EE 174: Digital Geiger Counter Project

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Abstract:

For our project we built a digital Geiger counter. Using a proper geiger counter wand and our own circuitry and a microcontroller we are able to accurately count incoming ionizing radiation particles and display them on an LCD. As this course is interested: the Geiger counter requires a 900 volt boost DC-DC converter using a transformer, the microcontroller and its LCD require a 5 volt buck DC-DC converter, and the rest of the circuits require several linear voltage regulators. Although the wand cannot be used to harvest energy it is very much a transducer because it translates incoming radiation into a voltage dip.

Introduction:

Geiger counters are devices that measure ionizing radiation intensity. Ionizing radiation, unlike non-ionizing radiation such as visible light, consists of particles that carry enough energy to free electrons from atomic orbit. Ionizing radiation is both harmful and imperceptible to human senses. Thus, while it is important to be able to measure its intensity, specialized instruments must be built in order to do so. Geiger counters are designed for that purpose.

Geiger counters are more of a novelty these days as we see a decline in public interest in nuclear technology. However, in the atomic age often considered to start in the 1940's and cease at the end of the cold war, Geiger counters and similar tools were necessary to determine the radioactivity emission of materials of the relative habitability of environments.

Theory:

There are several types of ionizing radiation, often released at the same time when radioactive atoms decay. These include alpha, beta, and gamma radiation. Alpha radiation is a stream of helium ions; as the particles are physically massive, alpha radiation does not have much potential to travel far outside of a vacuum. Gamma radiation is an electromagnetic emission, very high frequency and energy photon is released and it is very penetrative. This project is most interested in beta radiation. Beta particles are a release of high energy electrons or positrons (anti-electrons with positive charge); they can travel outside of vacuum better than alpha particles but not as well as gamma rays. Additionally, inert gasses are easily ionized by traveling electrons like beta particles e.g: neon lights.

The necessary sensor this device employs is a particle detecting wand. Essentially, it is an air gap capacitor with 900 volts applied to it but the dielectric is the inert gas Xenon instead of air. When the capacitor is charged it can be discharged when a beta particle ionizes the gas, creating a momentary short across the capacitor as shown in figure 1.

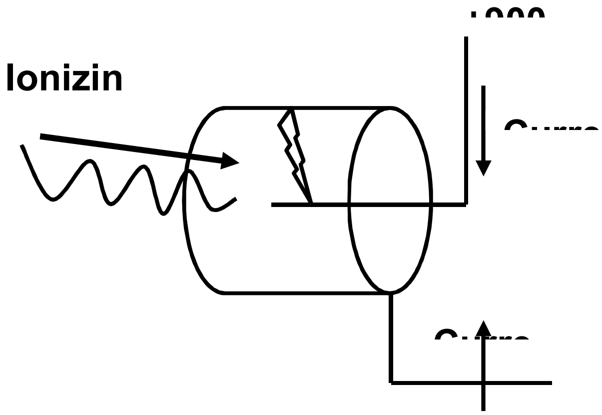

Figure 1: A simplified model of the physical Geiger discharge process.

The wand sensor used in this project is shown in figure 2:

Figure 2: Particle detection wand containing a 900-volt Geiger probe.

Procedure/Methodology:

The hardware we need must power everything from a 9-volt battery including the 900 volts for the wand, voltage for the pulse widening detection circuits, and 5-volts for the microcontroller and its peripherals. We employed a transformer-based switching boost DC-DC converter, linear voltage regulators, and a switching buck DC-DC converter.

The detection of a particle is represented by a voltage dip in the sensor wand. That dip is merely nanoseconds long so we deployed a pulse widening circuit with a PMOS input that triggers on that nanoscopic dip from 900 volts to 0 volts. The output signal from the pulse widening circuit is long enough and at the right voltage to be and GPIO input into the microcontroller with some low pass filtering. The pulse widening circuitry as well as the 900 volt supply are assembled on the breadboard shown in figure 3. The signal of a detected particle was captured on an oscilloscope in figure 4; in fact this figure has detected two consecutive particles close together in time.

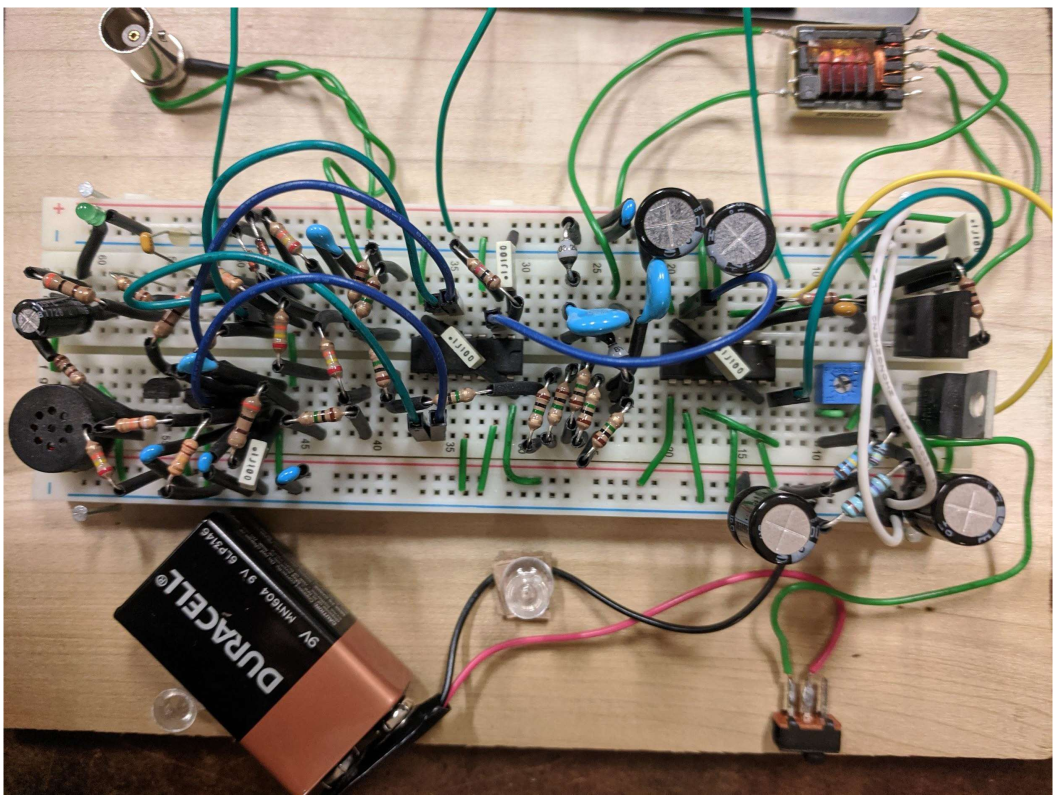

Figure 3: Analog components of Geiger counter including wand-powering hardware, pulse-widening circuits, coaxial connector, and a 9 volt battery.

Figure 4: Signal of sensor circuit detecting a beta particle.

The microcontroller is programmed to interrupt each time a new trigger comes in from the sensor circuits. The interrupt adds to a count which is averaged over an amount of time to produce units such as counts per minute and counts per second. They are displayed on an LCD display and the units can be toggled with a button press. The microcontroller, its 5 volt switching buck DC-DC power supply, and an LCD peripheral are on the breadboard in figure 5.

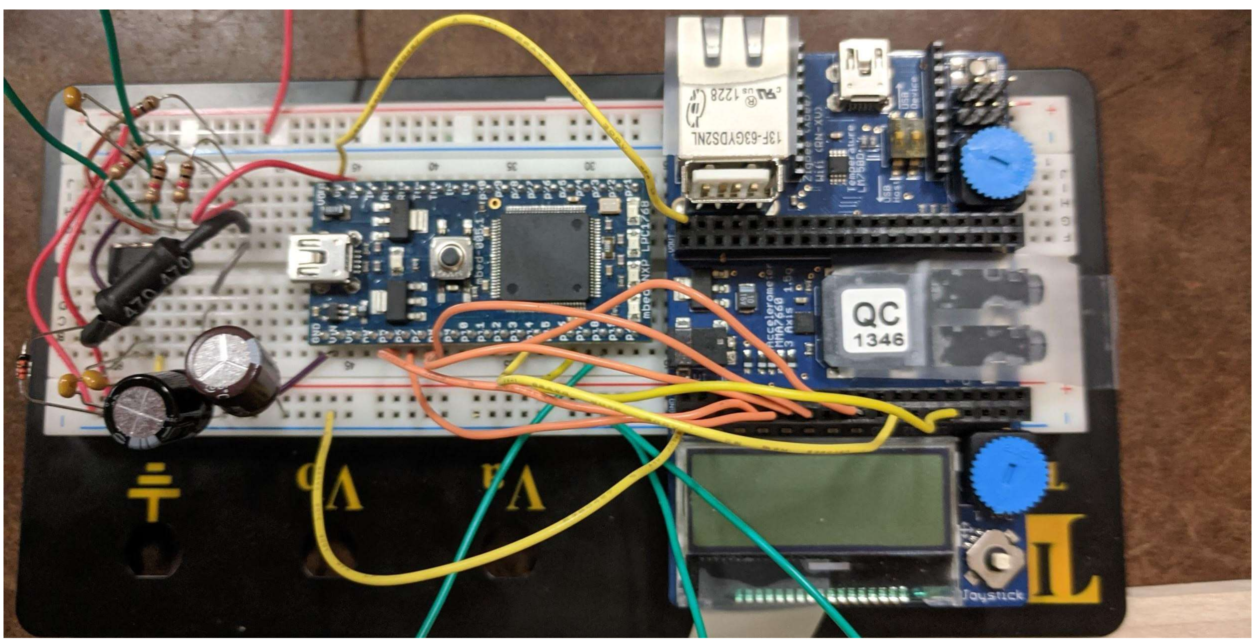

Figure 5: The microcontroller, its 5 volt power supply, and its LCD display.

Results:

We had access to a sample of depleted uranium that is attached to a counter from the 50s. we used it to test our sensor with real materials instead of just ambient radiation. When we compared our Gieger counter's count with the professional counter we found that they were calibrated near total agreement. Figure 6 shows an image of the LCD reading taken when the probe was disconnected:

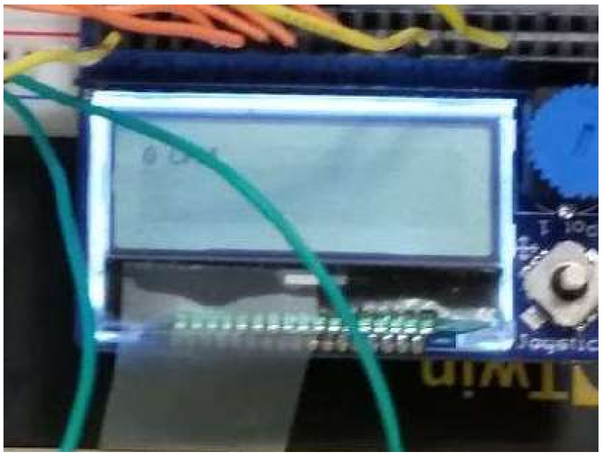

Figure 6: The LCD displaying a count of 0 particles per minute, when the wand was disconnected.

Conclusions:

Relevant to the class EE 174, our project employs an energy detector, voltage regulators, and a microcontroller. Not only can it sense radiation, our counter is able to accurately measure low to medium saturation radiation when we compared the output to an official tool.

There are several conventions for measuring radiation and exposure. We can easily add more units to calculate and display. We can also further calibrate the device's hardware to withstand and detect more radiation before the sensor saturates.