ECE137b Second Design Project Option

General Comments

You have a choice of doing one of three design projects, a fiber optic link, a switched mode power amplifier, or an acoustic phased array. All are intended to be
-Representative of real applications, incorporating aspects of both circuit and system design.
- Highly independent in character. It is strongly expected that there should be minimal similarity between projects designed by different groups.
-A significant fraction of the class grade and hence a significant time commitment

You will be working in groups of 2.

Construction Hints

These are high frequency circuits. Construction on a proto-board is of value for DC testing and for AC functional testing at signal frequency well below that of the real design. Functional high speed operation will require a soldered design with tight physical construction practices. Construction on a circuit board with a ground plane is very strongly recommended, as is signal wiring with adhesive copper tape. See the 137a web site for information on construction practices.

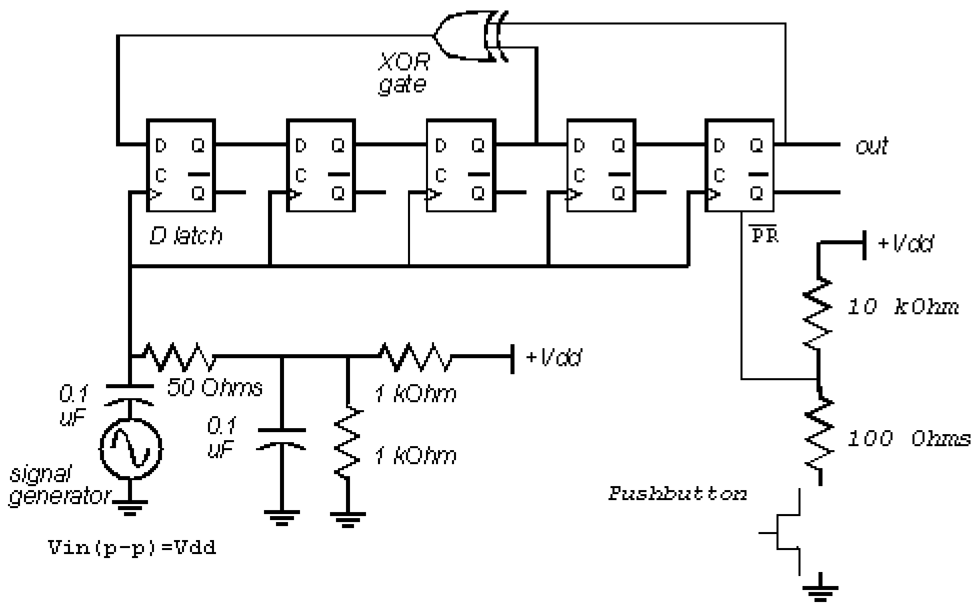
Lab Project Option #2: Fiber Optic Link

This is by far the less difficult of the 2 assignments

Background

data pattern generation

You will be building a an optical data transmission link. This will consist of a pseudo random data pattern generator, a transmitter, a length of fiber, a receiver, and a decision circuit.



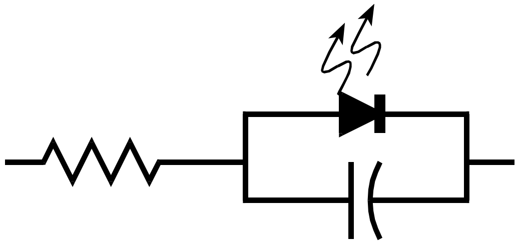
We need a pseudo random data pattern generator in order to generate data patterns to test the link. A logic level diagram is as shown above. It can be easily constructed from standard digital logic parts. The 4000-series CMOS logic gates are too slow for your purposes here, limiting you to a maximum of ~2 MHz data rate. Instead, you must use the 74HC CMOS logic family, specifically the MM74HC74A. Dual D-type flip flop (the preset_bar and clear_bar inputs should be tied to logic high) and the MM74HC86 exclusive OR gate. The pushbutton circuit is necessary to initialize the circuit on power-up. You should use a normally open switch, so that the preset_bar is normally connected to Vdd.

There is some flexibility, but I suggest operating the ICs from a power supply between ground and Vdd=+6 Volts

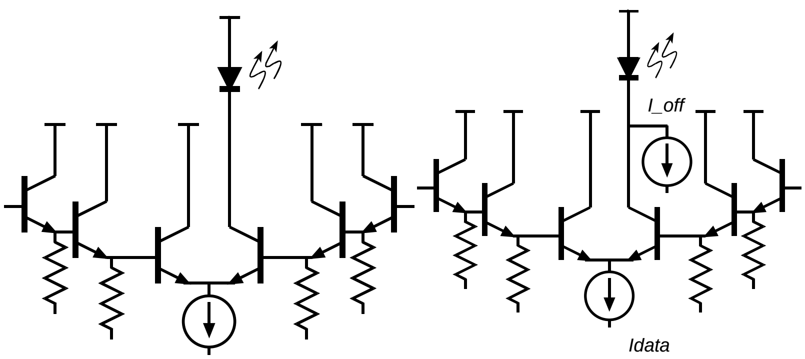
Principles of pseudo random pattern generators are described in http://www.newwaveinstruments.com/resources/articles/m_sequence_linear_feedback_shift_register_lfsr.htm , although it is not really necessary to read and understand this material.

Transmitter

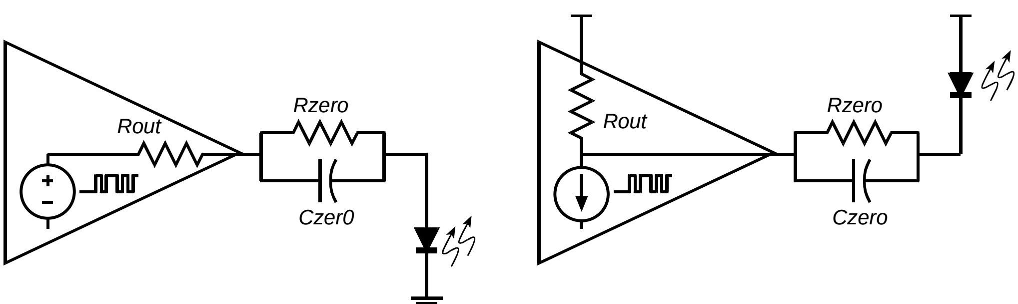
The transmitter takes data and uses it to drive current into either an LED or a laser diode, which then generates light (optical power) in proportion to the drive current. You will be using the IFE98 light emitting diode for the transmitter, and your data will be coming direct from the data pattern generator above. You will build the data pattern generator and the transmitter on a single board. The shop also has plastic optical fiber purchased from http://www.i-fiberoptics.com for connection of transmitter to receiver.



The objective is to convert the train of logic voltage pulses to a train of current pulses which drive the LED. The LED then coverts these into pulses of current. An approximate circuit model of an LED is as above: an ideal diode in parallel with diffusion+depletion capacitance, and then some series resistance.



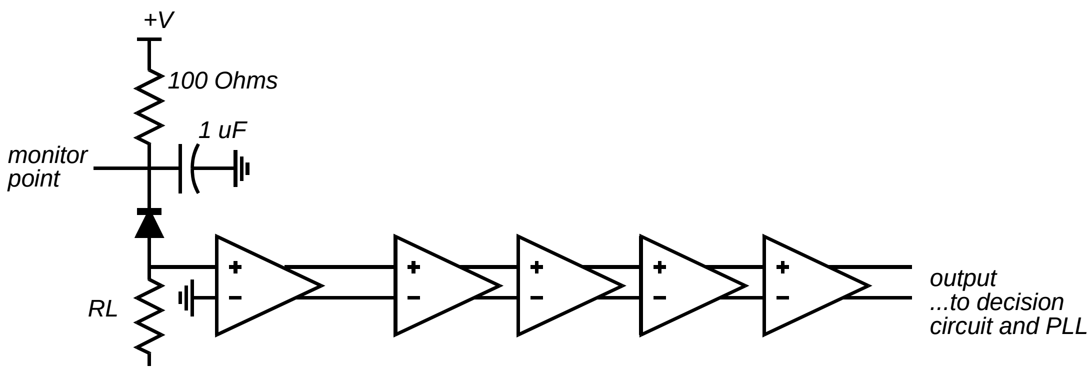
Because of this, while a simple buffered differential pair current switch might suffice (left), it may not be sufficiently fast. One technique is to add a small off-state current I_off (right) , about 5% of the data current. This keeps the diode in weak forward bias during a logical zero, so that the voltage 0<-->1 voltage change is reduced.



The other method of speeding up and LED is to add a zero to the pulse drive current transfer function. This is sketched above. Something similar is shown on the LED data sheet itself.

Points to bear in mind. Think about the DC drop of the LED and how it influences driver stage saturation. The DC drop is much larger than a normal diode. Do not exceed the maximum drive current to the LED, as replacing the LED is quite expensive.

The receiver



In the transmitter the data pattern is first converted back to electrical current using a reverse-biased diode: a photodiode IFD91. This current is then converted into a voltage by passing through a load resistor RL and then amplified. The more advanced technique of a *transimpedance amplifier* requires more detailed understanding and is not recommended except for the most talented circuit designers in the class. Because of both the photodiode capacitance and the amplifier input capacitance, large values of RL will result in small bandwidth. Very low load resistances will however result in high levels of *noise*; for this reason the load resistance must not be less than 500 Ohms.

Substantial gain is required after the preamplifier. Even with a few meters transmission distance in the fiber, losses in coupling into and out of the fiber are such that the photocurrent in this case is only ~20 microamps. One would like the receiver to function perhaps up to 10:1 additional loss (due to a long fiber in a real application). This then corresponds to 2 microamps photocurrent. We will assume that the decision circuits need a 500 mV peak-peak signal to function. If the load resistance were 1000 Ohms, then a 2 microamp peak-peak photocurrent would produce 2 mVpp signal voltage on RL, and an additional 250:1 voltage gain would be required from the gain stages.

The amplifier chain must not be DC coupled, both because the photodiode signal is unipolar, not bipolar, and because of the high gains required will result in loss of control of the DC bias. AC coupling is instead required; in order for this to not interfere with data transmission, the low-frequency cutoff must be below 1/10,000 of the data rate. Hence for 10 Mb/s, the low-frequency cutoff must be below 1 kHz.

In order of the receiver to function with a strong input signal, as well as a weak one, the amplifier must also amplify correctly when driven with signals strong enough to drive it into limiting (clipping). This forces use of differential circuits, with the circuit designed so that that both the positive and negative clipping limits are set by cutoff, not saturation.

Suggestions of circuit configurations would include differential pairs, perhaps with emitter follower input buffers, perhaps with cascode or folded cascode output stages. Cherry Hooper stages are used in industrial practice, but these require some understanding of feedback theory.

<u>The specific assignment</u>

first check off date

Construct and demonstrate a functioning pseudo random data generator. Determine the maximum clock frequency at which it works properly. Verify that the pattern is stable and repetitive.

second check off date

Your objective is to produce the fastest possible transmitter.

Demonstrate a pulse driver (transmitter) circuit connected to the pseudo random data generator. Measurements to be made include

-risetime and falltime of the optical waveform

-percent overshoot or undershoot in the optical waveform, if ringing is present. This must be less than 15% if the receiver is to function.

- percent droop or sag in the optical waveform, if present. This must be less than 10% if the receiver is to function. This would arise if the zero is added to the transmitter, but is incorrectly adjusted relative to the pole associated with the LED capacitance.

- the zero-state LED current is to be less than 1 mA, while the on-state LED current is to be greater than 10 mA.

-maximum data rate for a discernable data pattern on the oscilloscope.

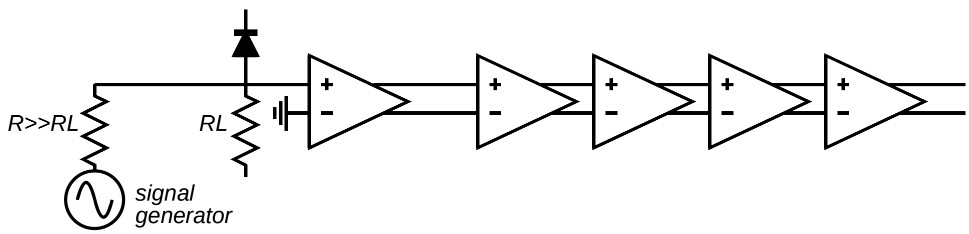
third check off date

At this point, the receiver has also been completed. Your objective, is to produce the fastest and most sensitive possible receiver. The receiver must have gain sufficient to produce a 500 mV pp output with a 2 uA photocurrent input. The photodiode load resistance must be at least 500 Ohms.

Note that sensitivities below ~ 1 uA photocurrent will likely be unattainable at data rates of ~10 MHz. At this level, electrical noise becomes a limit.

Measurements to be made include

-- The receiver gain and (f_low, f_high) bandwidth when driven electrically with an input sufficiently small that limiting is not occurring. The electrical gain can be measured thus:



-- Receiver operation with an optical input, when driven by the transmitter. This will test the receiver under strong-signal (limiting) conditions.

-- Receiver operation with an optical input, when driven by the transmitter, but with the optical fiber partially pulled out, reducing the signal level until a data pattern with > 100 mV pp amplitude can no longer be perceived at the amplifier output. This will test the receiver under small signal (limiting) conditions.