APPENDIX I

TRANSFORMER DESIGN

In a discontinuous-mode flyback regulator, the first design step is to determine the maximum on-time of the power transistor. This determines the maximum "volt-second" product and affects the primary current. For the flyback regulator with constant power output and frequency, Figures IA and IB show the required component ratings for designs having different maximum duty cycles. Note that all parameters are normalized to a maximum duty cycle of 50%. When this duty cycle is reduced in a given design:

(A) Current ratings of the switching transistor will be higher. However, the minimum blocking voltage required will be lower.

(B) Current ratings of the output rectifier will be lower. However, the minimum peak inverse voltage required will be higher.

(C) An output filter capacitor with higher ESR may be used to achieve the desired ripple voltage.

(D) I^2R losses remain constant even though the peak primary current increases.

(E) The maximum amount of energy stored in the transformer will remain the same.

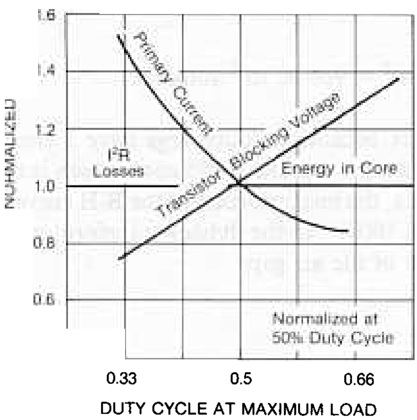

Figure IA. Primary Side

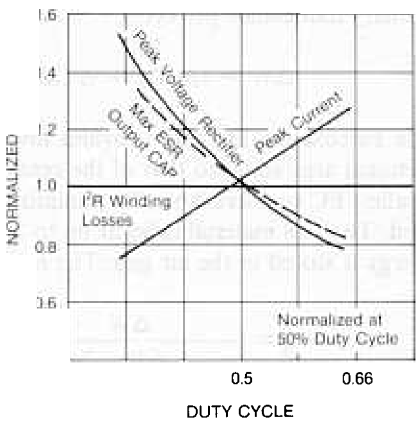

Figure IB. Secondary Side

Figure I. Effect of the Maximum Duty Cycle on the Design of a Flyback Regulator

In this design, the maximum duty cycle D_{max} was chosen at 45% to optimize the operating condition for the power MOSFET.

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The maximum on-time:

$$t_{on(max)} = \frac{1}{f_s} D_{max} = \frac{0.45}{80 \times 10^3} = 5.62\mu s$$

The peak primary current:

$$I_{pp} = \frac{2P_o}{\eta f_s \; V_{in(min)} \; t_{on(max)}} = \frac{2\,(60)}{(0.8)\,(80 \times 10^3)\,(100)\,(5.62 \times 10^{-6})}$$

where η = efficiency

$$= 3.44A$$

The required primary inductance is therefore:

$$L_p = \frac{V_{in(min)} \; t_{on(max)}}{i_{pp}} = \frac{100\,(5.62 \times 10^{-6})}{3.44}$$

$$= 165\mu H$$

To determine the necessary core parameters, we compute the required energy storage in the primary inductance per cycle:

$$\Delta W = \tfrac{1}{2} L \, i_{pp}^2 = \tfrac{1}{2}\,(165 \times 10^{-6})\,(3.44)^2 = 969 \times 10^{-6} \text{ Joules}$$

The Ferroxcube EC core provides low leakage flux because its outer legs have a cross-sectional area equal to that of the center leg. This design uses the EC35 core, which is the smallest EC core available. To minimize leakage flux, the linear portion of the B-H curve is used. The 3C8 material is linear up to 2000 gauss at 100°C. In the flyback transformer the energy is stored in the air gap. The required length of the air gap:

$$l_g = \frac{\Delta W}{.0312 \left(\frac{B_{max}}{2800}\right)^2 A_e}$$

where $B_{max} = 2800$
$A_e = .843$

$$= \frac{969 \times 10^{-6}}{.0312 \left(\frac{2000}{2800}\right)^2 (.843)}$$

$$= .072cm$$

The air gap l_g is divided equally among the two flux paths in the EC core.

The number of primary turns:

$$N_p \approx \frac{B_{max}\, l_g}{.4\pi\, i_{pp}} = \frac{(2000)\,(.072)}{(.4)\,(3.14)\,(3.44)} = 34 \text{ turns}$$

Figure IC shows details of the transformer construction.

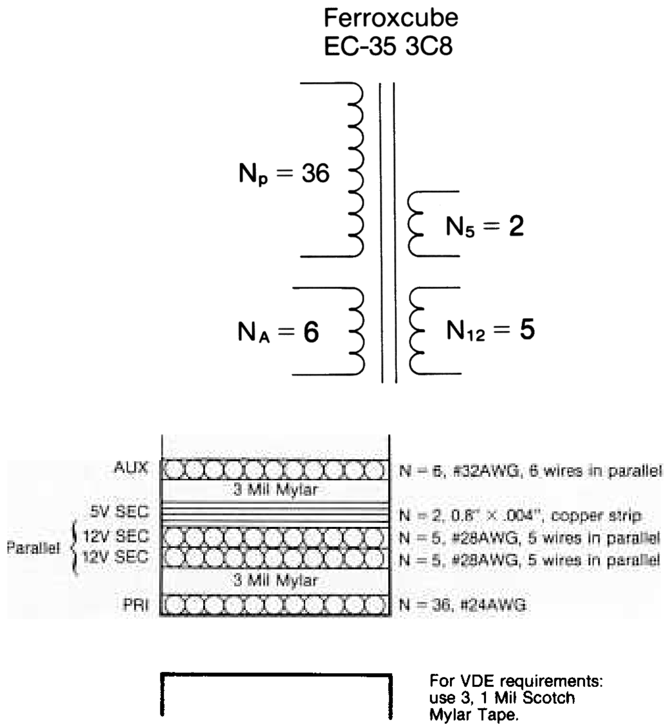

Figure IC. Construction of the Transformer Windings

The turns-ratio between primary to secondary can be calculated by the equation:

$$N_5 = N_P \frac{(V_{O5} + V_F)\,(4 - D_{max})}{V_{in(min)}\, D_{max}}$$

For +5V output, the turns-ratio;

$$N_5 = 34\,\frac{(5 + 0.6)\,(1 - 0.45)}{(100)\,(0.45)} = 2.4; \text{ use 2 turns.}$$

Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265