MASSACHUSETTS INSTITUTE OF TECHNOLOGY
6.071 Introduction to Electronics, Signals and Measurement
Spring 2006

Design, Build and Test a Heart Rate Monitor

Objective:
The objective of this laboratory is to design, build and test a device that measures your heart rate. The device will be based on a non-invasive sensor that detects the variation of the blood flow in your finger due to the heart action.

Expectations:
There are two parts to this project.
1. Design, build and test the instrument
2. Write a detailed report describing your design and the project in general. The report is due on Friday May 12.

You will be working with your lab partner in all aspects of the project except for the writing of the lab report, which must be done independently by each student.

Evaluation and grading will consider both the design and implementation of the circuit and the written report.

It is expected that the report contain, in the minimum, the following information:
- A brief review of the physics of the problem (and not just a reproduction of the description given here. We are focusing on electronics not physiology and thus the extent of this review should be appropriate)
- Systems description of the solution (using block diagrams show how the device works)
- Detailed presentation of each circuit (clean hand drawn circuits are acceptable but I prefer to have circuits drawn with spice or similar software)
- Detailed list of all components used in each circuit
- Plots of the signals at various crucial nodes of the circuit (you may copy screen data and use in your report)
- List of References

Laboratory Schedule:
It is expected that all students attend the regular scheduled times (MWF 12:30-2:30) in the laboratory. Additional times when the laboratory will be open will be posted on the class web site.

Project Description:

Physical description.
As the heart beats the pressure wave that is generated propagates along the arteries. Even though the pressure wave attenuates as a function of distance along the arterial system it is still very strong and may be felt at the extremities. It is very easy to for example sense the beating of the heart by simply touching the artery at the wrist. These pressure fluctuations result in a volumetric change of the blood in the tissue. The pulse that we feel at the wrist affects the blood volume in the fingers although we do not perceive it with our sense of touch.

Due to the changes in the blood volume in the tissue of a finger the transmission and the reflection of light through and from the tissue is altered. By placing a light source on one side of the finger and an appropriate light detector on the other side it is possible to detect changes in the transmitted light due to changes in the blood volume. We will build an apparatus to detect these changes and thus measure the heart rate.

System Description:
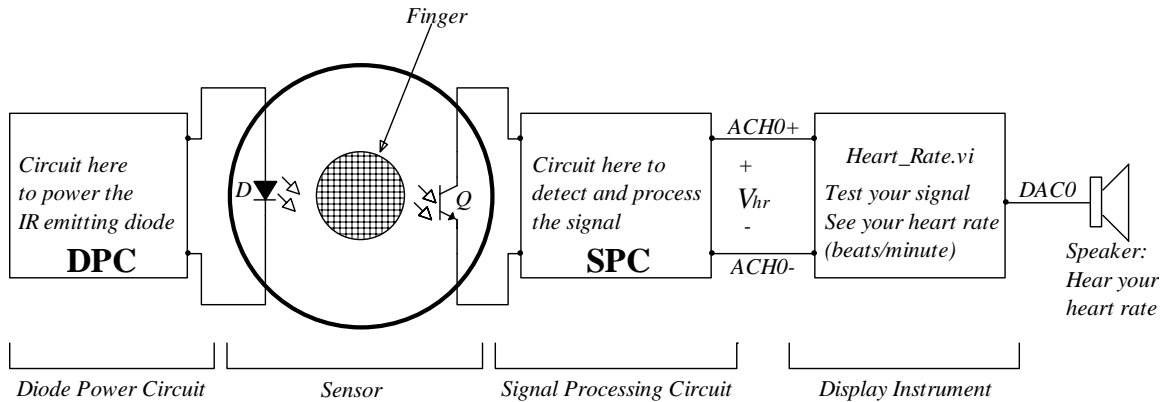The system schematic of the instrument you will be building is shown on Figure 1.

Figure 1. Complete system schematic

You will build and interface the various subsystems shown on Figure 1.

The *sensor*, shown separately on Figure 2, will be constructed using an infrared (IR) light emitting diode (LED) (*D*) and a phototransistor (*Q*). For D you will use the device QED123 and for *Q* you will use QSD124. Both of these devices are available in the laboratory. In addition the data sheets for them are available for viewing and downloading from the class web site. The mechanical characteristics of the sensor should be such that the finger, the diode and the phototransistor do not move during the measurement. Movement will result in signal fluctuations and up to a certain level, your circuit will (or should) account for them.
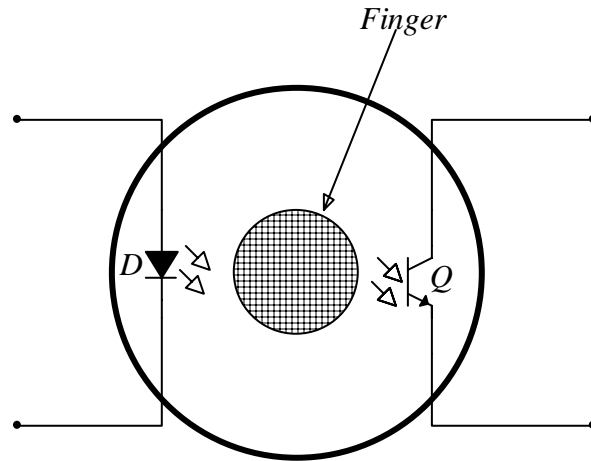
Figure 2. Sensor schematic

The radiant intensity of the IR diode is proportional to the forward current of the diode. You are expected to design the *Diode Power Circuit* (DPC) by taking into consideration the characteristics and ratings of the IR diode. (too much current and the diode is destroyed, too little and the diode does not radiate enough energy for your sensor) Therefore, the operating characteristics of the diode should be optimized for the desired performance.

You may find additional information about the design of LED circuits in the various documents listed at the class web site.

The phototransistor receives the radiant energy and the output signal will depend on the type of amplifier circuit used. You should describe in detail and characterize the behavior of the phototransistor interface circuit before proceeding.

The goal of the *Signal Processing Circuit* (CPC) is to accept as input the phototransistor signal and return signal V_{hr} at its output that has the following characteristics:

- Square wave ranging from 0 Volts to +5 Volts
- Voltage tolerance: $0V \pm 200mV$, $5V \pm 200mV$
- Duty cycle (*dc*) as close to 50% as possible but will accept it if it is in the range: $35\% < dc < 65\%$

In order to achieve these characteristics CPC should contain various sub circuits each performing a specific task. A schematic with some candidate SPC sub circuits is shown on Figure 3. Aside from the obvious position of the phototransistor interface circuit no order is implied or suggested for the other sub circuits.
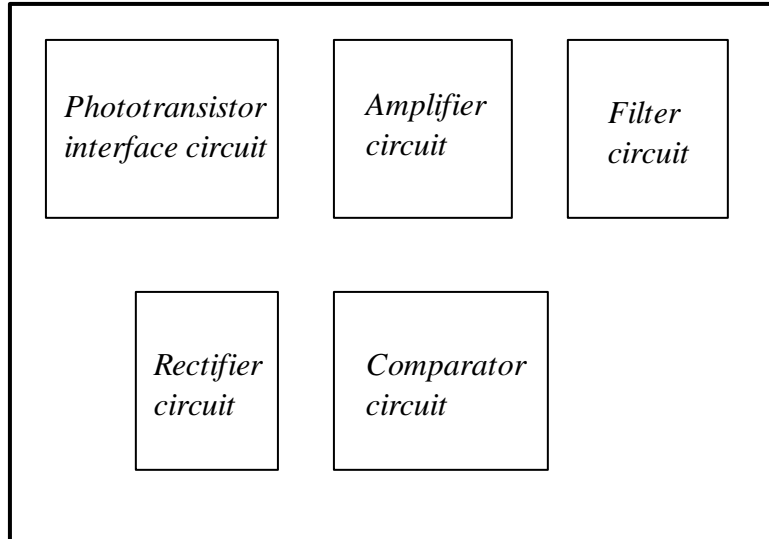
Figure 3. Possible sub-circuits of SPC

The output voltage V_{hr} of SPC will in turn be read by the LabView instrument **Heart_Rate.vi** from channel ACH0. This instrument will evaluate the signal V_{hr} based on the requirements listed above. If the V_{hr} passes these tests the heart rate, in beats per minute, will be calculated and displayed on the screen. Also the signal will be send back out to DAC0 so that you can connect it to your speaker for auditory feedback of the signal.

That's All. Have Fun.