by Tom Napier

Biassing G-M Tubes Isn't So Hard

A Minimal HV Generator Powers a Small Geiger-Müller Tube to Detect Ambient Radiation

Small Geiger-Müller (G-M) tubes make ideal sensors for pocket-sized devices to detect radioactivity. They have a high sensitivity to beta particles and some ability to detect gamma rays. Given a thin (and very fragile) mica window they will also detect alpha particles — most G-M tubes don't.

Still, even a small G-M tube needs an anode voltage in the 400 to 600 volt region. Here's how to generate that voltage from a 9 V battery. I first used this design in 1979 and I was pleasantly surprised to find that the parts are still available. I've even simplified things by driving the generator with a CMOS 555 timer.

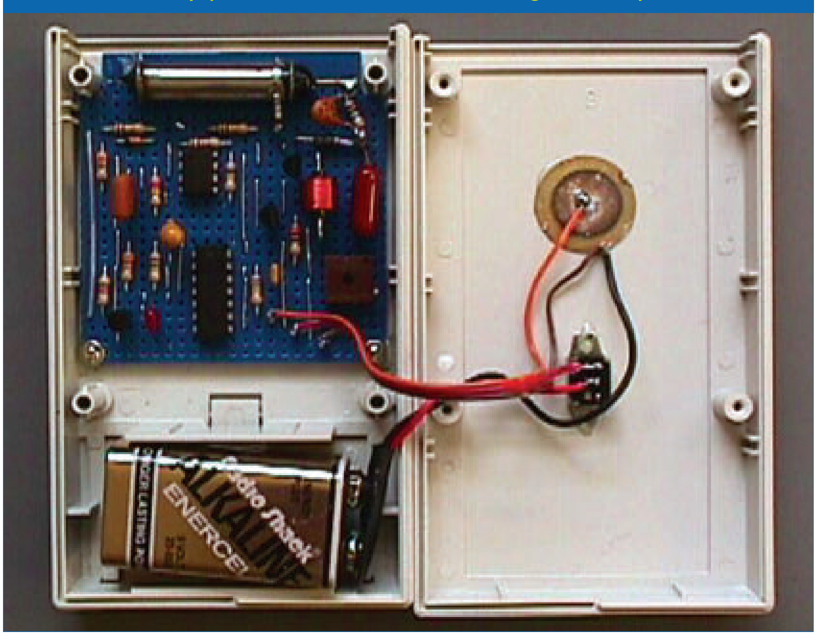
How Much HV?

Reference 1 gives a detailed description of how G-M tubes work. My detector uses a G-M tube 1.5-inches long and 0.3-inches in diameter. Its operating voltage is in the 400 to 500 V region but under normal conditions, it consumes virtually no current. Roughly speaking, each detected particle discharges the capacitance associated with the anode of the tube. Let's assume 450 V and 5 pF — that's 0.5 µJ of energy. At a background rate of one pulse every ten seconds, the mean current is just over 100 picoamps! In practice far more current goes to drive leakage than is needed by the tube. A rectifier with a microamp of reverse current is pretty good by ordinary standards, but would consume several thousand times as much power as the G-M tube! Even measuring the output voltage without drawing a disproportionate current would require a gigohm or so of sensing resistor and a very low bias-current amplifier. Therefore, we are much better off using a fixed-ratio converter and some well-chosen components.

Flyback Fun

In DC-DC converter handbooks, you'll find the flyback converter described as a constant-power device whose output voltage, unless stabilized, varies greatly with the load resistance. Each switching cycle delivers the power stored in an inductor to the load. Either the peak inductor current, or the switching frequency, is adjusted to maintain a constant voltage. What is less well known is that when the load current is low enough, a flyback converter behaves as a constant voltage source. It converts the peak inductor current to output voltage in a ratio that depends only on the inductor and the capacitance associated with it. This transimpedance ratio is the square root of L/C, and with practical components, can exceed 20 kV per amp. A 450 V output, for example, requires a peak inductor current around 20 mA. You can generate a stable high voltage with no transformers or voltage multipliers, just an inductor, a switch transistor, a rectifier and a reservoir capacitor.

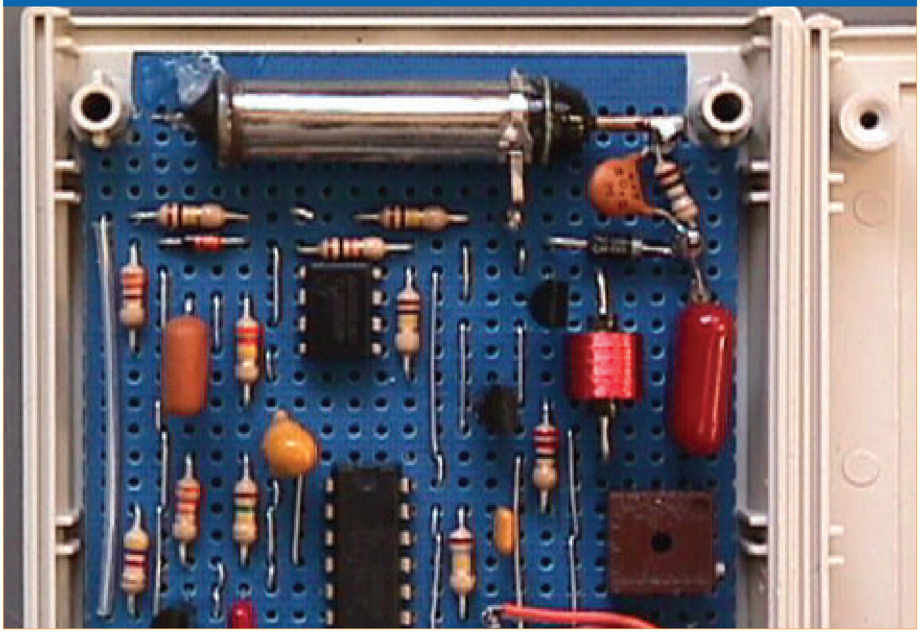
PHOTO 1. Everything fits easily in a small project box. The on/off switch is the only panel control, and above it is glued the piezo element.



A Practical Circuit

Figure 1 shows my implementation of this

PHOTO 2. A close-up of the prototype constructed on perf-board. The G-M tube fits across the top edge.



elegant converter. The CMOS 555 timer (U1) free-runs. Its on-time is about 30 µS, its off-time about 3 mS. The off-time is controlled by an RC network, and the on-time is set by the peak inductor current. The current is adjusted by VR1 to set the output voltage.

When the theshold current is reached, Q2 resets the 555. C2 then discharges through R1, eventually causing the 555 to retrigger. R1 is chosen to set a pulse rate that supplies sufficient output current while minimizing battery consumption. To avoid temperature drift, C2 should be a stable foil component, not ceramic.

When the output of the timer is high, C2 recharges rapidly via R2 and D1. At the same time, Q1 is turned on, causing the current through it and the inductor to rise by about a milliamp per microsecond. Q2 senses when the current reaches the preset value (around 25 mA).

This resets the timer, its threshold input is unused, and turns Q1 off, creating a positive half-sine-wave spike about 2 µS wide, and over 400 V high at the junction of the transistor and the inductor. D2, a fast high-voltage diode, passes this spike to C3, a 0.01 µF 630 V capacitor, to generate the G-M tube's anode supply. Since the output current is very low, the capacitor voltage remains constant.

The 555's discharge pin clamps Q1's base to ground. This not only achieves a rapid switch-off but also protects Q1 from high voltage breakdown. The negative half-cycle of the inductive spike is clamped via the collector-base diode of Q1.

The output voltage is directly proportional to the peak inductor current and is independent of the battery voltage.

The peak current is stable apart from a slight temperature coefficient so the circuit maintains a constant output without feedback from the output. Besides, G-M tubes are not fussy about their exact supply voltage. Despite the high peak current, the mean load on the battery is about 0.5 mA, giving several hundred hours of use.

Detecting Particles

The anode of the G-M tube is fed via a 10 M resistor, R6. This has a 4.7 pF capacitor (C4, rated at 630 V) across it. When a beta or gamma ray is detected the tube avalanches. The capacitor charges rapidly, dropping the voltage on the tube and giving a