Can a Leaf Make Music? Techniques and Aesthetics of Plant-Generated Control Voltage in Electronic Music

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Introduction

Plants are electrically active organisms. Improvisers, composers and performers can use plants' electric signals to create music in many different ways. Between their raw electrical signals and the sounds in a plant-influenced composition lie several layers of mediation. Artists such as Miya Masoka (Columbia University), Mamoru Fujieda (Kyushu University), Helen Hé (Oberlin), and Patitucci/Tyson (Data Garden) have produced significant musical works involving plants.

The goal of our project is to analyze plant-generated voltage in a way that is useful for a performer or improviser. There is a significant lack of information from this perspective. Most of the published literature consists either of highly controlled laboratory studies or discredited anthropomorphic fantasies in which plants feel emotions, cry out in pain, etc. (Tompkins and Bird*). While plants lack specialized cells or organs for transmitting electrical impulses (Alpi, *et. al.*,) they do have sophisticated mechanisms for sensing their environment. Plants often respond to the environment in ways that seem to show surprising awareness of the world around them. One researcher has suggested that plant behavior shows similarities to ant colonies, where the sum is more than the individual organisms or cells (Trewavas). Much is sill unknown about why and how plants transmit electrical signals through their tissues (Brenner, *et. al.*).

One popular and versatile way of interfacing with plants is through Instruo's *Scion* module. This is a widely available modular synthesizer module in Eurorack format. Using *Scion* along with an audio interface (Expert Sleepers *ES-8* and *ES-6*) and a custom-designed MAX/MSP patch, we recorded the module's output signals while subjecting two common household plants, *Dracaena fragrans* and *Crassula ovata*, to four different conditions. We then graphed and analyzed data from 14 sessions and drew some preliminary conclusions.

Although some musicians, improvisers and composers use commercial modules such as *Scion*, others have built home-grown DIY interfaces. Another option is the MidiSprout, which is a simple and attractive "plug-and-play" choice. Regardless of the interface employed, we believe that by understanding better the kinds of voltage that plant interface modules produce, musicians will be able to construct a set of expectations about what general results they might experience under given environmental circumstances. This will help people to collaborate more fruitfully with plants when making music together.

Electrical signaling in plants

It has been known that plants generate electrical signals since Charles Darwin first encountered the Venus Flytrap (*Dionaea muscipula*) in the nineteenth century. In 1973, a sensationalist bestselling book entitled *The Secret Life of Plants* (Tompkins and Bird) appeared, in which the authors presented hypotheses that plants could sense human feelings, experience emotions and predict the future. This provoked a violent reaction in the scientific community (Galston and Slayman) which stifled serious inquiry until the early 21st century (Pollan).

In the last fifteen years, significant work has been done on the causes, mechanisms, evolution and purposes of electrical communication in plants. The Society of Plant Signaling and Behavior (originally – and controversially – the "Society for Plant Neurobiology") was founded in 2005 to study these questions. The peer-reviewed journal *Plant Signaling and Behavior* started publishing monthly in 2006.

Plants produce two types of voltage: action potential (AP) and voltage potential (VP). AP travels much faster than VP through the plant's organs. Plants do not have specialized cells (neurons), synapses or neurotransmitters for electrical signaling. Instead they open gates in their cell membranes to exchange charged ions (sodium, potassium, calcium, etc.) between cells. These signals are most frequently conducted through xylem and phloem tubes. According to Fromm and Lautner's summary of a dozen published laboratory studies, plants transmit AP and VP to trigger movement (in the case of the *Dionaea muscipula* and *Mimosa pudica*), initiate gene expression (reproduction), control protein synthesis and regulate photosynthesis, respiration, and stem growth.

What do these graphs mean?

The data we collected is voltage, not sound. The "raw" data can be used directly as sound, but the control voltage (CV) information is meant to affect parameters in synthesizer modules. For example, *Scion's* four CV outputs can control the pitch of an oscillator, the cutoff frequency of a filter, the trigger on an envelope, or the amount of frequency modulation of a sound. The voltage curves suggest many appealing ideas for a musical composition, but they must be realized in some way through a stage of collaborative intervention or mediation. Voltage such as this can be used immediately, or recorded and played back through the synthesizer at a later time. These voltage curves are a general *Grundgestalt* for *a kind of music*.

Experimental data

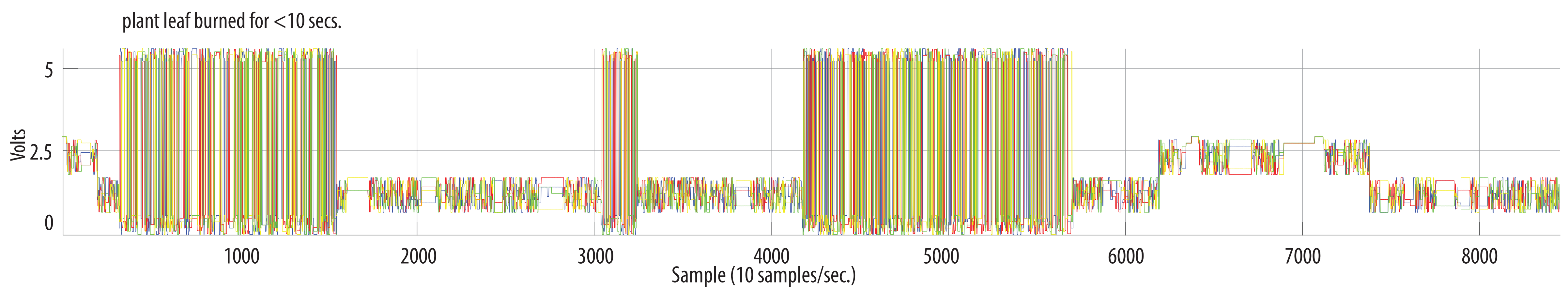
For each graph, the four CV (control voltage) outputs of the *Scion* interface are graphed in different colors. The last two graphs incorporate *Scion's* "raw" output in a separate plot underneath, in black.

1. Burning a leaf

We burned the tip of a leaf off *Dracaena fragrans*. The first chaotic pattern probably corresponds to AP while the later one represents VP. We are unsure why the voltage returned to a chaotic state for a short time between to two longer episodes.

4 September 2019, early afternoon. Sunny & warm.

8500 samples at 10 samples/sec. (about 15 minutes)

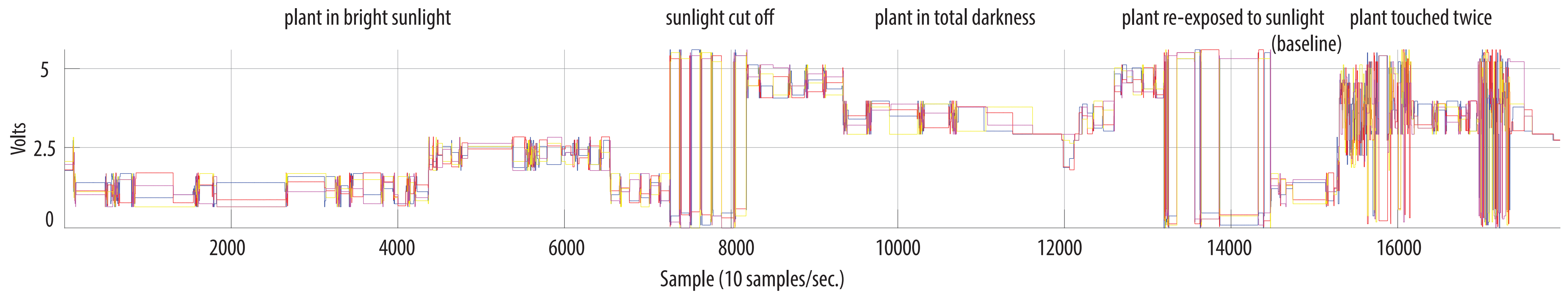


2. Cutting off light/touching plant

We let *Crassula ovata* sit in the sunlight for about a half hour, and then placed a large garbage bucket over it for ten minutes. Then we abruptly removed the bucket. This experiment was inspired by Beverly's research on the 2017 solar eclipse, which studied the response of plant ecosystems to unexpected light depravation. At the end of the data set, we touched the plant leaves to stimulate electrical response.

19 September 2019, early afternoon. Sunny & warm.

18000 samples at 10 samples/sec. (about 30 min.)

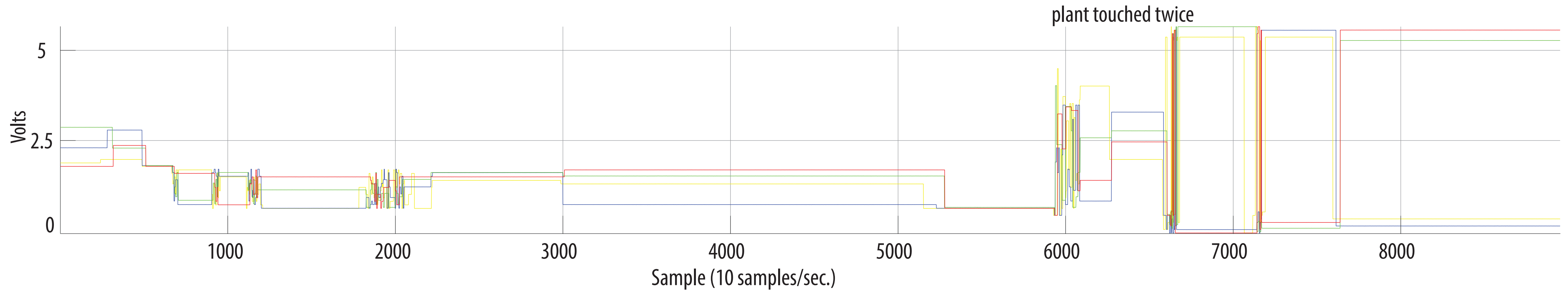


3. Nighttime – touching plant

We let *Crassula ovata* sit undisturbed for 10 minutes, then touched it for approximately 15 seconds. We repeated this a few minutes later. This data set shows that *Scion* will generate significantly different voltage outputs for the same plant, depending on the time of day.

24 October 2019 at 8:00 p.m. Warm, dry weather.

9000 samples at 10 samples/sec. (about 15 min.)



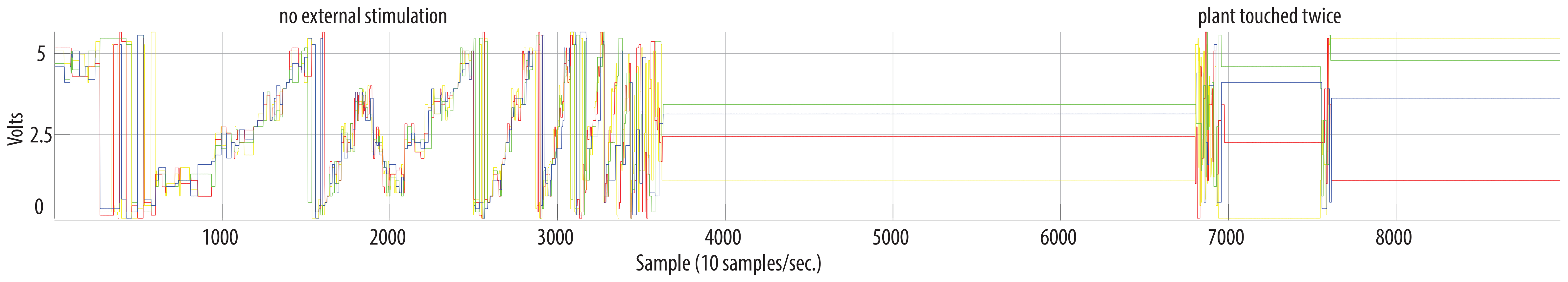
4. Nighttime – touching plant

We duplicated the conditions above for *Dracaena fragrans*. The beginning of this example (first 3000 samples, approximately 6 minutes) shows that it is not entirely possible to predict what will happen with *Scion's* voltge output, as the plant was simply taken outside without stimulating it in any special way.

One significant conclusion we drew from this and other data sets was that *Crassula ovata* only very rarely produces the ramped voltage seen with *Dracaena fragrans* in the first 6 minutes of this data set.

24 October 2019 at 8:30 p.m. Warm, dry weather.

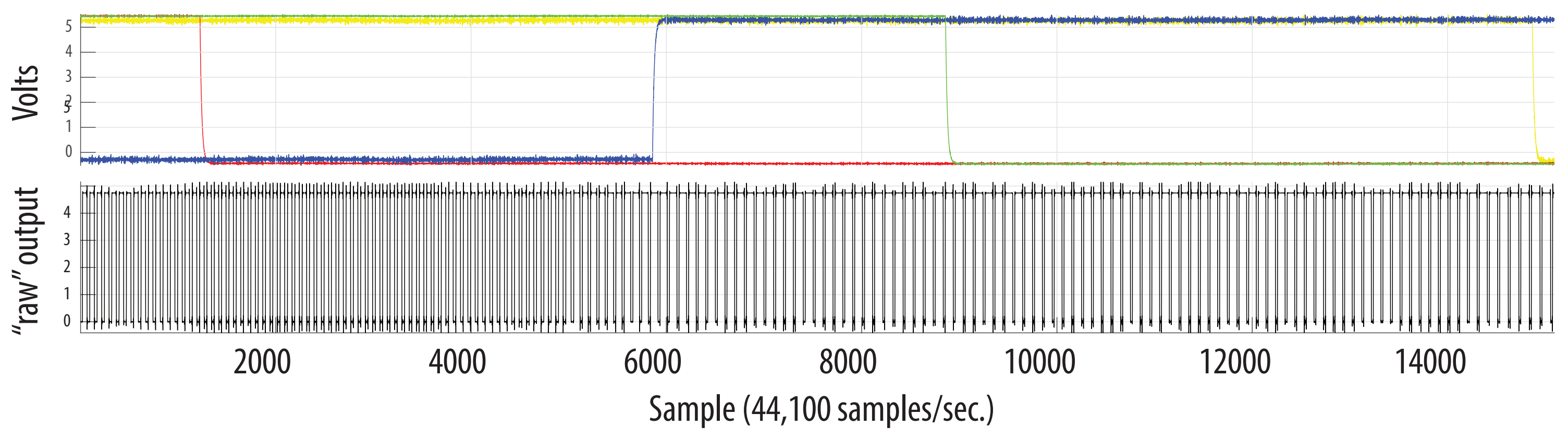
9000 samples at 10 samples/sec. (about 15 min.)



5. Analysis of *Scion's* "raw" output

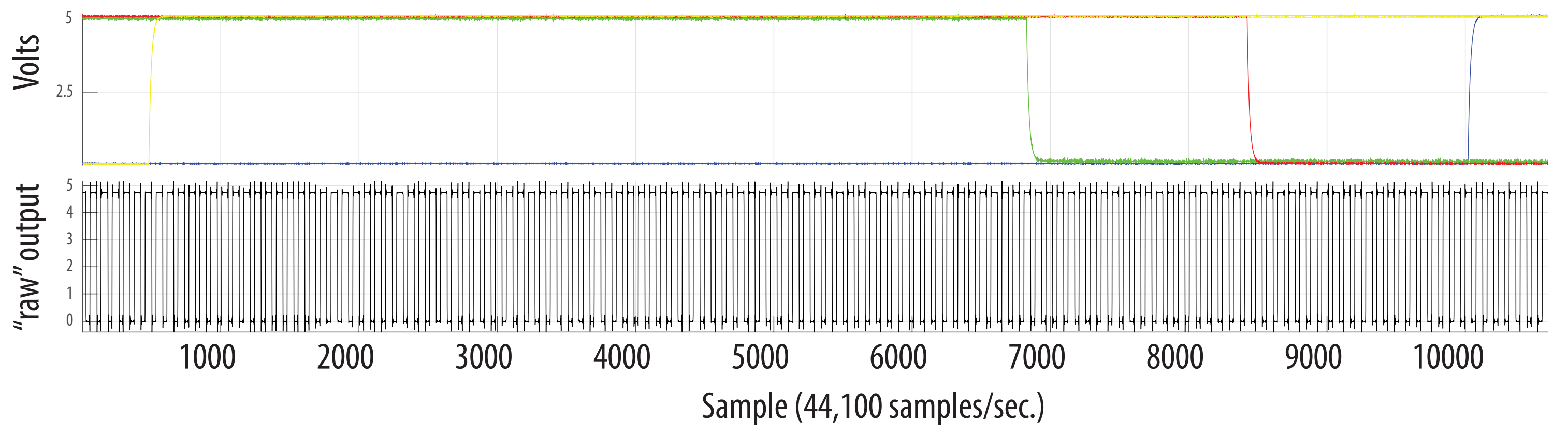
This data set shows a very short slice of time while *Dracaena fragans* was touched. Around 5100 samples through this example, the frequency and duty cycle of the square wave output changes, but only one of the four outputs changed voltage. This suggests that there is a complex and not entirely direct connection between *Scion's* raw output and the four CV outs.

1 November 2019 at about 11:00 a.m. 15000 samples at 44,100 samples/sec. (about 0.34 seconds)



This data set was produced under identical conditions to the previous one, but with *Crassula ovata*. This data again suggests that there is not always an obvious relationship between the structure of the raw output and *Scion's* CV outputs.

1 November 2019 at about 11:00 a.m. 11000 samples at 44,100 samples/sec. (0.25 seconds)



Hypotheses and methods

We hypothesized that the *Scion* interface module would produce significant voltage changes under the following conditions: (1) burning a leaf on a plant; (2) stimulating the plant mechanically (touch); (3) altering the amount of light falling on the plant; (4) at different times of day and night. We expected that *Scion's* "raw" output would correspond to its CV output in a recognizable way.

With two commonly available houseplants, we explored all four hypotheses. A MAX/MSP patch that Brian Riordan wrote allowed us to record voltage changes coming from *Scion* at an appropriate sample rate. Using inexpensive TENS electrodes attached to leaves (pictured on our companion web site), we fed the plant's input to *Scion*, through an audio interface, and into the laptop where data was recorded to text files. In the case of *Scion's* "raw" output, we sampled at audio rate (44.1kHz). This data was then plotted and rendered in MatLab. We sized and colorized the data in Adobe Illustrator.

Over the course of a month, we captured 14 data sets equalling over 4 hours and approximately 730,000 samples. To analyze *Scion's* "raw" output we recorded several short data sets at audio rate, totalling 52 million samples.

Because our primary purpose was to replicate general conditions that an ordinary improviser, musician or composer might encounter in a performance, we did not make use of a precise laboratory-controlled setting. Therefore, we acknowledge that there is some uncertainty to our data. Nevertheless, the quantity of data we collected suggests several results and conclusions (next panel).

Results and conclusions

The graphs to the left show the voltage changes in *Scion's* four CV outputs. The bottom two graphs show *Scion's* "raw" output. We conclude that:

(1) Each hypothesized method of inducing voltage change in *Scion's* output resulted in patterns that were different from baseline voltage observed.
(2) The *Scion* module produces different kinds of voltage for each plant – the ramped pattern for *Dracaena fragrans* were rarely observed in *Crassula ovata*.
(3) Each plant had episodes of unpredictable behavior (e.g., the first 3500 samples or 6 minutes of *Dracena's* nightime session).
(4) Frequency or duty cycle changes in *Scion's* "raw" square wave output do not always correspond to voltage changes in its CV outputs.

What's in this for a musician?

Composers, improvisers and performers use plant-generated electrical signals in many ways. All methods involve varying levels of mediation. A typical plant interface first mediates the plant's electric signals through a 555 timing integrated circuit, which generates the square wave in our last two data plots. *Scion* mediates the plant's voltage still further by producing four CV outputs.

One key question for many musicians is: how do we get from arbitrary data sonification (e.g. sonar, geiger counters) to an aesthetic creation?

Composers such as Mamoru Fujieda mediate plant voltage significantly, slowing down the waveform and mapping it to a particular tuning (often a diatonic scale). Others such as Miya Masaoka use custom-designed software. Data Garden's popular MidiSprout module (which is the source of *Scion's* software) has various sound environments preloaded into the hardware itself, so that the product often produces a pleasing, ambient soundscape (we call this "plambient"). The "raw" audio output can be manipulated in real-time and affected by live processing according to directions in a score, such as in Helen Hé's work. Another option is to use a modular synthesizer. This route opens many appealing possibilities since patching the synthesizer invites deeply personal choices.

Since Aristotle, taxonomists have placed plants and animals in entirely different kingdoms. We have "othered" plants for over two millenia. Plants have sophisticated ways of sensing the world and responding to it, but we usually do not notice this because they operate on time scales either either vastly longer than human life or much shorter (as in the case of annuals). Plant collaborations invite us to see our role in the cosmos differently, and remind us that we are but part of a vast ecosystem that is in a rapid state of decline thanks to relentless exploitation of natural resources. Making music with plants can be an effective and visceral form of advocacy not just for the botanical ecosphere, but also for the animals and people who depend on it for survival.

*Extras

Please visit **http://www.theoryofpaul.net/plants** for images of our plants, a bibliography, discography, and short bios of the presenters.