Optical Link Project

1. Introduction:

An optical link will be designed, implemented and tested in this semester-long project. Most of the course concepts will be covered in this project, including op-amp circuits, diodes, metal-oxide-semiconductor field effect transistors (MOSFETs), MOSFET digital gates, and bipolar junction transistors (BJTs).

In order to make the project easier to manage, the optical link is divided into five functional blocks. Each functional block is the basis of one Lab. Students will work in a team of two students; each team member should shoulder an equal share of the project responsibilities. The Labs must be completed according to the Laboratory schedule.

2. Optical Link Overview:

An optical link is a communication system using an optical transmitter, an optical receiver, and the electronic circuits necessary to convert information in the form of an electrical signal into an optical signal, and vice versa. Examples of optical links include optical trip wires for security systems, TV remote controls, and the laser based optical fiber communication systems that form the back bone of the internet.

Figure 1. System level schematic of an optical link.

The optical link consist of five functional blocks: a signal generator, a light emitting diode (LED) driver, a transimpedance amplifier, an active bandpass filter, and an amplifier. The system block diagram is shown in figure 1. Several items, such as the power supplies, are neglected in this diagram.

A short description of each functional block is given below. The functional blocks will be implemented in relation to the order the material is covered in lecture.

(A) Signal Generator (Lab 3):

All communication links require a carrier signal that is clocked at a certain frequency. In this project, the carrier is an optical signal which will be modulated with a pulse at a frequency of 20 kHz. The carrier signal will be generated using a digital oscillator.

In Lab 3 you will investigate NMOS and CMOS inverters and a CMOS oscillator circuit. You will compare the performance of the NMOS and CMOS inverters in terms of speed, DC power consumption and V_{OH}-V_{OL}-V_{IH}-V_{IL}. You will design, build and test a three-stage CMOS ring oscillator which should oscillate at your designated clock frequency, with a ±5% tolerance.

(B) LED Diver (Lab 4):

A light emitting diode generates light as current flows through the device. A typical conversion efficiency is less than one photon per electron. Bias currents for LEDs range from several mA to hundreds of mA which is more current than the signal generator will be able to supply. A circuit is needed to convert the output from the signal generator to a bias current needed by the LED.

There is a nearly linear relationship between current input and light produced by the LED. However, the LED has a non-linear, in fact exponential, current-voltage relationship. Thus, the LED driver circuit will converts a voltage signal to a current signal using a transconductance amplifier.

In Lab 4 you will design a LED Driver using an op-amp, a BJT, an LED and several resistors. The LED driver will convert the 0-5V signal from the oscillator circuit to a 0-40 mA current to drive the LED of the transmitter. An interface circuit will be used adjust the duty cycle of the oscillator to (50 ± 5)%.

(C) Transimpedance Amplifier (Lab 1):

The receiver of the optical link will convert the optical signal into an electrical signal. This is accomplished using a photodiode, which generates a current as a function of the optical power incident on the device. A typical conversion efficiency is less than one electron per photon, except for avalanche photodiodes and phototransistors, which have internal gain. The photodiode current signal, which can be on the order of several pA, needs to be amplified and converted into a voltage signal. The first stage of this process use a transimpedance amplifier (TZA), which converts a current input into a voltage output. This module will be implemented using an op-amp, a photodiode, a resistor and a capacitor.

In Lab 1 you will design, build and test your TZA amplifier. For testing purposes, you will drive an LED with a laboratory signal generator instrument, instead of the LED driver module, which will be built later.

(D) Active Bandpass Filters (Lab 2):

The output signal from the transimpedance amplifier will be in the several μV to hundreds of μV range, and will be superimposed on noise – both other signals as well as electronic noise. This signal will need to be filtered and further amplified to a useful level. An active bandpass filter will be used to simultaneously amplify and filter the signal.

In Lab 2 you will design, build and test an active bandpass filter chain. The filter should have a pass band centered at your clock frequency, and have sufficient bandwidth to operate with the ±5% tolerance of the clock signal.

(E) Voltage Amplifier (Lab 5):

The output signal of the active bandpass filter will be on the order of tens of mV. A MOSFET voltage amplifier will be used to further amplify this signal to the hundreds of mV to several V range.

In Lab 5 In this task you will design, build and test a common-source (CS) MOSFET amplifier to bring the signal from the active bandpass filter to 100 mV or larger.

3. Project Demonstration:

The final task in the ECE 342 Lab is to implement the optical link and achieve a transmission distance greater than 50 feet with an SNR of 6 dB. Two teams can pair up to form a four person team to try and achieve a maximum operating distance. The optical link will need to be demonstrated to the lab TA, who will verify optical link performance.

4. Optical Link Specifications:

Your objective is to design and build an optical link capable of transmitting over a distance of at least 50 feet, with a clock frequency of 20 kHz. The transmission distance will be determined by the signal-to-noise ratio (SNR) metric, where a minimum SNR of 6 dB V/V is required. The optical link specifications are given in Table 1.

Table 1. Specifications for the optical link

Minimum transmission distance (SNR = 6 dB V/V)	50’
Clock frequency	20 kHz
Clock frequency tolerance	±5%
Clock duty cycle	50% ± 5%
LED bias current (peak)	40 mA ± 5%
Transmitter power supply[1]	5V ± 2%

[1]The transmitter will be powered by a 9V battery. An LM7805 voltage regulator circuit will be used to convert it to 5V for the oscillator and LED driver circuits.

5. Lab Schedule:

The Lab schedule is presented in the Gantt chart in table 2. Each Lab consists of three phases: (i) a circuit design and simulation phase, (ii) a circuit construction, testing and data analysis phase, and (iii) a reporting phase which includes a demonstration of the circuit.

Table 2. Gantt Chart of the Discrete Transistor Operational Amplifier project

Lab: \ Week:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
TZA		[yellow]	[yellow]	[orange]	[red]											
Active BPF					[yellow]	[orange]	[orange]	[red]								
Signal Generator								[yellow]	[orange]	[red]						
LED Driver										[yellow]	[orange]	[red]				
CS Voltage Am												[yellow]	[orange]	[orange]	[red]	
Optical Link Demo															[orange]	
Final Report															[red]	[red]

Key:
- [yellow] Circuit Design and Simulation
- [orange] Circuit Implementation and Testing
- [red] Technical Report and Circuit Deminstration

Labs 1 through 5 have a circuit design and analysis phase, followed by a circuit construction, testing and data analysis phase. Teams are free to move on to circuit construction and testing as soon as they feel they have succeeded in the design component, as long as the TA reviews and approves their design. The final task is the demonstration of the optical link, which will take place during the last week of classes.

An interim report will be written for each Lab and submitted to the TA electronically, via e-mail, during the reporting period. A rough draft is due by 2:00 PM on Monday of the reporting period. The TA will be responsible to return the drafts with comments by 2:00 PM Wednesday. The final report is due by 2:00 PM Friday. The teams will have sufficient time to incorporate changes to their report suggested by Prof. Payne as well as the TAs before their final submission.

Each team will demonstrate to their TA that their circuit functioned according to task specifications during the reporting period. These demonstrations will typically be done during the regularly scheduled lab section. In exceptional cases, a team might ask to meet with their TA at another time.

The final comprehensive report on the optical link demonstration is due no later than 15 December 2017 (last day of finals week).

It should be noted that the Labs are inter-related, and each module must be completed for the optical link to function. Therefore, teams must finish each task even if they fail to meet specifications by the given deadlines.