PAPERS | SEPTEMBER 01 2022

Using Arduinos as Portable Measurement Devices

Gerd Kortemeyer

Phys. Teach. 60, 470 (2022)
https://doi.org/10.1119/5.0044134

Using Arduinos as Portable Measurement Devices

Gerd Kortemeyer, Michigan State University, East Lansing, MI

In recent years, do-it-yourself microcontrollers and sensors have gained increased attention as measurement devices for physics teaching (see, for example, Refs. 1-5). This is not surprising, since Arduinos are relatively cheap and ubiquitous, the code base and design are open source, and there is a wide variety of sensors available. Arduinos can be directly coupled to analysis programs on personal computers[6] and smartphones.[7] This article presents another way of using Arduinos for measurements, namely as portable, standalone devices that store their data on SD memory cards.

This is relatively easy to implement by using a Data Logger Shield, which cost around $14 in 2022 (without the memory card). As can be seen in Fig. 1, the shield (top blue circuit board) plugs between the microcontroller (bottom green circuit board) and whatever other setup you may already have, like the sensors (as can be seen in the figure, the shield simply extends the input/output connectors from the bottom to the top circuit board).

Figure 2, as an example, shows the code for a system that logs three-axis acceleration data in units of *g* as a tab-separated file on the SD card. That file in turn can be loaded into, for example, Excel after plugging the SD card into a personal computer.

The Serial.print statements are for debugging only when the Arduino is still connected to the IDE (integrated development environment). The chipSelect variable needs to be adjusted to the data logger you are using; this is documented in the SD card library.

When doing measurements, the Arduino can run standalone from a battery. Since there is no way to properly eject the memory card, in the above implementation, the file is opened and closed for every single appended data entry; this limits the sampling rate, and for higher rates, buffering might have to be implemented—this, like many things Arduino, takes a little (fun) experimentation.

The acceleration sensor is, of course, only an example, chosen for its simplicity; arguably, the same data recording could be accomplished with a smartphone. However, the technique works with most of the other available sensors: sonar distance, temperature, humidity, Geiger counter, CO_2, etc., most of them at less than a tenth of the cost of the sensors from the usual undergraduate laboratory equipment suppliers. Finally, of course, the whole setup costs far less than a tenth of the cost of a smartphone, so if something breaks during an experiment, it is no big deal.

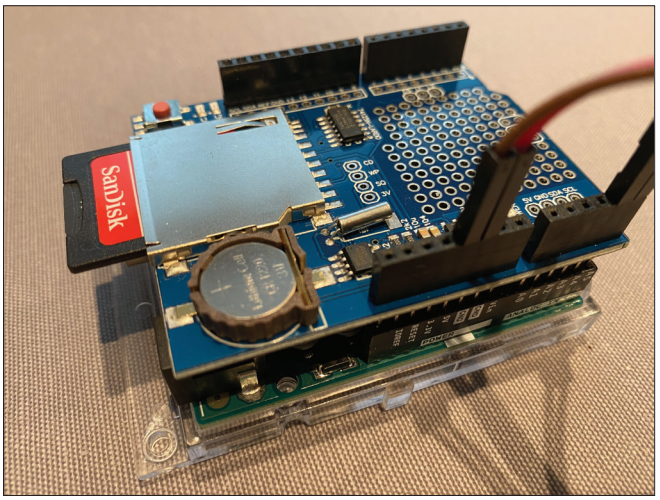

Fig. 1. Arduino with Data Logger Shield and SD memory card.

```
#include <SPI.h>
#include <SD.h>
#include <SparkFun_MMA8452Q.h>
MMA8452Q accel;

const int chipSelect = 10;

void setup() {
  Serial.begin(9600);
  while (!Serial) {
    ; // wait for serial port to connect. Needed for native USB port only
  }

  Serial.print("Initializing SD card...");

  if (!SD.begin(chipSelect)) {
    Serial.println("Card failed, or not present");
    // don't do anything more:
    while (1);
  }
  Serial.println("card initialized.");
  accel.init(SCALE_8G,ODR_1);
}

void loop() {
  if (accel.available()) {
    accel.read();
    String dataString=String(accel.cx,3)+"\t"
                      +String(accel.cy,3)+"\t"
                      +String(accel.cz,3);
    File dataFile = SD.open("datalog.txt", FILE_WRITE);
    if (dataFile) {
       dataFile.println(dataString);
       dataFile.close();
     } else {
       Serial.println("error opening datalog.txt");
    }
  }
}
```

Fig. 2. Arduino code for reading out a sensor and writing to the SD card.

References

1. C. Galeriu, S. Edwards, and G. Esper, "An Arduino investigation of simple harmonic motion," *Phys. Teach.* **52**, 157–159 (March 2014).
2. M. McCaughey, "An Arduino-based magnetometer," *Phys. Teach.* **55**, 274–275 (May 2017).
3. C. Galeriu, "An Arduino investigation of Newton's law of cooling," *Phys. Teach.* **56**, 618–620 (Dec. 2018).
4. A. A. Moya, "Studying Avogadro's law with Arduino," *Phys. Teach.* **57**, 621–623 (Dec. 2019).
5. F. Önder, E. B. Önder, and M. Oğur, "Determining transistor characteristics with Arduino," *Phys. Teach.* **58**, 422–424 (Sept. 2020).
6. D. Nichols, "Arduino-based data acquisition into Excel, LabVIEW, and MATLAB," *Phys. Teach.* **55**, 226–227 (April 2017).
7. S. V. Ballesta, R. Saez, J. Iglesias, and A. Vernet, "Arduino-smartphone device as a physical phenomena measurer," *Phys. Teach.* **58**, 663–665 (Dec. 2020).

Michigan State University, East Lansing, MI 48824; kortemey@msu.edu

 DOI: 10.1119/5.0044134