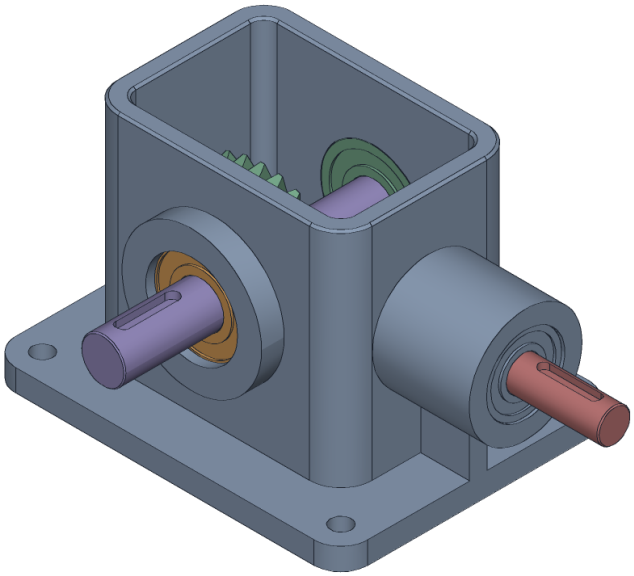
Right-angle bevel gearbox 2:1

Part number MP-EX01 · Revision A · 2026-10-25

VERIFIED: all 12 requirements are met



Overall size (X x Y x Z)	219.52 x 151.59 x 110 mm
Volume	674.97 cm3
Surface area	1830.79 cm2
Mass	2.505 kg
Material	Several: see the parts list
Process	Casting with machined features

1. What was asked for

Right-angle bevel gearbox, assembled, ratio 2:1. Straight bevel gears, module 2.5: a 16-tooth pinion on a 15 mm input shaft and a 32-tooth gear on a 20 mm output shaft, axes crossing at 90 degrees. Each shaft runs in two ball bearings, 6202 on the input shaft and 6204 on the output shaft, seated in a one-piece open-top housing with 8 mm walls and a 10 mm base that has four 9 mm mounting holes. Show the bearings as parts.

2. What was designed

Right-angle 2:1 reduction gearbox with module 2.5 straight bevel gears: a 16-tooth pinion on the 15 mm input shaft drives a 32-tooth gear on the 20 mm output shaft, with the axes meeting at 90 degrees. The pinion is overhung on two 6202 bearings in a cartridge boss on the right-hand wall, and the gear runs between two 6204 bearings, one in the front wall and one in the rear wall. The one-piece open-top cast housing has 8 mm walls and a 10 mm base flange with four 9 mm holes.

Decisions made where the request was silent

- Housing is sand-cast A356-T6 aluminium with machined seats and faces. Gears are 42CrMo4, quenched and tempered, with hardened flanks. Shafts are C45.
- Layout: the input shaft runs along X through the right-hand wall. The output shaft crosses the housing along Y, and its driven end leaves through the front wall. Both axes are about 60 mm above the mounting face, a height set by the gear tip clearance to the floor.
- The two shafts cross at the gear apex, so only one of them can span the housing. The output gear sits between its two 6204 bearings. The pinion is overhung on two 6202 bearings, 40 mm apart, in a cartridge boss with a central shoulder; a cast rib ties the boss to the base flange.
- The 10 mm base runs 22 mm outside the walls as a flange, so the bolts can be reached from above. The four 9 mm holes are at its corners and are ISO 273 medium clearance holes for M8 bolts.
- Face width is 14 mm, just under one third of the 44.7 mm cone distance.
- Gears are an interference fit (H7/s6) on plain shafts. Each gear hub bears on its bearing inner ring through a 1 mm shim pack, which also sets the mounting distance and the backlash. Add keys if the torque is above what the press fit

can carry.
- Bearings are sealed (2RS) and greased for life. The housing shoulders are 3 mm radial (dia 29 and dia 41), inside the makers' abutment limits. Circlips, shims, the gear keys and an end cap for the rear output bore are not modelled.
- Both shaft extensions are 40 mm long with DIN 6885 keyseats for couplings: 5 wide x 3.0 deep on the 15 mm shaft and 6 wide x 3.5 deep on the 20 mm shaft. The keys themselves are not modelled.

Every number in the request, and where it went

the checks were given with the request, so its numbers were not listed.

Specification written before the design

No specification was written before this design: a benchmark replay checks the engine, not the model's specification.

Research and calculations

No online research was done for this design: a benchmark replay checks the engine, not the model's research.

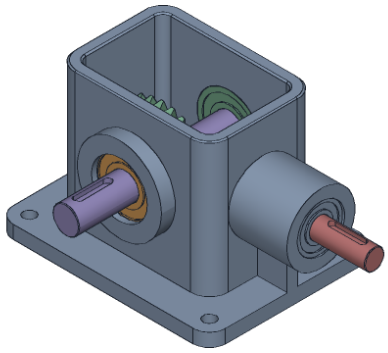
3. Verification against the request

Each requirement below was independently extracted from the request and checked by measuring the finished solid with the CAD kernel. PASS means a feature with the stated value exists on the solid, and on the part the requirement names when it names one (on every one of them when it names several of one kind); a size along a named axis is measured along that axis. CONFIRM means the point cannot be measured and needs a person to check it; the design is not called verified until every point is.

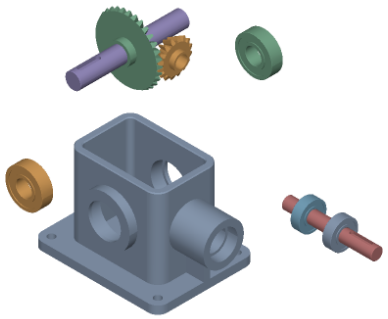
ID	Requirement	Measured on the solid	Result
R1	No two parts overlap	no two parts overlap (15 pairs that could touch were checked)	**PASS**
R2	At least nine parts: two gears, two shafts, four bearings, housing	9 part(s) in the model	**PASS**
R3	16 teeth on the pinion	16 identical, equally spaced features found	**PASS**
R4	32 teeth on the gear	32 identical, equally spaced features found	**PASS**
R5	Input shaft 15 mm	external diameter of 15 mm found (measured on part input_shaft)	**PASS**
R6	Output shaft 20 mm	external diameter of 20 mm found (measured on part output_shaft)	**PASS**
R7	Seats for 6202 bearings (35 mm)	internal diameter of 35 mm found	**PASS**
R8	Seats for 6204 bearings (47 mm)	internal diameter of 47 mm found	**PASS**
R9	Four 9 mm mounting holes	4 hole(s) of dia 9 mm found	**PASS**
R10	Base 10 mm thick	wall / plate thickness of 10 mm found	**PASS**
R11	Walls 8 mm thick	wall / plate thickness of 8 mm found	**PASS**
R12	Axes at 90 degrees	angle of 90 degrees found	**PASS**

4. Views of the built model

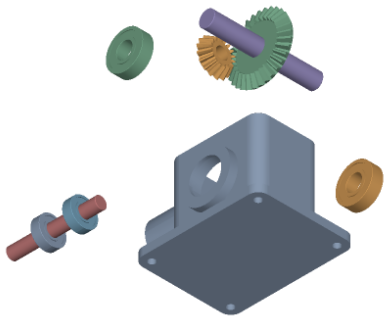
ISO assembled



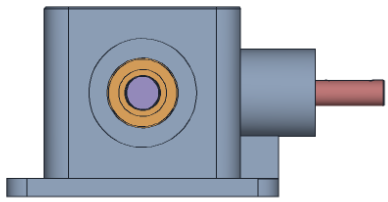
ISO exploded (front-right-top)



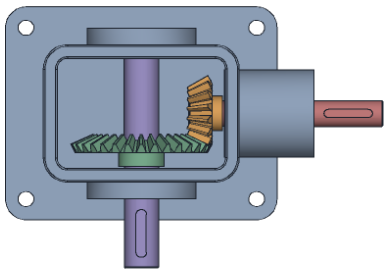
ISO exploded (back-left-bottom)



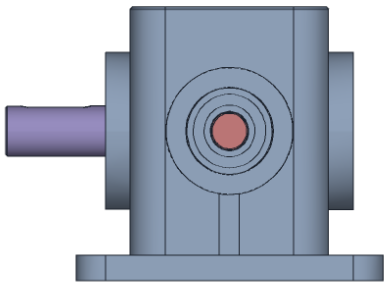
FRONT (looking along +Y)

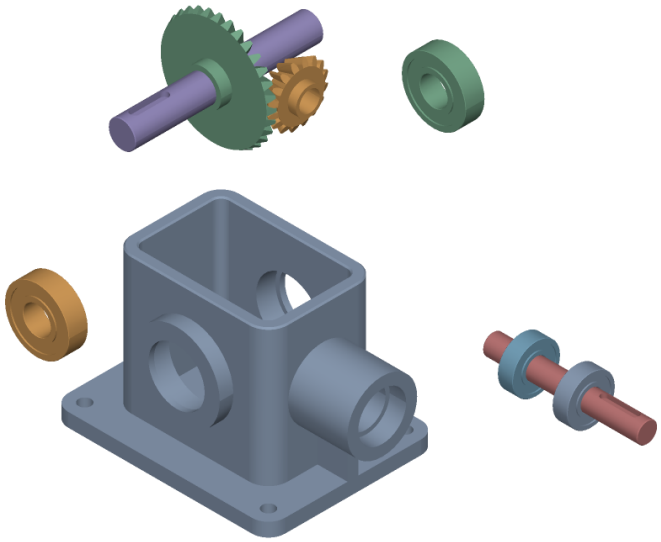


TOP (looking down -Z)



RIGHT (looking along -X)





Visual inspection was not run for this job.

5. Design parameters

The model is parametric. Any value below can be changed and the model, drawing and report regenerated without redesign.

Parameter	Value	Unit	Source	Description
module	2.5	mm	user	Bevel gear module at the large end

Parameter	Value	Unit	Source	Description
pinion_teeth	16		user	Pinion teeth, input shaft
gear_teeth	32		user	Gear teeth, output shaft (ratio 2 to 1)
shaft_angle	90	deg	user	Angle between the input and output shafts
face_w	14	mm	assumed	Tooth face width, under one third of the cone distance
input_d	15	mm	user	Input shaft diameter
output_d	20	mm	user	Output shaft diameter
input_bearing	6202		user	Input shaft bearings, two off
output_bearing	6204		user	Output shaft bearings, two off
wall	8	mm	user	Housing wall thickness
base_t	10	mm	user	Base thickness
mount_hole_d	9	mm	user	Diameter of the four mounting holes
pinion_hub_d	20	mm	assumed	Pinion hub diameter, bears on the bearing inner ring only
pinion_hub_l	6	mm	assumed	Pinion hub length
gear_hub_d	27	mm	assumed	Gear hub diameter, bears on the bearing inner ring only
gear_hub_l	8	mm	assumed	Gear hub length
hub_gap	1	mm	assumed	Shim space between each gear hub and its bearing
gear_clear	8	mm	assumed	Minimum clearance from the gear tips to the housing
input_span	40	mm	assumed	Centre distance of the two input bearings
boss_wall	8	mm	assumed	Wall around the bearing seats
shoulder	3	mm	assumed	Radial height of the bearing seat shoulders
seat_land	4	mm	assumed	Shoulder land behind each output bearing
cavity_r	6	mm	assumed	Inside corner radius of the housing
flange_w	22	mm	assumed	Width of the base flange outside the walls
hole_inset	12	mm	assumed	Mounting hole centres from the flange edges
rib_t	8	mm	assumed	Thickness of the rib under the input cartridge
input_ext	40	mm	assumed	Input shaft extension beyond the housing
output_ext	40	mm	assumed	Output shaft extension beyond the housing
key_len	28	mm	assumed	Length of the coupling keyseats on the shaft ends
shaft_chamfer	0.5	mm	assumed	Chamfer on the shaft ends
edge_break	1	mm	assumed	Chamfer on the top rim of the housing

Optimization

No optimization was run for this design: the fast tier does not optimize; ask for standard or max.

6. Physical properties

Overall size (X x Y x Z)	219.52 x 151.59 x 110 mm
Volume	674.97 cm3
Surface area	1830.79 cm2
Mass	2.505 kg
Centre of mass (X, Y, Z)	13.54, -4.64, 48.5 mm
Faces	483 (74 planar, 61 cylindrical, 220 conical, 0 toroidal/spherical, 128 free-form)
Solid check	Valid closed solid (kernel BRepCheck passed)

Item	Part	Material	Size X x Y x Z (mm)	cm3	Mass	Finish	Tolerance
1	housing	Aluminium A356-T6 (cast)	179.52 x 123.59 x 110	518.37	1.389 kg	RA 1.6 UM	H7 +0.025/0
2	pinion	Alloy steel 42CrMo4 / AISI 4140 (Q&T)	20.69 x 43.89 x 43.89	10.36	81.3 g	RA 1.6 UM	H7/s6 +0.018/0
3	output_gear	Alloy steel 42CrMo4 / AISI 4140 (Q&T)	82.24 x 18.59 x 82.24	30.90	242.6 g	RA 1.6 UM	H7/s6 +0.021/0
4	input_shaft	Carbon steel C45 / AISI 1045	112.92 x 15 x 15	19.56	153.5 g	RA 0.8 UM	k6 +0.012/+0.001
5	output_shaft	Carbon steel C45 / AISI 1045	20 x 137.59 x 20	42.67	335.0 g	RA 0.8 UM	k6 +0.015/+0.002
6	input_bearing_inner	bearing steel 100Cr6 (purchased 6202-2RS)	11 x 35 x 35	7.93	45.9 g	AS BOUGHT	MAKER'S
7	input_bearing_outer	bearing steel 100Cr6 (purchased 6202-2RS)	11 x 35 x 35	7.93	45.9 g	AS BOUGHT	MAKER'S
8	output_bearing_front	bearing steel 100Cr6 (purchased 6204-2RS)	47 x 14 x 47	18.62	105.6 g	AS BOUGHT	MAKER'S
9	output_bearing_rear	bearing steel 100Cr6 (purchased 6204-2RS)	47 x 14 x 47	18.62	105.6 g	AS BOUGHT	MAKER'S

Bearings, screws, nuts and washers from the standards library are purchased parts, drawn as simplified solids. Their masses are estimates for the real part (bearings to a few per cent, fasteners to about ten), not the mass of the solid shown.

7. Material and process

Material (unless the parts list says otherwise)	Aluminium A356-T6 (cast)
Density	2680 kg/m3
Young's modulus	72.4 GPa
Yield strength	165 MPa
Tensile strength	234 MPa
Thermal expansion	21.4 um/m/K
Process	Casting with machined features
Finish	Housing as cast; bearing seats machined Ra 1.6 um; base underside and top rim machined Ra 3.2 um. Gear flanks hardened.

8. Features found on the solid

Tag	Qty	Hole	Axis
A	4	Ø9 THRU - 4x dia 9 thru, for M8 mounting bolts	Z
B	2	Ø15 THRU, CBORE Ø29.4 x 1 DP, CBORE Ø29.4 x 1 DP, CSK Ø15.6 x 90°, CSK Ø15.6 x 90°	X
C	2	Ø20 THRU, CBORE Ø39.44 x 1 DP, CBORE Ø39.44 x 1 DP, CSK Ø20.6 x 90°, CSK Ø20.6 x 90°	Y
D	2	Ø41 THRU, CBORE Ø47 x 14 DP	Y
E	1	Ø15 THRU	X
F	1	Ø20 THRU	Y
G	1	Ø29 THRU, CBORE Ø35 x 11 DP, CBORE Ø35 x 12 DP	X

External diameters	Ø15, Ø20, Ø20.6, Ø27, Ø27.56, Ø35, Ø47, Ø51, Ø63
Internal diameters	Ø5, Ø6, Ø9, Ø15, Ø20, Ø29, Ø29.4, Ø35, Ø39.44, Ø41, Ø47
Fillet / corner radii	R2.5, R3, R6, R12, R14

Gear data (pinion)	straight bevel: module (large end) m 2.5; number of teeth z 16 (counted); pressure angle 20°; mate teeth 32; pitch cone angle 26.57°; reference dia d Ø40; tip dia da (large end) Ø44.472; face width b 14; profile shift x 0; accuracy grade to be stated. The 16 teeth were counted on the solid and the tip read there at Ø44.47; the other figures are those the library's builder drew it with.
Gear data (output_gear)	straight bevel: module (large end) m 2.5; number of teeth z 32 (counted); pressure angle 20°; mate teeth 16; pitch cone angle 63.43°; reference dia d Ø80; tip dia da (large end) Ø82.236; face width b 14; profile shift x 0; accuracy grade to be stated. The 32 teeth were counted on the solid and the tip read there at Ø82.24; the other figures are those the library's builder drew it with.

9. Tolerances

General tolerance: ISO 2768-m on machined features, ISO 2768-c on as-cast surfaces. Permitted deviation of the overall dimensions:

Dimension	Nominal	Permitted deviation
Overall X	219.52 mm	+/- 0.5 mm
Overall Y	151.59 mm	+/- 0.5 mm
Overall Z	110 mm	+/- 0.3 mm

Critical feature	Requirement	Reason
6204 seats dia 47, front and rear walls	H7, coaxial within 0.02, line bored in one setup	Output shaft bearing fit and alignment
6202 seats dia 35 in the input cartridge	H7, coaxial within 0.02	Input shaft bearing fit and alignment
Input and output bore axes	Perpendicular within 0.03 and intersecting within 0.03	Correct bevel mesh and tooth contact
Shaft journals dia 15 and dia 20	k6	Bearing inner ring fit
Gear bores dia 15 and dia 20	H7, with s6 on the shaft seats	Interference fit transmits the torque

Geometric tolerancing (GD&T)

Tolerancing system: ISO GPS (independence principle, ISO 8015); units mm. Standards applied: ISO 8015:2011 (GPS fundamentals: independence principle), ISO 1101:2017 (geometrical tolerancing: form, orientation, location, run-out), ISO 5459:2011 (datums and datum systems), ISO 2768-1:1989 and ISO 2768-2:1989 (general tolerances), ISO 286-1:2010 and ISO 286-2:2010 (limits and fits), ISO 2692:2021 (maximum material requirement), ISO 273:1979 (clearance holes for bolts and screws), ISO 965-1:2013 (ISO metric screw threads: tolerances), ISO 21920-1:2021 / ISO 1302 (surface texture indication). The scheme below was computed by rule from the measured geometry: it is a proposal for an engineer to confirm, not a toleranced drawing.

Datums

Datum	Feature	Basis
A	housing: mounting face: the flat face at Z = 0 (the underside of the part)	assumed: the face on Z = 0 of this part; faces are not classified per part in an assembly, so the design convention (mounting face on Z = 0) decided. The primary datum is the main mounting face: a plane that carries the functional contact, flat enough to seat (ISO 5459; ASME Y14.5-2018 section 7).
B	housing: bore Ø47 (91.59 long, axis Y)	the largest internal cylinder on the Y axis that is not one of a hole pattern; no bore lies on the Z axis. The secondary datum is the main bore (a cylinder, its axis): it locates the mating shaft or spigot (ISO 5459; ASME Y14.5-2018 section 7).
C	housing: side face: the flat face normal to X at X = -79.118	assumed: the side face at the minimum X of the bounding box (X = -79.118); the design convention centres parts on X or starts them at X = 0. The tertiary datum is a side face normal to the primary datum (ISO 5459; ASME Y14.5-2018 section 7).
A	pinion: end face: the flat face normal to X at X = 26.71	the part is round about X: its end face at the minimum X (X = 26.71), square to that axis. On a round part the primary datum is an end face square to its axis, the secondary its axis (ISO 5459; ASME Y14.5-2018 section 7).
B	pinion: bore Ø15 (18.959 long, axis X)	the largest internal cylinder on the X axis that is not one of a hole pattern; no bore lies on the Z axis. The secondary datum is the main bore (a cylinder, its axis): it locates the mating shaft or spigot (ISO 5459; ASME Y14.5-2018 section 7).

Datum	Feature	Basis
A	output_gear: end face: the flat face normal to Y at Y = -30.7951	the part is round about Y: its end face at the minimum Y (Y = -30.7951), square to that axis. On a round part the primary datum is an end face square to its axis, the secondary its axis (ISO 5459; ASME Y14.5-2018 section 7).
B	output_gear: bore Ø20 (15.136 long, axis Y)	the largest internal cylinder on the Y axis that is not one of a hole pattern; no bore lies on the Z axis. The secondary datum is the main bore (a cylinder, its axis): it locates the mating shaft or spigot (ISO 5459; ASME Y14.5-2018 section 7).
A	input_shaft: journal Ø15 from X = 48.698 to 59.098	a bearing journal of the shaft along X (2 journal stretches were measured; the two at its ends carry it). A shaft turns about the common axis of its bearing journals: they are datums A and B, and A-B the common datum (ISO 5459 common datum; ASME Y14.5-2018 7.12).
B	input_shaft: journal Ø15 from X = 88.698 to 99.098	a bearing journal of the shaft along X (2 journal stretches were measured; the two at its ends carry it). A shaft turns about the common axis of its bearing journals: they are datums A and B, and A-B the common datum (ISO 5459 common datum; ASME Y14.5-2018 7.12).
A	output_shaft: journal Ø20 from Y = -45.495 to -32.095	a bearing journal of the shaft along Y (2 journal stretches were measured; the two at its ends carry it). A shaft turns about the common axis of its bearing journals: they are datums A and B, and A-B the common datum (ISO 5459 common datum; ASME Y14.5-2018 7.12).
B	output_shaft: journal Ø20 from Y = 32.095 to 45.495	a bearing journal of the shaft along Y (2 journal stretches were measured; the two at its ends carry it). A shaft turns about the common axis of its bearing journals: they are datums A and B, and A-B the common datum (ISO 5459 common datum; ASME Y14.5-2018 7.12).

Feature control frames

ID	Feature	Characteristic	Tolerance (mm)	Datums	Rule
G1	housing: mounting face: the flat face at Z = 0 (the underside of the part)	flatness (FLAT)	0.4	-	ISO 2768-2 Table 1 (straightness and flatness), class K, for the 179.516 mm side: 0.4 mm. The datum face must be flat enough to seat. (The 110 mm height of the part has a size band of 0.6 under ISO 2768-m.) (ISO 2768-2:1989 Tables 1 to 4)
G2	housing: bore Ø47 (91.59 long, axis Y)	parallelism (PAR)	Ø0.6	A	ISO 2768-2 clause 5.3: parallelism equals the greater of the size tolerance of the distance to A (110 mm, ISO 2768-m: ±0.3, a band of 0.6) and the straightness tolerance over the 91.59 mm length (class K): 0.6 mm; the axis of B lies parallel to the mounting face. (ISO 2768-2:1989 Tables 1 to 4)
G3	housing: top face: the flat face at Z = 110	parallelism (PAR)	0.6	A	ISO 2768-2 clause 5.3: the parallelism of opposite faces equals the greater of the size tolerance of the 110 mm thickness (ISO 2768-m: ±0.3, a band of 0.6) and the flatness tolerance over 179.516 mm (class K: 0.4); the part is a plate (Z is its smallest extent). (ISO 2768-2:1989 Tables 1 to 4)

ID	Feature	Characteristic	Tolerance (mm)	Datums	Rule
G4	housing: 4 holes Ø9, axes parallel to Z	position (POS)	Ø1 (M)	A|B|C	ASME Y14.5-2018 Appendix B floating fastener: T = H - F = 9 - 8 = 1 mm, with H = Ø9 the clearance hole at MMC (ISO 273 medium clearance for M8) and F = 8 the screw's nominal diameter; both parts are taken to have clearance holes. The spec calls these holes '4x dia 9 thru, for M8 mounting bolts'. (ASME Y14.5-2018 Appendix B (fixed and floating fastener formulas); ISO 273 clearance holes)
G5	housing: 2 holes Ø41, axes parallel to Y	position (POS)	Ø1	A|B|C	Ø41 matches no ISO 273 clearance hole, so no fastener formula applies: position at the general tolerance, twice the ISO 2768-m linear tolerance (±0.5) for 179.516 mm. Name the fastener or the mating pin to tighten this. (ISO 2768-1:1989 Tables 1 to 3)
G6	housing: bearing housing seat Ø35	cylindricity (CYL)	0.013	-	Form of a bearing seat held within half the IT7 size tolerance (IT7 = 25 um at Ø35): 0.0125 mm; the ring must not be distorted (ISO 2768-2 clause 4; ASME Y14.5-2018 Rule #1 keeps form within size). (ISO 286-1:2010 Table 1 and ISO 286-2:2010 (printed tables encoded in mechpro/gdt.py); bearing makers' mounting guides)
G7	housing: bearing housing seat Ø35	circular runout (RUNOUT)	0.2	B	ISO 2768-2 Table 4 general circular run-out, class K: 0.2 mm about the datum axis B. (ISO 2768-2:1989 Tables 1 to 4)
G8	housing: bearing housing seat Ø47	cylindricity (CYL)	0.013	-	Form of a bearing seat held within half the IT7 size tolerance (IT7 = 25 um at Ø47): 0.0125 mm; the ring must not be distorted (ISO 2768-2 clause 4; ASME Y14.5-2018 Rule #1 keeps form within size). (ISO 286-1:2010 Table 1 and ISO 286-2:2010 (printed tables encoded in mechpro/gdt.py); bearing makers' mounting guides)
G9	pinion: end face: the flat face normal to X at X = 26.71	flatness (FLAT)	0.2	-	ISO 2768-2 Table 1 (straightness and flatness), class K, for the 43.8911 mm side: 0.2 mm. The datum face must be flat enough to seat. (The 20.6876 mm height of the part has a size band of 0.4 under ISO 2768-m.) (ISO 2768-2:1989 Tables 1 to 4)
G10	pinion: bore Ø15 (18.959 long, axis X)	perpendicularity (PERP)	Ø0.4	A	ISO 2768-2 Table 2 (perpendicularity), class K, by the shorter side (18.959 mm): 0.4 mm; the axis of B must stand square on the mounting face. (ISO 2768-2:1989 Tables 1 to 4)

ID	Feature	Characteristic	Tolerance (mm)	Datums	Rule
G11	output_gear: end face: the flat face normal to Y at Y = -30.7951	flatness (FLAT)	0.2	-	ISO 2768-2 Table 1 (straightness and flatness), class K, for the 82.2361 mm side: 0.2 mm. The datum face must be flat enough to seat. (The 18.5921 mm height of the part has a size band of 0.4 under ISO 2768-m.) (ISO 2768-2:1989 Tables 1 to 4)
G12	output_gear: bore Ø20 (15.136 long, axis Y)	perpendicularity (PERP)	Ø0.4	A	ISO 2768-2 Table 2 (perpendicularity), class K, by the shorter side (15.136 mm): 0.4 mm; the axis of B must stand square on the mounting face. (ISO 2768-2:1989 Tables 1 to 4)
G13	input_shaft: journal Ø15 from X = 48.698 to 59.098	circular runout (RUNOUT)	0.2	A-B	ISO 2768-2 Table 4 general circular run-out, class K: 0.2 mm of each journal about the common axis A-B; the spec or the bearing maker may ask for less. (ISO 2768-2:1989 Tables 1 to 4)
G14	input_shaft: journal Ø15 from X = 88.698 to 99.098	circular runout (RUNOUT)	0.2	A-B	ISO 2768-2 Table 4 general circular run-out, class K: 0.2 mm of each journal about the common axis A-B; the spec or the bearing maker may ask for less. (ISO 2768-2:1989 Tables 1 to 4)
G15	input_shaft: shaft journal Ø15	cylindricity (CYL)	0.009	-	Form of a bearing seat held within half the IT7 size tolerance (IT7 = 18 um at Ø15): 0.009 mm; the ring must not be distorted (ISO 2768-2 clause 4; ASME Y14.5-2018 Rule #1 keeps form within size). (ISO 286-1:2010 Table 1 and ISO 286-2:2010 (printed tables encoded in mechpro/gdt.py); bearing makers' mounting guides)
G16	output_shaft: journal Ø20 from Y = -45.495 to -32.095	circular runout (RUNOUT)	0.2	A-B	ISO 2768-2 Table 4 general circular run-out, class K: 0.2 mm of each journal about the common axis A-B; the spec or the bearing maker may ask for less. (ISO 2768-2:1989 Tables 1 to 4)
G17	output_shaft: journal Ø20 from Y = 32.095 to 45.495	circular runout (RUNOUT)	0.2	A-B	ISO 2768-2 Table 4 general circular run-out, class K: 0.2 mm of each journal about the common axis A-B; the spec or the bearing maker may ask for less. (ISO 2768-2:1989 Tables 1 to 4)
G18	output_shaft: shaft journal Ø20	cylindricity (CYL)	0.011	-	Form of a bearing seat held within half the IT7 size tolerance (IT7 = 21 um at Ø20): 0.0105 mm; the ring must not be distorted (ISO 2768-2 clause 4; ASME Y14.5-2018 Rule #1 keeps form within size). (ISO 286-1:2010 Table 1 and ISO 286-2:2010 (printed tables encoded in mechpro/gdt.py); bearing makers' mounting guides)

Fits

Feature	Nominal	Fit	Hole limits (mm)	Shaft limits (mm)	Clearance (mm)	Purpose
housing: bearing housing seat Ø35	Ø35	H7	+0.025 / 0	-	-	housing seat for a bearing of Ø35 outside diameter (6202): H7 per the spec's critical feature '6202 seats dia 35 in the input cartridge: H7, coaxial within 0.02' (spec critical feature '6202 seats dia 35 in the input cartridge'; ISO 286-1:2010 Table 1 and ISO 286-2:2010 (printed tables encoded in mechpro/gdt.py))
housing: bearing housing seat Ø47	Ø47	H7	+0.025 / 0	-	-	housing seat for a bearing of Ø47 outside diameter (6204): H7 per the spec's critical feature '6204 seats dia 47, front and rear walls: H7, coaxial within 0.02, line bored in one setup' (spec critical feature '6204 seats dia 47, front and rear walls'; ISO 286-1:2010 Table 1 and ISO 286-2:2010 (printed tables encoded in mechpro/gdt.py))
pinion: Gear bores dia 15 and dia 20	Ø15	H7/s6	+0.018 / 0	+0.039 / +0.028	interference 0.010 to 0.039	spec critical feature 'Gear bores dia 15 and dia 20': H7, with s6 on the shaft seats (Interference fit transmits the torque) (spec critical feature; ISO 286-1:2010 Table 1 and ISO 286-2:2010 (printed tables encoded in mechpro/gdt.py))
output_gear: Gear bores dia 15 and dia 20	Ø20	H7/s6	+0.021 / 0	+0.048 / +0.035	interference 0.014 to 0.048	spec critical feature 'Gear bores dia 15 and dia 20': H7, with s6 on the shaft seats (Interference fit transmits the torque) (spec critical feature; ISO 286-1:2010 Table 1 and ISO 286-2:2010 (printed tables encoded in mechpro/gdt.py))

Feature	Nominal	Fit	Hole limits (mm)	Shaft limits (mm)	Clearance (mm)	Purpose
input_shaft: shaft journal Ø15	Ø15	k6	-	+0.012 / +0.001	-	shaft journal for a bearing of Ø15 bore (6202): k6 per the spec's critical feature 'Shaft journals dia 15 and dia 20: k6' (spec critical feature 'Shaft journals dia 15 and dia 20'; ISO 286-1:2010 Table 1 and ISO 286-2:2010 (printed tables encoded in mechpro/gdt.py))
output_shaft: shaft journal Ø20	Ø20	k6	-	+0.015 / +0.002	-	shaft journal for a bearing of Ø20 bore (6204): k6 per the spec's critical feature 'Shaft journals dia 15 and dia 20: k6' (spec critical feature 'Shaft journals dia 15 and dia 20'; ISO 286-1:2010 Table 1 and ISO 286-2:2010 (printed tables encoded in mechpro/gdt.py))

General tolerances

Linear and angular dimensions	ISO 2768-m
Geometric tolerances without a frame	ISO 2768-K
Linear, 0.5 up to 3	±0.1
Linear, over 3 up to 6	±0.1
Linear, over 6 up to 30	±0.2
Linear, over 30 up to 120	±0.3
Linear, over 120 up to 400	±0.5
Angular	ISO 2768-m, by the shorter leg of the angle: ±1° (up to 10 mm); ±0°30' (over 10 up to 50 mm); ±0°20' (over 50 up to 120 mm); ±0°10' (over 120 up to 400 mm); ±0°5' (over 400 mm)
Radii and chamfers	ISO 2768-m, external radii and chamfer heights: ±0.2 (0.5 up to 3 mm); ±0.5 (over 3 up to 6 mm); ±1 (over 6 mm)
Source	ISO 2768-1:1989 Tables 1 to 3; ISO 2768-2:1989 Tables 1 to 4; the spec asked for 'ISO 2768-m on machined features, ISO 2768-c on as-cast surfa'

Surface texture

Surface	Roughness	Rule
all machined surfaces	Ra 1.6 um	From the spec's finish: 'Housing as cast; bearing seats machined Ra 1.6 um; base underside and top rim machined Ra 3.2 um. Gear flanks hardened.' (ISO 21920 / ISO 1302 indication)
housing: bearing housing seat Ø35	Ra 1.6 um	From the spec: 'seats machined Ra 1.6' (ISO 21920 indication)
housing: bearing housing seat Ø47	Ra 1.6 um	From the spec: 'seats machined Ra 1.6' (ISO 21920 indication)
input_shaft: shaft journal Ø15	Ra 0.8 um	Bearing seats: Ra 0.8 um (bearing makers' mounting guides; ISO 21920 indication)
output_shaft: shaft journal Ø20	Ra 0.8 um	Bearing seats: Ra 0.8 um (bearing makers' mounting guides; ISO 21920 indication)

Process capability

Process capability: Casting with machined features, typical achievable tolerance ±0.5 mm. Source: ±0.5 to ±1 mm as cast (ISO 8062 CT8 to CT10); machined features as CNC; typical figures from vendor design guides for each process (not a standard); the real capability depends on the shop, the machine and the feature.

G1 housing: mounting face: the flat face at Z = 0 (the underside of the part): flatness 0.4 mm is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining or a finer process.
G2 housing: bore Ø47 (91.59 long, axis Y): parallelism 0.6 mm is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining or a finer process.
G3 housing: top face: the flat face at Z = 110: parallelism 0.6 mm is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining or a finer process.
G6 housing: bearing housing seat Ø35: cylindricity 0.0125 mm is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining or a finer process.
G7 housing: bearing housing seat Ø35: circular runout 0.2 mm is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining or a finer process.
G8 housing: bearing housing seat Ø47: cylindricity 0.0125 mm is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining or a finer process.
G9 pinion: end face: the flat face normal to X at X = 26.71: flatness 0.2 mm is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining or a finer process.
G10 pinion: bore Ø15 (18.959 long, axis X): perpendicularity 0.4 mm is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining or a finer process.
G11 output_gear: end face: the flat face normal to Y at Y = -30.7951: flatness 0.2 mm is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining or a finer process.
G12 output_gear: bore Ø20 (15.136 long, axis Y): perpendicularity 0.4 mm is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining or a finer process.
G13 input_shaft: journal Ø15 from X = 48.698 to 59.098: circular runout 0.2 mm is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining or a finer process.
G14 input_shaft: journal Ø15 from X = 88.698 to 99.098: circular runout 0.2 mm is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining or a finer process.
G15 input_shaft: shaft journal Ø15: cylindricity 0.009 mm is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining or a finer process.
G16 output_shaft: journal Ø20 from Y = -45.495 to -32.095: circular runout 0.2 mm is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining or a finer process.
G17 output_shaft: journal Ø20 from Y = 32.095 to 45.495: circular runout 0.2 mm is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining or a finer process.
G18 output_shaft: shaft journal Ø20: cylindricity 0.0105 mm is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining or a finer process.
housing: bearing housing seat Ø35: H7 (hole band 0.025 mm) is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining (reaming, boring or grinding) or a finer process.
housing: bearing housing seat Ø47: H7 (hole band 0.025 mm) is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining (reaming, boring or grinding) or a finer process.
pinion: Gear bores dia 15 and dia 20: H7/s6 (hole band 0.018 mm) is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining (reaming, boring or grinding) or a finer process.
pinion: Gear bores dia 15 and dia 20: H7/s6 (shaft band 0.011 mm) is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining (reaming, boring or grinding) or a finer process.
output_gear: Gear bores dia 15 and dia 20: H7/s6 (hole band 0.021 mm) is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining (reaming, boring or grinding) or a finer process.
output_gear: Gear bores dia 15 and dia 20: H7/s6 (shaft band 0.013 mm) is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining (reaming, boring or grinding) or a finer process.
input_shaft: shaft journal Ø15: k6 (shaft band 0.011 mm) is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining (reaming, boring or grinding) or a finer process.
output_shaft: shaft journal Ø20: k6 (shaft band 0.013 mm) is tighter than the ±0.5 mm Casting with machined features typically holds: needs secondary machining (reaming, boring or grinding) or a finer process.

Validation of the scheme (CHECK: a rule is not met; an engineer must look)

Rule	Result	Detail
position tolerance within H - F (ASME Y14.5-2018 Appendix B)	**OK**	1 position frames checked
every frame's datums are defined	**OK**	18 frames, 11 datums
form tolerance within the size tolerance of its feature (ISO 8015: advisory, independence applies)	**OK**	7 form frames checked
fits named only on features measured on the solid	**OK**	6 fits, all on measured diameters
units consistent	**OK**	all tolerances and fits are in mm
lists bounded	**OK**	18 frames and 6 fits; at most 8 frames and 2 fits on one part, of 40 and 20 allowed

Notes

- ISO 8015 independence principle: a size tolerance does not limit form unless the envelope requirement (E) is stated; add (E) to the fits that mate (ISO 14405-1). MMC on the position frames is ISO 2692's maximum material requirement.
- 4 purchased part(s), whose makers' drawings apply, not this scheme: input_bearing_inner (deep-groove ball bearing 6202), input_bearing_outer (deep-groove ball bearing 6202), output_bearing_front (deep-groove ball bearing 6204), output_bearing_rear (deep-groove ball bearing 6204).
- Spec critical feature 'Input and output bore axes': Perpendicular within 0.03 and intersecting within 0.03 (Correct bevel mesh and tooth contact); it names no fit, so none was tabulated: confirm with the customer.

This tolerancing scheme is a proposal computed from the measured geometry, the stated process (Casting with machined features) and the spec, under ISO GPS (ISO 1101, ISO 2768, ISO 286). No person has reviewed it. A qualified engineer must confirm every datum, tolerance, fit and surface finish against the part's function before manufacture. Every feature control frame is listed in a table on the drawing; the frames whose feature the drawing can find are drawn on its views.

10. Manufacturability screening

Rule-of-thumb checks on measured geometry. A screen, not a sign-off.

Level	Check	Finding
WARNING	thin wall	Thinnest walls are about 2.411 mm (on 'pinion' (2.411 mm), 'output_gear' (2.414 mm)): sand castings need about 3 mm or more; die castings hold about 1 to 2.5 mm. Check with the foundry.
WARNING	draft	Surface without draft along the pull direction on 'housing' (53% along Z), 'pinion' (18% along Z), 'output_gear' (43% along Z) and 2 more. A cast face needs about 1 to 3 degrees to leave the mould or the die (faces machined after casting excepted).

Manufacturing notes

- Line-bore both 6204 seats in one setup and bore the 6202 cartridge square to them.
- Set backlash to 0.05-0.10 mm with the hub shims and check the tooth contact pattern with marking compound.
- Cast fillets R3 at internal junctions where not shown.
- Fit a guard or cover over the open top and a cap on the rear output bore before running.
- Gears are modelled with backlash and do not touch.
- Deburr all edges.

Files delivered

File	Contents	Size	SHA-256 (first 16)
MP-EX01_right-angle-bevel-gearbox-2-1.step	STEP AP242 - exact solid, opens in every CAD system	4794 kB	d72522cba2bdd9c6
MP-EX01_right-angle-bevel-gearbox-2-1.stl	STL (binary) - 3D printing mesh	1044 kB	dbb436e16a320078
MP-EX01_right-angle-bevel-gearbox-2-1.glb	glTF binary - web and AR viewers	507 kB	690dc6edefab5127
MP-EX01_right-angle-bevel-gearbox-2-1_parts.zip	Every part as its own file: 9 parts, each in STEP and STL, with drawings of 5 of them	1954 kB	07d26ba1b5c7b533
MP-EX01_right-angle-bevel-gearbox-2-1_drawing.pdf	PDF - 2D engineering drawing	182 kB	723d8237c55fab03
MP-EX01_right-angle-bevel-gearbox-2-1_drawing.dxf	DXF - 2D engineering drawing	1566 kB	a3243845002e1489
MP-EX01_right-angle-bevel-gearbox-2-1_parts.csv	Parts list (CSV) - for spreadsheets and ERP	1 kB	836a80e4901730a8

Checks on the delivered files

Check	Measured	Result
STEP file read back	9 of 9 solids, volume differs from the kernel model by 0.0000%	PASS
STEP files of the single parts	9 files; 9 read back, each one solid of the part's own volume	PASS
Drawings of the single parts	5 sheets in the zip of the single parts, each part drawn as it sits in the assembly; views from the mesh; none of the 4 purchased parts	INFO
Mesh (STL / 3MF / OBJ / GLB)	21380 triangles at 0.1154 mm chord tolerance; volume within 0.059% of the exact solid; closed (watertight)	PASS
Geometry health	smallest edge 0.42426 mm; 0 tiny edges, 0 sliver faces	PASS

Check	Measured	Result
Drawing views	exact hidden-line projection	INFO

Limits of this report

- This design, its drawing and this report were generated automatically. No engineer has checked them.
- Verification confirms that features with the stated dimensions exist on the solid. It does not confirm that the design is fit for its purpose.
- No stress, fatigue, thermal or tolerance stack-up analysis has been performed.
- Material properties are typical handbook values. Use supplier certificates for design calculations.
- Threads are not modelled. Tapped holes are modelled at tap-drill diameter and called out in the hole table.
- The geometric tolerances and fits are a proposal computed by rule from the measured geometry; an engineer must confirm them before manufacture.
- A qualified engineer must review the design before it is manufactured or put into service.