Acceleration of Gravity

Galileo Galilei is supposedly the first one to prove that the speed of a falling object is independent of its mass. He did this by demonstrating that a 100 pound cannonball and a one pound ball dropped at the same time from the Leaning Tower of Pisa reached the ground at the same time. The acceleration of gravity is therefore independent of mass and is expresses as follows:

$$g = \frac{2h}{t^2} \qquad \text{[eq.1]}$$

where g the acceleration of gravity, h is the distance an object falls, and t is the time for the object to fall a distance h.

If Galileo had chosen to drop a feather instead of the one pound ball, the result would have been different; unless of course he performed his experiment in a vacuum where there is an absence of drag.

The following describes the experimental setup for measuring the acceleration of gravity in vacuum. It can also be used for experiments to determine drag coefficients and Reynolds number for different objects at different pressures. For detailed discussions on drag, drag coefficients, and Reynolds number see http://princeton.edu/~asmits/Bicycle_web/blunt.html and http://www.ma.iup.edu/projects/CalcDEMma/drag

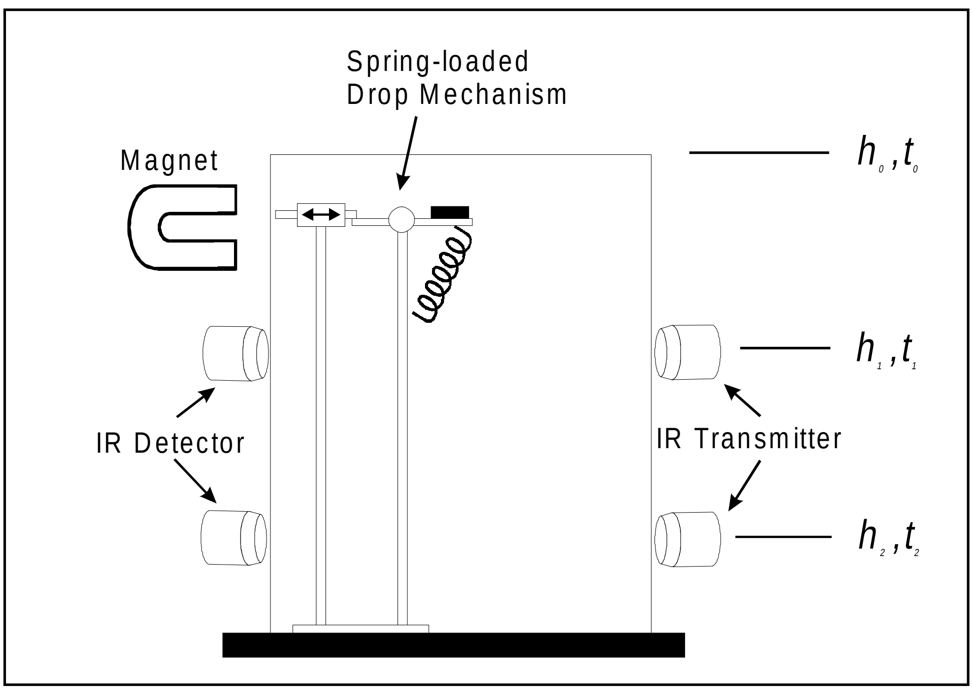

Figure 1. Vacuum chamber, drop mechanism, and IR emitters and sensors for measuring the accelaration of gravity for objects in vacuum or reduced pressures.

There are three main components for this exercise: (1) a vacuum system, (2), a drop mechanism, and (3) a timing device. The experimental setup is shown in figure 1. The vacuum system can be quite simple. A single stage pump with a polycarbonate vacuum jar capable of maintaining a pressure of a few millitorr will suffice. The drop mechanism must be controllable external to the vacuum chamber.

In this case, the measurement of the acceleration due to gravity is based on the time it takes an object to travel between to fixed points.

$$\Delta t = \sqrt{\frac{2(h_1 + h_2)}{g}} - \sqrt{\frac{2(h_1)}{g}}$$

[eq.2]

The timing device consists two sets of infrared transmitters (Optek infrared emitter OP133) and receivers (Optek photosensor OP803) and a control module. The schematics for the control module are shown in figures 2 -4. The schematics show the circuitry for an adjustable clock speed of about 5000Hz. The actual speed will have to be measured. The circuitry in figure 3 is for a counter resolution of 12 bits or 4096 clock pulses. This means that the beam spacing must be approximately six to ten centimeters in order insure that the counter capability is not exceeded . This allows for an overall timing resolution of ± 0.0002 seconds. If greater resolution is desired, the clock speed must be increased and the counter circuitry modified for 16 bit resolution. Regardless of counter resolution, the beam spacing must be such that the maximum drop time does not exceed the counting capability of the circuit.

A clock is used with a known time period . The clock is started and stopped, similar to a stopwatch. The falling object passes through two infrared (IR) beams which in turn provide start/stop signals for the clock. As the falling object passes through the first IR beam the counting of the clock pulses is initiated. After the object falls past the second IR beam the counting circuit receives a stop counting signal and the total number of clock pulses is displayed on a bank of LED’s in a binary format. The time for the object to fall between the two IR beams is then calculated according to equation 1. Using this time, the distance between the IR beams and the initial height of the object above the first IR beam the acceleration due to gravity can be calculated.

Δt is determined as follows:

1. convert the binary output to the decimal value of the number of clock pulses.

2. $$\Delta t = \frac{number\ of\ clock\ pulses}{clock\ speed}$$

3. rearranging equation 2

$$g = \frac{2h_1}{\Delta t^2}\left(\sqrt{\frac{h_1 + h_2}{h_1}} - 1\right)^2$$

[eq.3]

Because the earth is not a perfect sphere the acceleration of gravity must be corrected for latitude(ϕ) and elevation (H) in cm using Helmert's equation

$$g(\text{corrected}) = 980.616 - 2.5928 \cos 2\phi + 0.0069 \cos^2 2\phi - 3.086 \times 10^{-4} H$$

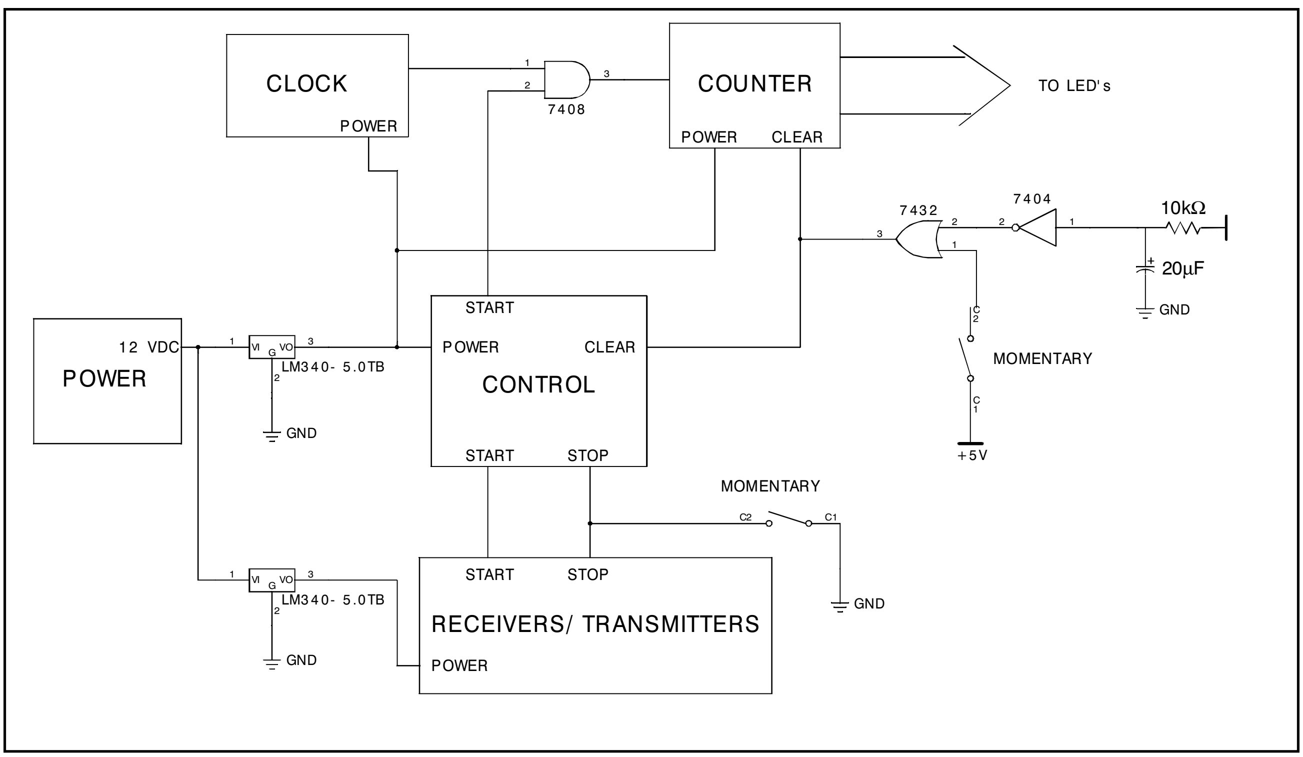

Figure 2. Block diagram of IR timing device

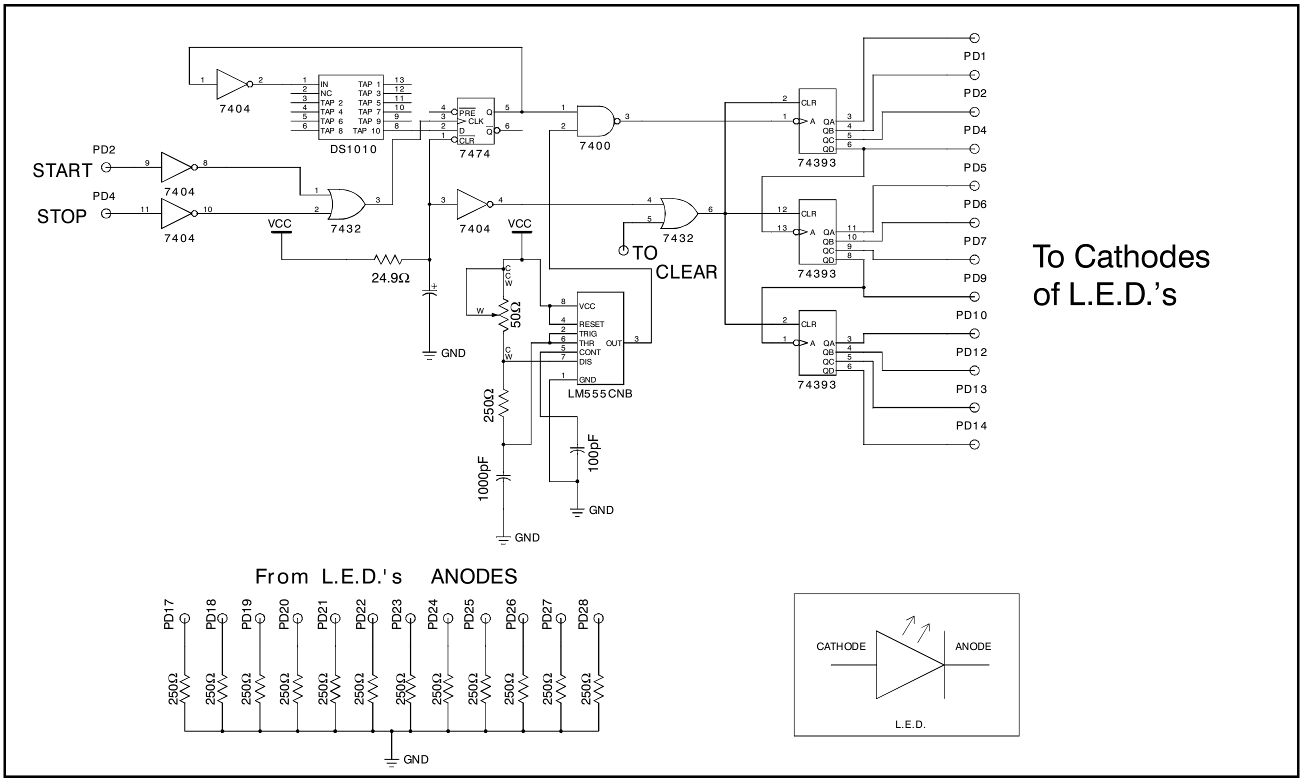

Figure 3. Schematic diagram of clock and counter

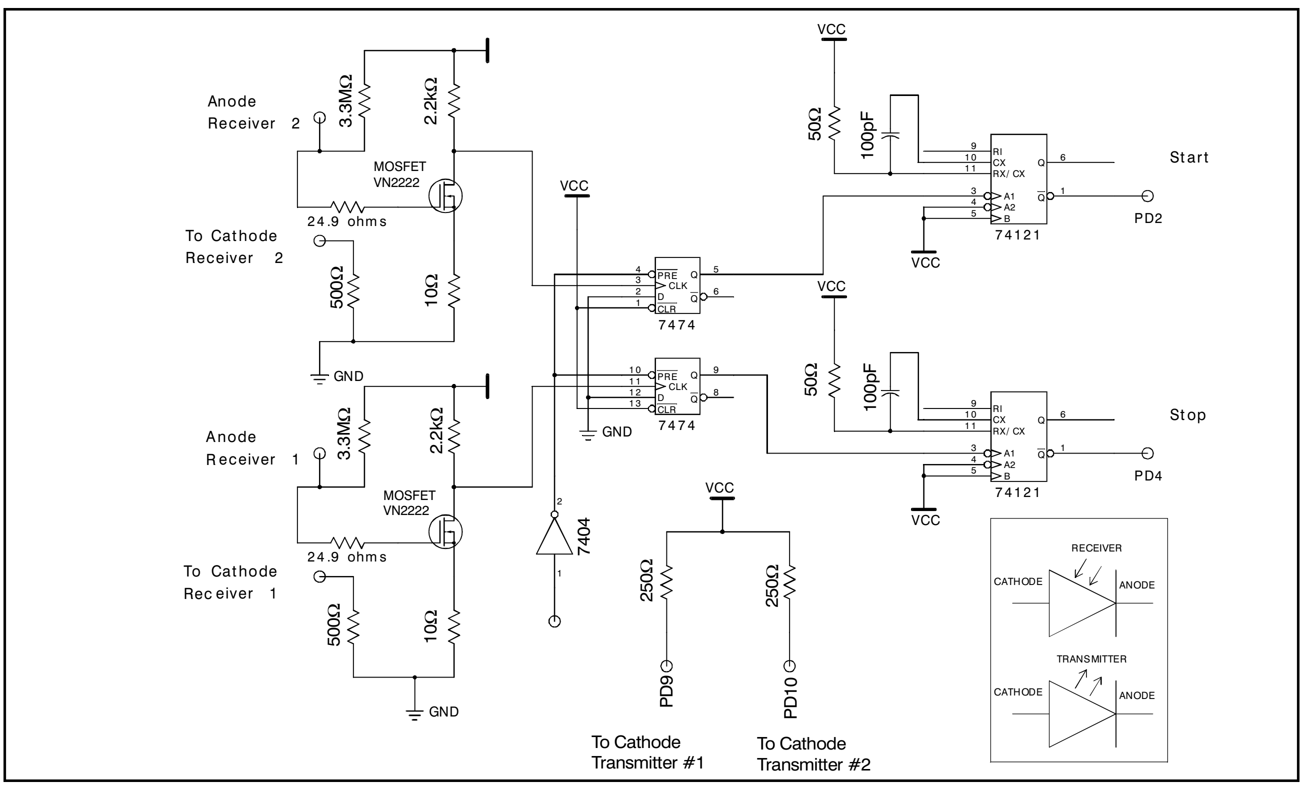

Figure 4. Schematic diagram of control and receiver/transmitter