Electrodermal Activity and the Lafayette Lx4000/Lx5000 Data Acquisition Systems

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The term *electrodermal activity* (EDA) was first suggested by Johnson and Lubin (1966) to describe the range of electrical phenomena associated with the skin. The unit of measurement for electromotive force is the *Volt* (V) for which small values are expressed as *microvolts* (µV). Field polygraph instruments measure EDA using exosomatic methods in which a small direct current (DC) voltage is applied to the skin, and by measuring changes in electrical activity that occur in response to test stimuli.

Electrical conductors have the properties of both *resistance* and *conductance*. The unit of measurement for electrical resistance is the *Ohm* (Ω). High resistance levels are described using the terms *kilohms* (kΩ) and 1 *megohms* (MΩ). The unit of measurement for electrical conductance is the *Siemens* (S), formerly referred to as the mho (i.e., the inverse of the ohm) until the late 1970s. Low levels of conductance are described using the term *microsiemens* (µS) which is equal to one millionth of one Siemen. Resistance and conductance are mathematically related such that 1MΩ = 1µS or 1S = 1/1Ω and 1Ω = 1/1S. If the exact value of either is known, the exact value of the other can be calculated.

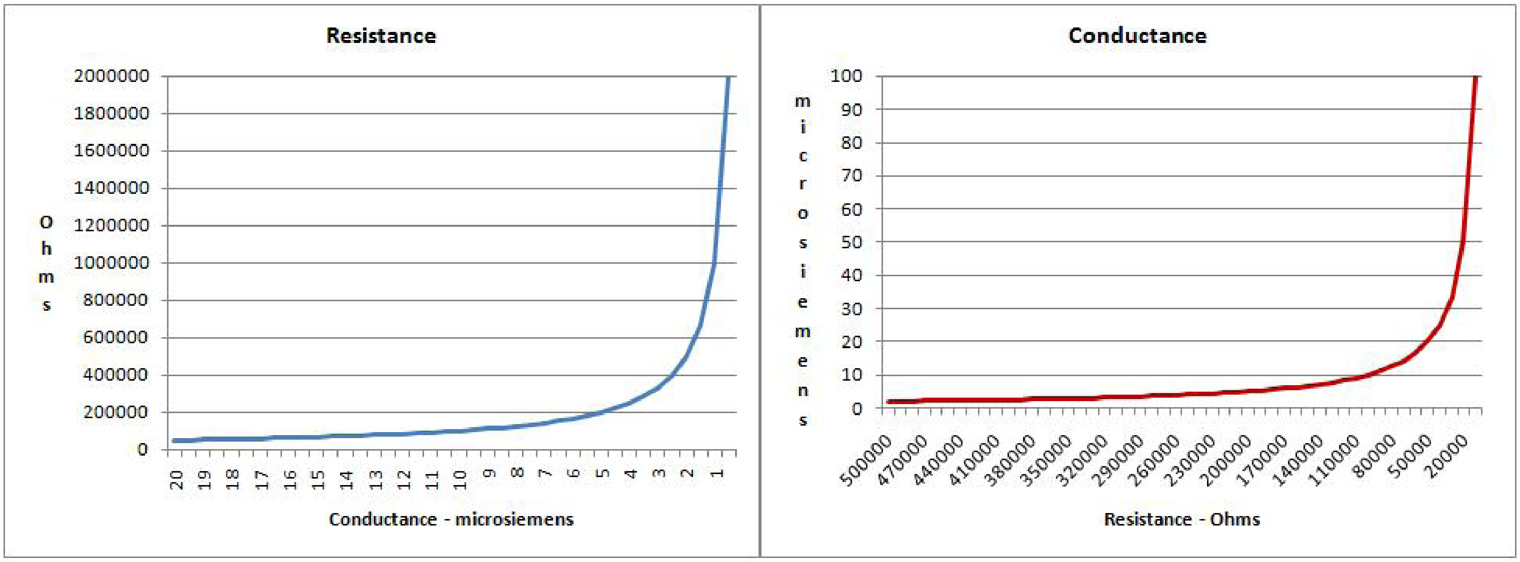
Brown (1967), Venables and Martin (1967) proposed the standard terminology that is used to describe and discuss EDA in the science of psychophysiology: *electrodermal level* (EDL) refers to the *tonic* level of EDA, while *electrodermal response* (EDR) refers to *phasic* EDA responses. Both EDR and EDL are of interest to researchers in psychophysiology. Field polygraph examiners measure and score EDRs using both manual and automated scoring algorithms, but generally use EDL only to evaluate the examinee's readiness for each test question stimulus.

Like all electrical circuits, an EDA circuit is said to be *closed* when the electrodes are connected to the examinee, allowing the flow of current through the circuit. Circuits are said to be *open* when it is disconnected, preventing the flow of current. Constant voltage circuits apply a known constant voltage to the skin in series with a resistor of a known value. Resistance of the skin can be determined by first measuring the amount of current across the known series resistance and then using Ohm's law to calculate the unknown skin resistance value. Constant current circuits apply a known constant current to the skin in series with a resistor of a known value. Skin resistance can be determined by monitoring the voltage in the circuit and using Ohm's law to calculate the unknown resistance value.

Polygraph recording instruments are not medical devices, and neither polygraph examiners nor polygraph instrumentation are subject to medical standards. Nonetheless, medical safety standards can provide an informative view regarding device safety. One stringent international standard for medical equipment, IEC 60601-1, does not consider voltage levels less than 60 volts (DC) to be a danger, and does not require engineers to take any special precautions to prevent someone from touching it. Both the LX4000 and LX5000 are powered by 5V from the USB connector, and are well within this voltage specification. An important safety standard is to ensure that any electricity that an examinee or examiner could come into contact with does not have any direct path to ground. This safety barrier is accomplished in the circuit design by electrically isolating the EDA electrodes. Isolation of this type means that if an examinee is wearing the electrodes and happens to touch a high voltage source, there would be no path to ground and the examinee would be safe from potential harm. Both the LX4000 and LX5000 devices are electrically isolated up to 2000V.

The normal range for tonic EDA has been reported as 2µS to 20µS, which is equivalent to 50KΩ to 500KΩ (Dawson, Schell, &

Image 1. Conductance and resistance plots



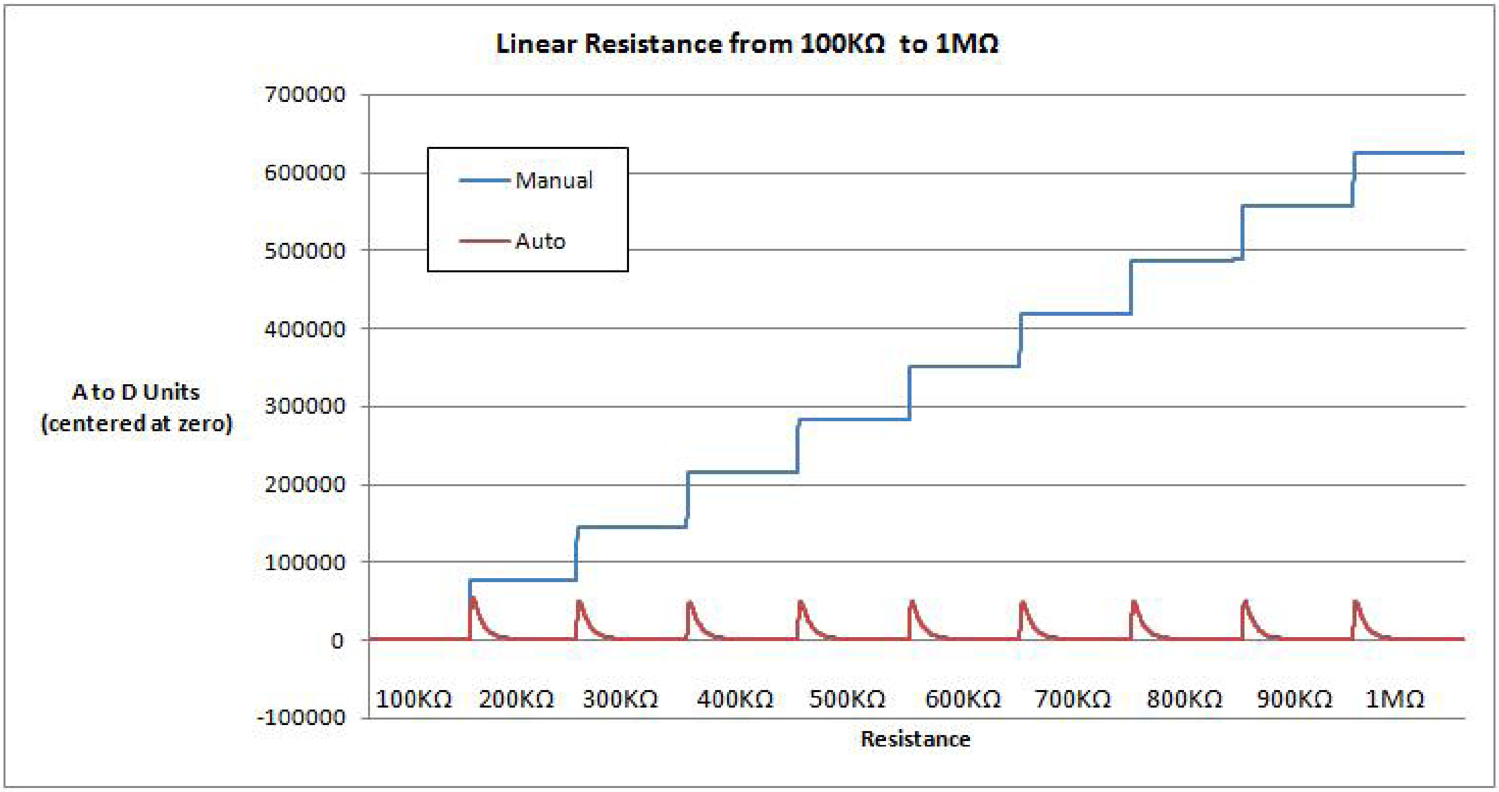
Filion, 2007). Although the relationship between resistance and conductance is mathematical, it is not linear. Image 1 illustrates the potential for non-linearity, and shows that non-linearity above the upper limit of the normal range (500KΩ) may impose practical usability limits due to the potential for data instability or noise. Linear changes in resistance will produce non-linear changes in conductance. Similarly, linear changes in conductance will produce non-linear changes in resistance.

The practical meaning of this is that the diagnostic value of EDA data outside the normal range (i.e., at high resistance levels) may not provide the same diagnostic value as EDA data within the normal range. However, data within the normal range can approximate linearity more closely. This should be studied further.

Exosomatic measurement of EDA can involve the use of either *constant voltage* circuits or *constant current* circuits. Both methods make use of Ohm's law, which mathematically defines the relationship between voltage, current and resistance (Ohm, 1827; Nilsson & Reidel, 2008). Ohm's law states that V = I x R (Voltage = Current x Resistance), which can be transformed mathematically into R = V / I (Resistance = Voltage divided by Current) or I = V / R (Current = Voltage Divided by Resistance). If two of the values are known the third can be calculated. The unit of measurement for electrical current is the *Ampere* (A). Small ampere values are expressed with the term *microampere* (μA), for which one million μA are equal to 1A.

The design of the LX4000 EDA is a constant current circuit of 6.7μA and has a range of 10kΩ to 2MΩ. The design of the LX5000 EDA includes both constant current and constant voltage circuits. The LX5000 constant current circuit uses a constant current of 4μA and can acquire data across a range of 10kΩ to 2.3MΩ. The LX5000 constant voltage circuit uses a constant voltage that is automatically ranged for each subject when the EDA circuit is closed and uses a maximum current of 10μA. The advantage of the auto-ranging design is to preserve response linearity at high resistance levels. The circuit is capable of acquiring data across a range from 5kΩ to 4MΩ. Both the LX4000 and LX5000 are well within published recommended maximum current density of 10μA/cm2 (Boucsein, Fowles, Grimmes, Ben-Shakkar, Roth, Dawson, & Filion, 2012). To illustrate further: AA batteries may have current capacities ranging from 1100mA/hour to 2700mA/hour, meaning that most small batteries are capable of providing current many thousand times greater than that of the LX4000 and LX5000 EDA electrodes.

Image 2. Linearity of resistance.



Regardless of whether *measured* using constant current or constant voltage methods, EDA measurements can be described or *displayed* using either conductance or resistance units. This is because an exact mathematical formula defines the relationship between conductance and resistance. If the exact value of one is known the exact value of the other can be calculated. Boucsien (2012) has suggested there is no actual scientific rational or plausible hypothesis suggesting one as scientifically superior to the other. Research psychophysiologists have preferred to discuss EDA in terms of conductance units, while field polygraph examiners have traditionally discussed resistance units. Processing of the EDA data for display and analysis is a function of the LXSoftware, and data are displayed as linear resistance units for both the LX4000 and LX5000 devices. Image 2 shows the linearity of resistance response from the LX5000.

LX4000 devices acquire and transmit EDA data to the computer at 120 samples per second. LX5000 devices are capable of acquiring data from 120 to 360 samples per second. Device firmware serves only to control the acquisition of data, creation of packet transmission, and communication with the computer using 24-bit analog-to-digital technology. No signal processing is done in the firmware of the LX4000 or LX5000 data acquisition systems.

For more information, or to contribute to the discussion, please contact Mr. Nelson or Mr. Smitley directly.

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Quotables

A successful man is one who can lay a firm foundation with the bricks others have thrown at him.

~David Brinkley