Solar Sound Arts: Creating Instruments and Devices Powered by Photovoltaic Technologies

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ABSTRACT
This paper describes recent developments in the creation of sound-making instruments and devices powered by photovoltaic (PV) technologies. With the rise of more efficient PV products in diverse packages, the possibilities for creating solar-powered musical instruments, sound installations, and loudspeakers are becoming increasingly realizable. This paper surveys past and recent developments in this area, including several projects by the author, and demonstrates how the use of PV technologies can influence the creative process in unique ways. In addition, this paper discusses how solar sound arts can enhance the aesthetic direction taken by recent work in soundscape studies and acoustic ecology. Finally, this paper will point towards future directions and possibilities as PV technologies continue to evolve and improve in terms of performance, and become more affordable.

Keywords
Solar Sound Arts, Circuit Bending, Hardware Hacking, Human-Computer Interface Design, Acoustic Ecology, Sound Art, Electroacoustics, Laptop Orchestra, PV Technology

1. INTRODUCTION
The phenomenon of photovoltaics (PV), the conversion of light energy into direct current, was initially discovered in 1839 by the French physicist Alexandre-Edmond Becquerel. Over the next hundred years, experiments in photovoltaics progressed slowly, and it wasn't until the 1950s that the technology began to be used in earnest for practical harvesting of energy in the space industry through sustained research at Bell Laboratories, AT&T, and Western Electric. The 1970s saw the mass production of solar panels, but the technology failed to progress rapidly and take hold as a viable alternative to fossil fuels due to powerful oil company lobbyists and a lack of government subsidy support. Within the last ten years, however, PV technologies have emerged as a real viable alternative, particularly in remote installations, as the many solar panels along roadsides and gas lines powering pumps and hazard lights attest.

The last ten years has also seen a rapid increase of the use of PV technologies in art, particularly art installations installed in remote locations, such as the Black Rock Desert in Nevada during the annual Burning Man Festival. As well, it seems that the various ecological threads of sustainability, including music's own acoustic ecology phenomenon, has created an environment in which outdoor, site-specific arts practice has grown into a real force of interest among many artists and curators. With an ever-emerging culture of DIY electronics and media art forms, it is not surprising that PV would offer attractive solutions to remote power needs, but it also offers a interesting new variable into the possibilities of environmental interaction. This paper will introduce some ideas towards putting PV to work in experimental sound works and instruments, with emphasis on environmental interaction through PV variability.

2. BACKGROUND
In 1979, Alvin Lucier, in collaboration with electronic designer John Fullemann, completed his solar-powered sound installation entitled *Solar Sounder I*. The piece was installed as a semi-permanent installation in the lobby of City Savings Bank in Middletown, CT. The solar panels were placed at ground level such that a person could cast a shadow over a panel and cause the sound to change. Speaking about this piece, Lucier tells us that the idea behind the piece is not that the audience can manipulate the sound, but that "the sound is changed by the rotation of the earth and the revolution of the sun, and so changes with the seasons" [5]. As the sun fell on the cluster of PV panels in different proportions based on the angle of the sun, which if course is dependent upon rotation and revolution, it caused the piece to sound in a distinctive way during that particular time of day and part of the year.

Craig Colorusso's *Sun Boxes* (2009-10) consists of twenty speakers with circuitry that play guitar loops of different lengths, each with independent solar PV systems, creating an evolving soundscape [1]. Like Lucier's work, this piece generates sound only when the sun falls on the solar panels, thereby linking the piece to real-time environmental factors. Jeff Federsen's *Earth Speaker* (2007), a series of PV-powered speakers and circuits, absorb sunlight during the day, and play low frequency sounds at night [6]. Nigel Helyer, a Sydney-based sculptor and sound artist, has created several interesting environmental works that are completely self-contained using PV technologies, including *Haiku* (2003), *Lotus* (2006), and *Meta-Diva* (2001), consisting of a group of loudspeakers on the ends of long aluminum pipes, sticking out of the water in a cluster. Each circuit is a solar-powered "voice," emitting short samples of the sounds of birds, frogs, insect sounds, etc, which are sounded at unique rhythms, creating a texture of natural voices [3].

These works all have different approaches to generating sound, but common among them is the way in which they relate to their environment, both in terms of their reliance on that environment's natural energy level, and in terms of the resulting soundscape. The approach to distributing power is partially responsible for this, having many self-contained, slightly individualistic objects that are part of a larger whole, but the sounding objects themselves utilize the variability of the power source in the sounds produced. In this way, the sounds are linked explicitly to environmental energy factors. This approach to dealing with power issues has interesting implications not only for sound installation work, but also for sound performance, improvisation, and composition.

3. SOLAR OBJECTS AND INSTRUMENTS

The author's own inquiry into this research comes from a long-standing practice of soundscape composition and site-specific performance, as well as through technological research interests and experiences in interactive instrument design and laptop performance [2][8]. Some general principles of the following designs include:

- Self-contained systems. The objects and instruments are conceived as all-in-one devices, featuring their own sound generation circuitry, loudspeakers and energy collectors (PV arrays).
- Portability. The objects are highly portable, and in the case of the instruments, they are small hand-held devices.
- Context sensitive. The objects respond directly and immediately to light both in terms of power and sound control.
- Recycled materials. The objects are constructed from inexpensive parts and recycled materials.

What follows are descriptions of several devices and instruments that have resulted from this preliminary research.

3.1 Solar Noise Discs

These small, handheld instruments grew out of some earlier experiments [2], and all have the same basic features. They are packaged in recycled film canisters, particularly small ones intended to house 3.5-inch reels of 16mm film. They have speaker holes on one side, from which the sound emits. On the other side, they feature three photocells, and five body-contact points via Canadian dimes, which when touched, use body capacitance to affect changes in the circuit (see Figure 1). The sound-producing circuits in these instruments are based on Schmitt trigger logic chips such as the 74C14 and the 4093. These bistable multivibrators can be used to produce a square-wave oscillator by connecting an RC circuit between input and output pins on the chip. Several oscillators can be produced with a single chip, and circuit-bending techniques are used to create modulations and instabilities in the circuit. The resulting sounds are amplified through an LM386 amplifier and a small speaker built in to the instrument. The instrument includes a 2.1 mm coaxial power jack for DC power, which connects to a PV array, or to any DC power source for that matter.

Figure 1: "Fly" Handheld Solar Electric Instruments

The instrument can be played by holding it between the hands like a tiny accordion. One hand becomes a kind of mute, which is essentially volume: to stop the sound, you just cover the holes, opening your hands up as you need more sound, which also changes the timbre. The other hand, of course, covers the three photocells and connects the body contacts in various ways, depending on how fingers are arranged. How one does this, and how it affects the sound is something that has to be experienced and practiced. It seems chaotic at first, but one soon learns that things can be controlled, and repeated, if conditions are just right. There are currently three of these instruments in existence, and a few oddball versions as well. Although they each sound different, due to variations in the circuitry, there is a quality about all of them that is similar due to the basic circuit design and the physical resonance properties of the case.

To power the instruments, there are two different "levels" of power, to allow for a couple of different types of lighting level requirements and volume levels. On sunny days, these instruments can be played with "solar flaps", which are essentially small solar arrays mounted on either side of a cardboard flap, which plugs into the instrument and kind of dangles, flapping in the wind if it happens to be windy (see Figure 2). This will supply a maximum of about 600 mW of power, more than enough to power the instrument quite sufficiently if its sunny, and it allows for the possibility of rapid changes of character since one can quickly move it in and out of shadows. The next power level is achieved by connecting the instrument to a larger solar panel that can be worn on a pack-back, or simply placed on the ground. The Go Power! DURAlite series of PV panels, manufactured by the Carmanah Technologies,[1] have proven to be the most effective solution in the field. These lightweight panels are designed for RV and marine usage, and they are quite robust due to the fact that the solar film is encased in a fiberglass laminate, making them virtually unbreakable, as well as waterproof and resistant to clouding by overexposure to intense sunlight. These products come in three varieties: 5, 10, and 20 watt panels, each with an operating voltage of 16 volts. Even in cloudy conditions, the 5 watt panel has proven to work very well.

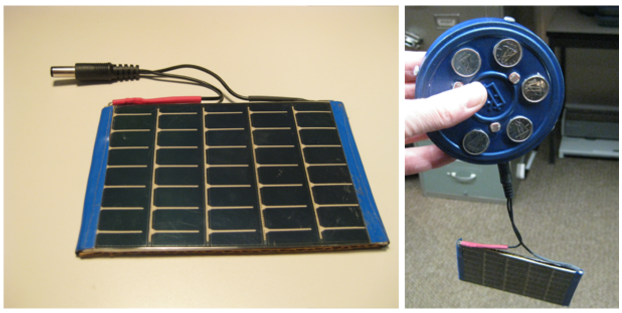

Figure 2: "Solar Flap"

3.2 Bird

This installation project was an attempt to create something that was completely self-contained, with the PV technologies being "built-in" to the object. Using small 500 mV cells generating about 17 mA of current, a ring of several of these were connected in series to form an a PV array, which were glued onto a small disc. This array, of course, failed to generate enough wattage to power the amp-speaker circuits used in the instruments above, but would work just fine powering piezo-elements. Sound generation was created using similar Schmitt trigger circuits to the instruments above, connected to piezo-speakers. The results are a series of beeping, twittering, and buzzing devices that are completely self-contained, each using about 40 mW of power.

In preparing for this work, the work of Ralf Schrieber and his "solarsoundmodule" designs were quite inspirational [7]. The key interest in this work was not so much in the individual design itself, but in the idea of several of these operating as a

[1] http://www.carmanah.com

series of voices in a single system. It became interesting to imagine walls covered with these devices, in clusters or spread throughout a space, or perhaps hanging from the ceiling in mobiles.

Figure 3: *Bird* (2009)

The resulting piece is indeed a mobile, named *Bird*, which consists of four round objects based on the 4093 chip, a piezo-speaker, a bottle-cap resonator, and a ring of seven small 500 mV solar cells in series, all housed in plastic juice bottle caps (see Figure 3). The four devices hang in a column, connected one to another by ball bearing fishing swivels, allowing each to turn freely. These hang inside a column of streamers made from ¼" red plastic leader tape. This allows for the wind to affect the sounds from the devices due to rippling shadows cast by the streamers, as well as helping to generate the force necessary to cause the devices to turn in response to the wind, creating an ever-changing sound based on the sun and the wind. Bird has been exhibited on its own, and as part of larger installations.

3.3 Domeintonators

These devices are hybrid installation objects and instruments, and were designed using circuitry similar to that of "Bird" above: a 4093 NAND gate chip with two distinct patterns of modulating square wave oscillators, each of which is sounded by one of two piezo speakers. The circuitry is installed in recycled security camera domes, and includes an audio jack for amplifying the signal (in stereo) of the domes if desired (see Figure 4). The devices also include two photocells, which are installed in the dark battery compartment in the bottom of the housing. When the door to the battery compartment is removed, the performer can manipulate the sound of the instrument by "playing" the photocells underneath the instrument, thus causing changes in the speed of the two modulated square waves.

These are powered by a 150 mW flexible solar strip by PowerFilm, Inc., which manufactures a variety of small to medium-sized flexible strips.[2] The solar strip is mounted in an arch over the circuitry inside of the clear dome top of the instruments. This makes the instrument completely self-contained, but it is expandable in the sense that it can be amplified using external equipment if desired.

Figure 4: "Domeintonators"

[2] http://www.powerfilmsolar.com

These instruments have been used in performances as well as in installation settings, but ultimately these might be best suited to an interactive installation in which the existing six devices could be "played" by listeners, while being further amplified by an additional solar-powered amplifier and loudspeaker, making the six instruments function as one larger, organ-like instrument.

3.4 Arcade Bells

The Arcade Bells resulted from a desire to move beyond these analog-ish methods for making sound by employing a small microprocessor. In addition, this piece uses piezo discs to explore ways to "ring out" or resonate larger objects, such as metal sheets, bowls, and other devices that might make nice resonators. This particular piece uses four small copper-plated footless goblets as transducers by gluing large piezo discs to the bottom of each and sending the leads through a hole drilled through the center. A housing container is attached to the bottom, made from recycled evidence containers, in which the circuitry resides.

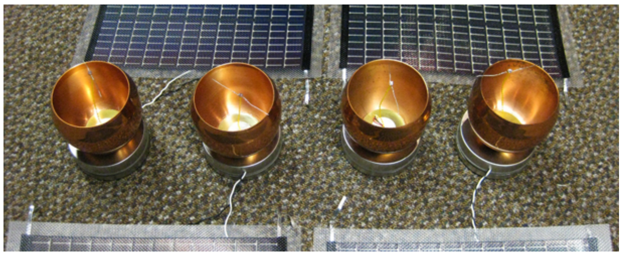

Figure 5: *Arcade Bells* (2010)

The circuitry consists of an ATMEL ATmega328 chip and its life support (voltage regulator and power capacitors, crystal clock, etc), a LM386 amplifier, a small transformer, and a photocell, which sticks out of the cup like a small flower. The chip is programmed to generate square waves at audio rates in patterns; specifically, ascending spectral arpeggios, similar to 1980s arcade game sound effects. The chip also monitors the state of the photocell, which when bright, means the spectral arpeggios get faster, and open up to more of a range. The sound created by the chip is amplified through the LM386, and impedance-matched to the piezo-disc, which then resonates through the brass cup.

Using the ATMEL chip requires more power than the simple logic chips used in previous experiments, but nevertheless they are quite capable of operating in low power states. This entire circuit consumes less than 500 mW and can operate with much less. The amplifier is powered outside of the 5 volt regulator's loop, allowing it to be more directly effected in volume by the full voltage coming in from the solar panel.

3.5 Solbutter Instruments

The final series of devices discussed here are a new series of microprocessor-based devices, based in part on the work done on the Arcade Bells above. These instruments also use the ATMEL ATmega328 chip to generate sound, as well as to read sensor data from various control sources. As of this date, two prototypes have been completed, both of which use the ATMEL's timer interrupts to generate waveforms other than square wave forms, including sine waves and FOF-based granular synthesis algorithms.

Like the noise disc instruments above, these are round, handheld instruments with a built-in speaker amplified by a LM386 chip, mounted on the bottom of the container. The instrument shown (figure 6) features two pushbuttons (taken from a recycled toy), a 50K ohm potentiometer, and four photocells.

Figure 6: "Solbutter I"

Code-wise, the sound producing methodology, written in the Arduino environment, uses the chip's PWM (pulse-width modulation) digital output capabilities to simulate analog waveforms, and also uses a timer-interrupt routine to ensure that the sound-producing part of the code gets priority. This device uses code based in part on the open-source "Auduino" project by Peter Knight, which implements a simplified FOF synthesis model to create a low-fidelity granular synthesis architecture [4].

Powering this instrument is accomplished the same way that the noise disc instruments are powered: either by plugging in a "solar flap", or a larger solar panel (or a battery or any other DC power source). This instrument requires at least 250 mW, and includes a voltage regulator and filter for the chip. The amplifier uses the raw voltage of the solar panel, meaning that the relative volume level is proportional to the power received from the PV source.

Figure 7: Performing with Tealfly in the Ravine

4. FUTURE WORK

While these humble beginnings have been instructive, it seems clear that this research has tremendous potential. It has already led to a number of interesting performances and installations, and it is my hope that through a combination of these obsessions and experiments, and the obsessions and experiments of others, a kind of "solar sonics practice" might emerge, which might open up a whole new world of site-specific and spatial performance concepts. In the words of Alvin Lucier: "Composers are thinking now of a timeless kind of depth; that is, of creating and going *into* a sound-space, rather than moving horizontally *along* it" [5]. This, to me, is what much of this work is about, and where much of its potential lies.

In addition, this work has tremendous potential for artists involved in the field and philosophy of acoustic ecology. In addition to the obvious utility of creating electronic music performances outdoors using sustainable technologies, the metaphor of real-time energy production as a sonic parameter is a powerful one, and will undoubtedly result in a variety of interesting sound work with explicit connections to environmental factors.

The future will bring a new series of installations, some of which will be prototyped and evaluated at the Burning Man Festival in 2011. Also planned is a PV-powered portable hemispherical speaker for supporting mobile outdoor performances with laptops and other electronics that require additional amplification. Finally, I intend to infect more people with this bug through instrument building workshops and skill sharing, both here in my community and beyond.

5. ACKNOWLEDGEMENTS

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Finally, I would like to acknowledge some of the manufacturers of the PV products that have been used in these experiments, particularly Carmana Technology Corp. and PowerFilm, Inc. In some ways, PV is still just getting off the ground, and the number of manufacturers of these products are small, mostly centered on products for large-scale power installations or home conversion systems. PowerFilm in particular is developing a wide variety of PV solutions that are especially of interest to sound artists and designers, since they are scalable, extremely robust, and easy to mount on any surface with foam tape or adhesives.

For more information on this project, including more details, photos, schematics, sound samples, and video clips of these and other instruments and devices, please visit the project website at:

http://www.ualberta.ca/~ssmallwo/see/.

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