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## ZAPI – BLE4 96V Premium – AC traction inverter

**Reference :** ZAP-BLE4-96V-SINCOS

**Options :**

No variants

**3D Model :** Not available

**EAN-13 :**

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AC traction inverter for 96 V traction systems in industrial mobile applications. Premium version dedicated to synchronous/brushless motor drives with sin/cos encoder feedback, FOC3 vector control and native CANopen. IP65 enclosure and integrated I/O for vehicle interfacing.

### General description

The **ZAPI BLE4** is an AC traction inverter designed for electric vehicles and machines, typically in material handling and industrial mobile applications (forklifts, tow tractors, service vehicles, access platforms, etc.). Motor control is based on **FOC3 (Field Oriented Control – generation 3)**, intended for **synchronous/brushless** motor drives with **sin/cos encoder** feedback, and configurable control laws in **speed** or **torque** mode depending on the vehicle architecture.

BLE4 integrates as the power stage between the battery (DC bus), protection devices (main contactor, fuses, precharge), and the three-phase motor (outputs **U/V/W**). System integration relies on **CAN** (ISO 11898-2) with **native CANopen**, a set of I/O for vehicle commands (direction, operator safety, pedal/joystick, braking, etc.) and a parameter setting/diagnostic ecosystem (service console, tester functions and logbook). The **Premium** version addressed here is dedicated to **sin/cos** feedback and uses an **AMPSEAL 35-way** connector for I/O and sensor signals.

### Key benefits

- **FOC3 vector control** for traction: speed stability, torque control, regenerative braking management and configurable ramps (accel/decel/reverse).
- **Premium sin/cos version**: closed-loop control suited to synchronous motor drives with sin/cos encoder, and **35-way** control connector for vehicle integration.
- **Dual-microcontroller safety architecture** (traction functions + safety functions) to support machine-level safety strategies at integration level.
- **CAN with native CANopen**: commands/status/diagnostics exchange, VCU/PLC integration, supervision and traceability.
- **IP65 enclosure**: intended for harsh environments provided connectors are correctly assembled and sealed.
- **Diagnostics and traceability**: alarms, event log (hourmeter and temperature at fault time), test functions and real-time monitoring via service tools.

- **On-board actuator driving:** main contactor output, electromechanical brake output, auxiliary outputs (valves/inductive loads) with load/short-circuit diagnostics.

## Technical specifications

| Item                                   | Value / description   |
|--|---|
| Product type                           | Three-phase AC traction inverter (outputs <b>U/V/W</b> ); DC bus <b>+B / -B</b>   |
| Control algorithm                      | <b>FOC3</b> (Field Oriented Control – generation 3)   |
| Control modes                          | <b>Speed</b> or <b>torque</b> (depending on software configuration)   |
| Target motor drives (this version)     | <b>Synchronous/brushless</b> motor drives (PMSM/PMAC/BLDC) with <b>sin/cos encoder</b> feedback   |
| Switching / operating frequencies      | Operating frequency 8 kHz; inverter frequency 16 kHz  |
| Voltage range (family)                 | Example <b>96 V nominal: 76.8 to 115.2 V</b> (conventional range)   |
| Rated currents (family – 96 V example) | Max 700 Arms; <b>2 min: 545 Arms</b> ; continuous: 295 Arms (achievable levels depend on thermal integration)                                 |
| Temperatures                           | Ambient: -40 °C to +40 °C; storage: -40 °C to +85 °C; current derating above 85 °C, protection up to 105 °C                                   |
| Ingress protection                     | <b>IP65</b>   |
| Control connector                      | <b>AMPSEAL 35-way</b> (Premium version)   |
| Motor feedback (Premium version)       | <b>Sin/cos encoder</b>  |
| Analog inputs                          | <b>10-bit</b> acquisition; potentiometers typically 0.5–10 kΩ; short-circuit protections to +B/-B   |
| Digital inputs                         | Inputs designed for -B / +B signals with thresholds suitable for system voltage; dual-channel plausibility recommended for critical functions |
| Communication                          | <b>CAN</b> ISO 11898-2; configurable 20 to 1000 kbit/s; optional 120 Ω termination via dedicated pin; <b>native CANopen</b>                   |
| Main contactor output (LC/MC)          | Open-drain PWM (voltage-controlled): 1.5 Arms continuous; 2 A peak 200 ms; PWM 1 kHz default; diagnostics (open/short/coil)                   |
| Electromechanical brake output (EB)    | Open-drain PWM: 2 Arms continuous; 3 A peak 200 ms; PWM 1 kHz; diagnostics (open/short/coil)  |
| Auxiliary outputs (valves/loads)       | EV1/EV4 ON/OFF; EV2/EV3 voltage PWM; EVP current PWM (up to 1.7 A peak) with configurable dither  |
| Standards / references                 | Designed for industrial applications (machine safety and EMC depend on the complete system integration)                                       |

## Thermal management and cooling

Current endurance and operating stability depend directly on heat dissipation through the base and heatsink. BLE4 can be supplied in **base-plate** configuration (mounted on a dissipating surface), with a **finned heatsink** (transversal or

longitudinal fin orientation depending on layout and airflow), or with **liquid cooling** when continuous power and duty cycle require reinforced thermal management.

With **liquid cooling**, a robust thermal design relies on the mechanical interface, contact quality, circuit sizing (pressure drop, bleeding, coolant quality) and a typical reference flow rate around **10 L/min**, to be validated against the vehicle architecture and duty cycle. This approach is used to increase sustained current capability and stabilize performance on demanding cycles.

## Typical applications

- Main traction for **forklifts** and material handling machines (counterbalance, VNA/HLOP).
- **Tow tractors**, internal logistics industrial vehicles and service vehicles.
- **Access equipment** (scissor lifts/platforms) and mobile machines requiring torque control and regenerative braking.
- **Traction + pump** architectures (hydraulic steering) coordinated via CAN (hydraulic request, timings).
- **Retrofit** and e-mobility projects where **sin/cos** feedback and EMC robustness are key.

## Test bench – inverter validation

A test campaign was carried out on a bench to qualify the behavior of the **BLE4 96V – 700A** inverter in **FOC** control on a **MXS16** traction motor (with **sin/cos** feedback). The protocol used a **96 V** supply during a campaign dated **18/03/2021**. The goal is to document control stability (current/torque and speed loops), repeatability across the operating range, and the inverter's capability to sustain high current levels in a configuration representative of traction duty.

Maximum values recorded (test configuration above):

| Metric      | Maximum             | RPM (at peak) | RMS current (A) | Power (W) | Torque (N·m) |
|-------------|---------------------|---------------|-----------------|-----------|--------------|
| Torque      | 133.5 N·m           | 500           | 607             | 6 991     | 133.5        |
| Motor power | 47 560 W (47.56 kW) | 3 580         | 577             | 47 560    | 126.9        |
| RMS current | 607 A               | 500           | 607             | 6 991     | 133.5        |
| Speed       | 6 000 rpm           | 6 000         | 323             | 44 619    | 71.0         |

Result analysis: the protocol swept speed over **0 to 6,000 rpm** while tracking speed, power and torque. The campaign shows a usable acceleration profile and stable control across the full range, with a **133.5 N·m** peak torque at **500 rpm** and a **47.56 kW** peak power around **3,580 rpm**. The achieved **RMS current** levels (up to **607 A**) illustrate the inverter's ability to support high traction demand in this test configuration.

Conclusion: the campaign illustrates typical traction behavior with a high-torque zone (order of magnitude **~130 N·m**) over **500 to 3,500 rpm**, followed by a near-maintained high-power zone (order of magnitude **~43 to 48 kW**) up to **6,000 rpm**, with a progressive torque decrease (down to **~71 N·m** at maximum speed). In this context, **BLE4** demonstrates a control platform usable for traction system sizing, with configurable ramps and limits (accel/decel, current/torque ceilings, transition handling) and a set of quantified results reusable to compare against application requirements in **96 V / BLE4 700A** configuration.

## Integration recommendations

- **System compatibility validation:** verify voltage/current fit with the battery architecture and protection chain (fuses, contactors, precharge), considering transients and duty cycle.
- **Parameter setting and configuration:** structure the calibration file (current/torque limits, ramps, regenerative braking, thermal protections, degraded modes) and ensure traceability (parameter/firmware versions) at machine level.
- **Mechanical and thermal integration:** ensure controlled thermal contact (flatness, interface material), size airflow/heat exchange, and select the appropriate variant (base plate, finned heatsink, liquid) for the required endurance.
- **Cable sizing and routing:** minimize lengths and current loops on power wiring; separate power/control; secure insulation and vibration constraints; keep the sin/cos harness routing clean.
- **Electrical protections and safety chain:** integrate emergency stop, interlocks, contactor control, thermal monitoring and fault strategy (controlled stop vs energy cut-off) based on system-level risk analysis.
- **EMC good practices:** manage grounding references, reduce loops, ensure shield continuity when applicable, filter and separate sensitive signals, and manage returns for sensors/control.
- **Diagnostics, maintenance and traceability:** provide CAN/CANopen access and safe measurement points, define event collection procedures (faults, temperatures, states) and log exploitation for maintenance.

## Operating conditions and limits

Nominal operation depends on the **thermal environment** (current derating above internal thresholds) and the quality of **thermal integration** (base plate, heatsink, liquid, airflow). **IP65** rating depends on complete connector assembly and sealing interfaces. Compliance (machine safety, EMC, fault behavior, thermal robustness, durability) depends on the full integration, wiring/protection choices and system-level validation.

## Liability and technical notice

The above information is provided for technical integration of a traction inverter within a vehicle architecture. Performance, robustness and regulatory compliance depend on sizing, parameterization, environment and electrical/mechanical integration (protections, wiring, thermal design, EMC, sensor chain). Final validation (functional, thermal, safety and EMC tests) is required prior to commissioning, with final responsibility resting with the integrator.

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