

## Applications Note

Copyright © 2004 All Rights Reserved

# Gating Image Intensifiers

## DEFINITIONS FOR:

- ✓ Gating Image Intensifiers
- ✓ Gating Intensified CCD Cameras
- ✓ Image Intensifier Gating

## INTRODUCTION

Most Frequently Asked Questions Regarding Image Intensifier Gating:

- What is gating?
- What are the applications for gating?
- How fast can gating be done?
- How can gating be implemented?
- What are the limitations?

### What is Gating?

Gating is a way of opening and closing the “gate” controlling the flow of electrons from the photocathode to the Micro Channel Plate (MCP) of the image intensifier. This gate is controlled by the voltage applied to the photocathode with respect to the voltage of the input of the MCP. To induce the normal flow of electrons from the photocathode to the MCP, the photocathode is biased with a negative voltage with respect to the MCP input. This opens the “gate”. To close the “gate” the photocathode is biased with a positive voltage with respect to the MCP thus repelling the flow of electrons and closing the “gate”.

### What are the applications for gating?

There are several applications for the use of gating since use of the gate is similar to using a shutter in an optical system. The difference is gating can be used as a shutter without any moving parts and attain very high Optical Gate Pulses. A fast shutter like this can take very short exposures allowing a fast moving object to be imaged without blurring.

This is useful for several key applications:

### EXPOSURE CONTROL

This occurs when it is necessary to control the exposure of the intensifier or intensified camera to bright input levels of light. The use of gating is a way to allow the intensifier to operate in a normal or high brightness situation without causing damage to the photocathode. Adjusting the gate pulse-width (manually or automatically) during each exposure or frame of information will insure that the video will not saturate and prevents any harm to the intensifier. During this type of operation the shorter the gate pulse the brighter the input may be. They are inversely proportional to each other. When single digit nanosecond pulses are used the intensifier can support many thousands of foot-candles (or lux) of illumination without any ill effects even for long periods of time. The maximum input light level for an

intensifier or intensified camera when operated in the DC or continuous mode is  $5.0 \times 10^{-4}$  foot-candles (or  $5.0 \times 10^{-3}$  lux). If it is operated in the gated or pulsed mode, the maximum allowable input light level is the maximum DC level divided by the duty cycle or:

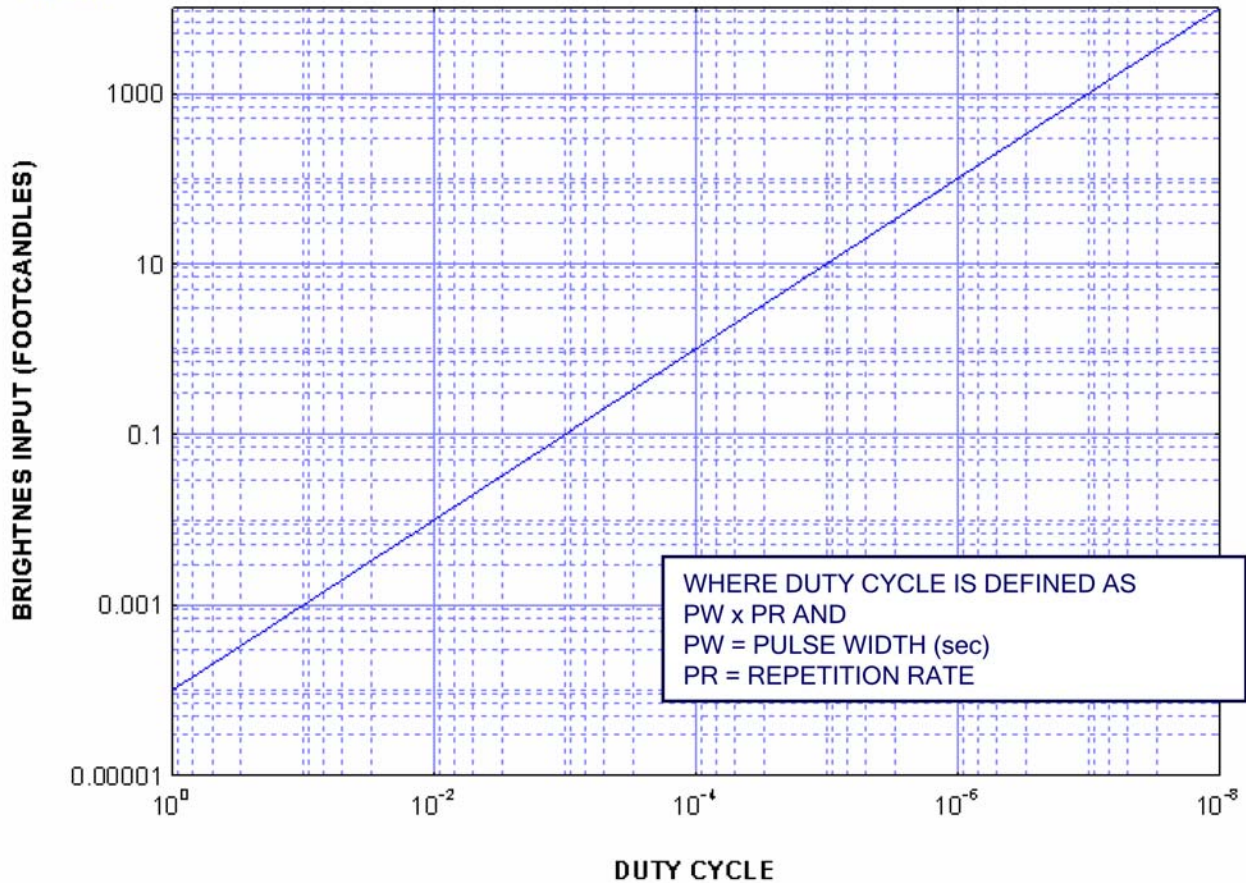
$$B_{IN} = \frac{5.0 \times 10^{-4} fc}{\text{Duty Cycle}}$$

Where the Duty Cycle is defined as the pulse-width (PW) times the repetition rate (RR). Therefore duty cycle = (PW)(RR).

The following graph is a plot of this equation for a duty cycle ranging from 1 to  $10^{-8}$ . It may be used to determine the maximum safe brightness input to a gated intensifier as a function of the duty cycle.

**BRIGHTNESS INPUT AS A FUNCTION OF DUTY CYCLE**

Figure 1:



Operation beyond these limits will result in reduction of photocathode sensitivity and therefore reduction of the useful life of the image intensifier or intensified camera. This same set of calculations holds true when the equivalent of  $5.0 \times 10^{-4}$  foot-candles is known in watts/cm<sup>2</sup> for a specific wavelength or a range of light. The above discussion is applicable for all gating applications.

CAPTURING FAST EVENTS IN THE TIME-RESOLVED DOMAIN

In this situation an event is taking place in a very short time span and there is a requirement to study the event during this short interval or for several of these short intervals. The intensifier or intensified camera is setup to take a short exposure every frame or other interval. This can be done for several times per frame to reveal the flight of a projectile. This way the speed of the object may be measured by measuring the time interval between images. Single events may be captured the same way by knowing the interval of the gate.

High-speed light decay of an object can be measured using this technique by collecting many short exposures of the object over a known time span and measuring the light output in each exposure as a function of time. This is one of the most popular uses for gating. The rep rate may be increased to study the event in a more compressed time frame using a high frame-rate camera or by using several cameras set for short exposures and fired off at very short intervals with respect to each other. The same relationships to the input light level mentioned in the previous section on 'Exposure Control' still hold for this application.

### **How fast can gating be done?**

The speed of the gate depends upon two major factors: the design of the image intensifier and the design of the gate circuit or electronic pulse generator.

Most standard designed image intensifiers can be taken down into the single digit nanosecond range. If it is required to go faster than this then special photocathode designs will be required to reduce the resistive and capacitive effects of the photocathode surface.

Other methods are sometimes employed to obtain faster gating below the single digit nanosecond range by reducing the photocathode voltage rather than redesigning it. This can affect the resolution of the tube but make it easier to achieve the required high speed. The second major factor is the gate circuit or pulse generator used to provide the voltage pulse to the photocathode. The circuit must be matched to the photocathode characteristics very carefully or the desired level of gating will not be achieved. It must be capable of providing not only the pulse but also maintaining a required rep rate for the application.

As an example, providing the 900 volts to a Generation III image intensifier photocathode can be problematic at very high rep rates. The 200 volts required for a Generation II image intensifier can be easier to handle in very short pulses; however, 3ns has been achieved on a Generation III image intensifier without any modifications. The time to recharge the circuit becomes a factor. This necessitates the use of high power electronics, which in most cases require an extra electronics enclosure. All of these points must be considered in achieving a desired gate level.

### **How can gating be implemented?**

Implementing the gating of an image intensifier requires that the image intensifier be coupled with a gate circuit to switch the photocathode on and off. This gate circuit is usually either a part of the intensifier power supply or an auxiliary circuit working through the intensifier power supply. The gate circuit usually requires that an input pulse be supplied to it of the same duration as the required gate. In some cases this input pulse is supplied from an external source in sync with the imaging device attached to the intensifier. The gate circuit responds by supplying the intensifier a pulse of the correct amplitude to turn the photocathode on for the required duration. When shorter gate pulses are required in the single nanosecond or lower range a separate instrument may be supplied which is tied directly to the photocathode. It will supply the high voltage pulse directly to the photocathode and has controls built into it for adjustment of the pulse. Whichever way it is implemented the equipment for gating must be specified and built into the electronics operating the image intensifier. It may require some mechanical and electrical modification to the unit if it is added later. In rare cases the intensifier may have to be replaced to meet the gating requirements.

### **What are the limitations?**

One of the major limitations beyond the equipment that is used is having enough light emitted or reflected from the image. The shorter the gate pulse (or exposure time) the higher the requirement is for light. Even with an image intensifier, there may not be enough light in a 2 nanosecond exposure to cause a camera to produce an image. And when no more illumination is available the process becomes impossible.

As previously discussed some limitations to the gating process may be imposed by the design of the

intensifier. However for most applications this is not a situation, which may inhibit the use of gating. Only those extreme applications will require special attention. Gates in the order of 100s of Pico seconds have been achieved with the technology we now possess.

Usually the gating process is used in conjunction with some kind of readout process to capture the image. Today an electronic imaging device such as a CCD camera records most of the high-speed events addressed by gating. This usually poses no limitations to the process unless high frame rates are required. This can cause conflicts with the decay rate of the phosphor. These are difficult conflicts to overcome, as faster decay phosphors have less efficiency. This results in reduced light levels presented to the camera. Film can also be used and the only limitation is the sensitivity of the film to the image intensifier's output brightness and phosphor spectral output. Other obvious limitations are rep rate and storing the images.

Some photocathodes may lack the physical characteristics to achieve propagation of the voltage across it in the desired time. In some cases novel designs have been incorporated into the photocathode to reduce or eliminate these effects. How far this is taken depends upon the speed one wants to achieve. Typically single digit nanosecond gates can be achieved with most photocathodes without resorting to special designs. Operating the photocathode at lower voltages to reduce the power required from the gate circuit can result in shorter pulse-widths; however, intensifier spatial resolution and gain may suffer. This tradeoff may be acceptable under certain circumstances when speed is the primary factor. Optical re-adjustment of the image may regain some of the resolution loss.

## **IMAGE INTENSIFIER GATING DEFINITIONS**

As previously discussed applying a gate pulse to the intensifier's photocathode gates an image intensifier. The gate pulse is negative going and it is usually biased with a positive voltage.

For example a Gen III is typically gated with a 940 V p-p pulse, biased at 40 V. The photocathode is held off when at +40 V and it is held on when at -900 V. (This voltage is measured with respect to the MCP). This transition from off-to-on and from on-to-off will be defined in subsequent paragraphs.

Figure2 shows the timing relationship between the gate trigger, the electrical gate, and the optical gate. The optical gate pulse is measured indirectly using an optical sampling technique.

A narrow pulse of light, less than 100ps FWHM, is used to sample the intensifier's gate pulse response. Since the photocathode has a small but finite response time, the intensified light appears at the edge of the phosphor screen and later at the center. The optical gate rise time is approximately the same for both the edge and the center of the intensifier's active area.

The optical gate response for the center can be delayed from the edge response where the photocathode design is incompatible with the required gate speed.

**These physical intensifier characteristics can be completely described using the following gate specification definitions:**

### **Gate Trigger**

**Trigger Delay:** The time measured between the 50% point of the gate trigger to the 50% point of the electrical gate pulse's leading edge.

**Jitter:** The p-p time variation of the trigger delay.

**Gate Repetition Rate (RR):** The gate repetition rate in pulses per second (PPS).

### **Electrical Gate**

**Rise time:** The time measured from the 90% point to the 10% point of the electrical gate pulse's leading edge.

**Fall time:** The time measured from the 10% point to the 90% point of the Electrical gate pulses trailing edge.

**Pulse-width (PW):** The time measured from the 50% point of the leading edge to the 50% point of the

trailing edge of the electrical gate pulse. (i.e. The full width at half maximum, FWHM)

### **Optical Gate**

**Iris Delay:** The time measured from the 50% point of the edge response to the 50% point of the center response of the optical gate pulse. The iris delay defines the minimum optical gate pulse achievable by the photocathode.

**Edge Rise Time:** The time measured from the 10% point to the 90% point of the optical gate edge response.

**Edge Fall Time:** The time measured from the 90% point to the 10% point of the optical gate edge response.

**Center Rise Time:** The same as edge rise time but for the optical gate center response.

**Center Fall Time:** The same as edge fall time but for the optical gate center response.

**Off-to-On Time:** The time measured from the 10% point of the edge response to the 90% point of the center response.

**On-to-Off Time:** The time measured from the 90% point of the edge response to the 10% point of the center response.

### **Optical Gate Pulse**

**Width:** The time measured from the 50% point of the leading edge of the edge response to the 50% point of the trailing edge of the center response. (i.e. the optical gate pulse width at FWHM).

Figure2: OPTICAL GATE WIDTH RELATIVE TO THE GATE PULSE

