

Report on Verifying Oscilloscope Hardware for 12-bit Resolution

报告：验证示波器硬件是否具有12位分辨率

Objective | 目标

This project aims to validate that the oscilloscope hardware supports 12-bit resolution by analyzing and manipulating its raw data. As a data engineering and data manipulation project, the analysis leverages Python scripts and relevant libraries to process, convert, and analyze the raw signal data. This is critical for applications requiring high-fidelity signal representation, where accurate data handling and analysis are essential for obtaining precise measurements and ensuring the reliability of the oscilloscope's performance.

本项目旨在通过分析和处理示波器的原始数据，验证其是否支持12位分辨率。作为一个数据工程和数据处理项目，本分析使用Python脚本和相关库来处理、转换和分析原始信号数据。这对于需要高保真信号表示的应用至关重要，其中准确的数据处理和分析对于获得精确的测量结果并确保示波器性能的可靠性是不可或缺的。

Methodology | 方法

Technology Used | 使用的技术:

The analysis was conducted using Python scripts, with libraries such as `pandas` and `openpyxl` for data manipulation and exporting results to Excel. To install these libraries, run the following commands:

```
pip install pandas
```

```
pip install openpyxl
```

1. Data Conversion | 数据转换:

Why Hexadecimal? | 为什么使用十六进制?

We use hexadecimal (base-16) during the conversion process because it provides a more compact and readable way to represent binary data. Each hexadecimal digit corresponds to four binary digits, making it easier to visualize and manipulate compared to raw binary data, which can be long and cumbersome.

我们在转换过程中使用十六进制（基数16），因为它提供了一种更紧凑、更易读的方式来表示二进制数据。每个十六进制数字对应四个二进制位，比起原始的二进制数据，它更易于可视化和操作，后者通常较长且难以处理。

```
FUNCTION convert_to_hex(num): IF num < 0 THEN RETURN hexadecimal((1 << 32) + num) without the first two characters ELSE RETURN format num as hexadecimal padded with zeros to ensure four characters ENDIF END FUNCTION
```

2. Bit Extraction and Conversion | 位提取和转换:

Binary Representation | 二进制表示

Binary data is the most fundamental form of data in computers. Here, we convert hexadecimal to binary to assess the oscilloscope's ability to capture subtle variations in electrical signals. This is essential for ensuring that the oscilloscope measures with high precision, as even the smallest variations in signal can impact measurements.

二进制数据是计算机中最基本的数据形式。在此，我们将十六进制转换为二进制，以评估示波器捕获电信号细微变化的能力。这对于确保示波器具备高精度测量至关重要，因为信号的最小变化也可能影响测量结果。

```
FUNCTION hex_to_binary(hex_str): RETURN binary representation of the hexadecimal string padded to 12 digits END FUNCTION CONVERTED_NUMBERS = MAP convert_to_hex OVER NUMBERS TWO TO FOUR PLACES = MAP extract 2nd to 4th rightmost characters OVER CONVERTED_NUMBERS BINARY_NUMBERS = MAP hex_to_binary OVER TWO TO FOUR PLACES
```

3. Coverage Analysis | 覆盖范围分析:

A 12-bit system uses twelve binary digits for each value it represents, allowing for 4,096 different potential states or values. This is important for oscilloscopes, which need to measure very precise voltage or signal levels across a wide range. A 12-bit system offers more fine-grained detail compared to lower bit systems, enabling the capture of subtle electrical changes.

12位系统使用十二个二进制位表示每个值，允许表示4096种不同的潜在状态或值。这对于示波器至关重要，因为它们需要在广泛的电压或信号范围内进行精确测量。12位系统比低位数系统提供了更细粒度的细节，使得能够捕捉到电气信号的微小变化。

Impact on Signal Integrity | 对信号完整性的影响:

Each additional bit in a digital system doubles the number of distinguishable states, enhancing the device's ability to detect finer differences in signal intensity. A 12-bit resolution allows the oscilloscope to detect subtle signal changes that lower resolution systems might miss, which is critical in high-precision applications like medical diagnostics and high-frequency signal processing.

数字系统中每增加一位，可区分的状态数量就翻倍，从而增强设备检测信号强度细微差异的能力。12位分辨率使得示波器能够检测到低分辨率系统可能遗漏的微小信号变化，这在医疗诊断和高频信号处理等高精度应用中至关重要。

```
SET all_possible_values TO all possible 3-character hexadecimal values from 000 to FFF SET unique_2_to_4_values TO unique values from two_to_four_places SET not_covered_values TO all_possible_values not in unique_2_to_4_values
```

Data Presentation | 数据展示:

```
OPEN a new Excel file 'oscilloscope_analysis.xlsx' WRITE binary_numbers TO 'Original and 2-4 Number with Binary' sheet WRITE not_covered_values TO 'Gaps' sheet CLOSE file
```

Results | 结果

The analysis revealed gaps in the data coverage, indicating that the oscilloscope does not capture all possible 12-bit values, potentially leading to inaccuracies in applications where precision is crucial.

分析显示数据覆盖存在间隙，表明示波器未能捕获所有可能的12位值，这可能导致在需要精度的应用中出现不准确的测量。

Detailed Results | 详细结果

Metric 指标	Value 值
Total numbers processed 处理的数字总数	10,002
Total possible 3-character values 所有可能的三字符十六进制值数量	4,096
Total 3-character values covered 覆盖的三字符十六进制值数量	841
Total 3-character values not covered 未覆盖的三字符十六进制值数量	3,255

Conclusion | 结论

Approximately 79% of the possible 12-bit values are missing from the dataset, indicating potential systematic errors in data capture or processing.

数据集中约79%的12位值缺失，表明数据捕获或处理中可能存在潜在的系统错误。

The oscilloscope hardware does not fully meet the 12-bit resolution requirement based on the analysis. Further investigation and adjustments to the hardware are necessary to ensure that the oscilloscope captures the full range of signal details required for high-precision applications.

基于分析，示波器硬件未完全满足12位分辨率要求。需要进一步调查并对硬件进行调整，以确保示波器能够捕捉到高精度应用所需的完整信号细节。