Electronic PRODUCTS

Making low-voltage energy harvesting practical: Part 1 – The history of energy harvesting

Bringing a sleeping giant to life

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Today s world-wide mantra is for everyone and everything to be wireless and as energy efficient as possible. Suddenly, being tethered to a line source or even a rechargeable battery-pack, is not acceptable.

Engineering has extended battery life to the point we now have the ability to cut the ac power cord for extended hours, in some cases portables units can 24 hours or more before requiring a recharging. Energy harvesting creates the next technology shift giving us the ability to cut, or at least reduce significantly, both the a/c cord and batteries with that will at some point require recharging.

Ultimately, the goal is to be able to capture any number of very low-state energy sources such as photovoltaic, piezoelectric, thermoelectric, wind, biomechanical or even ambient radio frequency (RF) and electromagnetic (EM) radiation harness this currently unused power to run any number of devices and products allowing them to be in a near –always charged" status.

We have come a long way. In the last few years. Energy-harvesting technology has evolved to capture accumulate, store and manage the energy available from these sources. Figure 1 shows the basic concepts of energy harvesting. But it has been a long journey since man first felt the sun s rays.

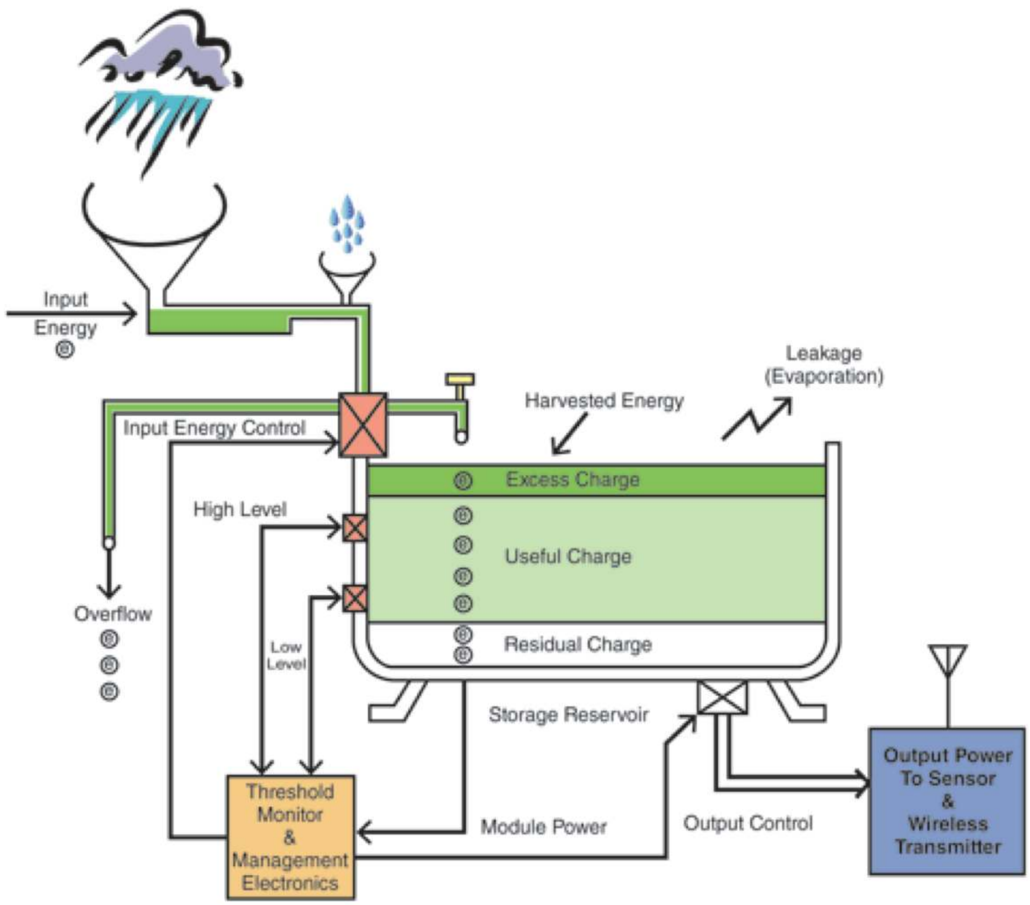


Fig. 1:Energy-harvesting overview. (Courtesy of Advanced Linear Devices.)

Thanks to fossil fuels

The interest in harvested energy was given a kick start in the late 1970s when the first energy crunch came about. Suddenly, fledgling technologies such as solar became all the rage, and large-scale wind farms started cropping up as well. Coincidentally, technology had evolved to make this somewhat practical. And contrary to most normal technological development tracks, the dynamics of large-scale wind and solar technology were much easier to implement than micro- and nano-scale technology. It seemed like the planets had aligned to present the ideal combination of circumstances to give birth to the energy-harvesting industry and bring it into the mainstream.

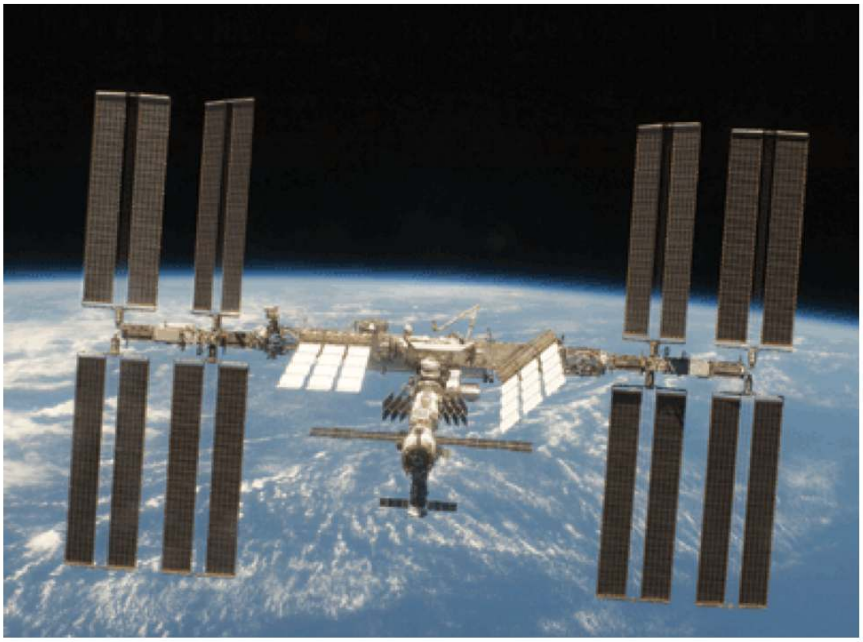
Of course, just because it can be done doesn t always mean it will be done. There was a lot of panic shortly after the first energy crisis, and that jump-started large-scale development of the only two practical sources of scavenged or free energy available at that time-wind and solar power. As fossil fuel prices adjusted to market demands over the next few years, the bump that wind and solar got from the initial panic seemed to fade into the background. Development continued, but alluring ROIs that the hand-wringers promised with the demise of fossil fuels never materialized. The cost of fossil fuels stabilized, and the cost of energy harvesting still had a fairly high amortization cost curve.

Solar power s contribution

Modern commercial photovoltaic technology was developed in the United States in 1954 when Daryl Chapin, Calvin

Fuller, and Gerald Pearson developed the first commercially producible silicon photovoltaic (PV) cell at Bell Labs. This first silicon solar cell offered a mere 4% efficiency.

It wasn t until the late 1960s that solar cell technology advanced enough to be implemented with some confidence on a larger scale. NASA decided solar was a better choice to power satellites than nuclear, which gave a green light to the technology for commercialization.



Solar-powered satellite. (Courtesy: NASA.)

Shortly thereafter, in the early 1970 s, Dr. Elliot Berman, backed by Exxon Corporation, designed a significantly less costly solar cell. This was accomplished by selecting a lower grade of silicon and evolving cheaper packaging. This reduced the cost of the cell by 80%, bringing it down from $100/W to $20/W. From this point on, solar started to find a home in more segments of industry.

But it wasn t until the 1990s that better and cheaper cells were developed by applying methods such as growing the silicon into shapes that eliminated most of the slicing or finding a way to simply apply solar cell material onto inexpensive, but rigid support structures, such as ceramic, glass, plastic, or steel.

Coming soon to an array near you are tomorrow s PV cells with an expected 40%+ efficiency from nanoparticle- and molecular beam epitaxy-based technologies currently on the drawing board. Essentially, the developments of the 1990s laid down the platform for today s 21st century micro- and nano-photovoltaic energy-harvesting technology.

Feel the wind

Over the years, man has used the wind to power an almost unimaginable array of devices.

Today, even human breath is capable of being harvested as a power source a far cry from the trade winds that powered early man to the far corners of the world.

The most ubiquitous wind harnessing device is the windmill. Other than the sail, the windmill concept is the basis for all wind-driven energy devices. Perhaps the most renowned utilization of windmills is the fabled Dutch windmill innovation that allowed them to drain lakes and rivers in Europe s Rhine river delta. As far back as 200 BC, the Chinese used windmills to pump water a technique that was refined well into the 19th century and used in farm irrigation. About the same time, the Persians used windmills to grind their grain. This same general windmill technique was later adapted to generate early forms of electricity.

The first wind turbine to generate electricity was developed by Professor James Blyth of Anderson s College in Glasgow. The configuration consisted of cloth sails resembling windmill blades. The generated energy was stored in accumulators and used to power the lights of his vacation cottage in Marykirk.

Today s wind turbines are a far cry from the windmills of bygone eras. Modern wind turbine fields can be seen in any number of geographic locations around the country and the world. According to the U.S. Department of Energy, by 2030, wind-generated energy will account for 20% of all of the generated energy in the U.S. Europe is expected to be even more wind powered by then.

Flip it around 180

Solar and wind have always been the predominant sources of scavenged/waste or free energy. Their success and what we have learned from them has inspired great thinkers to scale down energy harvesting to the micro level. As a result, the girth of energy harvesting has expanded beyond just wind and sun to include movement, heat, mechanical vibration, RF, and others, as mentioned previously.

Low-power energy harvesting is a technology of the 21st century. As such, its history is short but dynamic. Technology advancements of the late 20th century jump started this emerging field. The ability to reduce the power requirements of portable devices by orders of magnitude, in just the last 10 years, has made formerly unthinkable waste energy sources realistic for the next generation of portable and remote devices.

While low-power harvested energy has been on the drawing board since the late 1990 s, it wasn t until about 10 years ago that the first generation of low-power energy-harvesting devices emerged. They were designed to harvest micro power primarily from photovoltaic or piezoelectric sources. However, they were really designed more as backup sources to charging circuits and still required battery back-up. In 2007, the first true micro-powered energy-harvesting product was developed. It was capable of capturing energy not only from photovoltaic or piezoelectric, but also from virtually any micro-power source and its generating action, such as:

Mechanical: vibration, stress
Thermal: furnaces, heaters, friction
Light: photo-sensor, photo-diode
Electromagnetic:“inductors, coils, transformers
Natural Resources: wind, water, solar, human
Other: chemical, biological

The ability to capture waste energy is due to technology known as ~~z~~ero-—and ~~n~~ano-—powered metal-oxide semiconductor field-effect transistors (MOSFETs). These devices can be triggered by input voltages as low as 100 mV, and input power of as low as 200 nA. The ultra-low powered energy-harvesting modules are the technology that has unlocked the next generation of energy-harvesting devices (see Fig. 2). This technology will be discussed, in detail, in the next installment of this series.

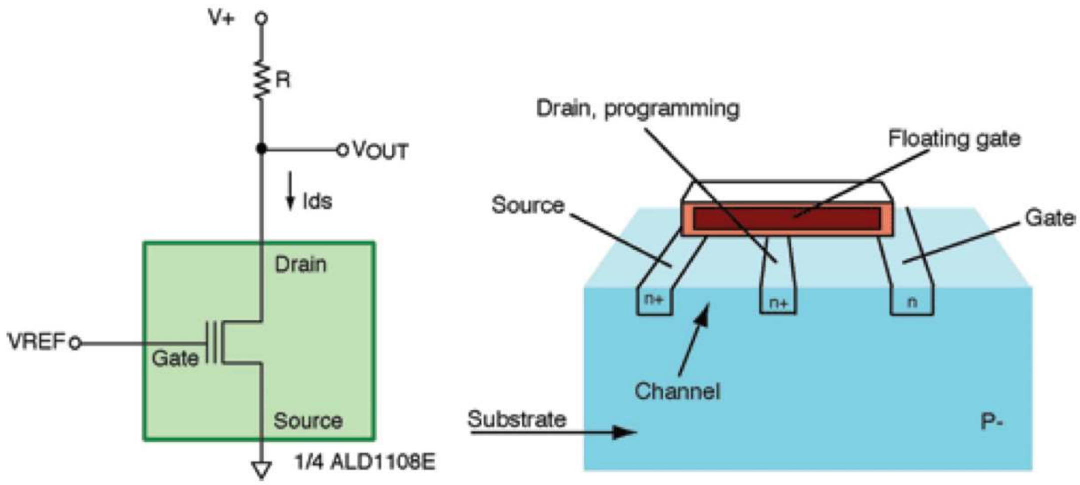


Fig. 2: Zero-Threshold and nanopower MOSFETs.

This leap in technology has generated a fast-forward movement in the development of true, untethered micro-powered energy-harvesting devices. The future of this technology will also be covered in detail, in the third and final article in this series.

The wheels have been greased   a glimpse of the future has been handed to us, and Moore s Law is starting to come into play in this arena. The history of energy harvesting is a colorful one- from Neanderthal man lying on a rock in the sun to warm up, to future miniature wind turbines that can capture waste heat and power from the breath of a human. Because micro-power energy harvesting is such a new platform, much of its history is still to be written. We are lucky to be at the forefront of the next evolution of energy harvesting. ■