The Home Brew Geiger Counter[1]

EpiphanyBySteveLee.com

Introduction:

This project offers two simple circuits for use in detecting the presence of ionizing radiation (e.g. x-rays, gamma rays, etc.), using a surplus Geiger-Muller tube (check on-line auction sites such as ebay, etc.). DANGER: High Voltage! This project is not for the novice!

How it works:

The radiation sensing component of these circuits is the Geiger-Muller ("GM") tube. Though this gas-filled GM tube requires a high voltage to work, the tube itself draws very little current. This allows us to use a 9 volt battery as the power source, stepped up through the DC-to-DC step-up convertor/multiplier section of a circuit composed an LM324 configured as an oscillator (the 555 timer configured as an astable oscillator could also be used if preferred), the step-up transformer (e.g. from a 120:5v "wall wart" power supply), and the diode/capacitor "ladder" at the right of the transformer in the diagram below.

In the circuit, we take the output of the Op Amp and deliberately feed it back to the *non-inverting* input. This *positive* feedback drives the Op Amp input higher, which is then amplified and fed back to the input again, etc. In other words, this positive feedback of energy effectively drives the amplifier into oscillation. Since the secondary side of the transformer (its right side) has roughly 20 times as many windings as the primary (the left side of the transformer), the oscillating collector voltage on the primary is stepped-up by a factor of ~20 into the secondary side[2]. This stepped-up voltage is then multiplied via the diode/capacitor "charge pump" ladder, providing the 425 volts needed to operate the GM tube (see detailed description of the ladder below).

The GM tube is basically a gas-filled vacuum tube, and it is the gas in the tube that allows us to detect any ionizing radiation that happens to pass through the tube. As this radiation moves through the gas, it collides with many of the gas molecules in its path, breaking the molecules into ionized fragments. Once these charged fragments are created, they are then drawn to the high voltage across the GM tube's electrodes. As these ions hit the electrodes, they create a brief current spike in the circuit, causing the piezo beeper to "chirp". The more radiation there is, the more ions, and thus the more the beeper chirps.

As for how 9v x 20 equals 425 volts... We could just explain it as "the *new math*", A.K.A. "the US public school system math" and leave it at that (and of course, if you were a product of the public school system, you would be lost by now anyways, so *QED*).

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1 See "EpiphanyBySteveLee.com" for additional information to be added over time.

2 For those who feel such step-up "black magic" somehow violates the "something for nothing" law, (i.e. the Law of Conservation of Energy), we point out that though voltage is stepped up due to the greater number of electrons being exposed in the larger number of turns of wire in the secondary, current at the same time is stepped *down* on the secondary side. Since Power (energy per second) is not just voltage, but rather the product of voltage * current (i.e. $P = V * I$), we don't actually break the universe every time we perform such a mystical voltage step-up. Good thing too, 'cause I'm thinking we've done this whole step-up thing at least a... *few* dozen times now since Maxwell and Tesla started the whole fad back in the 1800's.

Unfortunately, the IEEE takes a dim view of such sloppy explanations, therefore we are obliged to mention in passing that the diodes and capacitors aft of the transformer gizmo *might* possibly have something to do with it...

Configured as they are, these diodes and capacitors form a voltage multiplier (sometimes referred to as a “charge pump”, with charge “Q” related to voltage: Q = V * C). During the negative half alternations at the top of the secondary, the diodes with cathodes facing the top of the “ladder” are biased on, allowing current to flow through the capacitors across the top of this ladder developing a charge/voltage across their plates (negative to positive, left to right) equal to the *peak* voltage of the secondary (minus the diode drop). During the following positive half alternation, the diodes with their anodes pointed up are biased on, transferring the peak voltage from the transformer (less the diode drop) *plus* the charge/voltage now stored in the caps at the top (like batteries connected in series). This effectively places *double* the secondary voltage across each of the capacitors on the bottom of this ladder. When all of these bottom capacitors are thus charged, their total voltage adds in series to achieve the high voltage needed to operate the GM tube. If we attach scope probes to points in the ladder, we can see that it typically takes some 40 or 50 oscillator cycles (~40-50 mS) to build up to the full charge, as the charges are effectively “pumped” down the ladder. And that in a nutshell, is how we turn 9 volts into 425 volts.

Note that you may need to add or remove diode/capacitor pairs to achieve the required 425 v DC, depending on the step-up capability of the transformer you use (the labeling on many “wall-wart” transformers varies wildly, hence many labeled “5v DC” may be more like 10v peak[3] or more); put a scope across the bare secondary terminals to know for sure). Also, it is important to use caps in this section that are rated to withstand *twice* the peak secondary voltage, plus a little margin for safety (i.e. 2*[1.41*5v*20] **==>** 350 V DC).

We mention in passing that if we had designed the oscillator to run at a lower frequency (e.g. 60 Hz), we would need much higher capacitance values than what is shown. Higher capacitance coupled with a higher working voltage would imply very large and hence much more *expensive* capacitors. However running the oscillator at ~1000 Hz allows us to use only 0.1 uF disk caps (i.e. smaller time constants), since 1000 Hz equates to only 1 mS between each charging pulse, and 1 mS offers enough time to refresh the 0.1 uF caps before they discharge too much (note that higher cap values would help reduce “ripple”). (Note that we can't go too much higher in frequency, since a transformer is basically a pair of large coils, and the impedance of coils increases with increasing frequency.)

As a pulse of radiation ionizes the gas in the GM tube, a brief pulse of current is generated. This pulse of current across the 100k resistor below the GM tube, generates a short voltage pulse that briefly drives the piezo beeper into oscillation, giving us a short beep for every pulse of radiation detected. If desired, the user can attach a high impedance buffer amp at point “A”, followed by additional measuring circuitry for a more versatile measuring device if needed.

<u>Testing</u>:

To test the circuit, place the GM tube close to a spare chunk of radioactive Uranium or Plutonium (etc.). If your stash of U^{235} or U^{239} happens to be off in your Delorean at the moment, we can squeak by using one of those ancient Cathode Ray [“death”] Tubes (CRT) in an old color TV, or color computer monitor. Simply place the GM tube next to the CRT, turn it on and see if your detector lets out a few feeble chirps.

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3 Note that AC voltages are typically given in RMS values, where: Vpeak = 1.41 * Vrms

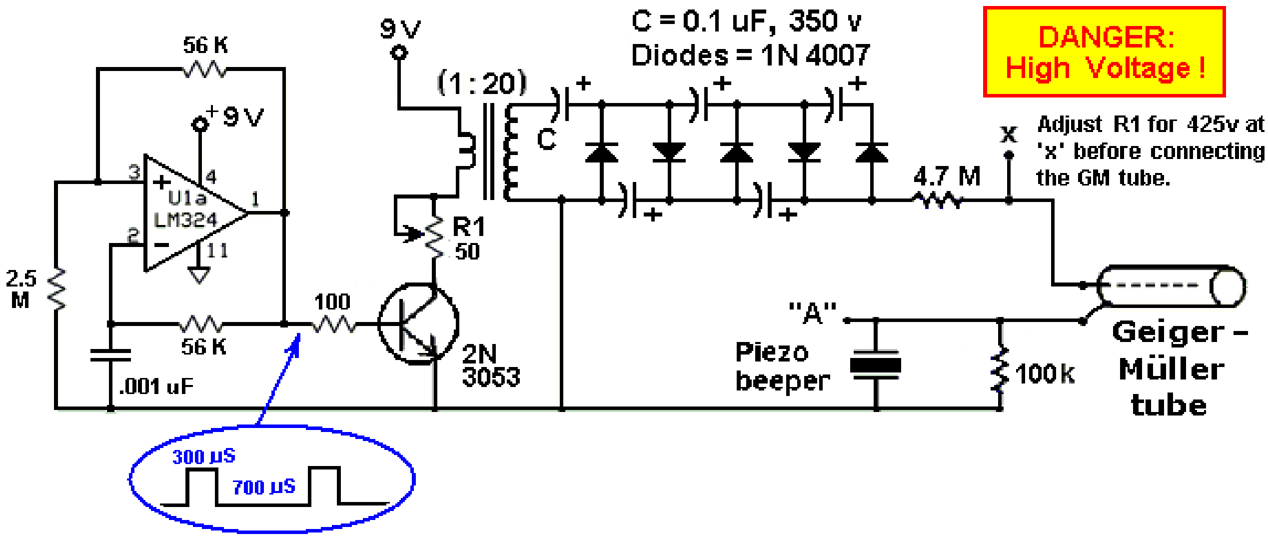
These old CRT's painted an image on the screen by shooting a beam of electrons at the phosphorus-coated face of the CRT, and then bending that beam back and forth to make it trace out one line at a time across the screen. Physics 101 tells us that anytime charge particles (in this case electrons) accelerate, they give off radiation; the greater the acceleration or deceleration, the greater the energy change, and hence the higher the energy in the emitted photon (E = hF, where h = Planck's constant). As these electrons impact the charged metal screen at the front face of the CRT (needed to attract the electrons and separate the phosphorus dots on the screen), they undergo a *very* rapid deceleration, which corresponds to a high change in energy over a very short amount of time, producing high frequency x-rays in the process (known as “Bremsstrahlung”).

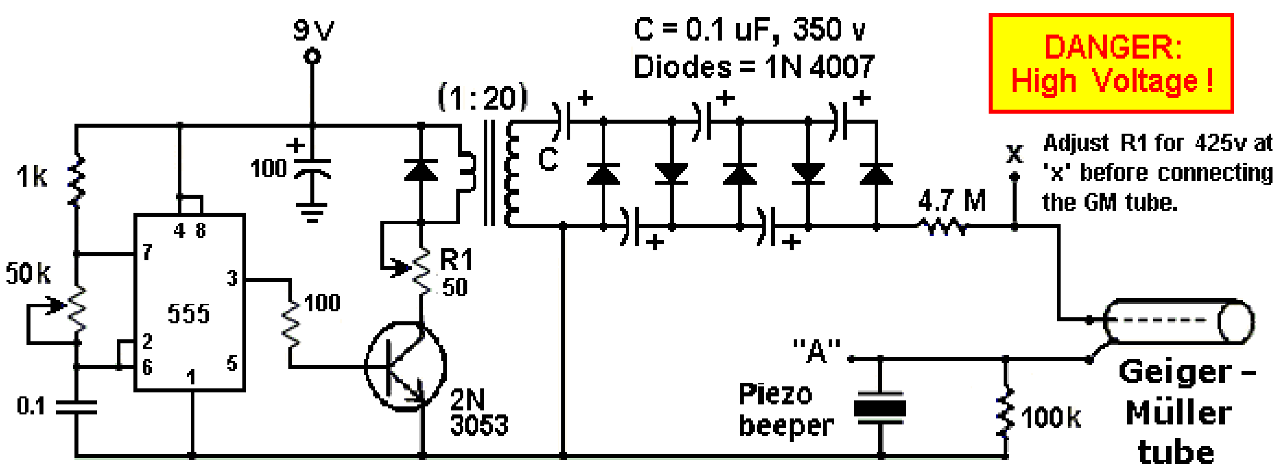
In color CRT's, more metal screening is used in order to isolate the red, green, and blue phosphorus dots on the screen. This in turn requires a higher voltage (~25,000 volts) on the CRT face to accelerate the electrons (compared to B&W). Higher voltage means faster electrons hitting the metal screen even harder in color CRTs than in B&W, giving off even more radiation than the B&W. All of this results to a good dose of x-rays every time you as a kid sat up close and personal (for *hours* at a time) watching “Starsky and Hutch” slap “huggy” up-side the head for laughs. This of course in turn explains *a lot* about how you turned out (i.e. the fact that you even watched “Starsky and Hutch”... not the close personal relationship you had with the death-ray CRT's; that relates more to how your three-headed offspring turned out... but that's a whole other topic of discussion).

WARNING: This circuit generates HIGH VOLTAGE which can cause serious bodily damage, including **permanent nerve damage** and **death**.

If you are not trained in handling high voltage, **DO NOT build this circuit**. If you are trained, make sure you follow all safety guidelines when constructing and/or using this device, including:

1) Absolutely **NEVER** touch any part of this circuit while it is operating.
2) Even if switched off and discharged (see below), NEVER touch any part of this circuit with both hands at the same time, as that will complete a circuit from one hand, across your chest (heart), and back to the circuit through your other hand.
3) Before handling this circuit, first unplug the battery and then bleed off the high voltage section using a well-insulated 10k, 1 watt resistor connected to ground, touching the free end of this resistor to each capacitor-diode junction in the high voltage section for several seconds, followed by touching point “x”, before proceeding to step four below.
4) Verify the high voltage section is fully discharged by probing each of the above junction points with a voltmeter (set to the 600 volt scale setting), using only one hand at a time, before attempting to work on this circuit.


56 K
9 V
+9 V
U1a
LM324
2.5 M
56 K
.001 uF
100
R1
50
2N 3053
(1 : 20)
C = 0.1 uF, 350 v
Diodes = 1N 4007
C
DANGER:
High Voltage !
Adjust R1 for 425v at 'x' before connecting the GM tube.
x
4.7 M
"A"
Piezo beeper
100k
Geiger - Müller tube
300 µS
700 µS


9 V
C = 0.1 uF, 350 v
Diodes = 1N 4007
(1 : 20)
DANGER:
High Voltage !
1k
100
C
Adjust R1 for 425v at 'x' before connecting the GM tube.
x
4.7 M
555
50 k
0.1
100
R1
50
2N 3053
"A"
Piezo beeper
100k
Geiger - Müller tube