PENGUKURAN DAN INSTRUMENTASI

Sub : Alat ukur digital

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W12-13

PERTEMUAN 12 – GARIS BESAR

- Digital Instruments
- Merits and Demerits of Digital Instruments over Analog Instruments
- Performance Characteristics of Digital Meters
- Digital Multimeter
- Digital Voltmeters
- Signal Generators

12.1

INTRODUCTION

- Nowadays everyone is familiar with analog signals. They are used for the movement of an electromagnetic meter to measure voltage, current, resistance, power, etc.
- Although the bridges and multipliers use electrical components for these measurements, the instruments described use no amplifiers to increase the sensitivity of the measurements.
- The heart of these instruments was the d'Arsonval meter, which typically cannot be constructed with a full-scale sensitivity of less than about 50 μA.
- Any measurement system using the d'Arsonval meter, without amplifiers, must obtain at least 50 μA from the circuit under test for a full-scale deflection.

- Electronic instruments, mainly electronic voltmeters, used either transistors or vacuum tubes.
- The later one is called the Vacuum Tube Voltmeter (VTVM) and the former one is called the Transistorised Voltmeter (TVM). In almost every field of electronics, VTVMs have been replaced by TVMs because of their numerous advantages.
- In TVM, due to the absence of a heating element, warm-up time is not required. It is portable due to the light weight of the transistor.
- VTVMs cannot measure current due to the very high resistance whereas due to the low resistance of the TVM, it can measure the current directly from the circuit.
- The only disadvantage of TVM over VTVM is that the TVM has very low input impedance.

12.2.1

ADVANTAGES OF DIGITAL INSTRUMENTS

1. ***Detection of Low Level Signals***

   Electronic voltmeter avoids the loading errors by supplying the power required for measurement by using external circuits like amplifiers. The amplifiers not only supply power for the operation but make it possible for low level signals, which produce a current less than 50 mA for full scale deflection, to be detected which otherwise cannot be detected in the absence of amplifiers.

2. ***High input impedance***

   The electronic voltmeter (EVM), can have input resistances from 10 MΩ to 100 MΩ with the input resistance remaining constant over all ranges instead of being different at different ranges, the EVM gives for less loading effects.

3. ***Low power consumption***

   Electronic voltmeters utilize the amplifying properties of vacuum tubes and transistors and therefore the power required for operating the instrument can be supplied from an auxiliary source. Thus, while the circuit whose voltage is being measured controls the sensing element of the voltmeter, the power drawn from the circuit under measurement is very small or even negligible.

4. ***High frequency range***

   Electronic voltmeters has a response which is made practically independent of frequency within extremely wide limits. Some electronic voltmeters permit the measurement of voltage from direct current to frequency of the order of hundreds of MHz.

5. ***Better Resolution***

In a digital instrument, the measured value is displayed directly on a LED or LCD panel whose resolution is solely determined by resolution of the analog to digital converter (ADC). Use of 12 bit (or higher) ADC can make a digital instrument to read as small as 0.001 V in 0 – 5 V range.

6. ***Storage facility***

Digital instruments have an additional optional advantage that their readings can be stored for future reference. Since the value displayed is obtained through an ADC, the digital data can be easily stored in a microprocessor or PC memory.

7. ***Accuracy***

In the digital instruments, there are very few moving parts (or even no moving parts), in general they are usually more accurate than the analog instruments. On the other hand, accuracy of a digital instrument will largely depend on accuracies of the large number of individual electronic components used for building the instrument.

12.2.2

DISADVANTAGES OF DIGITAL INSTRUMENTS

1. Effects on noise in more predominant on digital instruments than analog instruments. Analog instruments, due to inertia of its moving parts, normally remain insensitive to fast varying noise, while digital instruments continue to show erratic variations in presence of noise.
2. Analog instruments have higher overload capacity than digital instruments. The sensitive electronic components used in digital instruments are more prone to damage in case of even momentary overloads.
3. Digital instruments can sometimes loose its reliability and tend to indicate erratic values due to faulty electronic circuit components or damaged display.
4. Digital instruments and their internal electronic components are very much sensitive to external atmospheric conditions. In case of high humidity and corrosive atmosphere the internal parts may get damaged and indicate the faulty values.

12.3 PERFORMANCE CHARACTERISTICS OF DIGITAL INSTRUMENTS

1. Resolution

   Resolution defines the smallest increment in voltage that can be discerned. Evidently resolution depends on the number of bits, i.e., the smallest increment in output voltage is determined by the Least Significant Bit (LSB). Percentage resolution is $[1/(2^n - 1)]$ where n is the number of bits.

2. Accuracy

   It is a measure of the difference between actual output and expected output, expressed as a percentage of the maximum output voltage. If the maximum output voltage (or full scale deflection) is 5 volt and accuracy is ±0.1%, then the maximum error is (0.1/100) × 5 = 0.005 volt or 5 mV. Ideally the accuracy should be better than ±½ of LSB.

3. Linear Error

Linearity means that equal increments in digital input of digital instruments should result in equal increment in analog output voltage. If the values of resistances are very accurate and the other components are also ideal, there would be perfectly linear relation between output and input and output–input graph would be a straight line.

4. Monotonicity

A Digital to Analog (D/A) converter is monotonic if it does not take any reverse step when it is sequenced over the entire range of input bits.

5. Settling time

Settling time (fig 12.x) is defined as the time taken by the D/A converter to settle within ±½ LSB of its final value when a change in input digital signal occurs. But, in actual practice, the D/A converter takes some time to settle at the new position of the output voltage.

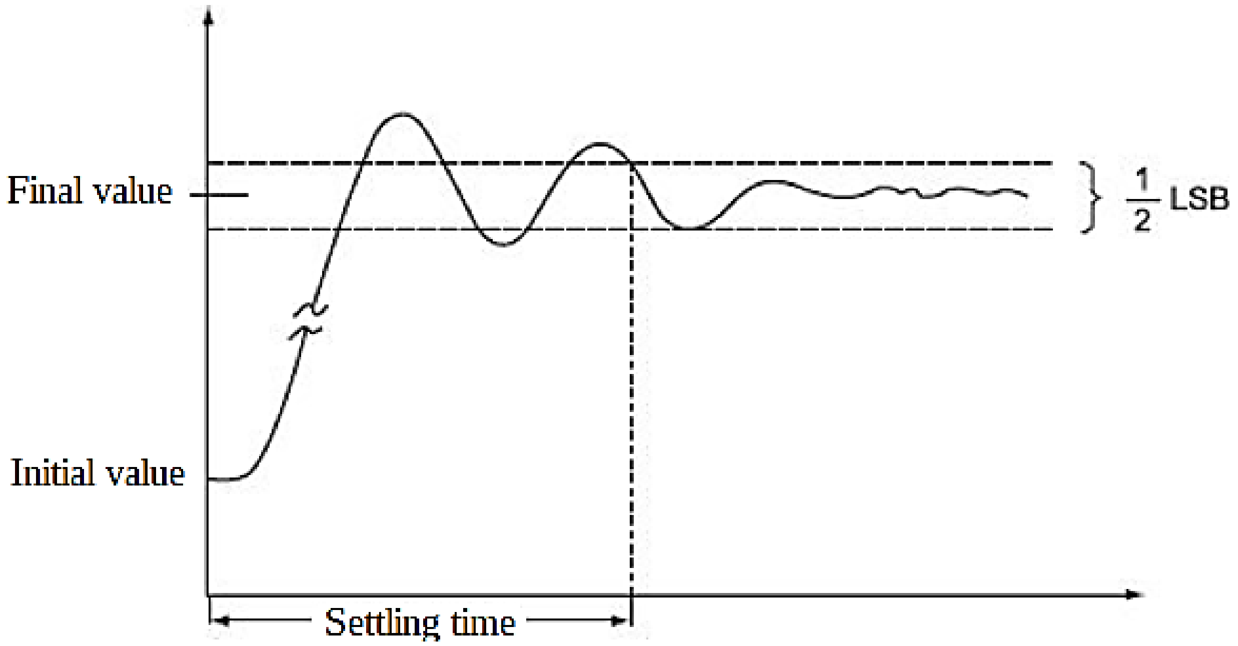


Figure 12.1 Settling time of a digital instrument

6. Temperature sensitivity

   The reference voltage supplied to the resistors of a D/A converter are all temperature sensitive. Remember that analog output voltage depends on the temperature. The range of temperature sensitivity for a D/A converter is from about ±50 to ±1.5 ppm/°C.

12.4

DIGITAL MULTIMETER

- A digital multimeter is an electronic instrument which can measure very precisely the dc and ac voltage, current (dc and ac), and resistance.
- All quantities other than dc voltage is first converted into an equivalent dc voltage by some device and then measured with the help of digital voltmeter.

1. Measurement of ac voltage

   The input ac voltage, is fed through a calibrated and compensated attenuator, to a precision full-wave rectifier circuit followed by a ripple reduction filter. The resulting dc is fed to an Analog Digital Converter (ADC) and the subsequent display system.

2. Current measurement

   The drop across an internal calibrated shunt is measured directly by the ADC in the ‘dc current mode’, and after ac to dc conversion in the ‘ac current mode’. In current measurement, a current-to voltage converter may also be used.

3. Resistance measurement

   Firstly by measuring the voltage across the externally connected resistance, resulting from a current forced through it from a calibrated internal current source. The accuracy of the resistance measurement is of the order of 0.1 to 0.5% depending on the accuracy and stability of the internal current sources

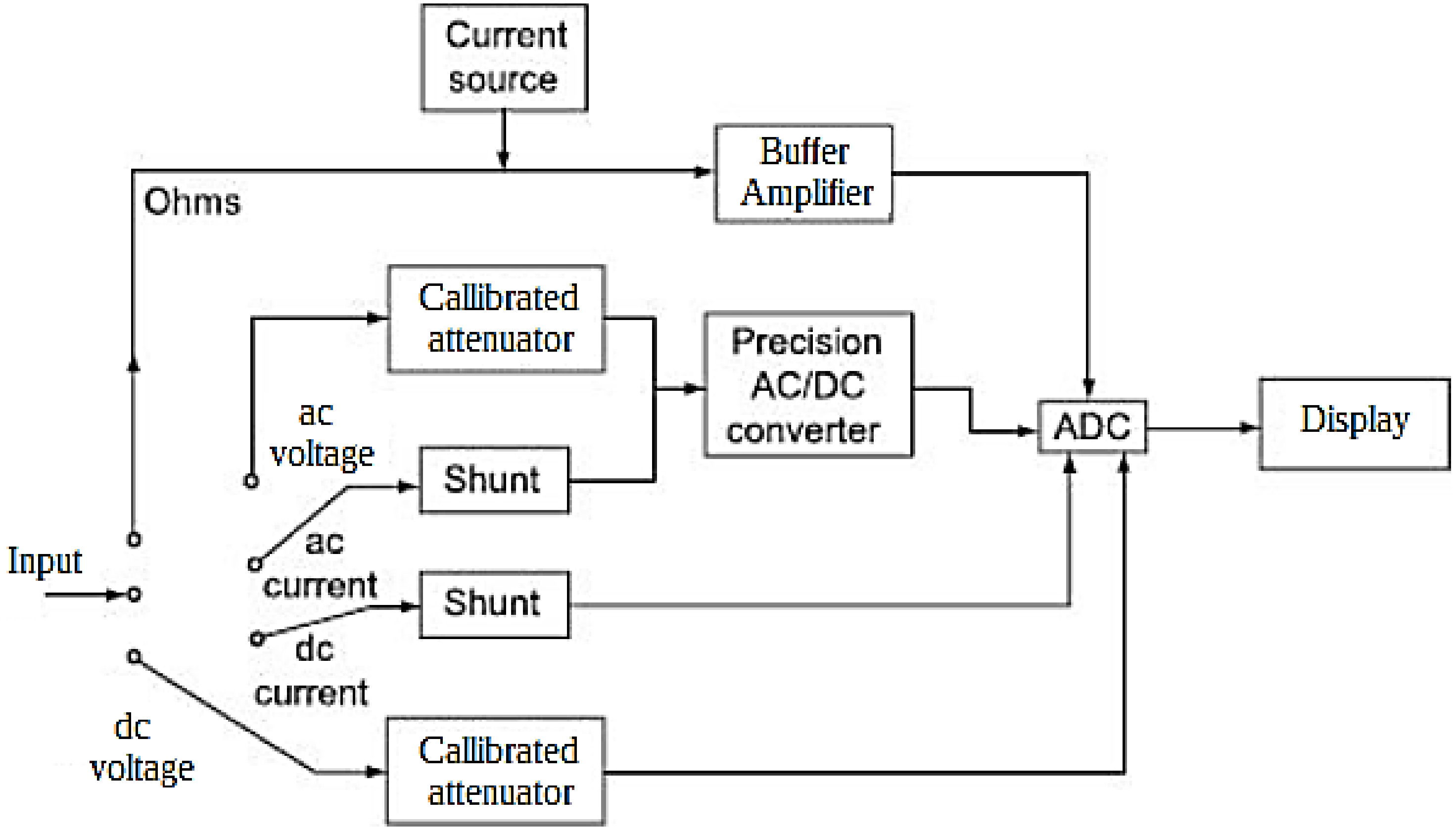


Figure 12.2 Block diagram of digital multimeter

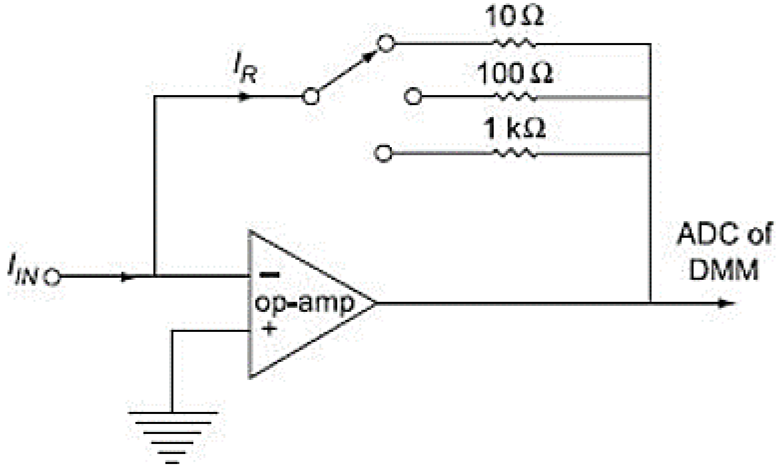


Figure 12.3 Current to voltage converter

Table 12.1 Comparison between analog and digital multimeter

Analog Multimeter	*Digital Multimeter*
No external power supply required.	An external power supply is required.
Visual indication of change in reading is better observable.	Less observable.
Less effect of electronic noise.	More affected by electronic noise.
Less isolation problems.	More isolation problems.
It has less accuracy.	Highly accurate instrument.
Interface of the output with external equipment is not possible.	Possible to connect an external instrument with the output reading.
Simple in construction.	Very complicated in construction.
Big in size.	Small in size.
Low cost.	More costlier instrument.
The output is ambiguous in many times.	Unambiguous reading due to digital indication.

12.5

DIGITAL FREQUENCY METER

- A frequency meter/counter is a digital instrument that can measure and display the frequency of any periodic waveform.
- It operates on the principle of gating the unknown input signal into the counter for a predetermined time. For example, if the unknown input signal were gated into the counter for exactly 1 second, the number of counts allowed into the counter would be precisely the frequency of the input signal.
- The term *gated* comes from the fact that an AND or an OR gate is employed for allowing the unknown input signal into the counter to be accumulated.

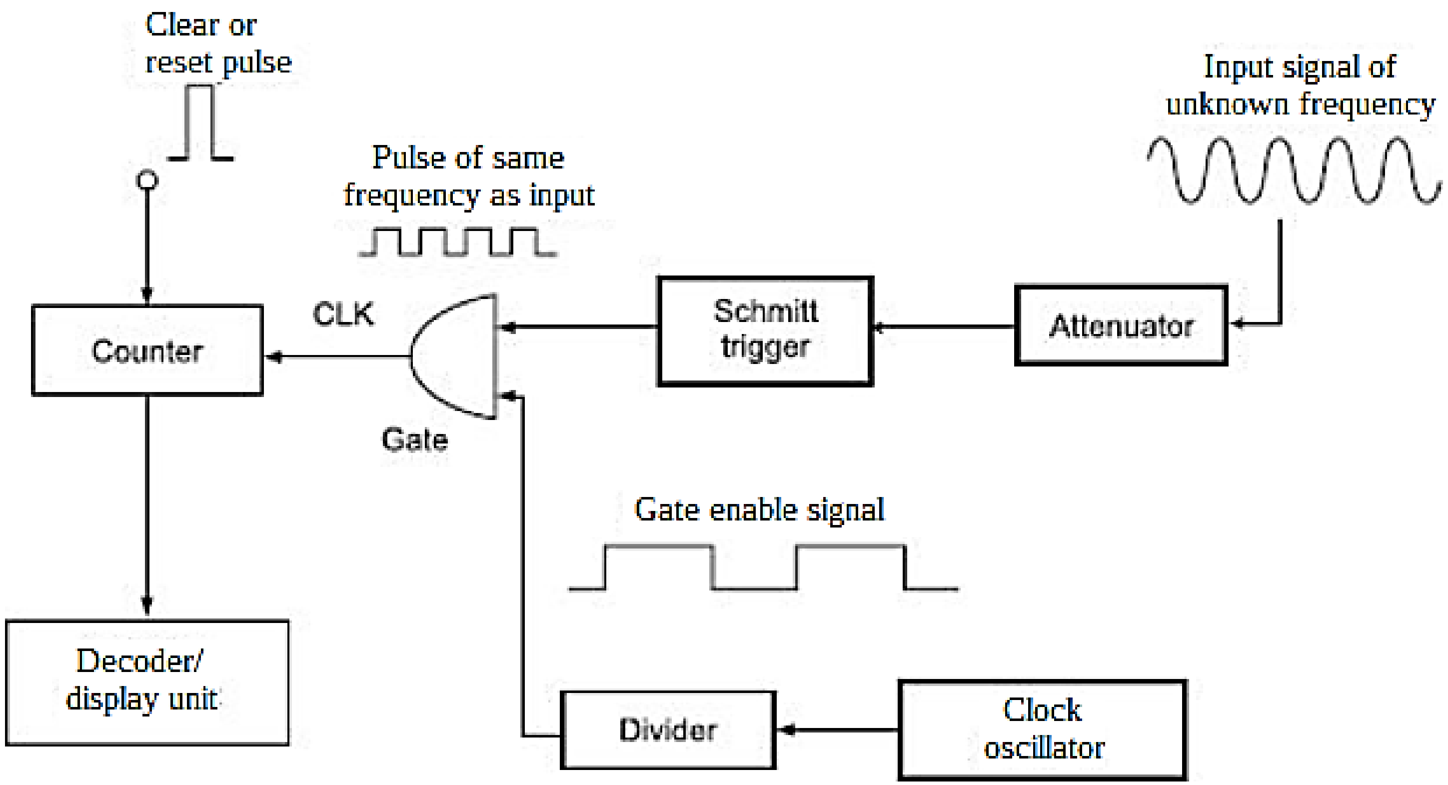


Figure 12.4 Block diagram of frequency counter

Refer to figure 12.4

- A counter is associated with display/decoder circuitry, clock oscillator, a divider and an AND gate.
- A GATE ENABLE signal of known time period is generated with a clock oscillator and a divider circuit and is applied to one leg of an AND gate.
- The unknown signal is applied to the other leg of the AND gate and acts as the clock for the counter. The counter advances one count for each transition of the unknown signal, and at the end of the known time interval, the contents of the counter will be equal to the number of periods of the unknown input signal that have occurred during time interval, *t*.
- In other words, the counter contents will be proportional to the frequency of the unknown input signal.

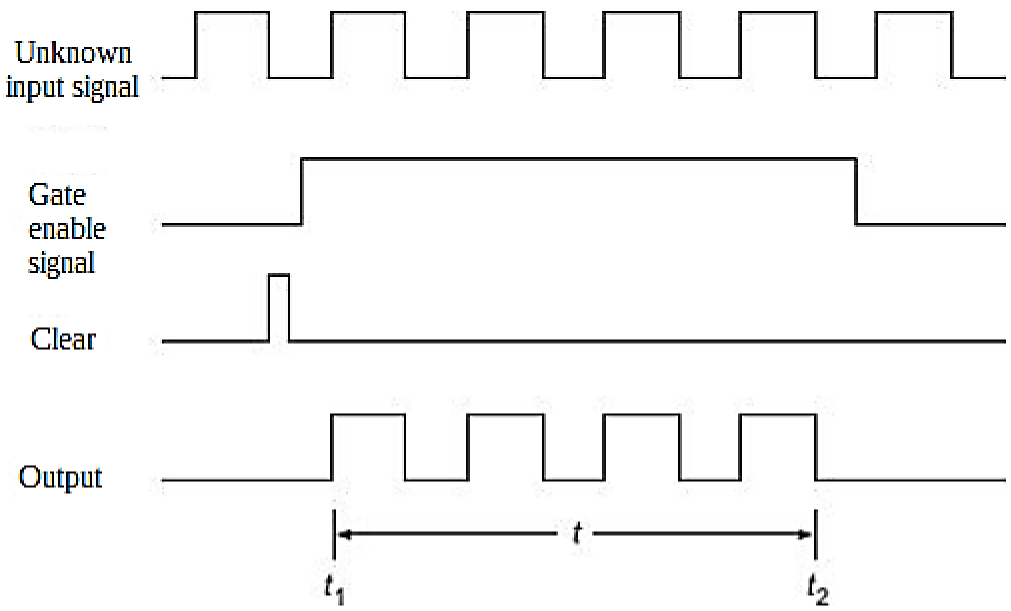


Figure 12.5 Different waveforms in a frequency counter

Thus, the counter will have counted the number of pulses that occurred during the time interval, *t* of the GATE ENABLE SIGNAL, and the resulting contents of the counter are a direct measure of the frequency of the input signal.

The accuracy of the measurement depends almost entirely on the time interval of the GATE ENABLE signal, which needs to be controlled very accurately.

12.6

DIGITAL VOLTMETER

- The Digital Voltmeter (DVM) displays measurement of ac or dc voltages as discrete numbers instead of a pointer deflection on a continuous scale as in analog instruments.
- DVM is a versatile and accurate instrument that is employed in many laboratory measurement applications.
- Because of development and perfection of IC modules, their size, power consumptions and cost of the digital voltmeters has been drastically reduced.
- The block diagram of a simple digital voltmeter is shown in Figure 10.7. The unknown signal is fed to the pulse generator which generates a pulse whose width is directly proportional to the input unknown voltage.

- The output of the pulse generator is applied to one leg of an AND gate. The input signal to the other leg of the AND gate is a train of pulses.
- The output of the AND gate is, thus, a positive trigger train of duration *t* second and the inverter converts it into a negative trigger train.

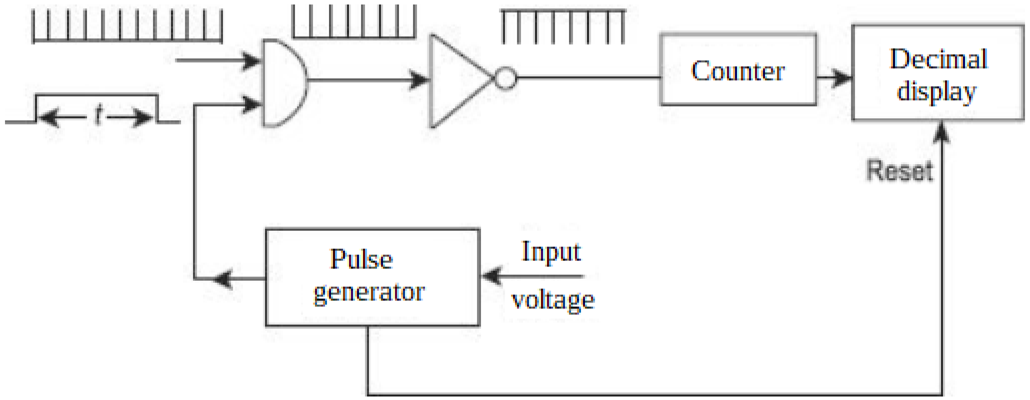


Figure 12.6 Block diagram of DVM

- The counter counts the number of triggers in *t* seconds which is proportional to the voltage under measurement.
- Thus, the counter can be calibrated to indicate voltage in volts directly.

- The DVMs described in figure 12.6 above is an Analog to Digital Converter (ADC) which converts an analog signal into a train of pulses, the number of which is proportional to the input voltage.
- So the DVMs can be classified on the basis of ADCs used as seen in figure below

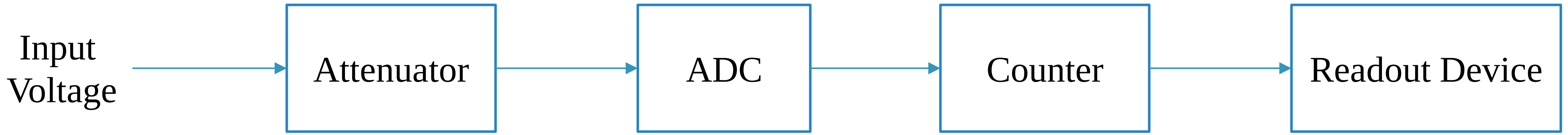
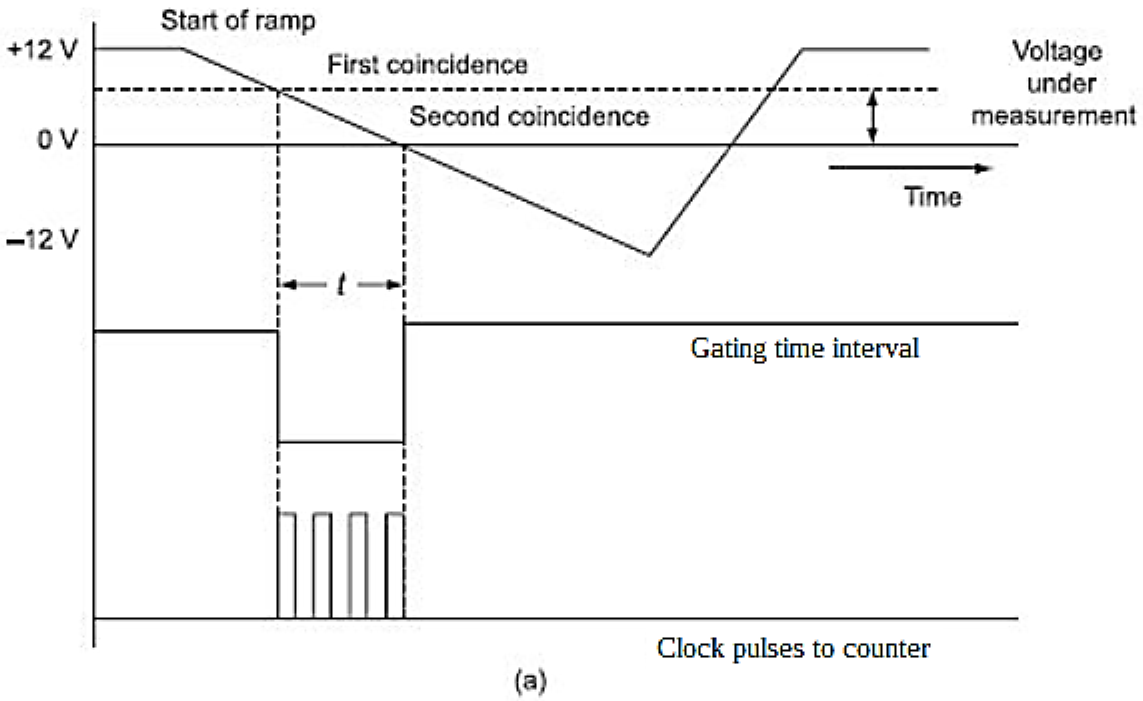


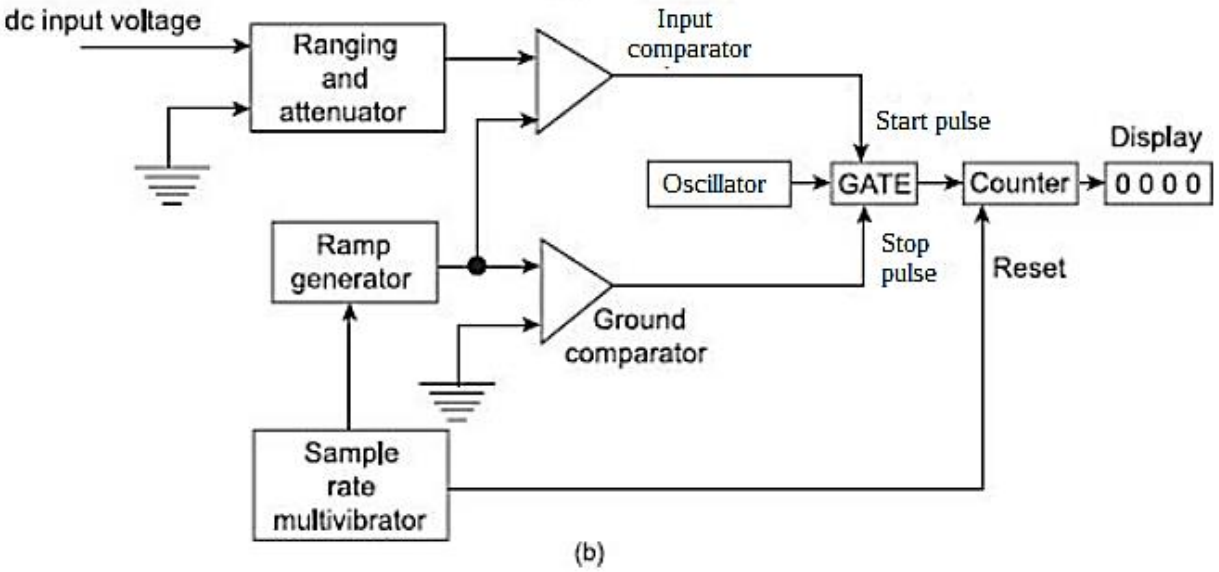
Figure 12.7 DVM's representation using blocks

12.6.1

RAMP – TYPE DVM

- The ramp-type DVM is based on the measurement of the time that a linear ramp voltage takes to change from the level of the input voltage to zero voltage or vice versa.
- This time interval is measured with an electronic time interval counter and the count is displayed as a number of digits on the electronic indicating tubes of the voltmeter output readouts.





12.8 (a) Voltage-to-time conversion (b) Block diagram of a ramp-type DVM

12.6.2

DUAL – SLOPE INTEGRATING – TYPE DVM

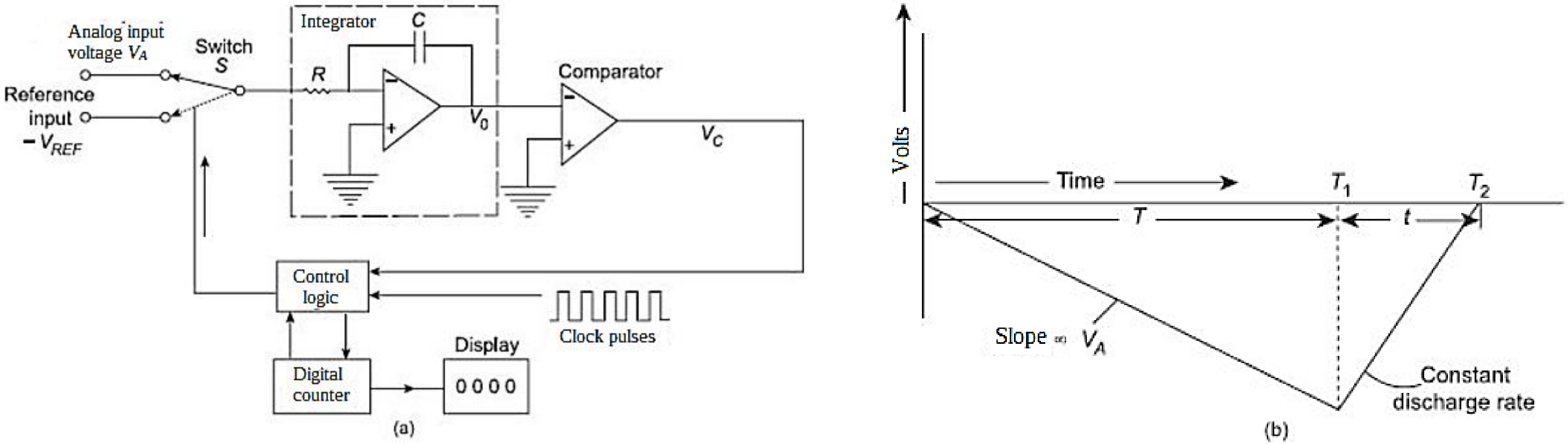


Figure 12.9 (a) Block diagram of a Dual-Slope Integrating-type DVM
(b) Principle of operation of dual-slope-type DVM

- The dual slope ADC consists of five blocks namely an OP-AMP employed as an integrator, a level comparator, a basic clock for generating time pulses, a set of decimal counter and a block of logic circuitry.
- For a fixed time interval (usually, the full count range of the counter), the analog input voltage to be measured, is applied through the switch *S* to the integrator which raises the voltage in the comparator to some negative value, as illustrated in Figure 12.9 (b).
- At the end of fixed time interval the voltage from the integrator will be greater in magnitude for larger input voltage, i.e., rate of increase of voltage or slope is proportional to the analog input voltage

$$V_0 = -\frac{1}{RC}\int_0^t V_A\,dt = -\frac{V_A\,t}{RC}$$

at t =T_1 (charging time) the value of the integrator output voltage $V_0 = -\frac{V_A\,T_1}{RC}$

During discharging, the output voltage is given as:

$$V_0 = \frac{1}{RC}\int_0^t -V_{REF}\,dt = -\frac{V_A T_1}{RC} + \frac{V_{REF} t}{RC}$$

At t = T_2 (the time measured by the counter), the output voltage of the integrator becomes zero

$$0 = -\frac{V_A T_1}{RC} + \frac{V_{REF}\,T_2}{RC} \rightarrow V_A = V_{REF}\,\frac{T_2}{T_1}$$

- The main advantages of dual slope integrating type DVM is the averaging characteristics and cancellation of errors that usually limit the performance of a ramp-type DVM are.
- The integration characteristics provide the average value of the input signal during the period of first integration. Consequently, disturbances, such as spurious noise pulses, are minimised.
- Long-term drifts in the time constant as may result from temperature variations or aging, do not affect conversion accuracy. Also, long-term alternations in clock frequency have no effect.

12.6.3

INTEGRATING – TYPE DVM

- Such a digital voltmeter makes use of an integration technique which employs a voltage to frequency (*V*/*f*) conversion.
- This voltmeter indicates the true average value of the unknown voltage over a fixed measuring period.
- An analog voltage can be converted into digital form by producing pulses whose frequency is proportional to the analog input voltage.
- These pulses are counted by a counter for a fixed duration and the reading of the counter will be proportional to the frequency of the pulses, and hence, to the analog voltage.

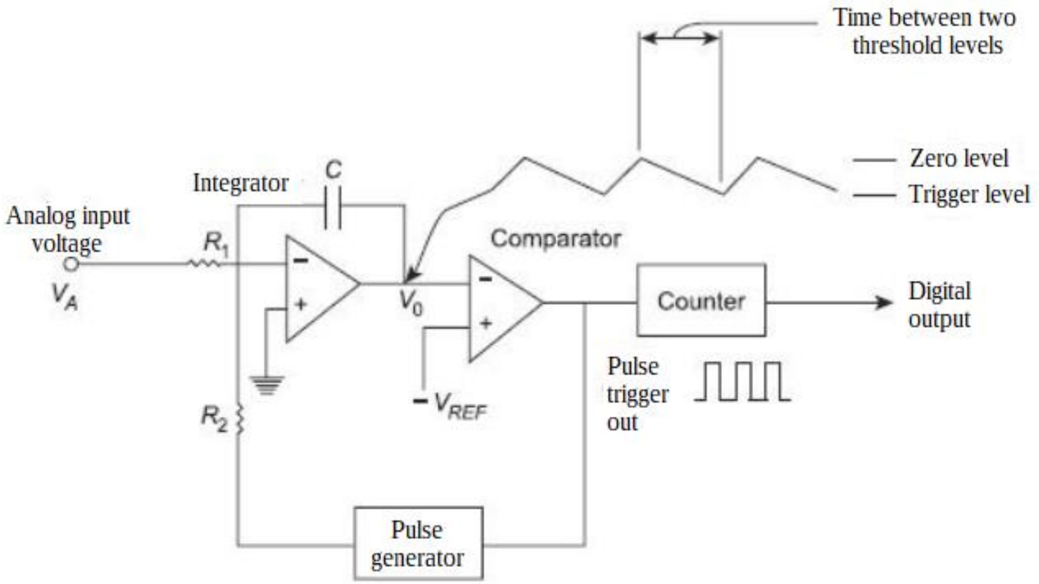


Figure 12.10 Block diagram of integrating – type DVM

The analog input voltage V_A is applied to an integrator which in turn produces a ramp signal whose slope is proportional to the input voltage.

When the output voltage V_0 attains a certain value, a trigger and current pulses is produced and generated respectively which is used to discharge the integrator capacitor *C*.

- A new ramp is initiated after discharging the capacitor C. The time between successive threshold level crossings is inversely proportional to the slope of the ramp.
- Since the ramp slope is proportional to the input analog voltage *VA*, the frequency of the output pulses from the comparator is, therefore, directly proportional to the input analog voltage.

APPLICATION OF DVM

- DVMs are often used in 'data processing systems' or 'data logging systems'.
- In some cases, a number of analog input signals are scanned sequentially by an electronic system and then each signal is converted to an equivalent digital value by the A/D converter in the DVM.
- The digital value is then transmitted to a pointer along with the information about the input line from which the signal has been derived. The whole data is then printed out.

12.8 SIGNAL GENERATORS

- It is an electronic device which produces repeating or non-repeating electronic signals (either analog or in digital patterns).
- A signal generator has a numerous synonym names as test signal generator, tone generator, arbitrary waveform generator, frequency generator, digital pattern generator, function generator, etc.
- These signals are utilised in testing, designing, troubleshooting and repairing electronic devices.

- Distinguisher between the signal generator and oscillator are, that signal generator is capable to modulate sinusoidal output signal with other signals.
- When an unmodulated sinusoidal output is generated by the signal generators then they are said to be producing CW (continuous height wave) signal.
- When they produce modulated output signals then they can be in the form of square waves, externally applied sine waves, pulses, triangular waves, or more complex signals, as well as internally generated sine waves.
- Although Amplitude Modulation (AM) or Frequency Modulation (FM) can be used, yet amplitude modulation is generally employed.

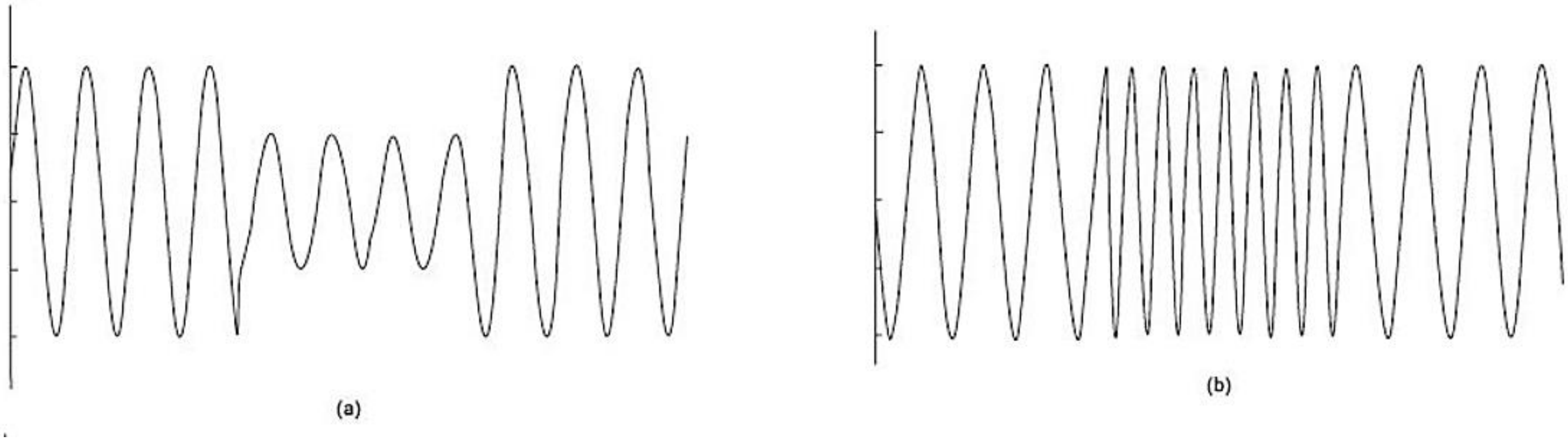


Figure 12.11 (a) Amplitude modulation (b) Frequency modulation

- A Radio Frequency (RF) oscillatoris applied for producing a carrier waveform whose frequency can be attuned typically from about 100 kHz to 40 MHz. With the help of vernier dial setting and range selector switch, carrier wave frequencies can be varied and displayed.
- Frequency dividers are employed to determine the range. An oscillators frequency stability is kept very high at all frequency ranges.

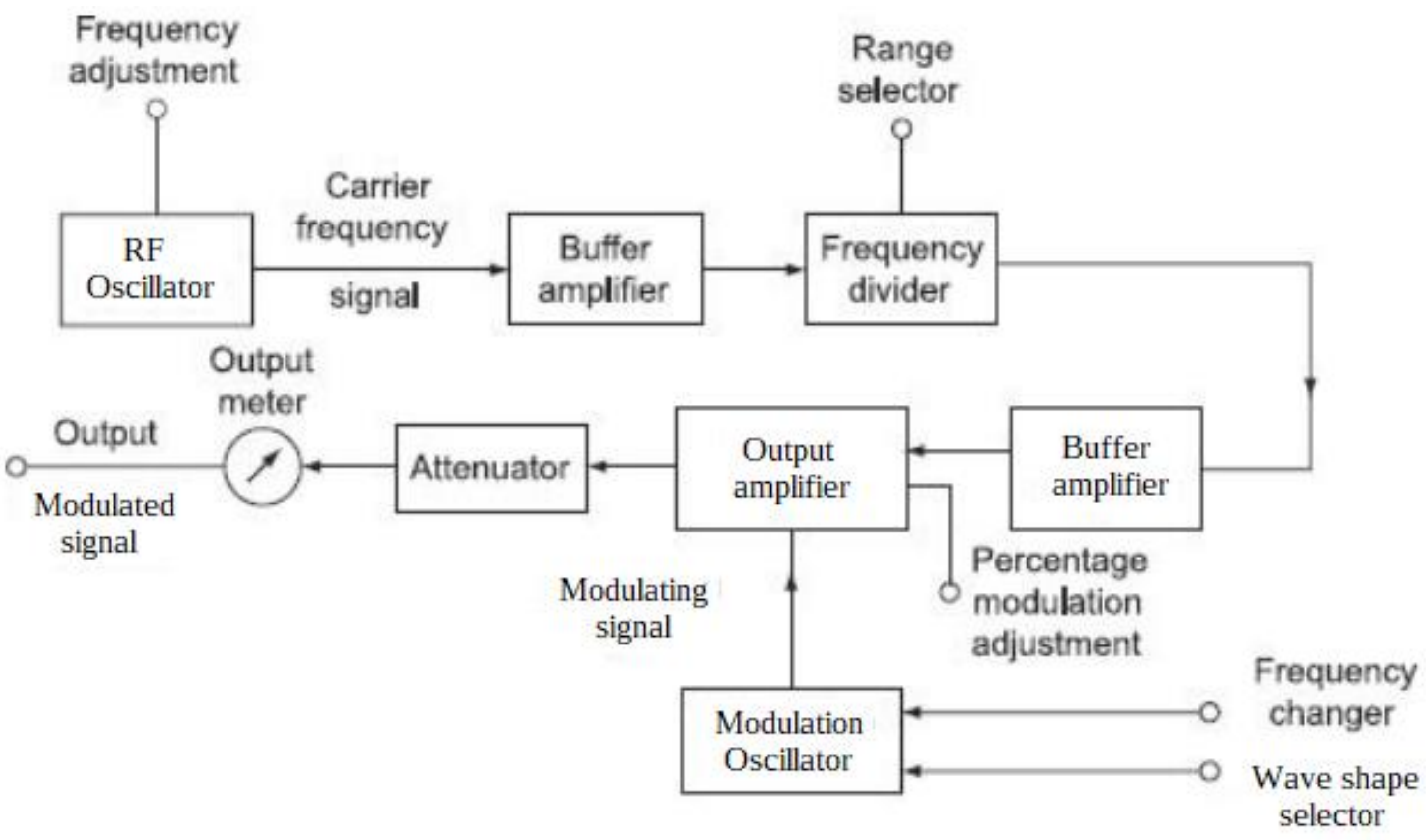


Figure 12.12 (a) Constructional details of induction-type single-phase energy meter
(b) Photograph of induction-type single-phase energy meter