LED Based Active Quenching Single Photon Detection

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Common Applications

Light sensing devices have many important applications in society today; however, this technology can be extremely costly. Commonly, high voltage avalanche photodiodes are used for the purpose of single photon detection, but this technology requires more complex circuitry in order to maintain and reset the high voltage bias across the photodiode.

An Alternate Solution

A very simple and inexpensive photon detector can be created simply by avalanching a light emitting diode more commonly called an (LED). LEDs are typically used for the process of emitting light. While emitting, current can only flow through the LED in one direction. By changing the polarity of the voltage across the LED, the LED can instead act as a photon detector.

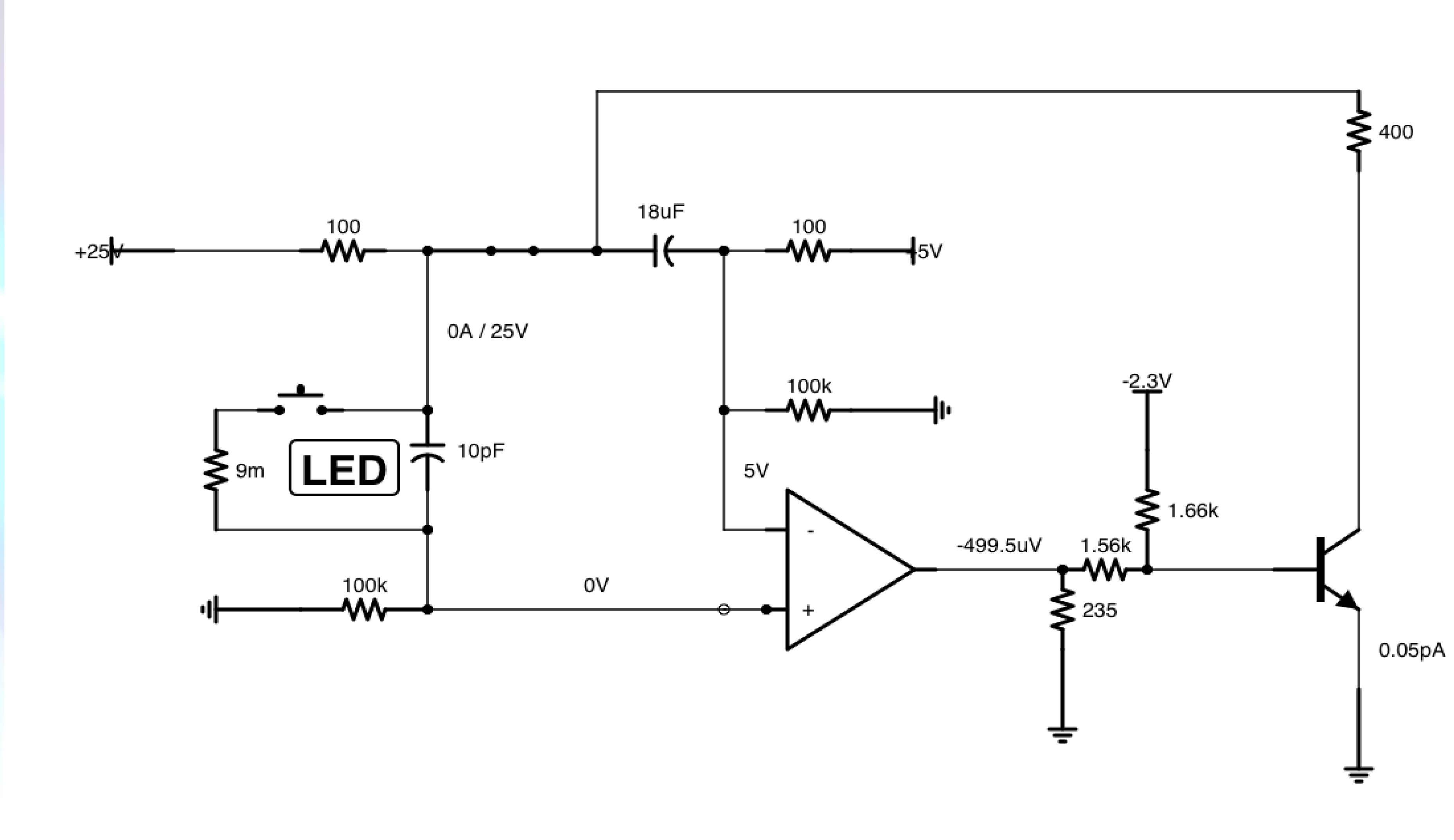
Our Objective

The purpose of our research has been to exploit this capability by avalanching the LED in much the same way one would avalanche a photodiode. By inserting this LED the “wrong way” in a circuit, it will block current from flowing through it. When a photon hits the negatively biased LED, it will allow a short burst of current to flow through it before it resets itself and returns to blocking the current. However, the natural reset time of the LED is too long to count repeated single photon encounters. That is, in the time it takes the LED to reset, more photons will strike the LED than it can count. Our research involved implementing a circuit which would considerably reduce the reset time after a photon occurrence so that the reset time would be short enough to count the next occurrence.

References

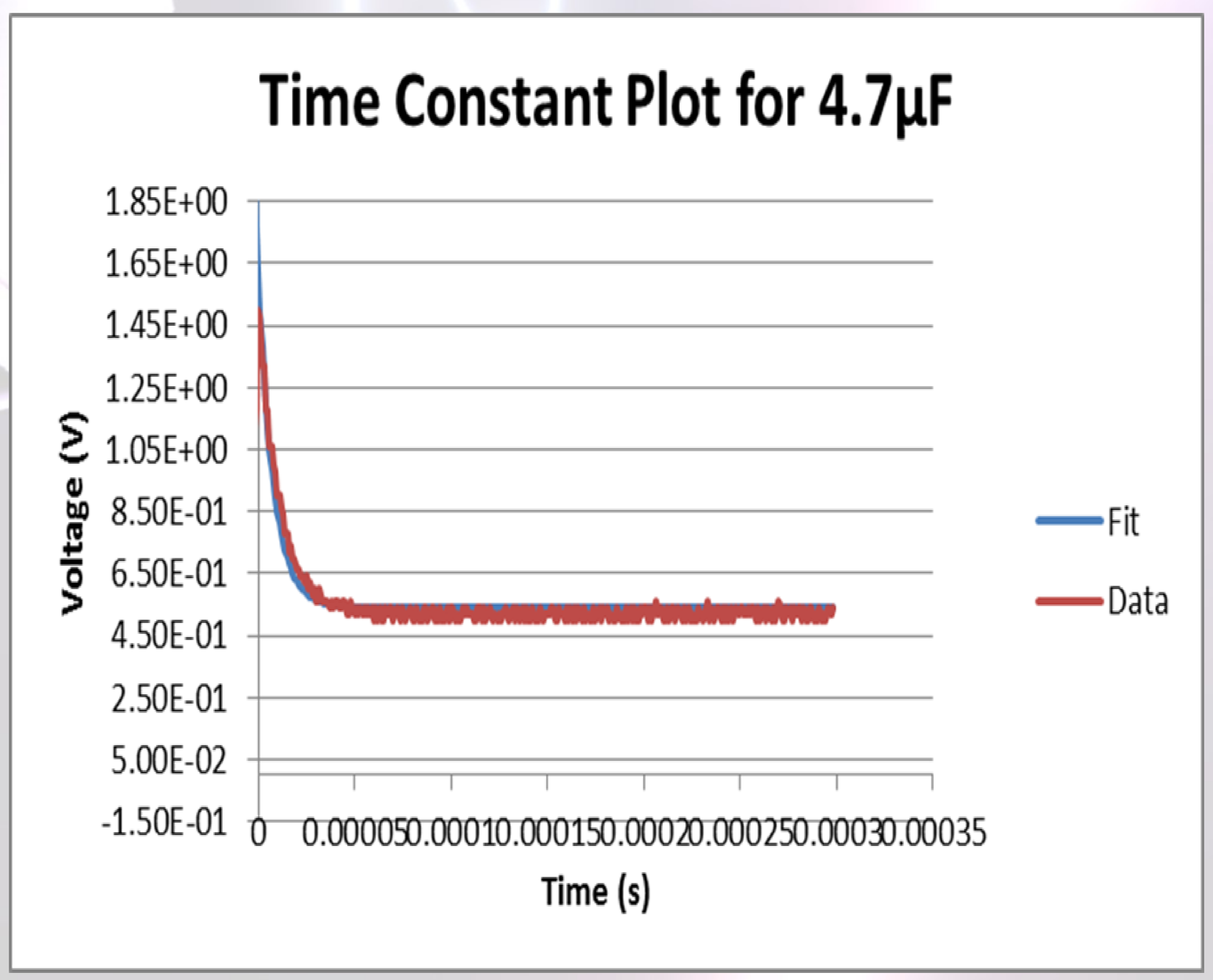
Walker, J., Halliday, D., & Resnick, R. (2011). *Halliday & Resnick fundamentals of physics* (9th ed.). Hoboken, NJ: Wiley.

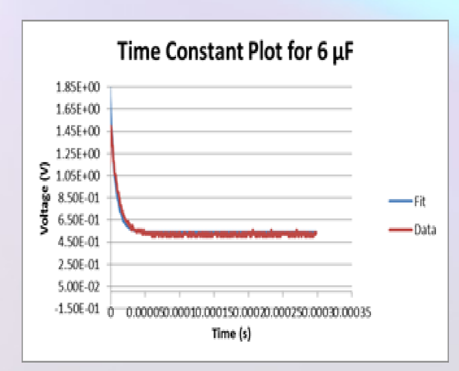
"What's A SPAD." *The Relaxatin Times* IV (May 2013): 3. *More to an LED than Meets the Eye*. TeachSpin, May 2013. Web. 07 Apr. 214.

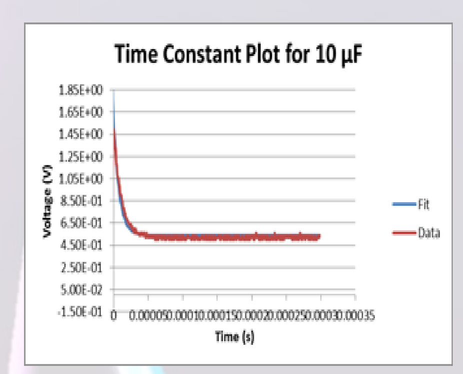


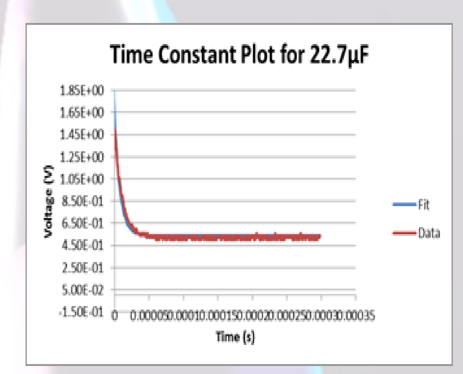
This is a schematic of the active quenching circuit used for photon detection. In the LED loop, if the LED is inserted into the circuit “backwards,” it will prevent current from flowing through it. However, if the potential difference across the LED exceeds its breakdown voltage, when a photon strikes the LED, it will temporarily act as a conducting path. Then, the circuit will reset the LED to its original voltage to prevent current flow again and prepare for the next detection.

This is the display of the oscilloscope which is used to monitor photon detection events. The probes of the oscilloscope are connected across the 100kΩ resistor which is located between one end of the LED and ground. When a photon strikes the LED and current is allowed to flow through it, all of this current flows through the 100kΩ resistor to ground. This creates a measureable voltage drop across the resistor which can be interpreted as a photon detection occurrence.

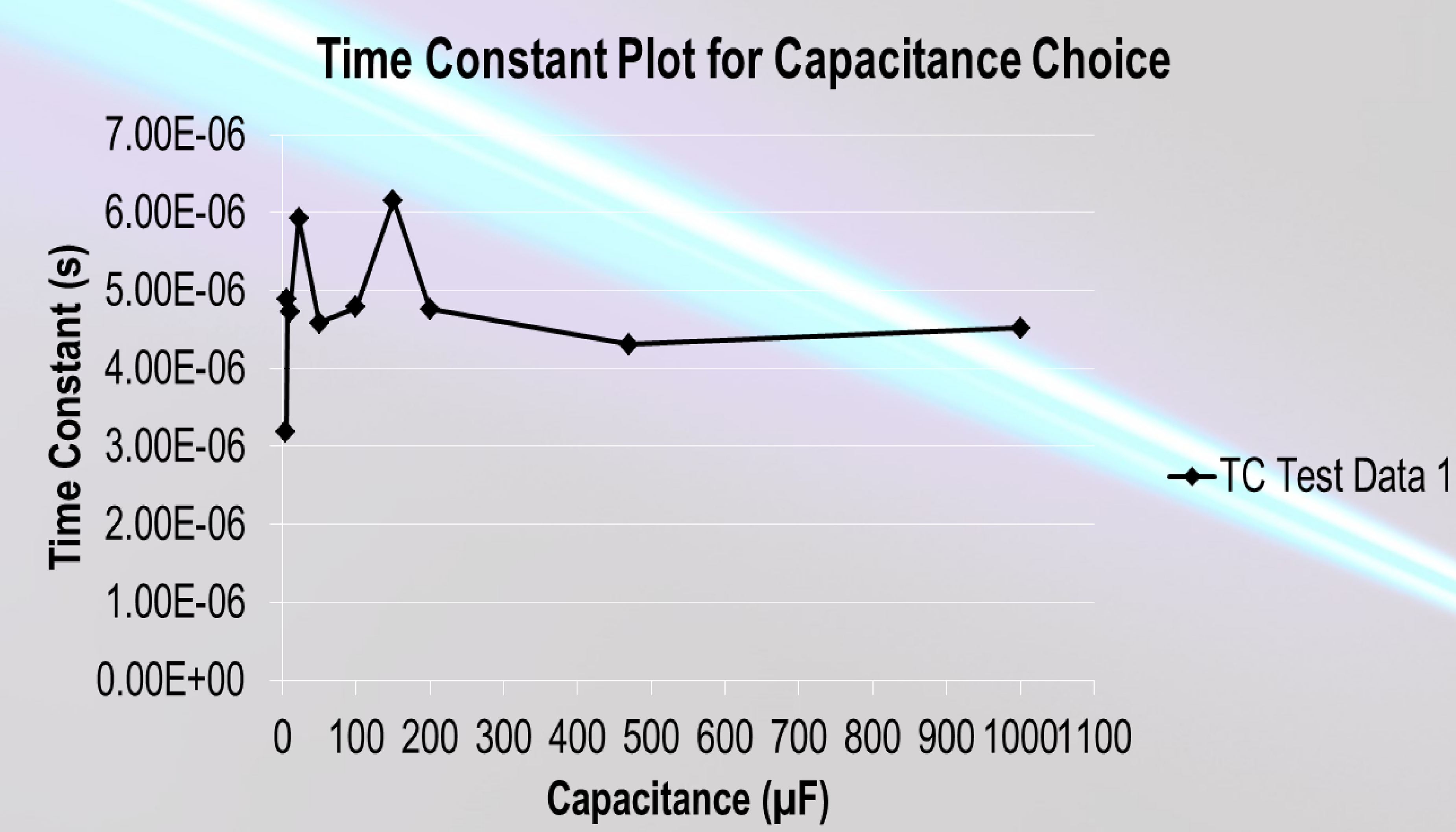








Oscilloscope readings were taken from the circuit for each capacitance value and plotted in Excel. From these plots, the time constant of the circuit could easily be determined, which allowed for comparisons on the circuit’s active quench speed with varying degrees of capacitance.



After obtaining values for the time constant corresponding to each capacitor, the time constant vs. the capacitance was plotted to attempt to determine a correlation between the two quantities. Unfortunately as can be seen above, a correlation which could be represented by a simple mathematical formula could not be found. Nonetheless, it is still evident which capacitance values were able to provide the most ideal time constant.