Breadboard Security System

The main objective of this project was to create a security system using a series of four different circuit modules which are briefly described below.

The system has two modes – day and night mode, which are controlled by using the cadmium sulfide (CdS) photocell and comparator in ***Module 1***. The light-emitting diode (LED) is used to indicate the output state of the comparator. The LED is off in day mode and on in night mode. The resistor values used were $R_1 = R_2 = 5.6$ kΩ and $R_{out} = 660$ Ω. A 47 kΩ resistor was used for R_x because the measured values of the day and night mode photocell resistances were 1 kΩ and 100 kΩ respectively. R_x forms a voltage divider with the photocell, and the voltage at V_p may be higher or lower than V_{ref} (which is about 2.5 V) depending on the photocell's resistance. Ideally, during day mode $V_P < 2.5$ V, (i.e. positive saturation/logic high) and during night mode $V_p > 2.5$ V (negative saturation/logic low). Using a 47 kΩ value for R_x results in:

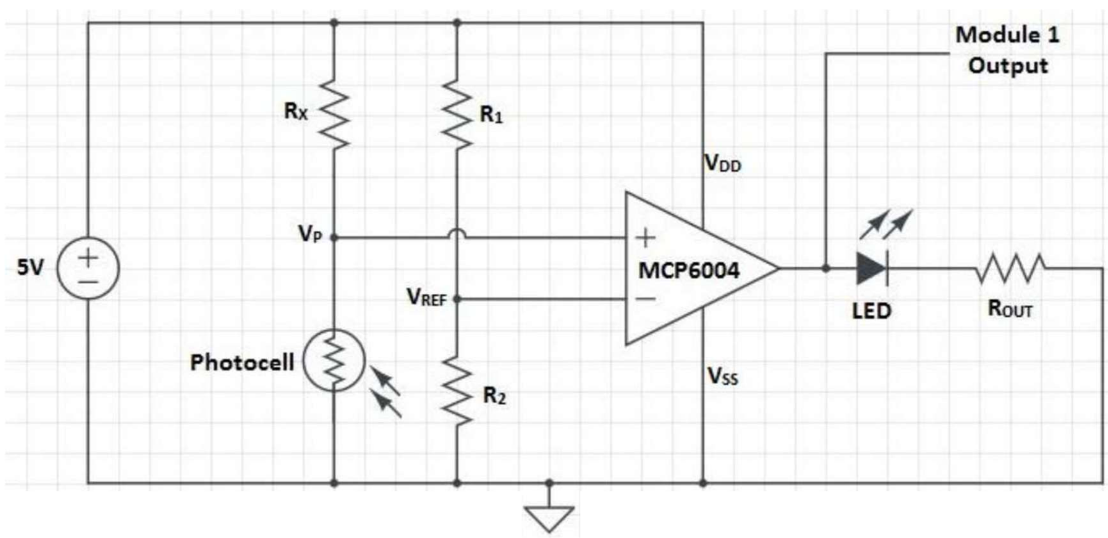
$$Daytime\ V_p = \frac{5\ V * R_X}{R_X + \boldsymbol{R_{Ph}}} = \frac{5(4.7 * 10^4)}{4.7 * 10^4 + \mathbf{10^3}} = 4.896\ V$$

$$Daytime\ V_p > 2.5\ V$$

$$Nighttime\ V_p = \frac{5\ V * R_X}{R_X + \boldsymbol{R_{Ph}}} = \frac{5(4.7 * 10^4)}{4.7 * 10^4 + \mathbf{10^5}} = 1.599\ V$$

$$Nighttime\ V_p < 2.5\ V$$

Note that about a 1 V offset from 2.5 V was chosen for night mode to serve as a safety margin.

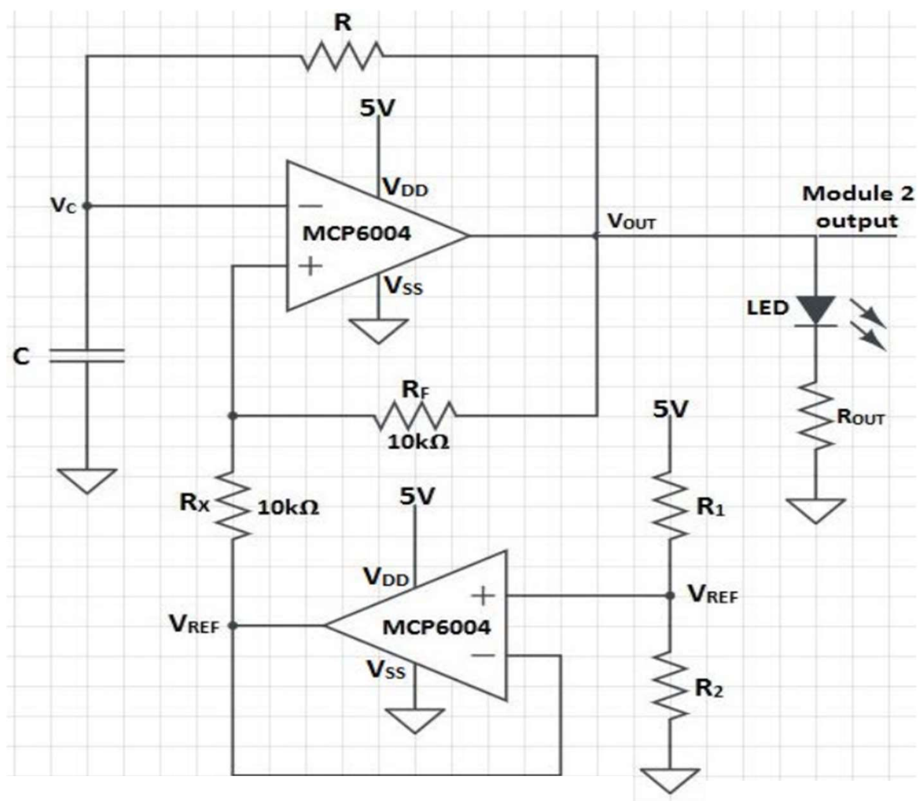


Module 1

Module 2 implements an RC oscillator using an operational amplifier with a positive feedback connection. The output of the oscillator is a digital square wave signal with only two states – on and off. The oscillator signal will be routed through ***Module 4*** and used to turn a piezoelectric buzzer on and off at a rate of approximately 2 – 6 Hz, similar to the beep rate of a typical smoke detector. The following values were used for ***Module 2***: R = 150 kΩ, $R_x = R_f = 10$ kΩ, $R_1 = R_2 = 5$ kΩ, $R_{out} = 660$ Ω, C = 1 μF. Based on the chosen components, the actual oscillation frequency of the buzzer was about 3 Hz:

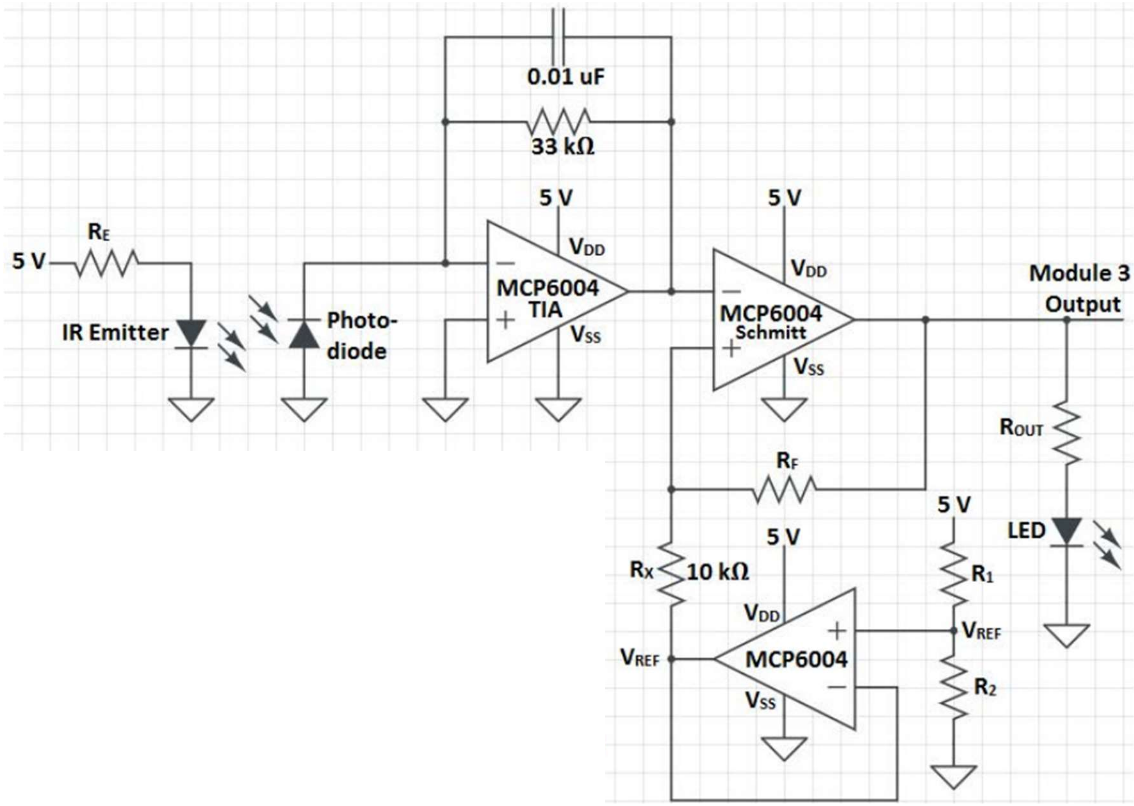
$$f_0 = \frac{1}{2RC * \ln\left(1 + \frac{2R_x}{R_f}\right)}$$

$$f_0 = \frac{1}{2(1.5 * 10^5)(1 * 10^{-6})\ln\left[1 + \frac{2(10^4)}{10^4}\right]} = 3.034\ Hz$$



Module 2

An infrared (IR) emitter and photodiode were utilized in ***Module 3*** to indicate whether an object (i.e., "intruder") has blocked the beam path between the components. The output from the photodiode is converted to voltage using a transimpedance amplifier (TIA), which is then connected to a Schmitt trigger in that same module. The Schmitt Trigger provides the required output states: high = LED on (beam path blocked), low = LED off (beam path clear). The following values were used for this module: R_E = 118 kΩ, R_F =135 kΩ (120 kΩ and 15 kΩ resistor in series), R_x = 10 kΩ, and R_{out} = 1 kΩ.



Module 3

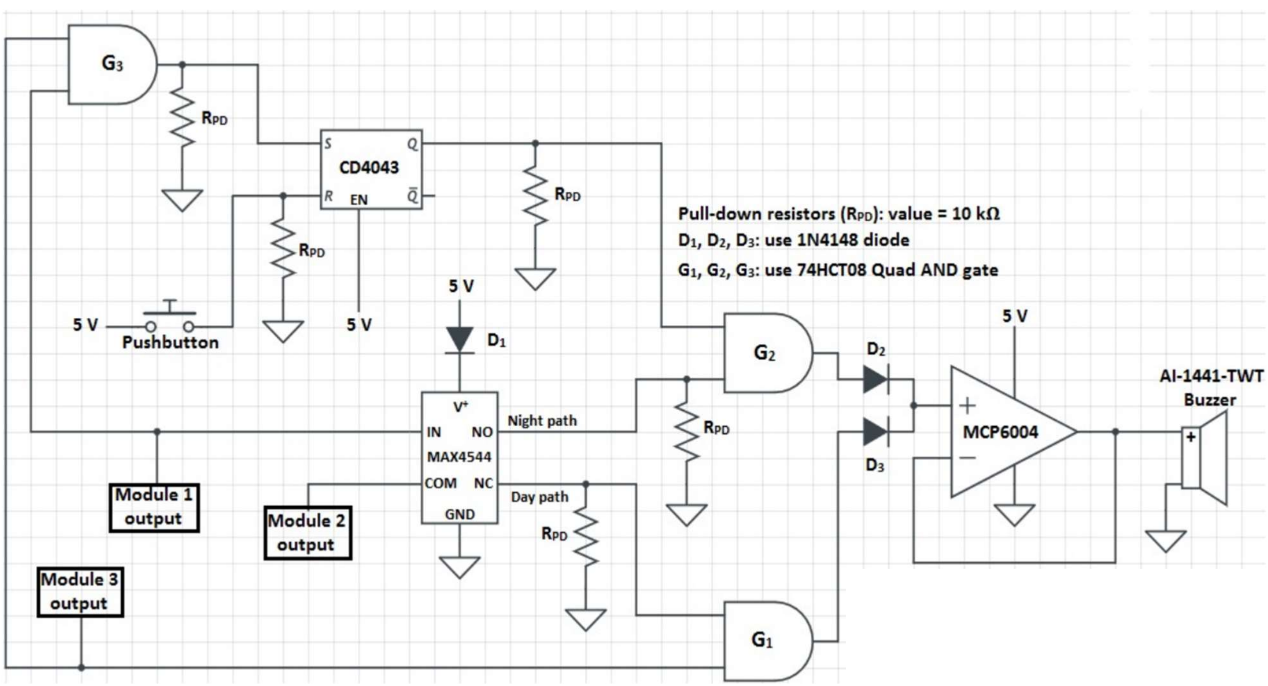
The three previous modules are combined into ***Module 4*** to route and control the signal according to day and night mode. The circuit functions as follows:

- Day mode: the buzzer is silent while the IR beam path is clear. The alarm sounds if the beam path is blocked. Once the blockage is removed, the buzzer shuts off.
- Night mode: the buzzer is silent while the IR beam path is clear. The alarm sounds once the beam path is blocked and continues sounding even if the blockage is removed. The alarm goes silent only when user presses the "reset" push button.

The set-reset latch (CD4043) is a one-bit memory element that is used during night mode to remember whether or not the alarm has been tripped by blockage of the IR beam. The SPDT (single-pole, double-throw) switch (MAX4544) is used to route a signal from a single input to one of two outputs (night or day path) depending on the input to the control pin.

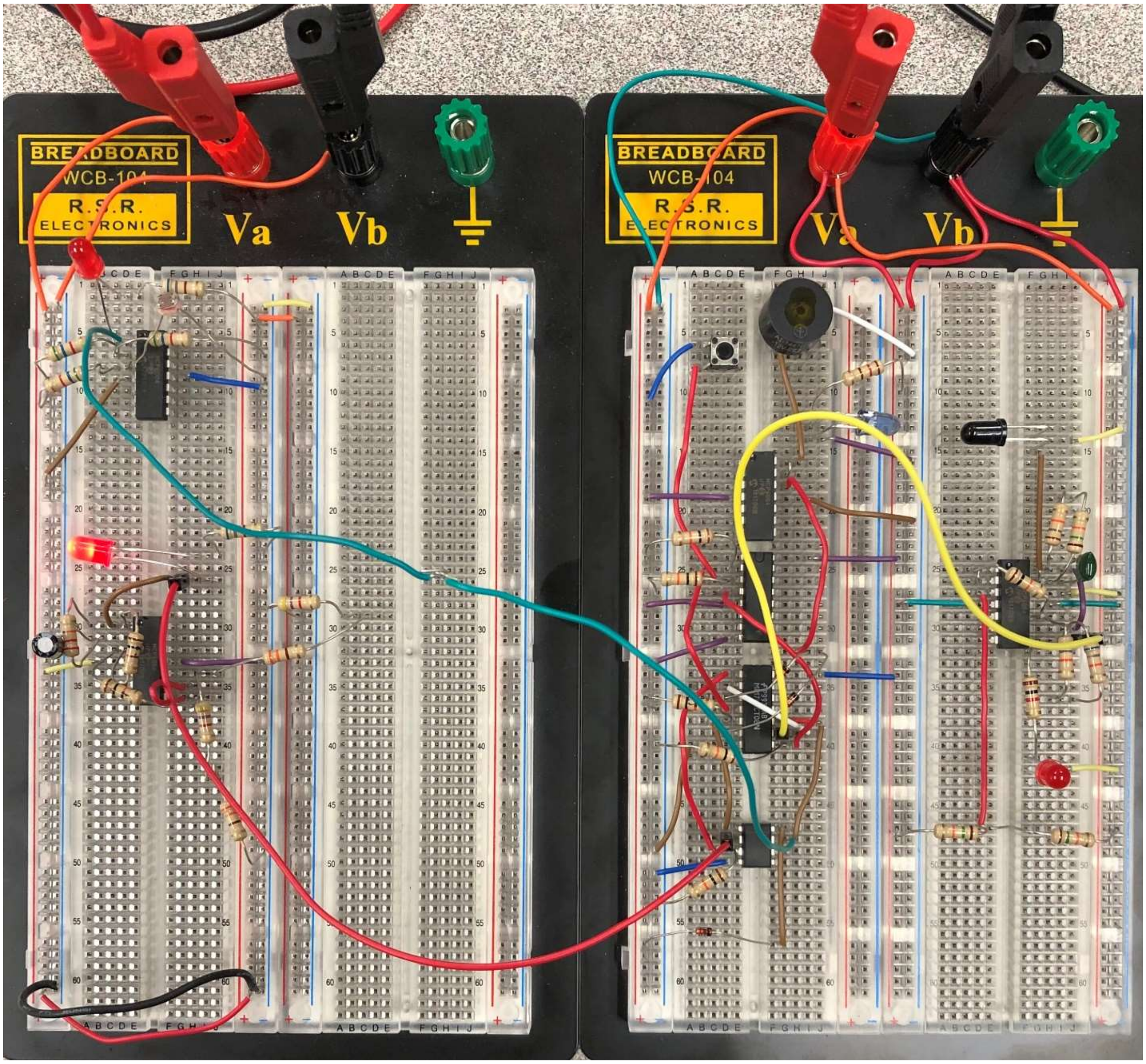
The dual input AND gates are logic devices used to control when a signal is allowed to pass through some portion of the circuit:

- Function of G_1: uses the signal from ***Module 3*** (TIA/inverting Schmitt trigger) to control whether the oscillator signal present on the "day path" is allowed to pass through to the buzzer.
- Function of G_2: in night mode, it uses the signal from the output (Q) of the set-reset latch to determine whether oscillator signal present on the "night path" is allowed to pass through to the buzzer.
- Function of G_3: sends a high signal to the "set" pin of set-reset latch when the following two conditions exist – the system is in night mode and the beam is blocked. The high signal present at the "set" pin sets Q to high, allowing oscillator signal to pass through G_2.



Module 4

Putting this all together, this is what the final implementation looked like:



For a demonstration of the system performing as intended, visit the following link:
https://www.youtube.com/watch?v=sROPdCLaZEc&ab_channel=NolanSpencer