DUAL-MOTOR PMSM DYNAMOMETER
CUSTOMER TECHNICAL FRD

SYSTEM ARCHITECTURE, CONTROL SOFTWARE & VALIDATION

TI C2000 F28069M dual-PMSM dynamometer, Simulink control architecture, CAN supervision, sensing, acquisition, and characterization

ENGINEERING REQUIREMENTS DOCUMENT | REVISION 3.0 | 26 AUGUST 2026

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Document scope	Customer-facing system requirements, hardware configuration, Simulink architecture screenshots, communications, sensing, acquisition, validation, and measured operating evidence
Evidence basis	Bench hardware photographs, Simulink screenshots, interface records, captured signals, and measured characterization outputs
Distribution	Customer-facing technical disclosure; source code and editable Simulink model files are intentionally withheld

DOCUMENT PURPOSE
Defines the functional, performance, interface, safety, verification, and acceptance requirements for the dual-motor PMSM dynamometer as a customer-facing engineering system. The report documents implemented behavior and visible model architecture without distributing source code or editable model files.

Functional Requirements Document Framework

WHY THIS IS AN FRD
This document defines what the system shall do, the interfaces and constraints under which it shall operate, and the objective evidence used for acceptance. Simulink screenshots, hardware photographs, and measured plots illustrate the delivered architecture; they are documentation evidence rather than redistributable implementation source.

Purpose, Scope, and System Boundary

This FRD governs the complete customer-visible dynamometer capability: controller and inverter platform, dual-machine operating roles, model-based field-oriented control, host supervision, CAN command/diagnostic exchange, encoder and ADC feedback, data acquisition, efficiency characterization, safeguards, and verification. Source code, generated code, editable .slx files, build artifacts, and proprietary implementation packages are outside the customer-facing release.

Boundary element	Included in this FRD	Excluded from customer package
Hardware platform	F28069M controller, two DRV8305EVM inverter stages, two encoder-equipped PMSMs, 24 V bench supply, CAN and host interfaces	Vendor manufacturing sources and internal fabrication packages
Control software	Operating modes, FOC architecture, real-time ownership, CAN behavior, sensing and interrupt specifications	Source code, generated code, editable .slx models and build products
Validation	Captured signals, operating envelope, efficiency methodology, result plots and acceptance criteria	Private raw development history and proprietary implementation internals

Users and Operational Scenarios

Actor	Primary interaction	Expected outcome
Customer / reviewer	Review requirements, architecture figures, interfaces, limits, and measured evidence	Clear understanding of delivered capability without source disclosure
Test engineer	Command operating points, observe state, acquire evidence, and review characterization outputs	Repeatable test evidence within defined limits
Controls engineer	Maintain target and host implementation against the documented interfaces and acceptance requirements	Traceable behavior while proprietary implementation remains controlled

1. Embedded and Host Operating Concept

The testbed uses two mechanically coupled encoder-equipped PMSMs. Motor 1 establishes shaft speed under closed-loop control while Motor 2 applies a bounded opposing or assisting q-axis current to create controllable load. The TI C2000 target owns the real-time control loops; the host system provides supervisory commands, acquisition, plotting, and test orchestration without becoming the high-bandwidth control clock.

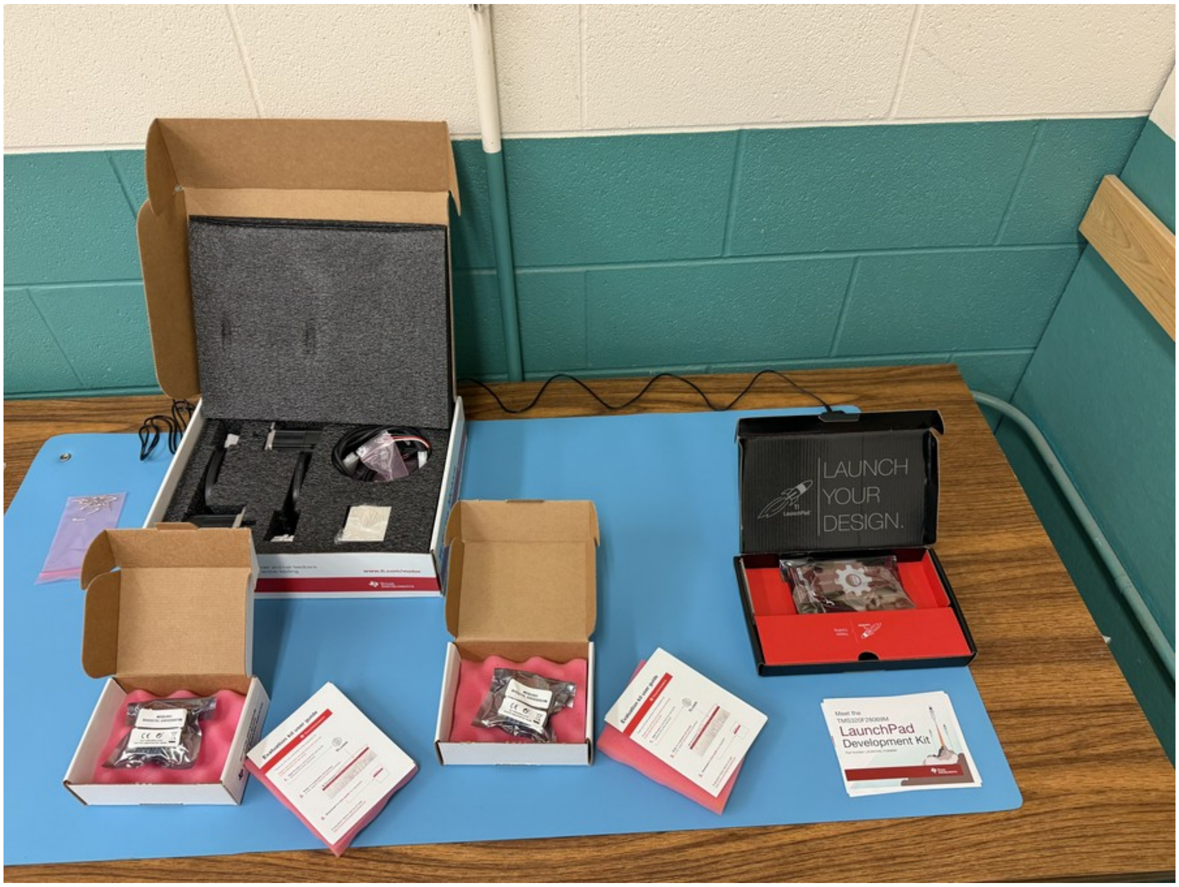


Figure 1. Customer-facing overview of the dual-motor dynamometer hardware platform.

Platform specification	Customer-facing value
Embedded controller	TI LAUNCHXL-F28069M (C2000 Piccolo)
Power stages	2 x BOOSTXL-DRV8305EVM three-phase inverter stages
Machines	2 x encoder-equipped PMSMs, mechanically coupled
DC bus / bench supply	24 V DC, current-limited bench source
Position feedback	Independent QEP/encoder channels for Motor 1 and Motor 2
Supervisory communications	CAN physical layer with command ID 0x100 and diagnostic/return ID 0x101
Host role	Supervisory command, acquisition, plotting, test orchestration, and post-run analysis

- Independent encoder and feedback paths are maintained for both machines.
- The control architecture uses field-oriented current control with Clarke/Park transforms, current regulation, inverse transforms, and space-vector/PWM reference generation.

- CAN supervision provides command and diagnostic exchange while preserving target-side real-time loop ownership.

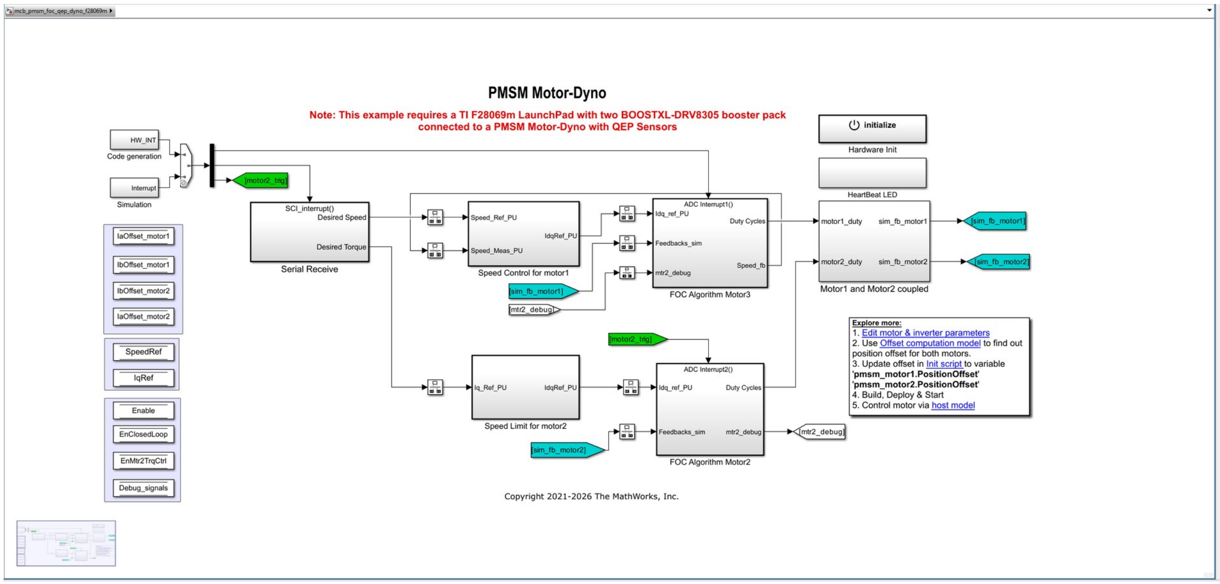
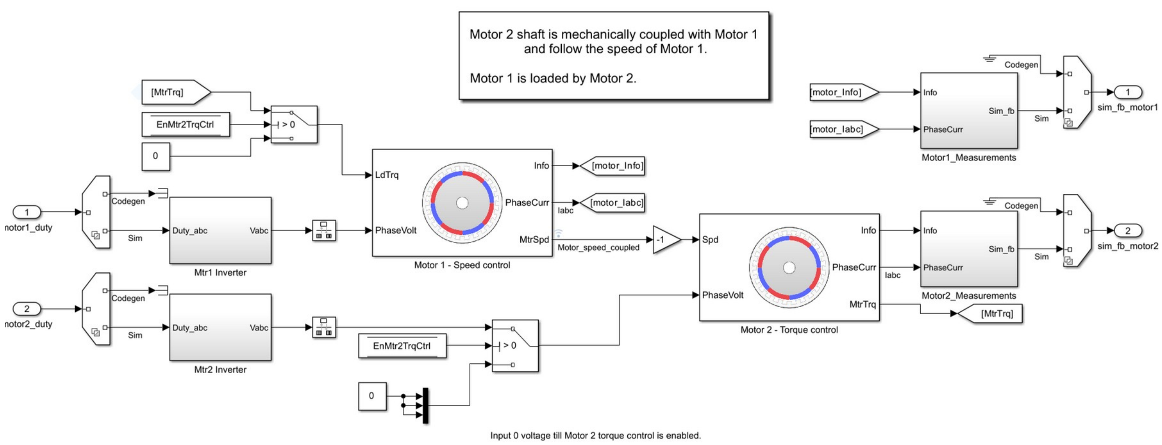


Figure 2. Top-level Simulink dynamometer model showing dual-machine command, speed-control, load-control, and FOC execution structure.

- The acquisition path exposes speed, current, voltage, torque-related, and power-related quantities for characterization and post-run review.

1.1 Operating Modes and Customer-Visible Configuration



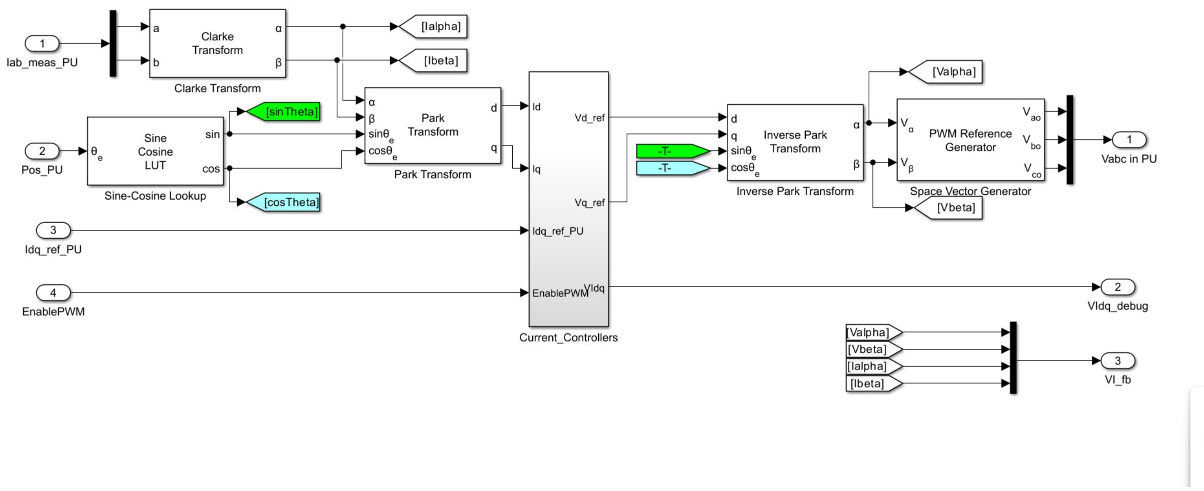


Figure 4. Field-oriented current-control architecture with Clarke/Park transforms, current regulators, inverse transform, and PWM reference generation.

Figure 3. Simulink plant/control view showing Motor 1 speed-control role and Motor 2 torque-control load role.

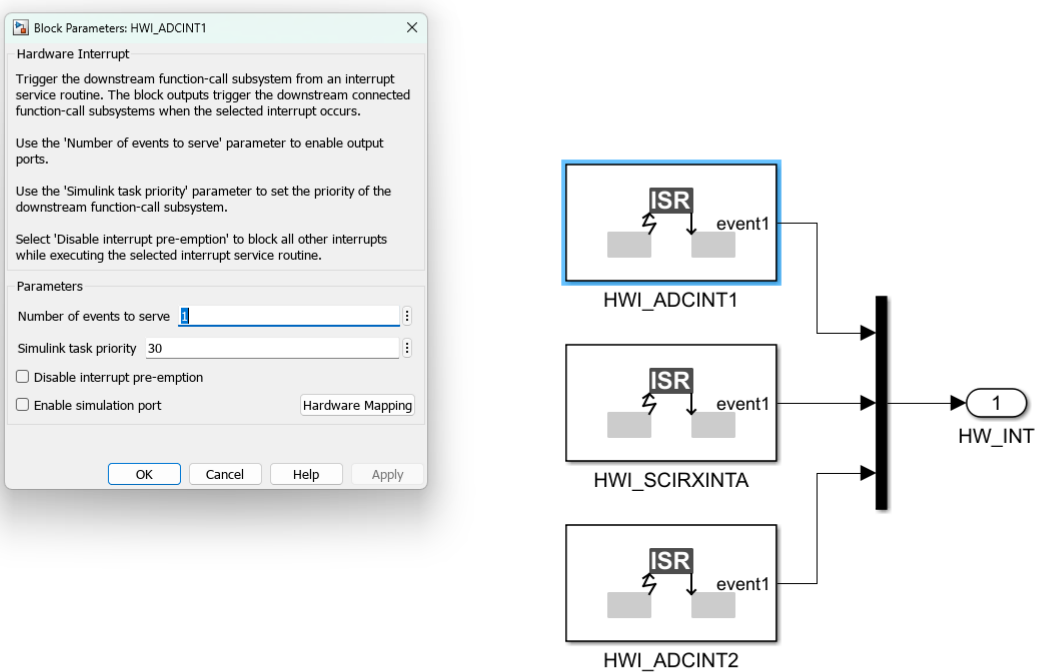


Figure 5. Simulink hardware-interrupt structure illustrating ADC and supervisory receive event integration.

Mode	Required behavior
Disabled / safe	Torque-producing references are inhibited and the platform remains in a non-driving state.
Drive-only	Motor 1 controls shaft speed while Motor 2 remains at bounded zero-load command.
Loaded dynamometer	Motor 1 regulates shaft speed while Motor 2 applies

Mode	Required behavior
	bounded q-axis load or assist.
CAN-supervised	Host command words are exchanged over the supervisory CAN interface while control loops remain target-resident.
Acquisition / characterization	Selected signals are recorded and analyzed without transferring real-time loop ownership to the host.

1.2 Requirement Conventions

Mandatory behavior is expressed using “shall.” Demonstrated items are supported by the available hardware, model, bus, or characterization evidence. Requirements that describe release boundaries or qualification limits are verified by document review.

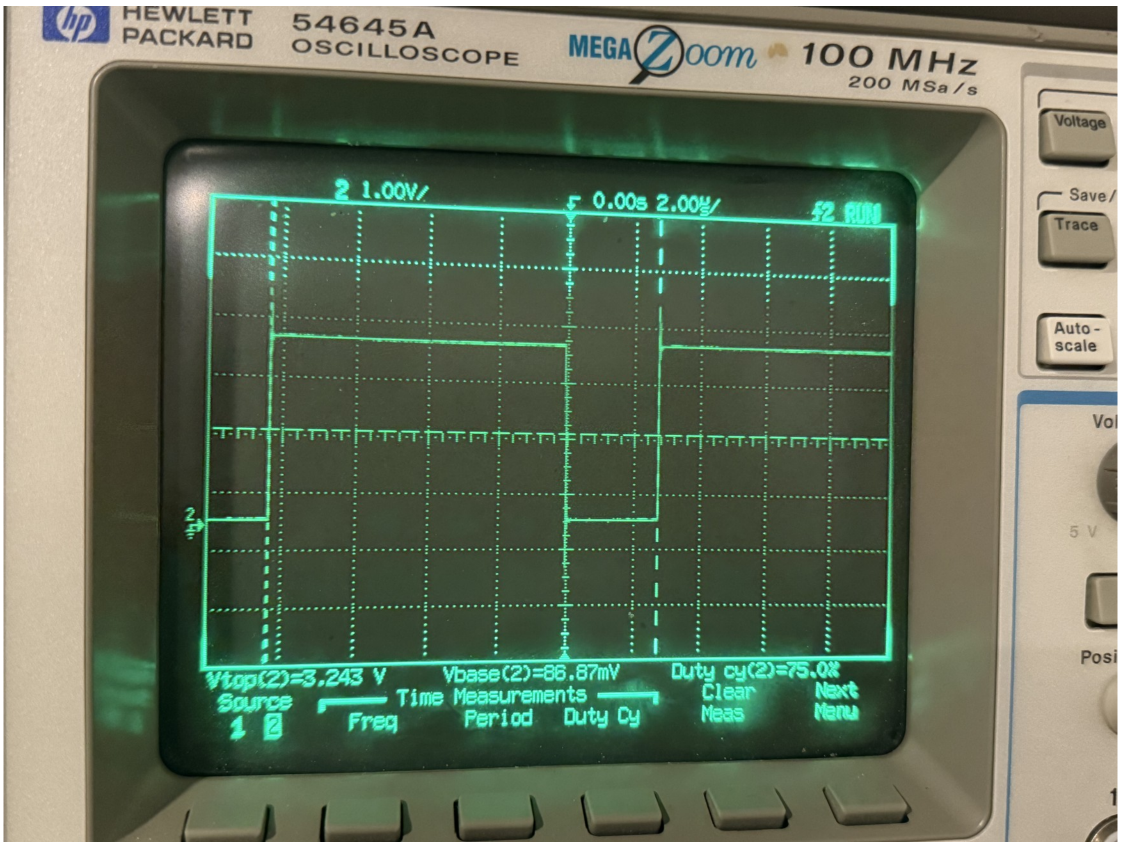


Figure 6. Representative oscilloscope capture from bench verification of the motor-drive test platform.

2. Embedded Control, Host, and Communications Requirements

ID	The system shall...	Verification	Status
SYS-001	use one TI LAUNCHXL-F28069M controller with two BOOSTXL-DRV8305EVM three-phase inverter stages.	Hardware inspection	Demonstrated
SYS-002	operate two mechanically coupled encoder-equipped PMSMs with independent feedback paths.	Hardware + feedback test	Demonstrated
SYS-003	execute target-side fast current control independently of host plotting, logging, or supervisory refresh timing.	Architecture inspection + bench test	Demonstrated
SYS-004	regulate Motor 1 speed and provide Motor 2 as a controllable load/assist machine through q-axis current command.	Model screenshot + functional test	Demonstrated
SYS-005	implement field-oriented current control using Clarke/Park transforms, current regulation, inverse transforms, and PWM reference generation.	Model screenshot review	Demonstrated
SYS-006	retain customer-visible architecture evidence while withholding source code and editable model files.	Package review	Verified
SYS-007	support supervisory acquisition and post-run review without changing real-time target ownership.	Host/target architecture review	Demonstrated

2.1 CAN Supervisory Interface Requirements

ID	The system shall...	Verification	Status
CAN-001	receive a standard CAN command frame on	Bus test	Demonstrated

ID	The system shall...	Verification	Status
	identifier 0x100.		
CAN-002	interpret the 8-byte command payload as four 16-bit command words mapped to the defined target command interface.	Interface review + bus test	Demonstrated
CAN-003	provide diagnostic/return traffic on identifier 0x101.	Bus test	Demonstrated
CAN-004	preserve target-side real-time loop ownership during loss, delay, or variation of supervisory CAN traffic.	Architecture review	Verified

4.1 Demonstrated Operating Envelope and Characterization Rules

Published test evidence includes operation approaching 4000 rpm. Principal loaded characterization points are concentrated at approximately 0.045-0.17 N*m; these values describe the retained evidence set rather than a certified continuous-duty machine rating.

The characterization workflow retains validity masks including electrical input power greater than 10 W, mechanical power greater than 3 W, and torque greater than 0.045 N*m before efficiency-map binning.

Mechanical power is evaluated as torque multiplied by angular speed. The retained dq electrical-power basis is 1.5 x Vq x Iq for the documented Motor 1 characterization path. Motor 2 electrical input power is not inferred by the same method because it is operated as the torque-controlled load machine.

Host pacing observed during the demonstrated workflow is approximately 0.96x real time. This is a supervisory execution characteristic and is not the timing source for the embedded current-control loops.

3. Sensing, ADC, and Real-Time Execution Requirements

The C2000 target uses PWM-synchronized sensing and interrupt-driven execution to support deterministic current-control updates. The documented implementation includes two added simultaneous ADC input pairs in addition to the base motor-control sensing paths. The underlying source is withheld, but the customer-facing interface and timing specifications are retained below.

ID	The system shall...	Verification	Status
ADC-001	support simultaneous sampling on SOC12/SOC13 using ADCINA2 and ADCINB2.	Implementation record review	Verified
ADC-002	support simultaneous sampling on SOC14/SOC15 using ADCINA1 and ADCINB1.	Implementation record review	Verified
ADC-003	trigger the added SOC pairs from ePWM1 with a seven-ADC-clock acquisition window.	Timing/configuration review	Verified
ADC-004	route EOC13 to ADCINT5 and EOC15 to ADCINT9.	Interrupt mapping review	Verified
ADC-005	use interrupt-driven execution for ADC and supervisory receive events with deterministic task prioritization.	Model screenshot review	Demonstrated

3.1 ADC and Interrupt Acceptance Mapping

SOC pair	Inputs	Trigger	Completion	Customer-visible specification
12/13	A2 / B2	ePWM1	EOC13 -> ADCINT5	Added simultaneous analog pair
14/15	A1 / B1	ePWM1	EOC15 -> ADCINT9	Added simultaneous analog pair

4. Acquisition, Characterization, and Performance Requirements

Characterization evidence is derived from recorded shaft speed, electrical variables, torque-related signals, and power calculations. Published efficiency products distinguish measured operating bins from sparse or unmeasured regions and retain sample-count evidence so the density of measurements remains visible.

ID	The system shall...	Verification	Status
DAT-001	expose shaft speed, current, voltage, torque-related, and power-related quantities required for dynamometer review.	Signal review	Demonstrated
DAT-002	support published operating evidence approaching 4000 rpm within the demonstrated test envelope.	Result review	Demonstrated
DAT-003	retain explicit validity criteria before efficiency-map binning, including minimum electrical power, mechanical power, and torque thresholds.	Analysis-record review	Verified
DAT-004	distinguish measured map bins from unmeasured regions and retain a sample-count view for density assessment.	Figure inspection	Verified
DAT-005	compute mechanical power from torque and angular speed and use the documented dq electrical-power basis for the retained characterization workflow.	Method review	Verified

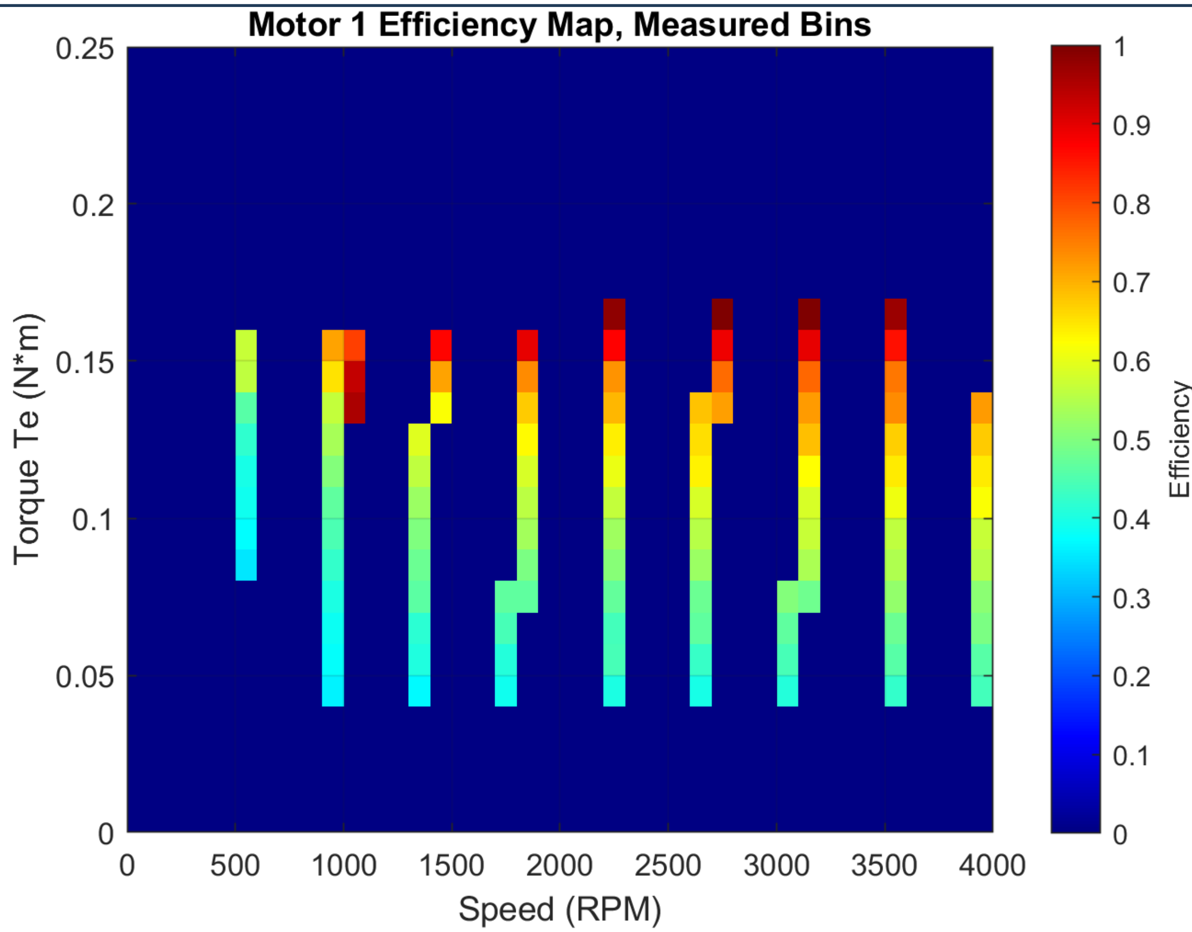


Figure 7. Measured-bin efficiency map retained as customer-facing validation evidence.

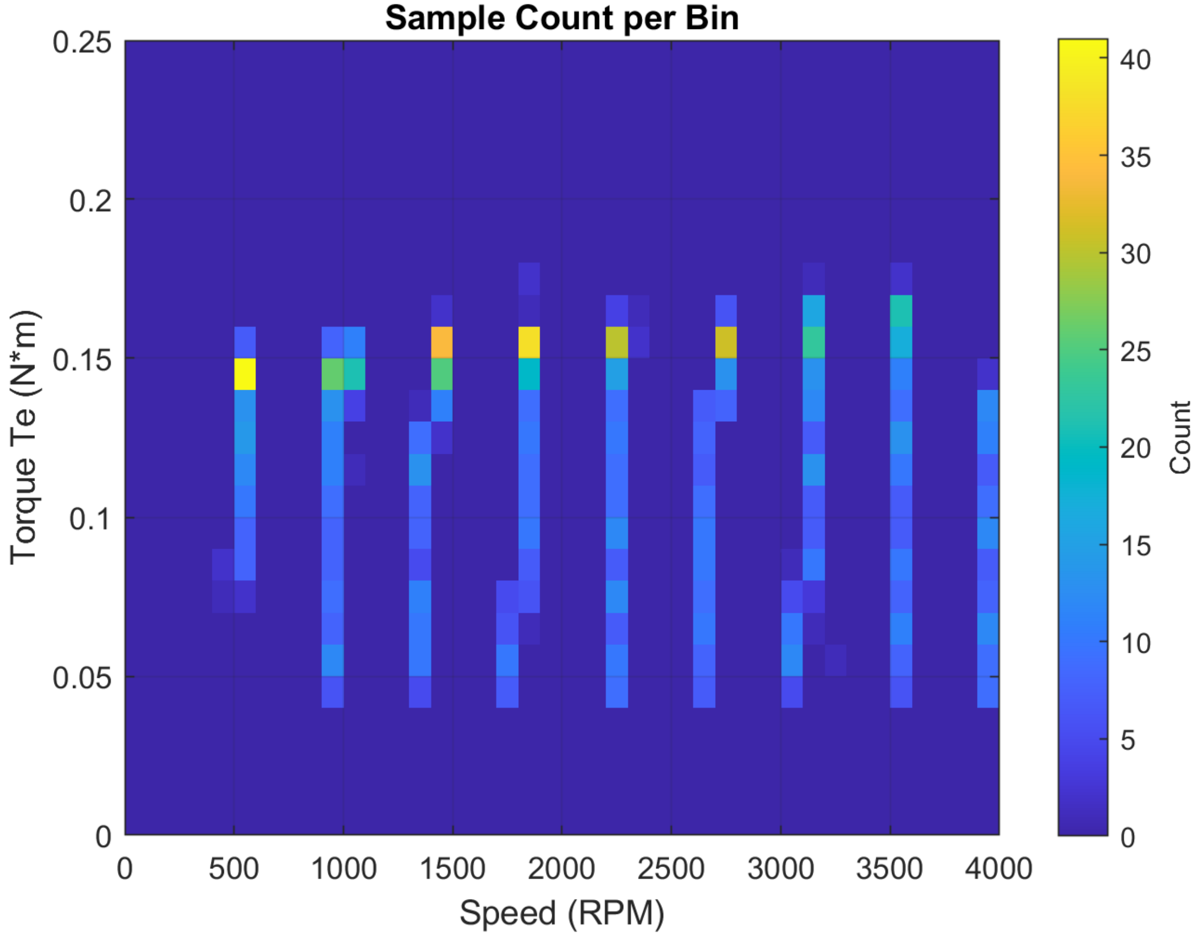


Figure 8. Sample-count map showing evidence density across the measured operating region.

5. Verification and Traceability

Verification combines model-architecture inspection, hardware inspection, CAN bench test, encoder/feedback observation, captured-signal review, and measured characterization. No source code or editable model file is required to understand the customer-facing requirement set.

Requirement group	Primary method	Customer-facing evidence	Acceptance basis
SYS	Architecture inspection + bench test	Hardware photographs and Simulink screenshots	Drive/load roles, FOC structure and target ownership are visible
CAN	Interface review + bus test	Documented IDs, payload structure and diagnostic behavior	Command and return paths demonstrated
ADC	Configuration record + model inspection	ADC/interrupt model screenshots and mapping table	Sampling, trigger and interrupt mapping match documented design
DAT	Signal + result inspection	Captured waveforms, measured efficiency map and density evidence	Published claims remain within demonstrated operating range

5.1 Release Limitations

- No calibrated metrology or independent torque-traceability claim is made.
- No production functional-safety, EMC, environmental, vibration, ingress, or endurance qualification is claimed.
- Source code, editable Simulink models, generated target code, binaries, build products, and licensed vendor packages are intentionally excluded from this customer-facing FRD package.
- Efficiency results are bench characterization of the demonstrated platform and shall not be interpreted as certified machine performance.

5.2 Customer Release Gate

ACCEPTANCE
This customer-facing FRD is accepted when each mandatory requirement has a defined verification method and evidence reference; hardware and Simulink architecture screenshots are readable; interface, sensing, operating-envelope, and characterization specifications are internally consistent; source code and editable model files are absent; and the rendered DOCX/PDF have been visually reviewed.