.

Figure 1.1: J-Actuator

1.2 Warranty

The component is covered by a 12-month warranty from delivery. Any tampering, modification or intervention not agreed with Automationware's technical staff will invalidate the product's warranty and the certifications attached to this instruction manual.

1.3 General notes

The company Automationware S.r.l does not take responsibility for damage caused by misinterpretation of the information contained in the instruction manual. Please read this document carefully before using the product. The end user, or the manufacturer of the machine or system in which "*J-Actuator*" is used as a component, is responsible for the safety of the machine or system, and is therefore obliged to install the actuator in accordance with the applicable safety regulations in force in the country of installation and use.

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2. Safety

2.1 Purpose of the product

The J-Actuator is built for indoor use and cleen environments. The product is, in fact, a rotary actuator with high torque density.

2.2 General Instructions

AWJoint is designed and built in accordance with state-of-the-art technology and in compliance with applicable safety standards.

WARNING: "*J-Actuator*" must be integrated into the machine and used only for the intended purpose in accordance with the limits specified in this manual and uniquely for the product's without any kind of problem.

WARNING: The integration and use of "*J-Actuator*" should only take place after reading and understanding this instruction manual.

WARNING: Eliminate any faults and/or malfunctions that might not guarantee the product's safe condition.

WARNING: The integrator of "*J-Actuator*" is responsible for the correct installation and use of the product.

WARNING: Always Must include the "*J-Actuator*" instruction manual; if integrated and/or resold, enclose all information provided by the manufacturer in the manual.

3. Actuator description

3.1 General Features

"The 'J-Actuator' is a rotary actuator with an integrated electronic motor control board.

It consists of:

- A permanent magnet synchronous 48 V torque motor;
- A harmonic reducer;
- A mechanical blocking system;
- An absolute encoder on the motor shaft;
- Optionally, a second absolute encoder mounted on the gearbox output shaft.
- Integrated motor control board with EtherCAT fieldbus and STO/SBC SIL3 Pl-e safety functions.

It is available in different sizes, with different gear ratios and motor windings so that the actuator can be customised for each application required in terms of output torque, speed and power consumption.

For customer-specific integration of the actuator, it is available in its '*naked'* version, i.e. without external aluminium alloy shell and plastic back cover.

3.2 Detailed product information

There are different sizes of actuator.

Below are the main characteristics of each size, from the smallest to the largest.

J17

Characteristics of motor and gear-box		Information on mechanics**		Information on electronics and con-trol	
Available reduction ratios	51-81-101-121	Max. dynamic tilting moment [Nm].	105,4	Encoder	Absolute 20 bit + 16 bit multiturn counter
Nominal motor speed [rpm]	3000	Max. axial load [N].	1888	Mechanical block	Pin-lock
Maximum motor speed [rpm]	5000	Max. radial load [N].	1266	Voltage [V]	48
Power [W]	219	Weight [kg]	3,8	Fieldbus	EtherCAT - CiA 402
Nominal torque [Nm].	35 to 51*	Hollow shaft in-ternal diameter [mm].	14	Electronic motor control board	STO/SBC - SIL 3, Pl-e
Repetitive peak torque [Nm]	44 to 70*	Operating tempe-rature [°C].	0-45		
* depends on the reduction ratio **referred to the complete version with encoder on both direct and de-ferred motion and with outer casing in aluminium alloy.		Humidity	Max. 90% non-condensing		

J20

Characteristics of motor and gearbox		Information on mechanics**		Information on electronics and control	
Available reduction ratios	51-81-101-121-161	Max. dynamic tilting moment [Nm].	159	Encoder	Absolute 20 bit + 16 bit multiturn counter
Nominal motor speed [rpm]	2000	Max. axial load [N].	2651	Mechanical block	Pin-lock
Maximum motor speed [rpm]	3200	Max. radial load [N].	1777	Voltage [V]	48
Power [W]	251	Weight [kg]	4,1	Fieldbus	EtherCAT - CiA 402
Nominal torque [Nm].	44 to 64*.	Hollow shaft internal diameter [mm].	15	Card control electronics motor	STO/SBC - SIL 3, PI-e
Repetitive peak torque [Nm]	73 to 120*	Operating temperature [°C].	0-45		
* depends on the reduction ratio **referred to the complete version with encoder on both direct and deferred motion and with outer casing in aluminium alloy.		Humidity	Max. 90% non-condensing		

J25

Characteristics of motor and gear-box		**Information on mechanics****		**Information on electronics and the control**	
Available reduction ratios	51-81-101-121-161	Max. dynamic tilting moment [Nm].	219	Encoder	Absolute 20 bit + 16 bit multiturn counter
Nominal motor speed [rpm]	1500	Max. axial load [N].	3958	Mechanical block	Electromagnetic
Maximum motor speed [rpm]	2500	Max. radial load [N].	2652	Voltage [V]	48
Power [W]	326	Weight [kg]	8,5	Fieldbus	EtherCAT - CiA 402
Nominal torque [Nm].	72 to 140*.	Hollow shaft internal diameter [mm].	20	Card motor control electronics	STO/SBC - SIL 3, Pl-e
Repetitive peak torque [Nm]	127 to 229*	Operating temperature [°C].	0-45		
* depends on the reduction ratio **referred to the complete version with encoder on both direct and deferred motion and with outer casing in aluminium alloy.		Humidity	Max. 90% non-condensing		

J32

Characteristics of motor and gear-box		**Information on mechanics****		**Information on electronics and control**	
Available reduction ratios	51-81-101-121-161	Max. dynamic tilting moment [Nm].	493	Encoder	Absolute 20 bit + 16 bit multiturn counter
Nominal motor speed [rpm]	1500	Max. axial load [N].	6937	Mechanical block	Electromagnetic
Maximum motor speed [rpm]	2500	Max. radial load [N].	4648	Voltage [V]	48
Power [W]	470	Weight [kg]	14,2	Fieldbus	EtherCAT - CiA 402
Nominal torque [Nm].	140 to 281*	Hollow shaft internal diameter [mm].	24	Electronic motor control board	STO/SBC - SIL 3, Pl-e
Repetitive peak torque [Nm]	281 to 484*	Operating temperature [°C].	0-45		
* depends on the reduction ratio **referred to the complete version with encoder on both direct and deferred motion and with outer casing in aluminium alloy.		Humidity	Max. 90% without condensation		

J40 LP

Characteristics of motor and gear-box		**Information on mechanics****		**Information on electronics and the control**	
Available reduction ratios	51-81-101-121-161	Max. dynamic tilting moment [Nm].	722	Encoder	Absolute 20 bit + 16 bit multiturn counter
Nominal motor speed [rpm]	1500	Max. axial load [N].	7863	Mechanical block	Electromagnetic
Maximum motor speed [rpm]	2500	Max. radial load [N].	5268	Voltage [V]	48
Power [W]	470	Weight [kg]	17	Fieldbus	EtherCAT - CiA 402
Nominal torque [Nm].	235 to 467*	Hollow shaft internal diameter [mm].	24	Electronic control board motor	STO/SBC - SIL 3, Pl-e
Repetitive peak torque [Nm]	675 to 841*.	Operating temperature [°C].	0-45		
* depends on the reduction ratio **referred to the complete version with encoder on both direct and deferred motion and with outer casing in aluminium alloy.		Humidity	Max. 90% without condensation		

J40 HP

Characteristics of motor and gear-box		**Information on mechanics****		**Information on electronics and the control**	
Available reduction ratios	51-81-101-121-161	Max. dynamic tilting moment [Nm].	722	Encoder	Absolute 20 bit + 16 bit multiturn counter
Nominal motor speed [rpm]	1200	Max. axial load [N].	7863	Mechanical block	Electromagnetic
Maximum motor speed [rpm]	2200	Max. radial load [N].	5268	Voltage [V]	48
Power [W]	570	Weight [kg]	17	Fieldbus	EtherCAT - CiA 402
Nominal torque [Nm].	320 to 586*	Hollow shaft internal diameter [mm].	24	Electronic motor control board	STO/SBC - SIL 3, Pl-e
Repetitive peak torque [Nm]	675 to 841*.	Operating temperature [°C].	0-45		
* depends on the reduction ratio **referred to the complete version with encoder on both direct and deferred motion and with outer casing in aluminium alloy.		Humidity	Max. 90% without condensation		

4. Transport, storage, disposal

4.1 Transport

The product is delivered packed. Keep attention to respect the safety conditions during the transport of the product by the operator, in particular wearing the appropriate personal protective equipment.

Please take care to prevent any shocks from damaging the actuator.

4.2 Transport

Store the product only in covered and dry areas. Protect the product from moisture and corrosive agents to avoid the risk of corrosion of the product due to incorrect storage.

4.3 Disposal

Inside the actuator there are steel components, aluminium alloys, copper parts and lubricants. For their disposal, we recommend handing them to a specialised company.

5. Operating conditions

The actuator can be used in a temperature range from 0 °C to +45 C°.

For any requirements other than those listed here, please contact Automationware for customisation.

6. Motor control board

Inside the actuator, there is a motor control board which implements the EtherCAT Slave functionality in a network based on the EtherCAT industrial field bus. To work, it needs to be connected to an EtherCAT Master, a safety system e.g. PLC and to the power supply.

6.1 Wiring

The wiring on the motor control board side is supplied by Automationware with labelling, while the preparation of the connections to the EtherCAT master, safety system e.g. PLC and power supply must be completed by the user following the colour scheme below. Automationware can provide remote assistance in this operation. If the connections are made independently, Automationware is released from any liability in case of incorrect connections and related failures or malfunctions.

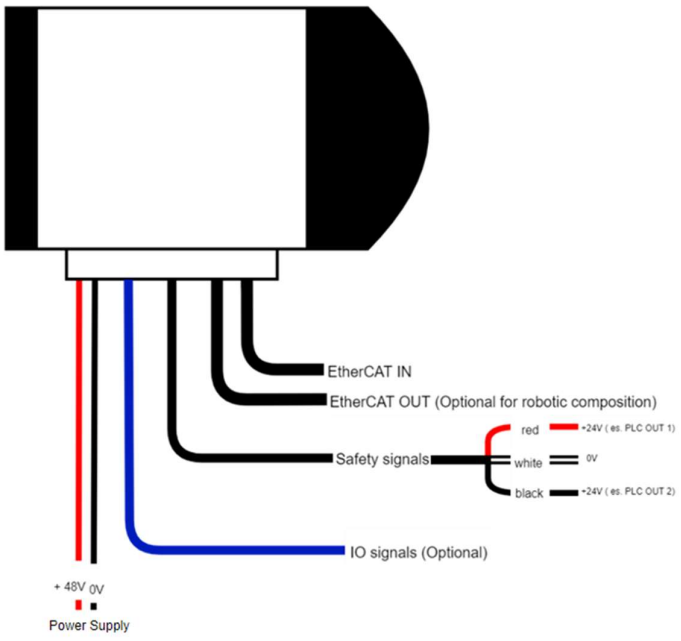

Figure 9: Control board wiring

Signal		Connector type / cable colour code		Pin Mapping / Description	
+ 48 V		Unipolar cable (red)		Motor control board power supply	
0 V		Unipolar cable (black)			
EtherCAT IN		RJ45		EtherCAT bus input	
EtherCAT OUT		JST GHR-08V-S / RJ45		EtherCAT bus output	
Safety signals		3-pole cable	Unipolar cable (red)	STO-SBC In 1 (+24V)	
			Unipolar cable (black)	STO-SBC In 2 (+24V)	
			Unipolar cable (white)	Safety GND	
I/O signals	Analog Inputs	Multi-core cable		Pin 1.1	+ 5V (External power supply)
				Pin 1.2	Analog IN 2 - (differential -)
				Pin 1.3	Analog IN 2 + (differential +)
				Pin 1.4	GND (Ground)
				Pin 1.5	Analog IN 1 (single ended 0-5 V)
	Digital I/O			Pin 2.1	+ 3.3V (External power supply)
				Pin 2.2	Digital I/O 1 (fast push-pull)
				Pin 2.3	Digital I/O 2 (fast push-pull)
				Pin 2.4	GND (Ground)
				Pin 2.5	Digital I/O 3 (fast push-pull)
				Pin 2.6	Digital Output 4 (slow push-pull)
				Pin 2.7	+ 5V (External power supply)
				Pin 2.8	Digital I/O 5 (slow-bidirectional)
				Pin 2.9	Digital I/O 6 (slow-bidirectional)
				Pin 2.10	GND (Ground)
				Pin 2.11	Digital Input 7 (slow 24 V)

The cable used for the EtherCAT OUT signal is optional, it can be terminated with a JST GHR-08V-S connector if the user needs to connect several J-Actuators together (in series) or an Ethernet RJ-45 connector if the need is to integrate the J-Actuator into a classic EtherCAT network. The 'Safety signals' cable allows the implementation of STO-SBC safety functions (with redundant dual-channel connection).

WARNING: If not using the STO-SBC function, connect a +24V power supply to the 'STO-SBC In 1' and 'STO-SBC In 2' pins and ground to the 'Safety GND' pin. It is possible to connect in cascade these signals to other drives.

The 'I/O signals' cable is a customised multi-core cable, the user will **have to communicate** his needs to Automationware in the order, Automationware itself will proceed to correctly configure the motor control board, choose the right cable and make the desired inputs/outputs available to the user.

6.2 Hardware Specifications

The control board uses two absolute encoders as position/speed sensors, both 16-bit multi-turn and 20-bit single-turn, the first connected directly to the motor shaft (fast shaft) while the second is connected to the output shaft after the gearbox (slow shaft). The board can manage these encoders in both multi-turn and single-turn mode. The encoder configuration is performed during production by Automationware.

The control board controls a blocking brake that incorporates the Safe Brake Control (SBC) safety feature.

6.3 Security Functions

The control board in fact offers two safety functions integrated in the drive according to EN 61800-5-2:2017 as a pure hardware solution:

1. STO (Safe Torque Off) prevents torque generation in the motor and allows uncontrolled stopping in accordance with stop category 0 of IEC 60204-1:2016.
2. SBC (Safe Brake Control) prevents the supply of electric current to the brake output and so safely engage the brake system.

Safety parameters	
Safety Integration level (SIL) according to IEC 61508:2010	SIL 3
Performance Level (PL) in accordance with ISO 13849-1:2015	PL e
Reaction time	10 ms

Safety parameters IEC 61508:2010	
Probability of dangerous failure per hour (PFH_d)	$1.59 * 10^{-10}/\text{hour}$
Probability of dangerous failure on demand (PFD_{avg})	$1.39 * 10^{-5}$
Safe failure fraction (SFF)	99.95 %
HW fault tolerance (HFT)	1
HW-type	Type A
Mission time T_M	20 anni
Supported safe modes	High, Low

Safety parameters ISO 13849-1:2015	
Category	Cat. 3
Mean time to dangerous failure ($MTTF_d$)	3319 years (with an upper limit of 100 years)
Diagnostic coverage (DC_{avg})	99 %
Common Cause Failure (CCF)	> 65

CAUTION: The safety circuit safely inhibits currents to the motor and brake when the STO-SBC command is given (e.g. by an emergency stop device e.g. emergency stop button, PLC etc.). When the command has been released (e.g. by manually resetting the emergency stop device), currents are allowed to flow to the motor and brake. The safety system must be designed in such a way that it fulfils the requirement: "restarting the machine after a stop must only be possible by actuating a specific control device intended for this purpose".

CAUTION: For SIL 3, PL e, cat.3 it is necessary to detect or prevent wiring faults. This can be achieved by:

- sending test pulses from the PLC **OR**
- ensure the fault resistance of the cabling, according to ISO 13849- 2:2012, between STO-SBC 1 and STO SBC 2 signals. This can be achieved:
    - connecting the wiring permanently (fixed) and protecting it from external damage, e.g. by ducting or armouring, **OR**
    - using multiple separate cables, **OR**
    - installing the wiring inside an electrical cabinet, **OR**
    - shielding the wiring individually with earth connection.

The maximum cable length is 30m.

6.4 Functionality

Automationware provides a "basic configuration" of the motor control board, which provides a "no-load" calibration, i.e. with no load connected. Within this 'basic configuration', Automationware itself will insert the correct motor parameters, encoder parameters and advanced control parameters (e.g. filters, etc.).

Users can proceed in the following ways to change data on the motor control board:

a) Contacting Automationware, they will receive support by AW about which parameters to change.

b) Proceeding independently, without contacting Automationware.

In case b), Automationware is released from any liability in the event of faults, malfunctions or abnormal behaviour of the actuator following the modification of the 'basic configuration'. Parameter changes by the user can **only** take place **via SDO communication**. To find out the exact addresses of the parameters to be changed, please refer to the CiA 402 Standard documentation:

https://www.can-cia.org/can-knowledge/canopen/cia402/

6.4.1 Mode of operation

The control board supports different modes of operation using either an internal trajectory controller (Profile modes) or needing to receive a point-by-point trajectory from a master device (Cyclic modes). A Homing mode is also available to return the motor to a specific position.

- **Cyclic modes: :** in cyclic synchronous modes, the trajectory must be calculated by the master and sent to the slave at 1ms intervals.
    - Cyclic synchronous torque (CST): in torque control mode, the master sends the desired torques to the drive.
    - Cyclic synchronous velocity (CSV): in speed control mode, the master sends the desired speeds to the drive.
    - Cyclic synchronous position (CSP): in position control mode, the master sends the desired positions to the drive.

- **Profile modes:** in profile modes, the trajectory is calculated directly by the slave, the task of the master is to command only the desired end reference.
    - Profile positio (PP): in profile position mode, the trajectory to the target position is generated by the drive, which communicates the outcome of the movement as feedback.
    - Profile velocity (PV): in profile velocity mode, the motor rotates at a target speed.
    - Profile torque (PT): in profile torque mode, the drive delivers a current to the motor to reach a target torque value.

- **Homing mode:** homing can be used to centre the motor on its current position or to move to a specific position (saved directly in the control board).

All of the above modes comply with the CiA402 standard.

6.4.2 PDO mapping

With the aim of having complete control of the '*J-Actuator*', Automationware provides a basic PDO configuration, which can be changed at will via an EtherCAT master using SDO communication. Modifications to the PDO fields can lead to incorrect operation of the actuator itself, Automationware releases itself from any liability in the event of faults, malfunctions or abnormal behaviour of the actuator following the modification of the 'basic configuration'.

- **RxPDO:**

Index (Object dictionary)	Field name	No. of bit
0x6040	Controlword	16
0x6060	Modes of operation	8
0x6071	Target Torque	16
0x607A	Target position	32
0x60FF	Target velocity	32
0x60B2	Torque offset	16
0x2701	Tuning command	32
0x60FE:1	Digital outputs: Physical outputs	32
0x60FE:2	Digital outputs: Bit mask	32
0x2703	User MOSI	32
0x60B1	Velocity offset	32

- **TxPDO:**

Index (Object dictionary)	Field name	No. of bit
0x6041	Statusword	16
0x6061	Modes of operation display	8
0x6064	Position actual value	32
0x606C	Velocity actual value	32
0x6077	Torque actual value	16
0x2401	Analog input 1	16
0x2402	Analog input 2	16
0x2403	Analog input 3	16
0x2404	Analog input 4	16
0x2702	Tuning status	32
0x60FD	Digital inputs	32

7. Testing Software Packages

7.1 Robotic joint testing with TwinCAT

Automationware provides the user with a prototype project developed using the TwinCAT tool provided by Beckhoff to command a sequence of simple movements to the robotic joint in the different operating modes on the EtherCAT fieldbus according to the CiA402 standard. TwinCAT implements the EtherCAT Master functionality on the PC/device where it is installed and started. For further details, please refer to the document **DOC_TWIN_AW** (available at https://github.com/Automationware/aw_doc). The project is available on GitHub at the following link: https://github.com/Automationware/aw_joint_twincat

7.2 Robotic joint testing with Robot Operating System (ROS)

Automationware provides users with a public repository on GitHub to run tests on individual 'J-Actuator' robotic joint and 'AWTube' robotic arm prototypes in a Robot Operating System (ROS) environment.

The software packages and their documentation are made for users who are familiar with the most common programming languages (C++, Python) and possess basic knowledge of the ROS framework.

Automationware, with regard to this repository, states that:

- it runs on the Linux operating system Ubuntu 18.04 LTS;
- it is public and accessible to all Internet users;
- the packages and documentation are written in English, purely prototypical without any safety functions implemented, and may be updated in the event of reports of malfunctions by the GitHub community;
- maintenance, updates and answers to users' questions will be handled as soon as possible consistent with the AW team's daily priorities;
- if the users want to create joint compositions or integrate them into different automation systems/robotic cells, they will have to compose and edit the xacro files and MoveIt packages theirselves;
- no user interface is currently made available.

For further details, please refer to the GitHub repository https://github.com/Automationware/aw_robotics

8. Actuator maintenance

8.1 General Precautions and Guidelines

"J-Actuator" maintenance operations must be performed by qualified, trained and informed personnel. Maintenance operators must be equipped with personal protective equipment that is appropriate for the operating environment.

It is mandatory for the operator to wear the minimum indicated personal protective equipment:



8.2 Extraordinary maintenance

If the actuator malfunctions and requires extraordinary maintenance, please contact Automationware technical staff.

8.3 Replacement of the actuator

The eventuality of replacing the actuator came when the product itself breaks down, when it malfunctions in a manner not compatible with the conditions of use, and when the rotary actuator is removed for complete dismantling of the equipment or machinery on which it is mounted.

For actuators with malfunctions or control faults, please contact Automationware for support.

When contacting Automationware technical support, always refer to the number on the actuator label.

8.4 Spare parts list

Component	Code
Gearbox assembly J40-100	AR00036
Gearbox assembly J32-100	AR00046
Gearbox assembly J25-80	AR00012
Gearbox assembly J25-100	AR00123
Gearbox assembly J20-50	AR00026
Gearbox assembly J20-80	AR00092
Gearbox assembly J17-50	AR00133
Gearbox assembly J17-80	AR00112
J25/32/40 motor control board	00950000
J17/20 motor control board	00949900
Encoder Assembly - J40/J32	AR00039
Encoder Assembly - J25	AR00015
Encoder Assembly - J20	AR00024
Encoder Assembly - J17	AR00110
Front interface flange - J40	DR00196
Front Interface Flange - J32	DR00195
Front interface flange - J25	DR00093
Front interface flange - J20	DR00094
Front interface flange - J17	DR00170

In case the component you need is not on the list, please contact Automationware for support.

8.5 Service and Support

For any problems, please contact Automationware S.r.l. - Via Cacace 5/7, 30030 Martellago (VE) - 041 5102028 - info@automationware.it - www.automationware.it.

9. Schemes and drawings

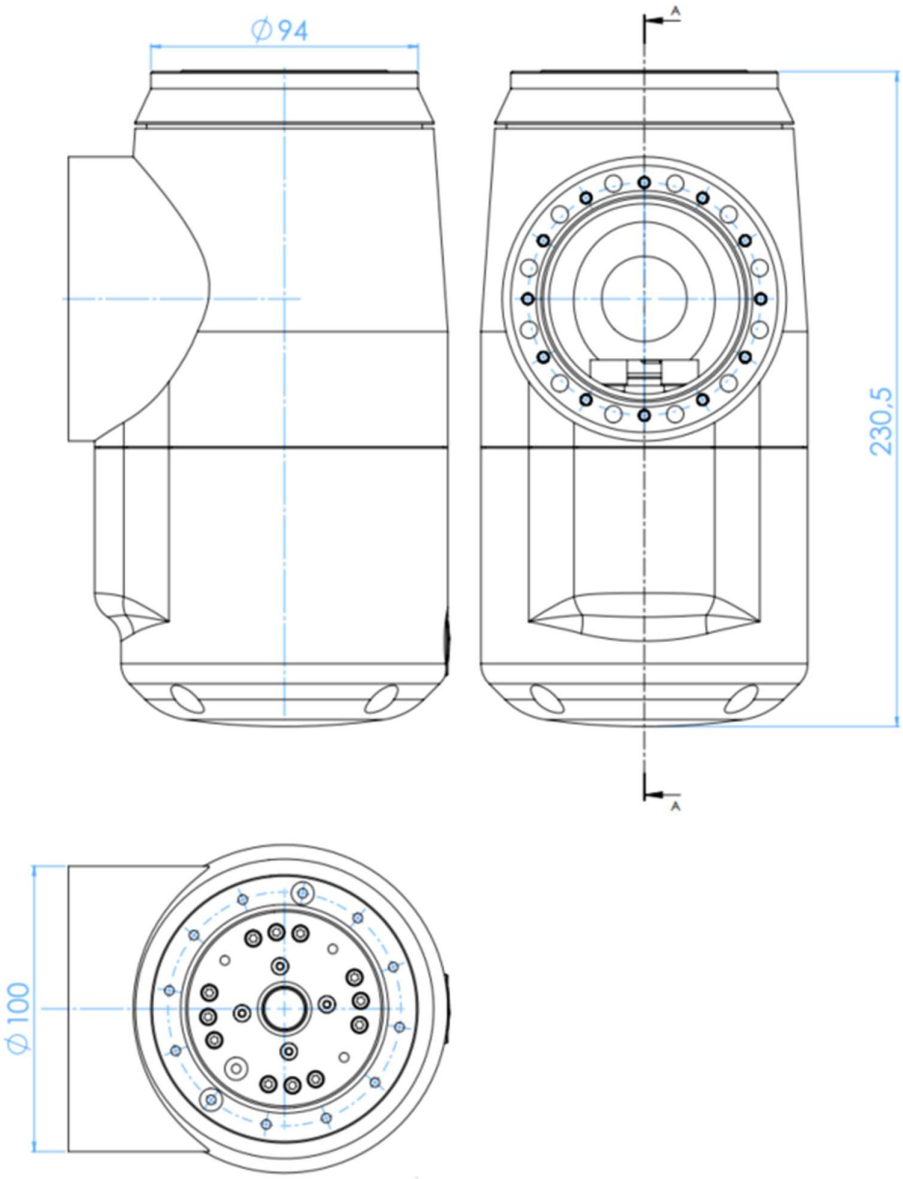

Figure 9.1 : J17 Overall dimensions

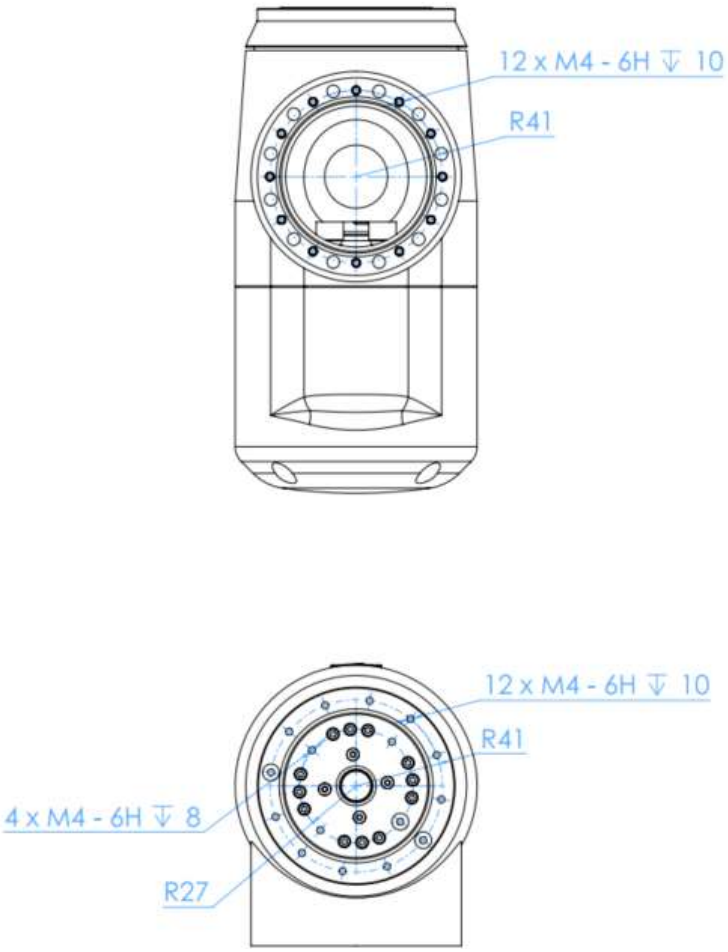

Figure 9.2: J17 Mounting holes and dimensions

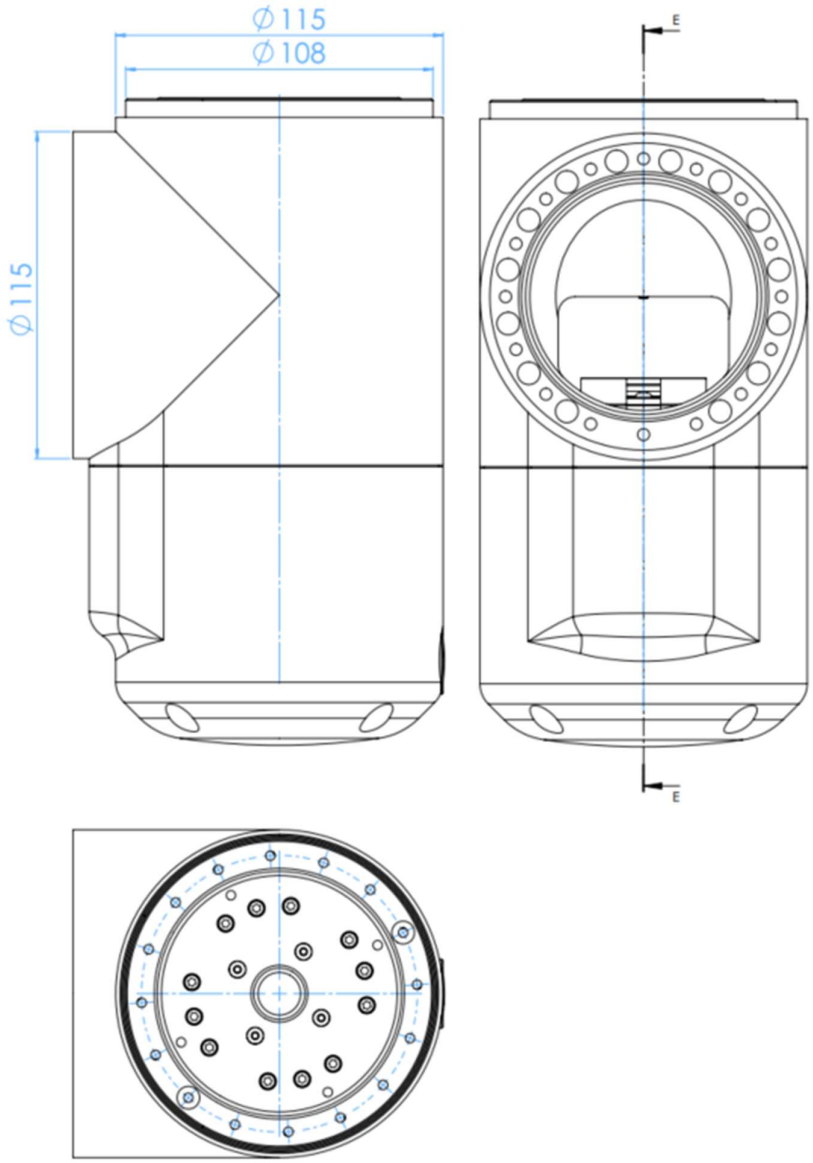

Figure 9.3: J20 Overall dimensions

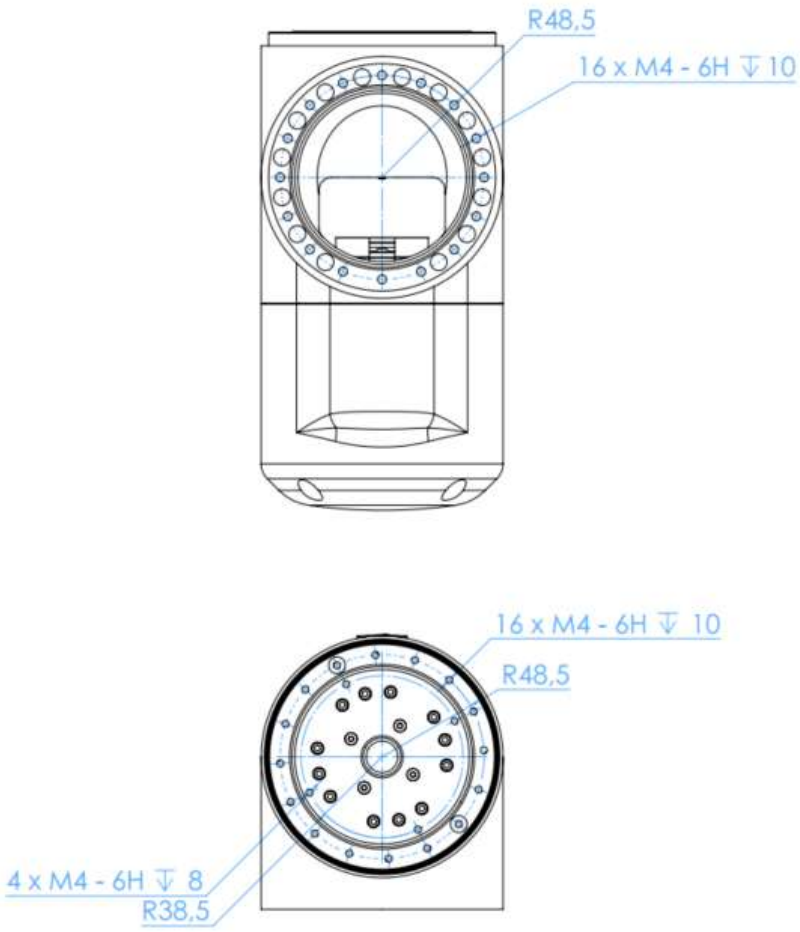

Figure 9.4: J20 Mounting holes and dimensions

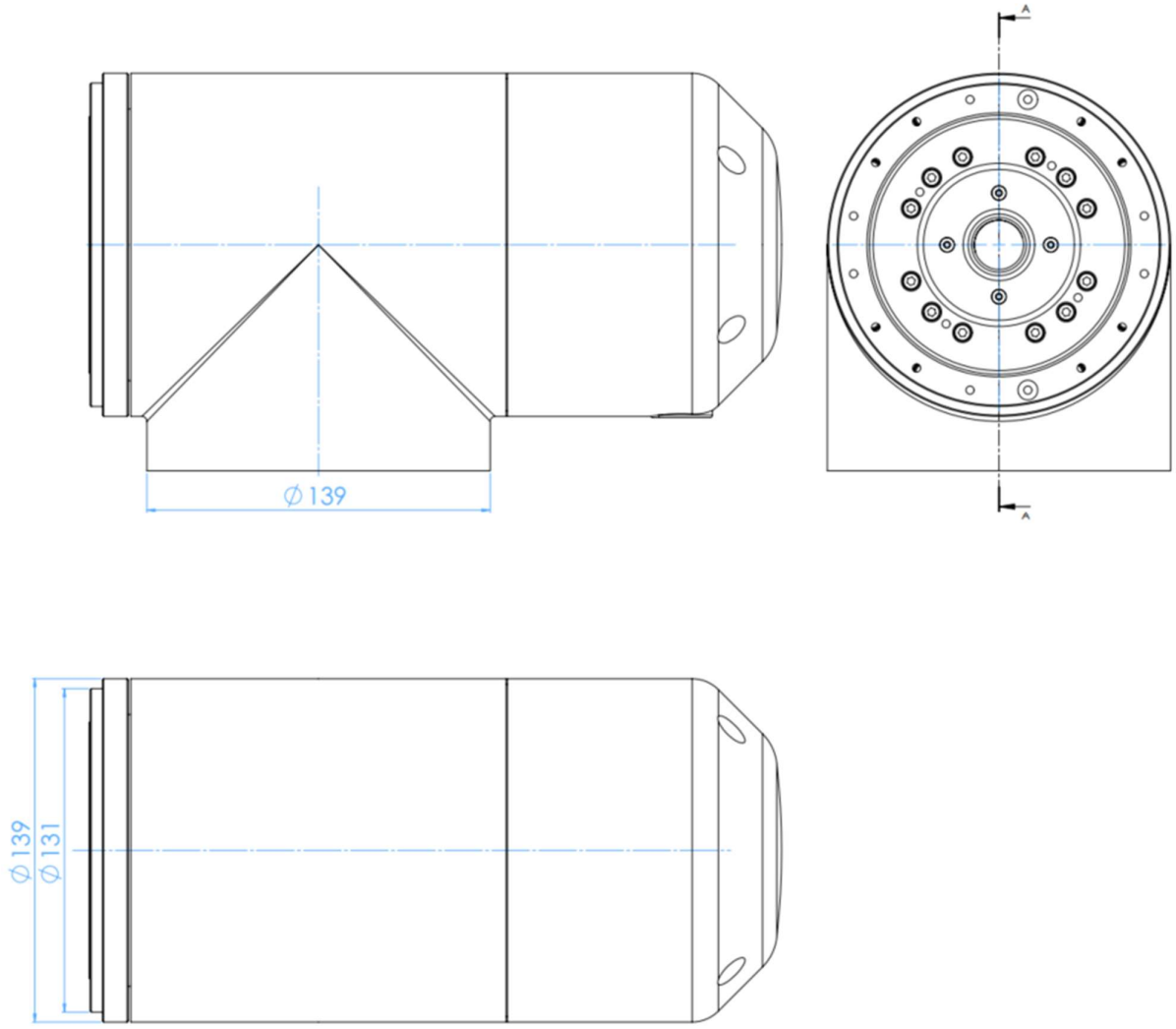

Figure 9.5: J25 Overall dimensions

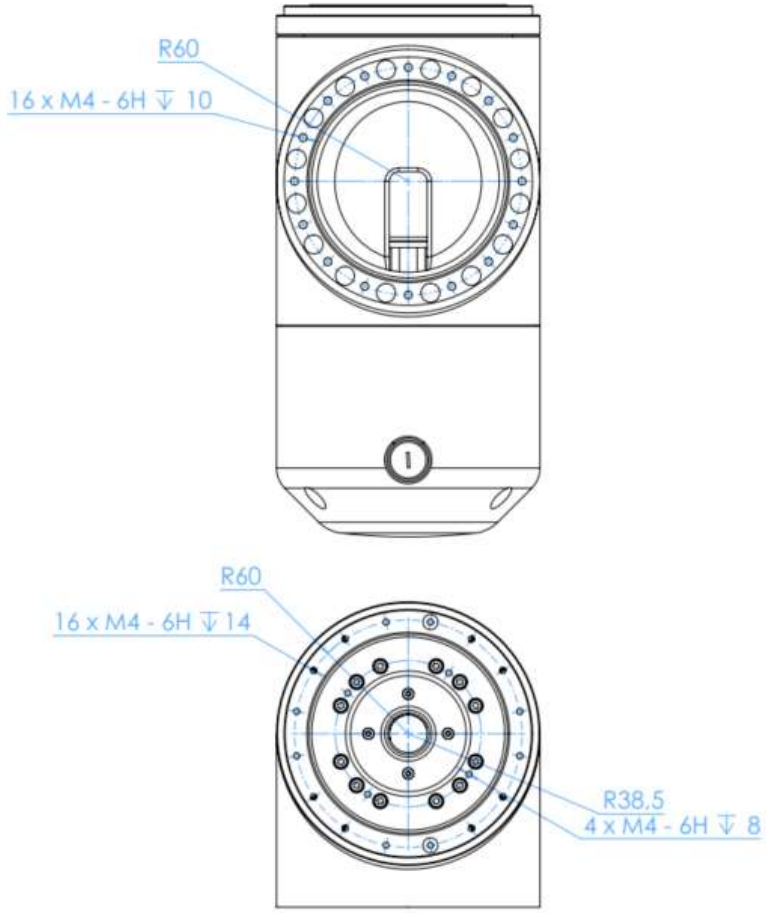

Figure 9.6: J32 Mounting holes and dimensions

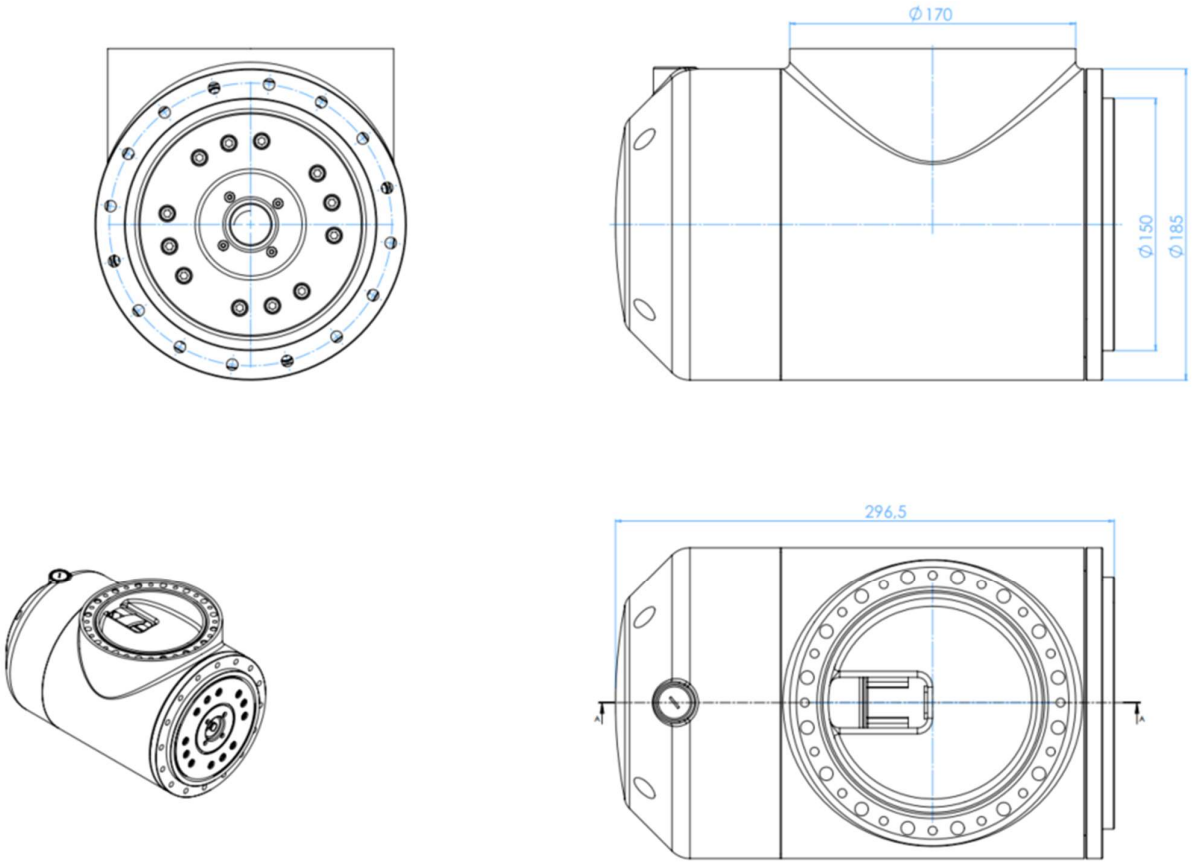

Figure 9.7: J32 Overall dimensions

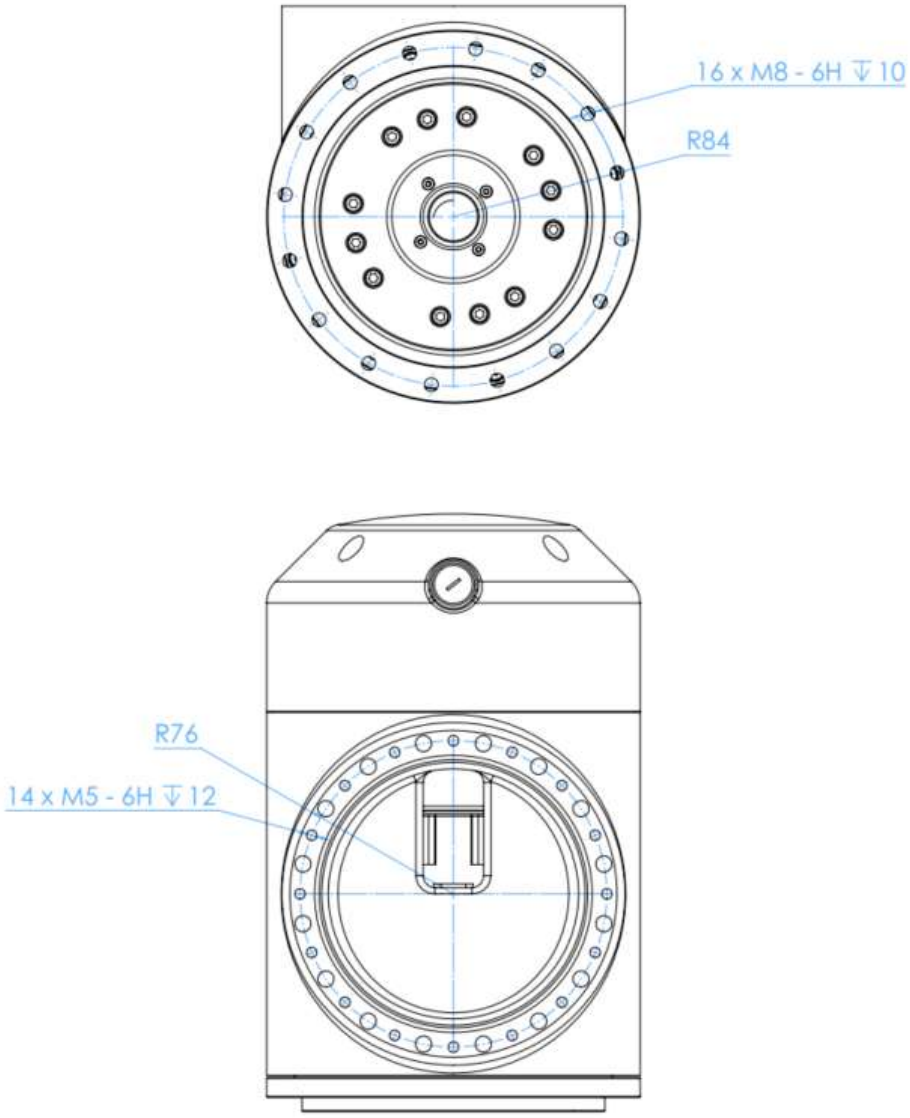

Figure 9.8: J32 Mounting holes and dimensions

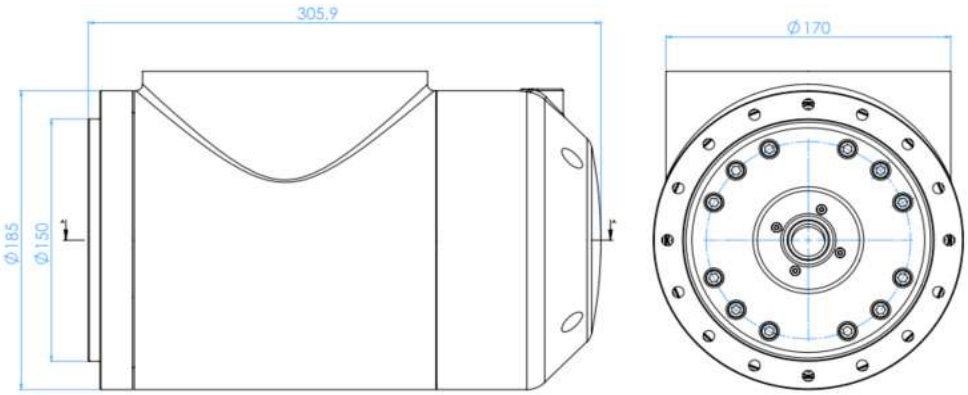

Figure 9.9: J40 Overall dimensions

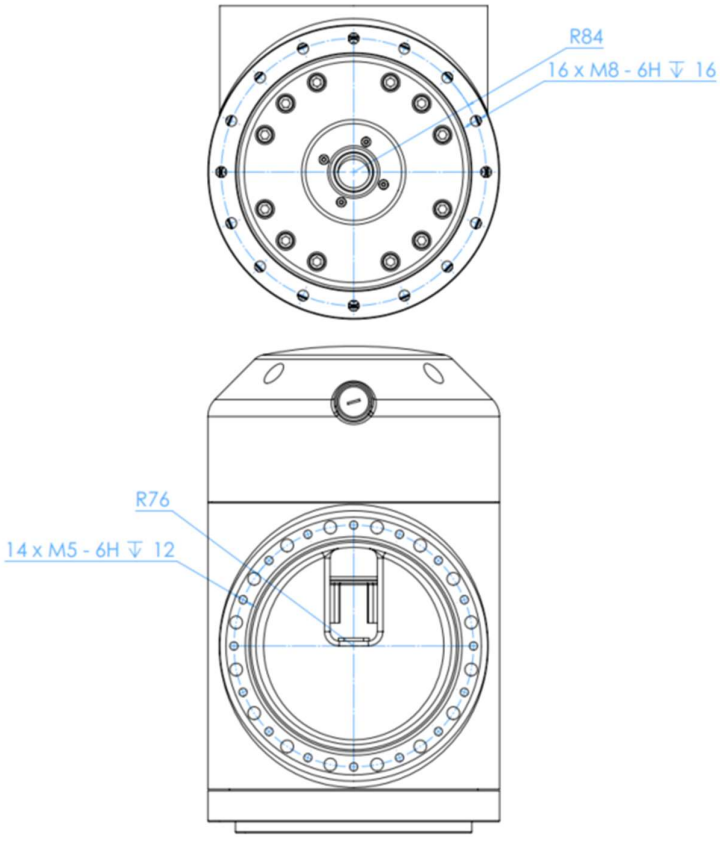

Figure 9.10: J40 Mounting holes and dimensions

End of document