Technical Information

UVTRON®

Flame / Discharge Sensors

UVTRON® Flame / Discharge Sensors

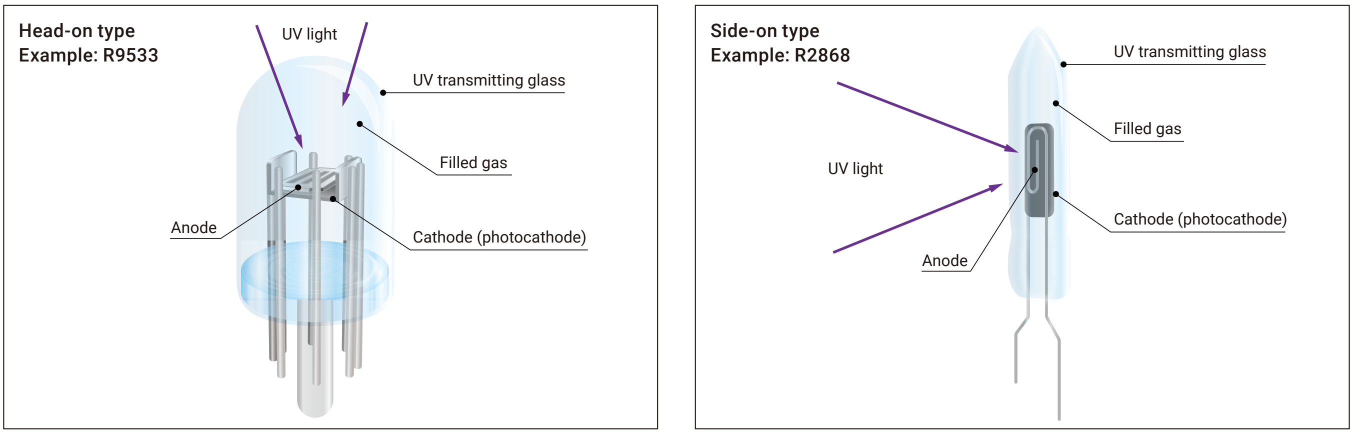
UVTRON® is a sensor sensitive only to UV light with wavelengths of 185 nm to 260 nm*1.
Featuring high sensitivity, high output, and high-speed response, UVTRON® is ideal for detecting electrical discharge and flame.

*1: For Ni electrode

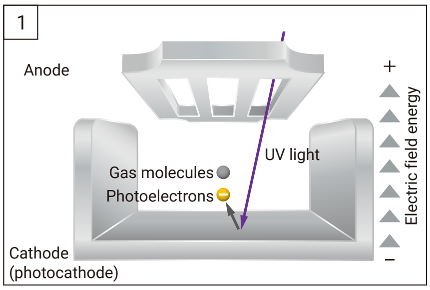
1 Structure and operating principle

UVTRON® is a type of gas-encapsulated discharge tube that discharges when UV light is incident on it, and outputs the current generated during discharge as a signal.
A tube voltage (rated voltage) that exceeds the discharge start voltage of the UVTRON® is supplied to the anode and cathode (photocathode). When more than a certain amount of UV light enters the cathode (photocathode) through the UV transmitting glass, photoelectrons (electrons) are emitted from the cathode surface due to the photoelectric effect of the electrode material. The emitted photoelectrons are attracted to the anode side by the electric field energy and collide with gas molecules in the tube as they accelerate, resulting in ionization of the gas molecules. The electrons and positive ions generated by the ionization then repeatedly collide with other gas molecules. This causes the number of electrons and positive ions in the tube to increase at an accelerated rate, and when the UVTRON®-specific discharge conditions are met, a large current suddenly flows between the anode and cathode, producing a discharge state.
When operating with a CR quenching circuit (see “3 Circuit Operation”), the UVTRON® intermittently generates a discharge phenomenon as long as UV light is incident, and extracts the discharge current as a pulse signal. Then, the discharge phenomenon stops simultaneously when the UV light ceases to enter.

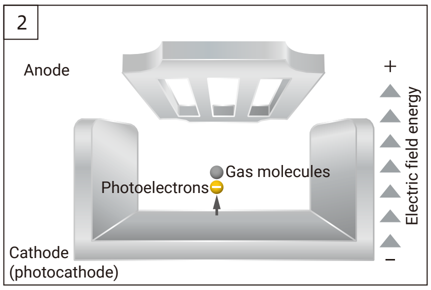
■ **Figure 1-1: Internal structure**



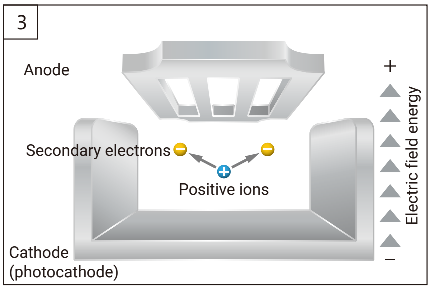
■ **Figure 1-2: Operating principle**



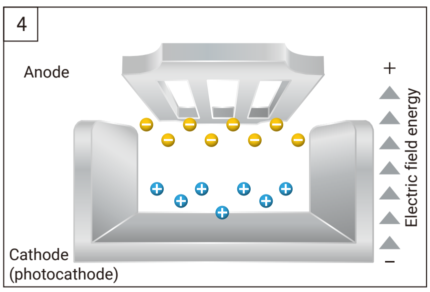
When more than a certain amount of UV light enters the cathode (photocathode) through the UV transmitting glass, photoelectrons (electrons) are emitted from the cathode surface due to the photoelectric effect of the electrode material.



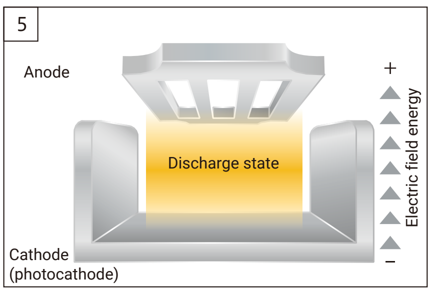
The photoelectrons are attracted to the anode side by the electric field energy and collide with gas molecules in the tube as they accelerate, resulting in ionization of the gas molecules.



Electrons and positive ions are generated by the ionization.



The number of electrons and positive ions increases at an accelerated rate as they repeatedly collide with other gas molecules.



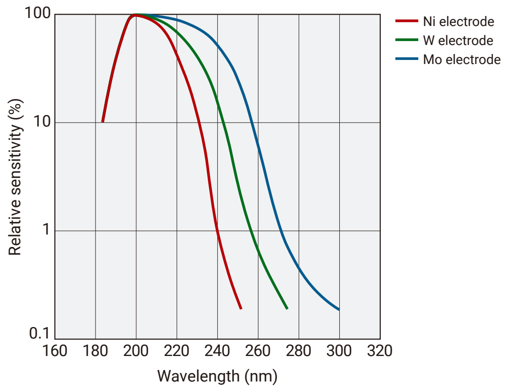
When the UVTRON®-specific discharge conditions are met, a large current flows drastically between the anode and cathode, producing a discharge state.

2 Spectral response range and solar blind characteristics

2-1 Spectral response range and glass/electrode materials

The range of wavelengths that the UVTRON® can detect depends on the transmission wavelength of the UV transmitting glass on the short wavelength side, and on the work function of the electrode material on the long wavelength side.
UVTRON® uses three electrode materials, namely, Ni (nickel), W (tungsten), and Mo (molybdenum) based on factors such as cutoff wavelength and durability.

■ Figure 2: Spectral response (Typ.)



Photoelectric effect refers to a phenomenon in which electrons inside a material are excited by light and ejected into a vacuum. The ejected electrons are called photoelectrons. The relationship between the kinetic energy (*E*) contained in these photoelectrons and the frequency (ν) of the incident light can be expressed by the following calculation formula.

(1) $$E = h\nu - e\Phi$$

h : Planck's constant
e : electron charge
Φ : work function

If the frequency of incident light is gradually decreased, the frequency limit (ν_0) at which photoelectrons are no longer be emitted can be expressed as follows, assuming that the kinetic energy (*E*) of the photoelectrons is 0.

(2) $$\nu_0 = \frac{e\Phi}{h}$$

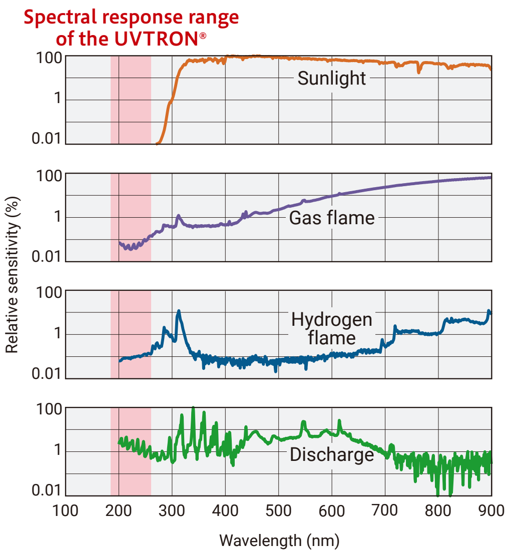
In addition, based on the wavelength (λ) = the speed of light (c)/the frequency of incident light (ν), the cutoff wavelength (λ_0) can be expressed by the following calculation formula.

(3) $$\lambda_0\ (nm) = \frac{hc}{e\Phi} = \frac{1240}{\Phi}$$

2-2 Solar blind characteristics

The spectral distribution of sunlight, gas flame, hydrogen flame, and discharge, and the spectral response range of the UVTRON® (Ni electrode) are shown below. The UVTRON® has a very narrow spectral response range of 185 nm to 260 nm and has no sensitivity to UV light from sunlight due to its solar blind characteristics, eliminating the need to use optical visible light cut filters, etc.

■ Figure 3: Spectral distribution (Our measured values)



3

Circuit operation

To operate UVTRON® properly, you need to have an understanding of UVTRON® itself and its circuit operation.
This section describes the operation of these circuits.

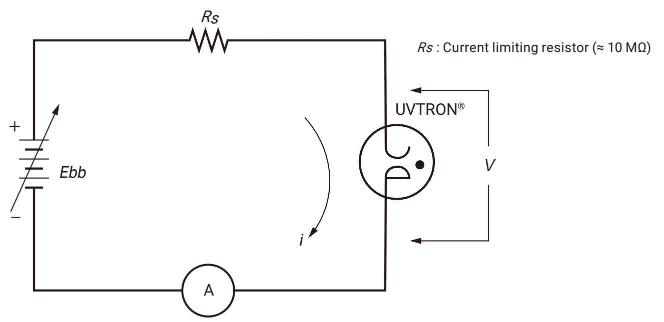
3-1 Circuit operation

The UVTRON® defines sensitivity as the number of counts of the output signal when UV light is incident. Some UV detector tubes define sensitivity as a current value, but the UVTRON® uses a cold cathode, so the number of counts is used out of consideration for lifetime characteristics. As the UVTRON® itself does not have a quenching function to temporarily stop the sustained discharge, external quenching (forcibly stopping the discharge by reducing the supply voltage) must be performed by the supply voltage circuit immediately after the discharge to perform counting operations. In addition, as the UVTRON® performs a glow discharge, if it is allowed to discharge for a long time without quenching, sputtering will occur, significantly affecting its lifespan.
When the UVTRON® is connected as shown in Figure 4 and UV light is incident with a voltage supplied, the photoelectric effect causes a sudden large current to flow between the anode and cathode, resulting in a discharge state. The tube voltage at this time is referred to as the discharge starting voltage (V_L). However, referring to Figure 4, once the UVTRON® starts to discharge, the tube is filled with electrons and positive ions, and the voltage across the cathode and anode becomes less than that before the discharge. This behavior is shown in Figure 5.

The current limiting resistor (R_S) in Figure 4 is expressed as a load line in Figure 5. The intersection of this line with the V-I curve is the operating point of the UVTRON® in this basic driving circuit. The tube voltage at this time is referred to as the discharge sustaining voltage (V_S) and is calculated using the following formula:

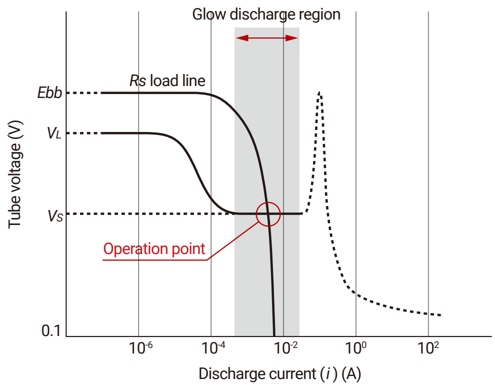
(4) $$V_S = E_{bb} - R_S \cdot i$$

■ Figure 4: Basic driving circuit configuration



NOTE: This is the circuit configuration for circuit operation.
To operate the UVTRON® properly, refer to the circuit configurations in "3-2 CR quenching circuit" and "3-3 DC/DC converter type high-voltage power supply circuit."

■ Figure 5: V-I (Typ.)



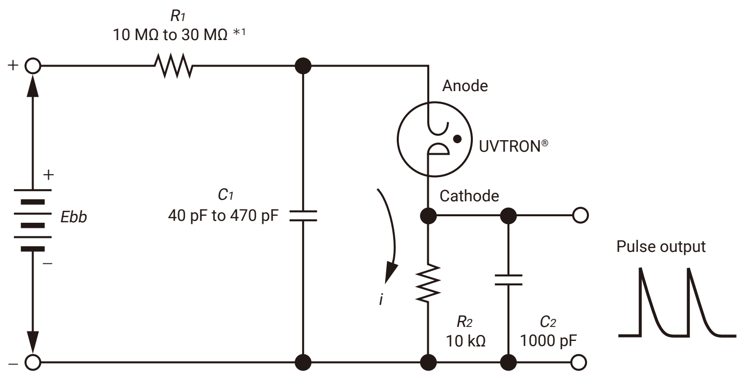
When the operating point of the UVTRON® is in the glow discharge region, the discharge sustaining voltage (V_S) is less than the discharge starting voltage (V_L). In this condition, once discharge starts, self-sustaining discharge continues until the supply voltage is below the discharge sustaining voltage (V_S), and the UVTRON® cannot function properly. As mentioned above, the operation of the UVTRON® requires the design of an external quenching circuit.

3-2 CR quenching circuit

Figure 6 shows the circuit configuration of an external quenching circuit with CR and a DC high-voltage source. Connect a high resistor (R_1: 10 MΩ to 30 MΩ) in series and a low-capacitance capacitor (C_1: 40 pF to 470 pF) in parallel from the high-voltage generating part to the UVTRON®. In addition, install circuit components (R_2 and C_2) to convert the discharge current into a pulse signal.

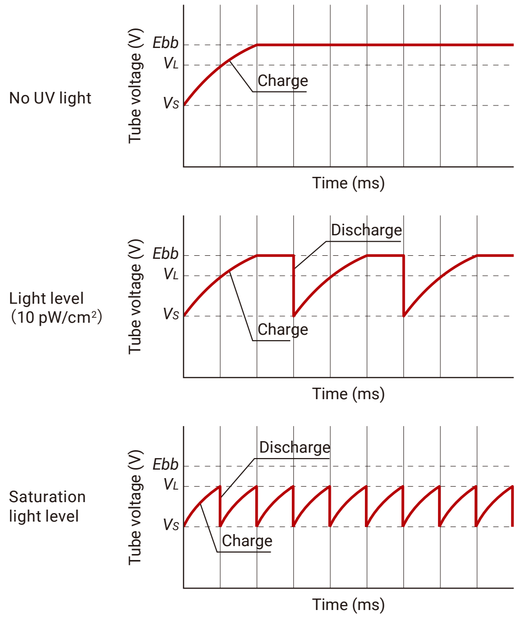
Once discharged, the UVTRON® stops discharging when the anode potential drops to the discharge sustaining voltage (V_S) while consuming the charge stored in the capacitor (C_1). After that, the capacitor (C_1) is charged again by the supply voltage (Ebb) through the high resistance (R_1), causing the anode potential to rise from the discharge sustaining voltage (V_S) to the discharge starting voltage (V_L) or the supply voltage (Ebb).

■ **Figure 6: Circuit configuration of an external quenching circuit with CR and a DC high-voltage source**



*1: Adjust the resistance value and capacitance of the capacitor according to the model to achieve the specified quenching time.

■ **Figure 7: Anode potential (Typ.)**



(1) Quenching time (tq) and ion extinction time (tx)

The time it takes for the anode potential of the UVTRON® to rise again from the discharge sustaining voltage (V_S) to the discharge starting voltage (V_L) or supply voltage (Ebb) is determined by the time constants of the high resistance (R_1) and capacitor (C_1) and is defined as the quenching time (tq). The quenching time (tq) is calculated using the following formula:

$$tq = C_1 \cdot R_1 \cdot \ell n \frac{Ebb-V_S}{Ebb-V_L} \tag{5}$$

When Ebb is at the recommended supply voltage:

$$\ell n \frac{Ebb-V_S}{Ebb-V_L} \fallingdotseq 0.5$$

Quenching time (tq) has significant importance in driving circuits that operate on DC power supplies. When the UVTRON® discharges, numerous positive ions are generated between the anode and cathode and remain floating for some time even after the discharge stops. If the anode potential increases again before these positive ions disappear, electrons are generated, which trigger a discharge. Consequently, discharge will be repeated regardless of the presence of UV light. The time it takes for the residual ions to disappear is called the ion extinction time (tx), which varies depending on the current value flowing through the UVTRON® and the ambient temperature. The quenching time (tq) for each product listed in the product catalog is set longer than the ion extinction time (tx), so please refer to the product catalog to determine the circuit constants (C_1, R_1).

(2) Discharge current of CR quenching circuit (i)

The average discharge current (i ave) flowing through the UVTRON® is calculated using the following formula, based on the charge (Q_1) supplied from the circuit constant (C_1) and the output pulse (number of discharges per second) (f):

$$i\ ave = f \cdot Q_1 \qquad Q_1 = C_1 \cdot (V_L - V_S)$$

therefore

(6)

$$i\ ave = f \cdot C_1 \cdot (V_L - V_S)$$

Since the output pulse (number of discharges per second) (f) has a maximum value of $1/tq$ at the saturation light level, the maximum average discharge current (i max) for this circuit is given by the following formula:

(7)

$$i\ max = \frac{1}{tq} C_1 (V_L - V_S)$$

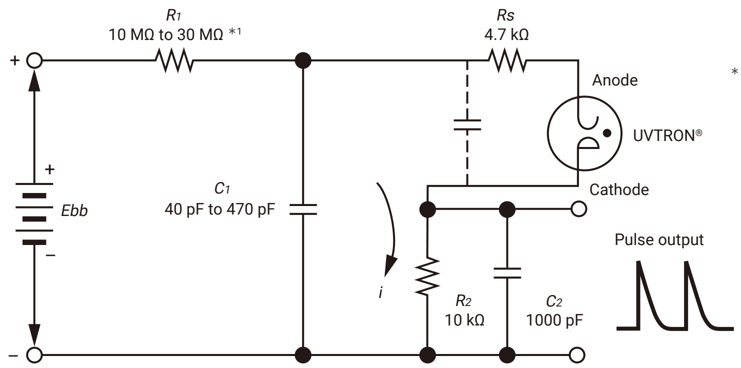
As the average discharge current (i ave) directly affects the life of the UVTRON®, please refer to the product catalog when determining each circuit constant.

(3) UVTRON® wiring

In the external quenching circuit using CR, wire the UVTRON®, the power supply circuit, and the signal processing circuit close together. Wiring on the same circuit board is ideal. If the cable has a high stray capacitance, the discharge current will also be high, which may damage the electrodes.
If the UVTRON® must be installed far away and the cable capacitance exceeds 100 pF, insert a current limiting resistor (Rs: 4.7 kΩ) immediately before (within 25 mm) the anode of the UVTRON®, as shown in Figure 8.

■ Figure 8: Circuit configuration of an external quenching circuit with CR

・If installing the UVTRON® far away

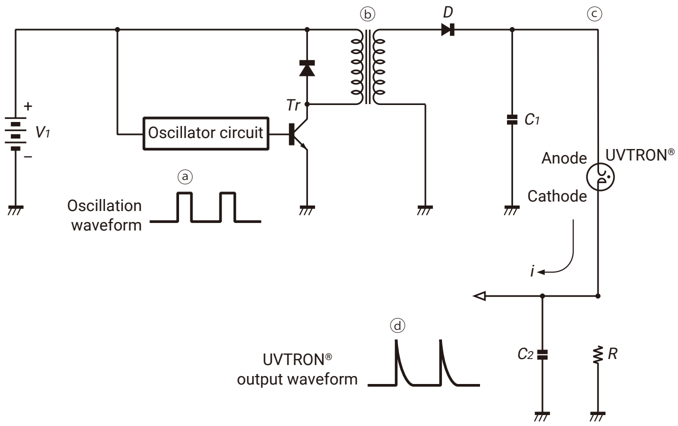


*1: Adjust the resistance value and capacitance of the capacitor according to the model to achieve the specified quenching time.

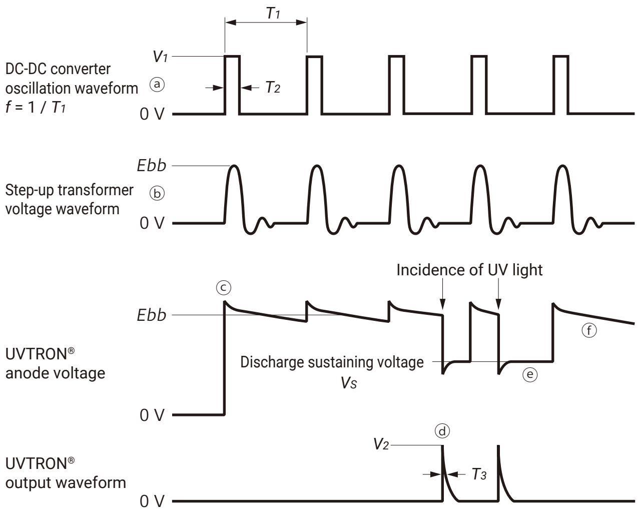
3-3 DC/DC converter type high-voltage power supply circuit

Driving the UVTRON® requires high voltage of 300 V or more. Figure 9 shows a circuit configuration and the operating waveforms of the DC/DC converter type high-voltage power supply circuit used in Hamamatsu's UVTRON® driver circuit C10807/C10423. In this case, it is important to lower the converter oscillation frequency (*f*), to reduce the capacitance of capacitor (C_1) for smoothing the rectified high voltage, and to raise the power supply output impedance.

■ Figure 9-1: Circuit configuration of DC/DC converter type high-voltage power supply circuit



■ Figure 9-2: Operating waveforms (Typ.)



The driving circuit operates in the following order:

ⓐ: This is the converter oscillation waveform. Pulses with widths of a few microseconds are generated at intervals of a few milliseconds to a few tens of milliseconds.

ⓑ: The height of pulses is raised in proportion to the winding ratio for the step-up transformer.

ⓒ: A rectifier diode (*D*) and a smoothing capacitor (C_1) apply the supply voltage (*Ebb*) to the anode of the UVTRON®.

ⓓ: Discharge starts when UV light enters the UVTRON®. The charge stored in the smoothing capacitor (C_1) flows as a discharge current (*i*), generating a thin pulse voltage at both ends of the resistor (*R*) and capacitor (C_2).

ⓔ: Discharge stops when the charge in the smoothing capacitor (C_1) is consumed, and the anode potential falls below the discharge sustaining voltage (*Vs*). The anode potential does not recover until the charge. During that period, the positive ions in the UVTRON® are quenched.

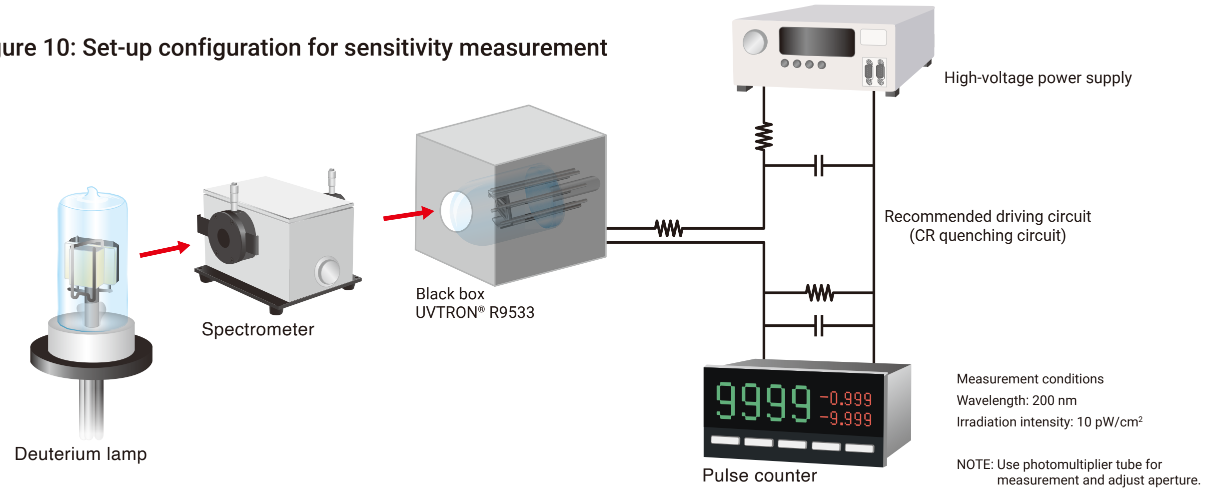
ⓕ: If no UV light enters the UVTRON®, the anode potential recovers to the supply voltage (*Ebb*), and there is no discharge until UV light is received.

The UVTRON® repeats this cycle to indicate the presence or absence of UV light with pulse signal output. Here, the oscillation interval (1/oscillation frequency (*f*)) of the converter should be longer than the quenching time (*tq*) specified for each model. In addition, the capacitance of the smoothing capacitor (C_1) affects the discharge current. It is recommended to reduce the capacitance to prevent wear and tear on the electrodes and to have less ions generated, with a value between 40 pF and 470 pF being optimal.

4 Sensitivity

The UVTRON® sensitivity is not defined by the discharge current but the discharge count (pulse count) of the CR quenching circuit that is configured. However, as indicated in the description of the circuit operation, the output pulse waveform and saturation characteristics vary depending on the circuit configuration and circuit constants. Therefore, the sensitivity is expressed with a relative value under certain conditions. Figure 10 shows the set-up configuration for sensitivity measurement. A 200 nm monochromatic light is used for the measurement.

■ **Figure 10: Set-up configuration for sensitivity measurement**



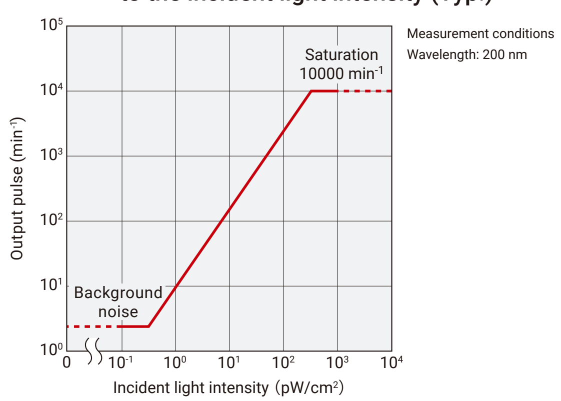
4-1 Sensitivity light level and saturation

In the circuit configuration of Figure 6, if the amount of UV light incident on the UVTRON® is increased, the output pulse also increases proportionally. However, when the amount of UV light exceeds a certain value, the output pulse becomes saturated at the quenching time (*tq*) defined by the circuit constants (C_1, R_1). The output pulse at this time is called the saturated output pulse (maximum number of discharges in one second) (*f max*) and is calculated using the following formula:

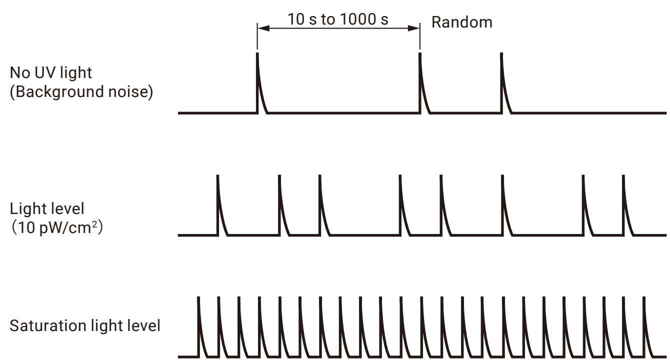
$$f\,max = 1/tq \quad \text{(count/s)} \tag{8}$$

Because the UVTRON® is useful only at levels below the saturation light level where linearity is observed, the sensitivity is defined at considerably weak light levels of 10 pW/cm² (at 200 nm). This behavior is shown in Figures 11 and 12. Since the proportional range varies significantly among units, and is very narrow, it is recommended to use the UVTRON® as an ON-OFF sensor to determine the presence of UV light, rather than for light level measurement.

■ **Figure 11: Sensitivity characteristics to the incident light intensity (Typ.)**



■ **Figure 12: Output pulse (Typ.)**

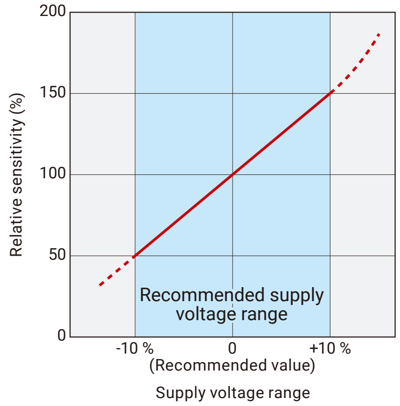


The radiant intensity of UV light from actual flames varies greatly depending on the combustible and combustion state. Consider the UVTRON® sensitivity to be merely a guideline for selecting the appropriate type.

4-2 Supply voltage and sensitivity

Figure 13 shows the relation between the supply voltage and the UVTRON® sensitivity. Sensitivity varies significantly with changes in supply voltage. Use within the recommended supply voltage range, as background noise increases when the supply voltage exceeds the recommended operating range, as shown in Figure 15.

■ Figure 13: Sensitivity characteristics to the supply voltage (Typ.)



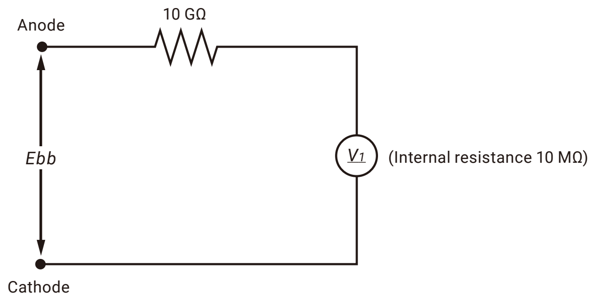
4-3 Supply voltage measurement method

As CR quenching circuits and DC/DC converter type high-voltage power supply circuits (Hamamatsu's UVTRON® driver circuit) have a high impedance, it is not possible to measure accurately even if a multimeter is connected directly between the anode and cathode because voltage dividing occurs according to the ratio of the impedance between the inside of the circuit and the inside of the multimeter. In this situation, insert a high resistance (10 GΩ) in series with the multimeter to decrease the voltage drop in the circuit to take the measurement. If a multimeter with a typical internal resistance of 10 MΩ is used, the supply voltage is calculated using the following formula and is displayed on the multimeter at approximately 1/1000. (When 350 V is shown, the actual value is 350 mV.)

(9)
$$V_1 = Ebb \times \frac{10\ \mathrm{M\Omega}}{10\ \mathrm{G\Omega} + 10\ \mathrm{M\Omega}}$$

Note that the internal resistance of your multimeter may be different. Check the specifications for your multimeter. Also, exclude the UVTRON® when you take the measurement. (Measurement is possible with the UVTRON® connected as long as no UV light is incident on it.)

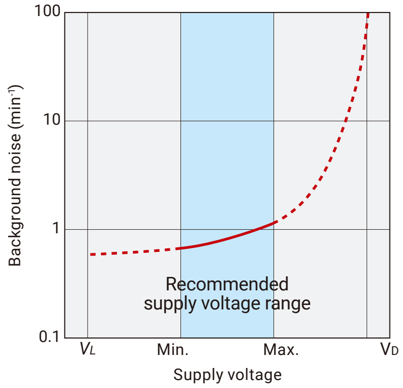
■ Figure 14: Voltage measurement circuit configuration with the high resistance



5 Background noise (BG)

On UVTRON®, discharges are caused by the photoelectric effect of UV light, but due to its structure and operating principle, sporadic discharges can be caused by radiation such as cosmic rays, as well as static electricity. This is called “background noise (BG)”. Background noise (BG)’s frequency of occurrence varies depending on conditions such as the supply voltage and driver circuit. The supply voltage is particularly significant, as shown in Figure 15, so use the UVTRON® within the recommended supply voltage range for designing a device with a good S/N. In addition, as discharges due to background noise (BG) are also counted as one signal output, they cannot be clearly distinguished from a signal output due to UV light from a detection target. Hence, to distinguish between them, a signal processing circuit that cancels the background (BG) is needed.

■ Figure 15: Background noise characteristics to the supply voltage (Typ.)



V_L : Discharge starting voltage under UV light
V_D : Dielectric breakdown voltage between electrodes under fluorescent light

Major causes of background noise (BG) are as follows:

(1) Radiation including cosmic rays

When radiation with higher energy than UV light is incident on the cathode (photocathode), a discharge can be caused due to the photoelectric effect.
As it is difficult to completely prevent the entry of radiation such as cosmic rays, which exist in nature, it is necessary to use a signal processing circuit to distinguish it from UV light from a detection target.

(2) X-rays

When X-rays with higher energy and penetrating properties than UV light is incident on the cathode (photocathode), a discharge can be caused due to the photoelectric effect.

(3) Static electricity

When an object charged with static electricity comes close to or makes contact with the UVTRON®, the high electric field may ionize the gas molecules in the tube and cause a discharge.

(4) High electric fields, high magnetic fields, and strong electromagnetic waves

Under high supply voltage conditions, the electric field emission from the cathode (photocathode) may cause photoelectrons to jump out, and this may trigger a discharge.

(5) Intense light (such as from lasers and LEDs) with extremely high radiant intensity greater than sunlight

When intense light with extremely high radiant intensity is incident on the cathode (photocathode), background noise can increase due to thermionic emission and other factors.

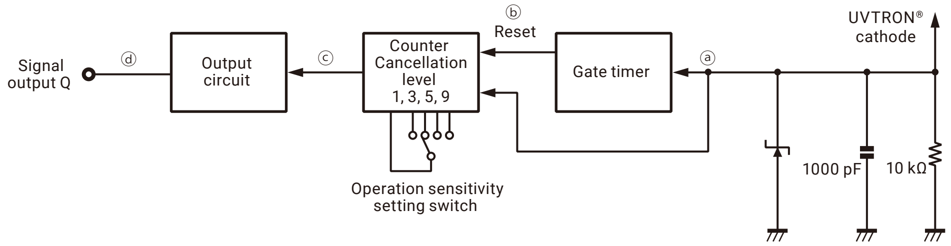
(6) Unintentional UV light

While this is normal for UVTRON® operation, UV light from sources other than a detection target may cause the device to malfunction. This also can be considered as a type of background noise (BG). UV light is also found abundantly in ordinary life. Especially outdoors, UVTRON® reacts to faint UV light from unexpected sources, such as sparks from arc welding or electrical sparks (sparks from a train pantograph). Take sufficient precautions for the area where the UVTRON® is installed and used.

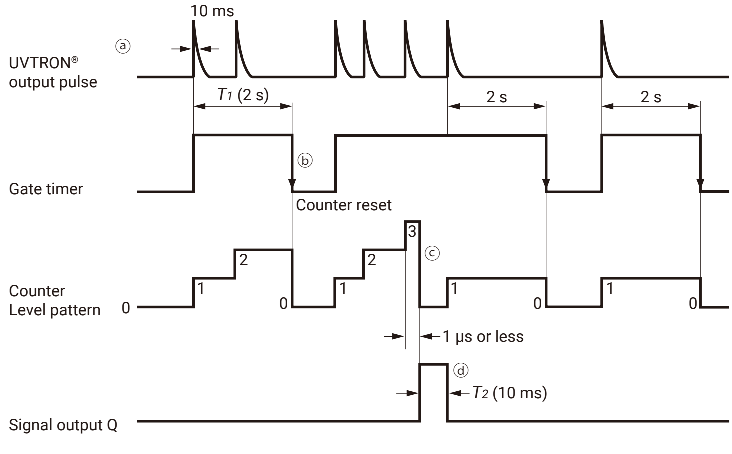
6 Signal processing circuit

As the output pulse waveform of the UVTRON® is exactly the same for UV light from a detection target and background noise (BG), it is not possible to distinguish between them as is. Therefore, we focus on the signal output frequency due to continuously radiated UV light from the detection target and the signal output frequency due to sporadic background noise (BG) and cancel the background noise (BG). Assuming that UV light is from the detection target when two or more signals are output within two seconds immediately after a single signal output, the circuit is configured to distinguish it from sporadic background noise (BG). Specifically, Figure 16 shows a circuit configuration of the signal processing circuit and Figure 17 its operation time chart.

■ Figure 16: Signal processing circuit configuration



■ Figure 17: Operation time chart



(Ex.) When 3 pulses enter in succession within an interval of 2 seconds, a pulse with a width of 10 ms is output as the signal output.

The signal processing circuit operates in the following order:

ⓐ: The output pulse from the UVTRON® enters simultaneously into the gate timer and counter. The gate timer will be in an open state. The counter counts the output pulses sequentially.

ⓑ: The gate timer maintains an open state as long as output pulses are received at intervals less than the set time (T_1). If output pulses are received at intervals longer than the set time (T_1), the gate is closed, and the counter is reset.

ⓒ: If consecutive output pulses are received, the counter continues counting. When a set value is reached, an output pulse occurs in the output circuit, and the counter is reset.

ⓓ: The output circuit extends the output pulse from the counter to the required time span (T_2) and outputs it.

The set time (T_1) must be shorter than the interval between background noise (BG) occurrences. Usually, safety is increased if it is kept within five seconds. However, please note that making it too short will prevent the detection of weak UV light.

7 Life

If the UVTRON® is used continuously in the discharge state, the characteristics will change as follows:

(1) Increased background noise (BG)

(2) Decrease in the sensitivity

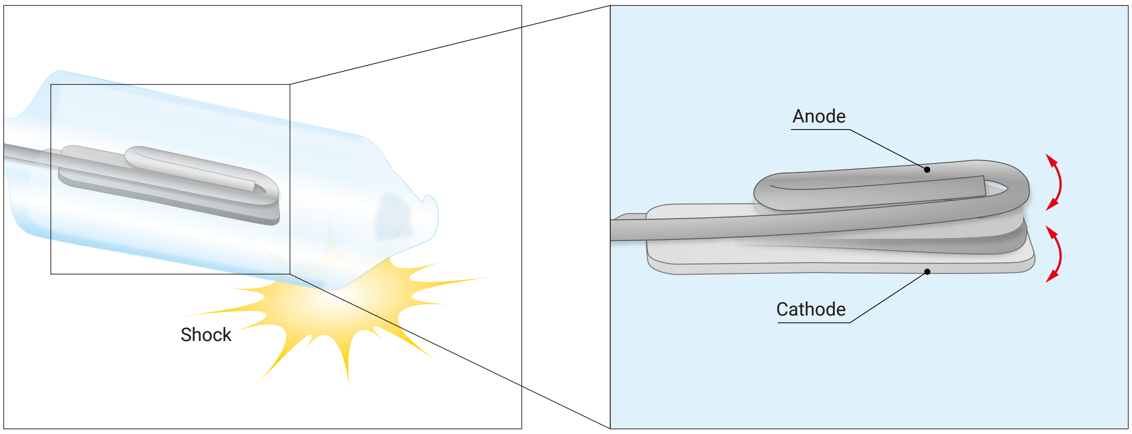
(3) Change in discharge starting voltage under UV light (*VL*)

As the positive ions reach the cathode, they hit the surface of the cathode hard, causing the surface to be worn down. Therefore, the electrodes will wear out after prolonged use, causing an increase in background noise. In addition, the shaved cathode adheres to the glass bulb, resulting in reduced transmittance and sensitivity. Furthermore, as the internal gas is adsorbed into the metal, the discharge starting voltage will be reduced.

NOTE: The progression of these phenomena is accelerated not only by prolonged use, but also by use under conditions such as current, voltage, and temperature above the rated values.

Excessive shock on the UVTRON® can cause the anode and cathode to come into contact with each other, which can significantly shorten its lifespan.

■ **Figure 18: Image of anode impact on the cathode surface of UVTRON® R2868**



8 Notes

Notes and requests on the product

https://www.hamamatsu.com/all/en/support/disclaimer.html

UVTRON® Precautions for use

https://www.hamamatsu.com/content/dam/hamamatsu-photonics/sites/documents/99_SALES_LIBRARY/etd/UVtron_TPT1038E.pdf

- Hamamatsu Photonics makes constant efforts to improve product quality and reliability, but this does not guarantee the product integrity of UVTRON®.
  Please implement a design providing ample safety (redundant design, fire spread prevention design, malfunction prevention design, etc.) within customer's equipment manufactured using a UVTRON® in order to avoid personal injury, fire and damage to society that might possibly occur in the unlikely event of a failure of the UVTRON®. In particular, when a UVTRON® is used in a piece of equipment or an environment where the malfunction or failure of the UVTRON® could result in personal injury, death or serious damage to property (hereinafter referred to as the "particular application"), the safety design must take into account the possible failures. We will not be liable for any use in such particular application unless we give our prior written consent by way of specification sheets, etc.
- Since the durability of UVTRON® varies depending on the operating environment and conditions, be sure to evaluate and confirm the operation of UVTRON® in the condition in which it is installed in the customer's equipment and in the actual operating environment. If any doubt arises about the safety of UVtron®, please notify us as soon as possible and also be sure to implement technical measures for the above stated safety design (redundant design, fire spread prevention design, malfunction prevention design, etc.).
- When exporting a UVTRON® (including cases when providing technology), please comply with export-related laws and regulations in your country, such as the Foreign Exchange and Foreign Trade Law of Japan, and be sure to obtain an export license or a service transaction license if necessary. Please contact our sales office for information on whether or not the UVTRON® is subject to these export-related laws and regulations.
- The application examples described in our product literature are not intended to guarantee suitability for any particular application or the success or failure of any commercial use. No guarantee or license is granted for the enforcement of any intellectual property rights. We will not be held liable for any intellectual property rights issues that may arise with third parties as a result of using this information.
- When disposing of a UVTRON®, take appropriate measures in compliance with applicable regulations regarding waste disposal, and correctly dispose of it yourself or entrust proper disposal to a licensed industrial waste disposal company. In any case, be sure to comply with the regulations in your country or state to ensure correct disposal.
- Please do not use UVTRON® in special environments such as in liquids, dust, or with high levels of corrosive gas.
- UVTRON® may malfunction due to unintentional UV light, such as sparks from arc welding or germicidal lamps. Take sufficient precautions for the area where the UVTRON® is installed and used.
- When storing or transporting a UVTRON®, keep it in the packing box. The product has passed the impact test method IEC 60068-2-27 however, if the packing box is dropped or bumped during storage or transportation, an excessive mechanical stress may be applied, causing damage or degradation of characteristics. Handle with care and take adequate measures to avoid dropping and bumping. The UVTRON® should be stored indoors at low humidity and stable room temperature where no corrosive gases are present and no condensation occurs.
- If a UVTRON® fails due to manufacturing defects within one year after delivery, we will replace it free of charge. The scope of the warranty is limited to replacement of the product. The product will be out of warranty in the case of use in a particular application without our prior consent.

* UVTRON (China, Japan, U.S.A.) is a registered trademark of Hamamatsu Photonics K.K.

Subject to local technical requirements and regulations, availability of products included in this promotional material may vary. Please consult with our sales office.

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