EC2254 – LINEAR INTEGRATED CIRCUITS

1.1. What is an integrated circuit?

An integrated circuit (IC) is a combination of interconnected circuit elements inseparably associated or with in continuous substrate.

1.2. Define substrate.

The substrate is the supporting material upon or with in which an IC is fabricated or to which an IC is attached.

1.3. Define monolithic IC.

A monolithic IC is an IC whose elements are formed in place upon or within a semiconductor substrate with at least one of the elements formed within the substrate.

1.4. What is a hybrid IC?

A hybrid IC consists of a combination of two or more IC types.

1.5. Define wafer.

It is the basic physical unit used in processing. It consists of large number of identical ICs.

1.6. What are the advantages of ICs over discrete circuits?

There are many advantages of ICs over discrete circuits. They are:

- Low cost.
- Small size.
- Improved performance.
- Low power consumption.
- High reliability.
- Mass production capability.
- Increased operating speed.
- Less weight.
- Easy replacement.

1.7. What are the limitations of ICs?

The limitations of ICs are as follows:

Since ICs are small and unable to dissipate large amount of power, the heat produced by large elements may destroy the IC. The transformers and inductors cannot be fabricated using IC technology.

1.8. What are the applications of ICs?

Integrated circuits have become part and parcel of human life. Computers cellular phones and other digital appliances are now inextricable parts of the structure of modern societies. That is, modern computing, communications, instrumentation, manufacturing and transport systems, including the internet, all depend on the existence of integrated circuits. Among the most advanced integrated circuits are the microprocessors and

microcontrollers which control everything from computers, cellular phones to household appliances.

1.9. What is the classification of ICs based on complexity level?

Based on the complexity level (number of gates on a chip) ICs are classified as

- Small scale integration (SSI).
- Medium scale integration (MSI).
- Large scale integration (LSI).
- Very large scale integration (VLSI).

1.10. What is the classification of ICs based on fabrication process?

Depending on the fabrication process ICs are classified as i) monolithic IC ii) Hybrid IC.

1.11. What is the classification of ICs based on the function performed?

Based on the functions performed integrated circuits can be classified into analog and digital ICs.

1.12. What is meant by epitaxial growth?

The term epitaxial growth means "arranging upon". It is the process of depositing a thin layer (0.5 to 20 microns) of single crystal material over a single crystal substrate.

1.13. What is photolithography?

Photolithography is a process used in semiconductor device fabrication to transfer a pattern from a photo mask to the surface of a wafer.

1.14. Define etching. What are the different types?

It is a process of removing a film or layer from the substrate in those areas not covered with photo resist. There are two types of etching i) wet etching and ii)dry etching.

1.15. What are the properties of the chemicals used for etching?

The chemicals used for etching (etchant) should have the following characteristics:

- It should react with the film etched in a smooth manner producing suitable products that can be carried away from the surface.
- It should not react with photo resist.
- It should be act with film to be etched and not with other microelectronic materials.

1.16. Define diffusion.

Diffusion is a process where the particles move from regions of higher concentration to regions of lower concentrations.

1.17. What is meant by ion implantation?

Ion implantation is the introduction of ionized particles atoms into targets with enough energy to penetrate beyond surface regions.

1.18. What are the advantages of ion implantation?

- Unlike diffusion, which is a high temperature process, ion implantation is a low temperature process.
- It permits greater flexibility in designing.
- It is a high precision tool. It precisely controls the number of dopant atoms.

1.19. What is meant by surface passivation?

The process of creating the protective SiO_2 layer on the wafer surface is known as surface passivation.

1.20. What is the purpose of formation of SiO_2 layer?

The formation of SiO_2 layer serves many purposes.

- It serves as diffusion mask and allows diffusion impurities through carefully defined windows etched into oxide.
- It serves as an insulator in the wafer surface.
- It protects the junction from moisture and other atmospheric contaminants.

1.21. What is meant by metallization?

After devices have been fabricated in the silicon substrate, interconnections must be made to link all the components on the chip. This process is called metallization.

1.22. Why aluminum is most preferred for metallization?

Aluminum is the mostly used metal for metallization. It has the following advantages:

- It is a good conductor.
- It makes good mechanical bonds with silicon.
- It is cheap.
- It is easy to deposit aluminum films using vacuum decomposition.

1.23. What are the different IC packages?

There are three different IC packages. They are

- To- glass metal.
- Ceramic flat package.
- Dual-in-line (ceramic or plastic type).

1.24. What are the different CMOS technologies?

The CMOS technologies are p-well process, n-well process, twin-tub process and silicon on insulator.

1.25. What is a differential amplifier? What is the ideal value of its gain?

A differential amplifier is one which amplifies the difference between its two input signals. The gain with which it amplifies the difference is called its differential gain and ideally it should be infinite.

1.26. What is common mode gain of a differential amplifier?

If the two input signals to a differential amplifier are same, then its output should be zero. But practically it produces a small output which is proportional to the average common level of the two input signals. The factor by which the differential amplifier amplifies the common mode signal is called its common mode gain.

1.27. What is CMRR? State its ideal value.

The ability of the differential amplifier to reject common mode signal is expressed by the ratio of differential gain to the common mode gain which is called its common mode rejection ratio CMRR. The ideal value of CMRR is infinite.

1.28. List out various configurations of a differential amplifier.

- Dual input, balanced output.
- Dual input, unbalanced output.
- Single input, balanced output.
- Single input, unbalanced output.

1.29. Why practically R_E cannot be selected very high?

Practically R_E cannot be selected very high because:

- Large R_E requires higher biasing voltages to set the proper operating point of the transistor.
- This increases the overall chip area.
- Smaller number of components can be installed on the same chip which is undesirable from integrated circuit point of view.

1.30. Why constant current source is used instead of R_E?

Without physically increasing the value of R_E , the R_E replaced by a transistor operated at a constant current. Such a constant current source circuit gives the effect of a very high resistance as the internal resistance of a constant current is infinite. And due to transistorized circuit, it needs smaller supply voltage; hence it does not affect the Q point of the basic circuit. Effect of higher value of R_E is provided by a constant current source due to which common mode gain becomes very small and due to which CMRR becomes very high.

1.31. What is current mirror?

The circuit in which the output current is forced to equal the input current is called current mirror.

1.32. List the advantages of current mirror.

- Provides very large emitter resistance R_E.
- Requires lesser components than constant current bias.

- Simple to design.
- Easy to fabricate.
- With properly matched transistors, collector current thermal stability is achieved.

1.34. Why current mirror circuit is often used?

The constant current bias can be easily replaced by constant current mirror circuit to improve CMRR. Due to these advantages, current mirror circuit is most commonly used in the integrated circuit op-amps.

1.35. What is active load? Why it is used in the differential amplifier?

The current mirror circuit is used as a collector load resistance is called an active load. This circuit provides high value of a.c. collector resistance which is required to achieve high differential gain but it does not disturb d.c. conditions of the circuit. The quiescent voltage required across the current mirror is a fraction of the supply stage. This eliminates the need for high biasing supply voltages. Due to all these advantages, active load is used in the differential amplifier circuit.

1.36. What is a voltage reference circuit?

A voltage reference circuit is a constant d.c. voltage source which acts as a reference or standard for other circuits and is independent of changes in parameters like temperature, line voltage, load current etc.

1.37. List the performance parameters of a voltage reference circuit.

- Line regulation.
- Load regulation.
- Long term stability.
- Ripple rejection ratio.

1.38. State the applications of bandgap reference circuit.

The various applications of bandgap reference circuits are

- Voltage regulators
- D/A and A/D converters.
- Voltage to frequency and frequency to voltage converters.
- Power supply surpervisory circuit.
- Bar graph meter.

1.39. Define slew rate.

Slew rate can be defined as the maximum rate of change of output voltage of op-amp with respect to time.

1.40. What causes slew rate?

The rate at which the internal or external capacitance of op-amp charges causes slew rate.

1.41. How can the slew rate made faster?

The slew rate can be made faster by having a high charging current or a small capacitance value.

1.42. Give the different types of IC packages.

ICs are available in three popular packages. They are:

- Metal can package.
- Dual-in line package.
- Flat package or flat pack.

1.43. What is an op-amp?

The operational amplifier is a multi-terminal device which is quite complex internally. An operational amplifier is a direct coupled high gain amplifier usually consisting of one or more differential amplifiers and usually followed by a level translator and an output stage. An operational amplifier is available as a single integrated circuit package. It is a versatile device that can be used to amplify dc as well as ac input signals and was originally designed for computing such mathematical operations.

1.44. Mention some applications of op-amp?

With the addition of suitable external feedback components, the modern day op-amp can be used for a variety of applications such as ac and dc signal amplification, active filters, comparators, oscillators, regulators and other applications.

1.45. What are the characteristics of ideal op-amp?

- Open loop voltage gain, (A_{ol}) = ∞.
- Input impedance (R_i) = ∞.
- Output impedance (R_o) = 0.
- Bandwidth (BW) = ∞.
- Zero offset V_0 = 0,when $V_1 = V_2 = 0$.

1.46. Define input offset voltage.

It is defined as the voltage that must be applied between the input terminals of an op-amp to nullify the output.

1.47. Define input bias current.

It is defined as the average of the current entering into the input terminals of op-amp.

1.48. Define input bias current.

It is defined as the average of the current entering into the input terminals of an op-amp.

1.49. What are the modes in which op-amp is operated with? Give the gain of the op-amp in each mode.

Open-loop mode: infinite gain. Example: comparator.
Closed-loop mode: finite gain. Example: amplifier.

1.50. What is an compensated op-amp?

Op-amp, such uses a capacitor internally for compensation is called a compensated op-amp. This op-amp has a high gain stability and low bandwidth.

1.51. What are the methods used in external compensation technique?

- Dominant-pole compensation.
- Pole-zero compensation.

1.52. What are the methods to improve slew rate?

- The slew rate can be improved with a higher closed-loop gain and dc supply voltage. But the slew rate also varies with temperature i.e. slow rate decreases with increase in temperature.
- Another method for improving slew rate is, the rate at which voltage across the capacitor increases is gained by

$$dVc/dt = I / C$$

where I is the maximum current furnished by the op-amp to the capacitor C. from the equation it is clear that for a higher slew rate, op-amp should have either a higher current or a small value of capacitor.

1.53. What are the AC characteristics of an op-amp?

- Frequency response.
- Slew rate.

1.54. What are the DC characteristics of an op-amp? Give typical values for an IC741.

- Input bias current: 500nA.
- Input offset current: 200nA.
- Input offset voltage: 6mV
- Thermal drift.

1.55. What produces more offset voltage at the output? Input offset current or input bias current?

Input bias current produces more offset voltage at the output.

1.56. In what way is 741S a better grade op-amp with a higher slew rate?

741 S is a military grade op-amp with a higher slew rate.

UNIT II

Applications of Operational Amplifiers

2.1. What is a practical Op-amp? Draw its equivalent circuit.

A practical Op-amp has voltage gain to be less than that of ideal one. Its input impedance is very high, bandwidth is very high ,offset voltage is near to zero , slew rate is very high, and output impedance is near zero.

2.2. What is linear op-amp circuit?

An op-amp circuit which has the output signal with the same shape as that of the input signal is called linear op-amp circuit. The op-amp does not go to saturation during its cycle.

2.3.What do you meant by linear circuits?

Linear circuits are the circuits in which the output signal varies with the input signal in a linear manner.

2.4. What is non linear op-amp circuit?

An op-amp circuit which has the output signal with a different shape from the input signal is called non linear op-amp circuit. The op-amp saturates during part of its input cycle.

2.5. List out some of the linear op-amp circuits.

Linear op-amp circuits are :

1. Inverting amplifiers,
2. Non inverting amplifiers,

3. Differential amplifiers,
4. Instrumentation amplifiers,
5. Current boosters ,
6. Adders/Subtractors,
7. Power amplifiers,
8. V-I and I-V converters.

2.6. List out some non linear op-amp circuits.

Non linear op-amp circuits are:

2.6.1.1. Comparators

2.6.1.2. Wave shapers

2.6.1.3. Active diode circuits

2.6.1.4. Rectifier circuits

2.6.1.5. Log and antilog amplifiers.

2.7. How is the gain stabilized by negative feedback?

Negative feedback is used mainly to stabilize the overall voltage gain. If the open loop voltage gain A_{OL} increases for any reason, the output voltage will increase and feeds back more voltage to the inverting input. This opposing feedback voltage reduces inverting input voltage V(-). Therefore even though A_{OL} has increased, inverting input voltage V(-) has decreased and the final output increases much less than that it would be without the negative feedback.

2.8. What is voltage follower?

Voltage follower is the circuit in which the output voltage follows the input voltage both in magnitude as well as in phase. The circuit diagram of voltage follower is given below:

2.9. List out the important features of an instrumentation amplifier.

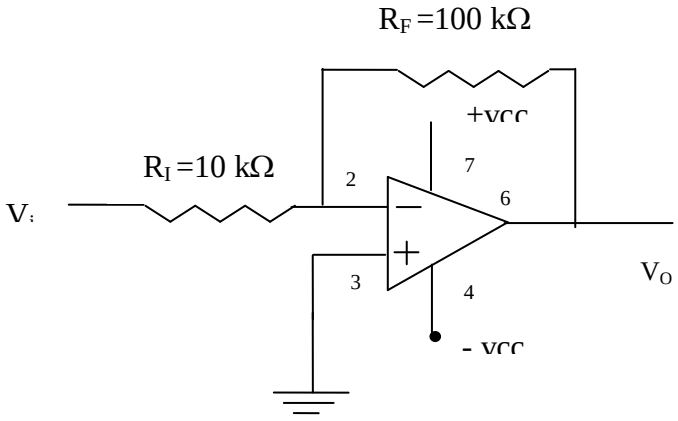
The Important features of an instrumentation amplifier are :

1. High gain accuracy
2. High CMRR
3. High gain stability with low temperature coefficient
4. Low dc offset

5. Low output impedance

2.10. What is an inverting amplifier?

Inverting amplifier is the one in which a signal is applied to the inverting input terminal. The output voltage is fedback to the inverting input terminal through feedback resistance (R_f) - input resistance (R_I) network. The output signal is the amplified form of input signal with a phase shift of 180° .The circuit diagram of inverting op-amp is given below:



2.11.List the applications of instrumentation amplifier.

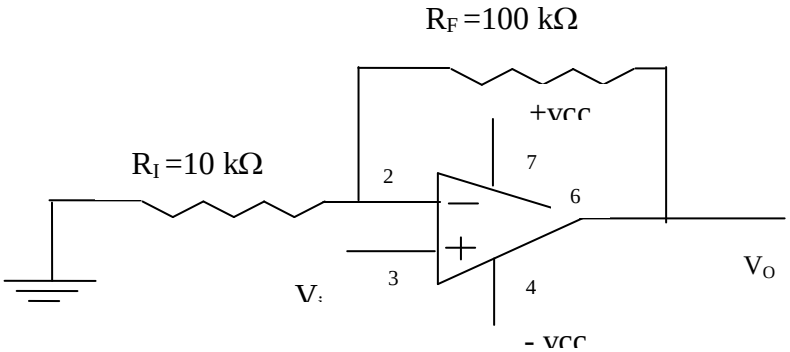
The applications of instrumentation amplifier are :
1. Temperature indicator
2. Temperature controller
3. Light intensity meter
4. Water flow meter

2.12. **List out the important features of an instrumentation amplifier.**

The Important features of an instrumentation amplifier are :
1. High gain accuracy
2. High CMRR
3. High gain stability with low temperature coefficient
4. Low dc offset
5. Low output impedance

2.13. What is a non inverting amplifier?

Non inverting amplifier is the one in which a signal is applied to the non inverting input terminal and the output is fedback to the inverting input terminal, the circuit amplifies without inverting the input signal. The circuit diagram of non-inverting amplifier is given below:



2.14. What are the basic requirements of instrumentation amplifier?

The basic requirements of instrumentation amplifier are :

1.High gain
2.High CMRR
3.High gain stability
4.Low DC offset

2.15. What is a differentiator?

A differentiator is the circuit which perform the mathematical operation of differentiation, i.e., the output waveform is the derivative of the input waveform. The output voltage is given by

$$V_O = -R_f C_i \ (d\ (V_i) / dt)$$

Where R_f is the feedback resistor, C_i is the input capacitance and V_i is the input voltage.

2.16. What are the main drawbacks of ideal differentiator?

The main drawbacks of ideal differentiator are :

1. At high frequency, the differentiator may become unstable and break into oscillation.

2. The input impedance decreases with increase in frequency, thereby making the circuit sensitive to high frequency noise.

2.17. Mention the main applications of differentiator.

The main applications of differentiator are :

- Used in wave shaping circuits to detect high frequency components in an input signal.
- Used as rate of change detector in FM modulations.

2.18. What is an integrator circuit? How is it obtained?

An Op-amp circuit that produces an output signal, which is an integral of input signal, is called as integrator circuit. It is obtained by simply interchanging resistor and capacitor of differentiator circuit.

2.19. List the drawbacks of ideal integrator.

The drawbacks of ideal integrator are :

- At low frequencies (dc), gain becomes infinity.
- When the op-amp saturates i.e. the capacitor is fully charged, ideal integrator behaves like an open circuit.

2.20. Why is the practical integrator called as lossy integrator?

The gain of the integrator at lower frequencies can be limited to avoid the saturation problem, if the feedback capacitor C_f is shunted by a resistor R_f .The parallel combination of R_f and C_f behaves like practical capacitor, which dissipates power, unlike an ideal capacitor. For this reason, the circuit is called as lossy integrator.

2.21. List any four applications of practical Integrator.

The applications of practical integrator are as follows :

1.Analog computers
2.Analog to digital computers
3.Wave shaping circuits
4.In ramp generators

2.22. Mention the two types of voltage to current converter?

Two types of voltage to current converter are:

- V-I converter with floating load

- V-I converter with grounded load

2.23. Give the applications of V-I converter.

The main applications of voltage to current converter are :

- Low voltage dc and ac voltmeter
- In LED and Zener diode tester

2.24. Define Electric filter.

An electric filter is defined as a frequency selective circuit that passes a specific band of frequencies and blocks or attenuates signals of frequencies outside this band.

2.25. Mention the classification of electric filters.

The classifications of electric filters are :

- Analog or digital
- Passive or active
- Audio (AF) or radio frequency (RF).

2.26. Mention the advantages of active filters.

The advantages of active filter are :

- Gain and frequency adjustment is flexible
- No loading problem
- Cost is low

2.27. List the advantages of active filters over passive filters.

The advantages of active filters are:

- 1.Flexibility in gain adjustments
- 2.Flexibility in frequency adjustments
- 3.No loading effect in signal source and driving circuit
- 4.Low cost due to absence of inductor

2.28. Mention the disadvantages of passive filters.

The Disadvantages of passive filter are :

- Inductors become large, heavy and expensive for low frequency applications.

- More number of turns of wire must be used which in turn adds to the series resistance degrading inductor's performance.(i.e.)low Q, resulting in high power dissipation.

2.29. Define frequency scaling.

Frequency scaling is defined as the procedure used to convert an Original cut-off frequency f_h to a new cut-off frequency f_h.

2.30. What is a comparator?

A comparator is a circuit which compares a signal voltage applied to one input of an op-amp with known reference voltage at other input. It is basically an op-amp with output $\pm (V_{sat})$.

2.31. What are the characteristics of the comparator?

The important characteristics of the comparators are :

1.Speed of operation
2.Accuracy
3.Compatibility of the output

2.32. List the different types of comparator?

There are basically two types of comparators :

1.Inverting comparators

2.Non- Inverting comparators

2.33. List out the applications of comparator.

The applications of comparator are:

- Zero crossing detector
- Window detector
- Time marker generator
- Phase meter

2.34.**What is Schmitt trigger?**

Schmitt trigger is an inverting comparator with positive feedback. It converts an irregular-shaped waveform to a square wave or pulse, and is called as squaring circuit.

III UNIT
ANALOG MULTIPLIER AND PLL

3.1. Name a few applications of an analog multiplier:

- Frequency doubling.
- Frequency shifting.
- Phase angle detection.
- Squaring.
- Multiplication.
- Division.
- Waveform generation.

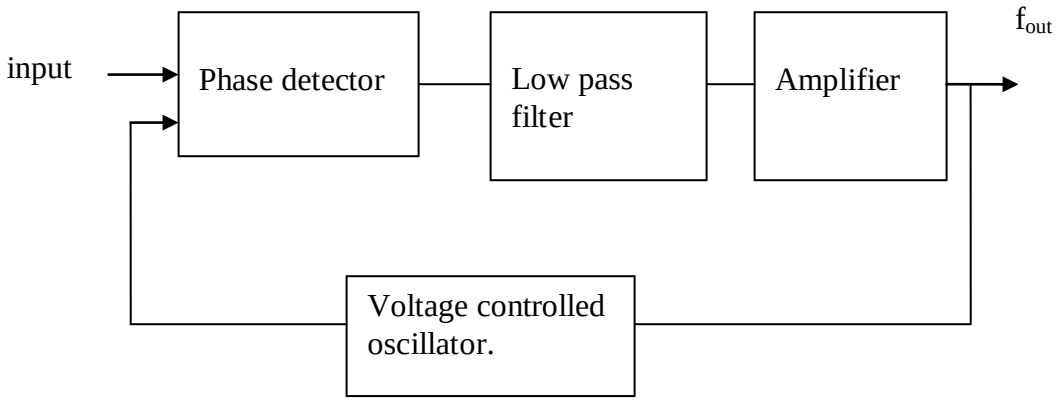
3.2. Define pull time of PLL.

Pull time of a PLL is defined as the total time taken by the PLL to establish lock.

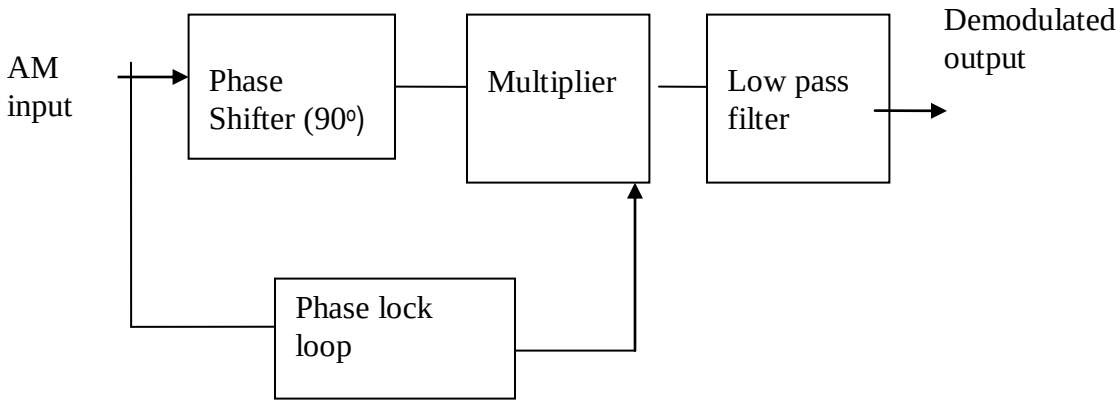
3.3. What are the functional blocks of PLL?

- Phase comparator.
- Low pass filter.
- Error amplifier.
- Voltage controlled oscillator.

3.4. Draw the functional block diagram of a PLL.



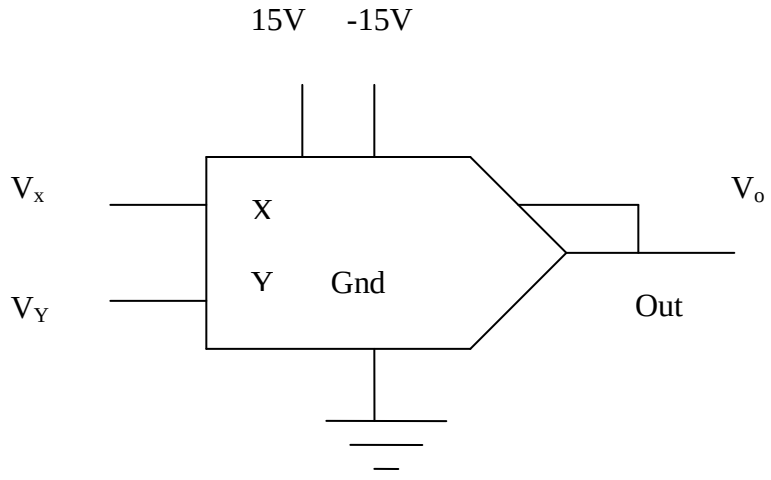
3.5. Draw circuit diagram of an AM detector using PLL.



3.6. Mention a few applications of PLL.

- Frequency multiplication.
- Frequency division.
- AM detection.
- FM detection.
- FSK demodulator.
- Frequency translation.

3.7. Give the schematic symbol of multiplier.



3.8. Define multiplier.

The multipliers are circuits used for multiplying two applied signals. Apart from this, multipliers can be used for phase angle detection, frequency doubling and shifting and for demonstrating the principle of amplitude modulation and demodulation.

3.9. Give the classification of multiplier.

- One- quadrant multiplier.
- Two- quadrant multiplier.
- Three - quadrant multiplier.
- Four- quadrant multiplier.

3.10. List the characteristics of multipliers.

- Bandwidth.
- Feed through.
- Zero train.
- Quadrant.
- Scale factor.
- Scale-factor train.
- Accuracy.
- Linearity.

3.11. What is a trans-conductance multiplier?

Log-amps require the input and reference voltages to be of the same polarity. This restricts log-antilog multipliers to one quadrant operation. A technique that provides four-quadrant multiplication is trans-conductance multiplier.

3.12. What is four quadrant multiplier?

If both inputs are positive, the IC is said to be a one-quadrant multiplier. A two-quadrant multiplier will function properly if one input is held positive and the other is allowed to swing both positive and negative. If both inputs are either positive or negative, the IC is called a four quadrant multiplier.

3.13. List the various multiplier techniques.

- Logarithmic multipliers.
- Quarter square multipliers
- Pulse width/height modulation multipliers.
- Variable trans-conductance multipliers.

3.14. What is the range of modulating input voltage applied to a voltage controlled oscillator?

The modulating input voltage ranges from 0.75Vcc to Vcc.

3.15. Define VCO.

The VCO is a free running multivibrator and operates at a set frequency called free running frequency. This frequency is determined by an external timing capacitor and an external resistor.

3.16. List the features of VCO.

- Wide supply voltage range from 10V to 24V.
- Very linear modulation characteristics.
- High temperature stability.
- Excellent power supply rejection.
- 10 to 1 frequency range with fixed C.
- The frequency can be controlled by means of a control voltage resistor or capacitor.

3.17. Give the applications of VCO.

- FM modulation.
- Signal generation(triangular or square wave)
- Function generation.
- In frequency multipliers.
- Converting low frequency signals such as EEG and ECG into audio frequency range signals.

3.18. What are the different stages of operation in a PLL?

- Free running range.
- Capture range.
- Locked or tracking range.

3.19. Define lock-in range.

The range of frequency over which the PLL can maintain lock with the incoming signal is called the lock-in range.

3.20. What is meant by capture range of PLL?

The range of frequency over which the PLL can acquire lock with an input signal is called capture range.

3.21. Give the types of analog phase detectors and digital phase detectors.

The types of analog phase detectors are as follows:

- Switch type phase detector.
- Balanced modulator type phase detector.

The types of digital phase detectors are as follows:

- X-OR phase detector.
- Flip-flop phase detectors.

3.22. List the advantages of flip-flop type phase detector over EX-OR phase detector.

The flip flop phase detector has the following advantages over the EX-OR circuit:

- The dc output voltage is linear over 2π radians or 360^o, as opposed to π or 180^o in the case of EX-OR detector.
- The flip-flop detector exhibits between capture, tracking, and locking characteristics than the EX-OR detector.
- The RS flip-flop works best with low duty cycle(50%) input waveform. However both the types of detectors are sensitive to harmonics of the input signal and change in duty cycle of f_i and f_o .

3.23. What should be the phase difference between the input signal and voltage controlled oscillator output to active lock?

Input signal and voltage controlled oscillator should be 90^o out of phase with each other.

3.24. A phase comparator is basically a **multiplier**.

3.25. The capture range is controlled by the **low pass filter** in a PLL.

3.26. Lock in range of a PLL is **greater than** capture range.

3.27. FSK means **frequency shift keying.**

3.28. Define amplitude modulation.

The amplitude of a high frequency carrier wave is varied in accordance with the message signal (input signal) and this process is called modulation.

3.29. Define demodulation.

Demodulation or detection is the process of recovering a modulating signal E_m from the modulated output voltage V_o.

3.30. What is the need for amplitude modulation?

The need for amplitude modulation is:

- Low frequency audio or data signals cannot be transmitted from antenna of reasonable size.
- Changing or modulating some characteristics of higher frequency carrier wave can transmit audio signals.
- Changing the frequency of the carrier is changed in proportion to the audio signal, the process is called amplitude modulation (AM).
- Changing the frequency or the phase angle of the carrier wave results in frequency modulation(FM) and phase angle modulation(PM) respectively.

- The original audio signal must be recovered by a process called demodulation or detection.

3.31. Define FSK techniques.

During digital data transmission, binary code is transmitted by shifting a carrier frequency between two frequencies. This type of transmission is called frequency shift keying technique.

3.32. A PLL has a free running frequency of 500 kHz and bandwidth of the low pass filter is 10 kHz. Will the loop acquire lock for an input signal of 600 kHz? Justify your answer. Assume that the phase detector produces 50 m and difference frequency components.

The phase detector output

$f_i + fc = 600 \text{ kHz} + 500 \text{ kHz}$
$= 1100 \text{ kHz}$

$f_i - fc = 600 \text{ kHz} + 500 \text{ kHz}$
$= 100 \text{ kHz}$

As both the components are outside the pass band of low pass filter, the loop will not acquire lock.

3.33. What is modulation?

Some characteristics of the carrier wave change in accordance with the instantaneous value of a incoming signal or modulating signal.

3.34. Give the advantages of variable Transconductance technique.

- Good accuracy.
- Economical.
- Simple to integrate into monolithic chip.
- Higher bandwidth.

3.35. What is companding?

The combination of words compression and expanding in a communication system is called companding. The compression is done in the transmitter and expanding is done in the receiver.

3.36. What is the purpose of companding?

The purpose of companding is to preserve the signal to noise ratio of the original signal and to avoid nonlinear distortion of the signal when the input amplitude is large.

3.37. Define scale factor of multiplier.

Scale factor is proportionally constant (k) relating the output voltage and the product of two input voltage.

$k = (V_o / V_1V_2)$.

3.38. Name two applications of PLL (may 2004)

- Frequency multiplier.
- Frequency shift keying (FSK) demodulator.
- Frequency translation.
- Frequency synthesizer.
- AM detection.
- FM detection.

3.39. What is an OTA?

An OTA(operational transconductance amplifier) is a voltage-input current output amplifier.

3.40. Give the applications of OTA.

- Programmable gain voltage amplifier.
- Sample and hold circuits.
- Programmable resistor or electronically tunable resistor or voltage controlled resistor.
- Current-controlled relaxation oscillator.
- Integrators in audio processing.
- Electronic music synthesis.

IV UNIT

ANALOG TO DIGITAL AND DIGITAL TO ANALOG CONVERTERS

4.1. Give an application of a sample and hold circuit.

- Digital interfacing.
- Analog to digital converters.
- Pulse code modulation systems.

4.2. Give few areas of applications where dual slope ADC is used.

Dual slope ADC is suitable for precise measurement of slow varying signals like the output of thermocouples and weighing scales. Hence they are used in digital panel meters, multimeters and monitoring systems.

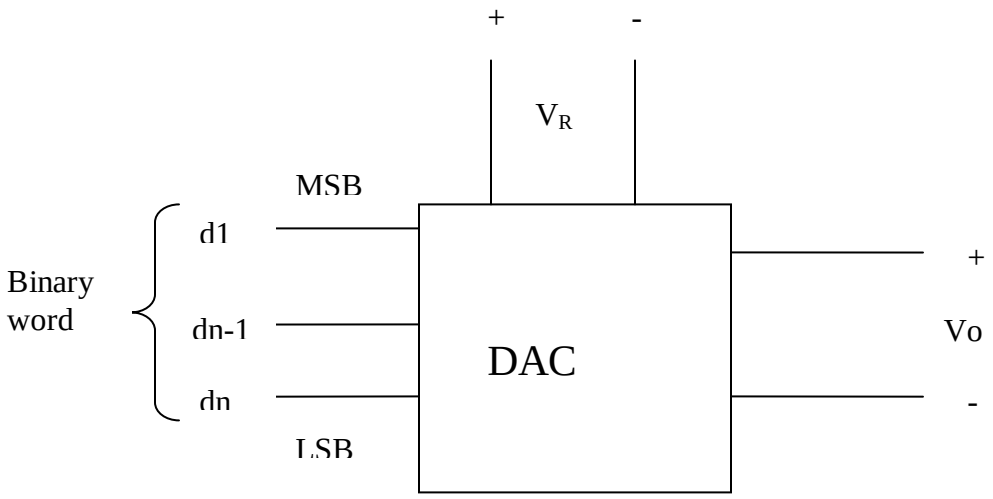
4.3. Where do we use successive approximating type ADC?

Successive approximating type ADC is used in applications where conversion speed is an important parameter. Hence it is used in data logger and instruments.

4.4. What is DAC?

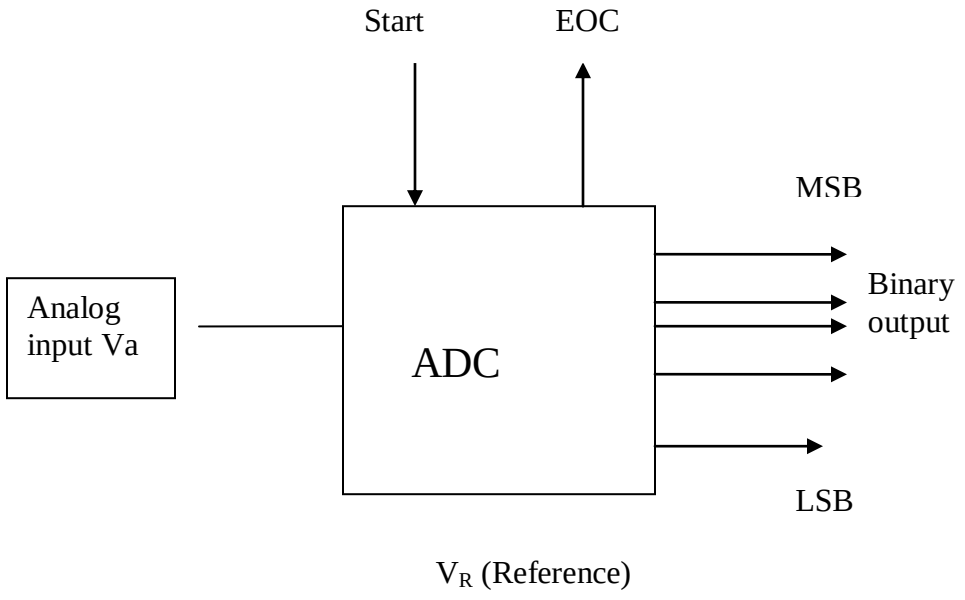
A digital to analog converter (DAC) is used to convert a digital signal to an analog signal. Hence the input is an n-bit binary word D and is combined with a reference

voltage V_R to give an analog output signal. The output of DAC is either a voltage or a current.



4.5. What is ADC?

An analog to digital converter is used to convert an analog signal to a digital signal. Hence the input is an analog signal, and digital output is an binary form.



The circuit accepts an analog input voltage V_a and produces an output word d_1, d_2, ……d_n of functional value of D., so that

$$D = d_1 2^{-1} + d_2 2^{-2} + \ldots\ldots d_n 2^{-n}$$

Where d_1 is the most significant bit, d_n is the least significant bit.

4.6. List the various ADC techniques.

ADC broadly classified into two types:

(i) Direct type ADC

- Flash type converter.
- Counter type converter.
- Tracking type converter (or) servo converter.
- Successive approximation type converter.

(ii) Integrating type ADC

- Charge balancing type converter.
- Dual slope type converter.

4.7. What is meant by direct type ADC?

Direct type ADC compares a given analog signal with the internally generated equivalent signal.

4.8. What is meant by integrating type ADC?

This type performs conversion in an indirect manner by first changing the analog input signal to time or frequency and then to digital code.

4.9. What are the advantages of ADC technique?

- It is possible to transmit frequency even in a noisy environment.
- Used for precision measurement of slow varying signal.

4.10. Mention the types of DAC techniques.

- Weighted resistance DAC.
- Inverted R-2R ladder DAC.
- R-2R ladder DAC.
- Multiplying DAC.

4.11. Give some sample and hold ICs.

Harris semiconductor HA2420, national semiconductor such as LF 198, LF398 are used as sample and hold ICs.

4.13. List the advantages of sample and hold circuit.

- The primary use of the sample and hold circuit is to hold the sampled analog input voltage constant during conversion time of A/D converter.
- In case of multi channel ADCs, synchronization can be achieved by sampling signals from channels at the same time.

- It also reduces the cross talk in the multiplexer.

4.14. Give some applications of sample and hold circuit.

- Digital interfacing.
- Analog to digital converter circuits.
- Pulse modulation systems.
- In reset-stabilized op-amps.
- In analog demultiplexers.

4.15. Write the important specifications of digital to analog converter (DAC) and analog to digital converter (ADC).

- Resolution.
- Linearity.
- Accuracy.
- Monotonic.
- Settling time.
- Stability.

4.16. Compare weighted resistor DAC over R-2R DAC?

Si.no.	Binary weighted resistor DAC	R-2R DAC
1.	Requires a wide range of resistor values.	Requires only 2 values of resistor
2.	Due to higher values of resistor required for LSB, the use of weighted resistor DAC in monolithic form restricted to 8-bits.	No such restriction as only 2 resistor values are used whatever may be number of inputs.

4.17. What is the advantage of inverted R-2R ladder DAC?

The most important advantage of the inverted ladder DAC is that, since the ladder node voltage remains constant, the stray capacitances are not able to produce slow down the effects on the performance of the circuit.

4.18. What are the switches used in DAC?

The switches used in DAC are in series with resistors, and therefore, their as on resistance must be very low. Bipolar transistors do not perform as well as monolithic switches due to the inherent offset voltage when in saturation. However, by using MOSFET, this can be achieved.

4.19. What is single slope ADC?

The single slope ADC is also known as integrating ADC. Instead of using a DAC with a ramped output, we use an op-amp circuit called an integrator to generate a saw tooth waveform, which is then compared against the analog input by a comparator. The

time it takes for the saw tooth waveform to exceed the input signal voltage level is measured by means of a digital counter closed with a precise-frequency square wave.

4.20. What are the advantages of dual slope ADC?

These are particularly suitable for accurate measurement of slowly varying signals, such as thermocouples and weighing scales. These are also used in digital panel meters and multimeters.

4.21. What is the disadvantage of dual slope ADC?

The main disadvantage of this type is the long conversion time.

4.22. What do you mean by delta modulation?

Delta modulation is a method of information transmission with the help of pulses. The modulation is done by using a dingle digit code that transmits information about the slope of the signal amplitude, rather than the actual amplitude, as in PCM or other pulse modulation systems.

4.23. What is the need of adaptive delta modulation?

Adaptive delta modulation is an improvement over delta modulation and overcomes the problem of slope overload that is often encountered in the latter when modulating signal varies at a fast rate. At this fast rate, the output signal will only alternate above and below the modulating signal and handling results.

4.24. What is voltage to time converter?

The linear ramp technique is essentially a voltage to time converter. As the name of this technique implies, a linear ramp is used to convert an analog dc signal into a front panel digital representation.

4.25. Give the advantages of voltage to time converter?

- Linearity.
- Accuracy.
- Absolute slope the ramp and the frequency setting.
- Stability of the oscillator.

4.26. What is voltage to frequency converter?

These converters convert the applied input voltage to an output frequency. This can be done using Teledyne 9400 series. The series includes the 9400, 9401 and 9402 converters. Using 2 capacitors, 3 resistor and reference voltage can form a complete circuit.

4.27. What is the resolution of DAC?

The resolution of a DAC is the smaller change in voltage which may be produced at the output or input of the converter.

4.28. The advantage of integrating type ADC technique is it **does not require a sample and hold circuit.**

4.29. The fastest conversion of analog input to digital output is possible in a **successive approximation type.**

4.30. What are the control lines of a ADC?

- Start input to tell the ADC when to start the conversion.
- EOC(end of conversion) output to announce when the conversion is completed.

4.31. List the advantages of R/2R ladder network.

- Easy to build accurately as only two precision metal film resistors are required.
- Number of bits can be expanded by adding more sections of same R/2R values.

4.32. What are the draw backs of weighted resistor D/A converter?

- Wide range of resistor values is required. For an 8-bit DAC the resistors required are 2^1R,2^2R ,2^3R,…..2^8R.. Therefore, the largest resistor is 128 times the smallest one.
- The wide range of resistor values has restrictions on both higher and lower ends. It is impracticable to fabricate large value of resistor in IC and voltage drop such a large resistor due to the bias current also affects the accuracy. For smaller values of resistors, loading effect may occur.
- The finite resistance of the switches disturbs the binary-weighted relationship among the various currents, particularly in the MSB positions, where the current setting resistance is smaller.

4.33. Define settling time.

The time required for the analog output to settle to within ± ½ LSB of the final value after a change in the digital input is usually specified by the manufacturers and is referred to as settling time.

4.34. Define conversion time.

It is the time required for conversion of analog signal into its digital equivalent. It is also called settling time. It depends on the response time of the switches and the output of the amplifier.

4.35. Define stability.

The performance of a converter changes with temperature, age, and power supply variations. So all the relevant parameters such as offset, gain, linearity error and monotonicity must be specified over the full temperature and power supply ranges. These parameters represent the stability of the converter.

4.36. Define accuracy.

The accuracy f a D/A converter is a measure of the difference between the actual output voltage and the expected output voltage. It is specified as a percentage of full-scale or (maximum) output voltage.

4.37. List the advantages of flash type A/D converter.

- It has high speed, as the conversion takes place simultaneously rather than sequentially.
- Typical conversion time is less.
- Conversion time is limited only by the speed of the comparator and of the priority encoder.

4.38. List the source of errors in ADC.

- Linearity error.
- Gain error.
- Offset error.

4.39. Give the basic problems in delta modulator circuit.

The delta modulator suffers from two basic problems. They are:

- Slope overload.
- Granule noise.

4.40. When will slope overload occur?

If the input analog signal changes faster than the speed of the modulator then a slope overload will result.

4.41. Define granule noise.

Granule noise is defined as the difference between step-size and sampled voltage.

4.42. What is adaptive delta modulation?

The overall performance of a delta modulator can be improved without significant increase of the bandwidth requirements. This improvement of delta modulator performance can be achieved if the step size of the modulator does not remain constant, but rather changes (adapts) to the input signal amplitude variations. This method is known as continuously variable slope delta modulation.

UNIT V
SPECIAL FUNCTION ICs

5.1. What is 555 timer?

The device 555 timer is a monolithic timing circuit that can produce accurate and highly stable time delays or oscillations. Like general purpose op-amps, the 555 timer is reliable, easy to use and economical.

5.2. List the important features of 555 timer.

The features of 555 timer are as follows:

- Operation on +5V to +18V supply voltage in both astable and monostable modes.
- Adjustable duty cycle.
- Timing from μ sec to hours.
- High current output.
- Capacity to source or sink current of 200 μ A.
- Output can drive TTL.
- Temperature stability of 50 points per million (ppm) ^{o}C changes in temperature or 0.005 % ^{o}C.
- Reliable, easy to use, & low cost like a general purpose op-amp.

5.3. Write the applications of a 555 timer in monostable mode of operation.

- Pulse width modulation
- Pulse stretcher.

5.4. What is a counter timer?

When a timer circuit is connected as an oscillator and is used to drive a counter, it is known as a counter timer.

5.5. Name one counter timer IC.

XR2240.

5.6.List the modes of operation of 555 timer.

555 timer is operated in two modes. They are:

- Astable mode of operation.
- Monostable mode of operation.

5.7.What mode of operation of the timer IC is utilized for a frequency divider?

Monostable mode of operation of the timer is utilized for frequency divider.

5.8. How do we vary the duty cycle of an astable multivibrator using op-amp IC?

The duty cycle is given by

$$D = \frac{\text{ON TIME}}{\text{TOTAL TIME}}$$

For an astable multivibrator

the % duty cycle = $\frac{R_A + R_B}{R_A + 2R_B} \times 100$.

Therefore adjusting R_A , and R_B the duty cycle of an astable multivibrator can be varied.

5.9.List the applications of 555 timer in astable mode of operation.

- Square wave oscillator.
- FSK generator.
- Pulse position modulator.

5.10. Give the classification of regulators.

Basically the regulators are classified as

- Linear regulator.
- Switching regulator.

5.11. Define voltage regulation.

It may be defined as the ability of a power supply to maintain a constant output voltage in spite of as input fluctuations and changes in load resistance.

5.12. Define load regulation.

Load regulation can be defined as the change in regulated output voltage when the load current changes from minimum to maximum.

Load regulation = $V_{NL} - V_{FL}$

Where V_{NL}= load voltage with no load current.

V_{NL}= load voltage with full load current.

5.13. Define line regulation.

Line regulation can be defined as the change in a regulated load voltage for a specified range of line voltage.

Line regulation = $V_{HL} - V_{LL}$

Where V_{HL}= load voltage with high line voltage.

V_{NL}= load voltage with low line voltage.

5.14. Define ripple rejection.

Voltage regulators stabilize the output voltage against changes in input voltage. Ripple is equivalent to a periodic change in the input voltage. Therefore a voltage regulator attenuates the ripple that comes in with the unregulated input voltage.
The ripple rejection is defined as
Ripple rejection (R.R) = (V_{Rout} / V_{Rin}).

5.15. What do you meant by fixed voltage regulator?

Fixed voltage regulators provide a fixed or constant output voltage as designed by the manufacturer. They are classified as positive voltage regulator and negative voltage regulator.

5.16. List the features of positive voltage regulators.

- Has internal thermal overload protection.
- Has internal short circuit current limiting.
- The difference between V_{in} and V_o is 2 V.

5.17. What do you meant by adjustable voltage regulator?

Adjustable voltage regulators overcome the problem of producing fixed voltage regulator in all ranges required to suit various applications. A single adjustable voltage regulator is capable of providing an output voltage ranging from 1.2V to 57 V and hence it could gain more popularity compared to fixed voltage regulators.

5.18. What do you mean by dual power supply?

Dual power supply provides a constant voltage of both positive and negative polarity simultaneously. This is used for biasing discrete and integrated circuit requiring both positive and negative bias.

5.19. List the limitations of 3 pin regulators.

The 3 pin regulators have the following limitations:

- There is no short circuit protection.
- The output positive and negative voltage is fixed.

5.20. Give the functional blocks of IC 723 regulator.

The functional blocks of IC 723 regulator are

- Reference section.
- Regulating section.

5.21. List the important features of IC 723 regulator.

- Input voltage 40V max.
- Output voltage adjustable from 2V to 37V.
- Can be used either as a linear or switching regulator.
- Input and output short-circuit protection is provided.
- Low temperature drift and high ripple rejection.
- Small size, lower cost.
- It has good line and load regulation.
- Input and output short-circuit protection is provided.

5.22. What are the components of a basic voltage regulator?

Reference: voltage, error amplifier, feedback network and series or shunt control element.

5.23. Give the advantages of voltage regulators.

- Regulators are versatile, low in cost and easy to use.
- Power supply design is simple.
- It has programmable output current/ voltage boosting facility.
- Internal short circuit current limiting is also available.

5.24. Differentiate between linear and switching regulators.

Linear regulators	Switching regulators
The series pass transistor operates in the active region	The series pass transistor operates either at cut-off or at saturation
The efficiency is less	The efficiency is more.
Since the pass transistor is always in active region, power dissipation is more.	Power dissipation is less.

5.25. What are the limitations of linear voltage regulators?

- It requires a bulky and expensive step-down transformer at the input.
- Low efficiency.
- Large values of capacitors are required to reduce the ripple.

5.26. What are the three terminal regulators?

The three terminal regulators are regulators in which the output voltage is set at some pre-determined value. It has one input; one output and one ground terminal, IC78XX, IC79XX, IC723 are a few examples of this family.

5.27. Differentiate between positive and a negative regulator.

Positive regulator	Negative regulator
Gives a fixed positive output voltage	Gives a fixed negative output voltage
78XX, LM340 are positive option	There is a nine-output voltage option.

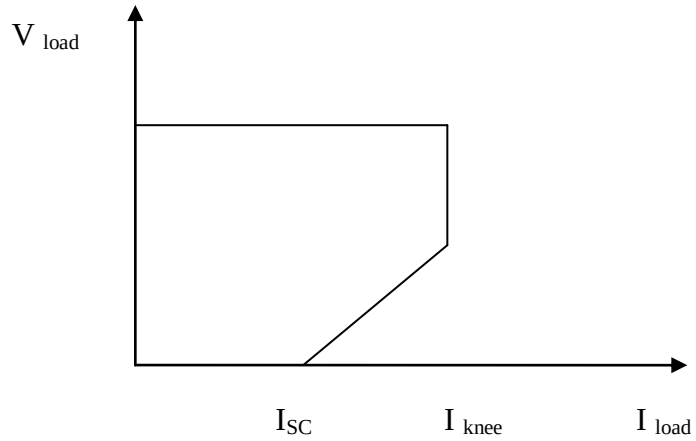
5.28. What is the principle of basic switching regulator?

Pulse width modulation is the basic principle of switching regulators. The average value of repetitive pulse waveform is proportional to the area under the waveform.

5.29. What is current fold back? Draw the characteristic curve.

Current fold back is the technique used to protect the IC regulator from the enormous current flow during short circuit or over-load conditions.

For a constant value of output voltage when the current demand increases beyond a particular value I_{knee} , the voltage and current drops down to avoid damage to the ICs.



Current fold back- characteristics curve.

5.30. What are the basic configurations of switching regulators?

- Step-down or buck switching regulator.
- Step-up or boost switching regulator.
- Inverting type switching regulator.

5.31. What is the need for a voltage regulator?

A voltage regulator is a circuit that gives a constant output voltage irrespective of the variations in input voltage and load current.

5.32. Why do switched regulators have better efficiency than the series regulators?

Power transistor in a switching regulator does not conduct current continuously.

5.33. Give the requirements for a power supply to be a voltage regulator.

- It must supply the required output power and losses associated with the switching regulators.
- It must be large enough to supply sufficient dynamic range for the line and load variations.

- It must be sufficiently high to meet the minimum requirements of the regulator.
- It must store energy for a specified amount of time during power failures.

5.34. List the advantages of switched capacitor filter.

- Very high value of resistors can be easily simulated using small value capacitance.
- Low system cost.
- High accuracy.
- Excellent temperature stability.
- Due to good temperature characteristics, the system has good temperature stability.
- Complete active filters can be easily obtained on a monolithic IC chip.

5.35. Define tuned amplifiers.

The tuned circuit is capable of selecting a particular frequency and rejecting all other frequencies. An amplifier with this tuned circuit as a load is known as tuned amplifier.

5.36. For what purpose tuned amplifiers are used?

Tuned amplifiers are used for amplifying narrow band of frequencies; hence it is also known as narrow band amplifiers or band pass amplifiers.

5.37. What is the need for tuned amplifier circuit?

In radio receivers or television receivers, it is necessary to select a particular channel from among the other channels available. Thus some sorts of frequency selective circuit is needed that will allow us to amplify the frequency band required and reject all the other unwanted signals. Such a circuit is known as tuned amplifiers.

5.38. List the important features of power amplifier.

- **L**arge amount of power to be delivered to the load.
- Power efficiency.
- Impedance matching to the output device.

5.39. List the features of LM 380 audio amplifier.

- Internally fixed gain (34 dB).
- Wide supply voltage range(5 to 22V)
- Output is automatically self centering to one half of the supply voltage.
- High peak current capability (1.3A maximum)
- High input impedance.
- Low total harmonic distortion.
- Standard dual in line package.
- A bandwidth of 100 kHz typically at an output of 2W and load of 8ohms.

5.40. For what purpose isolation amplifiers are used?

This is an amplifier that offers electrical isolation between its input and output terminals. Isolation amplifiers are often used when there is a very large common mode voltage difference between the input and output sides of the device.

5.41. What is a video amplifier?

A video amplifier has to amplify signals over a wide band of frequencies, say upto 20 MHz. the shape and form of the video waveform must be preserved during amplification. The shape of the complex waveform depends not only on the frequencies contained in the signal, but also upon the relative phases. It is therefore, necessary that;

- All the frequencies must be amplified equally to maintain the same relative amplitudes.
- The relative phases of all the frequency components in the output must be same as at the input.

5.42. What is an opto coupler?

The opto coupler circuit is a combined package of a photo emitting device and a photo sensing device. The basic opto-coupler circuit consists of a light emitting device and a photo sensing device.

5.43. List the characteristics of an opto coupler.

- Current intensity ratio.
- Isolation impedance.
- Response time.
- CMRR.
- Bandwidth.

5.44. Give the advantages of opto coupler.

- Better isolation between two stages.
- Impedance problem between stages is eliminated.
- Wide frequency response.
- Easily interfaced with digital circuit.
- Uni-directionalism.
- Compact and light weight.
- Problems such as noise, transients, contact bounce etc. are completely eliminated.

5.45. Give the applications of opt coupler.

Opto coupler can be used as a coupler between any two stages for better electrical isolation.