

# Driving Electromobility







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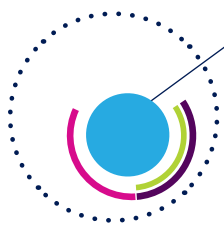
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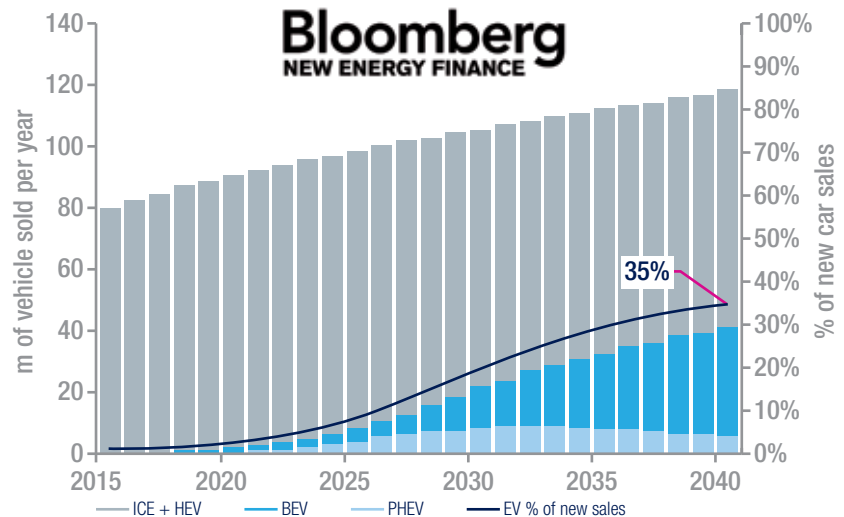
# The evolution of electromobility



## Electromobility is gaining momentum

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Electric vehicles recently have evolved from a niche solution to a reasonable alternative for mobility in the 21<sup>st</sup> century. On one hand, traditional combustion engine solutions are heavily criticized for their pollution; while on the other, technologies for batteries and electronics are reaching performance and maturity levels that allow viable economic solutions for customers. In addition, the infrastructure for charging electric vehicles is becoming denser and more efficient, allowing longer travel distances for users.



Furthermore, strong anti-pollution rules in all parts of the world as well as access limitations to city centers lead to a strong increase in the demand for electrified vehicles.

But electrification does not mean only 100% electric vehicles. It includes traditional combustion engine vehicles with start-stop functions at the 12 V level and vehicles equipped with extended start-stop functions and certain electric drive characteristics up to mild-hybrid vehicles with voltages up to 48 V. Cars equipped with such systems will offer drivers their first electric vehicle experience beginning with short distances that are usually needed for going to and from work.

Longer distances will still require diesel- or gasoline-powered systems until battery and charging technologies can offer the right autonomy in a not so far away future.

This market revolution is also reflected in the many studies by market research institutes all over the world. Bloomberg sees EV sales rising up to 35% in 2040, with significant growth starting around 2025.

Until then, a number of technological, technical, industrial and logistical issues have to be solved.

Users of electric vehicles will expect the same level of reliability in EVs as in traditional cars at the same cost. This will require important investments in the next years in order to reach the same maturity level for EV components as for ICE components.

STMicroelectronics is currently working in all areas of semiconductor technology in order to make this market revolution happen.

It concerns first of all the development of more efficient and less expensive power electronics solutions for all voltage levels between 12 and 900 V (1200 breakdown) including in particular the aspects of quality, functional safety, robustness, lifetime, reliability, availability and cost.

As a system solution and service provider in contact with many partners and customers, ST has a wide overview and experience in the development of custom-tailored component solutions.

Strongly integrated in the industrial ecosystem, ST is driving technology development of semiconductor technology and accompanying components like passives as well as industry standards through collaborative projects and active membership in a variety of national and international organizations.



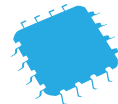
Quality-minded with state-of-the-art tools for die selection



In-house manufacturing capabilities for best wafer quality, low defect rates



Pioneer in Functional safety (ASIL-D compliant products)



Packaging know-how in particular for high temperatures



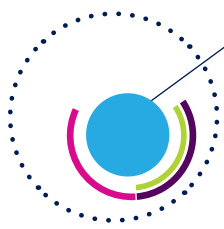
Flexible solution for customers (Bare dies or modules)



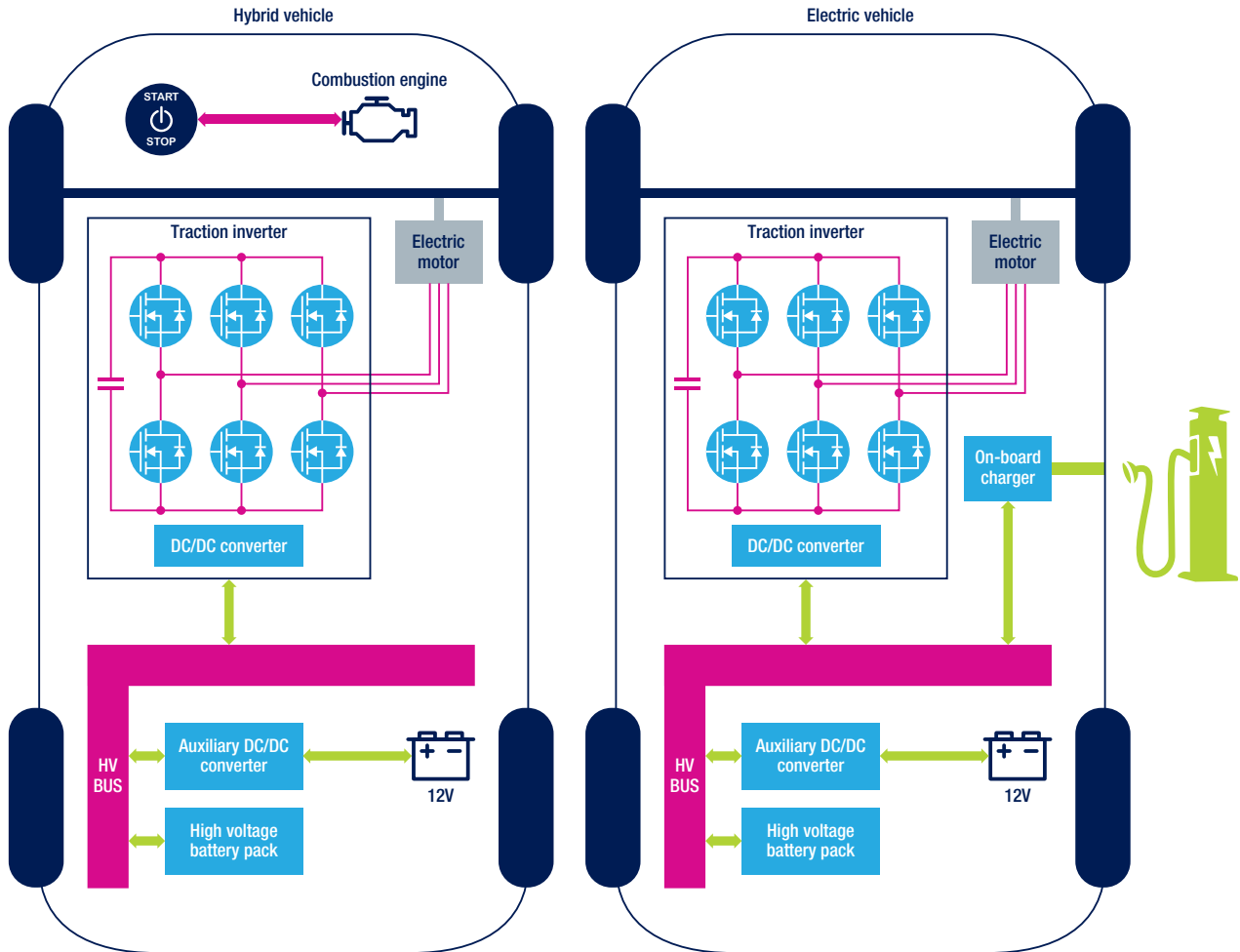
From service to guidance our teams help you to find the right answers to your questions



Leader in Power Electronics for more than 30 years



# (H)EV Systems



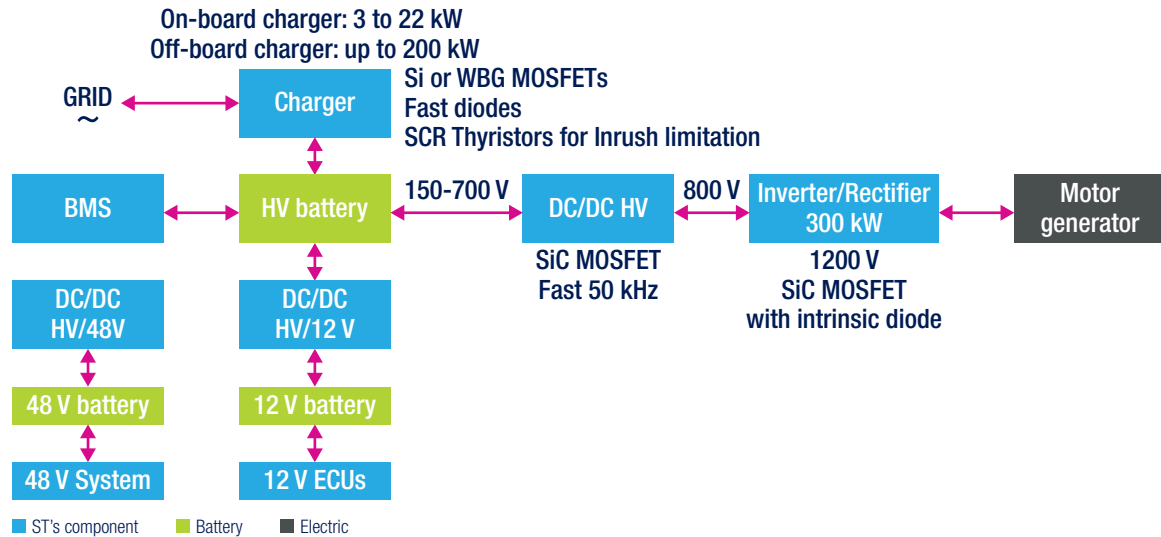
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For a semiconductor supplier, there is little difference between a hybrid electric vehicle (HEV) and a full electric vehicle (EV or FEV). In both cases, our components are used for motor or gear box controls, ignition or field controls, or power management.

For HEVs, the power management is autonomous, meaning that there is usually no interaction with the electric grid. This is different for EVs, where there needs to be a uni- or bidirectional charger and an interaction with the energy provider for billing.

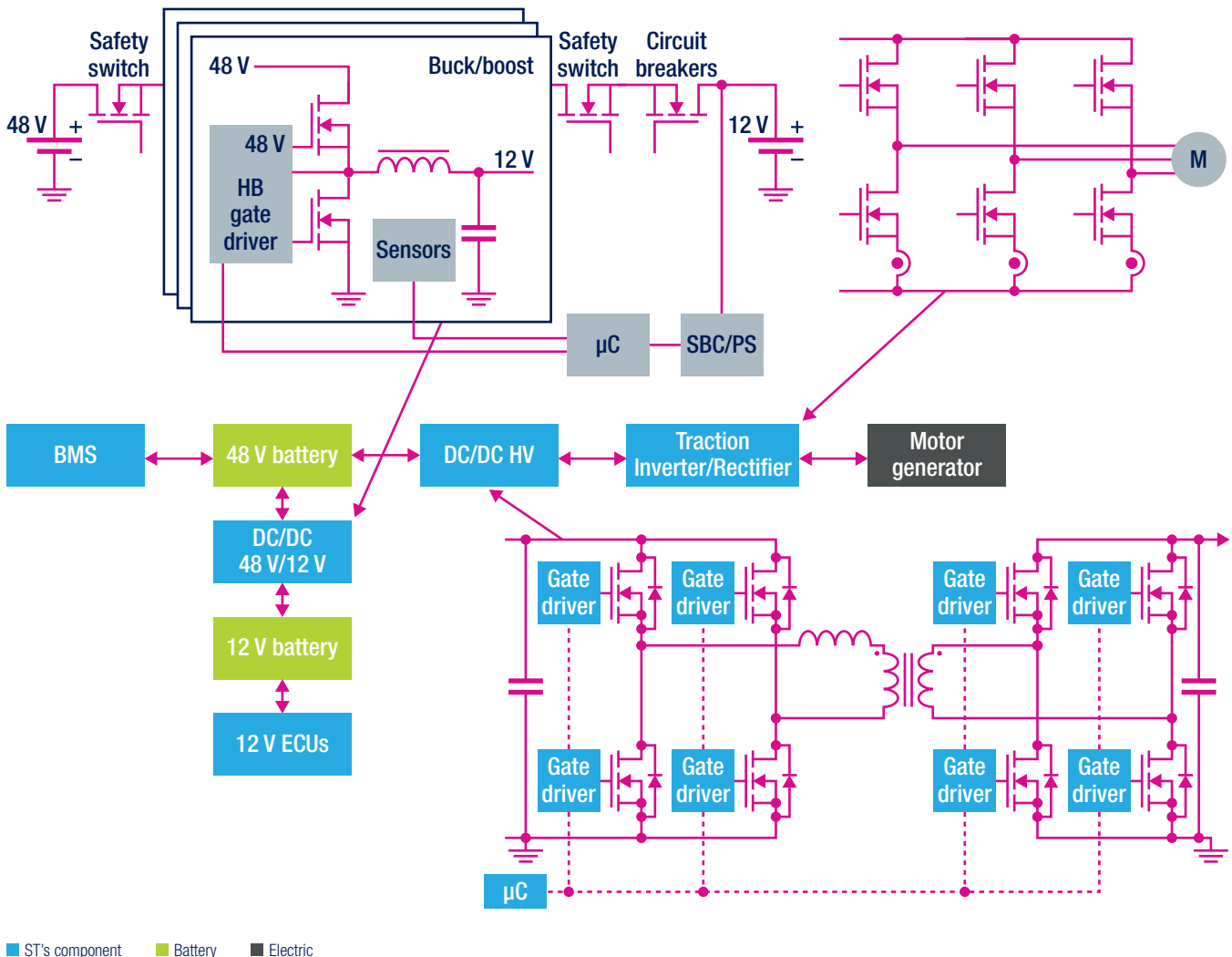
However, in HEVs, there is the interaction with the combustion engine, for example through a clutch and a gear-box actuated by electric motors.

ST supports these applications with a variety of products. Some of them can be found in the following figure.



## 48 V SYSTEM

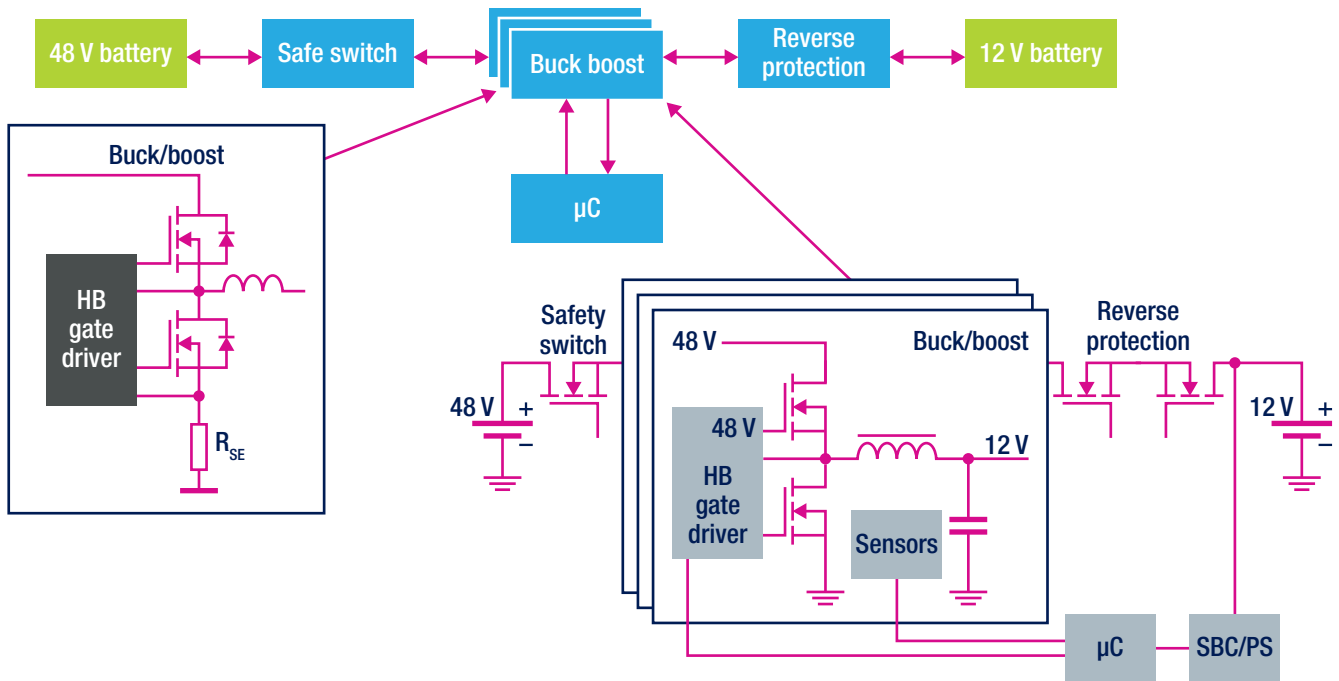
48 volts is the standardized supply voltage to supplement current 12 to 24 V levels as well as those above 60 volts. The main reason for this new voltage level is to supply components with high power loads such as the air conditioning compressor, electrical heater, pumps and steering system and to allow increased efficient recuperation. Most of those loads are nowadays propelled by mechanical force from main engine over shaft. Supply all such loads by electricity allows much more efficient operation causing reduction of CO<sub>2</sub> emissions. Moreover, the 48 V technology provides additional torque and enables more dynamic handling.



## DC/DC converters for 48 V systems

In conventional ICE vehicles, a 12 V battery supplied by the alternator was used to power the whole electric/electronic system. In (H)EVs, different voltage levels are possible, e.g. 48 V or higher. DC/DC converter to supply the different voltages needed by the various electronic components.

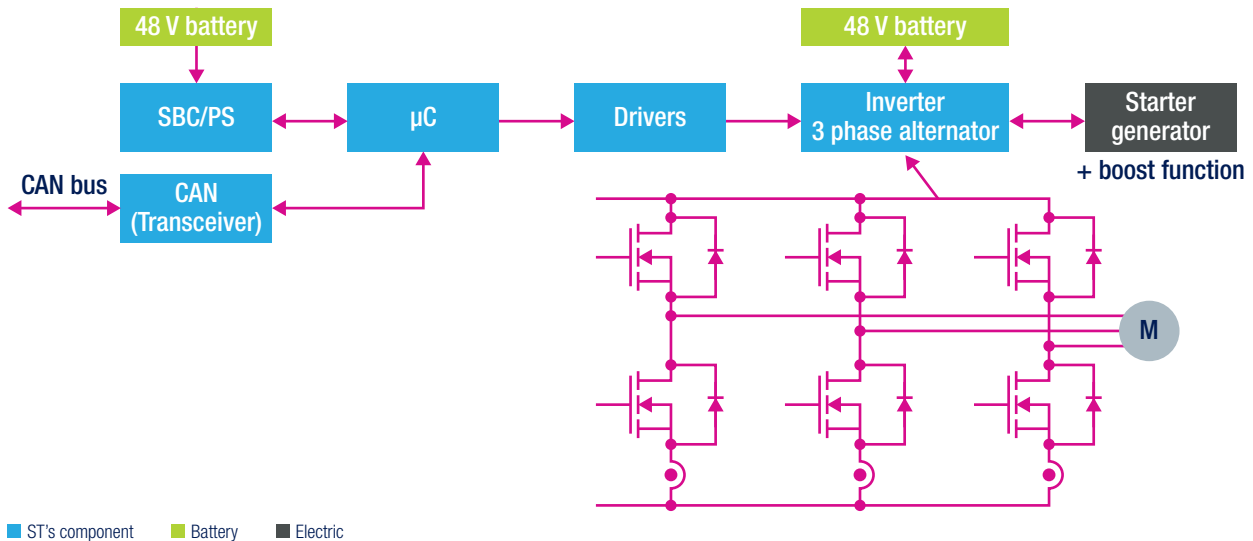
ST offer components for several DC/DC topologies. Here is one solution proposed by ST's experts for a specific topology using a 3-phase interleave buck/boost converter with synchronous rectification. The output power of this solution can reach from 2 up to 3 kW.



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■ ST's component ■ Battery ■ Electric

## Inverter/rectifier for 48 V systems



■ ST's component ■ Battery ■ Electric



## Main Inverter (Power Converter)

A key component in EV/HEVs, the main function of the traction inverter is to control both the traction and regenerative braking of the electric drivetrain. Logically, its characteristics strongly influence vehicle performance in regards to acceleration, speed and, in particular, driving range.

The power needed in passenger cars varies typically between 50 and 200 kW, while in busses and trucks it is often more. Power efficiency is key in such applications as well as costs.

While in the beginning the component parameters were very much linked to industrial applications in order to find

production synergies for reduced costs, today more and more custom specific solutions are requested by the market.

With its broad portfolio of **standard and customized power switches (IGBTs) together with the breakthrough Silicon carbide MOSFETs and diodes**, coupled with **microcontrollers and accompanying peripherals** with integrated **power supply and bus transceivers**, ST ensures the best solutions for your electric traction application with very low conduction and switching losses.

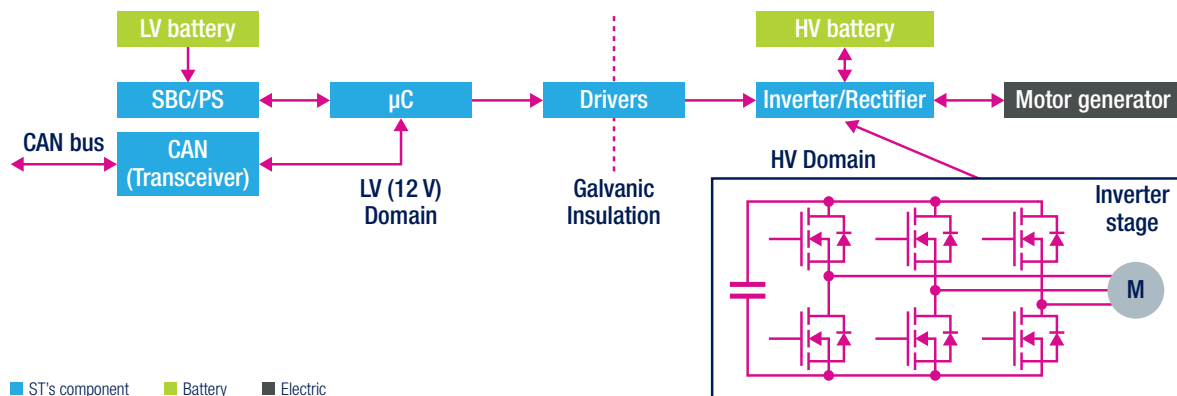
Dies are available without **packaging** (bare dies), as discrete components or in

customized module packages.

All our products for safety demanding applications, such as braking or steering systems, are designed to meet the most recent **functional safety** standards like ISO 26262 ASIL C/D.

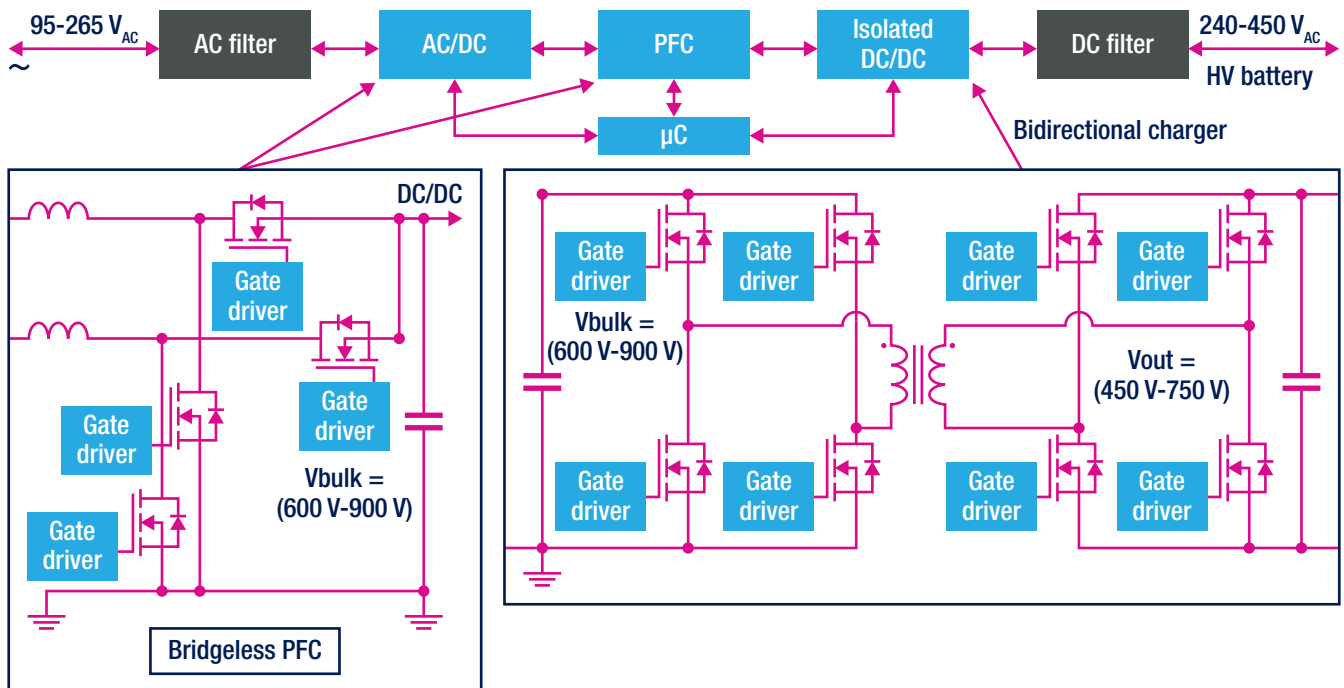
**Efficiency** is key for large power applications. It becomes better with increased voltage levels. Thus, the portfolio comprises also components designed for DC-link voltages up to 900 V that can offer excellent conductivity and switching behavior with smaller die sizes and hence **lower system costs**.

Naturally, ST can offer the corresponding **advanced isolated gate drivers**.



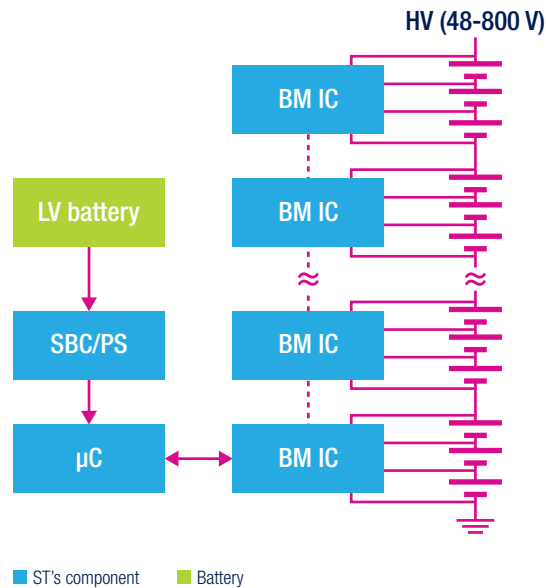
## Battery chargers

ST's R&D teams are very active in the field of HEV/EV battery charger systems including wireless, offboard and onboard charger solutions. With onboard battery chargers being the most used by car makers, ST offers the following high-efficiency solution for hybrid and electric vehicles. Use of SCR Thyristors can reduce bridge losses by about 30% and help increase lifetime of the components.



## Battery Management System (BMS)

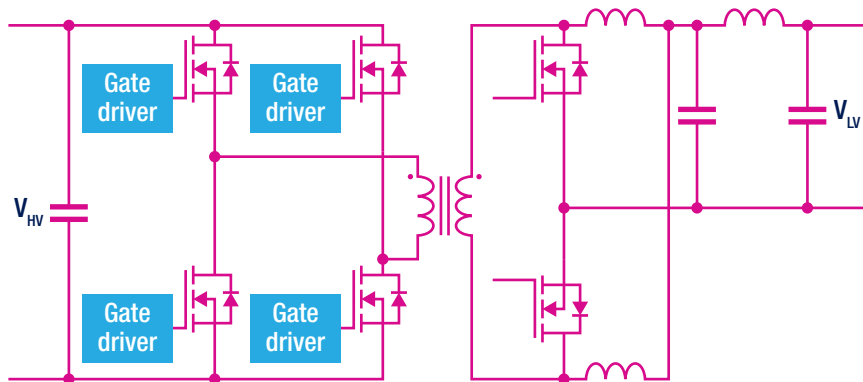
The battery management system (BMS) is one of the most important parts of an EV/HEV as it helps ensure the security of the vehicle's battery as well as improve its lifetime and autonomy.



## DC/DC converter

HEV still use an important number of system powered by a "12 V" DC voltage. Because of the batteries voltage, it is required to have a high power DC to DC converter. Among its main features we can mention the highest electric efficiency in the lowest volume and as light as possible (high power density).

To achieve these goals ST can provide a set of solutions summarized on the chart below:



Primary: Super-junction MOSFETs with fast switching diode or IGBTs with copacked diode, in through-hole or SMD packages.

Secondary: Low Voltage, Trench Gate MOSFETs, rated from 40 to 100 V, AEC-Q101 Qualified.

## FOCUS PRODUCTS

### High-voltage MOSFETs

Based on legendary design and manufacturing experience of high voltage MOSFETs since more than 40 years, ST offers AEC-Q101 super-junction state-of-the-art HV MOSFETs, focusing two types of use:

- **Hard switching - key feature low  $R_{DS(on)}$ :**  
for the PFC of the On Board Chargers, for instance. A way to identify them is the "M5" digits on the P/N
- **Soft-switching - key feature low  $Q_g$ :**  
including fast switching integrated diode: suitable for DC/DC converters or for the On Board Chargers' DC/DC converter. Thanks to the low gate charge switching losses can be reduced drastically. They can be easily identified thanks to the digits "DM2" or "DM6\*" in the commercial P/N

Note: \* Coming soon

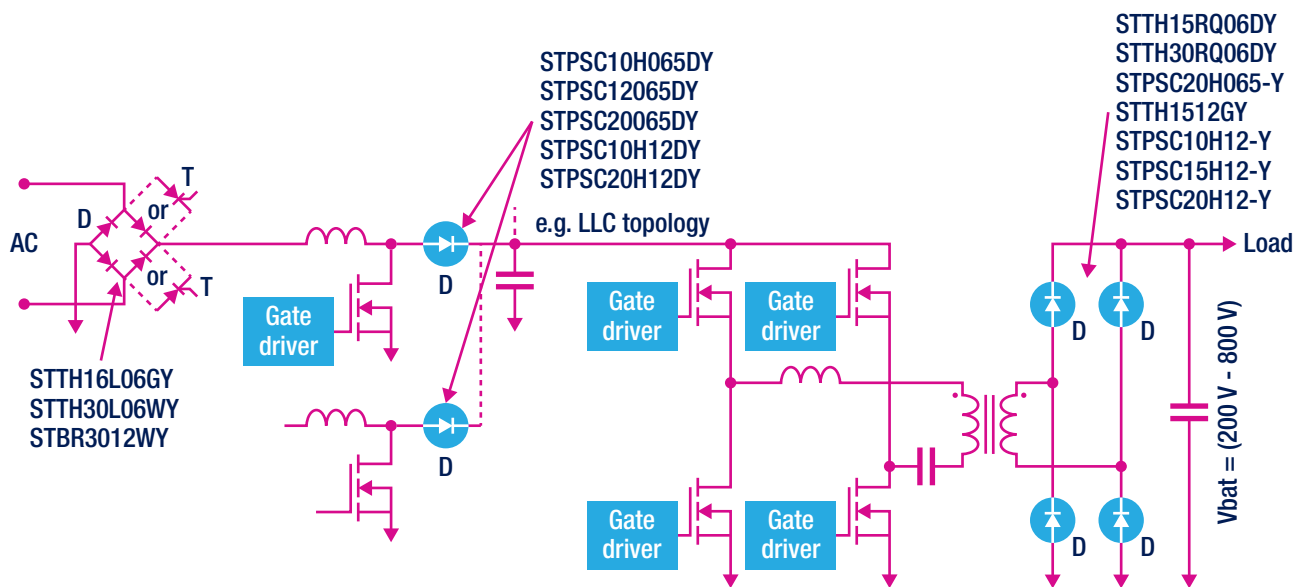
### MAIN FEATURES

- Available from 300 V up to 950 V in MDmesh™ super-junction technology
- $R_{DS(on)}$  from 24 mOhms typ (650 V)
- Available in through-hole and SMD packages

### High-voltage DIODES

When price is a key parameter and the system can use them, Silicon Power Rectifiers with low  $V_f$  are suitable for the INPUT bridge (AC rectification) and Ultrafast Diodes are used in the output section.

ST offers AEC-Q qualified high voltage diodes meeting these requirements. They are rated from 600 to 1200 V, with current capabilities from 5 A to 30 A, or 2 times 20 A (common cathode) for SiC Diodes, 650 V. Through-hole packages like TO220 & TO247 are available, as well as SMD packages like D<sup>2</sup>PAK. Here are some examples of ST offer on High Voltage Diodes:

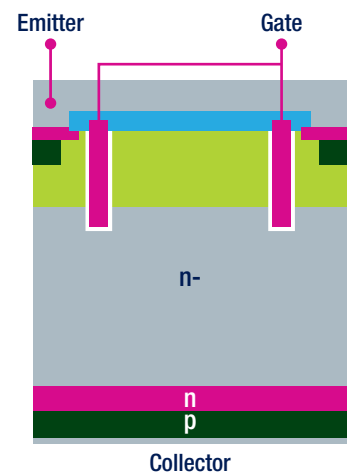
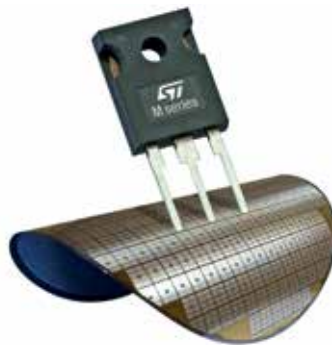


### SiC diodes

The wide bandgap of our siliconcarbide (SiC) diodes enables the design of high-voltage Schottky diodes offering negligible reverse recovery at turn-off and minimal capacitive turn-off behavior independent of temperature.

Our high-performance power Schottky rectifiers can handle up to 650 V with the lowest forward voltage drop ( $V_f$ ) on the market for optimal efficiency.

ST is the FIRST supplier worldwide to offer 100% automotive-grade SiC diodes (AEC-Q101 qualified and PPAP capable).



## IGBTs

Insulated gate bipolar transistors (IGBT) are ideally suited for all power applications.

While home appliances, such as washing machines, remain ST's most important sector, the use of IGBTs is fast growing in photovoltaic and automotive systems.

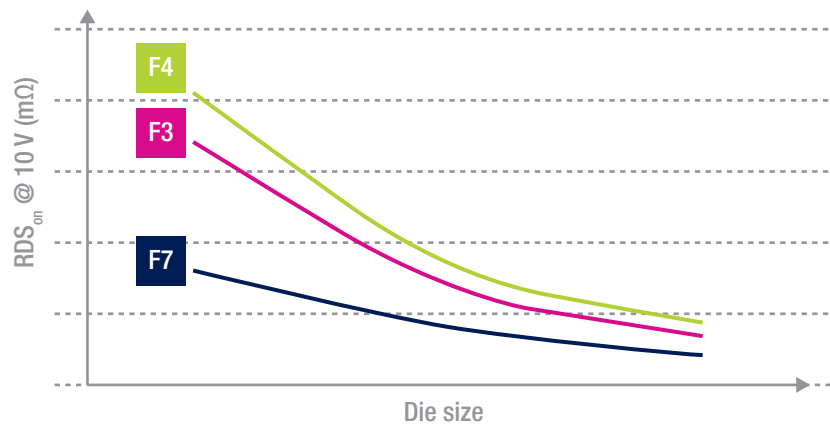
The need to supply IGBTs to automotive customers in larger quantity will certainly influence the development and manufacturing processes further.

For more information visit <http://www.st.com/igbt>

## Low-voltage MOSFETs (STripFET™ F7 Power MOSFETs)

The ST's latest STripFET F7 technology offers a number of significant improvements compared to previous technologies and also in comparison to competition:

- Continuous  $R_{DS(on)}$  reduction enables F7 technology to meet the most stringent efficiency requirements compared to previous generations
- Miller Capacity Reduction ( $C_{rss}$ ) is reduced thanks to a new sophisticated gate structure (double-electrode). Thus, F7 technology shows excellent dynamic performance
- Soft Capacity Ratio ( $C_{rss}/C_{iss}$ ) leads to a technology that shows excellent EMI performance and Miller effects immunity, especially for motor control applications
- Excellent diode performance, low  $Q_{rr}$  and soft behavior makes F7 technology perfectly suitable for synchronous rectification and motor control applications
- Thanks to excellent avalanche performance, F7 technology is immune to dynamic  $dv/dt$  failures
- Finally, a maximum junction temperature ( $T_j$ ) of 175 °C allows operation with reduced cooling for all packages in the whole portfolio, including PowerFLAT™



The STripFET™ F7 series offers:

- Breakdown voltage from 40 V to 100 V
- $R_{DS(on)}$  down to <1 m Ohm @ 40 V in PowerFLAT™ 5 x 6 package
- Wide product range up to 120 A
- 175 °C maximum junction temperature (meets automotive grade requirements)
- Safe paralleling

For more information visit <http://www.st.com/stripfetf7>



## SPC5 32-bit automotive microcontrollers

ST's SPC5 32-bit microcontrollers are designed using industry's standard Power Architecture® and ST's proprietary embedded Flash technology. They combine a scalable range of single-, dual- and multi-core solutions with innovative peripheral sets optimized for electrical car applications requiring long-term reliability:

- Single- and multi-core architectures
- Technology range from 90 down to 40 nm
- Full performance up to 150 °C
- 15 years product longevity
- High-end peripheral set, including ISO CAN FD
- Internal manufacturing (front-end and back-end) for security of supply
- Safety compliance with standards such as ISO 26262 (up to ASIL-D)
- Data security compliance with standards including SHE (Secure Hardware Extension) and EVITA (e-safety vehicle intrusion protected applications)
- Complete development environment (from free-of-charge IDE, code compiler and low-cost debugger solution up to high-end solutions supporting AUTOSAR designs)

For more information visit [www.st.com/spc5](http://www.st.com/spc5)



## STGAP1AS gapDRIVE

The STGAP1S gapDRIVE™ is a galvanically isolated single-gate driver for N-channel MOSFETs and IGBTs with advanced protection, configuration and diagnostic features. The STGAP1S's architecture isolates the channel from the control and low-voltage interface circuitry through true galvanic isolation. Main features include:

- High voltage rail up to 1500 V
- Driver current capability: 5 A
- $\pm 50$  V/ns dV/dt transient immunity
- Overall input/output propagation delay: 100 ns
- Separate sink and source
- Negative gate driver ability

For more information visit [www.st.com/stgap1s](http://www.st.com/stgap1s)



## Automotive power-rail transient voltage suppressor (TVS) protection

The SM6TY, SM15TY and SM30TY Transil series (respectively 600 W, 100 W and 3000 W) have been designed to protect sensitive automotive circuits against surges in compliance with ISO 7637-2 and against electrostatic discharges according to ISO 10605. Available voltage from 5 V to 82 V cover most of the automotive needs including 12 V, 24 V and 48 V systems.

The planar technology makes these devices compatible with high-end circuits where low leakage current and high junction temperature are required to provide reliability and stability over time. SM6TY and SM30TY are packaged in SMB and SMC (footprints in accordance with IPC 7531 standard).

### SM30T28CAY

- Surface mounted
- 3000 W in SMC package
- 28 V Breakdown voltage ( $V_{BR}$ )
- Automotive-grade qualified
- Max. operating temperature: 150 °C

### SM6T56CAY

- Surface mounted
- 600 W in SMC package
- 75 V Breakdown voltage ( $V_{BR}$ )
- Bidirectional
- Automotive-grade qualified
- Max. operating temperature: 150 °C



For more information, visit [www.st.com/protection](http://www.st.com/protection)

## ESDCAN and ESDLIN automotive-grade solutions simplify qualification and speed up time-to-market

CAN and LIN interfaces need dualchannel, bidirectional, 24 V protection devices.

After a first generation housed in SOT23-3L, STMicroelectronics has developed a family extension packaged in SOT323-3L.

The new family range provides improvements with regards to dimensions (40% smaller), line capacitance (3.5 pF vs 30 pF) and voltage range. Indeed, the new series includes also 37 V (VBR) products compatible with 24 V systems.

ESDCANxxY series is working up to 175 °C and sustains up to 30 kV ISO 10605 as well as ISO 7637 surges.

### KEY FEATURES

- Dual-line ESD and EOS protection
- Bidirectional devices
- Max pulse power: up to 250 W (8/20  $\mu$ s)
- Stand-off voltage: from 24 V up to 36 V
- Low clamping factor VCL/VBR ( $VCL < 40$  V)
- Low leakage current: 100 nA max
- Compliant with:
  - ISO 7637 3a and 3b
  - ISO 10605/IEC 61000-4-2: >25 kV air and contact

### KEY BENEFITS

- Robust and safe circuit at first design loop:
- CAN transceiver protected against ESD and EOS
- Enables high-density PCB thanks to the small package (SOT23-3L and SOT323-3L)
- Transparency in the application lowering the design effort with
- Capacitance compliant with CAN datarate





# Breakthrough technologies



## WIDE BAND GAP (WBG) TECHNOLOGIES REVOLUTIONIZE THE PERFORMANCE OF POWER DEVICES

The introduction of silicon carbide (SiC) and Gallium Nitride (GaN) technology further ensures the reduction of energy losses and, when used with a high-temperature material, can allow reduction of cooling effort.

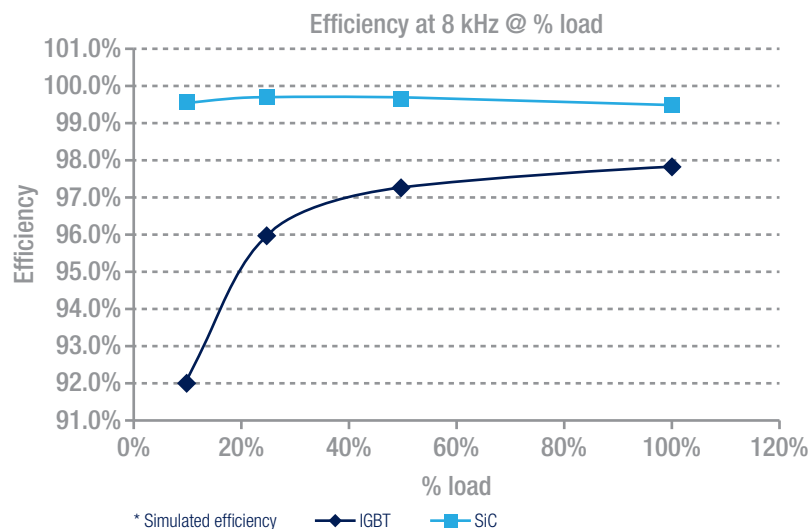
This is especially true in applications where higher switching frequencies can be favorably used to reduce losses, size and costs of transformers and coils.

In some cases ST can offer package solutions operating at up to 200 °C.

The reduction of the overall losses especially at low and mild loads (more close to the real mission profile of the EV) vs. the silicon IGBT together with the additional ability of the material to withstand higher temperatures allow to obtain lighter and smaller systems to save thus material costs.

Today, ST is significantly improving the industrialization of its SiC components with automotive-grade quality and the costs compatible with these applications.

### 1200 V SiC MOSFET vs IGBT solution in a traction inverter (90 kW, 8 kHz)





## PACKAGING EXPERTISE AND INNOVATIVE SOLUTIONS FOR INTER-CONNECTION

High performance and reliability as well as a neutral impact on environment are key features expected of semiconductors used for E-mobility solutions.

ST achieves these targets using concurrent engineering techniques and eco-design approaches to develop new and innovative dice and package solutions.

To obtain the best results, ST Packaging

Competence Centers have developed new bonding techniques, green and high-temperature (200 °C) molding compounds, and novel lead-free, high-performance, reliable die-attach materials.

Packages allowing dual-side cooling have been also introduced to improve the thermal performances leading to increased reliability and product lifetime.



## RIBBON BONDING

A specific bonding technique already used in traditional Si components, Ribbon bonding, can be used in high-current applications to increase the equivalent connection area between die and bonding as well as reduce mechanical stress. Today, ST uses this kind of bonding notably in an application for electric bicycles.

As an example, the wide bandgap of our siliconcarbide (SiC) diodes enables the design of high-voltage Schottky diodes offering negligible reverse recovery at turn-off and minimal capacitive turn-off behavior independent of temperature.

Our high-performance power Schottky rectifiers can handle up to 650 V with the lowest forward voltage drop (VF) on the market for optimal efficiency.

ST is the FIRST supplier worldwide to offer 100% automotive-grade SiC diodes (AEC-Q101 qualified and PPAP capable).

### KEY FEATURES

- 100% automotive-grade
- AEC-Q101 qualified
- PPAP capable
- Very low forward conduction losses
- Low switching losses
- Soft switching behavior
- High forward surge capability
- Contributes to safe energy
- Allows high switching frequency
- Reduced EMI
- High  $T_j$  capability  $T_j \text{ max} = 175 \text{ }^\circ\text{C}$
- 650 V guaranteed @  $-40 \text{ }^\circ\text{C}$

## COPPER CLIPS

In some high power applications, clip bonding can be a preferred solution.

This technology, which replaces partially traditional wire bonding, is characterized by better thermal performance and increased switching performance.

## FOCUSED ON QUALITY WITH THE LATEST STATE-OF-THE-ART TOOLS FOR SELECTION OF “KNOWN GOOD DIES”

Power devices often include numerous dice in the same package. For example, a module package can contain up to 72 SiC MOSFETs (ST's current record). With this in mind, it is of utmost importance to ensure that each of the components are performing perfectly and, in some cases, with matched parameters.

To ensure the components' quality, they undergo a full power test with specific patented tools that allow currents up to several hundreds of amps and more than a thousand volts.



## FD- SOI technology

The Fully Depleted Silicon On Insulator is a planar process technology that relies on two primary innovations, an ultra-thin layer of insulator, called the buried oxide, positioned on top of the base silicon and a very thin silicon film that implements the transistor channel. Thanks to its thinness, there is no need to dope the channel, thus making the transistor fully depleted.

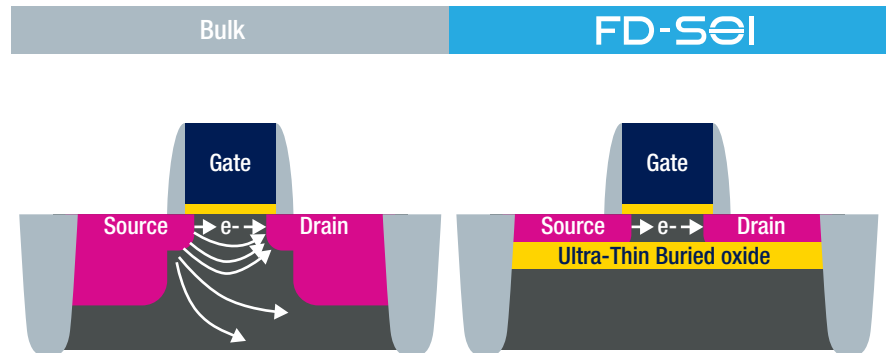
The combination of these two innovations is called “ultra-thin body and buried oxide fully depleted SOI” or UTBB-FD-SOI.

By construction, FD-SOI enables much better transistor electrostatic characteristics versus conventional bulk technology. The buried oxide layer lowers the parasitic capacitance between the source and the drain. It also efficiently confines the electrons flowing from the source to the drain, dramatically reducing performance-degrading leakage currents.

A very strong point of FD-SOI is its best-in-class immunity against radiation errors, bringing area savings and strong reliability to the system.

Some further advantages of 28nm FD-SOI technology:

- Fewer mask steps due to a simpler process
- Lower leakage power
- Multiple threshold voltage ( $V_T$ ) of the transistor are available allowing:
  - RVT device for regular- $V_T$  or standard- $V_T$  circuits,
  - LVT device for low- $V_T$  high-speed circuits
- Wide operating voltage range, for different applications with competitive PPA advantages:
  - Very low VDD for ultra-low-power applications
  - Reduced VDD for competitive speed at reasonable power consumption and nominal VDD for high-performance applications



## Application benefits by market segment

### Internet of Things, Wearable

- Ultra-low-voltage operation
- FBB optimizes power/performance
- Efficient RF and analog integration

### Automotive

- Well-managed leakage in high-temperature environments
- High reliability thanks to highly-efficient memories

### Networking Infrastructure

- Energy-efficient multicore
- Adapt performance & power to workload via FBB
- Excellent performance in memories

### Consumer Multimedia

- Optimized SoC integration (Mixed-signal & RF)
- Energy-efficient SoC under all thermal conditions
- Optimized leakage in idle mode

## Bipolar CMOS-DMOS (BCD) technology

Bipolar CMOS (complementary metal–oxide–semiconductor) - DMOS (double-diffused metal–oxide–semiconductor) is a key technology for power ICs.

Since inventing this revolutionary technology in the mid-eighties, ST has continually developed it, creating the BCD family which combines the strengths of the three different process technologies into a single chip:

- Bipolar for precise analog functions
- CMOS for digital design
- DMOS for power and high-voltage elements



## Addressing a wide range of applications

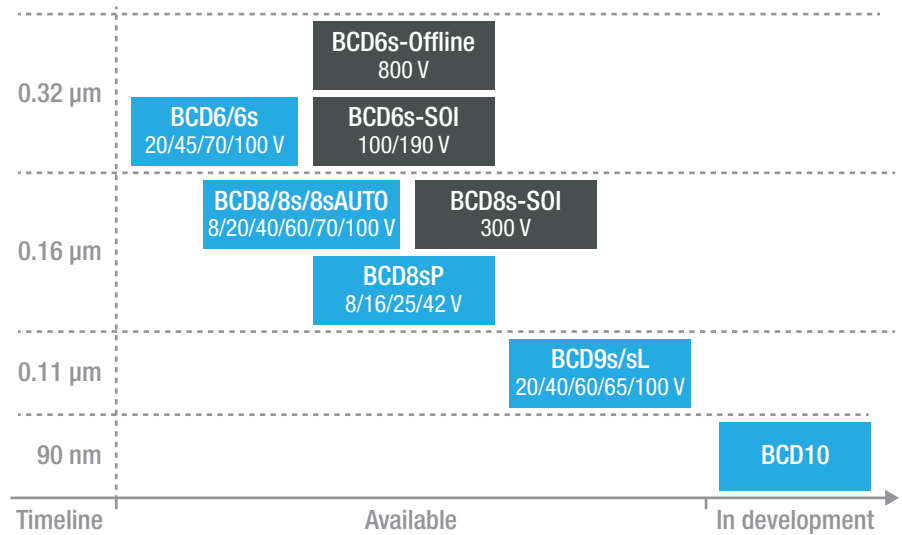
With know-how in process development and chip production honed over more than two decades, ST offers a unique range of BCD process technologies, each addressing specific application needs, with an optimal trade-off between functionality, performance and cost.

### HIGH-VOLTAGE BCD

Enables reliable coexistence on the same chip of low-voltage control circuits and very high-voltage DMOS stages with typical voltage capability up to 800V. The integration of BCD on SOI (Silicon On Insulator) substrates addresses specific high-value solutions in electro-medical, automotive safety or audio applications.

### HIGH-DENSITY BCD

Driven by the need to integrate more and more complex and diversified functions on the same chip and to guarantee high quality and reliability in all types of application environments.

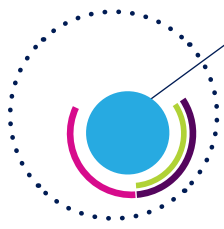


## Driving innovation in BCD

With its expertise in both “More-Moore” and “More-than-Moore” semiconductor technologies; by integrating DMOS architectures designed with a set of innovative techniques and by taking advantage of state-of-the-art wafer-processing fabs, ST has an unmatched capability to offer the best BCD solutions with best-in-class performance.

Moreover, ST has the capability to customize its BCD technologies to optimally address the most demanding markets, including automotive, aerospace and certain segments of the industrial market.

With its unique technical knowledge based on more than two decades of experience in the field, ST provides unrivaled technical support in order to guarantee the best BCD experience to its customers.



# ST's electromobility activities in the ecosystem



The electromobility market is still in its early stages.

The answers to the many technical, standardization and elementary questions will be found in a collaborative ecosystem.

ST is a very active contributor to these discussions through its participation in many funded research projects in Europe or industrial federations, for example in the German ZVEI or the French FIEEC.

ST is also involved in the discussions concerning the electromobility roadmap on the European level (ECPE, ERTRAC, EPOSS, EURIPIDES) and in France, where it is very engaged in competitive clusters like MOVEO, that bring together industrial actors with their vision of market needs and researchers with bright new ideas in order to create technical solutions, products, business and new companies.

Today, ST is actively participating in approximately 100 research projects around nanoelectronics including about 30 projects in the area of power electronics, electric mobility and packaging.

Hundreds of researchers at ST benefit from intellectual exchanges with more than 1,000 partners in this domain.

ST also very actively supports the training and education of engineers through conferences like the Automotive Power Electronics conference in Paris in cooperation with APE Japan or through schools and universities.





# life.augmented



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