

# ELEN0040 – Study guide for the theory exam

The exam content is specified here below in bullet points. Questions can be multiple choice or require written answers: questions will be in English, and answers in English or French will be accepted.

Questions can take many forms, such as:

- What is a  $x$  and draw the schematic.  
→ e.g. What is a *3-to-8 decoder* and draw the schematic.
- Explain what  $x$  is, and give an example.  
→ e.g. What is a *minterm*, and give an example using a Boolean function with 3 input variables.
- Is the following example  $x$  or  $y$ ? Explain.  
→ e.g. is the following example a Moore or a Mealy machine?
- What is  $x$  and why is it used? Give an example.  
→ e.g. What is a parity bit and why is it used? Can you give an example?
- What is the difference between  $x$  and  $y$ ? Draw a schematic and explain.  
→ E.g. what is the difference between SRAM and DRAM? Draw the transistor schematics of a static and dynamic RAM cell and explain.
- ...

The exam will focus on the conceptual understanding and applications of the studied principles.

## CHAPTER 2

- Analog and digital systems. What makes a digital system different from an analog system? What is the noise margin of a logic gate?
- What are asynchronous / synchronous circuits; combinational / sequential circuits.
- Positional / nonpositional number systems (*the exam will not contain questions about the conversions of numbers in base  $r$  to base  $q$* ).
- Parity bit.
- BCD code, Gray code.

## CHAPTER 3

- Boolean algebra; logic gates; Boolean algebra.
- Minterms / maxterms of a Boolean function. Give an example.
- What is the relationship between a minterm  $m_i$  and the corresponding maxterm  $M_i$ ? Give an example for an expression with 3 binary variables. Given a truth table, list the minterms (maxterms) resulting in a "1" ("0") output. How do you combine minterms and maxterms in canonical forms?
- SOM, POM, SOP, POS implementations. Convert from SOM to POM and from SOP to POS.
- Literal cost; gate input cost. Give an example. Calculate the gate input cost of a given Boolean expression and/or logic diagram.
- Karnaugh maps. What are don't care conditions? How do you generate a SOP / SOP expression using a Karnaugh map? Show implicants / prime implicants / essential prime implicants using a Karnaugh map.

- What is an odd/even Boolean function ? Give its expression as a sum of products and the corresponding truth table in the special case of the even/odd function with 4 variables. Name an important application of an even/odd function.
- Gate propagation delay, transport delay, inertial delay.
- Timing hazards in combinational circuits: static-1/static-0 hazards. Give an example. How do we use Karnaugh maps to eliminate static-1 and static-0 hazards ?

## CHAPTER 4

- What is a sequential circuit ? What is a synchronous / asynchronous sequential circuit ?
- Bistable RSAM cell. Where are the equilibrium points and the metastable point ? What is metastability ?
- SR and D latches: circuits, truth tables, examples, timing diagrams.
- SR pulse-triggered and D edge-triggered flip-flops: circuits, truth tables, examples, timing diagrams.
- What is the main difference between a latch and a flip-flop ? What is the advantage of a flip-flop over a latch ? What is a master-slave flip-flop ? What is an edge-triggered flip-flop ? What is a pulse-triggered flip-flop? Explain the "1st catching" problem in pulse-triggered SR flip-flops.
- How can a T flip-flop be realized from a D flip-flop and logic gates?
- Give the truth table of a T and JK flip-flop/latch.

## CHAPTER 5

- What is a decoder ? Explanation, example, schematic, synthesis. Sketch the schematic of a x-to-y decoder.
- What is a (priority) encoder ? Explanation, example, schematic. What is the difference between an encoder and a priority encoder ?
- What is a multiplexer ? Explanation, example, schematic. How do you use a multiplexer to synthesize a combinational circuit ? Give an example. Sketch the schematic of a  $2^n$ -to-1 multiplexer.
- What is a half-adder / full-adder ? Sketch the schematics.
- What is a ripple carry adder ? What is a carry lookahead adder ?
- How is the 2s complement used in a subtractor ?
- Explain the operation of an adder / subtractor. Sketch the schematic.
- How is overflow detected in a binary adder / subtractor ?

## CHAPTER 6

- Finite state machines.
- What are race conditions ? Give an example. Can you detect race conditions in a given schematic, e.g. by drawing a timing diagram ?
- What is the internal state of a sequential circuit ? How many internal states can be represented in a sequential system with N flip-flops ? What are state variables ?
- Derive state tables, state diagrams and excitation equations.
- What is a Moore / Mealy state machine ? What is the difference between a Moore machine and a Mealy machine ?
- What are equivalent states ? Can you find equivalent states in a given sequential system ?
- Name different ways of assigning the states of a system to n state variables. How can the choice of the state assignment method be important ? What are some state assignments that we have covered in the unit ?
- Analyse a given sequential circuit / design a given sequential circuit.

## CHAPTER 7

- What are integrated circuits ? What is a PCB ? What is glue logic ? What are logic families ?
- How do transistors work (basic switching behavior).
- Sketch inverter, NAND and NOR transistor circuits.
- Analyse a given transistor schematic and derive a truth table / boolean expression / logic diagram.
- Fan-in / fan-out. Explain what these terms are and how these are determined and influenced.
- CMOS static electrical behavior. What is ESD ?
- Transition time of CMOS gates. Calculate a given example.
- Gate propagation delay / transport delay / inertial delay. What is the difference between  $t_{PHL}$  and  $t_{PLH}$ ?
- Calculate static and dynamic power consumption in CMOS circuits. What parameters are important for reducing the static/dynamic/total power consumption ?
- Flip-flop timing: setup and hold time. Which timing needs to be respected to ensure the correct operation of a flip-flop ? Draw a figure.
- Sequential circuit timing. Calculate and evaluate a given example.
- What is clock skew ?
- What are transmission gates / Schmitt trigger inputs / three-state buffers / open-drain outputs and how do these circuits work.
- Synchronization, synchronizers, synchronizer failure and metastability. Explain the importance of synchronizing a sequential circuit, and how it can be improved. What is a metastable state and how can this occur? Analyze a given example.

## CHAPTER 8

- What is a register ? What is a storage/shift/general register ? Sketch a schematic. List possible applications of a register.
- What is a counter ? Describe the operation of the 1-bit counter; plot the time evolution of the characteristic variables of this counter.
- What is a ripple counter ? What is its disadvantage ?
- What is a synchronous counter ? Sketch a diagram of an x-bit synchronous counter.
- How do you initialize a counter? Give an example of good practice and an example of bad practice. What is a suicide counter ?

## CHAPTER 9

- What is RAM / ROM / EEPROM / SRAM / DRAM ? How does it work ? What are the main characteristics ? Sketch a diagram.
- What is static / dynamic memory ? Sketch a transistor schematic of both. What are the differences between static and dynamic memory ?
- What is a refresh of a dynamic memory, and why is it needed ?
- What is volatile memory ?