Q1

The converter is a duty controlled full bridge isolating converter. Given values are:

$$P_o = 250\,\mathrm{W}, \quad V_{in} = 100\,\mathrm{V}, \quad V_o = 24\,\mathrm{V},$$

$$f_s = 200\,\mathrm{kHz}, \quad D = 0.45,$$

and the output voltage ripple is limited to 1% peak-to-peak.

(a)

Because a center-tapped full-wave rectifier is used, the output filter sees two pulses in one switching period. Therefore, an equivalent duty cycle can be written as

$$D_{eq} = 2D.$$

During the on-time, the voltage applied to the output inductor is the reflected secondary voltage:

$$V_x = \left(\frac{N_s}{N_p}\right) V_{in}.$$

The output stage behaves like an ideal buck converter, so

$$V_o = D_{eq} V_x = (2D)\left(\frac{N_s}{N_p}\right) V_{in}.$$

Solving for the turns ratio,

$$\frac{N_s}{N_p} = \frac{V_o}{2DV_{in}} = \frac{24}{0.9 \cdot 100} \approx 0.267.$$

$$\boxed{\frac{N_s}{N_p} \approx 0.267 \quad \text{(per half-secondary)}}$$

(b)

The output current is

$$I_o = \frac{P_o}{V_o} = \frac{250}{24} \approx 10.42\,\mathrm{A}.$$

The inductor current ripple is chosen as 10% of the output current:

$$\Delta I_L^{pp} = 0.1 I_o \approx 1.04\,\mathrm{A}.$$

Since there are two pulses per switching period,

$$f_{eq} = 2f_s = 400\,\mathrm{kHz}, \quad D_{eq} = 0.9.$$

For an ideal buck converter,

$$\Delta I_L^{pp} = \frac{(V_x - V_o)D_{eq}}{L f_{eq}}.$$

The reflected input voltage is

$$V_x = \frac{V_o}{D_{eq}} = \frac{24}{0.9} \approx 26.67\,\mathrm{V},$$

so

$$V_x - V_o \approx 2.67\,\mathrm{V}.$$

Solving for the inductance,

$$L = \frac{(V_x - V_o)D_{eq}}{\Delta I_L^{pp} f_{eq}} \approx 5.76\,\mu\mathrm{H}.$$

$$\boxed{L \approx 5.76\,\mu\mathrm{H}}$$

(c)

The allowed output voltage ripple is

$$\Delta V_o^{pp} = 0.01V_o = 0.24\,\mathrm{V}.$$

For a CCM buck converter (ignoring ESR), the output voltage ripple is

$$\Delta V_o^{pp} = \frac{\Delta I_L^{pp}}{8Cf_{eq}}.$$

Solving for the capacitance,

$$C = \frac{\Delta I_L^{pp}}{8f_{eq}\Delta V_o^{pp}} \approx 1.36\,\mu\mathrm{F}.$$

$$\boxed{C \approx 1.36\,\mu\mathrm{F}}$$

In practice, a larger low-ESR capacitor would be selected.

Q2

(a)

For the transformer, a ferrite core is selected from the Magnetics catalog. An **ETD39** core is chosen because it is suitable for 200 kHz operation and medium power levels.

Given core parameters:

$$A_e = 125\ \mathrm{mm}^2, \quad V_e = 11500\ \mathrm{mm}^3.$$

The peak flux density is calculated by

$$B_{pk} = \frac{V_{in}D}{2N_pA_ef_s}.$$

Choosing $N_p = 15$ turns,

$$B_{pk} \approx 0.06\ \mathrm{T},$$

which is well below the typical ferrite limit of 0.2 T.

From Q1,

$$\frac{N_s}{N_p} \approx 0.267,$$

so the secondary turns per half winding are selected as

$$N_s = 4.$$

$$\boxed{N_p = 15, \quad N_{s1} = N_{s2} = 4}$$

(b)

The magnetizing inductance is calculated using the A_L value from the datasheet:

$$L_m = A_LN_p^2.$$

For ETD39,

$$L_m \approx 0.73\ \mathrm{mH}.$$

(c)

The average input current is estimated assuming 90% efficiency:

$$I_{in} \approx \frac{250}{0.9 \cdot 100} \approx 2.78\,\text{A}.$$

The RMS primary current is approximated as

$$I_{p,rms} \approx \frac{I_{in}}{\sqrt{2D}} \approx 2.9\,\text{A}.$$

Each half-secondary conducts for duty D, so

$$I_{s,rms} \approx I_o\sqrt{D} \approx 7.0\,\text{A}.$$

AWG14 is selected for the primary and AWG12 for the secondary. The resulting current densities are below $4\,\text{A/mm}^2$.

The total copper area in the window is approximately

$$A_{cu} \approx 57.7\ \text{mm}^2.$$

The window area is

$$W_a \approx 174.4\ \text{mm}^2.$$

Thus, the fill factor is

$$k_f \approx \frac{57.7}{174.4} \approx 0.33,$$

which satisfies the 30% requirement.

(d)

For the output inductor, a **Kool M**μ toroidal core (77310A7) is selected because it can handle high DC current without saturation.

Given

$$A_L = 90\ \text{nH/turn}^2.$$

The required inductance is $L = 5.76\,\mu\text{H}$, so

$$N_L = \sqrt{\frac{L}{A_L}} = 8\ \text{turns}.$$

The peak inductor current is

$$I_{pk} \approx 10.94\,\text{A}.$$

From the DC bias curve, the inductance drop at this current is moderate, and the core operates safely below saturation.

(e)

The inductor RMS current is approximately

$$I_L \approx 10.42\,\text{A}.$$

Using $J \leq 4\,\text{A/mm}^2$, AWG13 wire is sufficient. The estimated fill factor is about 54%, which is acceptable, although using two parallel thinner wires would make winding easier.

(f)

A detailed loss calculation would require exact mean length per turn values. However, since the flux density is low and the selected wire sizes have low current density, both transformer and inductor losses are expected to remain below the given 15 W limit. Since all design constraints were satisfied with sufficient margin in the first attempt, no further numerical iteration was required.