**Flyback converter with active clamp snubber.** A flyback converter containing an active clamp snubber circuit is illustrated in Fig. 2 below. A transformer model containing a magnetizing inductance, leakage inductance, and an ideal transformer is illustrated. Elements $C_s$, $L_M$, and $C_f$ are large in value, so that their switching ripples can be ignored. Element $C_1$, $C_2$, and $L_l$ are relatively small in value, and constitute the resonant tank elements. The current $i_l$ reverses in direction, leading to zero-voltage switching. Diode $D_3$ is ideal. The voltage $V_s$ is slightly larger than $V/n$.

![Fig. 2 Flyback converter with active-clamp snubber, Problem 2.](image)

Each switching period is composed of the following six subintervals:

1. **Subinterval 1:** $Q_1$ conducts. This interval ends when the controller turns $Q_1$ off.
2. **Subinterval 2:** all semiconductors are off.
3. **Subinterval 3:** Diode $D_3$ conducts
4. **Subinterval 4:** Conducting devices are $D_3$ and $D_2/Q_2$. $Q_2$ is turned on at zero voltage while $D_2$ conducts. This interval ends when $Q_2$ is turned off.
5. **Subinterval 5:** Diode $D_3$ conducts
6. **Subinterval 6:** Conducting devices are $D_3$ and $D_1/Q_1$. $Q_1$ is turned on at zero voltage while $D_1$ conducts. This interval ends when diode $D_3$ becomes reverse-biased.

The resonant intervals are subintervals 2, 3, 5, and 6. The converter operates with duty cycle control: the interval $DT_s$ is composed of subintervals 5, 6, and 1.

(a) Sketch the waveforms of $v_1(t)$ and $i_1(t)$.
(b) Sketch the state-plane diagram for this converter, and label the six intervals described above.
(c) What are the conditions for zero-voltage switching of $Q_2$? of $Q_1$?
(d) Analysis: solve the state plane diagram of part (b) as appropriate, to write the equations describing each subinterval length and beginning/ending current or voltage.
(e) Sketch the waveforms of the clamp capacitor current $i_s$ and the voltage across the magnetizing inductance $v_M$. Apply volt-second or charge balance to these waveforms as appropriate. Hence, write a complete set of equations for this converter, that could be solved to find the steady-state solution of the converter. It is not necessary to solve your equations.