## **Analytical Calculations(for 100kHz)**

In this part, analytical calculations of the flyback converter are made for the ideal case. According to the research, the duty cycle of the flyback converter should be lower than 0.5 to diminish output ripple, also we made sure of the proper operation of the switch. Therefore, we have decided the turn ratio(N1/N2) as 1.43 so that the duty cycle is changing between %23-%47.

The controller operates flyback in boundary and discontinuous conduction mode. All calculations are made assuming boundary mode operation. We have taken boundary mode results as the limit values for discontinuous conduction. Therefore, continuous current mode formulas are utilized for boundary condition calculations. When Vin=24V, it operates at boundary condition and when input voltage increases it passes to the discontinuous current mode,

* Duty cycle calculation,

When ,

The maximum required inductance can be calculated as follows [1],

[1] Texas Instruments, “LM34XX how to design flyback converter with LM3481 boost ... - ti.com.” [Online]. Available: https://www.ti.com/lit/an/snva761a/snva761a.pdf. [Accessed: 09-May-2022].

Setting the magnetizing inductor current as:

where,

• KL is the fraction chosen, we have chosen KL as 2 in order to set boundary operation.

* (ideal case)

Then, maximum magnetizing inductance is determined when Vin=24V so that it operates discontinous mode when input voltage increases.

After determining Lm, we can calculate minimum duty cycle when it pass to the DCM,

Minimum duty cycle is calculated when Vin=48V,

* Calculation of maximum voltages on diode and MOSFET,

Generally in applications, rated voltage of MOSFETs are chosen as 1.5 multiplication of maximum voltage while 1.2 multiple of maximum value in diodes,

* Output capacitance calculation,

Choose,

# Magnetic Design

## **a) Core selection**

For core selection, looking at area product of the core is a good start. Assume that the fill factor should be larger or equal to 0.3. Then, the limit of area product can be calculated as follows.

* **Choose Bac,max=0.12T** which is below the saturation point of the cores we are investigating (0.3-0.47T). Also, maximum magnetic flux density is obtained when Vin=24V.

**Jrms= 4A/mm2**

* **Choose WaAc of core=0.04cm4 which satisfies the above condition,**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Effective crosssectional area Ae (mm2) | Maximum Magnetic Flux density (T) | AL-value with the air gap (nH/N^2) |
| **B66307G0500X187** | **20.1** | **0.49** | **110** |

<https://www.tdk-electronics.tdk.com/inf/80/db/fer/e_16_8_5.pdf>

**This core is chosen since it has low AL with gapp and cross-section is small compared to the others. 110nH/T2 is required to obtain the assumed magnetic flux density. 110nH/T2 can be obtained by the addition of 0.24mm air gap. This will be proved after other calculations. Also, a minimum cross-section that satisfies area product expectations is selected to make the most compact design.**

**Saturation flux density of the core is checked, and saturation value of the core is 0.49T for N87 material. Therefore, the core would not saturate.**

**tablo içeren bir resim

Açıklama otomatik olarak oluşturuldu**

* **Calculation of turn numbers,**

**Firstly find the condition that satisfy the core is not saturated,**

**Find the turn number,**

As calculated, primary turn number is larger than saturation turn number.

As it is seen from the calculations, number of turns in primary secondary windings are selected as 12 and 8 respectively.

* Calculation of peak currents,

@ Vin=24V(BCM)

@ Vin=48V(DCM)

Since it is in BCM, ripple current is equal to maximum current,

* Also, it is important to be sure expected magnetic flux density is obtained,

## b) Cable Selection

Choose,

We have decided to use 4 parallel connected 26AWG instead of one AWG copper for primary, and 6 parallel connected 26AWG cable instead of one copper cable. Since cables with a larger cross-section have a smaller maximum frequency for 100% skin depth, we have decided to multiple cables that have enough maximum frequency for 100% skin depth instead of one cable. The maximum frequency for 100% skin depths is 107kHz for 26 AWG.This selection makes AC and DC resistances the same since we operate with 100% skin depth.

* Calculation of fill factor,

## **Analytical Calculations(for70kHz)**

In this part, analytical calculations of the flyback converter are made for the ideal case. According to the research, the duty cycle of the flyback converter should be lower than 0.5 to diminish output ripple, also we made sure of the proper operation of the switch. Therefore, we have decided the turn ratio(N1/N2) as 1.43 so that the duty cycle is changing between %23-%47.

The controller operates flyback in boundary and discontinuous conduction mode. All calculations are made assuming boundary mode operation. We have taken boundary mode results as the limit values for discontinuous conduction. Therefore, continuous current mode formulas are utilized for boundary condition calculations. When Vin=24V, it operates at boundary condition and when input voltage increases it passes to the discontinuous current mode,

* Duty cycle calculation,

When ,

The maximum required inductance can be calculated as follows [1],

[1] Texas Instruments, “LM34XX how to design flyback converter with LM3481 boost ... - ti.com.” [Online]. Available: https://www.ti.com/lit/an/snva761a/snva761a.pdf. [Accessed: 09-May-2022].

Setting the magnetizing inductor current as:

where,

• KL is the fraction chosen, we have chosen KL as 2 in order to set boundary operation.

* (ideal case)

Then, maximum magnetizing inductance is determined when Vin=24V so that it operates discontinous mode when input voltage increases.

After determining Lm, we can calculate minimum duty cycle when it pass to the DCM,

Minimum duty cycle is calculated when Vin=48V,

* Calculation of maximum voltages on diode and MOSFET,

Generally in applications, rated voltage of MOSFETs are chosen as 1.5 multiplication of maximum voltage while 1.5 multiple of maximum value in diodes,

* Output capacitance calculation,

Choose,

# Magnetic Design

## **a) Core selection**

For core selection, looking at area product of the core is a good start. Assume that the fill factor should be larger or equal to 0.3. Then, the limit of area product can be calculated as follows.

* **Choose Bac,max=0.12T** which is below the saturation point of the cores we are investigating (0.3-0.47T). Also, maximum magnetic flux density is obtained when Vin=24V.

**Jrms= 4A/mm2**

* **Choose WaAc of core=0.096cm4 which satisfies the above condition,**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Effective crosssectional area Ae (mm2) | Maximum Magnetic Flux density (T) | AL-value with the air gap (nH/N^2) |
| **CF139EE2005S-AG-0.25MM** | **33.5** |  | **200** |

<https://cdn.ozdisan.com/ETicaret_Dosya/15564_9555141.PDF>

**This core is chosen since it has low AL with gapp and cross-section is small compared to the others. 200nH/T2 is required to obtain the assumed magnetic flux density. 200nH/T2 can be obtained by the addition of 0.25mm air gap. This will be proved after other calculations. Also, a minimum cross-section that satisfies area product expectations is selected to make the most compact design.**

**Bsat=0.49???**

* **Calculation of turn numbers,**

**Firstly find the condition that satisfy the core is not saturated,**

**Find the turn number,**

As calculated, primary turn number is larger than saturation turn number.

As it is seen from the calculations, number of turns in primary secondary windings are selected as 10 and 7 respectively.

* Calculation of peak currents,

@ Vin=24V(BCM)

@ Vin=48V(DCM)

Since it is in BCM, ripple current is equal to maximum current,

* Also, it is important to be sure expected magnetic flux density is obtained,

## b) Cable Selection

Choose,

We have decided to use 4 parallel connected 26AWG instead of one AWG copper for primary, and 6 parallel connected 26AWG cable instead of one copper cable. Since cables with a larger cross-section have a smaller maximum frequency for 100% skin depth, we have decided to multiple cables that have enough maximum frequency for 100% skin depth instead of one cable. The maximum frequency for 100% skin depths is 107kHz for 26 AWG.This selection makes AC and DC resistances the same since we operate with 100% skin depth.

* Calculation of fill factor,