$(\sqrt{var} \cdot 4.65) + 2.71 - MDA$

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EASTERN TIME [GMT-4]

Radiographic X-Ray Edge Detection System

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INTRODUCTION

Field coincidence; which is also known as alignment or edge detection, is a test performed on projection radiographic equipment in order to ensure that the light field used by the technologist for patient positioning lines up with the X-Ray field. A few methods throughout history have included the following;

- Exact coin placement in the light field to see what appears in the resulting image.
- Placing radio-luminescent rulers that glow when exposed.
- Electronic photodiode detection ruler.

Any method used must have a level of accuracy that can measure at least within 2% of a systems SID. Typically at 100 cm SID that is 2 cm.

AIM

The goal of this experiment was to create a device according to the following conditions;

- Cost efficient.
- Reproducible with very little experience in the field of hobby electronics.
- Resolution that could detect a minimum 2% deviation at 100 cm SID (<2 cm precision).
- Can detect photons in the diagnostic radiography range.

As a comparison with current commercial offerings, a popular detector in the market today is the RaySafe DXR+ (DXR+).

The Raysafe DXR+ (DXR+) has multiple characteristics that define its performance. These were performance characteristics, parallel to industry standards, were used as a baseline to determine "acceptable" performance for this detector.

METHOD

The process for device selection over the wide range of photodiodes and phototransistors was the differential between output measured after exposure versus the background. The test circuit consisted of a Darlington Pair configuration for amplification.

In order to minimize the circuit/signal noise the semiconductor devices were reverse biased. The signal coming from the photodiode or transistor is then cascaded through two NPN transistors for signal amplification. Ultimately the signal was read from the last resistor in series with the NPN transistor.

The final version of the circuit consisted of an array of five phototransistors, due to their improved performance over photodiodes, each in series with one NPN transistor. Which resulted in measured voltages between 200 to 500 mV. Under normal operation, the detector is placed perpendicular to any edge of the light field.

METHOD CONT.

Electric tape covers the individual detectors in order to shield background lighting. Once turned on, the system begins measuring background readings until exposed and a resulting voltage was read from the detector with an Arduino converting it to a 10-bit digital number. The system reflects a drop in voltage during exposure. This number is then converted to relative voltage output based on the applied voltage to the detectors. To differentiate the measured output from background, a minimum detectable activity (MDA) must be established as a baseline for signal measurement. If we assume the derived (and digitized voltage is a linear representation of the number of counts, we can conservatively approximate the MDA by taking the variance of the background, or noise, and apply the following formula. Providing a voltage threshold which must be exceeded to have an ~95% chance to be a real signal.

$$MDA = \left(4.65 \times \sqrt{Background}\right) + 2.71 \approx 9$$

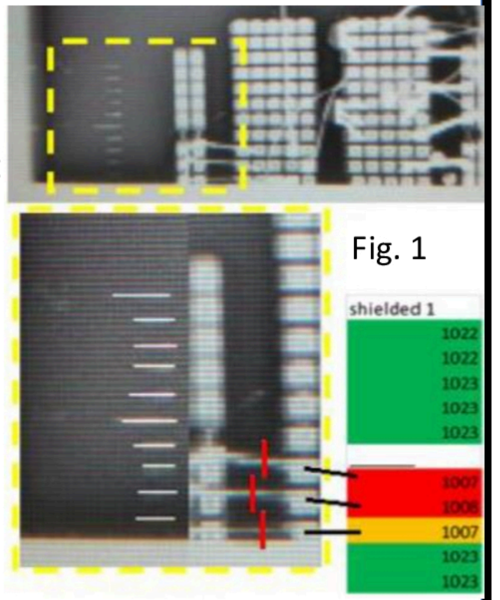

Fig. 1

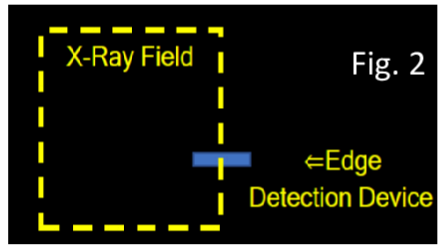

Fig. 2

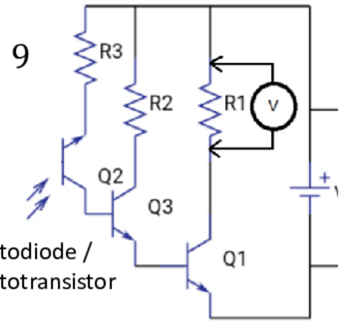

Fig. 3

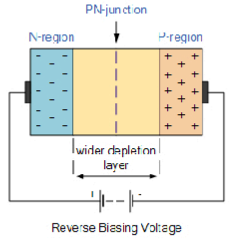

Fig. 4


Fig. 5

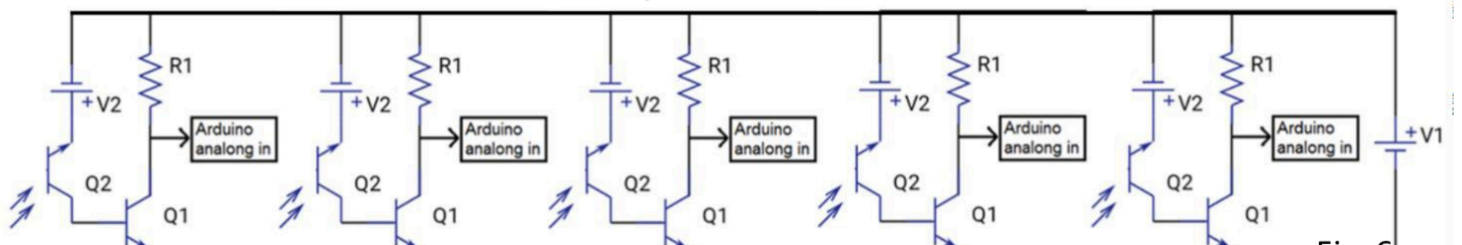

Fig. 6

Figure 1: Radiographic image of device outlined in yellow dash with the accompanying digital results of that exposure. Red rows indicates full exposure, yellow partial green is shielded. The red vertical lines give reference to the widths of the sensors. The gray horizontal lines are a radio-opaque ruler.

Figure 2: A diagram of the correct usage for the edge detection circuit.

Figure 3: Phototransistor connected to a Darlington Pair of two NPN transistors along with two batteries in parallel with one another to reduce internal resistance and the voltage drop being read from the R1 resistor.

Figure 4: Reverse bias operation of the semiconductor.

Figure 5: The Vishay BPW 85 phototransistor ultimately used for the experiment.

Figure 6: A schematic of the complete and final version of the edge detection circuit.

RESULTS

Testing included normal X-Ray exposures to the array of phototransistors that made up the detector sensors. Figures 7 & 8 show the results of testing conducted at 40, 50, 60, 70, 80 and 100 kV using 50 & 200 mAs. Each data point represents an average of 5 sensor measurements all under the same exposure. The horizontal lines shown in the two graphs indicate the required MDA to achieve a "true" count for three separate ambient lighting conditions. Comparing five sensor readings, where half of the five are covered by a lead sheet, for one exposed radiographic image, it is easy to see where a potential problem could occur if a sensor is placed exactly at the boundary of the X-Ray field. Circles, squares and diamonds indicate a high, moderate and low background noise, respectively.

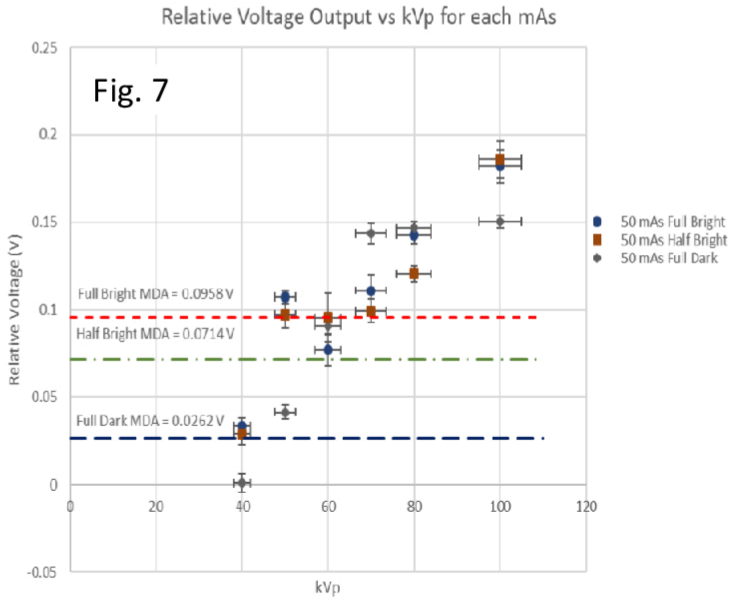

Fig. 7

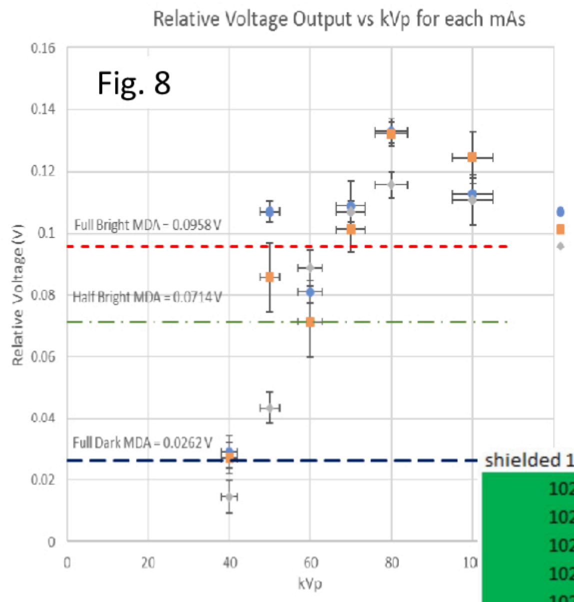

Fig. 8

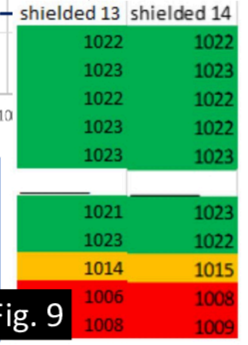

Fig. 9

Figure 9: The green rows indicate a sensor shielded with lead during exposure. The red row indicates a completely exposed sensor and a yellow row indicates that the sensor was at the exact boundary between being shielded and exposed. For this particular case, the room was completely dark and the threshold was calculated to be 1017.

CONCLUSION

We found that it is possible to design and implement a lower cost instrument that can perform comparably to a commercially available device. The low cost alternative is roughly 1/10 the cost and works within a similar kVp range but requires 2x the exposure rate. Further refinement can potentially increase the sensitivity (lowering the dose rate requirement) but will increase the cost (moderately).

	Test Device	DXR+
Cost	<$50	>$550
Resolution	3.0 mm	2.5 mm
Trigger Value	35.14 R/min	70 R/min
Operating Range for 320 mAs	60-80 kV	50-100 kV

ACKNOWLEDGEMENTS

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