Design and Validation of a X-ray Meter for the Developing World

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Abstract
In developing world hospitals, economic constraints do not allow the purchase of commercial diagnostic x-ray meters to evaluate the quality of x-ray machines. To provide hospitals a means of testing x-ray tube quality, a low cost x-ray meter was designed and validated with simulated signals and an x-ray machine. This meter was designed for Engineering World Health (EWH) to be distributed to developing world hospitals as a low cost alternative. The meter consists of a x-ray detector, x-ray Tube Quality circuit and Exposure Time circuit. The Tube Quality circuit compares the x-ray spectrum at two different kilovolt peak (kVp) settings, and the exposure time measurement has a resolution of 20 ms.

X-ray Production
X-ray machines produce photons of energies within the spectrum corresponding to the machines kVp value (Fig. 1).

Fig. 1: X-ray spectrum produced by an x-ray machine [3].

When x-ray tubes fail, they are not able to produce the proper amount of high energy x-rays and therefore cannot produce images with valid contrast.

X-ray Detector
The low cost detector utilized for the meter was designed previously [1]. Detector consists of a scintillation material coupled with a photoconductor and enclosed in a custom aluminum casing (Fig. 2).

Fig. 2: X-ray detector components & casing.

When x-rays encounter detector, its voltage output changes proportionally to the area under the spectrum, which is related to the photon energies present.

Detector has been validated and can distinguish varying kVps and x-ray energies [2].

Attenuation Concept
A filtering system is utilized to accomplish beam hardening. X-rays were attenuated by:

- Known amounts of 50, 60, and 70%
- Using aluminum plates
- Only higher x-ray energies are used in the tube quality determination.
- Attenuation increases detector sensitivity to changes in tube quality (Fig. 3)

Fig. 3: Attenuation of x-ray spectrum with aluminum filter plates.

During failure, the tube cannot produce high energy photons needed to create an attenuated output signal equal to a functioning tube [4].
- Higher output voltage from the detector for a failing tube

Meter Circuit Design
Meter consists of a tube quality circuit and an exposure time circuit (Fig. 4).

Circuits were validated using simulated signals

Tube Quality Circuit
- Compares output of detector to reference voltage at two kVp values.

Fig. 4: Overall meter circuitry. Comparator cascade consists of 8 comparators (3 shown).

Exposure Time Circuit
- Converts detector output to constant signal, integrates to determine time, and displays output with LEDs; each illuminated yellow LED represents 20ms of exposure time.

Fig. 5: Testing set up at Baystate Medical Center

Attenuation Testing
- Testing occurred on a Siemens Polypixos 50 x-ray machine at Baystate Medical Center
- Oscilloscope measured detector outputs

Future Work
- Design a new method for simulating a failing x-ray tube
- Set reference voltages for tube quality circuit

Conclusion
The initial attenuation testing resulted in significant differences in output between 50 and 70% attenuation, as well as between 60 and 70% at both 81 and 125 kVp. The results show the detector can detect a difference of 10% attenuation. The failing tube simulation results were not consistent with initial testing, therefore a new method to simulate a failing tube is needed. These results indicate that this novel design will be able to detect both tube quality and exposure time.

References

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