UNIT –III
SIGNAL GENERATORS &
ANALYZERS
Objectives

- **Describe** the basic block diagram of several types of signal generators and analyzers commonly used.
- **Explain** the function and operation of signal generators such as function and pulse generator.
- **Explain** the function and operation of signal analyzers such as spectrum and Fourier analyzer.
Introduction

- **A signal generator** is very useful and important equipment in electronic troubleshooting and development.

- Applications of a signal gen.:
  - checking the stage gain, S/N, bandwidth.
  - checking the frequency response
  - checking the alignment in receivers

- Oscillator – provides sinusoidal signal only
  - Converts a DC source to an AC energy (no energy is created).
  - Usually built-in in the instrument.
  - E.g: 1. Fixed freq – normally at 1000c/s.
    2. Variable freq – 100kHz - MHz
Introduction

- Generator – provides several types of waveforms including sine wave, square wave, triangular wave, pulse trains, as well as amplitude modulation (AM) waveform.
  - Available as a separate instrument.
  - Provide signals for testing purposes (eg: radio transmitter & receiver).
- There are several **requirements** for signal generator:
  - The frequency of the signal should be **known and stable**.
  - The amplitude should be **controllable** from small to large values.
  - The signal should be **distortion-free**.
Signal Generator

- Table 1 shows the band limit of various types of signal provided by an RF generator.

<table>
<thead>
<tr>
<th>Band</th>
<th>Approximate Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>AF</td>
<td>20Hz – 20kHz</td>
</tr>
<tr>
<td>RF</td>
<td>Above 30kHz</td>
</tr>
<tr>
<td>VLF – Very Low Frequency</td>
<td>15 – 100kHz</td>
</tr>
<tr>
<td>LF – Low Frequency</td>
<td>100 – 500kHz</td>
</tr>
<tr>
<td>Broadcast</td>
<td>0.5 – 1.5MHz</td>
</tr>
<tr>
<td>Video</td>
<td>DC – 5MHz</td>
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<tr>
<td>HF</td>
<td>1.5 – 30MHz</td>
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<tr>
<td>UHF</td>
<td>300 – 3000MHz</td>
</tr>
<tr>
<td>Microwave</td>
<td>Beyond 3000MHz (3GHz)</td>
</tr>
</tbody>
</table>

Table 1
Conventional Signal Generator

Figure 1: Conventional Standard Signal Generator
Figure 2: Modern Signal Generator
Signal Generator

- Highest freq. ranges are provided by RF Oscillator (34MHz – 80MHz).
- Lowest freq. ranges are obtained by using **frequency divider**.
  - 34MHz – 80MHz divided by 512 ($2^9$) → 67kHz – 156kHz.
- Buffer amplifiers ($B_1$, $B_2$, $B_3$) provide isolation between the master oscillator and power amplifier.
  - Eliminates frequency effects (signal distortion) between input and output circuits.
Signal Generator

- Compared to conventional std signal gen, modern signal gen uses same oscillator on all bands.
  - Eliminates range switching effects.
  - Master oscillator is tuned by a motor driven variable capacitor.
- Coarse freq. tuning – 7% frequency changes per second.
- Fine tuning – at 0.01% of the main dial.
- Modulation process is done at the power amplifier stage.
  - Two internally generated signal are used (400Hz & 1kHz) for modulation.
Function Generator

- A **function generator** produces different waveforms of adjustable frequency.
  - Capable of producing various outputs at the same time (e.g., a square wave to test an amplifier and a sawtooth to drive a CRO).

- The common output waveforms are the sine, square, triangular, and sawtooth waves.

- The block diagram of a function generator is shown in Figure 3.

- Freq. Control – regulates two current sources (control the freq).
  - Upper current source – supplies constant current to the integrator, produces an output voltage that is increasing linearly with time.
  - Lower current source – supplies a reverse current to the integrator so that its output decreases linearly with time.
Function Generator

Figure 3: Function Generator
Function Generator

- The integrator output voltage is given by:
  \[ V_0 = \frac{1}{C} \int_0^t i \, dt \]
  - Freq is controlled by varying upper and lower currents.
  - An increase or decrease in the current will increase or decrease the slope of the output voltage, hence controls the frequency.

- The voltage comparator – changes states at a pre-determined maximum and minimum level of the integrator output voltage.
  - When the pre-determined level is reached, it changes the state and switches the current source.
  - Produces a square wave.
Function Generator

- The **integrator** output is a triangular waveform whose frequency is determined by the magnitude of the constant current sources.
- The **comparator** output delivers a square wave of the same frequency.
- The **resistance diode network** produces a sine wave from the triangular wave with less than 1% distortion.
Function Generator

Figure 4: Basic Function Gen
Function Generator

- Figure 4 shows the circuit for a basic function generator.
- $V_{o1}$ is the square wave, $V_{o2}$ is the triangular wave, and $V_{o3}$ is the sine wave.
- The maximum amplitude of $V_{o2}$ is given by:

$$V_{o2} = \frac{R_1}{R_2} \times V_{CC}$$

- The frequency of output voltage is given by:

$$f = \frac{1}{4RC} \left( \frac{R_2}{R_1} \right)$$
Example 1: Figure shows a basic function generator. A variable resistor, R is used to tune the required freq of the waveform and the circuit is supplied by a voltage of 10V. If R is tuned to the value of five times the R₂ to produce a 1kHz triangular waveform with the amplitude equals to 0.8Vcc, find R₁, R₂ and R. Then, draw the output waveform at V₀₁ and V₀₂.
Pulse Generator

- **Pulse generators** are instruments that produce a rectangular waveform similar to a square wave but with a different duty cycle.
- **Duty cycle** is given by:

\[
\text{Duty cycle} = \frac{\text{pulse width}}{\text{pulse period}}
\]

- A square wave generator has a 50% duty cycle.
- The basic circuit for pulse generation is the **asymmetrical multi-vibrator**.
- Figure 6 shows block diagram of a pulse generator.
Pulse Generator

Figure 6: Block diagram of a Pulse Generator
Pulse Generator

- The duty cycle can be varied from 25-75%.
- Two independent outputs:
  - $50\Omega$ - supplies pulses with a rise and fall time of 5ns at 5Vp.
  - $600\ \Omega$ - supplies pulses with a rise and fall time of 70ns at 30Vp.
- The instrument can operate as a free-running or can be synchronized with external signal or circuit.
- **Basic generating loop** consists of the current sources, the ramp capacitor, the Schmitt trigger, and the current switching circuit as shown in Figure 7.
Figure 7: Basic Generating Loop
Pulse Generator

- Upper current source – supplies a constant current to the ramp capacitor and the capacitor voltage increases linearly.
- When the positive slope of the ramp reaches the upper limit, Schmitt Trigger will change its state.
  - Reverses the condition of the current switch.
  - Capacitor discharges linearly. (lower current source takes part)
- When the negative slope of the ramp reaches the lower limit, upper current will control the circuit.
- The process is repeated.
- The ratio $i_1/i_2$ determines the duty cycle, and is controlled by symmetry control.
- The sum of $i_1$ and $i_2$ determines the frequency.
- The size of the capacitor is selected by the multiplier switch.
Sweep Generator

- **Sweep frequency generators** are instruments that provide a sine wave in the RF range.
- Its frequency can be varied smoothly and continuously over an entire frequency band.
- Figure 8 shows the block diagram of the sweep generator.
- The **frequency sweeper** provides a varying sweep voltage for synchronization to drive the horizontal deflection plates of the CRO.
- A sweep rate can be of the order of 20 sweeps/sec.
- Figure 9 shows the modulated sinewave by a **voltage-controlled oscillator** (VCO).
Sweep Generator

Figure 9: RF signal modulated by an audio-frequency ramp voltage.
Radio Frequency Generator

- **Radio frequency generators** are designed to provide an output signal over a wide range of frequencies from approximately 30 kHz to nearly 3000 MHz.
- Contain a precision output attenuator network that permits selection of output voltages from 1 uV to 3V in precise steps.
- Output impedance = $50\Omega$.
- Figure 10 shows a block diagram for a basic RF signal generator.
- The frequency range is selected with the **band selector** and exact freq. is selected with the vernier freq. selector.
- Broadband amplifier – provides buffering between the oscillator and the load connected to the output terminal.
- The output of the attenuator is monitored by the output meter.
Radio Frequency Generator

Figure 10: Basic RF Signal Generator
Distortion Analyzer

- Distortion – the alteration of the original shape of a waveform.
- Function of distortion analyzer: measuring the extent of distortion (the o/p differs from the waveform at the i/p) introduced by the active or passive devices.
- An amplitude distorted sine wave is made up of pure sine wave components, including the fundamental frequency, $f$ of the input signal, and harmonic multiples of fundamental frequency, $2f$, $3f$, $4f$, etc.
- Harmonic distortion can be measured accurately using harmonic distortion analyzer, generally called a distortion analyzer.
- The total harmonic distortion (THD) is given by:

$$THD = \frac{\sqrt{\sum (\text{harmonics rms})^2}}{\text{fundamental rms}}$$
Distortion Analyzer

- The **total harmonic distortion** (THD) can also be written as:

\[
THD = \frac{\sqrt{E_2^2 + E_3^2 + \ldots + E_n^2}}{E_f}
\]

where

- \(THD\) = the total harmonic distortion
- \(E_f\) = the amplitude of fundamental frequency including the harmonics
- \(E_2, E_3 \ldots, E_n\) = the amplitude of the individual harmonics
Distortion Analyzer

Example 1:

Compute the THD of a signal that contains a fundamental signal of $E_f = 10V_{\text{rms}}$, harmonics $E_2 = 3V_{\text{rms}}$, $E_3 = 1.5V_{\text{rms}}$, and $E_4 = 0.6V_{\text{rms}}$.

Solution:

$$\text{THD} = \frac{\sqrt{(3V)^2 + (1.5V)^2 + (0.6V)^2}}{10V}$$

$$= 34.07\%$$
Wave Analyzer

- A harmonic distortion analyser measures the total harmonic content in a waveform.
- Any complex waveform is made up of a **fundamental** and its **harmonics**.
- **Wave analyzer** is used to measure the **amplitude** of each harmonic or fundamental frequency individually.
- Wave analyzers are also referred to as frequency selective voltmeters, carrier frequency voltmeters, and selective level voltmeters.
- The instrument is tuned to the frequency of one component whose amplitude is measured.
- Some wave analyzers have the **automatic frequency control** which tunes to the signal automatically.
Wave Analyzer

Fig. 9.1 (a) Basic Wave Analyzer
Wave Analyzer

- Figure 9.1 (textbook) shows a **basic wave analyzer**.
- The analyzer consists of a primary detector, which is a simple **LC circuit**.
- The LC circuit is adjusted for resonance at the frequency of the particular harmonic component to be measured.
  - It passes only the frequency to which it is tuned and provides a high attenuation to all other frequencies.
- The **full wave rectifier** is used to get the average value of the input signal.
- The indicating device is a simple dc voltmeter that is calibrated to read the peak value of the sinusoidal input voltage.
Heterodyne Wave Analyzer

- **Wave analyzers** – audio frequency range measurement only.
- **Heterodyne**: To mix two or more signals which produce sum and difference.
- **Heterodyne wave analyzers** are used to analyze signal in the RF range and above (MHz range).
- In this analyzer, the input signal is mixed with the internal signal to produce a higher IF frequency.
- Figure 9.4 (textbook) shows the block diagram of a RF heterodyne wave analyzer.
- The **local oscillator** is tunable to get all the frequency components of the input signal.
- Attenuator is used to modify the amplitude of the input signal.
- The **first mixer** stage produces an output of 30Mhz which is a difference between the input and oscillator signal.
Heterodyne Wave Analyzer

Fig. 9.4 RF Heterodyne Wave Analyzer
Heterodyne Wave Analyzer

- This 30MHz signal will be amplified by IF amplifier and fed to the second mixer.
- The second mixer will produce a 0 Hz signal which is the difference between IF and crystal oscillator signal.
- This signal will then be filtered by the active filter of a bandwidth less than 1500Hz.
- The amplitude of the selected frequency component can be read from the output meter in Volt or dB.
- This wave analyzer is operated in the RF range of 10kHz – 18MHz.
Spectrum Analyzer

- Oscilloscope is used to display and measure signal in a time-domain.
- It is also useful to display signal in the frequency domain.
- The instrument providing this frequency domain view is the spectrum analyzer.
- A spectrum analyzer display signal on its CRT with frequency on the horizontal axis and amplitude (voltage) on the vertical axis.
- Spectrum analyzers use either a parallel filter bank or a swept frequency technique.
Spectrum Analyzer
In a parallel filter bank analyzer, the frequency range is covered by a series of filters whose central frequencies and bandwidth are so selected that they overlap each other.

See Figure 9.9(a) – textbook.

For the RF or microwave signals, the swept technique is preferred.

Figure 9.9(b) shows the block diagram of a spectrum analyzer using swept receiver design.

In the figure, the sawtooth generator provides the sawtooth voltage which drives the horizontal movement of the scope and the frequency controlled element of the voltage tuned oscillator.
Fig. 9.9 (a) Spectrum Analyzer (Parallel Filter Bank Analyzer)
Spectrum Analyzer

Fig. 9.9 (b) Spectrum Analyzer
Spectrum Analyzer

- The **voltage tuned oscillator** will sweep from $f_{\text{min}}$ to $f_{\text{max}}$ of its frequency band at a linear recurring rate.

- The frequency component and voltage tuned oscillator frequency beats together to produce a difference frequency, i.e. IF (intermediate frequency).

- This IF will be amplified and displayed on the CRT screen of the spectrum analyzer.

- Figure 9.10, 9.11, and 9.12 (textbook) shows the spectrum produced if the input wave is a single tuned A.M. signal.
Digital Fourier Analyzer

- The basic principle of a digital Fourier analyzer is shown in Figure 9.14 (textbook).
- The **digital Fourier analyzer** converts the analogue waveform over time period $T$ into $N$ samples.
- A Fourier analyzer is based on the calculation of the **discrete Fourier transform** using an algorithm called the **fast Fourier transform**.
- This algorithm calculates the amplitude and phase of each signal component from a set of time-domain samples of the input signal.
- Figure 9.15 (textbook) shows the block diagram of a digital Fourier analyzer.
Digital Fourier Analyzer

Waveforms Sampled for Time $T$, $N$ Samples

Fig. 9.14 **Basic of a Digital Fourier Analyzer**

CRT Display is Equivalent to a Parallel Filter Bank Analyzer Having $N$ Filters with Band-width $1/T$
Digital Fourier Analyzer

Fig. 9.15 Block Diagram of a Digital Signal Analyzer
Digital Fourier Analyzer

- The block diagram is divided into 3 sections – input, control and display section.
- The input signal is applied to the input amplifier, where it is conditioned and passed through two or more anti-aliasing filters.
- A 12-bit ADC is used to convert the signal into a digital form.
- The output from the ADC is connected to a multiplier and a digital filter.
- The processing section of the analyzer provides FFT processing on the input signal to produce a magnitude and phase of input signal’s components.
Logic Probe

- A **logic probe** is a tool used in digital-circuitry troubleshooting.

- It is employed to trace logic levels and pulses through integrated circuitry to determine whether the point under test is logic high, low, bad level, open circuited, or pulsing.

- When the probe is touched to a high level point, a bright light appears around the probe’s tip, and the light goes out when it is touched on a low level point.

- Figure 14.18 (Larry textbook) shows a block diagram of the logic probe circuitry and its response to different inputs.
Logic Probe

FIGURE 14-18 Block diagram of the logic-probe circuitry and its response to different inputs. (Courtesy Hewlett-Packard Company.)