# ELECTRONIC MEARUREMENT AND TESTING

- Testing and test equipment are essential elements for the electronics industry. Not only is the test equipment important, but so are the methodologies and test techniques used.
- There is a large variety of electronic test equipment that is used in production, development, field test and general fault finding.

# OBJECTIVE

On completion of this section of the unit you will be able to describe :

- The function
- Features
- Characteristics

Of various electronic measurement and test equipment.

Categorises equipment according to:

- Measurement
- Electronic Test

# *Measurement instruments:*

- meters (voltmeter, ammeter)
- analogue/digital multimeter
- oscilloscope

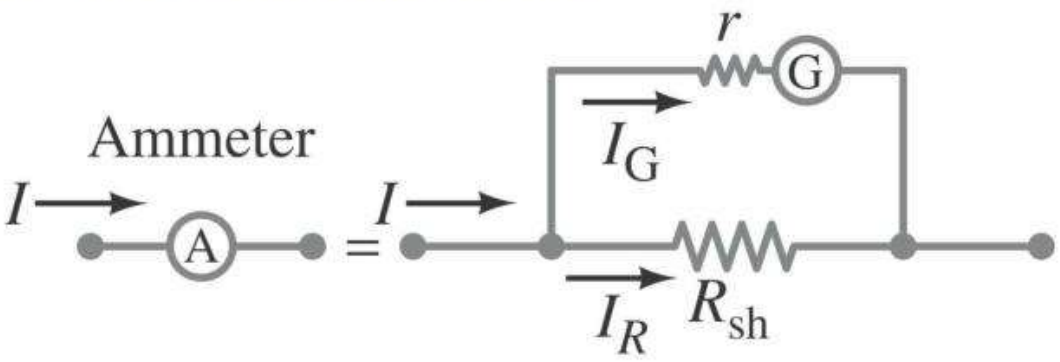

0
300
600
900
1200
1500
A
TP-80K
0
20
40
60
80
100
V


17.6
V
13.5
A

# Ammeters and Voltmeters*

**An ammeter measures current; a voltmeter measures voltage. Both are based on galvanometers, unless they are digital.**

**The current in a circuit passes through the ammeter; the ammeter should have low resistance so as not to affect the current.**

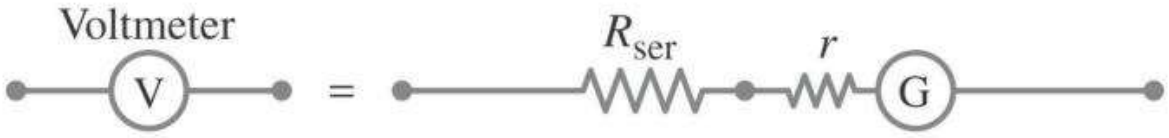





**Example : Ammeter design.**

**Design an ammeter to read 1.0 A at full scale using a galvanometer with a full-scale sensitivity of 50 $\mu$A and a resistance $r$ = 30 Ω. Check if the scale is linear.**

**A voltmeter should not affect the voltage across the circuit element it is measuring; therefore its resistance should be very large.**






**Example : Voltmeter design.**

**Using a galvanometer with internal resistance 30 Ω and full-scale current sensitivity of 50 $\mu$A, design a voltmeter that reads from 0 to 15 V. Is the scale linear?**

# MULTI-TESTER

- The multi-tester or Multi-meter is a sometimes called VOM(Voltmeter, Ohmmeter, Milliammeter) is the best instrument that can measure voltage, resistance, and current.

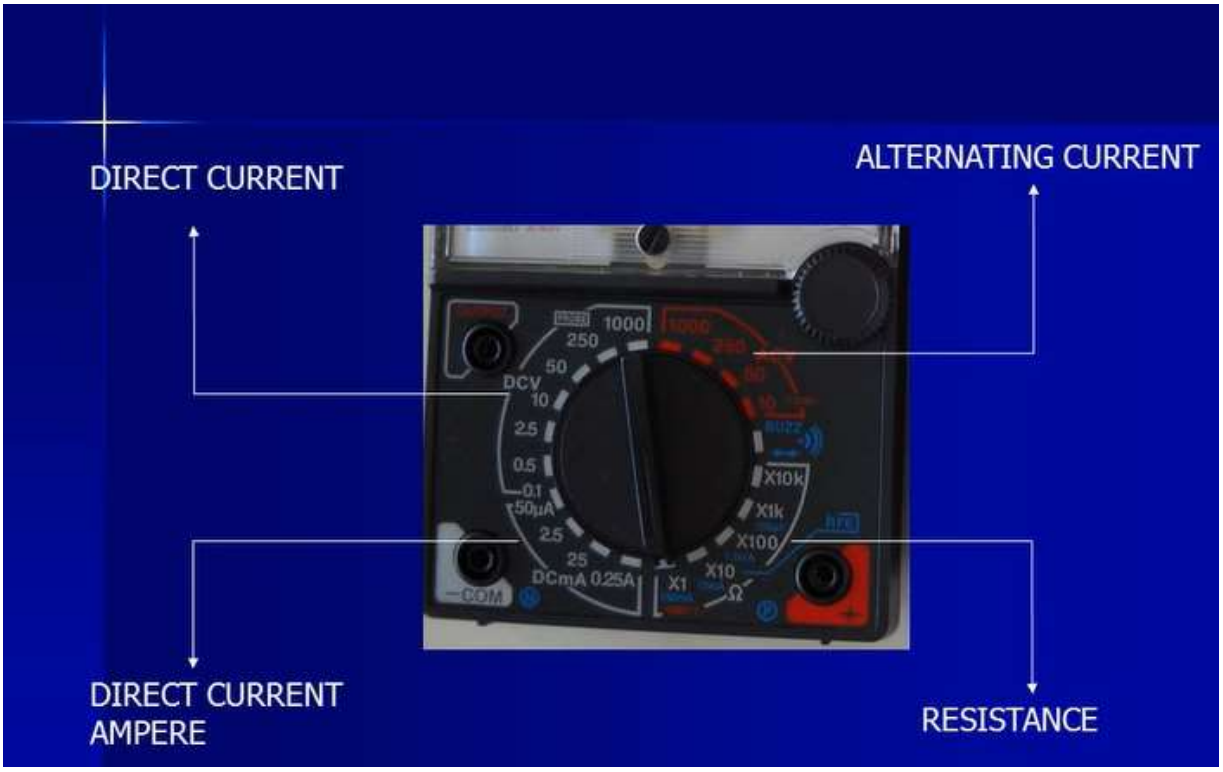
# TWO GENERAL TYPES OF MULTI-TESTER

1. ANALOG MULTI-TESTER
2. DIGITAL MULTI-TESTER

# MULTI TESTER

ANALOG MULTI-TESTER – Has a moving coil assembly which is characterized by a needle pointer.

# ANALOG MULTI-TESTER




# *Electronic test equipment*

- signal generator audio frequency (AF)
- radio frequency (RF) pulse generators
- waveform/function generators
- digital counter/frequency meter
- AC bridge
- logic probe
- logic pulser
- current tracer

# *Features of equipment:*

- displays and display technology
- input and output connectors
- attenuators
- manual and automatic range selection (auto ranging)
- in-built calibration facilities
- Portability
- power sources
- external bus interfaces

# Characteristics of equipment:

equipment specifications

- Input impedance
- Output impedance
- Resolution
- Accuracy
- Distortion
- Bandwidth
- Input signal range
- Output level
- Sample rate,
- trigger sources

# *Function of equipment* *(what does it do)*

Accurate measurement

- of alternating current (AC) and direct current (DC) voltage and current
- resistance
- waveform
- distortion measurement
- Accurate measurement of waveform parameters (period, duty cycle, on-time, off-time, rise time, fall time, frequency, pulse repetition frequency (PRF)
- Impedance
- logic level)

# Features and control

- Square wave Sine wave Triangle wave
- Frequency Range  eg 300 kHz to 3.6 GHz
- Test Port Impedance: 50 ohm
- The amplitude control
- Overshoot
- rise time
- The duty cycle

# Signal generator

- Signal generator come in many different forms. The most prevalent signal generator types include arbitrary waveform generators, function generators, RF signal generators, and basic analogue output modules. The signal generator types vary in their features and functionality and are suitable for many different applications

## 3.4 Audio Frequency (A.F.) Signal Generators

The signal generators which provide sinusoidal waveforms in the frequency range of 20 Hz to 20 kHz are called **audio frequency (A.F.) signal generators.** Depending upon the load, in modern AF signal generators a provision is made to select output impedance either 50 Ω or 600 Ω. To generate audio frequency signals, in practice RC feedback oscillators are used. The most commonly used RC feedback oscillators are **Wien Bridge oscillator** and **RC phase shift oscillator.** Let us discuss both the types of oscillators in detail.

| Band | Approximate range |
|---|---|
| Audio Frequency (AF) | 20 Hz - 20 kHz |
| Radio Frequency (RF) | Above 30 kHz |
| Very Low Frequency (VLF) | 15 - 100 kHz |
| Low Frequency (LF) | 100 - 500 kHz |
| Broadcast | 0.5 to 1.5 MHz |
| Video | 0 - 5 MHz |
| High Frequency (HF) | 1.5 - 30 MHz |
| Very High Frequency (VHF) | 30 - 300 MHz |
| Ultra High Frequency (UHF) | 300 - 3000 MHz |
| Microwave | Beyond 3 GHz |

A block diagram of a simple signal generator is as shown in the Fig. 3.1.

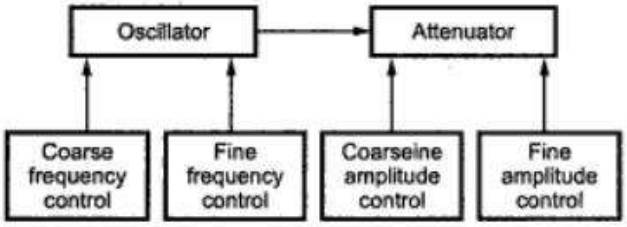



**Fig. 3.1 Block diagram of a signal generator**

A signal generator consists of two important main blocks,

i) Oscillator

ii) Attenuator

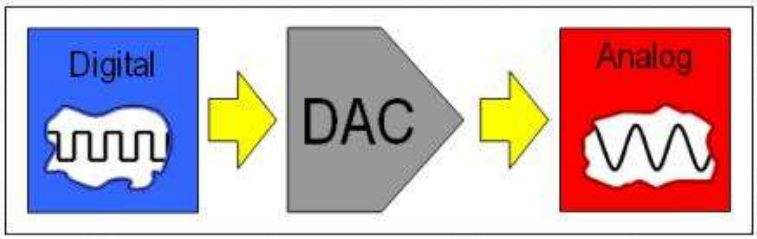
Generally the oscillator uses an active device such as an operational amplifier. The output of an operational amplifier is fed back in phase with input. This positive feedback causes regenerative action resulting an oscillation.

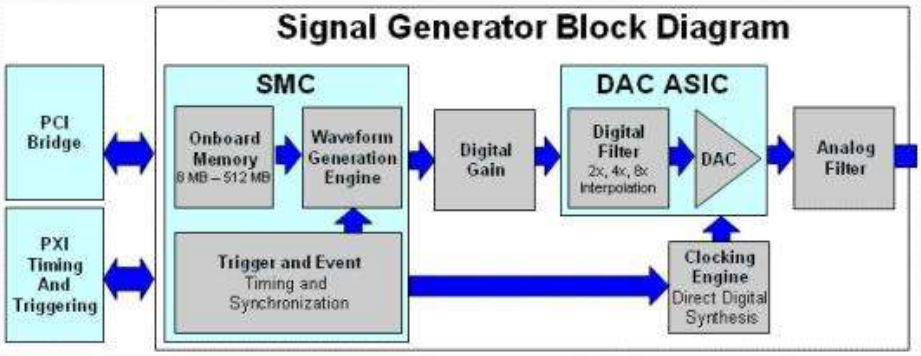
The attenuator provides amplitude control. Basically the attenuator is a device which reduces or attenuates the power level of the signal by fixed amount.

The proper functioning of a signal generator depends on the performance of an oscillator and attenuator.

While the fundamental building block of analogue signal generation is a Digital-to-Analogue Converter (DAC), the process of generating advanced analogue signals is much more complex.
factors that affect signal quality including:

1. bit resolution,
2. bandwidth,
3. sample rate,
4. interpolation
5. filtering



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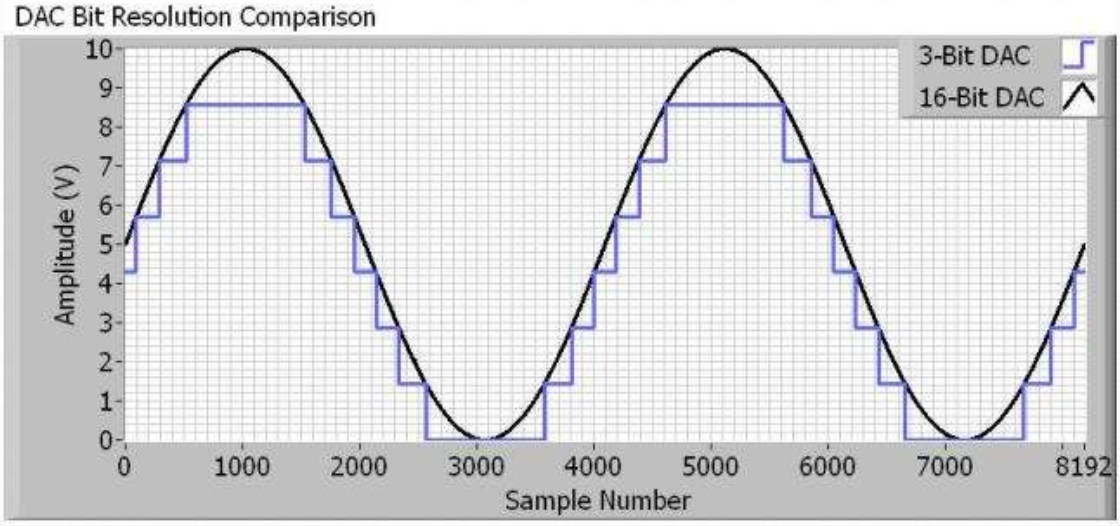
$$\text{DiscreteStepSize} = \frac{\text{Range}}{2^{\text{Bits}} - 1}$$




The difference between a 3-bit DAC with a 16-bit DAC is illustrated in the figure below.

- An example, consider a 3-bit DAC.

  With three bits of resolution, this DAC divides its vertical range into $2^3$ or 8 discrete analogue voltage levels.

  These 8 discrete voltage levels are divided across the entire vertical range and the voltage difference between each level is similar.

  Thus, when a 3-bit DAC is configured with an output range of 0-10 V, each level accounts for (10 V / 8) = 1.25 volts.

  Thus, at this range, a 3-bit DAC cannot generate voltage differences smaller than 1.25 V.

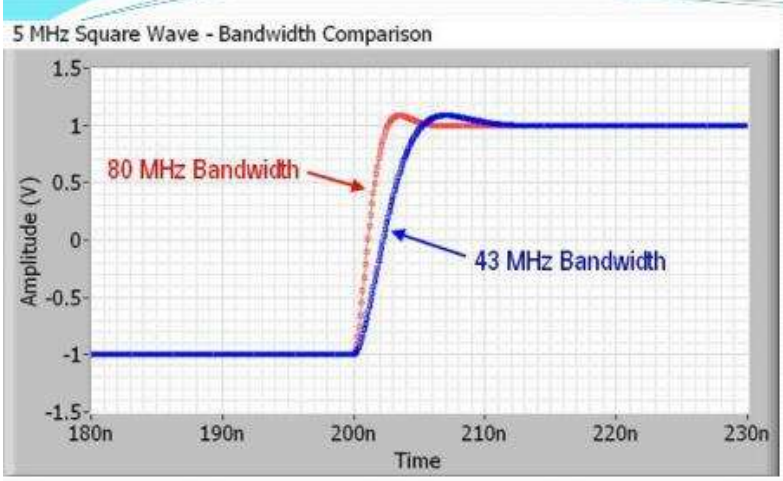
- On the other hand, consider a 16-bit DAC with the same output range.

  With 16 bits of resolution, this DAC is able to generate $2^{16}$ or 65,536 discrete voltage levels.

  In addition, with the same 10V vertical range, the signal generator is able to generate voltage differences as small as 153 μV.

# Bandwidth

- The bandwidth of a signal generator represents the maximum frequency that it can generate without significant attenuation. More specifically, bandwidth is defined as the maximum frequency at which the output is attenuated by 3 dB or less, relative to the amplitude of a DC or low frequency signal.
- Typically, bandwidth is limited by the specific DAC chosen and the design of the signal generator circuitry.
- In addition, it is an important specification because it determines both the maximum frequency of sine output, and specifications such as overshoot and rise time for the instrument.



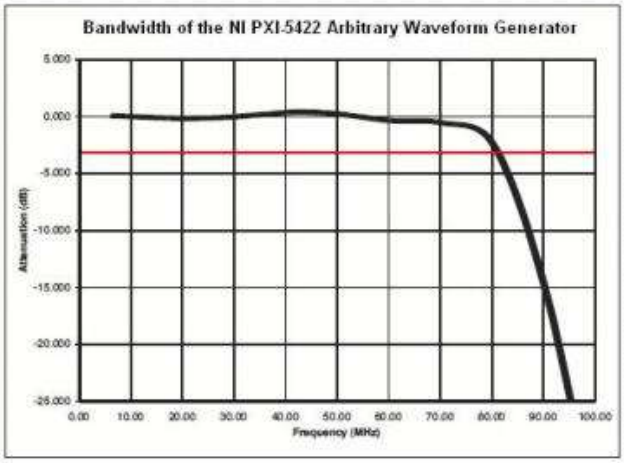

Bandwidth comparison for 5 MHz Square Wave

To illustrate the importance of bandwidth for square wave generation, we contrast the overshoot and rise time of a 5 MHz square wave that has been generated with two different signal generators.

As we can observe from the figure below, the square wave generated by the signal generated with 80 MHz bandwidth shows a smaller overshoot and faster rise time.

Thus, bandwidth is an important specification to characterize

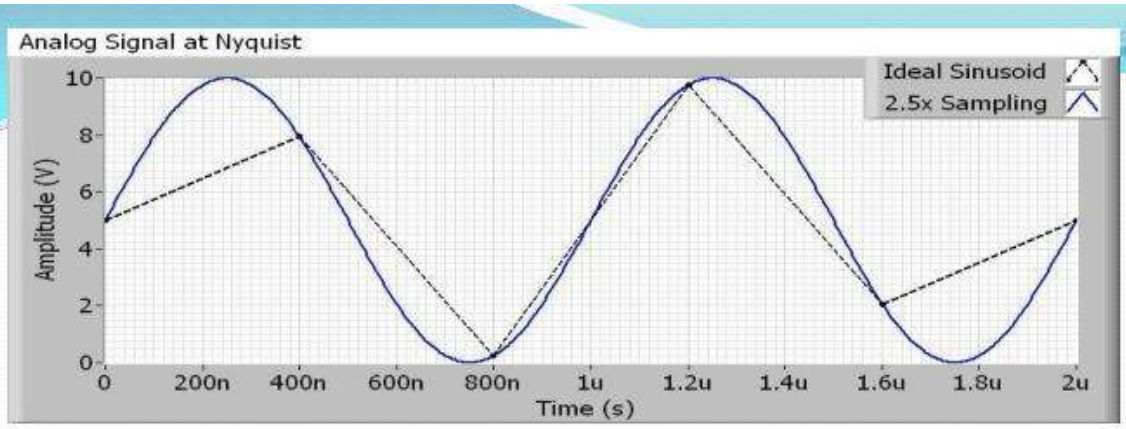
One way that bandwidth can be characterized is with a bode plot. Below, we show a bode plot for the NI 5422 signal generator, which graphs the amplitude (dB) versus the frequency (MHz).

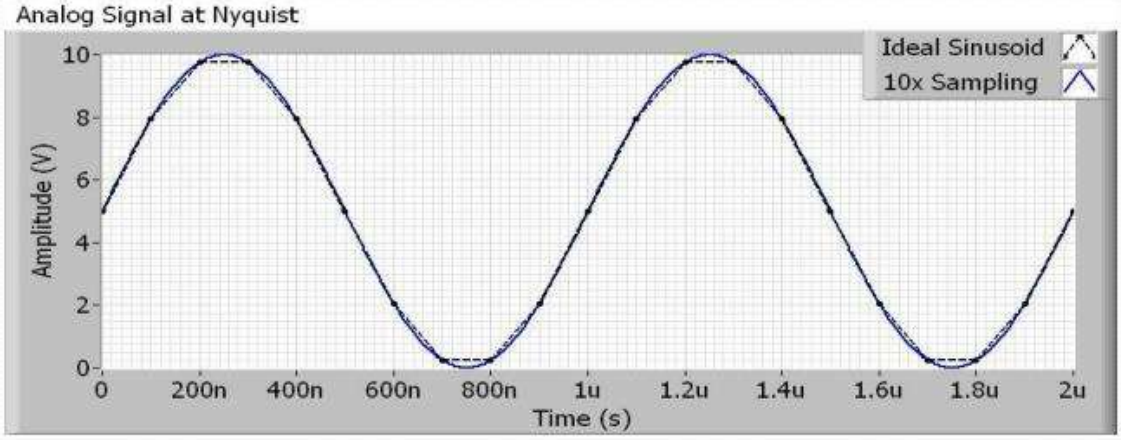


# Sample Rate Nyquist criteria

- The sample rate of a signal generator also determines the maximum frequency that can be generated. As we mentioned earlier, a DAC is able to approximate analogue signals by generating discrete voltage values over time. Thus, the sample rate of a signal generator is the rate at which the DAC can be updated to generate a new voltage level.
- Ideally, a DAC should have the highest sample rate possible to precisely represent high-frequency signals.

- The demand that for sinusoids, the sample rate must be at least twice the frequency of the signal to accurately represent its frequency.
- In addition, a sine wave must be sampled at 2.5 times its frequency to accurately represent its phase as well.
- Moreover, to represent the shape of a signal, it should be sampled at least 10 times its frequency. To illustrate this, we first show a sine wave that has been sampled a 2.5x its frequency


Analog Signal at Nyquist
Ideal Sinusoid
2.5x Sampling
Amplitude (V)
Time (s)
0
2
4
6
8
10
0
200n
400n
600n
800n
1u
1.2u
1.4u
1.6u
1.8u
2u


Analog Signal at Nyquist
Ideal Sinusoid
10x Sampling
Amplitude (V)
Time (s)
0
2
4
6
8
10
0
200n
400n
600n
800n
1u
1.2u
1.4u
1.6u
1.8u
2u