WHITEPAPER 10

From Specification to Production

A Qualification Plan for Custom Display and Touch Assemblies

Converting a display concept into controlled, repeatable production hardware

An end-to-end engineering plan for requirements, samples, optical and touch validation, environmental testing, golden units, change control and production acceptance.

Created by Crystal Display Systems Limited

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Executive summary

Custom display and touch assemblies combine components and processes whose interactions are not proven by individual data sheets. Reflections, touch noise, bond stress, thermal hot spots, cosmetic defects and enclosure tolerances emerge only at system level.

A robust qualification plan moves from measurable requirements through engineering, design and production validation. It then preserves the approved baseline using golden units, process controls, traceability and formal change management.

Core recommendation
Use an EVT-DVT-PVT sequence proportionate to risk, with objective acceptance criteria and traceable unit configuration. Do not release production from attractive but unrepresentative engineering samples.

How to use this whitepaper

- Use the requirement table to convert assembly qualification 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.

Contents

Key decision principles

- Convert every important requirement into a measurable method and limit before final samples are built.
- Qualify the final optical, touch, electrical and mechanical stack rather than separate supplier components.
- Use staged builds to retire the highest risks before committing to tooling and volume.
- Define golden units and production acceptance limits from controlled data, not from subjective memory.
- Freeze configuration and change-control routes at production release so qualification remains valid.

1. Define the qualification baseline before building final samples

A qualification plan should state the controlled configuration, sample stages, test coverage, acceptance methods, traceability and release authority. This prevents late debate over whether a prototype result applies to the production assembly.

Requirement domain	Questions to resolve
Requirements baseline	Measurable optical, touch, electrical, mechanical, environmental, cosmetic, lifecycle and regulatory acceptance criteria.
Configuration definition	Exact panel, touch, cover glass, coatings, adhesive, controller, cable, firmware, enclosure interface and supplier revisions.
Sample stages	Feasibility units, engineering validation samples, design validation units, pilot build and production validation lots.
Test coverage	Functional, optical, electrical, EMC, environmental, mechanical, reliability, chemical, human-factors and manufacturing tests.
Acceptance method	Equipment, fixture, test pattern, illumination, distance, sampling plan, pass/fail limits and treatment of borderline results.
Change and release	Golden units, drawings, BOM, firmware, process controls, deviation route, PCN, corrective action and requalification triggers.

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 qualification and production-release approach 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 assembly qualification 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 assembly qualification 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. Qualification stages and production assurance

2.1 Component-level qualification

Component qualification confirms that the LCD, touch sensor, cover lens, controller and adhesive individually meet their specifications. It is necessary for supplier control but does not establish the performance of the assembled HMI, where reflections, stress, noise and thermal interactions appear.

- Strengths: early screening, efficient supplier comparison and clear identification of incoming defects.
- Limitations: cannot prove system-level optical, EMC, touch or mechanical behaviour.
- Best fit: initial sourcing and risk reduction before assembly prototypes.

2.2 Engineering validation build (EVT)

EVT samples prove the architecture and expose integration failures. They should use near-final interfaces and mechanical stack while retaining instrumentation and design flexibility. The objective is learning and margin, not cosmetic sign-off.

- Strengths: early discovery of optical, touch, power, thermal and interface problems.
- Limitations: hand-built samples and provisional processes may not represent production variation.
- Best fit: architecture validation before tooling and process lock.

> **Evidence discipline**
> Record exact unit configuration, test equipment, software, environmental conditions and deviations. An attractive prototype with an unknown stack is not qualification evidence.

2.3 Design validation build (DVT)

DVT uses production-intent materials, tooling, firmware and mechanics to demonstrate compliance across environmental and reliability tests. Test units should represent worst-case tolerances and include destructive or accelerated samples where appropriate.

- Strengths: establishes product-level design compliance and exposes tolerance interactions.
- Limitations: expensive changes if requirements or processes remain unstable.
- Best fit: formal design qualification before pilot production.

2.4 Production validation and pilot build (PVT)

PVT demonstrates that the manufacturing process, fixtures, work instructions, inspection and suppliers can repeatedly build the qualified design. Process capability and yield are as important as functional pass results.

2.5 Ongoing production assurance

Incoming control, in-process checks, end-of-line testing, audit samples, change notification and corrective action maintain the qualification baseline. Without these controls, a successful DVT becomes a historical result rather than a production guarantee.

3. Comparative decision matrix

Criterion	Component only	EVT-focused	EVT+DVT+PVT	Full lifecycle control
Architecture risk coverage	Limited	Strong	Excellent	Excellent
Environmental evidence	Limited	Moderate	Excellent	Excellent
Production variation	Poor	Limited	Excellent	Excellent
Change-control strength	Limited	Limited	Strong	Excellent
Speed to first sample	Excellent	Excellent	Moderate	Moderate
Upfront cost	Excellent	Strong	Limited	Limited
Root-cause traceability	Moderate	Strong	Excellent	Excellent
Regulated-product suitability	Poor	Limited	Excellent	Excellent
Field-risk reduction	Limited	Moderate	Excellent	Excellent
Long-term reproducibility	Poor	Limited	Strong	Excellent

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

Example weighted scorecard

Criterion	Weight	EVT only	EVT + DVT	EVT + DVT + PVT
Optical / touch integration risk	5	3	5	5
Harsh-environment exposure	5	2	5	5
Production volume	4	2	3	5
Regulatory consequence	5	2	5	5
Schedule pressure	3	5	3	2
Yield / process risk	4	2	3	5
Long service life	4	2	4	5
Weighted total		**74**	**124**	**141**

For this rugged production HMI, the full EVT-DVT-PVT route leads because environmental, process and regulatory risks dominate. An EVT-only release appears faster but carries unacceptable production variation and field exposure.

Reading the result

- EVT is for proving architecture and margin, not for signing off uncontrolled hand-built construction.
- DVT should use production-intent materials, tooling and firmware and include tolerance extremes.
- PVT is required when yield, process capability and operator/fixture variation can alter the qualified result.

4. Engineering trade-offs that change the answer

4.1 Requirements must be testable

Terms such as sunlight readable, rugged or glove compatible need illumination, temperature, input object, method and numerical limits. Ambiguity shifts decisions into late subjective review.

4.2 Sample representativeness changes by stage

Early samples can use provisional tooling, but their limitations must be logged. Later qualification units must match production materials, processes and firmware.

4.3 Worst-case combinations matter

Minimum backlight, maximum cover reflection, thick adhesive, weakest touch signal and hot electronics may occur in one unit. Tolerance analysis should drive sample selection.

4.4 Environmental sequencing can reveal interactions

Humidity followed by cold, vibration before EMC or cleaning before impact can expose mechanisms not seen in isolated tests. Sequence should reflect the mission profile.

4.5 Cosmetic limits need controlled inspection

Mura, particles, bubbles, scratches and light leakage must be assessed with defined patterns, luminance, ambient light, distance and viewing angle.

4.6 A pass without traceability is weak evidence

Unit serial, BOM revision, firmware, test equipment calibration and deviations are needed to connect results to the production design.

5. Application-led recommendations

Custom bonded display module

Run EVT for optical/touch stack and bond process, DVT for environmental/mechanical stress, then PVT for bubble, alignment and cosmetic yield.

Industrial panel PC

Qualify display, touch, compute, thermal, EMC, software image and enclosure together under worst-case workload and ambient.

Medical or laboratory HMI

Add cleaning/disinfectant, leakage, usability and regulatory document controls; define software and calibration configuration precisely.

Low-volume bespoke equipment

A risk-based plan can reduce sample count, but should not remove tests for high-severity failure modes or rely on an untraceable prototype.

High-volume public terminal

Emphasise production capability, end-of-line automation, supplier changes, field replacement and audit sampling after design qualification.

6. Qualification and sourcing checklist

	Area	Verification action
[ ]	**Requirements**	Approve measurable optical, touch, electrical, mechanical, environmental, cosmetic and lifecycle criteria.
[ ]	**Configuration**	Control drawings, BOM, firmware, adhesives, coatings, cables, process parameters and supplier revisions.
[ ]	**EVT**	Verify architecture, interfaces, raw margins, thermal paths, touch tuning and optical stack with instrumented samples.
[ ]	**DVT**	Test production-intent units for environmental, reliability, EMC, mechanical, chemical and human-factors compliance.
[ ]	**PVT**	Demonstrate repeatable process, fixtures, work instructions, yield, capability and end-of-line detection.
[ ]	**Acceptance**	Define golden units, sampling, cosmetic conditions, functional limits and disposition of marginal units.
[ ]	**Traceability**	Record serials, lots, firmware, test equipment, results, deviations and corrective actions.
[ ]	**Change control**	Define PCN, deviation, supplier change, firmware release and requalification triggers.

Questions to ask a display partner

- Which requirements have objective methods and limits, and which remain subjective or undefined?
- How do EVT, DVT and PVT samples differ from final materials, tooling and process?
- Which tolerance extremes and combined worst cases are represented in qualification units?

- What test sequence reproduces the actual environmental and operating mission profile?
- How are golden units, cosmetic standards, firmware and process settings controlled?
- Which changes require notification, delta assessment or full/partial requalification?

Minimum evidence pack for design approval

- Approved requirements and verification matrix linking every requirement to method, sample and result.
- Controlled product configuration: drawings, BOM, firmware, stack-up and process specifications.
- EVT/DVT/PVT build records with serialised unit configuration and deviations.
- Complete test reports, raw data, equipment calibration and non-conformance disposition.
- Golden units, visual standards, end-of-line tests and production control plan.
- PCN/change-control procedure, approved supplier list and lifecycle support plan.

7. Beyond one-time qualification

Modern qualification programmes increasingly use digital traceability, automated measurement and continuous production data. These tools are valuable when they preserve the connection between fielded hardware and the approved baseline.

Digital requirements traceability

Linked requirement, risk, test and result records reduce gaps and make delta qualification faster. Governance is required to keep links current.

Automated optical and touch metrology

Camera and instrument systems can improve repeatability for luminance, uniformity, bubbles and touch maps, provided correlation and calibration are maintained.

Statistical process monitoring

Trend data can identify drift before failures exceed limits. Meaningful control limits must be based on process capability and measurement uncertainty.

Hardware-in-the-loop regression

Automated power, interface, touch and software tests can replay start-up and fault conditions after firmware or component changes.

Field-data feedback

Failure codes, temperatures and service returns can refine qualification. Data collection must be planned, interpretable and privacy/security appropriate.

> **Adoption gate**
> A qualification tool should enter the process only when it improves traceability, measurement repeatability or early detection and when its calibration, data ownership and change control are defined.

8. Working with Crystal Display Systems

Crystal Display Systems Limited supports custom display and touch programmes from requirements and sample selection through optical bonding, controller integration, ruggedisation, qualification builds and controlled production supply.

Relevant CDS resources

Resource	Purpose
LCD TFT Displays	Industrial panel range, long-life options and value-added integration.
Optical Bonding	Optical bonding options for readability, durability and condensation control.
LCD TFT Display Components	Display components, interface boards, touch sensors and specialist technologies.
Industrial Panel PC Solutions	Integrated industrial HMI and panel PC solutions with customisation options.
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

A production-ready display assembly is the result of a staged evidence process. Requirements, EVT, DVT, PVT, acceptance standards and change control must all refer to the same controlled configuration. The correct plan is risk based, but it cannot omit tests for severe or interacting failure modes simply to protect schedule.

Final engineering rules

- Write measurable requirements and verification methods before final sample commitment.
- Use staged builds to retire architecture, design and production-process risks in order.
- Qualify the complete assembly at tolerance extremes and realistic environmental sequences.
- Control golden units, cosmetic standards, firmware and process parameters.
- Maintain traceability and requalification rules after production release.

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.