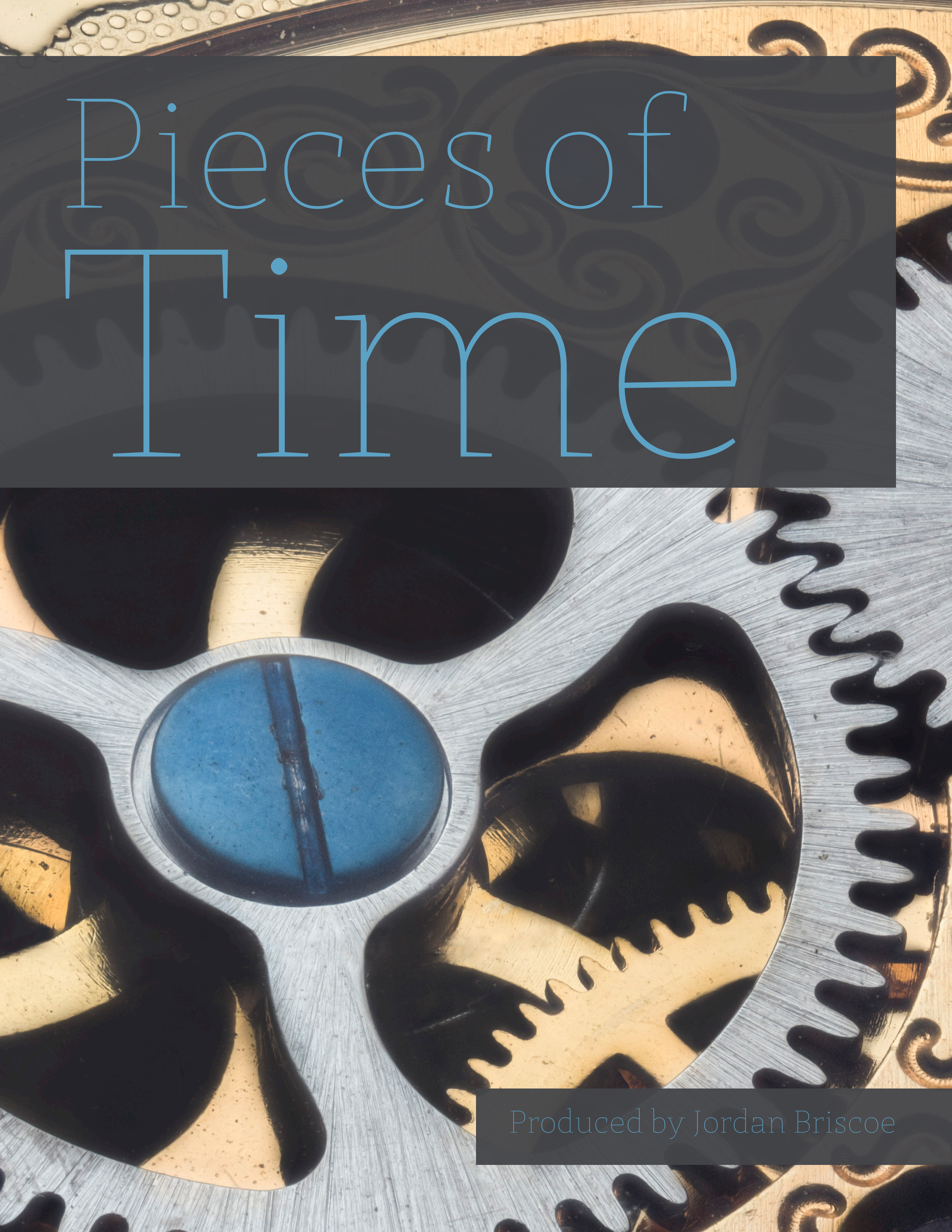
Pieces of Time



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A Brief History of Time Keeping

Our days are consistently divided into twenty-four hour periods, our weeks into seven of those twenty-four hour days, and our months into four of those seven day weeks. While it is unclear when and how the division of time as we know it began, it is known that in ancient times Egyptians utilized a calendar that had periods of time divided into twelve thirty-day months, which gets us close to our modern calendar year of 365 days. How 365 became the standard of time for a calendar year lies in the science behind the amount of time the Earth takes to make one full rotation around the sun, which realistically around 365.24 days. That added amount of time gets divided into every fourth year, which we refer to as a leap year. Before the advent of the atomic clock, people had been inventing and developing many forms of timekeeping devices, from sundials to pendulum clocks to the modern wristwatch.

When we take a step back and see how important time keeping is to our modern society, from planning out our daily lives to keeping an accurate record of the past, it really is no wonder that the practice of creating timepieces has been around since at least the 8th century BC. Then, sundials were used to divide the day by six equal parts. By the fourth century BC, the Romans had formally divided their day into two parts, now referred to as ante meridiem (a.m.) and post meridiem (p.m.). Today, we are able to divide our day into seconds and fractions of a second accurately. In each day there are 86,400 seconds, established by the science behind the atomic clock.

Time Measurement

Let's break it down into some common examples:

1 centisecond (one-hundredth of a second)
is about the length of time it takes for lightning to strike.

1 decisecond (one-tenth of a second)
is the amount of time it takes to blink your eye

1 second
is the average amount of time it takes for your heart to beat once.

60 seconds (one minute)
is how long it takes for one blood cell to make a full circulation in your body

60 minutes (one hour)
is about as long as your lunch break

8 hours
is an average workday in the United States

24 hours (one day)
is the approximate amount of time it takes for Earth to make one full rotation on its axis

365.24 days (one year)
is the calculated amount of time it takes for Earth to make one revolution around the sun

75 years
is the average lifespan of a human being in modern times

50,000 years
is how long modern man, *Homo sapiens*, has existed on Earth

4.5 billion years
is the estimated age of our planet Earth

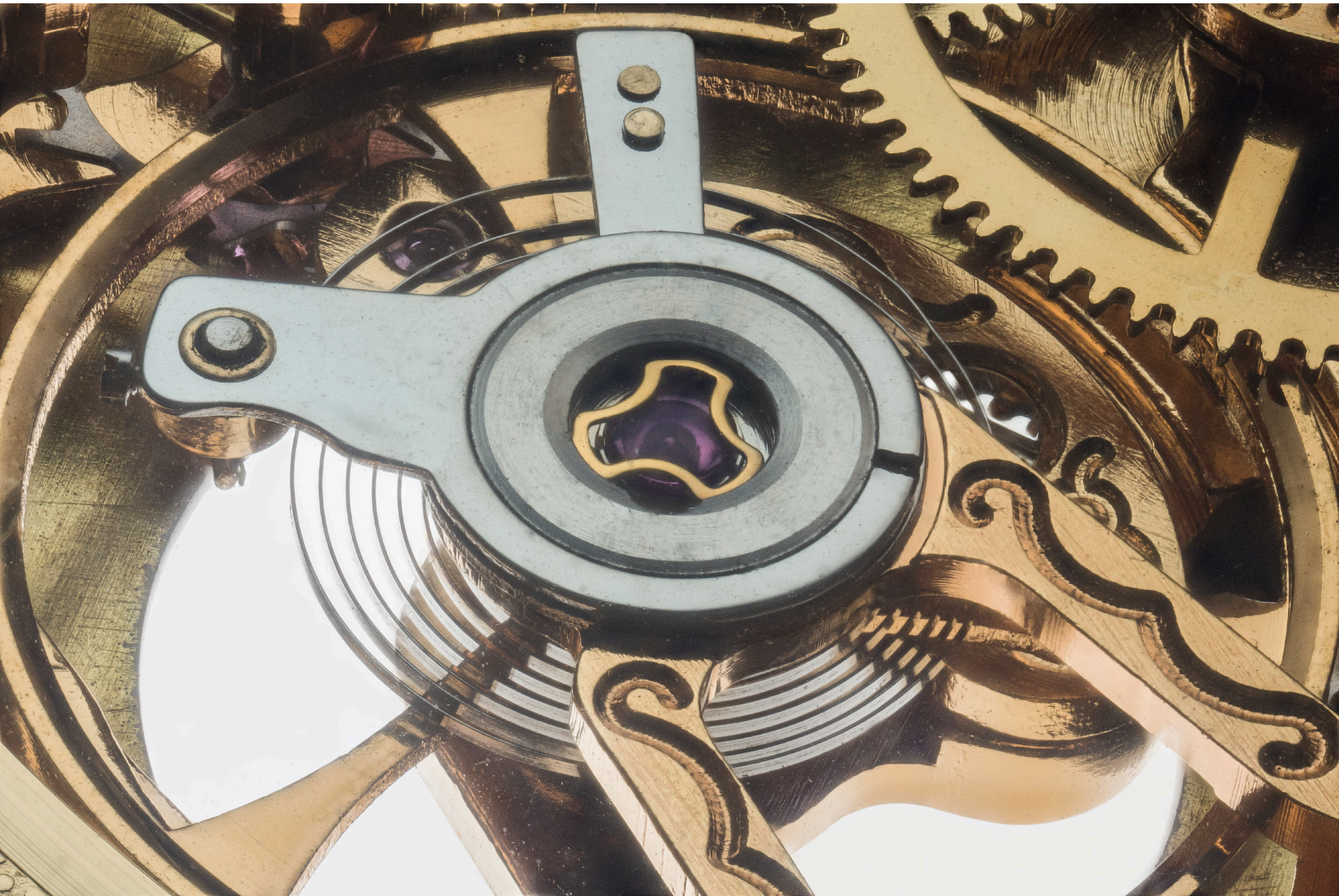
How Do Mechanical Watches Work?

At the end of the 14th century, the first mechanical clock had been created, using technology very similar to the wind-up mechanics we see today. For years after this foundation was built, scientists like Galileo Galilei, Robert Hooke, and Christiaan Huygens worked on the research and development of this amazing invention. Although this type of timepiece has been overshadowed by the technology that is the quartz watch, the allure and appreciation of the mechanical watch has not been lost yet.

Mechanical watches generally function using five main components that have been around for centuries. These components include: a winding mechanism to provide power in the form of kinetic energy, a mechanism for power storage like a mainspring, a gear train to transfer this power in a regulated manner, an escapement to control the gears motion, and a display, including the hands of the timepiece.

What Makes a Watch Tick?

The most important component of making a timepiece successful is the escapement. The escapement is the reason that timepieces are considered so reliable, because it is the mechanism that takes the energy stored and given out by the mainspring and transfers it in a regulated way to the gear train. From the mainspring, energy is transferred using a hairspring and a V- or Y-shaped pallet, where energy is transferred back and forth from each pallet arm to an escape wheel, and then to the gear train to be divided out into seconds. In an average modern mechanical watch, the energy transferred from the wound mechanism to the hairspring is much faster and more powerful than what is needed to produce movement in the second hand of a watch in the increment of one second. The escapement, which produces the ticking noise, ticks about five times per every one second. That energy transferred through the escapement is then sent through the gear train, which through gear ratios transfers that fast, high-power energy into slower increments. By using gears that are proportionally larger than the one before it, the energy from the beginning of the gear train will slow by the end, and will turn the arm of the second hand to match one second increments on the face of the watch.



The Automatic Watch

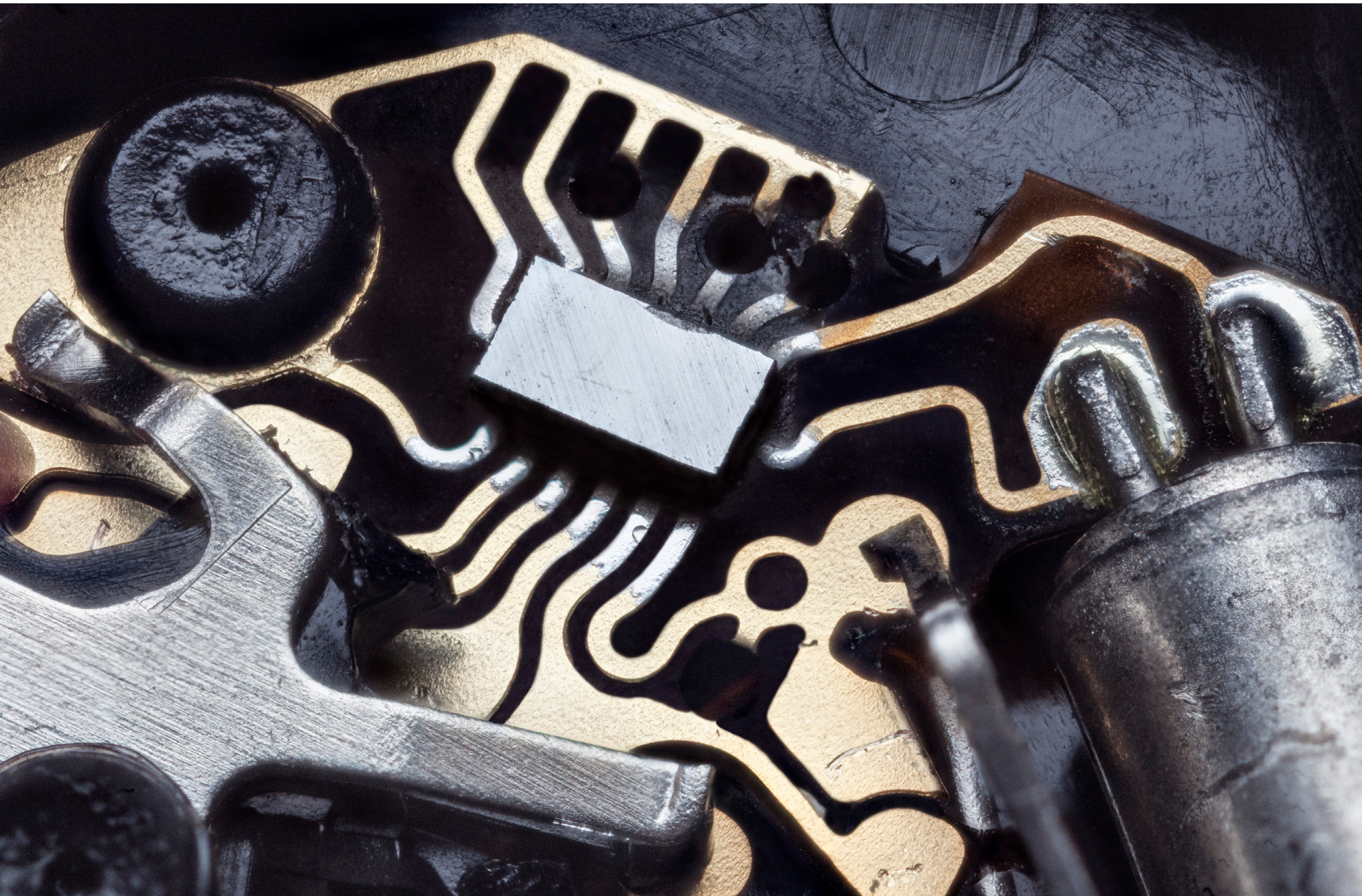
There are two different types of winding mechanisms, referred to as manual and automatic. Manual winding watches must be wound by hand periodically, using the set pin and a winding pinion, while automatic watches are designed to wind themselves. This is made possible by an eccentric weight, usually a metal or brass plate that swivels on a pivot on a staff when the wearer moves their arm. This staff is ratcheted to a winding mechanism that winds the mainspring through reverser and reducer gears. This makes it possible for the watch to run while its wearer moves their arms in all directions by using the force of gravity and the momentum of the plate to continuously wind the watch.

The Quartz Watch

One of the biggest advances in timepiece making was the introduction of the quartz watch. Mechanical watches had been the most popular before the 1960's, when the Bulova watch company had taken the step away from solely mechanical movements and began using batteries and a tuning fork, which oscillated at a regular frequency due to a transistor oscillator. This replaced not only the mainspring and the hairspring of the traditional mechanical watch, but also made it possible to break away from the watch that had to be maintained and wound frequently. Although these were necessary steps to get to the wristwatches we see today, there were still issues with the accuracy of timekeeping with a tuning fork, and finding a way to involve the newest technology by the 1970s- the integrated circuit. An integrated circuit is what we would refer to today as a "microchip," which is a small plate containing all of the circuit components on one semiconductive material, instead of the larger, individual components that you would find in a discrete circuit. The next problem had arisen to be solved- What new element could be used that was more accurate than a tuning fork, could run on very low power from a battery source, and use integrated circuitry?

The Quartz Crystal

The answer came in the form of a well-known crystal comprised of silicon dioxide, the same chemical compound of most sand. Quartz crystals were nothing new, and by the 1980s they were paired with sufficient enough circuitry to power wristwatches using small batteries. To do this, quartz crystals were modified and cut into small bars or disks, which have a piezoelectric quality to them. Piezoelectricity means that a material will produce an electric charge when it is compressed or bent mechanically. Quartz oscillators, although they are piezoelectric, also have a property called electrostriction, which means that when a charge is applied to the quartz crystal, it will also bend. In this way, when a voltage is applied to the quartz crystal, it bends and compresses, and in turn resonates at a precise frequency. The resonating vibrations produced by the quartz crystal are then converted by the integrated circuitry into pulses, which are translated to a small motor, and then to the gear train that will allow the second, minute, and hour hands to move along the watch face.



A Comparison

Advantages of Quartz Watches:

Starting in about 1970, the average consumer could afford a reliable timekeeping device.

Quartz crystals are able to give an accurate frequency of oscillation at relatively low power.

Quartz is unaffected by most solvents, and when exposed to temperatures in the high hundreds (Fahrenheit) it will maintain its size and shape.

Disadvantages of Quartz Watches:

Tend to become slightly less accurate over time- typically between one tenth and two seconds per day. Most watches, even inexpensive ones, are accurate to a few thousandths of a second per day.

A watch's precision can be affected by external factors such as temperature, humidity, and general wear and tear. These all affect the stability of the motors that produce the electric field used to run the watch, and can eventually negatively affect the accuracy of the watch.

No two quartz crystals are alike, and because most quartz pieces made for watches are made by thin sheets plated together, both contamination and difference in angle cut can lead to differences in accuracy between watches being made on the same assembly line.

Advantages of Mechanical Watches:

Batteries never need to be bought or replaced. Those who enjoy mechanical watches learn when they need to wind theirs, whereas a quartz watch battery may die without notice.

A well-maintained and regularly adjusted mechanical watch can last a very long time, decades or even generations as a family heirloom.

Mechanical watches involve a much more active timekeeping experience. Just as those who love driving enjoy manual transmission cars, those who enjoy timepieces appreciate mechanical watches.

Disadvantages of Mechanical Watches:

Mechanical watches must be wound periodically before the mainspring loses power to drive the gears of the watch to keep time.

Not quite as accurate as a quartz watch and can be affected by environmental factors easily. Mechanical watches must be maintained in order to stay accurate.

In modern times, mechanical watches can be more expensive than quartz watches, because the latter is much cheaper to build and takes less precision in manufacturing the parts.

How Does INDIGLO Work?

Some watches, like those made by the company Timex, have a "glow in the dark" feature that many have come to appreciate. In Timex watches, this feature is called Indiglo, and uses the same technology that makes neon lights and some small night-lights glow when plugged into a wall outlet. This technology is known as electroluminescence, the conversion of electrical energy directly into light.

While this technology does produce light, it is not similar to chemiluminescence, mechanoluminescence, or through incandescence, which is the way your light bulbs work. Incandescence is the emission of light by heat, which is created by the electrical signal. In electroluminescence, electricity is converted directly into light, which is much more efficient.

The way this is done by Timex to create the Indiglo feature is by using the battery in a watch combined with a transformer, to change the electrical signal from about 1.5 volts to around 200 volts. This high voltage is then applied to a capacitor, used to charge phosphor atoms located in between two conductors. When these phosphor atoms are charged, they emit photons, creating electroluminescence, and making your watch glow at the press of a button.

Resources

http://electronics.howstuffworks.com/gadgets/clocks-watches/quartz-watch1.htm
http://electronics.howstuffworks.com/gadgets/clocks-watches/how-accurate-is-my-watch2.htm
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http://en.wikipedia.org/wiki/Electroluminescence
http://en.wikipedia.org/wiki/Crystal_oscillator
http://www.explainthatstuff.com/quartzclockwatch.html

About the Author

As of December, 2013, I am a third-year student at the Rochester Institute of Technology in Rochester, New York, studying Photographic and Imaging Technologies with a focus in Biomedical Photographic Communications. Through RIT, I am concentrating on high magnification photography, and hope to pursue a career in photomicrography.

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