Making of
Combination Variable Capacitor
for Desktop MLA

MLA48 Southern California Branch
Record of Struggle

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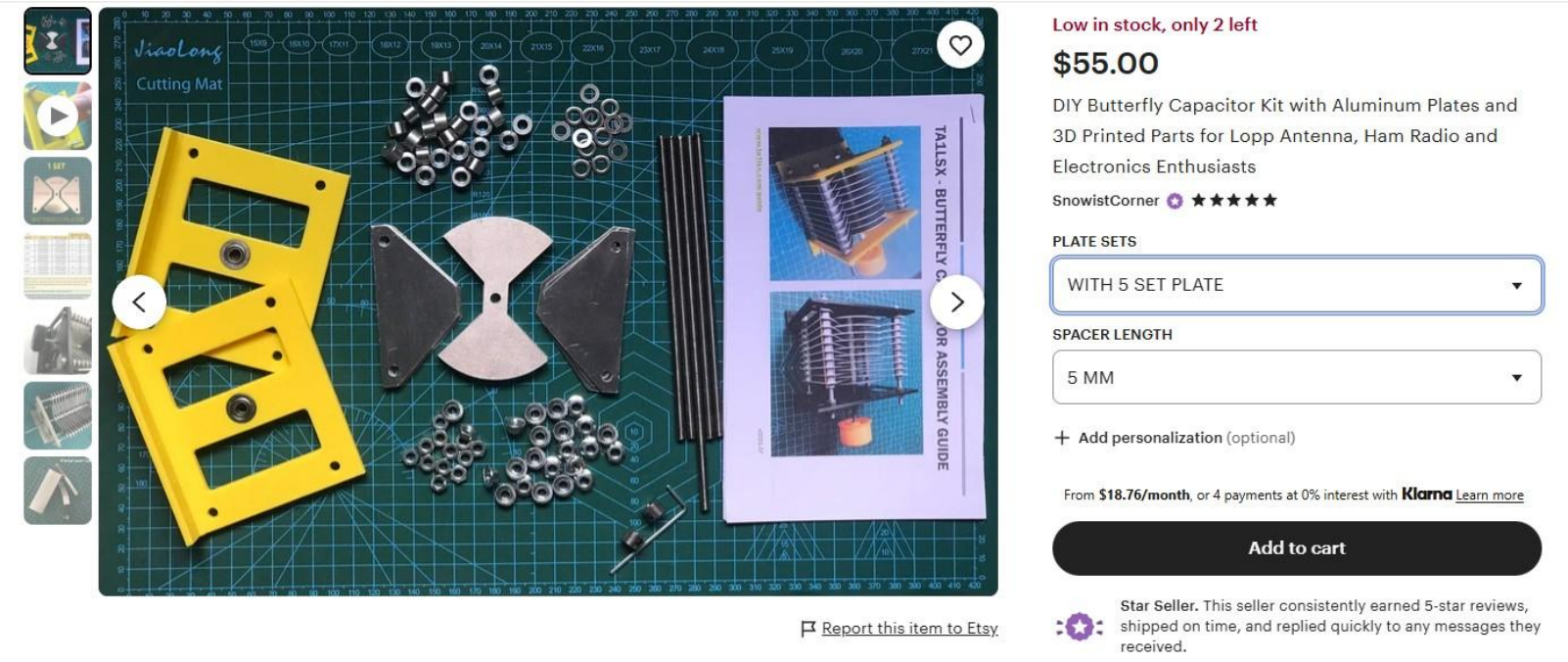
（Revised and Translated）

Motivation

- Combination Variable Capacitor is a required part of the matching system of Desltop MLA
- Ready-made part is not available in the market place
- The Butterfly Capacitor part is still available to buy from net shops like e-Bay. But...

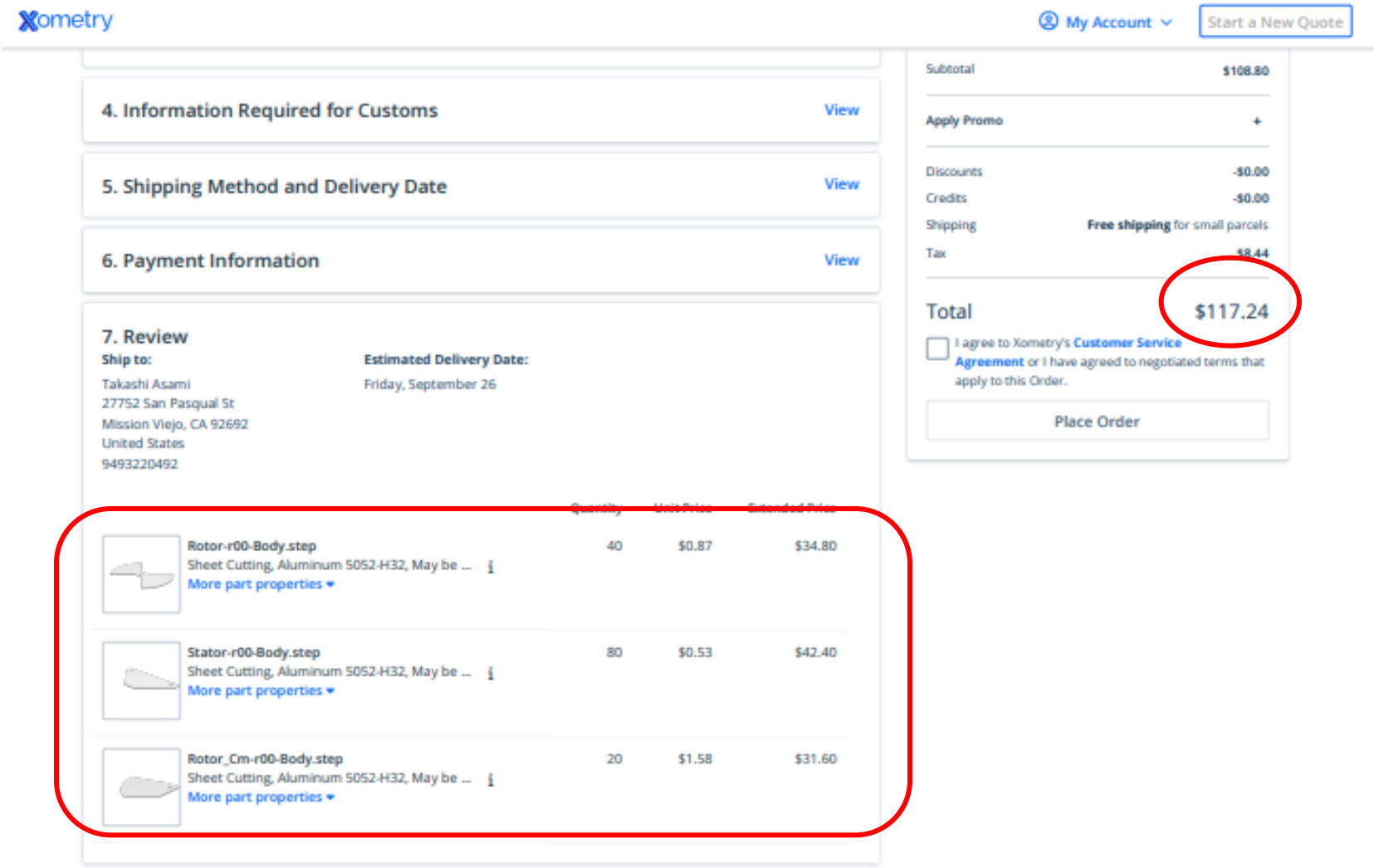


Motivation（２）

BUT!!

- The inventory seems to be low and freight charge sky-rocketed.
  - 5 plate set costs $55 + S&H $50
    If you want to build 20 plate capacitor, it costs $620!
- And the kit does not include the smaller Matching Capacitor.
- Southern California group, in order to advance our project to build our own Desktop MLA, searched for a workshop that can laser-cut metal plates to our shape and dimension.
  - Luckily, we found a vendor who would do that, and at an unexpectedly reasonable cost
  - The parts for Resonance and Matching Capacitor plates were built for two units, at $117.
    - The large part of the cost is the set-up charge, so for a larger order, per-unit cost can get significantly lower.

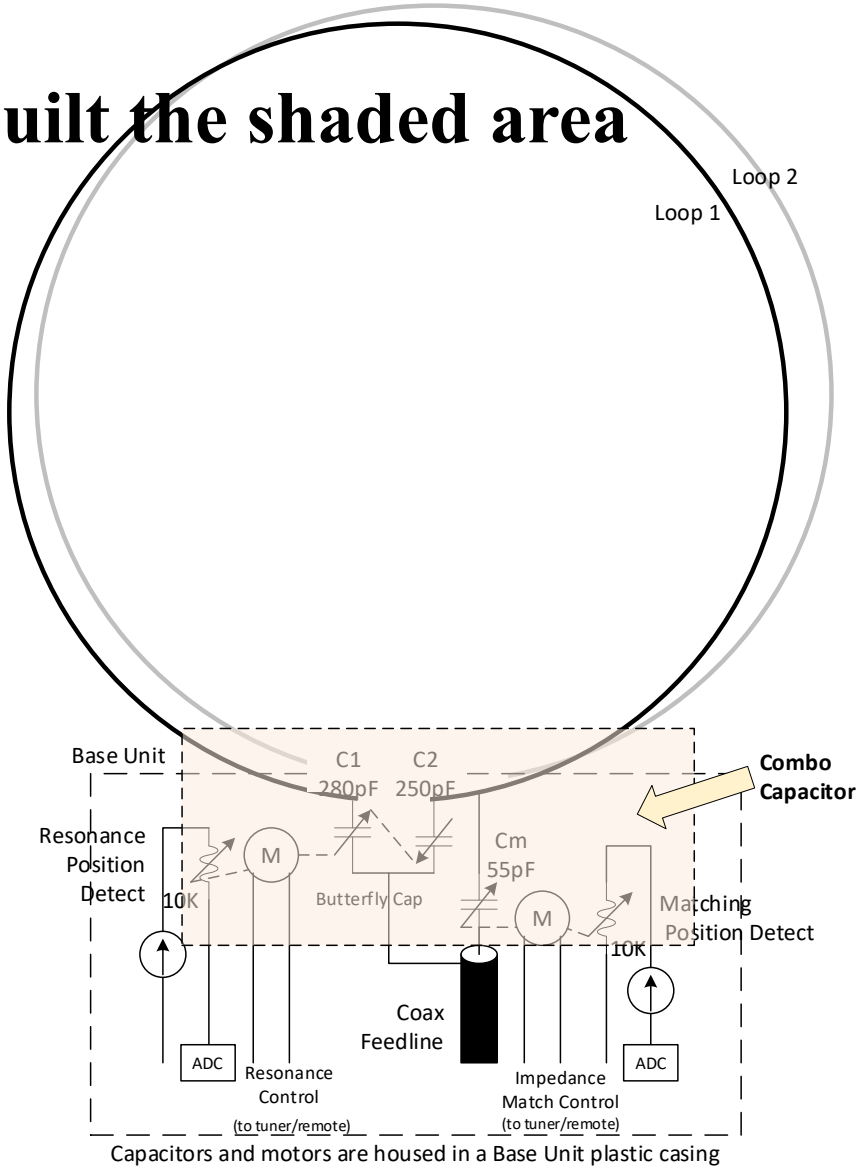
The Vendor's（Xometry.com) Estimate



Building it!

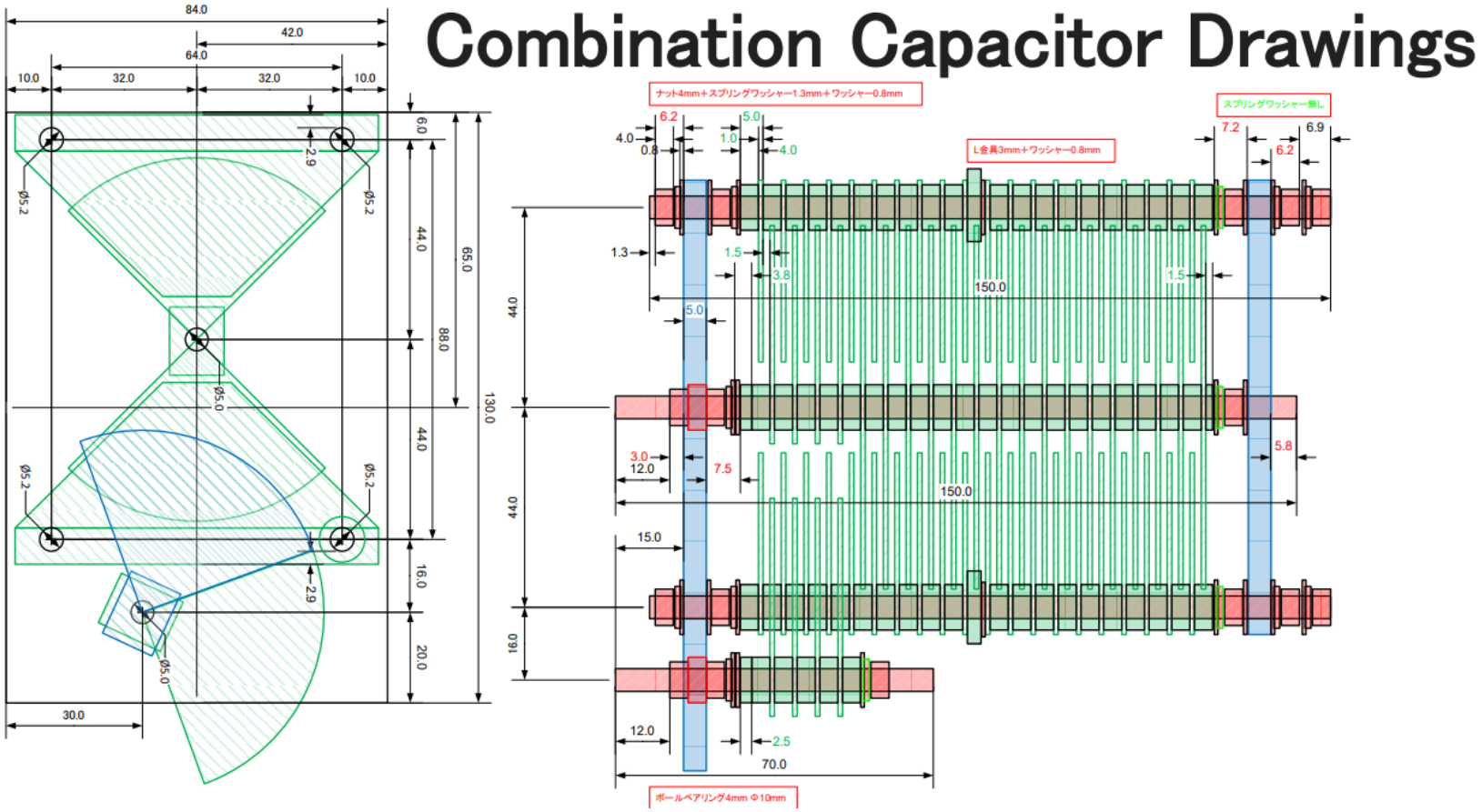
- Big hurdle of custom plate availability was overcome, we attempted to prototype the Combination Capacitor.
  - Many custom parts (except for the key hardware) were built using the 3d printer
    - PLA filament is too soft for the purpose
    - PETG can build a reasonably solid parts
    - PC, CF can also be used, but they are higher cost and high maintenance.
  - Metal hardware is ordered out, but the cost and availability become can become issue.
    The machining precision (especially thickness) is extremely important
    - Spacers
    - M5 Hardware
    - Washers, etc.
    - CMU (Capacitor Motorization Unit – Home made)
  - Several obstacles became apparent as building effort commenced
    We'll share some of them in this presentation

We built the shaded area



Combination Capacitor Drawings

Referenced from Mr. Uchida / JG1CCL's "HHE-122 Butterfly Capacitor Project"
（Showing the concept, but is **NOT** the same thing we are building）



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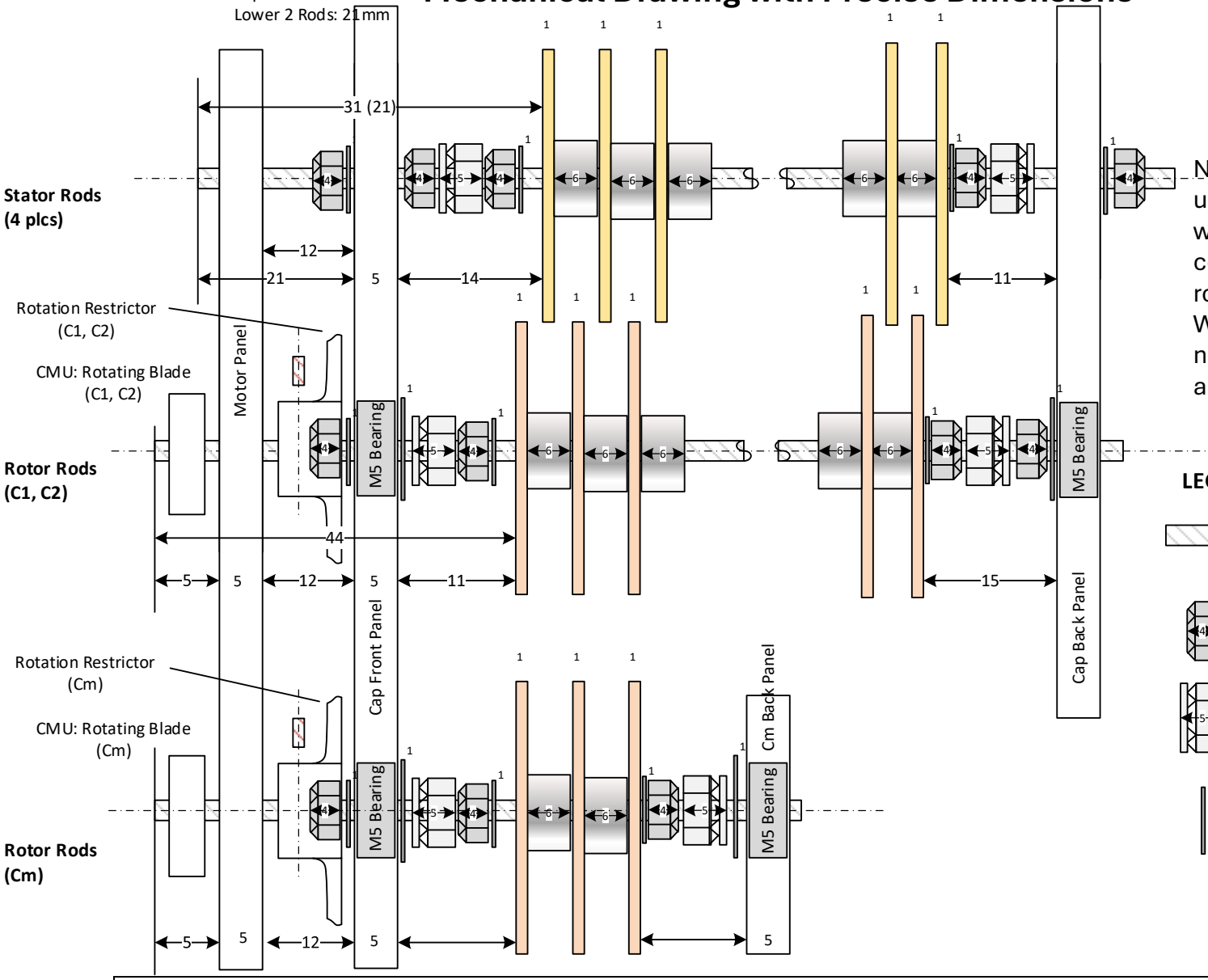
Mechanical Drawing with Precise Dimensions



Note: we are not using spring washers to avoid contortion of the rods
We used locking nuts to tighten the assemblies

LEGENDS

- M5 Threaded Rod
- M5 Nut（4mm）
- M5 Lock Nut（5mm）
- M5 Washer（1mm）

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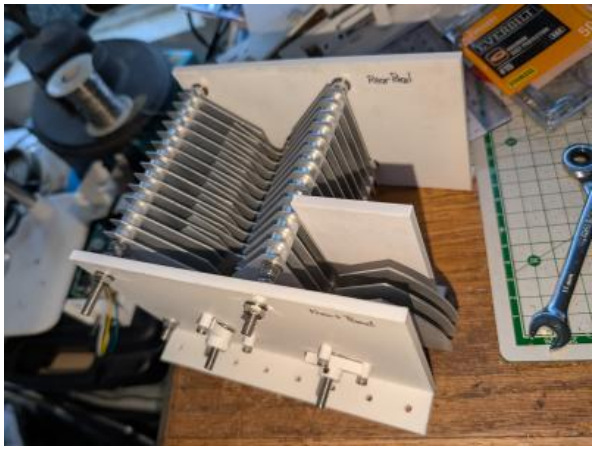
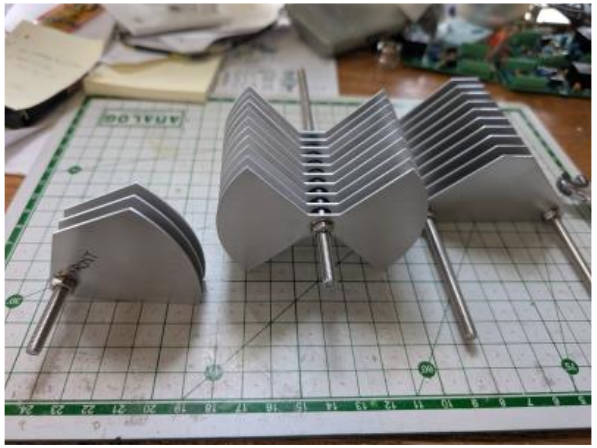
Overview of the Assembled Components

Rotor Assembly
Three blades are cut off on C2 side

Overview from the top
The Matching Capacitor on the right side





From the left:
Cm (Matching Capacitor) Rotor Assembly
C1, C2 Rotor Assembly
Stator Assembly

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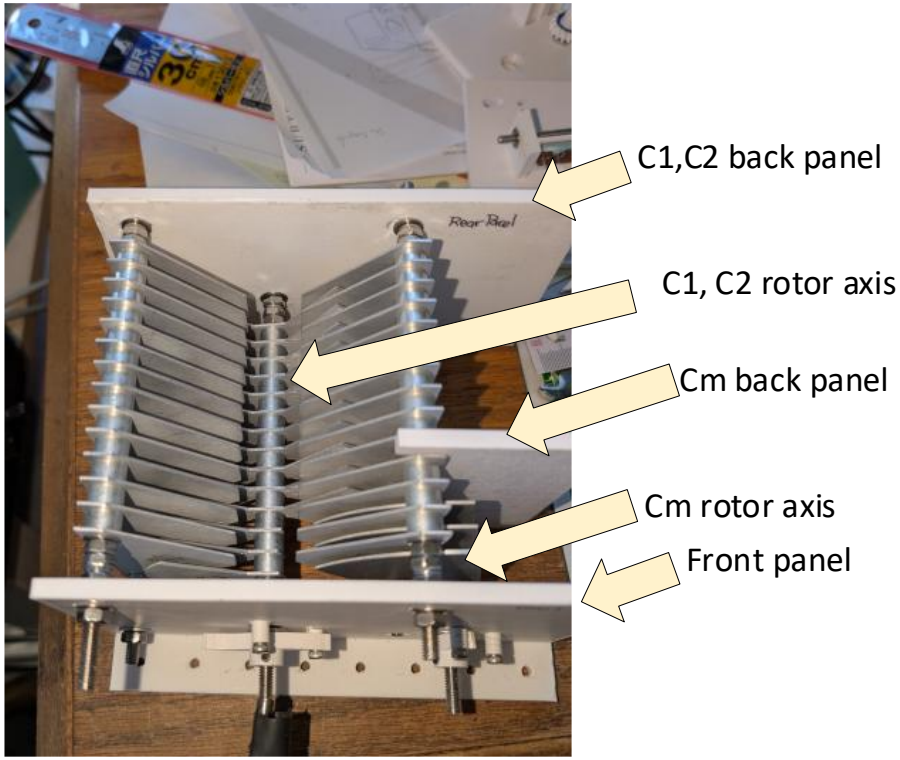
Prototype Overview（１）



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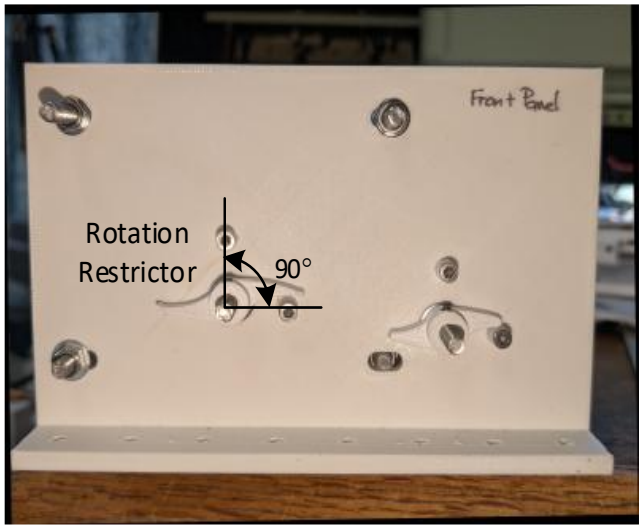
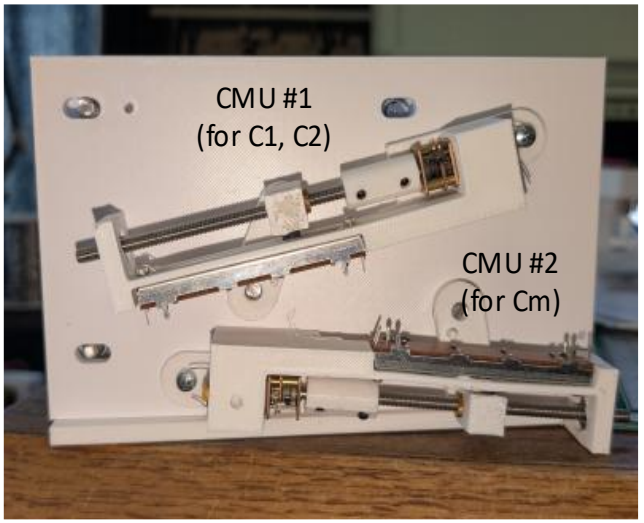
Prototype Overview（２）

Front Panel
(before Motor Panel is attached)
Rotation Restrictors are visible

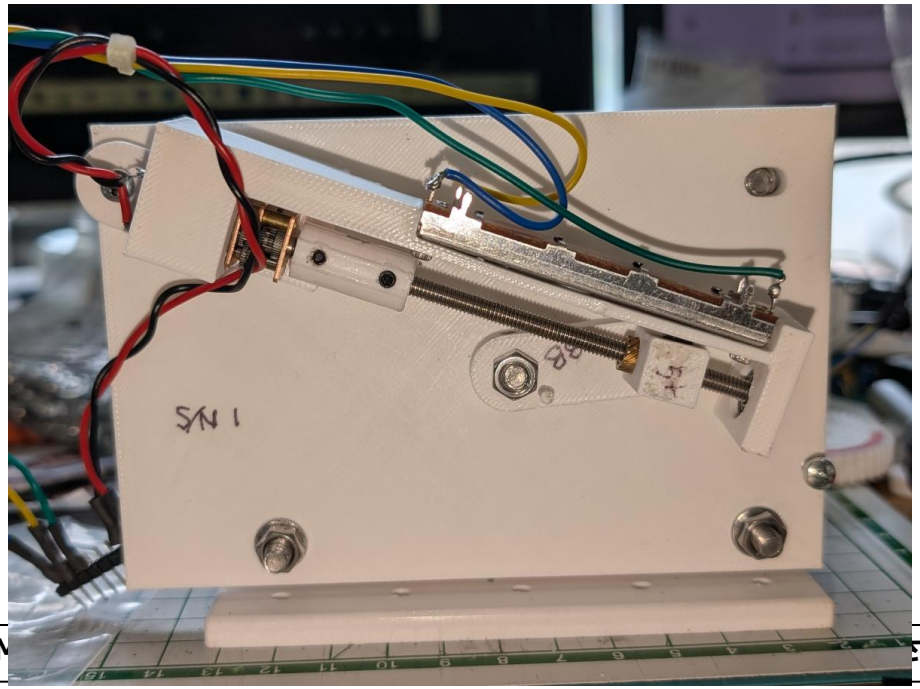


Mounting Motor Panel over the Front Panel with CMU's (Capacitor Motorization Units)



CMU (Capacitor Motorization Unit)

- Developed a motorization mechanism for the capacitor as an integral component
  - Very similar to JR1OAO's Desktop MLA system, but built with custom 3-d printed components
    - We are not a craftsmen of Mr. Nakajima's level
    - Due to lack of metal parts availability (he build one himself)
    - Some innovation was needed since plastic parts do not have stiffness of metal parts
    - As a result, the unit became a bit larger than Desktop counterpart



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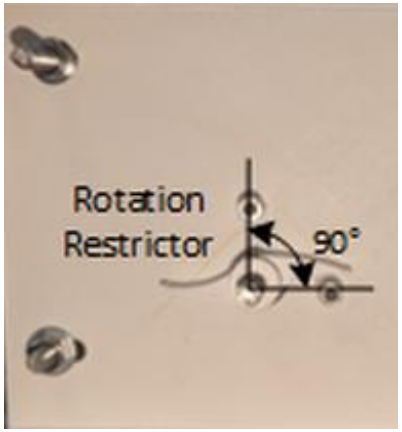
Rotation Restrictor

- Obviously, if you turn a capacitor 360 degree, capacitance increases, then decreases, increases again, on every 90 degree turn
- Without knowing the current orientation of the blades, opposite reaction to the matching network can occur.
  - It may be survivable for one-off project, if you build multiple units, it is important to set the initial conditions for CMU position, capacitor.
- On this project, we added a restrictor to the rotation axis of the rotor so it can only turn 90 degree.



- Pay attention to the angles / orientation or Cm and C2 blades.
  Or they can short each other.

About Spacer

- Due to cost and availability concern, 6mm spacers were used.
  - Desktop MLA uses 4mm spacer
  - Using 6mm can reduce the capacitance by 40% per blade
- There is a limit on the pre-cut lengths of threaded rods
  - The maximum length for pre-cut rods is 190mm
    Longer than that, one must cut stainless steel himself (NO).
  - It can only accommodate up to 14 blades, while Desktop MLA uses 20 blades.
  - That reduces the total capacitance by 30%, on top of reduced per-blade capacitance above
- Consequently, this prototype yields only 100pF per section
  - That can tune down only to 21MHz band
  - Desktop boasts up to 250pF per section to reach down to 7MHz
- Currently searching for the source for 4 or 5mm spacer
  - They are more expensive. Spacer is one of the most costly parts!

The Concern with 4mm Spacer

- Generally, zap immunity of air gap is said to be about 3KV/mm
- 4mm spacer gives blade-to-blade gap of 1.5mm
  - That gives up to 4.5KV high voltage immunity, **theoretically**.
  - 100W transmission on a loop with 1m diameter can generate more than 4KV at feed point gap at 7MHz
  - But C1 and C2 are connected series, so actual voltage across capacitor blades are half of that amount
- Therefore, 100W transmission on 4mm spacer is safe, but just barely.
  - This is assuming the rotor – stator gap is perfectly aligned. Any amount of variations can threaten the safety.
- ONE MUST BUILD IT VERY CAREFULLY!
- Mr. Nakajima suggested we can increase the HV immunity by 20% if we insulate the rotor blades.
  - (MLA-48 reported on that about a year ago)

Homework

- Achieve higher capacitance (over 200pF)
  - Use 4mm Spacer?
  - Increase the number of blades
  - Insulating rotor blades
- Develop a technique to connect the capacitor stator electrode to the MLA feed point directly
  - This is based on MLA-48 research about the high concentration of RF current at the middle of stator electrode. Objective is to increase Q and efficiency
- We are open to provide support for those willing to work to build for themselves
  - We can provide drawings and 3d files developed for this project, free of charge.
  - Drawings are made using freeCad. .step, .stl files can be provided
- At this time, we are not planning to distribute physical material
  - That can change, but will take time to get there

Partial Bill of Material (incomplete, sorry)

Combo Butterfly Cap Parts List		9/3/2025	
Alminum Plate Kit	C1-C2 Rotor	20	$ 11.00
	C1-C2 Stator	40	$ 22.00
	Cm Rotor	4	$ 2.75
Spacer, M5, 6mm, Al	need 84	100	$ 57.60
Face Plates	90mm x 115mm x 5mm	2	
bearing, M5	need 3	16	
Threaded Rod, M5 150mm	need 5	5	
Trheaded Rod, M5 70mm	need 1	1	
Nuts, M5, 3mm	need 28	100	
Nylon Locking Nuts	M5, need 8	27	
Washers	M5	100	
Spring Washers	M5	6	
Terminal Lugs	10 AWG stud	6	
Nylon Spacer M5 20mm			

CMU	needs 2 for each Combo Cap		
CMU body	3d print, PHAT_CMU-r06		
CMU slider	3d print, PHAT_CMU-Slider-r05		
CMU swing blade	3d print, PHAT_CMU_SwingBlade-r03B		
shaft coupler	3d print, PHAT_CMU_ShaftCoupler-r02D		
DC motor, 150rpm	need 1	3	$ 10.57
M4 threaded inserts	need 1	50	
M4 threaded rod, 80mm	need 1	15	$ 0.94
Slider VR, 10K B 63mm	need 1	5	
M3 set screw, 4mm	need 4	100	$ 0.34
M4 shaft bearing	need 1	6	
M2 hex screw, 5mm	need 2	120	$ 0.94
Coil spring, .4 x 4 x 35mm	need 1	20	$ 1.23

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