Flash Therapy

Laszlo-Edward Maksay, St Luke's Radiation Oncology Network

Saint Luke's
Radiation Oncology
Network

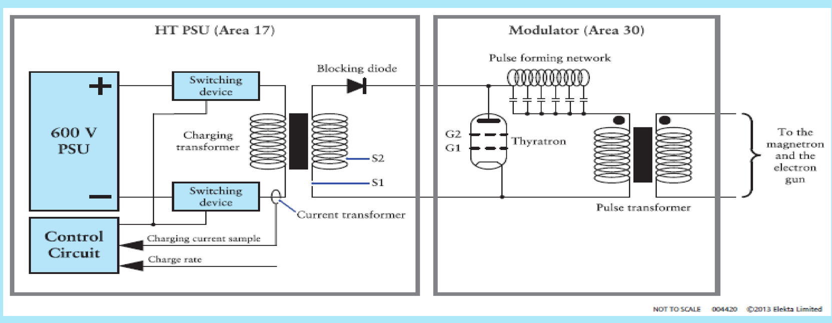
Introduction

There is emerging evidence that very high dose rates, referred to as Flash therapy, can provide significant benefits when using radiation for cancer treatment. Normal clinical linear accelerator (linac) operation delivers a dose rate about 10^{-2}Gy/s. The objective of this project is to design a device that will allow Flash Therapy which involves the modification of a linac to deliver 40-150Gy/s [1] in 1s bursts. This 400-1500 fold increase in dose rate can be achieved by increasing the gun current. The linac operates in pulsed mode with the pulses provided by a thyratron switch. Thyratron trigger pulses continue until a set dose is delivered. The trigger pulses are 3µs in length and spaced 2.5ms apart for 400 pulses/s or 5ms apart for 200 pulses/s. In order to deliver a high dose for one second the trigger pulses need to be counted and their delivery interrupted once the set condition is met.

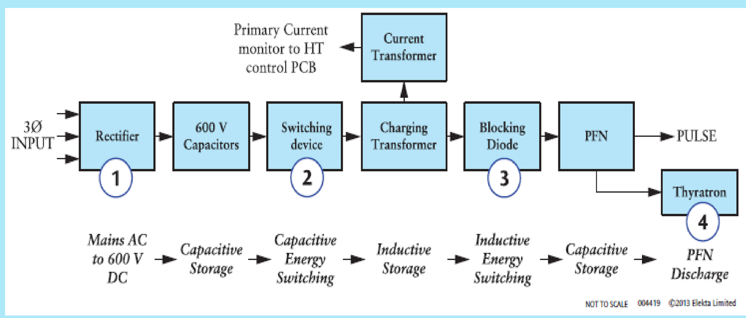
Method

A standard digital linear accelerator is not designed to deliver the very high dose rates required by Flash Therapy. The linac hardware is capable of delivering high dose rates but various protection mechanisms limit this to ensure safe patient treatment. The high dose rates can be achieved by increasing the gun current for a relatively short period of time of 1s.

To achieve a one second delivery time the number of trigger pulses delivered by the digital accelerator has to be controlled. This can be achieved by counting the number of thyratron pulses delivered and interrupting the beam once a set number have been achieved.



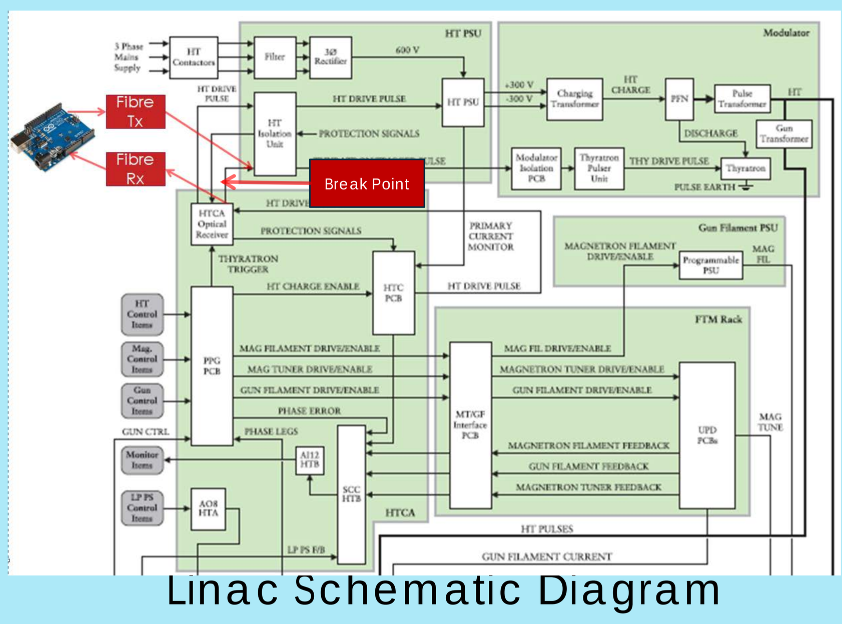
Schematic diagram of the HT system



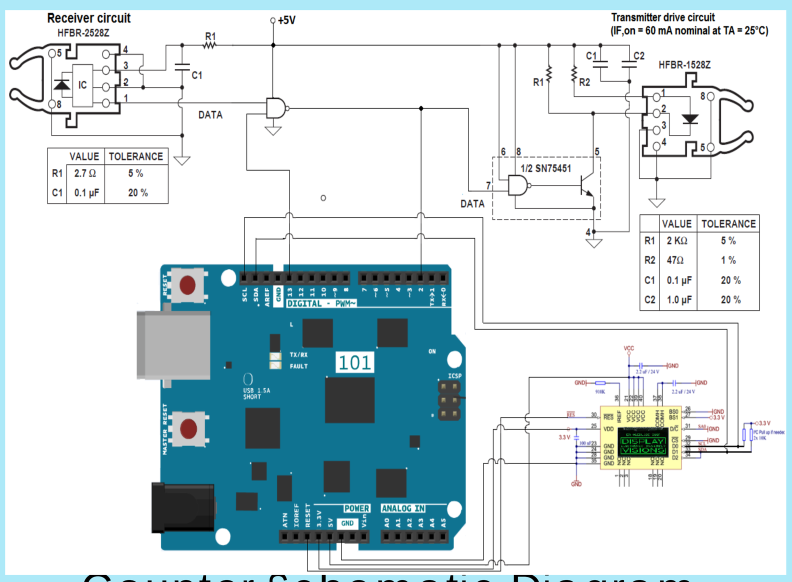
HT and RF charge cycle [2]

The additional circuit designed is based on an Arduino microcontroller and counts a set number of thyratron trigger pulses before sending a trigger to interrupt the beam. This is connected to additional interfacing hardware via optical fibre which allows the thyratron trigger pulses to be switched off by the Arduino counter once the conditions are met.

The connection point to the digital accelerator was achieved by interfacing the optic fibre in between the HTCA Optical Receiver and the HT Isolation Unit.



Linac Schematic Diagram



Counter Schematic Diagram

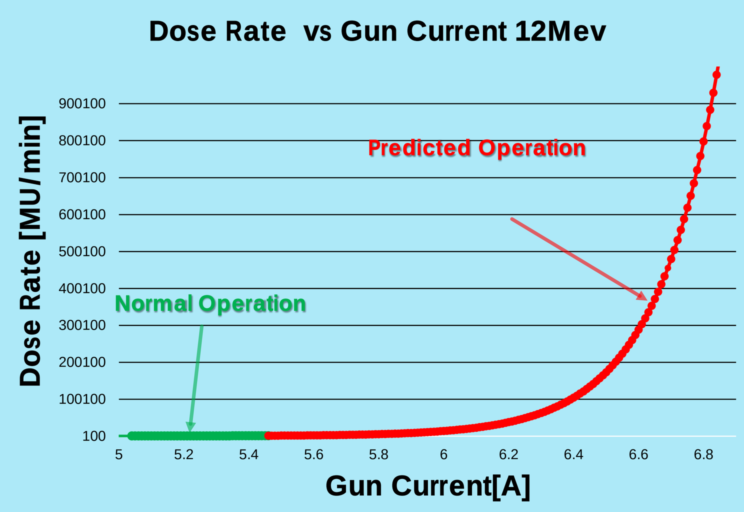
Key considerations to be taken into account when trying to control and monitor signals on a digital accelerator include:

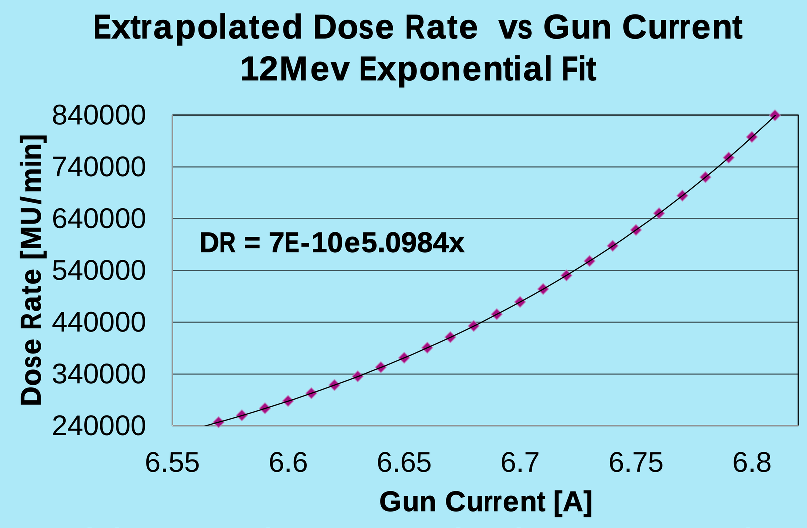
- **Electrical Noise**-As the thyratron trigger pulse is only 3µs in length an extra control circuit can induce extra trigger pulses, causing damage or unwanted behaviour of the linear accelerator.
- **Distance**-One of the main concerns when trying to connect to a digital accelerator is distance from the control point to the digital accelerator. In this case the cable length to the back of linac exceeds 15m and is prone to interference. Consideration of communication protocols that are immune to electrical noise and radiation are of great importance to ensure that the tool will perform as intended.
- **Galvanic Isolation**-One of the main concerns when connecting any circuit to the digital accelerator is the separation of functional sections of electrical systems to prevent current flow.

The development of the counter hardware went through four major hardware and software changes that led to the final implementation.

Results

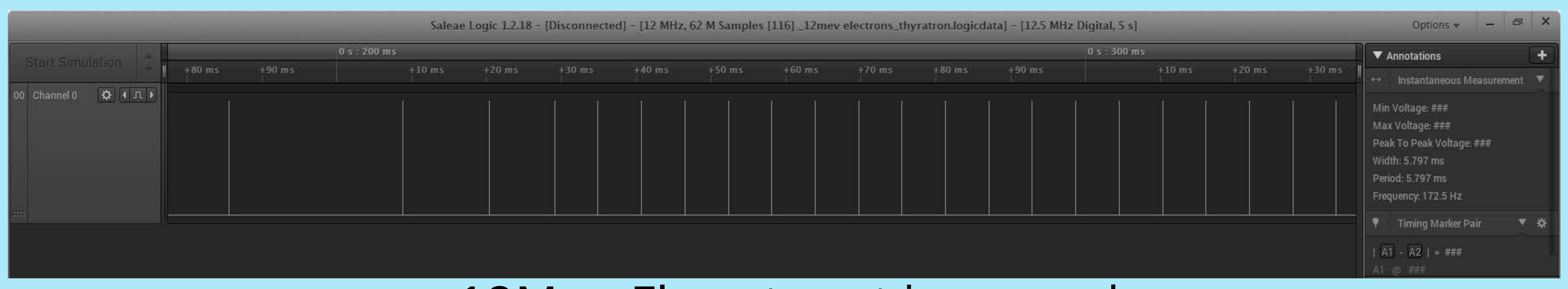
The measurements show the relationship between the dose rate and the gun current for a12Mev electron beam. In comparison, an exponential function fit was used to predict the required minimum dose of 240000MU/min.



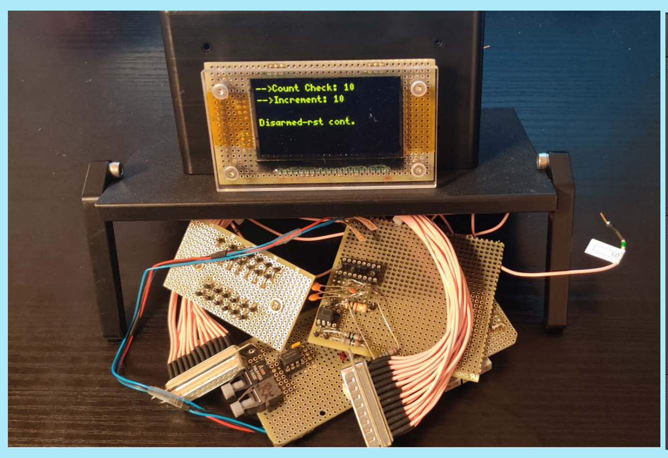


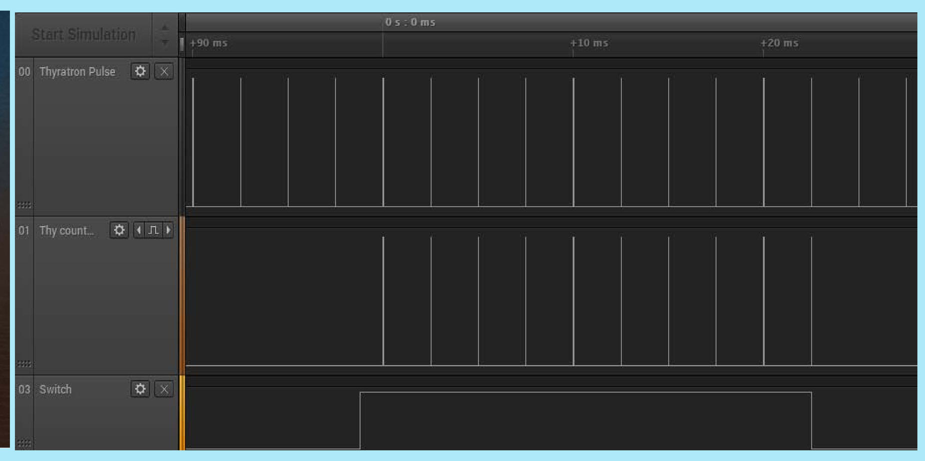
The measurements were performed in service mode in *Control Interlock, Group 8* where most of the safety features are disabled. However, the accelerator turned off at dose rates higher than 1500MU/min (25MU/s) due to its hardwired protection. In order to achieve the minimum required 240000MU/min dose rate the gun current needs to be increased to an approximate range of 6.5-6.8A as per the extrapolated data shown above. The maximum gun current that can be set is 8A, therefore, these dose rates should be achievable well within the operational range of the gun.

Thyratron pulse analysis recorded at HTCA Optical Receiver using a logic analyser are shown below.

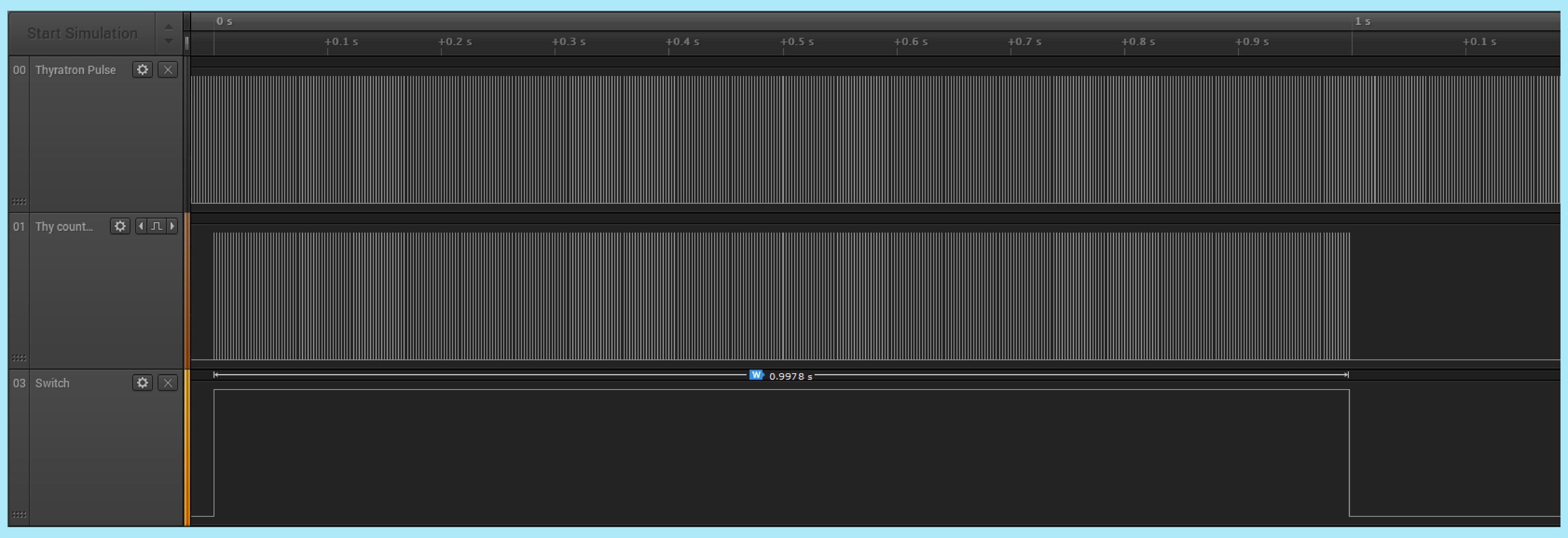


12Mev Thyratron trigger pulse





Built Prototypes Simulated pulse count



Linear accelerator 400 pulse count (1s) live

Conclusions

The timing controller achieved its goals by delivering repeatedly a measured dose of 10MU for a count set of 498 trigger pulses providing the proof of concept.

Further work is being progressed to develop a control circuit which will artificially generate the thyratron pulses unlike the current revision which manipulates the thyratron pulses generated by the linear accelerator.

Information gained from this work can be used by the manufacturer to develop a commercial application and progress to clinical trials, paving the way for more efficient treatment techniques. Further work in partnership with Elekta is in progress to find safe ways to deliver such high dose rates.

Acknowledgements

Robert Rooney from Elekta provided excellent help and support and all of my colleagues from St. Luke's Hospital that were involved in this project.

References

[1] Isra Israngkul-Na-Ayuthaya, Sivalee Suriyapee, Phongpheath Pengvanich, Evaluation of equivalent dose from neutrons and activation products from a 15-MV X-ray *LINAC*, *Journal of Radiation Research*, Volume 56, Issue 6, November 2015, Pages 919–926, https://doi.org/10.1093/jrr/rrv045

[2] Elekta Medical Linear Accelerator Corrective Maintenance Manual HT and RF Systems©2017 Elekta Limited.