AudioMoth Temperature Measurements

theteam@openacousticdevices.info

6th June 2020

The AudioMoth micro-controller contains a factory-calibrated temperature sensor.[1] This sensor has not been used in previous versions of the AudioMoth firmware. However, version 1.4.0 adds a temperature measurement at the start of each recording with the results written to the comments section of the WAV file header. This comment can be read directly in many operating systems (see Figure 1) and is also available in most audio applications that read WAV files.

More usefully, the comment can also be automatically extracted from the WAV files by a Python or R script. Figure 4 shows a Python script to extract the timestamp and timezone, the battery voltage, and the temperature from all the WAV files in the current directory. The script exploits the fact that AudioMoth recordings have a fixed format with the comments having a fixed location and length such that they can be read without having to parse the entire file.

The internal temperate sensor is calibrated at the factory when the micro-controller is manufactured and this calibration is read from memory whenever the temperature sensor is used. The calibration is an offset that is applied to the internal analog-to-digital converter (ADC) reading, and the value of the offset was determined at a nominal temperature of 25 °C at the factory. The gain is fixed for all devices and is described on the device data sheet. Silicon Labs do not make any claim on the accuracy of the factory calibration and in the worse case it may be up to ± 3°C as the nominal 25 °C is an assumed ambient temperature rather than a measured and controlled temperature.

[1] `https://www.silabs.com/documents/public/reference-manuals/EFM32WG-RM.pdf`

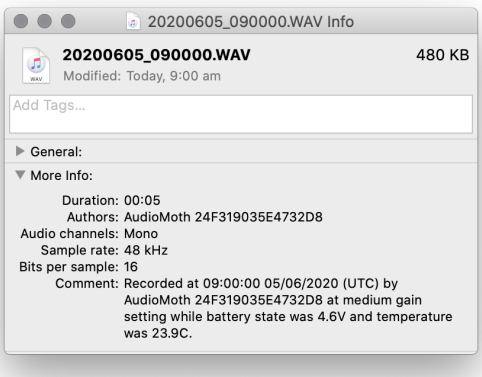

Figure 1: *WAV file header information.*

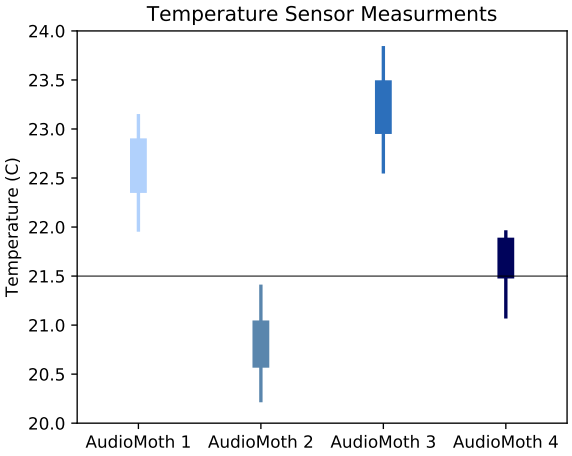

Figure 2: *Factory-calibrated temperature sensor measurements for four AudioMoth at 21.5 °C.*

Figure 2 shows factory-calibrated measurements from four AudioMoths made at one minute intervals for one hour deployed at a fixed temperature of 21.5 °C (measured using a calibrated temperature probe). The thin lines shows the minimum to maximum range over the hour, and the thick lines show the standard deviation. The repeatability is approximately ± 0.5 °C due to noise in the temperature sensor, and the factory-calibrated accuracy of the mean measurement for these four AudioMoth varies between -0.7 °C to +1.7 °C.

For many applications the factory-calibration of the temperature sensor will be sufficient. However, when more accurate measurements are required, the offsets calculated above at a known temperature can be applied as an additional correction. Figure 3 shows the same four AudioMoth deployed outside recording temperature over a 24 hour period (making 5 second audio recordings at the start of each minute). The top plot shows the factory-calibrated temperature measurements derived directly from the WAV file headers, and the bottom plot shows the corrected temperatures after the additional offsets calculated above are applied (specifically, -1.1 °C, +0.7 °C, -1.7 °C and -0.2 °C). After the correction each temperature measurement has a final accuracy better than ± 1 °C.

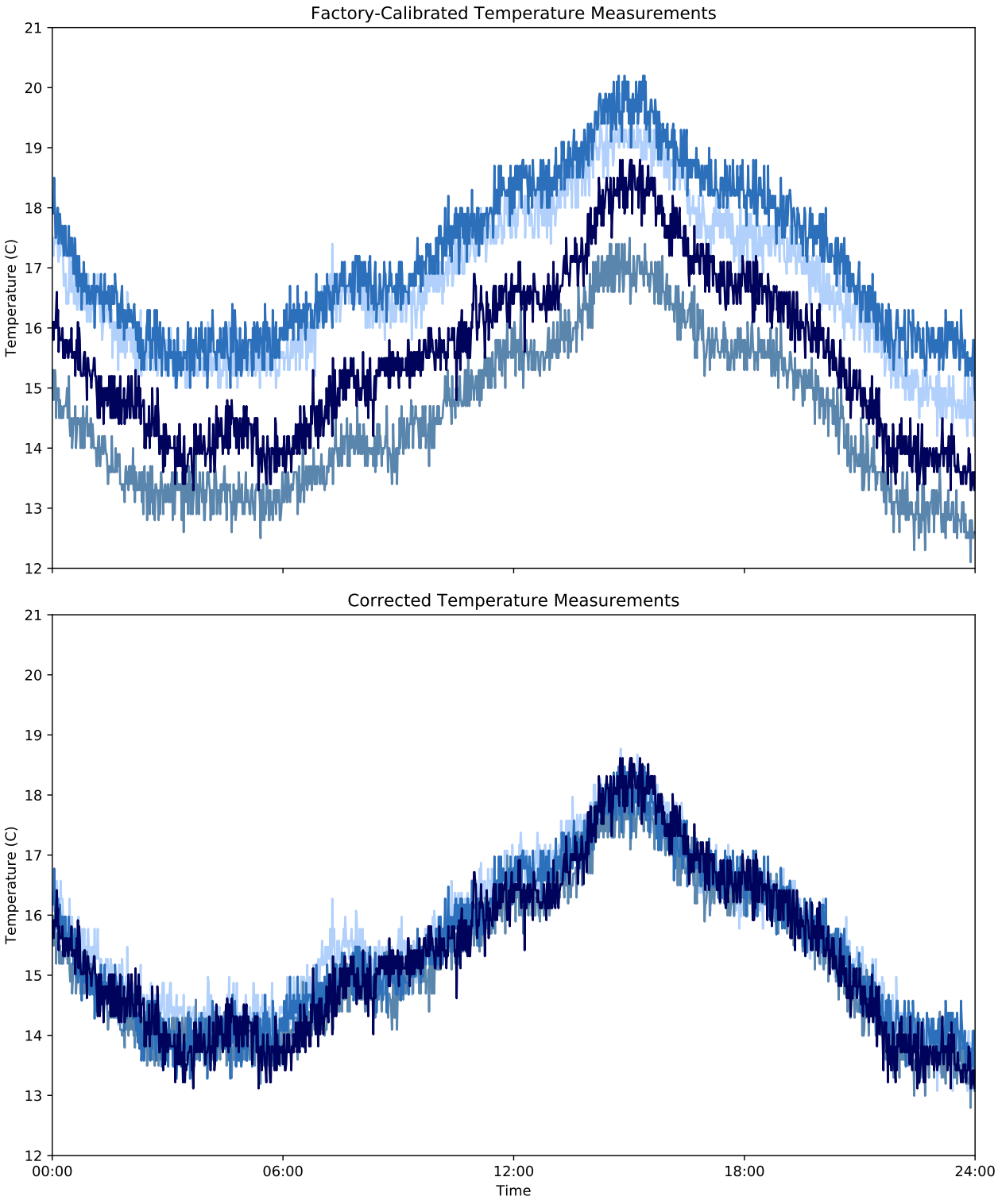

Figure 3: *Factory-calibrated and corrected AudioMoth temperature measurements over a 24-hour period.*

```
import re
import csv

from os import listdir
from os.path import isfile, join
from datetime import datetime, timezone, timedelta

directory = "."

COMMENT_START = 0x38
COMMENT_LENGTH = 0x180

files = [f for f in listdir(directory) if isfile(join(directory, f)) and ".WAV" in f]

with open("comments.csv", "w", newline="") as csvfile:

  csvWriter = csv.writer(csvfile, delimiter=",")

  csvWriter.writerow(["Index", "File", "Time", "Battery (V)", "Temperature (C)", "Comment"])

  for i, fi in enumerate(sorted(files)):

    with open(join(directory, fi), "rb") as f:

      # Read the comment out of the input file

      f.seek(COMMENT_START)

      comment = f.read(COMMENT_LENGTH).decode("ascii").rstrip("\0")

      # Read the time and timezone from the header

      ts = re.search(r"(\d\d:\d\d:\d\d \d\d/\d\d/\d\d\d\d)", comment)[1]

      tz = re.search(r"\(UTC([-|+]\d+)?:?(\d\d)?\)", comment)

      hrs = 0 if tz[1] is None else int(tz[1])

      mins = 0 if tz[2] is None else -int(tz[2]) if hrs < 0 else int(tz[2])

      timestamp = datetime.strptime(ts, "%H:%M:%S %d/%m/%Y")

      timestamp = timestamp.replace(tzinfo=timezone(timedelta(hours=hrs, minutes=mins)))

      # Read the battery voltage and temperature from the header

      battery = re.search(r"(\d\.\d)V", comment)[1]

      temperature = re.search(r"(-?\d+\.\d)C", comment)[1]

      # Print the output row

      csvWriter.writerow([i, fi, timestamp.isoformat(), battery, temperature, comment])
```

Figure 4: *Python code to extract the timestamp, battery voltage, and temperature from the WAV files in the current directory.*