Vibration Sensor Using Mercury Switch

Introduction

The objective of this laboratory is to give you experience with discrete BJT transistor design and exposure to the problem of conceptual design. Given a conceptual design problem, we’d like for you to come up with a prototype circuit design and implementation. For this reason you may notice that the specification for this lab design problem is somewhat vague. To make things more interesting, we will give extra credit to the groups which are able to design the circuit using fewer components than the TAs design¹.

The problem is this: Professor Pileggi seems to be having some difficulty training his dog to stay off of the couch when he isn’t home. Therefore we would like to design a sensor to monitor his couch so that if the dog jumps on the couch, an ultrasonic alarm goes off. The ultrasonic alarm will not be audible to humans, but will be loud enough and of the right frequency to chase the dog.

Various sensors could be used for this monitoring, but one of the simplest would be one which can sense vibration. For this reason we are providing you with a miniature vibration sensor that is made from a mercury switch. The spec sheet is attached to this lab. Design your circuit so that the ultrasonic alarm goes off while the vibration is occurring, and keeps going off for a short time when the vibration stops. For the alarm you will need to build an oscillator that produces an ultrasonic frequency, and you will drive this signal into a piezoelectric speaker which is also provided as part of the lab kit.

I. Vibration Detector

Design a vibration detector that uses the mercury switch. This switch is normally an open circuit when it is at rest in any position, but becomes a momentary short when it is vibrated.

When the switch is vibrated, your detector should notice the momentary short, and set off an ultrasonic alarm for 5-10 seconds. Since the alarm is not audible to humans, you will need to provide a visual indicator for when the alarm is

¹. Fewer components generally translates to lower manufacturing costs, hence larger profits!
activated. We are suggesting that you use an LED for this purpose. For testing purposes, we would also like your oscillator to have a variable frequency so that it may be adjusted down into the human audible range.

**Week 1: Variable Speed Oscillator**

For this week’s lab, design a transistor-level (no opamps please) variable speed oscillator which is capable of oscillating at frequencies between 15kHz and 25kHz. Some example oscillators can be found in the textbook\(^1\), or in one of the many analog circuits books that you will find in the library. Another simple way of designing an oscillator is via a ring oscillator. Simply use an odd number of series connected single transistor inverting amplifiers. **Prior to coming to lab, choose an amplifier configuration, and design the circuit on paper. Simulate it in Spice, and choose appropriate component values.** In lab, build your oscillator and use it to drive a pezoelectric speaker. Demonstrate to your TA that you have a working circuit, and that it drives the speaker at the required frequencies. Bring this circuit to next week’s lab.

During the remaining lab time experiment with your mercury vibration sensor. This will help you in designing the circuit for week 2.

**Week 2: Sensor and Timing Circuit**

For this week’s lab design a circuit that is able to detect the momentary change in resistance of the mercury switch, and activate the alarm for 5-10 seconds. For this

---

1. For example, refer to transistor-level LC oscillator shown on page 988 in the text.
part of the lab, consider the BJT as a voltage controlled current source, and recall the current to voltage relationship of a capacitor. It is possible to meter current through a capacitor, to create a time dependent voltage level. This voltage level can be used to drive an LED, and enable the connection between the oscillator, and the speaker. Thus, one possible block diagram of the circuit is as shown in Figure 3.

![Figure 3](image)

**Week 3: Final Circuit Assembly**

Now that you have built the main portions of this circuit design, use week three for the final assembly and testing of the prototype product. Extra points if you can videotape that it works on your pet at home!

**Parts List:**

1 Mercury Switch
1 Peizoelectric speaker
1 LED

As many PNP transistors, NPN transistors, and passive components as you need.