Poster: Applications of Energy-Driven and Transient Computing: A Wireless Bicycle Trip Counter

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ABSTRACT

Energy harvesting is an efficient solution to power embedded systems instead of using batteries. However, it has been traditionally coupled with large energy buffers to tackle the temporal variation of the source. These buffers require time to charge and introduce a cost, size and weight overhead. Energy-driven and transiently-powered systems can operate from an energy harvesting source, while containing little or no additional energy storage. However, few real-life applications have been considered for such systems to demonstrate that they can actually be realised. This poster presents a transiently-powered wireless bicycle trip counter which measures distance, speed and active cycling time, and transmits data wirelessly. The system sustains operation by harvesting energy from the rotation of the wheel, operating from 6kph.

CCS CONCEPTS

• **Hardware → Sensors and actuators**; Wireless devices;

KEYWORDS

Transient Computing; Embedded Systems; Energy Harvesting

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1 INTRODUCTION

Energy harvesting systems scavenge energy from environmental sources to power themselves, instead of relying on batteries. However, energy availability can fluctuate significantly depending on the temporal and spatial conditions. Relying solely on the harvested energy can, therefore, result in the system being unable to sustain computation. For this reason, energy buffers (rechargeable batteries or supercapacitors) are usually employed which introduce a size, weight and cost overhead. Energy-driven systems operate from a minimum of energy storage, enabling computation to be sustained despite the variable and unstable energy (sometimes referred to as a "transient source") harvested from the environment [1]. However, very few real-life applications have been implemented using transiently-powered systems to date because they cannot be designed considering only the application's requirements (without regard for the energy environment) and the limited energy budget that they normally offer. Examples include a transiently-powered energy harvesting step counter for integrated wearable applications [3] and an energy harvesting approach to energy metering [2].

In this poster, we report on a novel application of transient computing: a wireless bicycle trip counter which operates directly from a kinetic energy harvester. To the best of our knowledge, this is the first bicycle trip counter that considers changes in energy availability and is able to operate in a transient scenario.

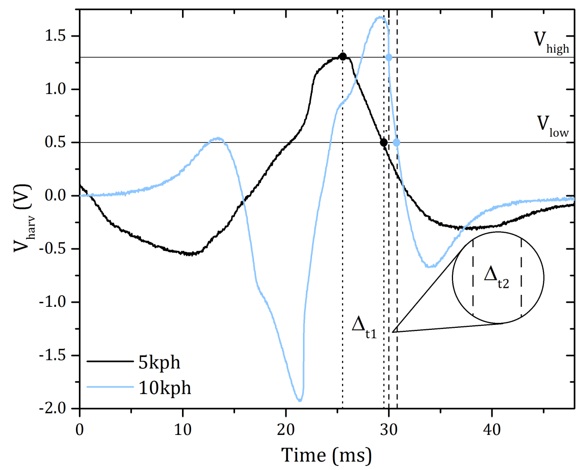

Figure 1: V_{harv} across the coil at different rotation speeds.

2 SYSTEM DESIGN

Figure 2 shows a schematic of the system. The energy harvester consists of a magnet attached on the wheel and a coil which is affixed to the frame of the bicycle. Compared to traditional systems, the coil in this case works both as the energy source and sensor which enables the miniaturisation of the system.

A rectifier converts the AC output from the harvester to DC, and a voltage doubler is used to boost the input voltage. A voltage detector switches the MCU on/off depending on the input voltage, so that the quiescent current of the MCU is reduced and the system is switched on when the input voltage exceeds threshold V_{th}. An MSP430FR5739 microcontroller (MCU) calculates the speed of the bicycle by measuring the time between two predefined voltage points (i.e. V_{high} and V_{low}) from the harvester pulse, as shown by

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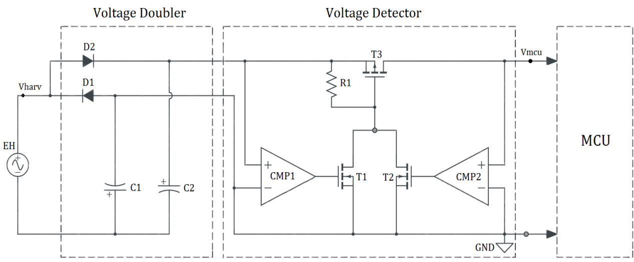

Figure 2: Schematic of the proposed system.

V_{harv} (V)	$V_{MCU_{max}}$ (V)	Speed (kph)	Mode
1.30	N/A	< 6.0	MCU off
1.50	2.12	$6.0 < u < 7.0$	Low speed
1.75	2.32	$7.0 < u < 7.5$	Measure
1.75	2.45	$7.5 < u < 8.0$	Calculate
1.77	2.50	> 8.0	Transmit

Table 1: Speed-dependent modes of operation.

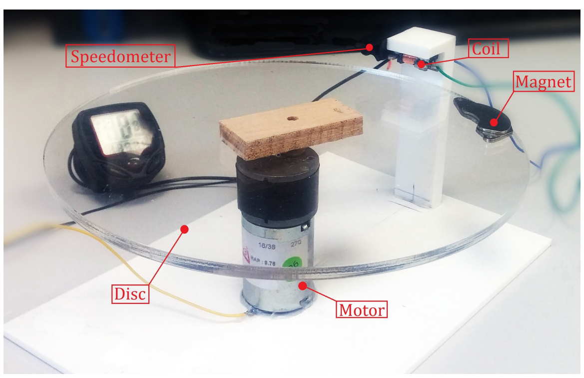

Figure 3: Experimental test setup of the system.

Δ_{t1} and Δ_{t2} in Figure 1. The distance covered by the bicycle and the active cycling time are determined based on the number of pulses generated by the harvester and the circumference of the wheel. These data are trasmitted wirelessly to nearby devices using an ultra low power transceiver (nRF24L01). If there is not enough energy, the system saves the data to NVM so that it can be transmitted once the available energy is sufficient. Because this is an energy-driven system, and the available energy is tightly couples to the speed, the system applies different operational modes at different speeds to scale performance. These modes are summarised in Table 1.

3 RESULTS

An experimental test setup was created (Figure 3), where a magnet is attached to a rotating disc (representing the wheel) controlled by a motor. A speedometer measures the actual speed for comparison with experimental results. Four GPIOs are configured to indicate the different stages of operation for debugging.

Figure 4 shows the operation of the system at a constant speed of 8kph. Once a voltage greater than V_{th} is detected, the MCU is configured and the sensor starts collecting information. Subsequently,

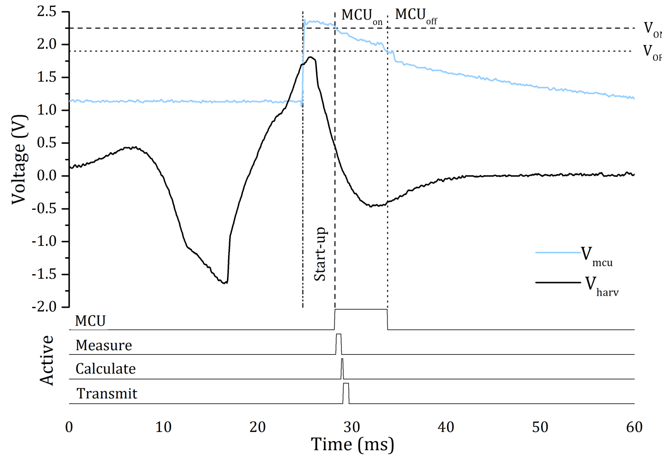

Figure 4: Operation of the the system at 8kph

Speed (kph)			Distance (m)			Active Time (s)		
A*	M**	Error	A*	M**	Error	A*	M**	Error
8.0	7.4	8.1%	101.4	98.3	3.1%	45.6	48.2	5.4%
10.1	10.0	1.0%	127.7	126.7	0.8%	45.3	45.0	0.7%
12.0	12.0	0.0%	151.4	151.9	0.3%	45.2	45.2	0.0%
14.1	14.1	0.0%	177.2	176.4	0.4%	45.2	44.5	1.6%

* A = Actual values **M = Measured values

Table 2: Accuracy measurements at different speeds.

the MCU calculates the speed, distance and active cycling time which are transmitted to the receiver. The system can sense and save data to NVM at 6kph, while a speed of 8kph is required for wireless transmission. Table 2 shows results on the measurement accuracy of the system, which increases with increasing speed.

4 CONCLUSION

In this poster, a novel transiently-powered wireless bicycle trip counter has been presented as a demonstrator of a real-life energy-driven and transient system. The system removes the need for additional energy storage and operates directly from the energy harvested from the rotation of the wheel. The system has been experimentally validated, showing successful operation from an intermittent supply.

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