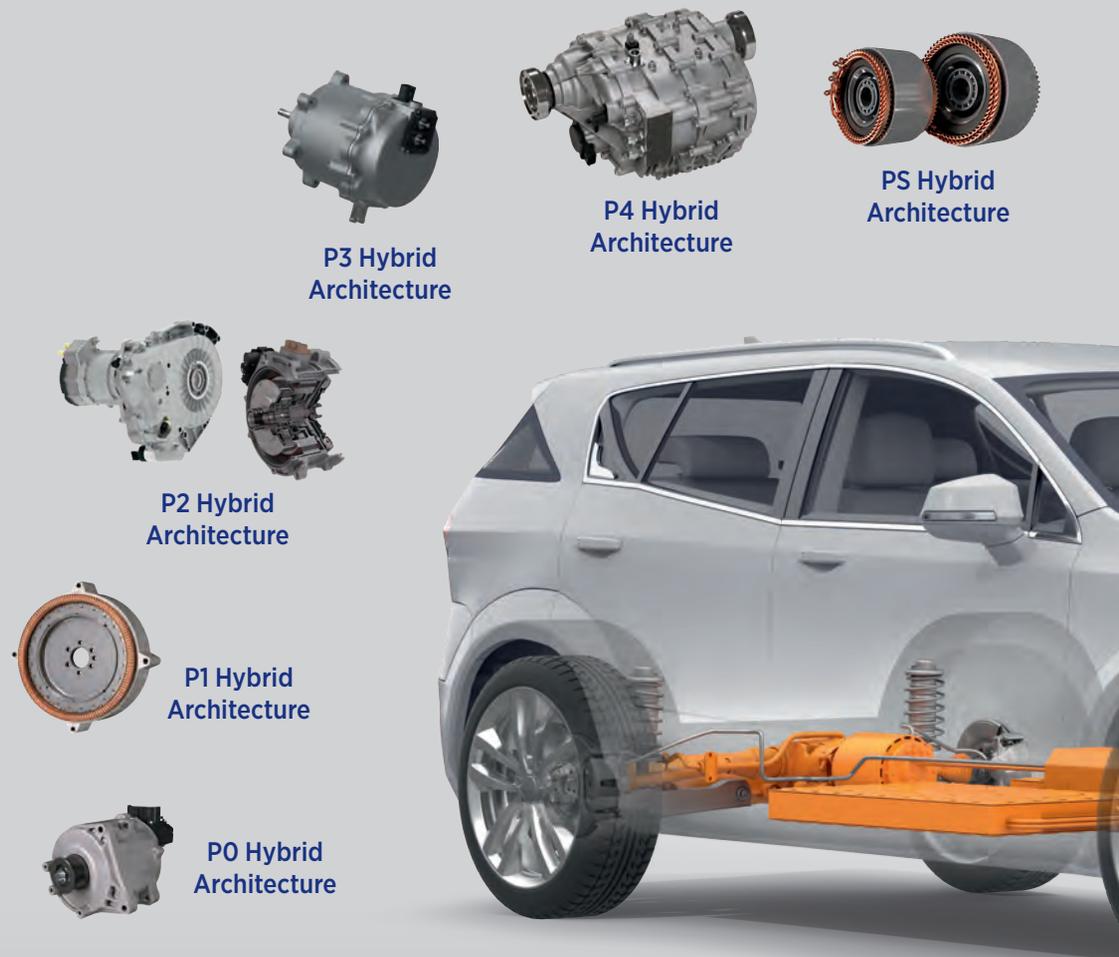




Hybrid

Hybrid Vehicle Technologies

We make vehicles generate energy – simply by driving.



Mild, full or plug-in hybrid technology is on the rise globally – opening up a vast array of potential drive architectures. Applicable for both the light and commercial vehicle markets, our creative solutions allow automakers flexibility in committing to propulsion technologies. With an equally comprehensive product portfolio, we offer vehicle manufacturers across the globe advanced solutions for all concepts.

With a broad range of knowledge and expertise, we are uniquely positioned to offer products in a variety of fields, including electric motors, power electronics and mechanical components. Seamlessly integrated into existing vehicle architectures, our products offer simplified hybridization options for automakers to expand their vehicle portfolios with less investment and more flexibility. With options for both on- and off-axis approaches, our techno-



Power Electronics



Battery Modules and Packs



Exhaust Gas Management



Thermal Management



Electric Boosting Technologies



logy allows fast-to-market hybridization for existing drivetrains.

Whether exhaust gas and thermal management, electric boosting, hybrid modules, or battery technology, our solutions provide critical advancements in fuel efficiency and emissions reductions. While delivering significant improvements for the internal combustion engine, our products also

support engine stop/start, regenerative braking and acceleration assist, among other benefits. With a focus on hybridization, we continue to innovate toward an increasingly clean, energy-efficient world.

Electric Boosting Technologies

BorgWarner turbochargers have been renowned for their exceptional efficiency for decades. Our electrically operated eBooster® and eTurbo™ turbocharging systems facilitate further significant improvements for the internal combustion engine in terms of fuel economy, emissions, and power delivery. Designed as powerful booster compressors in the 48V on-board power supply system, they improve both dynamic performance and fuel efficiency, particularly at low engine speeds.



eBooster® Electrically Driven Compressor

BorgWarner's eBooster® electrically driven compressor supplements conventional turbocharging systems. Placed either upstream or downstream of the regular turbocharger, the eBooster solution improves boost pressure and transient engine response at low engine speeds. In doing so, the technology virtually eliminates turbo lag.

FEATURES AND BENEFITS

- Reduced turbo lag: better low rpm engine torque, faster time-to-torque
- Smaller engine or lower speed engine can be used and have acceptable levels of torque and response
- Fuel economy improves due to downsized or lower speed engine



eTurbo™

Equipped with an ultra-high-speed electric motor, BorgWarner's next milestone in boosting technologies, the electrically-assisted turbocharger eTurbo™, can either enhance performance by adding torque to the turbine shaft or recuperate electrical energy from the exhaust gas flow.

FEATURES AND BENEFITS

- Single-machine solution for electrified boost assistance and recuperation
- Reduced turbo lag: better low rpm engine torque, faster time-to-torque
- Smaller engine or lower speed engine can be used and have acceptable levels of torque and response
- Fuel economy improves due to downsized or lower speed engine
 - Reduced P3 can improve engine pumping losses
- Wasted exhaust energy is converted to electrical energy
- Permanent-magnet high temperature motor
- 48V, 400V and 800V options available
- Power ranges from 3kW to 80kW including continuous operation
- Water and oil-cooled design
- Corresponding power electronics controller also available



eTurbocompound

Even though modern turbocharged combustion engines are remarkably efficient, useful energy can still be found in the exhaust gas flow. Positioned downstream of the after-treatment system, BorgWarner's turbine-driven, water-cooled generator eTurbocompound uses the remaining waste heat to generate electrical energy.

FEATURES AND BENEFITS

- Converts wasted exhaust energy to electrical power downstream of the aftertreatment (gives thermal priority to the aftertreatment)
- In certain conditions it can backpressure the engine slightly, aiding in driving the EGR to lower emissions
- The machine is oil-free so that it can be mounted far away and low (relative to the engine)



Organic Rankine Cycle Turbines/Pump-expanders

To make use of fuel energy wasted as heat during the combustion process, BorgWarner developed the Organic Rankine Cycle (ORC) waste heat recovery system. Combining multiple technologies such as a heat exchanger within an optimized overall package, the ORC generates electrical power while recovering about 50 percent of the energy wasted as heat.

FEATURES AND BENEFITS

- A broad product portfolio and system-level approach allow BorgWarner to maximize overall performance and durability at the lowest cost
- Proprietary software tools enable rapid specification to a customer's engine requirements
- System-level simulations, controls and testing have resulted in numerous design enhancements
- BorgWarner ORC components have run hundreds of hours on proprietary ORC system test rigs

Exhaust Gas Management

Modern engines make use of their exhaust gas in a variety of ways. Most commonly, the gas is recirculated in order to reduce combustion temperatures and thus reduce emissions. As a product leader, we are uniquely positioned to produce all EGR components, allowing us to design and develop fully integrated EGR systems.



EGR Modules

BorgWarner provides compact and highly efficient solutions, reducing fuel consumption and the associated CO₂ emissions, including exhaust gas recirculation (EGR) modules, valves and coolers.

FEATURES AND BENEFITS

- Compact gas side cross sections with interchangeable heat exchange technologies, lengths and interfacing connections
- Highly adaptable to different voltage, torque and power requirements
- Thermal decoupling of the tubes and shell with the floating core design
- Significant increase in thermal fatigue durability
- Less coolant flow is required to maintain product function and durability
- Low gas side and coolant side pressure drop
- High resistance to fouling



Exhaust Heat Recovery System

Energy recovery is a key player when it comes to increasing the efficiency of hybrid and combustion vehicles. BorgWarner's exhaust heat recovery systems transfer the heat that would normally go out the exhaust pipe to the vehicle's coolants and oils to reduce mechanical losses and increase passenger comfort.

FEATURES AND BENEFITS

- Heat exchanger with corrugated tube technology
- Pneumatic bypass valve
- Improves fuel economy during engine warm-up
- Flexible packaging and architecture
- Increases passenger comfort
- Significant fuel economy for full HEV/ PHEV
- Applicable to "off-cycle" credits
- Passenger comfort & security
- Low gas side and coolant side pressure drop



Organic Rankine Cycle Boilers

By principle, some fuel energy is wasted as heat during the combustion process. In order to recover some of this energy from the exhaust gas flow, BorgWarner's Organic Rankine Cycle (ORC) waste heat recovery systems utilize a heat exchanger to generate electrical power.

FEATURES AND BENEFITS

- Recovers part of the fuel energy wasted in heat rejection
- Improves FE and CO₂ generation from commercial vehicle on-highway long-haul trucks
- Potential fuel economy reduction of 3-5%
- Helps meet 2018+ CO₂ legislation in NA & EU
- Utilizes exhaust gas recirculation (EGR) technology best practices
- Other potential BorgWarner products in the system



P0 Hybrid Architecture

As components of the P0 hybrid architecture, BorgWarner's High Voltage Belt Integrated Starter Generator (BISG) and Belt Tensioner replace the alternator and allow for a silent engine start, while reducing the impact on the belt drive.



High Voltage Belt Integrated Starter (P0) Generator (BISG)

BorgWarner's Belt Integrated Starter Generator helps to reduce the reliance on the ring gear starter and features a variety of benefits, including engine stop/start, regenerative braking and torque assist.

FEATURES AND BENEFITS

- Motoring & generating capability
- Air-cooled, 125°C ambient inlet/liquid-cooled (WEG), 75°C inlet, 8 l/min
- ASIL capable with CAN communication
 - Compact size: 165 mm OD X 172 mm length
 - Rotor inertia (Kg-cm²): 45 (48V), 57 (240V)



Belt Tensioner

Belt Tensioner for P0 hybrid vehicles applications allows energy input or recuperation on a variety of engine platforms. By tuning the damping and the stiffness of the tensioner, the full capability of boosting and regenerating is achieved over all working conditions of the engine and electrical machine. Load transfer from inlet to outlet belt strand allows minimum preload on the system.

FEATURES AND BENEFITS

- Best-in-class mass and package size
- Sealed design protects internal components for improved durability and performance
- Flexible mounting options
- Designed to maximize system controllability under all working conditions
- Can be tuned for the optimum damping performance
- Easily scalable based on torque of electrical machine

P1 Hybrid Architecture

Positioned between the engine and transmission, the P1 hybrid architecture and High Voltage Integrated Starter Generators (HV ISG) enable high-efficiency power generation while featuring regenerative braking and acceleration assist.



High Voltage Integrated Starter Generators (HV ISG)

This hybrid technology enables high-efficiency power generation and motoring capability in a highly flexible package designed to fit between the engine and transmission.

FEATURES AND BENEFITS

- Permanent magnet rotor
- BorgWarner S-wind stator technology
- Air/oil/WEG cooling options available
- Highly adaptable to different voltage, torque and power requirements



P2 Hybrid Architecture

In order to support the transition to cleaner and more efficient vehicles, BorgWarner offers its P2 module for hybrid electric vehicles (HEVs). The company's highly flexible technology facilitates fast-to-market hybridization by enabling pure electric driving as well as hybrid functionalities such as stop/start, regenerative braking and supplemental electric propulsion.

By uniting all required components in a compact package, BorgWarner's advanced solution can easily be implemented in existing drivetrains, enabling high degrees of existing capital utilization and hybrid volume flexibility for automakers. Furthermore, both configurations of the company's P2 module provide significant CO₂ emission reductions with low added costs compared to other hybrid architectures.



P2 Hybrid Module – On-Axis

BorgWarner's P2 module converts a combustion-powered vehicle into a hybrid without changing the engine or transmission. That means automakers can easily expand their vehicle portfolio with less investment and more flexibility. Placed between the engine and transmission, the highly efficient P2 module combines a high voltage or 48V electric traction motor, engine disconnect clutch, launch device and dual mass flywheel into a compact package nested inside the motor.

FEATURES AND BENEFITS

- Compact hybrid module combining:
 - High voltage or 48V electric motor
 - Disconnect clutch
 - Up to triple clutch
- 350Vdc nominal operating system
- Different length configurations available
- P2 hybrid function – CO₂ savings
- 270 mm stator OD
- Integrated triple clutch system
- Compact coaxial package with short overall length
- 95% peak efficiency



P2 Hybrid Module – Off-Axis

BorgWarner's P2 module is also offered as an off-axis option, allowing for reduced powertrain axial length through a chain driven, off-axis motor.

FEATURES AND BENEFITS

- Self-contained P2 off-axis drive module for reduced powertrain axial length and electric motor modularity (48V/HV)
- Disconnect clutch with chain driven off-axis motor
- 48 V: 130 mm MG_i with WEG cooled motor and integrated power electronics
- HV: 146 mm MG_U with WEG (liquid-cooled)
- Less axial length increase as compared to on-axis P2
- Propulsion Chain has no power limitation
- Self-contained wet enclosure
- Replaces starter; can also drive AC compressor



Wet Disconnect Clutches

The BorgWarner HEV (Hybrid Electric Vehicles) Disconnect Clutch Modules series is based on the BorgWarner CCF (Common Clutch Family) system. This approach provides the flexibility to easily adapt the HEV Disconnect Clutch Module design to specific customer torque requirements.

FEATURES AND BENEFITS

- Designed for easy torque capacity adaptation
- Part of BorgWarner CCF series kit
- BorgWarner friction technology inside
- Improved fuel economy
- Adaptation to different transmission types
- Possibility for integration in existing transmission fluid environment
- Continuous slip capability
- Effective packaging
- Cost solution to upgrade transmission to hybridization
- Applicable to AT, CVT or DCT
- High durability



Hydraulic Controls

BorgWarner's electro-hydraulic control systems technology is integrated into the P2 module and exceeds customer expectations through a variety of systems benefits.

FEATURES AND BENEFITS

- Precise disconnect clutch control
- Flexible disconnect clutch lubrication control
- On-demand & conventional control strategies supported
- Integrated into main hydraulic control module or P2 Drive Module



Power Transmission Chain

BorgWarner's Power Transmission Chains provide an off-axis approach to hybridization with minimal axial package impact. While offering simple integration into existing transmission designs, the chains are highly efficient and reduce mass and NVH levels.

FEATURES AND BENEFITS

- Chain Drives achieve 99%+ efficiency in most conditions
- Proven NVH in OE systems with the ability to tune the chain frequency response to the application
- Easily spans long center distances, eliminating need for complex gear drives
- Simplified loading provides opportunities for reduced manufacturing and assembly costs

P3 Hybrid Architecture

BorgWarner's 48V Motor Generator and eRDM help to generate electrical power and enable torque vectoring within a vehicle. Positioned after the transmission output, the P3 hybrid architecture allows for simple integration into a variety of applications.



48V Motor Generator with Integrated Electronics (MGI)

This mild hybrid considerably reduces the cost of electrification when compared to high voltage hybridization and pure EV. The 48-volt technology provides higher system efficiency and improved energy recovery capability to meet increasing power demands.

FEATURES AND BENEFITS

- 48V motor generator to regenerate electrical power and motoring capability to engine crank with Integrated Power Electronics
- Direct drive, chain drive, belt drive, or integrated options
- Multiple electromagnetic variants exist to meet varying performance requirements
- Capable of up to 25kW input/output
- 4-quadrant motor drive
- 125°C ambient
- Liquid-cooled
- Compact size (dimensions excluding interfaces)
 - 150 – 180 mm OD X 200 mm length
- 20,000 max rotor speed
- Elimination of Phase Cables



eRDM with Electrical Torque Vectoring

Torque vectoring goes electric with BorgWarner's eRDM, which combines torque vectoring with full-function mechanical AWD for maximum vehicle stability. Front wheel drive vehicles can be transformed to AWD with the company's latest AWD coupling with integrated electric actuators.

FEATURES AND BENEFITS

- Electrical torque vectoring system
- Optional mode-switch to enable hybrid mode for CO₂ savings (P3 Hybrid)
- For mechanical drivelines or electric axles
- 48V or high voltage
- P3 HEV architecture with modular functionality
- Superior vehicle dynamics with electrical torque vectoring
- Lower losses than clutch-based TV systems
- Significant CO₂ savings (~10 – 20 g CO₂/km) with optional hybrid mode
- Enables creep and sailing at low speeds

P4 Hybrid Architecture

The AWD Coupling product portfolio provides a wide range of electronically-controlled, on-demand AWD coupling, as well as driveline disconnect solutions. Both electro-hydraulic and electro-magnetic clutch actuation technologies and controls deliver outstanding vehicle traction and handling performance.



48V eAWD

BorgWarner's eAWD is an innovative rear axle drive concept for hybrid and pure electrical vehicles, with optional torque vectoring to improve stability and vehicle dynamics.

FEATURES AND BENEFITS

- Compact 1 or 2-speed options, 48V secondary electric drive axle capable of regeneration/boost and limited AWD (P4 HEV)
- Capable of:
 - Regenerative braking
 - Creep capable for sustained stop/start
 - Rear axle launch assist torques of 1,500 Nm
 - Highway sailing sustained torque of 340 Nm
- 7% FE gain in addition to 48V BAS equipped vehicle (simulated)
- Deliver improved FE/CO₂ improvement
- Enables engine downsizing
- Lower cost compared to higher voltage systems
- Estimated to be cost and mass neutral compared to conventional mechanical AWD
- Eliminates PTU, propshaft tunnel, and driveshaft
- P4 system enables AWD capability up to disconnect speed
- Simplified vehicle integration and packaging



High Voltage eAWD

BorgWarner's High Voltage eAWD is integrated onto the secondary drive axle and provides through-the-road hybrid drive for emissions and fuel economy improvement.

FEATURES AND BENEFITS

- On-axis electric secondary drive axle (P4)
- Through-the-road hybrid drive for improved fuel economy and AWD
- High voltage
- P4 hybrid function - CO₂ savings
- Integrated e-machine disconnect
- Compact coaxial package
- >20% fuel economy gain + AWD

PS Hybrid Architecture

The Power Split Hybrid is an innovative solution which integrates a motor and generator into a vehicle's transmission. With engine stop/start and regenerative braking potential, the Power Split Hybrid allows for drastic increases in fuel economy.



High Voltage Permanent Magnet (PM) Machines

The HVH and S-wind motor lines are powerful, durable and rugged electric motor/generators for use in on- and off-highway vehicles, power generation and other special high power demand applications.

FEATURES AND BENEFITS

- Peak efficiencies >95 %
- Designed with 120 years of automotive experience for ultimate reliability
- World class power density
- Multiple electromagnetic variants to meet a range of applications
- Global sales and tech support



Friction Plates

BorgWarner's proprietary friction materials withstand high-energy events, allowing the friction plate to hold higher torque without slipping.

FEATURES AND BENEFITS

- Optimized groove patterns between segments of friction material to increase oil flow
- Improves cooling
- Prolongs clutch life
- Drag and spin improvements, resulting in increased fuel economy

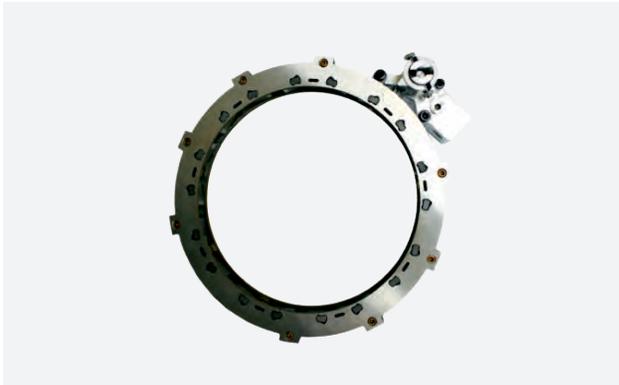


Solenoids

The BorgWarner Proportional Direct-Acting Solenoid is a high-flow device designed for the direct control of shifting and launch clutches. It is available in both normally low and normally high pressure configurations, as well as multiple hydraulic and electric interfaces.

FEATURES AND BENEFITS

- Highly precise, high flow
- 3-way solenoid for direct clutch control
- Low hysteresis, excellent stability, fast response
- Very low sensitivity to supply pressure and temperature
- Effective where the challenging creep control function of launch clutches is required



Multi-mode Clutches

The BorgWarner Multi-Mode Clutch is a multi-mode rotation device. The flexible clutch design can provide up to four different modes and combinations: Overrun Mode, Lock Mode, One-way Clockwise Mode, and One-way Counter Clockwise Mode.

FEATURES AND BENEFITS

- Improved fuel economy
- High torque capacity
- Flexible engagement control
- Better shift feel
- Lower system total mass
- Lower rotating mass
- Optimal fail-safe mode cam plate flexibility
- Centrifugally engaging or disengaging locking elements
- Simplified manufacturing
(Bearing grade steels NOT required)
- Small cross-section requirements – axially and radially
- Can reduce total number of clutches in transmission
- Can be used for either rotating or stationary clutch applications or as a friction clutch backing plate
- Has best-in-class hydraulic response
- Electro-mechanical actuation available

Thermal Management

A keen market sense coupled with tightly aligned processes, manufacturing excellence and fast implementation makes BorgWarner a market and product leader. Our thermal management systems are designed to meet the needs of our global customers while also improving fuel economy and reducing emissions.



Battery Heaters

BorgWarner electrical Battery Heaters provide rapid heating of passenger compartments for both electric and hybrid vehicle (high-voltage) applications. Designed for placement within cooling water systems, these innovative heating units offer a “plug and play” module solution with no secondary costs shifted to the OEM.

FEATURES AND BENEFITS

- Operating voltage: 250 – 500V
- Heating power range: 5 – 9 kW
- Thick Film Heating Element technology
- No local overheating
- ASIL B/C safety capability
- Compact dual-plate heater design achieves efficiency > 97 %
- Closed loop control
- LIN communication



Cabin Heaters

BorgWarner’s Cabin Heater quickly warms the vehicle’s interior and provides enough power to de-ice the windshield. Proprietary designs deliver industry-leading safety performance. True dual zone heating and full power delivery with low air turbulence provide passenger comfort with minimal energy use for extended battery-powered driving range.

FEATURES AND BENEFITS

- Operating voltage: 250 – 500V
- Heating power range: 3.7 – 6.7 kW
- Odorless heating
- PTC stone-based heaters intrinsically safe against overheating
- Compact, modular packaging
- Quick, efficient heating for extended battery-powered driving range
- Low air turbulence for nearly silent operation
- Continuously adjustable heating control
- Dual zone driver/passenger controls
- CAN and LIN communication

Battery Modules and Packs

BorgWarner's Battery Modules deliver crucial improvements in driving range and charging time for the next generation of vehicles. Developed with thermal management expertise, these modules provide leading performance and a scalable design for automakers.



Battery Module

BorgWarner's compact battery packs for plug-in hybrid and electric vehicles perform better and last longer thanks to industry-leading energy density and battery management.

FEATURES AND BENEFITS

- Intelligent battery management systems with proprietary algorithms for enhanced performance and cycle life
- Proprietary thermal engineering for active and passive cooling
- Scalable design means faster go-to-market for customers with custom modules
- Highest energy density, longest range and fastest charging time
- 2,000+ cycles
- 10+ years
- 300,000 miles



Power Electronics

Our range of motor controllers utilizes a highly-flexible control logic architecture to deliver a unique, feature-rich set of functions and is well-matched to satisfy automotive, commercial and construction markets' electrification needs.



High Voltage Motor Controllers

BorgWarner offers two voltage family classes of 400V and 800V. The High Voltage Motor Controllers are a new family of AC Motor Controllers/Inverters designed to meet the high performance requirements of on-road and off-road electric (EV) and hybrid electric vehicles (HEV).

FEATURES AND BENEFITS

- 3-phase 400V and 800V product ranges
- Applications: iDM, P1, P2, P4, PS
- High performance field-oriented control for permanent magnet or induction machines
- High efficiency
- Continuous power range: 55 - 120 kW
- Peak power: 120 - 250 kW
- Nominal voltage: 350/800V
- Flexible and robust design for integrated applications
- Flexible and full ability to calibrate AUTOSAR motor controls, SW and diagnostics
- DPWM, SVPWM and Six-Step switching options for performance optimization
- Automotive standard diagnostics and current and voltage protection
- ISO 26262; 16750 and 6469 compliant





48V Motor Controllers

BorgWarner offers a family of three-phase 48-volt high power AC Motor Controllers designed to meet the high performance requirements of on-road and off-road electric (EV) and hybrid electric vehicles (HEV).

FEATURES AND BENEFITS

- Applications: P0, P1, P2, P3
- High performance field-oriented control for permanent magnet or induction machines
- High efficiency
- Continuous power: 12 kW
- Peak power: 25 kW
- Nominal voltage: 350/800V
- Flexible and robust design for integrated applications
- Flexible and full ability to calibrate AUTOSAR motor controls, SW and diagnostics
- DPWM, SVPWM and Six-Step switching options for performance optimization
- Automotive standard diagnostics and current and voltage protection
- ISO 26262; 16750 and 6469 compliant



Paving the way for a clean, energy-efficient world.

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