

## UNIT II

### Fixed frequency AF oscillator

A self contained oscillator circuit is an integral part → generate a signal at specified audio frequency range ( 20 HZ - 20KHZ)

- ❖ The fixed frequency might be
- ❖ 400 HZ signal → audio testing
- ❖ 1000 HZ signal → exciting a bridge circuit

Oscillations can be easily generated by the use of

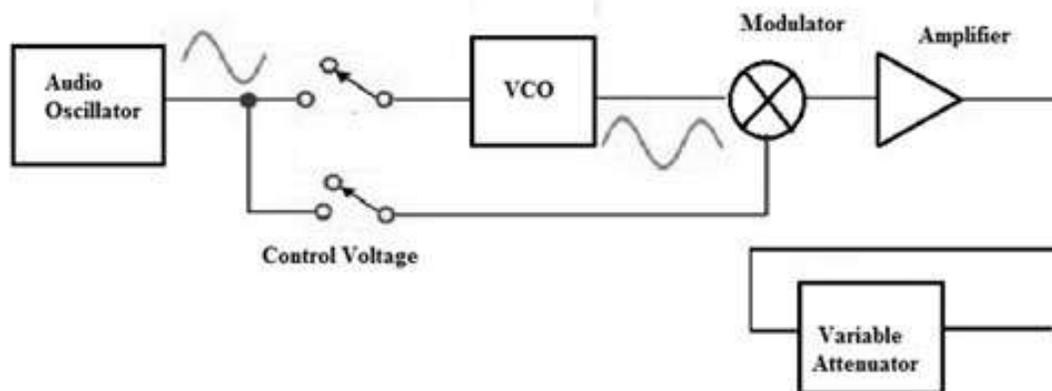
- ❖ Iron core transformer → inductive coupling b/w the primary & secondary windings → to obtain positive feedback.

### Variable frequency AF oscillator:

- ❖ Generates a audio frequency signal in the range of 20 HZ TO 20 KHZ → fairly constant pure sinusoidal wave output

### SIGNAL GENERATOR:

#### Block diagram of signal generator:



### Introduction

- A VCO-based signal generator is an electronic instrument used to generate frequency-modulated (FM) signals.
- The frequency of the output signal varies in accordance with an input control voltage.
- It is widely used in communication system testing, especially for FM transmitters and receivers.

### Audio Oscillator

- The audio oscillator generates a low-frequency signal known as the modulating signal.
- Output waveform is usually a sine wave, but sometimes square or triangular waves may be used.
- Frequency range lies between 20 Hz to 20 kHz.
- This audio signal represents the information signal to be transmitted.
- The output of the audio oscillator is fed to the control voltage circuit.

### Control Voltage Circuit

- Converts the audio signal into a suitable control voltage.

- The amplitude of this control voltage determines the amount of frequency deviation.
- A higher control voltage results in a larger frequency variation in the VCO output.
- Ensures smooth and linear frequency variation.

### **Voltage Controlled Oscillator (VCO)**

- A VCO is an oscillator whose output frequency depends on the applied control voltage.
- Produces a carrier signal.
- When no control voltage is applied, it operates at its center (free-running) frequency.
- When control voltage varies, the carrier frequency varies proportionally.
- Thus, the output of the VCO becomes a frequency-modulated signal.
- Output waveform is generally a sine wave.

### **Modulator**

- The modulator combines:
  - ❖ The carrier signal from the VCO
  - ❖ The modulating signal (audio)
- Performs the process of frequency modulation.
- The output contains information in the form of frequency variation rather than amplitude variation.
- Ensures proper modulation depth.

### **Amplifier**

- The modulated signal from the modulator is usually weak.
- The amplifier increases the signal strength to a usable level.
- Provides sufficient power for output or further processing.
- Does not alter the frequency or modulation characteristics.

### **Variable Attenuator**

- Used to control the amplitude of the output signal.
- Allows smooth variation of signal level without distortion.
- Protects test equipment from excessive signal levels.
- Helps in calibration and accurate testing.

### **Output Signal**

- The final output is a frequency-modulated signal with:
  - ❖ Controlled frequency deviation
  - ❖ Adjustable amplitude
- Used as a test signal in communication systems.

### **Overall Working Principle**

- Audio oscillator generates a modulating signal.
- Control voltage derived from audio signal is applied to VCO.
- VCO generates a carrier whose frequency varies with control voltage.
- Modulator produces an FM signal.
- Amplifier boosts the signal strength.
- Variable attenuator adjusts the output level.
- Final FM signal is obtained at the output terminal.

### **Applications**

- Testing FM transmitters and receivers
- Communication system analysis
- Laboratory experiments
- Signal processing research
- Educational demonstrations

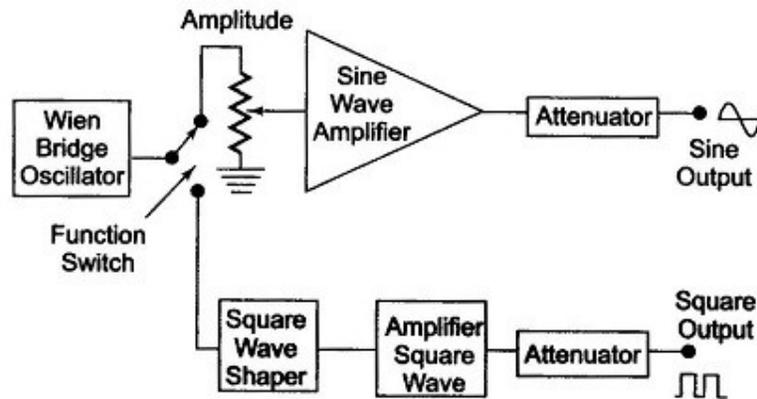
## Advantages

- Wide frequency range
- Good frequency stability
- Easy control of frequency deviation
- Suitable for FM signal generation

## Conclusion

- The VCO-based signal generator is an important instrument in electronics and communication.
- It efficiently generates FM signals using control voltage variation.
- Its flexibility and accuracy make it ideal for testing and educational purposes.

## AF SINE WAVE AND SQUARE WAVE GENERATOR:



## Introduction

An Audio Frequency Oscillator is an electronic instrument used to generate periodic waveforms such as sine and square waves in the audio frequency range (20 Hz to 20 kHz). It is widely used in laboratories and industries for testing audio amplifiers, communication circuits, filters, and measuring frequency response.

The given block diagram represents an AF oscillator that produces both sine wave and square wave outputs using a Wien bridge oscillator and shaping circuits.

### Wien Bridge Oscillator

- The Wien Bridge Oscillator is the core signal-generating circuit.
- It produces a pure sine wave with very low distortion.
- It consists of a frequency-selective RC bridge network.
- The oscillation frequency is given by:

$$f = \frac{1}{2\pi RC}$$

- It provides:
  - ❖ Good frequency stability
  - ❖ Smooth sinusoidal waveform
  - ❖ Simple circuit structure

### Function Switch

- The function switch selects the type of output waveform required.
- It routes the oscillator output either to:
  - ❖ The sine wave amplifier path, or

- ❖ The square wave shaper path
- This enables easy selection of output without changing the circuit.

#### **Amplitude Control Circuit**

- The amplitude control adjusts the signal strength.
- It prevents distortion due to excessive output.
- Ensures stable oscillations in the Wien bridge oscillator.
- Maintains uniform waveform quality.
- Usually implemented using a variable resistor or automatic gain control.

#### **Sine Wave Amplifier**

- The sine wave from the oscillator is weak and needs amplification.
- The sine wave amplifier increases the signal amplitude.
- Provides sufficient output power for external circuits.
- Maintains waveform purity and minimizes harmonic distortion.
- The amplified signal is then fed to the attenuator.

#### **Attenuator (Sine Wave Section)**

- The attenuator controls the output voltage level.
- It allows fine adjustment of the sine wave amplitude.
- Protects the device under test from high voltages.
- Provides calibrated output for accurate measurements.

#### **Sine Wave Output**

- The final sine wave output is obtained after attenuation.
- Frequency range: 20 Hz – 20 kHz
- Applications include:
  - ❖ Audio amplifier testing
  - ❖ Frequency response measurement
  - ❖ Signal tracing and calibration

#### **Square Wave Shaper**

- The square wave shaper converts the sine wave into a square wave.
- It uses circuits such as:
  - ❖ Comparator
  - ❖ Schmitt trigger
  - ❖ Clipping circuits
- It removes gradual transitions of the sine wave.
- Produces sharp rising and falling edges.

#### **Square Wave Amplifier**

- The shaped square wave is amplified.
- Provides sufficient amplitude for output terminals.
- Improves waveform symmetry and sharpness.
- Ensures stable square wave signal.

#### **Attenuator (Square Wave Section)**

- Controls the output amplitude of the square wave.
- Prevents excessive voltage levels.
- Allows precise adjustment based on testing requirements.
- Ensures safety of the connected circuits.

#### **Square Wave Output**

- The final square wave output is obtained.
- Contains odd harmonics.
- Used for:
  - ❖ Transient response testing
  - ❖ Digital circuit testing

❖ Pulse and timing analysis

**Overall Working**

- Wien bridge oscillator generates a sine wave.
- Function switch selects the desired waveform.
- Sine wave is amplified and attenuated to obtain sine output.
- Sine wave is shaped into square wave.
- Square wave is amplified and attenuated.
- Required waveform is delivered at the output terminals.

**Applications**

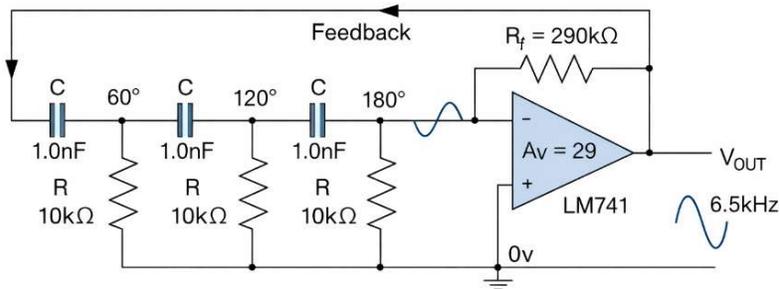
- Testing audio amplifiers
- Measuring frequency response
- Laboratory experiments
- Educational and training purposes
- Communication system testing

**Advantages**

- Generates multiple waveforms
- Simple and reliable circuit
- Low distortion sine wave
- Adjustable amplitude
- Wide frequency range

The AF oscillator is a versatile signal generator capable of producing both sine and square waves in the audio frequency range. Its simple construction, stable output, and wide applications make it an essential instrument in electronics laboratories.

**RC PHASE SHIFT OSCILLATOR**



$$f_1 = \frac{1}{2\pi\sqrt{2N}RC} = \frac{1}{2\pi\sqrt{6}RC} = \frac{1}{15.4RC} = 6500\text{Hz}$$

$$R_f = A_v \times R = 29 \times 10\text{k}\Omega = 290\text{k}\Omega$$

**Introduction**

The given circuit is an RC Phase Shift Oscillator which uses an operational amplifier (LM741) along with a three-section RC feedback network to generate a sinusoidal output waveform. It does not require any external input signal.

**Principle of Operation**

The oscillator works based on the Barkhausen criterion, which states that for sustained oscillations:

- Loop gain ( $A\beta$ ) must be equal to or greater than 1
- Net phase shift around the loop must be  $0^\circ$  or  $360^\circ$

In this circuit, these conditions are satisfied using an RC network and an inverting op-amp.

### Circuit Components

The circuit consists of the following components:

- Operational Amplifier: LM741
- Resistors:
  - ❖ Three resistors each of  $10\text{ k}\Omega$  in the RC network
  - ❖ Feedback resistor  $R_f = 290\text{ k}\Omega$
- Capacitors:
  - ❖ Three capacitors each of  $1.0\text{ nF}$
- Power supply: Dual supply for LM741 (not shown in diagram)

### RC Phase Shift Network

- The feedback network consists of three identical RC sections.
- Each RC section produces a  $60^\circ$  phase shift.
  - ❖ Total phase shift by the RC network:  
 $60^\circ + 60^\circ + 60^\circ = 180^\circ$
- The RC network also attenuates the signal, so amplification is required.

### Role of the Op-Amp

- The LM741 is configured as an inverting amplifier.
- An inverting amplifier produces a  $180^\circ$  phase shift between input and output.
  - ❖ Thus, total phase shift in the loop:  
 $180^\circ$  (RC network) +  $180^\circ$  (op-amp) =  $360^\circ$
- This satisfies the phase condition of Barkhausen criterion.

### Gain Requirement

- The RC network attenuates the signal to  $1/29$  of its value.
- Therefore, the op-amp must provide a minimum gain of 29.

### Gain of the inverting amplifier:

$$A_v = \frac{R_f}{R}$$

Given:

- $R = 10\text{ k}\Omega$
- $A_v = 29$

$$R_f = 29 \times 10\text{ k}\Omega = 290\text{ k}\Omega$$

### Frequency of Oscillation

The frequency of oscillation for an RC phase shift oscillator is given by:

$$f = \frac{1}{2\pi\sqrt{6}RC}$$

Approximate form:

$$f = \frac{1}{15.4RC}$$

Substituting values from the circuit:

- $R = 10k\Omega$
- $C = 1.0nF$

$$f \approx 6500 \text{ Hz}$$

### Output Signal

- The output voltage  $V_{out}$  is a sinusoidal waveform.
- Frequency of output signal is approximately 6.5 kHz.
- The waveform is continuous and stable once oscillations start.

### Starting of Oscillations

- Oscillations start due to noise or small disturbances in the circuit.
- The feedback network reinforces signals at the oscillation frequency.
- Gain stabilizes the amplitude of oscillations.

### Advantages

- Simple and low-cost circuit
- No inductors required
- Suitable for audio and low-frequency applications

### Disadvantages

- Poor frequency stability compared to crystal oscillators
- Limited to low-frequency range
- Output amplitude is relatively small

### Applications

- Audio signal generators
- Function generators
- Testing and measurement instruments
- Educational and laboratory experiments

## FUNCTION GENERATOR:

### Definition

- A function generator is an electronic test instrument used to generate different types of waveforms.
- It acts as a signal source for testing and analyzing electronic circuits.

### Output Waveforms

A function generator can produce the following waveforms:

- Sine wave
- Square wave
- Triangular wave
- Saw tooth wave

### Frequency Range

- The frequency of output waveforms can be adjusted from:
  - ❖ Fraction of a hertz ( $\approx 0.01 \text{ Hz}$ )

- ❖ Up to several hundred kHz ( $\approx 100$  kHz)
- Frequency control is continuous and smooth.

#### **Versatility of Function Generator**

- Function generators are highly versatile instruments.
- Each waveform produced is suitable for different applications.
- A single instrument can replace multiple signal sources.

#### **Applications of Different Waveforms**

- Sine wave:
  - Used in amplifier testing and frequency response analysis.
- Square wave:
  - Used for digital circuit testing and timing analysis.
- Triangular wave:
  - Used where a linearly increasing or decreasing signal is required.
- Saw tooth wave:
  - Used in sweep circuits, oscilloscopes, and X–Y recorders.

#### **Simultaneous Waveform Generation**

- Many function generators can generate two waveforms simultaneously.
- Outputs are available from separate terminals.
- This feature is useful in complex testing applications.

#### **Practical Example of Dual Outputs**

- A square wave may be used for:
  - ❖ Linearity measurements in an audio system.
- At the same time, a saw tooth wave may:
  - ❖ Drive the horizontal deflection amplifier of an oscilloscope.
- This provides a visual display of the measurement.

#### **Phase-Related Waveform Generation**

- A triangular wave and sine wave of the same frequency can be generated simultaneously.
- If their zero crossings coincide, a linearly varying waveform starting at zero phase of the sine wave is obtained.

#### **Phase-Locking Capability**

- Some function generators can be phase-locked to an external signal source.
- One function generator can:
  - ❖ Phase lock another generator.
  - ❖ Produce signals with adjustable phase difference.

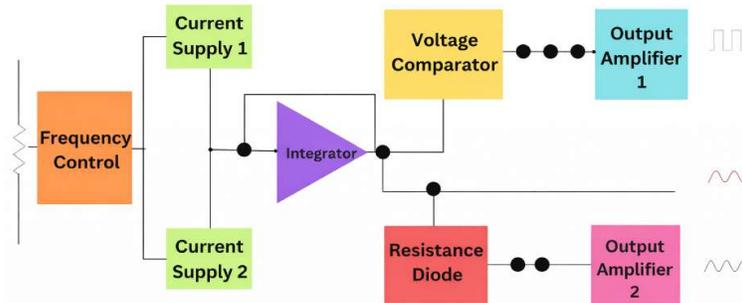
#### **Harmonic Generation and Waveform Synthesis**

- A function generator can be phase-locked to:
  - ❖ A harmonic of another generator's sine wave.
- By adjusting:
  - ❖ Phase
  - ❖ Amplitude of harmonics
- Almost any complex waveform can be generated by summation.

#### **Frequency Stability**

- A function generator can be locked to an accurate frequency standard.
- All output waveforms then have:
  - ❖ High accuracy
  - ❖ High stability
  - ❖ Same reference frequency

## Block Diagram:



### Frequency Controlled Voltage Source

- This block provides a control voltage that determines the operating frequency of the function generator.
- The frequency control knob varies this voltage.
- The output of this block does not directly generate waveforms.
- Instead, it controls the amount of current supplied to the constant current sources.
- By adjusting this voltage, the frequency of all output waveforms is varied simultaneously.

### Constant Current Sources (Two Current Sources)

#### a) Constant Current Source 1

- Supplies a constant positive current to the integrator.
- Causes the integrator output voltage to increase linearly with time.
- The magnitude of current decides the slope of the rising waveform.
- Higher current → steeper slope → higher frequency.

#### b) Constant Current Source 2

- Supplies a constant negative (reverse) current to the integrator.
- Causes the integrator output voltage to decrease linearly with time.
- It operates alternately with current source 1.
- Together, both sources ensure continuous charging and discharging of the integrator.

### Integrator

- The integrator is usually an op-amp integrator circuit.
- It integrates the constant current supplied by the current sources.
- When supplied with constant current:
  - ❖ Output voltage rises or falls linearly with time.
- The output of the integrator is a triangular waveform.
- The frequency of the triangular wave depends on:
  - ❖ Magnitude of the constant current
  - ❖ Switching levels of the comparator

### Voltage Comparator (Multivibrator)

- The voltage comparator monitors the output of the integrator.
- When the integrator output reaches a preset upper voltage level:
  - ❖ The comparator changes its state.
  - ❖ Current source 1 is switched OFF.
  - ❖ Current source 2 is switched ON.
- When the integrator output reaches a preset lower voltage level:  
The comparator switches back.

- This repetitive switching action produces:  
A square wave output from the comparator.
- The square wave has the same frequency as the triangular wave.

### **Resistance–Diode Shaping Network**

- This network is used to convert the triangular wave into a sine wave.
- It consists of:
  - ❖ Resistors
  - ❖ Diodes arranged symmetrically
- The network:
  - ❖ Changes the slope of the triangular waveform near its peaks.
  - ❖ Smooths the sharp corners of the triangular wave.
- The result is a low-distortion sine wave.
- Typical distortion is less than 1%.

### **Overall Working**

- Frequency controlled voltage sets the current level.
- Constant current sources charge and discharge the integrator.
- Integrator produces a triangular wave.
- Voltage comparator generates a square wave and controls current switching.
- Resistance–diode network converts triangular wave into a sine wave.
- Thus, square, triangular, and sine waves are available simultaneously.

### **Frequency Control Principle**

- Frequency is controlled by varying the magnitude of current supplied to the integrator.
- Increasing current:
  - ❖ Increases slope
  - ❖ Increases frequency
- Decreasing current:
  - ❖ Reduces slope
  - ❖ Reduces frequency

### **Operation of Integrator**

- Constant current source 1 supplies current to the integrator.
- The integrator output voltage: Rises linearly with time.
- This produces a linearly increasing waveform.

### **Role of Voltage Comparator**

- The voltage comparator changes state when: Integrator output reaches a preset maximum level.
- This action:
  - ❖ Cuts off current supply source 1
  - ❖ Switches ON current supply source 2

### **Reverse Current Operation**

- Current supply source 2 supplies reverse current to the integrator.
- The integrator output: Falls linearly with time.
- When a minimum level is reached, the comparator switches again.

### **Triangular Wave Generation**

- The continuous charging and discharging of the integrator:  
Produces a triangular wave
- Frequency depends on:  
Magnitude of constant current supplied

### **Square Wave Generation**

- The output of the voltage comparator:  
    Produces a square wave
- The square wave has the same frequency as the triangular wave.

### **Sine Wave Generation**

- The triangular wave is applied to a resistance–diode network.
- This network:
  - ❖ Changes the slope as amplitude varies
  - ❖ Shapes the triangular wave into a sine wave
- Distortion is typically less than 1%.

### **Conclusion**

- A function generator is an essential laboratory instrument.
- It provides multiple waveforms, wide frequency range, and phase control.
- Widely used in testing, measurement, education, and research.

## **INTRODUCTION TO WAVE ANALYZER**

- The analysis of electrical signals is essential in many scientific, industrial, and communication applications.
- Signal analysis helps in determining:
  - ❖ Frequency components
  - ❖ Amplitude
  - ❖ Phase angle (in some cases)
- Various instruments used for signal analysis include:
  - ❖ Wave analyzers
  - ❖ Distortion analyzers
  - ❖ Spectrum analyzers
  - ❖ Audio analyzers
  - ❖ Modulation analyzers
- Although all these instruments measure frequency characteristics, they differ in operating techniques.

### **Definition of Wave Analyzer**

- A wave analyzer is a frequency-selective voltmeter.
- It is designed to measure the amplitude of a single frequency component present in a complex waveform.
- The operating frequency range of a wave analyzer typically lies between 10 Hz and 40 MHz.
- It accurately tunes to the desired frequency while rejecting all other frequencies.

### **Principle of Operation**

- Any periodic waveform can be represented as:
  - ❖ A DC component
  - ❖ A series of sinusoidal harmonic components (Fourier series)
- Waveform analysis involves determining:
  - ❖ Amplitude of harmonics
  - ❖ Frequency of harmonics
  - ❖ Phase angle (if required)

- Mathematical and graphical methods are available but are:
  - ❖ Time-consuming
  - ❖ Laborious for complex waveforms
- A wave analyzer performs this analysis electrically using a band-pass filter network.

### **Band-Pass Filter Network**

- The band-pass filter:
  - ❖ Allows only a narrow band of frequencies to pass
  - ❖ Provides high attenuation for all other frequencies
- By tuning the filter to a specific frequency:
  - ❖ Individual harmonic components can be isolated
  - ❖ Their amplitudes can be measured accurately

### **Working of a Wave Analyzer**

- The input complex signal is applied to the analyzer.
- A frequency-calibrated dial is used to select the desired frequency.
- At resonance:
  - ❖ Maximum output amplitude occurs
  - ❖ The selected harmonic frequency is isolated
- The amplitude of the selected frequency is displayed using:
  - ❖ A sensitive voltmeter, or
  - ❖ A Cathode Ray Oscilloscope (CRO)

### **Functions of a Wave Analyzer**

- Measures the relative amplitudes of individual frequency components.
- Separates harmonic components from complex waveforms.
- Acts as a high-selectivity measuring instrument.
- Helps in detailed spectrum analysis of signals.

### **Applications of Wave Analyzer**

Wave analyzers are widely used in the following fields:

#### **Electrical Measurements**

- Analysis of harmonics in power systems
- Measurement of noise and distortion in electrical circuits
- Testing of amplifiers and oscillators

#### **Sound Measurements**

- Identification of noise frequencies in audio systems
- Acoustic testing and sound quality analysis
- Noise control in industrial environments

#### **Vibration Measurements**

- Detection of vibration frequencies in machines
- Identification of mechanical faults
- Resonance analysis in rotating machinery

#### **Industrial Applications**

- Used in industries to reduce sound and vibration caused by:
  - ❖ Rotating electrical machines
  - ❖ Mechanical apparatus

- The wave analyzer helps to:
  - ❖ Identify the source of noise and vibration
  - ❖ Determine discrete frequencies and resonances
- Once identified:
  - ❖ Corrective measures such as balancing, damping, or redesign can be applied
  - ❖ Noise and vibration can be minimized or eliminated

### **Types of Wave Analyzers**

Based on the frequency range and method of operation, wave analyzers are classified into two types:

#### **Frequency Selective Wave Analyzer**

- Uses tuned LC or RC band-pass filters
- Directly selects the desired frequency
- Suitable for low and medium frequency ranges
- Simple in construction but limited in frequency range

#### **Heterodyne Wave Analyzer**

- Uses the heterodyne principle (frequency mixing)
- Converts the input frequency to a fixed intermediate frequency
- Offers:
  - ❖ High selectivity
  - ❖ Wide frequency range
- Commonly used for high-frequency applications

#### **Advantages of Wave Analyzer**

- High accuracy in frequency measurement
- Good selectivity and sensitivity
- Suitable for harmonic analysis
- Essential tool for noise and vibration studies

## **INTRODUCTION TO HARMONIC DISTORTION ANALYZERS**

- A harmonic distortion analyzer is an instrument used to measure the distortion present in an electronic system.
- It evaluates how much the output signal deviates from an ideal sinusoidal waveform.
- These analyzers are commonly used to test:
  - ❖ Amplifiers
  - ❖ Audio equipment
  - ❖ Communication circuits
- The analyzer separates the fundamental frequency from its harmonics and measures the level of distortion.

### **Harmonic Distortion**

- Ideally, when a pure sinusoidal input is applied to an electronic instrument, the output should also be sinusoidal.
- In practice, the output waveform is not an exact replica of the input.

- This deviation is known as distortion.
- Distortion mainly occurs due to:
  - ❖ Non-linear characteristics of electronic components
  - ❖ Improper biasing
  - ❖ Overloading of amplifiers
- Non-linearity introduces harmonic frequencies (integer multiples of the fundamental frequency).
- The distortion caused by these harmonics is called harmonic distortion.

### **Causes of Harmonic Distortion**

- Non-linear behavior of active devices such as:
  - ❖ Transistors
  - ❖ Diodes
  - ❖ Vacuum tubes
- Operation of amplifiers beyond their linear region
- Improper design or component tolerances
- Presence of reactive components causing phase shift

### **Types of Harmonic Distortion**

Harmonic distortion can be classified into the following types:

#### **Frequency Distortion**

- Frequency distortion occurs when:
  - ❖ The amplification factor (gain) of an amplifier varies with frequency.
- Different frequency components of the input signal are amplified by different amounts.
- This results in alteration of the signal shape at the output.
- Common in:
  - ❖ RC-coupled amplifiers
  - ❖ Improperly compensated amplifiers
- Frequency distortion affects the frequency response of the system.

#### **Amplitude Distortion**

- Amplitude distortion occurs due to:
  - ❖ Generation of harmonics of the fundamental frequency.
- It is caused by the non-linear transfer characteristics of amplifiers.
- When an amplifier is overdriven, the output waveform gets clipped.
- Clipping introduces higher-order harmonics.
- Amplitude distortion mainly affects the magnitude of the signal.

#### **Phase Distortion**

- Phase distortion occurs due to:
  - ❖ Presence of energy storage elements such as capacitors and inductors.
- These elements cause the output signal to be shifted in phase with respect to the input.
- Different frequency components undergo different phase shifts.
- Though amplitude may remain constant, the waveform shape changes.
- Phase distortion is significant in:
  - ❖ Wideband amplifiers

- ❖ Communication systems

### **Intermodulation Distortion**

- Intermodulation distortion occurs when:
  - Two or more different frequencies are applied simultaneously.
- Due to non-linearity, these frequencies interact or heterodyne.
- The output contains new frequencies equal to:
  - ❖ Sum of input frequencies
  - ❖ Difference of input frequencies
- These unwanted frequencies were not present in the original input.
- Intermodulation distortion is particularly undesirable in:
  - ❖ Communication systems
  - ❖ Audio systems

### **Need for Harmonic Distortion Analyzer**

- To measure and quantify distortion accurately
- To ensure quality and fidelity of electronic equipment
- To test performance of amplifiers and audio devices
- To improve system design by reducing distortion

### **Applications of Harmonic Distortion Analyzer**

- Testing audio amplifiers and sound systems
- Measuring distortion in communication transmitters
- Quality control in electronic manufacturing
- Research and development laboratories

### **Advantages**

- Accurate measurement of harmonic distortion
- Helps in improving circuit linearity
- Essential tool for performance evaluation

## **SPECTRUM ANALYZER**

### **Introduction**

- A spectrum analyzer is an electronic instrument used to analyze signals in the frequency domain.
- Unlike a CRO, which displays amplitude vs time, a spectrum analyzer displays:
  - ❖ Amplitude vs frequency
- It is widely used in:
  - ❖ Communication systems
  - ❖ Audio and RF measurements
  - ❖ EMI/EMC testing

### **Definition**

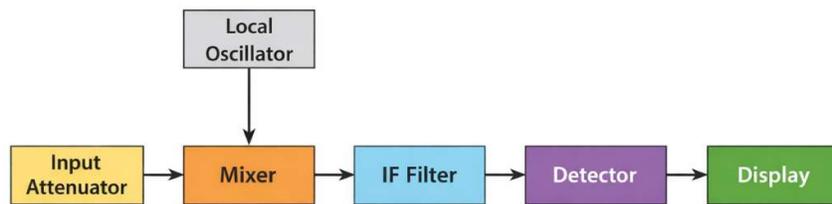
- A spectrum analyzer is an instrument that measures the magnitude of an input signal as a function of frequency.
- It shows how the signal power or voltage is distributed over a range of frequencies.

### **Principle of Operation**

- Any complex signal can be represented as a combination of:

- ❖ Fundamental frequency
- ❖ Harmonics
- ❖ Noise components
- The spectrum analyzer separates these frequency components and measures their amplitudes.
- It works based on:
  - ❖ Frequency selection
  - ❖ Frequency conversion (heterodyne principle) or
  - ❖ Fast Fourier Transform (FFT) in modern analyzers

### Block Diagram of Spectrum Analyzer



### Explanation of Block Diagram

#### Input Attenuator

- Reduces the input signal level.
- Protects the mixer from high-level signals.
- Allows measurement over a wide dynamic range.

#### Mixer

- Mixes the input signal with the local oscillator (LO) signal.
- Produces:
  - ❖ Sum frequency
  - ❖ Difference frequency
- The desired frequency is converted to a fixed Intermediate Frequency (IF).

#### Local Oscillator

- Generates a variable frequency signal.
- Sweeps across a selected frequency range.
- Determines which input frequency is displayed.

#### IF Filter

- Selects a narrow band of frequencies.
- Provides high selectivity.
- Determines frequency resolution of the analyzer.

#### Detector

- Converts the IF signal into a proportional DC voltage.
- Represents the amplitude or power of the frequency component.

#### Display Unit

- Displays amplitude versus frequency.
- Output can be shown on:
  - ❖ CRT

- ❖ LCD or digital screen

## **Types of Spectrum Analyzers**

### **Swept-Tuned Spectrum Analyzer**

- Uses superheterodyne principle.
- Frequency is swept over a range.
- Commonly used for RF and microwave measurements.

### **FFT Spectrum Analyzer**

- Uses digital signal processing.
- Performs Fast Fourier Transform.
- Suitable for:
  - ❖ Audio
  - ❖ Low-frequency measurements

### **Important Parameters of Spectrum Analyzer**

- Frequency Range
- Resolution Bandwidth (RBW)
- Video Bandwidth (VBW)
- Dynamic Range
- Sensitivity

### **Applications of Spectrum Analyzer**

- Measurement of signal bandwidth
- Harmonic and spurious signal analysis
- Noise measurement
- EMI/EMC testing
- Communication system testing
- Audio system analysis

### **Advantages**

- Provides complete frequency-domain analysis
- High accuracy and resolution
- Detects unwanted harmonics and noise
- Essential tool in RF and communication fields

### **Limitations**

- Expensive compared to CRO
- Requires skilled operation
- Complex internal circuitry

### **Comparison with Wave Analyzer**

- Spectrum analyzer shows entire frequency spectrum at once.
- Wave analyzer measures one frequency at a time.
- Spectrum analyzer is faster for complex signals.