JURNAL MULTIDISIPLIN MADANI (MUDIMA)
Homepage: https://journalmudima.my.id/index.php/mudima
ISSN: 2808-5639 (Online)
Research Article

Vol. 6, No. 9, Seotember (2026)	DOI: https://doi.org/10.55927/mudima.v6i9.127	Page: 1233–1241

Optimizing Fault Diagnosis of Air Conditioning Compressor Magnetic Clutch in Nissan X-Trail T30 Based on a Universal Scanner

I Wayan Dikse Pancane
Universitas Pendidikan Nasional, Denpasar
Corresponding Author: I Wayan Dikse Pancane ; diksapancane@undiknas.ac.id

ARTICLE INFO

Keywords: Diagnosis, Compressor Clutch, Electrical Open-Circuit, Nissan X-Trail T30, Universal Diagnostic Scanner, Vehicle HVAC System.

Received : 4 July 2026
Revised : 24 August 2026
Accepted : 25 September 2026

©2026 Pancane : This is an open-access article distributed under the terms of the Creative Commons Atribusi 4.0 Internasional.

ABSTRACT

This study investigates an open-circuit fault in the automotive air conditioning (A/C) compressor magnetic clutch circuit of a Nissan X-Trail T30 by integrating a universal OBD-II diagnostic scanner with a digital multimeter. The vehicle manifested a typical non-cooling symptom: the blower fan and dashboard A/C indicator operated normally, but the compressor clutch failed to engage. A systematic, sequential diagnostic workflow was executed, tracing from electronic control requests down to physical actuator responses. Live data from the scanner verified seamless communication with the Engine Control Module (ECM) and confirmed the acceptance of the A/C request command without active Diagnostic Trouble Codes (DTCs). Upstream electrical measurements validated that the 10 A A/C fuse, relay coil supply, contact points, and output voltage at A/C relay E5 terminal 5 functioned within OEM specifications. However, battery supply voltage was absent at the compressor magnetic clutch connector E34 terminal 1. Continuity testing between E5 terminal 5 and E34 terminal 1 revealed an infinite resistance or open circuit (OL). A direct 12 V battery actuation test produced a definitive mechanical engagement click, confirming stator coil and armature plate integrity. Following conductor and terminal remediation, circuit continuity and nominal terminal voltage were restored, re-establishing normal clutch engagement. All diagnostic findings were validated against the factory criteria of the Nissan X-Trail T30 Service Manual. The results demonstrate that combining electronic live data with physical continuity, voltage drop, and direct actuation tests successfully isolates wiring harness anomalies, preventing erroneous and costly complete compressor replacements

INTRODUCTION

Automotive air conditioning (A/C) systems serve as an essential component of vehicular cabin thermal management, directly governing passenger thermal comfort while simultaneously interacting with total vehicle powertrain efficiency and fuel economy. The cooling efficacy of an automotive A/C system depends on dynamic thermodynamics across interconnected components, including the compressor, condenser, thermal expansion valve, evaporator, blower motor, refrigerant charge, multi-parameter pressure and temperature sensors, and electronic control logic. Recent investigations underscore that the adoption of low-GWP alternative refrigerants, advanced capacity modulation strategies, and varying operational loads critically influence the system's coefficient of performance (COP) and power consumption profile (Al-Zahrani, 2024; Guo et al., 2024; Ko et al., 2021).

In conventional internal combustion engine (ICE) vehicles equipped with fixed-displacement compressors, mechanical torque transmission from the engine crankshaft to the compressor input shaft is modulated via an electromagnetic clutch (magnetic clutch). When the stationary stator coil is energized, it generates an electromagnetic flux that attracts the

spring-loaded armature plate firmly against the continuously rotating drive pulley. The dynamic engagement behavior of this clutch assembly is governed by multiple electrical and mechanical variables, including coil DC resistance, excitation current, static air gap clearance, operating temperature, and friction surface degradation (Diao et al., 2024). Furthermore, mechanical valve fatigue, abnormal pressure pulsations, and internal compressor vibration demand rigorous physical evaluation beyond digital electronic monitoring (Gao et al., 2024).

A primary diagnostic dilemma encountered in automotive service workshops is the highly non-specific nature of HVAC failure symptoms. A general customer complaint such as "blower operates normally, yet discharged air remains uncooled" can stem from diverse root causes. These include refrigerant undercharge or leakages, condenser cooling fan malfunction, faulty evaporator/cabin thermistors, blown circuit protection fuses, stuck relay contacts, broken wiring harnesses, degraded stator coil windings, excessive clutch air gap, or internal compressor seizure. Reliability analyses of passenger vehicle HVAC systems demonstrate that operational failure modes are broadly distributed across distinct electrical, electronic, and mechanical subsystems. Consequently, an ordered, hierarchical diagnostic strategy is imperative to prevent the misdiagnosis and unnecessary replacement of healthy, functional assemblies (Kale et al., 2024; Sachelarie et al., 2025).

Electronic scan tools (OBD-II scanners) play a vital role in modern workshops by retrieving Diagnostic Trouble Codes (DTCs), monitoring A/C request switch states, verifying compressor control commands from the Engine Control Module (ECM), and evaluating engine telemetry. Nonetheless, an ECM output status indicating "Compressor Command: ON" solely validates the control unit's logical decision; it does not corroborate whether sufficient excitation current traverses the harness, whether the electromagnetic field overcomes spring tension, or whether the compressor successfully generates refrigerant pressure differentials (Bi et al., 2024; Hossain et al., 2024). While state-of-the-art literature emphasizes machine learning paradigms, deep neural networks, and high-frequency time-series vibration analysis for fault classification (Forbicini et al., 2025; Ma et al., 2024; Song et al., 2023; Yan & Zhou, 2022), such computational frameworks remain impractical for mainstream automotive repair shops due to hardware and cost constraints.

Consequently, a distinct engineering gap persists regarding the optimization of workshop-accessible diagnostic procedures utilizing conventional testing apparatus. This study aims to investigate and optimize the fault diagnostic process for an inoperative A/C compressor magnetic clutch on a Nissan X-Trail T30. By synthesizing universal scanner live telemetry with systematic digital multimeter measurements and direct-actuation testing, the findings are benchmarked against the factory criteria of the Nissan X-Trail T30 Service Manual (Revision July 2006) to establish a rigorous method for eliminating misdiagnoses and avoiding unnecessary component replacements.

METHODS

This study employs a descriptive diagnostic engineering case-study methodology aimed at resolving automotive electrical faults systematically through empirical verification.

Research Setting and Vehicle Platform

Experimental field diagnosis and measurements were conducted at Pandit Co. Automotive Workshop, located on Jalan Raya Munggu–Kapal, Cepaka, Kediri, Tabanan Regency, Bali. The test subject was a first-generation Nissan X-Trail (chassis code T30) powered by a 2.4-liter QR24DE petrol engine. The vehicle exhibited an active failure mode: the HVAC blower motor operated smoothly across all speed settings and the dashboard A/C indicator illuminated, yet the discharge air temperature remained at ambient level due to an unengaged compressor clutch.

Apparatus and Diagnostic Instrumentation

The engineering diagnostic setup utilized standard automotive workshop tools:

- Universal Diagnostic Scan Tool: A LAUNCH diagnostic platform paired with a DBScar 5 Vehicle Communication Interface (VCI) utilizing ISO/SAE standard OBD-II protocols to interrogate ECM live telemetry, command states, and stored DTC logs.
- Automotive Digital Multimeter: An autoranging digital multimeter used to perform DC voltage measurements, resistance tests, and closed-circuit continuity checks.
- Auxiliary Diagnostic Equipment: A 12 V automotive incandescent test lamp, fused direct-actuation jumper leads, and standard mechanical hand tools.

Diagnostic Workflow and Data Acquisition

The diagnostic procedure followed a sequential upstream-to-downstream workflow, tracing electrical energy flow from control inputs to actuator response:

1. Preliminary Visual Inspection: Examining auxiliary serpentine drive belt tension, pulley alignment, harness integrity, and connector corrosion around the compressor housing.
2. Electronic Control Interrogation: Interfacing the LAUNCH DBScar 5 scanner with the vehicle Data Link Connector (DLC) to scan for active/history DTCs and evaluate live data parameters, specifically A/C Request Signal and A/C Relay Control Command.
3. Power Distribution and Circuit Protection Verification: Verifying the structural integrity of the 10 A A/C fuse (Fuse No. 15) in the engine compartment fuse box and measuring DC battery supply voltage at the A/C relay socket (Relay E5 terminals 1 and 3) relative to chassis ground.
4. Relay Switching Function Test: Testing relay coil pull-in behavior and validating voltage availability at the relay load output terminal (E5 terminal 5).
5. Harness and Load Voltage Measurement: Measuring the operating voltage at the compressor magnetic clutch harness connector (Connector E34 terminal 1) with the A/C commanded ON, followed by an unpowered continuity test between relay socket E5 terminal 5 and compressor socket E34 terminal 1.
6. Direct Battery Actuation Test: Supplying a fused +12 V DC source directly to the positive pin of the magnetic clutch coil to evaluate electromagnetic coil integrity and armature plate displacement independent of the vehicle harness.
7. Harness Remediation and Post-Repair Verification: Repairing the severed conductor segment, installing protective heat-shrink conduit, and repeating all voltage, continuity, and functional engagement tests under actual running conditions.

Table 1. A/C Compressor Clutch Circuit Diagnostic Criteria Based on Nissan OEM Service Manual

Inspection Point	Test Condition	OEM Standard Criteria	Diagnostic Significance
Battery Terminal Voltage	Key ON / Self-diagnosis mode	$\geq$ 12.0 V DC	Prevents false DTCs and unreliable ECM relay switching due to undervoltage
Compressor Positive Terminal (E34 pin 1)	Engine running, Blower & A/C ON	Battery voltage (~12–14 V)	Confirms operating potential reaches the magnetic clutch stator coil

Inspection Point	Test Condition	OEM Standard Criteria	Diagnostic Significance
A/C Relay Supply Terminals (E5 pins 1 & 3)	Ignition switch ON	Battery voltage (~12–14 V)	Confirms constant B+ and ignition-switched power feed relay coil and contact
Harness Run (E5 pin 5 to E34 pin 1)	Ignition OFF, connectors disconnected	Continuity present (≤ 1.0 Ω)	Infinite resistance (OL) indicates an open conductor or terminal fretting

Source: Adapted from Nissan Motor Co., Ltd. (2006)

,Data Analysis Technique

Field test data were compared categorically against threshold specifications outlined in the Nissan X-Trail T30 Service Manual. Diagnostic success criteria were defined by: (a) restoring nominal excitation voltage across the actuator terminals, (b) recovering harness continuity within acceptable low-resistance limits, and (c) achieving definitive mechanical clutch engagement under operational engine loads.

RESULTS AND DISCUSSION

Inspection Findings and Fault Localization

Initial inspection confirmed customer complaints: upon depressing the A/C cabin switch with the blower operating, the compressor armature plate remained stationary while the pulley freewheeled, leaving cabin discharge air unchilled. Multi-stage diagnostic testing yielded comparative empirical data before and after repair, as detailed in Table 2.

Table 2. Categorical Diagnostic Test Results Before and After Electrical Repair on Nissan X-Trail T30

Diagnostic Parameter	OEM Benchmark Criteria	Pre-Repair Status	Post-Repair Status
Scanner to ECM Communication	Normal communication link	Connected (No DTCs)	Connected (No DTCs)
A/C Request Status (Live Data)	ON when switch is depressed	Active (ON)	Active (ON)
10 A A/C Fuse (Fuse No. 15)	Closed circuit / continuous	Normal / Intact	Normal / Intact
Relay Supply Voltage (E5 pins 1 & 3)	Nominal battery voltage	Normal (12.4 V)	Normal (13.8 V running)

Diagnostic Parameter	OEM Benchmark Criteria	Pre-Repair Status	Post-Repair Status
Relay Contact Switching (Pins 3 to 5)	Continuity upon activation	Functional	Functional
Relay Output Voltage (E5 pin 5)	Battery voltage with A/C ON	Voltage present (12.4 V)	Voltage present (13.8 V)
Compressor Terminal Voltage (E34 pin 1)	Battery voltage with A/C ON	No voltage detected (0 V)	Voltage present (13.8 V)
Continuity (E5 pin 5 to E34 pin 1)	Continuity confirmed ($\leq$ 1 Ω)	Open-Circuit (OL)	Continuity normal (0.2 Ω)
Direct Battery Actuation Test	Audible snap / engagement	Normal engagement	Not required
A/C Compressor Clutch Engagement	Locked rotation with pulley	Disengaged (0 RPM)	Engaged normally

Source: Field Experimental Data, Pandit Co. (2026), and Nissan Motor Co., Ltd. (2006)

Verification of Repair Against Factory Service Criteria

Data presented in Table 2 clearly demonstrate that upstream control circuits—comprising dashboard HVAC command modules, ECM bus communication, protective fuses, and the electro-mechanical A/C relay—operated without defect. The LAUNCH scan tool confirmed that the ECM recognized driver demand and enabled the compressor control routine without interruption from the refrigerant triple-pressure switch or engine coolant temperature protection algorithms. Nevertheless, the 12 V potential originating from relay socket E5 terminal 5 failed to reach compressor connector E34 terminal 1. An open-loop reading (OL) during digital multimeter continuity testing isolated the failure to a physical conductor severance within the harness run.

Table 3. Evaluation of Field Measurement Results Against Nissan OEM Service Manual Standards

Test Parameter	Nissan OEM Manual Criteria	Pre-Repair State	Post-Repair State
Relay Terminal Voltage (E5 pin 5)	Battery voltage with engine idling & A/C ON	Voltage present	Voltage present
Compressor Feed Voltage (E34 pin 1)	Battery voltage with engine idling & A/C ON	Voltage absent (0 V)	Battery voltage present
Line Continuity (E5 pin 5 to E34 pin 1)	Continuity present ($\leq 1\ \Omega$) with key OFF	Infinite resistance (OL)	Continuity restored
Direct Stator Coil Response	Armature snaps into engagement with B+ feed	Normal engagement	Not required
Operating Clutch State (A/C ON)	Continuous mechanical engagement	Disengaged	Engaged normally
Center Vent Duct Temperature	Thermodynamic cooling test post-stabilization	Beyond research scope	Beyond research scope
Manifold Gauge Pressures (Hi/Lo)	Refrigerant cycle pressure verification	Beyond research scope	Beyond research scope

Source: Compiled from Empirical Testing and Nissan Motor Co., Ltd. (2006)

Discussion

Integrating a universal OBD-II scanner with fundamental electrical testing instruments established an efficient diagnostic protocol that dramatically minimized troubleshooting time. Interrogating live data streams and confirming the complete absence of DTCs eliminated false suspicions regarding powertrain protection interventions (e.g., high coolant temperature cutoff, low evaporator freeze cutoff, or refrigerant pressure boundary trips). This corroborates assertions by Bi et al. (2024) and Hossain et al. (2024), who emphasized that digital control decisions must be corroborated with localized electrical verification to achieve dependable automotive diagnostics.

Electrical Circuit Analysis: The detection of 12.4 V at relay socket E5 terminal 5 concurrent with 0.0 V at compressor harness connector E34 terminal 1 localized the defect precisely to the intermediate wiring harness routed along the lower engine compartment. In the Nissan X-Trail T30 platform, this sub-harness is exposed to high ambient heat dissipation from the cylinder block and exhaust manifold, alongside continuous mechanical vibration

transferred from the engine mounting bracket. Over prolonged operational cycles, these thermal and mechanical stresses degrade insulation and induce copper fatigue fracture, culminating in an open-circuit failure directly adjacent to connector E34.

Verification of Magnetic Clutch Integrity: Executing a direct battery actuation test represented a crucial confirmatory milestone prior to initiating wiring repairs. Supplying a fused battery voltage directly to the compressor terminal elicited an immediate, crisp mechanical snap as the armature plate bonded to the spinning pulley. This empirical response confirmed that the internal electromagnetic coil winding remained intact (free from open circuits or inter-turn shorts to ground) and that the working air gap remained within serviceable engineering tolerances (Diao et al., 2024). Replacing the damaged conductor segment with cross-linked polyethylene automotive wiring and encasing it in a corrugated heat-resistant conduit permanently restored circuit continuity without dismounting the compressor.

Maintenance Economics and Service Malpractice Mitigation: In automotive service environments, an unengaged compressor clutch is frequently misdiagnosed as an internal compressor seizure or defective magnetic coil, resulting in unwarranted component replacements and inflated repair costs for vehicle owners. This study highlights how a structured, hierarchical diagnostic methodology prevents component misdiagnosis, providing high repair accuracy and significant cost efficiency (Panda & Singh, 2023; Sachelarie et al., 2025).

CONCLUSION

This study demonstrates that the failure of the A/C compressor magnetic clutch to engage on the investigated Nissan X-Trail T30 was caused by an electrical open circuit within the wiring harness between A/C relay socket E5 terminal 5 and compressor clutch connector E34 terminal 1. Interrogating the vehicle control system with a universal LAUNCH DBScar 5 scan tool validated the upstream command pathway from the ECM, while digital multimeter continuity testing and direct battery actuation isolated the physical conductor failure and confirmed the functional integrity of the clutch assembly. Targeted conductor replacement successfully restored nominal operating voltage and reinstated normal cooling performance.

From an engineering and workshop management perspective, service facilities are strongly encouraged to implement structured diagnostic checklists that mandate DTC scanning, voltage drop measurements, line continuity testing, and direct component actuation prior to prescribing costly component overhauls. Future studies may expand upon this electrical diagnostic protocol by incorporating dynamic thermodynamic evaluations, such as continuous manifold gauge high/low pressure logging and computerized duct temperature profiling under controlled ambient test cells..

REFERENCES

Al-Zahrani, A. (2024). Investigating new environmentally friendly zeotropic refrigerants as possible replacements for carbon dioxide (CO2) in car air conditioners. Sustainability, 16(1), 358. https://doi.org/10.3390/su16010358

Bi, J., Wang, H., Yan, E., Wang, C., Yan, K., Jiang, L., & Yang, B. (2024). AI in HVAC fault detection and diagnosis: A systematic review. Energy Reviews, 3(2), 100071. https://doi.org/10.1016/j.enrev.2024.100071

Chen, J., Zhang, L., Li, Y., Shi, Y., Gao, X., & Hu, Y. (2022). A review of computing-based automated fault detection and diagnosis of heating, ventilation and air conditioning systems. Renewable and Sustainable Energy Reviews, 161, 112395. https://doi.org/10.1016/j.rser.2022.112395

Diao, Z., Zhang, Y., Li, C., Liu, X., & Liu, Z. (2024). Dynamic characteristics of an automotive air-conditioning electromagnetic clutch. Processes, 12(1), 80. https://doi.org/10.3390/pr12010080

Forbicini, F., Pinciroli Vago, N. O., & Fraternali, P. (2025). Time series analysis in compressor-based machines: A survey. Neural Computing and Applications, 37, 11001–

11038. https://doi.org/10.1007/s00521-025-11065-0

Gao, F., Yang, B., Li, X., & Wu, J. (2024). Noise analysis and structural optimization of automobile scroll compressor air valve. Applied Sciences, 14(11), 4875. https://doi.org/10.3390/app14114875

Göltz, S., & Sawodny, O. (2023). Design and comparison of model-based controllers for an automotive air conditioning system in an electric vehicle. Control Engineering Practice, 130, 105376. https://doi.org/10.1016/j.conengprac.2022.105376

Gunawan, G., Saksono, P., Abidin, J., & Plengsa-ard, C. (2022). An experimental study on the performance of air conditioning system using R-134a and MC-134 refrigerant in D8R Caterpillar units. Journal of Engineering and Applied Technology, 3(1), 42–52. https://doi.org/10.21831/jeatech.v3i1.48823

Guo, B., Zhao, L., Zhou, J., Sun, X., & Yang, Z. (2024). Experimental investigation on the R1234yf air conditioning system with a battery cooling loop under realistic conditions of electric vehicles. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 238(7), 1913–1930. https://doi.org/10.1177/09544070231156953

Hossain, M. N., Rahman, M. M., & Ramasamy, D. (2024). Artificial intelligence-driven vehicle fault diagnosis to revolutionize automotive maintenance: A review. Computer Modeling in Engineering & Sciences, 141(2), 951–996. https://doi.org/10.32604/cmes.2024.056022

Kale, S. K., Shelar, M., Auti, S., Ingle, P. V., Roy, A., Sonawane, C. R., & Patil, R. B. (2024). Investigating the reliability of heating, ventilation, and air conditioning systems utilized in passenger vehicles. Applied Sciences, 14(22), 10522. https://doi.org/10.3390/app142210522

Ko, G. S., Raza, W., & Park, Y. C. (2021). Capacity control of a vehicle air-conditioning system using pulse width modulated duty cycle compressor. Case Studies in Thermal Engineering, 26, 100986. https://doi.org/10.1016/j.csite.2021.100986

Ma, Q., Yue, C., Yu, M., Song, Y., Cui, P., & Yu, Y. (2024). Research on fault diagnosis strategy of air-conditioning system based on signal demodulation and BPNN-PCA. International Journal of Refrigeration, 158, 124–134. https://doi.org/10.1016/j.ijrefrig.2023.12.008

Nissan Motor Co., Ltd. (2006). Nissan X-Trail T30 service manual: Manual air conditioner (MTC) and automatic air conditioner (ATC) (Revision July 2006).

Panda, C., & Singh, T. R. (2023). ML-based vehicle downtime reduction: A case of air compressor failure detection. Engineering Applications of Artificial Intelligence, 122, 106031. https://doi.org/10.1016/j.engappai.2023.106031

Parent, T., Defoe, J. J., & Rahimi, A. (2024). Controller design for air conditioner of a vehicle with three control inputs using model predictive control. Modelling, 5(1), 117–152. https://doi.org/10.3390/modelling5010008

Sachelarie, D., Achitei, G., Munteanu, A. I., Sachelarie, A., Dontu, A. I., Tcaciuc, G. D., & Popescu, A. (2025). Air conditioning systems in vehicles: Approaches and challenges. Sustainability, 17(12), 5257. https://doi.org/10.3390/su17125257

Song, Y., Ma, Q., Zhang, T., Li, F., & Yu, Y. (2023). Research on fault diagnosis strategy of air-conditioning systems based on DPCA and machine learning. Processes, 11(4), 1192. https://doi.org/10.3390/pr11041192

Wu, J.-D., Ke, J.-Y., Shih, F.-Y., & Shyr, W.-J. (2022). Fault diagnosis for vehicle air conditioning blower using deep learning neural network. Journal of Low Frequency Noise, Vibration and Active Control, 41(3), 910–925. https://doi.org/10.1177/14613484221085891

Yan, K., & Zhou, X. (2022). Chiller faults detection and diagnosis with sensor network and adaptive 1D CNN. Digital Communications and Networks, 8(4), 531–539. https://doi.org/10.1016/j.dcan.2022.03.023

Zhai, C., Jiang, B., Sun, D., Zhang, H., Tang, H., & Zhang, R. (2024). Research on fault diagnosis of on-board air conditioning refrigeration system. Journal of Hefei University of Technology (Natural Science), 47(3), 324–328. https://doi.org/10.3969/j.issn.10035060.2024.03.006