MAHLE

Driven by performance

COMPLETE POWER FOR YOUR VEHICLE

Drive systems for battery supplied vehicles

DRIVE SYSTEMS

ELECTRIC DRIVES
AND APPLICATIONS

MORE PERFORMANCE, PRECISION, AND PASSION FOR YOUR SUCCESS.

» We see ourselves not just as a supplier, but much more as a reliable guide and expert partner that helps you better reach your goals. «

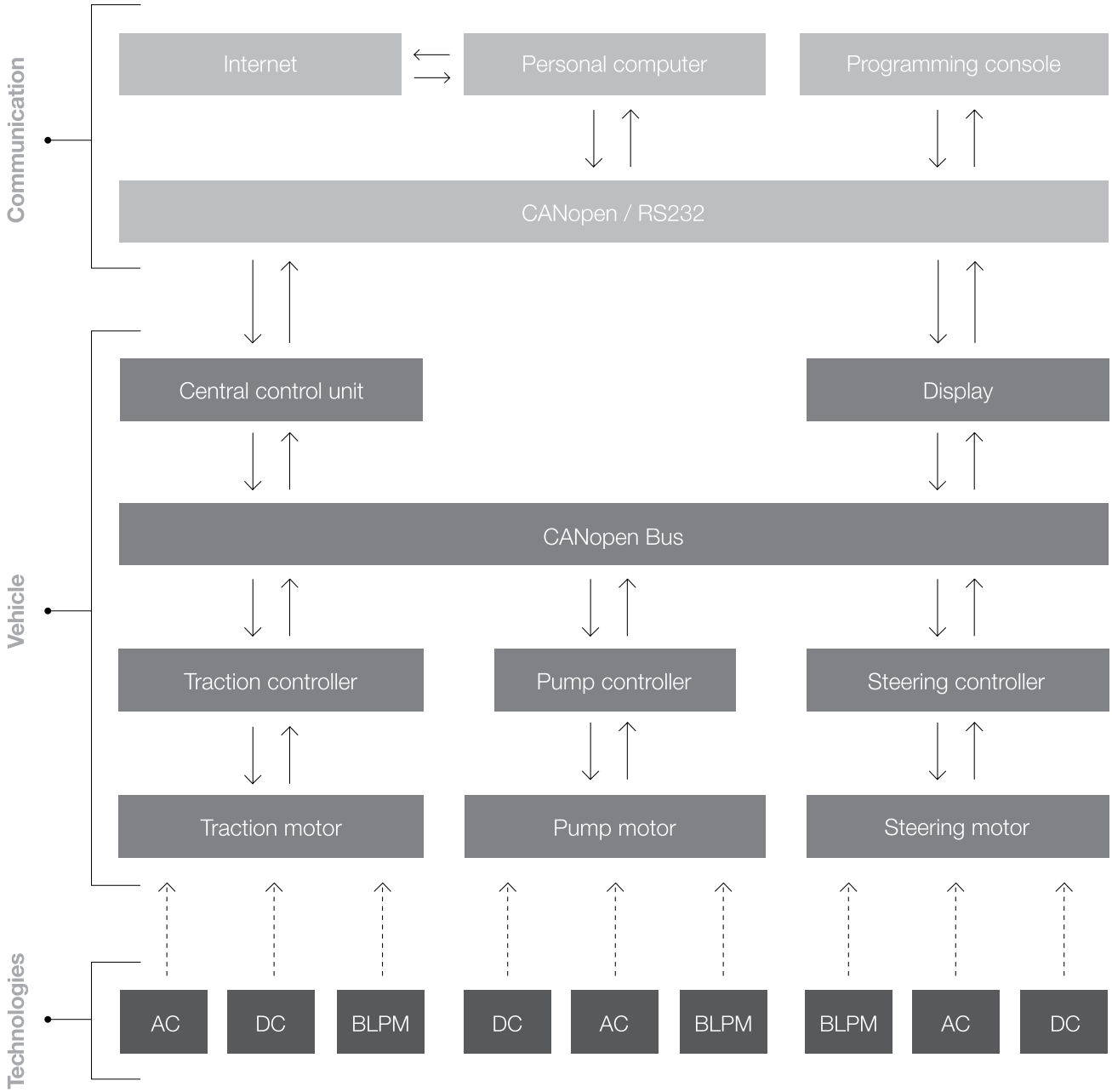
MAHLE is a leading global development partner for the automotive and engine industry with unique systems competence in the areas of engine systems, filtration, electrics/mechatronics, and thermal management. Automobile and engine manufacturers worldwide rely on products and solutions from MAHLE.

This unique expertise and outstanding development competence can be found in our products and solutions around the globe: in commercial vehicles, ships, trains, agricultural and construction machinery, electric vehicles, and other demanding industrial applications such as forklifts, mobile hydraulics and factory equipment.

As your development, systems, and service partner, we know your requirements and processes. We know what you and your customers need and, together with you, we create added value that brings fresh power to your success: tailor-made solutions with the highest performance and reliability, durability, and economic efficiency, which sustainably contribute to increasing energy efficiency and ecological added value.

WE DRIVE YOUR SUCCESS. WORLDWIDE.
WITH PERFORMANCE, PRECISION, AND PASSION.
MAHLE — DRIVEN BY PERFORMANCE.

MOTORS AND CONTROLLERS FOR ELECTRICAL VEHICLES



Based on the given specification of your vehicle and various requirements you might have, our engineers will study and explore different possible solutions and prepare the best proposal for you. No matter what kind of drive system is chosen the best combination of motor, control and other elements will be used to build the most efficient and cost effective system for your vehicle. Research and development work is supported by computerised simulation of complete systems and our laboratories are equipped with highly professional testing devices.

TYPICAL APPLICATIONS

Traction applications

Motors and controllers are designed for traction applications including hybrid vehicles and adapted for long-lasting operations at declared load (usually S1 or S2 = 60 min). Products are designed to provide long life operation. Various mounting flanges are available to mount on different types of gearboxes. Motors are available in DC commutator (permanent magnet, series, split field or separately excited winding), AC induction and BLPM version, voltage range from 12 V up to 80 V and power up to 18 kW. Microprocessor based controllers for series wound commutator motors, induction AC and BLPM motors are available, to form an effective and tuned drive system.

Hydraulic applications

Motors and controllers for hydraulic applications are designed for intermittent periodic operation at declared load (usually S3 = 5 up to 15% of duty cycle) mainly in one direction of rotation. Products are designed to be resistant against short time overloading and overheating. Motors are adapted to standard assembly dimensions of hydraulic pumps and can be oil proof on the drive end side. Motors and controllers are available in DC commutator, AC induction and BLPM version, voltage range from 12 V up to 80 V and power up to 28 kW. Easy programming of user defined parameters via laptop or a dedicated programming unit.

Steering applications

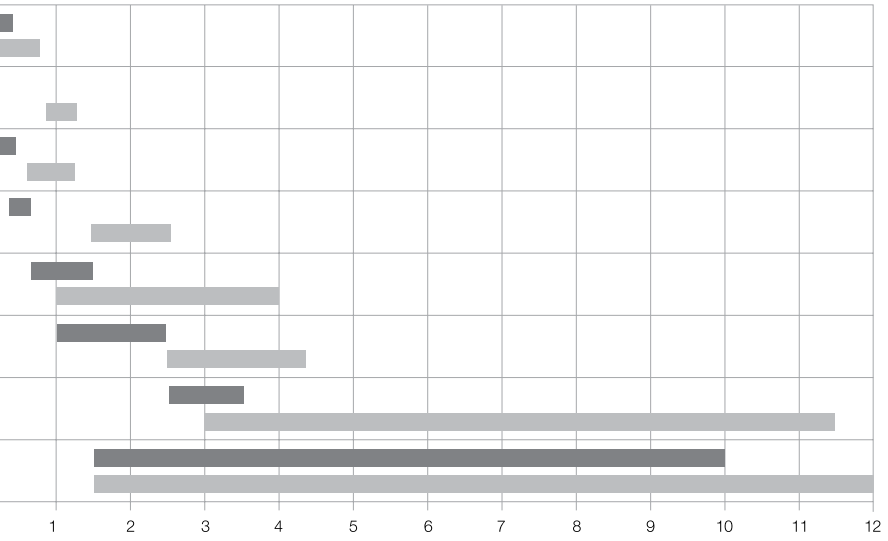
Brushless and commutator motors are produced for automotive industry, electrical forklifts and marine applications. Available as EHPS and EPS solution with built-in controller are designed to meet the international safety regulations. The main features are excellent dynamics, simple mounting, easy adaption to special requirements, high efficiency, low noise, EMC compatibility and optionally low maintenance. Available voltage range from 12 V up to 80 V and power up to 2 kW.

Other applications

We are producing also systems for other applications such as electric winches, air conditioning systems, industrial cleaning machines, platforms, etc. All of these designs are specially trimmed according to customer requirements such as type and duration of operation, protection against splashing water or very special mounting requirements. Many of the user defined controller parameters can be easily programmed via a laptop or a dedicated programming unit.

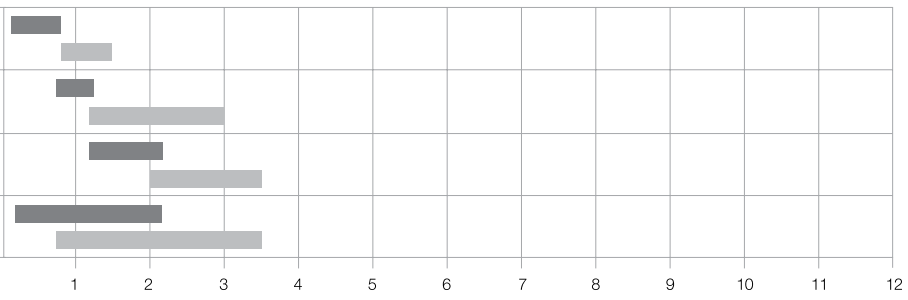
DC motors and controllers

TYPE	POWER (kW)
AME 80 mm	0.1 - 0.2 0.15 - 0.8
AMF 93 mm	0.9 - 1.2
AMG 106 mm	0.25 - 0.4 0.6 - 1.2
AMJ 112, 114 mm	0.4 - 0.6 1.5 - 2.5
AMK 125, 130 mm	0.65 - 1.5 1.0 - 4.0
AMP 150 mm	1.0 - 2.5 2.5 - 4.3
AMT 178 mm	2.5 - 3.5 3.0 - 11.5
DC CONTROLLERS	1.5 - 10.0 1.5 - 12



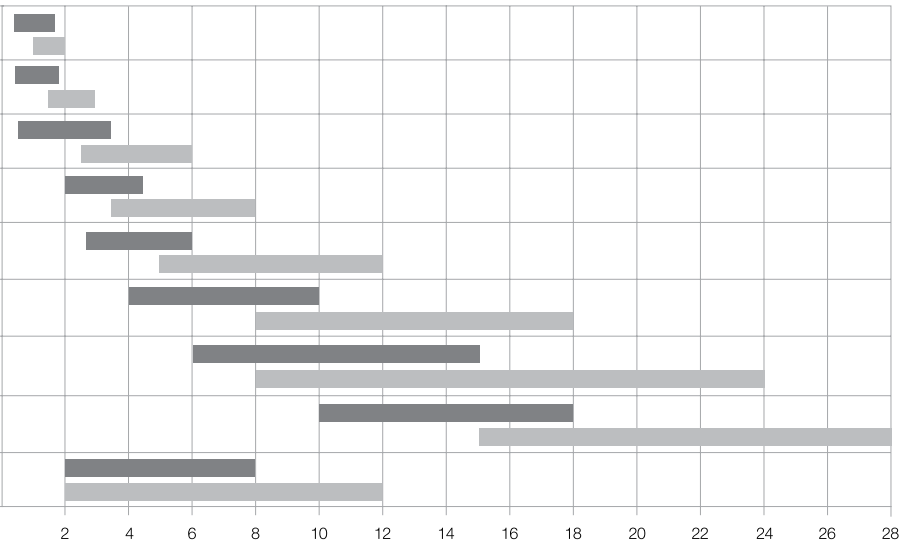
BLPM motors and controllers

TYPE	POWER (kW)
AMG 106 mm	0.15 - 0.8 0.8 - 1.5
AMK 125 mm	0.7 - 1.2 1.2 - 3.0
AML 132 mm	1.2 - 2.2 2.0 - 3.5
BLPM CONTROLLERS	0.15 - 2.2 0.7 - 3.5



AC induction motors and controllers

TYPE	POWER (kW)
AMG 106 mm	0.5 - 1.5 1 - 2
AMK 120 mm	0.7 - 1.8 1.5 - 3
AML 135 mm	0.7 - 3.5 2.5 - 6
AMP 150 mm	2 - 4.5 3.5 - 8
AMT 170 mm	2.5 - 6 5 - 12
AMV 200 mm	4 - 10 8 - 18
AMW 240 mm	6 - 15 8 - 24
AMZ 270 mm	10 - 18 15 - 28
AC CONTROLLERS	2 - 8 2 - 12



AME / AMG

Design
- Excitation by high quality ferrite 4 or 6 pole permanent magnets
- Compact design
- Motors with mounted switch available
- Custom design drive end brackets
- One or two terminal versions
- UL design available on request
- EMC filter for AME motors available
- High quality thermal resistant materials
- Free of asbestos, lead cadmium, beryllium and ammonia

Applications
- Pump drive
- Winches
- Traction
- Marine applications

Features
- High specific output power
- Long brush life
- High ambient resistance

Main technical data

Type	AME			AMG		
Nominal voltage (V)	12	24	48	12	24	36
Nominal power (kW)	0.1-0.8	0.35-0.8	0.5 - 0.8	0.25-1.1	0.4-1.2	0.5
Yoke diameter (mm)	80			106		
Length (mm)	137			136 - 174		
Weight (kg)	2.6			4 - 5.7		
Stator	6 permanent magnets			4 permanent magnets		
Degree of protection	IP 54, IP 65			IP 22, IP 54		
Ambient temperature (°C)	-20 to +70					
Thermal protection	Optional					

DC permanent magnet motors

AMF / AMJ

Design
- Four pole motor with field coils excitation
- Series, compound and split field versions
- AMF only series wound
- AMJ heavy duty versions available
- UL design available on request
- EMC compatible
- Compact design
- High quality thermal resistant materials
- Free of asbestos, lead cadmium, beryllium and ammonia

Applications
- Pump drive
- Traction
- Winches
- Marine applications

Features
- High specific output power
- Long brush life
- High ambient resistance

Main technical data

Type	AMF		AMJ				
Nominal voltage (V)	12	24	12	24	36	48	72
Nominal power (kW)	0.9	1.2	0.7-2.1	0.4-2.5	1.7	2.0	2.0
Yoke diameter (mm)	93		112-114				
Length (mm)	125		150 - 250				
Weight (kg)	3.5		5.3 - 9				
Stator	4-pole windings						
Degree of protection	IP 54, IP 65		IP 23, IP 44, IP 54				
Ambient temperature (°C)	-20 to +70						
Thermal protection	No		Optional				
Internal fan	No		Optional				

DC motors

AMK / AMP / AMT

Design
- Four pole motor with field coil excitation
- Series, compound or SEM versions
- EMC compatible
- UL design available on request
- Available in EE version
- High quality thermal resistant materials
- Free of asbestos, lead cadmium, beryllium and ammonia

Applications
- Pump drive
- Traction
- Winches
- Marine applications

Features
- High specific output power
- Ventilated or enclosed versions
- High ambient resistance

Main technical data

Type	AMK				AMP				AMT				
Nominal voltage (V)	12	24	48	72	24	36	48	80	24	36	40	48	80
Nominal power (kW)	1.8-2.4	0.65- 4.0	3.0	1.0	1.0-4.1	4.1	1.0-4.3	3.0	4.3-5.5	6.9	3.8	2.5-11.5	7.6
Yoke diameter (mm)	125-130				150				178				
Length (mm)	175 - 283				250 - 350				260 - 430				
Weight (kg)	10.5 - 16.5				20 - 25				22 - 34				
Stator	4-pole windings												
Degree of protection	IP 12, IP 20, IP 43, IP 44, IP 54				IP 12, IP 21, IP 23, IP 24				IP 12, IP 21, IP 22, IP 24				
Ambient temperature (°C)	- 20 to + 70												
Thermal protection	Optional												
Brushware indicator	No				Optional				Optional				

DC motors

AMG / AMK / AML

Design

- Compact design with integrated electronic or separated controller
- Programmable functions: soft start, speed loop option, analogue input for speed control, current limit
- CAN open communication
- EMC compatible
- UL design available on request
- Over-voltage and under-voltage protection
- Permanent magnets on rotor
- Three phase windings on stator
- Available with planetary gear box
- Available with electromagnetic brake

Applications

- EHPS - electro hydraulic power steering
- Utility pump drive
- Traction systems
- Fan drive
- EPS - electric power steering (steer by wire)
- EPAS electric power assisted steering
- Compressor drive for air conditioning and others

Features

- Low noise operations
- High efficiency > 85 %
- Long lifetime > 10,000 hours
- Integrated temperature protection
- Simple installation

Main technical data

Type	AMG					AMK				AML	
Nominal voltage (V)	12	24	36	48	80	12	24	48	80	24	80
Nominal power (kW)	0.15-1.0	0.15-1.5	0.3-1.5	0.5 - 0.8	0.8	0.7-2.0	0.7-3.0	1.5	1.2	1.2-2.2	2.0-3.5
Yoke diameter (mm)	106					125				132	
Length (mm)	134 - 235					265				350	
Weight (kg)	3.5 - 8					10				20	
Stator	Three phase										
Degree of protection	IP 54										
Ambient temperature (°C)	-20 to +60										
Thermal protection	Optional										

BLPM motors with integrated electronics

AMG / AMK / AML / AMP / AMT

Design
- Three phase four pole induction motor
- Aluminium squirrel cage rotor
- Different encoder options available
- UL design available on request
- Available in EE version
- High quality thermal resistant materials
- Free of asbestos, lead cadmium, beryllium and ammonia
- EMC compatible
- Available with planetary gearbox
- Available power cables directly from the motor

Applications
- Traction motor
- Pump drive
- Steering motor

Features
- High specific power
- Low performance sensivity to motor temperature (no permanent magnets)
- Compact size
- Low noise operation
- Long life maintenance free operation
- Excellent dynamic response
- Precise control

Main technical data

Type	AMG	AMK	AML	AMP	AMT
Nominal voltage (V)	24 - 48	24 - 48	24 - 48	24 - 80	24 - 80
Nominal power (kW)	0.5 – 2.0	0.7 – 3.0	0.7 – 6.0	2.0 – 8.0	2.5 – 12.0
Yoke diameter (mm)	106	120	135	150	170
Length (mm)	150 – 200	200 – 260	180 – 325	260	250 - 360
Weight (kg)	5 – 9	12 – 18	15 – 25	20 – 28	25 - 45
Stator	Three phase 4-pole				
Degree of protection	IP 20 - IP 54 (higher on request)				
Ambient temperature (°C)	-20 to +60				
Thermal protection	Thermo sensor KTY 84 - 130				

AMV / AMW / AMZ

Design

- Three phase four pole induction motor
- Aluminium squirrel cage rotor
- Different encoder options available
- UL design available on request
- Available in EE version
- High quality thermal resistant materials
- Free of asbestos, lead cadmium, beryllium and ammonia
- EMC compatible
- Available power cables directly from the motor

Applications

- Traction motor
- Pump drive

Features

- High specific power
- Low performance sensivity to motor temperature (no permanent magnets)
- Compact size
- Low noise operation
- Long life maintenance free operation
- Excellent dynamic response
- Precise control

Main technical data

Type	AMV	AMW	AMZ
Nominal voltage (V)	24 - 80	48 - 96	48 - 96
Nominal power (kW)	4 – 18	6 – 24	10 – 28
Yoke diameter (mm)	200	240	270
Length (mm)	180 – 320	250 – 330	280 - 400
Weight (kg)	33 – 65	55 – 90	80 - 120
Stator	Three phase 4-pole		
Degree of protection	IP 20 - IP 54 (higher on request)		
Ambient temperature (°C)	-20 to +60		
Thermal protection	Thermo sensor KTY 84 - 130		

AEK / AEH

Applications

- Traction
- Pump drive
- EPS / EPAS
- EHPS
- Fan drive
- Compressor drive
- Boat propulsion

Features

- Mosfet power section
- Microcontroller failsafe logic
- Flash EEPROM memory
- High efficiency
- Thermal protection
- Overvoltage and undervoltage protection
- All inputs and outputs short circuit protected
- Adjustable characteristics via programming console or PC
- CANopen Bus communication
- PC connection for programming and diagnostics
- Speed loop option
- Full 4-quadrant control
- Field weakening mode
- Complies with European CE Standards
- UL design available on request

Main technical data

Type	AEK, AEH
Nominal voltage (V)	12 to 80
Maximal current (A)	50 to 300
Operating frequency (Hz)	15,000
Ambient temperature (°C)	-20 to +55
Degree of protection	IP 65

AEK / AEH / AES

Applications

- Traction
- Pump drive
- Fan Drive
- Servo steering systems

Features

- Mosfet chip and wire power section
- State of the art DSP processor
- Flash EEPROM memory
- Space vector modulation
- Full 4-quadrant operation
- Field oriented control algorithm for the highest performance
- 12 digital inputs available
- 9 digital outputs available
- 2 analogue inputs available
- 4 digital outputs PWM controlled
- All inputs and outputs are short circuit protected
- Reverse polarity protection
- Available combi version
- Controller thermal protection
- Motor thermal protection
- Hardware and software overvoltage protection
- High low speed torque
- CANOpen Bus communication
- RS 232 communication
- PC connection for programming and diagnostics
- Internal hour meter and battery discharge indicator
- Complies with European CE Standards
- UL design available on request

Main technical data

Type	AEK, AEH, AES
Nominal voltage (V)	24 to 80
Maximal current (A)	150 to 500
Operating frequency (Hz)	10,000
Ambient temperature (°C)	-30 to +55
Degree of protection	IP 65

Controllers for AC induction motors

ARD

Applications
- Industrial electric trucks
- Battery powered vehicle accessories
- Electric road vehicles
- Marine equipment
- Railway equipment

Features
- Different switch holders
- Direct current loads
- Excellent conductivity

Solenoid switches

Main technical data

Type	ARD			
Rated voltage (V)	12	24	36	48
Nominal current (A)	80, 120, 150,300	80, 120, 150,300	60, 100	60
Maximal permanent current (A)	80, 120, 150,300	80, 120, 150,300	60, 100	60
Short time maximal current (A)	300, 350, 500	300, 350, 500	200, 350	200
Degree of protection	IP 54, IP 65, IP 66, IP 67			
Ambient temperature (°C)	-20 up to +60			

KEY PADS

Key pad is an electronic product that - when it is connected to electrical vehicle system consisted of AC controller, EPAS/EPS steering system, vehicle master control unit and display - gives us the opportunity to replace the key switch and allows log in. Through the CANOpen network we receive different information regarding the system and driving modes.

Features
- Key switch replacement
- Login with appropriate password as:
  - Administrator
  - User
- Demanded length of the password: 4 characters
- Max number of the users: 200
- Last 2000 transactions will be retained in the data bank. (A transaction is a record between one login and logout).
- Automatic logout when the lift truck is stopped (after few minutes)
- Automatic STOP mode when the lift truck is in log off state (after few minutes)
- Secure lock “out time” after 5 (default value) tamper attempts;
- Information recorded and seen on display:
  - Driver (PIN)
  - Trip distance
  - Date and time (at login)
  - Traction time
  - Pump time
  - Log on time
  - Crash sensor (Optional)
  - Crash counter (Optional)

Applications

Built in electrical vehicle drive system

Main technical data

Type	AED
Nominal voltage (V)	24
Nominal current (when replaced key switch) (A)	15
Communication type	CANOpen 4.0.2
Ambient temperature (°C)	-30 to +45

Key pads

DRIVER DIAGNOSTIC DISPLAY (DDI)

When display is connected to electric system consisted of AC controller, EPAS/EPS steering system, and vehicle master control unit, it enables us to see different information regarding the system.

Information seen on display

- Traction mode indication
- Battery discharge status
- Error code numbers
- Four different hour meters
- Which dig. inputs of AC controller are momentarily active (connected)
- Which dig. inputs of vehicle master control unit are momentarily active (connected)
- Software versions of all components connected in truck system
- EPAS torque, steering angle, battery current, battery voltage, AC motor voltage, phase currents, controller temperature, motor temperature...
- List of software parameters
- UL design available on request

Main technical data

Type	AEB
Nominal voltage (V)	12, 24, 36
Communication type	CANOpen 4.0.2
Ambient temperature (°C)	-20 to +60

Driver diagnostic display

VEHICLE MASTER CONTROL UNITS (MCU)

Vehicle master control unit is a type of a master unit that when it is built in an electric vehicle makes through hardware and CANOpen network request for appropriate vehicle operation.

Functions

- Sending request to controller for speed and rotating direction of traction motor
- Sending request to controller for speed of DC pump motor
- Sending request to controller for PWM on proportional valve
- Sending request to controller for belly switch function activation
- Sending request to controller for horn activation
- Sending request to controller for snail switch function activation
- Sending information to controller of steer angle
- Sending information to EPAS system of truck speed
- All messages to DDI display for different pictures are sent by MCU electronics
- Software parameters can be reprogrammed with appropriate use of switches on tiller head
- UL design available on request

Main technical data

Type	AED
Nominal voltage (V)	24
Communication type	CANOpen 4.0.2
Ambient temperature (°C)	-20 to +55

Vehicle master control units

MOTOR REQUIREMENTS FORM

Company: _____

Address: _____

Application

☐ Driving pump ☐ Winch ☐ Traction motor ☐ Steering

☐ Other: _____

Ambient conditions

Temperature range:

from _____ to _____ °C

Electrical and mechanical requirements

Nominal ratings:

☐ 12 V ☐ 24 V ☐ 36 V ☐ 48 V ☐ 72 V ☐ 80 V ☐ 96 V

Speed n_n = _____ RPM

Current I_n = _____ A

Torque T_n = _____ Nm

Power P_n = _____ kW

S2 = _____ min

S3 = _____ % ED

S1 = _____

Maximal load:

Current I_{max} = _____ A

Torque I_{max} = _____ Nm

S2 = _____ min

S3 = _____ % ED

Maximal no - load speed:

N_{max} = _____ RPM

Direction of rotation:

View from drive end of shaft

☐ ← ☐ ↔ ☐ →

Excitation:

☐ Series wound ☐ SEM – Sepex

☐ Parallel wound ☐ Split field

☐ Compound wound ☐ AC

☐ Permanent magnets ☐ BLPM

Operating mode

1 cycle is _____ s ON and _____ s OFF

at I = _____ A and U= _____ V

Encoder

Encoder type: _____

No. of pulses: _____

Insulated ground

☐ Yes ☐ No

Insulation

Insulation strength _____ V_{RMS} per 1 min.

Insulation resistance > _____ Mohm

Special electrical requirements

_____

_____

_____

Design requirements

Max diameter _____ mm

Max length _____ mm

Grade of protection according (din 40050)

IP _____

External appearance

☐ Black varnished ☐ Zinc plated

☐ Other _____

Dimensional requirements

(specify / sketch) or enclose drawing

_____

_____

Environmental conditions

☐ Salt spray ☐ High temperatures

☐ Humidity ☐ Dust

☐ Other _____

Environmental conditions

Safety standard: _____

Specification standard: _____

(please add copies)

Date: _____ Signature: _____

Return this form by Fax to 00 386 5 33 93 817

CONTROLLER REQUIREMENTS FORM

Customer: _____

Address: _____

Applications

☐ Traction ☐ Traction & Pump ☐ Pump ☐ Traction & Hydraulic valve ☐ Steering

Type of system

☐ DC Series wound ☐ AC ☐ BLPM ☐ Other

Technical requirements

Voltage range _____ V
Max current limit _____ A
Operating frequency _____ kHz
Acceleration slope _____ s
Deceleration slope _____ s
No. of analogue inputs _____
No. of analogue outputs _____
No. of digital inputs _____
No. of digital outputs _____
Operating temperature _____ °C
Protection _____ IP

Accelerator type

☐ Classic resist ☐ Hall ☐ Optical ☐ Other

Communication type

☐ RS 232 ☐ RS 485 ☐ CAN ☐ Other

Programming device type

☐ Programming console ☐ PC ☐ Other

System diagnostics

☐ PC ☐ Programming console ☐ Battery discharge indicator ☐ Error indicator ☐ Hour-meter

Functional requirements

Constant torque braking
☐ YES ☐ NO

Constant distance braking
☐ YES ☐ NO

Brake on pedal release
☐ YES ☐ NO

Brake on direction invert
☐ YES ☐ NO

Accelerator position follower
☐ YES ☐ NO

Additional brake pedal input
☐ YES ☐ NO

Field weakening option
☐ YES ☐ NO

Difference speed load/no-load
☐ YES ☐ NO

Speed loop
☐ YES ☐ NO

Speed limit input (s)
☐ YES ☐ NO

Additional inputs
☐ YES ☐ NO

Electromagnetic brake drive
☐ YES ☐ NO

Main contactor drive
☐ YES ☐ NO

Proportional valve drive
☐ YES ☐ NO

Real time clock
☐ YES ☐ NO

Time to service counter
☐ YES ☐ NO

Error history
☐ YES ☐ NO

Software in-field update
☐ YES ☐ NO

Date: _____ Signature: _____

Return this form by Fax to 00 386 5 33 93 817

VEHICLE REQUIREMENTS FORM

Customer: _____

Address: _____

Truck data

Truck model _____

Truck weight with battery _____ kg

Truck rated load _____ kg

Truck system voltage _____ V

Drive wheel material _____

Drive wheel diameter _____ mm

Gear ratio _____

Rolling resistance - estimated _____ %

Transmission efficiency _____ %

Type of gear _____

Traction motor

No. of motors on the truck _____

Type of motor on the truck

☐ DC ☐ AC ☐ Other

Max truck speed at no load _____ km/h

Truck speed with rated load _____ km/h

Truck gradeability - no load _____ % at speed _____ km/h

Truck gradeability - rated load _____ % at speed _____ km/h

Traction motor controller

Controller model _____

Max field current (DC motors) _____ A

Min field current (DC motors) _____ A

Max armature current (DC Motors) _____ A at S2= _____ min

Max phase current (AC Motors) _____ A at S2= _____ min

Pump motor

Type of pump motor

☐ DC ☐ AC

Pressure at no load _____ bar

Pressure at rated load _____ bar

Type of operation S3 _____ %

Max pressure _____ bar

Oil flow at no load _____ l/min

Oil flow at rated load _____ l/min

Pump capacity _____ ccm/rev

Pump motor controller

Controller model _____

Max field current (DC motors) _____ A

Min field current (DC motors) _____ A

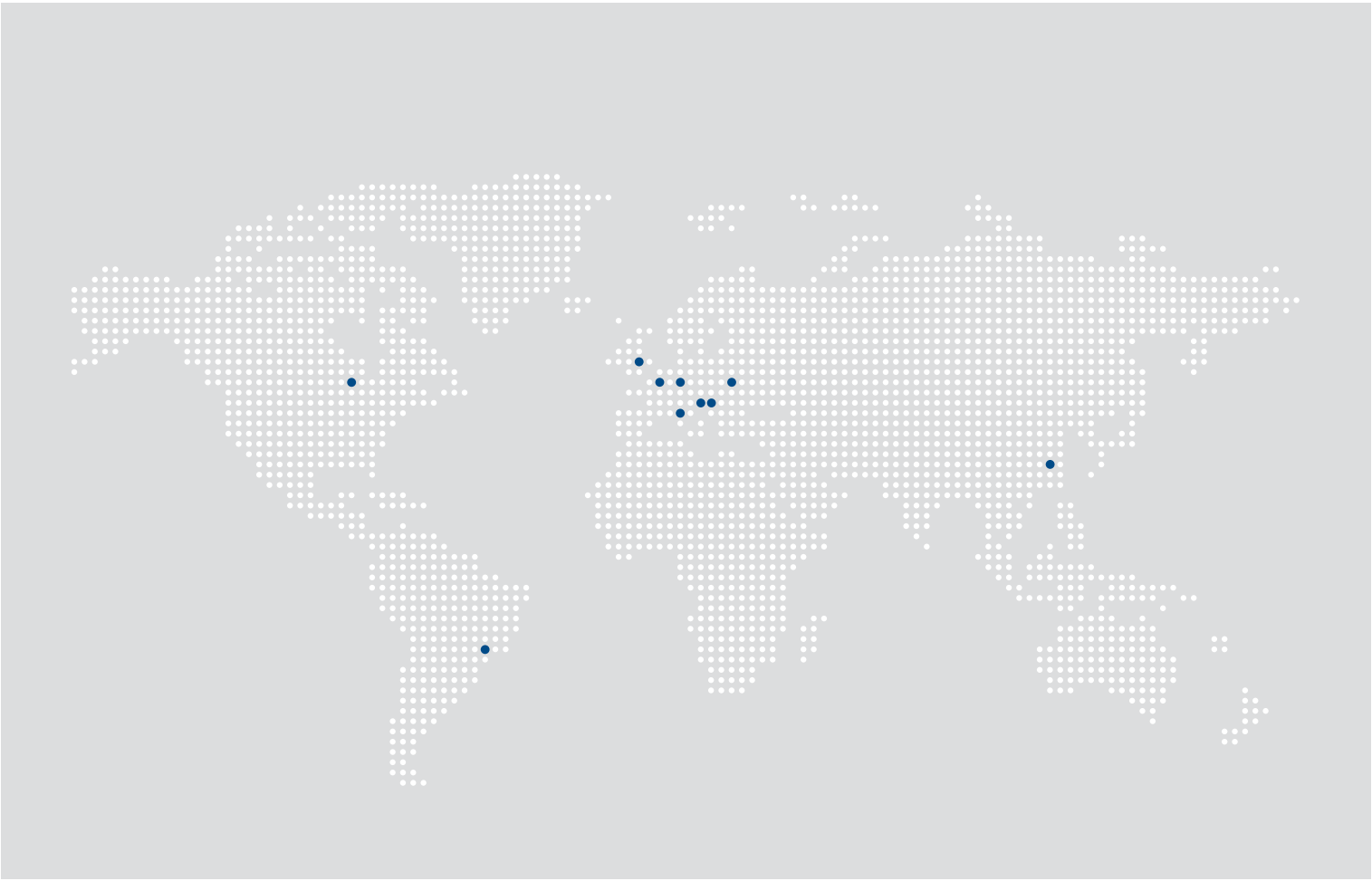
Max armature current (DC Motors) _____ A at S3= _____ %

Max phase current (AC Motors) _____ A at S3= _____ %

Date: _____

Signature: _____

Return this form by Fax to 00 386 5 33 93 817



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