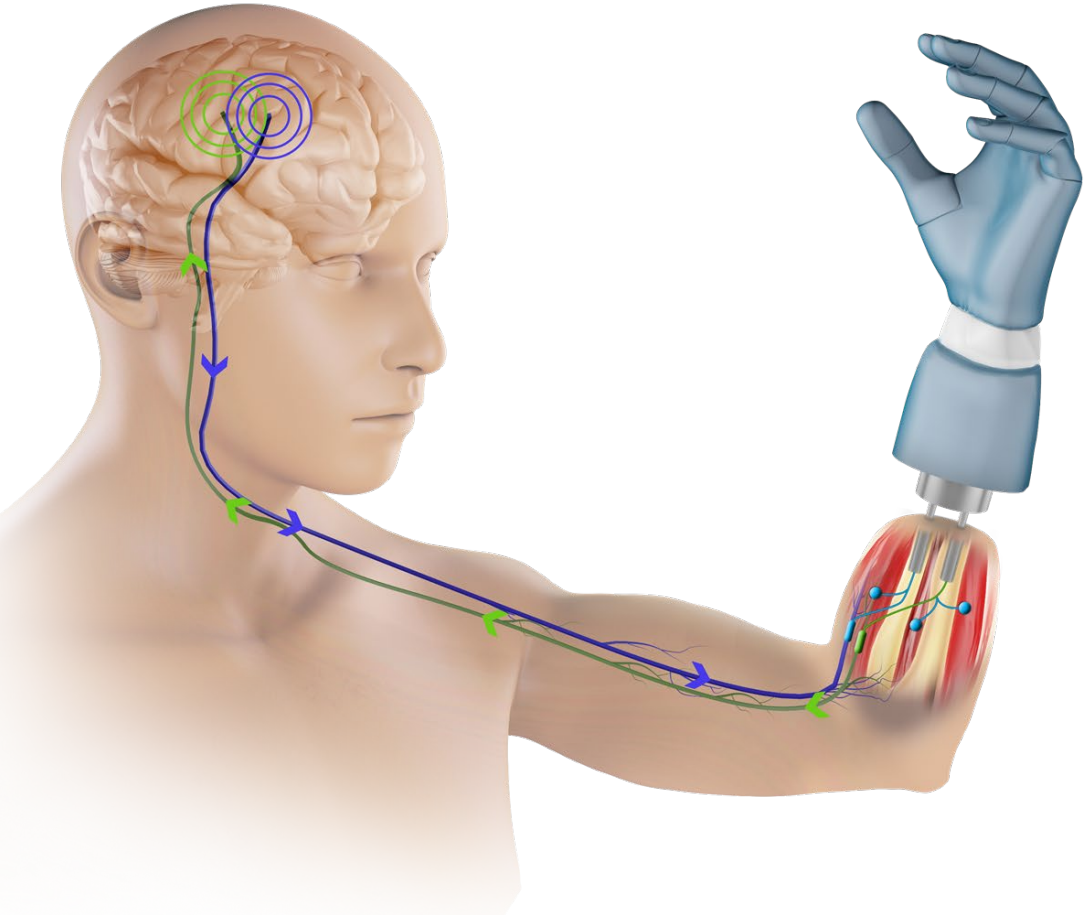
Cross-Channel Impedance Measurement for Monitoring Implanted Electrodes



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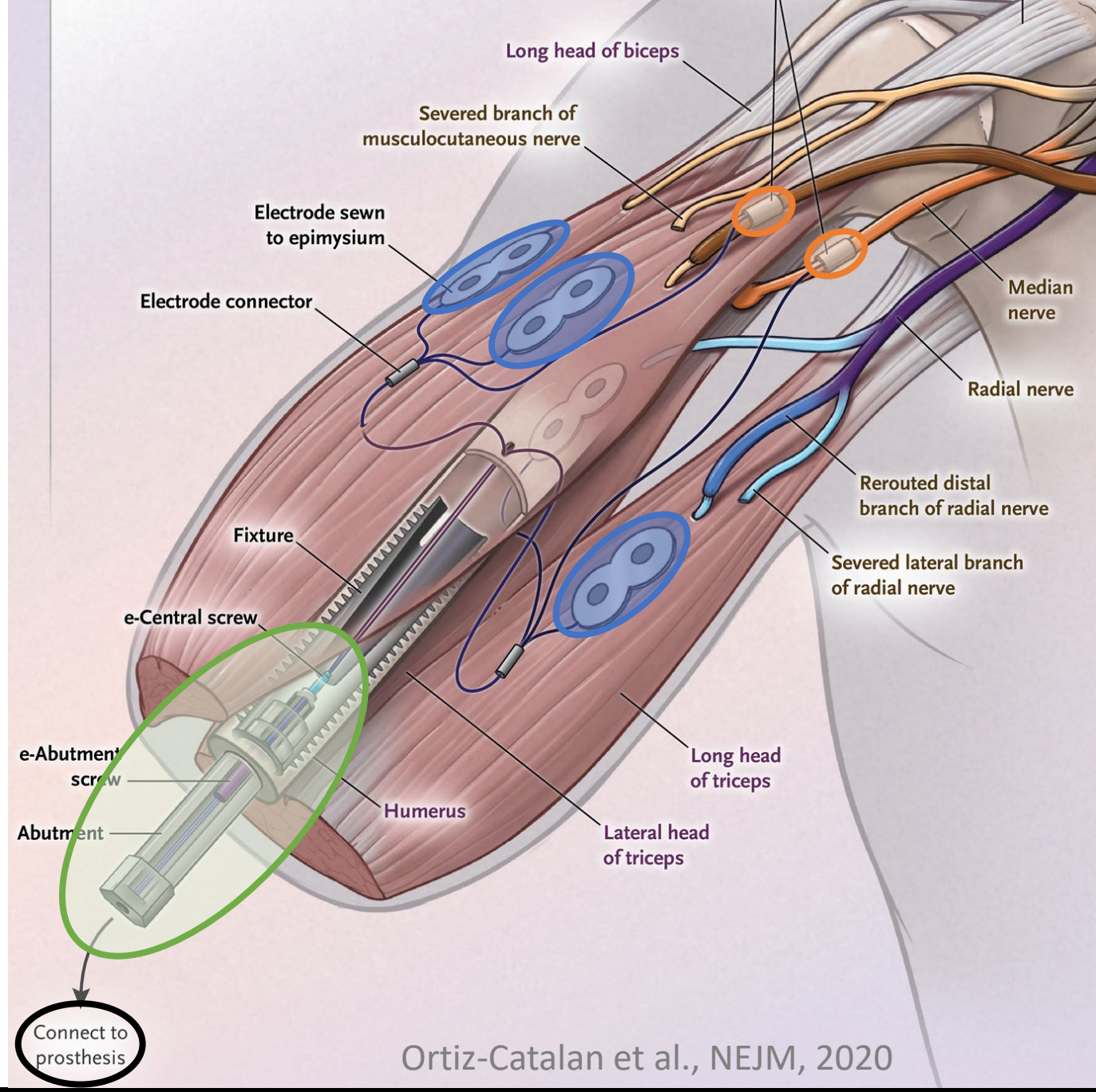
Nerve cuffs

Intramuscular and epimysial electrodes

Abutment

(electrical ground)



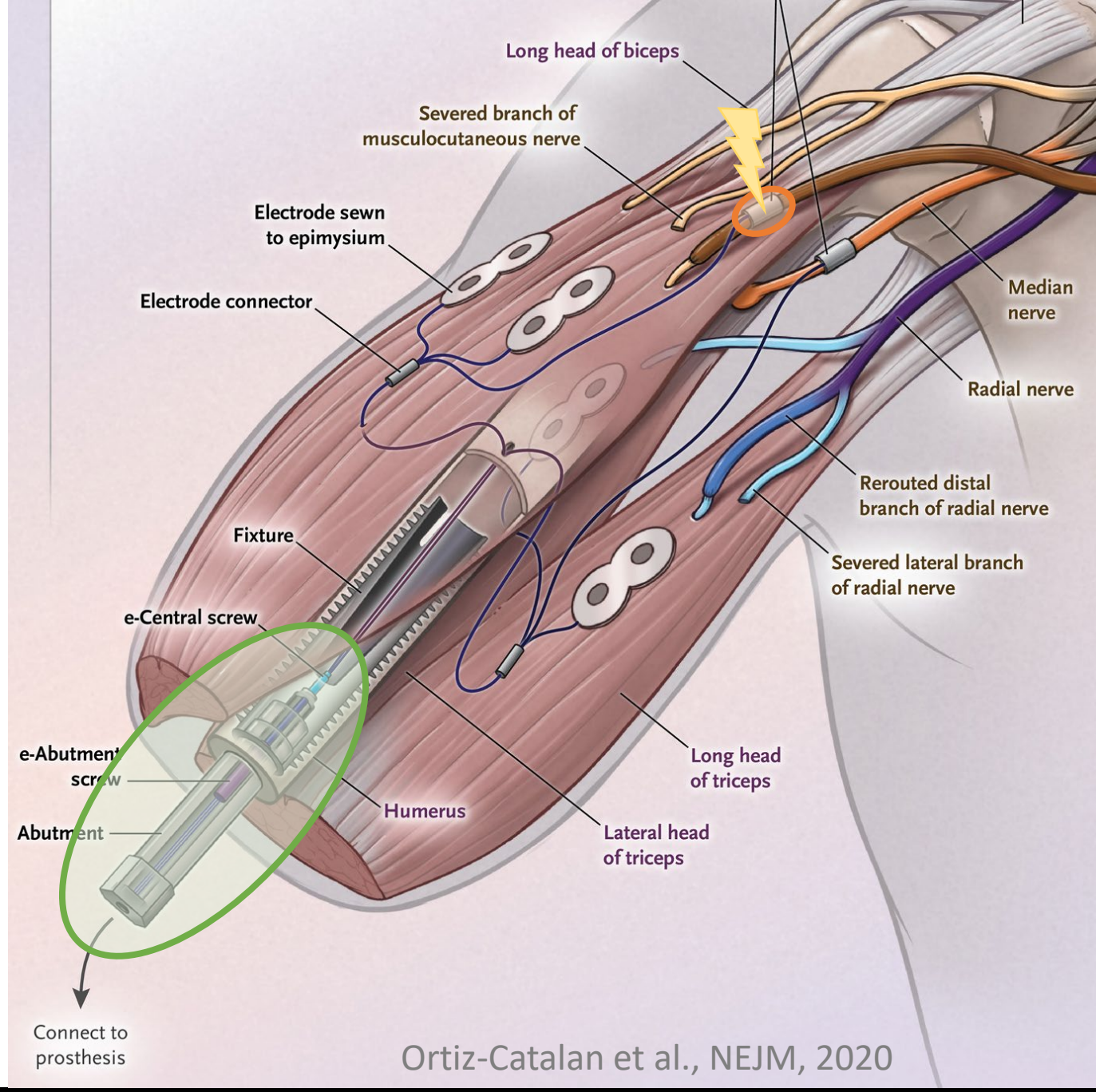
Ortiz-Catalan et al., NEJM, 2020

Measuring impedance:

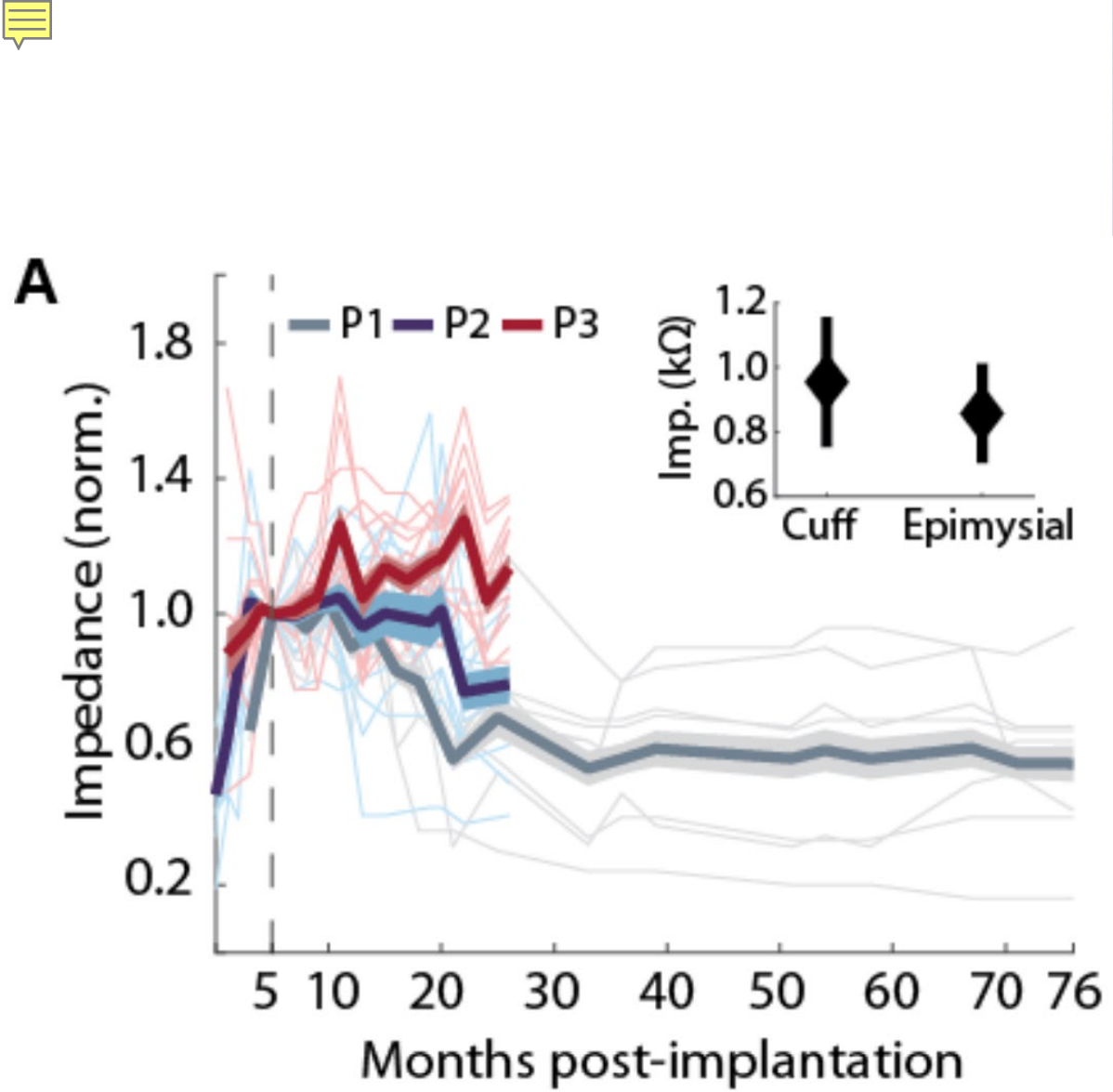
Stimulate **channel** with known **current**

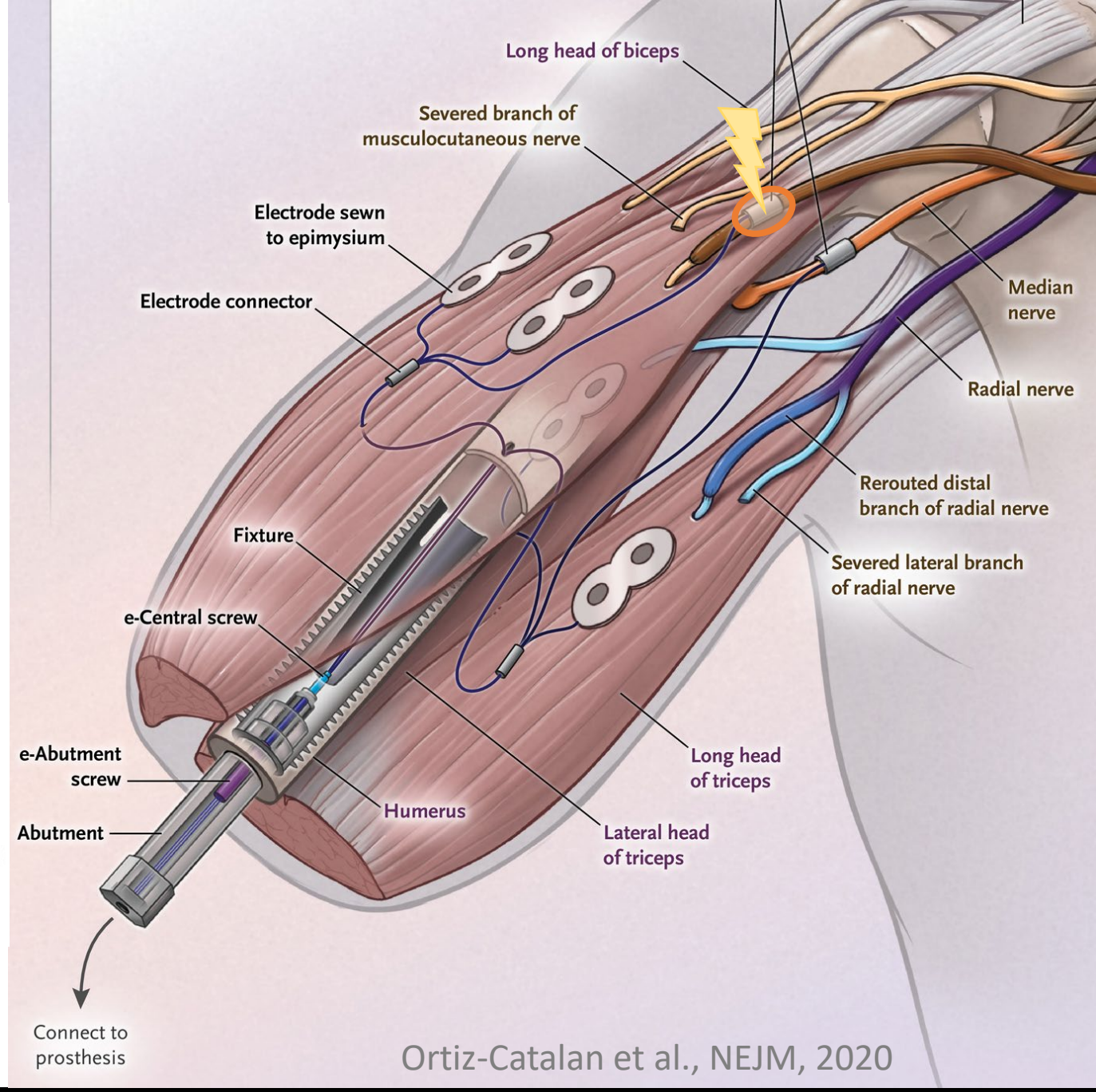
Measure voltage between **channel** and **abutment**

$$Z = \frac{V}{I}$$



Ortiz-Catalan et al., NEJM, 2020

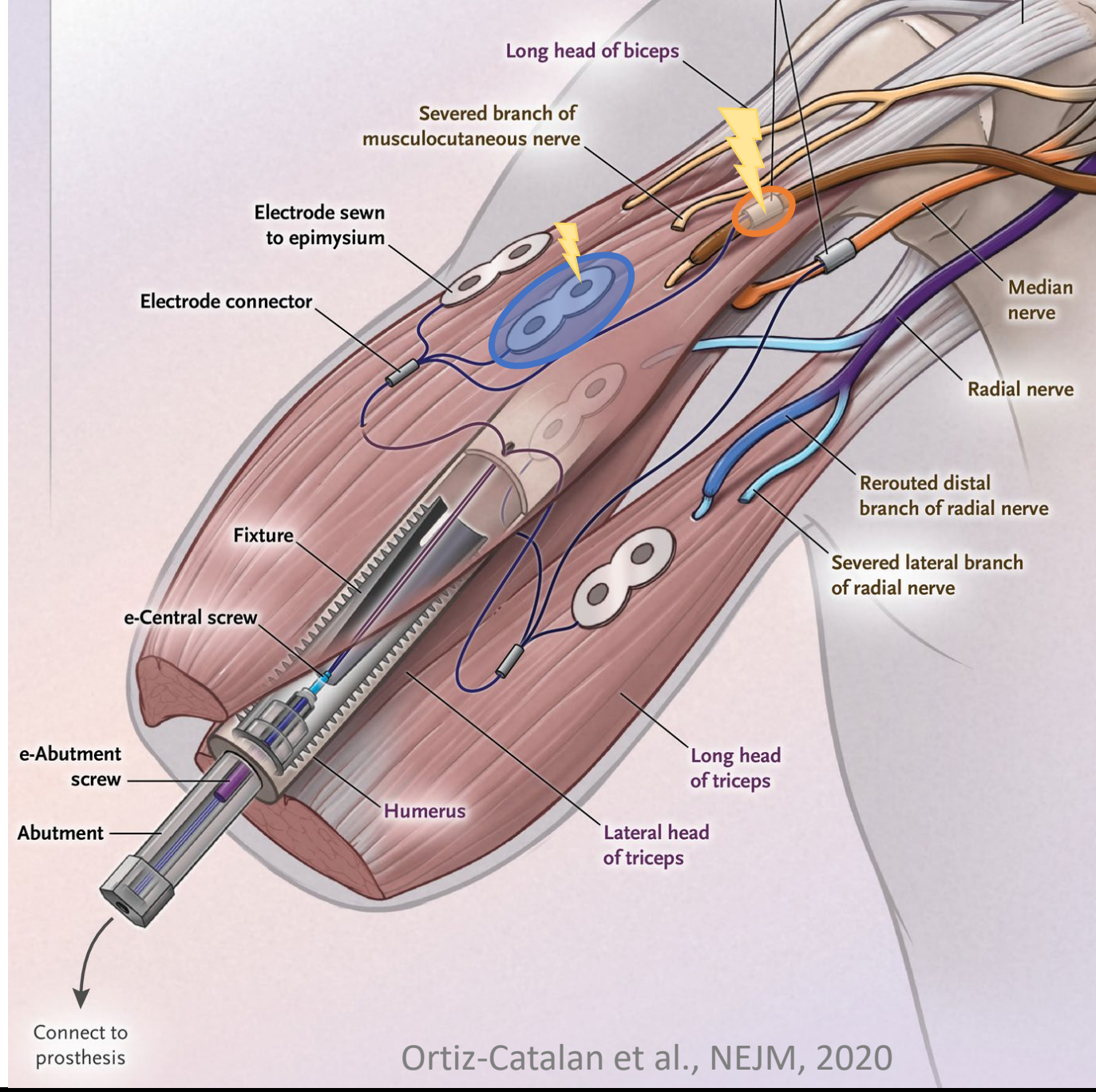




Ortiz-Catalan et al., NEJM, 2020

This method cannot detect
shorts
between electrodes,

which may explain behavior like
stimulation artifacts
in EMG channels



Ortiz-Catalan et al., NEJM, 2020

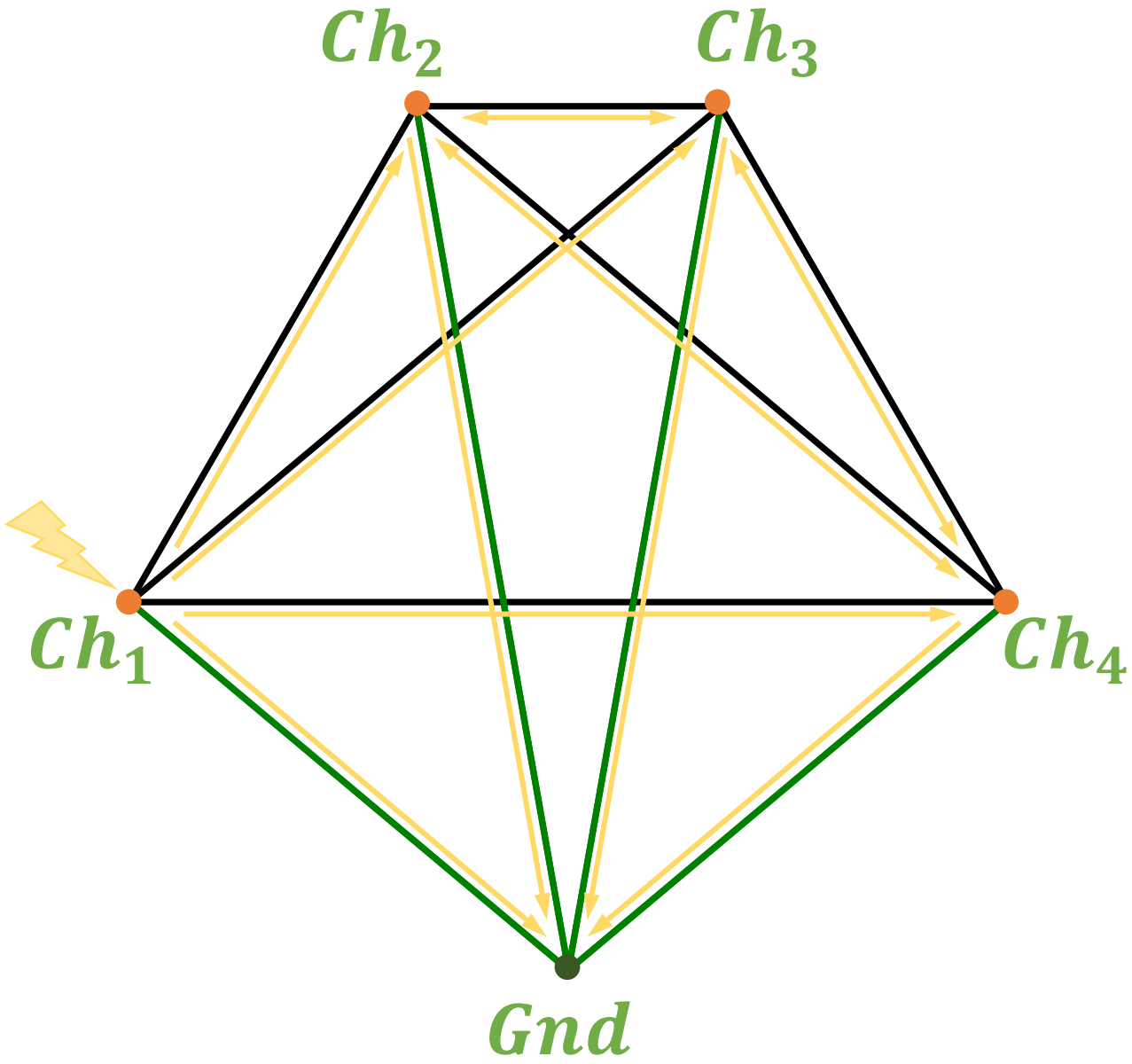
We propose a method of

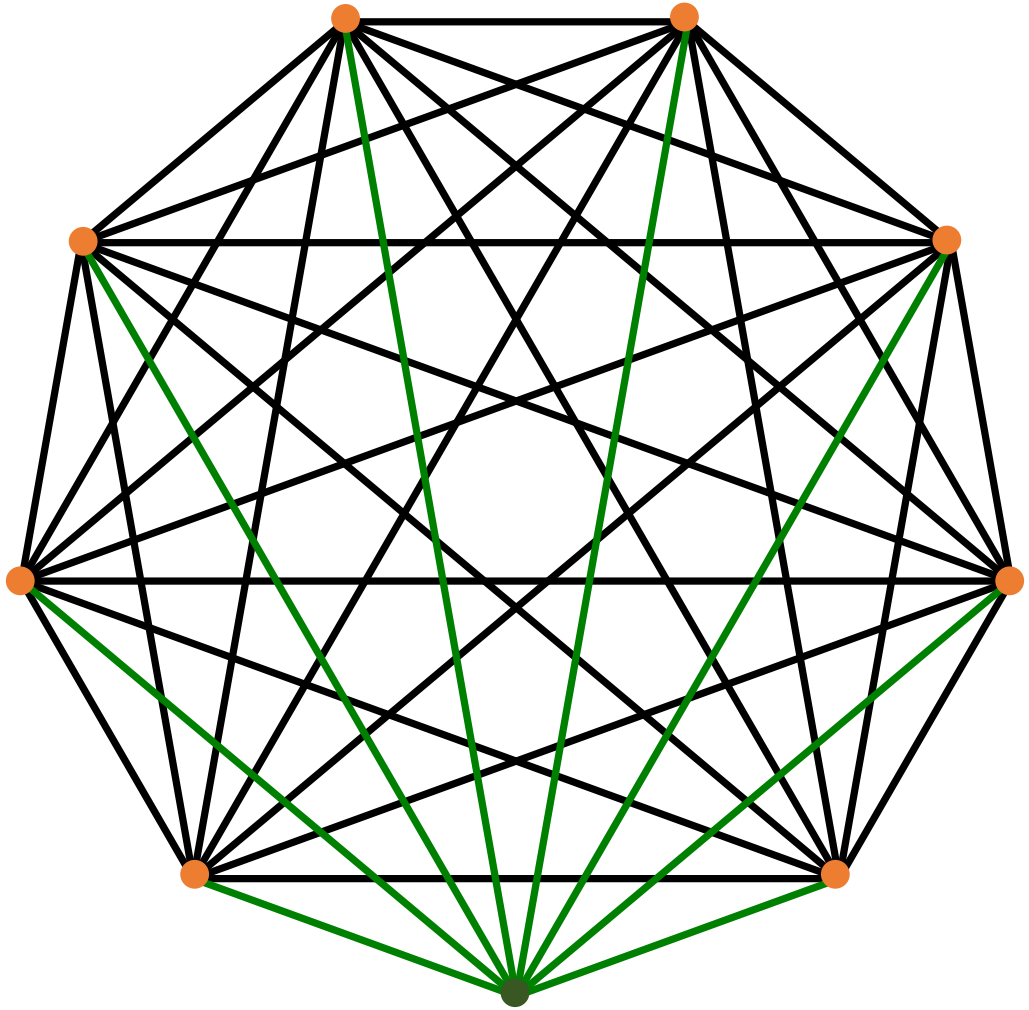
Cross-Channel Impedance Measurement

for monitoring implanted electrodes
with a common ground

This method:

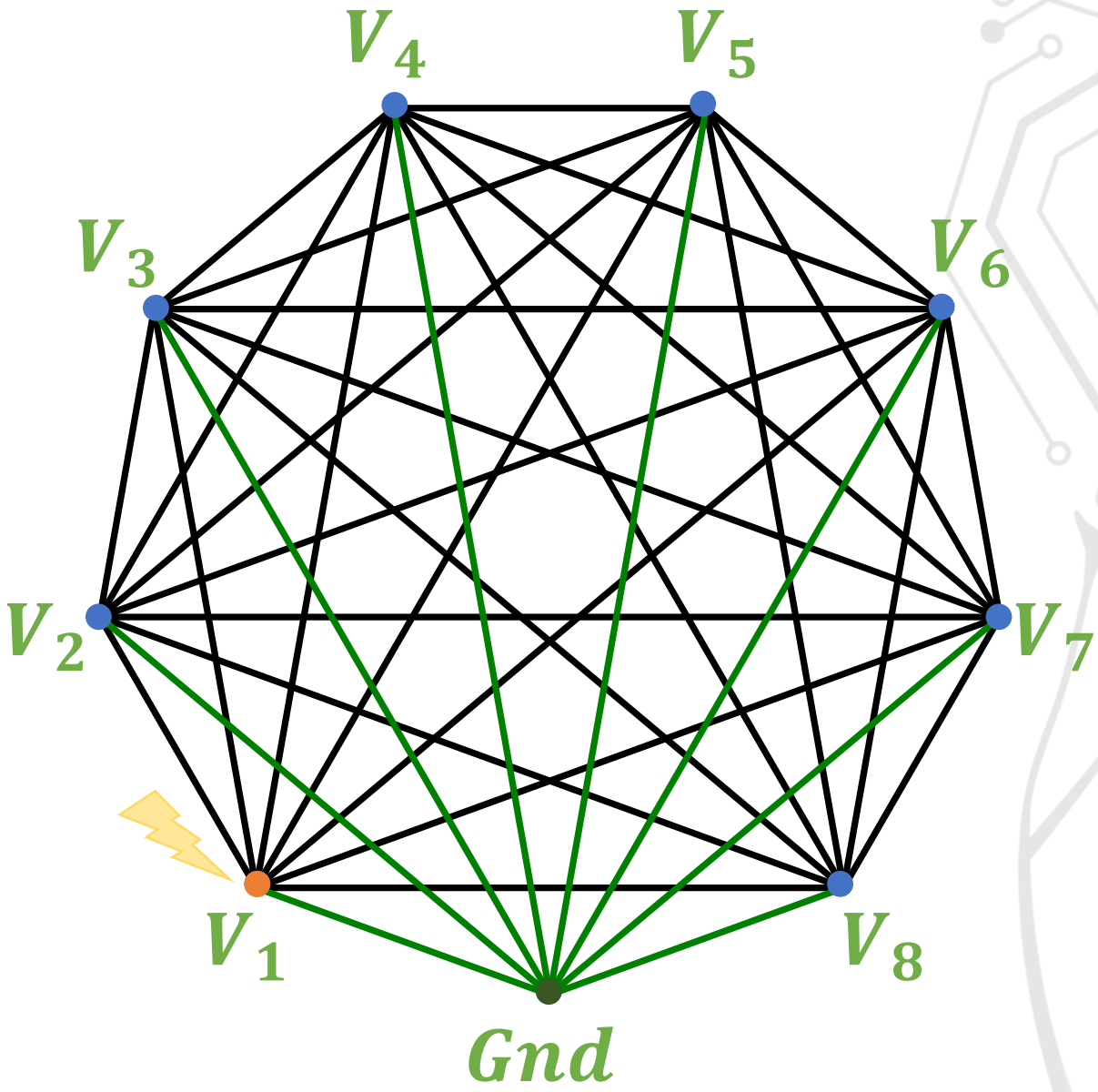
- ✓ is system-agnostic
- ✓ requires only conventional equipment
- ✓ is computationally simple for embedded systems


Ch_2
Ch_3
Ch_1
Ch_4
Gnd



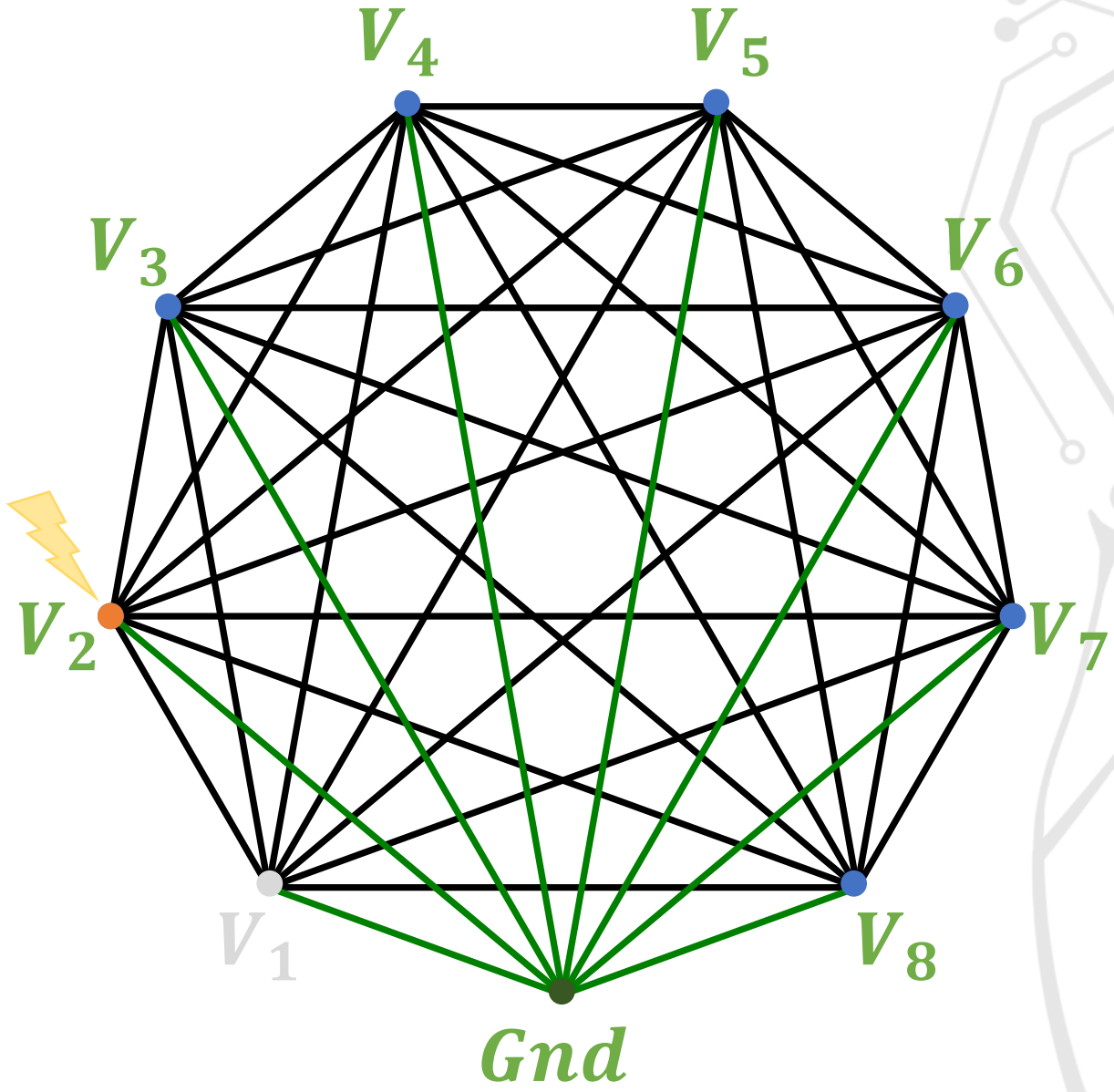
Cross-Channel Impedance Measurement

1) Stimulate first **channel** with known **current**
2) Measure **voltage** at all **channels**



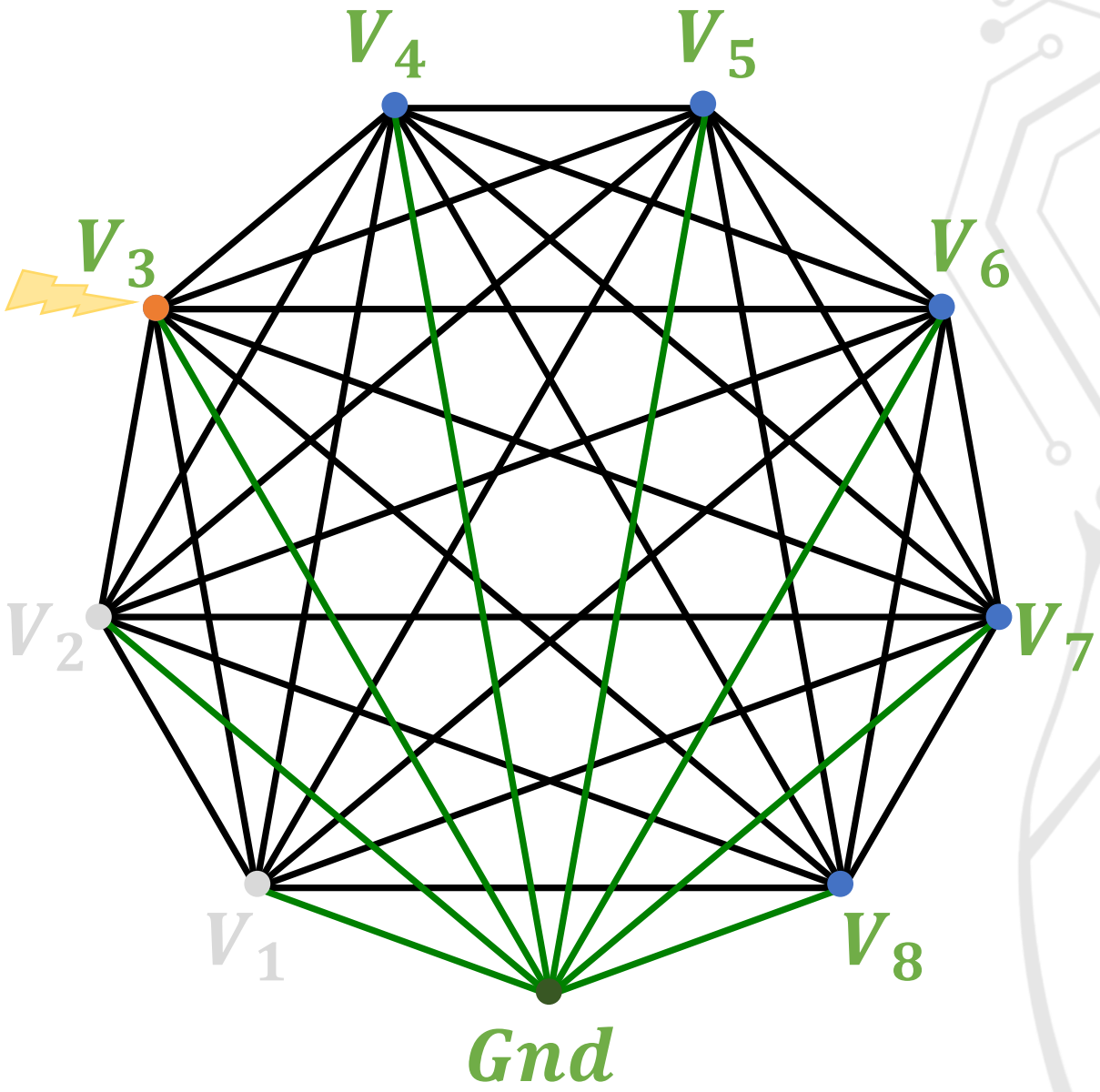
Cross-Channel Impedance Measurement

1) Stimulate first **channel** with known **current**
2) Measure **voltage** at all **channels**
3) Stimulate next **channel** with known **current**
4) Measure **voltage** at all **channels** except previous



Cross-Channel Impedance Measurement

1) Stimulate first **channel** with known **current**
2) Measure **voltage** at all **channels**
3) Stimulate next **channel** with known **current**
4) Measure **voltage** at all **channels** except previous
5) Repeat



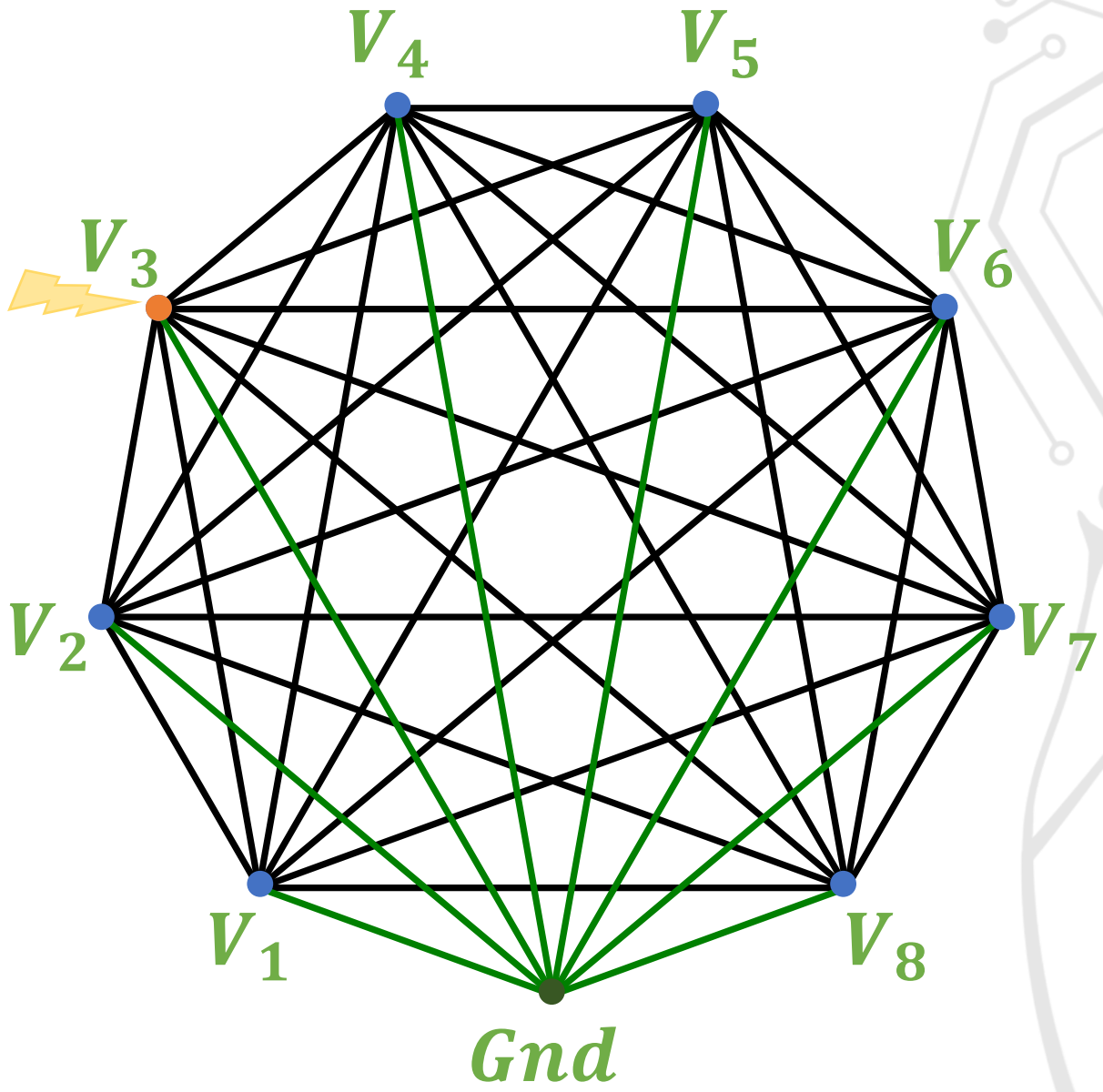
Cross-Channel Impedance Measurement

The current through each channel is described as:

$$I_{in} = \frac{V_i}{Z_i} + \sum_{j \neq k} \frac{V_i - V_j}{Z_{ij}}$$

Direct impedance

Cross-channel impedance



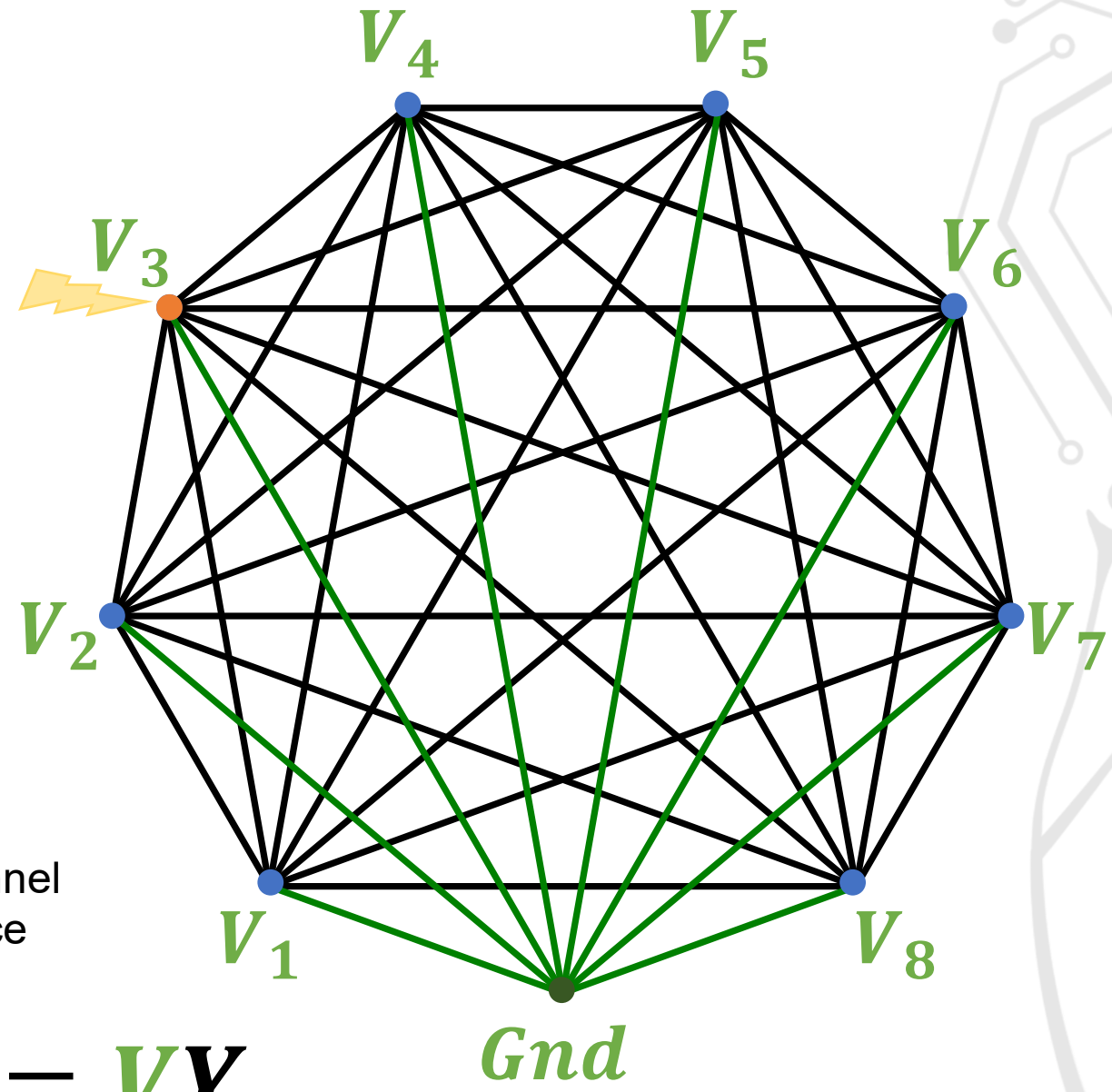
Cross-Channel Impedance Measurement

The current through each channel is described as:

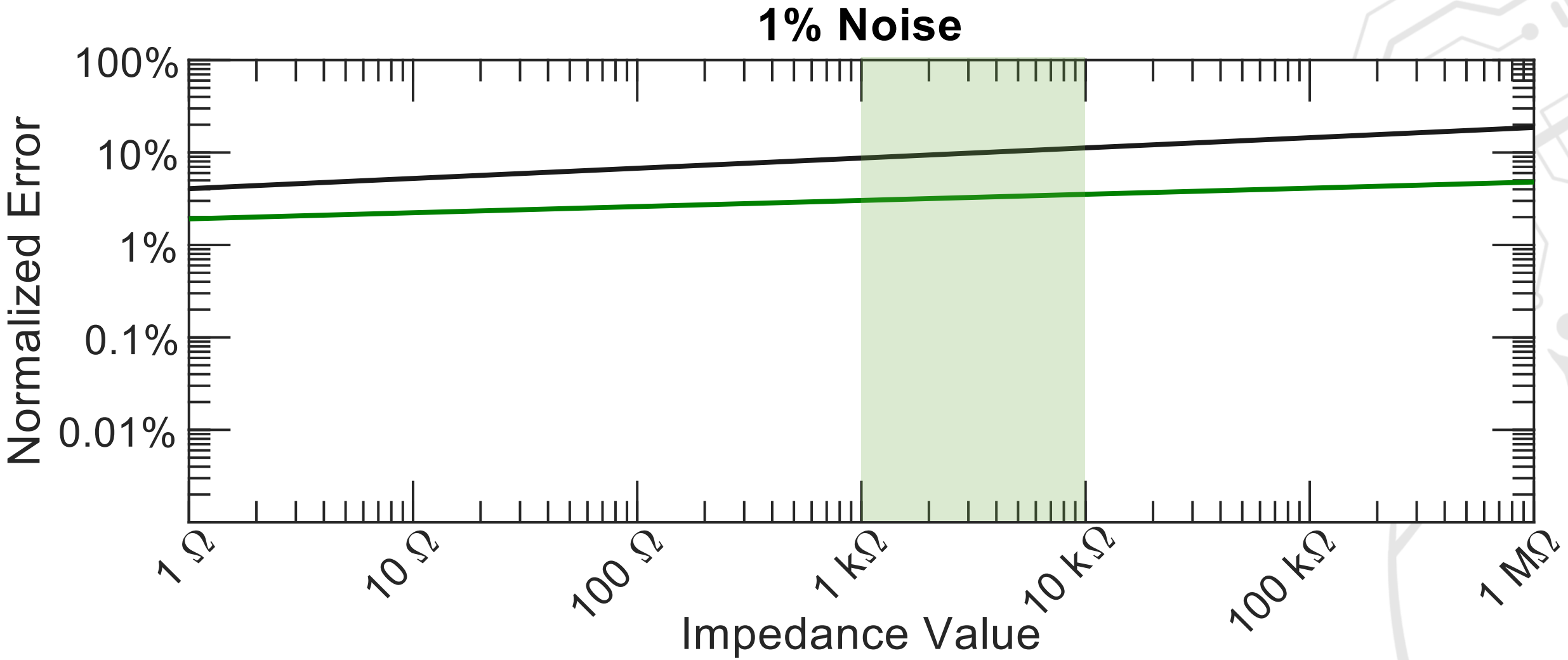
$$I_{in} = V_i Y_i + \sum_{j \neq k} (V_i - V_j) Y_{ij}$$

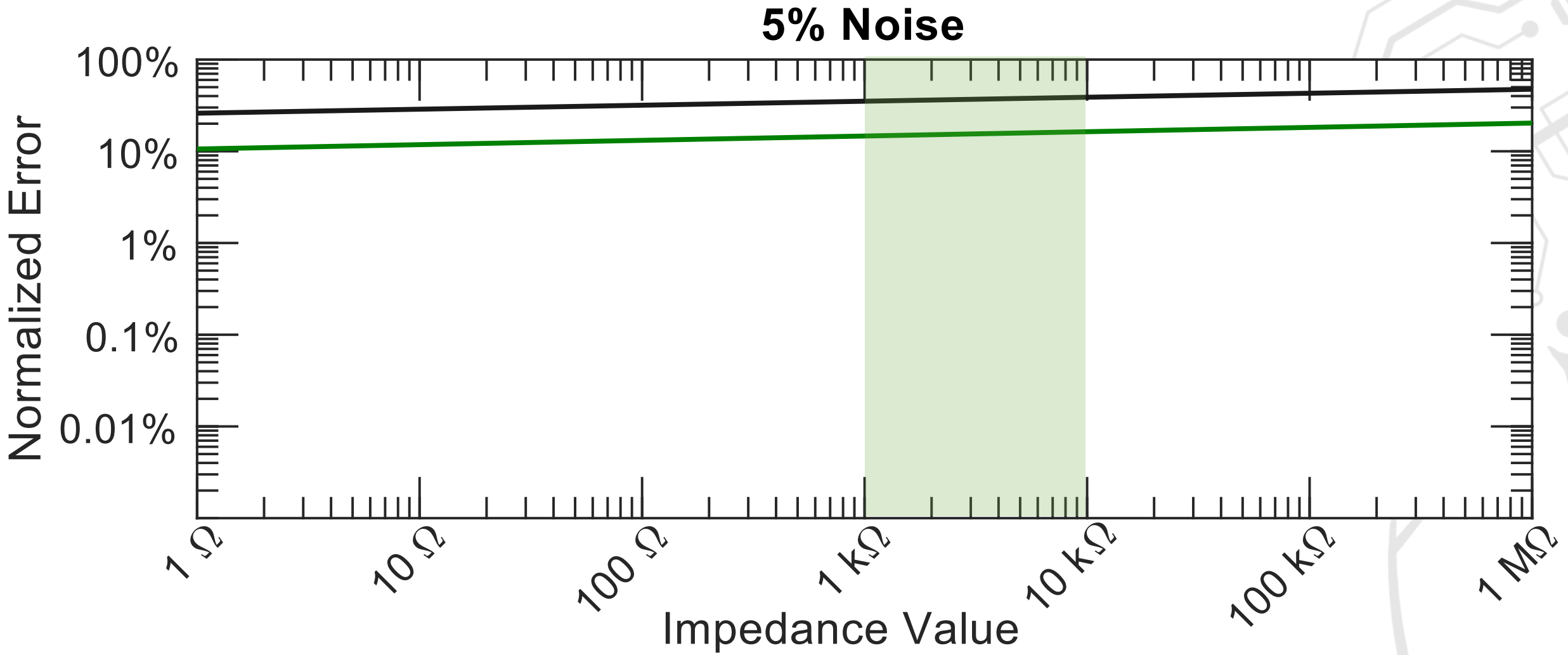
Direct admittance

Cross-channel admittance



This can be written as a system of linear equations: $\boldsymbol{I = VY}$


1% Noise
100%
10%
1%
0.1%
0.01%
Normalized Error
1 Ω
10 Ω
100 Ω
1 kΩ
10 kΩ
100 kΩ
1 MΩ
Impedance Value


5% Noise
100%
10%
1%
0.1%
0.01%
Normalized Error
1 Ω
10 Ω
100 Ω
1 kΩ
10 kΩ
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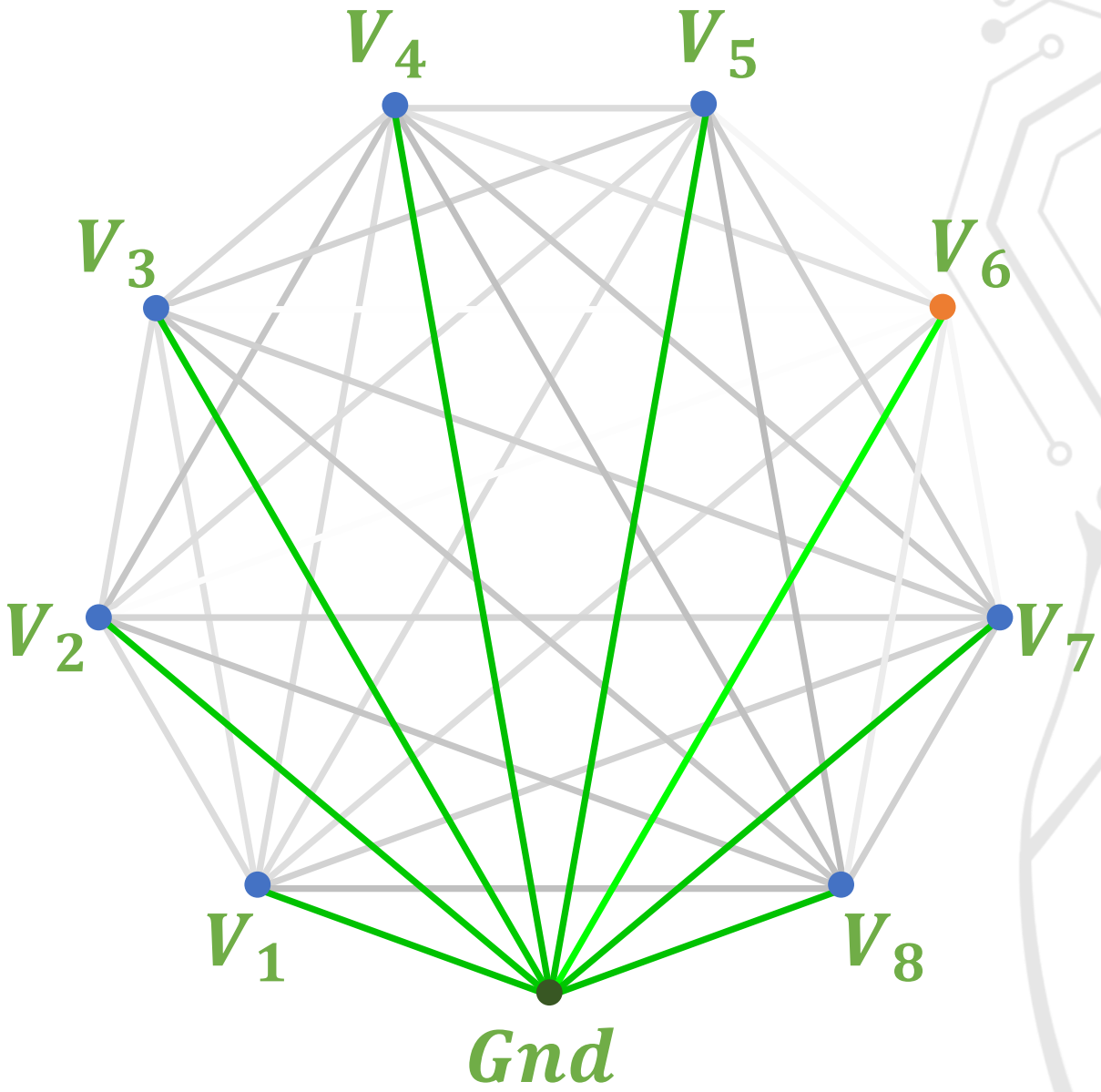
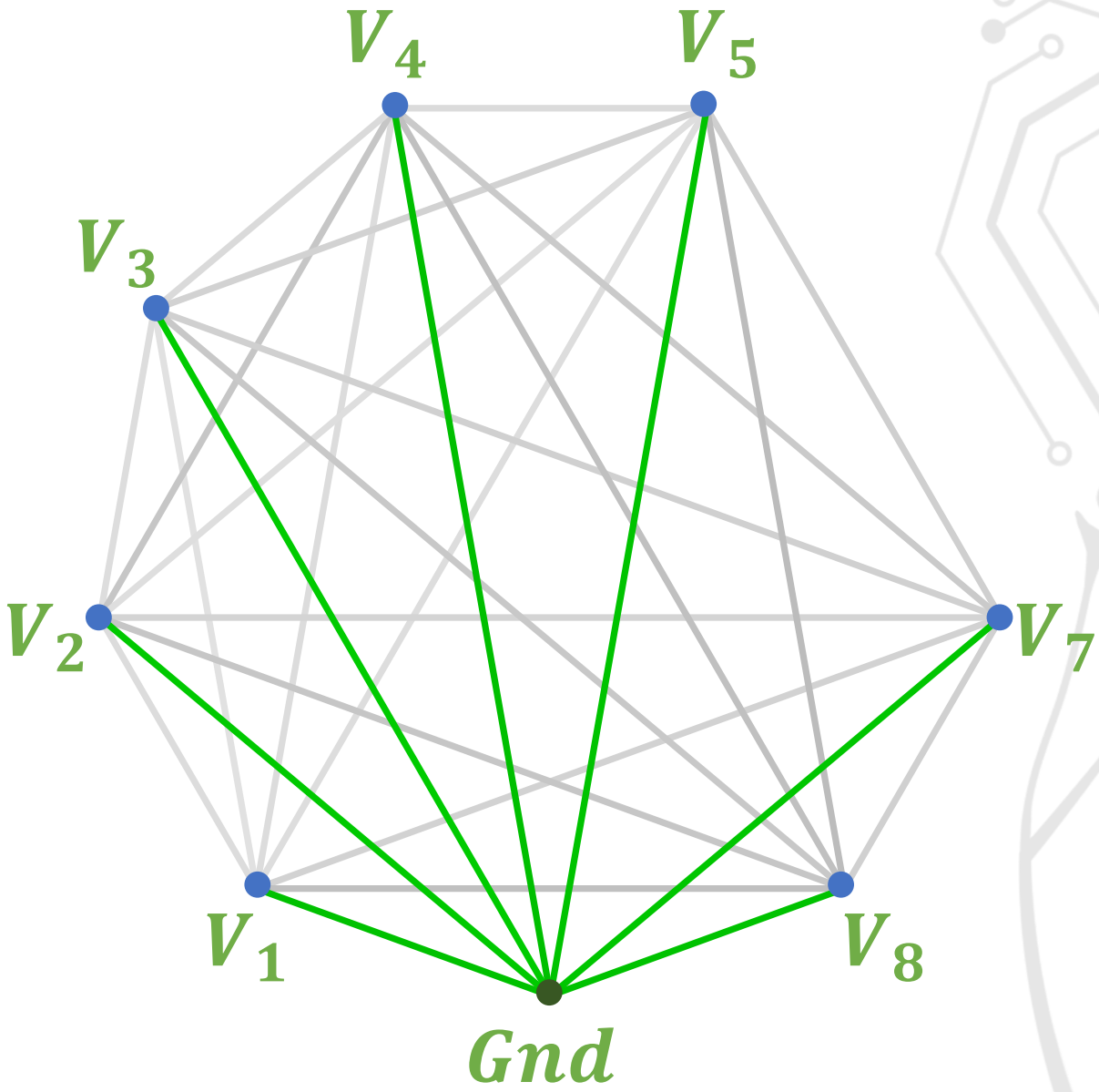
1 MΩ
Impedance Value

If a channel is broken and all impedances are high, calculations will be more inaccurate

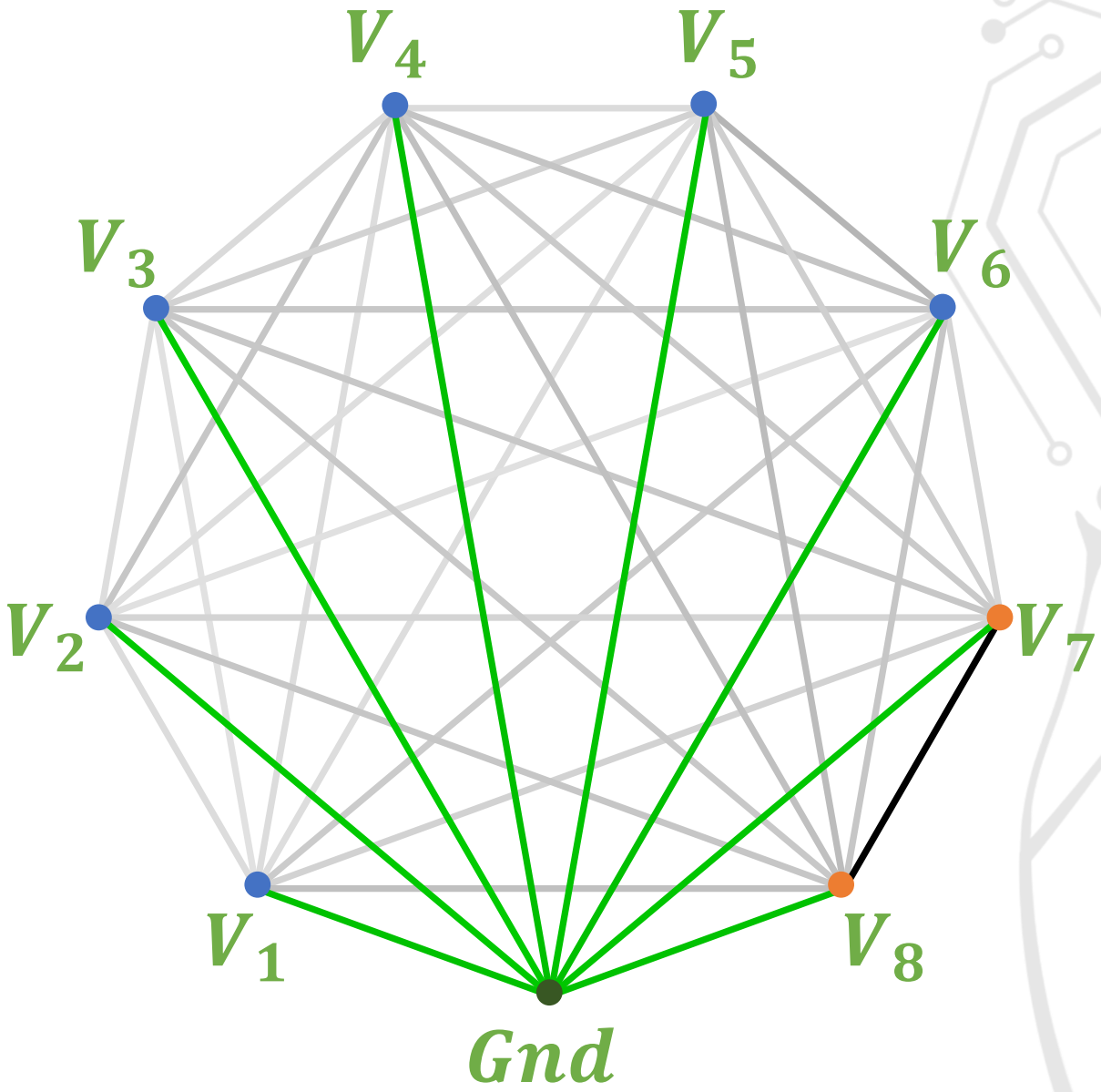


If a channel is broken and all impedances are high, calculations will be more inaccurate

Removing the channel from the model may improve estimates for other channels

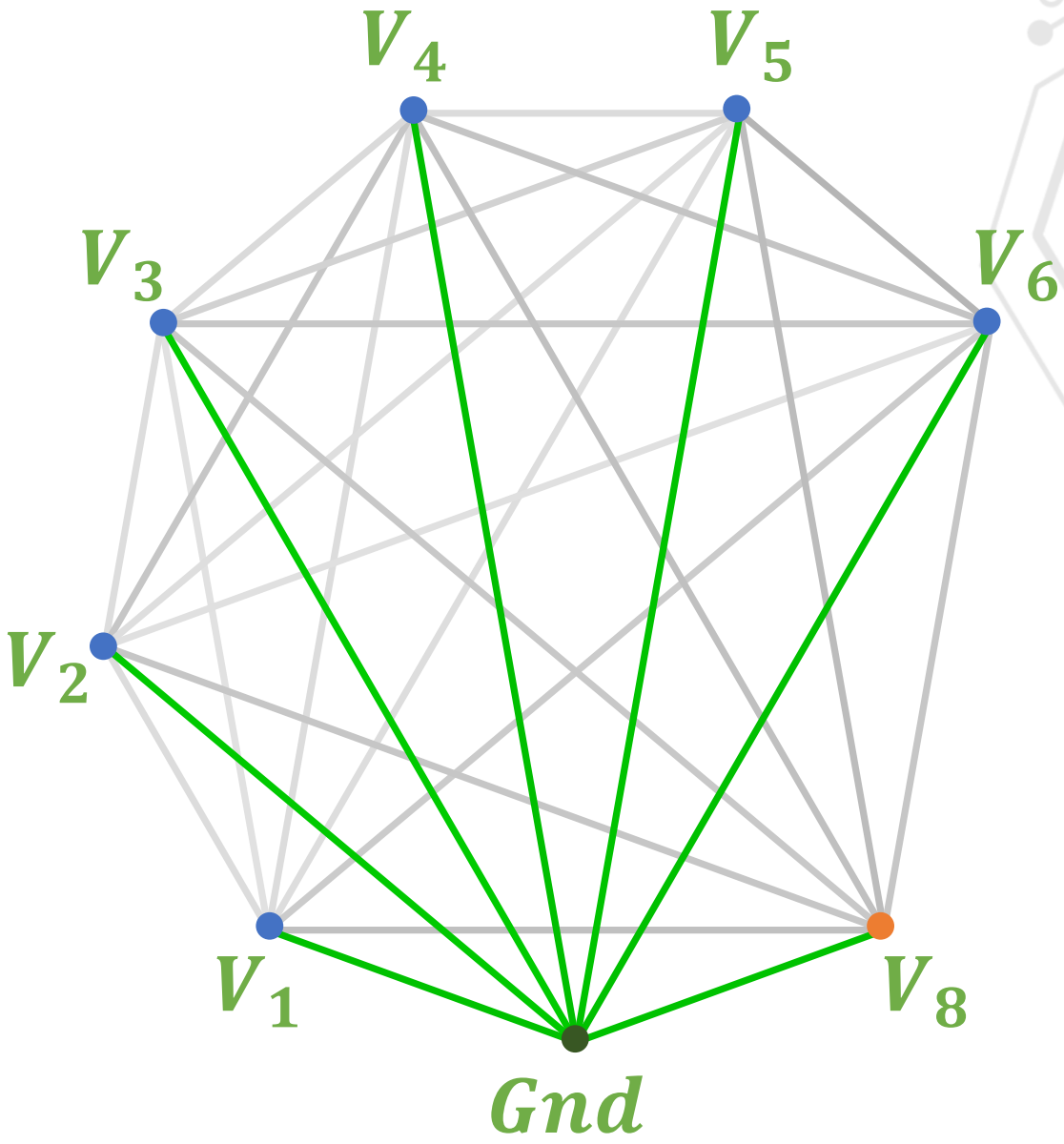


If two channels are shorted, they essentially act as one



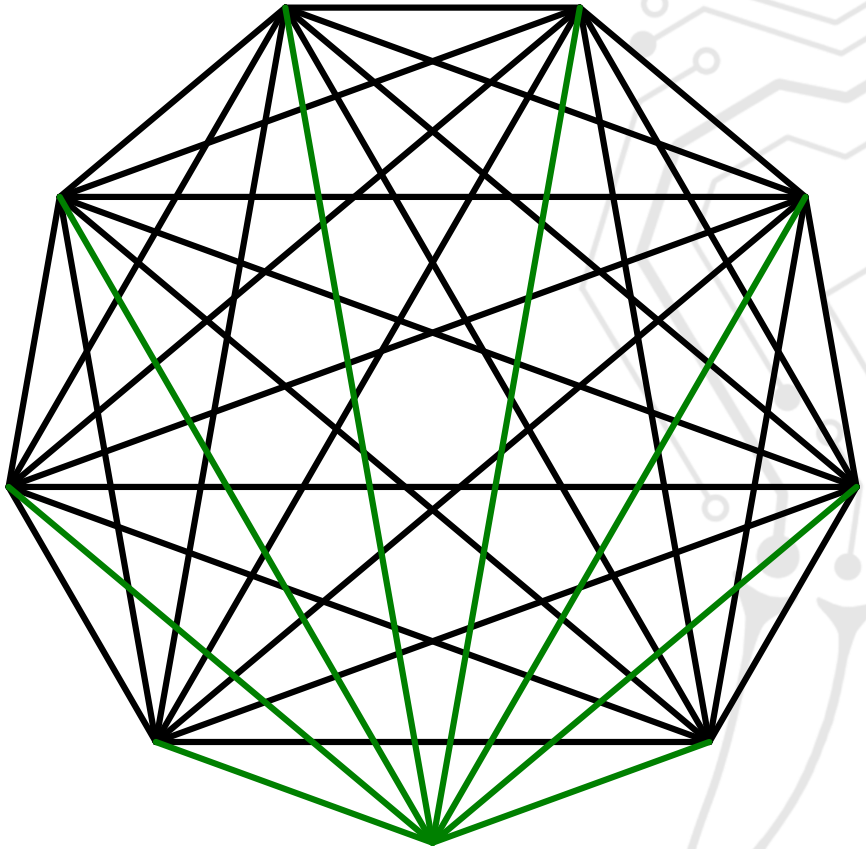
If two channels are shorted, they essentially act as one

Merging the channels may improve calculation accuracy



Cross-Channel Impedance Measurement

- ✓ system-agnostic
- ✓ conventional equipment
- ✓ computationally simple



This method may aid in the longitudinal tracking of implanted electrode performance and early identification of electronics failures

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MATLAB Repository

Open Science Framework

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