Crystal Display Systems Ltd

WHITEPAPER 04

Projected Capacitive Touch Through Thick Glass, Gloves and Water

Designing a Robust PCAP Interface

Sensor stack-up, controller tuning and EMC design for demanding touch interfaces

A practical engineering framework for achieving reliable projected-capacitive touch through protective glass and under gloved, wet, noisy and grounded operating conditions.

Created by Crystal Display Systems Limited

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Executive summary

Projected-capacitive touch can operate through thick protective glass and with gloves while retaining a sealed, optically clear front surface. Achieving this performance requires more than selecting a controller with a glove-mode checkbox.

The sensor geometry, cover dielectric, adhesive, display noise, grounding, mechanical preload and firmware thresholds all determine the usable signal margin. Water rejection and high sensitivity pull the design in opposite directions, so realistic mode definitions and validation are essential.

> **Core recommendation**
> Design the touch stack and controller tuning as one system. Require measured channel-level signal margin with the production cover, gloves, water, mounting and electrical environment before approving the interface.

How to use this whitepaper

- Use the requirement table to convert robust projected-capacitive touch 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 the sensor, cover lens, mechanics, grounding and firmware together; controller tuning cannot rescue an uncontrolled stack.
- Define gloved and wet-touch behaviour as measurable actions, including what must be rejected as well as detected.
- Maintain signal-to-noise ratio across production tolerances, temperature, moisture and all power/earth states.
- Keep noisy display and power circuitry away from touch electrodes and provide a deliberate return/reference strategy.
- Freeze controller firmware and tuning parameters under the same revision control as the hardware.

1. Define the touch task before selecting the sensor and controller

A robust specification states cover thickness, approved gloves, required gestures, water conditions, electrical grounding, EMC environment, target sizes, response time and acceptable false-touch rate. These requirements must be verified on the final stack, not inferred from a controller data sheet.

Requirement domain	Questions to resolve
User and input	Bare finger, work glove, medical glove, conductive stylus, water film, droplets, contaminants, gesture set and minimum target size.
Cover stack	Glass type and thickness, air gaps, adhesive, coatings, black mask, curvature, mounting, seal compression and nearby metal.
Sensor design	Electrode pitch, channel count, mutual/self-capacitance mode, border electrodes, tail routing, shield layers and sensor-to-display spacing.
Electrical environment	Display noise, switch-mode supplies, motors, inverters, charger states, earth connection, floating operation, ESD and radiated RF.
Controller tuning	Baseline acquisition, touch threshold, glove mode, water rejection, palm rejection, frequency hopping, filters and recalibration triggers.
Validation and production	Golden samples, cover-lens tolerance, sensor lot variation, firmware revision, calibration retention and end-of-line functional tests.

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 touch sensor and controller 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 robust projected-capacitive touch 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 robust projected-capacitive touch 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. Sensor, controller and fallback architectures

2.1 Standard mutual-capacitance PCAP

Mutual-capacitance PCAP measures the coupling at intersections of transmit and receive electrodes. It supports accurate multi-touch and strong spatial resolution, but thick glass, gloves and water reduce or distort the incremental signal. Electrode geometry and controller dynamic range determine the available margin.

- Strengths: multi-touch, smooth gestures, sealed front surfaces and excellent optical integration.
- Limitations: reduced sensitivity through thick dielectrics, susceptibility to conducted/display noise and water-induced false touches without appropriate algorithms.
- Best fit: mainstream industrial HMIs with controlled cover thickness and primarily bare-finger use.

2.2 High-sensitivity industrial PCAP

Industrial PCAP systems use optimised sensor pitch, higher drive levels, low-noise analogue front ends, frequency selection and application-specific tuning to recover signal through thick glass or gloves. High sensitivity increases the need for disciplined grounding, shielding and false-touch control.

- Strengths: glove support, thicker cover lenses, vandal-resistant fronts and configurable wet-operation modes.
- Limitations: more engineering effort, greater dependence on stack tolerances and potential false detections from water, EMI or large nearby conductive objects.
- Best fit: outdoor kiosks, machinery, transport and medical equipment requiring a sealed, durable interface.

> **Tuning control**
> Treat the tuning file and controller firmware as released design artefacts. Record thresholds, scan frequencies, filters, recalibration behaviour and diagnostic data for every approved stack.

2.3 Self-capacitance and hybrid sensing

Self-capacitance measures each electrode relative to a reference and can provide higher sensitivity for gloves or proximity. It is more vulnerable to ghost ambiguity in multi-touch and to changes in system grounding. Hybrid controllers may switch or combine modes to balance sensitivity, water rejection and gesture capability.

- Strengths: high sensitivity and useful proximity or thick-glass performance.
- Limitations: multi-touch ambiguity, stronger dependence on reference capacitance and possible instability in floating systems.
- Best fit: single-touch or limited-gesture applications where heavy gloves and thick glass dominate.

2.4 Active stylus or conductive passive stylus

A dedicated active stylus transmits a known signal and can provide high precision through cover glass. Conductive passive styli behave more like a finger and depend on sensor sensitivity. Stylus support adds protocol, storage, durability and user-management considerations.

2.5 Resistive or physical-control fallback

Where reliable operation under standing water, very thick non-conductive covers or arbitrary gloves cannot be guaranteed, resistive touch, sealed switches, rotary controls or a hybrid interface may be lower risk. The correct design protects the operator task rather than insisting on PCAP for cosmetic reasons.

3. Comparative decision matrix

Criterion	Standard PCAP	Tuned industrial PCAP	Self/hybrid PCAP	Resistive / controls
Bare-finger multi-touch	Excellent	Excellent	Moderate	Limited
Thick-glass capability	Limited	Excellent	Excellent	Strong
Heavy-glove capability	Limited	Excellent	Excellent	Excellent
Water rejection	Limited	Excellent	Moderate	Strong
Optical clarity	Excellent	Excellent	Excellent	Moderate
EMC tolerance	Moderate	Strong	Limited	Excellent
Grounding sensitivity	Moderate	Strong	Limited	Excellent
Gesture richness	Excellent	Excellent	Moderate	Limited
Tuning burden	Strong	Limited	Limited	Excellent
Front-surface durability	Excellent	Excellent	Excellent	Moderate

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

Example weighted scorecard

Criterion	Weight	Standard PCAP	Tuned industrial PCAP	Resistive touch
5 mm cover glass	5	2	5	4
Gloved operation	5	2	5	5
Rain and water rejection	5	2	5	4
Multi-touch gestures	3	5	5	2
Optical appearance	4	5	5	3
EMC environment	4	3	4	5
Development risk	3	5	3	5
Weighted total		**92**	**135**	**118**

For this outdoor machine HMI, tuned industrial PCAP leads because the application requires thick glass, gloves, rain rejection and modern gestures. Resistive touch remains technically credible where gesture richness is less important; standard PCAP fails the sensitivity and water margins.

Reading the result

- Standard PCAP should be rejected when the production glass and glove signal cannot maintain defined SNR margin.
- Tuned PCAP wins only if water rejection and EMC are demonstrated across all grounding and power states.
- Resistive touch remains a valid fallback when deterministic pressure input matters more than optical and gesture performance.

4. Engineering trade-offs that change the answer

4.1 Cover thickness reduces coupling non-linearly

Increasing glass thickness and dielectric spacing reduces the touch delta and spreads the field. Sensor pitch, electrode shape and drive amplitude must be selected before the cover design is frozen.

4.2 Glove detection and water rejection compete

Higher sensitivity helps detect a gloved finger but also increases response to droplets, films and palms. Modes must define whether the system tracks, rejects or temporarily suppresses touch under water.

4.3 Grounding changes the apparent user signal

A mains-earthed kiosk, battery-powered handheld and vehicle-mounted HMI present different return paths. Test with the operator isolated, grounded and connected through real cables and chargers.

4.4 Display noise can alias into the touch scan

LCD common-electrode switching, backlight PWM and DC/DC converters can overlap touch scan frequencies. Coordinate frame timing, frequency hopping, shielding and cable routing.

4.5 Mechanical compression changes baseline capacitance

Gaskets, bezel pressure, cover deflection and adhesive movement can shift channels or create edge hot spots. Tune and test with production mounting torque and environmental expansion.

4.6 Automatic recalibration can hide or create faults

Recalibration is useful after power-up and environmental change, but can absorb a stationary finger or water film into the baseline. Define triggers, lockouts and diagnostic reporting.

5. Application-led recommendations

Outdoor kiosk in rain

Use tuned mutual-capacitance PCAP with optical bonding, water-rejection firmware, grounded metalwork and drainage geometry. Define whether touch is disabled under standing water.

Industrial machine with work gloves

Select sensor pitch and controller gain using the thickest approved glove and cover stack. Increase UI target size and provide visual or acoustic confirmation.

Medical device with cleaning fluids

Validate thin medical gloves, liquid films, repeated disinfectant exposure and false-touch suppression during cleaning. Provide a software cleaning lockout where appropriate.

Vehicle or mobile equipment

Test cranking, alternator noise, chargers, floating ground, vibration and operator body coupling. Use robust ESD protection without adding excessive electrode capacitance.

Vandal-resistant public terminal

Thick chemically strengthened glass may require high-sensitivity tuning and careful edge design. Confirm impact deflection does not contact the LCD or cause stuck touches.

6. Qualification and sourcing checklist

	Area	Verification action
[ ]	**Signal margin**	Record raw counts, baseline, touch delta, noise and SNR for all channels across glass, gloves, temperature and production variation.
[ ]	**Water behaviour**	Test droplets, streams, films, salt water and wet gloves; verify required touches and rejected gestures.
[ ]	**EMC**	Run conducted RF, radiated RF, EFT, surge, ESD and display/power-noise tests while monitoring raw touch data.
[ ]	**Ground states**	Verify mains earth, protective earth disconnected, battery operation, chargers, long cables and representative operator coupling.
[ ]	**Mechanical**	Test cover deflection, gasket compression, mounting torque, vibration, impact and thermal expansion.
[ ]	**Firmware**	Freeze controller version, tuning file, scan frequencies, thresholds, recalibration rules and diagnostic interface.
[ ]	**Environmental**	Test hot/cold operation, humidity, condensation, UV and chemical exposure with touch performance active.
[ ]	**Production**	Define sensor and glass tolerances, end-of-line channel checks, calibration limits and golden units.

Questions to ask a display partner

- What raw signal and noise margin remains with the thickest glass and least conductive approved glove?
- How does the controller distinguish a water film, a droplet and an intentional wet finger?
- Which scan frequencies, filters and display synchronisation are used to avoid LCD and power-converter noise?

- How does performance change between earthed, floating, battery and charger-connected conditions?
- What mechanical tolerances or gasket loads were included in the tuned samples?
- How are firmware, tuning parameters and controller silicon revisions controlled and notified?

Minimum evidence pack for design approval

- Controlled sensor, cover-glass, adhesive, display and mechanical stack drawing.
- Raw-channel signal/noise report across gloves, water, temperature, grounding and production samples.
- EMC/ESD test results with touch-function monitoring and defined recovery behaviour.
- Firmware/tuning release package with checksum, parameter list and revision history.
- Environmental/mechanical qualification report and chemical/cleaning compatibility data.
- End-of-line test method, golden units, acceptance limits and PCN/EOL strategy.

7. Beyond conventional finger touch

Industrial touch interfaces are moving toward multi-modal sensing and stronger on-device diagnostics. These features should be used to increase task reliability, not to mask insufficient sensor margin or an uncontrolled mechanical stack.

Multi-frequency and spectral scanning

Controllers can move between frequencies or analyse interference signatures. The benefit depends on validated selection logic and recovery time under real noise sources.

Force and pressure augmentation

Adding force sensing can distinguish intentional input from water or resting palms and enable gloves, but adds mechanical calibration and drift mechanisms.

Active stylus protocols

Active pens provide precision and robust detection through glass, but require protocol support, charging or replaceable batteries and a field-service strategy.

Touch-health diagnostics

Raw-channel monitoring can detect contamination, cracked sensors, disconnected tails and drifting baselines. Diagnostics need thresholds, logging and service interpretation.

Haptic and physical feedback

Surface haptics, local vibration or adjacent physical controls can reduce operator uncertainty when gloves and harsh conditions make purely visual confirmation inadequate.

> **Adoption gate**
> A new touch feature should enter production only when it improves a defined operator task, maintains raw signal margin across the qualified stack, and has deterministic behaviour under water, noise, grounding changes and faults.

8. Working with Crystal Display Systems

Crystal Display Systems Limited supports custom PCAP touch programmes including sensor and controller selection, custom cover glass, optical bonding, glove/water tuning, interface electronics and rugged display or panel PC integration.

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.
Sunlight Readable Displays	High-brightness and optically engineered outdoor display solutions.
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

Robust PCAP is achieved by preserving signal-to-noise margin across the complete sensor, cover, display, grounding and firmware system. Thick glass and gloves are feasible, but increased sensitivity must be balanced against water, EMI and mechanical baseline shifts. The production design must therefore control both hardware stack-up and controller tuning as released engineering items.

Final engineering rules

- Define required and prohibited touch behaviours for gloves, water and contaminants.
- Select electrode geometry and controller capability before freezing cover thickness and mechanics.
- Measure raw-channel SNR across temperature, grounding, EMI and production tolerance.
- Control firmware, tuning files and recalibration logic under formal revision management.
- Provide a lower-risk fallback where PCAP cannot guarantee the operator task.

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.