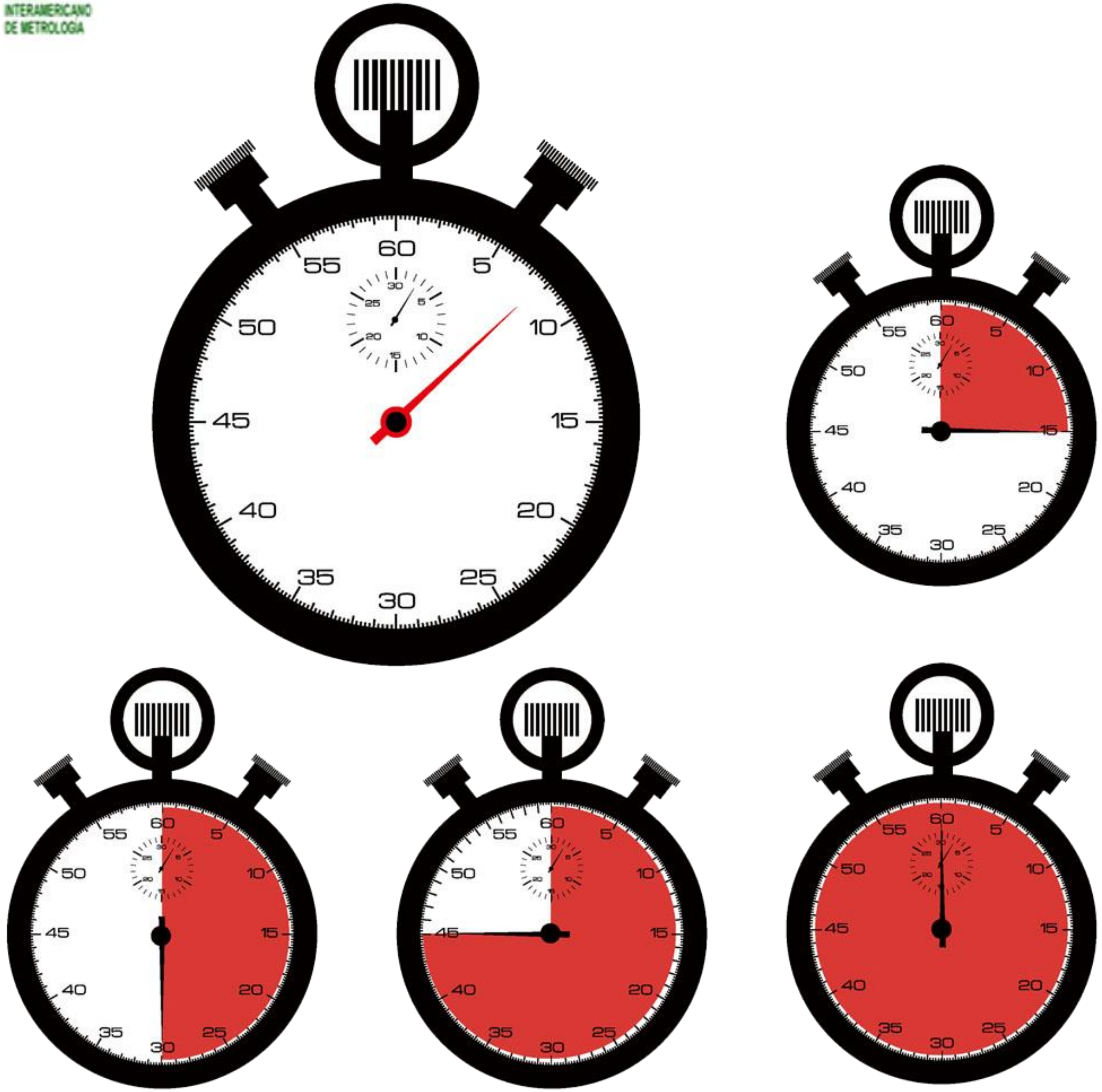
Time, Time Difference and Time Interval

2022 SIM TFMWG Virtual Workshop

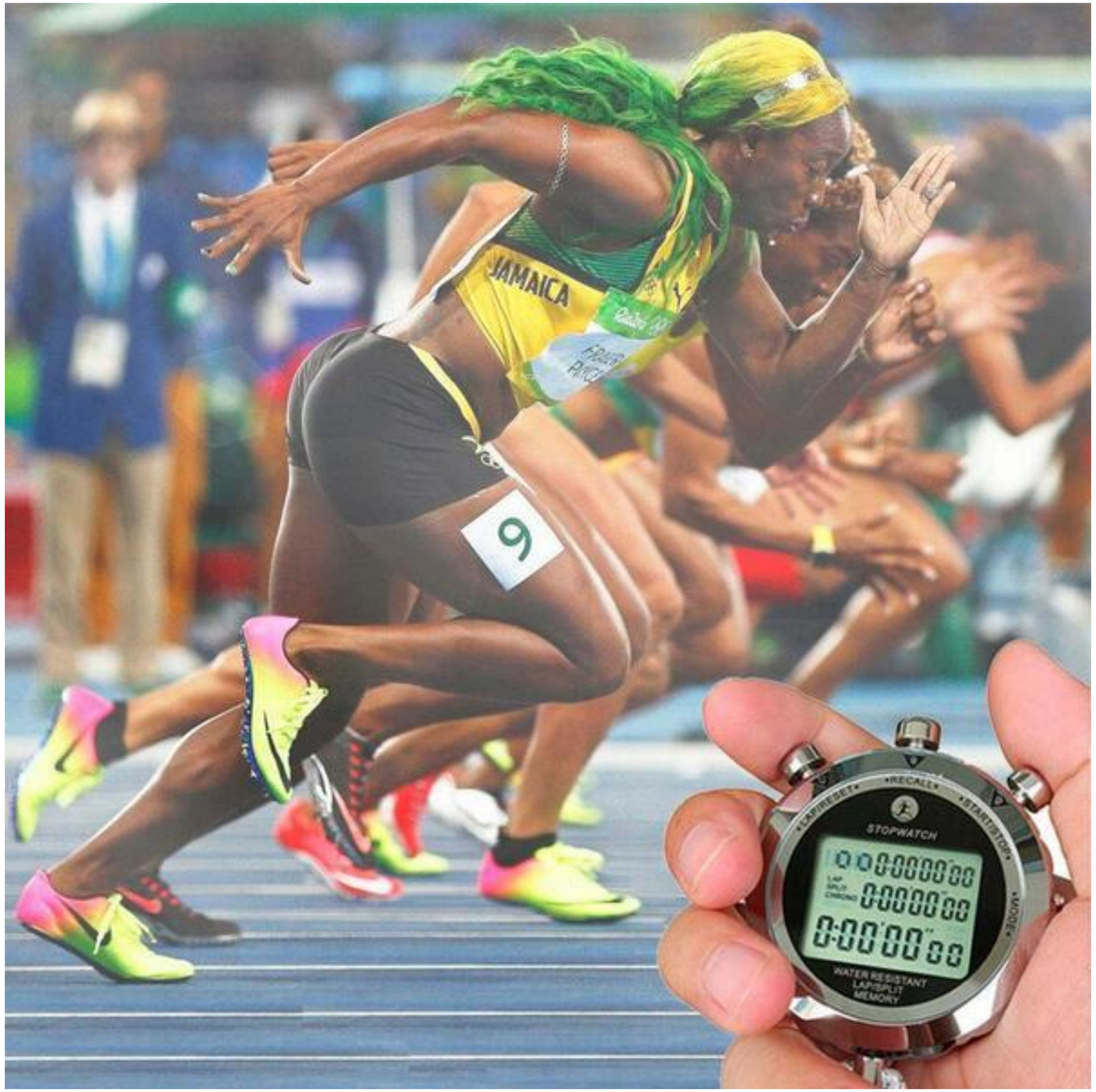
Time Interval Measurements



A time interval measurement is a measurement of the elapsed time between some designated START phenomena and a later STOP phenomena.

Tiempo y Frecuencia

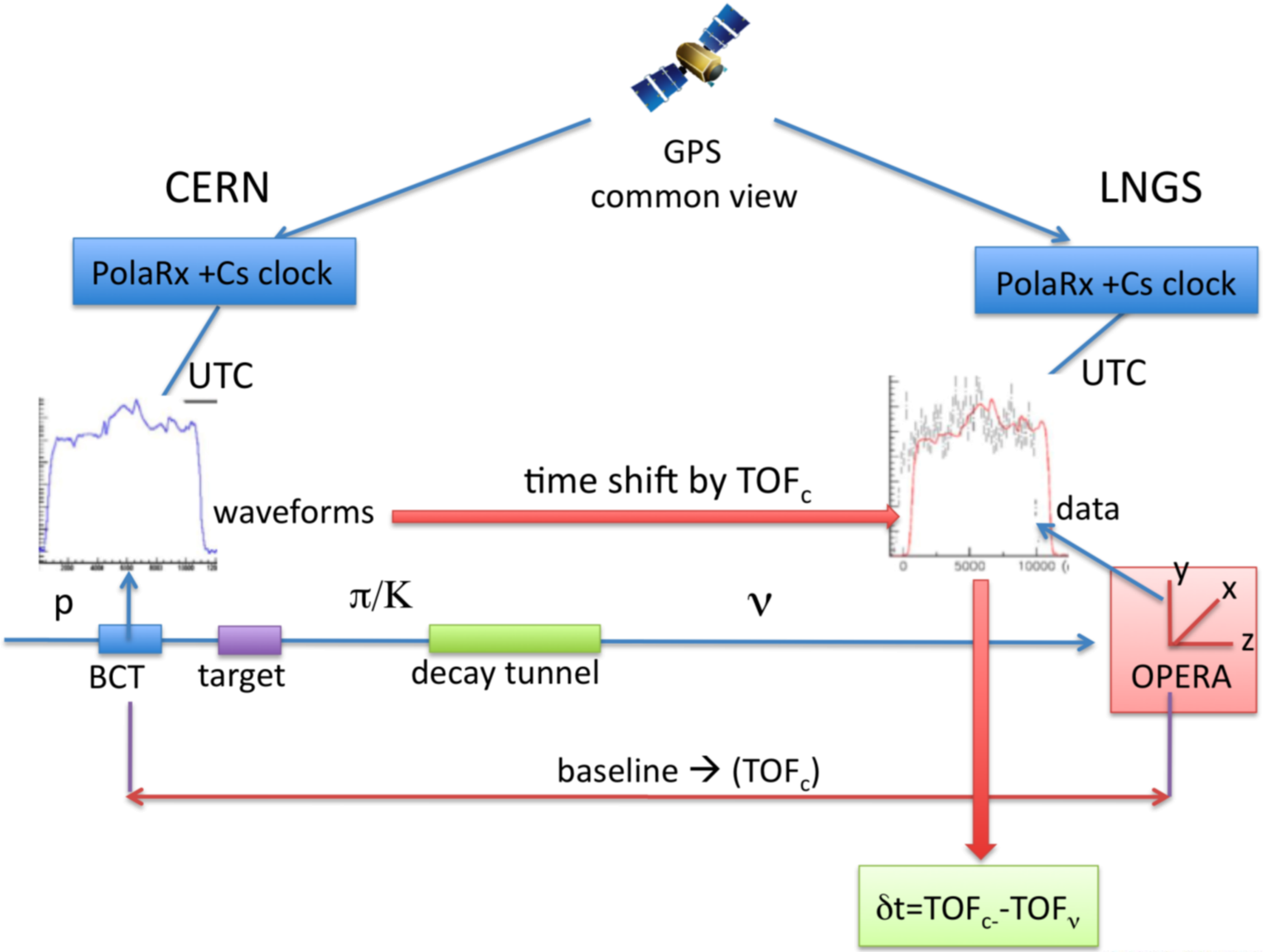
Time Interval Measurements



Time Interval Measurements

Tiempo y Frecuencia

Time Interval Measurements



GPS
common view

CERN

PolaRx +Cs clock

UTC

LNGS

PolaRx +Cs clock

UTC

waveforms

time shift by TOF_c

data

p

π/K

ν

BCT

target

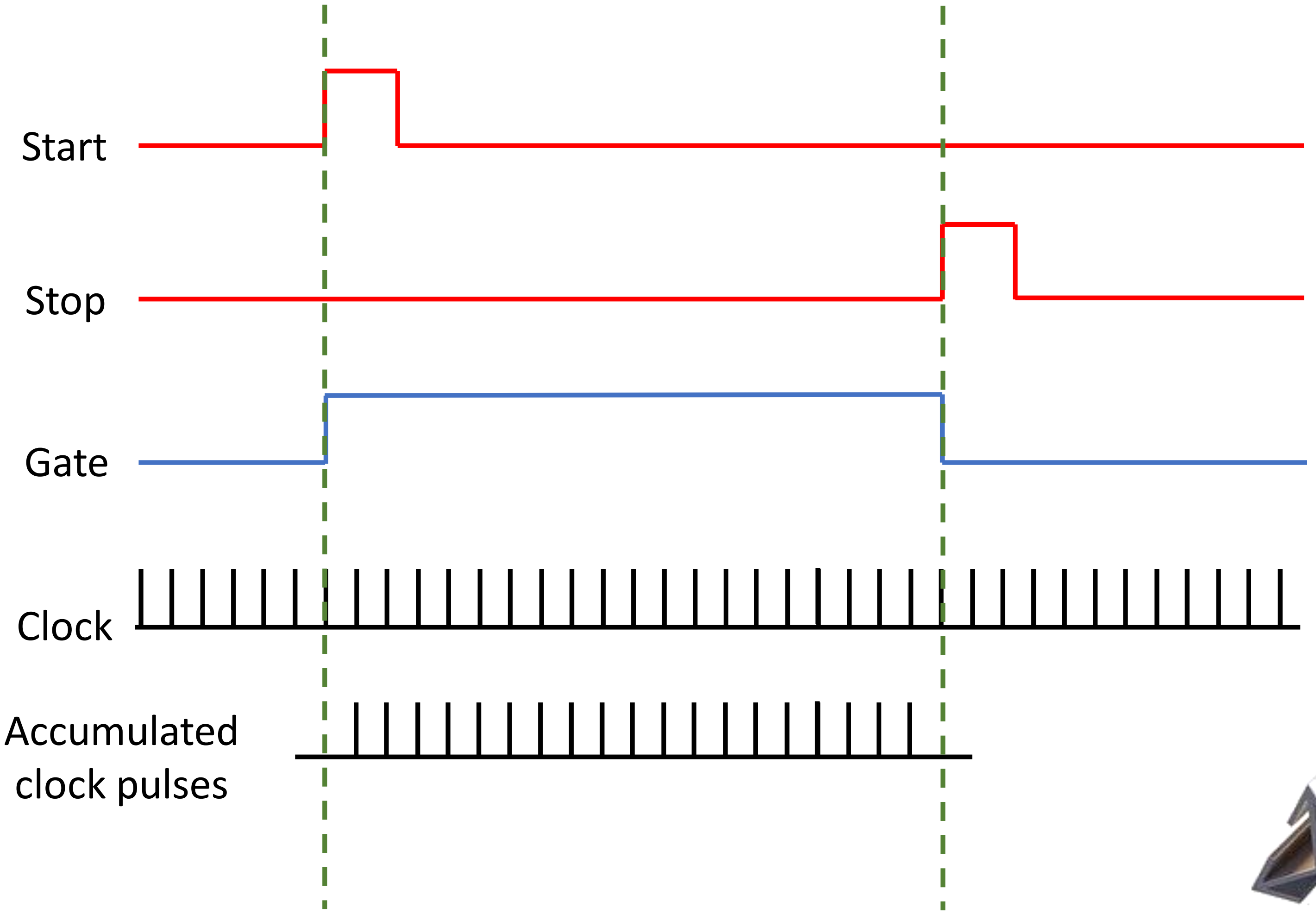
decay tunnel

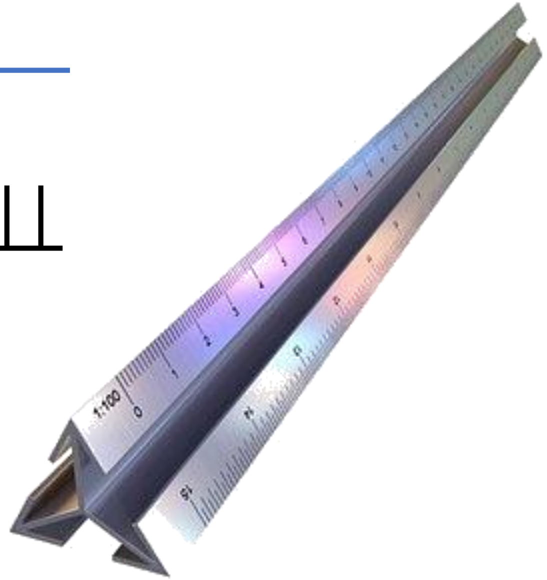
OPERA

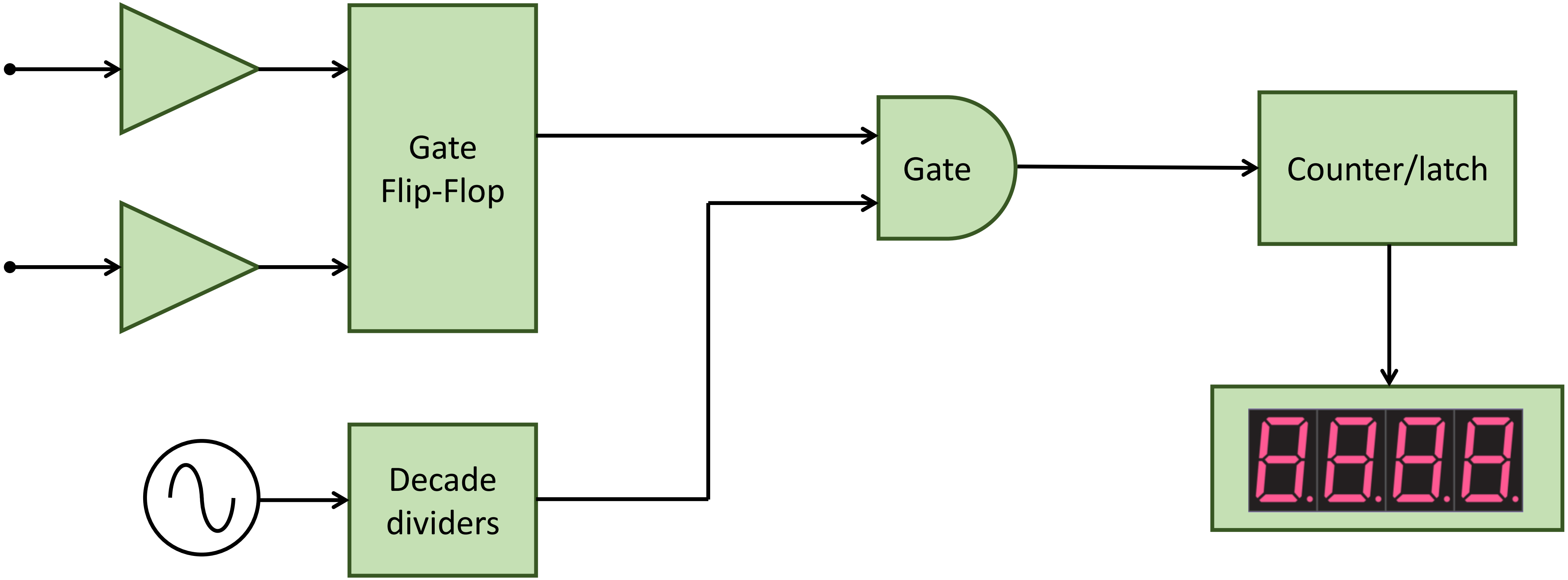
baseline → (TOF_c)

$\delta t = TOF_{c} - TOF_{\nu}$

Electronic Counter







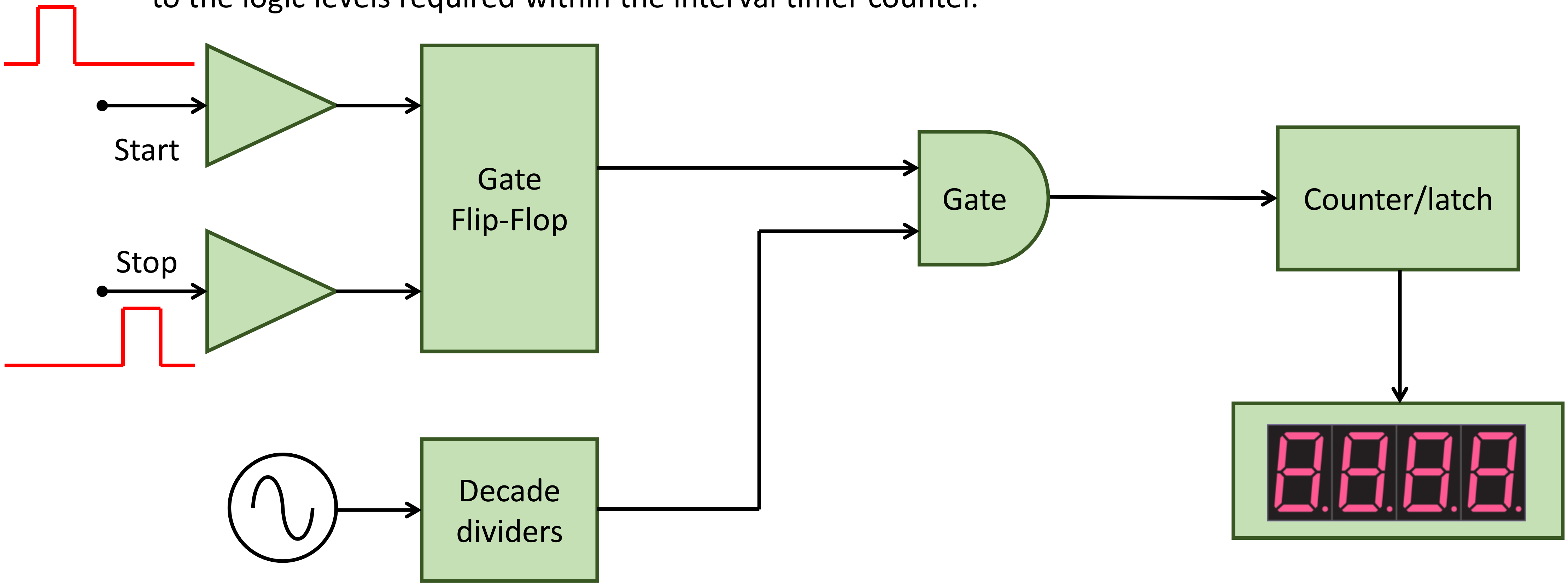
Gate Flip-Flop

Gate

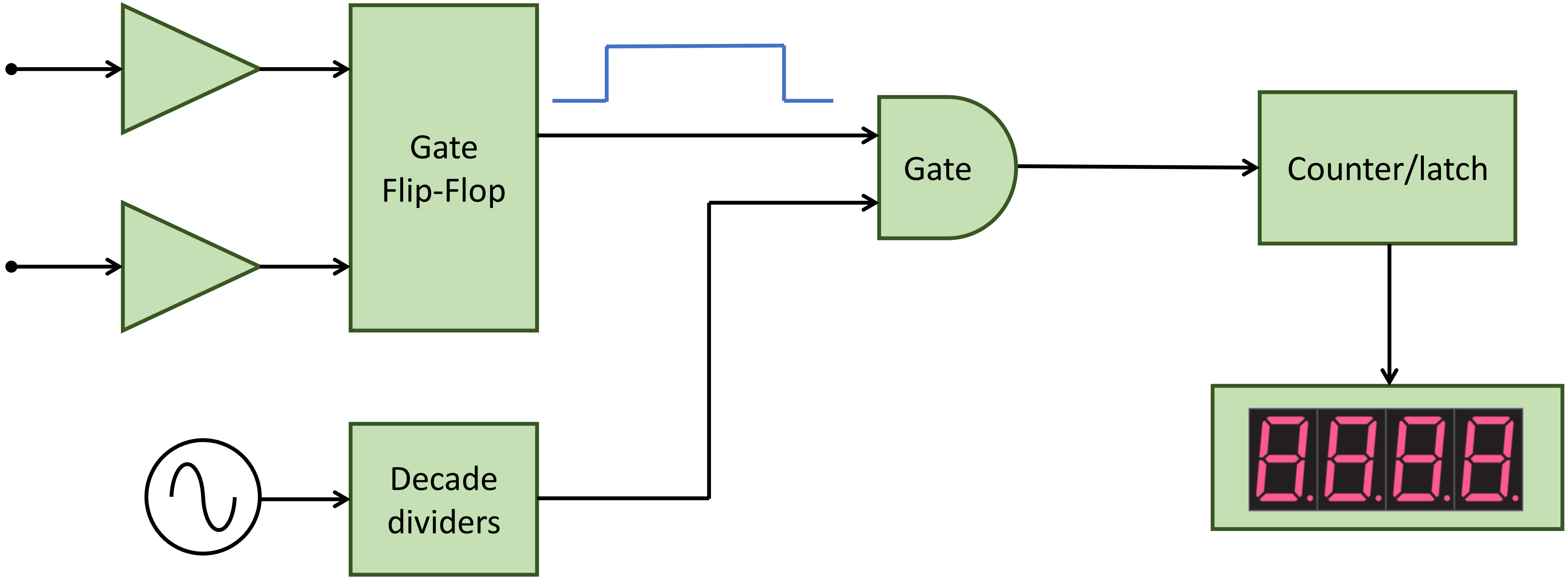
Counter/latch

Decade dividers

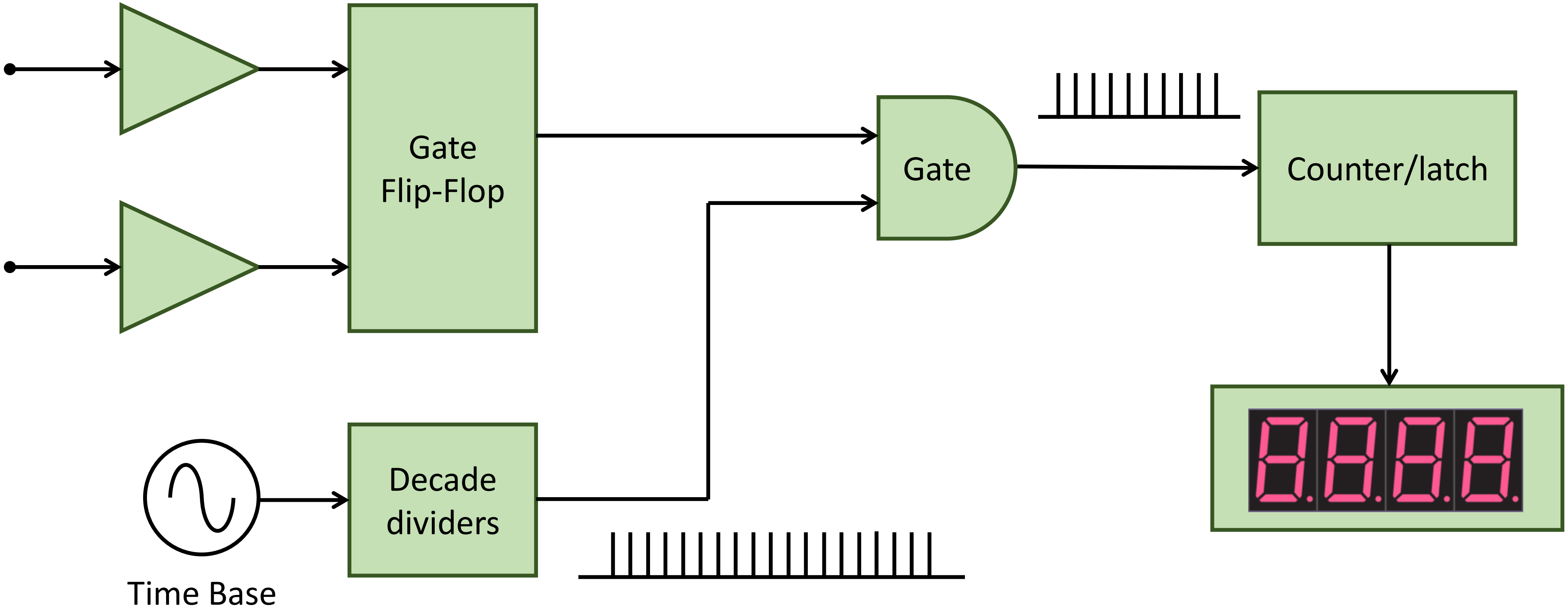
Signal input stages: The input stages condition the input signals and convert them to the logic levels required within the interval timer counter.



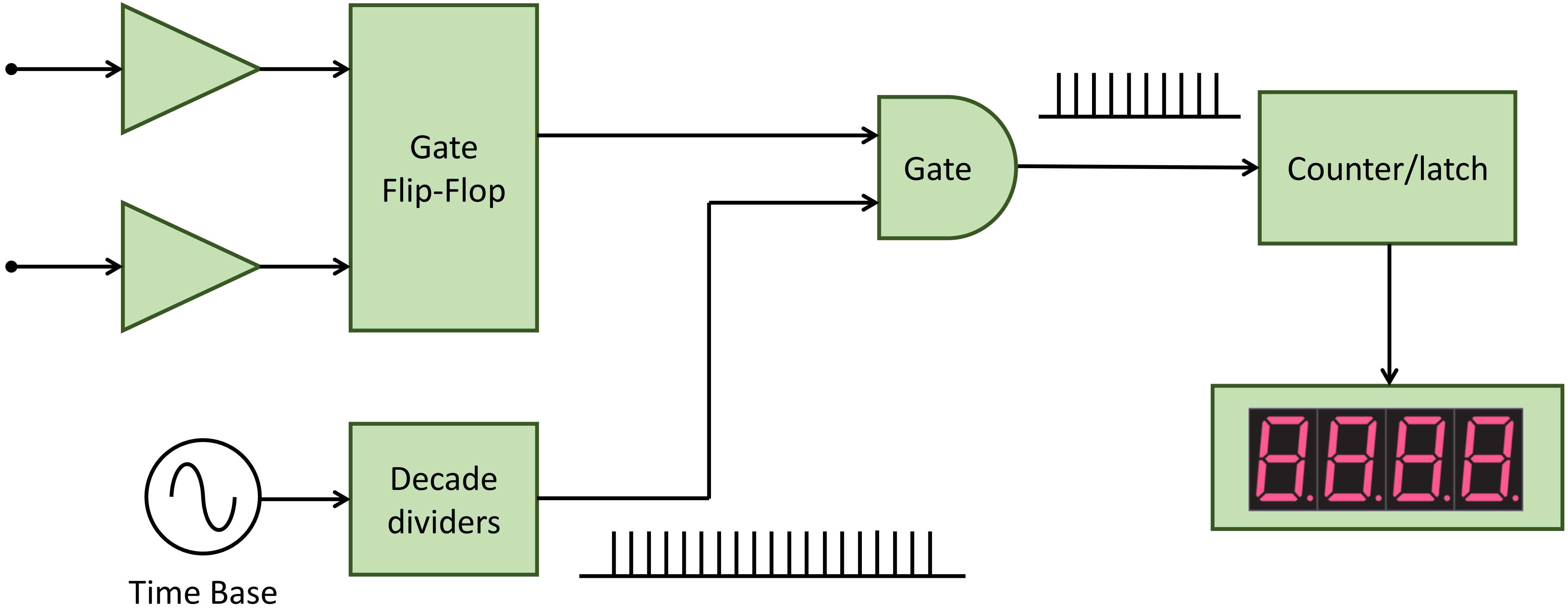
Gate Flip-Flop: The Gate Flip Flop then generates a pulse equal to the length of the timer interval required.



Oscillator and gate: Elapsed time between start and stop is measured by counting the Time Base frequency while the gate is open.

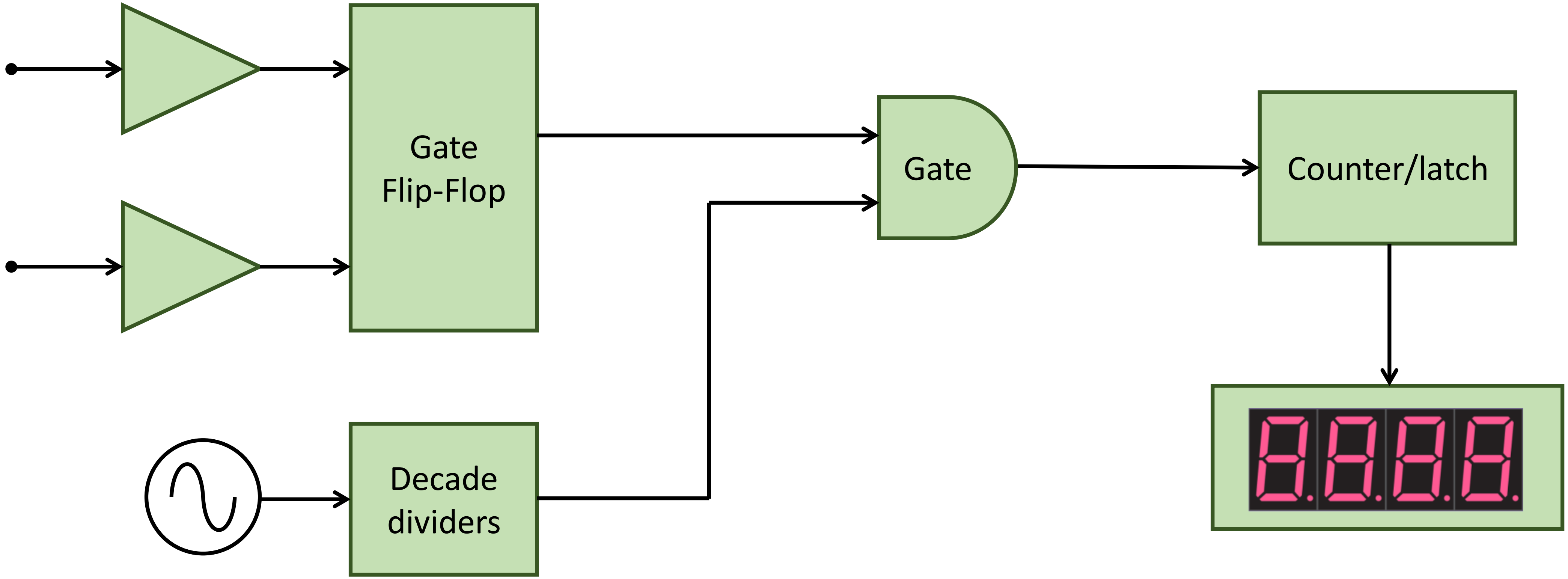


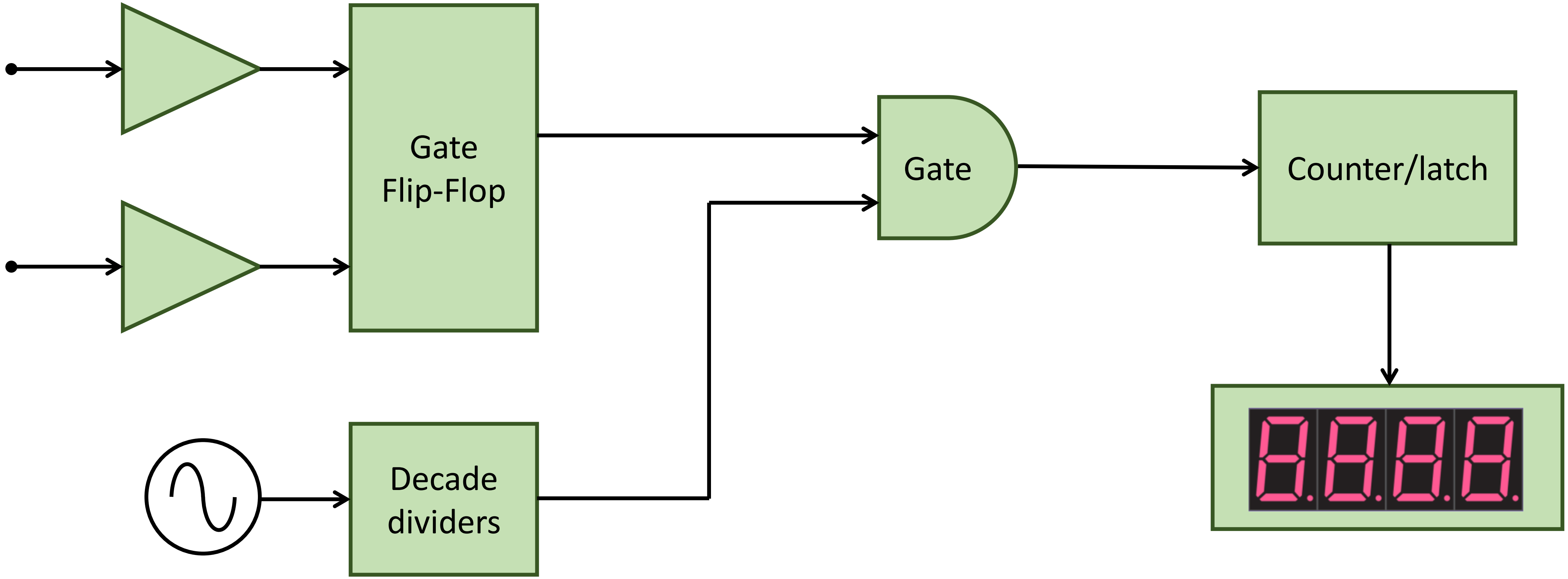
Oscillator and gate: Elapsed time between start and stop is measured by counting the Time Base frequency while the gate is open.



For conventional counters, direct readout is achieved by using clock frequencies related by powers of 10 — i.e., 1 MHz, 10 MHz, 100 MHz, etc., (period of 1 μs, 100 ns, 10 ns, respectively)

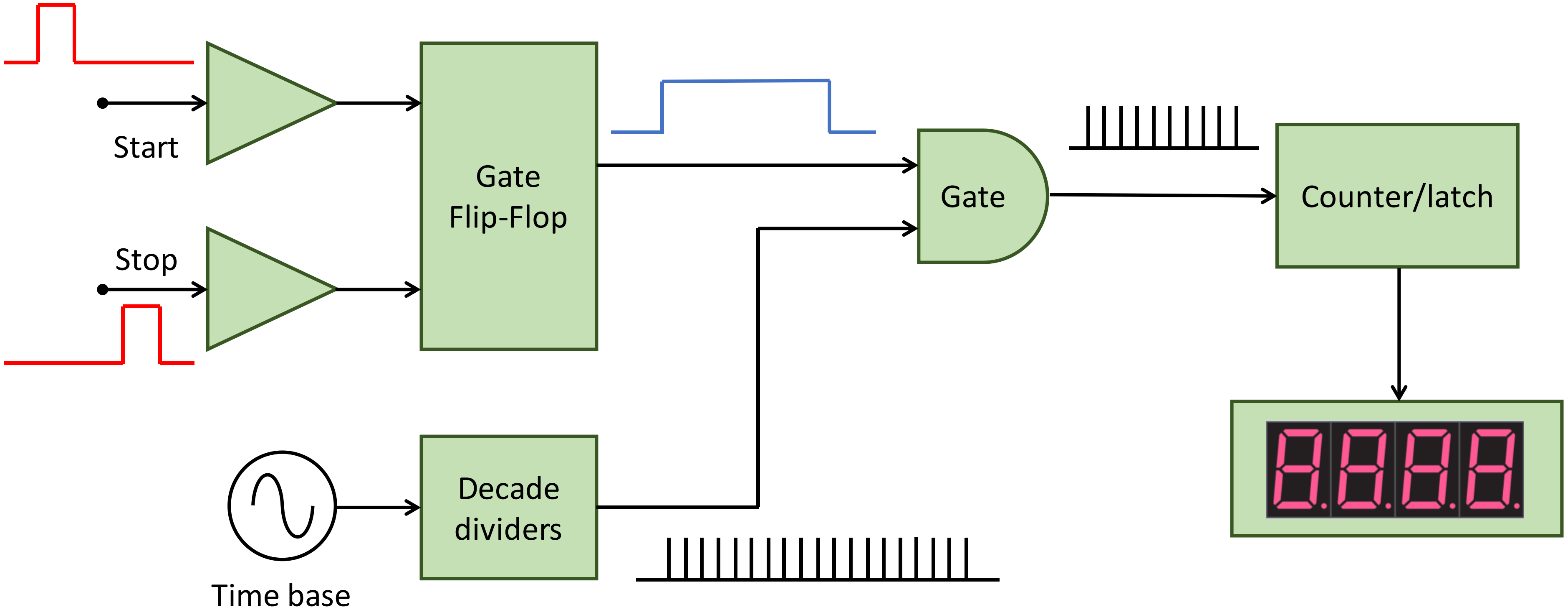
Counter/ latch: The counter takes the incoming pulses from the gate. It has a set of divide-by-10 stages as a decimal based display is required. The number of stages within the overall counter is equal to the number of display digits minus 1. As the counters are chained the first stage is the input divided by ten, the next is the input divided by 10 x 10 (100) as it has been divided by two stages, and so forth.



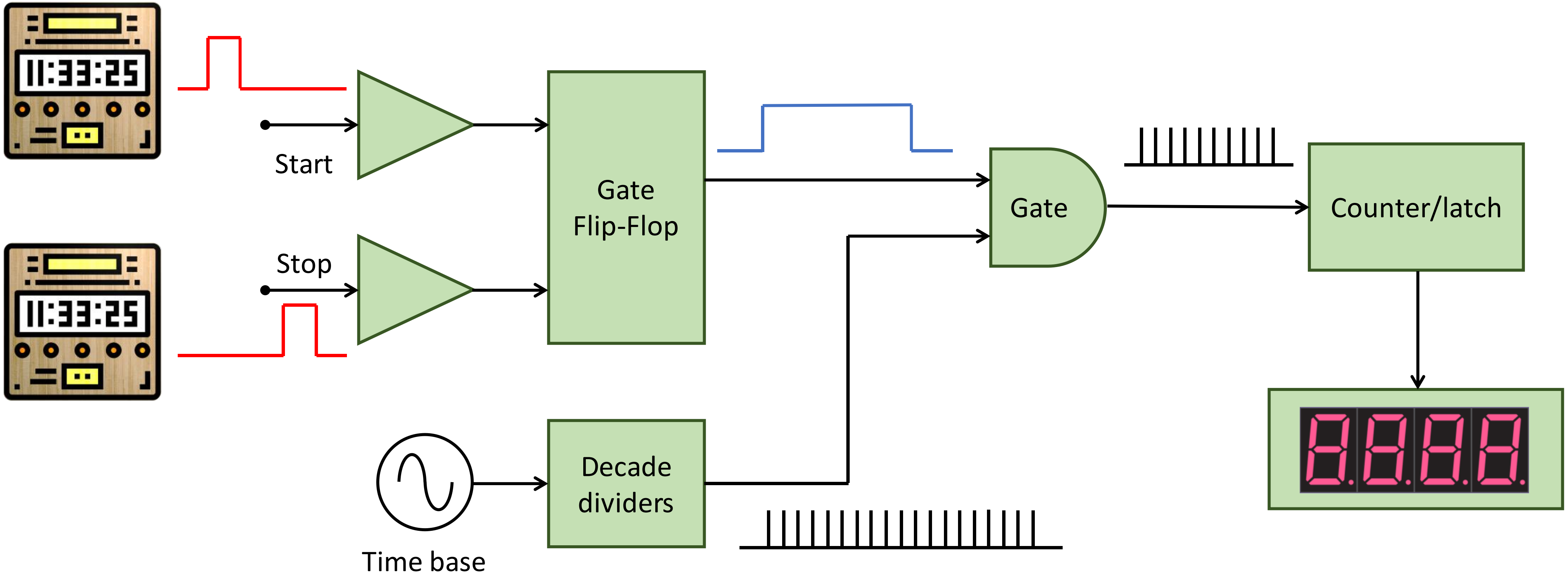


Display: The display takes the output from the latch and displays it in a normal readable format. There is a digit for each decade the counter can display. The display will be programmed to place the decimal point in the correct position. For example for the 1 second time interval with a 1 MHz clock, 1 000 000 pulses are counted and the decimal point will need to be placed after the figure 1 to indicate 1.000 000 seconds.

Time Difference Measurements

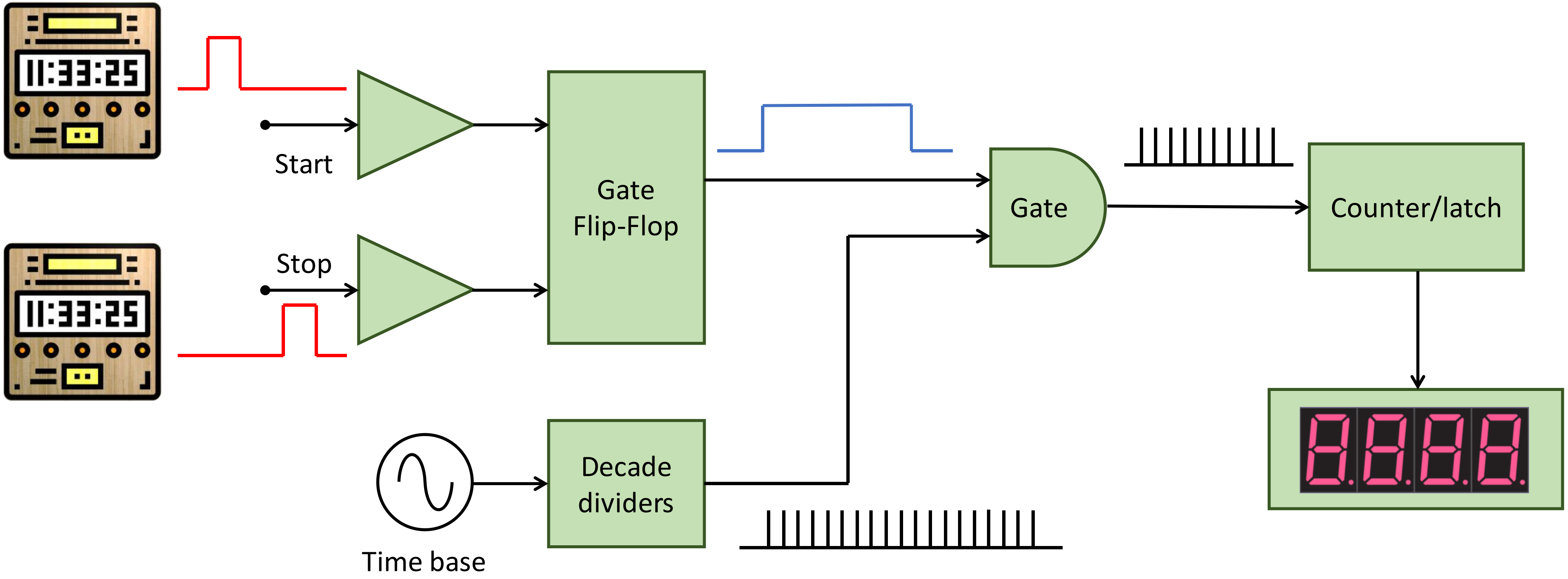


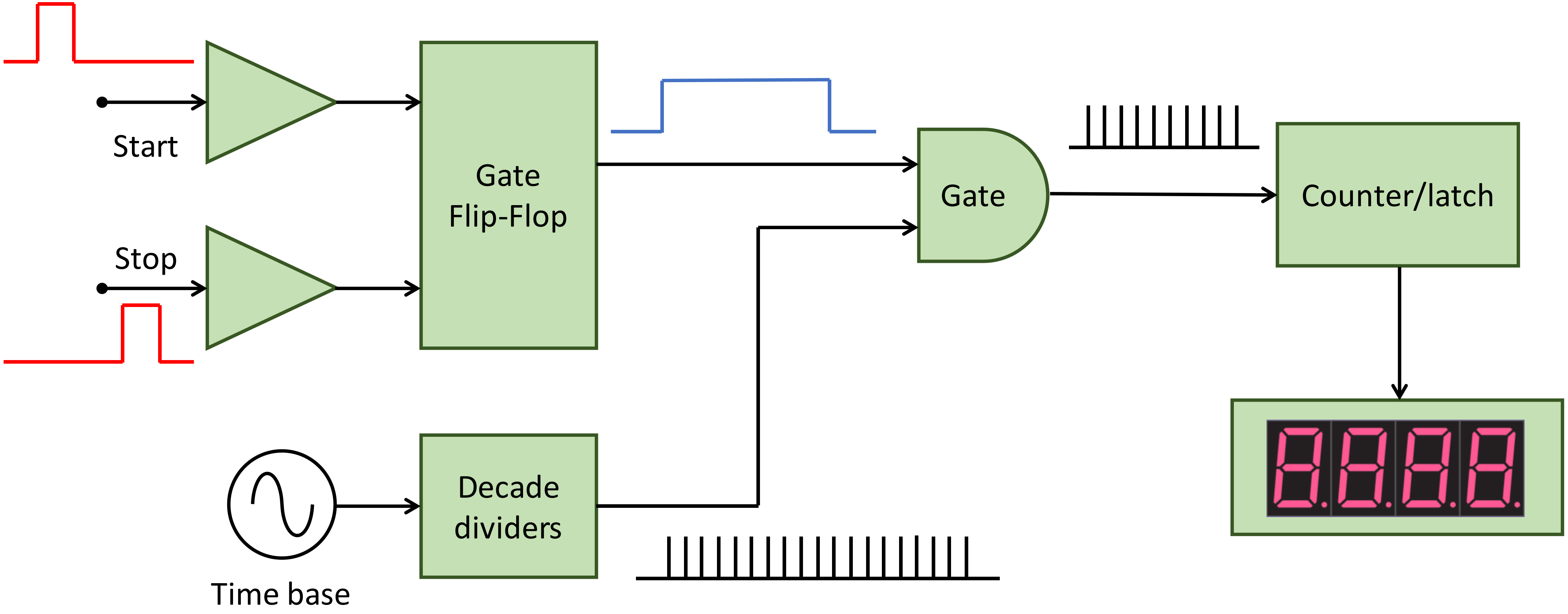
Time Difference Measurements



Time Difference Measurements

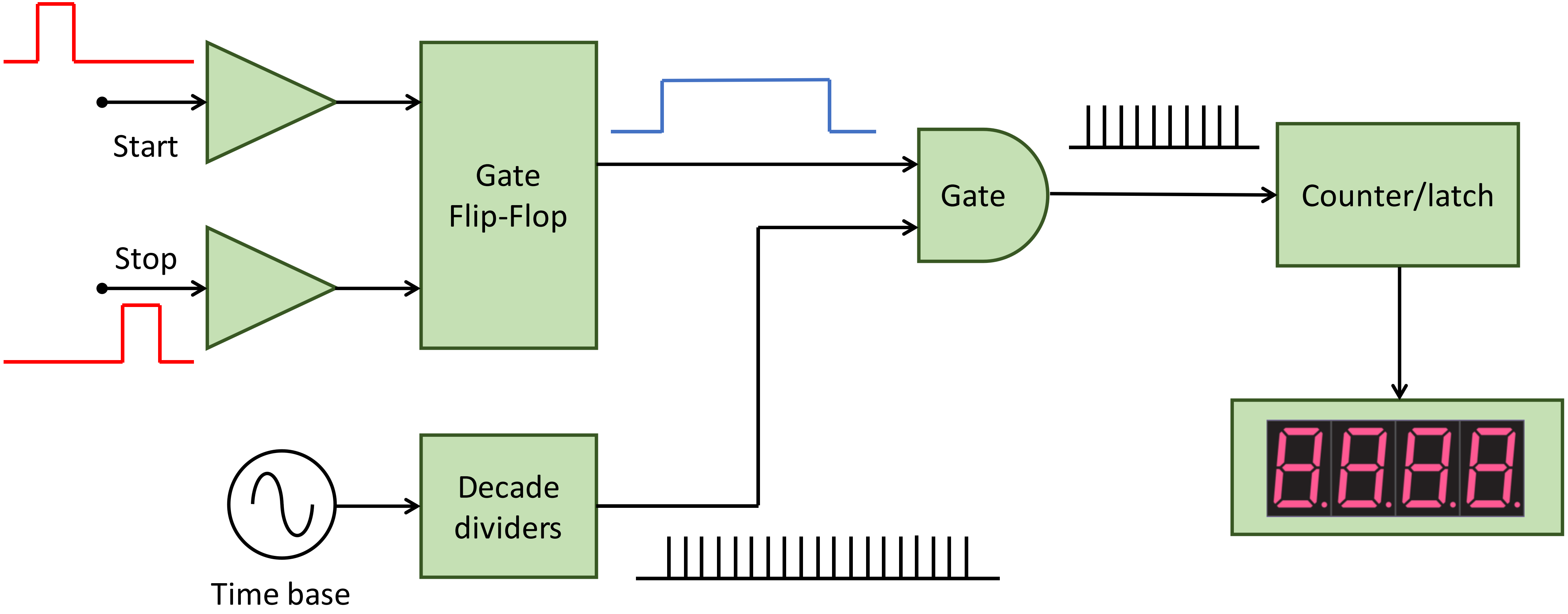
The difference between one measurement of time and another



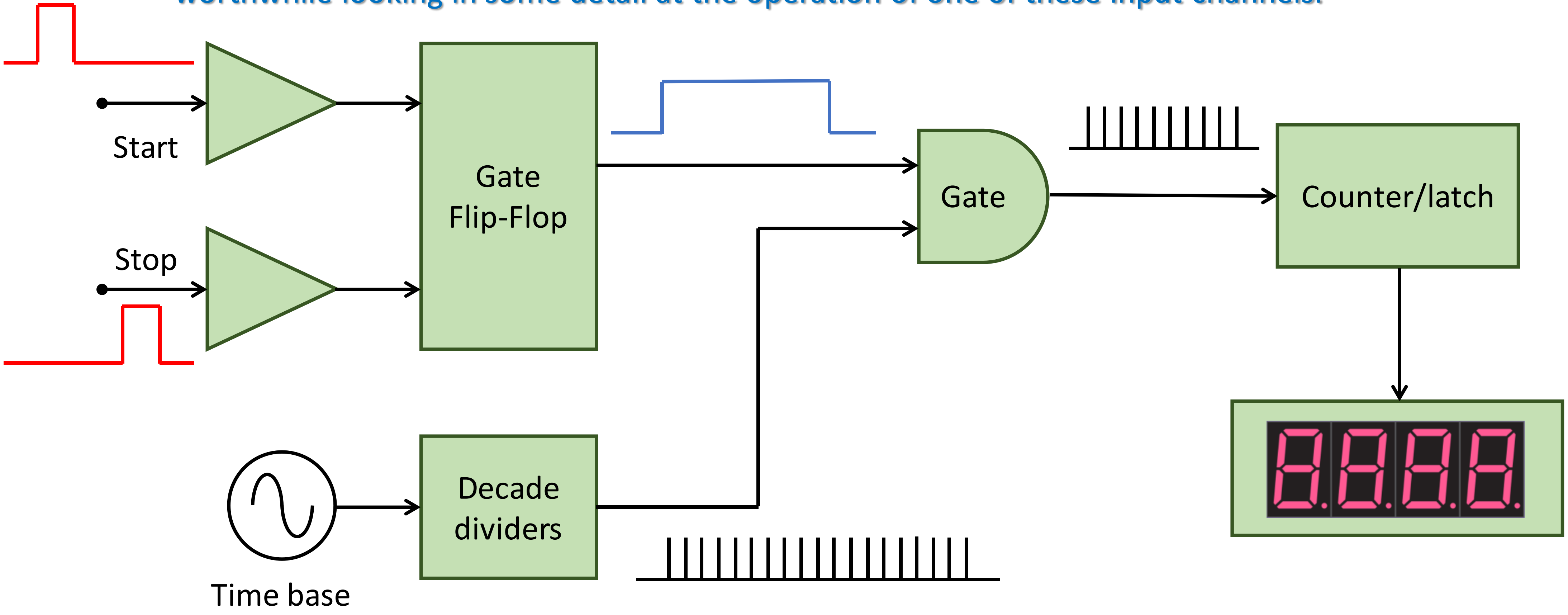


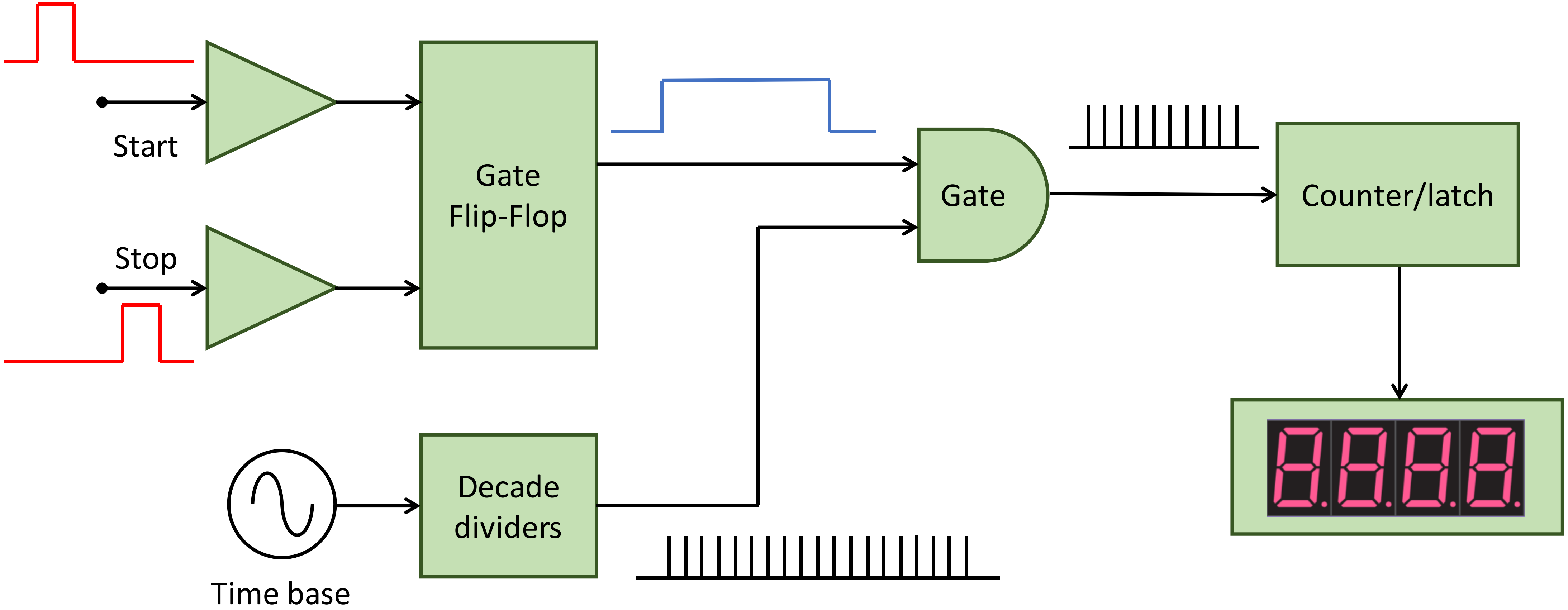
The resolution of a conventional time interval counter is determined by its time base frequency. A frequency of 1 MHz gives 1 μsec resolution, 100 MHz gives 10 ns resolution, 500 MHz gives 2 ns resolution and so on.

Since the input amplifier-trigger circuits of the counter are the interface from the signal of interest to the counter they are one of the most critical circuit elements in accurate time interval measurements.



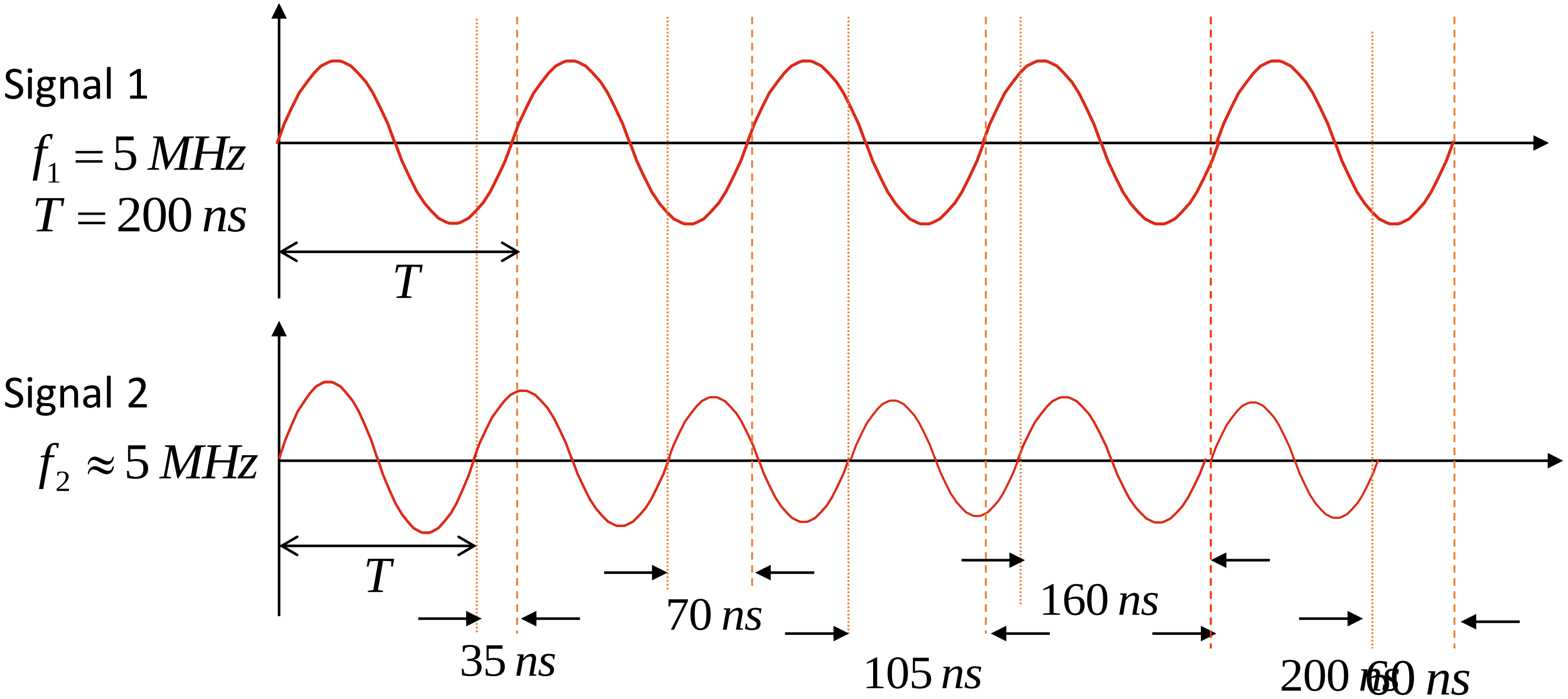
The input amplifier and trigger circuits establish the voltage level at which an input signal will trigger the counter. Noise, drift, ac-dc coupling, and other factors relating to these circuits all influence the measurement. Since these circuits are so important it is worthwhile looking in some detail at the operation of one of these input channels.

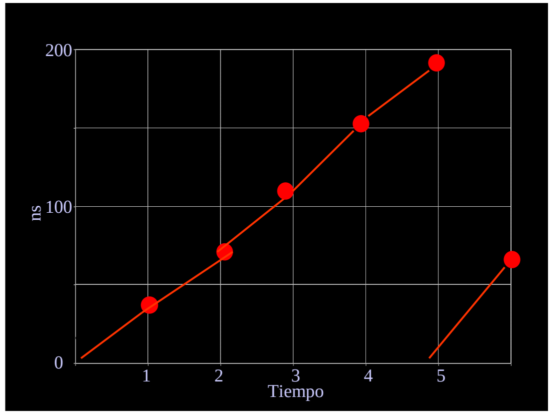


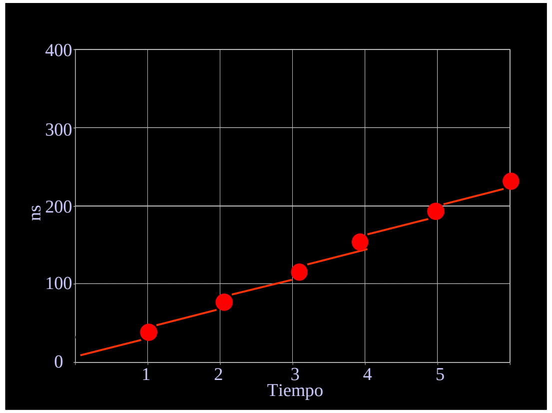


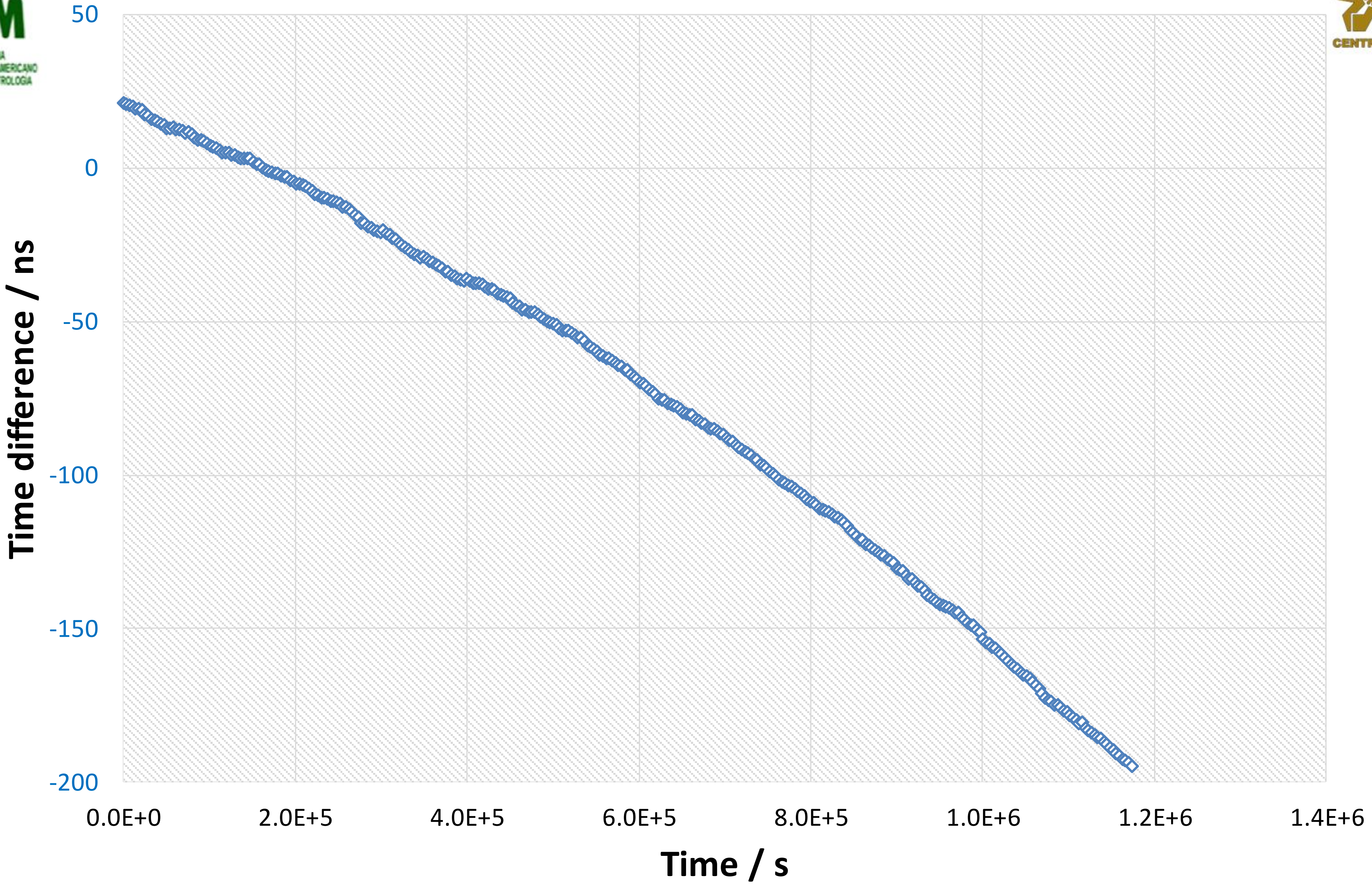
The measurement accuracy of the time interval counter is dependent upon the clock oscillator

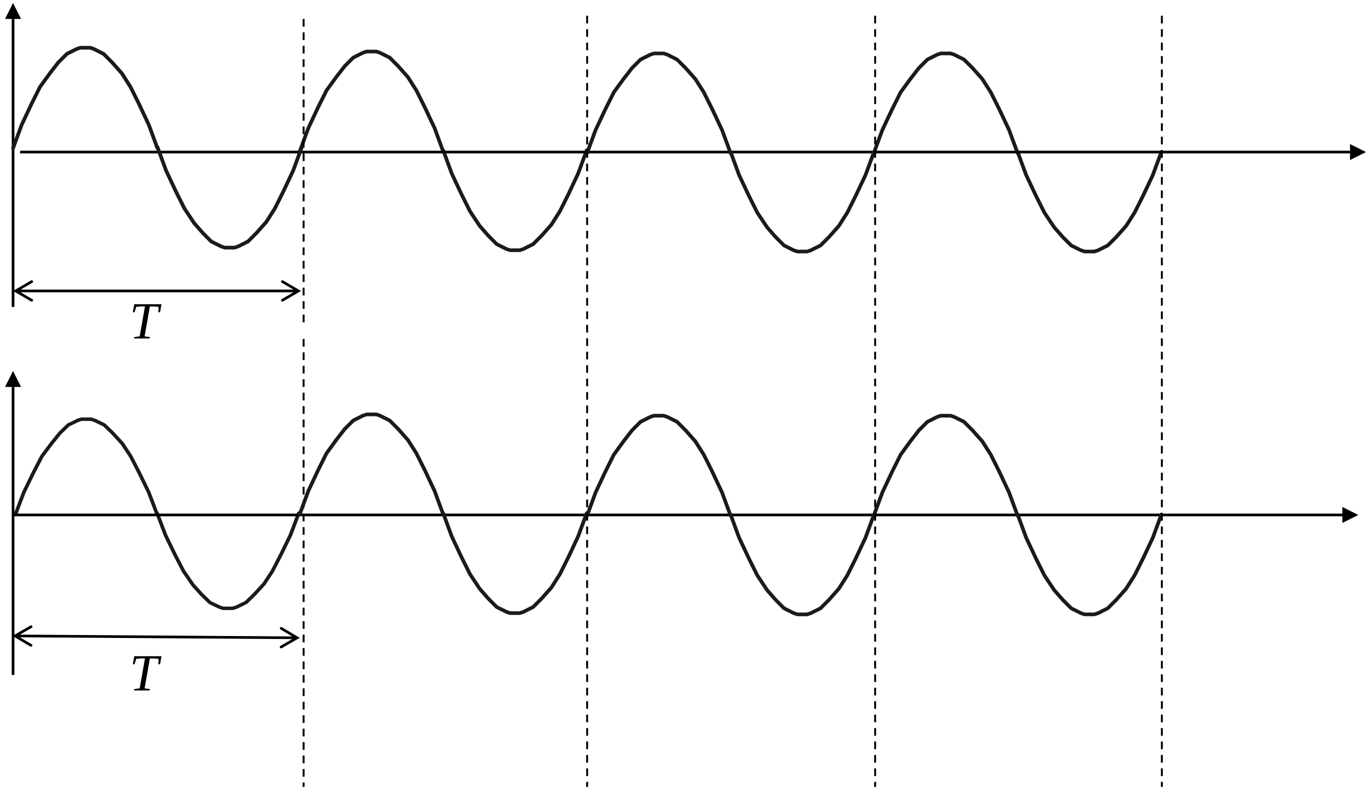
Time Difference Measurements Example








50
0
-50
-100
-150
-200
Time difference / ns
0.0E+0
2.0E+5
4.0E+5
6.0E+5
8.0E+5
1.0E+6
1.2E+6
1.4E+6
Time / s



Signal 1

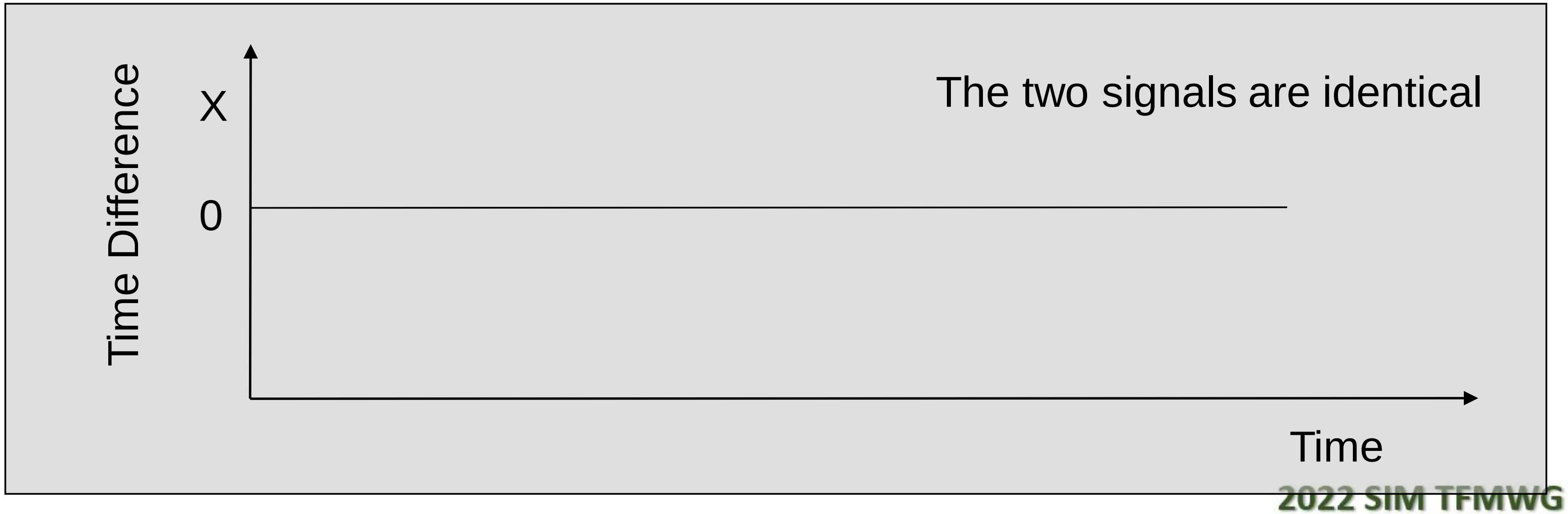
$$f_1 = 5\, MHz$$

$$T = 200\, ns$$

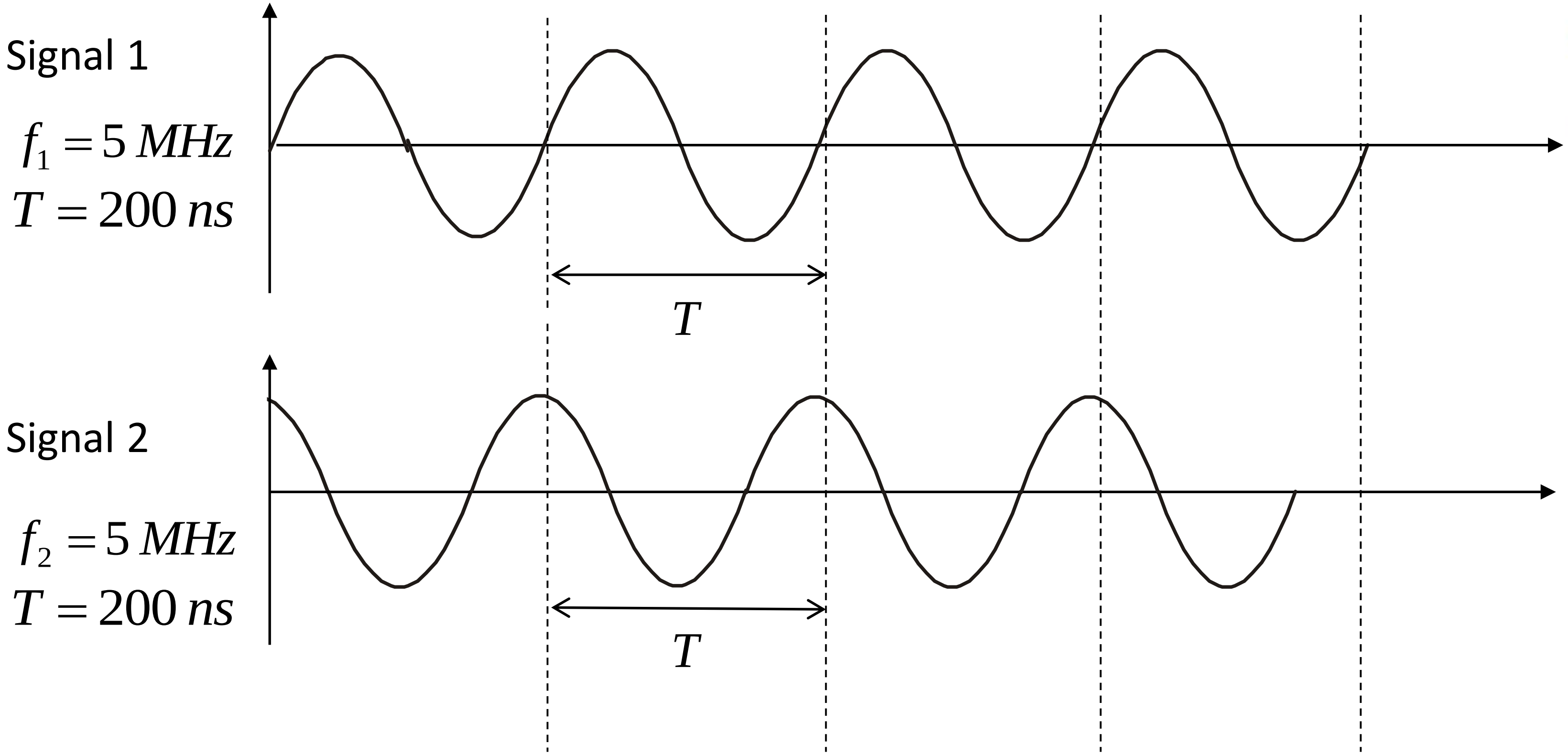
Signal 2

$$f_2 = 5\, MHz$$

$$T = 200\, ns$$



The two signals are identical


Signal 1

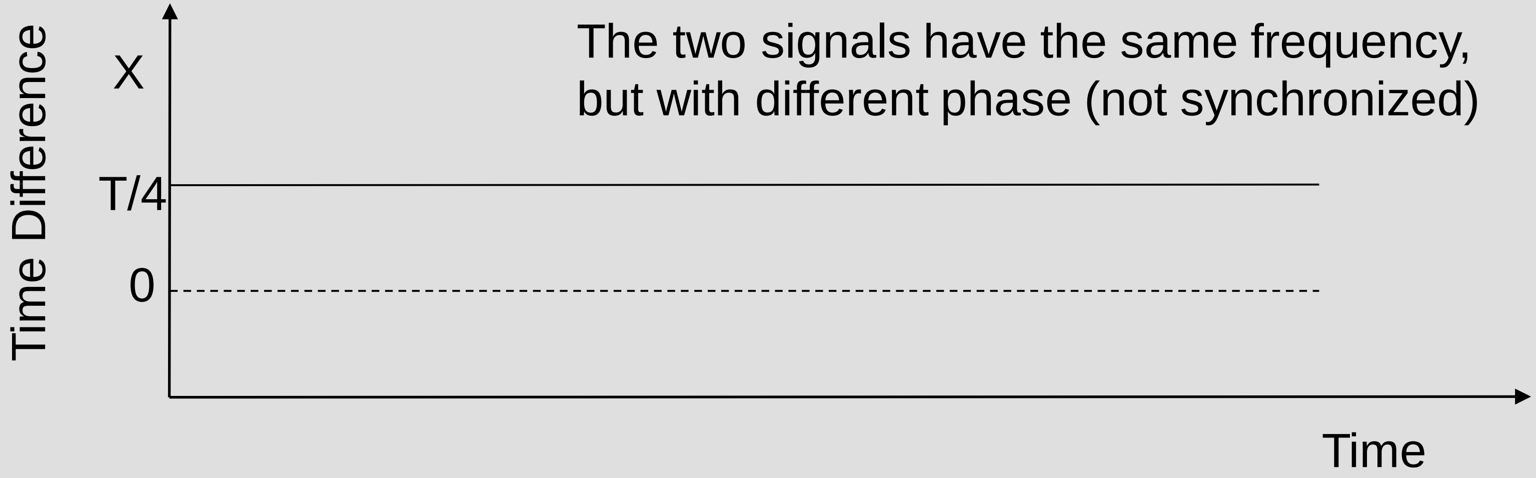
$f_1 = 5\,MHz$

$T = 200\,ns$

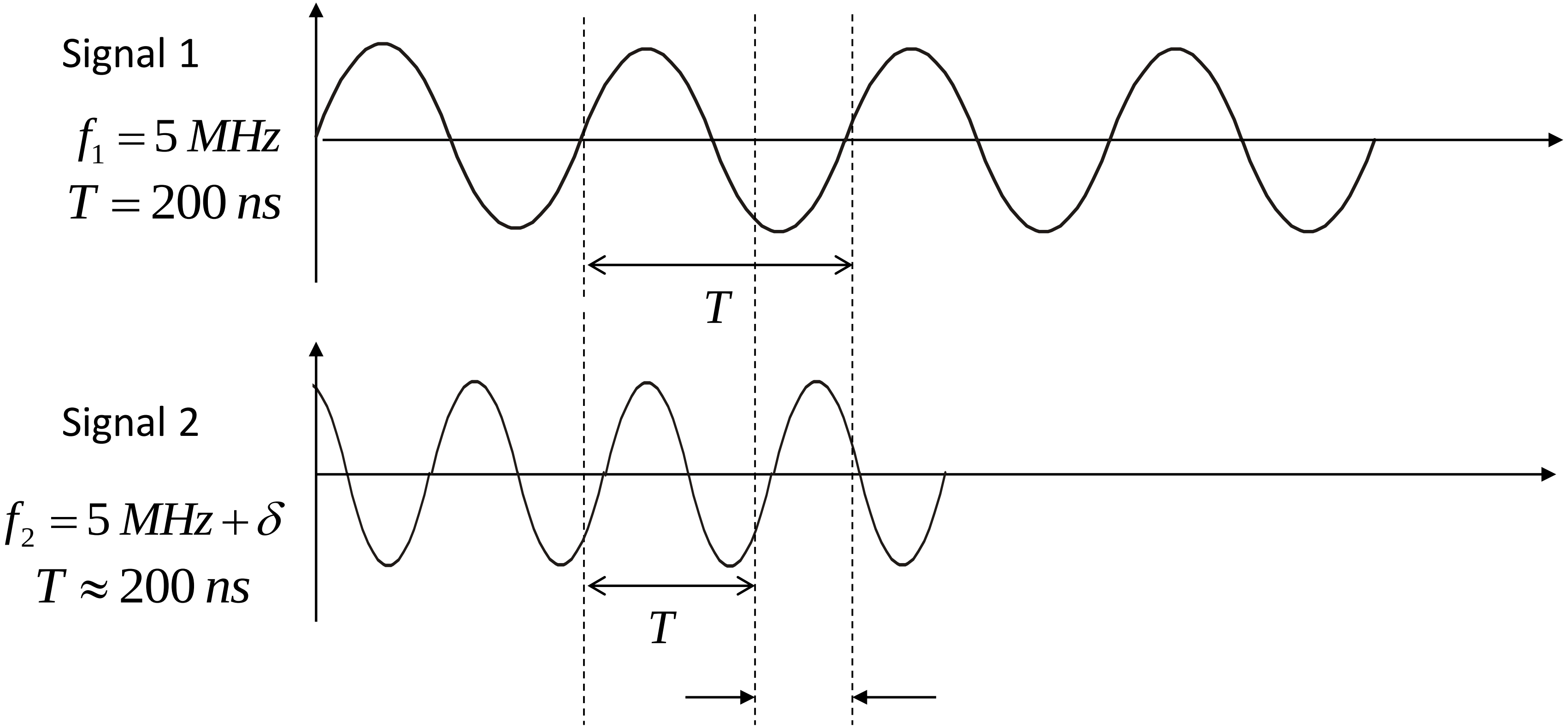
Signal 2

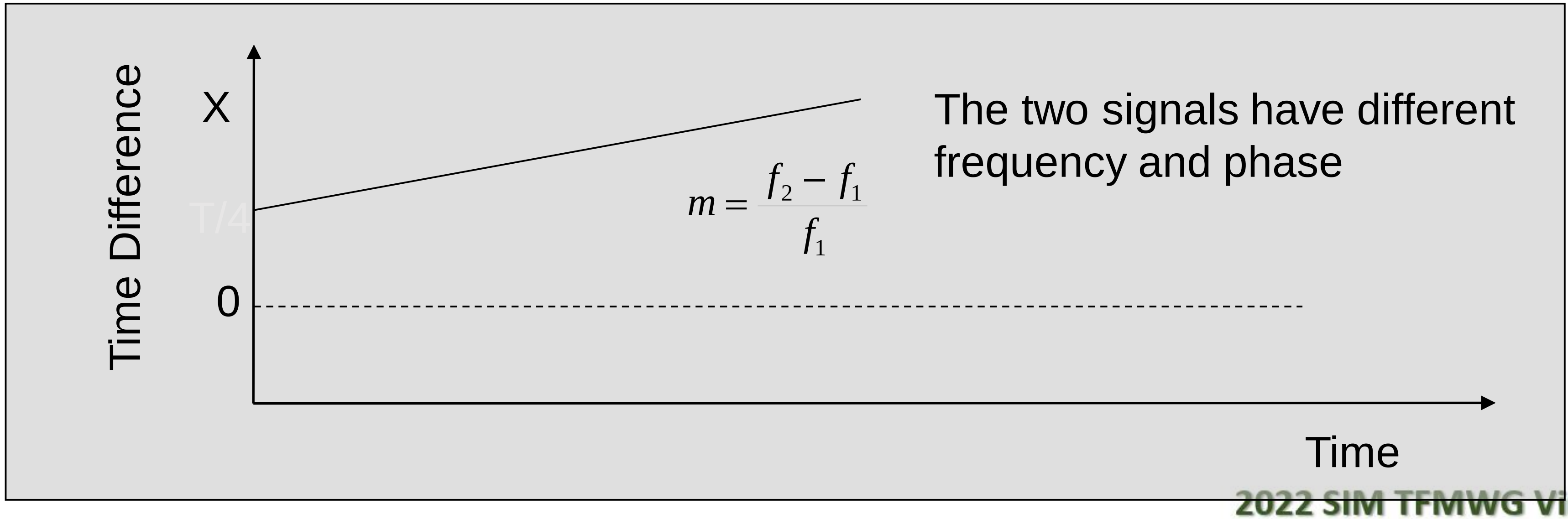
$f_2 = 5\,MHz$

$T = 200\,ns$

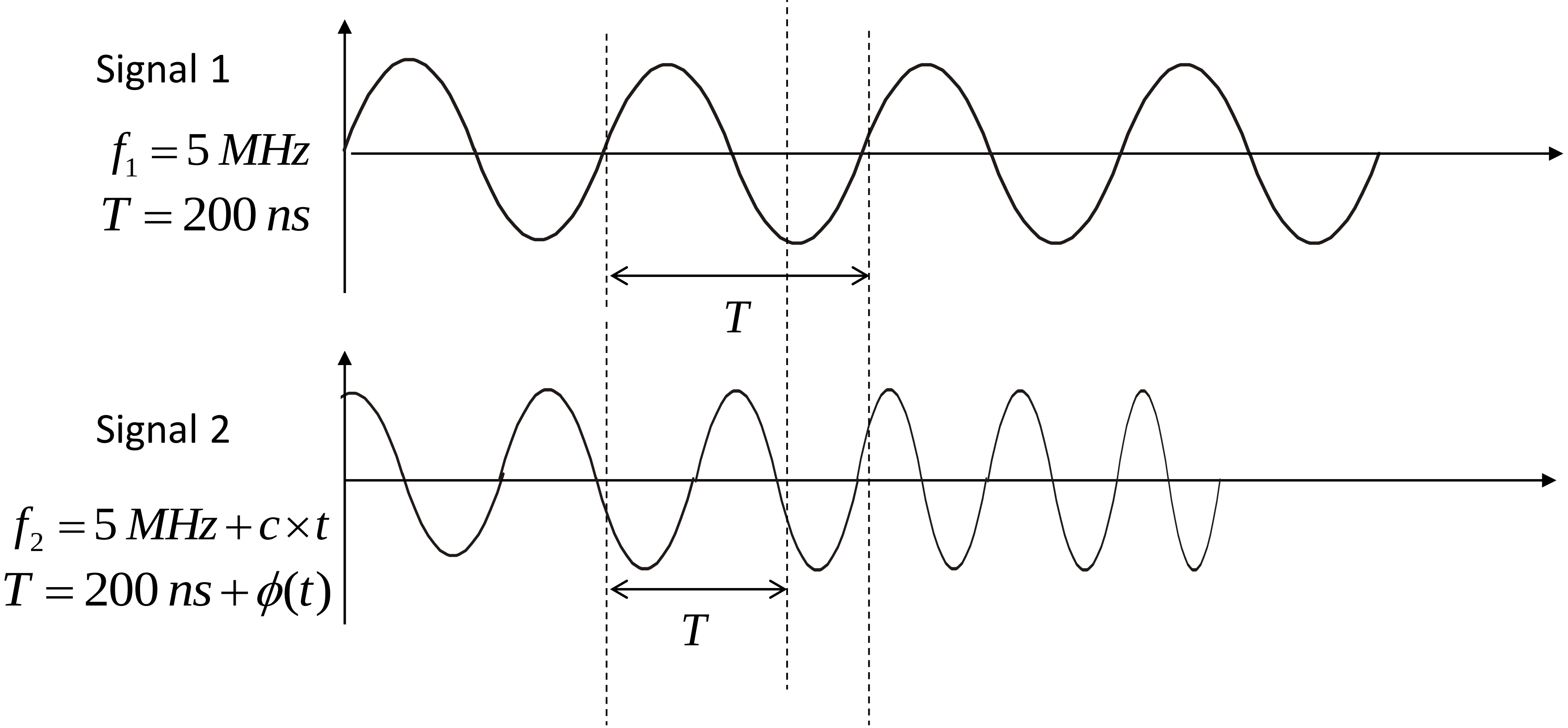


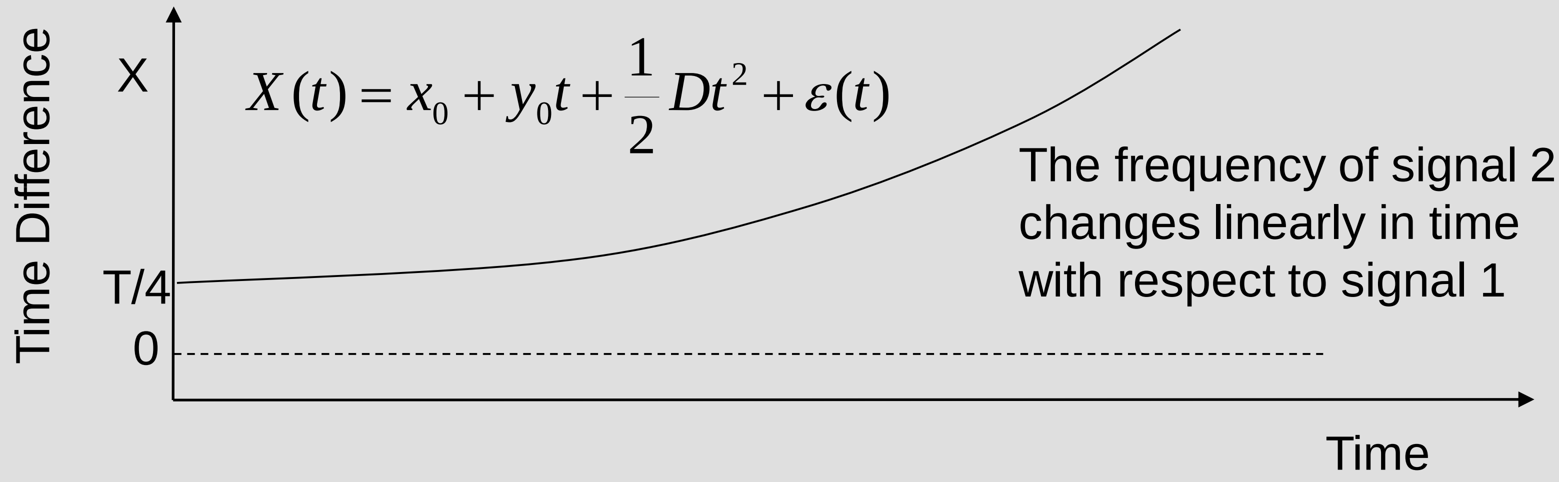
The two signals have the same frequency, but with different phase (not synchronized)





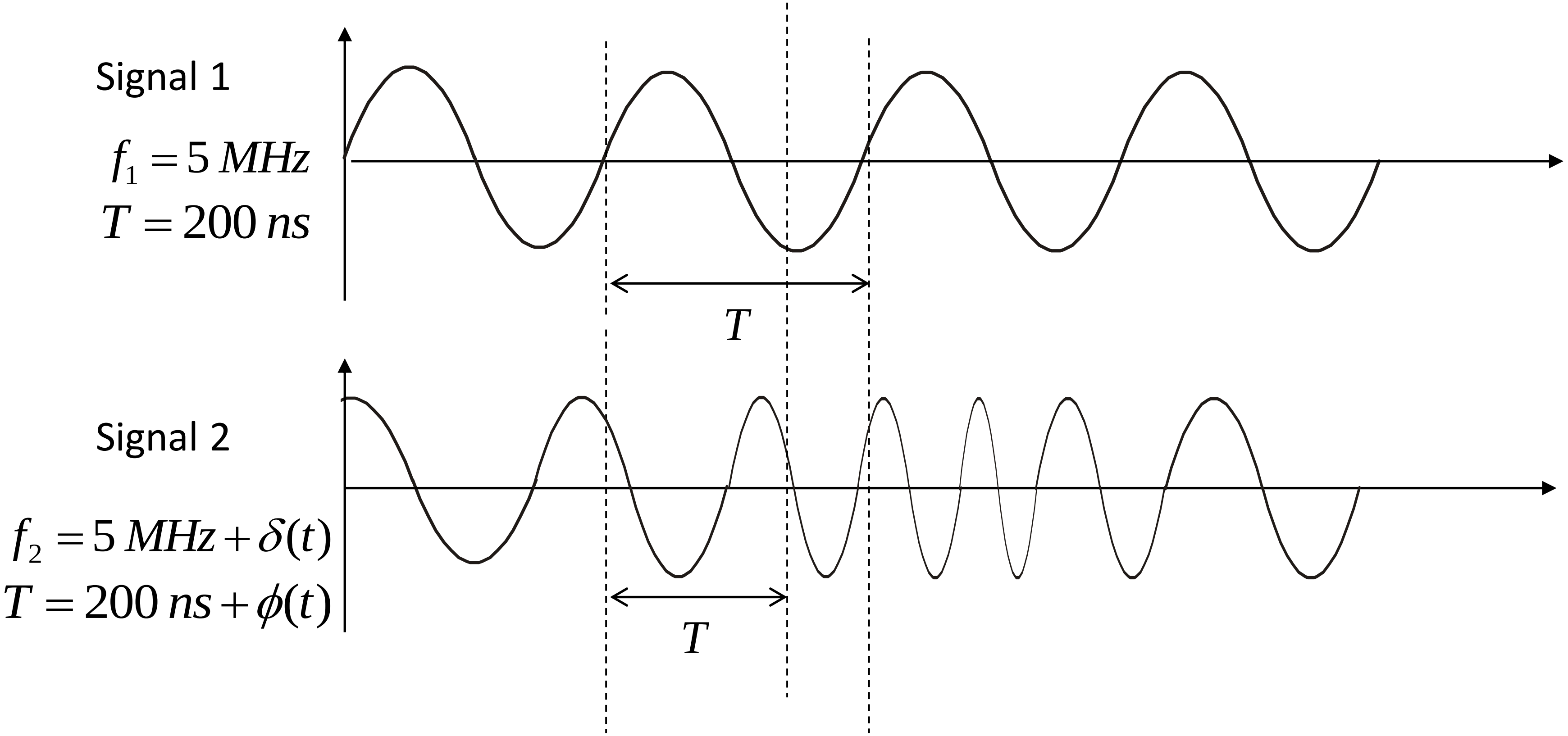
The two signals have different frequency and phase





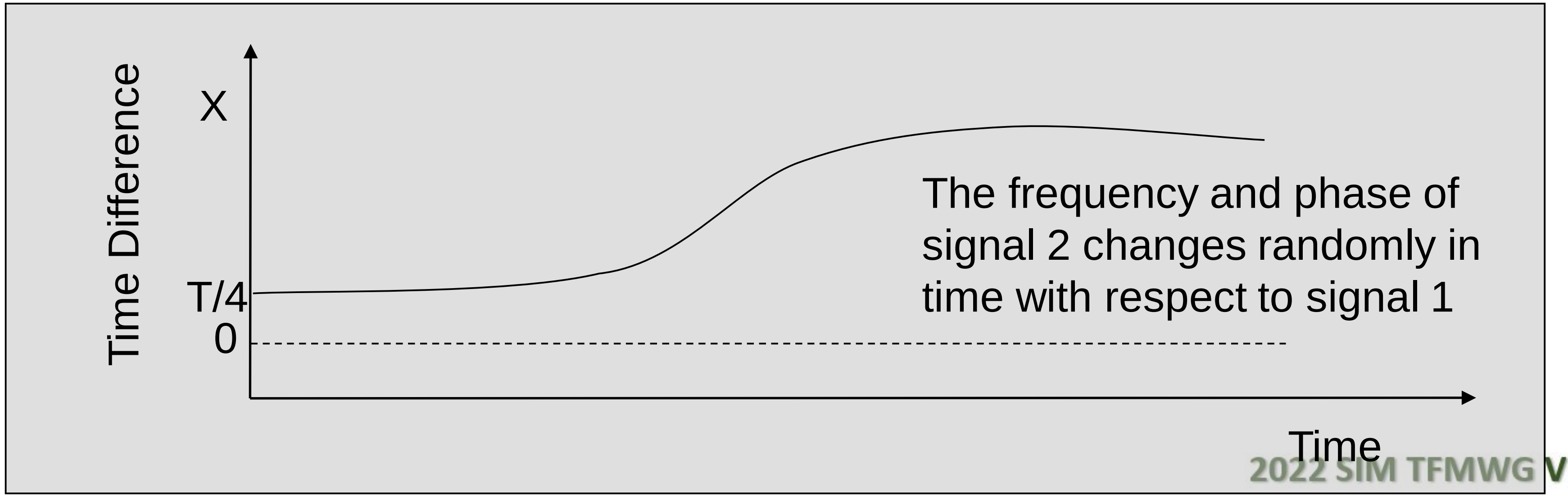
$$X(t) = x_0 + y_0 t + \frac{1}{2} D t^2 + \varepsilon(t)$$

The frequency of signal 2 changes linearly in time with respect to signal 1

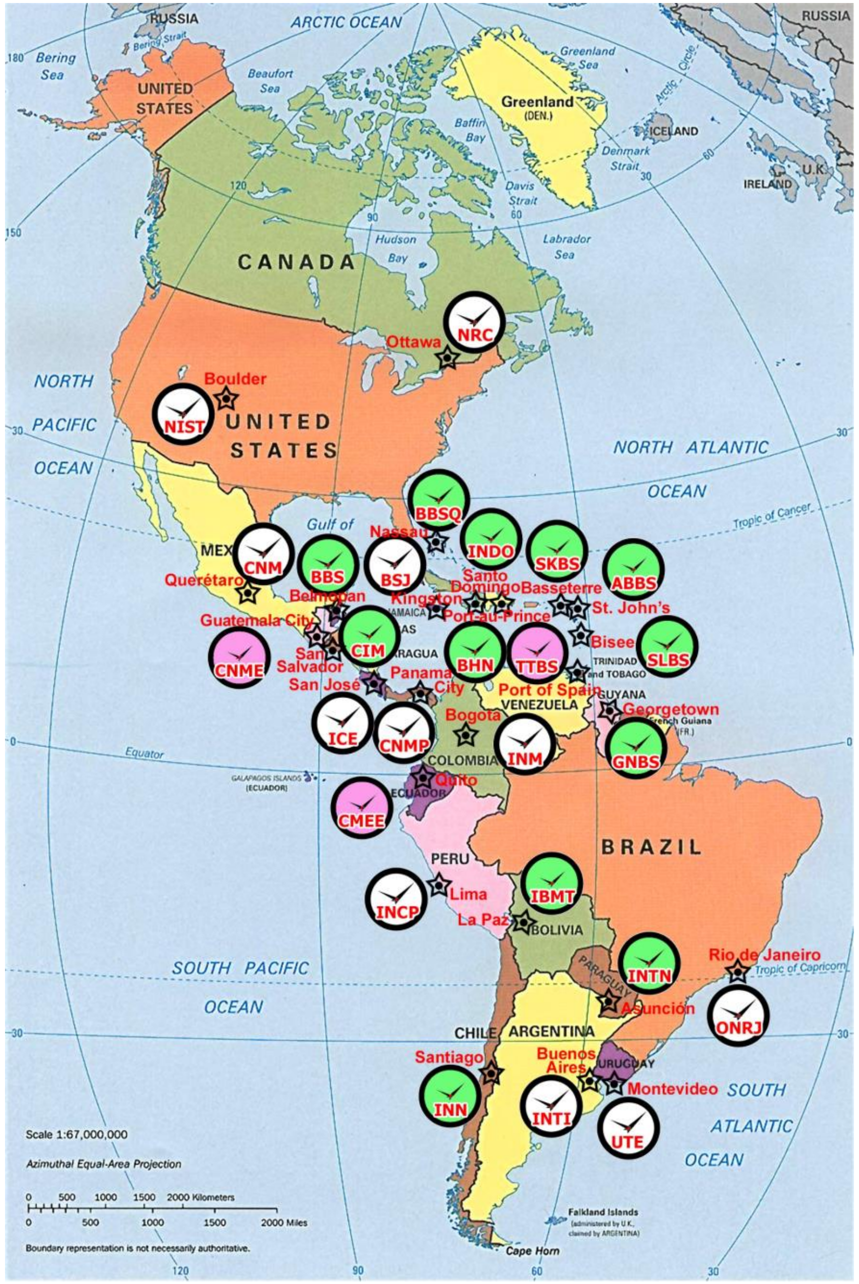


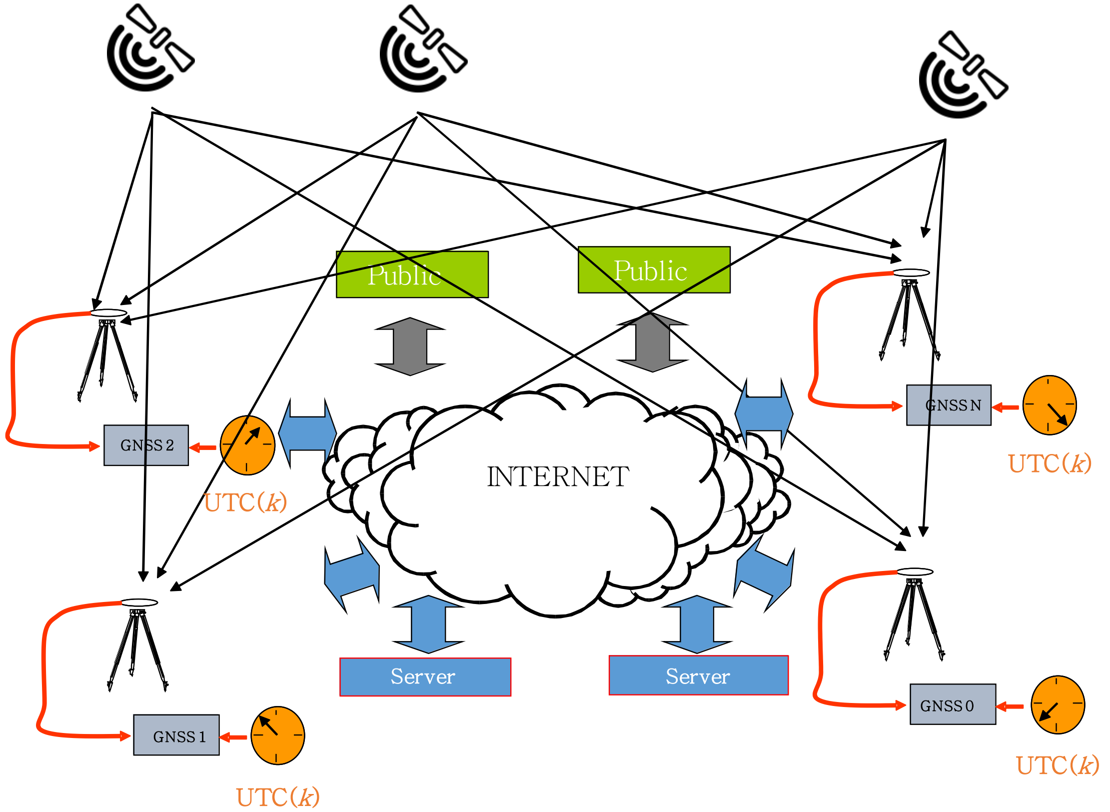
$$f_1 = 5\,MHz$$
$$T = 200\,ns$$

$$f_2 = 5\,MHz + \delta(t)$$
$$T = 200\,ns + \phi(t)$$

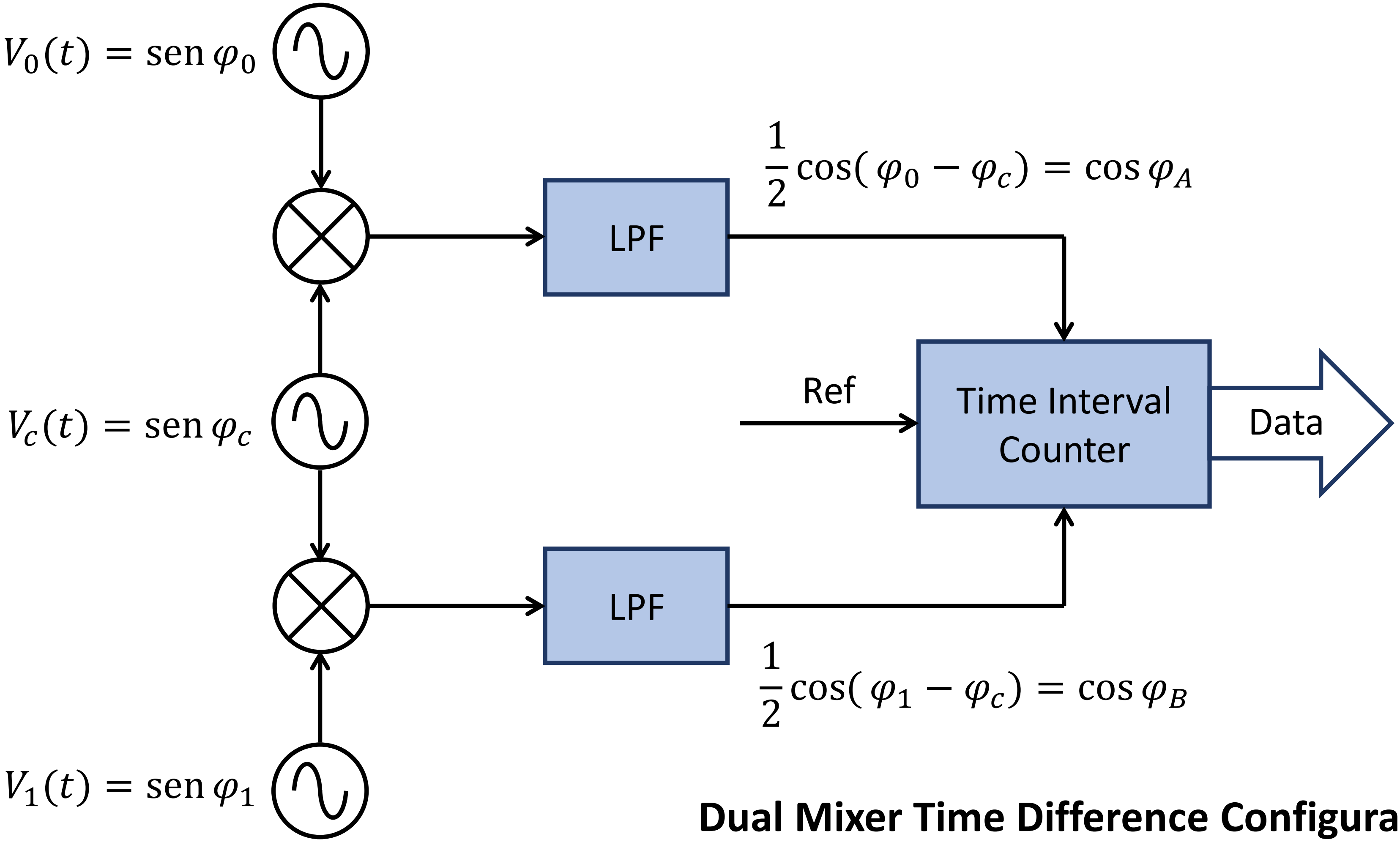


The frequency and phase of signal 2 changes randomly in time with respect to signal 1


NRC
Ottawa
Boulder
NIST
CNM
Querétaro
BBSQ
Nassau
INDO
SKBS
ABBS
BBS
Belmopan
BSJ
Kingston
Santo Domingo
Basseterre
St. John's
Port-au-Prince
Guatemala City
CIM
San Salvador
San José
CNME
BHN
TTBS
SLBS
Bisee
Panama City
Port of Spain
Georgetown
ICE
CNMP
Bogota
INM
GNBS
Quito
CMEE
Lima
INCP
IBMT
La Paz
INTN
Asunción
Rio de Janeiro
ONRJ
Santiago
INN
Buenos Aires
INTI
Montevideo
UTE
CANADA
UNITED STATES
BRAZIL
NORTH PACIFIC OCEAN
NORTH ATLANTIC OCEAN
SOUTH PACIFIC OCEAN
SOUTH ATLANTIC OCEAN
ARCTIC OCEAN
Scale 1:67,000,000
Azimuthal Equal-Area Projection
Boundary representation is not necessarily authoritative.


Public
Public
INTERNET
Server
Server
GNSS 2
UTC(k)
GNSS 1
UTC(k)
GNSS N
UTC(k)
GNSS 0
UTC(k)

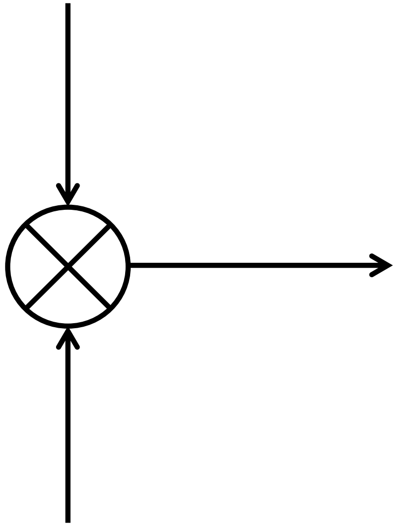
High Resolution Time Difference Measurements



Dual Mixer Time Difference Configuration

Operating Principle of a Frequency Mixer

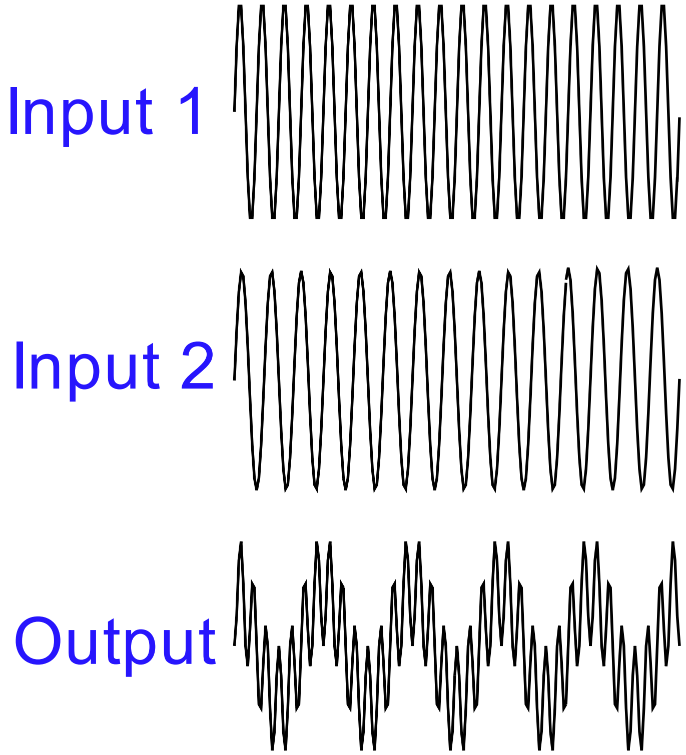
$$V_1(t) = A_1 \operatorname{sen} \phi_1$$



$$V(t)$$

$$V_2(t) = A_2 \operatorname{sen} \phi_2$$

$$\begin{aligned} V(t) &= V_1(t) \times V_2(t) \\ &= A_1 \operatorname{sen} \phi_1 \times A_2 \operatorname{sen} \phi_2 \end{aligned}$$



Operating Principle of a Frequency Mixer

$$V(t)=V_1(t)\times V_2(t)=A_1 sen\phi_1\times A_2 sen\phi_2$$

$$=A_1\left(\frac{e^{i\phi_1}-e^{-i\phi_1}}{2i}\right)\times A_2\left(\frac{e^{i\phi_2}-e^{-i\phi_2}}{2i}\right)$$

$$=A_1A_2\left(\frac{e^{i\phi_1+i\phi_2}-e^{i\phi_1-i\phi_2}-e^{-i\phi_1+i\phi_2}+e^{-i\phi_1-i\phi_2}}{4\times i\times i}\right)$$

$$=A_1A_2\left(\frac{e^{i(\phi_1+\phi_2)}+e^{-i(\phi_1+\phi_2)}-e^{i(\phi_1-\phi_2)}-e^{-i(\phi_1-\phi_2)}}{4\times 1}\right)$$

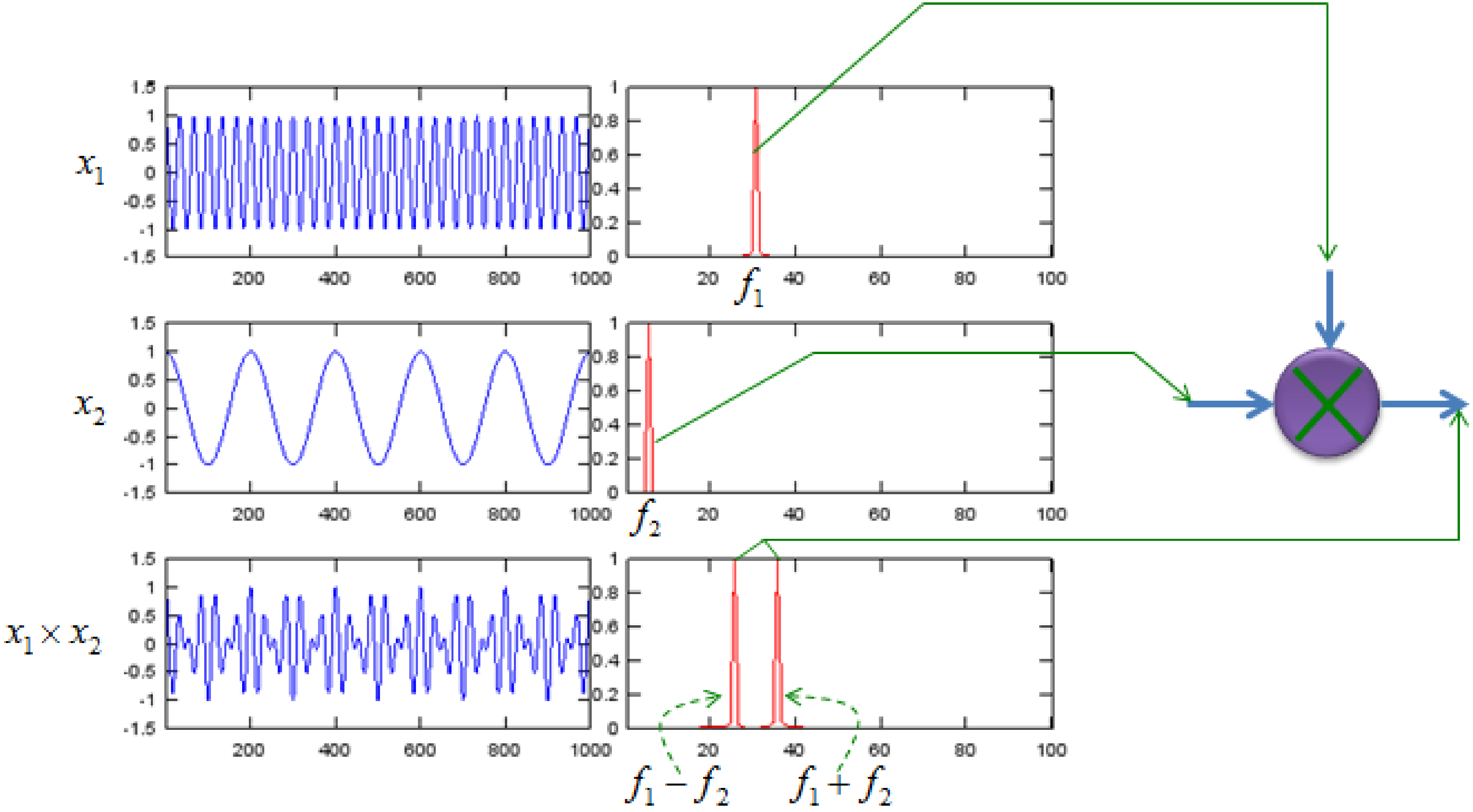
$$=\frac{A_1A_2}{2}\left(\frac{e^{i(\phi_1+\phi_2)}+e^{-i(\phi_1+\phi_2)}}{2}-\frac{e^{i(\phi_1-\phi_2)}+e^{-i(\phi_1-\phi_2)}}{2}\right)$$

$$\boxed{=\frac{A_1A_2}{2}\left(COS(\phi_1+\phi_2)-COS(\phi_1-\phi_2)\right)}$$

$$\boxed{sen\theta=\frac{e^{i\theta}-e^{-i\theta}}{2i}}$$

$$\boxed{\cos\theta=\frac{e^{i\theta}+e^{-i\theta}}{2}}$$

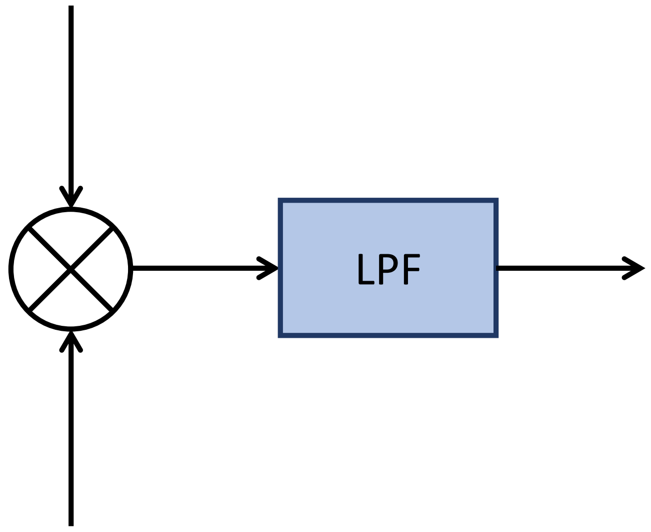
Operating Principle of a Frequency Mixer



Tiempo y Frecuencia

Operating Principle of a Frequency Mixer

$$V_1(t) = A_1 \operatorname{sen}\phi_1$$



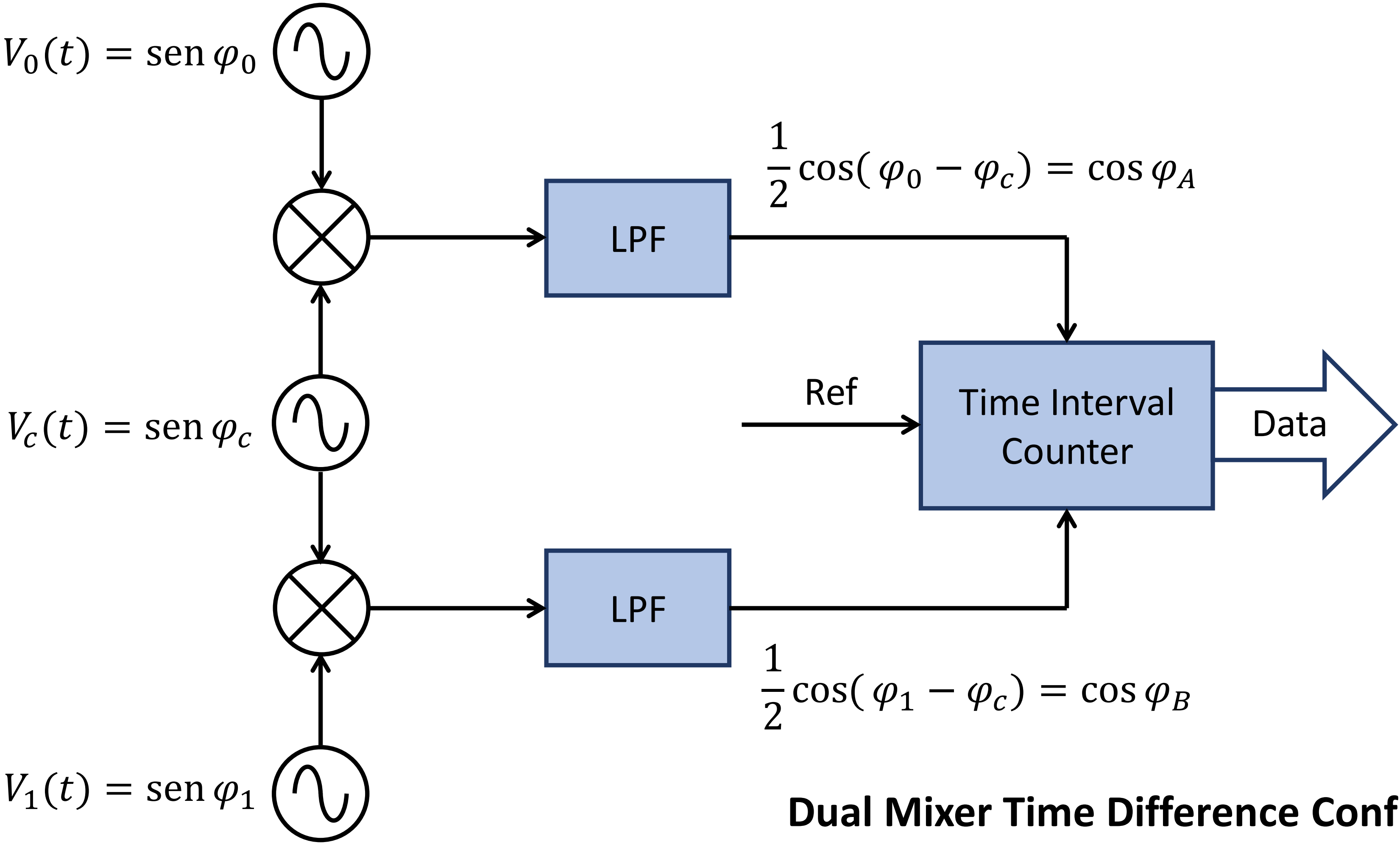
$$V_2(t) = A_2 \operatorname{sen}\phi_2$$

$$V(t) = V_1(t) \times V_2(t)$$
$$= A_1 \operatorname{sen}\phi_1 \times A_2 \operatorname{sen}\phi_2$$

$$V(t) = \cancelto{0}{\frac{A_1A_2}{2}\cos(\phi_1+\phi_2)} - \frac{A_1A_2}{2}\cos(\phi_1-\phi_2)$$

$$V(t) = \frac{A_1A_2}{2}\cos(\phi_1-\phi_2)$$

High Resolution Time Difference Measurements



$V_0(t) = \operatorname{sen} \varphi_0$

$V_c(t) = \operatorname{sen} \varphi_c$

$V_1(t) = \operatorname{sen} \varphi_1$

$\frac{1}{2} \cos(\varphi_0 - \varphi_c) = \cos \varphi_A$

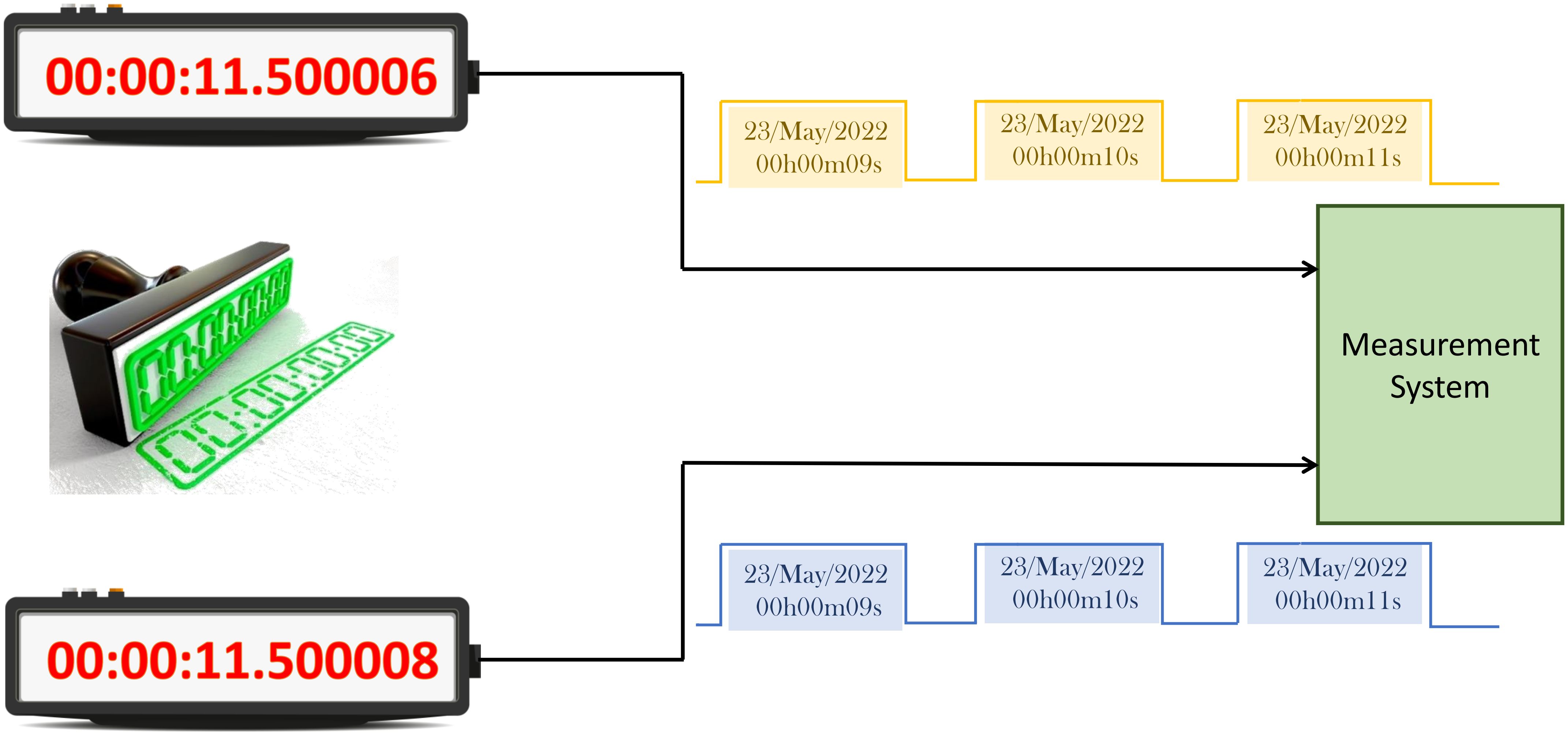
$\frac{1}{2} \cos(\varphi_1 - \varphi_c) = \cos \varphi_B$

Dual Mixer Time Difference Configuration

Time Measurements

Tiempo y Frecuencia

Time Measurements



00:00:11.500006

23/May/2022
00h00m09s

23/May/2022
00h00m10s

23/May/2022
00h00m11s

Measurement System

23/May/2022
00h00m09s

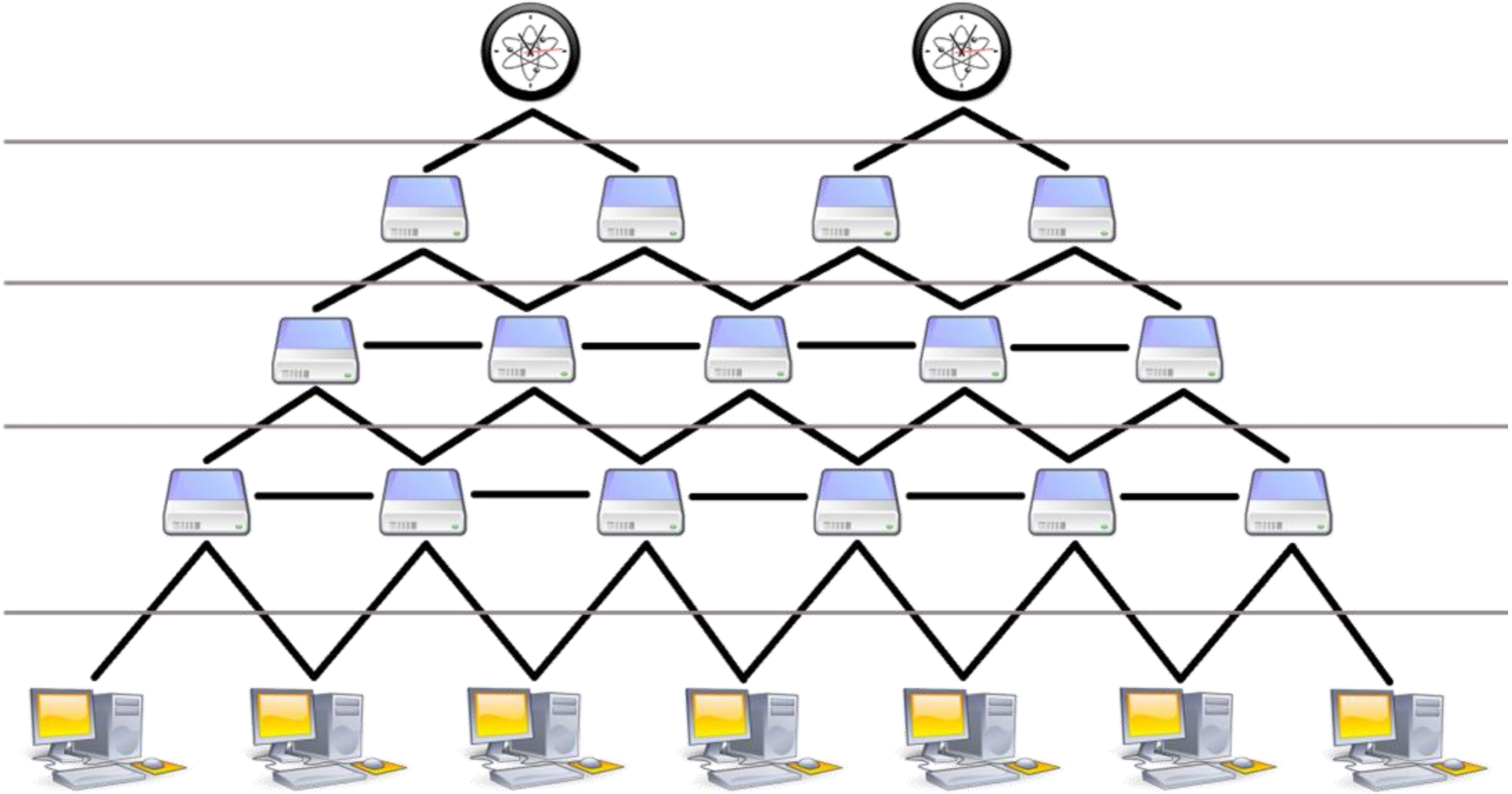
23/May/2022
00h00m10s

23/May/2022
00h00m11s

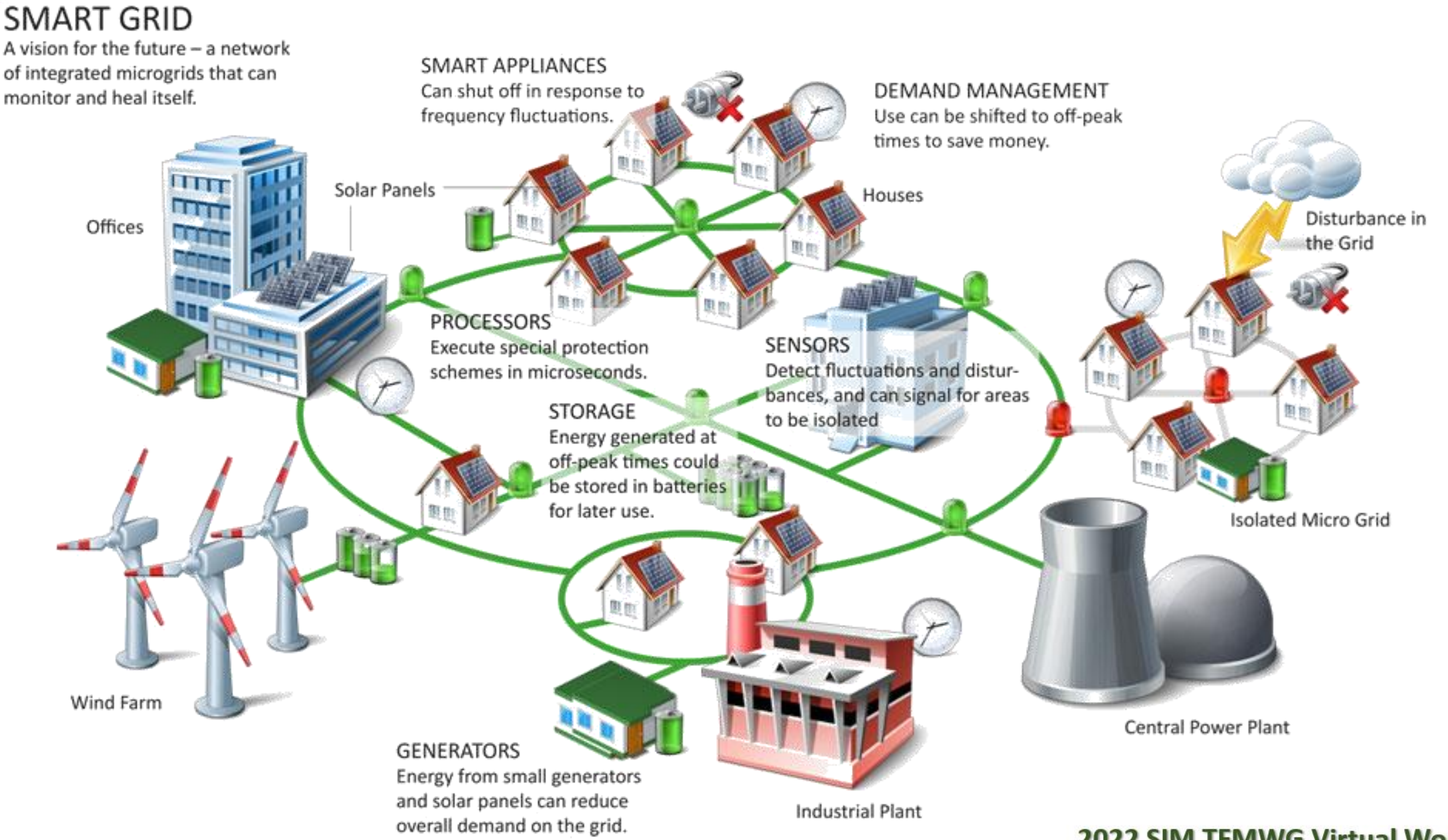
00:00:11.500008

Time Synchronization

Time Measurements



Time Measurements



SMART GRID

A vision for the future – a network of integrated micrgrids that can monitor and heal itself.

SMART APPLIANCES
Can shut off in response to frequency fluctuations.

DEMAND MANAGEMENT
Use can be shifted to off-peak times to save money.

PROCESSORS
Execute special protection schemes in microseconds.

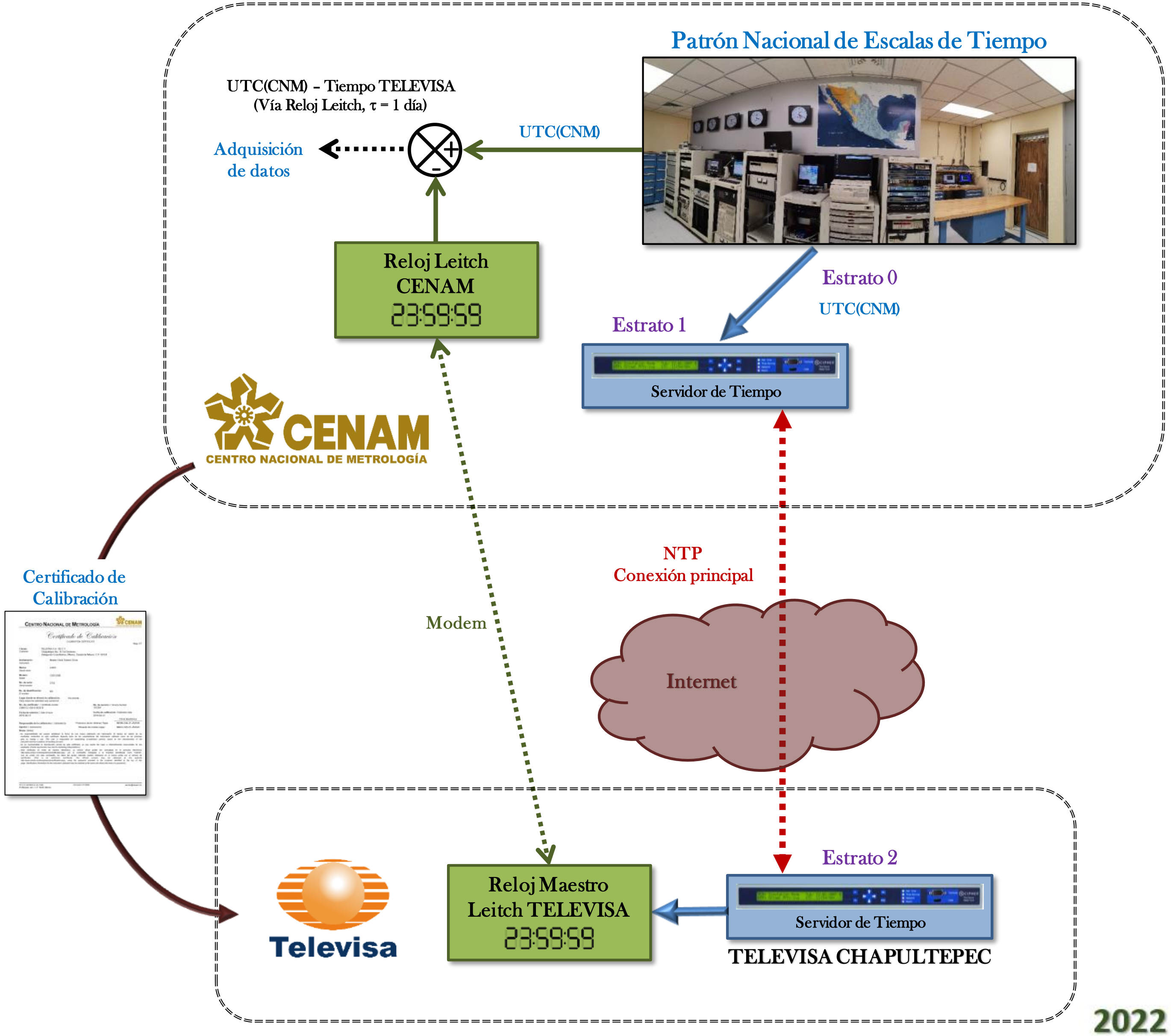
SENSORS
Detect fluctuations and disturbances, and can signal for areas to be isolated

STORAGE
Energy generated at off-peak times could be stored in batteries for later use.

GENERATORS
Energy from small generators and solar panels can reduce overall demand on the grid.

Tiempo y Frecuencia

Time Calibration Example



Patrón Nacional de Escalas de Tiempo

UTC(CNM) – Tiempo TELEVISA
(Vía Reloj Leitch, τ = 1 día)

Adquisición de datos

UTC(CNM)

Reloj Leitch CENAM
23:59:59

Estrato 0

UTC(CNM)

Estrato 1

Servidor de Tiempo

Certificado de Calibración

Modem

NTP
Conexión principal

Internet

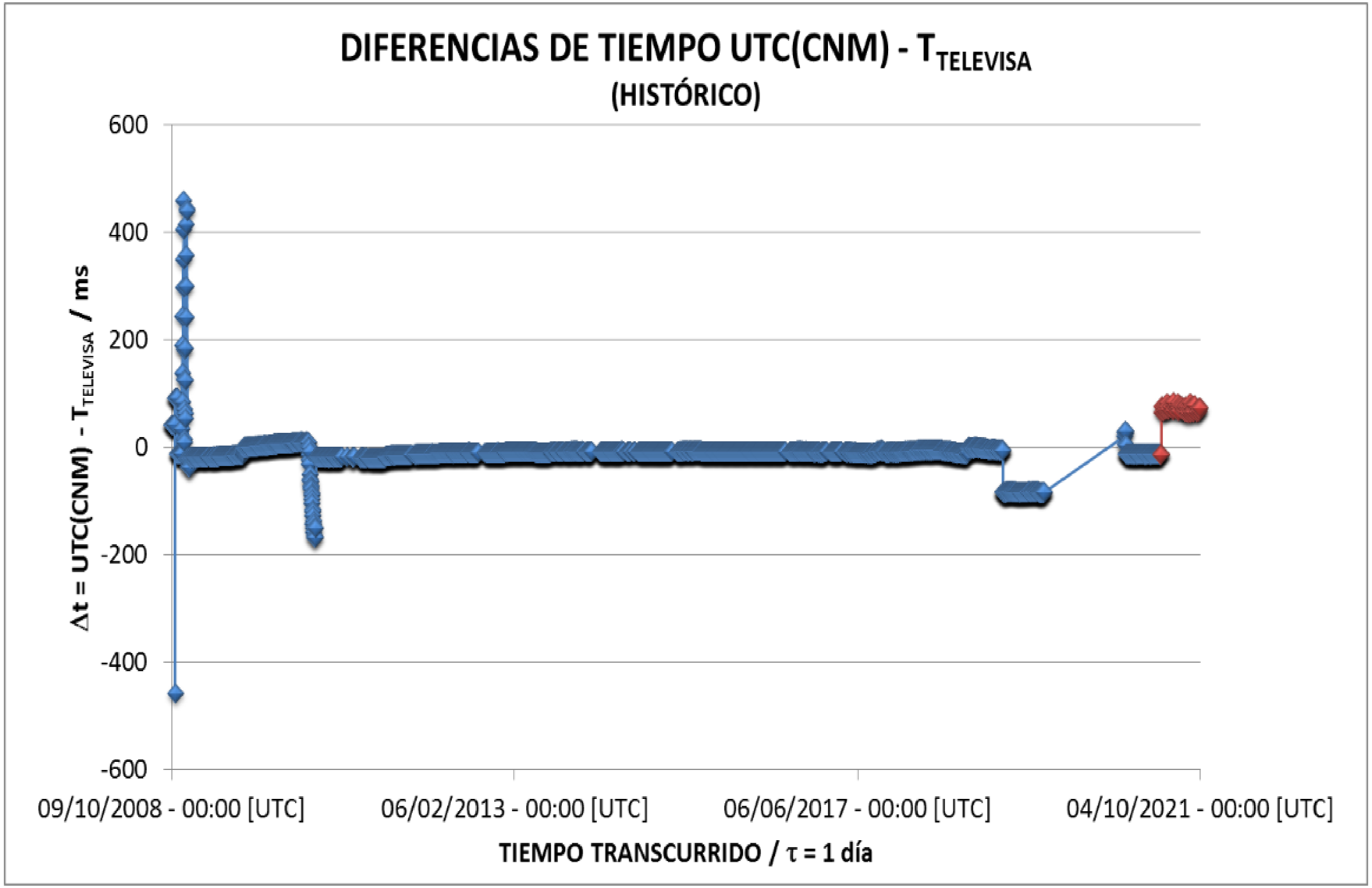
Estrato 2

Reloj Maestro Leitch TELEVISA
23:59:59

Servidor de Tiempo

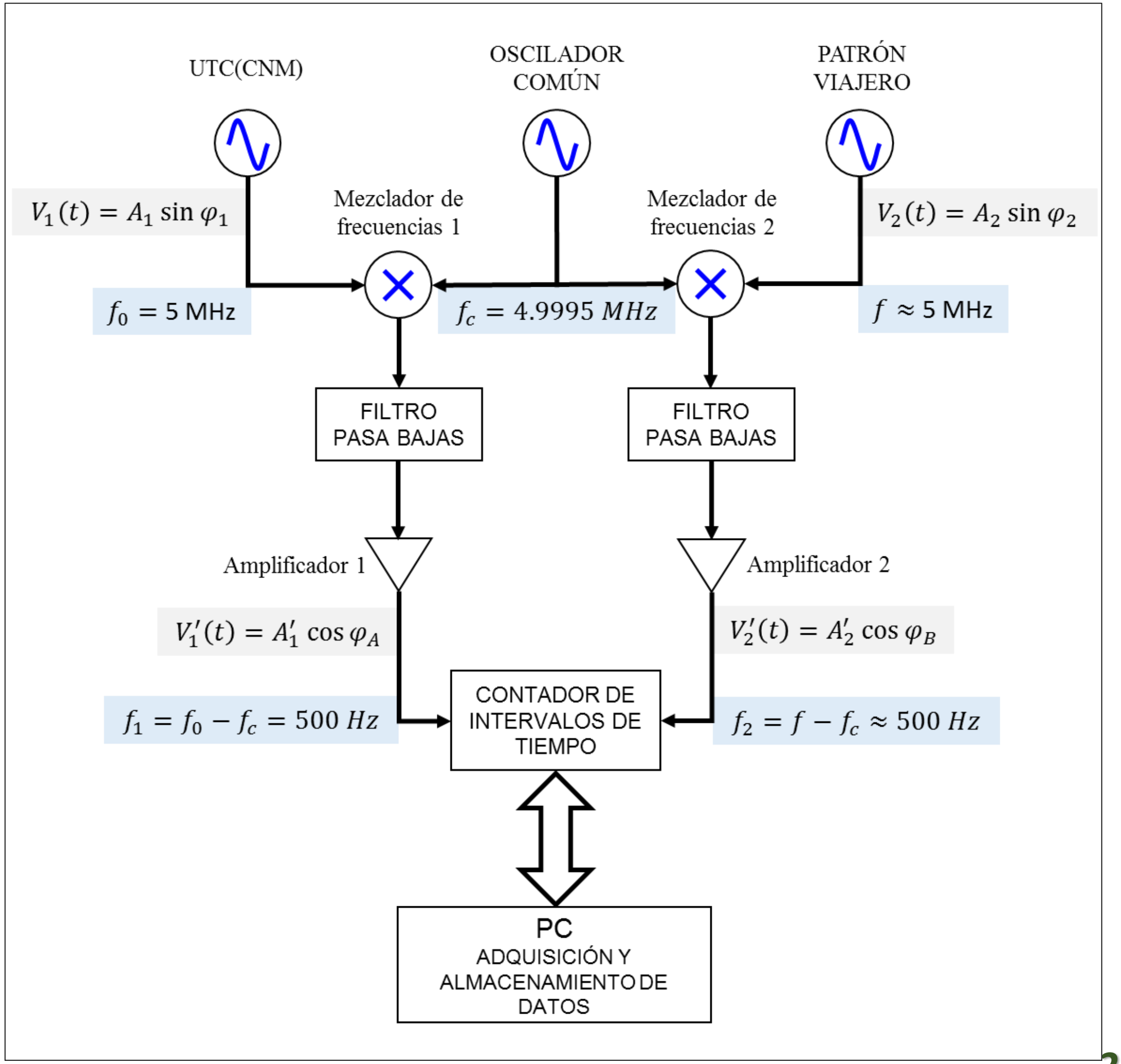
TELEVISA CHAPULTEPEC

Time Calibration Example

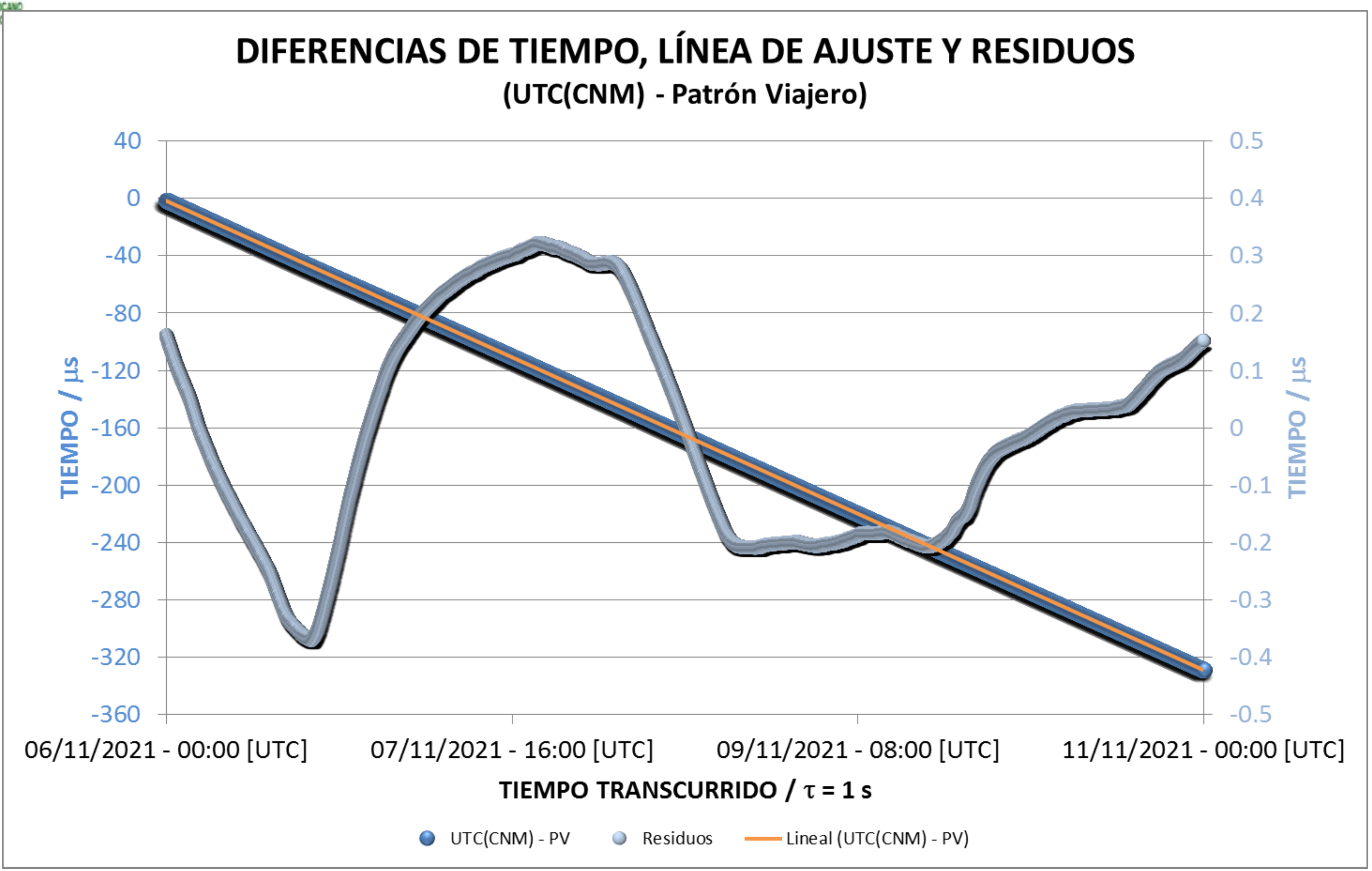


Tiempo y Frecuencia

Time Difference Calibration Example

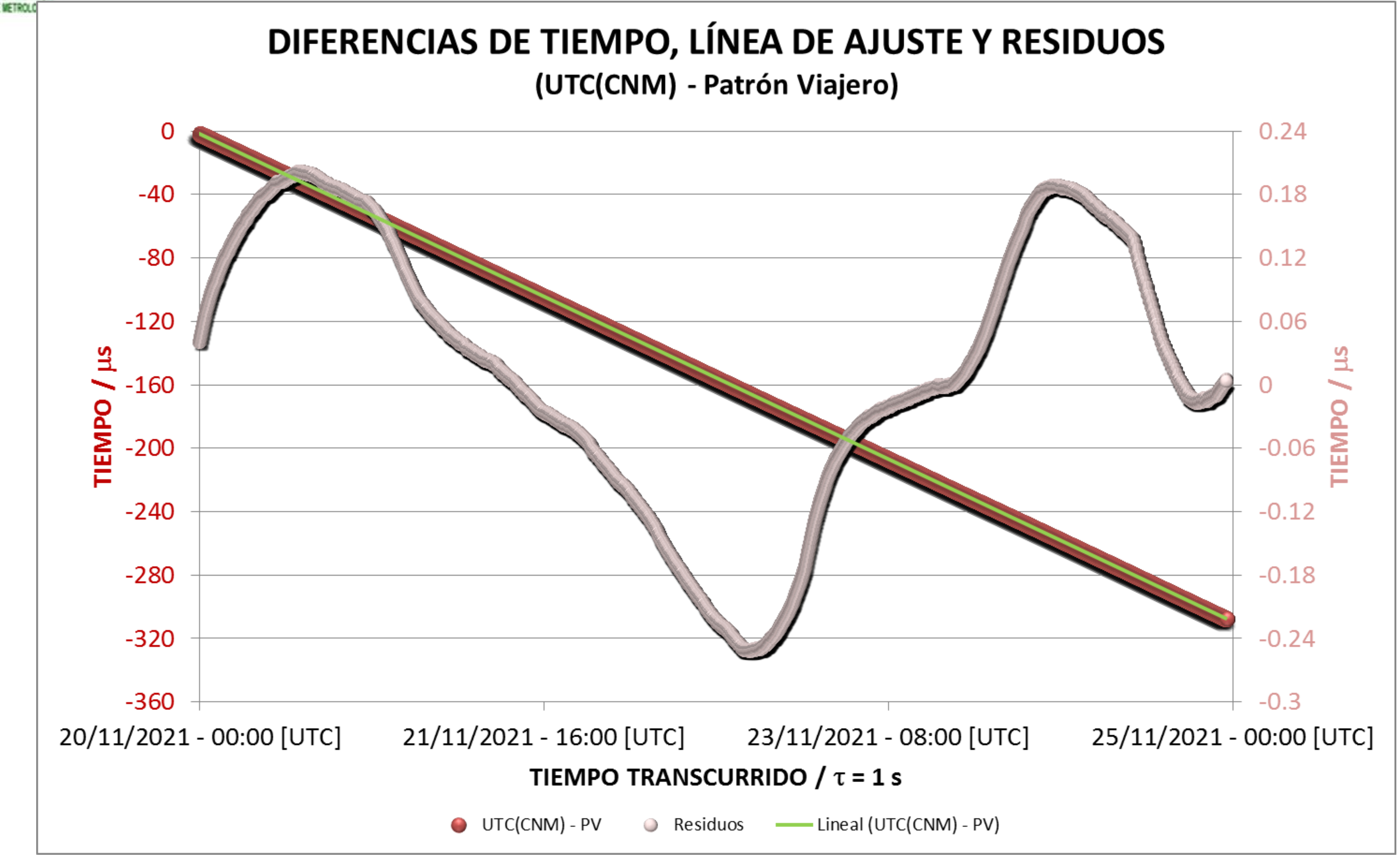


Time Difference Calibration Example



Tiempo y Frecuencia

Time Difference Calibration Example



Tiempo y Frecuencia

2022 SIM TFMWG Virtual Workshop

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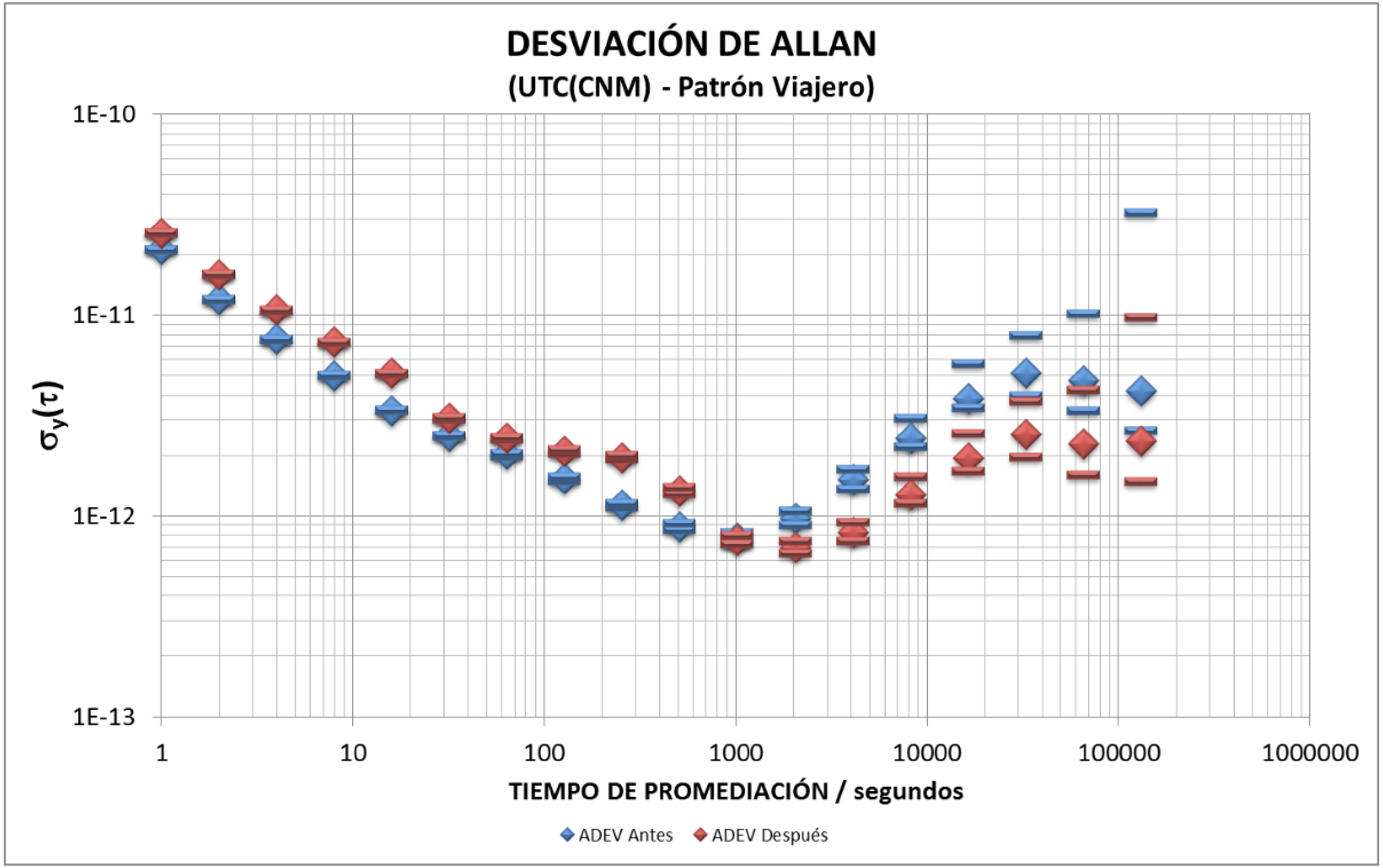

Tiempo y Frecuencia