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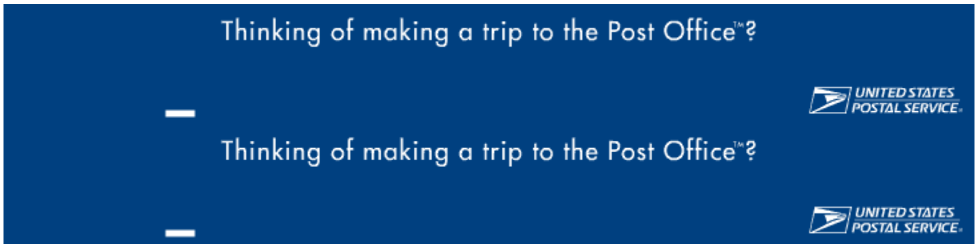

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## Implementing Flyback Transformer Design for Continuous Mode

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In **last month's Power Design column**, we examined the functional principles of continuous mode (or incomplete energy transfer mode) of a flyback transformer. In this
ferrite core.

### Transformer Design Example

**Fig. 1** shows a typical flyback converter as used for single output application. **Fig. 2** shows typical waveforms found in continuous mode operation. In this mode, energy
the secondary when Q1 turns OFF We have a variable (top) part of the waveform, and an effective dc component, (as there would be in an output smoothing choke in a

For this transformer design example, we'll assume an output power requirement of 100W. The input voltage is 100V. The secondary voltage is 20V at a mean current of
The example assumes 100% efficiency and zero diode drop.

The first step is to decide the load current range over which the continuous mode of operation is to be maintained. The larger the load range, the more turns and inducta
This choice results in a ripple current of half the mean value at maximum load. The waveforms in **Figs. 2** and **3** show this condition. We must choose the maximum flux
optimum choice is where total copper loss equals the core loss. This is an iterative process and can't be fully established at this stage. It must be checked in the final de
provides a 50% flux margin for the dc polarizing force shown as *Bdc* on the vertical B scale in **Fig. 3**.

Further Flyback

- Designing Flyback Transformer for Discontinuous Mode
- Choosing Core for Flyback Transformer and Choke Designs
- Improving the Performance of Flyback Power Supplies

We can now calculate the minimum primary turns Np; (See **Equations**)

Vp = 100V, t (the ON period of Q1) is 10µs, B max is 0.166 Tesla and Ae (the area of the core) is 100 $\text{mm}^2$

Hence the primary turns (Np) will be 60 turns.

The primary inductance can be calculated as follows; Assuming 100% efficiency at a power of 100W and an input voltage of 100V the time averaged input current will b
this example). From inspection of the top part of **Fig. 2**, the primary current change is from 1.5A to 2.5A, a ΔI of 1A. The ON period is 10µs, and we can now calculate t

The primary inductance

This will be 1000 µH. (See **Equations**)

While the OFF (flyback) period of Q1 is also 10µs, the secondary volts per turn during the flyback period will be the same as the primary volts per turn during the ON pe
transformer like ratio won't apply, and you must obtain the secondary turns from the calculated secondary inductance, in the same way as it was in the discontinuous m

The secondary current ratio follows the turns ratio, since the primary ampere turns product must be maintained. Thus, Is = Ip × 60/12. As shown in **Figs. 2** and **3**, the
average at 20V and power equality is maintained.

The "transformer" is now wound using a wire size for the 60 turns primary that will use less than 50% of the bobbin area to allow for insulation. The remaining space is
no direct transformer action (because the primary and secondary aren't conducting at the same time), the leakage inductance should still be minimized. As Q1 turns OF
commutation and will produce a voltage overshoot on the primary when Q1 turns OFF. Hence, the windings would normally be interleaved — ½ primary, secondary and
However, it can also be calculated. (See **Equations**.)

The main advantage of the continuous mode is reduced ripple current. The disadvantages are that the "transformer" must support a dc current component, the output d
plane zero" in the transfer function leading to poor transient response. However, the reduced ripple current, makes this mode more suitable for higher power application

The mode of operation was defined by adjusting the inductance, (by using a smaller air gap). Low inductance (large air gap) leads to the discontinuous mode, while larg
gap, or a combination of these.

For multiple outputs, sum the total output power and use this value in the equations when calculating the primary and secondary inductance of the main controlled outp

Although we've ignored the transformer action, as it's not a design parameter, it still exists. The flyback voltage is reflected back to the primary winding during the OFF p

The following equations are dimensionally modified to yield convenient answers.

### Equations

**Primary Turns**

Where:

$N_P$ = Primary Turns

$V_P$ = Primary Voltage

t = Q1 ON time (µs)

ΔB = Peak flux density (tesla)

Ae = effective area of center pole ($\text{mm}^2$)

**Primary Inductance Where:**

$L_P$ =Primary inductance (μH)

$\Delta t$ = Q1 ON time (μs)

$\Delta I_P$ = Current change $I_1$ to $I_2$ (A)

**Inductance Factor**

Where:

$A_L$ = Inductance of a single turn (μH)

**Secondary Inductance** $L_S = N_S^2 \times A_L$

Where:

$L_S$ = Secondary inductance (μH)

$N_S$ = Secondary turns

**Secondary Turns**

**Air Gap Length**

Where:

Air gap = (mm)

$\mu o = 4 \pi \times 10^{-7}$

$N_P$ = Primary turns

Ae = Area of core($mm^2$)

$L_P$ = Primary inductance (mH)

$\alpha$ = Air Gap (mm)

**ac Flux Density**

**dc Flux Density**

where $\alpha$ = Air Gap (mm)

In the next Power Design column, we'll cover a transformer design for a forward converter, including alternative core materials.

*Keith Billings is president of DKB Power Inc. (***dkbp@rogers.com***) and author of the Switchmode Power Supply Handbook published by McGraw Hill ISBN 0-07-006719-8.*

## References

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