Design and Fabrication of High Precision Readout Electrodes for GEM and Multiwire Grids For Neutron 2D PSD

Vaibhav B Kulkarni, Shraddha S Desai*, Rohit Chandak, Mala N Rao
Solid State Physics Division, Bhabha Atomic Research Centre, Trombay, Mumbai 400085

Introduction

In-house development of these detectors is carried out for utilization at National Facility for Neutron Beam Research at Dhruva reactor. Detectors with various size, shape and sensitivity have crucial anode-cathode readout assembly for unform electric field distribution. The symmetric alignment of electrodes decides the performance of simple coaxial detectors to multiwire based large area position sensitive detectors (PSD).

Detectors with advance geometry such as Gas Electron Multiplier (GEM) [1] and 2-D PSDs based on multiwire [2] need to be assembled with precise electrodes, inter-wire and inter-grid spacing. Position accuracy and uniformity of response of detectors depends on the Gerber designs of readout electrodes and multiwire grids. All the gerber designs for these electrodes with 1 µm accuracy are prepared indigenously for tailor-made size and operating parameters of the detectors. Sensitive area of detector, wire material and diameter and sag-free wire mounting determines the perfection in detector performance. Designs of the gerber files for readout electrodes are prepared using electronic design automation softwares such as KiCad [3] and OrCAD [4]. These are the open-source software and efficient tools for designing hardware. Recent developments of detectors supported by these high accuracy PCB designs are presented. Tools are also used to create artwork, Gerber files, and 3D models of the PCB and its components.

Software Tools for Gerber Design

KiCad is a software that facilitates the design and simulation of electronic hardware for printed circuit boards (PCB) manufacturing, schematic capture, PCB layout, file viewing, and engineering calculation.

*Electronic address: ssdesai@barc.gov.in

It uses an integrated environment for the stages of the design process: Schematic capture, PCB layout, Gerber file generation and library editing. This tool supports 32 copper layers, with precision of nanometer scale and overall dimensions of ~2.0 meters. Number of plugins are used for high quality silkscreen label generators and assembly viewers. Schematic symbols are very loosely coupled to circuit board footprints for reuse. A single 0805 footprint is used for capacitors (C), resistors (R), inductors (L), essential for LC chain of delay components and resistive chain for charge division on cathode grids.

OrCAD software is used for electronic design to create schematics, and perform mixed-signal simulation and electronic prints for manufacturing PCB. Designer includes various automation features for PCB design, board-level analysis and design rule checks. The design is accomplished by manually tracing pads, curved PCB tracks, geometric shapes, and ground planes. Readout pads of circular or square size, solder pads are edged with triangular strips. Apex of which is aligned with wires on multiwire grids very accurately Precision alignment of all three grids determine the position accuracy by reading projection of charge corresponding to incoming neutrons.

Readout Electrodes for GEM Detectors

GEM technology is extensively used for charge particle detection in mega facilities as CERN. GEM electrode is a thin polymer foil with copper coating on both the sides and a pattern with periodic structure of holes are created using micro-drilling process and lithography. Large internal gains can be attained using small bias voltage due to a very thin (< 100-500 µm) insulating foil between the electrodes. These multiple foils are inserted between a drift and a charge collection electrode.

Electron charge cloud amplified through GEM is collected on readout electrodes. The GEM geometry replaces the multiwire grid of 2D detector and improves the limitations on position resolution caused by constraints on wire spacing.

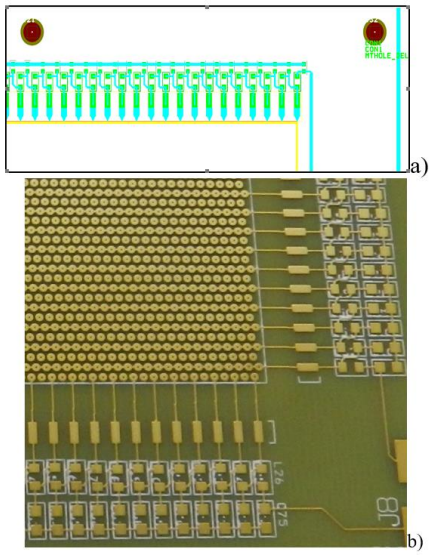

Fig. 1 a) Gerber display of readout grid with LC mounting pads and b) Readout PCB for GEM

Stack of GEM foils and readout electrode are mounted in a gas filled chamber for neutron detection. Charge travels in the direction of incident neutron and induces an equal and opposite charge on the readout grid. The readout electrode of 12 x 12 cm consists of a 2D array of 25600 circular charge collection pads arranged in honeycomb structure at the pitch of 0.75 mm. These are orthogonally connected from front and back side of PCB to read X and Y positions. The pitch determines the position resolution of the detector. This charge is distributed with the chain of resistors or LC SMDs depends on the readout encoding method of interest. Delay line position encoding is designed as shown in Fig 1a and 1b.

Readout PCB for Multiwire 2D PSD

Multiwire geometry for sense electrodes consists of an array of precisely equi-spaced wires which are hanging under tension in the gas volume. Central anode grid is sandwiched between two orthogonal cathode readout grids. Cathode grids have array of wires terminated with the either R or LC components for Challenges are also faced for the etching of this dimensions of PCBs.

Wire spacing varies from 1.25 mm to 5 mm which is the limit of position resolution, unless each wire is handled with centroid finding readout method. The wire spacing and tension needs to be precise for uniformity of electric field distribution, which determines avalanche and pulse amplitude. Fig 2 shows the anode PCB fabricated using the tailor-made gerber file. It consists of 130 pads of 2 mm width and at the pitch of 5 mm. Wires with ±50 µm accuracy are fixed on the supporting PCB and position read of automated grid winding machine is ±1 µm.

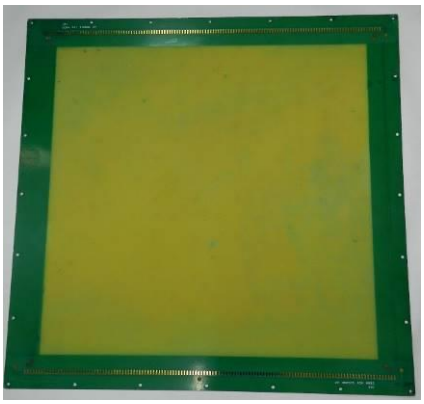

Fig. 2 PCB 720 x 720 mm for anode grid with gold plated pads for precise wire alignment

Conclusion

Indigenous Gerber designs were successfully utilized to support the development of GEM and multiwire based novel detectors. High accuracy needed for the design is well supported by KiCad and OrCAD softwares.

References

[1] S. Bachmann, et al. Nuclear Instruments and Methods A, 438 (1999), p. 376

[2] Fabio Sauli, Nucl. Instrum. and Meth A, Volume 805, 1 January 2016, Pages 2-24

[3] https://home.cern/news/news/computing/kicad-software-gets-cern-treatment

[4] https://www.cadence.com/en_US/home/tools/pcb-design-and-analysis/orcad.html