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IoT-Based Vibration Analysis for Induction Motor Damage Monitoring

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Abstract

Induction motors are an important component in various industrial applications due to their reliability in long-term opeation. Failure of induction motors can cause production disruptions and significant repair costs. This research develops an Internet of Things (IoT)-based vibration monitoring system using ADXL345 accelerometer sensors and ESP32 microcontrollers. The vibration data obtained is sent to a computer via asynchronous serial communication, where the computer performs FFT calculations and frequency analysis to extract dominant information from the vibration signal. Damage detection is performed using a combination of heuristics and threshold rules to classify the motor status as healthy or ambiguous. The classification results are then sent back via the MQTT protocol and can be visualized in real-time through a dashboard. This system enables predictive maintenance, thereby minimizing the risk of sudden failure and increasing operational efficiency.

Keywords*:* Mikrokontroler, FFT, Motor Induksi, IoT

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INTRODUCTION

Induction motors are the main drivers in various industrial lines due to their simple construction, low maintenance costs, and long-term operational reliability. In condition-based maintenance (CBM) practices for rotating machines, vibration monitoring is a key indicator of asset health because small changes in mechanical conditions will manifest in vibration signals in the time, frequency, and time-frequency domains[1].

Induction motor failure can trigger production disruptions and high repair costs (downtime, scrap, and lost opportunity cost). Industrial studies on pumps/rotating machines show the importance of early detection of failure modes such as imbalance, misalignment, bearing wear, seal leakage, and cavitation; good vibration monitoring has been proven to reduce downtime and increase productivity through timely maintenance interventions [2].

One of the most widely used approaches to detecting potential damage to rotating machinery is the analysis of vibration patterns that arise during operation. Measurements of vibration acceleration/velocity in the bearing housing or frame and feature extraction in the time domain (RMS, kurtosis, skewness) and frequency domain (1×RPM peak, BPFI/BPFO, blade-passing, etc.) enable early identification of abnormalities before fatal failures occur.

IoT frameworks with smart sensors (both wired and wireless) have been widely applied for real-time monitoring of rotating machine conditions. The system architecture generally consists of MEMS sensors capable of detecting vibration and temperature, data collectors, and integration with cloud or edge computing. With this scheme, data can be continuously sent to a central server for automatic analysis. Field verification results show that wired sensor-based systems can achieve a diagnosis accuracy of more than 85%, making them a reliable solution in predictive maintenance practices [3].

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[1] Elena Quatrini and others, 'Condition-Based Maintenance-An Extensive Literature Review', in *Machines*, no. 2, preprint, 2020, VIII, doi:10.3390/MACHINES8020031; Wim J.C. Verhagen and others, 'Condition-Based Maintenance in Aviation: Challenges and Opportunities', *Aerospace*, 10.9 (2023), doi:10.3390/aerospace10090762; Tyler Ward and others, 'A Comprehensive Review of Machine Learning Techniques for Condition-Based Maintenance', *International Journal of Prognostics and Health Management*, 15.2 (2024), doi:10.36001/ijphm.2024.v15i2.3850; Omri Matania and others, 'Signal Processing for the Condition-Based Maintenance of Rotating Machines via Vibration Analysis: A Tutorial', *Sensors*, 24.2 (2024), doi:10.3390/s24020454; Jong Ho Shin and Hong Bae Jun, 'On Condition Based Maintenance Policy', *Journal of Computational Design and Engineering*, 2.2 (2015), doi:10.1016/j.jcde.2014.12.006.

[2] Pere Marti-Puig and others, 'Industrial AI in Condition-Based Maintenance: A Case Study in Wooden Piece Manufacturing', *Computers and Industrial Engineering*, 188 (2024), doi:10.1016/j.cie.2024.109907.

[3] Kritsana Sureeya, Chalakorn Karupongsiri, and Tanakorn Inthasuth, 'A Deep Learning Framework for Anomaly Prediction in an HVAC System Using IoT-Based Vibration Data', *IEEE Internet of Things Journal*, published online 2025, doi:10.1109/JIOT.2025.3627959; Mangalpady Aruna and others, 'Enhancing Safety in Surface Mine Blasting Operations with IoT Based Ground Vibration Monitoring and Prediction System Integrated with Machine Learning', *Scientific Reports*, 15.1 (2025), doi:10.1038/s41598-025-86827-w.

In addition, artificial intelligence-based approaches have also been explored, one of which is by classifying defects in impellers and cavitation in centrifugal pumps using Multi-Layer Perceptron (MLP). This method utilizes statistical features from vibration signals, such as mean, variance, skewness, kurtosis, and RMS. The results show that these features are effective enough to distinguish between healthy and defective conditions in real-time, allowing MLP to be integrated into modern monitoring systems.

Other studies emphasize the use of the ISO-10816 standard as a reference for evaluating machine condition[4]. In misalignment scenarios, measurements using ADXL345 accelerometer sensors combined with FFT analysis have been proven to accurately map vibration levels. The data was then processed and visualized through the Node-RED dashboard for logging and prediction. This implementation resulted in an accuracy of 99.87% in the 20 Hz test, demonstrating strong potential for international standard-based monitoring.

An experimental study was also conducted by comparing healthy and defective pump conditions to identify the most critical cases. Through spectrum and time signal analysis, researchers found that pedestal looseness was one of the conditions with the highest vibration amplitude. These results were linked to the ISO-10816 standard as the basis for classifying machine operating conditions, so they can be used as a reference for determining safety limits [5].

Not only in academic aspects, industry guidelines also emphasize the importance of sensor installation and selection of appropriate monitoring techniques. The approach used can be continuous monitoring with permanent sensors, or periodic monitoring using portable sensors. Dynamic monitoring techniques and 4–20 mA outputs are also combined for various industrial applications. This guide emphasizes best practices in selecting accelerometer measurement points and shows that early detection of damage can be done up to 18 months before breakdown, making vibration an important indicator in predictive maintenance strategies [6].

Based on these findings, this study aims to develop an Internet of Things (IoT)-based vibration monitoring system using accelerometer sensors integrated with an ESP32 microcontroller. Vibration data is processed through digital filtering, RMS calculation,

[4] Grymmaldi Harindah, 'Implementasi Pemeliharaan Prediktif Berbasis Analisis Getaran Menggunakan Standar Iso 10816 Pada Mesin Diesel Di PLTD Tobelo', *Jurnal Sosial Teknologi*, 4.7 (2024), doi:10.59188/jurnalsostech.v4i7.1326; N. Jamil and others, 'Predictive Maintenance for Rotating Machinery by Using Vibration Analysis', *Journal of Mechanical Engineering and Sciences*, 15.3 (2021), doi:10.15282/jmes.15.3.2021.07.0651.

[5] Quatrini and others, 'Condition-Based Maintenance-An Extensive Literature Review'.

[6] Tamíris Pacheco da Costa, Daniele Mesquita Bordalo da Costa, and Fionnuala Murphy, 'A Systematic Review of Real-Time Data Monitoring and Its Potential Application to Support Dynamic Life Cycle Inventories', in *Environmental Impact Assessment Review*, preprint, 2024, CV, doi:10.1016/j.eiar.2024.107416; Houcheng Liu and others, 'Dynamic Monitoring Technique of Bored Pile Pouring Process Based on Multi-Frequency Ultrasound', *Journal of Civil Structural Health Monitoring*, 12.2 (2022), doi:10.1007/s13349-021-00528-2.

and FFT, then sent via publish/subscribe using MQTT to be visualized in real-time on the Node-RED dashboard, enabling early warnings for predictive maintenance

RESEARCH METHODS

This study aims to develop an Internet of Things (IoT)-based vibration monitoring system for induction motors to predict potential damage [7]. The system is designed to perform real-time monitoring, provide early warnings, and support predictive maintenance strategies, thereby reducing the risk of sudden failure and improving operational efficiency. The research method includes several main stages that are interconnected, starting from data collection, signal processing, frequency analysis, damage detection, to motor status transmission. The research flowchart illustrates the complete flow from the sensor to the monitoring dashboard. The stages of the flowchart are as follows:

Data Collection

Vibration data is obtained using an ADXL345 accelerometer sensor, which is installed at critical points of the induction motor, such as the bearings and motor casing, to capture vibrations in three axes (X, Y, Z). This sensor is connected to an ESP32 microcontroller, which functions as a data collector and initial data transmitter. The ESP32 sends accelerometer data to the computer via asynchronous serial communication, with the sampling rate adjusted to the motor characteristics (e.g., fs = 1600 Hz) to ensure adequate representation of the vibration spectrum. The data received by the computer is then temporarily stored in a buffer for further analysis.

Data Preprocessing

Before analysis, vibration data is processed to eliminate noise and minor irrelevant disturbances. This step includes averaging (DC offset removal) and applying digital filters to extract the relevant frequency range, for example 0–500 Hz, which covers the critical frequencies of induction motors and pump components. This process also ensures signal stability before statistical and frequency analysis is performed.

Root Mean Square (RMS)

RMS is calculated for each data window during a specific period (e.g., 15 seconds) to assess the total vibration energy. Consistent RMS values within normal limits indicate healthy motor conditions, while a significant increase in RMS indicates the possibility of mechanical damage, such as misalignment, rotor imbalance, or bearing wear. RMS is also used as a normalization reference for the peak amplitude of a specific frequency before calculating ratios or thresholds. Thus, damage detection becomes more resistant to minor fluctuations in the signal. Integrating RMS with frequency analysis (FFT) enables quantitative and qualitative evaluation of vibration conditions, including the identification of ambiguous conditions or early signs of damage .

Frequency Analysis with FFT

The processed vibration signal is analyzed using Fast Fourier Transform (FFT) to obtain the dominant frequency spectrum. FFT helps identify critical frequencies associated with mechanical components of the motor, such as the rotor, impeller, or bearings, which may indicate damage.

[7] Mattia Ragnoli and others, 'A Condition and Fault Prevention Monitoring System for Industrial Computer Numerical Control Machinery', *IEEE Access*, 12 (2024), doi:10.1109/ACCESS.2024.3359424; Mayank Mishra, Paulo B. Lourenço, and G. V. Ramana, 'Structural Health Monitoring of Civil Engineering Structures by Using the Internet of Things: A Review', in *Journal of Building Engineering*, preprint, 2022, XLVIII, doi:10.1016/j.jobe.2021.103954; Zhoujing Ye and others, 'Real-Time and Efficient Traffic Information Acquisition via Pavement Vibration Iot Monitoring System', *Sensors*, 21.8 (2021), doi:10.3390/s21082679.

The amplitude spectrum is then analyzed to find frequency peaks at key points (e.g., 50 Hz, 150 Hz, 200 Hz)The research methods used in this article should be mentioned clearly and explicitly.

Sending Analysis Results via MQTT Protocol

After the vibration data is analyzed on the Mini PC, the results in the form of motor condition status are sent using the MQTT (Message Queuing Telemetry Transport) protocol. MQTT was chosen because it is lightweight and efficient for IoT data communication, enabling real-time information delivery to servers or the cloud with low latency and minimal bandwidth consumption.

Display Results in Dashboard

The data received by the MQTT broker is then forwarded to the Node-RED-based monitoring dashboard. This dashboard displays information on the health status of the motor. With an interactive interface, users can easily monitor the condition of the motor and receive early warnings if signs of damage are detected.

The architecture of this Internet of Things (IoT)-based induction motor vibration monitoring system is shown in Figure 1. An accelerometer sensor is installed on the induction motor to measure mechanical vibrations, and the data is then sent to a microcontroller (ESP32) for acquisition and preprocessing. Next, the data is sent to a Mini PC that acts as an edge device for further processing and status transmission via the MQTT protocol to the broker. Motor status information is received and visualized in a Node-RED-based monitoring dashboard, which allows users to monitor the motor's condition in real-time via the internet. This architecture supports an efficient predictive maintenance system that can be accessed remotely.

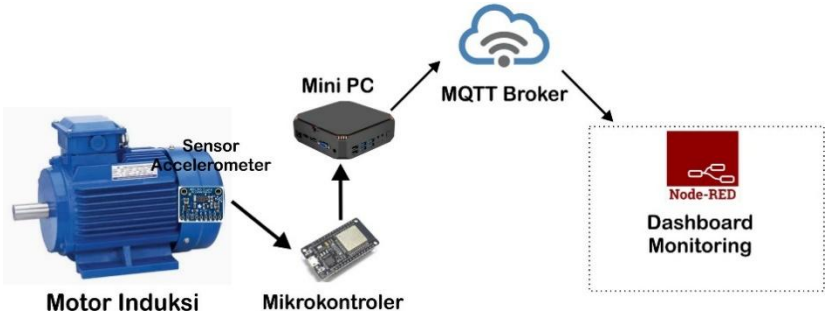
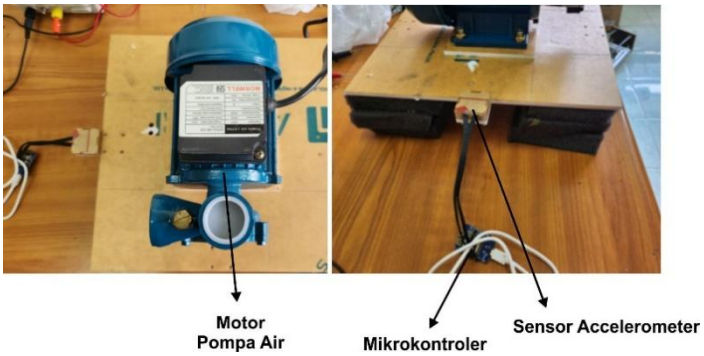


Figure 1. Architecture of a water pump condition detection system based on vibration sensors

Figure 2 shows the implementation of a vibration monitoring system on a water pump motor using an accelerometer sensor and a microcontroller. On the left side, the water pump motor is mounted on a board as a test base. Meanwhile, on the right side, it shows how the microcontroller is connected directly to the accelerometer sensor installed at the bottom of the motor. This sensor functions to capture the vibrations produced by the motor during operation, while the microcontroller is tasked with processing and sending the vibration data to the monitoring system for further analysis.



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Figure 2. Photo of the mechanical system and sensor placement location.

RESULT AND DISCUSSION

The test results were conducted on a water pump motor with a nominal speed of 2850 RPM. Vibration data was collected at specific time intervals under various conditions, ranging from healthy conditions to simulated damage conditions in the form of unbalanced loads on the rotor. Figures 3 and 4 show the results of water pump motor vibration measurements using an accelerometer sensor analyzed through the time and frequency domains. Figure 3 shows the water pump motor in normal condition, where all mounting screws are perfectly installed. The time signal graph shows a stable amplitude without noticeable fluctuations. In the frequency domain of the Welch ASD transformation results, the main peaks are seen at frequencies of 49.83 Hz and 99.98 Hz, as well as harmonics at 300.05 Hz. This pattern indicates consistent and balanced vibration, so the system concludes that the status is healthy. Figure 4 shows the condition when one of the motor mounting screws is loosened, causing mechanical imbalance. The time signal graph shows greater fluctuations compared to normal conditions. In the frequency domain, additional frequencies appear, namely 50.05 Hz, 150.02 Hz, and 199.95 Hz, which indicate abnormal vibrations. Although there is a similarity to the motor's fundamental frequency, the appearance of these additional harmonics indicates system imbalance, so the system detects the status as ambiguous.

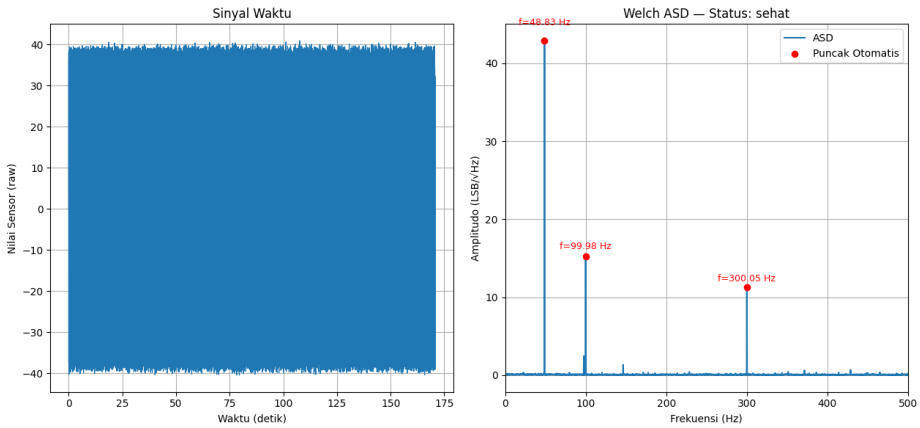


Figure 3. Measurement results when the screw is perfectly attached to the pump motor foot

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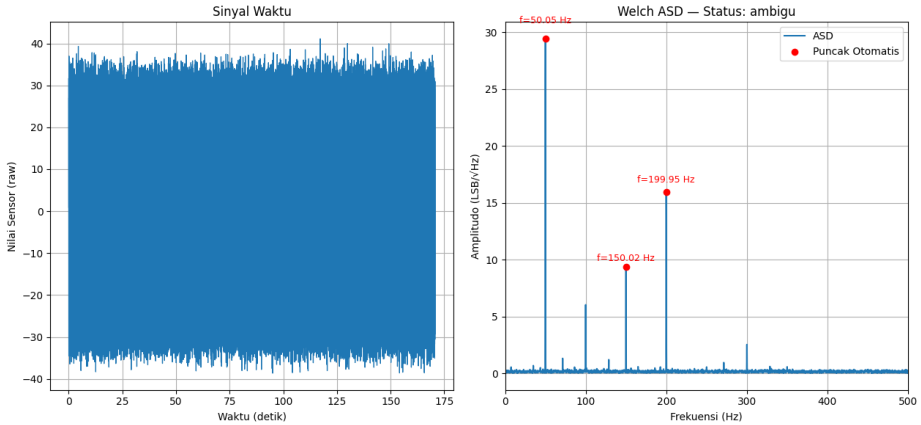


Figure 4. Measurement results when one of the screws on the pump motor foot is loose.

The MQTT system successfully sent the status within <1 second from the time of detection to the dashboard, thereby meeting the need for real-time monitoring.

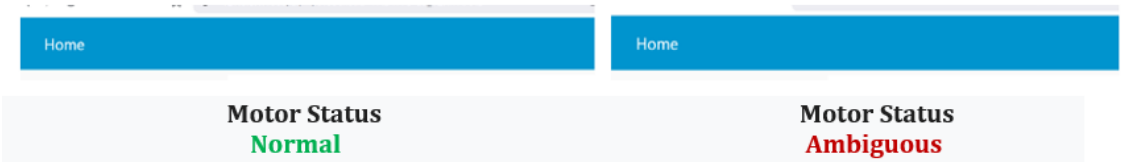


Figure 5. Monitoring dashboard display with the Node-Red application

Table I presents the results of testing the abnormality identification system on water pump motors through vibration analysis. Under normal motor conditions (rows 1, 4, and 6), the system consistently provides a “Normal” detection result, indicating that the system can recognize the motor operating in a stable condition. However, when the motor mounting screws were loosened in various positions (rows 2, 3, 5, and so on), the system detected the result as “Ambiguous”. This indicates that the system is able to respond to changes in vibration, but is not yet able to specifically classify the type of damage. Thus, the system has demonstrated sensitivity to changes in mechanical conditions, but further development is still needed, such as training a more precise classification model or improving the threshold marking method to produce more accurate detection.

Table 1. Testing to identify motor abnormalities

No.	Action	Detection result
1	Motor Bormal	Normal
2	Loosen screw 1 on the motor mount	Ambiguous
3	Loosen screw 2 on the motor mount	Ambiguous
4	Loosen screw 3 on the motor mount	Normal
5	Loosen screw 4 on the motor mount	Ambiguous
6	Motor Normal	Normal
7	Loosen screw 1 and 2 on the motor mount	Ambiguous
8	Loosen screw 2 and 3 on the motor mount	Ambiguous

9	Loosen screw 3 and 4 on the motor mount	Ambuguous
10	Loosen screw 4 and 1 on the motor mount	Ambiguous

CONCLUSION

This research successfully developed an IoT-based vibration monitoring system for induction motors using ADXL345 sensors and ESP32 microcontrollers. This system is capable of detecting motor damage conditions in real-time through RMS and FFT signal processing, as well as providing damage status through an MQTT-based dashboard. Increased RMS values and the appearance of spectrum peaks at certain frequencies have proven effective in identifying damage conditions such as unbalance and misalignment.

This system has the potential to be applied in industrial environments as a cost-effective and reliable predictive maintenance solution. Further development could include the use of machine learning-based classification models for higher accuracy and simultaneous multi-fault detection.

BIBLIOGRAPHY

Aruna, Mangalpady, and others, 'Enhancing Safety in Surface Mine Blasting Operations with IoT Based Ground Vibration Monitoring and Prediction System Integrated with Machine Learning', *Scientific Reports*, 15.1 (2025), doi:10.1038/s41598-025-86827-w

Costa, Tamíris Pacheco da, Daniele Mesquita Bordalo da Costa, and Fionnuala Murphy, 'A Systematic Review of Real-Time Data Monitoring and Its Potential Application to Support Dynamic Life Cycle Inventories', in *Environmental Impact Assessment Review*, preprint, 2024, CV, doi:10.1016/j.eiar.2024.107416

Harindah, Grymmaldi, 'Implementasi Pemeliharaan Prediktif Berbasis Analisis Getaran Menggunakan Standar Iso 10816 Pada Mesin Diesel Di PLTD Tobelo', *Jurnal Sosial Teknologi*, 4.7 (2024), doi:10.59188/jurnalsostech.v4i7.1326

Jamil, N., and others, 'Predictive Maintenance for Rotating Machinery by Using Vibration Analysis', *Journal of Mechanical Engineering and Sciences*, 15.3 (2021), doi:10.15282/jmes.15.3.2021.07.0651

Liu, Houcheng, and others, 'Dynamic Monitoring Technique of Bored Pile Pouring Process Based on Multi-Frequency Ultrasound', *Journal of Civil Structural Health Monitoring*, 12.2 (2022), doi:10.1007/s13349-021-00528-2

Marti-Puig, Pere, and others, 'Industrial AI in Condition-Based Maintenance: A Case Study in Wooden Piece Manufacturing', *Computers and Industrial Engineering*, 188 (2024), doi:10.1016/j.cie.2024.109907

Matania, Omri, and others, 'Signal Processing for the Condition-Based Maintenance of Rotating Machines via Vibration Analysis: A Tutorial', *Sensors*, 24.2 (2024), doi:10.3390/s24020454

Mishra, Mayank, Paulo B. Lourenço, and G. V. Ramana, 'Structural Health Monitoring of Civil Engineering Structures by Using the Internet of Things: A Review', in *Journal of Building Engineering*, preprint, 2022, XLVIII, doi:10.1016/j.jobe.2021.103954

Quatrini, Elena, and others, 'Condition-Based Maintenance-An Extensive Literature Review', in *Machines*, no. 2, preprint, 2020, VIII, doi:10.3390/MACHINES8020031

Ragnoli, Mattia, and others, 'A Condition and Fault Prevention Monitoring System for Industrial Computer Numerical Control Machinery', *IEEE Access*, 12 (2024), doi:10.1109/ACCESS.2024.3359424

Shin, Jong Ho, and Hong Bae Jun, 'On Condition Based Maintenance Policy', *Journal of Computational Design and Engineering*, 2.2 (2015), doi:10.1016/j.jcde.2014.12.006

Sureeya, Kritsana, Chalakorn Karupongsiri, and Tanakorn Inthasuth, 'A Deep Learning Framework for Anomaly Prediction in an HVAC System Using IoT-Based Vibration Data', *IEEE Internet of Things Journal*, published online 2025, doi:10.1109/JIOT.2025.3627959

Verhagen, Wim J.C., and others, 'Condition-Based Maintenance in Aviation: Challenges and Opportunities', *Aerospace*, 10.9 (2023), doi:10.3390/aerospace10090762

Ward, Tyler, and others, 'A Comprehensive Review of Machine Learning Techniques for Condition-Based Maintenance', *International Journal of Prognostics and Health Management*, 15.2 (2024), doi:10.36001/ijphm.2024.v15i2.3850

Ye, Zhoujing, and others, 'Real-Time and Efficient Traffic Information Acquisition via Pavement Vibration Iot Monitoring System', *Sensors*, 21.8 (2021), doi:10.3390/s21082679