TIME MACHINES

Diving deeper into timing machinery

TIME MACHINES

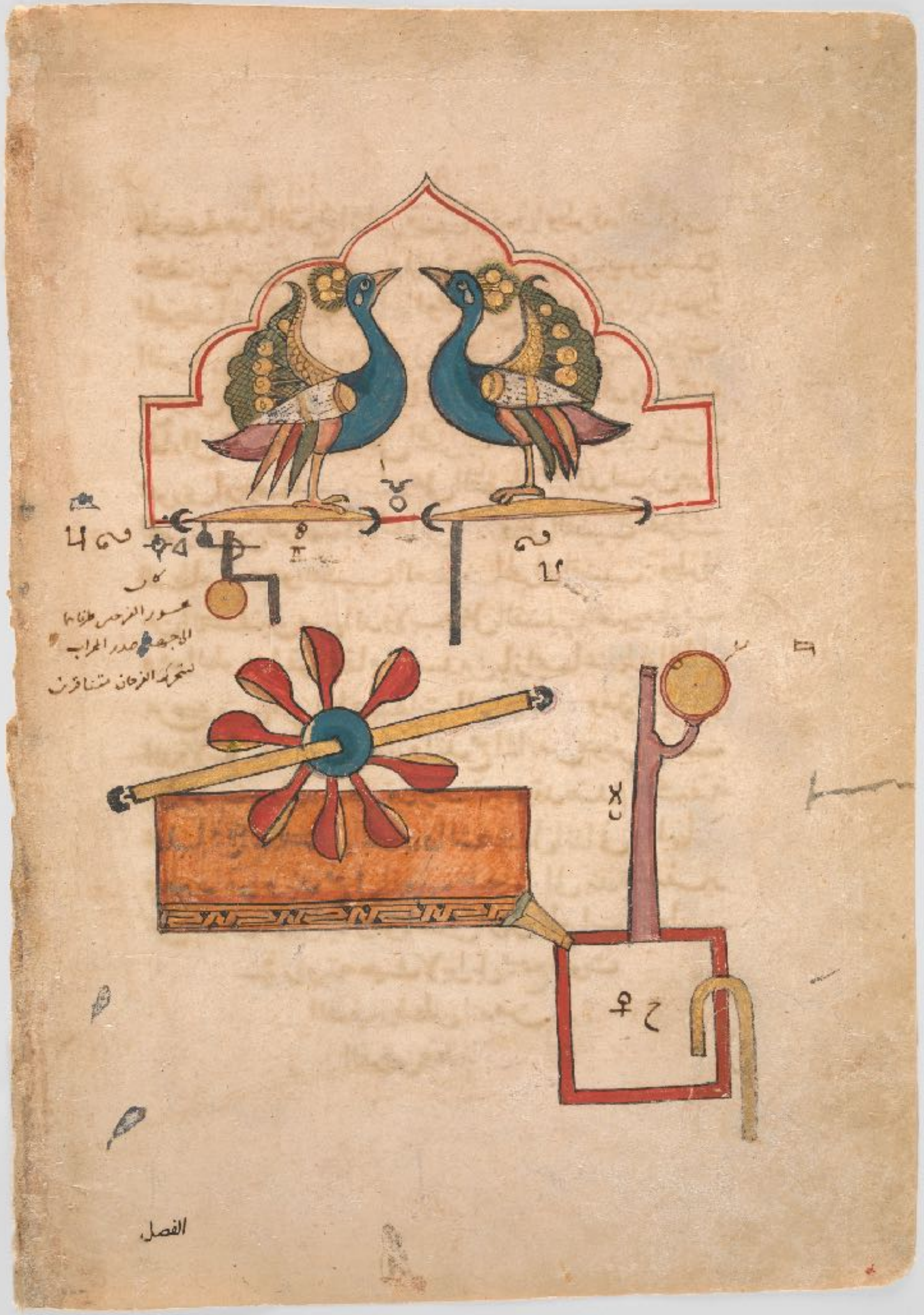

TIM
POLICE
HOT TUB
TIME MACHINE

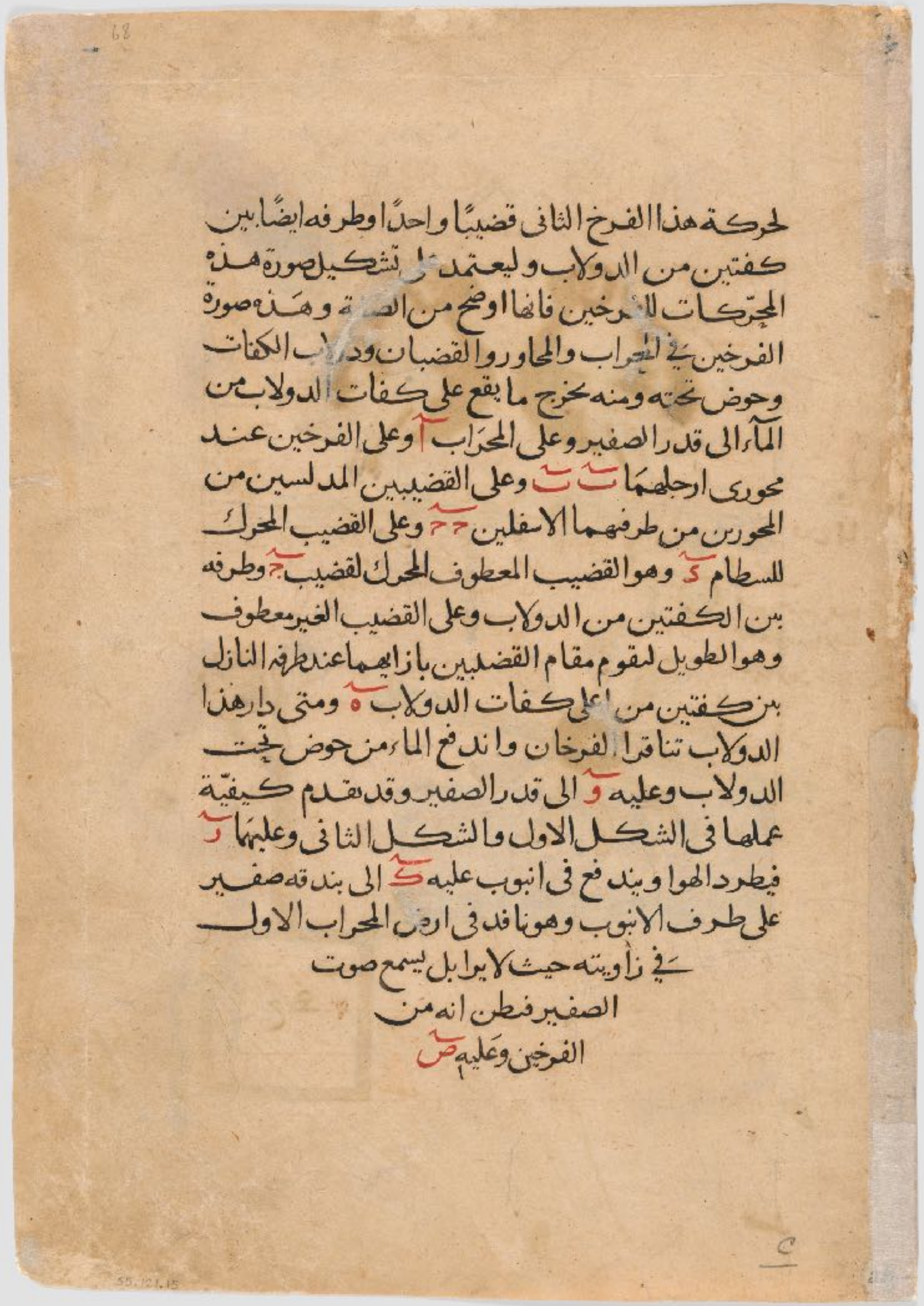
Water clocks, clepsydras, sundials, hour glasses – all are "flow" based measures of time.

Continuous flow is hard to count…

"Continuity is only a mathematical technique for approximating very finely grained things. The world is subtly discrete, not continuous. The good Lord has not drawn the world with continuous lines: with a light hand, he has sketched it in dots, like the painter Georges Seurat."

Carlo Rovelli



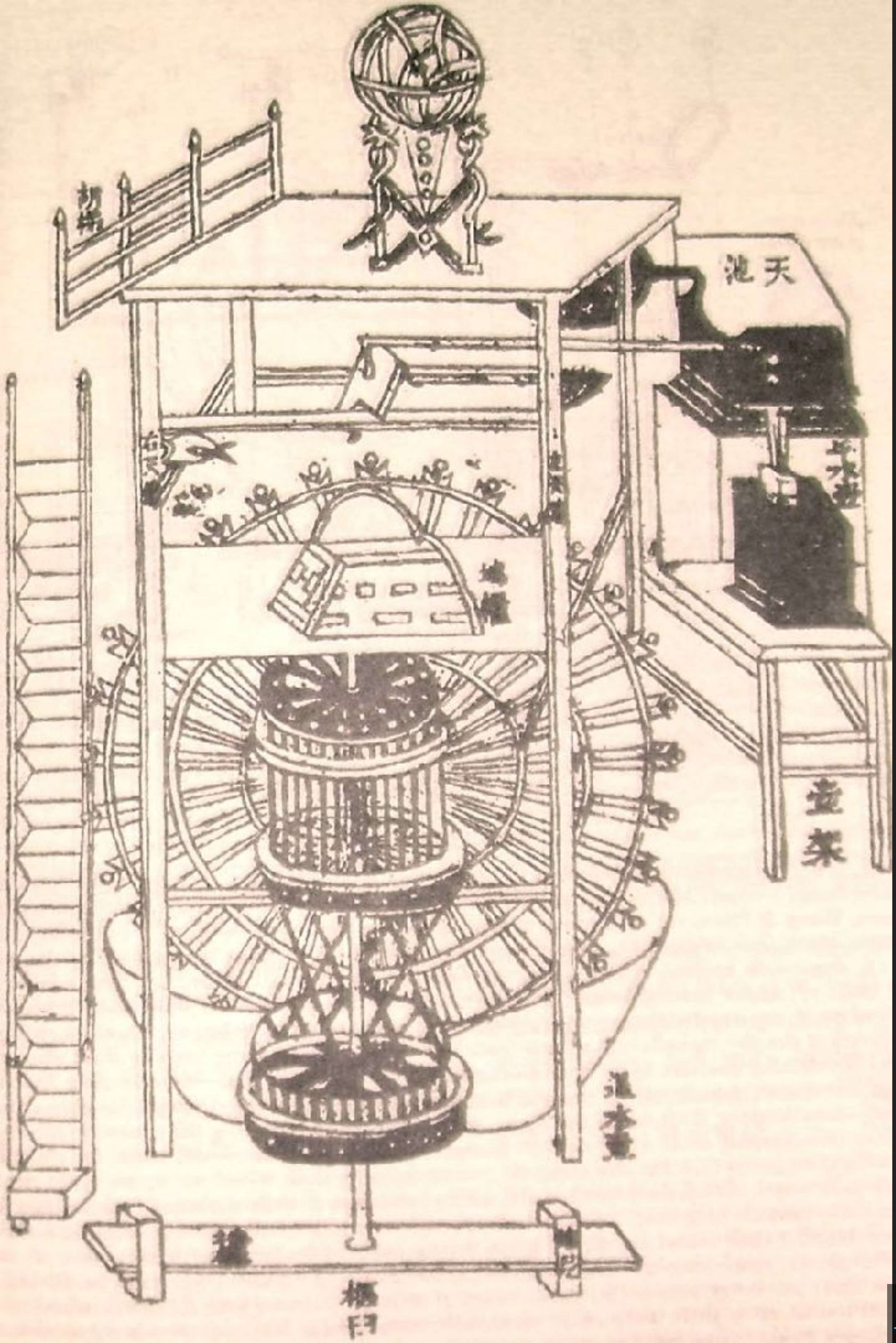


حركة هذا الفرخ الثانى قضيبًا واحدًا وطرفه ايضًا بين
كفتين من الدولاب وليعتمد على تشكيل صورة هذه
المحركات للفرخين فانها اوضح من الصفة وهذه صورة
الفرخين فى المحراب والمحاور والقضبان ودولاب الكفات
وحوض تحته ومنه تخرج ما يقع على كفات الدولاب من
الماء الى قدر الصفير وعلى المحراب ا وعلى الفرخين عند
محورى ارجلهما ب ب وعلى القضيبين المدلسين من
المحورين من طرفيهما الاسفلين ج ج وعلى القضيب المحرك
للسطام د وهو القضيب المعطوف المحرك لقضيب ج وطرفه
بين الكفتين من الدولاب وعلى القضيب الغير معطوف
وهو الطويل لقوم مقام القضيبين بازايهما عند طرفه النازل
بين كفتين من اعلى كفات الدولاب ه ومتى دار هذا
الدولاب تناقرا الفرخان واندفع الماء من حوض تحت
الدولاب وعليه و الى قدر الصفير وقد تقدم كيفية
عملها فى الشكل الاول والشكل الثانى وعليهما ز
فيطرد الهوا ويندفع فى انبوب عليه ح الى بندقة صفير
على طرف الانبوب وهو نافذ فى ارض المحراب الاول
فى زاويته حيث لا يرا بل يسمع صوت
الصفير فظن انه من
الفرخين وعليه ط

"Design for the Water Clock of the Peacocks", from the *Kitab fi ma'rifat al-hiyal al-handasiyya* (Book of the Knowledge of Ingenious Mechanical Devices) by Badi' al-Zaman b. al Razzaz al-Jazari

1315 CE

https://www.metmuseum.org/art/collection/search/451302

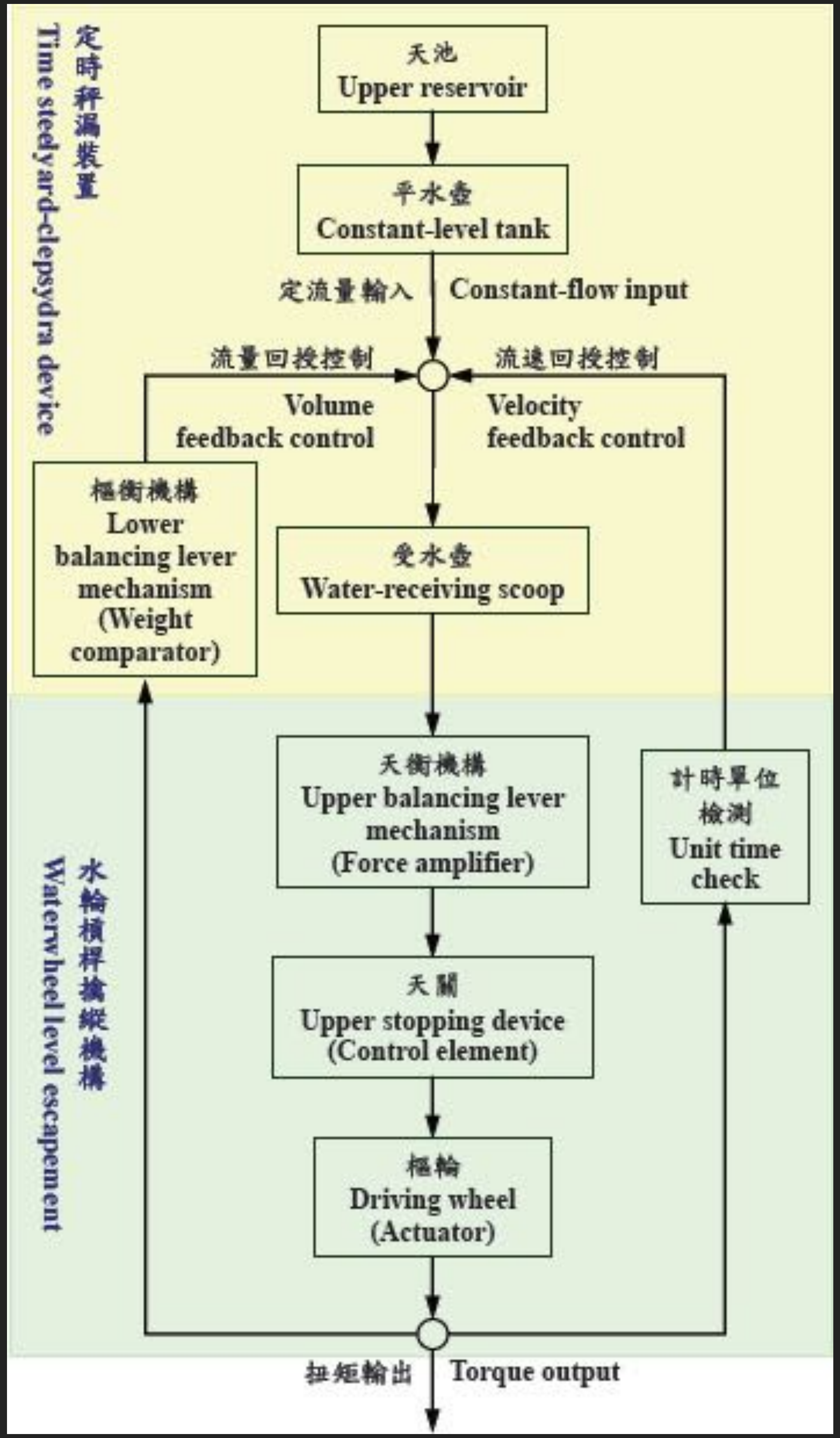


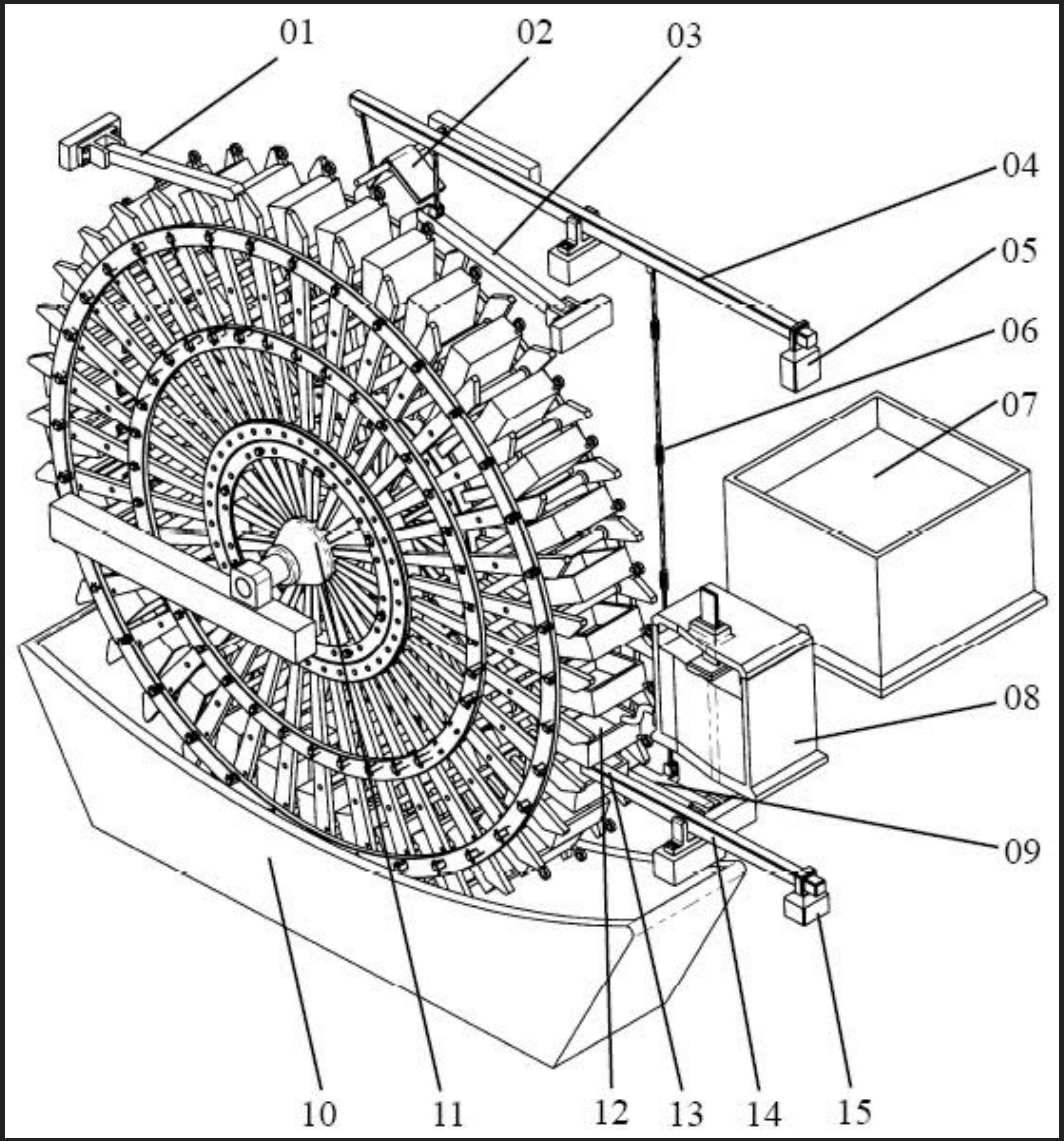
https://www.revolution.watch/past-masters-the-astronomical-water-clock-of-su-song

SU SONG ASTRONOMICAL WATER CLOCK

01094 CE, EARLY ESCAPEMENT

"Thus if the water is made to pour with perfect evenness, then the comparison of the rotary movements (of the heavens and the machine) will show no discrepancy or contradiction; for the unresting follows the unceasing."

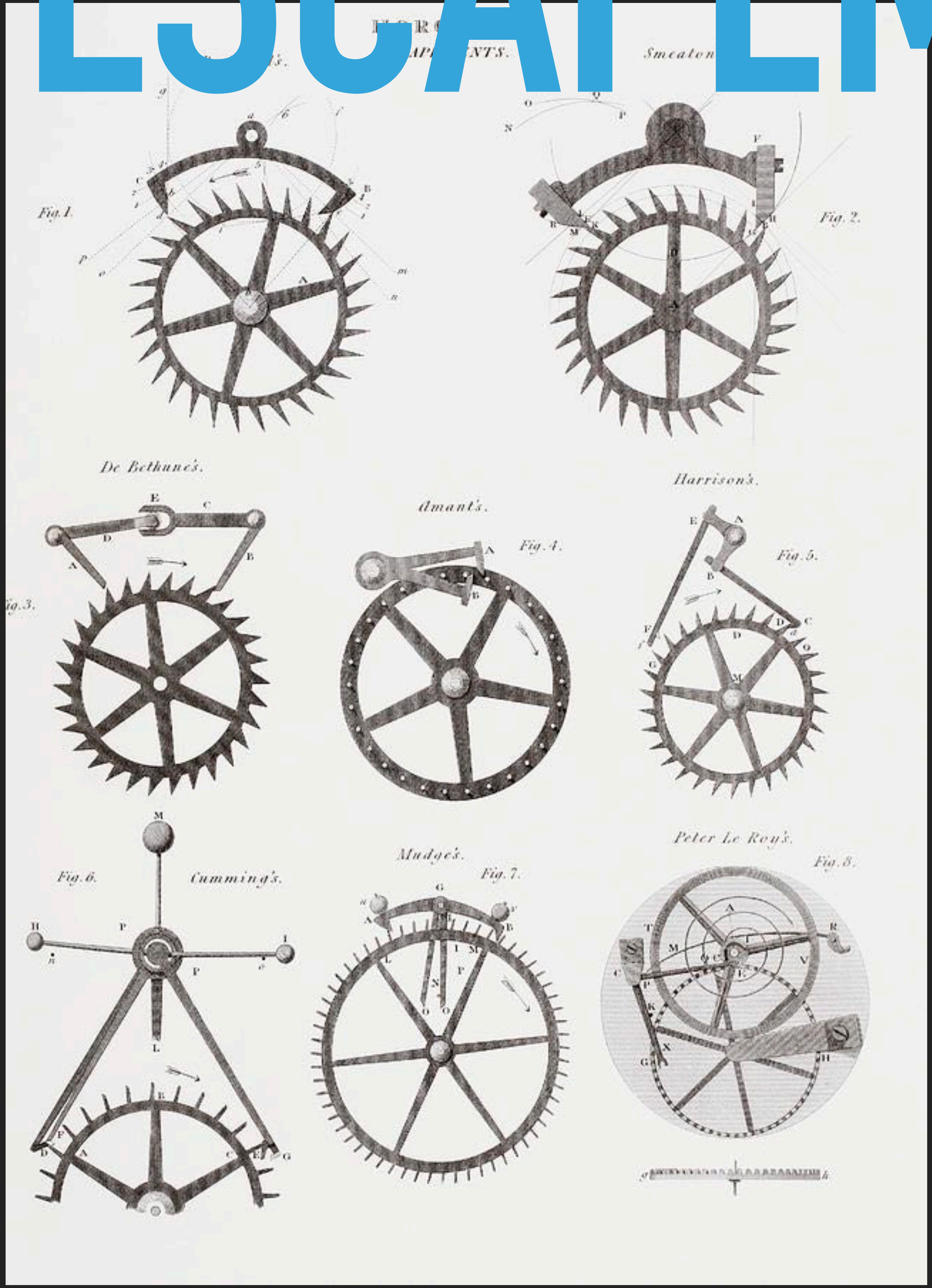


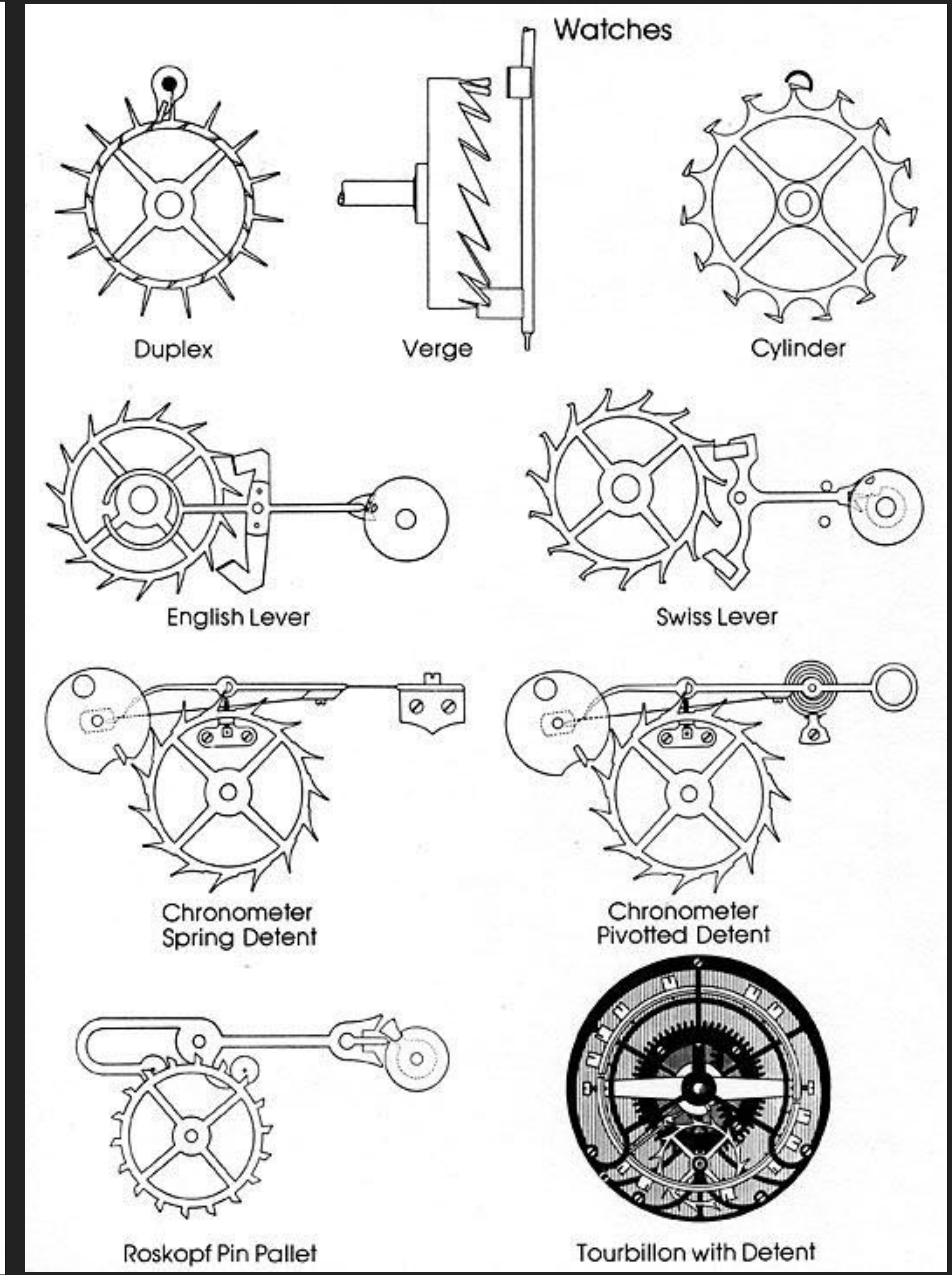


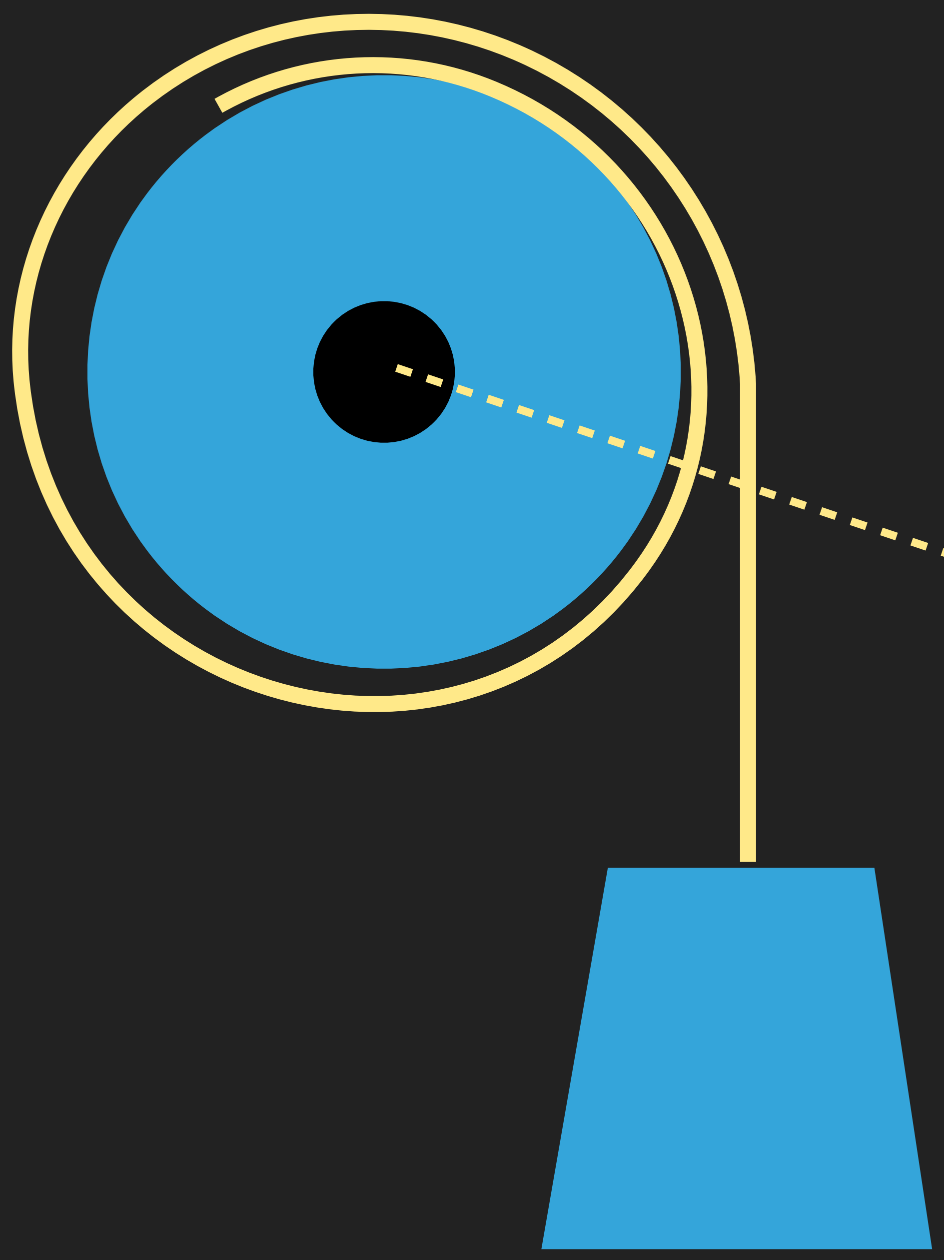
Detail

https://amc.stust.edu.tw/en/node/wt

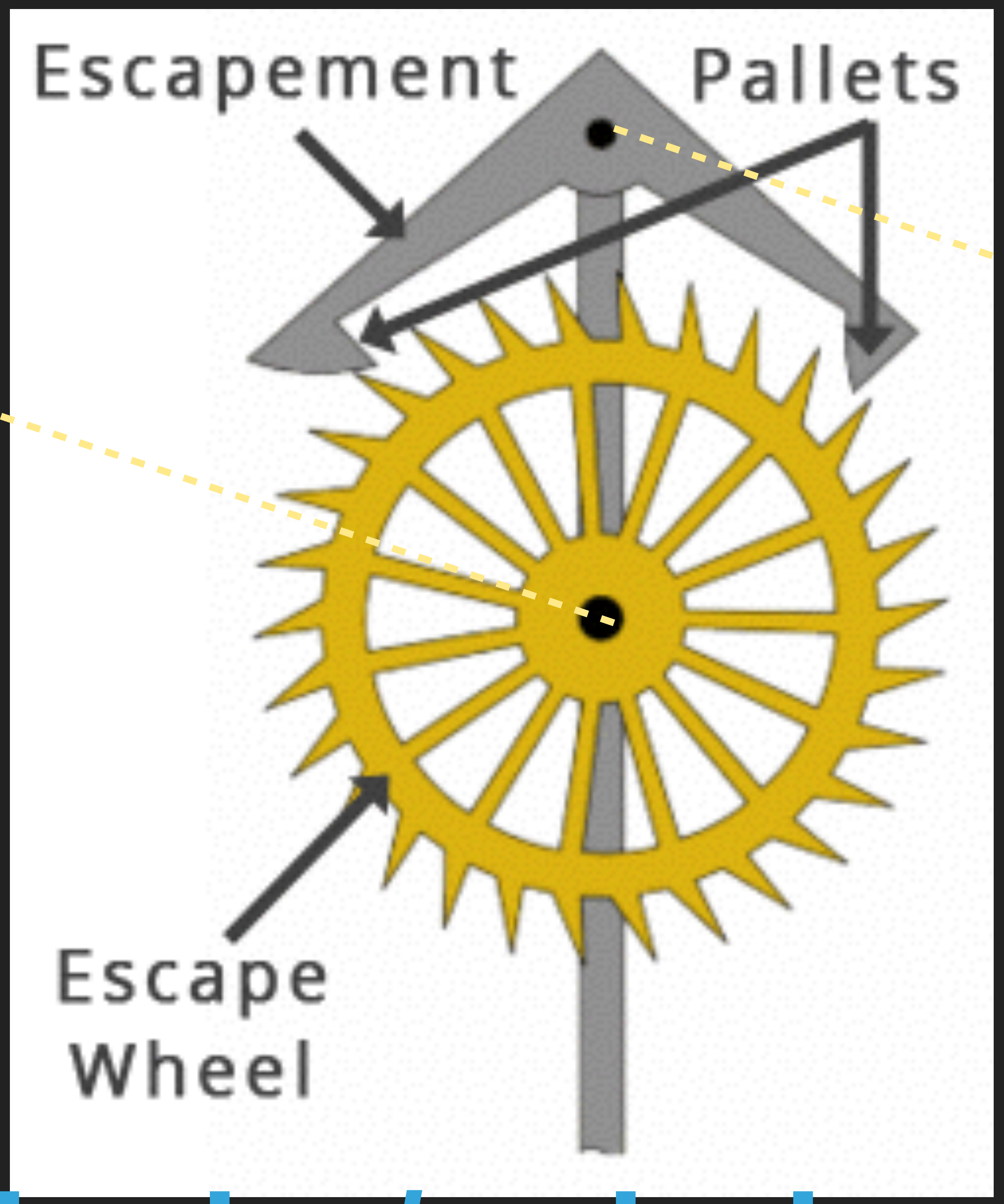
ESCAPEMENTS



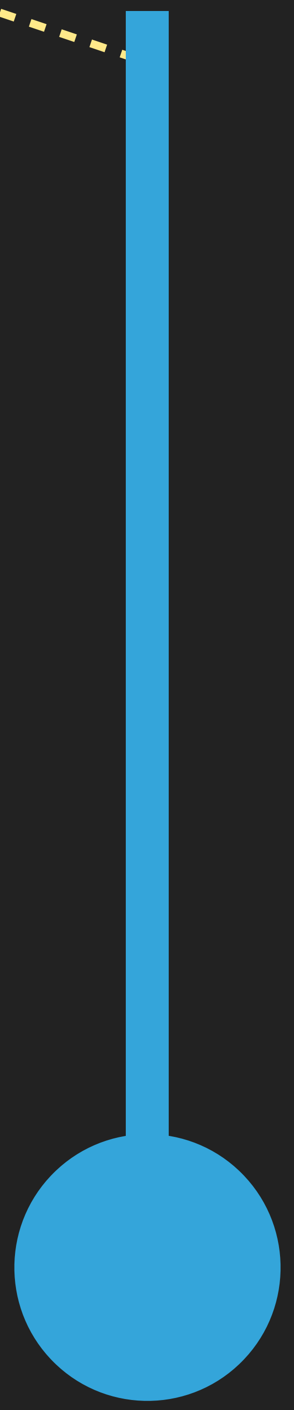




Energy: falling weight, wound spring

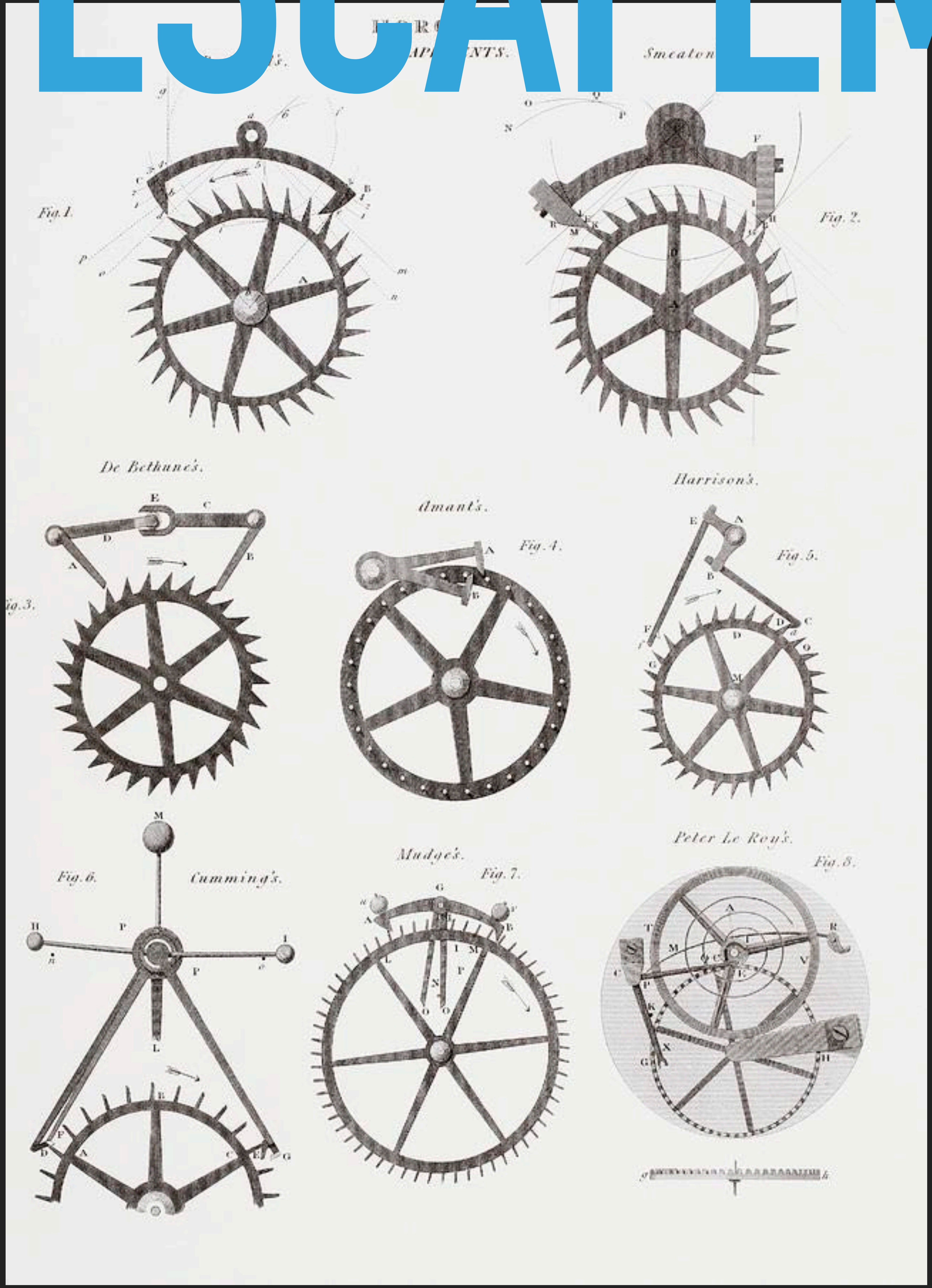


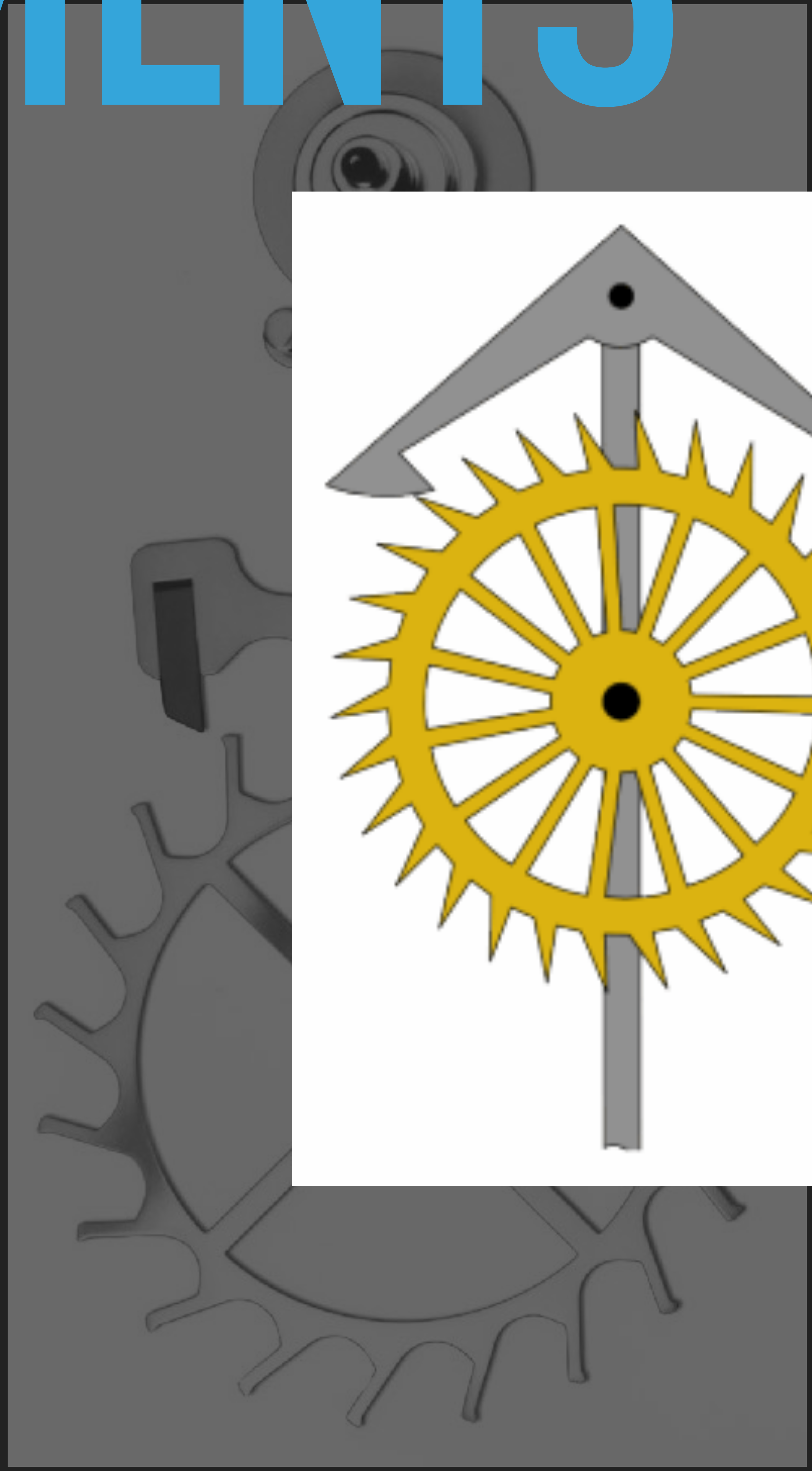
Locks / unlocks energy source; transfers energy to oscillator

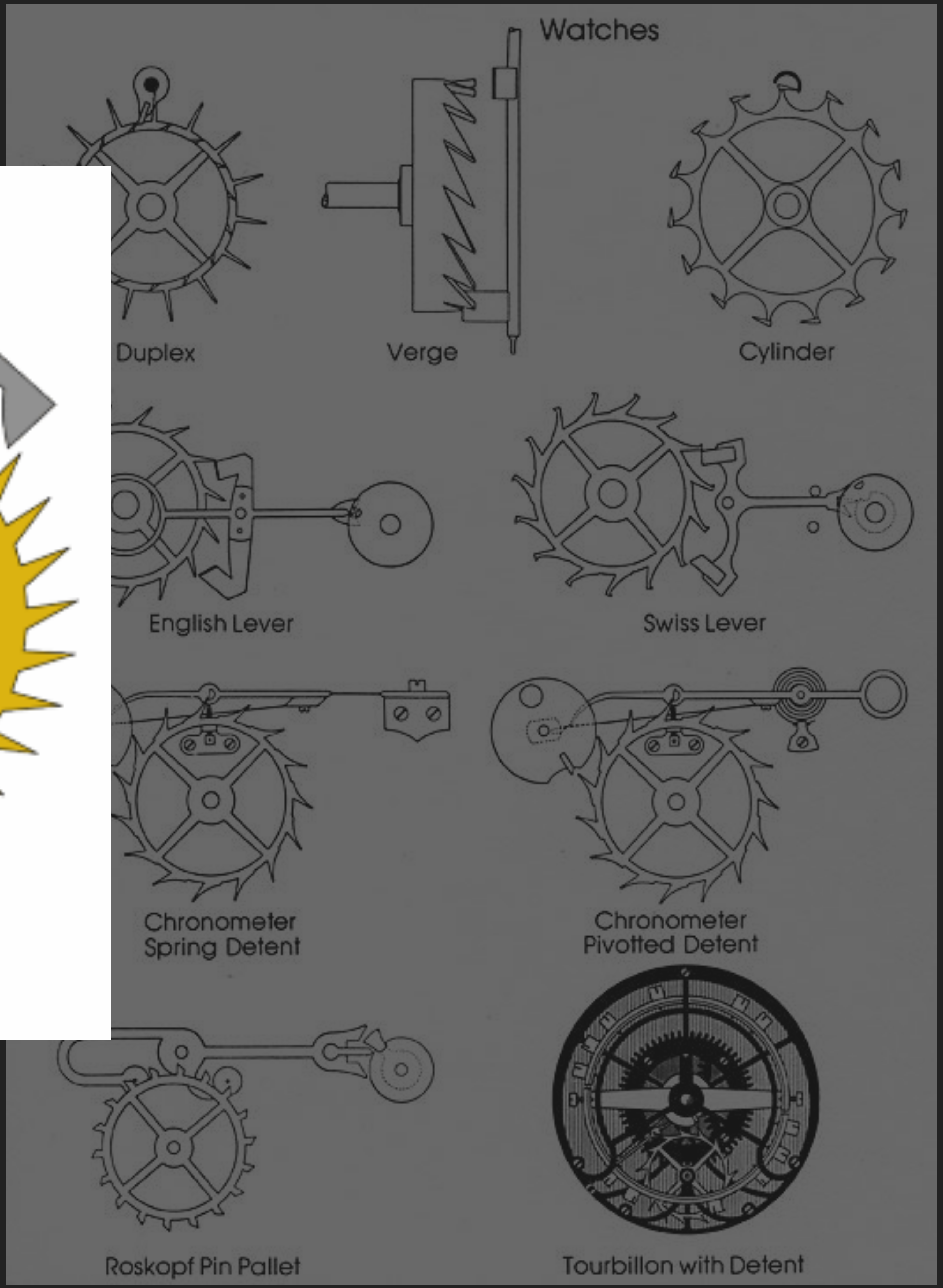


Oscillator

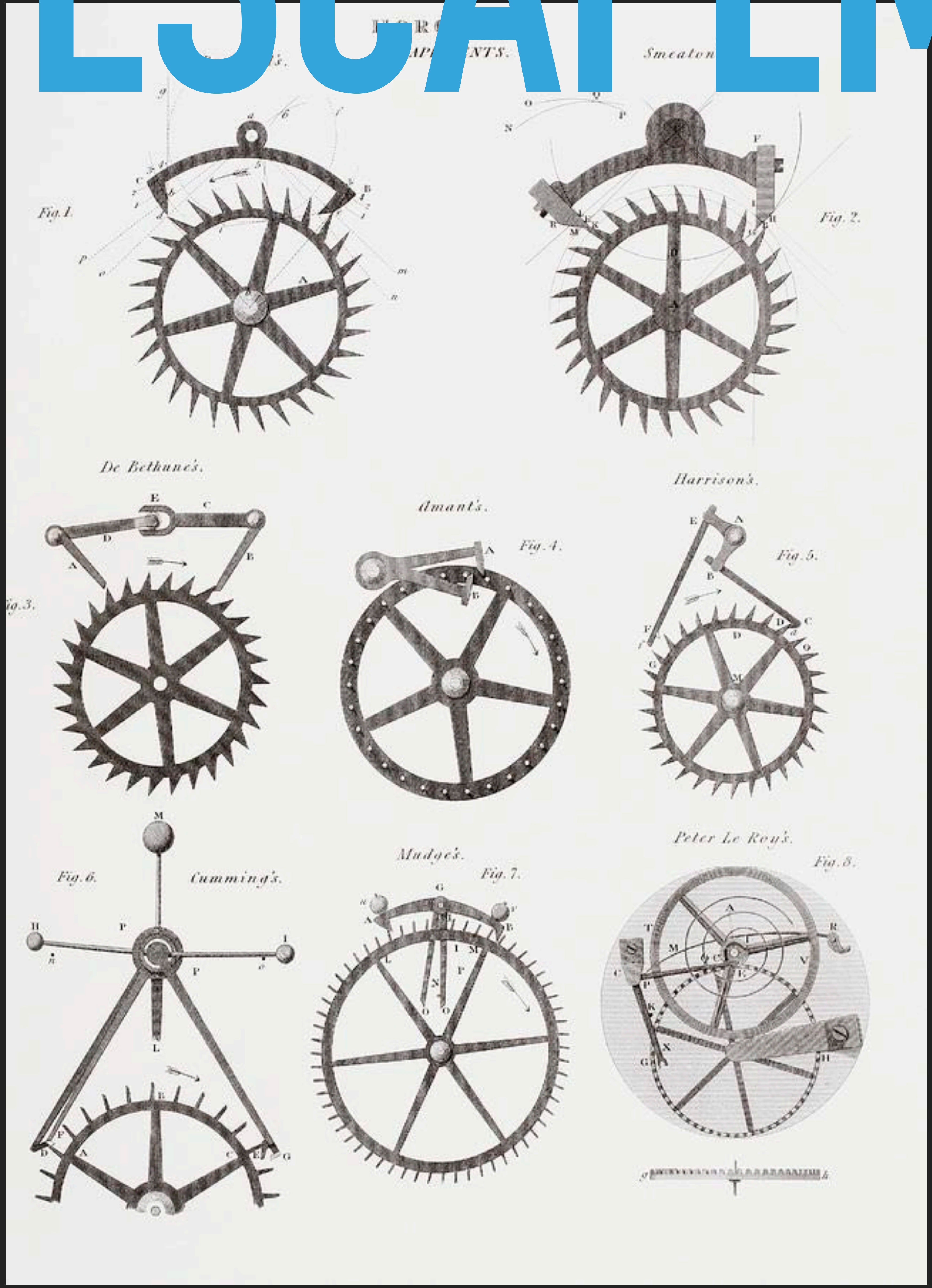
ESCAPEMENTS

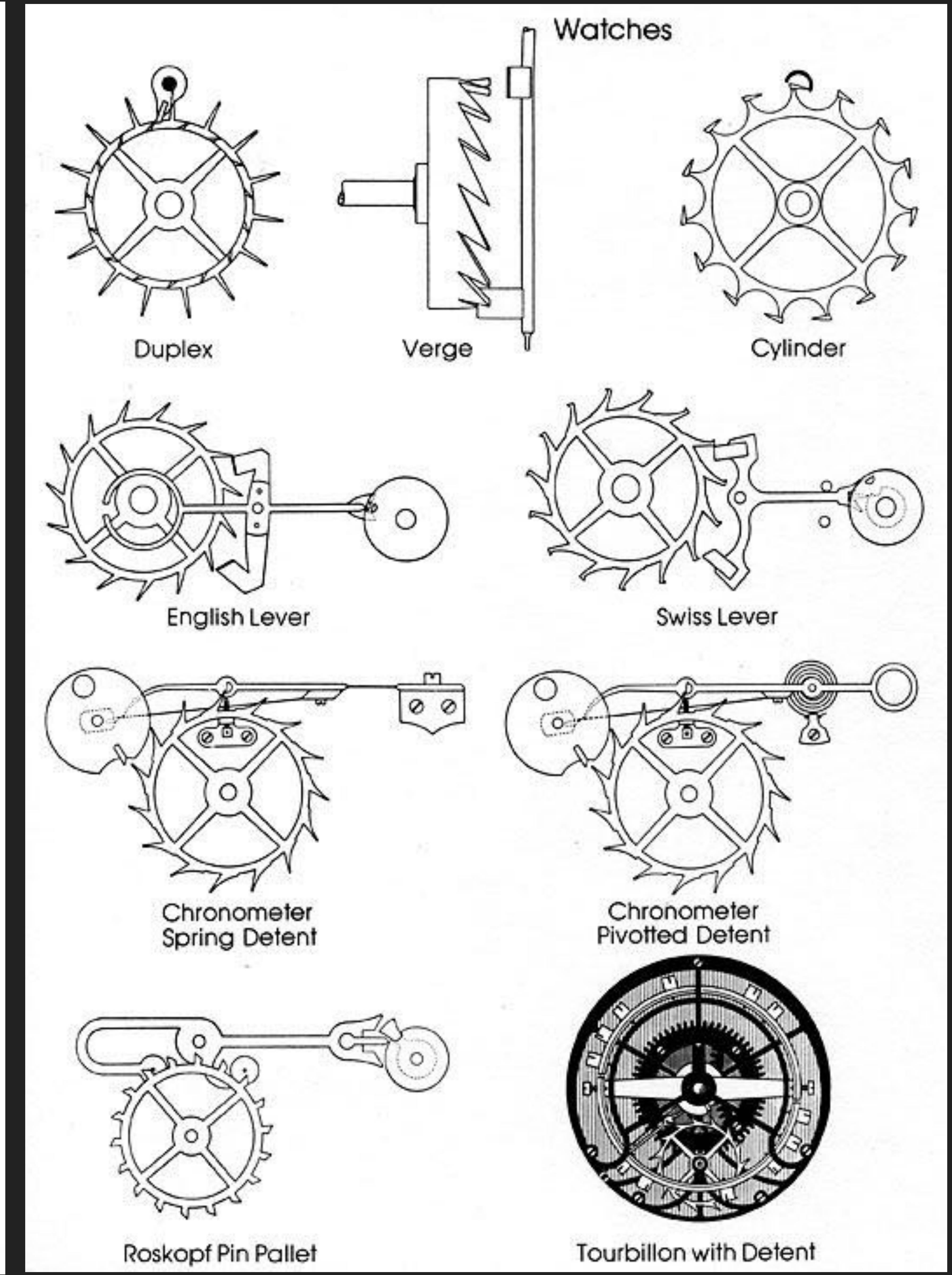






ESCAPEMENTS

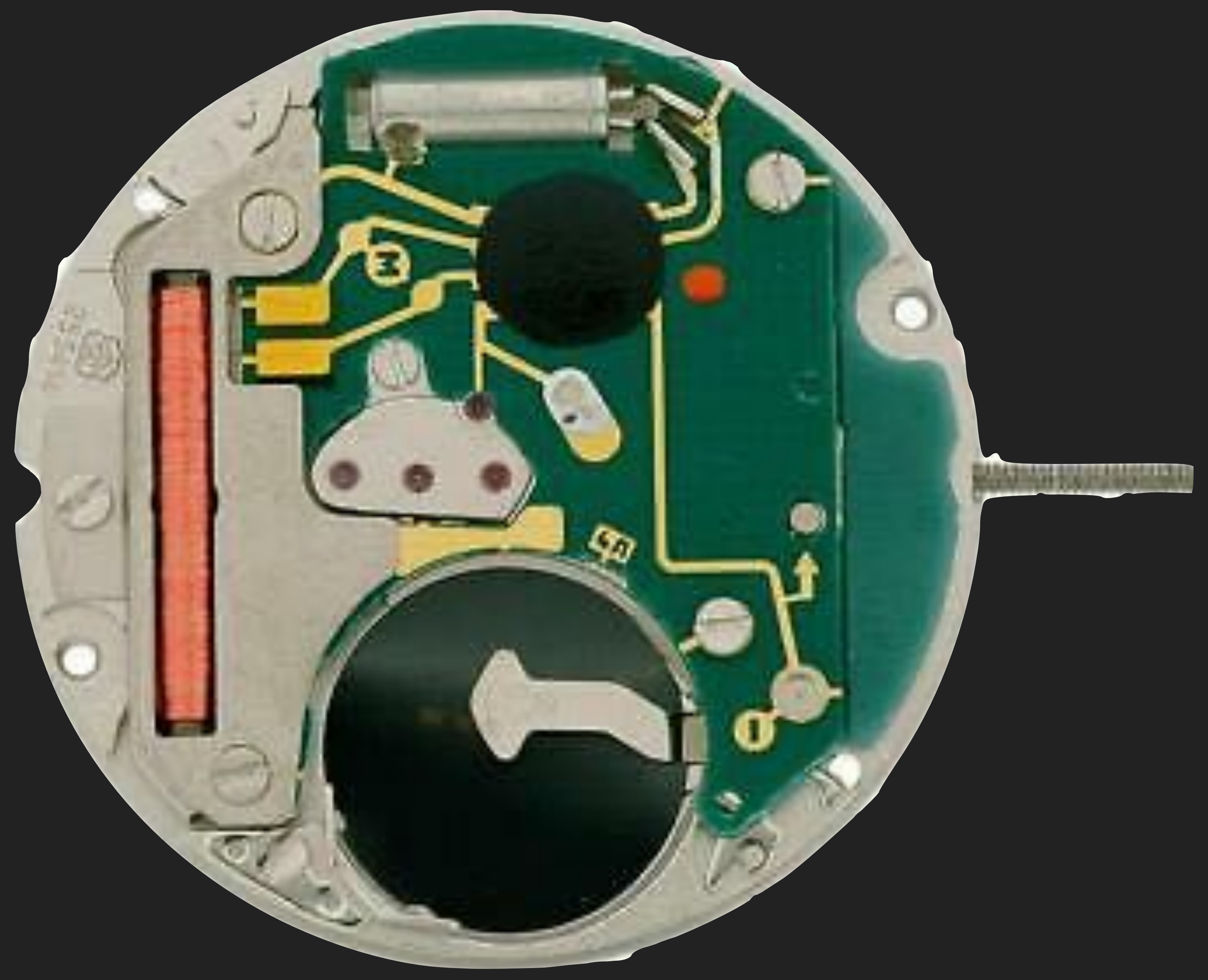




OSCILLATORS

Mechanical
40–208 BPM =
.67Hz – 3.5Hz

OSCILLATORS



Mechanical
~4–10 Hz

Last accurate, most expensive

Longest history, most repairable

Electromechanical
360 Hz

(No longer made)

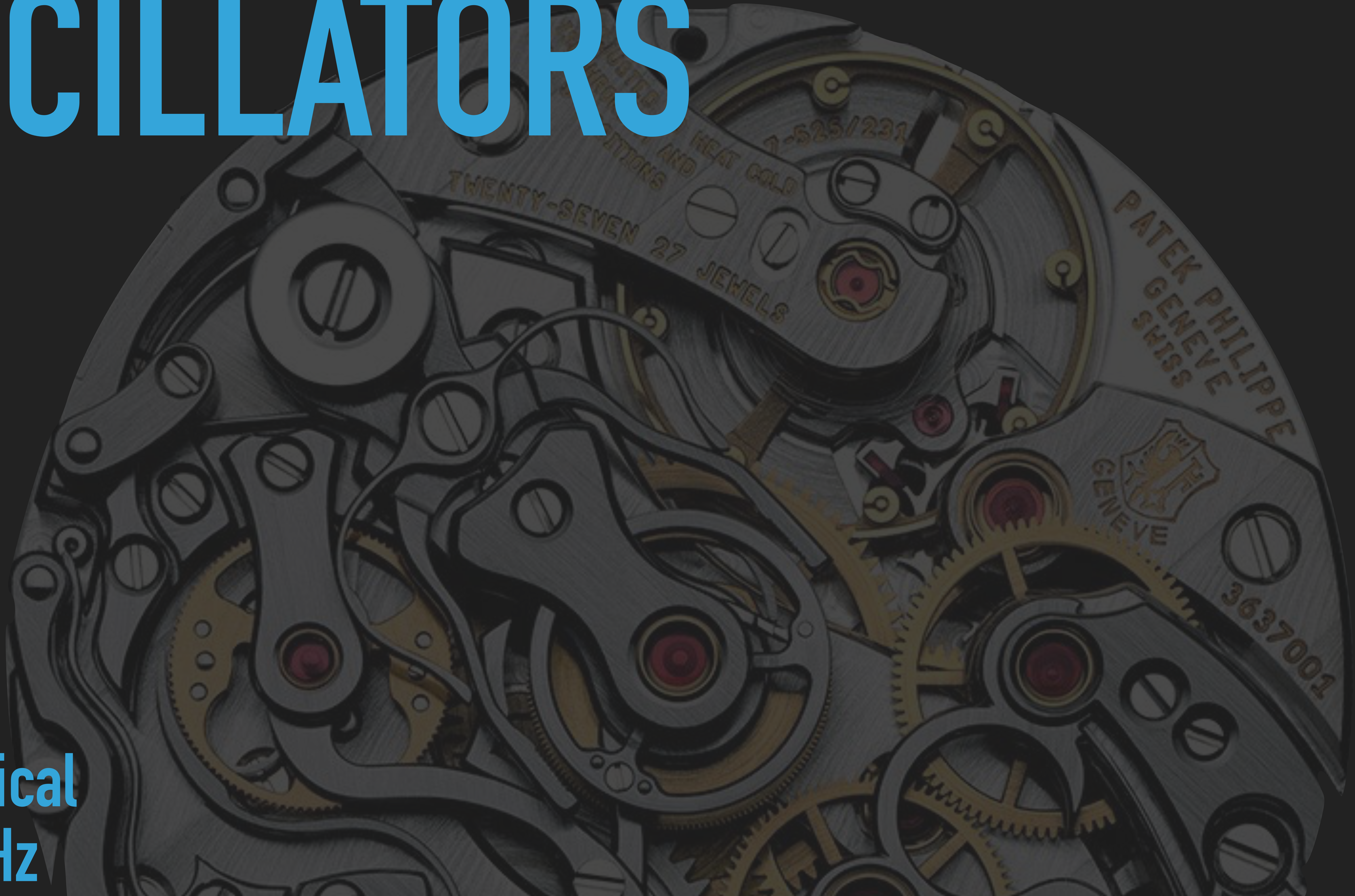
Technological dead end, unrepairable

Quartz
32,768 Hz

Most accurate, least expensive

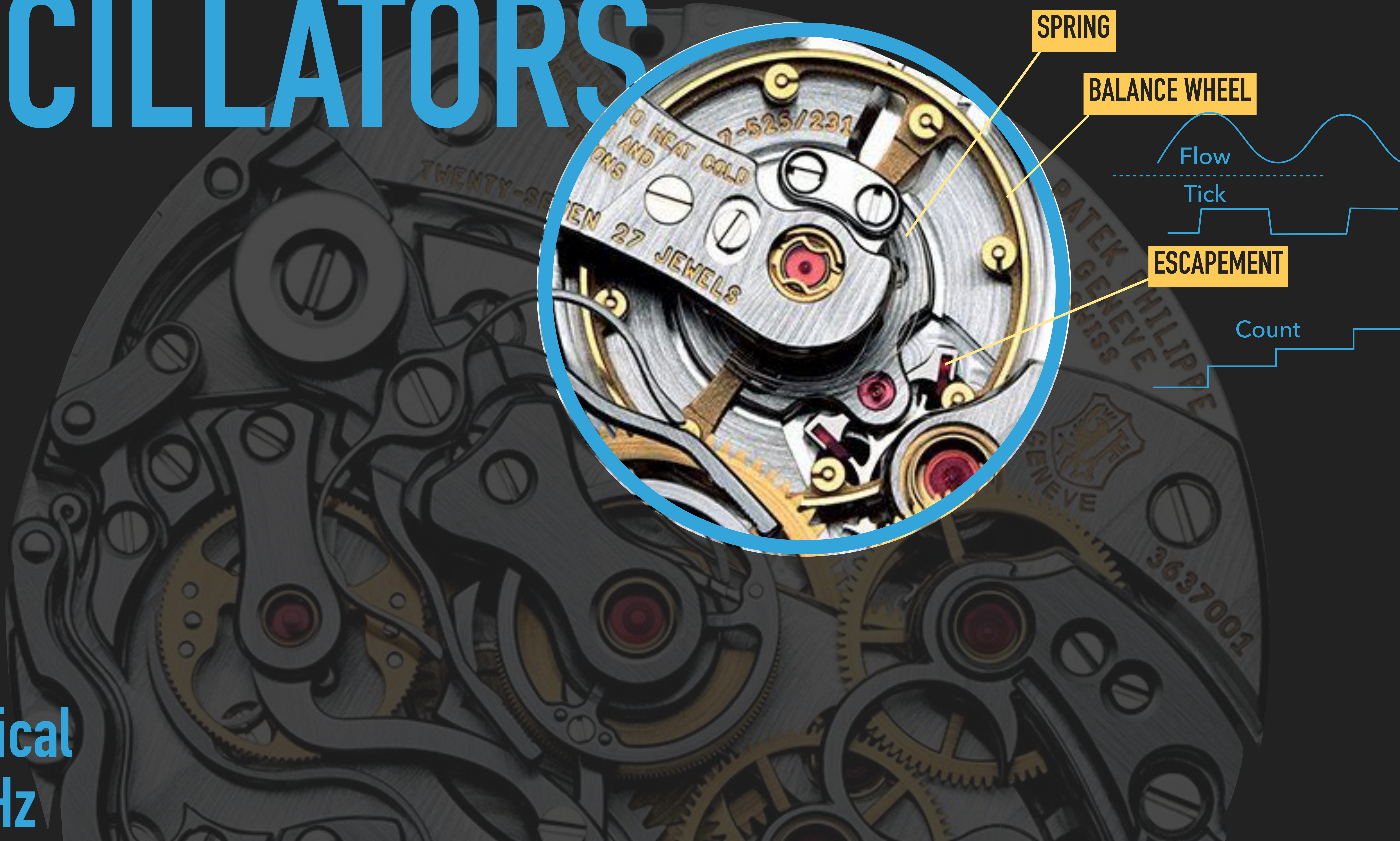
Unrepairable, common, disposable

OSCILLATORS



Mechanical
~4–10 Hz

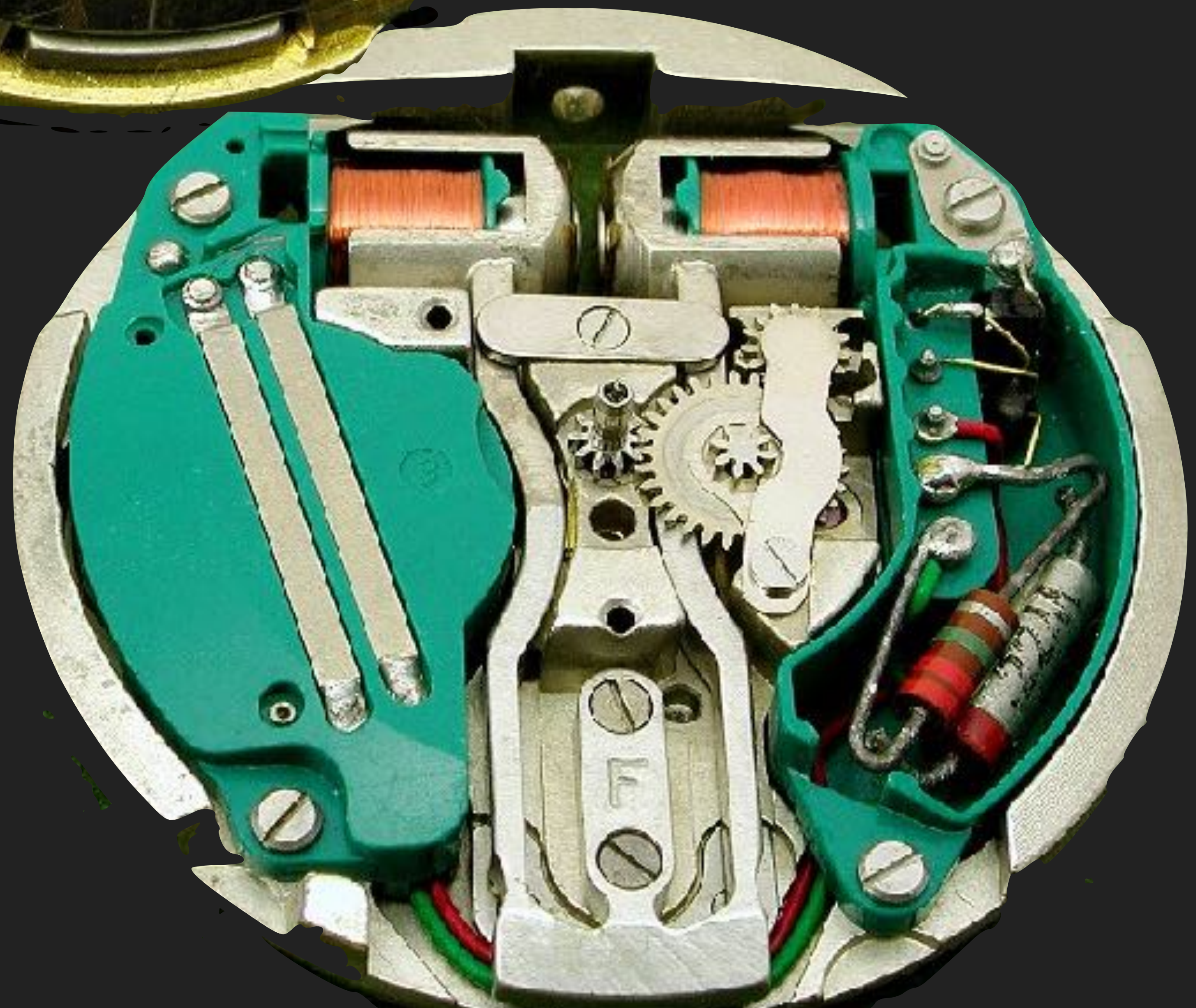
OSCILLATORS



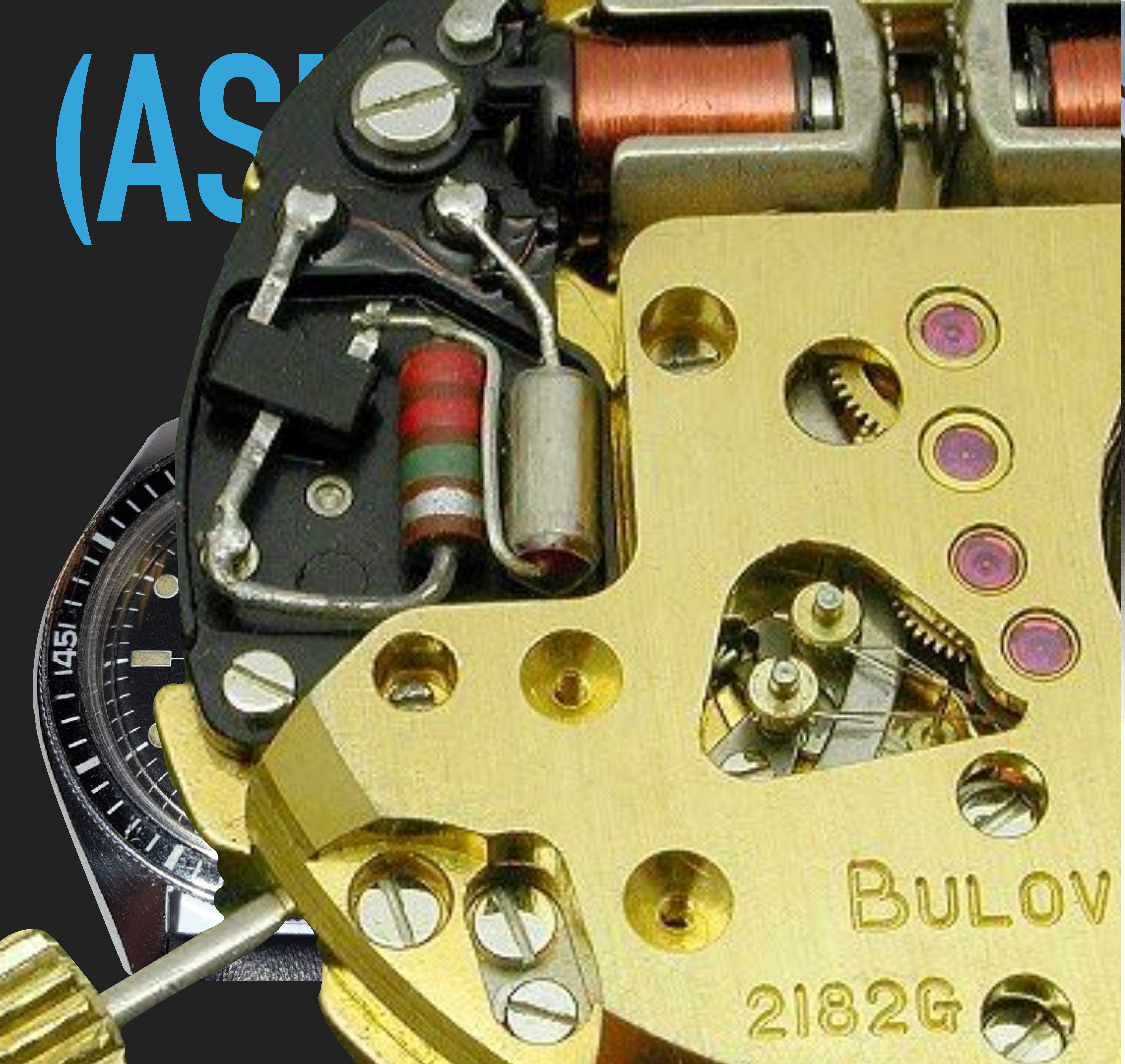
Mechanical
~4–10 Hz

(ASIDE)

Bullova Accutron tuning fork movement, 1960 - 1977



(AS


145
BULOV
2182G


diapason
bobine détectrice de phase et bobine motrice
transistor
conducteurs d'électricité
pile
résistance
Bulova Accutron,
première montre électronique à diapason.
L'électricité lui donne son énergie, l'électronique sa haute précision.
Dans une Bulova Accutron, l'énergie d'une pile est transmise à un diapason au moyen d'un circuit électronique intégré. Parce que l'énergie électrique n'a jamais été un facteur déterminant de précision, ce circuit électronique détecte et maintient à un degré constant la fréquence des oscillations du diapason (au moins 360 par seconde): ce qui permet d'obtenir au porter une précision de 99,9977 % garantie par écrit. On est loin de l'à-peu-près d'un mécanisme traditionnel à balancier! Les deux montres ci-contre font partie des 100 modèles de la collection Bulova Accutron pour hommes et dames que vous trouverez chez tous les bijoutiers horlogers concessionnaires de la marque Bulova (à partir de 595 F)
BULOVA ACCUTRON
A chaque seconde, une certitude.
® marque deposée
PUBLICIS H 2004

(ASIDE)

Super-Accurate Thousand-Dollar Quartz Watches...

Now There's One Under $200!

Here's the ultimate in timekeeping: Watches below are among the first models to appear in the U.S. Produced in limited quantity, all are slightly larger and heavier than conventional watches. Timex' new quartz was not available for this photo.

They hum like amplifiers, and their vibrating crystals insure accuracy of seconds a month

By OSCAR SCHISGALL

"The most accurate timepiece ever devised by man." That's how watch makers describe the newest thing in timekeeping: the electronic quartz watch. Some also call it "the most important new way of measuring time developed in more than 200 years."

Sound wild? It's not an exaggeration. The electronic quartz concept is so different and important that the watch industry may never be the same again.

Big problem with quartz watches until now: They're terribly expensive. The first models coming out of Switzerland and Japan start at $595 in stainless steel, go up to $2,200 in gold. That's why they've been manufactured in limited quantities and only a few have been sold. Now Timex has announced a new model scheduled to go on sale late next month. The price, as of this writing, is estimated at somewhere between $150 and $185.

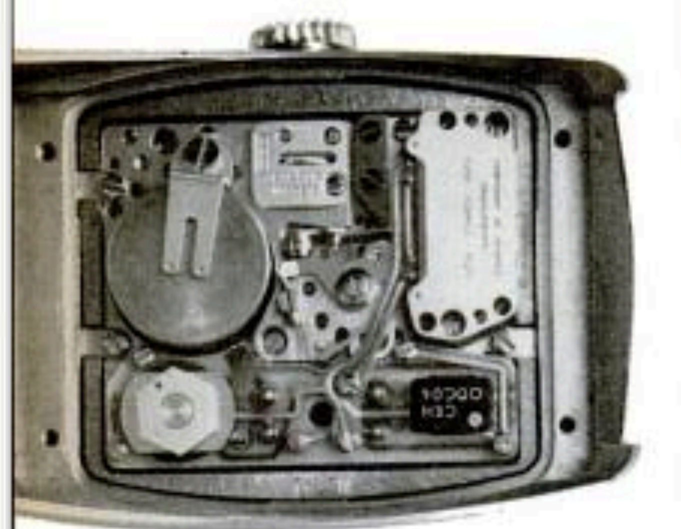
What's an electronic quartz watch? How does it differ from others? How good is it? Let's take these questions one at a time.

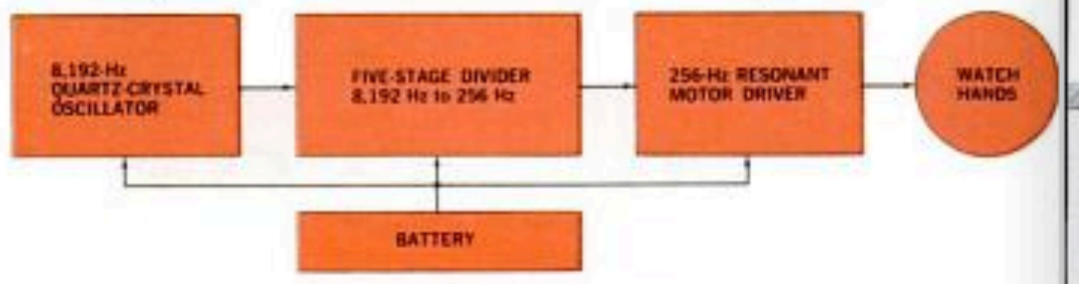
The quartz watch is based on a principle entirely different from those of all other watches. Most watches rely on the familiar balance wheel. A carefully balanced spring-driven wheel rocks back and forth at a rate (usually five times a second) determined by its size and weight. The accuracy with which it maintains that base rate largely determines the watch's accuracy. A top-quality balance-wheel movement keeps accurate time to within perhaps four minutes a month. The tuning-fork concept is more sophisticated. The tuning fork, much like the one the piano tuner uses, vibrates or oscillates 360 times per second; and it results in a watch that's accurate to within a minute a month.

The quartz watch completely abandons the *mechanical* time-regulating device—balance wheel or tuning fork. Instead, it uses an electronic oscillator much like the one that controls the frequency of a broadcast station. The frequency of this oscillator—exactly as in a radio station—is determined by a bar-shaped sliver of quartz. Most quartz watches use quartz oscillators

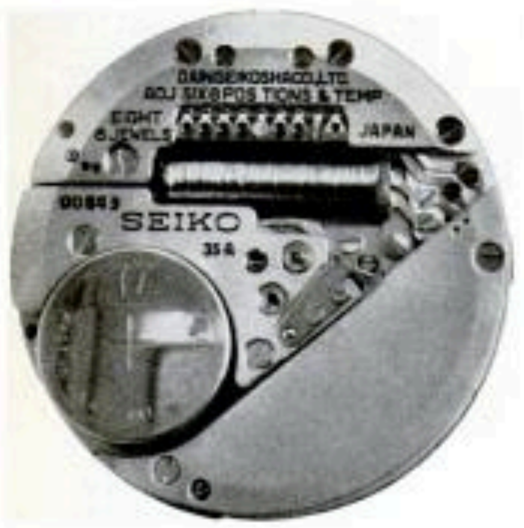
Continued

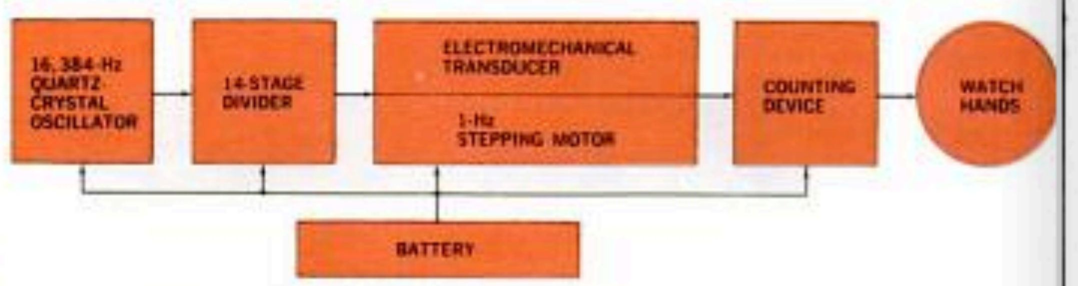
There are at least two reasons why the Timex is so much cheaper – advanced mass-production technology and a circuit that's still top secret





SWISS-CEH **The Swiss Center** of Electronic Horology developed this quartz watch for its member companies, among them Bulova and Omega. The 8,192-Hz quartz oscillator goes through a five-stage divider in a micro-electronic integrated circuit. The resulting output is 256 Hz. This frequency goes to an electromagnetic motor which further di vides the pulse into one-second intervals Using this pulse, the wheel train turns th hands. Omega's integrated circuit contain 21 transistors and 61 other electronic ele ments. Member companies in the CEH or ganization may alter the basic movemen slightly to fit an individual watch case.





SEIKO **This quartz** has five major components: 16,384-Hz quartz-crystal oscillator circuit, integrated circuit with a 14-stage divider, stepping motor with an electromechanical transducer, and silver-oxide battery. The divider circuit halves the 16,384-Hz frequency 14 times (8,192; 4,096; etc.—down to a single pulse). The electromechanical transducer convert the one-pulse signal into mechanical mo tion, to turn the six-pole stepping motor i 60-degree increments. Finally, the countin device moves the second hand at exact one second intervals. Pulling out the crown stop the second hand, for precise control. Batter life is claimed to be one year.

with 8,192 Hz—vibrations per second. If you listen to a quartz watch, it hums like a tuning fork—but it's far more accurate.

Quartz, the familiar transparent crystalline mineral, is a remarkable substance. It has piezoelectric characteristics. If a voltage is applied across a slab of quartz, it bends slightly. Put the quartz in an oscillator circuit and it will vibrate at its natural frequency, which is determined by its size and shape.

This natural oscillation frequency is so precise that quartz watches are accurate to within seconds per month. Most quartz-watch makers guarantee accuracy to within five seconds a month; the Timex people conservatively claim an accuracy of 15 seconds a month.

How they work. Most quartz watches operate on the same general principle. (Longines work differently; Timex, we can't say.) First, you have a quartz-crystal oscillator circuit. Next, a small mercury or silver oxide battery to provide voltage so the quartz can oscillate. But the quartz crystal's natural vibrating frequency is too high; more manageable speeds are needed to move around the hands.

Micro-electronic integrated circuits come in here. "Dividers" in these circuits "step down" the frequency by halving it several times (8,192 frequency is the 13th power of $2-2^{13}$). The number of dividers in the circuit depends on the quartz-crystal frequency and other circuitry a particular company uses.

Whether the pulse is divided down to one pulse or a slightly higher frequency (256 in the Swiss movements), an electro-mechanical motor receives the pulse and converts electrical energy to mechanical energy. This drives the wheel train that eventually turns the hands. Of course, each company's watch works a little differently. (See explanations above.)

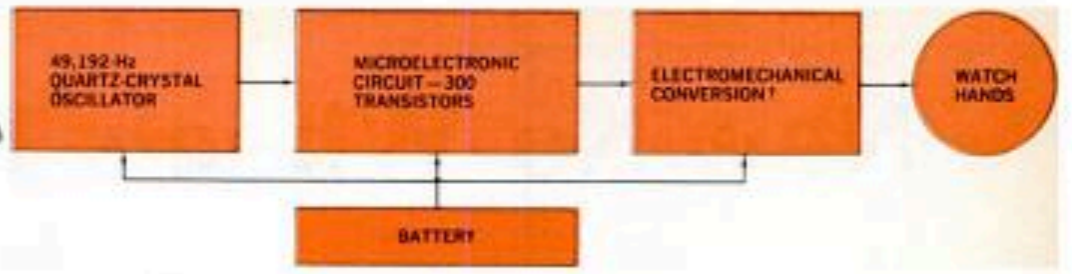
Still, the big mystery is why the Timex is so much cheaper—between a third and a quarter of the price of its nearest competitor. Undoubtedly, there are at least two reasons.

First, a technology geared to enormous production. "We have developed mass-production techniques unmatched outside the United States," says Joakim Lehmkuhl, president of Timex. "You can't produce 19 million watches a year, as we've been doing without learning a great deal abou automated mass production and meth ods of cost control. When it came t actually manufacturing the quart watch we already had a backlog o experience in essential fields like th design and manufacture of parts, es pecially miniaturized parts."

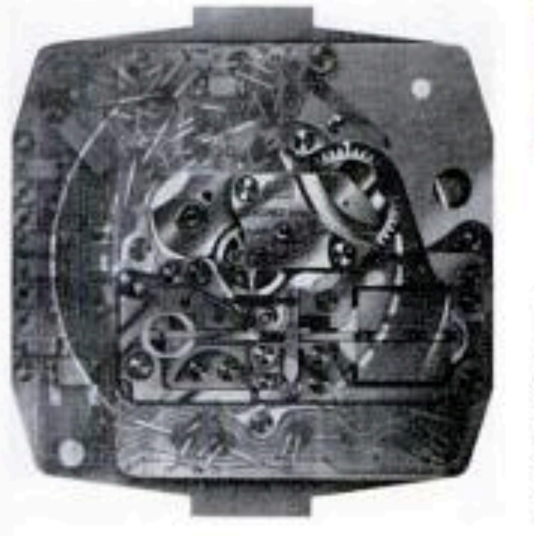
Timex produces all the parts in it watches—except the quartz-crystal os cillator and the circuit. At Water bury, Conn., I watched skilled work ers assemble the watches.

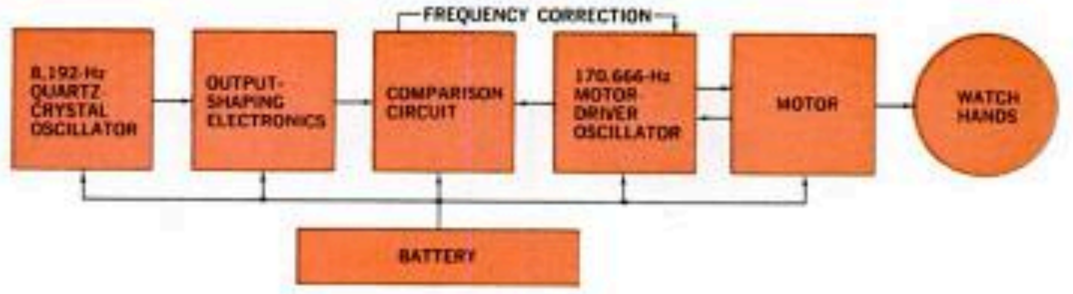
My guide, an engineer, pointed ou that in the field of conventiona watches, Timex has been manufactur ing pin-lever movements, which ar less expensive to produce than th Swiss and Japanese jeweled move ments. But he, like the others I talke to at Timex, would not agree tha their quartz-crystal watch used a ba sically less-advanced mechanism tha its competition. This leads directl to the second reason for lower cost.

Despite the lack of any availabl proof, Timex has apparently figure out some way to simplify the desig and reduce the cost of building a quartz-crystal watch with a super



TIMEX **What's inside?** We don't know yet. At press time the technical information was still "top secret." We do know that the Timex movement uses a crystal oscillator with a 49,192-Hz frequency—far higher than any other quartz on the market. This frequency is not a power of two as in the others—which makes it even more mysterious. It has a micro-electronic circuit—about one centimeter square—containing 300 transistors. It also uses a silver-oxide battery good for a year. It could have several things in it—including some kind of comparison circuit, or a digital or analog means of controlling the watch's speed. It's accurate to 15 seconds a month.





LONGINES **This one's unique:** A comparison circuit detects error in the watch's output and self-corrects. A 9,350-Hz quartz oscillator is the frequency reference—which is not divided, as in other watches. A 170-Hz servomotor, independent and operating by itself, turns the hands. Mechanical output is compared with the quartz signal. If there's an error signal in the comparison circuit, a correction is applied to the motor. If motor frequency and crystal frequency are in step, the error signal is zero. The circuit has 14 transistors, 19 resistors, and seven capacitors. Insurance against loss or theft for one year comes with the watch.

high frequency. The company has apparently made an important breakthrough in quartz-watch technology—one that gives it a tremendous advantage—and company engineers and executives are understandably reluctant to reveal their secret.

Although the Timex people showed me various versions of their watch, they refused permission to photograph it—face or movement. Nevertheless, Timex executive vice-president Robert Mohr did give POPULAR SCIENCE some exclusive technical information, emphasizing that "our watch, as far as I know, is entirely different from any other quartz watch." This, along with our speculation of what's inside it, is above.

How about watch performance? Reliability? "Since there are virtually no moving parts," says Lehmkuhl, "very little can go wrong. We have put the watch through every conceivable test of temperature, altitude, and humidity. We have made every test for position error—dial up, dial down, three o'clock up, six o'clock up, nine o'clock up. Where we found bugs we corrected them."

And shock and water resistance? "Water resistant, yes. As for being shock resistant...," Lehmkuhl smiled. "It is sturdy, but we don't recommend that you hurl it against walls as we did in torture tests with our conventional watches. We wouldn't recommend such treatment for any item that costs over $100."

In any event, Timex seems destined to be the first to market the new watch in quantity, and Seiko threatens to be a close second. Why aren't the Swiss (such as Bulova, Omega, Longines, and others) marketing quartz watches in large numbers?

Tuning-fork watches. Bulova has had a lot of success with its Accutron tuning-fork watch. Now other Swiss companies have been licensed by Bulova to make tuning-fork watches. As one Swiss manufacturer said, "We want to make the most of our tuning-fork watch, which represents a heavy investment. Time enough for the quartz watch when the tuning-fork has passed the peak of popularity."

Another predicted differently. "Timex and its advertising campaign for the quartz watch may well be the catalyst that will compel all of us to jump in and compete."

I asked Joakim Lehmkuhl of Timex how far away he thought the era of the quartz watch might be.

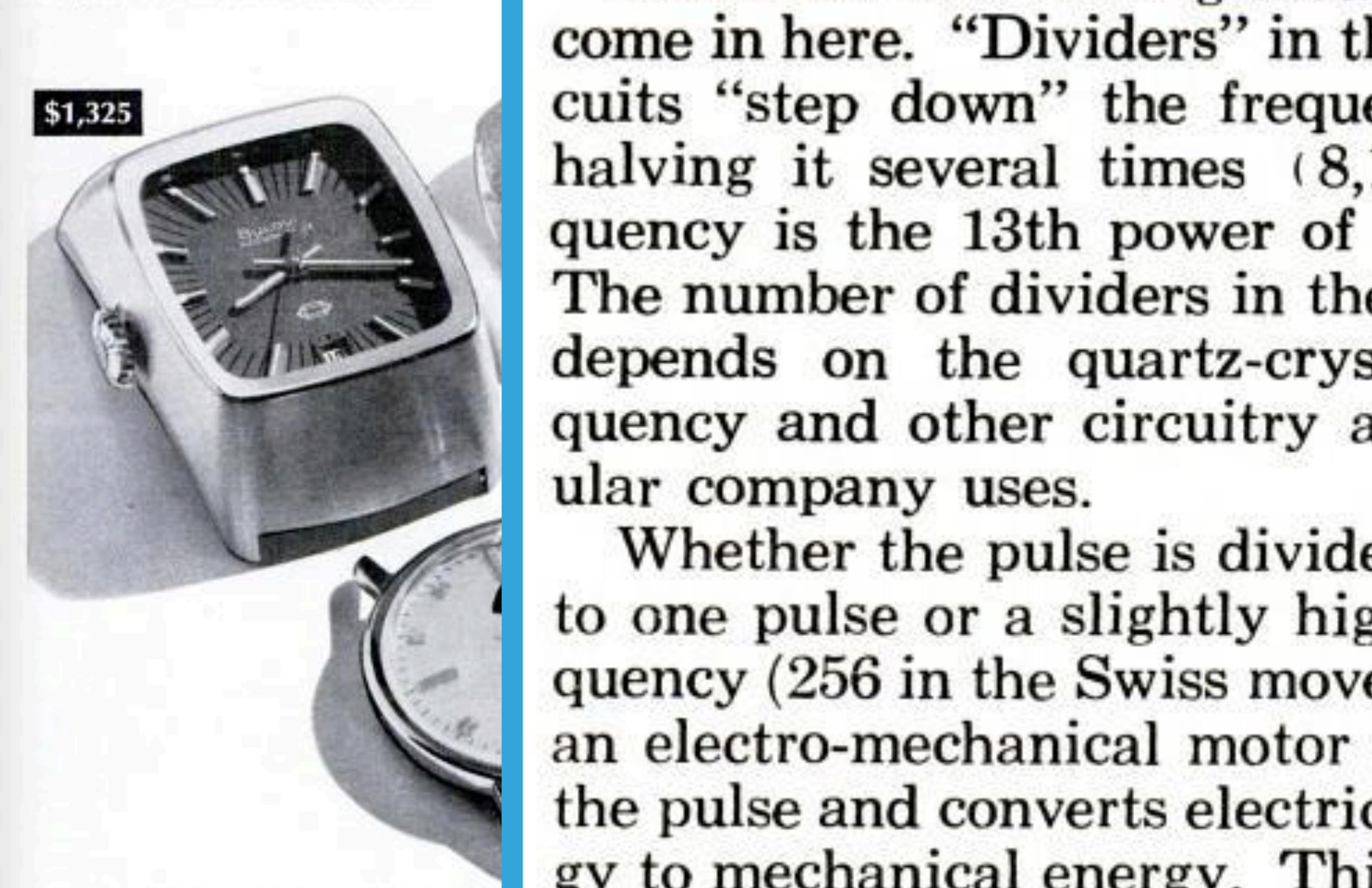
"We don't expect a hundred million Americans to throw away their watches tomorrow morning in order to buy a quartz watch. We are dealing not only with watches, but with human nature. We expect, as new watches are bought, that purchasers will want the latest and most accurate type. Simply because the quartz watch is unquestionably the newest and most accurate example of horology man has so far achieved, we are confident that it will be, if not the dominant watch of tomorrow, surely that of the day after tomorrow."

And what can we expect, the day after *that*? Nuclear timekeeping. Some day you may be able to buy a watch containing a milligram of an alpha-particle-emitting radioactive isotope as a power source. It may be accurate to within a few seconds a year—almost as accurate as the movement of the Earth itself! Although Bulova's engineers are already exploring nuclear timekeeping, they believe it's a long way off. Name? What else but the atomic watch?

Super-Accurate Thousand-Dollar Quartz Watches...

Now There's One Under $200!

Here's the ultimate in timekeeping: Watches below are among the first models to appear in the U.S. Produced in limit... are slightly larger and heavier than conventional w... new quartz was not available for this photo.



Micro-electronic integrated circuits come in here. "Dividers" in these circuits "step down" the frequency by halving it several times (8,192 frequency is the 13th power of 2—2^{13}). The number of dividers in the circuit depends on the quartz-crystal frequency and other circuitry a particular company uses.

Whether the pulse is divided down to one pulse or a slightly higher frequency (256 in the Swiss movements), an electro-mechanical motor receives the pulse and converts electrical energy to mechanical energy. This drives the wheel train that eventually turns the hands. Of course, each company's watch works a little differently. (See explanations above.)

They hum like amplifiers, and their vibrating crystals insure accuracy of seconds a month

By OSCAR SCHISGALL

"The most accurate timepiece ever devised by man." That's how watch makers describe the newest thing in timekeeping: the electronic quartz watch. Some also call it "the most important new way of measuring time developed in more than 200 years."

Sound wild? It's not an exaggeration. The electronic quartz concept is so different and important that the watch industry may never be the same again.

Big problem with quartz watches until now: They're terribly expensive.

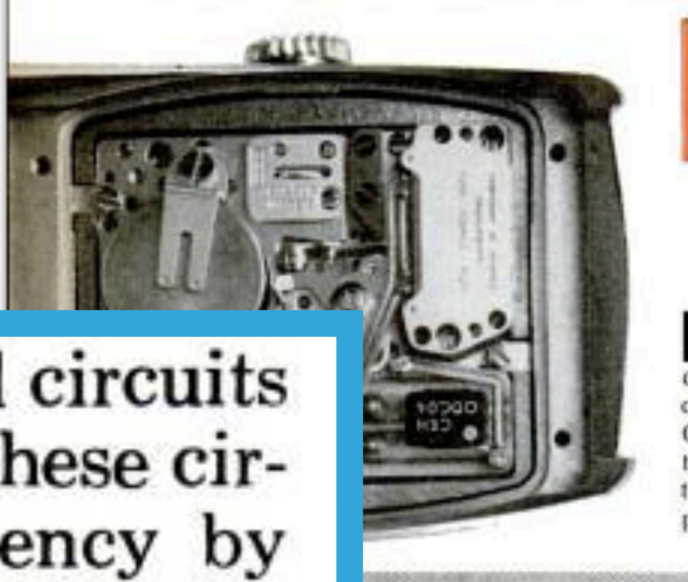
The ... zerla... stain... That... ture... a few... anno... go o... as ... some...

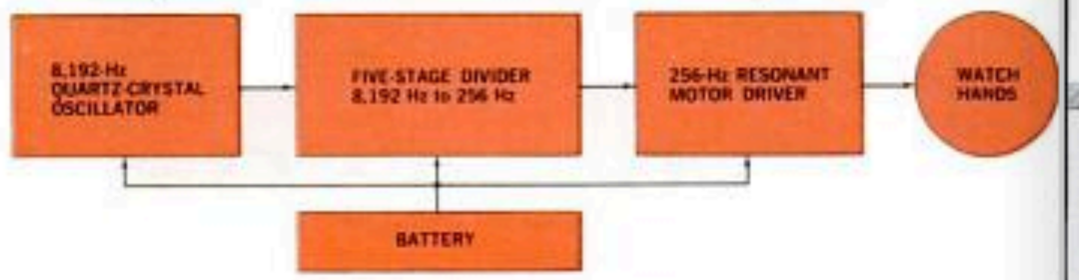
W... How does it differ from others? How good is it? Let's take these questions one at a time.

The quartz watch is based on a principle entirely different from those of all other watches. Most watches rely on the familiar balance wheel. A carefully balanced spring-driven wheel rocks back and forth at a rate (usually five times a second) determined by its size and weight. The accuracy with

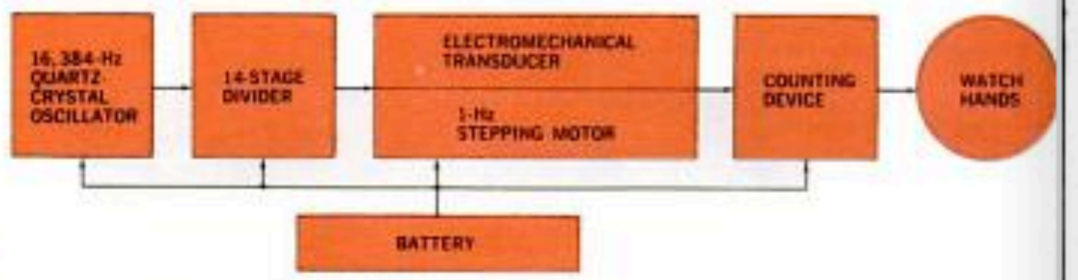
... The quartz watch completely abandons the *mechanical* time-regulating device—balance wheel or tuning fork. Instead, it uses an electronic oscillator much like the one that controls the frequency of a broadcast station. The frequency of this oscillator—exactly as in a radio station—is determined by a bar-shaped sliver of quartz. Most quartz watches use quartz oscillators

Continued

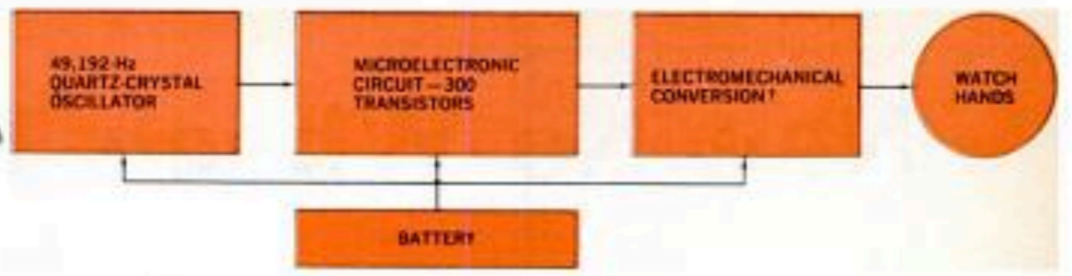




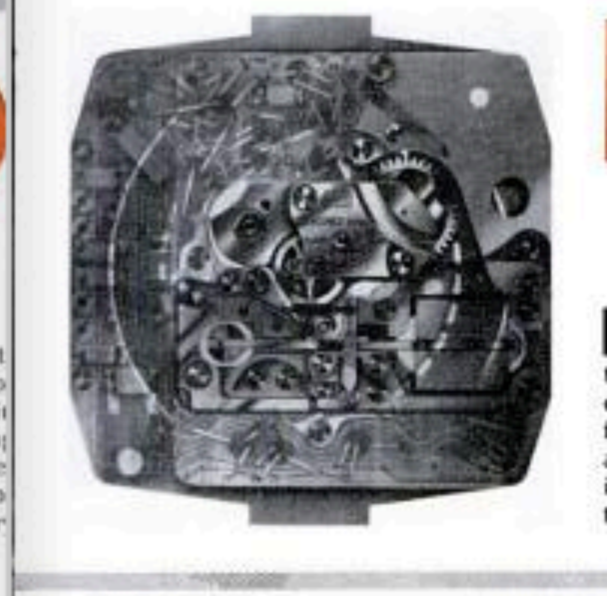
SWISS-CEH **The Swiss Center** of Electronic Horology developed this quartz watch for its member companies, among them Bulova and Omega. The 8,192-Hz quartz oscillator goes through a five-stage divider in a micro-electronic integrated circuit. The resulting output is 256 Hz. This frequency goes to an electromagnetic motor which further divides the pulse into one-second intervals. Using this pulse, the wheel train turns the hands. Omega's integrated circuit contains 21 transistors and 61 other electronic elements. Member companies in the CEH organization may alter the basic movement slightly to fit an individual watch case.

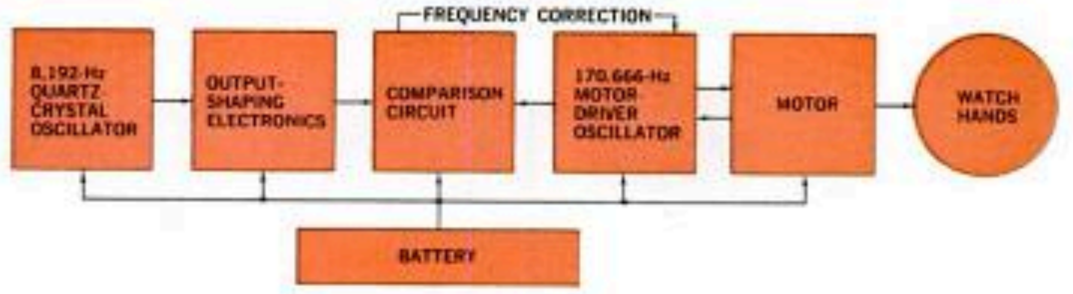


SEIKO **This quartz** has five major components: 16,384-Hz quartz-crystal oscillator circuit, integrated circuit with a 14-stage divider, stepping motor with an electromechanical transducer, and silver-oxide battery. The divider circuit halves the 16,384-Hz frequency 14 times (8,192; 4,096; etc.—down to a single pulse). The electromechanical transducer converts the one-pulse signal into mechanical motion, to turn the six-pole stepping motor in 60-degree increments. Finally, the counting device moves the second hand at exact one second intervals. Pulling out the crown stops the second hand, for precise control. Battery life is claimed to be one year.



TIMEX **What's inside?** We don't know yet. At press time the technical information was still "top secret." We do know that the Timex movement uses a crystal oscillator with a 49,192-Hz frequency—far higher than any other quartz on the market. This frequency is not a power of two as in the others—which makes it even more mysterious. It has a micro-electronic circuit—about one centimeter square—containing 300 transistors. It also uses a silver-oxide battery good for a year. It could have several things in it—including some kind of comparison circuit, or a digital or analog means of controlling the watch's speed. It's accurate to 15 seconds a month.





LONGINES **This one's unique:** A comparison circuit detects error in the watch's output and self-corrects. A 9,350-Hz quartz oscillator is the frequency reference—which is not divided, as in other watches. A 170-Hz servomotor, independent and operating by itself, turns the hands. Mechanical output is compared with the quartz signal. If there's an error signal in the comparison circuit, a correction is applied to the motor. If motor frequency and crystal frequency are in step, the error signal is zero. The circuit has 14 transistors, 19 resistors, and seven capacitors. Insurance against loss or theft for one year comes with the watch.

...ibrations per second. ... a quartz watch, it ...ng fork—but it's far ...

...amiliar transparent ...ral, is a remarkable ...s piezoelectric char... voltage is applied ...uartz, it bends slight...z in an oscillator cir...ibrate at its natural ... is determined by its ...

...scillation frequency ...t quartz watches are ...n seconds per month. ...ch makers guarantee ...hin five seconds a ...ex people conserva...ccuracy of 15 seconds

How they work. Most quartz watches operate on the same general principle. (Longines work differently; Timex, we can't say.) First, you have a quartz-crystal oscillator circuit. Next, a small mercury or silver oxide battery to provide voltage so the quartz can oscillate. But the quartz crystal's natural vibrating frequency is too high; more manageable speeds are needed to move around the hands.

Micro-electronic integrated circuits come in here. "Dividers" in these circuits "step down" the frequency by halving it several times (8,192 frequency is the 13th power of 2—2^{13}). The number of dividers in the circuit depends on the quartz-crystal frequency and other circuitry a particular company uses.

Whether the pulse is divided down to one pulse or a slightly higher frequency (256 in the Swiss movements), an electro-mechanical motor receives the pulse and converts electrical energy to mechanical energy. This drives the wheel train that eventually turns the hands. Of course, each company's watch works a little differently. (See explanations above.)

Still, the big mystery is why the Timex is so much cheaper—between a third and a quarter of the price of its nearest competitor. Undoubtedly, there are at least two reasons.

First, a technology geared to enormous production. "We have developed mass-production techniques unmatched outside the United States," says Joakim Lehmkuhl, president of Timex. "You can't produce 19 million watches a year, as we've been doing without learning a great deal about automated mass production and methods of cost control. When it came to actually manufacturing the quartz watch we already had a backlog of experience in essential fields like the design and manufacture of parts, especially miniaturized parts."

Timex produces all the parts in its watches—except the quartz-crystal oscillator and the circuit. At Waterbury, Conn., I watched skilled workers assemble the watches.

My guide, an engineer, pointed out that in the field of conventional watches, Timex has been manufacturing pin-lever movements, which are less expensive to produce than the Swiss and Japanese jeweled movements. But he, like the others I talked to at Timex, would not agree that their quartz-crystal watch used a basically less-advanced mechanism than its competition. This leads directly to the second reason for lower cost.

Despite the lack of any available proof, Timex has apparently figured out some way to simplify the design and reduce the cost of building a quartz-crystal watch with a super high frequency. The company has apparently made an important breakthrough in quartz-watch technology—one that gives it a tremendous advantage—and company engineers and executives are understandably reluctant to reveal their secret.

Although the Timex people showed me various versions of their watch, they refused permission to photograph it—face or movement. Nevertheless, Timex executive vice-president Robert Mohr did give POPULAR SCIENCE some exclusive technical information, emphasizing that "our watch, as far as I know, is entirely different from any other quartz watch." This, along with our speculation of what's inside it, is above.

How about watch performance? Reliability? "Since there are virtually no moving parts," says Lehmkuhl, "very little can go wrong. We have put the watch through every conceivable test of temperature, altitude, and humidity. We have made every test for position error—dial up, dial down, three o'clock up, six o'clock up, nine o'clock up. Where we found bugs we corrected them."

And shock and water resistance? "Water resistant, yes. As for being shock resistant...," Lehmkuhl smiled. "It is sturdy, but we don't recommend that you hurl it against walls as we did in torture tests with our conventional watches. We wouldn't recommend such treatment for any item that costs over $100."

In any event, Timex seems destined to be the first to market the new watch in quantity, and Seiko threatens to be a close second. Why aren't the Swiss (such as Bulova, Omega, Longines, and others) marketing quartz watches in large numbers?

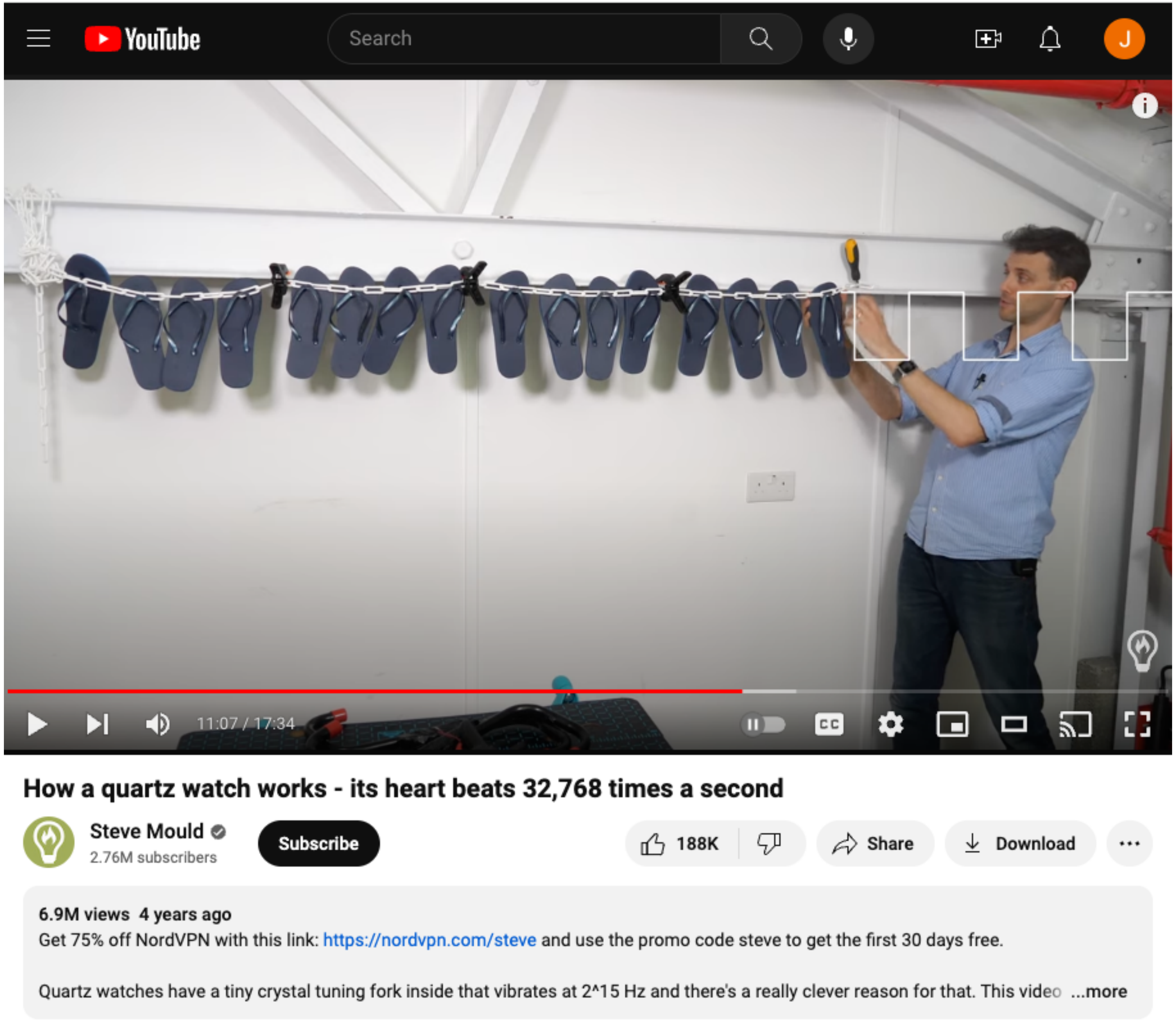
Tuning-fork watches. Bulova has had a lot of success with its Accutron tuning-fork watch. Now other Swiss companies have been licensed by Bulova to make tuning-fork watches. As one Swiss manufacturer said, "We want to make the most of our tuning-fork watch, which represents a heavy investment. Time enough for the quartz watch when the tuning-fork has passed the peak of popularity."

Another predicted differently. "Timex and its advertising campaign for the quartz watch may well be the catalyst that will compel all of us to jump in and compete."

I asked Joakim Lehmkuhl of Timex how far away he thought the era of the quartz watch might be.

"We don't expect a hundred million Americans to throw away their watches tomorrow morning in order to buy a quartz watch. We are dealing not only with watches, but with human nature. We expect, as new watches are bought, that purchasers will want the latest and most accurate type. Simply because the quartz watch is unquestionably the newest and most accurate example of horology man has so far achieved, we are confident that it will be, if not the dominant watch of tomorrow, surely that of the day after tomorrow."

And what can we expect, the day after *that*? Nuclear timekeeping. Some day you may be able to buy a watch containing a milligram of an alpha-particle-emitting radioactive isotope as a power source. It may be accurate to within a few seconds a year—almost as accurate as the movement of the Earth itself! Although Bulova's engineers are already exploring nuclear timekeeping, they believe it's a long way off. Name? What else but the atomic watch?

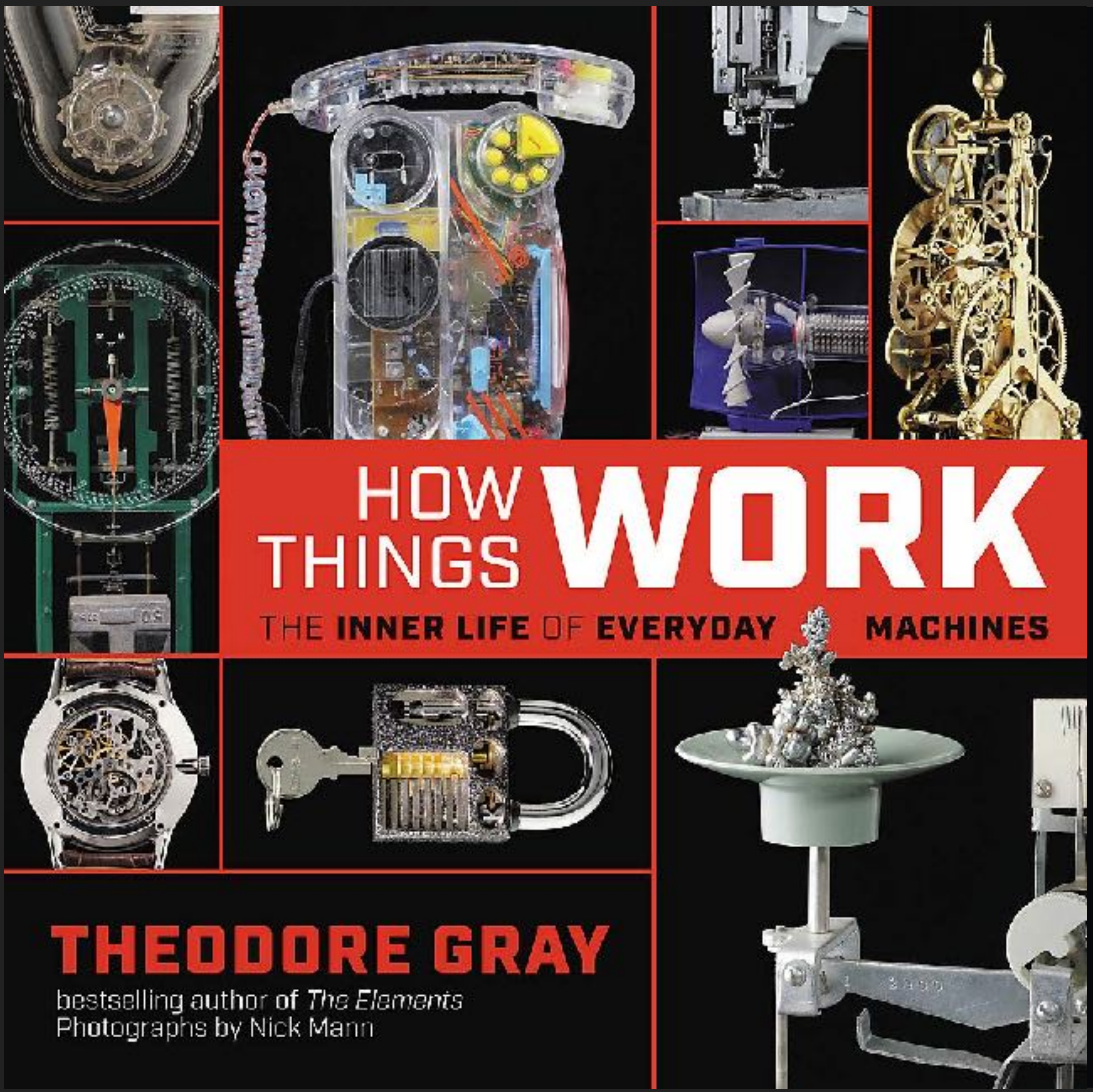


https://www.youtube.com/watch?v=_2By2ane2I4&t=351s

TIME MACHINES

CONTINUED

Diving even more deeper into timing machinery



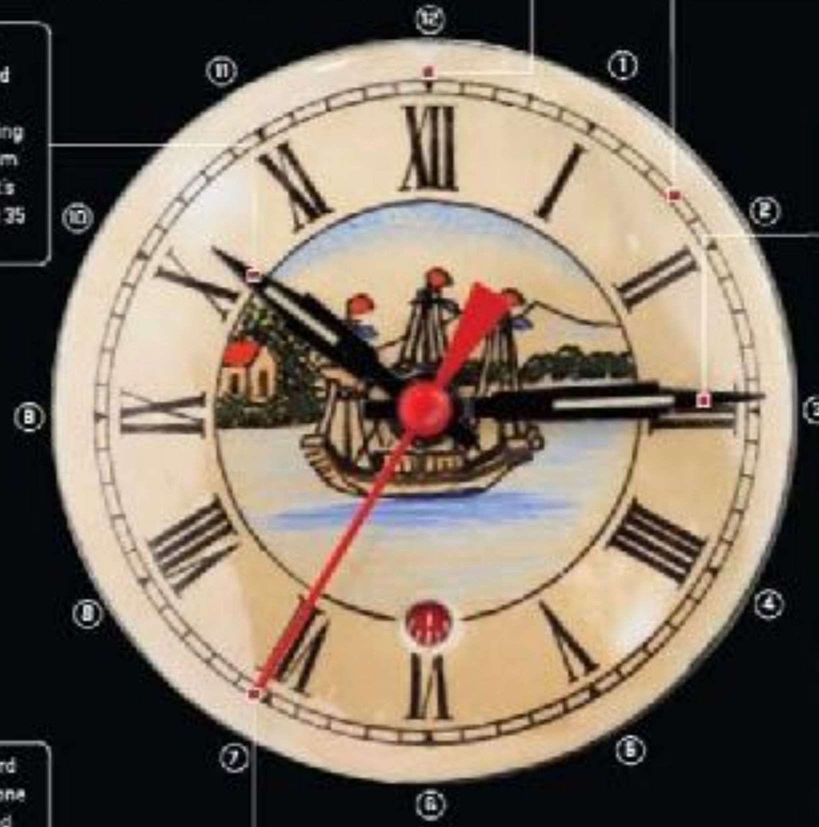
Pendulum Clocks

THE FIRST REALLY GOOD mechanical clocks were tick tock style pendulum clocks. The invention of the pendulum as a way of telling time was a huge advance in accuracy. Overnight, clocks went from drifting off by 15 minutes or more every day, to the best staying within 10 seconds per day.

This Chinese copy of an old French design shows off the very definition of "clockwork." Gears upon gears, folded in on each other, all moving together in ways that are, well, pretty confusing. To help make things understandable, I've made a spread-out model for you.

FOR THE BENEFIT of those of you born in the present millennium, a primer on clocks of the old school. This is the universal symbol of time, the clock face. There are three "hands," which all turn around the same central point. Around the outside there are two sets of marks: one set of 60 small tick marks for seconds and minutes, and one set of 12 large tick marks for hours. This clock is showing 10:14:35 (14 minutes and 35 seconds after 10 o'clock).

The three hands on a clock are all turning around the same point, but they are turning at wildly different speeds. It takes 60 times longer for the minute hand to go around than the second hand, and the hour hand is another 12 times slower. For every complete turn of the hour hand, the second hand has to go around 720 times. This huge difference in speed is created by a mess of gears on the back of the clock.



▲ There is something amusing in the fact that the telephone app on today's iPhones has an icon that looks like a phone no one has used in twenty years, and the clock app looks like a clock most people rarely see anymore. (It's also amusing that a separate telephone app is necessary on a device that is, by name, already a phone. But, the truth is, making phone calls is one of the iPhone's least commonly used functions.)

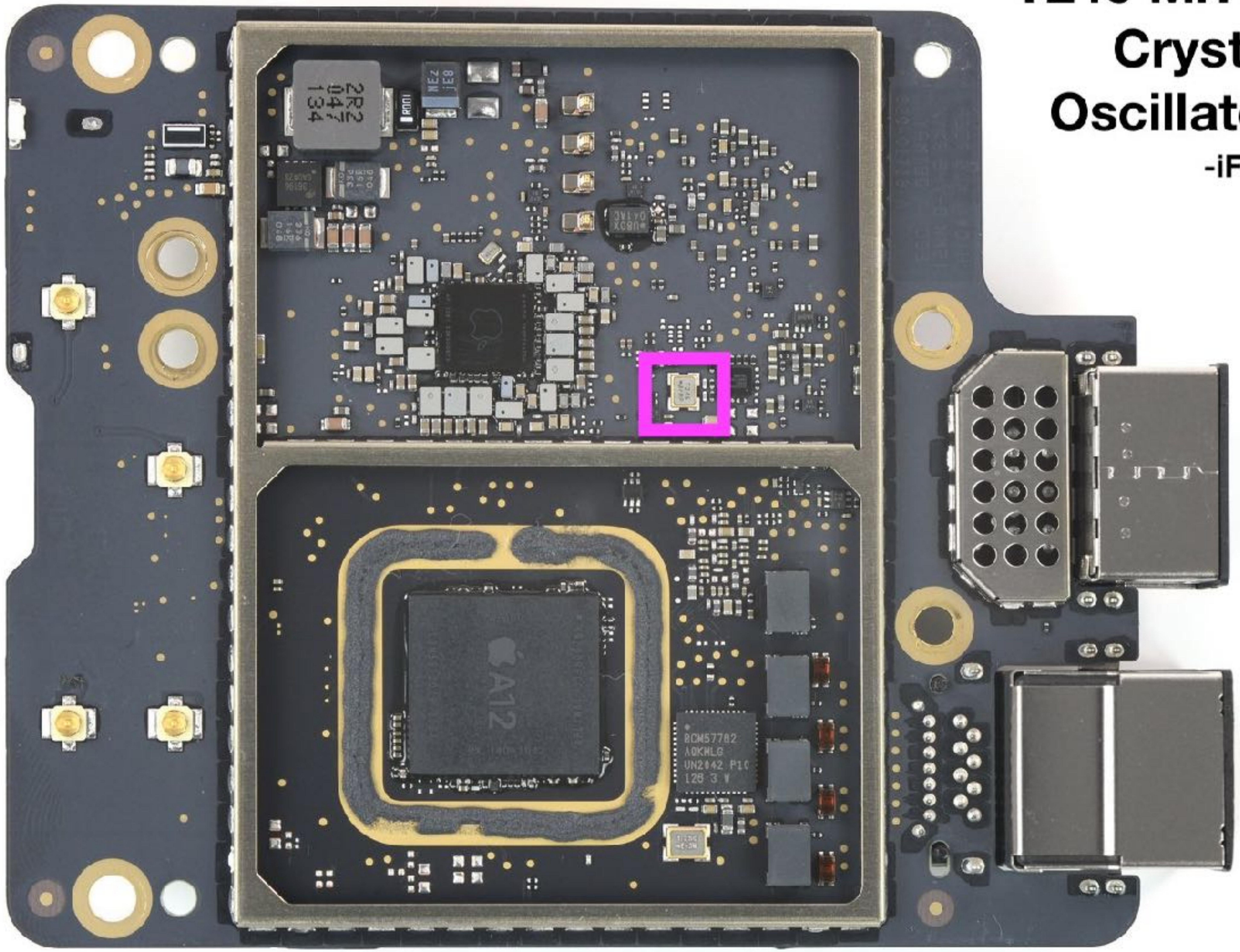
"We've now arrived at the subject of really accurate time. Earlier I said that up until 1955 a glorified sundial was the most accurate clock in existence. Another way of saying this is that we were using the rotation of the earth as the reference standard for time, because we didn't have anything better.

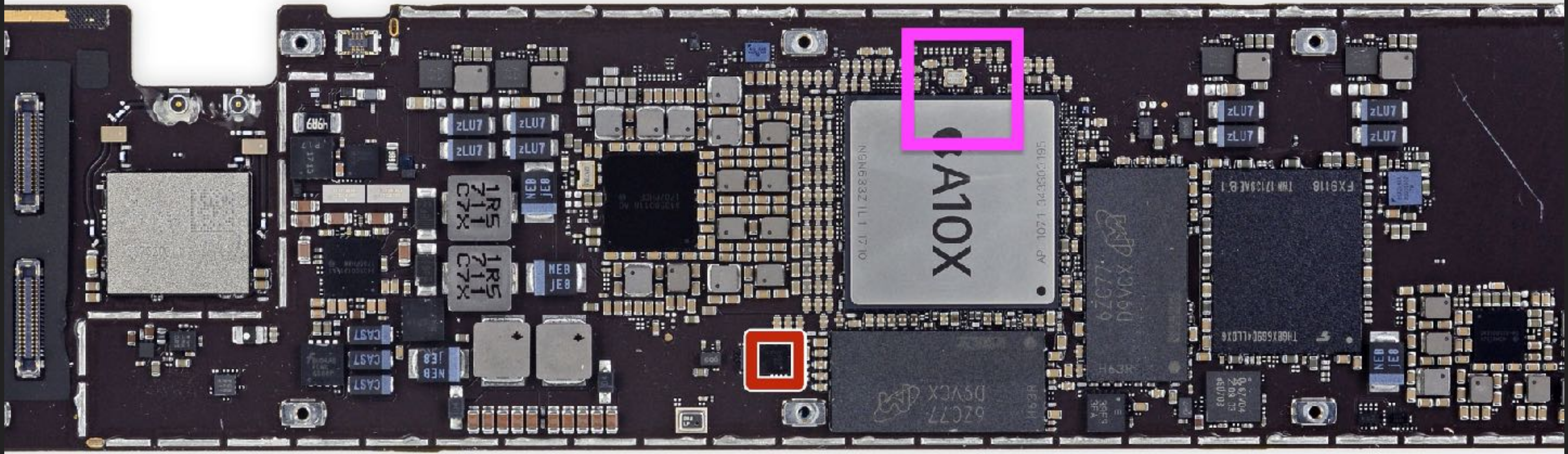
Every day the time told by the world's best clocks was compared to the exact moment that a set of reference stars past directly overhead at the Greenwich Observatory in London. If there was a deviation between when the clocks said the stars should pass overhead and when they actually did, we trusted the stars over the clocks, and reset the clocks. Based on everything we knew about the earth and the clocks there was no reason to think that the clocks were a more accurate measure of time to the rotation of the earth.

Two clocks, even if one is the earth, are not enough. But if you have three clocks, and you find that two of them stay exactly in sync with the third one drifts away, now you've got some evidence that the third one is the problem. If you have 100 clocks spread all over the world, built by different people using different methods, and all but one of them agree with each other, then you can be pretty sure that the outlier is the problem, not the other 99 clocks. In 1955 the earth became that outlier – not because of anything changed about the earth but because we suddenly got much better at building clocks. What changed in 1955 with the invention of the cesium atomic clock."

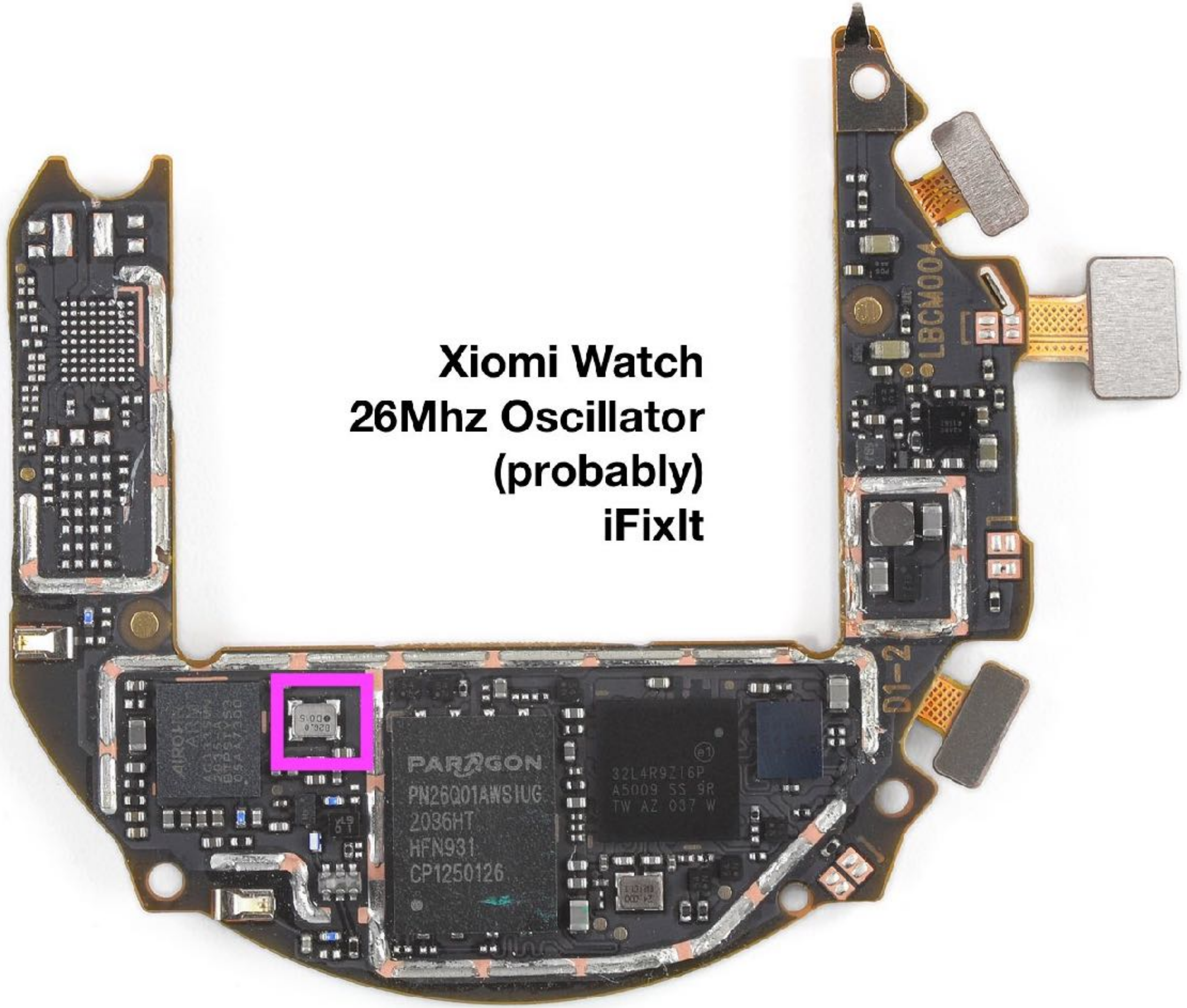
T245 MrHP Crystal Oscillator

-iFixIt




A10X

24.000



Xiomi Watch
26Mhz Oscillator
(probably)
iFixIt

NBVSBAXXX Series

2.5 V/3.3 V, LVPECL Voltage-Controlled Crystal Oscillator (VCXO) PureEdge™ Product Series

ON Semiconductor®

http://onsemi.com

The NBVSBAXXX series voltage−controlled crystal oscillator (VCXO) devices are designed to meet today's requirements for 2.5 V and 3.3 V LVPECL clock generation applications. These devices use a high Q fundamental mode crystal and Phase Locked Loop (PLL) multiplier to provide a wide range of frequencies from 60 MHz to 700 MHz (factory configurable per user specifications) with a pullable range of ±100 ppm and a frequency stability of ±50 ppm. The silicon−based PureEdge™ products design provides users with exceptional frequency stability and reliability. They produce an ultra low jitter and phase noise LVPECL differential output.

The NBVSBAXXX series are members of ON Semiconductor's PureEdge™ clock family that provides accurate and precision clock generation solutions.

Available in the industry standard 5.0 x 7.0 x 1.8 mm and in a new 3.2 x 5.0 x 1.2 mm SMD (CLCC) package on 16 mm tape and reel in quantities of 1,000.

MARKING DIAGRAM

6 PIN CLCC
LN SUFFIX
CASE 848AB

NBVSBAXXX
XXX.XXXX
AWLYYWWG

6 PIN CLCC
LU SUFFIX
CASE 848AC

NBVSBAXXX
XXX.XXXX
AWLYYWWG

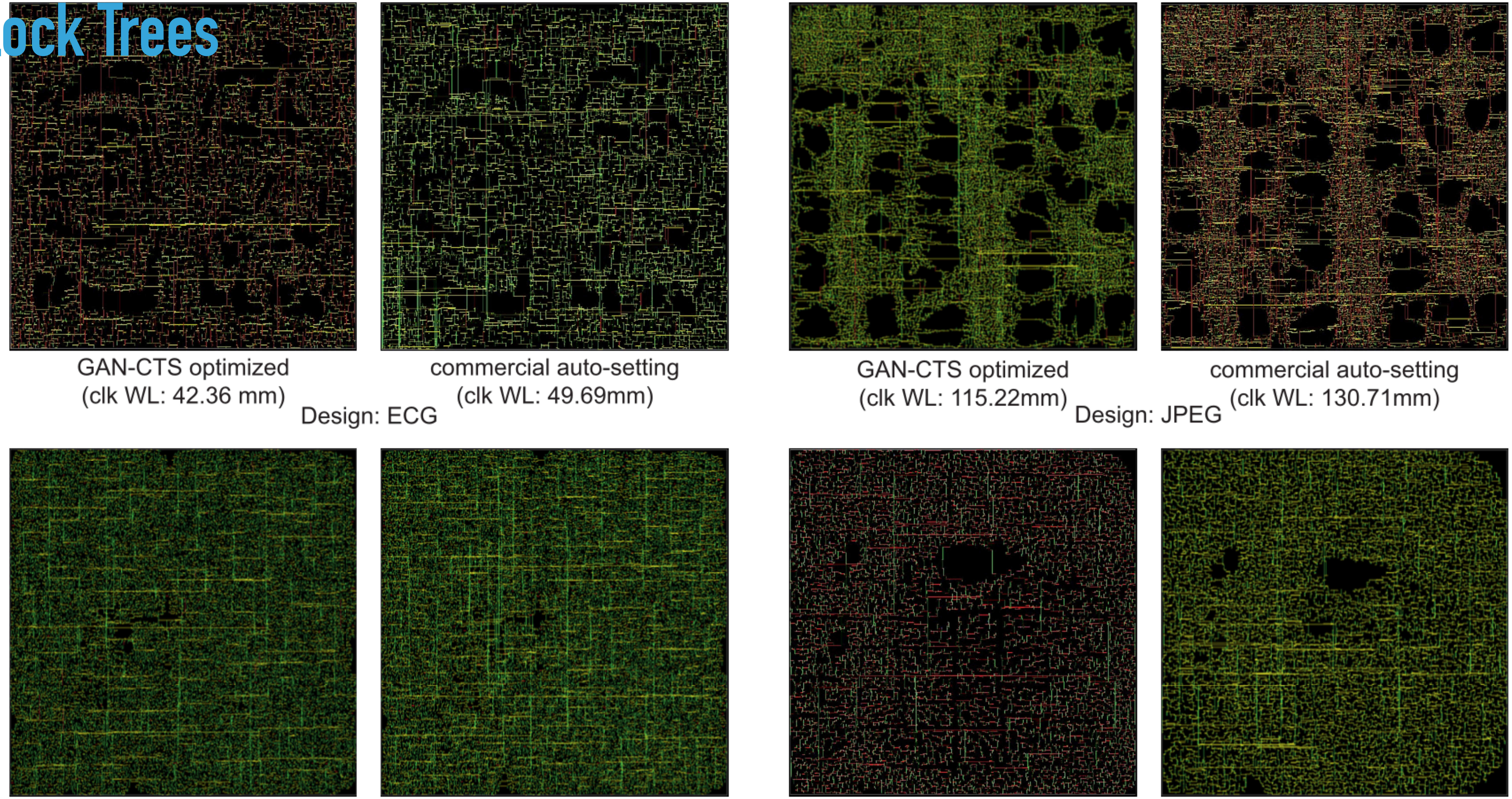
NBVSBAXXX = NBVSBAXXX (±50 ppm)
XXX.XXXX = Output Frequency (MHz)
A = Assembly Location

Features

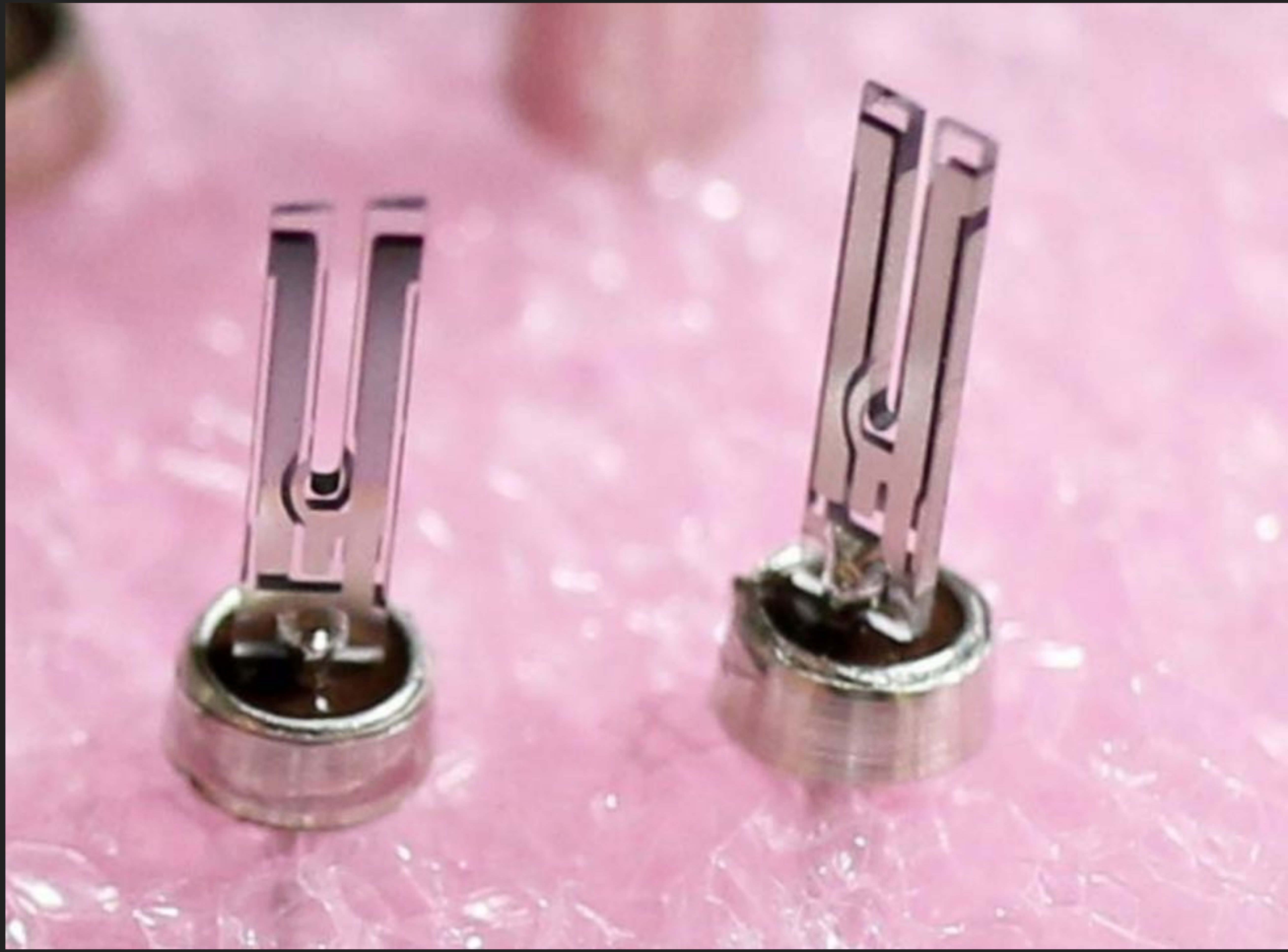
- LVPECL Differential Output
- Operating Range: 2.5 V ±5%, 3.3 V ±10%

ONSEMI A037L 707.35MHZ VCXO

Clock Trees



"A Clock Tree Prediction and Optimization Framework Using Generative Adversarial Learning"

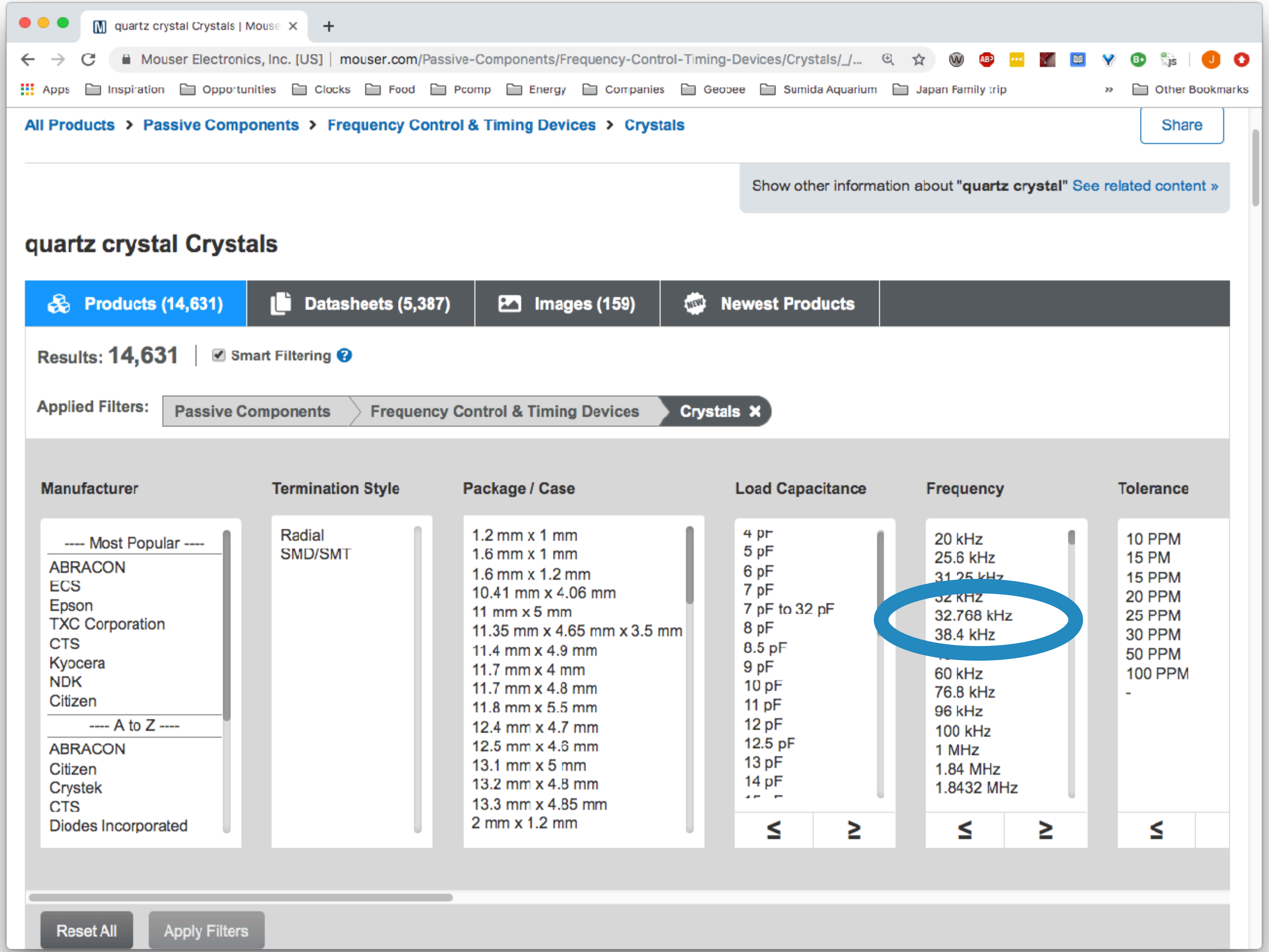



diapason
bobine détectrice de phase et bobine motrice
transistor
conducteurs d'électricité
pile
résistance
Bulova Accutron, première montre électronique à diapason.
L'électricité lui donne son énergie, l'électronique sa haute précision.
Dans une Bulova Accutron, l'énergie d'une pile est transmise à un diapason au moyen d'un circuit électronique intégré. Parce que l'énergie électrique n'a jamais été un facteur déterminant de précision, ce circuit électronique détecte et maintient à un degré constant la fréquence des oscillations du diapason (au moins 360 par seconde): ce qui permet d'obtenir au porter une précision de 99,9977 % garantie par écrit. On est loin de l'à-peu-près d'un mécanisme traditionnel à balancier! Les deux montres ci-contre font partie des 100 modèles de la collection Bulova Accutron pour hommes et dames que vous trouverez chez tous les bijoutiers horlogers concessionnaires de la marque Bulova (à partir de 595 F)
BULOVA ACCUTRON
A chaque seconde, une certitude.
PUBLICIS H 2004
® marque déposée

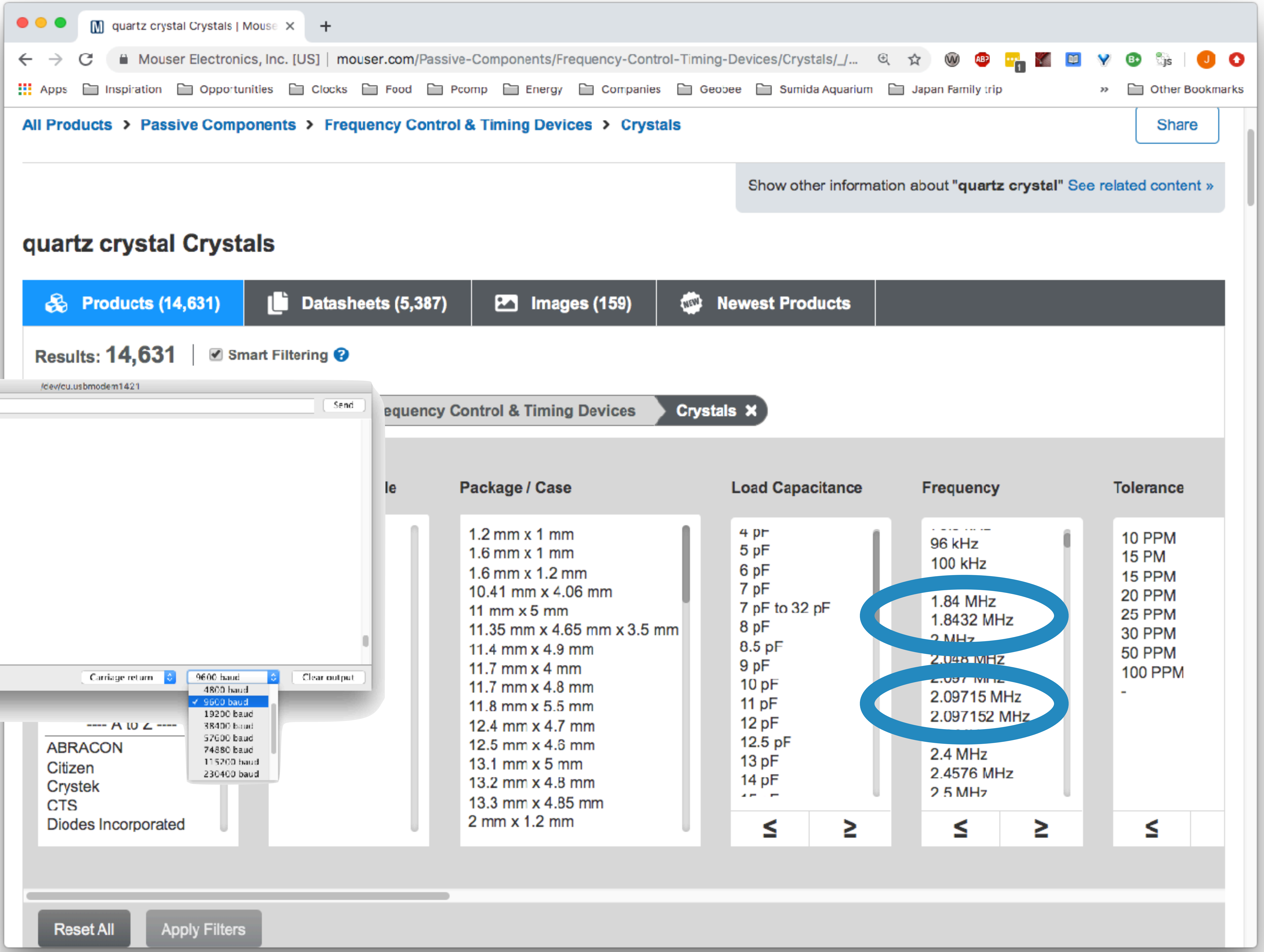

NOVEMBER
DECEMBER
JANUARY

Standard quartz clock timer

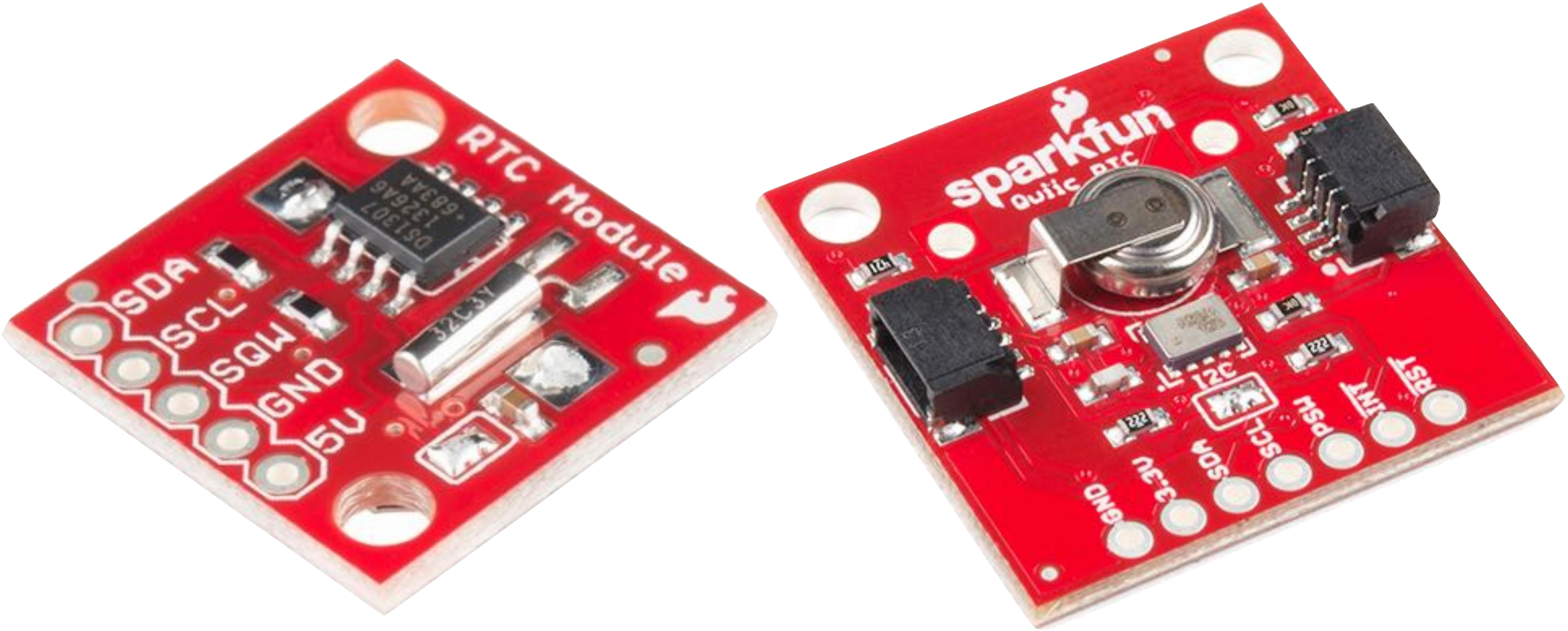
32,768 = 2^15



Precision timer
2,097,152 = 2^21

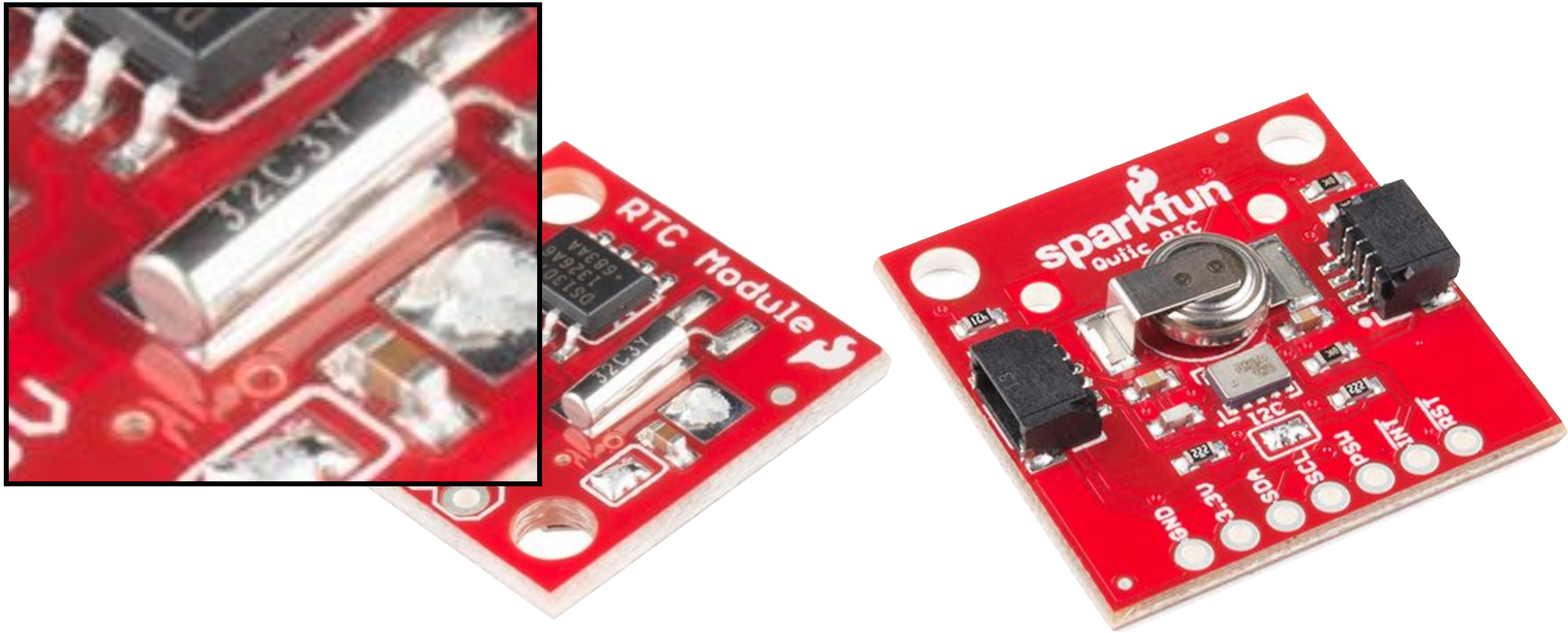


1,843,200 / 16 = 115,200
/32 = 57,600
/192 = 9600



Sparkfun RTC Breakout boards

https://github.com/ITPNYU/clock-club/tree/master/RTC_Clock_Examples



Sparkfun RTC Breakout boards

https://github.com/ITPNYU/clock-club/tree/master/RTC_Clock_Examples

19. RTC – Real-Time Counter

19.1 Overview

The Real-Time Counter (RTC) is a 32-bit counter with a 10-bit programmable prescaler that typically runs continuously to keep track of time. The RTC can wake up the device from sleep modes using the alarm/ compare wake up, periodic wake up, or overflow wake up mechanisms

The RTC is typically clocked by the 1.024kHz output from the 32.768kHz High-Accuracy Internal Crystal Oscillator(OSC32K) and this is the configuration optimized for the lowest power consumption. The faster 32.768kHz output can be selected if the RTC needs a resolution higher than 1ms. The RTC can also be clocked from other sources, selectable through the Generic Clock module (GCLK).

The RTC can generate periodic peripheral events from outputs of the prescaler, as well as alarm/compare interrupts and peripheral events, which can trigger at any counter value. Additionally, the timer can trigger an overflow interrupt and peripheral event, and can be reset on the occurrence of an alarm/compare match. This allows periodic interrupts and peripheral events at very long and accurate intervals.

The 10-bit programmable prescaler can scale down the clock source. By this, a wide range of resolutions and time-out periods can be configured. With a 32.768kHz clock source, the minimum counter tick interval is 30.5µs, and time-out periods can range up to 36 hours. For a counter tick interval of 1s, the maximum time-out period is more than 136 years.

19.2 Features

- 32-bit counter with 10-bit prescaler
- Multiple clock sources
- 32-bit or 16-bit Counter mode
  - One 32-bit or two 16-bit compare values
- Clock/Calendar mode
  - Time in seconds, minutes and hours (12/24)
  - Date in day of month, month and year
  - Leap year correction
- Digital prescaler correction/tuning for increased accuracy
- Overflow, alarm/compare match and prescaler interrupts and events
  - Optional clear on alarm/compare match

SAM D21 Family
RTC – Real-Time Counter

19.3 Block Diagram

Figure 19-1. RTC Block Diagram (Mode 0 — 32-Bit Counter)

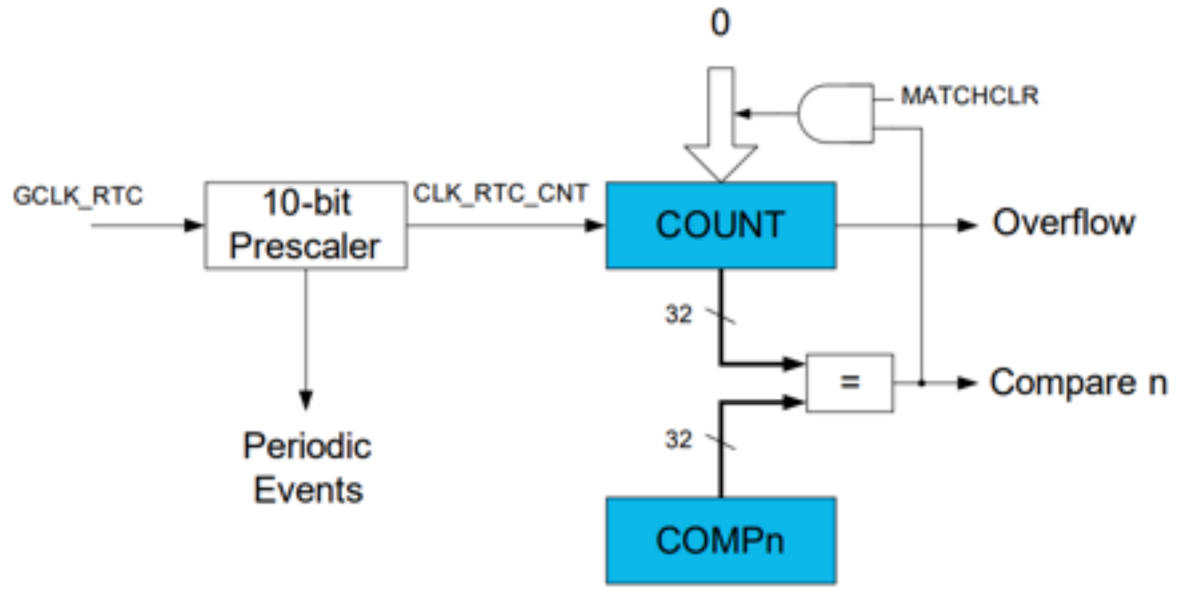


Figure 19-2. RTC Block Diagram (Mode 1 — 16-Bit Counter)

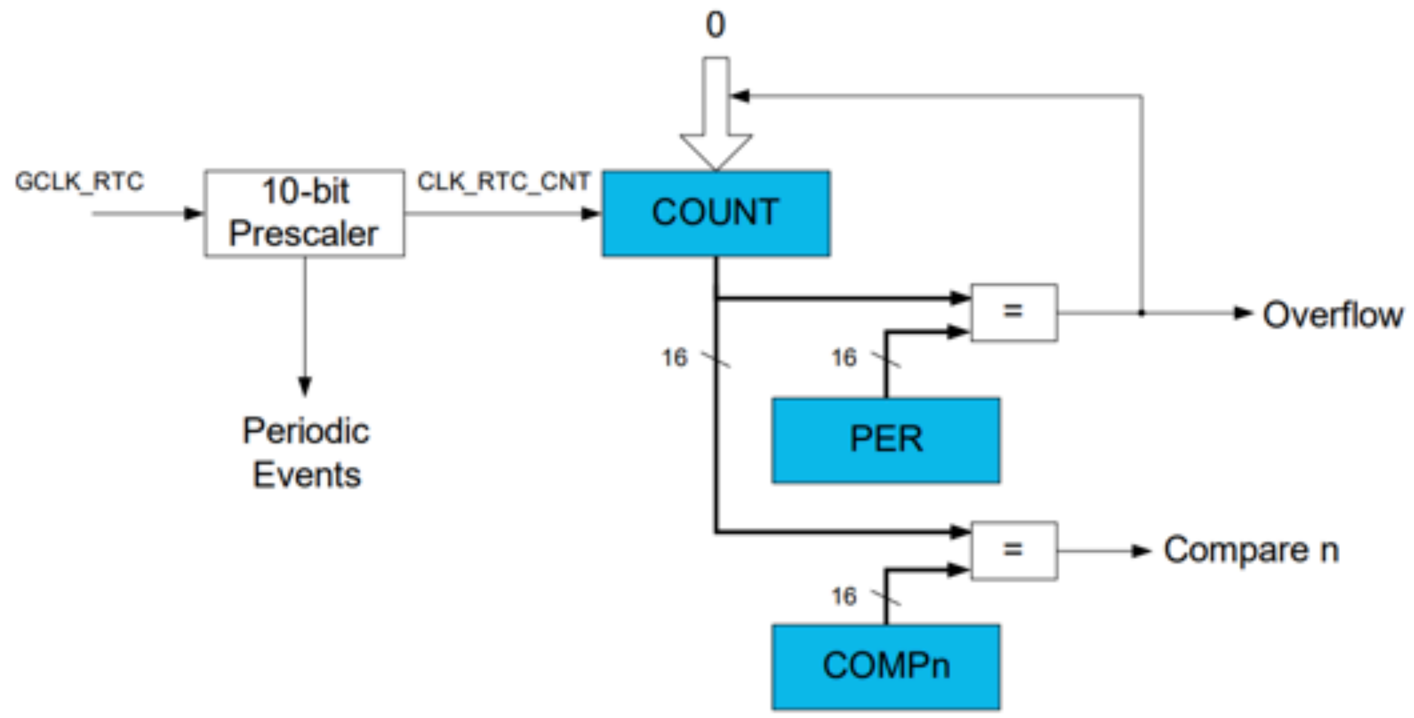
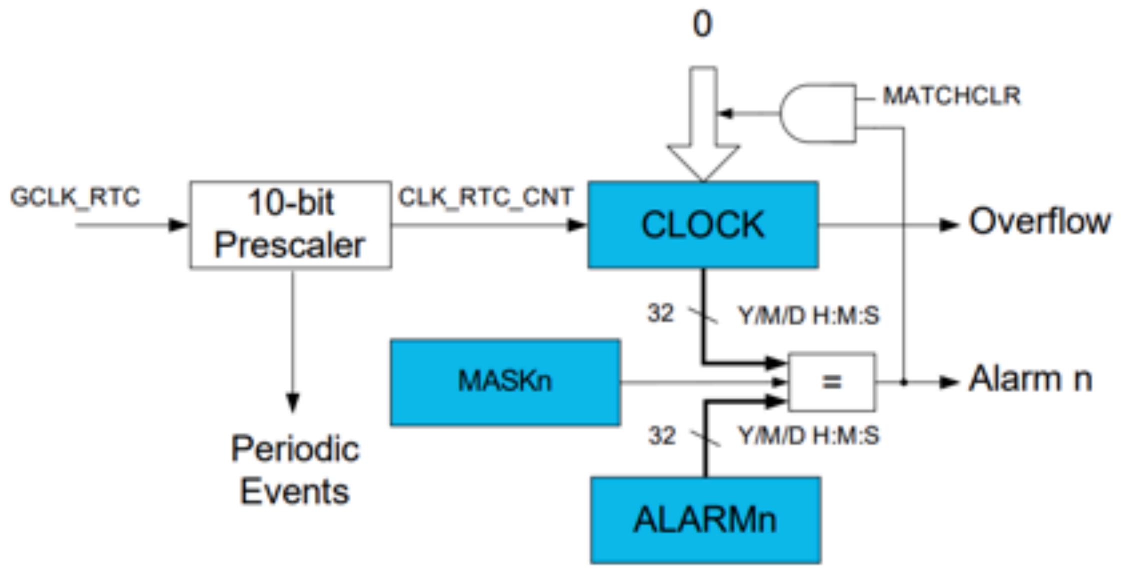


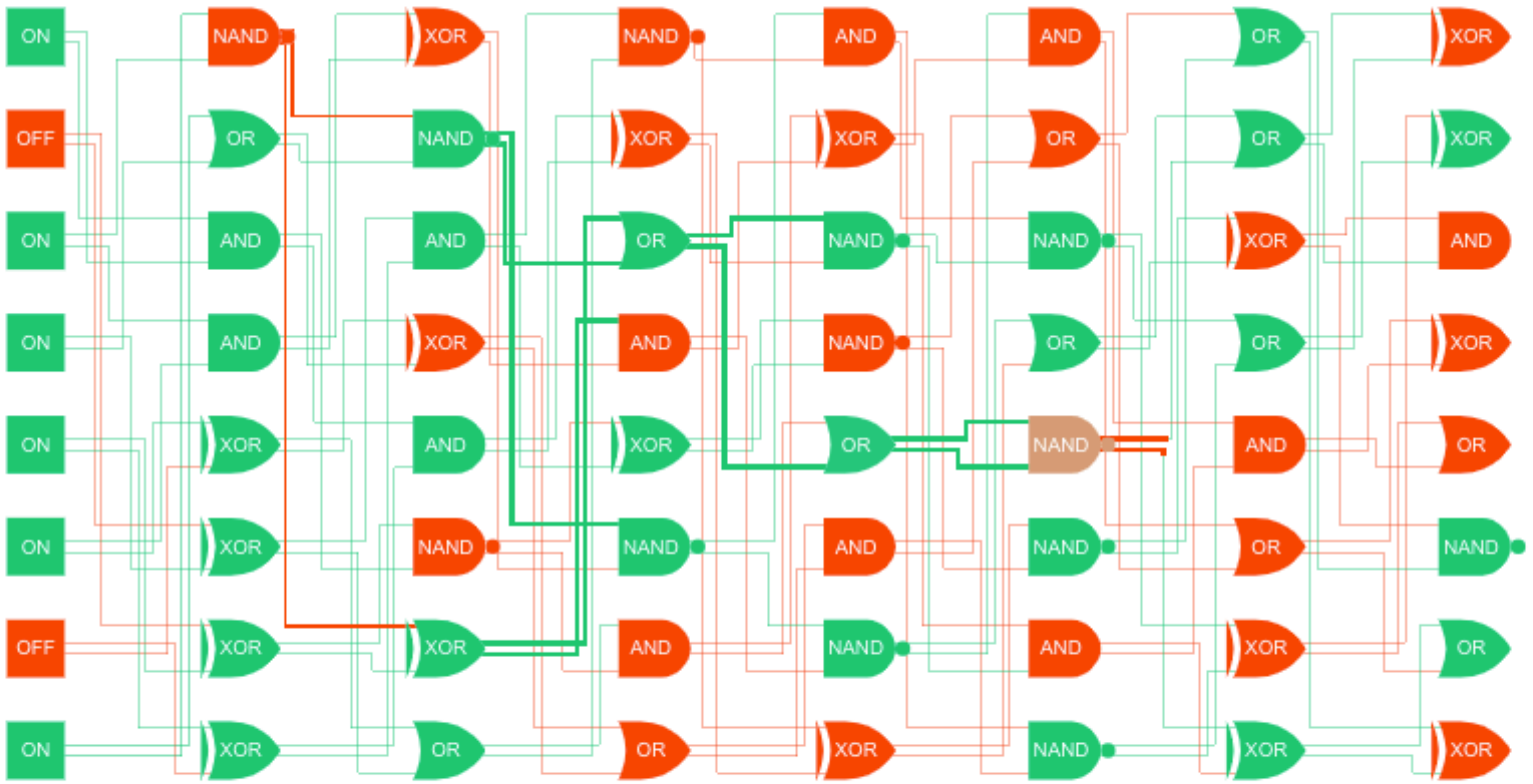
Figure 19-3. RTC Block Diagram (Mode 2 — Clock/Calendar)

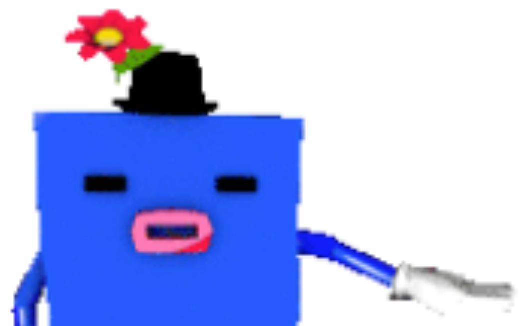


2

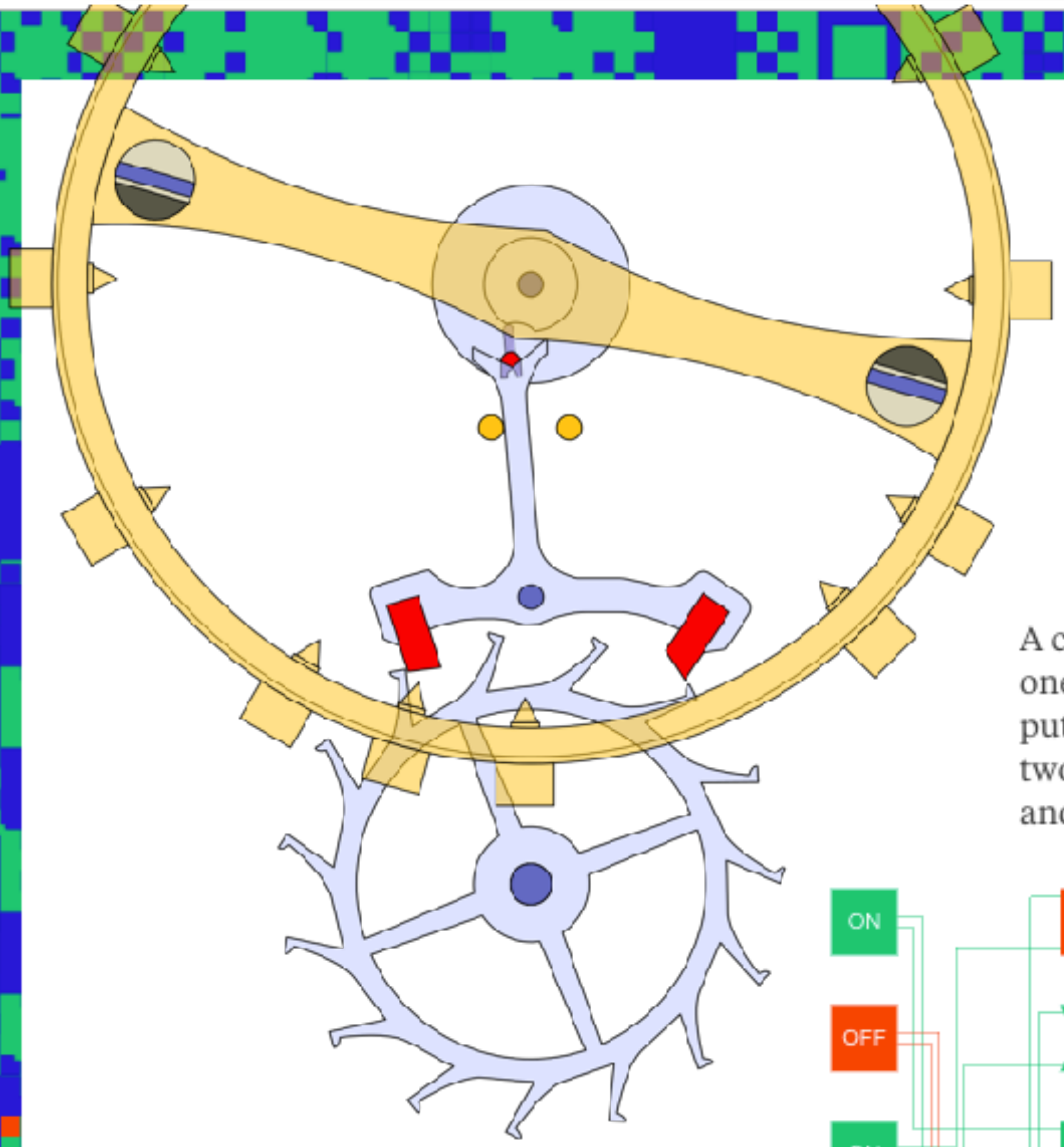
Let's Begin

A computer is a clock with benefits. They all work the same, doing second-grade math, one step at a time: Tick, take a number and put it in box one. Tick, take another number, put it in box two. Tick, *operate* (an operation might be addition or subtraction) on those two numbers and put the resulting number in box one. Tick, check if the result is zero, and if it is, go to some other box and follow a new set of instructions.





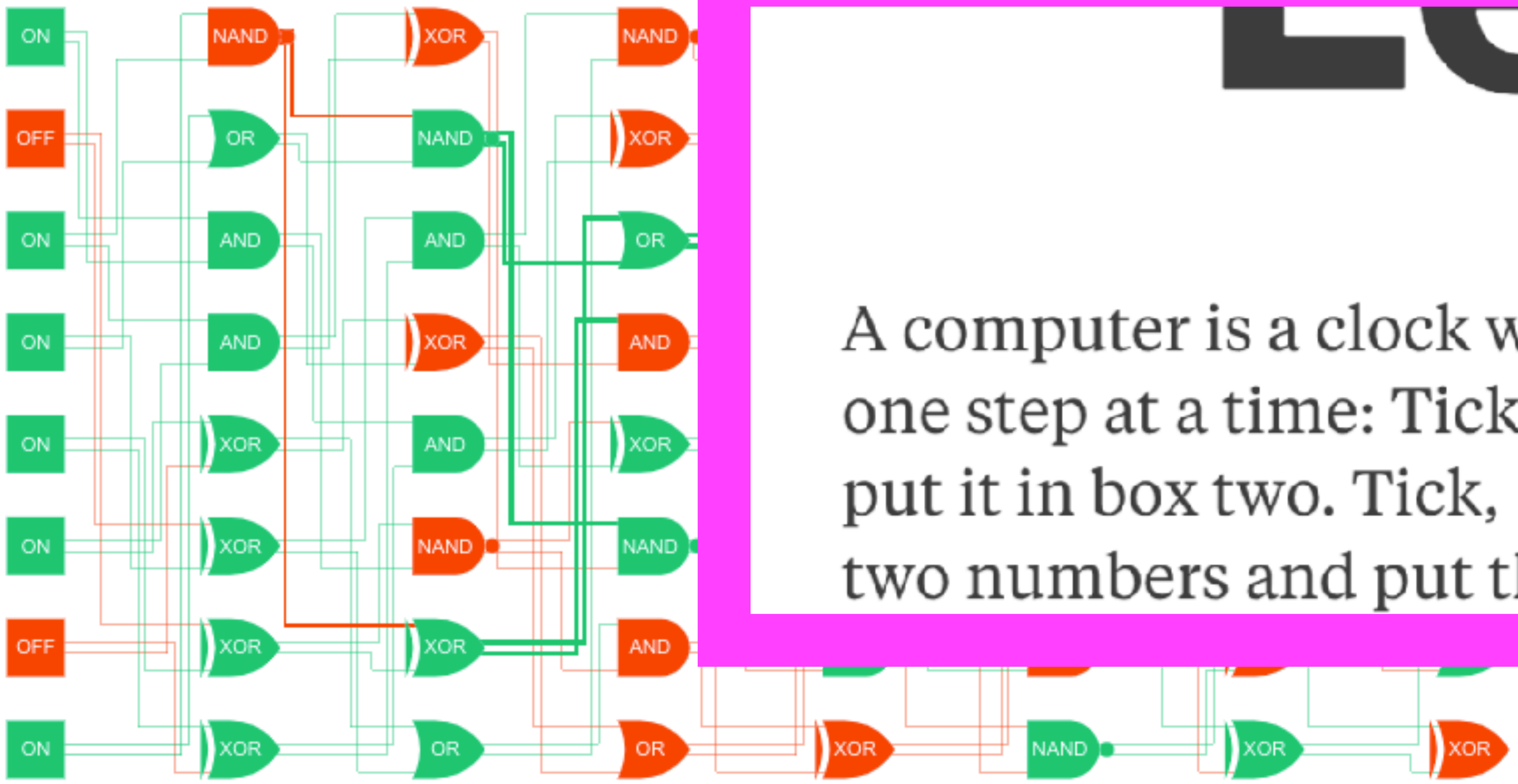
This is simulated circuitry that's computing as you watch. The switches on the left turn the current on and off at random, and the logic gates direct the flow of the current. Click the boxes to change the circuits. Enough of these can compute anything computable.



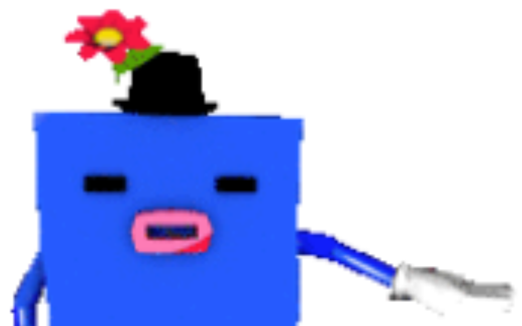
2

Let’s Begin

A computer is a clock with benefits. They all work the same, doing second-grade math, one step at a time: Tick, take a number and put it in box one. Tick, take another number, put it in box two. Tick, *operate* (an operation might be addition or subtraction) on those two numbers and put the resulting number in box one. Tick, check if the result is zero, and if it is, go to some other box and follow a new set of instructions.



Let’s Be
A computer is a clock with benefits. They all work the
one step at a time: Tick, take a number and put it in b
put it in box two. Tick, *operate* (an operation might b
two numbers and put the resulting number in box on



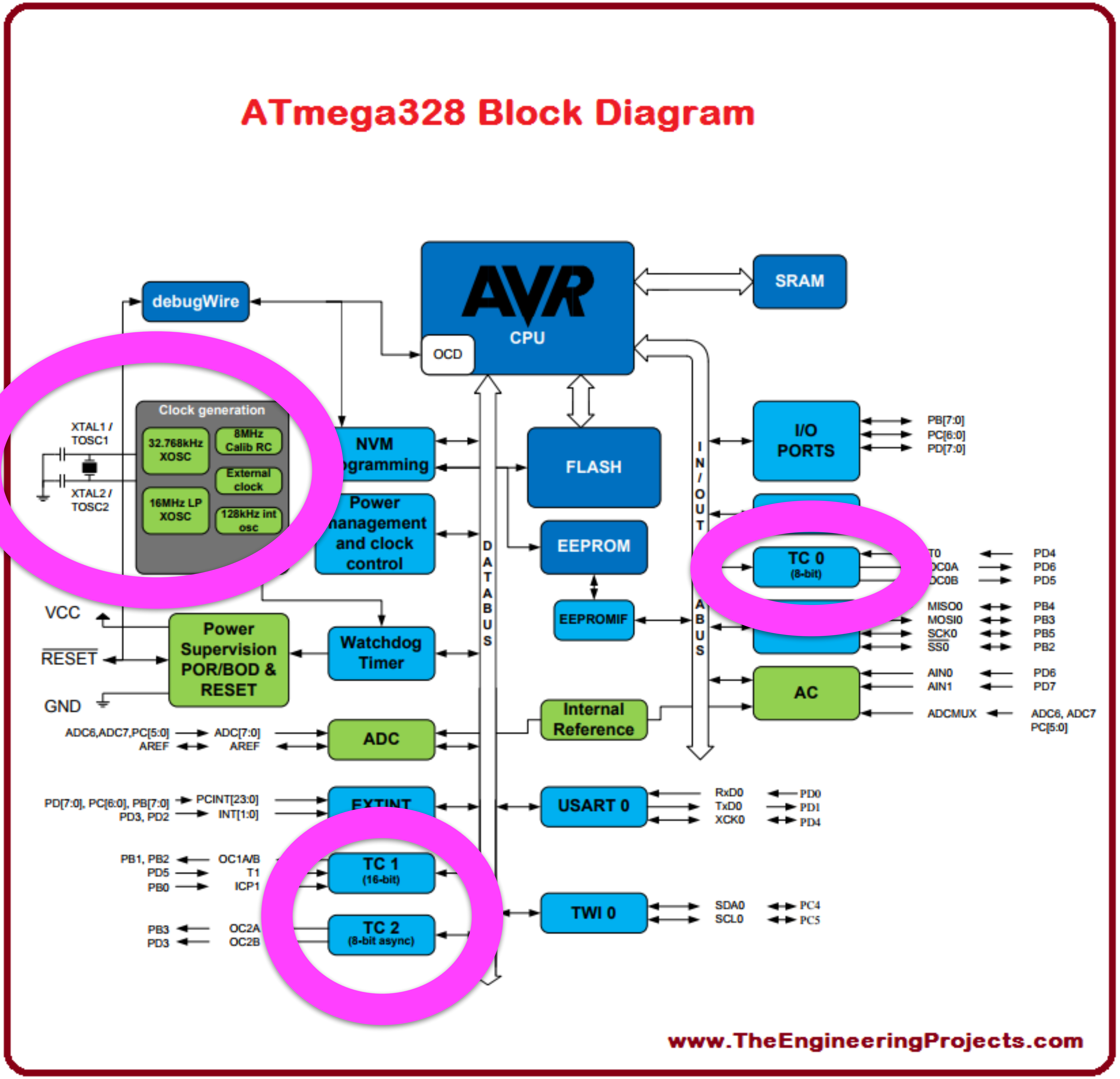
This is simulated circuitry that’s computing as you watch. The switches on the left turn the current on and off at random, and the logic gates direct the flow of the current. Click the boxes to change the circuits. Enough of these can compute anything computable.

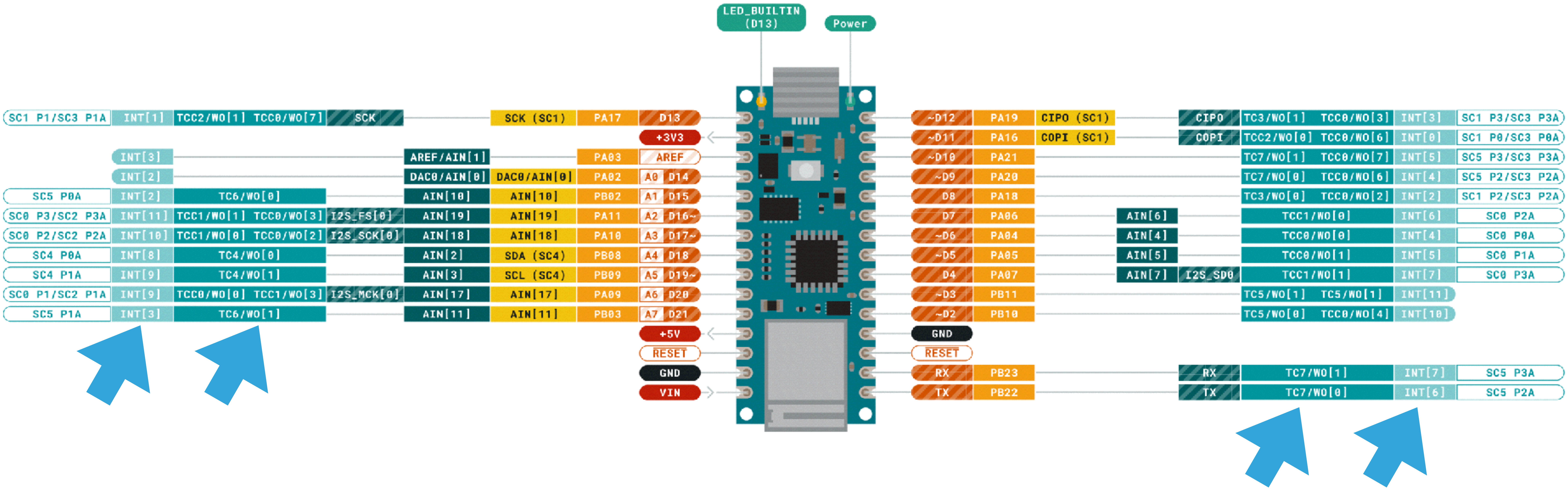

sketch_sep29a | Arduino 1.8.13
sketch_sep29a
void setup() {
// put your setup code here, to run once:
}
void loop() {
// put your main code here, to run repeatedly:
}
sketch_200929a | Processing 3.5.3
Java
sketch_200929a
void setup() {
}
void draw() {
}
Console
Errors
Updates
p5.js Web Editor
editor.p5js.org
File
Edit
Sketch
Help
English
Hello, jfeddersen!
Auto-refresh
Nettle cardboard
sketch.js
Preview
function setup() {
createCanvas(400, 400);
}
function draw() {
background(220);
}
Console
Clear
ARDUINO
PROCESSING
P5JS
"TICK"

TIMER/COUNTERS ARE PRIMARY BUILDING BLOCKS OF MICROCONTROLLERS

Timing-based functions (analogWrite, tone, servo, etc.) make use of internal timers. These timers can trigger time-based interrupts, triggering functions.

However, accessing these timers typically involves architecture-specific registers and these change from chip to chip.





- Ground
- Power
- LED
- Internal Pin
- SWD Pin
- Digital Pin
- Analog Pin
- Other Pin
- Microcontroller's Po
- Default
- Analog
- Communica
- Timer
- Interrupt
- Sercom

MAXIMUM current per pin is 7mA

MAXIMUM source current is 46mA

MAXIMUM sink current is 65mA per pin group

VIN 5-21 V input to the board.

NOTE: CIPO/COPI have previously been referred to as MISO/MOSI

ARDUINO.CC

Last update: 3/11/2021

Reference > Language > Functions > Time > Delay

delay()

[Time]

Description

Pauses the program for the amount of time (in milliseconds) specified as parameter. (There are 1000 milliseconds in a second.)

Syntax

`delay(ms)`

Parameters

`ms`: the number of milliseconds to pause. Allowed data types: `unsigned long`.

Returns

Nothing

Example Code

The code pauses the program for one second before toggling the output pin.

```
int ledPin = 13;              // LED connected to digital pin 13

void setup() {
  pinMode(ledPin, OUTPUT);    // sets the digital pin as output
}

void loop() {
  digitalWrite(ledPin, HIGH); // sets the LED on
  delay(1000);                // waits for a second
  digitalWrite(ledPin, LOW);  // sets the LED off
  delay(1000);                // waits for a second
}
```

Notes and Warnings

While it is easy to create a blinking LED with the `delay()` function and many sketches use short delays for such tasks as switch debouncing, the use of `delay()` in a sketch has significant drawbacks. No other reading of sensors, mathematical calculations, or pin manipulation can go on during the delay function, so in effect, it brings most other activity to a halt. For alternative approaches to controlling timing see the Blink Without Delay sketch, which loops, polling the millis() function until enough time has elapsed. More knowledgeable programmers usually avoid the use of `delay()` for timing of events longer than 10's of milliseconds unless the Arduino sketch is very simple.

Certain things do go on while the delay() function is controlling the Atmega chip, however, because the delay function does not disable interrupts. Serial communication that appears at the RX pin is recorded, PWM (analogWrite) values and pin states are maintained, and interrupts will work as they should.

```
void delay(unsigned long ms) {
   uint32_t start = micros();

   while (ms > 0) {
      yield();
      while ( ms > 0 && (micros() - start) >= 1000) {
         ms--;
         start += 1000;
      }
   }
}
```

micros() function on next slide

https://github.com/arduino/ArduinoCore-avr

```
unsigned long micros() {
    unsigned long m;
    uint8_t oldSREG = SREG, t;

    cli();
    m = timer0_overflow_count;
#if defined(TCNT0)
    t = TCNT0;
#elif defined(TCNT0L)
    t = TCNT0L;
#else
    #error TIMER 0 not defined
#endif

#ifdef TIFR0
    if ((TIFR0 & _BV(TOV0)) && (t < 255))
        m++;
#else
    if ((TIFR & _BV(TOV0)) && (t < 255))
        m++;
#endif

    SREG = oldSREG;

    return ((m << 8) + t) * (64 / clockCyclesPerMicrosecond());
}
```

8-Bit Timer/Counter

Do some math to internal timer register to return run time in microseconds

https://github.com/arduino/ArduinoCore-avr

https://web.engr.oregonstate.edu/~traylor/ece473/lectures/tcnt0.pdf

Note - does not use micros()

```
/* Delay for the given number of microseconds.  Assumes a 1, 8, 12, 16, 20 or 24 MHz clock. */
void delayMicroseconds(unsigned int us) {
    // call = 4 cycles + 2 to 4 cycles to init us(2 for constant delay, 4 for variable)
    // calling avrlib's delay_us() function with low values (e.g. 1 or
    // 2 microseconds) gives delays longer than desired.
    //delay_us(us);
. . .

#elif F_CPU >= 16000000L
    // for the 16 MHz clock on most Arduino boards
    // for a one-microsecond delay, simply return.  the overhead
    // of the function call takes 14 (16) cycles, which is 1us
    if (us <= 1) return; //  = 3 cycles, (4 when true)

    // the following loop takes 1/4 of a microsecond (4 cycles)
    // per iteration, so execute it four times for each microsecond of
    // delay requested.
    us <<= 2; // x4 us, = 4 cycles

    // account for the time taken in the preceeding commands.
    // we just burned 19 (21) cycles above, remove 5, (5*4=20)
    // us is at least 8 so we can substract 5
    us -= 5; // = 2 cycles,

. . .

// busy wait
    __asm__ __volatile__ (
        "1: sbiw %0,1" "\n\t" // 2 cycles
        "brne 1b" : "=w" (us) : "0" (us) // 2 cycles
    );
    // return = 4 cycles
}
```

Several #elif directives covering different clock speeds

Countdown in Assembly:
SBIW - Subtract Immediate from Word
BRNE - Branch if Not Equal

https://github.com/arduino/ArduinoCore-avr

ANALOGWRITE

```
else
{
        switch(digitalPinToTimer(pin))
        {
                // XXX fix needed for atmega8
                #if defined(TCCR0) && defined(COM00) && !defined(__AVR_ATmega8__)
                case TIMER0A:
                        // connect pwm to pin on timer 0
                        sbi(TCCR0, COM00);
                        OCR0 = val; // set pwm duty
                        break;
                #endif

                #if defined(TCCR0A) && defined(COM0A1)
                case TIMER0A:
                        // connect pwm to pin on timer 0, channel A
                        sbi(TCCR0A, COM0A1);
                        OCR0A = val; // set pwm duty
                        break;
                #endif

                #if defined(TCCR0A) && defined(COM0B1)
                case TIMER0B:
                        // connect pwm to pin on timer 0, channel B
                        sbi(TCCR0A, COM0B1);
                        OCR0B = val; // set pwm duty
                        break;
                #endif

                #if defined(TCCR1A) && defined(COM1A1)
                case TIMER1A:
                        // connect pwm to pin on timer 1, channel A
                        sbi(TCCR1A, COM1A1);
                        OCR1A = val; // set pwm duty
```

TONE

```
// Set timer specific stuff
// All timers in CTC mode
// 8 bit timers will require changing prescalar values,
// whereas 16 bit timers are set to either ck/1 or ck/64 prescalar
switch (_timer)
{
  #if defined(TCCR0A) && defined(TCCR0B) && defined(WGM01)
  case 0:
    // 8 bit timer
    TCCR0A = 0;
    TCCR0B = 0;
    bitWrite(TCCR0A, WGM01, 1);
    bitWrite(TCCR0B, CS00, 1);
    timer0_pin_port = portOutputRegister(digitalPinToPort(_pin));
    timer0_pin_mask = digitalPinToBitMask(_pin);
    break;
  #endif

  #if defined(TCCR1A) && defined(TCCR1B) && defined(WGM12)
  case 1:
    // 16 bit timer
    TCCR1A = 0;
    TCCR1B = 0;
    bitWrite(TCCR1B, WGM12, 1);
    bitWrite(TCCR1B, CS10, 1);
    timer1_pin_port = portOutputRegister(digitalPinToPort(_pin));
    timer1_pin_mask = digitalPinToBitMask(_pin);
    break;
  #endif
```

https://github.com/arduino/ArduinoCore-avr

https://www.microchip.com/webdoc/AVRLibcReferenceManual/assembler_1ass_example.html

Reference > Language > Functions > Time > Delay

delay()

[Time]

Description

Pauses the program for the amount of time (in milliseconds) specified as parameter. (There are 1000 milliseconds in a second.)

Syntax

`delay(ms)`

Param

`ms`: the

Retur

Nothin

Examp

The co

```
int le

void s
  pinM
}

void loop() {
  digitalWrite(ledPin, HIGH); // sets the LED on
  delay(1000);                // waits for a second
  digitalWrite(ledPin, LOW);  // sets the LED off
  delay(1000);                // waits for a second
}
```

see the Blink Without Delay sketch, which loops, polling the millis() function until enough time has elapsed. More knowledgeable programmers usually avoid the use of **`delay()`** for timing of events longer than 10's of milliseconds unless the Arduino sketch is very simple.

Certain things do go on while the delay() function is controlling the Atmega chip, however, because the delay function does not disable interrupts. Serial communication that appears at the RX pin is recorded, PWM (analogWrite) values and pin states are maintained, and interrupts will work as they should.

Notes and Warnings

While it is easy to create a blinking LED with the `delay()` function and many sketches use short delays for such tasks as switch debouncing, the use of `delay()` in a sketch has significant drawbacks. No other reading of sensors, mathematical calculations, or pin manipulation can go on during the delay function, so in effect, it brings most other activity to a halt. For alternative approaches to controlling timing see the Blink Without Delay sketch, which loops, polling the millis() function until enough time has elapsed. More knowledgeable programmers usually avoid the use of `delay()` for timing of events longer than 10's of milliseconds unless the Arduino sketch is very simple.

Certain things do go on while the delay() function is controlling the Atmega chip, however, because the delay function does not disable interrupts. Serial communication that appears at the RX pin is recorded, PWM (analogWrite) values and pin states are maintained, and interrupts will work as they should.

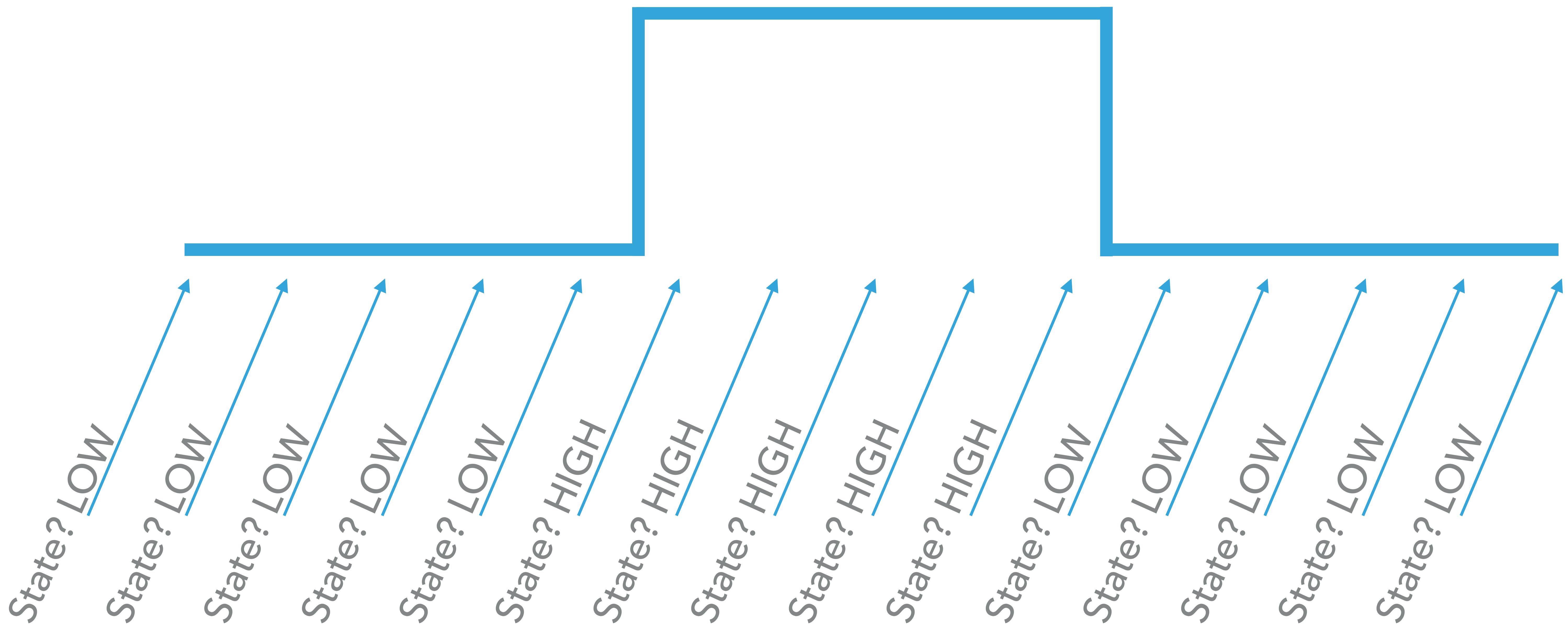
INTERRUPTS

Microcontrollers can process **interrupts**: functions called automatically by hardware changes.

Changes include:

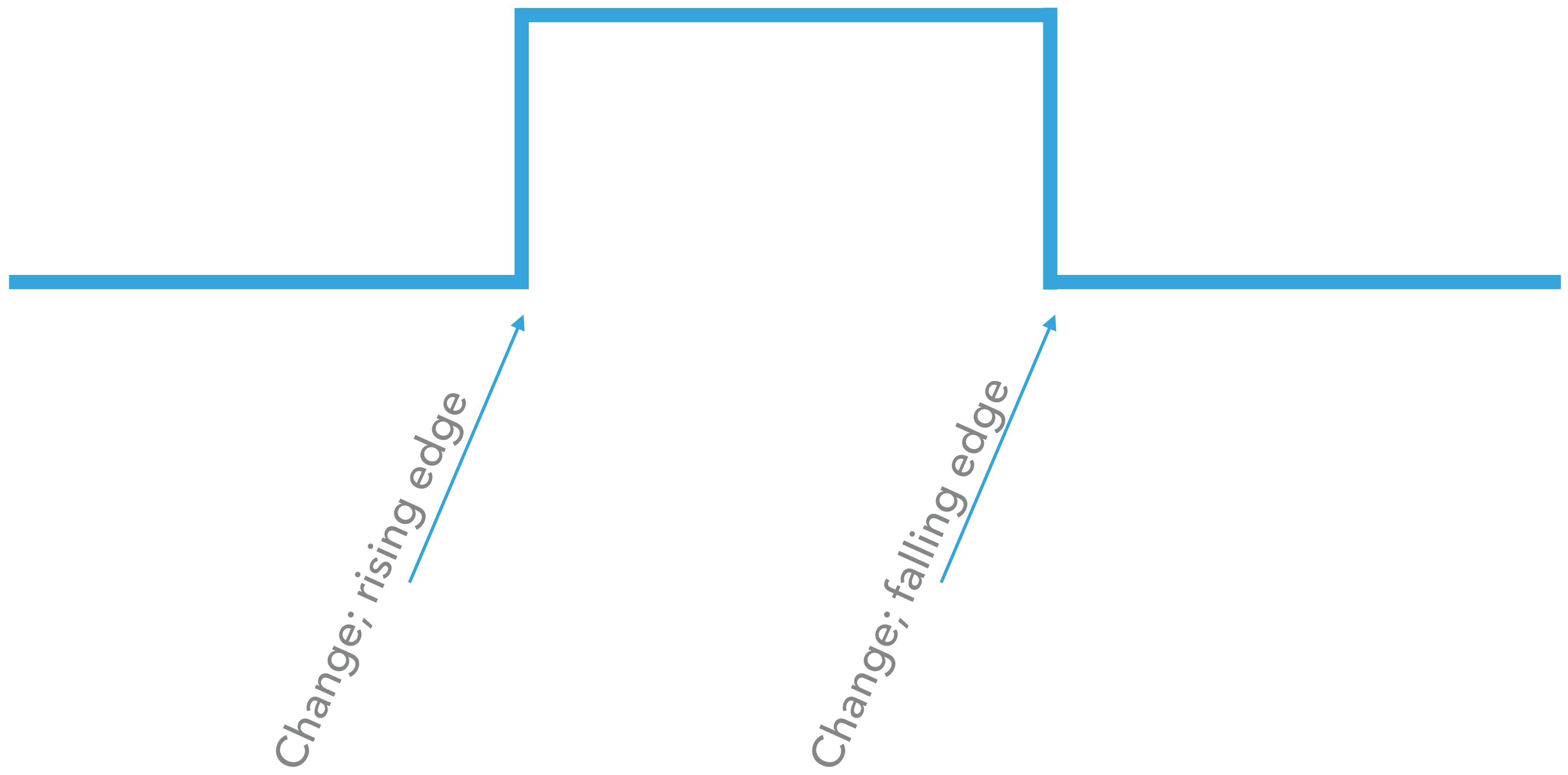
- **external,** such as voltage changes on an interrupt-enabled pin, or
- **internal**, from changes in an internal hardware **timer** (basically, a counter incrementing each clock cycle) reaching a certain value.

POLLING



In main loop, use digital read to check the state of an input pin. Decide what to do if it is low, high, changed, etc.

INTERRUPTS



Define interrupt service routines (ISRs) for hardware changes: rising edge, falling edge, and/or change. These will be called immediately when the pin changes.

INTERRUPTS

Basic Idea: You identify a function to call when an interrupt even occurs. This function is the "Interrupt Service Routine" or ISR. ISRs should run as quickly as possible. Any variables accessed by the ISR must be declared "Volatile"

1

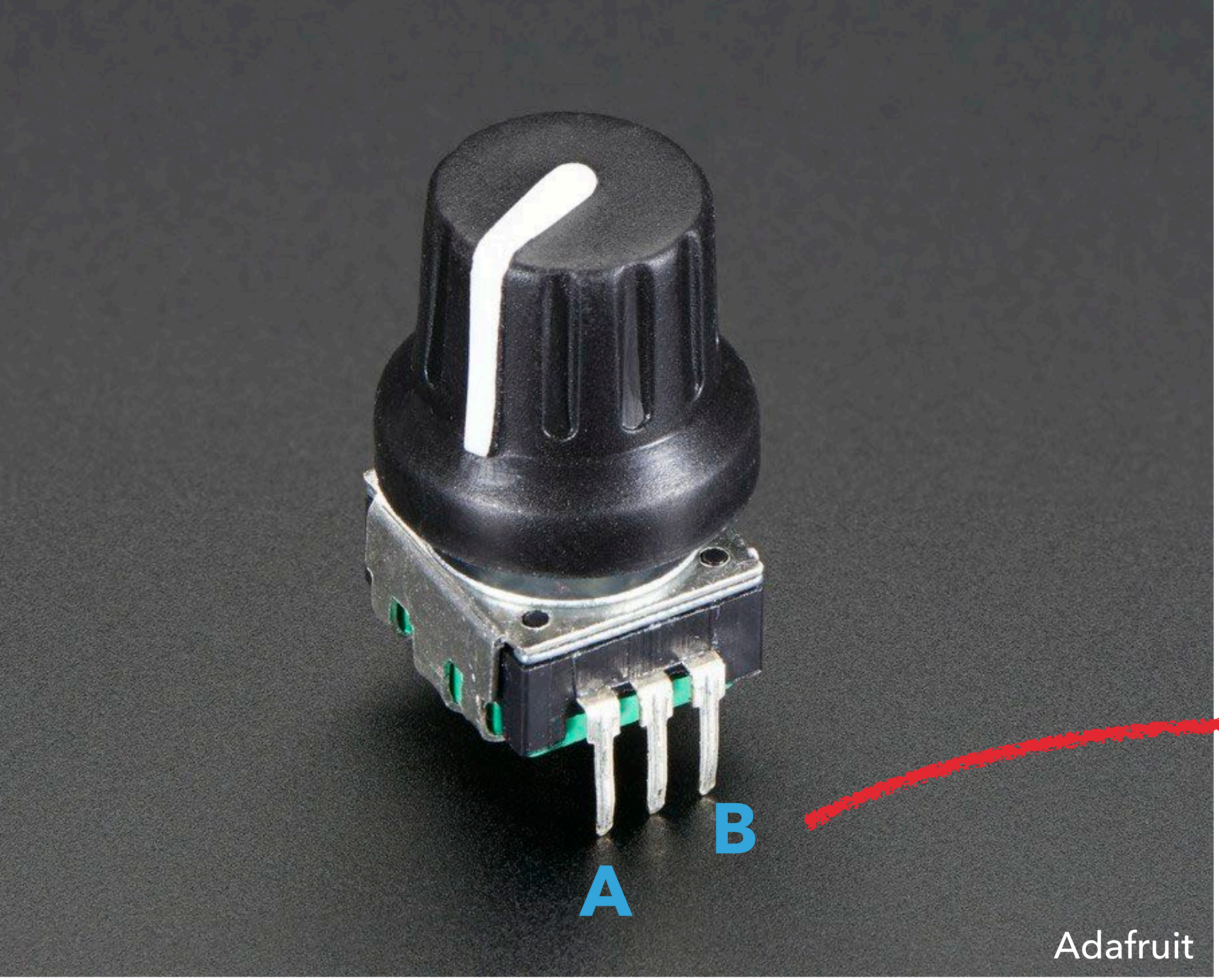
```
volatile bool ledState = LOW; //note new qualifier "volatile" - this indicates a variable may change while handling an interrupt
```

2

```
attachInterrupt(digitalPinToInterrupt(INTERRUPT_PIN), myISR, CHANGE);
// trigger when button pressed, but not when released.
```

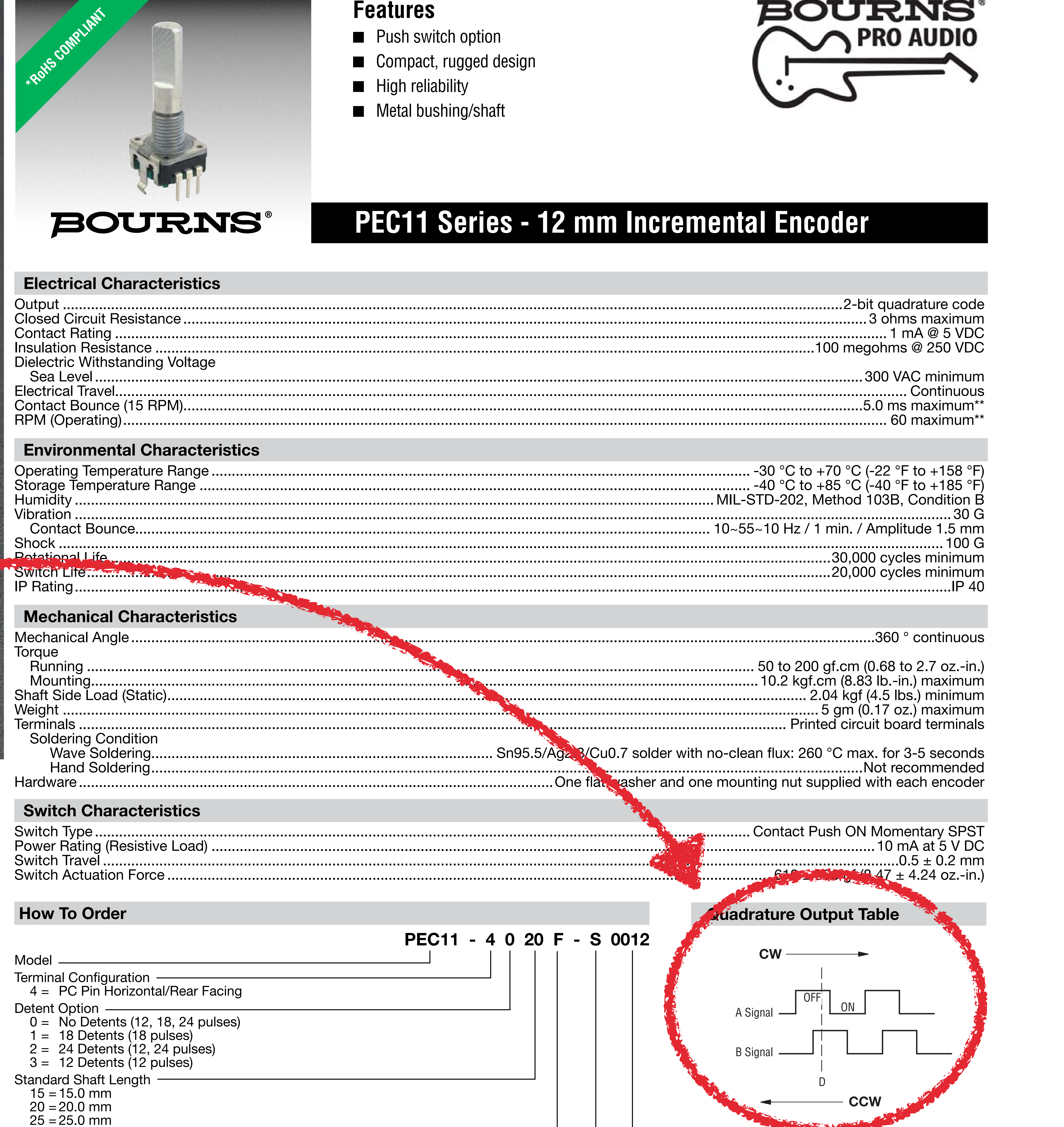
3

```
void myISR() {isrCount ++;
  if ((long)(micros() - lastMicros) > debounceTimeMicros) {
    ledState = !ledState;
    lastMicros = micros();
  }
}
```



INTERRUPTS

Excellent for resolving fast-changing inputs such as the signals from rotary encoders.


*RoHS COMPLIANT

BOURNS®

Features

- Push switch option
- Compact, rugged design
- High reliability
- Metal bushing/shaft

BOURNS® PRO AUDIO

PEC11 Series - 12 mm Incremental Encoder

Electrical Characteristics

Output .... 2-bit quadrature code
Closed Circuit Resistance .... 3 ohms maximum
Contact Rating .... 1 mA @ 5 VDC
Insulation Resistance .... 100 megohms @ 250 VDC
Dielectric Withstanding Voltage
  Sea Level .... 300 VAC minimum
Electrical Travel .... Continuous
Contact Bounce (15 RPM) .... 5.0 ms maximum**
RPM (Operating) .... 60 maximum**

Environmental Characteristics

Operating Temperature Range .... -30 °C to +70 °C (-22 °F to +158 °F)
Storage Temperature Range .... -40 °C to +85 °C (-40 °F to +185 °F)
Humidity .... MIL-STD-202, Method 103B, Condition B
Vibration .... 30 G
  Contact Bounce .... 10~55~10 Hz / 1 min. / Amplitude 1.5 mm
Shock .... 100 G
Rotational Life .... 30,000 cycles minimum
Switch Life .... 20,000 cycles minimum
IP Rating .... IP 40

Mechanical Characteristics

Mechanical Angle .... 360 ° continuous
Torque
  Running .... 50 to 200 gf.cm (0.68 to 2.7 oz.-in.)
  Mounting .... 10.2 kgf.cm (8.83 lb.-in.) maximum
Shaft Side Load (Static) .... 2.04 kgf (4.5 lbs.) minimum
Weight .... 5 gm (0.17 oz.) maximum
Terminals .... Printed circuit board terminals
  Soldering Condition
    Wave Soldering .... Sn95.5/Ag3.0/Cu0.7 solder with no-clean flux: 260 °C max. for 3-5 seconds
    Hand Soldering .... Not recommended
Hardware .... One flat washer and one mounting nut supplied with each encoder

Switch Characteristics

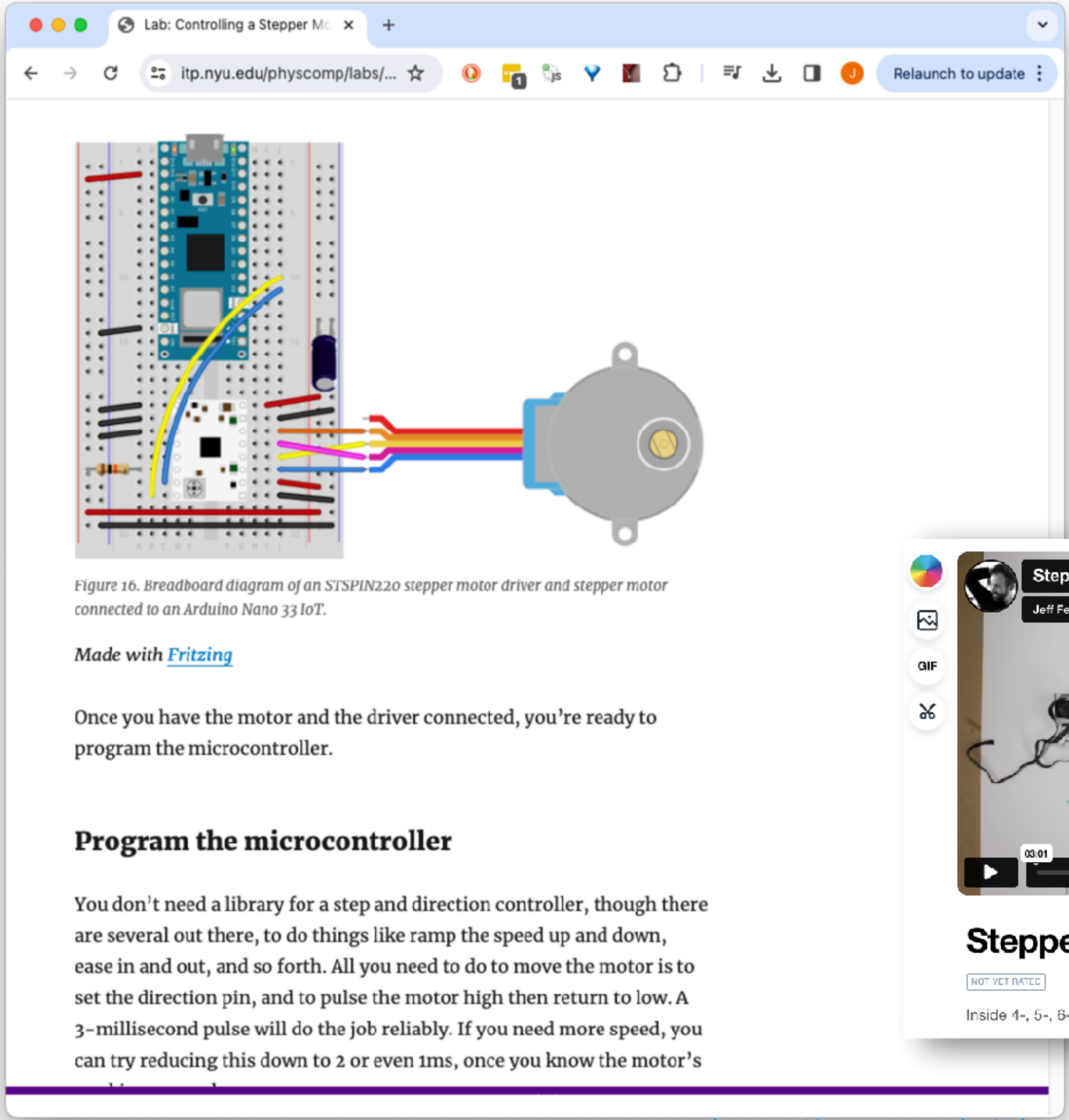
Switch Type .... Contact Push ON Momentary SPST
Power Rating (Resistive Load) .... 10 mA at 5 V DC
Switch Travel .... 0.5 ± 0.2 mm
Switch Actuation Force .... (8.47 ± 4.24 oz.-in.)

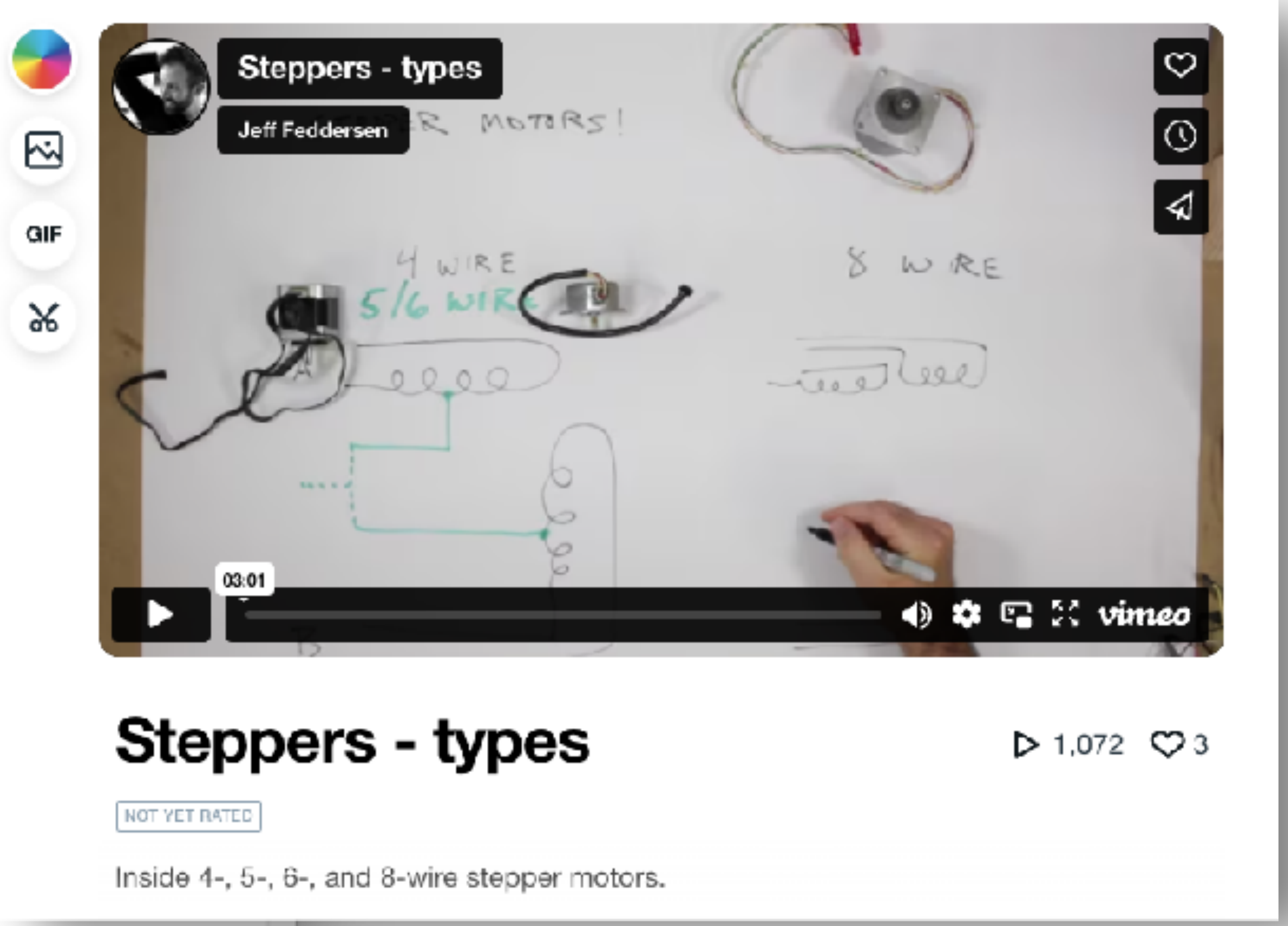
How To Order

PEC11 - 4 0 20 F - S 0012

Model
Terminal Configuration
  4 = PC Pin Horizontal/Rear Facing
Detent Option
  0 = No Detents (12, 18, 24 pulses)
  1 = 18 Detents (18 pulses)
  2 = 24 Detents (12, 24 pulses)
  3 = 12 Detents (12 pulses)
Standard Shaft Length
  15 = 15.0 mm
  20 = 20.0 mm
  25 = 25.0 mm

Quadrature Output Table



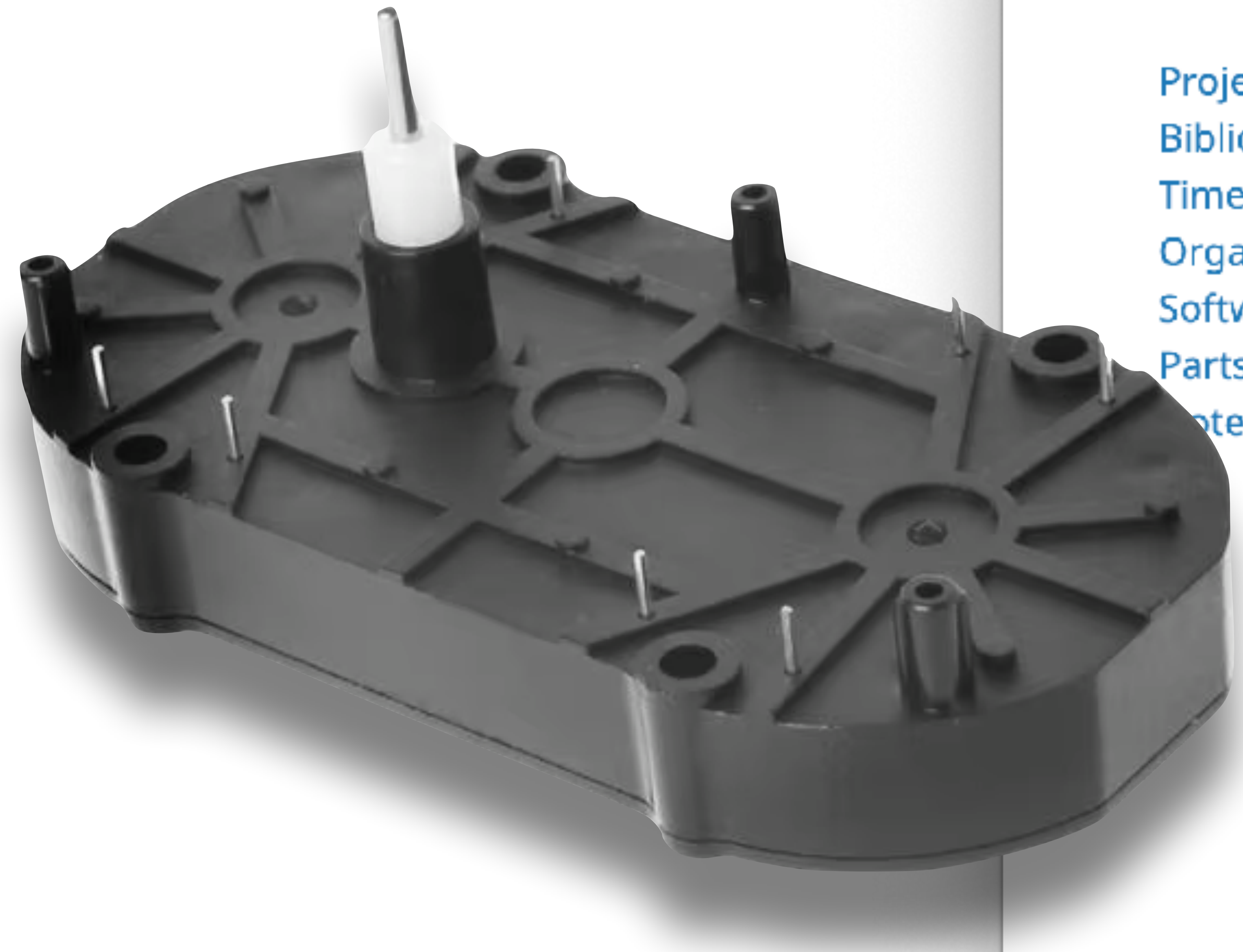


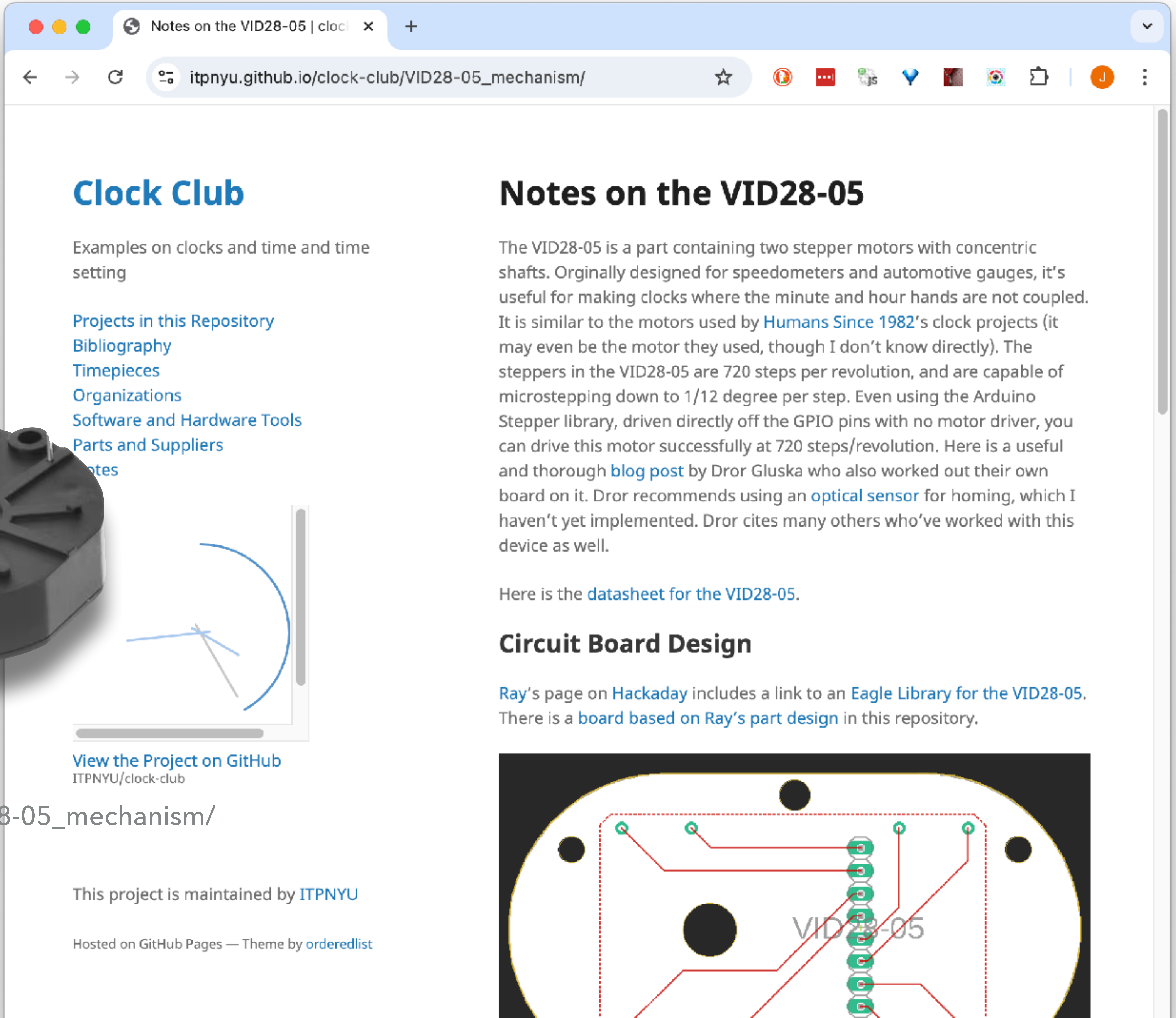
STEPPERS

Almost the "inverse" of encoders: send pulsed info to the stepper and it turns. See pomp site for tons of info.

https://itp.nyu.edu/physcomp/labs/motors-and-transistors/lab-controlling-a-stepper-motor-with-a-step-and-direction-driver/


STEPPERS





Notes on the VID28-05 | cloc

itpnyu.github.io/clock-club/VID28-05_mechanism/

Clock Club

Examples on clocks and time and time setting

- Projects in this Repository
- Bibliography
- Timepieces
- Organizations
- Software and Hardware Tools
- Parts and Suppliers
- otes

View the Project on GitHub
ITPNYU/clock-club

This project is maintained by ITPNYU

Hosted on GitHub Pages — Theme by orderedlist

Notes on the VID28-05

The VID28-05 is a part containing two stepper motors with concentric shafts. Orginally designed for speedometers and automotive gauges, it's useful for making clocks where the minute and hour hands are not coupled. It is similar to the motors used by Humans Since 1982's clock projects (it may even be the motor they used, though I don't know directly). The steppers in the VID28-05 are 720 steps per revolution, and are capable of microstepping down to 1/12 degree per step. Even using the Arduino Stepper library, driven directly off the GPIO pins with no motor driver, you can drive this motor successfully at 720 steps/revolution. Here is a useful and thorough blog post by Dror Gluska who also worked out their own board on it. Dror recommends using an optical sensor for homing, which I haven't yet implemented. Dror cites many others who've worked with this device as well.

Here is the datasheet for the VID28-05.

Circuit Board Design

Ray's page on Hackaday includes a link to an Eagle Library for the VID28-05. There is a board based on Ray's part design in this repository.

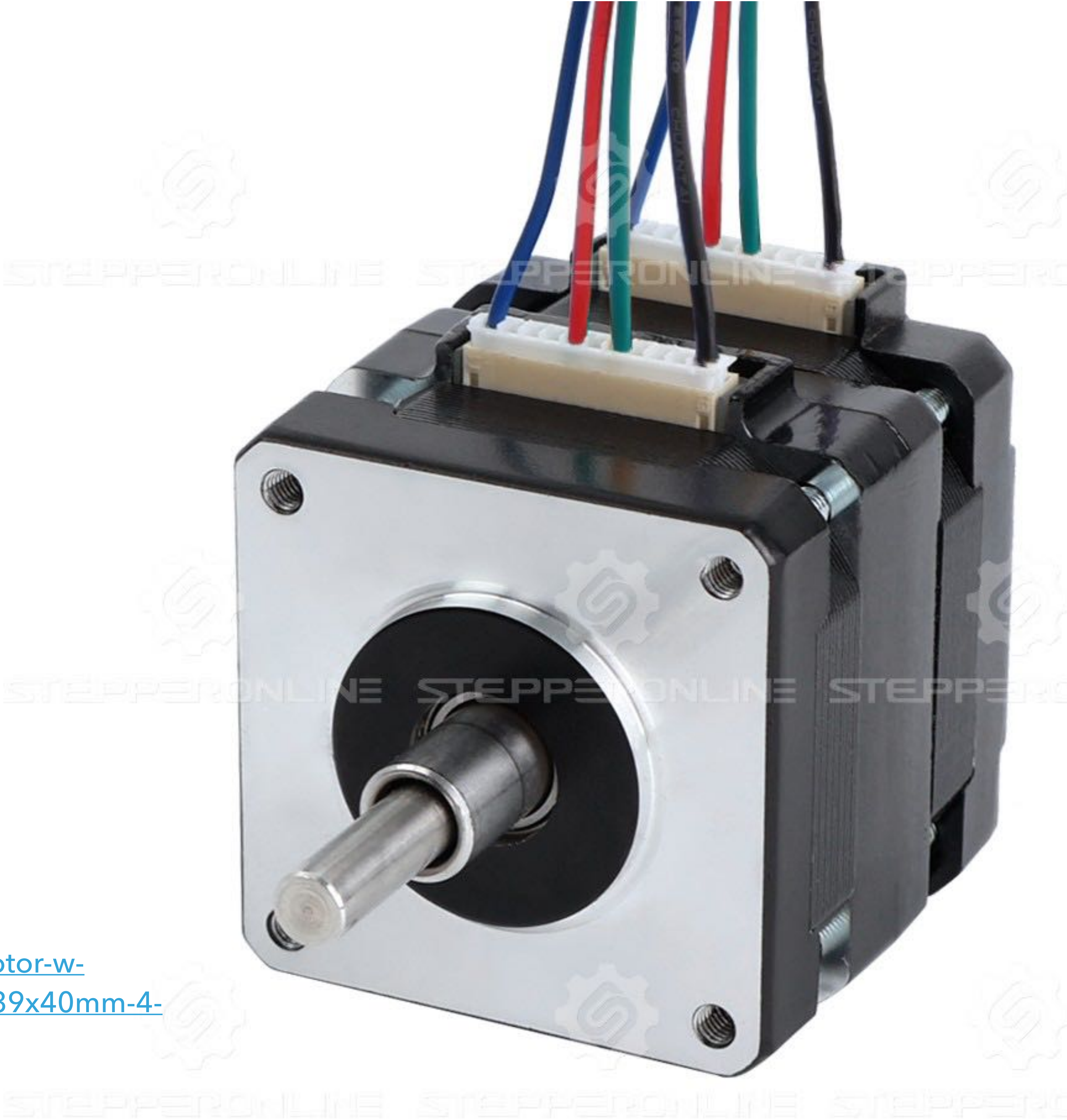
STEPPERS

https://itpnyu.github.io/clock-club/VID28-05_mechanism/

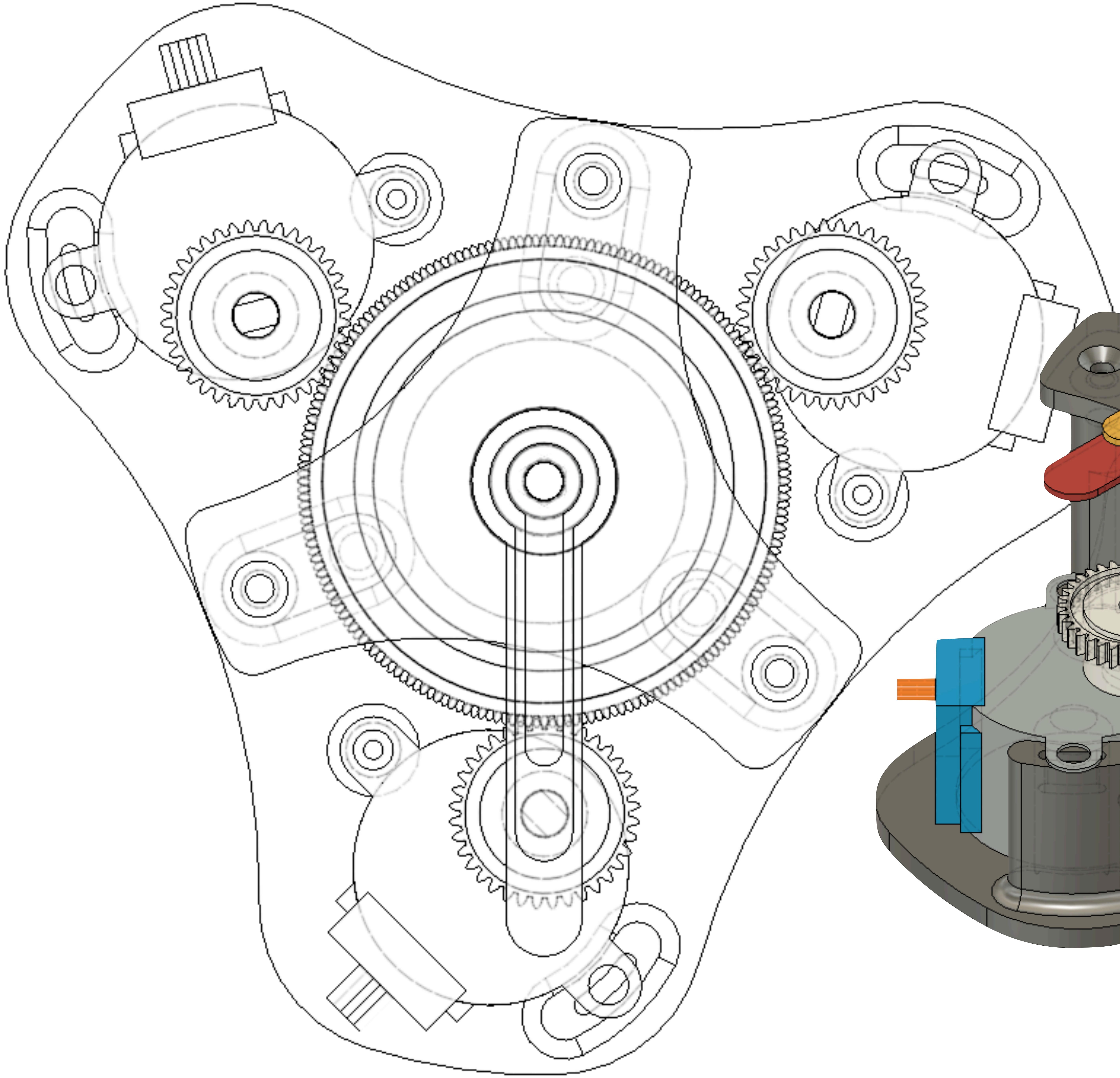
STEPPERS

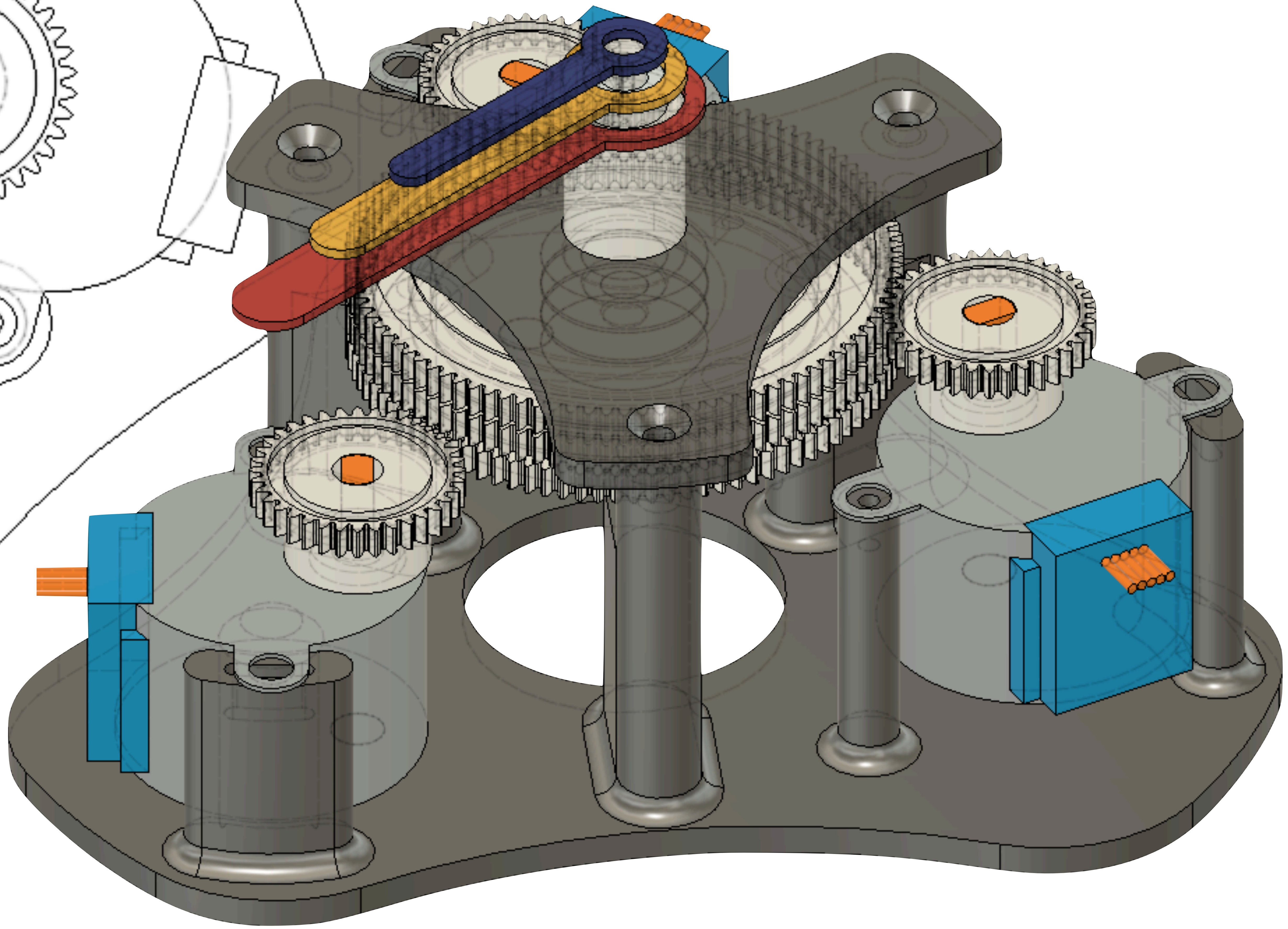
https://mcuoneclipse.com/2019/11/24/world-stepper-clock-with-nxp-lpc845/

Nema 16 Assembled Motor w/ Hollow & Solid Shaft

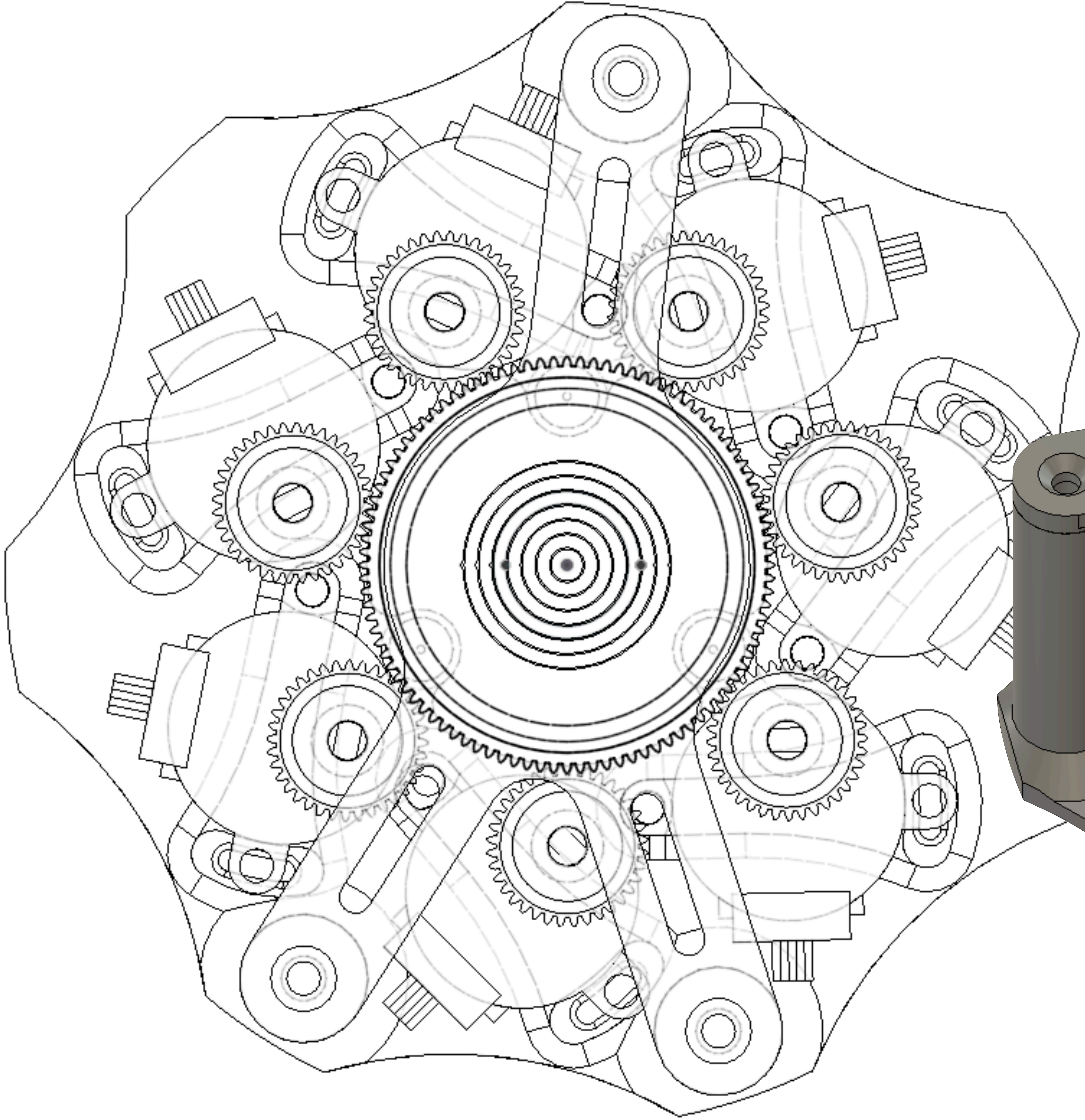
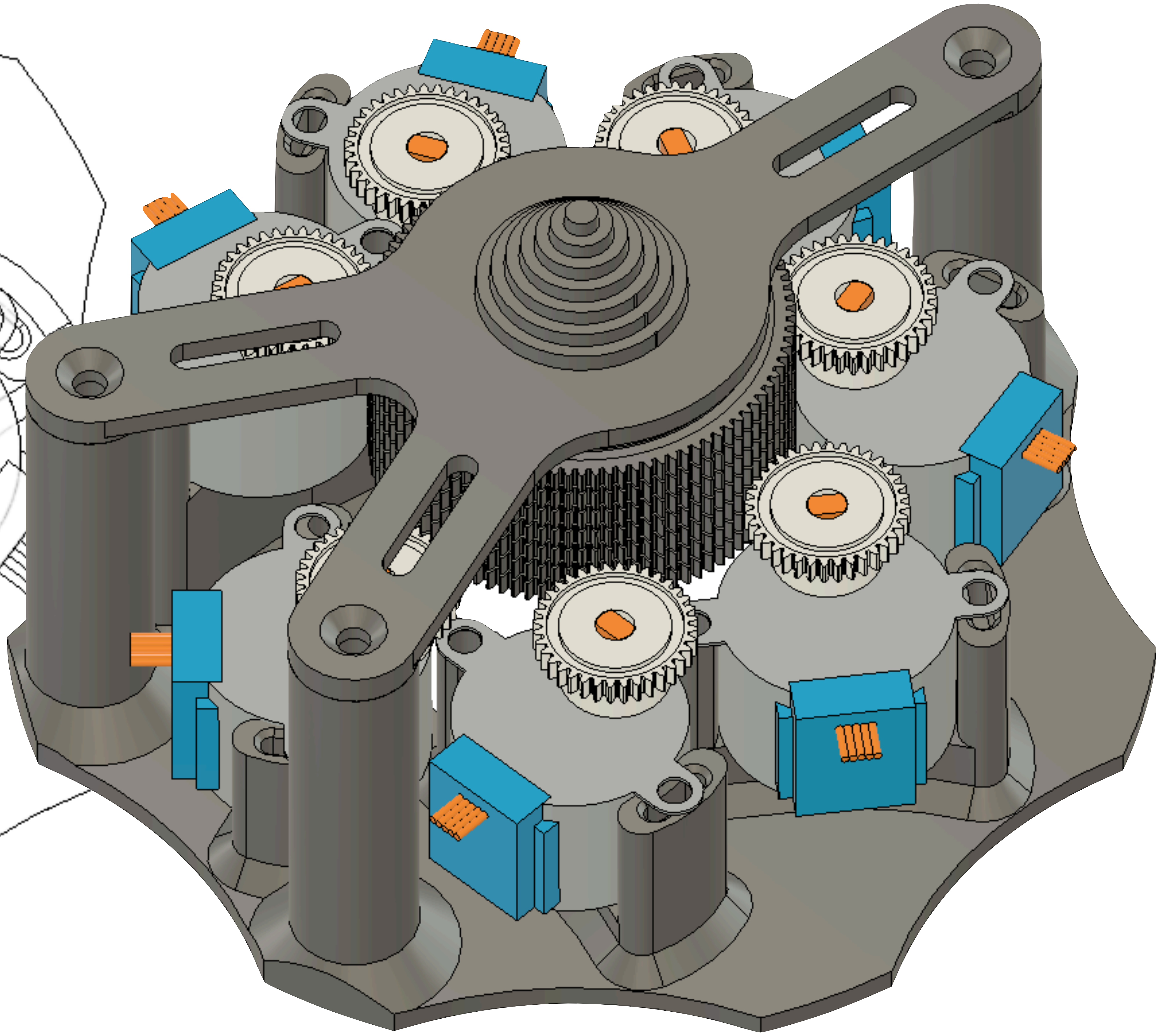


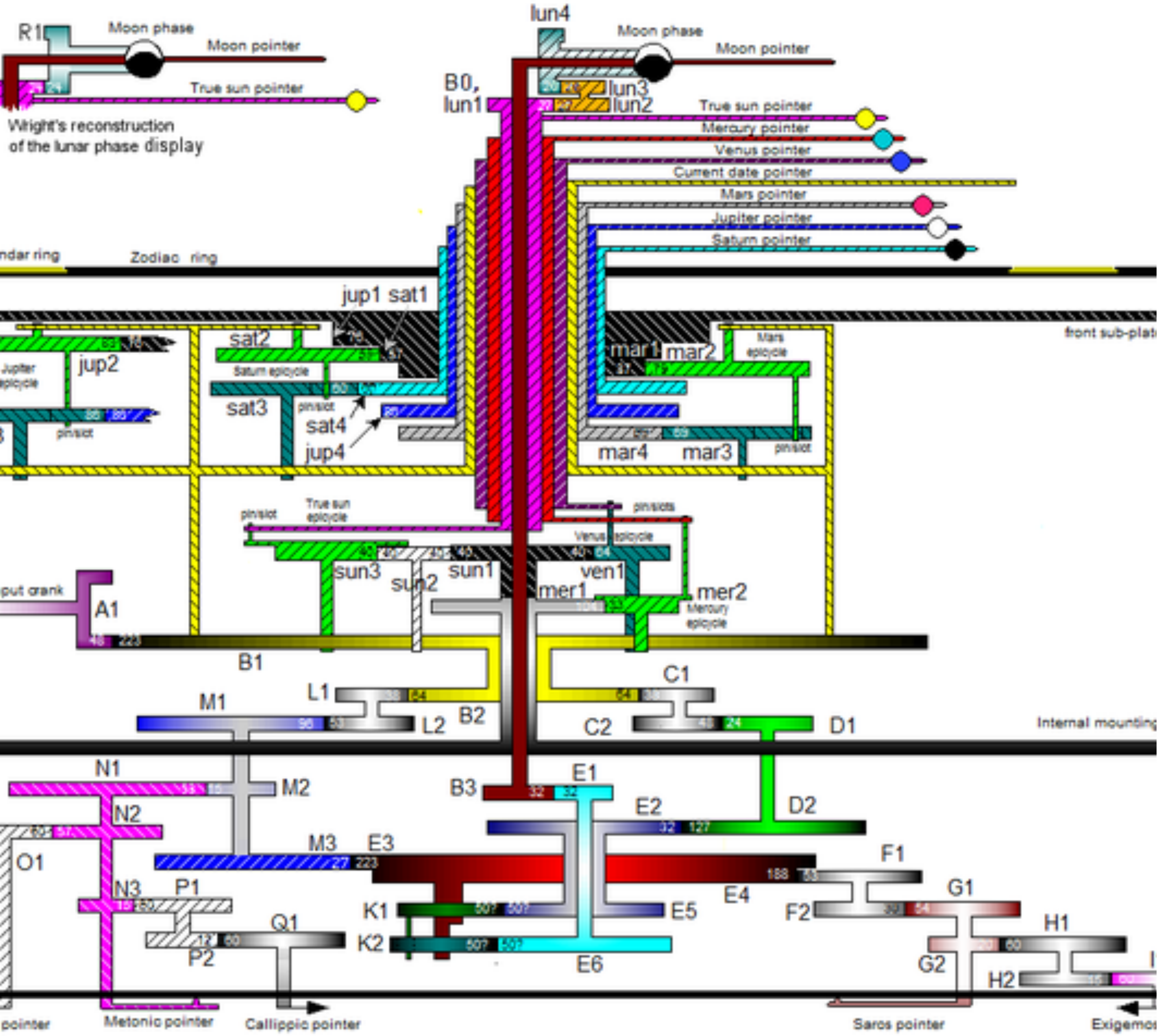
https://www.omc-stepperonline.com/nema-16-assembled-motor-w-hollow-solid-shaft-bipolar-1-8deg-8ncm-11-33oz-in-0-3a-39x39x40mm-4-wires-16hs16-0304s-c1






LONG NOW

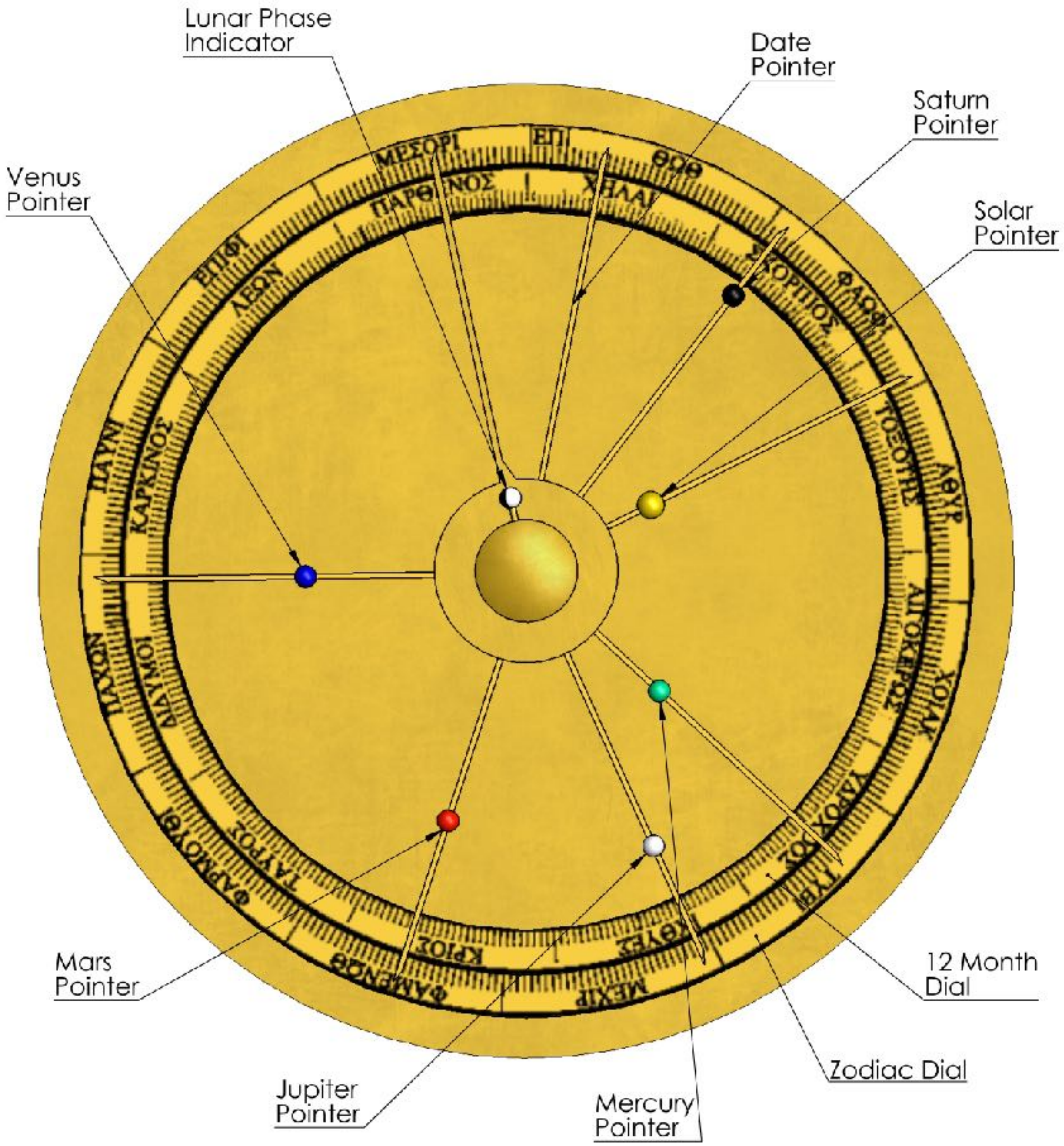





The Front Face of the Antikythera Mechanism

Freeth and Jones Proposal

Modelled by Scott Shambaugh



DATA TO MEANING