CHAPTER 6

CONCLUSION AND RECOMMENDATION

It is recommended to try a sinusoidal wave inverter with higher frequency of operation instead of a square wave inverter in order to reduce the size of the filter capacitor and to minimize the output ripple voltage. Further improvement may be achieved in reducing line frequency hum by proper printed-circuit board layout and through selection of low-noise and temperature compensated components.

CHAPTER 7

APPENDIX A

7.1 Calculation of Inverter

Given $P_{out} = 5.2$ W

$V_{in} = 25$ V

$V_{out} = 650$ V

$$P_{in} = \frac{P_{out}}{\eta} = \frac{5.2}{0.8} = 6.5 \text{ W}$$

$$I_c = \frac{P_{in}}{V_{in}} = \frac{6.5}{25} = 0.26 \text{ A}$$

$$I_o = \frac{P_{out}}{V_{out}} = \frac{5.2}{650} = 0.008 \text{ A}$$

Select 2N1484, silicon, npn, transitor which is characterized by :

$I_{c_{max}} = 3$A, $I_{B_{max}} = 1.5$ A, $V_{cEo_{min}} = 55$, $P_{max} = 25$W,

$h_{FE_{min}} = 20$

$$I_B = \frac{I_c}{h_{FE_{min}}} = \frac{0.26}{20} = 0.013 \text{ A}$$

Select TDK, H5B, EP20 core, which is charaterized by $A_{core} = 0.84$ cm^2, $W = 0.3875$ cm^2, $l_w = 4.06$ cm, $B_{sat} = 4100$ gauss, $k_w = 0.5$

From eq. (2.8)

$$J = \left[\frac{2 \; P_{out} n}{l_w \; W K_w} \right]^{1/2} = \left[\frac{2 \times 5.2 \times 0.005}{1.72 \times 10^{-6} \times 4.06 \times 0.3875 \times 0.5} \right]^{1/2}$$

$$= 196 \quad A/cm^2$$

$$\frac{1}{J} = \frac{1}{196 \times 5.07 \times 10^{-6}} = 1006 \quad \text{cir.mils./A}$$

$$B_{max} = 0.8 \; B_{sat} = 0.8 \times 4100 = 3280 \text{ gauss}$$

Then from eq. (2.5)

$$f = \frac{K_i \; P_{out} \times 10^8}{2k_w \; B_{max} J A_c \; W} = \frac{2 \times 5.2 \times 10^8}{2 \times 0.5 \times 3280 \times 196 \times 0.84 \times 0.3875}$$

$$= 4.97 \text{ kHz}$$

From eq. (2.6) and eq. (2.7)

$$T_p = \frac{V_{in} \times 10^8}{4f \; B_{max} \; A_c} = \frac{25 \times 10^8}{4 \times 4.97 \times 10^3 \times 3280 \times 0.84} = 45.6 \text{ turns.}$$

$$T_s = K_1 T_p \frac{V_{out}}{V_{in}} = 1.05 \times 45.6 \times \frac{650}{25} = 1245 \text{ turns.}$$

From eq. (2.9) and eq. (2.10)

$$\text{wire size of } T_p = \frac{1}{J} \; \frac{I_c}{2} = 1006 \times \frac{0.26}{2} = 130 \text{ cir.mils}$$

$$\text{" \quad " } \quad T_s = \frac{1}{J} \times I_{out} = 1006 \times 0.008 = 8 \quad \text{cir.mils}$$

7.2. <u>Calculation of Oscillator</u>

Given : $V_{cc} = 15 \; V$

$V_E = 0.8 \; V$

$$I_B = 0.013 \ \text{A}$$

$$I_c = 1 \ \text{mA}$$

$$f = 4.97 \ \text{kH}_z$$

$$\therefore Rc' + R_{23} = \frac{V_{cc}}{I_B} = \frac{15}{.013} = 1.15 \ k\Omega$$

choose $R_{23} = R_{24} = 150\,\Omega$, $R_{c'} = 1000\ \Omega$

From eq. (2-11)

$$C_9 \geqq \frac{T}{20R_{23}} \geqq \frac{1}{20 \times 150 \times 4970} \geqq 0.067\ \mu f$$

choose $C_9 = C_{10} = 0.1\ \mu f$

Given : Power dissipated on clamp circuit = 0.05 P_{out}

$$R_{25} = \frac{(2\ V_{in})^2}{0.05\ P_{out}} = \frac{(2 \times 25)^2}{0.05 \times 5} = 10\ k\Omega$$

$$C_{11} \geqq \frac{20T}{R_{25}} \geqq \frac{20}{10 \times 10^3 \times 4.97 \times 10^3} \geqq 0.4\ \mu f$$

choose $C_{11} = 1\ \mu f$

Select MPS 3706, npn, Si transistor as Q7, Q8, Q9, Q10.

The MPS 3706 is characterized by $I_{c_{max}} = 600$ mA,

$V_{cEo} = 20$ V, $V_{EBo} = 5$ V, $P_{max} = 310$ mW, $h_{FE(min)} = 30$,

Gain bandwidth = 100 MHz

$$I_b' = \frac{1}{h_{FE}} \times \frac{V_{cc}}{R_c'} = \frac{1}{30} \times \frac{15}{1k} = 0.5\ \text{mA}$$

$$R_{b'} = \frac{V_E - 0.7}{I_{b'}} = \frac{0.8 - 0.7}{0.5 \times 10^{-3}} = 200 \ \Omega$$

$$R_e = \frac{V_E}{I_c - I_{b'}} = \frac{0.8}{(1.0-0.5)\times 10^{-3}} = 1.6 \ k\Omega$$

$$R_c = \frac{V_{cc}-V_E-0.3}{I_c} = \frac{15-0.8-0.3}{10^{-3}} = 13.9 \ k\Omega$$

$$R_b = \frac{\left[V_{cc}-V_D-0.7-V_E\right]h_{FE}}{I_c} = \frac{\left[15-0.6-0.7-0.8\right]\times 30}{10^{-3}}$$

$$= 387 \ k\Omega$$

From eq. (2.13)

$$C = \frac{T}{2R_b \ln(2)} = \frac{1}{2\times 387\times 10^3 \times 0.693 \times 4.97\times 10^3}$$

$$= 375 \ pF$$

7.3 Calculation of Multiplier and Filter

Given

$M = 2$

$I_L = 2$ mA

$V_{pp} = 1300$ V

$V_D = 1$ V

$f = 4.97$ kHz

$C_M = .047 \ \mu F$

$N = 2$

$E_{oR} < 10$ mV

$C_F = 1 \ \mu F$

From eq. (2.16)

$$E_{ODC} = MV_{pp} - \frac{I_L}{fC_m} \sum_{i=1}^{M} (i)^2 - \frac{M(M+3)}{2} V_D$$

$$= (2)(1300) - \left[\frac{2 \times 10^{-3}}{4.97 \times 10^3 \times .047 \times 10^{-6}}\right]\left[1^2 + 2^2\right] - \frac{2(2+3)}{2} \times 1$$

$$= 2552 \quad V.$$

From eq. (2.15)

$$E_{IR} = \frac{I_L}{fC_m} \times \frac{M(M+1)}{2}$$

$$= \frac{2 \times 10^{-3} \times 2 \times (2+1)}{4.97 \times 10^3 \times 0.047 \times 10^{-6} \times 2}$$

$$= 25.7 \quad V.$$

Voltage drop in filter circuit = 2552-2500 V

= 52 V

$$R_F = \frac{V_{drop}}{NI_L} = \frac{52}{2 \times 2 \times 10^{-3}} = 13 \quad k\Omega$$

From eq. (2.18)

$$E_{OR} = \left[\frac{X_{CF}}{R_F}\right]^N E_{IR} = \left[\frac{\frac{1}{2\pi \times 4.97 \times 10^3 \times 10^{-6}}}{13 \times 10^3}\right]^2 \times 25.7\,V = 0.156\ mV$$

$\therefore E_{OR} = 0.156$ mV which is less than 10 mV

7.4 Calculation of Feedback Network

Given HV = 2500 V

V_{ref} = 8.5 V

$$R_{31} = 200 \quad M\Omega$$

$$E_{eq} = V_{ref} = 8.5 \quad V$$

From eq. (2.25)

$$\therefore \quad R_{32} = \frac{R_{31} \cdot E_{eq}}{HV-E_{eq}} = \frac{200 \times 10^{6} \times 8.5}{2500-8.5}$$

$$= 680 \quad k\Omega$$

7.5 Calculation of Protection Circuit

Given $I_{Limit} = 2 \quad mA$

$$V_z = 11 \quad V$$

$$R_{33} = 10 \quad \Omega$$

$$R_{34} = 1 \quad k\Omega$$

From eq. (2.31) and eq. (2.32)

$$A_f = \frac{V_z}{I_{Limit} R_{33}} = \frac{11}{2 \times 10^{-3} \times 10} = 550$$

$$R_{36} = A_f R_{34} = 550 \times 1k = 550 \ k\Omega$$

7.6 Calculation of the values of the resintances in power supply II

Given : $V_{o_{pos}} = +15 \quad V$

$$V_{o_{neg}} = -15 \quad V$$

$$R_2 = 3 \quad k\Omega$$

$$R_4 = 43 \quad k\Omega$$

Select LM 723 C, voltage regulator which is characterized by P_{max} = 900 mW, $I_{o_{max}}$ = 150 mA, $V_{in_{max}}$ = 40 V,

V_{ref} = 6.95 V

From eq. (2.27)

$$R_1 = R_2 \left[\frac{V_{o_{pos}}}{V_{ref}} - 1 \right] = 3 \times 10^3 \times \left[\frac{15}{6.95} - 1 \right]$$

$$= 3.48 \times 10^3 \ \Omega$$

choose R_1 = 3.6 kΩ

From eq. (2.30)

$$R_5 = - \left[R_4 \frac{V_{o_{neg}}}{V_{o_{pos}}} \right] = - \left[43k \times \frac{-15}{15} \right]$$

$$= 43 \ k\Omega$$

7.7 Calculation of % variation in HV output

From fig. 27 and fig. 29

Given : voltage output of DC Transfer Standard = 1000 mV

sensitivity of recorder = 1 mV/div.

$\therefore$ variation in HV output = $\frac{1 \times 100}{1000}$ = 0.1 %/div.

APPENDIX B

SPECIFICATIONS OF OAEP 1409 HIGH VOLTAGE POWER SUPPLY

OUTPUT POLARITY Positive or negative, selected by switch on rear panel

OUTPUT RANGE 1 to 2500V; minimum usable voltage 50 V

OUTPUT LOAD CAPACITY 0 to 2 mA.

REGULATION $\leqq$ 0.01 % variation in output voltage for line variation from 200 to 240 at constant load, and ambient temperature.

TEMPERATURE STABILITY $\leqq$ 0.11 % /°C variation in output voltage after 30 min warmup.

LONG-TERM DRIFT $\leqq$ 0.05 % /hr variation in output voltage at constant input line voltage, load and ambient temperature after 30 min warmup.

OUTPUT RIPPLE < 20 mV peak to peak at full load

OVERLOAD PROTECTION Built-in overload and short-circuit protection with maximum current of $\approx$ 2 mA.

OUTPUT LEVEL a 3-turn precision potentiometer is used to adjust output level. The linearity and accuracy is better than $\pm$ 10 %

POWER REQUIREMENTS 220V, 50 Hz, 18W is the maximum power required by the H.V. supply

DIMENSIONS Standard triple-width module

WEIGHT (Net) 3.7 Kg.

APPENDIX C

PRICE LIST OF THE PART OF OAEP 1409 HIGH VOLTAGE POWER SUPPLY

Part	Unit price (Baht)	Total (Baht)
IC1, IC2	20	40
IC3, IC4, IC5, IC6, IC7	10	50
Q1, Q2, Q3, Q4	6	24
Q6, Q7, Q8, Q9, Q10	5	25
Q13	20	20
Q15	30	30
Q11, Q12, Q14	30	90
Q5	20	20
D1, D2, D3, D4	5	20
D5	80	80
D6, D7	20	40
D13, D14, D15, D16	50	200
SCR1	20	20
D10, D11, D12	50	150
R1-R43	1	37
R26, R27, R28, R29, R32	8	40
R31	50	50
T2	100	100
T1	150	150
S101	50	50
S102	100	100
P1	150	150
Counting dial	250	250
SHV connector	100	200
M panel meter	100	100
NIM housing	500	500
Total		2536