MRPC Lab in Academia Sinica, Taiwan

DRD1meeting on June 17th, 2024

Chia-Yu Hsieh

on behalf of AS group

Group Members and Work

- **Institutions**
  - Institute of Physics, Academia Sinica, Taiwan (**AS**)
- **Nuclear physics group**

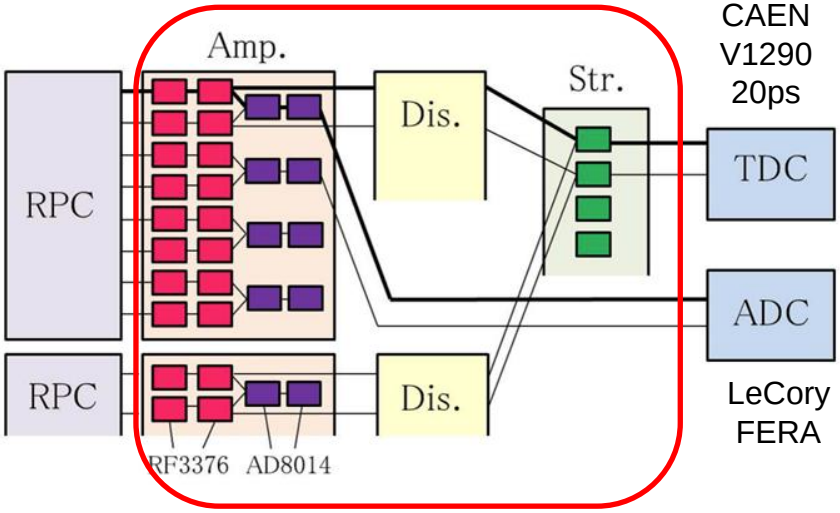
  MRPC working members from AS
  - Dr. Wen-Chen Chang (Group leader)
  - **Dr. Ming-Lee Chu (Engineer)**
  - Dr. Chia-Yu Hsieh (Postdoc)
  - Shih-Yu Lin (Assistant)
- **MRPC project in Taiwan**
  - Collaborating w/ **Prof. Tomida Natsuki (Kyoto University)** in developing MRPC and the readout electronics for the SPring-8 LEPS2, FNAL EMPHATIC, J-PARC E88 and experiments since 2012, ex. **RF amplifier, discriminator, stretcher (not used Anymore).**
  - Setting the MRPC lab since 2022. The R&D work includes the **reduction of noise (low-pass filter, shielding), signal reflection (transmission line), carbonless, Mylar spacer, and PCB self-sealing chamber**, etc.

Chang, Wen-Chen / *Research*

Chu, Ming-Lee / *Senior Research Scientist*

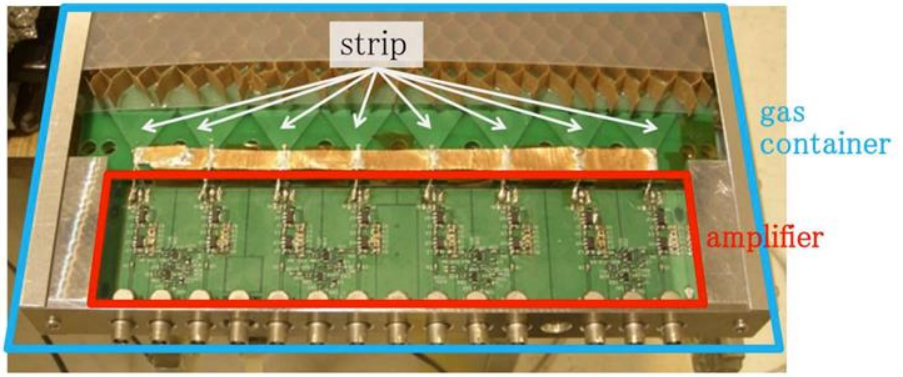
Chia-Yu Hsieh/postdoc

FEE



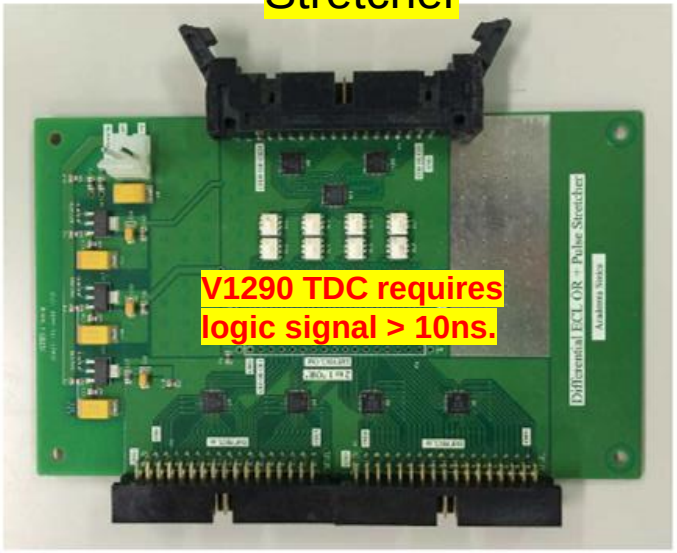
Work of Dr. Chu Ming-Lee.

Amplifier



Discriminator

Stretcher

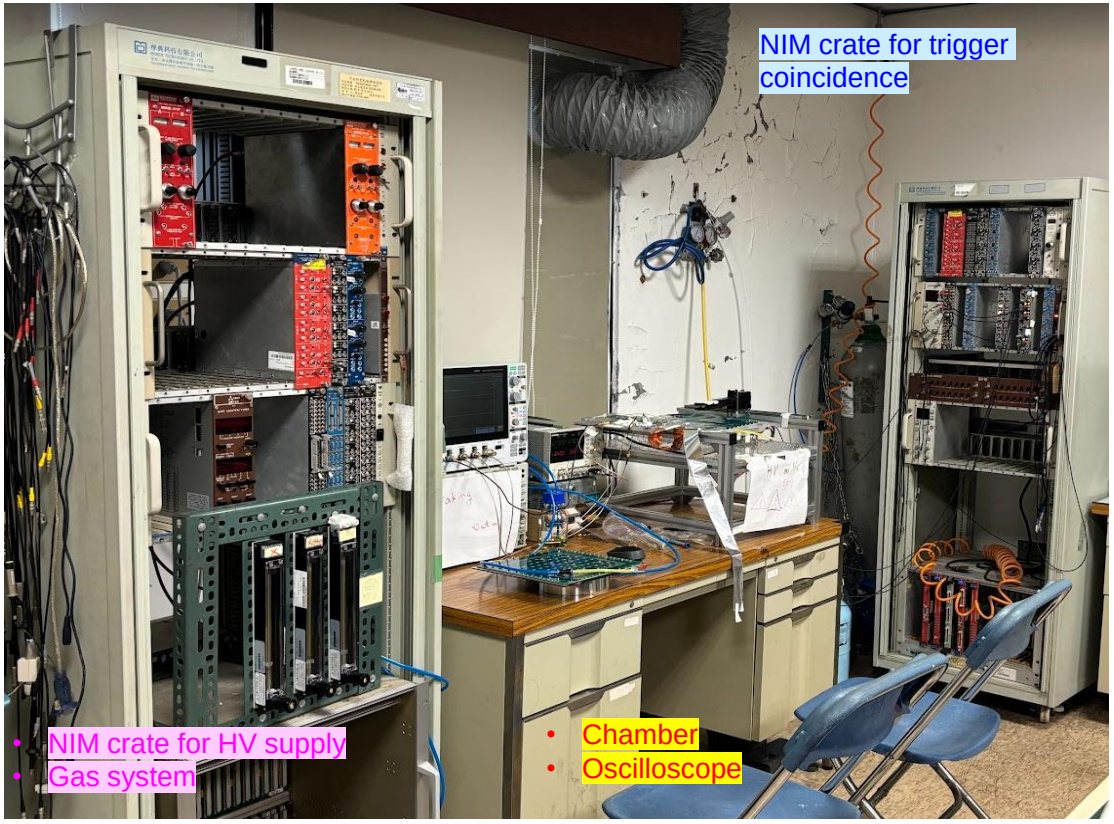


Details of FEE are in backup.

MRPC Development in Taiwan

- Despite of the successfully running detectors in several experiments, we encountered several problems in the past. Starting in 2022, we assembled MRPC in Taiwan and tested several new ideas to solve the problems.

① **Carbonless electrode**
(out off carbon tape supply)
① **Mylar spacer**
(replace fishing line)
① **Gas sealing**
(glue ➔ mechanical gas seal)
① **Noise**
(low pass filter)
① **Signal Reflection**
(transmission line)



Carbonless MRPC Prototype

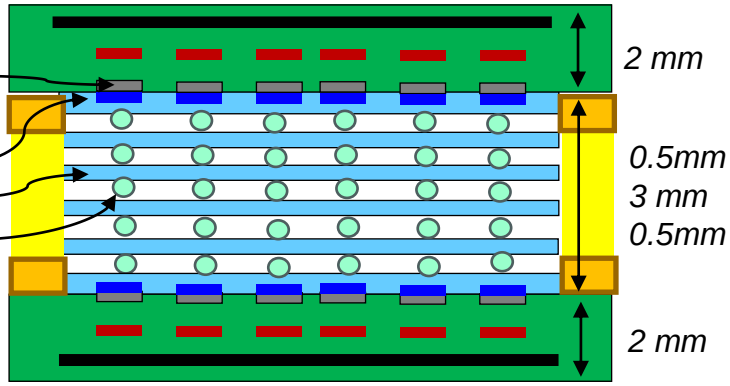
PCB self-sealing

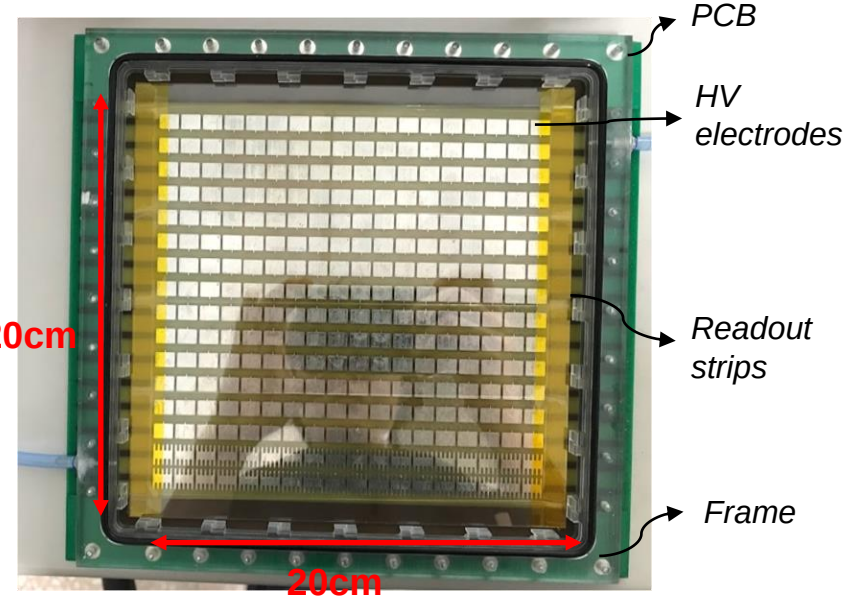
PCB ground layer
readout strip
copper pad electrode

Conductive tape
Glass
Mylar sticker

Acryl frame
Silicon sheet

1 stack * 5 gaps * 260um
20cm * 20cm Active Area



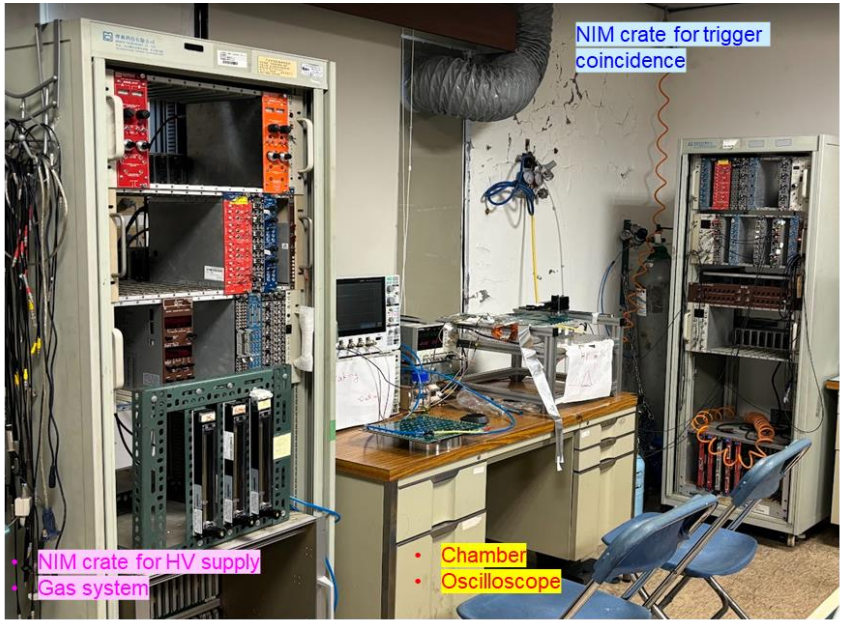


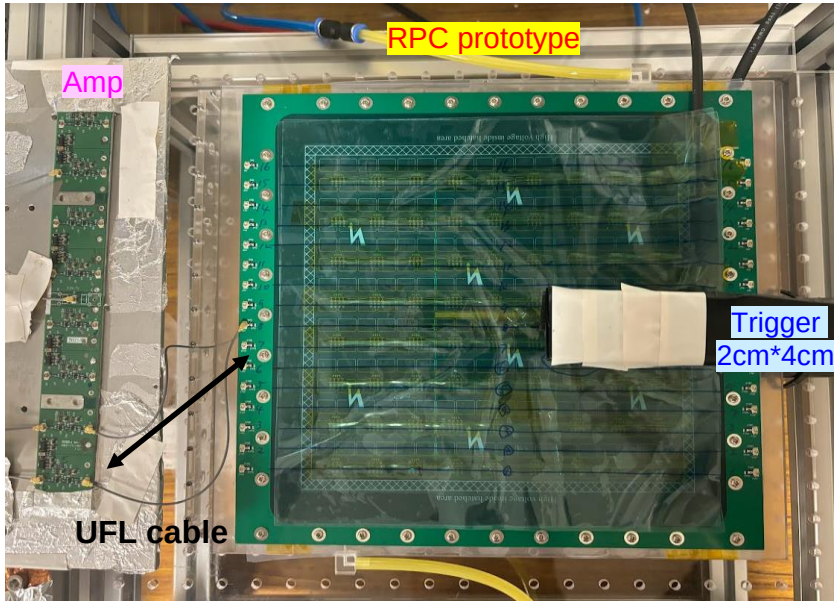
Multi-layer PCB : One **PCB includes ground layer, the readout strip, and electrodes**, and is used as the **cover of the chamber, creating a so-called self-sealing chamber**. The PCB must be **as thick as possible** to provide strong support for the gas chamber (1.5mm in our case). **The amplifier can be connected outside the gas chamber in this case.**

Conductive tape: From the past experience, we learned that the attachment between copper electrode and the most outer glasses are very important to have proper HV applied. 3M ZYZ conductive tape is chosen to do the work (https://www.mouser.tw/datasheet/2/1/ECATT_9703_Data_Sheet-1506912.pdf).

Mechanical gas seal : **solid silicon gasket**. The thickness of the solid silicon gasket varies from 0.1 mm to 1 mm. This allows us to have a very thin chamber. Material budget is reduced. We are testing test two kinds of thickness of frame with 2.5m and 3mm height accompanying with 0.5mm-thick silicon gasket.

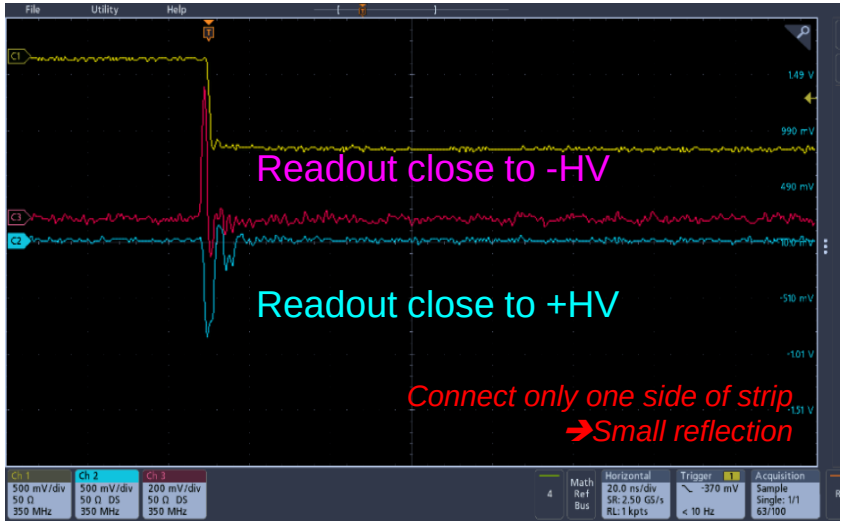
CR Test Setup of MRPC in AS





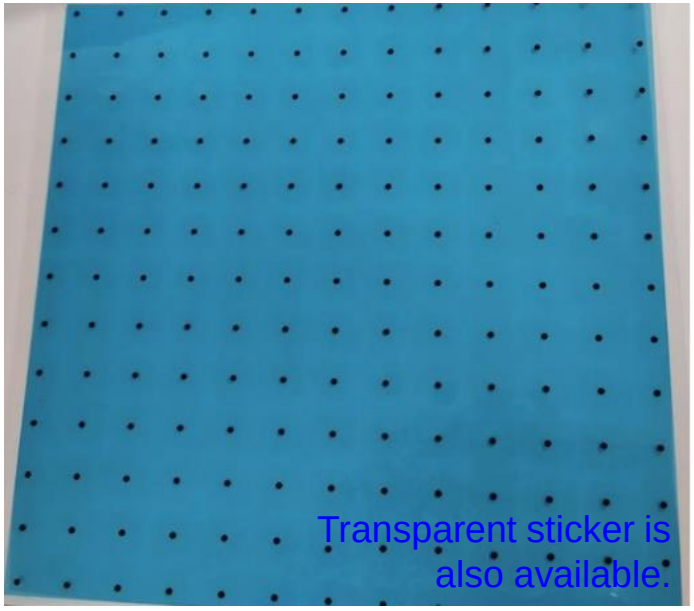
Small carbonless MRPC with 20cm*20cm active area are developed in AS.

① 1 stack * 5gaps * 260um gap * 400um glass
② Size of chamber 25cm *25cm
③ Size of active area 20cm*20cm
④ 16 ch, 4mm*26cm strip and 11mm pitch
⑤ Amplifiers placed outside chamber with UFL
⑥ Carbonless electrode
⑦ Mylar spacer to create gas gap
⑧ Solid silicon gasket to do gas seal



CR testes are done. Beam test will come in July.

Mylar Sticker

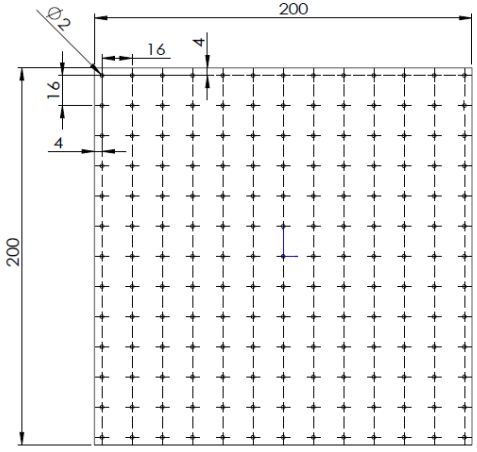


- **Company in Taiwan**

Panel Group 佳值集團
Contact person : Sean Chen 陳傑雄
TEL : +886222212510 Mobile: +886987625807
email : sean@panel.com.tw
http://www.panel.com.tw/?lang=en

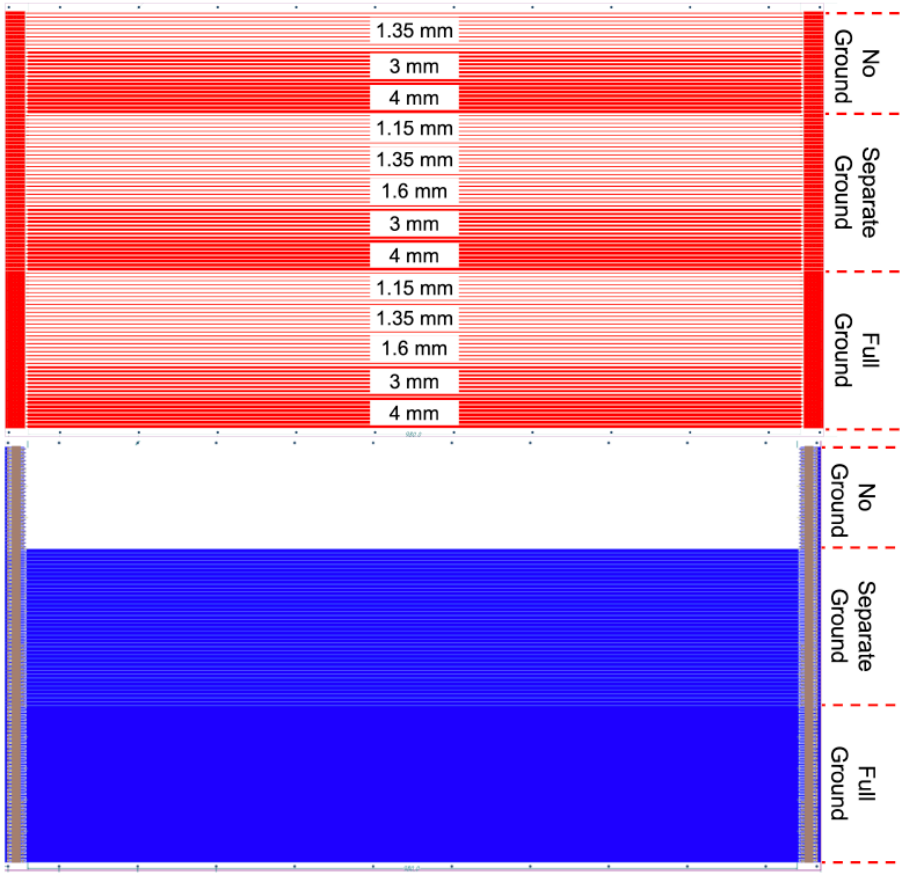
- **Production limitation of Mylar sticker**
- **thickness : min = 0.07mm, max = 1.5mm**
- diameter : min = 1mm
- distance : min = 1mm
- In our case : 0.26mm = 0.25mm Mylar + 2* 0.05 tapes
- **Teflon and Kapon are also possible.**

- **If you are interested in testing Mylar sticker, we can help with contact.**
- **This supplier provide various kinds of material which use in our MRPC including silicon gasket, 3M conductive tape, mylar sticker, etc. Customize shape and small order is possible.**



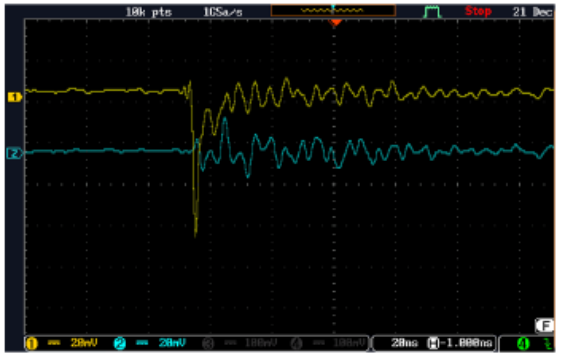
Groud Layer for Transmission Line Calculation To Reduce the Signal Reflection

MARQ Tracker prototype



4mm strip width

No ground

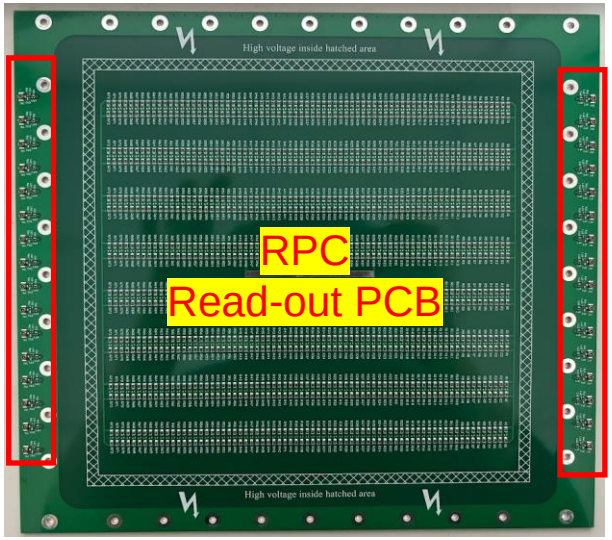


Separated ground

Full ground

Smaller reflection w/ full ground.

Noise Reduction with 3-Stages Low-Pass Filters



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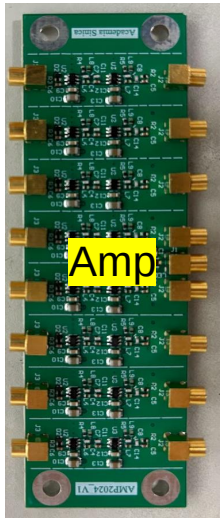


Low pass filter on read-out side

1st stage

Low pass filter on Amp side

2nd and 3rd stages

- Three-stage low pass filters will be implemented, one on read-out PCB (one stage) and another on the side of amplifier (two stages).
- RPC signals are < 1GHz and the environments signals from radio or cell phones are usually > 1GeHz. Low pass filters are designed to amplify only RPC signals.

Mechanical Shop in AS

We have professional mechanical shop in AS with 4 full-time machenical engineers. They gave **useful suggestion in the mechanical design of frame and the gas seal.** R&D is much faster and easier with their help.

Summary and To Do

- Our group at Academia Sinica, Taiwan, has been collaborating with Prof. Tomida Natsuki from Kyoto University in developing the MRPC since 2012. Our main contribution to this collaboration has been in the development of the FEE. In 2022, we initiated the construction of MRPC prototypes to address several challenges we had encountered. The prototypes have been successfully built, and initial tests with cosmic rays indicate that the chambers are functioning as expected. We plan to conduct beam tests in the upcoming July and present our findings at the RPC2024 workshop.

- To do and ideas
  - Extend MRPC to large one (1m)
  - Two stack PCB-self sealing MRPC.
  - Combine Amp and Discriminator to one board
  - Glass supplier in Taiwan
  - Different material for spacer

Back up

Specification of Amplifier Chip

RFMD
rfmd.com

停產

RF3376

General Purpose Amplifier

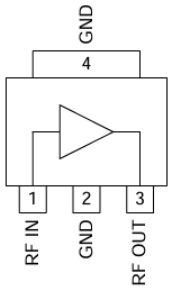
Package Style: SOT8

Features

- DC to >6000MHz Operation
- Internally Matched Input and Output
- 22dB Small Signal Gain
- +2.0dB Noise Figure
- +11dBm Output P1dB
- Useable with 5V Supply

Applications

- Basestation Applications
- Broadband, Low-Noise Gain Blocks
- IF or RF Buffer Amplifiers
- Driver Stage for Power Amplifiers
- Final PA for Low-Power Applications
- High Reliability Applications



Functional Block Diagram

Product Description

The RF3376 is a general purpose, low-cost RF amplifier IC. The device is manufactured on an advanced Gallium Arsenide Heterojunction Bipolar Transistor (HBT) process, and has been designed for use as an easily-cascadable 50Ω gain block. Applications include IF and RF amplification in wireless voice and data communication products operating in frequency bands up to 6000MHz. The device is self-contained with 50Ω input and output impedances and requires only two external DC-biasing elements to operate as specified.

https://www.mouser.com/datasheet/2/412/f3376_data_sheet-973800.pdf

BGA2866

MMIC wideband amplifier

Rev. 4 — 13 July 2015 Product data sheet

1.1 General description

Silicon Monolithic Microwave Integrated Circuit (MMIC) wideband amplifier with internal matching circuit in a 6-pin SOT363 plastic SMD package.

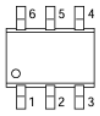
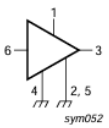
1.2 Features and benefits

- Input internally matched to 50 Ω
- A gain of 23.2 dB at 250 MHz increasing to 24.3 dB at 2150 MHz
- Output power at 1 dB gain compression = 4 dBm
- Supply current = 17.4 mA at a supply voltage of 5 V
- Reverse isolation > 32 dB up to 2150 MHz
- Good linearity with low second order and third order products
- Noise figure = 3.8 dB at 950 MHz
- Unconditionally stable (K > 1)
- No output inductor required

1.3 Applications

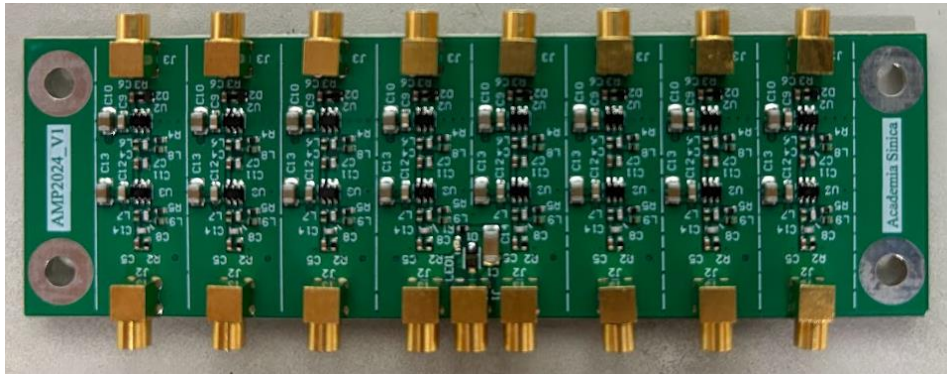
- LNB IF amplifiers
- General purpose low noise wideband amplifier for frequencies between DC and 2.2 GHz

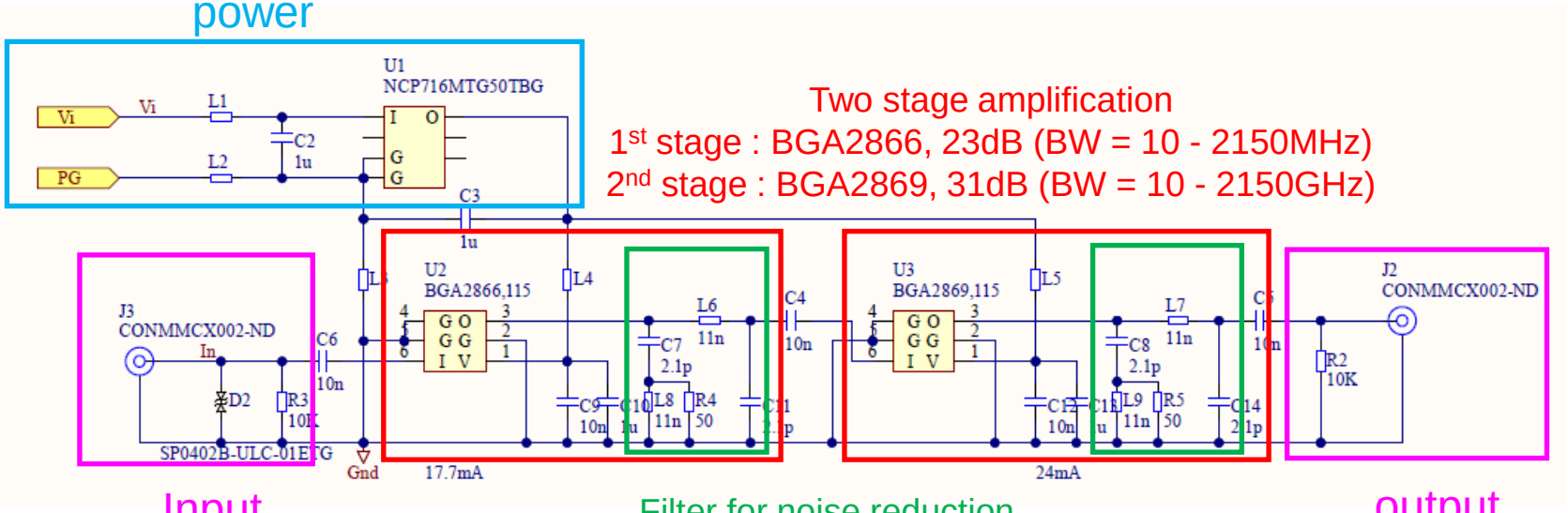
Table 1. Pinning

Pin	Description	Simplified outline	Graphic symbol
1	V_{CC}		
2, 5	GND2		
3	RF_OUT		
4	GND1		
6	RF_IN		

https://www.nxp.com/docs/en/data-sheet/BGA2866.pdf

Design of Amp w/ LP Filter





Chip of Discriminator

ANALOG DEVICES

Ultrafast 3.3 V/5 V Single-Supply SiGe Comparators

Data Sheet **ADCMP572/ADCMP573**

FEATURES

- 3.3 V/5.2 V single-supply operation
- 150 ps propagation delay
- 15 ps overdrive and slew rate dispersion
- 8 GHz equivalent input rise time bandwidth
- 80 ps minimum pulse width
- 35 ps typical output rise/fall
- **10 ps deterministic jitter (DJ)**
- 200 fs random jitter (RJ)
- On-chip terminations at both input pins
- Robust inputs with no output phase reversal
- Resistor-programmable hysteresis
- Differential latch control
- Extended industrial −40°C to +125°C temperature range

FUNCTIONAL BLOCK DIAGRAM

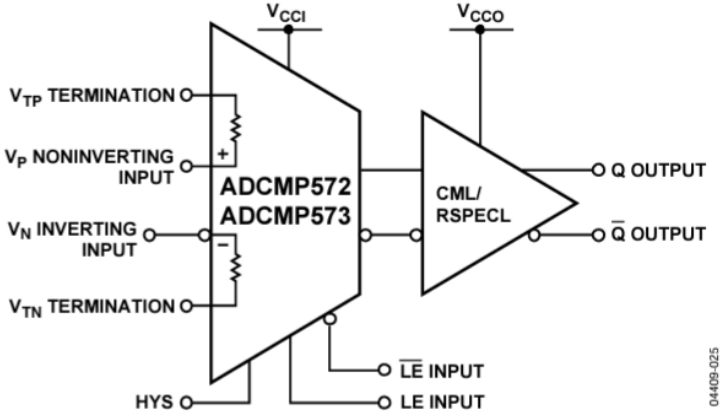
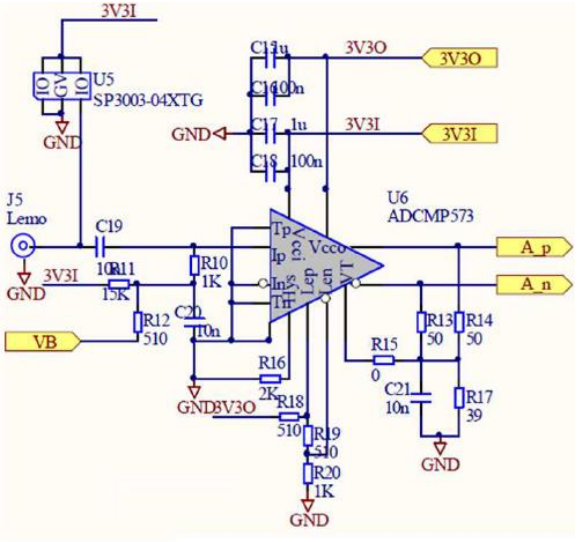


Figure 1.

https://www.analog.com/media/en/technical-documentation/data-sheets/ADCMP572_573.pdf

Design of Discriminator



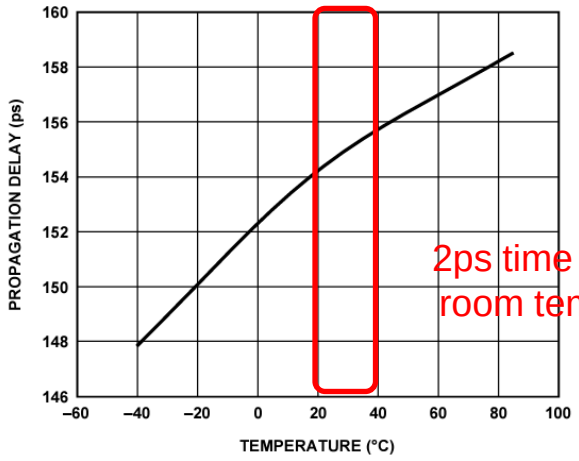


Figure 5. Propagation Delay vs. Temperature

2ps time jittering in room temperature

Signal Reflection : Transmission Line Calculation (1)

Typical RPC is designed to be like Transmission Line (TL), However not in typical PCB Planar TL structure.

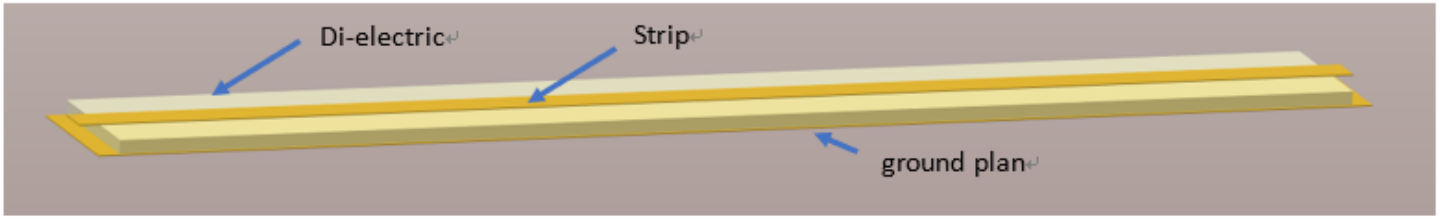
A. No metal ground plan along with signal strip,

B. Two signal strips in parallel, one strip for +HV Carbon signal induction, the other for -HV carbon signal induction.

Not so easy to practice "Impedance match" like most of strip type TL.

Multiple reflected signals often overlap with original signal, degrades timing measurement quality.

Basic Transmission Line: Microstrip as example



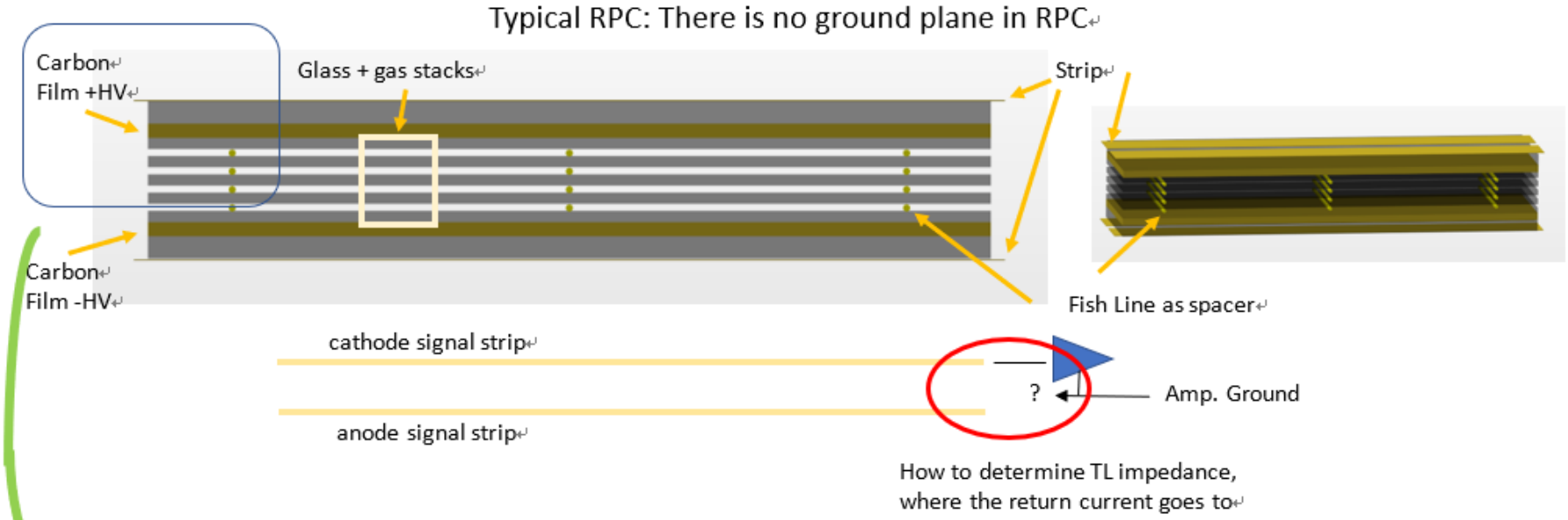
Characteristic Impedance = R=V/I

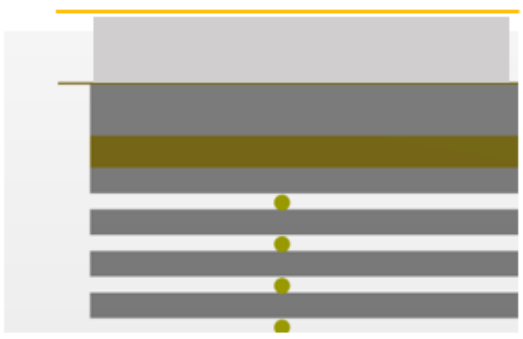
Matched Load

Matched condition: TL's characteristic impedance = Load resistance ➔No reflection.

Within 10% mismatched is considered to be usable (10% V reflection)

Signal Reflection : Transmission Line Calculation (2)





Our modified MRPC

Use multi-Layer PCB to include both strip layer and ground layer

- Multi-Layer PCB designed simple TL can result good impedance match
- Issue: Not many PCB manufacturer is capable making long multi-layer PCB