

# Timing

# Timing

Ability to measure of time necessary for:

Sound generation

Time of day clock

Event timing

Multitasking

# Timing

Components required:

Clock source

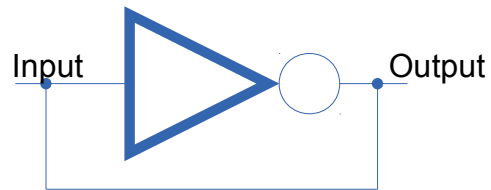
Counters

Digital comparators

# Timing

Clock source:

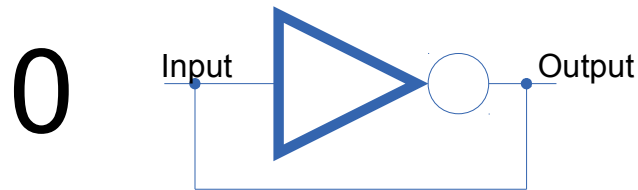
A periodic digital signal can be used as a clock source  
Simple way to implement this: use an inverter



# Timing

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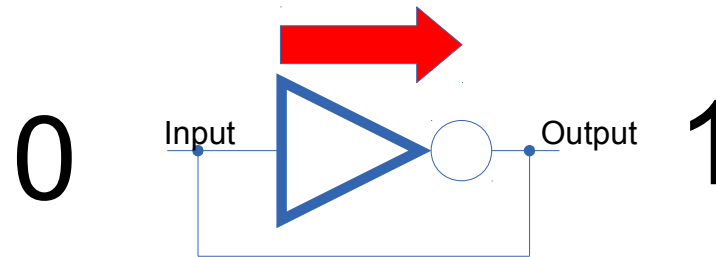


Initially: Input is zero

# Timing

Clock source:

A periodic digital signal can be used as a clock source  
Simple way to implement this: use an inverter

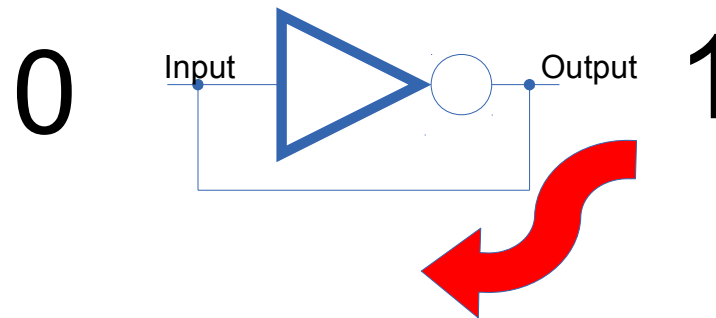


Input of zero makes output 1

# Timing

Clock source:

A periodic digital signal can be used as a clock source  
Simple way to implement this: use an inverter

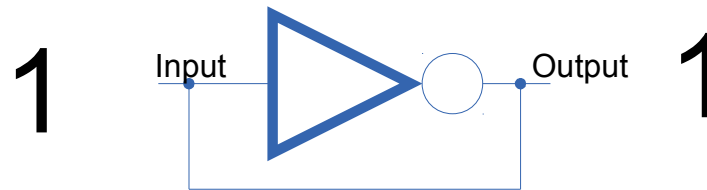


Output of 1 propagates back  
to input

# Timing

Clock source:

A periodic digital signal can be used as a clock source  
Simple way to implement this: use an inverter



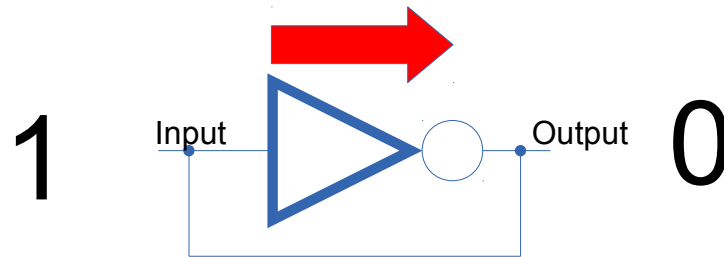
Input is now 1



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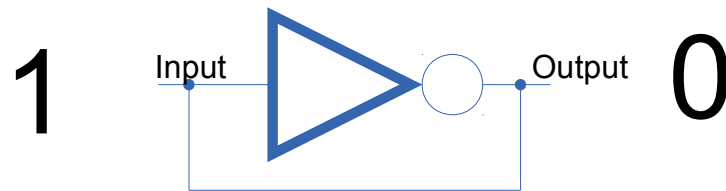


Input of 1 propagates to  
output making it zero

# Timing

Clock source:

A periodic digital signal can be used as a clock source  
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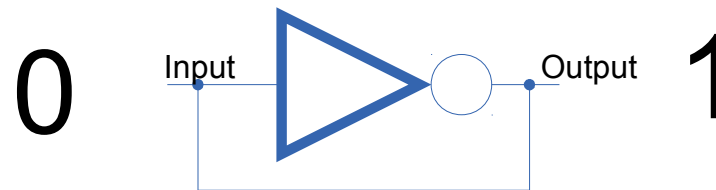


System now oscillates

# Timing

Clock source:

A periodic digital signal can be used as a clock source  
Simple way to implement this: use an inverter



System now oscillates

# Timing

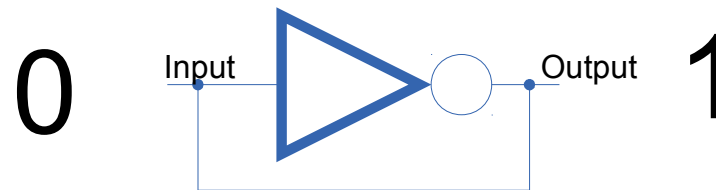
What frequency does this oscillate at?

It depends on:

- Temperature

- What sort of stuff is nearby

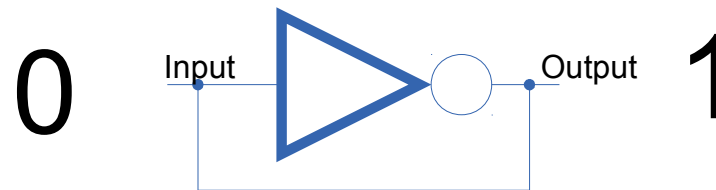
- Nearby electric and magnetic fields



# Timing

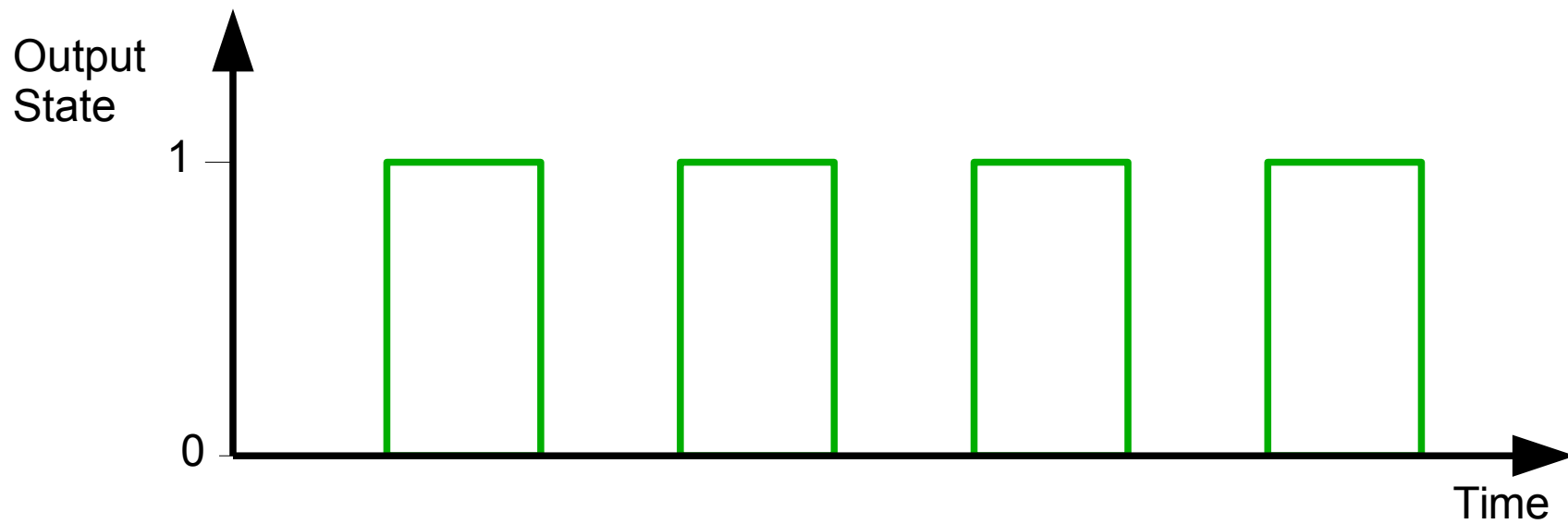
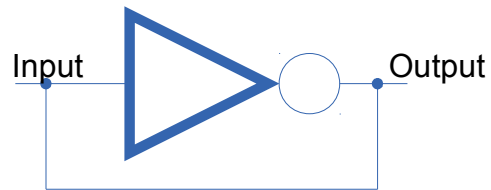
What frequency does this oscillate at?

The frequency is in fact quite unpredictable



# Timing

A graph of the output state vs. time looks like this:



# Timing

- This sort of clock source has limited use
  - We can not use it to make a time of day clock
  - We can't use it to measure intervals
  - We can use it for applications where timing accuracy is not critical

Timing

Making a better clock





# Timing

- Tuning forks resonate at a particular frequency
- Frequency is determined by size of the fork
- Smaller fork, higher frequency



# Timing

A 512Hz tuning fork



# Timing

- High frequency tuning forks are small
- Computers typically make use of frequencies of greater than 1000000Hz
- Sometimes even greater than a gigahertz i.e. 1000000000Hz
- Can we make a tuning fork run at those speeds?

Timing

Sort of...

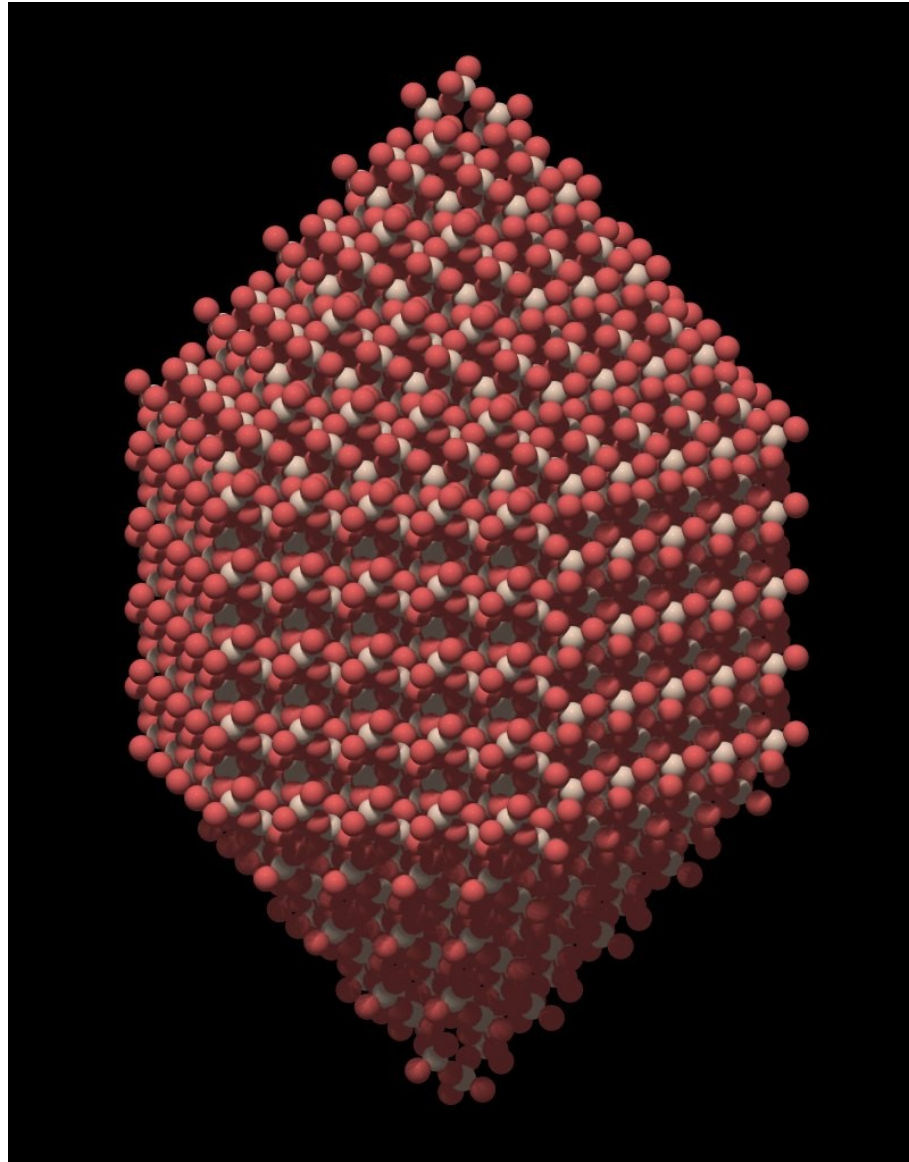
# Timing

This is Quartz



# Timing

Quartz is a crystal



## Timing

- Crystals have a regular mechanical structure
- They resonate
- They can be cut to resonate at a particular frequency
- Mechanical movement in quartz also produces useful electrical effects – Piezo Electricity

## Timing

- Quartz crystals are often used in oscillator circuits
- The circuits lock in to resonant frequency of the crystal
- Manufacturers make crystals with particular resonant frequencies.



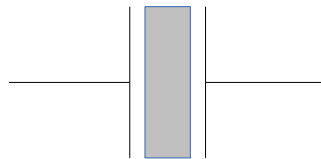
# Timing



A 16MHz crystal



A watch crystal: 32786 Hz

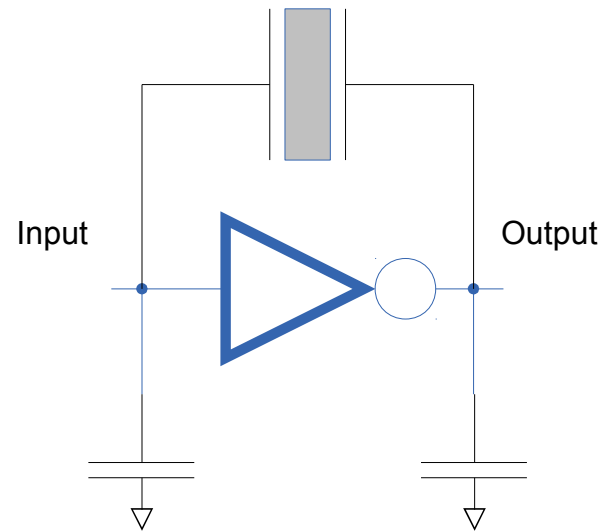


Electrical symbol  
for crystal

# Timing

A crystal controlled oscillator (Pierce oscillator)

Typical accuracy:  $\pm 30\text{ppm}$



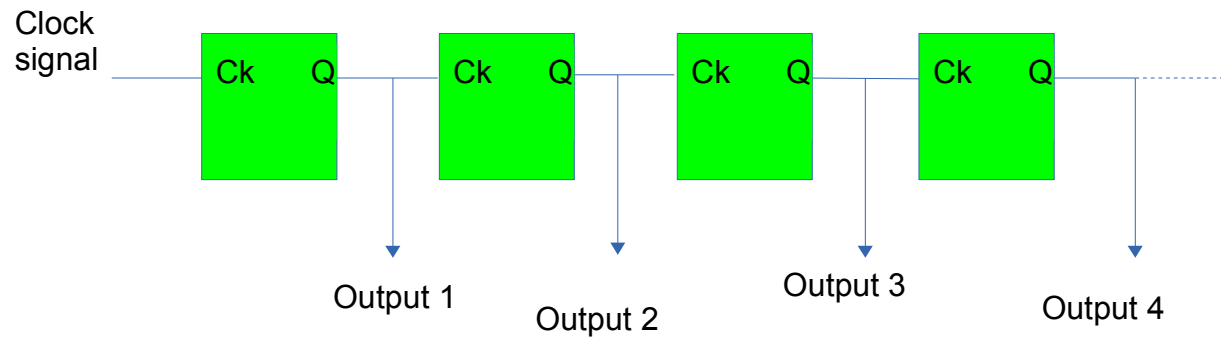
## Timing

- Now have accurate clock signal
- Next requirement: A counter.

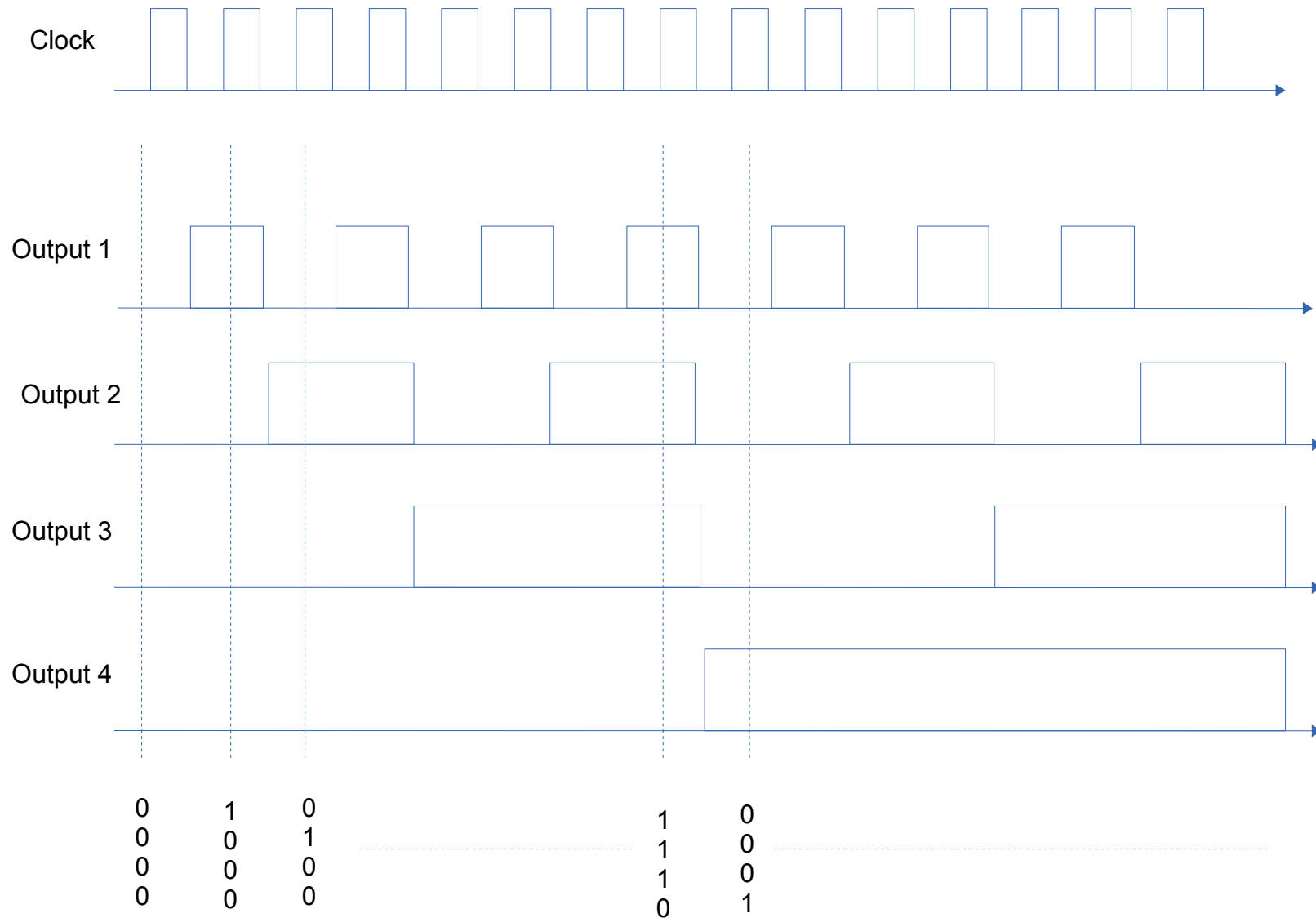
# Timing

A counter consists of an array of flip flops (latches)

The output (Q) of these flip flops changes state when the input (Ck) goes from high to low (a negative edge)



# Timing

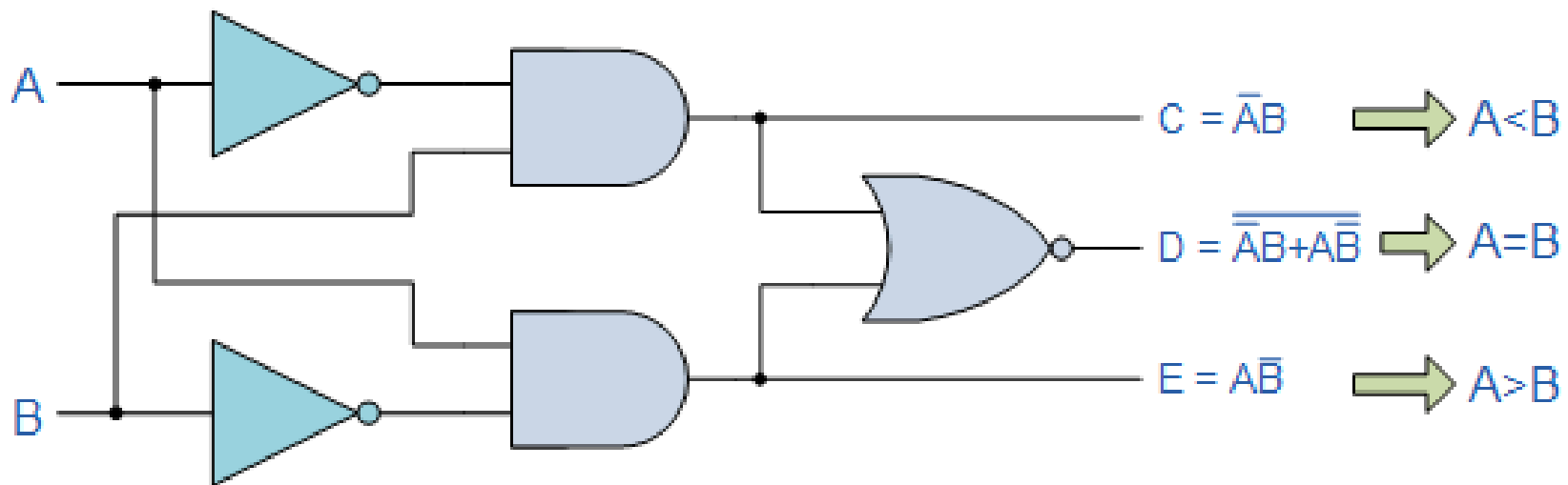


## Timing

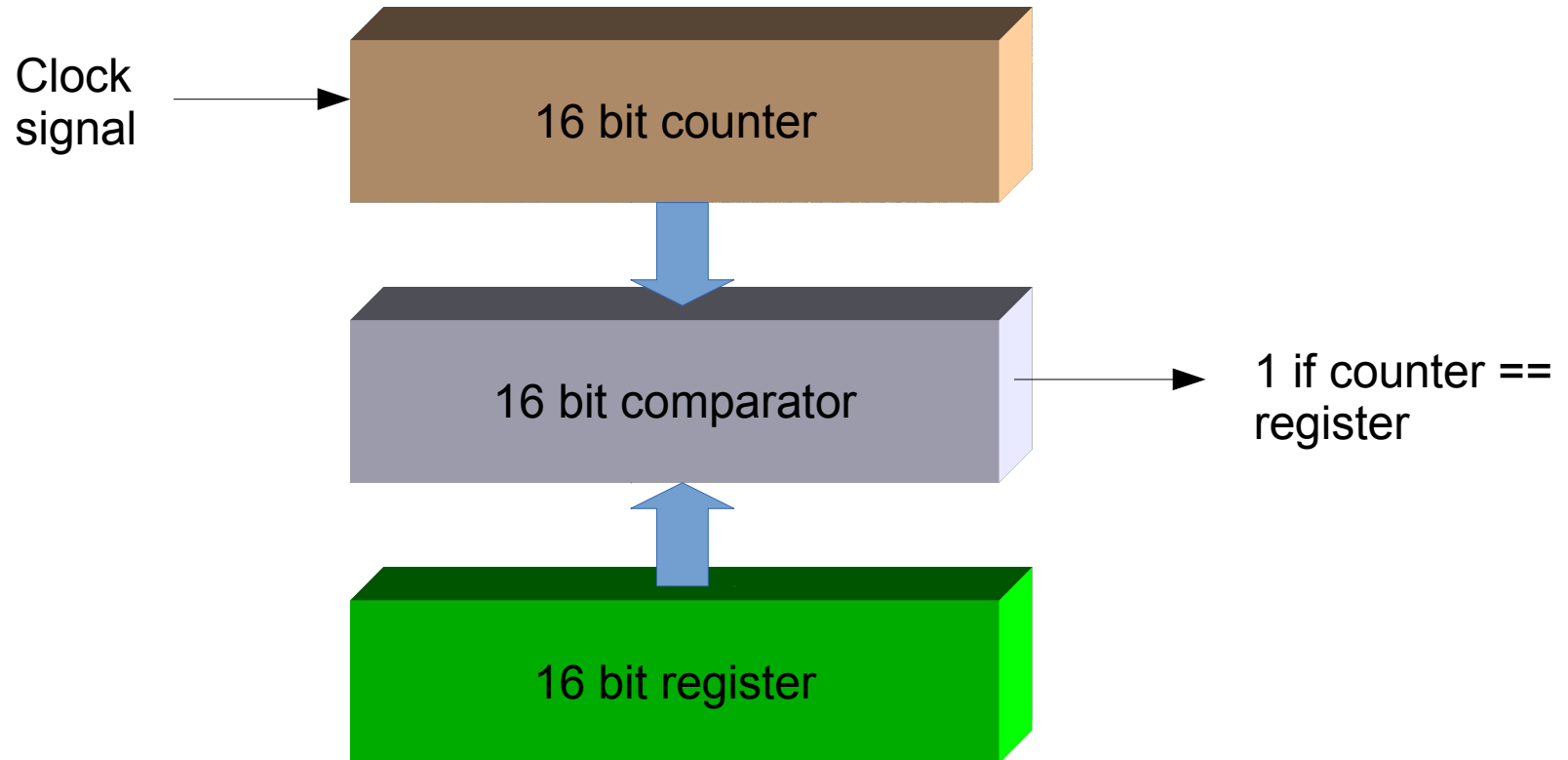
- Counters can be made to count down as well as up
- Counter outputs can be compared with other values
- If Counter value matches some other value then an event can be generated

## Timing

- A 1 bit comparator
- Middle output (D) is 1 if  $A=B$

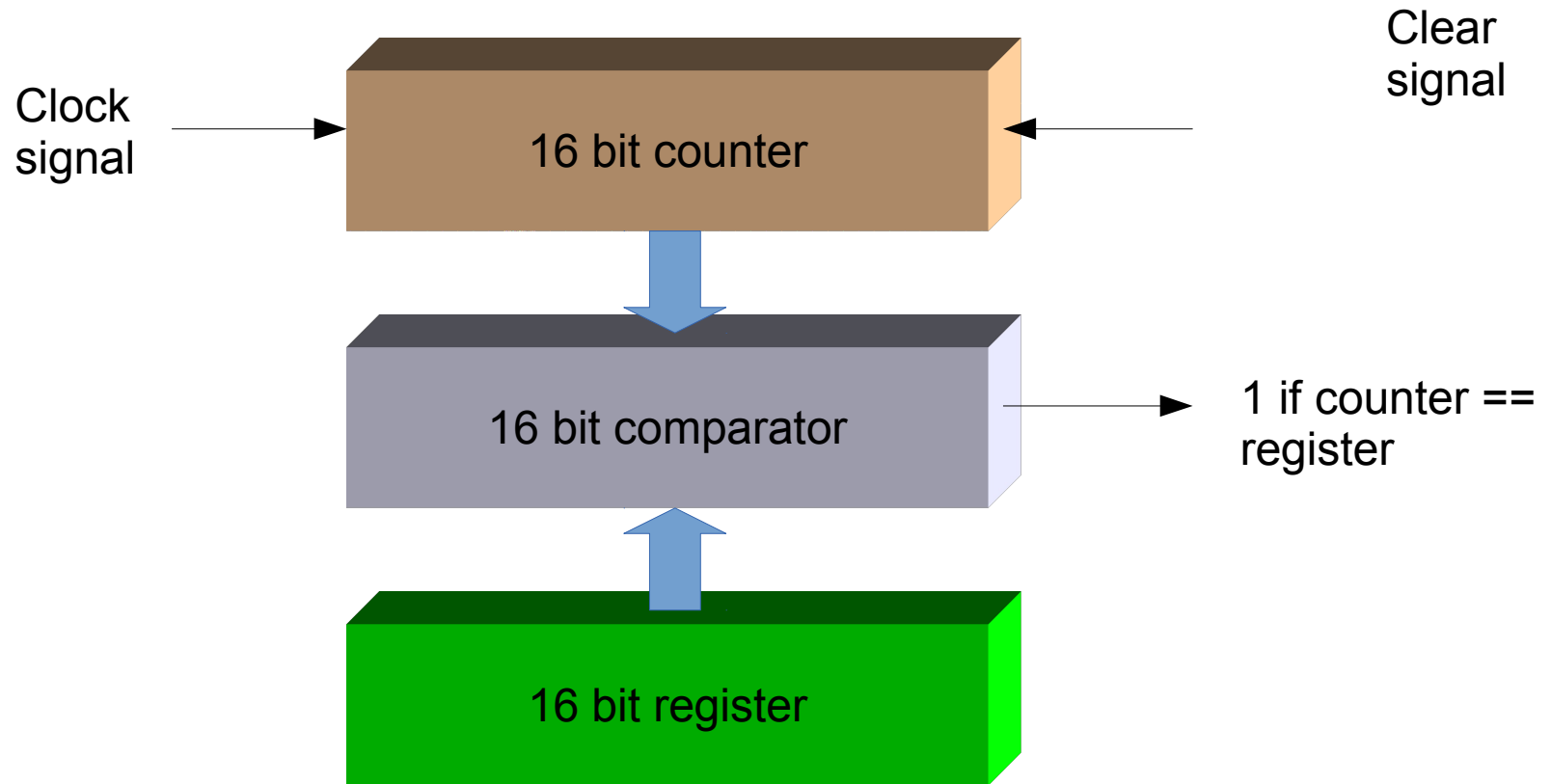


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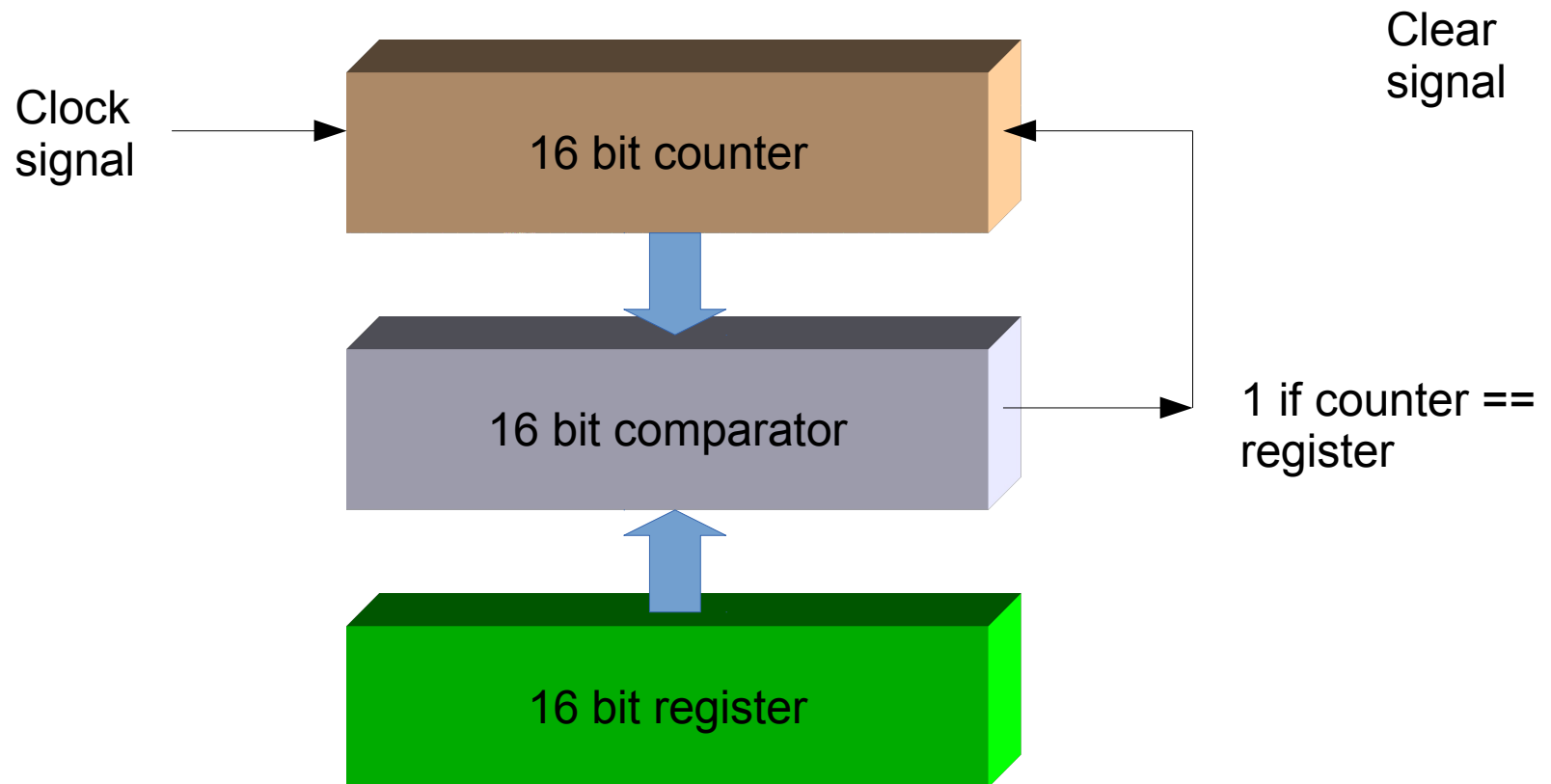


# Timing



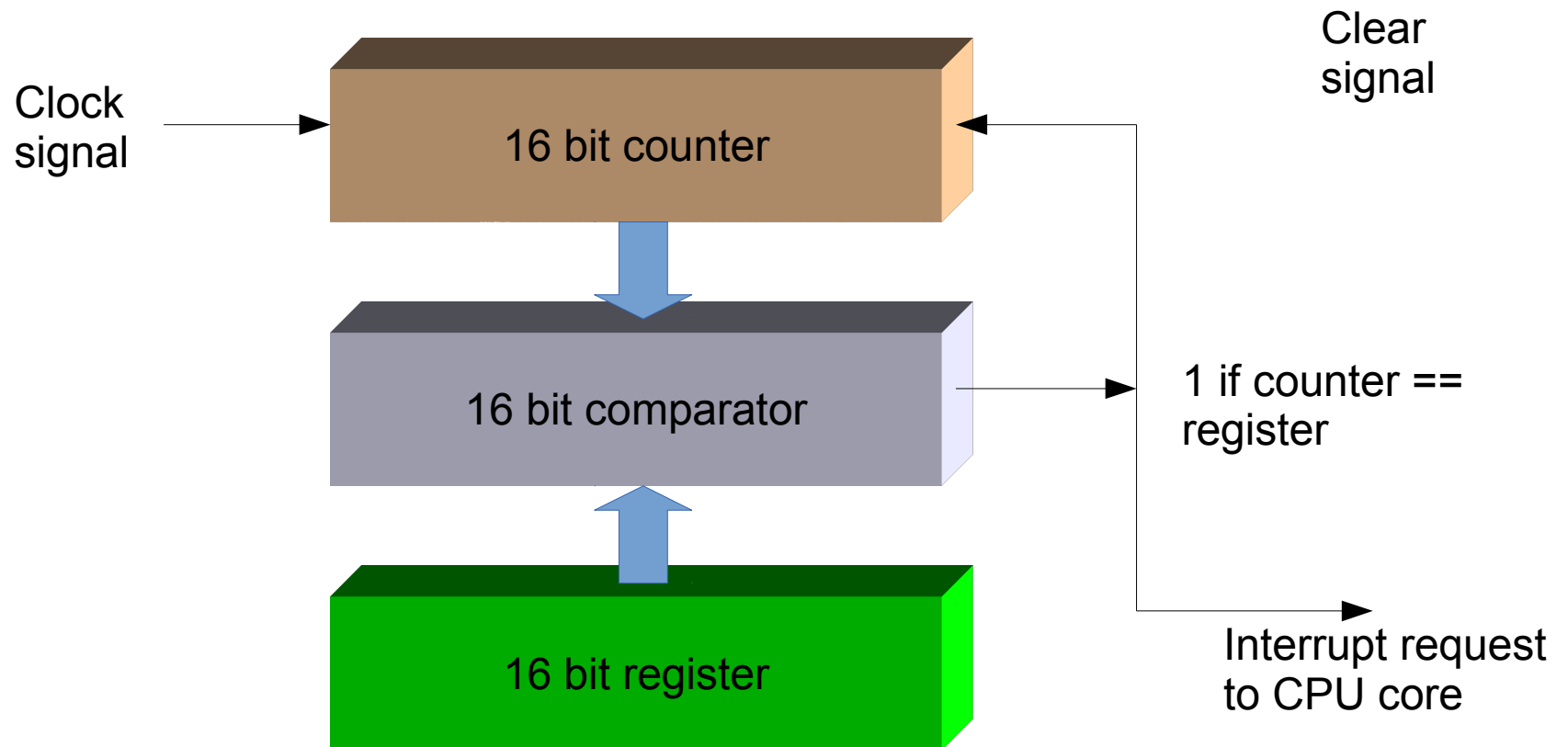
Counters usually have a “clear” input

# Timing



What happens when we connect the “match” signal to the clear signal?

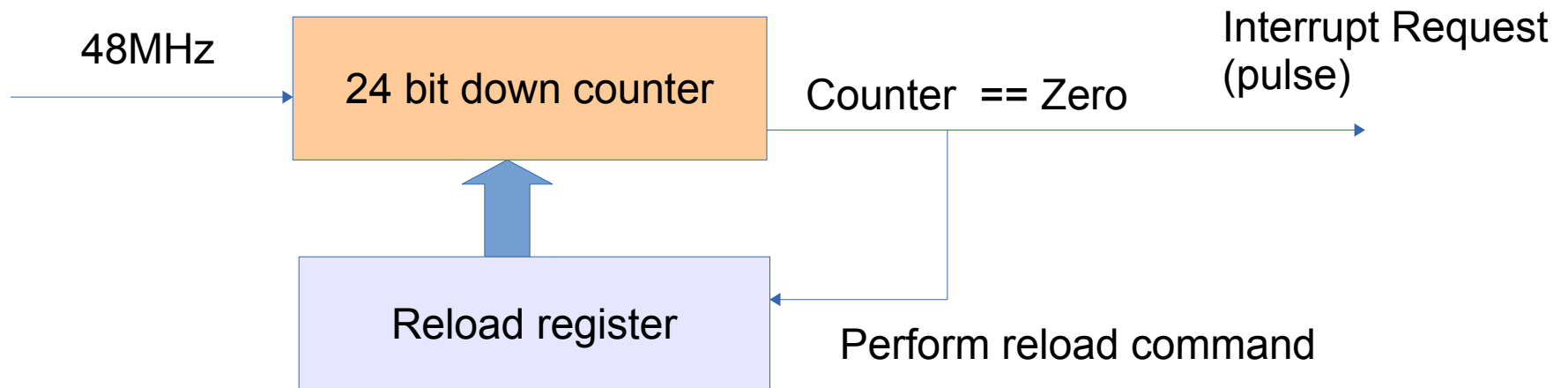
# Timing



We can use this periodic pulse to control the execution of a program

# Timing

- The Cortex M SysTick interrupt
- Used to generate periodic interrupts
- Useful for:
  - General timing duties
  - Multitasking



# Timing

- What is the slowest interrupt request rate?
- What goes in the reload register for 100Hz interrupt rate?

