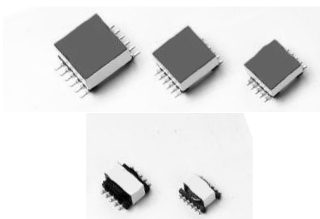
Using the Versa-Pac as a flyback transformer



Overview

The Versa-Pac range of transformers is one of the many products offered from Eaton. Versa-Pac is available in five sizes and is suitable for flyback circuits with power levels up to 35 W and a maximum switching frequencies of 500 kHz.

The VP series was designed, primarily, for low voltage applications typically 3.3 V, 5 V and 12 V. With the addition of the VPH products to the range the Versa-Pac can now be used for 24 V, 48 V and, at higher frequencies, even 120 V 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 500 Vdc. Full product data is available on our website: www.eaton.com/electronics

Design procedure

In order to design a flyback transformer using the Versa-Pac the following information is required:

- nominal,minimum and maximum input voltages (Vin(nom), Vin(min) & Vin(max))
- output voltage (Vo)
- output current (Io)
- switching frequency (Fs).

For the purpose of our example let's take the following values:
Vo = 5 V, Io = 1 A, Vin(min) = 40 V, Vin(nom)=48 V , Vin(max) = 56 V and Fs = 200 kHz.

Using the information in Figure 1 for Unipolar (Flyback) Power vs. Frequency from the data sheet select the required Versa-Pac size by reading off your required output power and operating frequency. At 200 kHz and 5 W this gives a VP3 size.

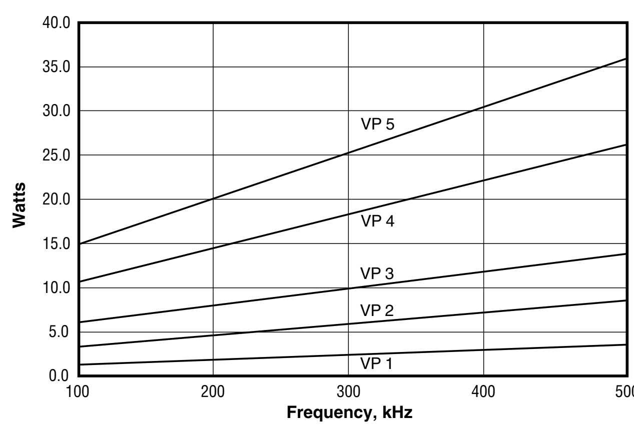


Figure 1. Unipolar (Flyback) Power vs Frequency graph

Design procedure

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;

Vo/Vin(nom) = Nsec/Npri x (D/1-D) (1)

Where Nsec is the number of secondary windings and Npri is the number of primary windings, Npri/Nsec 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 = Nsec/Npri x 0.5/(1-0.5)
Npri/Nsec = (48x1)/5 = 9.6
Rounding down, Npri/Nsec = 5 (max ratio)

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

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

5/56 = (1/5) x 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:

Primary Vs = D x Ts x Vin(max) (2)
Where Ts = 1/Fs

This value should be less than the rated primary Volt-μsec, if the primary uses one winding the rated Volt-μsec is the same as Volt-μsec(Base). If the primary is two windings in series then the rating is then 2 x Volt-μsec(Base) and for 3 series windings 3 x Volt-μsec(Base) etc. If the Volt-μsec 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.

Primary Vs = 0.309 x 1/200x10^3 x 56 = 86.52 Vμsec

The VP3 has a Volt-μsec(Base) of 27.7 Vμsec, multiplying this by 5 gives a rating of 138.5 Vμsec. 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 Vin(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.

Io (boundary) = Ts x Vo x (1-D(max))^2/(2 x Ls) (3)

Where Ls is the secondary inductance and Dmax is the duty cycle at Vin(min).

Selecting the VP3-0780:
D(max) = 0.625/1.625 = 0.385
Ls = 63.2 μH
Io (boundary) = 5x10^{-6} x 5 x (1-0.385)^2/(2 x 63.2x10^{-6}) = 0.075A

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:

Ipri(peak) = Nsec/Npri x (1/1-D(max)) x Io + (Vin(min) x Ts x D(max))/2 x Lpri (4)
Where Lpri is the primary inductance.

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

dIpri = (Vin(min) x D(max) x Ts)/Lpri (5)

Ipri(avg-pk) = (Ipri(peak) + (Ipri(peak) - ΔIpri))/2 (6)

Ipri(rms) = (D(max) x (Ipri(avg-pk))^2)$^{0.5}$ (7)

Ipri(peak) = 0.2 x 1/(1-0.385) + (40 x 5x10^{-6} x 0.385)/(2 x 5^2 x 63.2x10^{-6}) = 0.35 A

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

Ipri(peak) = 0.2 x 1/(1-0.385) + (40 x 5x10^{-6} x 0.385)/(2 x 5^2 x 11.2x10^{-6}) = 0.462 A
dIpri = (40 x 0.385 x 5x10^{-6})/(5^2 x 11.2x10^{-6}) = 0.275 A
Ipri(avg-pk) = (0.462 + (0.462 – 0.275))/2 = 0.325 A
Ipri(rms) = (0.385 x 0.325^2)$^{0.5}$ = 0.202 A

For the VP3-0138 the Irms rating is 1.47 A and the Isat(base) is 0.59 A 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:

Ipri(avg)= (Vo x Io)/(Vin(min) x Efficiency) (8)
Ipri(peak) = (2 x Ipri(avg))/D(max) (9)
Ipri(rms) = ((Ipri(peak)^2 x D(max))/3)$^{0.5}$ (10)

You can now check these results against the Isat and Irms ratings, bearing in mine that the actual Isat rating:

= (6 x Isat(base))/Number of windings driven (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 Isat is actually 3 times Isat(base).

Finally, calculate the maximum rms secondary current,

For continuous mode:
Isec(rms) = ((1-D(max)) x (Io/(1-D(max)))^{2})$^{0.5}$ (12)

For discontinuous mode:
Isec(rms) = ((1-D(max))/3 x (Isec(peak))^{2})$^{0.5}$ (13)

Where, referring to equation 9:

Isec(peak) = Ipri(peak) x Npri/Nsec (14)

Isec(rms) = ((1-0.385) x (1/(1-0.385))^{2})$^{0.5}$ = 1.275 A

The VP3-0138 has an Irms(base) rating of 1.47 A

Application examples

SLIC Power Supply
By connecting three secondary windings in series much higher output voltages can be achieve, in this example each secondary winding has a -24 V output therefore providing the -48 V and -72 V supplies required in SLIC applications (Figure 2).

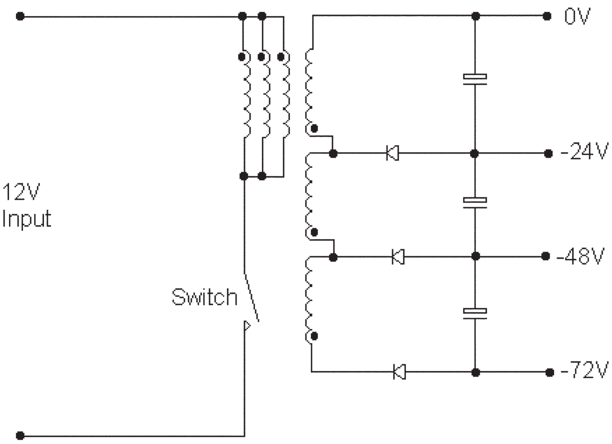


Figure 2. SLIC power supply

Split +/-12 V 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 handle more current and reduce losses (Figure 3).

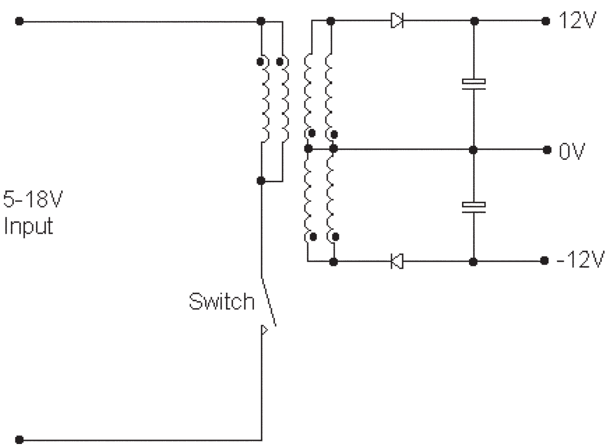


Figure 3. +/- 12 V supply

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