APPENDIX

APPENDIX I

FILTERS

The band-pass-filters were used for the work presented here (Fig. A).

For example : The BPF with a band pass range of 60 Hz to 240 Hz

$$f_1 = 60 \text{ Hz}, \; f_2 = 240 \text{ Hz}$$

$$f_o = \sqrt{f_1 f_2} = 120 \text{ Hz} \qquad ..(1)$$

$$Q = \frac{f_o}{f_o - f_1} = \frac{120}{240 - 60} = 0.6666 \qquad ..(2)$$

$$K = 5.0 - \frac{2}{\sqrt{Q}} = 2.876 \qquad ..(3)$$

$$= 1 + \frac{R_4}{R_5} \qquad ..(4)$$

Further if

$$R_1 = R_2 = R_3 = R_4 = R$$

$$R = \frac{\sqrt{2}}{\omega_o C} = 18.76 \text{ kohms} \qquad ..(5)$$

Looking at the availability of resistances

We have chosen

$$R_1 = R_2 = R_3 = R_4 = R = 18.2 \text{ K ohms} \qquad ..(6)$$

$R_5 = 10$ kohms

$C = 0.1$ µF

Similarly for BPF range of 500 Hz to 2500 Hz

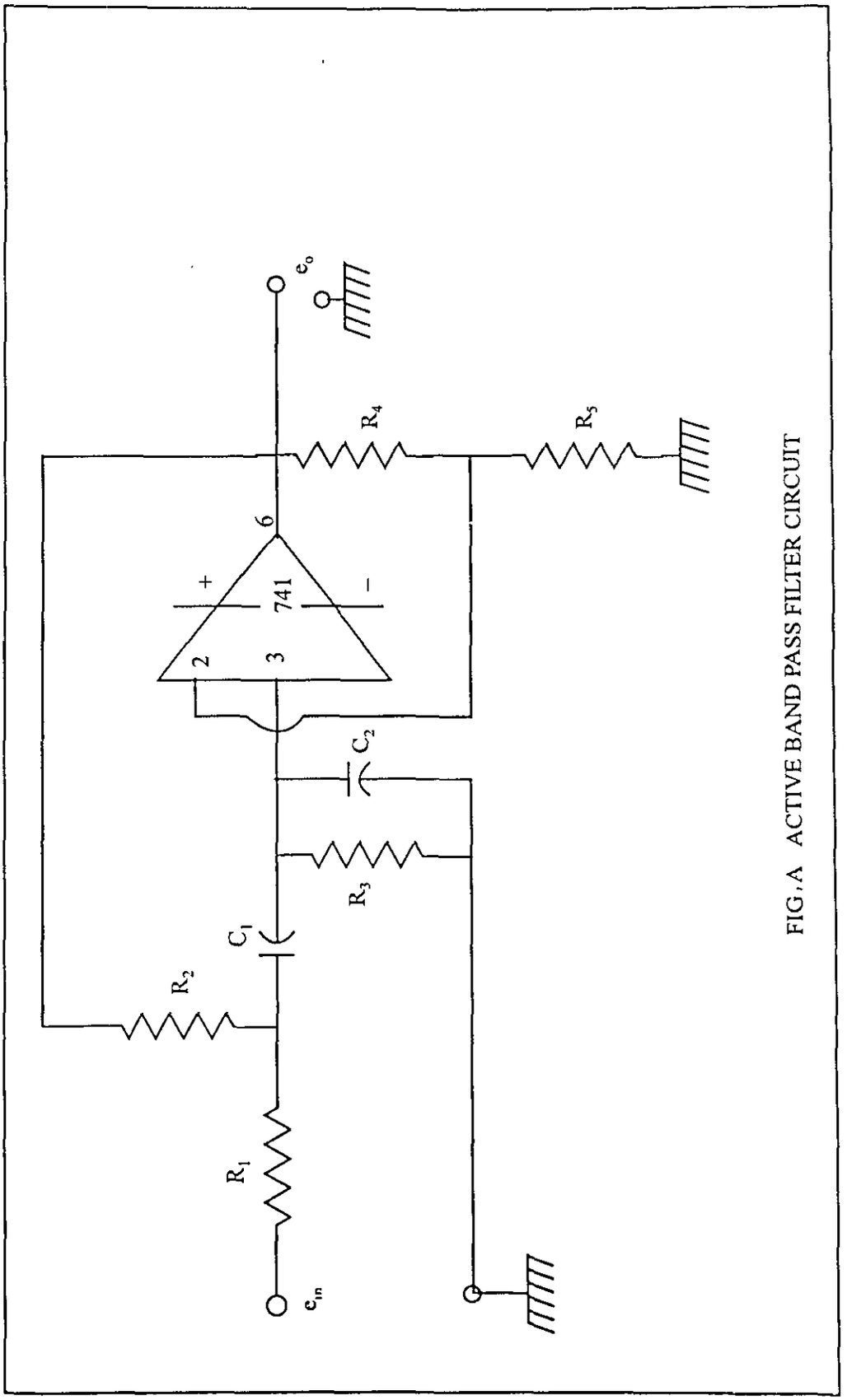
$$R_1 = R_2 = R_3 = R = 2.0 \text{ kohms} \qquad ..(7)$$

$R_4 = 14.7$ kohms

$R_5 = 10.0$ kohms

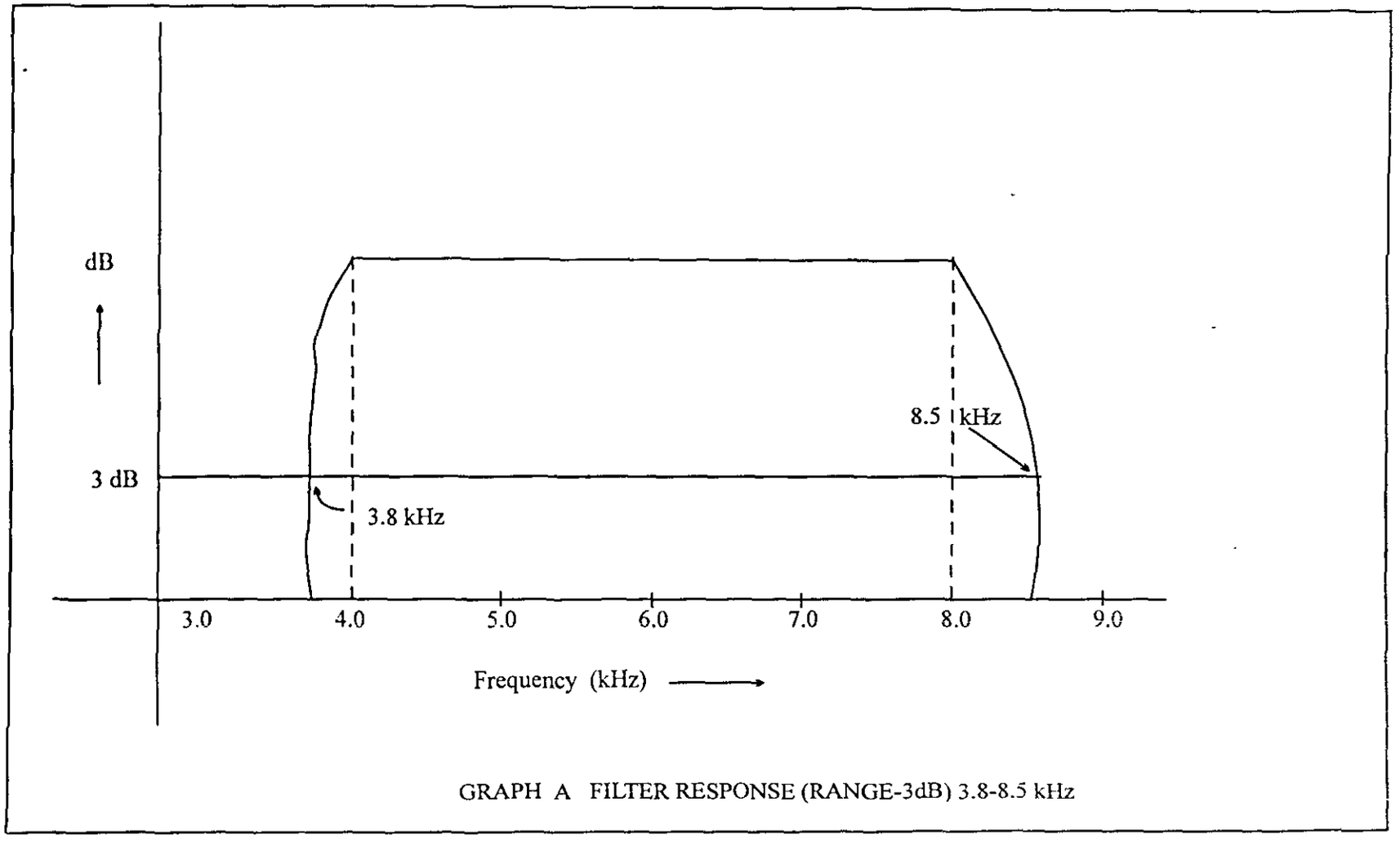
$C = 0.1$ µF

Accordingly other BPF have been designed with usual notations and expressions and were used (Fig A). The frequency-response curve of the BPF of 4000 Hz – 8000 Hz with 3 dB range as 3800 Hz – 8500 Hz is shown as an example in Graph A.



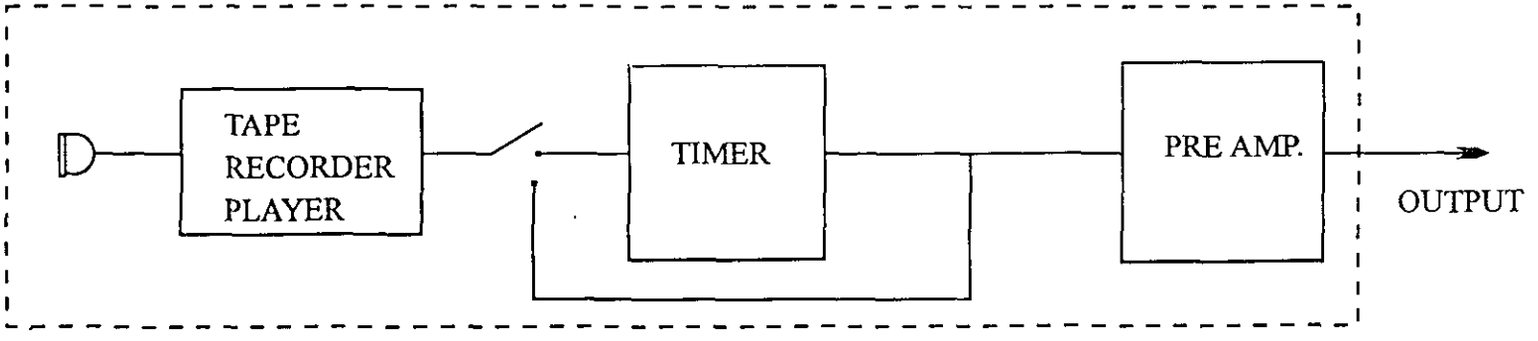
FIG, A ACTIVE BAND PASS FILTER CIRCUIT

(250)



GRAPH A FILTER RESPONSE (RANGE-3dB) 3.8-8.5 kHz

APPENDIX II



TAPE

MICRO PHONE
SENSITIVITY : 57 dB / 1000 Hz
FREQ. : 20 Hz - 10 kHz
INPUT : 50 kohms

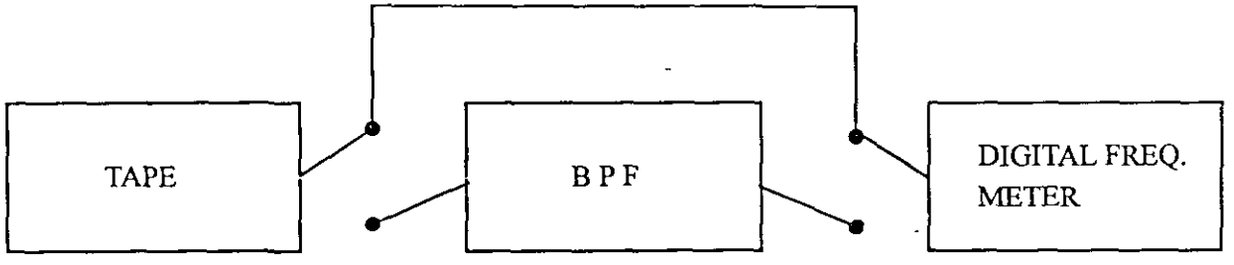
TAPE RECORDER
TAPE SPEED : 4.75 Cm/Sec
FREQ. : 20 Hz - 10 kHz
RECORDING : A.C. BIAS
CONDENSER MICROPHONE
BUILT IN WOW - 0.35 %
SPEED REDUCTION POSSIBLE

TIMER
DIGITAL TYPE WITH DISPLAY
ACCURACY : 0.5 %
CYCLIC OR ONE SHOT OPERATION
THUMB WHEEL SETTING

PRE AMPLIFIER
INPUT RANGE : μ_v
FREQ : 20 Hz - 10 kHz
OUTPUT : 1 mV - 1.00V IN 6 STEPS

FIG. B INPUT FOR ANALYSIS PURPOSES

APPENDIX III



B P F

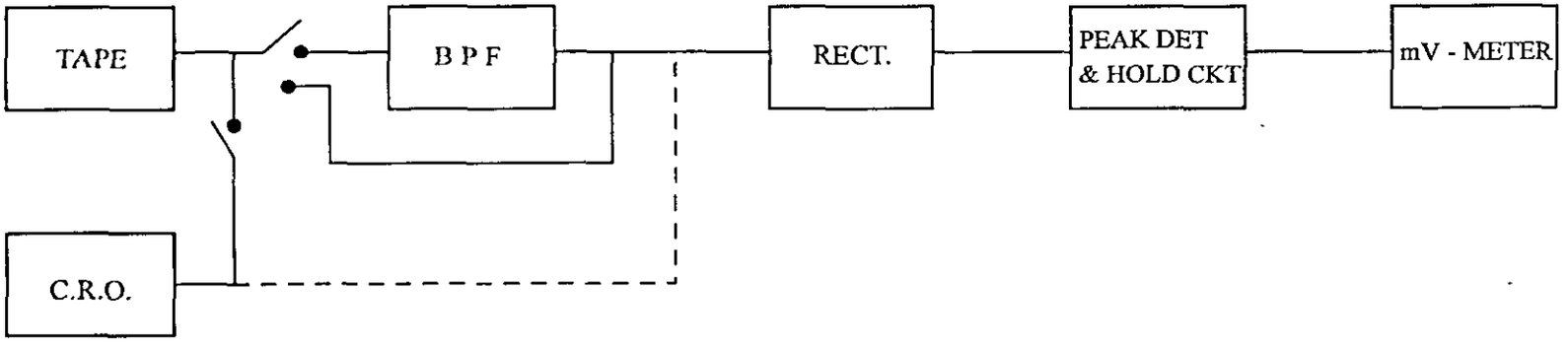
40	-	200 Hz
200	-	550 Hz
500	-	1500 Hz
1500	-	3500 Hz
3500	-	4000 Hz
4000	-	8000 Hz

DIGITAL FREQ. METER 5 DIGIT

RANGE : 10 Hz TO 1 MHz
ACCURACY : ± 0.01 % ± 1D
RESOLUTION UP TO 5 KHz :
LOWER RANGE 0.1 Hz
HIGHER RANGE 1.0 Hz
SENSITIVITY 10 mV
INPUT 10 mV - 100 V

FIG.C FREQUENCY MEASUREMENT

APPENDIX IV



STORAGE C.R.O.
BAND WIDTH : DC- 20 MHz
RISE TIME : 17 ns
TIME BASE : 0.5 μ_s TO 0.25 μ_s
SAMPLING RATE : 5 MHz
ACCURACY ± 3 %
SENSITIVITY 5 mV/ DIV. TO 20 V /DIV.
MEMORY SIZE 1024 X 8 bit / CH

B P F

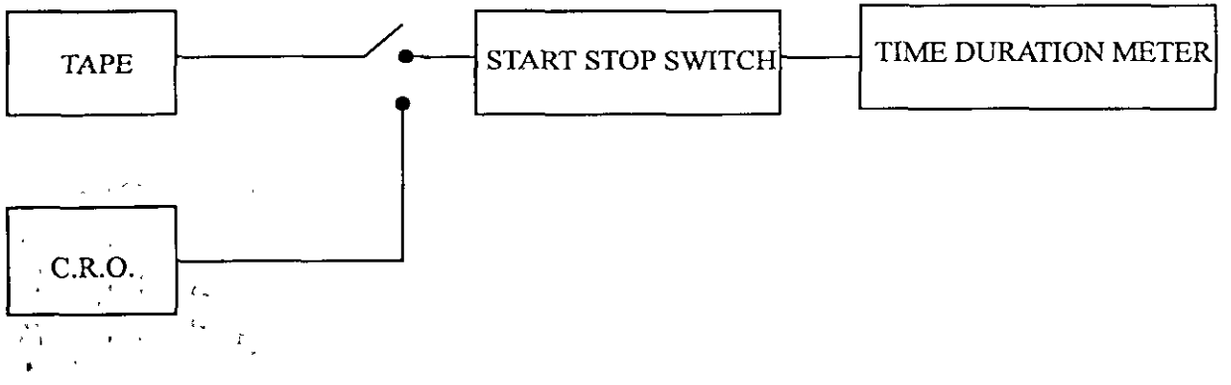
40	-	200 Hz
200	-	550 Hz
500	-	1500 Hz
1500	-	3500 Hz
3500	-	4000 Hz
4000	-	8000 Hz

DIGITAL D.C. VOLT METER

RANGE : 10 mV TO 100 v
RESOLUTION : IN mV RANGE - 0.001mV
ACCURACY ± 0.01 % ± 1D

FIG. D AMPLITUDE MEASUREMENT

APPENDIX V



STORAGE C.R.O.
BAND WIDTH : DC- 20 MHz
RISE TIME : 17 ns
TIME BASE : 0.5 μ_s TO 0.25 μ_s
SAMPLING RATE : 5 MHz
ACCURACY ± 3 %
SENSITIVITY 5 mV/ DIV. TO 20 V /DIV.
MEMORY SIZE 1024 X 8 bit / CH

DIGITALTIME DURATION METER 5 DIGIT

RANGE : 1 mS TO 99.9 SEC
ACCURACY ± 0.02 % COUNT
SENSITIVITY : 10 mV
RESOLUTION : 1 μ_s
INPUT : 10 mV - 100V

FIG-E TIME DURATION MEASUREMENT

APPENDIX VI

SAMPLE CALCULATIONS FOR DETERMINATION OF LEVEL OF PREGNANCY.

Inverse Interpolation : The process of estimating the value of x (month) for a given value of y (frequency), which is not in a table is called inverse interpolation.

Formula used for inverse interpolation is

$$x = \frac{(y-y_1)(y-y_2)\ldots(y-y_n)}{(y_0-y_1)(y_0-y_2)\ldots(y_0-y_n)}x_0 + \frac{(y-y_0)(y-y_1)\ldots(y-y_n)}{(y_1-y_0)(y_1-y_2)\ldots(y_1-y_n)}x_1 + \ldots$$

$$\ldots + \frac{(y-y_0)(y-y_1)\ldots(y-y_{n-1})}{(y_n-y_0)(y_n-y_1)\ldots(y_n-y_{n-1})}x_n \qquad \ldots(1)$$

(a) अ (for observed frequency = 354 Hz)

y = 354 Hz

Level of pregnancy (month)	x_0 (2nd)	x_1 (3rd)	y_2 (7th)	x_3 (8th)
Peak frequency (Hz)	$y_0 = 364.7$	$y_1 = 329.4$	$y_2 = 351.5$	$y_3 = 374.1$

$$x = \frac{(354-329.4)(354-351.5)(354-374.1)}{(364.7-329.4)(364.7-351.5)(364.7-374.1)} \times 2$$

$$+ \frac{(354-364.7)(354-351.5)(354-374.1)}{(329.4-364.7)(329.4-351.5)(329.4-374.1)} \times 3$$

$$+ \frac{(354-364.7)(354-329.4)(354-374.1)}{(351.5-364.7)(351.5-329.4)(351.5-374.1)} \times 7$$

$$+ \frac{(354-364.7)(354-329.4)(354-351.5)}{(374.1-364.7)(374.1-329.4)(374.1-351.5)} \times 8$$

$= 0.56444 - 0.04625 + 5.61745 - 0.55437$

$= 5.58126 \cong 6$

Hence the level of pregnancy is of 7th month.

(b) अ (for observed frequency = 332 Hz)

y = 332.0 Hz

Level of preg. (month)	2nd	3rd	5th	6th
Pea k Frequency (Hz)	364.70	329.40	322.0	335.3

Using equation 1, we have

$x = -0.00387 + 2.1005 - 0.3338 + 2.2111$

$= 3.9817 \cong 4$

Hence the level of pregnancy is of 3rd month.

(c) च (for observed frequency = 358 Hz)

y = 358 Hz

Level of preg. (month)	3rd	4th	5th	6th
Peak Feeq. (Hz)	362.1	303.3	354.2	367

Using equation 1, we have

$x = 2.4656 - 0.002941 + 1.96077 - 1.2798$

$= 3.1436 \cong$ 3rd

Hence the level of pregnancy is of 3rd month.

(d) च (for observed frequency = 370 Hz)

y = 370 Hz

Level of preg. (month)	2nd	3rd	6th	7th
Peak frequency (Hz)	391.5	362.5	367.0	395.4

Using equation 1, we have

$x = 0.41249 - 1.14474 + 7.8485 - 0.92926$

$= 6.18699 \cong 6$

Hence the level of pregnancy is of 6th month.

APPENDIX VII

SAMPLE CALCULATIONS FOR DETERMINATION OF MODEL PARAMETERS

(a) च (4th month)

m (mass of foetus) = 200gm (std value)

From Graph No. 6.80 A, we have

20 log (1/k) = 2.05 volt.

or K (spring restoring force of umblical cords) = 0.7897

ω_n (natural frequency of vibration) = $\sqrt{K/m} = \sqrt{\frac{0.7897}{200}}$

= 0.0628 rad/sec

From Graph No. 6.79

Peak overshoot = 6.0 (non pregnant value)

From equation 6.6

$$6.0 = \omega_n \exp\left(-\frac{1}{A}\tan^{-1} A\right) \text{ ; where } A = \frac{\sqrt{1-\zeta^2}}{\zeta}$$

$$= 0.0628 \exp\left[-\frac{1}{A}\left(A - \frac{A^3}{3} + \frac{A^5}{5} + \ldots\right)\right]$$

$$= 0.0628 \exp\left[-1 + \frac{A^2}{3}\right]; \text{ neglecting 5th and higher order terms}$$

or $$A = 4.0839 = \frac{\sqrt{1-\zeta^2}}{\zeta}$$

Therefore $\zeta = 0.2378$ (damping ratio)

and η (viscous friction of amniotic fluid) = $2\xi\sqrt{Km}$

$= 2 \times 0.2378 \sqrt{07897 \times 200} = 5.9771$

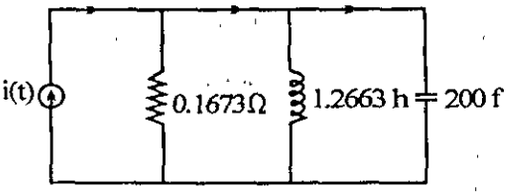
From Table No. 4.1

L (inductance) = 1/K = 1.2663 henery

R (resistance) = $1/\eta$ = 0.1673 ohm

C (capacitance) = m = 200 farad

Now the eletrical model of womb for 4th month of pregnancy scan be represented as :



$$Z_o' \text{ (input impedance)} = \frac{\omega^2L^2R + jR^2(\omega L - \omega^3L^2C)}{(R - \omega^2RLC)^2 + \omega^2L^2} \quad ...(1)$$

At F_1 = 232.5 Hz (first formant frequency); $\omega = 2\pi F_1 = 1460.841$
Putting the values of R,L,C,ω in equation 1 and after simplification, we have

$$Z_o' = (7.00 \times 10^{-11} - j\ 3.423 \times 10^{-6}) \text{ ohm}$$

Therefore $|Z_o'| = 3.423 \times 10^{-6}$ ohm

(b) च (8th month)

m(mass of foetus) = 2000 gm (std value)
From Graph No. 6.80 B, we have

20 log (1/k) = 1.2 volt.

or K (spring restoring force of umbilical cord) = 0.8709

$$\omega_n \text{ (natural frequency of vibration)} = \sqrt{\frac{K}{m}} = \sqrt{\frac{0.8709}{2000}}$$

$$= 0.0208 \text{ rad/sec.}$$

From Graph No. 6.79
Peak overshoot = 6.0 volt
From equation 6.6

$$5.1 = 0.0208 \exp\left(-\frac{1}{A}\tan^{-1}A\right)$$

$$= 0.0208 \exp\left(-1 + \frac{A^2}{3}\right)$$

or $A = 4.4714 = \sqrt{\frac{1-\zeta^2}{\zeta}}$

Therefore ζ (damping ratio) = 0.2182

and η (viscous friction of amniotic fluid) = $2.\zeta\sqrt{km}$

= 18.2131

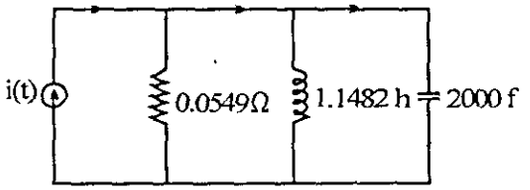
From Table No. 4.1

L (inductance) = 1/K = 1.1482 henery

R (resistance) = $1/\eta$ = 0.0549 ohm

C (capacitance) = m = 2000 farad.

Now the electrical model of womb for 8th month of pregnancy can be represented as :



At F_1 = 364.3 Hz (First formant frequency); $\omega = 2\eta F_1$ = 2288.96

Putting the values of R, L, C, ω in equation 1 and after simplification we have,

$Zo' = (8.6913 \times 10^{-13} - j\ 2.1844 \times 10^{-7})$ ohm

Therefore $|Zo'| = 2.1844 \times 10^{-7}$ ohm

Calculated model parameters using 'अ'

Month	m (gm)	K	η	ξ	ω_n	R = $1/\eta$ (ohm)	L = 1/K (Henery)	C = m (Farad)	Z_o' at F_1 (chm)
4th	200	0.7897	6.0600	0.2411	0.0628	0.1650	1.2663	200	3.423×10^{-6}
5th	450	0.7328	8.4368	0.2323	0.0403	0.1185	1.3646	450	1.444×10^{-6}
6th	900	0.7762	11.9730	0.2265	0.0293	0.0845	1.2883	900	5.699×10^{-7}
7th	1250	0.8365	14.5124	0.2244	0.0258	0.0689	1.1954	1250	3.564×10^{-7}
8th	2000	0.8709	18.4301	0.2208	0.0208	0.0542	1.1482	2000	2.184×10^{-7}
9th	3000	0 8511	21.9705	0.2174	0.0168	0.0455	1.1749	3000	1.315×10^{-7}

Since model parameters are almost same for 'अ' / 'च'. Hence model parameters will remain similar for all the linguistical segments (only sample has been shown).