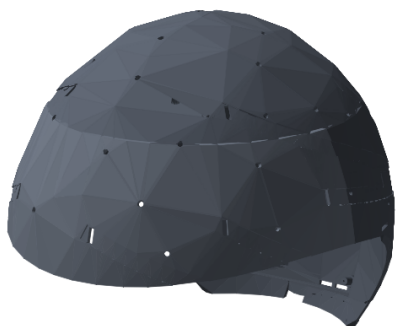


exocortex v1

Order and build package: 960-channel dry-EEG helmet. 16 identical tiles (EXO-410 contact board + EXO-420 controller board), the v1 PETG shell (EXO-140...144) and the EXO-430 hub.

Generated 2026-10-27 13:54 PDT from the exocortex repo at f418a02 by **uv run python -m exo.report**. Every status and quantity below is read from the generated design outputs; prices are research figures (2026-10-27), not quotes. Nothing has been ordered, built or measured.

front left



rear right: hub pod, battery cover



The v1 shell as modelled: crown, band front and back, and the hub pod with its battery cover at the back. FPC slots and channels on the outer face run to the pod; a beanie goes over all of it.

Status

item	what it is	state	orderable?
EXO-420 controller board	RP2040, flash, crystal, LDO, FPC to the hub; 6-layer 1.0 mm	routed, 131 traces / 112 vias, 0 DRC errors; Gerbers, CPL and JLC BOM generated	yes, with EXO-410
EXO-410 contact board	60 ball-pin nuts, 62 followers, 8 × ADS131M08, 4 laser optical encoders; 6-layer 1.0 mm, HDI (blind laser vias)	routing in progress (Freerouting with blind laser vias); best finished run (6-layer, b3-fine25): 4 open net(s), no shorts or clearance errors	not yet
v1 shell EXO-140...144	PETG, Ender-3 V3 SE	34/34 design checks pass; 34.7 h / 428 g PETG (CuraEngine)	printable now
ball-pins EXO-5075...5125	custom gold spring ball-pins, 6 lengths	CAD + drawing data; RFQ drafted, not sent	RFQ to send
hub EXO-430	reference/bias, clock, 16 tile ports, battery, USB-C/Wi-Fi	circuit as code and BOM (≈ \$33/board); no land patterns, outline or routing	not designed yet

What to do, in order

The first order is a **bench order of 2 tile pairs** (two EXO-410 + EXO-420 stacks), not a helmet: the hub has no layout yet, and two tiles prove the contacts, noise and the stack before 16 are bought. The shell can be printed in parallel.

#	step	detail
1	Settle the open decisions (page “Open decisions”)	FPC pinout reversal safety, op-amp, UL1 height, panelization. Two change the copper (UL1 package, a symmetric FPC pinout): settle them before the board order.
2	Finish EXO-410 routing, then quote both boards at JLCPCB	6-layer 1.0 mm ENIG. EXO-410 needs HDI (1st-order blind laser vias, bottom to the layer above) and via-in-pad. Upload the Gerbers, the JLC BOM and CPL (out/pcb/<board>/), panelized 2 × 2 (each board is 44.2 mm, under Standard PCBA's 70 mm minimum).
3	Consign the optical sensors	PAT9125EL-TKMT is not stocked at LCSC/JLC. Buy from WPG Americas (MOQ 125, ≈ \$5.64) and consign 8 to JLC (≈ \$30 consignment fee).
4	Buy the op-amps through JLC Global Sourcing	MCP6V31UT-E/LT: 4 at LCSC, thousands at DigiKey; 124 for 2 tiles. Or switch to OPA391DCKR (same pinout, 1,641 at JLC; ≈ 15 % more noise at 5 MΩ).
5	Send the ball-pin RFQ	To Promax, Richconn and Shenzhen Sandum (text in docs/sourcing.md §5). Bench lot ≈ 130 pins; the six lengths differ only in the barrel.
6	Buy the mechanical hardware	M1.6 × 8 ISO 1207 screws, nylon spacers, FPC jumpers, PETG (list on the “Order D” page).
7	Print and assemble the shell	34.7 h of printing, 428 g PETG; assembly steps on the “Build” page.
8	Bring up the two tiles on the bench	Without the hub, a tile needs 3.6 V, a 2.048 MHz clock, SYNC and a 3 Mbaud UART on its 12-pin FPC: a small breakout + a Pico/FTDI and a bench supply (not designed here).
9	Lay out the hub (EXO-430)	Land patterns, 72 × 56 mm 4-layer outline, placement, routing; then the 16-tile order.

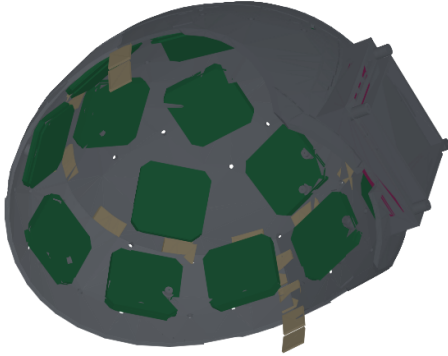
Cost, first order (2 tile pairs)

item	estimate	basis
Electronic parts, 2 tile pairs	≈ \$373 (MCP6V31) / ≈ \$304 (OPA391)	docs/sourcing.md §6: ≈ \$186.50 / \$151.80 per tile pair at JLC library prices
JLC PCBA fees	≈ \$280	setup, stencils, ≈ 20 extended types, joints, handling, Global Sourcing markup, consignment
Bare boards, 6-layer 1.0 mm ENIG	quote needed	EXO-420 standard; EXO-410 HDI (blind vias): JLC publishes no HDI price
PAT9125EL, MOQ 125	≈ \$705 cash (8 used)	WPG Americas \$5.64; the rest covers a helmet + spares
Ball-pins, ≈ 130 prototype	≈ \$130–390 + setup	\$1–3/pin for a prototype lot (unquoted)
Screws, spacers, FPCs, PETG, epoxy	≈ \$60–90	retail packs (unverified)
Total cash out, before board fabrication	≈ \$1,550–1,850	≈ \$650 of it is the tiles' parts + PCBA; the PAT9125 MOQ is the largest single line

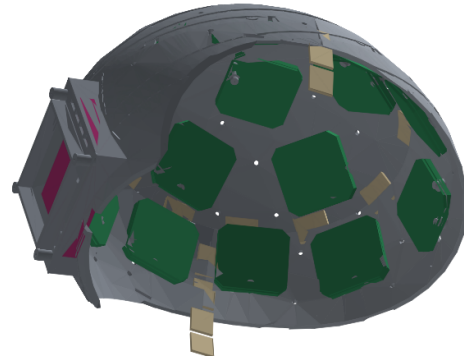
For a full helmet (16 tiles) sourcing.md estimates ≈ \$3,200 for tile parts + PCBA (≈ \$200 per tile pair), plus pins (≈ \$300–1,000 for 1,046), the hub (≈ \$33 of parts + fees + a 4-layer board) and the shell (≈ \$20 of PETG).

Renders

inside, from below: 16 tile stacks (green), hub (magenta), splice tabs (tan)

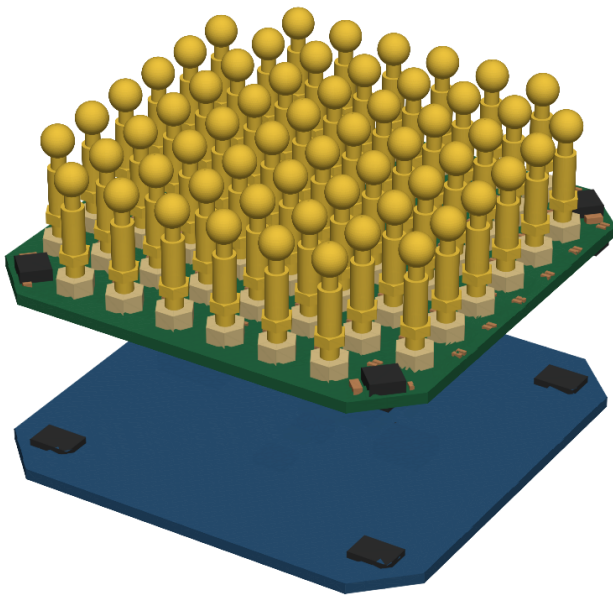


inside, from below left: the hub sits behind T12, under the pod

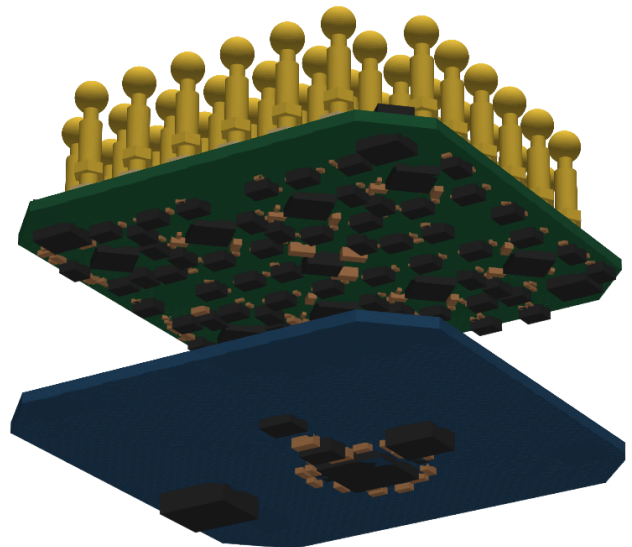


Inside the shell: the 16 flat tile stacks on printed standoffs (green), the hub on its standoffs under the pod (magenta), and the epoxied splice tabs (tan) across the three seams.

scalp side: 60 gold ball-pins on M1.6 SMT nuts,
4 laser optical encoders at the corners



from below: EXO-420 controller (blue, exploded 16 mm)
under EXO-410's back (8 ADS131M08, 62 followers)



One tile, exploded. EXO-410 (green) faces the scalp: 60 gold ball-pins screwed into M1.6 SMT nuts, $2 \times 100\text{ k}\Omega$ protection per pin, laser optical encoders at the corners; its back carries 62 followers, 8 converters and the analog LDO. EXO-420 (blue) mates 1.5 mm behind it on four DF40 pairs. Component envelopes are illustrative (courtyard $\times$ typical height).

EXO-5075
7.5 mm
190/helmet



EXO-5085
8.5 mm
334/helmet



EXO-5095
9.5 mm
284/helmet



EXO-5105
10.5 mm
113/helmet



EXO-5115
11.5 mm
35/helmet

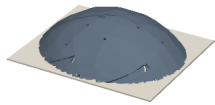


EXO-5125
12.5 mm
4/helmet

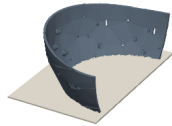


The six ball-pin lengths (EXO-5075...5125): M1.6 thread, 2.5 mm hex collar, Ø2.0 barrel, Ø1.3 plunger with 1.5 mm travel, Ø3.0 gold ball. Lengths follow the flat board's distance to the scalp, which grows toward the tile corners.

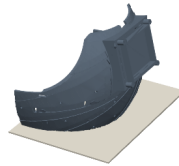
EXO-140 crown
12.3 h, 153 g



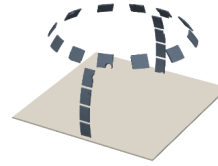
EXO-141 front
4.5 h, 73 g



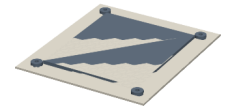
EXO-142 back + pod
15.4 h, 183 g



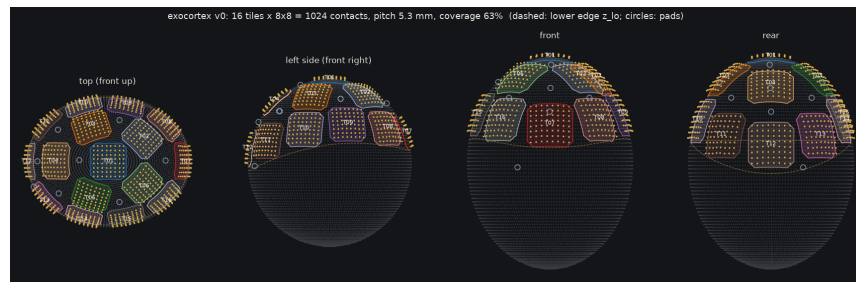
EXO-143 splice tabs
2.0 h, 10 g



EXO-144 battery cover
0.5 h, 9 g

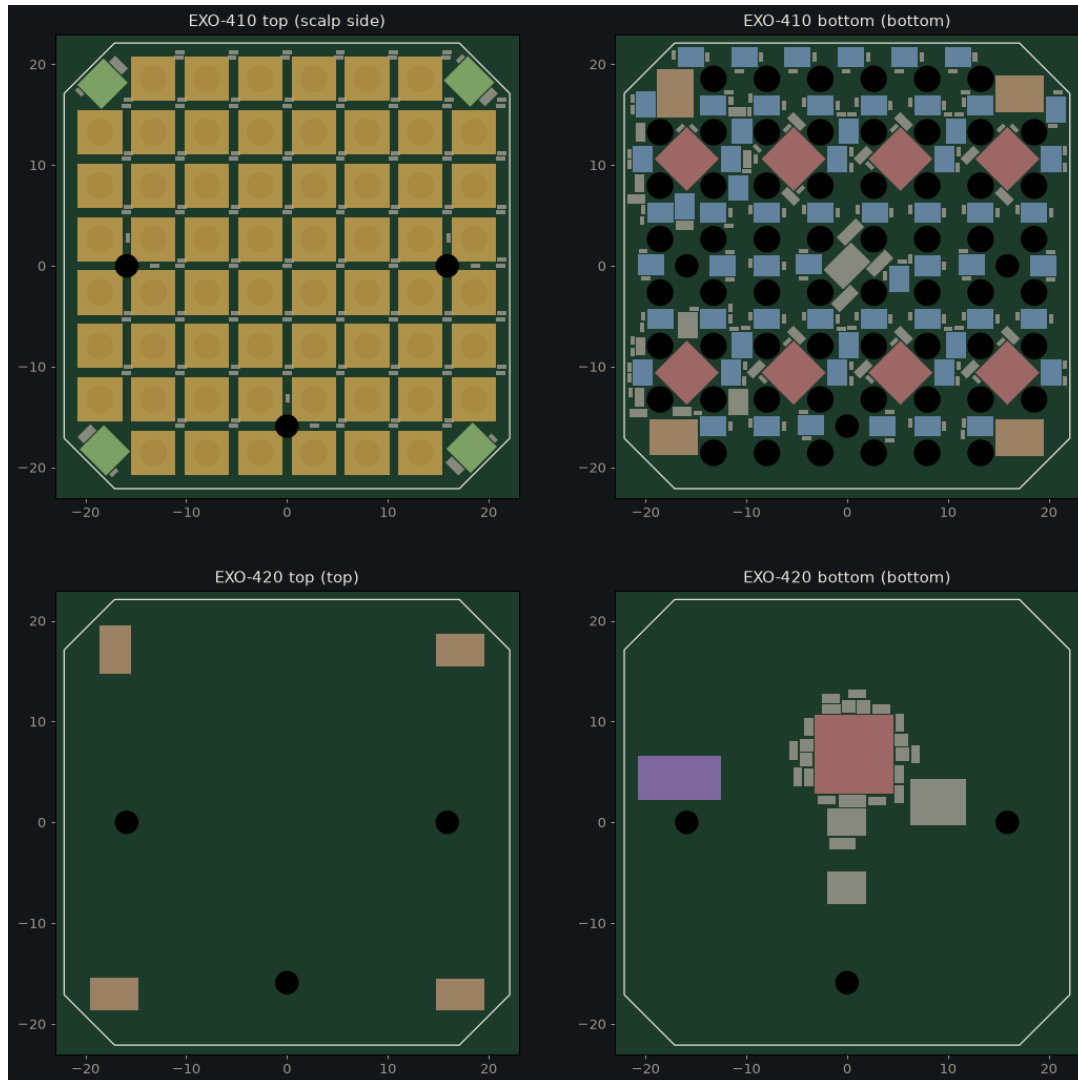


Shell parts in print orientation on the Ender-3 V3 SE bed, with CuraEngine's time and filament per part.

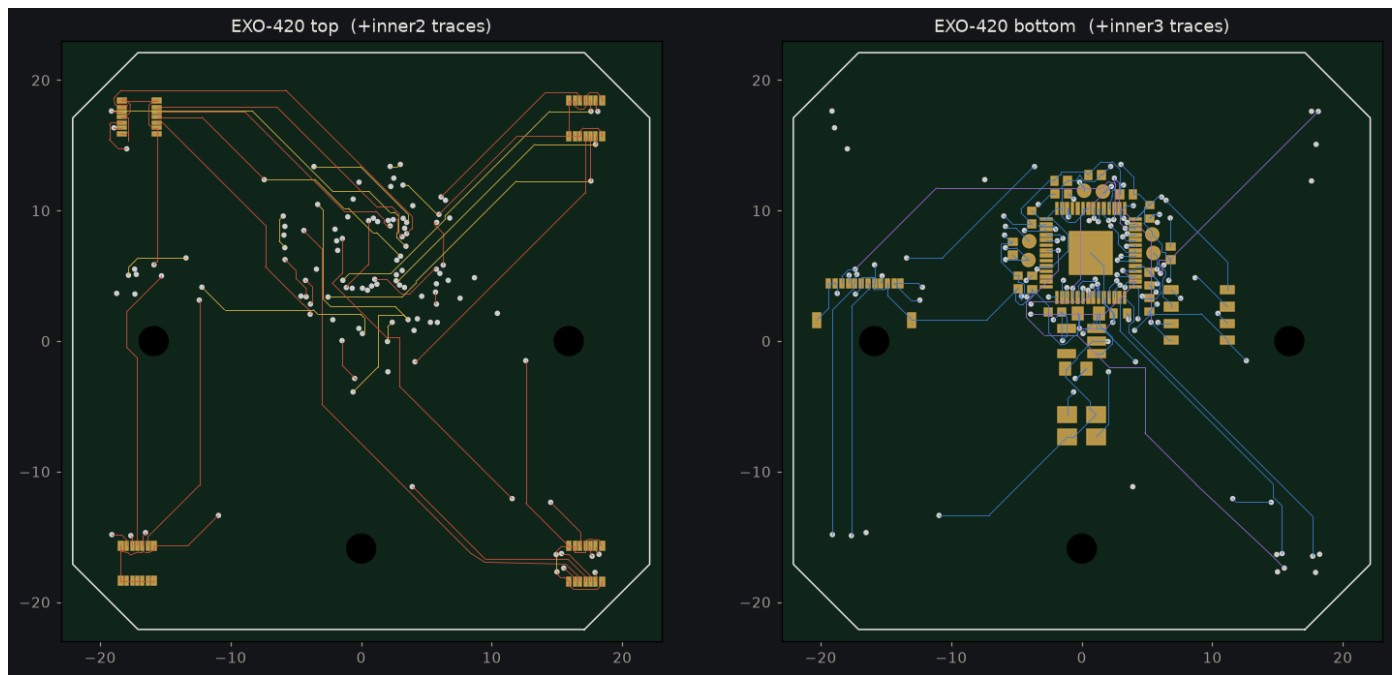


The 16-tile layout on the headform (5.30 mm contact pitch).

Boards



Placement of both boards (courtyards). EXO-410's back: converters (red diamonds) at 45° between the nut pilot holes (black), a follower (blue) behind every pin.



EXO-420 routed copper (131 traces, 112 vias, 0 DRC errors).

Order A: JLCPCB boards and assembly

Files per board in **out/pcb/<board>/**: gerbers/ (copper, mask, paste, silk, edge, drill files per layer span), fab/<board>-bom-jlc.csv, fab/<board>-cpl-jlc.csv. Quantities below are per tile and for the 2-tile bench order.

	EXO-410 contact board	EXO-420 controller board
size / layers / thickness	44.2 mm chamfered square, 6 layers, 1.0 mm	same outline, 6 layers, 1.0 mm
stackup	JLC06101H-3313 (thin L1-L2 prepreg); for the blind vias the L5-L6 dielectric must be $\leq$ the laser drill (1:1 rule): confirm in the HDI quote	JLC06101H-3313
finish / mask	ENIG; nut pads $\varnothing$ 4.2 copper, mask opening + 0.04	ENIG
vias	through 0.25/0.15 (via-in-pad, filled + capped); blind laser 0.225/0.075 bottom-In4 in the ADS131M08 pins (1st-order HDI)	0.3/0.2 through
min trace / space	0.09 / 0.09 mm	0.1 / 0.1 mm
holes	60 $\times$ $\varnothing$ 2.54 NPTH (nut pilots), 3 $\times$ $\varnothing$ 2.2 NPTH (M1.6 screws)	3 $\times$ $\varnothing$ 2.2 NPTH
assembly	Standard PCBA, both sides (0201 parts); panelize 2 $\times$ 2 with rails + fiducials	Standard PCBA, both sides
status	routing in progress (Freerouting with blind laser vias); best finished run (6-layer, b3-fine25): 4 open net(s), no shorts or clearance errors	ready

EXO-410 BOM

line	designators	footprint	LCSC #	MPN	per tile	2 tiles
100k 1%	RA1,RB1,RA2 ... (120)	R 0201 0603Metric	C106224	RC0201FR-07100KL	120	240
MCP6V31UT-E/LT	U1,U2,U3 ... (62)	SC70-5	C623527	MCP6V31UT-E/LT	62	124
M1.6 SMT nut	J1,J2,J3 ... (60)	SMT Nut M1.6 Hex3.18 Pad4.2	C2928168	SMTSO1615MTJ	60	120
1uF X5R 10V	CC1,CC2,CC3 ... (60)	C 0201 0603Metric	C2846675	FH 0201 1uF 10V X5R	60	120
2.2M 1%	RH1,RH2,RH3 ... (60)	R 0201 0603Metric	C474576	RC0201FR-072M2L	60	120
1uF X7R 10V	CR1,CA1,CD1 ... (17)	C 0402 1005Metric	C52923	CL05A105KA5NQNC	17	34
ADS131M08IRSNR	UA1,UA2,UA3 ... (8)	TI RSN WQFN-32 4x4mm P0.4mm EP2.8mm	C5124126	ADS131M08IRSNR	8	16
220nF X7R	CP1,CP2,CP3 ... (8)	C 0201 0603Metric	C18164549	CCTC 0201 220nF 10V X5R	8	16
100nF X7R	CF1,CF2,CF3 ... (8)	C 0201 0603Metric	C22435929	HRE 0201 100nF 16V X7R	8	16
100nF	CUB1,CUB2,CSB1 ... (6)	C 0201 0603Metric	C22435929	HRE 0201 100nF 16V X7R	6	12
DF40C-10DS-0.4V(51)	J200,J201,J202 ... (4)	Hirose DF40C-10DS-0.4V	C424636	DF40C-10DS-0.4V(51)	4	8
PAT9125EL-TKMT	US1,US2,US3 ... (4)	PixArt PAT9125EL LGA-8	consigned	PAT9125EL-TKMT	4	8
4.7uF X5R 6.3V	CSA1,CSA2,CSA3 ... (4)	C 0402 1005Metric	C380302	CCTC 0402 4.7uF 6.3V X5R	4	8
100k 0.1%	RRA,RRB	R 0402 1005Metric	C852472	RT0402BRD07100KL	2	4
SN74LVC1G17DCKR	UB1,UB2	SC70-5	C10425	SN74LVC1G17DCKR	2	4
4.7uF X5R 10V	CL1,CL2	C 0603 1608Metric	C19666	CL10A475KO8NNNC	2	4
2.2M 1%	RR2	R 0402 1005Metric	C11490	0402WGF2204TCE	1	2
TPS7A2033PDBVR	UL1	SOT-23-5	C2862740	TPS7A2033PDBVR	1	2
3.3k	RSDIO	R 0402 1005Metric	C25890	0402WGF3301TCE	1	2
10uF X5R 10V	CBULK	C 0603 1608Metric	C19702	CL10A106KP8NNNC	1	2
10k	RMOT	R 0402 1005Metric	C25744	0402WGF1002TCE	1	2

Notes: MCP6V31UT-E/LT (C623527) has 4 at LCSC: order through Global Sourcing or switch to OPA391DCKR (C2871876).

DF40C-10DS (51) C424636 has 15 at JLC, enough for 2 tiles (8); for a helmet use C6601481 (the (58) suffix, confirm with Hirose).

Where the stocked part differs from the value text: 220 nF 0201 is X5R, the 0402 1 μ F is X5R 25 V. M1.6 nuts: 634 at JLC, enough for 2 tiles (120), not for 16 (960).

EXO-420 BOM

line	designators	footprint	LCSC #	MPN	per tile	2 tiles
100nF	CF1,CM1,CM2 ... (8)	C 0402 1005Metric	C1525	CL05B104KO5NNNC	8	16
DF40C-10DP-0.4V(51)	J210,J211,J212 ... (4)	Hirose DF40C-10DP-0.4V	C424635	DF40C-10DP-0.4V(51)	4	8
4.7uF X5R 10V	CL3,CL4	C 0603 1608Metric	C19666	CL10A475KO8NNNC	2	4
15pF C0G	CX1,CX2	C 0402 1005Metric	C1548	0402CG150J500NT	2	4
1uF	CM7,CM9	C 0402 1005Metric	C52923	CL05A105KA5NQNC	2	4
TPS7A2033PDBVR	UL2	SOT-23-5	C2862740	TPS7A2033PDBVR	1	2
RP2040	UM1	RP2040 QFN-56 7x7mm P0.4mm EP3.2mm	C2040	RP2040	1	2
W25Q16JVSNIQ	UF1	SOIC-8 3.9x4.9mm P1.27mm	C2456211	W25Q16JVSNIQ	1	2
X322512MSB4SI	Y1	Crystal SMD 3225-4Pin 3.2x2.5mm	C9002	X322512MSB4SI	1	2
1k	RX1	R 0402 1005Metric	C11702	0402WGF1001TCE	1	2
10k	RRUN	R 0402 1005Metric	C25744	0402WGF1002TCE	1	2
HC-FPC-05-10-12RLTAG	J100	HCTL FPC 12P P0.5mm	C5213732	HC-FPC-05-10-12RLTAG	1	2

Orders B-D: everything outside the JLC order

B. Consigned and globally sourced parts

part	qty (2 tiles / helmet)	source	price	note
PAT9125EL-TKMT laser optical encoder	8 / 64	WPG Americas eshop.wpgam.com	≈ \$5.64, MOQ 125	consign to JLC; broker 'TKIT' listings are not trusted
MCP6V31UT-E/LT op-amp	124 / 992	JLC Global Sourcing (DigiKey 8.6k)	≈ \$1.45 / \$1.20	or OPA391DCKR C2871876 at JLC, \$0.89

C. Ball-pins (custom, RFQ)

part	length	per helmet	order qty (helmet + spares)	barrel
EXO-5075	7.5 mm	190	207	2.35 mm
EXO-5085	8.5 mm	334	362	3.35 mm
EXO-5095	9.5 mm	284	308	4.35 mm
EXO-5105	10.5 mm	113	124	5.35 mm
EXO-5115	11.5 mm	35	39	6.35 mm
EXO-5125	12.5 mm	4	6	7.35 mm

Spec: M1.6x0.35, hex 2.5 A/F, Ø2.0 barrel, Ø1.3 plunger, Ø3.0 ball, 1.5 travel, brass, Au over Ni. Bench order: ≈ 130 pins (2 tiles × 60 + spares); the bench tiles can use one length (EXO-5095) since they don't sit in the shell. Makers to ask: Promax Pogo Pin, Richconn, Shenzhen Sandum (closest existing M1.6 threaded pin). The RFQ text is in docs/sourcing.md §5.

D. Mechanical hardware and cables

item	per helmet	2-tile bench	note
M1.6 × 8 ISO 1207 / DIN 84 slotted cheese head, A2	48	6	Ø3.0 head max: an M2 head (Ø3.5) would short the four nut pads around each hole
Nylon spacer Ø4 × 1.5 mm, 2.2 bore (M2 size)	48	6	between the boards at each screw; = DF40 mated height
M2 × 6 ISO 7380 button head (hub)	4	—	
M2 × 3 heat-set insert (OD 3.2) + M2 × 5 button head	4 + 4	—	battery cover
12-pin 0.5 mm FPC jumper	16 (1 × 80 mm, 2 × 150 mm, 3 × 200 mm, 2 × 250 mm, 3 × 300 mm, 4 × 350 mm, 1 × 400 mm)	2 (any length)	same-side vs opposite contacts: see the FPC decision; lengths include 40 mm slack
LiPo pouch ≈ 4000 mAh, ≈ 60 × 50 × 8 mm	1	—	hub battery (compartment 62 × 52 × 9)
PETG 1.75 mm, 1 kg	1	—	428 g used
Slow epoxy, Kapton tape, 1 mm foam pad	1 each	—	seams, FPC routing, battery
M1.6 tap + Ø1.3 drill, M2 tap, 0.4 × 2.0 slotted driver	tools	tools	

Build: the v1 shell

Ender-3 V3 SE, PETG, 0.4 nozzle, 0.2 mm layers, 6 walls, 5 top/bottom, 20 % infill, 240/80 °C, brim. STLs are already in print orientation (out/stl/EXO-14x.stl). Times are CuraEngine estimates, ± 20 %.

part	what	orientation	supports	time	PETG
EXO-140	crown	split plane on the bed	tree, roof + standoff tips	12.3 h	153 g
EXO-141	band front	upside down on the split plane	none	4.5 h	73 g
EXO-142	band back + hub pod	upside down on the split plane	tree, under the pod	15.4 h	183 g
EXO-143	splice tabs (20)	flat	none	2.0 h	10 g
EXO-144	battery cover	flat	none	0.5 h	9 g
	total			34.7 h	428 g

Assembly

- Remove supports; check every standoff face is flat (it is the board datum) and sand it if not.
- Tap the 48 Ø1.3 tile pilots M1.6 and the 4 Ø1.7 hub pilots M2, 5–6 mm deep. Heat-set the 4 battery-cover inserts.
- Glue band front to band back with the EXO-143 band tabs, then the crown with the ring tabs (dry-fit first; the tabs only fit one way).
- On the bench: screw the ball-pins into each contact board's nuts, mate EXO-410 and EXO-420 on the four DF40 pairs, plug the FPC into J100.
- Mount the hub first, from inside, on its 4 standoffs (M2 $\times$ 6 from the scalp side).
- Mount the tiles from the vertex down: FPC out through the tile's slot, a spacer at each hole, M1.6 $\times$ 8 from the scalp side between the pins; snug only (≈ 0.05 N·m).
- Lay each FPC in its channel (port per tile in out/shell_v1_report.json $\rightarrow$ fpc_mm), tape every ≈ 40 mm, over the pod wall and down its ceiling slot into the hub.
- Battery lead through the ceiling into the BAT JST, pouch on a foam pad, EXO-144 cover on. Liner, beanie and retention dial as in v0.

Design checks

34 of 34 shell checks pass (out/shell_v1_report.json). Tightest margins:

check	value	need
standoff neck fits the hole keep-out on the controller back	2.2	≤ 2.24 mm (free radius from circuit.json)
shell inner face clears every controller's back parts	0.56	≥ 0.5 mm
tile screw head clears the nut pads' mask openings on the contact board	0.108	≥ 0.05 mm
UL1 (TPS7A2033PDBVR, SOT-23-5) margin in the board gap	0.05	≥ 0 mm
hub stack (board, both faces, REF/BIAS pins) clears every tile stack	3.28	≥ 3.0 mm
helmet goes on over the head (rim lowered to the hub, every ball tip at full travel)	{"shift_mm": -2.0, "worst_margin_mm": 1.2}	≥ 0 mm for some fore-aft shift
FPC channels run clear of the hub pod	0.86	≥ 0 mm

Open decisions

decision	options	recommendation	changes copper?
FPC pinout is not reversal-safe	VIN on pins 1-2, GND on 11-12: a flipped cable shorts the hub supply. Pick same-side vs opposite-side contact cable and confirm pin 1 on a real HCTL part, or make the pinout symmetric.	make it symmetric (mirror the supply pins), so either cable type and orientation is safe	yes, both boards' J100 nets + hub
Op-amp	MCP6V31U via Global Sourcing (best noise: 1.62 μ V at 1 M Ω) vs OPA391DCKR at JLC (1.89 μ V; 1,641 in stock)	MCP6V31U for the bench order; OPA391 if Global Sourcing stalls	no (same pinout)
UL1 height in the 1.5 mm board gap	TPS7A2033PDBVR is 1.45 mm max: 0.05 mm margin, nothing for solder or bow. Options: TPS7A2033DQNR X2SON (0.4 mm, C46459900), or a taller DF40 stack	X2SON-4 for UL1 (new footprint, re-place + re-route EXO-410)	yes, EXO-410
Panelization	44.2 mm boards are under Standard PCBA's 70 mm minimum	2 x 2 panel with 5 mm rails and fiducials (or let JLC panelize)	no
HDI for EXO-410	blind laser vias in the converter pins are the only way the 0.4 mm QFN pins escape between the nut pilot holes (through vias would hit the top-side nut pads)	accept HDI; quote it	already in the route
DF40 receptacle suffix	(51) C424636: 15 at JLC; (58) C6601481: 940	(51) for the bench order; confirm (58) on Hirose's drawing before a helmet	no

Not decided here, needs a bench

Contact impedance and noise on a real head; motion artefacts and whether the corner optics help; pin force and comfort (60 springs per tile); leakage and fault injection; clock skew over 16 FPCs; thermal; EMC; gold pin on a tin-plated nut (fretting); USB isolation while worn.