ELECTRONIC CIRCUITS AND APPLICATIONS

SUMMARY

Unit – 1

Amplifiers:

- Amplifiers can be classified based on configuration, operating point, number of stages, type of output, frequency range, band width and devices used(BJT or FET)
- CE stage has large current gain, voltage gain and power gain. Output voltage has 180^0 phase shift with respect to input it has moderate input impedance
- CC stage has high current gain, unity voltage gain, good power gain = current gain. It has no phase shift of output with respect to input. It features high input impedance and low output impedance
- CB stage has current gain < 1, high voltage gain and power gain. There is no phase shift in current or an voltage. It has large output and low input impedance
- For low frequency BJT can be represented by H parameters for AC. It can also be represented in “re” model.
- The parameters are specified at a particular operating point and they change with operating point.
- FET amplifier also can be represented in CS, CD, CG, in a similar way to BJT.
- For simplified case CE can be represented by hie at input and a current source of hfe . iv at output in h model.
- In re model it can be simplified as βre at input and βiv at output
- A common collector stage can be simplified to β hie at input.
- A CB stage can be simplified to hie at input and current source hfb . ie at output. However hfb is approximately = 1
- A CS amplifier is simplified to open circuit at input and a current source of gm Vgs at output

STABILIZING

- Q operating point is determined by drawing low line and finding intersection point with specified base current.
- Operating point moves up with increase of Ib and moves down with decrease of Ib
- The location of Q and single amplitude are confined to active region
- When BJT is cutoff Vc = Vcc and when in saturation Ic = Vcc / Rl (approx.)

COUPLING AND BYPASS CAPACITORS

- Coupling capacitors together with Rl and Ri determine low frequency cutoff. Shunt capacitors and input capacitance together with Rl and Ri determine HF cutoff f2.

HYBRID π MODEL

- At high frequencies BJT can be better represented by π model. The resistors are rbb^1 , rb^1e, rμ, rce and at output a current source = $gmvb^1e$ is used. b^1 is an imaginary internal base in addition to physical terminal.
- Important parameters are gm = Ic/Vt ; rb^1 = hfe / gm ;
- rbb^1 = hie – rb^1e ; rb^1c = rb^1e/hre ; gce = 1/rce = hoe – (1+hfe)gb^1e
- Current gain Ai = -hfe / 1 + j (f/fβ)
- fβ = 1 / 2π rb^1e (cb^1e + cb^1c) ≈ 1/2π rb^1e cb^1e
- fβ = β cutoff frequency
- Similarly fα can be defined as fα = $\dfrac{hfe.f\beta(cb^1e+cb^1c)}{cb^1e}$ ≈ hfe . fβ ≈ Ft
- fβ = frequency at which current gain falls by 1 / v (hfe)
- α cutoff frequency is the frequency at which α falls to 0.707 α
- Ft is gain bandwidth product where current gain = 1.
- ft = hfe . fα = $\dfrac{gm}{2\pi(cb^1e+cb^1c)} = \dfrac{gm}{2\pi cb^1e}$

HYBRID CONDUCTANCES

- gm = ∂Ie / ∂ vbe = Ic / Vt
- gb^1e = 1/ rb^1e = input conductance
- gb^1c = 1/rb^1c = feed back conductance
- gce = 1/rce = output conductance
- above in terms of others are
- 1) gm = | ic | / vt 2) gb^1e = 1/rb^1e = gm / hfe 3) rbb^1 = hie – rb^1e
  - 4) rb^1c = rb^1e / hre or gb^1c = hre / rb^1e
  - 5) gce = 1/rce = hie – (1+hfe) gb^1c

HYBRID CAPACTANCES

- 1) Transition capacitance cb^1c due to reverse biased cb junction
  2) diffusion capacitance ce of be junction.
  3) Ce ∝ Ie ; Ce = gm . W^2 / 2De

VARIATION OF HYBRID PARAMETER

- hybrid parameters are considered linear up to ft/3
- gm is independent of Vce but varies directly with | ic | and inversely with T.
- rbb^1 decreases with Ic and increases with temperature
- rb^1e decreases with Ic and increases with temperature
- Ce ∝ Ic and decreases with Vce
- hfe decreases on either side of a particular value of IC
- hie decreases with ic.

UNIT – II

MULTISTAGE AMPLIFIER

- In order to achieve high voltage and power game, drive low impedance output & take input from high / low impedance sources, to achieve high gain and bad width there is a need to employ more than One amplifiers in cascade.
- Three coupling scheme are employed. They are direct coupled DC, RC coupled and transformer coupled between Two stages of amplifiers.
- Only DC amplifier gives bandwidth down from DC.
- DC output DC voltage effects input of next stage.
- DC biasing can be independently designed and used in RC coupled amplifier and inter stage coupling is done by suitable value of coupling capacitors. This capacitors determines low frequency cut off.
- At mid band couple capacitors, emitter / source by-pass capacitors offer low / short resistance in the circuit.
- Transformer coupling isolate DC and can be employed to match input impedance to required output impedance between stages. Transformer coupling like RC determines low frequency cutoffs. It also suffer from result frequency of primary and secondary windings.
- Effective load on multistage amplifier is determined by capital Rl 1 and Ri 2 still parallel.
- Overall voltage gains $V_0 / V^i = A_{v0}.A^{v1}$............Avn. and phase shift $\theta_n = \theta_1+\theta_2$..............$\theta_n$
- Overall current gain Ain = $Ai^1\ A'_{i2}$..........A'_{in}
- $A_{ik} = -h_{fek} / (1+h_{oe}.R_{ln})$
- $R_{in} = h_{ie} + h_{re}\ A_{in}\ R_{ln}$
- For estimating input impedance multistage amplifier start from last stage to determines A_{in}, R_{in}, & proceed back to first stage progressively
- .
- Output impedance of first stage R01 = 1/y01; y01 = hoe- $\dfrac{hre*hfe.}{hie+Rs}$
  - Rot1 = $\dfrac{Ro1Rc1}{Ro1+Rc1}$

  Rot1 forms source impedance to calculate Y_{02} for second stage.

REVIEW OF BJT AMPLIFIERS

CE	Ai = hfe/1+hre*Zl; Av = Ai* Zl/Zi; Zi = hie- hfe*hre / (Yl+hoe) Y0 = hoe – hfe hre / (hie + Rs) Approximately Ai=hfe; Av= hfe Rl/Ri; Ri = hie
CB	Ai=hfb / 1+hobRl; Zi=hib+hrb Ai Zl Ab=Ai*Rl/Ri; Ro=1/Y0; Y0 = hob – hfb hrb / (hib+Rs) Approximately Ai=hfb=α; Av=hfbRl/re; Rv= ∞
CC	Ai=1+hfe; Zi=(1+hfe) Rl; Av=1-hie/Ri Z0= (hie + Rs) / (1+hfe) Approximately Ai=(hfe+1); Zi=hfe Re; Z0=re

REVIEW OF FET

CS Zi=Rg; Av= -gmRl; Z0=Rl
Approximately Zi=∞; Z0=∞; Av=-gmRl; μ = gm.rp

CG Av=(gmrd+1)Rd/(rd+Rd)

CD Av=gm.Rs/(1+gmRs)

DISTORTIONS

- Non linear distortion is caused by non linearity of collector / drain currents and voltages
- Frequency distortion is caused by variation of gain with respect to frequency. These are determent by passive capacitors in coupling input output.
- Phase distortion is counter part of frequency distortion. Phase shift varies with frequency. Caused by coupling capacitors and capacitors at input and output.

FREQUENCY OF AMPLIFIERS

- Frequency and phase shift response is plotted by BODE plots.
- A=A0/(1+j f/fp); f0 = 1 / ($2\pi R_1C_1$), $\theta = \tan^{-1}$ (f/fp)
- Slope of gain is 20 db/decade or 6db/octave. Octave means frequency ratio of ½ or 2. For multistage amplifier A=A0/(1+jf/fp1)(1+jf/fj2)…..(1+f/fpn)
- fp1………fpn are called poles of response
- If poles are at least 4 times apart from each other, lowest of these called dominant pole and overall cutoff frequency is determined by dominant pole.

STEP RESPONSE

- If hf response can be very efficiently be determined by response to step input.
- tr=rise time is time taken for 10 to 90% of steady state. Tr=.35/BW
- Tilt gives indication of low frequency cutoff.
- % tilt P = t1 / (R1C1) x 100%.
- Overall f_H is given by $\dfrac{1}{\sqrt{1+(f_{H*}/f_{H1})^2}}$ X……… $\dfrac{1}{\sqrt{1+(f_{H*}/f_{Hn})^2}}$ = $1/\sqrt{2}$
- For 'n' amplifiers of same f_H $f_H*/(f_H) = \sqrt{(2^{1/n}-1)}$
- For $fL*/(fL) = 1 / \sqrt{(2^{1/n}-1)}$
- Empirically $1/f_H = 1.1\sqrt{(1/f1^2 + 1/f2^2 \ldots + 1/fn^2)}$
- $tr = 1.1 \sqrt{(tr1^2 + tr2^2 + \ldots + trn^2)}$

MILLER EFFECT

- The feedback capacitance between output and input can be represented either at input or at output by using millers theorem.
- At input C=(1+A)Cc, at output Cc.A / (1-A)
- This method is very effective and useful in simplifying amplifier analyzed by hybrid π circuit.

OTHER MULTISTAGE AMPLIFIERS

- Transformer coupled amplifier isolates to stages of amplifiers. Tran ratio of primary to secondary is determined to match impedances
- Inductance determines low cutoff frequency of the amplifier.
- While determine turns ratio winding resistance forms part of impedances being matched.
- An impedance Rl is reflected to primary as $(n1/n2)^2$ Rl]
- Low cutoff frequency f is determined by $2 \pi fL = R0$
- Cascade amplifier consists of CE feeding to CB. This amplifier completely isolates impedances $Av = gm1\ Rc$ where Rc is collector resistance of CB
- Darlington pair is used to give high input impedance $Ri=\beta_1\ hie_2$ current gain $=\beta_1 \beta_2$
- In CB-CC amplifier CC is used to offer low output impedance to the load and high input impedance to the previous stage.
- Differential amplifier is a multistage amplifier to give two signals 180˚ in out of stage.

UNIT – III

POWER AMPLIFIER

- Amplifier which drive loads like loudspeaker outputs of Radio and Television etc., require large current and voltages. They dissipate heat in operate at high current/voltage.
- Devices used for power amplifier features high current, power rating and are relatively big inside suitable for mounting heat sinks or mounted or chases.
- Power amplifiers are classified based on conduction angle of current through the device. BJT / FET. They are class A, B and C.
- Class A amplifier operate in linear regions of device and current close to device for full period 0-360˚ of signal.
- Class B amplifier operate exactly half period of signals or 0-180˚. They are essentially biased to cutoff initially. Only signals drive to conduction of exactly ½ cycle or period.
- Class C amplifier operates for small period of input cycle i.e. is less than 180˚. These devices are operated beyond cutoff and essentially used as tuned amplifier over a small band of frequency.

CLASS A AMPLIFIER

- Class A operation requires operating point in linear region and its location control maximum undistorted output signal. In a BJT class A amplifier, Q point can be controlled by increasing / reductions of base current. The operation is limited to region between saturation region and cutoff. This region is considered linear. Vce (sat) < 1 volt, Vce cutoff ~ Vcc. IC sat = Vcc-Vce (sat) / R else. Strait line joining Vcc / Rl and Vcc is called load line. Q goes up on load line with increase of IB which increases IC. Q point goes down with degrees of IB. The voltage Vc is – 180˚ out of phase with input while IC is in phase with IB.
- If Q point is exactly at Vce sat + (Vcc – Vce sat) / 2 or approximately Vcc / 2 the amplifier gives maximum voltage and current signal. Otherwise output gets truncated clipped to Vcc or Vce sat.
- Product of Vce & Ic is power dissipated in collector and $Irms^2$ Rl = P0 or Pac = output power. Input DC power Pi = Vcc.Icq

- Amplifier is operated such that instantaneous power dissipated is with in specified limit of device. This limit is hyperbolic on Vc, Ic curve. Maximum dissipation occurs under no signal condition.
- The ratio of Pac / Pdc expressed in percentage is called collector efficiency of amplifier.
- The maximum efficiency possible in class A amplifier is 25% for resistive load. Operating point shall be located at Vceq = Vcc/2, Icq=Icmax/2.

TRANSFORMER COUPLED CLASS A

- In case of class A amplifier employing transformer, operating point is determined first by DC resistance of primary windings and IB supplied from base circuit. From this point AC load line can be drawn Rl(ac) = $(n1/n2)^2$.Rl
- For maximum efficiency to shall be located at Icq=Vcc/Rlac. Vac p-p=2Vcc. Iac max (p-p) = Vcc/Rl(ac).
- Maximum efficiency possible in transformer coupled class A is 50%.

HORMONIC DISTORTION

- Power amplifier are operated over large signal in device in linear and non-linear regions. Hence signals are distorted in varying proportions. Collector current can be expressed by $ic=Ic+B0+B1\cos\omega t + B2\cos 2\omega t$.
- The coefficients B0,B1 and B2 can be expressed in terms of ic max.
- B0 = B2 = (Icmax-Icmin-2Icq) / 4, B1=(Ic(max)-Ic(min)) / 2
- Harmonic distortion is expressed as ratio of these coefficients wrtB1
- Second harmonic distortion D2=modules B2/B1x100%.
- Harmonic distortion = modules Bn/B1 x 100%.
- Total harmonic distortion $D=\sqrt{}D2^2+D3^2+\ldots\ldots\ldots\ldots\ldots+Dn^2$

CLASS A PUSHPULL AMPLIFIER

- Class A push pull amplifier employs 2 class A stages of mirror reflection of each other.
- Class A push pull amplifier is free from even harmonic distortion and delivers large hours.

CLASS B PUSHPULL AMPLIFIER

- Class B is always realized using in push pull transformer coupled are complimentary stage configuration.
- Class B requires 0 and 180˚ out of phase signals requiring a center tapped driver transformer are phase splitter circuit driving through capacitors.
- Class B suffers from crossover distortion which is due to non conduction of device for small period of input.
- Crossover distortion can be avoided by biasing devices to near conduction.
- Class B push pull amplifier features efficiency = 87.5%.

COMPLIMENTARY SYMMETRY AMPLIFIER

- A pair of NPN & PNP transistor matched to each other in respect of Vbe, β and Vcc and Imax rating are employed in this amplifier.
- This amplifier is initially biased at cutoff and can be DC coupled at input and coupled to load directly. This amplifier is essentially an emitter follower with mirror reflector stage and therefore can drive loads directly.
- For complimentary amplifier input DC is 0 an output DC also is 0 voltage. It employs + Vcc and – Vcc.
- Efficiency of this amplifier is 87.5% max.
- This amplifier suffer from crossover distortion which can be prevented by biasing arrangement near conductions by use of (1) 2 forward biased diodes (2) use of ½ Amp (3) Vbe multiplier circuit
- By using capacitors at output input it is possible to realize complimentary stage with single supply.

CLASS C TUNED AMPLIFIER

- Class C amplifier employed a tuned circuit and is biased beyond cutoff.
- Different biasing arrangements are possible for class C operation.
- The efficiency = 90-99% and class C employed in HF outputs of Radio & TV.

SWITCHING POWER AMPLIFIER

- Switching power amplifier employs N and P channels MOSFETS with center tapped driver input.
- Output is a tuned LC circuit with series load Rl.
- This circuit offers high efficiency but operates only at one frequency.

UNIT V

REGULATED POWER SUPPLIES.

VOLTAGE MULTIPLIERS.

- From an AC supply it is possible to generate high dc voltage in integral multiples of peak ac voltage.
- A half wave doubler consists of a half wave rectifier with capacitor filter followed by a clamper. Doubler gives dc voltage = 2 Vp.
- By joining half wave rectifiers + and – ve outputs we can get Full wave doubler.
- It is possible to derive ' nVp ' dc voltage using 'n' diodes in chain.
- Irrespective of High voltage generated each capacitor is charged to '2Vp.' And hence each diode used shall have piv = 2 Vp.
- HV generated has lot of applications in nuclear physics, TV and instruments.

VOLTAGE REGULATORS

- Due TO variation of input ac mains voltage dc voltages generated using rectifiers is subject to fluctuations even if load is constant. The to internal resistance of rectifier diodes dc changes with load.
- A regulated voltage supply gives constant dc voltage against large changes in ac voltage and load. They also reduce ripple drastically.
- Line regulation = $\{ Vo\Delta / \Delta Vi \}$ X 100 %
- Load regulation = $[\{Vo(nl) - Vo(fl)\} / Vo(nl)]$ X 100 %
- Output resistance $Ro = \Delta Vo / \Delta Io$.
- A dc voltage produced is also subject to change with temperature.
- $St = \Delta Vo / \Delta T$
- The over all change in out put
- $\Delta Vo = (\partial Vo / \partial Vi) \Delta Vi + (\partial Vo / \partial Io) \Delta Io + (\partial Vo / \partial T) \Delta T$.

TYPES OF VLOTAGE REGULATORS.

- Basically there are 2 types of regulators. (1) zener (2) feed back type
- Feed back type regulators are 3 types.
- series (2) shunt (3)switching.

ZENER REGULATOR

- A fixed regulated voltage = Vz can be generated to overcome line and load fluctuations.
- A zener is always operated in reverse bias.Alwaya a minimum current Iz (min) is assured in zener supply for proper operation. A zener current Iz(max) is also observed such that under no load and and when .
- Vi is highest, current through zener is kept < Iz(max).
- If not specified Iz(max) = Pz/Vz. And Iz(min)= Iz(max)/10.
- A zener regulated power supply is simplest regulator which uses a series resistor Rs in series with zener connected across unregulated voltage Vi. Load is connected in parallel with zener.
- Current through zener is maximum when input voltage Vi is high and load minimum .

- Current through is minimum when input is min Vi(min) and load current at maximum.
- Rs can be determined by
- Rs={ (Vimin-Vz)}/(Izmin + I l Max)
- =(Vimax-Vz)/Izmax+Il Min).
- any ripple at Dc Current can be determined by Δvo= Δ Vi.Rz/(Rs+Rz).
- When Load current is maximum together with Vi permitted minimum can be determined by Vz= Vi min . Rl/(Rl+Rs). And Rl= Vz/I l max.

FEED BACK REGULATORS.

- Block diagram of feed back regulator consists of 4 basic blocks viz control element, sampling ckt, reference voltage, comparator/error amplifier.
- Output voltage is sampled , compared against reference at error amplifier which drives control element to change output.
- Based on functional features of control element , feed back regulators are further classified to series, ,shunt and switching regulators.
- In series regulator Vo = Vi- Io .Rs. Series element acts as variable resistance to drop voltage under varying Vi and Io.
- In shunt regulator Vo = Vi-Rs(Io+Ish).Shunt regulator acts as a variable shunt resistor to drain away current to maintain specified output Vo.
- In switching regulator Vo = Vi. Ton/(Ton+Toff). Switching element acts as toggle switch to connect Vi to output into LC filter for variable period so as to charge capacitor to Vo under varying Vi and Io. To keep Vo constant.

SERIES REGULATORS.

- Series regulator in simplest form has a series pass transistor that is driven by an error amplifier where sample of output Vo.R2/(R1+R2) is compared against reference voltage usually a zener Vz .Series pass transistor actually an emitter follower connected on error amplifier.
- Vz+Vbe = Vo. R2/(R1+R2) determines Vo.
- It is customary to maintain Iz min in zener.R2< (Vi+Vo)/Ib max.
- Ib max = Io/β1.
- This type of regulator gives Vo > Vz.
- To assure same load regulation even at Vi min , a pre regulator is employed in place of R3(resistor between Vi and base of series pass transistor) to provide constant current 'Ib1' required for max load current.
- Even OP Amps can be used as error amplifiers.
- It is desirable to supply Is through Vo instead of Vi to obtain small ripple.
- Current rating can be increased by use of boost up transistor as Darlington pair.
- Short circuit protection can be achieved by including a current sense resistor in output and connecting a transistor between base and output .This transistor is turned on by drop in current sense resistor to cut off series pas transistor.
- Fold back operation is one which limits current in load less than maximum in case of short circuit. This can be achieved by pre biasing base of sc protection control transistor connected BE junction of series pass transistor.
- Rof = ΔVo/Δ Io = (Vt/Io). (Vo.Vr).(1/Aol).
- Δ Vo/Vo = (ΔIo/Io).(Vt/Vr).(1/Aol).

SHUNT REGULATOR

- Shunt regulator acts as a current draining circuit connected in shunt with Rl.
- When Io= 0, all the current (Vi-Vo)/Rs flows through shunt transistor and dissipation is maximum.
- Maximum load current the supply can give is (Vi-Vo)/Rs.
- Simplest form of shunt regulator employs a zener connected between base and Vo. This zener can be biased to Iz min by connecting a resistor Rz between base and ground . Rz = Vbe/Izmin. Vbe=0.7v.
- Shunt regulator is preferred for small currents.

IC REGULATORS.

- 78xx, series Ics are 3 terminal fixed voltage regulators over a range of output voltages 6, 9, 12, 15, 18, ..24
- for +ve or 79XX series are –ve voltage. These are available in I0 220, TO 2O2 and TO3.
- These regulators require min differential voltage 2v in excess of Vo.
- Current boosting can be achieved by connecting a transistor externally between Vi and Vo.

ADJUSTABLE REGAULTOR

- LM 317, LM337 are adjustable voltage regulators in 3 pin package available in TO 202,220 and also in TO2, TO3.
- LM 317 gives 1.25 v between Vo and center pin and a resistance of 240 ohms is recommended at these pins.. By connecting variable resistance ground and center pin variable voltage Vo = Vref(1+ R2/R1) can be achieved.

LM 723.

- LM 723 is a multi pin adjustable voltage regulator.
- It is available in 10 pin metal package and 14 pin DIL package.
- 723 is versatile IC and can be used for + and – ve regulators with all improvements like sc, current boost, fold back etc..
- 723 contains a reference amplifier that gives 7v ref voltage, error amplifier with INV,NIV inputs. Error amplifier is connected to 2 transistors to be used for current boost, short circuit and fold back protection.
- When VO < 7v output Vr is attenuated and when Vo > 7v vr is connected directly to INV input.
- For short circuit protection Rs is connected between CS and CL. Terminals.

SWITCHING REGULATORS

- There are 3 types of switching regulators. Buck, Boost, Invert types. Buck is step down and Boost is step up.
- Block diagram of switching regulator consists of a switch controlled by a sample of out put . Switch connects Vi to a LC filter whose out put is sampled for control of switch.
- For step down regulator the switch is in series with to filter and for step up it is in shunt to out put after an inductor.
- Switching regulators give regulated out put less than greater than or inverted to input and achieve efficiencies close to 100 %.

IC SWITCHING REGULATOR

- 78 S40 is a an example of IC switching regulator.
- This IC consists of a reference 1.25v, an oscillator, gate generator, error amplifier and a switch (Flip flop).
- This IC gives step up, down or inverting voltage. Accepts Vi =2 to 40v and gives Vo between 1.5- 40v @ Ipk 1,5 Amp.

UNIT – IV

TUNED AMPLIFIER

- Communication circuit very widely use tuned amplifier they are used in MW & SW radio frequency 550 KHz – 16 MHz, 54 – 88 MHz, FM 88 – 108 MHz, cell phones 470 - 990 MHz
- Band width is 3 dB frequency interval of pass band and –30 dB frequency interval is called Skirt.
- Tune amplifiers are also classified as A, B, C similar to power amplifiers based on conduction angle of devices.
- Tune amplifiers are series and parallel tuned type.

SERIES RESONANT CIRCUIT

- Series resonant features minimum impedance (RS) at resonant.
- f r = ½π√LC; q = ωL/Rs at resonance ωL=1/ωc, BW=fr/Q
- It behaves as purely resistance at resonance, capacitive below and inductive above resonance

PARALEL RESONANT CIRCUITS

- Paralel resonance features maximum impedance at resonance = L/RsC
- At resonance $Fr=1/2\pi\sqrt{1/(LC-Rs^2/L^2)}$; if Rs=0, $fr=1/2\pi\sqrt{(LC)}$
- At resonance it exhibits pure resistance $R=1/R_sC$. This resistance can also be expressed as parallel resistance $Rp=Q_0\omega_0L$, $Z_0 = R=1/LR_s = \omega_0LQ$ or Q/ω_0C or R_sQ^2
- Below fr parallel circuit exhibits inductive and above capacitive impedance

ANALYSIS OF TUNED CIRCUIT IN AMPLIFIERS

- At resonance since parallel circuit is a resistance Rt gain of BJT CE circuit with tune circuit is –gmRt. Where Rt = rd || R || Ri
- Gain in any frequency away from f0 Ar = A0/1+2jδQ $\delta=\omega-\omega_0/\omega_0$
  Qe=Rt/ωL or ω0CRt, Z=Rt/1+2jδQe
- BW = 2δω0 = ω0/Q = 1/RtC
- GBW = gm/C

INTERSTAGE COUPLING METHODS

- Output of one tuned amplifier stage can be coupled to next stage by (a) inductive/magnetic coupling so as to match impedances (b) tapped inductor forming part of tuned circuit with capacitors (c) coupling through capacitors without any tapings. No effort made to match impedances (d) magnetically coupled secondary tuned circuit with controlled coupling.

DOUBLE TUNED AMPLIFIER

- A tuned circuit at output of amplifier is coupled to next stage by another tuned circuit at input of succeeding stage with controlled coupling makes a double tuned amplifier.
- When coupling coefficient Kc = 1/√(Q01.Q02) is called critical coupling and response looks like a single tuned circuit.
- Inductance of primary shall be Lp=M where M=bMc. B=coupling coefficient Mc=mutual inductance at critical coupling.
- When loosely coupled the amplifier gives lower BW.

- When over coupled bandwidth BW increases with a dip at center in W shape.
- 3dB BW = $\omega 0/Q \sqrt{((b^2-1) \pm 2b)}$
- Double tuned amplifier gives nearly 3 times BW of single stage.

SYNCHRONOUS TUNING

- Tuned amplifier tuned to a frequency f0 and having same bandwidth can be cascaded. Such tuning is called synchronous tuning.
- Synchronous tuning features increased gain but reduced VW with respect to single tuned amplifier stage. As amplifiers are tuned to same frequency and have same BW.
- Overall gain of 'n' similar stages with synchronous tuning gives

$$\left|\frac{A}{A_0}\right|^n = 1/\{\sqrt{(1+(2\delta Q)^2)}\}^n$$

- 3dB BW of 'n' such stages = $BW\sqrt{(2^{1/n}-1)} = f_0/Qe\sqrt{(2^{1/n}-1)}$

STAGER TUNING

- Stager tuning is employed to achieve large bandwidth in cascading without aiming increase of gain.
- Generally odd numbers of stages are employed. One at the center of required band and two either side at equidistant in frequency intervals in pairs. All amplifiers so stager tuned have same BW but different tuned frequency as required.

IC TUNED AMPLIFIER

- In IC tuned amplifier circuit has provision to connect tuned circuit from outside at input or output.
- A diode is employed to enable tuned circuit.
- One such IC is MC 1550 which is connected in cascode amplifier.

INSTABILITY & STABILISATION METHODS

- Feed back capacitances between input and output tuned circuits together with amplifier gain gives rise to undesired oscillation below tuned frequency. This is called instability.
- In simple case instability can be prevented by (a) connecting a series LC circuit between collector & BJT to prevent oscillation. (b) Power supply is connected at tap of an inductor and a capacitor is connected between base and other end of coil. Adjusting C to prevent oscillation.
- More sophisticated methods are by (a) Hazel tine (b) Rice (c) Common feedback. These are improved schemes based on simple methods narrated.
- Hazel tine method uses splitting of inductor of second tuned circuit to in equal parts L2a, L2b, connect supply from junction of these inductors. And Cn between input and output of inductance of L2a. At balance Cn = Cf.(L2b/L2a)
- Rise scheme is similar to hazel tine scheme, which employs splitting of inductance at input tuned circuit to equal parts. Cn = Cf
- Common circuit neutralization scheme handles feedback effects at microwave frequencies. Consists of capacitance Cn from ground lead.

CLASS 'C' TUNED AMPLIFIERS

- Current in class C tuned amplifier slows for < 180˚, few degrees around 90˚. Hence amplifier is biased far below cutoff.
- This amplifier features tuned circuit purely as a resistive load for tuned frequency.
- And efficiency of nearly 90-99% can be achieved.