Whitepaper:

In-situ sensing of human body electrostatic charge.

Introduction

At IONA Tech, we believe that the current landscape of electrostatic discharge (ESD) mitigation products is lagging behind today's technological capabilities. Tethered grounding wrist straps are certainly effective at a stationary workstation, but user compliance remains an issue. Conductive flooring installations can enable worker mobility, but the quality of the conductive path to ground remains an ongoing concern. Certification and testing methods are one-off procedures that can't ensure day to day compliance. Electric field meters and ESD event detection devices may store data but require antiquated hardware connections and proprietary software that hampers proper analysis of the data.

The patented StatIQ™ Band measures the real time electrostatic charge on all users in an ESD Protected Area (EPA). Users wear an unobstructive arm band that emits audible alarms when the user is charged above programmable thresholds, as well as when a potentially damaging electrostatic discharge occurs. Meanwhile, data from multiple StatIQ Bands is streamed over Bluetooth Low Energy (BLE) to a centrally located Hub, which sends the data to a cloud-based server via the local WiFi network. A browser accessible dashboard provides visualization of the measurements, logging of alarms, and control of editable thresholds. This enables a QC manager who is in charge of ESD mitigation in a facility to access the exact ESD history of all personnel in a facility, which can then be provided as a certification along with deliverable assets.

Figure 1: StatIQ™ Band hardware

Conventional Human Body Voltage Measurements

Industry standard systems for measuring human body voltage generally rely on a handheld probe which is connected by wire to a surface voltmeter. This voltmeter measures the electric potential of a charged plate connected to the user, so as not to drain or affect the charge on the body. Some of these meters are handheld devices, but still require a tethered reference to Earth ground.

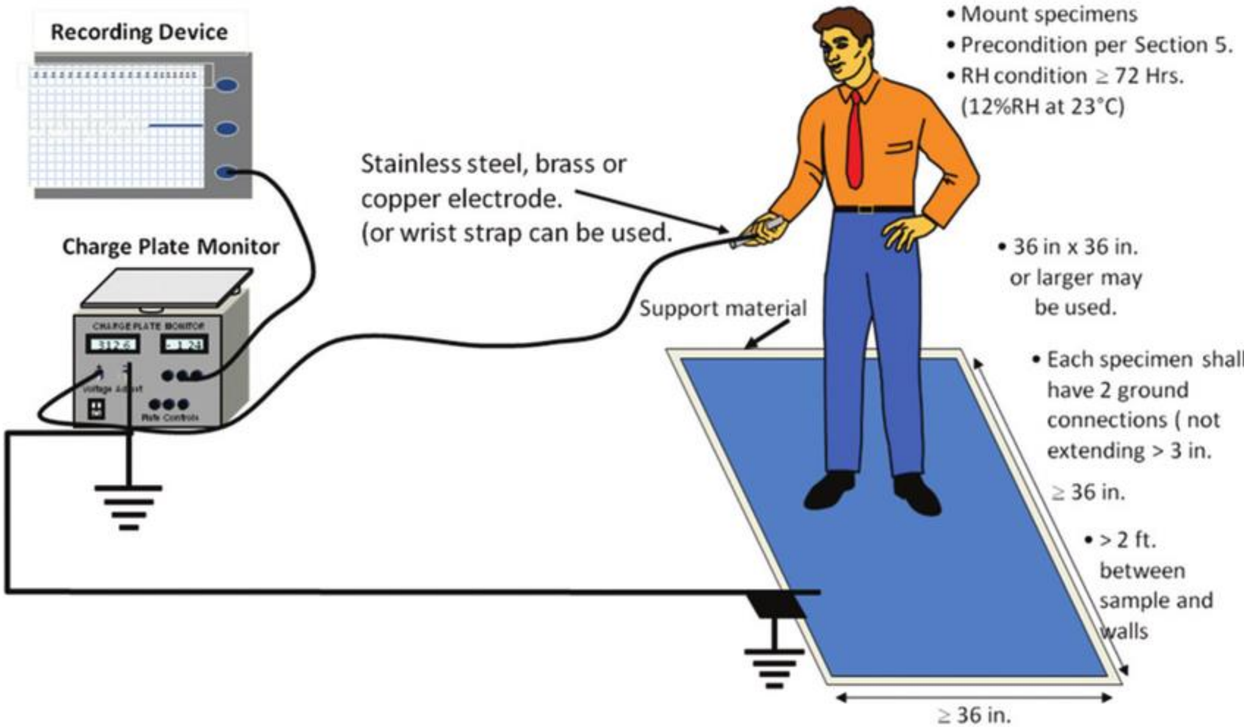


Figure 2: Walking body voltage test setup by ANSI/ESD STM97.2

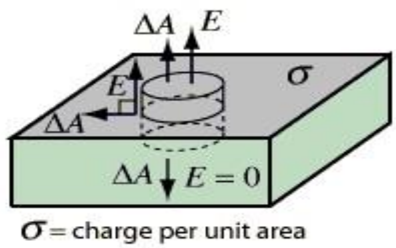
Now imagine having access to this data in real time for all users of a facility, without requiring any tethers. In this whitepaper, we intend to show you how this is possible with the StatIQ™ ESD Monitoring System.

On Body Electric Field Measurements

Electric voltage measurements are, by definition, a measure of the difference, or delta of electric potential. Therefore, voltage measurements require a reference to some ground. Electric charge, on the other hand, is absolute. When the human body is at a non-zero potential, it contains a net electrostatic charge q. Because the body is a conductor, this charge is distributed along its surface with local surface charge density σ [Coulomb/m^2], where $q = \int \sigma dA$. This charge density cannot be measured outright, but due to the fundamental properties of electrostatics, it can be inferred by measuring the local electric field on the surface.

Consider the Gaussian surface on a conductor in Figure 4. The electric field adjacent to the surface is known to be perpendicular because any orthogonal component would rearrange the charge distribution until the field is perpendicular. By the same argument, the electric field inside the conductor is zero. If

Gauss' law in Eq. 1 is applied to the cylindrical surface in Figure 4 with infinitesimal height and small radius R, Eq. 3 results because the dot product exists only on the top edge of the cylinder. **This dictates that the electric field E measured at the surface of a conductor is directly correlated to the underlying surface charge density σ.**



$$\oint \vec{\mathrm{E}} \cdot \mathrm{d}\vec{\mathrm{A}} = \frac{\mathrm{Q}}{\epsilon_0} \qquad (1)$$

$$E_n \pi R^2 = \frac{\sigma \pi R^2}{\epsilon_0} \qquad (2)$$

$$\overrightarrow{E_n} = \frac{\sigma}{\epsilon_0}\hat{n} \qquad (3)$$

Figure 4: Gauss' law applied to the surface of a conductor

The StatIQ™ Band contains a proprietary field mill of unprecedented size and accuracy which measures the local electric field, and thereby the underlying charge density on the user's arm. As the shutter of the field mill rotates, the stationary electrode pairs are alternatively exposed to and occluded from the external electric field. The resulting AC signal is amplified and filtered in hardware, while software algorithms determine the resulting magnitude and polarity of the electric field to high accuracy. The measurement is especially agnostic to drift and offsets from ionic air particles as they are equally absorbed by both electrodes, which is important in EPAs that rely on the use of air ionizers.

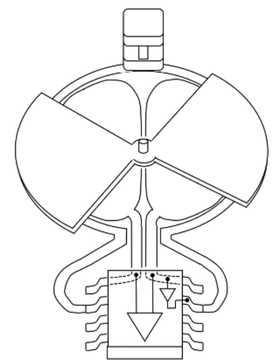


Figure 3: Simplified diagram of IONA Tech field mill

Relation between electrostatic potential and charge density

So how does the charge density on the human body relate to its electric potential?

The total charge is related to voltage by $q = CV$, where C is the body's self-capacitance. For a simple sphere, capacitance can be calculated as $C = R/k$ (where k is Coulomb's constant), and the charge is equally distributed along the surface of the sphere. For a complex object like the human body, the charge distribution is nonlinear and depends heavily on its geometry. It can be calculated numerically by solving the differential form of Gauss' law (Poisson's equation).

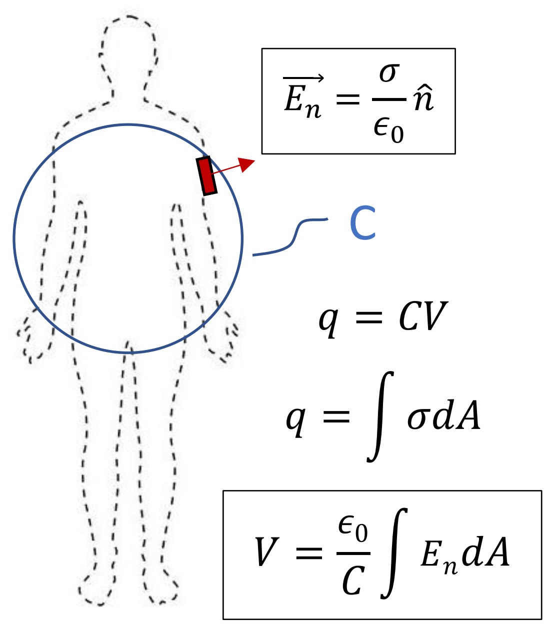


Figure 5: Voltage and charge relationship on the human body

By meticulously comparing StatIQ™ Band data to human body voltage measurements, it has been empirically verified that the field measurement at the upper arm tracks the human body voltage with high linearity. At extremities with sharp geometries (such as hands and feet), high charge concentrations can exist, which is why the StatIQ™ Band is located at the upper arm, whose position does not vary dramatically relative to the body's core.

The StatIQ™ Band measurement can therefore be used as a proxy for the electric potential of the human body, in so far as is necessary to determine undesirable ESD conditions.

$$V_{body} \propto E_{arm} \qquad (4)$$

The plot in Figure 6 show a comparison of StatIQ™ Band E-field measurements [V/m] multiplied by a constant factor according to the average human body capacitance (which gives a good conversion from V/m to V for most body sizes), compared with human body voltage measurements from an 3M 711 Charge Plate DC Voltmeter. Other systems such as the Prostat PGA-710 were also used for testing, but the 3M was found to have the least drift, fastest response, and highest accuracy. The measurements agree to high accuracy while the user performs four walking test sequences – two on conductive floor and two on non-compliant carpet.

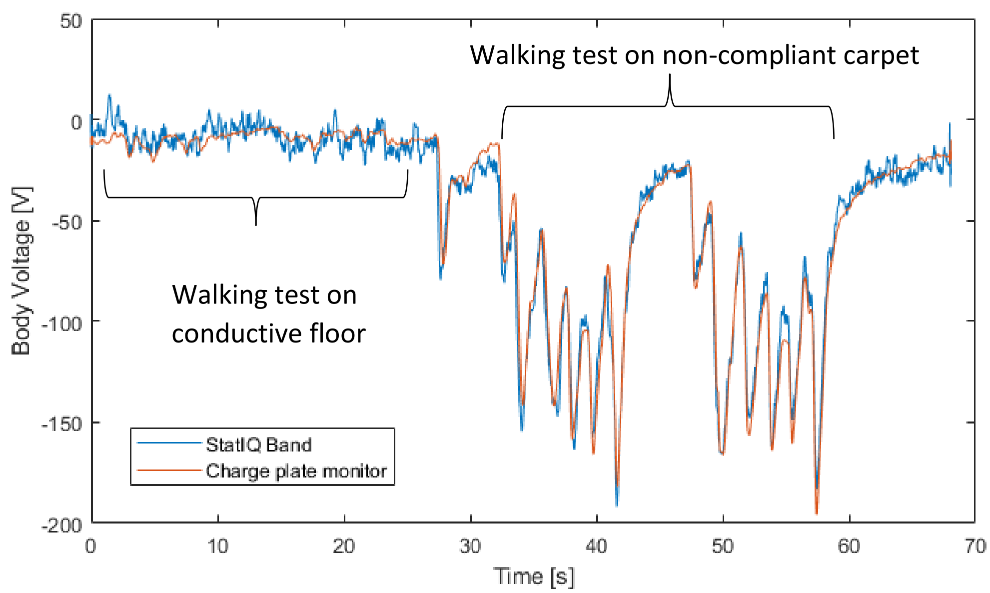


Figure 6: Comparison of human body voltage sensed by the IONA StatIQ Band and charge-plate monitor measurement

Minimal deviations between human body voltage and the local charge density measurement are possible, for example when the user's capacitance changes slightly due to varying body positions. Another scenario exists where nearby objects result in induced charges on the body and the charge distribution becomes non-symmetric. Without diminishing the value of body voltage measurements, we have come to realize at IONA that the charge density measurement is in fact more indicative of impending ESD events than the body voltage. For example, the charged engineer in Figure 7 who is about to fry an expensive sensor, will experience a higher charge density at the location of the impending ESD event due to induced charges from the grounded workpiece.

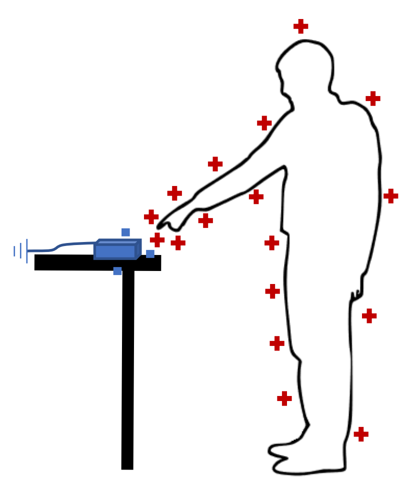


Figure 7: Bad technician

ESD Detection

Existing ESD Event Detection devices rely on the detection of electromagnetic waves generated during the occurrence an ESD event. In order to convert this to a voltage drop, accurate knowledge of the distance from the meter to the location of the ESD event is required. In other words, they rely on the device being stationary relative to a specific workpiece to gather useful ESD event data only for that specific workpiece.

Figure 8: A $4500 ESD event detection meter from Desco

The electric field mill of the StatIQ Band has an internal sampling rate of 1200 Hz (832 µs period). Therefore, the microcontroller can detect the rate of change in the electric field, and thereby the human body voltage, with great accuracy. This allows for an ESD detection algorithm that identifies rapid voltage changes which can only happen by a sudden transfer of charge from a grounding event. These events are distinguishable from triboelectric and atmospheric charge transfers, and can be detected at voltage deltas much smaller than what is humanly perceptible as an electrostatic shock. It is these low voltage ESD events that are most concerning in an ESD environment, as they go unnoticed and can cause latent damage to electronics. With the patent pending StatIQ System, these events are easily and reliably identified.

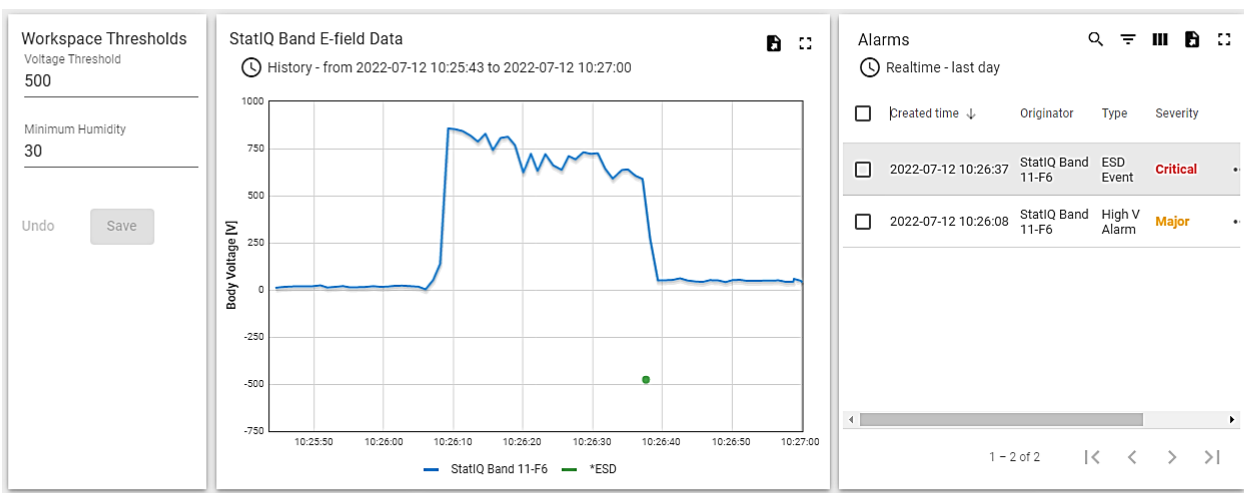


Figure 9: Image of the StatIQ^{TM} Dashboard showing alarms.

The above screenshot of the StatIQ^{TM} Dashboard shows a user who was charged up by getting up out of a noncompliant chair, walked around for 30 seconds on noncompliant flooring, and consequently touched an Earth ground point. Alarms are generated when the preset voltage threshold is surpassed, and when the grounding ESD event occurs. The user is also alerted of these ESD dangers via audible alarms, and therefore can easily avoid damage to sensitive electronics assets in the lab.

Please reach out to info@iona.tech or fill out this form for more information. Or purchase a StatIQ^{TM} Band from www.iona.tech/statiq-band today.