August 2019

Test Results IMPACT Power Meter

Huron Cycling LLC

Summary

In this white paper test results are reported on the Huron Cycling IMPACT power meter for bicycles. The power meter is based on the unique features of a novel type of carbon crank set with improved cycling efficiency. In our earlier white paper of October 2018 the IMPACT crank set was reported to improve cycling efficiency by up to 4 % [1, 2]. The power meter described in this document is not based on strain gauges, but on inexpensive rotary sensors, making it more affordable than conventional power meters.

IMPACT Power Meter

The Huron Cycling IMPACT crank set has springs in the cranks which allow both crank arms to rotate by several degrees with respect to the spindle. The rotation angle is proportional to the load applied to the left and right pedals and, therefore, to the torque on the left and right crank arm. The instantaneous power applied by the cyclist is the sum of the left side and right side products of torque and angular velocity.

The IMPACT crank set has a scientifically proven improvement in cycling efficiency by reducing the effect of the dead spot during the crank revolution [1,2]. It also may delay the onset of muscle fatigue [3] and reduce injuries such as patellar tendonitis and chondromalacia [4].

We have developed Bluetooth and ANT+ enabled power meters with resistive and magnetic rotary sensors. Huron Cycling's IMPACT crank sets have a pivot point, either on the crank or on the spindle. The two parts that come together at the pivot point, can rotate with respect to each other over a small angular range, up to about 5 degrees, when a load is applied at the pedal. The unique feature of the IMPACT power meters is their use of inexpensive rotary sensors rather than strain gauges to measure torque. The IMPACT cranks are spring-loaded, which forces the angle at the pivot point back to zero in rest position, when no load is applied. The excursion angle is proportional to torque applied to the crank. The rotary sensor system measures this angle with an accuracy better than 0.1 degree.

Figure 1 shows the system diagram of the resistive sensor based power meter. The left and right sensors are simple miniature rotary potentiometers R1 for left torque and R2 for right torque measurement, with their outputs connected to analog inputs on the microprocessor board. The microprocessor is a Nordic Semiconductor device with Bluetooth and ANT+ wireless capability.

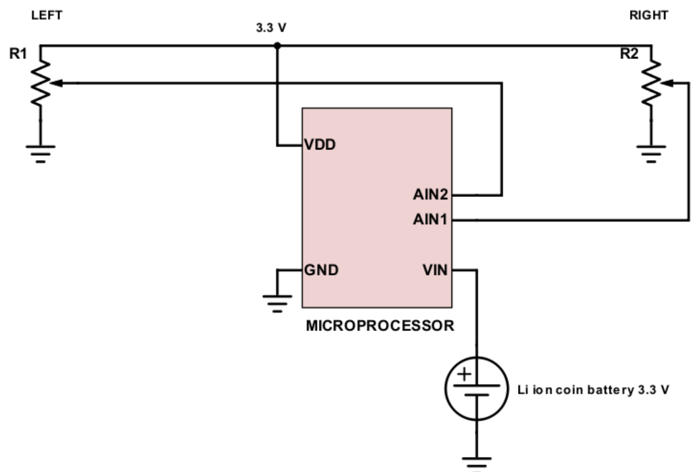

Figure 1. Schematic diagram of power meter with resistive rotary sensors

This system is working well, but the resistive sensors are contact sensors with the central wiper touching the resistor layer. They have a limited rated lifetime of 1 million rotations and create some noise during measurement. We therefore replaced the resistive sensors with non-contact magnetic rotary sensors which can measure an unlimited number of rotations with better than 0.1 degree accuracy (figure 2). They are inexpensive, reliable and widely used in automotive applications and have low noise. The magnetic rotary sensor is based on the Hall effect and consists of a mixed-signal chip and a small cylindrical NdFeB magnet. The magnet is mounted on one of the two rotating components (the spindle of the IMPACT crank set) and the chip is placed on the other (the crank arm of the IMPACT crank set) at the pivot point, as illustrated in figure 3. The chip digitizes the magnetic sensor data and converts it back to a low noise analog voltage value corresponding to the angle between crank arm and spindle. The power meters use a single microprocessor board with wireless capability and a single Li ion battery. One of the sensors is connected to the microprocessor board on the other side through the hollow spindle. This simplifies the system and reduces its overall cost, while maintaining the capability of independent left and right torque measurement.

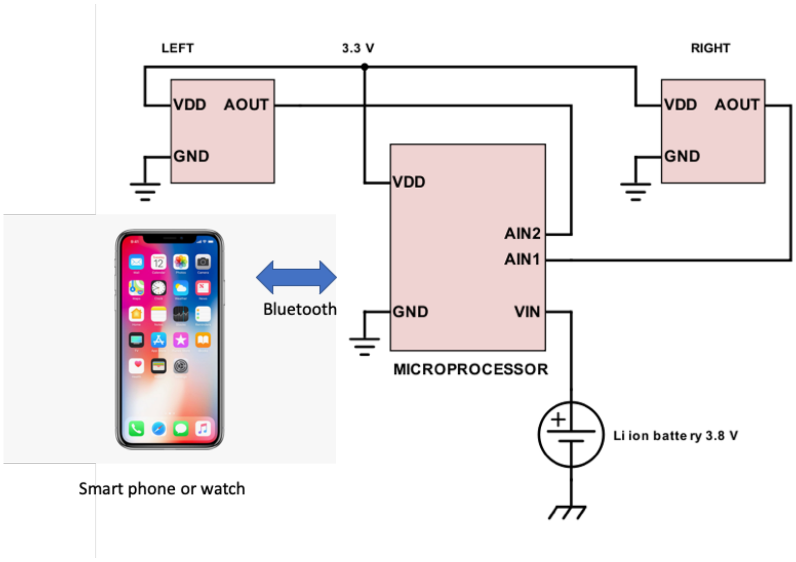

Figure 2. Schematic diagram of power meter with left and right magnetic rotary sensors and Bluetooth connection to a smart phone for data collection

Figure 3. Location of magnetic rotary sensor between crank arm and spindle

The power meter is installed on the Huron Cycling IMPACT crankset of a bicycle (figure 3), which is mounted on a home trainer for testing. Both left and right torque are measured simultaneously 1500 times per second (1500 Hz sampling rate). To evaluate the resulting left and right torque profiles vs. time, each set of 5 consecutive data points are averaged and the averaged data is transferred at 300 Hz rate by the microprocessor via BLE (Bluetooth Low Energy) wireless protocol to an app on a smart phone. A smart watch can also be used. The wireless transferred data can be downloaded from the app into an Excel spreadsheet. Results for the system with magnetic sensors are shown in figure 4 and 5. Figure 4 shows a few revolutions of the crank set under load of the cyclist's efforts, with left and right signal alternatingly peaking during the downstroke at each of the pedals.

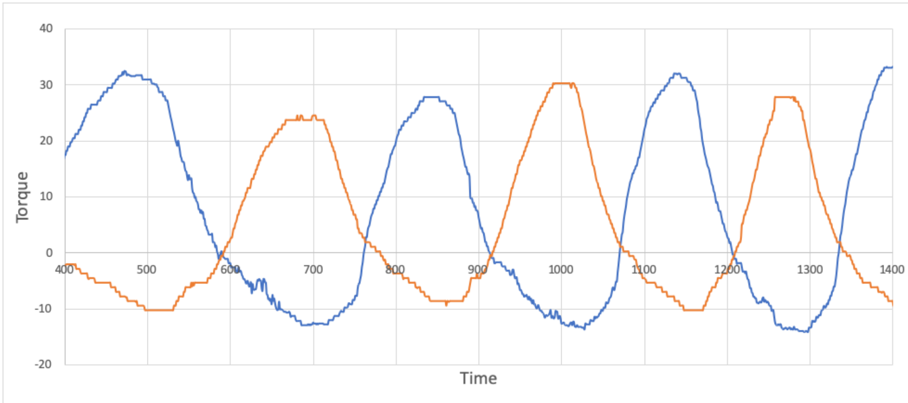

Figure 4. Measurement of left torque (in blue) and right torque (in red) acquired at 1500 Hz

The system can be calibrated with weights on the pedals or using the rider weight, if it is accurately known, along with zero calibration at zero load. This is illustrated in figure 5 which shows the torque profiles for a longer time, incl. periods where the rider was standing on the pedals with the left foot forward and then the right foot forward without rotating the cranks. These analog signal levels can be used for calibration. In this case the total torque is zero, since the rider weight is split 50/50 between the forward and backward foot resulting in positive torque on the forward foot and negative torque of equal magnitude on the backward foot. The part of the traces at far right in figure 5 represent zero load.

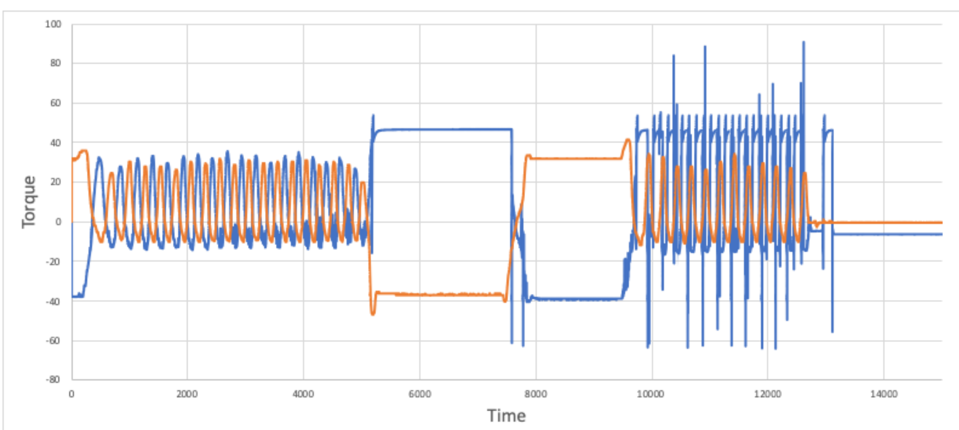

Figure 5. Measurement of left (blue) and right (red) torque for a longer period of time, including flat profiles when the cyclist is standing on the pedals without rotating the cranks

Total instantaneous power *P(t)* is given by:

$$P(t) = \omega\,(\tau_{left}(t) + \tau_{right}(t)),$$

where ω is the angular velocity of the crank and $\tau_{left}(t)$ and $\tau_{right}(t)$ are the instantaneous torque on the left and right crank, respectively. The instantaneous power and torque vary during the pedal revolution, with a maximum during the downstroke, as shown in figure 4 . The average power during a trip can be calculated from the instantaneous power data.

For our set of measurements all the raw data at 1500 Hz from the sensors was transferred to the app on the smart phone at 300 Hz in order to analyze the torque profiles. In a practical power meter most of the calculations to obtain running power and average power will be done on the microprocessor of the power meter prior to wireless transfer to ensure compatibility with ANT+ standard protocols and GPS handlebar units from various manufacturers. We are also planning a more conventional IMPACT app for smart phones and smart watches. Cyclists riding with IMPACT drivetrains will be able to receive and exchange their power data in real time in a user-friendly way with the IMPACT app. The IMPACT app will offer the possibility to set up connected communities for users of the IMPACT drivetrain and connect these user groups with sport apps such as Strava.

Conclusion

The Huron Cycling IMPACT power meter can measure left and right torque on IMPACT crank sets at 1500 Hz sampling rate with better than about 2 % accuracy and low noise. The power meter uses inexpensive rotary sensors widely used in the automotive industry and is more affordable than conventional power meters based on strain gauges. The IMPACT power meter adds further value to the IMPACT crank set which improves cycling efficiency by up to 4 % [1, 2].

References

[1] White Paper IMPACT crank set October 2018 (www.huroncycling.com)

[2] https://journals.lww.com/acsm-msse/Fulltext/2019/06001/Novel_Crank_with_Elastomer_Spring_Improves.2834.aspx#print-article-link

[3] www.free-power.jp

[4] https://www.youtube.com/channel/UCAY-rz2yNvN7WGuqgRwrddg
https://biosporttech.wixsite.com/biosporttech/blog