Roger W. Riehl and the Synchronar

World's First Solar-Powered Wristwatch

BY RANDY JAYE (FL)

From ancient times humanity has been using sunlight to measure time. The earliest known sundial or shadow clock[1] (Figure 1) has been dated to 1500 BC when the Egyptians used the device to measure worker hours for construction projects in the Valley of the Kings.[2] It took 3,500 years after the origin of the sundial or shadow clock before a solar-powered wristwatch[3] became a reality. The world's first solar-powered wristwatch was invented by Roger William Riehl, a self-taught electronics expert. He coined the name Synchronar—also referred to as the Synchronar 2100—from SYNchronous CHRONometer calendAR (Figure 2). Riehl built and tested prototypes from the late 1960s into the early 1970s, and the first production model was released in 1972. After the Synchronar was released, Riehl worked on innovative improvements to the original design for the rest of his life. Over a 33-year span Riehl designed and released four models of his Synchronar wristwatch: Mark I, II, III, and IV, and the less expensive version, Sunwatch. The cases were available in stainless steel, black ceramic, solid gold, gold plating, rhodium plating, and titanium.

Figure 1. World's earliest known sundial, also referred to as a shadow clock, was discovered in Egypt's Valley of the Kings and dates to 1500 BC. COURTESY OF UNIVERSITY OF BASEL.

The Synchronar wristwatch marks an important chapter in horological

Figure 2. Synchronar, world's first solar-powered wristwatch, ca. 1972.

Figure 3. Roger W. Riehl, left with his back facing the camera, demonstrates his grand prize winning pinball machine to classmates in 1950. COURTESY OF HOWARD RIEHL (2).

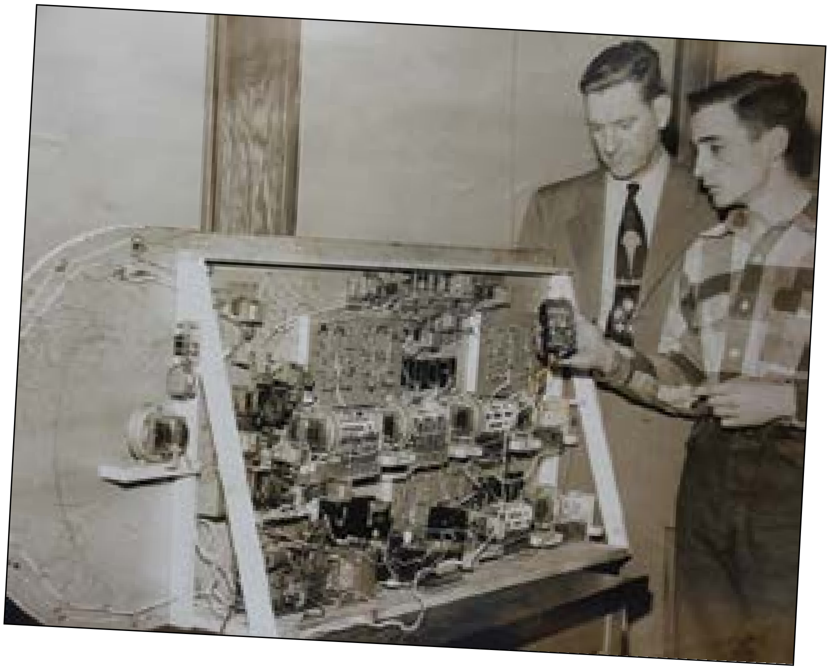

Figure 4. Roger W. Riehl, right wearing the plaid shirt, operates his first prize winning electronic football field scoreboard in 1952.

history, because solar power, a renewable energy source, made it possible to energize wrist-worn timepieces.

Riehl was born on Christmas Day, December 25, 1935, in Brooklyn, NY, and died on February 16, 2005, in New Berlin, NY. He graduated from Whitesboro Central School in Whitesboro, NY, in 1953 and attended a technical college in 1954, but he did not complete a degree program. He had three sons: Roger, Barry, and Howard.

Riehl demonstrated an aptitude for electronics when he taught himself how to repair television sets at the age of 11. At age 15 he designed and built a pinball machine (Figure 3) in the basement of his parents' house, and his entry won the 1950 ninth-grade grand prize at the third annual Herkimer Science Congress at North School in Herkimer, NY.

At age 16 he designed and assembled an electronic football field scoreboard (Figure 4) made from junk and discarded parts, which included old electric train transformers, six soup cans, damper motors from heat control systems, wire from coin machines, and a curtain rod. This feat won him a first prize in the 1952 Whitesboro Central School physics competition. In a July 9, 1952, *Utica* (Utica, NY) *Dispatch-Observer* article titled "He Knows the Score," Riehl was referred to as a "young genius."

At age 18 he wrote an article titled "The Electronic Regulation of the Audible Spectrum." This article and his demonstration of equipment, which included a record player, electrical meters, and vacuum tubes, won the grand prize in the chemistry, biology, and physics contest at Whitesboro Central School in 1953. In 1952 and 1953 he also participated in the State Science Congress sponsored by the New York State Science Teachers Association for Future Scientists of America.

Riehl became a self-taught engineer who visualized

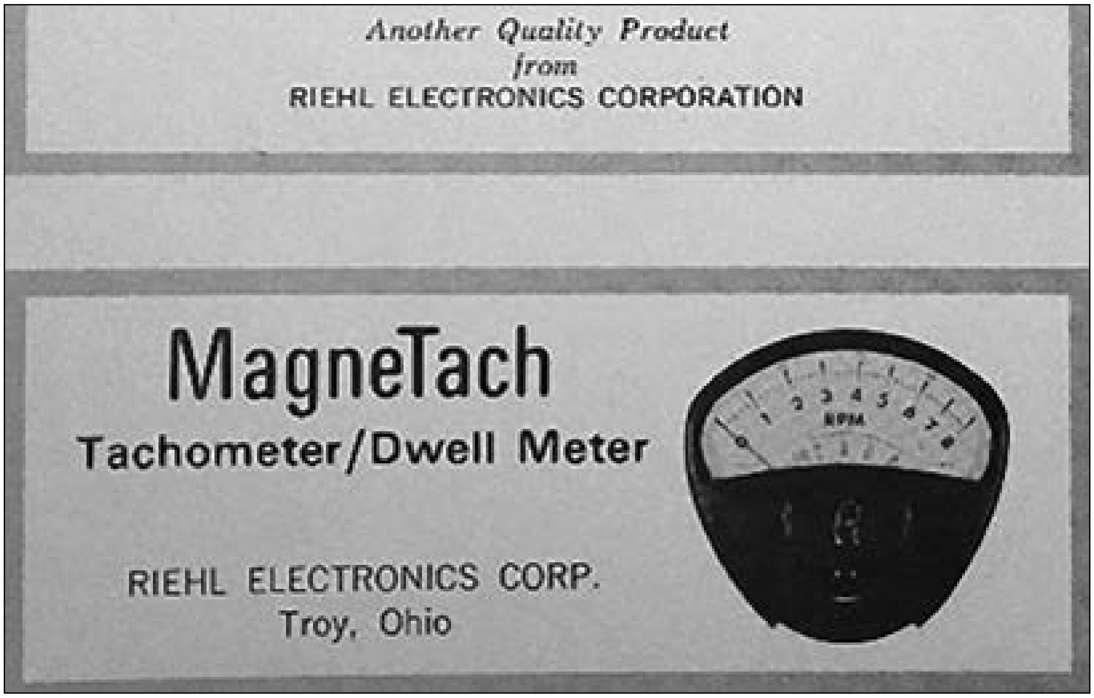

Figure 5. MagneTach product advertisement from Riehl Electronics Corp., ca. late 1960s.

and conceptualized new electronic devices and possessed the uncanny ability to design and invent them without a formal engineering education. He honed his electronic and design skills at various companies before taking on the personal challenge of designing and constructing a digital solar-powered wristwatch.

From 1954 to 1957 he repaired televisions and built custom hi-fi sound systems in the Utica, NY, area. In 1958 he moved to Cincinnati, OH, and worked at a cousin's television appliance business as a television repairer. In 1959 he got the idea for a digital solar-powered wristwatch after he realized how military devices were using integrated circuits (ICs).[4]

In 1960 he worked as an engineer at Dayton Aviation Radio Equipment (DARE Electronics, Inc.) on two-way FM radio development. While at DARE he flew worldwide as a flight crew member testing navigation equipment for US Air Force and Navy applications. He also obtained a FCC second class technical license in 1960.

He started Riehl Engineering in 1960 and worked out of a room in his house. Here he worked on his idea to design a digital solar-powered wristwatch device. He also designed and marketed a transistor ignition system called Spitfire,[5] which claimed to keep an automobile engine in proper timing (up to ten times longer) and to increase horsepower by 20 percent.

Throughout the mid- to late-1960s he explored many ideas related to solar-powered devices and how to design a wristwatch with wire filaments and an electronic digital display that worked by storing energy in a solar cell.

He operated Riehl Engineering until late 1964. Then, in 1965 he opened Riehl Electronics Corp. (REC) in an industrial building in Troy, OH. This company made and distributed various electronic products, including the MagneTach tachometer/dwell meter (Figure 5), and heat sinks.

Figure 6. Roger W. Riehl's various clay prototype models for the digital solar-powered wristwatch case, ca. 1970-1972.

Riehl also worked on his solar-powered wristwatch concept and completed various prototypes from 1968 to 1972. The prototypes and the production models had a "space age" appearance, which made the concept even more revolutionary. His space age case designs (Figure 6) and actual circuitry designs (Figures 7 and 8) were well on their way to becoming a revolutionary working digital solar-powered wristwatch.

From 1969 through 1970 he worked as an electronics engineer at Hobart Manufacturing in Dayton, OH. (Here he was instrumental in the design of the world's first digital delicatessen scale, for which he was granted a US patent.[6]) He continued to work on his designs and testing of his digital solar-powered wristwatch concept in addition to his responsibilities at Hobart.

In 1970 he returned full time to Riehl Electronics Corp.

Figure 7. Roger W. Riehl's solar-powered wristwatch prototype with digital display view, ca. 1968-1970.

Figure 8. Roger W. Riehl's solar-powered wristwatch prototype's top view with circuitry exposed, ca. 1968-1970.

Figure 9. Roger W. Riehl's solar-powered wristwatch prototype with the two push-button control design that failed waterproof testing, ca. 1970.

to bring his dream of a digital solar-powered wristwatch to reality. Late in 1970 Riehl completed a fully functional prototype of a digital solar-powered wristwatch that featured two push-button controls (Figure 9).

He discovered that the push-button controls leaked during waterproof testing. This problem forced him to go back to the drawing board to develop a more reliable waterproof design that controlled the functions of the wristwatch.

In 1971 Riehl began selling stock in REC to fund the digital solar-powered wristwatch project. He filed for a US patent on May 3, 1971.[7]

From late 1971 to early 1972 Riehl completed a working prototype of a digital solar-powered wristwatch (Figures 10 and 11) that included two revolutionary slider control switches on the top of the case. This slider control design passed all of his intense waterproof testing, and the push-button control concept was discarded.

Later in 1972 Riehl completed the world's first production-ready digital solar-powered wristwatch that featured custom state-of-the-art complementary metal-oxide semiconductor (CMOS)[8] circuits that he designed. Riehl's goal to design and build an exceedingly accurate solar-powered wristwatch that required no service, withstood wide variations in temperature, was shockproof, was waterproof to considerable depths, included a digital display that was visible in natural lighting conditions, and had multiple user-friendly functions was achieved. The introduction of the Synchronar (Figure 12) with all of these features proved that the world's first digital solar-powered

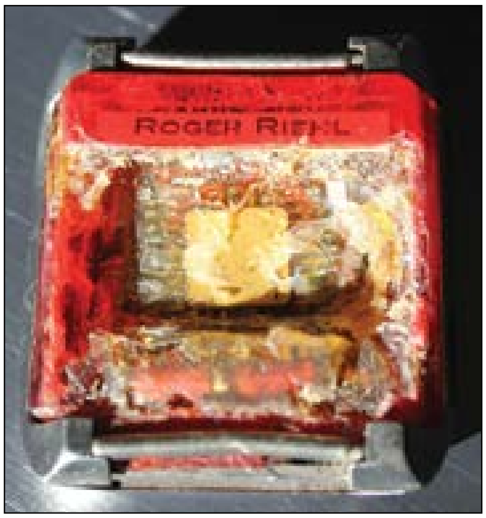

Figure 10. Roger W. Riehl's solar-powered wristwatch prototype. Note the name on the case back is "Roger Riehl"—the only one known to exist—because the name "Synchronar" was not yet coined, ca. 1971-1972.

Figure 11. Roger W. Riehl's solar-powered wristwatch prototype with waterproof slider controls on the top of the case, ca. 1971-1972.

Figure 12. One of Roger W. Riehl's first production Synchronar wristwatches. Note the name "Synchronar" and the low S/N 3, ca. 1972.

Figure 13. Roger W. Riehl's hand drawing of a Synchronar concept wristwatch with a cushion-style case and oval solar panels, ca. 1975.

wristwatch was not just a space age aberration but a challenge to the mainstream traditional wristwatch designs of the 1970s.

The first Synchronar production wristwatches were made at Riehl Electronics Corp. in Troy, OH. Ness Time marketed most of the first production Synchronar wristwatches during 1972 and into 1973 and was tasked with finding a CMOS circuit manufacturer in the Silicon Valley area of California, but it could not contract one. Riehl decided to sever the partnership with Ness Time and worked with Ragen Semiconductor, a subsidiary of Ragen Precision that became the sole supplier of the unique CMOS circuits.

Riehl also sold some of his earliest watches to the Hammacher Schlemmer store in New York, NY, and many were marketed through its mail-order catalog.

The Synchronar is a unique wristwatch and remains a futuristic curiosity even today. The top of the watch looks similar to a cobra's head and houses a silicon solar cell. The time is displayed in red digits by a light-emitting diode (LED)[9] display on the side of the watch. The design of the watch was so revolutionary that Riehl Electronics Corp. filed for a US patent on November 6, 1973.[10]

In a December 1973 article in *Popular Mechanics* titled "World's First Solar-Powered Watch," Riehl explained that "the circuit is a breakthrough in the number of components used—about 1100—to achieve its functions. An equivalent circuit would require about 4500 transistors."

The Synchronar Mark I included the following features:

- Timekeeping accuracy within a minute a year
- Three output brightness level intensities that automatically adjust to ambient light conditions
- True perpetual calendar that incorporates leap years and does not need to be reset until the year 2100
- First LED wristwatch display visible in full sunlight
- Module sealed with injection-molded Lexan®[11] that is filled with a jelled epoxy that can withstand up to 5,000-G shocks
- Temperature tolerances from boiling to freezing.

The setting and operation functionality was a new concept for a wristwatch device.

- To show the date, slide the upper right-side switch toward the display
- To show the time, slide the upper right-side switch away from the display
- To show the counting seconds, slide the lower left-side switch toward the display
- To adjust for time zone differences, slide the lower left-side switch away from the display.

In 1974 Riehl joined Ragen Semiconductor Inc. in Whippany, NJ, as vice president of operations for the Synchronar solar-powered wristwatch. Riehl became president in 1975. Starting in 1974 and continuing into 1976 Ragen Semiconductor manufactured and marketed the Synchronar. During this time the Mark I and Mark II (released in 1975) models were produced. The Mark II model also had a digital frequency synthesizer that increased its accuracy. (The user adjusted the frequency with magnets.)

To prove the versatile and rugged nature of the Synchronar, Ragen Semiconductor included a performance certification with all its watches, which stated that the Synchronar will normally survive the following tests:

- Pressure cook: 24 hours in salt brine at 60° C
- Salt spray: Salt water spray for 100 hours
- Trip hammer: 1,000 drops 1 foot onto a marble slab
- Oven bake: 100 hours at 80° C in the air
- Freeze test: Storage at -40° C for 100 hours

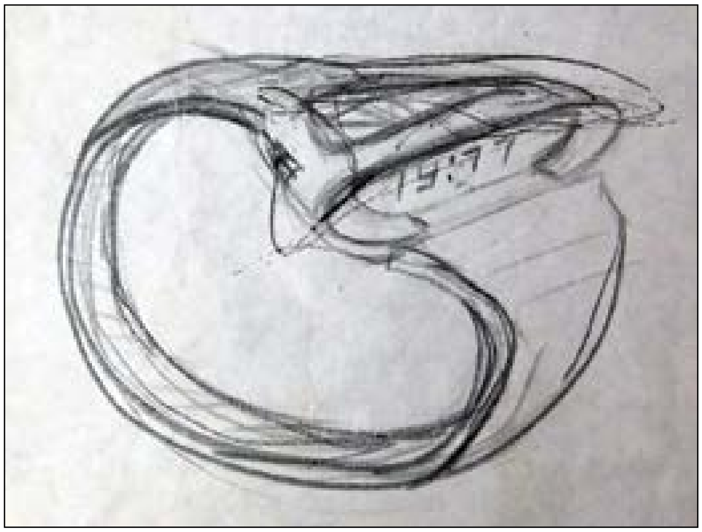

Figure 14. Roger W. Riehl's hand drawing of a Synchronar concept wristwatch side and full bracelet view with an unconventional triangular case and faceted triangular solar panel, ca. 1975.

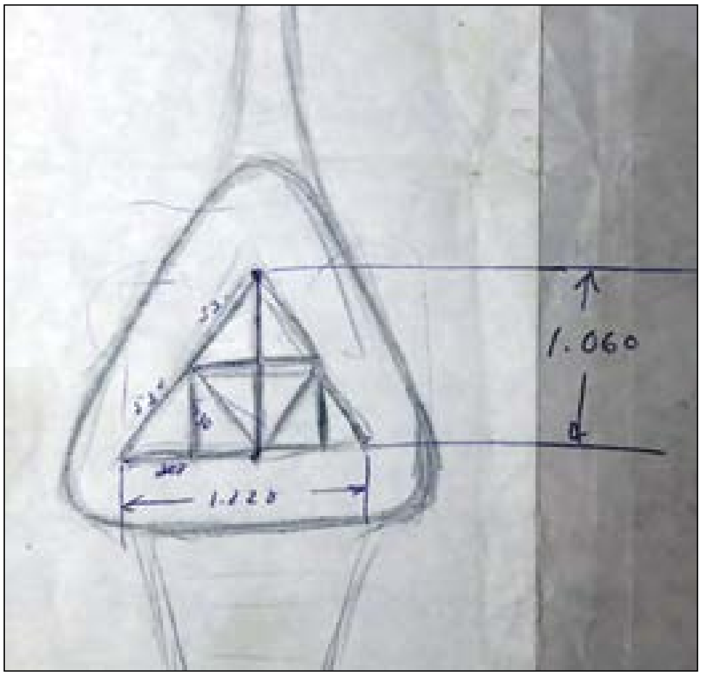

Figure 15. Roger W. Riehl's hand drawing of a Synchronar concept wristwatch top view, including various dimensions, with an unconventional triangular case and faceted triangular solar panel, ca. 1975.

- Altitude: 100,000 feet elevation for 100 hours.

These tests were confirmed by two independent laboratories. (Copies of actual test reports are available upon request.)

After the Mark II model was released, Riehl was brainstorming even more offbeat and futuristic versions of the Synchronar. In 1975 he envisioned a cushion-style case with slider switches on the side of the case and a pair of oval solar panels on top (Figure 13). He was also considering an unconventional triangular case with slider switches on the side of the case and a faceted triangular solar panel on top (Figures 14 and 15). Unfortunately, these concepts never reached production. They might have caused quite a stir in the 1970s wristwatch industry because of their offbeat and futuristic designing.

Late in 1976 Ragen Semiconductor Inc. discontinued operations due to intense competition from cheaper liquid crystal display (LCD)[12] wristwatches being produced in Asian countries. Riehl purchased all inventory and equipment associated with Synchronar production and started a new company in Whippany, NJ, in 1977 that he named Riehl Time Corp. (RTC). A new direct mail-order marketing strategy that concentrated on technical and gadget-oriented customers was launched. The Mark III Synchronar and the Mark III Sunwatch models were released in 1977. New features of the Mark III model allowed the user to see the frequency numbers while making accuracy adjustments.

The Sunwatch is a cost-effective version of the Synchronar. It was Riehl's answer to the Quartz Revolution,[13] which was pricing the Synchronar and mechanical watches out of the market. It had a plastic (Lexan®) center bar on the top of the case, but in 1980 the top design was changed to be totally flat without a bar, and an inexpensive bracelet that was priced at $129 versus the Synchronar that was priced at $199 in 1977.

In 1978 a design change to the case was prompted when Riehl said too many customers were calling the service department and asking why they could see batteries in a solar-powered wristwatch. He decided to change the transparent red Lexan® case backs to a dark black color on all Synchronar and Sunwatch models. This design change effectively eliminated customer questions and concerns about seeing batteries.

The Mark IV model was released in 1982. True to Riehl's standards of always increasing functionality, this model had more advanced features than its predecessors. An RTC news release from 1982 states that the Synchronar 2100 is "the World's First Fully Automatic Timepiece—Programmed for perfect operation through the 21st century. Adjusts automatically for such alterations as daylight saving time and extra day of leap year." It was also described as "the World's First Perpetual Watch—It will run indefinitely on the sun's energy . . . no battery replacement . . . ever." The Mark IV model also included the following features: timing adjustment of up to four seconds per year, alarm, dual stopwatch, dual time zones, and an elapsed time flasher. A later modification in 2000 added a thin layer of stainless steel on the case back cover that did not allow the Lexan® material to be in contact with the wearer's skin.

On September 29, 1983, RTC filed for Chapter 11 bankruptcy. In late 1984 RTC completely ceased operations and closed its doors.

Riehl acquired the assets from RTC and in 1985 Custom Circuits Corp. (CCC) was launched, and it continued to produce Synchronar and Sunwatch model wristwatches

Figure 16, left. Roger W. Riehl designs the Synchronar Mark V model in 2003 at his workbench. COURTESY OF FRANCIS FULLAM AND HOWARD RIEHL.

Figure 17. President Mohamed Hosni Mubarak of Egypt is wearing a Synchronar. COURTESY OF *NATION'S BUSINESS*.

in small quantities. In addition to his work at CCC Riehl worked as a technical consultant for Machine Technology Inc. in Parsippany, NJ, from 1986 through 1987. One of his accomplishments at Machine Technology was a special balancing chuck[14] he designed to enable proper alignment for semiconductor wafer manufacturing.

Starting in the 1990s Riehl was working on a new Synchronar design, the Mark V (Figure 16), and was planning to complete and release it in 2006. The Mark V was to have quite a list of advanced features, including multiple time zone capability, a 100-day countdown timer, a moon phase, a sidereal time function (a reference to stars), and a storage box with a built-in light for solar cell recharging. Unfortunately, Riehl passed away in 2005, and the Mark V was never released into production, although he had completed more than 90 percent of the design work.

Riehl's youngest son Howard began making the Synchronar Legacy Edition in 2006 to commemorate his father's achievements. These solar-powered wristwatches use the basic design of the Mark IV model and are limited to only a few per year. As a result, the Synchronar has been in continuous production for more than 40 years, which makes it one of the longest runs for any wristwatch model, especially a digital solar-powered watch.

The exact total number of Synchronar wristwatches produced is not known, but, according to Howard Riehl, approximately the following 60,000 total modules were made over the years:

- 20,000 Synchronars (Mark I through Mark IV models)
- 15,000 Sunwatches
- 25,000 modules for the Synchronar and Sunwatch

Many of these were used for upgrades or replacements for previously sold watches.

Widespread international appeal for the Synchronar ranged from the president of Egypt, Mohamed Hosni Mubarak, who was photographed wearing a Synchronar in a March 1982 article in the *Nation's Business* (Figure 17), to Paul McCartney of the Beatles rock group who was wearing one on a June 13, 2001, CNN broadcast of the *Larry King Live* television show.

Synchronar was promoted with some aggressive marketing campaigns from the 1970s to the early 1980s. Popular publica-

Figure 18, below. From left, Synchronar, sun-powered 100-year calendar watch; square-faced 18 kt. Traveler's Watch by Bueche-Girad; stainless steel bracelet clip-on watch by Gueblin. COURTESY OF *PLAYBOY*.

Figure 19. Synchronar Mark II featured in this brochure is described as "the avant chic of our time." COURTESY OF SYNCHRONAR MARK II INFORMATION BROCHURE (2).

Figure 20. Synchronar Mark II featured in this brochure for female consumers is described as "The Time of Your Life."

tions of this era, including *Playboy* (Figure 18), *Wall Street Journal, Discover, Guns & Ammo, Solar Age, Omni, Science News, Popular Mechanics,* and *Popular Science,* advertised Synchronar wristwatches.

The Synchronar Mark II information brochure asked, "Who Should Wear the Synchronar 2100?" The answer was, "This watch is the avant chic of our time. A brilliant display of technological genius. A versatile, formal, sporting, self-indulgent, solid state timepiece suited to the trendsetter" (Figure 19).

The Synchronar Mark II information brochure also targeted women by claiming it was a fashion statement. "It is as appropriate for a woman as a man, and especially suited to the woman in business—the woman with a head for value, a feeling for fashion and a self-indulgent heart. Find the Synchronar 2100 in the finest stores. The Synchronar 2100—The Time of Your Life" (Figure 20).

A 1975 television commercial for the Synchronar 2100 featured American astronaut, Gordon Cooper.[15] His narration stated, "This is the world's first solar-powered watch. I'm Gordon Cooper, astronaut, and this is the Synchronar 2100, an advanced solid-state timepiece that is powered by Skylab-like[16] solar cells that beam the hours, minutes and counting seconds. This Ragen micro-circuit computer is programmed to display the correct month and day for the next century. When you've depended on advanced technology to return safely to Earth it takes a lot to impress you. I'm impressed! See it at your jewelers. You'll be impressed!" Because the Synchronar was waterproof to depths of 750 feet, Divetime Industries of Hicksville, NY, marketed it as the "Divemaster ET." Appealing dive features of the watch were an automatic display of the elapsed bottom time while diving and at the end of each dive the total bottom time stored in memory.

Summary

Riehl not only invented the world's first solar-powered wristwatch but he was instrumental in the following innovations in electronic timekeeping: smart calendar programming, owner-controlled calibration, automatic daylight saving time, leap year adjustments, perpetual calendars, the first wristwatch with an accuracy to within plus or minus four seconds per year, the first wristwatch to have three built-in light intensities that automatically adjusted to ambient light conditions, and the first light-emitting diode (LED) digital electronic wristwatch to be waterproof to a depth of 750 feet.

One can only wonder if it was not for the Quartz Revolution how popular and widespread the Synchronar would have become around the world. After all, Riehl was always challenging the status quo within the wristwatch industry. He managed to bring numerous concepts to reality through his visionary ideas, design capabilities, and vigorous testing processes that were not only innovative but were surely ahead of their time.

Acknowledgments

I thank Roger W. Riehl's sons Howard and Barry for their cooperation and information that led to a much more informative article. I especially thank Howard. He met with me in June 2015 and provided many details that were previously unknown and several historical family photographs, including the photo of Roger W. Riehl circa 1973 on the first page of this article, and artifacts that I photographed and included in this article in Figures 7-13.

Notes

1. A sundial or shadow clock is a device that measures time by using a light spot or shadow cast by the position of the Sun on a reference scale. Sundials appear in the archaeological record of all major cultures and increased in sophistication and accuracy as the cultures advanced their knowledge base.

2. The Valley of the Kings is a geographic valley in Egypt where tombs were built for pharaohs and powerful nobles for 500 years from the sixteenth to the eleventh century BC.

3. The basic functionality of a solar-powered wristwatch is that it absorbs sunlight and artificial light into a solar panel located in the watchcase; more recent designs have solar panels behind the crystal. The dial can be on a layer above or actually on the solar panel. This solar panel converts the light into electrical energy that serves as the power source for the watch. The watch typically can store energy in a rechargeable cell, so it has enough power to run at night or when the watch is in the dark.

4. Integrated circuits (ICs) are also referred to as microchips or chips. They are a set of electronic circuits attached to a small plate or chip that is usually very compact and made of silicon. By the mid-twentieth century this technology was an enormous improvement over the manual assembly of circuits that used discrete electronic components, including vacuum tubes and diodes.

5. The Spitfire Transistor Ignition System claimed to correct two basic faults in the conventional automotive system and offered advantages. It increased fuel economy, eliminated condenser replacement, provided faster starting, and increased engine life.

6. "Weighing scale with digital display: US 3741324 A," Google Patents, accessed February 11, 2016, https://www.google.com/patents/US3741324.

The following is an abstract from the patent application: "A weighing scale having a vertical housing with front and back walls includes electronic means for displaying visually the price per unit weight and the total price of goods placed on the scale platform. The housing also includes an optical chart, having human recognizable and machine recognizable indicia representing the weight of the goods placed on the scale platform, which moves through a distance proportional to the weight of the goods. Optical paths are provided to display visually the weight of the goods on ground glass plates mounted to be visible through the front and back walls, and a third optical path directs the machine recognizable indicia onto photodetectors to provide an electrical representation of the weight of the goods. An electronic computer within the scale computes the total value of the goods and displays this information visually, along with price per unit weight information provided by a manually operated keyboard, on electronic readout tubes."

7. "Solid state electronic timepiece: US 3823551 A," Google Patents, accessed February 11, 2016, https://www.google.com/patents/US3823551.

The following is an abstract from the patent application: "A wristwatch has a plurality of light-emitting digital readout elements that are located along one end of the watch above the watchband. A hermetically sealed time capsule is enclosed within the watch case and includes an integrated circuit chip that divides the frequency output of a battery-powered quartz crystal oscillator into a series of pulses that are counted and selectively interrogated to provide a series of electrical outputs corresponding to seconds, minutes, hours, days, months, and years. The time capsule includes sealed control switches that are actuated by magnets mounted on the case and provide for selecting different outputs for visual display on the readout elements, corresponding to either hours or minutes, month and day or seconds. The electronic circuitry automatically compensates for twenty-eight, thirty and thirty-one day months as well as for leap years, and the readout may be selected for repetitive twelve hours or twenty-four hour display. When the twelve hour readout is selected, the AM/PM indicating light is energized when the hours and minutes readout is selected. A solar cell is positioned on the top surface of the watchcase and functions to control the intensity of the readout elements according to the intensity of ambient light and to recharge the batteries. The control switches also provide for setting the watch by either changing the minutes output while holding the seconds output at zero, or by changing the hours output without changing the minutes, seconds, and days outputs, or by changing the days output without changing the second, minutes, hours, and months outputs."

8. Complementary metal-oxide semiconductor (CMOS) is a technology that constructs integrated circuits (IC) that are used in devices that include microprocessors, microcontrollers, and other digital logic circuits.

9. A light-emitting diode (LED) is a two-lead semiconductor light source that emits light when activated.

10. "Wristwatch: US D229085 S," Google Patents, accessed February 11, 2016, http://www.google.com/patents/USD229085.

The following information came from the patent application: "Des. 229,085 Patented Nov. 6, 1973 United States Patent-WRISTWATCH-Donald J. Lutenegger, Dayton, OH, assignor to Riehl Electronics Corporation, Troy, OH. Filed Apr. 20, 1972, Ser. No. 246,122. Term of patent 14 years Int. Cl. D10-02 US. Cl. D428 R FIG's. 1-6 shows a perspective view of a wristwatch showing my new design . . . I claim: The ornamental design for a wristwatch, substantially as shown and described. References Cited UNITED STATES PATENTS 11/1972 Osawa D42-8 R D. 202,911 11/1965 Beyner D428 R JOEL STEARMAN, Primary Examiner N. C. HOLTJE, Assistant Examiner."

11. Lexan® is a trademarked name for strong polycarbonates, a synthetic thermoplastic resin that is generally used for molded products, films, and nonbreakable windows. Some grades are optically transparent.

12. Liquid crystal display (LCD) is an electro-optical device used to display digits, characters, or images that have low electrical power consumption, which enables it to be used in battery-powered electronic devices, such as digital watches, calculators, and portable computers.

13. The Quartz Revolution (also known as the Quartz Crisis) is a term used in the watchmaking industry that refers to the early 1970s to the early 1980s when the introduction of mass-produced quartz watches caused a major economic upheaval throughout the industry, especially in Switzerland. The majority of world watch production rapidly shifted to quartz technology in Asian countries as mechanical watch production promptly and significantly declined.

14. "Balancing chuck: US 4711610 A," Google Patents, accessed February 11, 2016, https://www.google.com/patents/US4711610.

The following is an abstract from the patent application: "A balancing chuck is disclosed for semiconductor wafers that have a flat region that typically causes wafer imbalance on spinning equipment. The wafer's flat region is determined by a proximity sensor mounted on a centering arm overlying the wafer. The chuck is constructed to include an annular race containing a spherical counterweight. As the chuck is rotated to determine the wafer's flat region, a magnet prevents movement of the spherical counterweight within the race and allows for its subsequent alignment with the mass imbalance. A plurality of circumferential pockets is provided within the race to retain the position of the counterweight, which functions as a counterbalance maintained in proper angular alignment during spinning of the chuck."

15. Leroy Gordon "Gordo" Cooper Jr. (March 6, 1927-October 4, 2004), popularly known as Gordon Cooper, was an American aerospace engineer, US Air Force colonel and pilot, and one of the seven original astronauts in Project Mercury, the first manned space program of the United States. He was the last American to be launched alone to conduct an entirely solo orbital space mission.

16. Skylab was the United States's first space station, launched in 1973 by NASA. It orbited the Earth for six years and various onboard scientific experiments were conducted. It reentered the Earth's atmosphere and disintegrated in 1979.

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Randy Jaye has served for many years as president of Chapter 154 in Daytona Beach, FL. He has held various chair positions at past Florida Mid-Winter Regionals and is the general chair for the 2016 Florida Mid-Winter Regional. He has presented programs on various watch and clock subjects to eight Chapters and at several Regional events. He is a "generalist" collector and restorer of clocks and watches, which provides him with various subjects to continue his horological research endeavors. He has contributed several articles to the *Watch & Clock Bulletin* and is anticipating more in upcoming publications. Contact Jaye at randyjaye@gmail.com.