Conductive polymer hybrid aluminum electrolytic capacitors

Eaton's EHBSA conductive polymer hybrid aluminum electrolytic capacitors are engineered for high-reliability systems operating in harsh environments. With AEC-Q200 qualification, the EHBSA capacitors ensure dependable performance across a wide temperature range, making them ideal for automotive applications where ambient temperatures can exceed +100 °C near heat-intensive components like power electronics and exhaust systems. The construction of these capacitors delivers the high capacitance of the electrolytic type with the low ESR and high ripple current capabilities of polymer capacitors. As a result, the need for parallel configurations in space-constrained designs is reduced. This application note examines technical specifications, performance advantages, and the key considerations for using Eaton EHBSA capacitors in automotive systems, industrial equipment, telecommunications infrastructure, and consumer electronics.

Product overview

In developing its EHBSA family, Eaton adopted a hybrid approach to capacitor design, combining two distinct electrolytic systems into a single package. Standard aluminum electrolytic capacitors contain liquid electrolyte systems with relatively high capacitances but increased equivalent series resistance (ESR) and limited temperature operation.

On the other hand, solid polymer capacitors use conductive polymer materials to achieve low ESR and better high-frequency performance, with the limitation of relatively low capacitance values and voltage ratings. The EHBSA family integrates both technologies to maximize their complementary strengths.

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The internal construction of the EHBSA capacitors follows the traditional wound structure of aluminum electrolytic capacitors, which includes an anode foil, cathode foil, and a separator. The difference lies in the combination of electrolyte systems. This hybrid approach creates a component that retains the high capacitance characteristic of the liquid electrolyte systems while maintaining a conductive polymer material's high conductivity. The resulting electrical performance is lower ESR and higher ripple current ratings compared with standard aluminum electrolytic capacitors; this performance extends the usable frequency range and enhances the overall efficiency in power circuits.

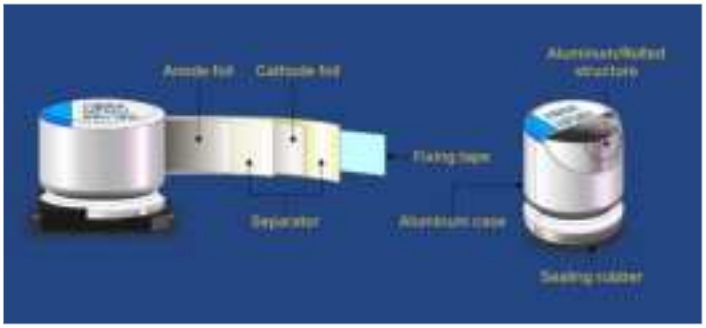

Figure 1: Construction of the EHBSA

EHBSA capacitors are designed with a sophisticated multi-stage process beginning with foil slitting, followed by stitching and winding operations to form basic capacitor structures. The process continues through carbonation, reforming, and the polymerization stage, where the conductive polymer is integrated. After impregnation assembly and aging processes, these capacitors undergo cleaning before final base assembly and testing to meet Eaton's stringent performance and reliability standards.

The hybrid structure of the EHBSA addresses several limitations of alternative technologies. The polymer component improves ESR performance, while the liquid electrolyte preserves high capacitance values. This combination improves temperature stability across the operating range and extends the operational lifetime in applications that require continuous operation in thermally challenging environments, such as automotive applications.

Specifications and performance characteristics

Below are some key specifications of Eaton's EHBSA hybrid capacitors:

- **Voltage range:** 16 Vdc to 80 Vdc (with corresponding surge voltage ratings of 20 V to 100 V)
- **Capacitance range:** 10 µF to 820 µF (measured at 120 Hz)
- **Operating temperature range:** –55 °C to +125 °C
- **Operational life:** 4000 hours at +125 °C
- **ESR values:** 11 mΩ to 120 mΩ (measured at 100 kHz)
- **Ripple current capability:** 0.7 A to 4.0 A (at 100 kHz, +125 °C)
- **Case sizes (metric):** Multiple SMD options, including 0606, 0608, 0810, 1010, 1012, 1016
- **Dissipation factor (tan δ):** 0.08 to 0.16 (at 120 Hz)
- **Humidity resistance:** +85 °C at 85% relative humidity (RH)
- **Qualification standard:** AEC-Q200 qualified for automotive applications
- **Mounting type:** Surface mount (SMD) with T&R packaging options
- **Construction:** Aluminum case with rubber sealing and rolled internal structure
- **Marking:** Includes series designation (HBSA), date code, rated voltage, and capacitance value

As specified above, EHBSA capacitors are available in voltage ratings of 16 V to 80 V and capacitances of 10 µF to 820 µF. This broad selection allows engineers to match capacitor selections to circuit requirements, optimizing performance and board space utilization.

Also, these capacitors feature low ESR values, measured at 100 kHz, ranging from 11 mΩ to 120 mΩ depending on the specific part. Ultra low impedance characteristics provide high ripple current-handling capabilities, with ratings of up to 4.0 A at +125 °C. Their low ESR also translates into reduced power losses and heat generation in high-current applications, improving overall system efficiency. Moreover, the capacitors maintain a low leakage current, with values proportional to their capacitance and voltage ratings.

Qualified for operation from –55 °C to +125 °C, these capacitors deliver stable performance across the full temperature range and are rated for 4,000 hours of operation at +125 °C. This extended high-temperature capability meets a key requirement in automotive environments, where components are often placed near heat sources such as engines, power electronics, or exhaust systems.

Physical construction and reliability metrics

The series is available in multiple case sizes (metric), including 0606, 0608, 0810, 1010, 1012, and 1016. The standard SMD package formats facilitate automated assembly and integration into today's manufacturing processes. For ease of identification during assembly and field service, each component has clear markings for series designation, date code, rated voltage, and capacitance value.

Figure 2: EHBSA body marks

The EHBSA family's AEC-Q200 qualification ensures compliance with automotive reliability requirements, including resistance to thermal shock, vibration, and humidity. The capacitors demonstrate excellent humidity resistance (up to +85 °C at 85% RH), outperforming pure solid polymer capacitors. Additionally, the 4000-hour operational life at +125 °C exceeds the typical requirements for automotive components, ensuring long-term reliability in harsh conditions. The hybrid design of the EHBSA family also minimizes parameter drift due to aging effects, while maintaining capacitance values and ESR performance throughout its operational life.

Comparative analysis vs. alternative capacitor technologies

Eaton's EHBSA hybrid technology offers several benefits when compared directly with other capacitor technologies. As Figure 3 shows, the hybrid approach combines the strengths of both aluminum electrolytic and solid polymer capacitors while minimizing their limitations.

In terms of static capacitance, hybrid capacitors achieve a very good ("★★") rating with high capacitances, matching the performance of aluminum electrolytic types while outperforming conductive solid capacitors, which offer low capacitance values. In terms of leakage current, hybrid technology matches aluminum electrolytic capacitors with a very good rating and low leakage, addressing a key weakness of conductive solid capacitors.

For humidity resistance, hybrid capacitors exhibit excellent performance (+85 °C at 85% RH), identical to aluminum electrolytic capacitors and substantially better than conductive solid capacitors (which are limited to +60 °C at 95% RH). For the maximum voltage capability, hybrid technology also achieves a very good rating with values of up to 100 V. That figure positions the technology between aluminum electrolytic capacitors (450 V) and conductive solid capacitors (limited to about 50 V).

Hybrid designs excel in ripple current handling and ESR performance, achieving very good ratings with large ripple current capability and low ESR, matching the strengths of conductive solid capacitors in these critical areas while outperforming aluminum electrolytic capacitors. Similarly, hybrid capacitors exhibit very good ratings with their high temperature capability, matching conductive solid capacitors and surpassing aluminum electrolytic technology.

Classification	Al. electrolytic		Solid polymer		Hybrid polymer	
Electrolyte	Electrolyte liquid		Conductive polymer		Conductive polymer + Electrolyte liquid	
Static capacitance	++	Large	+	Low	++	Large
Leakage current (LC)	++	Low	+	High	++	Low
Humidity resistance	++	85C 85%RH	+	60C 95%RH	++	85C 85%RH
Max voltage	++	High (450V)	+	Low (50V)	++	High (100V)
Ripple current	+	Low	++	Large	++	Large
ESR	+	High	++	Low	++	Low
Temperature	+	Low	++	High	++	High

Figure 3: Capacitor technology comparison

Major applications

Automotive headlight assembly

Headlight assemblies for vehicles require smoothing capacitors to maintain reliable current delivery to LEDs. The EHBSA capacitors' low ESR can minimize voltage ripple at the driver output. A high operating temperature range also ensures reliable operation in the thermally challenging headlight assembly environment.

Figure 4 shows how EHBSA capacitors can be placed at the output of an LED driver's DC/DC control IC. Here, they serve as output-smoothing capacitors, positioned between the switching regulator and a high-brightness LED array. In this position, the capacitors filter the switching frequency ripple, preventing LED flickering. The input voltage can be 48 V or 12 V, with the EHBSA capacitor connected in parallel with the LED string.

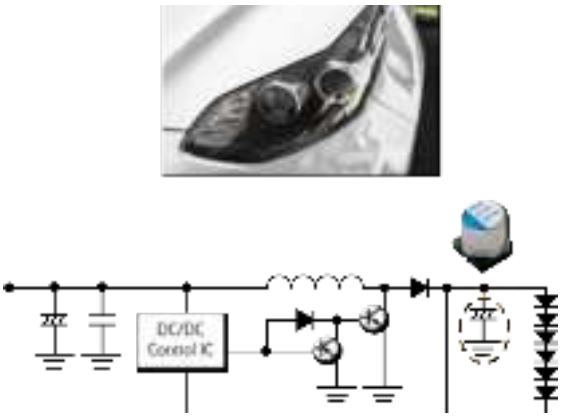

Figure 4: EHBSA capacitor in an automotive headlight assembly

Battery management system

EHBSA capacitors are AEC-Q200 qualified to meet the automotive sector's stringent reliability requirements for safety-critical systems, like battery management systems (BMS). BMS requires input filtering for 12 V/24 V/48 V power systems that monitor and control battery performance.

Figure 5 shows the BMS connected to DC/DC control circuitry via dual EHBSA capacitors. These capacitors are placed in parallel on the input side of the control system, where they filter transients and stabilize the input voltage.

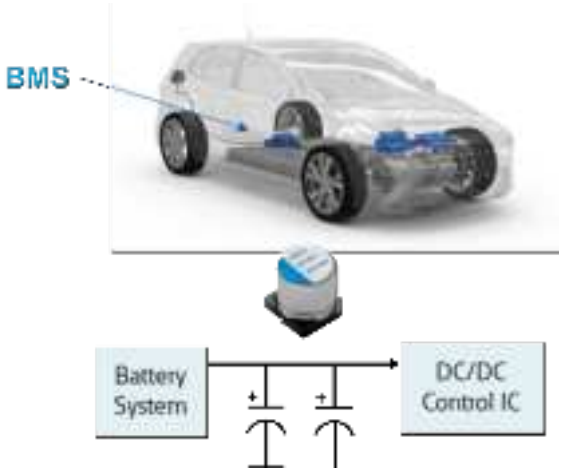

Figure 5: EHBSA capacitor in a vehicle's BMS

The low leakage current characteristics of the EHBSA help to preserve battery charge, while the wide temperature range ensures reliable operation across varying environmental conditions. Moreover, the capacitors' ability to handle high ripple currents without overheating can also improve system efficiency, vehicle range, and battery life.

48 V mild hybrid DC/DC converter and DC link

Mild hybrids are one of the most demanding applications for EHBSA capacitors. Figures 6 and 7 show two key implementations: in DC/DC converter circuits and DC link applications.

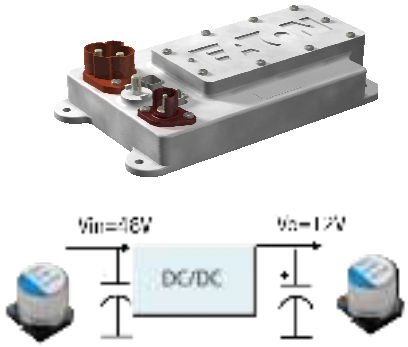

Figure 6: EHBSA capacitors in a mild hybrid DC/DC converter

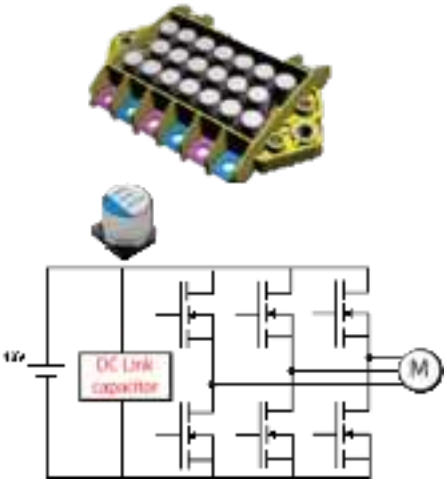

Figure 7: EHBSA capacitor in a mild hybrid DC link circuit

In the DC/DC converter implementation, the EHBSA capacitors are positioned at both input (48 V) and output (12 V) sides of the converter to stabilize the voltage and filter noise during power conversion. In the DC link implementation, the EHBSA is placed between the 48 V source and the inverter, serving as a crucial energy buffer during high-current switching operations. These circuits may require as many as 10 capacitors per vehicle, operating under high current conditions with high ripple current requirements.

Industrial applications

Industrial equipment containing stepper motors is a key application for EHBSA capacitors. This equipment requires input filtering capacitors for 25 V to 80 V power rails, as well as output capacitors for 16 V to 35 V driver circuits. The stepper motor application in Figure 8 shows two EHBSA capacitors positioned at two critical points: at the input of the DC/DC converter (Vin = 12/24/48 V) and at the output between the DC/DC converter and ASIC driver (Vout = 5/12/24 V).

The input capacitor filters the noise from the power source while the output capacitor stabilizes the voltage delivered to the stepper motor driver.

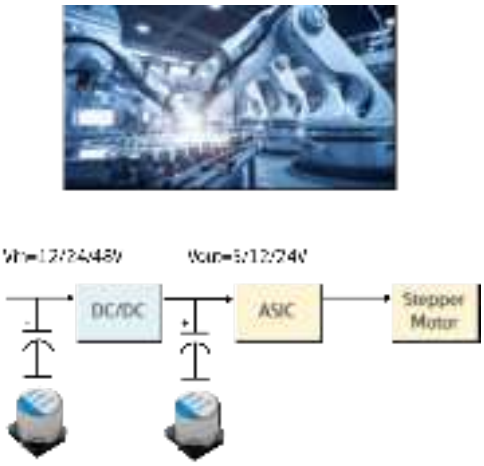

Figure 8: Industrial equipment application for Eaton EHBSA capacitors

This application demonstrates how EHBSA capacitors are placed in parallel with the power lines to maximize filtering effectiveness. These capacitors' low ESR helps to minimize voltage drops during high-current stepping operations, improving positioning accuracy and reducing heat generation. Their operating temperature range also accommodates the environments in which industrial equipment is used (for example, refrigerated warehouses and hot manufacturing floors).

Telecommunications

5G infrastructure components, including core network equipment, edge/cloud computing systems, switches, routers, and network interface cards, can benefit from the EHBSA's performance characteristics. The telecom application in Figure 9 shows a multi-stage power conditioning system with EHBSA capacitors placed at strategic positions. Here, we can see a 48 V input (Vin = 48 V) feeding through two DC/DC conversion stages with capacitors placed after each conversion. The final stage feeds specialized components, including CPUs, ASICs, FPGAs, and SoCs. EHBSA capacitors work to filter electrical noise between each power conversion stage, ensuring clean power delivery to sensitive digital components.

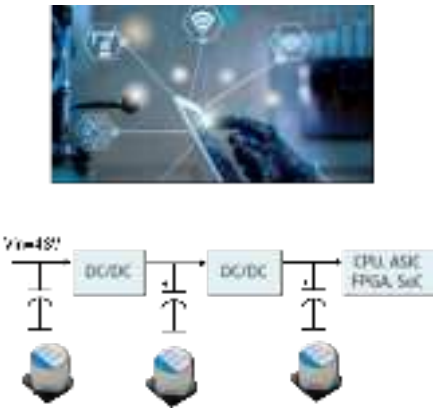

Figure 9: EHBSA capacitors in a telecommunications system

Figure 9 shows how three EHBSA capacitors are positioned to filter each stage of the power conversion process; at the input, mid-conversion, and at point-of-load. The EHBSA's low ESR improves power efficiency, while the high ripple current capabilities accommodate the substantial current flows in these high-performance systems.

Servers

Server infrastructure is another demanding computing application, where EHBSA capacitors can deliver several advantages. Figure 10 illustrates a power distribution system with Vin = 48/24 V feeding through multiple DC/DC conversion stages to power CPUs, memory, PCH, and I/O interfaces. EHBSA capacitors have been placed at three critical positions: at the input of the first DC/DC converter, between converter stages, and at the output feeding the computing components. This multi-stage filtering approach ensures clean power delivery to all sensitive server components.

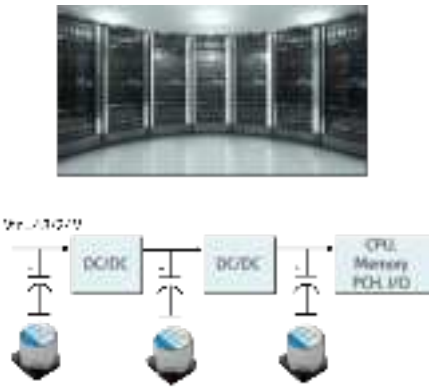

Figure 10: EHBSA capacitors in a server application

The high ripple current capabilities of the EHBSA are critical to accommodate the substantial current flows in high-performance computing applications. Moreover, their wide temperature operation can handle the elevated ambient temperatures common in densely packed server environments.

Conclusion

Eaton's EHBSA family of conductive polymer hybrid aluminum electrolytic capacitors combines the advantages of liquid electrolyte and polymer technologies to achieve an optimal balance of capacitance, ESR, temperature stability, and operational lifetime. Design engineers facing thermal management challenges, high ripple current requirements, and high-reliability needs can use these capacitors to simplify their designs while enhancing system performance. The AEC-Q200 qualification ensures that components are suitable for deployment in automotive environments, while their electrical characteristics make them equally valuable in industrial, telecommunications infrastructure, computing, and consumer electronics applications.

For more information on the EHBSA family capacitors or to discuss your specific application requirements, please visit the **website**. Technical support is available from Eaton application engineers, who can assist with component selection, application guidance, and more to help you optimize your design for performance and reliability.

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