ACCEP
Communication and Computer Engineering Program

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# ECE 211

# Measurements and Instrumentations

(2022 - 2023) term 231

## Lecture 6: Digital Voltmeters and Digital Frequency Meters.

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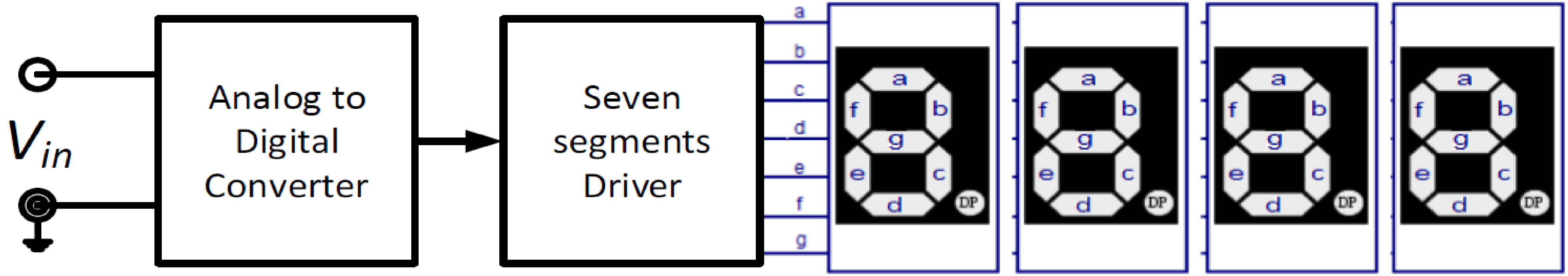
# Chapter Outline:

1) **Ramp Type Digital Voltmeters.**
2) Dual Slope Digital Voltmeters.
3) DVM Range Changing.
4) Digital Voltmeter Accuracy.
5) Types of Digital Multi-meters.
6) Basic Digital Frequency Meters (DFM).
7) Frequency Range Changing.
8) Frequency Meter Accuracy.
9) Reciprocal Digital Frequency Meters (DFM).

# Introduction:

- Two types will be covered: **Ramp-type** and **Dual slope Integrator** DVMs.
- Digital voltmeters (DVM) are essentially **analog-to-digital converters** with **digital displays** to indicate the measured voltage.

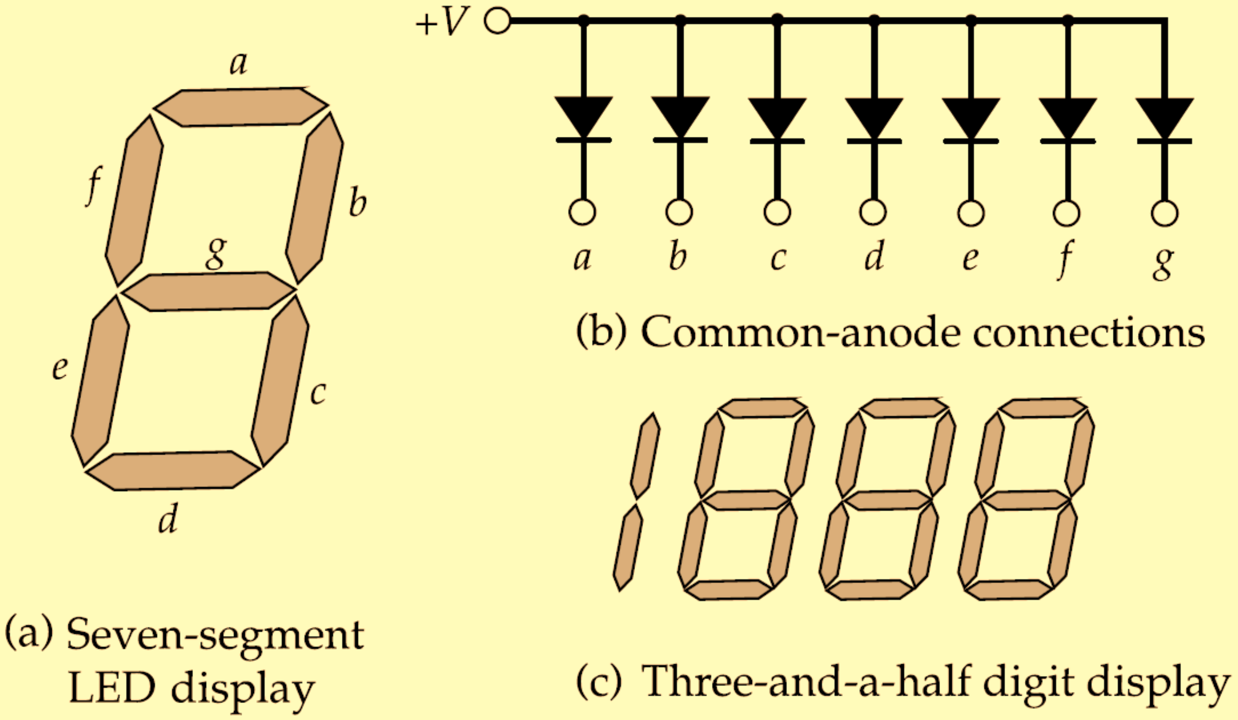


Digital Voltmeter Basic Block Diagram

# Seven-Segment LED Display

There are two types:

1. Common Anode
2. Common Cathode



(a) Seven-segment LED display

(b) Common-anode connections

(c) Three-and-a-half digit display

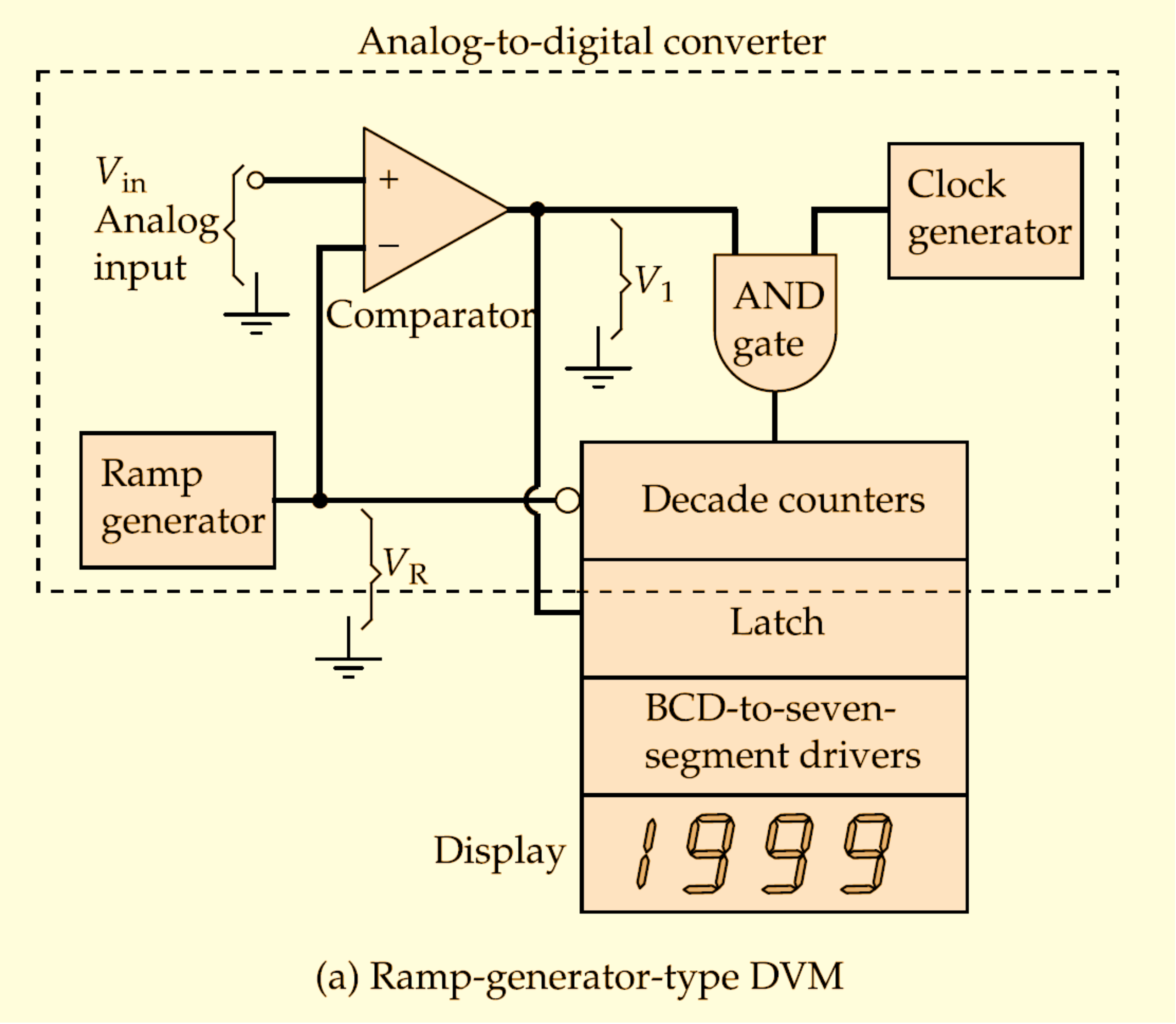
**Figure 6-10** Light-emitting diodes arranged in a *seven-segment* format can display any numeral from 0 to 9.

# 1.Ramp Type Digital Voltmeters:

- **A ramp signal is generated.**
- **The comparator compares the input $V_i$ with the ramp $V_R$.**

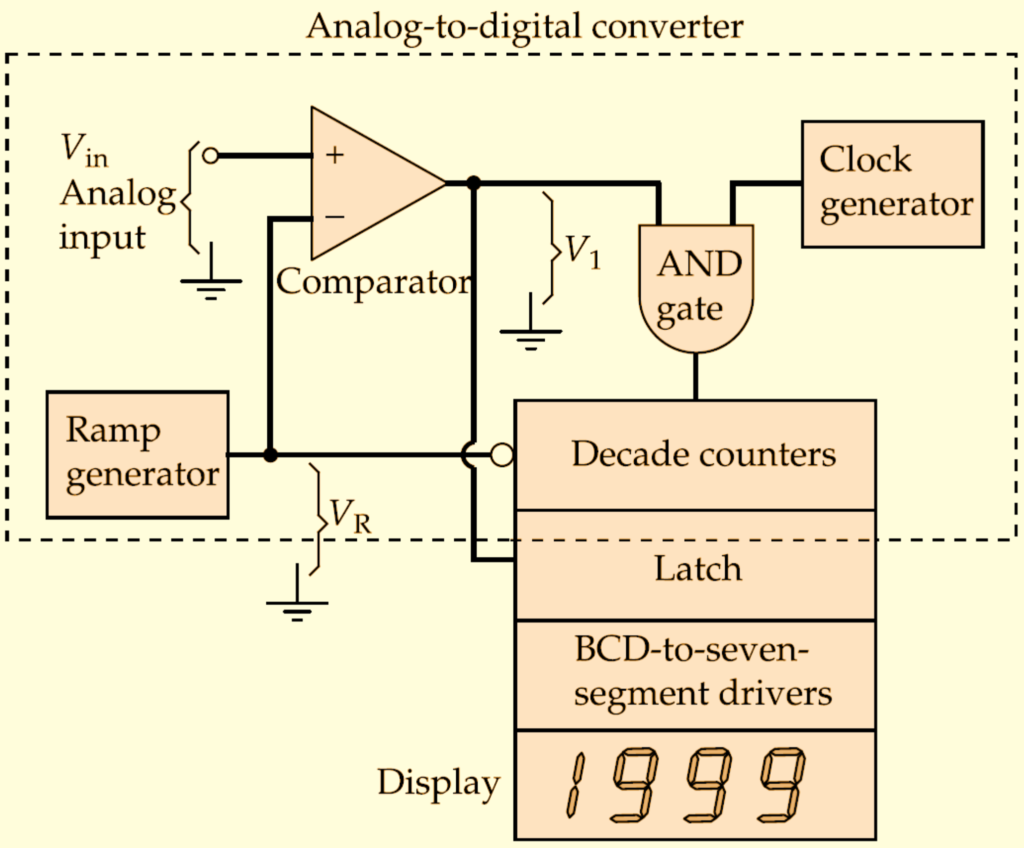
$$V_1 = \begin{cases} 1, & \text{if } V_i \geq V_r \\ 0, & \text{if } V_i < V_r \end{cases}$$

- **If the comparator output $V_1$ is high, the counting circuit will count the pulses from clock generator.**
- **If the output $V_1$ is low, the counting will stop.**
- $\boxed{N_{pulses} \propto V_i}$.
- **The value of Vi will be displayed**

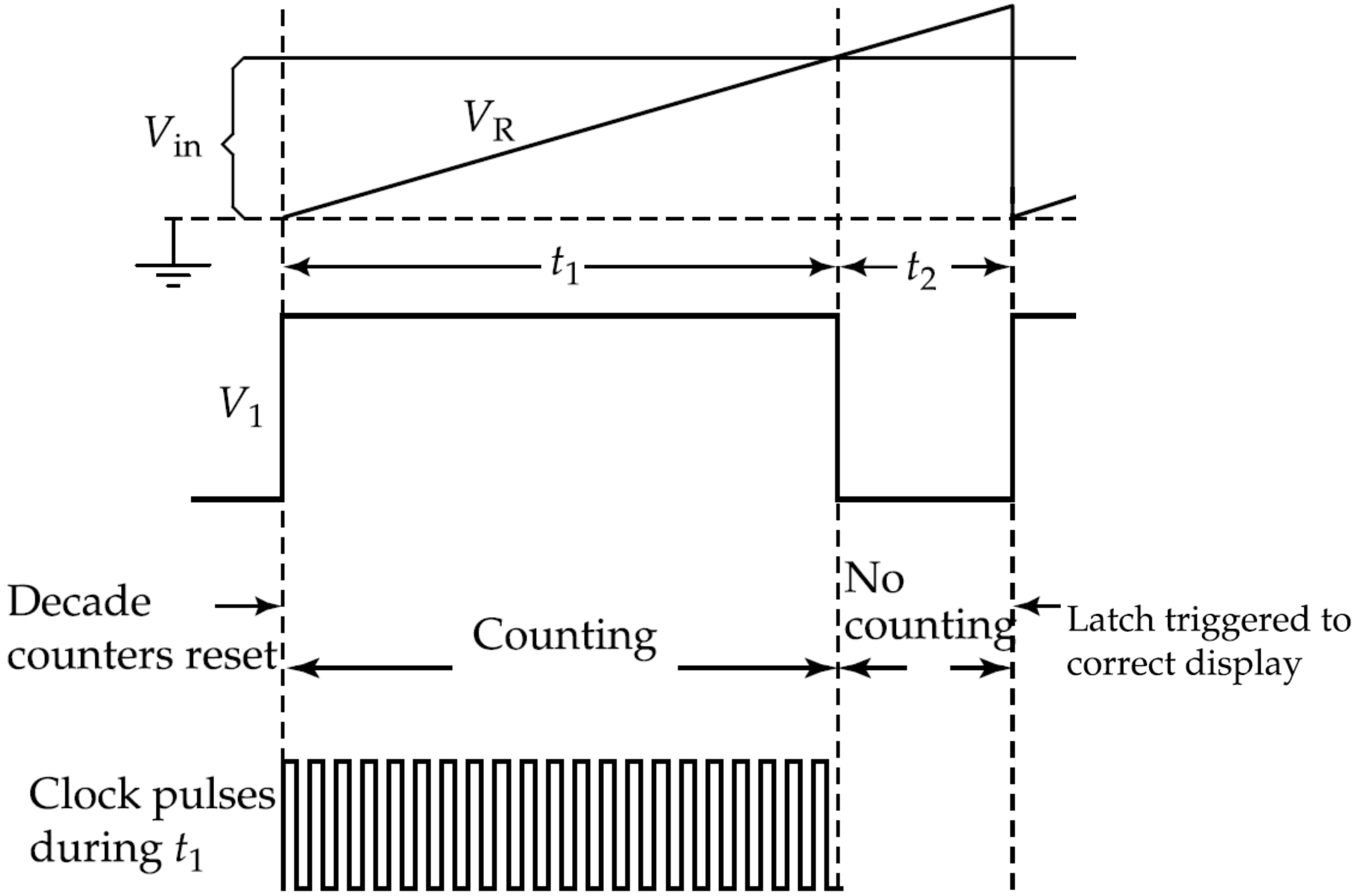


(a) Ramp-generator-type DVM

# 1. Ramp Type Digital Voltmeters (Cont.):



(a) Ramp-generator-type DVM

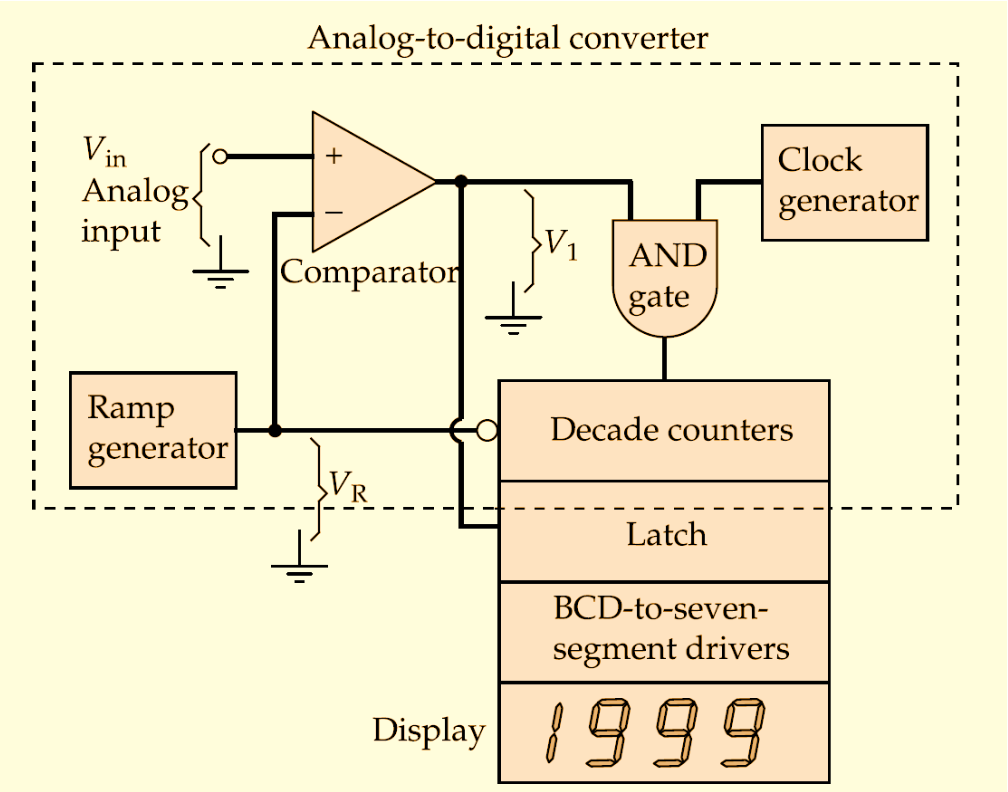


(b) DVM waveforms

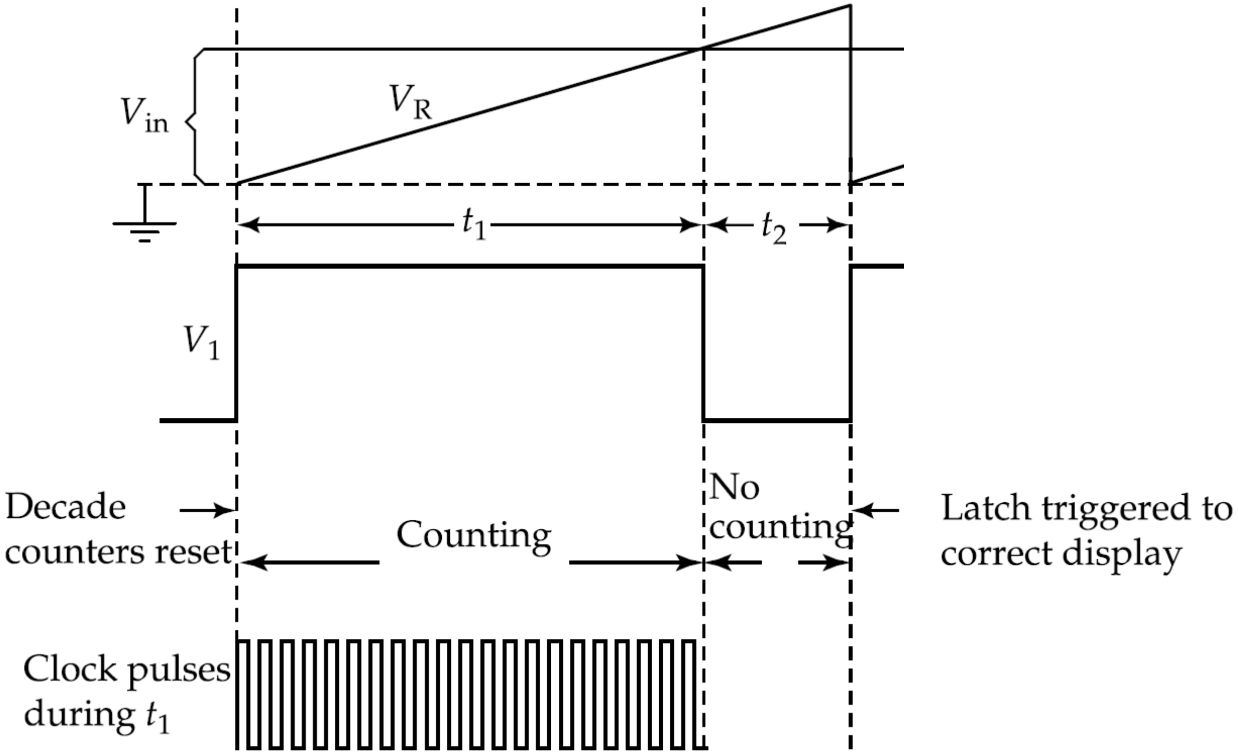
# 1. Ramp Type Digital Voltmeters (Cont.):

## The use of the Latch:

1. The latch isolates the display from the counting circuit during the t1.
2. It will connect the display to the counting circuit at the rising edge of the comparator output.



(a) Ramp-generator-type DVM



(b) DVM waveforms

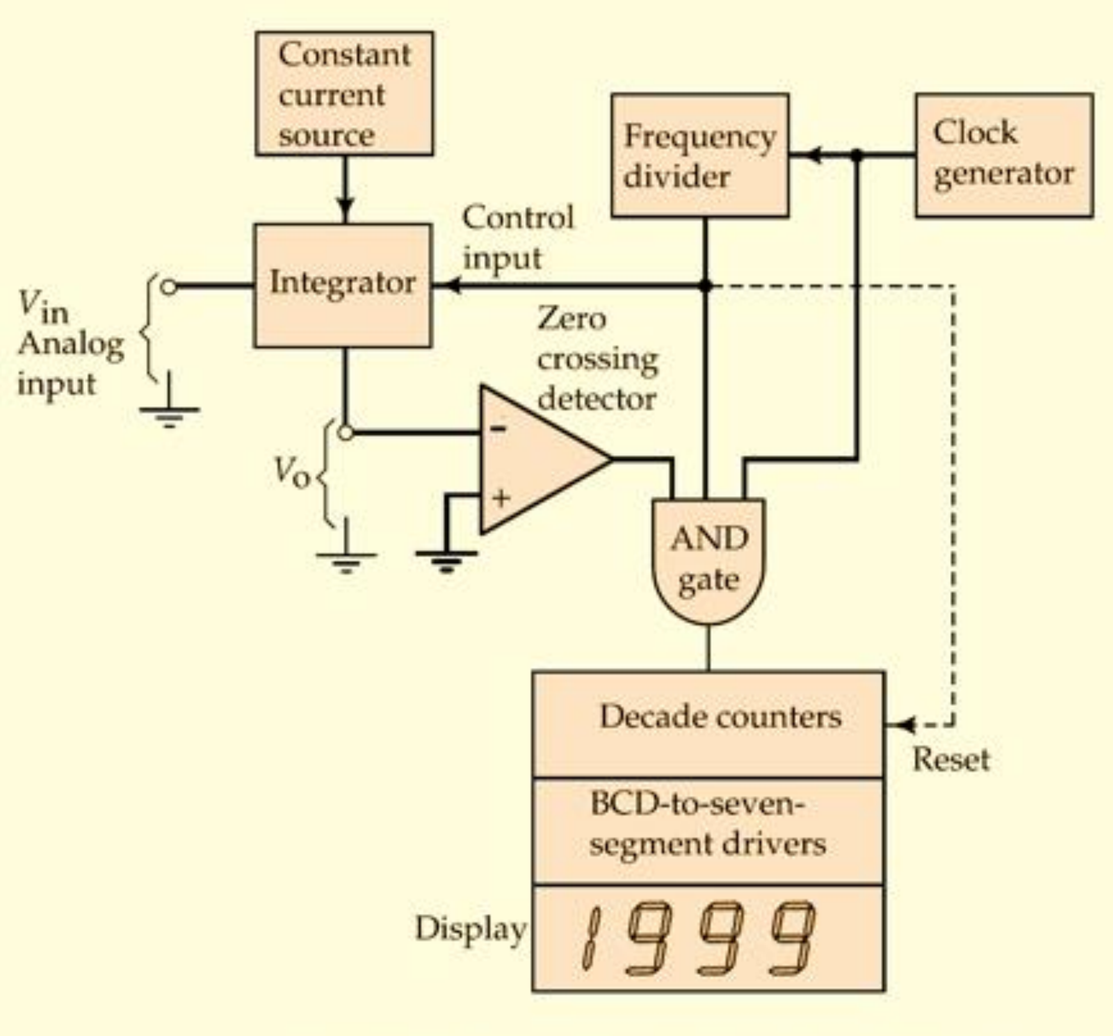
# Chapter Outline:

1) Ramp Type Digital Voltmeters.
2) **Dual Slope Digital Voltmeters.**
3) DVM Range Changing.
4) Digital Voltmeter Accuracy.
5) Types of Digital Multi-meters.
6) Basic Digital Frequency Meters (DFM).
7) Frequency Range Changing.
8) Frequency Meter Accuracy.
9) Reciprocal Digital Frequency Meters (DFM).

# 2. Dual Slope Digital Voltmeters:

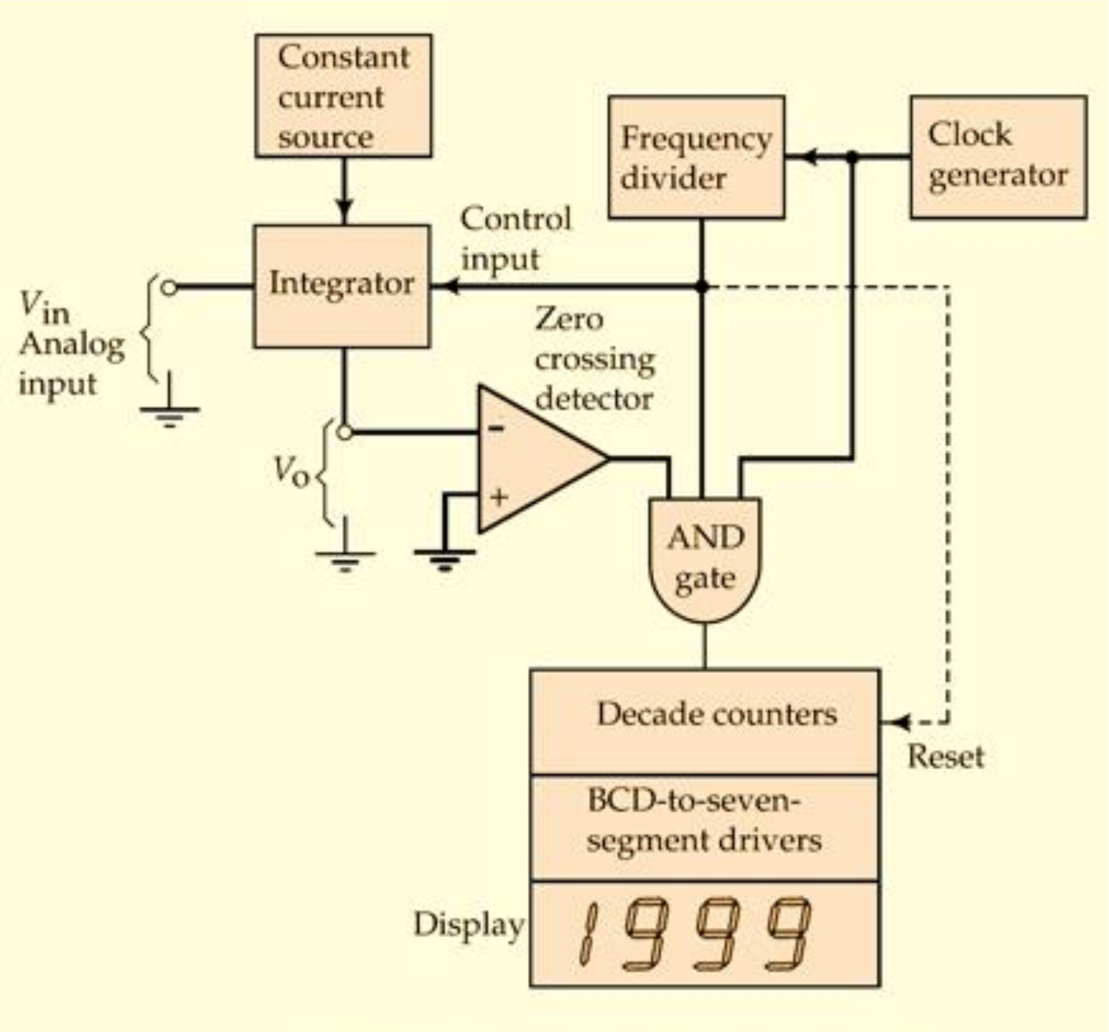
**Limitations of Ramp type DVM**

- The ramp type DVM requires **precise ramp voltage** and **precise time periods.** (Not accurate)
- The Dual-slope-integrator DVM eliminates this requirement.



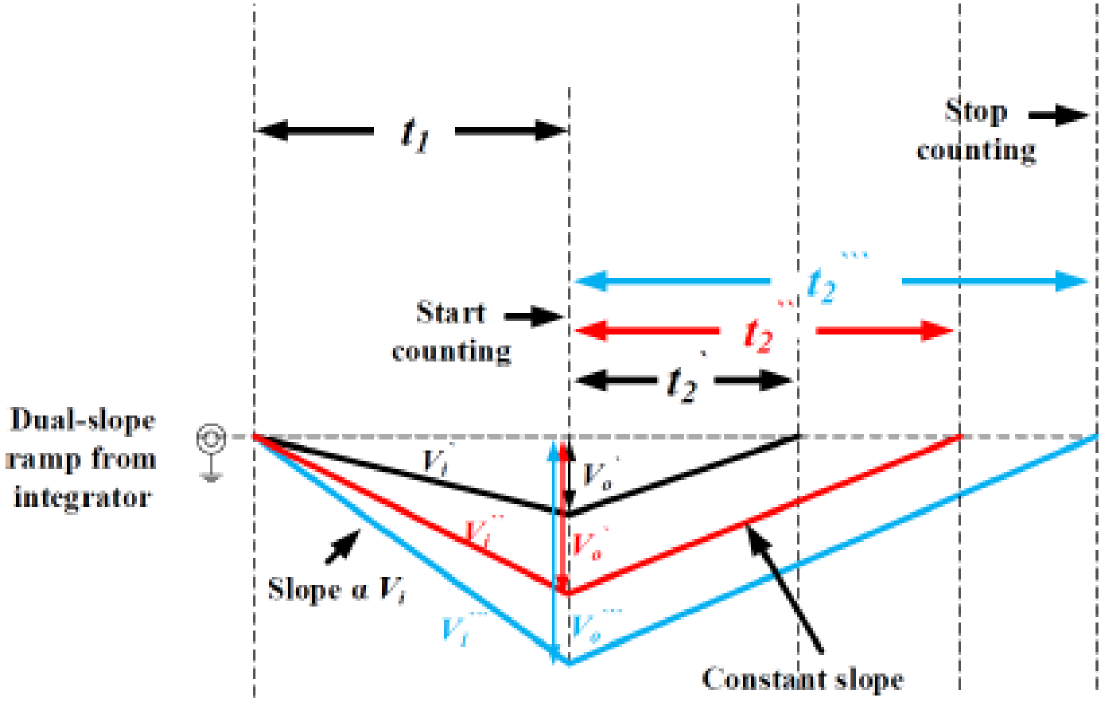
(a) Dual-slope-integrator DVM block diagram

# 2. Dual Slope Digital Voltmeters (Cont.):

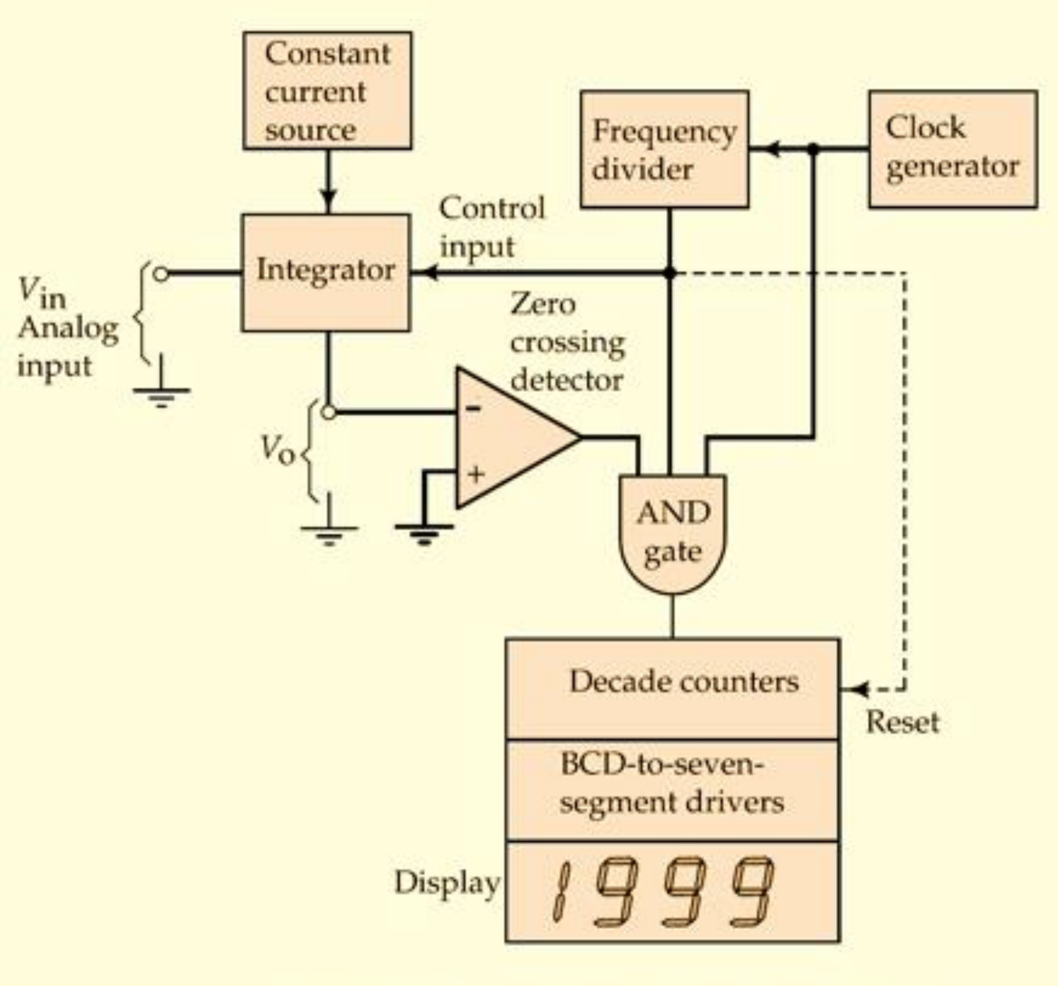


(a) Dual-slope-integrator DVM block diagram

- An integrator (e.g. capacitor) is either charged negatively from $V_i$ or discharged at a constant rate according to the control signal.
- The charging and discharge result in two slopes (dual slope)



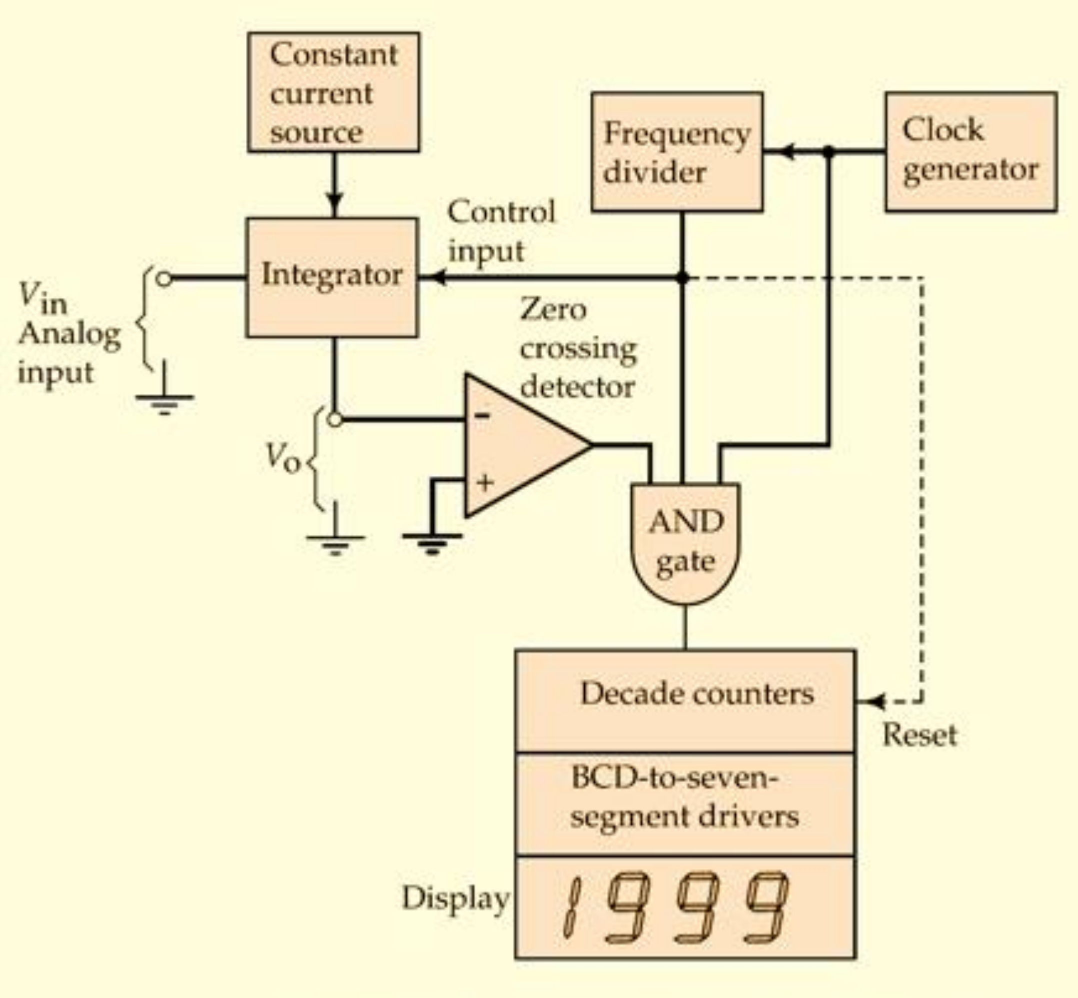
# 2. Dual Slope Digital Voltmeters (Cont.):



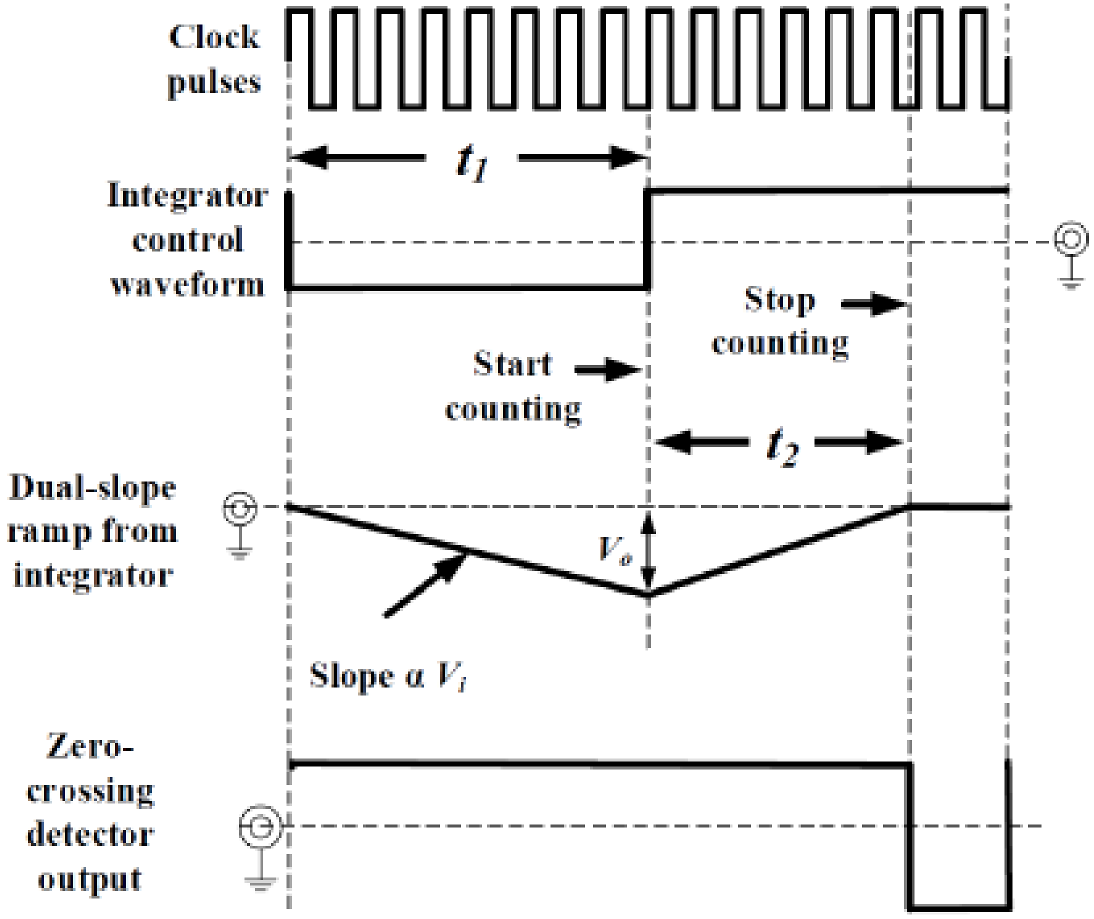
(a) Dual-slope-integrator DVM block diagram

- The control signal is derived from the clock generator and a frequency divider.
- During the charging time $t_1$, the integrator is charged to $V_o$ that depends on $V_i$.
- During the discharging, the integrator is discharged in constant rate in duration $t_2$ that depends on $V_o$ and hence on $V_i$.
- A voltage comparator is used as zero-crossing-detector to output high if integrator voltage is lower than zero.

# 2. Dual Slope Digital Voltmeters (Cont.):



(a) Dual-slope-integrator DVM block diagram



DVM waveform

# 2. Dual Slope Digital Voltmeters (Cont.):

How the Dual slope integrator DVM eliminates the need for accurate timing ?

(1) During charging:

$$V_o = -V_i t_1$$

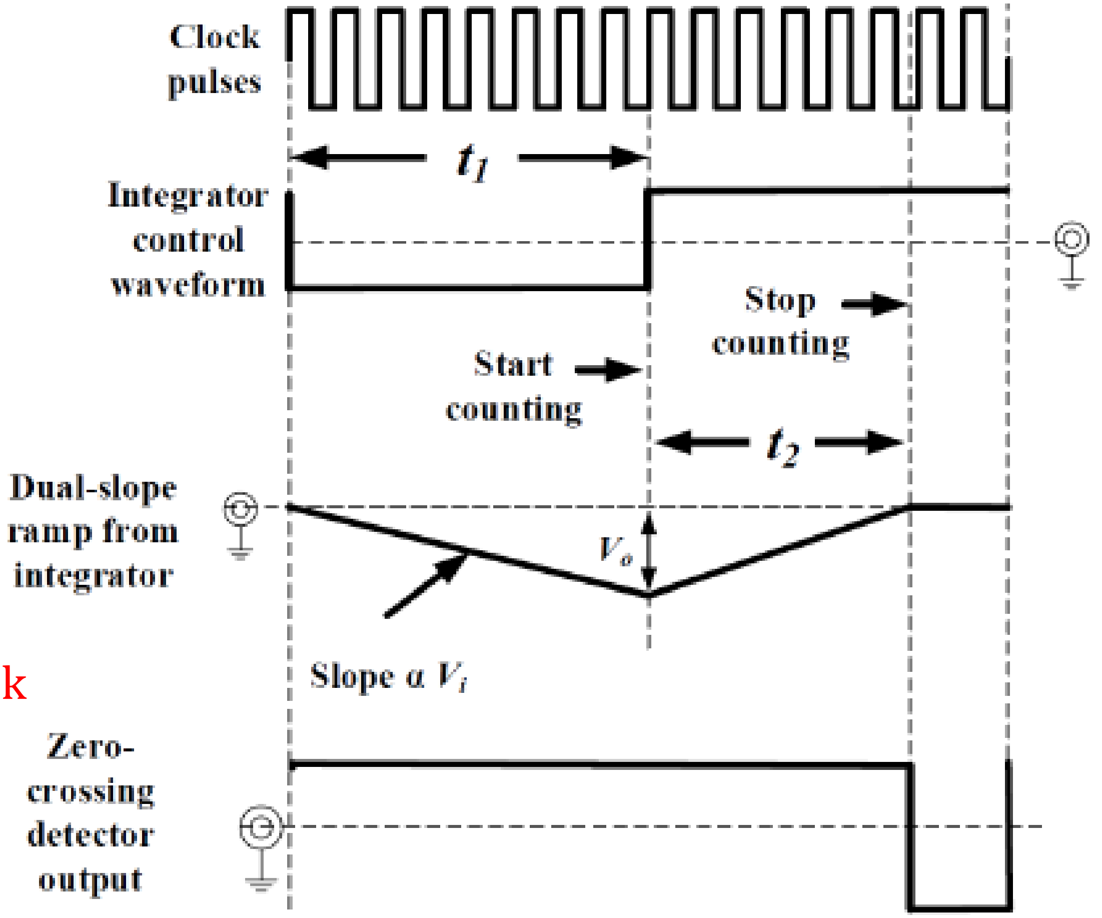
(2) During discharging:

$$V_o = K t_2 \quad K \text{ is constant}$$

So,

$$\boxed{V_i = -K\frac{t_2}{t_1}}$$

Thus the input voltage measurement is not dependent on the clock frequency, but depends on the ratio $\frac{t_1}{t_2}$.



DVM waveform

# Chapter Outline:

1) Ramp Type Digital Voltmeters.
2) Dual Slope Digital Voltmeters.
3) **DVM Range Changing.**
4) Digital Voltmeter Accuracy.
5) Types of Digital Multi-meters.
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7) Frequency Range Changing.
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# 3. DVM Range Changing:

- The attenuation circuit is used to select the range of input voltage:
  - if $V_{in} \leq 1.999\ V$, the input is applied directly on the comparator.
  - if $1.999\ V < V_{in} \leq 19.99\ V$, the input is attenuated and the decimal point is changed.
  - and so on for $19.99\ V < V_{in} \leq 199.9\ V$

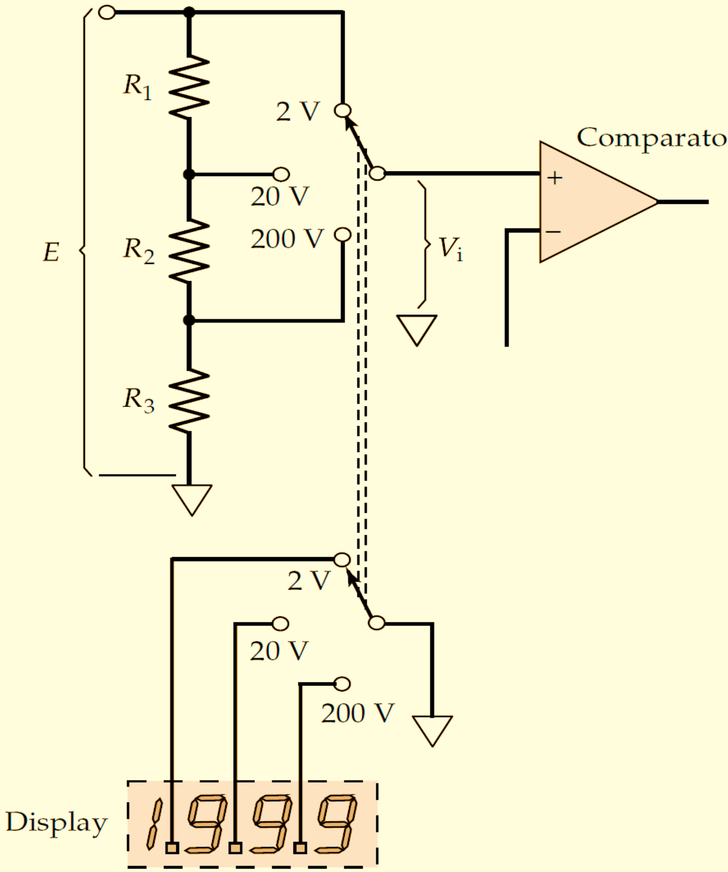

**Figure 7-3** Range-changing method for digital voltmeter. The decimal point is switched at the same time as the voltage range.

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# 4. Digital Voltmeter Accuracy:

## Accuracy in DVMs:

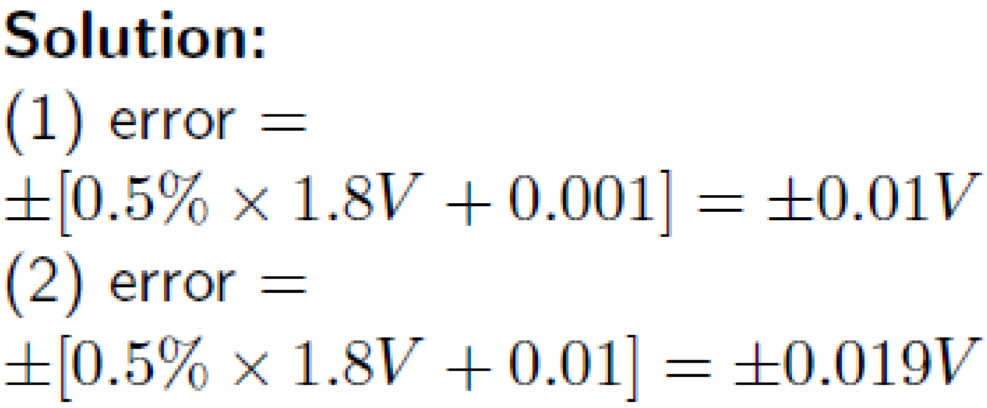
Digital voltmeter accuracy is usually stated as:

± (0.5% rdg + 1digit)

where 1 digit refers to the extreme right (**least significant digit**) that depends on the range.

## Example

If the accuracy is ±(0.5% rdg + 1 digit)
What is the maximum error of reading 1.800 V on:
(1) the 2 V scale.
(2) the 20 V scale



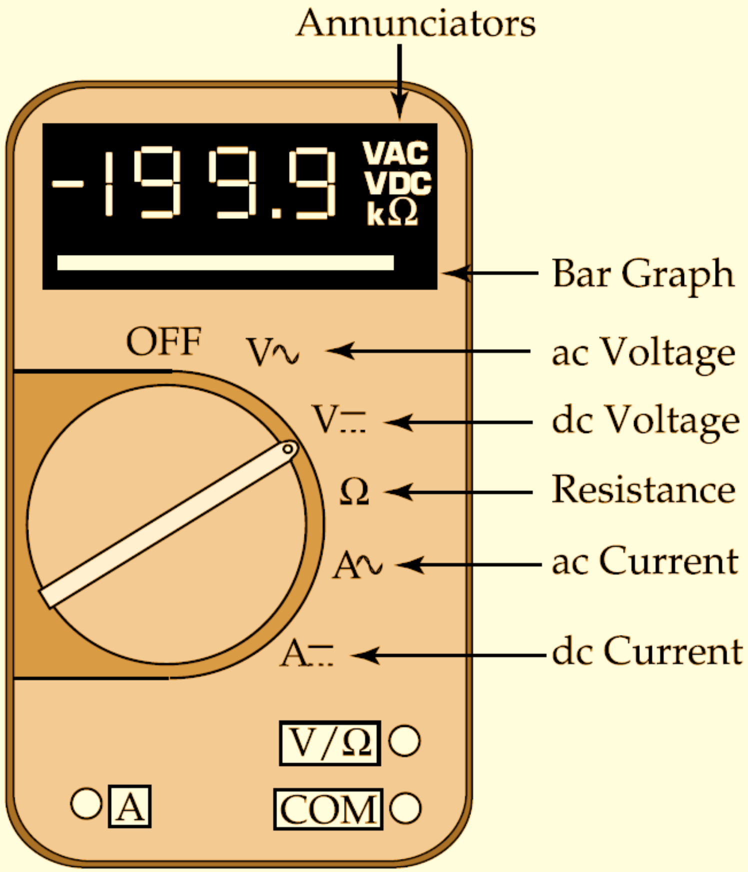
**Solution:**

(1) error $=$
$\pm[0.5\% \times 1.8V + 0.001] = \pm 0.01V$

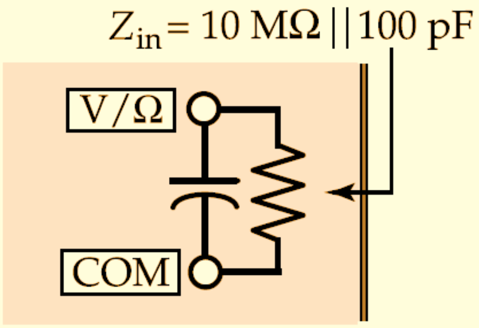
(2) error $=$
$\pm[0.5\% \times 1.8V + 0.01] = \pm 0.019V$

# 5. Types of Digital Multi-meters:

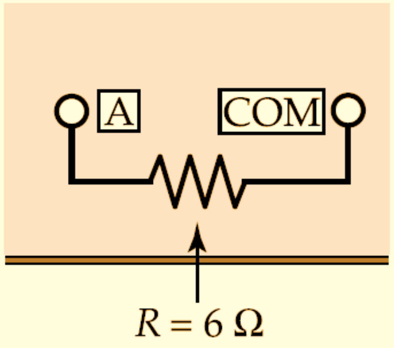
## 1. Basic Hand-held Digital Multimeter



(a) Portable digital multimeter



(b) The input impedance for voltage measurements is typically 10 MΩ || 100 pF



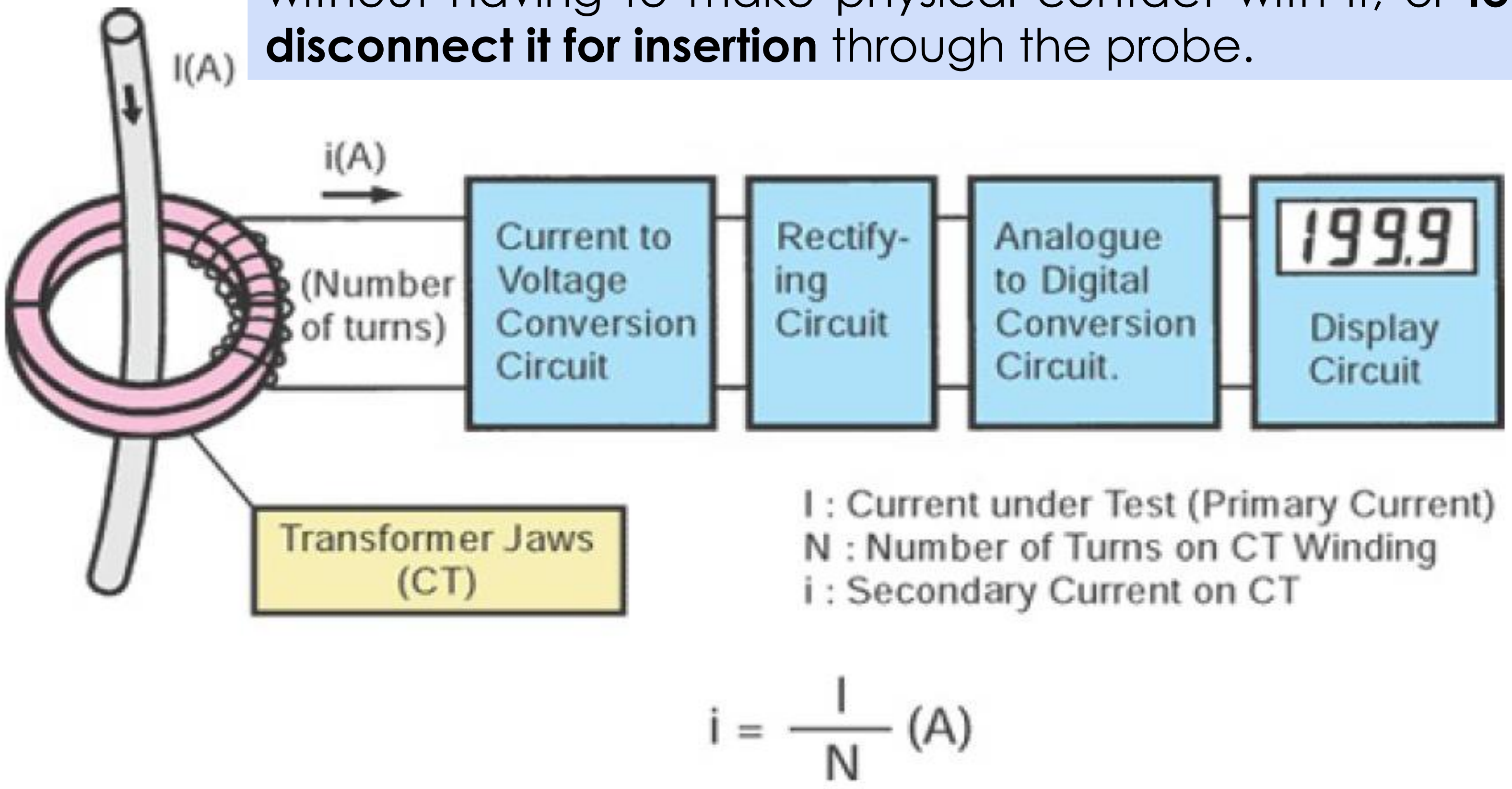
(c) The current measuring circuit typically has a 6 Ω resistance

# 5. Types of Digital Multi-meters:

## 2. Clamp Meters:

### Advantage:

It is an electrical device having two jaws which open to allow **clamping around an electrical conductor.** This allows to measure electric current through conductor, without having to make physical contact with it, or **to disconnect it for insertion** through the probe.



I : Current under Test (Primary Current)
N : Number of Turns on CT Winding
i : Secondary Current on CT

$$i = \frac{I}{N} \text{ (A)}$$

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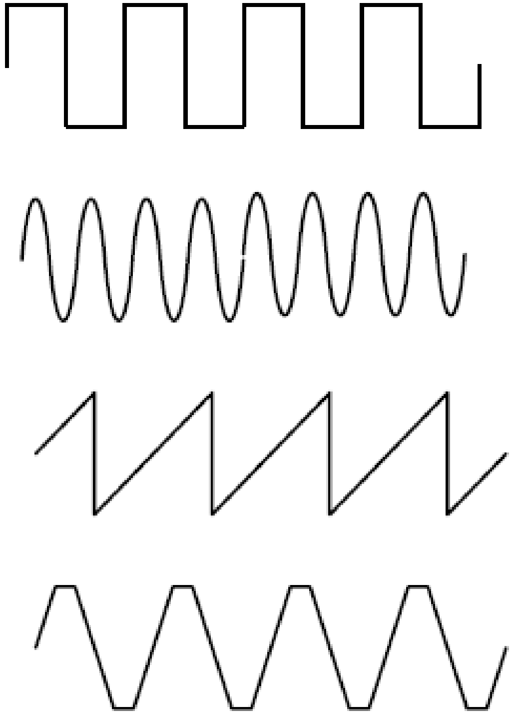
# 6. Basic Digital Frequency Meters (DFM)

## Introduction

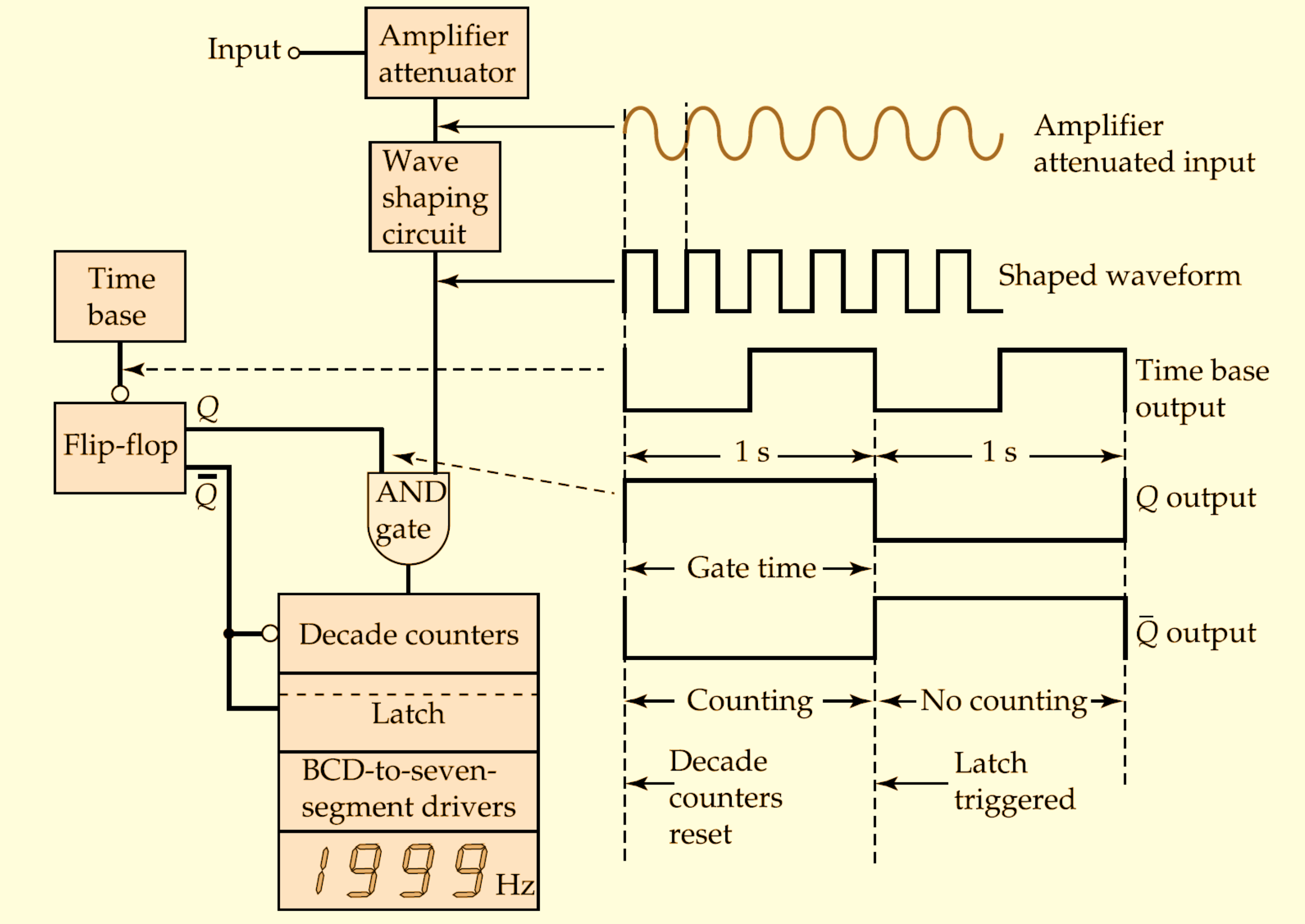
- Frequency of **a periodic signal** is defined as: the number of occurrences of a repeating event per unit time = Number of signal's cycles per one second.



### 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.

# 6. Basic Digital Frequency Meters (DFM) (Cont.):



(a) Frequency meter system (b) System waveforms

## The basic DFM consists of:

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

# 6. Basic Digital Frequency Meters (DFM) (Cont.):

## 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 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 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 Q output.

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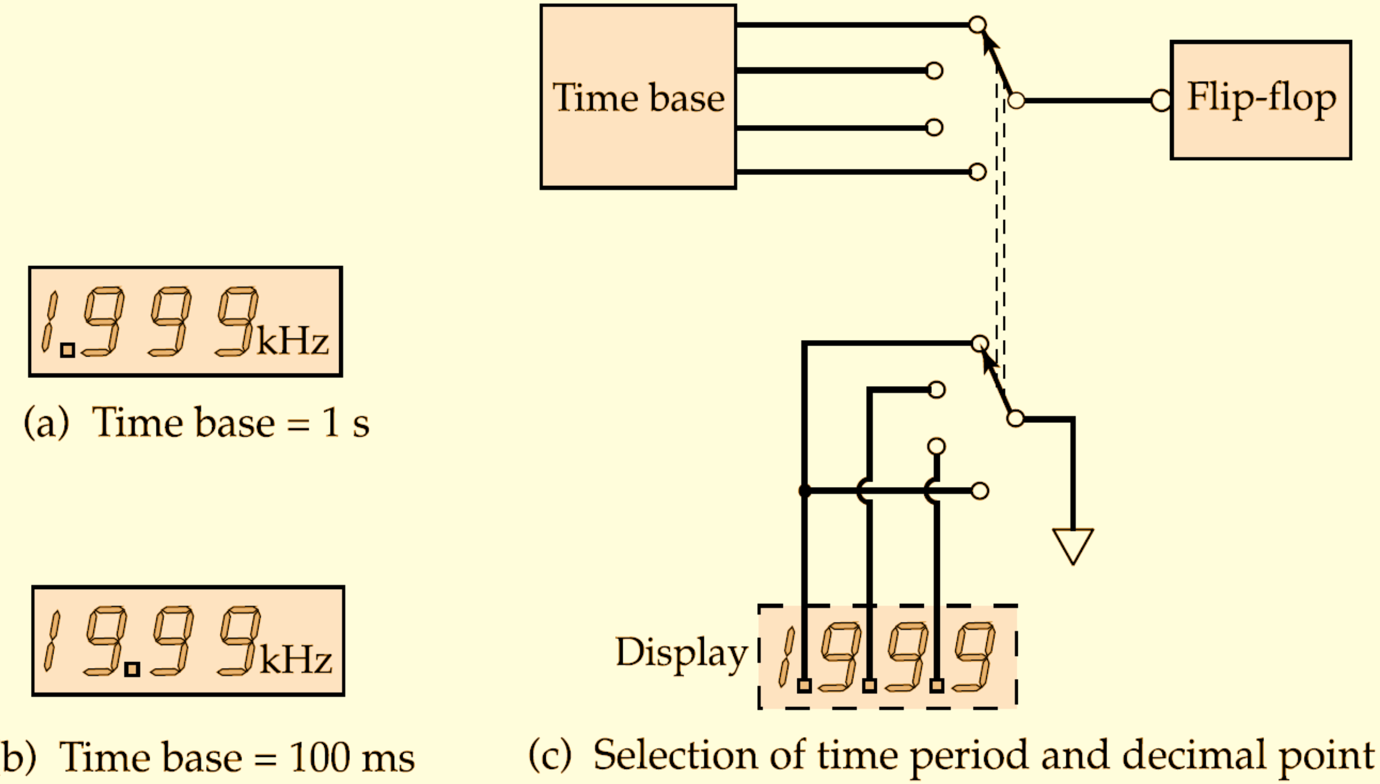
# 7. Frequency Range Changing:

- 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.



(a) Time base = 1 s

(b) Time base = 100 ms

(c) Selection of time period and decimal point

**Figure 7-7** Time period and decimal point selection for a digital frequency meter. When the time period (or gate time) is 1 s, a count of 1999 pulses is displayed as 1.999 kHz.

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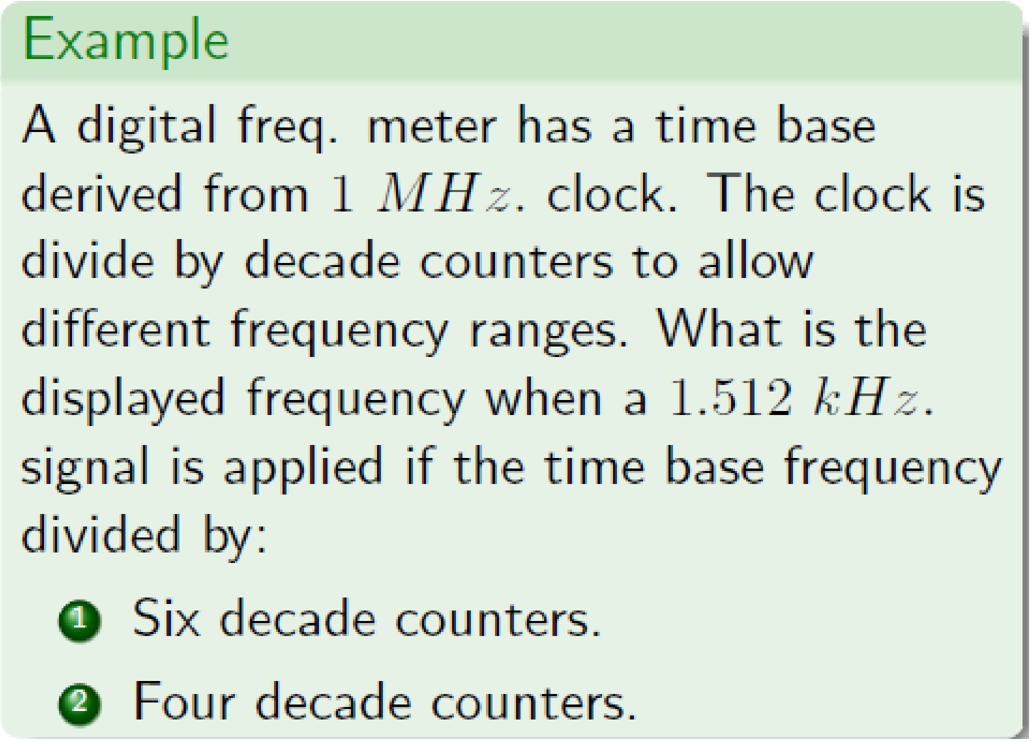
# 8. Frequency Meter Accuracy:

- Range Selection Error :

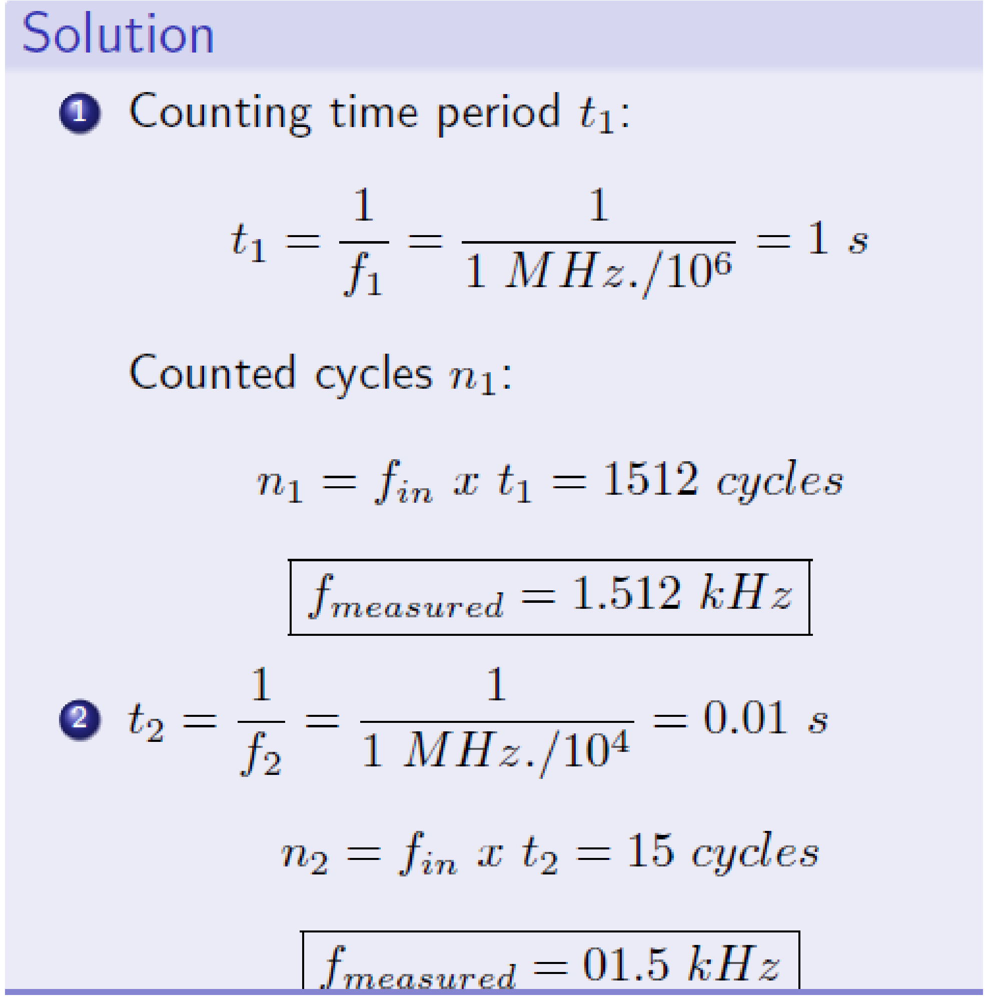
The lowest possible frequency range should be used for the greatest measurement accuracy.



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

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

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

# 8. Frequency Meter Accuracy (Cont.):

## Accuracy Specification

- Also, the time base error *Etb* due to freq. variation will give a reading error in the measured frequency *fi* as: time base error = *fi x Etb.* $Etb = 10^{-6}$

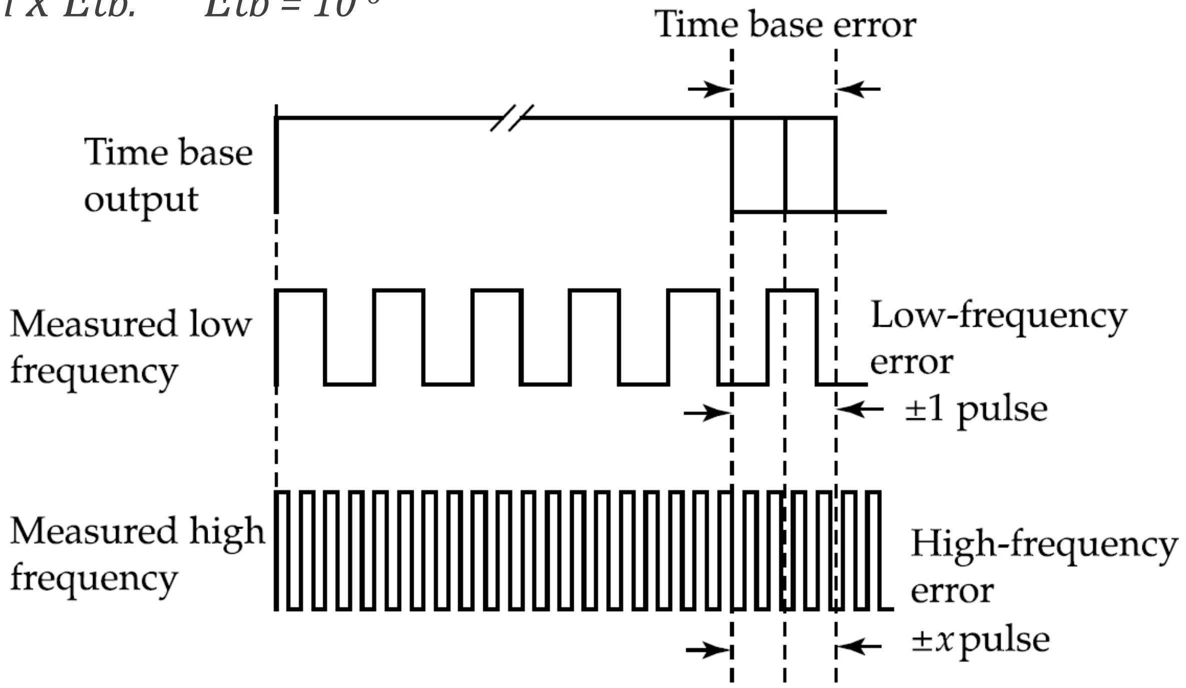


**Figure 7-8** Time base error can produce errors in the number of cycles counted, and thus in the indicated frequency.

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

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

# 8. Frequency Meter Accuracy (Cont.):

## 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.

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

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

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

**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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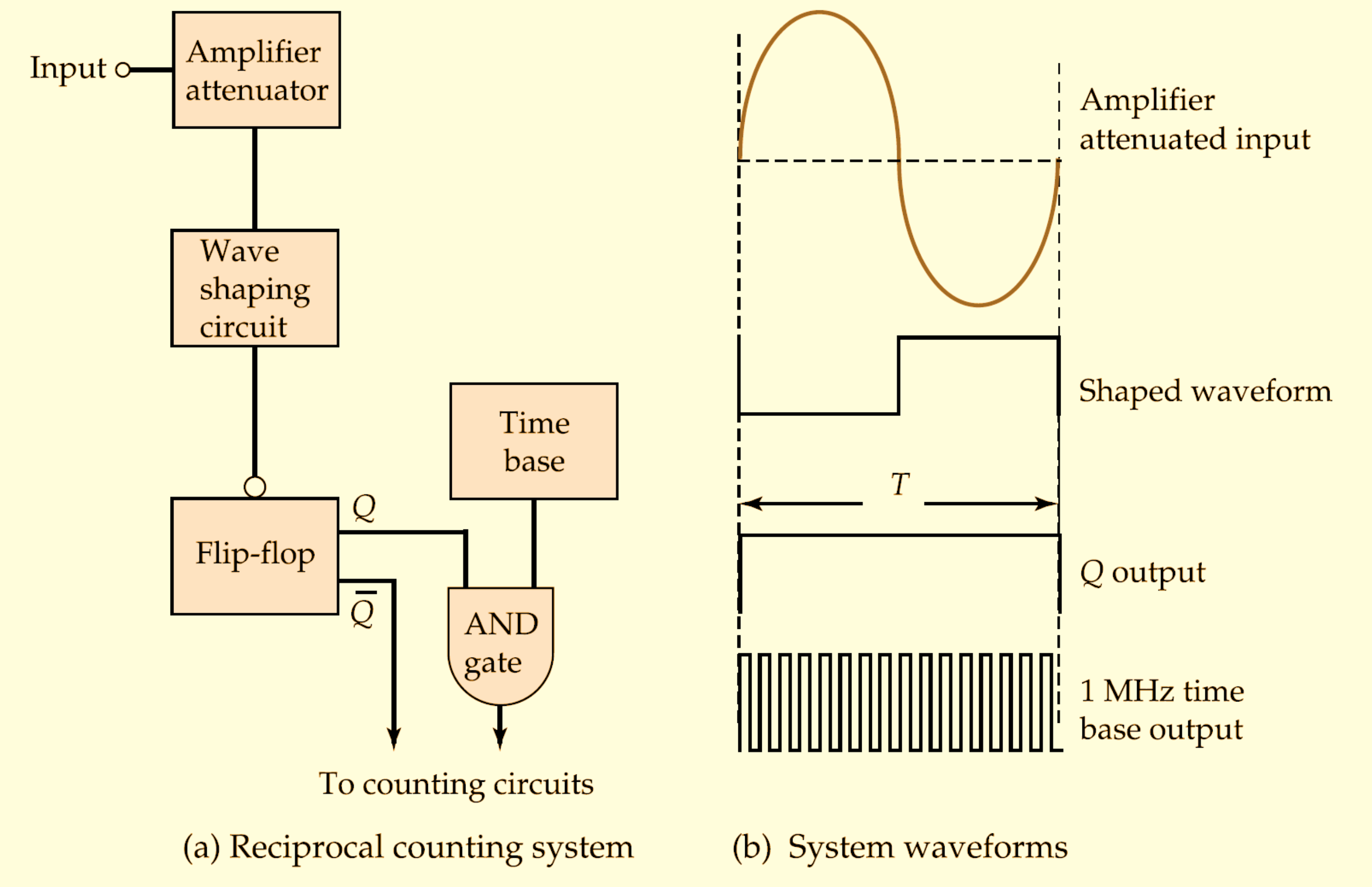
# 9. Reciprocal Digital Frequency Meters (DFM):



(a) Reciprocal counting system (b) System waveforms

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 measured frequency *fin* is:

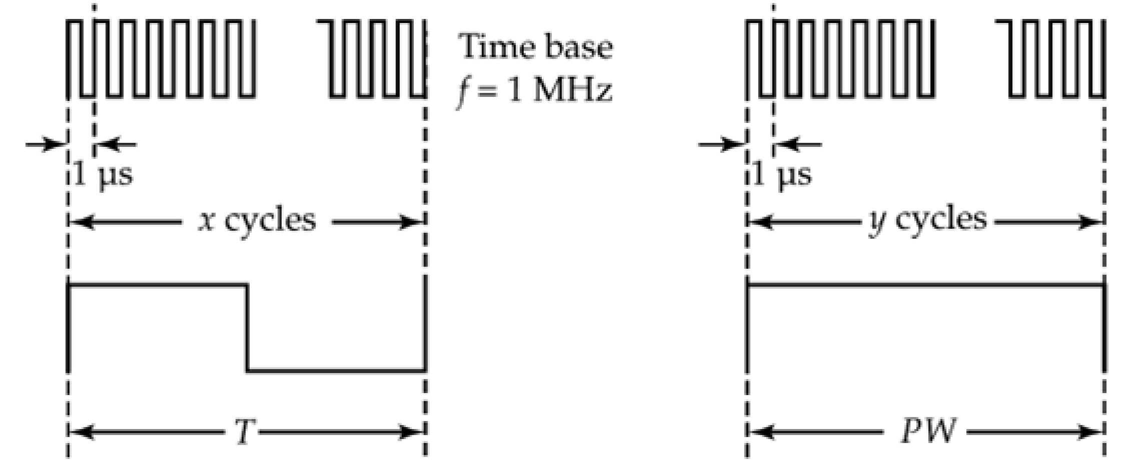
$$\boxed{f_{in} = \frac{f_{time\ base}}{n}}$$

- n is the number of pulses.

# 9. Reciprocal Digital Frequency Meters (DFM):

## 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.

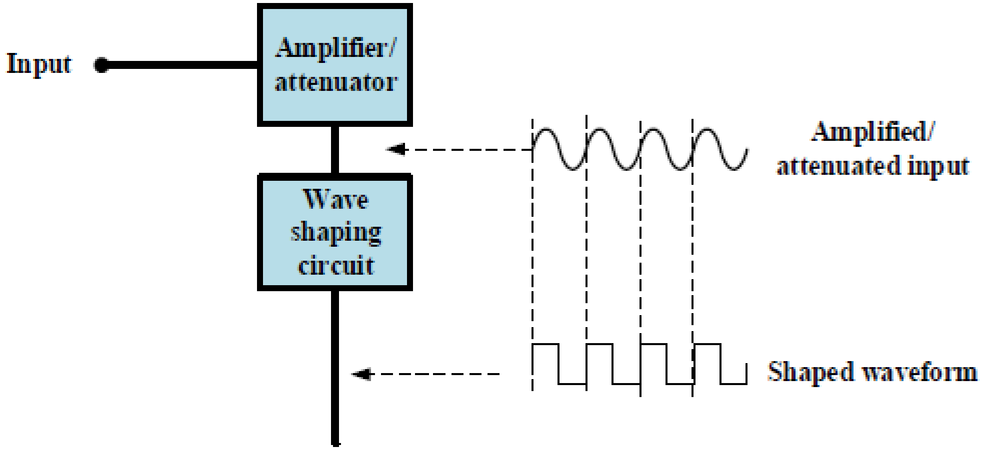


(a) Measurement of time period
$T = x$ pulses × 1 μs = $x$ μs

(b) Measurement of pulse width
$PW = y$ pulses × 1 μs = $y$ μs

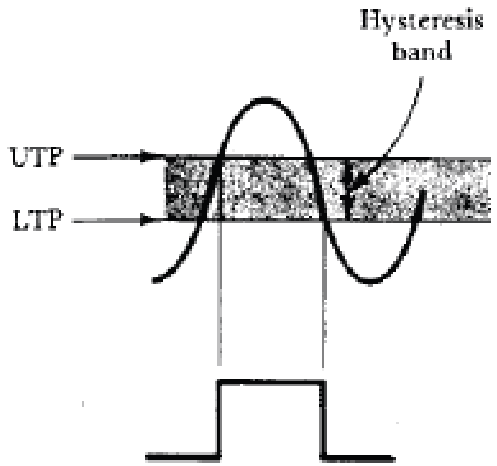
# Digital Frequency Input Stage:

## 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.

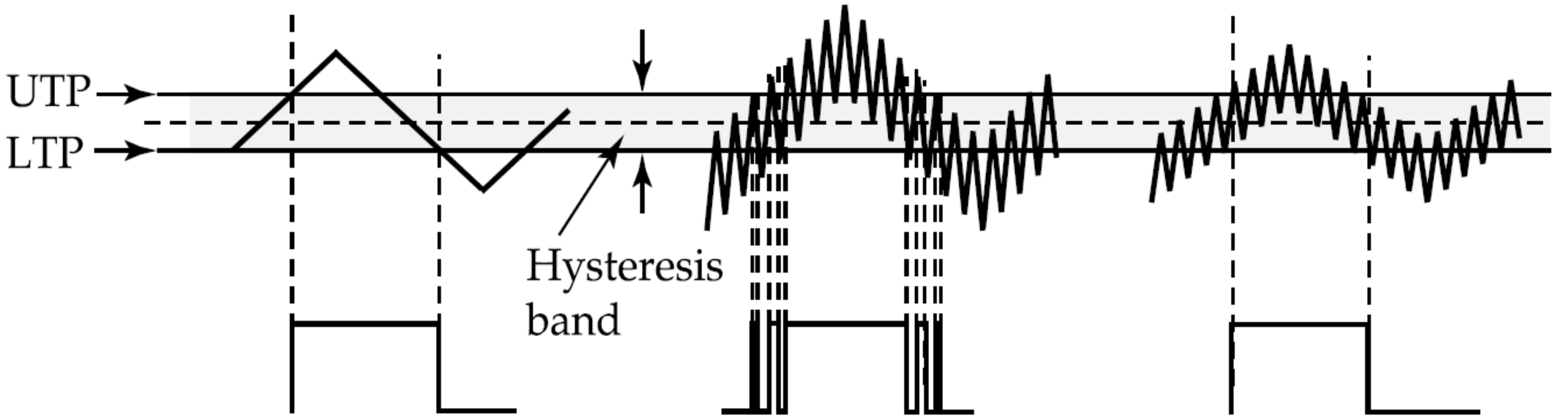


The small input signal could be amplified to make it suitable to be triggered by UTP and LTP.

# Digital Frequency Input Stage:

## Why we use the attenuator/amplifier in input ?

- In the case of noisy input signal, an error is existing 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.



(a) Clean triangular wave crosses the hysteresis band twice during each cycle

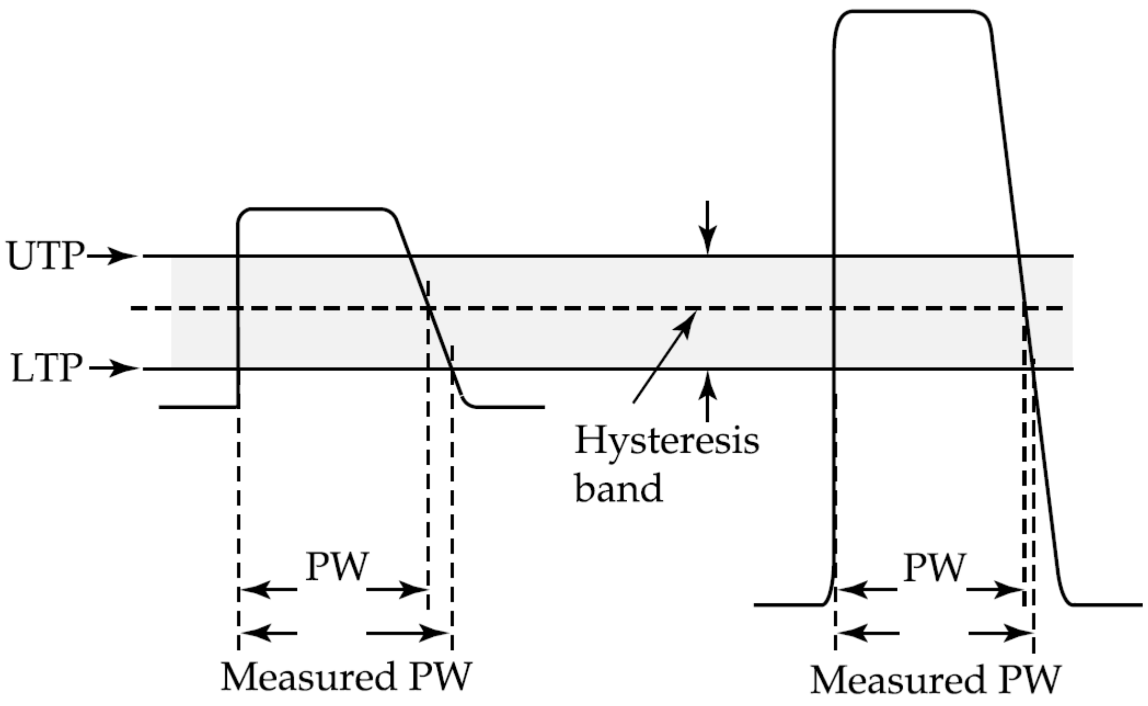
(b) Noisy waveform crosses the hysteresis band several times during each cycle

(c) Attenuated noisy wave crosses the hysteresis band twice during each cycle

**Figure 7-11** Noisy input signals can produce counting errors on a digital frequency meter. Signal attenuation adjustment usually eliminates the problem.

# Digital Frequency Input Stage:

## Why we use the attenuator/amplifier in input ?



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

(b) Amplification can minimize the pulse width measurement error

**Figure 7-12** Long rise and fall times can cause errors in pulse width measurements on a digital meter. Signal amplification usually eliminates the error.

# END OF LECTURE

# BEST WISHES