CPM Test Limitation Study for AC, Pulsed AC and High Frequency AC Ionizers vs. DC based Ionizers

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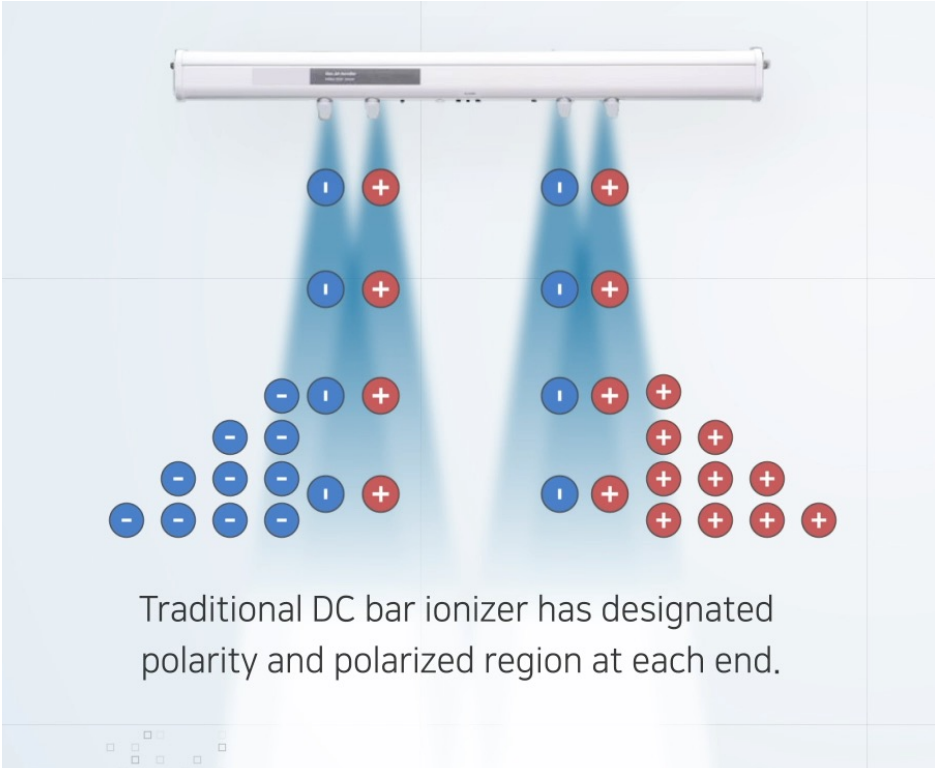
CORE INSIGHT, INC.

Objectives

- **Technical limitation with current charge plate monitor (CPM) technologies** for switching high voltage type of ionizers such as AC, pulsed AC and high frequency AC ionizers.
- Technical limitation is mainly related with **response speed of CPM instruments and portable testing kits** for ionizer balance measurement.
- ANSI/ESD S20.20 and STM 3.1 guide to measure **offset value of ionizer for balance** and this can't be achieve **switching high voltage type of AC ionizers**.
- This study found that **peak value** should be record for all ionizer balance measurement rather than offset value and current CPM technologies are limited due to speed response of CPM instrument

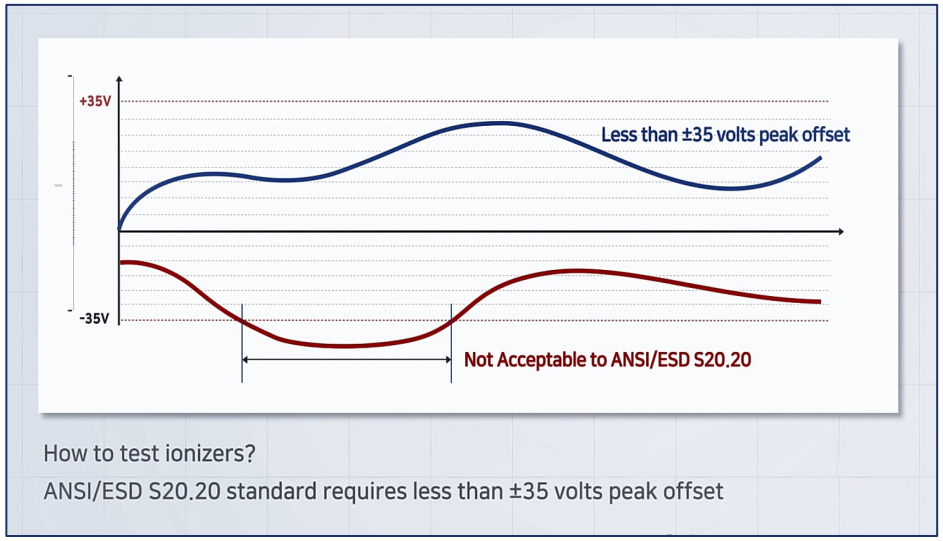
Pulsed AC Bar Ionizer

- Over a decade ago, DC type of ionizer adopted in FPD processes and found **ESD damage occurs** by ionizers due to polarization effect.
- Thus, Switching High Voltage Alternating Current (AC) ionizer developed and used in FPD environment for uniform neutralization to minimize **Electrostatic Attraction (ESA)** issue.

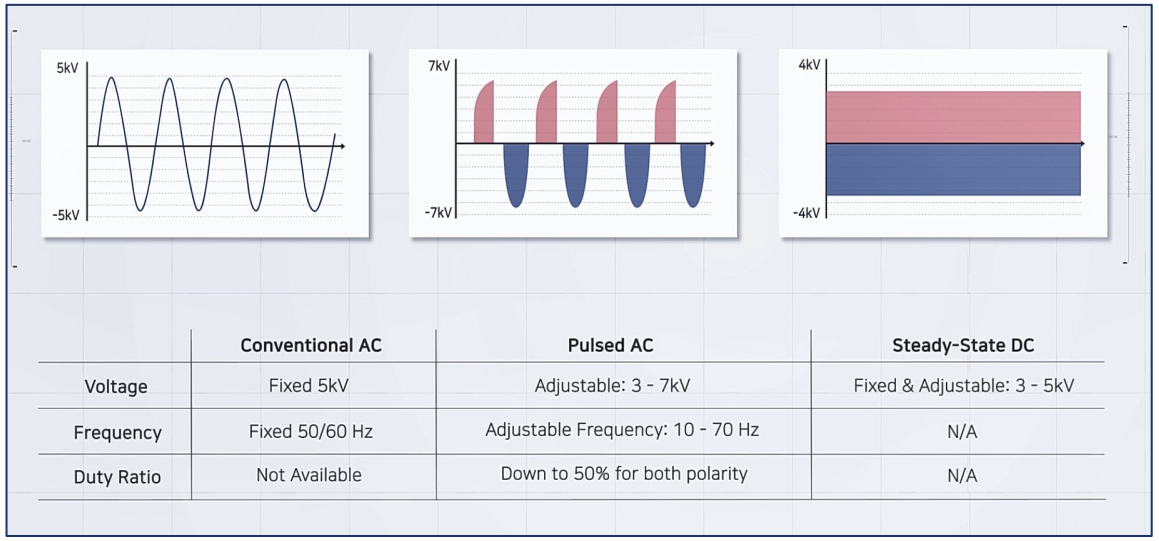


Ionization Technology Overview

- **ANSI/ESD S20.20-2021** (and **IEC 61340-5-1**) has updated ionizer balance should be maintain **peak offset voltage** less than ±35 volts.
- AC ionizer using high voltage AC sources which is **switching voltages** and give induction fields while it neutralizing targets.
- On the contrary, DC ionizer **do not use switching technique** and applied constant DC high voltages on emitter points. Built-in balance circuit inside of power supplies or external feedback sensor can maintains low peak offset voltage of DC ionizers.



ANSI/ESD S20.20-2021 Table 3. Ionization Requirement

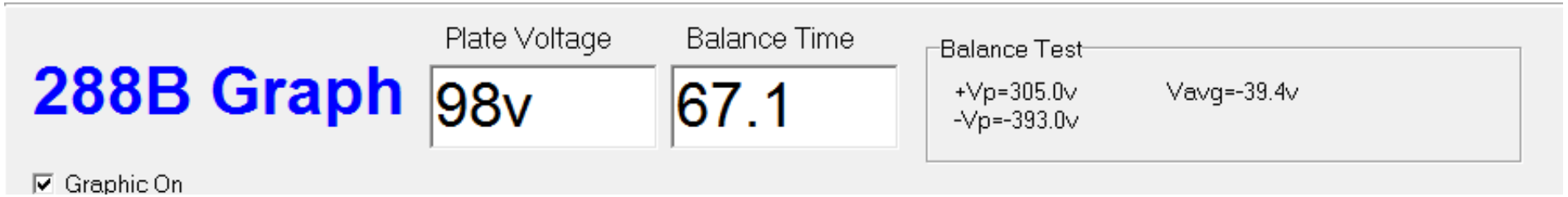


	Conventional AC	Pulsed AC	Steady-State DC
Voltage	Fixed 5kV	Adjustable: 3 - 7kV	Fixed & Adjustable: 3 - 5kV
Frequency	Fixed 50/60 Hz	Adjustable Frequency: 10 - 70 Hz	N/A
Duty Ratio	Not Available	Down to 50% for both polarity	N/A

Ionization Technology Comparison for AC, Pulsed AC and DC ionizers

CPM Instruments Specification Review

- Most of CPM operating speed is quite slow around **10Hz** for full scale of 2000Vp-p
- Fast operation speed of CPM is **1kHz** for small signal which is **20Vp-p only**
- There are several type of AC switching high voltage ionizers operating 10 Hz to 70 kHz



Model #	Speed of Response	Accuracy	Manufacturer
Model 300	6 Hz	2%	Monroe
Model 288	1 kHz 20 Vp-p 10 Hz 2000 Vp-p	0.1% (-3dB)	Monroe
Model 156A/1	1 kHz 20 Vp-p 10 Hz 2000 Vp-p	0.1% (-3dB)	Trek
Model 157	80 Hz	1% (-3dB)	Trek

CPM Limitation and Issues

- Charge Plate Monitor (CPM) has developed to measure ionizer performance comparison using with **chopper stabilized sensor** of a fieldmeter which response speed is 10Hz.
- 6x6 inch plate selected as standard measurement and this intended to measure discharge time estimation for **6-inch wafer** which is 20pF capacitance
- In the early 1990s, the **voltage following technique** was introduced as in Figure 2.

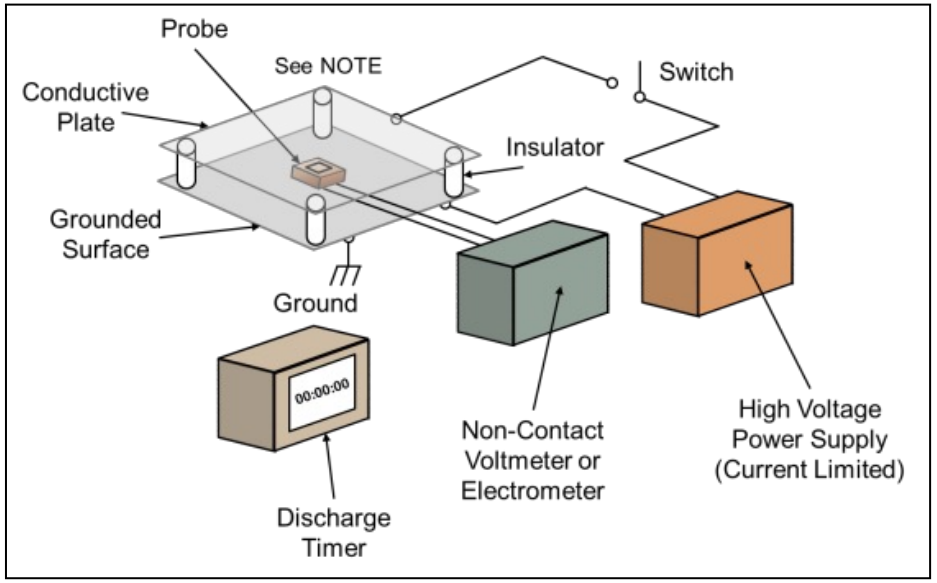


Figure 1 - Fieldmeter Based CPM Plate Structure

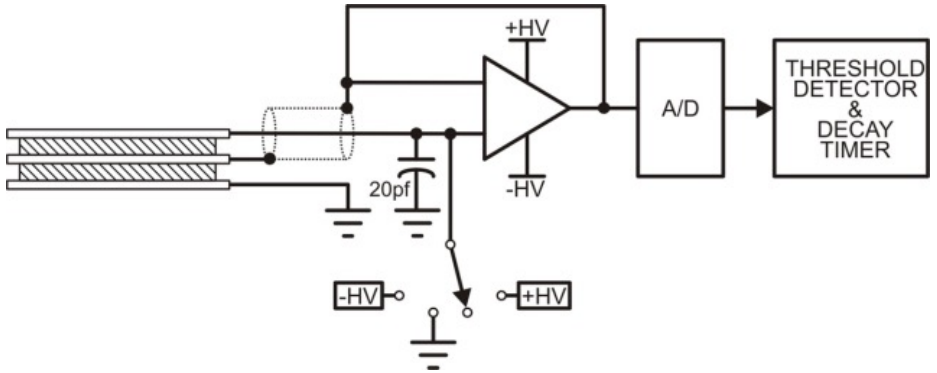


Figure 2 - Voltage Following Technique CPM

CPM Limitation and Issues

- This voltage following technique used same CPM plate size 6x6 inch plate with **wire connection to meter** and claimed to match **20pF capacitance in circuit at activated mode**
- Both technique CPM instruments have limits. Typically, these limits are a maximum of **DC to 10Hz at 2000Vp-p** and **DC to 1kHz at 20Vp-p**. Some instruments have claimed response speed at **DC to 80Hz at -3dB**.
- Thus, it is limited to accurate measurement for AC signal as shown in Figure 3.

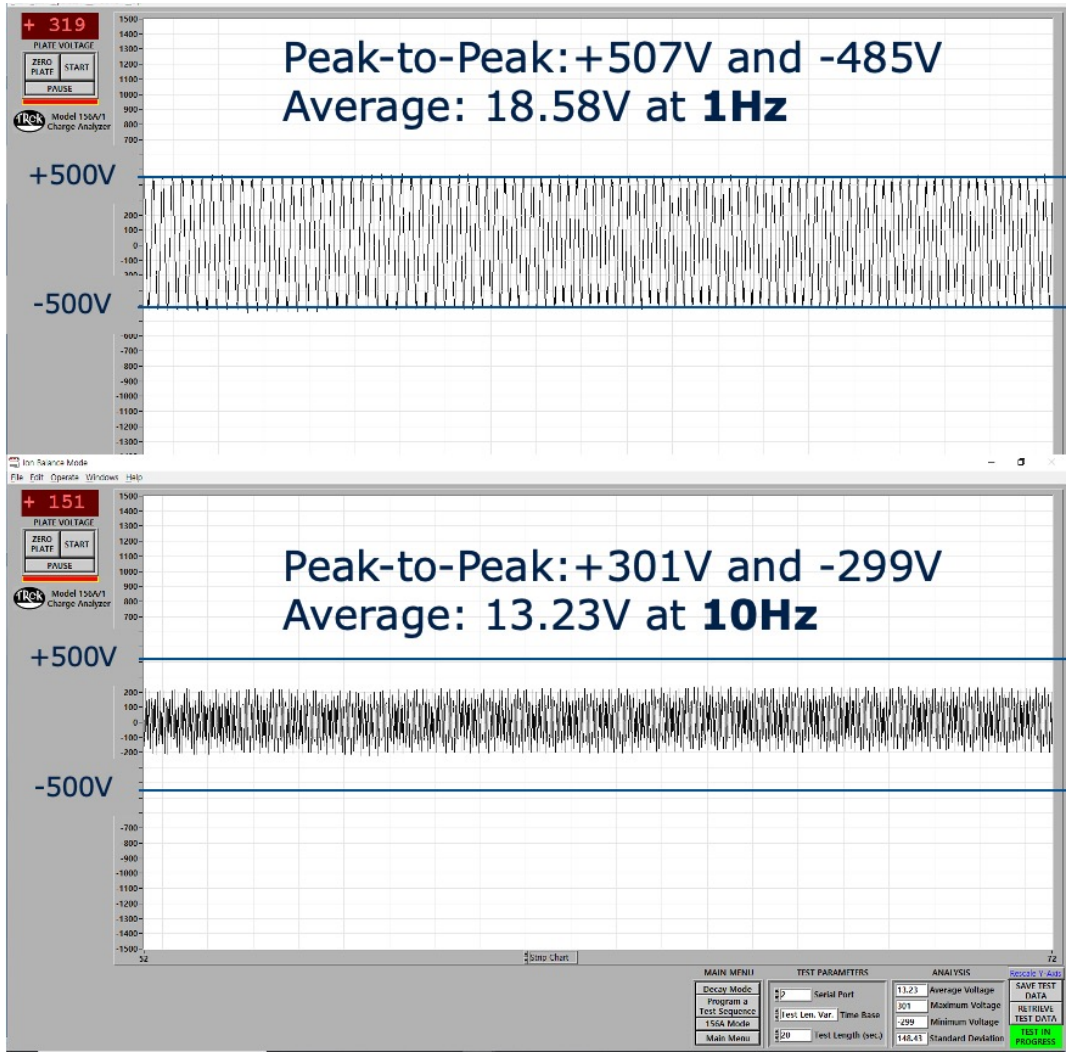


Figure 3 - CPM Measurement Example of AC High Voltage

CPM Limitation and Issues

- Plate Size
  - 6x6” CPM plate vs. 1x1” CPM plate offset voltage reading are not the same due to total capacitance has set by internal circuit does not match to 20pF with 1” plate
- If we using smaller plate which means **smaller capacitance** than 20pF, we could measure higher offset voltage from exact same ionizer with this technology of CPM instruments follows by Coulomb’s Law. **V = Q/C**
- SP3.4 document designed for periodic verification, and this could be an issue

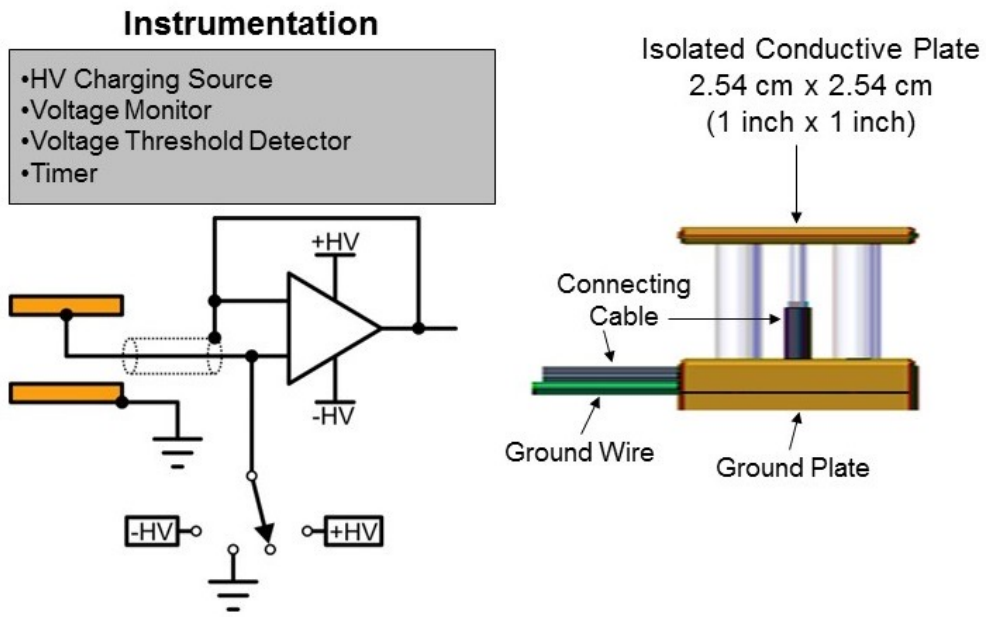
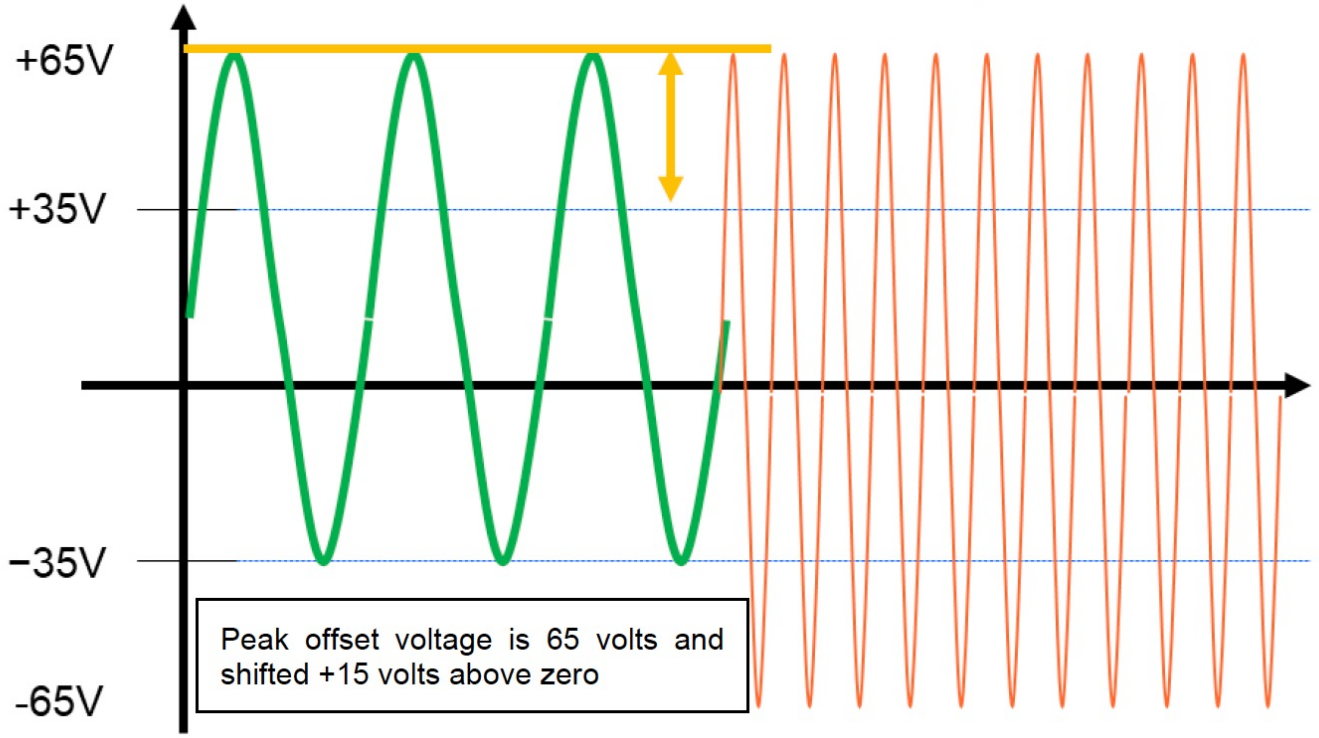


Figure 4 - SP3.4 Small Plate Fixture

ANSI/ESD STM3.1-2022 Revision

- **ANSI/ESD STM3.1-2022** Revision has updated and added new **ANNEX C**.
- Annex C (Informative) - Balance Measurement Limitation of Current CPM Technology
- ESD Stress Testing for HBM and CDM are conducted in both polarity: **Positive and Negative in DC mode**. If we are using AC ionizers, how this impact to our ESD control?

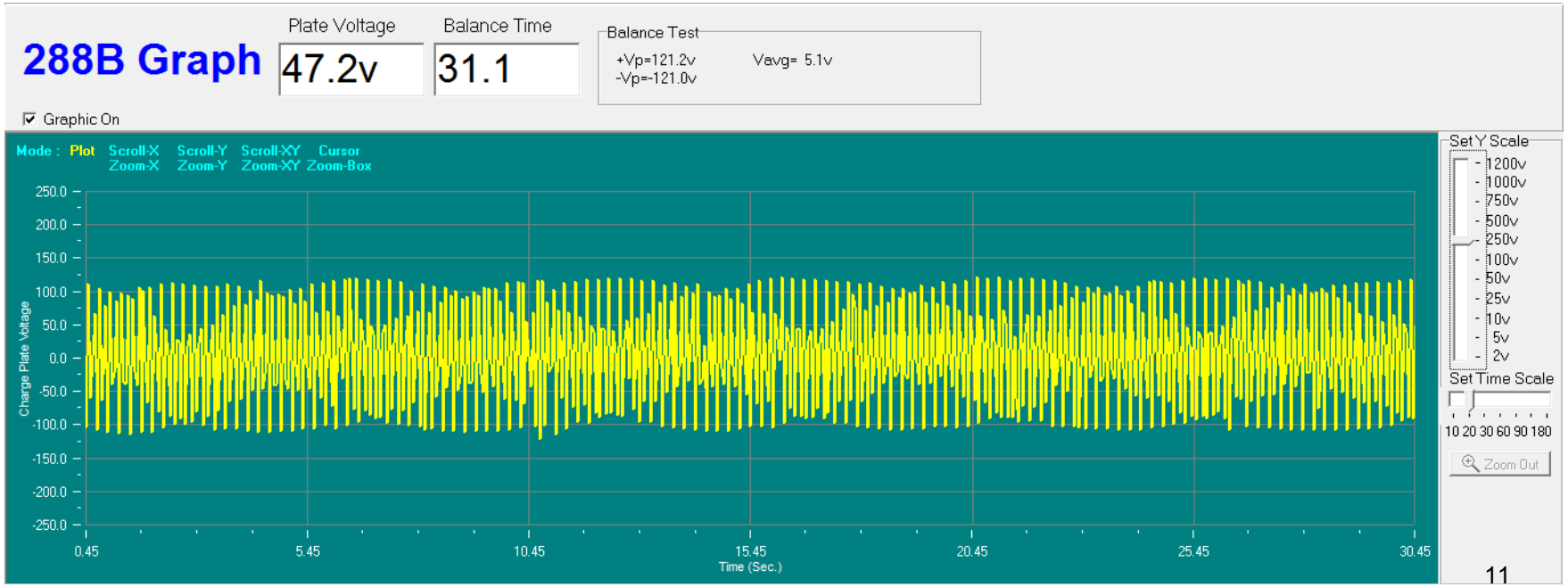


CPM Measurement Examples

- Changed CPM speed up to 10Hz Full scale and 1kHz 20Vp-p
- **Ionizer Output**: 5.5kV Pos. and 4.8kV Neg. with **12Hz** as first test
- The peak-to-peak value greater than 6Hz CPM measurement
- **Min (V) = -393V, Max (V) = +305V**, Ave (V) = -39.4V
- Then, which number we should pick for balance in this result?

CPM Measurement Examples

- Then, changed output frequency of ionizer at 30Hz as same as second test. It shows peak voltage drops with all same output parameters.
- CPM Speed of Response: 10Hz Full / 1kHz 20Vp-p
- **Ionizer Output**: 5.5kV Pos. and 4.8kV Neg. with **30Hz**
- The peak-to-peak value significantly reduced measured than 12Hz
- **Min (V) = -121V, Max (V) = +121V**, Ave (V) = 5.1V

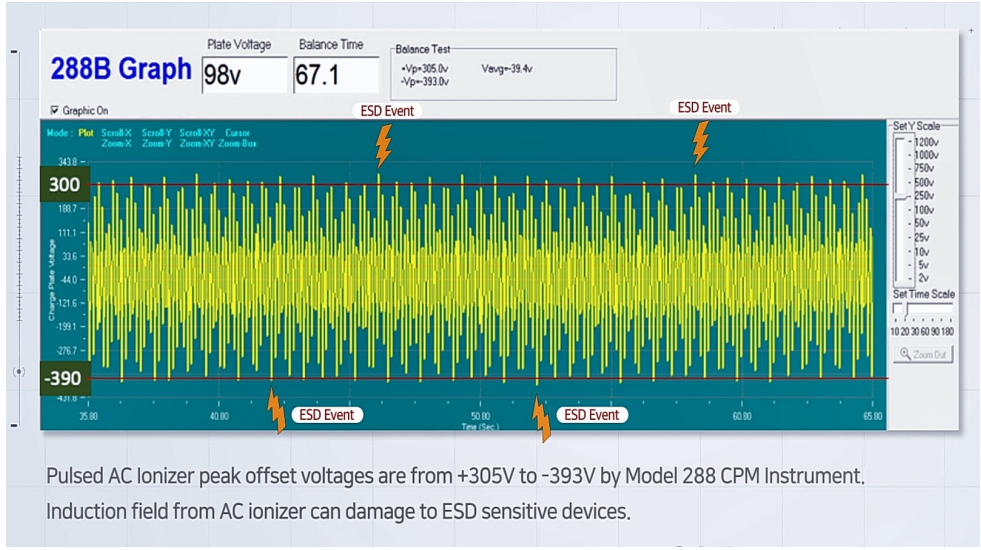



SIB7 Ion Bar
SUNJE
F - 10
288B Graph
0.7v
6.0
https://youtu.be/7hhVCPpSv1o
CHARGE PLATE MONITOR
MONROE ELECTRONICS
732
DELL
INSPIRON

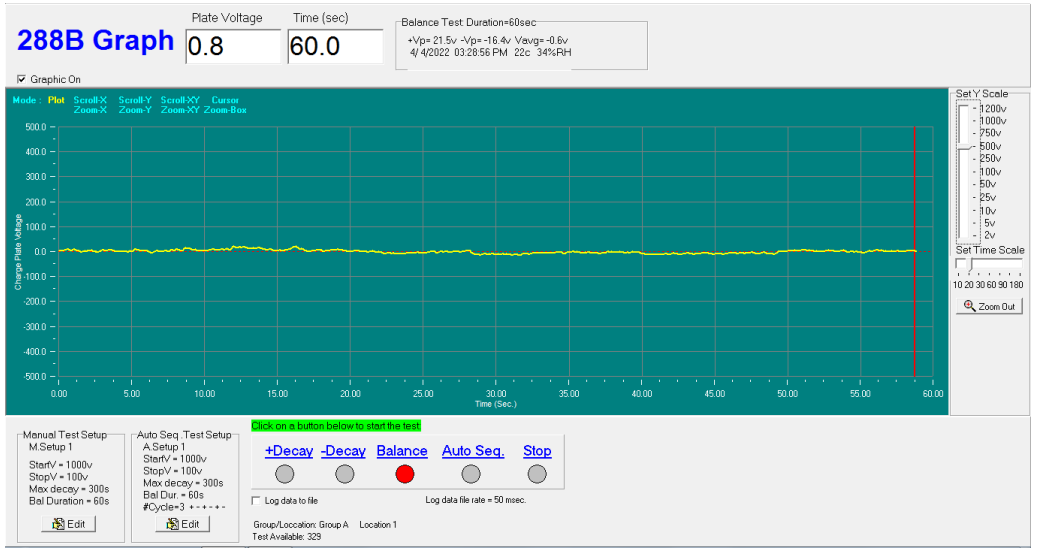

Model 7380d
Steady-State DC Air Assist Bar Ionizer
CORE INSIGHT
Model 7110
288B Graph
-5.5v
0.8
https://youtu.be/aJYCFu7Mg9U
CHARGE PLATE MONITOR
MONROE ELECTRONICS
DELL
INSPIRON

Comparison Test Results: AC vs. DC Ionizers

- Actual AC/Pulsed AC ionizer measurements shows this switching induction fields and this led to ESD events could occurs to devices.
- Steady-State DC ionizer measurements shows much different and maintain low peak offset voltage less than ±25 volts.
- Steady-State DC ionizer is the only available corona discharge ionization technology that can be fully compliance to ANSI/ESD S20.20 program and safe handling devices from CDM ESD risks.



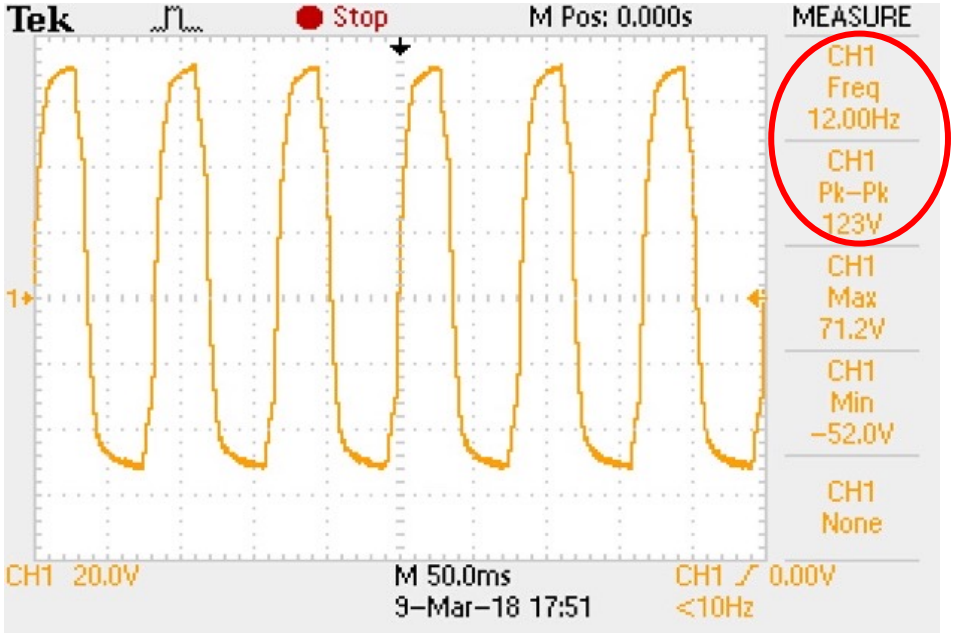
Actual ion balance measurements of AC/Pulsed AC ionizers and peak offset voltages was **-393 volts.**

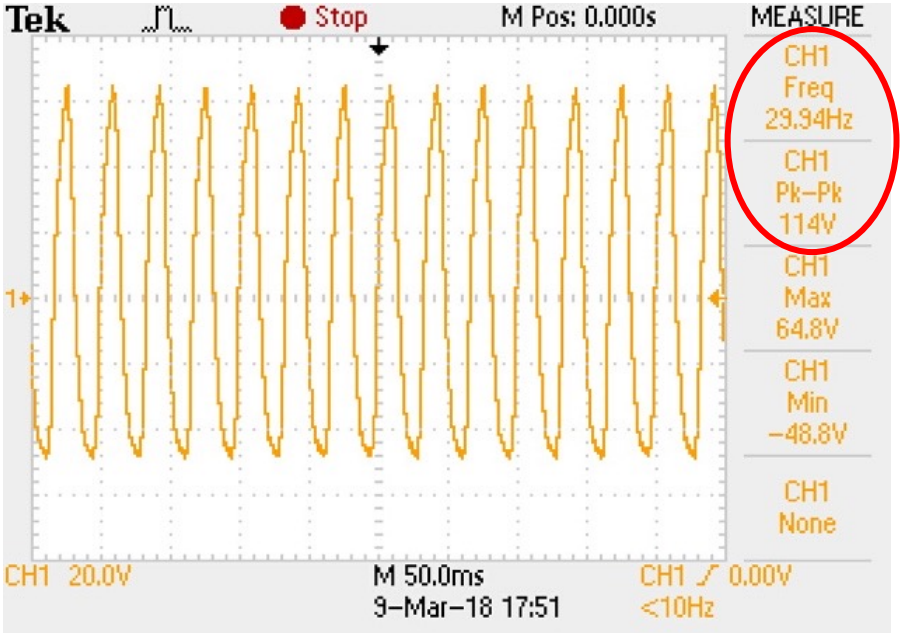


Actual ion balance measurements of Steady-State DC ionizers and peak offset voltages was **+17 volts.**

Actual Voltage Measurement Experiments

- So, it is important to make sure the real high voltage on emitter points and their voltage drop ratio based on frequency changes of ionizers
- Using Tektronix TDS2022C oscilloscope and P6015A high voltage divider, measurement results shows the output high voltage from ionizer slightly drops from **12.3 kVp-p** to **11.4 kVp-p** (7%) when switching frequencies from 12Hz to 30Hz.



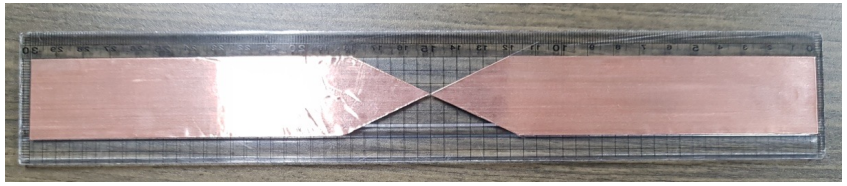


Conclusion - Cont.

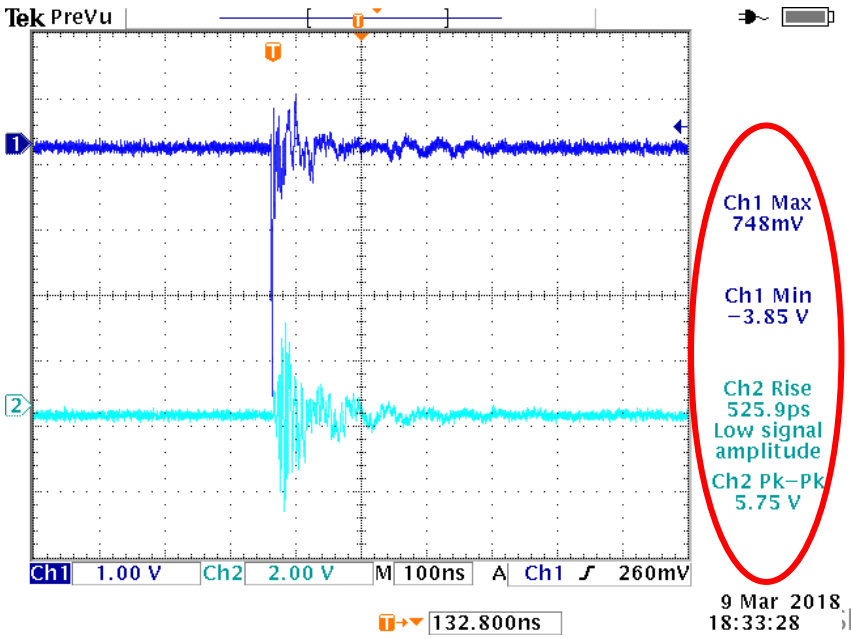
- Various type of ionizers are installed and operate at short distance from ESD sensitive devices such as inside of process equipment and automated handlers.
- All experiments demonstrate that **current CPM technology** is suitable for **DC based ionizers** and relatively slow **pulsed DC ionizers**.
- Current CPM technology is **limited to evaluate performance and accurate measurement** of switching high voltage ionizers such as **AC, pulsed AC and high frequency AC ionizers**

Discharge Current Measurement

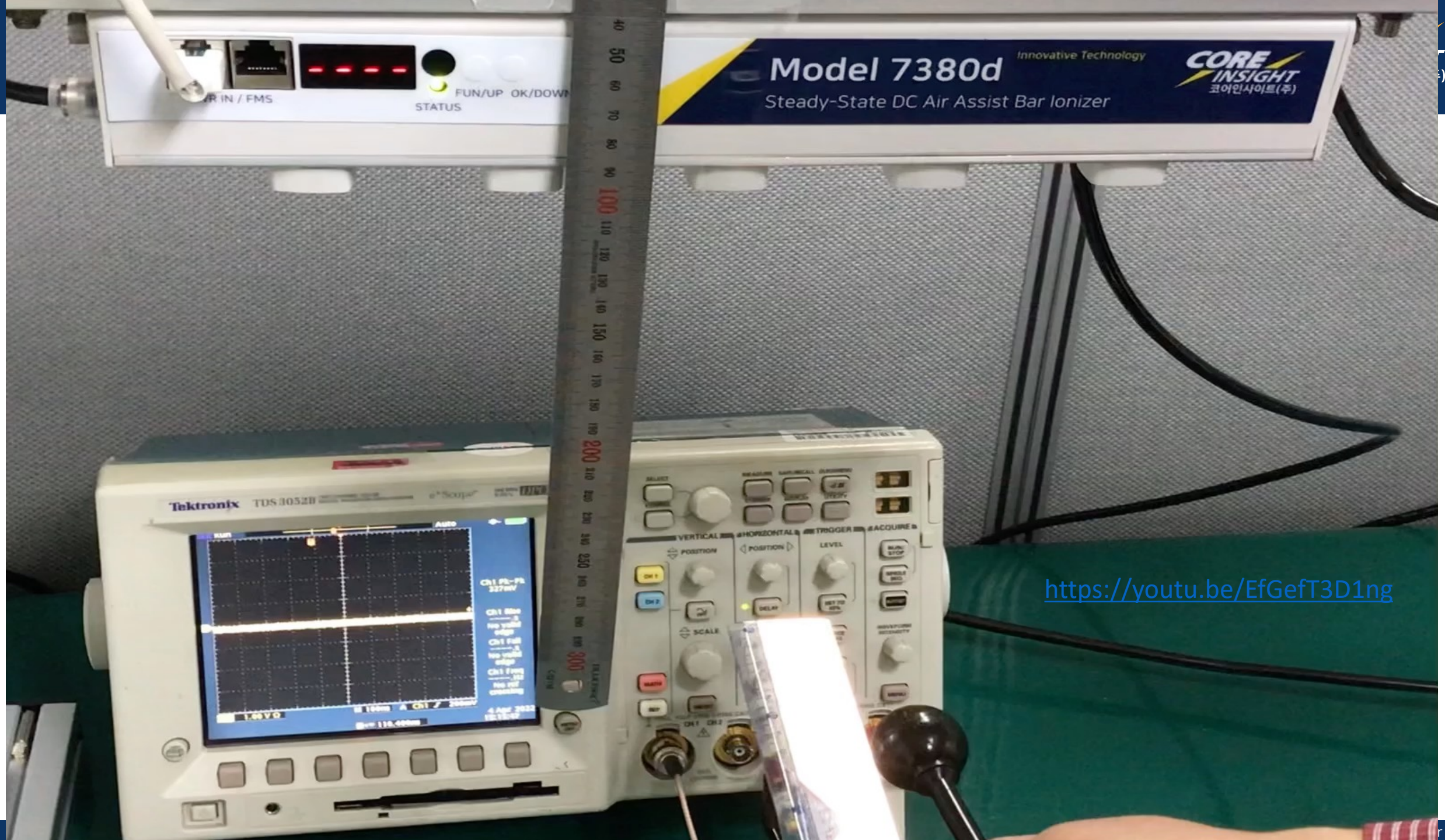
- For ESD event measurement, copper taped insulator with micro gap apparatus prepared. CT-1 probe soldered one side to ground with TDS 3052B (500MHz) scope to measured discharge current.
- This test apparatus placed at 200mm distance from air assist ionizers and start ESD discharge current measurement
- 2GHz RF Antenna also located at 1m distance from ionizers to detect ESD event signature
- **Discharge Current** measured very high current over **770mA** through this test apparatus.
- At the same time, **RF noise detected 5.75V** peak-peak at 1 meter distance from ionizer as ESD event signature with short time delay



D.C. Smith, System Level ESD/EMI

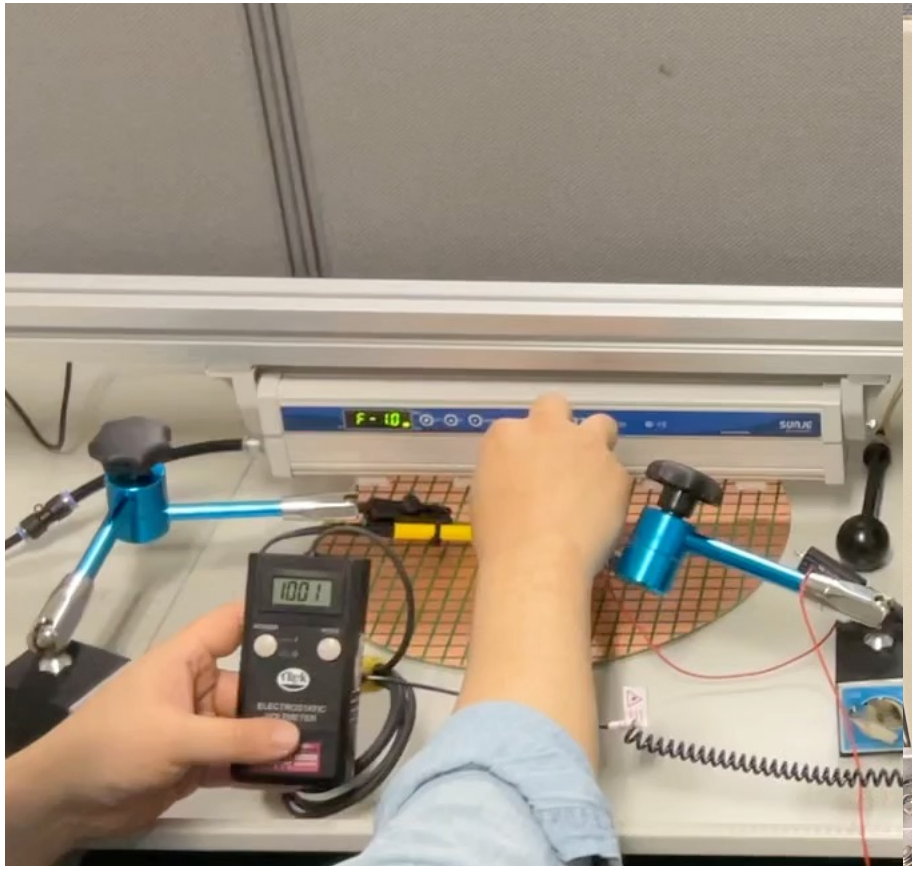


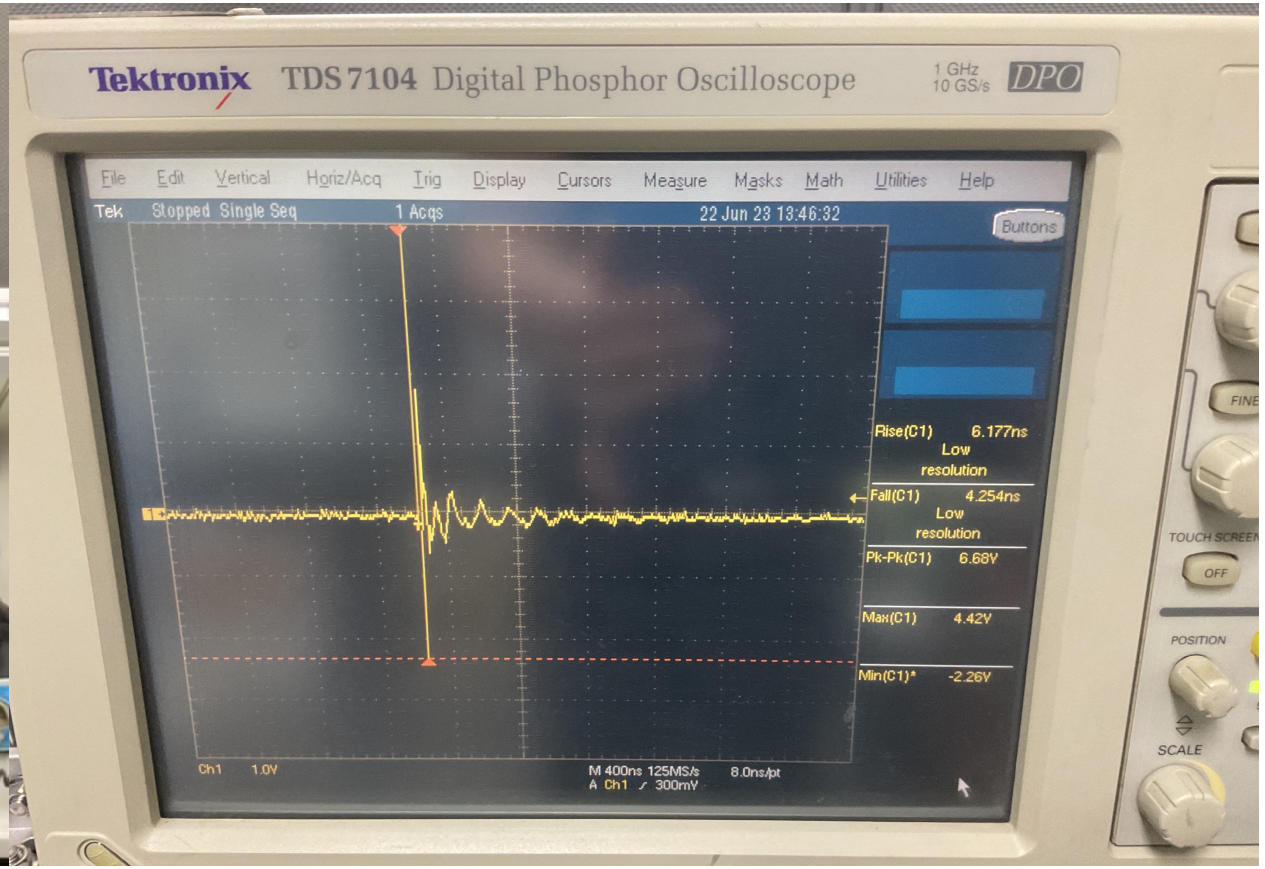

CORE INSIGHT
SIB7 Ion Bar
SUNJE
Tektronix TDS 3052B
https://youtu.be/KfcTGRh0h0I


Model 7380d
Innovative Technology
Steady-State DC Air Assist Bar Ionizer
CORE INSIGHT
코어인사이트(주)
STATUS
FUN/UP OK/DOWN
Tektronix TDS 3052B
https://youtu.be/EfGefT3D1ng

Discharge Current Measurement

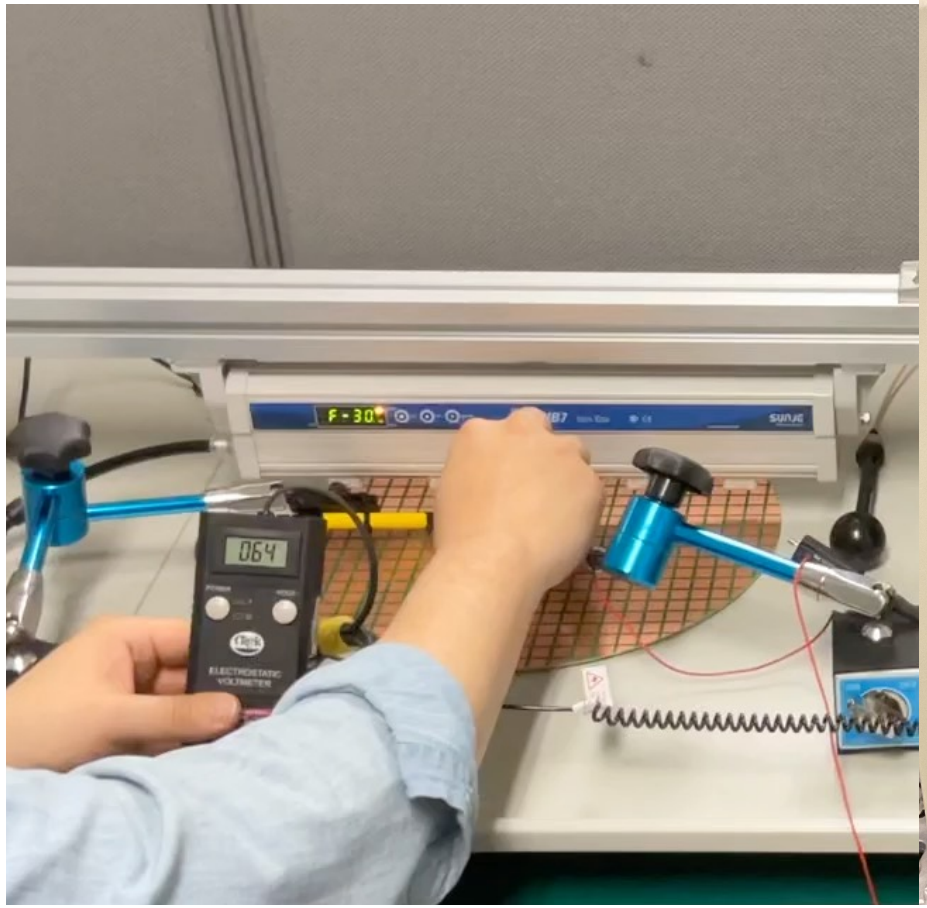
- Pulsed AC Bar Ionizer
- Discharge Current via CT-1 current probe for both bar ionizers at 1-inch distance emitter point to PCB wafer when Pulsed AC Bar Ionizer operates at 10 Hz. **880.4mA**

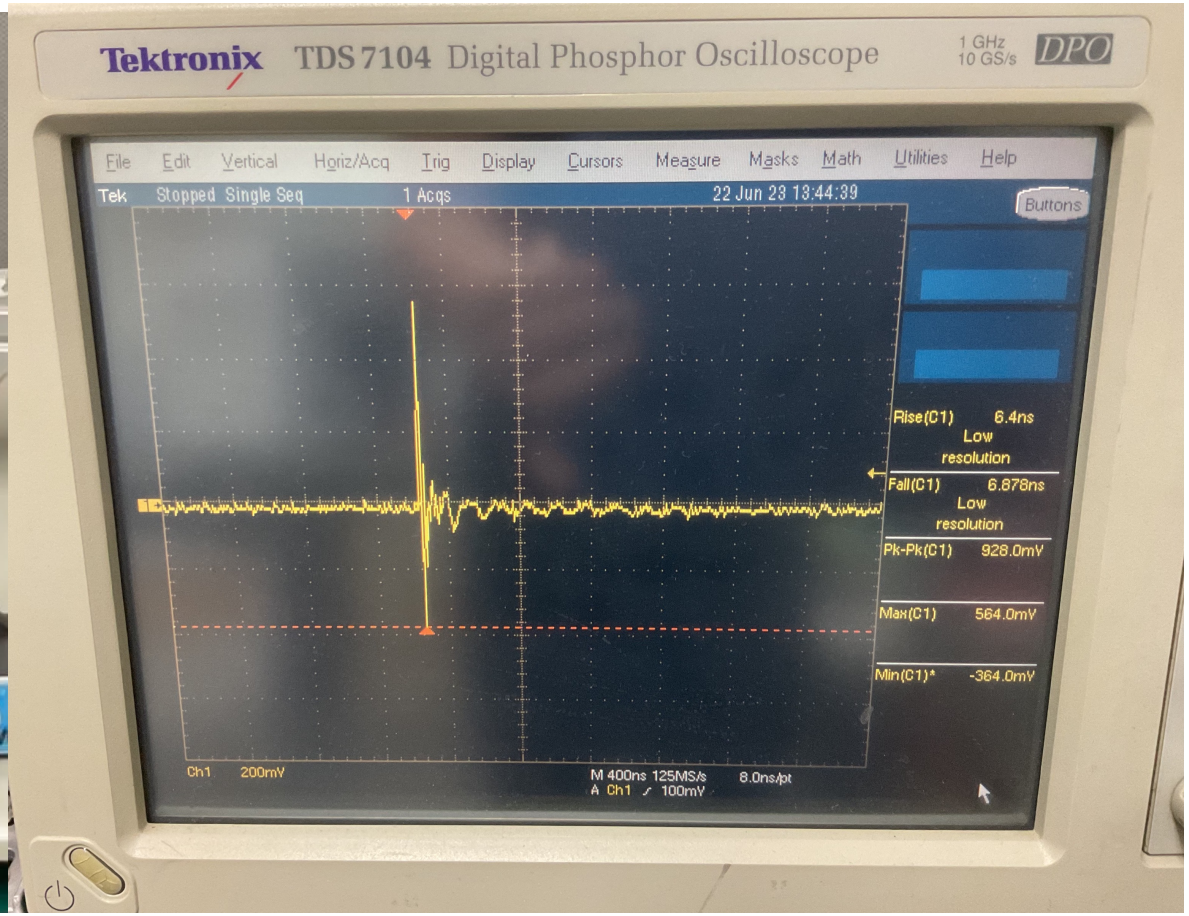




Discharge Current Measurement

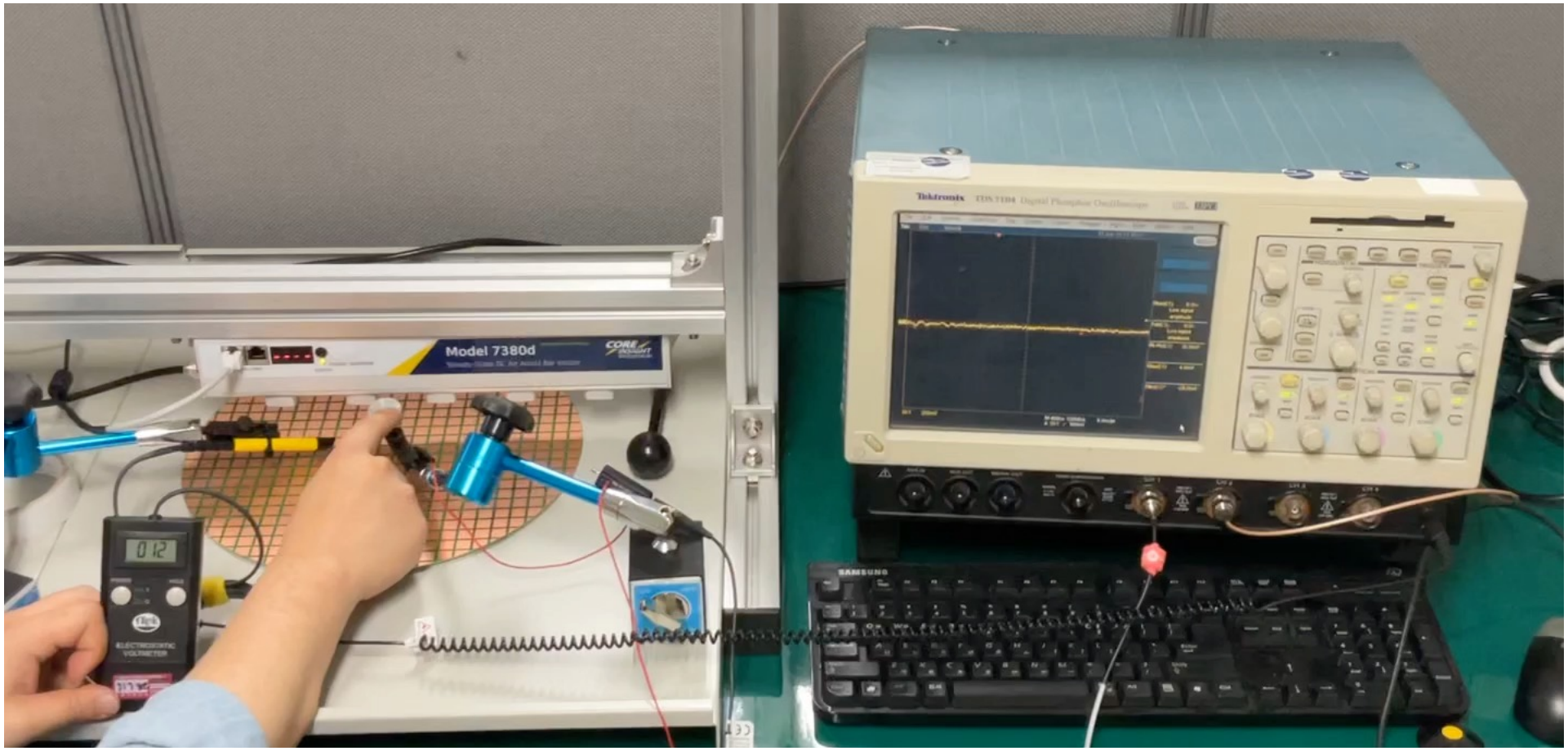
- Pulsed AC Bar Ionizer
- Discharge Current via CT-1 current probe for both bar ionizers at 1-inch distance emitter point to PCB wafer when Pulsed AC Bar Ionizer operates at 30 & 100 Hz. **112 mA**





Discharge Current Measurement

- Steady-State DC Bar Ionizer (Core Insight)
- Discharge Current via CT-1 current probe for both bar ionizers at 1-inch distance emitter point to PCB wafer and no discharge observed.



Discharge Current Measurement with IC and PCB Handling

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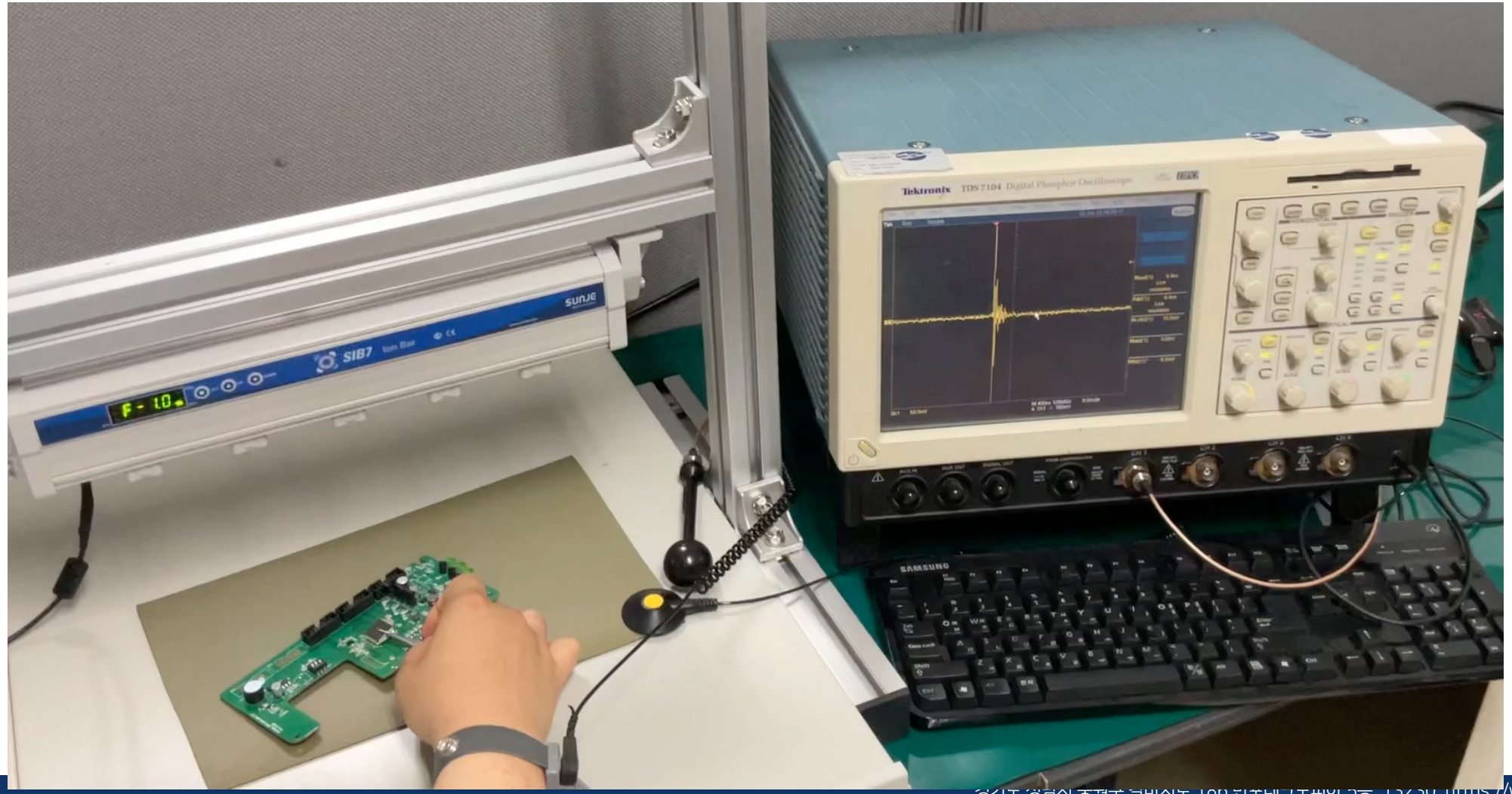
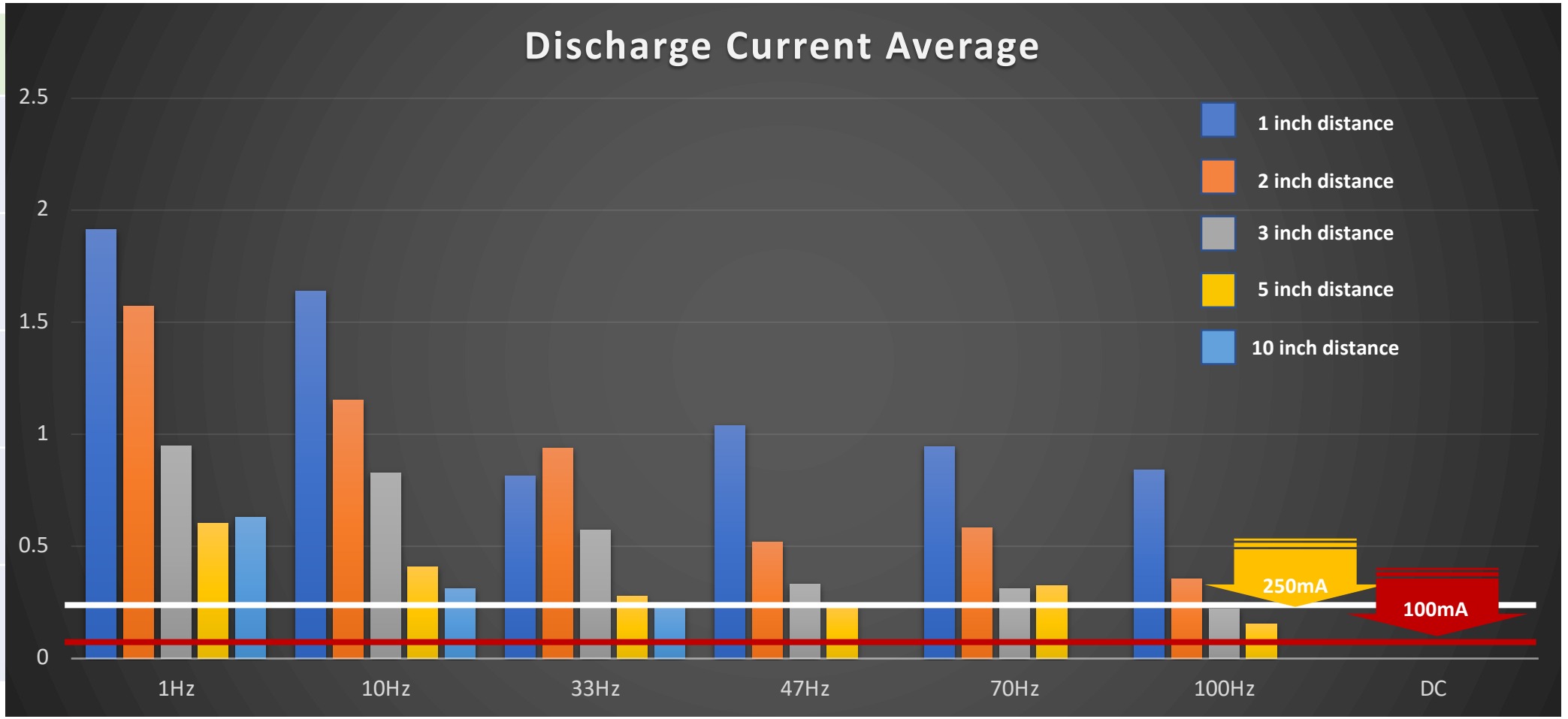
코어인사이트(주)

- Pulsed AC Bar Ionizer placed about 150 - 200mm distance
- ESD event occurs when IC has placed on Printed Circuit Board



Discharge Current Measurement

- Pulsed AC Bar Ionizer (Japanese) vs. Steady-State DC Bar Ionizer (Core Insight)
- Discharge Current (CT-1 Probe by Tektronix) Average Data



Alternative Measurement Test Experiment

- High-Speed Oscilloscope Setup
  - Tektronix TDS 3052B used for measurement
  - **Input Capacitance**: Varying by models and manufacturers. 13pF to 38pF or more.
  - **Input Impedance**: Most of high-speed oscilloscope have input impedance switching for 50 ohms or 1 megaohms. Select 1 megaohms for high voltage range measurement
  - **Reference DC power supply**: Model 812 from Electro-Tech Systems and display applied voltage level ±1000V
  - **Probe Setup**: Adjust probe gain ratio from 1X to 200X to match 1000V measurement to match reference DC power supply
  - 1Megaohm resistor attached between DC power supply and CPM plate

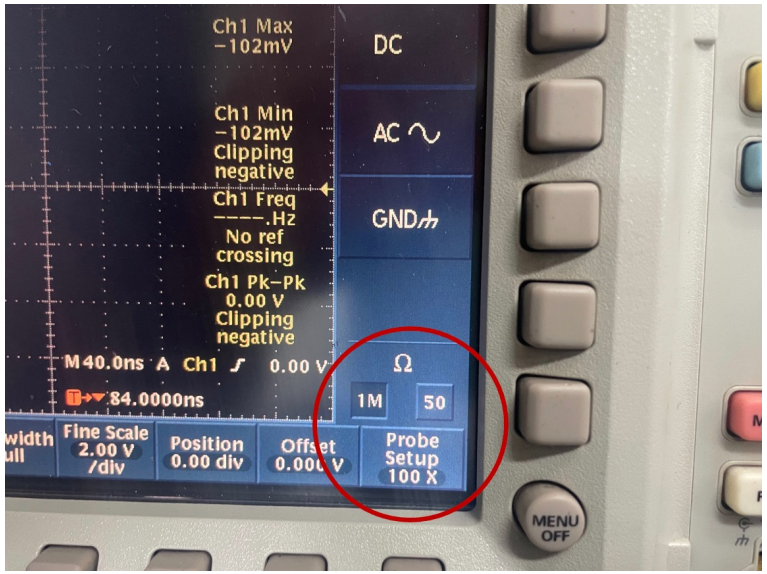


Figure 5 - Oscilloscope Input Parameters

Figure 6 - CPM Plate to Oscilloscope and DC high voltage source

Alternative Measurement Test Experiment

- DC High Voltage Reference Test
  - Monroe Electronics' Model 288 CPM has used as reference measurement compare with Oscilloscope measurement values
  - Applied +100V to Model 288 CPM and voltage readings are in accuracy and CPM plate to scope looks same
  - Various voltage applied to both system and test results in Table 1.
- AC High Voltage Reference Test
  - Trek's Model 10/10A high voltage amplifier and Tektronix's CFG 250 function generator used as AC source.
  - Applied 1000V with 815.4 Hz AC signal to CPM and Scope instrument setup and verified accurate readings in Figure 7.

Model 812 DC Power Supply	Model 288 CPM	CPM plate with Oscilloscope
+ 100.0 V	+ 101.0 V	+ 100.0 V
+ 500.0 V	+ 500.0 V	+ 500.0 V
+ 1000.0 V	+ 1002.0 V	+ 1000.0 V
- 100.0 V	- 99.0 V	- 100.0 V
- 500.0 V	- 500.0 V	- 500.0 V
- 1000.0 V	- 999.0 V	- 1000.0 V

Table 1 - DC Reference Voltage and Measurements

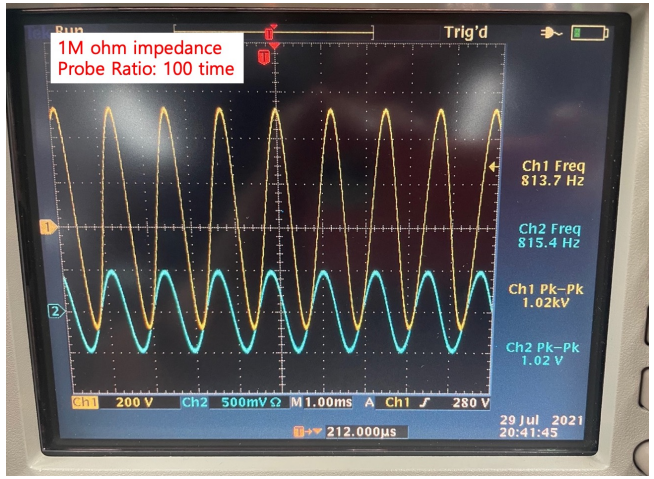


Figure 7 - AC Reference Voltage and Measurements

경기도 성남시 중원구 갈마치로 186 반포테크노피아 5층. 13230. https://www.coreinsight.co.kr

Alternative Measurement Test Experiment

- DC Ionizer Test by CPM Instrument
  - Core Insight's Model 7380d QuadPoint® DC Bar Ionizer has set at 12-inch and 2-inch distances from CPM plate and make measurements in Figure 8.
  - Test results are Figure 9 & 10
    - 300mm Distance: +9.7 V, -0.3 V
    - 50mm Distance: **+7.6 V, -25.5 V**

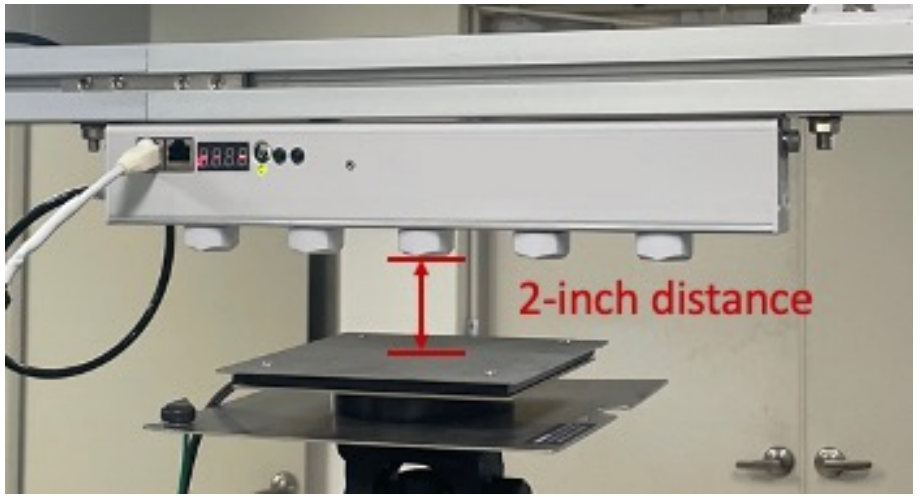


Figure 8 - DC Ionizer at 2-inch distance

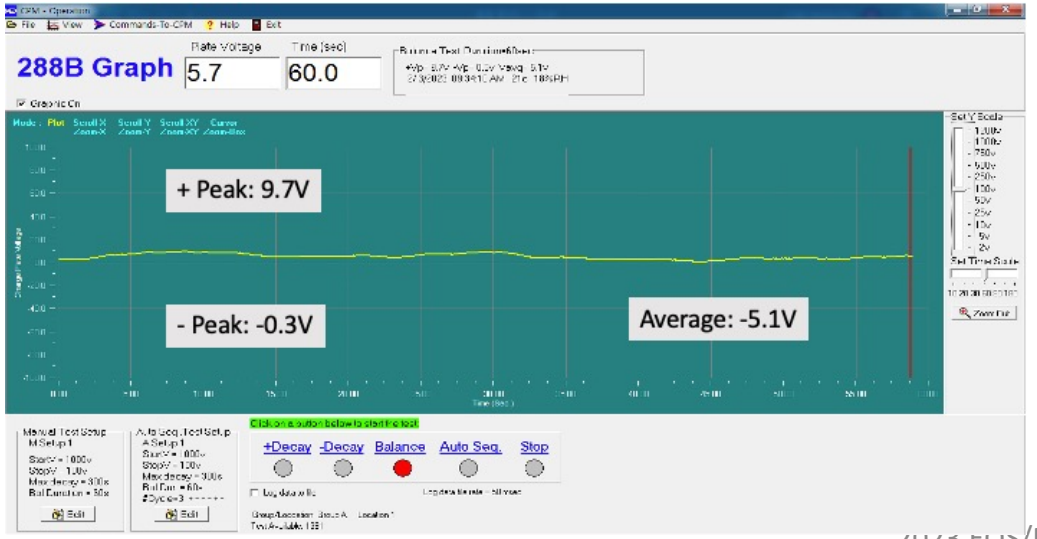


Figure 9 - DC Ionizer Test Results at 12-inch distance

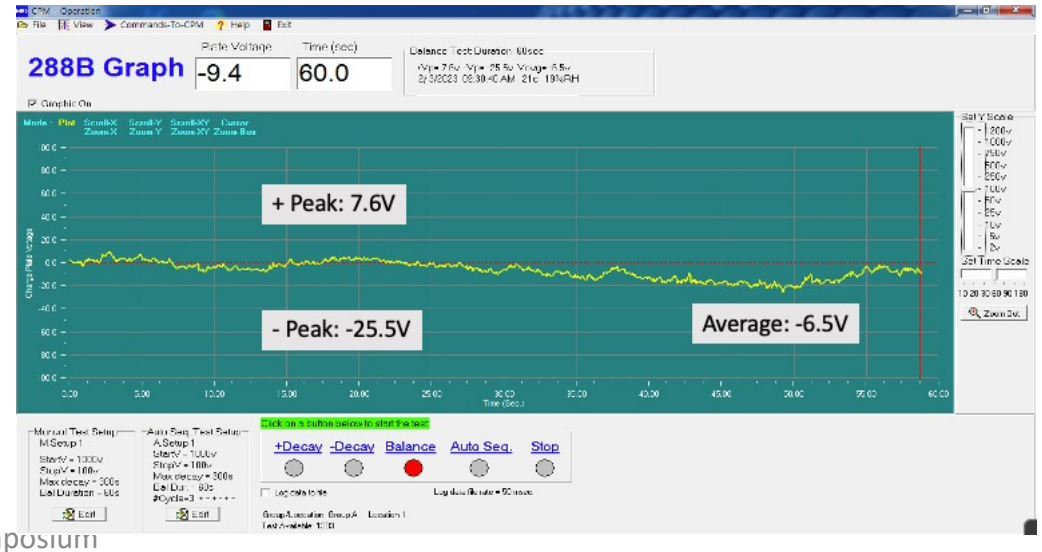


Figure 10 - DC Ionizer Test Results at 2-inch distance

Alternative Measurement Test Experiment

- Pulsed AC Ionizer Test by CPM Instrument
  - Pulsed AC Bar Ionizer has set at 12-inch and 2-inch distances from CPM plate and make measurements in Figure 11.
  - Test results:
    - 300mm Distance: +132V, -70V
    - 50mm Distance: **+816V, -875V**

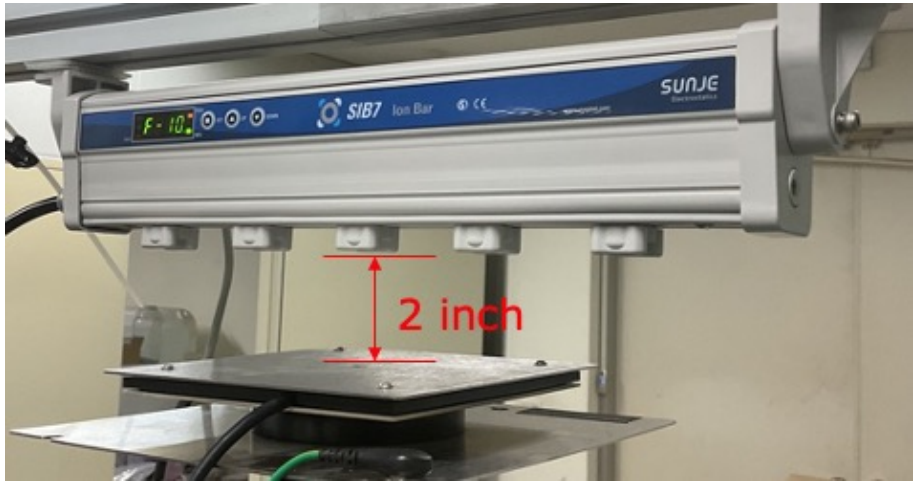


Figure 11 - Pulsed AC Ionizer at 2-inch distance

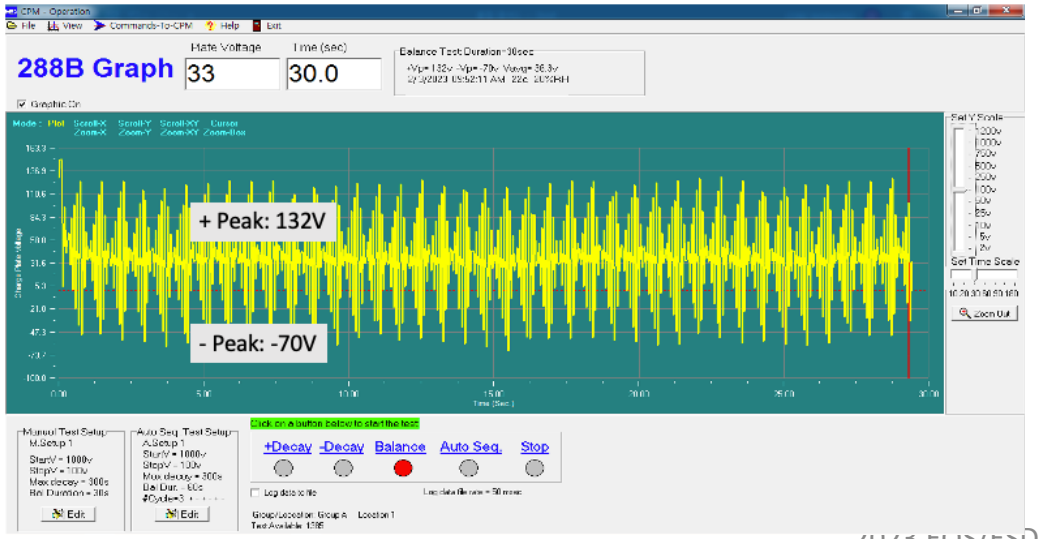


Figure 12 - Pulsed AC Ionizer Test Results at 12-inch distance

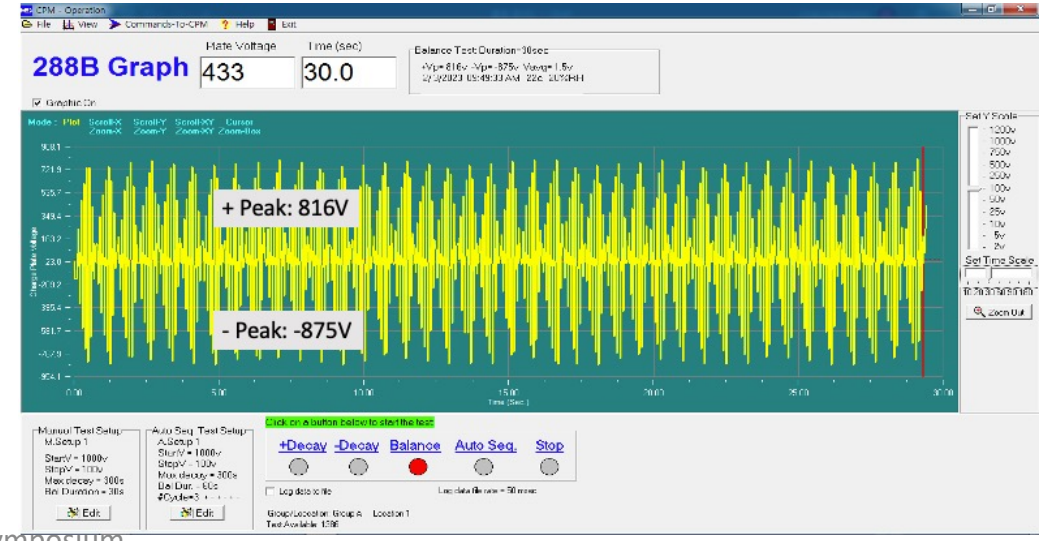


Figure 13 - Pulsed AC Ionizer Test Results at 2-inch distance

Alternative Measurement Test Experiment

- High Frequency(HF) AC Ionizer Test by CPM Instrument
  - HF AC Bar Ionizer has set at 12-inch and 2-inch distances from CPM plate and make measurements in Figure 14.
  - Test results:
    - 300mm Distance: **+2.1 V, -7.5 V**
    - 50mm Distance: **+20 V, -14.9 V**

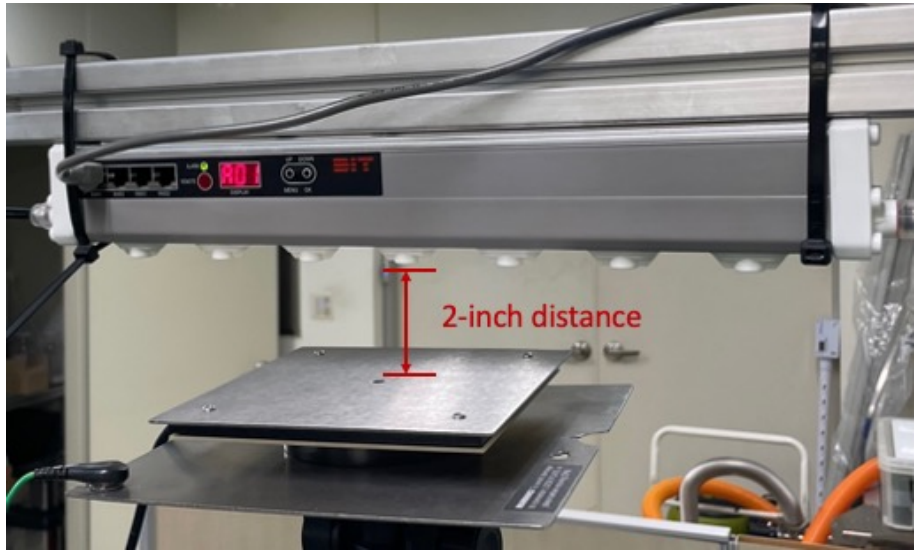


Figure 14 - HF AC Ionizer at 2-inch distance

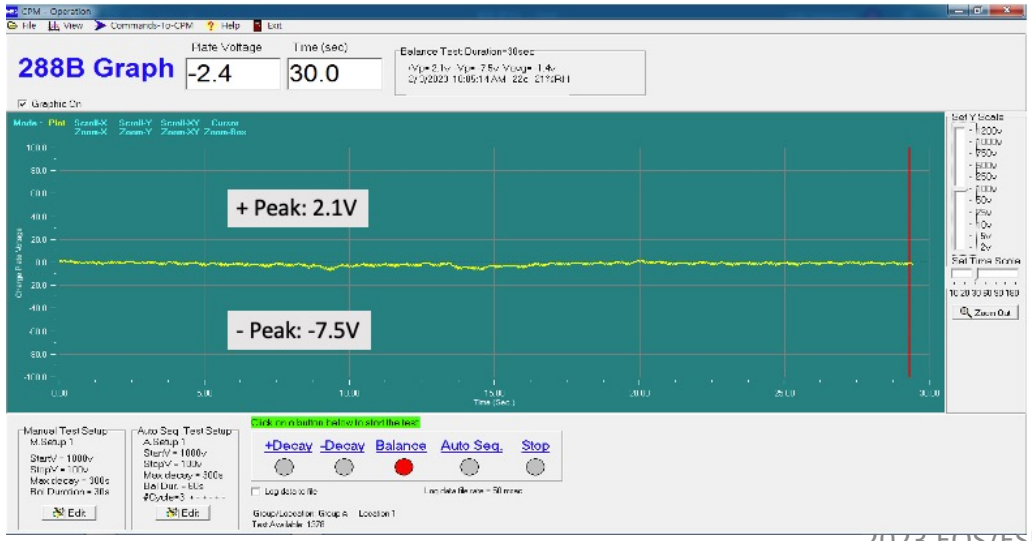


Figure 15 - HF AC Ionizer Test Results at 12-inch distance

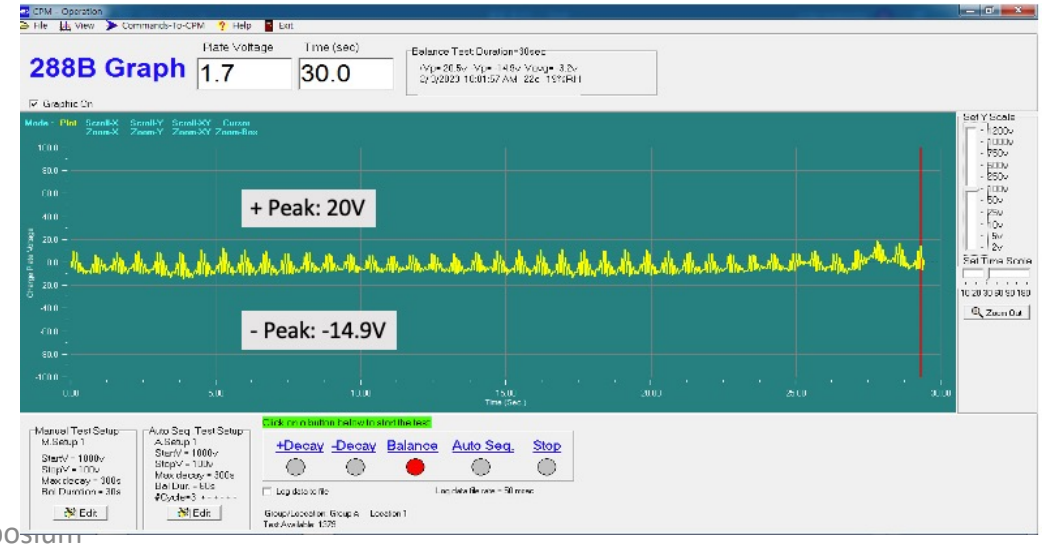


Figure 16 - HF AC Ionizer Test Results at 2-inch distance

Alternative Measurement Test Experiment

- DC Ionizer Test by Scope + CPM Plate
  - Test results by CPM Instrument
    - 300mm Distance: +9.7 V, -0.3 V
    - 50mm Distance: **+7.6 V, -25.5 V**
  - Test results by Scope + CPM Plate
    - 300mm Distance: +6 V, -36 V
    - 50mm Distance: **+46 V, -62 kV**

Figure 17 - DC Ionizer at 2-inch distance

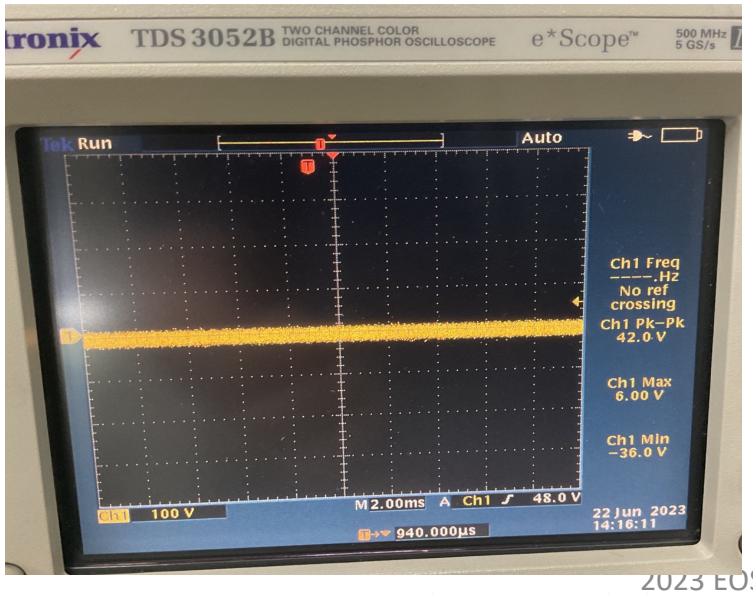


Figure 18 - DC Ionizer Test Results at 12-inch distance

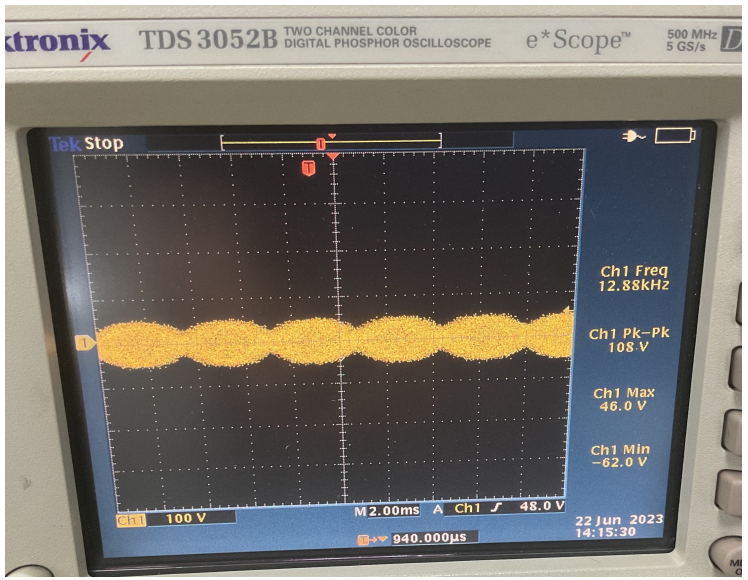


Figure 19 - DC Ionizer Test Results at 2-inch distance

Alternative Measurement Test Experiment

- Pulsed AC Ionizer Test by Scope + CPM Plate
  - Test results by CPM Instrument
    - 300mm Distance: +132V, -70V
    - 50mm Distance: **+816V, -875V**
  - Test results by Scope + CPM Plate
    - 300mm Distance: +91V, -80V
    - 50mm Distance: **+384V, -404V**

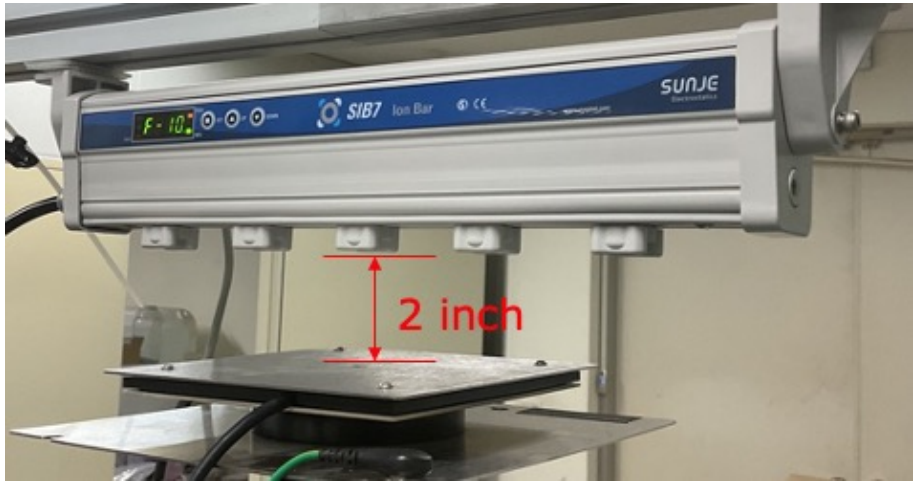


Figure 20 - Pulsed AC Ionizer at 2-inch distance

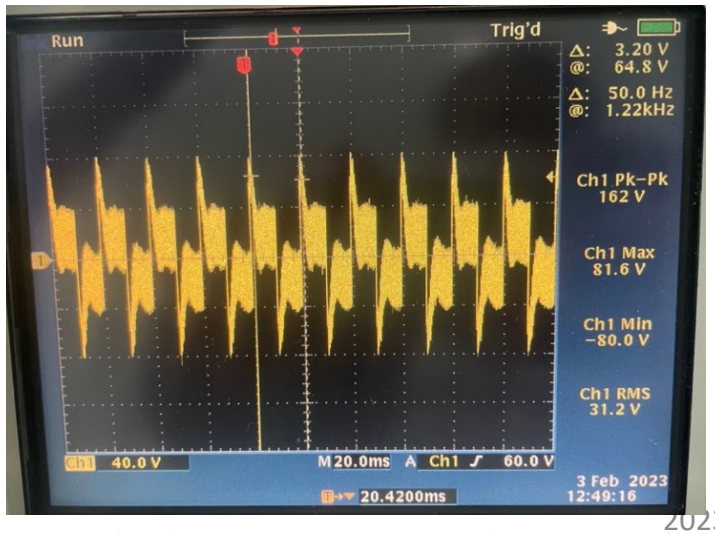


Figure 21 - Pulsed AC Ionizer Test Results at 12-inch distance

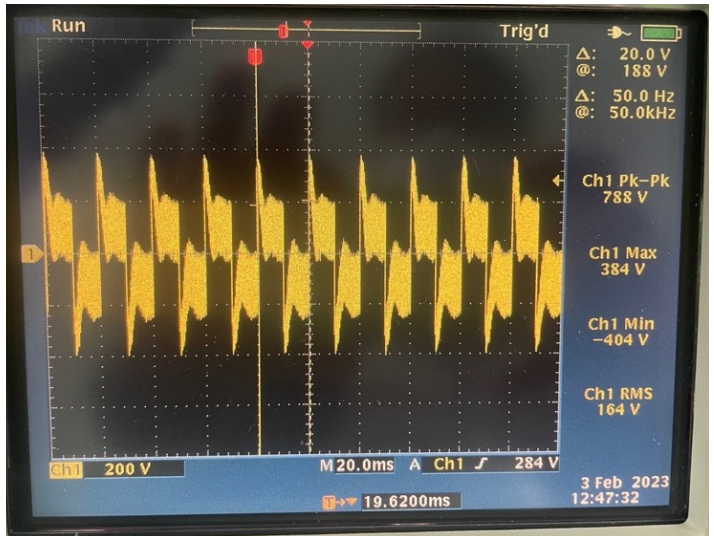


Figure 22 - Pulsed AC Ionizer Test Results at 2-inch distance

Alternative Measurement Test Experiment

- High Frequency(HF) AC Ionizer Test by Scope + CPM Plate
  - Test results by CPM Instrument
    - 300mm Distance: **+2.1 V, -7.5 V**
    - 50mm Distance: **+20 V, -14.9 V**
  - Test results by Scope + CPM Plate
    - 300mm Distance: **+188 V, -192 V**
    - 50mm Distance: **+1.14 kV, -1.18 kV**

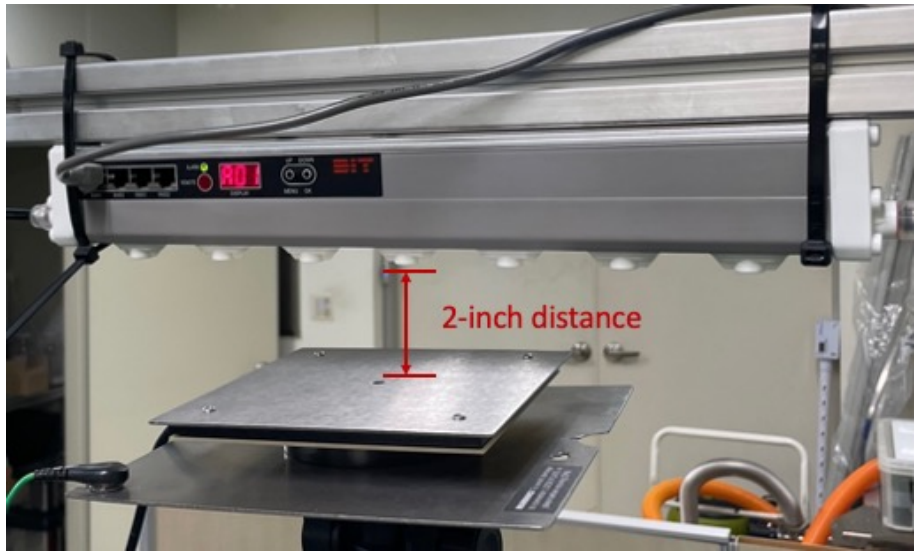


Figure 23 - HF AC Ionizer at 2-inch distance

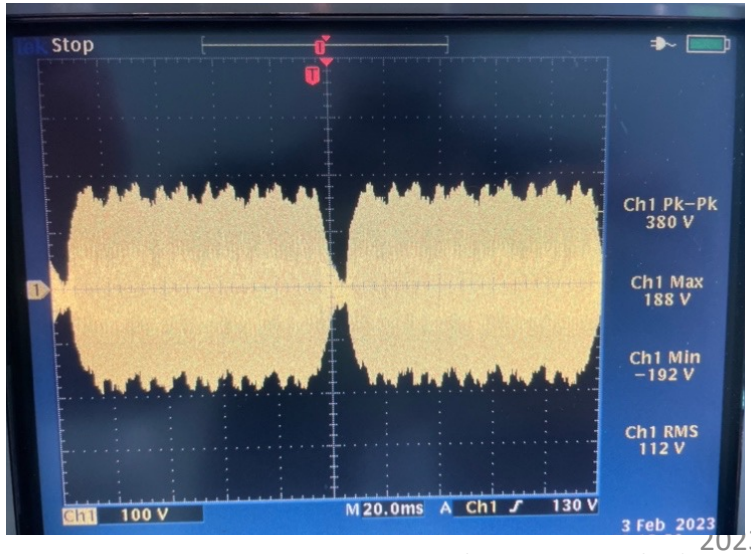


Figure 24 - HF AC Ionizer Test Results at 12-inch distance

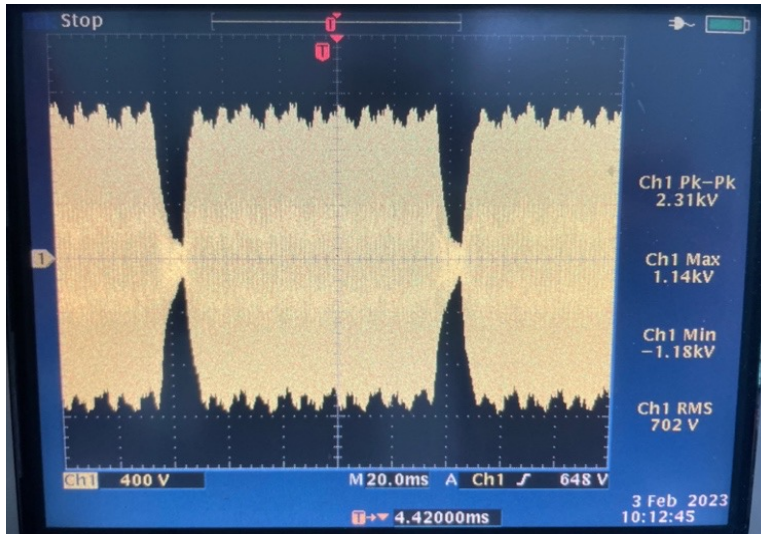


Figure 25 - HF AC Ionizer Test Results at 2-inch distance

Conclusion

- Standard CPM has designed for DC ionizer or relatively slow pulsed ionizers, not capable to measure AC ionizers.
- CPM test results shows **significant voltage drops (or get higher)** when ionizer operating frequencies high than response speed of CPM Instrument
- Current CPM technology will give **incorrect information to users** when they used AC ionizers and claims that it is suitable to meet ANSI/ESD S20.20 ESD control program
- **Alternative measurement** by high-speed oscilloscope and CPM plate assembly make possible to accurately measure absolute peak offset voltage for ALL type of ionizers
- **Input impedance** and **gain ratio** changes of Oscilloscope and reference voltage measurement could help accurate peak offset voltage measurement of all type of AC ionizers

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