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Wiegand-Effect-Powered Wireless IT Sensor Node

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1. Introduction

With the growing interest in small distributed sensors for the "Internet of Things", more attention is being paid to energy harvesting techologies. Reducing or eliminating the need for external power sources or batteries make devices more self-sufficient, more reliable, and reduces maintenance requirements. The Wiegand effect is a proven technology for harvesting small amounts of electrical power from mechanical motion.

2. Wiegand Effect

In the 1970's John Wiegand (Fig1) discovered the anisotropic magnetic properties of a specially treated (annealing & coldworking), thin wire of specific ferromagnetic alloys (typically FeCoV (Vicalloy)) causing it to be preferable magnetized in one of the two directions along the wire axis.

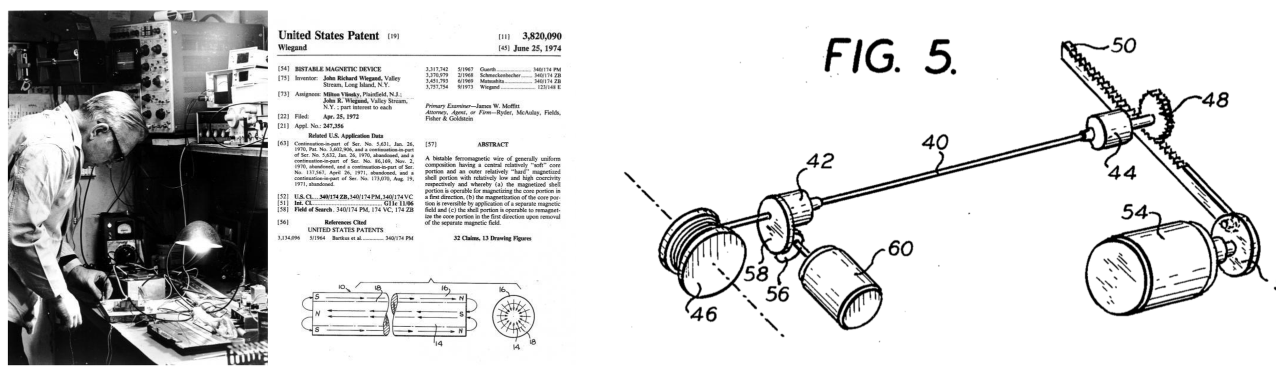

Fig 1: John Wiegand in his Laboratory, Original Patent and Device for Coldworking the Wire..

No matter how slow the external magnetic field changes, the transition between these two bistable states, often referred to as macroscopic Barkhausen effect, takes place almost instantaneously (Fig 2) and is associated with a release of magnetic energy that can be picked up as induction voltage in a surrounding coil (Fig3).

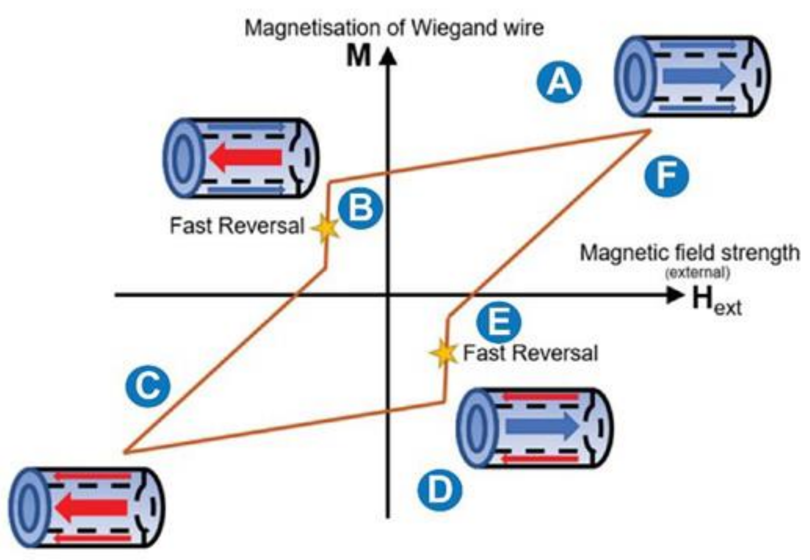

Fig 2: Wiegand Cycle.

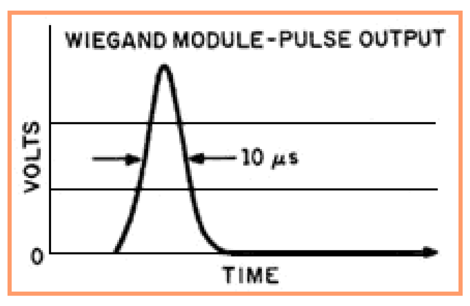

Fig 3: Typical Wiegand Pulse.

- Symmetric Switching Induced by Permanent Magnet (typ. 1-10mT)
- Pulse Independent of Field Strength and Change Rate
- Typically 2-10V Peak, 10-20µs Width

Current commercial Wiegand Sensors provide an energy output which does not exceed 200 nJ. They are well established in low-power applications such as revolution counters in rotary encoders or flow meters.

2. Wiegand Generator

By upscaling the sensor and further optimizations (wire , coil, ferrites), the energy output can be increased drastically to about 6-8 µJ for a coil of 21 mm length and 7.5 mm diameter under otherwise optimal conditions even in the low-speed limit, as shown by the green curve in Fig 4.

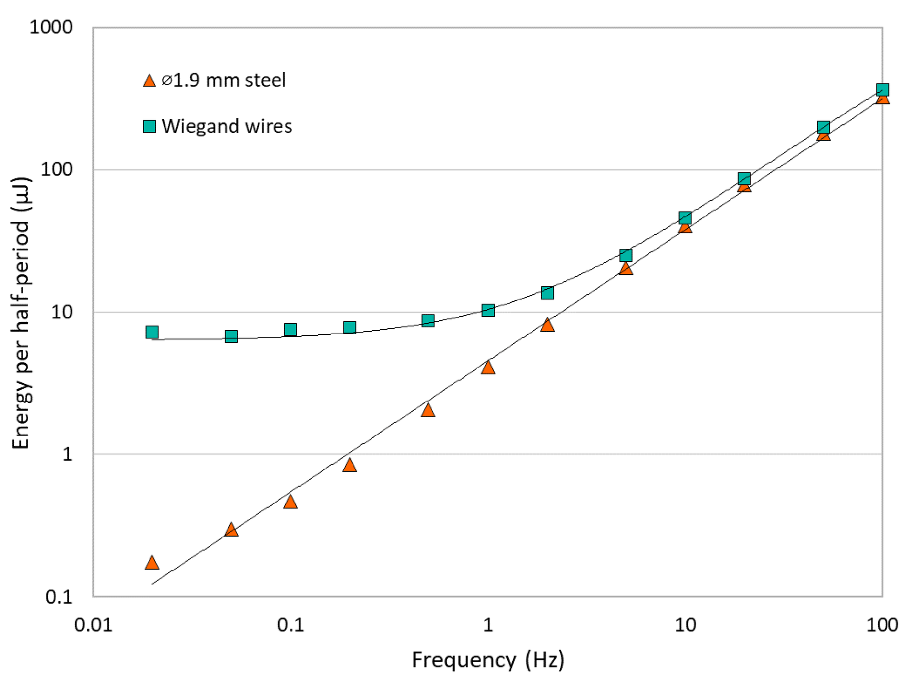

Fig 4: Frequency dependency of energy output of Wiegand effect compared to regular induction. Coil (8000 wdgs), oscillating field (16mT), Joule heating power in a 3 kΩ resistor measured.

Fig 5: Wiegand sensor for energy-self-sufficient motion sensing (top) and Wiegand generator (right)

The Wiegand Generator (Fig 5) can be excited by moving two or more bar-shaped permanent magnets with alternating magnetization. This configuration tolerates large misalignments (Fig 6). Other systems, like rotating magnets, can be used for to trigger the Wiegand wire as well.

3. Operating Mode

Continuous harvesting systems (e.g. vibration) typically provide enough power to exceed the consumption in some sleep mode and to charge a battery or super-cap, allowing to perform more energy intensive operations (reading sensors, data processing, storage,transmission) from time to time.

Event based harvesters, like Wiegand generators, provide a specific amount of energy at one stroke. They also can be operated with periodic excitation, but if the system is designed accordingly, this single amount of energy will be sufficient to perform an operation (such as reading a Hall sensor), even if no power is provided in between the events.

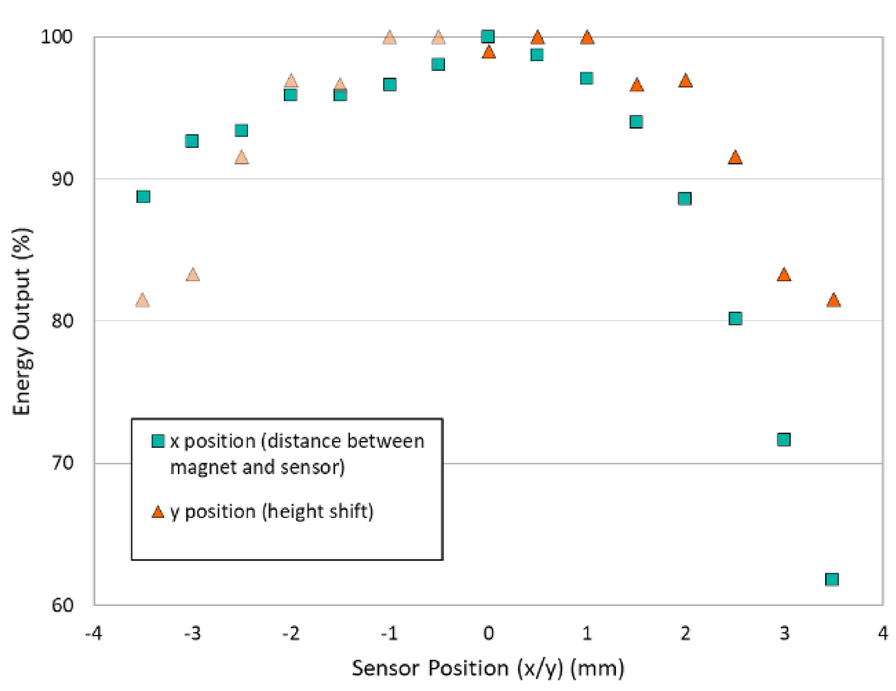

Fig 6: Mounting tolerances of the magnets with respect to the Wiegand generator.

4. Window Opening Sensor with UWB Technology

A Wiegand powered proof-of-concept system, using off-the-shelf components, is designed to be operated in such an event-based mode and to acquire and transmit the data wirelessly. As application a window opening sensor is chosen and shown as a demonstrator (Fig 7).

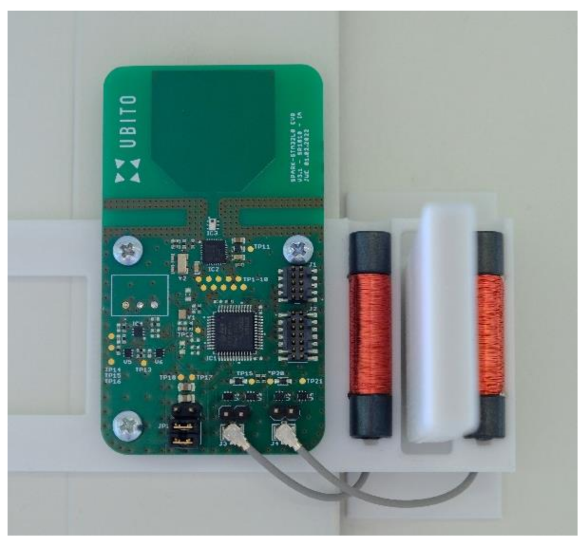

Fig 7: Demonstrator PCB

Ultra-wideband (UWB) wireless technology transmits ultra-short electromagnetic pulses (3-11 GHz). The shortness in the time domain translates into a wide spectrum in the frequency domain with very low spectral energy density. Therefore UWB signals only increase the general RF noise-floor by a negligible amount, thus the technology can coexist with narrowband (NWB) technologies in the same frequency range.

At the same time UWB is the suitability for high precision ranging ToF measurements using the precise timing of the pulses and it has a principle-related very low power consumption.

This results in UWB being a promising candidate for a wireless transmission technology using energy harvesting from a Wiegand generator.

5. Design and Results

The system consists of the wireless sensor node (transmitter) powered by a Wiegand generator and a UWB base station or IoT-gateway (receiver) powered by an external source. Figure 8 shows the architecture of the wireless sensor node. SPARK Microsystems' SR1000 IC family is used as UWB transceiver.

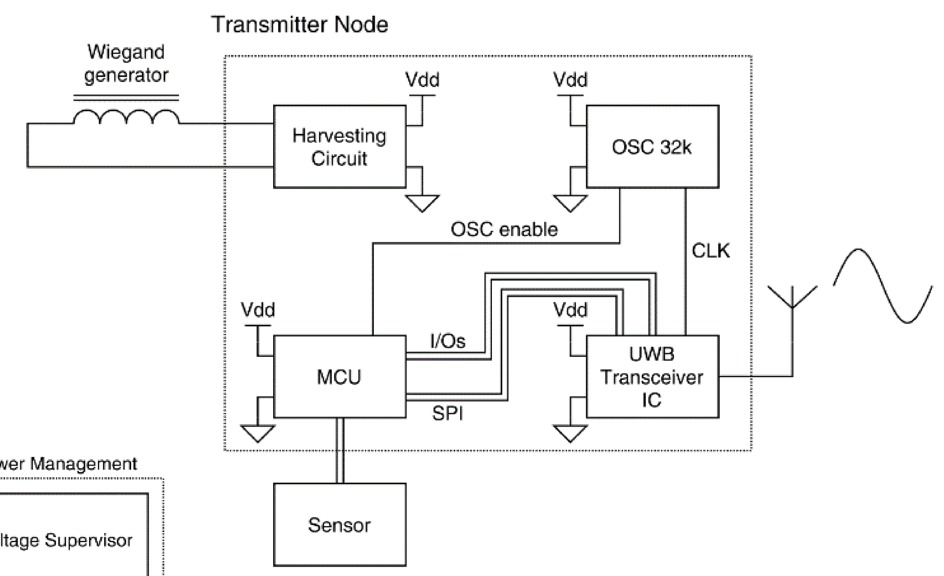

Fig 8: Digital circuit containing the UWB transceiver, MCU, oscillator and an external sensor

Figure 5 shows the structure of the harvesting circuit. The output current of the Wiegand generator is rectified and charged into a capacitor, from which the components of the digital circuit draw their power after sufficient energy has been harvested.

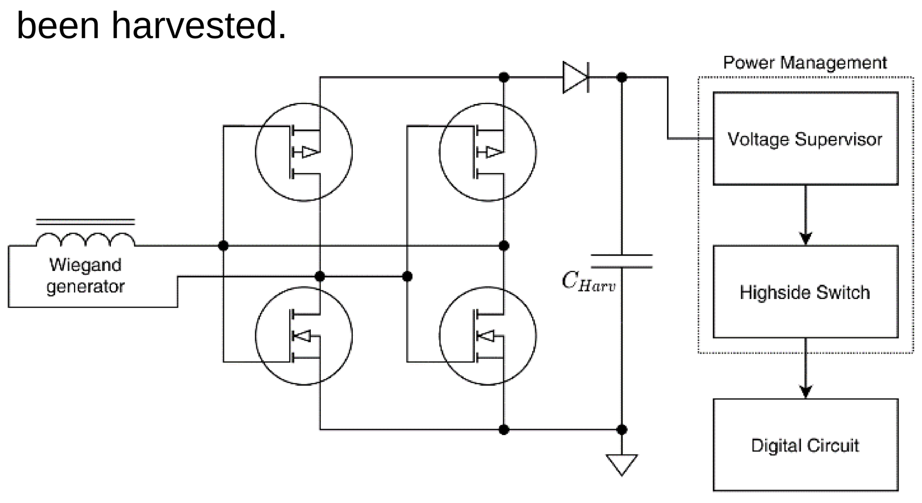

Fig 9: Harvesting circuit supplying the digital circuit with energy from the Wiegand generator

- Various Rectifier Designs using Schottky Bridge and Schottky FET tested
- Schottky FET RB751S performs best with only 0.6% loss

An analysis of the energy distribution introduced by different components and phenomena is shown in Figure 10. The two Wiegand generators with two magnetic inversions per triggering event theoretically generate 29.6 µJ. This energy was measured in a homogeneous magnetic field with an optimal resistive load (3 kΩ), thus yield in a realistic scenario differs.

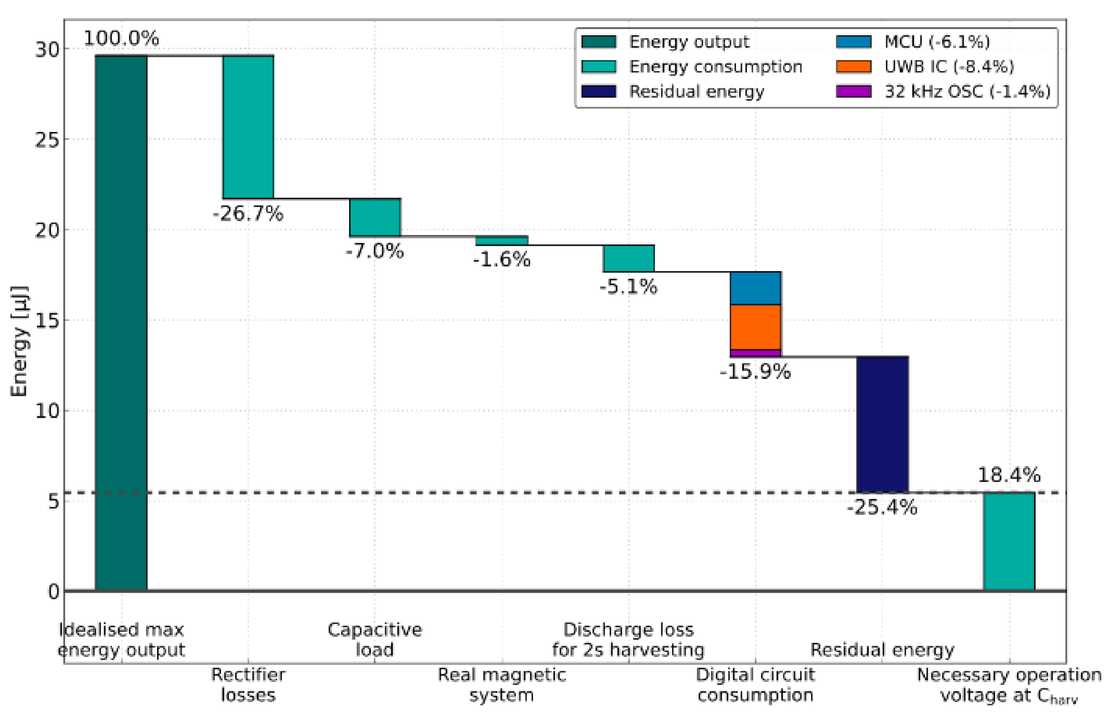

Fig 10: Energy distribution and losses during a pulsed-operation cycle

An average of 25.4 % (7.5 µJ) residual energy can be used for additional sensor readouts, further MCU calculation for stability and security or increased UWB payload data transfer.

These findings lead to the conclusion that the supply of a wireless sensor node with a Wiegand generator is generally possible and promising.

A comprehensive analysis of various configurations of the UWB IC result in an achievable open-field range of around 60 m for the SR1010 at 4 GHz frequency with a power consumption of 500 nJ for a 100 byte data payload transfer. When optimizing the parameters for energy efficiency, the consumed energy can be reduced to just 75 nJ for 100 byte, while still achieving 30 m of range.

6. Conclusion

The demonstrator proves viability of using energy harvesting based on the Wiegand Effect to power a circuit that performs data acquisition, processing, and wireless transmission in a pulsed, event based operating mode.

Obvious applications for such a system include door or window opening sensors for smart home or industrial door applications. The ability to sense other physical properties also makes this idea suitable for monitoring applications in the vicinity of moving parts (pumps, wind mills, turbines, wheels, assembly belts, etc.). This can result in a novel plug-and-play solution for situations, where a power supply via cable, battery or other energy harvesting technologies was so far impossible or not economical.

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