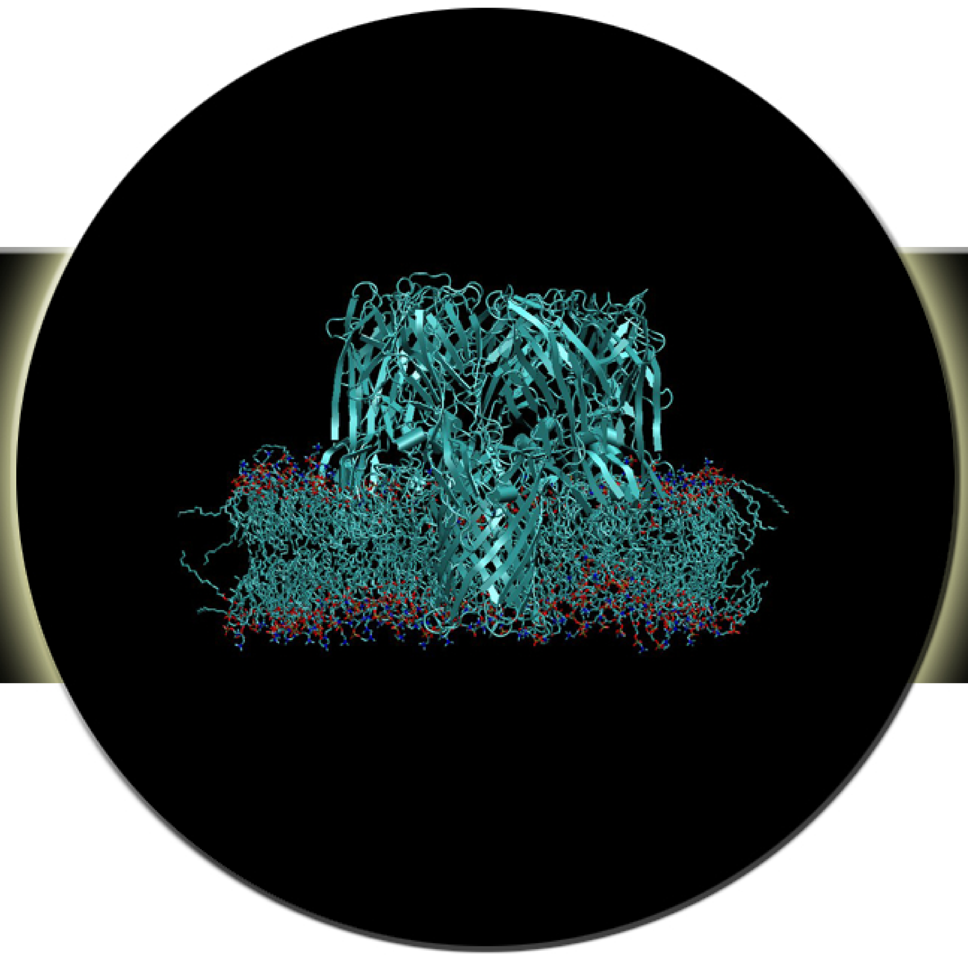

System Identification - Modeling the Nanopore

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Objective

To complete a System Identification of the entire Nanopore system, shown below. Success in doing so will allow the verification and optimization of unknown portions of the Nanopore system.

Background

System Identification is a methodical process involving mathematical algorithms that build models from data. I am looking to build a model that yields an output as closely as possible to the recorded output.

There are two varieties of System Identification - Black Box and Grey Box Modeling. Black Box Modeling has no prior models available, but Grey Box Modeling involves building a model where some parts are unkown, but enough is known to construct a base model. The Nanopore System yields a Grey Box Model.

The Alpha Hemolysin Nanopore (Top left Picture) is an exciting new opportunity for cheaper, faster DNA sequencing. This poster portrays the steps taken to acquire a successful System Identification of the Nanopore System.

Acknowledgements

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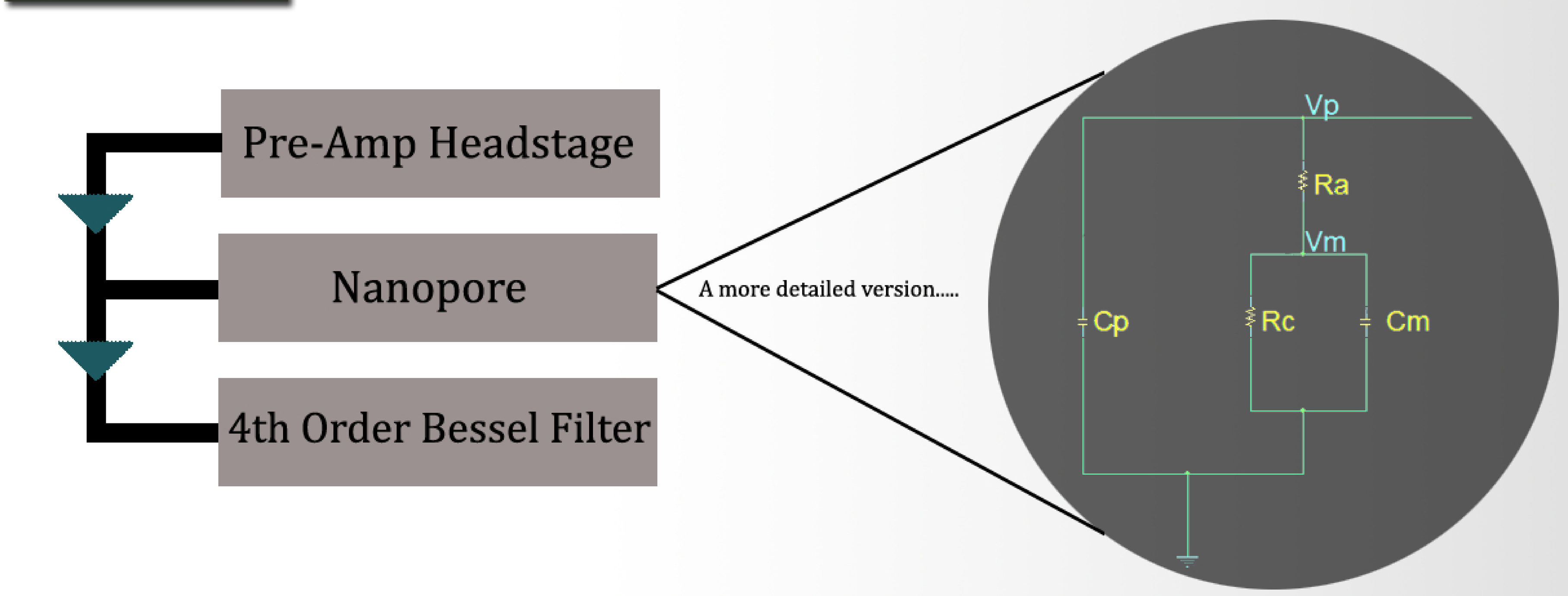
Reference: System Identification Theory for the User Lennart Ljung

Pictures: Jirasak Wong-Ekkabut

Step 1 KNOW Your System



The Parameters

The Nanopore System is a Grey Box Model where the parameters within the Preamp Headstage and the 4th Order Bessel Filter are known. There are 3 unknown parameters, which have only been estimated.

- Ra - The access resistance from the electrode to the nanopore
- Cp - The stray parasitic capacitance to the ground
- Cm - The capicitance across the Lipid Membrane

Step 2 CHOOSE Your Model

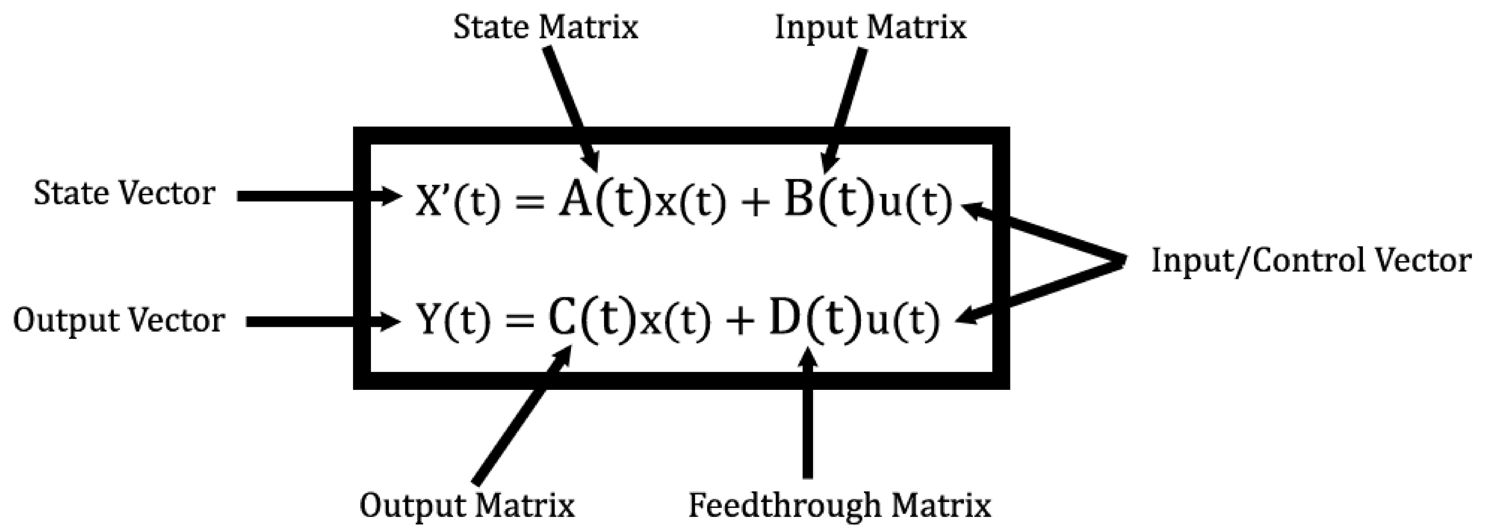
A model is a mathematical representation that describes a system's dynamics. From the wide variety of models to choose from, the form for the model picked was a State Space Model.

A State Space Model:

1. Describes the relationship between input, noise, and output signals as a system of first-order differential equations in the form of a state vector x(t).
2. The ability to model noise is much more dynamic in this system than other models.
3. Can represent continuous time, single-input/single-output systems very well.
4. Can easily be represented by computer simulation (As it is a first order).

Converting to State Space

1. Write a single, proper transfer function of all 3 circuit elements.
2. Convert, by hand, into the state space form of:



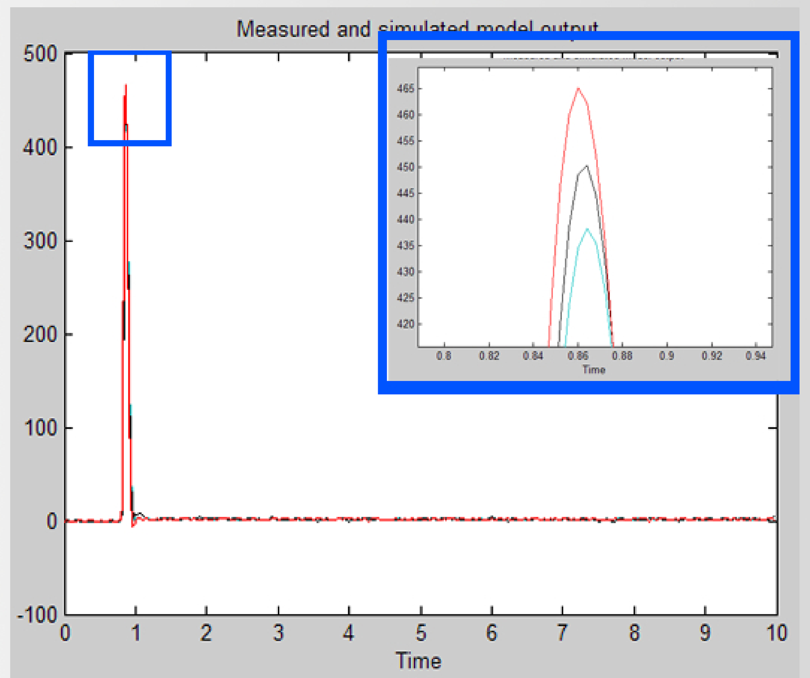
NOTE: The Nanopore system itself has 6 states, 2 from the Nanopore and Preamp Headstage and 4 from the Bessel Filter.

Step 3 VERIFY & OPTIMIZE

The State Space representation of the Nanopore System was entered into Matlab and processed using the System ID Toolbox.

This figure plots the curves of real data fed through mathematically derived Models versus the actual output. The percentiles show the percentage that the generated outputs match the real data.

The closeness of the colored curves proves the knowledge of the system to be sound.



BLACK (data) represents the actual output.

RED (90.07%) represents a model formulated using the methods described above.

BLUE (94.57%) represents the red model but optimized using Perimeter Estimation Methods (PEM) within Matlab.

Conclusions

Using the PEM Model, which yielded the best fit, nominal values for the unknown parameters were able to be found:

- Ra = 0.0116 GigaOhms
- Cp = 2.0022 PicoFarads
- Cm = 4.7847 PicoFarads

These values are all valid, except for Ra which is larger than estimated. A solution to solve this would be to then Model the Pre-Amp, which was previously thought to be known.