Electrical and Electronic Measurements, Part 2

Lecture 2: Digital Frequency Meters

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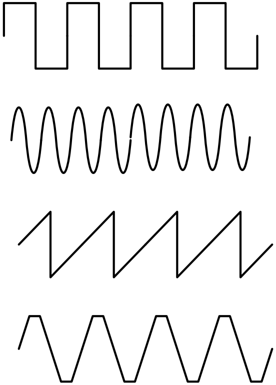
Lecture Outline:

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

Table of Contents

Introduction to Digital Frequency Meters:

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.

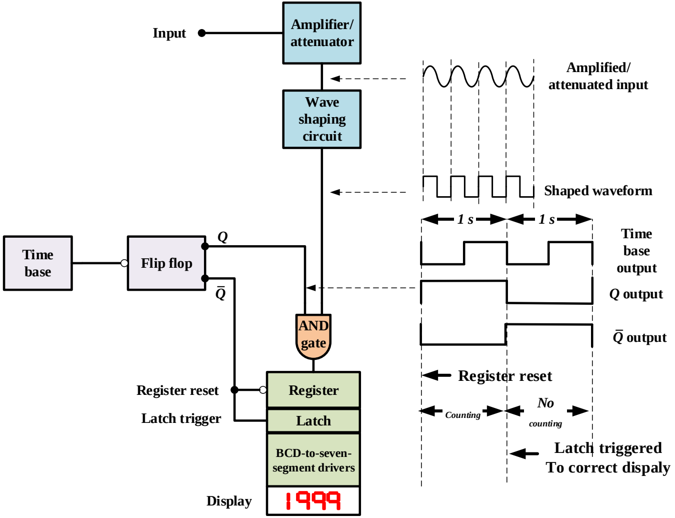


Principle of Frequency Meters:

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.

Table of Contents

Basic Digital Frequency Meters (DFM):



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.

Basic Digital Frequency Meters (DFM):

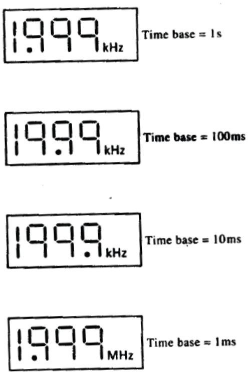
The operation of basic DFM:

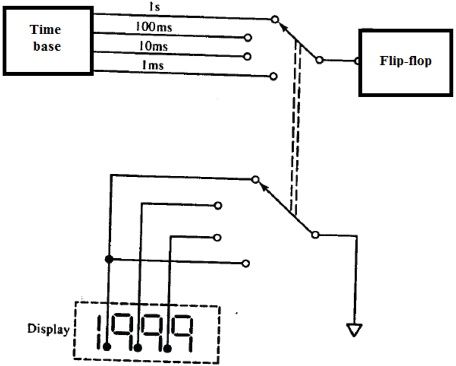
1. The input signal is amplified or attenuated as necessary.
2. The input signal is converted to a square wave and is fed to one terminal of the AND gate.
3. The time base signal with 1 Hz. freq. is fed to a flip-flop.
4. The flip-flop changes its state at each falling-edge of the time base. It divides the frequency by 2 giving a *high* on the Q terminal for 1 s and a low for another 1 s. The terminal $\bar{Q}$ is an inverted version of Q.
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).
6. The counter will reset to zero at each negative (falling) edge of the $\bar{Q}$.
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.

Table of Contents

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 counter**. Each decade counter divides the frequency by 10.





Frequency Range Changing

Table of Contents

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.

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.

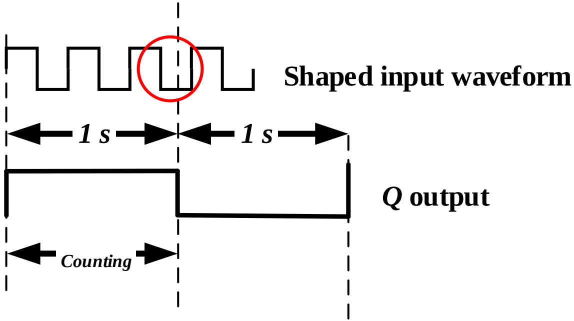
$$n_2 = f_{in}\ x\ t_2 = 15\ cycles$$

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

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)*.

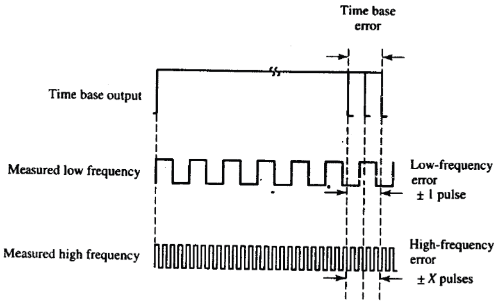


Frequency Meter Accuracy:

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:

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



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

$$\boxed{\pm 1\ LSD\ \pm\ time\ base\ error}$$

See Example 6-4

Frequency Meter Accuracy:

Accuracy Specification

Example

A frequency counter with an accuracy of $\pm 1\ LSD \pm (1\ x\ 10^{-6})$ 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.

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

$$error \approx \pm\ count$$

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

Solution

At $f_i = 1$ MHz.

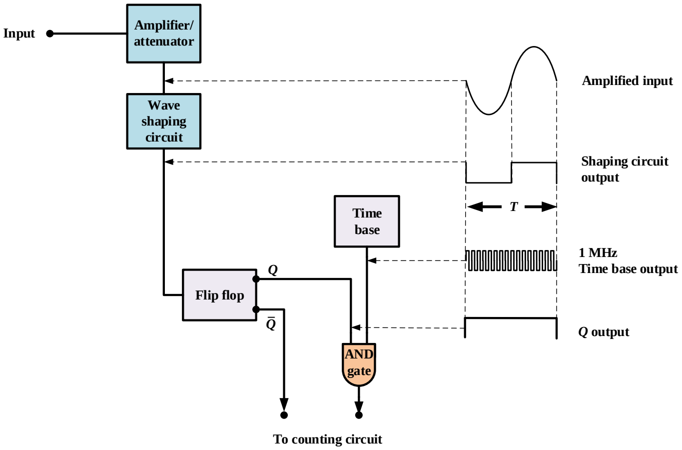
$$error = \pm\ (1\ count + 1\ MHz\ x\ 10^{-6})$$

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

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

Table of Contents

Reciprocal Digital Frequency Meters (DFM):



Reciprocal Digital Freq. Meter:

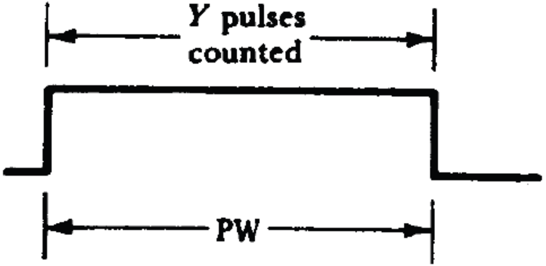
- The time base signal with 1 MHz. is applied directly to the AND gate.
- The reshaped input signal is employed to toggle the flip-flop circuit.
- It is better for measuring **low frequencies** than the direct frequency meters.
- The measure frequency f_{in} is:

$$f_{in} = \frac{f_{time\ \ base}}{n}$$

Time and Ratio Measurements:

Frequency Ratio Measurement

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

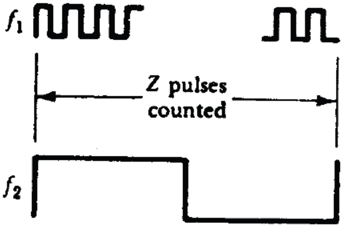


Digital measurement of pulse width

PW = Y μs

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.

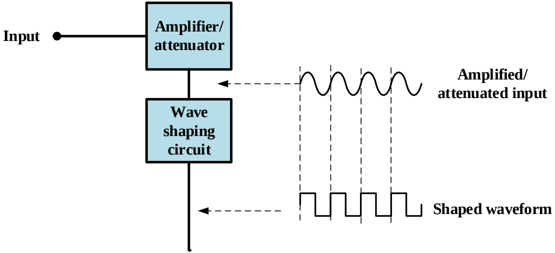


Digital measurement of ratio of two frequencies

$$\frac{f_1}{f_2} = Z$$

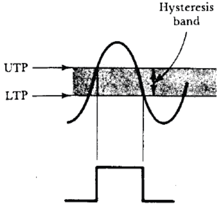
Digital Frequency Input Stage:

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.

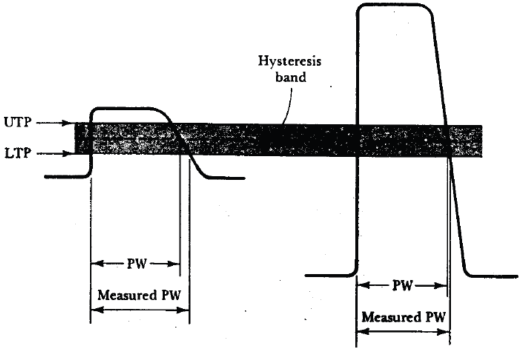


- The small input signal could be **amplified** to make it suitable to be triggered by UTP and LTP.

Digital Frequency Input Stage:

Why we use the attenuator/amplifier in input ?

- Also, **amplification** could help in reducing the measurement error due to hysteresis when measuring the Pulse Width (PW).



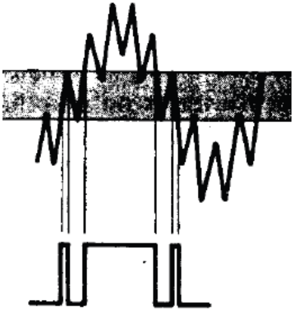
(a) A low amplitude input pulse can produce errors in pulse width measurement

(b) Amplification of the input pulse minimizes the pulse width measurement

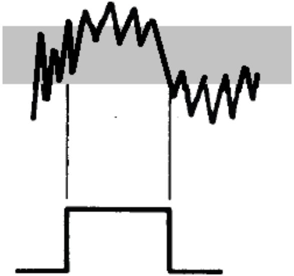
Digital Frequency Input Stage:

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