General Information and Communication Technology I — Course: 350101
Jacobs University Bremen — Date: 2014-10-28
Dr. Jürgen Schönwälder — Due: 2014-11-04

Module 3 — Problem Sheet #1

Please upload a pdf file with your solutions (legibly hand-written and scanned, or a typeset document) to https://jgrader.de by Tuesday, November 4, 23:59.

Problem 1.1: *NAND as a universal logic gate* (10+10+10 = 30 points)

The NAND gate is called a universal logical gate since it can be used to emulate the other logical gates. Show how the following gates can be emulated using a NAND $\bar{\wedge}$ gate:

- AND ($\wedge$)
- OR ($\vee$)
- XOR ($\oplus$)

For each gate, write down the logic formula and the corresponding digital circuit diagram. Here is an example for the NOT ($\neg$) gate:

- NOT ($\neg$): $\neg A = A \bar{\wedge} A$

Problem 1.2: *full adder using NAND gates* (10+10 = 20 points)

A full adder digital circuit was introduced in class.

a) Find out how this circuit can be implemented using NAND gates only. How many NAND gates are needed and how does this compare to the number of gates used by the circuit shown in class?

b) Assume that every gate has a certain gate delay. The gate delay is the length of time which starts when the input to a logic gate becomes stable, to the time that the output of that logic gate is stable. What is the overall delay for the N-bit ripple adder implemented using NANDs and how does it compare to the gate delay using the circuit presented in class?

Problem 1.3: *machine program for the simple central processing unit* (50 points)

Write a program for the simple central processing unit introduced in class. The program should add the numbers from 1 to 10 and leave the result in memory location 15. Fill in table as follows:

#	Machine Code	Assembly Code	Description
0			
1			
...			