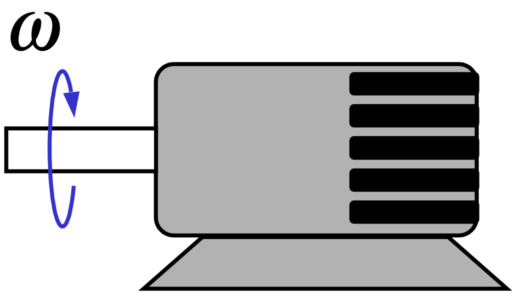
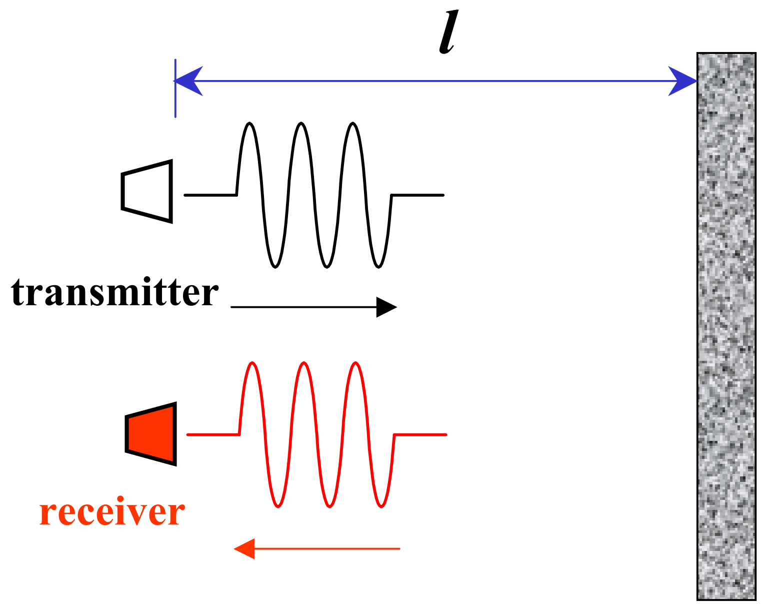
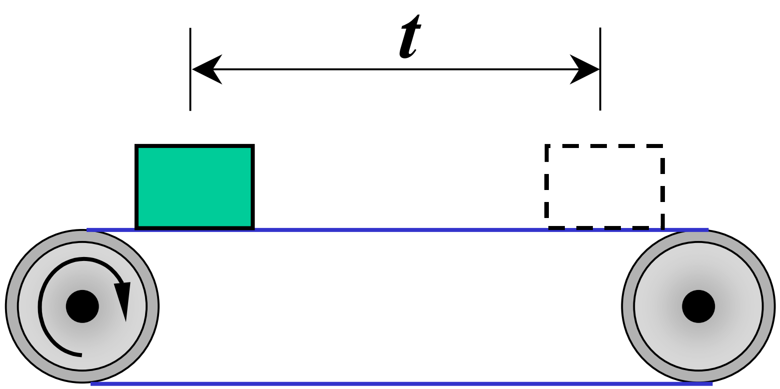
Frequency and Period Measurement

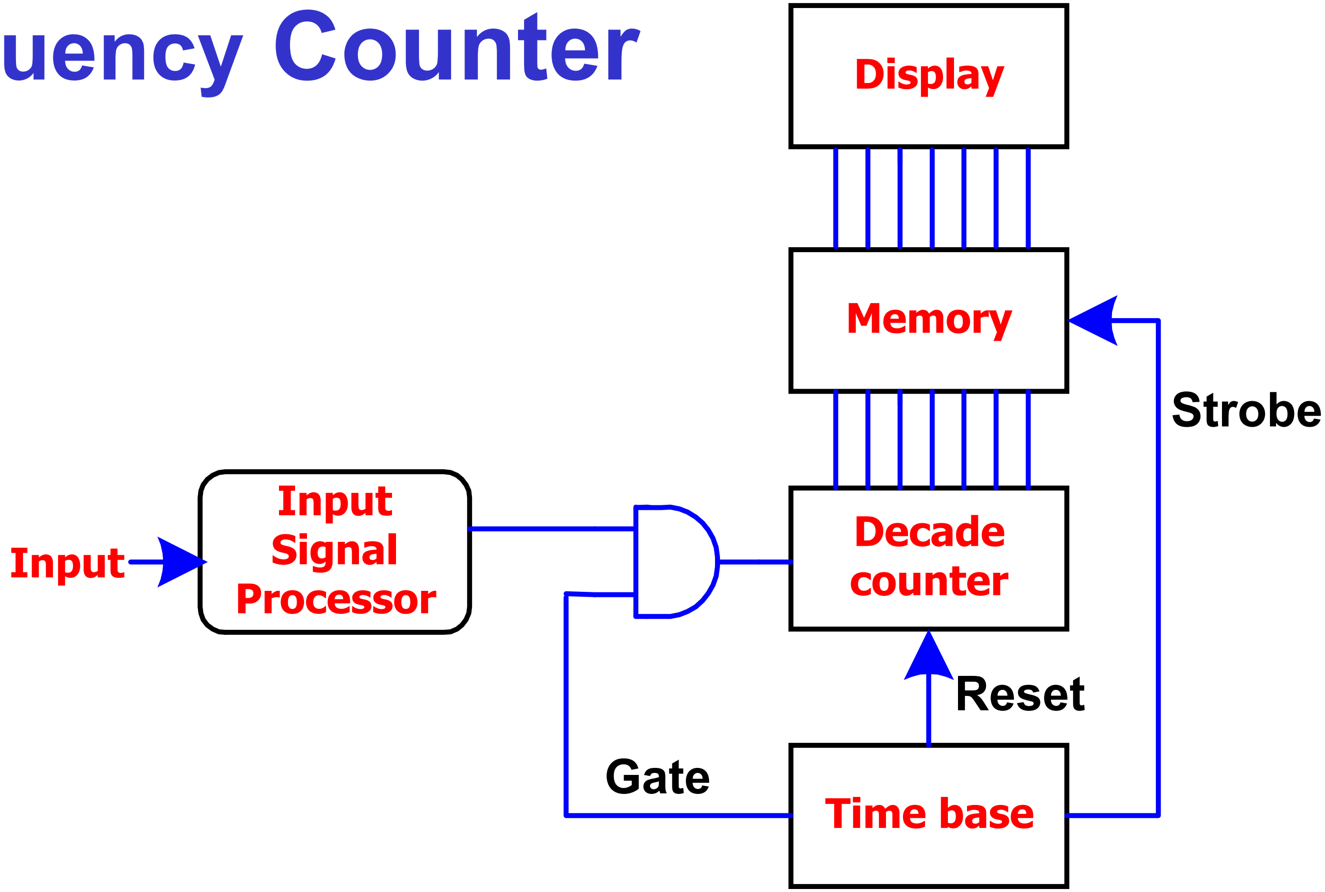


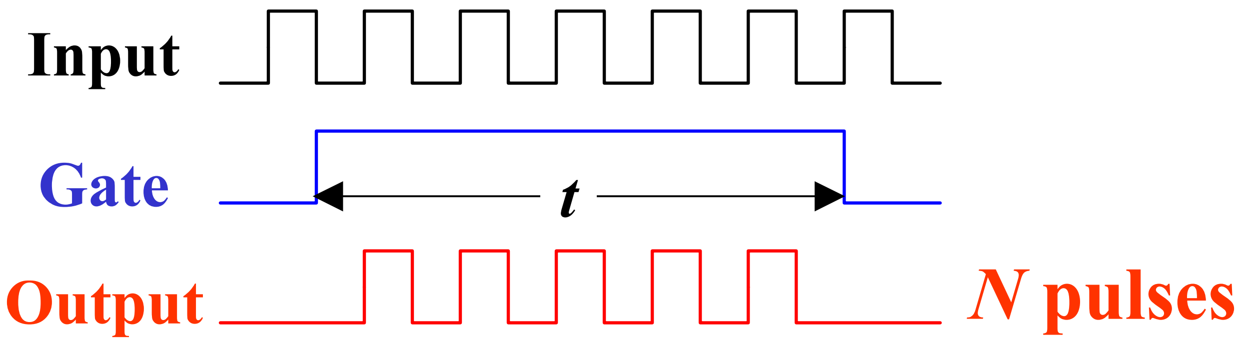


$$l = \frac{v\,t}{2}$$



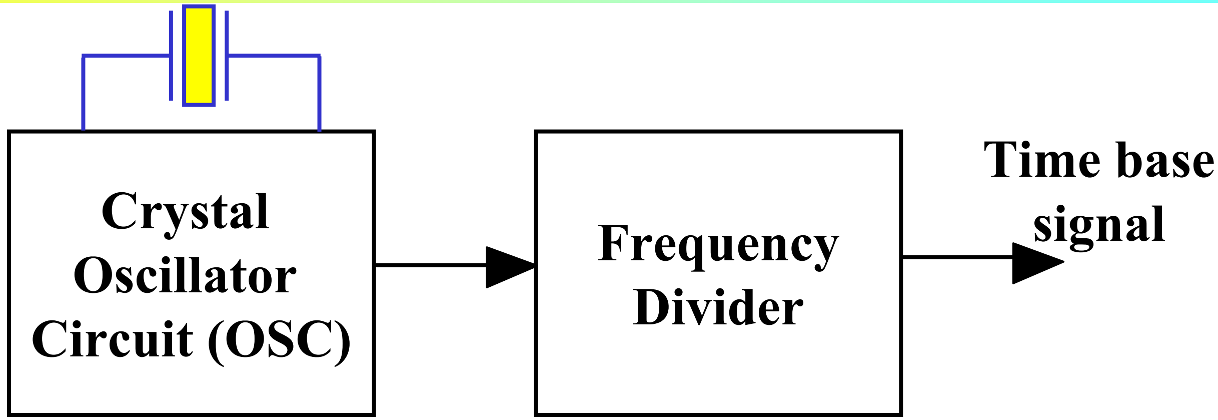
Frequency Counter





$$f = \frac{N}{t}$$

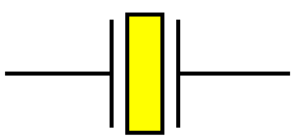
Time Base



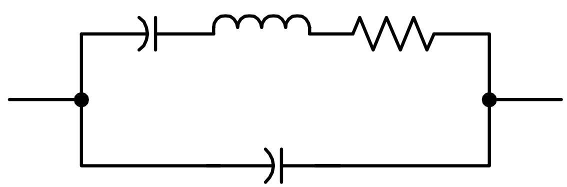
- Non-compensated OSC
- Temp. compensated OSC
- Oven-type OSC

Quartz crystal

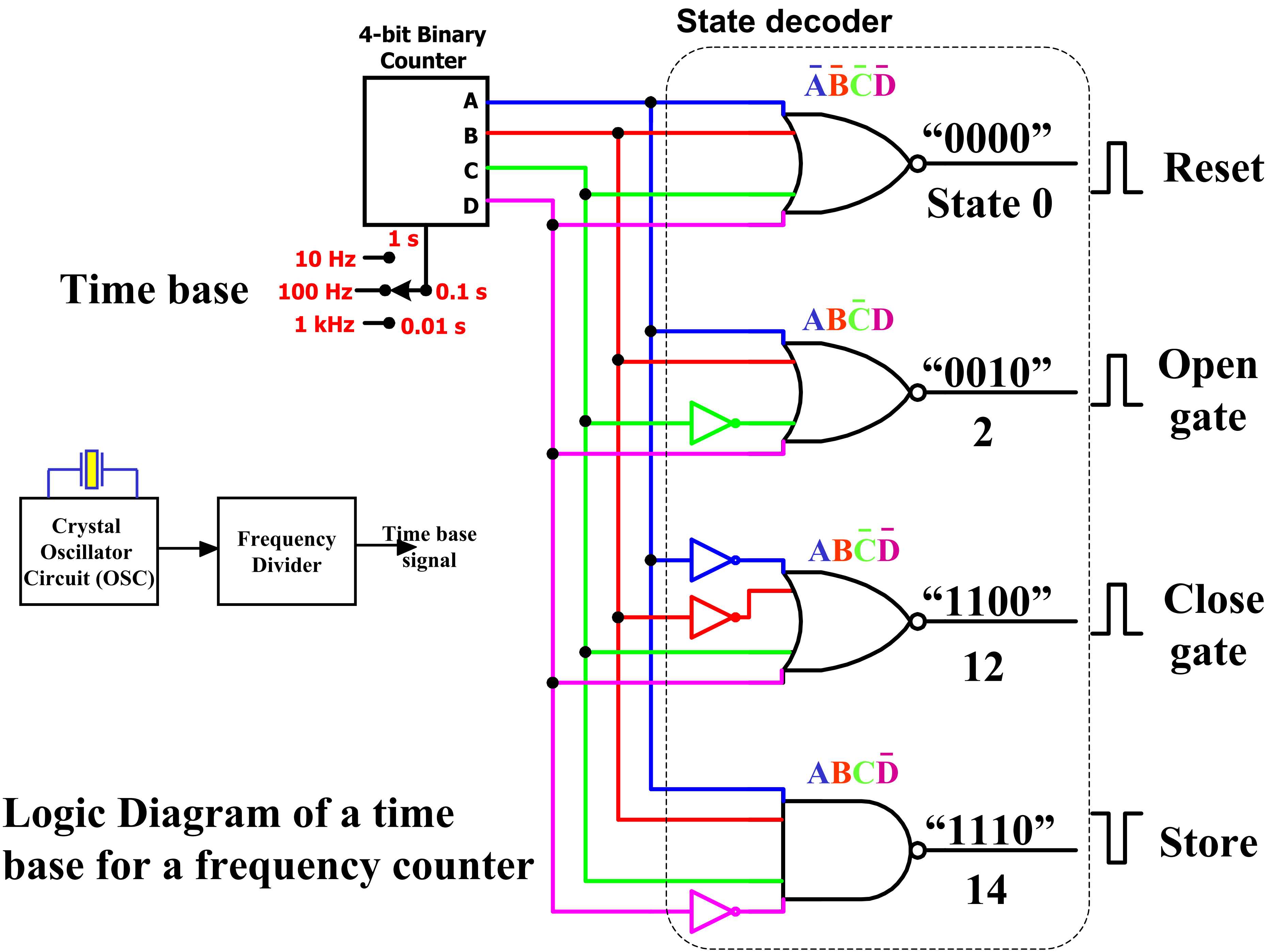
High Q ~ 10000



symbol

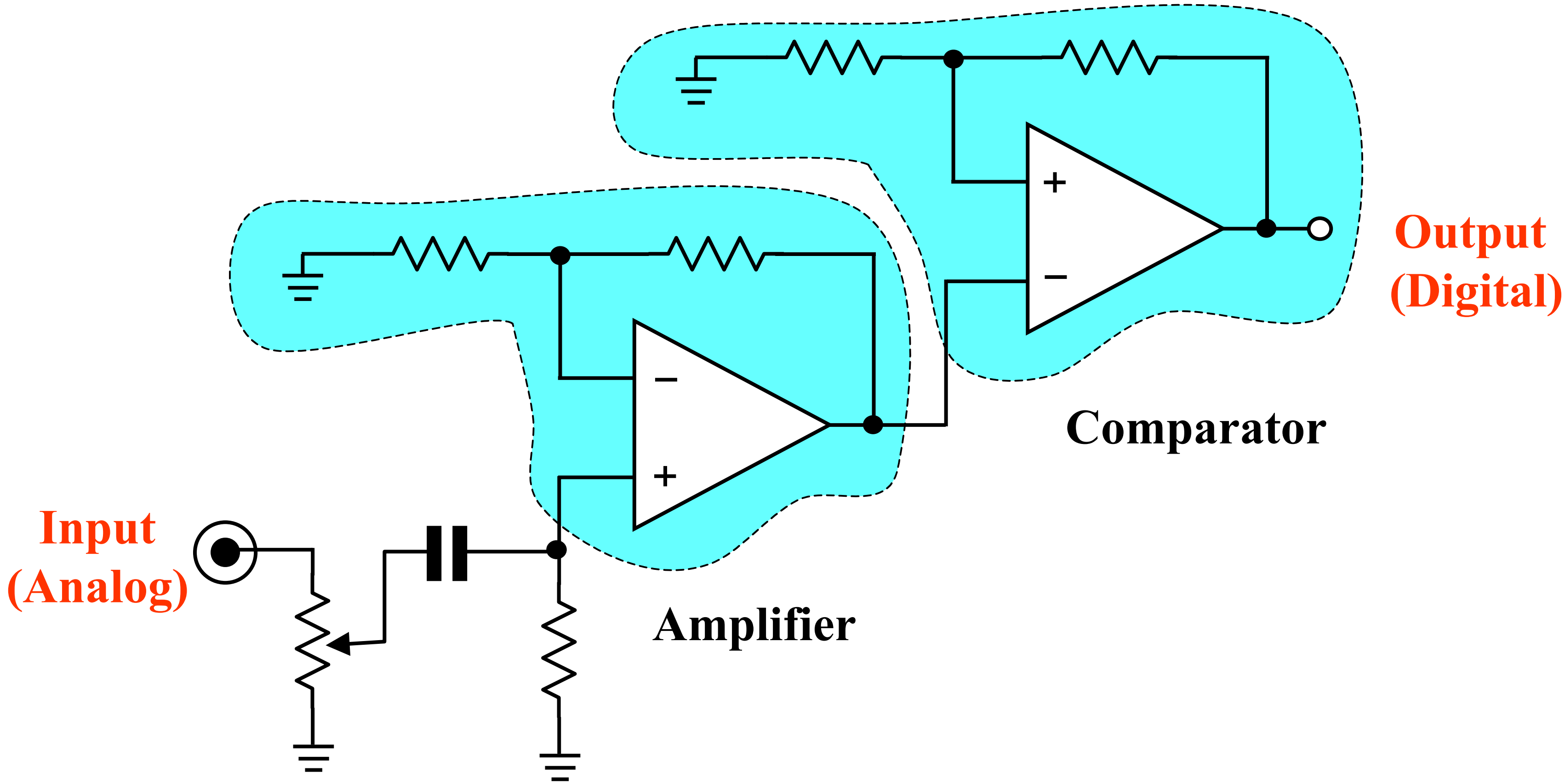


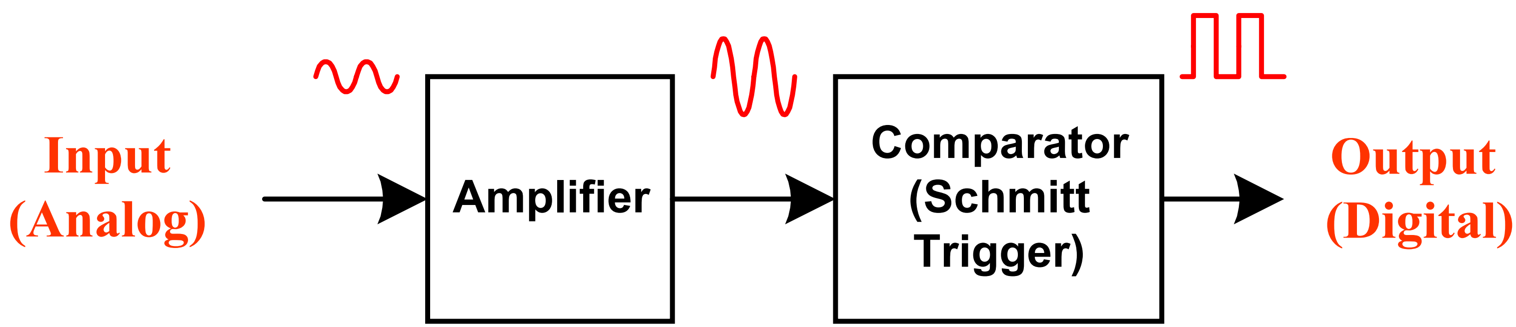
Equivalent circuit



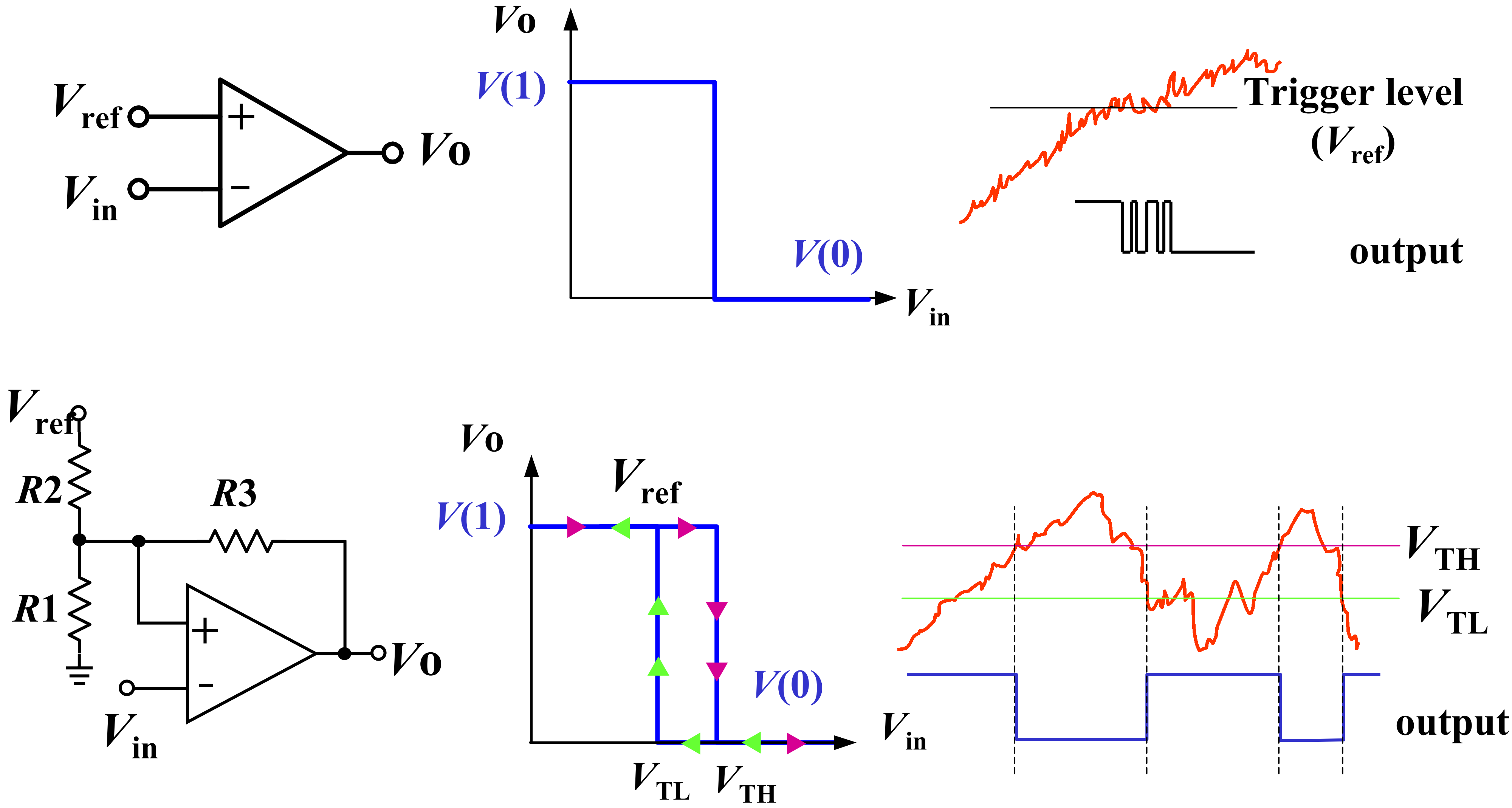
Logic Diagram of a time base for a frequency counter

Input Signal Processing

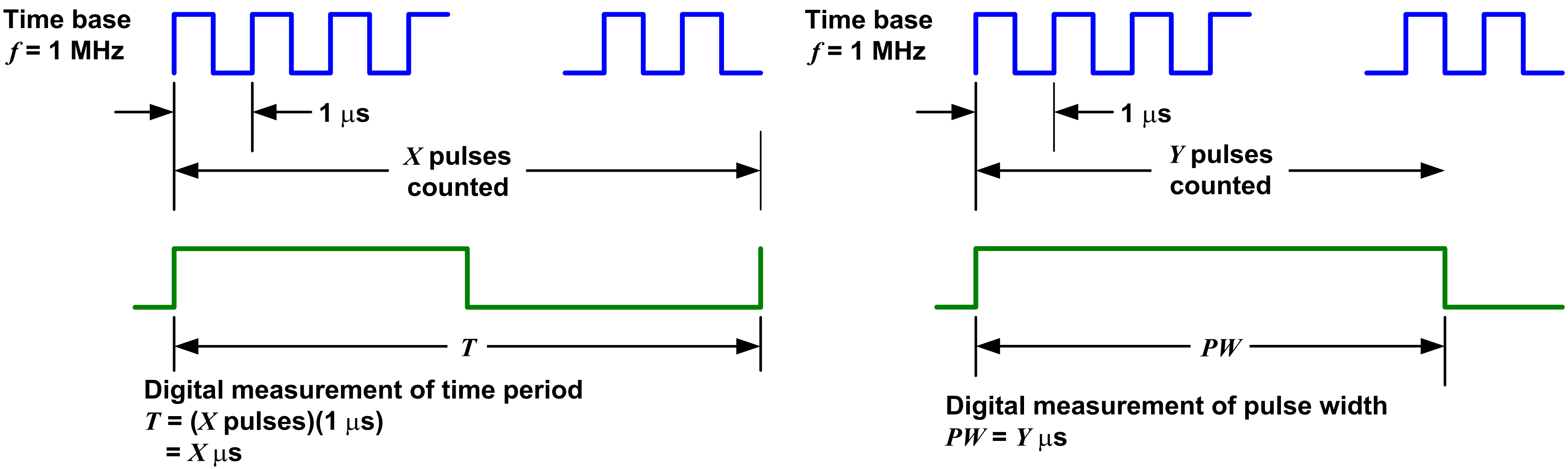




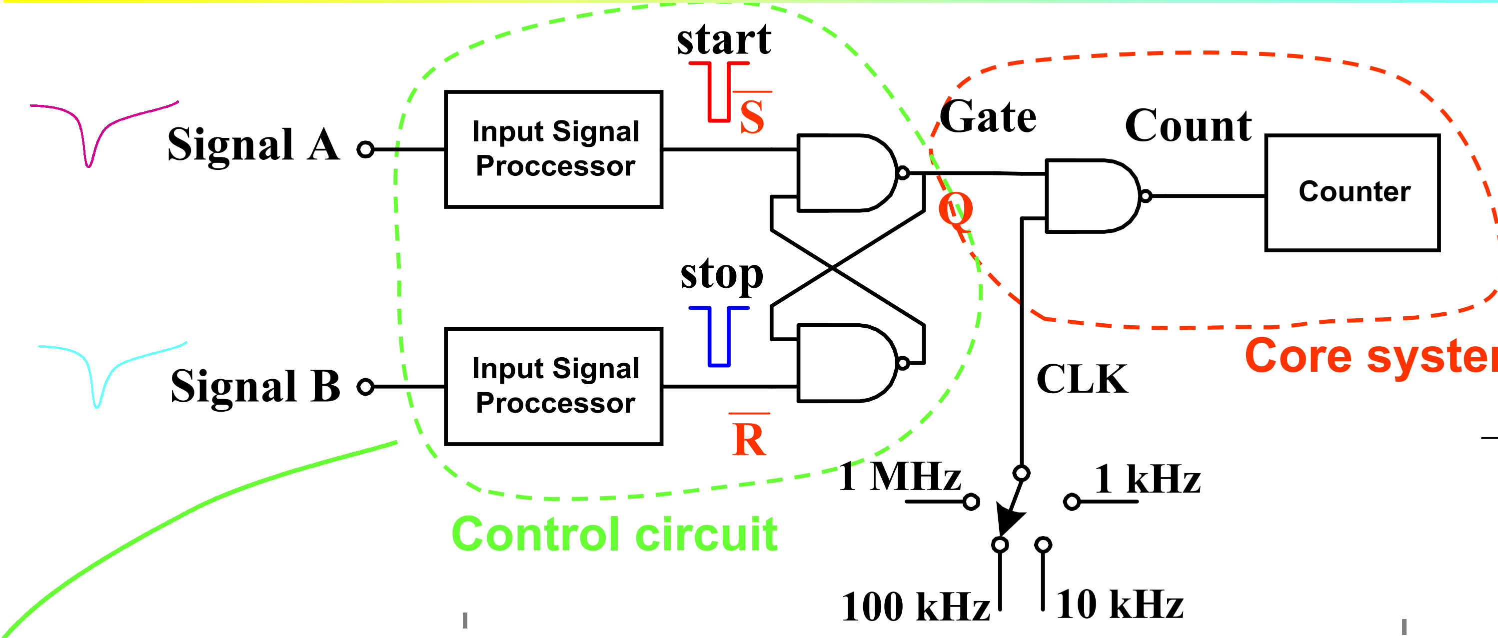
Schmitt Trigger: Comparator with Hysteresis



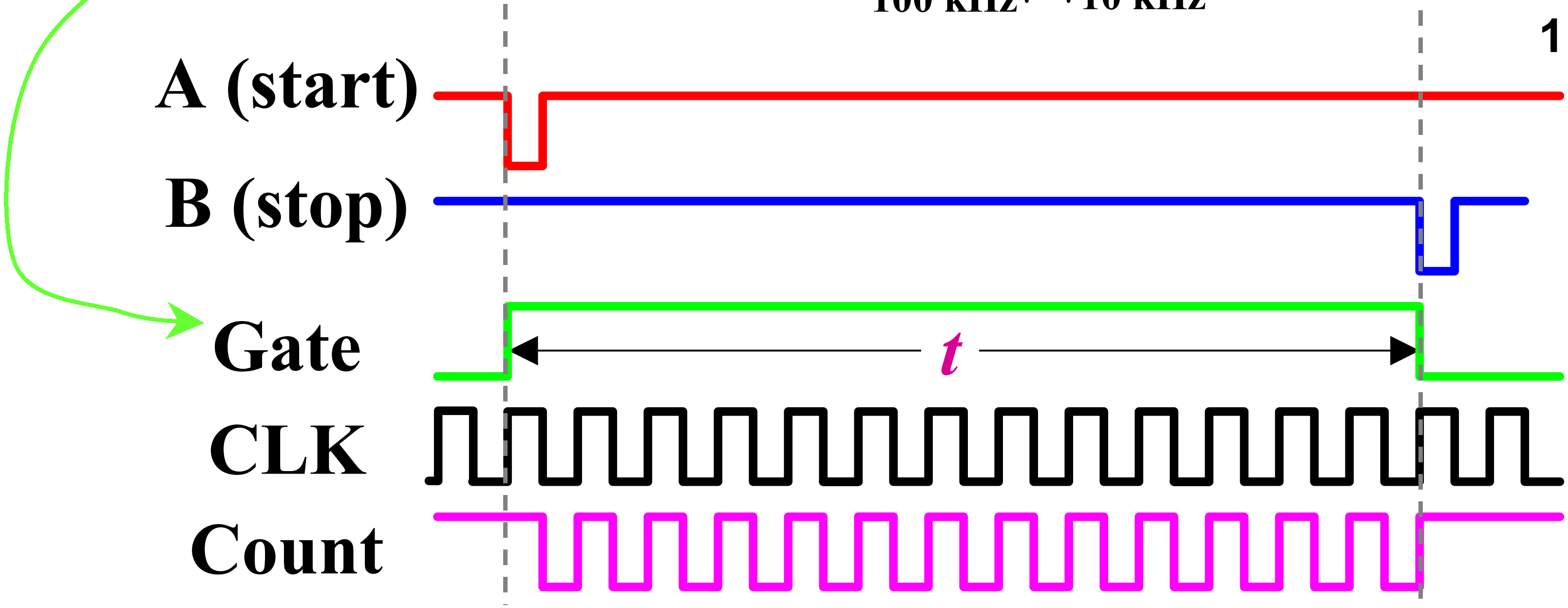
Period Measurement



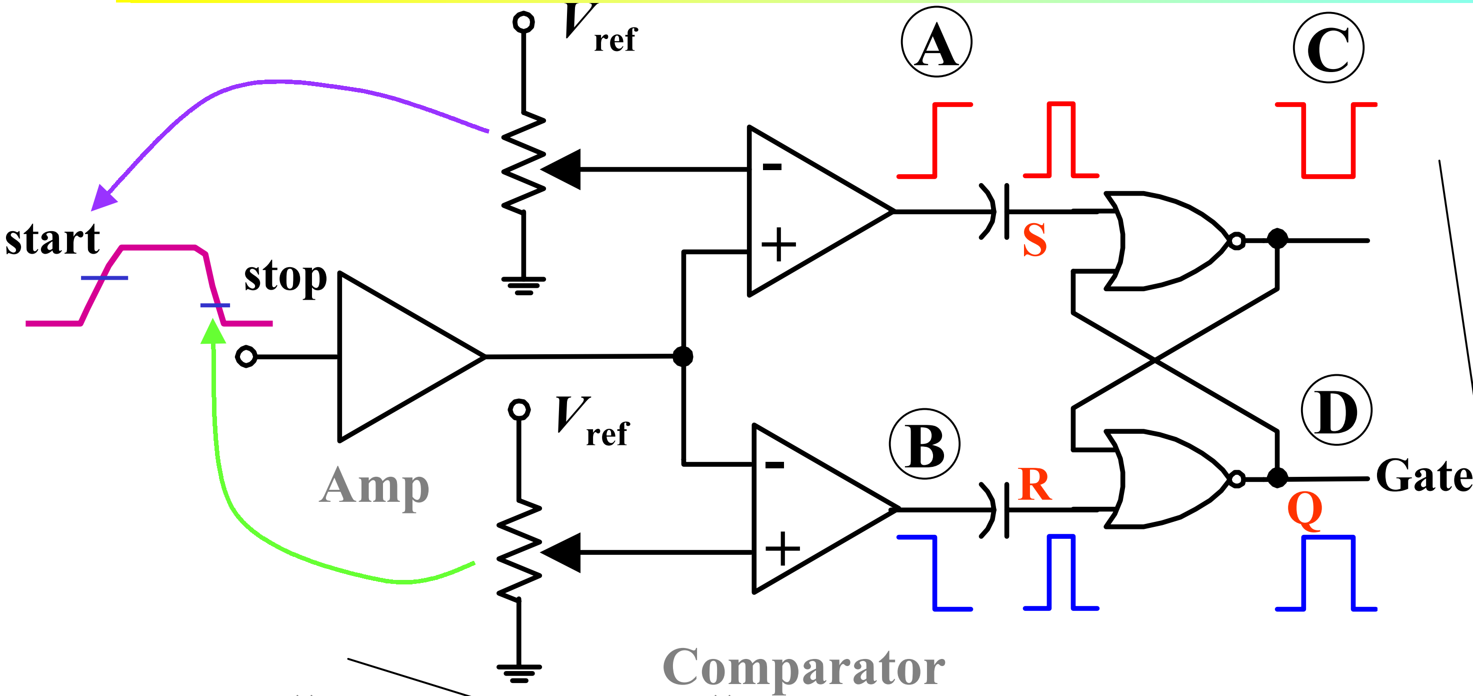
Period Measurement (between pulses)



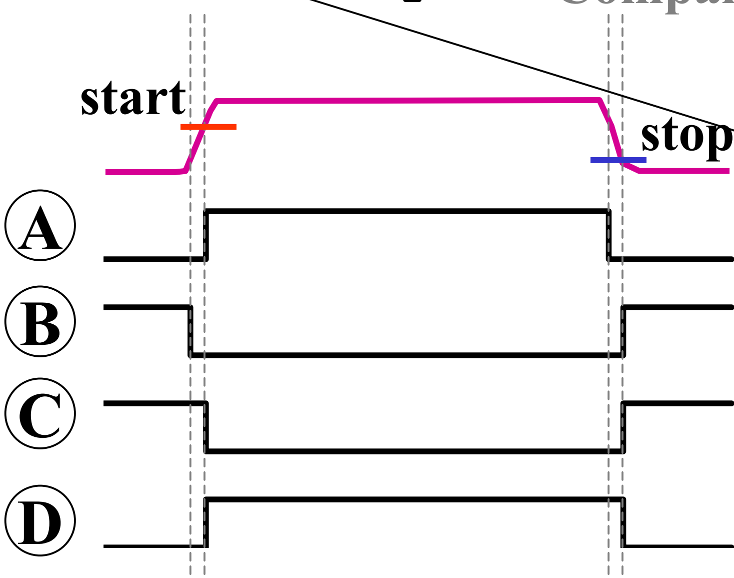
S	R	Q
0	0	Not use
0	1	1
1	0	0
1	1	No change

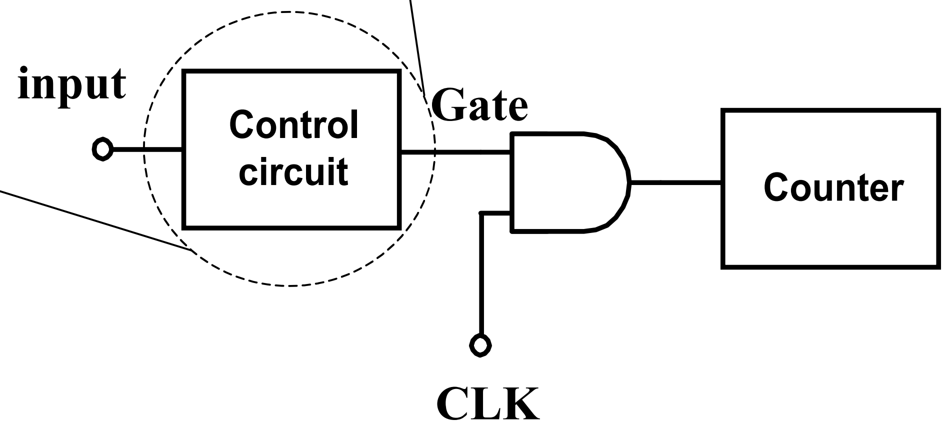


Period Measurement (pulse duration)

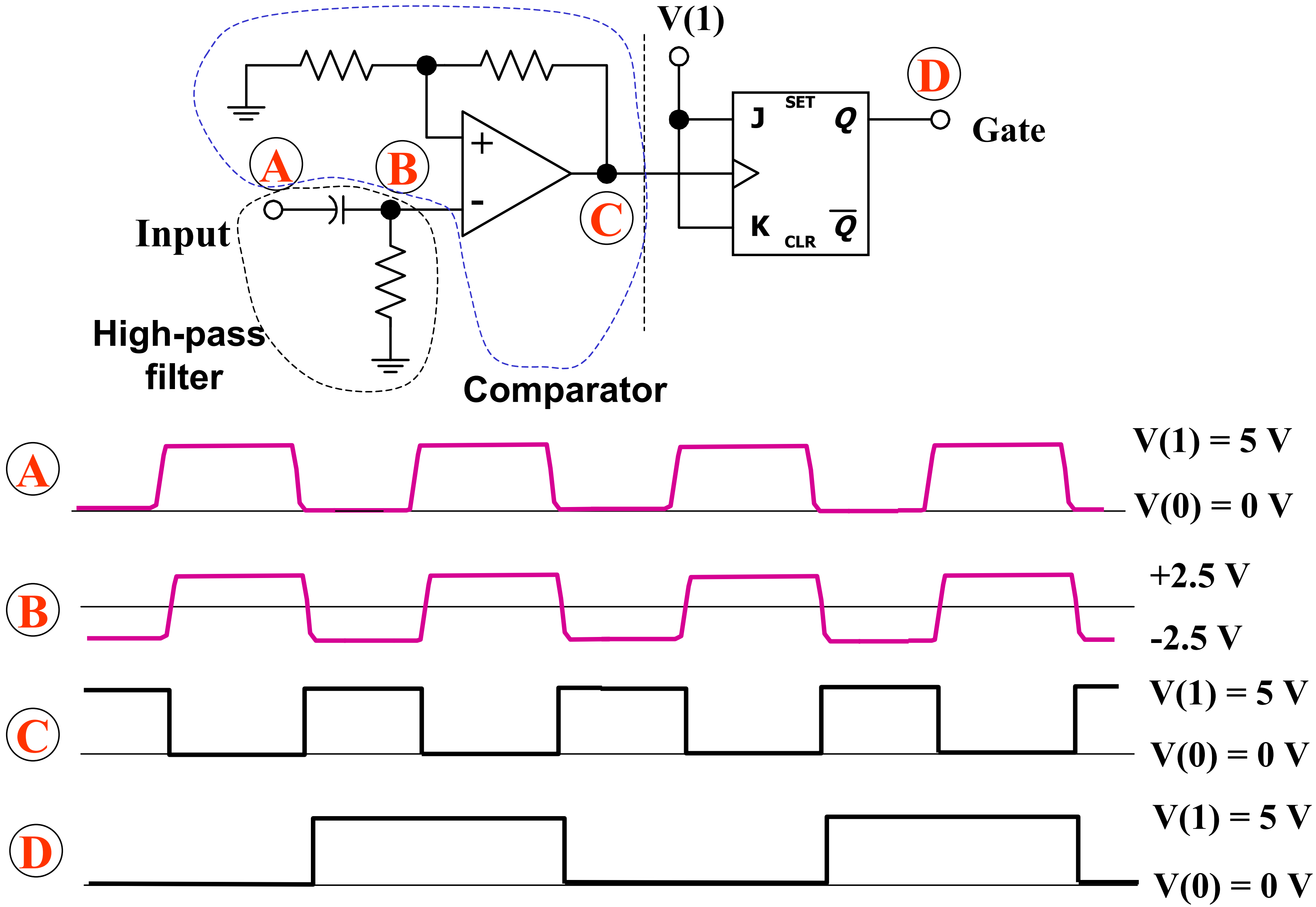


S	R	Q
0	0	No change
0	1	0
1	0	1
1	1	Not use



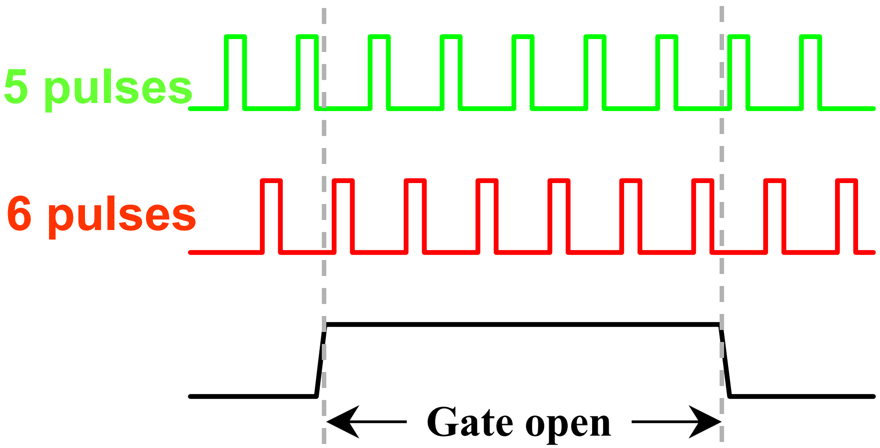


Period Measurement (pulse period)



Measurement Error

1) Gating error (± 1 count)



Frequency measurement

If f_{in} = 10 Hz, Gate time = 1 s
Display count: 10±1 counts

If f_{in} = 1000 Hz, Gate time = 1 s
Display count: 1000±1 counts

If $f_x < f_o$ Period measurement
if $f_x > f_o$ Frequency measurement

f_c: clock frequency f_x: unknown frequency

Period meas.: the number of pulses (N_p)

$$N_p = f_c/f_x$$

Frequency meas.: with 1 s gate time the number of pulses (N_f)

$$N_f = f_x$$

The crossover frequency (f_o) $N_p = N_f$

$$f_c/f_o = f_o; f_o = \sqrt{f_c}$$

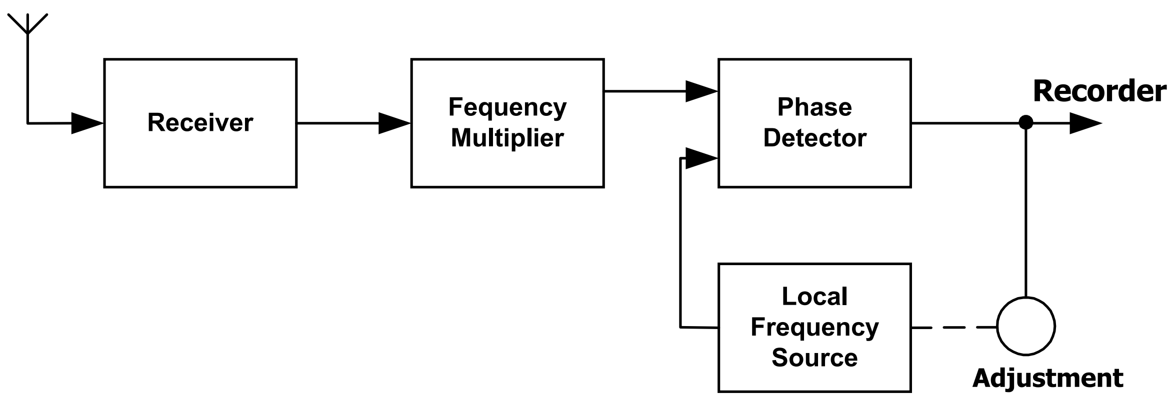
Measurement Error

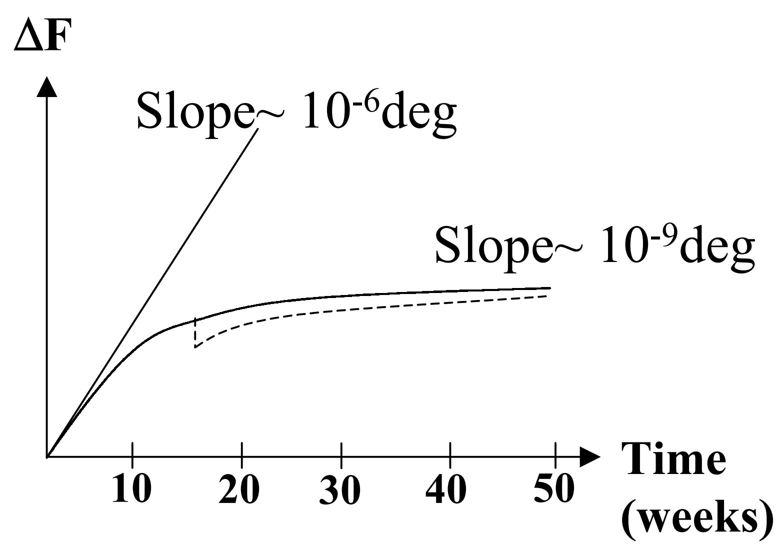
2) Time-base Error

- Oscillator calibration errors
- Short-term crystal stability errors
  (voltage transient, shock, vibrate, temperature)
- Long-term crystal stability errors
  (aging, deterioration of crystal)

National Institute of Standards and Technology, 60 kHz

Loran-C, a navigation signal at 100 kHz





Ex A frequency counter with an accuracy of $\pm$ 1 LSD $\pm$ (1×10^{-6}) is employed to measure frequencies of 100 Hz, 1 MHz, and 100 MHz. Calculate the percentage measurement error in each case.

At f = 100 Hz

$$\text{error} = \pm(1 \text{ count} \pm 100 \text{ Hz} \times 10^{-6})$$
$$= \pm(1 \text{ count} \pm 1 \times 10^{-4} \text{ count})$$
$$\approx \pm 1 \text{ count}$$

$$\%\ \text{error} = \pm\left(\frac{1}{100 \text{ Hz}} \times 100\%\right)$$

$$= \pm 1\%$$

At f = 1000 Hz

$$\text{error} = \pm(1 \text{ count} \pm 1 \text{ MHz} \times 10^{-6})$$
$$= \pm(1 \text{ count} \pm 1 \text{ count})$$
$$= \pm 2 \text{ count}$$

$$\%\ \text{error} = \pm\left(\frac{2}{1 \text{ MHz}} \times 100\%\right)$$

$$= \pm 2 \times 10^{-4}\ \%$$

At $f = 100$ MHz

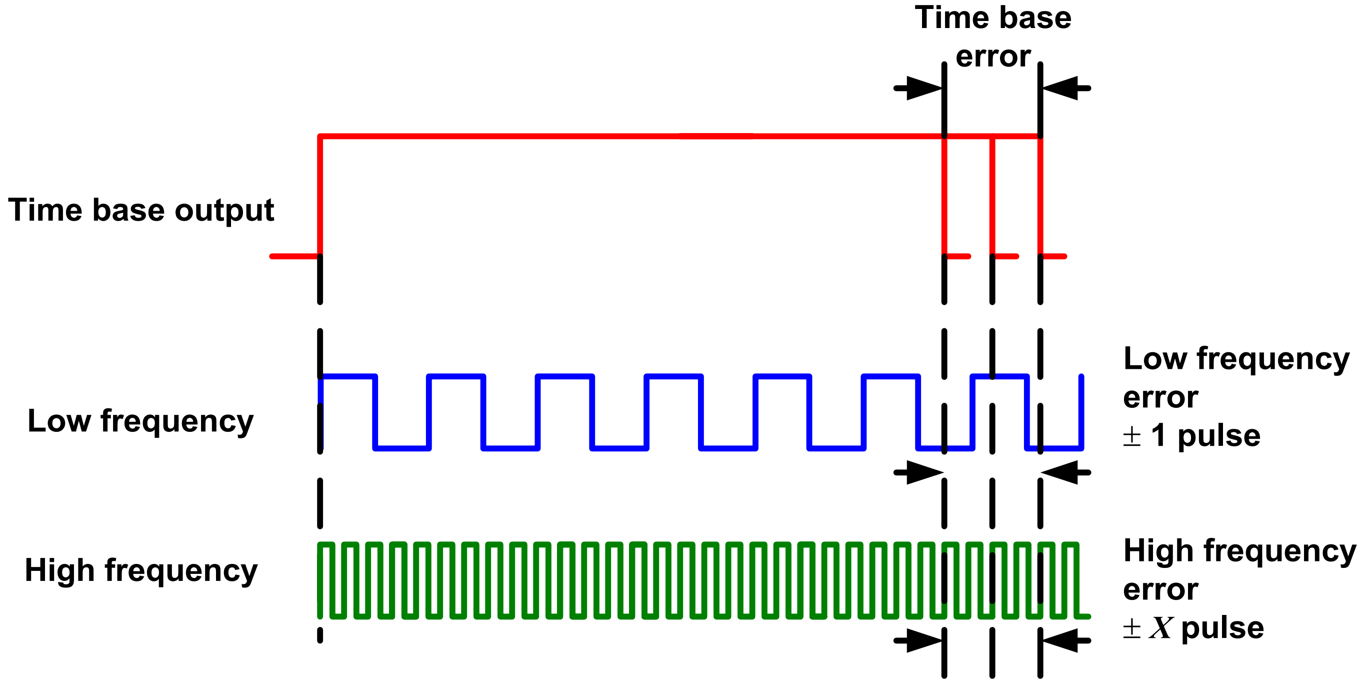
$$\text{error} = \pm(1 \text{ count } \pm 100 \text{ MHz} \times 10^{-6})$$

$$= \pm(1 \text{ count } \pm 100 \text{ count})$$

$$= \pm 101 \text{ count}$$

$$\%\ \text{error} = \pm\left(\frac{101}{100 \text{ MHz}} \times 100\%\right)$$

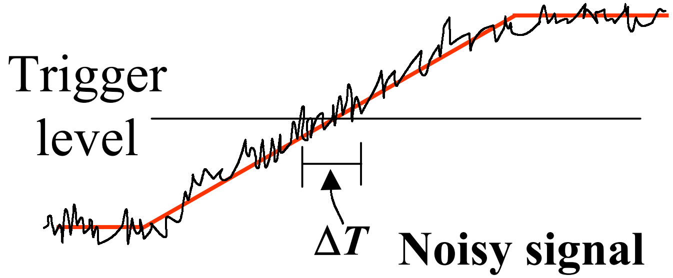
$$= \pm 1.01 \times 10^{-4}\ \%$$

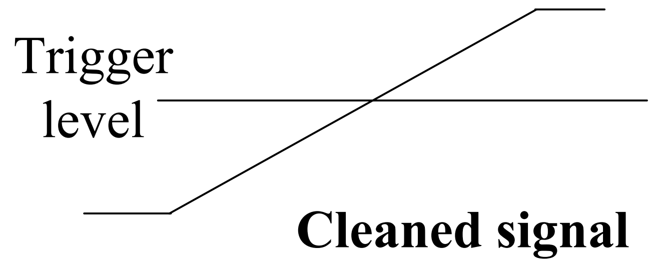


Measurement Error

3) Trigger Level Error (Noise)

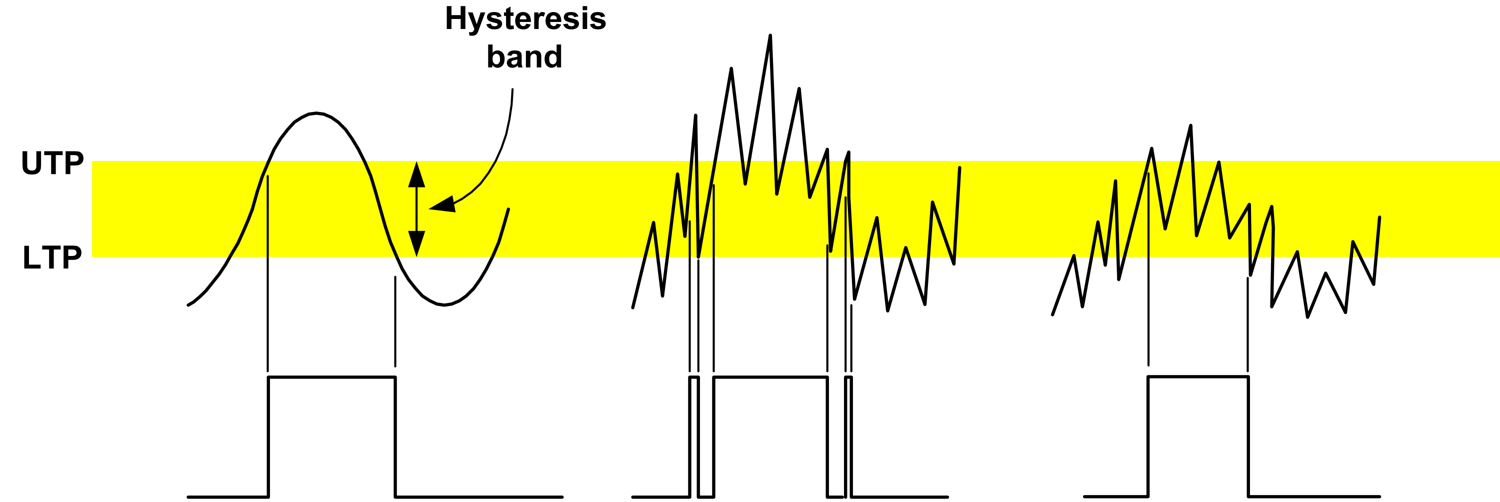
-Use large signal amplitudes and fast rise time





Maximum accuracy could be obtained by

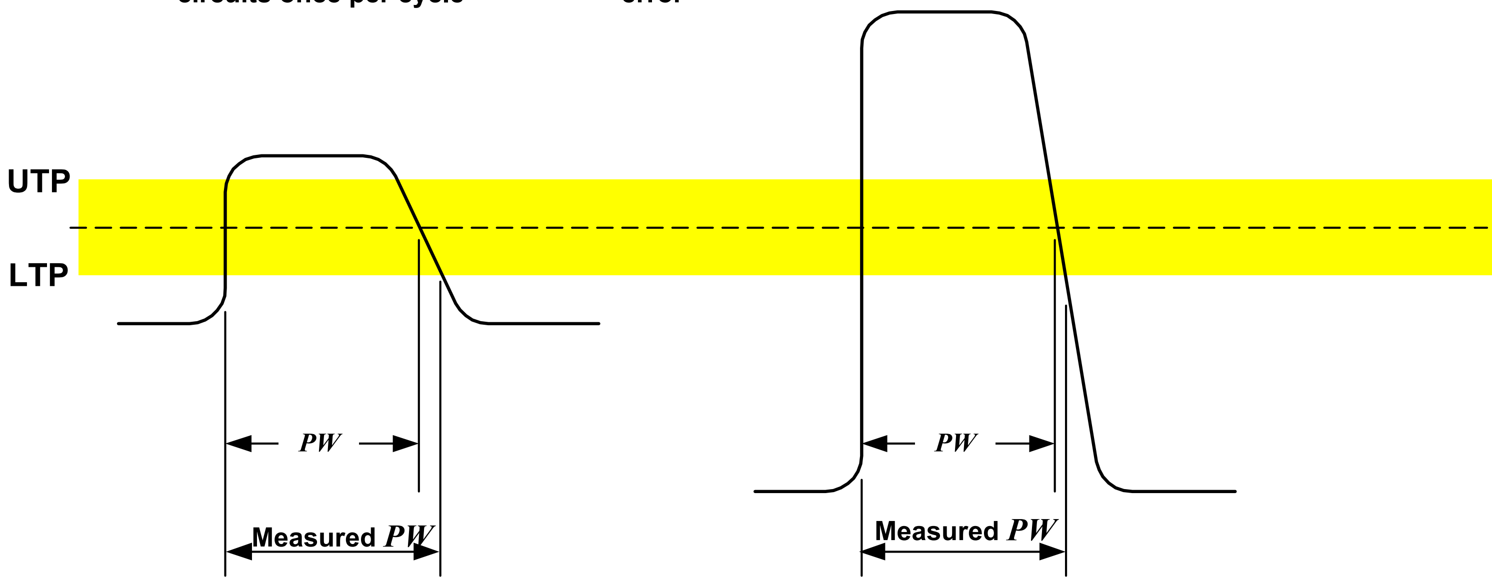
1) use period measurement if $f_x < f_c$
use frequency measurement if $f_x > f_c$
2) Calibrate regularly to prevent long-term stability error
3) Reduce trigger level error in time measurement by using large signal and fast rise time



'clean' sine wave crosses the hystereis band twice during each cycle - triggering counting circuits once per cycle

Noisy sine wave crosses the hystereis band more than twice during each cycle - produce counting error

Attenuated noisy wave form crosses the hystereis band twice during each cycle



A low amplitude input pulse can produce errors in pulse width measurement

Amplification of the input pulse minimizes the pulse width measurement

Ex จงหา resolution และค่าความถี่สูงสุดที่สามารถแสดงผลได้ในเครื่องวัดความถี่ที่มีการแสดงผลแบบ 7 หลัก ถ้าเวลาของสัญญาณเกตถูกตั้งไว้ที่ 1 วินาที (resolution = 1 Hz, Max. freq. = 9,999,999 Hz)

Ex เครื่องวัดความถี่เครื่องหนึ่งมีความผิดพลาดจากการนับ ±1 ครั้ง (±1 count) และมีความผิดพลาดจากฐานเวลา 5 ส่วนในล้านส่วน (ppm: part per million) <u>จงหาค่าเปอร์เซ็นต์ความผิดพลาดเมื่อใช้วัดความถี่ 1 kHz</u>

ความผิดพลาดรวมเท่ากับผลรวมของความผิดพลาดทั้งสอง

ความผิดพลาด $= \pm(1 \text{ count} + 1 \text{ kHz} \times 5 \text{ ppm})$

$= \pm(1 \text{ count} + 0.005 \text{ count})$

ค่าเปอร์เซ็นต์ความผิดพลาด $= \pm \dfrac{1.005}{1000} \times 100 = 0.1\%$

Specifications of a freq./period Measurement

Frequency mode

Range: DC to 50 MHz

Gate time: Manual 1 ms to 100 s in decade step

Automatic up 1 s gate time

Period mode

Range: 1 μs to 1 s unit in μs

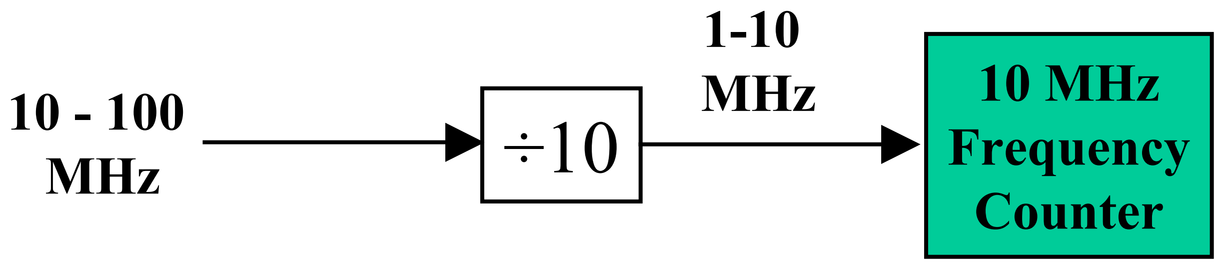
Duration mode

Range: 100 ns to 10^4 s

Inputs: 2 channels for start signal and 1 channel for stop signal

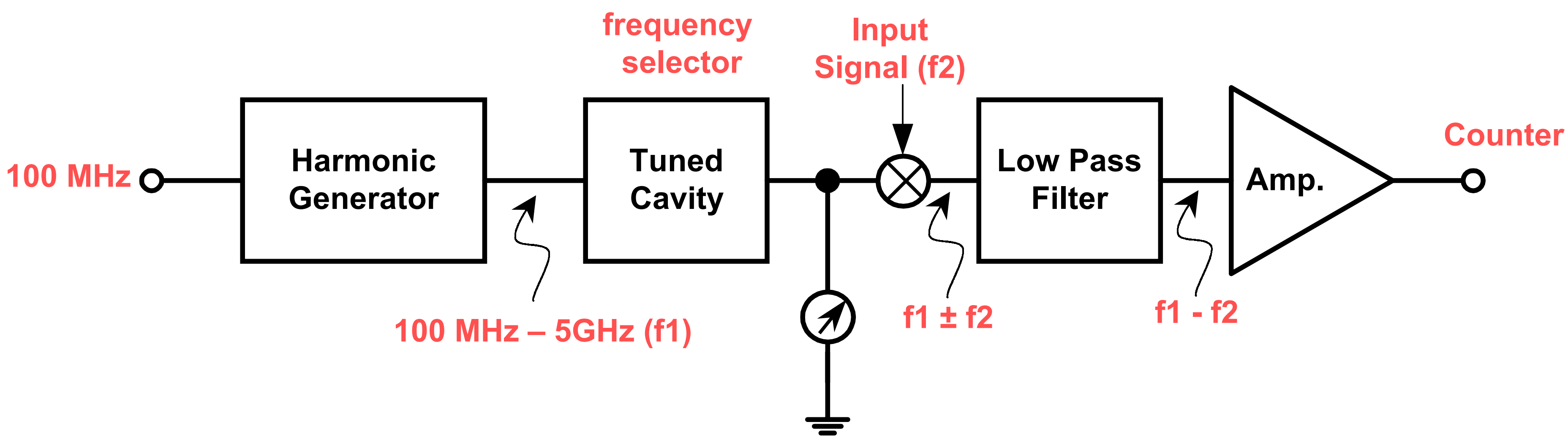
Extending the frequency range of a counter

❖Prescaler (upto 1.5 GHz)

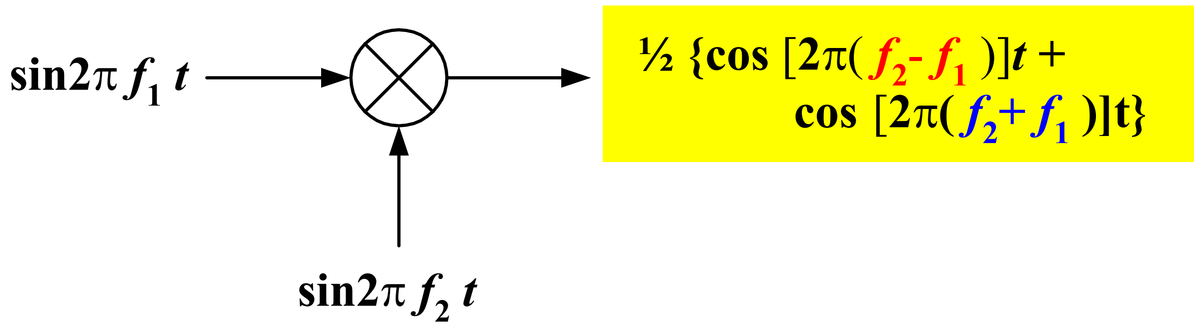


Reduce resolution but can be improved by extending gate time

❖Heterodyne Technique

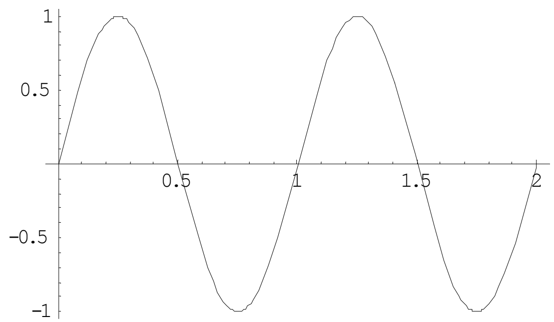


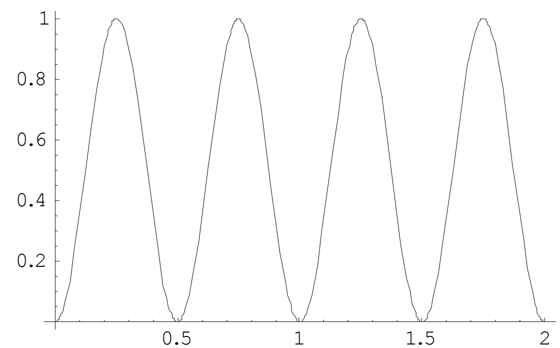
Homodyne and Heterodyne technique



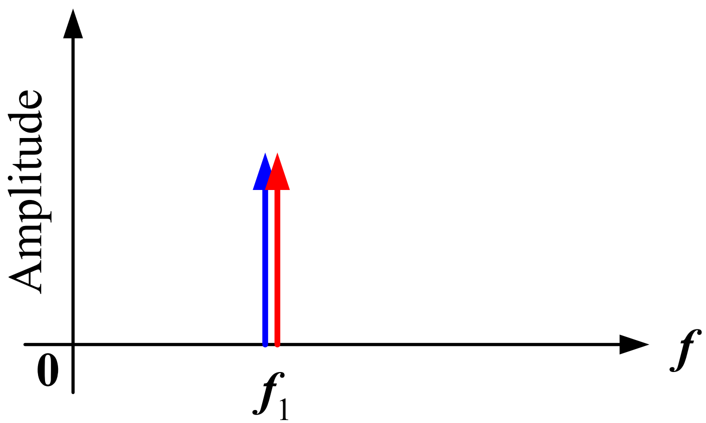
If $f_1 = f_2$; Homodyne

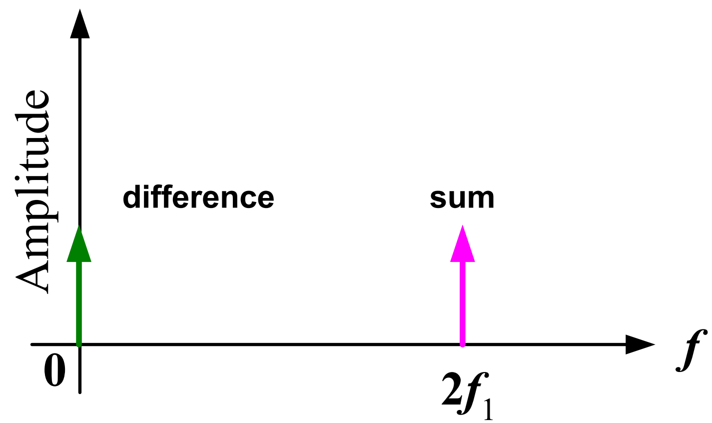
Time domain





Frequency domain

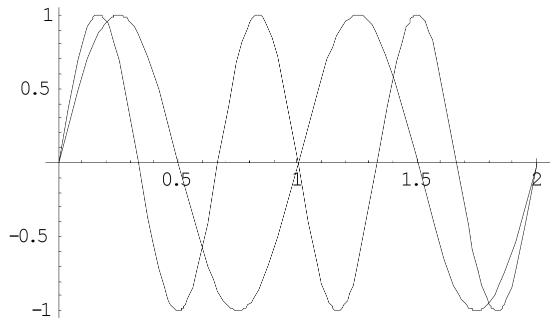


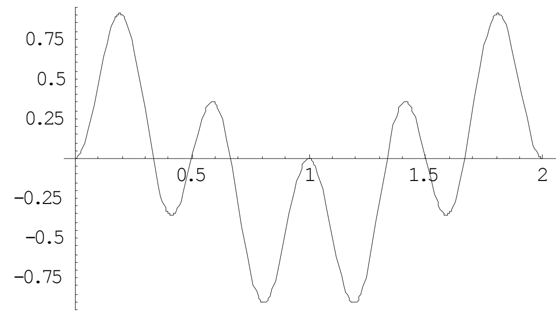


Homodyne and Heterodyne technique

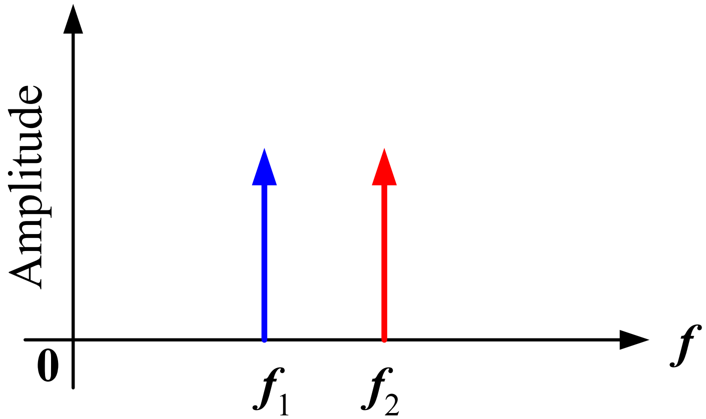
If $f_1 \neq f_2$; Heterodyne

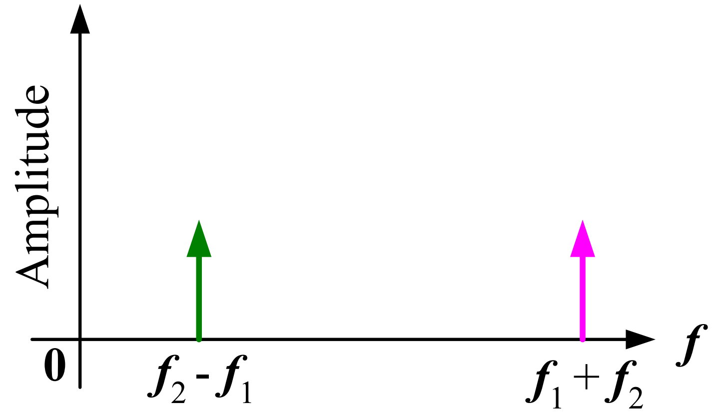
Time domain





Frequency domain



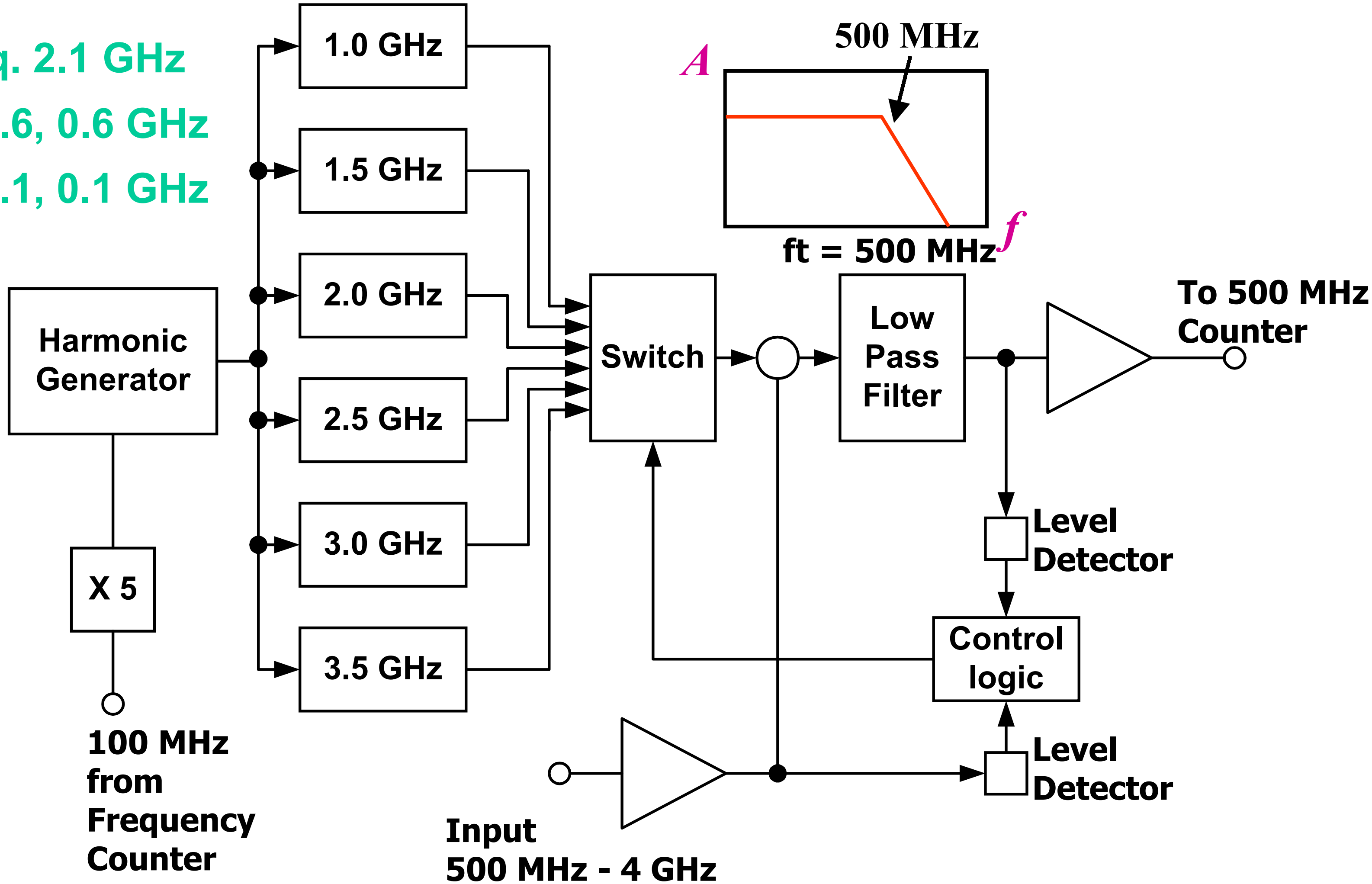


Automatic Heterodyne Unit

Ex input freq. 2.1 GHz

1.5 ± 2.1 =3.6, 0.6 GHz

2.0 ± 2.1 =4.1, 0.1 GHz



Accuracy

❖Prescaler

Displayed freq. = $\frac{f_{in}}{N}t$

f_{in}: input freq.
N : divider of prescaler
t : gate time

Accuracy $\propto t$ exactly the same as the counter without a prescaler

❖Heterodyne Technique

Gate time, $t = \frac{Q}{f_c}$

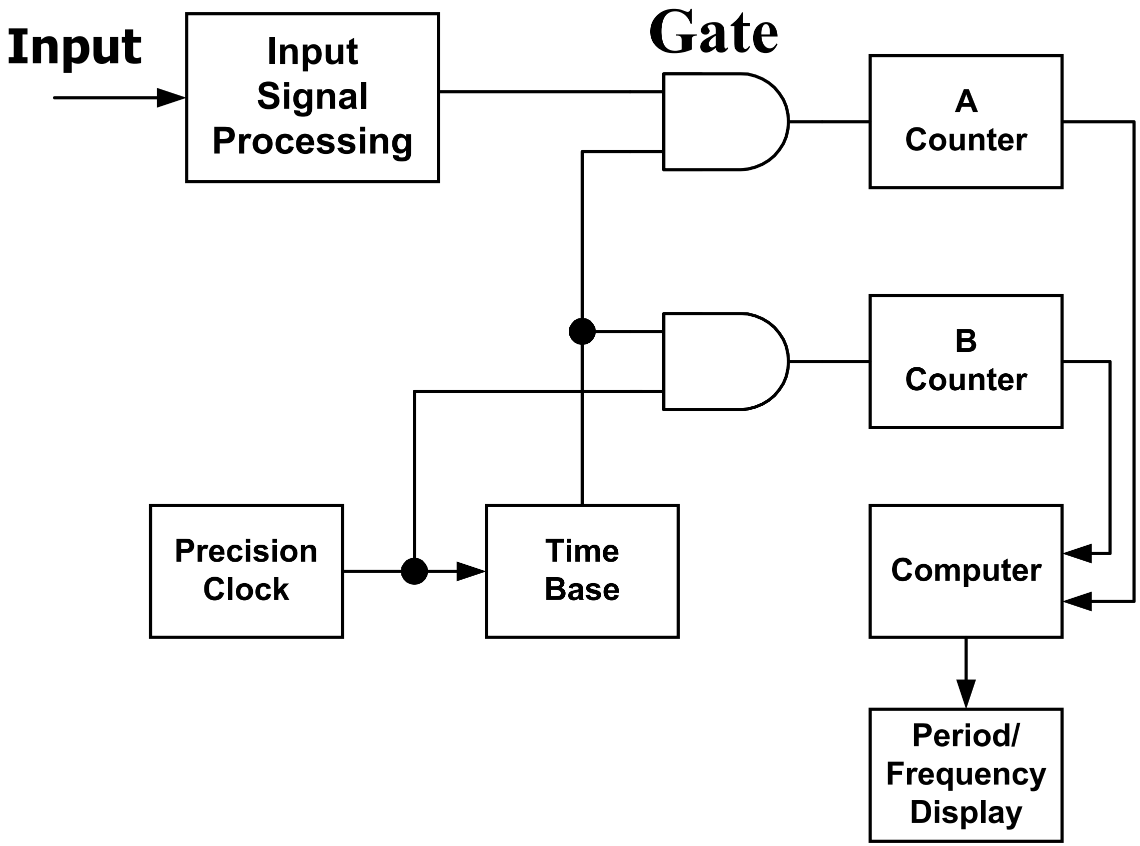
Q : Time-base Divisor
f_c : Time-base Clk freq.
N : Harmonic number

Input freq., $f_{in} = f'_{in} \pm Nf_c$

Displayed freq. = $f_{in}\frac{Q}{f_c} = f'_{in}\frac{Q}{f_c} \pm NQ = f'_{in}t \pm NQ$

Accuracy $\propto t$; (NQ is constant)

Computing Counter



$$\text{Input freq.} = \frac{\text{Count in A}}{\text{Count in B}}$$

$$\text{Input time} = \frac{\text{Count in A}}{\text{Clk freq.}}$$

- ✓ Opening and Closing gate are controlled from either the input signal or the internal clock.
- ✓ Computer will help to determine whether freq./period will be performed.