CHAPTER - II

TIME, G.P.S. TIME AND IONOSPHERIC EFFECTS

2. TIME, G.P.S. TIME AND IONOSPHERIC EFFECTS :

Good examples of the need to support time and frequency metrology are plentiful in the telecommunication industry, which is relying more and more on digital, optical fiber systems requiring highly precise and co-ordinated timing between sender and receiver.

Table 2.1

Basic unit	Derived unit	Standard & calibration	Applications
Time	UTC	Globle Time Service	1 Stop light synchronization. 2 Global positioning system. 3 TV-network synchronization.
	frequency	Laser freqency and precision frequency	1 Digital watch crystals

The most accurate determination of time typically employs cesium clock. The Boulder, Colo., Laboratory, NIST (National Institute of standards and Technology in Gaithersberg, Md.) can measure time with an accuracy of four parts in 10 to the power 14 far beyond what everyday applications demand but vital for global positioning using satellite systems.

Most clock, especially the very accurate ones are based on frequency standards. A clock, typically, is little more than a mechanism that counts and accumulates the cycles of frequency standards and usually, displays the result. Even rudimentary clocks built about 335 years ago were based on this principle Their frequency standard was a pendulum. Today, most clocks use a quartz crystal as their frequency base.

The performance of frequency standards is usually described in terms of accuracy, reproducibility, and stability. Accuracy is the degree to which a measured or calculated value confirms to some specified value or definition. Reproducibility is the extent to which there is agreement among a set of independent device of same devices of the same design after adjustment of appropriate parameters in each device. Alternatively it is the ability to produce previous value. Stability refers to the frequency or time domain behavior of a process.

Since 1967, the basic unit of 'time, the second, has been defined in terms of quantum mechanical relationship between the frequency of electromagnetic radiation and the difference between energy states of an atom!!' specifically, one second is defind as "the duration of 9192631770 periods of radiation corrosponding to the transition between the two hyperfine levels of the ground state of cesium - 133 atom." Cesium is chosen because its electronic structure is relatively simple, and this structure is used to lock the frequency of a microwave oscillator.

The most accurate determination of time typically employ cesium clock. The atoms of cesium have one electron in their outer shell, and the possible energy levels this electron can occupy multiply in the presence of weak magnetic field. For example, the levels labeled f=3 and f=4 split up in to seven and nine sublevels, respectively. The arrow indicates the energy level transition used in the operation of the cesium clock and caused by the absorption of a very narrow, spike shaped spectrum of microwave energy. The spectrum peaks at Vo, a frequency known to great precision and exploited for the highly accurate time measurments. Other reasons for using the cesium atom to define second include the the convenience of the microwave frequency of transition to the magnetic field, and the low value of the cesium melting point, making it easy to create a beam of cesium atoms at temperatures below 100 degree centigrade .

In addition, the ultimate accuracy of the method is improved if selected atoms, as they go through microwave cavity are interrogated with microwave fields having two different frequencies.
This leads to a very narrow peak, or structure at the centre of absorption. (Fig 2.1)
Norman Ramsey proposed this structure as part of his work on oscillatory mechanism and their application to atomic clocks, for which he shared the Nobel prize in physics in 1989.
Within the next few years, further gains in accuracy may be possible with a new kind of clock based on cooled mercury ions. The mercury ions behaves in much the same way as the cesium atom, except it has a very narrow electronic transition in the optical range. This offers the opportunity for a much more accurate

clock, provided that the mercury ions can be cooled to temperatures very close to absolute zero. New techniques have been developed, using the pressure of optical radiation to cool ions contained by an electromagnetic trap.

2.2 Time measurement

Time measurement or timing is important in industry as very often certain processes are either initiated or stopped after certain time interval. Measurement of such time intervals is performed by what is known as timers. The length of these intervals range from seconds to hours or days. In specific cases, this may be weeks in a weekly run establishments. Depending on the types of use, timers are classified as :

I) time switch.

II) time delay or simply delay timer.

III) interval timer

IV) recycling timer

V) time meter (computerisation of time signals)

Time switch opens or closes a circuit after a specified interval in a longer unit of time. Time delay timer keeps a circuit open and then close it for specified interval. The interval of closing and keeping open may be different. Interval timer closes a circuit as seen as the timer itself is on and after a predetermined period the circuit is put off. The recycling timer goes on closing and opening a circuit at pre-selected time gaps indefinitely.

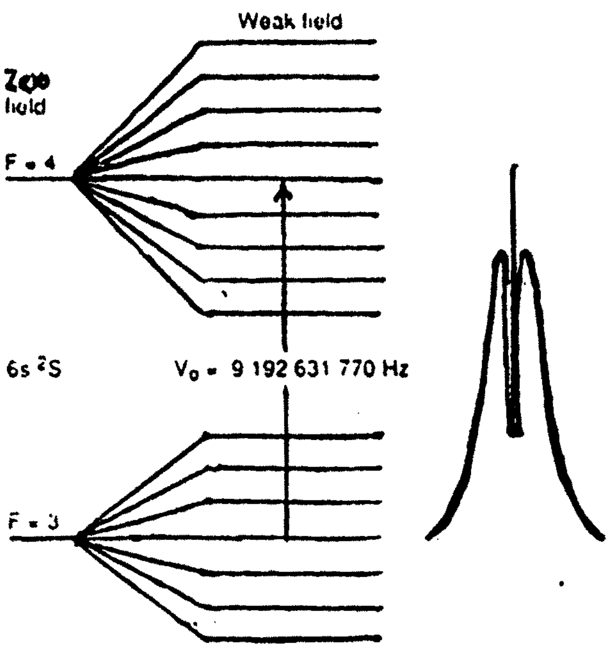

Fig. 2.1: Structure at the Centre of absorption.

Finally the time meter measures the total time of machine only when it is running.

The block schematic diagram of a general timer is Fig 2.2

Fig. 2.2

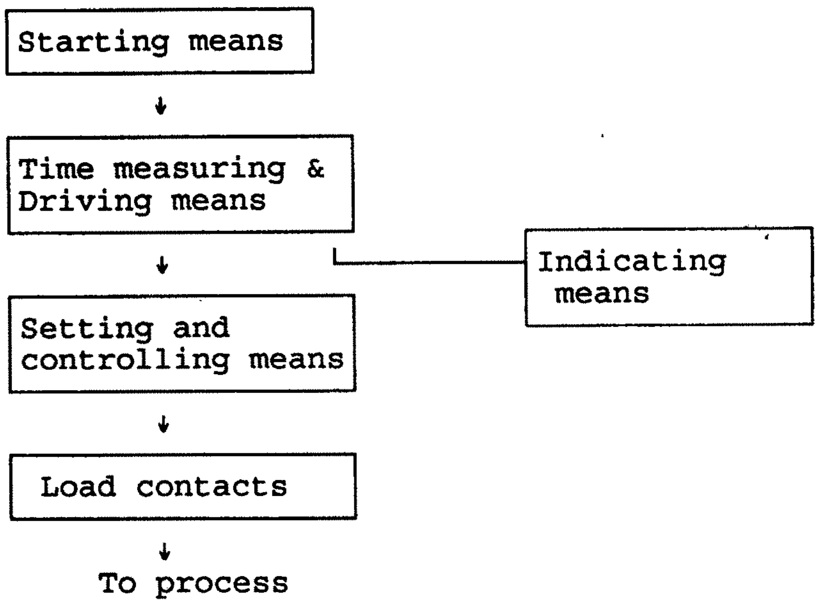

Fig. 2.1 The block diagram of a general timer.

2.3 Transistorized Timing Circuit

Timers depends upon a time base either generated internally or applied from an external source. The spring driven clock, for example generates its own time base, whereas the ordinary electric clock uses an external time base the period of the a-c- line voltage. The first consideration in the design of transistorized timers is the generation of suitable time base.

1. RC - Time - Base generators

Analysis of a Theoretical circuit :

The time base for a simple low cost circuit may be established by the use of a resistor(R), a capacitor(C), and a sensing network, as shown in Fig 2.3 Ignoring the loading of the sensing network, the time, t, for capacitor C to charge to voltage Vc in the simple timing circuit is

$$t = RC \log(Vb / (Vb - Vc)) \quad 2.1$$

The accuracy of a time base derived from the circuit is dependent on the stability of the RC product, of Vb and of the sensing network. The change in the time base produced by an incremental change in the RC product with all other variables held constant is

$$\blacktriangle t = \blacktriangle Rc \log (Vb /(Vb - Vc)) \quad 2.2$$

Where delta t ($\blacktriangle t$)is incremental change in t and $\blacktriangle RC$ = incremental change in the RC product. The equation shows that a precentage change in the RC product will produce an equal precentage change in the time base. The error in the time base produced by an incremental change in the source voltage Vb will be

$$\blacktriangle t = - \blacktriangle Vb\, Vc\, Rc / (Vb (Vb -Vc)) \quad 2.3$$

Where $\blacktriangle$ Vb = incremental change in Vb. The error in the time base produced by an incremental change in Vc be

$$\blacktriangle t = \blacktriangle Vc\, Rc / (Vb - Vc) \quad 2.4$$

Where $\blacktriangle$ Vc = incremental change in capacitor voltage

2.4. Analysis of Transistorized Timing Circuit.

A practical timing circuit is shown in Fig. 2.4 The sensing circuit is designed to supply current to R1 when

$$Vc = Vz + Vbe\ (on) \qquad 2.5$$

Vc = voltage across the capacitor

Vz = zener voltage of D1.

Vbe (on) = base - emitter ON voltage of transistor Q1.

The time t1 for the RC circuit to charge to the voltage which operates Q1 is

$$t1 = R1c \log \frac{Vb1 - Icbo\ R1}{Vb1 - Icbo\ R1 - Vz - Vbe\ (ON)} \qquad 2.6$$

Where $R1 = \frac{R\ Rs}{R + Rs}$ $\qquad Vb1 = Vb \frac{Rs}{R + Rs}$

and Icbo = collector - base reverse current of Q1 with the emitter open circuited and Vbe (ON) = base - emitter ON voltage of Q1. All variables in eq. 2.6 are dependent on temperature;

In this circuit transister is to be operated as a saturated switch, two cases must be considered the ON case and the OFF case. The circuit should be so designed that the transistor will saturate at the lowest operating temperature and to ensure that transistor will be held Off at the heighest temperature

A technique which will meet these requirements requires a d-c analysis of the equivalent circuit for both the ON and OFF states

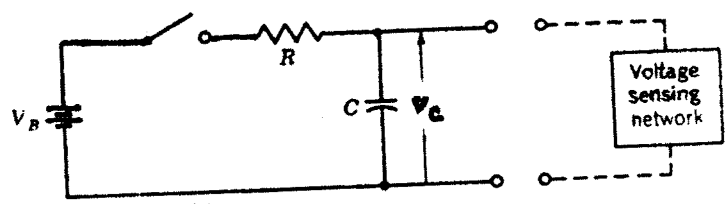

Fig.2.3

RC-time-Baase generator

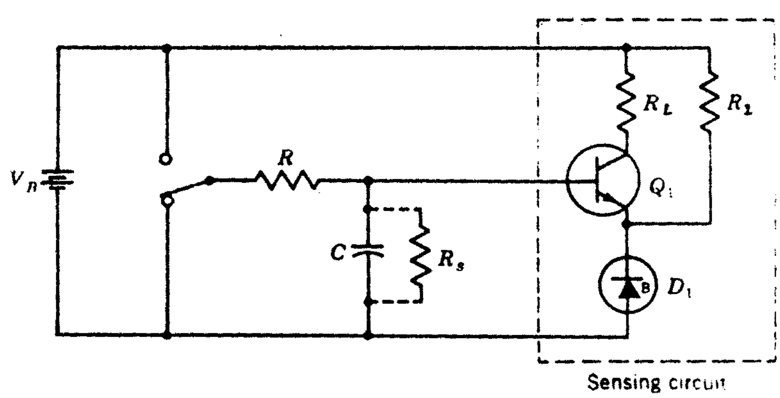

Fig.2.4

Transistorized timing Circuit

of the transistor. The following considerations should be made in the design of the sensing network.

For the On case, the collector current of Q1 is

$$Ic = \frac{Vb - Vce\ (sat) - Vz}{R1} \qquad 2.7$$

Where Vce (sat) = collector - emitter saturation voltage .

The maximum base current required to saturate device is

$$Ib\ (max) = \frac{Ic}{Hfe\ (min)} = \frac{Vb - Vce\ (sat) - Vz}{Hfe\ (min)\ R1} \qquad 2.8$$

Where Hfe (min) = minimum current gain of the device.

The available base current is

$$Ib = \frac{Vb\ Rs - (Vz + Vbe\ (on))\ (R1 + Rs)}{R1\ Rs} \qquad 2.9$$

Thus Hfe (min) must be chosen so that

$$Ib >= Ib\ (max) \qquad 2.10$$

collector power dissipation during the ON time is

$$Pc\ (on) = Ic\ Vce\ (sat) \qquad 2.11$$

This equation may be used to determine the collector dissipation rating when

$$T\ on >> Qj\text{-}c\ C\ j\text{-}c >> Tsw \qquad 2.12$$

Where

T on = ON time

Tsw =time to switch the transistor from OFF to ON states

Qj-c Cj-c = junction thermal time constant.

For large values of R and C, the time requieed to switch the transistor may be long compared to thermal time constant of the transistor. Thus, the collector dissipation rating for this case should be determined from the equation

$$Pc = \frac{(Vb - Vz)^2}{4\ Rl} \qquad 2.13$$

During the OFF time, the collector- emitter and emitter base voltage - breakdown ratings must not be exceeded. The collector reverse current Icbo should be small compared to the capacitor - charging current.

As noted in eq. 2.6 components in the RC network will affect the stability of the time base.

2.5 Integrated Circuit Timer

Now-a-days mechanical and electromechanical timers are being replaced by solid state timers. All the electronic timing circuits utilize the time relationship of voltage across a capacitor. An active element like the BJT or the UJT is used to discharge the capacitor periodically. IC555 is a highly stable monolithic timing circuit capable of producing accurate time delays or oscillations. The time period is controlled by an external resistor-capacitor combination. There is provision for triggering and resetting of the timer.

2.6 CLOCK GENERATOR

The timer 555 triggers itself and free runs as a multivibrator in the circuit configuration as shown in Fig 2.5 The moment the power is on, the circuit gets triggered and the output is at its high level(slightly less than Vcc). The capacitor then gets charged through (R1+R2) until the voltage across it reaches 2/3(Vcc). It can be shown that the charging time is given by

$$T1 = 0.693(R1+R2)C \qquad 2.14$$

At this point , the threshold camparator resets the FF(flip-flop), ground pin 7 and the output returns to its low state (slightly higher than zero). The capacitor then gets discharged through R2 during the interval

$$T2 = 0.693\ (R2)(c) \qquad 2.15$$

at the end of which the trigger camparator switches FF, which in turn switches Q_1 OFF and the output returns to its high value. The charge and discharge times are independent of supply voltage. The total time prriod T and frequency f of the resulting square wave are given by

$$T = T1+T2 = 0.693(R1+2(R2))C \qquad 2.16$$

And $f = 1/T = 1.443/(R1+2(R2))C$ 2.17

The duty cycle (D) = (R1+R2)/(R1+2(R2)) 2.18

D can be varied by varying R1 or R2 or both.

2.7 Ionospheric Effects As From A Timing Circuit

2.7 (a) Ionospheric Pulse Amplitude modulation (IPAM) :

Pulse modulation is widely used in digital communications. In this type of modulation the information to be received is converted in to pulses of various sizes and shapes. the process of converting data in to pulses can be carried out in variety of ways and is called encoding. So received time signal is encoded time signal. Time signals received by radio receiver can be called as classical time signal.

Ionospheric amplitude modulation can be expected to occure and can be illustrated using the circuit as shown in Fig. 2.6

Essentially we propose to measure the ionospheric effect on a signal. As there is change in ionospheric conditions, Each time a clock pulse is present at C will have a pulse at the output of the gate and pulse amplitude is proportional to the ionospheric inference.

While this type of modulation can be very easily realized, also its noise rejection is good. But if we are receiving PAM (pulse amplitude modulation) with large amount of noise, then the receiver sees the noise also as the signal content.

The time base of circuit may vary with the fast changes in the ionosphere. The time base may be established by the use of resistor capacitor and a sensing network as shown in Fig. 2.7

$$t = R1c \log (Vb / Vb - Vc) + t1 \qquad 2.19$$

The accurancy of a time base derived from circuit is dependent on

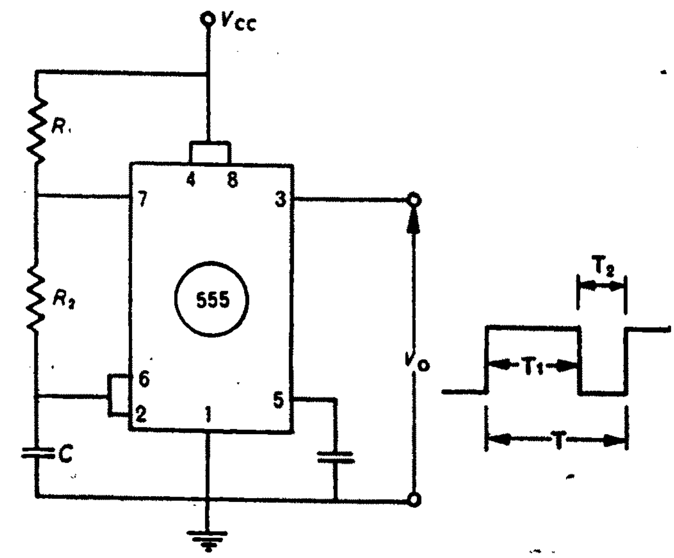

Fig.2.5
Multivibrator

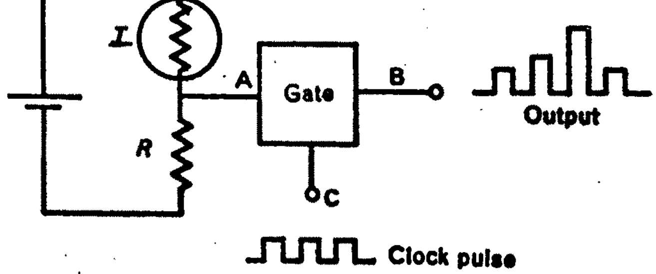

Fig.2.6
Timing circuit to
Study Ionospheric Effects

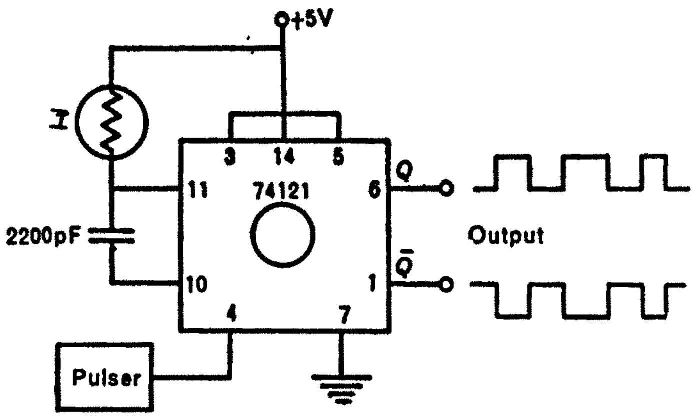

Fig.2.7

simple circuit to Sttudy IPDM

the stability of RC product, of Vb, of sensing network and of ionospheric drifts / disturbances. The change in the time base produced by an incremental change in RC product and time delay due to ionospheric conditions with all other variables held contant is

$$\Delta t = \Delta R1 \, c \log (Vb / Vb - Vc) + \Delta t1 \qquad 2.20$$

Where Δt = incremental change in t

and ΔRC = incremental change in RC product

$\Delta t1$ is incremental cahnge in t1 depending on stability of ionosphere and can be calculated from the difference in phase path length Δp introduced by the ionization as,

$$\Delta t1 = \Delta p / c \qquad 2.21$$

Where c is velocity of light.

As a result, the output pulse width varies in accordance with ionospheric disturbances.

2.7 (b) Ionospheric Pulse Duration Modulation And Ionospheric Pulse Position Modulation (IPDM & IPPM) :

Fig. 2.7 shows a simple circuit to produce IPDM (Ionosheric pulse duration modulation). It is a monostable multivibrator with an elements that controls the width of the output pulse i.e., output pulse is modulated. Also one can obtain IPPM (Ionosheric pulse position modulation) by differentiating and rectifying the PDM signals.

The recognition of these new parameters viz IPAM, IPDM, IPPM defined by us, as extermely useful to analyze the significance of ionospheric effects on the time signals propagation, delay and shifts constitutes an important findings of our research at the General Physics laboratories at Shivaji University, Kolhapur. No doubt these indices would serve in due course of time for global studies of ionospheric effects on time signals and Global time standards.

Preliminary results and findings made in the present investigations at our laboratories are very encouraging and eventually will prove to be very fruitful.

2.8 Adoptability of GPS Time for Shared Satellite Channel Access

To increase the relaibility and to improve operational flexibility of communication Synchronomous channel access protocols (TDMA) needs clock frequencies for all other stations derived from single source. This helps to achieve synchronization and improved system noise performance, so that performance to timing delays and the timing logics are realized with global - synchronized device by a master station simultaneously. This avoids having seperate link at every station to receive synchronization from master station and all stations will call global time to avoid interference of random access.

In synchronous communication, satellite channel drives protocol access with time slots differing by some amount of guard time. Thus a global frame clock will be available easily without number of impeding factors, such as the

1) Propagation delay.

2) Mismatch of timing.

3) Drift of clock.

2.8.1. Constraints :

Drawback of using this type of communication are listed below,
If there is a loss of frame clock by some resons, it may be taken as the loss of slot clock synchronization and receptors will wait for correct reception and there will be clock delay.
Reasons for break will be

(i) Error in transmission data with dummy like synchronized pattern.

(ii) Error itself in the frame clock pattern.

(iii) Delink with master station.

(iv) Selection of protocol without errors and having proper frame clock synchronized pattern, which leads selection of elaborate protocols. There will be misleading of frame synchronized pattern due to error rate, frame length, etc.

Solution to avoid all these difficulties is to adopt GPS time at a low cost of operation.

2.8.2 Discussion :

One microsecond accuracy of GPS time will be maximum limit for synchronous communication rate.
Gaurd time between two time slots will depend upon, the following factors.

1) Geographical structure will introduce time delay of link.

2) Range differnece and corresponding time delays can be calculated and varies between 3.9 ms to 4.7 ms.

3) Time uncertainty due to location change of satellite or ground station. Usually one neglets the effect of the satellite inclination.

4) Time uncertainty due to station clock which in turn depend on local clock.

5) Inaccuracy of a station clock.

2.8.3 Application of GPS - time :

Adoption of GPS time and GPS receiver enhances channel capacity upto 99% (or more) : IN TYPICAL DATA COLLECTION USING SATELLITE LINK SAMPLING RATE 4800 BPS, BURST TIME 88 MS, GUARD TIME 5 MS AND FRAME DURATION OF 1 HR. ONE FRAME CARRIES 38700 TIME SLOTS. Thus it is reported that, GPS time & GPS receiver with synchronous protocol TDMA enhances network efficiency and can be used as a time refernece in PCM exchange.

for timing circuit build and tested in laboratory timing cycle is periodic. For e.g.illustrated for Astable multivibrator in Fig.2.8

Fig.2.8 Calculation of periodic time Astable Multivibrator

with ;

R_1 = 22 K ohm() and R_B = 56 K, (ohm) C= 0.1 uF

Then periodic time T by calculation is

$T = 0693\ (R_1 + 2\ R_2)\ C$

T = 9.2862 ms.

and when output wave from on CRo is obtained then periodic time T by calibration is

T = wavelength division x time base

$T = 5.2 \times 2 \times 10^{-3}$ sec.

T = 10.4 ms.

CHAPTER - 2

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