Wrocław University of Science and Technology

Intermediate Project

Bicycle power measure system

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Abstract:

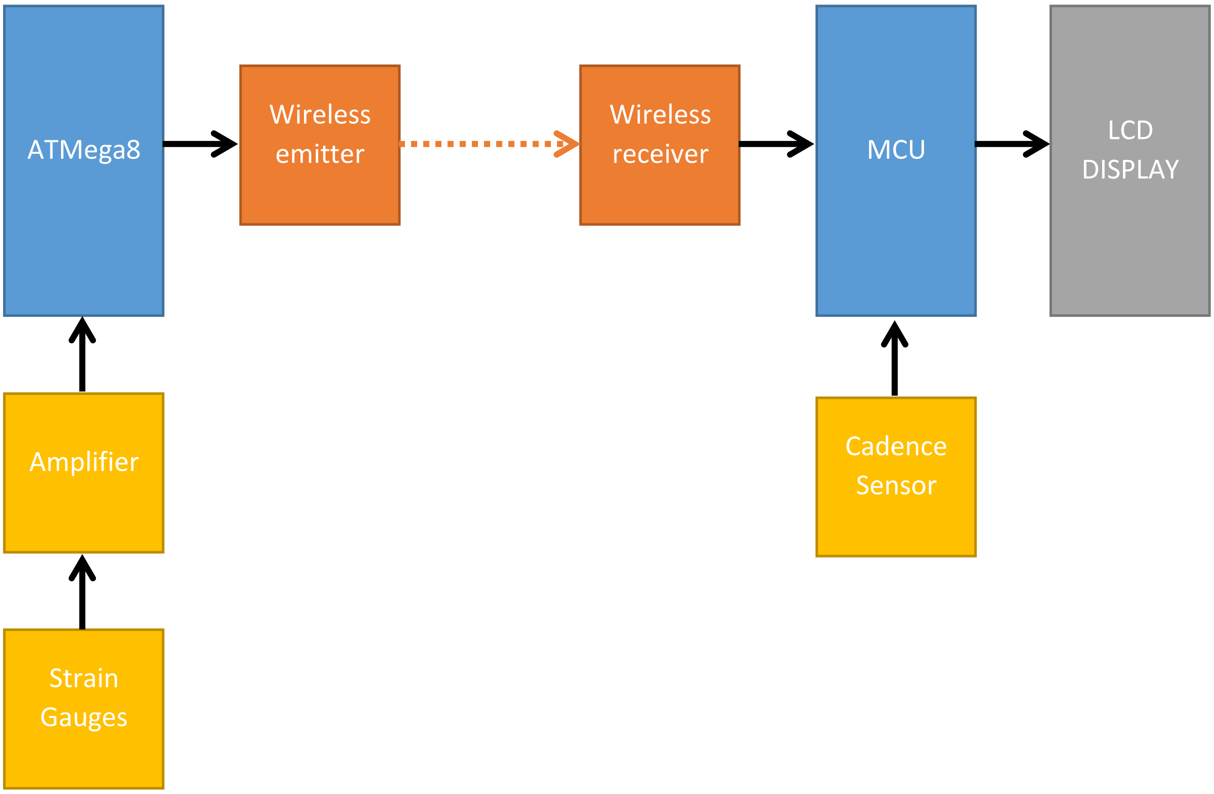
The goal of this paper was to design cheap and efficient bicycle power measurement system based on microcontroller application. Afterwards the data were to be displayed on the LCD screen. Project uses strain gauge sensors mounted on the bicycle crankarm, cadence sensor and radio transceivers. All the primary goals were achieved. Project may be developed in future as a stand-alone or a measurement part of more complex device.

Introduction

The aim of the project is to build a bicycle power measurement system. The device has to be cheap and efficient. Due to bicycle construction, it has to consist of two separate and wirelessly connected parts. The first one, mounted on the crankarm, measures the contact force of the cyclist. The second one receives wirelessly data from the first part. It also measures the pedaling cadence. Afterwards it calculates the cyclist power. In the future the system can be extended with a LCD screen and a SD card storage. There is a probability of connecting the system with the Bachelor of Science Thesis Project – a bike trainer.

Project description

The main constraint of the projected system was the target application. The bicycle moves outside, so it is prone to weather conditions and dirt from the road. Moreover the space is limited and the device has to be compact-size. All the parts have to be immune to vibration, as the environment of operation forces them to be. The idea of the project is shown on following concept graph:



Hardware description

Following parts were selected for the project:

BF1000 strain gauges – strain gauges are transducers converting mechanical force to an electric signal, which can be easily measured. When the sensor is deformed, the foil changes its length, which causes change of resistance. Temperature may similarly affect the measurement. To overcome this problem a Whetstone bridge is applied. It connects four sensors in a proper setting and prevents the strain gauges' zero point from changing. This model of strain gauge was selected due to its high resistance (1000 ohms). They are also suitable for mounting on aluminum surface.

AD 623 – the operational amplifier has to be used due to very low amplitude of strain gauge signal. To make signal readable by microcontroller it had to be amplified 1000 times. The model was selected for it low power operation. It has variable gain in range from 1 to 1000, which matches the requirements.

ATMega8 – an electric signal has to be converted so it can be sent wirelessly. A microcontroller was used for this purpose. ATMega8 is a microcontroller which is cheap and easily accessible. It is equipped with 10-bit analog-digital converter. It has also hardware SPI. Moreover its sleep modes reduce the power consumption. This is the smallest and the cheapest of Atmel microcontrollers which fulfills the above requirements.

Cadence sensor – made with magnetic sensor and a magnet mounted at the end of the crankarm. With each revolution the sensor closes the circuit calling an interrupt in the microcontroller.

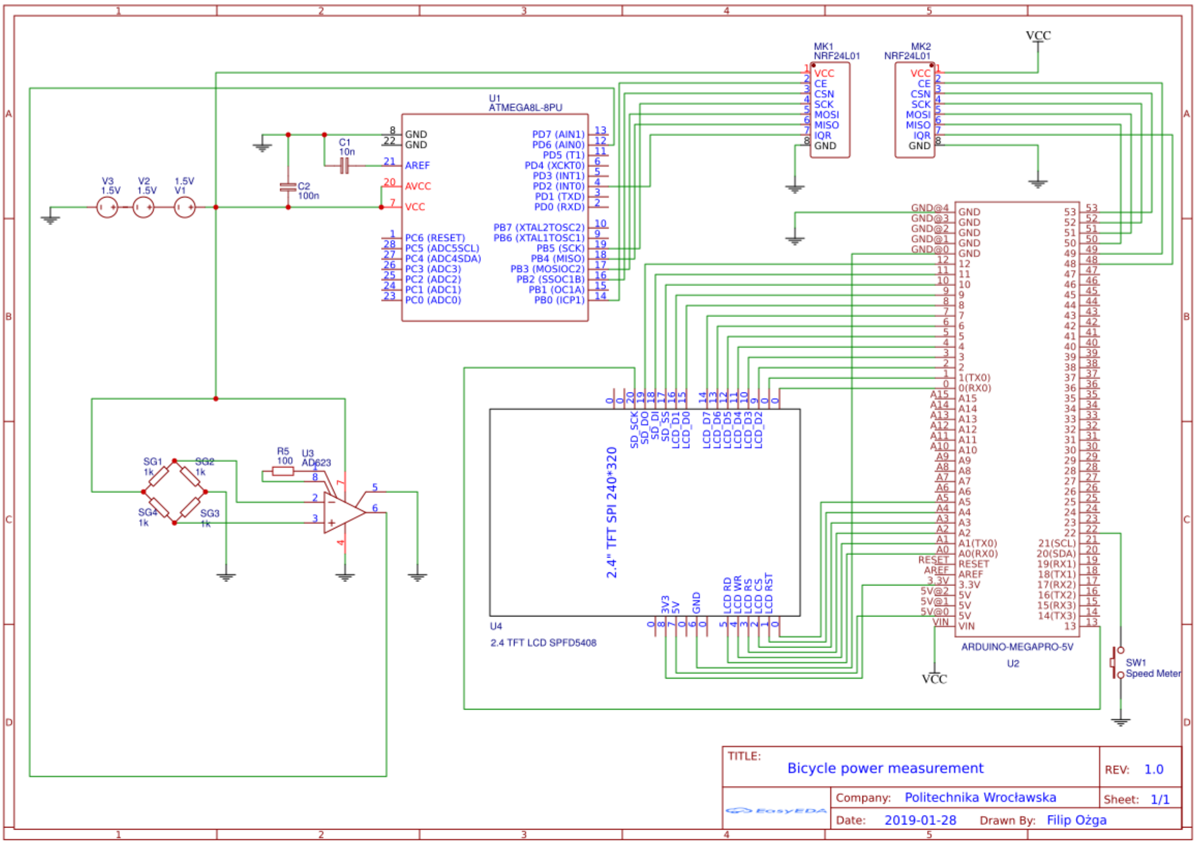
NRF24L01 – to send data wirelessly a 2.4 GHz transducer was used. It has up to 2Mbps data transmission which is enough for this application. It also communicates with microcontroller via SPI, which is convenient for both microcontrollers. Another advantage is the price of the module.

SPFD5408 – the device is also equipped with peripheral output, which is LCD screen. The display is a breakout board for Arduino devices. It is easily connected with Arduino Mega. The diagonal size is 2.4”. The resolution is 240x320 pixels.

Arduino Mega – this device is the most important part of whole project. It collects all the sensors data and displays it. It also allows to communicate the system with other devices. The biggest microcontroller board of Arduino family was used because LCD display takes a lot of space and with smaller Arduino devices it would be impossible to connect other devices.

Implementation description

Four strain gauges were mounted on bicycle crankarm as following: R1 and R3 on the top, R3 closer to pedal, R2 and R4 on the bottom, R4 closer to pedal. Strong neodymium magnet was glued to the end of a crankarm and a magnetic sensor was placed adequately on the chainstay. The devices were wired and hot-glued to the crankarm. Display part was mounted on the handlebar. The hardware design is shown in schematic:



ATMega program reads the data from ADC converter, sends them via SPI and puts the device into sleep. Arduino reads continuously the revolution with interrupts and measuring time between them. It also collects data from wireless receiver and then computes the Power from average torque and angular speed. Afterwards the data are displayed on the LCD screen.

Measurements

The equation for a Wheatstone bridge setting is following:

$$V_{out} = \left(\frac{R_1}{R_1 + R_2} - \frac{R_4}{R_3 + R_4}\right) V_{in}$$

Bending can be isolated with a full-bridge circuit and four strain gauges. By using four strain gauges, the equation can be simplified to:

$$V_{out} = \frac{GF}{4}(\varepsilon_1 - \varepsilon_2 + \varepsilon_3 - \varepsilon_4) V_{in}$$

$$\varepsilon - strain$$
$$GF - gauge\ factor$$

The measurements received in microcontroller are computed to calculate the torque:

$$\tau = k * V_{in} * r$$

The parameter r is the length of the crankarm and equals 0.135m. The parameter k was experimentally stated in the test number 4 from the “Tests” section and equals 250.

Power is computed from equation:

$$P = \tau * \omega$$
$$\omega = \frac{2\pi RPM}{60}$$

The torque is summed during the rotation, the time of full rotation is measured by microcontroller and the frequency is computed:

$$f = \frac{1}{T}$$
$$RPM = 60 * f = \frac{60}{T}$$

Final formula for power computing is following:

$$P = \tau * \omega = \tau * \frac{2\pi RPM}{60} = \tau * \frac{2\pi}{T}$$

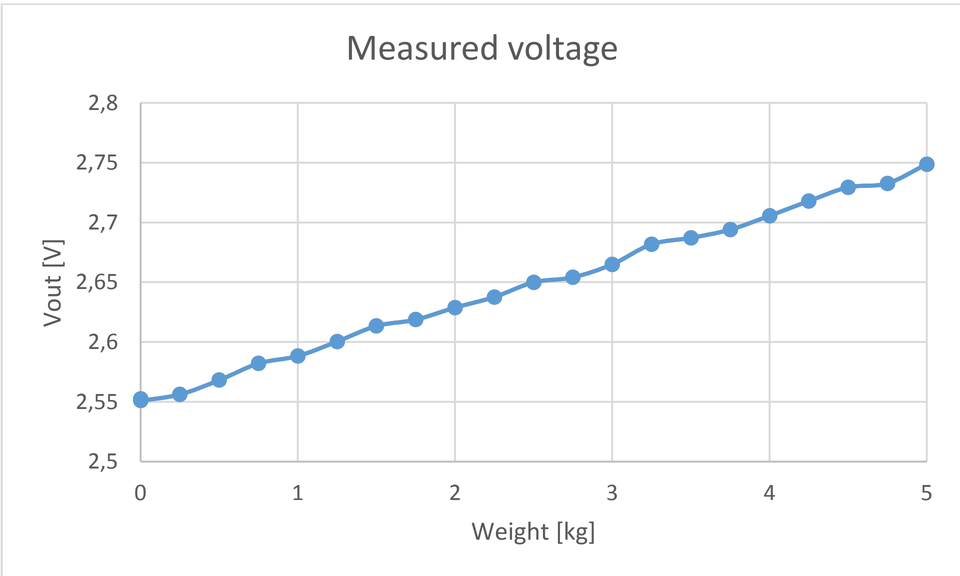
Tests

To investigate proper operation of the system following tests were conducted:

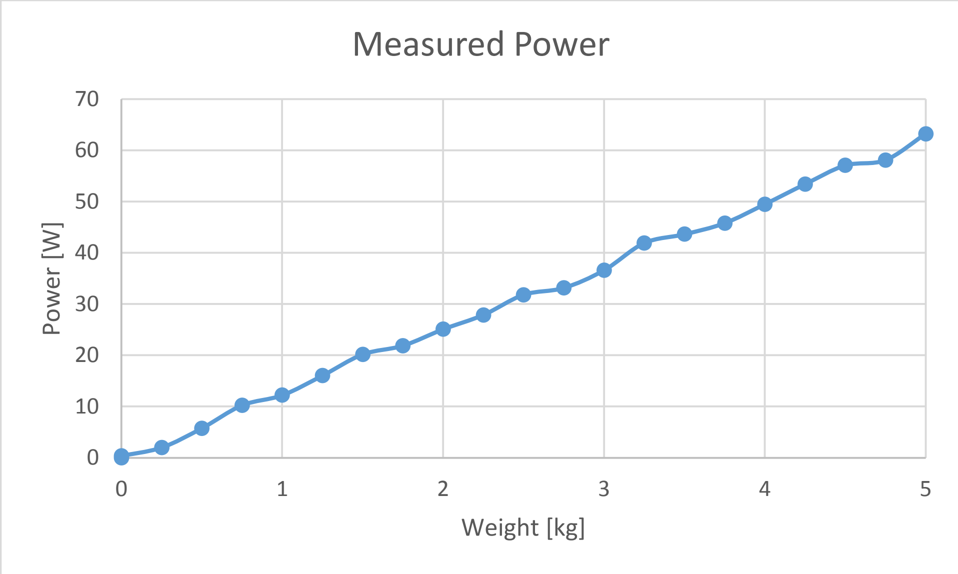
ATMega microcontroller was programmed to send wirelessly incrementing numbers. Arduino Mega was to receive it and display on LCD display and serial port. All the data was properly received.

The crankarm was rotated with known resolution. The measurements were displayed on both LCD display and serial port. There were no problems with measurements.

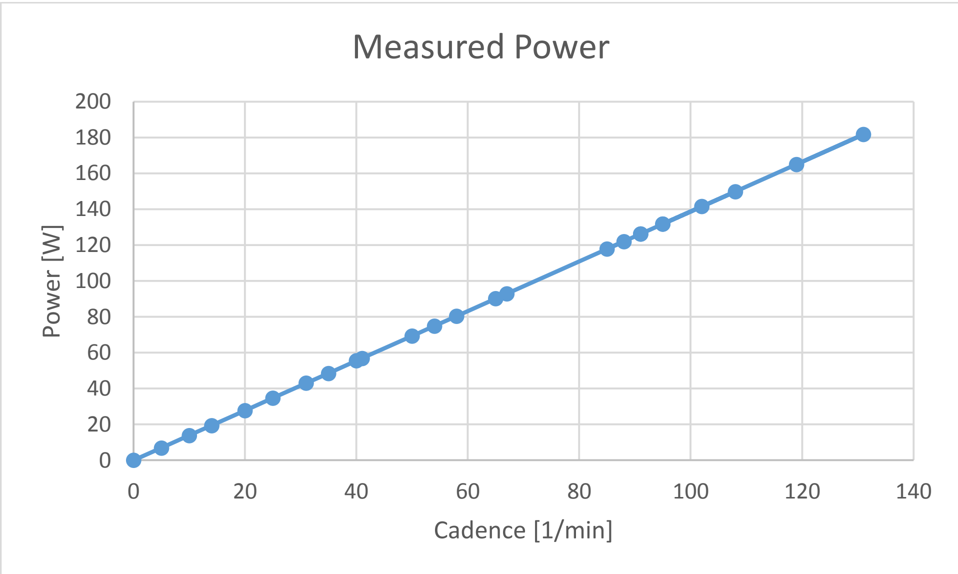
Set of weights were prepared for the test. Their mass was validated on scale. Afterwards the crankarm was blocked in horizontal position and loaded with subsequent weights. Voltmeter was connected to the microcontroller inputs. Moreover measured data was displayed on LCD screen and serial port. Obtained results are shown in the following chart:



To measure the power, the revolution of crankarm was programmed to be 90 RPM. Thereafter the crankarm is loaded analogically to previous test. Computed power is shown in following chart:



The last test was investigating proper operation of cadence sensor. The system was programmed as if it was loaded with 10 kg. The crankarm was rotated with increasing speed. The results were observed on LCD display and the serial port. Obtained data are shown in the following chart:



Results

The results of the tests are satisfying. The device can be applied and used in training. The measurements are very precise, measuring perpendicular force with 1,2N precision. The system can be enhanced by adding SD card to it, to store and preview the stored data. The device can be also further developed, e.g. by connecting Bluetooth transceiver to Arduino Mega and connecting with smartphone application. It can be also integrated with cycling trainer.

Resources

1. *Bicycle Power Meter*. L. Brophy, A. Dibble, C. Reardon, S. Langan, I. Gielar. Rochester Institute of Technology.
2. *Development and validation of a track bicycle instrument for torque measurement using the zigbee wireless sensor network*. Sadik Kamel Gharghan, Rosdiadee Nordin, Mahamod Ismail.International Journal on Smart Sensing and Intelligent Systems, January 2017.
3. *Development of Power Meter for a Bicycle*. Milan Paudel, Fook Fah Yap. Nanyang Technological University, May 2018.
4. *Sensor Technologies for Determining Cyclist Power Output: A Comparison of Smartphone, Opposing Force and Strain Gauge Power Measurement Technologies Using Spatial Analysis*. Doug Daniels. USC Graduate School University of Southern California, May 2017.
5. *Strain Gage Selection: Criteria, Procedures, Recommendations - Tech Note TN-505-6*. Micro Measurements.
6. https://belchip.by/sitedocs/28808.pdf
7. https://www.analog.com/media/en/technical-documentation/data-sheets/ad623.pdf
8. http://ww1.microchip.com/downloads/en/DeviceDoc/Atmel-2486-8-bit-AVR-microcontroller-ATmega8_L_datasheet.pdf
9. https://www.sparkfun.com/datasheets/Components/nRF24L01_prelim_prod_spec_1_2.pdf
10. https://cdn-learn.adafruit.com/downloads/pdf/adafruit-2-4-color-tft-touchscreen-breakout.pdf