Impedance Spectroscopy

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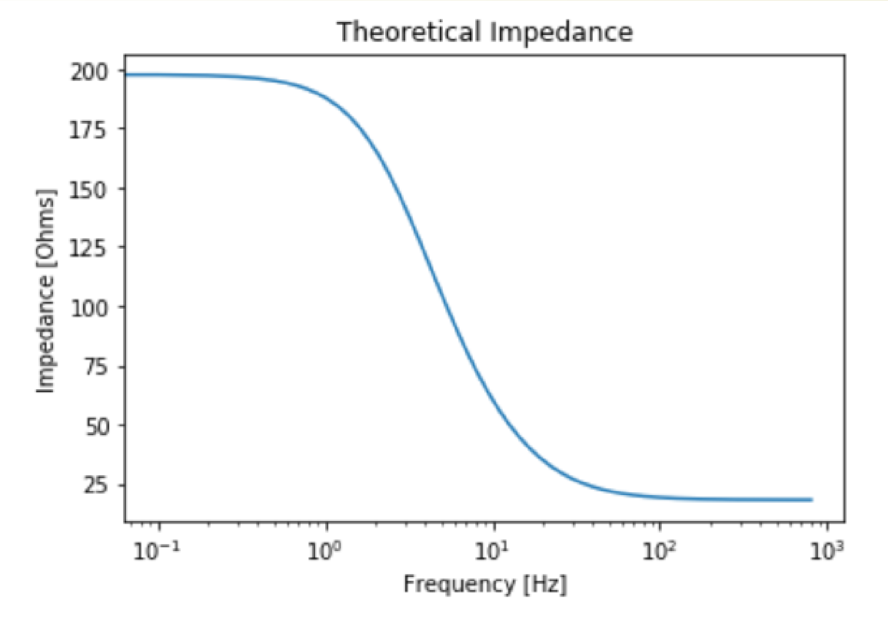
Frequency Dependence of Impedance

- **Impedance** is a measure of how current flow is hindered in a system.
- $Z_{series} = \sum_i Z$ and $\frac{1}{Z_{parallel}} = \sum_i \frac{1}{Z}$
- $Z_R = R$ and $Z_C = \frac{1}{j\omega C}$
- So, for our system under test, we end up with

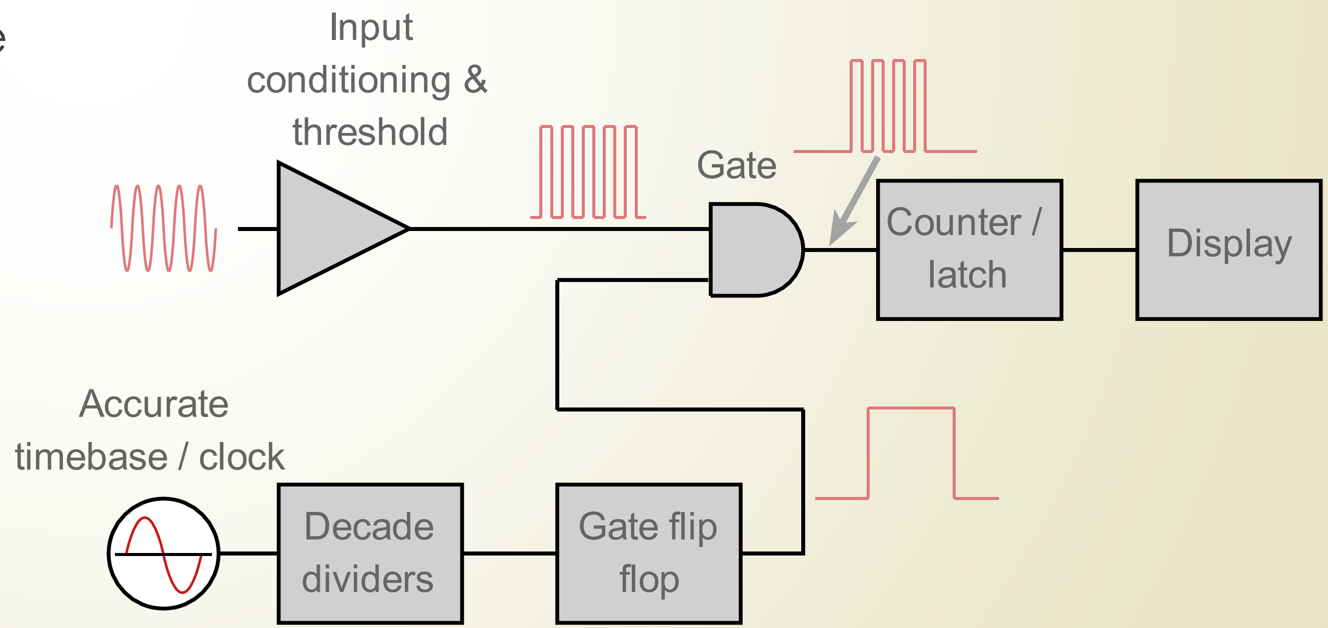
$$Z = \left(\frac{1}{Z_1} + \frac{1}{Z_2}\right)^{-1} = \left(\frac{1}{R_1} + \frac{1}{\frac{1}{j\omega C} + R_2}\right)^{-1} = \frac{\mathrm{R}_1(1 + \omega^2 C^2 R_2(R_1 + R_2) - j\omega C R_1)}{1 + \omega^2 C^2 (R_1 + R_2)^2}$$

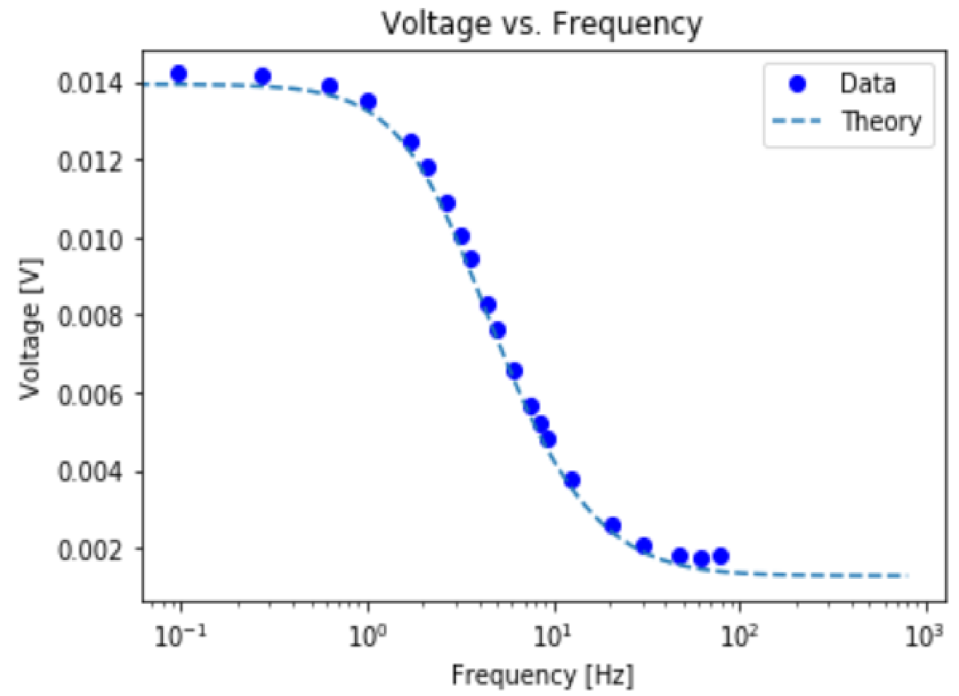
- As frequency approaches zero, the system behaves more like a DC circuit and charge cannot cross the branch containing the capacitor, so $Z \cong R_1$.
- As frequency becomes arbitrarily large, the current can arc across the capacitor, effectively ignoring its presence, and $Z \cong \frac{R_1 R_2}{R_1 + R_2}$.
- $V = I|Z|$

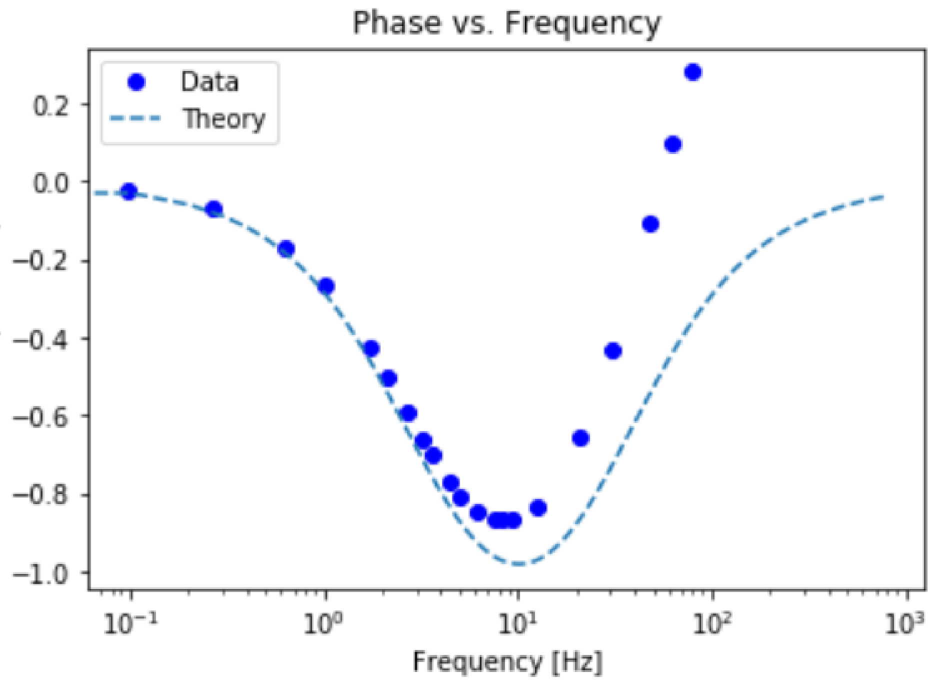


Frequency Meter

- A digital frequency counter measures frequency by taking counts of a periodic function over a **gate time.**
- **Direct counting** methods measure how many times the voltage (or other property being measured) passes a given threshold.
- **Reciprocal** frequency counters measure the period of a cycle and take the inverse.
- A clock produces a signal which is divided by the **decade dividers** into the appropriate gate time.
  - The "gate flip flop" receives this information and signals when the next set of counts should begin.
  - The **latch** holds the last value so that it can continue to be displayed while the counter is updating based on a new set of data.







Prediction vs. Data

Voltage Data

- We see an almost perfect correlation here, especially in the center.
- Asymptotes match fairly well
- Standard deviation: $8*10^{-8}$[V]

Phase Data

- The left half of the plot appears to be roughly correct.
- The dip occurs at the right point.
- We have positive phase; this should be impossible with an ideal circuit of our type
- Possible explanation: Something within the circuit is behaving as an inductor, producing a field opposing the current, causing the positive phase.
- Standard deviation: 0.05 [radians]

References

How Does a Frequency Counter Work. (n.d.). Retrieved from Electronics Notes: https://www.electronics-notes.com/articles/test-methods/frequency-counter-timer/how-does-a-frequency-counter-work-operation.php

laserjocky. (2014). *Digital Frequency Counter*. Retrieved from instructables: https://www.instructables.com/id/Digital-Frequency-Counter/