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# Hardware Specifications

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VERSION v3.2.1

PAGES 44

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DEVICE VELO-X Gen 3 · Assembly Rev C



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## 01 – System Overview

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The Velo-X Gen 3 is a wearable sleep intervention device designed for home use. It monitors sleep physiology and delivers sub-threshold optical cues during REM sleep. The device consists of a flexible headband with embedded electronics and replaceable electrode contacts.

Total weight: 18 g (without packaging)

Dimensions: 340 mm × 28 mm × 9 mm (headband flat)

Materials: Knit polyester/elastane (band), medical-grade silicone (contacts), FR4 PCB, ABS enclosure, stainless steel electrode studs



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## 02 — *Mechanical Assembly*

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The headband is constructed from a 340 mm flat-knit band with an integrated flex-PCB spine. The central enclosure (PCB housing) is ABS-molded and attached to the band via four stainless M1.2 screws.

EOG contact arms extend from the enclosure at 45° and are adjustable over a ±8 mm range via a threaded barrel mechanism. Contact pads are replaceable without tools (twist-lock, quarter-turn).

The LED diffuser assembly is a separate sub-component clipped onto the underside of the enclosure. It can be removed and replaced (part LD-03).



## 03 – Main PCB (Rev C)

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The main PCB is a 4-layer FR4 design, 52 mm × 22 mm.

Rev C addresses the oscillator drift issue present in Rev B (firmware workaround available but hardware fix preferred).

Layer stackup:

- L1: signal (top)
- L2: ground plane
- L3: power distribution
- L4: signal (bottom)

Test points are accessible via pogo-pin fixture (TP-24 jig, internal tool).



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## 04 — Microcontroller — nRF5340

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The nRF5340 is a dual-core Arm Cortex-M33 SoC with integrated BLE 5.3.  
Application core: 128 MHz, runs the signal processing firmware.  
Network core: 64 MHz, runs the BLE stack.

Memory: 1 MB Flash (application), 512 KB RAM

NVS storage: 128 KB allocated for user parameters and session logs

Operating voltage: 1.7–5.5 V (run at 3.0 V regulated)

Sleep current: 2.6  $\mu$ A (System OFF, RTC active)



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## 05 – *EOG Electrode System*

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Two dry Ag/AgCl electrodes monitor the corneo-retinal potential difference.

Electrode spacing: 40 mm center-to-center (fixed for Gen 3).

Input range:  $\pm 500$   $\mu\text{V}$  differential

Target signal range: 12–40  $\mu\text{V}$  (saccades during REM)

Electrode impedance requirement:  $< 5$   $\text{k}\Omega$  (warning above 8  $\text{k}\Omega$ )

The analog front-end uses a fully-differential instrumentation amplifier (INA333) with a gain of 500 V/V, followed by a 12-bit SAR ADC at 256 Hz.



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## 06 — *LED Driver & Optics*

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Two red LEDs (625 nm dominant wavelength) are driven by a constant-current LED driver (BCR402W) operating in PWM mode.

LED forward voltage: 2.1 V @ 5 mA

PWM frequency: 4 kHz (above flicker fusion threshold)

Resolution: 12-bit intensity control

Operational range: 0.02-0.8 cd/m<sup>2</sup> at diffuser surface

The diffuser (LD-03 subassembly) uses a 2 mm PMMA disc with 40° half-angle dispersion. This ensures even illumination across the closed eyelid.







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## 08 — IMU — BMI270

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The BMI270 is a 6-axis IMU (3-axis accelerometer + 3-axis gyroscope) from Bosch. It runs in low-power mode during sleep monitoring.

Accelerometer range:  $\pm 2g$  (default),  $\pm 4/8/16g$  selectable

Accelerometer resolution: 16-bit, 0.061 mg/LSB at  $\pm 2g$

Gyroscope range:  $\pm 250^\circ/s$  (default)

Sampling rate: 50 Hz (current firmware)

Current draw (low-power mode): 180  $\mu A$

The BMI270 FIFO (1 KB) buffers sensor data between MCU wake cycles, allowing the MCU to remain in deep sleep for up to 640 ms at a time.



## 09 – Power System

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Battery: 150 mAh LiPo, 3.7 V nominal

Battery management: BQ25180 (TI), I2C interface

Charging: USB-C, 5V/500mA input, CC/CV 4.2 V cutoff

Regulator: TPS62840 buck converter, 3.0 V output, 95% efficiency

Typical power consumption:

Standby (sensors off): 0.8 mA

Monitoring (no cue): 1.8 mA

Cue event (LED on): 7.2 mA (peak, 50 ms)

BLE advertising: 4.1 mA

BLE connected: 6.8 mA

Estimated battery life: 8–10 hours monitoring (no BLE), 6–8 hours with BLE







## 11 – *Firmware Changelog*

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### v3.2.1 (November 2024)

- Fixed LF/HF display bug in companion app (10x scaling error)
- Added NVS write-wear leveling for parameter store
- Reduced BLE advertising current by 0.4 mA

### v3.2 (September 2024)

- Improved REM classifier (+3.1% sensitivity)
- Fixed HRV gate drift after 4h sessions
- Added motion artifact score to session report
- Reduced idle current 0.3 mA (IMU duty cycle)
- Corrected pulse timing jitter (12 ms → 2 ms max)

### v3.1.4 (June 2024)

- Hotfix: factory reset occasionally failed to clear adaptive state
- Increased NVS partition size from 64 KB to 128 KB



## 12 – Manufacturing & Compliance

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VELO-X Gen 3 is manufactured in a contract facility operating to ISO 9001.  
PCB assembly: IPC-A-610 Class 2.

This product is not classified as a medical device in any jurisdiction.  
It has not been submitted for CE, FDA 510(k), or equivalent approval.  
Users assume all responsibility for use and any adverse outcomes.

RoHS compliance: yes (Directive 2011/65/EU)

WEEE: device must be disposed of as electronic waste

Battery: contains Li-ion cell, subject to IATA DGR for air transport



## *Appendix A – Component Bill of Materials*

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Full BOM for Assembly Rev C. Reference designators correspond to schematic v3.2.1-RC. Quantities are per-unit.

Critical components with long lead times are marked (\*).  
Approved substitutes are listed where available.





## *Appendix B — Pinout Reference*

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Main PCB connector and test point locations.

All measurements from PCB origin (bottom-left corner, PCB top face).

J1 (USB-C): power input and firmware programming

J2 (EOG): 4-pin flex connector, 0.5 mm pitch

J3 (LED): 4-pin flex connector, 0.5 mm pitch

J4 (PPG): 6-pin flex connector, 0.5 mm pitch

J5 (haptic): 2-pin JST SH, 1.0 mm pitch





## Appendix C – BLE Characteristic UUIDs

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All characteristics use the vendor service UUID as base.  
Read/Write/Notify as specified.

CHAR\_SESSION\_STATUS (0x0001): R/N – current session state  
CHAR\_CONFIG\_WRITE (0x0002): W – parameter write (NVS)  
CHAR\_SESSION\_LOG (0x0003): R/N – last session data export  
CHAR\_DEVICE\_INFO (0x0004): R – serial, firmware version  
CHAR\_OTA\_CONTROL (0x0005): W – firmware update initiation  
CHAR\_SIGNAL\_STREAM (0x0006): N – real-time signal data (debug)



