Charger-Surfing: Exploiting a Power Line Side-Channel for Smartphone Information Leakage

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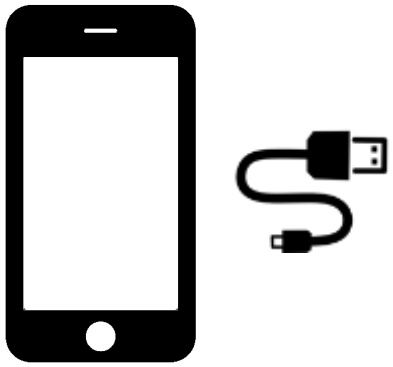
Charger-Surfing

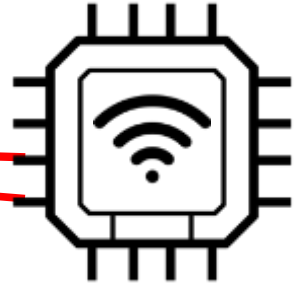
- Shoulder Surfing attack via the charger
- Can we utilize the power signal from a charger to infer what is on the screen?

Attack

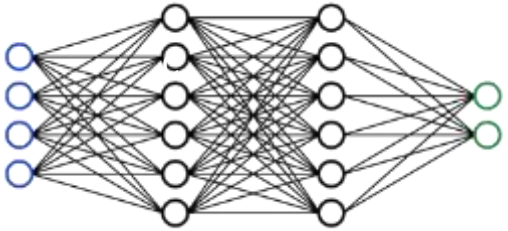
User Plugs Device into Public Charger and Uses as Normal



Attacker Monitors Voltage via hidden probe



Attacker Uses Neural Network to Read User's Presses



1 3 2 7

The Threat of Public Charging

- Can an attacker gain any information about the user's activity or private information with just the power trace?
  - Activity/potentially the app [1]
  - Internet browsing [2]

1Yimin Chen, Xiaocong Jin, Jingchao Sun, Rui Zhang, and Yanchao Zhang. POWERFUL: Mobile App Fingerprinting via Power Analysis. In Proceedings of the IEEE Conference on Computer Communications, 2017
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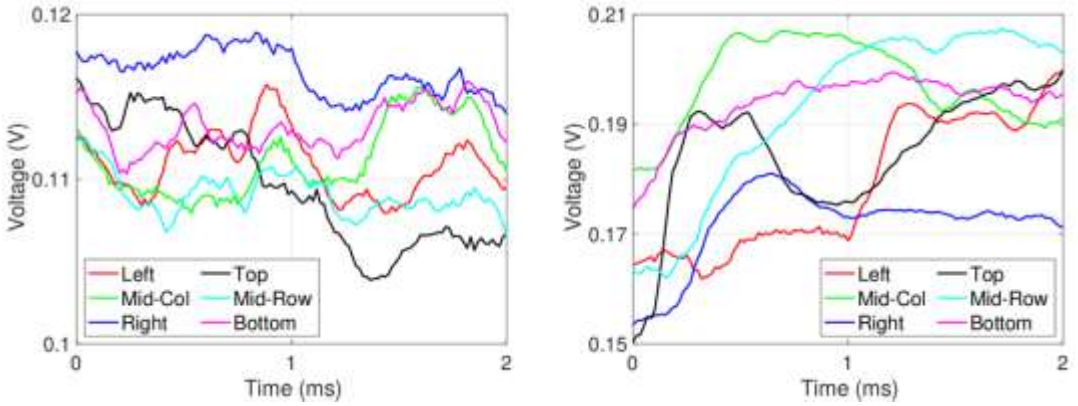
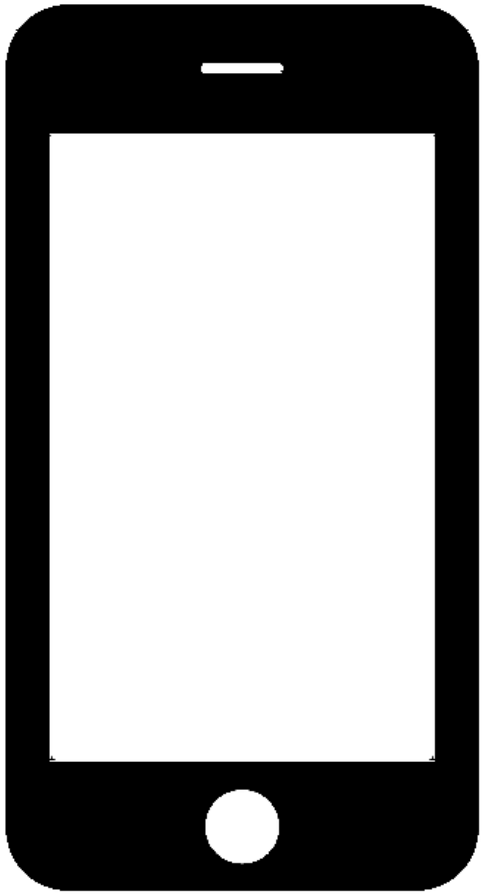
Intuition

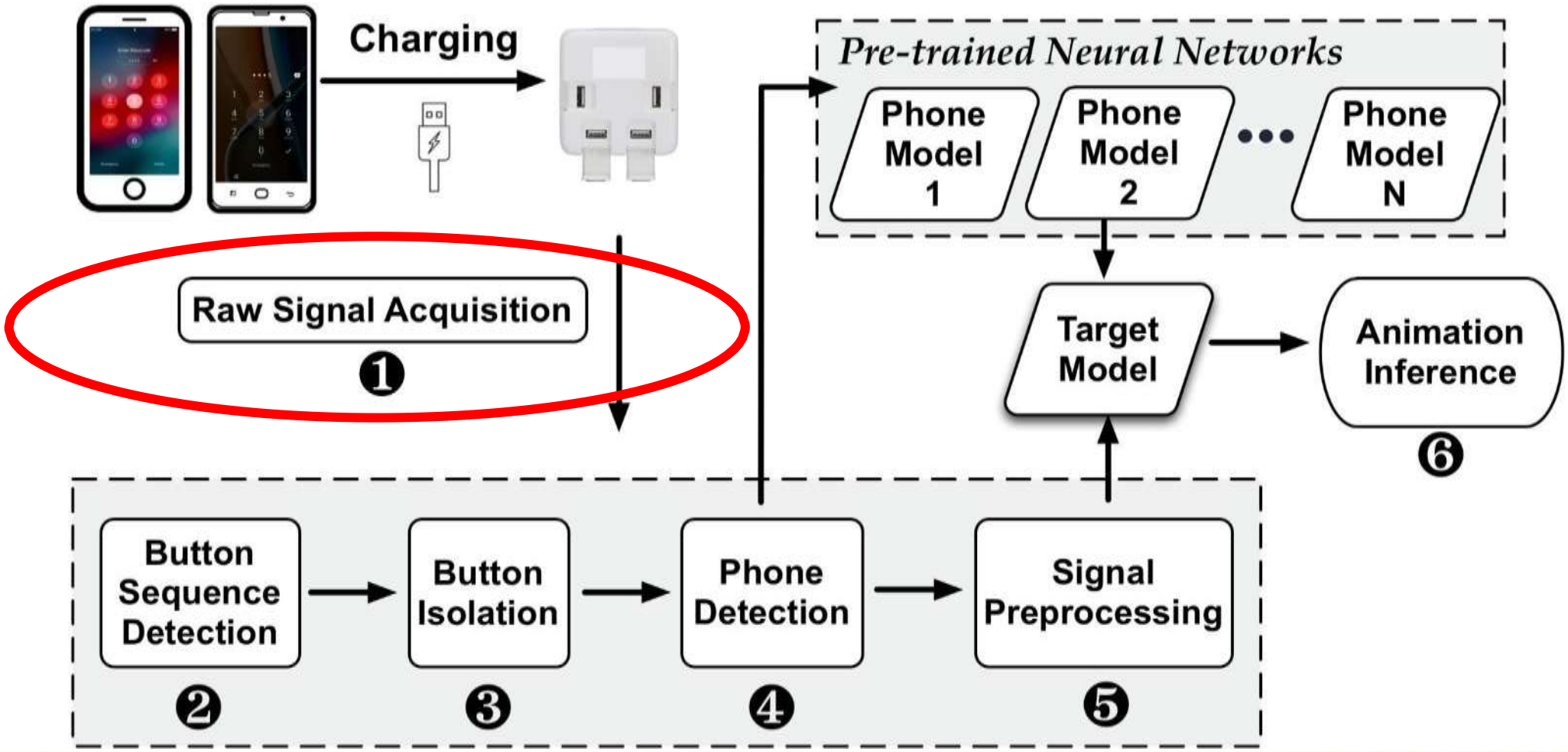
- Phone screen refreshes left to right top to bottom
- Different energy costs to change pixel colors
- Different locations produce different signals



Power signal shape for animations in different locations

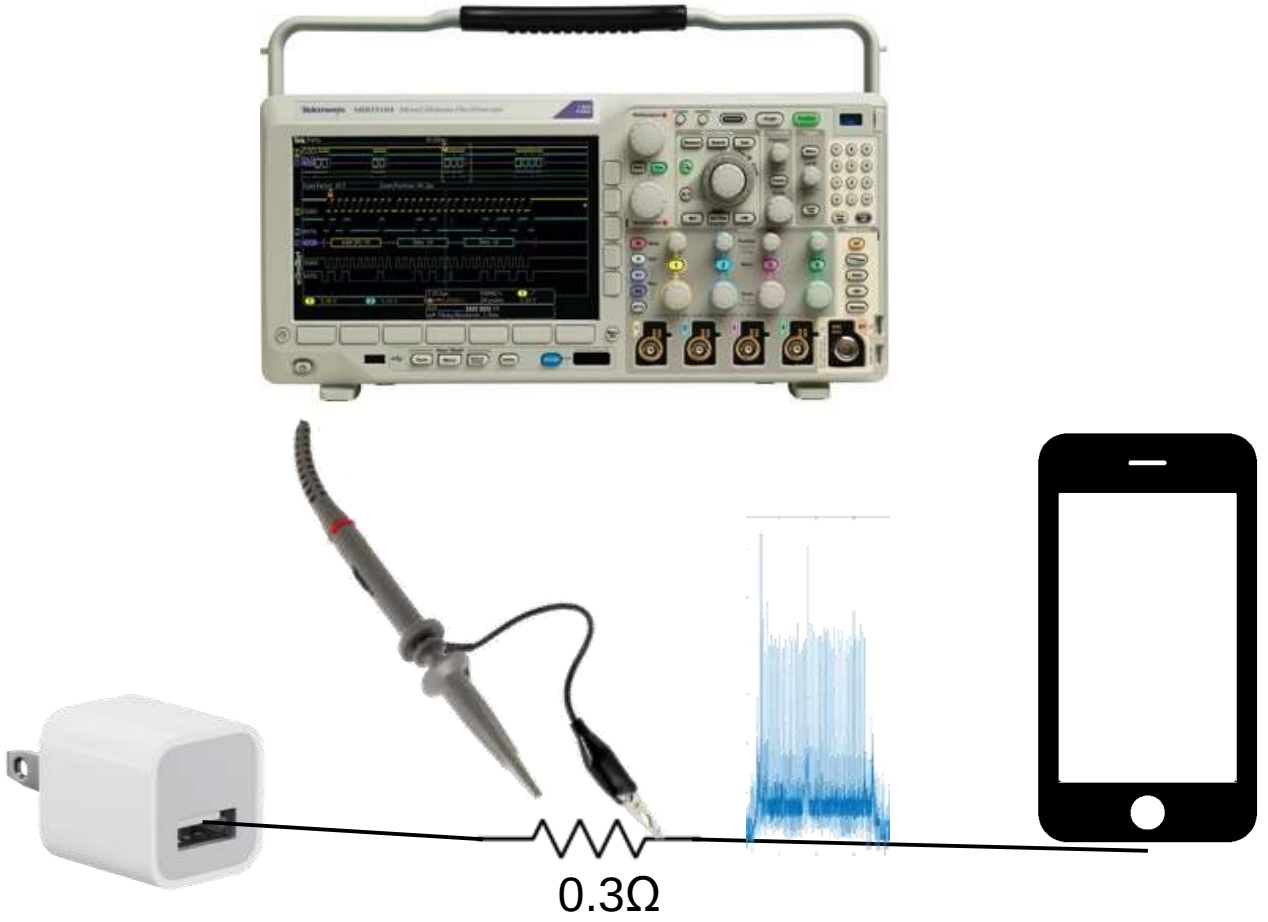


System Design

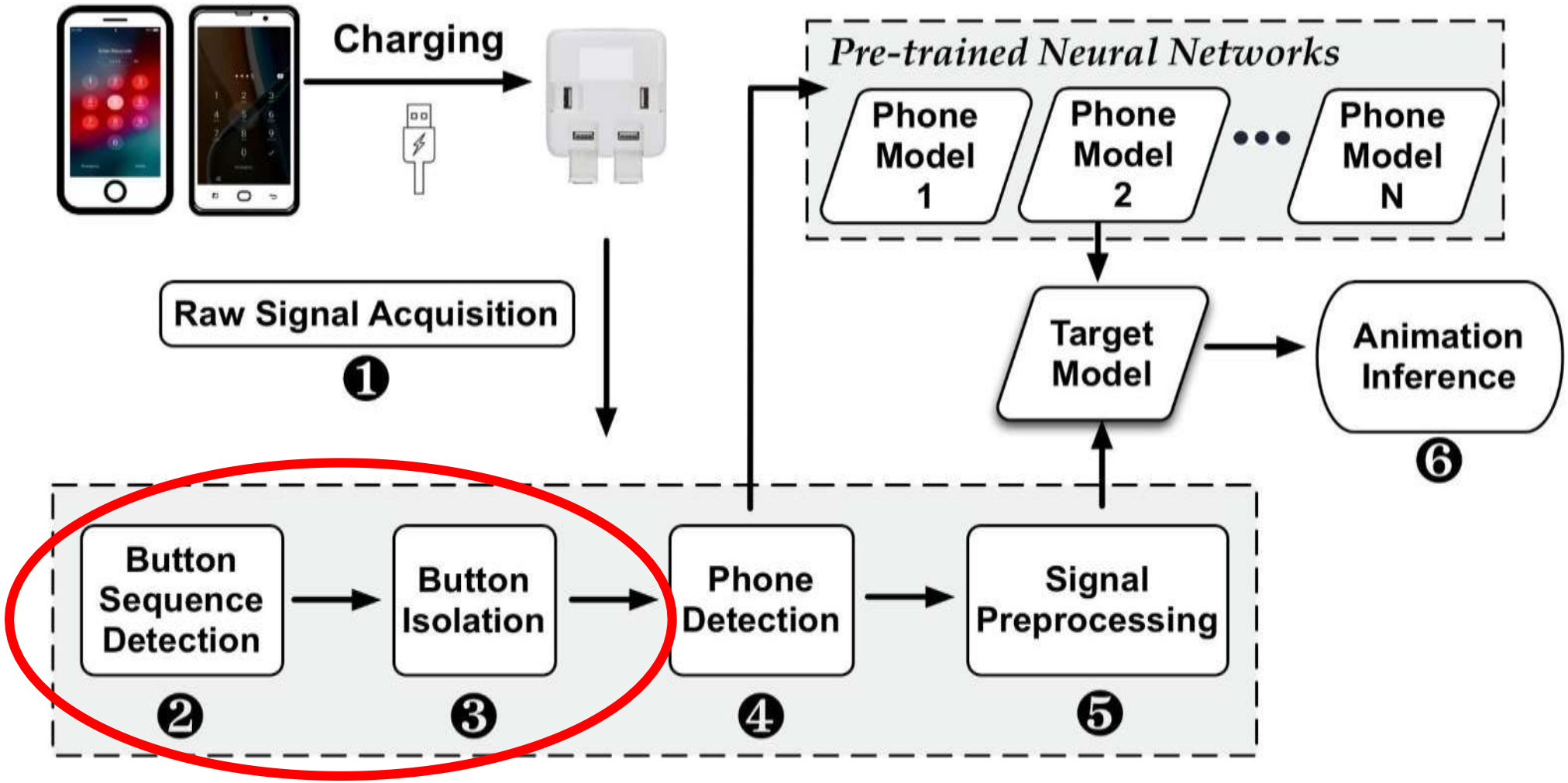


Raw Signal Acquisition

- Oscilloscope / Other Voltage Monitor
- Small resistor inserted into charging cable or circuitry

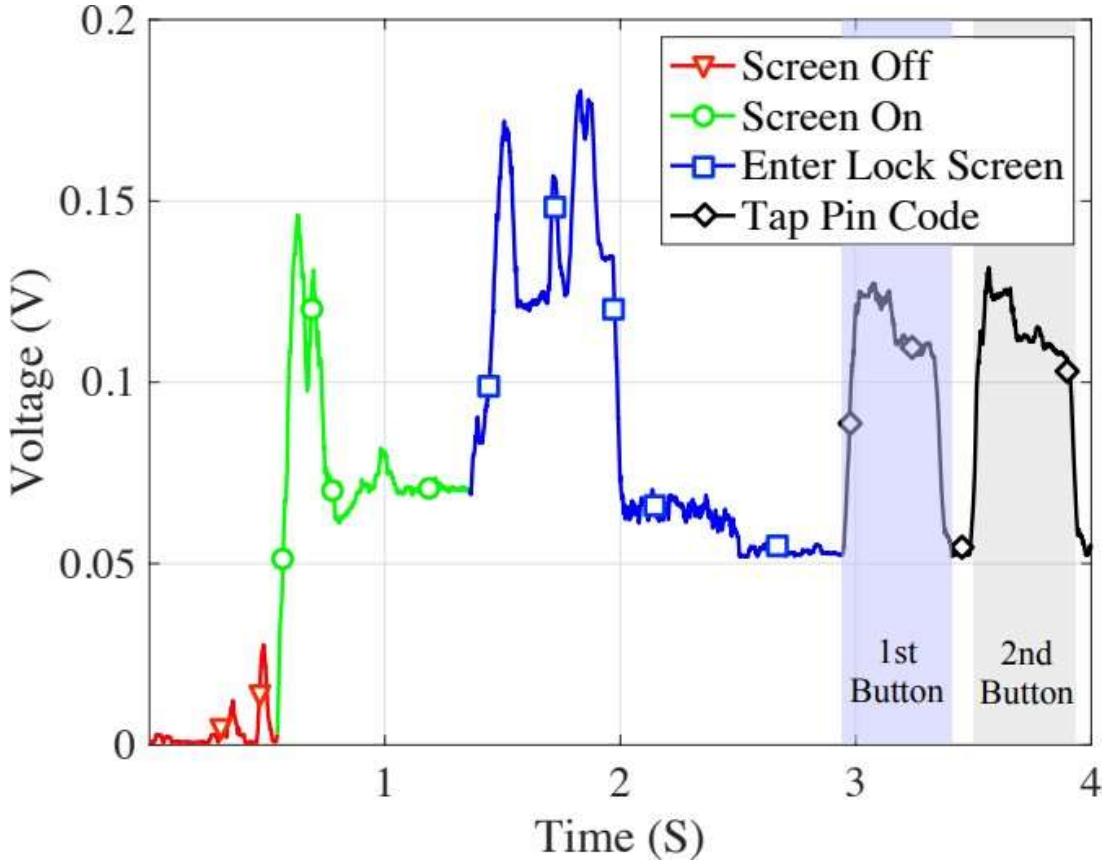


System Design



Detecting Events

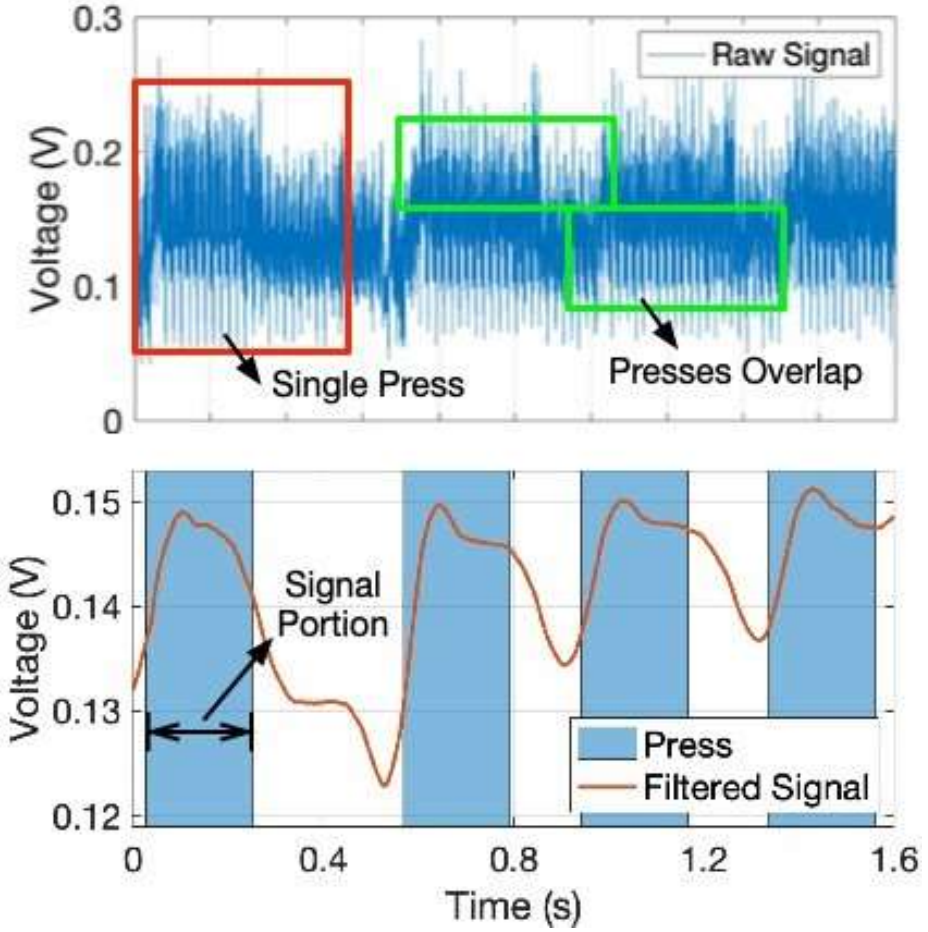
- Different states of the phone screen are observable via just the power trace



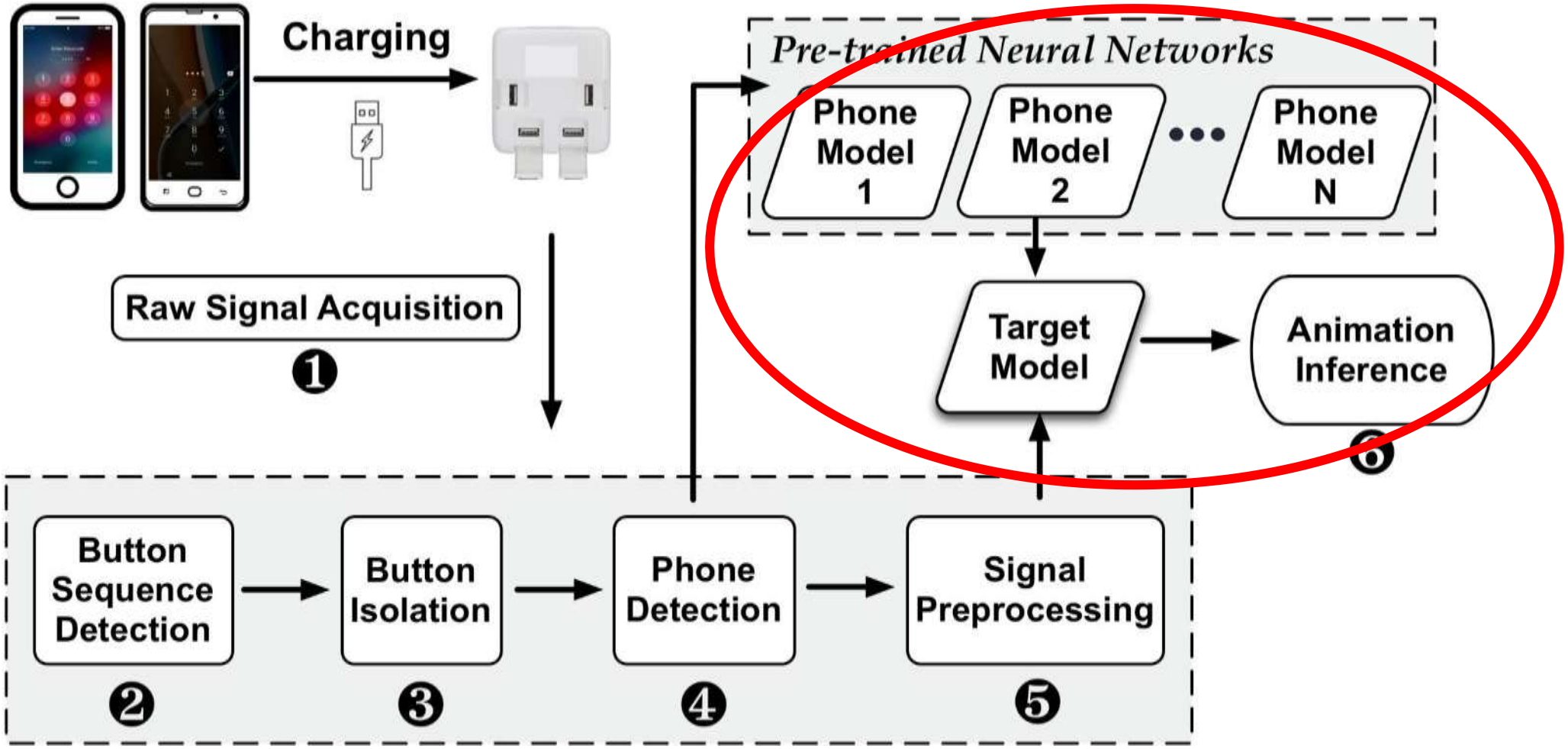
Smoothed Power Trace of Phone Unlock

Preprocessing

- Presses can overlap
- Signal smoothing clearly shows button press actions
- Signal thresholding allows for extraction of each press



System Design



Experimental Goals

- Two goals
  - Demonstrate effectiveness of Charger-Surfing across a wide range of phones with multiple users
  - Demonstrate the transferability of Charger-Surfing across phones of the same model and in a wide range of situations

Broad Analysis
- 4 Different Phones
- Feasibility
- Passcode Inference
- Practicality
- 15 Different Users

Detailed Analysis
- Cross Device Testing
- Configuration Testing
- Defenses
- 33 users

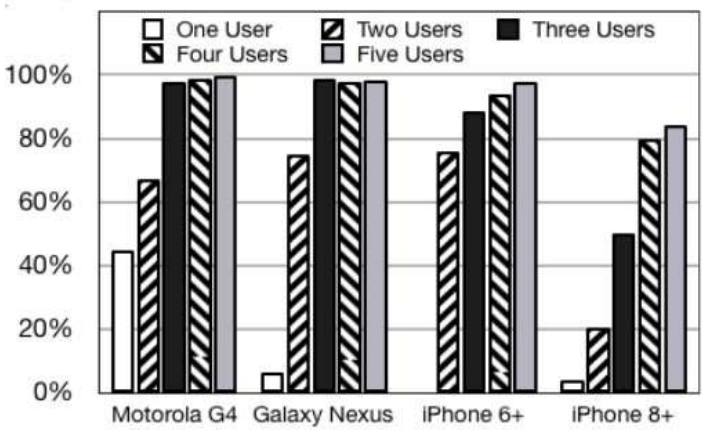
Broad Analysis

- Vary the number of training users
- Diminishing returns as more users are added
- 98.7% accuracy with 5 training users
- Variations in the way users tap the screen lead to the necessity of more training users

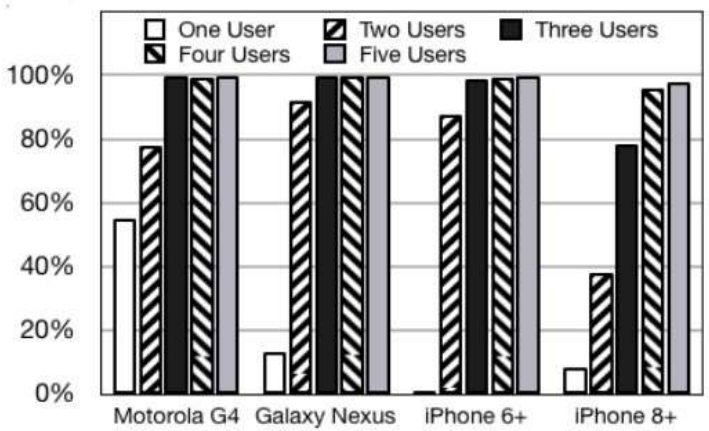
# of Training Users	Phone			
	Motorola G4	Galaxy Nexus	iPhone 6+	iPhone 8+
1	82.0%	50.0%	23.8%	44.6%
2	90.0%	95.0%	93.3%	67.1%
3	99.6%	99.1%	96.9%	88.7%
4	99.7%	99.4%	98.5%	94.5%
5	99.9%	99.6%	99.5%	95.8%

4-Digit Passcode Inference

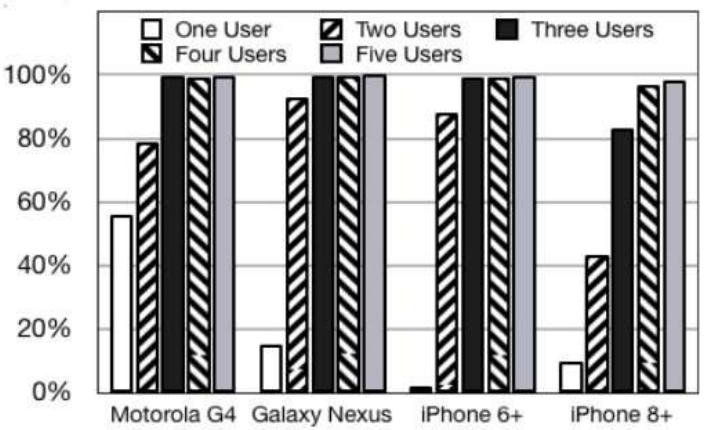
- Examine accuracy across multiple button presses and guesses
- 95.1% success on the first attempt and 99.5% success on the tenth trial with five training users



(a) 1st Trial



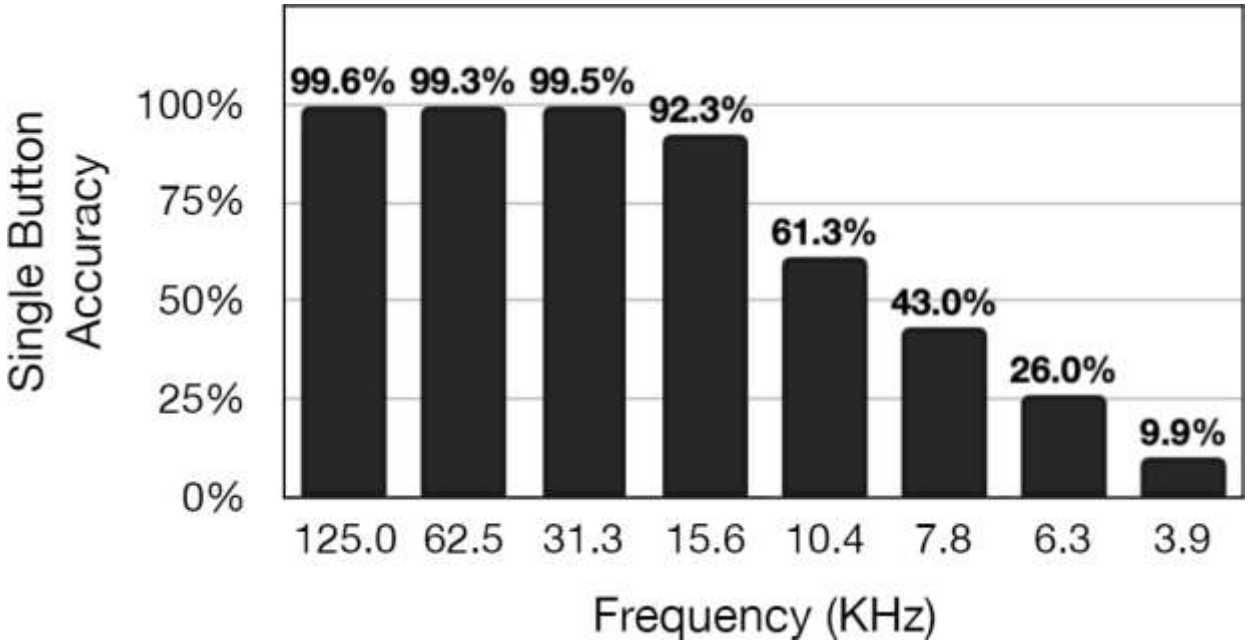
(b) 5th Trial



(c) 10th Trial

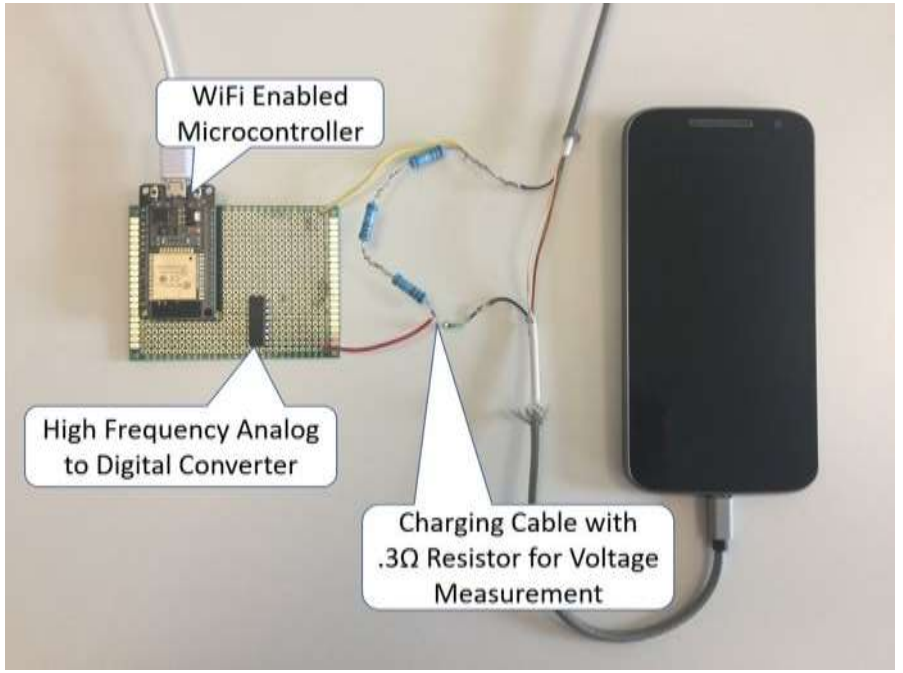
Feasibility Analysis

- Expensive and impractical to use an oscilloscope!
- Sampling frequency can determine practicality of attack
- Minimal accuracy loss with sampling frequency above 31.3KHz



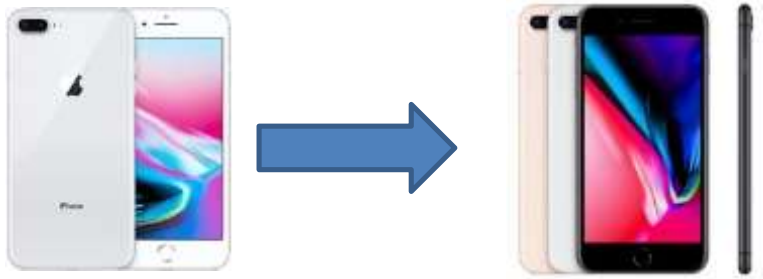
Low Cost Attack

- ESP32 WiFi/Bluetooth enabled Microcontroller
- Analog Devices AD7813 Analog to Digital Converter
- Cost < $20



Detailed Analysis

- Able to attack users on different phones
- Able to attack users with different settings
  - Brightness
  - Wallpaper
  - Haptics
  - Charge levels
- Defenses?



Cross Device Experiments

- Attacker won't have access to victim's phone beforehand!

Train on one phone

Attack different phone?

Cross Device Results

- Minimal accuracy loss when trained on one device and tested on different device

Attempt	Single Button Press
1	99.1%
2	99.4%
3	99.4%

Trial	Passcode	
	4-Digit	6-Digit
1	96.5%	94.6%
5	97.4%	95.6%
10	97.4%	96.2%

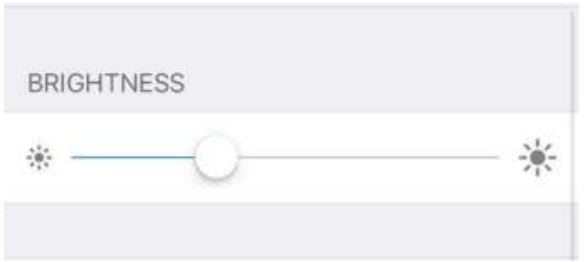
iPhone 6+

Attempt	Single Button Press
1	99.7%
2	99.8%
3	99.8%

Trial	Passcode	
	4-Digit	6-Digit
1	99.0%	98.6%
5	99.1%	98.6%
10	99.1%	98.7%

iPhone 8+

Attack Effectiveness

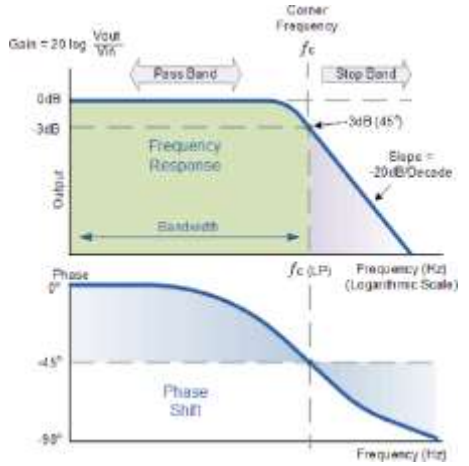


- Minimal impact of differing phone conditions!

Configuration	Static Wallpaper		Brightness			Charge	Haptics
	1	2	0%	50%	100%		
Accuracy (1st Attempt)	99.3%	98.0%	98.0%	97.3%	100%	99.2%	100%

Countermeasures?

- Can Charger-Surfing be defended against?
  - Add noise?
    - Live Wallpaper
  - Filter power output?
    - Power Filter



Thank You!