University of Utah
UNDERGRADUATE RESEARCH JOURNAL

RESEARCH PROCESS FOR DESIGNING CIRCUITRY TO ACHIEVE AN 8 MONTH LIFETIME FOR A NANOGAP GAS SENSOR

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The increasing developments within Internet of Things (IoT) are demanding sensors capable of achieving minimal power consumption while following strict size constraints. IoT devices are commonly equipped with sensors that detect environmental characteristics. Once these sensors characterize the environment, the information is internally analyzed, and the device transmits a respective output to its users. Typically, IoT devices are wireless for user convenience. This results in a demand for a circuit design that enables an extended lifetime to further enhance the effectiveness of the device for its users. In the current state, IoT devices are draining excessive energy to accomplish their task, which causes a frequent battery recharge or replacement. In this research, a circuit was designed to theoretically power a nanogap gas sensor for over 8 months on a single battery while also enabling an alert system when the targeted gas is captured. This research was completed by segmenting the approach into 4 steps.

The first step within this research was to understand and implement a method to power a light-emitting diode (LED) with a power supply of 1 Volt. To achieve the maximum brightness within a typical red LED, a power supply of 1.7 Volts is needed, so the given power supply needed to be transformed upwards from 1 to 1.7 Volts. This transform was achieved by implementing a double-wounded toroid- the Joule Thief. The joule thief utilized properties of a transistor, which was able to achieve a power spike whenever the magnetic field collapsed. As the double-wound toroid's magnetic field would collapse at a frequency of 20 kHz, the red LED appeared to be constantly on.

After powering the red LED with a single volt, the sensor was to be implemented into the system. However, the sensor had a resistance of 1 GΩ when the target molecule was not captured and a resistance of 1 MΩ when it was. The desire was to ensure the LED was on when the target molecule was captured and off when it was not. However, this was not able to be achieved by connecting the joule thief directly as the current dropped drastically due to the sensor's internal resistance. Thus, the current needed to be magnified to properly operate the joule thief and power the LED. This was achieved by implementing a sziklai transistor pair. This pair consists of two bipolar transistors that have opposite polarities – one was a npn transistor while the other was a pnp transistor. This transistor pair was able to spike the current with only a forward voltage of 0.7 Volts, which was accessible from the limited 1 Volt power supply. The sziklai transistor pair boosted the current by a theoretical factor of 10,000. This would cause the LED to appear on when a target molecule was captured and off when it was not.

After successfully achieving an LED alert system with the sensor, a battery and operating schedule was chosen to ensure a lifetime of 8 months. A SPICE model of the circuit design was created and simulated to drain 3.7 mW when on and less than 1 μW when off. By utilizing the Tenergy-10400 AAA 1,000 mAh 1.2V Nickle-Metal-Hydrate button-top battery an effective schedule was able to be considered. With a single respective battery, the system would be powered for 289 days, well over 8 months, if the sensor had a schedule of turning on 6 times a day for 10 minutes each time it is turned on.

Lastly, the overall size of the circuit system was large due to the joule thief utilizing a double-wounded toroid. In reducing the size, two discrete inductors and a npn transistor was utilized in place of the joule thief, significantly reducing the overall size of the system by half. In addition, the circuit design only utilized off-the-shelf components, which allowed for a more cost-effective method of production.

After completing each segment of the research, an abstract was written and accepted for the 33^{rd} IEEE MEMS conference. Once the abstract was accepted, a paper was written and published. Furthermore, this research was presented in Vancouver for the respective conference.