

Top-down stereo safety sensor for cobot cells

Mounted above the cell, Safety-Cam measures the robot's envelope every frame and grades the robot's speed by the distance to the nearest person, instead of stopping at a fixed zone boundary. Values are for the production design point: 100° lenses, 3.0 m top-down mount. The dev rig uses 70° lenses, which limits its coverage to 3.5 × 2.2 m.

7.2 × 4.5 m
floor area monitored from 3.0 m

1.5 m/s
full robot speed, every side open (40 mm detection)

40 mm
detection capability target (hand)

PLd · Cat 3
ISO 13849-1 target, two diverse channels on one module

SENSING		
Cameras	4 × OV9281 global shutter, NIR monochrome	M
Arrangement	Two stereo pairs over the same field of view, facing down	T
Resolution	1280 × 800 per camera	M
Disparity range	128 levels	M
Field of view	100° × 73° per camera (dev rig: 70° × 47°)	T
Stereo baseline	150 mm per pair (dev rig: 61 mm)	T
Illumination	940 nm flood + dot projector covering the 100° field, per-emitter power control, Class 1 (IEC 60825-1)	T
Frame rate	60 fps per pair target (streaming). Today: 45.7 fps fabric per pair, ~11 fps end to end on the dev rig	M
Lens monitoring	Conductive ITO trace on each window, resistance monitored	T
DETECTION · 3.0 M MOUNT		
Monitored floor area	7.2 × 4.5 m (scales 2.38 H × 1.49 H with mount height H)	D
Monitored height	Floor to 2.37 m (0.63 m minimum range)	D
Lateral resolution	5.6 mm/px at floor; 20 mm separation grid	D
Height resolution	50 mm at 1 m above floor, 112 mm at floor, per disparity step	D
Detection capability	40 mm (hand); 70 mm (body) minimum (IEC TS 61496-4-3)	T
Separation distance	S _p 1.27 m at full speed, 0.59 m at 25% (1.5 m/s cobot, 0.9 m reach)	D
Max robot speed, all sides open	1.5 m/s with 40 mm detection; 0.57 m/s with 70 mm (1.2 m/s at a 3.5 m mount)	D
Human approach speed	1.6 m/s assumed (2.0 m/s unconstrained)	A
PROCESSING		
Platform	One AMD Kria K26 SOM (Zynq UltraScale+ MPSoC) for both channels	M
Depth pipeline	FPGA fabric: rectification, 9×7 census, Hamming cost, 4-path SGM, winner-take-all, 3×3 median	M
Pipeline sharing	One pipeline serves both pairs in turn; known-answer test rows in every frame, checked against the golden result	T
Verification	Bit-exact vs reference over 1,009,968 disparities	M
Channel A decision	Cortex-R5F lockstep, bare-metal software	T
Channel B decision	Isolated fabric logic (AMD Isolation Design Flow)	T
Non-safety domain	Cortex-A53, Linux: configuration, logging, video	M

SAFETY FUNCTION		
Principle	Gap between the measured robot envelope and any other object, compared with S _p (ISO/TS 15066)	T
Robot data needed	None at runtime. Stopping time and speed set at commissioning	T
Response time	≤ 35 ms: 2 frames at 60 fps + output	D
Fault reaction time	≤ 35 ms, no slower than a detection	T
Diagnostics	Known-answer test rows (every frame), channel cross-check, frame watchdog, depth plausibility, robot-found, floor drift, dot density, lens integrity, supply cross-monitoring	T
Speed levels	100 / 75 / 50 / 25% / protective stop	T
Safe state	Both OSSD outputs off; protective stop. Outside the view counts as occupied	T
SAFETY RATING		
Performance level	PLd, Category 3 (ISO 13849-1)	T
SIL	SIL 2 (IEC 62061)	T
Architecture	Category 3: channel A software, channel B hardware, cross-checked; CCF ≥ 65	T
MTTF _D / DC _{avg}	High (≥ 30 yr) / ≥ 60%, per channel	T
PFH _D	< 10 ⁻⁶ per hour	T
Standards	ISO 10218-2:2025, ISO/TS 15066, ISO 13849-1, IEC 62061, IEC 61496-1, IEC TS 61496-4-3, ISO 13855, IEC 60825-1	
INTERFACES		
Safety outputs	2 × OSSD, one per channel, pulse-tested with read-back	T
Robot link	Ethernet safety message, 20 Hz: speed level, gap, diagnostics. CRC-32 + sequence; 200 ms timeout to stop	M
Data	Ethernet: depth, video, configuration, diagnostics (non-safety)	M
Commissioning	Cell file: grid, robot base anchor, floor model, robot stop parameters	T
ELECTRICAL AND ENVIRONMENTAL		
Supply	24 V DC	T
Power isolation	Isolated, protected supply per channel (cameras, illumination, watchdog, OSSD)	T
Power, SOM	~1.3 W (fabric + R5), one module, from the routed design	D
Power, carrier	≤ 3 W per channel budget	T
Operating ambient	0 to +60 °C, passive cooling	T
Ingress protection	IP65	T