

TBBL Impedance Data Analysis

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Time: June 9, 2022

Goal: Automate IDE impedance data analysis process. Avoid copy & paste!

Follow these steps for Accelerated Aging Testing!

Data Collection (about 3min / device)

Step 1: Setup the IDE in the Ferrari Cage. (1min/IDE)

Step 2: Turn on Autolab and connect to the lab Dell PC.

Step 3: Open Nova2.1.4 software with the procedure **"FRA MUX 1ch 50mV 10k-10Hz - automated"**.

Step 4: Change the export file-name to corresponding IDE.

E.g:

IDE-12-8-m means IDE-12, 12 μ m, mutual.

IDE-16-16-s means IDE-16, 16 μ m, shunt

Step 5: Click on the run button and wait for the test result. (1min/IDE)

Step 6: Nova2.1.4 will auto-generate a csv file for each IDE in the ASCII format. File location: Desktop/IDE-data.

Step 7: Edit the "date.csv" file to keep track of the experiment dates.

Step 8: Clean the IDE and put it back to the Lab Armor.

Data Analysis

Step 1: Open the Jupyter Notebook "**[20220609]TBBL-Impedance Data Analysis**".

Step 2: Make sure you change to the right file address so Jupyter can access the impedance data.

Step 3: Run Jupyter Notebook and get your awesome data graphs!

```
In [1]: # Step 0: Import Library & Check system requirement
import numpy as np
import pandas as pd
import matplotlib as mpl
import matplotlib.pyplot as plt
import seaborn as sns
```

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```
if "Frequency" in row[0]:
    idx_stamp = idx

if (idx - idx_stamp) > 25:
    # For our impedance testing, only the first 25 data are important.
    df = df.drop(idx)

#Export cleaned data
df.to_csv(file, index=False)

def getGraph(self, IDE_name, df, df_date, date_idx, Rs, Rct, C):
    # iloc[1:27, 0] means row 1 to 27, and column 0
    # datetime.date(2022, 5, 31)

    # IDE Graph - Canvas Size - Common sizes: (10, 7.5) and (12, 9)
    fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(20, 10), constrained_layout=True)
    fig.suptitle('IDE-' + file[-4:], fontsize = 30)

    # Set the axis scales & both axes to Log scale
    ax1.set_xlim=(10, 100000), ylim=(10000, 1000000000), xscale="log", yscale="log"
    ax1.set_xlabel("Frequency (Hz)")
    ax1.set_ylabel("Impedance (\Omega)")
    ax1.grid(color='lightgrey', linestyle='-', linewidth=0.5)

    ax2.set_xlim=(10, 100000), ylim=(0, 90), xscale="log"
    ax2.set_xlabel("Frequency (Hz)")
    ax2.set_ylabel("-Phase (%)")
    ax2.grid(color='lightgrey', linestyle='-', linewidth=0.5)

    fig2, (ax3, ax4, ax5) = plt.subplots(1, 3, figsize=(21, 7), constrained_layout=True)

    ax3.set_xlabel("Day")
    ax3.set_ylabel("Rs")
    ax3.grid(color='lightgrey', linestyle='-', linewidth=0.5)

    ax4.set_xlabel("Day")
    ax4.set_ylabel("Rct")
    ax4.grid(color='lightgrey', linestyle='-', linewidth=0.5)

    ax5.set_xlabel("Day")
    ax5.set_ylabel("C")
    ax5.grid(color='lightgrey', linestyle='-', linewidth=0.5)

    i = 0
    j = 0
    day_idx = 0

    if date_list[0] == "dry":
        start = date_list[1]
    else:
        start = date_list[0]

    start = self.getDatetime(start)

    while j < len(df):
        i += 1 # ith loc
        j = i + 25
        x_freq = df.iloc[i:j,0].astype(float) #frequency
        y_imped = df.iloc[i:j,1].astype(float) #impedance
        y_phase = df.iloc[i:j,2].astype(float) #-phase

        # Graph 1: Impedance Z(\Omega) vs Frequency(Hz) - labeled by dates
```

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```
import datetime
mpl.rcParams['axes', labelsize=16, titleSize=20]

# Python Version Requirement
print("Matplotlib Version", mpl.__version__) #> 3.0.0
print("Seaborn Version", sns.__version__, "\n") #> 0.9.0

# Step 1: Define IDE as a class for recurring use.
class IDE:
    """
    Built-in function to initialize the IDE object
    self: no need to put in parameters, built-in structures in Python Class
    name: a string, number of the IDE
    miu_m: a list, tested channels (E.g: [2,4,8,16])
    capa: a list, type of capacitance ("m": mutual, "s": shunt)
    data_format: a string, file format ("csv")
    """

    # Initialize IDE object
    def __init__(self, name, miu_m, capa, data_format):
        """
        Auto-generate a list of data file for each IDE
        E.g:
        IDE_20 = IDE(20, [2,16], ["m","s"], "csv")
        Will generate
        data_list = [
            "20-2-m.csv",
            "20-2-s.csv",
            "20-16-m.csv",
            "20-16-s.csv"]
        Totally 4 data .csv files for IDE_20.

        """
        for m in self.miu_m:
            for c in self.capa:
                file_name = str(self.name) + "-" + str(m) + "-" + c + "." + self.data_format
                self.data_list.append(file_name)

        #Number of tested channels
        self.num_channels = len(self.data_list)

    def getDataFile(self):
        return self.data_list

    def getName(self):
        return "IDE-" + str(self.name)

    def cleanData(self, df):
        # Add one row for checking if the freq is in the first row
        for idx, row, in df.iterrows():
            # idx is the index of the row
            # row is a Series: Frequency f = row[0], Impedance Z = row[1], -Phase Rct = row[2], Resistance Rs = row[3], Capacitance C = row[5]
            # Resistance Rs = row[3], Rct = row[4], Capacitance C = row[5]
```

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```
date = date_list[date_idx]

if date == "dry":
    prefix = "Day-0"
else:
    date = self.getDatetime(date)
    day_diff = date - start
    day_actual = self.getActualDates(day_diff.days, 70.5, 37.0)

    prefix = "Day-" + str(1 + day_actual)
    date = date_list[date_idx]

ax1.plot(x_freq, y_imped, 'o-', label = prefix + ": " + date)

# Graph 2: -Phase(%) vs Frequency(Hz) - Labeled by dates
ax2.plot(x_freq, y_phase, 'o-', label = prefix + ": " + date)

i = j
day_idx += 1

ax3.plot(Rs)
ax4.plot(Rct)
ax5.plot(C)

ax1.legend(loc='upper right', fontsize = 15)
ax2.legend(loc='upper right', fontsize = 15)
plt.show()

# plt.savefig('G-' + file[-4:] + ".jpg")

# Table 3: Summary of R_s(kΩ), R_ct(GΩ), C(pF)
print("\n\n")
return None
```

```
def getRC(self, df, value):
    """
    Get the table of R_s over time
    """
    data = []
    idx = 0

    if value == "Rs":
        idx = 3
    if value == "Rct":
        idx = 4
    if value == "C":
        idx = 5
    # remove strings

    j = 1
    while j <= len(df):
        data.append(float(df.iloc[j, idx]))
        j = j + 26

    return data

def getActualDates(self, day_diff, room_temp, device_temp):
    # Accelerated Aging Test Formula
    exp = (room_temp - device_temp)/10.0
    factor = 2**exp
    day_real = day_diff * factor
    return int(day_real)

def getDatetime(self, m_d_y):
    date = datetime.datetime(m_d_y[0], m_d_y[1], m_d_y[2], 0, 0, 0)
```

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```

"""
m_d_y is a string in month, day, year format
"""

time_list = m_d_y.split("/")
date = datetime.date(2022, int(time_list[0]), int(time_list[1]))
return date

```

```

def addNewIDE(start, end):
"""
Create a list of new IDE with names.
start: the start number of IDE
end: the end number of IDE
"""

L = []
for i in range(start, end):
    L.append(str(i) + "-m")
    L.append(str(i) + "-2-s")
    L.append(str(i) + "-4-m")
    L.append(str(i) + "-4-s")
    L.append(str(i) + "-8-m")
    L.append(str(i) + "-8-s")
    L.append(str(i) + "-16-m")
    L.append(str(i) + "-16-s")

```

```

df_new_IDE = pd.DataFrame(L, columns=['new IDE name'])

#Export a csv file with new IDEs
df_new_IDE.to_csv("new_IDE.csv", index=False)
return df_new_IDE

```

```

def graphLifeSpan(df):
#   file =
#   # creating the dataset
#   data = {'C':20, 'C++':15, 'Java':30,
#           'Python':35}
#   courses = list(data.keys())
#   values = list(data.values())

#   fig = plt.figure(figsize = (10, 5))

#   # creating the bar plot
#   plt.bar(courses, values, color = 'maroon', width = 0.4)

#   plt.xlabel("IDEs")
#   plt.ylabel("Days to fail")
#   plt.title("Life Span of IDEs")
#   plt.show()
#   return None

```

Matplotlib Version 3.5.1
Seaborn Version 0.11.2

In [2]: # Step 2: Initialize tested IDEs

```

# Read experiment date file.
date = "date.csv"
df_date = pd.read_csv(date)

# Initialize IDEs
#Old Devices
IDE_12 = IDE(12, [8], ["m","s"], "csv")
#IDE_14 = IDE(14, [16], ["m","s"], "csv")

```

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```

IDE_16 = IDE(16, [2,4,8,16], ["m","s"], "csv")
IDE_20 = IDE(20, [2,16], ["m","s"], "csv")

```

#New Devices

```

IDE_22 = IDE(22, [2,4,8,16], ["m","s"], "csv")
IDE_26 = IDE(26, [2,4,8,16], ["m","s"], "csv")
IDE_27 = IDE(27, [2,4,8,16], ["m","s"], "csv")
IDE_28 = IDE(28, [2,4,8,16], ["m","s"], "csv")
IDE_31 = IDE(31, [2,4,8,16], ["m","s"], "csv")

# Track device results
total_channels = 0
num_failed = 0
num_good_2 = 0
num_good_4 = 0
num_good_8 = 0
num_good_16 = 0

```

List of all IDEs

```
IDE_list = [ IDE_12, IDE_16, IDE_20, IDE_22, IDE_26, IDE_27, IDE_28, IDE_31]
```

IDE_12 as an example

```
# Iterate through one IDE
```

```
date_idx = 0
```

```
for ide in IDE_list:
```

```
ide.setData()
```

```
for file in ide.getDataFile():
    df = pd.read_csv(file)
```

```
#First clean the data to only include the 25 items
ide.cleanData(df)
```

```
#Read the data again
df = pd.read_csv(file)
```

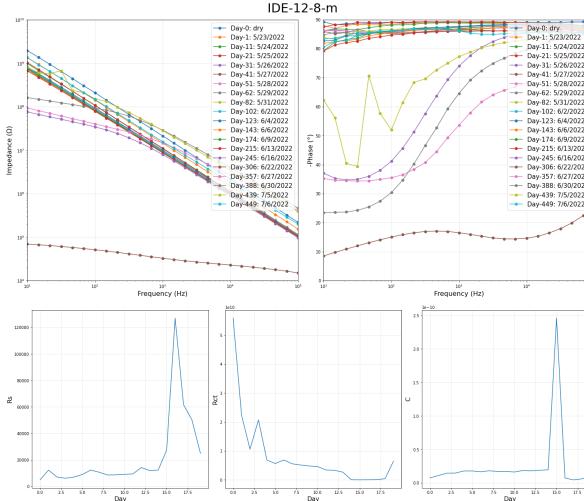
```
#Then
```

```
Rs = ide.getRC(df, "Rs")
Rct = ide.getRC(df, "Rct")
C = ide.getRC(df, "C")
```

```
ide.getGraph(file, df, df_date, date_idx, Rs, Rct, C)
```

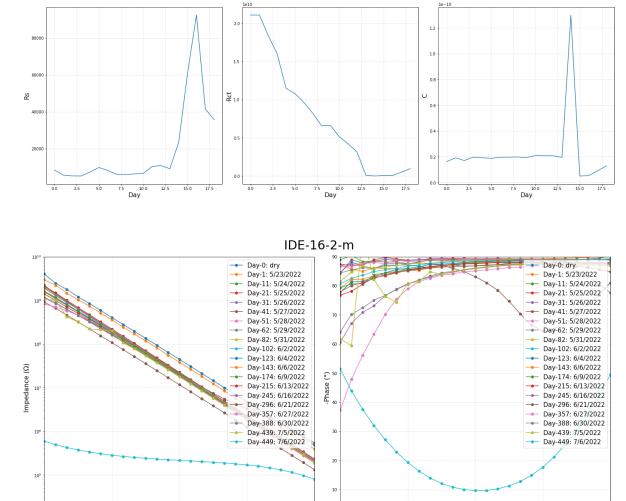
```
date_idx += 1
```

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