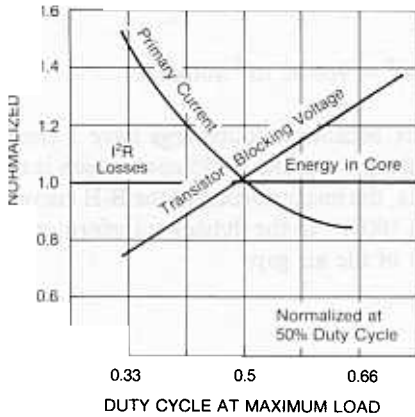


## APPENDIX I

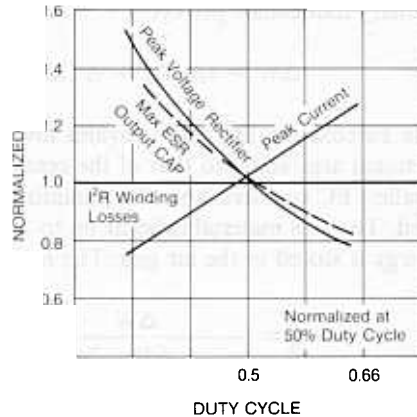
### TRANSFORMER DESIGN

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.

The maximum on-time:

$$t_{on(max)} = \frac{1}{f_g} D_{max} = \frac{0.45}{50000} = 5.62 \mu s$$

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  $\eta$  = 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:

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

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

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

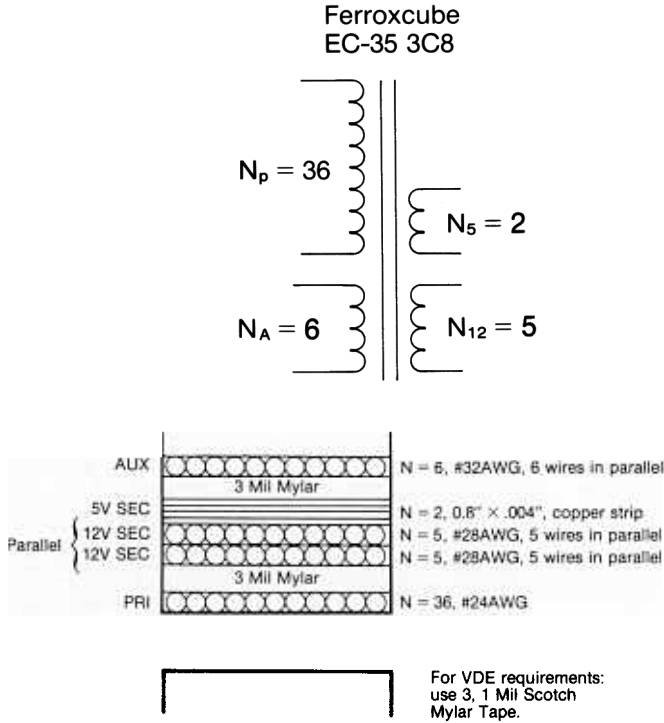
$$= .072cm$$

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;

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

## IMPORTANT NOTICE

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgment, including those pertaining to warranty, patent infringement, and limitation of liability.

TI warrants performance of its products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

Customers are responsible for their applications using TI components.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such products or services might be or are used. TI's publication of information regarding any third party's products or services does not constitute TI's approval, license, warranty or endorsement thereof.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations and notices. Representation or reproduction of this information with alteration voids all warranties provided for an associated TI product or service, is an unfair and deceptive business practice, and TI is not responsible nor liable for any such use.

Resale of TI's products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service, is an unfair and deceptive business practice, and TI is not responsible nor liable for any such use.

Also see: [Standard Terms and Conditions of Sale for Semiconductor Products](http://www.ti.com/sc/docs/stdterms.htm). [www.ti.com/sc/docs/stdterms.htm](http://www.ti.com/sc/docs/stdterms.htm)

### Mailing Address:

Texas Instruments  
Post Office Box 655303  
Dallas, Texas 75265