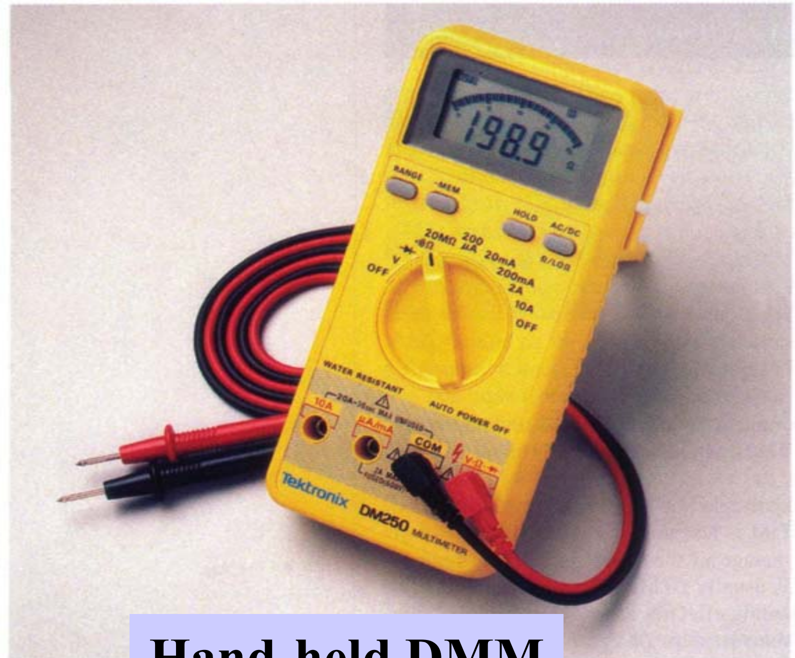
Digital Multimeter (DMM)

Portable Analog Multimeter

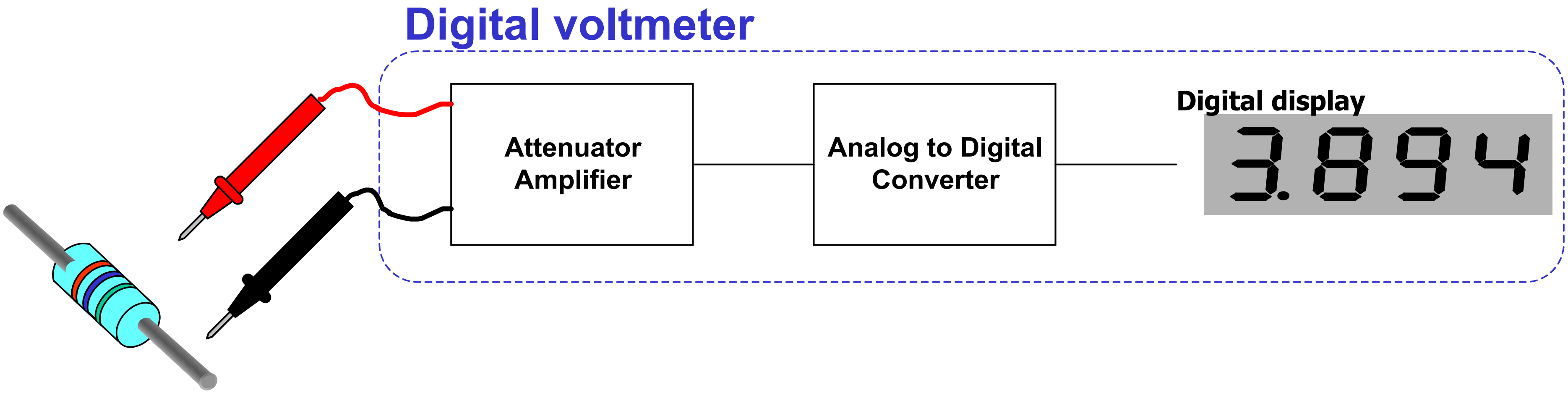


Hand-held DMM

Bench-top DMM

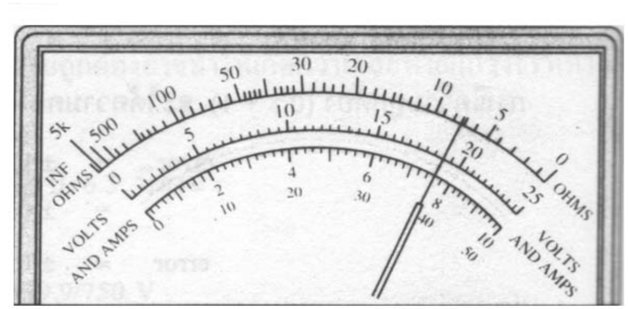
Digital Voltmeter (DVM)

DVM is essentially an Analog to digital converter (A/D) with a digital display



Digital MultiMeter (DMM) **= electronic Volt Ohm Millimeter with digital display**

Comparison of Digital and Analog Meter



Digital meter	Analog meter
Leaves no doubt about the measured quantity.	Wrong scale might be used or might be read incorrectly.
Superior resolution and accuracy. (±0.5% or better)	Inferior resolution and accuracy. (±3% in common)
Indicates a negative quantity when the terminal polarity is reversed	Pointer attempts to deflect to the left when the polarity is reversed
No usually damaged by rough treatment	Can be damaged when dropped from bench level

Analog to Digital Conversion

A/D converts ***an analog signal into the digital code which is proportional to the magnitude of the coming signal.***

$$V_{in} \approx k \times \text{Digital output}$$

Where ***k*** is step size or resolution

Ex. Signal from 800-1500 mV may be converted to 8-bit binary codes starting from 01010000_2 (80_{10}) to 10010110_2 (150_{10}). In this case, the step size ***k*** is equal to 10 mV.

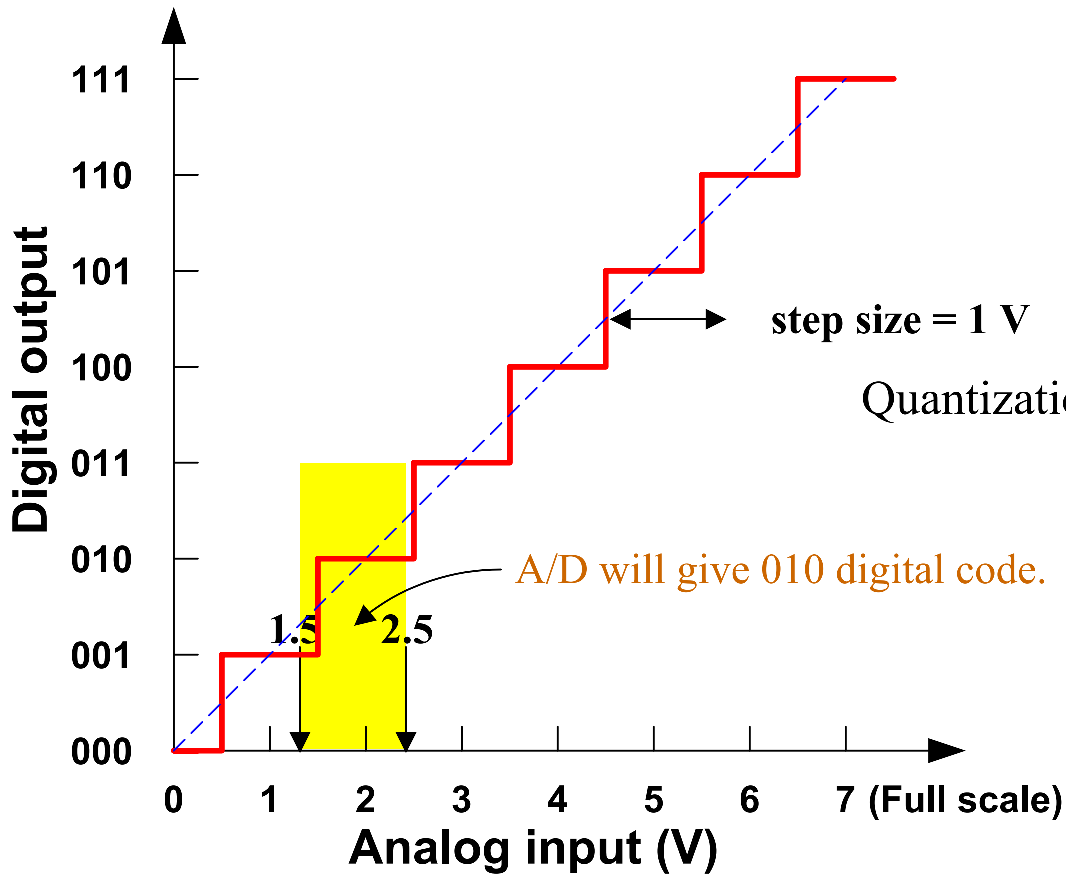
Quantization error or Conversion error of a A/D

$$\text{Quantization error} = \frac{\text{step size}}{\text{full scale}} \times 100 = \frac{1}{2^N - 1} \times 100\%$$

Where *N* is the number of bit

Analog to Digital Conversion

Conversion time, T_c time requires to convert an analog signal to the corresponding digital code.



Quantization error = 1/7 × 100 =14.3%

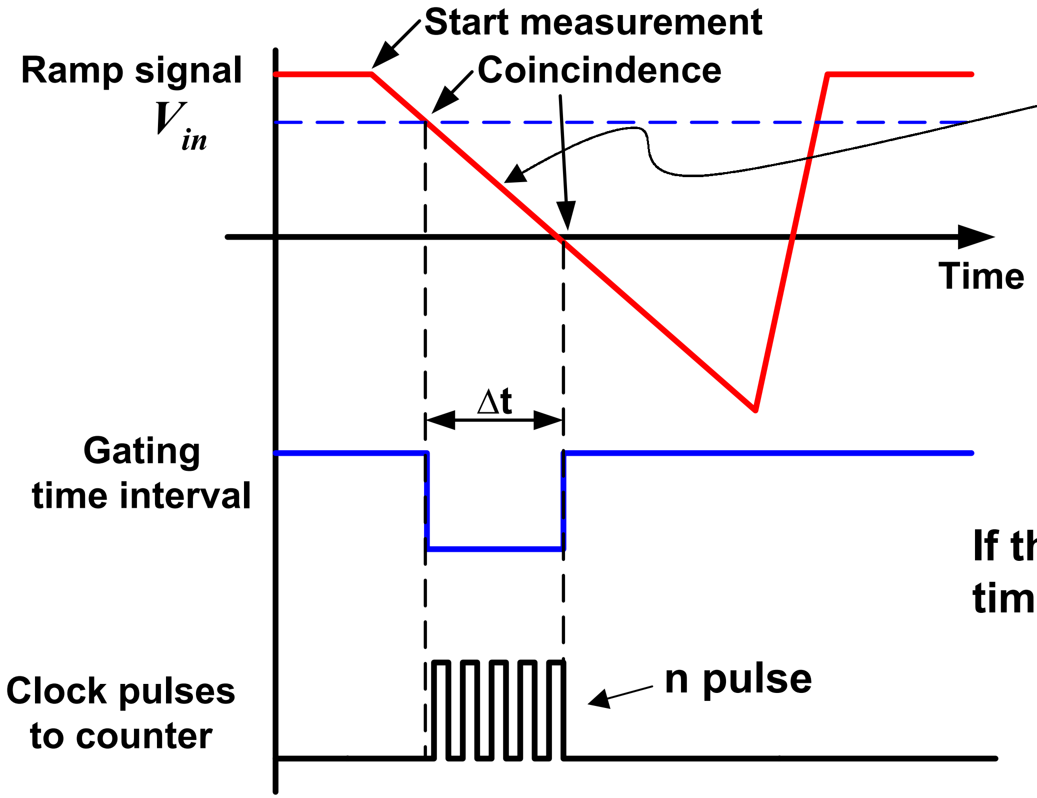
Ex. An analog inputs 1.5-2.5 V will be represented by digital output 010

An example of 3 bit ADC

Ramp-type Digital Voltmeter

(also called single slope)

Operation principle: The measurement of the time it takes for a linear ramp voltage to rise from O V to the level of the input voltage, or to decrease from the level of the input voltage to zero. This time interval is measured with an electronic time-interval counter.



$V_{ramp}(t) = V_o - m\,t$

Where m is the ramp rate

$V_{ramp}(t_1) = V_{in} = V_o - m\,t_1$

$V_{ramp}(t_2) = 0 = V_o - m\,t_2$

$\Delta t = t_2 - t_1 = V_{in}/m$

If the period of the clock is T, then during the time interval Δt_1, the number of pulses is

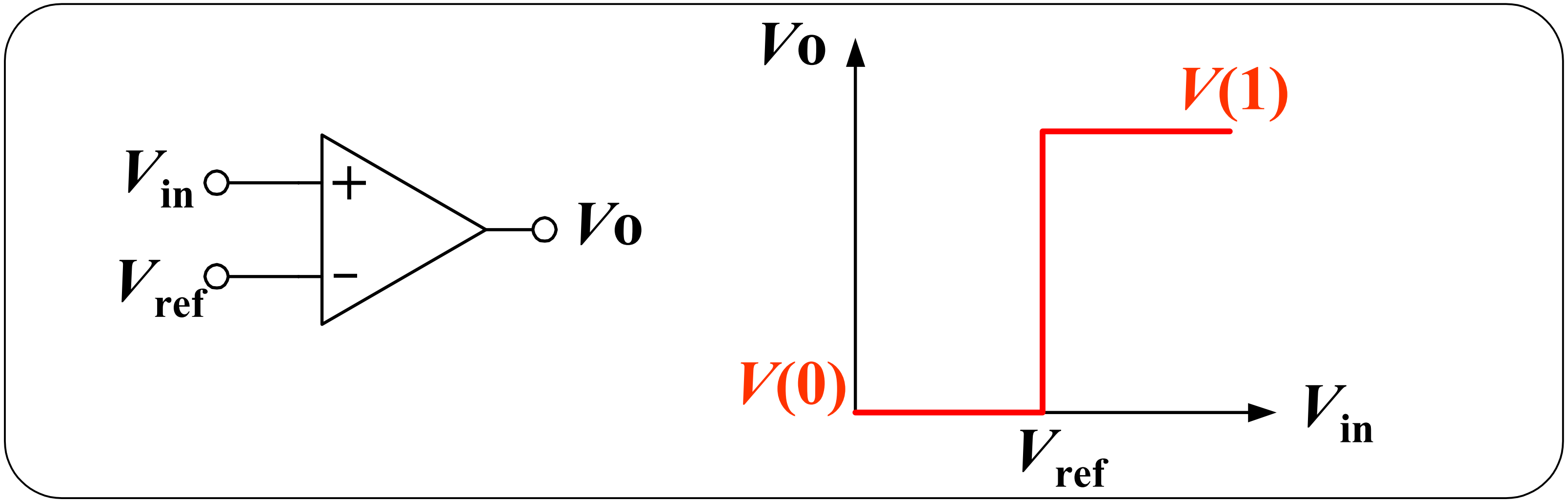
$\Delta t \approx nT$ or $V_{in} \approx nmT$

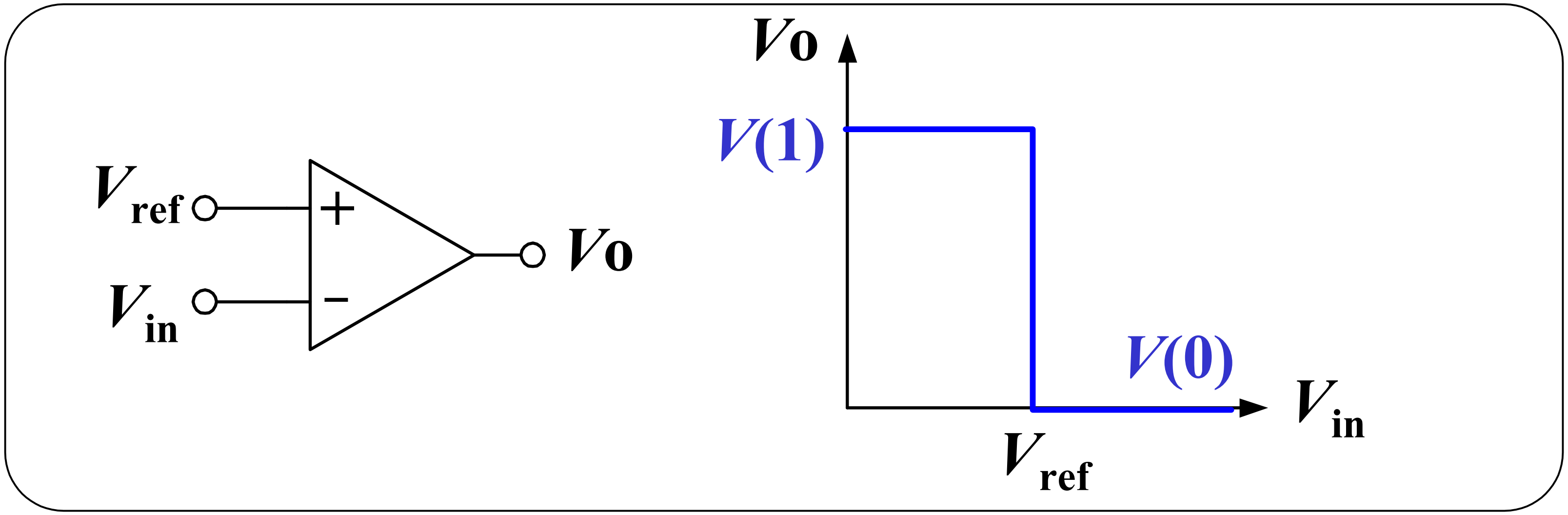
- Accuracy depends on both the ramp rate and clock period.

Voltage-to-time conversion using gated clock pulses.

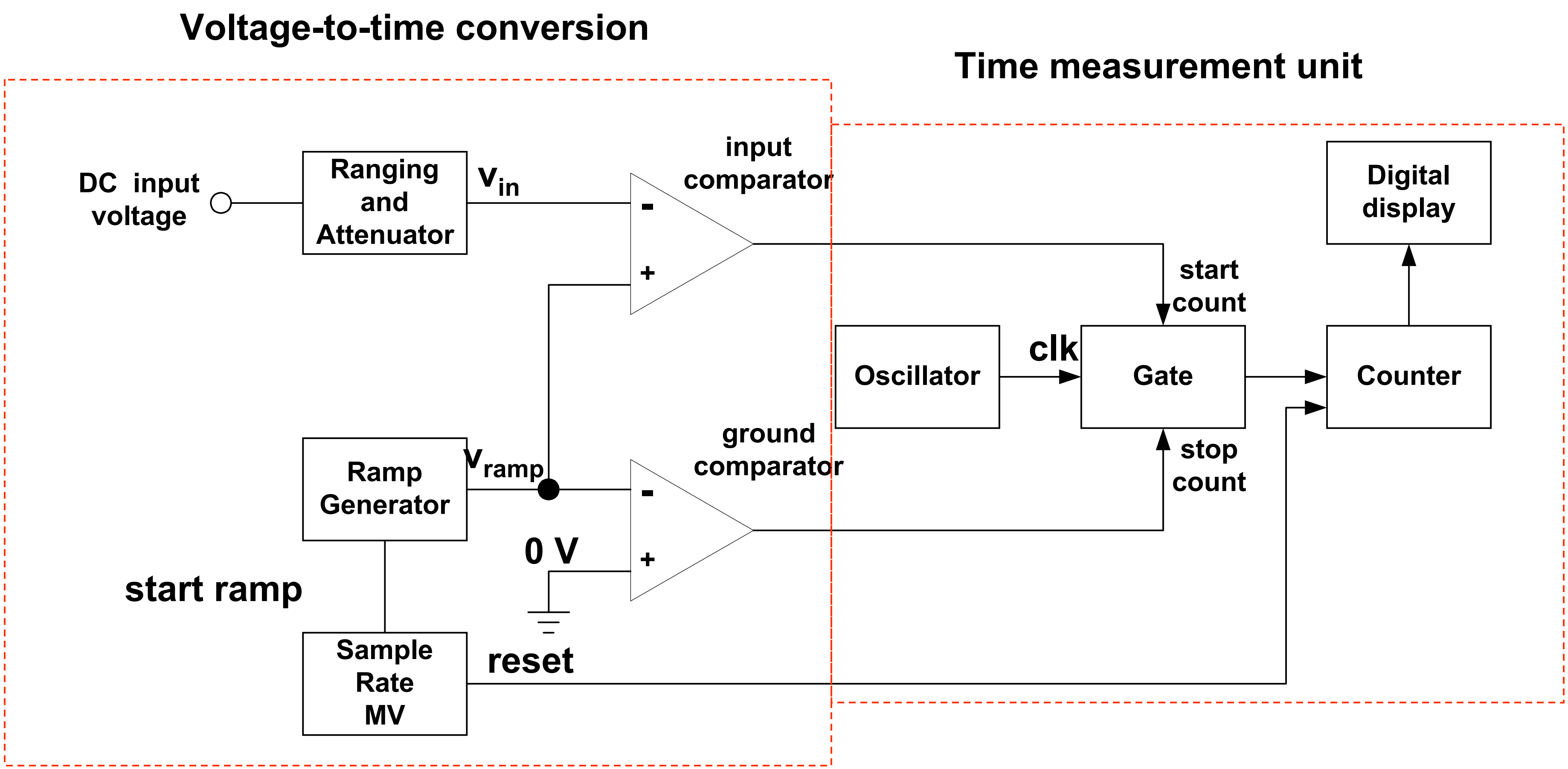
Comparator

$V+ > V-$; $Vo = V(1)$ Logic high
$V+ < V-$; $Vo = V(0)$ Logic low





Ramp-type Digital Voltmeter

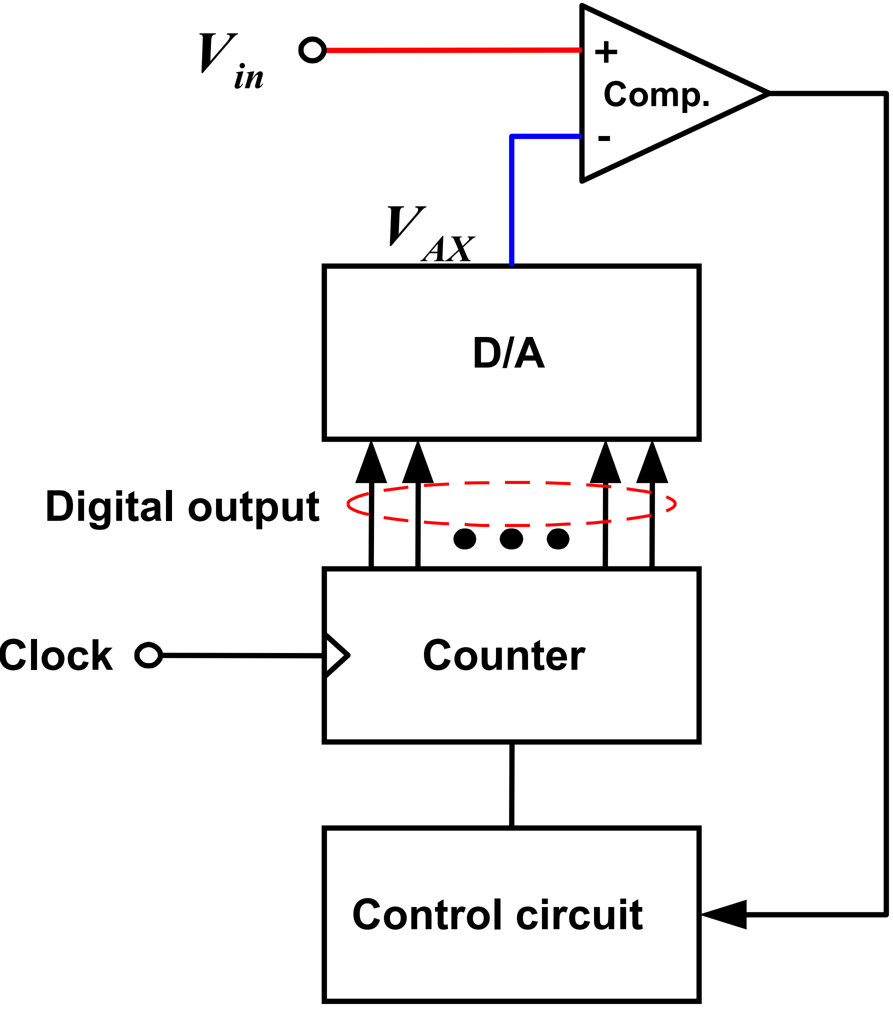


Block diagram of a ramp-type digital voltmeter.

Staircase Ramp Digital Voltmeter

(also called digital ramp)

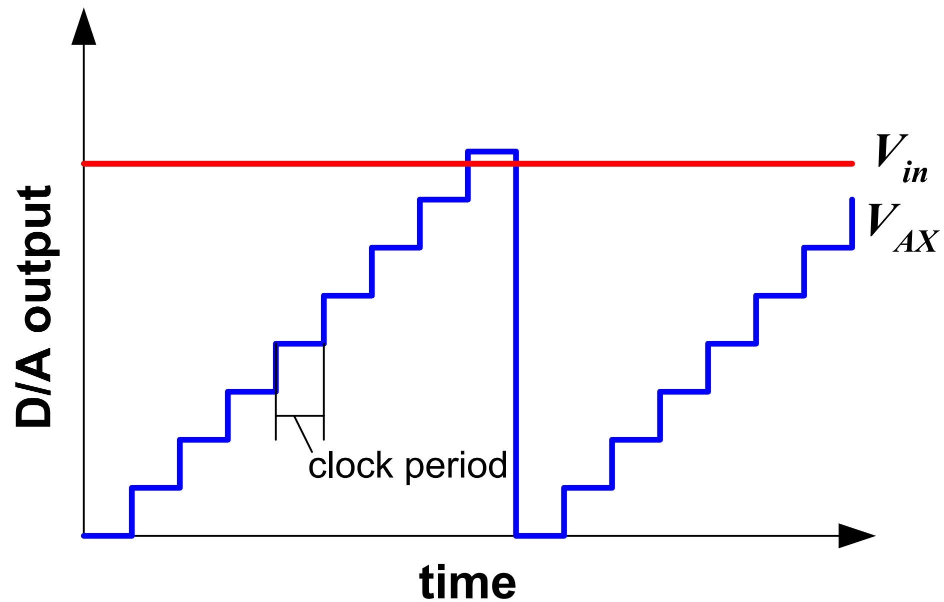
Compare the input voltage to the internally generated stair case ramp.



Block diagram

- The most simple A/D
- Slow conversion and conversion time depends on the magnitude of input signal.

$$T_{C,max} = (2^N - 1) \times \text{Clock period}$$



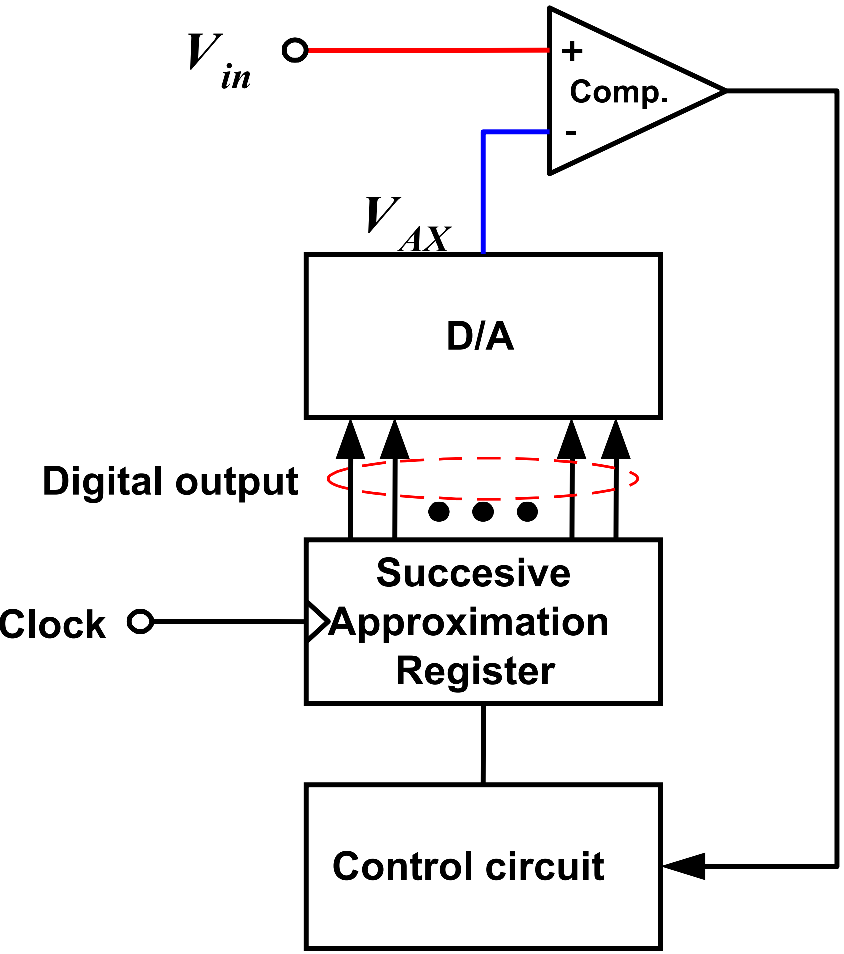
Successive Approximation Digital Voltmeter

Ex. To determine a number between 0 – 511 (9 bit binary), given, the number to be determined is 301

No.	Estimate		Results
1	256	1 0000 0000	$V_{in} > V_{AX}$
2	256+128 = 384	1 1000 0000	<
3	256+64 = 320	1 0100 0000	<
4	256+32 = 288	1 0010 0000	>
5	288+16 = 304	1 0011 0000	<
6	288+8 = 296	1 0010 1000	>
7	296+4 = 300	1 0010 1100	>
8	300+2 = 302	1 0010 1110	<
9	300+1 = 301	1 0010 1101	**Finished**

Successive Approximation Digital Voltmeter

Compare the input voltage to the internally generated voltage

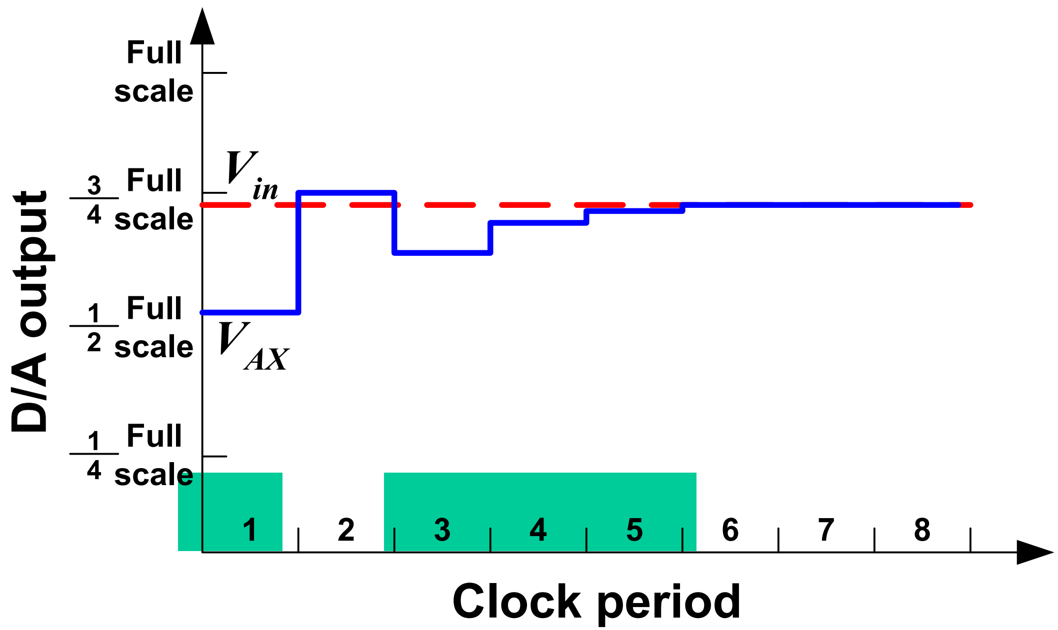


Block diagram

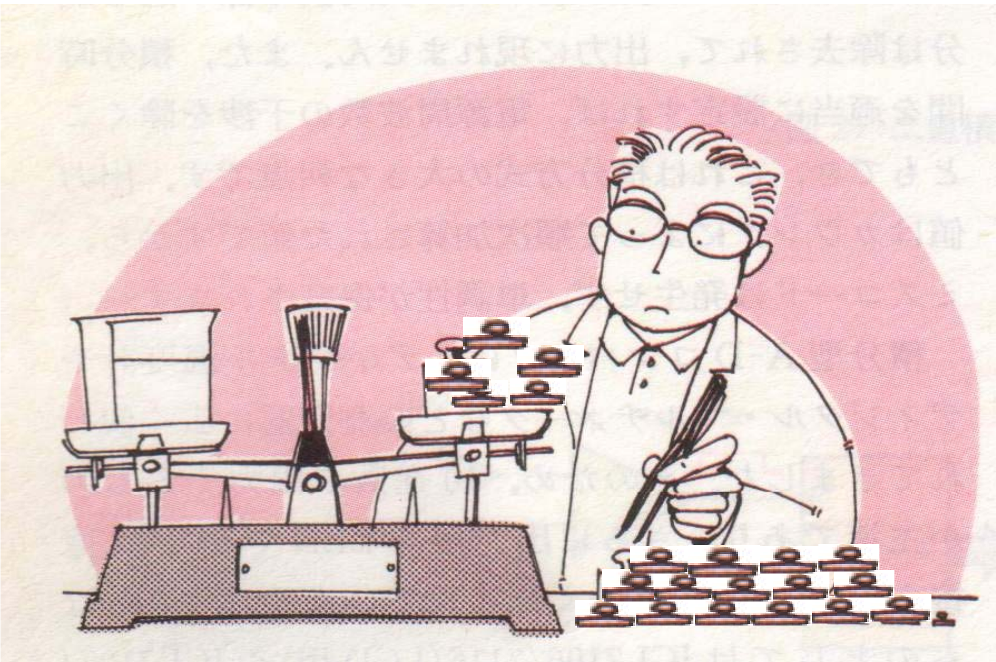
- The most common A/D for general applications
- Conversion time is fixed (not depend on the signal magnitude) and relatively fast

$$T_C = N \times \text{Clock period}$$

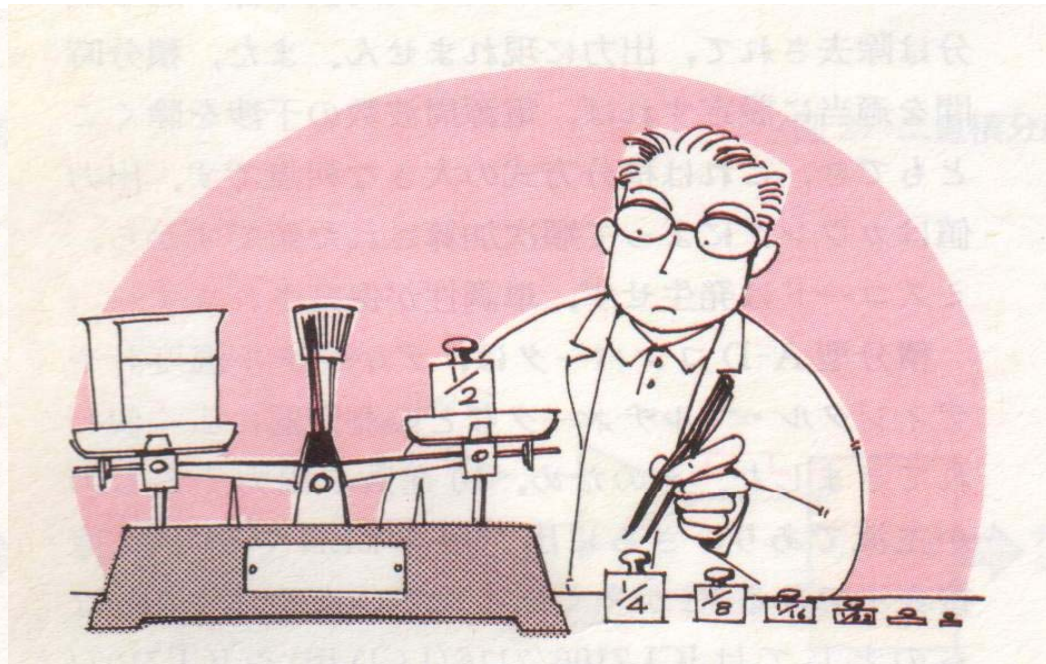
where N is the number of bits



Digital Ramp VS Successive approximation

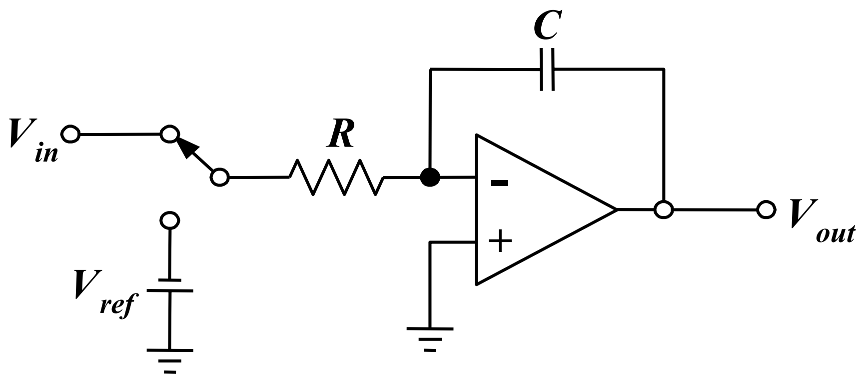


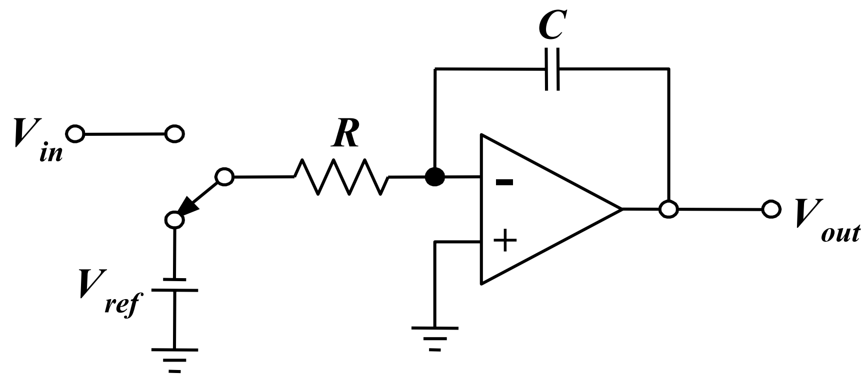
Digital Ramp method



Successive approximation method

Dual-slope Digital Voltmeter





Phase 1: charging C with the unknown input for a given time.

Phase 2: discharging ***C*** with the reference voltage until the output voltage goes to zero.

Assume $V_c(0) = 0$

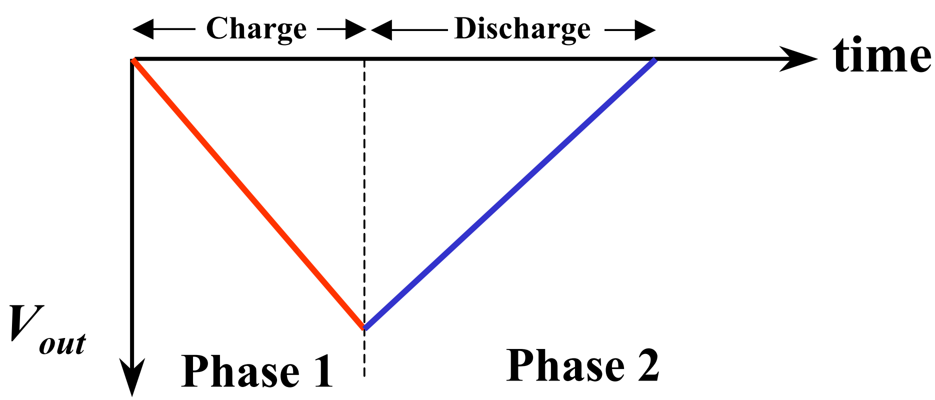
$$V_{out1} = -\frac{V_{in} T}{RC}$$

where ***T*** is the charging time

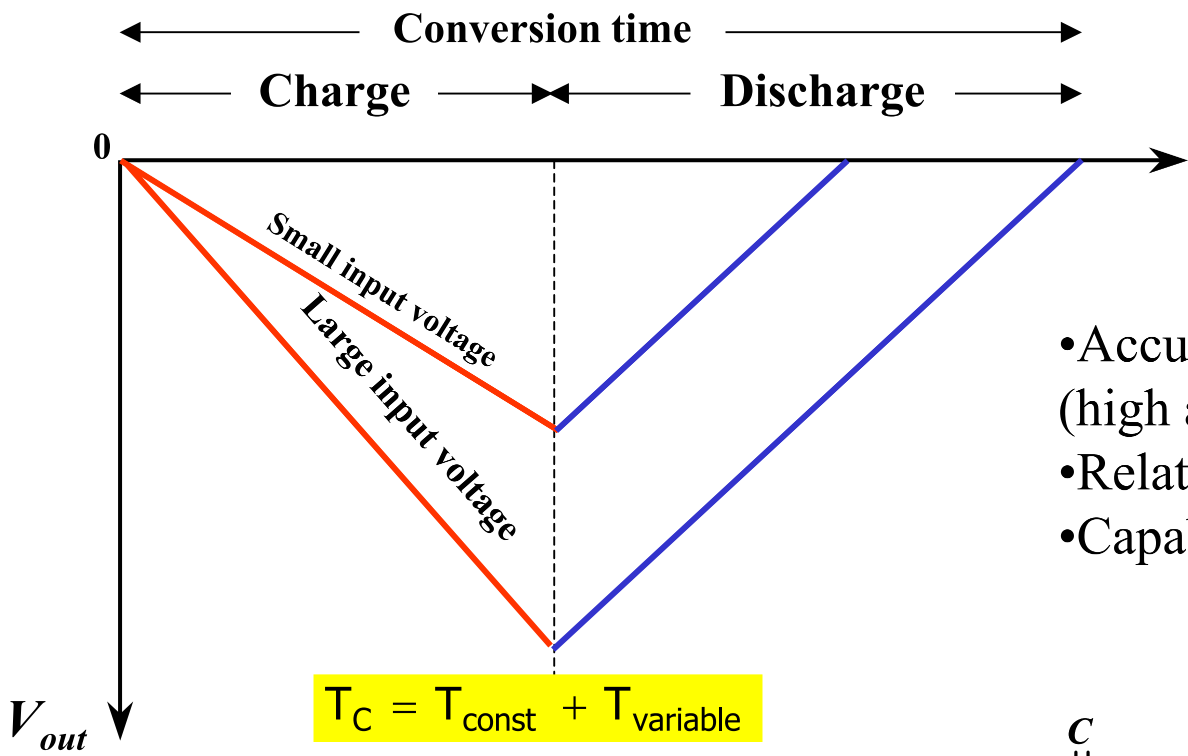
$$V_{out} = \frac{V_{ref} T_x}{RC} + V_{out1}$$

find T_x at which V_{out} becomes zero

$$T_x = \frac{V_{in} T}{V_{ref}}$$

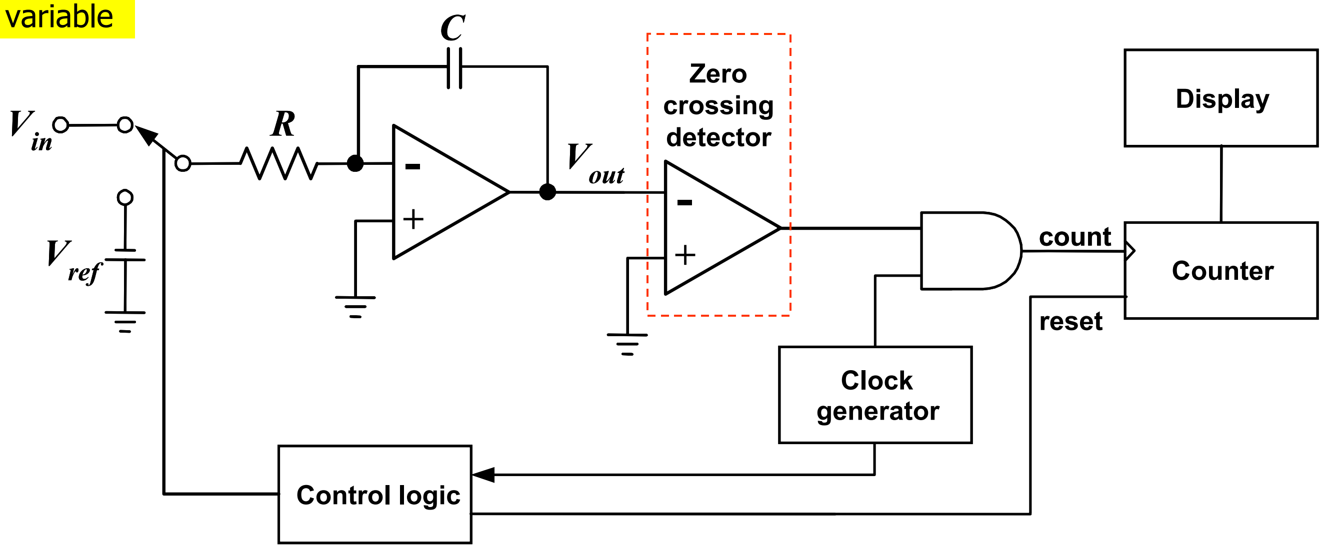


Dual-slope Digital Voltmeter



$T_C = T_{const} + T_{variable}$

- Accuracy does not depend on ***R C*** and Clock (high accuracy)
- Relatively slow
- Capable to reject noise



Ex A dual slope A/D has ***R***= 100 kΩ and ***C*** = 0.01 μF . The reference voltage is 10 volts and the fixed integration time is 10 ms. Find the conversion time for a 6.8 volt input.

$$T_x = \frac{V_{in} T}{V_{ref}} = \frac{(6.8\ \text{V})(10\ \text{ms})}{(10\ \text{V})} = 6.8\ \text{ms}$$

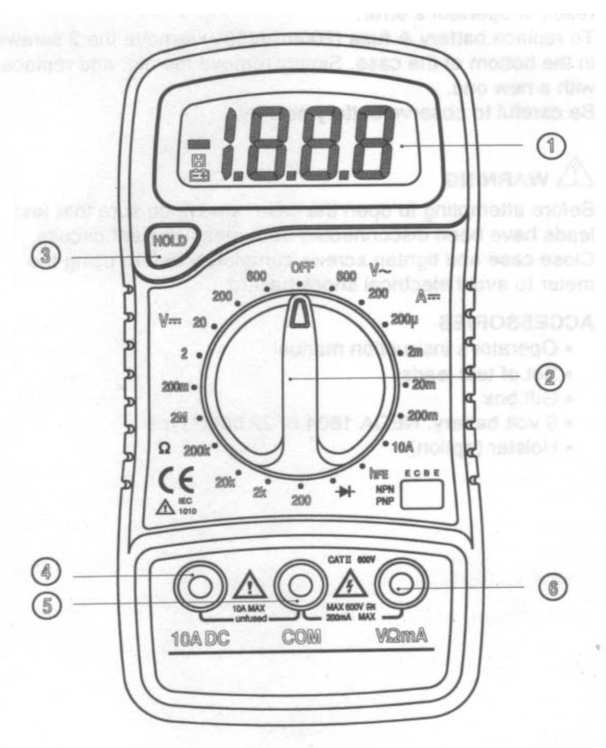
The total conversion time is then 10 ms + 6.8 ms = 16.8 ms **Ans**

Ex Find the successive approximation A/D output for a 4-bit converter to a 3.217 volt input if the reference is 5 volts.

(1) Set $D_3 = 1$ $V_{AX} = 5/2 = 2.5$ Volts
$V_{in} > V_{AX}$ leave $D_3 = 1$
(2) Set $D_2 = 1$ $V_{AX} = 5/2 + 5/4 = 3.75$ Volts
$V_{in} < V_{AX}$ reset $D_2 = 0$
(3) Set $D_1 = 1$ $V_{AX} = 5/2 + 5/8 = 3.125$ Volts
$V_{in} > V_{AX}$ leave $D_1 = 1$
(4) Set $D_0 = 1$ $V_{AX} = 5/2+5/8+5/16 = 3.4375$ Volts
$V_{in} < V_{AX}$ reset $D_0 = 0$

By this procedure, we find the output is a binary word of 1010_2 **Ans**

Typical specification of DMM



General

Maximum voltage between terminals	:600 V
Fuse protection	:200mA/250V
Power	:9V battery
Display	:LCD 31/2 digits, updates 2-3/ sec.
Input impedance	:10 MΩ
Frequency range	:40-400 Hz
Measuring method	Dual-slope integration
Over range indication	Only figure “1” on the display
Polarity indication	“-” displayed for negative polarity

Accuracy of DMM

Indicate as ± (% of reading + No. of digits)

Ex. ± (0.5% of rdg + 1 digits) sometimes simplify as ± (0.5 + 1)

Ex. For an accuracy of ± (0.5 + 1) , calculate the maximum error of in the 1.800 V reading

error = ± (0.5% of 1.800 + 0.001 V)

= ± (0.009 + 0.001 V) = ± 0.01 V or ± 0.56% of reading

Ex A 20 V dc voltage is measured by analog and digital multimeters. The analog instrument is on its 25 V range , and its specified accuracy is ± 2%. The digital meter has 3 ½ digit display and an accuracy of ±(0.6+1). Determine the measurement accuracy in each case.

Analog instrument:

$$\text{Voltage error} = \pm\, 2\%\ \text{of}\ 25\ \text{V}$$
$$= \pm\, 0.5\ \text{V}$$
$$\text{error} = \pm\, \frac{0.5\ \text{V}}{20\ \text{V}} \times 100\%$$
$$= \pm\, 2.5\%$$

3½ digit display

Digital instrument:

For 20 V displayed on a *3 ½ digit display*

$$1\ \text{Digit} = 0.1\ \text{V}$$
$$\text{Voltage error} = \pm\, (0.6\%\ \text{of reading} + 1\ \text{Digit})$$
$$= \pm\, (1.2\ \text{V} + 0.1\ \text{V})$$
$$= \pm\, 0.22\ \text{V}$$
$$\text{error} = \pm\, \frac{0.22\ \text{V}}{20\ \text{V}} \times 100\%$$
$$= \pm\, 1.1\%$$