Passive Quench Circuit Simulation

Experiment 4

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1 Objectives

The objectives of this experiment are as follows:

- To simulate a passive quench circuit.
- To observe the effect of the load resistance on the total dead-time.
- To establish the impact of the photodiode parasitics on the dead-time.

2 Equipment

- 1 PC (not supplied)
- SIMetrix circuit simulation software (supplied)

3 Passive Quench Circuit Simulation

- Install the SIMetrix/SIMPLIS Intro SPICE circuit simulator software from the supplied CD.
- Run the software and open a new file. In this file build the circuit shown in Fig. 1. This circuit is similar to the passive quench circuit in Module 6 Section 2.1. The photon counting detector is modelled using a parallel combination of a resistor and a capacitance. The resistor represents the diode series resistance and the capacitor the total diode capacitance, including bondpad capacitance. The Geiger-mode operation and the absorption of a photon is modelled using a voltage source (representing the diode breakdown voltage) and a voltage controlled switch that closes when a photon

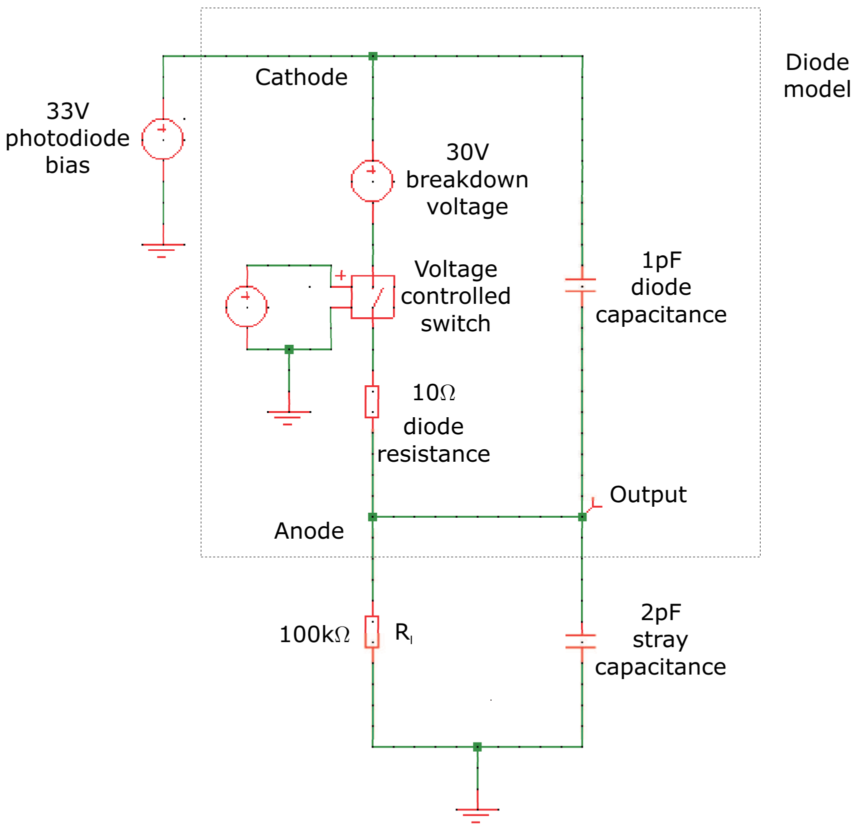
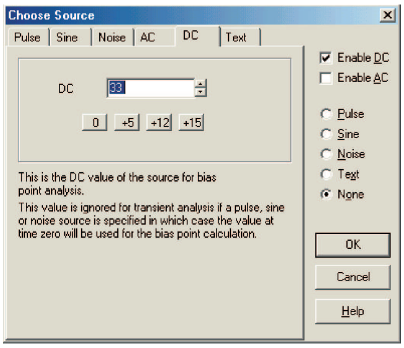


Figure 1: Passive quench circuit.

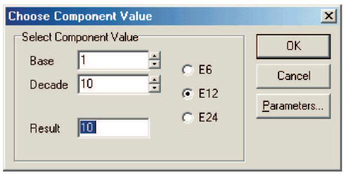
is absorbed and opens after the quench time. The stray capacitance resulting from the connection of the diode to the circuit is modelled using a capacitor. Quenching is established using a load resistor.

The various components can be found by going to 'Place' on the main menu and the following:

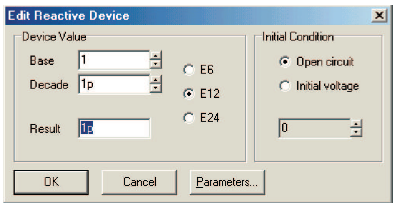
- Passives -> Resistor - for all resistances,
- Passives -> Capacitor - for all capacitances,
- Sources -> Universal - Source for all voltage sources,
- Analog Functions -> Switch - for the switch,
- Connectors -> Ground - for all grounds.



(a)



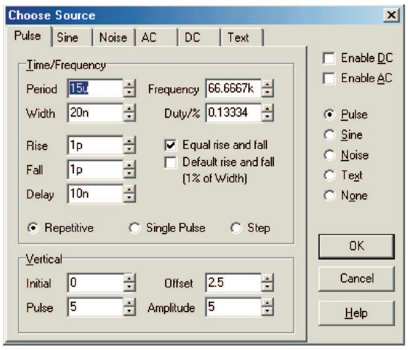
(b)



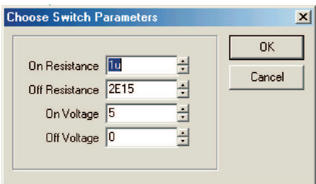
(c)

Figure 2: (a) Voltage, (b) resistance and (c) capacitance value settings.

- Join all the circuit components using the wiring tool. The wiring tool can be obtained by pressing the 'Toggle Wire Mode' toolbar icon. The terminal of a component can be connected to that of another component by clicking on the components. Right clicking will terminate the wires.
- Once the circuit is drawn, place a voltage probe at the output to observe the voltage there. A 'Fixed Voltage Probe' can be found from 'Probe' on the main menu.
- To set the values of each component, select the component, right click and select 'Edit Part'. The various components are set as follows:



(a)



(b)

Figure 3: (a) Pulse voltage controlling switch and (b) voltage controlled switch settings.

- Photodiode bias - set to a DC voltage of 33 V (see Fig. 2(a)).
- Breakdown voltage - set to a DC voltage of 30 V (see Fig. 2(a)).
- Diode resistance - set to $10\ \Omega$ (see Fig. 2(b)).
- Diode capacitance - set to 1 pF (see Fig. 2(c)).
- Stray capacitance - set to 20 pF (see Fig. 2(c)).
- Pulse voltage (controlling the switch) - set as shown in Fig. 3(a).
- Voltage controlled switch - set as shown in Fig. 3(b).

• Set the simulation to run for $30\ \mu$s. To do this go to 'Simulation' on the main menu followed by 'Choose Analysis'. Select the check box transient for the type of simulation. Press the transient tab and type '30u' into the 'Stop Time' box.

• Run the simulation by going to 'Simulator' on the main menu and then 'Run'. Observe the passive quenching. It should appear as shown in Fig. 4.

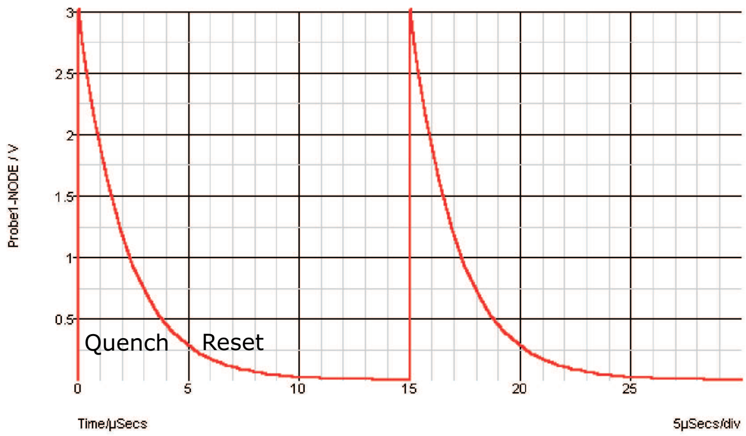


Figure 4: Passive quenching.

- Measure the quench time, t_{quench}, and the reset time, t_{reset}. Calculate the total dead-time using:

$$t_{dead} = t_{quench} + t_{reset} \tag{1}$$

- Calculate the time constant governing the quench stage using:

$$Quench\ time\ constant = R_s\,(C_d + C_s) \tag{2}$$

  where R_s is the diode series resistance, C_d is the diode capacitance and C_s is the stray capacitance.

  Calculate the time constant governing the reset stage using:

$$Reset\ time\ constant = R_l\,(C_d + C_s) \tag{3}$$

  where R_l is the load resistance.

- How do the calculated values compare with the simulated values? Remember it will take ≈ 5 time constants for a complete charge or discharge.

- Repeat the above procedure for various excess biases (**note:** the excess bias was 3 V in the above procedure).

- Repeat the above procedure for various values of the load resistance.

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4 Summary

After completing Experiment 4, the reader should be able to answer the following questions:

1. What affect does excess bias have on passive quenching?
2. What affect does load resistance have on the dead-time?
3. What impact do the photodiode characteristics have on the dead-time?

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5 Acknowledgements

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