CYCLOTRON BEAM CURRENT AMPLIFIER: REDESIGN AND EXPANSION

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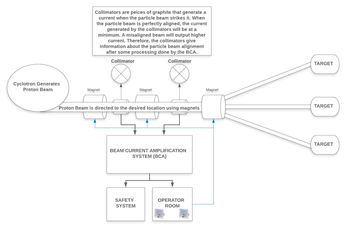
Cyclotron

- The Particle Cyclotron creates proton and neutron beams to remove tumor cells in cancer patients. [2]
- As more cyclotrons have moved towards using proton beam radiation therapy, the cyclotron at UW Medicine is the only one left in the US that uses neutrons to kill cancerous cells. [2]
- Being developed in the 1980s, the cyclotron has many components that are now outdated and that require redesign consideration.

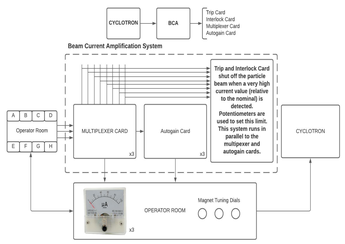
Beam Current Amplifier (BCA) System

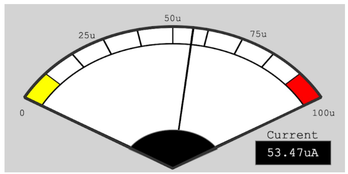
- The BCA System works by receiving feedback from devices that narrow beams and particles throughout the system, known as collimators. [2]
- The BCA System receives the collimators' current when the particle beam is misaligned and represents it using a digital dial.
- Operators use this information to tune the trajectory of the beam.



BCA System Features

- The received data is sent through two paths: through towards digital conversion and through a Trip and Interlock safety circuit system.
- Trip and Interlock circuits are responsible for shutting down the cyclotron if the beam is misaligned by a specified value by potentiometers in the circuits. [2]
- The analog signal is converted to a digital signal, which is then sent to a digital display controlled by operators who can adjust values.





Requirements

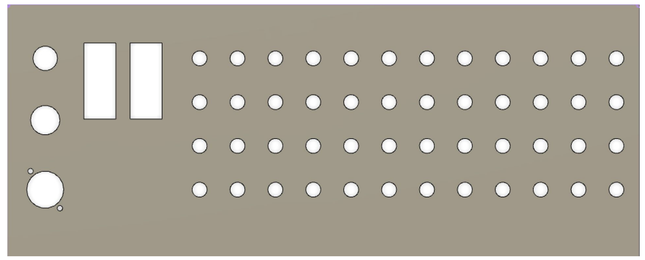
- The system should be able to handle 48 input channels in total for safety
- The circuit card should not create any additional physical spacing for the standard housing unit of a 16in x 3u rack.
- The BCA should implement 30 interlock circuits and 30 trip circuits to reduce failure alignment for the cyclotron.
- Input signal is received ranging between nanoamperes and microamperes and is sensed using an OPA380 Transimpedance Op Amp and 18-bit A/D converter.

Component Replacements

- Surface mount components are generally more compact and less expensive than through hole components are, making surface mount ideal to reduce large circuit architectures.
- However, through hole components are best to withstand rigors of environmental stress.
- The system uses surface mount components on breakout boards to simulate through-hole packaging, albeit this usage is limited to essential components for space reduction.

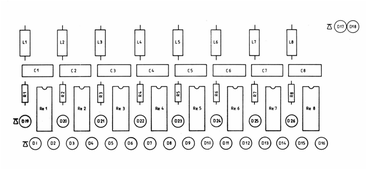
Input Channels and Interlock Cards

- The previous design concept of the BCA System operated with 24 input channels and 6 Interlock circuits and 6 Trip circuits.
- We increased these totals to 48 and 30, respectively, to increase safety in the system via redundancy and increased reliability.
- 48 input spaces, 50-pin ELCO connector spaces, new ethernet port, and power are shown.

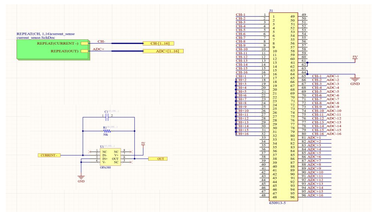


PCB and Circuit Schematic Redesigns

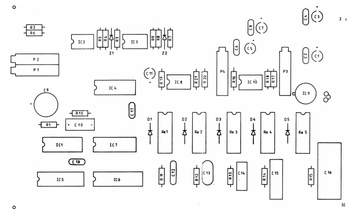
- One of our main goals in this redesign project is to modernize circuit structures and reduce space as much as possible.
- The images [top, middle] show both the PCB layouts for the Multiplexer and AutoGain Cards, respectively.
- The image beneath shows the new Beam Current Signal Conditioner Card layout.



Multiplexer Card PCB Layout



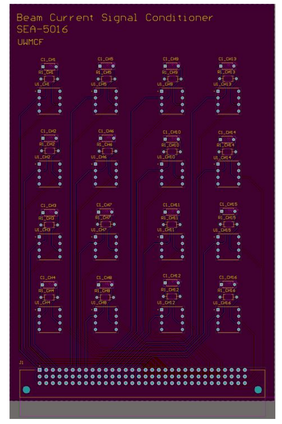
Beam Current Signal Condition Card PCB Layout

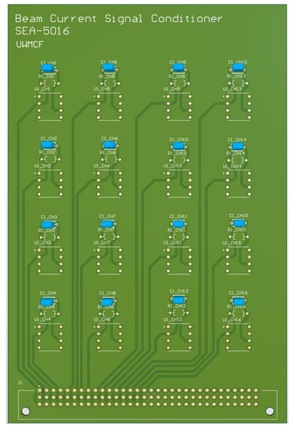


AutoGain Card PCB Layout

Beam Current Signal Conditioner Card

- The previous design concept of the BCA System required both a Multiplexer Card and an AutoGain Card to combine and read in low-level signals. The natural bulkiness and component-heavy nature of this causes spacing and safety replacement issues
- The redesigned system, now called the Beam Current Signal Conditioner Card, transitioned from an analog system to a digital system
- The previous system which relied on >15 unique and obsolete parts, now relies on only 3 parts that are repeated per channel.
- This was achieved by using an ultra-low noise transimpedance amplifier capable of sensing 1nA signals. The output of the system is digitized using a 18 bit ADC and uploaded to the network. [1]





Conclusion

- Facility engineers are satisfied with modernized circuits and increased safety.
- Displays output feedback at a precision of nanoamperes, previously microamperes.
- Overall, facility engineers approve of completed work and increased inputs.
- Our group learned to highly consider environmental stress in high workload systems, not simply prioritizing high-efficiency performance.

Future Work, References, and Acknowledgments

Future Work:

- Find alternative circuit configurations to further reduce components in Trip Card
- See through PCB connection and implementation
- Further digitize more displays for the BCA control center

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Teaching Assistant: Daniel King
Industry mentors: Marissa Kranz, Rob Emery, Eric Dorman

References:
[1] Python Code for Digital Displays
[2] BCA Reference Manual

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