

CHAPTER - 2

BACKGROUND DISCUSSION

In this chapter the information related to the development of hardware & software of a variable frequency VLCRQ meter is discussed. The information about the circuit layout of single frequency LCRQ meter is presented in section-1. The data sheets of various integrated circuits in the hardware design are given in section-2. The section-3 discusses the macroassembler for 8085 & its. While the section-4 is devoted to few calculations of capacitance.

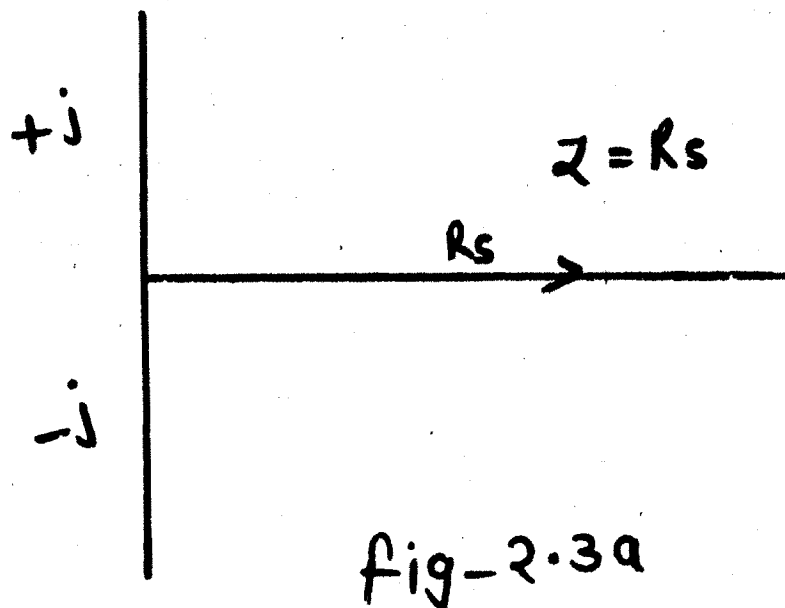
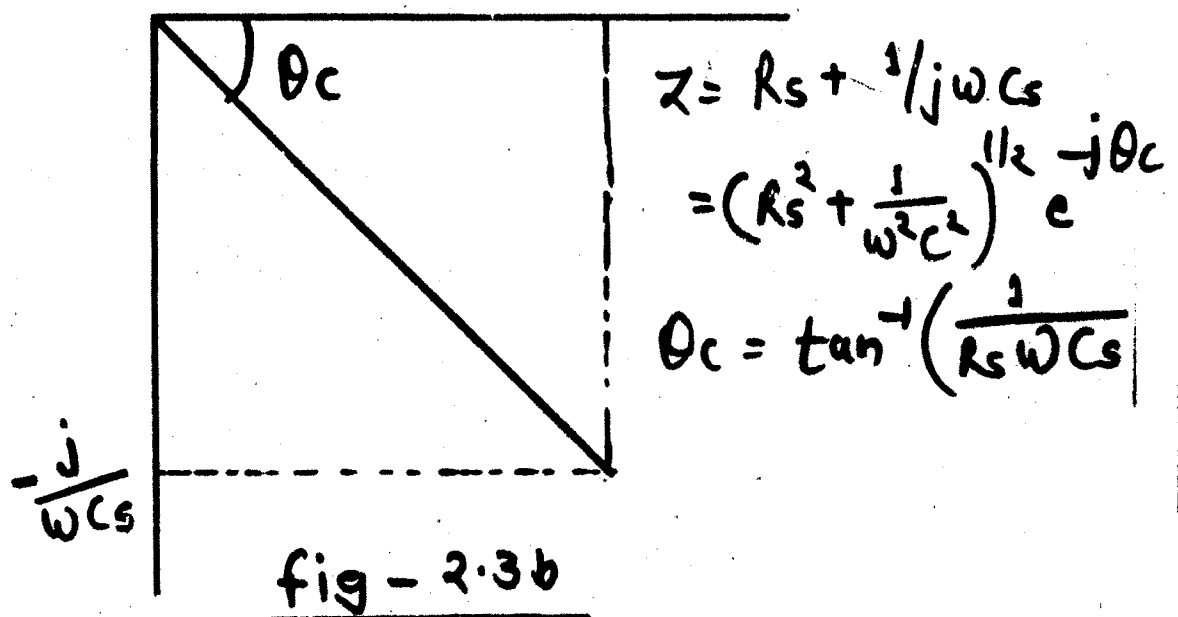
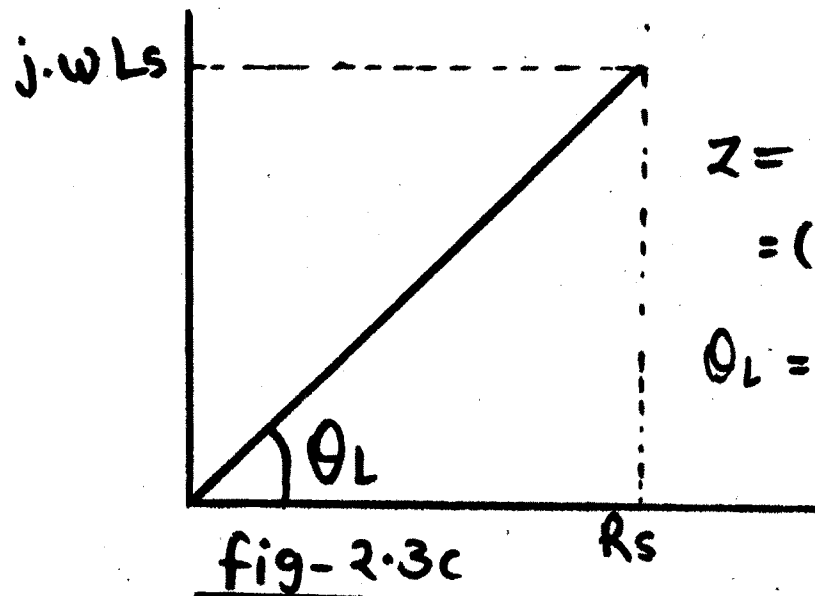
2.1 : THE IMPEDANCE OF NON-IDEAL CAPACITANCE & INDUCTANCE

The reactive components used in the circuit possess a resistive component in addition to the reactive component. Thus the nature of impedance offered by the device is always complex. For the determination of the reactance and the quality factor, nature of the complex impedance plays very important role. The possible amount of error in the measurement & the limitations of the measuring circuit are the outproduct of this complex impedance. The complex impedance 'Z' could be represented as in eqⁿ - (1)

$$Z = A + jB \quad (1)$$

Where A is the resistive component & B is the reactive component. As far as the capacitance & inductance is concerned the fig 2.3b & 2.3c represent the phasor diagrams.





FREQUENCY VERSUS IMPEDANCE TABLE FOR VARIOUS INDUCTANCES

TABLE : 2.2

| Inductance frequency | 40 μ H | 400 μ H | 4mH | 40mH | 400mH | 4H | 40H |
|-------------------------|----------------------------|----------------------------|----------------------------|---------------|---------------|---------------|----------------|
| 100Hz | $25 \times 10^{-3} \Omega$ | $25 \times 10^{-2} \Omega$ | $25 \times 10^{-1} \Omega$ | 25 Ω | 250 Ω | 2.5K Ω | 25K Ω |
| 1KHz | $25 \times 10^{-2} \Omega$ | $25 \times 10^{-1} \Omega$ | 25 Ω | 250 Ω | 2.5 Ω | 25K Ω | 250K Ω |
| 10KHz | $25 \times 10^{-1} \Omega$ | 25 Ω | 250 Ω | 2.5 Ω | 25k Ω | 25K Ω | 2.5M Ω |
| 100KHz | 25 Ω | 250 Ω | 2.5K Ω | 25K Ω | 250K Ω | 2.5K Ω | 25M Ω |
| 1mHz | 250 Ω | 2.5K Ω | 25K Ω | 250K Ω | 2.5M Ω | 25m Ω | 250M Ω |
| 10MHz | 2.5K Ω | 25K Ω | 250K Ω | 2.M Ω | 25M Ω | 250M Ω | 2500M Ω |

2.1.1 : EQUIVALENT CIRCUITS FOR THE CAPACITANCE

The capacitors are formed in general by placing a dielectric material between two conducting plates. The available types of capacitors are paper condensers etc. The classification is on the basis of dielectric constant of the spacing. The material property of dielectric, leads of the capacitor or shape of the conducting plates is effective in deciding the complex impedance of the capacitor. At present we shall discuss the representation of the impedance & admittance of a capacitor in the parallel & series equivalent forms.

Parallel Equivalent form :

The parallel equivalent form is given in fig.2b & 2.1a. The impedance & admittance of this equivalent form are given as in equations (2) & (3) prespectively -

$$Z_p = \frac{R_p - j.W.C_p.R_p^2}{W^2.C_p^2.R_p^2 + 1} \quad (2)$$

$$A_p = W C_p - j/R_p \quad (3)$$

It is observed in this case that the admittance of the capacitor has a simpler form.

The equations (4) & (5) represent the impedance & admittance in the series equivalent form.

$$Z_s = \frac{R_s.W.C_s - j}{W.C_s} \quad (4)$$

$$A_s = \frac{R_s.W^2.C_s^2 + j.W.C_s}{R_s^2.W^2.C_s^2 + 1} \quad (5)$$

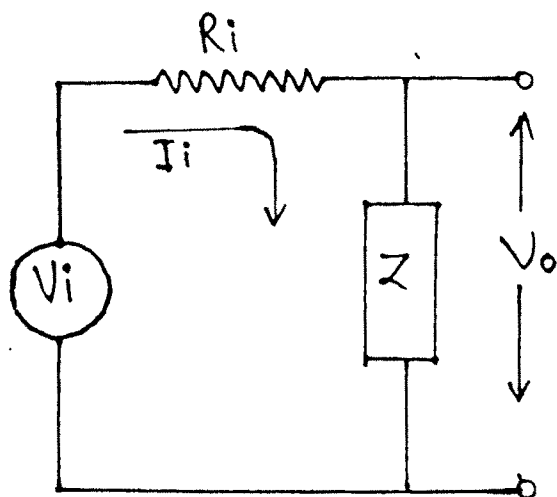
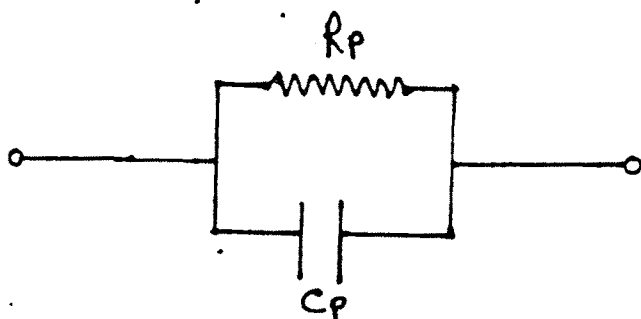
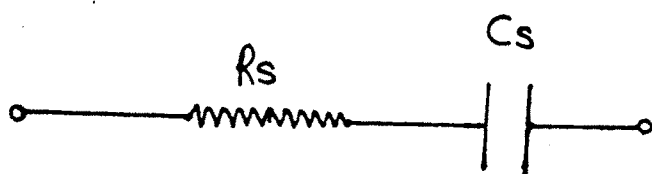


fig-2a



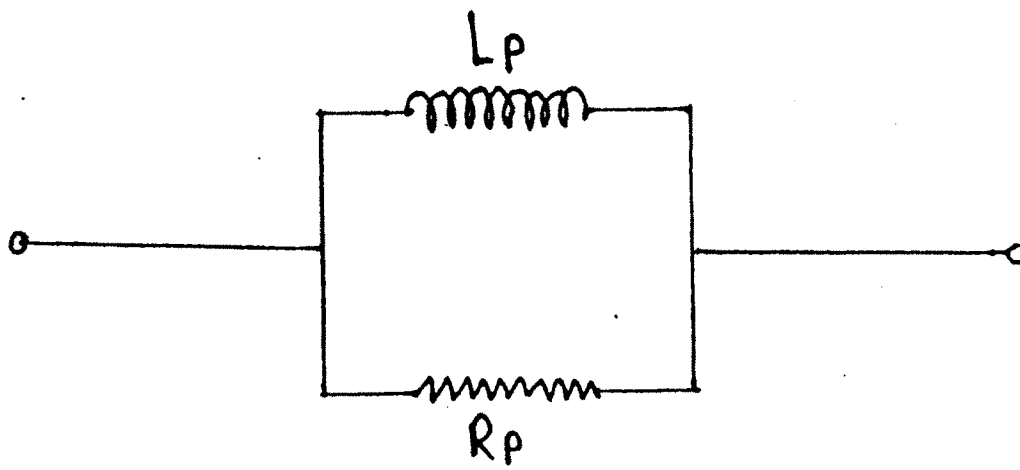
Parallel Equivalent Model for capacitance

fig-2b



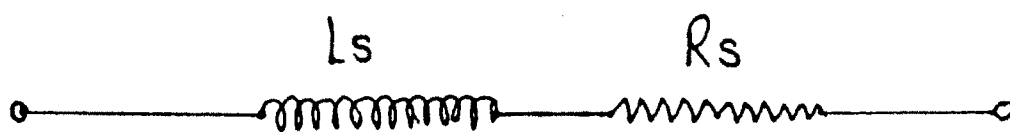
Series Equivalent Model for capacitance

fig-2c



Parallel Equivalent Model for inductance

fig-2.11a



Series Equivalent Model for inductance

fig-2.11b

Comparing equations (1),(2) &(4) it is apparent that the complex impedance determined in a measurement may represent very different values of its reactance. This happens because of the equivalent circuit used. The resistance & reactance in the parallel & series combination is interconvertible if we define the Quality Factor Q as in equation (6).

$$Q = \tan^{-1}(-B/A) \quad (6)$$

Therefore Q in series parallel forms is given in equations (7) & (8).

$$Q = \tan^{-1}\left(\frac{X_s}{R_s}\right) = \tan^{-1}\left(\frac{1}{j\omega C_s R_s}\right) \quad (7)$$

$$Q = \tan^{-1}(R_p/X_p) = \tan^{-1}(j\omega R_p C_p) \quad (8)$$

$$C_p = \frac{C_s}{1 + d^2} \quad (9)$$

$$\& R_p = \left(\frac{1+D^2}{D^2}\right).R_s \quad (10)$$

The equations 9 & 10 relate the resistance & reactance in the two equivalent forms. Further, table 2.1 represent the reactance versus frequency of the capacitor. These values are used to discuss the circuitry. As a general observation the impedance varies over twelve decades for the change in capacitance from 40pF to 40μF & frequency variation from 100Hz to 1 MHz.

The similar theory could be developed for the inductance also.

2.2 : SINGLE FREQUENCY LCRQ METER

Before we discuss the actual circuit layout reference is made to the text on LCRQ meters, Ref. Appendix A. Initially we shall discuss a few models for the capacitance measurement.

As shown in fig. 2.1. $V_o = I_i / \omega C$

$$C = 1/\omega \cdot \frac{I_i}{V_o} \quad (11)$$

from eqn (11) it is apparent that the value of capacitance is proportional to the ratio of I_i & V_o . Thus the measurement circuit should be able to determine I_i & V_o separately. The ω is assumed fixed. It is not very easy even for a single frequency to device a single circuit which can provide I_i & V_o accurately for non-ideal capacitors. The reason is obvious from table 2.1. The reactance of C at 100Hz varies between nearly 40×10^6 ohm to 40 ohm for the variation of C between 40 pF to 40 μ F. Therefore the instruments rely upon different modes of Z_c [Z_p or Z_s] in different ranges of C.

For the lower ranges of C (from 40nf to 400nf) parallel equivalent circuit is adopted, while for higher ranges series equivalent circuit is adopted. The practical circuit in these configurations are shown in fig. (2a), (2b) & (2c), 2.1a & 2.1b.

2.2.1 :

In fig. (2a), R_i is far less than

$$1/\omega C_p [e^{qns} 2 \& 3]$$

$$\text{Therefore } I_i = V_i \times A_p = V_i (WC_p - j/R_p) \quad (12)$$

$$\begin{aligned} V_i &= R_i \times I_i \\ &= R_i \times V_i [WC_p - j/R_p] \end{aligned} \quad (13)$$

The in phase component of equation (13) provides value of C , while the out of phase component could be used to determine the value of Q or $\tan\delta$.

The differential voltage $V_2 = V_i$ as R_i is far less than Z_p [ref. table 2.1 & 2.2]

$$C_p = \frac{V_i}{V_2} \times \frac{1}{R_i \cdot W} \quad (14)$$

Now eqn (14) could be used easily for a single frequency to calibrate the meter by selecting R_i . The value of $\tan\delta$ in this configuration is given by eqn (7). The out of phase component of eqn (13) is given as in eqn (15).

$$V_i(\text{OUTphase}) = \frac{R_i \cdot V_i}{R_p} \quad (15)$$

Therefore ratio of $V_i(\text{OUTphase})$ with V_2 provides value of \tan

i.e.

$$\frac{V_i(\text{OUTphase})}{V_i(\text{INphase})} = \frac{1}{R_p \cdot W \cdot C_p} \quad (16)$$

The basic difficulty with this model is, it is valid only if the actual device is representable in the parallel equivalent form. Further if we change the frequency, the calibration of R_i also changes. We shall discuss this point further in chapter (3).

2.2.2 : THE SERIES EQUIVALENT FORM

This form is used when Z_c is very small. In this case Z_c is treated as Z_s .



It is assumed that $R_i \gg Z_s$. Therefore -

$$I_i = \frac{V_i}{R_i} \quad (17). \text{ Thus } V_1 = V_i$$

$$\text{Now } V_2 = Z_s \cdot I_i = \frac{R_s \cdot V_i}{R_i} - \frac{j}{\omega C_s} \cdot \frac{V_i}{R_i} \quad (18)$$

$$\text{Therefore in this case } V_1/V_2(\text{outphase}) = \omega C_s \cdot R_i \quad (19)$$

In this case also the instrument could be calibrated by selecting values of R_i . Further, to determine $\tan \delta$ (eqn 8) one may determine the ratio V_2 (outphase) to V_2 (Inphase). The switching logic of the resulting meter is not straight forward & the instrument sets a limit on minimum value of $\tan \delta$ that could be measured. Using these principles the instrument available in market are VLCR-17, Pacific, Agronic, Aplab etc. From the discussion above it is obvious that the circuit principle is useful only if operating frequency is maintained constant. It is otherway to say that to have a variable frequency meter, the circuit model is not useful.

As the circuit requires to extract inphase & out of phase components, one needs to have phase-sensitive detectors. Further as the ratio is to be extracted, one or the other form of divider circuit is essential. Therefore accuracy of the measurement will depend on the phase-sensitive detectors & analog dividers used. It is observed that a few circuits make use of PSD of a PLL for e.g. (NE 565). It is to be noted that the output of PSD in PLL is not linearly proportional to the amplitude of V_i . Therefore the circuit may introduce an additional error. In our

design we make use of (LTMX) XR-2208 as a PSD, though the device is a bit costly (Rs.400/- per chip).

2.3 In this section we shall discuss the data sheets.

2.3.1. : As the data sheets of XR-2208 were not available, here we shall refer to another equivalent. IC chip MC 1494, whose working principle is similar to that of XR-2208 but not pin-to-pin replaceable to XR-2208.

The data sheets are enclosed as appendix-E.

The Monolithic analog multipliers are the devices which perform complex mathematical operations as division. multiplication, squaring, squarerooting etc. Even, they could also be used as modulators, phase detectors, freq, converters etc. Basically any analog multiplier should have an output which is related to its two inputs by the equation. $V_{out} = K.V_x.V_y$ where K is any suitable scale factor. Generally this multiplier also includes a third variable 'Z' which could be used in division mode. Of course slight non-linearity is observed which is a function of both x & y inputs & expressed in percentage of full scale output. The nonlinearity & offset error drift are to be taken special care of, in the division mode. Feedthrough is one of the specifications which specify the amount of output present even when, one of its input is made zero. The most important is the accuracy which includes the effects of i/p-o/p imperfections, non-linearity, feedthrough & hence contribute for the total error of a multiplier.

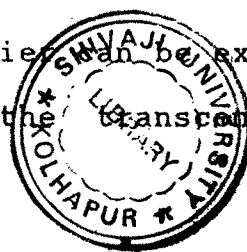
There are various analog multiplication techniques

available such as quarter-square multiplier, logarithmic summing multiplier, pulse height/width modulation multipliers. All these multipliers have one or the other major drawback associated with them & hence not widely accepted. The most accepted technique which averages all other techniques is variable transconductance multiplication technique. It is also referred to as Linear Transconductance Multiplier or simply LTM. This technique, basically, makes use of the dependence of the transistor transconductance on the emitter-current bias. The LTM has certain important features which make it suitable for monolithic realization, such as, it is easy to integrate on a chip, it is cheaper & possesses good accuracy, available in all four quadrants, & operates at very high speeds inherently because it is a current-mode device. Even the bandwidths of more than 10 MHz are achievable. Here we shall focus our discussion specifically upon LTM, because it is the one, which we are going to use in our hardware.

LINEARIZED TRANSCONDUCTANCE MULTIPLIER (LTM)

As mentioned in its introduction, this multiplier is based on the fact that the collector current & the transconductance of a bipolar transistor are linearly related. It is also named as Gilbert's cell, after its inventor.

Referring to fig(3.4e), which shows a differential amplifier, in which we find that the small signal differential o/p of the amplifier can be expressed as $V_{out} = R_L / r_e = g_m R_L V_x$ where g_m is the transconductance of the



kT matched transistors & $g_m = \frac{1}{q \cdot I_E}$ where K is the Boltzmann's constant, T is absolute temperature in °K & q , the electron charge.

$$V_{out} = \frac{qI_E}{KT} \cdot R_L \cdot V_x.$$

If now, a simple constant current source is replaced by a voltage controlled current source as shown in fig.(3.4e), we get $I_D = V_y/R_y = 2I_E$, neglecting the drop across diode, D

$$V_{out} = \frac{qR_L}{KTR_y} (V_x \cdot V_y) \quad , \text{ which shows that the}$$

output voltage is proportional to the product of V_x & V_y .

Although, theoretically, this model looks correct, it suffers from several shortcomings, such as -

- 1] V_y has to be always +ve & greater than V_D .
- 2] A portion of V_x input always appears at the output unless & until I_E is reduced to absolute zero.
- 3] V_x must be small signal to keep the differential pair within the linear region.
- 4] Output is not centered around zero voltage.

All the above shortcomings are solved by resorting to a complex structure as shown in fig.(3.4e). The first problem is tackled by adopting a different method of voltage to current conversion. The input voltage, V_y appears across the common resistor, R_y , producing a current that adds or subtracts from the two quiescent collector currents of Q_5 & Q_6 . The result is that the differential output current of this stage is proportional to the differential i/p voltage, V_y , down to

zero volts.

The second problem is a case of feed through. This has been overcome by replacing the simple multiplier cell of fig.(3.4e) ($Q1, Q2$ in that case) with the help of a cross-coupled balanced structure comprising of two differential pairs ($Q7, Q8, \& Q9, Q10$) with two unbalanced current sources comprising $Q5 \& Q6$ at the emitters of the two differential pairs. It can be shown that when the differential voltage input at the bases of $Q7, Q8, Q9, \& Q10$ is zero, the differential voltage at the collectors of $Q7 \& Q10$ is also zero, irrespective of whether the currents through $Q5 \& Q10$ are matched or not. When the differential base voltage is non-zero, the output voltage is a product of this input voltage & the difference between the mismatched currents. The balanced modulator structure comprising $Q5-Q10$ thus behaves as a true four-quadrant multiplier.

The problem of very small allowable signal swing at the X-input is taken care of by a logarithmic type amplitude compression circuit using diodes, $D1 \& D2$. As shown in fig. (3.4e), the differential input voltage, V_x , is first converted to a differential current in the same way as V_y . The two collector currents of $Q1 \& Q2$ are made to pass through two matched diodes, the drop across which form the differential input signal, in an amplified form, for the multiplier cell comprising $Q7-Q10$. Since the current through the diodes & the drop across them are logarithmically related, the range of the actual V_x input over which the cell operates linearly is stretched

significantly.

The above deliberations result into a complete analog multiplier having inherently good performance characteristic. One more opamp is added to this to bring out a single ended output from the multiplier & the resulting structure is precisely what is adopted by the monolithic analog multipliers available.

XR-2208, which is an example of a versatile LTM, is used in the hardware developed for C-Td measurement. The case-study & necessary specifications are given in Appendix E.

The versatility of XR-2208 lies in the fact that the scale factor is adjustable by two external resistors R_X & R_Y & the chip also contains a high frequency buffer amplifier. The buffer amplifier can be connected in variety of fashions depending upon the specific application.

DESIGN GUIDELINES FOR DEVICE TYPE XR-2208 :

Let us consider device type XR2208 for design purpose. It is required to design the multiplier for an input dynamic range of $\pm 10V$ with an output swing of $\pm 10V$. The gain equations for the multiplier and amplifier of the device XR 2208 are -

$$K_m \approx \frac{20}{R_X R_Y}$$

$$K_A = \frac{R_2}{5 + R_1}$$

where $R_Y = 2 R_X$ and all resistors are in $k\Omega$.

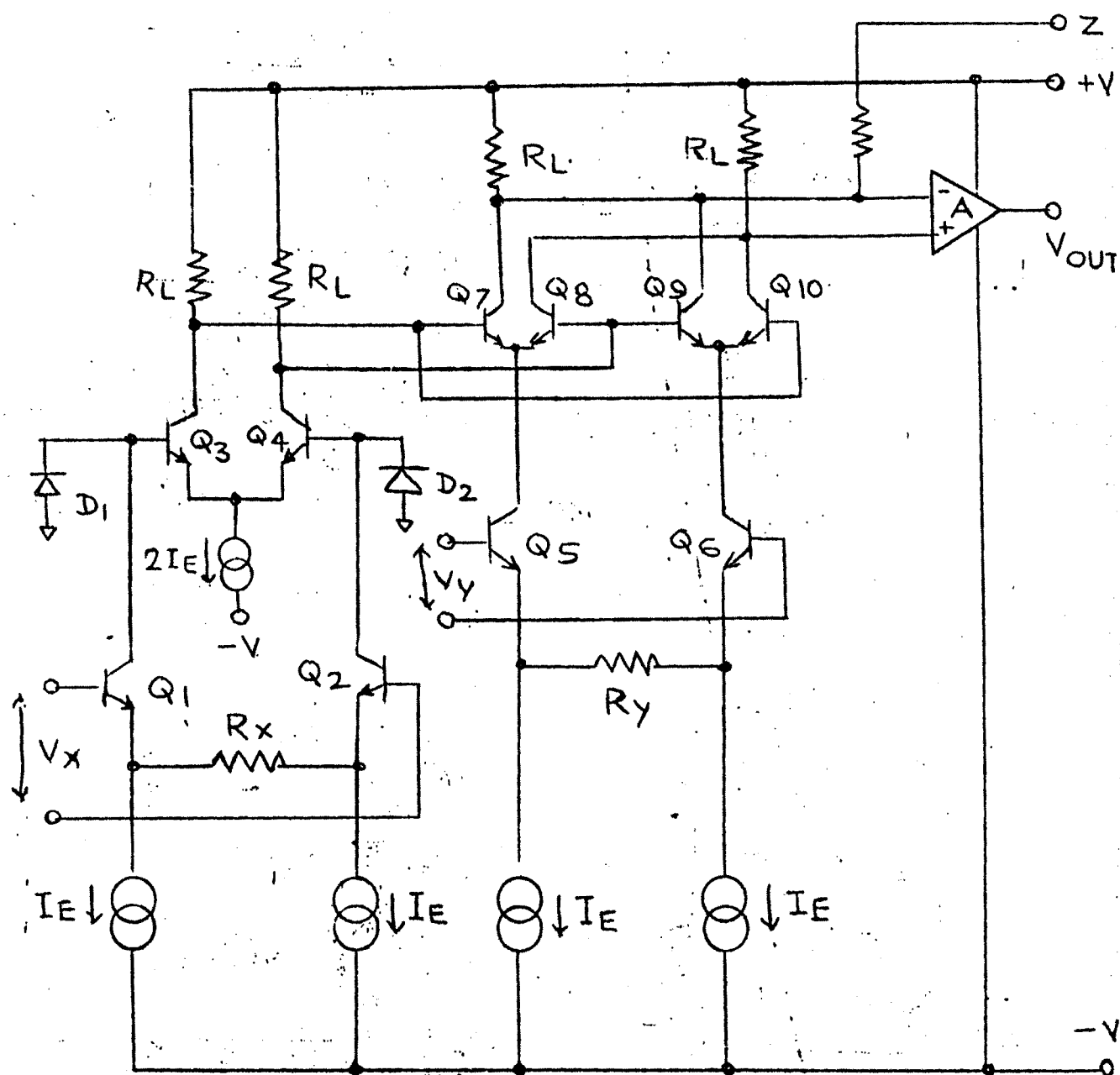


FIG. 3.4e STRUCTURE OF LINEARISED
TRANSCONDUCTANCE MULTIPLIER.

The first step in the design is to consult data sheet for the specific application. Then a general scheme is found out and the gain constant of the multiplier is determined. For the device, the gain constant of multiplier is -

$$k = K_m K_A = \frac{V_z}{V_x V_y} \cdot \frac{V_a}{V_z}$$

A k value of 0.1 is desired when the maximum input and output values are substituted into the above equation. The next step is to determine the actual component values required to set the gain control. The gain is usually set slightly higher than 0.1 and then finally tuned by the scale factor adjust resistor. The desired value for K_m and K_A are then substituted above into Eqs. and the resistor values are computed. The component values are for typical values selected for R_x , K_m , and K_A . The Trimming procedure for the circuit is as follows :

- (1) Apply zero volt to both inputs and adjust the output offset to zero volt using the output offset control.
- (2) Apply 20 Vp-p at 50 Hz to the X input and zero volt to the Y input. Trim the Y offset adjust for minimum peak-to-peak output.
- (3) Apply 20 Vp-p to the Y input and 0V to the X-input. Trim the X offset adjust for minimum peak-to-peak output.
- (4) Repeat step 1.
- (5) Apply + 10V to both inputs and adjust the scale

factor for $V_a = +10V$. this step may be repeated with different amplitudes and polarities of input voltages to optimize accuracy over the entire range of input voltage, over any specific portion of the input voltage range.

2.3.2 : LM301

OPAMP, LM301, has been used in the circuit essentially because it is an externally frequency compensated Opamp.

One more facility which is provided by this opamp is, the o/p amplitude of an amplified signal can be limited to a required level simply by connecting zenerdiode to pin no.5 of LM301. The amplitude could also be limited in reverse direction too. In our hardware we have made use of this facility of limiting the amplitude in both directions by connecting a pair of back-to-back zener diodes to pin no.5 of the IC. Although the IC has lesser freq. stability for larger bandwidths & slew rates, compared to internally freq. compensated opamps, it is mainly selected for obtaining extended bandwidth. The datasheets for LM301A are enclosed in Appendix B. & the reference is made to the book "OPAMPS & LIC's" by R.F.COUGHLIN & F.F.DRISCOLL.

The amplitude limiter ckt for the OPAMP-LM301 is shown in fig.(3.4a). This feature of LM301A is particularly useful, when we are interfacing this IC to the DTL or TTL (digital) devices. But here, we have made use of this feature to avoid reverse breakdown voltage V_{BERev} of transistor fig.(3.4a) & to limit the o/p of the opamp to a

level which is within the ratings for the analog input of an A/D converter IC 7109A.

2.3.3 : INSTRUMENTATION AMPLIFIER

Readily available instrumentation amplifiers are avoided mainly because of their cost. Instead, the three opamp configuration, with variable gain has been used in the hardware for R & V measurements. Generally instrumentation amplifiers are used in the circuits, where the transducers are located away from the measurement system & the common-mode difference signal is of greater strength. As in our system we are going to measure the temperatures & temp. differences, instrumentation amplifier is the ultimate choice. Secondly, the differential input capability with high common-mode rejection, even with sources having unbalanced high o/p impedances, is very useful in instrumentation system. The low o/p impedance of the I.A. facilitates for further processing of the analog signal. The detailed analysis for I.A. is given in the book 'Integrated Circuits' by K.R. Botkar.

IC LM324, which is a quad opamp, is used in the three opamp configuration for instrumentation amplifier fig.(3.2b) LM324 has four high gain freq. compensated opamps & operates on wide supply range. The necessary specifications for LM324 are given in the appendix B.

2.3.4 : PRECISION VOLTAGE REGULATOR

IC type $\mu A723$, is used as a low voltage precision regulator to provide the regulated bias of +5V for the circuit for R-measurement. Precision regulator is required is the ckt since it has to drive the opamp load which is used as a current source to supply very low current values of the order of $1\mu A$. Since the line regulation & load regulation is excellent for the type $\mu A723$, it has been selected. The IC also incorporates a temperature compensated zener diode which extends the temp range for the device. The data sheets & application notes are supplied in Appendix-B

2.3.5 : ICL 7109 :- A/D CONVERTER

It is a μp compatible 12-bit A/D converter IC essentially used to achieve maximum accuracy for the reading. It is based on the principle of dual-slope A/D conversion. It provides the user with two ranges for measurement purpose. One is the millivolt range & the other is the voltage range. Depending upon the input signal level one can select the desired range. In the hardware, we have made use of this facility to switch from one range to the other range depending upon the input signal level & using the necessary switching logic circuitry. The necessary requirements for range switching are met with the overrange flag. It is made use of while switching the range. The required data sheets & timing waveforms are provided in the Appendix F.

2.3.6 : LATCHES

Latch 74LS373 is used in the hardware to latch the control-word sent by the system. The latch is necessary in our measuring system because the microcomputer system will be handling many tasks simultaneously & hence the control word sent by the system will be available on the data Bus for brief time & will vanish out at the next instruction. For the measurement system to process the signal, it is necessary that control signal should be continuously present. This is achieved with the help of a latch, 74LS373. 74LS373 is an example of a transparent latch which includes two control signals. The latch is transparent only when it is clocked. The data sheets for 74LS373 is provided in the Appendix G.

2.3.7 : ANALOG SWITCHES

Analog switches find their use mainly in analog instrumentation systems, such as Data Acquisition Systems. In DAS, it is required to handle many channels simultaneously. This is achieved with the help of an analog switch. It can be used as an analog multiplexing or demultiplexing switch. When using it as a multiplexer, many analog channels are connected as the inputs & a single o/p is connected to further processing circuitry. In our system, IC CD4051 is used as an analogMUL/DemUL switch. It is mainly used in the system to change the operating frequency, to change the values of current limiting resistances & for channel multiplexing. Autoranging was

possible only because of analog switches. They are playing very important role in the measuring system developed.

2.3.8 : FUNCTION GENERATORS

XR-205 : The schematic diagram of XR-205 as an analog building block is given in fig.

The schematic diagram shows the oscillator & modulator sections with the relevant waveforms. The oscillator is essentially an emitter coupled multivibrator with constant current sources at the emitter terminals. In the fig.(3.4d) the current sources are shown to be of equal magnitude to produce square waveforms at the collectors of T1 T2. However, one of them can be varied to achieve duty cycles other than 50%. In practice, this is achieved by inserting an $1k\Omega$ potentiometer between pins 13 & 14 of the IC. The freq. of oscillation is determined by Co. In the actual IC, the squarewave output from one of the collectors is buffered & brought on pin-12. The output frequency can be modulated by varying the two current sources simultaneously with a control voltage V_c applied to pin 13. The modulator section performs two basic functions. The initial differential stage formed by T3 & T4 derives the triangular waveform by subtracting the two linear ramps, V_A & $V_B(t)$ as shown in the fig.(3.4d). This stage of modulator also achieves the sinewave generation by excess emitter degeneration instead of by classical function filters. As we know, if the resistance R_E is highly reduced, an overdrive condition can exist where in the two transistors T3 & T4 are driven to cut

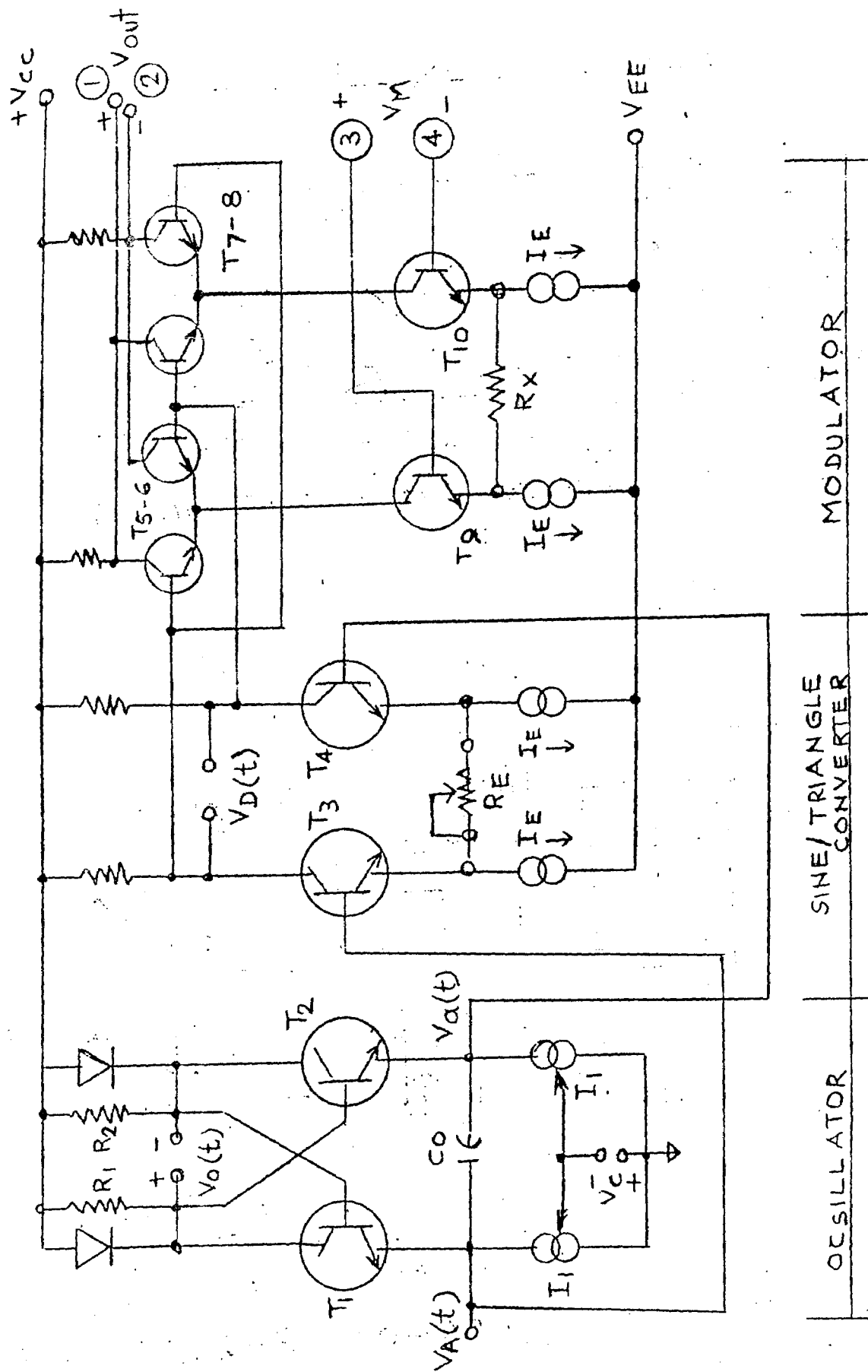


FIG. 3.4d SCHEMATIC DIAGRAM OF XR-205 BUILDING BLOCKS

off. The gradual transition between active & cutoff regions is exponential in nature & is used to round off the sharp peaks of the triangular waveform. The potentiometer between pin 7 & 8 of the IC, thus, can be adjusted to convert the triangular o/p from the chip into a sinusoidal one. The harmonic distortion of the sine wave is quite significant & is nearly 2.5%. The second job which the modulator section performs is amplitude & phase modulation of the waveforms. Transistors T5-T10 form a cross-coupled transconductance type multiplier. The differential modulating input, V_m is applied to the bases of T9 & T10 & modulates the amplitude in accordance with the following equation -

$$V_{out}(t) = \frac{R_L}{R_E \cdot R_x \cdot I_E} V_m(t) V_D(t)$$

The phase of the output waveform can also be reversed by 180° by applying bipolar pulses between pin 3 & 4 of the IC. The complete connection diagram of the IC, which also includes an optional output amplitude adjuster & Major specifications of XR-205 are given in appendix A & appendix-D.

IC XR-205 forms the heart of the C-measurement system. This IC is used to generate the sine function which is an input to the Device under Test (DUT), either a cyor a inductor. The freq. range is selected by an external capacitor C_o . Using the sweep input the frequency output could be varied in the ratio 10.1. (fig.3.4C).

2.3.9 : CURRENT SOURCES

Various types of current sources are available & the choice is based on following factors.

- 1) Is the load floating ?
- 2) Is bipolar capability required ?
- 3) Should the current be capable of being controlled by the voltage ?
- 4) What is the compliance voltage required? (compliance voltage is the maximum value of voltage permissible across the current source).
- 5) Other requirements such as to switch the current ON or OFF also arises. The required stability (with time & temp), o/p impedance & accuracy are the other imp. considerations.

Two types of configuration are more widely used -

- 1) Floating load configuration
- 2) Grounded load configuration.

Floating Load Configuration

The stability of this ckt is dependent on the reference voltage source used. The bias current of the opamps affects the accuracy of the current at very low current values, when the required current is of the order of few microamperes. The FET i/p is preferred. This ckt has bipolar capability i.e. direction of the current through the load could be changed.

One practical floating load configuration is shown in the next page which contains an opamp & a driving

transistor.

This ckt functions like a non-inverting amplifier with V_1 appearing across R_1 , so that the load current is always $V_1/R_1 = I_L$ & this is independent of load resistance variations as long as total drop across R_1 & R_L does not exceed the voltage range of the op-amp & as long as transistor has sufficient collector emitter voltage to keep it operational. For if the load current requirement is not exceeding 10mA, the transistor is not required. Voltage V_1 can be obtained from a potential divider or from zener-diode. The ckt can be called voltage-to current converter because the load current is proportional to the i/p voltage V_1 . In bipolar transistor load current is the transistor collector current but actually it is less than I_L by the amount of base current. Substituting a n-channel FET in place of BJT improves the ckt performance, because in FET drain & source current are equal that is why the load current is more precisely equal to current through R_1 .

2.4 : XASM 85 .COM

The XASM 85 is a macrossembler for assembly language routines of 8085. The assembly language of 8085 has been discussed in ref.4. The assembly language has four fields.

The assembly language source file is created using any standard editor for e.g. EDLIN.COM, WORDSTAR in NONDOCUMENT mode etc. The XASM85 is IBM PC compatible. It is invoked with file name of assembly language source. File for assembly language source file. ASM is a default extension.

The XASM85 performs the assembling in two passes. It produces an object code file with extension.obj in the INTEL HEX format. These files could be downloaded on 8085 kit using a serial interface control & the concurrent software. The dynalog microsystems have prototype, a 8085 based kit with serial communication interface, ILCV2. This kit could be serially interfaced to a IBM PC. A software TANGDQ.EXE performs the serial communication from IBM PC to kit.

In addition to the object-code files the printable files are also produced. These files provide memory addresses & the object codes of the assembly language source. These files could be used to burn EPROM's manually.

2.5 : CALCULATION OF C FOR THE FERROELECTRIC MATERIALS

The commercial capacitors using these materials have values in the range of a few microfarads. For these capacitors the series equivalent mode of measurement is valid. We wish to develop the LCRQ bridge which is meant for testing the physical properties of ferroelectric ceramics. Usually the samples grown are of cylindrical type with one to 1.5 cm as the diameter and one to four mm as its thickness. The relative permeabilities ϵ_r/ϵ_0 are of the order of 10^3 . We have calculated the values of capacitor formed due to these ceramics in the parallel plate configuration. The calculation part performs using the following program in microsoft basic.

Selected values of C are given in (table 3.6a). It is observed that all these values are in picofarad range. The

```
10 FOR I = 1 TO 6
20 READ F(I)
30 NEXT I
40 FOR I = 1 TO 7
50 READ C(I)
60 NEXT I
70 VO1 = 4,096
80 VO2 = 4096
90 LPRINT "      "; "F      "; "      "; "C      "; "      "; "T      ";
100 LPRINT STRING$(60,"_")
110 FOR J=1 TO 6
120 FOR K=1 TO 7
130 II=VO1*F(J)*2*3,142*C(K)
140 IF II > .05 THEN 150 ELSE LPRINT F(J);TAB(13)C(K);TAB(30)II;TAB(50)VO1
150 II=VO2*F(J)*2*3,142*C(K)
160 IF II > .05 THEN 150 ELSE LPRINT F(J);TAB(13)C(K);TAB(30)II;TAB(50)VO2
170 NEXT K
180 LPRINT STRING$(60,"_")
190 NEXT J
200 DATA 100,1000,10000,100000,1000000,10000000,100000000,400E-12,4E-9,4E-9,400-9
210 DATA 4E-6,40E-6, 400E-6
```

```
10 FOR I = 1 TO 6
20 READ F(I)
30 NEXT I
40 FOR I = 1 TO 7
50 READ C(I)
60 NEXT I
70 FOR I = 1 TO 6
80 READ T (I)
90 NEXT I
100 LPRINT "      "; "F      "; "      "; "C      "; "      T      ";
      R "
110 LPRINT STRING$(55,"_"):LPRINT
120 FOR I=1 TO 6
130 FOR J=1 TO 7
140 FOR K=1 TO 6
150 R=T (K)/((2*3.142*F(I)*C(J))
155 IF R < 4 THEN 170
160 LPRINT F(I);TAB(13);C(J);TAB(30);T(K);TAB(45);R
170 NEXT K
180 NEXT J
190 LPRINT STRING$(55,"_");LPRINT
200 NEXT I
210 DATA 100,1000,10000,100000,1000000,10000000,400E-12,4E-9,4E-9,400-9
220 DATA 4E-6,40E-6, 400E-6
230 DATA ,08,.1763,.2679,.3640,.4773,.5774
```

```
10 FOR I = 1 TO 6
20 READ F(I)
30 NEXT I
40 FOR I = 1 TO 7
50 READ C(I)
60 NEXT I
70 VO1 = 4,096
80 VO2 = 4096
90 LPRINT "      "; "F      "; "      "; "C      "; "      T      ";
100 LPRINT STRING$(55,"_"):LPRINT
110 FOR J=1 TO 6
120 FOR K=1 TO 7
130 II=VO1*F(J)*2*3,142*C(K)
140 IF II > .05 THEN 150 ELSE LPRINT F(J);TAB(13)C(K);TAB(30)II
150 II=VO2*F(J)*2*3,142*C(K)
160 IF II > .05 THEN 150 ELSE LPRINT F(J);TAB(13)C(K);TAB(30)II
170 NEXT K
180 LPRINT STRING$(55,"_")
190 NEXT J
200 DATA 100,1000,10000,100000,1000000,10000000,400E-12,4E-9,4E-9,400-9
210 DATA 4E-6,40E-6, 400E-6
```

commercial meters use parallel equivalent circuit in these ranges (section 2.2.2) Actually it would have been a series equivalent model, as it is a dielectric capacitance. We conclude this chapter with assertion that the design of LCRQ bridge should be independent of the equivalent circuit forms.

8085 ASSEMBLY LANGUAGE FORMAT

A typical assembly language programming statement is divided into four parts called fields, viz. label, operation code (opcode), operand and comments. These fields are separated by delimiters for the cp/m assembler as shown in the following table.

Table :-

| DELIMITER | PLACEMENT |
|--------------|-------------------------------------|
| 1. Colon | After label (optional) |
| 2. Space | Between an opcode & an operand |
| 3. Comma | Between two operands |
| 4. Semicolon | Before the beginning of a comments. |

The assembler statements have a free-field formats, which means that any number of blanks can be left between the fields. Comments are optional but they are generally included for good documentation. Similarly, a label for an instruction is also optional, but its use generally facilitates specifying jump locations. For e.g. a typical assembly language statement is written as

| Label | OPcode | Operate | Comments |
|-------|--------|---------|----------|
|-------|--------|---------|----------|

START : LXI SP,20FFH ;initialite stock pointer.

Delimiters include the colon following START, the space following LXI, the comma following SP, & semicolon preceeding the comment.

Assembler Directives

The assembler directives are the instructions to the assembler concerning the program being assembled. The directives are also called pseudo instructions or pseudo opcodes. These instructions are neither translated into machine code nor assigned any memory locations in the object file. Some of the important assembler directives are listed & described below :

| ----- Assembler directives ----- | ----- Example ----- | ----- Description ----- |
|---|---------------------------|---|
| 1. ORG (origin) | ORG 0100H | The next block of instructions should be stored in memory locations starting at 0100H. |
| 2. END | END | End of assembly. The HLT instruction suggests the end of a program, but that does not mean it is the end of the assembly. |
| 3. EQU | PORT1 EQU 20H | The value of the term port-1 is equal to 20H. Generally, this means port-1 has the port address 20H. |
| | INBUF EQU 2099H. | The value of the term INBUF is 2055H. This may be a memory location or |

| | | |
|-------|-------------------|---|
| | STACK EQU INBUF+1 | two byte number. The equate can be expressed by using the label of another equate. This example defines the stack as next location of INBUF. |
| 4. DB | DATA:DB A2H,9FH | Initializes an area byte by byte. Assembled bytes of data are stored in successive memory locations until all values are stored. This is convenient way of writing a data string. The label is optional |
| 5. DW | DW 2050H | Initializes an area two bytes at a type. |
| 6. DS | OUTBUF:DS 4 | Reserves a specified number of memory locations. In the example given, four memory locations are reserved for OUTBUF. |

The assembler is a tool for developing programs with the assistance of a computer. Assemblers are absolutely essential for writing industry-standard software; manual assembly is too much difficult for programs with more than 50 instructions. The assembler performs many functions in addition to translating the mnemonics. The salient features of assembler are.

- 1] The assembler translates mnemonics into binary code with speed & accuracy, thus eliminating human errors in looking up the codes.
- 2] The assembler assigns appropriate values to the symbols used in a program. This facilitates specifying jump locations.
- 3] It is easy to delete or insert instruction in a program; the assembler can reassemble the entire program quickly

with new memory locations & modified addresses for jump locations. This avoids rewriting the program manually.

- 4] The assembler checks syntax error, such as long labels & expressions, & provides error messages. However, it cannot check logic errors in a program.
- 5] The assembler can reserve memory locations for data or results.
- 6] The assembler can provide files for documentation.
- 7] A program such as DDT can be used in conjunction with the assembler to test & debug an assembly language program.

The assembler could be either a one pass or two pass process. This has been describe in the standard text (5).