1. What is Barkhausen Criteria for sustained oscillation? (APRIL/MAY 2011)

\[
A_{se}(s) = \frac{A}{1 + A \beta}
\]

Barkhausen Oscillation Criteria

A feedback amplifier will have sustained oscillation if \(A \beta = -1\).

Barkhausen Criteria often given in different ways by different authors. There are nontrivial subtle differences in how it is presented and not all are correct.

2. Draw the block diagram of spectrum analyzer. (APRIL/MAY 2011)
3. What is intermodulation distortion? (Nov/DEC 2012)

Intermodulation or intermodulation distortion (IMD) is the amplitude modulation of signals containing two or more different frequencies in a system with nonlinearities. The intermodulation between each frequency component will form additional signals at frequencies that are not just at harmonic frequencies (integer multiples) of either, but also at the sum and difference frequencies of the original frequencies and at multiples of those sum and difference frequencies. Intermodulation is caused by non-linear behavior of the signal processing being used.

4. In a sweep frequency generator tow oscillator on with the frequency range of 3 to 5 GHz is heterodyne with second oscillator having the fixed frequency of output 3 GHz. How the output frequency varies? (Nov/DEC 2012)(May' 2004 ECE).

The range of output frequency is 0-2 GHz.

5. What is wave analyzer? (Nov/DEC 2011)

A wave analyzer in an instrument designed to measure the relative amplitude of single frequency component in a complex or distorted waveform.

6. What is the use of attenuator in sine wave generator? Nov/DEC 2011

**Why We Need To Use Digital RLC Meters?**

*RLC Meter Is Used To Measure Q Factor Of L And C.*

7. **Briefly Explain About Frequency Synthesizer.**

The Frequency Generators Are Of Two Types.

1. One Is Free Running Frequency Generators In Which The Output Can Be Tuned Continuously Either Electronically Or Mechanically Over A Wide Frequency Range. The Generators Discussed Uptill Now Are Of This Type.

2. The Second Is Frequency Generator With Frequency Synthesis Technique. The Synthesis Means To Use A Fixed Frequency Oscillator Called Reference Oscillator Or Clock And To Drive The Wide Frequency Range In Steps From The Output Of The Reference Oscillator The Stability And Accuracy Of Free Running Frequency Generator Is Poor While Frequency Synthesizers Provide Output Which Is Arbitrarily Selectable, Stable And Accurate Frequency.

8. **What are the signal sources? What are the desirable characteristics of a signal.** (May’ 2004 ECE).

Signal source is equipment, which accepts an electrical signal from a battery and convert it into output signal. This output signal is a cyclic repetition of electrical voltage or current having predetermined frequency, waveform and amplitude. It can generate a variety of waveform including sine wave, square wave, triangular wave.

Characteristics:

(i) The frequency of the signal should be stable.
(ii) The amplitude should be controllable from very small to large values.
(iii) The output signal should be free from distortion.

9. **What do you mean by heterodyne principle?**  
(May’ 2005 ECE).

Heterodyning i.e. mixing is the input signal to be analyzed is mixed to a higher intermediate frequency (IF) by an internal local oscillator.

10. **Define total harmonic distortion or distortion factor**  
(May’ 2005/ Nov’ 2003 ECE).

The total harmonic distortion is measured in terms of the harmonic content of the wave. It is also called as distortion factor.

\[
\text{THD} = \sqrt{\frac{\sum (\text{harmonics})^2}{\text{fundamental}}}
\]

11. **Define harmonic distortion**.  
(May’2003/May’ 2006 ECE)

When a sinusoidal input signal is applied to an electronic device like amplifier, the o/p of amplifier should be sinusoidal waveform. However it is seen that the o/p that the o/p is not the exact replica of the i/p because of various types of distortion that occur. The distortion may be result of the inherent non-linear characteristics of the different components used in the electronic circuit. This non-linear behavior introduces harmonics of the fundamental frequency in the output and the resultant distortion is called harmonic distortion.

12. **Give any two applications of wave analyzer.**  
(May’ 2006 ECE)

(i) To measure the harmonic distortion of an amplifier. The contribution of each harmonic to the total distortion also can be determined.

(ii) To measure relative amplitudes of signal frequency components in a complex waveforms.

13. **What is spectrum analyzer?**  
(May’ 2006 ECE)

The study of energy distribution of a signal as a function of frequency is called as spectrum analysis. The instrument which graphically presents an energy distribution of the signal as a function of frequency on the C.R.O is called as spectrum analyzer.

14. **Mention any four signal generating instruments.**  
(May’ 2006 ECE)

   i. Sine-wave generator.
   ii. Square wave generator.
   iii. Sweep generator.
   iv. Frequency synthesizer.

15. **What are the requirements of signal generator?**  
(Nov’ 2006 ECE)

The requirements of signal generator are

(i) The frequency of the signal should be stable.

(ii) The amplitude should be controllable from very small to large values.

(iii) The output signal should be free from distortion.
16. **What is a real time spectrum analyzer?** (Nov’ 2006 ECE)

The real time spectrum analyzer is non scanning type. Its function is to present the effect of changes in all input frequencies on its spectrum display instantly. It is not used at RF or microwave frequencies, used only in the audio frequencies. The range of real time spectrum analyzer is from 50Hz-10KHz.

17. **Give the function of attenuator in signal generator.** (May 2007)

An attenuator is a device that will reduce the power level of signal for which the amplitude is easily measured and calibrating the attenuator stops. Moreover the attenuator reduces the power of an input such that the ratio of the input power to the output power is a constant.

13. **What are the drawbacks of tuned circuit analyzers?** (May 2007)

i) At low frequencies, very large values for L and C are required and their physical size becomes rather impractical.

ii) Harmonics of the signal frequency are often very close in frequency so that it becomes extremely difficult to distinguish between them.

14. **How are the digital voltmeter classified?** (May 2007-R01)

Digital voltmeters are classified as:

i) Ramp type DVM
ii) Integrating DVM
iii) Continuous-balance DVM
iv) Successive-approximation DVM

15. **What is the need for guarding?** (May 2007-R01)

The effects of leakage paths on the measurement are usually removed by guarding circuit.

16. **Write the function of distortion analyzer.** (May 2007-R01)

The function of distortion analyzer is to determine the harmonic content of a waveform.

17. **State the need for isolation between the signal generator output and oscillator? How can this be done?** (Nov 2007)

The main purpose of providing isolation between signal generator and isolator is to reduce output distortion. This can be achieved by feedback.

18. **How is voltage converted to frequency in V/F Conversion.** (May 2008)
Integrating type digital voltmeter employs an integration technique which uses a voltage to frequency conversion. This converter functions as a feedback control system which governs the rate of pulse generation in proportion to the magnitude of input voltage.

19. How are signal generators classified? (Nov 2009)
   Signal generators are classified as square wave generator, function generator, sweep generator.

20. What is the dynamic range of a spectrum analyser if the noise level of the display is equal to -80 dB and two -10 dB signal produce third order inter modulation products that just appear above the noise? (Nov 2009)
   Refer book

21. List the application of the wave analyzer. (May 2010)
   A wave analyzer is used to measure the relative amplitude of signal frequency component in a complex waveform. These are applied industrially in the field of reduction of sound and vibration generated by rotating electrical machine and apparatus.

22. What is the difference between a wave analyzer and a harmonic distortion analyzer?
   A wave analyzer is an instrument that measures amplitudes of the harmonic components of complex signal. A harmonic distortion analyzer is an instrument that measures total harmonic distortion by determining the harmonic components of a given waveform.

23. State the applications of spectrum analyzer.
   It is used for
   - Observing purity of a signal
   - Analyzing modulated signals
   - Studying harmonic components of a signal
   - Finding the intermodulation content.

24. Give two applications of function generators.
   It is used for
   - Generating sine, square, triangle, sawtooth waveforms etc.
   - Modulating amplitude, frequency and pulse width of the signal.

25. What is harmonic distortion?
   It is a form of distortion caused by a signal passing through a non-linear system in which harmonics are added to the fundamental signal.

26. Define rise time and fall time of a pulse.
Rise time: It is the time required for a pulse to rise from 10 to 90% of its normal/final amplitude.

Fall time: It is the time required for a pulse to fall from 90 to 10% of its normal/final amplitude.

27. What is a distortion analyzer?

It is an instrument that measures total harmonic distortion by determining the harmonic components of a given waveform.

28. What is a pulse generator?

It is a device which generates pulses of controlled amplitude, width and repetition rate.

29. What is meant by frequency synthesis?

The generation of stable output frequency derived from multiples or submultiples of one or more crystal controlled oscillators is called frequency synthesis.

30. What is a sweep generator?

It is a device which generates a waveform whose frequency can be varied at a selected rate between a minimum and maximum value.

31. What is a spectrum analyzer?

It is an instrument with a CRT that displays the frequency components of complex signal.

32. List the types of spectrum analyzer?

- Swept tuned radio frequency spectrum analyzer
- Swept superheterodyne frequency spectrum analyzer
- High frequency spectrum analyzer

33. Define duty cycle.

It is a ratio of pulse width time to the signal period.

34. What is settling time?

The time required for a signal to decrease to a given percentage typically 1 to 5% of its peak value is called as settling time.

35. What is ringing?

The positive and negative peak distortion excluding overshoot or undershoot, on the pulse top or base line is called as ringing.
36. What are the types of wave analyzers?

- Wave analyzer
- Distortion analyzer
- Spectrum analyzer
- Digital fourier analyzer
- Audio analyzer

37. What is a wave analyzer?

It is an instrument designed to measure the relative amplitude of single frequency components in a complex or distorted waveform.

38. What are the uses of wave analyzers?

- Measuring the amplitudes of individual components of a complex frequency system.
- Measuring the signal amplitudes in the presence of noise and interfering signals.
- Measuring the energy in a specific well defined bandwidth.

39. Give the drawbacks of tuned circuit harmonic analyzer.

- At low frequencies, very large values for L and C are required and their physical size becomes rather impractical.
- Harmonics of the signal frequency are often very close in frequency, so that it becomes extremely difficult to distinguish between them.

Part B
1. Explain in detail about Function generator?

FUNCTION GENERATOR

A function generator produces different waveforms of adjustable frequency. The common output waveforms are the sine, square, triangular and saw tooth waves. The frequency may be adjusted, from a fraction of a Hertz to several hundred kHz lie various outputs of the generator can be made available at the same time. For example, the generator can provide a square wave to test the linearity of a rectifier and simultaneously provide a saw tooth to drive the horizontal deflection amplifier of the CRO to provide a visual display. Capability of Phase Lock the V (rms). The output is taken through a push-pull amplifier. For low output, the impedance is 6000. The square wave amplitudes can be varied from 0 - 20 v (peak). It is possible to adjust the symmetry of the square wave from 30 -70%. The instrument requires only 7W of power at 220V 50Hz.
The front panel of a signal generator consists of the following.

1. Frequency selector: It selects the frequency in different ranges and varies it continuously in a ratio of 1:11. The scale is non-linear.

2. Frequency multiplier: It selects the frequency range over 5 decades from 10 Hz to 7 MHz

3. Amplitude multiplier: It attenuates the sine wave in 3 decades, $x1 \times 0.1$ and $x0.01$.

4. Variable amplitude: It attenuates the sine wave amplitude continuously.

5. Symmetry control: It varies the symmetry of the square wave from 30% to 70%.

6. Amplitude: It attenuates the square wave output continuously.

7. Function switch: It selects either sine wave or square output.

8. Output available: This provides sine wave or square wave output.

9. Sync: This terminal is used to provide synchronization of the internal signal with an external signal.

10. On-Off Switch

**FUNCTION GENERATOR**
A function generator produces different waveforms of adjustable frequency. The common output waveforms are the sine, square, triangular and saw tooth waves. The frequency may be adjusted, from a fraction of a Hertz to several hundred kHz lie various outputs of the generator can be made available at the same time. For example, the generator can provide a square wave to test the linearity of a rectifier and simultaneously provide a saw tooth to drive the horizontal deflection amplifier of the CRO to provide a visual display. Capability of Phase Lock the function generator can be phase locked to an external source.

One function generator can be used to lock a second function generator, and the two output signals can be displaced in phase by adjustable amount. In addition, the fundamental frequency of one generator can be phase locked to a harmonic of another generator, by adjusting the amplitude and phase of the harmonic; almost any waveform can be generated by addition. The function generator can also be phase locked to a frequency standard and its output waveforms will then have the same accuracy and stability as the standard source. The block diagram of a function generator is illustrated in fig. Usually the frequency is controlled by varying the capacitor in the LC or RC circuit. In the instrument the frequency is controlled by varying the magnitude of current, which drives the integrator.

The instrument produces sine, triangular and square waves with a frequency range of 0.01 Hz to 100 kHz. The frequency-controlled voltage regulates two current sources. The upper current source supplies constant current to the integrator whose output voltage increases linearly with time, according to the equation of the output signal voltage. An increase or decrease in the current increases or decreases the slope of the output voltage and hence controls the frequency.

2. Draw the block diagram of pulse wave generator and explain. (nov/dec 2011) Discuss the principle of pulse and square wave generator and also the pulse characteristics required to analyses the quality of the pulse. (May 2008)

Square and Pulse Generator
These generators are used as measuring devices in combination with a CRO. They provide both quantitative and qualitative information of the system under test. They are made use of in transient response testing of amplifiers. The fundamental difference between a pulse generator and a square wave generator is in the duty cycle. Duty cycle = A square wave generator has a 500/o duty cycle.

Requirements of a Pulse

1. The pulse should have minimum distortion, so that any distortion, in the display is solely due to the circuit under test.
2. The basic characteristics of the pulse are rise time, overshoot, ringing, sag, and undershoot.
3. The pulse should have sufficient maximum amplitude, if appreciable output power is required by the test circuit, e.g. for magnetic core memory. At the same time, the attenuation range should be adequate to produce small amplitude pulses to prevent over driving of some test circuit. 4. The range of frequency control of the pulse repetition rate (PRR) should meet the needs of the experiment. For example, a repetition frequency of 100 MHz is required for testing fast circuits. Other generators have a pulse-burst feature, which allows a train of pulses rather than a continuous output.
5. Some pulse generators can be triggered by an externally applied trigger signal; conversely, pulse generators can be used to produce trigger signals, when this output is passed through a differentiator circuit.
6. The output impedance of the pulse generator is another important consideration. In a fast pulse system, the generator should be matched to the cable and the cable to the test circuit. A mismatch would cause energy to be reflected back to the generator by the test circuit, and this may be rereflected by the generator, causing distortion of the pulses.
7. DC coupling of the output circuit is needed, when dc bias level is to be maintained. The basic circuit for pulse generation is the asymmetrical multi-vibrator. A laboratory type square wave and pulse generator is shown in Fig.

The frequency range of the instrument is covered in seven decade steps from 1Hz to 10 MHz, with a linearly calibrated dial for continuous adjustment on all ranges. The duty cycle can be varied from 25 - 75%. Two independent outputs are available, a 50Ω source that supplies pulses with a rise and fall time of 5 ns at 5V peak amplitude and a 600Ω source which supplies pulses with a rise and fall time of 70 ns at 30 V peak amplitude. The instrument can be operated as a free running generatoror, it can be synchronized with external signals. The basic generating loop consists of the current sources, the ramp capacitor, the Schmitt trigger and the current switching circuit as shown in the fig 6.2.
The upper current source supplies a constant current to the capacitor and the capacitor voltage increases linearly. When the positive slope of the ramp voltage reaches the upper limit set by the internal circuit components, the Schmitt trigger changes state. The trigger circuit output becomes negative and reverses the condition of the current switch. The capacitor discharges linearly, controlled by the lower current source. When the negative ramp reaches a predetermined lower level, the Schmitt trigger switches back to its original state. The entire process is then 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. The unit is powered by an internal supply that provides regulated voltages for all stages of the instrument.

**SQUARE WAVE GENERATOR**

The circuit configuration of a square wave generator consists of the basic elements of a sine wave generator (i.e., Wien bridge oscillator, attenuator) and square wave shaper and square wave amplifier. Figure 9.2 shows the block diagram of a square wave generator.

A square wave is obtained by feeding the sinusoidal output of the Wein bridge oscillator to the square wave Shaper circuit. The square wave shaper is usually a sine-to-square wave converter. The square wave is further processed through square wave amplifier and attenuator in order to obtain a square wave of desired amplitude. The frequency of the square wave can be varied by varying the oscillation frequency of Wein bridge oscillator.

**RF SIGNAL GENERATOR**

A standard signal generator produces known and controllable voltages. It is used as power source for the measurement of gain, signal to noise ratio (SN), bandwidth standing wave ratio and other properties. It is extensively used in the measuring of radio receivers and transmitter.
The carrier frequency is generated by a very stable RF oscillator using an LC tank circuit, having a constant output over any frequency range. The frequency of oscillations is indicated by the frequency range control and the variable dial setting. AM is provided by an internal sine wave generator or from an external source.

The signal generator is called an oscillator. A Wien bridge oscillator is used in this generator. The Wien bridge oscillator is the best of the audio frequency range. The frequency of oscillations can be changed by varying the capacitance in the oscillator. The frequency can also be changed in steps by switching the resistors of different values. The output of the Wien bridge oscillator goes to the function switch. The function switch directs the oscillator output either to the sine wave amplifier or to the square wave shaper. At the output, we get either a square or sine wave. The output is varied by means of an attenuator. The instrument generates a frequency ranging from 10 Hz to 1 MHz continuously variable in 5 decades with overlapping ranges. The output sine wave amplitude can be varied from 5 mV to 5 V.

**Sweep Generator**

It provides a sinusoidal output voltage whose frequency varies smoothly and continuously over an entire frequency band, usually at an audio rate. The process of frequency modulation may be accomplished electronically or mechanically. It is done electronically by using the modulating voltage to vary the reactance of the oscillator tank circuit component, and mechanically by means of a motor driven capacitor, as provided for in a modern laboratory type signal generator.
BASIC BLOCK DIAGRAM OF A SWEEP GENERATOR.

The frequency sweeper provides a variable modulating voltage which causes the capacitance of the master oscillator to vary. A representative sweep rate could be of the order of 20 sweeps/second. A manual control allows independent adjustment of the oscillator resonant frequency. The frequency sweeper provides a

Synchronization to drive the horizontal deflection plates of the CRO. Thus the amplitude of the response of a test device will be locked and displayed on the screen.

To identify a frequency interval, a marker generator provides half sinusoidal waveforms at any frequency within the sweep range. The marker voltage can be added to the sweep voltage of the CRO during alternate cycles of the sweep voltage, and appears superimposed on the response curve. The automatic level control circuit is a closed loop feedback system, which monitors the RF level at some point in the measurement system. This circuit holds the power delivered to the load or test circuit constant and independent of frequency and impedance changes. A constant power level prevents any source mismatch and also provides a constant readout calibration with frequency.

3. Draw the block diagram of sweep-frequency generator and explain. (april/May 2011)

SWEEP OR TIME BASE GENERATOR

A continuous sweep CRO using a UJT as a time base generator. The UJT is used to produce the sweep. When the power is first applied, the UJT is off and the CT charges exponentially through RT. The UJT emitter voltage VE rises towards VBB and when VE reaches the peak voltage VP, as shown in Fig. the emitter to base ‘1’ (B1) diode becomes forward
biased and the UJT triggers ON. This provides a low resistance discharge path and the capacitor discharges rapidly. The emitter voltage $V_E$ reaches the minimum value rapidly and the UJT goes OFF.

The capacitor recharges and the cycle repeats. To improve sweep linearity, two separate voltage supplies are used, a low voltage supply for UJT and a high voltage supply for the RTCT circuit. CRT is used for continuous control of frequency within a range and CT is varied or changed in steps for range changing. They are sometimes called as timing resistor and timing capacitor respectively. The sync pulse enables the sweep frequency to be exactly equal to the input signal frequency, so that the signal is locked on the screen and does not drift. Visit www.engineering-grs.com

**Basic principal involved in Signal Display Unit**

The amplitude of a voltage may be directly measured on a calibrated viewing screen from the length of the straight line trace it produces. This is entirely satisfactory for dc voltage. But the straight line tells little, or practically nothing, about the waveform of an ac voltage, pulsating voltage or transient. What is required is a graph of the voltage traced on the screen by the ac spot (a graph of amplitude versus time).

To obtain such a display the signal voltage is applied to the vertical plates (directly or through the vertical amplifier) and it moves the spot vertically in positions, corresponding to the instantaneous values of the signal. Simultaneous the spot is moved horizontally by a sweep voltage applied to the horizontal plates. The combined action of these two voltages causes the spot to produce a trace on the screen. The horizontal sweep voltage produces the time base by moving the spot horizontally with time, while the signal moves the spot vertically in proportional to the voltage at a particular instant of time.

![fig 5.1 Waveform of sweep voltage](image)

There are two important sweep generator requirements:

1. The sweep must be linear (the sweep voltage must rise linearly to the maximum value required for full screen horizontal deflection of the spot).
2. The spot must move in one direction only, i.e. from left to right only, else the signal will be traced backwards during the return sweep. This means that the sweep voltage must drop suddenly after reaching its maximum value.

These requirements call for a sweep voltage having a linear saw tooth waveform, as shown in Fig. 5.1. Now at time t₀, the sweep voltage is -E₂, and the negative horizontal voltage moves the spot to point 1 on the screen. At this instant, the signal voltage is 0, so the spot rests at the left end of the zero line on the screen.

At time t₁ the linearly increasing saw tooth reaches –
E₁ which, being more positive than –
E₂, moves the spot to the screen, point 2.

At this instant, the signal voltage is e, the +ve peak value, so the point represents its maximum upward deflection of the spot.

At time t₂, the saw tooth voltage is 0, there is no horizontal deflection and the spot is at the centre, point 3. At this instant the signal voltages is 0V. so, there is no vertical deflection either.

At time t₃, the saw tooth voltage is +E₁ moving the spot to point 4. At this instant, the signal is -e, the -ve peak value, so point 4 is the maximum downward deflection of the spot.

At time t₄, the saw tooth voltage is +E₂, moving the spot to point 5. Now the signal voltage is 0, so the spot is not vertically reflected.

Between t₄ and t₅, the saw tooth voltage falls quickly through 0 to its initial value of -E₂, snapping the spot back to point 1, in time to sweep forward on the next cycle of signal voltage. When sweep and signal frequencies are equal, a single cycle appears on the screen, when the sweep is lower than the signal, several cycles appear (in the ratio of the two frequencies), and when sweep is higher than signal, less than one cycle appears. The display is stationary only when the two frequencies are either equal or integral multiples of each other. At other frequencies the display will drift horizontally.

A saw tooth sweep voltage is generated by a multi vibrator, relaxation oscillator or pulse generator. The upper frequency generated by internal devices in the oscilloscope is 50-100 kHz in audio instruments, 500-1000 kHz in TV service instruments and up to several MHz in high quality laboratory instruments. In some oscilloscopes the sweep is calibrated in Hz or kHz, and in others it is calibrated in time units (us, ms, and s).

The different types of sweep generator are as follows:
1. **Recurrent Sweep**: When the saw tooth, being an ac voltage alternates rapidly, re display occurs repetitively, so that a lasting image is seen by the eye. This -treated operation is recurrent sweep.

2. **Single Sweep**: The signal under study produces a trigger signal, which in turn produces a single sweep.

3. **Driven Sweep**: The saw tooth oscillator is a free running generator when p crated independently. There is a chance that the sweep cycle may start after the signal cycle, thereby missing a part of the signal. Driven sweep removes this possibility because it is fixed by the signal itself. The sweep and signal cycles start at the same time.

4. **Triggered Sweep**: In a recurrent mode, the pattern is repeated again and again. In this mode the voltage rises to a maximum and then suddenly falls to a minimum. Electron beam moves slowly from left to right, retraces rapidly to the left and I, pattern is repeated. The horizontal
sweep action takes place whether the input signal is applied to the oscilloscope or not, and a horizontal line is displayed on the scope screen. A triggered sweep, on the other hand, does not start unless initiated by a trigger voltage, generally derived from an incoming signal. In the absence of the input signal the sweep is held off and the CRT screen is blanked. The continuous or recurrent sweep uses a free running multi vibrator (m/v) which covers a wide frequency range and can be locked into synchronization by input signal. Sync takes place when the sweep frequency and the input signal frequency are the same or when the former is a multiple of the latter.

A triggered scope does not use a continuous or recurrent sweep, but uses a mono stable multi vibrator which is in its off state until a trigger pulse arrives; hence there is no deflection on the screen. When an input signal is applied, a trigger pulse is generated and applied to the multi vibrator, which switches on and produces a sweep signal, and a trace appears on the screen. After a specific voltage, depending on the CRT beam arriving on the RHS, the multi vibrator switches back to its off state, causing the beam to return rapidly to the LHS. (The basic difference between recurrent and triggered scopes is that the recurrent sweep locks at the frequency of the input signal, while the triggered scope displays a trace for a specific period of time. Hence, the triggered scope is ON during a specific time interval and will display a waveform or a segment of waveform (e.g. a one shot waveform) regardless of the signal frequency. Hence transients or single clamped oscillations can be observed on the screen.) Most triggered scopes use a convenient feature of calibrating the sweep speed, in time per cm or division. Sweep frequency is the reciprocal of the time period.

4. Explain in detail the Frequency synthesizer

FREQUENCY SYNTHESIZER
A frequency synthesizer is an electronic system for generating any of a range of frequencies from a single fixed timebase or oscillator. They are found in many modern devices, including radio receivers, mobile telephones, radiotelephones, walkie-talkies, CB radios, satellite receivers, GPS systems, etc. A frequency synthesizer can combine frequency multiplication, frequency division, and frequency mixing (the frequency mixing process generates sum and difference frequencies) operations to produce the desired output signal.

Three types of synthesizer:
1. Direct Analog Synthesis
2. Direct Digital Synthesizer (DDS)
3. Indirect digital (PLL) synthesizers
THE BASICS OF PLL FREQUENCY SYNTHESIS

The phase locked loop (PLL) method of frequency synthesis is now the most commonly used method of producing high frequency oscillations in modern communications equipment. There would not be an amateur or commercial transceiver of any worth today that does not employ at least one if not several, phase locked loop systems, to generate stable high frequency oscillations.

PLL circuits are now frequently being used to demodulate FM signals, making obsolete the Foster-Seely and ratio detectors of early years. Other applications for PLL circuits include AM demodulators, FSK decoders, two-tone decoders and motor speed controls.

The PLL technique has, surprisingly, been around for a long time. In the 1930s the superheterodyne receiver was in its heyday (and it's still going strong today), however attempts were made to simplify the number of tuned stages in the superheterodyne.

BASIC VOLTAGE CONTROLLED OSCILLATOR

There are oscillators that will operate over a large range of frequencies. Variable frequency oscillators (VFOs) are made to change frequency by changing the value of one of the frequency determining circuits. A voltage-controlled oscillator (VCO) is one in which the frequency-determining component is made to change electrically.

Figure 2 shows a basic voltage controlled oscillator. The frequency of oscillation is determined by L1, C2 and D2. The diode is a varactor, sometimes called a varicap. Most ordinary PN junction diodes will behave as a varicap diode when reverse-biased, but must be operated below the junction breakdown voltage.

With reverse bias, the diode will act as a capacitor, its depletion zone forming the dielectric. Changing the amount of reverse bias within the breakdown limits of the diode will alter the width of the depletion zone and hence vary the effective capacitance presented by the diode. This in turn changes the resonant frequency of the oscillator circuit.

This is all well and good, but how does it help us? After all, the VCO is not stable. Any slight voltage variation in the circuit will cause the frequency to shift. If there was some way we could combine the flexibility of the VCO with the stability of the crystal oscillator: we would have the ideal frequency synthesis system.
THE HOMODYNE RECEIVER

Around 1932, British radio engineers developed a new type of receiver to challenge the 'superhet' - it was called the homodyne or synchrodyne.

The idea was simple: the receiver consisted of a mixer and a local oscillator, followed immediately by an audio amplifier!

When the input signal and local oscillator are mixed at the same phase and frequency, the output is an exact audio representation of the modulated carrier.

Problems, however, occurred in trying to keep the local oscillator on the same phase and frequency as the input signal. To counteract local oscillator drift, the output of the local oscillator was fed together with a sample of the input signal to a phase detector. The output of the phase detector was a correction voltage which was then applied to the local oscillator to keep it on frequency.

It was this type of feedback circuit, which led to the evolution of the phase locked loop. The homodyne receiver was superior to the superheterodyne but the cost of the PLL circuit outweighed its advantages, so the idea did not take off.

In the late 80's some single-chip receivers were developed using the homodyne principle. Such receivers are referred to by some manufacturers as zero intermediate frequency receivers since there is a direct conversion from RF to audio.
If two signals are fed into a phase detector and these signals are equal in phase and frequency, there will be no output from the detector. On the other hand, if the signals are not in phase, the difference is converted to a DC output voltage. The greater the frequency/phase difference in the two signals, the larger the output voltage.

Now, where were we? Right, take a look at Figure 3. The outputs of the VCO and the crystal oscillator are combined with a phase detector and any difference will result in a DC voltage output. Now, suppose this DC voltage is coupled back to the VCO in such a manner that it drives the output of the VCO towards the crystal oscillator frequency - eventually the VCO will lock onto the crystal oscillator frequency. This is a PHASE LOCKED LOOP in its most basic form. Only part of the VCO output need be sent to the phase detector. The rest can be usable output.

![Figure 3 - Using the output from the Phase Detector to provide a phase lock](image)

The reference crystal in this case is 10.24 MHz, but note that in this instance the reference crystal is not oscillating at the reference frequency - its signal is passed through a 1024 divider to give us a reference frequency of 10 kHz. This 10 kHz reference signal is passed to the phase detector.

Now we know that the signal coming from the VCO must be divided to 10 kHz before being applied to the phase detector - but notice one thing: in this system our VCO must oscillate at around 36 MHz to give us the correct output frequency. This frequency is going to take a lot of dividing to get it down to the 10 kHz reference frequency.

So here a cunning method has been used to convert the VCO frequency to a workable value before division. This is where the 11.2858 MHz crystal oscillator comes into play. It's an overtone oscillator producing an output on the third overtone of the crystal's fundamental frequency - i.e. 33.8575 MHz. This signal is then mixed with the VCO output, the difference frequency being around 2 to 3 MHz. This signal can then be divided to 10 kHz quite simply and applied to the phase detector.

**PRINCIPLE OF PLL SYNTHESIZERS**
A phase locked loop is a feedback control system. It compares the phases of two input signals and produces an error signal that is proportional to the difference between their phases.[11] The error signal is then low pass filtered and used to drive a voltage-controlled oscillator (VCO) which creates an output frequency. The output frequency is fed through a frequency divider back to the input of the system, producing a negative feedback loop. If the output frequency drifts, the phase error signal will increase, driving the frequency in the opposite direction so as to reduce the error. Thus the output is locked to the frequency at the other input. This other input is called the reference and is usually derived from a crystal oscillator, which is very stable in frequency. The block diagram below shows the basic elements and arrangement of a PLL based frequency synthesizer.

The key to the ability of a frequency synthesizer to generate multiple frequencies is the divider placed between the output and the feedback input. This is usually in the form of a digital counter, with the output signal acting as a clock signal. The counter is preset to some initial count value, and counts down at each cycle of the clock signal. When it reaches zero, the counter output changes state and the count value is reloaded. This circuit is straightforward to implement using flip-flops, and because it is digital in nature, is very easy to interface to other digital components or a microprocessor. This allows the frequency output by the synthesizer to be easily controlled by a digital system.

Suppose the reference signal is 100 kHz, and the divider can be preset to any value between 1 and 100. The error signal produced by the comparator will only be zero when the output of the divider is also 100 kHz. For this to be the case, the VCO must run at a frequency which is 100 kHz x the divider count value. Thus it will produce an output of 100 kHz for a count of 1, 200 kHz for a count of 2, 1 MHz for a count of 10 and so on. Note that only whole multiples of the reference frequency can be obtained with the simplest integer N dividers. Fractional N dividers are readily available

5. What is wave analyzer? How it analyzes the harmonics? Explain. (8)(Apr/May 2011)
WAVE ANALYZER
The wave analyzer consists of a very narrow pass-band filter section which can be tuned to a particular frequency within the audible frequency range(20Hz to 20 KHz)).
The complex wave to be analyzed is passed through an adjustable attenuator which serves as a range multiplier and permits a large range of signal amplitudes to be analyzed without the output of the attenuator being fed to a selective amplifier, which amplifies the selected frequency. The driver amplifier applies the attenuated input signal to a high-Q active filter. This high-Q filter is a low-pass filter which allows the frequency which is selected to pass and reject all others. The magnitude of this selected frequency is indicated by the meter and the filter section identifies the frequency of the component.

The filter circuit consists of a cascaded RC resonant circuit and amplifiers. For selecting the frequency range, the capacitors generally used are of the closed tolerance polystyrene type and the resistances used are precision potentiometers. The capacitors are used for range changing and the potentiometer is used to change the frequency within the selected pass-band. Hence this wave analyzer is also called a Frequency selective voltmeter. The entire AF range is covered in decade steps by switching capacitors in the RC section. The selected signal output from the final amplifier stage is applied to the meter circuit and to an unturned buffer amplifier. The main function of the buffer amplifier is to drive output devices, such as recorders or electronics counters. The meter has several voltage ranges as well as decibel scales marked on it. It is driven by an average reading rectifier type detector. The wave analyzer must have extremely low input distortion, undetectable by the analyzer itself. The band width of the

**fig 1 Frequency wave analyzer**

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instrument is very narrow typically about 1% of the selective band given by the following response characteristics shows in fig.1.2

APPLICATIONS OF WAVE ANALYZER
1. Electrical measurements
2. Sound measurements
3. Vibration measurements.

In industries there are heavy machineries, which produce a lot of sound and vibrations, it is very important to determine the amount of sound and vibrations because if it exceeds the permissible level it would create a number of problems. The source of noise and vibrations is first identified by wave analyzer and then it is reduced by further circuitry.

6. Explain the distortion analyzer with the help of suitable diagrams

DISTORTION ANALYZER
Distortion refers to the deviation in any parameter (like amplitude, frequency, shape) of a signal from that of an ideal signal. The non-linear characteristics of the elements of an electronic circuit give rise to harmonics in the output signal which in turn causes distortion of the output signal. The distortion caused due to harmonics is known as harmonic distortion.

The different types of harmonic distortions caused by an electronic circuit (for example, electronic amplifier are as follows,
(i) Amplitude distortion
(ii) Frequency distortion
(iii) Phase distortion
(iv) Crossover distortion
(v) Inter modulation distortion.

(i) Amplitude Distortion
When the amplitude of the output signal is not a linear function of the amplitude and input signal is distorted under specific conditions then such type of distortion are known as **Amplitude distortion**.

Amplitude distortion occurs when the amplifier gives rise to harmonics of the fundamental frequency of the input signal.

(ii) **Frequency distortion**
Frequency distortion of a signal takes place when the signal is amplified by different amounts at different frequencies. This is caused mainly due to the combination of active devices and components in an amplifier.

For Example, the non uniform frequency response of RC-coupled cascade amplifier refers to frequency distortion.

(iii) **Phase Distortional:**
If different amounts of phase shifts occur at different frequencies of an output signal than it becomes necessary to compensate for such phase distortions. While if same amount of phase shift occurs at all frequencies then such phase distortion cannot be ignored .the phase distortion arises due to presence of storage elements in the circuit.

(iv) **Crossover Distortion**
The improper biasing voltages of the electromagnetic components of an amplifier (for example push-pull amplifier give rise to crossover distortion)

(v) **Inter modulation Distortion**
When two signals of different frequencies are mixed together (i.e., heterodyned) the resultant signal will be a sum or difference of the actual frequencies of the signals. Thus, when the signals are heterodyned, additional frequencies are generated which are undesirable andthereby leads to distortion. The distortion caused by heterodyning of frequencies is known as inter modulation distortion. The various distortions in the signal can be analyzed using a distortion analyzer (for example, harmonic distortion analyzer).

7. Define the harmonic distortion and total harmonic distortion. Explain the parts of fundamental suppression HD analyser, its working and its advantages. (May 2008)

**HARMONIC DISTORTION ANALYZER**

**TOTAL HARMONIC DISTORTION (THD) ANALYZERS**

They calculate the total distortion introduced by all the harmonics of the fundamental frequency wave. In most cases THD is the amount required to be calculated, rather than distortion caused by individual harmonics. This type of analysis is very important in systems (e.g. Audio) in which filters with extremely small passband/ stopband are desired, such as a notch filter in a parametric equalizer.
This is a specific type of THD analyzer, in which basically the fundamental frequency of the input wave is suppressed so as to remove it from the spectra of the meters used for distortion measurement, and the total gain of all the harmonics is calculated, thus obtaining the total distortion caused by the harmonics. The frequency response of a Fundamental Suppression Analyzer

A block diagram of a Fundamental Suppression Analyzer is shown in Fig.1. This basic construction consists of three main sections: Input section with impedance matcher, a rejection amplifier section and an output metering circuit. Notice the feedback from the bridge amplifier to the pre-amp section, that enables the rejection circuit to work more accurately.

**Working**
The applied input wave is impedance matched with the rejection circuit with the help of an attenuator and an impedance matcher. This signal is then applied to a pre-amplifier which raises the signal level to a desired value. The following section consists of a Wien bridge. The bridge is tuned to the fundamental frequency by frequency control and it is balanced for zero output by adjusting the bridge controls, thus giving a notch in the frequency response of the rejection section. After the Wien Bridge, a bridge amplifier follows that simply amplifies low harmonic voltage levels to measurable higher levels. A feedback loop is formed from Bridge Amp o/p to the Pre-Amp i/p thus eliminating even the slightest effect of fundamental frequency. This filtered
output is then applied to a meter amplifier which can be an instrumentation amplifier. This amp raises the voltage levels to the compatibility of the meter scale/digital meter which follows. Thus the total voltage obtained at the meter output shows the amount of distortion present in the wave due to harmonics of fundamental.

1. **Fundamental Suppression Type**

Distortion analyzer measures the total harmonic power present in the test wave rather than the distortion caused by each component. The simplest method is to suppress the fundamental frequency by means of a high pass filter whose cut off frequency is a little above the fundamental frequency. This high pass allows only the harmonics to pass and the total harmonic distortion can then be measured. Other types of harmonic distortion analyzers based on fundamental suppression are as follows.

![Fig 3.1 Resonance Bridge](image)

2. **Wien Bridge Method**

The bridge is balanced for the fundamental frequency. The fundamental energy is dissipated in the bridge circuit elements. Only the harmonic components reach the output terminals. The harmonic distortion output can then be measured with a meter. For balance at the fundamental frequency

\[ C_1 = C_2 = C, \quad R_1 = R_2 = R, \quad R_3 = 2R_4. \]

3. **Bridged T-Network Method:**

The L and C's are tuned to the fundamental frequency, and R is adjusted to bypass fundamental frequency. The tank circuit being tuned to the fundamental frequency, the fundamental energy will circulate in the tank and is bypassed by the resistance. Only harmonic components will reach the output terminals and the distorted output can be measured by the meter. The Q of the resonant circuit must be at least 3-5.

One way of using a bridge T-network is given in Fig. 3.4. The switch S is first connected to point A so that the attenuator is excluded and the bridge T-network is adjusted for full suppression of the fundamental frequency, i.e. Minimum output indicates that the bridged T network is tuned to the
fundamental frequency and that fundamental frequencies is fully suppressed.

8. Draw the block diagram general purpose spectrum and explain (Nov/Dec 2011)

**Basic Spectrum Analyzer**

The most common way of observing signals is to display them on an oscilloscope with time as the X-axis (i.e. amplitude of the signal versus time). This is the time domain. It is also useful to display signals in the frequency domain. The providing this frequency domain view is the spectrum analyzer.

A spectrum analyzer provides a calibrated graphical display on its CRT, with frequency on the horizontal axis and amplitude (voltage) on the vertical axis.
Displayed as vertical lines against these coordinates are sinusoidal components of which the input signal is composed. The height represents the absolute magnitude, and the horizontal location represents the frequency. These instruments provide a display of the frequency spectrum a given frequency band. Spectrum analyzers use either parallel filter bank or a swept frequency technique.

In a parallel filter 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, as shown in fig 4.1. Typically, an audio analyzer has 32 of these filters, each covering one third of an octave. For wide band narrow resolution analysis, particularly at RF or microwave signals, the swept technique is preferred.

Basic Spectrum Analyzer Using Swept Receiver Design Referring to the block diagram of fig. 4.2, the sawtooth generator provides the sawtooth voltage which drives the horizontal axis element of the scope, and this sawtooth voltage is the frequency-controlled element of the voltage tuned oscillator. As the oscillator sweeps from fmin to fmax of its frequency band at a linear recurring rate, it beats with the frequency component of the input signal and produce an IF, whenever a frequency component is met during its sweep. The frequency component and voltage tuned oscillator frequency beats together to produce a difference frequency, i.e. the IF corresponding to the component is amplified and detected if necessary and then applied to the vertical plates of the CRO, producing a display of amplitude versus frequency.
One of the principal applications of spectrum analyzers has been in the study of the RF spectrum produced in microwave instruments. In a microwave instrument, the horizontal axis can display as a wide a range as 2 - 3 GHz for a broad survey and as narrow as 30 kHz, for a highly magnified view of any small portion of the spectrum. Signals at microwave frequency separated by only a few KHz can be seen individually. The frequency range covered by this instrument is from 1 MHz to 40 GHz.

The basic block diagram is of a spectrum analyzer covering the range 500 kHz to 1 GHz, which is representative of a super heterodyne type.

fig 4.3 Test Wave seen on ordinary CRO

fig 4.4 Display on the spectrum CRO

fig 4.5 Test waveform as seen from X-axis(Time) and Z-axis (Frequency)
The input signal is fed into a mixer which is driven by a local oscillator. This oscillator is linearly tunable electrically over the range 2 - 3 GHz. The mixer provides two signals at its output that are proportional in amplitude to the input signal but of frequencies which are the sum and difference of the input signal and local oscillator frequency.

The IF amplifier is tuned to a narrow band around 2 GHz since the local oscillator is tuned over the range of 2 - 3 GHz, only inputs that are separated from the local oscillator frequency by 2GHz will be converted to IF frequency band, pass through the IF frequency amplifier, get rectified and produce a vertical deflection on the CRT. From this, it is observed that as the saw tooth signal sweeps, the local oscillator also sweeps linearly from 2 - 3 GHz.

The tuning of the spectrum analyzer is a swept receiver, which sweeps linearly from 0 to 1 GHz. The saw tooth-scanning signal is also applied to the horizontal plates of the CRT to form the frequency axis. (The spectrum analyzer is also sensitive to signals from 4 - 5 GHz referred to as the image frequency of the super heterodyne. A low pass filter with a cutoff frequency above 1 GHz at the input suppresses these spurious signals.) Spectrum analyzers are widely used in radars, oceanography, and bio-medical fields.

9. Explain in detail about Digital Spectrum Analyzer

DIGITAL SPECTRUM ANALYZER
A spectrum analyzer, which uses computer algorithm and an analog to digital conversion phenomenon and produces spectrum of a signal applied at its input is known as digital Fourier or digital FFT or digital spectrum analyzer.

**PRINCIPLE**
When the analog signal to be analyzed is applied, the A/D converter digitizes the analog signal (i.e., converts the analog signal into digital signal). The digitized signal, which is nothing but the set of digital numbers indicating the amplitude of the analog signal as a function of time is stored in the memory of the digital computer. From the stored digitized data, the spectrum of the signal is computed by means of computer algorithm.

**DESCRIPTION:**
The block arrangement of a digital Fourier analyzer is illustrated in the figure above fig 5. The analog signal to be analyzed is applied to the low pass filter, which passes only low frequency signals and rejects high pass spurious signals. This filter section is used mainly, to prevent aliasing. The output of low pass filter is given to the attenuator. The attenuator is a voltage dividing network whose function is to set the input signal to the level of the A/D converter. The use of attenuator prevents the converter from overloading. The function of A/D converter is to convert the samples of analog data into digital i.e., to digitize the analog signal. When the output of A/D converter is applied to the digital computer, the computer analyzes the digitized data and adjusts the attenuator setting accordingly in order to obtain the maximum output from the inverter without any overloading. As soon as the entire analog signal is sampled and digitized by the A/D converter) computer performs calculations on the data according to the programmed algorithm and the calculated spectral components are stored in the memory of the digital computer.
computer. If the spectral display is to be viewed on the oscilloscope, the digital values of spectral components stored in the computer memory are converted into analog by using D/A converters and then applied to the CRO. Thus the spectral display of the input waveform is obtained on the CRT screen.

**Advantages**
1. The use of computer avoids most of the hardware circuitry such as electronic switches, Filters and PLLs. The use of less hardware reduces the cost of the analyzer.
2. More mathematical calculations can be carried-out on the spectral display.
3. The rate of sampling analog signal can be modified in order to obtain better spectral display.

### 10. DIFFERENCES BETWEEN WAVE ANALYZER AND HARMONIC DISTORTION ANALYZER

<table>
<thead>
<tr>
<th>Wave analyzer</th>
<th>Harmonic distortion analyzer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. These are designed to measure the relative amplitude of each harmonic or fundamental components separately.</td>
<td>1. These are designed to measure the total harmonic content present in a distorted or complex wave form.</td>
</tr>
<tr>
<td>2. They indicate the amplitude of single frequency component</td>
<td>2. They do not indicate the amplitude of single frequency component</td>
</tr>
<tr>
<td>3. These are tuned to measure amplitude of one frequency component within a range of 10Hz to 40MHz</td>
<td>3. These can be operated with in a band of 5Hz to 1 MHz frequency</td>
</tr>
<tr>
<td>4. These are also known as frequency selective voltmeters, selective level voltmeters, carrier frequency voltmeters</td>
<td>4. It is general know as distortion analyzer</td>
</tr>
<tr>
<td>5. These are used with a set of tuned filters and a voltmeter</td>
<td>5. These can be used along with a frequency generator</td>
</tr>
<tr>
<td>6. Wave analyzers provide very high frequency resolution.</td>
<td>6. They measure quantitative harmonic distortions very accurately</td>
</tr>
<tr>
<td>7. These can be used for electrical measurements, sound, vibration, noise measurement in industries</td>
<td>7. These can be used to measure frequency stability and spectral purity of signal sources</td>
</tr>
</tbody>
</table>

### 11. Explain in detail about FET Spectrum Analyzer

**FFT Spectrum Analyzer**
There are two main types of spectrum analyzer technology. One is the swept frequency, or super heterodyne spectrum analyzer and the other is the FFT spectrum analyzer technology. Of the two, the FFT analyzer technology is the less commonly used on its own, but it is able to offer some distinct advantages over the more common swept frequency analyzer. By combining the two technologies, the advantages of each can be utilized to offer extremely high performance items of test equipment.

In general, spectrum analyzers are used to provide a view of radio frequency, or in some cases audio frequency waveforms in the time domain. With other instruments able to provide views of other aspects of signals, the spectrum analyzer is uniquely placed to offer views of the spectrum of a signal, revealing aspects that other instruments are unable to do. With the FFT analyzer able to provide facilities that cannot be provided by swept frequency analyzers, enabling fast capture and forms of analysis that are not possible with sweep / super heterodyne techniques alone.

**BLOCK DIAGRAM**

The block diagram and topology of an FFT spectrum analyzer are different to that of the more usual super heterodyne or swept spectrum analyzer. In particular, circuitry is required to enable the digital to analogue conversion to be made, and then for processing the signal as a Fast Fourier Transform. This means that the block diagram for the FFT spectrum analyzer is very different to that of the more familiar super heterodyne spectrum analyzer.

The FFT spectrum analyzer can be considered to comprise of a number of different blocks:

**FFT SPECTRUM ANALYZER BLOCK DIAGRAM**

Analogue front end attenuators / gain: The FFT analyzer requires attenuators of gain stages to ensure that the signal is at the right level for the analogue to digital conversion. Analogue low pass anti-aliasing filter: The signal is passed through an anti-aliasing filter. This is required because the rate at which points are taken by the sampling system within the FFT spectrum analyzer is particularly important. The waveform must be sampled at a sufficiently high rate. According to the Nyquist theorem, a signal must be sampled at a rate equal to twice that of the highest frequency, and also any component whose frequency is higher than the Nyquist rate will appear in the measurement as a lower frequency component - a factor known as “aliasing”.

Sampling and analogue to digital conversion: In order to perform the analogue to digital conversion, two elements are required. The first is a sampler, which takes samples at discrete time intervals - the sampling rate.

**FFT analyzer:** With the data from the sampler, which is in the time domain, this is then converted into the frequency domain by the FFT analyzer. This is then able to further process the data using digital signal processing techniques to analyze the data in the format required.
Display: With the power of processing it is possible to present the information for display in a variety of ways.

Advantages and disadvantages of FFT analyzer Technology
FFT spectrum analyzer technology has a number of advantages and disadvantages when compared to the more familiar super heterodyne or swept frequency analyzer. When choosing which technology will be suitable, it is necessary to understand the differences between them and their relative merits.

Advantages of FFT spectrum analyzer technology

- **Fast capture of waveform**: In view of the fact that the waveform is analysed digitally, the waveform can be captured in a relatively short time, and then the subsequently analysed. This short capture time can have many advantages.

- **Able to capture non-repetitive events**: The short capture time means that the FFT analyzer can capture non-repetitive waveforms, giving them a capability not possible with other spectrum analyzers.

- **Able to analyze signal phase**: As part of the signal capture process, data is gained which can be processed to reveal the phase of signals.

Disadvantages of the FFT spectrum analyzer technology

- **Frequency limitations**: The main limit of the frequency and bandwidth of FFT spectrum analyzers is the analogue to digital converter, ADC that is used to convert the analogue signal into a digital format. While technology is improving this component still places a major limitation on the upper frequency limits or the bandwidth if a down-conversion stage is used.

- **Cost**: The high level of performance required by the ADC means that this item is a very high cost item. In addition to all the other processing and display circuitry required, this results in the costs rising for these items.

12. Explain the vector network analyzer and list its application. (8)(Apr/May 2011)

NETWORK ANALYZER
A network analyzer is an instrument that measures the network parameters of electrical networks. Today, network analyzers commonly measure s-parameters because reflection and transmission of electrical networks are easy to measure at high frequencies, but there are other network parameter sets such as y-parameters, z-parameters, and h-parameters. Network analyzers are often used to characterize two-port networks such as amplifiers and filters, but they can be used on networks with an arbitrary number of ports. Network analyzers are used mostly at high frequencies; operating frequencies can range from 9 kHz to 110 GHz. Special types of network analyzers can also cover lower frequency ranges...
down to 1 Hz. These network analyzers can be used for example for the stability analysis of
open loops or for the measurement of audio and ultrasonic components.
The two main types of network analyzers are

- **Scalar Network Analyzer (SNA)** — measures amplitude properties only
- **Vector Network Analyzer (VNA)** — measures both amplitude and phase properties

A VNA may also be called a gain-phase meter or an Automatic Network Analyzer. An SNA is
functionally identical to a spectrum analyzer in combination with a tracking generator. As of
2007[update], VNAs are the most common type of network analyzers, and so references to an
unqualified —network analyzer‖ most often mean a VNA.

A new category of network analyzer is the Microwave Transition Analyzer (MTA) or Large Signal
Network Analyzer (LSNA), which measure both amplitude and phase of the fundamental and
harmonics. The MTA was commercialized before the LSNA, but was lacking some of the user-
friendly calibration features now available with the LSNA.

The basic architecture of a network analyzer involves a signal generator, a test set, and one or
more receivers. In some setups, these units are distinct instruments

**Signal generator**

The network analyzer needs a test signal, and a signal generator or signal source will provide
one. Older network analyzers did not have their own signal generator, but had the ability to
control a stand alone signal generator using, for example, a GPIB connection. Nearly all modern
network analyzers have a built-in signal generator. High-performance network analyzers have
two built-in sources. Two built-in sources are useful for applications such as mixer test, where
one source provides the RF signal, another the LO, or amplifier intermodulation testing, where
two tones are required for the test.
Test set

The test set takes the signal generator output and routes it to the device under test, and it routes the signal to be measured to the receivers. It often splits off a reference channel for the incident wave. In a SNA, the reference channel may go to a diode detector (receiver) whose output is sent to the signal generator's automatic level control. The result is better control of the signal generator's output and better measurement accuracy. In a VNA, the reference channel goes to the receivers; it is needed to serve as a phase reference.

Directional coupler. Two resistor power divider. Some microwave test sets include the front end mixers for the receivers (e.g., test sets for HP 8510). The test sets may also contain directional couplers to measure reflected waves. Transmission/reflection test set. S-parameter test set.

Receiver

The receivers make the measurements. A network analyzer will have one or more receivers connected to its test ports. The reference test port is usually labeled R, and the primary test ports are A, B, C,... Some analyzers will dedicate a separate receiver to each test port, but others share one or two receivers among the ports. The R receiver may be less sensitive than the receivers used on the test ports.

For the SNA, the receiver only measures the magnitude of the signal. A receiver can be a detector diode that operates at the test frequency. The simplest SNA will have a single test port, but more accurate measurements are made when a reference port is also used. The reference port will compensate for amplitude variations in the test signal at the measurement plane. It is possible to share a single detector and use it for both the reference port and the test port by making two measurement passes.

For the VNA, the receiver measures both the magnitude and the phase of the signal. It needs a reference channel (R) to determine the phase, so a VNA needs at least two receivers. The usual method down converts the reference and test channels to make the measurements at a lower frequency. The phase may be measured with a quadrature detector. A VNA requires at least two receivers, but some will have three or four receivers to permit simultaneous measurement of different parameters.

There are some VNA architectures (six-port) that infer phase and magnitude from just power measurements.

Calibration

The accuracy and repeatability of measurements can be improved with calibration. Calibration involves measuring known standards and using those measurements to compensate for
systematic errors. After making these measurements, the network analyzer can compute some correction values to produce the expected answer. For answers that are supposed to be zero, the analyzer can subtract the residual. For non-zero values, the analyzer could calculate complex factors that will compensate for both phase and amplitude errors. Calibrations can be simple (such as compensating for transmission line length) or involved methods that compensate for losses, mismatches, and feedthroughs.

A network analyzer (or its test set) will have connectors on its front panel, but the measurements are seldom made at the front panel. Usually some test cables will go from the front panel to the device under test (DUT) such as a two-port filter or amplifier. The length of those cables will introduce a time delay and corresponding phase shift (affecting VNA measurements); the cables may also introduce some attenuation (affecting SNA and VNA measurements).

S-parameter measurements have a notion of a reference plane. The goal is to refer all measurements to the reference plane.
Using ideal shorts, opens, and loads makes calibration easy, but ideal standards are difficult to make. Modern network analyzers will account for the imperfections in the standards. Automated calibration fixtures

A calibration using a mechanical calibration kit may take a significant amount of time. Not only must the operator sweep through all the frequencies of interest, but the operator must also disconnect and reconnect the various standards. To avoid that work, network analyzers can employ automated calibration standards. The operator connects one box to the network analyzer. The box has a set of standards inside and some switches that have already been characterized. The network analyzer can read the characterization and control the configuration using a digital bus such as USB.

AC network analyzers were much used for power flow studies, short circuit calculations, and system stability studies, but were ultimately replaced by numerical solutions running on digital computers. While the analyzers could provide real-time simulation of events, with no concerns about numeric stability of algorithms, the analyzers were costly, inflexible, and limited in the number of busses and lines that could be simulated. Since the multiple elements of the AC network analyzer formed a powerful analog computer, occasionally problems in physics and chemistry were modelled (by such researchers as Gabriel Kron of General Electric), during the period up to the late 1940s prior to the ready availability of general-purpose digital computers.

**DIGITAL RLC METER**
**BLOCK DIAGRAM:**
Front-Panel Display
A 5-digit LED display shows measured values, entered parameters, instrument status, and user messages. When making measurements, the major parameter (L, C or R) is shown on the left display and the appropriate minor parameter (Q, D or R) is shown on the right display.

Making Measurements

Measurements can be performed at test frequencies of 100 Hz, 120 Hz, 1 kHz, 10 kHz and 100 kHz (SR720 only). A built-in drive voltage can be set to preset values (0.1, 0.25 and 1.0 V) or adjusted from 0.1 to 1.0 V in 50 mV increments. Measurements are taken at rates of 2, 10 or 20 samples per second. Consecutive readings can be averaged between two and ten times for increased accuracy. Both series or parallel equivalent circuit models of a component are supported. Capacitor measurements use either the internal 2.0 VDC bias or an external source of up to 40 VDC.

Simple to Operate
The power and flexibility of the SR715/720 does not come at the expense of ease-of-use. A convenient AUTO measurement mode automates the selection of setup parameters and quickly determines the appropriate device model for whatever component is being measured. Up to nine instrument setups can be stored in non-volatile memory.

RESISTANCE
Ranges: 20W ,200W ,2KW ,20KW ,200KW ,2MW ,20MW
Resolution: 20W range 10mW
Accuracy: ±(1.0%rdg + 10digs) on 20W range
±(0.3%rdg + 3digs) on 200W range
±(0.3%rdg + 1dgt) on 2KW to 2MW ranges
±(2.0%rdg + 2dgt) on 20MW range
Open circuit volts:
6.5VDC on 20W to 200W Ranges
1.2VDC on other range
Overload protection: All ranges 25VDC or AC rms
Note: in the range 20W, subtract residual offset reading from result.

DIODE TEST
Including: , , microwave, zener (<6.8V)
Test current: 3mA (approx)
Open voltage: 8VDC typical
Accuracy: ±(10%rdg +10dgts)
Display: forward junction voltage
Overload protection: 25VDC or AC rms

CAPACITANCE
Ranges: 200pF, 2nF, 20nF, 200nF, 2μF, 20μF, 200μF, 2000μF
Accuracy: ±(1.0%rdg + 3dgts) on 200pF to 200nF ranges ±(2.0%rdg + 3dgts) on 2μF to 200μF ranges
±(3.0%rdg + 3dgts) on 2000μF range: £1000μF
±(5.0%rdg + 10dgts) >1000μF
Test frequency:
1000Hz on 200pF to 2μF range
100Hz on 20μF to 200μF range
10Hz on 2000μF range
Temperature Coefficient:
£0.5μF: 0.1%/°C
>0.5μF: 0.2%/°C
Overload protection: 0.1A/250V fast blow fuse
Note: in lower range 200pF, 2nF subtract residual offset reading from result with test leads opening.

OPERATION
However, electrical noise or intense electromagnetic fields in the equipment may disturb the measurement circuit. Measuring instruments will also respond to unwanted signals that may be present within the measurement circuit. Users should exercise care and take appropriate precautions to avoid misleading results when making measurements in the presence of electronic interference.

Capacitance

1. Discharge capacitors before trying to measure it.
2. Set the Range to the desired C range.
3. Insert the leads directly in to socket or test leads sockets.
4. Never apply an external voltage to sockets damage to the meter may reset.
5. Read the capacitance directly from the display.
Note: in lower range 200pF, 2nF subtract residual offset reading from result with test leads opening.