Electrical and Electronic Measurements

Lecture 7: Digital Frequency Meters

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October 2018

Lecture Outline:

1. Basic Digital Frequency Meters (DFM).
2. Frequency Range Changing.
3. Frequency Meter Accuracy.
4. Reciprocal Digital Frequency Meters (DFM).

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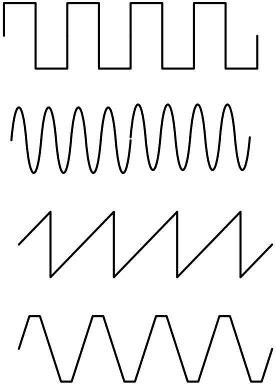
Introduction:

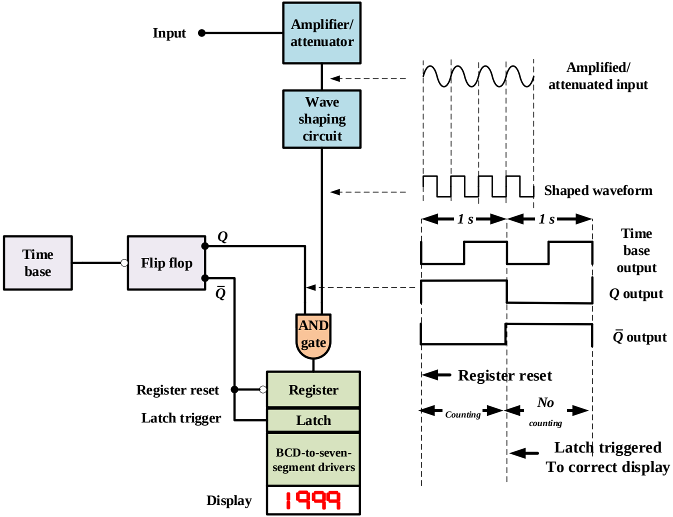
1. Frequency of a **periodic signal** is defined as: the number of occurrences of a repeating event per unit time = Number of signal's cycles per one second.



Principle of Frequency Meters:

To measure the frequency of a certain periodic signal, the **waveform of that signal** is used to **toggle a counter for a certain fixed time**. The number of counted cycles per unit time indicates the signal frequency.

Basic Digital Frequency Meters (DFM):



Basic Digital Freq. Meter

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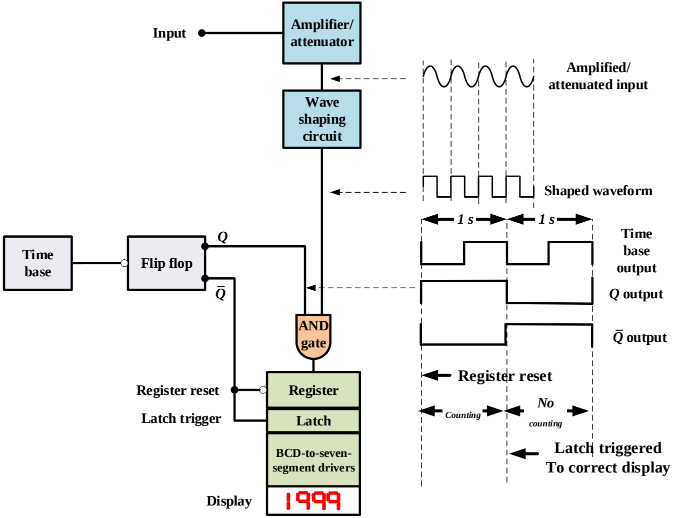

Basic Digital Freq. Meter

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- Accurate timing source (time base) with frequency of 1 Hz.

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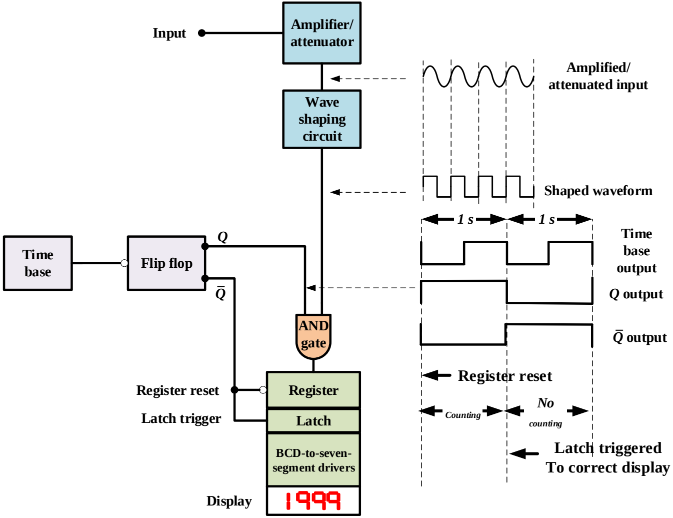

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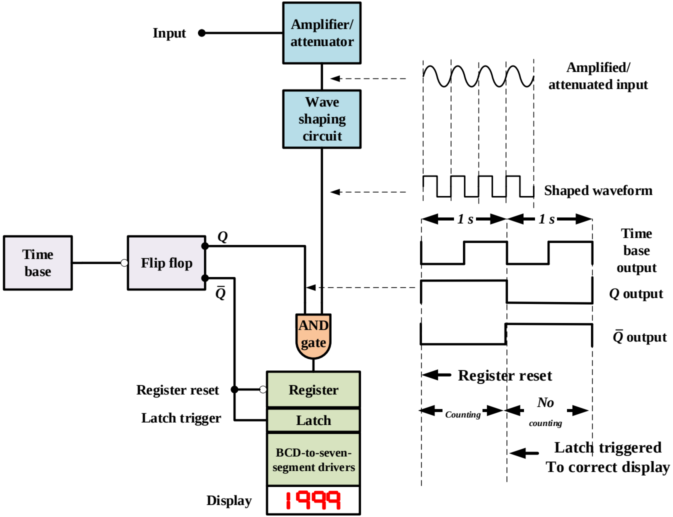

Basic Digital Freq. Meter

The basic DFM consists of:

- Accurate timing source (time base) with frequency of 1 Hz.
- Digital counting circuit to count the input waveform cycles.
- Amplifier/Attenuation circuit to amplify or attenuate the input signal.
- Waveform shaping circuit to convert the input signal to square wave.

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The operation of basic DFM:

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5. One terminal of the AND gate is fed from the flip-flop Q output and the other terminal is fed from the shaped input signal. So, the counter circuit will count the input pulses for the duration of $1\ s$. (Frequency).

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7. The latch will isolate the counting from the display during the first $1\ s$ and will update the display on the rising edge of $\bar{Q}$ output.

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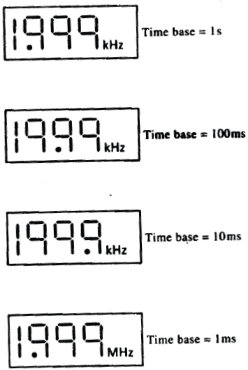
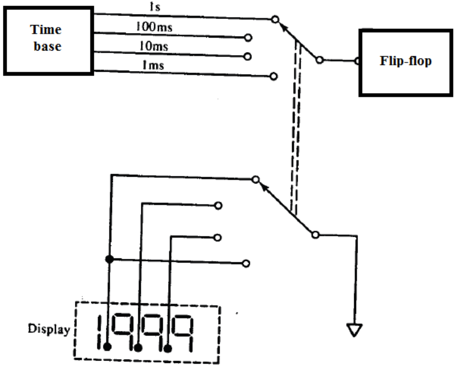
Frequency Range Changing:

- Different time-base frequencies could be used to give several range of frequency measurements.
- The different time base could be achieved by connecting series **decade counters**. Each decade counter divides the frequency by 10.





Frequency Range Changing

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Frequency Meter Accuracy:

Range Selection Error

The **lowest possible frequency** range should be used for the **greatest measurement accuracy**.

Example

A digital freq. meter has a time base derived from $1\ MHz$. clock. The clock is divide by decade counters to allow different frequency ranges. What is the displayed frequency when a $1.512\ kHz$. signal is applied if the time base frequency divided by:

1. Six decade counters.
2. Four decade counters.

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Solution

1. Counting time period t_1:

$$t_1 = \frac{1}{f_1} = \frac{1}{1\ MHz./10^6} = 1\ s$$

Counted cycles n_1:

$$n_1 = f_{in}\ x\ t_1 = 1512\ cycles$$

$$\boxed{f_{measured} = 1.512\ kHz}$$

2. $t_2 = \frac{1}{f_2} = \frac{1}{1\ MHz./10^4} = 0.01\ s$

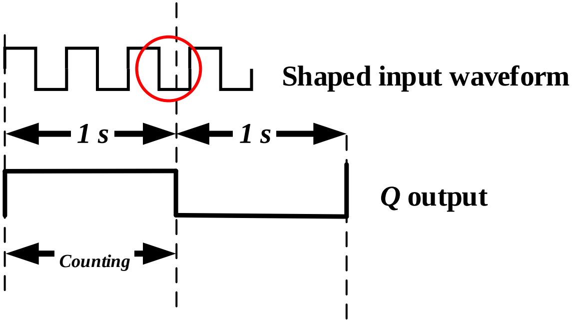
$$n_2 = f_{in}\ x\ t_2 = 15\ cycles$$

$$\boxed{f_{measured} = 01.5\ kHz}$$

Frequency Meter Accuracy:

Accuracy Specification

- There is always **a possible error of ± 1 cycle in the measured frequency due to the partial input pulse** that may or may not succeed in triggering the counting circuit. This one cycle is defined as *least significant digit (LSD)*.

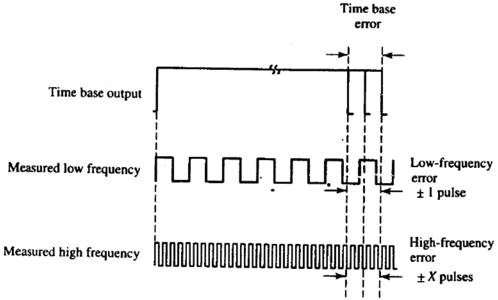


Frequency Meter Accuracy:

Accuracy Specification

- Also, the time base error E_{tb} due to freq. variation will give a reading error in the measured frequency f_i as:

$$time\ base\ error = f_i\ x\ E_{tb}$$



- So, the total accuracy of digital frequency meter is specified as:

$$\boxed{\pm(1\ LSD\ + f_i * time\ base\ error)}$$

See Example 6-4

Frequency Meter Accuracy:

Accuracy Specification

Example

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

Solution

At $f_i = 100$ Hz.

$$error = \pm\ (1\ count + 100\ Hz\ x\ 10^{-6})$$

$$error \approx \pm\ 1\ count$$

$$\%\ error = \pm(\frac{1}{100\ Hz}\ x\ 100\%) \approx \pm\ 1\%$$

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Solution

At $f_i = 1$ MHz.

$$error = \pm\ (1\ count + 1\ MHz\ x\ 10^{-6})$$

$$error \approx \pm 2\ counts$$

$$\%\ error = \pm(\frac{2}{1\ MHz}\ x\ 100\%) \approx \pm\ 2\ x\ 10^{-4}\%$$

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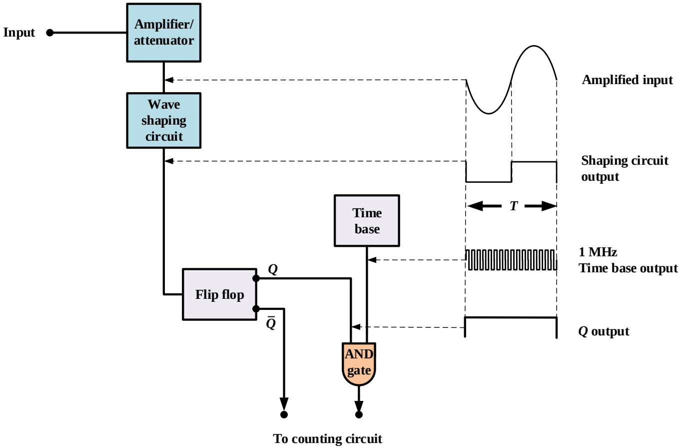
Reciprocal Digital Frequency Meters (DFM):



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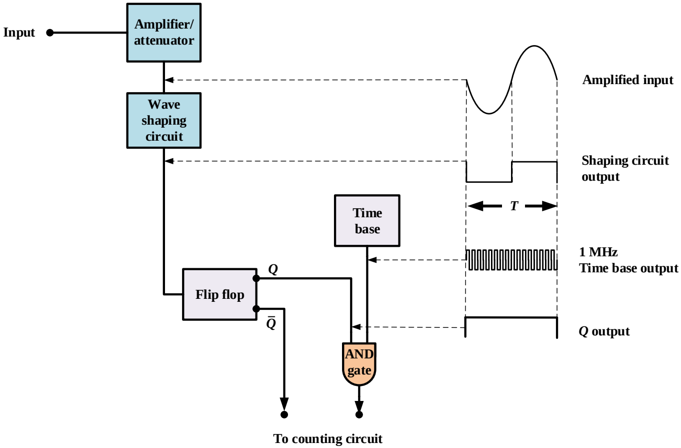

Reciprocal Digital Freq. Meter.

- The time base signal with $1\ MHz.$ is applied directly to the AND gate.

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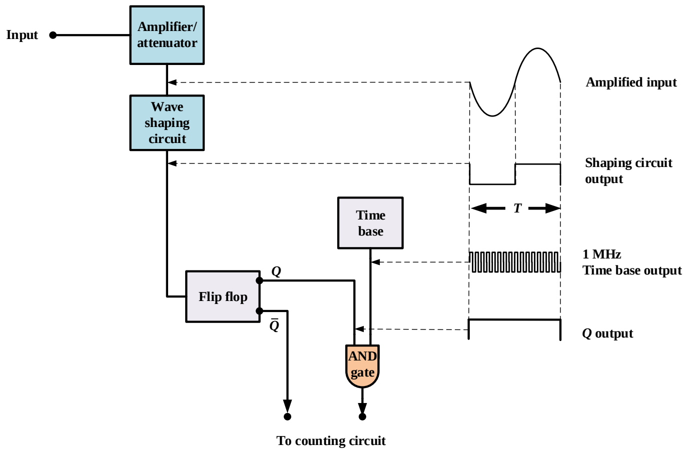

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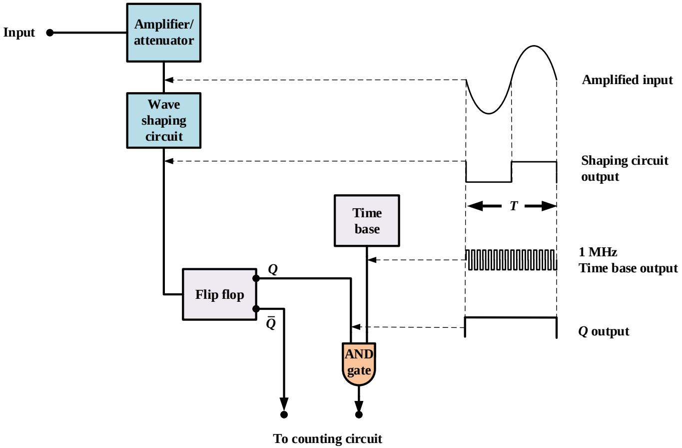

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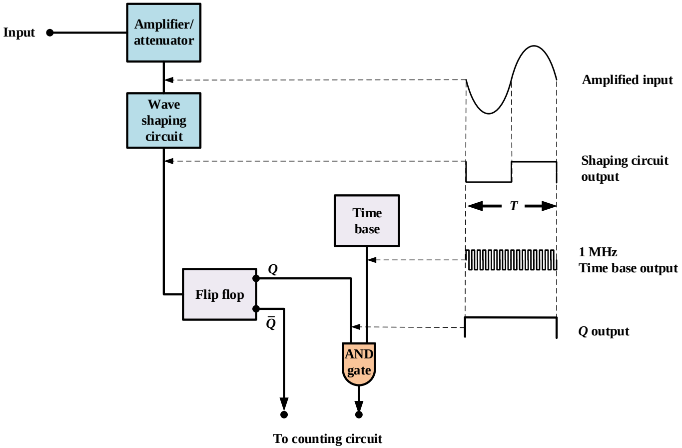

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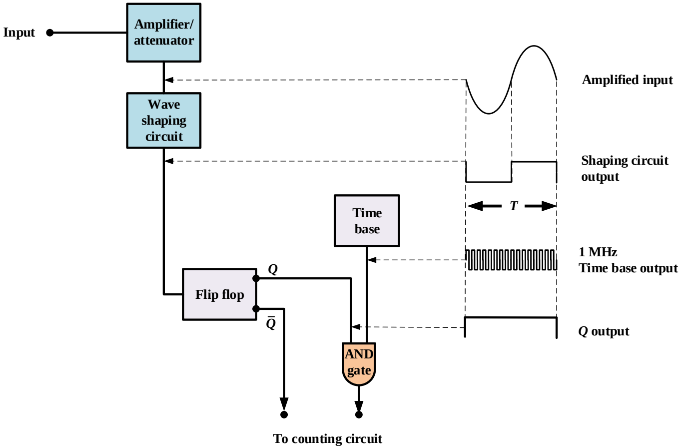

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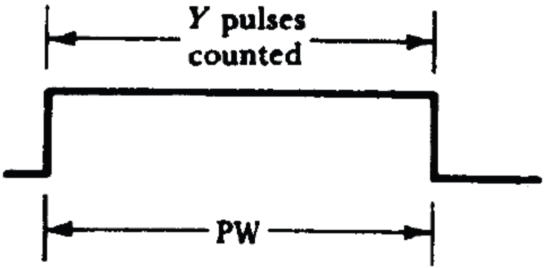
- n is the number of pulses.

Time and Ratio Measurements:

Pulse Width Measurements

If the flip-flop in Reciprocal FM is made to toggle on +ve and -ve edges, we can measure the input pulse width.



Digital measurement of pulse width
PW = Y μs

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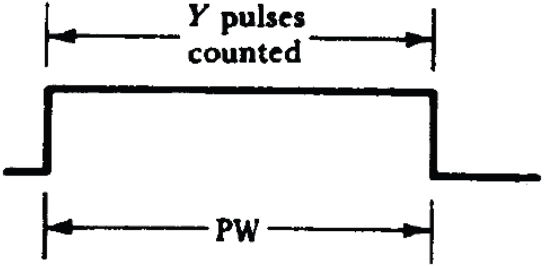
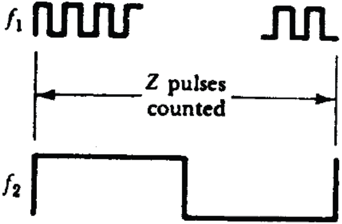


Digital measurement of pulse width
$PW = Y\ \mu s$

Frequency Ratio Measurement

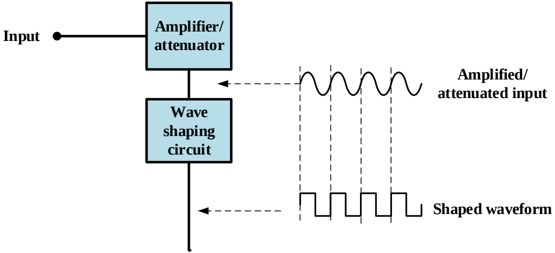
To find the ratio between tow frequencies f_1 and f_2, the higher frequency signal is fed to the AND while the lower frequency is applies to the flip-flop.



Digital measurement of ratio of two frequencies
$$\frac{f_1}{f_2} = Z$$

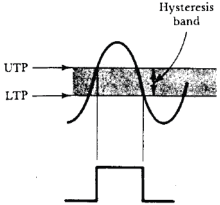
Digital Frequency Input Stage:

Why we use the attenuator/amplifier in input ?



UTP: Upper Triggering Point.
LTP: Lower Triggering Point.

- Usually a Shmitt-Trigger with two triggering levels (UTP and LTP) is used to convert a periodic signal into square wave signal.

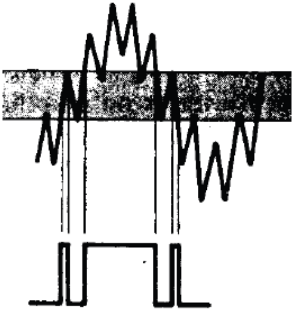


- The small input signal could be **amplified** to make it suitable to be triggered by UTP and LTP.

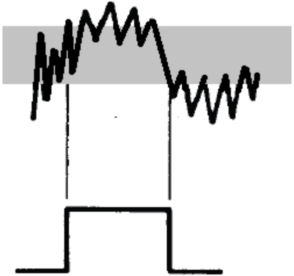
Digital Frequency Input Stage:

Why we use the attenuator/amplifier in input ?

- In the case of noisy input signal, an error is exist due to the amplified signal and the amplified noise.



- To reduce the effect of noise, the input signal should be **attenuated** to attenuate the input noise.



End of Lecture

Best Wishes