



WHITEPAPER 17

Designing Touch Interfaces for Operators Wearing PPE

Human Factors Beyond Touch Sensitivity

Combining touch hardware, UI geometry and feedback for reliable gloved operation



An engineering guide to target size, gesture design, viewing angle, feedback, fatigue, accessibility, error reduction and hardware selection in PPE-intensive environments.



Created by Crystal Display Systems Limited

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Executive summary

An HMI can register a gloved finger and still be difficult or unsafe to use. PPE enlarges the contact area, reduces dexterity and feedback, changes viewing geometry and increases fatigue.

A robust design therefore links touch hardware to target size, gesture vocabulary, confirmation and physical controls. Validation measures task completion and error recovery rather than only touch detection.

Core recommendation

Design the operator task first. Use glove-capable touch for navigation, but allocate high-consequence or frequently used controls to the most deterministic input and validate with real PPE users.

How to use this whitepaper

- Use the requirement table to convert PPE operator interaction expectations into measurable pass/fail criteria.
- Use the comparison matrix to shortlist architectures without allowing one headline specification to dominate.
- Apply the weighted scorecard using the actual operating environment, duty cycle and commercial lifecycle.
- Validate the preferred approach in the final mechanical, optical, electrical and software implementation.

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Key decision principles

- Design around the operator task and worst approved PPE, not a bare-finger demonstration.
- Increase target size and spacing before increasing touch sensitivity or adding complex gestures.
- Use redundant visual, audible and tactile feedback appropriate to the PPE and environment.
- Protect high-consequence actions with confirmation, physical separation or dedicated controls.
- Validate task completion, errors and fatigue with representative operators in the real posture and lighting.

1. Define the operator, PPE and task before tuning touch sensitivity

A useful requirement identifies gloves and other PPE, task sequence/frequency, target accuracy, viewing posture, contamination, feedback channels, safety consequence and acceptable error. These inputs determine both hardware and UI design.

Requirement domain	Questions to resolve
PPE definition	Glove material, thickness, fit, contamination, double gloving, sleeves, eye protection, face shield, hearing protection and mobility limits.
Operator task	Frequency, urgency, sequence, safety consequence, required precision, one/two-handed use, posture and cognitive workload.
Viewing environment	Distance, angle, movement, vibration, luminance, glare, fogged eyewear, colour perception and night adaptation.
Touch hardware	PCAP tuning, resistive/force input, cover texture, screen size, bezel, wet operation, physical controls and haptics.
UI design	Target dimensions/spacing, dwell/drag, gestures, confirmation, undo, lockout, alarm hierarchy, text and language/accessibility.
Validation	Representative operators, real PPE sizes, task simulation, error/response metrics, fatigue, training and abnormal/fault scenarios.

A practical weighting model

Assign each criterion a weight from 1 (low importance) to 5 (critical). Score each candidate from 1 (poor fit) to 5 (strong fit), then multiply score by weight. The arithmetic does not replace engineering judgement, but it exposes where the interaction and input architecture depends on assumptions, incomplete test evidence or optimistic supplier data.

Do not average away a fatal constraint

A candidate that fails a non-negotiable requirement for PPE operator interaction should be removed before weighted scoring. Typical fatal constraints include unsafe operation, an unachievable environmental limit, incompatible interfaces, unacceptable field reliability or no credible supply route.

Recommended process

- Set pass/fail gates for the mandatory PPE operator interaction requirements before comparing desirable features.
- Agree criterion weights with electronics, mechanical, software, product, service and procurement stakeholders.
- Score only from controlled data, supplier evidence or representative testing; mark unknowns explicitly.
- Run sensitivity checks by changing the highest weights and identifying whether the preferred architecture changes.
- Document assumptions, test conditions and revision status so the decision can be revisited after a component or firmware change.

2. PPE-oriented input and interface architectures

2.1 Glove-capable PCAP interface

Tuned PCAP can detect many work and medical gloves through protective glass while retaining multi-touch and a sealed front. Signal margin varies with glove material, cover thickness, grounding and water. UI targets must still account for the larger, less precise contact area.

- Strengths: durable glass, modern UI, easy cleaning and optional wet/glove modes.
- Limitations: not every glove is conductive enough; high sensitivity can increase water/EMI false touches.
- Best fit: machinery and medical HMLs with a controlled PPE list and need for a sealed contemporary interface.

2.2 Pressure-based resistive or force touch

Resistive or force-sensing input responds to pressure rather than conductivity and works with arbitrary gloves or tools. It can provide deterministic activation but may require greater force, show surface wear and support fewer gestures.

- Strengths: broad glove compatibility and clear intentional actuation.
- Limitations: lower optical quality, fatigue at high force, calibration/surface life and limited multi-touch.
- Best fit: simple gloved control, stylus tasks and environments where PCAP margin is uncertain.

2.3 Touch plus dedicated physical controls

A hybrid HMI uses touch for navigation and data while retaining emergency, jog, start/stop or acknowledgement controls as sealed keys, encoders or guarded switches. This improves deterministic operation and muscle memory for critical tasks.

- Strengths: clear high-consequence control, operation without visual search and robust fallback.
- Limitations: extra hardware, sealing, wiring, labels and reduced UI flexibility.
- Best fit: industrial equipment where some actions must remain reliable under heavy PPE, motion or screen contamination.

Critical-action allocation

Classify actions by consequence and assign the most deterministic input. Do not place emergency or hazardous motion commands behind gestures that are difficult to verify through PPE.

2.4 Large-target single-touch UI

A simplified UI can improve gloved performance without changing sensor technology. Large targets, spacing, limited gesture vocabulary, clear state and reversible actions reduce errors and training burden.

2.5 Remote, voice or auxiliary input

Voice, barcode, foot controls or remote pendant can support tasks where hands are occupied or contaminated. Noise, authentication, accidental activation, latency and fallback need task-specific evaluation.

3. Comparative decision matrix

Criterion	Glove PCAP	Pressure touch	Hybrid controls	Auxiliary / simplified UI
Thin-glove precision	Excellent	Strong	Excellent	Excellent
Heavy-glove operation	Moderate	Excellent	Excellent	Excellent
Complex gestures	Excellent	Limited	Moderate	Limited
Critical-action certainty	Moderate	Strong	Excellent	Strong
Wet / dirty tolerance	Moderate	Strong	Excellent	Strong
Optical / cleaning	Excellent	Moderate	Strong	Strong
Fatigue	Excellent	Moderate	Excellent	Strong
Hardware simplicity	Excellent	Excellent	Limited	Moderate
Accessibility flexibility	Strong	Moderate	Excellent	Excellent
Training burden	Strong	Strong	Excellent	Moderate

Indicative only. Actual performance depends on the complete system architecture, supplier implementation, environmental conditions and validation method.

Example weighted scorecard

Criterion	Weight	Glove PCAP UI	Pressure touch UI	Hybrid touch + controls
Heavy insulated gloves	5	3	5	5
Frequent navigation	4	5	3	5
Hazardous motion commands	5	3	4	5
Washdown / contamination	4	4	4	5
Operator fatigue	4	5	3	5
Panel complexity / cost	3	5	5	2
Error recovery	5	4	4	5
Weighted total		121	120	141

For this machine-control application, the hybrid interface leads because hazardous motion commands and heavy gloves carry high weight. Glove PCAP remains the best navigation method; pressure touch is robust but increases fatigue and limits UI richness.

Reading the result

- Glove PCAP should be approved only with the thickest, most contaminated glove and production cover stack.
- Pressure touch can reduce false activation but must not impose excessive repetitive force.
- Hybrid controls justify their cost when they reduce high-consequence errors or preserve operation during touch degradation.

4. Engineering trade-offs that change the answer

4.1 Sensitivity is not pointing accuracy

A sensor can detect a glove yet the operator may not place the enlarged fingertip accurately. Target size, spacing, parallax and viewing posture decide task success.

4.2 PPE changes feedback channels

Hearing protection reduces audible cues, thick gloves reduce vibration perception and face shields alter viewing angle. Use redundant feedback with clear state change.

4.3 Complex gestures create hidden failure modes

Pinch, edge swipes and long drags are difficult with gloves, vibration or wet surfaces. Prefer taps, short movements and explicit controls.

4.4 Screen position drives fatigue

A high, far or near-horizontal screen creates shoulder, wrist or neck load. Evaluate reach envelope, mounting angle and repeated action frequency.

4.5 Confirmation can help or hinder

Confirm dangerous actions, but avoid confirmation for every routine tap. Use differentiated controls, hold-to-act, undo and clear mode indication based on consequence.

4.6 Cleaning and lockout are operator interactions

Provide a cleaning mode or physical lock where wiping can trigger inputs. Make lock/unlock obvious through PPE and in poor visibility.

5. Application-led recommendations

Heavy industrial machine

Use large-target PCAP navigation plus physical start/stop/jog controls. Validate gloves, vibration, lighting and emergency sequences.

Cleanroom or medical isolator

Support double gloves, disinfectants and limited reach. PCAP or resistive may work; avoid gestures requiring fine edge access.

Cold-store terminal

Combine thick-glove input, large targets, high contrast, condensation handling and minimal repetitive force.

Vehicle operator HMI

Design for glanceability, vibration and one-handed use. Avoid precise dragging and place critical functions in fixed physical controls.

Chemical or washdown process

Use a sealed interface, cleaning lockout and feedback visible through face shields. Test wet/contaminated gloves and accidental sleeve/palm contact.

6. Qualification and sourcing checklist

	Area	Verification action
☐	PPE matrix	Test every approved glove/PPE combination, size, wet/dirty state and end-of-life condition.
☐	Touch performance	Measure task taps, misses, false activations, drag/hold success, edge targets and response time.
☐	Human factors	Run representative tasks with operators; record completion time, errors, recovery, workload and fatigue.
☐	Viewing	Test distance, angle, glare, fogged shields, colour/contrast and movement.
☐	Feedback	Verify visual, audible, haptic and physical confirmation through the actual PPE.
☐	Critical actions	Test guarding, confirmation, hold-to-act, mode errors, cancellation and safe recovery.
☐	Environment	Combine gloves with water, chemicals, vibration, temperature and cleaning states.
☐	Production	Control touch tuning, UI version, target geometry, hardware controls and acceptance tests.

Questions to ask a display partner

- Which exact PPE combinations and conditions define the approved operator population?
- What minimum target size and spacing were validated with representative users?
- Which actions are safety or high consequence, and why is their input method appropriate?

- How is feedback perceived through hearing protection, gloves and face shields?
- How does the interface behave during cleaning, wet surfaces, vibration and accidental palm/sleeve contact?
- What UI or touch-firmware changes trigger repeated human-factors validation?

Minimum evidence pack for design approval

- Operator/PPE/task definition including consequence and environment.
- Touch hardware stack and controlled tuning/firmware configuration.
- UI geometry, gesture, feedback and critical-action design specification.
- Human-factors test report with task times, errors, recovery and fatigue.
- Environmental/contamination qualification with representative PPE.
- Golden units, UI/touch change-control and production acceptance plan.

7. Beyond touch sensitivity

Future PPE-focused HMIs will combine multiple input and feedback channels. The value lies in reducing operator workload and error while maintaining deterministic control.

Adaptive UI based on detected PPE

The system may change target size or gesture set when glove mode is active. Mode detection and visible state must be reliable.

Force and grip sensing

Force can confirm intentional action, while glove-integrated sensing could improve precision. Calibration, wear and interoperability need evidence.

Surface haptics through gloves

Higher-energy or localised haptics may improve confirmation, but perception varies with glove and mounting.

Voice and speech in industrial noise

Directional microphones and constrained vocabularies can support hands-busy tasks. Noise, language, privacy and false activation remain.

AR or wearable task guidance

Head-mounted guidance can reduce visual search, but field of view, PPE compatibility, latency and safety approval must be addressed.

Adoption gate

A new interaction mode should enter production only when representative operators complete defined tasks with fewer errors or lower workload and the mode has clear fallback and fault behaviour.

8. Working with Crystal Display Systems

Crystal Display Systems Limited supports industrial touch and HMI programmes with glove/water-capable PCAP, resistive and hybrid inputs, custom cover glass, optical bonding, rugged monitors and panel PCs.

Relevant CDS resources

Resource	Purpose
LCD TFT Display Components	Display components, interface boards, touch sensors and specialist technologies.
Optical Bonding	Optical bonding options for readability, durability and condensation control.
Industrial Panel PC Solutions	Integrated industrial HMI and panel PC solutions with customisation options.
Industrial Automation Displays	Display, monitor and computing solutions for automation and machine HMI.
CDS Presentation Download Centre	Product and capability presentations for displays, touch and embedded systems.
CDS Knowledge Centre	Display guides and technical training documents.
Request a Quote	Submit project requirements for technical and commercial review.
Contact CDS	Contact details and enquiry routes.

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Conclusion

PPE-compatible HMI design is a human-factors and task-allocation problem. Touch sensitivity is necessary but does not guarantee accuracy, feedback or safe action. The strongest design combines a proven sensor stack with large, well-spaced targets, simple gestures, redundant feedback and physical controls for high-consequence functions.

Final engineering rules

- Validate with the exact PPE, posture, contamination and viewing conditions.
- Increase target geometry and simplify gestures before raising sensor sensitivity.
- Use redundant feedback that remains perceptible through PPE.
- Assign hazardous or emergency actions to deterministic controls.
- Retest human factors when UI geometry, touch tuning or PPE assumptions change.

Disclaimer

This whitepaper provides general engineering guidance and does not replace application-specific design review, supplier specifications, regulatory assessment or formal product qualification. Performance depends on the exact components, implementation, environment and usage profile.