EE3C11 Exercises Electronics Part 2 (V1)

February 27, 2020

These exercises are to help you to develop skills and understanding about selectec topics in network theory and the concept of poles and poles and zeros. You can work on these exercises during the entire teaching period. Please take sufficient time to work on an exercise and completely understand the way to come to a solution[1]. There is no educational value in finding the correct solution by repeating a "trick" that you have seen others apply before you. The exercises can also be found in Chapter 18 of the course book. To verify results you could use simulators like LTSspice and SLICAP.

[1]You can always contact one the teaching staff for assistance if you need help solving the exercises during or outside lecturing hours or the lecturing period.

Exercise 1:
Fig.1 shows some RC network models of linearized dynamic systems with a source and a detector. The source is either a voltage source or a current source. The detector (the component that senses the output signal of the network) can be a voltage detector or a current detector. For example, in circuit (7) the source is a current source and two possible detectors are indicated. The red plus and minus sign indicate a voltage detector. This means the voltage between the nodes next to the + and the - , which is in this case the voltage across the capacitor, is taken as the output signal of the network. The current detector in circuit (7) is indicated by the red arrow.

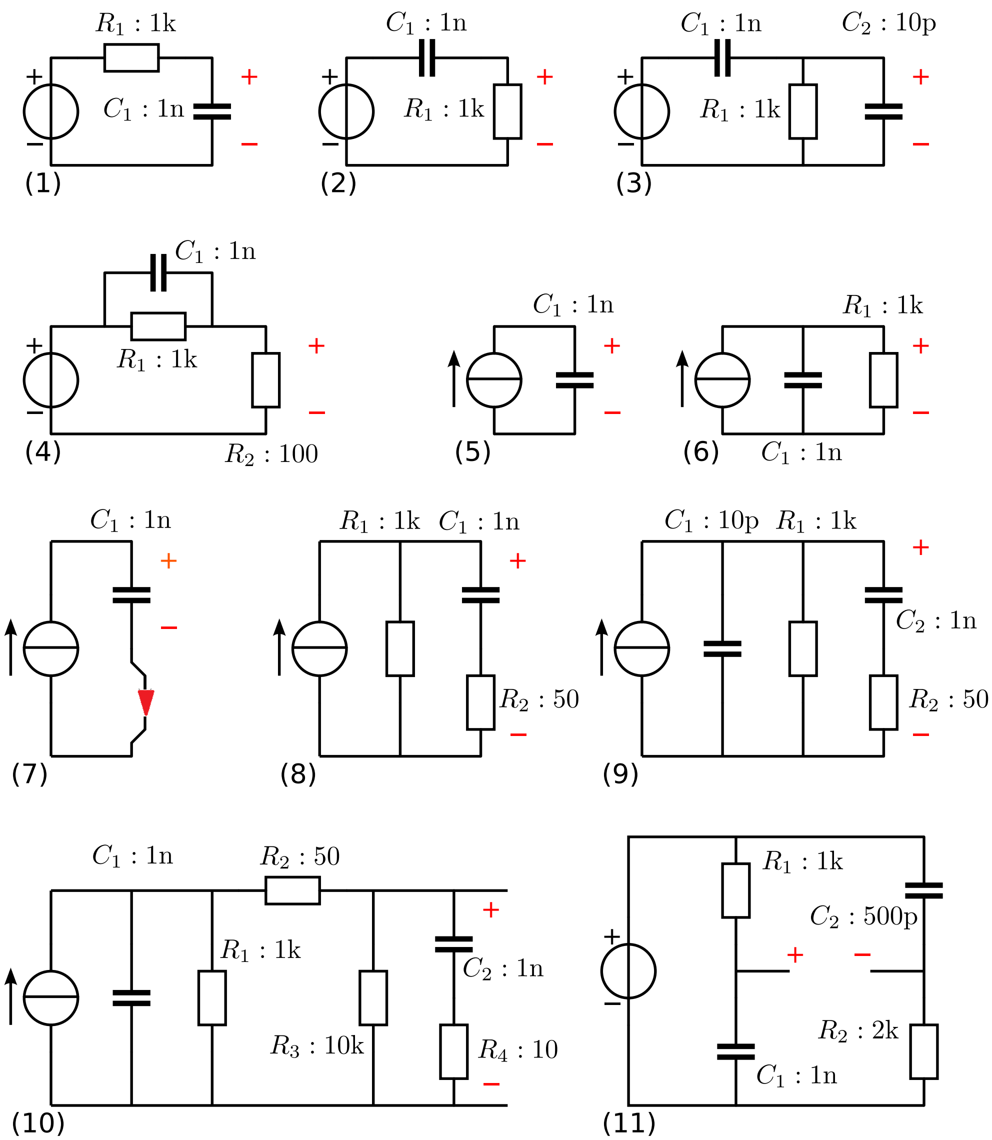

Figure 1: RC networks for estimation of the poles and zeros.

Please answer the following questions for each circuit:

1. How many poles does the circuit have?
2. Are there any poles with zero frequency?
3. How many zeros does the source-detector transfer have?
4. Are there any zeros with zero frequency?
5. Give approximate symbolic expressions for the source to detector transfer.
6. Sketch the Bode diagrams of the source-detector transfer.
7. Sketch the unit step responses of the source-detector transfer.
8. Are there any non-observable poles in this transfer?

Background theory: Non-observable and non-controllable states
(see 11.5.4 in the book)

Non-controllable state variable.
A non-controllable state variable of a network is one that cannot be changed by excitation(s) applied to the input(s) of a network.
Consider, for example, the network from Figure 2. It shows a passive network with an input port and an output port. The output voltage of the network is the capacitor voltage, which is the only state variable of the net-work. Although this voltage can be observed at the output port, it cannot be controlled by a current or by a voltage applied to the input port. In other words, the transfer from a current or voltage applied to the input port to the voltage across the capacitor is zero. Hence, in this network, the state variable is not controllable.

If we determine the poles and the zeros of the transfer parameters of this network, we would find one pole and one zero with equal frequencies. The pole is associated with the independent capacitor voltage. Because it cannot be controlled, it is cancelled by a zero.

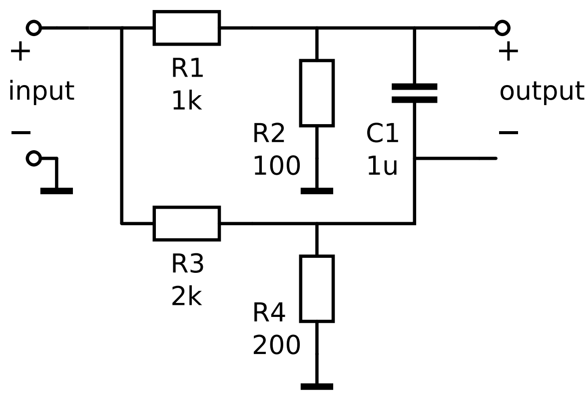

Figure 2: Passive two-port network with a non controllable state.

Non-observable state variable.
A non-observable state variable of a network is one that cannot be observed at the output(s) of the network.
Let us now consider the network from Figure 3. It shows a passive network with an input port and an output port. There exists a nonzero transfer from a voltage or from a current applied to the input port to the voltage across the capacitor. Hence, the voltage across the capacitor is controllable. However, the transfer from the capacitor voltage to the voltage or current in the output is zero. So, in this network, the state variable is not observable

If we were to determine the poles and the zeros of the transfer parameters of this network, we would find one pole and one zero with equal frequencies. The pole is associated with the independent capacitor voltage. Because it cannot be observed, it is cancelled by a zero.

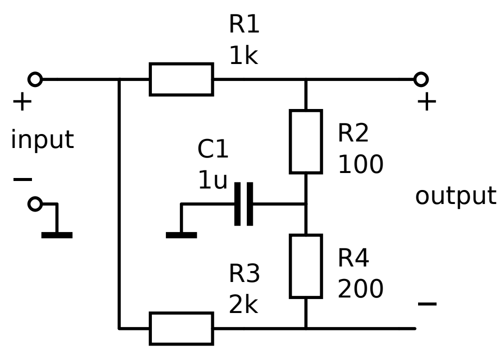

Figure 3: Passive two-port network with a non-observable state.

Exercise 2:
The circuit from Figure 4 shows the equivalent network for a passive 10× attenuation oscilloscope probe connected to an ideal voltage source. The capacitor C_2 represents the total of the cable capacitance and the capacitance of a variable capacitor. If well adjusted: $R_1C_1 = R_2C_2$.

Sketch the pole-zero diagram, the Bode plots and the unit step response of the probe circuit for the following situations:

1. The probe is well adjusted: $R_1C_1 = R_2C_2$.
2. The probe is under compensated $R_1C_1 > R_2C_2$.
3. The probe is over compensated $R_1C_1 < R_2C_2$.

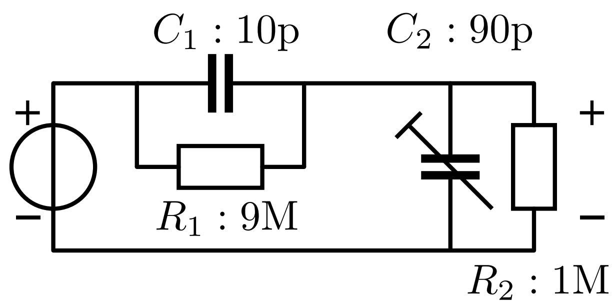

Figure 4: the equivalent network for a passive 10 × attenuation oscilloscope probe connected to an ideal voltage source

Figure 5 gives a more realistic probe model. In this model the probe is connected to a 50Ω source and a small series inductance accounts for a minimum probe ground lead and tip length. Sketch the pole-zero diagram, the Bode plots and the unit step response of this probe circuit for the situation that is has been adjusted correctly.

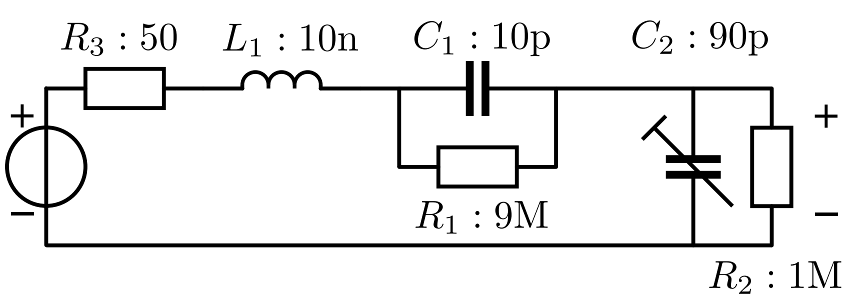

Figure 5: the equivalent network for a passive 10 × attenuation oscilloscope probe connected to an ideal voltage source