



SensePay 

The SensePay logo consists of the word "SensePay" in a large, white, sans-serif font. To the right of the text is a white icon depicting a hand holding a smartphone. On the screen of the phone, the word "PAY" is visible, accompanied by a small circular signal icon.

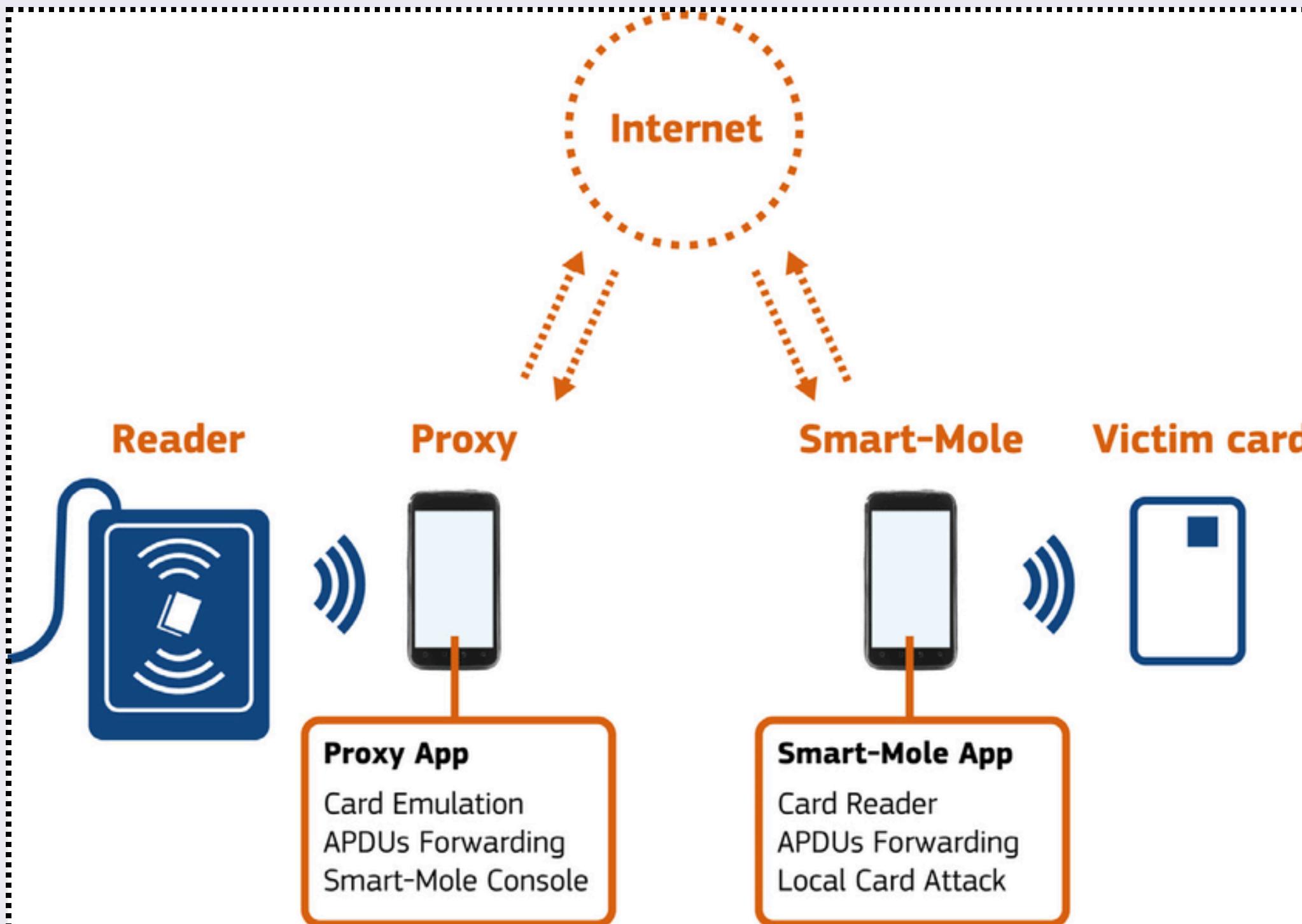
Maxwell. B Antwi
cc: Dr. Robert Sowah

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Contactless Payment System



Relay Attacks



Main Challenge

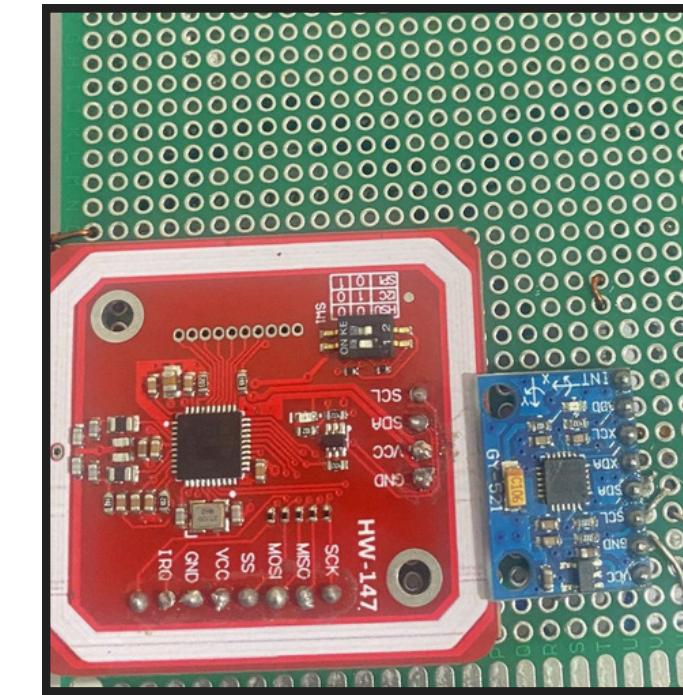
- Failure to verify proximity

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SensePay



ML-Based Intelligent Terminal



Embedded IMU Card

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Project Requirements



Proximity Verification

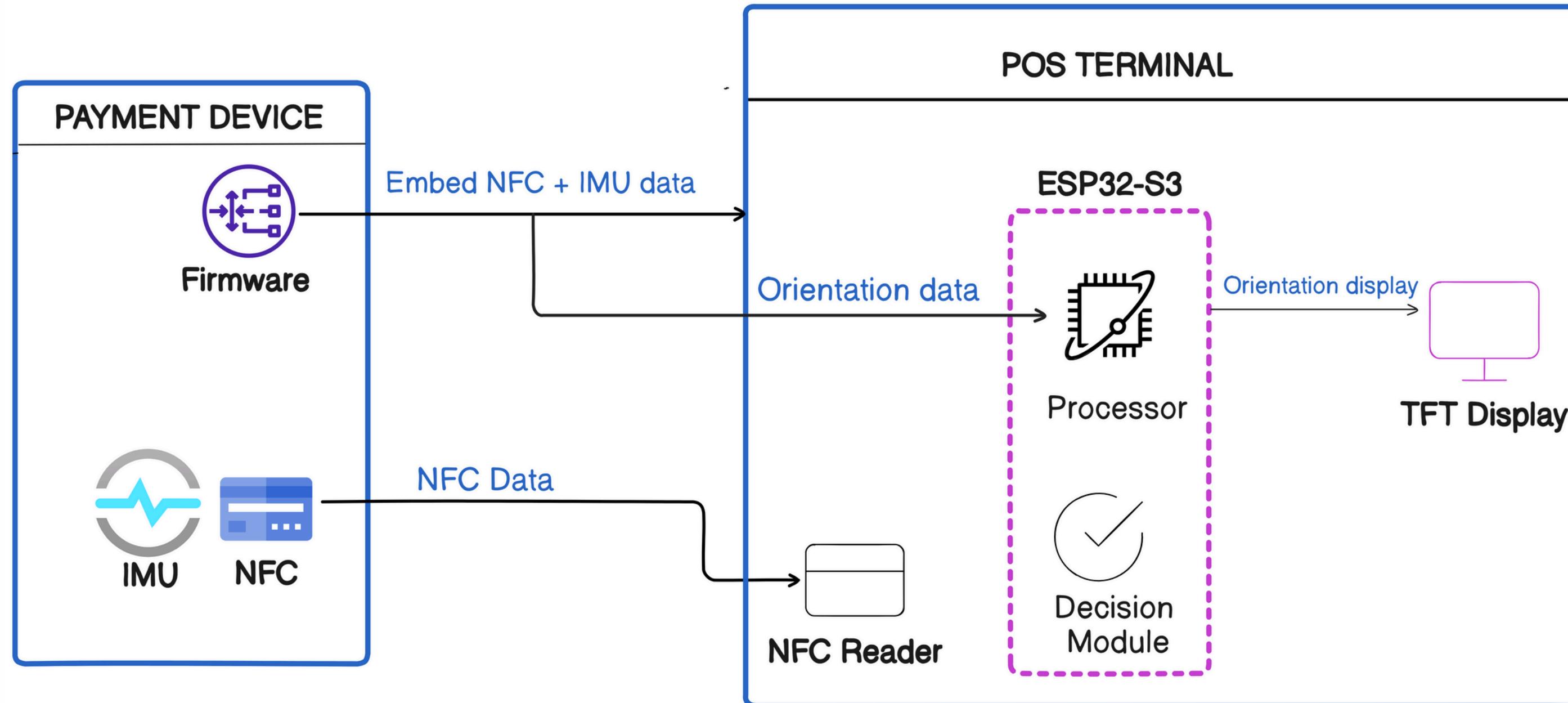


Anomaly detection



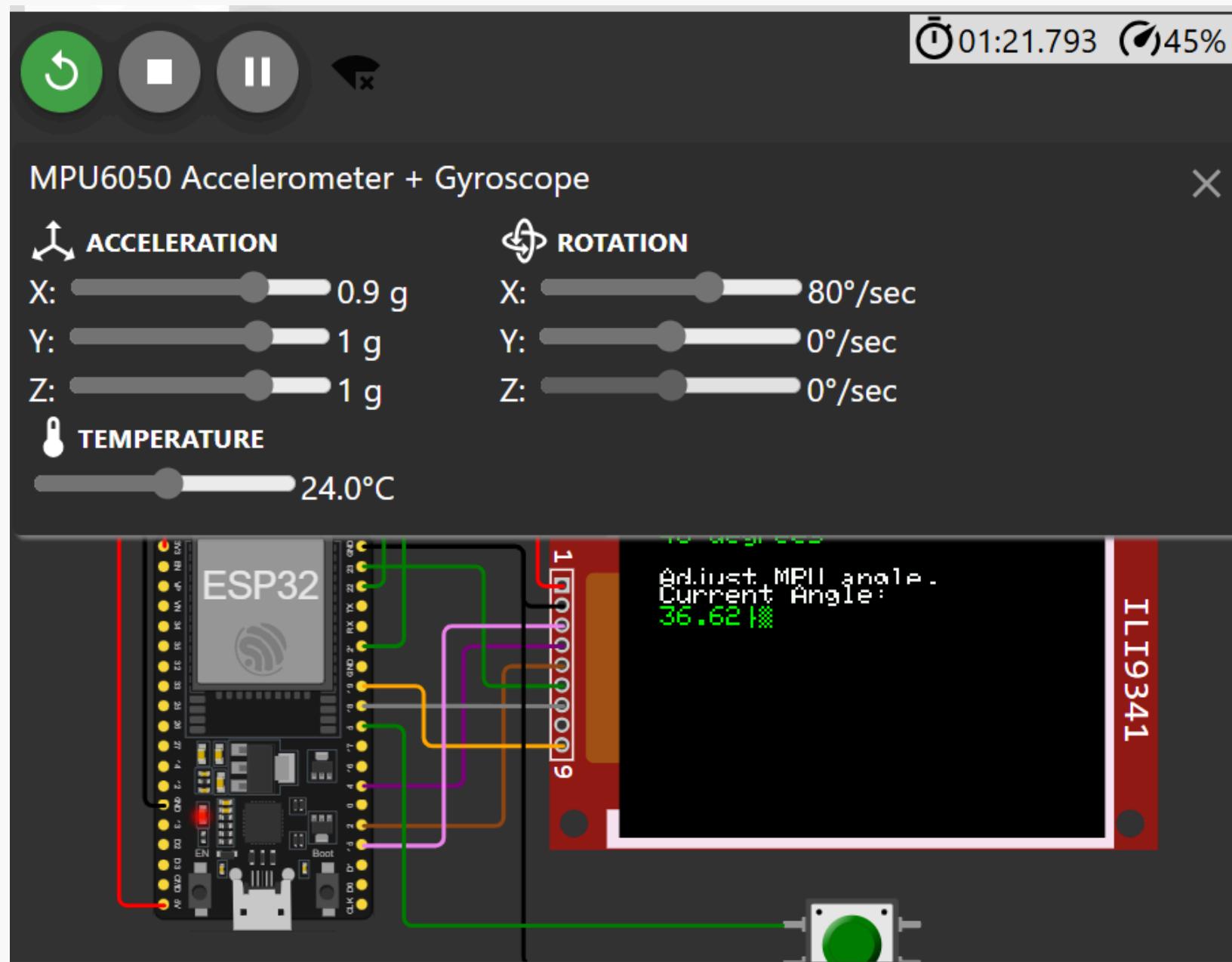
Accuracy and
Low Latency

System Design

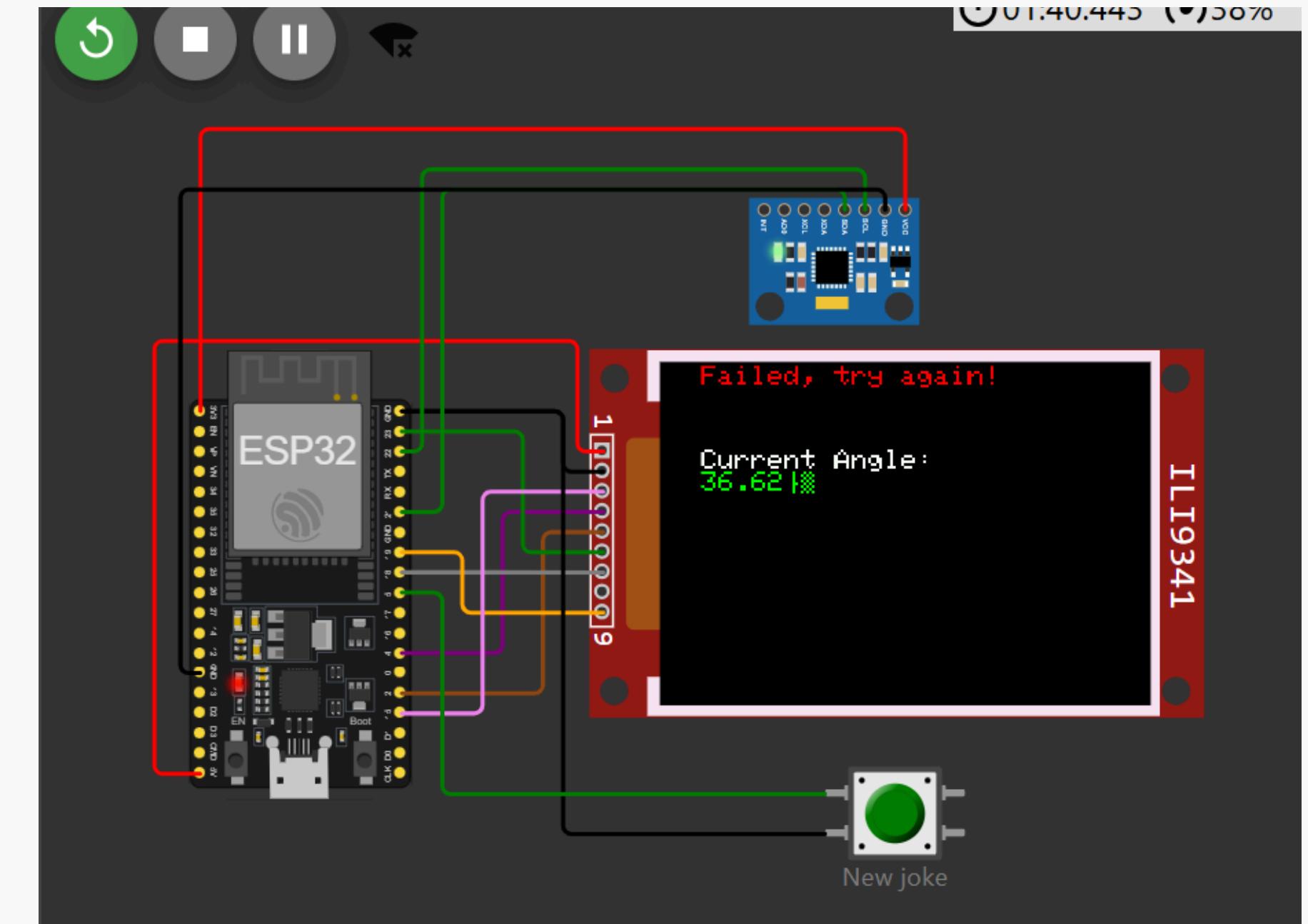


Architectural Design

Software Simulation

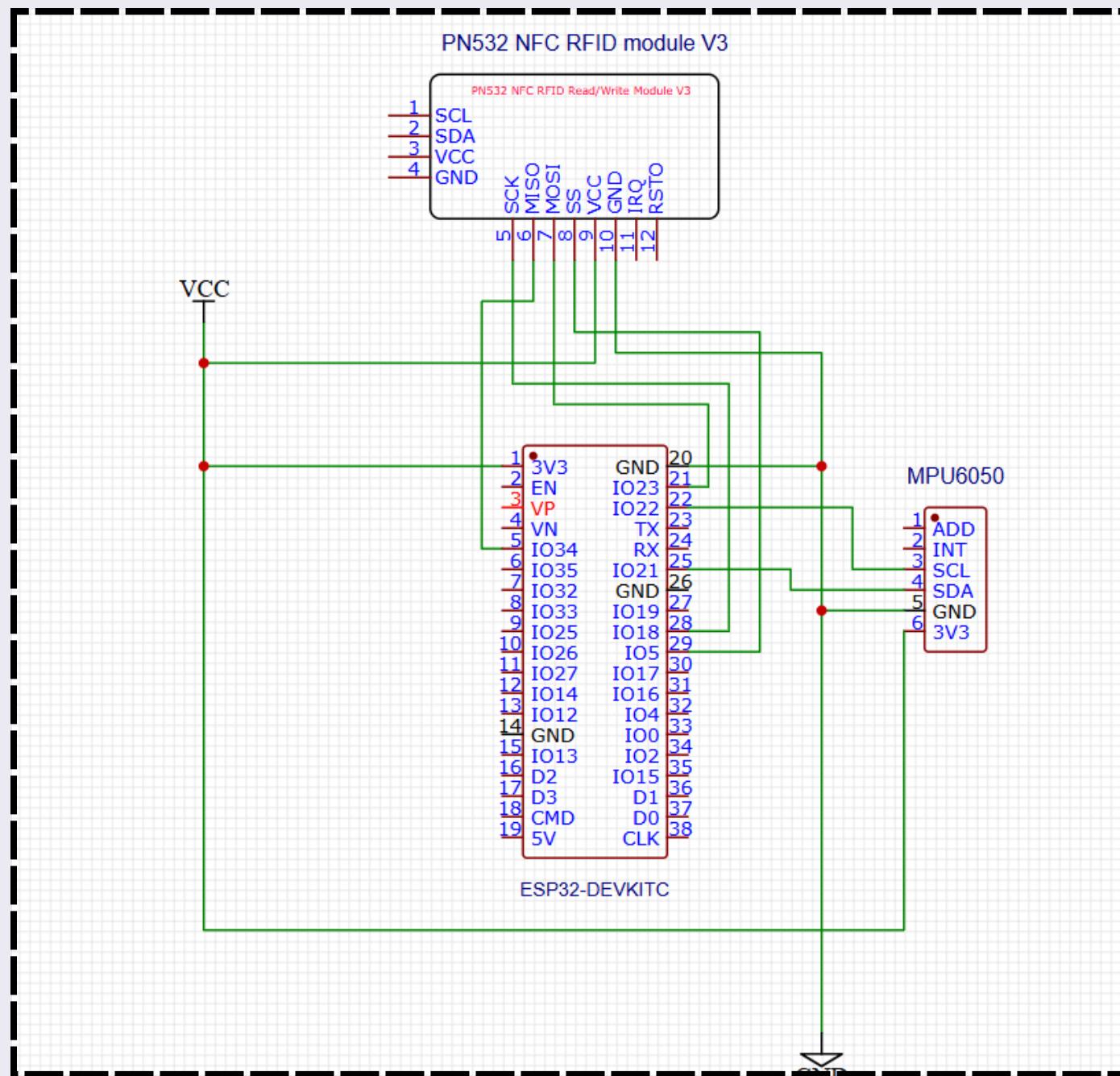


Orientation adjustment

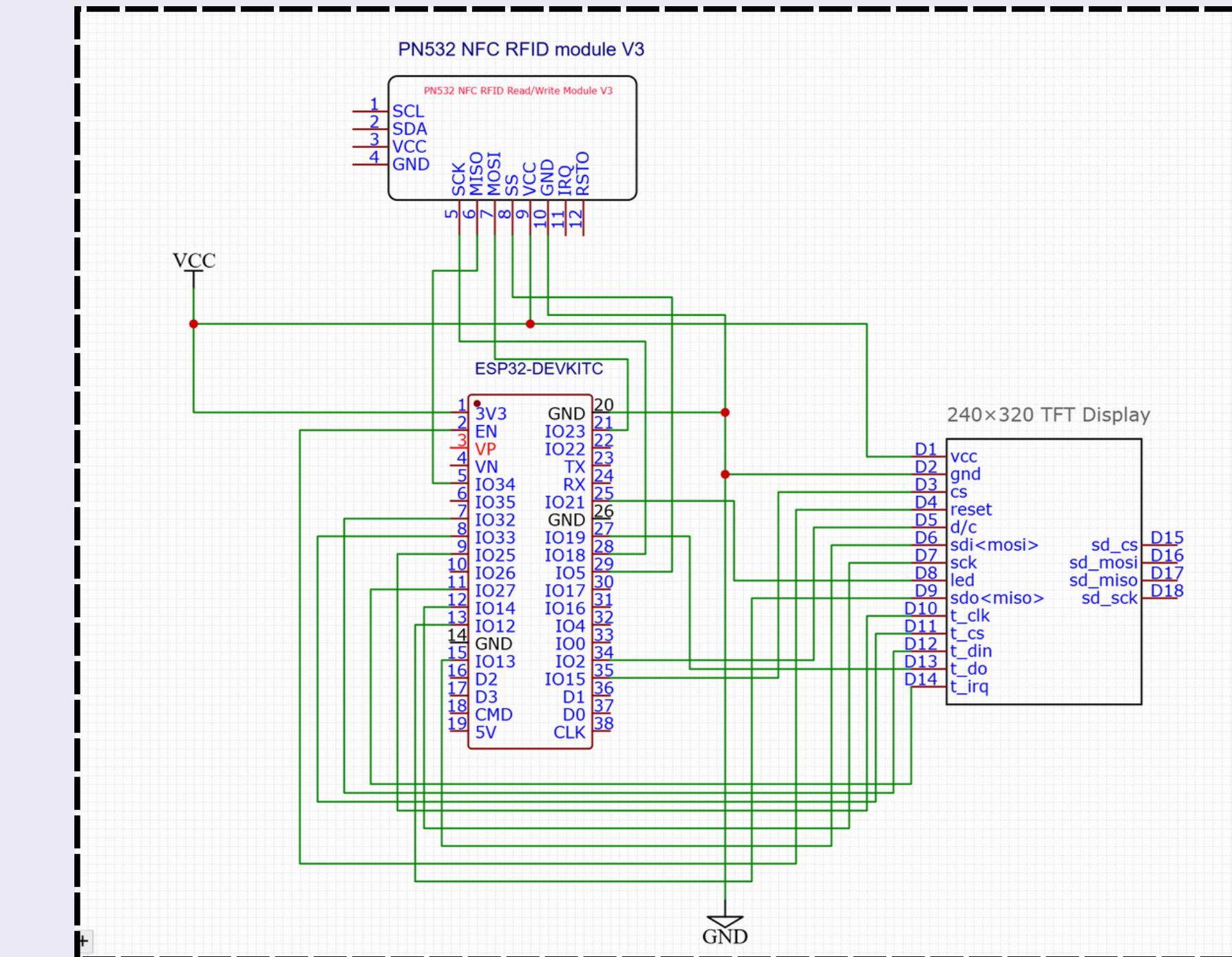


Wrong orientation detected

Schematic Designs

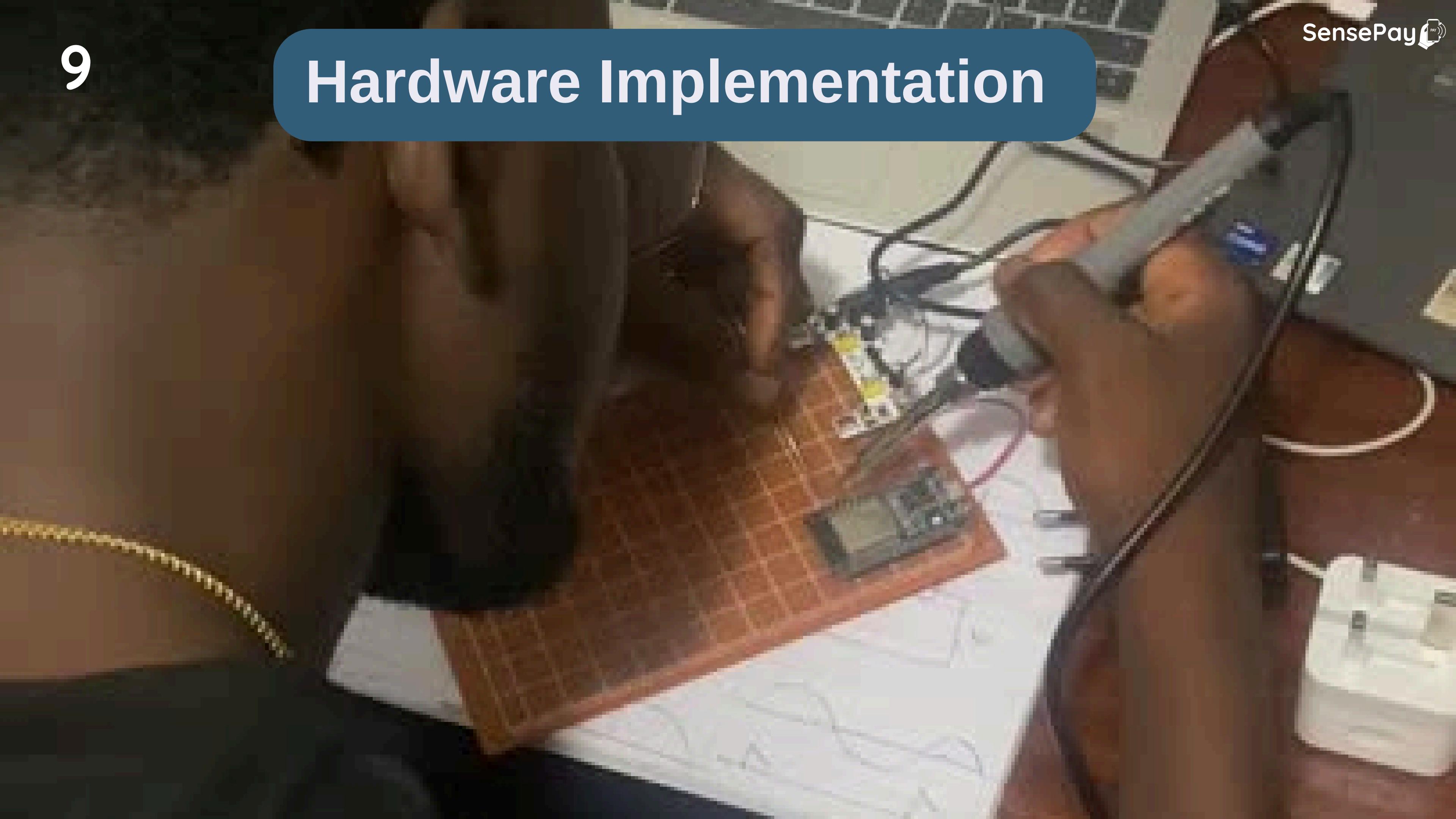


Payment Card



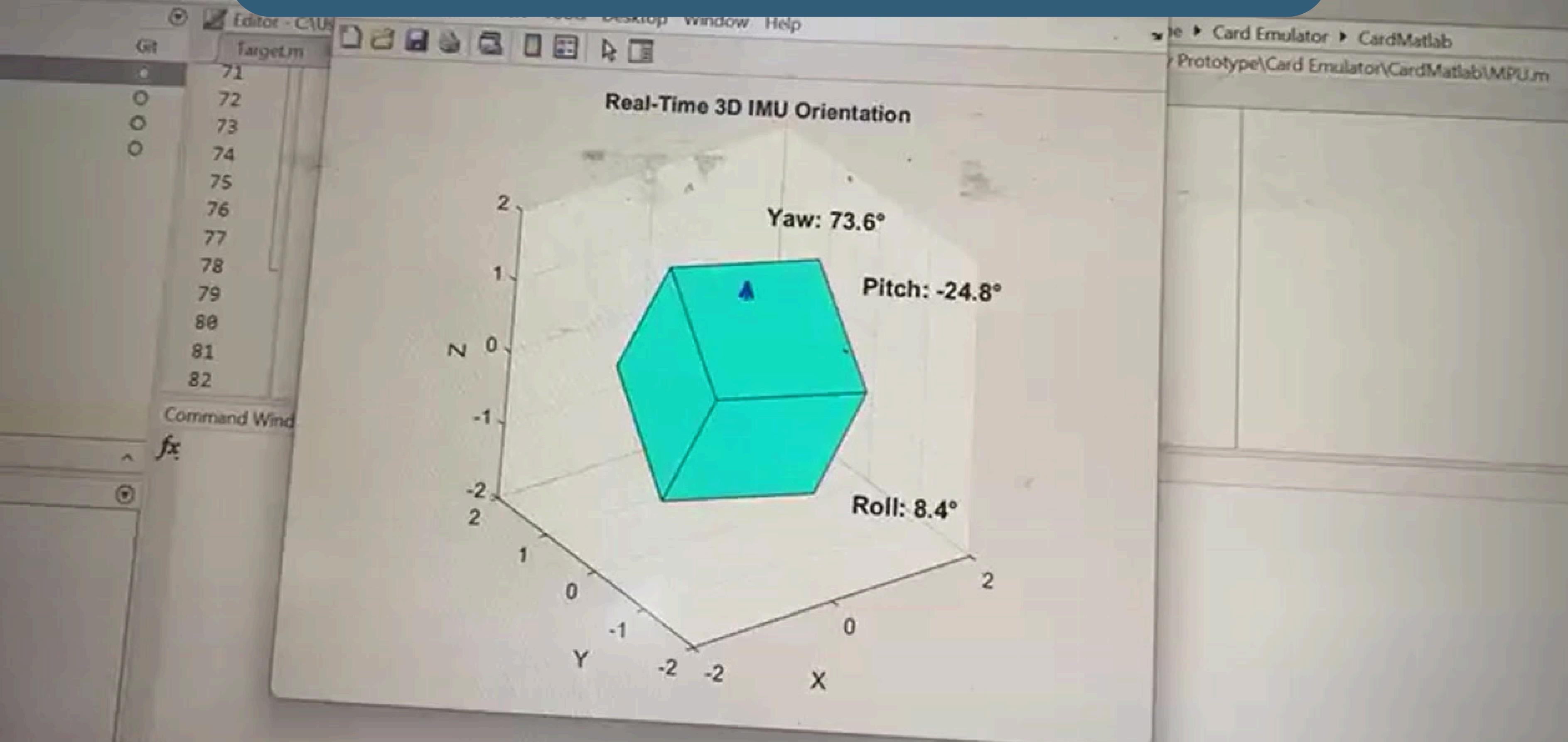
POS Terminal

Hardware Implementation



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3D Analysis of Orientation Data



IMU Implementation Constraints



Sensor Noise



Sensor Drift

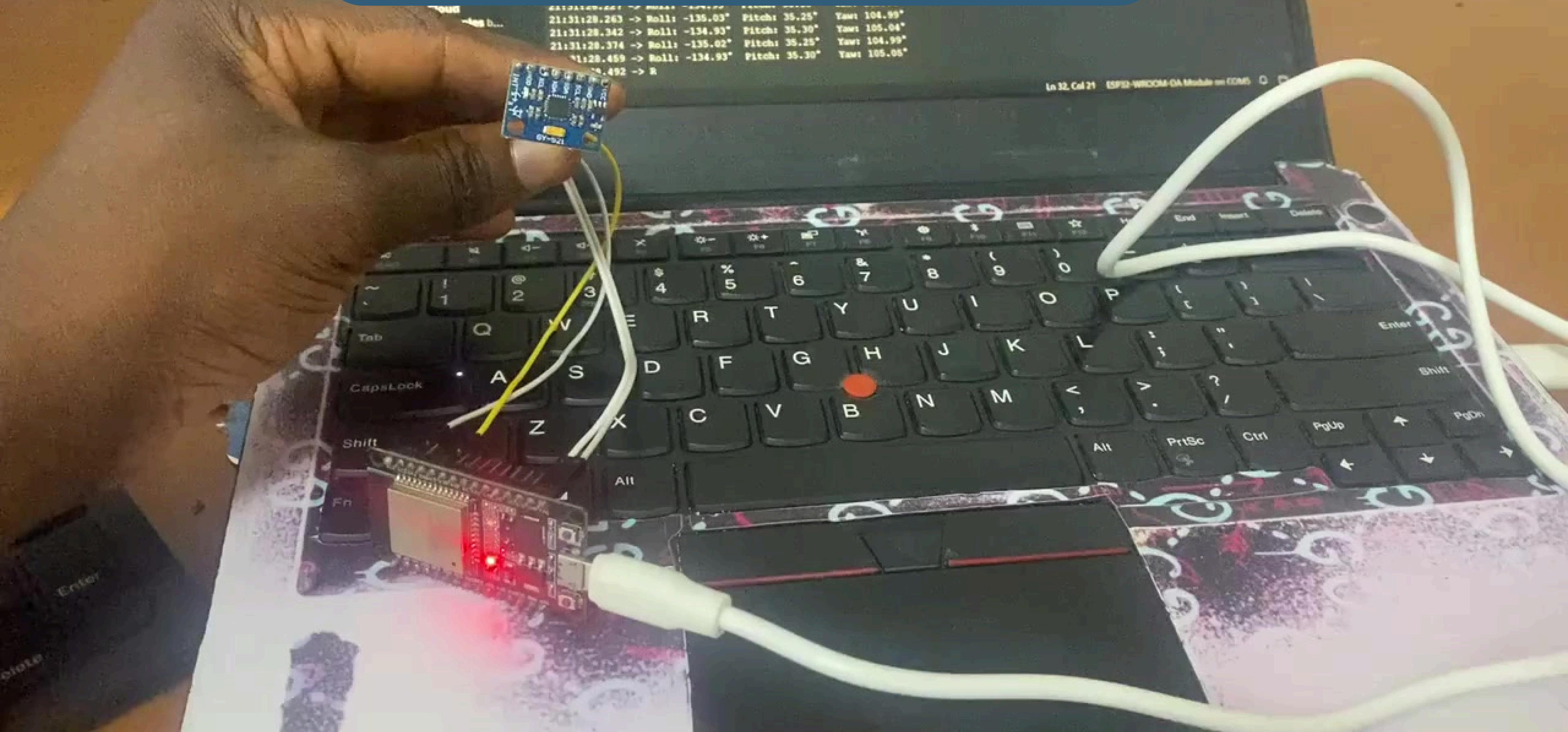
SOLUTION



- Sensor Fusion via DMP
- Euler Angle Algorithm

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Additional Calibrations



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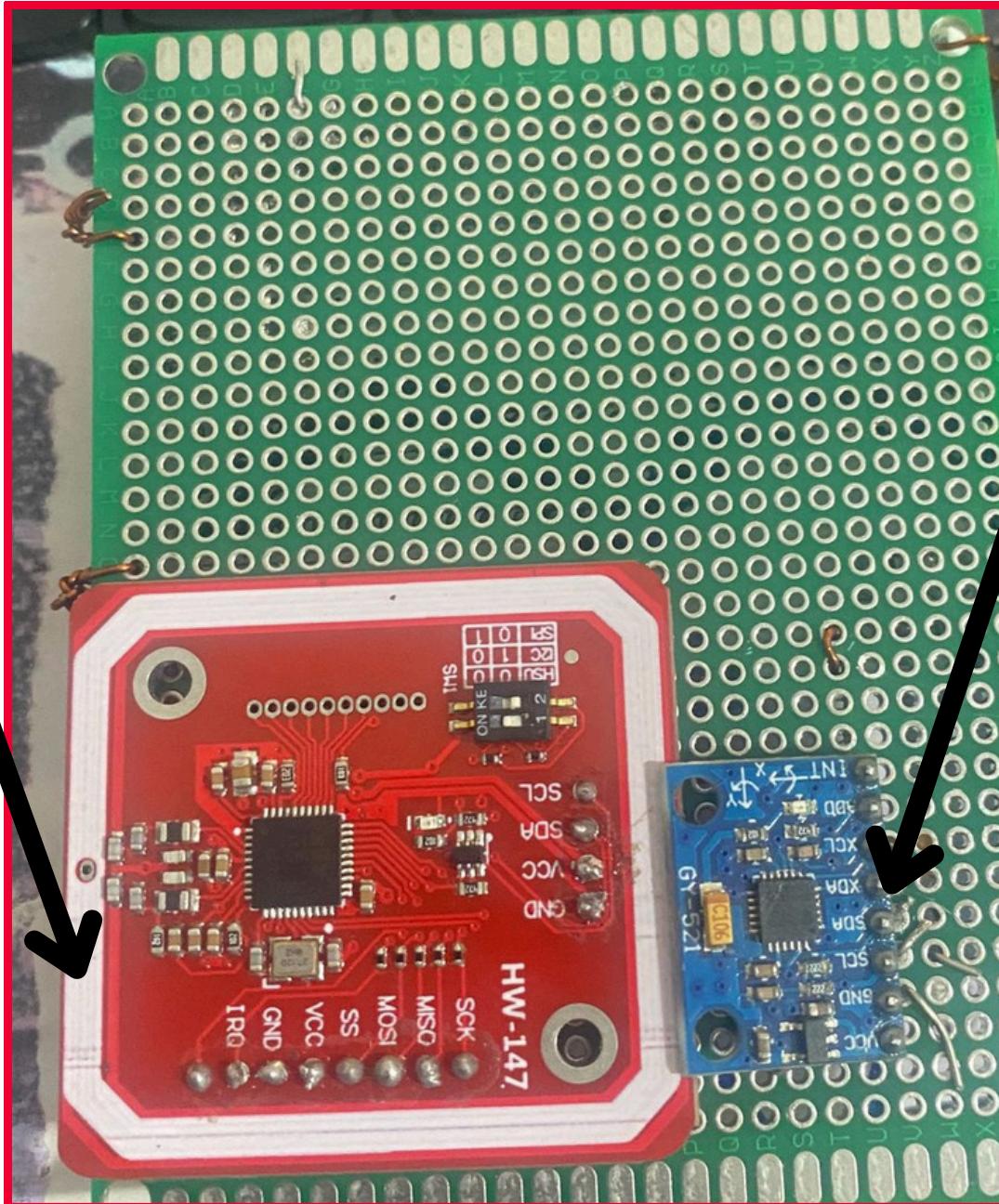


How will the orientation value be received at the terminal?

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Data Fusion and AES Encryption

NFC
(PN532)



Payment Card

IMU Sensor
(MPU6050)

13-Bits Binary Packets

Bit Index	Content	Size (Bits)
0	Start marker (0XAA)	1
1-4	Yaw	4
5-8	Pitch	4
9-12	Roll	4

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Anomaly Detections

$N = 1000$

$$\mu = \frac{1}{N} \sum_{k=1}^N x_k$$
$$\sigma = \sqrt{\frac{1}{N} \sum_{k=1}^N (x_k - \mu)^2}$$



95% Confidence Interval

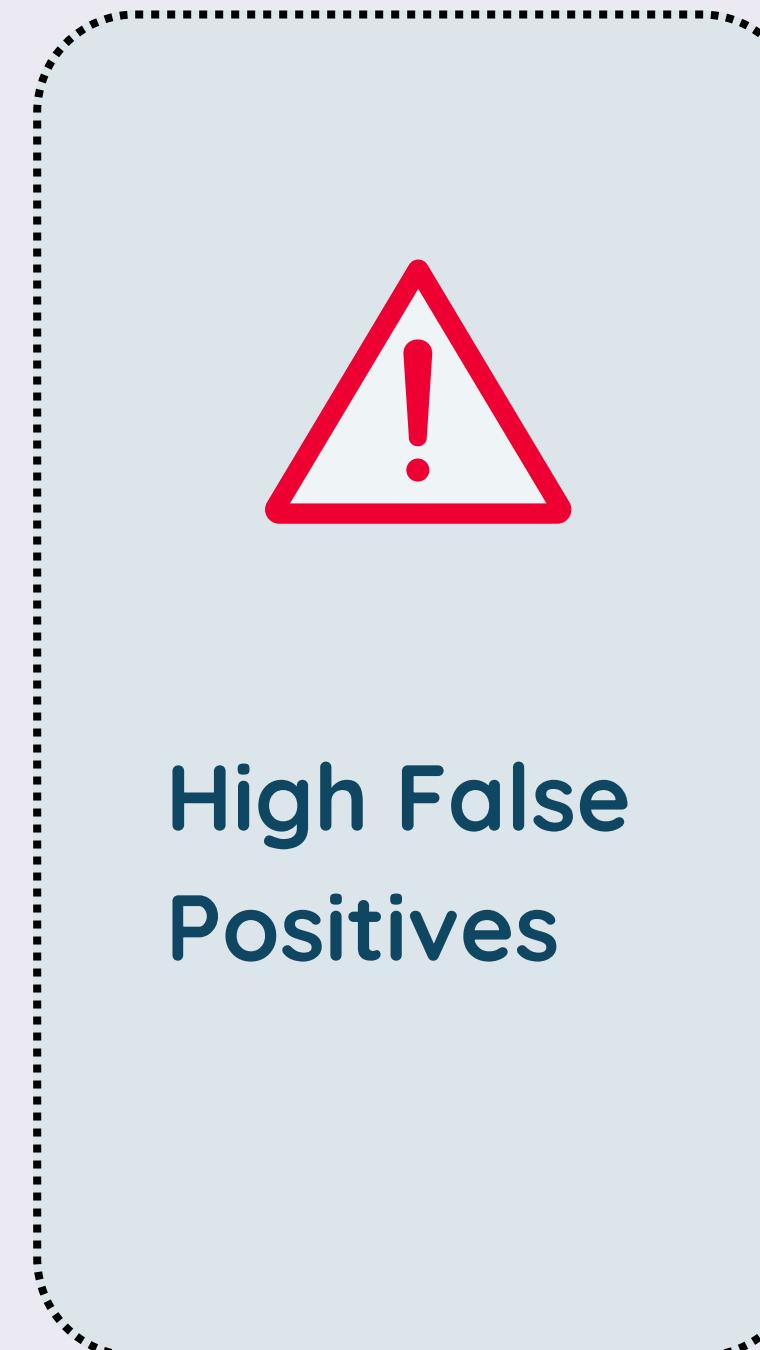
$$CI = \mu \pm Z \cdot \frac{\sigma}{\sqrt{n}}$$

$|168| \pm 12$ degrees

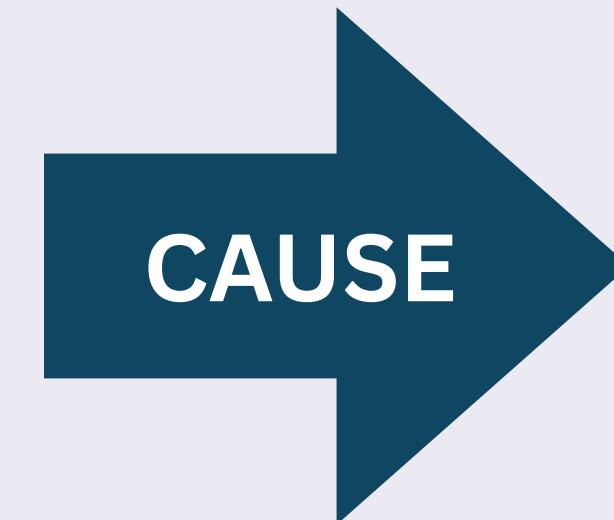
Acceptable Range

156 - 192 degrees

Testing Errors and Post-hoc Analysis

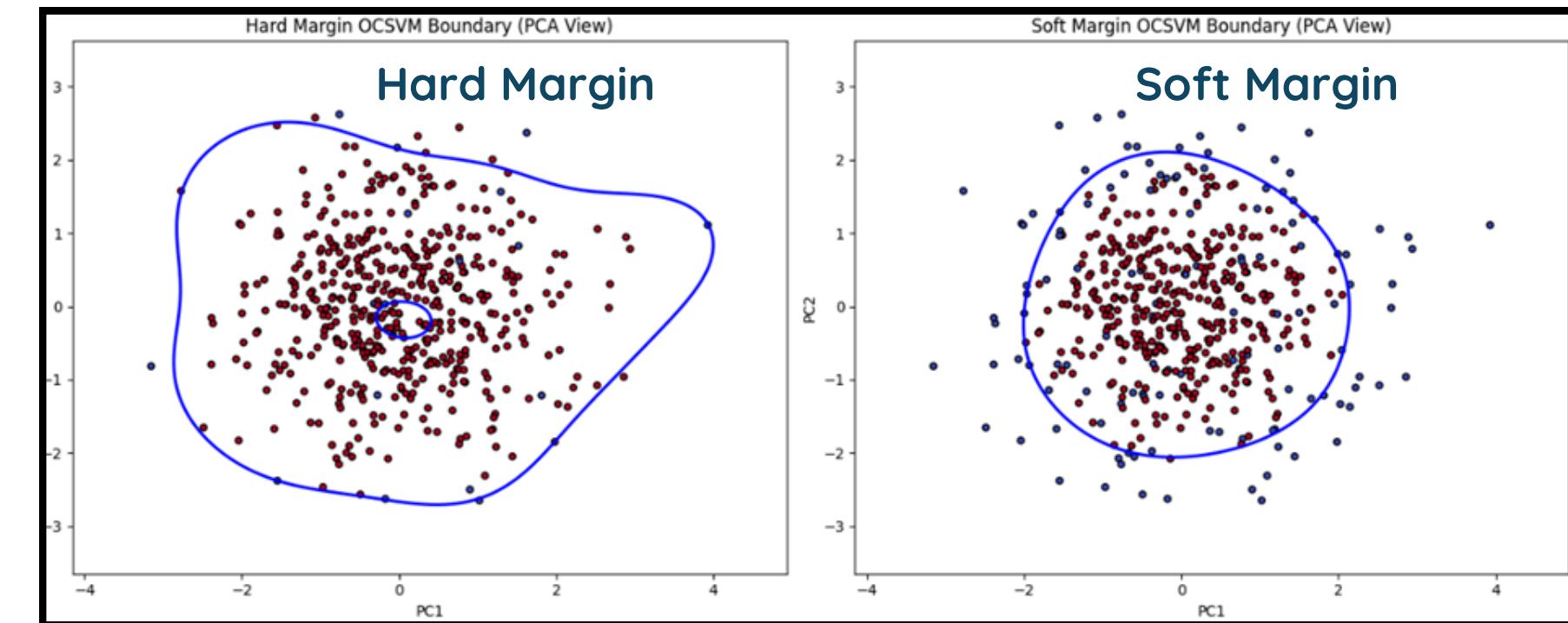
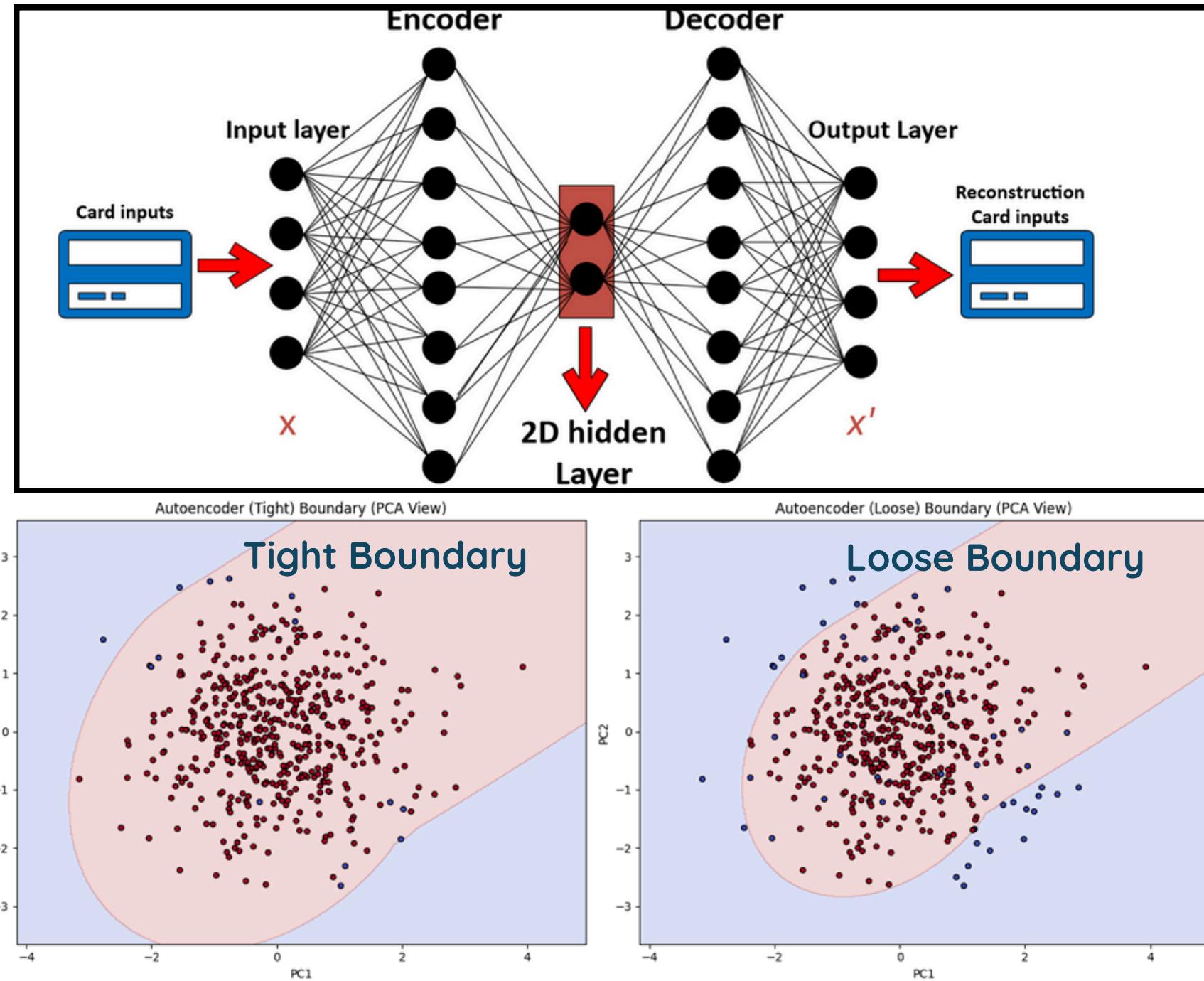


High False
Positives



- Fixed Pitch/Roll
- Signal Attenuations

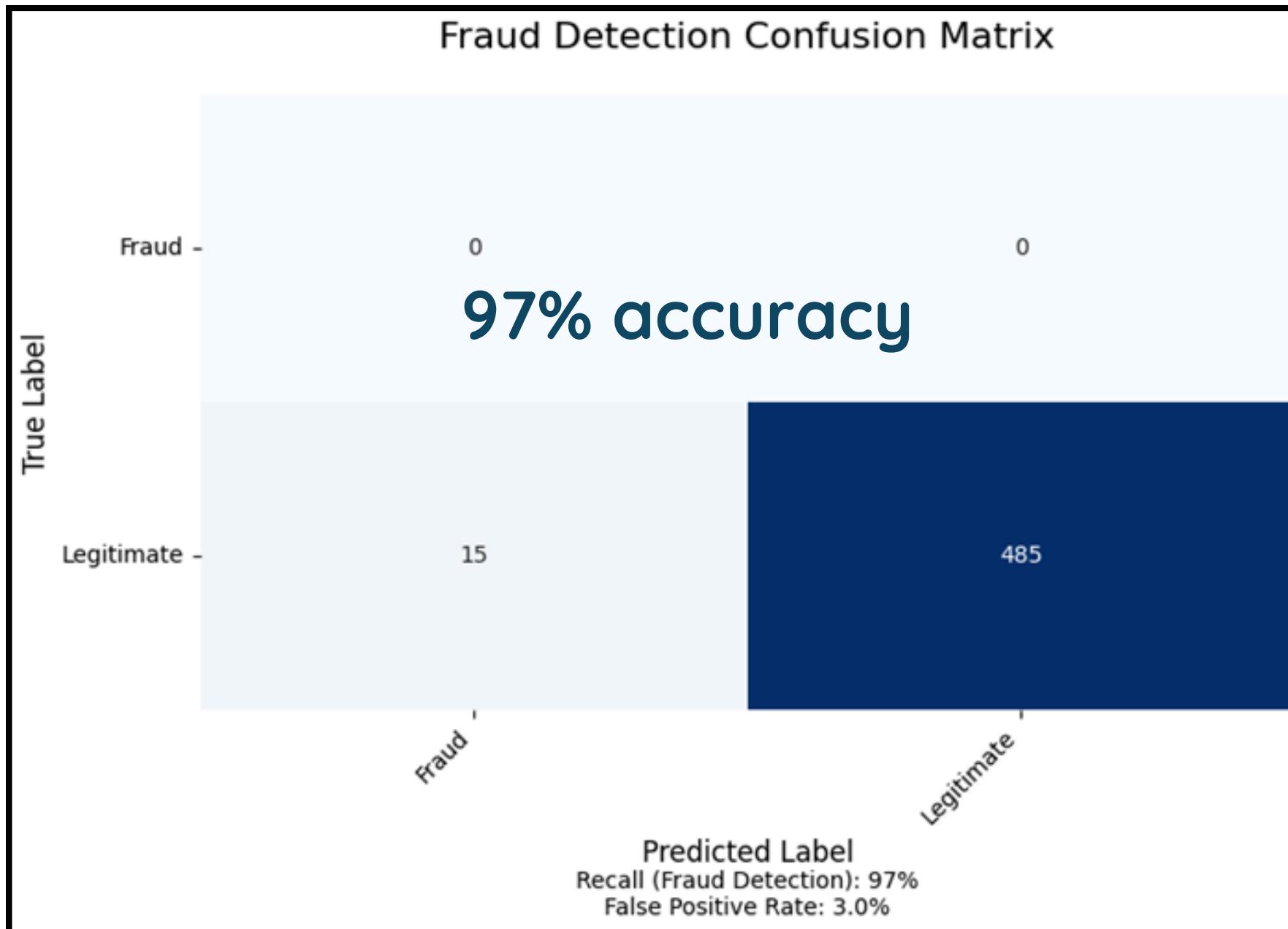
Machine Learning Based Model



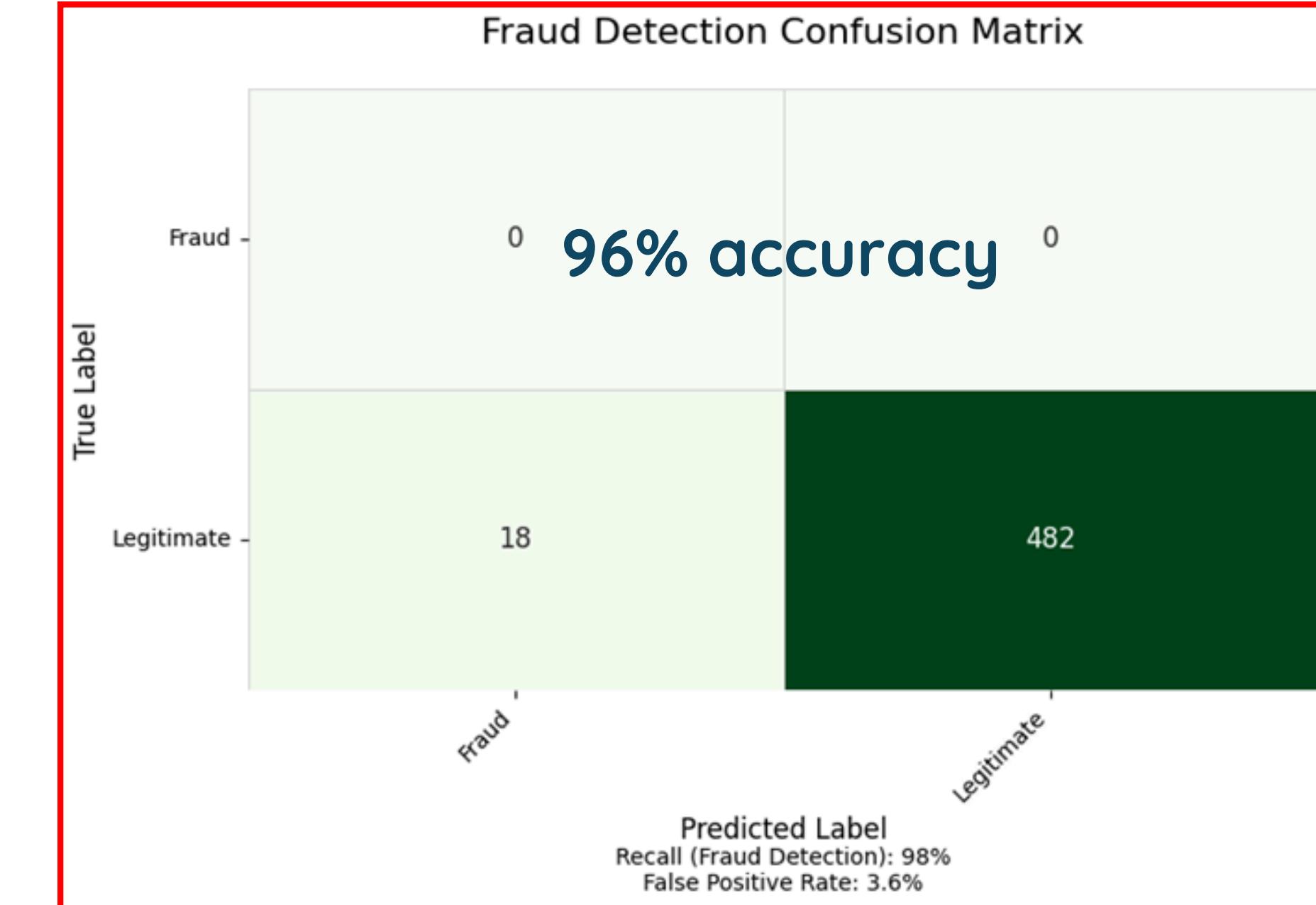
One Class SVM

Autoencoder Neural Network

Model Performance Metrics



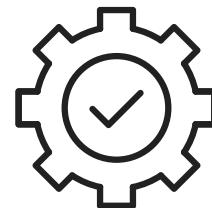
Autoencoder Neural Network



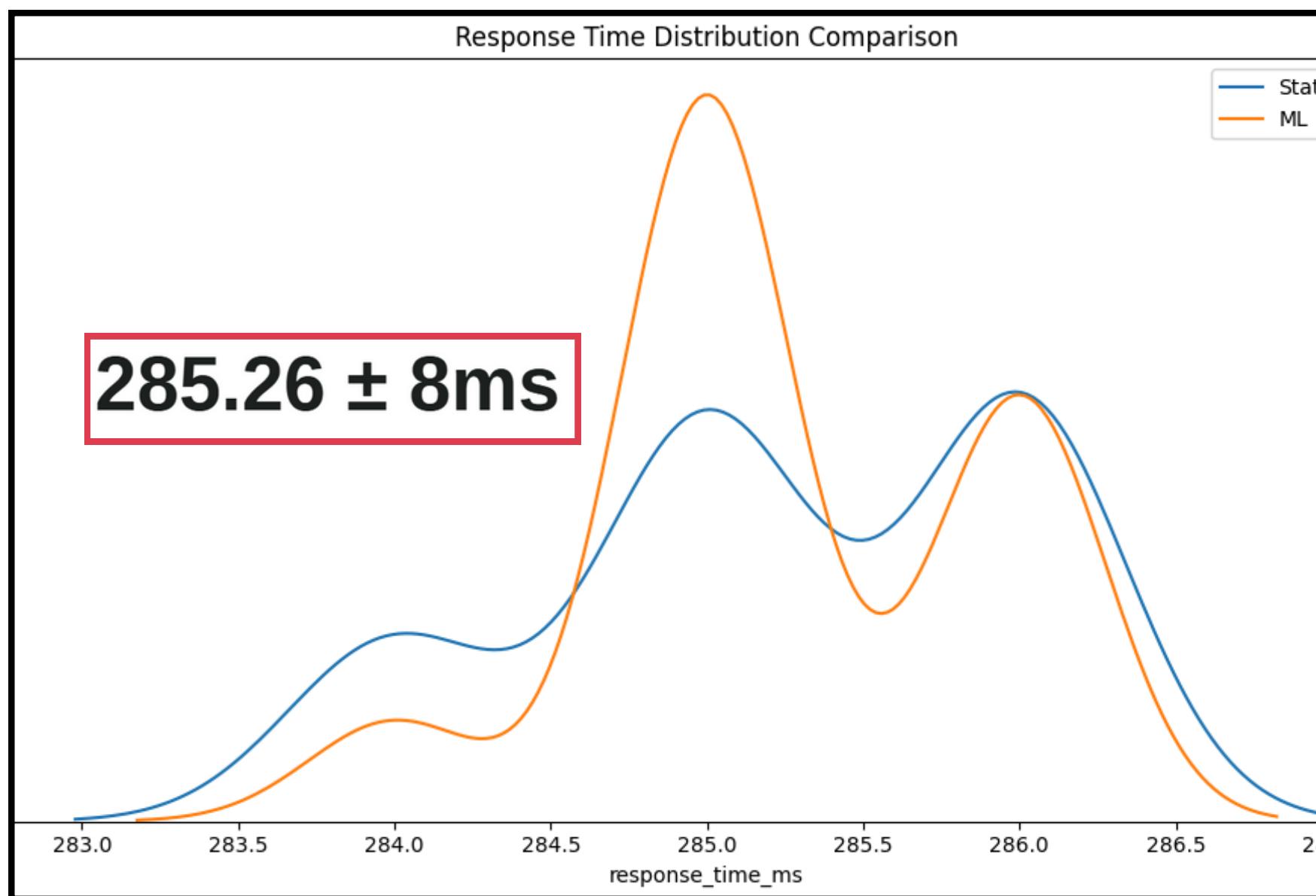
One Class SVM

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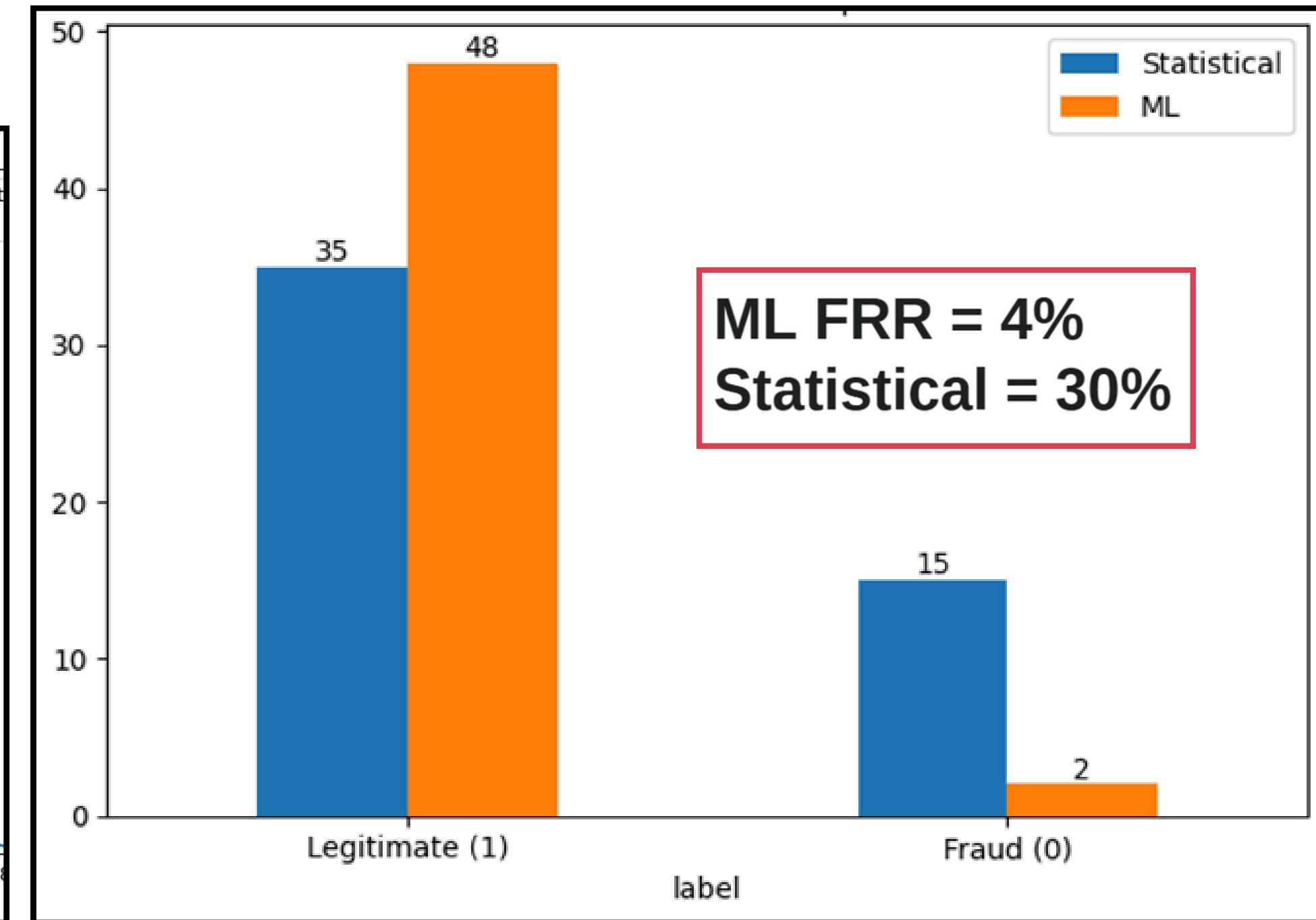
Testing & Results



Functional Testing



Response time



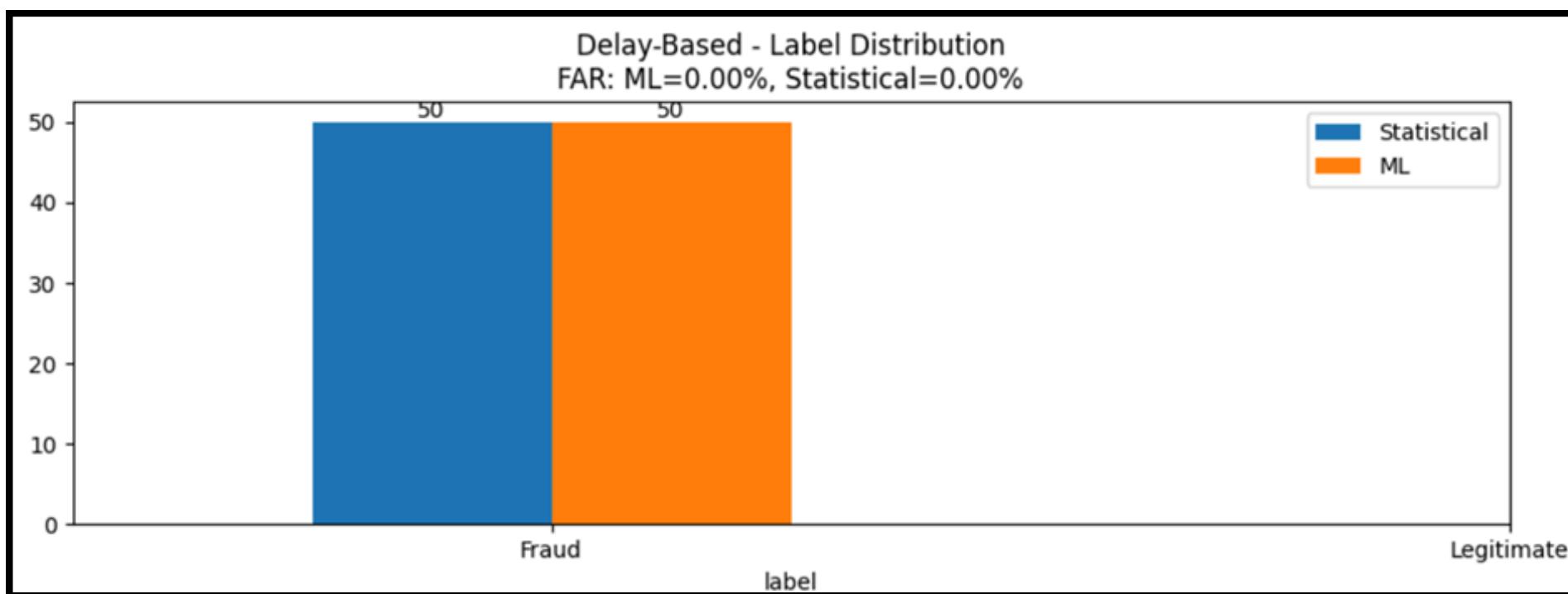
Transaction reports

Testing & Results

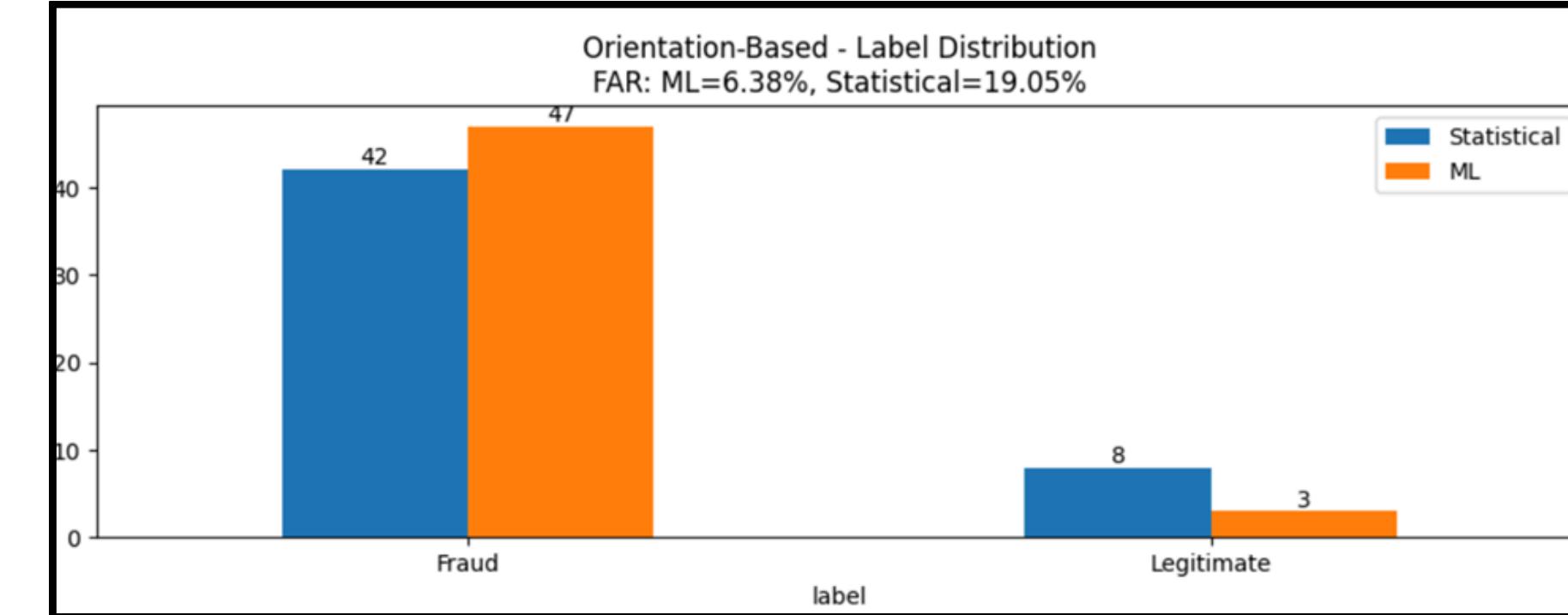


Attack Simulations

FAR ML = 6.38%
Statistical = 19.05%



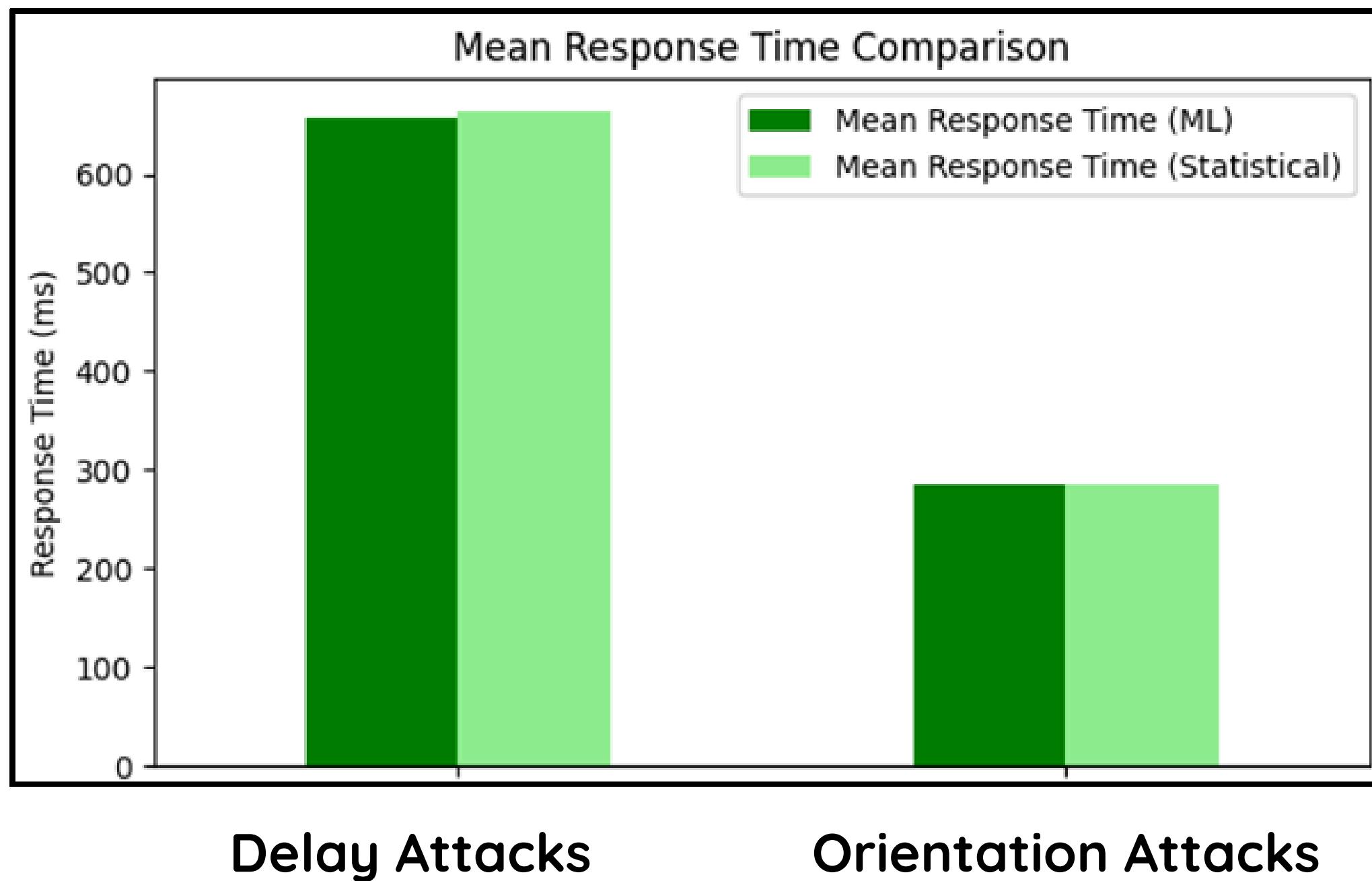
Delay-Based Relay Attack



Orientation-Based Relay Attack

Testing & Results

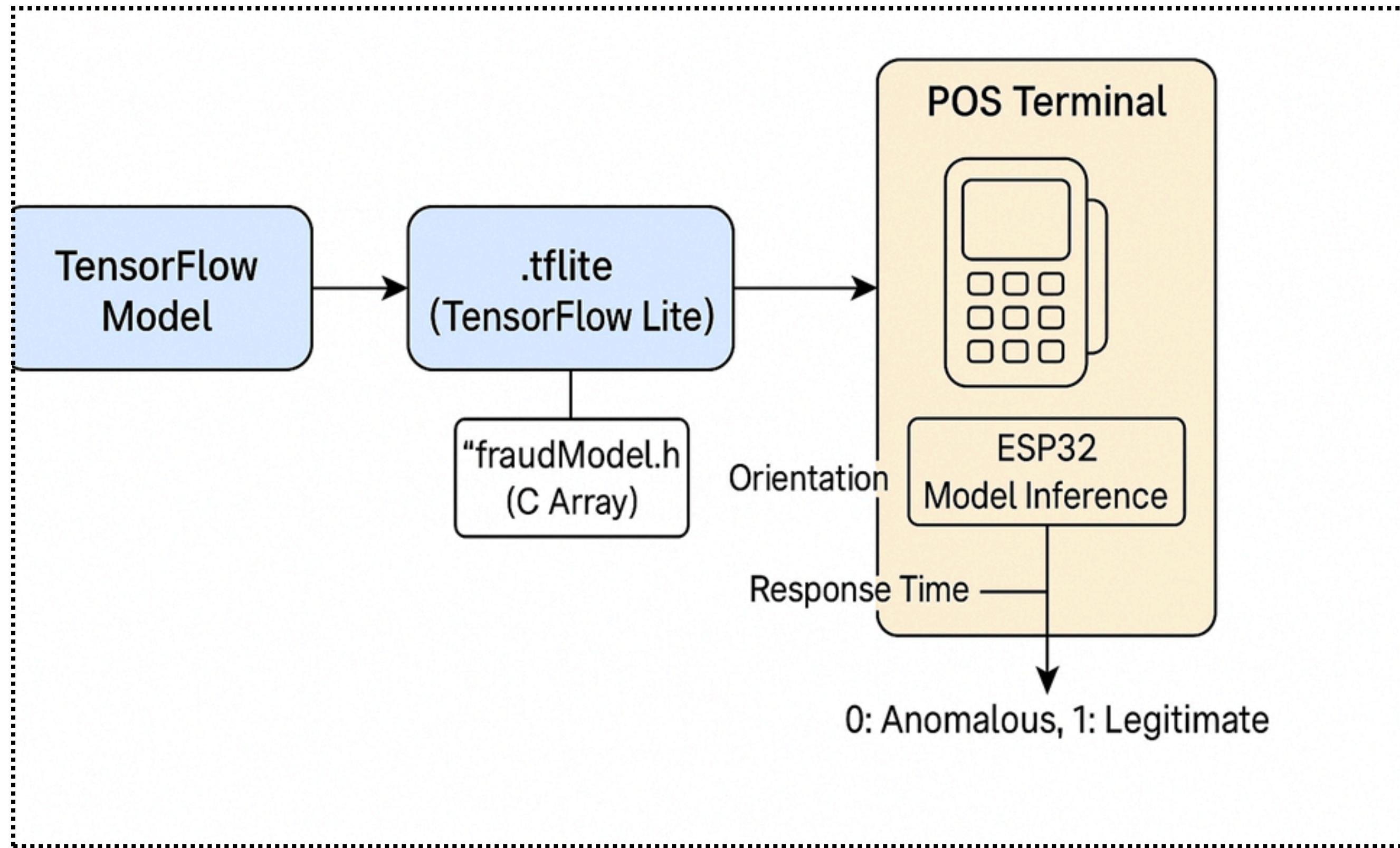
Mean Response Time



Chi-Square Test

$\chi^2 (1, N = 100) = 10.2025,$
 $p = 0.0014$

Model Integration into POS



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Practical Implementation Considerations

**1 - 50mW with
optimal of 20mW**

IMU Power Requirements

3.9mA, 12.87mW

Considerations

- Ultra-Low-Power IMUs
- Duty Cycling
- Energy Storage

Thank you
very much!

MAXWELL B. ANTWI

CC: DR. ROBERT SOWAH