EPAS700 Autonomous System

User Guide

Issue 1.0

Contents

1 Technical Support

For technical support, please contact:

sales@dcemotorsport.com (Europe) or salesusa@dcemotorsport.com (Americas)

The table below lists the ways to contact DC Electronics:

Contact Method	Europe	Americas
Company:	DC Electronics	DCE Inc.
Website:	www.dcemotorsport.com	www.dcemotorsport.com
Email:	sales@dcemotorsport.com	salesusa@dcemotorsport.com
Telephone:	+44 (0)1621 856451	+1 (704) 230 4649
Mail:	DC Electronics – Motorsport Specialist Ltd Unit 1 Quayside Industrial Park Bates Road Maldon ESSEX CM9 5FA United Kingdom	DCE Inc 138 Cayuga Drive Suite C Mooresville NC 28117 USA

2 Operating Parameters

Below are the operating parameters of the EPAS700 Autonomous ECU.

Parameter	Value	Notes
Voltage	Max 16V	Over voltage will cause the ECU to shut down and could cause permanent damage.
	Min 8V	Under voltage will cease control of the motor.
Operational Temperature	Min -40°C / 40°F	
	Max +85°C / +185°F	
Current	Max 40A Standby Mode 50mA	
In-Line Fuse Rating	40A	Standard automotive ATO blade fuse.
Default CANBus Baud Rate	500 Kbps	250 Kbps, and 125 Kbps also configurable.
CAN Format	CANOpen	Standard Length
Minimum CAN Message Cycle Time	40mS	Recommended 50mS
CANBus Termination	Yes	120 Ohm termination in ECU
Motor Duty Rating	S2	
Rated Working Time	2 minutes	
No Load Rotational Speed	760° per second	+/-10%

3 Electrical Connections and Installation Guide

3.1 Pre-Installation Notes

Before Installation is undertaken, please read the following notes.

3.2 Welding

Electronic components situated within the motor assembly and control unit could be damaged if welding takes place upon the vehicle chassis or frame.

If welding is to take place it is advisable to remove both the motor assembly and the control unit from the vehicle.

If only the control unit can be removed, ensure both electrical connections to the motor assembly are disconnected and the vehicles battery is removed.

UNDER **NO** CIRCUMSTANCES SHOULD ANYTHING BE WELDED TO THE CASING OF THE MOTOR ASSEMBLY.

3.3 Electrical Connections

The electronic power assisted steering system should be connected using the two EPAS700 Autonomous wiring harnesses.

FAILURE TO CORRECTLY CONNECT VEHICLE POWER SUPPLY WILL DAMAGE THE CONTROL UNIT.

3.4 EPAS700 Autonomous Harnesses Electrical Connections and Set Up

Connect the green Torque and Angle connectors as shown. Note the angle sensor is installed on the MGU input shaft to detect the steering angle position. The angle sensor is not IP rated so the MGU should be mounted in a dry area.

Connect the wiring harnesses to the ECU as shown in the picture below. The connectors from left to right are signal connector, motor connector, and power connector.

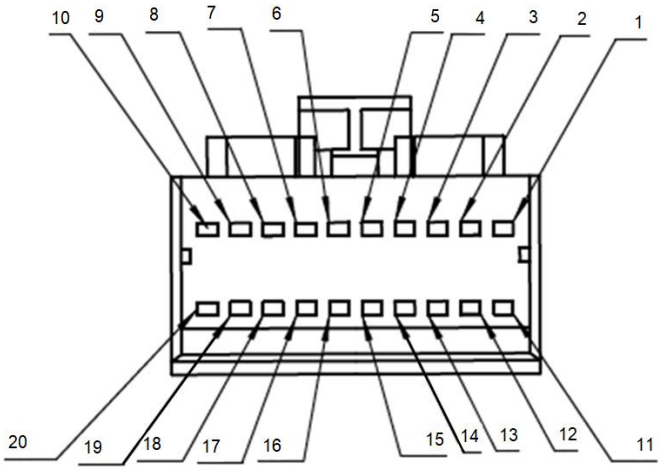
Find a suitable location for the ECU (within vehicle, away from heat and moisture). Mount using the 2x M6 threaded mounting holes ensuring there is free airflow around the ECU heatsink.

It is recommended that the ECU is secured using anti-vibration mounts to isolate the ECU from any chassis vibrations.

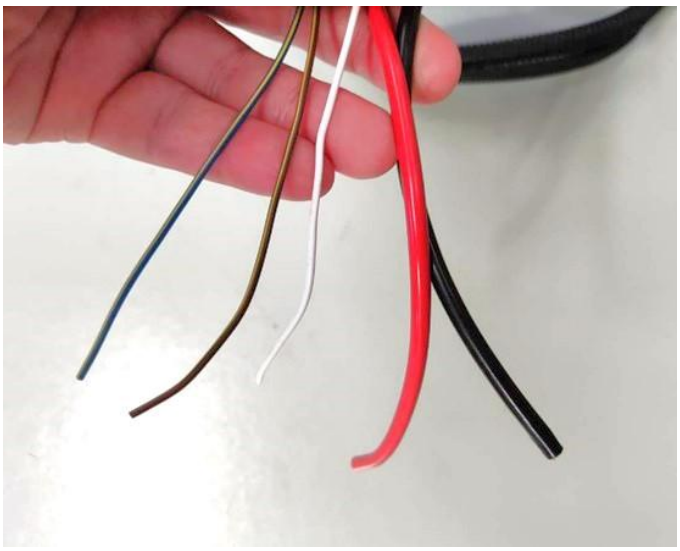
Signal Connector Pin Definitions.

Pin Number	Description	Wire Color
1	Not Used	
2	Torque & Angle Sensor Ground	Green
3	Torque Sensor +5V	Orange
4	Not Used	
5	Torque Sensor Signal Auxillary	Black
6	Fault Light	Brown
7	Not Used	
8	Angle Sensor Signal Main	Black
9	Angle Sensor Signal Auxillary	White
10	Ignition +12V	White
11	Angle Sensor +12V	Grey/Red
12	Not Used	
13	Torque Sensor Signal Main	White
14	Not Used	
15	Not Used	
16	Not Used	
17	CAN Lo	Brown/Yellow
18	Not Used	
19	Not Used	
20	CAN Hi	Blue/Yellow

Signal Connector Pin Numbering (Harness Connector Face View)



Within the two harnesses are 5 unterminated wires, these are from left to right: CAN_H (Blue_Yellow), CAN_L (Brown_Yellow), 12V ignition Signal (White), Power Supply Positive (Red), and Power Supply Negative (Black).



Connect the Power Supply Positive red wire with its 40A in-line fuse to +12V battery positive.

Connect the Power Supply Negative (Black) wire to battery negative.

Connect the +12V ignition Signal (White) to a switched +12v supply. The ignition signal turns on the EPS controller when a voltage of 9V-16V is present.

The two CAN wires CAN_H (Blue_Yellow), and CAN_L (Brown_Yellow) need to be connected to your corresponding CAN network. The EPAS ECU incorporates a 120 ohm termination resistor when powered.

4 CANBus System

4.1 CAN IDs and Structure

Control of the Autonomous ECU and EPAS can be performed with a suitable CANBus controller. The following CAN IDs are used in this system:

4.2 CAN Message #1

Provides feedback from EPAS ECU which includes Torque, Angle, Mode etc.

Message ID: 0x401 (fixed)
Description: EPAS_Feedback_1
Update rate: 50ms

Message Byte	Signal	Value
D0	Working Mode	0x00 = Mechanical mode active (No power assist) 0x10 = Power assist mode active (Manual EPAS) 0x20 = Autonomous angle control mode active (Autonomous EPAS) 0x01 = Mechanical limited mode (Angle mode prohibited) 0x02 = Mechanical limited mode (Power-assisted mode prohibited) 0x03 = Mechanical limited mode (Full function prohibited) 0x13 = Autonomous mode Prohibit (Angle mode prohibited) 0x23 = Power assist mode prohibit (Angle mode prohibited)
D1	Steering Wheel Torque (Nm)	The data range is 1-254, the offset is 128, the unit is Nm Torque calculation formula: Torque = Byte(D1)*0.1–12.8
D2	Fault Code 1	See Fault Code Table Below
D3	Steering Angle MSB (degrees)	Offset = -1024 Minimum = -900 degrees Maximum = 900 degrees Angle calculation formula: Angle = Byte(D3)*256+Byte(D4)-1024
D4	Steering Angle LSB (degrees)	
D5	Angle Alignment Feedback	0x00 = No angle alignment has been performed 0x55 = Angle alignment has been performed 0x11 = Angle alignment failed 0xEE = Angle alignment is successful
D6	Fault Code 2	See Fault Code Table Below
D7	Check Sum 1	XOR check sum of the first seven bytes

4.2.1 Fault Codes

Fault codes are communicated by byte D2 (Fault Code 1) and byte D6 (Fault Code 2) of CAN ID 0x401. If there is a single fault, fault code 1 will indicate it first, with a second fault being displayed by fault code 2. Additional faults will overwrite fault code 1 and 2 so that they will always display the most recent faults. Fault codes will affect the fault mode and can only be cleared by rectifying the fault and power cycling the EPAS off for 10 seconds.

Fault Code Value		Fault Code Meaning
Hex	Decimal	
0x10	16	No external crystal oscillator
0x12	18	The steering angle midpoint is not written
0x14	20	EEPROM read and write failure
0x21	33	The main torque sensor is disconnected
0x22	34	The output of main torque sensor is abnormal
0x23	35	The auxiliary torque sensor is disconnected
0x24	36	The output of auxiliary torque sensor is abnormal
0x25	37	The main and auxiliary torque sensor difference is too large
0x26	38	The difference between the main torque before and after amplification is too large
0x32	50	Motor without power assistance
0x33	51	Over current
0x34	52	Power module failure
0x35	53	Motor current abnormal
0x36	54	Power assist function failure
0x41	65	Power supply under voltage
0x42	66	Power supply over voltage
0x43	67	Motor terminal voltage is abnormal
0x46	70	Thermal protection excessive temperature detected
0x51	81	The steering angle has exceeded limits
0x55	85	Incorrect XOR Checksum value being sent on the command message 0x469
0x61	97	Pinion angle sensor is disconnected
0x62	98	Middle gear angle sensor disconnected

4.3 CAN Message #2

Provides feedback from the EPAS ECU, only transmitted when receiving autonomous steering commands on 0x469.

Message ID: 0x402 (fixed)
Description: EPAS_Feedback_2
Update rate: 50ms

Message Byte	Signal	Value
D0	Control Method	0x00 = Mechanical mode 0x10 = Power assist mode 0x20 = Autonomous angle control mode
D1	Angle Command Received Counter MSB	The angle command received counter increments when receiving autonomous commands. The range of the counter is 0-65,535. It will roll over back to zero after reaching the max value.
D2	Angle Command Received Counter LSB	
D3	Demanded Angle MSB	Offset = -1024 Minimum = -900 degrees Maximum = 900 degrees Angle calculation formula: Angle = Byte(D3)*256+Byte(D4)-1024
D4	Demanded Angle LSB	
D5	Measured Angle MSB	Offset = -1024 Minimum = -900 degrees Maximum = 900 degrees Angle calculation formula: Angle = Byte(D5)*256+Byte(D6)-1024
D6	Measured Angle LSB	
D7	Check Sum 2	XOR check sum of the first seven bytes

4.4 CAN Message #3

This message is received by the EPAS ECU. It is used to send configuration and control commands to the EPAS ECU.
Message ID: 0x469 (fixed)
Description: EPAS_Config_and_Control_Commands
Update rate: 50ms

Message Byte	Signal	Value
D0	Control Method Command	The default EPAS mode is power assisted. If you want autonomous mode or mechanical mode the relevant control message must be sent to the EPAS every 50ms. 0x00 = Sets EPAS to mechanical mode. No output from EPAS motor. 0x10 = Sets EPAS to power assisted mode. EPAS provides manual assistance when sensing a torque signal resulting from manual driver manipulation of steering. 0x20 = Sets EPAS to autonomous mode. EPAS provides autonomous steering in response to angle and speed commands over CAN. Needs to be sent every 50ms otherwise EPAS will revert to 0x10 mode.
D1	Reserved	
D2	Reserved	
D3	Demanded Angle Command MSB	Offset = -1024 Minimum = -900 degrees Maximum = 900 degrees Angle calculation formula: Angle = Byte(D3)*256+Byte(D4)-1024
D4	Demanded Angel Command LSB	
D5	Angle Alignment Command	0x55 = Sets the current position to center position, only to be performed in mechanical or power assisted modes. 0x401 message will return Angle = 04 00 on bytes D3 & D4, and EE (successful angle alignment) on byte D5. ECU will need a 10s power cycle before calibration is complete. 0x00 = Default message if no angle alignment is needed.
D6	Angular Velocity Control	Controls the speed of rotation. The given range of angular velocity is from 20 to 250 in decimal (0x14 to 0xFA in hex), the corresponding motor speed is 120r/m – 1500r/m, the reduction ratio from the motor to the output shaft is 16.5:1, and the corresponding steering wheel speed is 43°/s - 545°/s. This angular velocity is the target value, and the actual angular velocity that can be achieved is related to the vehicle load. Velocity calculation formula: Velocity r/m = Byte(D6)*6
D7	Check Sum	XOR check sum of the first seven bytes.

5 Calibration of EPAS700 Autonomous MGU

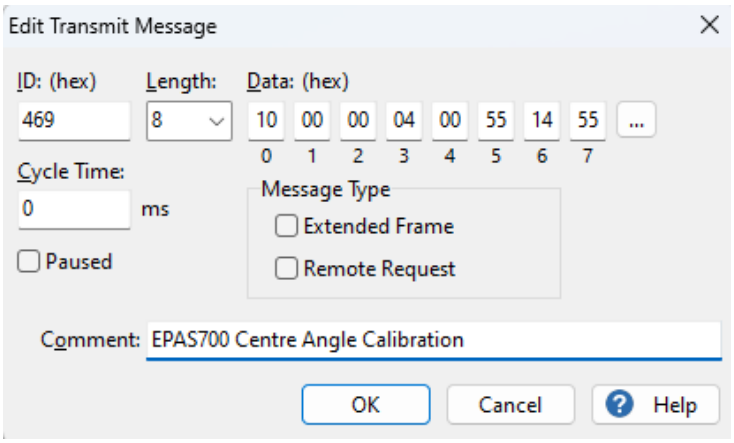
The CAN interface is for operation of the EPAS, and can also be used for calibration commands of its sensors and change the Baud rate of the CANBus connection.

5.1 Steering Angle Sensor Calibration

Before the system can be used a calibration of the steering angle sensor needs to be performed.

With the system connected as per SECTION 3.1, mechanically align the vehicle's steering to its centre position. You now need to set the steering angle sensor and ECU to store this as the steering angle sensor's zero position.

Use PCAN or a similar CAN controller and send a set zero command on CAN-ID 469h with the data LSByte 10 00 00 04 00 55 14 55 MSByte as shown below.



If successful, this will set the angle sensor output on CAN-ID 401h MSB byte 03 and LSB byte 04 to 04 and 00 respectively (Midpoint).

CAN-ID	Type	Length	Data
401h		8	10 80 00 04 00 EE 00 7A
402h		8	10 00 12 04 00 02 48 11

After the alignment is successful, power off the controller for 10s and then power on again. Calibration only needs to be carried out once at installation as the settings will be retained, even when power is removed. The user can reset the zero position by repeating this process if required.

Note: The angle sensor is a multi-turn type however the firmware in the ECU sets a limit on the MGU of 5 turns end to end. If you manually or autonomously move the MGU to Greater Than or Equal to 07 85 or Less Than or Equal to 00 7B the MGU will steer up to that position, then go into fault mode for reaching a mechanical limit.

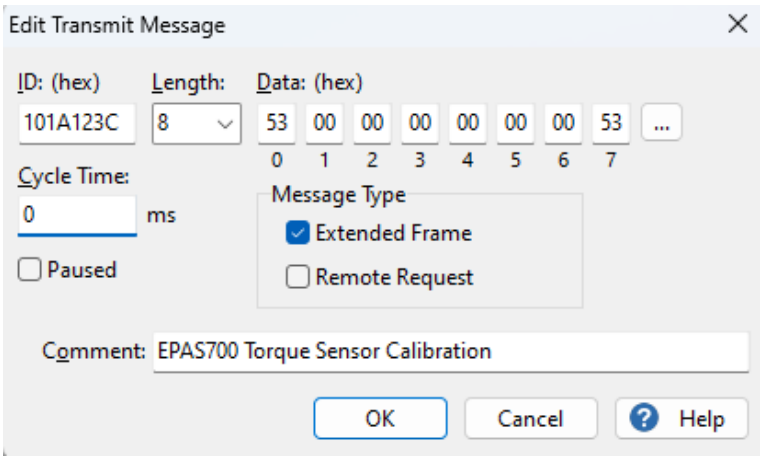
To reset this, return the steering to a range of 00 7B to 07 85 power cycle the ECU off for 10 seconds.

5.2 Torque Sensor Calibration

The torque sensor can be calibrated via CAN. The torque sensor measurement is displayed on the second bit of CAN ID 401h. Under normal operating conditions with no torque applied to the steering the value should be 0x80 +/- 0x4 which is 7C to 84. If the torque is outside of this then a torque sensor calibration should be performed.

If a fault code of 0x11 is returned by the controller indicating torque midpoint value is not written, a torque sensor calibration will be necessary.

To calibrate the torque sensor, ensure there are no external forces applied to the steering system. Send a single extended frame CAN message to CAN ID 101A123Ch, the contents of the torque alignment message needs to be LSByte 53 00 00 00 00 00 00 53 MSByte as below



If successful, the EPAS ECU will return an extended CAN message on 101A12C3h with the second byte being 0x11 as below. If the second byte is 0x55, it means the alignment has failed and should be repeated.

CAN-ID	Type	Length	Data
401h		8	13 80 51 01 04 55 00 92
101A12C3h		8	53 11 00 00 00 00 00 00

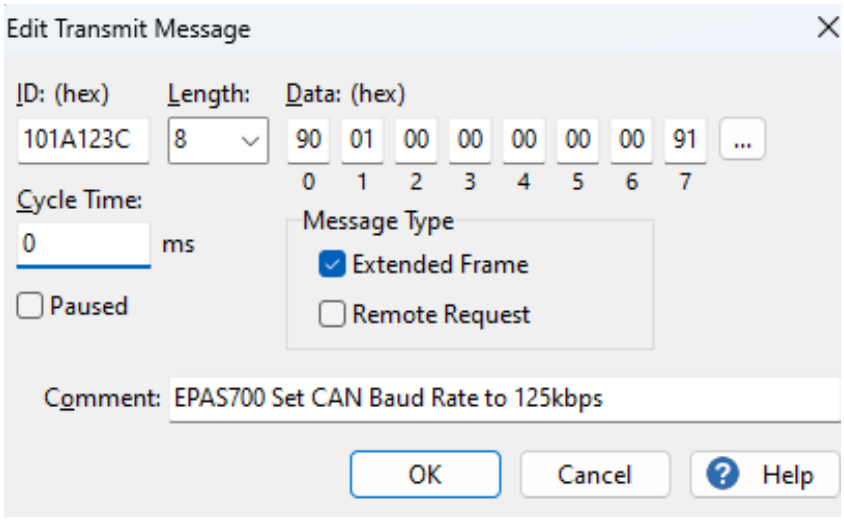
After a successful calibration the EPAS ECU should powered off, and after 10s powered on again. The fault code bit in the 0x401 message should then return to 0x00 indicating the torque misalignment fault has been cleared.

5.3 CAN Baud Rate

The EPAS CAN supports 3 baud rates which are 500kbps, 250kbps, and 125kbps, with the default baud rate being 500kbps.

To change the baud rate, send a single extended frame CAN message to CAN ID 101A123Ch, the contents of the message depends on the desired baud rate as below.
90 03 00 00 00 00 00 93 (500kbps)
90 02 00 00 00 00 00 92 (250kbps)
90 01 00 00 00 00 00 91 (125kbps)

The example below shows a CAN baud rate change message for 125kbps.



If the message delivery is successful, the EPAS ECU will return an extended CAN message on 101A12C3h with the second byte being 0x11 as below. If the second byte is 0x55, it means the change request has failed and should be repeated.

CAN-ID	Type	Length	Data
401h		8	10 80 00 02 04 55 00 C3
101A12C3h		8	90 11 00 00 00 00 00 00

Note the baud rate will not change immediately and the EPAS ECU should by powered off, and after 10s powered on again, only then will the baud rate change to the new requested speed. Remember you will also need to change your CAN controller to reflect the new CAN baud rate.

6 Autonomous Operation Commands

6.1 Sending Angle and Speed Commands

With the zero-angle position set, the torque sensor operating correctly and no other errors from the EPAS it is now possible to send autonomous steering commands.

Note do not send angle request commands less than or equal to 00 7B or greater than or equal to 07 85 as the MGU will steer up to that position then go into fault mode for reaching a mechanical limit. To rectify this the steer angle needs to be within 00 7B to 07 85 and a power cycle of the ECU is needed.

Note in the demand angle calculations, to steer to a positive angle add the zero position to your demand angle, and to steer to a negative angle subtract the zero position from the demand angle

Example 1 (Positive Angle)

To control the EPAS in autonomous mode and steer it to an angle of 260 degrees at a speed of 1200r/m.

Byte D0 - set to 0x20 for autonomous mode

Byte D1 - not used set to 0x00

Byte D2 - not used set to 0x00

Byte D3 & D4 - are the demand angle

Convert angle to Hex then add Zero position = 0x0104 + 0x0400 = 0x0504

Byte D5 not used set to 0x00

Byte D6 set to 0xC8 for Speed = 1200r/m

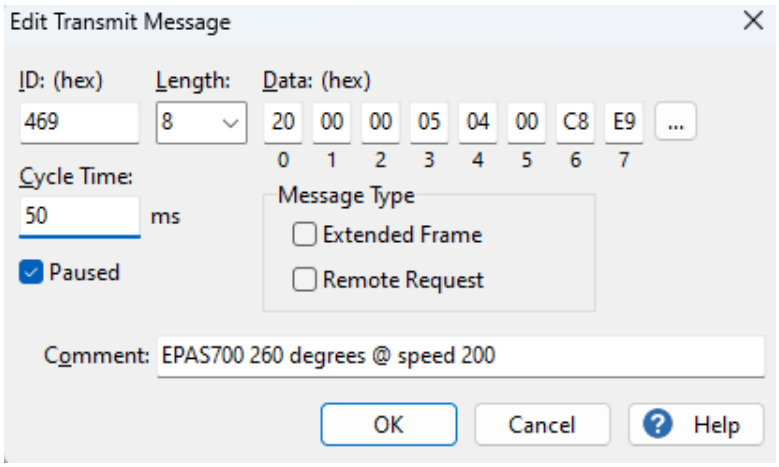
A demand speed of 0xC8 = 200 decimal. 200*6 = 1200r/m

A Motor RPM of 1200 = 1200/16.5 Output shaft RPM = 72.72 RPM

Byte D7 check sum calculation.

Check Sum = 0x20 Xor 0x00 Xor 0x00 Xor 0x05 Xor 0x04 Xor 0x00 Xor 0xC8 = 0xE9

Full message = 0x 20 00 00 05 04 00 C8 E9



Example 2 (Negative Angle)

To control the EPAS in autonomous mode and steer it to an angle of -252 degrees at a speed of 996r/m.

Byte D0 - set to 0x20 for autonomous mode

Byte D1 - not used set to 0x00

Byte D2 - not used set to 0x00

Byte D3 & D4 - are the demand angle

Convert angle to Hex then subtract from Zero position = 0x0400 - 0x0FC = 0x0304

Byte D5 - not used set to 0x00

Byte D6 - set to 0xA6 for Speed = 996r/m

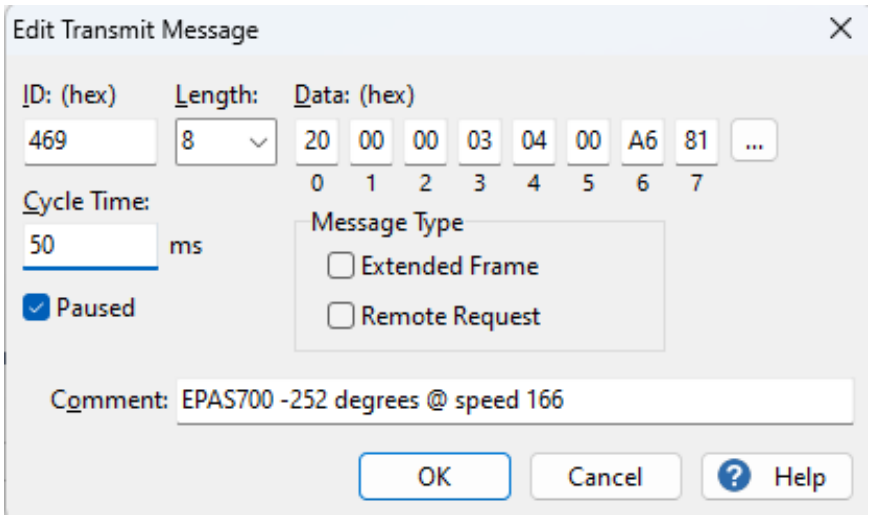
A demand speed of 0xA6 = 166 decimal. 166*6 = 996r/m

A Motor RPM of 996 = 996/16.5 Output shaft RPM = 60.36 RPM

Byte D7 - check sum calculation.

Check Sum = 0x20 Xor 0x00 Xor 0x00 Xor 0x03 Xor 0x04 Xor 0x00 Xor 0xA6 = 0x81

Full message = 0x 20 00 00 03 04 00 A6 81



7 Manual Operation Mode

7.1 Notes On Manual Operation

The system will enter manual operation mode depending on the following conditions:

- The system does not receive a valid autonomous CAN signal every 50ms. It will revert to manual mode until a valid CAN signal is received
- The system is commanded to go into manual mode over CAN. It will remain in manual mode until a valid autonomous CAN command is received.

Note in manual mode there is no input/compensation for vehicle speed. The level of assistance is fixed.

8 Troubleshooting

Problem	I can't connect to the EPAS700 Autonomous ECU or read/write its parameters.
Cause	The EPAS700 Autonomous ECU is not powered up.
Action	Ensure there is power applied to main power connector and the Ignition (pin 10 white wire) on the signal connector.
Cause	The connections are not making a good connection.
Action	Ensure all connectors are fully home and that the leads are not damaged in any way.
Cause	No CAN Communications.
Action	The CAN connection is not configured correctly, check your CAN controller baud rate (500Mbps is default).
Cause	No CAN Communications.
Action	Ensure your CAN controller is connected correctly CAN high to CAN high, and CAN low to CAN low, and correctly terminated.
Cause	EPAS not responding to CAN commands.
Action	Zero point has not been set on steering angle sensor. Set Zero position.
Cause	EPAS not responding to CAN commands.
Action	Torque sensor error, recalibrate torque sensor.
Cause	Steering operating in manual mode with no torque applied.
Action	Torque sensor error, recalibrate torque sensor.

9 Error Messages

The autonomous EPAS ECU will report failure modes and faults over the CAN interface.

9.1 Fault Modes

The byte D0 of CAN ID **0x401** is used to indicate the current “Working Mode”. When there is a fault condition with the ECU some or all of the functions could be prohibited.

CAN ID 401h	Condition
0x00	Mechanical mode active (No power assist). Operating Ok
0x10	Power assist mode active (Manual EPAS). Operating Ok
0x20	Angle control mode active (Autonomous EPAS). Operating OK
0x01	Mechanical limited mode (Angle mode prohibited). Check angle sensor operation.
0x02	Mechanical limited mode (Power-assisted mode prohibited). Check torque sensor and motor operation.
0x03	Mechanical limited mode (Full function prohibited). Torque or angle sensor failure, motor failure or at mechanical end stops.
0x13	Angle mode prohibited. after receiving mode change request from CAN controller. Possible angle sensor fault check angle sensor operation.
0x23	Assist mode prohibited, after receiving mode change request from CAN controller. Possible torque sensor fault check torque sensor operation.

9.2 Fault Codes

Fault codes are communicated by byte D2 (Fault Code 1) and byte D6 (Fault Code 2) of CAN ID **0x401**. If there is a single fault, fault code 1 will indicate it first, with a second fault being displayed by fault code 2. Additional faults will overwrite fault code 1 and 2 so that they will always display the most current faults.

Fault codes will affect the fault mode and can only be cleared by rectifying the fault and power cycling the EPAS off for 10 seconds.

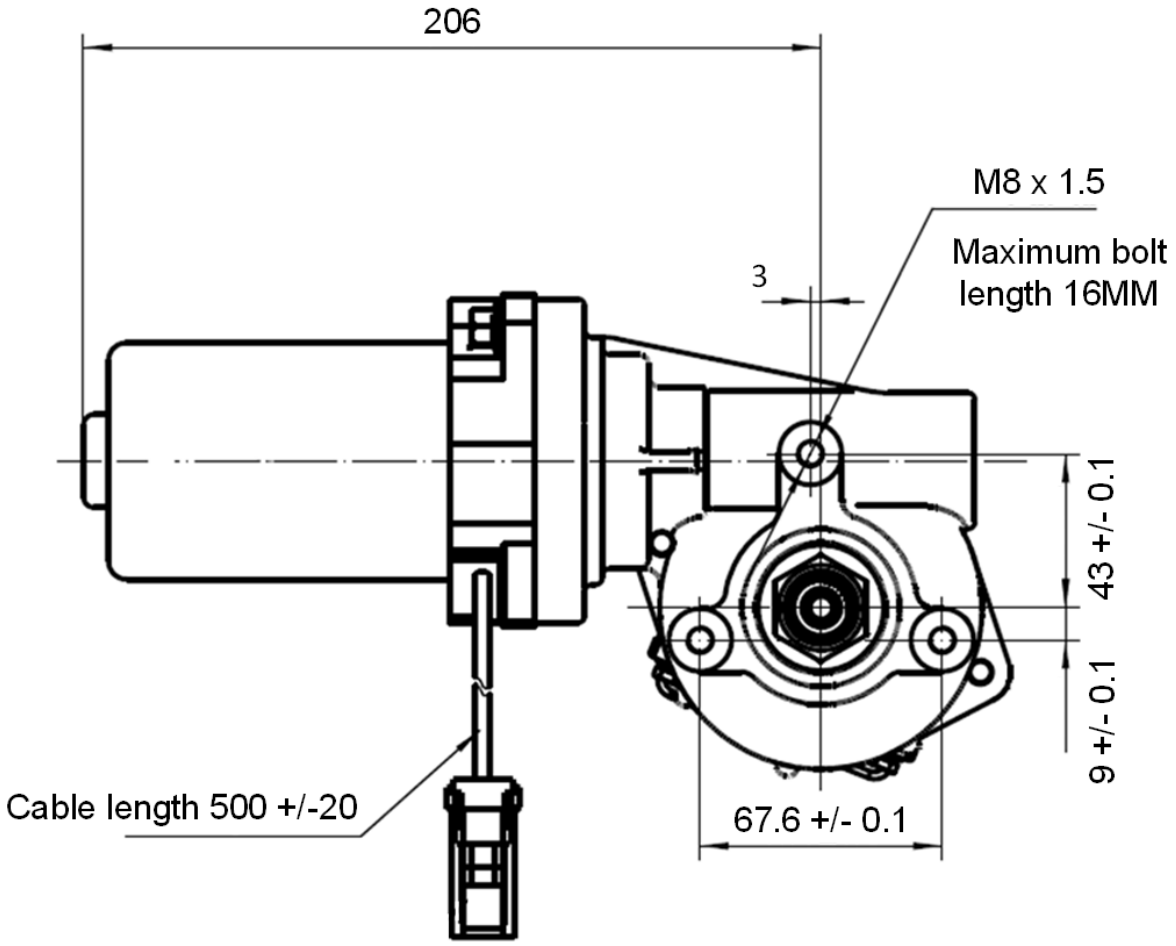
Fault Code Value		Fault Code Meaning
Hex	Decimal	
0x10	16	No external crystal oscillator
0x12	18	The steering angle midpoint is not written
0x14	20	EEPROM read and write failure
0x21	33	The main torque sensor is disconnected
0x22	34	The output of main torque sensor is abnormal
0x23	35	The auxiliary torque sensor is disconnected
0x24	36	The output of auxiliary torque sensor is abnormal
0x25	37	The main and auxiliary torque sensor difference is too large
0x26	38	The difference between the main torque before and after amplification is too large
0x32	50	Motor without power assistance
0x33	51	Over current
0x34	52	Power module failure
0x35	53	Motor current abnormal
0x36	54	Power assist function failure
0x41	65	Power supply under voltage
0x42	66	Power supply over voltage
0x43	67	Motor terminal voltage is abnormal
0x46	70	Thermal protection excessive temperature detected
0x51	81	The steering angle has exceeded limits
0x55	85	Incorrect XOR Checksum value being sent on the command message 0x469
0x61	97	Pinion angle sensor is disconnected
0x62	98	Middle gear angle sensor disconnected

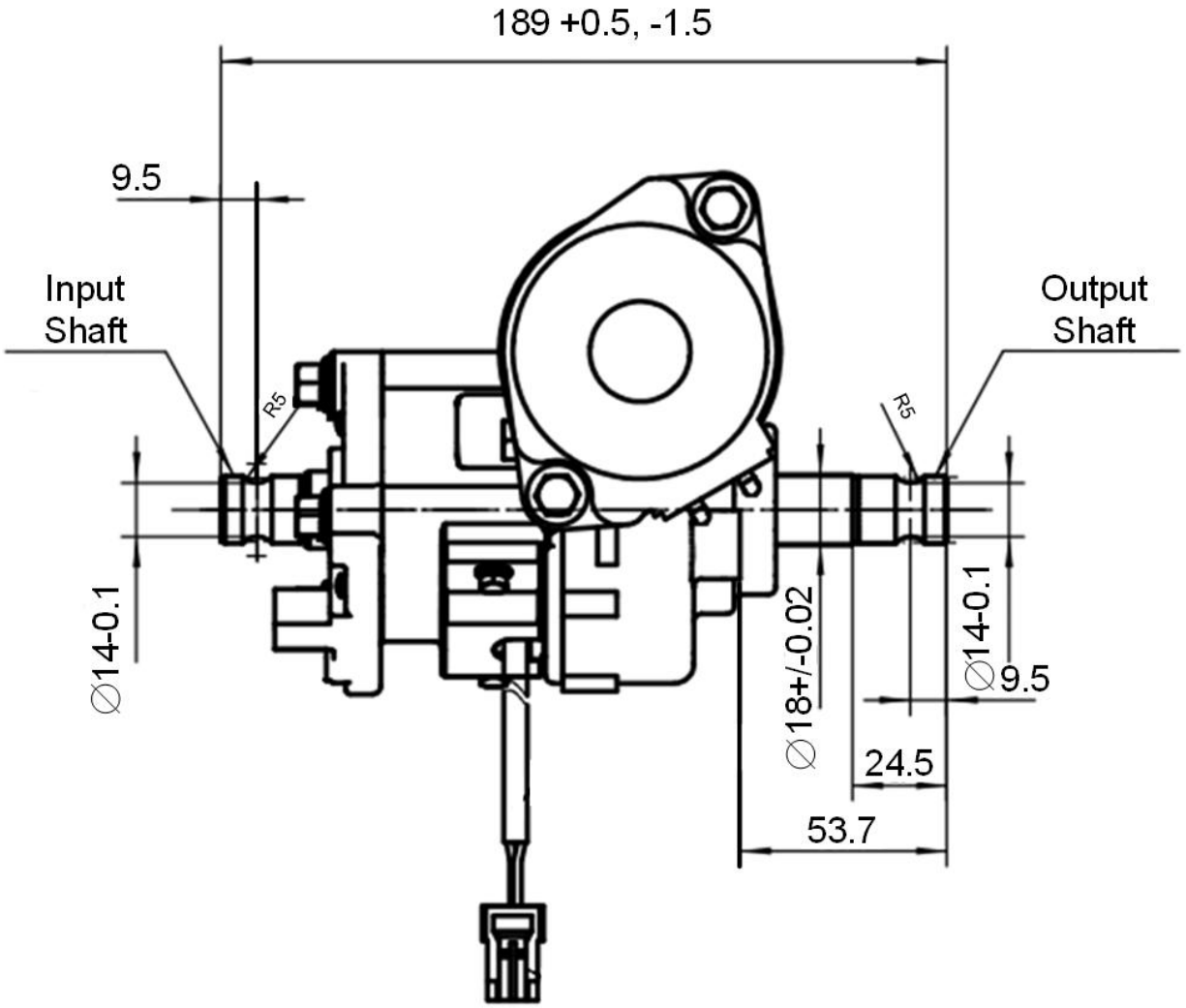
10 Fault Light

The Red LED mounted within the wiring harness is not used for autonomous ECUs as all fault modes are communicated over the CAN interface.

11 Dimensions

11.1 MGU Dimensions (mm)




189 +0.5, -1.5
9.5
Input
Shaft
Output
Shaft
R5
R5
∅14-0.1
∅18+/-0.02
∅14-0.1
9.5
24.5
53.7

11.2 ECU Dimensions (mm)