

TOPSwitch®-FX Flyback

Design Methodology

Application Note AN-25



This application note introduces a simple methodology for the design of off-line flyback power supplies using the TOPSwitch-FX family. It is fundamentally the same as AN-16, "TOPSwitch Flyback Design Methodology", which was intended for TOPSwitch and TOPSwitch-II families. Several modifications reflect the features of TOPSwitch-FX. In addition to addressing basic design issues specific to TOPSwitch-FX, many other general enhancements over AN-16 were also implemented. A brief summary of the major differences between this document and AN-16 is provided in Appendix B as a quick reference for readers already familiar with AN-16.

Introduction

The design of a switching power supply, by nature, is an iterative process with many variables that have to be adjusted to optimize the design. The design method described in this document consists of two major sections: The design flow chart and the step-by-step design procedure. The flow chart shows design sequence at conceptual level for TOPSwitch-FX flyback power supply design. The step-by-step procedure gives details within each step of the design flow chart including rules of thumb and look up tables. All key equations and guidelines are provided wherever possible to assist the readers in better understanding and/or further optimization.

Basic Circuit Configuration

Because of the high level integration of TOPSwitch-FX, many power supply design issues are resolved in the chip. Far fewer issues are left to be addressed externally, resulting in one common circuit configuration for all applications. Different output power levels may require different values of some circuit components, but the circuit configuration stays unchanged. TOPSwitch-FX is a feature rich product family. Advanced features like Under-Voltage, Over-Voltage, External I_{LIMIT} , Line Feed Forward, Remote ON/OFF are easily implemented with a minimal number of external components, but do require additional design considerations. Please refer to the TOPSwitch-FX data sheet for details. Other application specific issues such as constant current, constant power outputs, etc. are beyond the scope of this application note. However, such requirements may be satisfied by adding additional circuitry to the basic converter configuration. The only part of the circuit configuration that may change from application to application is the feedback circuitry. Depending on the power supply output requirement, one of the two feedback circuits, shown in Figures 3 and 4, will be chosen for the application.

The basic circuit configuration used in TOPSwitch-FX flyback power supplies is shown in Figure 1, which also serves as the

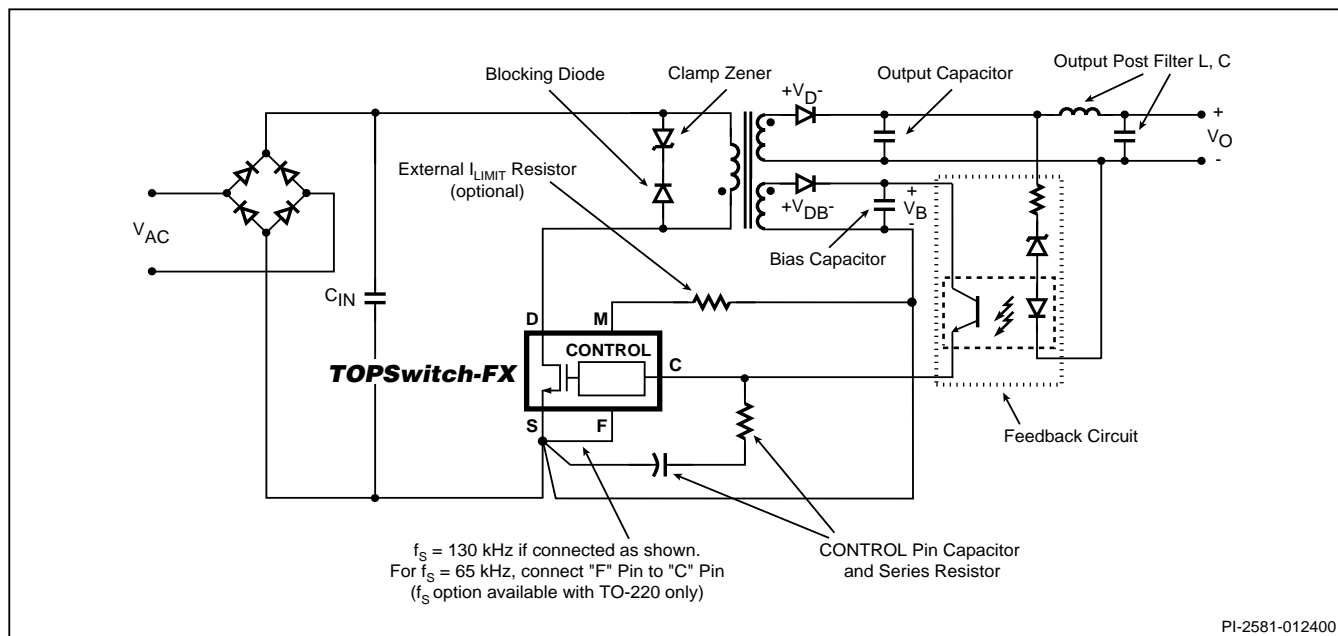


Figure 1. Typical TOPSwitch-FX Flyback Power Supply.

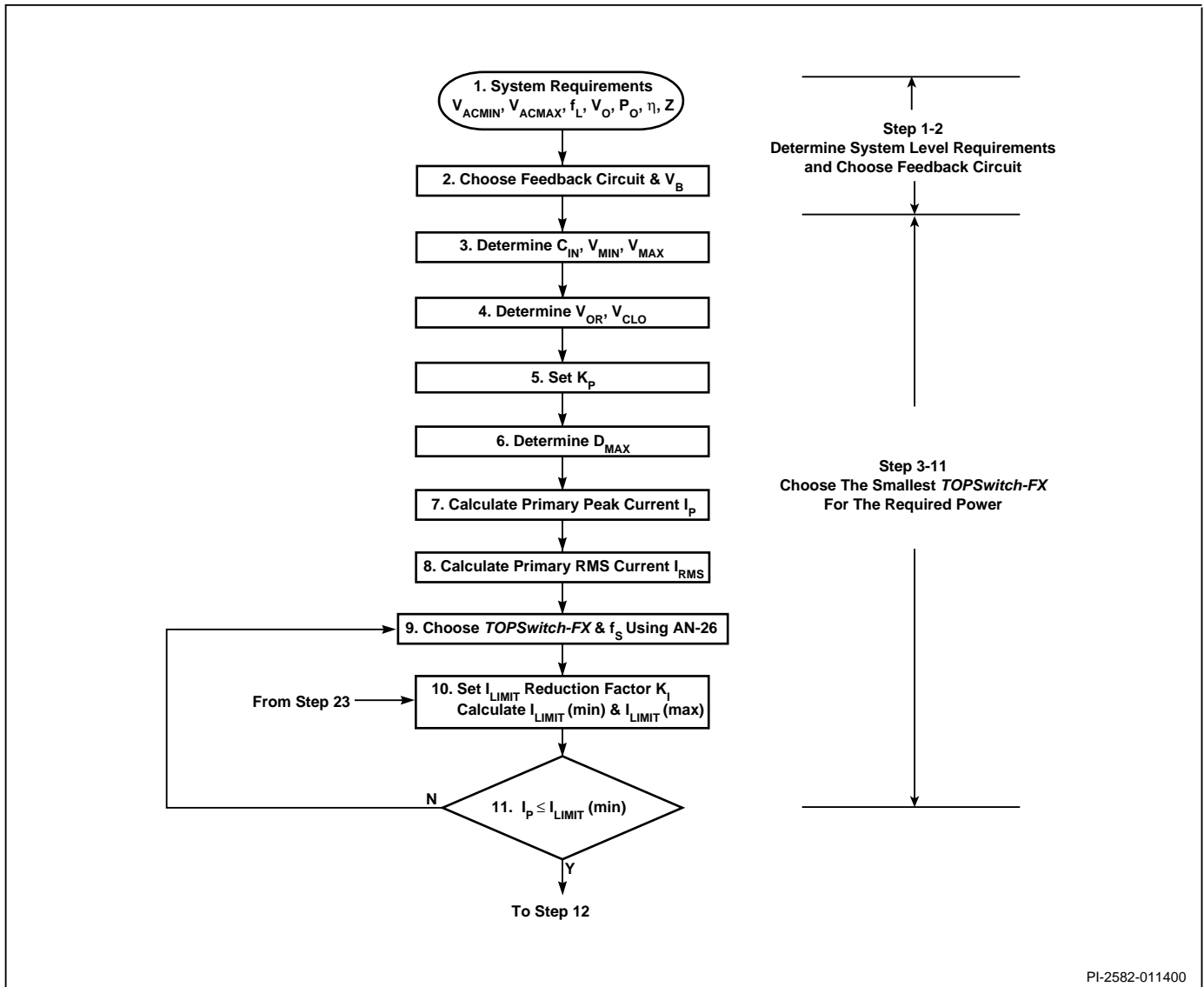


Figure 2A. TOPSwitch-FX Design Flow Chart. Step 1 to 11.

reference circuit for component identifications used in the description throughout this application note.

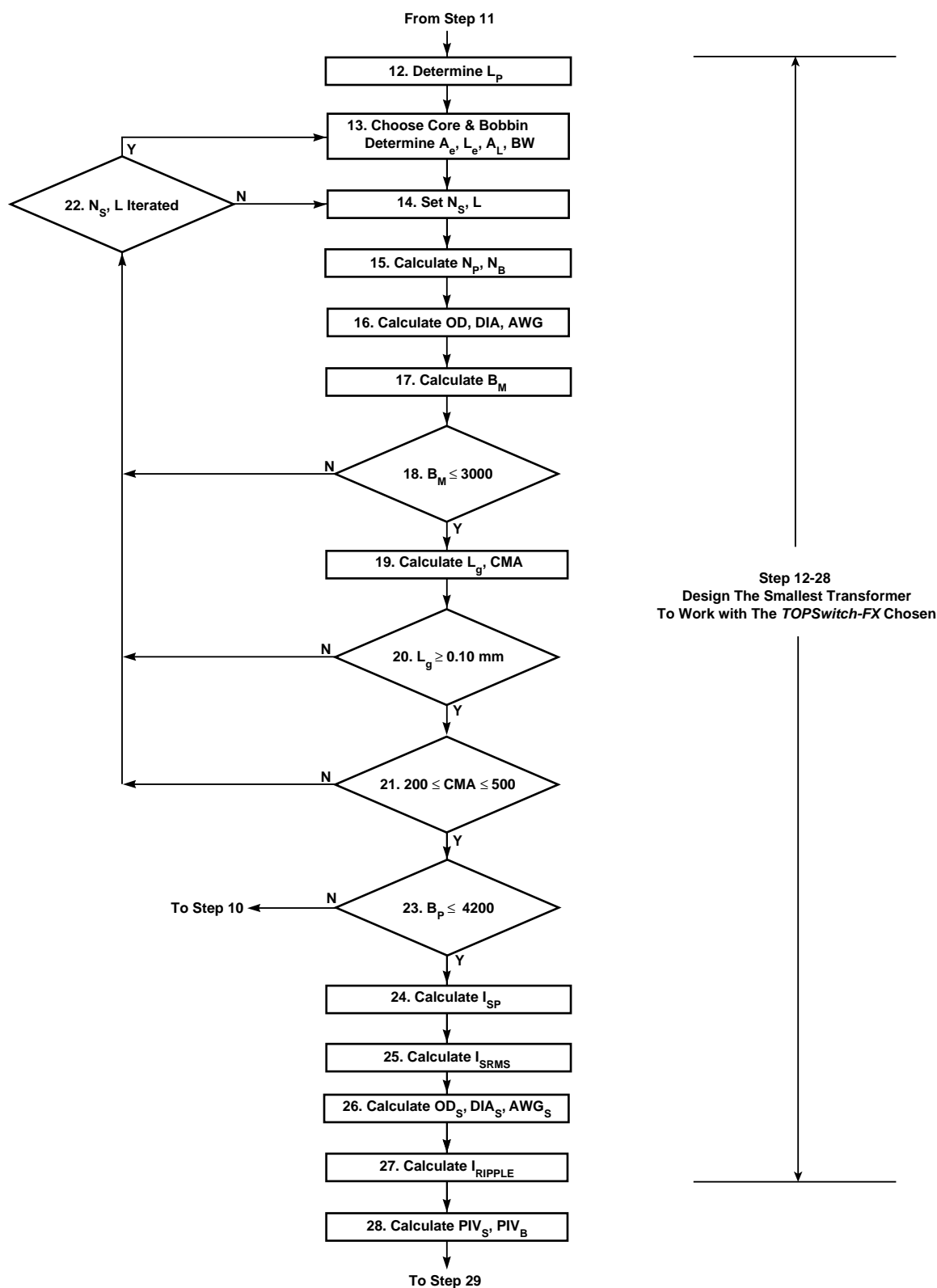
Design Flow

Figures 2A, 2B and 2C present a design flow chart showing the complete design procedure in 37 steps. With the basic circuit configuration shown in Figure 1 as its foundation, the logic behind this design approach can be summarized as following:

1. Determine system requirements and decide on feedback circuit accordingly.
2. Choose the smallest TOPSwitch-FX capable for the required output power.

3. Design the smallest transformer for the TOPSwitch-FX chosen.
4. Select all other components in Figure 1 to complete the design.

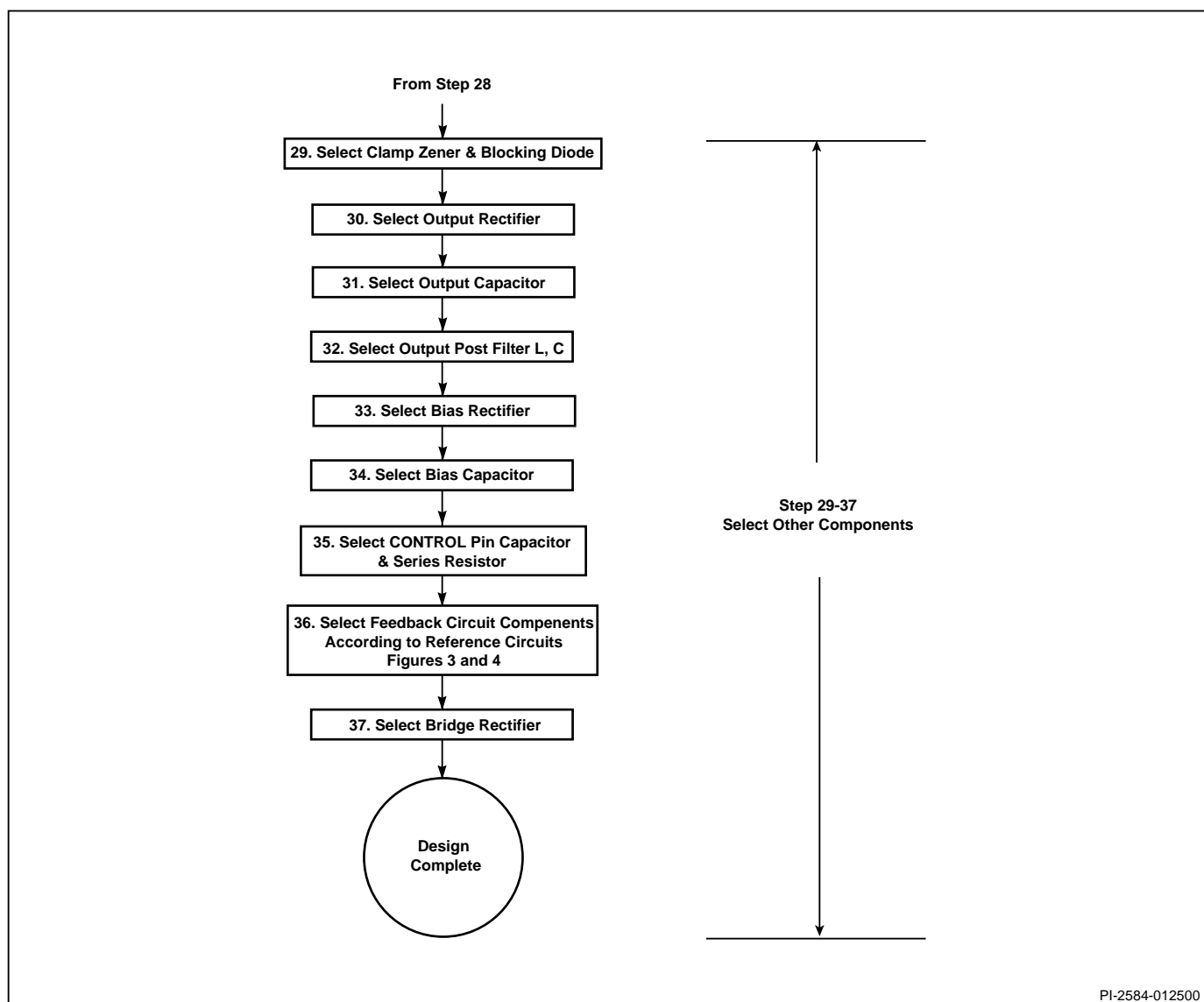
The overriding objective of this procedure is “design for cost effectiveness”. Using smaller components usually leads to a less expensive power supply. However, for applications with stringent size or weight limitations, the designer may need to strike a compromise between cost and specific design requirements in order to achieve the optimum cost effectiveness for the end product.



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Figure 2B. TOPSwitch-FX Design Flow Chart. Step 12 to 28.





PI-2584-012500

Figure 2C. TOPSwitch-FX Design Flow Chart. Step 29 to 37.

Step by Step Design Procedure

This design procedure uses the *TOPSwitch-FX* continuous/discontinuous flyback design spreadsheet (available from Power Integrations) which contains all the important equations required for a *TOPSwitch-FX* flyback power supply design, and automates most calculations. Designers are, therefore, relieved from the tedious calculations involved in the complicated and highly iterative design process. Note that all user provided inputs are in column B and all spreadsheet calculated results are in column D. Column C is reserved for intermediate variables needed in some complicated calculations. Look up tables and rules of thumb are provided where appropriate to facilitate the design task.

Step 1. Determine system requirements: V_{ACMAX} , V_{ACMIN} , f_L , V_O , P_O , η , Z

- Minimum AC input voltage, V_{ACMIN} : in Volts.
- Maximum AC input voltage, V_{ACMAX} : in Volts.
- Recommended AC input ranges:

Input (VAC)	V_{ACMIN} (VAC)	V_{ACMAX} (VAC)
Universal	85	265
230 or 115 with doubler	195	265

Table 1.

- Line frequency, f_L : 50 Hz or 60 Hz.
- Output voltage, V_O : in Volts.
- Output power: P_O : in Watts.
- Power supply efficiency, η : 0.8 if no better reference data available. (Refer to AN-26)
- Loss allocation factor, Z : If $Z = 1$, all losses are on the secondary side. If $Z = 0$, all losses are on the primary side. Set $Z = 0.5$ if no better reference data available.

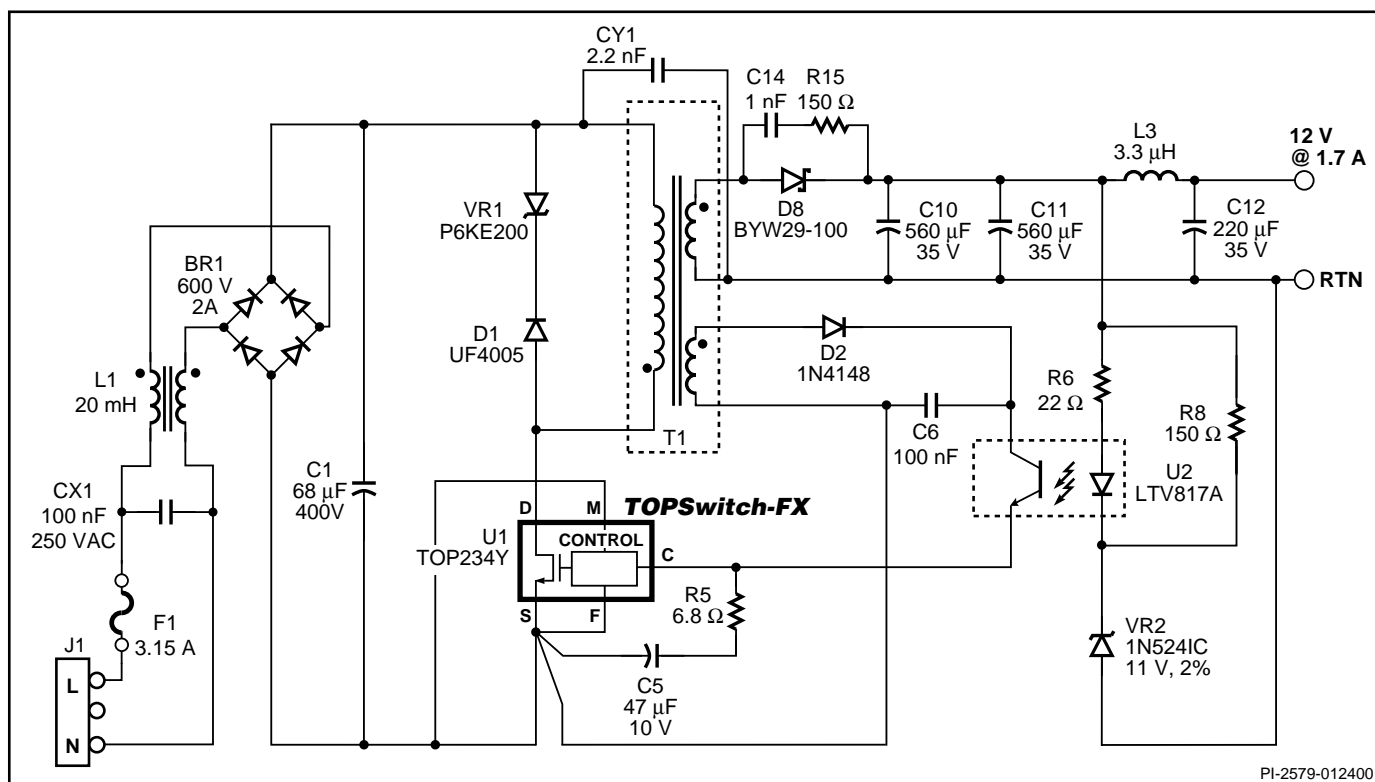
Step 2. Choose feedback circuit and bias voltage V_B based on output requirements

Feedback Circuit	V_B (V)	Output Accuracy	Load* Reg.	Line Reg.	Ref. Circuit
Opto/Zener	15	$\pm 5\%$	$\pm 1\%$	$\pm 0.5\%$	Figure 3
Opto/TL431	15	$\pm 1\%$	$\pm 0.2\%$	$\pm 0.2\%$	Figure 4

*Over 10% to 100% Load Range.

Table 2.

- Use Opto/Zener for lower cost.
- Use Opto/TL431 for better performance.
- Although not included in Table 2, primary feedback may also be used with *TOPSwitch-FX* design.
- Bias voltage V_B : 15 V recommended. May be set to different value if needed.



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Figure 3. Opto/Zener Feedback Reference Circuit.

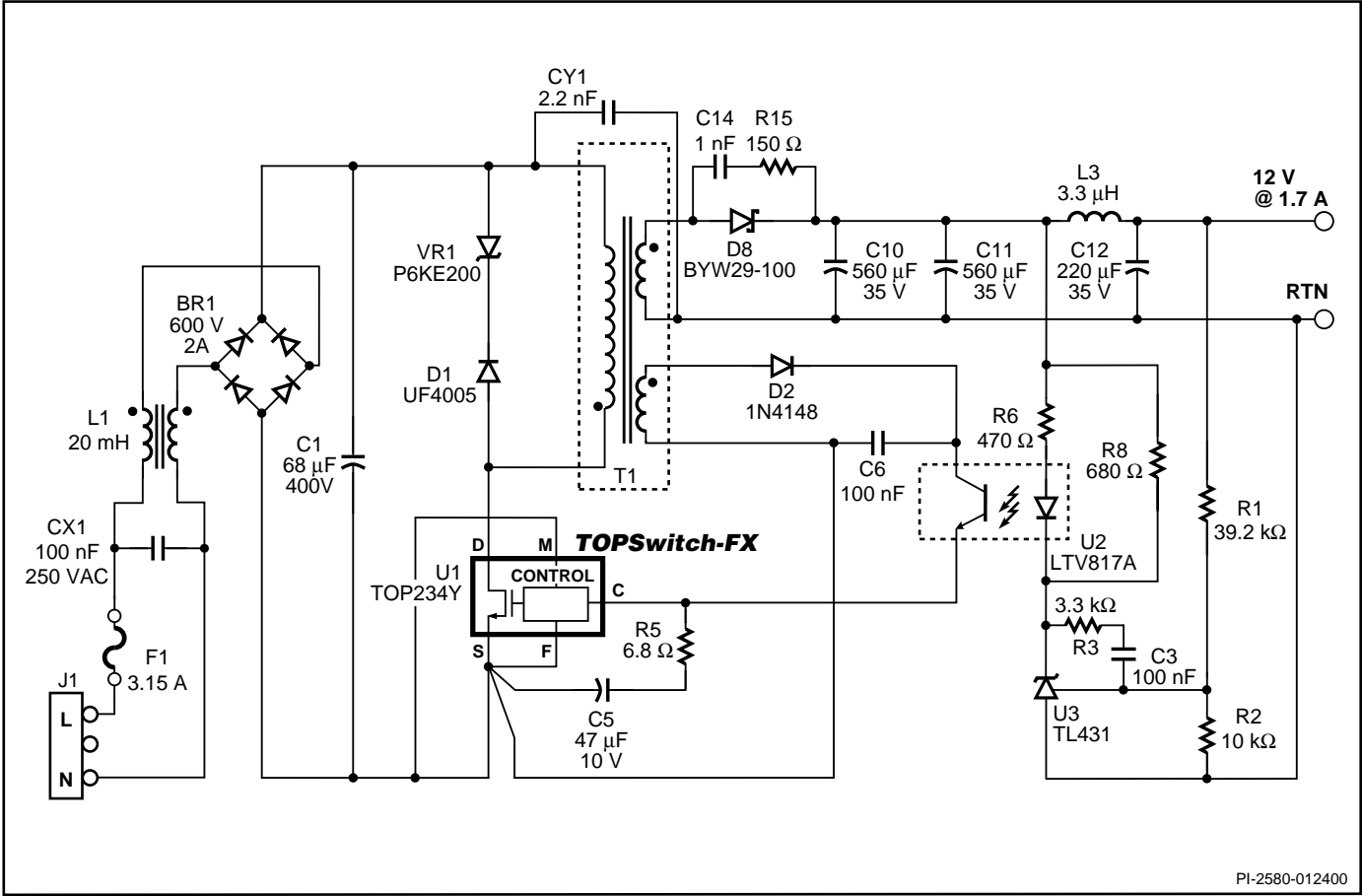


Figure 4. Opto/TL431 Feedback Reference Circuit.

Step 3. Determine minimum and maximum DC input voltages V_{MIN} , V_{MAX} and input storage capacitance C_{IN} based on AC input voltage and P_o (Figure 5)

- Choose input storage capacitor, C_{IN} per Table 3.

Input (VAC)	$C_{IN} (\mu F/Watt \text{ of } P_O)$	$V_{MIN} (V)$
Universal	2 ~ 3	≥ 90
230 or 115 with doubler	1	≥ 240

Table 3.

- Set bridge rectifier conduction time, $t_c = 3 \text{ ms}$.
- Derive minimum DC input voltage V_{MIN}

$$V_{MIN} = \sqrt{(2 \times V_{ACMIN})^2 - \frac{2 \times P_o \times \left(\frac{1}{2 \times f_L} - t_C \right)}{\eta \times C_{IN}}}$$

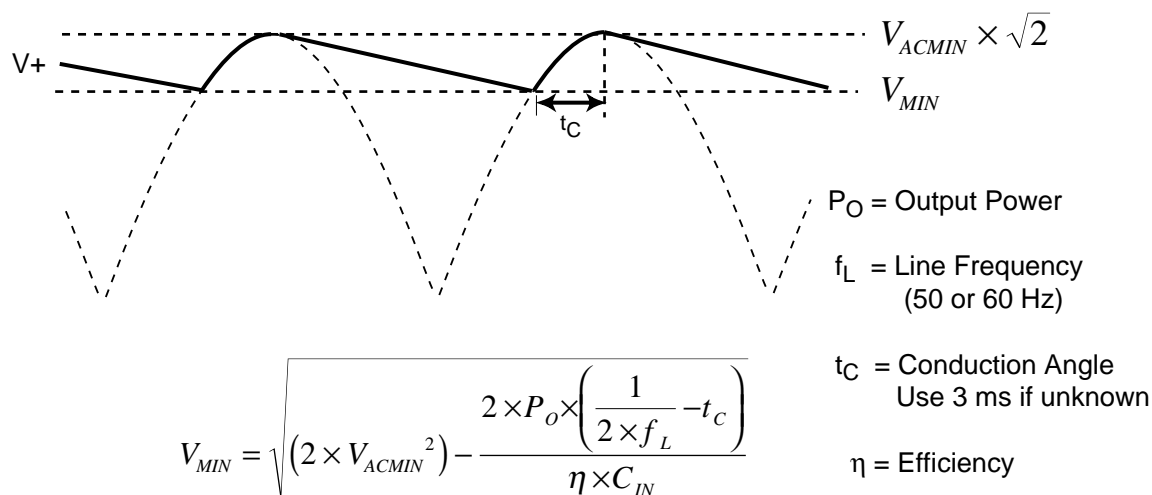
where units are volts, watts, Hz, seconds and farads

- Calculate maximum DC input voltage V_{MAX} :

$$V_{MAX} = \sqrt{2} \times V_{ACMAX}$$

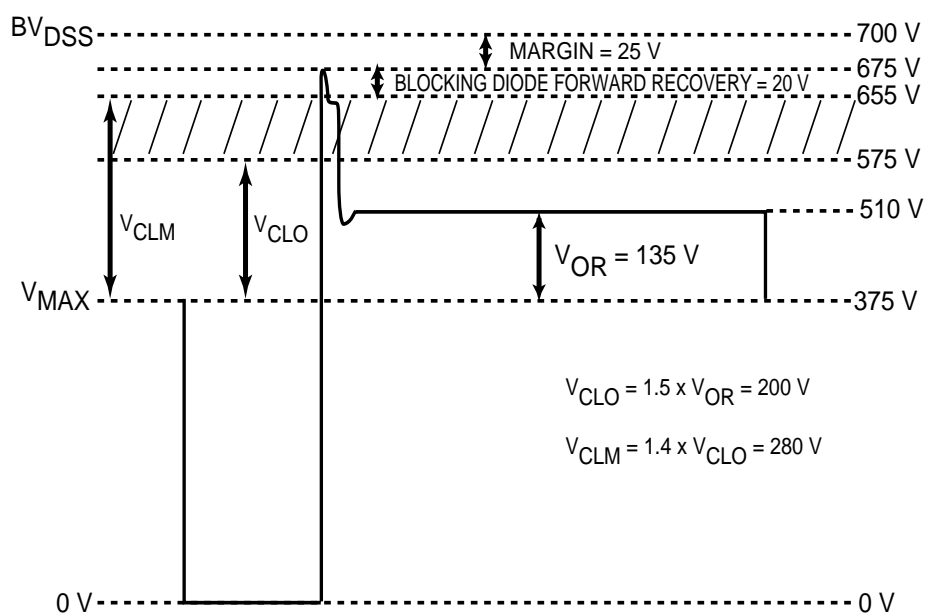
Step 4. Determine reflected output voltage V_{OR} and clamp Zener voltage V_{CLO} based on input voltage (Figure 6)

- Set reflected output voltage, $V_{OR} = 135\text{ V}$.
- Use 200 V clamp Zener, $V_{CLO} = 200\text{ V}$.
- RCD (Resistor/Capacitor/Diode) clamp may be used with *TOPSwitch-FX* for increased V_{OR} and wider D_{MAX} when and only when current limit is set externally with current limit reduction as a function of line voltage. Compared to Zener clamp, designs using RCD clamp usually have slightly lower efficiency at light load. In addition, great care must be taken in RCD clamp design. Because of its inherent variation in clamp voltage over load range, if not designed properly, RCD clamp may fail to protect *TOPSwitch-FX*, especially under startup or output overload conditions.



PI-2585-012500

Figure 5. Input Voltage Waveform.



Universal/230 VAC Input
 Use $V_{OR} = 135 \text{ V}$ and 200 V Zener Clamp

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Figure 6. Reflected Voltage V_{OR} and Clamp Zener Voltage V_{CLO}

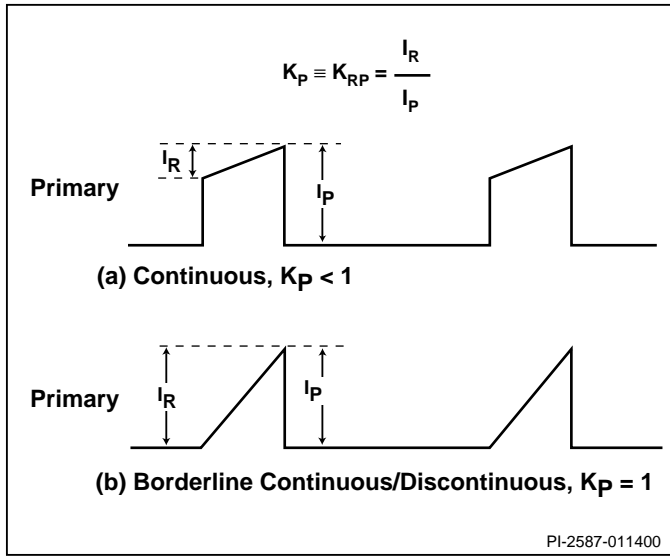


Figure 7. Continuous Mode Current Waveform, $K_p \leq 1$.

Step 5. Set primary current waveform parameter K_p for desired mode of operation and current waveform: $K_p \equiv K_{RP}$ for $K_p \leq 1.0$ and $K_p \equiv K_{DP}$ for $K_p \geq 1.0$ (Figures 7 & 8)

- For $K_p \leq 1.0$, $K_p \equiv K_{RP}$, continuous mode (see Figure 7)

$K_p \equiv K_{RP} = \frac{I_R}{I_p}$ where I_R is primary ripple current and I_p is primary peak current.

- For $K_p \geq 1.0$, $K_p \equiv K_{DP}$, discontinuous mode (see Figure 8)

$$K_p \equiv K_{DP} = \frac{V_{OR} \times (1 - D_{MAX})}{(V_{MIN} - V_{DS}) \times D_{MAX}}$$

- For continuous mode design, set $K_p = 0.4$ for universal input
0.6 for 230 VAC or 115 VAC with doubler.
- For discontinuous mode design, set $K_p = 1.0$.
- K_p must be kept within the range specified in Table 4.

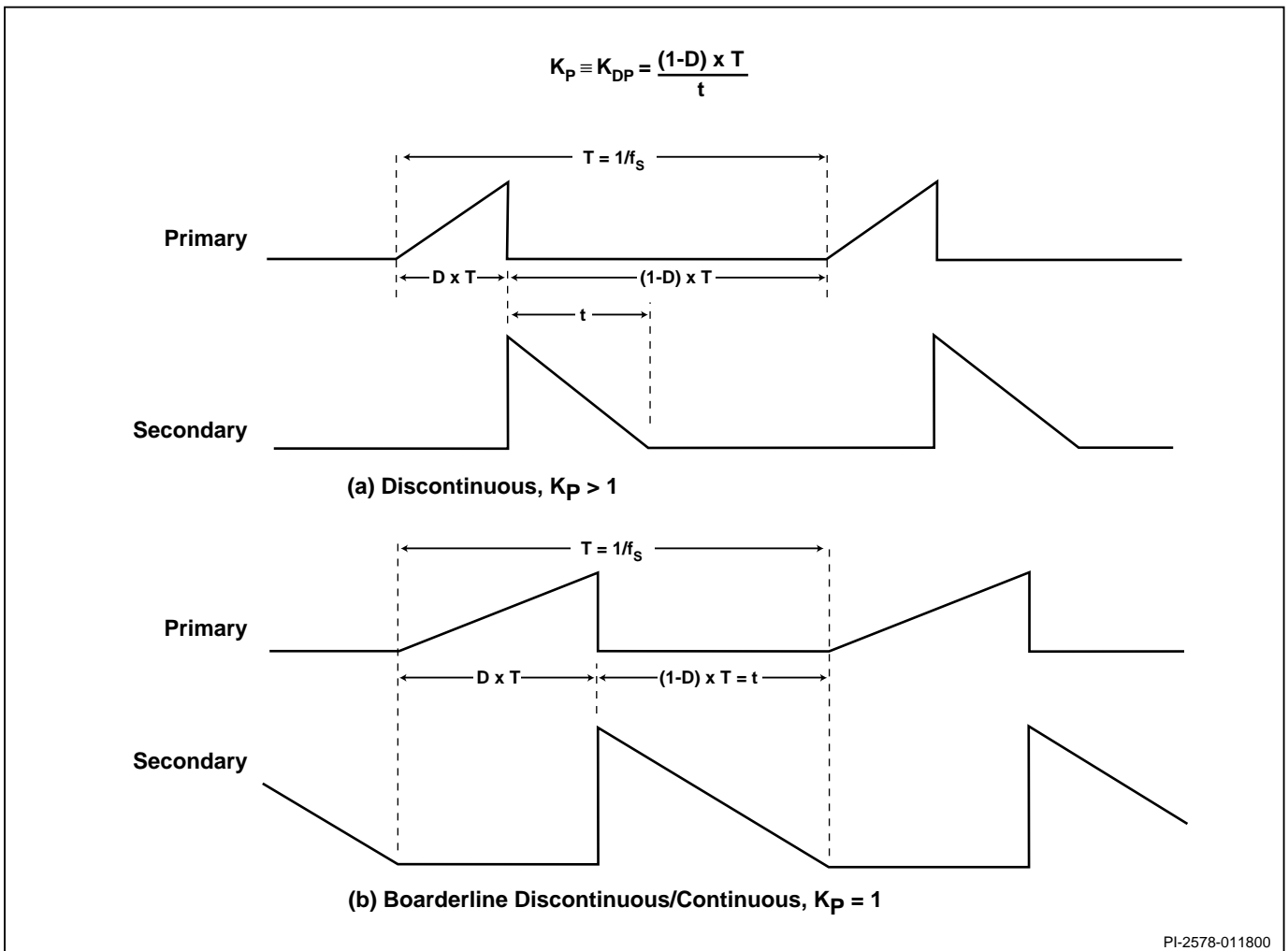


Figure 8. Discontinuous Mode Current Waveform, $K_p \geq 1$.

Input (VAC)	K_p	
	Continuous Mode	Discontinuous Mode
Universal	0.4~1.0	≥ 1.0
230	0.6~1.0	≥ 1.0

Table 4.

Step 6. Determine D_{MAX} based on V_{MIN} and V_{OR}

- Continuous mode

$$D_{MAX} = \frac{V_{OR}}{(V_{MIN} - V_{DS}) + V_{OR}}$$

- Discontinuous mode

$$D_{MAX} = \frac{V_{OR}}{K_p \times (V_{MIN} - V_{DS}) + V_{OR}}$$

- Set *TOPSwitch-FX* Drain to Source voltage, $V_{DS} = 10$ V.

Step 7. Calculate primary peak current I_p

- Continuous mode ($K_p \leq 1.0$)

$$I_p = \frac{I_{AVG}}{\left(1 - \frac{K_p}{2}\right) \times D_{MAX}}$$

- Discontinuous mode ($K_p \geq 1.0$)

$$I_p = \frac{2 \times I_{AVG}}{D_{MAX}}$$

- Input average current $I_{AVG} = \frac{P_o}{\eta \times V_{MIN}}$

Step 8. Calculate primary RMS current I_{RMS}

- Continuous mode

$$I_{RMS} = I_p \times \sqrt{D_{MAX} \times \left(\frac{K_p^2}{3} - K_p + 1\right)}$$

- Discontinuous mode

$$I_{RMS} = \sqrt{D_{MAX} \times \frac{I_p^2}{3}}$$

Step 9. Choose *TOPSwitch-FX* based on AC input voltage, P_o and η using AN-26 selection curves

- Choose the smallest *TOPSwitch-FX* using *TOPSwitch-FX* Selection Curves in AN-26.
- Identify appropriate selection curves according to AC input voltage.
- Continuous mode: Use selection curves as is.
- Discontinuous mode: Use selection curves with the output power derated by 33%. This effectively makes a 10 W discontinuous design equivalent to a 15 W continuous design in *TOPSwitch-FX* selection.
- Switching Frequency f_s : For DIP and SMP packages, set $f_s = 130$ kHz. For TO-220 package, choose between 65 kHz and 130 kHz.

Step 10. Set I_{LIMIT} reduction factor K_I for External I_{LIMIT}

- $K_I = \frac{\text{external } I_{LIMIT}}{\text{default } I_{LIMIT}}$ where $0.4 \leq K_I \leq 1.0$

- K_I is set by the value of the resistor connected between M pin and SOURCE pin (Refer to *TOPSwitch-FX* data sheet).
- For applications demanding very high efficiency, a *TOPSwitch-FX* bigger than necessary may be used by lowering I_{LIMIT} externally to take advantage of the lower $R_{DS(ON)}$.
- If no special requirement, set $K_I = 1.0$.
- Calculate $I_{LIMIT}(\text{min})$ and $I_{LIMIT}(\text{max})$

$$I_{LIMIT}(\text{min}) = \text{default } I_{LIMIT}(\text{min}) \times K_I$$

$$I_{LIMIT}(\text{max}) = \text{default } I_{LIMIT}(\text{max}) \times K_I$$

Step 11. Validate *TOPSwitch-FX* selection by checking I_p against $I_{LIMIT}(\text{min})$

- For $K_I = 1.0$, check $I_p \leq 0.96 \times I_{LIMIT}(\text{min})$.
- For $K_I < 1.0$, check $I_p \leq 0.94 \times I_{LIMIT}(\text{min})$.
- Choose larger *TOPSwitch-FX* if necessary.

Step 12. Calculate primary inductance L_p

- Continuous mode

$$L_p = \frac{10^6 \times P_o}{I_p^2 \times K_p \times \left(1 - \frac{K_p}{2}\right) \times f_s(\text{min})} \times \frac{Z \times (1 - \eta) + \eta}{\eta}$$

where units are μH , watts, amps and Hz

- Discontinuous mode.

$$L_p = \frac{10^6 \times P_o}{I_p^2 \times \frac{1}{2} \times f_s (\text{min})} \times \frac{Z \times (1 - \eta) + \eta}{\eta}$$

where units are μH , watts, amps and Hz

- Z is loss allocation factor and η is efficiency from Step 1.

Step 13. Choose core and bobbin based on f_s and P_o using Table 5 and determine A_e , L_e , A_L and BW from core and bobbin catalog

- Core effective cross sectional area, A_e : in cm^2 .
- Core effective path length, L_e : in cm.
- Core ungapped effective inductance, A_L : in nH/turn^2 .
- Bobbin width, BW: in mm.
- Choose core and bobbin based on f_s , P_o and construction type.

Output Power	65 kHz		130 kHz	
	Triple Insulated Wire	Margin Wound	Triple Insulated Wire	Margin Wound
0-10 W	EFD15 EF16 EE16 EE22 EFD20 EE19	EEL16 EF20 EEL19	EFD15 EF16 EE16	EEL16
10-20 W	EF20 EI25 E24/25 EI30	EFD25 EF25 EFD30 EF20	EE22 EFD20 EE19	EF20 EEL19
20-30 W	EF25 EI28	EER28 EF30	EI25 E24/25	EFD25 EF25
30-50 W	EI30 EF30 EER28 ETD29 EER28L	ETD29 EER28L ETD34	EF25 EI28	EFD30 EI30 EER28 EF30
50-70 W	EI35 ETD34	EI40 EER35 EER28	EI30 EF30	ETD29 EER28L
70-100 W	EI40 EER35	ETD39 EER40 EI35 ETD34 EI40 EER35	ETD29 EER28L EER35 ETD39 EER40	ETD34 EI40

Table 5.

Step 14. Set value for number of primary layers L and number of secondary turns N_s (may need iteration)

- Starting with $L = 2$ (Keep $1.0 \leq L \leq 2.0$ through out iteration).
- Starting with $N_s = 0.6$ turn/volt.
- Both L and N_s may need iteration.

Step 15. Calculate number of primary turns N_p and number of bias turns N_b

- Diode forward voltages: 1.0 V for fast P/N diode, 0.7 V for ultra fast P/N diode and 0.5 V for Schottky diode.
- Set output rectifier forward voltage, V_D .
- Set bias rectifier forward voltage, V_{DB} .
- Calculate number of primary turns.

$$N_p = N_s \times \frac{V_{OR}}{V_o + V_D}$$

- Calculate number of bias turns N_b .

$$N_b = N_s \times \frac{V_B + V_{DB}}{V_o + V_D}$$

Step 16. Determine primary winding wire parameters OD, DIA, AWG

- Primary wire outside diameter in mm.

$$OD = \frac{L \times (BW - 2 \times M)}{N_p}$$

where L is number of primary layers,
BW is bobbin width in mm,
M is safety margin in mm.

- Determine primary wire bare conductor diameter DIA and primary wire gauge AWG.

Step 17 to Step 22. Check B_M , CMA and L_g . Iterate if necessary by changing L, N_s or core/bobbin until within specified range

- Set safety margin, M. Use 3 mm (118 mils) for margin wound and zero for triple insulated secondary.
- Maximum flux density: $3000 \geq B_M \geq 2000$; in gauss.

$$B_M = \frac{100 \times I_p \times L_p}{N_p \times A_e}$$

where units are gauss, amps, μH and cm^2

- Gap length in mm: $L_g \geq 0.1$

$$L_g = 40 \times \pi \times A_e \times \left(\frac{N_p^2}{1000 \times L_p} - \frac{1}{A_L} \right)$$

where L_g in mm, A_e in cm^2 , A_L in nH/turn^2 and L_p in μH

- Primary winding current capacity in circular mils per amp:
 $500 \geq \text{CMA} \geq 200$

$$\text{CMA} = \frac{1.27 \times \text{DIA}^2 \times \frac{\pi}{4}}{I_{\text{RMS}}} \times \left(\frac{1000}{25.4} \right)^2$$

where DIA is the bare conductor diameter in mm

- Iterate by changing L , N_s , core/bobbin according to Table 6.

		B_M	L_g	CMA
L	↑	-	-	↑
N_s	↑	↓	↑	↓
core size	↑	↓	↑	↑

Table 6.

Step 23. Check $B_p \leq 4200$. If necessary, reduce current limit by lowering I_{LIMIT} reduction factor K_i

- $B_p = \frac{I_{\text{LIMIT}}(\text{max})}{I_p} \times B_M$
- Check $B_p \leq 4200$ gauss to avoid transformer saturation at startup and output over load.
- Decrease K_i if necessary until $B_p \leq 4200$.

Step 24. Calculate secondary peak current I_{SP}

$$I_{\text{SP}} = I_p \times \frac{N_p}{N_s}$$

Step 25. Calculate secondary RMS current I_{SRMS}

- Continuous mode

$$I_{\text{SRMS}} = I_{\text{SP}} \times \sqrt{(1 - D_{\text{MAX}}) \times \left(\frac{K_p^2}{3} - K_p + 1 \right)}$$

- Discontinuous mode

$$I_{\text{SRMS}} = I_{\text{SP}} \times \sqrt{\frac{1 - D_{\text{MAX}}}{3 \times K_p}}$$

Step 26. Determine secondary winding wire parameters OD_s , DIA_s , AWG_s

- Secondary wire outside diameter in mm

$$\text{OD}_s = \frac{BW - (2 \times M)}{N_s}$$

- Secondary wire bare conductor diameter in mm

$$\text{DIA}_s = \sqrt{\frac{4 \times \text{CMA}_s \times I_{\text{SRMS}}}{1.27 \times \pi}} \times \frac{25.4}{1000}$$

where CMA_s is secondary winding current capacity in circular mils per amp. Minimum wire diameter is calculated by using a CMA_s of 200.

- Determine secondary winding wire gauge AWG_s based on DIA_s . If the bare conductor diameter of the wire is larger than that of the 27 AWG for 130 kHz or 25 AWG for 65 kHz, a parallel winding using multiple strands of thinner wire should be used to minimize skin effect.

Step 27. Determine output capacitor ripple current I_{RIPPLE}

- Output capacitor ripple current

$$I_{\text{RIPPLE}} = \sqrt{I_{\text{SRMS}}^2 - I_o^2}$$

where I_o is the output DC current

Step 28. Determine maximum peak inverse voltages PIV_s , PIV_b for secondary and bias windings

- Secondary winding maximum peak inverse voltage.

$$\text{PIV}_s = V_o + (V_{\text{MAX}} \times \frac{N_s}{N_p})$$

- Bias winding maximum peak inverse voltage.

$$\text{PIV}_b = V_b + (V_{\text{MAX}} \times \frac{N_b}{N_p})$$

Step 29. Select clamp Zener and blocking diode for primary clamping based on input voltage and V_{CLO}

- Use 200 V Zener such as Motorola P6KE200 for the clamp.
- Use ultra fast diode such as General Instruments UF4005 for the blocking diode.

Step 30. Select output rectifier

- $V_R \geq 1.25 \times \text{PIV}_s$; where PIV_s is from Step 28 and V_R is the rated reverse voltage of the rectifier diode.
- $I_d \geq 3 \times I_o$; where I_d is the diode rated DC current and $I_o = P_o / V_o$.



Step 31. Select output capacitor

- Ripple current specification at 105 °C, 100 kHz: Must be equal to or larger than I_{RIPPLE} , where I_{RIPPLE} is from Step 27.
- ESR specification: Use low ESR, electrolytic capacitor. Output switching ripple voltage is $I_{\text{SP}} \times \text{ESR}$, where I_{SP} is from Step 24.

Step 32. Select output post filter L, C

- Inductor L: 2.2 to 4.7 uH. Use bead for low current ($\leq 1\text{A}$) output and standard off-the-shelf choke for higher current output. Increase choke current rating or wire size if necessary to avoid significant DC voltage drop.
- Capacitor C: 120 uF, 35 V, low ESR, electrolytic capacitor.

Step 33. Select bias rectifier

- $V_R \geq 1.25 \times \text{PIV}_B$; where PIV_B is from Step 28 and V_R is the rated reverse voltage of the rectifier diode.

Step 34. Select bias capacitor

- Use 0.1 uF, 50 V, ceramic.

Step 35. Select CONTROL pin capacitor and series resistor

- CONTROL pin capacitor: 47 uF, 10 V, low cost electrolytic (Do not use low ESR capacitor).
- Series resistor: 6.2 ohm, 1/4 W (Not needed if $K_p \geq 1$, i.e. discontinuous mode).

Step 36. Select feedback circuit components according to applicable reference circuits shown in Figures 3 and 4

- Applicable reference circuit: Identified in Step 2.

Step 37. Select input bridge rectifier

- $V_R \geq 1.25 \times \sqrt{2} \times V_{\text{ACMAX}}$; where V_{ACMAX} is from Step 1.
- $I_{\text{ACRMS}} \geq 2 \times I_D$; where I_D is the bridge rectifier rated RMS current and I_{ACRMS} is the input RMS current.

Note: $I_{\text{ACRMS}} = \frac{P_o}{\eta \times V_{\text{ACMIN}} \times \text{PF}}$; where V_{ACMIN} is from

Step 1 and PF is the power factor of the power supply which is typically between 0.5 and 0.7. If no better reference information available, use $\text{PF} = 0.5$.

Appendix A

Multiple Output Flyback Power Supply Design

The only difference between a multiple output flyback power supply and a single output flyback power supply of the same total output power is in the secondary side design. Instead of delivering all power to one output as in single output case, a multiple output flyback distributes its output power among several outputs. Therefore, the design procedure for the primary side stays the same while that for the secondary side demands further considerations.

Design with lumped output power

One simple way of doing multiple output flyback design is described in detail in AN-22, “Designing Multiple Output Flyback Power Supplies with *TOPSwitch*”. The design method starts with a single output equivalent by lumping output power of all outputs to one main output. Secondary peak current I_{sp} and RMS current I_{SRMS} are derived. Output average current I_o corresponding to the lumped power is also calculated.

Assumption for simplification

The current waveforms in the individual output windings are determined by the impedance in each circuit, which is a function of leakage inductance, rectifier characteristics and capacitor value. Although this current waveform may not be exactly the same from output to output, it is reasonable to assume that, to the first order, all output currents have the same shape as for the single output equivalent of lumped power.

Output RMS current vs. average current

The output average current is always equal to the DC load current, while the RMS value is determined by current wave shape. Since the current wave shapes are assumed to be the same for all outputs, their ratio of RMS to average currents must also be identical. Therefore, with the output average current known, the RMS current for each output winding can be calculated as

$$I_{SRMS}(n) = I_o(n) \times \frac{I_{SRMS}}{I_o}$$

where $I_{SRMS}(n)$ and $I_o(n)$ are the secondary RMS current and output average current of the n^{th} output and I_{SRMS} and I_o are the secondary RMS current and output average current for the lumped single output equivalent design.

Customization of secondary designs for each output

The turns for each secondary winding are calculated based on the respective output voltage $V_o(n)$:

$$N_s(n) = N_s \times \frac{V_o(n) + V_D(n)}{V_o + V_D}$$

Output rectifier maximum inverse voltage is

$$PIV_s(n) = V_{MAX} \times \frac{N_s(n)}{N_p} + V_o(n)$$

With output RMS current $I_{SRMS}(n)$, secondary number of turns $N_s(n)$ and output rectifier maximum inverse voltage $PIV_s(n)$ known, the secondary side design for each output can now be carried out exactly the same way as for the single output design.

Secondary winding wire size

TOPSwitch-FX design spreadsheet assumes a CMA of 200 when calculating secondary winding wire diameters. This gives the minimum wire sizes required for the RMS currents of each output using separate windings. Designers may wish to use larger size wire for better thermal performance. Other considerations such as skin effect and bobbin coverage may suggest the use of a smaller wire by using multiple strands wound in parallel. In addition, practical considerations in transformer manufacturing may also dictate the wire size.

Appendix B

AN-25 and AN-16 Comparison Table

Design Methodologies	AN-16	AN-25
Applicable products	<i>TOPSwitch</i> <i>TOPSwitch-II</i>	<i>TOPSwitch-FX</i>
Product selection basis	$I_{LIMIT}(min) \geq I_p$	AN-26 selection curves
Product selection validation	power dissipation	$I_{LIMIT}(min) \geq I_p$
Mode of operation	continuous	continuous and discontinuous
Switching frequency f_s	100 kHz	130 kHz or 65 kHz
Maximum duty cycle D_{MAX}	64%	75%
I_{LIMIT} reduction factor K_I	N/A	$1.0 \geq K_I \geq 0.4$
Core selection table	100 kHz	130 kHz & 65 kHz
Flux density limitation	design for $B_M \leq 3000$ & $B_p \leq 4200$	design for $B_M \leq 3000$ & adjust I_{LIMIT} to meet $B_p \leq 4200$
Minimum gap size	$L_g \geq 0.05$ mm	$L_g \geq 0.1$ mm
Secondary winding wire size	calculated based on primary CMA	calculated based on CMA of 200 for minimum wire size
Secondary side design for multiple outputs	N/A	yes

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