BioOne COMPLETE

Circuitry and Coding Used in a Flight Mill System to Study Flight Performance of Halyomorpha halys (Hemiptera: Pentatomidae)

Authors: Hahn, Noel G., Hwang, Michael C., and Hamilton, George C.

Source: Florida Entomologist, 100(1) : 195-198

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.100.0133

BioOne Complete (complete.BioOne.org) is a full-text database of 200 subscribed and open-access titles in the biological, ecological, and environmental sciences published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Complete website, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Complete content is strictly limited to personal, educational, and non - commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Downloaded From: https://complete.bioone.org/journals/Florida-Entomologist on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

Circuitry and coding used in a flight mill system to study flight performance of *Halyomorpha halys* (Hemiptera: Pentatomidae)

Noel G. Hahn, Michael C. Hwang, and George C. Hamilton*

Flight mills have been used by researchers to explore the flight capacity of many insects. The effects of biotic factors such as sex, age, and mating status, or abiotic factors such as temperature or humidity have been tested in the laboratory with insects from a number of orders including Diptera, Lepidoptera, Hemiptera, and Coleoptera (Schumacher et al. 1997; Sarvary et al. 2008; Zhang et al. 2008; Taylor et al. 2010). Different designs of the physical flight mill apparatus have been created and used. Early flight mill systems were designed to assess flight of mosquitoes, including several *Aedes* species (Diptera: Culicidae), and some papers detailed the associated circuitry for recording data (Hocking 1953; Rowley et al. 1968). Several other flight mills were designed and tested by Clements (1955) and Atkins (1961), including mills for use with Mexican fruit fly (Diptera: Tephritidae) and boll weevil (Coleoptera: Curculionidae) (Chambers & Connell 1969; McKibben 1985). Weber et al. (1993) used polarized magnets to repel each other to create a frictionless pivot and suspended an axle with support arms to secure the insect. Current flight mills use similar designs, and data recording is conducted through the use of photogates or Hall effect sensors (Jones et al. 2010), data collection modules, and accompanying software (Bradley & Altizer 2005; Castro et al. 2014; Lee & Leskey 2015). The declining cost of electronics and access to open-source software has made it relatively easy to create individualized data recording modules and programs. We designed and created circuitry and a program to measure flight capacity of *Halyomorpha halys* Stål (Hemiptera: Pentatomidae), the brown marmorated stink bug, coupled with a photogate and an Arduino board, an open-source hardware platform.

Our original designs were based on work of Rowley et al. (1968). The current iteration of our flight mill uses 2 small magnets (1 for counterbalance) attached to prongs on the underside of the hub. These magnets spin with the hub, and circle over a Hall effect sensor used to record the number of rotations the insect flew by counting the instances of the magnets passing over the sensor. The data acquisition software DASYLab® Basic (Registration No. 1919405, National Instruments Corporation, Austin, Texas, 2014) and accompanying data collection module, USB-1024 (Measurement Computing Corporation, Norton, Massachusetts), were used to measure the number of rotations flown by the insect.

A new design was created to account for problems encountered with the model described above by using household circuitry, hardware, and complimentary software of Arduino to create a laser tripwire system. This design records every time the insect breaks the path of the laser, which then is recorded on an associated computer with the hardware of the Arduino circuit board and is cost efficient in comparison with much of the commercial software available for data acquisition. A single Arduino board and breadboard and associated circuitry can run up to 6 flight mills. Components for a recording from a single flight mill include two 100-Ohm ½-Watt resistors, a coil of wire, 1 LED bulb, a photoresistor (light-dependent resistor), and a 1.5 V laser pointer (with a power source) (Fig. 1). The laser tripwire is created by pointing a laser at a photoresistor, a resistor whose resistance is lowered with increasing light intensity, which in this arrangement is triggered by the photons emitted by a laser pointer. If the laser is broken, the Arduino board and computer register on which mill the break was detected, record the time of the break, and add an increment to a counter.

The Arduino program is able to detect the voltage running through the circuit. We can record exactly when the path of the laser has been broken because of the voltage change in the circuit due to the resistance change of the photoresistor. The change in voltage also influences a second circuit wired to an LED bulb. When the voltage breaks a certain threshold, the LED bulb is turned on, signaling the break in the laser's path and incrementing a counter variable. The process is timed and recorded to the nearest millisecond, allowing the user to determine average and instantaneous speeds.

The coding for the recording of the flight mills is in the Arduino coding language, which is an open-source software (https://www.arduino.cc/en/Main/Software). Our code allowed us to record the number of rotations and the time when the laser was interrupted (Fig. 2). Although there are 2 metal arms, the code allows for the voltage threshold to be such that the thin metal does not influence readings and only records when the insect or a paper tab breaks the laser. In addition to the timing, humidity and temperature are recorded with a DHT22 sensor (Aosong Electronics Co., Ltd, Guangzhou, China). This sensor, connected to an Arduino board, accurately displays the humidity, temperature, and heat index. Additional open-source software called CoolTerm (http://www.freeware.the-meiers.org/) allows all data to be printed in the Arduino serial monitor and saved as a text file.

With a maximum of 6 flight mills per Arduino board, the laser tripwire is a cost-efficient addition to the flight mill apparatus that is not hindered by magnetic fields, interference, complex wiring, or programming, and is simple and editable. An Arduino Uno can be purchased on the company's website for US$25 (https://store.arduino.cc/product/GBX00066), and resistors, LED bulbs, photoresistors, a breadboard, and wiring should cost between US$20 and US$30.

Rutgers University, Department of Entomology, New Brunswick, NJ 08901, USA; E-mail: nghahn@gmail.com (N. G. H.), mchwang0002@gmail.com (M. C. H.), hamilton@aesop.rutgers.edu (G. C. H.)
*Corresponding Author; email: nghahn@gmail.com (N. G. H.)

Downloaded From: https://complete.bioone.org/journals/Florida-Entomologist on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

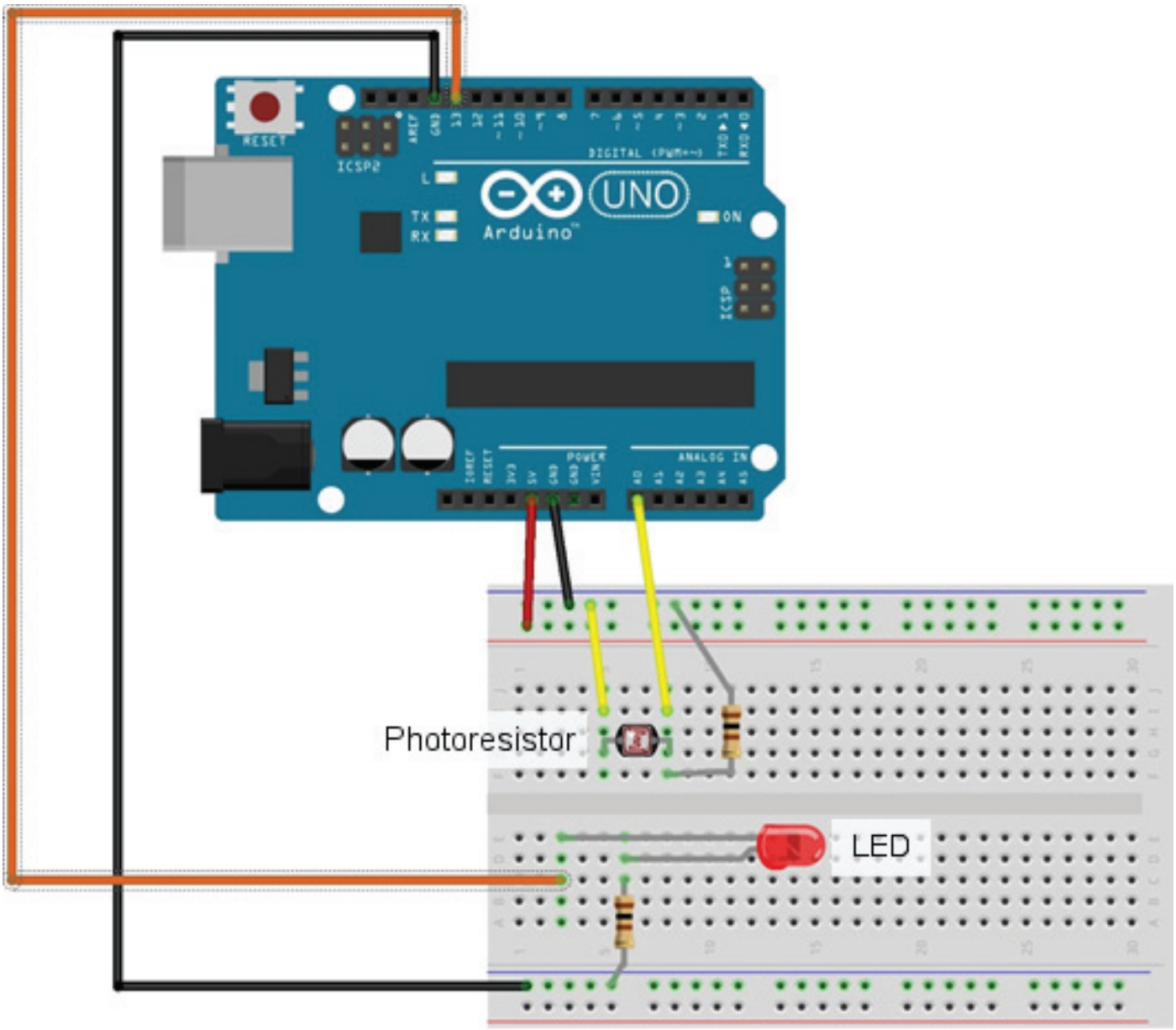


Fig. 1. The schematics for 4 laser trip wire systems on a single breadboard and a single Arduino board. Lasers have been excluded. Note how the Arduino board allows for the hybrid use of both analog and digital circuitry systems.

Summary

We present the circuitry design and plans of a photogate and accompanying Arduino board with coding for a data recording program used with a flight mill apparatus. These are being used to test the flight capacity of *Halyomorpha halys* Stål (Hemiptera: Pentatomidae) under various environmental conditions.

Key Words: brown marmorated stink bug; laser; Arduino; flight capacity

Sumario

Presentamos el diseño de circuitos y los planos de un fotogate (un aparato que mide pequeños intervalos de tiempo entre eventos) y el tablero Arduino que lo acompaña con codificación para un programa de grabación de datos usado con un aparato de molino de vuelo. Estos se están utilizando para probar la capacidad de vuelo de *Halyomorpha halys* Stål (Hemiptera: Pentatomidae) bajo diversas condiciones ambientales.

Palabras Clave: chinche café marmorado; láser; Arduino; capacidad de vuelo

Downloaded From: https://complete.bioone.org/journals/Florida-Entomologist on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

```
//Initializing temperature/humidity sensor
#include "DHT.h" //comment out this and additional coding
#define DHTPIN 2 //referring to temperature/humidity if
#define DHTTYPE DHT22 //not using DHT sensor
DHT dht(DHTPIN,DHTTYPE);

//Static variables - initializing
unsigned long count1; //creating the value count1, a counter
unsigned long time; //making a variable to record time
int ledpin1 = 13; //the pin the LED is connected to
int photopin1 = A0; //the pin the photoresistor is connected to
int threshold1 = 100; //threshold value for photoresistor
int photostate1 = 0; //value of the photoresistor

//Changing variables - initializing
int photoswitch1; //photoresistor value as a 1 or 0
int lastswitch1; //needed to make photoresistor act like a switch

void setup() //this is initial setup when the program starts
{
 Serial.begin(9600); //this initializes the code at 9600 bits per second
 pinMode(ledpin1,OUTPUT); //this sets pin 13, connected to LED1, to output
 count1 = 0; //sets count1 to 0 when the program starts
 Serial.print("TIME"); //prints "TIME"
 Serial.print("\t"); //prints a tab
 Serial.print("MILL 1"); //prints "MILL 1"
 dht.begin(); //starts the temperature/humidity sensor
}

void summary() //function to use to print out values
{
    float h = dht.readHumidity(); //creates a variable to record humidity
    float t = dht.readTemperature(); //creates a variable to record temperature in Celsius
    time = millis(); //records the time in milliseconds
    Serial.println(""); //add a blank line
    Serial.print(time); //prints time since start in milliseconds
    Serial.print(","); //prints a comma
    Serial.print("\t"); //prints a tab
    Serial.print(count1); //prints current number of count
    Serial.print(",");
    Serial.print("\t");
    Serial.print(h); //prints humidity
    Serial.print(",");
    Serial.print(t); //prints temperature in Celsius
    Serial.print(" C");
}
```

Fig. 2. The coding used to record the number of rotations flown by the insect on the flight mill.

Downloaded From: https://complete.bioone.org/journals/Florida-Entomologist on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use

References Cited

Atkins MD. 1961. A study of the flight of the Douglas-fir beetle *Dendroctonus pseudotsugae* Hopk. (Coleoptera: Scolytidae): III flight capacity. The Canadian Entomologist 93: 467–474.

Bradley CA, Altizer S. 2005. Parasites hinder monarch butterfly flight: implications for disease spread in migratory hosts. Ecology Letters 8: 290–300.

Castro LA, Peterson JK, Saldana A, Perea MY, Calzada JE, Pineda V, Dobson AP, Gottdenker NL. 2014. Flight behavior and performance of *Rhodnius pallascens* (Hemiptera: Reduviidae) on a tethered flight mill. Journal of Medical Entomology 51: 1010–1018.

Chambers DL, Connell TBO. 1969. A flight mill for studies with the Mexican fruit fly. Annals of the Entomological Society of America 62: 917–920.

Clements AN. 1955. The sources of energy for flight in mosquitoes. Journal of Experimental Biology 32: 547–554.

Hocking B. 1953. The intrinsic range and speed of flight of insects. Transactions of the Royal Entomological Society of London 104: 223–345.

Jones VP, Smith TE, Naranjo SE. 2010. Insect Ecology and Behavior Laboratory: Flight Mill Studies. http://entomology.tfrec.wsu.edu/VPJ_Lab/Flight-Mill.html (last accessed 10 Dec 2016).

Lee DH, Leskey TC. 2015. Flight behavior of foraging and overwintering brown marmorated stink bug, *Halyomorpha halys* (Hemiptera: Pentatomidae). Bulletin of Entomological Research 105: 566–573.

McKibben GH. 1985. Computer-monitored flight mill for the boll weevil (Coleoptera: Curculionidae). Journal of Economic Entomology 78: 1519–1520.

Rowley WA, Graham CL, Williams RE. 1968. A flight mill system for the laboratory study of mosquito flight. Annals of the Entomological Society of America 61: 1507–1514.

Sarvary MA, Bloem KA, Bloem S, Carpenter JE, Hight SD, Dorn S. 2008. Diel flight pattern and flight performance of *Cactoblastis cactorum* (Lepidoptera: Pyralidae) measured on a flight mill: influence of age, gender, mating status, and body size. Journal of Economic Entomology 101: 314–324.

Schumacher P, Weyeneth A, Weber DC, Dorn S. 1997. Long flights in *Cydia pomonella* L. (Lepidoptera: Tortricidae) measured by a flight mill: influence of sex, mated status and age. Physiological Entomology 22: 149–160.

Taylor RAJ, Bauer LS, Poland TM, Windell KN. 2010. Flight performance of *Agrilus planipennis* (Coleoptera: Buprestidae) on a flight mill and in free flight. Journal of Insect Behavior 23: 128–148.

Weber DC, Ferro DN, Stoffolano JG. 1993. Quantifying flight of Colorado potato beetles (Coleoptera: Chrysomelidae) with a microcomputer-based flight mill system. Annals of the Entomological Society of America 86: 366–371.

Zhang Y, Wang L, Wu K, Wyckhuys KAG, Heimpel GE. 2008. Flight performance of the soybean aphid, *Aphis glycines* (Hemiptera: Aphididae) under different temperature and humidity regimen. Environmental Entomology 37: 301–306.

Downloaded From: https://complete.bioone.org/journals/Florida-Entomologist on 29 Mar 2024
Terms of Use: https://complete.bioone.org/terms-of-use