

Using the Versa-Pac as a Flyback Transformer

The Versa-Pac range of transformers is one of the many products manufactured under the Cooper Coiltronics® brand of power magnetics from Cooper Bussmann. Versa-Pac is available in five sizes and is suitable for flyback circuits with power levels up to 35W and a maximum switching frequencies of 500kHz. The VP series was designed, primarily, for low voltage applications typically 3.3V, 5V and 12V. With the addition of the VPH products to the range the Versa-Pac can now be used for 24V, 48V and, at higher frequencies, even 120V applications. Each transformer has six identical windings that can be configured in series and parallel to produce the required transformer design, the isolation between these windings is 500Vdc. Full product data is available on our website: www.cooperbussmann.com

Design Procedure

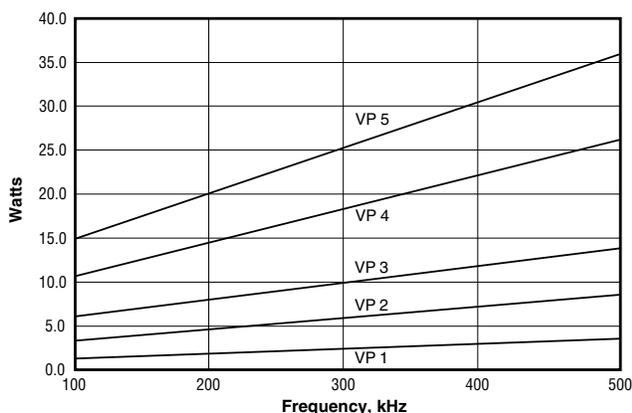
In order to design a flyback transformer using the Versa-Pac the following information is required: nominal, minimum and maximum input voltages ($V_{in(nom)}$, $V_{in(min)}$ & $V_{in(max)}$), output voltage (V_o), output current (I_o) and switching frequency (F_s).

For the purpose of our example let's take the following values:

$V_o = 5V$, $I_o = 1A$, $V_{in(min)} = 40V$, $V_{in(nom)} = 48V$, $V_{in(max)} = 56V$ and $F_s = 200kHz$

Using the graph for Unipolar (Flyback) Power v Frequency from the data sheet select the required Versa-Pac size by reading off your required output power and operating frequency.

Unipolar (Flyback) Power vs Frequency



At 200kHz and 5W this gives a VP3 size.

If the output power requirement can't be met then the Versa-Pac is unable to offer a flyback transformer solution. It may be worth considering a Push-Pull topology, as this will give better transformer utilization allowing high output power levels for the same transformer size.

Calculate the turns ratio for a duty cycle (D) of 0.5 using the equation;

$$V_o/V_{in(nom)} = N_{sec}/N_{pri} \times (D/(1-D)) \quad (1)$$

Where N_{sec} is the number of secondary windings and N_{pri} is the number of primary windings, N_{pri}/N_{sec} is the turns ratio which must be rounded to the nearest achievable value (i.e. 0.5, 0.667, 1, 1.5, 2, 3 etc).

$$5/48 = N_{sec}/N_{pri} \times 0.5/(1-0.5)$$

$$N_{pri}/N_{sec} = (48 \times 1)/5 = 9.6$$

Rounding down, $N_{pri}/N_{sec} = 5$ (max ratio)

$V_{in(nom)}$ and 0.5 duty cycle are used only as a starting point, it is possible that using $V_{in(min)}$ with lower or high duty cycles you may achieve a more suitable turns ratio.

Calculate the actual duty cycle for $V_{in(max)}$ using equation 1 and the calculated turns ratio rounded up or down to the nearest achievable value.

$$5/56 = (1/5) \times D/(1-D)$$

$$0.446 - 0.446D = D$$

$$D = 0.446/1.446 = 0.309$$

Calculate the primary volt-seconds product using the following equation:

$$\text{Primary } V_s = D \times T_s \times V_{in(max)}$$

$$\text{Where } T_s = 1/F_s \quad (2)$$

This value should be less than the rated primary Volt- μ sec, if the primary uses one winding the rated Volt- μ sec is the same as Volt- μ sec(Base). If the primary is two windings in series then the rating is then 2 x Volt- μ sec(Base) and for 3 series windings 3 x Volt- μ sec(Base) etc. If the Volt- μ sec rating can not be achieved using the selected Versa-Pac size then you will need to select a larger size or increase the switching frequency.

$$\text{Primary } V_s = 0.309 \times 1/200 \times 10^3 \times 56 = 86.52 \text{V}\mu\text{sec}$$

The VP3 has a Volt- $\mu\text{sec}(\text{Base})$ of $27.7 \text{V}\mu\text{sec}$, multiplying this by 5 gives a rating of $138.5 \text{V}\mu\text{sec}$. So the VP3 size meets the volt-seconds requirements.

If the required volt-seconds rating can't be achieved you can reduce the required rating by increasing the switching frequency. Alternatively you can recalculate the turns ratio using $V_{in(\min)}$ as this may increase the number of series primary windings.

Starting with the highest inductance value for the selected VP size, calculate the output current at which current conduction is at the boundary between continuous and discontinuous.

$$I_o(\text{boundary}) = T_s \times V_o \times (1-D(\max))^2 / (2 \times L_s) \quad (3)$$

Where L_s is the secondary inductance and D_{\max} is the duty cycle at $V_{in(\min)}$.

Selecting the VP3-0780:

$$D(\max) = 0.625 / 1.625 = 0.385$$

$$L_s = 63.2 \mu\text{H}$$

$$I_o(\text{boundary}) = 5 \times 10^{-6} \times 5 \times (1-0.385)^2 / (2 \times 63.2 \times 10^{-6}) = 0.075 \text{A}$$

As the boundary current is less than the maximum output current the transformer is operating in continuous mode.

Calculating the peak and rms primary currents we can determine if the selected Versa-Pac meets the specified requirements.

For Continuous mode conduction:

Peak Primary Current:

$$I_{pri(\text{peak})} = N_{sec}/N_{pri} \times (1/(1-D(\max))) \times I_o + (V_{in(\min)} \times T_s \times D(\max)) / 2 \times L_{pri} \quad (4)$$

Where L_{pri} is the primary inductance.

In order to calculate the rms primary current you first need to calculate the primary current delta and average peak.

$$\Delta I_{pri} = (V_{in(\min)} \times D(\max) \times T_s) / L_{pri} \quad (5)$$

$$I_{pri(\text{avg-pk})} = (I_{pri(\text{peak})} + (I_{pri(\text{peak})} - \Delta I_{pri})) / 2 \quad (6)$$

$$I_{pri(\text{rms})} = (D(\max) \times (I_{pri(\text{avg-pk})})^2)^{0.5} \quad (7)$$

$$I_{pri(\text{peak})} = 0.2 \times 1 / (1-0.385) + (40 \times 5 \times 10^{-6} \times 0.385) / (2 \times 5^2 \times 63.2 \times 10^{-6}) = 0.35 \text{A}$$

Peak current is higher than the I_{sat} rating for the VP3-0780, which is equal to $6/5 \times I_{sat(\text{base})}$. So moving up to the VP3-0138, we once again find that conduction is mainly continuous mode and so peak primary current:

$$I_{pri(\text{peak})} = 0.2 \times 1 / (1-0.385) + (40 \times 5 \times 10^{-6} \times 0.385) / (2 \times 5^2 \times 11.2 \times 10^{-6}) = 0.462 \text{A}$$

$$\Delta I_{pri} = (40 \times 0.385 \times 5 \times 10^{-6}) / (5^2 \times 11.2 \times 10^{-6}) = 0.275 \text{A}$$

$$I_{pri(\text{avg-pk})} = (0.462 + (0.462 - 0.275)) / 2 = 0.325 \text{A}$$

$$I_{pri(\text{rms})} = (0.385 \times 0.325^2)^{0.5} = 0.202 \text{A}$$

For the VP3-0138 the I_{rms} rating is 1.47A and the $I_{sat(\text{base})}$ is 0.59A both of which are sufficiently high to meet the primary current requirements.

For discontinuous mode conduction:

First we need to calculate the average primary current:

$$I_{pri(\text{avg})} = (V_o \times I_o) / (V_{in(\min)} \times \text{Efficiency}) \quad (8)$$

$$I_{pri(\text{peak})} = (2 \times I_{pri(\text{avg})}) / D(\max) \quad (9)$$

$$I_{pri(\text{rms})} = ((I_{pri(\text{peak})}^2 \times D(\max)) / 3)^{0.5} \quad (10)$$

You can now check these results against the I_{sat} and I_{rms} ratings, bearing in mind that the actual I_{sat} rating:

$$= (6 \times I_{sat(\text{base})}) / \text{Number of windings driven} \quad (11)$$

The number of windings driven for a flyback transformer is the number of series windings used to make up the primary. So for two series primary windings the rated I_{sat} is actually 3 times $I_{sat(\text{base})}$.

Finally, calculate the maximum rms secondary current,

For continuous mode:

$$I_{sec(\text{rms})} = ((1-D(\max)) \times (I_o / (1-D(\max))))^{0.5} \quad (12)$$

For discontinuous mode:

$$I_{sec(rms)} = ((1-D(max))/3 \times (I_{sec(peak)})^2)^{0.5} \quad (13)$$

Where, referring to equation 9:

$$I_{sec(peak)} = I_{pri(peak)} \times N_{pri}/N_{sec} \quad (14)$$

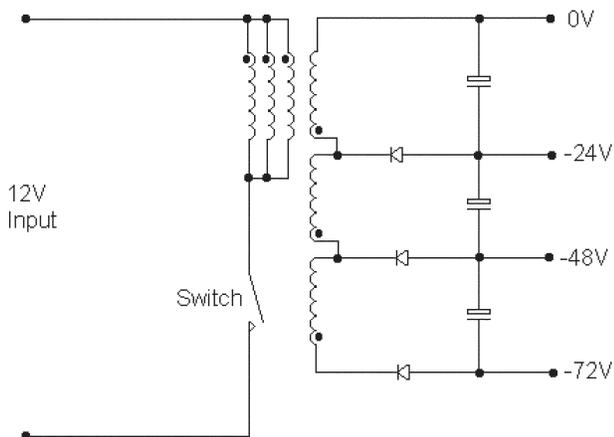
$$I_{sec(rms)} = ((1-0.385) \times (1/(1-0.385))^2)^{0.5} = 1.275A$$

The VP3-0138 has an $I_{rms(base)}$ rating of 1.47A

Examples:

SLIC Power Supply

By connecting three secondary windings in series much higher output voltages can be achieved, in this example each secondary winding has a -24V output therefore providing the -48V and -72V supplies required in SLIC applications.



Split +/-12V Supply

Using a secondary center tap allows the winding to be configured for positive and negative outputs. Extra windings are paralleled with the primary and secondary windings in order to handle more current and reduce losses.

