

6

An Antenna (or) Aerial is a system of elevated conductors which couples (or) matches the transmitter or receiver to free space.

A transmitting antenna connected to a transmitter by a transmission line, forces electromagnetic waves into free space.

A receiving antenna connected to a radio receiver, receives a portion of electromagnetic waves travelling through space.

Radiation pattern:

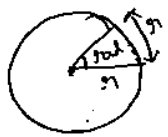
Radiation pattern of an antenna is nothing but a graph which shows the variation in actual field strength of electromagnetic field at all points which are at equal distance from the antenna.

If the radiation from the antenna is expressed in terms of field strength (E), the radiation pattern is called as the "field strength pattern".

Radiation Intensity:

Radiation intensity is defined as power per unit solid angle. Units of radiation intensity is watts/steradian (or) watts/radian

Radian & Steradian:



One radian is defined as the plane angle with its vertex at Centre of circle of radius 'r' & ~~subtended~~ subtended by an arc whose length is 'r'.

→ One steradian is defined as the solid angle with its vertex at Centre of a sphere of radius 'r'.

Area of sphere = $4\pi r^2$

∴ There are 4π steradians in a closed sphere ($\frac{4\pi r^2}{r^2}$)

— The infinitesimal (extremely small) area ds on a surface of sphere of radius 'r' is $ds = r^2 \sin\theta d\theta d\phi$.

So the element of solid angle $d\Omega$ of a sphere is $d\Omega = \frac{ds}{r^2} = \sin\theta d\theta d\phi$

Max. radiation intensity from a reference antenna with same power point

$$(or) \text{ Gain} = \frac{\text{Max. Power received from given antenna } (P_1)}{\text{Max. power received from reference antenna } (P_2)}$$

Directivity (D) :

The Max. directive gain is called ^{as} directivity of an antenna & it is denoted by D.

$$D = \frac{\text{Max. Radiation intensity of test antenna.}}{\text{Avg. Radiation Intensity of test antenna.}}$$

$$D = \frac{\phi(\theta, \phi)_{\text{max.}}}{\phi_{\text{av}}} \text{ both of test antenna}$$

(or)

$$D = \frac{\text{Power radiated from a test antenna}}{\text{Power radiated from an Isotropic antenna.}}$$

Directive gain (G_d) :

$$G_d = \frac{\text{Radiation Intensity in a particular direction}}{\text{Avg. radiated power}}$$

Antenna efficiency (η)

The efficiency of antenna is defined as the ratio of power radiated to the total i/p power supplied to the antenna.

$$\eta = \frac{\text{Power radiated}}{\text{Total I/p power.}}$$

Effective area (or) Effective aperture (or) capture area:

$$\text{Effective area} = \frac{\text{Power received at the antenna load terminal}}{\text{Power density (E_o Propagating vector)}}$$

$$A_e = \frac{W_b}{P}$$

$$\boxed{\text{Power density} = W/m^2}$$

Antenna Beam width :

It is a measure of directivity of an antenna. Antenna beam width is an angular width in degrees, measured on the radiation pattern b/w points where the radiated power has fallen to half its max. value. This is called as "beam width" b/w half power point (or) half power beam width (HPBW), because power at half power points is just half. This is also known as 3dB beam width.

Antenna
 A antenna defined as the structure associated with the region of transition between a guided wave and free space wave (or) vice versa

Transmitting antenna is a region of transition from guided wave on a transmission line to free space.

Receiving antenna is a region of transition from a space wave to a guided wave on transmission line.

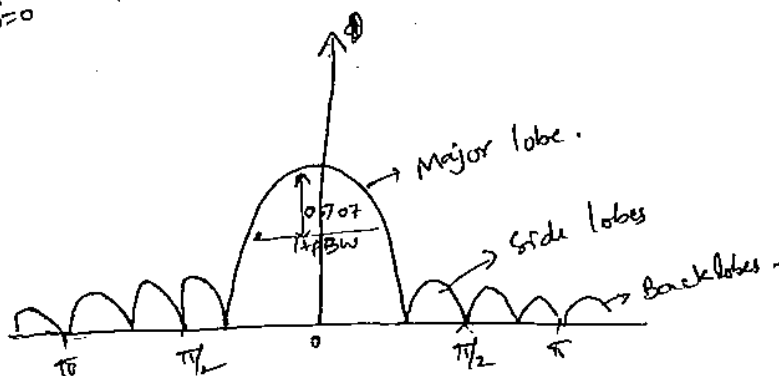
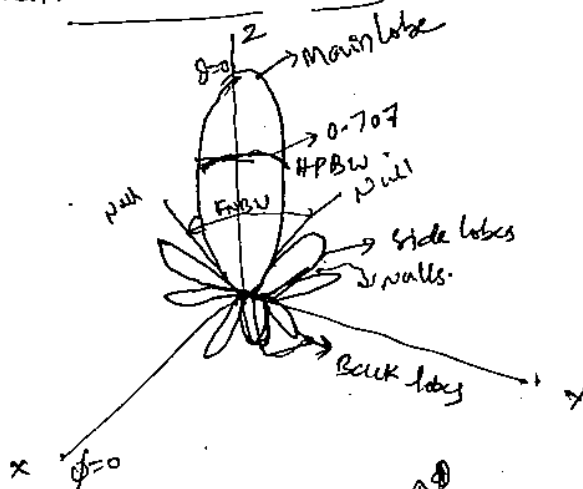
Pattern

Radiation pattern of an antenna is nothing but a graph which shows the variation in actual field strength of electromagnetic field at all points.

~~Radiation pattern~~

If the radiation from the antenna is expressed in terms of field strength (E), the radiation pattern is called as "field pattern".

Three dimensional field pattern



Major lobe \rightarrow It is called as main beam & is directed in the maximum wave

containing the direction of max. radiation.

Minor lobe: It is any lobe except a major lobe. i.e. all lobes except major lobe.

Side lobe: Normally a side lobe is adjacent to the main lobe.

Back lobe: Normally refers to minor lobe that occupies the hemisphere in a direction opposite to that of major lobe.

Antenna Beam width:

It is a measure of directivity of an antenna. Antenna beam width is an angular width in degrees, measured on the radiation pattern.

The angular ^{beam} width at the half power level is called Half power beam width "HPBW".

The Beam width at first nulls is called "FNBW" (~~HPBW~~ Beam width first Nulls. (FNBW)).

(P) An Antenna has a field pattern given by $E(\theta) \cos^2 \theta$ for $0 \leq \theta \leq 90^\circ$. Find HPBW.

Sol

$$E(\theta) \text{ at half power} = 0.707$$
$$\text{Thus } 0.707 = \cos^2 \theta \Rightarrow \cos \theta = \sqrt{0.707}$$
$$\theta = 33^\circ$$
$$\text{HPBW} = \underline{\underline{66^\circ}} \text{ (Ans)}$$

(P) An Antenna has a field pattern given by $E(\theta) = \cos \theta \cos 2\theta$ for $0 \leq \theta \leq 90^\circ$. Find (a) HPBW (b) FNBW.

Sol

$$E(\theta) \text{ at half power} = 0.707$$
$$0.707 = \cos \theta \cos 2\theta = \frac{1}{\sqrt{2}}$$
$$\cos 2\theta = \frac{1}{\sqrt{2} \cos \theta} \Rightarrow 2\theta = \cos^{-1} \left[\frac{1}{\sqrt{2} \cos \theta} \right]$$
$$\theta = \theta' = \text{at } 20.5^\circ$$

(a) \therefore HPBW = $2\theta = 41^\circ$.

(b) FNBW

$$0 = \cos \theta \cos 2\theta \Rightarrow \theta = \underline{\underline{45^\circ}}$$

$$\therefore \text{FNBW} = \underline{\underline{90^\circ}}$$

Beam Area

The beam area Ω_A is the solid angle through which all of the power radiated by the antenna ^{would stream} if $P(\theta, \phi)$ maintained its maximum value over Ω_A & zero elsewhere.

Thus power radiated = $P(\theta, \phi) \Omega_A$ with

$$\Omega_A = \int_{\phi=0}^{2\pi} \int_{\theta=0}^{\pi} P_n(\theta, \phi) d\Omega$$

→ The beam area (or) beam solid angle (or) Ω_A of an antenna is given by integral of the normalized power pattern over sphere.

$$\Omega_A = \int_{\phi=0}^{2\pi} \int_{\theta=0}^{\pi} P_n(\theta, \phi) d\Omega \quad \text{where } d\Omega = \sin\theta d\theta d\phi$$

→ The beam area in terms of angles subtended by two principal planes is B

$$\text{Beam area} = \Omega_A = \frac{\phi_{HP} \theta_{HP}}{S_n}$$

ϕ_{HP}, θ_{HP} Half power beamwidth in the two principle planes

Note Normalized power = $P_n(\theta, \phi) = \frac{S(\theta, \phi)}{S(\theta, \phi)_{max}}$

(p) An Antenna has field pattern given by $E(\theta) = \cos^2 \theta$ for $0 \leq \theta \leq 90^\circ$. Find beam area of this pattern.

$$\begin{aligned} \Omega_A &= \int_0^{2\pi} \int_0^{\pi/2} \cos^4 \theta \sin \theta d\theta d\phi \\ &= \int_0^{2\pi} d\phi \int_0^{\pi/2} \cos^4 \theta \sin \theta d\theta \\ &= \int_0^{2\pi} d\phi \cdot \left[-\frac{\cos^5 \theta}{5} \right]_0^{\pi/2} = \frac{-2\pi}{5} \left[-\frac{1}{5} \right] = \frac{2\pi}{5} = 1.26 \text{ sr} \end{aligned}$$

Approximate relation

$$\Omega_A \approx \phi_{HP} \theta_{HP}$$

$$\Omega_A = 66^\circ \times 66^\circ = 4356 \text{ Sq deg.}$$

$$\text{Beam area} = \Omega_A = 4356 \text{ Sq degrees.} \\ \approx 4356 \approx 1.33 \text{ sr}$$

$$1 \text{ sr} = 3283.2$$

$$1 \text{ sr} = 3283. \text{ Sq}$$

Beam efficiency

The Ratio of main beam area to total beam area is called beam efficiency.

Total beam area = main beam area + minor lobe area.

$$\therefore E_M = \frac{\Omega_M}{\Omega_A} \quad \text{where } \Omega_M = \text{Main beam area} \\ \Omega_A = \text{Total beam area} \\ = \Omega_M + \Omega_m$$

The ratio of ~~total~~ ^{minor} lobe area to the beam area is called stray factor.

$$E_m = \frac{\Omega_m}{\Omega_A} \quad \therefore \text{Stray factor.}$$

Note: $\therefore E_M + E_m = 1$

Radiation Intensity: The power radiated from an antenna per unit solid angle is called radiation intensity. watts/steradian.

Directivity: The directivity of antenna is equal to ratio of max. power density $P(\theta, \phi)_{\max}$ (watts/m²) to its avg. value over a sphere as observed in the far field of antenna.

$$\therefore \text{Directivity } D = \frac{P(\theta, \phi)_{\max}}{P(\theta, \phi)_{\text{avg}}}$$

Directivity gives the capacity of antenna to concentrate the radiated power with the limited solid angle.

The Directivity is a dimensionless ratio ≥ 1 .

The Avg. power density over a sphere is given by.

$$P(\theta, \phi)_{\text{avg}} = \frac{1}{4\pi} \int_0^\pi \int_0^{2\pi} P(\theta, \phi) \sin \theta \, d\theta \, d\phi$$

$$= \frac{1}{4\pi} \int_{4\pi} P(\theta, \phi) \, d\Omega \quad \text{w/sr}$$

$$\therefore \text{Directivity } D = \frac{P(\theta, \phi)_{\max}}{\frac{1}{4\pi} \int_{4\pi} P(\theta, \phi) \, d\Omega} = \frac{1}{\frac{1}{4\pi} \int_{4\pi} \frac{P(\theta, \phi)}{P(\theta, \phi)_{\max}} \, d\Omega}$$

$$D = \frac{4\pi}{\int_{4\pi} \frac{P(\theta, \phi)}{P(\theta, \phi)_{\max}} \, d\Omega} = \frac{4\pi}{\Omega_A}$$

 Directivity for beam Area

Note: ^{we} smaller beam area, the larger the directivity

Isolated Isotropic antenna has lowest Directivity $D=1$ ($\because \Omega_A = 4\pi$)

Gain: It is ratio of max. power density of the antenna under test to the max power density of the reference antenna.

$$\text{Gain } G = \frac{P_{\max}(A.V.T)}{P_{\max}(\text{ref. antenna})} \times G(\text{ref. ant.})$$

Antenna efficiency factor: It is ratio of gain to Directivity

$$k = \frac{G}{D}$$

k = efficiency factor

range is $0 \leq k \leq 1$

→ If the half power beam width is known, then the directivity is

$$D = \frac{41253}{\theta_{HP} \phi_{HP}}$$

Antenna Aperture

It is a ratio of power received at the antenna load terminal to the power density of incident wave.

Aperture area (or) capture area = $\frac{\text{Power received}}{\text{power density of incident wave}}$

$$A_e = \frac{W}{P} \quad (\text{max}) \quad A_e = \text{aperture area}$$

W = power received

P = power density of incident wave

Aperture efficiency $\epsilon = \frac{A_e}{A_p}$

A_e = effective aperture

A_p = physical aperture.

Aperture - beam area relation

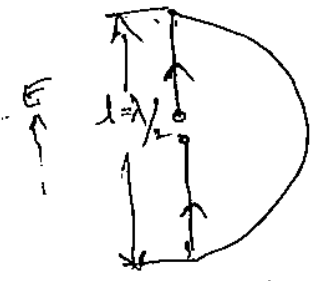
$$\lambda^2 = A_e \Omega_A$$

$$\text{Thus } D = \frac{4\pi}{\Omega_A} = \frac{4\pi \cdot A_e}{\lambda^2}$$

Effective height may be defined as the ratio of the induced voltage to the incident field ϵ

$$h = \frac{V}{E} \text{ m.}$$

Consider, a vertical dipole of length $l = \lambda/2$, immersed in an incident field E , & the current distribution is sinusoidal with an avg value $2/\pi$ so its effective height is $h = 0.64l$



Note: If the current distribution is uniform, then the effective height is 'l'.

For an antenna of radiation resistance R_r , matched to its load, then the power ~~delivered~~ delivered to the load is equal to,

$$P = \frac{1}{4} \frac{V^2}{R_{in}} = \frac{h^2 E^2}{4 R_{in}} \quad \text{--- (1)}$$

In terms of the effective aperture the same power is given by

$$A_e = \frac{P_{in}}{P} \Rightarrow \frac{P}{P} = \frac{P}{S}$$

$$P = A_e S$$

$$P = \frac{E^2}{Z_0} A_e \quad \text{--- (2)}$$

$$\frac{h^2 E^2}{4 R_{in}} = \frac{E^2 A_e}{Z_0} \Rightarrow \boxed{h_e = 2 \sqrt{\frac{A_e R_{in}}{Z_0}}}$$

$$\boxed{A_e = \frac{h^2 Z_0}{4 R_{in}}}$$

Fields from oscillating dipole

If a charge moving with uniform velocity along a straight conductor does not radiate.

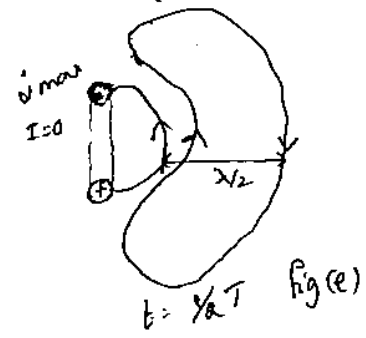
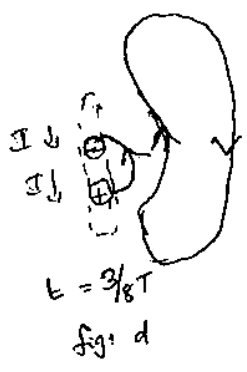
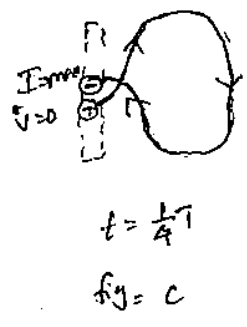
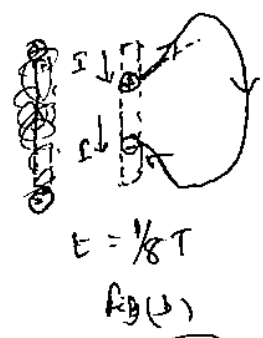
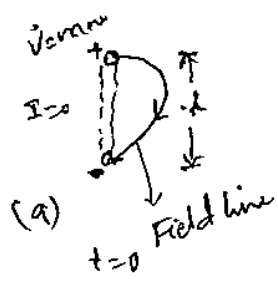
If a charge moving back & forth in simple harmonic motion along the conductor is subject to acceleration (or deceleration) & radiates.

To illustrate radiation from a dipole antenna, let us

Consider a dipole, that has two equal charges of opposite sign oscillate up & down in harmonic motion with separation l .

At $t=0$, the charges are at the max. separation & undergo max. acceleration a as they ~~are~~ reverse direction. At this instant the current I is zero. shown in fig a,

At an $\frac{1}{8}$ period later, the charges are moving toward each other & at a $\frac{1}{4}$ period later they pass at mid point. As this happens the field lines detach & new ones of opposite sign are formed. At this time the equivalent current I is a maximum & charge acceleration is zero. As time progresses to a $\frac{1}{2}$ period, fields continue to move out, as shown in d & e.



Antenna field zones

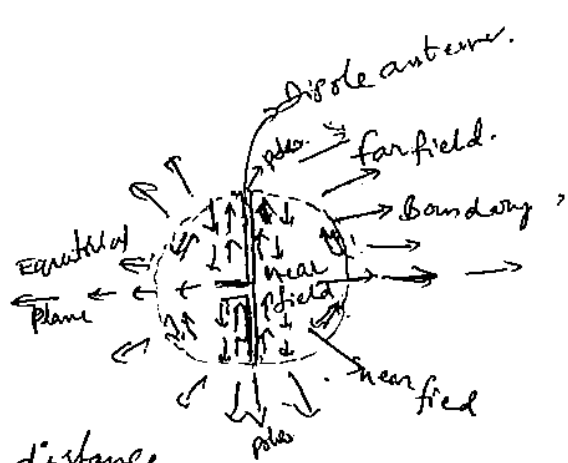
The fields around an antenna may be divided into two principle regions one near the antenna called near field (or) Fresnel zone & one at large distance called the far field (or) Fraunhofer zone.

The boundary b/w the two may be arbitrary taken to be at a radius $R = \frac{2L^2}{\lambda}$ m where L = antenna length, λ = wave length of m.

→ In the far (or) Fraunhofer region, the

measurable field components are transverse to the radial direction from the antenna. & all power flow is directed radially outward.

In the farfield the shape of the field pattern is ~~independent~~ independent of the distance.



- In the near field (or) Fresnel region, the longitudinal component of the electric field may be significant. & power flow is not entirely radial. In the near field the shape of the field pattern depends, in general, on distance.

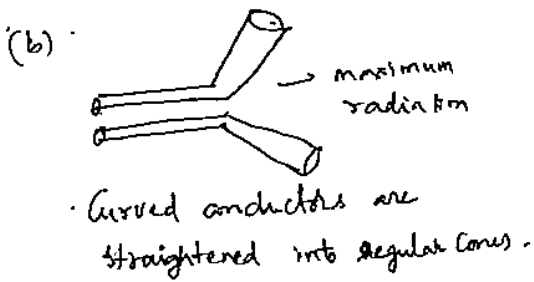
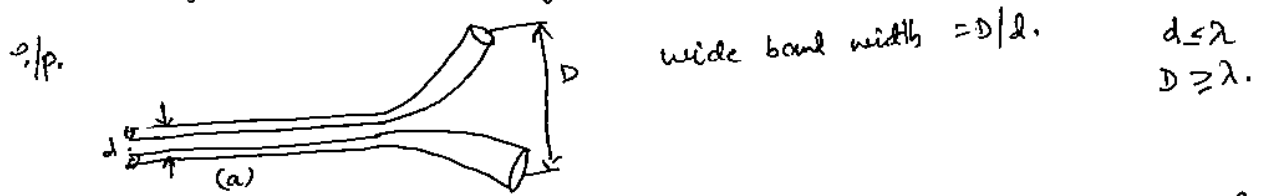
- The region near the ^{poles of the sphere} ~~poles~~ act as a reflector. & the waves expanding perpendicular to the dipole in the equatorial region of the sphere & partially transparent in this region.

- For a $\lambda/2$ dipole antenna, the energy stored at one instant of time in the electric field, mainly near the ends of antenna (or) max. charge regions. While a $\frac{1}{2}$ period later, the energy is stored in the magnetic field mainly near the center of the antenna (or) max. current region.

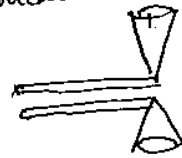
Shape & Impedance Considerations:

It is possible in many cases to deduce the qualitative behaviour of an antenna from its shape.

Starting with the opened-out two conductor transmission line, if we extend far enough, a nearly constant impedance will be provided at the o/p. we find that

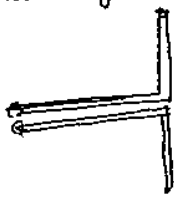


(c) The cones are aligned collinearly, forming a biconical antenna.



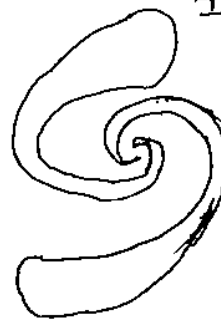
(b) and (c) are narrow B-W

(d) Cones degenerate into straight wires.

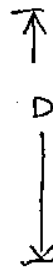


Narrow B-W

(e)



Spiral antenna.



wide Band width

The antennas a & b are unidirectional, with beams to right, the other antennas c & d are omnidirectional. B.W of relatively constant impedance tends to decrease from a to d. The spiral antenna has wide B.W.

Another set of antennas, antennas are fed from coaxial transmission lines.

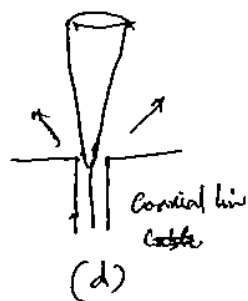
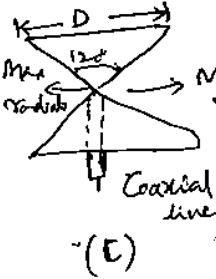
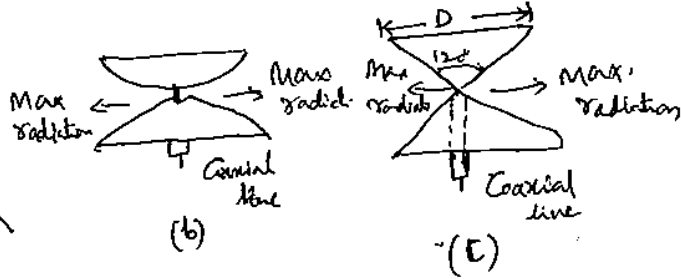
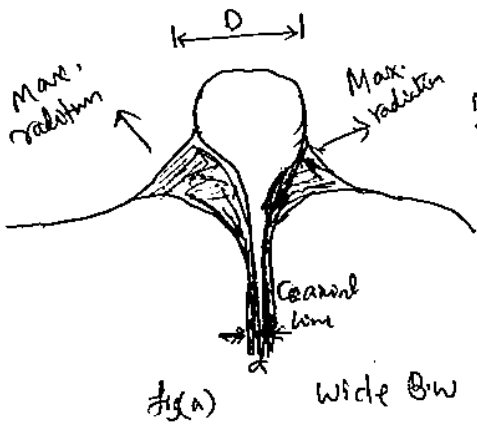
By ~~gradually~~ gradually tapering the inner & outer conductors (or) a coaxial transmission line, a very wide band antenna with an appearance of a volcanic crater & puff of smoke is obtained. shown in fig (a).

The volcano form is modified into a cone antenna shown in fig (a). and another one is two wide angle cones. All of these antennas are omni directional in a plane \perp to their axes. & all have ~~wide~~ wide B.W

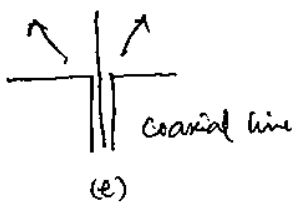
Another one is Biconical antenna, with a full cone angle of 120° has an omnidirectional pattern & nearly constant SWR if impedance shown in fig (c).

Increasing the lower cone angle to 150° while reducing the upper cone angle results to the antenna shown in fig (d).

collapsing the upper cone into a thin stub, we will get the another antenna shown in fig (e).



Narrowest B.W.



Narrowest B.W

Antenna temperature:

The brightness temperature of an extended source of radiation measured in a particular direction is the temperature of a black body which fields brightness equal to that of source under consideration.

The brightness B is defined as the power received per unit area of aperture per cycle of B.W per unit solid angle.

At radio & radar freq., the brightness temp is

$$B = 2kT_B / \lambda^2$$

k = Boltzmann Const. 1.68×10^{-23} J/K
 λ = wave length

- Mean brightness temperature in the field of antenna pattern is called the antenna temperature.

Front to back Ratio:

The ratio of energy radiated in the front & back directions through the main & back lobes is termed as front to back ratio.

~~Properties of Antennas~~ Antennas are as under the properties:

Equality of directional pattern: The directional pattern of a receiving antenna is identical with the directional pattern as a transmitting antenna.

Equality of transmitting & receiving antenna impedance: The impedance of an isolated antenna when used for receiving is the same as when used for transmitting.

Equality of effective length: The effective length of an antenna for receiving is equal to its effective length as a transmitting antenna.

Basic Maxwell Equations

The relevant equations involving electric field intensity E (V/m), electric flux density D (C/m²), magnetic flux density B (weber/m²), magnetic flux intensity H (A/m), current density J (A/m²) & charge density ρ (C/m³) are given below. A is magnetic vector potential.

$$\nabla \times H = J + \frac{\partial D}{\partial t} \quad \text{— Ampere's law.}$$

$$J = \sigma E$$

σ = Conductivity

$$\nabla \times E = -\frac{\partial B}{\partial t} \quad \text{— Faraday's law}$$

$$\nabla \cdot D = \rho \quad \text{— Gauss law (E field)}$$

$$\nabla \cdot B = 0 \quad \text{— Gauss law (H-field)}$$

$$D = \epsilon E, \quad B = \mu H.$$

→ Retarded (time-varying) potentials

$$E = -\nabla V$$

$$\nabla^2 V = -\rho/\epsilon \quad \& \quad \nabla^2 V = 0 \quad \text{if } \rho = 0$$

$$B = \nabla \times A$$

$$\nabla^2 A = -\mu J \quad \& \quad \nabla^2 A = 0 \quad \text{for } J = 0$$

$$\nabla \times E = \nabla \times (-\nabla V) = 0.$$

(\because curl of a gradient is zero)

$$\text{Let } E = -\nabla V + N.$$

$$\nabla \times E = \nabla \times (-\nabla V) + \nabla \times N$$

$$= 0 + \nabla \times N$$

$$-\frac{\partial B}{\partial t} = -\frac{\partial (\nabla \times A)}{\partial t} = \nabla \times N$$

$$\text{Thus } \nabla \times N = \frac{-\partial (\nabla \times A)}{\partial t}$$

$$= -\nabla \times \frac{\partial A}{\partial t}$$

$$= \nabla \times \frac{\partial A}{\partial t}$$

$$\therefore N = \frac{\partial A}{\partial t}$$

$$E = -\nabla V - \frac{\partial A}{\partial t}$$

$\frac{\partial A}{\partial t}$ \rightarrow time rate of change of vector magnetic potential.

$$(2) \nabla \cdot D = \nabla \cdot (\epsilon E) = \epsilon \nabla \cdot E$$

$$= \epsilon \nabla \cdot (-\nabla V - \partial A / \partial t)$$

$$\rho = \epsilon [-\nabla \cdot \nabla V - \partial / \partial t (\nabla \cdot A)] = \rho$$

$$\text{from the above relation } \underline{\nabla^2 V + \partial / \partial t (\nabla \cdot A) = -\rho / \epsilon}$$

$$\nabla^2 V = -\rho / \epsilon \quad \text{for static conditions}$$

$$\nabla^2 V = -\rho / \epsilon - \partial / \partial t (\nabla \cdot A) \quad \text{for time varying conditions.}$$

$$(3) \nabla \times H = J + \frac{\partial D}{\partial t}$$

$$B = \mu H \quad (\text{or}) \quad H = B / \mu$$

$$\underline{\text{LHS}} \quad (\nabla \times B) / \mu = \frac{(\nabla \times \nabla \times A)}{\mu} = [\nabla (\nabla \cdot A) - \nabla^2 A] / \mu.$$

$$\underline{\text{RHS}} : J + \epsilon \frac{\partial E}{\partial t} = J + \epsilon \partial (-\nabla V - \partial A / \partial t) / \partial t$$

$$= J + \epsilon \left(-\nabla \left(\frac{\partial V}{\partial t} \right) - \frac{\partial^2 A}{\partial t^2} \right)$$

$$= J - \epsilon \left[\nabla \left(\frac{\partial V}{\partial t} \right) + \frac{\partial^2 A}{\partial t^2} \right]$$

$$\therefore \nabla (\nabla \cdot A) - \nabla^2 A = \mu J - \mu \epsilon \left(\nabla \left(\frac{\partial V}{\partial t} \right) + \frac{\partial^2 A}{\partial t^2} \right)$$

As per the statement of Helmholtz Theorem, "A vector field is completely defined only when both its curl & divergence are known".

There are some conditions which specify the divergence of A. These are Lorentz gauge condition & Coulomb's gauge condition.

$$\nabla \cdot A = -\mu \epsilon \frac{\partial V}{\partial t} \rightarrow \text{Lorentz Condition}$$

$$\nabla \cdot A = 0 \rightarrow \text{Coulomb's Condition.}$$

Using Lorentz gauge condition.

$$\nabla^2 V = -\rho / \epsilon - \partial / \partial t \left(\mu \epsilon \frac{\partial V}{\partial t} \right)$$

$$= -\rho / \epsilon - \mu \epsilon \frac{\partial^2 V}{\partial t^2}$$

$V e^j$

$$\nabla^2 A = -\mu J + \mu \epsilon \left(\frac{\partial^2 A}{\partial t^2} \right).$$

For sinusoidal time variation characterized by $e^{j\omega t}$

$$V = V_0 e^{j\omega t} \quad \epsilon A = A_0 e^{j\omega t}$$

$$\rightarrow \nabla^2 V = -\rho / \epsilon - \mu \epsilon \omega^2 V \quad \nabla^2 A = -\mu J + \mu \epsilon \omega^2 A$$

Resolution :

The Resolution of an antenna may be defined as equal to the half ^{power} beam width b/w the first nulls (FNBW)/2.

Half the beam width b/w first nulls is approximately equal to the half power beam width (HPBW)

$$\therefore \frac{\text{FNBW}}{2} = \text{HPBW}$$

$$\text{Thus } \Omega_A = \left(\frac{\text{FNBW}}{2} \right) \theta \left(\frac{\text{FNBW}}{2} \right) \phi$$

The number N of radio transmitters (or) point sources of radiation ~~scattered~~ distributed uniformly over the sky which an antenna can resolve is given by

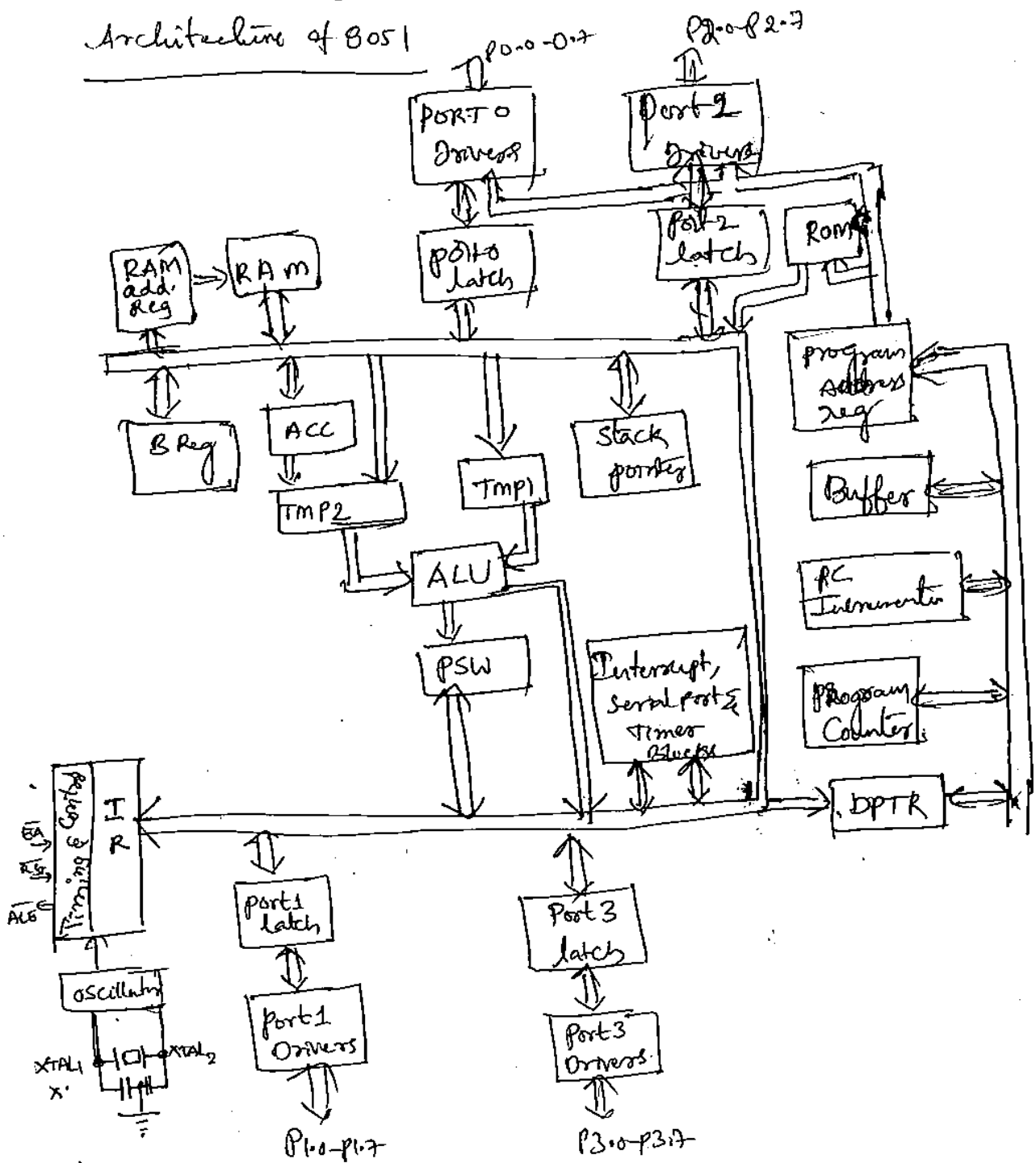
$$N = \frac{4\pi}{\Omega_A}$$

Ω_A = beam area

However $D = \frac{4\pi}{\Omega_A}$

$$\therefore \boxed{N = D}$$

Architecture of 8051



Accumulator (ACC): The ACC (or) 'A' acts as an operand register. This is either be implicit or specified in the instruction. The ACC Register address is allotted in the on-chip Special function register bank.

B Register: It is used to store one of the operands for multiply & divide ~~operations~~ instructions.

program status word: This set of flags contains the status

information & is considered as one of the SFR.

Stacks pointer: This register contains 8 bit stack top address.

The stacks may be defined anywhere in the on-chip 128 bytes RAM. After Reset, the SP register is initialized to 07.

DPTR: This 16-bit Register contains a higher byte (DPH) & the lower byte (DPL) of a 16-bit ~~off~~ external data RAM address. It is accessed as a 16-bit register or two 8-bit registers as specified above.

Port 0 to 3 latches & drivers: These four latches & driver pairs are ~~also~~ allotted to each of the four on-chip I/O ports. These latches have been allotted address in the SFR bank. Using allotted address user can communicate with these ports. These are P0, P1, P2, P3.

Timer Register: ~~There are~~ There are two timer registers T0, T1. These two are 16-bit registers. These can be accessed as two 8-bit registers.

Control registers: The special function registers IP, IE, TMOD, TCON, SCON, & PCON contain control & status information for the interrupts, timers/counters & serial port.

Timing & Control Unit: This unit derives all the necessary timing & control signals required for the internal operation of the circuit. It also derives control signals required for controlling the external system bus.

Oscillator: This circuit generates the basic timing clock signal for the operation of the circuit using crystal oscillator.

Instruction register: This register decodes the opcode of an instruction to be executed & gives the information to the timing & control unit to generate the necessary signals for the execution of the instruction.

ALU: The arithmetic and logic unit performs 8-bit arithmetic and logical operations over the operands held by the temporary registers TMP1 & TMP2. Users can not access these temporary registers.

pin diagram of 8051

P1.0	1	8	VCC
P1.1	2	0	P0.0 (AD0)
P1.2	3	5	P0.1 (AD1)
P1.3	4	1	P0.2 (AD2)
P1.4	5		P0.3 (AD3)
P1.5	6		P0.4 (AD4)
P1.6	7		P0.5 (AD5)
P1.7	8		P0.6 (AD6)
Reset	9		P0.7 (AD7)
RXD P3.0	10		31 EA/VPP
TXD P3.1	11		30 ALE/Porg
INT0 P3.2	12		29 PSEN
INT1 P3.3	13		28 P2.7 (AD7)
RD P3.4	14		27 P2.6 (AD6)
WR P3.5	15		26 P2.5 (AD5)
P3.6	16		25 P2.4 (AD4)
P3.7	17		24 P2.3 (AD3)
XTAG1 P3.8	18		23 P2.2 (AD2)
XTAG2 P3.9	19		22 P2.1 (AD1)
VSS	20		21 P2.0 (AD0)

Register set of 8051

Registers of 8051.

A, B, PSW, P0, P1, P2, P3, SP, IE, JCON, SCON,

SP, DPH, DPL, TMOD, TH0, TLO, TH1, TLI, SBUF, PCON.

- And also ⁴ register banks for general purpose registers

Bank 0 → R0-R7

Bank 1 R0-R7

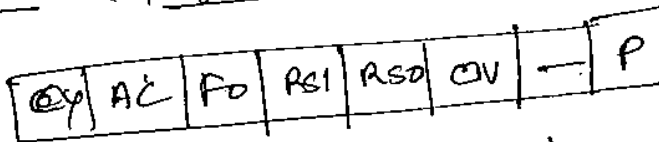
Bank 2 R0-R7

Bank 3 R0-R7

- General purpose reg. are stored in the on-chip RAM. Starting 32 bytes are reserved for this (0000 to 001FH).

- Addresses of the remaining registers are available in the second function Bank.

PSW : (Program Status Word)

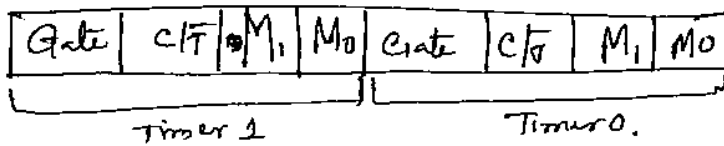


RS1	RS0	Reg. Bank	Address
0	0	Bank 0	00-07H
0	1	Bank 1	08-0FH
1	0	Bank 2	10H-17H
1	1	Bank 3	18H-1FH

OV - overflow flag

P - parity flag

TMOD Format

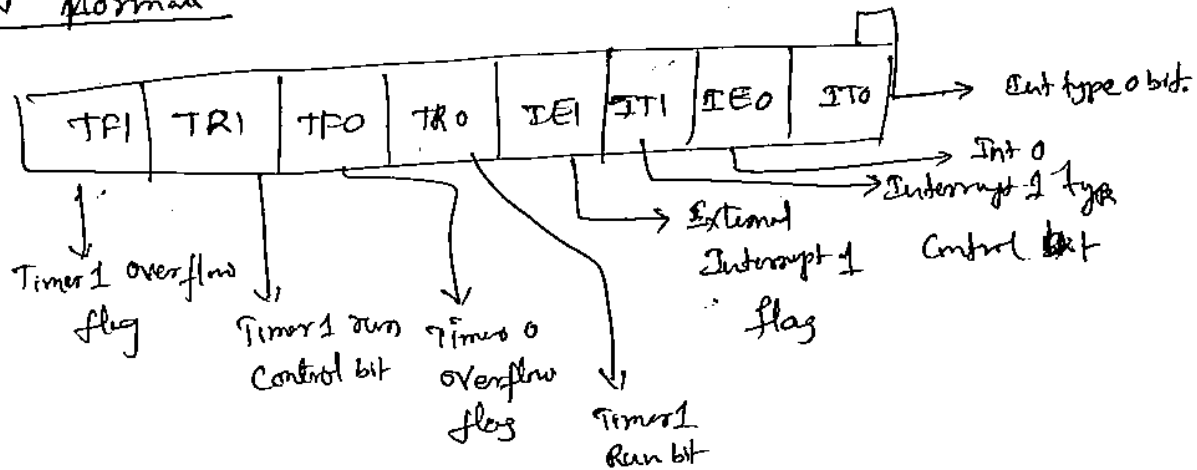


Gate: When TRX (in TCON) is set & Gate = 1, Timer/Counter will run only while INTX pin is high, when Gate = 0, Timer/Counter will run only while TRX = 1.

C/T → Timer/Counter selector.
It is ~~to~~ zero select the timer operation other wise Counter.

M₁ M ₁ M ₀	operation
0 0	Mode 0, 13 bit Timer
0 1	Mode 1, 16 bit Timer/Counter
1 0	Mode 2, 8 bit auto Reload Timer
1 1	Mode 3. (Timer 0) TLO is an 8 bit Timer/Counter controlled by the Timer 0 control bits, THO is an 8 bit timer & controlled by Timer 1 control bits.
1 1	Mode 3 - (Timer 1) Timer/Counter 1 Stopped.

TCON Format

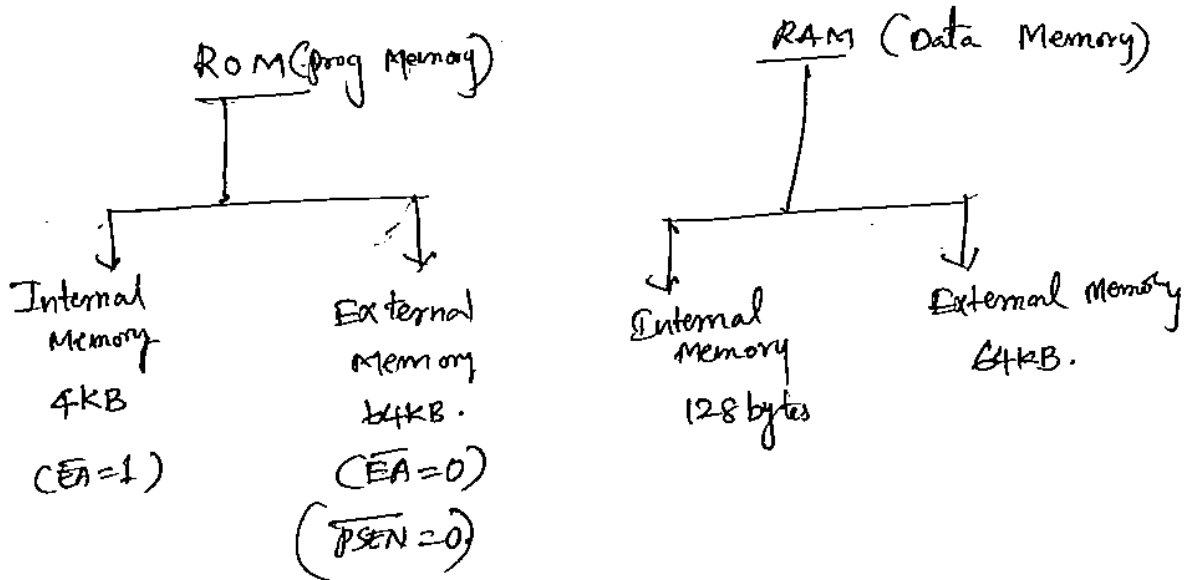


TF1 → This is set by H/w when Timer/Counter 1 overflows & is cleared by H/w as processor vectors to the interrupt service routine.

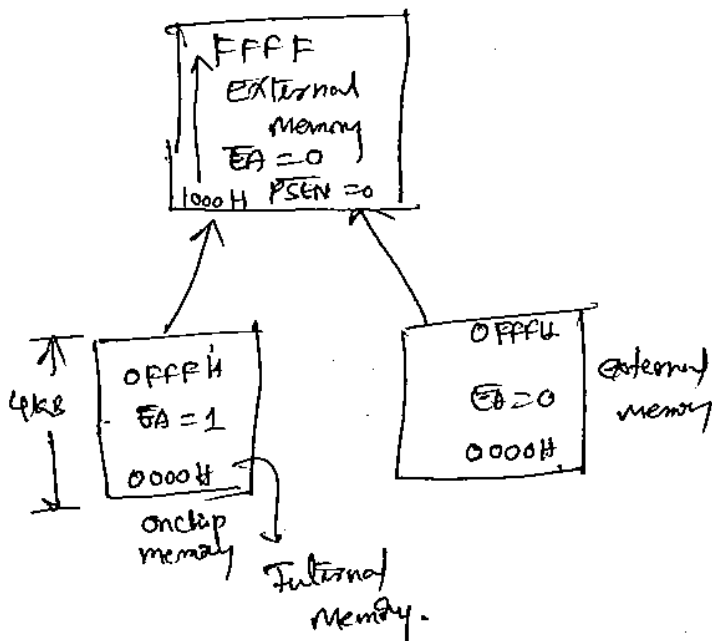
TR1 → This is set/cleared by S/w to run Timer/Counter 1 ON/OFF.

IE1 → This is set by H/w when external interrupt edge is detected & is cleared by H/w when the interrupt is processed.

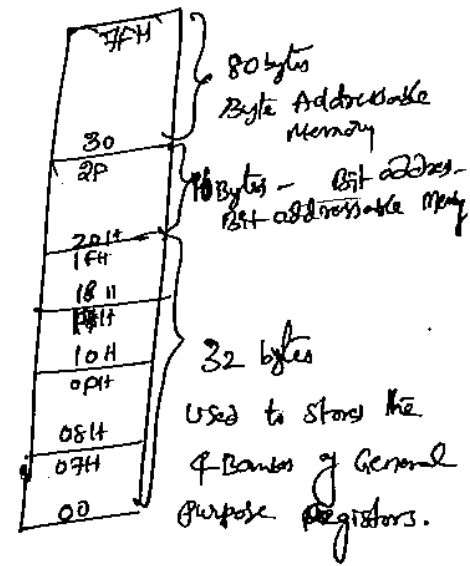
Memory organization



ROM



RAM (128 bytes)



Internal RAM

1. First 32 bytes from address 00H to 0FH are reserved for 4 banks of 32 general purpose registers.
2. Next 16 bytes that is from 20H to 2FH is bit addressable memory. An addressable bit may be specified by its bit address of 00H to 7FH. For Ex., the bit address 4FH is also a bit of 7 of the byte address 29H. Addressable bits are useful when the prog. need only remember a binary event. (Switch ON (or) light OFF. etc).

Interrupts 8051

8051 five sources of interrupts.

Interrupt Source	Priority
IE0 - External (INT0)	Highest
IE1 (Timer 0)	↓
IE2 (External INT1)	↓
TF1 (Timer 1)	↓
RI = EI (Serial port)	Lowest

Interrupt Enable Register

EA	ET2	ES	ET1	EX1	ET0	EX0
----	-----	----	-----	-----	-----	-----

- If EA=0, no interrupt will be acknowledged.
- EA=1, each interrupt source is enabled or disabled by setting (or) clearing its enable bit.
- ET2. ^{This enables} Timer 2 overflow (or) [8052]
- ES - This enables (or) disables the serial port interrupt.
- ET1 - This enables (or) disables Timer 1 overflow interrupt.

Interrupt Priority Register

-	-	PT2	PS	PT1	PX1	PT0	PX0
---	---	-----	----	-----	-----	-----	-----

- PT2 - This defines the Timer 2 interrupt priority level.
- PS - This defines the serial port interrupt priority level.
- PT1/PT0 → This defines the Timer 1/Timer 0 interrupt priority level.
- PX1/PX0 - This defines the INT1/INT0 priority level.

Addressing Modes:

- ① Direct addressing mode
- ② Indirect addressing mode
- ③ Register addressing mode
- ④ Register specific (Register implicit addressing mode)
- ⑤ Immediate addressing mode
- ⑥ Indexed addressing mode

① Direct addressing Mode:

In this addressing mode, the 8 bit address of an operand are specified ~~is~~ is specified directly in the instruction.

EX Mov R0, 80H.

② Indirect addressing mode:

In this mode, the 8 bit address of an operand is stored in register. & the register, instead of 8 bit address, is specified in the instruction.

ADD A, @R0.

③ Register Addressing mode: Specify the operand by means of any register.

EX : Mov A, R0.

Mov A, R1.

④ Immediate Addressing mode:

Specify the data directly in the instructions.

EX Mov A, #50H.

Instruction set

External data Move Instruction :

$\text{MOVX } A, @R_p$; copy of the contents of the external address in R_p to A

$\text{MOVX } @DPTR, A$; Copy data A to the 16 bit external address in $DPTR$.

$\text{MOVX } @RO, A$; copy data from A to the 8 bit address in RO .

Code memory Read only data moves

$\text{MOVC } A, @A+DPTR$; copy the code byte from address found by adding of A & $DPTR$ to A .

$\text{MOVC } A, @A+PC$; Copy the code byte ^{from} address found by adding of A and the PC to A .

Push & Pop instructions:-

push add ; Increment SP ; copy the data in ^{address} add to the internal RAM address contained in SP .

pop add ; copy the data from the internal RAM address contained in SP to add ; decrement the SP .

Data exchanges :

$\text{XCH } A, R_n$; Exchange the data bytes b/w reg R_n and A .

$\text{XCH } A, \text{add}$; Exchange the data bytes b/w add and A .

$\text{XCHD } A, @R_p$; Exchange the lower nibble in A & the add . in R_p .

Byte level Logical Operations :

$\text{ANL } A, \#n$; AND each bit of A with the same bit of immediate number n ; & put the result in A .

$\text{ORL } A, \#n$; OR each bit of A with the same bit of immediate number n ; & put the result in A .

$\text{XRL } A, \#n$; XOR each bit of A with the same bit of immediate number n ; & put the result in A .

CLRA ; clear each bit of the A register to 0.
CPL A ; complement each bit of A ; every 1 becomes a 0 ; &
each 0 becomes a 1.

Bit level logical operations.

ANLC, b ; AND C and the addressed bit ; put the result in C.
ANL C, /b AND C and the complement of the addressed bit. &
put the result in C & the addressed bit is not altered.
ORC, b OR C and the addressed bit ; put the result in C.
CLR b Clear the addressed bit to 0.
MOV C, b : ~~to~~ copy the addressed bit to the C flag.
SETB C Set the C flag to 1.
SETB b Set the addressed bit to 1.

Rotate and Swap operation Instructions.

RLA ; Rotate A register one bit position to the left.
RLC A Rotate the Register & the carry flag as ninth bit, one bit position to the left.
RRA ; Rotate A register one bit position to the right.
RRC A ; Rotate A register ~~to~~ Carry flag as ninth bit, one bit position to right i.e. bit A0 to C, C to A7, A7 to A6, A6 to A5 etc.
SWAP A ; Interchange the nibble of register A.
i.e. put the higher nibble in the low nibble position &
the lower nibble in the high nibble position.

Arithmetic Instructions.

ADD A, #n ; Add A & the immediate number n; put the sum in A.

SUBB A, #n ; Subtract immediate value from A and the result is stored into A.

MUL AB ; Multiply A by B - put the low order byte of the result in A & put the high order byte in B.

DIV AB ; Divide ~~by~~ A by B ; put the integer part ^{Quotient} into A & ~~the~~ integer part of remainder into B.

INC A ; Add 1 to the A reg.

DEC A ; Subtract '1' to the A reg.

DA A ; Adjust the sum of two packed BCD numbers found in A register; leave the adjusted number in A.

Jump Instructions

JC radd ; Jump ^{to} relative address if the carry is set to 1.

JB b, radd ; Jump to relative address if the addressable bit is set to 1.

JNB b, radd ; " " if the addressable bit is reset.

JBC b, radd ; " " if the addressable bit is set & clear the addressable bit to 0.

CJNE A, add, radd ; compare the contents of A reg with the contents of the direct address; if they are not equal, then jump to the relative address. Set the carry flag 1 if A is less than the contents of the direct address.

CJNE A, #n, radd.

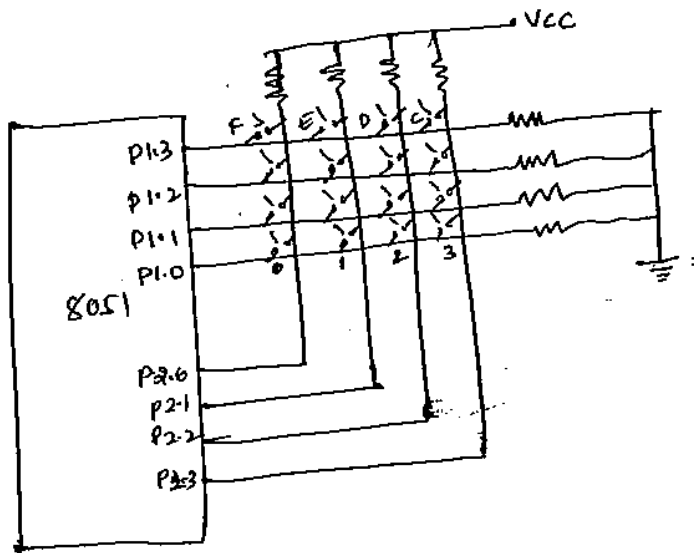
DJNE Rn, add ; Decrement the reg. Rn by 1 & Jump to the relative address if the result is not zero. No. flags are effected.

Differences between Microprocessors & Microcontrollers.

Micro processors	Micro Controllers
① Micro processors does not have on chip memory, timers, I/O ports.	① Micro Controllers has on chip memory, timers & I/O ports.
② It has one (or) two bit handling instructions	② It has more number of bit handling instructions.
③ Access time for memory & I/O is more.	③ Access time is less.
④ It requires more hardware	④ It requires less H/w.
⑤ More flexible	⑤ More Less flexible.
⑥ Less Number of bit pins are multiplexed.	⑥ More No. of pins are multiplexed.

Key Board Enterfacing. With 8051

(7)



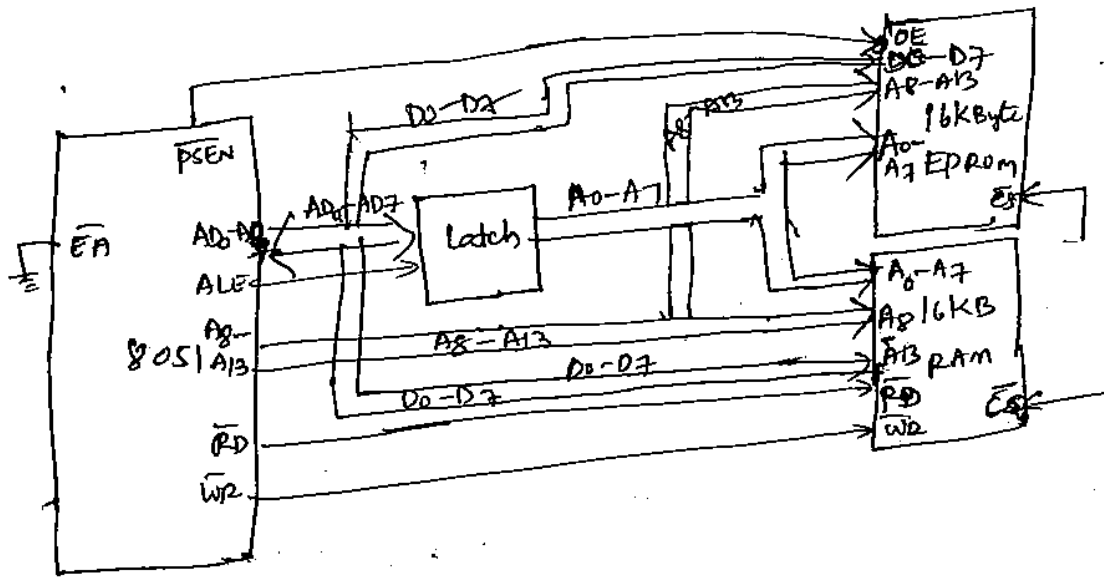
```

Mov p2, # FFH
GoS: Mov p1, # 00H
      MOV A, P2
      ANL A, # 0FH
      CJNE A, # 0FH, Go
      ACALL Delay
Go2:  Mov P1, # 00H
      MOV A, P2
      ANL A, # 0FH
      CJNE A, # 0FH Go1
Go1:  ACALL Delay
      MOV P1, # 1111 110B (FEH)
      MOV A, P2
      ANL A, # 0FH
      CJNE A, # 0FH, Row-0
      MOV P1, # 1111 1101 B
      MOV A, P2
      ANL A, # 0FH
      CJNE A, # 0FH, Row-1
      MOV P1, # 1111 1011 B
      MOV A, P2
      ANL A, # 0FH
      CJNE A, # 0FH, Row-2
      MOV P1, # 1111 1011 B
      MOV A, P2
      ANL A, # 0FH
      CJNE A, # 0FH, Row-3
      MOV DPTA, # Kcode0
      SJMP Find
      MOV DPTA, # Kcode1
      SJMP Find
      MOV DPTA, # Kcode2
      SJMP Find
      MOV DPTA, # Kcode3
      SJMP Find
      RRC A
      JNC Bit
      INC DPTA
      SJMP Find
      CLR A
      MOV A, @A + DPTA
      MOV P0, A
      SJMP Go
      ORG 0000H
      Kcode0: DB '0', '1', '2', '3'
      Kcode1: DB '4', '5', '6', '7'
      Kcode2: DB '8', '9', 'A', 'B'
      Kcode3: DB 'C', 'D', 'E', 'F'
      END
      Delay:  Mov R1, # FFH
  
```

```

MOV P1, # 1111 0111 B
MOV A, P2
ANL A, # 0FH
CJNE A, # 0FH, Row-3
LJMP Go2,
Row-0: MOV DPTA, # Kcode0
      SJMP Find
Row-1: MOV DPTA, # Kcode1
      SJMP Find
Row-2: MOV DPTA, # Kcode2
      SJMP Find
Row-3: MOV DPTA, # Kcode3
      SJMP Find
Find:  RRC A
      JNC Bit
      INC DPTA
      SJMP Find
Bit:   CLR A
      MOV A, @A + DPTA
      MOV P0, A
      SJMP Go
ORG 0000H
Kcode0: DB '0', '1', '2', '3'
Kcode1: DB '4', '5', '6', '7'
Kcode2: DB '8', '9', 'A', 'B'
Kcode3: DB 'C', 'D', 'E', 'F'
END
Delay:  Mov R1, # FFH
  
```

Memory Interfacing of 8051



Interfacing

If $RS=0$; Command register is selected, allowing the user to send a Command such as clear display, cursor at home.

$RS=1$, data reg. is selected, allowing the user to send data to be displayed on the LCD.

$R/W=0$ → write the information to the LCD.

$R/W=1$ → Read the information from it.

E = Enable the LCD.

D_0-D_7 → Used to send the information to the LCD (or) read the contents of the LCD's internal reg.

LCD Command Codes

01 → clear display screen.

02 → Return home.

04 - shift cursor to left

06 - shift cursor to Right.

05 - shift display right

07 - shift display left.

08 - display off, cursor off

0A - display off, cursor on

0C - display on, cursor off

0E - display on, cursor blinking

0F - display on, cursor blinks

10 - shift cursor position to left

14 - shift cursor position to RT

18 - shift entire display to left

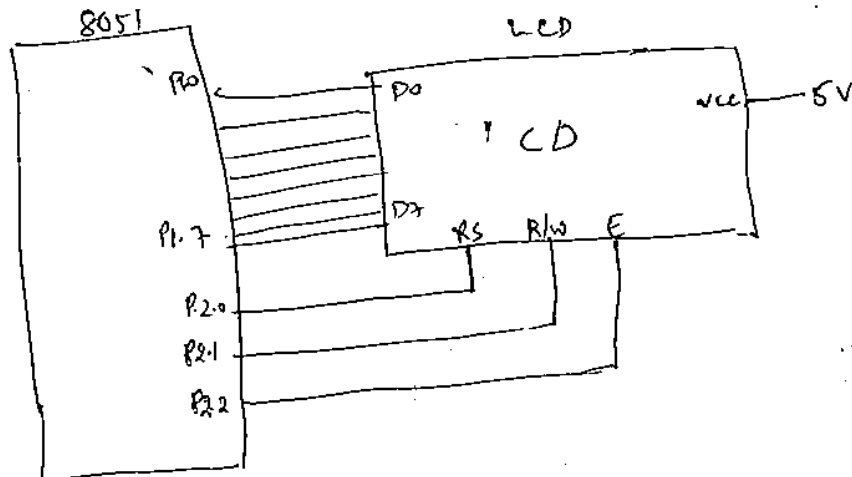
1C - shift entire display to RT

80 - force cursor to beginning of 1st line

C0 - force " " 2nd line

39 - 2 lines & 5x7 matrix.

Interfacing diagram



ORG 0000H

```

MOV A, #38H ; Initialize LCD & lines, 5x7 matrix.
ACALL command COMMAND ; Call Command Subroutine.
ACALL delay.
MOV A, #0EH ; Display on, cursor on.
ACALL Command
ACALL delay.
MOV A, #01 ; clear LCD
ACALL Command
ACALL delay
MOV A, #06H ; shift cursor right.
ACALL Command
ACALL delay.
MOV A, #80H ; cursor at line 1, pos 1
ACALL Command
ACALL delay.
MOV A, #'H' ; Display letter H.
ACALL Display
ACALL delay
MOV A, #'E' ;
ACALL Display
ACALL delay.

```

again; SJMP again.

Command:

```

MOV P1, A ; Copy reg A to port A
CLR P2-0 ; RS=0, for command.
CLR P2-1 ; R/W=0, for write
SETB P2-2 ; E=1 for high pulse
ACALL delay
CLR P2-2 ; E=0, for H-to-L pulse.
RET.

```

Display:

```

MOV P1, A ; Copy reg A to port A
SETB P2-0 ; RS=1, for data
CLR P2-1 ; R/W=0 for write.
SETB P2-2 ; E=1
ACALL delay
CLR P2-2 ; E=0 for H-to-L pulse.
RET.

```

```

Delay: MOV R3, #150
loop1: MOV R4, #200
loop: DJNZ R4, loop
      DJNZ R3, loop1

```


Serial Data Communication

SCON is used to control the data communication & SBUF is used to hold the data, PCON controls the data rates.

The serial data flags in SCON, TI & RI are set when ever a data byte is transmitted (TI) or received (RI).

Data Transmission:

Transmission of serial data bits begins any time data is written to SBUF. TI is set to 1 when the data is transmitted & signifies that SBUF is empty & that another data byte can be sent.

Data Reception:

Reception of serial data will begin if the receive enable bit (REN) bit in SCON is set to 1 for all modes. In addition, for mode 0 only RI must be cleared to 0. Receiver Interrupt flag (RI) is set after data has been received in all modes.

SCON Register Format

SM0	SM1	SM2	REN	TBS	RBS	TI	RI
-----	-----	-----	-----	-----	-----	----	----

SM0	SM1	mode	Description	Baud Rate
0	0	0	Shift register	oscillator/12
0	1	1	8-bit UART	variable
1	0	2	9 bit UART	$f/32$ (or) $f/64$
1	1	3	9 bit UART	variable.

SM2 → This enables the multiprocessor communication feature in mode 2 & 3.

In mode 2 (or) 3, if SM2 = 1 & then RI will not be activated, if the received 9th bit (RBS) is 0.

In mode 1, if SM2 = 1, then RI will not be activated, if a valid stop bit was not received.

In mode 0, SM2 is should be 0.

REN - 1: Receiving Enabled
= 0; Receiving disabled.

TBS - This selects q^{th} bit that will be transmitted in modes 2 & 3.

RBS - This is q^{th} data bit that was received in mode 2 & 3.

TI \rightarrow Transmit Interrupt flag - this is set by H/w at the end of the 8^{th} bit time in mode 0 (or) at the beginning of the stop bit in other modes. This is must be cleared by S/w.

RI - Receive Interrupt flag - this is set by H/w at the end of the 8^{th} bit time in mode 0 (or) Half way through the stop bit time in other modes excepting the case where SM2 is set. This must be cleared by S/w.

PCON

SMOD	-	-	-	GFI	GFO	PD	IDL
------	---	---	---	-----	-----	----	-----

SMOD = ~~0~~ 1 = Double baud rate is selected for timer 1 in mode 1, 2, 3
SMOD = 0 = Same baud rate. of timer 1.

GFI & GFO \rightarrow General purpose user defined flags.

PD = 1 \rightarrow power down mode is selected

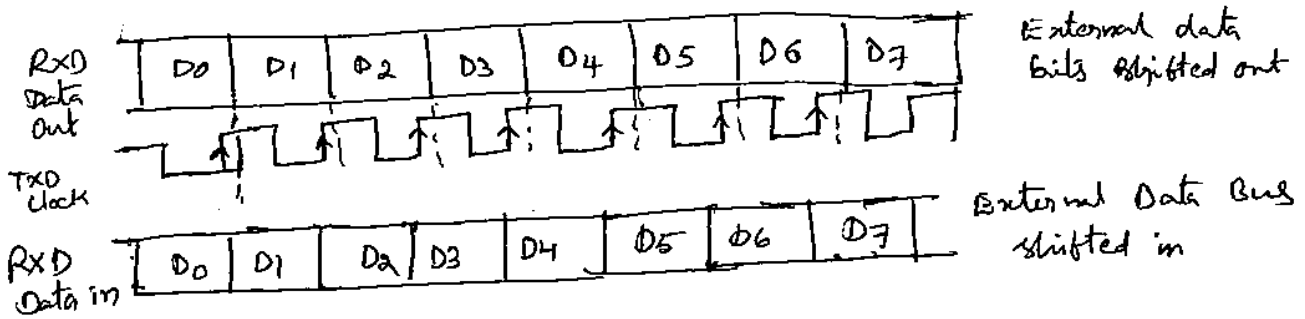
IDL = 1 \rightarrow Idle mode is selected.

Serial Data transmission modes

Mode 0: Shift Register mode:

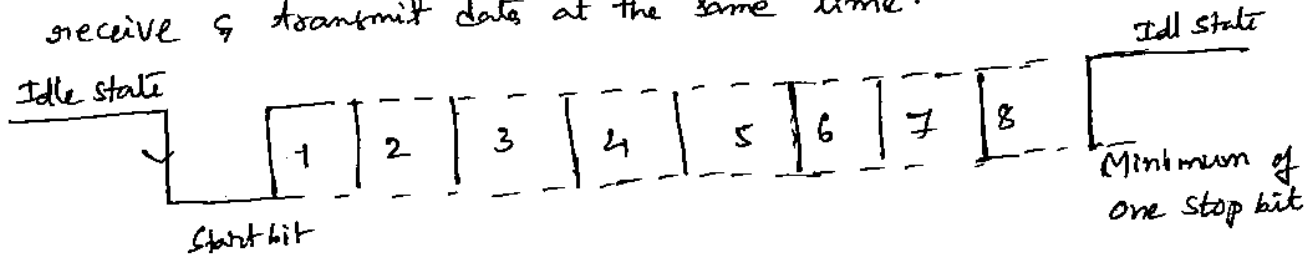
Setting bits SM0, SM1 in SCON is 00 configures SBUF to receive or transmit 8 bits using Pin RXD for both functions. Pin TXD is connected to the internal shift frequency pulse source to supply the pulses to external circuits.

When transmitting, data is shifted out of RXD, the data changes on the falling edge (or) one clock pulse after the raising edge of the O/P TXD shift clock.



Mode 1 (Standard UART)

SBUF becomes 10 bit full duplex receiver/transmitter that may receive & transmit data at the same time.



Mode 1 Baud rates:

Timer 1 is used in timer mode 2, then Baud rate

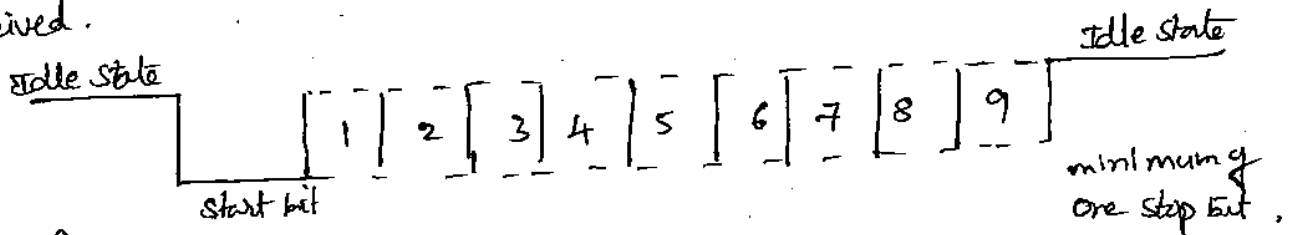
$$f_{\text{Baud}} = \frac{2^{\text{SMOD}}}{32d} \times \frac{\text{oscillator frequency}}{12d [256d - (TH1)]}$$

If timer 1 is not run in timer mode 2, then Baud rate is

$$f_{\text{Baud}} = \frac{2^{\text{SMOD}}}{32d} \times (\text{Timer 1 overflow frequency}).$$

Serial Data Mode 2: Multiprocessor mode.

Similar to mode 1, except 11 bits are transmitted; a start bit, 9 data bits, one stop bit. The 9th data bit is copied from bit TB8 in SCON during transmit & stored in bit RB8 of SCON when data is received.



$$f_{\text{Baud}} = \frac{2^{\text{SMOD}}}{32d} \times \text{oscillator frequency}.$$

Mode 3 :

Mode 3 is identical to mode 2, except that the baud rate is determined exactly as in mode 1 using timer 1.

Timers & Counters :

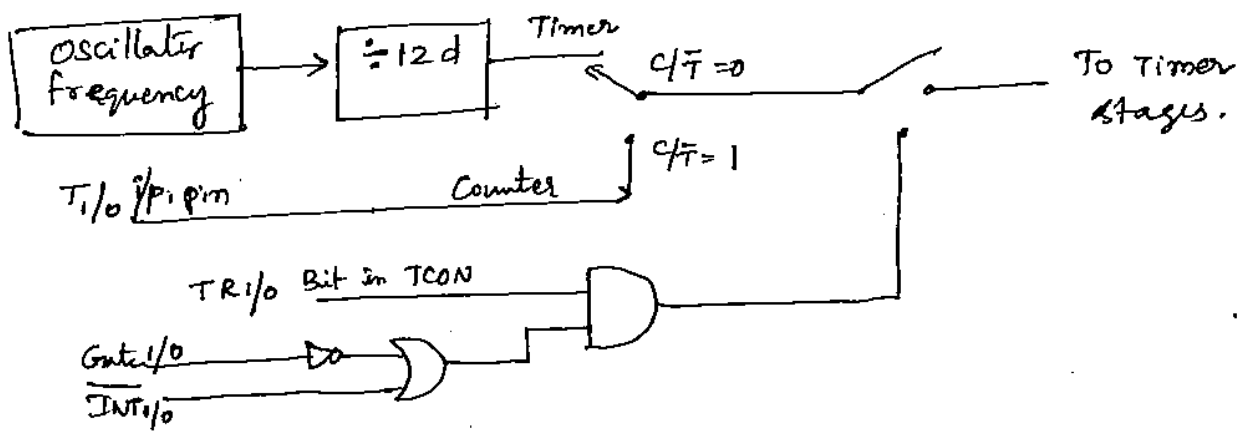
~~explain~~ ~~how~~ ~~it~~

Counter may be programmed to count the internal clock pulses as a timer (or) programmed to count external pulses as a counter.

When used as a timer, clock pulses are sourced from the oscillator through the divide by 12 circuit, when used as a counter pin T_0 supplies pulses to counter 0 & pin T_1 supplies pulses to counter 1.

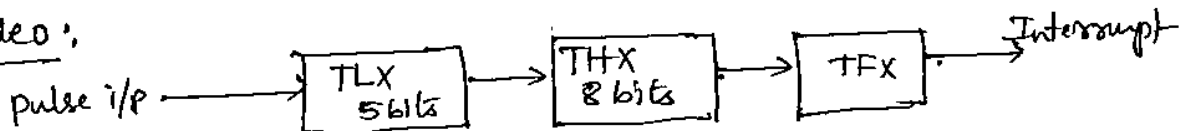
Then explain TCON & TMOD registers. These are ~~also~~ explained in the previous topic.

Logic diagram of Timer/Counter

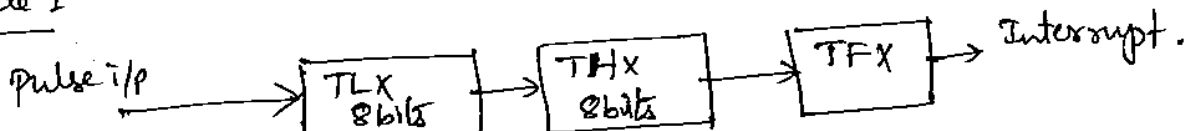


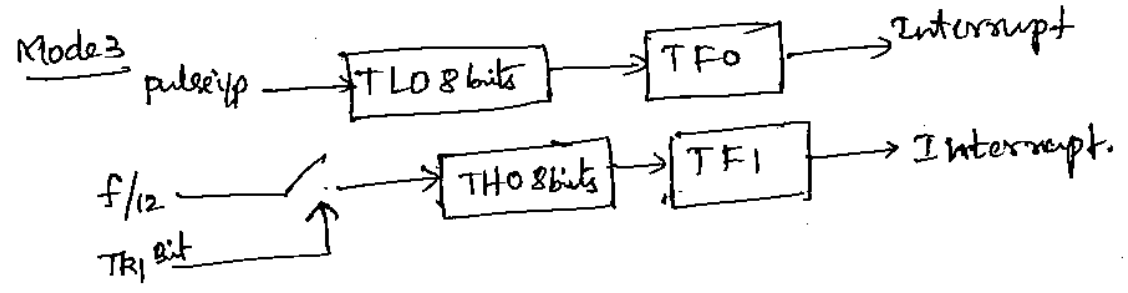
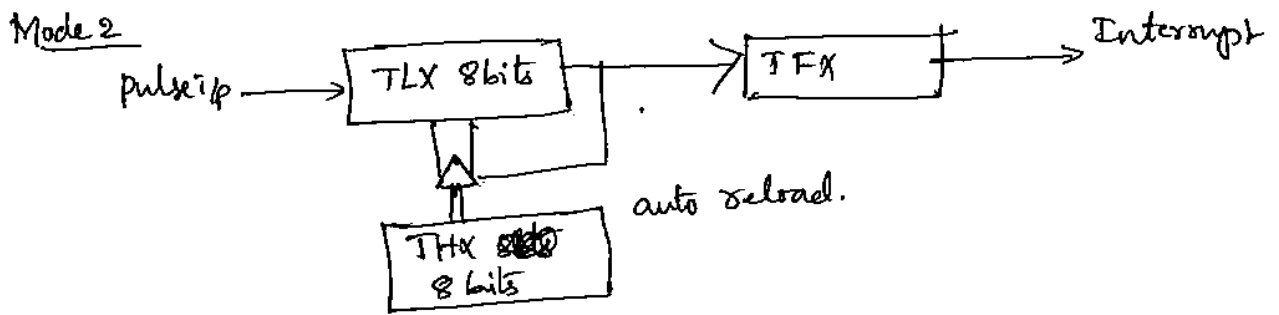
Timer Modes

Mode 0 :



Mode 1





IO ports :

IO ports

Port 0 (P0.0 to P0.7) (P00 to P0.7)

Port 0 is an 8-bit bidirectional bit addressable IO port. This has been allotted an address in the SFR address range. Port 0 act as multiplexed address/data lines during external memory access.

Port 1 (P1.0 to P1.7) :

Port 1 act as a 8-bit bidirectional bit addressable ^{IO} port. This has been allotted an address in SFR address range.

Port 2 (P2.0 to P2.7) :

Port 2 acts a 8-bit bidirectional bit addressable IO port. During the external memory access, port 2 emits higher eight bits of address lines which are valid w^h ALE=1, EA=0.

Port 3 (P3.0 to P3.7) : Port 3 is an 8-bit bidirectional bit addressable IO port. The port 3 pins also serve the alternate functions.

- P3.0 → Acts as Serial i/p data pin (RXD)
- P3.1 → Acts as Serial o/p data pin (TXD)
- P3.2 → Acts as External interrupt pin 0 ($\overline{INT0}$)
- P3.3 → Acts as " " " 1 ($\overline{INT1}$)
- P3.4 → Acts as External i/p to timer 0 (T0)

P3.6 - Acts as write control signal for external data memory (\overline{WE})

P3.7 → Acts as read control signal for external data ~~mem~~ memory (\overline{RD}).

(1) Assigning interrupt priorities.

```
MOV IE, #8CH ; Enable EX1 & ET1
SETB PT1 ; Timer 1 interrupt has high priority.
```

(2) Initializing Timer 1 in mode 1

```
MOV TMOD, #01H ; Timer 1 mode 1.
SETB TR1 ; start timer 1.
CLR TR1 ; stop timer 1
$: SJMP $
```

(3) Program to initialize timer 1 in mode 1

```
MOV SP, #54
MOV TMOD, #00010000B ; Timer 1 in mode 1
SETB ET1 ; Enable the timer 1 interrupt
SETB TR1 ; start timer 1
SETB EA ; Enable all interrupt access.
$: SJMP $
```

Note: The above prog. will start timer 1 and when it overflows timer 1 interrupt is generated, which will cause the PC to jump to vector location 000BH.

(4) Initializing timer 0 in mode 2.

```
MOV TMOD, #00000010B;
MOV TH0, #33H
MOV TL0, #33H.
SETB TR0
$: SJMP $
```

(5) prog. to generate 2kHz square waves on P1.0 of port 1 using timer 0 autoreload mode

```
MOV SP, #54H
MOV TMOD, #00000010B ; timer 0 mode 2
MOV TH0, #06H
MOV TL0, #06H
SETB TR0 ; start timer 0
Loop: JB TFO, Compli
      SJMP Loop
Compli: CPL P1.0 ; Toggle bit P1.0
      SJMP Loop
```

```

ORG 0000H
AJMP start
ORG 000BH
AJMP INT_TFO
start: MOV SP, #54H
      SETB ETO
      SETB EA
      MOV TMOD, 00000010
      MOV TH0, #06H
      MOV TLO, #06H
      SETB TRO
here: SJMP here
INT_TFO: CPL P1.0
      RETI
      END

```

⑦ write 8051 program to receive a serial byte through RXD

```

ORG 0000H
MOV SCON, #01010000
MOV TMOD, #00100000
MOV TH1, #230d (1200 Baudrate)
SETB TRI
CLR RI
here: JNB RI, here
      MOV A, SBUF
      END

```

Transmission

```

ORG 0000H
MOV SCON, #01000000B
MOV TMOD, #00100000
MOV TH1, #230d
SETB TRI
MOV SBUF, #56H
here: JNB TI, here
      CLR TI.

```

⑧ write 8051 program as example interrupt call to routine, timer 0 is used in mode 0 to overflow & set the timer 0 interrupt flag. when interrupt is generated, the program vectors to the interrupt routine, resets the timer 0 interrupt flag, stops the timer & returns.

```

MOV TMOD, #00H.
CLR TFO.
MOV IE, #82H
SETB TRO.

wait: SJMP wait

ORG 000BH
MOV EA, #00H
CLR TRO
RETI

```

⑨ what is the use of mode 0 of serial communication in 8051. write a program to transmit a data 45H in mode 0.

```

ORG 0000H
MOV SCON, #00H
MOV SBUF, #45H.

Again: JNB TI, Again
      CLR TI.

```