TIME MACHINES

Diving deeper into digital timing machinery

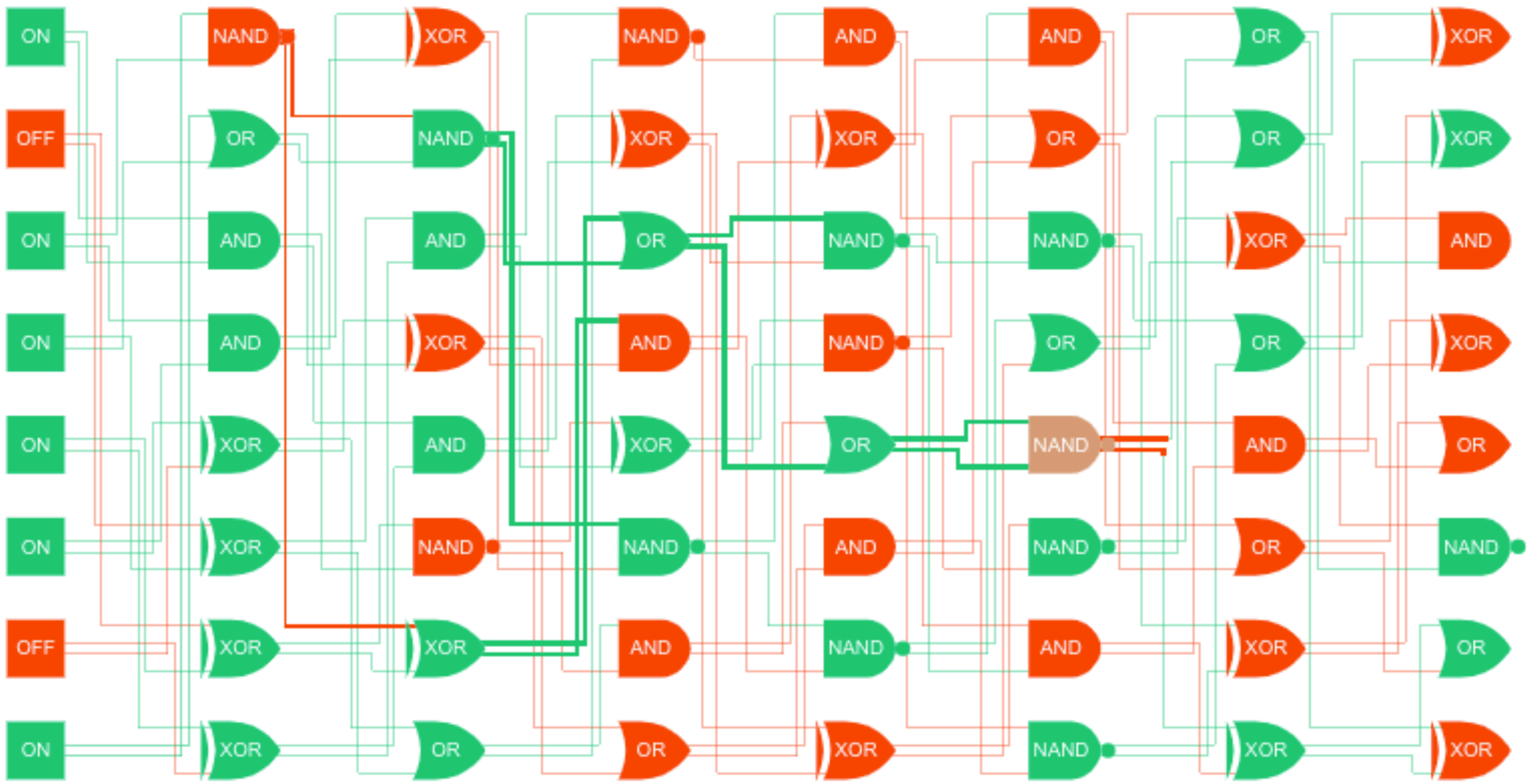

TIME MACHINES
POLICE
CSM-101
HOT TUB
TIME MACHINE

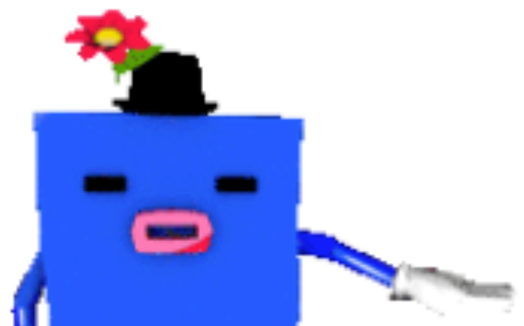

TIM
POLICE
HOT TUB
TIME MACHINE

2

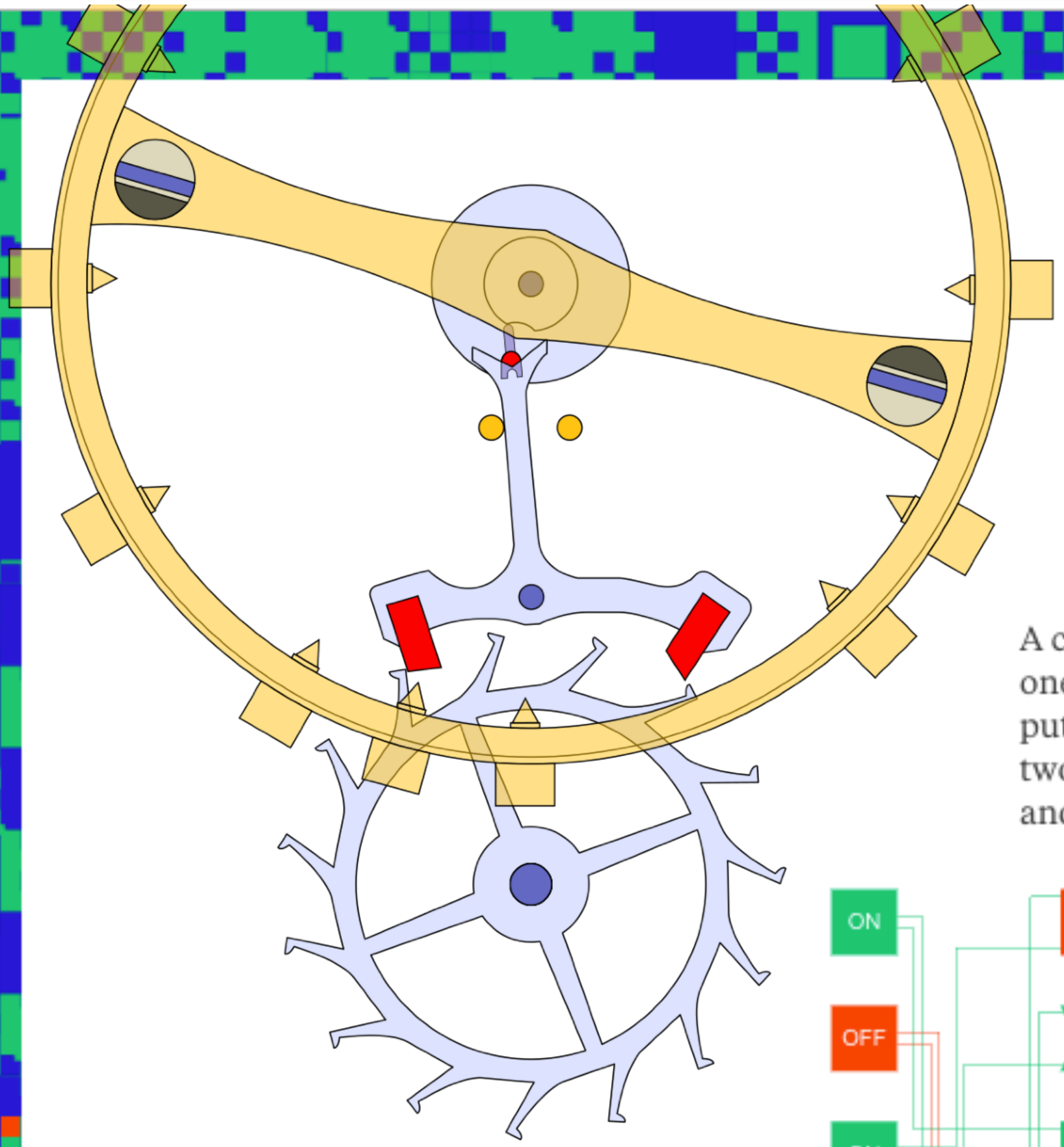
Let’s Begin

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

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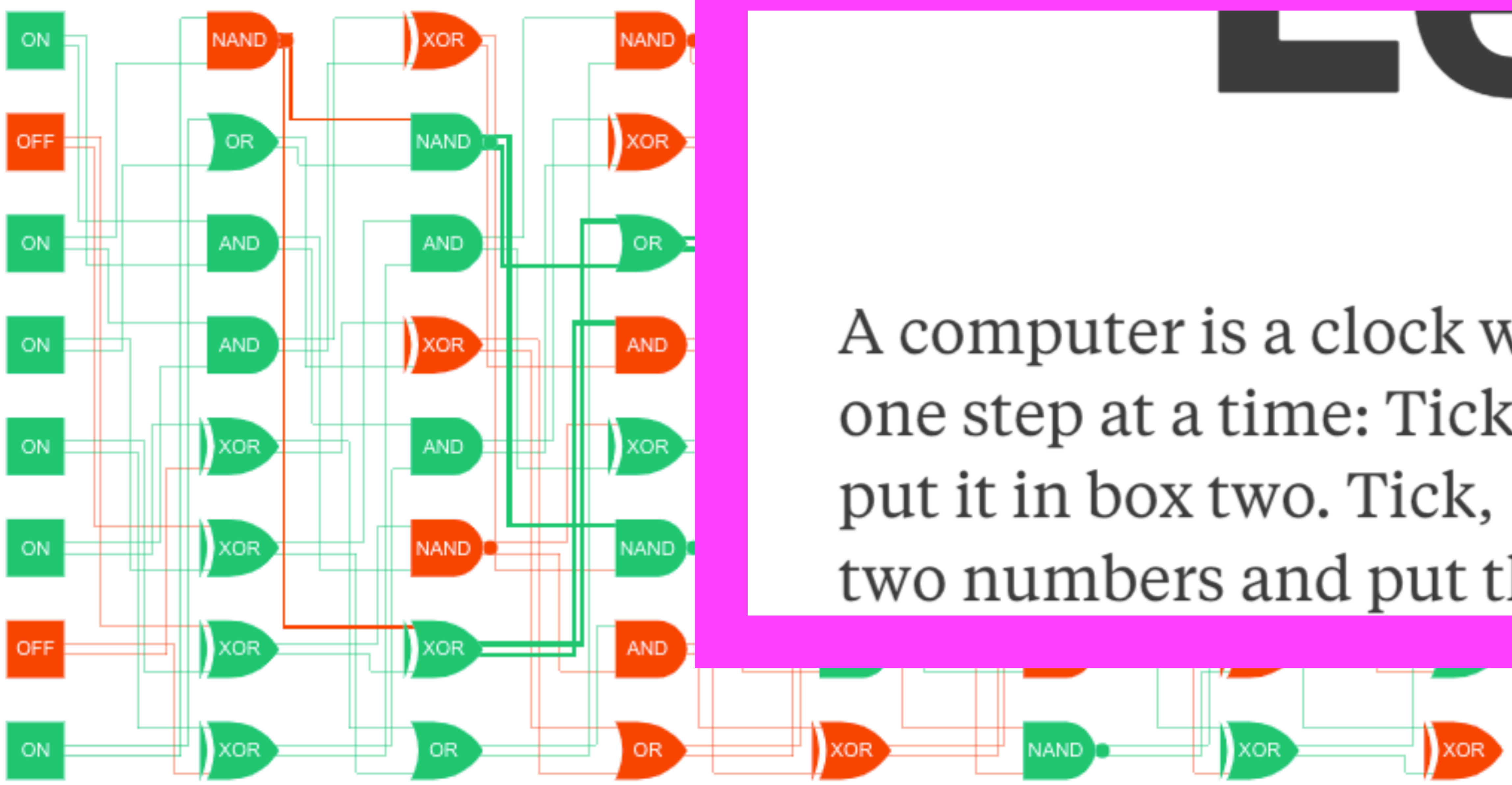

Let's Be
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sketch_sep29a | Arduino 1.8.13
sketch_sep29a
void setup() {
// put your setup code here, to run once:
}
void loop() {
// put your main code here, to run repeatedly:
}
sketch_200929a | Processing 3.5.3
Java
sketch_200929a
void setup() {
}
void 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"

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

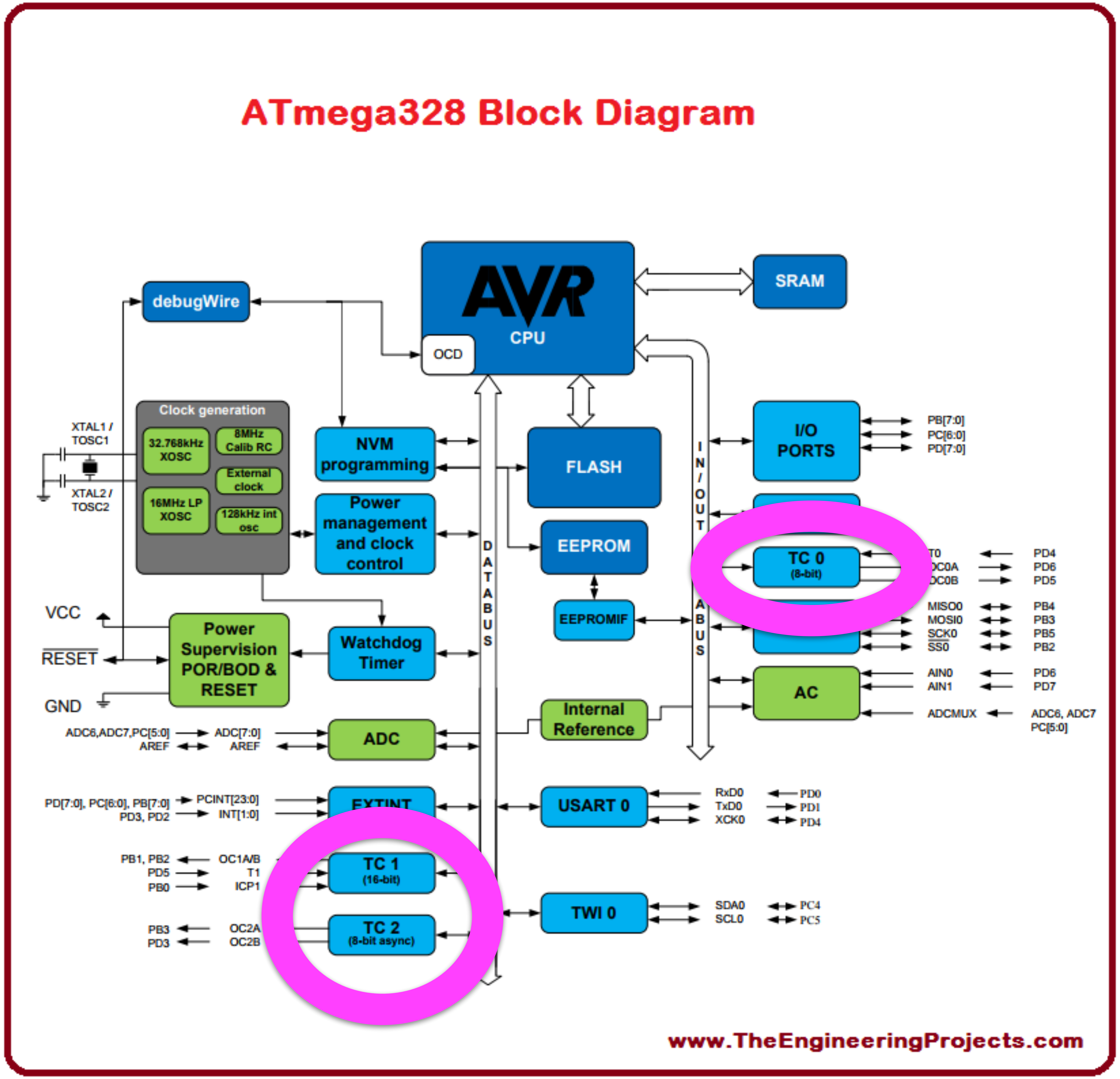
https://github.com/arduino/ArduinoCore-avr

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

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.



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

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

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

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

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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.

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Param

`ms`: the

Retur

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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
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}
```

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.

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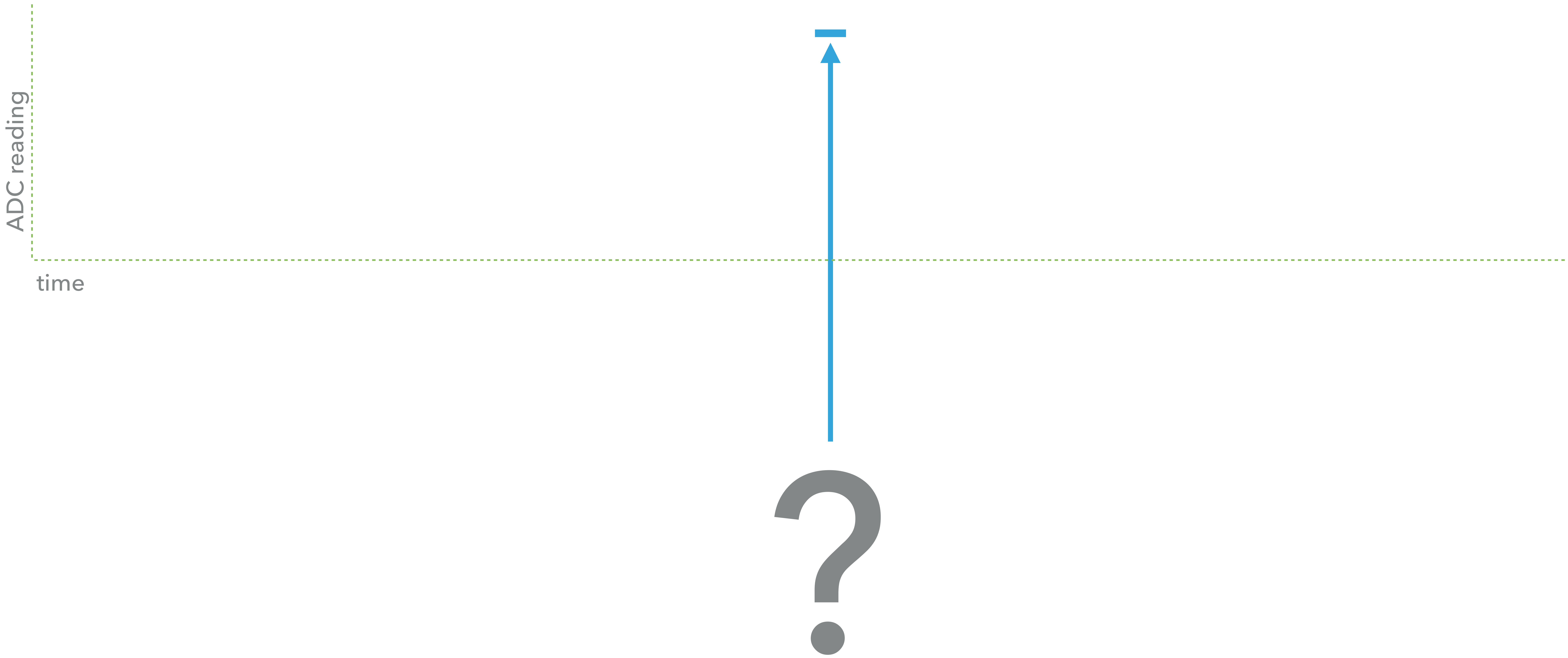
DATA TO MEANING



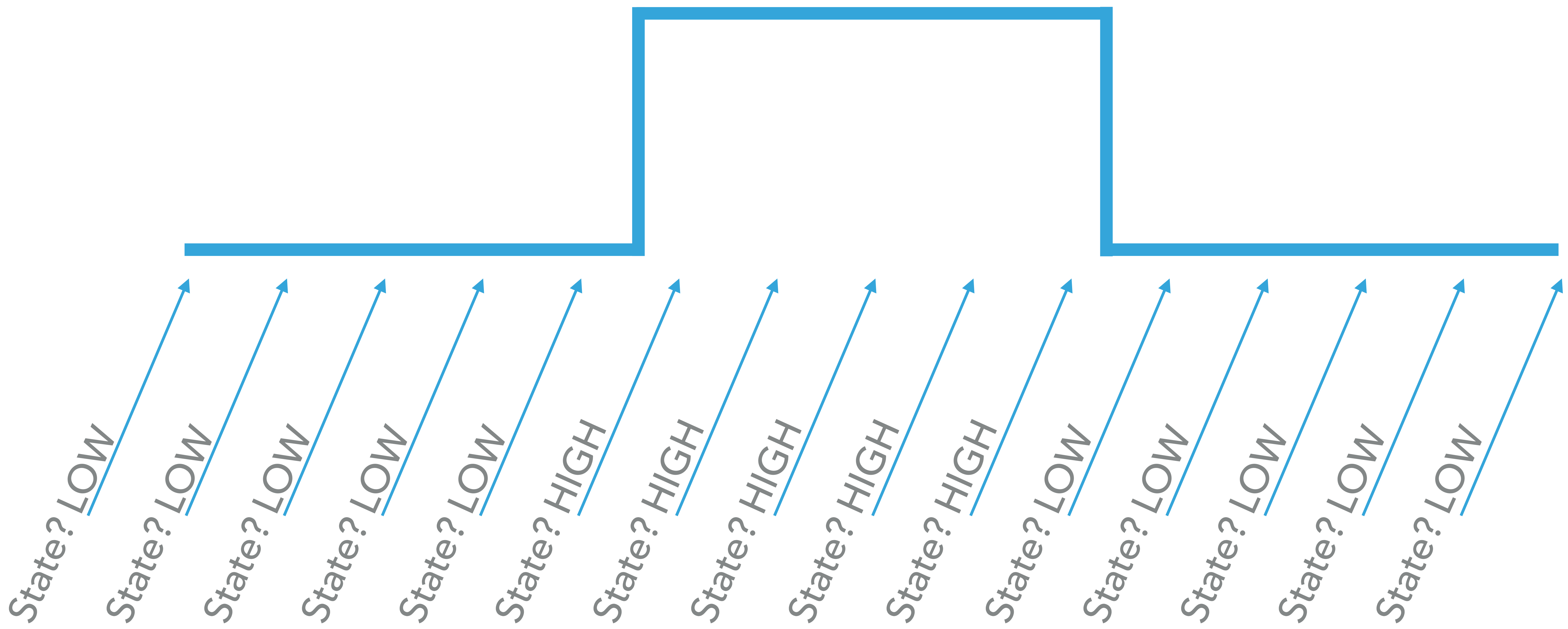
INTERRUPTS

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

Changes include:

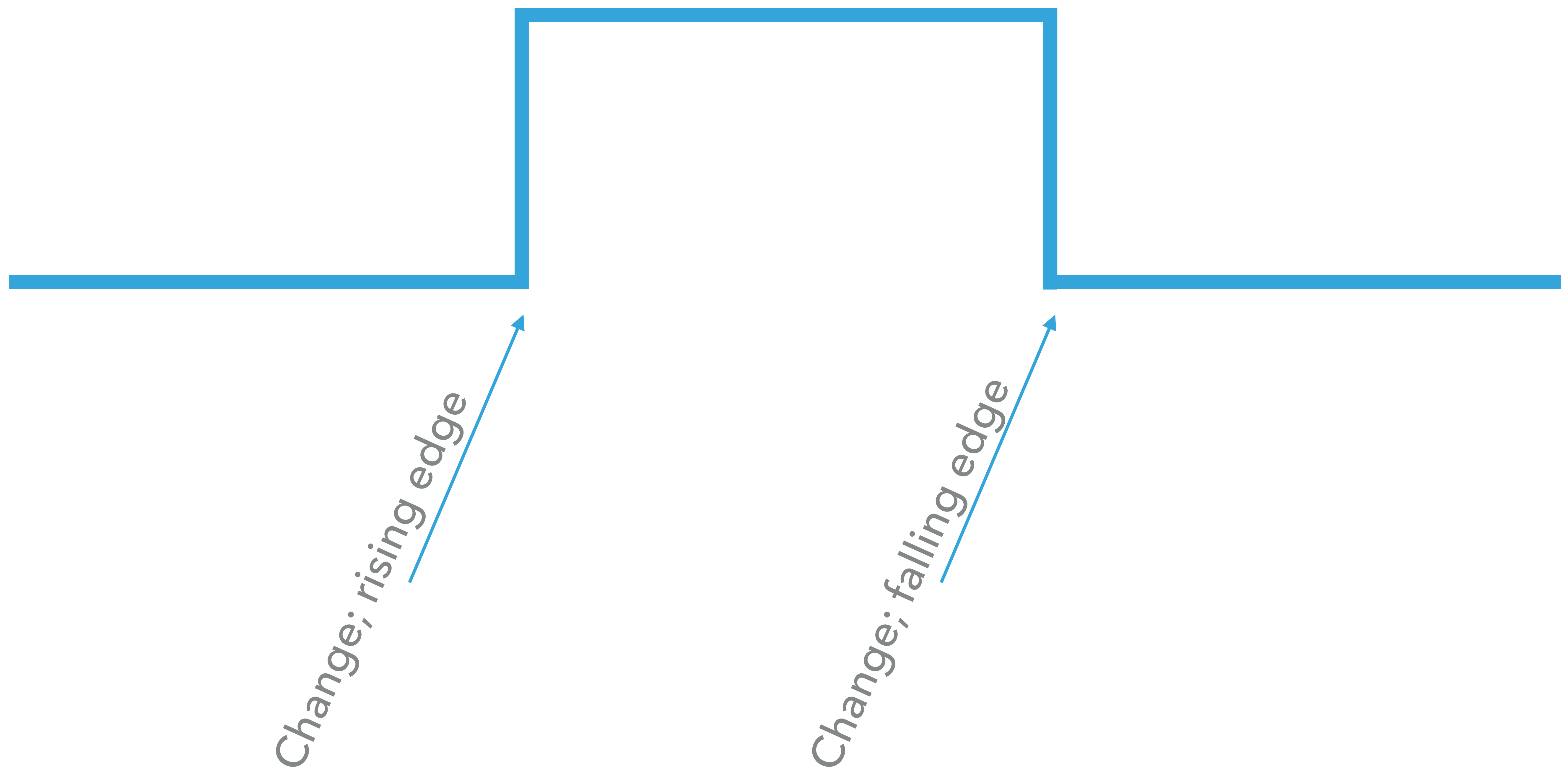
- **external,** such as voltage changes on an interrupt-enabled pin, or
- **internal**, from changes in an internal hardware **timer** (basically, a counter incrementing each clock cycle) reaching a certain value.

POLLING

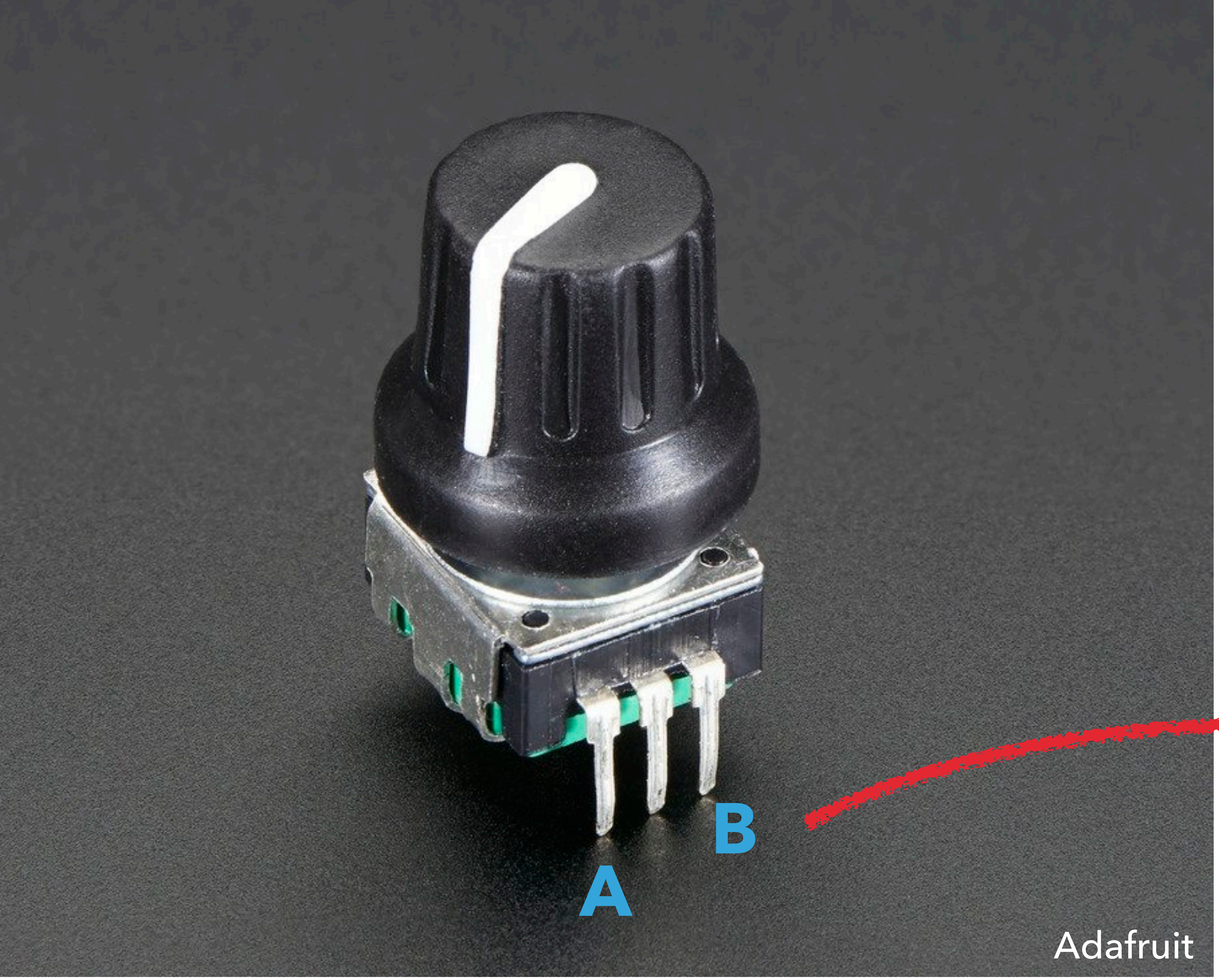


In main loop, use digital read to check the state of an input pin. Decide what to do if it is low, high, changed, etc.

INTERRUPTS

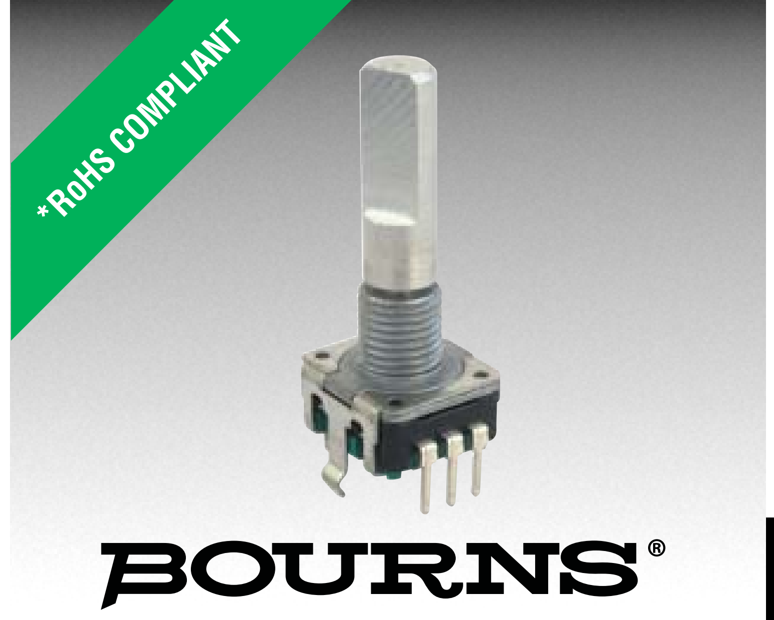


Define interrupt service routines (ISRs) for hardware changes: rising edge, falling edge, and/or change. These will be called immediately when the pin changes.



INTERRUPTS

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



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/Ag3.8/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

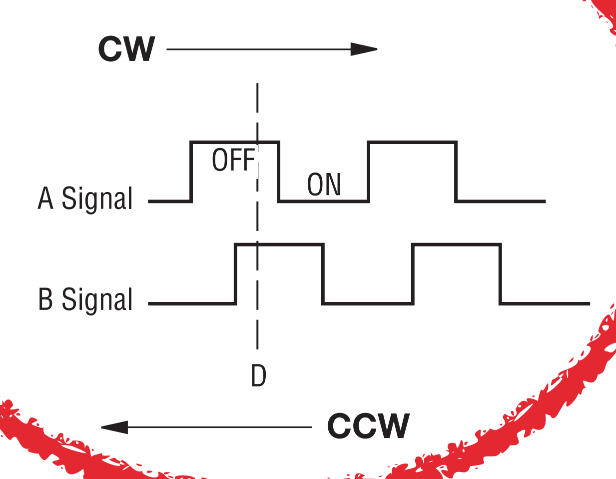
Switch Type	Contact Push ON Momentary SPST
Power Rating (Resistive Load)	10 mA at 5 V DC
Switch Travel	0.5 ± 0.2 mm
Switch Actuation Force	610 ± 300 gf (8.47 ± 4.24 oz.-in.)

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

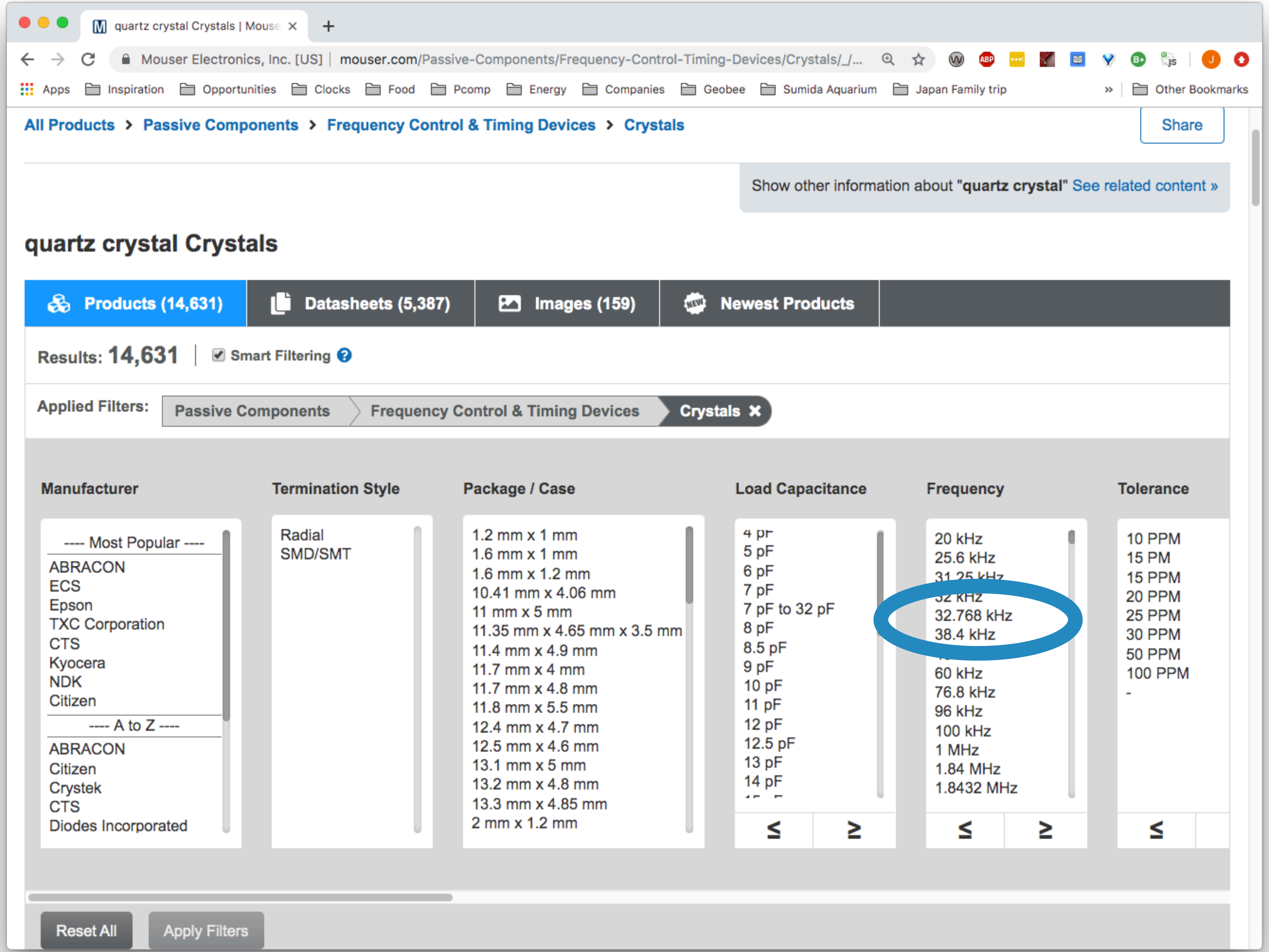
Quadrature Output Table



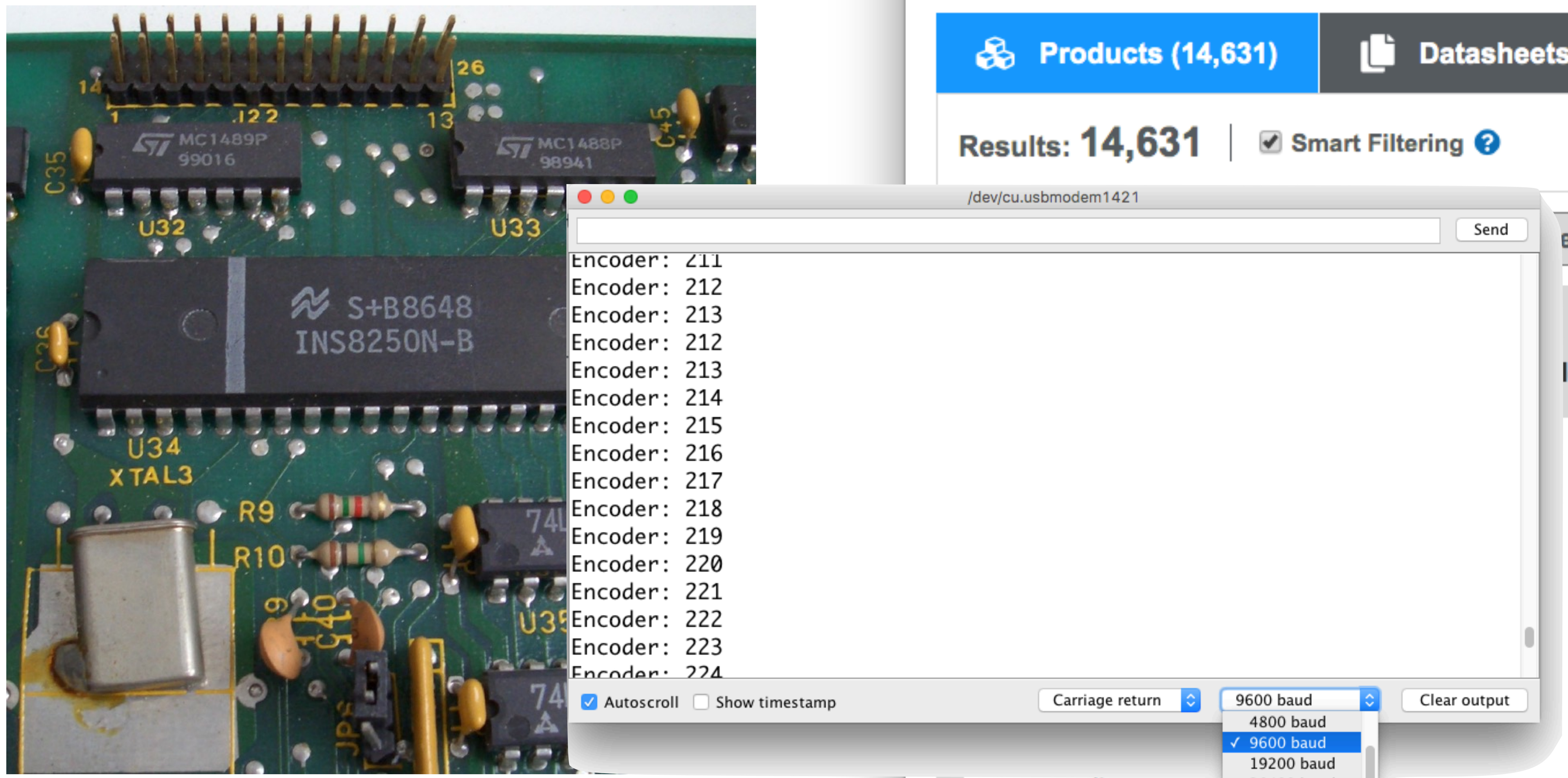
Metronome

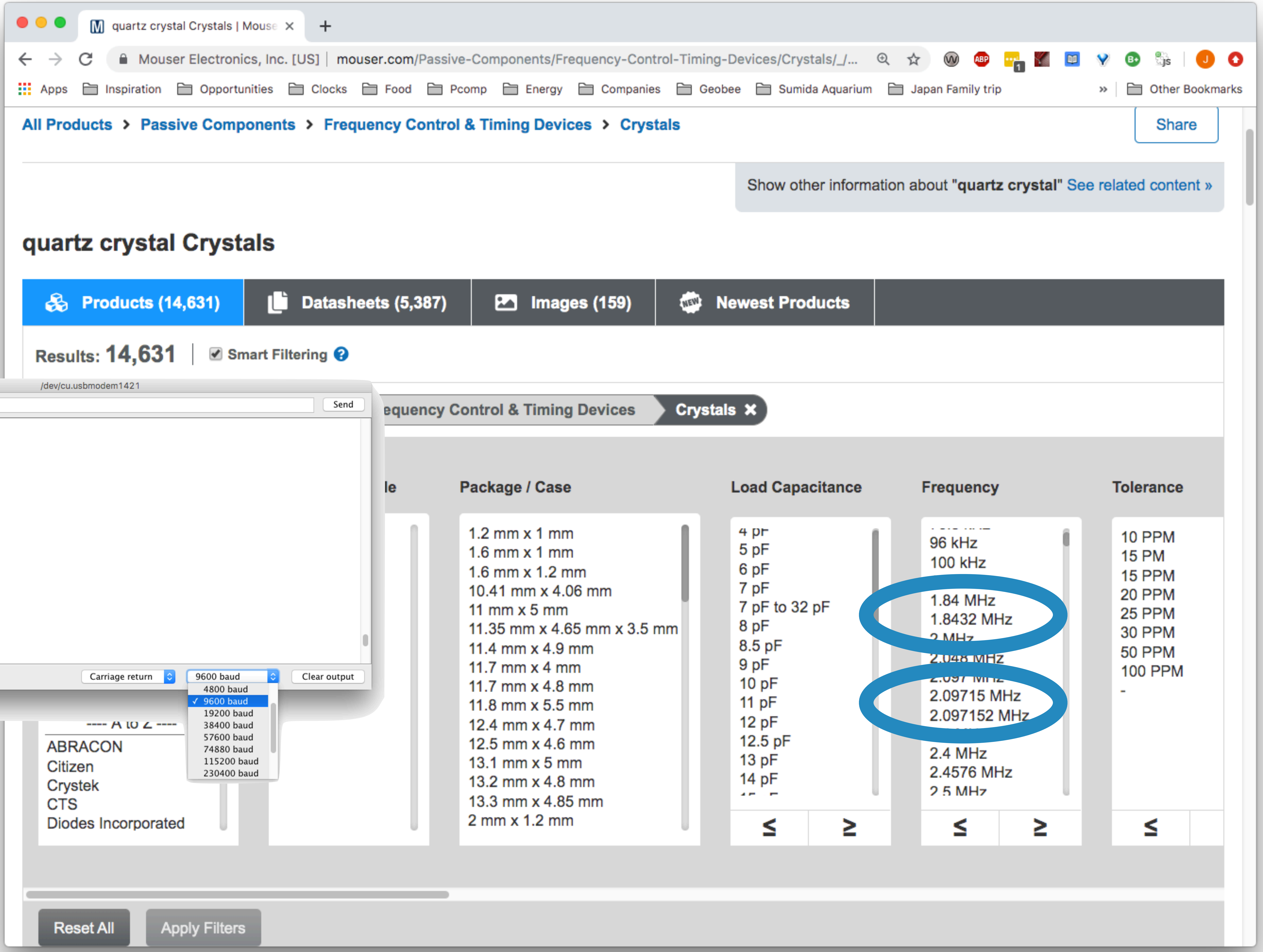
Standard quartz clock timer

32,768 = 2^15



Precision timer
2,097,152 = 2^21

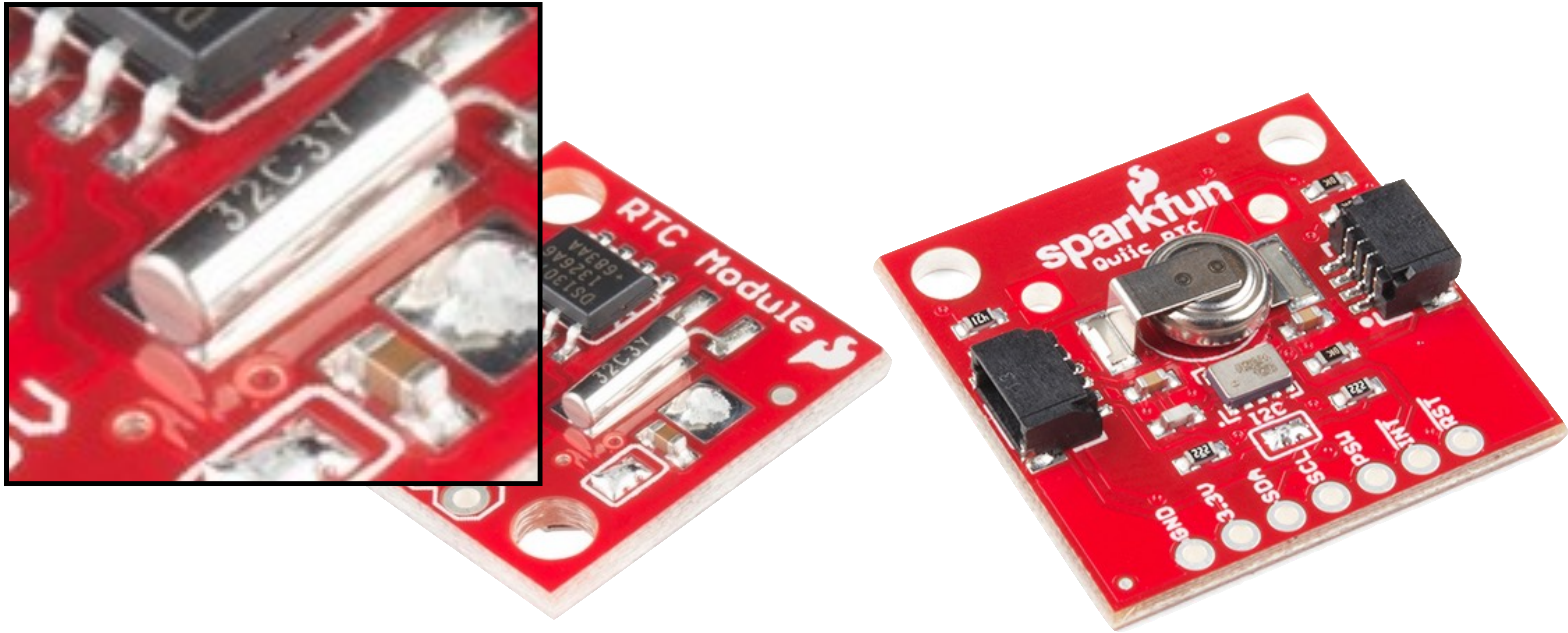




1,843,200 / 16 = 115,200
/32 = 57,600
/192 = 9600

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

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.

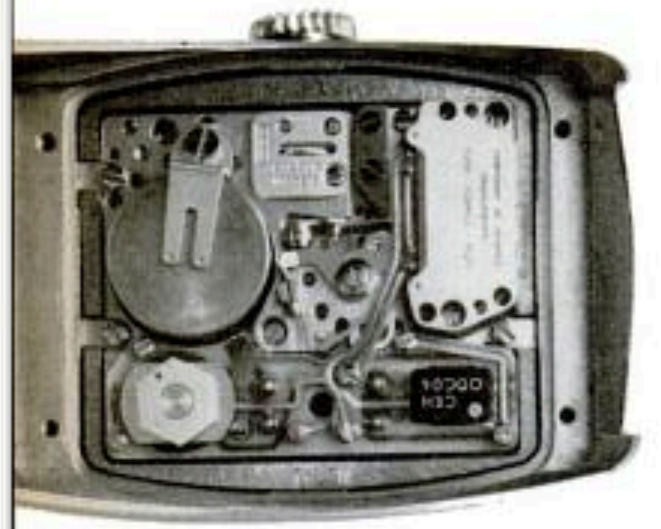
What's an electronic quartz watch? How does it differ from others? How good is it? Let's take these questions one at a time.

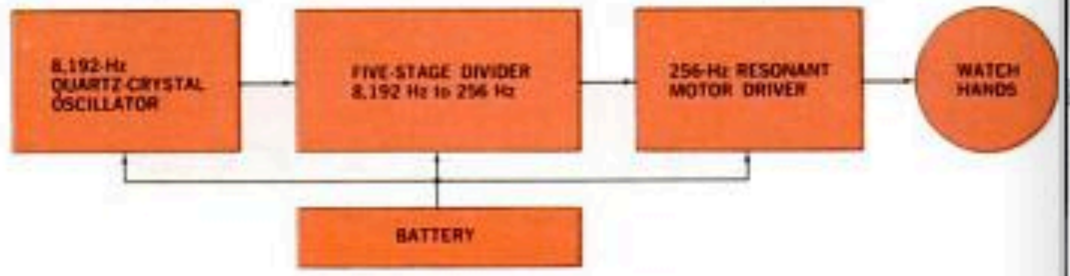
The quartz watch is based on a principle entirely different from those of all other watches. Most watches rely on the familiar balance wheel. A carefully balanced spring-driven wheel rocks back and forth at a rate (usually five times a second) determined by its size and weight. The accuracy with which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

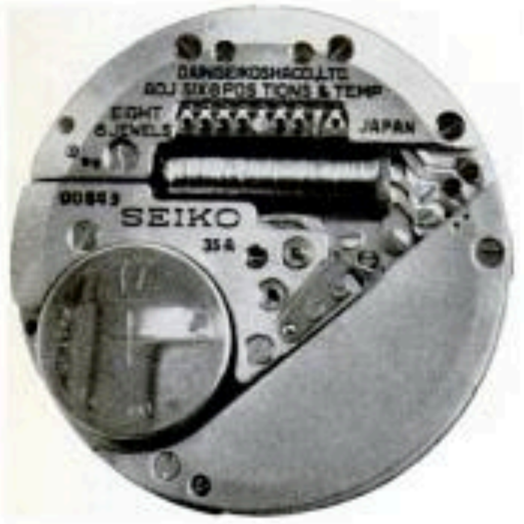
Continued

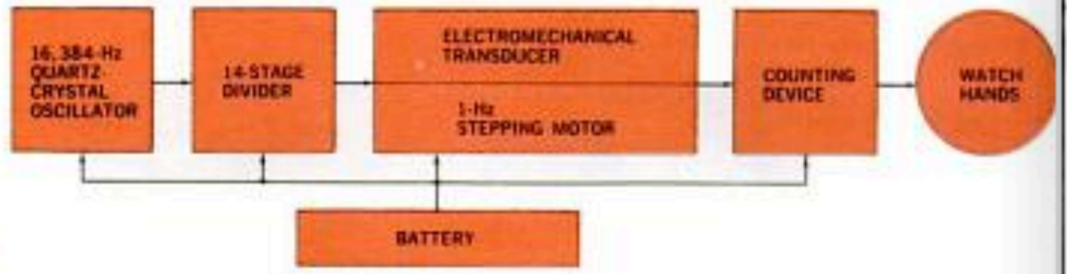
There are at least two reasons why the Timex is so much cheaper – advanced mass-production technology and a circuit that's still top secret



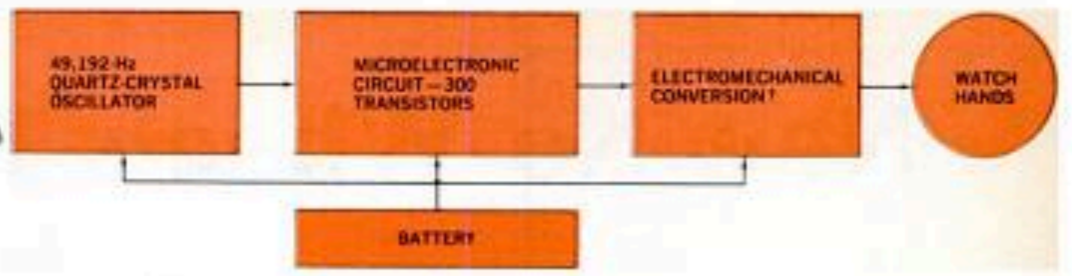


SWISS-CEH **The Swiss Center** of Electronic Horology developed this quartz watch for its member companies, among them Bulova and Omega. The 8,192-Hz quartz oscillator goes through a five-stage divider in a micro-electronic integrated circuit. The resulting output is 256 Hz. This frequency goes to an electromagnetic motor which further divides 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.

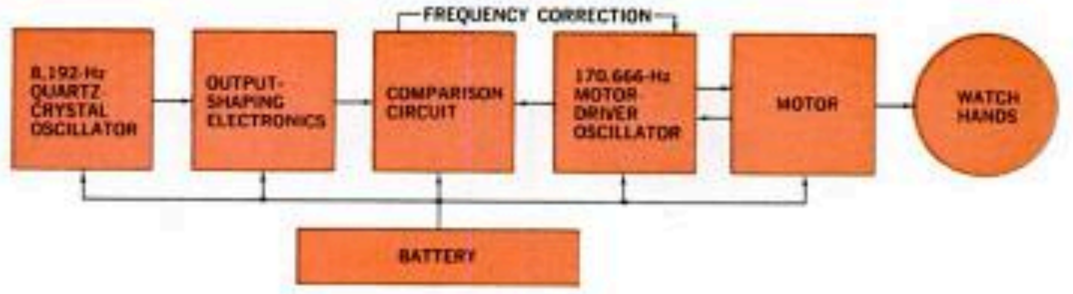




SEIKO **This quartz** has five major components: 16,384-Hz quartz-crystal oscillator circuit, integrated circuit with a 14-stage divider, stepping motor with an electromechanical transducer, and silver-oxide battery. The divider circuit halves the 16,384-Hz frequency 14 times (8,192; 4,096; etc.—down 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.



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.

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.

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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 limite... are slightly larger and heavier than conventional wa... 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.

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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.

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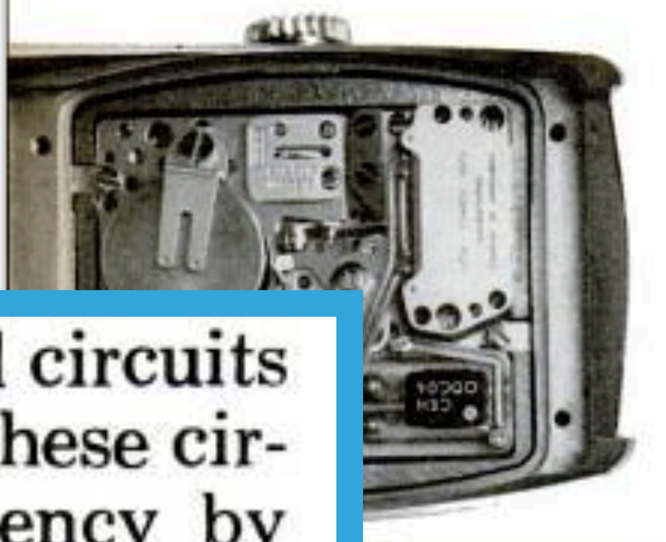
W... How does it differ from others? How good is it? Let's take these questions one at a time.

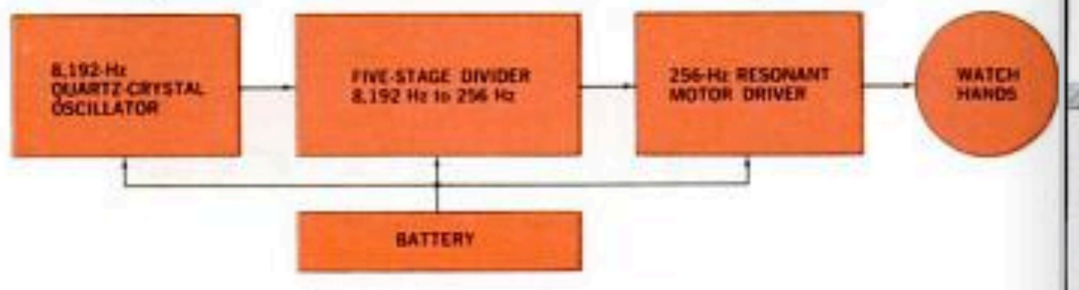
The quartz watch is based on a principle entirely different from those of all other watches. Most watches rely on the familiar balance wheel. A carefully balanced spring-driven wheel rocks back and forth at a rate (usually five times a second) determined by its size and weight. The accuracy with

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

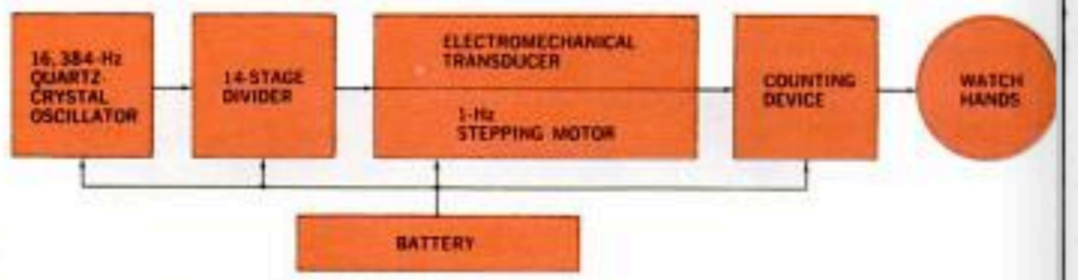
Continued

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

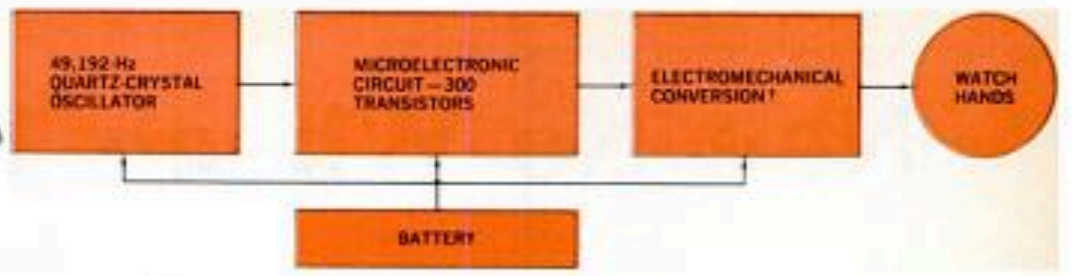




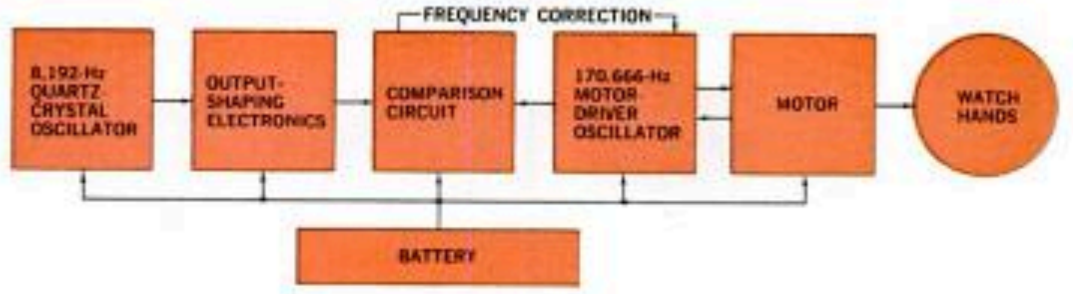
SWISS-CEH The Swiss Center of Electronic Horology developed this quartz watch for its member companies, among them Bulova and Omega. The 8,192-Hz quartz oscillator goes through a five-stage divider in a micro-electronic integrated circuit. The resulting output is 256 Hz. This frequency goes to an electromagnetic motor which further 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 ...al, 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 ...

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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.

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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)

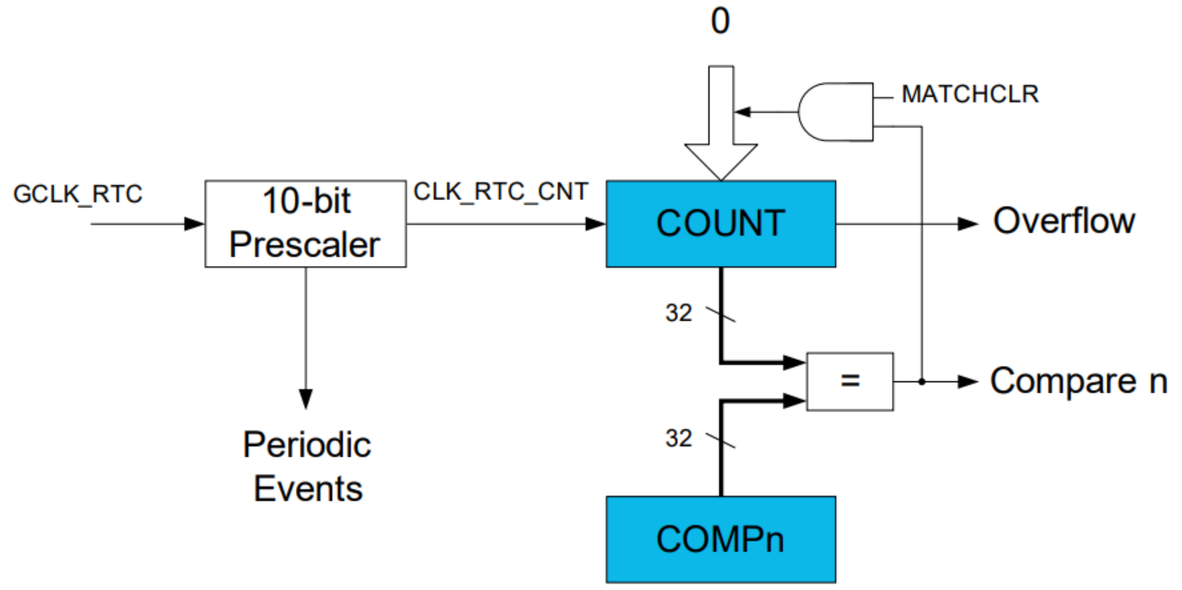

Figure 19-2. RTC Block Diagram (Mode 1 — 16-Bit Counter)

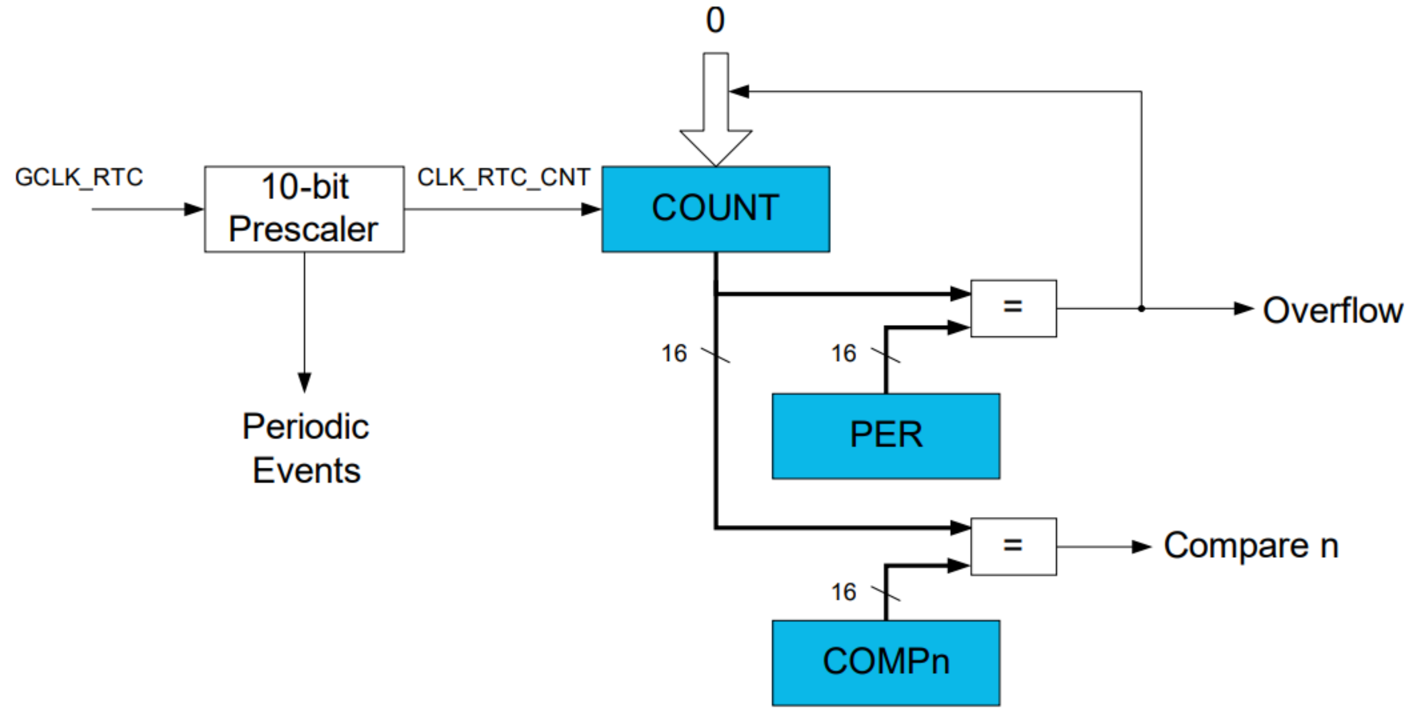

Figure 19-3. RTC Block Diagram (Mode 2 — Clock/Calendar)