**Simulations**

Simulation is done with LTSpice. Two-switch forward converter topology is implemented at the simulation. Simulation is done with maximum and minimum input voltages. Spikes or over-voltages are observed, and they will be considered for a component selection.

metin, ekran görüntüsü, çizgi, yazı tipi içeren bir resim

Açıklama otomatik olarak oluşturuldu

Figure X. Forward Converter Schematic with LTSpice

MBR20100CT diode and BSB014N04LX3 MOSFET is selected for a simulation. Required inductor is calculated as 100 µH in the theoretical calculations. Designed inductor’s inductance is around 139.83 µH and series resistance is calculated as 0.8 ohm. Resistance value is quite high, and it will cause high loss at the inductor. So, used wire and core can be changed. However, simulations done with these values.

Turns ratio is determined 1.5 and this value is implemented to primary and secondary winding inductance. Transformer design’s experiments and measurements give us some leakage inductance and serial resistance at primary and secondary side. They are measured as 9.81 µH and 9.8 mohm at the primary side. Then at the secondary side, leakage inductance is around 20 µH and resistance is around 21.8 mohm. These values are acceptable due to some theoretical results and turns ratio. Magnetizing inductance value at the primary side is around 130 µH and at the secondary side is around 274 µH. These values are acceptable too. So, with these values, practical system is implemented, and simulation results are observed.

**Case 1: Minimum Input Voltage**

Simulations done with 20 V input voltage. Leakage inductance, magnetizing inductance and resistance is added. According to these simulations, waveforms on diodes, mosfets, required duty cycle and load characteristics are observed.

**MOSFET WAVEFORMS**

çizgi, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, diyagram, ekran görüntüsü içeren bir resim

Açıklama otomatik olarak oluşturuldu

Figure X. M-2 Voltage and Current Waveform

çizgi, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, diyagram, sayı, numara içeren bir resim

Açıklama otomatik olarak oluşturuldu

Figure X. M-1 Voltage and Current Waveform

According to simulations, voltage and current characteristics on the MOSFET’s are very similar, peak current goes 9.5 A and peak voltage on the VDS is around 21 V. VRMS on the VDS is around 14.302 V and IRMS is around 6.072 A. According to these information, MOSFET selection will be done.

**DIODES WAVEFORMS AT PRIMARY SIDE**

çizgi, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, paralel içeren bir resim

Açıklama otomatik olarak oluşturuldu

Figure X. Voltage Waveforms of the Diodes at Primary Side

çizgi, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, diyagram, paralel içeren bir resim

Açıklama otomatik olarak oluşturuldu

Figure X. Current Waveforms of the Diodes at Primary Side

From the simulations, voltage and current characteristics of diodes at primary side is nearly same. According to waveforms, maximum current is around 9.5 A and maximum voltage when reverse biased is around 20 V. At the simulations, forward bias voltage is can be seen. So, from these results, diodes at the primary side will be selected.

**DIODES WAVEFORMS AT SECONDARY SIDE**

çizgi, ekran görüntüsü, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, yazı tipi içeren bir resim

Açıklama otomatik olarak oluşturuldu

Figure X. Current Waveforms of the Diodes at Secondary Side

çizgi, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, yazı tipi, diyagram içeren bir resim

Açıklama otomatik olarak oluşturuldu

Figure X. Voltage Waveforms of the Diodes at Secondary Side

From the voltage and current waveforms, characteristics of the diodes are observed. Very big oscillation is observed at the voltage waveforms. Current waveforms are stable and maximum current rating is around 5.3 A. When voltage waveforms are examined, spike reverse biased voltages can goes up to 80 V. Normally, it is around 30 V without oscillation. So, from these observations, diode will be selected.

**INDUCTOR WAVEFORM AT THE SECONDARY SIDE**

çizgi, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, diyagram, yazı tipi içeren bir resim

Açıklama otomatik olarak oluşturuldu

Figure X. Voltage and Current Waveform of the Inductor

From the inductor waveform, voltage on the inductor has very big oscillation and current varies between 4.80-5.30 A. So, system operates in continuous conduction mode. Ripple is around. 0.5 / 5 = 10%.

**LOAD CHARACTERISTICS**

For observing 5 A at load, load is selected as 2.4 ohm.

çizgi, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, sayı, numara, yazı tipi içeren bir resim

Açıklama otomatik olarak oluşturulduFigure X. Voltage and Current Waveforms at Load

From the characteristics of the load, required output voltage and current is provided. Ripple at outside is calculated as 0.36 / 5 = 7.2%. It is quite high according to system specification, so output capacitor will be selected as 1 µF in order to 470 nF. This system is operating with 0.5 duty cycle as expected. However, with ideal system, it should be operated with 0.4 duty cycle. However, with leakage inductances and resistances, this value increase to 0.5. So, for the safety of operation and operating without saturation of the core, transformer design may be redesigned.

**Case 2: 40 V Input Voltage Case**

Simulations done with 20 V input voltage. Leakage inductance, magnetizing inductance and resistance is added. According to these simulations, waveforms on diodes, mosfets, required duty cycle and load characteristics are observed.

**Diodes at Primary Side**

çizgi, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, metin, sayı, numara içeren bir resim

Açıklama otomatik olarak oluşturuldu

Figure X. Voltage Waveforms of the Diodes at Primary Side

From the simulations, voltage, and current characteristics of diodes at primary side is nearly same. According to waveforms, maximum current is around 8.5 A and maximum voltage when reverse biased is around 40 V. At the simulations, forward bias voltage is can be seen. So, from these results, diodes at the primary side will be selected. Also, oscillations are observed. IRMS value is around 245 mA and VRMS is around 24.58 V.

**MOSFET WAVEFORMS**

çizgi, metin, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, yazı tipi içeren bir resim

Açıklama otomatik olarak oluşturuldu

Figure X. Voltage and Current Waveforms of the MOSFET’s at Primary Side

According to simulations, voltage and current characteristics on the MOSFET’s are very similar, peak current goes 8.5 A and peak voltage on the VDS is around 40 V. VRMS on the VDS is around 24.302 V and IRMS is around 3.56 A. According to these information, MOSFET selection will be done. Moreover, oscillation is observed when switch is closed. However, this oscillation is not higher. Because of used topology, RCD snubber circuit is not required.

**Inductance Waveforms of TRANSFORMER**

çizgi, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, ekran görüntüsü, diyagram içeren bir resim

Açıklama otomatik olarak oluşturuldu

Figure X. Current Waveforms of Inductance at Transformer

I(L1) and I(L4) are current waveforms of winding and magnetizing inductance. As expected, current on magnetizing inductance goes 0 when switches are off and charging when switches are on. It is a good operation mode for protection from saturating of core.

**DIODES WAVEFORMS AT SECONDARY SIDE**

çizgi, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, yazı tipi, ekran görüntüsü içeren bir resim

Açıklama otomatik olarak oluşturuldu

Figure X. Current and Voltage Waveforms of Diodes at Secondary Side

From the voltage and current waveforms, characteristics of the diodes are observed. Very big oscillation is observed at the voltage waveforms. Current waveforms are more stable, but it has oscillation at off period and maximum current rating is around 5.3 A. When voltage waveforms are examined, spike reverse biased voltages can goes up to 150 V. Normally, it is around 30 V without oscillation. So, from these observations, diode will be selected.

**INDUCTOR WAVEFORMS AT SCONDARY SIDE**

metin, çizgi, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, ekran görüntüsü içeren bir resim

Açıklama otomatik olarak oluşturuldu

Figure X. Voltage and Current Waveforms of Inductor at Secondary Side

From the waveform characteristics of the inductor, current varies between 4.69 A and 5.28 A. Voltage has very big spikes at inductor. However, these spikes occur at very small time intervals. Spikes can go up to 130 V. It is quite high value. Filter for the output side can be considered.

**LOAD CHARACTERISTIC**

çizgi, ekran görüntüsü, sayı, numara, paralel içeren bir resim

Açıklama otomatik olarak oluşturuldu

Figure X. Current Waveform of Load

From the waveform of the load, current varies between 4.75 A and 5.23 A. Average value is around 5 A. However, ripple at load is around 0.5 / 5 = 10%. It is quite high. Again output capacitor will be considered again and 1 µF capacitor will be used in order to 470 nF capacitor.